WP1 - Policy, Stakeholder and Service Analysis

D1.5 Innovation needs and opportunities

Project Identification	
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History of Changes

Date	Version	Comments
2-12-2021	V0	Draft outline of the deliverable report (Linda van Duivenbode, dotSPACE)
28-2-2022	V1	Draft submitted for revision (Andrei Bocin-Dumitriu & Miraslava Kazlouskaya, dotSPACE, Nina Costa, NDConsult)
9-3-2022	V2	Final version revised after review

List of Acronyms

AI	Artificial Intelligence
AGRI	Directorate-General Agriculture and Rural Development
BASS	Business Applications and Space Solutions
BDA	Big Data Analytics
C3S	Copernicus Climate Change Service
CAP	Common Agricultural Policy
CEMS	Copernicus Emergency Management Service
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
CO	Citizen Observatory
CwRS	Control with Remote Sensing
DaaS	Data as a Service
DEFIS	Directorate-General Defence Industry and Space

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List of Acronyms

DIS-SMEs	Demand-driven Innovation Support for SMEs
DL	Deep Learning
EARSC	European Association of Remote Sensing Companies
EDC	Euro Data Cube
EEA	European Environment Agency
EIB	European Investment Bank
EIP	European Innovation Partnership
EMSA	European Maritime Safety Agency
ENVI	Directorate-General Environment
EO	Earth Observation
ESA	European Space Agency
eShape	EuroGEO Showcases: Applications Powered by Europe
EU	European Union
EUSPA	EU Agency for the Space Programme
FP7	EU Seventh Framework Programme
GMES	Global Monitoring for Environment and Security
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GSTP	General Support Technology Programme
H2020	Horizon 2020
HSI	Hyperspectral
IaaS	Infrastructure as a Service
JRC	Joint Research Centre

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List of Acronyms

KPI	Key Performance Indicator
LULUCF	Land use, land-use change, and forestry
MARE	Directorate-General Maritime Affairs and Fisheries
ML	Machine Learning
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
NSO	Netherlands Space Office
NWO	Dutch Research Council
OCRE	Open Clouds for Research Environments project
OECD	Organisation for Economic Co-operation and Development
OTSC	On-the-spot Checks
OS	Operating System
PaaS	Platform as a Service
PB	Petabytes
PCP	Pre-Commercial Procurement
PR	Public Relations
PwC	PricewaterhouseCooper
RACE	Rapid Action on Coronavirus and EO
RS	Remote Sensing
RTD	Directorate-General Research and Innovation
SaaS	Software as a Service
SAR	Synthetic Aperture Radar
SDG	Sustainable Development Goal
SIRA	Strategic Innovation Strategic Innovation and Research Agenda

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List of Acronyms

SME	Small and Medium Enterprise
TDE	Technology Development Element Programme
TEP	ESA's Thematic Exploitation Platform
TEU	Treaty on the European Union
TFEU	Treaty on the Functioning of the European Union
UN	United Nations
UNEP	UN Environmental Programme
VAS	Value Added Service
VHR	Very High Resolution
Water-ForCE	Water scenarios for Copernicus Exploitation
WFD	Water Framework Directive
WoLLs	Water-Oriented Living Labs
WP	Work Package

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1. Introduction

1.1 Project & work package introduction

The **Horizon 2020** project **Water-ForCE** (Water scenarios for Copernicus Exploitation) is developing a Roadmap to better integrate the entire water cycle within the **Copernicus services**, thereby addressing needs and requirements from the user community, the current disconnects between remote sensing / in-situ observations and upgrade of the modelling algorithms. The clarity in terms of the needs and expectations of both public and private sectors from the core Copernicus Program and the wider research and business innovation opportunities will be delivered. The Roadmap will then also advise on a strategy to ensure effective uptake of water-related services by end-users and further support the implementation of relevant directives and policies.

The Water-ForCE consortium is led by the University of Tartu (Estonia) and consists of 20 organisations from all over Europe. It will bring together experts on water quality and quantity, in policy, research, engineering, and service sectors. Through close collaborations with these communities, Water-ForCE will among others:

- **Analyse EU and international policies** to identify where the Copernicus services can improve monitoring programs and how the Copernicus data can be more effectively used in developing and delivering the next versions of EU legislations.
- **Specify the technical requirements** for future Copernicus missions in order to make them more suitable for inland and coastal water remote sensing (e.g. adding new spectral bands on Sentinel-2E and onward, improved spatial resolution, hyperspectral sensors).
- **Optimise future exploitation** of Copernicus Services for inland water monitoring, management, legislation implementation, service provision and research & development through enlarged service portfolio and optimised delivery of water related products and services.

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The project is divided into eight work packages (WP), each of them focusing on a specific problem and/or target of the Copernicus service (see Figure 1). The project started 1 January 2021 with a duration of three years.

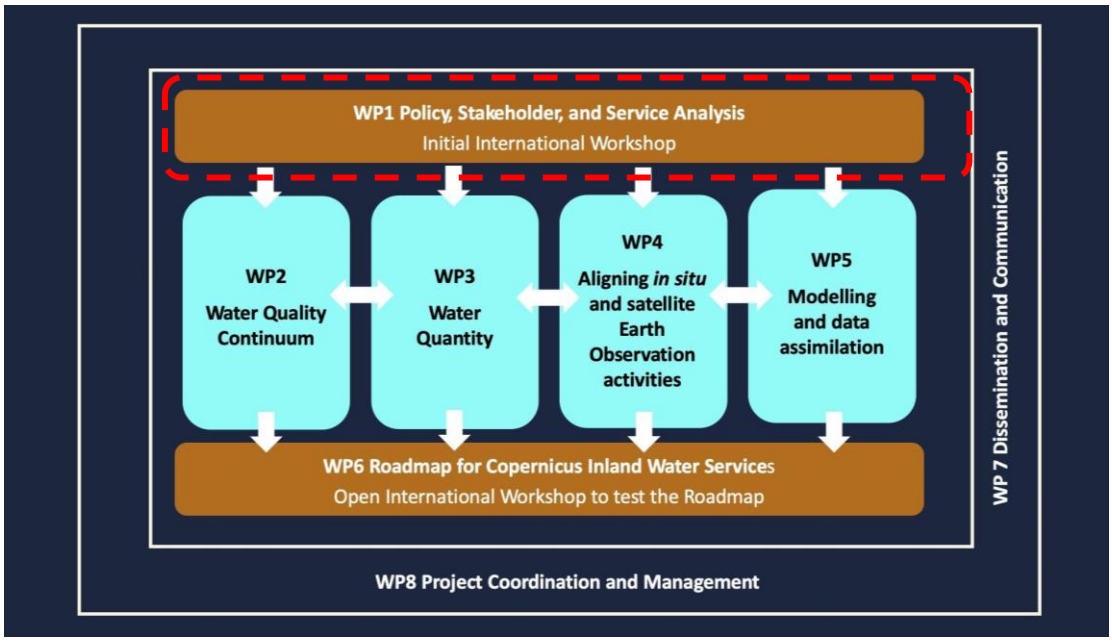

Figure 1 : Organisational structure of the different work packages in the Water-ForCE project.

This report delivers the result of Task 1.5 (T1.5): Innovation needs and opportunities (Deliverable 1.5 - **D1.5**).

1.2 WP1 overall aim and expected impact

The overall aim of WP1 is to identify key users within the different public domains and business sectors and evaluate whether operational services can meet policy goals. The expected impact is increased coverage of EU policies clearly identifying which and how the project would like to address them.

WP1 has six tasks and two milestones, as shown in the table below. The tasks and milestones are closely linked and together provide input to WPs 2-6.

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Table 1: overview of WP1 tasks and deliverables

Task	Deliverable
T1.1 Value chain and stakeholder identification	D1.1 List of stakeholders (M7)
T1.2 Public domain and business sector identification	D1.2 Report with assessment of domain-specific and sectoral policies and legislation (M10)
T1.3 Links between mission-service-application	D1.3 Report with analysis of links within Copernicus programme and between Copernicus programme and domain / sector policies (M14)
T1.4 End-user needs and requirements identification	D1.4 Report with end-user needs and requirements (M14)
T1.5 Innovation need and opportunities	**D1.5 Report with analysis of business opportunities, validated by industry (M14)**
T1.6 Contribution towards societal challenges, missions and SDGs	D1.6 Report on links and gaps between satellite EO and water related SDGs and climate indicators (M14)
MS1	WP1 Participants workshop (M4)
MS2	Input to the Roadmap (WP6)

This report is the deliverable for Task 1.5.

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1.2 Objectives T1.5

The objective of this task is the identification and development of innovation needs and business opportunities and assess if and how industry and SME policy and instruments support innovation. Advances take place in technology outside the space sector, such as 3D printing, miniaturisation, Internet of Things, virtual and augmented reality data visualisation, computer processing and storage of power, and in the space sector, such as sensors attached to aeroplanes (SkyFlox), high altitude platforms and large smallsat constellations (companies Planet and Satellogic provide daily global imagery, Hiber provides global low power IoT solutions). In addition to technology, a number of projects have pioneered the role of citizen science and Earth Observation. These developments offer much scope for innovation in remote sensing - adding sources and layers of data to the currently available data products and services. At the same time, there is discussion about the role of the public sector (how far down the chain should publicly funded Copernicus services go) and the private sector (when does the private sector step in to develop novel products and services). In this task we will, in consultation with industry, identify what the needs and opportunities are across the whole Earth Observation (EO) value chain (upstream - applications).

1.3 Method

Deliverable 1.2 provides the basis for the description of business sectors and the analysis of opportunities, based on innovation needs. Through desk research, we carried out a quick literature review to determine key search words with which to identify which of the markets and business domains are of most relevance to Copernicus. The starting point is the European Association of Remote Sensing Companies' (EARSC) taxonomy of markets and business domains (as the starting point)., selecting those of greatest relevance to the (inland) water domain.

In this document we take the work from D1.2 a step further to a more in-depth analysis, starting with an overview of the Inland water as an industry sector (section 2) before

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zooming in on the EO Water applications and industry state of play (section 3). From this, we provide an overview of innovation needs and opportunities (section 4). In section 5 we provide conclusions and recommendations.

2. Inland water as an industry sector

2.1. Setting the Scene

In Europe alone, the blue economy, which includes water and marine resources, already provides 5 million jobs and contributes around €550 billion to the EU economy (EEA 2018). This forms part of the global water-related economy valued at €62.9 trillion (Water Europe 2017).

According to an EEA article - Water use in Europe – quantity and quality face big challenges (EEA 2018[1]):

> 'Europeans use billions of cubic metres of water every year not only for drinking water, but also for use in farming, manufacturing, heating and cooling, tourism and other service sectors. With thousands of freshwater lakes, rivers and underground water sources available, the supply of water in Europe may seem limitless. But population growth, urbanisation, pollution and the effects of climate change, such as persistent droughts, are putting a huge strain on Europe's water supplies and on its quality.'

Besides droughts, climate change is also leading to more and more extreme weather events including heavier precipitation, resulting in more frequent and intense flood events.

[1] https://www.eea.europa.eu/signals/signals-2018-content-list/articles/water-use-in-europe-2014

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This article lists the sources of freshwater water (for drinking and other uses) as 88.2 % from rivers and groundwater, while the rest comes from reservoirs (10.3 %) and lakes (1.5 %). Regarding the use of water, agriculture accounts for the largest use of water: around 40 % of the total water used per year in Europe. This is expected to continue increasing as more and more farmland needs to be irrigated, especially in southern European countries. Energy production also uses 28% annually (for cooling in nuclear and fossil fuel-based power plants and to produce hydro-electricity), while mining and manufacturing accounts for 18 %, followed by household use, which only accounts for around 12 %. It is forecast that water use worldwide will increase by 55% by 2050 (Water Europe, 2017).

In 2016, Water Europe - a European Technology Platform for Water - drew up a Vision document (Water Europe, 2017) for the future of the water sector, and to tackle the pressing issues faced by Europe. This document suggests a paradigm shift in the industry towards a water-smart society that reflects the true economic value of water. This is enabled by new ***'digital water technologies'***, and 'multi-stakeholder governance' among four key components. Novel technologies and strategies will be needed to optimise the management of our water resources. Currently Europe is lacking in detailed water management information , and there is a pressing need to increase the level of monitoring of the quality and quantity of water availability and use. GIS-based knowledge management systems with active measuring and monitoring technologies, will support better decision making, especially at regional and supra-regional levels. In order to achieve a Water-Smart Society and promote systematic innovation, Water Europe identified in 24 European countries 105 Water-Oriented Living Labs (WoLLs[2]).

[2] "real-life, water oriented and demo-type and platform-type environments with a cross-sector nexus approach, which have the involvement and commitment of multi-stakeholders (including water authorities) and a certain continuity, and provide a "field lab" to develop, test, and validate a combination of solutions as defined in the Strategic Innovation Strategic Innovation and Research Agenda (SIRA), which include technologies, their integration as well as combination with new business models and innovative policies based on the value of water."

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It is in these areas of digital technologies and GIS-based management information that EO could support the water sector, together with in-situ technologies like smart sensors, drones, etc. The wide coverage of EO facilitates environmental monitoring and cross-border management of rivers, lakes, reservoirs, etc. EO also enables cross-sector monitoring such as water and energy, water and agriculture, or water and hazards. For example, EO is extensively used for land-side information for the agriculture sector, and this could be leveraged to monitor water usage by farmers (e.g. levels of irrigation and illegal abstractions).

Water Europe (2017) specifies five main user groups of water - Industry, Agriculture, Homes, Service and recreation (including tourism), and Nature. While water infrastructure includes the following categories:

- clean water supply
- water storage
- recreation and tourism
- energy
- biodiversity protection
- treatment & purification
- food provision (agriculture)
- groundwater recharge
- flood control & disaster risk reduction

These infrastructure categories mostly reflect the water applications analysed (from an EO perspective) in D1.4 - Report with end-user needs and requirements, viz. Drinking Water management, Aquaculture/fisheries, Agriculture, Urban Water management, River basin management, Hazards/Emergencies, Coastal Zone management, Biodiversity, Energy. One striking difference is the exclusion of marine related sectors, such as Aquaculture/fisheries

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and Coastal zone management. Although having said this, Water Europe recognises the important sources of brackish water and salty water to supplement the fresh water supply.

2.2 EU and International Policy Drivers

Business innovation opportunities in the inland water sector are highly influenced by policy and legislative actions within the EU and intergovernmental organisations, which follows from the analysis in Water-ForCE deliverable D.1.3. Thus, opportunities arise from the EU Space Programme Regulation itself, EU sectoral policies, international treaties, resolutions, and other guiding instruments.

Under the Space Programme Regulation (EU) 2021/696, acceptable activities for Copernicus and its services, according to Articles 50-51, must include novel use cases for water management, as well as inland water quality and quantity monitoring. As a result, making open-source platforms accessible and understandable to end-users is crucial for ensuring successful policy implementation through better decision-making. The investigated sectoral regulations (in D1.3) do not hinder the development of Copernicus applications: although in most cases not directly, they facilitate its uptake. The Water Framework Directive (WFD), as the key policy driver for inland water monitoring, does not explicitly mention space methods of monitoring, but calls for more effective methods for water quality and quantity monitoring. As also found by the comparative analysis of WFD methods in Water-ForCE deliverable D.1.3, indicators derived from EO data greatly supplement routine sampling while significantly expanding geographical and temporal coverage, particularly in bigger bodies of water. Other core documents in this domain include the Environmental Quality Standards Directive, the Groundwater Directive, and the Floods Directive. Further thematic directives include the Urban Waste Water Treatment, Nitrates Directive, and Industrial Emissions Directive. None of them refer to EO methods however together with the traditional monitoring techniques, based on their subject, these directives allow for alternative techniques, which opens the potential for innovative actions within Copernicus services.

