GEO AquaWatch Initiative
Implementation Plan

AquaWatch
The GEO Water Quality Initiative

Vers 2.1 – July 31, 2019

AquaWatch
The GEO Water Quality Initiative

Table of Contents

1 Executive Summary

Water quality is essential for human, ecosystem and economic health. Degradation of water quality can result in human exposure to disease and harmful chemicals, reduction in productivity and diversity of ecosystems and damage to aquaculture, agriculture and other water-related industries. Water quality monitoring is a large multi-faceted field that is directly related to a number of the Group on Earth Observation's societal benefit areas as well as a variety of policy and sustainable development goals. There are many available data products offered by data service providers, which are funded through a variety of regional, national, and international sources for which minimum quality standards and best practices are lacking.

The overall goal of the AquaWatch Initiative is to develop and build the global capacity and utility of Earth Observation-derived water quality data, products and information to support effective monitoring, management and decision making. The objectives to achieve this goal are:

Objective 1: Facilitate effective partnerships between the producers, providers and users of water quality data, products and information.

Objective 2: Improve quality, analysis, and integration of in situ and remote sensing water quality data.

Objective 3: Develop and deliver best practices, minimum quality standards, and independent tools for users to assess fit-for-purpose water quality products and information services.

Objective 4: Support technology transfer and access to water quality data products and information.

Objective 5: Advocate for increased education and capacity for the use of water quality information for decision making.

As a GEO Initiative, AquaWatch will support the need for global water quality data, products and information. This support will be implemented by five working groups: 1) outreach and user engagement, 2) observations and data, 3) products and information, 4) distribution access and visualization, and 5) education and capacity building. It is expected that the work of the AquaWatch Initiative will improve decision making, support sustainable development and protect ecosystems. AquaWatch will add value by improving access to data and information, providing a venue for the sharing of best practices and advocating for the importance of sustained and routine water quality monitoring at the global scale. AquaWatch will also link communities with common interests in the freshwater and support global water quality information needs.

AquaWatch is working towards building a single network that integrates existing water quality monitoring efforts for the benefit of the global community. This flagship effort is termed the Global Water Quality Information Service (WQIS) (See section 8.2.1). This multifaceted project requires the concerted effort of all 5 working groups and their collective efforts contribute to the components required for the construction of the WQIS, as well as other activities aligned with the AquaWatch objectives, None of these objectives have a greater priority as all play an integral part in the WQIS.
AquaWatch participants currently include representatives from various organizations including state, federal, and international governmental agencies, private consulting companies, nonprofit organizations,

nongovernmental organizations and academic institutions. Over the coming year, AquaWatch will work to expand its focus on inclusion of representatives from the in situ and user communities and identify and develop working group activities. Over the next three years, AquaWatch will also work to supporting related Group on Earth Observations activities and will continue work on a long-term project to develop a global water quality information service.

1.1 Looking towards the future
In August of 2018, the AquaWatch community met in Stirling, Scotland to define priority actions for the coming year. Actions for 2018-2019 include:

1.) Capacity Building, Outreach and Education

- Develop software application decision tree
- Survey of training needs and existing capacity
- Guidelines for materials for training/capacity building
- Compilation/vetting of existing training/ gap identification surveys
- Demonstration Projects
- Further development and enhancements of AquaWatch website
- Continued support for Webinar series

2.) Observations and Data; Data Products, Information and Validation; and Distribution, Access, and Visualization

- Update existing data product inventory on AW website (In situ, remote sensed, portal/static data sets), gap analysis and develop a database that is query-able.
- Library of Algorithms - Develop a review paper on this library of algorithms
- Document on optical standards for optical properties – inventory of protocols.
- Citizen science efforts- Papers being developed on smart phones, drones, low-cost sensors
- Provide support for SDG efforts

2 Purpose: Synopsis of Objectives and Benefits

Water quality is essential for human, ecosystem and economic health. Degradation of water quality can result in human exposure to disease and harmful chemicals, reduction in productivity and diversity of ecosystems and damage to aquaculture, agriculture and other water-related industries. The monitoring of water quality allows countries to identify and track water quality degradation and the associated impacts on ecosystems and human health.

2.1 Importance of Water Quality Monitoring to the Group on Earth Observations

Water quality monitoring is a large multi-faceted field that is directly related to a number of the societal benefit areas identified in the Group on Earth Observations (GEO) 2016-2025 Strategic Plan:

- Disaster Resilience,
- Food Security and Sustainable Agriculture,
- Water Resources Management,
- Energy and Mineral Resources Management,

- Public Health Surveillance,
- Biodiversity and Ecosystem Sustainability, and
- Sustainable Urban Development [1].

Water quality monitoring is also required for the successful implementation of policy and sustainable development goals that GEO seeks to support including the United Nations (UN) 2030 Agenda's Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction [2, 3]. Water quality monitoring is particularly relevant to tracking progress towards SDG targets 6.3, 6.6 and 14.1:

> **6.3:** By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
>
> **6.6:** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
>
> **14.1:** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution [2].

For disaster risk reduction, water quality monitoring and forecasting is critical for the development and assessment of safe water and sanitation systems required for successful implementation of the Sendai Framework [3, 4].

