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Research and Innovation Action

Delivering Advanced Predictive Tools from Medium to Seasonal Range for Water Dependent Industries Exploiting the Cross-Cutting Potential of EO and Hydro-Ecological Modelling

PrimeWater Multi User Panel Stakeholders Week (15-19 November 2021) – Summary report

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Executive Summary

PrimeWater is a Horizon2020 funded research project that generates information on the effects of upstream changes on future water quality and quantity. Building on advanced Earth-Observation (EO) data products, integration with additional data sources and diagnostic modelling tools, public and private sector decisions for water resources management are provided with better and actionable information. Within PrimeWater, a co-development strategy is used which aims to bring together various perspectives of stakeholders in the design, development and implementation of end-products which are adopting EO-based systems in water quality management.

To facilitate co-development, an international Multi-User Panel (MUP) has been established involving industry representatives and experts from across the water sector. This second MUP Stakeholders Week took place from 15 November through 19 November 2022. This document provides a summary of the discussions and activities during the week which are informing the continued development of products and services under PrimeWater. There were 518 registered attendees throughout the week, with 63% from government organizations and university/research institutes. Participants with interest and experience in water resources management, disaster risk management, potable water, energy, amenity and recreation, and aquaculture provided inputs on problems and current response, as well as feedback on their perspectives of the application of EO monitoring and forecasting services in dealing with water quality and quantity issues.

In each sector, the lack of reliable forecast data, resulted in a lack of preparedness, which subsequently affected costs, operations, service provision, and compromised infrastructure. These concerns were addressed with prospective solutions that rely on the future development of EO-derived services and products. This includes forecasts of major events such as harmful algal blooms (HABs), floods, and droughts, and climate change predictions.

Each day the PrimeWater platform and its applications through case studies from Italy (Lake Mulargia), Australia (Lake Hume and Melbourne Western Water Treatment Plant), and the USA (Lake Harsha) were presented. The tool can be used to simulate multiple hydrological processes including algal growth, nutrient fluxes, water flow, and physico-chemical parameters. The models performing the simulations use different forms of data for calibration like meteorological forcing, in situ measurements, historical data, and EO images.

Sectoral specific presentations and discussions confirmed that each sector values the need for reliable forecasting data for the operation of systems. Predicting HABs, dissolved oxygen levels, and pollutant tracking help stakeholders plan (e.g., aquaculture harvests), take prevention measures, and secure resources to meet water demand. Many speakers mentioned a lack of reliable information resulted in higher costs due to damage, loss of aquaculture, and reactive treatment after the event

occurs. Knowing when droughts and flooding will occur also affects energy generation, infrastructure integrity, and water supply. Stakeholders prefer forecasts at least 2 weeks ahead to take proactive measures.

Coupling EO services with different methodologies (climate models, machine learning, local knowledge) was the main solution suggested throughout the week. Stakeholders pooling funds for improved access to data and services was the other option as financial limitations play a role in the type of data some companies can use. There is no 'one size fits all' solution as different geographical regions and sectors have different problems which require various EO services and products. End users' capacity building can ensure that EO service providers can tailor the services to the needs of the region and/or sector.

Along with sectoral discussions, participants engaged in GroupMap sessions, on Days 2 (Disaster Risk Management) and 5 (Amenity & recreation, and Aquaculture), to gather feedback and inputs of the participants on indicators and parameters for HAB outbreaks, as well as the barriers to water quality forecasting and warning. An important water quality indicator for both sectors is chlorophyll which is unsurprising as it can be measured in-situ and by satellite. Impact indicators identified related to disaster risk management include reduced fish productivity, reduced tourist numbers, and increase salt content which can affect agricultural production. Both sectors identified a lack of data or monitoring of water quality parameters, and the relevance of warnings to stakeholder activities as main barriers to warnings and forecasts. Financial investment was a concern from the disaster risk management sector, whereas reliability featured more prominently with the amenity & recreation, and aquaculture sectors. Finally, reflections on the benefits and impacts of 10-day forecasts highlighted that EO products and services plays an important role in overall monitoring and can provide essential early warning as well as increased reliability. Detailed descriptions of the results for each day can be found in sections 3.2 and 3.5.

Participants were also guided through a short interactive session which prepared them to complete the User preferences for Earth Observation services survey.

MUP Stakeholders Week Evaluation

A feedback survey was circulated after the MUP week and was completed by 5% of participants. Based on the responses to this survey, the majority (47%) of the participants thought the week was excellent, 33% felt it was very good, and 2% thought it was fair. The survey also asked about the technical content and its usefulness and applicability where 56% of the participants replied that the content was acceptable, and applicable in their respective sectors. For future MUPs, most of the participants responded that they would prefer the focus be on monitoring, while the remainder of respondents prefer decision support systems, and forecasting. The full breakdown of the feedback survey can be found in section 4.

1. Introduction

This report provides the outcomes of the process undertaken by PrimeWater to 1. understand how different sectors are using Earth Observation (EO) technologies to address issues such as extreme hydrological events (EHEs) and harmful algal blooms (HABs) and 2. Identify the added value of PrimeWater products (e.g., advanced predictive tools based on hydrological and ecological forecasts; Early Warning System; EO-monitoring and hydro-ecological modelling tools; near-surface and satellite remote sensing and hydrodynamic modelling tools) when addressing these issues. This report presents the results from the discussion that took place during the PrimeWater Multiuser Panel Stakeholders Week (15-19 Nov 2021) between representatives from the following sectors: Water Resource Management; Disaster Risk Management; Potable Water; Energy; and Amenity, Recreation and Aquaculture.

The adoption of EO-based systems in these sectors requires integration of ecological, financial, and social perspectives. These are needed to shape how information from EO systems is packaged and then used to inform real-world decision-making. Co-development is a strategy that aims to bring together various perspectives of stakeholders in the design, development, and implementation of end-products. The co-development approach intensifies the co-operation between different water-related sectors and the developers, which in turn improves the level of confidence in the final system.

PrimeWater has designed a comprehensive consultation procedure that is being deployed from the early stage of the project throughout the development phase. This approach consolidates user requirements into the system design, followed by an industry evaluation of the end products, to achieve wide acceptance and uptake by different sectors. To facilitate co-development, an international Multi-User Panel (MUP) has been set up and includes industry representatives and experts in diverse thematic areas of the water sector actively engaging them in the co-development process from the early design to the development stages. The first MUP workshop, held in October 2020, gathered initial feedback on what different users think about different services (e.g., monitoring water quality, forecasting, and provision of decision support on forecast and observations).

The process of defining end-user requirements is meant to ensure that project objectives incorporate sound understanding of the needs and expectations of the end-users from an early stage through continuous engagement and feedback throughout the project. This creates ownership and interest in application of the relevant tools to their operations.

This document summarises information gathered during the PrimeWater MUP Stakeholders Week (15-19 Nov 2021) of how different sectors are using Earth Observation technologies and how the products developed within PrimeWater can be used to address issues such as HABs in each of the sectors. This report provides the structure of the MUP week and results obtained from the discussion with the different sectors.

2. Consultations with PrimeWater Multi-User Panel

Consultations to assess end-user needs were initiated through an MUP set up by the PrimeWater project. The purpose of the MUP is to serve as an international panel of users of EO downstream services who provide expert feedback on the EO-enabled services developed and how they can be extended in the context of the PrimeWater project and participate in the co-generation process itself through dialogue. The activities of the MUP are a complementary tool for disseminating project outcomes, with members also serving as project ambassadors.

Initially, the MUP was intended to comprise at least 20 representatives from the private sector, government and research institutes or experts in their respective fields, covering all thematic areas addressed by the project (i.e., environmental protection, water resources management, emergency planning, potable water production, amenity and recreation, hydropower production). As all engagement has been online, PrimeWater has used this opportunity to expand the involvement of interested representatives from different thematic areas.

Specific activities of the MUP include:

- Participation in the annual MUP workshops to provide feedback and inputs into PrimeWater products (e.g., are they relevant, how can they be integrated into different sectors) and inform strategic choices made during the lifespan of the project.
- Participation in on-line discussions, workshops, surveys, blogs, and any other strategies to consolidate the participatory process between consecutive workshops.
- Co-hosting seminars and panel discussions at industry events; and
- Dissemination of the project results through their networks, elaboration of recommendations and feedback to the consortium partners.

The MUP is scheduled to meet 3 times over the course of the project (3 years). The first meeting took place remotely on October 21st, 2020 and used a combination of presentations and interactive tools to inform PrimeWater of what issues, gaps and services end-users need. The second MUP was organised from 15th-19th November as ‘Stakeholder’s week’. Stakeholders from different sectors were invited to a 2.5-hour session each day focusing on a sector-specific discussions.

The meeting planned for 2022 will ideally be in-person but will adapt to the global situation due to the COVID-19 pandemic. Between meetings, the consortium is engaging with MUP members through a variety of approaches including newsletters, webinars and additional online discussions focusing on more specific issues (e.g., applicability of information on forecasting for specific parameters and a specific sector) (see Figure 1). The expected time for the MUP is between 10 – 20 hours per year, depending on the level of involvement.

