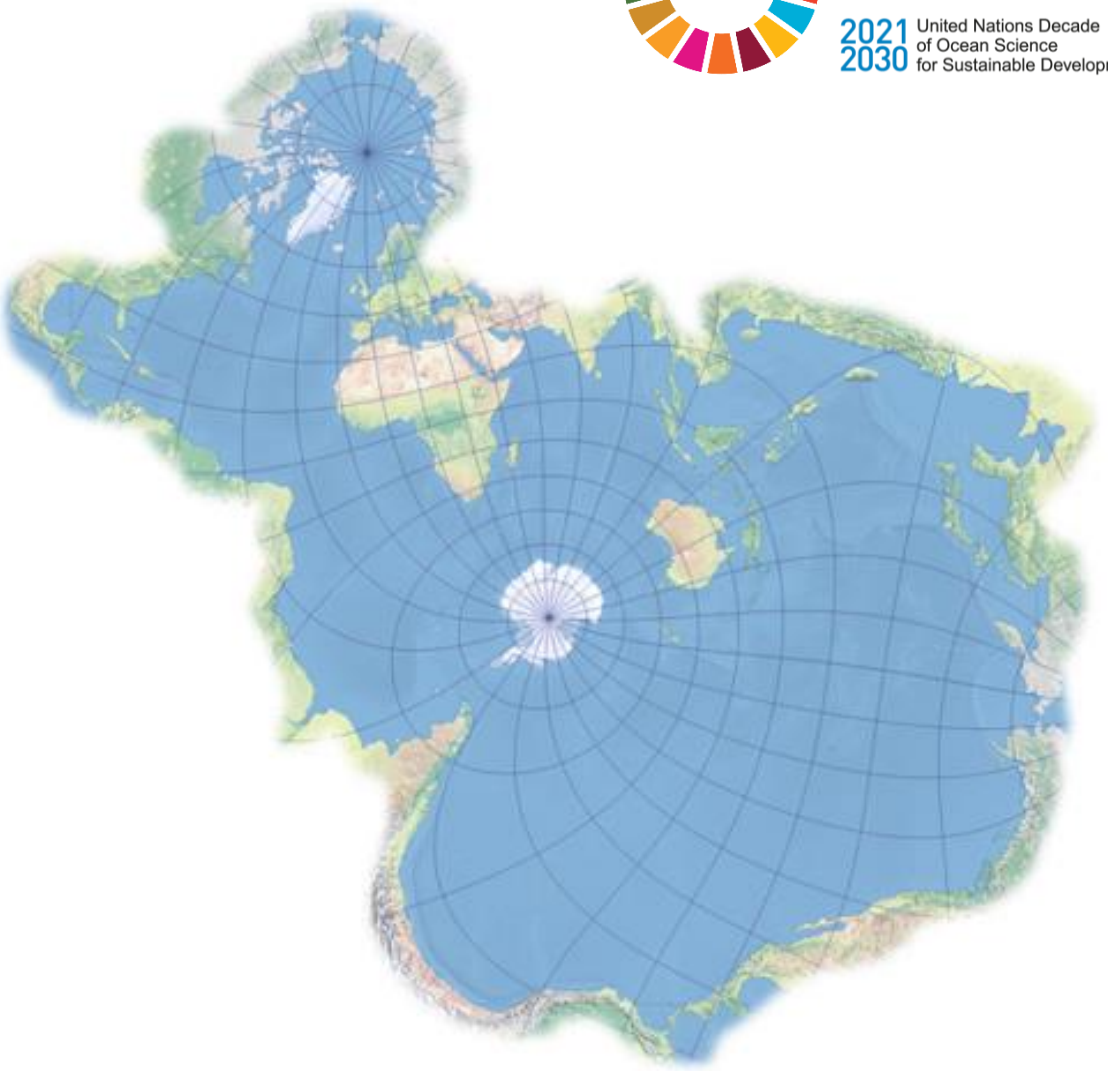
2021 2030 United Nations Decade of Ocean Science for Sustainable Development



Operational Framework for Integrated Marine Geospatial Information Management (UN-IGIF-Hydro)

Part Two: The Strategic Pathways

United Nations Committee of Experts on Global Geospatial Information Management
Working Group on Marine Geospatial Information
July 2023

A note on the cover image. *The cover image shows the "Spilhaus Projection." Athelstan F. Spilhaus, a South African-American geophysicist and oceanographer, is attributed this projection circa 1942. The projection defines a world ocean map that intersects the oceans as little as possible, showing the globe with the oceans as the main focus. This image portrays the aim of this guide, a "water-centric" and integrated view of the world, and reflects the UN-IGIF's integrated philosophy.*

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Introduction

The United Nations Committee of Experts on Global Geospatial Information (UN-GGIM), at its twelfth session, welcomed and endorsed the Operational Framework for Integrated Marine Geospatial Information Management Part One – The Strategic Overview (hereafter the UN-IGIF-Hydro Part One), which is an executive summary of the overall Operational Framework. The UN-GGIM emphasized that the Operational Framework must provide practical guidance that Member States could use to enhance the availability and accessibility of marine geospatial information, including but not restricted to hydrography, oceanography, marine geology, marine biology, human-related activities and maritime governance, and that future marine geospatial infrastructures should be integrated with the broader geospatial ecosystem essential for the sustainable development of the world's resources and vital for responding to the impacts of climate change, which are particularly relevant to small island developing States.

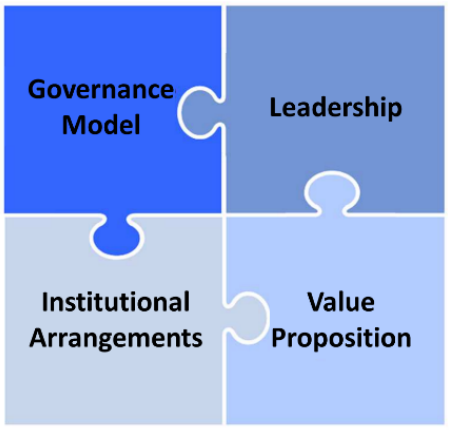
The UN-IGIF-Hydro Part One is a high-level introduction that describes the "why" of the Operational Framework. It provides supporting background, context, and an initial presentation of the value propositions for implementing the United Nations Integrated Geospatial Information Framework (UN-IGIF) at the country-level in a way which embraces all the watered surfaces of the Earth.

In making decision 12/111, the UN-GGIM noted the continuing efforts of the Working Group on Marine Geospatial Information to advance the UN-IGIF and its nine strategic pathways with the UN-IGIF-Hydro. UN-GGIM noted that the UN-IGIF-Hydro Part One and Part Two were being developed to leverage the guidance offered in the UN-IGIF and the UN-IGIF Implementation Guide to provide practical guidance for countries to extend the nine strategic pathways into the hydro domain. The guidance within the Operational Framework for Integrated Marine Geospatial Information Management (UN-IGIF-Hydro) should help countries working towards the integration of the hydro domain into the global geospatial information ecosystem and help enhance the ability of countries to make informed decisions to support the preservation and management of inland waterways and waterbodies, seas, oceans and their respective resources.

In this Operational Framework for Integrated Marine Geospatial Information Management Part Two – The Strategic Pathways (hereafter the UN-IGIF-Hydro Part Two), the UN-IGIF nine strategic pathways are presented and elaborated for the hydro domain. UN-IGIF-Hydro Part Two presents the "how" and includes examples and guidance for including the hydro domain when implementing the UN-IGIF at the country-level.

Throughout the UN-IGIF-Hydro Part One and this document, we intend the terms "hydro" and "marine" to be all-encompassing of all marine, coastal, and inland waters. As described in the UN-IGIF-Hydro Part One, the intended audience for this Operational Framework are Member States implementing the UN-IGIF at the country-level and looking to integrate the hydro domain into their national geospatial information ecosystems.

Strategic Pathway 1 Governance and Institutions



This section describes the unique characteristics of the hydro domain and how they relate to the UN-IGIF Strategic Pathway (SP) 1 - Governance and Institutions. In the implementation of the UN-IGIF at the country-level, there should be a focus on a governance model, institutional arrangements (that is, the arrangements of the geospatial agencies making up the total national geospatial landscape and custodianship), and the value propositions specific to the hydro domain. Value propositions are presented in the UN-IGIF-Hydro Part One and in Appendix I - Value Propositions of this document, and are not presented further in the main text. However, we anticipate that future work of the Working Group on Marine Geospatial Information will further develop the value propositions associated with integrating the hydro domain into larger geospatial ecosystems.

1.1 The Governance Model

The UN-IGIF governance model under SP1 – Governance and Institution provides a methodology for developing a coherent picture of how institutional arrangements meet the needs of the country through the geospatial infrastructure. The primary paradigm shift of recent decades is to view geospatial data as the product of a single state function—an integrated agency with defined custodians responsible for individual domains equipped with a presumption of reuse and interoperability. Geospatial data, though, seldom reside within a single institution. This is a particularly acute issue in consideration of the hydro domain.

Member States need clearly defined requirements to set agendas for governance. This is particularly needful when addressing challenges to integrate with the terrestrial domain. The hydro domain often has a focus on transboundary arrangements and international obligations, which can pose additional challenges to integrate with terrestrial and cadastral requirements. Often, countries can agree on matters of hydrography, but there can be substantial differences to address when working towards an effective nationally integrated geospatial information management arrangement, including the ability to share data between agencies.

The integrated concept of “one hydro” reflects the dynamic nature of the medium and the importance of working to establish cooperation across national boundaries. Seas and oceans also have considerations with no terrestrial equivalent, such as the United Nations Treaty of the High Seas (also known as the Biodiversity Beyond National Jurisdiction Treaty (BBNJ)). Therefore, countries need specific structures and policies covering the Treaty of the High Seas and mapping outside the Exclusive Economic Zone (EEZ). Another important observation is that sovereignty is of a different concept to land or terrestrial. Oceanic sovereignty can be partial (that is, extending only to certain resources), whereas sovereignty of land is often a complete jurisdiction.

The Governance Framework, from the hydro domain perspective, therefore, has to balance the countries' political requirements, internationally and regionally, together with domestic priorities and user needs and respecting international treaties and conventions. The Governance Framework also must provide the basis on which the hydro domain interests are coordinated using the institutional arrangements that are in place.

Reconciling terrestrial interests should be driven from the central governance model to avoid a slide into conflicting and inefficient silos. Characteristic of the hydro domain is the high quantity and diversity of skill sets which are often shared between individuals in a small entity. For a small country, often the requirement is to have governance in place to form partnerships to fill crucial skills gaps. But such partnerships also need to take account of the need to develop or strengthen capacity over time. Often limited resources can make training prohibitive. Such highly specialized skills and technically focused subject matter can often impede the integration across sectors at a high level so solutions must communicate value propositions and encourage a long-term sustainable governance arrangement with scarce resources.

For the hydro domain to be fully incorporated in the governance model, several factors should be considered (in addition to those specified in the UN-IGIF Implementation Guide: SP1, 1.6.4):

- how are international obligations being met,
- how are international relations supported by geospatial agencies, and
- how are domestic requirements harmonized with international obligations and foreign affairs policy.

From a hydro domain perspective, the following suggested questions assess how integrated the hydro domain is, in all its forms, within a pre-existing infrastructure:

- Is there a coherent picture of the "coastal zone?" Are responsibilities and interfaces clearly defined?
- Are maritime zones defined in legislation and given due publicity in accordance with international conventions and commitments under domestic legislation? Are adequate, documented geospatial data in the public domain? Does the infrastructure address the characteristic differences from the hydro domain perspective (e.g., EEZs, high seas, and sovereignty)?
- Do terrestrial mapping efforts reconcile with regulated nautical charts, especially for rivers, tributaries and deltas, and inland waterbodies?
- Does an accurate and comprehensive tidal model cover the extents of all zones?
- Is it possible to capture the reuse of data (for example, between terrestrial and marine institutions, defence and civil institutions, legislative and mapping institutions, and mapping and scientific institutions)? Do all institutions enable reuse of data for stakeholders?

Within the hydro domain there may be ample opportunity to reuse existing governance models developed internationally by, for example, the International Hydrographic Organization (IHO) and International Maritime Organization (IMO). The governance model is where the core integrative approach of the UN-IGIF is defined and then implemented via the institutional arrangements that are put in place.

1.2 Leadership and Institutional Arrangements

Ensuring that the interests of the hydro domain are included in the national geospatial leadership is imperative to the success of advancing an integrated geospatial information management programme nationally. Overall, governance of geospatial capacities, capabilities, and resources sets the framework against which specific policies, norms, and guidance are put in place. These, discussed in Section 1.1 The Governance Model, implement the overall Governance Framework. The Governance Framework should set and balance all priorities and core objectives that include implementation of specific international conventions and treaties.

Geospatial data play a key role in the expression of regulatory and planning processes. From the hydro domain perspective, leadership of the national geospatial strategy will drive a transformational approach that is able to harmonize the domains and requirements of land and sea, of terrestrial and marine, and inland waters and other watered areas or surfaces.

> **"Institutional arrangements"** - "Formal and informal cooperation structures that support and link public and private institutions and or organizations, and which are used to establish the legal, organizational and productive frameworks to allow for sustainable management of geospatial information, inclusive of its creation, updating and dissemination, thereby providing an authoritative, reliable and sustainable geospatial information base for all users." - UN-IGIF SP1 - Governance and Institutions

The allocation of responsibilities to a number of institutions is a key determinant of the outputs of the governance arrangement. Often, and historically, these lines of division between institutions responsible for data are drawn between functional areas of the state or the domains which they cover. Concepts specific to the hydro domain can be difficult to communicate due to their specialized nature and the fundamental differences in some of the domain concepts, such as sovereignty and BBNJ.

As is seen in UN-IGIF SP4 – Data and UN-IGIF SP6 – Standards, there are substantial differences between different domains, and this is often reflected in the way the geospatial institutional arrangements are aligned. In institutional arrangements for geospatial information management, an institution may be "responsible" for data (that is, the institution is authoritative for that particular domain in terms of custodianship under UN-IGIF SP4 - Data) and this allocation of custodianship is often delineated across domain boundaries. The UN-IGIF SP1 – Governance and Institution describes this observation:

"*Within countries, there are often a number of national institutions responsible for the management of geographic information, depending on their needs and/or mission. The division of roles and responsibilities is usually domain-specific where urban, transport, rural, forestry, environment, cadastral, topographic, statistical mapping and remote sensing are conducted by different organizations and institutions. There are typically very limited policies or agreements in place to mandate and encourage the required coordination and data exchange, and often no underlying organizational culture of sharing information.*"

The UN-GGIM's "Future Trends in Geospatial Information Management: the five to ten year (Third Edition)"[1] also noted:

Fundamentally all governance arrangements can be represented in this way: Their function against the domains they are "responsible for."

The hydro domain is fundamentally different, in its nature and requirements.

