
Land Sea Interoperability Audit, Methodology and Tool Creation

A technical report for Work Package 3.3/3.4/3.7 & 3.8 of the BLAST INTERREG IVB North Sea Region Programme

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1 Introduction

1.1 Introduction to this report

Work Packages 3.3, 3.4, 3.7 and 3.8 of the BLAST INTERREG IVB North Sea Region Programme deal with developing a prototype interoperable land-sea reference base, each package managed by SeaZone Solutions, with input from a number of Project Partners.

This report describes the audit, methodology and tool creation involved in the development of this interoperable land-sea reference base for the agreed BLAST project areas.

1.2 Key challenges in integrating marine and terrestrial data

The primary focus of the BLAST project is on “bringing land and sea together”, by harmonising and integrating data between land and sea. With respect to geographic data, a fundamental problem exists across the North Sea Regions, in that terrestrial data is collected and maintained by topographic mapping or cadastral agencies and utilised primarily for economic development, spatial planning, conservation and environmental protection etc, while marine data is collected by hydrographic survey services and private survey companies, for navigation or exploration purposes.

One of the most significant challenges is harmonising the representation of the coastal zone using the best available data from these distinct terrestrial and marine datasets.

As an example, in the UK, the terrestrial data (Ordnance Survey MasterMap) has to be integrated with the marine data (UK Hydrographic Office Electronic Navigation Charts), using Mean High Water (MHW) as the boundary between the Ordnance Survey’s responsibility for mapping land areas and UKHO’s responsibility for charting the intertidal and marine zones. Inconsistencies exist between the depiction of the coastal zone by the UK Hydrographic Office (UKHO) and the Ordnance Survey (OS) in the representation of the intertidal zone and these are caused by:

- The use of different vertical datums
- Differences in data collation periods
- Different interpretations of primary source data such as aerial photographs
- Different interpretations of Low Water
- Differing scale resolution of capture
- Different purpose of data representation

For instance, in the UK, Low Water is represented by the land mapping authority (Ordnance Survey) as Mean Low Water (MLW) and by UK Hydrographic Office as Lowest Astronomical Tide (LAT).

These differences have created considerable contrast in representations of marine data within the intertidal zone.

This project methodology seeks to produce a seamless representation of the coastal zone where features which cross the boundary between the terrestrial and marine data, (either duplicated between the two

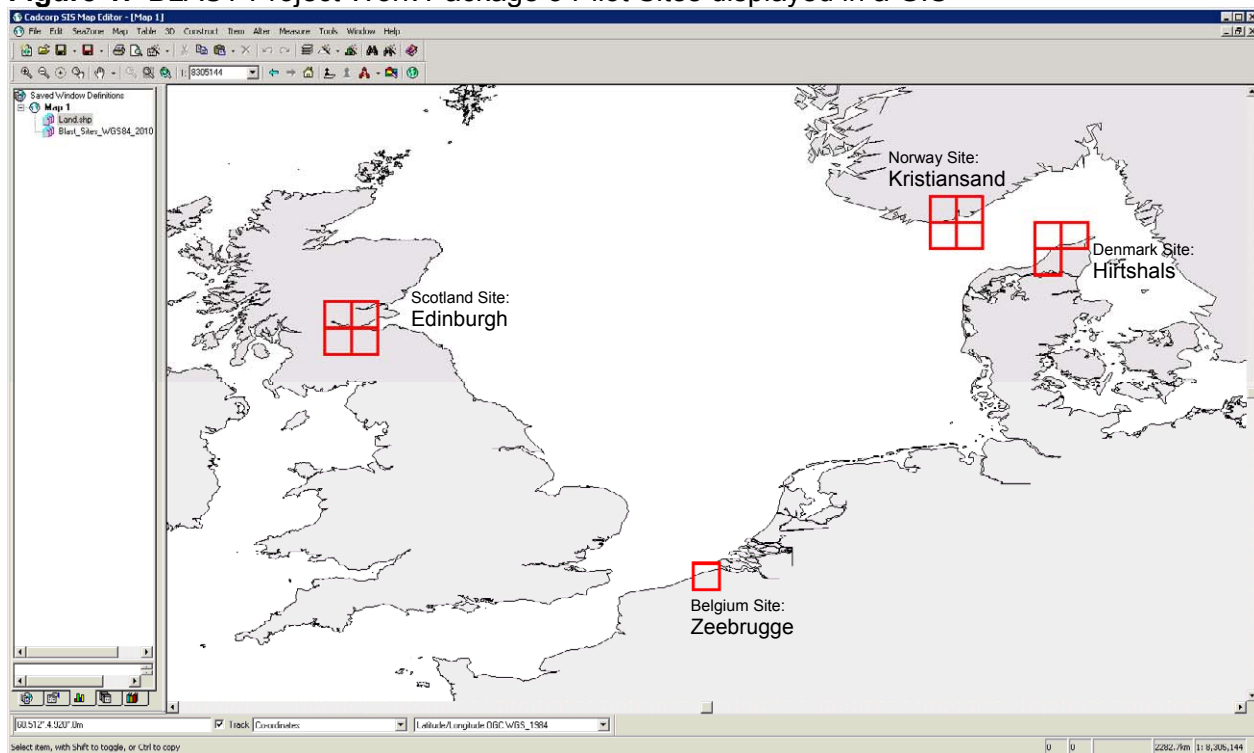
datasets or represented by only one dataset) will be edited such that the final project output will exhibit a single best-resolution depiction.

1.3 Project areas

Four project areas were chosen (by consent from all Project Partners involved in WP3) as pilot sites for the interoperable land-sea reference base. These sites were chosen to encompass a range of different marine environments (containing both natural and human-altered landscapes) to allow a methodology to be developed that can be applied across a wide range of geographical locations. The project areas chosen are listed below and shown in Figure 1 below.

- 1) Scotland Site: Edinburgh
- 2) Norway Site: Kristiansand
- 3) Denmark Site: Hirtshals
- 4) Belgium Site: Zeebrugge

Figure 1: BLAST Project Work Package 3 Pilot Sites displayed in a GIS



1.4 Overall methodology

At the start of the BLAST project, SeaZone was in the process of developing a Product Specification for its marine topographic data product range, HydroSpatial I and II.

However, due to the nature of the differing source datasets (formats, update regimes, encoding and attribution) used in these products, it was a significant challenge to up-scale to a North Sea level and harmonise all aspects of the data model to provide one North Sea wide data reference base. Therefore, part of the process for defining the BLAST interoperable land-sea reference base was identifying a more efficient way of creating and maintaining a Product Specification and underlying data model to encompass all four pilot sites.

It was decided that the best way of delivering a North Sea wide land-sea reference base would be to develop a HydroSpatial Base layer type product to show core features, upon which additional datasets can be layered (such as an integrated land-sea geology bedrock dataset), specific to a particular feature type or a particular geographical area. This base layer is then supplemented with the elevation surface to create the interoperable land-sea reference base.

Based on this methodology, the creation of the interoperable land-sea reference base will require two major inputs for each of the BLAST project areas:

1. Interoperable land-sea topographic data layer
2. Interoperable land-sea elevation surface layer

Separate methodologies (and associated tool development) have been created for each of these input layers, and these will be detailed in this report. Both methodologies can easily be up-scaled to create a North Sea wide reference base, if the required input data is available.

2 Methodology for creation of the interoperable land-sea topographic data layer

The following sub-sections detail the methodology for creating the interoperable topographic data for the Land-Sea Reference Base.

2.1 Data management and storage

Data collation has been undertaken in line with the requirements and recommendations of all WP3 Partners and from the outputs of the development of the Data Register (output from Work Package 3.2.0). Datasets can be grouped into general themes, which have been listed in Figure 1 below.

Figure 2: List of data themes pertinent to the development of an interoperable land-sea reference base

Coastline: MHW(S) / MLW(S) / LAT
Elevation: Bathymetry / Coastal LiDAR / Terrestrial Survey
Tidal Elevations: Surfaces
Tidal Elevations: Tide Stations
Seabed and Coastal Geology: Superficial Deposits
Seabed and Coastal Geology: Bedrock
Offshore Infrastructure: Oil & Gas Installations
Offshore Infrastructure: Cables
Offshore Infrastructure: Pipelines
Aquaculture infrastructure : e.g. fish farms
Wrecks, Obstructions and Navigational Hazards
Shoreline Constructions e.g. pontoons, piers, wharves, piles
National Limits and Boundaries: e.g. 12 Nautical Mile / Fishing / Continental Shelf
Licensed Development and Activity Areas: Aggregate Extraction
Licensed Development and Activity Areas: Renewables
Licensed Development and Activity Areas: Oil & Gas
Named Sea Areas: Marine Gazetteer
Protected & Conservation Areas
Flora & Fauna

Metadata for all datasets is managed as part of Work Package 3.2.0, with the creation of a Metadata Portal (see Annex B for screenshots).

In general, in order to develop a land-sea topographic reference base, a core terrestrial dataset and core marine dataset are used as base layers, upon which additional source datasets are added. These datasets vary across the project areas; there is not one dataset that covers all four project areas. The base marine datasets used across the project area are Electronic Navigational Charts (ENCs). An ENC is an official database created by a national hydrographic office or registered publishing agency. It conforms to standards stated in the International Hydrographic Organization (IHO) Special Publication S-57.

All datasets are assessed against a number of criteria, including accuracy, scale, provenance, geographical scope, capture scale and technique, currency, coordinate reference systems, geometries,

attribution, metadata and licensing terms. Results of this assessment fed into the specification of the Data Management Model. This assessment identified some key elements that would influence the development of the Data Management Model:

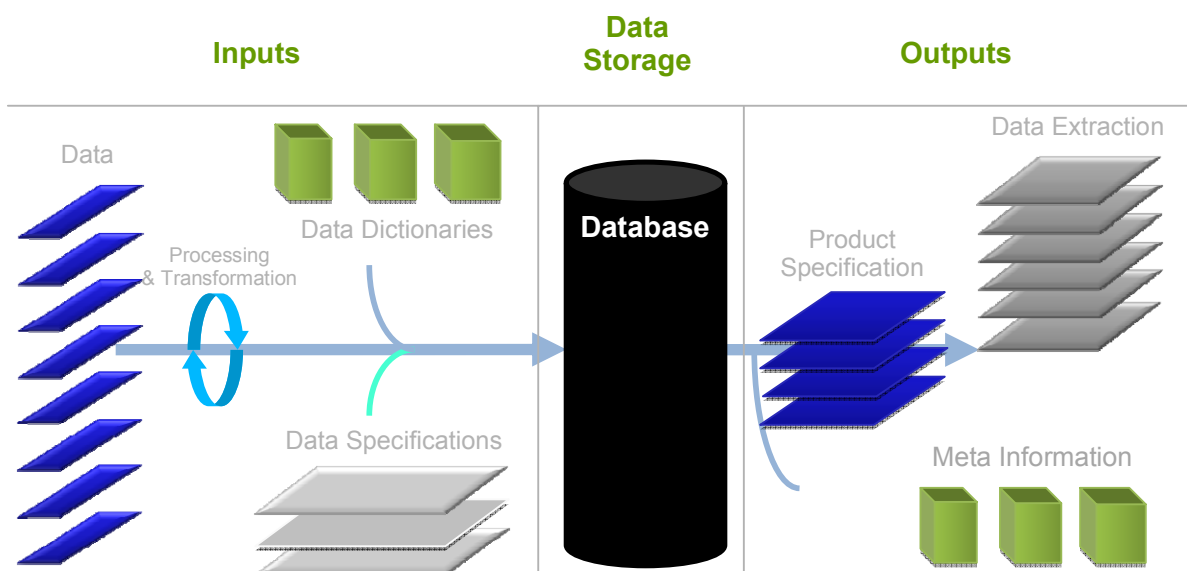
- Varying data standards
- Inconsistent data formats and types
- Inconsistent data encoding
- Inconsistent data attribution
- Inconsistent feature depiction and symbology
- Varying scale of data capture
- Varying data hierarchy and structures
- Varying horizontal and vertical reference frames
- Varying quality of feature geometries/topologies
- Vast quantities of data, updated frequently, some with Change Only Updates

In assessing the requirements for the data management model, three key factors had to be taken into account:

- Accessibility – Taking into account the types of data to be uploaded into the model, stored and extracted from the model, and the types of user needing to access maintain and update model
- Capacity – Taking into account the size and complexity of the data, how many concurrent users must the model support and what kind of spatial operations / processes must be undertaken.
- Compatibility – Taking into account the compatibility with different data standards and formats, software packages and applications.

A simplified diagram of the data model is shown in Figure 3, below.

Figure 3: Simplified diagram of the data management model



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The data management model was principally housed in an Oracle Database 11g Enterprise Edition 11.2.0.1.0

The database was set up in a series of schemas using relational database technology. Three core database schemas were set up, two topology schemas to hold the data and one product schema to hold the data product. An example of the one of the topology schemas is shown in Figure 4.

2.2 Topological data structures and the database

Within the database, the topographic data is structured using topology as a way of defining the interconnections between features. Topologised data allows us to structure data based on the principles of feature adjacency and feature connectivity, using a set of rules and behaviours that model how points, chains and polygons share geometry.

The data used as input in the BLAST project are delivered as simple geometries or features, such as points, lines and areas. The geometries in their topological form are referred to as “Seeds” (Point, Chain or Polygon), to emphasise their inherent difference from simple geometries. All seeds are constructed using a network of primitives. Primitives are therefore the geometric framework upon which seeds reside.

Primitives consist of a set of geometries (i.e. nodes and links) which provides the topology for making up points, chains and seeds, to ensure that all features connected use the same geometries. The benefit of this process is that the movement of one link or node moves all the objects connected to that primitive. This is the most efficient way of manipulating the data in the database.

Two topology models were developed in the Oracle database, one to manage the incoming ENC data and another to manage non-ENC terrestrial or coastal vector datasets. Figure 6 is an Entity Relationship Diagram of one of these topology models within Oracle.

All ENC data maintained to the S-57 standard was uploaded to a schema which was created specifically to host ENC data. The data was topologised at the point of upload. Within the database, the data was maintained in a series of relationship tables, some of which hold geometry information (including topology), whilst others hold object attribution.

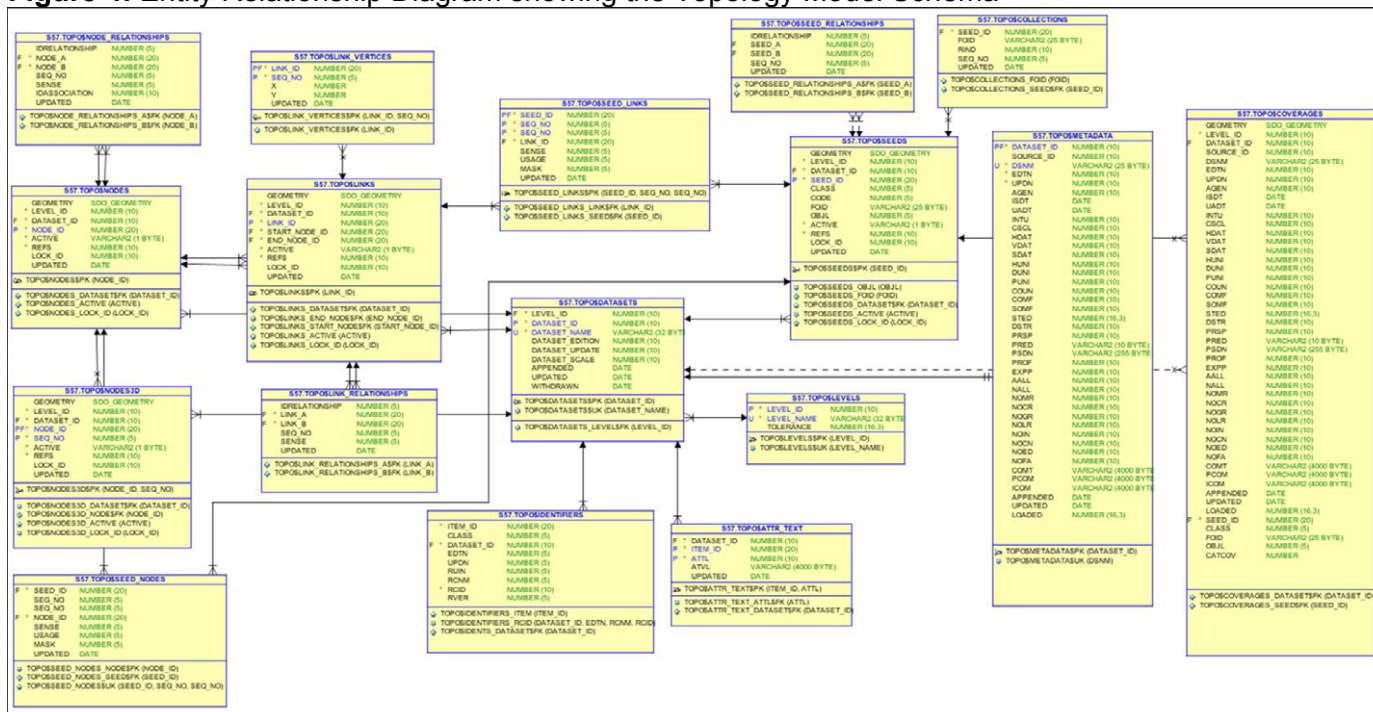
The non-ENC datasets, which do not conform to the S-57 standards, were treated as ‘source’ datasets and attributed with another ‘data level’ to segregate them within the database. These additional datasets were uploaded into a second ‘source topology’ model schema. The underlying topology model for the ENC and Non-ENC topology models is the same, but it is the unique nature of the ENC data, which conforms to S57 standards, that separates these two topology models.

In order to integrate ENC data with Non-ENC data, the data was brought into a common topology model to allow editing with a common set of topological primitives. The topologised ENC data was brought through into the ‘source topology’ model using a ‘cookie-cut’ function’ to remove overlaps from different scale levels.

Data stored within these two topology models is referenced to the Geodetic WGS84 coordinate reference system (EPSG code 4326 =urn:ogc:def:crs:EPSG::4326), therefore, any data being uploaded without this horizontal reference, had to be transformed first using SafeFME software or a GIS software package such as ESRI ArcGIS. In all cases, after consulting with source dataset provider, for this transformation,

parameters set out by the EPSG Geodetic Parameter Registry (which is maintained by the Geodesy Subcommittee of OGP <http://www.epsg-registry.org/>) were used.

Figure 4: Entity Relationship Diagram showing the Topology Model Schema



2.3 Data management toolkit

Data management tools were developed to allow the input data to be uploaded, mapped and specified within the database. These tools were developed to link the Oracle Spatial Database with the GIS software (specifically CadCorp SIS 6.2). The key tools developed are:

- 1) Source Data Upload Tool: Enables the user to select a dataset, specify metadata and upload into the specified database tables and schemas.
- 2) ENC Data Upload Tool: Enables the user to batch upload multiple ENC datasets into the specified database tables and schemas.
- 2) Data Mapping Tool: Allows the data columns and column values to be mapped to standard values specified in the dictionary of attributes and attribute values in the database, which helps the user to further define features, their attributes and the values of these attributes, in line with end user requirements.
- 3) Data Specification Tool: Allows the user to create a Data Specification at point of data upload. A dataset consists of a set of data representing features in the real world. Each feature may have several attributes to define its characteristics. An attribute can be of different types and therefore the values it takes are different. For instance, a value can be a single string or number, or a list of strings or numbers.