2.2 Necessity for the Initiative and Expected Outcomes

Water quality monitoring can be grouped into two approaches: 1) remotely-sensed water quality data from satellite, airborne or ground-based sensors and 2) in situ water quality data, with the development of new information systems including water-quality data assimilation systems focused on sediment and nutrient fluxes and budgets. These approaches, sometimes in concert, can address water quality at local, regional and global scales. . However, many traditional ground-based water quality monitoring programs are deficient. For example, many countries lack the required technical, institutional and financial capacities to develop and maintain water quality monitoring programs necessary to conduct proper water quality assessments on a long-term basis.

As outlined in the GEOSS Water Strategy Report, operational water quality monitoring systems need to be enhanced and expanded and the resulting data and information made openly available as part of the Global Earth Observation System of Systems [5]. Monitoring water quality using remote sensing, in conjunction with strategic in-situ analysis, is needed to monitor and assess water quality conditions to anticipate, mitigate, and even avoid future water quality challenges.

It is feasible to implement a fully operational, spatially comprehensive water quality information system globally relying on systematic observations from past, present and future water quality data. By combining information from multiple water quality variables based on Earth observation, water quality indices such as eutrophication, primary productivity and carbon contents may be calculated. Through fusing data from earth observation with other sources of data such as water quantity, hydrodynamics, biogeochemical modelling it becomes possible to generate hindcast, nowcast and forecast trends and anomalies in nutrient, carbon or primary productivity.

As a GEO Initiative, AquaWatch will support the need for global water quality data, products and information. AquaWatch will add value to by improving access to data and information, providing a venue for the sharing of best practices and advocating for the importance of sustained and routine water quality monitoring at the global scale. AquaWatch will also link communities with common interests in the freshwater and support global water quality information needs.

The Global Environment Monitoring System for Water (GEMS/Water) Programme of the United Nations Environment Programme (UN Environment) is one international programme that will benefit from the AquaWatch Initiative. GEMS/Water is maintaining a global water quality monitoring network that is based on governmental and research monitoring programs to enhance the global water quality database and information system GEMStat. GEMStat relies on voluntary data submissions from UN member states and collaborating partners and lacks comprehensive global spatial and temporal coverage due to capacity constraints of its partners as well as missing data exchange standards. AquaWatch will support the development of water quality data products and data fusion techniques to improve GEMStat's data coverage. AquaWatch will also work with GEMS/Water and other water-related UN programmes to develop and showcase case studies and products that can be leveraged and implemented by UN stakeholders and support capacity building efforts by informing the community on how new technologies (remote sensing, automated sampling systems, etc.) can be used to improve water quality monitoring.

AquaWatch will benefit other GEO Initiatives, Flagships, Community Activities and Foundational Tasks by supporting their water quality data and information needs. This will reduce duplication of efforts within the GEO community and increase collaboration within GEO.

2.3 Mission

The mission of the AquaWatch Initiative is to improve the coordination, delivery and utilization of water quality information for the benefit of society.

2.4 Goal and Objectives

The goal of the AquaWatch Initiative is to develop and build the global capacity and utility of Earth Observation-derived water quality data, products and information to support effective monitoring, management and decision making.

The objectives to achieve this goal are:

Objective 1: Facilitate effective partnerships between the producers, providers and users of water quality data, products and information.

Objective 2: Improve quality, analysis, and integration of in situ and remote sensing water quality data.

Objective 3: Develop and deliver best practices, minimum quality standards, and independent tools for users to assess fit-for-purpose water quality products and information services.

Objective 4: Support technology transfer and access to water quality data products and information.

Objective 5: Advocate for increased education and capacity for the use of water quality information for decision making.

Figure 1. Illustration of the AquaWatch workflow with the five smaller circles representing the five objectives (and associated working groups) which all support the development and use of the water quality information system.

3 Background and Previous Achievements

AquaWatch (previously referred to as the GEO Water Quality Community of Practice or the GEO Inland and Near-Coastal Water Quality Working Group) was formed in response to the need for an international operational (i.e., routine and sustained) water quality information system. The group stemmed from a GEO Inland and Nearshore Coastal Water Quality Remote Sensing Workshop that was held in Geneva, Switzerland, on 27-29 March 2007. This gathering of experts from around the world was hosted by the GEO Secretariat and Co-chaired by representatives from GEO and the Integrated Global Observing Strategy Partnership (IGOS-P) Integrated Global Water Cycle Observation (IGWCO). The workshop was endorsed by GEO as a part of their activities on water resources and water quality initiated in 2006. The workshop was attended by 55 participants representing a diversity of backgrounds, expertise and regions of the world, with a total of 26 countries being represented. Follow up workshops included a Water Quality Algorithm Workshop in Washington D.C. in 2009 and a Water Quality summit in Geneva in 2015.

