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Open Geospatial Consortium

GOOD PRACTICES REPORT FOR OGC FEDERATED MARINE SDI 2024 PILOT - BRIDGING LAND AND SEA

DISCUSSION PAPER

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I EXECUTIVE SUMMARY

The 'white ribbon', a term first coined by the British Geological Survey, is the well-known region spanning the land-sea interface. There is an equally well-known lack of data for this region: generally, too shallow for most traditional bathymetric survey methods and too deep for land-based surveys. This inter-tidal and nearshore region is, however, of crucial importance to a wide variety of stakeholders.

This report provides guidance on practices addressing the gaps in geospatial information for coastal area management and offers a set of strategies satisfying the core tenets of the FAIR (Findability, Accessibility, Interoperability, Reusability) Data Principles. The results promote a standards-based, integrated coastal observation framework as an effective means to measure and predict the near-term and climatic-scale changes of our coastal environments.

The practice recommendations focus on the key aspects required to confidently fill the data gaps between land and sea. These recommendations address the two main components of a coastal observation strategy – resolving the spatial height observations to a common reference frame and identifying strategies to fill in the geospatial data voids.

This report is intended to document good practices for broad consideration by the community working with coastal geospatial information. The OGC welcomes all comments on this report. Comments and further research will be used to develop a formal Best Practices document based on this initial report.

Surface Elevation Profiles
A foundational aspect of this project relates to the vertical profile of the earth's surface ranging from the inshore terrain and stretching out to the seaward subtidal realms. Geospatial data voids within the coastal area are an artifact of the breaks and vertical steps between hydrographic data and land data. This is an artificial consequence of long-standing and institutionalised domain requirements.

To address the gaps and overlaps of domain-specific datasets, a topo-bathymetric profile may be derived from a set of topographic and hydrographic surveys or directly observed using, for example, airborne and spaceborne lidar observing platforms. Economic constraints of airborne observing strategies continue to affect the global coverage of these systems while space-borne observing platforms trade off coverage for accuracy and resolution.

A key consideration in determining this 'shape' of the coastal region requires a common frame of reference against which observations are made. As in the case of coastal inundation modelling, the risk of flooding and coastal erosion during extreme events is exacerbated by climate-related sea level rise and amplified by land subsidence caused by ground-water extraction in coastal areas. This highlights the dynamic frame of reference across the land and sea extents of the coastal area and requires the use of a common *Geodetic Reference Frame* to provide a standardized baseline for referencing positions against the earth's surface. This is predicated against a modern height reference model involving an active vertical control network, a gravity-based vertical datum as the baseline zero-height reference surface and a vertical separation framework to transform hydrographic observations to a standardized geodetic datum.

Data Products

Investments in the various observation techniques are dictated by the fiscal, technical capabilities, and application requirements of stakeholders. To maximize the effectiveness of these data campaigns, each generated data product must carry a set of appropriate descriptors to allow stakeholders to identify its 'fit for purpose'.

In accordance with the ISO 19131 Data Product Specification standard, survey-based observation data products must provide both metadata and data quality indicators associated with the observation datasets. This allows such data products to be registered against a federated catalog for the purpose of discovery and reusability.

Governance and Institutional Requirements
Governance of the coastal zone requires multi-agency engagement and cooperation to ensure transparency throughout the policy-making supply chain. To meet this requirement, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) has developed the Integrated Geospatial Information Framework (IGIF) providing a structured approach to the development of a national geospatial strategy. By extension, the IGIF-Hydro Maturity framework provides the Umbrella Governance Model designed to coordinate the efforts of national, regional and local agencies and align stakeholder interests towards effective policy management of coastal areas.

II KEYWORDS

The following are keywords to be used by search engines and document catalogues.

ogcdoc, OGC document, best practice, fmsdi, fmsdi-2024

III PREFACE

This document outlines the main challenges and key considerations in integrating land and marine data. It brings together valuable insights, case studies, and foundational guidance that can be helpful to practitioners working in the coastal data space.

The report focuses the core requirements for establishing a seamless coverage of geospatial information across the transitional boundary of the coastal environment. It is designed to help stakeholders involved in coastal planning better understand the capabilities and limitations when connecting land and sea datasets and offers practical advice on how to make data from different sources work together. The guide aims to improve collaboration between agencies and support real-world stakeholder needs in response to a changing climate.

The guide takes the approach of describing the foundational issues a coastal planner may experience and provides guidance to ensure a user understands how to navigate each problem, the complexity of the challenges, and how they can resolve the issue or ideally, prevent them in the first place.

These recommendations represent an initial set of patterns and practices to be extended over a longer-term roadmap championed through the Open Geospatial Consortium (OGC) and its partner organizations. Eventually, a formal Best Practices document will be published by OGC based on feedback for this report and further research.

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Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which the recipients may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

IV SECURITY CONSIDERATIONS

No security considerations have been made for this Standard.

V SUBMITTING ORGANIZATIONS

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VII TERMS AND DEFINITIONS

FAIR principles[1]	The approach of making digital assets Findable, Accessible, Interoperable, and Reusable.

Abbreviated terms

OS	Ordnance Survey
NRCan	Natural Resources Canada
CHS	Canadian Hydrographic Service
IHO	International Hydrographic Organization
CRS	Coordinate Reference System
SRS	Spatial Reference System

VIII ACKNOWLEDGEMENTS

OGC appreciates the continued support from the following member organizations as sponsors of this project.

[1]further reading: https://www.go-fair.org/fair-principles/

National Oceanic and Atmospheric Administration (NOAA)

UK Hydrographic Office (UKHO)

National Geospatial-Intelligence Agency (NGA)

1

INTRODUCTION

1 INTRODUCTION

Coastal areas support a diverse range of ecosystems on which human activities directly depend. Presently about 40% of the world's population lives within 100 kilometers of the coast. Beyond their social and economic value, coastal areas provide crucial habitats for a wide range of species while offering key carbon sequestering opportunities to mitigate the effects of climate change. Additionally, the coastal environment provides natural barriers to the increasing risks associated with storm-induced flooding and coastal inundation.

According to the Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), global sea-levels have risen by approximately 20 cm since the start of the 20th century, with projections of an additional rise of 30 to 60 cm by the year 2100. The velocity of sea level changes poses a significant risk to coastal environments and requires a comprehensive mitigation and adaptation strategy. Unfortunately, public awareness and economic constraints continue to hamper the progress required to respond to the immediate and long-term impact of changing sea levels in coastal areas.

To set policy, stakeholders need to establish risk – an informative measure of those essential variables that have a direct impact on the health and welfare of coastal communities. Coastal climate risk indicators capture key aspects of coastal ecosystems susceptible to anthropogenic and climate related forcings such as sea level change and land subsidence. These provide a level of understanding of the impact of climate change on coastal communities, including the potential for infrastructure damage, displacement, and economic loss.

Various approaches to coastal climate planning assessments involve hydrodynamic models, used to simulate flood risk under various climate scenarios; ecosystem assessment models projecting the benefits of coastal ecosystems and how sustainable natural habitats can lower the risk of coastal inundation and storm surge events; strategies incorporating nature-based solutions (NbS) building resilience into coastal areas; and vulnerability assessment models to incorporate factors such as social and economic conditions in low-lying coastal areas.

Fundamentally, however, coastal risk and adaptation policy is severely affected by a lack of geospatial information related to the coastal zone. Although land-use models may be quite extensive, as demonstrated by the extent of topographic and cadastre data products, reliable coastal data products that seamlessly transition from the land to the marine environment, are limited.

This report focuses on addressing the foundational challenges of filling the geospatial data void of the coastal area and its direct relationship to projecting sea level rise over near-term timescales.

1.1. The White Ribbon Problem

The white ribbon, a term first coined by the British Geological Survey, is a metaphor used by hydrographers and geospatial experts to describe the region spanning the land-sea interface that tends to lack data. This area, alternately covered and uncovered by tides, can be too shallow for most traditional bathymetric survey methods and too deep for land-based surveys. This inter-tidal and nearshore region is, however, of crucial importance to a variety of stakeholders.

This area is:

- Highly dynamic (constantly changing with tides, waves, and sediment movement)
- Hard to measure accurately with a single method
- Covered by different agencies (marine vs. land authorities), each using different data standards and tools

The graphic below illustrates where the problem lies.

The White Ribbon Problem

The problem touches on both technical and governance issues.

Technical

- Data Gaps and Overlaps: Land and sea data often don't align well in this zone, leading to mismatches or missing information.
- Different Measurement Methods: Land elevation and sea depth are measured using different technologies (e.g., LiDAR vs. sonar), and datums, making it hard to merge them.
- Inconsistent Standards: Agencies use different formats, scales, and update cycles, which complicates integration.

Governance

The governance challenge in connecting land and sea data stems from the fact that different organizations and jurisdictions are responsible for managing land and marine environments. These types of issues include the following.

- Mixed /Split accountabilities:
  - Land data is managed by national or regional land agencies;

    - Marine data is handled by hydrographic offices or maritime authorities; and
    - The intertidal zone falls between these and is often not clearly assigned to either side.

- Different Legal Frameworks:
    - Land and sea are governed by different laws, policies, and property rights; and
    - This creates gaps or overlaps in authority, especially in coastal development, conservation, and disaster response.

- Inconsistent Standards and Tools:
    - Agencies use different data formats, coordinate systems, and update cycles; and
    - This makes it hard to merge datasets or create a unified view of the coast.

- Lack of Coordination:
    - Without a shared governance model, agencies may duplicate efforts, miss critical data, or make conflicting decisions and importantly, make it difficult to find and access the needed data either by machine or human.

- Funding and Prioritization Issues:
    - Coastal integration projects often fall between funding categories (land vs. marine), making them harder to support.

1.1.1. Real World Impact

If land and sea data cannot be seamlessly connected, it creates serious challenges across many sectors. Land and sea systems are deeply linked—weather, ecosystems, transportation, and emergencies don't stop at the shoreline. When data from these areas can't be combined smoothly, it causes problems such as the following.

Coastal Impacts

- Inaccurate Flood Risk Maps: Sea level rise affects coastal land, but if land elevation data and sea level data aren't integrated, flood models can't accurately show which areas are at risk.
- Weaker Early Warning Systems: Storm surges and high tides can combine with rising sea levels to cause sudden flooding. Without real-time land-sea data integration, alerts may be delayed or inaccurate.

- Poor Infrastructure Planning: Coastal cities need to plan roads, buildings, and defenses based on future sea levels. Disconnected data makes it harder to predict where and when flooding will happen.
- Environmental Blind Spots: Rising seas can push saltwater into freshwater systems and wetlands. Without linked land-sea data, it's harder to track these changes and protect ecosystems.
- Inconsistent Climate Models: Sea level rise is a global issue, but its local effects depend on both ocean and land conditions. Without seamless data, models miss key details, leading to poor policy decisions.

Emergency Response

- Slower disaster response: In events like hurricanes or tsunamis, responders need to track how sea conditions affect coastal areas. Disconnected data can delay help or misdirect resources.
- Poor flood prediction: Coastal flooding depends on both rainfall (land) and tides/storm surges (sea). Without combined data, forecasts are less accurate.

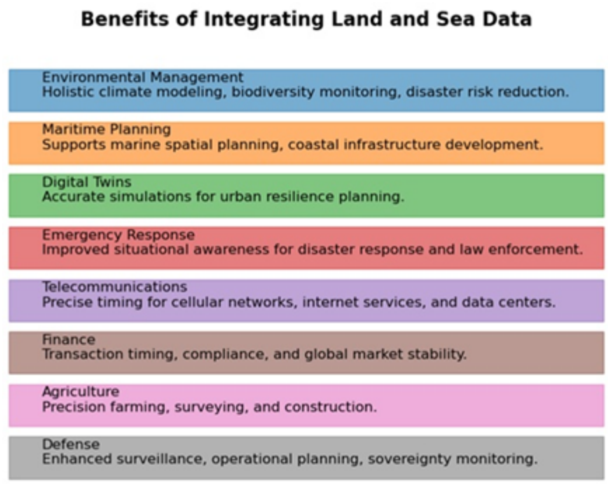
Transportation and Trade

- Shipping delays: Ports rely on both marine and land data to manage traffic and cargo. Gaps in data can cause congestion or safety risks.
- Navigation errors: Ships and trucks need coordinated routing. Disconnected systems can lead to inefficiencies or accidents.

Environment and Science

- Weaker ecosystem monitoring: Many species move between land and sea (like salmon or seabirds). Without integrated data, it's harder to protect them.
- Pollution tracking: Oil spills or plastic waste often move from sea to land or vice versa. Disconnected data makes it harder to trace and clean up.
- Data silos: Scientists may duplicate work or miss key insights because they can't access or align data from both domains.

Selected examples of the benefits of overcoming the challenges are summarized in the table below. At the highest level, overcoming the challenge ultimately has a high socio-economic impact.