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Among policies, a major step is made under the EU Missions Initiative, which is a new feature of the Horizon Europe research and innovation programme for the years 2021-2027. Inland water management falls at the Mission Area "Healthy Oceans, Seas, and Coastal and Inland Waters". It asserts that Europe will demonstrate worldwide leadership in managing transboundary inland waters by 2030 in order to protect climate-resilient water ecosystems. Inland water management is critical to ecosystem resilience to climate change, hence comprehensive monitoring of their status is critical. Simultaneously, forests and wetlands have a direct impact on inland waterways, allowing ecosystems to deal with fast change, absorb excess rainfall or drought, preserve biodiversity, and absorb carbon. As a result, it is necessary to monitor not just the bodies of water themselves, but also the ecosystems that impact them, such as forests. Thus, satellite imagery and other Earth observation tools are cited in the Water Mission Paper as a driver of research and innovation in this field, as they provide new insights into the water supply in parts of the world where traditional land-based methods of measuring water supply are not possible or practical.

Besides the water sector, inland water management is inextricably tied to agricultural and environmental policies, which also drive Copernicus uptake. On December 2, 2021, the new Common Agricultural Policy (CAP) was formally adopted. One of its instruments, EU Regulation 2021/2116 3 on the financing, management, and monitoring of the CAP, encourages the use of Copernicus data or information products to ensure that comprehensive and comparable data is available for monitoring agri-environment-climate policy. Furthermore, open formulations of other regulations in this sector provide a prospect for Copernicus. Opportunities for Copernicus in the environmental sector stem from the objectives of the European Green Deal (COM/2019/640), as well as a broad description of preferred strategies for attaining them. Other instruments, which include requirements for forests, ecosystems, and climate monitoring, which is associated with inland water management, do not offer any impediments to Copernicus.

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Water is also a significant matter for international action, with a number of intergovernmental treaties and recommendations in place. Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) of 1992, Convention on wetlands of international importance especially as waterfowl habitat (Ramsar Convention) of 1971, Convention on Biological Diversity of 1992 are key international treaties obliging to implement monitoring measures in the domains which concern inland waters. Even without reference to EO data in those documents, Copernicus could contribute to the further implementation of these treaties' requirements. Besides treaties, there are a number of instruments providing non-binding recommendations. Though there are no legal obligations in such documents, they are still of high political value. Such instruments in the inland water management domain are the Sendai Framework for Disaster Risk Reduction 2015-2030, UN Environmental Programme (UNEP) Resolution 3/10 'Addressing water pollution to protect and restore water-related ecosystems' of 2018, the 2030 Agenda for Sustainable Development, Guidelines for safe recreational water environments 2003, the Intergovernmental Hydrological Programme (IHP-IX), World Bank Strategic Plans. As found in D.1.3, many of them directly refer to the use of space technologies and/or precisely EO data.

2.3 SDG Drivers

Copernicus Services hold an important role in helping to achieve the UN's SDGs (described in detail in D1.6). In 2018, Copernicus outlined how their existing services are contributing to SDGs. In particular, the existing Copernicus Land Monitoring Service (CLMS) can address SDG 6 (Clean Water and Sanitation). The existing CLMS provides "near- real time information on global inland water bodies and their seasonal replenishment, lake and river water levels, temperature, turbidity and trophic state, including potential water availability from snow and ice cover" (Copernicus, 2018). Work done by IHE Delft Institute for Water Education indicates that for the management of water use and its scarcity, EO contributes to the monitoring of various components of the water balance. The list includes monitoring

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measures related to precipitation, evapotranspiration, storage change (Grace), soil moisture. Moreover, IHE demonstrated that current increasing temporal and spatial resolution data availability together with continuous data sets for various water resources and improved data reliability, also greatly contribute to the development of opportunities for water quantity monitoring. In addition, with more and more data sets becoming open access, all necessary measurements can be accessed near real time and the information can be used retrospectively.[3]

Further, in addition to Copernicus' assessment, the analysis in Water-ForCE D1.6 identified the possible links between EO parameters specific for the inland water quality and quantity and 12 of the UN Sustainable Development Goals. This highlights the relevance of EO capabilities towards achieving the SDG targets by 2030, and demonstrates the need for broad spatial scale and fine temporal resolution global monitoring of inland waters to achieve the SDGs. Furthermore, a future dedicated inland water service can address more SDGs (See Section 3 and Table 1 therein from D1.6) and provide new indicators for achieving the SDGs.

2.4 Technology Drivers

Artificial Intelligence (AI), Cybersecurity, Internet of Things, Big Data, High Performance Computing, 5G, and Software are the main digital specialisations for Europe's digital transformation by 2030 (Europe's Digital Decade, 2021). In addition, the Digital Europe Programme (DIGITAL) has a global dimension, where the EU's work on digital policies focuses on various geographical areas. In this context, the conversion of data collected from space into knowledge will help decision-makers in their work while the AI-based big-data

[3] Marloes Mul, Water Accounting plus using remote sensing for monitoring SDG 6 https://files.lobelia.earth/web-waterforce/webinar-wa4sdgs-waterforce.pdf; *see also* IHE Delft Water Accounting Project https://www.un-ihe.org/water-accounting-project-website (https://www.wateraccounting.org/).

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analysis bears the promises to revolutionise the use of satellite data by allowing to ingest and process huge amounts of information at once.

The synergies between Europe's Digital transformation and the EU Space Programmes lead to Destination Earth (DestinE), which aims by 2030 to develop a high precision digital model of the Earth to monitor and simulate natural and human activity. DestinE will therefore contribute to achieving the objectives of the twin transition, green and digital as well as reinforce Europe's industrial and technological capabilities in simulation, modelling, predictive data analytics, AI and High-Performance Computing (HPC).

AI4Copernicus (one of the AI4EU projects) aims to bridge AI with the EO community and sector by making the developed AI4EU AI-on-demand platform the digital environment of choice for users of Copernicus data, for researchers and innovators. This is being done by organising four Open Calls, two launched in late 2021 and two opening in March 2022. The objectives of these calls are to:

i. expand and deepen the integration of AI4EU with DIAS platforms to enrich the AI4EU service offering and enable far-reaching innovation;

ii. kickstart the innovation cycle by incentivising diverse AI4EU and Copernicus communities to solve real problems of business and societal value;

iii. drive the evolution, uptake, and impact of all involved platforms: AI4EU and the DIAS platforms, especially WEkEO, CREODIAS and MUNDI.

Water is not mentioned as a standalone vertical sector but it can be addressed within other verticals such as Agriculture or Marine. Within one of the calls Illegal Fishing is considered one of the societal challenges and projects focusing on this topic are expected.

The Euroconsult report (2021) identifies AI, machine learning (ML) or cloud-computing as trending technologies and enablers for EO applications and services. AI to EO computer vision applications is one of the biggest contributors, with learning algorithms able to

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reduce the error rate of detection or identification. An important aspect of ML is the availability of sufficient training datasets which increases the quality of the algorithms and results overall. For instance, for water quality assessment, the ML needs sufficient in-situ data which is often not available. Projects like MONOCLE or Hypernets are trying to fill the gap of open ground truth/training datasets. Other AI applications to EO include data processing, change detection, object recognition, identification, prediction and so on. Deep learning (DL), a subset of ML, uses multilayered neural networks and extracts features and patterns from raw data. In the context of EO, DL is mainly used for computer vision applications, such as object recognition (e.g., roads, cars, oil storage tanks, ships, planes, fields). However, full automation with 100% accuracy is not possible in some sectors such as emergency and early warning, and then, automated procedures with human control (hybrid-AI) are used for this type of applications. Another important area of application is to build predictive tools which involve statistical models collecting third-party data, such as geostatistical information on the environment. Though, these are still in the early stage of development.

For the past years, computing has migrated towards online or web platforms which allow access or share configurable resources via the Internet, i.e., cloud-computing. It enables EO service providers to offer lower-cost services based on the web, bypassing in this way for their customers mounting infrastructure (hardware and software) costs or maintenance and paying only for the services which are provided with. On the service provider side, cloud services have evolved towards several business models:

- Infrastructure as a Service (IaaS) where users outsource data storage, network and OS management by buying resources rather than server, data centre, or computers (e.g. EC2 - Amazon Web Services, Google Compute Engine). The targeted customers are satellite and ground segment operators.
- Platform as a Service (PaaS) which provides access to large volumes of historical data and sometimes API (Application Programming Interface) in an environment where developers can create new applications (e.g., GBDX - Maxar, One Atlas

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Sandbox - Airbus, Google Earth Engine, Sentinel Playground & EuroDataCube - Sinergise). The targeted customers are in general developers.

- Data as a Service (DaaS) which allows easy access through a web based interface or a GIS plugin to proprietary up-to-date and third-party data with analytics tools (e.g. Copernicus DIAS, SecureWatch - Maxar, WEkEO, EuroDataCube). The targeted customers are analysts and end-users.
- Software as a Service (SaaS) when users can access software applications through a web based interface or deployed behind a proprietary firewall to access information (many of the EO service providers listed by EARSC). The targeted analysts are in general end-users.

These new business models closely reflect the part of the EO for Water value chain presented in the next chapter.

2.5 The role of CS

Citizen science (CS) has been used in a wide range of areas around the world since the 20th century, and on the SciStarter website (scistarter.com) there are more than 3,000 searchable global citizen science projects. The Citizen Observatory (CO) term is related to the Citizen Science concept, and represents community-based environmental monitoring and information systems that invite individuals to share observations, typically via mobile phone or the web. Some include the use of Earth observation technology in CO where citizens not only collect data but are also empowered by the information generated from these data to participate in environmental management[4].

According to a study carried out by Palacin-Silva et al.(2016) for the Finnish Environment Institute, USA, UK and Canada are the leaders in citizen observatories and environmental citizen observatories in the world. Within Europe, over 16 countries are actively involved in

[4] https://www.weobserve.eu/about/citizen-observatories/

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running some type of environmental citizen observatory. The UK is by far the most active country in this field with 38% of the total citizen observatories in the continent, followed by Ireland with 13% of observatories, and Spain, Switzerland and Denmark with 5% each. This study identified 108 citizen observatories worldwide. According to their focus, they were classified into eight major domains and applications:

1. **City Management**: Grouped observatories that support decision makers managing city issues such as: transportation, bicycle routes, land usage, energy consumption, surroundings classification, environmental conditions, traffic and parking monitoring, citizen needs and perceptions.
2. **Species monitoring**: Involving single species monitoring projects: insects, bats, birds, butterflies, sea species and game animals.
3. **Water, streams, snow, sea**: Observatories that are collecting data about water quality, precipitation, streams, lakes, snow, ice and sea environments.
4. **Biodiversity monitoring**: Observatories that focus on monitoring biodiversity, flora, forests, mountains, biosphere and trees.
5. **Air and spectrum monitoring**: Observatories that gather data about air quality, noise, sounds and radiation.
6. **Tools for citizen observatories**: Involving tools that are useful for creation or integration of citizen observatories, such as: configurable citizen observatories (plug and play tools), image classification components and sensors monitoring components.
7. **Global monitoring**: Astronomy and climate change observatories that monitor global trends.
8. **Disasters monitoring**: Observatories that are looking at earthquake monitoring and early detection.

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Kullenberg et al. (2016) indicated that the largest impact of citizen science has been in research on biology, conservation and ecology, and is utilised mainly as a methodology of collecting and classifying data. Many CS projects relate to astronomy and natural resources (e.g. species and biodiversity monitoring), but there are also examples of CS related to the water:

- CS is used to characterise ocean dynamics and tracking marine debris. For example, the mobile app Marine Debris Tracker is a joint partnership of National Oceanic and Atmospheric Administration (NOAA) and the University of Georgia. Long term sampling efforts such as the continuous plankton recorder have been fitted on ships of opportunity since 1931. Plankton collection by sailors and subsequent genetic analysis was pioneered in 2013 by Indigo V Expeditions as a way to better understand marine microbial structure and function (Lauro et al., 2014).
- CS has recently developed in Coral reef studies. For example, the *Monitoring through many eyes* project collates thousands of underwater images of the Great Barrier Reef and provides an interface for elicitation of reef health indicators (Queensland Gov). Additionally, the National Oceanic and Atmospheric Administration offers opportunities for volunteer participation. By taking measurements in The United States' National Marine Sanctuaries, citizens are able to contribute data to a variety of marine biology projects. By enabling these citizens, NOAA benefited from 137.000 hours of research during 2016. (NOAA).
- FreshWaterWatch is a global CS project from Earthwatch Europe – an international non-profit environmental organisation that addresses global change through a time-tested model of citizen science and community engagement (earthwatch.org). The aim of FreshWaterWatch (freshwaterwatch.thewaterhub.org) is to ensure that citizens across the globe can monitor the health of the lakes, rivers, streams, wetlands and reservoirs. They issue measurement kits for the monitoring of water

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quality, including nitrate and phosphate levels, turbidity, and visual factors by volunteers and the results are reported on the world-wide data repository (freshwaterwatch.thewaterhub.org/our-data/explore-our-data).

- A novel collection aggregated through citizen science campaigns which includes
    - Eye On Water
    - Seen-monitoring in Europe
    - The Secchi-Dip In in North America
    - State level efforts for citizen science focusing on freshwater in Minnesota, Wisconsin, Michigan, and Maine

  Together these campaigns have collected hundreds of thousands of observations available to researchers. The new AquaSat database from Ross et al. (2019) uses Google Earth Engine to extract coincident (+/- 1 day) Landsat reflectance values for in situ measurements found in the WQP and LAGOS-NE . The result is the first dataset of its kind, providing over 500,000 paired observations of reflectance values and associated water quality parameters in optically complex waters dating back to 1984. Databases such as these provide data continuity, cost and time savings for researchers, and large calibration and validation samples for model development.

The WeObserve website (www.weobserve.eu) lists four EO plus CS projects that were funded under H2020. Two of these (GROW Observatory[5] and Landsense[6]) relate to agriculture and land use & land cover respectively, while the SCENT[7] CO concerns land cover use monitoring for efficient flood management. The Ground Truth 2.0 project[8] encompassed the development of six COs for the improved management of natural resources, two of which covered water topics. 'Grip op Water' included information on local weather, current

[5] growobservatory.org

[6] landsense.eu

[7] scent-project.eu

[8] gt20.eu

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water levels and ground water levels, as well as actions and tips to avoid damage from pluvial flooding, and extreme weather alerts, for the Altena region in The Netherlands. The other was a CO and information platform (called VattenFokus) on fresh water quality/water health for the Mälarendalen region of Sweden. VattenFokus worked in close collaboration with FreshWaterWatch, and the results of their CS campaigns are included in the FreshWaterWatch data repository.

Earthwatch Europe is also a partner in the Monocle project, which is developing low-cost optical sensors, methods and technologies to support water quality monitoring by regional and national agencies. This project is investigating the complementarity of CS and in-situ monitoring, and the role citizens and communities can play in the maintenance and deployment of sensors.

These examples show that CS or COs can make a value contribution to water monitoring, as part of in-situ measurements, to complement information derived from EO.

3. EO water applications and industry state of play

In this section we present the state of play of the EO industry. Our starting point is an explanation of the EO value chain and information provided in market and trend reports available for Space and EO. These high level reports cover all EO applications, but mentions of water applications are highlighted. The focus of this chapter then moves onto the role of EO and Copernicus Services in the Water sector. We also present the outcomes of interviews carried out with industry players (in WP1), and finally a SWOT (strengths, weaknesses, opportunities and threats) analysis highlights some issues regarding EO applications for water.