"*The marine element of established National Spatial Data Infrastructure (NSDI) is often less well developed and the overall need for better integration of marine data is becoming more apparent. As a component framework within a NSDI, national hydrographic offices are mostly separate entities with somewhat loose connections to the National Mapping Agencies (NMAs) or National Geospatial Information Agencies (NGIAs). Integrating marine-based charting and land-based mapping as one continuous surface continues to be a constraint; for this to be achieved, new tools, new data collection methods, data specification standardization, and improved data management will be required.*"

Figure 1 shows some examples of how this might manifest itself in a geospatial arrangement where the geographic or physical domain is split between "Land Agencies" and "Marine Agencies". Other institutions responsible for stakeholder groups such as civil mapping, Defence, Legislative and other responsibilities may have a domain covering the entire physical domain and are charged with data integration. This traditional approach is seen in many jurisdictions.

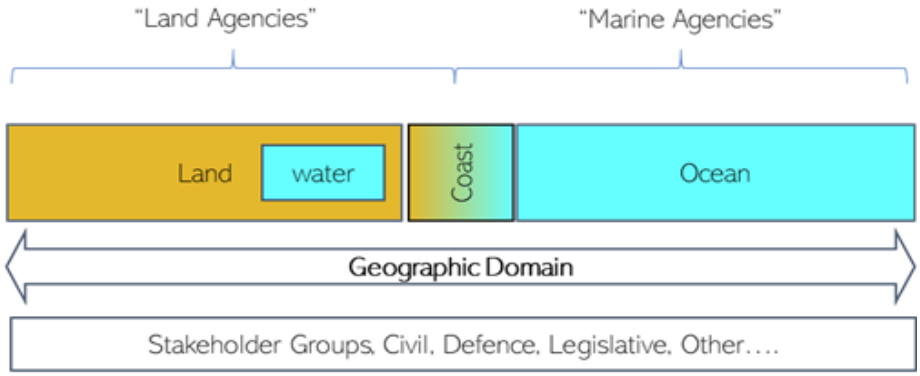


Figure 1. Potential institutional arrangements in the hydro domain.

The diagram illustrates the two main degrees of freedom in the institutional arrangements within an administration in respect to the hydro domain delimited by "end users" and the physical domain. Examples of institutions could be

- A civil terrestrial mapping agency responsible for terrestrial mapping including internal waters and waterways as well as a portion of the coastal zones (e.g., Ordnance Survey of Great Britain and Northern Ireland[2]),
- A defence organization producing terrestrial mapping for the defence domain,

[1] https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/Future_Trends_Report_THIRD_EDITION_digital_accessible.pdf

[2] https://www.ordnancesurvey.co.uk/

- A hydrographic office which produces charts for both civil and defence uses covering oceans and seas as well as coastal waters (e.g., United Kingdom Hydrographic Office[3]),
- Legislative bodies and subsidiary entities responsible for legal instruments covering law of the sea and the United Nations Convention on the Law of the Sea (UNCLOS), the Treaty of the High Seas (BBNJ), as well as legislative management for land and property rights and the cadastre, and
- Other levels of government, agencies, and groups (e.g., research and development, scientific, oceanographic, statistical, environmental).

There could also be agencies responsible for "marine" engineering and infrastructure including coastal protection, ports and harbors, marine protected areas or parks, and maritime affairs.

This is rarely a complete picture. Institutional arrangements when considered in their entirety represent a complex network of interactions between primary institutions, users and intermediaries.

The UN-IGIF does not promote a single, optimal assignment of individual functions to institutions. Under UN-IGIF these are defined by the implementer using the guiding principles to define an integrated geospatial information management strategy towards an enabling, vibrant, and dynamic environment. The UN-IGIF recommends an integrated governance and management approach which may challenge and redefine existing structures.

There are "correct" ways to arrange institutions but it is not "one size fits all."

In any implementation there are always:

- boundaries between functional areas and their domains of responsibility which must be defined and managed, and
- responsibilities and custodianship which may not be shared, such as the fulfillment of international obligations like Safety of Life at Sea (SOLAS) and UNCLOS, balanced with domestic and regional obligations (e.g., European Union Marine Strategy Framework Directive (EU-MSFD)).

This arrangement issue is often very noticeable in the hydro domain. For example, in many countries around the world, nautical charting and ocean mapping are controlled by navies or uniformed services who may have little or no contact with national mapping or geospatial information authorities or agencies. This can be problematic for several reasons. Primarily, it creates a divide between land or terrestrial mapping agencies who are almost always civilian and are often responsible for non-navigable waters and their management. Such a separation can result in some data, such as high-density bathymetry, being classified for military use only. Such restrictions are far easier to enforce at sea where satellites cannot reach and it is cost-prohibitive to put data in the public domain. Such difficulties are often concentrated and most apparent in the coastal zone where agreement on shoreline and boundaries can be a challenge. Since shoreline forms the basis for maritime boundaries,

Share experiences and use acknowledged good practices.

[3] www.ukho.gov.uk

this has the potential for follow-on negative impacts when establishing ocean resource planning and regulations, including fishery management and oil/mineral exploration.

Another challenge with regard to military custodianship of marine geospatial data is that of restricted availability. Many view marine geospatial information as a national security asset and limit distribution to what is included on nautical charts. This may not be in line with what land/terrestrial mapping agencies make publicly available and severely inhibit the return on public investments. Often, scientific and oceanographic applications and broader uses for marine spatial planning (MSP) rely on seamless datasets spanning land and water; divisions at fundamental organizational levels are difficult to overcome. The military/classified nature of some data and the specialized nature of other geospatial data types means some cross-institutional responsibilities and restrictions are inevitable. This places a requirement, driven from the governance model, to ensure interoperability, reuse and integration.

Availability is critical to realizing the full value of data in any geospatial domain. Whether or not control of geospatial information in the hydro domain is located within the military, it is important to ensure the UN-IGIF recommended geospatial coordination unit [UN-IGIF Implementation Guide SP1, 1.6.2] establishes a structure where institutions follow the guidance of, and participate in, a national geospatial leadership board. Under UN-IGIF, this drives requirements for standards adoption, data sharing, and interoperability.

Similarly, many administrations separate responsibilities between the terrestrial and hydro domains at a fundamental institutional level. This risks incompatibilities within data and inconsistencies that may be felt at the boundaries of responsibilities, most often in the coastal zone where differences of datum, projection, data collection, purpose and usage need attention to ensure consistent and integrated data is the product of the arrangement.

Often a large degree of institutional fragmentation is visible when the entire hydro domain is considered, including waterways and waterbodies management, marine spatial planning, fishing limits and management of natural resources. Such fragmentation along functional lines has the result of fragmenting data and increasing the requirements for interoperability across and geospatial data/information infrastructure dramatically.

Key, therefore, to defining institutions and charging them with custodianship is the Governance, policy and structure which provides sound, rigorous interfaces between the domains and enables common, open standards (UN-IGIF SP6) covering data (UN-IGIF SP4) produced and used throughout the infrastructure. Addressing the boundaries between the land and hydro domains can produce an integrated management and production of data and specific key technical areas contribute to this goal. Integrated vertical datums, harmonized scale considerations, interoperable domain content models and adoption of open standards can contribute to a harmonized coastal zone, but organizational drivers must act in tandem with the technical aspects to achieve a long-term sustainable integrated model spanning the domains.

The governance model is key to balancing different needs and defining an optimum structure.

As will be seen many times in this Operational Framework, these dividing lines of responsibility, whether geographic, political, cartographic, administrative, or semantic, require attention to detail and will benefit the most from the implementation of the UN-IGIF. The governance model should be specific enough to determine the responsibility and establish custodianship of data

within the administration. Institutional responsibilities could be defined, for example, in reference to vertical tidal datums or zones defined in core legislation, the key artifact being the state's baseline.

For some a single geospatial agency, for others a demarcated coordinated federated structure.

Diverging management principles within institutions in the hydro domain from that of the national policy set for land/terrestrial geospatial information can substantially reduce the return on investment for the public. The governance model must drive reconciliation of these principles in these institutions to achieve maximum benefit for the public.

Administrations with their own local hierarchies (federal/state) often present another axis of complexity with relationships and responsibilities to be defined. In general, international obligations (more common in the hydro domain than terrestrial) are normally dealt with from a federal level while more domestic issues such as planning/zoning and licensing are normally dealt with by sub-national authorities, so interoperability, redundancy, and data-sharing need to be established along with a way of resolving issues should they arise.

1.3 Testing the Outputs

As with most UN-IGIF strategic pathways, there are no fixed outputs from the process against which an implementation can be tested. These should be defined as the implementer goes through the UN-IGIF Implementation Guide: SP1 recommended actions. Some example outputs listed in the Implementation Guide under SP1 are

- a governing board, such as a steering committee and agreed charter for a steering committee;
- a fully operational geospatial coordination unit appropriately staffed and with delegated powers, roles and responsibilities with funding, including processing resources;
- fully functioning specialist working groups (or subcommittees or technical working groups) with specific terms of reference;
- geospatial information management strategy;
- a change strategy including
    - data inventory and gap analysis,
    - institution culture assessment and gap analysis,
    - data acquisition and supply chain assessment,
    - technology assessment and gap analysis,
    - policy and legal review and gap analysis, and
    - capacity assessment and gap analysis;
- a Country-level Action Plan, including a schedule of actions and priorities;
- a monitoring and evaluation framework and success indicators for effective multi-stakeholder monitoring of actions under any Country-level Action Plan and its implementation roadmap; and
- a geospatial value proposition and socio-economic Value Assessment.

The questions below suggest some hydro domain specific tests to ensure a truly integrative approach has been taken in the application of the UN-IGIF.

- Does the governing board and coordination unit represent the interests of the entire geospatial ecosystem and environment, including land/terrestrial, coastal zones, ports and harbors, the outer limits of UNCLOS zones (territorial seas, boundaries, exclusive economic zones (EEZ), etc.) and all defined internal waters and waterbodies, rivers and wetlands? Is there a defined policy covering the BBNJ?
- Do the Specialist Working Groups have roles and responsibilities similarly integrated between
    - international and domestic requirements;
    - land, sea and internal waters; and
    - the scientific, mapping, and planning/legislative communities?
- Do the institutional arrangements reinforce an integrative, custodianship arrangement and working approach and discourage the development of domain-specific silos?
- Is the specialist and scarce nature of the skills required for sound management of the hydro domain accounted for in the governing board and coordination unit?
- Do the value propositions encompass and communicate the value of geospatial data in the hydro domain and its contribution to the value proposition of the geospatial programme and arrangement as whole?
- Do the institutional arrangements enable a long-term sustainable production of data, which is integrated between the land/terrestrial, cadastral and hydro domains through sound technical architectures within sound and robust policy and legal structures?

Strategic Pathway 2 Policy and Legal

This section focuses on the policy and legal frameworks that drive and address the characteristics specific to the hydro domain, which should be considered when implementing the UN-IGIF at the country-level.

Key observations within the hydro domain demonstrate that policy and legal frameworks and their defining geospatial data are co-dependent. On one hand, it is impossible to build policy and legal frameworks without placing an integrated dataset at their source. On the other hand, the creation of geospatial data is impossible without a policy and legal framework supporting their collection and reuse. The relationship between the law of the sea and cartography is strong and has been mostly defined using data from nautical charts. However, this area is still undervalued, and the aim of an effective national integrated geospatial information framework should be to fully value this relationship.

As outlined in UN-IGIF SP1 – Governance and Institution, the implementation of the UN-IGIF at the country-level should recognize the importance of delimiting geospatial roles and responsibilities among its priorities. A fundamental difference between land/terrestrial, cadastral and hydro domain roles and responsibilities is the nature of the space on which they are drawn and the length and modalities of the relevant processes for their definition. The development of the international legal framework surrounding the definition of maritime boundaries has become a specialized discipline through decades of practice by Member States, codification of rules and the case law of international courts and tribunals. Significant and diverse technical skills, often shared between a small number of specialists in hydrography and nautical charting have been—and still are—required to shape these foundations. In such a context, the recommended governing board (UN-IGIF Implementation Guide: SP1) and geospatial coordination unit (UN-IGIF Implementation Guide: SP1) are entrusted with ensuring that an integrated approach is taken with respect to the collection and use of data and the building of any policy and legal frameworks (**Figure 2**).

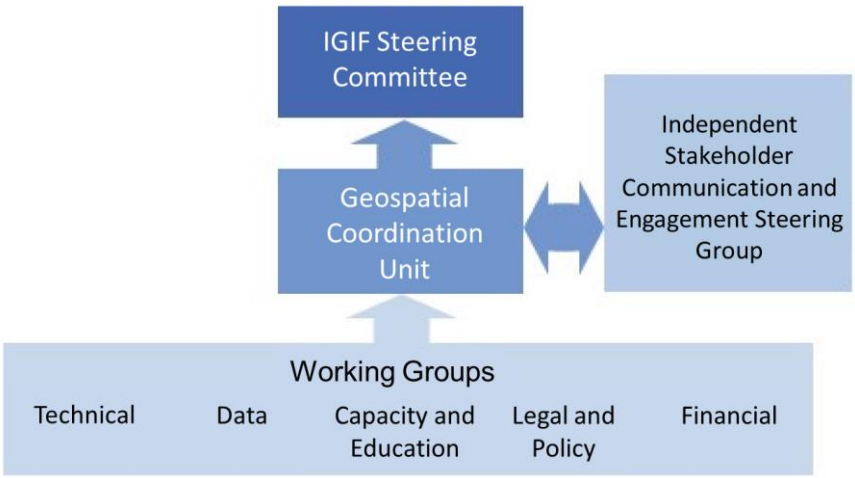


Figure 2. The work of the Geospatial Coordination Unit.

As stated in the UN-IGIF overview, the emphasis should be on a "multi-thematic" approach where different uses and stakeholders are addressed simultaneously. Within this context (the above diagram is taken from UN-IGIF Implementation Guide: SP1), the UN-IGIF process should ensure that:

- The Country-level Action Plan details how international legal instruments concerning the maritime zones and their representation on charts are implemented. This stage mainly includes consideration of the SOLAS Convention (in particular, Chapter 5, Regulation 9, "Hydrographic services", in relation to mapping) and the UNCLOS (in relation to those obligations concerning the establishment, deposit and publicity of charts or lists of coordinates – specifying the geodetic datum – of fundamental maritime zones). Obligations deriving from these instruments require specific actions at the policy level to enable implementation of the relevant actions and define custodianship, management and updating of data.
- Where geospatial data is required to support further regional obligations by zoning or delimitation (e.g., the delineation and declaration of marine protected areas), then these are defined as marine geospatial data under a suitable custodianship and could be recorded and represented in an integrated cadastre.
- Where a national marine spatial planning framework is required, it is built on the fundamental marine zones as defined in the UNCLOS.
- Inland waterways and inland waterbodies and their relation to oceans and seas should be approached in an integrated manner. This may require the establishment of an integrated coastal zone framework or management plan.
- Critical to effective, integrated geospatial information management is a harmonized, sustainable model of all such data, ensuring that data are fit for purpose, both legally and geo-politically.

The implementation of the UN-IGIF should ensure maintenance of a network of interoperable agencies and effective institutional arrangements mandated with the production of reusable data that meet the relevant needs, enabling the benefits detailed in the value proposition and implementing the provisions of the governance model or arrangement.