Benefits of Integrating Land and Sea Data
Environmental Management
Holistic climate modeling, biodiversity monitoring, disaster risk reduction.
Maritime Planning
Supports marine spatial planning, coastal infrastructure development.
Digital Twins
Accurate simulations for urban resilience planning.
Emergency Response
Improved situational awareness for disaster response and law enforcement.
Telecommunications
Precise timing for cellular networks, internet services, and data centers.
Finance
Transaction timing, compliance, and global market stability.
Agriculture
Precision farming, surveying, and construction.
Defense
Enhanced surveillance, operational planning, sovereignty monitoring.

2

CHALLENGES

2 CHALLENGES

When integrating land and sea datasets, several critical aspects need to be addressed. These range from establishing a common understanding of the terms and vocabulary used in different domains; limited coverage of topographic and hydrographic datasets transitioning the water's edge; reliably developing a coastal surface model representative of the area of interest; and governance restrictions affecting the accessibility and usability of existing datasets.

2.1. Geodetic Reference Frames

Coastal monitoring programs provide observations and measurements of the physical environment. Each monitoring program is designed specifically to observe the phenomenon within its domain at a precise time and location. A collection of observations for a particular monitoring program result from the observational strategy defined over an area of interest (a spatial extent) and time period. To reliably determine the position of an observation requires the establishment of a geodetic reference frame.

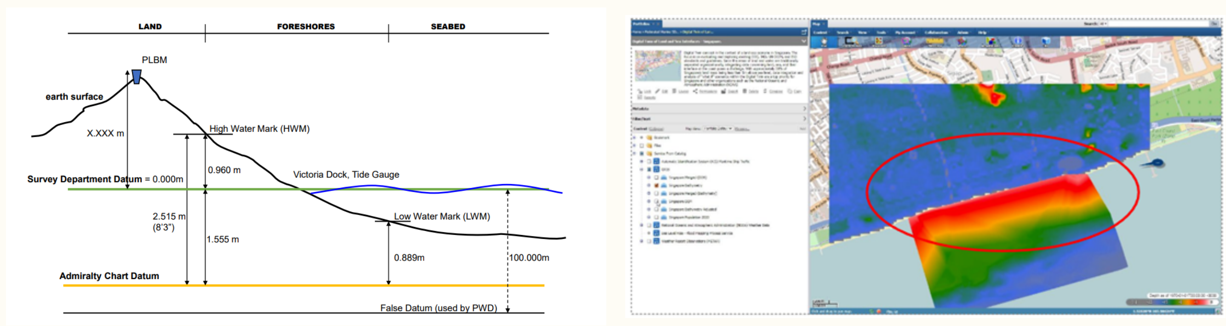
When combining the observational coverage of cross-domain monitoring programs, the geodetic reference frame of each program must be considered and transformed to a common frame of reference.

A fundamental requirement for projecting the impact of rising sea levels is accurately measuring the geospatial relationship between sea level and the land surface. This relationship is dependent on determining the topographic and bathymetric profile of the coastal area and requires a seamless topo-bathymetric surface model measured against a common vertical frame of reference.

Traditionally, topographic surveys rely on either an active network of control points based on GNSS observations or on a passive network of control points as the basis of a precision levelling network. In both cases, the topographic height observations use an ellipsoidal reference frame as its surface model. Hydrographic surveys, on the other hand, use a local water level Chart Datum to derive bathymetric observations against a regionally defined tidal level – usually the Lowest Astronomical Tide level — to provide a 'safe' vertical reference datum for navigation purposes.

To understand the relationship between sea level rise and coastal inundation, long-term and spatially relevant sea level records are an important element. Coastal sea levels are provided through tidal observation platforms and provide measurements of sea level relative to a local tidal datum. A seamless coverage of height observations across land and sea requires a common spatial reference frame defined over a relevant temporal reference period to ensure absolute measurements are equivalent across the boundary of land and sea. The OGC Federated Marine Spatial Data Infrastructure Pilot 2023 — Connecting Land and Sea for Global Awareness program highlighted this effect.

The Singapore Land Authority uses the Singapore Height Datum (SHD) for land and cadastre features while the Maritime and Port Authority (MPA) measures the bathymetric profile against its national Admiralty Chart Datum.



The Singapore Height Datum is derived from the localized Mean Sea Level calibrated against a tide gauge previously located at Singapore's Victoria Dock. This vertical datum is the baseline for Singapore's extensive precise levelling network and provides a common reference point for integration with Singapore's bathymetric profile. Singapore's multi-beam bathymetric surveys are based off the Admiralty Chart Datum which is offset from the Singapore Height Datum by a fixed vertical distance of ~1.56m which must be compensated for to compose a continuous topo-bathymetric coverage.

2.2. Geospatial Data Voids

Where no data exists that extends across the coastal area, the challenge of deriving the key variables associated with the effects of sea level rise is even more difficult.

Nearshore elevation data voids may exist due to the inherent difficulty of surveying these areas. Traditional hydrographic methods are often ineffective in shallow waters while the dynamic nature of the coastal environment, driven by tides, poses challenges for conventional land survey techniques. Coastal sea level records may also be difficult to construct based on a relative sparsity of tidal observation platforms and historic tide level observations.

2.3. Governance

Effective coastal planning involves multiple levels of organizations, each with specific roles and responsibilities, that together provide the framework for developing sound policy on behalf of local, regional and national interests. No one agency has the authority or capability to impart policy without the coordination of other stakeholder agencies. To deliver to the basic requirements of managing the coastal environment, it is essential to effect governance policies that allow the discovery and reuse of topographic and hydrographic survey information across agencies.

While data may be captured across the intertidal zone by academic and government agencies with open access licensing, commercial organizations may institute restrictive licensing that limits access outside of its principal use.

Without effective governance policy, accessibility and reliability of critical datasets required for coastal planning is severely impacted – to effectively cause artificial data voids within the coastal area of interest.

2.4. Metadata and Quality control

A further challenge exists due to the inherent uncertainty in bathymetric surveys, which arises from factors such as varying survey techniques, environmental conditions, and differing levels of data quality. There are still difficulties with calculating uncertainty for bathymetric datasets as this is only created as part of specific bathymetric processing workflows which may not be used everywhere. These challenges are further compounded by issues of scale and resolution, where mismatches between terrestrial and marine datasets can lead to significant discrepancies in elevation models, feature alignment, and data interpretation.

This complexity often results in confusion or misapplication of data, particularly when datasets are repurposed beyond their original intent. A key part of addressing these challenges lies in comprehensive metadata. Well-documented metadata provides critical information about how, who, when, and why data were collected, including limitations and intended use. This transparency empowers users to assess the suitability of datasets for specific applications to coastal planning and analysis.

2.5. Semantic Interoperability

Land and marine data can have very different terminology, data structures, and capture methodologies which makes it difficult to integrate these datasets across transitional boundaries. Where a user has not worked with either land or marine data in the past, it is important to understand specific aspects that are unique to each of these domains.

As an aid to the reader, a set of introductory concepts are included in Annex B and Annex C. Further development of a best practices framework that formally addresses the semantic requirements of an integrated land-sea information model is reserved as a future work effort.

3

KEY CONCEPTS AND TERMINOLOGY

3 KEY CONCEPTS AND TERMINOLOGY

The following concepts are central to understanding the basis for the practices recommendations. These concepts serve to introduce the reader to the important ideas referenced within the set of practices and is not meant to represent an exhaustive list of normative definitions.

Table 1 — Key Concepts

CONCEPT	DEFINITION
Spatial Reference System (SRS)	A spatial reference system defines the fundamental parameters needed to describe the positions of points in space (e.g., the origin, orientation and scale of the coordinate system, and the size and shape of any reference ellipsoid). NRCan Geodetic Reference Systems
Spatial Reference Frame	A reference frame is the actual realization of a reference system and is typically defined by the coordinates assigned to geodetic control points in the system. NRCan Geodetic Reference Systems
Geoid	The geoid is a continuous, equipotential surface representative of global mean sea level under the force of gravity. It is used to measure precise surface elevations across land and sea.
Vertical Datum	*[a datum of vertical reference]* A zero-reference surface representing elevations above mean sea level over land and water
Orthometric Height	*[orthometric elevation]* Height of a point relative to the geoid and generally referred to as height above Mean Sea Level.
Chart Datum	A permanently established surface from which soundings or tide heights are referenced, usually low water (IHO GI Registry/IHO S-32 Hydrographic Dictionary).
Tidal Height	The vertical distance of the sea surface at any time relative to the established Chart Datum.
Coastal DEM	A digital elevation model representative of Earth's solid surface over the extent of a coastal area of interest inclusive of topological and bathymetric heights measured relative to a common vertical datum.
Vertical Separation Surface (VSS)	A coverage of vertical offsets between an ellipsoidal reference frame, geoidal reference frame and tidal datum.
Mean Sea Level	The average height of the surface of the sea at a tide station for all stages of the tide over a 19-year period, usually determined from hourly height readings measured from a fixed predetermined reference level. https://isotc211.geolexica.org/concepts/1562/

CONCEPT	DEFINITION
Global Navigation Satellite System	Global navigation satellite system (GNSS) is a general term describing any satellite constellation that provides positioning, navigation, and timing (PNT) services on a global or regional basis.
Coordinate Transformation	A mathematical operation on coordinates that includes a change of datum. The parameters of a coordinate transformation are empirically derived from a dataset containing the coordinates of a series of points in both a source and target coordinate reference system. http://www.opengis.net/def/glossary/term/CoordinateTransformation
Positional Accuracy	the "closeness" of a coordinate value to its true or accepted value in a specified reference system.
Spatial Resolution	the smallest difference between two features of interest that can be meaningfully distinguished.
Uncertainty	An estimate characterizing the range of values within which the true value of a measurement is expected to lie as defined within a particular confidence level.

4

AUDIENCE

4 AUDIENCE

This guide is aimed at Practitioners working in the land-sea interface and organizations capturing data in this domain. While some nations are very advanced with integrating their land and sea data and have developed methods and strategies to build on, other nations may have more limited capability. This document is designed to provide an overview of the issues and best practices applicable for nations to either start to build a strategy or implement methods that will work in their situation.

The guide uses a story-based design to model a user working in across the coastal domain and uses various scenarios address questions about the data they are using to ensure that it is fit for the intended purpose.

To achieve this, the following questions are provided as context for data and Interoperability requirements.

- What is my goal?
- Where am I getting my data from?
- What information needs to be in that dataset?
- What do I need to know about the data to ensure it is fit for my purpose?

5

APPROACH

5 APPROACH

The FMSDI 2024 pilot was managed through the OGC Collaborative Solutions and Innovation (COSI) Program.

The approach taken by this project is to focus on the requirements of a scalable coastal monitoring framework that allows users to leverage existing data infrastructure to evaluate key climate risk indicators associated with coastal environments. In particular, the requirements align with the Global Climate Observing System (GCOS) Climate Monitoring Principles with focus on those variables associated with the coastal zone.

Where possible, established design patterns adopted within government agencies and international standards bodies are referenced as a baseline for a recommended set of best practices.

5.1. Standards Alignment

Internationally recognized standards provided through the Open Geospatial Consortium (OGC), the International Hydrographic Organization (IHO), the International Organization for Standardization (ISO), and the UN Global Geodesy Centre of Excellence (UN-GGCE) can be a good way of structuring a national strategy and implementing recognized practices.

5.2. Communities of Practice

Key initiatives set out by various agencies and stakeholders were used to benchmark this reports set of recommendations. These initiatives were evaluated for their effectiveness in modelling the core components of a coastal observation framework while highlighting inter-agency requirements and the role of data governance.

Other parties have also been looking at this topic including the UN-GGIM and UN-GCCE and the best practice guide will be shared with these organizations to add additional perspectives into their ongoing work. The UN-GGIM IGIF-Hydro (Integrated Geospatial Information Framework – Hydrographic module) is particularly relevant in this area as it provides a strategic and technical foundation for integrating land and sea geospatial data within a unified national framework. It recognizes the critical interdependence between terrestrial and marine environments, particularly in coastal zones where risks, infrastructure, and ecosystems span both domains. By promoting common standards, interoperable data systems, and shared governance, IGIF-Hydro ensures that hydrographic data such as bathymetry, tides, and sea level information, are treated as essential components of national geospatial infrastructure alongside land-based datasets.

6 OBJECTIVES

6 OBJECTIVES

The objective of this document is to provide insight into the main issues experienced when trying to join land and sea data and how these can be overcome to enable users to actively undertake projects using a combination of land and sea data.

This document provides guidance on standards that can be implemented to better handle the land-sea interface with a particular focus on metadata and its importance in understanding data quality.

The aim is for a user to be able to identify the status of the datasets and data services they are intending to use and assess their suitability for their intended purpose. Where data is assessed as suitable, it will give guidance on what is needed to integrate the data including how to fill the *white ribbon*.