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A traditional view of the EO value chain (see figure below) is needed to better understand the market and trend reports. The figure below[9] shows four simple classifications - upstream (satellites), midstream (operations and data downloads) and downstream applications (image processing and value added services). The fourth group are the end users that are clustered according to thematic domains.

In reality, the value chain is more complex and is further clarified with respect to EO and water applications in section 3.1 of this report.

According to the PwC report on Main Trends & Challenges in the Space sector (2020), the upstream space value chain is changing from the traditional technology push to a more demand driven pull from the applications markets. The EO sector is also evolving through increasing demand from different groups of customers, new satellite suppliers, and innovative delivery models for data and analytics to support situational awareness. The EO market has grown strongly over the last years due to new constellations of small private satellites, increased downward pressure on the price of data, low cost cloud storage and big-data analytics (BDA) and services. Within the EO sector, there is also a growing interest for insight-based analytics exploiting heterogeneous data sources.

[9] taken from PWC report - Main Trends & Challenges in the Space Sector (2020)

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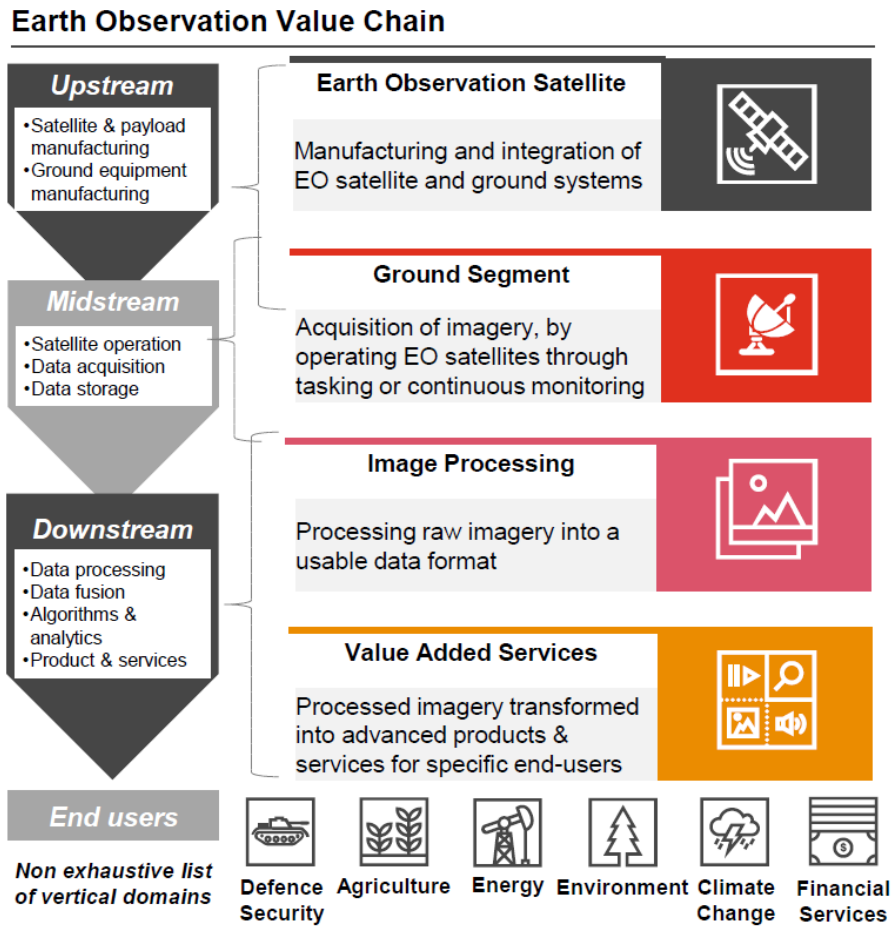

Figure 2: EO Value Chain. Source: PWC, 2020.

The Euroconsult report (2021) indicates that the EO value-added services (downstream applications) market is highly fragmented globally, but that the services business is becoming more integrated as satellite operators are looking to provide services rather than just data, and service providers use multi-source analytics. According to this report, the user segment for Water Management falls under the Natural Resources Monitoring domain and requires a ground resolution of > 5m and low revisit times. Under Disaster Management, early warning systems and post-disaster applications require a ground spatial resolution of

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less than 1 m and a digital elevation model. *Such a high-level report does not give a sufficiently detailed analysis to accurately elucidate the requirements of the water sector.*

The European Union Agency for the Space Programme (EUSPA) EO and GNSS Market Report includes analysis of over 100 EO applications split over 16 market segments. Water is mentioned under a number of these segments:

- Biodiversity, Ecosystems and Natural Capital (where water is a key natural resource).
- Environmental Monitoring (ecosystems monitoring and water pollution).
- Fisheries and Aquaculture.

Under the domain of Maritime and Inland Waterways, this report focuses on navigation through Inland Waterways, but does mention that EO can contribute with water level information. According to this report EO data has proven useful for mapping natural resources, and detecting water quality parameters such as the chlorophyll-a, which in combination with in-situ data and numeric modelling, leads to more precise results and a reduction in the costs of in-situ monitoring only. Looking at the industry revenues breakdown for ecosystems monitoring, the revenue from EO service sales for Water Ecosystem monitoring represents a very small proportion (5%) of overall revenues from those of the Terrestrial ecosystem, Coastal ecosystem, and Snow and Ice Ecosystem.

The recent EARSC Industry Survey (2021) looks at the state of the EO industry in Europe. The number of companies operating in this sector grew by 24% in 2020. Unfortunately this report did not include the number of water applications or services. The Copernicus programme continues to have a strong influence on the European EO sector as an important reference customer for data and for services as well as a source of free and open data, and almost 90% of the EO service providers expect it to have an even bigger impact in future. SMEs and start-ups account for more than 93% of European EO companies, showcasing the importance of small companies in this sector.

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These reports imply that the role of EO in the water sector is currently limited to a few specific applications, but none of these reports have specifically focussed on this sector. In contrast, Dekker and Pinnel (CEOS, 2018) undertook a feasibility study for an Aquatic Ecosystem Earth Observing System and they succinctly summed it up in the following statement:

> 'Many Earth observing sensors have been designed, built and launched with primary objectives of either terrestrial or ocean remote sensing applications. Often the data from these sensors are also used for freshwater, estuarine and coastal water quality observations, bathymetry and benthic mapping. However, such land and ocean specific sensors are not designed for these complex aquatic environments and consequently are not likely to perform as well as a dedicated sensor would.'

This study included coastal applications, but this statement is equally applicable to the inland water sector.

3. 1 EO Value Chain for the water sector

Here we present an expanded EO chain (based on the methodology followed in the EUSPA EO and GNSS Market report). This methodology includes 6 levels:

- Infrastructure providers: providers of various types of computing infrastructure upon which EO data can be accessed, stored, distributed or manipulated.
- Data providers: providers of unprocessed or pre-processed EO data.
- Platform providers: providers of online platforms and/or digital services, through which users can utilise tools and capabilities to analyse EO data, develop algorithms and build applications.
- EO products and service providers: providers of products (e.g. land cover classifications) or services (e.g. ground motion monitoring) that make full use of EO data and processing capabilities offered by data and platform providers.

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- Information providers: providers of sector-specific information that incorporates EO data along with non-EO data.
- End Users: the final users who benefit from the applications and services offered by information providers.

This has been developed specifically for the water sector in the diagram below and includes the names of public offerings and private companies operating in the sector (non-exhaustive).

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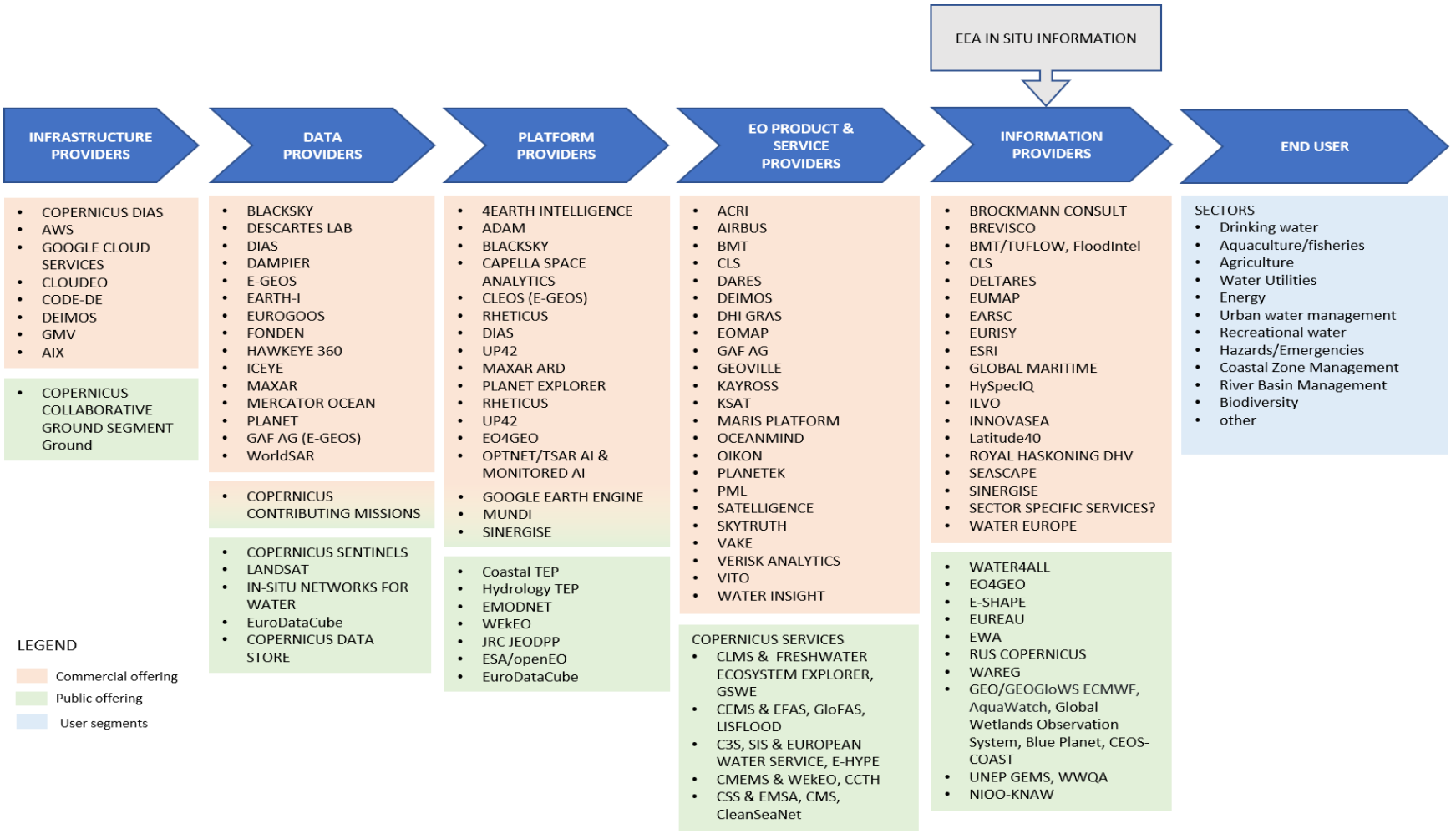

Figure 3: The EO Value Chain for the inland water sector based on EUSPA's EO market report (2022) and Water-ForCE expert interviews..

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The end user groups for water applications can be segmented in various ways as evidenced from the EO Market reports and the Water Europe report (2017). For consistency we have followed those presented in the User requirements analysis (D1.4) in Figure 3 above.

3.2 Interviews with industry

During December 2021 - January 2022, dotSPACE held seven interviews with experts from the public or commercial sectors, and from various links in the EO Value Chain and water sector. For all the interviews we used a set of core questions addressing the project target (i.e., business and innovation opportunities) to which we added questions addressing the specific needs, barriers or lessons learnt specific to each sector to which the experts belong.

The following experts were interviewed:

- Klaas Kuitenbrouwer (13-12-2021) representing the **Zoöp Project** implemented at Het Nieuwe Instituut, Rotterdam, The Netherlands.
- Dedmer van de Waal (14-12-2021) representing the **Institute of Ecology** (NIOO-KNAW) from The Netherlands.
- Daniela Iasillo (15-12-2021) representing **Planetek Italia.**
- Expert from commercial EO leading provider (**EO provider**) of high-resolution satellite imagery for governments and commercial customers (06-01-2022)**.** This EO Provider has chosen to stay anonymous.
- Fiona Heuff and Maurice Willekens (12-01-2022) representing **Royal HaskoningDHV, a global** engineering consultancy with headquarters in The Netherlands.
- Grega Milcinski (12-01-2022) representing **Sinergise**, Slovenia (Water-ForCE partner).
- Septimiu Szabo (20-01-2022) representing **Mureș Water Basin Administration**[10], Romania.

[10] Septimiu Szabo expressed his expert opinion which does not represent the formal view of the institution he works for.

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The experts' distribution and the organisations or projects which they represent covers the entire EO Value Chain as seen in Figure 4 below. Their position in the value chain will to some extent determine their responses to the questions and so this should be kept in mind when evaluating them.

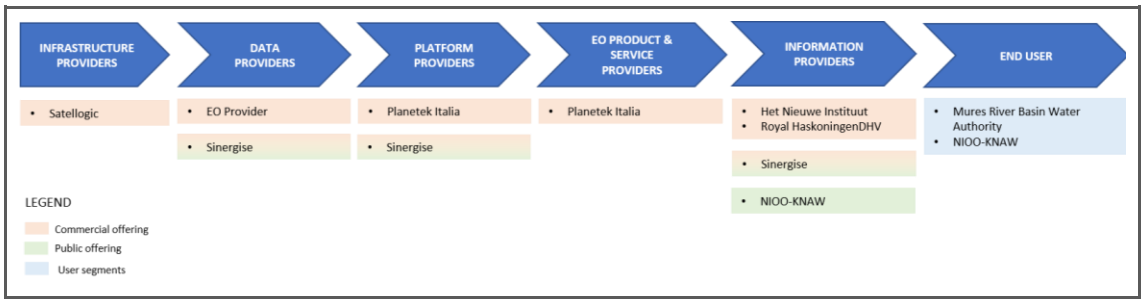

Figure 4. The position of each interviewed experts' organisation in the EO Value Chain for the inland water sector.

In the following, the answers to the questions are summarised, together with important facts derived from the specific competency or knowledge inferred from each of the interviewed experts.

Q: What are your main activities related to inland water?

All seven experts indicated that they have activities related to the inland water sector.

Company & Role	Response
EO Infrastructure provider, EO data provider	This EO Provider intends to create a Searchable Earth by 2025. This EO Provider is a vertically integrated satellite operator which provides the most affordable high resolution EO to decision-makers worldwide. Within hours from a flooding event, This EO Provider has the capability to allow its users to task (two times per day) through an online operated tasking platform, their satellite constellation in order to provide the necessary imagery and data

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Company & Role	Response
	products.
Sinergise EO data provider, Platform provider	Sinergise is the creator of the Sentinel Hub. Sentinel Hub is the most important open source web platform for satellite imagery archiving, processing and distribution service. The platform includes all existing Sentinel Mission data as well as several EO applications used world-wide (EO Browser, Sentinel Playground). Sinergise is also part of 4 Copernicus Data and Information Access Services (DIAS) out of 5. Sinergise is currently developing and operating ML based solutions for monitoring agriculture activities. Sinergise produced the "Blue Dot Water Observatory – automated monitoring of the extent of water bodies", and its flagship product, Sentinel Hub which is used by Copernicus Emergency Service.
Planetek Italia Platform provider, EO Product and Service Provider	Planetek, as EO service supplier, provides products and applications for water quality monitoring either for regulatory (WFD implementation) or commercial purposes. In their portfolio Planetek has products that measure water quality variables, for example water turbidity for aquaculture (e.g., fishponds, mussels, shrimp). They also monitor the Arctic Sea, providing a vessel and iceberg identification service.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	Their new organisational model of ecological ecosystem called Zoöp incorporates water bodies which can vary in size and morphology, from small ponds (the first proto-Zoöp located in front of the museum) to lakes and rivers or dugout canals (Abcoude Fort).