Supporting international, regional, and domestic obligations with marine geospatial information

One of the main purposes of ensuring the inclusion of the hydro domain when implementing the UN-IGIF at the country-level lies in supporting the implementation of international conventions. As stated above, SOLAS and UNCLOS are the two main maritime and legal conventions, and of late, BBNJ, but others exist that have significant geospatial components and require consideration in national legislation and governance structures. Instances are to be found in the International Convention for the Prevention of Pollution from Ships (MARPOL) regulations, in further instruments adopted under the auspices of the IMO including spatial and navigational measures, as well as in international, regional, and sub-regional legal frameworks to be implemented through area-based management tools. Regional examples such as the EU Marine Strategy Framework Directive have broader remits impacting multiple sectors.

Additionally, more specific obligations, deriving from international legal obligations and involving the analysis, definition, and use of geospatial data collected from the hydro domain, may be recalled and detailed in bilateral agreements between neighboring coastal states, typically in a delimitation process. These obligations and data can also govern:

- prospecting, exploration, and exploitation of marine natural resources;
- trade and commercial development;
- environmental protection and management (pollution prevention);
- responses in case of emergency;
- fishing limits and controls;
- search and rescue;
- scientific research;
- maritime limits and boundaries;
- tourism and recreation;
- blue economy; and
- marine protected areas (MPAs) and other effective area-based conservation measures (OECMs).

The implementation of the UN-IGIF at the country-level should support the implementation of a legal framework with unambiguous, fully populated, and non-duplicated data, representing the precise geographical scope of each relevant agreement, convention, and domestic legislation.

If the relevant legal instrument is defined appropriately, with an integrated approach, it will consider—although without necessarily encompassing them all in the same text—inland waterways regulations (including prevention of land-based marine pollution), restrictions on trade and commercial development, domestic pollution, coastal zone management regulations and legislations, administration of maritime spaces, blue economy, ecotourism, etc.

The goal of compliance with obligations deriving from international treaties and conventions with scopes of application geographically defined, therefore, is a big determinant in the production of geospatial data. However, the challenge is the reuse of such data and the production of data in an interoperable way that also serves domestic requirements and needs, such as sustainable development, addressing climate challenges, and research. This section further details some of the legal aspects to be considered when representing the hydro domain when implementing the UN-IGIF at the country-level, with special focus on representing the hydro domain within an emerging integrated framework between law and geospatial data collection, representation, and management.

2.1 International Conventions

Among the international conventions relevant in the implementation of the UN-IGIF at the country-level, SOLAS and rules and regulations concerning the safety of navigation dominate the discourse in terms of concrete actions to be undertaken by technical experts and in terms of ongoing activities required, such as timely updates of charts and compliance with standardization efforts at the international level. However, UNCLOS has potentially far greater significance because of its nature as the global reference treaty for what concerns the administration of maritime spaces and relevant domain, and because of its role in regulating relationships among neighboring Member States in terms of spatial delimitations. Other instruments should be included, such as MARPOL, IMO resolutions, and regional instruments

(e.g., EU Marine Strategy Framework Directive) and arrangements that exist across multiple sectors (pollution prevention; fisheries regulation, administration, management, and control; marine spatial planning; environmental protection; marine protected areas; integrated coastal zone management; etc.).

From the UN-IGIF point of view, the challenge is securing coherence between the production of such marine geospatial data alongside the reuse of data to comply with domestic requirements. The implementation of the UN-IGIF emphasizes the interoperability of such data and the need to comply with legal obligations by producing geospatial information in a coordinated manner through balanced institutional arrangements.

2.1.1 Navigation and SOLAS

Production of nautical charts discharge a state's SOLAS obligations. These datasets have value beyond maritime navigation.

SOLAS is the main international convention driving the production of geospatial data in the hydro domain. It is primarily concerned with the maritime domain (that is, the production and maintenance of geospatial data in the form of nautical charts for the purpose of ensuring the safety of [primarily commercial] maritime transportation and shipping[4]).

For many years, nautical charts have been viewed as cartographic paper artefacts undertaken to satisfy the requirements of the SOLAS Convention. However, these instruments also represent geospatial datasets. The International Hydrographic Organization (IHO) provides the framework and the organization for the establishment and production of nautical charts. Its activities have included the identification of the necessary practical means, including standards, capacity development support, and technology resources. Cooperation and innovation are two essential complementary aspects of chart production. Full use should be made of the resources available at the global level.

The SOLAS Convention requires the carrying of nautical charts on commercial vessels and presupposes the existence of an arrangement within a Member State to support this.

The relevant definition can be found in SOLAS, Chapter 5, Regulation 2:

> *2.2 Nautical chart or nautical publication is a special-purpose map or book, or a specially compiled database from which such a map or book is derived, that is issued officially by or on the authority of a Government, authorized Hydrographic Office or other relevant government institution and is designed to meet the requirements of marine navigation.*

[4] This is normally within the EEZ. This detail is not explicitly stated but is largely accepted, mostly by omission (that is, charting the high seas is not covered by any international convention).

The mandatory carriage of charts is provided in Regulation 19:

> *19.2.1 All ships irrespective of size shall have:*
>
> *19.2.1.4 nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements of this subparagraph. Ships to which paragraph [2.10] applies shall comply with the carriage requirements for ECDIS detailed therein;*

The relevant updating obligation is described in Regulation 27:

> *Nautical charts and nautical publications, such as sailing directions, lists of lights, notices to mariners, tide tables and all other nautical publications necessary for the intended voyage, shall be adequate and up to date.*

These three regulations in the SOLAS Convention provide the underpinning framework for the functioning of hydrographic offices and services worldwide. They are often enshrined in the domestic legislation of SOLAS States parties, with specific emphasis given to their legal implications.

There is, therefore, an intrinsic legal liability in the production of nautical charts and publications, which is often undervalued by the legal instruments themselves. Such underestimation contradicts the evident relationship between the function of charting and the legal implications of actions or occurrences that are regulated or measured, respectively, within any national geospatial information management arrangement. For instance, one of the defining aspects of maritime transportation is the amount of liability involved. The environmental and financial consequences of maritime accidents are often far larger compared to the terrestrial ones. Navigational information issued by the Member State carries an enormous liability should an incident arise through error or omission. This liability is borne by the Member State and, where appropriate, by the actual producers of nautical charts. The "liability question" is, thus, a major determinant of the scale and nature of the operations required by a producing Member State and should represent an important consideration both in the governance structure (UN-IGIF SP1) and in the policy and legal structure (UN-IGIF SP2).

2.1.2 Establishment of Limits and Boundaries

The implementation of UNCLOS with respect to the establishment of maritime limits and boundaries is pursued by legislation of Member States that include geospatial references.

Limits are likely to encompass the potential maritime zones described in UNCLOS (including exclusive economic zones and outer continental shelves), and boundaries are likely to be already settled in arrangements with a long history of regulations, legislations, and international relations. The implementation of the UN-IGIF at the country-level would have to consider such existing legislation and treaties and their supporting policies and processes as elements of the broader framework of the integrated geospatial information management arrangement, infrastructure, and resources. The UN-IGIF emphasizes the definition of a sustainable approach that guarantees long-term reuse of such data through interoperability.

Although limits and boundaries are likely to be pre-existing, their use must be integrated and sustainable.

Some examples of elements to be defined are the following:

- establishing processes and organizational structures to support the acquisition and compilation of data for the definition of a baseline and its component parts,
- defining maritime limits and boundaries,
- supporting national legislative processes, and
- depositing standardized data as part of statutory policies at national level and depository obligations under UNCLOS with the UN Division for Ocean Affairs and the Law of the Sea (DOALOS).

The geospatial nature of UNCLOS provisions is undeniable. This presents challenges in any national arrangement as it requires the combination of advanced skills in both the legislative and geospatial domains, and demonstrates the need to integrate pre-existing (often historical) data into contemporary systems. By providing the legal framework for all maritime activities, UNCLOS eventually requires the establishment of geospatial datasets and sustainable management processes of marine geospatial information. Policy and legal frameworks should promote this element as a central component when implementing UN-IGIF at the country-level that has to include the hydro domain.

2.2 Other Primary Policy and Legal Considerations

In addition to compliance with obligations derived from international treaties and conventions, implementing the UN-IGIF at the country-level should seize the opportunity to bridge global standards and domestic requirements and provide a comprehensive national integrated geospatial information framework for meeting the principles and goals of the UN-IGIF and the Sustainable Development Goals (SDGs). As noted earlier, the tensions between domestic and international and cross-sectoral competences need to be addressed in a holistic manner. Few agencies serve only a single purpose, and data are required to meet many international and regional commitments. Integrated marine geospatial information management relies heavily on data to demonstrate legal compliance and technical coherence with international treaties and conventions, regional and sub-regional agreements and arrangements, and domestic legal and policy requirements.

2.3 Non-Navigational Considerations

Broader uses of the same data can be enabled by technological and organizational means. A comprehensive policy and legal framework with full consideration of the variety of uses of the hydro domain should ensure that the relevant data are not produced for a single purpose only.

A considerable amount of data is produced to satisfy navigation-based uses. Reuse of these data should be envisaged that encompasses other uses. A UN-IGIF implementation needs assessment should identify a need for “strong influence” (in UN-IGIF terminology) in assuring reuse of data in the hydro domain outside the navigational use case.

Similarly, there is a need for strong influence when defining policy and legal structures aimed at ensuring that data are made available for the purposes of scientific research and education. UN-IGIF places great emphasis on these elements and again, the production of data is often focused solely on navigational needs and does not take a balanced approach across multiple stakeholders and sectors.

Scientific research often requires data from across domains; therefore, standardization and interoperability are required to ensure that data are fit for such reuse by the scientific community. Adoption of international standards can be crucial to ensure interoperability between different national stakeholders. Scientific research is critically dependent on data that spans domains, and the hydro domain, due to its fluid nature, is acutely sensitive to these dynamics.

2.4 Data Protection, Licensing and Sharing

The fundamental nature of mapping within the hydro domain and the high cost of data acquisition give marine geospatial data a substantial value. The “official” or authoritative view of maritime-related mapping and charts can attract value from outside the navigation community. Seamless integration with terrestrial data can also increase such value for ancillary purposes. Similarly, other institutions can often hold data which has “value” across many different sectors. Most institutions create by-products alongside their primary responsibilities which have value elsewhere. The value of such datasets can sometimes outweigh the value of the processed, finished product.

The aim, in the hydro domain, therefore, is to ensure that the significant value of data gathered is realized within the policy and legal framework. Any policy or legal framework should promote an enabling environment, provide a sustainable business model for its institutions, and provide guidance on how and to what extent data in the national context can be licensed, shared, used, and reused.

The most common example is navigational charting, as a primary output of the hydrographic offices which can be monetized and can provide a sustainable commercial basis (at least in part) for the offices’ operations.

The decision and adoption of a business model should be predicated on a broad picture of the value proposition for the country as a whole. Monetizing any data can restrict its supply to those who are able and willing to pay. This should be balanced against the income generated (which can sustain many infrastructures). This consideration exists across all domains, but especially in the hydro domain because of:

- the highly regulated and authoritative nature of nautical charting data and the sustainable direct revenue stream it can generate and
- the high cost of acquisition and processing of nautical charting data.

Commercial distribution often leads to requirements for data protection and licensing. In the hydro domain, where data are released for navigational purposes, the implicit risk and extremely high impact are important considerations. Legal liability for navigational data is generally borne by the state, and this can affect the cost of its acquisition and processing significantly. The critical importance of safety in marine transport (both in marine areas and inland waters) emphasizes the need for data integrity. It is easier to exert control over sub-surface information either for commercial or military purposes as much of the domain is out of reach of Earth observation systems, which enables a long-term scarcity of data and a lack of commoditization. A range of technologies and standards can be implemented to maintain both data confidentiality and data integrity when distributed among stakeholders. How data integrity is assured for data custodians and their users is therefore a high priority.

2.5 Outcomes

The UN-IGIF presents a set of outcomes for the implementation of SP2 – Policy and Legal as follows:

- sound and enabling policy and a legal environment that maximizes the utility of marine geospatial information and safeguards a jurisdiction or entity's interest;
- effective and secure management, sharing, integration, and application of marine geospatial information;
- a policy and legal framework that evolves over time, responds to societal progress and technological developments, and keeps pace with quickly changing economic, societal, and personal landscapes; and
- clarity in responsibilities and mandates, strengthening governance and accountability in nationally integrated geospatial information management.

The following suggestions are made for outcomes from the implementation of the UN-IGIF SP2 - Policy and Legal for the hydro domain. These complement those set by the UN-IGIF.

- The concepts of authority and custodianship, legally and organizationally, should define the custodians for the fundamental data making up the elements of the hydro domain.
- There is an understanding of how legal responsibility is devolved into the participating institutions in respect of custodianship.
- A clear policy and legal framework exists which covers custodianship and production of data for international treaties and conventions and which supports domestic legislation and planning. This framework should also satisfy national requirements with the hydro domain equally represented alongside any terrestrial or cadastral domains.

- A commercial framework for data licensing exists, which balances the utility of free and open data release with the need to provide a sustainable business model for all institutions.
- A rigorous assessment of legal liability has been completed with particular reference to maritime and inland navigation.
- There is an understanding of how to implement mandatory elements of internal processes, operations, and/or infrastructure for interoperability, and there is consistent use of consensus-based, open, and free standards.
- A viable, sustainable resource framework for the institutions in the national arrangement exists, including a business model.
- There is an understanding of how institutional arrangements are implemented. Key areas specific to the hydro domain, such as the coastal zone, have well defined responsibilities for interoperability and data sharing.

Strategic Pathway 3 Finance

This strategic pathway establishes the business model, develops financial partnerships, and identifies the investment needs and means of financing for delivering integrated geospatial information management, as well as recognizes the milestones that will achieve and maintain momentum and realize benefits.

There is no one-size-fits-all methodology for creating a business model.

While the core concepts of this strategic pathway are the same as those within the broader UN-IGIF, the implementation guidance provided within UN-IGIF-Hydro is intended to highlight and address considerations specifically focused on marine geospatial information and its integration.

Financial governance, planning, management, and investment are required to achieve sustainable integrated geospatial information management. Investment will typically be realized when governments can see evidence that geospatial information will deliver social, environmental, and economic benefits nationally, and there is a corresponding and credible financial plan to realize these targeted benefits.

These benefits may not be realized in a manner with a clear financial “return-on-investment” lens. Some investments may provide less direct economic benefit but instead primarily provide benefit to society or the environment, such as supporting marine protected areas. Other investments may support opportunities where the benefits realization may not be easily quantifiable. If the benefits are quantifiable, perhaps they are not fully known for many years (e.g., climate change). With some data, particularly from nautical charting there is a case to be made which is not profit/loss or cost-based, as there is a substantial cost in terms of liability of not providing safe, complete navigational data.

A national geospatial programme should establish a business model that is compatible with their country and organizational fiscal policy—preferably one that is documented and agreed upon at the highest appropriate level; identify opportunities for aligning marine geospatial data use cases with national development priorities, partnerships, and potential benefits; determine the business case for why investment is needed now, how much is needed, what are the funding sources, and what is the economic return; and decide on a method to evaluate, monitor, or measure benefits realized through the investment.