What this guide does *not* do

This guide will not specify specific tools or methods that should be used as these will vary depending on the software, data and technical abilities available to the user. Different nation states may have different starting points and data available, and any user should familiarize themselves with their nation's strategy in this regard.

7

GOOD PRACTICES

7 GOOD PRACTICES

Before any kind of data processing can be undertaken, the user must fully understand the provenance and suitability of the datasets they intend to use. To aid in this understanding, the following questions should be answered and documented alongside any project material. The details, training and capacity building of the technical aspects of how or specifically what needs to happen with the user's data are not covered in this guide and will be the subject of future work.

Coordinate Reference Systems

- Do I know what Vertical and Horizontal Reference Systems, including epoch, the data I have created is in?
- Do I know what Vertical and Horizontal Reference Systems the data I have received is in? If the answer is NO to either of these then you have to find out before proceeding any further.
- Do I know what CRS is appropriate to accurately represent the area I am modelling?

Transformations

- If observation datasets are captured using different Coordinate Reference Systems, how do I harmonize the results to meet the requirements of my coverage model?
- Do I know what transformation methods are available in the software I am using? What is set as default; what options could I choose?
- Do I know what the effects on accuracy are depending on what transformation method I use?
- What are my accuracy requirements? Do I need meter or sub-meter level accuracy? This will inform which CRS and transformation should be used?

Resolution

- Do I know the resolution of the data I am combining?
- Do I know what effect changing the resolution will have on the intended outcomes?

  If I use the lower resolution of the marine data, what information am I losing from the terrestrial data? If I match the higher resolution terrestrial data, what am I "making up" in the marine area and how do I document the lineage from the original observation datasets to the derived datasets?

- How do I harmonize the resolution across the topo-bathymetric coverage when, for example, the Land Elevation Model has a 5m resolution per pixel and the Marine bathymetric coverage has a 30m resolution per pixel?

Temporal Reference Frames

- Do I know the age of the data I am working with? Are the observation results still valid for my specific use case?
- If datasets range across different temporal periods, which datasets are fit for purpose based on my temporal range of interest. Historic, near-term and climatic timescales may require interpolation or extrapolation of observation datasets to fit my specific scenario?

7.1. Good Practice: Establish a Common Geodetic Reference Frame

A key consideration in determining the 'shape' of the coastal area is a common frame of reference against which land and marine observations are accurately measured. A Geodetic Reference Frame is fundamental to modelling the earth's surface over a specific temporal period and serves to precisely define the position of a feature of interest at the time of observation.

Coastal observation programs, such as topographic and bathymetric surveys, are often captured to different horizontal and vertical datums in order to optimize accuracy and usability for specific use cases and areas of the world. Land based datums prioritize accuracy on land masses, using locally determined ellipsoids that fit the geographic region of interest. Reference systems used for marine applications are more likely to be global (e.g., ITRF) to be consistent over areas of global extent. In most cases, marine datasets sourced from national hydrographic offices are captured in WGS84 ellipsoidal reference frame as a requirement for charting and satellite navigation.

As in the case of coastal inundation modelling, the risk of flooding and coastal erosion during extreme events is exacerbated by climate-related sea level rise and amplified by land subsidence caused by, for example, ground-water extraction in coastal areas. This highlights the dynamic nature of the land, sea, and coastal areas, requiring a monitoring strategy which necessitates the use of modern Spatial Reference Systems (SRS's) that take these into account.

7.1.1. Vertical Control Network

A vertical control network (VCN) is a key component of a modern geodetic reference frame as it provides a baseline of accurate elevations against which all other features of interest may be observed. This includes a network of Global Navigation Satellite System Continuously Operating Reference Stations and survey marks to provide an authoritative and accurate network in support of positioning applications.

The geoid as the key to data integration
Elevation data products required in each domain-specific use case are derived from observation campaigns that may use different reference systems or map projections; they each may have allowances for various degrees of accuracy and resolution; and may have differing temporal ranges of applicability. There are at least two variables that must be considered when modelling

coastal inundation — absolute sea level rise & vertical land motion. This produces the relative rates of change in sea level to land over a specific period of time. The velocity of this key indicator provides a measure of risk to coastal ecosystems and requires accurate observations of coastal surface levels, including tidal sea surface heights, across historic, near-real time and climatic timescales.

A vertical datum represents a surface of zero elevation to which heights of various points are referenced. Traditionally, vertical datums have used classical survey methods to measure height differences (e.g. geodetic leveling from a point defining mean sea level across continental-scale distances) to best estimate elevations above sea level everywhere on the earth. However, this approach inherently accumulates systematic errors and over time, is affected by elevation changes such as glacial isostatic rebound. Leveling networks are, as well, extremely difficult to implement over nearshore and offshore archipelagic environments.

To establish a consistent frame of reference that scales across land and sea, surface levels can only be accurately observed when benchmarked against measurements of gravity.

> *Good Practice*
> *The geoid should be used as the primary height reference surface*

The geoid reference level is defined as an equipotential surface of Earth's gravitational field representative of the mean sea surface level obtained from a predefined collection of tidal observing stations.

On a global scale, change in mean sea level provides a measure of the net change in ocean mass due to melting of glaciers and ice sheets, and net change in ocean volume due to thermal expansion. On regional scales, changes in sea level can be far greater because of changes in temperature, salinity and circulation. By establishing the geoid reference level and using it as the baseline zero-reference elevation for land and sea, relative changes in surface levels can be detected with higher accuracy and with a higher temporal cadence.

7.1.2. Vertical Separation Surfaces

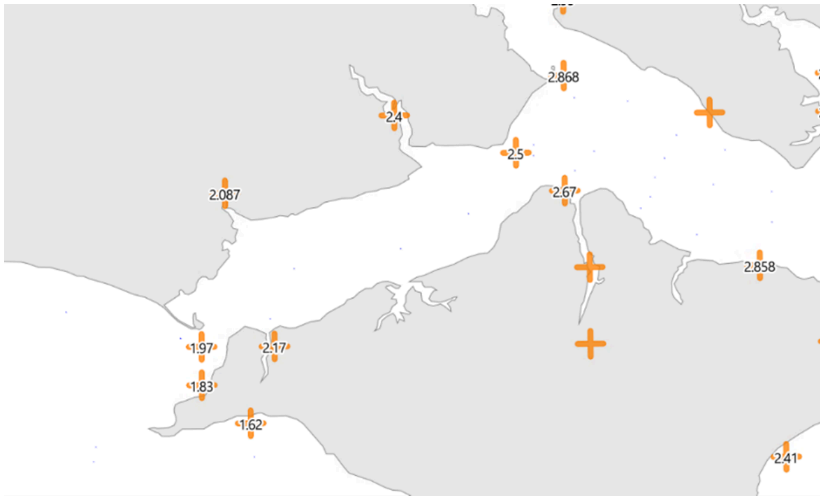
Land and marine data are usually captured in the frame of reference relevant to their individual requirements and/or convenience. These differences mean the data cannot be used together without applying some form of offset and transforming them against a single Vertical Datum.

> *Good Practice*
> The geoid model must provide separation values – the geoid height – representing the difference in elevation between the equipotential surface level and the ellipsoidal surface for a Geographic 3D reference system

If not adjusted for, comparing observations across domains may give incorrect responses when used in the modelling.

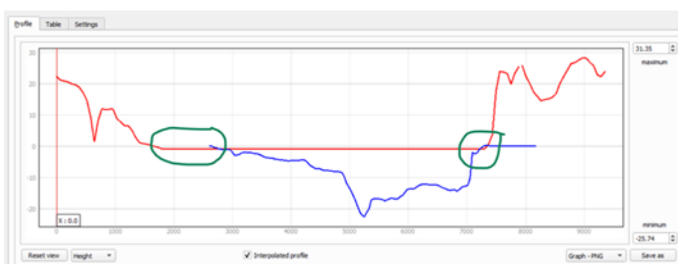
7.1.3. Tidal Datums

Even within a single domain, height observations are dependent on the feature of interest and its regional extent. As an example, tidal stations provide observations of the sea surface height relative to the local tidal datum. With reference to the case study area of The Solent, UK, the height of Mean Sea Level can differ over a relatively small area and requires a vertical offset to transform each station's calculated level to a common datum. If a single offset is applied across the entire area, it may produce distortions in the output.



Mean Sea Level offsets to Chart Datum across The Solent

It is critical that the metadata supplied with any datasets includes information on the Vertical Datum the data is referenced to. Without this information, it is not possible to apply the correct transformations and would therefore inherently be introducing significant uncertainty into any modeling.



Offsets when viewing a single profile across land (red) and marine (blue) elevation models

Good practice requires the data to be transformed into a single vertical datum. The decision as to which vertical datum chosen will be impacted by a number of factors — the size of the area being modelled; the validity of the datum (some land based datums may not be valid in the marine area); and whether there are accurate transformation methods available.

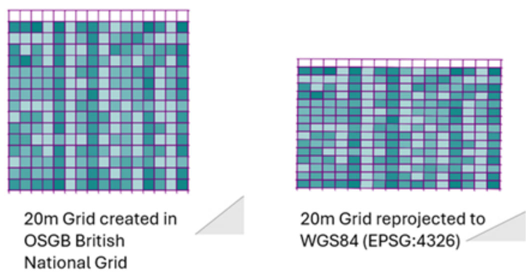
> *Good Practice*
> The tidal datum is to be projected to the geoidal reference surface using a defined vertical separation model.

The first step should be to determine whether your nation has produced a vertical separation surface. Examples of nations that have created a national geodetic program based on a geoidal frame of reference with defined separation surfaces are the United States (VDatum), the United Kingdom (VORF), and Canada (HyVSEPs). However, if not available for small areas, it may be possible to do a single offset based on tidal levels. This is not appropriate if the size of area being modelled is large because the difference between land and marine vertical datums varies around the coastline.

While doing any transformation between vertical datums, it is important that the transformation method is recorded as well as any changes in accuracy of the dataset. This should be included in the metadata of the transformed dataset and should be shared alongside the data. This enables future users to assess the suitability of the dataset for their purposes.

7.1.4. Horizontal Reference Frames

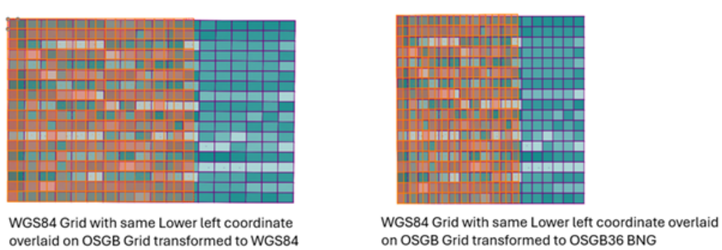
When looking at the impacts of different horizontal reference frames, transforming raster (gridded) data between coordinate reference systems means that a new grid must be created to keep the cells square in the new coordinate reference system. To enable this, some level of interpolation will have to happen which can introduce artfacts and inaccuracies into the dataset. The figures below show some of the changes to raster datasets when they are reprojected.

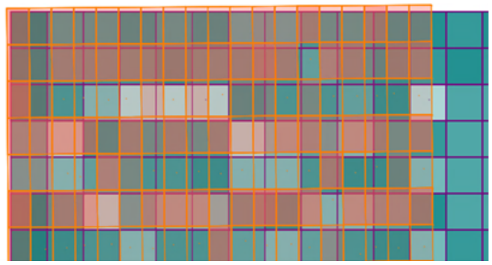


Reprojection from OSGB British National Grid to WGS84

Blue Grids have started as British National Grid, Orange Grids as WGS84. Where reprojection happens, the grid is distorted, and the new cells must be recalculated. This is most obvious in the final image where the overlap between cells increases the further away from the origin.

The diagrams below demonstrate the effect of a Raster grid over 300m with a cell size of 20m. This results in a grid covering a much larger area with increased distortion and, therefore, therefore interpolation would be much greater.





A further issue with Horizontal datums is they are appropriate for defined areas. If the area being modelled covers a larger area than the CRS or spans two CRS (e.g., across state or country boundaries), then a more appropriate CRS which covers the whole area will be required. This will require the data to be transformed using the appropriate transformation methods for the adopted CRS.

> *Good Practice*
> Land and Sea datasets should be transformed to a valid, ITRF-based coordinate reference system applicable to the coastal area of interest.

Transformation accuracy can vary from millimeters to meters. For Coastal Inundation projects millimeter accuracy may not be required when the assessment of the impact of inundation on buildings and infrastructure is likely to be at the meter level.

> *Good Practice*
> Ensure the accuracy of the transformation and selected CRS is appropriate for your intended project.