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Company & Role	Response
NIOO-KNAW Information provider, End user	NIOO department of water ecology performs fundamental research for inland water ecology. They run experiments on various scale water field enclosures from small to large and they monitor two large lakes in the Netherlands. Their work focuses on research questions related to water quality, turbidity (when and how appears), harmful algal blooms occurrences (mostly) in freshwater systems. Recently, the NIOO-KNAW institute started to work together with the Netherlands National Water Authority on a monitoring program for cyanobacteria and water quality.
Royal HaskoningDHV (RoyalDHV) Information provider	Experts mentioned that their main focus is on digital applications, and they concentrate on coastal rivers or international projects related to inland water. In their work they use either aerial or satellite observations in order to survey inland waters. An important aspect in their work is the use of Artificial Intelligence (AI) and Machine Learning (ML) algorithms (e.g. Delfland Water Authority project) in combination with EO and aerial imagery for mapping or the identification of premises. Currently, they are also working on a proposal for the World Bank related to dam identification combined with risk assessment using EO and ML.
Mures Water Administration (MuresWA) End user	The organisation is the sole operator for natural or landscaped surface water resources and groundwater resources. MWA allocates the right to use water resources with their natural potential, in accordance with the law and the specific regulations in force.

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Q: Who are your main stakeholders?

Company & Role	Response
EO Infrastructure provider, EO data provider	This EO Provider mentioned EO VAS service providers and any other end-users of high resolution EO
Sinergise EO data provider, Platform provider	• Sentinel Hub users • National paying agencies for management of agriculture policies • European agencies like EEA or ESA
Planetek Italia Platform provider, EO Product and Service Provider	• Public authorities: Lombardia Environmental Agency, Ispra Environmental Agency, Apulia Region, Adriatic Sea, Arabian Water Agency • Commercial: Aquaculture Italian Association for Mussels
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	• Proto-Zoöps such as: HNI Museum, Fort Abcoude, Bodemzicht, Zeeland Environmental Federation • The Ocean Space in Venice which among other events and exhibitions raises awareness and focuses on the quality of the Venice lagoon • Several Dutch regions water authorities such as De Dommel and Vallei en Veluwe • A decommissioned oil rig in the North Sea • An eel reservation located in Sloterplas, Amsterdam
NIOO-KNAW Information	• Water management companies • Water resources companies

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Company & Role	Response
provider, End user	• Local, regional authorities (e.g., Delfland) and the Dutch Water Authorities.
Royal HaskoningDHV (RoyalDHV) Information provider	RoyalDHV provides a lot of project based solutions but also mentioned several stakeholders • Public authorities such as Dutch regional water authorities (e.g., Delfland), local environmental agencies (i.e. permits for cooling stations) • Private businesses • Banks like the World Bank or the Asian Pacific Bank
Mures Water Administration (MuresWA) End user	• River basins water administrations • Water management systems • Romanian ministries like the Ministry of Environment, Water and Forests, Ministry for Development, Public Works and Administration, Ministry of Internal Affairs, Ministry of Foreign Affairs • NGOs • Other private entities

Q: How do you measure or monitor aquatic systems at the moment? Are you also using in-situ measurement?

Company & Role	Response
EO Infrastructure provider,	This EO Provider can provide a dedicated satellite constellation for its customers. Direct tasking is possible for assessing and monitoring areas of interest and floods events.

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Company & Role	Response
EO data provider	
Sinergise EO data provider, Platform provider	Sinergise has developed the BlueDot Water Observatory which is an EO-based solution that provides automated monitoring for surface water levels of water bodies across the globe; the application has a database with more than 40,000 water bodies, from which more than 7,000 are monitored and displayed in the Water Observatory Dashboard.
Planetek Italia Platform provider, EO Product and Service Provider	Planetek is currently using for its online platform applications, Rheticus Marine and Rheticus Aquaculture, many CMEMS products and services.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	EO (products and services) are set to become one of the required tools and methods (so-called zoönomic instruments) used by zoöps to track and read the development of their local zoönomy. ZoöpHNI also plans to set-up a prototype, within a 30 x 30 m area, where to install and test in-situ sensors (sound, vibration, water quality, spectrometers, etc.) and correlate these with aerial or EO imagery.
NIOO-KNAW Information provider, End user	Currently, the norm at the NIOO-KNAW is to use in-situ observation as the main component. They use a national standardised in-situ method which involves sample collection and laboratory analyses. Also, they run calibration and validation of the in-situ measurements.
Royal	RoyalDHV uses EO products and services (though mostly VHR

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Company & Role	Response
HaskoningDHV (RoyalDHV) Information provider	optical data) for water domain projects, developed together with other partners (e.g., WaterInsight, Deltares), AI and ML algorithms and in-situ (ground-truth) and expert (ecologists) input.
Mures Water Administration (MuresWA) End user	MuresWA's basic information necessary for the hydro meteorological information system of water management on the surface of the Mureș river basin is based only on in-situ measurements (i.e., 3 meteorological radars:, 113 hydrometric stations, 103 rainfall stations, 19 meteorological stations, and 4 rainfall stations)

Q: Are you already using Copernicus products or you are planning to?

Company & Role	Response
EO Infrastructure provider, EO data provider	Being a data provider themselves, they currently use only their proprietary data for developing new payloads and sensors. However, in the more than a decade of developing their vertically integrated space industry business they have used Copernicus Sentinel data to develop past prototypes for their technology.
Sinergise EO data provider, Platform provider	Sinergise's business model is based on Copernicus data. Sinergise either consumes or produces Copernicus data and services. As such the following activities were mentioned: • Developed a generic service for a Common Agriculture Policy market, • Developed cloud detection algorithm (i.e., s2cloudless),

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Company & Role	Response
	• Participated to several ESA-funded and H2020 projects related to Copernicus data, • Developed EuroDataCube which provide access to large number of data collections, including Copernicus Services data • Rapid Action on Coronavirus and EO (RACE) Dashboard which lists also 10 water indicators • Developed and operates EO Browser and Sentinel Playground, which provides free access to Copercnius data and applications to about 50,000 users monthly
Planetek Italia Platform provider, EO Product and Service Provider	Planetek makes extensive use of CMEMS and Mercator products and services registered under the CMEMS portal. They work with Sentinel-1,-2,and -3 data using a large subscription to CMEMS. They also use VHR optical imagery from commercial providers when the resolution of Copernicus data is too coarse.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	ZoöpHNI indicated that they have used Copernicus data (Sentinel-1./-2) in order to develop a proof-of-concept for two of their proto-zoops (NDVI, NDWI, Chlorophyll content indexes). Furthermore, they intend to use EO Copernicus satellite data in order to retrieve an objective and bird-eye view about all zoops regardless of their location. This allows them to define, compare and calibrate the KPIs that characterise the zoönomic model and further certify the set up of this new type of regenerative ecological ecosystem.
NIOO-KNAW Information provider,	At the moment they do not use Copernicus EO but there are new experiments set up which will involve this type of data. Moreover, together with Deltares and WaterInsight, NIOO-KNAW submitted

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Company & Role	Response
End user	a proposal for a grant which involves using in the future Copernicus EO for water quality.
Royal HaskoningDHV (RoyalDHV) Information provider	RoyalDHV tested Copernicus Sentinel-2 data but the resolution was too coarse for the solution that their clients needed. If in the future, better resolution and accuracy (especially MSI or HSI) data are made available, then they will start using it.
Mures Water Administration (MuresWA) End user	At the moment they do not use EO for their river basin assessment and monitoring work. However, they are starting to build knowledge and seeking for new proof-of-concepts that will help them to develop new solutions which are mentioned below in the answer regarding the business and innovation opportunities of using Copernicus services.

Q: Do you see any business or innovation opportunities for using Copernicus services in your work/research/business?

Company & Role	Response
EO Infrastructure provider, EO data provider	For this EO Provider there is the huge opportunity to become part of the Copernicus Contributing Missions data providers. Also, in their view, Copernicus is not seen as a competitor, since it creates a lot of awareness and value within the sector. Satelllogic fills one of the gaps of Copernicus Sentinel Missions, by being able to offer to possible customers higher resolution optical and hyperspectral data.

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Company & Role	Response
Sinergise EO data provider, Platform provider	Copernicus services represent the basis of their business model and besides the existing products and operations services they provide they see further opportunities related to area monitoring wrt climate change and green transition.
Planetek Italia Platform provider, EO Product and Service Provider	They see a lot of opportunities for them and other EO service providers to use CMEMS to develop new products and applications which can be offered to their ongoing or growing base of customers.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	ZoöpHNI estimates that through future research funding it will be possible to accelerate the adoption of the zoöp model and instrument which is going to be based among others on Copernicus data and services.
NIOO-KNAW Information provider, End user	NIOO-KNAW specified several business and innovation opportunities: • Monitoring cyanobacteria risk (spatial and temporal assessment), • Inland waterways navigation monitoring (e.g., for the National Water Authority) to map vegetation growth that could hinder (propelled) vessels movement on water • Quality of the drinking water affected by algal blooms and cyanobacteria • Space upstream sector to provide higher resolution and accuracy EO data for water quality measurements.
Royal HaskoningDHV	RoyalDHV identified some opportunities of using Copernicus data but most of the time they need to concentrate a lot on higher

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Company & Role	Response
(RoyalDHV) Information provider	resolution data due to their clients' needs. However, they see value-add from the presence of the Copernicus data archive and its continuity, which together with new disruptive technologies such as AI and ML, allows them to move from baseline assessments to monitoring. They provided the example of the permit checks for cooling stations, through monitoring with EO. They used EO imagery to fill the gap in the information about the whereabouts of the cooling stations through detection of the cooling towers. In this way, they enabled their customer to create a complete database for surveillance and inspection.
Mures Water Administration (MuresWA) End user	They identified a long list of business and innovation opportunities: • rapid delimitation of minor riverbeds of watercourses • a semi-automatic determination of hydro-morphologically active areas • determination of the critical points of the longitudinal flood prevention infrastructures on the watercourses (dams, shore defences, etc.) to prioritise investments. • following the exploitation perimeters of the mineral aggregates and their influence on the watercourses • monitoring / evaluation of watercourse properties, in accordance with in-situ measurements from hydrometric stations, such as surface area occupied by water, transport capacity in transverse profiles established on watercourses, especially in areas not monitored by hydrometric stations

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Company & Role	Response
	• monitoring the evolution of watercourses and land use in the major riverbeds/riparian areas • a better assessment of the possible effects of floods and the sizing of response capacity • to monitor legislative compliance with land use regulations adjacent to watercourses • for public awareness / education on the importance of watercourse protection • for the detection of possible negative effects caused by constructive interventions harmful to the environment / evolution of watercourses.

Q: Do you foresee any growth for these opportunities (business or innovation) if the right private or public investments are done?

Company & Role	Response
EO Infrastructure provider, EO data provider	This EO Provider bets on the increasing awareness about EO data-driven solutions within various markets which will bring new clients, as well as through their satellite constellation and the Searchable Earth by 2025. They aim to offer access to a large geospatial infrastructure which provides data and accessibility to satellite tasking at a fraction of the existing costs. In this sense, they intend to disrupt the EO data market by vertical integration of their business and bringing down the costs..
Sinergise EO data provider,	Sinergise is of the opinion that the research and technology was the main driver in the past but now it is all about end-users and

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Company & Role	Response
Platform provider	market needs. They also identified the following important drivers of growth: open data policy, CAP - Area monitoring system (automated monitoring of agriculture activities), Green Deal LULUCF[11] (governmental monitoring, corporative monitoring of suppliers, carbon neutral initiatives - SDGs).
Planetek Italia Platform provider, EO Product and Service Provider	Planetek has been involved in the InnoLabs (Apulia region) which is an EU REGIO project for research and innovation (Smart Specialisation). This project aimed to connect potential users with solution developers for the experimentation of new products or services (i.e., Planetek's EO VASs) useful for solving specific problems of social relevance. Planetek acknowledged the Open Clouds for Research Environments project (OCRE), which is a public investment (H2020 RIA) that aims to encourage the development of more EO Services on the Copernicus DIAS enabling the research community to find and use these services. Ready-to-use service agreements and €9.5 million in adoption funding are made available for the research and education community in this way.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	ZoöpHNI reports that the zoöps depend on their own turnover and the bigger the contribution the faster the new applications and services based on EO for their businesses will be adopted. The key to successfully implementing EO solutions is to have one

[11] LULUCF (Land use, land-use change, and forestry) - Land use and forestry regulation for 2021-2030

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Company & Role	Response
	or two of the bigger zoöps adopt satellite data, then the rest will follow.
NIOO-KNAW Information provider, End user	NIOO-KNAW specified that the right investments should go in the direction of providing/acquiring higher resolution and improved accuracy EO imagery and towards making the information more accessible to its end-users. NIOO-KNAW also highlighted the fact that the uptake of new (EO inland water) methods has to be accompanied by the democratisation of the EO know-how in order to complement or disrupt the standard measurements methodologies. Otherwise the resistance to change will still be high.
Royal HaskoningDHV (RoyalDHV) Information provider	RoyalDHV cited a specific issue for the Dutch water authorities which is the ageing of their staff. More than 30% of their staff will leave due to retirement within the next several years and their positions are not going to be filled. This gap needs to be met by the accelerated digitalisation of their assets and processes which should be done by data driven working methods. As such, the public authorities are looking towards alternative solutions, using more and more EO driven models with an emphasis on high quality and accuracy data. RoyalDHV also receives a lot of requests for early warning systems for algal blooms but the temporal resolution (every 5 days or thick cloud coverage) and spatial resolution (>10 m) of the Sentinels data is not sufficient. If these shortcomings are addressed, then the development of early warning systems becomes possible, fulfilling the currently unmet potential.

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Company & Role	Response
Mures Water Administration (MuresWA) End user	MuresWA foresees a significant increase in the use of Copernicus services, especially within NGOs with environmental activity, or within state institutions, such as the Ministry of Environment, Waters and Forests, and probably also by the Ministry of Education.

Q: Do you consider that the current policies stimulate the uptake of Copernicus applications or not?

Only three out of seven interviewed experts responded to this question. This demonstrates that either the policies are not stimulating the uptake of Copernicus services within the EO Value Chain, or very few policies (at any scale) are in the operational stage of adopting Copernicus data. Some explanations found during the interviews were:
i. the limited knowledge of the decision makers about EO, and
ii. the fact that EO services preponderantly focus on expert users and few of them deliver actionable information to non-expert users.

Planetek identified WFD as the main policy driver behind the uptake of Copernicus data with water quality products and services requested by many of their customers.

Sinergise identified the following policies: i. Copernicus open data policy, ii. Common Agriculture Policy (on-the-spot checks (OTSC) and Control with Remote Sensing (CwRS), iii. The Green Deal and the Land use, land use change and forestry (LULUCF) which stimulates governmental monitoring or corporate monitoring of suppliers, carbon neutral with EO.

MuresWA named the current policies for establishing the cadastral limits of watercourses in Romania as a very good and concrete candidate for supporting the uptake of remote

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sensing services. By adopting these services the public authorities will be able to delimit the areas covered with water, and regulate the use of adjacent areas, as well as their monitoring.