The approach to implement this strategic pathway for the hydro domain consists of four elements, each with its own set of guiding principles, key actions for strengthening geospatial information management, tools to assist in completing the actions, interrelated actions, and outcomes. Additional information on the approach and on each of its components is contained within the UN-IGIF Implementation Guide: SP3.

Implementing the aforementioned approach will deliver needed and sustainable national outcomes and benefits for a country, including:

- an investment plan that includes current funding sources, obligations, and estimates for future years;
- new funding initiatives identified to meet the priorities for integrated geospatial information management;
- a financial accounting of costs associated with all aspects of a nationally integrated geospatial information programme; and
- the socio-economic value of geospatial information that is well defined and aligns with the financial plan to realize benefits, quantified to the most appropriate quantifiable value.

While the UN-IGIF and UN-IGIF-Hydro serve as bases and guides for developing, integrating, and strengthening marine geospatial information management, there is substantial flexibility within the approach. Each individual country's governance, plans, policies, and value outlooks can and likely will lead to different implementations through the UN-IGIF Implementation Guide: SP3.

3.1 Business Model

Some Member States will choose to provide information for free to allow for maximum equitable access to their data; some Member States will decide to charge for their data; and while it is not recommended, some Member States will allow very limited access to their data. Governments and organizations following each of these business models exist within the hydro domain, though they are present in the broader geospatial domain as well. These business models, and others, are further detailed within the UN-IGIF SP3 - Financial.

3.2 Opportunities

The hydro domain offers a unique set of investment opportunities and challenges in comparison to terrestrial and/or cadastral domains. Ocean-related geophysical processes do not start or end at the edge of territorial boundaries or EEZs, and a significant portion of the ocean lies beyond the limits of national jurisdiction.

Opportunities in the hydro domain include the realm of ocean and marine science, sonar data collection, ocean bathymetry, and the blue economy. Given the span of the seas and oceans and its processes, regional and international partnerships can be beneficial in providing opportunities to join investment with capability for the benefit of all involved.

3.3 Investment

Discovering opportunities to recoup investments in integrated marine geospatial information management, its infrastructures, and national programmes can be a challenge, but opportunities do exist for Member States to consider within the context of their national development strategy and priorities. A practical manner to address this challenge could be identifying opportunities specifically aligned with maritime geospatial information programmes supporting national goals, international treaties, contracts, and partnerships.

The hydro domain is exceptional in this regard. Where many other domains provide their geospatial data freely, within the hydro domain, some pay walls to access geospatial still exist. The high costs associated with data acquisition and processing and issues surrounding liability and authority when providing data for the safety of navigation allow the persistence of paywalls to recoup some costs. This business model is common throughout the hydro domain.

For example, one common national objective is the production and distribution of nautical charts (in digital or paper format) to fulfill obligations under SOLAS. The sale of these nautical charts and the products and services derived from them provides one method to at least partially recuperate funds invested into the collection and processing of data and the dissemination of products and services. Some countries may opt to join a Regional Electronic Navigational Chart (ENC) Coordination Center (RENC), which will assist its Member States in managing the distribution chain (from the Hydrographic Office), to the value-added reseller, to the mariners and users), assist with quality assurance, and return regular distribution of payment from the sales of charts and other products and services.

An additional consideration for investment regarding the hydro domain includes investment in education. Funding requirements for the education systems related to the marine geospatial domain must be assessed and quantified to ensure a sustainable education pipeline that will service the Member States' requirements. This may necessitate direct investment in a focused education system and should include funding administration and education quality assurance at the country-level, rather than relying on unstructured evolution of an education system as a market-led response to demand. Course fees associated with gaining practical field and sea experience for marine geospatial specialists are often significant and market-based education solutions are likely to require direct investment and ongoing administrative and funding requirements to ensure a sustainable supply of participants within the marine domain.

3.4 Benefits Realization

In most cases, marine geospatial data can provide positive benefits to at least one - if not many - of the Sustainable Development Goals locally, nationally, regionally, and potentially globally. These benefits may not be strictly financial, and the realization of some benefits may be clear while others remain more difficult to define and measure. Particularly, if dealing with the ocean and its far-reaching impacts, the measure of benefit financially, socially, environmentally, and economically may be better viewed through a wider lens.

When implementing SP3 – Finance, a country should identify whether revenue will realistically cover all or part of the costs associated with data acquisition, processing, and management and whether such costs are viewed as "sunk costs" because the data and data management provide benefits in terms of liability, public good, or environmental health. Given the typical costs of marine geospatial data acquisition and production, it is unlikely to be a positive business case when viewed from a purely financial perspective. There should be evidence that the country has undertaken such a process of discovery when implementing the UN-IGIF at the country-level.

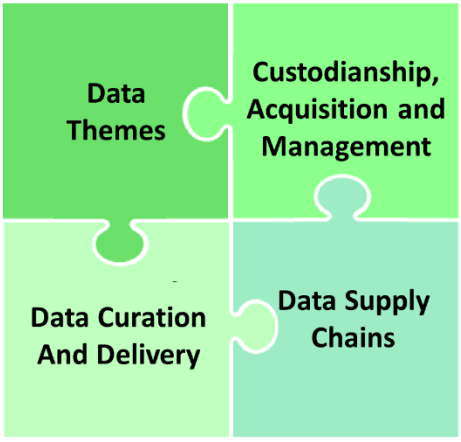
If data are to be sold on a commercial basis, then the impact on distribution, innovation, and use in diverse sectors should be quantified. Access and rights for onward use are important. Ease of access to data directly affects how much people use that data.

3.5 Outcomes

The following suggestions are made as outcomes from implementing the UN-IGIF SP2 – Financial for the hydro domain. These complement those set by the UN-IGIF. Outcomes for the hydro domain should include:

- a structured financial model and plan;
- financial mechanisms in place for financing operations and activities, particularly those involving data acquisition where it is impossible to achieve outcomes through established means such as Earth observation;
- a benefits realization plan that fully balances the costs of data acquisition in terms of liability, discharging liabilities under SOLAS, ensuring management under blue economy, and meeting regional obligations such as EU-MSFD; and
- an overall understanding that full benefits are not fully described by a revenue model.

Strategic Pathway 4 Data



Data are one of the central elements of any nationally integrated geospatial information management and its infrastructures and systems. This strategic pathway must not be implemented in isolation, but rather in coordination with the other eight strategic pathways, in particular UN-IGIF SP1 – Governance and Institutions and UN-IGIF SP2 – Policy and Legal. Within the hydro domain, the co-dependence of data assets with their defining environments is common. There are many defining characteristics specific to the hydro domain which are explored further in this section.

From the hydro domain, defining characteristics include the requirement to implement data to support international treaties and conventions, such as SOLAS and BBNJ for the production of standards conformant nautical charts, and data to support legislative and planning processes. This section also looks at how the hydro domain is approached domestically, both for oceans, seas, and inland waterways and waterbodies. A well-coordinated geospatial programme will establish an integrated infrastructure, and there is always a need when implementing the UN-IGIF for an integrative approach. This section looks at how the hydro domain can be included and integrated when implementing the UN-IGIF at the country-level, specifically the guidance provided in the UN-IGIF Implementation Guide: 4. This section focuses on how data representing the hydro domain can be considered in emerging national geospatial information management arrangements and its infrastructures and systems and how interfaces between institutional arrangements can be established to enhance reusability within different custodianship arrangements.

The key to an integrative approach is a balance between the custodianship implemented by the institutional arrangements and the interoperability demanded by the different stakeholders. The hydro component within a national geospatial infrastructure is no different in this regard. Whatever the institutional arrangements implemented, the integrative approach should measure and develop reuse between institutions, partners, and innovators in pursuit of the SDGs.

4.1 Data in the hydro domain

Because the hydro and terrestrial domains are fundamentally different, there is often a focus on their defining models and the difference between them. A model is a description of the underlying structure of its content and the relationships of its component parts. Models represent a core part of the technical element of data and are an abstract description of a domain in standardized form. There is a strong link between the development of models and standards associated with them, and interoperability is founded on compatible models and standards.

Within the hydro domain, a couple of model characteristics are strongly evident when implementing the UN-IGIF strategic pathways:

- Within the hydro domain, there is a common model for the representation of data focused on the production of nautical charts. This is an inherently international model in focus and scope and requires a knowledge of the treaties and conventions they are designed to implement.
- Domestic requirements dominate modeling of the hydro domain for inland waterways and waterbodies, including rivers, watercourses, and coastal zones. Often these models are integrated with models designed for terrestrial mapping, planning, and other functional areas. Therefore, there is a need for interoperability between international and domestic models.

The key to integrating the diverse nature of terrestrial and marine domains is through models which describe their structure.

The core challenge is to develop and implement content models which fulfill the UN-IGIF requirement for interoperability. This is described further in the section on Strategic Pathway 6 Standards.

A focus on this (UN-IGIF Implementation Guide: SP3) and actions of key stakeholders (UN-IGIF Implementation Guide: SP9) is vital in any geospatial strategy when implementing the UN-IGIF at the country-level. In order to break down this challenge, the Fundamental Geospatial Data Themes, as adopted by UN-GGIM, are a practical starting point. The model underlying any data is crucial to its continued use and reuse. Promotion and distribution of models in technically rigorous form alongside simple, digestible documentation should be a prerequisite for all institutional arrangements.

In most, if not all situations, data are partitioned according to content into a number of fundamental geospatial data themes, and implementing the UN-IGIF is no exception. Note that these partitions do not always necessarily match the institutional boundaries defined within the section SP1 – Governance and Institutions. Indeed, such an approach should not be seen as defining exclusive boundaries or division, but merely a high-level grouping of data content.

Models should fulfil a requirement for interoperability.

The next subsections focus on the fourteen Global Fundamental Geospatial Data Themes as adopted by UN-GGIM and recommended by the UN-IGIF[5], and on how the hydro domain can be represented in each theme. We reference models and standards which may already exist as a starting point.

4.2 The Global Geospatial Fundamental Themes

The 'Hydro' fundamental data are central to the purpose of the UN-IGIF-Hydro Part Two. This is the area where data representing hydro domain are centralized. These data can represent any of the broad array of features within the hydro domain, such as oceans and seas and inland waterways and waterbodies—including rivers and watercourses, lakes and reservoirs, and wetlands and glaciers. Water and the data derived from it are unique in many ways—the extent to which water influences physical processes, water's qualities as a natural resource, and the many uses of water and data in relation to human existence.

[5] https://ggim.un.org/documents/Fundamental%20Data%20Publication.pdf

Although other Fundamental Geospatial Data Themes include hydro elements by reference (described in the next section), this section articulates the nature of data in the hydro domain and some of its primary qualities, which form core elements within the fundamental geospatial data themes.

The hydro domain is characterized by several phenomena:

- The hydro domain is four-dimensional. Because of the domain's dynamic nature, it is characterized by movement in time. So, attribution of time is often a primary concern in the data.
- The primary temporal measurements associated with the hydro domain are tides and flows. Tides and tidal currents, caused by gravitational effects, and the flow of rivers and watercourses influence all of the hydro domain's geospatial data to some degree. Many aspects of the fundamental data described in the next section stem from this dynamic nature.
- The dynamic nature and its impermeability make it a technically challenging phenomena to measure. The cost of data acquisition is high compared to terrestrial acquisition, and the hydro domain's characteristics can make it difficult to analyze via satellite imagery. Hydrographic survey and the creation of usable is still a highly skilled field with a high degree of processing involved. The cost of data acquisition has always been high, and the datasets reflect this. Such data are often priced at a premium and rely on a long, historical backlog of data due to the cost of periodic resurvey.
- Data associated with hydro domain reflect uncertainties (e.g., data quality and uncertainty models and zoning via delimitation, rather than the demarcation of terrestrial zones).

These aspects are reflected in any model describing features within the hydro domain, whether those features are oceans and seas or internal waterways and waterbodies. The links between SP4 – Data and SP1 – Governance and Institutions and SP6 – Standards are crucial (**Figure 3**).

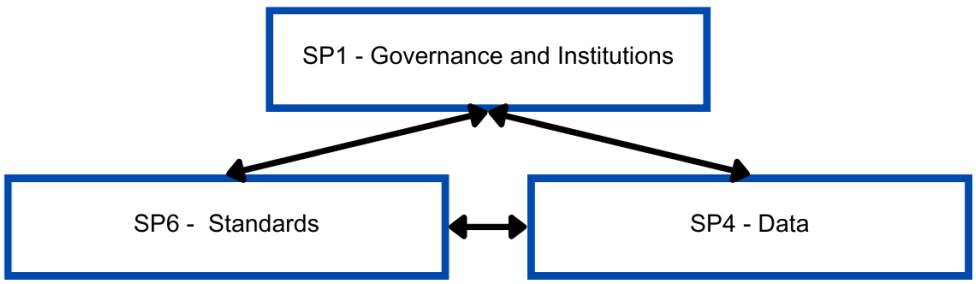


Figure 3. Linking governance and strategy with standards and data.

This is the starting point for an integrated approach to the hydro domain. In the remainder of this section, we look at how the geospatial data content of the UN-IGIF can accommodate a hydro dimension by examining the most relevant parts of the global fundamental geospatial data themes.

Themes undoubtedly will reflect the country's delineation of responsibilities, its physical geography, priorities, neighbors, and other factors, and will naturally develop over time. By understanding both the unique defining elements and the characteristics of the domain and how it can be represented within a country's Action Plan to implement the UN-IGIF, a country could fulfill the vision of an integrative approach across the geospatial information ecosystem.

4.3 Other Fundamental Geospatial Data Themes

The ***Global Geodetic Reference Frame*** has many aspects which affect integrated marine geospatial information management. A reference frame provides the mechanism for measurement of any spatial data, giving a meaning relative to the Reference Frame of "where" the data are. A "position" is meaningless without association to some form of reference frame.

- The Global Geodetic Reference Frame (GGRF) represents a single, consistent reference frame that can enable interoperability within a spatial infrastructure and across a region or globally. Ultimately, the goal of clarity within any exchange of geospatial data is defined by "where it is." Clarity of location is dependent on clarity of the associated reference frame.
- Within the hydro domain, often mapping and charting are referenced to old, historical, and possibly obsolete datums. Due to the cost of acquiring and processing marine data, older datums can exist in official datasets for many years. In addition, legislative instruments may use old agreements and treaties referencing locations. Referencing these datasets can pose challenges. In these cases, textual recording of such positions and datums can form part of its metadata.
- Modern nautical charts are mandated by content standards to use the World Geodetic System 1984 (WGS84). This has modernized many older datasets, and all modern survey outputs for charting use WGS84. WGS84's relationship with GGRF and International Terrestrial Reference Frame (ITRF) is mostly manageable in the context of mapping and charting with minimal practical differences. Conformance to standards and an awareness of the issues is an important aspect. Modern content standards, such as the IHO S-100 suite of standards, allow a range of both horizontal and vertical reference frames. For many reuse cases and for domestic use, a sound reconciliation between horizontal datums is crucial for all elements.
- Resolution of vertical datum differences between land and tidal water areas often require the production and definition of a correction surface. These surfaces are often key to production of data which are integrated in coastal zones and tidal watercourses and should be a priority when implementing the UN-IGIF at the country-level. Accurate vertical datum harmonization is key to data management for many uses, including flood management, inundation, and modelling of coastal zone processes for many stakeholders.