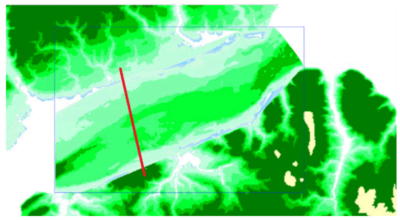
When performing any transformation between horizontal coordinate reference systems (CRS), it is essential to record the transformation method used, along with any changes in the dataset's accuracy. A centralized global database, the EPSG Geodetic Parameter Dataset (epsg.org) maintained by the International Association of Oil & Gas Producers (IOGP) provides authoritative information on coordinate systems and valid transformations between them. Users need to confirm that the parameters in their software match the EPSG parameters on EPSG.org when using EPSG codes and describe any discrepancy in metadata. This information should be included in the metadata of the transformed dataset and shared alongside the data. Doing so allows future users to evaluate the dataset's suitability for their specific applications.

7.1.5. Orientation of Vertical

Most observation programs define 'up' as a positive value relative to the vertical datum and 'down' as a negative value. Hydrographic convention, however, is positive measurements are 'below datum' whereas negative measurements are interpreted as 'above datum'.

> *Good Practice*
> Bathymetric survey observation datasets should be oriented using a right-handed Cartesian coordinate system

The coastal elevation model of The Solent shows the bathymetric elevation model with the coastal topographic elevation model.



Coastal Elevation Model of The Solent

The darker the color the higher the elevation value, suggesting there are hills where there is actually water.

As the bathymetric data uses values Positive Down while the land data is Positive Up, it interprets the elevation of deep water above the topographic surface. The following example demonstrates the issue using a vertical profile of the coastal interface between land and sea. The blue line misinterprets the bathymetric elevation values (*depth*) as positive values above sea level.

Vertical Profile of The Solent across Land & Sea interface as captured

To use the datasets together, the bathymetric data requires inverting to the Positive-Up convention, as shown in the image below. This is consistent with the requirements for encoding bathymetric surveys using the “Bathymetric Attributed Grid” (BAG) community standard developed through the Open Navigation Surface Project and adopted for approval by the OGC.

Vertical Profile of The Solent across Land & Sea interface as transformed to right-handed Cartesian coordinate system

7.2. Good Practice: Discovery and Analysis Readiness

Understanding data quality is essential to establish whether the data in question is fit for the user's purpose. Without metadata the lineage, resolution and positional accuracy of the data would not be known and it would be impossible to assess the risks of misusing the data. This becomes particularly important when managing data from different domains that may use different metadata standards and data formats.

In this area there are well used Standards which aid the capture and sharing of the metadata, both in terms of Data Products and their Specifications, and international metadata standards.

7.2.1. Data Products

Investments in the various observation techniques are dictated by the fiscal and application requirements of stakeholders. To maximize the effectiveness of these data campaigns, each generated data product must carry a set of appropriate descriptors to allow stakeholders to identify its 'fit for purpose'. In accordance with the ISO 19131 standard, a data product specification defines the requirements for a data product. It forms the basis for producing, acquiring and exploiting a data product. It may also help potential users to evaluate the data product to determine its fitness for use. Survey-based observation data products must provide both metadata and data quality indicators associated with the observation datasets. The metadata being provided with an observation data product may also be provided in a catalogue for the purpose of discovery and interoperability.

7.2.2. Metadata & Data Quality

ISO 19115 (Geographic Metadata) is the international standard for describing geographic information. Many tools—often embedded within GIS software—support the capture of quality and lineage information alongside spatial data. Countries frequently implement their own profiles of this standard, adapting it to the needs of specific communities by, for example, defining which metadata elements are mandatory or conditional, and narrowing allowed values (e.g., for spatial reference systems).

> *Good Practice*
> Ensure metadata is created covering both lineage and quality indicators and this is supplied with any data

In the UK, the GEMINI metadata profile is widely used and is mandated across government departments. Although these profiles are customized, they remain conformant with ISO 19115, ensuring metadata remains compatible across systems and simplifying both data discovery and sharing.

Implementing these standards or profiles provides a structured framework for documenting critical information about datasets, allowing users to evaluate how well the data aligns with their intended use.

For elevation data, understanding vertical uncertainty is essential for assessing fitness for purpose. However, this information is often missing from existing survey datasets. For example, the BAG format was designed to address this gap by including an uncertainty layer directly within the dataset, allowing it to be shared alongside the depth values. Unfortunately, this layer is frequently left unpopulated, largely due to limitations in survey systems and workflows that do not generate or export uncertainty metrics. Additionally the S-102 Data Product Specification also provides a means to capture uncertainty.

Creating metadata according to recognized standards and supplying it with datasets supports the FAIR data principles—Findable, Accessible, Interoperable, and Reusable — ultimately improving data transparency, usability, and long-term value.

7.3. Good Practice: Filling the Geospatial Data Void

Often marine and land surveys do not meet or overlap, as depicted in Figure 1. On the left, gaps are highlighted between marine (blue) and land (green data); on the right, the black box highlights the gap between the land (red) and marine (blue) profiles (horizontal red line is no data value in profile). These gaps are primarily due to differing areas of responsibility between land and marine organizations responsible for the capture and their overarching purpose. Hydrographic Offices who may be responsible for surveying the marine domain have a primary focus of safety of navigation and focus their data capture around areas of significant levels of shipping.

Land agencies may have responsibility beyond the High-Water line but they may not comprehensively survey the intertidal zone. Where there is a gap between the datasets, the user needs to identify the most appropriate method to fill those gaps.

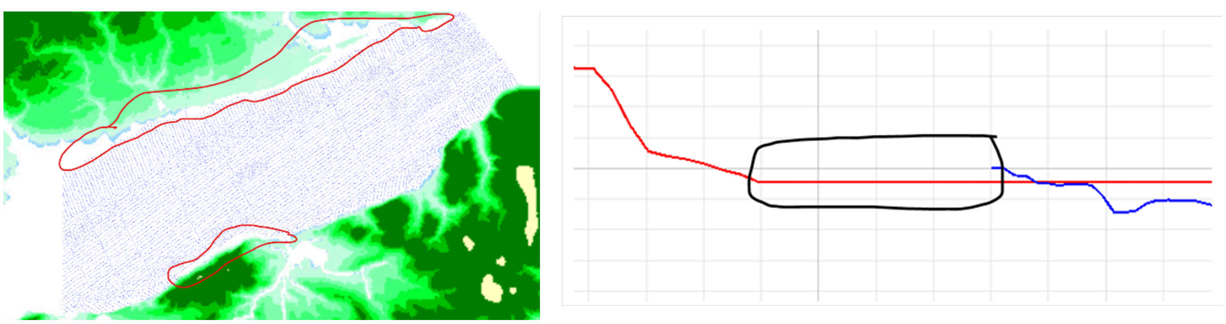


Figure 1 — The 'white ribbon' of The Solent

Options include sourcing alternative data such as satellite-derived elevation or bathymetry products or by re-surveying the area using airborne LIDAR observing programs. The selection of an appropriate method depends on the specific requirements and constraints of the project, particularly in terms of budget, resolution needs, and the physical environment, as each method has distinct cost and performance implications.

Remote sensing offers a range of global data sources for both terrestrial and marine elevation. For land elevation, satellite-based products may be made available from commercial vendors (e.g., Maxar, Airbus) and/or from government and academic agencies. These datasets are typically derived using multi-image photogrammetry techniques and are available at resolutions ranging from 0.5 m to 5 m. However, update frequency is irregular which may cause problems due to the need for sufficient imagery coverage over time to construct high-quality models. In dynamic coastal environments, this can lead to data artefacts—such as inconsistent depiction of anthropogenic features—arising from variations between image capture times.

For marine elevation, data can be derived from both commercial multispectral imagery and publicly available sources such as Sentinel-2 (10 m resolution) and Landsat (30 m resolution). Commercial sources offer higher-resolution products (0.5 m to 3 m). Bathymetric data may be updated more frequently than terrestrial models, since a single cloud-free, high clarity image is sufficient to generate a depth model. In optimal conditions, daily coverage of a site is theoretically possible depending on location.

That said, satellite-derived bathymetry is only effective in clear, shallow waters—typically to depths of 0–20 m, with up to 30 m achievable in ideal circumstances. In turbid waters, such as estuaries or high-sediment coastlines, this method becomes unreliable or unusable, as suspended particles obstruct light penetration. Consequently, its effectiveness is geographically variable—well suited to regions like the Caribbean or Pacific islands but may be limited elsewhere.

Data products are usually delivered in OGC-compliant formats, including GeoTIFF and 3D tiles, and are increasingly made available through web services such as the OGC Web Coverage Service (WCS) Interface. However, the extent of these delivery options varies by vendor and reformatting may occasionally be required for full interoperability.

Cost structures for elevation data vary significantly. Terrestrial satellite-based elevation models typically range from $5 to $35 per square kilometer, depending on resolution and provider. Marine elevation products tend to be more expensive, ranging from $10 to $75 per square kilometer—or higher—depending on resolution, area, and the number of images required to generate the data. Global coverage is generally good for terrestrial products, though some areas may have reduced availability due to persistent cloud cover or lack of archived imagery. In contrast, satellite-derived bathymetry (SDB) is inherently restricted by water clarity and depth, making its coverage far more variable and context-dependent.

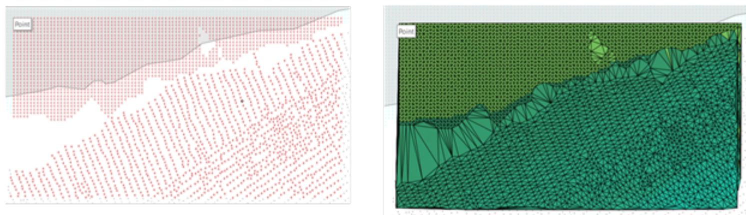
If gaps cannot be addressed through satellite-derived data products, airborne LIDAR remains a viable option, as demonstrated in the projects ISPRA Marine Ecosystem Restoration and Norway's Marine Base Map in the Coastal Zone. This approach provides high-resolution data but requires clear water conditions for bathymetric application. LIDAR systems typically penetrate water up to 40 m depth under ideal conditions; in more turbid environments, they may fail to return data beneath the water surface, instead only capturing the seabed where it is exposed at low tide. Thus, surveys must be carefully timed with tidal conditions, and their feasibility is strongly influenced by local water quality.

Where neither remote sensing nor re-survey is practical, interpolation may be used. It is the most cost-effective method but carries inherent limitations. Techniques include linear interpolation, nearest neighbor, and cubic spline. Each method behaves differently:

- Linear interpolation connects known data points with straight lines, assigning intermediate values between the known points, which may oversimplify complex seabed features;

- Nearest neighbor assigns values based on the closest existing point, which can create artificial boundaries; and
- Cubic spline produces smooth curves between points but can introduce artefacts in rapidly changing terrain.

The image shows how a triangulation (nearest neighbor in this case) can infill the gap between data points. This creates a smooth surface between the points and can be effective over small gaps; however may miss real features if the gap between data points is more significant.



Triangulation to fill the gap

Given that seabed morphology is rarely linear, these methods may misrepresent true topography. Consequently, any errors introduced during interpolation could propagate into downstream applications such as coastal inundation modelling, potentially undermining the reliability of hazard assessments or planning models. For this reason, interpolation methods must be selected and tested carefully, with an emphasis on error quantification and understanding the underlying bathymetric complexity.

> *Good Practice*
> Gaps should ideally be filled with new captured data from alternative sources (new surveys or remote sensing)

7.4. Good Practice: Multiagency Governance

The coastal zone is a unique environment in that it has both common and competing interests in its use. On the landward side, the economic interests alone disproportionately shape the use of the region. Direct interests involve the buildout of port facilities, designation of aquaculture development areas, and management of navigation rights-of-way and tourism. Environmental interests attempt to maintain the natural state of the coastal waters while emphasizing the sustainable use of its resources.

Governance of the coastal area requires multiagency engagement to ensure transparency throughout the policy-making supply chain. It provides the framework for decision-making and helps agencies develop a clear strategy to bridge the issues of overlapping interests within the shared space of the coastal area. These issues include:

Mixed /Split accountabilities

Land data is primarily managed by national or regional land agencies while marine data is primarily handled by hydrographic offices or maritime authorities. The intertidal zone falls between these and is often not clearly assigned to either side.

Different Legal Frameworks
Land and sea are governed by different laws, policies, and property rights. This creates gaps or overlaps in authority, especially in coastal development, conservation, and disaster response.

Inconsistent Standards and Tools
Agencies use different data formats, coordinate systems, and update cycles. This makes it hard to merge datasets or create a unified view of the coast.

Lack of Coordination
Without a shared governance model, agencies may duplicate efforts, miss critical data, or make conflicting decisions and importantly, make it difficult to find and access the needed data either by machine or human.

Funding and Prioritization Issues
Coastal integration projects often fall between funding categories (land vs. marine), making them harder to support.