It can have a finite possibility of single values (i.e. enumeration) or infinite possibilities of values and combinations of values (i.e. list). In this project, datasets consist of a collection of rows and columns where a row represents a feature and a column defines a piece of information about this feature, an attribute. However, not all data from a source dataset are of interest to the project or not all of the attributes are of interest (for example identifiers that are used in the source providers own database), and so a specification is defined to link together the data of interest within the dataset and the central storage in the database. This data specification is created at point of data upload and allows fast data refresh as an up-to-date version of the dataset becomes available.

2.4 Product Specification

2.4.1 Creating the Product Specification within the Database

Within the data management model, a Product Specification has been developed as a series of relational database tables. This Product Specification has been developed with three main objectives:

1. Identifies, for the interoperable land-sea reference base, what feature types should exist in the product, and defined attributes and attribute values for each feature type
2. Defines, within the database, the hierarchy within which a feature or a number of features sit
3. Specifies the datasets from which the data is sourced in the development of the interoperable land-sea reference base

The Product Specification is used to:

1. Control the product build process
2. Create the Feature Catalogue – by extracting the implementing rules and hierarchy from the Product Specification and publishing these into a single xml file
3. Create the Application Schema – by extracting the implementing rules and hierarchy from the Product Specification and publishing these into a single xml file.

In conjunction with the creation of the Product Specification, Data Dictionaries were developed to allow feature encoding to be translated in the database into human-readable attributes.

The overall data structure used within the Product Specification was developed as a series of Topics, Themes and Sub Themes. A summary of which feature types have been included in this structure, is shown in Figure 7 below.

Figure 5: Overall data structure showing Topics, Themes and Sub Themes

TOPIC	THEME	SUB THEME
Bathymetry and Elevation	Bathymetry	Depth contour
Bathymetry and Elevation	Bathymetry	Dredged area
Bathymetry and Elevation	Bathymetry	Sounding
Bathymetry and Elevation	Bathymetry	Depth area
Bathymetry and Elevation	Elevation	Land elevation
Environment and Heritage	Environmental Indicators	Water
Environment and Heritage	Habitats and Biotopes	Habitats
Environment and Heritage	Habitats and Biotopes	Species
Environment and Heritage	Heritage and Wrecks	Historic Features

TOPIC	THEME	SUB THEME
Environment and Heritage	Heritage and Wrecks	Wrecks
Environment and Heritage	Heritage and Wrecks	Historic Indicators
Environment and Heritage	Protected Site Designations	Conservation Sites
Environment and Heritage	Protected Site Designations	Heritage Sites
Environment and Heritage	Protected Site Designations	Parks
Environment and Heritage	Protected Site Designations	Reserves
Environment and Heritage	Protected Site Designations	Sanctuary Sites
Geographical Cover	Sea Cover	Ice Area
Geographical Cover	Sea Cover	Sea Area
Geographical Cover	Sea Cover	Seabed Forms
Geographical Cover	Sea Cover	Water Turbulence
Geographical Cover	Land Cover	Coastline
Geographical Cover	Land Cover	Land Area
Geographical Cover	Land Cover	Vegetation Cover
Geographical Cover	Land Cover	Land Forms
Geographical Cover	Hydrology	Hydro Feature
Geographical Cover	Hydrology	Water Body
Geographical Cover	Hydrology	Water Course
Geographical Cover	Geology and Sedimentology	Bedrock
Geographical Cover	Geology and Sedimentology	Geo-Activity
Geographical Cover	Geology and Sedimentology	Sedimentology
Marine and Coastal Infrastructure	Constructions	Coastal Defences
Marine and Coastal Infrastructure	Constructions	Military Constructions
Marine and Coastal Infrastructure	Constructions	Standalone Structures
Marine and Coastal Infrastructure	Constructions	Shoreline Constructions
Marine and Coastal Infrastructure	Constructions	Stations-Terminals
Marine and Coastal Infrastructure	Installations	Cable and Pipeline Installations
Marine and Coastal Infrastructure	Installations	Docking-mooring Installations
Marine and Coastal Infrastructure	Installations	Industrial Installations
Marine and Coastal Infrastructure	Installations	Navigational Installations
Marine and Coastal Use	Activity and Licence	Aquaculture and Fisheries Activity
Marine and Coastal Use	Activity and Licence	Land Use
Marine and Coastal Use	Activity and Licence	Licensed Area
Marine and Coastal Use	Activity and Licence	Military Activity
Marine and Coastal Use	Activity and Licence	Oil and Gas Activity
Marine and Coastal Use	Activity and Licence	Production-storage area
Marine and Coastal Use	Activity and Licence	Renewable Energy Activity
Marine and Coastal Use	Activity and Licence	Other Activity
Marine and Coastal Use	Admin and Regulation	Administration Area
Marine and Coastal Use	Admin and Regulation	Limits and Boundaries
Marine and Coastal Use	Social and Demography	Health and Safety Activity
Marine and Coastal Use	Social and Demography	Services
Marine and Coastal Use	Social and Demography	Tourism and Recreation
Marine and Coastal Use	Transportation and Communications	Communication Activity
Marine and Coastal Use	Transportation and Communications	Traffic Regulation
Marine and Coastal Use	Transportation and Communications	Transport Activity
Marine and Coastal Use	Transportation and Communications	Transport Routes
Meteorology, Climate and Oceanography	Climate Change Data	Emission Scenarios
Meteorology, Climate and Oceanography	Model Output Data	Flood Risk
Meteorology, Climate and Oceanography	Model Output Data	Sediment Mobility
Meteorology, Climate and Oceanography	Oceanographic Data	Derived parameters
Meteorology, Climate and Oceanography	Oceanographic Data	Remote Sensor
Meteorology, Climate and Oceanography	Oceanographic Data	Smart Buoys Network

TOPIC	THEME	SUB THEME
Meteorology, Climate and Oceanography	Tides and Currents	Currents
Meteorology, Climate and Oceanography	Tides and Currents	Tide Line
Metafeatures	Extents	Compilation scale of data
Metafeatures	Extents	Coverage
Metafeatures	Extents	Horizontal datum of data
Metafeatures	Extents	Horizontal datum shift parameters
Metafeatures	Extents	Nautical publication information
Metafeatures	Extents	Navigational system of marks
Metafeatures	Extents	Production information
Metafeatures	Extents	Sounding datum of data
Metafeatures	Extents	Units of measurement of data
Metafeatures	Extents	Vertical datum of data
Metafeatures	Survey	Accuracy of data
Metafeatures	Survey	Control point
Metafeatures	Survey	Measurement location
Metafeatures	Survey	Quality of data
Metafeatures	Survey	Survey reliability
Metafeatures	Survey	Unsurveyed area
Metafeatures	Survey	Cartographic
Metafeatures	Survey	Aggregation
Metafeatures	Survey	Association
Metafeatures	Survey	Text
Metafeatures	Metadata	Metadata

2.4.2 INSPIRE compliance

Each of the features in the Product Specification has a searchable attribute that identifies the relevant INSPIRE theme and feature type from those INSPIRE data specifications already published in Annex I. This enables users to filter and query for features in line with INSPIRE themes. For features that are expected to fall under themes within Annex II & III, an attribute identifies the ‘suggested INSPIRE Theme and Feature Type’ which can be updated as Annex II & III are published. For features which SeaZone believe should fall within Annex I, but have not been defined as an INSPIRE Feature Type, this is also added as a ‘suggested’ INSPIRE Theme and Feature Type.

Each feature will have associated with it, the following INSPIRE related attributes:

- INSPIRE Theme (INSPTH): A grouping of spatial data according to Annex I, II and III of the INSPIRE Directive
- INSPIRE Feature Type (INSPFT): A spatial object type or abstraction of a real world phenomenon as defined in the INSPIRE Directive.
- Suggested INSPIRE Theme (INSPTH): Suggested grouping of spatial data according to Annex I, II and III of the INSPIRE Directive

- Suggested INSPIRE Feature Type (INSPFS): Suggested spatial object type or abstraction of a real world phenomena as defined in the INSPIRE Directive.

Users can query for attribute values from these fields to find all features of interest.

2.5 Data editing and data integration







2.5.1 Data editing toolkit

In order for terrestrial and marine datasets to be harmonised along the coastline, the topology of the data has to be edited using a topology editing tool. This tool allows a user to edit the topology of the data so that one seamless data layer is produced, incorporating both terrestrial and marine data. The TOPO Tool was developed as a plugin tool to link the Oracle Spatial Database with the GIS software (specifically CadCorp SIS 6.2).

2.5.2 Automatic data hard clip

For the ENC data, individual datasets are supplied according to scale level, as shown in the Figure 8 below.

Figure 6: Nominal scales for each ENC cells per level

LEVEL_ID	Level	Colour		Nominal Scale
1	Overview	Blue		1:500,000
2	General	Turquoise		1:200,000
3	Coastal	Green		1:75,000
4	Approach	Orange		1:25,000
5	Harbour	Red		1:10,000
6	Berthing	Violet		1:5,000

Within any one geographical area, multiple ENC datasets may exist at different scale levels. Data in and around harbours, will be gathered at the higher scales (Berthing, Harbour or Approach), while offshore data, where there are less hazards to navigation are gathered at the lower scales (Overview, General).

Within the database, an automatic hard-clip was undertaken in order to maintain the best available scale data in each pilot site. This hard-clip maintained the best scale dataset (highest scale) then clipped each of the next best scale surrounding datasets.

2.5.3 Coastline edge matching

The aim of this task is to produce a single continuous best available representation of the coastline from the ENC data, using the links of the best scale data available.

Once the automatic hard clip of the data is completed, an edge-matching process has to be applied to all coastline links and nodes along the edge of the ENC cells to create a seamless continuation of the feature between them. Within the GIS, the TOPO Tool is used to match the edges of the coastline feature by selecting and combining the nodes at the ENC boundaries, as shown in Figure 9 below.

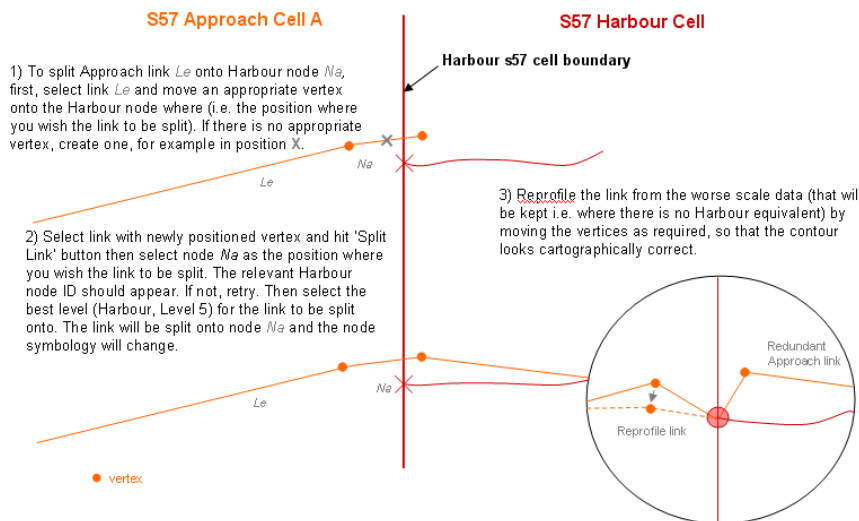


Figure 7 (left): Edge matching between different-scales: Splitting links from smaller scale data onto larger scale data.

Due to the differences between the scales of depiction in the same scale range, the actual mean scale could differ between both ENC coverages and therefore this stage in the method may also be required along the boundaries of ENC cells that lie within the same scale.

2.5.4 Conflict resolution

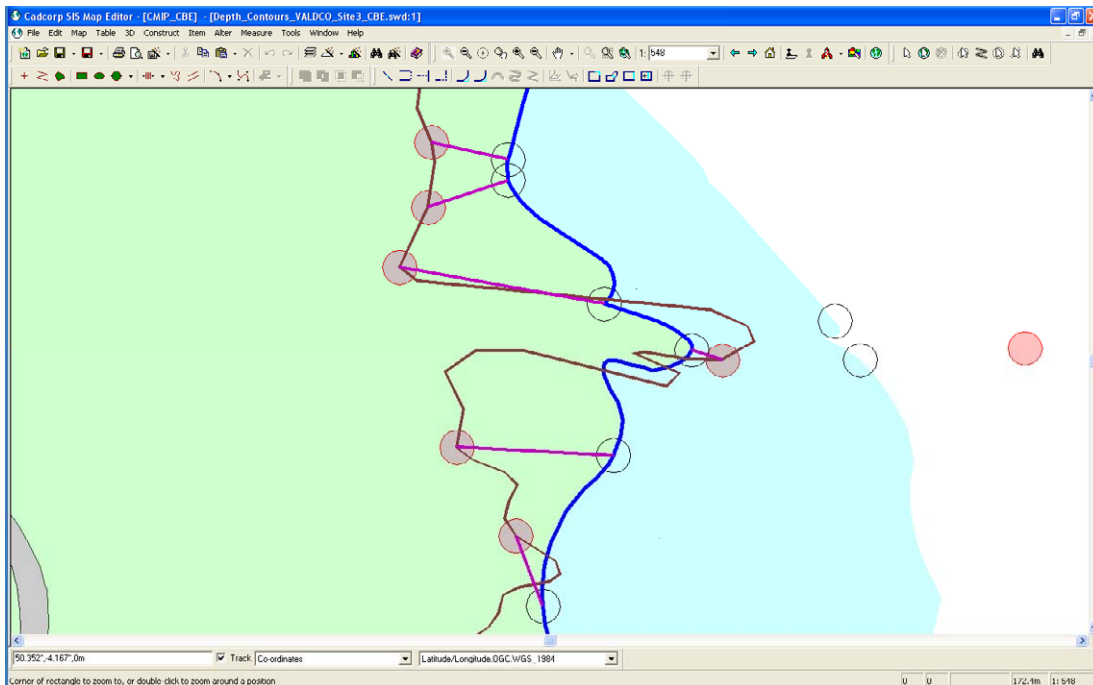
This method aims to produce, in one topological layer, the best available data from different data sources at varied levels of detail. Conflicts are likely to happen during this process and it is the editor's role, using the context information (e.g. satellite imagery) and common sense, to spot the conflicts and to find the best way to resolve them.

For example, when there is enough evidence to show that a feature in question is wrongly displayed in the data, the feature can be re-profiled or relocated to a correct location. This can be done using the TOPO Tool in the GIS.

2.5.5 Coastline association

The aim of this task is to produce a single continuous representation of the coastline by associating the links from the marine coastline feature to the links of the terrestrial coastline feature. This association is conducted using the TOPO Tool and allows the GIS technician to identify a link, selecting both of its nodes and moving these onto the appropriate nodes of the terrestrial data, thus the links become associated. The process is shown in Figure 10 below.

Figure 8: Association of links and nodes between the terrestrial coastline feature (blue line) and marine coastline feature (brown line)



To maintain the integrity of the data, a threshold in line with the scale of dataset exists in the process and nodes are not moved if the distance between them falls outside this threshold.

This feature association methodology is conducted where the terrestrial data is considered to depict the real world more accurately (i.e. captured to a better scale) than the marine ENC. For the BLAST pilot sites, this is the case for the UK, Denmark and Norway, however, for the Belgium, the terrestrial source datasets were smaller scale than the marine ENC datasets, and so the association was reversed (i.e. the terrestrial coastline was associated to the better scale marine coastline).

2.5.6 Merge land based features

The purpose of this stage is to identify features along the coastline which lie beyond the MHW line, (such as piers, pontoons, bridges, or offshore structures), present in both the marine and terrestrial datasets and merge them to create the best scale representation of the feature. To do this, the TOPO Tool is used to merge the seeds from both datasets onto a new dataset level, and transferring the attribution and geometry of the feature onto this level. This method could only be conducted for the UK pilot site – data for each of the other pilot sites was not detailed enough to require this stage to be completed.

2.5.7 Product Build

Following geometry and attribute editing, the final product was built in the destination schema in Oracle. This product build reflects all the geometric and attribution edits applied in the previous stages mentioned

above. The product build procedure populates the product tables with feature types, attributes and attribute values, as per Product Specification.

2.6 Data extraction

The data was extracted from the Oracle product tables within the product database schema in line with the Product Specification using an Extractor Tool. This extractor tool was developed in FME. Required geographical extents are specified within the GIS and the Extractor Tool references these extents and extracts all the feature types (and attributes) listed in the Product Specification. Data is extracted to the user required formats (usually Personal Geodatabase).

2.7 Quality assessment and testing

A number of quality checks are undertaken at each stage of the methodology, as follows:

ENC data upload: The ENC Data Upload tool checks, as each dataset is uploaded, if any features have failed to upload and if any files have been rejected. Using attribution, checks are made in the database to identify if ENC's have been withdrawn, cancelled, reissued or replaced. Issues are resolved as necessary. History is available in the database to record every ENC dataset change.

Source data upload: As source datasets are uploaded into the database, queries are created in the database to identify if feature counts are correct, if update dates are revised and if feature and attribute mapping has worked correctly.

Topology edits: Following any edits made in the topology model in Oracle, database queries are created to identify any missing links, dead links and geometry spiking. Issues are resolved as necessary.

Data extraction: Following data extraction, feature type counts, attribution, mapping and symbology are all checked in the output data files. Data formats are checked by opening files in relevant software packages.

3 Methodology for creation of the interoperable land-sea elevation surface layer

3.1 Data management and storage

3.1.1 Data management model

Bathymetry and Elevation data for the BLAST project is stored in the SeaZone Bathymetry Data Model which has been designed specifically to store XYZ data within a database environment to maximise the potential for management and analysis of the data.

It consists of:

- Storage tables within an RDMS (Oracle)
- (PL/SQL, COM and VCL)
- Loader Tool (Standalone)
- Viewer Tool (Cadcorp GISLink)
- BathySIS (Post processing Analysis, Contouring & Visualisation Tool)

The system manages Soundings within a database and controls the associated ISO19139 Metadata. It stores the data and metadata centrally, allowing for recent surveys to be deconflicted and therefore temporal analysis to be accomplished – including generation of the “most recent or appropriate” surface.

During the upload process, the data is split in to the blocks of 250,000 soundings for the ease of management. Approximate boundary generation can be completed as part of the uploading process.

The tools can optionally create and store a surface based on the points. This allows for accurate boundary generation, visual or themed quality checking and subsequently 3D display.

Within a GIS application, the data can be visualised and selected. Soundings can be selected and removed manually, giving options for maintenance of the Latest or Best surveys depending on the criteria used for selection. The data can then be used in Grid based analysis.