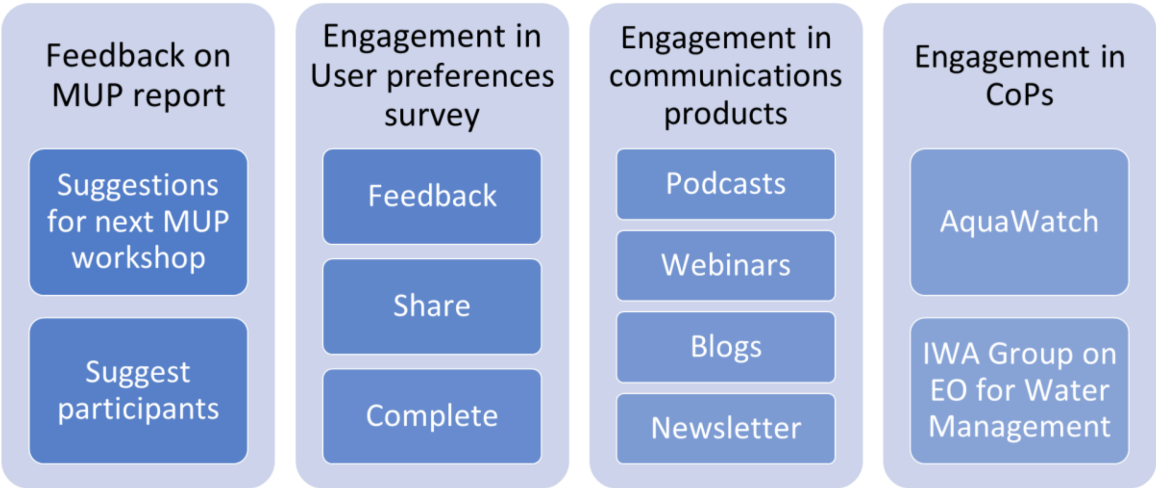

Figure 1. Engagement mode for PrimeWater MUP

2.1 Objectives and structure of the PrimeWater Multi User Panel Stakeholders Week

The objectives of the PrimeWater MUP Stakeholders Week were to:

- Provide an overview and update on the services that PrimeWater can offer to participants.
- Understand how different sectors (Water Resource Management; Disaster Risk Management; Potable Water; Energy; and Amenity Recreation and Aquaculture) are using EO service to address issues such as EHEs and HABs.
- Discuss the added value of PrimeWater products when addressing these issues (e.g., advanced predictive tools based on hydrological and ecological forecasts; Early Warning System; EO-monitoring and hydro-ecological modelling tools; near-surface and satellite remote sensing and hydrodynamic modelling tools).

These three objectives were addressed across five sessions of around 2-2.5 hours each day organised from 15th to 19th November. Interested participants could register for more than one session over the week, and registration and participation were made publicly available. The overall structure of each session was:

- Part 1 – Introductory session with presentation "Setting the Scene" according to the topic of the day and presentation of PrimeWater's operational platform;
- Part 2 – Experts' presentation with moderated discussion with Q&A from audience.

- Part 3 – Engaging the audience in PrimeWater survey "User preferences for Earth Observation services", in moderated discussion using the collaborative tool GroupMap or in the Call4Water serious game, according to the day.

The agenda for the meetings is available in Annex 1.

2.2 Participation in 2nd MUP

Overall, **518 people** registered to attend the PrimeWater MUP Stakeholders week and the 5 days recorded **219 unique views**. Below (Figure 2) the percentage of participants who joined one or more sessions is presented. 47% participants joined only one day of the MUP week, 19% joined two days of the week, 10% joined three days, 8% joined four sessions and 15% joined each day of the week.

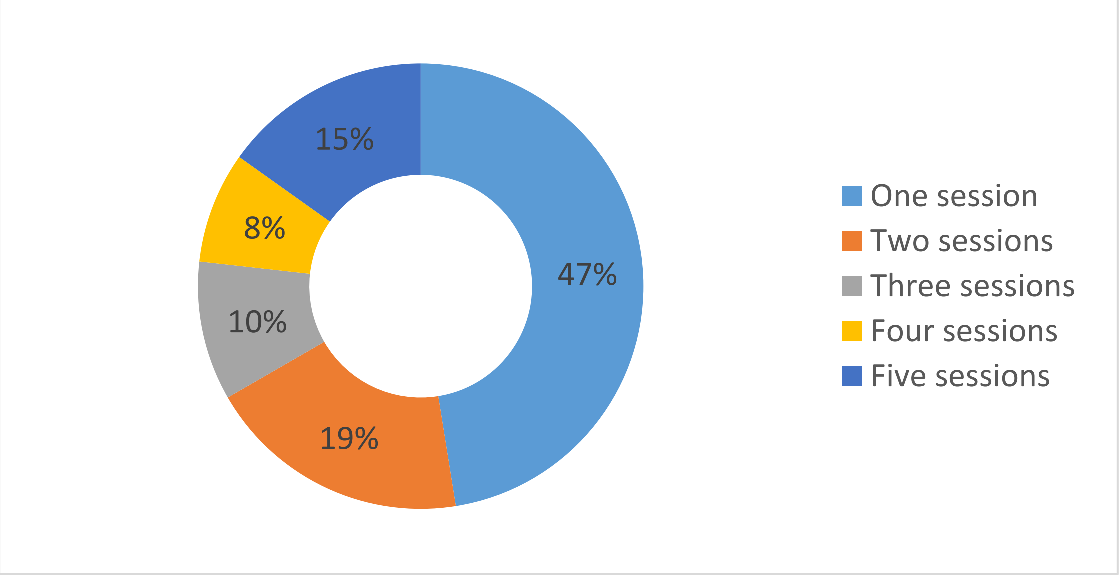

Figure 2. Percentage (%) of participants who joined one or more sessions during the 5 days of the PrimeWater MUP Stakeholders Week (sample = 219)

During each day of the MUP Stakeholders week, a poll was used to analyse the sectors of the participants (Figure 3) and if they use EO technologies in their job (Figure 4). Over the 5 days, 56 participants responded to the poll.

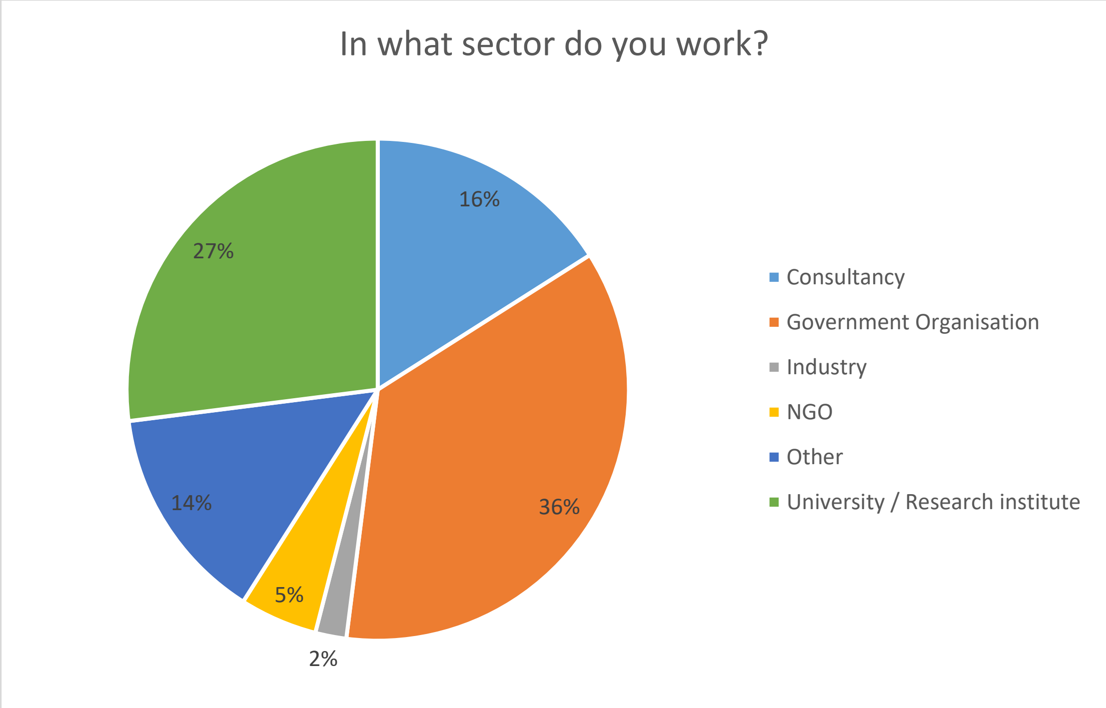

Figure 3. Distribution of the sectors of the participants over the 5 days of the PrimeWater MUP Stakeholders Week (sample = 56)

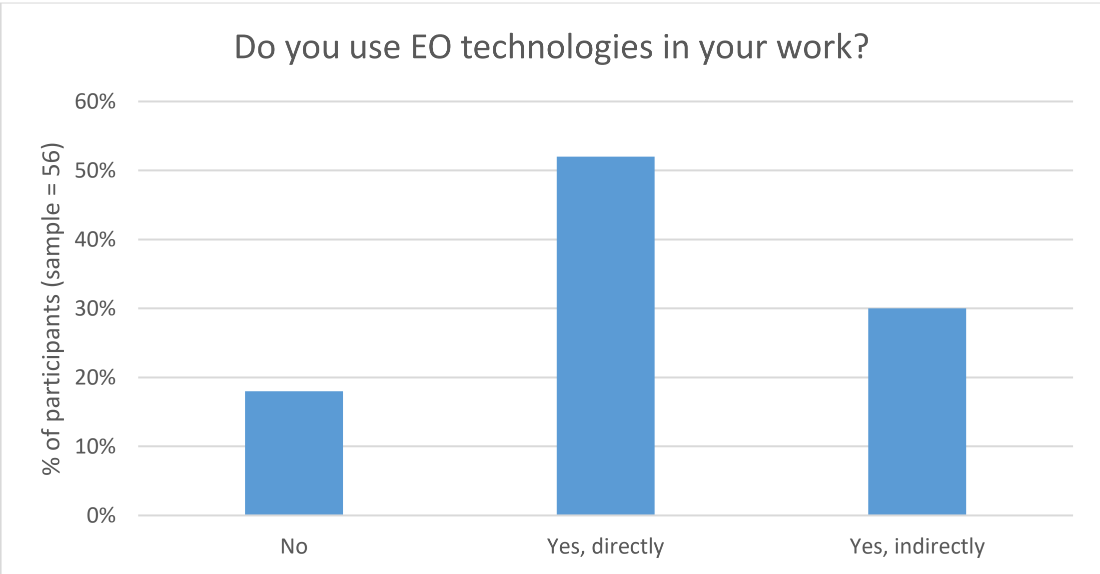

Figure 4. Percentage (%) of participants according to the use of EO in their work over the 5 days of the PrimeWater MUP Stakeholders Week (sample = 56)

3. Summary of each session

3.1 Day 1 – Water Resource Management

The first day of the PrimeWater MUP Stakeholders Week (15 Nov) focused on Water Resources Management.

The recording of the day is available here.