7.4.1. IGIF-MSDI Maturity Roadmap

The IGIF-MSDI Maturity Roadmap is an initiative developed in conjunction with the UN-GGIM, IHO, OGC, and World Bank, with participation from the US National Oceanic and Atmospheric Administration (NOAA) as Chair of the UN-GGIM Working Group on Marine Geospatial Information (WG-MGI). Its intent is to provide a prescriptive framework for agencies to develop policy aligned with the World Bank Integrated Geospatial Information Framework (IGIF) methodology.

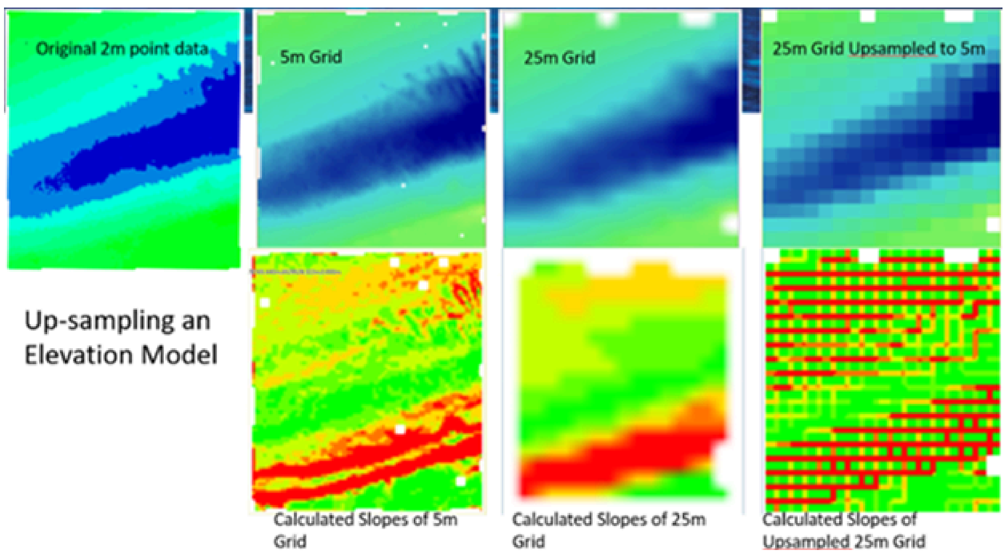
> *Good Practice*
> The Umbrella Governance Model of the IGIF-MSDI Maturity Roadmap as a foundational principle of multi-agency governance

The project objective is to provide guidance to all stakeholders across the marine and terrestrial domains to ensure cross-agency engagement and the development of a fully integrated spatial data ecosystem for national, regional and local interests. The framework provides the basis for establishing governance policies across agencies using its Umbrella Governance Model – a recommended Best Practice to address the requirements of an integrated coastal management plan. The framework recognizes the critical interdependence between terrestrial and marine environments, particularly in coastal zones where risks, infrastructure, and ecosystems span both domains. By promoting common standards, interoperable data systems, and shared governance, the IGIF Umbrella Governance Model ensures that terrestrial and hydrographic data are treated as essential components of national geospatial infrastructure.

7.5. Good Practice: Managing Resolution

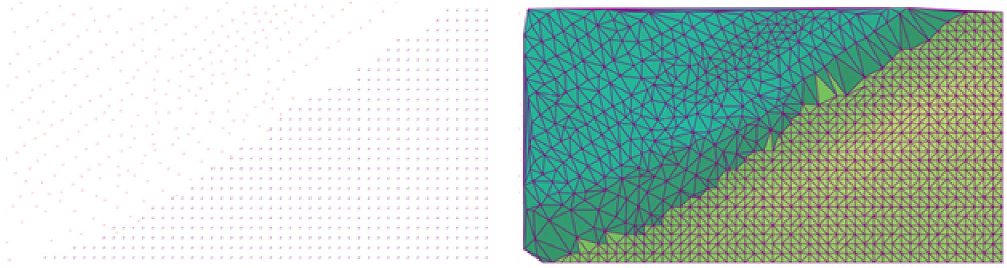
Marine and land datasets are often captured at different resolutions and with different context – partly due to the environmental challenges of the survey area or to meet specific guidelines and standards particular to its intended purposes. Historically, complete detailed surveys of the seabed were not possible due to the technologies available. While the advent of multibeam has enabled much more comprehensive seabed coverage in any single survey, many areas will still only have single beam or potentially even leadlined surveys with much sparser coverage.

The causes issues when trying to create a seamless elevation model between source data at different resolutions. A dataset may be required to be upsampled or downsampled to make the data consistent across an area of interest. Downsampling reduces the level of detail available in the data, while upsampling increases the density of the data points but does not increase accuracy. If a low-resolution dataset is upsampled, it has the potential to generate inaccurate features, shown in the image below which could affect the outcome of the modelling.



Examples of the effects of upsampled elevation datasets

To reduce the impact of resolution differences it may be best to start with point cloud or vector-based datasets. While Raster datasets are good for speed of data processing, point and vector datasets have the advantage they can be easily transformed with least loss of accuracy using standard GIS software and the point datasets can be used as a basis for creating TIN (Triangulated Irregular Network) models which will produce improved interpolation across data gaps. The TIN accommodates sources of different resolutions into a single model (as visible in the image below) and then can be converted into a grid with appropriate resolution for onward processing into modelling software.



TIN model for improved interpolation across data gaps

The downside of modern point cloud datasets is they can be very large so some GIS systems may struggle to handle them, particularly multibeam data, meaning for processing they may need to be split into batches or need very large computer resources.

> *Good Practice*
> Use point datasets as a starting point for building elevation models to get all sources into the same resolution (point spacing) rather than resample grids

8

FUTURE DIRECTIONS

8 FUTURE DIRECTIONS

Application Profiles
Accessing datasets across the geospatial sector remains challenging. While significant efforts are being made to promote FAIR data principles, these initiatives are often fragmented between land and marine portals. There is opportunity to build on the recommended set of best practices with specific application profiles based on the core OGC standards. Standards identified for further investigation include OGC DGGS, OGC GeoDatacube, OGC Coverages, OGC Analysis Ready Datasets and the OGC Connected Systems. The OGC GeoDCAT initiative highlights requirements focused on data discovery across domain-specific observing platforms.

Industry Collaboration
There is considerable focus on this area amongst other organizations and it should be ensured that these are working in tandem with the OGC. The work being done via the UN-GCCE and UN-GGIM continues to research how countries are currently approaching this and what assistance they need to improve.

Vertical Land Motion
Vertical land motion has a significant impact on correctly ascertaining height information in many countries, and particularly the effect of using previously collected data and new data together needs to be better understood with best practices developed for handling this situation.

Semantic Interoperability
For properly integrated land and sea data, semantic differences must be resolved and shared vocabularies defined and published in a machine readable way. Further work is required on understanding the definitions in each domain and how these definitions can be resolved.

Temporal Reference Frames
With plate tectonics moving the earth's landmasses, Coordinate Reference Systems change over time. It is important to consider the epoch of the CRS when integrating data of different ages. With existing GIS systems this can be hard to do if CRS epochs and the associated transformations are not built in to the software. Further work is required to understand the effect of epochs and how transforming between these can be implemented.

MetOcean
Sea level and sea state modelling requires meteorological observation datasets to properly account for external forcings such as wind speed and coastal water currents to derive the extent of storm surge within a coastal area of interest. Wave energy is enhanced or diminished by the effects of wind, breaking waves, and energy exchanges between the various physical components of the local environment. Future work will benefit from integrating with real-time and forecasted meteorological observation platforms with focus on deriving a set of best practices for an integrated Land, Sea & Air feature model.

Bathymetric and Topographic Pathways
Future work is required to integrate a harmonized topo-bathymetric coverage model with wave energy models to properly account for water flow pathways affecting the extent of storm surge and coastal inundation.

Land Administration
Administration of the coastal zone requires tight integration between land and maritime agencies. The ISO Land Administration Domain Model (LADM, ISO 19152) provides a standardized framework for representing land administration information including legal interests, rights, restrictions, and responsibilities. This complements the efforts of the IHO and its S-121 Maritime Limits & Boundaries standard and together, provides for the representation of legal and physical aspects across coastal boundaries.

Further to the discussions related to multi-agency governance and coastal zone management, profiling an integrated coastal administration framework based on the LADM and IHO S-121 standards would be of benefit.

Capacity Building
Resources to support these best practices are currently limited. To support training and capacity building in this area should be a future focus to ensure users are able to implement the recommended practices in a pragmatic way suitable for environment and budgetary constraints.

A

ANNEX A (INFORMATIVE) COMMUNITIES OF PRACTICE

A

ANNEX A (INFORMATIVE) COMMUNITIES OF PRACTICE

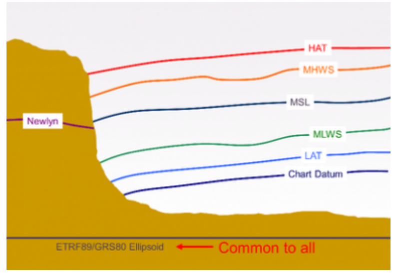
A.1. United Kingdom

In the United Kingdom, topographic land data is captured and managed by Ordnance Survey (OS), the national land mapping agency. Marine data is primarily sourced, managed and delivered by the UK Hydrographic Office (UKHO), the UK government's centre for hydrography and seabed mapping. As part of its Public Task, UKHO has a key focus on providing hydrographic products and services for the safe navigation of large vessels in support of its Safety of Life at Sea (SOLAS) obligations.

Neither organization has full responsibility for mapping the intertidal zone. The primary focus of UKHO is to provide data for maritime safety and the protection of the marine environment. Ordnance Survey captures features down to Mean Low Water but in the intertidal zone, these are primarily features that are required for land navigation needs. As a result, neither organization has full responsibility for mapping the intertidal zone and in many cases, a geospatial data void remains across these jurisdictional boundaries.

To address this situation, in 2002, the UK Government provided funding to maritime local authorities to establish coastal monitoring programs with the primary aim to map and collect data across the *white ribbon*. These programs are still ongoing and publish all their data in an online catalogue and realtime viewer (CoastalMonitoring.org). The survey data is shared with UKHO and used in the production of nautical charts, giving better coverage across these coastal areas.

In 2003, the Integrated Coastal Zone Mapping project between OS, UKHO and British Geological Survey outlined the need for a vertical separation model based on the geoid. Subsequently, the UKHO, in collaboration with University College London (UCL), developed a Vertical Offshore Reference Frame (VORF) solution for the UK and Ireland.



Vertical Offshore Reference Frames (VORF)

Regardless of the vertical reference frame a dataset is in, VORF provides modeled surfaces as outputs from the transformation data grids calculated based on the difference between different vertical reference frames (Horizontal Datum for VORF UK and Ireland is ETRS89).

The Vertical Offshore Reference Frame (VORF) was published in 2008 and is available as a paid-for dataset - datahub.admirality.co.uk/portal. The outputs may also be accessed for free under certain terms of use such as academic research.

The United Kingdom does not have a single definition of a coastline and at present there is no intention of generating one. Specific Coordinate Reference Systems (CRS) have been defined for use within the UK and its environs and are documented in the UK Geospatial Data Standards Register. They include references to both 2D and 3D CRS; however there is no reference to marine vertical datum references or methods to transform from these.

Each agency has different data product specifications (and reference feature catalogues) when it comes to features that are captured in the intertidal zone. This affects both the positional accuracy of the feature and the definition of the feature captured. For example, comparing IHO S-57 Electronic Navigational Chart (ENC) datasets with various Ordnance Survey (OS) topographic products found that scale, classification, and generalization significantly impacted alignment between datasets. Coastline definitions vary across OS products and differ from the S-57 data, particularly in terms of Mean High Water and tidal boundaries, leading to ambiguity. Discrepancies were also observed in the representation of jetties, pontoons, low water marks, navigation aids, and pipelines.

S-57 and OS products often classify the same feature (representation of the real-world phenomena) differently based on the primary purpose of the data product. Overall, the study highlights a need for clearer definitions and harmonization by implementing semantic and structural interoperability between OS and UKHO data to improve the accuracy of coastal mapping.

A.2. United States

In the US, land topographic data is primarily managed by the US Geological Survey (USGS) while marine data is overseen by the National Oceanic and Atmospheric Administration (NOAA) specifically through the National Geodetic Survey (NGS) and Office of Coast Survey (OCS).

As in the UK, no single agency is fully responsible for the intertidal zone; however NGS has responsibility of surveying the shoreline, including (depending on sensors used) depths down to 10m which then joins up with OCS data capture. NOAA's nautical charts aim to support Safe Navigation, with shoreline representations mostly based on the Mean High Water (MHW) line, while USGS topographic maps may use different shoreline references, often leading to discrepancies at the land-sea interface.