There are various options for exporting the data from the Model, either as XYZ, TIN or Boundaries.

3.1.2 Data management tools

A Bathymetry Data Loader has been created to upload XYZ data into the data model in Oracle. This tool connects directly to the database and batch imports data into the model. It manages the localised Metadata, but also detects and uploads the ISO19139 Metadata if this is available with the dataset.

It has options to:

- translate both the coordinates and the orientation of the original dataset
- create surfaces, sorts (bins) and boundaries
- edit user specified tolerances

A Bathy Viewer Tool has been created as an extension to Cadcorp SIS to enable the user to view the bathymetry data that is held in the database. This Tool connects directly to the Model in the associated database. It contains functionality to select and view the datasets – boundaries, surfaces or actual soundings; to edit the data within the model, as well as the localised Metadata and to regenerate features once editing has taken place. This functionality prepares the data for onward analysis, for example in BathySIS. This tool inherits all the standard tools and visualisation capabilities that are available within the GIS.

3.2 Product Specification

The requirement was to develop an elevation surface for each BLAST WP3 Pilot Site, to be used as an interoperable layer in the Land-Sea Base Reference. This elevation surface is described as a coverage based dataset. Coverage is represented by a simple grid consisting of a set of rows and columns, providing organisation to a set of pixels/grid cells. Each pixel/grid cell contains attribution relating to elevation, in metres.

This elevation surface is a geo-referenced elevation model of the seabed, supplied as gridded data. These grids have been extracted from a high resolution model created from deconflicted, best available bathymetry. The model is made up, preferentially, of high density, recent LIDAR or multibeam data. In areas where this is unavailable the next best available bathymetry data is used, whether this is less recent multibeam data, high density single beam data or, in the worst case, best scale charted bathymetry data.

3.3 Creation of the elevation surface

3.3.1 Data inputs

Data inputs used for the surface models are shown in Figure 9 below.

Figure 9: Formats and Reference Systems of the various elevation datasets received.

Pilot Site	Organisation	Data Type	Horizontal CRS	Vertical Datum	Format
Norway	Norwegian Mapping Authority	Bathymetry	WGS84 UTM 32N	Chart Datum	.xyz
Norway	Norwegian Mapping Authority	Terrestrial	EUREF89	NN1984	.xyz
Denmark	Danish Maritime Safety Administration	Bathymetry	WGS84 UTM 32N	DVR90	Binary Grids
Denmark	National Survey and Cadastre (KMS)	Terrestrial	ETRS89 UTM 32N	DVR90	.txt
UK	Ordnance Survey	Coastal DEM	OSGB36 BNG	Ordnance Datum Newlyn	.dxf, .ntf
UK	British Geological Survey	LiDAR	OSGB36 BNG	Ordnance Datum Newlyn	.xyz
UK	British Geological Survey	Bathymetry	WGS84 UTM 30N	Chart Datum	.xyz

UK	UK Hydrographic Office	Bathymetry	WGS84 LL	Chart Datum	Oracle DB
Belgium	Flemish Hydrography	Bathymetry	WGS84 UTM 31N	Lowest Astronomical Tide	.txt
Belgium	Agency for Maritime and Coastal Services (MCS)	LiDAR	Lamert72	TAW	.txt

3.3.2 Data preparation and survey deconfliction

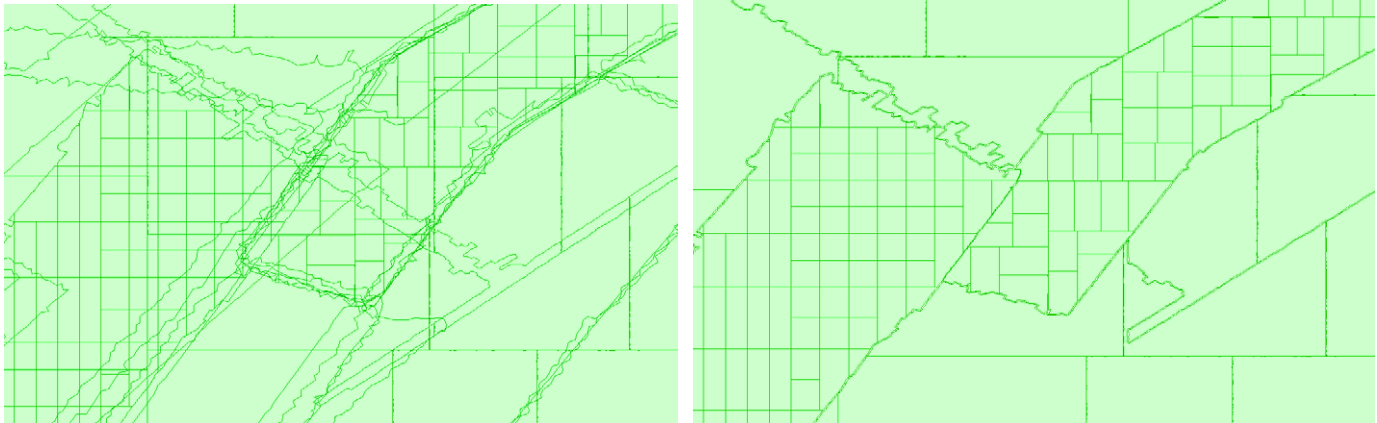
After the data is uploaded in the database it must go through a process of survey deconfliction before it can be used as input into the surface modeling. Bathymetry survey datasets are uploaded into the SeaZone bathymetry database in XYZ format. Depending upon the sub-sampling specification made by the relevant Hydrographic Office at the time of post processing, the sounding density will vary from one multi beam survey to another. Boundaries around survey soundings are detected from the edge links of a Triangulated Irregular Network (TIN) and therefore provide a close fitting, mathematical extent around the soundings to aid in the survey deconfliction (where required). These boundaries are checked and if necessary, edited.

Typically in any one area, there may be numerous overlapping surveys, particularly in areas that are surveyed regularly. The aim of the survey deconfliction is to create a single seamless surface of soundings representing the most up to date and most dense survey data available (i.e. no overlaps, thereby removing the likelihood of confounding the data in the modelling process). The work, referred to as 'survey deconfliction', is undertaken using specially designed applications that read survey points directly from Oracle.

The deconfliction work clips the many overlapping surveys against each other based on a number of rules or attributes, most importantly survey age, survey type and sounding density. The result is a set of modified survey extents which are clipped against one another to keep the best available data in full, creating a seamless surface of soundings. The clipped survey extents are used to label each sounding in the Oracle database, with an active or inactive identifier, so that only the active soundings from each survey are used as input into the elevation surface.

Figures 10 and 11 (over the page) show an area in the North Sea with numerous multi beam and single beam surveys overlapping one another. Specifically, Figure 10 is the unedited survey extents that require deconfliction, whilst Figure 11 shows the same area following survey deconfliction.

Figure 10 and 11: North Sea bathymetry survey extents, before (left) and after (right) deconfliction



Extraction of the soundings from deconflicted surveys on an area by area basis is done via the SeaZone Bathymetry tool. These are used as the data input into the elevation surface model.

Data supplied in .txt format (e.g. LiDAR) represents a continuous best-available surface of points and requires no deconfliction work. This data was uploaded into the database and used in the same way in the modelling process.

For gridded data, xyz points were extracted from grids at the resolution of 10m-50m, depending on the resolution of the original grids. These XYZ data was stored in the database, for use as input to the modelling.

As XYZ data is uploaded into the database, large files (>20MB) are split into more manageable blocks of 250,000 soundings to aid processing time.

All data used to create the surface model are initially transformed to geodetic ETRS 1989 coordinate reference system (EPSG urn:ogc:def:crs:EPSG::4258) for the purpose of modelling. Depths within the surface model are referenced to local Chart Datum, for the purpose of modelling.

3.3.3 Data modelling

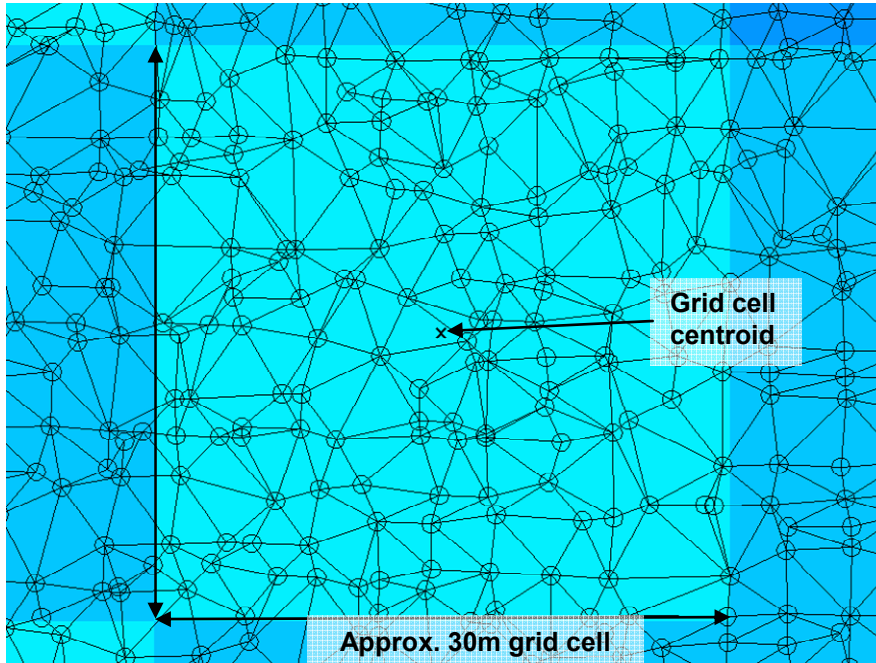
The surface model is created using BathySIS modelling software, CadCorpSIS Map Modeller both linked in to the Oracle Database.

Using BathySIS, XYZ data are used to create a triangulated irregular network (TIN) model, using Delaunay triangulation methods.

Using the TIN and a pre-determined grid cell spacing, BathySIS identifies the position of the grid cell centroid location and drills down into the corresponding TIN Surface (i.e. the face) to determine the interpolated height value from the face at that centroid location.

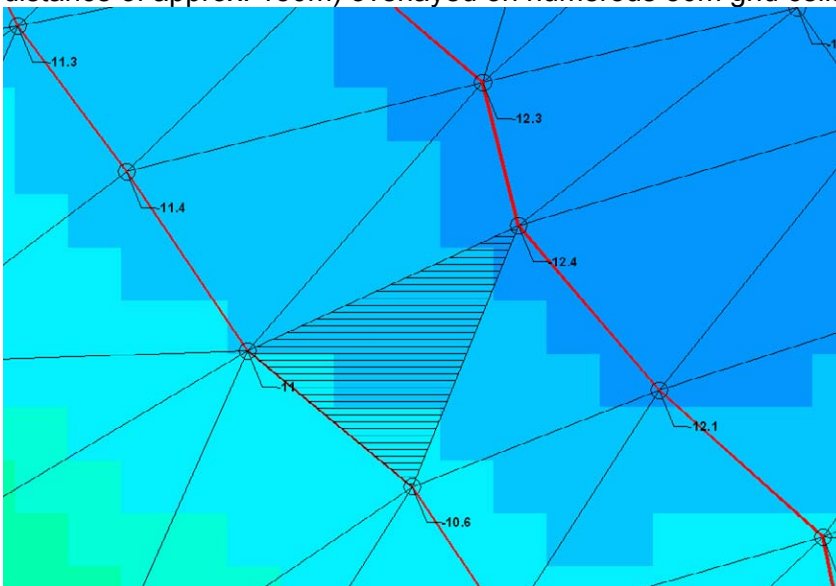
An example of an area modelled with dense multi beam data is shown in Figure 16 below, where 153 soundings intersect the grid cell shown. These soundings indicate proximal observations for the interpolated centroid value which gets applied to the grid cell.

Figure 12: Surface model created using dense multibeam data, at a 1arc-second resolution.



For areas modelled with coarser XYZ data, more typical of offshore areas, there may be more than one grid cell obtaining its height value from the same TIN face, but it will do so at different elevations depending on where the centroid of the grid cell sits within the TIN face. This is shown in Figure 17 below.

Figure 13: TIN surface created from coarse single beam survey data (with an average cross track distance of approx. 150m) overlaid on numerous 30m grid cells.



3.4 Data extraction

Using BathySIS, the elevation surface is exported to ESRI ASCII grid files of 1 arc second resolution. Using ESRI ArcGIS, the ASCII Grids were converted to Binary grids.

3.5 Quality assessment

Checking of the model output occurs on three levels:

- 1) Assessment of flat areas;
- 2) Assessment of spurious artefacts apparent in the bathymetry surface;
- 3) Checking for spurious triangulation;

If issues are identified, the area is remodelled based on an iterative case-by-case assessment.

3.6 Associated risks

The horizontal resolution of the data product is determined by the grid resolution (grid cell size). With cell postings every 1 arc second (urn:ogc:def:uom:EPSG::9104), this approximates to a resolution of between 20m and 30m for areas between 50 degrees North and 60 degrees North (the approximate latitude of the BLAST pilot site area).

The elevation surface is generated using data supplied by the various sources, but mainly from Hydrographic authorities. Much of this data is controlled to IHO standards for Hydrographic Surveys. These datasets are deemed by the Hydrographic authorities to be fit for the purpose that they were collected for and that they meet the specification given to the surveyor at the time of surveying. However, the current IHO S-44 Edition 5 specification for surveys allows for approximately 50cm vertical uncertainty in the data (1st order capture) for coastal surveys, and greater vertical uncertainty is permissible in offshore areas. Older editions and 2nd and 3rd Order capture of the existing edition allow for more uncertainty, for example Edition 1 in force in 1975 allowed for 1.0m depth and 0.5m tidal uncertainty. Occasionally, linear artefacts may be visible in the grids as a result of these levels of uncertainty in the source data.

4 Challenges in integrating marine and terrestrial data

4.1 Differences in scale of capture and resolution

In the UK, it is often the case that terrestrial topographic data is more accurate and captured to a higher scale than the marine ENC datasets. However, this is not the case for other national datasets, specifically Norway and Belgium.

Work on the Norwegian site data concluded that the terrestrial and marine data had the same scale of capture at Harbour level. In Belgium, the marine ENC datasets always displayed better depiction than the terrestrial datasets provided. These differences meant that the methodology needed to be flexible enough to take account of the differences in scale and the deconfliction processes could be edited to suit the dataset requirements.

4.2 Documentation and Metadata

Variations in languages across the BLAST project area have highlighted some issues with understanding data documentation. Improved communication with data providers is required in these instances. This has highlighted the importance of having clear documentation and formal metadata files to support a dataset.

4.3 Variations in file formats and horizontal and vertical reference frames

When several datasets need to be edited together within the database, common formats and horizontal and vertical references need to be used. One issue when dealing with datasets from several different countries and several different project partners is that there is no consistency in these factors and so time and resource need to be built into the project plan to ensure processing can take place to resolve these issues. When dealing with huge bathymetric data files, the processing time required for transformations before upload into the database and after extraction from the database takes a considerable length of time and so needs to be taken into account when planning resources for the work.

4.4 Data quantity / file size

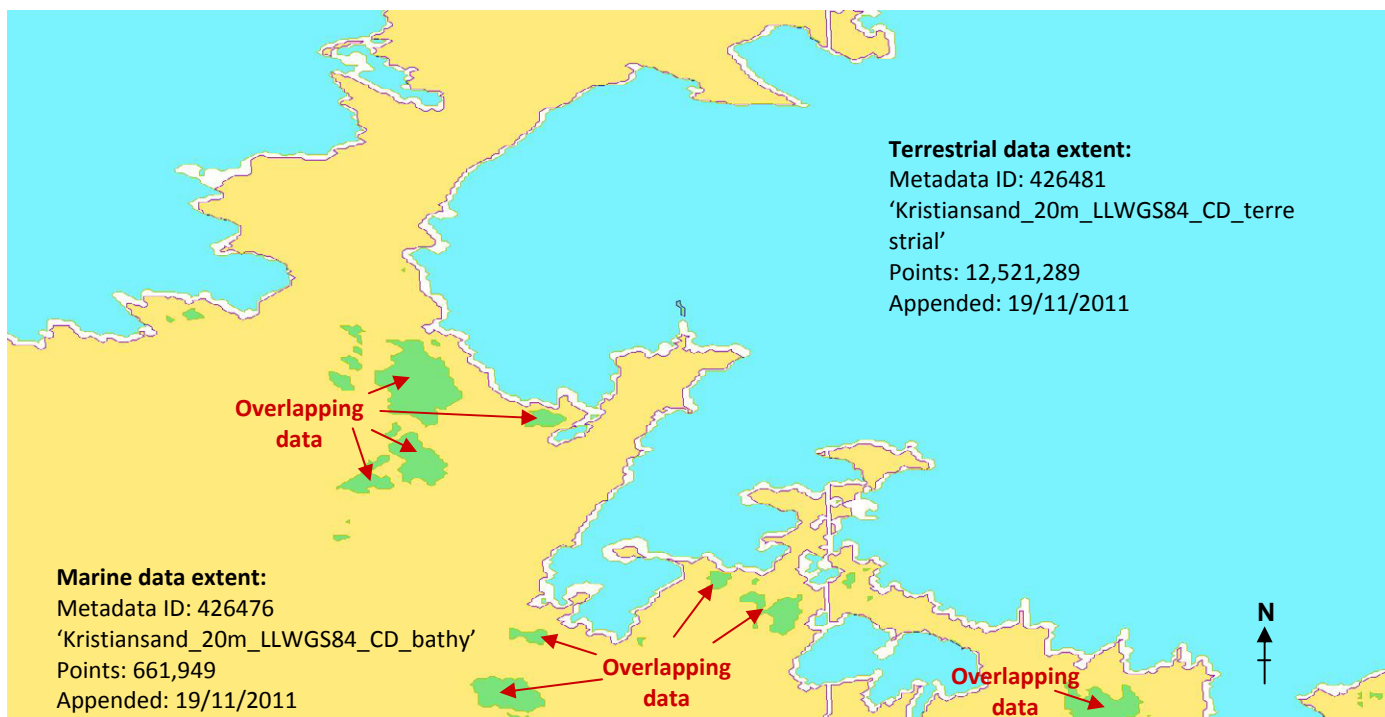
Bathymetric/LiDAR datasets used within the project were several gigabytes in file size and processing of these datasets often had to run overnight in the database. In particular, the density of the point data for the Belgium site did not allow the whole site to be processed at once, so the site had to be split into more manageable extents for modeling, then merged together.

4.5 Overlapping depth/height data

In some instances, the extents of the marine and terrestrial elevation data overlapped each other. In order to create the elevation surface, the decision has to be made which dataset takes priority in the model at each overlap. Decisions were made based on the following factors:

- 1) Density of data
- 2) Date of data capture
- 3) Method of data capture

Figure 14: Example in the Norway pilot site, where the terrestrial and marine datasets overlapped.