During the 2015 summit, the group produced a draft 10-year strategic plan for developing water quality assessment products to be used globally. The summit participants also advocated implementing a GEO Water Quality Community of Practice that would complement other GEO activities [6]. In early 2016, the community established a Secretariat and was rebranded as "AquaWatch". In June of 2016, AquaWatch hosted a meeting at the German Federal Institute of Hydrology where priority projects for 2016 – 2017 were identified. Other activities in 2016 included the initial development of a water quality monitoring project inventory (revised in 2019), and AquaWatch support of the Meridian Institute and Pisces Foundation in preparations for a workshop in Wisconsin – *Using Remote Sensing to Empower the Public to Address Water Pollution*. AquaWatch also worked with the Meridian Institute to set up SharePoint site to support future collaboration between Wisconsin workshop attendees titled "Using Remote Sensing to Address Water Pollution Collaboration Hub".

In 2017 we produced an informational booklet on the monitoring of Earth Observation of water quality, the production of a new website (www.geoaquawatch.org) and transitioned to the governance structure of AquaWatch. During the 2018 workshop in Stirling, UK we developed 2018-19 annual work plan with specific task for cross-functional teams comprised of members of 2-3 related working groups to accomplish within the next 12-18 months. The tasks advance the goals of the identified work packages, including a revised approach to building the Water Quality Information Service leveraging existing data products and infrastructure.

Much has changed in the water quality field in the decade+ that AquaWatch has been active. The technology to monitor water quality is continually improving and becoming more effective (see section 8). A portion of AquaWatch's charge is to keep current and relevant in the community and evolve along with the technology. New cloud-based computing efforts and machine learning are rapidly advancing our monitoring and data gathering abilities.

AquaWatch has been and continues to be, for the most part, a "best effort" activity, relying on participants to volunteer their time. This model has always been a challenge and member involvement varies as their schedule permits. The funding by US NOAA to support a part time Secretariat and Director has greatly accelerated the development of the AquaWatch initiative. This support together with the construction of the governance structure and filling key leadership positions has brought much needed continuity and stability to the initiative. Continued funding for programmatic support will always be a challenge

4 Relationship to GEO Engagement Priorities and to other Work Programme Activities

AquaWatch activities will be conducted on a global scale with prototype projects being focused at the local and regional scale (see section 8.1.2). These demonstration projects are seen as a stepping stone towards the full buildout of the WQIS. Management and coordination activities will be conducted initially by the AquaWatch leads and the Secretariat. In the 4th quarter of 2017, these tasks became the responsibility of the Steering Committee and Working Groups outlined in section 9.

AquaWatch activities will support and be coordinated with many other GEO Work Programme activities. Existing ties with other GEO Work Programme activities include:

<u>GEO GLOWS:</u> One of the co-leads of AquaWatch (Paul DiGiacomo) is on GEO GLOWS Steering Committee. The AquaWatch Secretariat strives to collaborate with GEOGLOWS on projects within the areas of overlap between Initiatives.

<u>GEO Health</u>: We have actively supported their data collection activities in 2018 and collaborated with Oceans and Society – Blue Planet on aspects of fulfilling SDG 14.1.1- Coastal Eutrophication efforts for monitoring plastics and water quality in inland and coastal waters, and the open ocean. We are also forming a collaboration team on turbidity and chlorophyll products as they relate to human pathogens and drinking water safety.

<u>Oceans and Society – Blue Planet:</u> The AquaWatch Secretariat, Emily Smail, and Paul DiGiacomo, AquaWatch co-lead, are actively involved in Blue Planet. Blue Planet and AquaWatch participate on SDG working groups for Coastal Eutrophication and in support of a UNESCO effort for global chlorophyll a product to demonstrate ecosystem status and ecosystem change over time.

Moving forward, AquaWatch will continue to build collaborative relationships and projects within the GEO community with assistance from the GEO Secretariat. Whether funded or unfunded, such relationships will rely on mutual agreement that all tasks which may also support any annual work plans or Initiative work packages will be recognized as “AquaWatch – affiliated activities” as the beneficial outcome of that relations for AquaWatch. The Initiative may freely advertise and cross-promote accomplishments of “AquaWatch-affiliated activities” within GEO, on our website, and through community announcements. Collaborations will focus, where possible, on efforts that support the GEO engagement priorities of the SDGs and the Sendai Framework. Potential collaborators for the SDGs and Sendai Framework are outlined below.

SDG 6

- AfriGEOSS: Reinforcing Regional African Engagement
- AmeriGEOSS
- Asia-Oceania GEOSS (AOGEOSS)
- Earth Observations for Health (EO4HEALTH)
- Earth Observations in Service of the 2030 Agenda for Sustainable Development (EO4SDGs)
- GEO Global Water Sustainability (GEOGLOWS)
- GEO Wetlands
- In-situ Observations and Practices for the Water Cycle
- Integrated Global Water Cycle Observation (IGWCO)

SDG 14

- AfriGEOSS
- AmeriGEOSS
- AOGEOSS

- EO4SDGs
- Oceans and Society: Blue Planet
- GEO Health

Sendai Framework

- AfriGEOSS: Reinforcing Regional African Engagement
- AmeriGEOSS
- AOGEOSS
- Data Access for Risk Management (GEO-DARMA)

4.1 Working Group Activities

Activities to achieve the Initiative's objectives will be conducted by five working groups of experts that will focus on transforming water quality data to information and decision-support tools based on user needs (Figure 2). The activities of the working groups directly support the objectives of AquaWatch.

Figure 2: AquaWatch working groups. The five working groups work in a collaborative manner to achieve AquaWatch's objectives.