The presentations are available here.

During the **first session**, participants were welcomed by Dr Samuela Guida, from the International Water Association (IWA). Apostolos Tzimas (EMVIS) introduced the topic of the day and Evangelos Romas (EMVIS) presented the PrimeWater's operational platform.

The format for the **second session** was experts' presentation (Figure 5) and moderated discussion. Speakers included:

- Christophe Brachet, INBO – Presentation title: *Spatial altimetry and applications in Pilot River/Lake Basins*
- Stephanie Schollaert Uz, NASA – Presentation title: *Preparing for upcoming hyperspectral missions: PACE and SBG*
- Henrique Reisdorfer Leite, LACTEC, Presentation title: *Earth observation for water management - Use cases in Brazil*
- Megan Coffer, US EPA (moderator)

Figure 5 - Postcard used for the promotion of Day 1 – Water Resources Management

Panellists in the **first and second sessions** were asked a range of questions respective to their presentations. Evangelos Romas was asked if the confidence level is based on a statistical model or on model efficiency, and he stated that the confidence interval is available on the machine learning (ML) models. Many ML models are trained, and based on the answers of each model, they can quantify the confidence level. Stephanie Schollaert Uz was questioned on the challenges which satellite data can help users address, and the obstacles hindering it. Schollaert Uz highlighted that the resource managers in the Chesapeake area would like the satellite imagery to provide early warning for multiple events including harmful algal blooms, polluted runoff, and hypoxia (this is specific to the region). The main obstacle, however, is cloud cover. Even though they are using the forecast produced by NOAA, higher spatial resolution and more frequent revisits have been requested to see between the clouds. Schollaert Uz also mentioned the use of Glimmer data that would increase data and improve the decision-making process.

Henrique was questioned on the integration of commercial satellite data into their research methods. He stated clearly that pricing is a very serious issue due to the economic situation of Brazil. Christophe Brachet tackled 2 questions: one about the realistic temporal resolutions of the products used in decision-making processes, and the other on the presence and quality of disaster responses. Christophe stated depending on the different satellites, data can be received every 7-10 days, or sometimes 15+ days, thus making it useless for early warning systems. So, in conjunction with satellite altimetry data, in-situ measurements are used to improve results.

Finally, during the **third session**, Nikos Georgantzis (BSB) guided the participants through the survey "User preferences for Earth Observation services". The survey is targeted at anyone interested in water monitoring and forecasting services and it will help us study the attitudes of users and stakeholders towards Earth Observation services. The survey is part of our co-creation approach, integrating the users' preferences and associating user characteristics and needs with specific aspects of available products and services (Note: The resulting dataset will be processed and stored anonymously. All information and results will always be presented in an aggregate form and will be used for the purpose of this research only.)

3.2 Day 2 – Disaster Risk Management

During day 2 (16 Nov 2021), the focus was on Disaster Risk Management (Figure 6).

The recording of the day is available here.

The presentations are available here.

Figure 6 – Day 2 of the PrimeWater MUP Stakeholders Week with focus on Disaster Risk Management

During the **first session**, participants were welcomed by Dr Samuela Guida, from the International Water Association. Apostolos Tzimas (EMVIS) introduced the topic of the day and Evangelos Romas (EMVIS) presented the PrimeWater's operational platform.

The format for the **second session** was experts' presentations and moderated discussion. Speakers included:

- Carlos Uribe, UNDRR ROAMC Panama US Disaster risk management – Presentation title: *The Disaster Risk Reduction Landscape in the Americas and the Caribbean*
- Dr RP Singh, ISRO – Presentation title: *Satellite based assessment and forecasting*
- Cindy Lebrasse, US EPA (moderator)

The **third session** was organised as an interactive discussion with all participants using GroupMap, a collaborative tool moderated by Katharine Cross (IWA Consultant). The purpose was to gather feedback and inputs of the participants on key components for a forecasting-based disaster risk management service (i.e., early-warning) for HAB outbreaks. The results of the discussion are in the sections below.

3.2.1 Stakeholder mapping

Participants were asked to place the organization in the quarter of the disaster risk management matrix where best fits in terms of core business:

- Risk knowledge and analysis → focus on understanding risks in an area
- Monitoring and warning services → providing information to relevant authorities on water related events

- Response capability → this would be response on the ground, possible coordinating response in the event of a disaster
- Dissemination and communication → when there is a disaster, coordinating communication between stakeholders and to the public

The results of the mapping exercises are in Figure 7. It was noted that most organisations have multiple responsibilities, and the majority of organisations focus on monitoring and warning services.

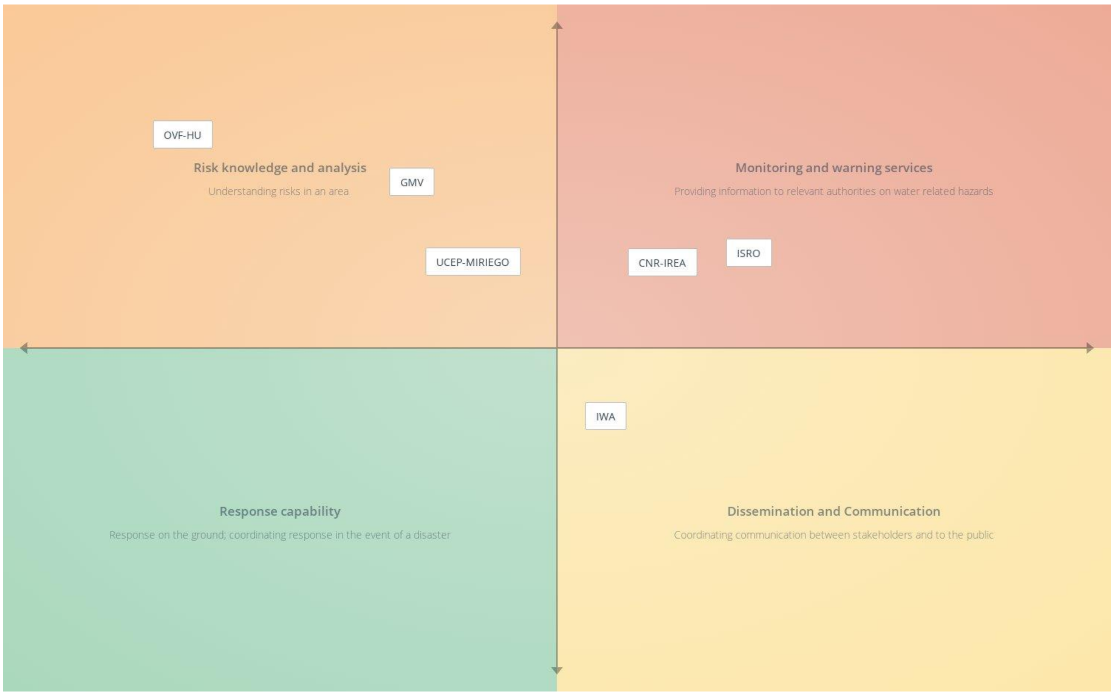

Figure 7. Stakeholder mapping of end-users focusing on disaster risk management

The following questions from the mapping exercise were to determine the types of water bodies participants deal with in their hydroecological operations. There were then questions to determine the 1) level of engagement in early warning, and 2) how important early warning is for an organisation (Figure 8).

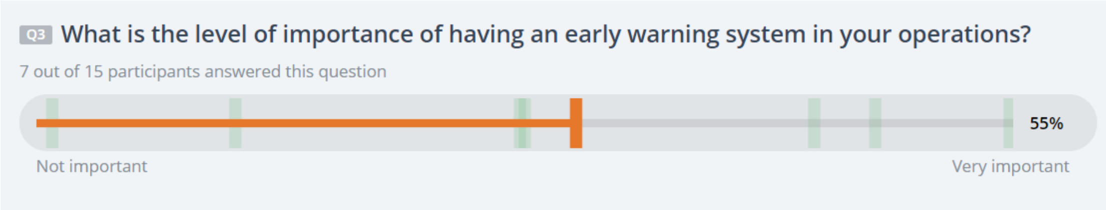

Figure 8. Mapping operations and early warning system engagement of workshop participants

Most of the participants focused on rivers, and only two responded that they also operated or focused on lakes/reservoirs as well. The engagement of organisations in supporting an early warning system, and the level of importance in operations was varied, probably because not all participants specifically focused on early warning issues.

3.2.2 Prioritizing indicators and parameters to describe Phytoplankton Outbreaks

Context

There are different forecasting approaches that can be used for early warning of water quality issues (Figure 9).

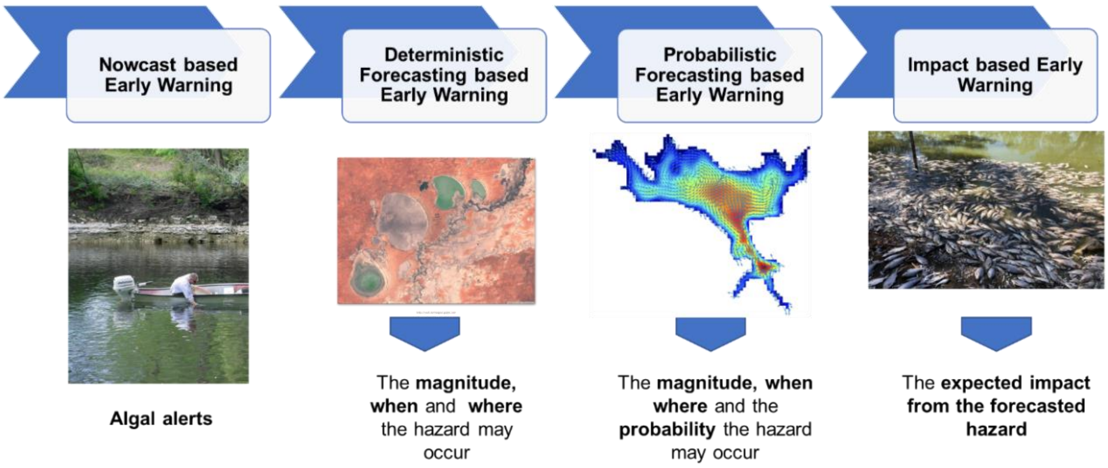

Figure 9. Forecasting approaches to support early warning

The most common are **Nowcast based Early warning.** This uses grab samples and lab analysis, and monthly sampling campaigns. The results are algal alerts as they are happening so reactive measures can be taken,

What is being explored is the use of:

1) **Deterministic Forecasting based Early Warning**, which uses modelled measures of physical, chemical, and biological contaminants; and provides forecasts up to 10 days in advance. This provides information on the magnitude, when and where a hazard may occur.