4.6 Gaps in depth/height data

Alternative data sources were investigated for any areas where there were significant gaps in the data (i.e. the distance between the terrestrial and marine datasets was >300m). For example, in the UK pilot site, some data gaps existed along the coast and to infill these, in the absence of any data with a better resolution, Charted Bathymetry data was used (depth soundings and contours).

In a few areas, particularly along the coast, there were gaps in the coverage where no data exists. An example of this can be seen in Figure 18, for the intertidal area surrounding the Fugløyne peninsula, south of Kristiansand Airport. In the absence of infill data, triangulation is created across the gaps

between the marine and terrestrial data. These are the areas where, for future work, additional surveying would be required to fill the data gaps.

Figure 15: Example in the Norway pilot site, where there are gaps in data coverage surrounding the Fugløyna peninsula, south of Kristiansand Airport.



5 Output data requirements and compliance

5.1 INSPIRE

All BLAST data deliverables should comply with EU regulations. For the project outputs relating to Work Package 3 (mainly spatial data), this includes a requirement to follow the INSPIRE data specifications and standards. At the time of executing the BLAST project, only the metadata and Annex I data specifications were available for use on the project. The specifications for Annex II and Annex III were still in development.

Accordingly BLAST adopted the Inspire metadata specifications for its deliverables and used the experience of BLAST to guide the development of the Inspire data specifications for Annex III. Members of the BLAST project were members of the Inspire drafting teams for Sea Regions and Oceanographic Geographical Features. An extract of the model developed for SeaAreas is given below in Figure 17.

Figure 16: SeaAreas data model

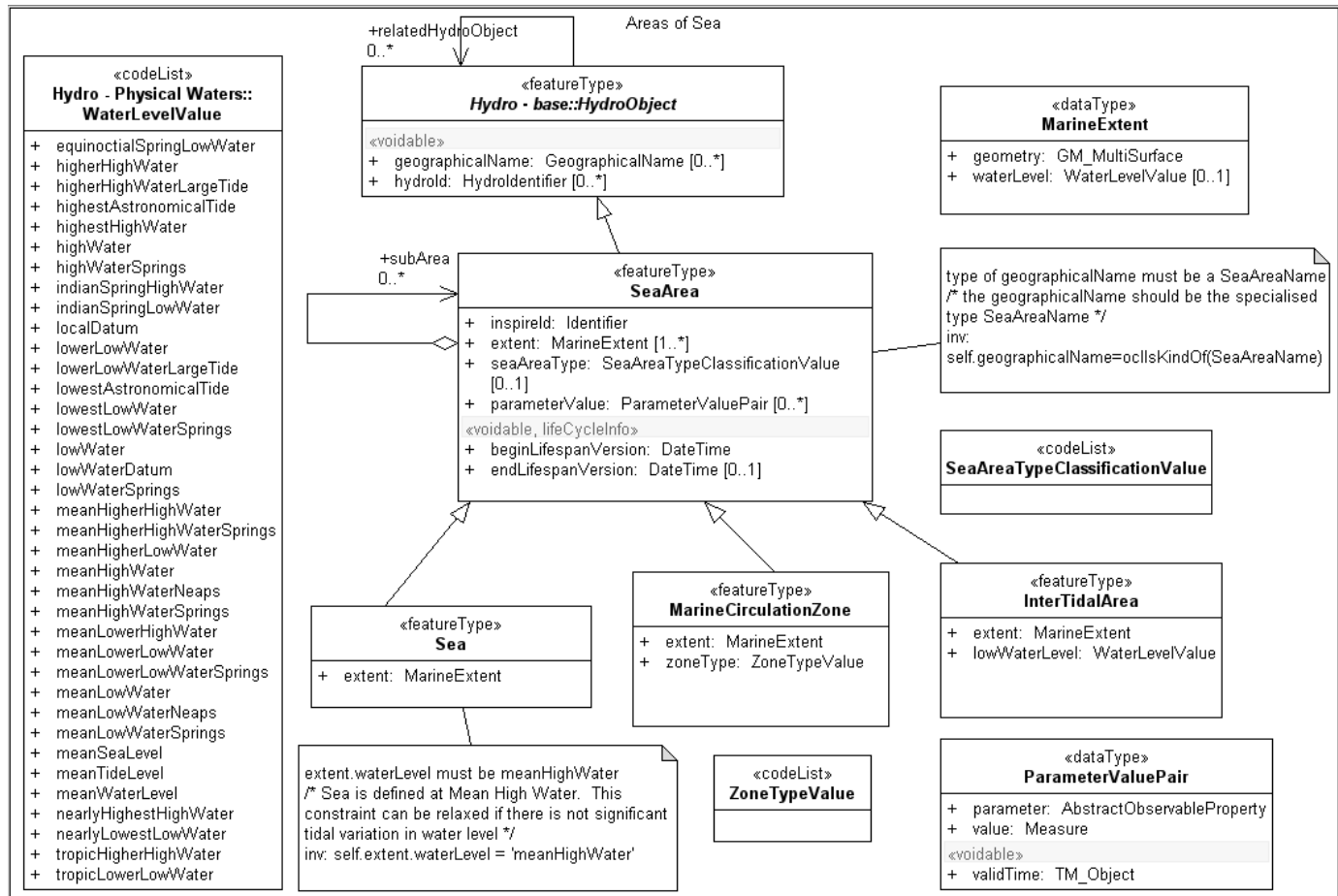
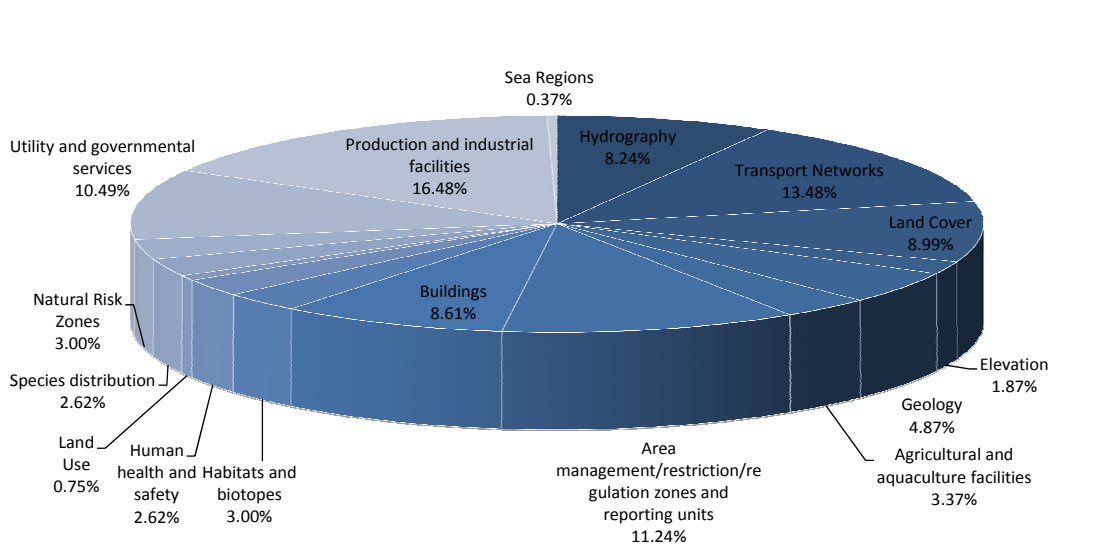


Figure 17 over the page shows a mapping of the BLAST Feature Types to the Inspire Data Themes. As can be seen from this, 'marine' topics such as Sea Regions and Hydrography represent less than 10% of the total feature types with most being attributed to Production and Industrial Facilities.

Figure 17: Mapping of BLAST feature types to the INSPIRE Data Themes



The INSPIRE data specifications (for Annex II and Annex III the current drafts were used) were evaluated for land-sea data interoperability, with two key objectives:

1) To identify project related feature types not currently contained within the standard

A number of feature types, that have significance in the development of an interoperable land-sea reference base, were found to be omitted from the standard. In particular, bathymetric datums, classification of seabed types and classification of shoreline types. Details of these have been fed back into the relevant INSPIRE Working Group.

2) To allow an INSPIRE compliant Product Specification, Application Schema and Feature Catalogue to be developed

Feature types within the Product Specification were mapped onto the relevant INSPIRE Themes Feature Types where possible (where the relevant Annex has been published). This ensures features have associated with them, specific INSPIRE related attributes (as detailed in section 2.4.2).

As well as the prototype interoperable land-sea reference base being compliant with the INSPIRE data specifications (where developed), the output data also adheres to the general INSPIRE principles, including:

- Use of input data that has been collected only once in any one area
- Storage of data in a database where it can be maintained most effectively

- Development of a seamless spatial dataset, created from numerous different sources, that can be shared across many users and applications
- Easy to access, search, query and evaluate data using a variety of tools and applications
- Project outputs available to all project partners for decision making and analysis

5.2 Vertical and Horizontal References

As part of the INSPIRE data specifications, there are recommendations for the use of Horizontal and Vertical Reference Systems. For the height component, INSPIRE mandates the use of the European Vertical Reference System (EVRS) for the areas within the geographic scope of EVRS. Other vertical reference systems may be used in areas that are outside the geographical scope of EVRS. In terms of map projections for the representation of data in plane coordinates in general applications, the projections recommended by the “European Reference Grids” workshop and by the “Map Projections for Europe” workshop are mandated as Lambert Conformal Conic (ETRS-LCC) for conformal pan-European mapping at scales smaller or equal to 1:500,000 (EPSG: 3034; urn:ogc:def:crs:EPSG::3034;ETRS89 / LCC Europe)

Output data was transformed to these specified reference systems using the following:

1) Vertical transformation: BLAST Height Transformation Tool, developed as part of Work Package 3 (3.5) to allow vertical transformation between various source vertical datums and the recommended vertical reference system. This tool is made available via the BLAST Project website (<http://www.blast-project.eu/index.php?page=articles&artid=167>).

2) Horizontal transformation: SafeFME, and ArcGIS, using defined parameters within the software or specifying transformation parameters available from the EPSG Registry (EPSG: 3034; urn:ogc:def:crs:EPSG::3034;ETRS89 / LCC Europe).

5.3 Output data formats

Feedback from other Work Packages within the BLAST project has defined the output data format requirements for Work Package 3. The interoperable Land-Sea Reference Base data was supplied via FTP in the following formats:

Topographic data - ESRI Personal Geodatabase and fully symbolized ESRI Workspace .mxd document

Elevation surface - ASCII Grids and Binary Grids 1arc-second resolution

Images of the outputs (interoperable land-sea reference base) of this work package are shown in Annex C.

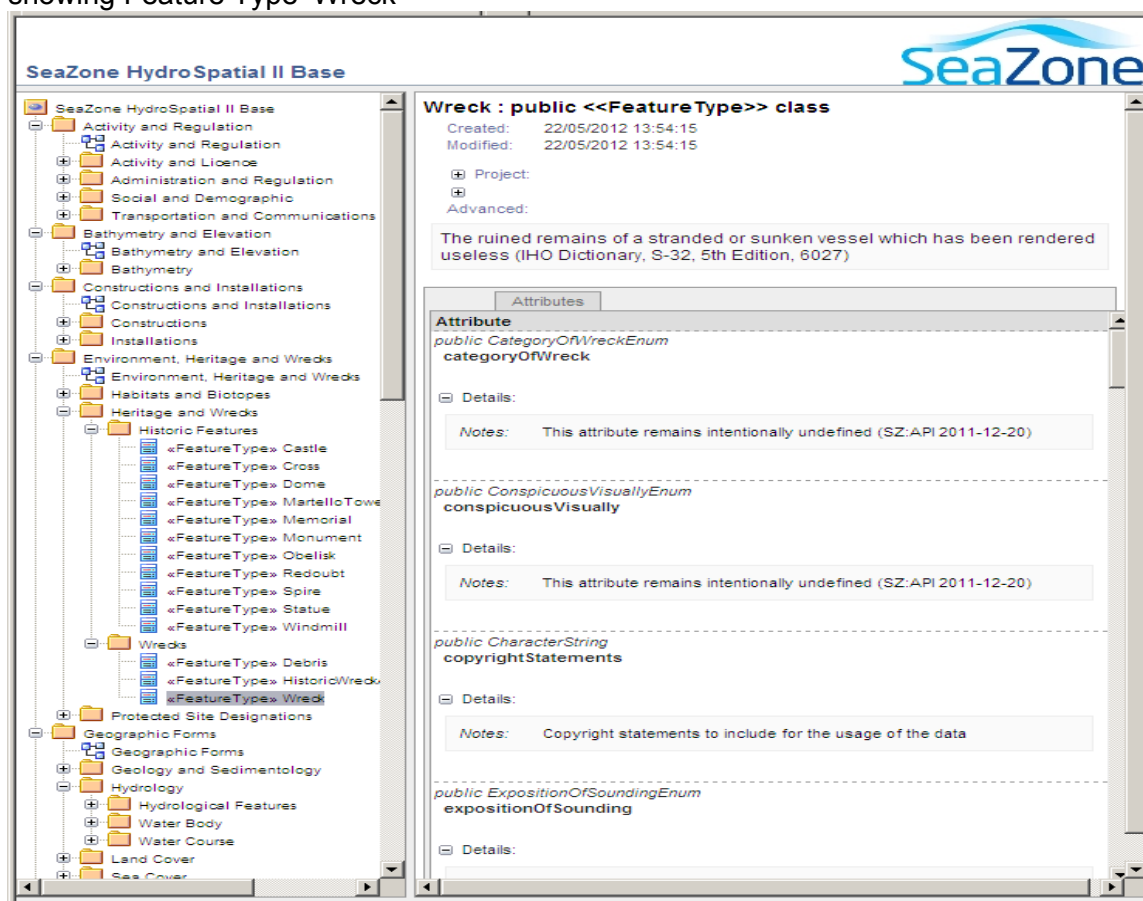
6 Application Schemas

INSPIRE compliant Application Schemas were developed for the prototype interoperable land-sea reference base, to support reference base encoding (see Figure 18 below).

Feature type definitions were extracted from an Oracle based Feature Catalogue using an application written in Microsoft C#. Data extracted from the catalogue were written to an Enterprise Architect (EA) file using the EA Microsoft .NET API. This file was created in such a way that, when opened in EA, it produced a UML (Unified Modelling Language) model which formed the application schema. Feature types comprised of classes in the normal way.

The application schema is a very simple data tool that shows a set of unrelated UML classes, however, its creation was useful because it allowed the visualisation of the data in the feature catalogue and highlighted some issues which were corrected (for example, attribute inconsistencies). When creating the application schemas, the convention of using UpperCamelCase for class names and lowerCamelCase for attribute names was followed.

Figure 18: Screenshot of the HydroSpatial Application Schema developed for the BLAST Project, showing Feature Type 'Wreck'



7 Feature Catalogue

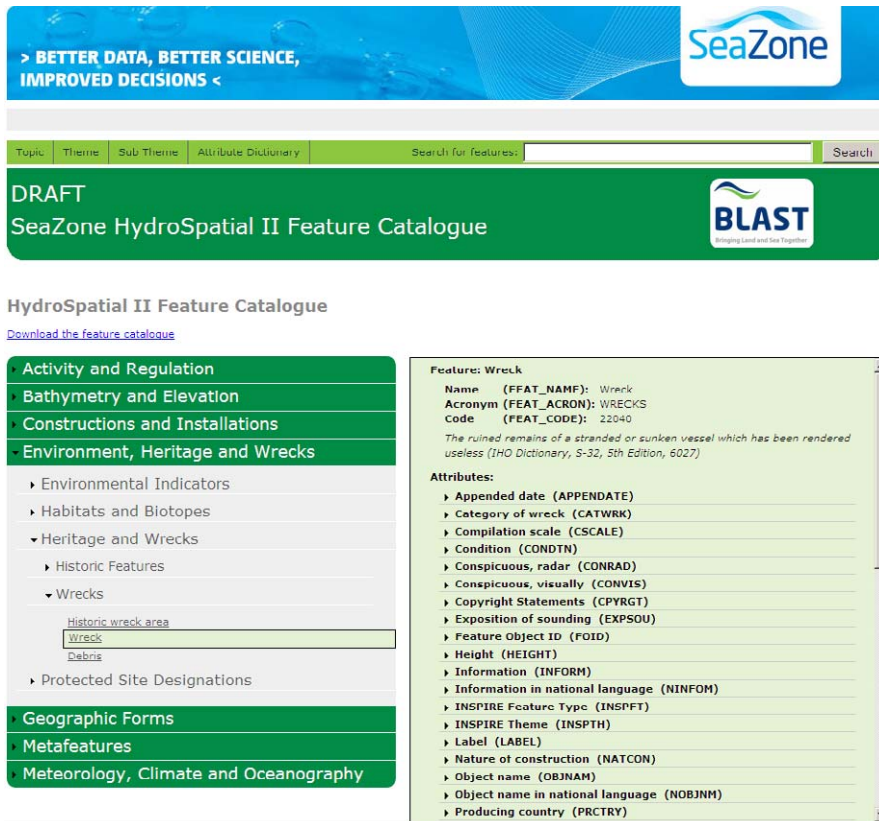
An INSPIRE compliant Feature Catalogue was developed for the interoperable land-sea reference base, to support user requirements (see Figure 19 below).

The Feature Catalogue is comprised of two main components:

- 1) A single ISO 19110:2006 compliant XML document
- 2) A set of HTML pages that provide a visual and searchable representation of the XML document

The XML document is created by mapping items in the Product Specification to corresponding elements in the ISO 19110:2006 schema. These mappings are then used to generate XML elements for each feature in the product.

The ISO 19110:2006 schema does not contain elements that can represent the hierarchical classification of feature types used in the BLAST data product. As the hierarchy is valuable for the HTML representation of the catalogue an additional XML document is created to summarise this classification.



The screenshot shows the 'SeaZone HydroSpatial II Feature Catalogue' interface. At the top, there is a blue banner with the text '> BETTER DATA, BETTER SCIENCE, IMPROVED DECISIONS <' and the 'SeaZone' logo. Below this is a green header bar with the text 'DRAFT SeaZone HydroSpatial II Feature Catalogue' and the 'BLAST' logo. The main content area is divided into two panels. The left panel, titled 'HydroSpatial II Feature Catalogue', contains a sidebar with a tree view of feature categories: 'Activity and Regulation', 'Bathymetry and Elevation', 'Constructions and Installations', 'Environment, Heritage and Wrecks', 'Geographic Forms', 'Metafeatures', and 'Meteorology, Climate and Oceanography'. The 'Environment, Heritage and Wrecks' category is expanded, showing sub-categories like 'Environmental Indicators', 'Habitats and Biotopes', 'Heritage and Wrecks', and 'Wrecks'. The 'Wrecks' category is further expanded, showing 'Historic wreck area', 'Wreck', and 'Debris'. The right panel, titled 'Feature: Wreck', displays the details for the 'Wreck' feature. It includes the Name (FFAT_NAME): Wreck, Acronym (FEAT_ACRON): WRECKS, and Code (FEAT_CODE): 22040. Below this is a description: 'The ruined remains of a stranded or sunken vessel which has been rendered useless (IHO Dictionary, S-32, 5th Edition, 6027)'. The 'Attributes' section lists various metadata fields such as 'Appended date (APPENDATE)', 'Category of wreck (CATWRK)', 'Compilation scale (CSCALE)', 'Condition (CONDITN)', 'Conspicuous, radar (CONRAD)', 'Conspicuous, visually (CONVIS)', 'Copyright Statements (CPYRGRT)', 'Exposition of sounding (EXPSOU)', 'Feature Object ID (FOID)', 'Height (HEIGHT)', 'Information (INFORM)', 'Information in national language (NINFOM)', 'INSPIRE Feature Type (INSPFT)', 'INSPIRE Theme (INSPTH)', 'Label (LABEL)', 'Nature of construction (NATCON)', 'Object name (OBJNAM)', 'Object name in national language (NOBJNM)', and 'Producing country (PRCTRY)'.