To help bridge this divide, NOAA maintains the National Shoreline, a high-resolution, photogrammetrically-derived shoreline dataset aligned with the MHW datum. However, variations in datum definitions and methods across agencies persist, this is improving with USGS using the NGS defined vertical datum. Data is made available via NOAA's Office of Coast Survey, and also contributes to National Map products through interagency collaboration.

Recognising the challenges posed by disparate vertical datums, NOAA developed VDatum, a vertical datum transformation tool that allows users to transform elevation data between tidal, orthometric (e.g., NAVD88), and ellipsoidal (e.g., NAD83) datums. VDatum surfaces are generated by integrating tide models, geoid models, and water level station observations, creating a seamless transformation model across the coastal zone. This tool is publicly available and has become critical for supporting coastal resilience, habitat modelling, and seamless land-sea elevation integration.

In parallel, NOAA and USGS collaborate on the Coastal National Elevation Database (CoNED), which integrates topographic and bathymetric data into continuous elevation models across the coastal zone. CoNED DEMs are produced using LiDAR, sonar, and satellite data and are referenced to a common vertical datum using VDatum. These models support storm surge modelling, floodplain mapping, and coastal planning. Projects have covered key regions such as the Northern Gulf of Mexico, Southern California, and parts of the US East Coast.

While a single authoritative definition of the US coastline does not exist, NOAA's Legal Shoreline and National Shoreline datasets are increasingly used for federal planning and charting, both versions of the shoreline have different applications so are valid in different situations. NOAA's Digital Coast platform provides access to shoreline, elevation, and land cover datasets along with tools for visualization and download.

Despite efforts, vertical and horizontal datum inconsistencies remain a barrier to fully integrated coastal mapping in the US. The upcoming replacement (currently in alpha phase) of NAVD88 and NAD83 with the new North American-Pacific Geopotential Datum of 2022 (NAPGD2022) and North American Terrestrial Reference Frame of 2022 (NATRF2022) is expected to improve consistency, particularly when integrated with future versions of VDatum.

B

ANNEX B (INFORMATIVE) INTRODUCTION TO LAND DATA

B ANNEX B (INFORMATIVE) INTRODUCTION TO LAND DATA

For those new to working with land data this section provides an introduction into some of the terminology and specific considerations that need to be understood to successfully work with land data.

Land data is generally referenced to a single national coordinate reference system (horizontal) and a national vertical datum. However, individual building plans and engineering drawings are often drawn to a local horizontal reference with the 0,0 coordinate frequently being the bottom left of the drawing. This is not then easily translatable into national real-world coordinates.

National mapping data sets are created and managed in a continuous way so features are not disjointed or separated at tile boundaries. With data capture being easier on land (in general), there is often considerably more data of higher accuracy and specification available.

Most countries have an authority or agency responsible for capturing land data – both the shape of the land (topography), the features on the land (buildings, infrastructure and natural features) and the cadastre. Advanced land data capture is highly structured, containing multiple attributes which conform to an overarching data model. However, depending on how advanced the data capture is from other sources buildings and infrastructure may be “spaghetti” lines – not joined up to define features e.g. a rectangular building may be made up for 4 separate lines to define the edges rather than created as a single polygon. This can make the data less ready for onward analysis and use in other systems.

Data interoperability can also be improved by a better definition and semantic understanding of the data. For example, the UK Ordnance Survey define a lighthouse as a building, whereas the UKHO definition is more likely to be as an aid to navigation.

Similarly, the “coastline” actually varies in its definition — both between land and marine agencies and between countries. Understanding how your country and the organizations producing the data define the coastline and the common features on it will help make judgements on how land and sea data can be combined.

B.1. Horizontal Datums

Most countries have a single national horizontal coordinate reference system (CRS) that is used for land data. For example, in the UK Ordnance Survey British National Grid (EPSG:27700) is a

2D projection (Transverse Mercator) system giving easting and northing coordinates used for all national land mapping and by the majority of land-based users.

Nationwide modern coordinate systems are frequently realized via data from a number of CORS (Continuously Operating Reference Stations) GNSS stations and transforming these coordinates into the chosen projection providing eastings and northings.

In the UK, OS uses its OS Net CORS GNSS stations using the ETRS89 coordinate system, and their OSTN15 transformation, to realize their national OSGB36 (EPSG:27700) coordinate system. The exception may be individual building and engineering data which are often referenced to a local CRS of a limited extent.

B.2. Vertical Datums

On land, there is usually a single national vertical datum. In a similar way to horizontal datums, modern vertical datums are also realized via data from a number of CORS GNSS stations and transforming the heights into the local vertical datum required.

In the UK mainland, this is based on the mean sea level (MSL) established from continuous tide readings between 1915 and 1921 at Newlyn, Cornwall – called Ordnance Datum Newlyn (ODN). This is now realized via the OS network of CORS GNSS stations, and their height corrector surface (OSGM15) which allows an accurate transformation between the regional (ETRS89) satellite coordinate system and the ODN datum. Some countries have also developed Surface Separation Models which allow accurate transformation between the Land Datum and various Marine Datums in use in those countries e.g. Canada, US, UK, Australia.

B.3. Sources of Data

National mapping agencies will usually be the primary comprehensive source of data; however, the level of detail may vary. Data usage must be understood — some datasets may be based on legal definition and not necessarily correspond to physical boundaries e.g., cadastral land parcels or ward boundaries. Users must be aware of the intended purpose of the data to ensure it is used appropriately.

Commercially captured data will range from local datasets through to nationally or internationally captured remote sensing datasets.

B.4. Scale and Specification

Land based mapping data is generally captured at a national level, to a particular specification. In the UK the specification will vary according to the "standard" scales of 1:1250 in urban areas

1:2500 in rural areas and 1:10,000 for mountain and moorland. Smaller scale mapping products are usually derived from these basic scales.

Other datasets produced specifically for a project, e.g. building and engineering plans will be more varied.

B.5. Land-specific terminology

Topography – the physical appearance of the natural features of an area of land, especially the shape of its surface

Cadastre — a register of real estate boundaries, including the legal representation and record of ownership

Zoning — Legal regulations on how land can be used (residential, industrial, etc.).

Land Cover — what's physically there (e.g., forest)

Land Use — how the land is used (e.g., recreation)

C

ANNEX C (INFORMATIVE) INTRODUCTION TO MARINE DATA

C ANNEX C (INFORMATIVE) INTRODUCTION TO MARINE DATA

For those new to working with marine data this section provides an introduction into some of the terminology and specific considerations that need to be understood to successfully work with marine data.

Land data is generally referenced to a single national coordinate reference system (horizontal) and national vertical datum. In the marine space many different coordinate reference systems and vertical datums are used. How to transform between these and the national land coordinate reference systems and datums is complex and users need to be aware of what the options are, and which method is appropriate for their use. This includes needing to understand what the software systems being used have as their default options.

Scale and resolution of data can also vary considerably because it can be so expensive and complex to capture data in the marine domain. Understanding this and the impact it can have on the use of data when combining with land datasets is very important.

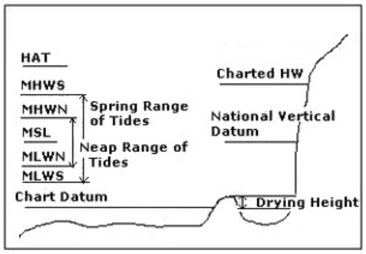
Something seemingly as simple as the “coastline” varies in its definition — both between land and marine agencies and between countries. Understanding how your country and the organizations producing the data define the coastline will help make judgements on how land and sea data can be combined.

Although seabed mapping supports a diverse range of applications, the majority of bathymetric data is captured across the globe for the purpose of safety of navigation and often by a nation’s defense agencies. This can lead to data being either not shared or shared in a way that makes it inappropriate for other uses. An understanding of these issues is required to enable the data to be shared and used for different purposes.

C.1. Vertical Datums

On land there is usually a single national vertical datum defined based on either benchmarks levelled with GNSS or, more recently, defined using a Geoid model. In the marine domain, it is more complicated as it isn’t possible to establish benchmarks to check against. Tides have an impact on any levels measured in the marine space, and as these change, agreement has to be made on what level the tide is referenced to. On a nautical chart, depths will be referenced to Chart Datum, but this is often specific to the Chart being used, and the adjacent chart may use a different value for Chart Datum. Different nations will use different vertical datums as their Chart Datum. For example, the UKHO uses approximately the level of Lowest Astronomical

Tide (LAT) as Chart Datum. NOAA uses Mean Lower Low Water (MLLW) while the Canadian Hydrographic Service (CHS) uses lower low water, large tide (LLWLT). A High Water Level (HWL) Height Datum, such as Highest Astronomical Tide (HAT) or Highest High Water (HHW), is used for height measurements and vertical clearances. This is critical for ensuring safe passage under overhead obstructions such as bridges.



Simplified diagram of vertical datums that may be used within the marine domain

A list of Vertical Datums used by IHO Member States to describe Chart Datum is available from IHO Services and Standards — Vertical Datums.

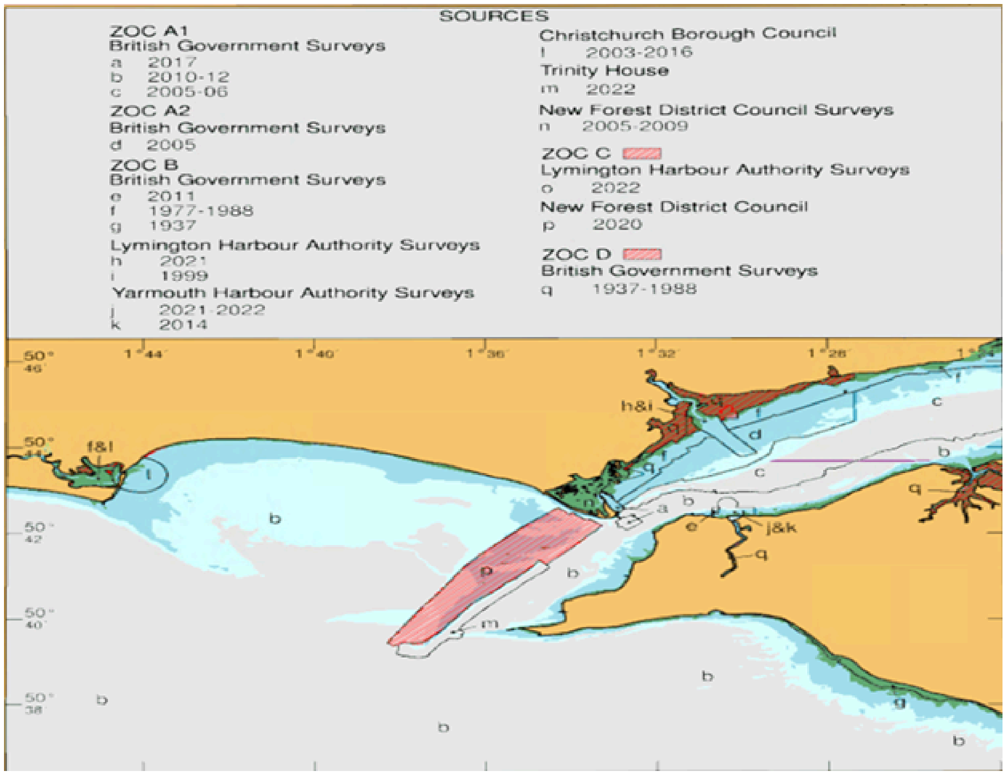
C.2. Sources of Data

A primary source of marine data often comes from nautical charts provided by National Agencies (Hydrographic Offices). However, how accessible this data is varies considerably between nations. Some countries make the data freely available; others license it for non-navigational purposes; and others only allow it be made available for navigation purposes – in these places there may not be any other source of marine data. Digitizing paper or raster versions of paper charts is often prohibited due to copyright laws which can also restrict access to data.

In the marine domain, much more data is commercially captured (e.g. by offshore energy providers). However, this can be difficult to find and access, and may be restricted as confidential or not willing to be shared due to the costs of capture.

Within a nautical chart, it may not be obvious the age and quality of the data that is being displayed. For example, some depth soundings on charts may be based on historic surveys which may make them unreliable for other purposes. Users are required to check metadata sources, as well as Notices to Mariners for chart updates.

Paper charts, as the following image demonstrates, contain a Source Data Diagram that communicates the degree of confidence users should have in the adequacy and accuracy of charted depths and their positions.



Paper Nautical Chart Source Data Diagram

The Source Data Diagram provides, for example, information about the collecting authority, collection year and method used or a Zone of Confidence (ZOC) diagram with information about the horizontal and vertical uncertainty and sea bottom coverage and feature detection. However, this is only indicative of the bathymetric data included in the charts and doesn't necessarily demonstrate quality and age of other feature types.