2) **Probabilistic Forecasting based Early Warning**, which uses an ensemble of modelled measures of physical, chemical, and biological contaminants; and provides forecasts up to 10 days in advance. This provides the same information as deterministic forecasting but also includes the probability of a hazard occurring in time and space.

In deterministic models, the output of the model is fully determined by the parameter values and the initial values, whereas probabilistic (or stochastic) models incorporate randomness in their approach. Deterministic risk considers the impact of a single risk scenario, whereas probabilistic risk considers all possible scenarios, their likelihood, and associated impacts.

The final type of early warning being explored is **Impact based Early Warning**, which uses problem specific Impact Indicators; providing forecasts up to 10 days in advance on the expected impact of the forecasted water quality hazards (such as population affected, or loss in fish productivity).

Results of prioritization of parameters and indicators

An initial list of parameters and indices that could be used as proxy indicators to describe cyanobacteria outbreak areas were provided to participants (Table 1).

Table 1. List of parameters and indicators that could be used as proxy indicators to describe cyanobacteria outbreak areas

	Parameter
Rivers	Outflow from sub-catchments
	Nitrogen, Phosphorus and Sediment loads from sub-catchments
	Temperature of water from sub-catchments
Lakes/ Reservoir	Chlorophyll (green algae, cyanobacteria, diatoms) inside the reservoir
	Cell counts/ bio volume concentration
	Nitrogen (NO3, NH4), Phosphorus (PO4) inside reservoir
	Water temperatures inside reservoir
	Dissolved oxygen inside reservoir
	Indicator
Rivers & Lakes/Reservoirs	Intensification of cyanobacteria bloom Description: The indicator can be calculated from localized changes in chlorophyll levels, providing an indication of Increase/decrease or the Rate of increase/decrease of the cyanobacteria 10 days in advance.
	Evenness of cyanobacteria community Description: The indicator can be calculated based on forecasted values of the different members of cyanobacteria community, based on Pielou' s evenness index. The evenness index (J') might serve as an estimate of the diversity of the algal community describing the change in the dynamics of the cyanobacteria community 10 days in advance.

Lakes/ Reservoir	Reservoir stratification tendency Description: The evolution of various limnologic indicators such as Depth of the thermocline, Lake number, Wedderburn number, Schmidt stability can be calculated based on the forecasted water mixing patterns 10 days in advance.

The participants had the possibility of adding any additional parameters or indices that were relevant to their context. Additions included – irradiance intensity.

The next step was to prioritize these parameters and indicators in descending order as proxies for cyanobacteria outbreaks (Table 2**Error! Reference source not found.**). It should be noted that participants did not need to rank all parameters so those chosen by the majority of participants had a higher overall ranking. Furthermore, as most participants answering focused on rivers, the lake/reservoir specific parameters were not relevant.

Table 2. Consolidated ranking of parameters/indicators to use as proxy indicators to describe cyanobacteria outbreak areas (disaster risk management)

Rank	Title
1	Nitrogen (NO3, NH4), Phosphorus (PO4) inside reservoir
2	Chlorophyll (green algae, cyanobacteria, diatoms) inside the reservoir
3	Intensification of phytoplankton bloom
4	Evenness of phytoplankton community
5	Temperature of water from sub-catchments
6	Water temperatures inside reservoir
7	Reservoir stratification tendency
8	Nitrogen, Phosphorus and Sediment loads from sub-catchments
9	Irradiance intensity
10	Dissolved oxygen inside reservoir
11	Cell counts/ bio volume concentration
12	Outflow from sub-catchments

Impact indicators

The concept of impact indicators was presented which considers how the impact of a HAB event across the various environmental, societal, and economic sectors (or even within the same sector) could be different. Figure 10 depicts the different sectors around Lake Hume, Australia as an example that could be impacted by a HAB outbreak. For example, a HAB outbreak in a water body will require a high level of response in the potable water sector due to the health risks, but this may be less of an issue for the hydropower sector. The impact can also depend on available treatment processes between potable water service providers. Participants were asked to consider the correlations between a HAB event and the impact. The approach would be to identify an appropriate HAB threshold beyond which impacts are acceptable, or the level of impact is unacceptable.

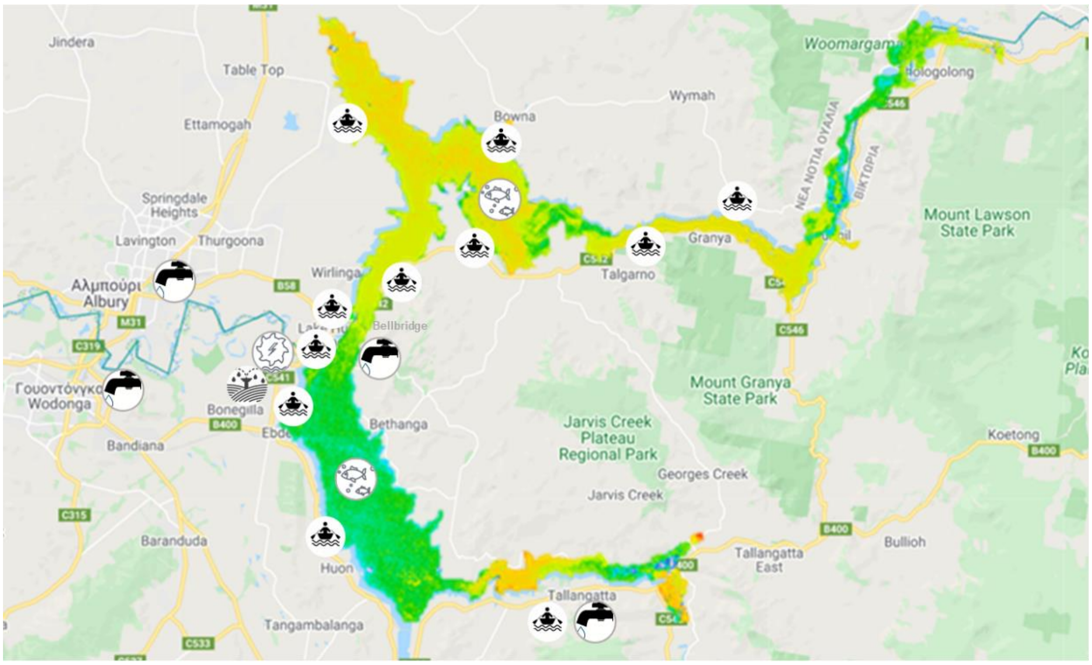

Figure 10. Map of Lake Hume, Australia with different water sector users depicted

Participants were asked to suggest any impact indicators across various socio-economic and environmental domains that could be used to quantify the impact of a cyanobacteria outbreak. The following were suggested:

- Amenity and Recreation → decrease in the number of tourists after an intense bloom event
- Freshwater Fishing or Aquaculture Operations → fish productivity change
- Irrigation → higher salt content

3.2.3 Barriers to water quality forecasting and warning

Participants were asked to reflect on the barriers to water quality forecasting and warning. A suggested list was provided below:

- Lead time of forecasts to incorporate implementation actions
- Level of financial investment and resources required to use forecasts and warnings
- Preference to maintain existing practices
- Relevance of warnings to stakeholder activities – Successful interpretation of forecasts into warnings (hazard proxy indicators, triggers, and impact determination)
- Reliability of forecasts (magnitude, when and where the hazard will occur)

An additional barrier suggested was:

- Lack of data or monitoring of water quality parameters

As with the parameters, the next step was to list the main barriers to forecasts and warnings listed below from greatest to least in descending order (Table 3**Error! Reference source not found.**). It should be noted that as with the parameters exercise, the participants did not need to rank all barriers so those chosen by the majority of participants had a higher overall ranking. Unsurprisingly, a lack of data or monitoring was a key barrier as forecasts need this information to be developed. Secondly, there needs to be sufficient resources invested in developing forecasts to ensure they are produced and of good quality.

Table 3. Ranking of main barriers to forecasts and warnings listed below from greatest to least in descending order (disaster risk management)

Rank	Title
1 (greatest)	Lack of data or monitoring of water quality parameters
2	Level of financial investment and resources required to use forecasts and warnings
3	Relevance of warnings to stakeholder activities – Successful interpretation of forecasts into warnings (hazard proxy indicators, triggers and impact determination)
4	Preference to maintain existing practices
5	Lead time of forecasts to incorporate implementation actions
6	Reliability of forecasts (magnitude, when and where the hazard will occur)

3.3 Day 3 – Potable water

Day 3 (17 Nov 2021) focused on Potable Water (Figure 12).

The recording of the day is available here.

The presentations are available here.

Figure 11 - Day 3 of the PrimeWater MUP Stakeholders Week with focus on Potable Water

During the **first session**, participants were welcomed by Dr Samuela Guida, from the International Water Association. Andrea Virdis (ENAS) introduced the topic of the day and Evangelos Romas (EMVIS) presented the PrimeWater's operational platform.

The **second session** was moderated by Katharine Cross. Speakers included:

- Cláudia Guerreiro, Aquapor – Presentation title: *Earth Observation in water safety planning – A Utility Perspective*
- Klara Ramm, EurEau - Presentation title: *Chamber of Economy Polish Waterworks*

Following the presentations in the first and second sessions, speakers and audience were engaged in a moderated discussion.