For the HTML Feature Catalogue, individual HTML files are created directly from the ISO 19110:2006 XML document for each feature and for each attribute.

A navigation framework document is created from the summarised classification using a set of HTML templates. This framework contains links to the individual feature and attribute documents; when a user selects a feature or attribute the appropriate document is displayed in a panel within the framework.

Figure 19 (left): Screenshot of the HydroSpatial Feature Catalogue developed for the BLAST Project, showing Feature Type 'Wreck'

8 Potential future developments

8.1 Data enhancements

The following enhancements should be considered when investigating project extensions / improvements:

- Supplementing the reference base with additional thematic layers, such as average sea surface temperature, significant wave height and ocean colour (or proxies thereof).
- Digitising of additional datasets that would have significance in the project, such as shipping density data.
- Using the outputs from research projects such as those relating to flood risk, renewable energy site suitability, seabed characterisation, seabed scour models etc to supplement data layers.
- Where depth/height data gaps exist in coastal/intertidal areas, additional air borne, water borne or mobile LiDAR surveys could be conducted, to ensure full data coverage.
- Extending pilot sites to incorporate wider project areas.

8.2 IHO S-100 audit

Full audit of the IHO S-100 Hydrographic Geospatial Standard for Marine Data to help enhance the BLAST Product Specification.

The current s57 has many limitations which affect the BLAST project, notably, the lack of flexibility in allowing feature type updates through a consistent feature encoding system and the unsupported data formats, such as gridded bathymetry.

The development of the IHO Bathymetric Surface Product Specification S-102, as the standard in which Hydrographic organisations will distribute their bathymetric products (for navigation and other use) will help support future BLAST output developments. This will ensure High-Definition Gridded Bathymetry data can be transferred more easily between geographical areas for use within projects such as BLAST.

9 References

INSPIRE Infrastructure for Spatial Information in Europe: D2.8.I.1 Specifications on Coordinate Reference Systems Draft Guidelines, v3.1, Published 03/05/2010.

Web reference: <http://inspire.jrc.ec.europa.eu/index.cfm/pageid/241/documentid/1696>

Annoni et al. (2003) "Map Projections for Europe" Annoni, Alessandro; Luzet, Claude; Gubler Erich u.a. (Eds.) Web reference : <http://mapref.org/Annonietal.2003-MapProjectionsforEurope.html#Zweig230>

Report on "BLAST vertical datums: Overview, conventions and recommendations" Published June 20, 2011. Authors: Strykowski G., O.B. Andersen, I. Einarsson and R. Forsberg (DTU Space, Denmark) L. Doorst; T. Ligteringen, (Hydrographic Service of the Royal Netherlands Navy, The Netherlands)

Web reference: <http://www.blast-project.eu/index.php?page=articles&artid=167>

Report on "BLAST Height Transformation Tool" Published October 25, 2011. Author: Indrisi Einarsson, DTU Space. Web reference: <http://www.blast-project.eu/index.php?page=articles&artid=167>

EPSG Geodetic Parameter Registry: <http://www.epsg-registry.org/>

"IHO S-100 The Universal Hydrographic Data Model" Author Robert Ward (International Hydrographic Bureau) and Barrie Greenslade (United Kingdom Hydrographic Office)

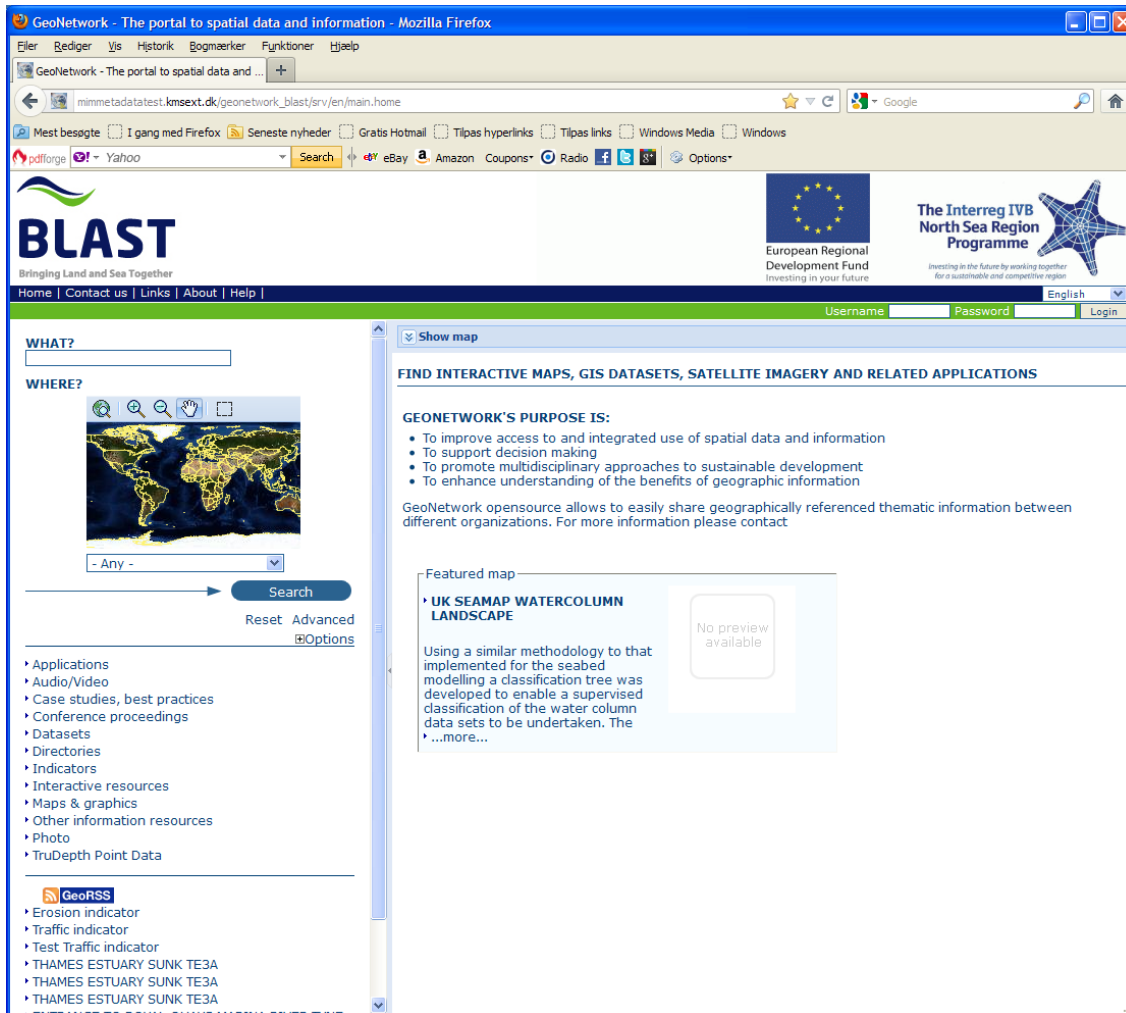
Annex A Software

The table below lists the software that has been used in the development of the BLAST project deliverables within the work activities described in this report.

Name	Description
Cadcorp SIS Map Modeller Version 6.2.1582	Cadcorp GIS Software used to undertake the data preparation, analysis and editing phases of the project
BathySIS Version 4.1.19	Bathymetry Modelling software package developed by Geomod and used to create elevation surfaces in ASCII grids
Oracle Database 10gR2 Enterprise Edition	Database software used to store all input data
ESRI ArcGIS Version 9.1 & 9.3.1	ESRI GIS Software used in some data preparation, analysis and editing phases of the project and in particular in the quality checking of the elevation model
SafeFME Desktop 2012 sp1	Spatial data management and transformation software, used in the development of workspaces for processes such as horizontal coordinate transformation.

Annex B Screenshot images of the Metadata Portal (referenced in 2.1)

Screenshot of Metadata Portal's homepage and an example of a dataset entry in the Portal:



Screenshot of Metadata Portal's homepage and an example of a dataset entry in the Portal:

The screenshot shows a web browser window displaying the GeoNetwork portal. The page features the BLAST logo and the Interreg IVB North Sea Region Programme logo. The main content area is divided into two sections: a search interface on the left and a detailed dataset entry on the right.

Search Interface (Left):

- WHAT?** and **WHERE?** search fields.
- A world map with a search overlay.
- A dropdown menu set to **- Any -**.
- A **Search** button.
- Links for **Reset**, **Advanced**, and **Options**.
- A list of categories including Applications, Audio/Video, Case studies, Conference proceedings, Datasets, Directories, Indicators, Interactive resources, Maps & graphics, Other information resources, Photo, and TruDepth Point Data.
- A **GeoRSS** section with links to Erosion indicator, Traffic indicator, Test Traffic indicator, THAMES ESTUARY SUNK TE3A, and THAMES ESTUARY SUNK TE3B.

Dataset Entry (Right):

- Identification info:**
 - Title: Licensed Disposal Sites
 - Date: 2009-11-13
 - Date type: Publication: Date identifies when the resource was issued
 - Abstract: The data shows spatial coverage of Licensed Disposal sites along with depth, country, distance offshore, the site licence number
 - Purpose: --Suggested use WP3--Suggested use WP6--
- Point of contact:**
 - Organisation name: Department of Environment, Northern Ireland
 - OnLine resource: <http://www.doeni.gov.uk/>
 - Role: Point of contact: Party who can be contacted for acquiring knowledge about or acquisition of the resource
- Descriptive keywords:** waste disposal , waste legislation .
- Topic category code:** Environment
- Extent:**
 - Geographic bounding box:**
 - WGS 84
 - North bound: 60.48000
 - West bound: -34.00000
 - East bound: 3.98000

Annex C Images of the interoperable land-sea reference base data layers

BLAST WP3

INTEROPERABLE LAND-SEA REFERENCE BASE IMAGES

Figure 1: **Norway Project Site (Kristiansand)**, showing interoperable land-sea topographic map

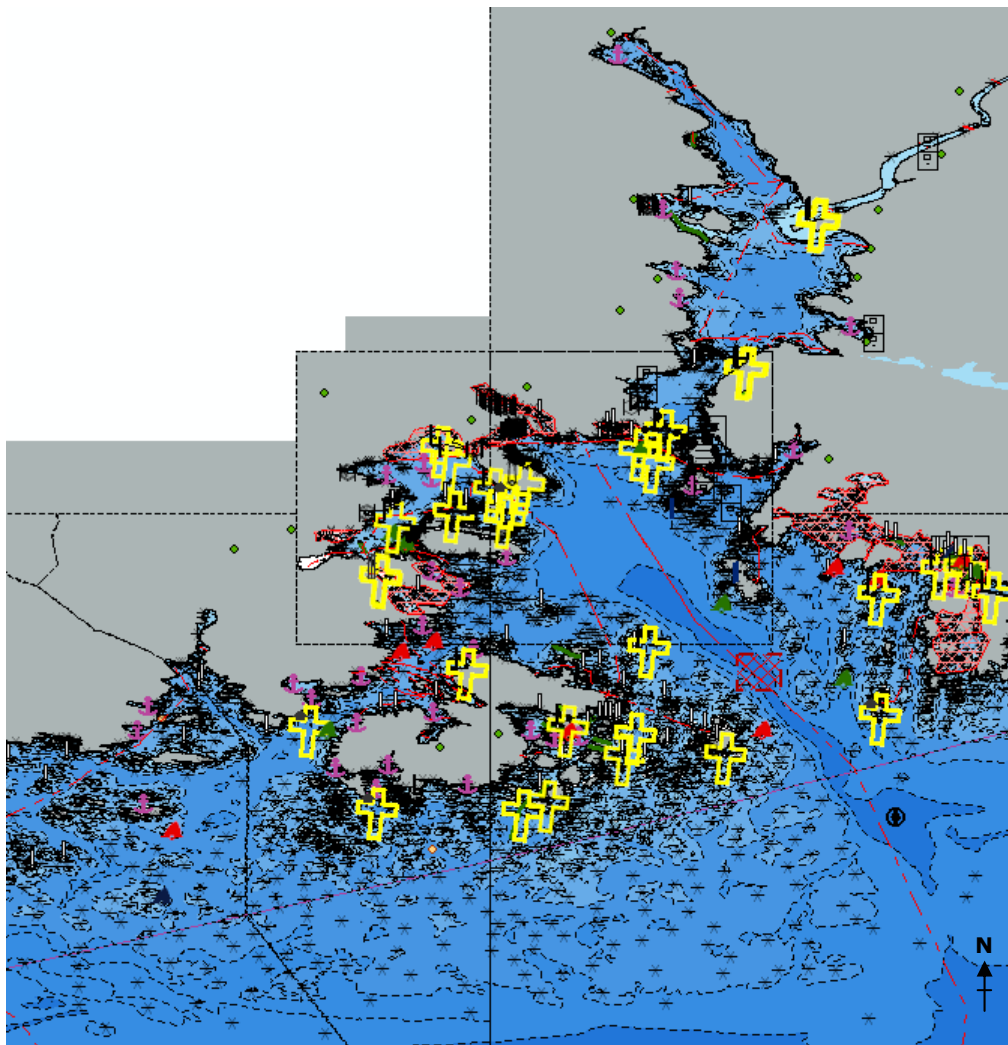


Figure 2: **Norway Project Site (Kristiansand)**, showing interoperable land-sea topographic map

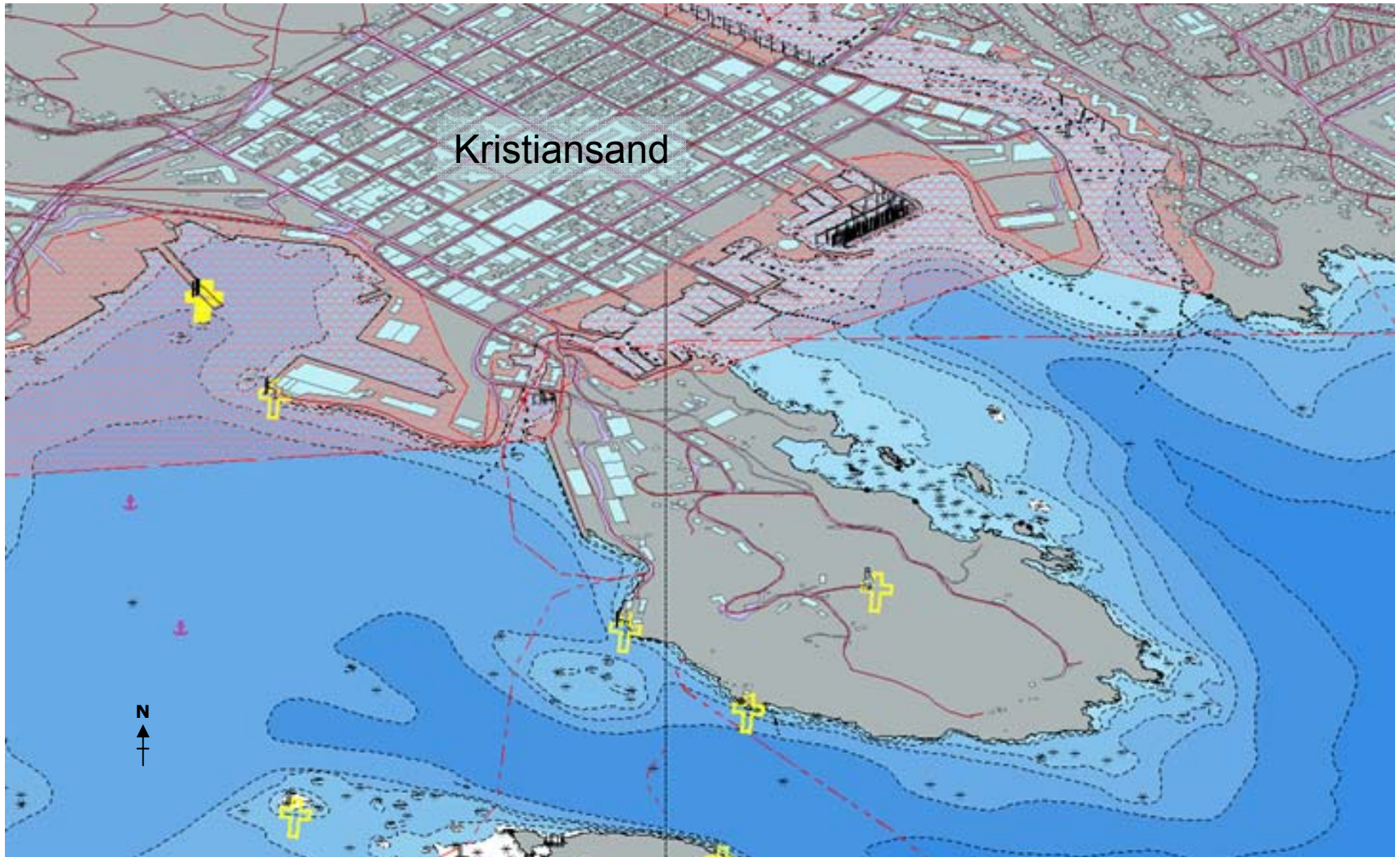


Figure 3: **Norway Project Site (Kristiansand)**, showing interoperable land-sea topographic map