The Working Groups are standing bodies of experts that will conduct the activities outlined below on an ongoing basis.

Working Group 1 – Outreach and User Engagement: Working Group 1 will be responsible for facilitating effective partnerships between the producers, providers and users of water quality data, products and information. Activities of this working group will include the generation of a communication strategy for AquaWatch and information from other GEO water quality-related activities as well as the development of the AquaWatch website (www.geoaquawatch.org) into a knowledge hub for water-quality related activities (within and outside of GEO. This group will also work to identify current and potential users and create partnerships with providers and users.

Working Group 2 – Observations and Data: Working Group 2 will be responsible for improving analysis and integration of in situ and remote sensing water quality data. Activities of this group will include identifying and linking key data sets from remote sensing and in situ data sources and identifying data and observation gaps.

Working Group 3 – Products and Information: Working Group 3 will be responsible for developing and delivering fit-for-purpose water quality products and information services. The group will be tasked with generating and evaluating products derived from complementary remote sensing and in situ data sets, as well as supporting modeling and data assimilation activities for regional and global water quality nowcasts, forecasts and predictions.

Working Group 4 – Distribution, Access, and Visualization: Working Group 4 will be responsible for supporting technology transfer and access to water quality data products and information. The group will be tasked with distributing scientific, technical and other outputs to applicable end users and facilitating access to making products and derived information.

Working Group 5 – Education and Capacity Building: Working Group 5 will be responsible for advocating increased capacity and use of water quality information for decision making. The group will be tasked with generating educational content for policy makers, decision makers, and the environmental mangers. This group will also support, identify and lead capacity building efforts in developed and developing nations to expand the effective and timely utilization of Earth observations for societal benefits.

4.2 Projects

The AquaWatch working groups will work in a coordinated manner on collaborative projects that support the initiative's objectives. The project currently being pursued by AquaWatch is the development and uptake of a global water quality information service. This effort will enable users open access to readily available water quality data through data sharing and capacity building, particularly in developing countries.

5 Stakeholder Engagement and Capacity Building

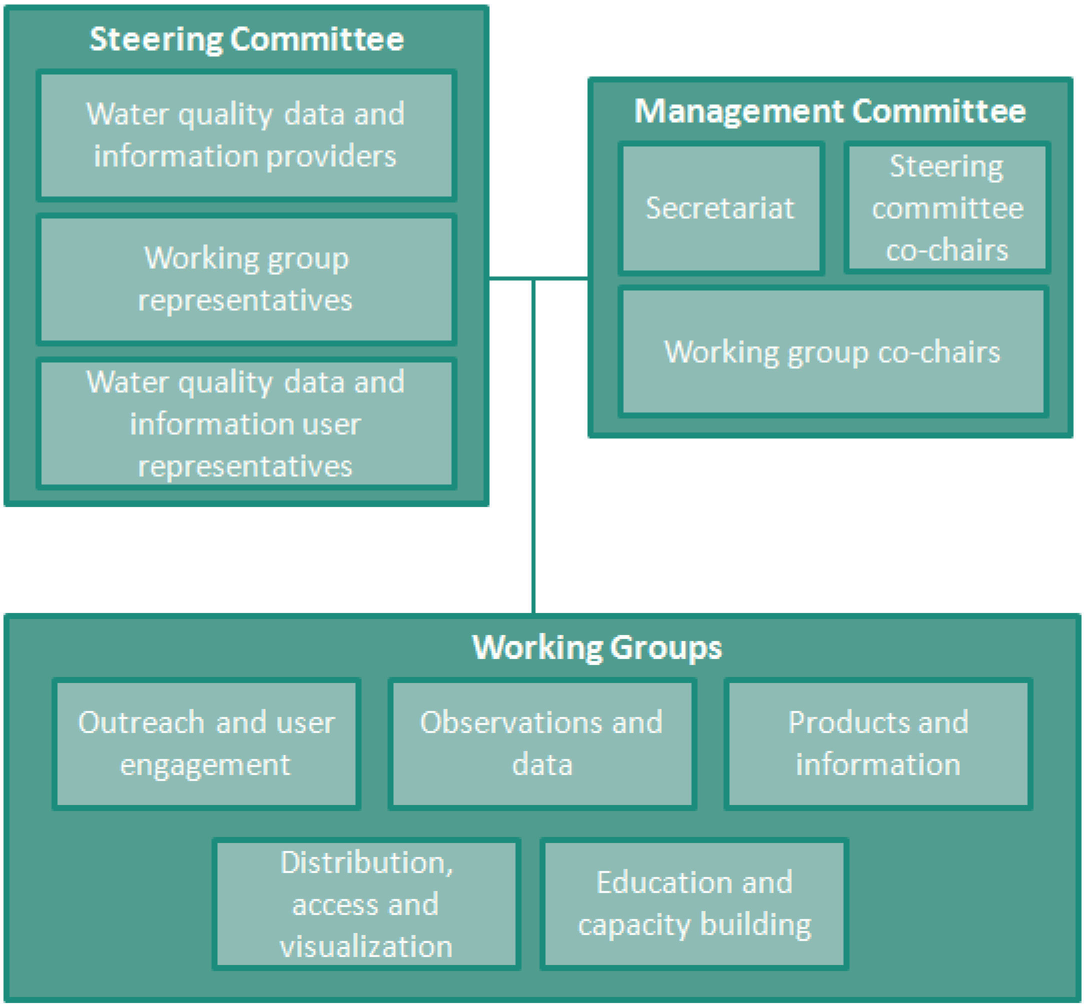
There are many types of users of water quality monitoring and including the science community, industry, UN groups, environmental managers, regulators, policy makers, non-governmental organizations, non-profit organizations and recreational users. End users currently have roles in working groups and chairing the Steering Committee