EO-enabled products and services are being used increasingly within the water sector as more and more utility operators and regulators see the benefits. Understanding the process of getting results to the end-user is important for the application and implementation of these products and services. Kyriakos Kandis of EMVIS explained that training machine learning models requires 100-150 observational data which is about 5-6 years of measurements. These figures reflect the necessary information to have meaningful and accurate development of data driven solutions. For water quality forecasting, Evangelos Romas (EMVIS) stated that the PrimeWater tool utilises Delft3D for reservoir modelling, specifically a coupling of the Delft3D-FLOW and Delft3D-WAQ models for hydrodynamic and water quality modelling, respectively. As both models are 3-dimensional, cell size is 100x100 and the reservoir is discretised in 10-20 vertical layers depending on the depth. The hydrodynamic model is run first to resolve the circulation patterns and water temperature. That information is then added to the water quality model to generate data on nutrient fluxes which then resolves the trophic status of the reservoir. Consequently, physico-chemical parameters like chlorophyll, nutrients, and dissolved oxygen can be simulated in the model. With this, a threat like a HAB can be predicted, giving utilities and water operators time to prevent it.

The challenges utilities face when using these products and services, and overall, are caused by multiple factors including geography, economy, and professional capacity. In order to reduce risks, Cláudia Guerreiro of Aquapor, stated that more complex probes and online spectrophotometers are required for contaminant analysis. Guerreiro went on to highlight that the economic perspective is the 'real' issue. The costs of improved evaluation and analysis can be offset if all stakeholders (upstream, downstream, consumers) pool together and contribute, in a form of hybrid management, transitioning from focusing only on the utility or a reservoir to a systems approach. Regarding leak detection, Klara Ramm, of the Chamber of Economy Polish Waterworks - EurEau, mentioned that it is difficult to accomplish this in all terrains of water distribution networks. Ramm, in response to a participant's encouragement of research in multiple terrains, stated that it requires a large amount of data as well as a very excellent GIS system to generate a digital twin of the network.

On key barriers to using EO in the water sector in their areas of work, Cláudia and Klara responded with the following:

Cláudia: "We understand that this technology is [very] valuable in our area but it is very expensive for the kind of usage that utilities can take advantage of. Technologically we will have to reduce those constraints regarding accuracy so that anyone can use it in their own context; then you would have more engagement. If we have some costs compensation from the stakeholder point of view, then cost is no longer an issue. We are in the beginning of something that will evolve. It will take some time to overcome some challenges (technical, implementation, and data analysis levels) …"

Klara: "… EO is a very prospective solution, but the water utilities are other clients of these services, so they don't do it themselves, they buy data and services (like leak detection) … I think the most challenging and needed is tracing pollutants. If EO can trace pollutants it could detect the migration of micropollutants, especially in waters. Everyone needs systems which will inform us where the micropollutants are, and we would be prepared to treat them properly. Plus, we can find the source of these pollutants."

Finally, during the **third session**, Nikos Georgantzis (BSB) guided the participants through the survey "User preferences for Earth Observation services".

3.4 Day 4 – Energy

The focus of Day 4 (18 Nov 2021) was the energy sector (Figure 13). The recording of the day is available here. The presentations are available here.

Figure 12 - Day 4 of the PrimeWater MUP Stakeholders Week with focus on the Energy Sector

During the **first session**, participants were welcomed by Dr Samuela Guida, from the International Water Association. Ilias Pechlivanidis (SMHI) introduced the topic of the day with a presentation titled "State of the art hydrological forecasting for the hydropower sector". Evangelos Romas (EMVIS) presented the PrimeWater's operational platform.

Dr Ilias Pechlivanidis of SMHI started the discussion in response to a question about why the service, provided by SMHI, does not use sub-seasonal forecasts to predict a month ahead. Ilias stated that the new type of climate models is necessary in order to predict information at the sub-seasonal range. This will require an evolution of service of PrimeWater tools to accomplish these predictions. Ilias also highlighted the ease of setting up hydrological services at other domains in the world using the worldwide hydrological models in the PrimeWater tool. He outlined the process of customisation which includes data extraction, re-delineation to the relevant resolution, parameter recalibration, and finally running the models to provide daily information. He affirmed that setting up global domains is straightforward, and it is just a matter of adapting frameworks that already exist to the region.

Evangelos Romas and Kyriakos Kandis of EMVIS continued by answering queries about the specifics of the PrimeWater tool. When asked about the type of datasets required to set up water quality forecasting in 3D reservoir models, Evangelos stated that both meteorological forcing and hydrological forecasting are used for the hydrodynamic and the water quality models. The meteorological forcing provides parameters that help predict the growth processes of algal species within the reservoirs, and hydrological forecasting help to simulate river discharge and nutrient fluxes. For model calibration, water quality measurements from inside the reservoir are preferred from a historical period of 2-3 years. Following that, Kyriakos was asked, “If I have for a reservoir weekly samples of water quality parameters for a period of 2 years, is this enough for training a machine learning model?”. He responded saying that the data collected would be insufficient. As with all data-driven problems, data adequacy depends on the scale, the complexity, and the dimensions of a problem, and phytoplankton dynamics can be highly non-linear, complex, and a multi-dimensional problem to simulate. So, it was suggested that 200 observational data corresponding to a 5–6-year time period, would work better in the credible development of a data-oriented model.

The **second session** was moderated by Katharine Cross. Cristina Diez Santos (Open Hydro) was the invited expert with a presentation titled “What are the current gaps in hydropower services?”. Cristina and Ilias joined an expert panel moderated by Katharine Cross.

During the panel discussion, hydropower operation in uncertainty, the effects of climate change on energy generation, and the role of technology in the advancement of the sector, were discussed.

Addressing technology’s role in sector advancement, Cristina stated that the new types of technology are great and essential for the water and energy sectors but, highlighted the need for better, more reliable data in this time of vulnerability due to climate variability. “… it is important to have good forecasting and reliable EO data to be able to manage the demand from the reservoir (hydropower, irrigation, water supply, environment). We have the opportunity now to digitalize and improve systems that have been operational for 50 years [or more], making them more flexible and able to produce viable renewable energy.” Ilias continued by stating that sophisticated EO data and the use of UAVs (drones) is the new era of the energy sector. The use of these new methods of data collection, coupled with the new methodologies of machine learning brings added value to forecasting and decision-making.

The effects of climate change stretch across every sector, so understanding how it can affect hydro-energy production and the continued development of the sector is key. Responding to this, Cristina averred that it has a significant impact. It exacerbates the existing challenges in energy production like sediment management, water quantity, and storage capacity. Therefore, proper data forecasting the effects of climate change can allow hydropower companies to improve and make better informed decisions in mitigation, increased resilience through infrastructure safety, sediment management, water flows and downstream impacts, and adaptive measures in extreme events. Ilias added that the impact of climate change varies by region, thus droughts and floods can occur at the same time, just in different places. The seasonality, intra-annual variability, is the change hydropower companies are noticing. There are regions that have observed snowmelt occurring earlier in the year, which requires preparedness by the sector and amended regulation. With this uncertainty, Ilias concluded that for the sector to develop throughout climate change, monthly adaptation is required.

Data reliability is a key factor in the decision-making process; thus, it continuously needs to be improved. Ilias mentioned that service providers need to communicate the reliability to the users. Also, frequent initialisation of the service, and the introduction of sub-seasonal forecasts help to improve data reliability. From an Open Hydro perspective, Cristina stated that forecasting reliability is a challenge with needs differing by the region. Finance, lack of in situ and satellite data, and capacity cause implications on reliable forecasts. Therefore, EO coupled with capacity building, can bridge the gap, and improve the decision-making processes.

From the audience, panellists were questioned on the partnerships with other regions to improve access to data and its reliability, and how EO can help address conflicts which arise when new dams are proposed. Responding to the former, Ilias mentioned that engagement of local partners is paramount because they hold much of the knowledge of the region. A participatory approach is encouraged when generating a service, as local partners would be able to finetune and tailor the service to the region's needs. Also, in response to the latter question, Ilias stated that mid- to end-of-century hydrological projections can be considered in investors decisions but, political affiliations impact the decisions as well. Cristina added that it depends on where these new dams have been proposed. There are regions where the potential has been exhausted and therefore, there is only a need to improve operations. However, adding new capacity needs proper assessments to understand the possible impacts, and for that EO and local data forecasting are essential.

For the **third session**, Ilias guided the participants through the Call4Water serious game (developed in the CLARA H2020 (https://www.clara-project.eu/) project and is also part of the HEPEX (https://hepex.inrae.fr/) initiative) which follows a storyline that sets the decision-making context. The game can be found in https://hypeweb.smhi.se/showcases/call4water-game/, while a publication is available at https://journals.ametsoc.org/view/journals/bams/102/9/BAMS-D-20-0169.1.xml. Participants play the role of reservoir managers of a fictional reservoir which supplies water to a town. The main objectives are first to ensure a water supply to the "Thirsty town" for the summer season, and second to manage an available budget while securing the water supply to the town.

The objective of the game is to train participants to specific forecasting concepts, and to investigate how forecasts are used in decision-making contexts. With an increasing number of hydroclimate services being developed in the past years, it becomes crucial to understand how users apprehend and make use of the forecast quality information provided alongside these services.

The game is not limited to any participant group: participants could have a background on, among others, hydrology, climate, engineering, economy, environment, and agronomy. Additionally, participants could be forecasters, consultants, researchers, decision-makers, traders and other. Through this role-playing game, one can achieve the following:

(1) train participants to the concepts of uncertainty and reliability in seasonal forecasting, and

(2) help service providers investigate the levels of uncertainty and reliability participants are willing to base a risky decision.

3.5 Day 5 – Amenity & Recreation and Aquaculture

The recording of the day is available here.

The presentations are available here.

The final day of the PrimeWater MUP Stakeholders Week focused on Amenity & Recreation and Aquaculture.

During the **first session**, participants were welcomed by Dr Samuela Guida, from the International Water Association. Eva Haas (EOMAP) introduced the topic of the day with a presentation titled "Intelligent water services for Amenity & Recreation, and Aquaculture". Evangelos Romas (EMVIS) presented PrimeWater's operational platform.

Following the presentations, was a moderated discussion based on questions from participants. Eva Haas (EOMAP) started the discussion by responding to questions on the resolution limits for water quality applications, and the length of time it takes to get the final product. Haas stated that EOMAP's use of commercial satellite data allows for the software to read several times daily in terms of temporal observation, and for spatial resolution up to 2 metres. Haas continued the discussion, outlining the process of getting the final product to the user, which starts the moment the satellite data is collected. It is then passed through automated processing chains and quality control. After 3 hours — which is near real-time— users can expect to have the requested image.