Geographical Names - Geographical names are crucial to national geospatial information management. Within oceans and seas, names frequently take on significant geopolitical dimensions and have international considerations, from the content of the name itself and the geospatial limits associated with it. Part of establishing custodianship arrangements should be to ensure clear responsibilities, models, and standards relating to naming that extend well into the domain (e.g., including islands, low tide elevations, subsurface features as well as rivers, lakes, and regions), to curate what can be an extensive historical and complex archive, and to ensure domestic and international requirements are met (e.g., language, translations, pronunciations, display and colloquialisms). A framework for representing and defining names of marine features exists in the IHO standards, and guidance is contained in IHO B-6. INSPIRE and the United Nations Group of Experts on Geographical Names' (UNGEGN) Glossary of Terms for the Standardization of Geographical Names and Manual for the National Standardization of Geographical Names are examples of good practice approaches to harmonizing naming and language across multiple domains.

Addresses - Addresses are normally conceived of in the context of land and buildings for identification of named locations. Addresses underpin many functions of local and national government. Consideration of the hydro domain is generally a spatial relationship; ensuring that land/water boundaries are stored and clear and that custodianship arrangements promote such clarity. As with many other data themes, where the domains intersect is often an area which requires precise definitions (e.g., addresses of water-borne vessels whose locations may move or ensuring the delimiting area of addresses are coincident when they include hydro components, such as residential perimeters on the coast or on waterways). Addresses may use named, located hydro-based identifiers, which should be harmonized within models for geographical names. Addresses for major maritime infrastructure, such as large ports, terminals, and vessel berths, are crucial for international trade, and their accuracy and interoperability can have a substantial impact on the efficiency of infrastructure.

Functional Areas - Functional areas underpin the "zoning" process as noted in UN-IGIF Implementation Guide: SP1 and SP2. Functional areas must contain adequate expressivity to describe hydro (or maritime) based zones as well as the numerous and complex domestic and terrestrial features within this theme. As described in UN-IGIF Implementation Guide: SP1, functional areas as a theme will include administrative areas with a significant international and transboundary element and with significant geopolitical implications. Both the foundational data, baseline, territorial sea, and EEZ are within this theme as well as marine spatial planning and planning zones such as fishing limits, planning zones, flood limits, local jurisdictions for local authorities, ports, harbors, and other regulatory authorities, and marine protected areas. Transboundary agreements and treaties require clear, unambiguous representation which is interoperable with national implementations of their principles. IHO content standards under S-100, S-121, and S-57/S-101 contain minimum themes for administrative and functional areas. An example of marine administrative areas is contained in INSPIRE. A national implementation may be influenced heavily by local geography and institutional arrangements.

Land Parcels and Properties - An integrated cadastre is fast becoming a reality, and its importance is starting to be recognized. The connection between geo-regulation and cadastral management is significant, and within the hydro domain, the relationship between cadastre and functional areas should be close and clearly defined. International Organization for Standardization (ISO) 19152 is an international standard which apportions rights, responsibilities, and restrictions to collections of geospatially delimited features. Recent work is extending this to marine administrative areas. This will result in a sound conceptual foundation for an integrated cadastre which can be built and adapted to country requirements. As with administrative areas, models for cadastre should be defined which meet domestic requirements and ensure spatial harmonization between institutions.

Elevation and Depth - Depth, as the corollary of elevation, provides unique challenges and tests as to the interoperability of data relating to the hydro domain. Depth can be used as a test case to assess the extent of the integrative power of implementing the UN-IGIF. At its heart, depth and elevation are both measurements from a reference surface and should be viewed conceptually as two complementary aspects of the same phenomena. A closely derived concept is the contour line, a line of equal depth or elevation and, specific to the hydro domain, a depth area, an area where all depths fall between two defined values. These are the fundamental building blocks of any model integrating elevation and depth.

Having both elevation and depth referenced to the GGRF is essential to an integrated spatial infrastructure, and the modeling and custodial arrangements should ensure that both aspects are clearly defined to meet user needs. Harmonization of vertical datums is a particular issue between terrestrial and marine data and is crucial for an integrated geospatial information management. The maritime component of the hydro domain is often subjected to tidal forces. The dynamic nature of the medium means that data of the hydro domain have a more complex vertical datum and also an implicit temporal quality. Many maritime infrastructures, oriented primarily at nautical charting, use multiple vertical datums to represent “safest” margins to their primary users. Chart datums, based predominantly on Lowest Astronomical Tide and clearances/elevations referenced against Highest Astronomical Tide or Mean High Water Springs, mean there is a requirement to hold a multiplicity of vertical datums for them to co-exist within geospatial datasets and for accurate and reliable tidal recording and modeling to be an integral part of the data model.

By contrast, terrestrial domains are founded around a single referenced vertical datum, and their quality is its consistency around that datum. The meeting point of depth and elevation should be a particular focus point. In order to enable interoperability between elevation and depth data in coastal zones, the last 20 years have seen an increase in technologies for the creation of correction surfaces.

Depth is one of the four dimensions within the hydro domain and appears in an incredibly broad range of contexts. Application models such as data acquisition through survey, selective (shoal) mapping of depths, tides and currents, flood mapping, erosion and many other elements of the spatial data infrastructure depend on sound modeling, data management, and

interoperability. There may be substantial dependencies between institutions and use cases (e.g., elevations of navigationally significant features). References such as INSPIRE (elevation) and IHO standards provide conceptual foundations for integrated approaches to modeling elevation and depth. These foundations should be a starting point for implementing the UN-IGIF, especially regarding geospatial strategy and a Country-level Action Plan in relation to this theme.

Geology / Soils - Geology and soils data should include the ability to integrate hydro-specific elements, including seabed, riverbed, wetlands, and coastal regions, as well as other characteristics such as permeability and flooding. Bathymetric and backscatter data are a means to gain information about the substrate, both in shape and type. These data can be used to identify habitats, bottom types, and geomorphology and can contribute to risk analyses of coastal erosion and slope stability.

Land Cover / Land Use - Land use and cover data must include consideration of the hydro domain in their modelling and are a key component in many management elements of the SDGs. Climate change impacts, flood management, conservation, and marine spatial planning can all be included in a harmonized classification system of "use." Clearly defined boundaries (where the land meets the sea) are crucial to ensure accuracy of delimitation, and the dependencies on cadastre, marine spatial planning, marine protected areas, and administrative areas are key to efficient data representation. As referenced in the fundamental geospatial data themes, land use information, like functional areas, is often required in disaggregated levels to allow local, regional, and national spatial data infrastructure to function. Data models and custodianship arrangements need to be able to accommodate such flexibility through interfaces and an integrated strategy and action plan at the country-level. The data inventory should be able to explain how such interoperability is achieved in the hierarchy as well as across the entire spatial domain.

4.4 Acquisition and Management

Within the hydro domain, cost of data acquisition, processing, and production is a major factor in data management, as well as management of old data and the need to ensure proper custodianship. The cost of data acquisition inevitably leads to the inclusion of a large quantity of old data, so most survey projects are highly selective, regarding where data acquisition is needed most. This can be in areas of perceived high risk (serving the needs of the navigation community), areas of high temporal change (due to seafloor condition or aftermath of natural disasters), or other areas (e.g., mapping critical habitats for endangered species, identifying the extents of highly productive areas for commercial fisheries, protection of the ecosystem and other maritime infrastructure developments).

The cost of acquisition and processing of marine geospatial data is high. These costs influence use and management throughout the processing and supply chain.

There is a need, therefore, in the hydro domain to ensure decisions on resource allocation account for the high cost and benefits of multi-use data. Because of the high cost of data acquisition, the need to survey for multiple purposes is vitally important. This is not always possible but should be a large part of the consideration.

Acquisition also needs to consider all opportunities to gather data through surveys for other purposes (e.g., exploration and science). There is also a need to promulgate surveys for other purposes (e.g., to reach out to user communities and conduct extensive user needs analysis).

The high cost of data acquisition has other consequences:

- the need to establish custodianship with an appreciation of the broad use cases for such data and
- a requirement to hold comprehensive archives, alongside populated metadata in a structured form.

Unlike the terrestrial domain, countries rarely survey their entire region to a consistent scale given the high costs involved, so many hydrographic data producers prioritize capture to areas which are used heavily.

4.5 Data Quality

Data quality is a frequent topic in all geospatial data domains and is of particular interest in the hydro domain. Although current data have a certain value (and are the subject of many use cases) historical data are of profound importance for scientific research (e.g., climate change and tidal modeling). Data quality is an essential component of metadata for all content, and extensive models are devoted purely to the subject of data quality, which can extend over multiple sub-domains and sub-genres.

4.6 Custodianship

Custodianship is a major principle within the UN-IGIF, and one where the fundamental geospatial data themes within the UN-IGIF play a key role. Assigning custodianship within the hydro domain has some specific challenges similar to those seen in previous sections within UN-IGIF-Hydro Part Two. In data terms, custodianship recognizes the “authoritative” nature of the custodian. The responsibility for interoperability of data should be implicit in the role of the custodian.

There are specific aspects with data derived from the hydro domain in terms of legal liability that increase the responsibilities of institutions. These aspects may influence the use of, for example, digital signatures and secure communications channels to ensure data integrity. For other types of hydro-related data in the scientific domain, there is often no legal liability, and standards may not be well established, and metadata may not be understood or completed rigorously.

Custodianship confers a requirement to maintain identifiers.

Persistent, unique identifiers are a key element of data under custodianship. When data are defined, an identifier is created and retained for its lifecycle. Themes need to define the form and content of such identifiers, ideally within an overarching standards framework. This, from a technical standpoint, is what custodianship is, the authority over data which represents a real-world entity. Its identifier is the map from the entity to its logical representation(s). Custodianship infers a strong requirement to maintain such mappings. The hydro domain can place many challenges in this respect as data acquisition costs and its dynamic nature can make identifiers difficult to maintain.

4.7 Interoperability

If consideration is given to the global fundamental geospatial data themes, vis-à-vis the hydro domain is to be included in nationally integrated geospatial information management and models describing the structure of data within all the domains, then interoperability can be developed and allowed to grow and mature.

Interoperability of data content is fundamental. With custodianship, interoperability defines how data “moves” within a system and spatial data infrastructure. This view of freely moving data is the key transformative vision of an integrated geospatial infrastructure. Standards have an important part to play in this process. The key to the success is to:

> Ensure interoperability between the data representing the hydro domain and the rest of the geospatial domains

***How should such interoperability be achieved*?** The hydro domain, as described elsewhere in this guide, can be overtly predicated on meeting international treaties and conventions, but these treaties and conventions may not be concerned with non-navigable waterways and may miss more complex use cases involving water supply, flood management, leisure and recreational use, and coastal and intertidal zones.

Models to describe these areas can be complex, whereas SOLAS charting is relatively simple. The example below in **Figure 4** and **Table 1** contrasts the INSPIRE model for watercourse network models and rivers within the IHO S-101. Each model represents different essential facets of the nature of a river—its flow, width, geometry, network characteristics, names, and identifiers.

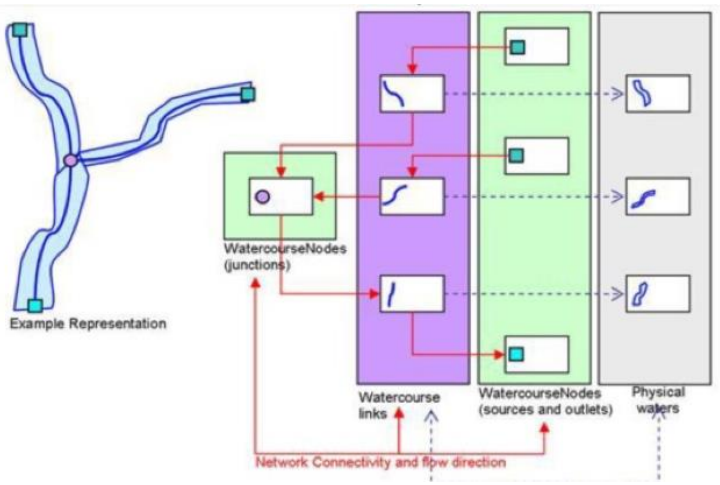


Figure 4. Waterways and Rivers, INSPIRE

IHO Definition: **RIVER**. A relatively large natural stream of water. (IHO Dictionary – S-32)				
S-101 Geo Feature: River (RIVERS)				
Primitives: Curve, Surface				
Real World	*Paper Chart Symbol*	*ECDIS Symbol*		
S-101 Attribute	**S-57 Acronym**	**Allowable Encoding Value**	**Type**	**Multiplicity**
Feature name			C	0,*
Display name			(S) BO	0,1
Language		ISO 639-1	(S) TE	0,1
Name	*(OBJNAM) (NOBJNM)*		(S) TE	1,1
Status	(STATUS)	5 : periodic/intermittent	EN	0,1
Scale minimum	(SCAMIN)	See clause X.X	IN	0,1

Table 1. Waterways and Rivers, IHO S-101

So, the implementation of the UN-IGIF at the country-level must ensure that either

- data exchange between institutions uses identical technical content standards, or
- institutions work from a common data model which encompasses all domains.

As noted elsewhere, the diversity of requirements around the hydro domain (international versus domestic) and the fundamentally different qualities of water, such as its flow and its temporal and changing nature, can make such requirements challenging. The UN-IGIF's strategic pathways provide guidance and recommendations for designing and ensuring interoperability when prioritizing actions under the UN-IGIF SP4 - Data.

Interoperability should deliver the ability to transform data between two different models (independently of format) using automated transformations rather than requiring manual interventions. Automated transformations convert data instances (e.g., features like that in **Figure 5**) from one domain to another. The domains in question are often embodied in content standards or derived directly from them.

The issues, frequently in the hydro domain are

- extremely specific combinations of features and attributes are required to satisfy strict SOLAS requirements that may not be captured or met in domestic data capture programmes and
- datums between terrestrial and maritime data collection may not be harmonized.

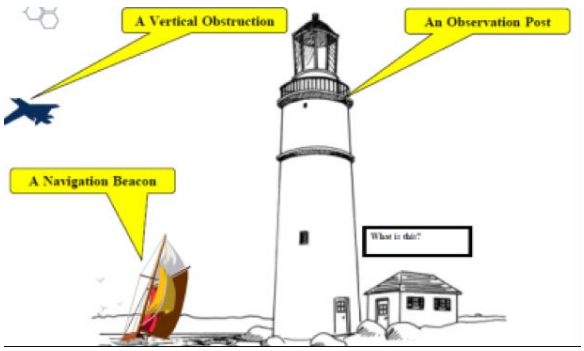


Figure 5. Differences of interpretation of features

Ultimately, a practical model must be arrived at which expresses each entity, its identifier, component parts, and the relationships the entity has with other entities, along with a defined association to “where” it is. This assessment and encoding of a real-world entity have a long- and well-established technical methodology and results in the construction of models which describe the structures used across the infrastructure for storing, managing, and encoding geospatial data. The overarching ISO19100 series of standards presents a general feature model which can be adapted for any number of different domains. The ISO framework is implemented by IHO and Open Geospatial Consortium (OGC) standards. Under the ISO approach, a model is formed of a domain with features, identifiers, and names alongside its location.