While AquaWatch has begun to identify and engage the user community, an increase in this effort will take place over the coming years. Moving forward, AquaWatch will seek involve more end-users Working Groups. Users will be directly involved in the identification and development of AquaWatch services to ensure that services are functional and tailored to their needs.

6 Governance

To date, AquaWatch active participants are associated with various organizations including state, federal, and international governmental agencies, private consulting companies, nonprofit organizations, nongovernmental organizations and academic institutions. Participants are part of the AquaWatch network and contribute to AquaWatch in a variety of ways depending on their interests and availability. The organization of AquaWatch is reflected in the Figure 3.

Figure 3: The governance structure of AquaWatch.



<u>AquaWatch Leadership:</u> The primary leadership point of contact for AquaWatch is Director Steven Greb -University of Wisconsin-Madison. The co-leads are Paul DiGacomo - National Oceanic and Atmospheric Administration (NOAA) and Arnold Dekker - SatDek Pty Ltd.

<u>Steering Committee</u>: Guidance for, and approval of, workplan activities and expanding into new work areas are the main work product for the Steering Committee. The three roles for members are: promoting the initiative to all sectors, connecting the initiative with funders and funding sources, and garnering broader initiative participation (capacity building). In 2018 the Steering Committee was formed comprised of 9 members of the international science community representing North America, Europe, Africa, Latin America, Caribbean, and Asia; plus the co-chairs of Working groups 2, 3, and 5. Participants range from data users to data providers from the non-profit sector, national space agency, governmental agency, private industry, and academia. Leadership of the Steering Committee rotates through three elected positions each lasting 1 year in duration (Chair, Vice-Chair, and Vice-chair-elect). Annual elections are held from the nominations among Steering Committee members. Steering Committee meetings are held quarterly with an annual meeting.

<u>Working Groups:</u> Currently AquaWatch Working Group representatives are presented in attached Table A. Over the coming years, AquaWatch will be working to expand participation in the Working Groups. One co-chair from Working Groups 2, 3 and 5 also serve on the Steering Committee.

<u>Secretariat:</u> The Secretariat scientific coordinator duties are conducted Merrie Beth Neely (Global Science and Technology). Both the Director and scientific coordinator positions are supported part-time through funding provided by U.S. NOAA/NESDIS/STAR Satellite Climate and Oceanography Division. Expansion to include future full-time or part-time positions to conduct Initiative activities under consideration.

7 Resources

AquaWatch is supported part time by a NOAA-funded Secretariat based in Madison, WI. Other support includes the support of the web page by the Commonwealth Scientific Research Organisation of Australia (previously supported by Swiss Federal Institute of Aquatic Science and Technology), hosting of an AquaWatch SharePoint site by the United States Environmental Protection Agency, and funding of the production and printing of AquaWatch informational booklet by the International Centre for Water Resources and Global Change (ICWRGC) a UNESCO Category 2 Centre in Koblenz, Germany.

AquaWatch will seek additional resources to support activities during the 2020-22 time period.

8 Technical Synopsis

Water quality monitoring technology is rapidly advancing on a number of fronts. Moderately priced data sondes can be placed in the water column to measure basic water quality parameters (e.g. water temperature, suspended solids, conductivity, color) and left for extended periods of time with internal memory to periodically measure and record (e.g. hourly) water quality changes. Above-water fixed instrumentation such as the AERONET-OC program can measure and transmit surface reflectance at prescribed wavelengths. The use of drones equipped with multispectral to hyperspectral instruments use has increased and proved useful in a niche of smaller and harder to access water bodies.
With respect to space borne measurements, the radiometric, spatial and temporal resolution provided today by the new generation of satellite sensors (and those planned) have increased our capabilities to confidently quantify water quality in a large percentage of surface waters globally. Algorithms for biogeochemical parameters have evolved and improved considerably going from simple empirical approaches to analytically-based inversion models together with new machine learning techniques. Though advances have been made, challenges still remain with the critical issue of atmospheric correction. Given adequate resources, an enormous amount of water quality information could be gathered from space-borne measurements for ambient monitoring, trends, alert systems. The recent advances in the Copernicus Land Products have begun to demonstrate the efficacy of this technology by establishing near real-time water quality information on a subset of large lakes using Sentinel-3.

A number of in situ data bases exist today. Most notable examples include the UNEP GEMS and US EPA's Water data portal. These databases provide a common repository for global data collected by numerous country and local jurisdictions. AquaWatch does not intend to recreate or develop new data systems but integrate the various disparate data systems currently available (see section 9).