Q: Do you see any role of your organisation in stimulating the use of the Copernicus program? What would be the main driver behind it?

Only two experts provided answers to the question regarding their role and contribution in stimulating the use of Copernicus data and services. Sinergise's whole business model is built around Copernicus and their main mission is to promote the uptake of Copernicus data and services. Planetek is also deeply involved in promoting and organising capacity building events which in their view increases the awareness and brings new business opportunities. Planetek is involved in co-developing solutions for end-users by working together with their customers on new EO proof-of-concepts. Most of the time these prototypes are based on Copernicus data and services. Moreover, Planetek has the experience of participating in pre-commercial procurement package development of remote sensing solutions for coastal and marine areas. This is another way in which Planetek contributes to Copernicus program uptake.

Company & Role	**Response**
EO Infrastructure provider, EO data provider	*The expert did not voice a specific answer. Based on answers provided to other questions, the EO Provider is focused on developing their technology without making use of Copernicus. However, they see the huge potential of joining the Copernicus Contributing Missions which in this case can be the main driver for them leading to larger scale of Copernicus uptake.*
Sinergise EO data provider, Platform provider	Sinergise is by far the biggest contributor to the Copernicus program uptake from all the interviewed organisations, most

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Company & Role	Response
	likely since they are high up in the value chain (offering EO data and a platform). Their services include: i. Sentinel Hub distributes hundreds of millions of requests worldwide every month worth of 50 PB of data, ii. their participation in 4 out of 5 DIASs, iii. the systematic replication of Sentinel data to global access cloud storage providers such as AWS and Microsoft Azure, iv. the development of EO Browser and Sentinel Playground which are two online platforms for post-processing Sentinel data (which also allows via custom codes data visualisation and interpretation), v. the development of the EuroDataCube platform, vi. the participation in OCRE initiative, vii. the maintenance and operation of Sentinel-2 Global Mosaic service, part of Copernicus Land Monitoring Services, and, viii. the building of a large scale automated EO monitoring system in the future.
Planetek Italia Platform provider, EO Product and Service Provider	Planetek is very active in the promotion and stimulation of the Copernicus services and program. Planetek is doing this by integrating Copernicus services in their VAS and products portfolio, and by organising annual GIS and RS course webinars. Planetek developed an e-learning multilingual online course for EO which also includes several modules focusing on the water sector. Planetek provides support to the Water and Food Security Planning and Investments in Indonesia and promotes the internationalisation of the maritime sector and EO/VAS through a REGIO/COSME project. Based on their business model built on

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Company & Role	Response
	Copernicus data,
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	*not relevant*
NIOO-KNAW Information provider, End user	*not relevant*
Royal HaskoningDHV (RoyalDHV) Information provider	*not relevant*
Mures Water Administration (MuresWA) End user	*not relevant*

The other participants have not provided a specific answer even though they have been asked. This is because they are not aware or see themselves as having an active role in stimulating Copernicus uptake. Either they are too focused on the customer needs or developing commercial solutions without involving Copernicus or they are not yet at the stage of implementing at operational level solutions derived from Copernicus.

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Q: What needs and opportunities do you see across the whole EO value chain regarding upstream (payloads) and downstream (services/APIs) applications? What are the company/sector needs?

Company & Role	Response
EO Infrastructure provider, EO data provider	This EO Provider offers their customers the possibility to host payloads. If customers wish to develop technology, test it on-board of their satellite they can use the EO Provider constellation and orbits. For the past years this EO Provider identified, within EO downstream, the entrance into the market of new players such as the insurance companies. For example, the EO Provider can provide insurance companies with the level of destruction due to flooding events within hours. The insurance companies can then very rapidly assess the damage to their insured assets, avoiding unnecessary delays and costs by conducting field investigations.
Sinergise EO data provider, Platform provider	Sinergise sees Copernicus as an enabler for: i. VAS directly on Copernicus data (Sentinel Hub, precision farming, etc.), ii. EO service providers business models by prototyping first on Copernicus and only afterwards adding commercial data to their solution, and, iii. other tips, such as using Copernicus for systematic monitoring, then commercial data for in-depth specific use-case detailed analysis. Sinergise sees opportunities in the future end users requests for monitoring of carbon policies and the corporate monitoring of "carbon neutral" activities underpinned by the Green Deal policy, the Fit for 55 and SDGs.

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Company & Role	Response
Planetek Italia Platform provider, EO Product and Service Provider	Planetek sees a lot of opportunities coming from the water sector for the upstream industry, for example: development of new satellite constellations for the coastal zones, specific water monitoring dedicated sensors, sensors in different ranges of the spectrum, new payloads with HSI, SAR and VHR optical sensors. Another trend for the upstream innovation is the possibility to perform processing on board. Planetek is currently working within one of their internal departments on a solution focusing on EO onboard processing. For the downstream there are many opportunities and potential in the application and integration of different technologies including AI and ML. In terms of needs, Planetek prefers more awareness within public authorities and private customers.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	ZoöpHNI shared the opinion that the fact that Copernicus is a free access service where users can download and use data for free is not very well known outside the space community. Also, they identified the need for development and promotion of best practices. As needs for their organisation and sector in general, they identified the following opportunities: i. providing access to funding for small farms above and beyond CAP, big farms, or lobbying companies, ii. support alternative agriculture logic, iii user accessibility to the data whereas the lack of actionable information is still a barrier but also an opportunity to meet, iv. more focus on the vertical market needs and not only geophysical variables, i.e. meet the particular data needs of the best practices, such as those for regenerative agriculture, or

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Company & Role	Response
	rewilding.
NIOO-KNAW Information provider, End user	NIOO-KNAW anticipates the development of early warning monitoring systems and risk assessment for inland water. For their institution specifically, the possibility to assess the effectiveness of remote sensing services and their applicability to water quality measurements, restoration measures, or nature-based solutions, etc. Another important trend is to move from mostly local observations measurements to more detailed monitoring systems which allows remote observation of the spatial and temporal distribution of water processes in more detail. This will contribute to decision making. Another identified opportunity is the integration of in-situ (ground-truth) measurements with EO and the development and correlation with citizen science observations. NIOO-KNAW recapitulated their needs which includes: i. capacity building, ii. more awareness about EO within the institution, iii. better data resolution, and iv. better access to tools and applications. The inland water sector needs tools and maps to monitor and assess water quality parameters such as chlorophyll-a, or cyanobacteria.
Royal HaskoningDHV (RoyalDHV) Information	RoyalDHV receives a constant request for the development of water quality alerts. RoyalDHV also sees the potential of working with public authorities, but these organisations sometimes spend too much time on the R&D before making the decision to invest

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Company & Role	Response
provider	in EO based solutions. Increasingly requests are coming from aquaculture and fisheries, which potentially can be met by using EO data and services. In order to meet their customers' challenges, RoyalDHV needs in general higher temporal and ground sampling resolution data, as well as the availability of MSI and HSI data.
Mures Water Administration (MuresWA) End user	The expert didn't provide a specific answer to this question either written or during the interview. The reason behind this is that the institution does not use EO yet and it cannot provide an accurate answer. However, the expert provided a detailed answer regarding the potential use of EO applications by its institution and voiced the need for higher resolution data and integration with LiDAR data for more accuracy.

Q: If and how current industry and SMEs policies and instruments support innovation?

Company & Role	Response
EO Infrastructure provider, EO data provider	In the past few years, many small and medium-sized enterprises have emerged and entered the downstream applications market. This indicates that the current policy does not create any obstacles for the companies' establishment. However, financing is a big barrier to the development of such enterprises. It is the funding policies that must be developed. It should be noted that in Europe there are good tools to stimulate innovation, and this is not limited to the ESA tender portal.

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Company & Role	Response
Sinergise EO data provider, Platform provider	Sinergise received significant grants from Horizon calls and ESA grants. Moreover, SMEs should take benefit from the provided network of resources, such as for instance ESA funded initiative to sponsor usage of EO data and services to final users. This can actually be seen as the best practice in the field, as it is supporting demand, rather than supply. Further, Green Deal is believed to increase the uptake of EO data significantly as the satellite imaginary provides continuous monitoring of our planet's environment and activities damaging it.
Planetek Italia Platform provider, EO Product and Service Provider	Planetek is very active in promoting Copernicus not only through the implementation of public services but also through the development of professional and educational programs. They provide a course on GIS and remote sensing, webinars, and masterclasses. A special training course for students and young professionals on the use of Copernicus services is also being developed. Thus, Planetek influences general policy by popularising Copernicus.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	The European Green Deal provides many options for business development. Its requirements create many potential opportunities and good conditions for the prosperity of projects of medium and small enterprises, as well as farms. The Green Deal perfectly complements the conservative agrarian lobby.
NIOO-KNAW Information provider, End user	*not relevant*

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Company & Role	Response
Royal HaskoningDHV (RoyalDHV) Information provider	*not relevant*
Mures Water Administration (MuresWA) End user	*not relevant*

Q: Can you identify what are the main challenges that EO services and their business models have at this moment and how you foresee tackling them?

Company & Role	Response
EO Infrastructure provider, EO data provider	One of the most serious issues is the cost of space data. If we take the example of giving monitoring services to farmers, it must be realised that this product cannot be too expensive, because the farmer will be unable to pay for it, as this would raise the agricultural enterprise's production expenses. Even in the absence of EO data, a farmer will carry on with his or her operations. However, we propose a solution that will make this activity more efficient and, as a result, lower expenses. Therefore, it is very important for companies to solve the problem of pricing the images they provide, which are currently at a level that can hinder the growth of the industry. The second challenge is the transitivity of space data. At the moment, we have a very traditional approach

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Company & Role	Response
	that involves contacting companies that have been using remote sensing data for their decisions for a long time. It should be possible to offer such services to different industries, given that the potential of today's monitoring technologies can bring benefits almost everywhere.
Sinergise EO data provider, Platform provider	Sinergise resolved such challenges as access to the data (which is provided currently by platforms like Sentinel Hub), and processing the sources (solved by AWS, GCP, DIAS, etc.). However, many challenges in this sector are still in place. With the open access, companies still have to go through the time-consuming and cumbersome sales process, where preset large minimum orders make data very expensive. This also leads to the disconnection between tenders in terms of the cost of operation and such unlimited data consumption. Furthermore, some regulations leave it uncertain for obtaining a licence for data use. There is also no common awareness of the already existing things, thus making companies duplicate the efforts. On top of that, while EU institutions provide significant budgets for funding the R&D of EO services after they are developed, there is very little use by the institutions themselves.
Planetek Italia Platform provider, EO Product and Service Provider	Planetek sees as a challenge the attraction of private customers to increase the market uptake for EO data services. For example, if a space company wants to provide services for financial institutions, it needs to understand how this sector works and what its needs are - and sometimes, this is a completely different professional "language". Such sectors are not interested in seeing

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Company & Role	Response
	the satellite image or raw data - they need already processed information ready for the product implementation. Thus, one of the main problems seems to be the need to develop businesses that would translate such technical data into a language understandable to other industries. Also, it is necessary to make such a translation for services that are of interest to ordinary citizens, such as tourism. Thus, there is a need to adapt EO data for a specific market niche, where new effective solutions can be developed on its basis.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	First of all, it is necessary to facilitate access to technology, and integration of results into water management. In addition, there is a goal in combining satellite data with ground observation, however, not in the sense of a rigid merger, but as two different sources that complement each other. It also meets the task of developing scientific knowledge, where it is necessary to develop all types of knowledge simultaneously.
NIOO-KNAW Information provider, End user	The spatial component for risk monitoring in water management is indeed quite limited at the moment, and in general there is little know-how in this field. In addition, such a service must be adapted for users. Furthermore, there is a need for more targeted monitoring of individual sites and components, when there is, for example, an indication of a potentially elevated biomarker in a water body. On the other hand, the development of water monitoring services makes it possible to provide much more information through the spatial component on how individual measures work, for example, to ensure water quality, control its

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Company & Role	Response
	turbidity, restoration, etc. On top of this, it is necessary to understand that the introduction of high-tech innovations in a particular area can also affect jobs both positively and negatively. In the context of water management, many experts focus on monitoring with in situ tools. Such specialists may lose their jobs with the introduction of more widespread use of satellite monitoring.
Royal HaskoningDHV (RoyalDHV) Information provider	*not relevant*
Mures Water Administration (MuresWA) End user	The main challenges are the improvement of the resolution and the time period of data acquisition, as well as the algorithms of water detection. Further, it would be interesting to process the data available so far by compiling a database of water-covered land surfaces that allows a filtering of the data from the temporal point of view of the land cover with water, for the time period of the data availability. In addition, it is necessary to create an application or service that will achieve the correlation between In-Situ and satellite measurements.

Q: What kind of procurement mechanism do you use and which one would be more beneficial if you would like to switch (PCP, green procurement, innovation procurement)?

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Only one expert provided a response. *Planetek Italia* (Platform provider, EO Product and Service Provider) covered PCP related to co-design. For the marine activities, Planetek participated in the first PCP for the space sector marine, and they were involved in all three phases/projects, and they lead one of the project consortia. They met with users and found out about their needs. The main EO services were the monitoring of environmental marine areas, aquaculture, and monitoring of the arctic sea, vessel and iceberg identification. The advantage is that they work together with the customer, they follow a step by step procedure as defined in the PCP and most of the time the solutions are already integrated in the PCP procedure. Other speakers had no answer because they were not familiar with the subject, or because they, or their institution, did not use the procurement procedures which were used as examples.

Q: How do you see the role of the public sector in general in this topic, i.e. business or innovation opportunities using EO services for the inland water sector? How do you see the role of the private (or public-private(-research) partnerships) sector in general in the same topic?

Company & Role	Response
EO Infrastructure provider, EO data provider	The role of government authorities is to ensure competition for the private sector. In turn, private companies provide the public sector with solutions that help in better decision making.
Sinergise EO data provider, Platform provider	For the development of new technologies and scientific discoveries, it is necessary to have an effective partnership between the public and private sectors. For example, most often in the scientific field, the goal is to prove a principle and demonstrate how it works. After this, scientists often move on to the next research, but leave a discovery that, in its pure form,

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Company & Role	Response
	works only for a limited circle of users. At this point, it is important to involve companies that can evaluate these results from a business perspective for the end-users among citizens and public authorities. With such an approach, we will have joint cooperation in the space sector, where scientists will invent, companies will optimise, and governments, if possible, will finance and use the obtained results in decision-making.
Planetek Italia Platform provider, EO Product and Service Provider	At the moment, the public sector is the main customer of space services. Planetek works with many governmental authorities, from local to national levels. Moreover, there is always an opportunity to obtain governmental funding through participating in public tenders. Another but more difficult way is to conclude a direct contract with the public administration. Further, a company can engage public authorities in their research: as governments can be end-users, it is essential to let them test a solution. This also allows a company to understand the needs of policymakers and hence simplify information. Innovative activity from governmental structures should be channelled to the private sector, which will be able to develop more products and services for Copernicus. EO data is provided for free, which in itself creates a basis for business, such as the provision of services for the analytics of this data. In doing so, it also creates the ground for integrating the private and public sectors. At the same time, there is a need to create international forums to enable private companies to enter an international professional network. This way they will also have an idea of how to develop business outside of Europe.