Electronic Navigation Charts (ENCs) include a meta object, Quality of Data (M_QUAL) which are captured to provide an assessment of the quality of bathymetric data. The attribute Category of Zone of Confidence in data (CATZOC) is mandatory providing six different zones of confidence. These values are assigned to geographical areas indicating whether data meets a minimum set of criteria for positional accuracy, depth accuracy and seafloor coverage, to assist mariners with determining a safe Under Keel Clearance.

Quality of other feature types within the ENC is catered for by other Objects and Attributes including the meta object, Accuracy of non-bathymetric data (M_ACCY), the Quality of Position (QUAPOS), Positional Accuracy (POSACC), Vertical Accuracy (VERACC) and Survey Reliability (M_SREL). Source Indication (SORIND) and Source Date (SORDAT) provide the means to communicate source and date of non-bathymetric information on individual objects where this information is considered to be useful to the mariner.

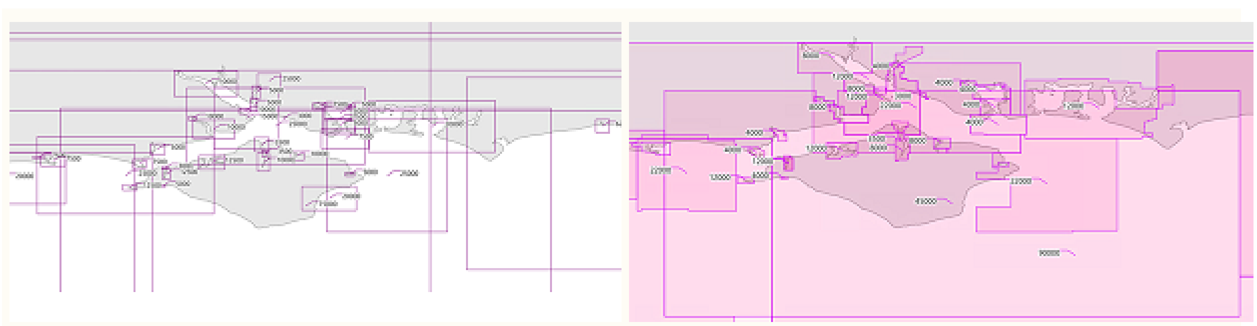
By understanding the accuracy limitations of the underlying data in greater detail, the mariner can manage the level of risk when navigating in a particular area.

C.3. Scale and Resolution

Unlike land data, navigational charts act as a key data product to deliver marine data. Produced primarily in support of the safe navigation of vessels subject to the International Convention for Safety of Life at Sea (SOLAS), areas that are not frequently navigated by large vessels may, as a result, have limited coverage or quality. More recently as part of national MSDI objectives, hydrographic offices are applying additional focus on data collection supporting a broader range of applications including offshore energy and infrastructure to marine ecosystem science.

Land datasets are often supplied in a neat tiled format where features at the edges of tiles join cleanly; this is often not the case with marine datasets. Nautical charts are usually produced (for historical reasons) to cover an area that make sense to the navigator when they are planning and navigating their route (the approaches to a port, a particular sea area) and printed to specific size of paper that would fit on a Chart table on a vessel. This results in Charts with different scales and coverage and possibly gaps between charts of the same scale.

As an example, across UKHO Chart holdings, 89 different scales are used ranging from 1:2,000 to 1: 45,000,000 and this variation in scale can create challenges when integrating marine data with GIS systems. The image below shows a selection of Raster Chart boundaries and their associated scales.



According to the IHO S-65 ENCs Production, Maintenance and Distribution Guidance standards, ENC borders should be rectangular while the data coverage can assume any shape within those geographic extents (i.e. the data may not cover the entire ENC area). Each Hydrographic Office is encouraged to update their coverage schema to a rectangular gridded system; however, due to ENCs historically being produced by digitization of the paper charts, this type of grid schema has not yet been globally achieved. Similarly, Electronic Navigational Charts can be many different scales depending on coverage.

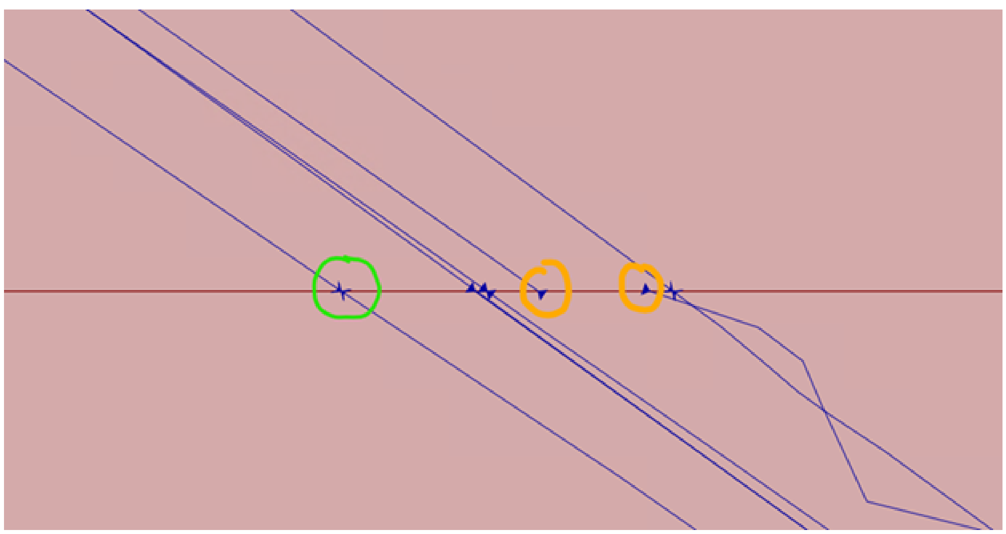
Many Hydrographic Offices are going through a re-scheming process in support of data improvement initiatives which include:

- Harmonizing and upgrading the ENC content to create consistency in scale and content, so the original footprint of paper charts is not visible in the reschemed data;
- The opportunity to incorporate user feedback to improve the user experience, safety and or ensure future maintenance is more efficient; and

- Preparing for S-101 conversion and aligning limits with future S-100 data product specifications in mind (ref: Introduction to the IHO S100 Standard).

Re-scheming Process Improvements

As each chart was often created individually, features do not necessarily join at the edges and a pipeline or contour may not look like a continuous line and may have a jump between Charts (orange highlight) or they may “join” but be two separate pieces of geometry (green) which if being used for analysis may give a different result.



Discontinuous features at chart boundaries

Historically, Electronic Navigational Charts were created by digitizing paper charts. Where features are not fully depicted on a paper chart, the associated ENC may result in missing parts of features. This is a specific issue that would be unlikely to occur in land datasets but with more modern approaches to data capture, this has changed and features are stored and edited in databases allowing for the source data to be more accurate representations.

C.4. Tides

Tides are the regular rise and fall of sea level caused by the gravitational pull of the sun and moon. The rise and fall is generally predictable every day with most places having two high and two low tides. The predicted height of the tide is calculated using mathematical modelling (harmonic constituents) and means it can be predicted almost infinitely into the future.

Tide heights are referenced to a vertical datum. The actual depth of water at the location will be the tidal height plus the depth from the datum to the seabed.

Tide levels will vary from prediction due to atmospheric influences – air pressure, wind strength and direction, and if in a river or estuary then rainfall can impact the actual height. A positive difference (actual height is higher than predicted) between the predicted value and the actual height is called a Surge and a negative difference is called a Cut or Negative Surge.

There are certain locations in the ocean which effectively have no tide change. These are called amphidromic points.

C.5. Marine-specific terms

Shoal Bias – nautical charts published for navigation will always show the shallowest depths in an area to ensure that vessels know what is the minimum depth they will be traversing across. This is known as Shoal Bias. While this ensures safe navigation, it can misrepresent the actual seabed topography, making it unsuitable for scientific seabed analysis or infrastructure planning. If a user is intending to place something on the seabed (pipeline, cable, wind turbine) they would need to know the exact depths.

Underkeel clearance – the distance (usually a required minimum distance) between the lowest point of a ship's hull and the sea bed (IHO Data Registry: Underkeel). A vessel will require a particular depth of water underneath it for safe passage. To know they have the needed depth they would need to know the exact height of tide, depth of the seabed and how much water the vessel needs between it and the seabed for safe passage.

Intertidal – the area between the high and low tide levels that will be covered with water for parts of the day. (IHO Data Registry: Intertidal) The actual definition of where the highest and lowest levels are will depend on the nation.

Bathymetry — the determination of ocean depths. The general configuration of sea floor as determined by profile analysis of depth data. (IHO Data Registry: Bathymetry)The shape of the seabed below sea-level. Bathymetric data is primarily collected using sonar, LiDAR, and satellite-derived methods.

Hydrography – hydrography is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection. (IHO Data Registry: Hydrography)

D

ANNEX D (INFORMATIVE) IHO S-57 ENC-OS LAND DATA COMPARISON – A UK PERSPECTIVE

ANNEX D (INFORMATIVE) IHO S-57 ENC-OS LAND DATA COMPARISON – A UK PERSPECTIVE

This limited assessment compared IHO S-57 ENC chart data with various OS topographic products to examine how features were represented differently in and near the coastal zone. We chose to use one ENC cell, GB5DEVRC, covering the southern part of Southampton Water, which was the largest scale chart available for this area (Compilation scale 1:12000). We also loaded the OS data products for the equivalent area. The different map and chart products were prepared at different scales. Our goal was to evaluate the range of products to determine whether one was more suitable than the others. The OS products used were:

- OS National Geographic Database (NGD)
- OS MasterMap Topographic (1:1250 scale)
- OS Vector Map Local (VML) (1:10,000 scale)
- OS Vector Map District (VMW) (1:25,000 scale)

The OS National Geographic Database is a data-rich product for land-based applications and provides a high level of detail, particularly with building footprints. The coastline feature in ENC cells for UK waters is based on the coastline in the NGD, so the high tide boundary categories were included in the comparison.

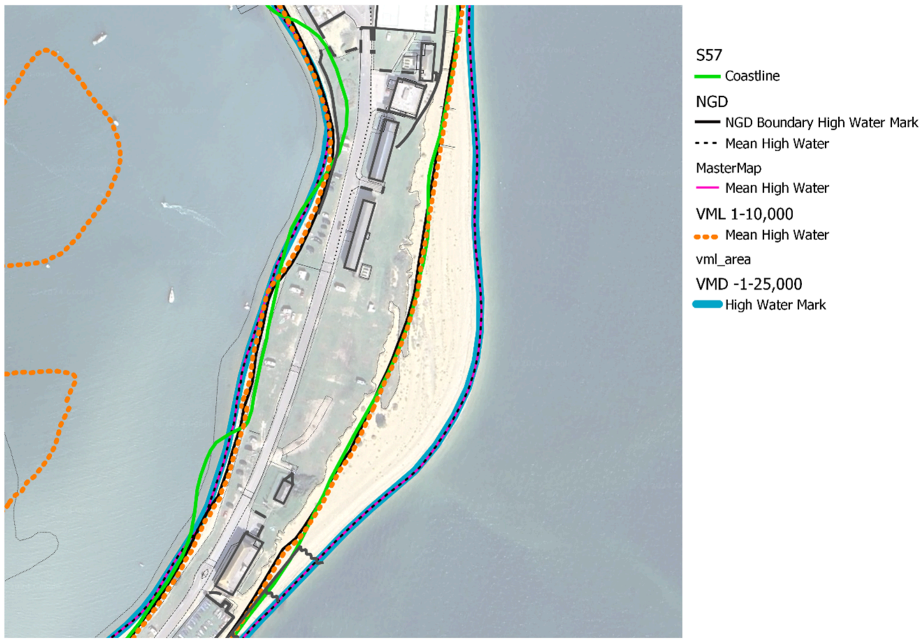
The next section considered different features highlighting examples.

Coordinate Reference Systems used:

- OS – VM: EPSG:27700 British National Grid
- UKHO ENC: EPSG:4326 WGS 84 Geographic Coordinate Reference System

D.1. Coastline

The coastline is the basis for everything else we will be examining, so we felt it was important to start by determining whether there is agreement on its geographical location. To identify the coastline, we loaded the ENC S-57 dataset Coastline features alongside the high-water datasets from the OS datasets.



Coastlines derived from different products

This map of the Calshot Spit area shows that the S-57 does not directly correspond to the OS high water marks which we understand is due to some generalization. It mostly follows the NGD Boundary High Water Mark. For more details on the definition of this line, refer to the OS NGD: Boundary High Water Mark. The NGD also provides a further Tidal Boundary feature, which includes low and mean high water. For more information, see OS NGD: Tidal Boundary.

The Boundary High Water Mark is a legal boundary rather than a physical boundary which is why there is a difference in depiction. The map also shows that MasterMap and Vector Map District (VMD) follow the Mean High Water while Vector Map Local (VML) follows the Boundary High Water Mark.