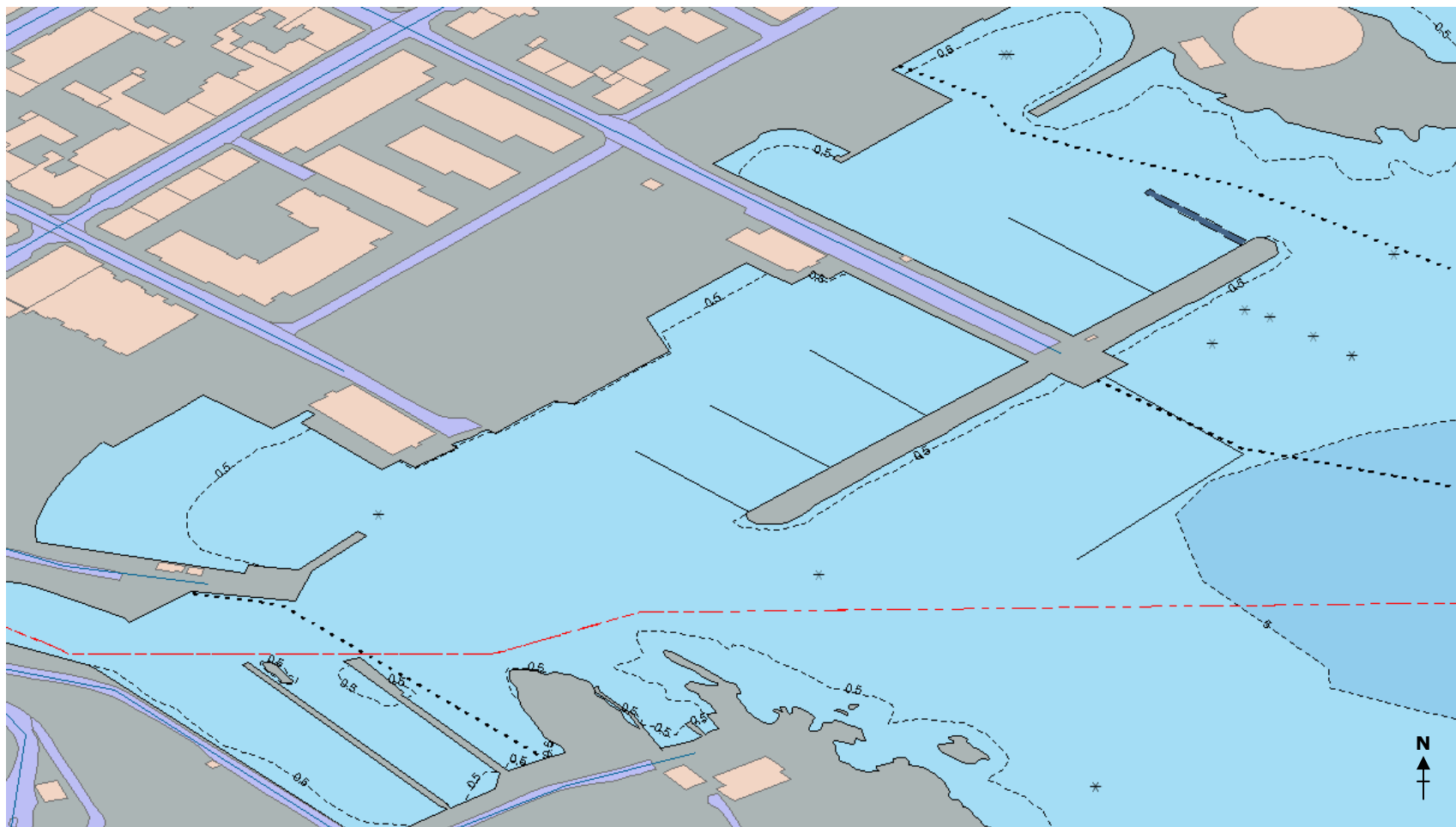


Figure 4: **Norway Project Site (Kristiansand)**, showing interoperable land-sea seabed sediments map



Figure 5: **Norway Project Site (Kristiansand)**, showing interoperable land-sea bedrock map

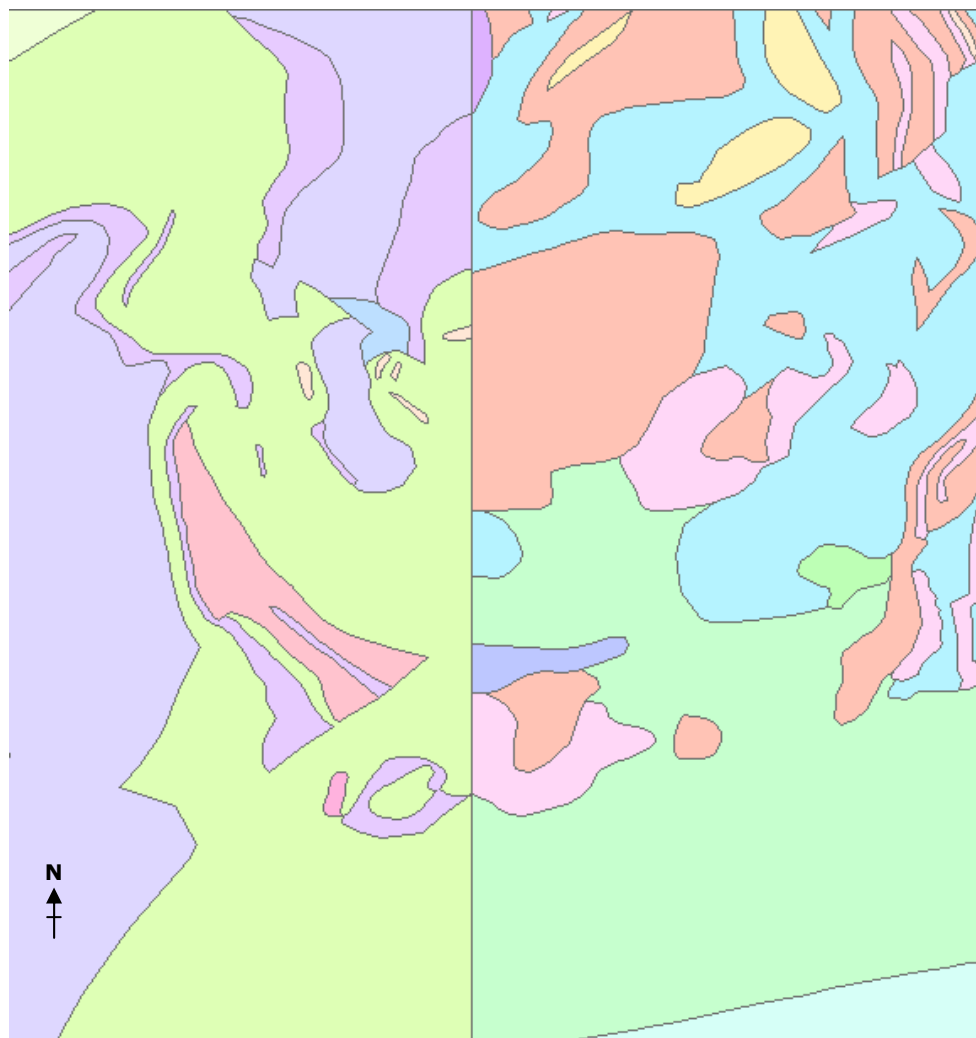


Figure 6: **Norway Project Site (Kristiansand)**, showing interoperable land-sea elevation map

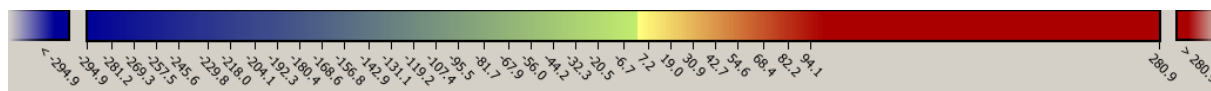
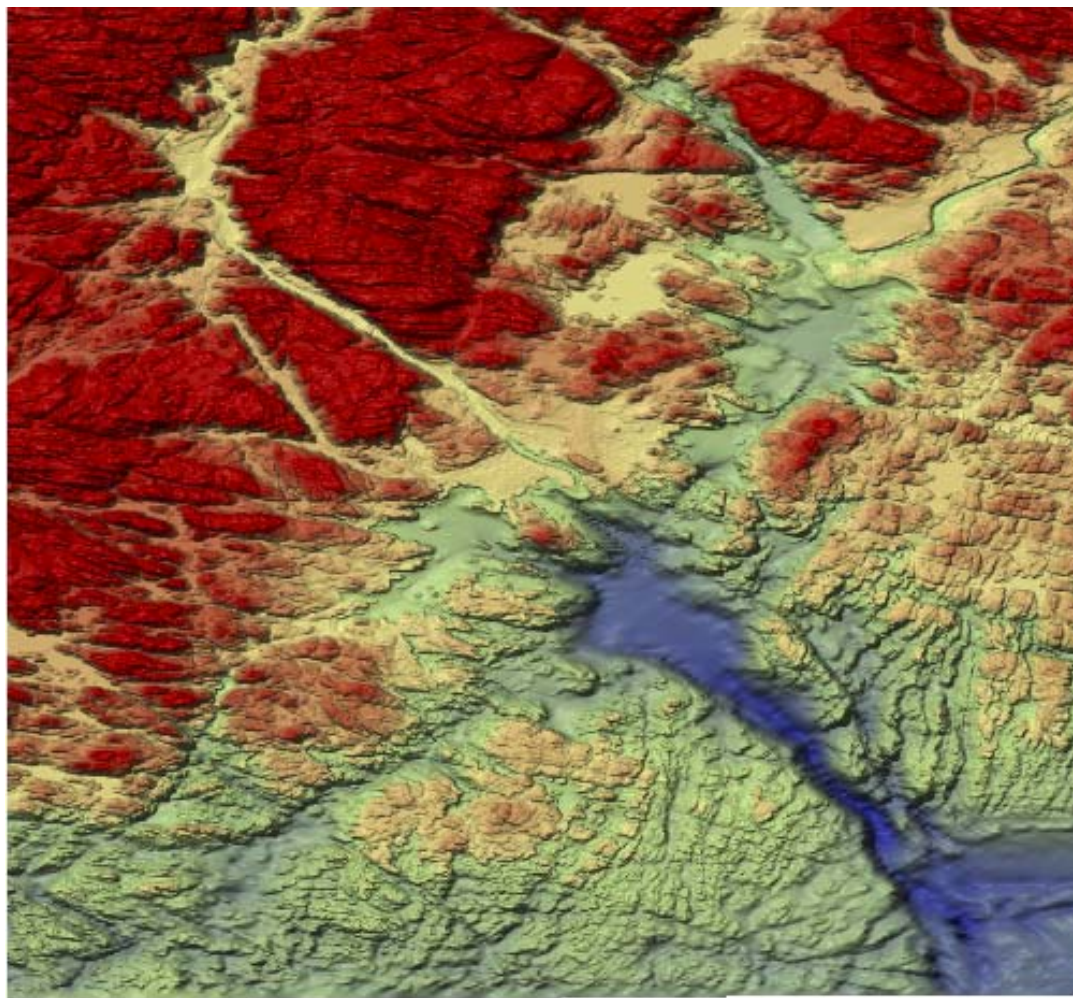


Figure 7: **UK Project Site (Edinburgh)**, showing interoperable land-sea topographic map

Firth of Forth

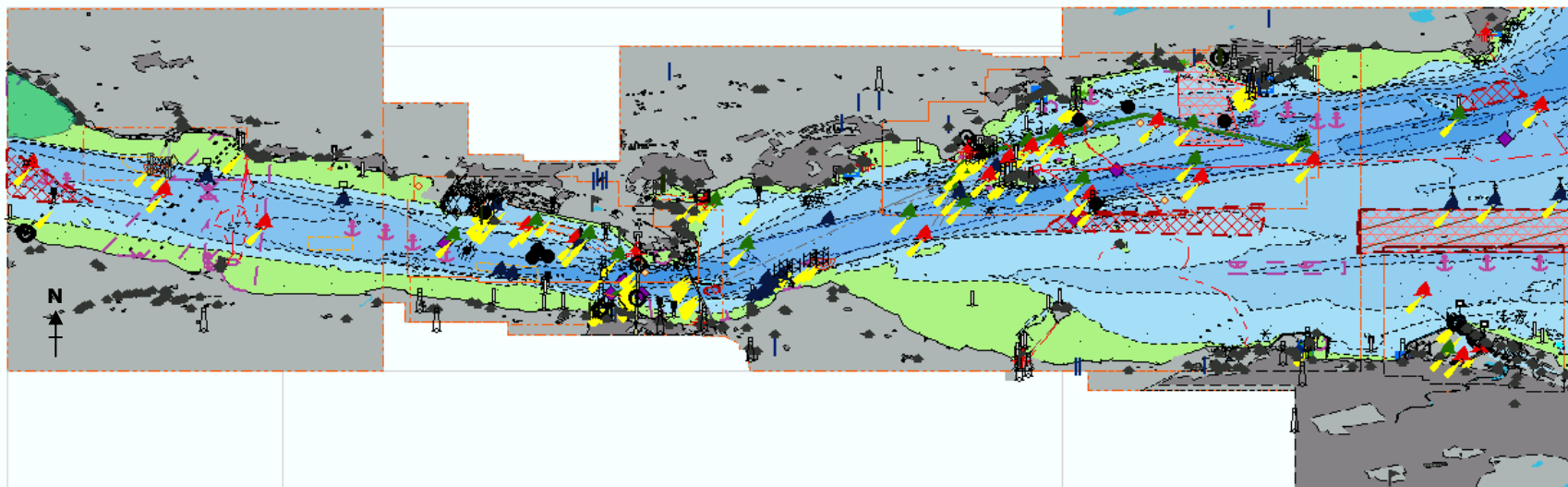


Figure 8: **UK Project Site (Edinburgh)**, showing interoperable land-sea topographic map

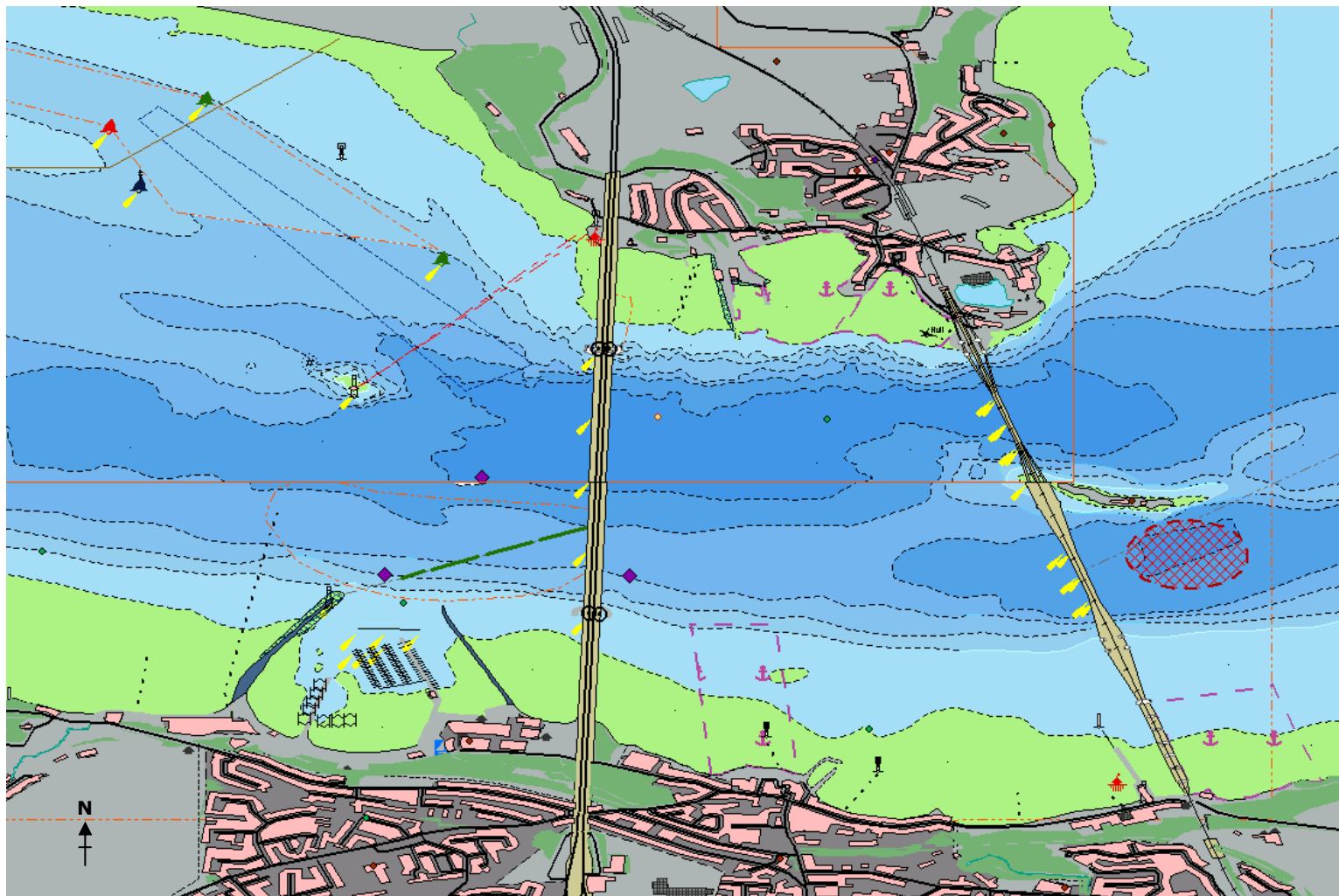


Figure 9: **UK Project Site (Edinburgh)**, showing interoperable land-sea topographic map

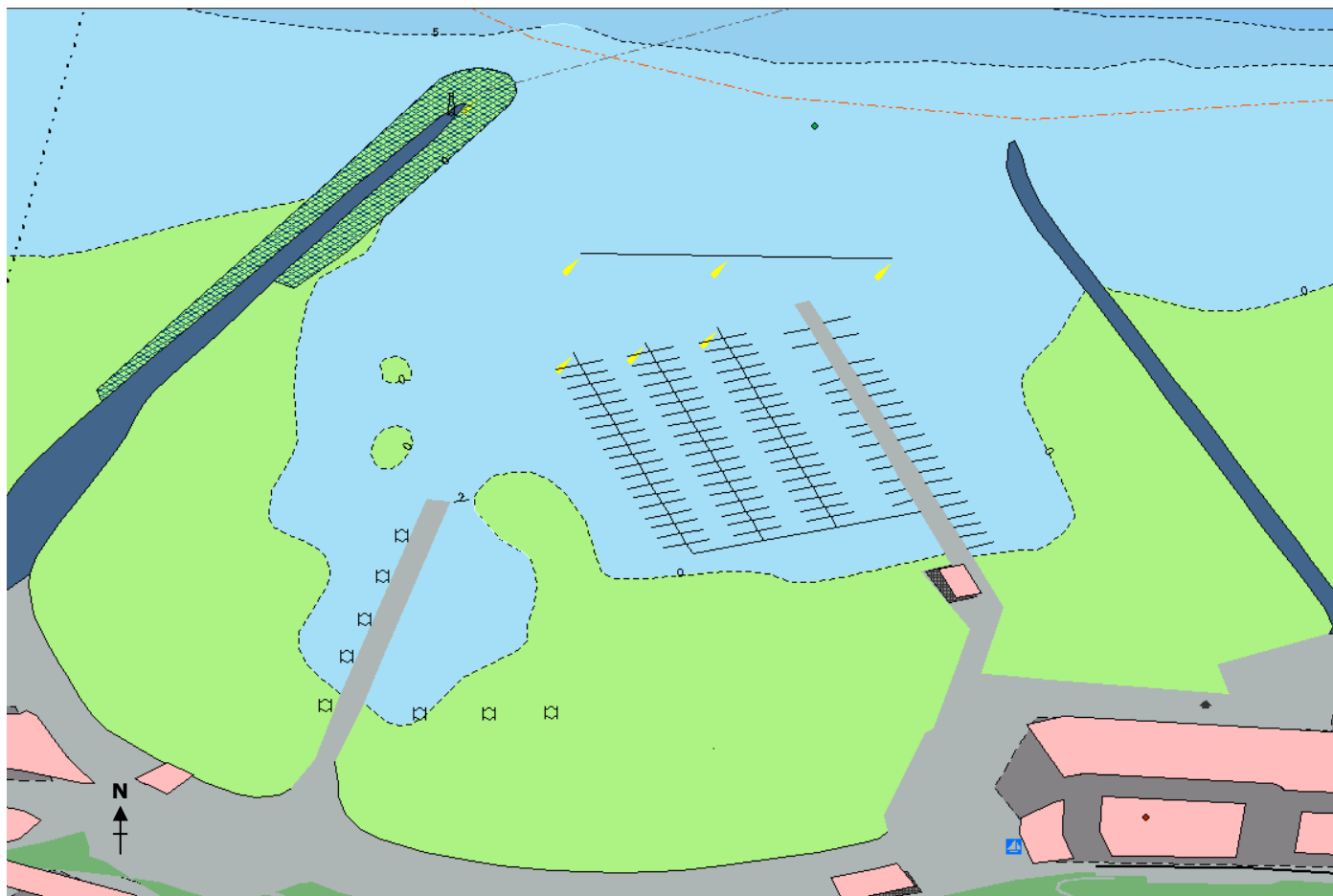


Figure 10: **UK Project Site (Edinburgh)**, showing interoperable land-sea superficial geology map