8.1 Activities and Projects

Working Groups will identify and organize the implementation of activities related to their area of expertise on an ongoing basis. Working groups may form temporary task teams to address specific interests. Working Group leaders are responsible for coordinating activities within their activity and with the Secretariat and Steering Committee. Planning and implementation will be conducted largely through electronic means to reduce resource requirements.
AquaWatch projects that require work across working groups will be reviewed by the Steering Committee. Upon approval of a project by the Steering Committee, the workflow will begin with work package selection by the leadership committees and flow through the working groups to completion (Figure 4).

1. Project selection: The Steering Committee will review any proposed projects and select projects for AquaWatch to pursue based on interest, user need and resources.

2. Work package selection: The Steering Committee discusses work packages options and selects project work packages.

3. Work package leader selection: Steering Committee and Management Committee discuss the work packages and identify each work package leader.

4. Tasks identified and assigned to working groups: The work package leader and Management Committee determine the tasks and sub-tasks required to complete the work package and assign duties to the different working groups as applicable.

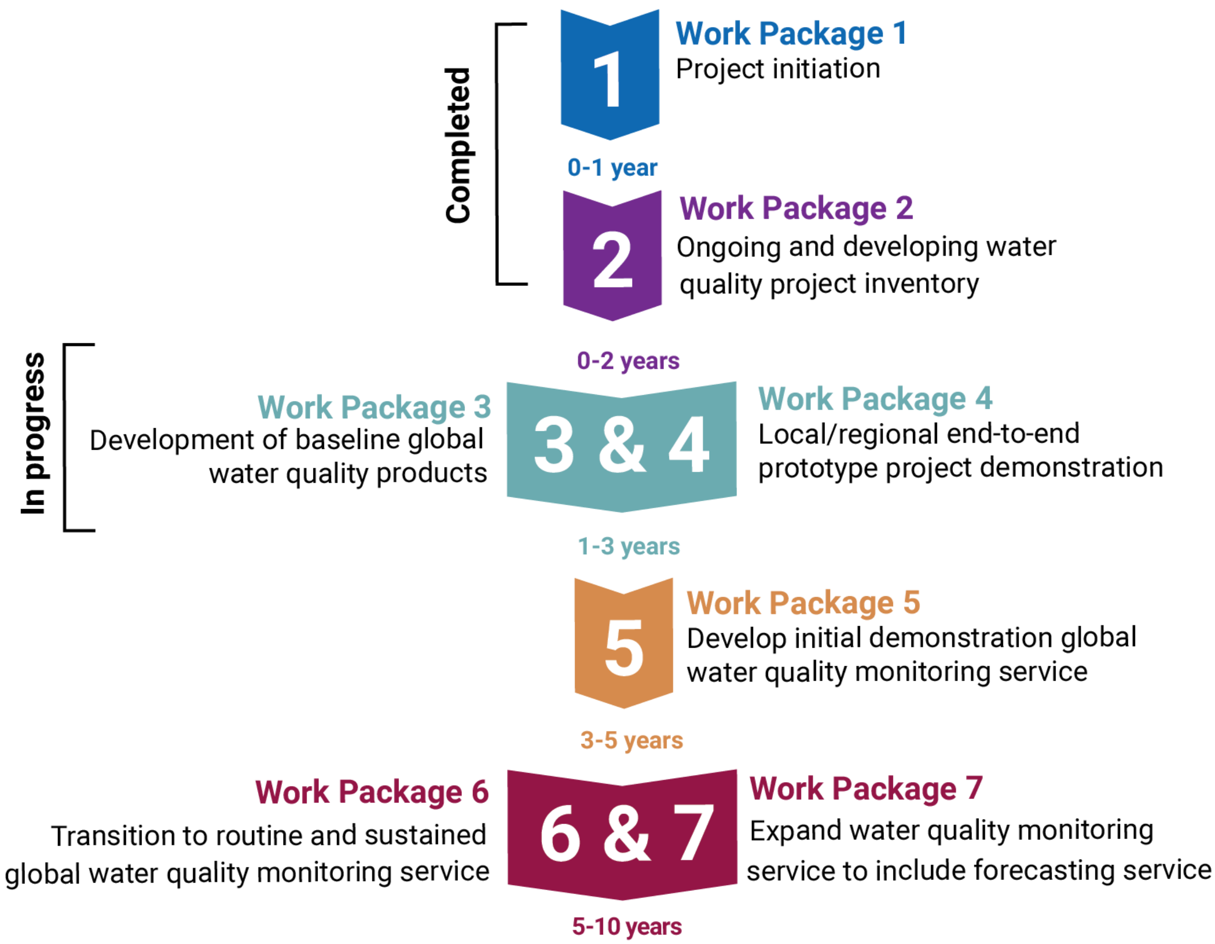
5. Task completion: Working groups complete assigned work package tasks and sub-tasks.

Figure 4: AquaWatch Project Implementation

8.1.2 Water Quality Information Service Project

Implementation of the water quality information service is organized into seven work packages (Figure 5). In the future, additional work packages may be added. Work necessary to complete the work packages will be carried out by specialists from the working groups as outlined above.

Figure 5: The work packages of the AquaWatch water quality information service project.