Our immediate conclusion is that making comparisons between ENC S-57 and OS data products is complicated as there is no complete agreement between the products regarding the location of the coastline/MHW(S) mark. There are even differences within the UK – with Scotland using Mean High Water Springs and England/Wales using Mean High Water. This should be clarified to ensure appropriate use of the Features. The ENC S-57 Coastline does not appear to be a straightforward generalization of the NGD data. Instead, it includes its own distinctive deviations, which are not always consistent with a smoothed or generalized line. This is particularly evident on the western side of the spit.

D.2. Low Water

The zero contour defines “Low water” as the Lowest Astronomical Tide (LAT) in the UK. This differs from Mean Low Water Springs (MLWS), which is used on Ordnance Survey maps. As these have different definitions, it is not easy to provide any direct spatial comparisons. There is some consensus over MLWS in the different OS products; however, the VML product seems to vary considerably.

Calshot Bary: Red= S-57 LAT | Continuous Blue=OS MLWS (most products) | Dashed Blue =OS VML MLWS

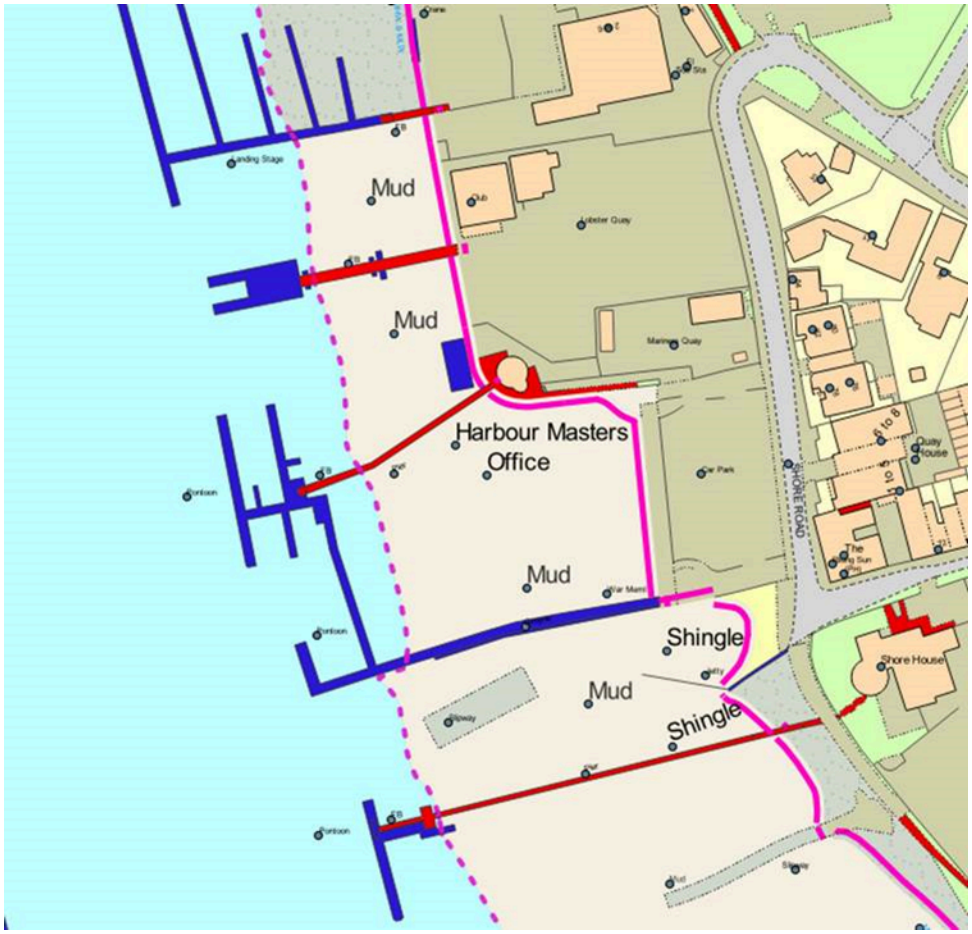
D.3. Jetty Structures and Pontoons

Both S-57 ENC and OS products represent jetties and pontoons depending on scale. In some cases, there is a differentiation between them, while in others, there are inconsistencies within the products. In S-57 ENC, jetty structures are defined as ‘Shoreline Construction’ features (OBJ 122) and pontoons as ‘Floating Structures’ (OBJ 95). However, there are inconsistencies in how these are encoded.

The image below is an example from the Hamble River. The area highlighted in yellow shows floating pontoons that are classified as Shoreline Construction features while other pontoons in the marina to the west are classified differently. Photos of the area in question can be used to help verify this.

River Hamble: Red dashed = S57S-57 Floating Structures|
Black dashed = S57S-57 Shoreline Construction

Ordnance Survey NGD and MasterMap has a detailed representation of the same area with a clear distinction between jetty and pontoons, which reflects reality.



Warsash, Hamble River: OS NGD: Red=Jetties | Blue =pontoons

They are represented as polygon and line features. For example, a pontoon has the following classifications:

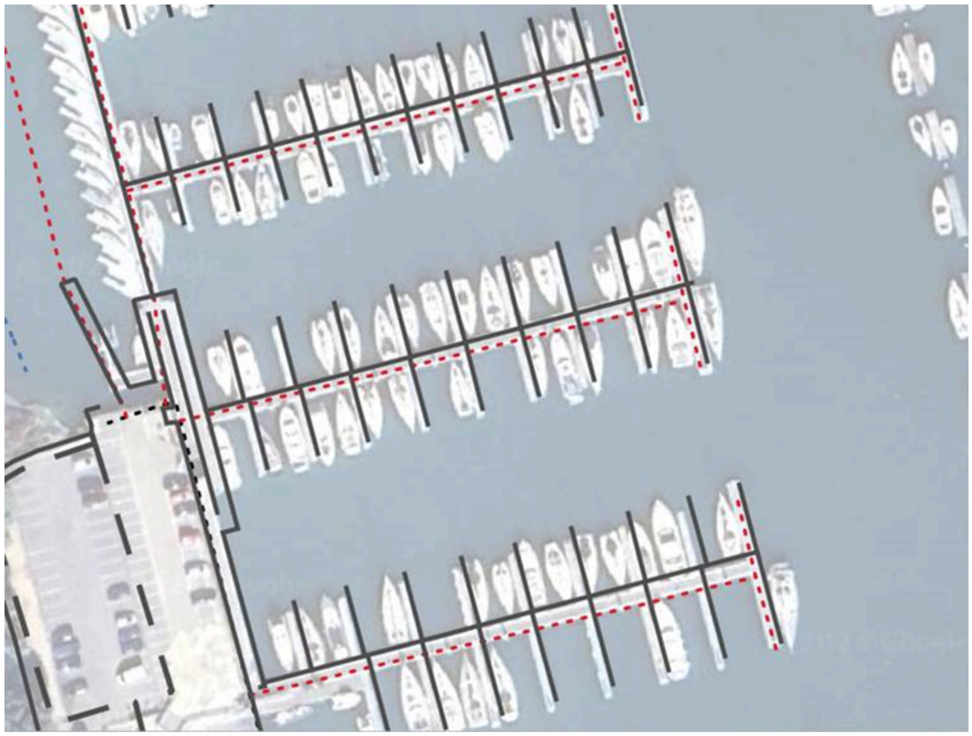
- Structure line feature: Description: Built Structure
- Structure Area feature: Description: Floating Structure
- OSMM Cartographic text feature spatially near but not connected to the feature. Descriptive Group = Structure with text string: pontoon

A jetty structure has the following classifications:

- Structure line feature: Description: Built Structure
- Topographic area feature: Descriptive Group = Path, Structure; Descriptive Term: Footbridge; Theme: Roads Tracks And Paths, Structures
- Cartographic text feature spatially near but not connected to the feature; Descriptive Group = Structure with text string: FB

OS VML provides a simplified linear representation of the same features but does not distinguish between fixed structures and floating pontoons. The lines are classified as 15032 Rural general line detail or 15031 Urban general line detail without any consistency.

The following images show the difference in the spatial location of pontoons using the transformation method: OSTN15_NTv2.

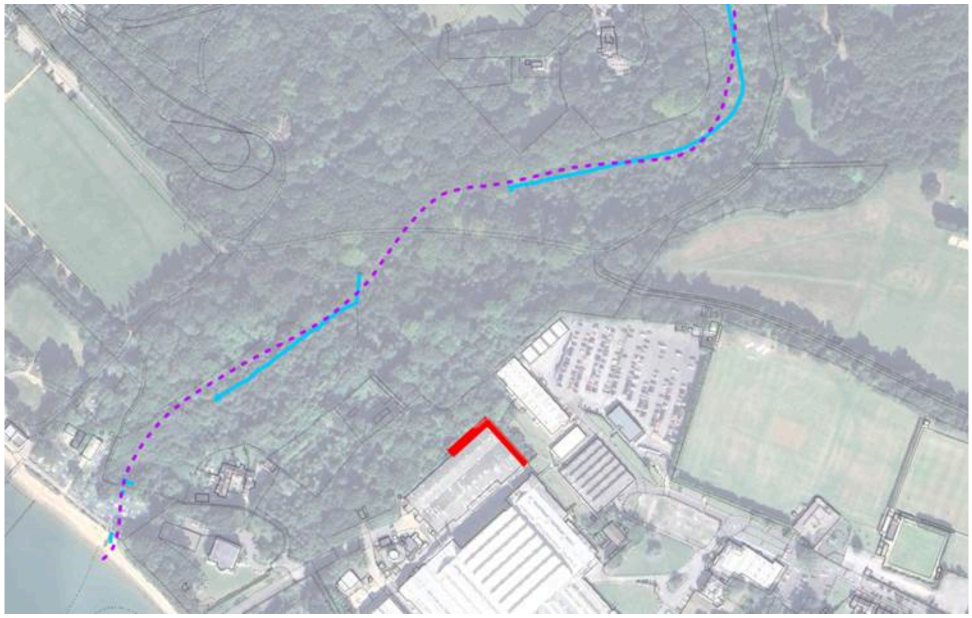


Hamble Point Marina: Grey line: OS VML, Red dashed: S-57

D.4. Rivers

From the data considered, the relationship between the classification of rivers in S-57 and OS is straightforward. The rivers assessed were all small and represented by line features in all datasets. There are not many rivers in the sample area.

OS MasterMap and VML provide more detail and do not depict the watercourse where it runs underground. S-57 provides a more generalized view of the entire watercourse.



Eastern shore of Southampton Water: Blue: OS MasterMap | Purple dash: S-57

D.5. Navigation Markers

Some beacons are depicted on OS maps whereas buoys are not captured. There were no lighthouses in our sample area so we could not test these. Beacons on OS NGD / MasterMap do not have a specific classification; they are generally represented by points (where present), and the feature code can vary depending on the construction of the beacon.

For example, in the following sample, the mark is represented by a point with the descriptive group Roadside, Structure, and the descriptive term Post. The associated cartographic text refers to Post (Green), positioned as two separate points from the feature.

Southampton Water Eastern Shore: Green circle: S-57, Blue Circle: OS MM, Labelling from OS MM

D.6. Pipelines

For the examples assessed, pipelines (that cross into the sea) present a complex picture. OS MasterMap appears to depict more pipelines than can be found in S-57. Nevertheless, in the OS dataset, they are just classified as general detail, which is also used for many unrelated features.

D.7. Summary

There are complications when trying to integrate S-57 and OS Data products. The examples provided demonstrate inconsistencies in the positioning and classification of real world features — particularly in the representation of coastlines, tidal boundaries, jetties, pontoons, and pipelines. While the ENC coastline is stated to be based on OS NGD's high water mark, it exhibits notable deviations inconsistent with the simple generalization. Differences in the coordinate reference system (WGS 84 vs. British National Grid) and tidal reference datum used (LAT vs. MLWS) further complicate direct comparisons.

Both organizations are producing data 'fit for purpose' to the specific requirements and use cases of their application. In the case of ENCs, for example, the focus is on meeting the information requirements of its mariner audience to support planning and safety of navigation. Gaps and inconsistencies between domain-specific data products can make it difficult for users to seamlessly integrate and harmonize the data products across the land-sea interface.

E

ANNEX E (INFORMATIVE) REVISION HISTORY

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DATE	RELEASE	AUTHOR	PRIMARY CLAUSES MODIFIED	DESCRIPTION
2025-07-16	0.0.1	Glenn Laughlin	all	draft
2025-07-25	0.0.2	Glenn Laughlin	all	updates based on review from UKHO
2025-07-28	0.0.3	Glenn Laughlin	all	rework issues with asciidoc and metanorma for general review and approval
2025-07-31	0.0.4	Glenn Laughlin	all	minor updates for bibliography, terms and key concepts
2025-08-08	0.0.5	Glenn Laughlin	Appendices for CoP, Intros to Land,Marine	updates based on feedback from UKHO

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