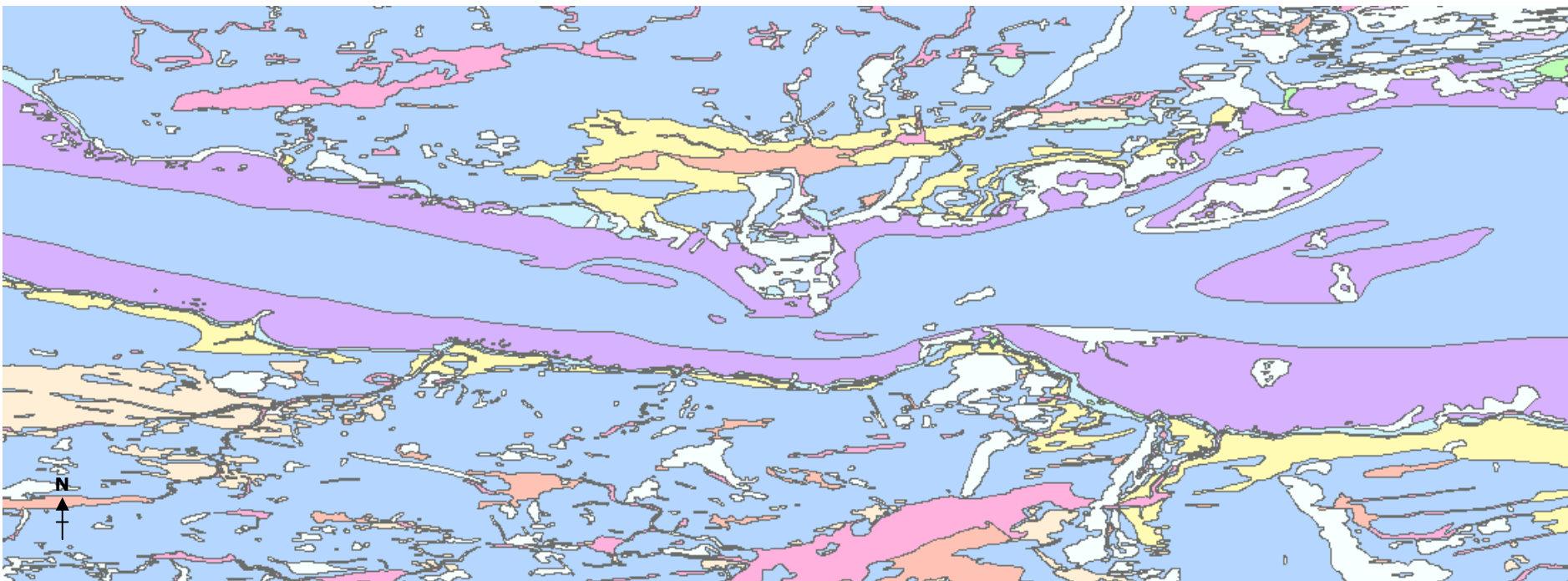


Figure 11: **UK Project Site (Edinburgh)**, showing interoperable land-sea bedrock map



Figure 12: **UK Project Site (Edinburgh)**, showing interoperable land-sea elevation map

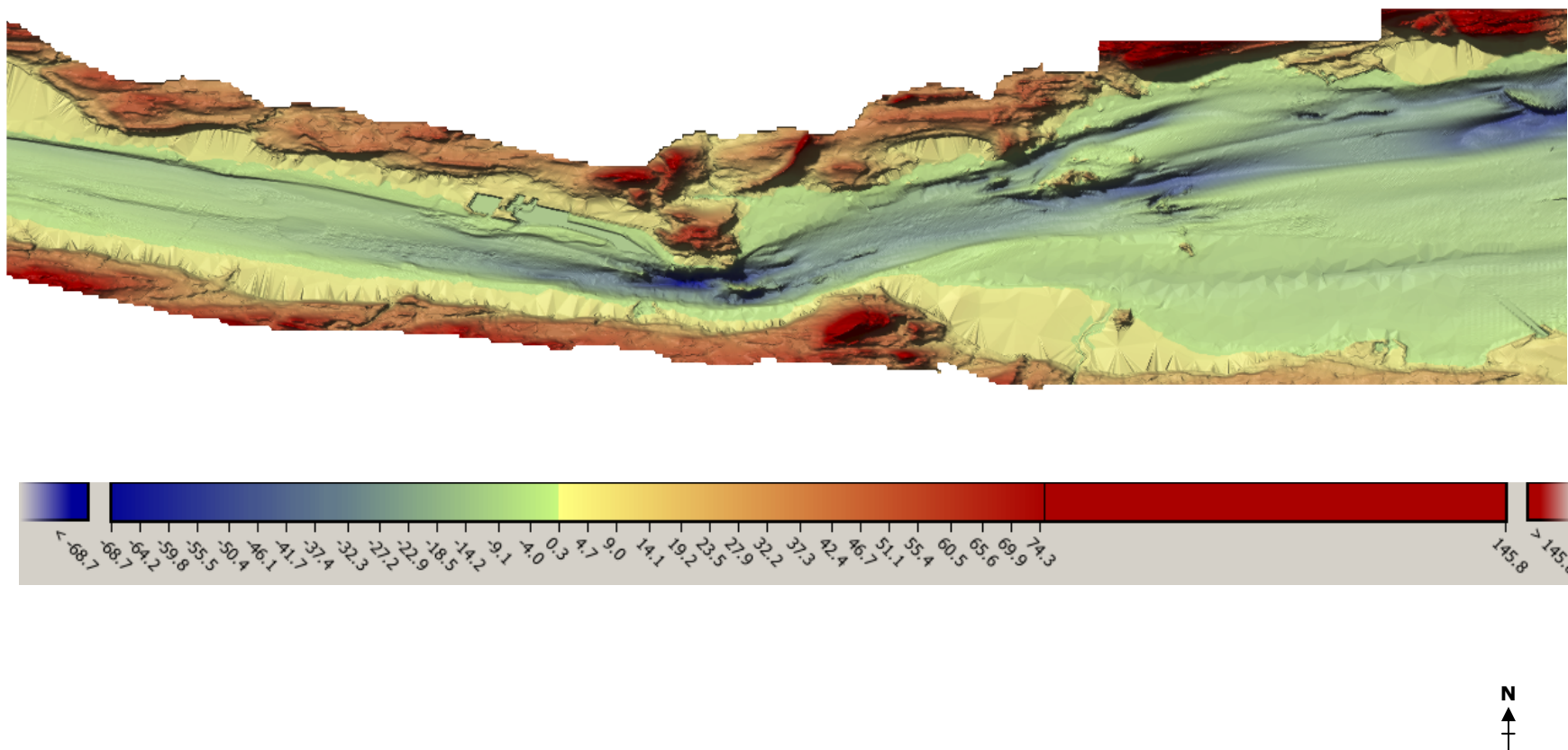


Figure 13: **Denmark Project Site (Hirtshals)**, showing interoperable land-sea topographic map

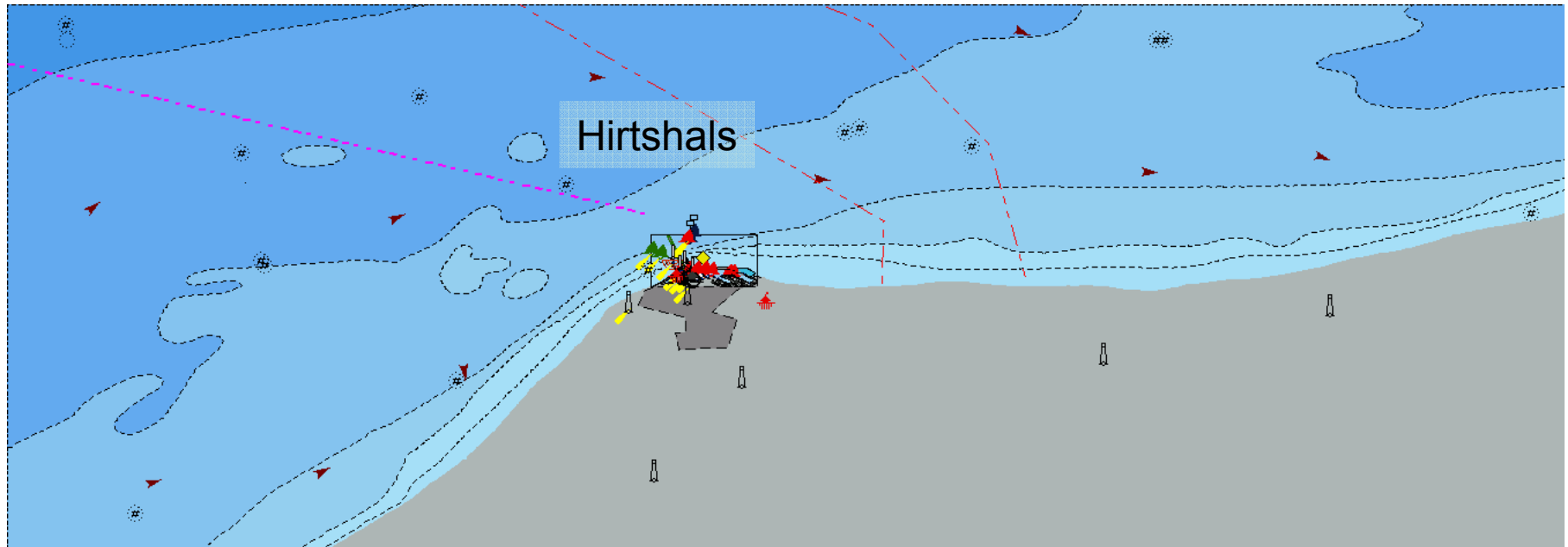


Figure 14: **Denmark Project Site (Hirtshals)**, showing interoperable land-sea topographic map

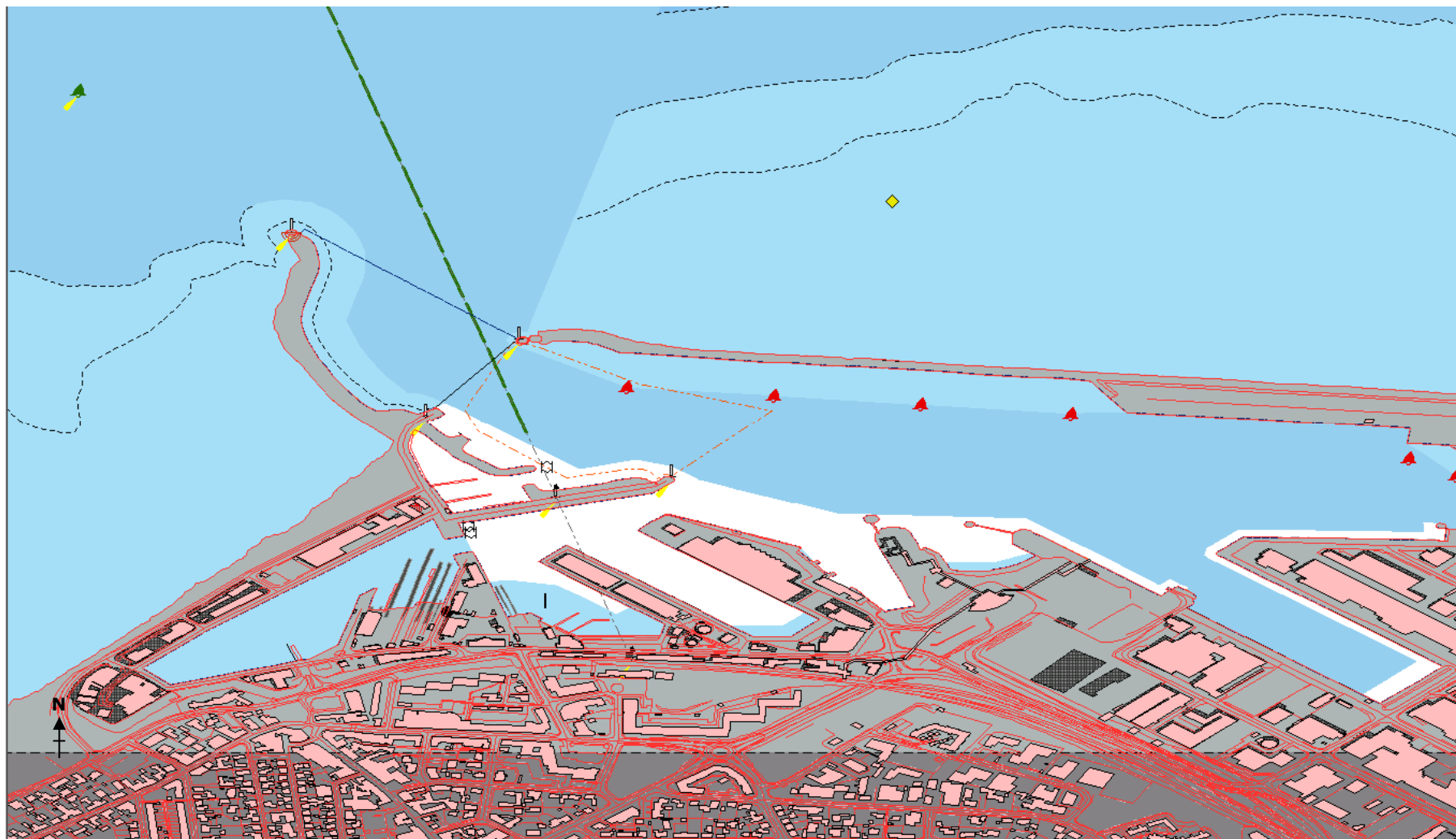


Figure 15: **Denmark Project Site (Hirtshals)**, showing interoperable land-sea topographic map

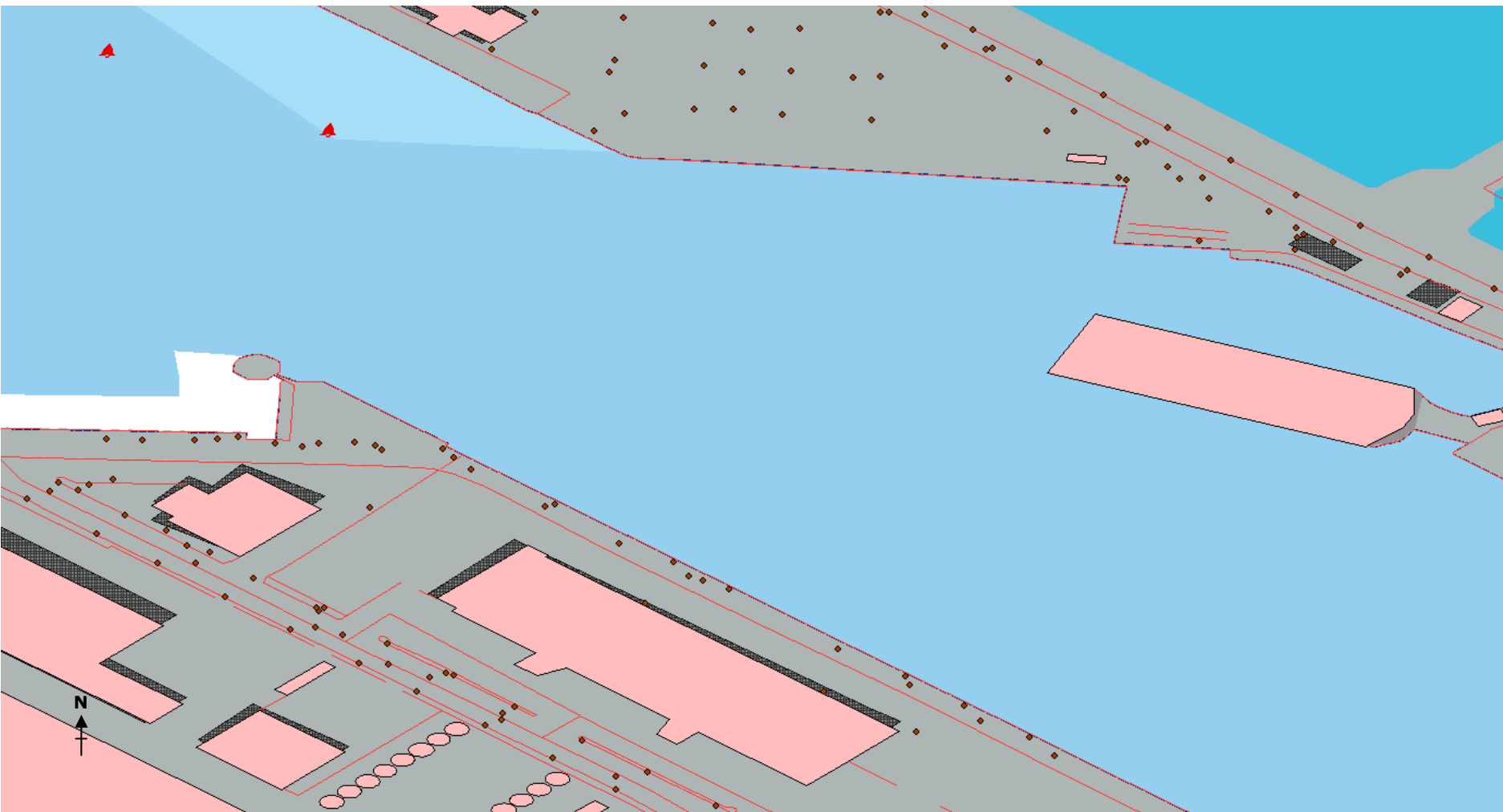


Figure 16: **Denmark Project Site (Hirtshals),** showing interoperable land-sea elevation map