8.2 Milestones and Deliverables

<u>Governance transition date:</u> In 2017, AquaWatch transitioned to the new governance structure outlined in section 9 and has been functioning with Initiative Secretariat support throughout 2018-19.

<u>Working group expansion and activities</u>: During 2020-22, AquaWatch will work to expand and identify initial activities. Working group expansion will be focused on inclusion of representatives from the in situ and user communities. Working groups will work to undertake and expand activities. Topical task teams

may be formed by working groups based on interest and need. Working groups will also contribute to water quality information service activities as needed.

Communication and community building activities: AquaWatch will work to further develop the website into a knowledge hub and produce other outreach materials. We will update brochures, stock presentations, and posters as needed to reflect accomplishments and new areas.

Water quality information service activities: During 2020-22, AquaWatch will undertake work to move the development of the water quality and information service forward as outlined below.

- *Water quality information service work packages 1 & 2:* Work package 1 (the initiation of the water quality information service activity) has been completed and a third version of work package 2 (the project inventory) has been produced. The inventory is a living document that will be continually updated.

- *Water quality information service work package 3*: AquaWatch will work to developing an initial product suite that will include a Nephelometric Turbidity Unit (NTU) turbidity product, a Secchi disk depth product, a diffuse attenuation coefficient product, and a surface reflectance product. Absorption and scattering information will also be included where appropriate for added value and product comparability. The product will be done at three resolutions – 1 km, 300 m and 100 m. The product will be coherent globally at the 1 km level, continent or country level at 300m and regional "zoom-in" at the ≤100 m level. The further development of this product suite as well as the production of additional products will be pursued in 2018 and 2019 depending on the availability of funds and resources.

- *Water quality information service work package 4*: The AquaWatch community produced a booklet highlighting the functionality of prototype projects that include in situ data, remote sensing data and modelling titled "Advanced techniques for monitoring water quality using earth observation". The booklet is used to educate potential end users about available functionality in water quality monitoring and forecasting and spur interest and funding for the development of new AquaWatch prototype projects. The booklet was completed in the summer of 2017. Depending on available funds and resources, new prototype projects will be identified and started in 2018 and 2019.

- *Water quality information service work package 5:* AquaWatch will initiate the development of the initial demonstration water quality monitoring service.

8.3 Evaluation and Reporting

Evaluation will be conducted by the Steering Committee. The Committee will regularly track implementation, milestones, deliverables and resource needs.

The AquaWatch Secretariat will report progress to the community at least quarterly and to the GEO Secretariat on an as needed, or annual, basis. The AquaWatch Secretariat will also report progress to country level GEO groups as requested.

9 Data Management and Data Policy

AquaWatch will primarily leverage existing data, systems and services. A number of in situ data bases exist today. Most notable examples include the UNEP GEMS and US EPA's Water data portal. These databases provide a common repository for global data collected by numerous country and local jurisdictions. AquaWatch does not intend to recreate or develop new data systems but integrate the various disparate data systems currently available. The Initiative will work to encourage other data providers to comply with GEOSS data sharing and data management principles. Data and metadata will be managed and delivered by leveraging existing information platforms which are hosted by supporting agencies. Services developed for AquaWatch will aim to present data and information in a format that is useful to target users and beneficial to data providers. Data products and services developed by AquaWatch will be linked to the GEOSS Common Infrastructure.

AquaWatch will comply with and promote all of the GEOSS Data Sharing and Data Management Principles [7]. A key focus of data management will be to increase data accessibility and user awareness of available data and the benefits of concepts of open data, data services and data interoperability. AquaWatch will engage with many other GEO initiatives and other national, regional or global activities to help develop identify data needs and tools related to water quality monitoring and forecasting.

Annex I – Acronyms and Abbreviations

GEMS/Water	Global Environment Monitoring System for Water (GEMS/Water)
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GCI	Global Earth Observation System of Systems Common Infrastructure
ICWRGC	International Centre for Water Resources and Global Change
IGOS-P	Integrated Global Observing Strategy Partnership
IGWCO	Integrated Global Water Cycle Observation
NOAA	National Oceanic and Atmospheric
NTU	Nephelometric Turbidity Unit
SDGs	Sustainable Development Goals
UN	United Nations
UN Environment	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

Annex II – List of References

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Annex III – CV of Initiative Director

Steven R. Greb

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Education

M.S.	Forest Hydrology	1986	Utah State University
B.S	Chemistry	1978	University of Wisconsin-Stevens Point
B.S.	Water Res. Mangt.	1978	University of Wisconsin-Stevens Point

Employment

2018-present	Director, GEO AquaWatch Initiative
2017-present	Honorary Fellow - University of Wisconsin Aquatic Sciences Center
1992-2018	Research Hydrologist/Limnologist - Wisconsin Department of Natural Resources
2006	Sabbatical appointment to UNESCO International Hydrologic Programme
1986-1992	Water Resources Project Position - Wisconsin Department of Natural Resources
1984-1986	Teaching Assistant - Utah State University
1978-1984	Head Chemist - State of Wyoming Water Quality Laboratory

Research and Professional Interests

Satellite remote sensing applications for inland and coastal water quality, optical properties of inland lakes, ecosystem management, riparian nutrient loss, thermal pollution in the urban environment, effects of forestry best management practices on stream water quality, impact of climate change on hydrologic regimes and lake carbon dynamics, and interactions between hydrologic regimes and water quality.