Participants wanted to know more about the application of PrimeWater tool in monitoring phosphorus, the input needed to predict chlorophyll-a concentrations in data-driven models, and how the models used are calibrated, and their dimensions. Evangelos Romas (EMVIS) explained that phosphorus concentrations are simulated with the water quality and eutrophication models by Deltares, coupled with a hydrodynamic model. In addition, the same process is carried out with other nutrients and parameters like nitrogen, oxygen, and suspended sediments. It was highlighted that these are all non-optical parameters but with water quality modelling, they can be quantified and used in forecasting. On chlorophyll-a concentrations, Kyriakos Kandis (EMVIS) stated that the data driven solutions that are available and provided are all driven by hydrometeorological achieved variables. A comprehensive list including hydrological inflows from upstream catchments, nutrient influxes and weather data related to radiation, winds, air, temperature, and precipitation are necessary inputs. Kandis remarked that the variables listed were only a subset of what drives the models, but thorough processing selects the relevant ones for increased accuracy and less uncertainty.

Evangelos continued by stating that the models are calibrated with historical data sets including both EO and in-situ data sets. In terms of dimensions, the hydrological models are performed at the catchments level using the European and worldwide version of the model. For PrimeWater, the 4 case studies have been extracted and downscaled using final catchment delineation. In figures, the worldwide set-up uses an average size of 1000 km^2 while in PrimeWater, the US and Australian case studies are using an average catchment size of 500 km^2. The Sardinia case study is using 300 km^2. For the water quality model, it is performed inside the reservoir, using a much smaller cell size. Typically, 100×100 m^2 is selected but this is dependent on the size of the reservoir. Vertical layer thickness is usually 5 m, but this can vary subject to the thermocline in the reservoir. Due to this, stratification events in the reservoir can be resolved without using too many layers which can lead to excessive run times.

During the **second session**, Katharine Cross moderated an expert panel discussion using the collaborative tool GroupMap (https://join.groupmap.com/C63-179-E77) (Figure 13). Finally, during the **third session**, Nikos Georgantzis (BSB) guided the participants through the survey “User preferences for Earth Observation services”.

Figure 13 – Expert panel during Day 5 of the PrimeWater MUP Stakeholders week with focus on Amenity, Recreation and Aquaculture.

The purpose of **second session** was to gather feedback and input on key components how PrimeWater can provide EO services to the aquaculture and amenity & recreation sectors (including early warning). During the GroupMap exercise, the panellists gave their inputs on the questions asked. The expert panel included:

- Jennifer Dorton, SECOORA
- Merrie Beth Neely, GEO AquaWatch
- Emily Smail, NOAA
- Kerstin Stelzer, Brockmann Consult

The sections below summarise the results from GroupMap and the expert panel discussion.

3.5.1 Stakeholder mapping

Participants were asked to indicate their area of interest in either aquaculture, amenity & recreation, or other areas. The majority of those that responded were engaged in either aquaculture or amenity & recreation, or both (Figure 144).

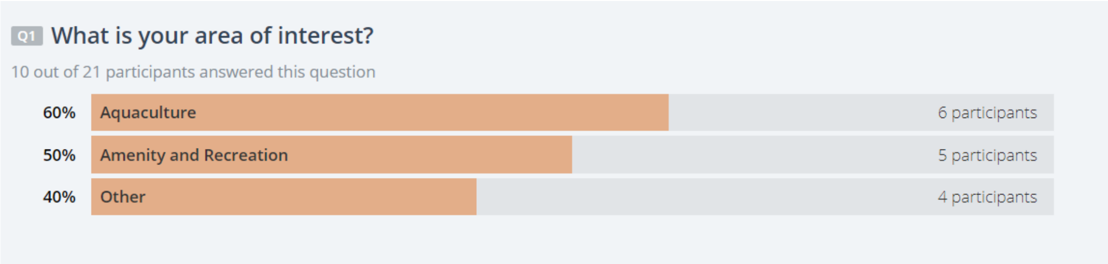

Figure 14. Area of interest of participants in aquaculture, amenity & recreation or other areas

Participants could provide more information on their interest and indicated the following:

- EO related applications
- Water quality (surface and underground water)
- Helping aquaculture users find Earth Observation data to help address management needs
- Water quality
- EO water quality services for different applications for water quality monitoring

3.5.2 Adaptation to HAB outbreaks

Participants were then asked an aquaculture specific question on how best to adapt during a HAB outbreak (Figure 155). Other measures not listed included to harvest early and sell stock.

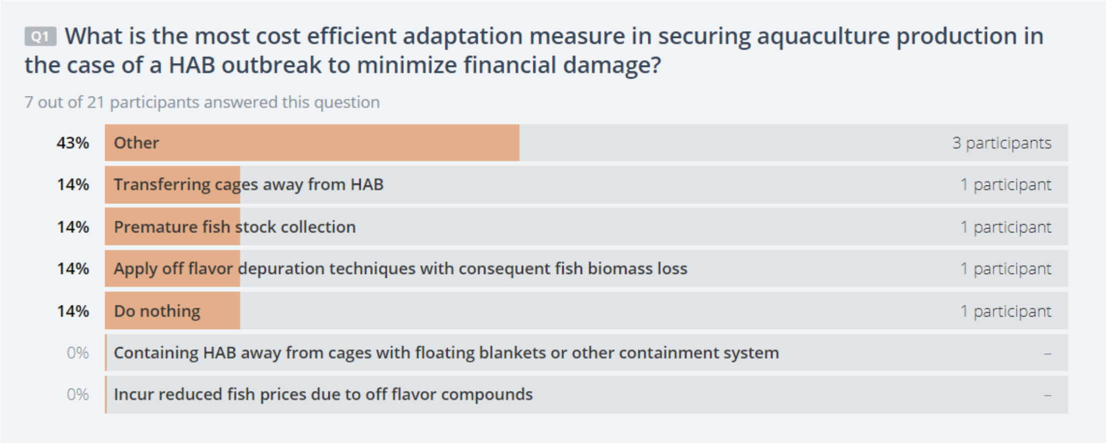

Figure 15. Overview of how best to adapt aquaculture operations during a HAB outbreak

This list was created following a previous discussion with Stakeholders. In particular, premature fish stock collection refers to the action of collecting the fishes from the cages before they are fully matured in order to be able to better market the stock and allow for longer shelf life.

The panellists agreed that adaptation measures strongly depend on the regulations in place in the country where these are applied.

The next set of questions focused on the usefulness of forecasting information and EO for both aquaculture and amenity & recreation. The first focused on whether a 10-day forecast would be useful in either 1) optimising aquaculture production; or 2) ensuring safe condition for amenity & recreation. The respondents indicated that it would somewhat assist to assist significantly, signalling the importance of forecasting information in planning and response in these sectors (Figure 166).

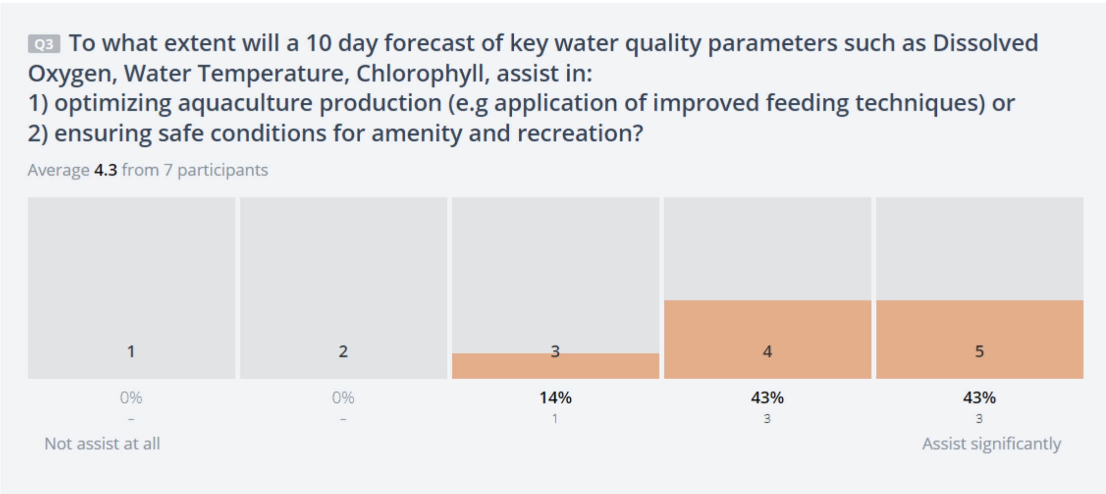

Figure 16. Importance of forecasting information for aquaculture and amenity & recreation

This was followed by a series of questions assessing whether EO can assist with 1) regulatory compliance (e.g., for human health); 2) sustainable production; and 3) environmental protection (Figure 177). Overall, EO was considered most important for environmental protection.

Figure 17. Importance of EO information in aquaculture and amenity & recreation

Discussion with expert panel

Regarding the benefits and impacts of 10-day forecasts on key water quality parameters on aquaculture production, amenity, and recreation, Kerstin stated that the combination of modelling and forecasting using EO, is a benefit. When only using EO, there is observation but not the transition to the future. In order to take actions, advanced insight of what might happen to fish stock is best. Therefore, the combination is preferred as EO brings more reliability to the model result and the simulation. Kerstin also highlighted that while 10 days is quite good, 3 days are even better. Merri Beth echoed Kerstin's sentiments on this, and stated that within Aquawatch, the whole package of EO in-situ observations, and modelling is the gold standard for that, but it requires a bit of trust. Emily added that the users want as much lag time as they can get, however 10 days is still helpful. Emily went on to describe examples off the coast of Chile, where a lot of salmon aquaculture stakeholders have dealt with major losses due to HABs and other events. These users have become interested in forecasting as they have been very important for some of the fisheries there. Emily also supported Kerstin and Merrie Beth on the importance of combining modelling and EO in-situ observations, as well as regionally relevant data. Jennifer responded by mentioning that in her field of work, DO is the most important parameter and having forecasts would allow for big harvests for increased sales and reduces losses.