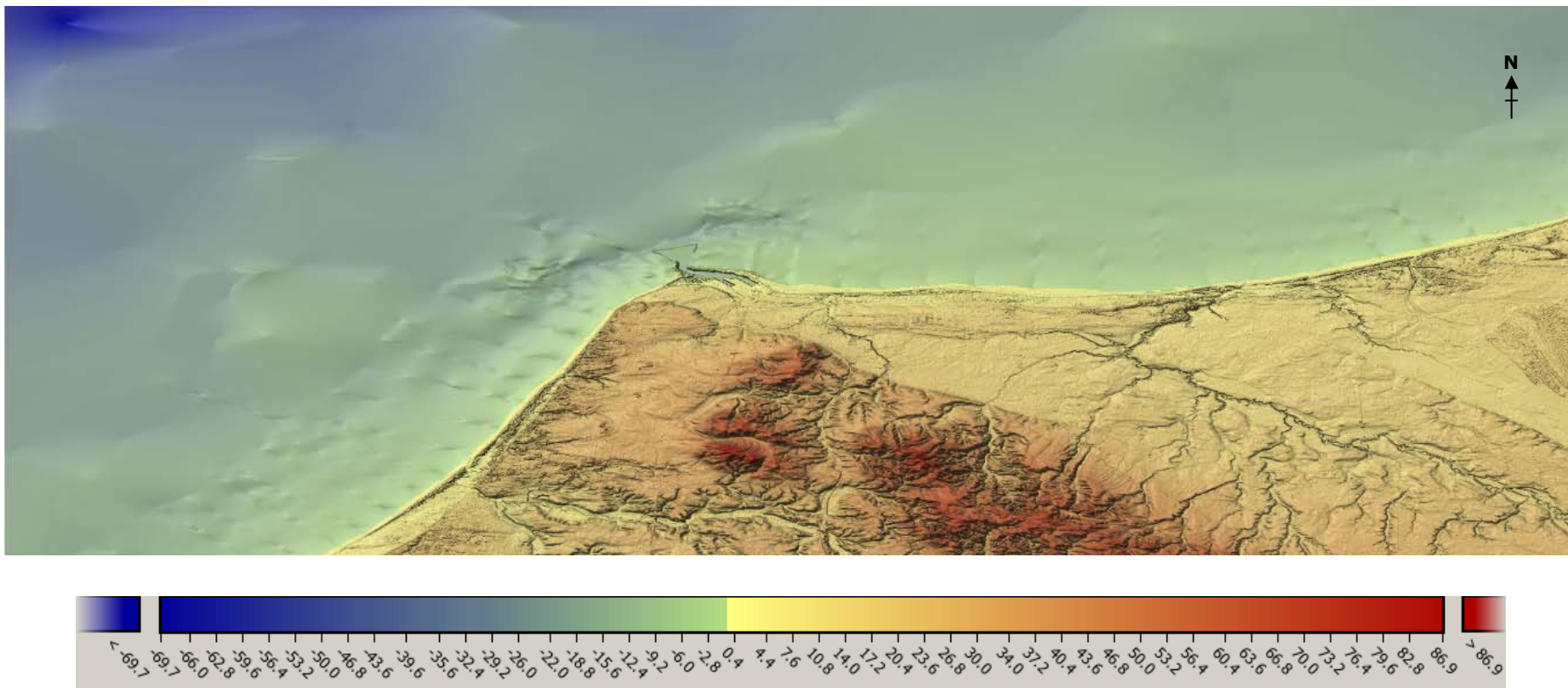


Figure 17: **Belgium Project Site (Zeebrugge)**, showing interoperable land-sea topographic map

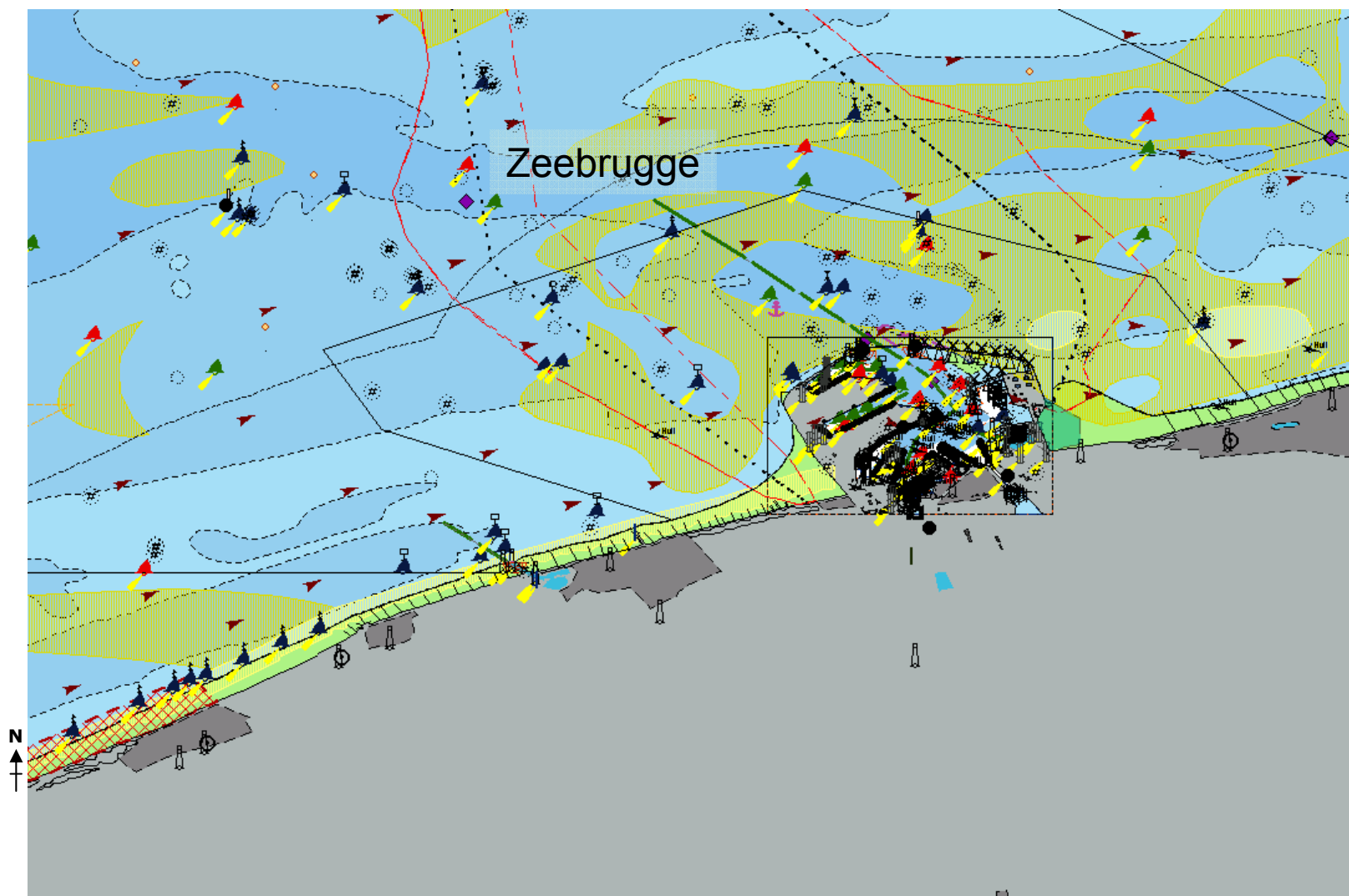


Figure 18: **Belgium Project Site (Zeebrugge)**, showing interoperable land-sea topographic map

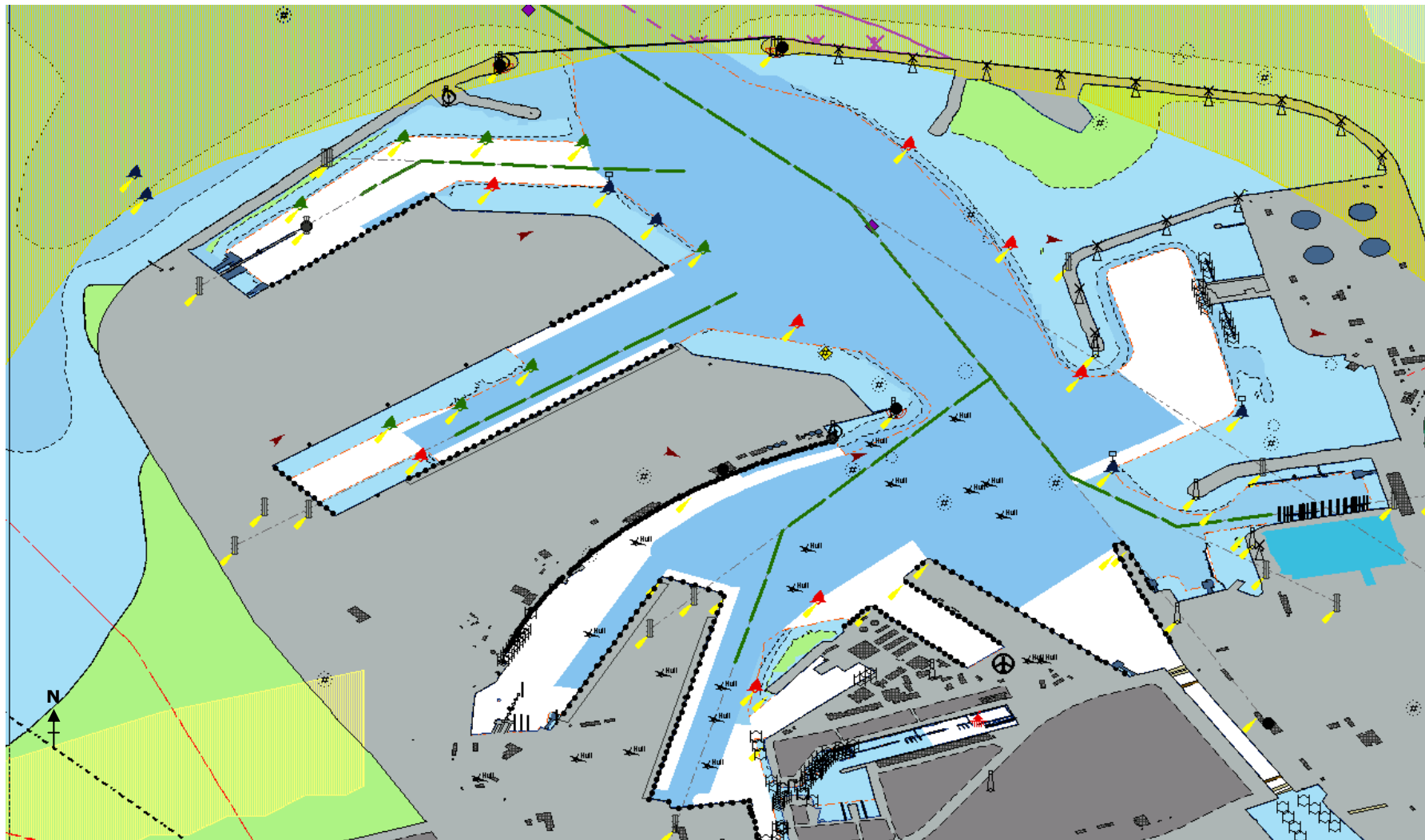


Figure 19: **Belgium Project Site (Zeebrugge)**, showing interoperable land-sea topographic map

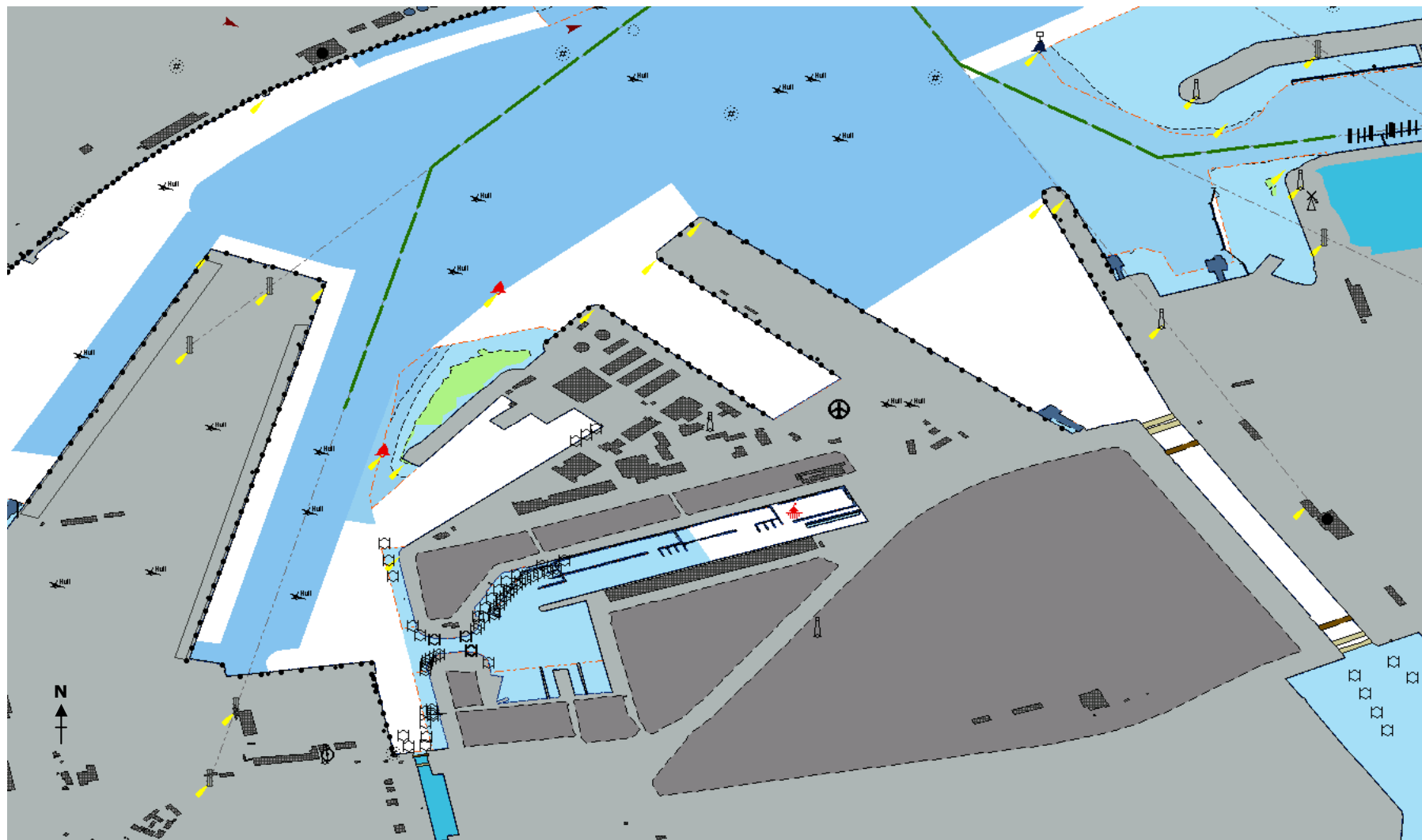
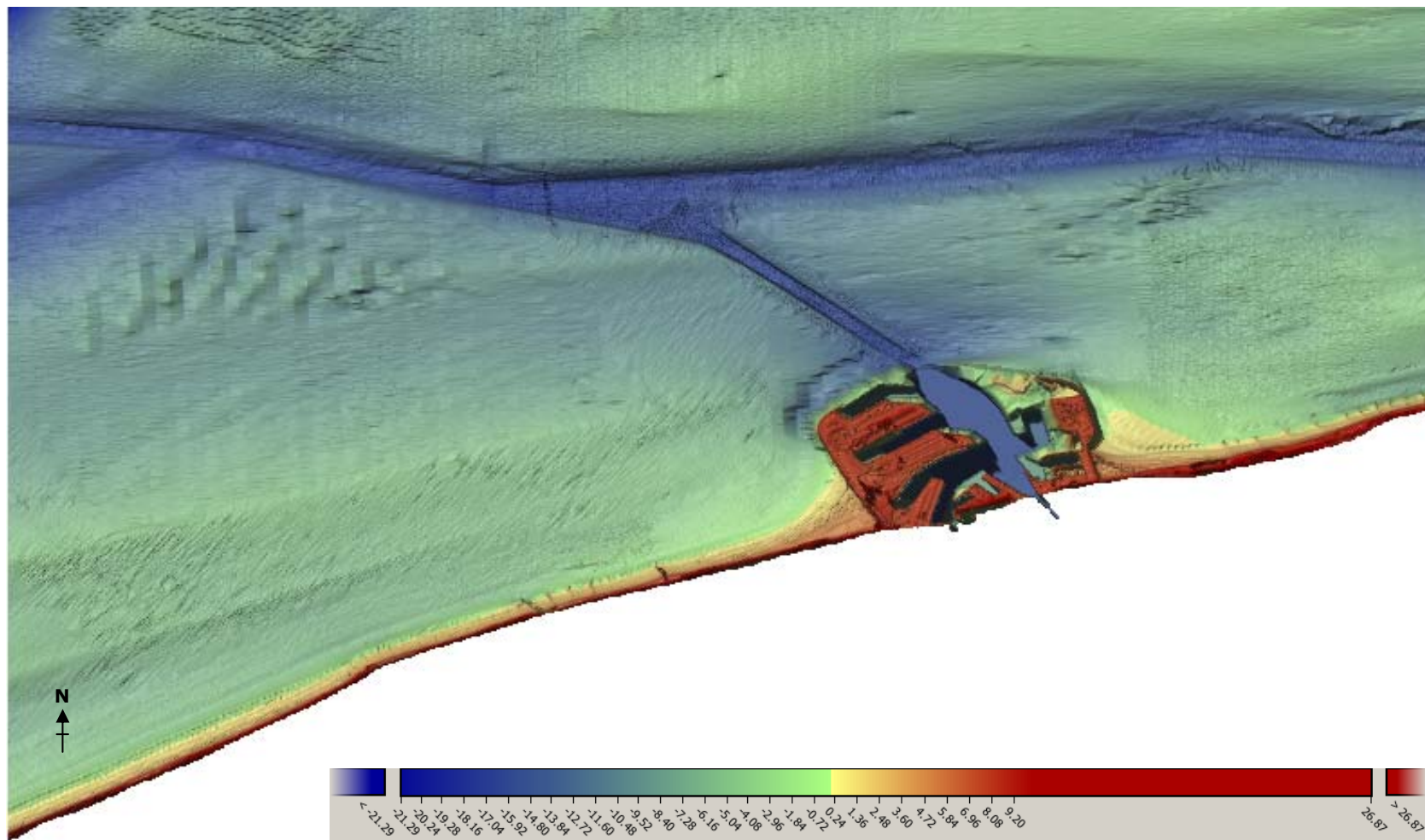


Figure 20: **Belgium Project Site (Zeebrugge)**, showing interoperable land-sea elevation map





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