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Company & Role	Response
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	The public sector needs to create a level playing field, so then the private sector can fill it with innovations. In the case of water management, it should be noted that water is a commons, and we must treat it accordingly. Consequently, the public sector, in particular the European Commission, has a special role here, and this issue should be included in its agenda. Another subject that the public sector should pay attention to is the more effective implementation of PR practices for highlighting activities related to the use of Copernicus data. This will open up an even larger set of possibilities and further ideas. It is important to explain on a popular level that satellite data can show not only melting glaciers, but also things that are important to the general public, such as the cleanliness of water bodies.
NIOO-KNAW Information provider, End user	The water authorities are quite ambitious in increasing risk analysis. To do this, it is worth passing the initiative to the private sector, which can offer a product that meets the needs of the public sector. At the same time, the latter can intervene by investing in the development of the product they need. The participation of citizens also plays an important role. For people, it is important to have, for example, water in which they can swim in the summer, and by demanding this, they influence the water policy. The policy, in turn, dictates the direction of innovation and the allocation of funds for projects to maintain it.
Royal HaskoningDHV (RoyalDHV)	Many public organisations are not fully aware of the possibilities of using space technologies, and therefore they have difficulty in communicating their requirements to the private sector. On the

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Company & Role	Response
Information provider	other hand, there are commercial organisations that provide space data that probably need to do more to bring all the possibilities to the general public.
Mures Water Administration (MuresWA) End user	The public sector should be more interested in satellite services, as their use in our institutions is still insignificant. Probably due to the growing interest of environmental NGOs in the use of satellite data, services that work with these data will be implemented in state institutions as well.

Q: Are you using any measurements (remote sensing or in-situ) that might help you in further integration-consolidation-facilitation of/with EO products and services? Are you using any (ecosystem) KPIs derived from EO services? What would be the market potential for such applications (in the context of your business/vertical market/sector) and who would be its end users?

Company & Role	Response
EO Infrastructure provider, EO data provider	This EO Provider aims to deploy a constellation of more than 300 satellites with global coverage daily which will allow users to create a searchable earth, a near real time live catalogue of everything.
Sinergise EO data provider, Platform provider	For Sinergise, Copernicus services represent the basis for their business model, for instance they developed applications for on-the-spot control systems for agriculture or a solution for automated area check using ML for EU CAP. They see further

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Company & Role	Response
	opportunities with a growing market for automation and area monitoring for climate change, green transition, or building.
Planetek Italia Platform provider, EO Product and Service Provider	Planetek has delivered a dashboard with water quality underpinned by WFD.
Het Nieuwe Instituut ***(ZoöpHNI)*** Information provider	ZoopHNI is planning to start a new prototype this year which allows them to test the instrumental aspects of monitoring zoops. This proof-of-concept will be installed in a 30 x 30 m area and it will serve as a natural laboratory where the best practices for a zoop will be also developed. The prototype uses among other measurements EO products and services. It gives access to time series and historical data (i.e., the past and present status of the area of interest) and it allows the assessment and mapping of the differences between the zoop and surrounding areas as well as observing the impact of their impact to the natural ecosystem. Using EO services and products gives in general the possibility to develop comparable KPIs and their calibration.
NIOO-KNAW Information provider, End user	NIOO-KNAW was requested by the Netherlands Water Authority and water management companies to develop a dashboard (traffic light) for cyanobacteria monitoring in the bathing and drinking waters.
Royal HaskoningDHV (RoyalDHV)	RoyalDHV received a request from a customer to build a dashboard for water quality which gives appropriate information based on KPIs. Within the dashboard the information should be

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Company & Role	Response
Information provider	in the form of a trigger (i.e. actionable information) which will inform them about the quality of the water. Others requested the development of a system for algal bloom prediction together with a traffic light system.
Mures Water Administration (MuresWA) End user	*no written response was provided*

When asked about the market potential for applications which uses or involves EO data and services, all experts provided qualitative answers, in general estimating the potential as being large or very large and addressing the needs of both public and private stakeholders.

As interesting and informative as these interviews were, it should be kept in mind that these do not necessarily reflect the views of the whole industry. Only a limited number of experts were interviewed (seven) with only one to two representatives from each section of the value chain.

3.3 SWOT analysis of EO and water sector

Finally, we present a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) of EO and Copernicus in the inland water sector to highlight the key issues internal to this nexus of satellite data & information provision and demand from the water segments/ application areas.

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Strengths	Weaknesses
➔ EO can offer an excellent overview over a wide geographic area, allowing quick identification of algal bloom 'hotspots' for example ➔ Copernicus Contributing Mission filling the operational and monitoring gaps ➔ 20+ years guaranteed continuity: new generation of Sentinels launched between 2022 and 2029 ➔ newly funded six Copernicus Expansion Missions (Earth Guardians)[12] available second half of 20s (mainly for research) ➔ existing or planned data and services infrastructure Copernicus DIAS, WEkEO, TEPs ➔ Copernicus Services and Copernicus Evolution are funded until 2027 ➔ develop the general Copernicus Services (or the future inland	➔ inland water is not a primary objective for any of the current or future Sentinel missions ➔ the monitoring of small lakes and rivers (10 -20 m) is currently a challenge only for EO ➔ satellites cannot be used to monitor many chemical pollutants in water (e.g. nitrates, phosphates, etc.) ➔ the difficult EO calibration with in-situ (e.g., material or location dependent) which can lead to low accuracy or errors ➔ the CLMS is the only Copernicus service that has defined an inland water theme within their services ➔ the use of EO is not suggested in any of the EU water policy directives ➔ weak links between in-land water and space sector

[12] Six high-priority candidate missions (Copernicus Expansion Missions) are being studied, to address EU policy and gaps in Copernicus user needs, and to expand the current capabilities of the Copernicus space component.

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platform) to follow the example of the CMEMS and C3S data portals ➔ EO monitoring is more efficient for surveying large areas than regular, costly field work ➔ push from policy, EU Space Program, Copernicus Program, EUSPA, Horizon Europe, Horizon Mission on restoring the Ocean and waters by 2030, European Partnership for Water (Water4All) ➔ Horizon Europe research and innovation funding ➔ EU R&I support for SMEs ➔ EIB and InvestEU for space funding mechanism (see section 4.3 below) ➔ EARSC's taxonomy and marketplace ➔ The first Earth Observation Pre-Commercial Procurement ➔ EuroDataCube service for EO applications (see below section 4.4) ➔ Erasmus+ EO4GEO which supports the uptake of the Copernicus data and services	➔ currently no dedicated market segment for EO water data and services (focus is only on marine) ➔ slow uptake of new or disruptive technologies such AI, BigData, Cloud by users ➔ EO data too complicated for non-expert ➔ water quantity monitoring is under represented in many studies ➔ in Copernicus Services data products related to precipitation and/or snow & ice parameters are more present, while products related to drought, evapotranspiration, floods and water bodies are far less even though in high demand ➔ one of the key issues for the Copernicus Services platforms seems to be the data awareness among the end users and wider community ➔ the general search engine for all Copernicus Services is too limited for proper use because the filters are too basic ➔ similar products that only differ slightly in terms of coverage or

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	spatiotemporal resolution, are sometimes scattered amongst multiple Copernicus Services.
Opportunities	**Threats**
➔ EO can complement current in-situ monitoring to a greater extent ➔ the current low level of uptake of EO in the inland water sector can can be addressed ➔ free EO data from Copernicus ➔ the increasing of spatial resolution with new satellites ➔ propose future mission requirements for system design focusing on water sector EO user needs ➔ increasing portfolio of products with Copernicus Expansion Missions ➔ enhanced continuity with the new generation of Sentinels ➔ CS represents a valuable complementary data source to EO, and engages the public in water quality monitoring and environmental stewardship ➔ update or elaborate new modern water policy and regulations	➔ Copernicus does not currently offer a service or hub with a focus on fresh water ➔ high heterogeneity of water policies and regulations implementation at Member State or regional level ➔ EO suppliers to this market are fragmented, with no one company exerting influence ➔ the inland water sector is not well represented in EARSC applications taxonomy or the EO market reports ➔ no clear economics for EO beyond the general or sectoral Cost Benefit Analysis to facilitate new business models ➔ slow uptake of EO by water sector, public or private, businesses ➔ lack or limited knowledge of decision makers or regulators about EO potential for water sector

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➔ operationalisation of water policies ➔ increase the EO role in water quality and quantity management and monitoring ➔ more SDG indicators using EO ➔ EU's Digital Strategy and synergy with Destination Earth (DestinE) ➔ EO standardisation and harmonisation for the water sector ➔ more sustainable inland water industry ➔ the Green Deal and green taxonomy to support investment in EO services for the water sector ➔ Blue economy ➔ grow a new market for EO water data and VAS ➔ make the use of EO competitive ➔ adopt new concept to increase EO uptake such digital water concept (WaterEurope) ➔ digital twins for inland water to be integrated with other digital twins (e.g., ILIAD - digital twin of the ocean) ➔ capacity building in order to increase uptake	➔ service discontinued due to space threats (e.g., debris, magnetic storms, malfunctions)

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Comments on the SWOT

Here we present some of the issues identified in the SWOT matrix in more depth based on desktop research conducted under work package 1 of the Water-ForCE project.

Copernicus Missions (Sentinels, Next Generation of Sentinels, HPCM) together with Copernicus Contributing Missions can build toward the water policy operationalisation with EO replacing or complementing the in-situ or obsolete methods for water management and monitoring. In doing so new opportunities for updating or elaborating modern water policies might arise.

The Copernicus satellite constellations' (enhanced) capabilities and Copernicus Services continuity can stimulate a higher uptake of EO data and VAS in the inland water sector and lead to the development of new water related EO products and services.

The new package of EU space policies and the funding opportunities for space within EU programs can lead to manifold increase of R&D and secure the role of EO in the water quality and quantity management and monitoring.

Copernicus (services) and EO services industry can contribute significantly to the objectives of the Green Deal, Blue Economy or SDGs by providing standardised and harmonised solutions for a greener and more sustainable water sector.

The EU's digital strategy and the EU investment in digital and cloud infrastructures or high performance computing clusters can lead to the digital transformation of the inland water sector and contribute to the digital water concept. Furthermore, new technologies such as AI, IoT and cloud computing can facilitate the development of the digital twins in the water sector and the overall integration into Destination Earth by 2030.

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EU Erasmus+, Copernicus Academy or EU funded project for EO knowledge sharing can speed up the capacity building and uptake of EO in sectors other than the space industry. In this way it will increase awareness and engagement within businesses, public authorities and citizens.

The enhanced capabilities of Copernicus satellites sensors coupled with the development of new solutions specifically focusing on the inland water sector can lead to the crystallisation of a water theme underpinning the update of EO taxonomy with a rolling effect for a broad adoption by policy and markets

Copernicus Services Evolution can favour the establishment of Copernicus Water Thematic Hub and further boost the uptake of EO by the water sector, public or private, and businesses.

The EU R&I support for SMEs and backing investment in the space sector can lead to the growth of a EO-based market and new business models for the inland water sector. Evenmore, it will reduce the market fragmentation and lead to a competitive sector to the benefit of the water sector end-users and stakeholders.

Continuous improvement of Copernicus Services and its satellite component as well as its integration with in-situ observation can lead to the development of new best practices and guidelines for the water policy implementation at various scales. The technological push and user demand pull can overcome the high heterogeneity of the water policies and regulations at EU level.

Copernicus Contributing Missions and the access to New Space data and applications can complement the existing service capabilities and abate or mitigate any eventual Copernicus Services discontinuity (e.g. Sentinel-1B).

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EO4GEO or PCP for EO can generate more awareness within decision makers or regulators about the EO potential for the water sector. It will also help to co-design solutions based on end-users needs, scale up the uptake and increase the engagement of public authorities or businesses with EO.

One of the recurring user needs is the Sentinels payload system design, resolution and accuracy capabilities which hinder the development of EO applications to address inland water challenges. The new generation of Sentinels, CCM or Copernicus Expansion Missions payload capabilities leading to better and more accurate EO services can overcome the current limitation of monitoring small lakes and rivers and further contribute to a better and inclusive operationalisation of water policies.

The trend within the Copernicus Evolution and EO services in general is to provide end-users with better management and monitoring tools and actionable information. In this way it will overcome the complicated EO data processing and interpretation, otherwise inaccessible to non-expert users, and increase the EO uptake or engagement for various stakeholders or decision makers.

4. Overview of innovation needs and opportunities

4.1 Opportunities for the EO downstream sector

The innovation needs and business opportunities for EO in the water sector, can be informed by the emerging user needs described in D1.4 from across the application areas, especially those categorised as 'Evolving needs for new products and services'. Moreover, the identified needs and opportunities from the EO downstream sector correlate well with

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the views expressed by industry experts (see industry experts interviews from above). Thus, the opportunities afforded to EO downstream service providers are listed here according to the number of applications that requested this data and information (from high to low):

1. Water quality and water levels (quantity) not only on major lakes, but also in smaller reservoirs and rivers and much finer scale (catchment scale). The need for such information has been identified by most of the experts and organisations interviewed for this report (see interviews summary above)
2. Inclusion of microbial, toxin, algal and metal indicators and plastic pollution indicators. Dashboards or early warning systems for algal blooms and cyanobacteria are recurrently identified also in the experts interviews.
3. Watershed modelling, hydrological and hydrodynamic modelling
4. Detection of dissolved organic matter
5. Chlorophyll-a concentration in lakes and inland waters in general. NIOO-KNAW's water ecology department is currently conducting exploratory research in order to test the feasibility of using EO data for monitoring Chlorophyll-a concentration in lakes and rivers.
6. Coupling groundwater level monitoring to land use change
7. Discrimination of permanent and temporary water bodies
8. Risk-related indices to water systems: congestion, fishing jetties, flow speed, overgrowth, subsidence, sedimentation.
9. Monitoring of fast growing water plants and algae. NIOO-KNAW received a request from the Dutch National Water Authority to map the vegetation growth that could hinder vessels movement on inland waterways.
10. Better resolution of the algal community structure and biomass
11. Hydrological models to calculate hydrological fluxes for small streams or entire river basins in connection with sea
12. Information to monitor ground-water aquifers
13. Dedicated services for water level, altimetry, bathymetry

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14. Inland waterways, canals, ditches, culverts. RoyalDHV has developed a prototype for monitoring small canals, ditches and inland waterways for vegetation growth (e.g., duckweed) and dredging sludges
15. Detect leakage from supply network
16. Soil moisture/soil water balance (observations and forecasts)
17. Service for evapotranspiration process (observations and forecasts)
18. Frequent mapping of CDOM (coloured dissolved organic matter)/DOC (dissolved organic carbon) products to assist on drinking water quality monitoring
19. Monitoring service for drinking water quantity and quality. Parameters such as a) cyanobacterial harmful algal blooms, b) Frequency of algal bloom occurrence. NIOO-KNAW is monitoring (though only in-situ at the moment) the drinking water quality for water resources management companies. Presently, the institute is investigating the possibility to use EO products and services for the same objectives
20. Regular information on river dynamics and especially river runoff, interfaces with seas/oceans and overall hydrological dynamics
21. Water-related forecasts and water-related climate record
22. Floods and droughts forecasting and monitoring. Near 'real time' forecasts. The EO Provider we interviewed has indicated a new upcoming market sector for the EO, the insurance companies which requests more and more data for mapping and assessing floods damages
23. Detection of soil salinization
24. Forecast models and provision of early warning for food production and sustainable agriculture
25. Monitoring of drinking water quality in reservoirs
26. Sea Surface temperature in coastal and inland water
27. Basin-scale high resolution surface models and topography data
28. Services dedicated to coastal areas. Planetek developed for their customers a commercial application for monitoring aquaculture and fisheries (Rheticus Aquaculture). RoyalDHV is also tapping into the same sector of aquaculture and

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fisheries. Planetek also identified as an opportunity the: development within the upstream sector of new satellite constellations focusing on the coastal zones. This is based also on the active participation of Planetek to the establishment of the Copernicus Thematic Hub for Coastal Zones and their participation into several REGIO and H2020 projects focusing on the internationalisation of maritime and EO services.