Further in the discussion, panellists were asked to reflect on the results around HAB adaptation approaches, and the views on how EO can assist with regulatory compliance, sustainable production, and environmental protection. Kerstin started by stating that for regulations it is always a combination of monitoring systems that are already in place and taking EO as additional information — perhaps optimising the existing monitoring programmes — because EO provides insight on where the in-situ measurements should be taken and when. From another perspective, Merrie Beth stated that in the US, EO is useful as an early warning system for when to shut down the shellfish industry and when to start satellite sampling. However, that does not meet the regulatory burden in the US. Lab-based analysis of shellfish meat is still required before any sort of regulatory action can be taken such as a ban placed on, or lifted from, sales.

3.5.3 Prioritizing indicators and parameters to describe Phytoplankton Outbreaks

As on Day 2, an initial list of parameters and indices that could be used as proxy indicators to describe cyanobacteria outbreak areas were provided to participants (Table 1).

The participants had the possibility of adding any additional parameters or indices that were relevant to their context. Additions included – phytoplankton species.

The next step was to prioritize these parameters and indicators in descending order as proxies for cyanobacteria outbreaks (Table 4**Error! Reference source not found.**). It should be noted that participants did not need to rank all parameters so those chosen by the majority of participants had a higher overall ranking. Parameters directly associated with phytoplankton were the top 3 (chlorophyll, phytoplankton species, evenness of phytoplankton community).

Table 4. Consolidated ranking of parameters/indicators to use as proxy indicators to describe cyanobacteria outbreak areas (aquaculture and amenity & recreation)

Rank	Title
1	Chlorophyll (green algae, cyanobacteria, diatoms) inside the reservoir
2	Phytoplankton species

3	Evenness of phytoplankton community
4	Reservoir stratification tendency
5	Water temperatures inside reservoir
6	Dissolved oxygen inside reservoir
7	Intensification of phytoplankton bloom
8	Cell counts/ bio volume concentration
9	Nitrogen, Phosphorus and Sediment loads from sub-catchments
10	Nitrogen (NO3, NH4), Phosphorus (PO4) inside reservoir
11	Irradiance intensity
12	Temperature of water from sub-catchments
13	Outflow from sub-catchments

Participants were asked to provide threshold information on the top 2 parameters/indicators selected based on specific best practices or industry standards. There were only two people who answered these questions providing the following:

- Intensification of phytoplankton bloom - it depends on the water type and the purpose of the alert.
- Nitrogen - depending upon species 5-fold increase over a 2-week time period
- Dissolved oxygen - Drop below 4mg/L

Discussion with expert panel

On the prioritisation of parameters, Emily described why chlorophyll was a popular indicator since it can be used in both satellite and in-situ observations. Plus, from an EO standpoint, it is often used for the initial detection of phytoplankton. For more in-depth information, detecting the type of bloom, and the species causing the bloom are important. Kerstin echoed Emily's sentiments, and Jennifer mentioned that in the future, some perspective should be given for the ocean as aquaculture does not only occur in catchments or reservoirs. From the management lens, Merrie Beth ranked DO highest due to some mitigation techniques being applied in certain areas and water bodies. Continuing, Merrie Beth was pleased to see phytoplankton ranked very high because of algal blooms, mentioning that not all blooms are harmful and negative. Only when it is out of control and posing a threat to aquaculture and the overall health of the water body.

3.5.4 Barriers to water quality forecasting and warning

Participants were asked to reflect on the barriers to water quality forecasting and warning. The same suggested list as on was used on Day 2 (see 3.2.3) including the addition suggestion of "Lack of data or monitoring of water quality parameters".

Additional barriers suggested were:

- Knowledge transfer of conducting water quality exercise

- Short pollution events
- Formatting of the warning or forecast is received matters a LOT - people like it pushed to them and with the option to activate the internet (if they are on the water not practical)

As with the parameters, the next step was to list the main barriers to forecasts and warnings listed below from greatest to least in descending order (Table 3**Error! Reference source not found.**). It should be noted that as with the parameters exercise, the participants did not need to rank all barriers so those chosen by the majority of participants had a higher overall ranking. Again, a lack of data or monitoring was a key barrier as forecasts need this information to be developed. Secondly, relevance of warning to stakeholder activities is important so the information can be effectively used. And thirdly, the reliability of forecasts was also an important issue to address.

Table 5. Ranking of main barriers to forecasts and warnings listed below from greatest to least in descending order (aquaculture and amenity & recreation)

Rank	Title
1 (greatest)	Lack of data or monitoring of water quality parameters
2	Relevance of warnings to stakeholder activities – Successful interpretation of forecasts into warnings (hazard proxy indicators, triggers and impact determination)
3	Reliability of forecasts (magnitude, when and where the hazard will occur)
4	Lead time of forecasts to incorporate implementation actions
5	Knowledge transfer of conducting water quality exercise
6	Short pollution events
7	Preference to maintain existing practices
8	Format the warning or forecast is received matters a LOT - people like it pushed to them and with the option to activate the internet (if they are on the water not practical)
9	Level of financial investment and resources required to use forecasts and warnings

Discussion with expert panel

The final discussion point was on the barriers and enablers to forecasts and warnings, and how they can be addressed and enhanced, respectively. Emily was hopeful that things will be better for data acquisition in coastal areas, owing to the release of new missions and data products. Emily also mentioned that data sharing amongst stakeholders and engaging with them to ensure the products are accurately tailored to their needs for maximum efficiency. Emily continued the difficulty of capturing short-term pollution events with satellites. They require the use of alerts like in-situ data, stationery platforms, and sensors on aquaculture pens for detection. To close, Emily stated that industry-driven investments are a viable alternative, as it promotes collaboration to produce better products for the region that will improve day-to-day operations.

Kerstin remarked that the point on “preference to maintaining existing practice” is a development that has changed over the past years. 10 years ago, it was difficult to bring EO into practice but now it is an accepted method. This means that EO is increasingly being integrated into practice, which is a good thing. Regarding end user designed alerts, Kerstin underlined how important it is to develop something that can be used as immediately as necessary.

Jennifer added that the format of the warning or forecast is ranked highly mainly because there is a broad range of aquaculture and recreational activities in the Southeastern USA, and the information would be relevant for both groups. So, figuring out how to target and make that information accessible — user friendly like in apps and not websites —is paramount.

4. Evaluation of the PrimeWater MUP Stakeholders Week

After the workshop, a feedback survey was circulated. The results are presented below (considering 44 replies to the feedback survey, ***update: 31 Dec 2021***).

When asked about the duration of the Stakeholders Week, 88% of the people who completed to the feedback survey, replied that the duration was **adequate**; 9% considered it **too long** while 3% considered it **too short**.

When asked about the overall impression of the MUP Stakeholders Week, 47% replied “excellent” while just 2% replied “Fair” (Figure 18).

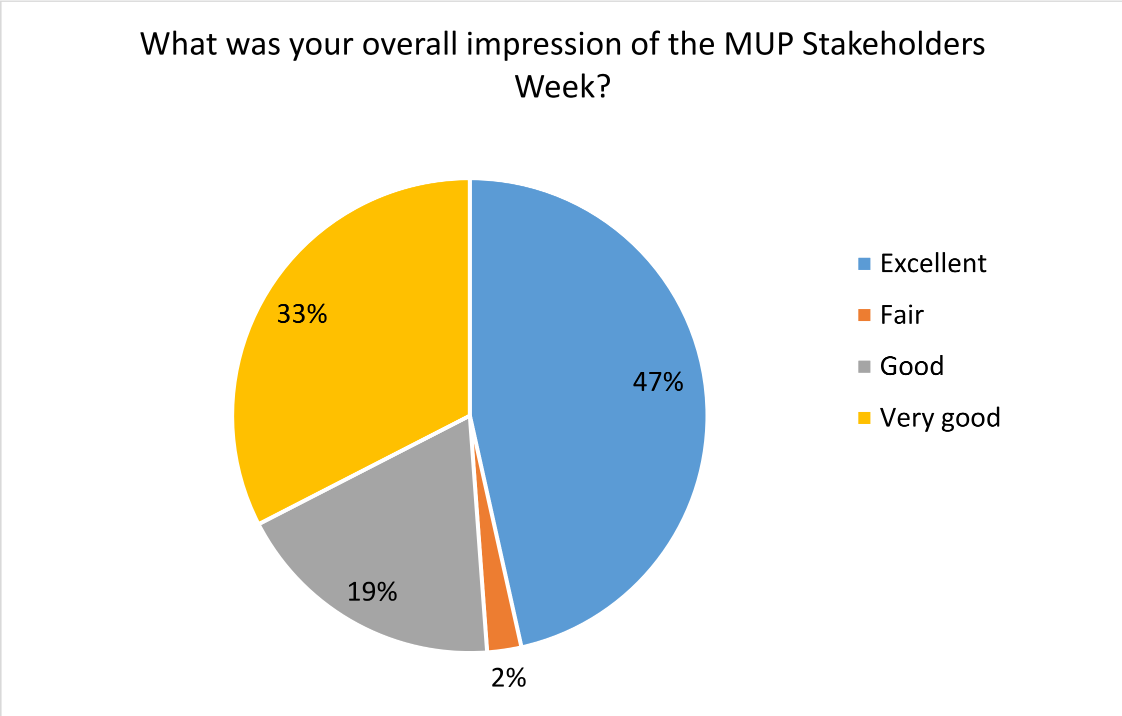

Figure 18. What was your overall impression of the MUP Stakeholders Week? (n = 43)

When asked about the technical content of the MUP Stakeholders Week (Figure 19), 56% replied that it was “acceptable”; 2% said it was “too complex” while 9% said it was too simple. This is to be referred to the sectors of the participants and their knowledge about Earth Observation Technologies.