Models should not be confused with formats. The model is a representation of the data, its structure, relationships, and entities. The format is the digital encoding for exchange of the data between participants.

The initial data framework within the hydro domain, therefore, should place great emphasis on ensuring commonality of underlying data models and interoperability between data models for all domains established within any geospatial information management and its infrastructure and system, and focus on the interface between domains.

Some examples where different domains may need to harmonize data and modeling are:

- baseline points established on land,
- coastal zone delimitation,
- navigationally significant land features,
- common depth area delimitations between major ports and hydrographic office inputs/outputs,
- vertical datum definitions and types for reconciling terrestrial and maritime datasets, and

- coordinates used in environmental legislative frameworks for marine protected areas which require promulgation via navigational or nautical charts as restricted areas of operation.

The data inventory, established as part of UN-IGIF Implementation Guide: SP4, should record model characteristics, pathways, and interoperability details between participants in all the geospatial domains and their custodians.

4.8 Actions – the National Integrated Geospatial Information Framework

The National Integrated Geospatial Information Framework, an outcome from the implementation of the UN-IGIF at the country-level, should represent the hydro domain elements alongside all other content seamlessly. This national framework produces a description of data, its defining models, and the definitions of content.

In the hydro domain, the challenge is to harmonize domestic needs and requirements with those defined under international treaties and conventions and their obligations. For instance, the requirement to produce nautical charts forces the existence of a focused nautical survey programme to ensure safe navigation and the production of datasets reflecting international standards for nautical charts as well as the raw survey data (and its metadata). Similarly, nearly 200 data “types” are defined by electronic charts (normally, but not always, aggregated together in a single logical data store).

It is not difficult to find examples where states have institutions responsible for implementation and maintenance of aids to navigation—ports with significant amounts of charted infrastructure, canals, waterways, waterborne transportation and trade. The state may also require many different kinds of reuse of marine geospatial data (e.g., energy production and domestic legislative purposes, such as exploration, research, and marine spatial planning). Some of these institutions will produce data for their own purposes with a secondary responsibility to share data with the nautical charting office.

4.9 Data Supply Network

During the last twenty years, the method of delivery of all geospatial data has undergone a seismic shift. The advent of web mapping and the range of technologies supporting it promoted a decentralized approach. Previously, geospatial data were invariably transported wholesale and viewed within standalone geographic information systems only. This necessitated a physical transfer of data permanently from one location to another. When the OGC and others developed early web services, web mapping from geospatial web services with portrayal and data content specified became a reality. Web mapping, with the advent of vector tiling and various mapping frameworks, is now a well-defined area with many participants and a fast rate of development.

In the supply chain for mainstream geospatial data, distribution via Application Programming Interfaces (APIs) is fast becoming the preferred method among many providers. In this case, data are not permanently transferred, but downloaded and rendered when required. In the hydro domain, however, mapping and charting remains a static use case with navigation under ECDIS requiring timestamped safety critical data in place for live navigation. Nautical charting is not a real-time use case like much geospatial data.

So, there is often a disparity of data supply between core marine geospatial data (however much is distributed online) and its reuse via web service APIs. Due to diverse data models, integrated datasets are often scarce.

The other reason for static data transfer is where large network latency and speed of transfer of large data volumes are a consideration. Within big data fields and data science, API access is often not efficient enough to consider data science. High performance and analytical systems must cache data locally for optimal performance.

New “user to the data” approaches are now being used which solve some of the problems associated with static data transfer. These approaches allow algorithms to be transferred to locations where large volumes of data are located, and they allow analysis to be completed efficiently with large data volumes without physically moving the data. A good example of a “user to the data” approach is the European Space Agency’s Earth Observation Exploitation Platform Common Architecture (EOEPCA).

4.10 Overall outcomes – Testing the Outputs

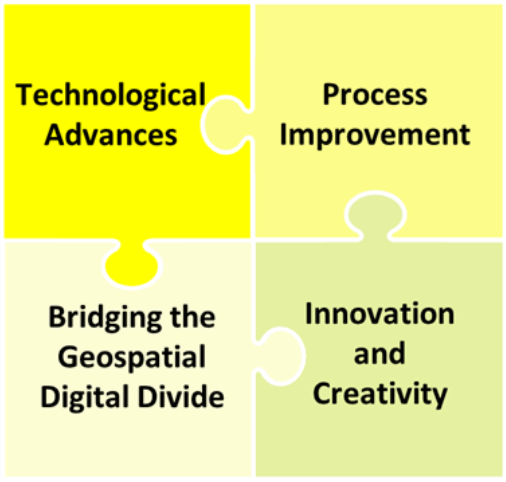
In terms of measuring the outcomes from implementing the UN-IGIF SP4 – Data, the following observations are made:

- The inclusion of hydro domain elements and marine geospatial data within the national integrated geospatial information management and its infrastructure and system ensure clarity over custodianship and content.
- A focus on interoperability and inclusion to harmonize disparate international and domestic requirements will enable coordination of the hydro component within any nationally integrated geospatial information management.
- Only through focused resourcing and interoperability will potentially benefits, resource optimization, and cost savings identified in the UN-IGIF be realized. Integration, nationally and globally, is achievable through a systematic sharing of technology and data modelling expertise throughout any nationally integrated geospatial information management arrangement. Therefore, education and communication are vital.

In terms of testing the outputs, what characterizes an UN-IGIF implementation and its outcomes?

- existence of hydro domain elements within a nationally coordinated management arrangement for geospatial information, represented in all forms within the national arrangement—oceans, seas, coastal zones, inland waterways, rivers, lakes, watercourses, and wetlands.
- an approach to interoperability where defined use cases are implemented in models which are integrated; should include a model of persistent, unique identifiers which is similarly integrated and implemented by custodians across the national arrangement.
- clarity of definition and content at borders between domains (e.g., land, sea, inland waterways and waterbodies, and boundaries); coastline is a particular focus. This harmonizes datums, content, and metadata. The implementation should cover a variety of use cases and stakeholders (e.g., ports and harbors, flood management, sea level monitoring, mapping, and scientific/research).

Strategic Pathway 5 Innovation



With the accelerated digital transformation of the hydro domain, innovation is critical to ensure systems and practices are kept relevant. Innovation offers the opportunity for governments, businesses, academia, and civil societies to leapfrog to the up-to-date marine geospatial information management, practices, products, and services. Innovation as the centerpiece of the UN-IGIF holds true for the sustainable implementation and use of marine geospatial information. Sustained innovation is also critical to realizing the positive impacts and value of marine geospatial information. The promotion of innovation requires awareness of the potentially disruptive trends in the hydro domain which could be addressed within the four key elements of technological advances, innovation and creativity, process improvement, and bridging the geospatial digital divide.

The hydro domain is often a leader when it comes to innovation. Programmes can leverage newly established technology and process improvements to give them an opportunity to leapfrog aging systems and standards that consume valuable resources. For example, data collection within the hydro domain is an expensive prospect, and innovation can lead to faster, more affordable, and more accessible data collection.

Recognizing innovation as a critical pathway early in a programme's development lifecycle can help pave the way for advances in technology, creative solutions to problems, process improvement, and bridging the geospatial digital divide.

In the hydro domain, there are a few strong, supporting mechanisms that help make innovation a priority,

- reliance on a wide variety of marine scientists and other professionals to have new ideas and leverage others' work for their own needs;
- ease of collaboration through open platforms, open access, and open source;
- a very strong private sector network that often supports innovation through technology assistance and training; and
- international institutions (e.g., the IHO) which provide access to resources like capacity development programmes and an innovation laboratory.

In short, innovation and the benefits that a commitment to innovation can provide are important. Innovation is a continual process. It is important to emphasize, when implementing the UN-IGIF SP2 – Policy and Legal, that regulations should be constructed to promote an environment for innovation.

5.1 Actions – the National Integrated Geospatial Information Framework

Understanding and leveraging the latest appropriate cost-effective technologies, innovations, and process improvements across the evolving national geospatial landscape, including the hydro domain, requires a balance between considered and concerted promotion and ensuring a conducive environment with ongoing monitoring and review which seeks efficiencies and productivity. This is becoming particularly relevant as national geospatial information agencies or authorities (including those with responsibility for nautical charting) transition from traditional data supply models to more modern 'data on demand' and 'knowledge services' approaches.

Consideration should be given to include the hydro domain, as appropriate, in:

- the development of the national geospatial digital transformation strategy (UN-IGIF Implementation Guide: SP5 - Action 5.6.9);
- monitoring and advising on the technology and innovation developments, trends, and future directions for marine geospatial information management;
- proposing process improvements and innovation efforts that are in line with cross-government priorities and are delivered in the national interest;
- directing and monitoring ongoing innovation programmes and outcomes, and making recommendations for improvement where necessary;
- reviewing any policy issues arising from the implementation of new technologies and methods and making subsequent recommendations;
- coordinating initiatives with other specialist working groups (Data, Capacity and Education, Policy and Legal, Financial, etc.) that are established in the implementation of the UN-IGIF at the country-level, avoiding duplicative efforts, and managing programme interdependencies, such as the need for capacity development in new technologies;
- guiding the development of new policies, guidelines, and reports related to technological innovation and digital transformation; and
- engaging with stakeholders on technology, process improvement, and innovation opportunities so that efforts are directed towards national priorities and needs.

5.2 Outcomes

When implemented, the actions and any interrelated actions (e.g., policy and legal considerations) will enable the achievement of the four key elements which will in turn deliver significant and sustainable national outcomes and benefits at the country-level. These outcomes include attaining:

- improved processes for the collection, management, distribution, and analysis of marine geospatial information, leading to more efficient use and reuse of data and effective, evidenced-based decision-making;
- increased productivity and efficiency achieved through an innovation-enabled environment;
- an innovative workforce that creates and executes new processes and develops new products and services; and
- the ability to bridge the geospatial digital divide through appropriate adoption of enabling technologies achieved through an innovation ecosystem.

Strategic Pathway 6 Standards

Hydrography, as a science, was historically built from a firm requirement for nautical charting, propelled by the international requirement for safe and efficient shipping to underpin global trade and defence. Still a major driver (alongside scientific and environmental research), the production of nautical charts shapes much of the geospatial data in the hydro domain and its availability to the broader community. Indeed, the marine spatial data infrastructure movement was borne out of the IHO's Marine Spatial Data Infrastructures Working Group (MSDIWG) with its roots in standardization efforts and the realization of the value of geospatial data representing the seas and oceans.

The globalization of the electronic navigation charts as the mandated regulated primary means of navigation for commercial shipping is a success of international cooperation through adherence and application of geospatial standards. The IHO standards cover acquisition, compilation, validation, encoding, portrayal, and update within a global type approval regime for commercial navigation systems used in some of the most challenging and safety critical regimes in the world. Standards underpin this entire ecosystem of interlocking parts, so it is not surprising that many of the standards in the hydro domain stem directly from this use case.

A key defining characteristic of marine geospatial data is the requirement to meet international obligations as well as satisfying domestic responsibilities.

The hydro domain, however, has a much greater reach, as do the potential use cases associated with it. Most national geospatial infrastructure will cover the mapping of waterways, lakes, coastal zones, estuaries, wetland, and other categories of land use.

As was noted in the UN-IGIF SP1 – Governance and Institution, frequently the delimiting of institutional arrangements separates land/terrestrial from seas and oceans resulting in a gap between models and their inability to span the border; this often results in duplication and mismatch within coastal zones. Additionally, a mismatch between production of geospatial data for defence and civil purposes can result in similar mismatches between datasets produced in different parts of the national geospatial infrastructure.

Standardization of geospatial data in all domains can give power to data from different sources, whether from different Member States or from different institutions within the same national geospatial infrastructure. Shipping, as one of the most globalized industries in the world, is acutely focused on international standardization. Conversely, geospatial data for internal waters is often produced to satisfy internal, domestic, or local needs and requirements.

This section focuses on how these needs can be reconciled using standardization and good practices and on the unique challenges of standardization within the hydro domain.

6.1 The Community of Practice

One of the key differentiators of the hydro domain is the complex relationship between international and transboundary issues and domestic agendas. The UN-IGIF Community of Practice, in relation to standards for the hydro domain, is a case in point which bears some closer examination. A national standards strategy from the national implementation of the UN-IGIF, managed by the national standards committee will promote interworking between the communities domestically, regionally, and internationally (**Figure 6**).

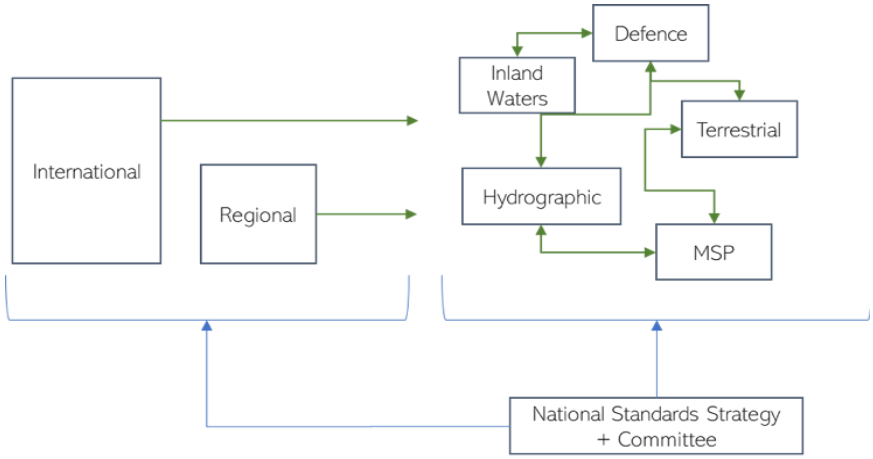


Figure 6. How A "multi-thematic" national strategy oversees domestic and international standards

In the hydro domain, the international and national standards bodies together constitute the community of practice.

The diagram above shows a typical situation with various institutions and some examples of interoperable data interfaces. In the diagram, the national standards strategy and its standards committee oversee all the organizations and their activities in relation to standards, including international and regional representation. This responsibility should not be seen as an overhead responsibility. In the hydro domain, particularly for hydrography, the international influence is considerable on standards, and regional groups, primarily the Regional Hydrographic Commissions (RHCs), act as valuable implementation testbeds and forum for the exchange of good practices. Many of the RHCs have extensive MSDIWG subgroups as well (e.g., Meso American & Caribbean Sea Hydrographic Commission [MACHC], Southern African and Islands Hydrographic Commission [SAIHC], Baltic, Arctic, and East Asia) which are able to contribute to good practices and regional norms.

Integrating international standards with national requirements is a major challenge.