Note that this list is only a first indication of the applications that are important to the water sector. The priorities may be skewed by the selection of interviewees.

4.2 Opportunities for the Copernicus Program

Around five years ago CEOS (Committee on Earth Observation Satellites) commissioned a study (CEOS, 2018) on the feasibility of designing an Earth observing satellite mission focused on the Aquatic Ecosystem including the biogeochemistry of inland, estuarine, deltaic and near coastal waters as well as mapping macrophytes, macro-algae, sea grasses and coral reefs. They noted that these environments need higher spatial resolution than current and planned ocean colour sensors and need higher spectral resolution than current and planned land Earth observing sensors offer. This includes the topic of this analysis - inland lakes, reservoirs, lagoons, rivers, etc. and they present detailed analysis of characteristics that would be required in a dedicated upstream EO sensor and satellite system. This could be taken into consideration for the future generations of Sentinels.

The analysis presented in D1.4 - Report with end-user needs and requirements, also highlights the upstream requirements of the water sector through their synthesis of 'Sensor requirements and capabilities'.

These include the following for upstream capabilities:

1. Spatial resolution of 1-5 m

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2. Increased resolution (sub 1 m) in order to identify smaller inland water bodies and provide information on the hydromorphology of rivers
3. Spatial resolution 5-20m, pixel resolution to 1 ha minimum mapping unit
4. Time resolution yearly and seasonal maps based on daily to weekly information
5. Ideal inland and near coastal water quality sensor for general use and covering the needs of most applications (imaging spectrometer with 5-8 nm spectral bands from 340 to 1000 nm, and a minimum of three SWIR bands, Spatial resolution: 5-10 m ground sampling distance (GSD), Revisit frequency should be high as possible: daily for reservoirs/dams, and weekly for lakes/rivers, monthly for coastal).

As well as the following capabilities that can be interpreted as midstream capabilities:

6. Integration of radar data and services
7. Integration of spectroradiometers in the existing infrastructures
8. Wider collection of hyperspectral radiometry
9. Hyperspectral data for water quality, algal blooms and shallow water.

Moreover, from the interviews with experts the following requirements were identified which will have an impact to their business or organisation:

10. Access to very high resolution data from the Copernicus Contributing Missions
11. Become a contributing mission to the Copernicus Contributing Missions
12. More focus from Copernicus and ESA for the co-design and co-develop applications with end-users than only building services
13. Customers request actionable information (dashboards, decision making tools) instead of specialised services
14. Capacity building for end-users
15. Integration with in-situ component
16. Digital transformation using EO
17. Using AI, ML, automation and cloud infrastructure for providing EO solutions

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This highlights issues that could be taken into account in the further development of the Copernicus Programme.

4.3 Opportunities offered to the business sector

As mentioned in the EARSC Industry Survey (EARSC, 2021), SMEs and start-ups account for more than 93 % of European EO companies. Small and medium enterprises (SMEs) contribute to finding solutions for the implementation of EU policy regarding the use of satellite data and water. With sufficient funding, businesses can thrive, expand and further contribute to the economic growth of their sector. This section presents the opportunities that SMEs are given and that could be used for developing EO VAS for water management.

Funding instruments for space

The initiatives outlined below do not indicate particular financing for inland water monitoring programs. These policies, however, do not restrict the objects to which space innovations can be directed. As a result, developments in downstream space applications are also covered by these funds. Hence, companies that use Copernicus data for water management may fully benefit from these opportunities.

- *EU Space Programme under EUSPA*

Finance of Copernicus programmes falls under the new Space Programme developed by EUSPA for years 2021-2027 which gives €13.2 billion to finance space activities. Particularly for Copernicus, €5.8 billion are allocated. Under the Space Programme, this aid will foster innovation in the space industry by giving access to SMEs and start-ups to risk finance.

- *CASSINI*

In January 2022, a brand new CASSINI Space Entrepreneurship Initiative for 2021-2027 was launched. The CASSINI fund provides a minimum of **€1bn** investment capacity for space

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start-ups over the duration of the CASSINI initiative. There will also be the Cassini Business Accelerator, a six-month intense program that will provide top-level business coaching, training, events, and seed investment to startups and scale-up businesses

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Company Stage	Type of finance	Other support	Instrument	Provider	Direct YES/NO	Space-specific YES/NO	Conditions	More info/apply
• Start-ups • Early stage	Close-to-market procurement (co-funding)	• Incubation • Tech transfer • BIC	• Boost! • BASS • InCubed+ • GSTP Develop, Make, Fly • Navisp	ESA	YES	YES	• Co-funding% • Viable business plan • SMEs from participating countries	All calls on emits.sso.esa.int; Boost! BASS GSTP Navisp
• Start-ups • Early stage • Mature	Grants		Horizon Europe: "Digital, Industry and Space"	EC	YES	PARTLY		
• Start-ups • Early stage	Grants, blended finance, equity		European Innovation Council: EIC Accelerator	EC	YES	NO	• SMEs from participating countries • Non-bankable • High-potential, market creating • TRL 6 and above	EIC Accelerator
• Start-ups • Early stage • Growth	Equity		Various instruments InnovFin Equity Space pilot	EC > EIF > VCs	NO	NO		Orbital Ventures UnternehmerTUM VC Primo Space
• Scale-ups • Growth	Venture debt		European Guarantee Fund (EGF); European Growth Finance Facility (EGFF)	EC > EIB	YES	NO	• SMEs (& mid-caps) in participating Member States / EU-27; • Innovation driven • Proven technology • Investment plan ~ 3-4y • Ticket size: EURm 3-35 / 7.5-50 • EIB co-financing: 50%*	EIB Venture debt EGF EIB Advisory Services Innovation Finance Advisory
• Mature • SME and mid-caps	Debt	• Advisory via the InvestEU Advisory Hub	InvestEU; EIB own instruments	EC > EIB; EIB	YES	NO	• Bankable • Ticket size: min EUR 25m • Investment plan: 3-4 years • EIB co-financing: 50%	EIB mandates EIB loans for the private sector EIB support to SMEs and midcaps *InvestEU available as of summer 2021*
• Mature • SME and mid-caps	Debt		InvestEU; EGF; EIB own instruments	EIB > NPBs; commercial banks; other financial intermediaries	NO	NO	• Bankable • Depending on requirements from the financial intermediary	EIB intermediated lending *InvestEU available as of summer 2021*

Figure 5. ESA, European Investment Bank: Financing space: option for SMEs and midcaps. Source: ESA & EIB conference (2021).

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- *ESA Opportunities*

1. ESA Business Incubation Centres (ESA BICs)

ESA BICs across Europe were established to empower entrepreneurship and to allow local economies to benefit from space data and technologies. It provides zero-equity funding for product development & patent. The fields of application also range, with possibilities to work on EO data for environmental monitoring.

2. ESA procurement policy on fair access for SMEs

To ensure equal access to its programs for all types of businesses, ESA developed and implemented a series of procurement provisions known as "the C1-C4 clauses": C1: Activities in open competition, limited to the non-primes; C2: Activities in open competition, where a significant participation of non-primes (including SMEs) is requested; C3: Activities limited to SMEs & R&D organisations, preferably in co-operation; C4: Activities in open competition, subject to the SME subcontracting clause. The C1-C4 clauses have improved access to ESA activities for SMEs and Non-Primes.

3. ESA's LET-SME

Leading-Edge Technologies from Small and Medium-Sized Enterprises is a program devoted to facilitating the spin-in of leading-edge technologies from SMEs into the space. Since its inception in 1998, the program has routinely issued Invitations to Tender for the development and delivery of innovative technologies, which are exclusively reserved for high-tech SMEs. SMEs are encouraged to collaborate with research institutions, and the technologies targeted have a high potential for innovation.

4. 35% advance payment for SMEs

From 2017, SMEs functioning as either prime contractor or subcontractor with ESA will be automatically given an advance payment of 35% of the contract price without needing to demonstrate a strong need for cash disbursement at the start of the contract. This approach

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is a method of systematically ensuring a cash flow neutrality for SMEs, hence boosting their financial survival.

5. Technology Development Element Programme (TDE)

The Technology Development Element (TDE) is in charge of the early phases of development for all ESA service and technology sectors, adopting cutting-edge concepts and assessing their appropriateness for space applications. It is the sole ESA technology program that supports all of ESA's fields of operation across the whole spectrum of technical disciplines, serving as the technological foundation for the majority of future advances. Annual procurement plans are developed, with 100% of contracts given to industry and institutions on an open competitive basis. Tender invitations are issued constantly throughout the year using ESA's esa-star publication tool.

6. General Support Technology Programme (GSTP)

The General Support Technology Programme (GSTP) advances previously established concepts to the next level of engineering. Through GSTP, ESA, participating states, and industry collaborate to transform innovative technical concepts into a diverse range of usable products. The program takes cutting-edge technologies that are not yet ready for launch into space and develops them for use in future missions. Except for telecommunications, it encompasses all technological fields and applications.

7. Discovery & Preparation

Discovery & Preparation sponsors research and development in all areas of space technology and study. It helps ESA directorates as well as ESA's future initiatives through this research. Discovery & Preparation invites small businesses and universities to engage in this research for a diversity of ideas and inputs. On a regular basis, Discovery & Preparation issues open calls to tender in esa-star publication tool. The Open Space Innovation Platform is also used to solicit new activity ideas.

8. BASS – Business Applications and Space Solutions

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ESA Space Solutions is the place to go for innovative business ideas incorporating space in all aspects of society and the economy. Its purpose is to assist European entrepreneurs in the growth of their businesses via the use of satellite applications and space technology. ESA Business Applications is a component of ESA Space Solutions, which promotes the development of sustainable services that make use of space assets. It offers businesses investment opportunities as well as expert guidance.

9. Future EO – Earth Observation science for society

Future EO is an ESA initiative that will provide the groundwork for European Earth Observation systems and capabilities over the next few decades. It addresses all areas of Earth Observation, including system and architectural studies, instrument pre-development, mission development and operations, and the encouragement of creative Earth scientific and EO application advancements. The Future EO programme's EO Science for Society component provides a flexible structure to support rapid developments addressing priority interests and emerging opportunities for novel use of EO within the scientific community, national, regional, and international public sector institutions, and private sector operators.

10. InCubed – Investing in Industrial Innovation

InCubed, which stands for 'Investing in Industrial Innovation,' is a Public Private Partnership co-funding initiative managed by the ESA Φ-lab. InCubed is dedicated to creating new and financially successful products and services that capitalize on the value of Earth observation images and databases. The initiative has a broad scope and may be used to co-fund anything from satellite construction to ground applications and anything in between, as well as the development of new EO business models.

- The PARSEC Accelerator

PARSEC is a business accelerator that promotes the development of innovative EO-based goods and services. The accelerator is designed for SMEs, start-ups, entrepreneurs, and

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researchers that wish to make a difference in the developing Food, Energy, and Environment sectors.

The comprehensive two-stage acceleration program will provide a total of €2.5 million in equity-free investment to 100 recipients, as well as other critical resources (coaching, matching, and advertising) required to create and launch 15 new goods and services into the worldwide market.

- *SERAPHIM*

SERAPHIM's mission is to find, support, and grow early-stage SpaceTech firms across their entire life cycle. They have the support of renowned space corporations and international space agencies, including Airbus, SES, Teledyne, Telespazio, SSTL and accelerator partnerships with Rolls Royce, Inmarsat, European Space Agency, and UK Space Agency. As a result, SERAPHIM invests throughout the whole SpaceTech ecosystem and has already backed 63 start-ups.

Funding instruments for water projects

In the framework of this analysis, one should also include funding initiatives geared explicitly towards water projects, rather than just space activities. Such finance strategies provide a clear goal for the enterprise's orientation but do not limit the methods of accomplishing that goal. As a result, space enterprises performing inland water monitoring activities might obtain the required aid from environmental investment programs.

- *The DIS-SMEs*

The European Innovation Partnership on Water has designated the DIS-SMEs Action Group ("Demand-driven Innovation Support for SMEs through the Network of National Water Partnerships for Jobs and Growth in Europe") as a priority. The EIP Water program is part of

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the European Commission's EU 2020 Innovation Union. It promotes the development of new solutions to significant European and worldwide water concerns. Simultaneously, the EIP Water promotes the development of business potential for these technologies both inside and outside of Europe. The Action Group's overarching aim is to increase chances for SMEs to effectively bring new water technology to the (international) market and to collaborate in a smart, pan-European network.

- *The Cohesion Fund*

Cohesion Policy continues to invest in drinking water and sanitation, devoting EUR 15 billion to water management in the 2014-2020 programming period, despite the fact that spending will last until 2023. The Cohesion Fund is the principal EU source of investment in water infrastructure that is tailored to the individual requirements of benefitting Member States. In doing so, it assists them in meeting their basic water demands while also promoting compliance with the EU's water-related environmental acquis.

- *JASPERS*

JASPERS is a technical assistance collaboration. It facilitates the absorption of European money by cities and regions through high-quality initiatives. The goal is to accelerate the utilization of ESIF funding in order to promote greater European integration. It is projected to play a critical role in enabling a rapid start of cohesion policy expenditures in 2021-2027.

- *EQT*

EQT invests in small firms with the goal of helping them grow into great and sustainable businesses. It is aimed at businesses who are focused on implementing the Sustainable Development Goals (SDGs) through their technology. As a result, EQT has already invested in six firms working on SDG 6 water and sanitation solutions.

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General instruments

Both space firms focusing their EO operations on inland waters and companies whose primary activity is inland water management can benefit from the opportunities provided by common tools to assist small and medium enterprises.

- European Innovation Council (EIC)

The European Innovation Council (EIC) was created as part of the EU Horizon Europe initiative. The EIC seeks to uncover and support game-changing ideas and breakthroughs in order to establish new markets and scale up worldwide. Since 2018, EIC has assisted over 2600 SMEs and start-ups. In 2022, EIC funding opportunities totalling more than €1.7 billion are available. The EIC offers the following chances to innovative businesses: EIC Pathfinder funds multidisciplinary research teams to conduct visionary research that has the potential to lead to technological breakthroughs; EIC Transition funds start-ups and SMEs to develop and scale-up high impact innovations that have the potential to create new markets or disrupt existing ones; and EIC Accelerator funds start-ups and SMEs to develop and scale-up high impact innovations that have the potential to create new markets or disrupt existing ones. Furthermore, all EIC projects have access to Business Acceleration Services, which include coaches, mentors, and experts, as well as partnership possibilities with corporations, investors, and others, as well as a variety of additional services and events.

- *Eurostars*

The Eurostars program is a financing and assistance initiative intended for R & D-performing SMEs that want to capitalise on the benefits of international collaboration. Eurostars has been deliberately designed to meet the special demands of SMEs, and it focuses on the

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creation of innovative goods and services, facilitating access to worldwide markets through the transnational nature of each project consortium. Since 2014, 1.75 billion euros have been invested through Eurostars.

- *European Investment Fund*

The European Investment Fund, a part of the EIB Group, is a specialised supplier of risk finance to European SMEs. The European Fund for Strategic Investments (EFSI) is the foundation of the European Investment Plan. It offers first-loss guarantees, allowing the EIB Group to participate in more risky projects. So far, the EFSI-approved projects and agreements have mobilised €535.4 billion in investment, with examples in both space and water domains.

- *The European Regional Development Fund*

The European Regional Development Fund (ERDF) aims to improve economic, social, and territorial integration in the European Union by addressing regional imbalances. It will allow investments in a smarter, greener, more connected, more social Europe that is closer to its residents between 2021 and 2027.