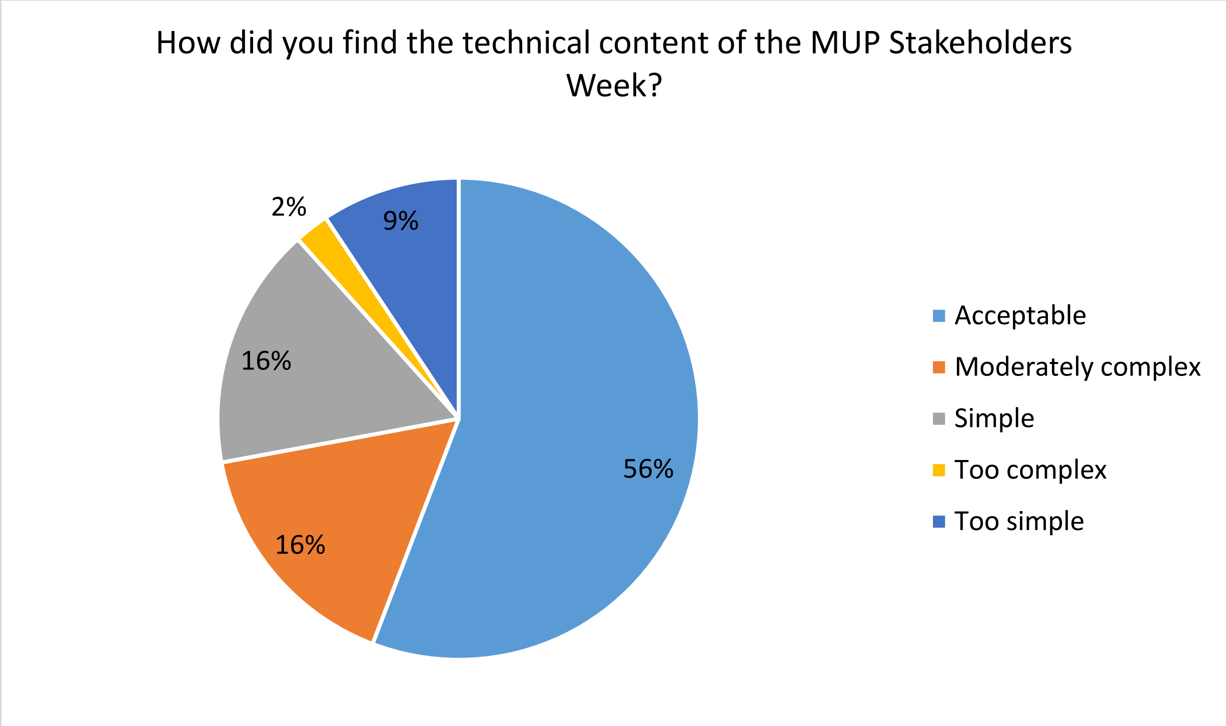

Figure 19. How did you find the technical content of the MUP Stakeholders Week? (n = 43)

The majority of participants (56%) also agreed that knowledge and information gained from the session(s) they attended will be useful/applicable in their work (Figure 20).

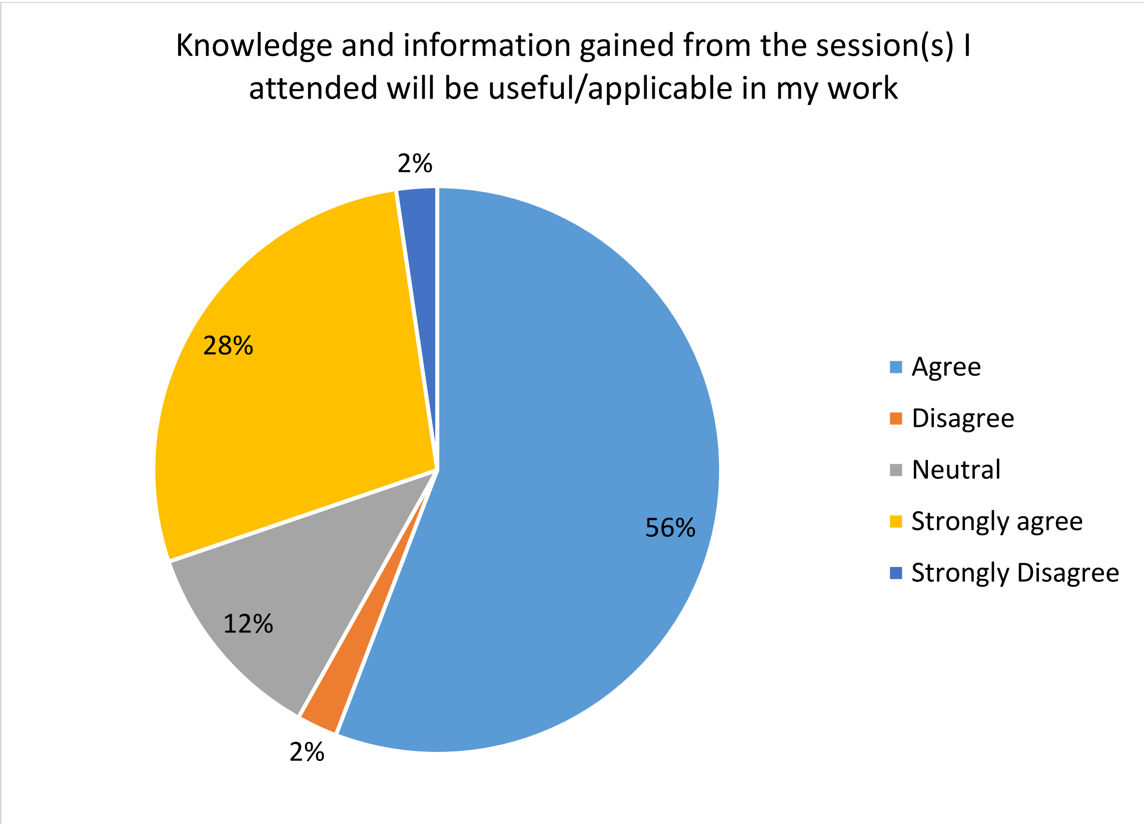

Figure 20. Level of agreement with the following statement "Knowledge and information gained from the session(s) I attended will be useful/applicable in my work" (n = 43)

When asked about the focus of future meetings, Monitoring appeared to attract the most interest from the participants, followed by Decision support system and Forecasting (Figure 21)

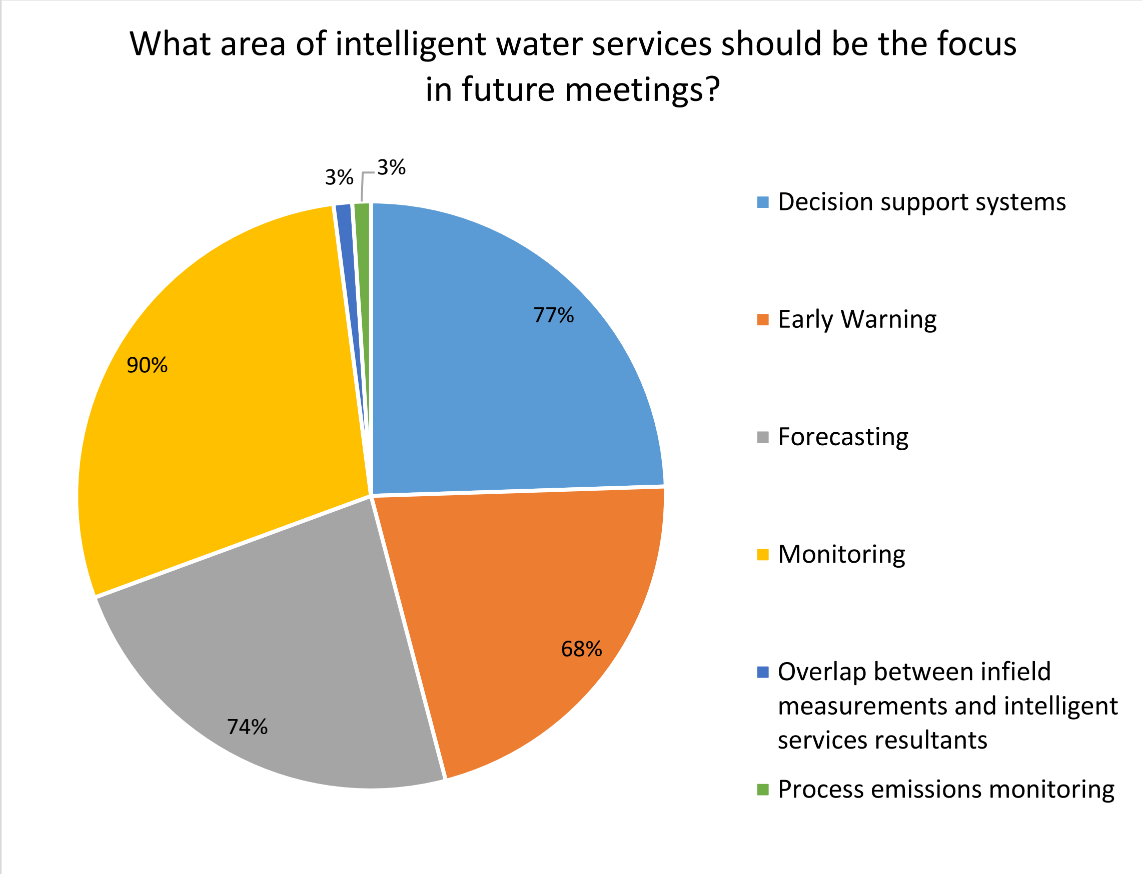

Figure 21. What area of intelligent water services should be the focus in future meetings? (n = 43)

Annex 1

Agenda of the PrimeWater MUP Stakeholders week

The agenda of the 5 days can be downloaded from PrimeWater website:

- Day 1 - agenda
- Day 2 - agenda
- Day 3 - agenda
- Day 4 - agenda
- Day 5 - agenda

EMVIS S.A.

National Research Council of Italy

Swedish Meteorological and Hydrological Institute

EOMAP GmbH & Co.KG

International Water Association

Burgundy School of Business

Ente Acque della Sardegna

US Environmental Protection Agency

Commonwealth Scientific and Industrial Research Organization

Melbourne Water

SatDek Pty Ltd

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