The influence of international standards on hydrography is felt at all levels, from data acquisition to data management, cartography, validation, and distribution. It is easy for hydrographic standards to sit in isolation of national and domestic standards and their management. However, it is vital to integrate through interoperability common semantic models, institutional arrangements, data management processes, and standards across the infrastructure. Areas such as inland waterways, coastal zones, and large inland bodies of water will require standards to meet international mandates as well as domestic agendas. Inland waterways are a prime example where the Inland

Electronic Navigational Chart (IENC) standard covers features in the domain of safe navigation, but domestic data standards may cover different domains of water flow, flood management, and planning. Harmonizing these standards requires a methodology and structured approach. Hydrography, with its core stemming from internationally standardized nautical charts, has developed a comprehensive framework, IHO S-100, which encompasses many hydrographic, meteorological, and maritime domains and is probably one of the most significant developments in such frameworks in the hydro domain.

The combination of national and international groups and representation forms the true Community of Practice, bodies with shared goals working cooperatively using open, consensus-based standards. The combination represents the truly integrative approach and shows how the hydro domain can act as a catalyst in establishing international relationships in pursuit of the UN-IGIF goals and outcomes and the SDGs.

Internationally, the standards ecosystem is dominated by the IHO, the only international standards development organization solely devoted to standards in the hydro domain. The IHO's flagship standards framework, the IHO S-100, has matured in the last few years alongside its content standard product specifications and the IHO's comprehensive geospatial registry, and the IHO S-100 continues to be developed to meet the needs of many stakeholders.

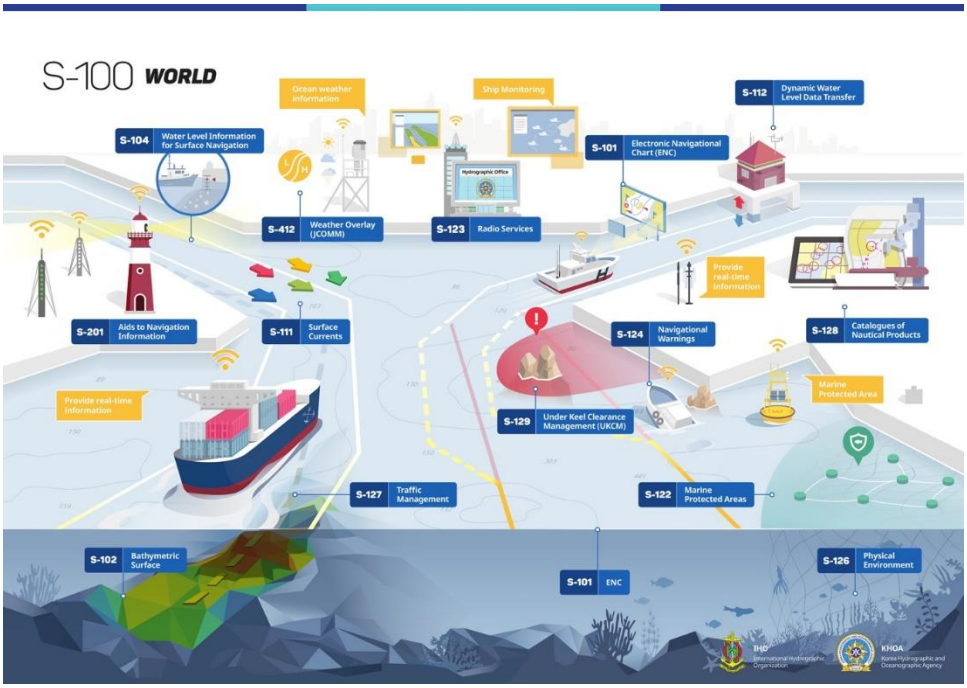


Figure 7. The S-100 ecosystem

Inland, there is no single model which will meet all stakeholder and community requirements, and local geography will also likely form and influence the standards implemented. However, interoperability with the hydro domain is highly desirable for many reasons (see value propositions presented in UN-IGIF-Hydro Part One). Policy and Governance should set this as an objective and develop a roadmap to interoperability. For instance, ports and harbors form major interface points between land, sea, and internal waterways where standards for

terrestrial data, spatial, mapping, commercial, and logistics meet hydrographic standards and survey.

Another area requiring standardization is the creation and use of persistent identifiers (PIDs), a long-lasting reference to a digital resource, which gives a unique name to a document, file, web page or other object. The importance of creating PIDs and using and maintaining PIDs created by others can be a challenge. Many systems struggle to maintain externally provided PIDs, which are vital for tracing lineage and authoritative versions of datasets through interoperable systems.

A position on open standards versus proprietary and industry standards should be developed, detailing the extent to which a commitment to open standards can be adopted. This may not be entirely possible across all institutions, the production of marine geospatial data is frequently performed within commercial off-the-shelf (COTS) packages, but the transfer of data between institutions (via download or API) should use open standards as far as possible, mandated by policy at a national level.

The INSPIRE model is worth consideration as an example of how a regional standards approach has defined an abstract framework and content standards covering all of the hydro domain for a number of stakeholders.

6.2 The Importance of Open Standards

Open standards are those standards which are free to use, implement, and share. Many spatial data infrastructures are built on open standards (the IHO standards base is completely open, as are all OGC standards and many broader standards in the hydro domain). Many studies have been done evaluating the value of open standards and open data to stakeholders and this should be a consideration when implementing the UN-IGIF at the country-level.

A useful reference in application of open standards is the 'Guide to the Role of Standards in Geospatial Information Management'[6] also referred to as the "Standards Guide" jointly prepared by the IHO/OGC/ISO. Although not specific to any domain, it presents an integrated view of the use of standards for geospatial information management from the perspective of the leading global standards development organizations.

6.3 Standards and Interoperability

Standards development in the hydro domain reflects, the diverse nature of the domain and the contrast between international concerns and domestic and regional perspectives. Many guides to standards reference lists of standards, their component parts, and hierarchies. Such lists are incomplete by definition as they invariably omit national and domestic standards, profiles, and encoding guidelines that may exist.

[6] http://standards.unggim.ogc.org/index.php

Some standards are necessary as a prerequisite for implementation of additional standards within the hydro domain. For example, the IHO S-57 and S-101 implement navigational charting with IHO and International Electrotechnical Commission standards tightly regulating equipment. The ISO framework is another example which is ubiquitous across all geospatial domains, and the IHO S-100 draws heavily from it in order to define a set of hydro-specific product specifications.

There is no single exhaustive list of standards necessary for implementation with the hydro domain.

Many existing institutions have skills in data modeling and a comprehensive knowledge of standards gained from lifetimes of experience working with geospatial data. The most important elements are to:

- ensure the hydro domain is adequately represented in any data inventory, data framework, and metadata when implementing the UN-IGIF;
- establish interoperability between those standards adopted for international requirements (e.g., nautical charting) and standards used for representation of domestic and regional structures; and
- ensure participation in the community of practice encompasses the hydro domain community.

Within the standards community, interoperability is the quality which allows data to be reused by others. In the context of implementing the UN-IGIF and including the hydro domain as an integrated element within nationally integrated geospatial information management, interoperability of data under standards means that data conforming to standards and representing the hydro domain can be used by all participants and stakeholders alongside the other elements without requiring “special” considerations or manual effort.

Interoperability can be considered and assessed in two ways, which are reflective of the two main elements of geospatial standards:

- technical interoperability, where standards are mostly concerned with a content neutral technological interoperability (this can be, for instance, harmonizing digital formats or API technologies) and
- semantic interoperability, ensuring the model used to represent the digital data is interoperable with others (this, in a standards context, is only concerned with those geospatial standards which model particular domains, and not the digital formats or encodings used).

In the context of the hydro domain, standards focus primarily on semantic interoperability because of the diverse nature of the domains involved.

Within the hydro domain, there is a dominance of international hydrographic standards (e.g., IHO S-100) and ISO standards under the ISO19100 framework which define the foundation for many geospatial infrastructures.

The IHO provides an ISO standards base oriented towards international standardization over much of the oceans and seas and their phenomena, but an abundance of models also exists in within the hydro domain. For example:

- inland waterway navigation under the IENC set of standards;
- INSPIRE provides a comprehensive set of models in many contexts including watercourses and administrative areas; and
- defence standards defined by the North Atlantic Treaty Organization (NATO)-supporting Defense Geospatial Information Working Group (DGIWG), such as Additional Military Layers (AML).

In order to achieve the desired UN-IGIF's outcomes:

- Each custodian must be given the authority and responsibility to publish and maintain their definitions, implementation of models, and data implementing those models.
- Where interoperability is required, the governance and policy must assign responsibility for that interoperability. This can be achieved through each participating institution, a national infrastructure, or through partnering arrangements with third parties.
- Communication is vital, and well publicized models with normative definitions are crucial to ensuring informed interoperability and an efficient implementation.

Data models used by specialist working groups within the domain of the national community of practice should be charged with the responsibility of ensuring semantic interoperability. Enabling and managing such interoperability is a challenging process. Often models are built into proprietary GIS for production of standardized data. This has the advantage of producing a COTS product for specific purposes, but can be restrictive in engineering interoperable solutions without customizations.

Progressive, incremental development can be made towards models which accommodate local nuances and integrate the terrestrial and hydro domains. What is important, from the UN-IGIF Implementation Guide recommendation on direction-setting perspective, is to acknowledge and record such customizations and maintain a knowledge base of which standards are being implemented, their scope/limitations, and roadmaps, and how transformations of data and knowledge of the standards can map the different domains to meet many different needs.

The initial UN-IGIF Implementation Guide recommended action—baseline survey of standards—is a good place to start. The baseline survey should take into account how and to what extent major international treaties and conventions are being met (e.g., SOLAS through charts, whether produced nationally or on behalf of; UNCLOS and its zones with requirements for domestic mapping of internal waterways, their boundaries, depths, centerlines, and flow models) and should arrive at a managed, universal understanding of how the hydro domain is approached within any nationally integrated geospatial information management arrangements and of the dependencies that exist.

A subsequent gap analysis will likely cover national, regional (e.g., immediate neighbors and stakeholders), and international elements and how they should be addressed. This gap analysis can then consider existing obligations (e.g., pollution control, fishing limits, and marine spatial planning), and how fulfillment of those obligations works alongside regional and international compliance. The UN-IGIF Implementation Guide recommended a standards inventory cover all 'hydro' standards alongside all other standards and highlight where there may be substantial overlap in domain content (e.g., coastal zone, inland waterways, and inland waterbodies).

Start with inclusion of all 'hydro' related standards in the baseline survey.

6.4 Geospatially enabled Statistics

The UN-IGIF makes a point of contributing to geospatially enabled statistics in order to contribute to the SDGs, and the ability of data from the hydro domain to do that should be a prime consideration when considering standards. Standards and statistics are wholly reliant on consistent, global definitions. Again, a reliable interoperability mechanism backed by a comprehensive data framework forms the foundation of this capability with standards playing a key role in its implementation.

Geospatially enabled statistics place a further requirement on interoperable geospatial data.

The challenge of deeper integration with statistics is the requirement to transform data to models for statistical production, which will require international harmonization. This is likely to increase the requirement for intelligent transformation of data and the technical methods which support it. This is in addition to the need to support international and domestic obligations within data (identified as a key element throughout the UN-IGIF and UN-IGIF-Hydro) and points to an enhanced requirement for skills in data transformation, modeling, interoperability, and standards. Standards have a key role to play in ensuring such broad interoperability, and education and a commitment to developing skills in key personnel are crucial to reaping long-term benefits.

Strategic Pathway 7 Partnerships

A core element of the "People influence" of the UN-IGIF is partnerships, and this is highlighted in the 'White Paper on Readily Available and Accessible (Open) Marine Geospatial Information[7]' prepared by the Working Group on Marine Geospatial Information established by the United Nations Committee of Experts on Global Geospatial Information.

While the Working Group makes many suggestions throughout the paper, one of the Working Group's main recommendations includes "developing data-sharing partnerships" to facilitate the timely sharing of data between Member States, government agencies, research and academia, private data-providers, and other stakeholders. Legislation can facilitate data-sharing partnerships, but the Working Group suggests using legislation sparingly to avoid situations where legislation encourages agencies currently sharing data to cease if the mandate is not explicitly applied to their mission. Data-sharing partnerships can exist outside governments as well, and the Working Group highly recommends maintaining relationships with the private sector, academia, and other stakeholders, to increase access to geospatial data and new geospatial technologies.

As with many other aspects of the hydro domain, there are a national and international aspects to be addressed. Because many phenomena, wildlife, and natural features span international boundaries, the establishment of partnerships frequently require international collaboration to be truly effective. Thus, regional partnership organizations can have great significance. Of particular note are the extensive uses made of partnerships for data acquisition and management, as a direct by-product of the high costs of acquisition across the entire hydro domain. There is, consequently, a large reliance on extensive partnership networks in the hydro domain.

A more recent development globally is the emerging field of crowd-sourced data. Most official institutions gather data from private sector networks and citizens, but the advent of inexpensive, global navigation satellite system (GNSS) enabled handheld mobile devices, greater connectivity, and reduced cost applications, has greatly increased the ability of the public to contribute to geospatial data gathering. In the hydro domain, this is seen less so than in the terrestrial domain (e.g., there is no direct parallel to OpenStreetMap). However, the great cost of marine geospatial data acquisition confers a high value on data sourced from citizens if suitably validated and attributed with appropriate metadata. The rise in the popularity and potential of this data gathering should be acknowledged.

The other crucial aspect of establishing partnerships is to support transformational research. Innovation is essential, as is participation in global research efforts. Education and participation in the global community are vital. Partnerships with trade organizations and sharing of common data models can ease interoperability of collected data. To this effect, expanding partnerships

[7] https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/E-C.20-2020-31-Add_2-White-paper-on-readily-available-and-accessible-marine-geospatial-information-23Jul.pdf

to other non-hydro technical and economic domains will become increasingly important to advance innovation for the Blue Economy.

The challenge within the hydro domain is one of managing partnerships across multiple sectors, across boundaries internationally, and with internal stakeholders.

Examples of formal partnerships include

- the Global Ocean Observing System (GOOS),
- the ARGO programme,
- the Nippon Foundation GEBCO Seabed 2030 Project, and
- the Sea Level Monitoring Facility of IOC-UNESCO.

Examples of less formal partnership networks include

- whale spotting,
- catch/bycatch reporting systems for fishing, and
- marine debris tracking.

7.1 Opportunities for Partnerships

For the hydro domain, partnership opportunities should be carefully evaluated given the nature of the domain and its national and international obligations. There are many models for evaluating partnership opportunities and formalizing a partnership, but there is no single correct approach as observed by the UN-IGIF Implementation Guide: SP7.

As opportunities arise, organizations in the hydro domain need practical guidance on forming strategic partnerships, whether they are public, public-private, or civil society, and where to begin the partnership development process. For this reason, a process to evaluate partnership opportunities should be considered at the outset. There are many models for evaluating partnership opportunities and formalizing a partnership. Any approach will depend on the type of partnership being evaluated, cultural sensitivities, national policy, and legal frameworks in place.

Typically, a geospatial-related partnership will include eight major steps (***Figure 8***):

(1) establishing selection criteria for the specific partnership being considered;
(2) identifying potential partners;
(3) conducting preliminary research and fact finding;
(4) initiating engagement strategies (e.g., ‘Request for Information’ or ‘Request for Proposal’);
(5) evaluating options and identifying operational implications;
(6) preparing resource impact assessment and financial analysis;
(7) conducting negotiations and formalizing the partnership; and
(8) implementing governance and a communication plan.