4.4 Research opportunities under Horizon Europe & Horizon 2020

Horizon Europe

Horizon Europe, with a budget of €95.5 billion, is the EU's primary financing initiative for research and innovation. In its clusters, it provides open calls for projects in different domains, where the use of EO technologies is beneficial.

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Inland water and EO-related calls under Horizon Europe projects include the following opportunities:

- HORIZON-CL4-2021-TWIN-TRANSITION-01-14 - Deploying industrial-urban symbiosis solutions for the utilisation of energy, water, industrial waste and by-products at regional scale;
- HORIZON-CL4-2021-SPACE-01-44 - Copernicus evolution for cross-services thematic domains;
- HORIZON-CL4-2022-SPACE-01-43 - Copernicus Land Monitoring Service evolution;
- HORIZON-EUSPA-2021-SPACE-02-51 - EGNSS and Copernicus applications fostering the European Green deal;
- HORIZON-CL6-2021-CLIMATE-01-01 - Improved understanding, observation and monitoring of water resources availability;
- HORIZON-INFRA-2022-EOSC-01-03 - FAIR and open data sharing in support of healthy oceans, seas, coastal and inland waters;
- HORIZON-CL6-2021-BIODIV-01-09 - Assessing and consolidating recent scientific advances on freshwater ecosystem restoration;
- HORIZON-CL6-2021-BIODIV-01-16 - Biodiversity, water, food, energy, transport, climate and health nexus in the context of transformative change;
- HORIZON-CL6-2022-FARM2FORK-01-05 - Integrated and sustainable freshwater bioeconomy: Combining aquaculture, biodiversity preservation, biotechnology and other Uses;
- HORIZON-CL6-2021-ZEROPOLLUTION-01-03 - Preventing and managing diffuse pollution in urban water runoff;
- HORIZON-CL6-2022-ZEROPOLLUTION-01-01 - Preventing groundwater contamination and protecting its quality against harmful impacts of global and climate change;

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- HORIZON-CL6-2022-ZEROPOLLUTION-01-04 - Securing drinking water quality by protecting water sources against pollution, providing innovative monitoring and treatment solutions and ensuring safe distribution;
- HORIZON-CL6-2021-CLIMATE-01-01 - Improved understanding, observation and monitoring of water resources availability;
- HORIZON-CL6-2022-CLIMATE-01-01 - Climate sensitive water allocation systems and economic instruments;
- HORIZON-CL6-2022-GOVERNANCE-01-06 - Water governance, economic and financial sustainability of water systems;
- HORIZON-CL6-2022-CLIMATE-01-04 - Fostering the resilience of agricultural production: from observation of changes to the development of resilience strategies.

Under Horizon 2020, a number of SPACE calls were specifically aimed at 'Taking EO downstream applications to market'. These covered all application areas, but quite a few focussed on water applications, such as:

- CyanoAlert (https://project.cyanoalert.com/) - The Cyanobacteria Blooms Public Information Service
- DIANA (https://diana-h2020.eu/) - Detection and Integrated Assessment of Non-authorised water Abstractions using EO. Note that the DIANA services are being offered in Spain under the name HidroGestor® and in Italy under the name Irrisat®.
- Primewater (https://www.primewater.eu/) - Delivering Advanced Predictive Tools from Medium to Seasonal Range for Water Dependent Industries Exploiting the Cross Cutting Potential of EO and Hydro-Ecological Modelling.

Similarly, EO companies looking to develop new products and services for the water sector, could look to the Horizon Europe calls to initiate the development of these. These can even

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lead to commercial products and services as illustrated by the DIANA project. Additionally, EU research funding (under FP6, FP7, H2020 and others) has given many companies the opportunity to scale-up their business offering through the development of water-related services. Some examples are listed here:

- Planetek Italia's Rheticus® AquaculturePlus for aquaculture farmers, which was developed through co-design with aquaculture farmers through e-shape EuroGEO Showcases projects (Pilot 5.7).

- GeoVille GmbH benefited from substantial research and development resources (participating in more than 465 projects) that allowed them to grow from a startup to an established EO company with global presence. GeoVille's contribution to the water sector is mainly from the water relevant components of the Copernicus Land Monitoring Service. GeoVille has also collaborated with international EO and GIS communities to develop applications such as the TIGER Water Observation Information System (WOIS) for African water authorities.

- WaterInsight participated in several international research projects (e-Shape Pilot 5.6, EOMORES, HBOTE[13]) and offers operational commercial water quality remote sensing products and services. They developed their own "close sensing" water quality spectrometers with the objective to bridge the gap between satellite monitoring and in situ sampling. They offer EOMORES products and services for water quality monitoring of inland and coastal water bodies, which were developed under the EU funded project of the same name.

- 3edata is a spin-off from the University of Santiago de Compostela (USC), recognized by the Spanish Ministry of Science, Innovation and Universities in 2018 as innovation SME. 3edata develops new tools for the assessment, evaluation and monitoring of

[13] A Netherlands directorate-general for Public Works and Water Management (Rijkswaterstaat), Netherlands Space Office and RVO SBIR funded project

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natural resources using EO technologies in the fields of forestry, agriculture and water quality. They have participated for the past five years in several European (H2020) or national (Spain) R&D projects: HIREMOT (High-resolution in-situ and surface measurements of optical and temperature lake characteristics) and DROWN (Downscaling Remote Sensing Observations to resolve Water optical variability in Natural conditions) under auspices of AQUACOSM Network, or LIFE TREMEDAL project.

- isardSAT is an R&D enterprise which provides services and solutions using EO including algorithm development, geophysical validation, instrumental calibration, or toolboxes. Part of isardSAT research concentrates on using EO data for hydrology and agriculture applications, such as: coordinator of TEP Hydrology, surface water mapping EO Clinic, altimetry algorithm development for Sentinel-6 GPP and Sentinel-3 MPC, calibration and validation of Sentinel-6 and the definition of requirements for the future SMOS microwave observation system, applications and services under EU H2020 funding REC and ACCWA.

eShape

eShape (EuroGEO Showcases: Applications Powered by Europe) is a project which was launched in 2019 that develops and promotes EO products and applications in order to increase the knowledge and awareness for its European stakeholders and end-users. Currently, eShape includes 27 cloud-based applications under seven thematic areas (showcases): agriculture, health, energy, ecosystem, water, disasters, and climate . Water is specifically addressed by one of the showcases (Showcase 5) and it integrates seven pilots. These pilots are:

- Pilot 5.1: Improved historical water availability & quality information service. The expected outcome of this service is to contribute to an improved set of the HYPE hydrological model output data, including river discharge, lake and river water level,

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water balance (precipitation, evapotranspiration, runoff), and total and key water storages (snow, canopy, soil, lakes, rivers).

- Pilot 5.2: Satellite Earth Observation-derived water bodies & floodwater record over Europe. The final 'default' product will be a database ("record") of flooding-related observations derived from >6 years of 20 m resolution Sentinel-1 observations made over Europe: floodwater extent, exclusion mask (i.e. unclassified areas), permanent water bodies, classification uncertainty. In addition, higher level products will be derived from the 'default' product based on specific user requirements (e.g. maximum flood extent map, aggregate monthly extent map, number of persons affected by floods, critical infrastructure impacted by floods, etc.).
- Pilot 5.3: Dive - Diver Information on Visibility in Europe. The final product will be a mobile phone application that will allow divers to easily check the expected visibility of a dive site.
- Pilot 5.4: Sargassum detection for seasonal planning. The pilot will be a service for the end-user support decision making on sargassum seasonal planning and spread awareness on the sargassum influxes in the Atlantic by providing: i. a one-year time series of sargassum detection on the whole Atlantic basin; ii. seasonal forecasts of sargassum drift.
- Pilot 5.5: Monitoring fishing activity. This pilot aims to produce a web based tool to disseminate geo-referenced information on: i. the activity of fishing fleets operating in deep sea areas of the Northeast Atlantic, targeting big pelagic species; and, ii. environmental characterization for these areas.
- Pilot 5.6: EO based phytoplankton biomass for WFD reporting. One of its objectives is to provide WFD ecological status products of phytoplankton biomass for management of selected water bodies, based on Chlorophyll-a concentrations derived from EO data. The other objectives are focusing on the larger scale adoption of the service, generating recognition for the suitability of EO based products water quality and falling under the scope of the EU WFD, or the technology push for new

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techniques and practices that encourages the satellite-based monitoring for water quality measurements in support to the implementation of the WFD.

- Pilot 5.7: Rheticus AquaculturePlus. Planetek delivers a service (Rheticus® Aquaculture) which was co-designed with aquafarmers and uses satellite data and derived measurements of water parameters and a model for shellfish growth, in order to provide information about mussels' growth rates. Some of the concrete outputs are weekly bulletins with indicators calculated by the service algorithms.

Moreover water is being present in other showcases (thematic areas) with pilots focusing on agriculture and water stress or irrigation (Pilot 1.2: CAP support), disasters in urban environment (Pilot 6.2), resilient agriculture (Pilot 6.4), or flood risk and assessment (Pilot 6.5).

Euro Data Cube

The Euro Data Cube (EDC) collects services and applications developed by the research community or EO service providers (public or commercial) in a single platform connected to the Copernicus or other cloud-based infrastructures (e.g. DIAS systems). It is a one-stop-shop for browsing, analysis and processing of EO data, from source up to the final product. In this way, the platform users have access to huge data volumes and computing power. EDC users have access to the complete and global EO archives from main all open missions (e.g. Sentinel, Landsat, MODIS, etc.), commercial satellites (PlanetScope, Pleiades, SPOT, WorldView, etc.) as well as Level 3 products from Copernicus Land Monitoring Services, CMEMS, C3S, etc.). It allows them to produce information on the spot and in an "analysis ready" format which are further disseminated using toolboxes or virtual models to be used by end-users from different thematic areas. The Euro Data Cube is also an open EO data and services factory (in the US, called data refineries, e.g., DescartesLab) where value adders can plug-in their own algorithm to generate and deliver industry leading services, easily integrated in user-facing web applications, further enriching the information offer. Taking stock of the platform capabilities, several applications are already available and ready to deliver EO solutions for floodings, CAP, water quantity or water quality. The most notable is the RACE (Rapid Action on Coronavirus and EO), which is a dashboard which can illustrate

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these socio-economic and environmental changes related to Coronavirus at global scale. It collects different analyses from a wide range of EO data coming from the Copernicus Sentinels and Third Party Missions, as well as ground-based observations and advanced numerical models via the Copernicus Services. For instance it contains CMEMS's product on Water Quality but integrates also data with water quality time series or water quality regional maps.

5. Conclusions and recommendations

Information provided in market and trend reports available for Space and EO imply that the role of EO in the water sector is currently limited to a few specific applications, but there is no specifically identified EO market for Water. Most of the time this market is hidden or segmented underneath other market sectors (e.g. agriculture, natural resources, emergency). This could be due to the fact that Water is a transversal sector on which many other sectors rely or exist. However, the definition of EO inland water as a stand-alone market sector can lead to a better representation within the existing market taxonomy for EO data and services focusing on the water sector.

Having said this, the overall size of the water market and the move towards smart water management indicates vast opportunities for EO service providers. This is further reinforced by the general evolution of the EO VAS market from technology push to market pull and an increasing demand from different user groups for water applications. The analysis of the emerging user requirements from within Water-ForCE, points to ample research and business opportunities in the water sector and for SMEs. In D1.4, a large number of emerging needs have been identified for which innovative products and services can be developed by research projects, existing EO businesses and SMEs, or even spin-off companies. Such developments should use multi-source analytics in conjunction with EO and work towards systems for situational awareness in water management. Customers would like seamless links between the information from EO, drones, citizen science and in-situ monitoring. This

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is now enabled by the move to digital technologies and developments in smart sensors, IoT, big data analytics, AI, etc.

Another way of looking at the business opportunities, is to keep the economic importance of the different applications in mind, for example agriculture (as the biggest user of water), or the costs of damage due to floods and droughts. Clearly, all these requirements will fill the gap in data and information for water management, and serve to inform the 'value of water' (See Water Force report 2017). In danger of pointing out the obvious, EO and satellite data cannot meet all these requirements 'on its own', but it can contribute significantly to many of these information requirements.

Opportunities in the EO market and industry for Water can also be expected to grow with the emergence of VHR and VVHR (very very high resolution) satellite data for improved spatial resolution, and constellations of small satellites for better temporal resolution. As mentioned above, the strong link between Water and Agriculture also offers business opportunities. The use of water for Agriculture is one of the largest water markets, and the use of EO for agricultural monitoring is already a large, established market (second only to defence & security). A key opportunity lies in developing EO VAS services for the water component of the Agriculture market.

D1.6 identified a large number of possible links between EO parameters specific for the inland water quality and quantity and 12 of the UN Sustainable Development Goals. This highlights the relevance of EO capabilities towards achieving the SDG targets by 2030, and demonstrates the need for broad spatial scale and fine temporal resolution global monitoring of inland waters to achieve the SDGs. However, these have been identified as potential links that have not yet been addressed. This highlights many opportunities for research, industry and Copernicus.

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The industry interviews (in section 3.2) helped us to identify innovation and business opportunities distributed across the whole EO Value Chain. It showed also that many participants are either using or planning to use Copernicus and in general they perceive it as a good or excellent potential for their business or organisations. Additionally, the interviews provided a series of unanticipated findings such as the willingness to become part of the Copernicus Contributing Missions or the request for Copernicus Services to be more responsive by adjusting the focus towards service co-design or co-development, with end-users in mind and service KPIs based on the actual use. Other findings confirm the trending need of end-user groups for better accuracy and resolution imagery in order to assess or monitor water bodies regardless of scale, or the need of end-users of being provided with actionable information in order to make better decisions. Realistically speaking, many of the more onerous user requirements (e.g. 1 m spatial resolution with daily coverage) will not be met, in the near future, by EO alone, but rather will require the integration of EO data with that from other sources such as in-situ, citizen science and drone campaigns.

The interviews also provide hints about the EO capabilities to accelerate the digital transformation of water resources management and monitoring and the capacity of new technologies such as AI, ML, automation and cloud infrastructure to provide solutions to the sector challenges and barriers. Capacity building and increasing awareness among end-users is identified as an important driver which has capacity to increase the uptake of the Copernicus program and create new opportunities to innovate or generate new business models (e.g., aquafarming, insurance, tourism).

The use of Copernicus for water management can be potentially driven by EU and international policies, which comprises a plethora of instruments with varying legal standing. However, the great majority of directive texts do not specify the use of EO data as a method to accomplish the aims of improving certain water-related sectors. Having said that, many documents providing policy actions or recommendations do promote EO data

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as a viable technology for relevant applications. Thus, the use of Copernicus can be boosted by policy makers. At the same time, there is no need to describe specific techniques to accomplish one or more results in the field of inland water management: on the contrary, general formulations such as, for instance, the demand for monitoring or mapping measures already entails the use of space technologies, and hence, Copernicus.

Currently, monitoring of inland water is not defined as a primary objective of current or future Sentinel missions or Copernicus services. The EO downstream sector (offering water products and services) currently leverages on the Sentinel data primarily designed for other applications and utilises components of the Copernicus services developed for the land, atmosphere, climate, emergency and marine thematic areas. This highlights a gap specifically for the inland water sector regarding EO upstream infrastructure and services. This should be addressed by raising the awareness of the importance of the water sector (drinking water, food security, leisure, etc.) within the space domain, and highlighting the user requirements for information emanating from this sector (as per the Water-ForCE project). These user requirements should contribute to the planning and development of future payloads and satellite constellations. We can also highlight the lack of Water information services based on multi-source data and analytics, and indicators towards the SDGs.

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