Figure 8. An example of a process for evaluating geospatial-related partnerships

A great use case for geospatial-related partnerships is marine spatial planning (MSP). MSP is a process that encourages multi-sectorial data collection since the MSP process is inherently inclusive and participative. MSP often spans multiple domains and uses and can be greatly beneficial with functional partnerships in place.

Strategic Pathway 8 Capacity and Education

The 'White Paper on Readily Available and Accessible (Open) Marine Geospatial Information' prepared by the Working Group also stressed the importance of capacity development to allow and actively share and transfer knowledge, practices, experiences, tools, and techniques that facilitate the collection, management, and sharing of marine geospatial information to developing counterparts.

The UN-IGIF stresses the importance of capacity and capability development and education. Capacity development is a useful tool to aid countries and other stakeholders in collecting and managing their marine geospatial information. However, limitations on available resources for capacity development are recognized. Member States are encouraged to focus on the active, in-kind transfer of knowledge of tools and techniques that facilitate the effective collection, management, and sharing of marine geospatial information.

Member States are also encouraged to focus on making their own marine geospatial information available and accessible as this can help countries without comprehensive datasets by alleviating costs associated with initial data collection.

Under the UN-IGIF, capacity development is defined as the "process of developing and strengthening the skills, instincts, abilities, processes, and resources that organizations and communities need to survive, adapt, and thrive in a fast-changing world." Capacity development may suggest building something new and the term "capacity development" is therefore often used to demonstrate the process of building onto existing skills and knowledge.

In the hydro domain the specific challenges are

- the traditional, highly specialized skills required due to the nature of the domain,
- the requirement for capacity to satisfy national and international responsibilities, and
- the diversity of areas in which the hydro domain exists and requires consideration.

The implementation of the UN-IGIF places capacity and education directly alongside the operational areas of implementation, shown in ***Figure 9***.

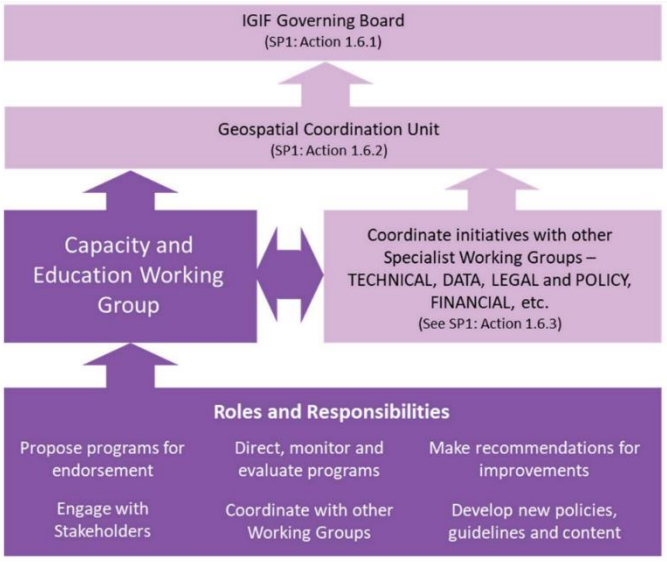


Figure 9. Capacity and education

The measurement of the success of any capacity development under the United Nations Development Programme (UNDP) is that it leads to change which is sustained by those whom it is meant to benefit. Any programme must also be sustained, generated, and guided by those for whom it is meant to empower. Measuring the success of a development programme is therefore an integral part of the UN-IGIF implementation.

8.1 Capacity development programmes

Capacity development programmes should, therefore, take note of the unique challenges of the hydro domain and the special skills required and seek to make sure they are covered by the programmes proposed by any national capacity and education working group (***Figure 9***). Some specific targets could be ensuring:

- education and training represent all domains;
- development content represents a consistent view of domains, which complement, not contradict, each other;
- state-specific, regional, and international elements are well represented; and
- certification is internationally accredited where such structures exist.

Some examples of existing capacity development programmes are listed below.

- Under the Inter-Regional Coordination Committee of the IHO, a capacity building and technical cooperation programme, works with international partners and regional IHO groups to develop states' capacity according to need. This is done through accredited international training programmes and technical cooperation visits. The programme covers many different sub-domains, including governance and production.
- IHO Regional Electronic Navigation Chart Coordination Centres (RENCs) establish cooperation and training programmes between Member States to ensure harmonization of data content and validation.

Strategic Pathway 9 Communication and Engagement

From a government and institution perspective, open communication and dissemination of data enables better, evidence-based understanding of decisions. Open communication and dissemination also allow third parties and the public to analyze and validate information and decisions derived from data.

Use and re-use of data are more efficient and can spur innovation and benefit within the private sector.

When implementing the UN-IGIF at the country-level and including the hydro domain countries should consideration internal and external communications.

Internal Communication should focus on essential details such as standards, metadata, interoperability, and discoverability. Messaging should highlight how these elements increase our ability to do more with the data generated and the potential for a higher return on investment when others do innovative things with available data.

External Communication should include similar messages, but also focus on the value of citizen science, Indigenous knowledge, and other non-traditional ways of obtaining and disseminating geospatial data. External messaging should highlight that the more everyone contributes, the better the outcome will be for everyone.

9.1 Identifying Stakeholders within the Hydro Domain

Suggestions for potential stakeholders to engage in the hydro domain are listed below based on the categories included in the UN-IGIF Implementation Guide: SP9. These are only suggestions but could be used to start a stakeholder analysis by looking for comparative national and regional equivalents.

Table 2. Suggestions for potential stakeholders to engage in the hydro domain

Stakeholder(s)	Example(s)
Politicians and Policy Makers	• Bodies enacting legislation across the hydro domain • International relations
Government Organizations	• May perform statutory functions (e.g., nautical charting, marine pollution, maritime safety, and maritime search and rescue)

Multilateral Organizations and development/donor programmes	
UN Agencies and other national governments or NGOs	• United Nations Office of Legal Affairs, Division for Ocean Affairs and the Law of the Sea • Intergovernmental Oceanographic Commission of UNESCO (International Oceanographic Data and Information Exchange/IOC/UNESCO) • International Hydrographic Organization and its Regional Hydrographic Commissions
Geospatial Information Users	• Mapping and charting • Marine transportation • Ports and harbors authorities • Fisheries • Tourism and recreational users
Scientific Organizations	• Oceanographic institutions • Tidal modeling • Research institutes and universities
Private sector suppliers	• Geospatial analytics • Transportation research and analysis • Maritime shipping and transportation
Government sector suppliers	• National hydrographic offices • National oceanographic institutes • National Oceanographic Data Center (NODC)
Professional Bodies	• Fishing organizations and cooperatives
Consumers and Citizens	• Map users • Postal services and routing • Leisure and tourism

Other classifications of stakeholders exist. For example, the **Figure 10** describes stakeholder classifications according to the OGC.

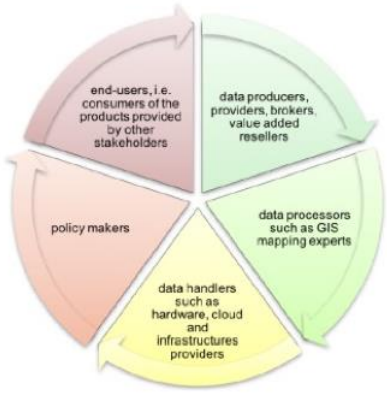


Figure 10. Classes of Stakeholders

The OGC Marine Spatial Data Infrastructure Concept Development Study also identified a comprehensive list of stakeholders who may wish to make use of marine geospatial information.

Table 3. List of stakeholders identified by OGC's MSDI Concept Development Study

MSDI Stakeholders	Policy Makers	Data Producers	Data Processors	Data Handlers	End Users
Academic and educational institutions		✓	✓	✓	✓
Archaeology, marine, hydrography, ecology science					✓
Authorities: Port Authority, Marine Transportation	✓	✓		✓	✓
Commercial data / analytic providers		✓	✓		
Diplomatic and national security officials	✓				✓
Enviromental Protection Agencies	✓				
Federal, state, provincial government agencies	✓	✓	✓	✓	✓
Fishing companies					✓
GIS and Information Technology		✓			
Insurance companies	✓	✓	✓		✓
Internet and Social Media Providers		✓		✓	
International Intergovernmental Organizations	✓				
Local Government Agencies	✓			✓	
Mapping and GIS experts			✓		
Marine and Oceanographic boards and groups	✓	✓	✓	✓	✓
Military Organizations	✓	✓	✓	✓	✓
Mining companies					✓
NGO Service Providers					✓
Port managers and harbormasters					✓
Public Authorities	✓				
Public Works	✓				✓
Researchers for climate conservation					✓
Search and rescue officials					✓
Shipping and cruise ship companies					✓
Software developers			✓		
Standards Developing Organizations	✓				
The General Public		✓			✓
Transportation			✓		✓
Untility companies/organizations: Oil and Gas, Power		✓			✓

Once the stakeholders are identified, the UN-IGIF presents a rigorous pathway for defining communication plans, reviewing, and benchmarking of communication effectiveness. This includes a Geospatial Brand definition and methods for engagement.

9.2 Measuring Communication and Engagement

The hydro domain has some significant challenges in communication and engagement, mainly due to the specialized and broad nature of its subject matter. As described in other strategic pathways, the difficulties of communicating plans, priorities, and strategies to non-specialists can require many resources from organizations that are often already constrained. It is undeniable that communication and engagement for smaller states may be a more ad hoc process, but communication should still be seen as a priority, and communication strategies should be put in place according to the UN-IGIF Implementation Guide.

Measuring the effectiveness of communication and engagement is also extremely challenging, even for well-developed, larger states with dedicated communications organizations. The key differentiators in the hydro domain are the greater emphasis on international communication and the ability to communicate the benefit of marine geospatial information across a wide variety of value propositions.

Any definition of a national geospatial brand should have the hydro domain at its heart, so a measurement of communication effectiveness would be a recognition of such differentiators by stakeholders and evidence of “heightened awareness” of the hydro domain in accordance with UN-IGIF strategic pathways.

Summary

The Operational Framework for Integrated Marine Geospatial Information Management (UN-IGIF-Hydro) serves as a supplement to the Implementation Guide of the United Nations Integrated Geospatial Information Framework (UN-IGIF) for the hydro domain or the marine environment and presents an expanded set of value propositions to justify the "why" marine geospatial information programmes are integral parts of digital information ecosystems and investment in them is foundational for sustainable national development and nationally integrated geospatial information management. The UN-IGIF provides, including for the hydro domain, the overarching paradigm, the basis and guide for developing, integrating, strengthening and maximizing geospatial information management and related resources in all countries, assisting countries in bridging the geospatial digital divide, securing socio-economic prosperity, and leaving no one behind.

Approximately seventy percent of the Earth's surface is water-covered - lakes, rivers and tributaries, deltas, seas, and oceans. Water is critical to socio-economic development, energy and food production, healthy ecosystems, and to overall human survival. Water is at the heart of successful adaptation to climate change and serves as a crucial link between society, the global economy, and the environment. More than four billion people depend on marine waters for fish as a primary source of protein[8], and an estimated 90% of the world's trade is conducted upon the seas and oceans[9].

To sustainably manage that significant portion of the Earth's surface that is covered by water - lakes, rivers and tributaries, deltas, seas, and oceans and all that it has to offer, governments will need to ensure that marine geospatial information management is fully integrated within the wider digital information ecosystem for evidence-based policy development and decision making. This is a strategically crucial step for hydro or marine programmes to make as they work to increase their value and recognition within national infrastructures. National geospatial programmes that support development priorities, including the ability to track progress on the Sustainable Development Goals (SDGs), must ensure that marine geospatial capabilities are integrated. It is equally important for national hydrographic or marine programmes to understand, and be partners in, national integrated geospatial information management programmes. Such an integrated, and well managed marine geospatial information programme nationally will be a necessity to meet the challenges of governance, planning, managing and coordinating resources, transportation, coastal resilience, recreation, and other aspects of the blue economy.

The most beneficial implementations of the UN-IGIF at the country level include adequate representation and integration of the hydro domain within larger national and global geospatial ecosystems. This is primarily because successful integration of the hydro domain increases the value of the overall geospatial ecosystem. Domain integration and interoperability promote data reuse, improve resource planning and management, and provide a means of measuring progress towards national and international priorities (e.g., SDGs).

[8] Food and Agricultural Organization 2014

[9] International Maritime Organization, 2015

Fully integrating the hydro domain into a national or global geospatial ecosystem presents many challenges. The successful integration of domains and data requires use of consistent or compatible standards and models, equal representation in national geospatial committees, shared guiding principles, integrated data sharing agreements, and adherence to policy and legal requirements. Additionally, countries will have to balance domestic, regional, and international responsibilities, obligations and priorities. Perhaps most difficult, countries must develop a business model which can sustain their geospatial programme, including a potentially high-cost hydro component.

The hydro domain's unique characteristics - in addition to presenting challenges - have prompted the hydro community to lay a lot of great groundwork for solutions to domain integration and data interoperability. The hydro domain takes advantage of many well-established standards (e.g., ISO and IHO standards). Many hydrographic institutions have developed successful business models to at least partially recoup costs associated with data acquisition, processing, and management. The hydro domain is also full of institutional, national, and regional partnerships which provide templates for interoperability, data-sharing, and capacity development.

As with implementing the UN-IGIF, there is not a "correct"' or "one size fits all" approach to integrating the hydro domain into larger geospatial ecosystems. The UN-IGIF-Hydro Part Two presents complexities alongside real-world examples to aid countries in their efforts to fully leverage the hydro domain and to integrate it into their geospatial frameworks. The Working Group on Marine Geospatial Information anticipates that this document and future work on value propositions will be "living" in nature, and the Group intends to update this operational framework with lessons learned and updated guidance and examples as the geospatial community implements the UN-IGIF.

UN-IGIF-Hydro Part One – The Strategic Overview provides a high-level strategic overview of the Operational Framework in order to present the case for investing in (and improving) marine geospatial information management programmes around the world. It serves as an introduction to assist in explaining the importance of integrated marine geospatial information management to senior level policy and decision-makers, managers, and those new to the concept of integrated marine geospatial information management.

UN-IGIF-Hydro Part Two – The Strategic Pathways further provides a number of unique value propositions and more elaborated guidance. It also presents the "how" for the implementation of the UN-IGIF for the hydro domain leveraging the nine strategic pathways of the UN-IGIF with guidance and examples of good practices, for including the hydro domain when implementing the UN-IGIF at the country-level.

The UN-IGIF-Hydro, developed and presented as a two-part document to leverage the guidance offered in the UN-IGIF, provides practical guidance for countries to extend the nine strategic pathways in the hydro domain, ultimately working towards the vision of the integration of the marine geospatial information management into the global geospatial information ecosystem and to enhance the ability to make informed decisions to support the preservation and management of the Earth, including inland waterways and waterbodies, seas and ocean's resources

Appendix I - Value Propositions

The following presentation slide includes a list of value propositions discussed by the Working Group on Marine Geospatial Information.