Professional Memberships

American Water Resources Association
International Water Association
International Association of Great Lakes Research
Remote Sensing and Photogrammetry Society
North American Lake Management Society

Past and Current Synergistic Activities

Integrated Global Observing Strategy (IGOS) (member of the scientific steering committee)
International Ocean Color Coordinating Group (IOCCG) committee member
Group on Earth Observations (GEO) chair of water quality working group
Integrated Global Water Cycle Observation (IGWCO) Science Advisory Committee
Reviewer: Water Resources Research, Journal of the American Water Resources Bulletin, Remote Sensing of the Environment, Watershed Science Bulletin.
NASA Energy and Water Cycle Study Program Review
Wisconsin Climate Change Initiative (hydrologic working group)
National Water Quality Monitoring Council Committee Member

GloboLakes Project, led by University of Stirling, UK - Advisory panel
Global Lakes Sentinel Services, led by Water Insight, Wageningen, The Netherlands. Advisory Panel -e
Lake Michigan Monitoring Coordinating Council, current co-chair

Recent talks and poster presentations

Greb, S.R. and D. Gurlin. 2018. The End-to-End Value Chain of Wisconsin's Statewide Landsat 7 ETM+ and Landsat 8 OLI-TIRS Water Clarity Products. AGU Ocean Sciences Meeting. Portland, Oregon. Feb. 2018
Smail, E., Greb, S.R., and G. Canonico. 2018. Group on Earth Observations (GEO) Town Hall: Ocean science-related GEO Initiatives. AGU Ocean Sciences Meeting. Portland, Oregon. Feb. 2018
Greb, S.R., A. P. DiGiacomo, E. Smail. 2017. AquaWatch – the GEO Water Quality Community of Practice. ASLO Ocean Sciences Meeting Honolulu, Hawaii.
Greb, S.R. The GEO AquaWatch Community. May 2017. International Ocean Colour Sciences Meeting. Lisbon, Portugal.
Greb, S. R. and D. Gurlin. April 2016. Statewide Aquatic Remote Sensing Program in Wisconsin. Wisconsin Lakes Convention, Stevens Point, WI
Greb, S., P.J. Garrison May 2016. The National Coastal Condition Assessment of Western Lake Michigan and Southern Lake Superior. National Water Quality Monitoring Conference. Tampa, Florida.
Greb, S. R. and D. Gurlin. April 2016. Advances in the Development of a Statewide Aquatic remote Sensing Program. National Water Quality Monitoring Conference. Tampa, Florida.
Greb, S.R., P. DiGiacomo, and A.Dekker. March 2016. Water Quality Remote Sensing Report. International Ocean Color Coordinating Group Annual Meeting. Santa Monica, Ca.
Greb, S.R., P. DiGiacomo, and A.Dekker. June 2015. Development of a GEO Global Water Quality Monitoring and Forecasting Service. International Ocean Color Sciences Meeting. June 2
Gyawali, R., Greb S., and Block, P.M., (2014), "Application of hydraulic and regression based models to assess hydrologic impacts on Wisconsin River Islands." World Environment and Water Resources Congress, Austin, TX, May 17–21, 2015, ASCE.
Gyawali, R. and S. Greb March 14, 2014. Seasonal Streamflow Changes in Wisconsin Watersheds American Water Resources Association, Wisconsin Section, Wisconsin Dells, WI.
Greb, S., P. Garrison and G. LaLiberte. October 17, 2013 Spatial and Temporal Variability of Water Quality in Nearshore Areas of Western Lake Michigan. Lake Michigan: State of the Lake Great Lakes Beach Conference
Greb, S. April 24, 2014 Water Quality of Lake Nicaragua. Wisconsin Lakes Partnership Conference. Stevens Point, WI
Greb, S. April 3, 2014. Remote Sensing of Water Quality in Wisconsin. April 3, 2014 Global Lakes Sentinel Services Project meeting U. of Tartu, Estonia
Greb, S. March 12, 2014. Great Lakes Remote Sensing Workshop. Cleveland, Ohio
Greb, S., R., Gyawali, C. Noll, R. O'Connor. March 4, 2014 Wisconsin River Island Project Update. Milwaukee, WI.
Greb, S. Jan. 14, 2014 Remote Sensing in Inland Waters. GloboLakes Conference. Stirling, Scotland.
Greb, S. Dec 16, 2013 Remote Sensing of Lakes. GEO Webinar (remote presentation)

Recent Research Grant Activities

Project manager and principal investigator (unless noted otherwise) for the following research studies:

- Remote Sensing of Wisconsin Lakes

Cooperators-UW-Madison Duration- 4 years Total project funds –$85,000/year

- Lake Michigan Nearshore Water Quality Dynamics

Cooperators UWM Water Institute, Duration-ongoing Total project funds $35,000/year

- NASA Inland and Coastal Water Quality Workshop Coordination

Cooperators UW-Madison 2012. Duration one year Total project funds $30,000

- Water Quality in Lake Michigan Areas of Concern (AOCs)

Cooperators USEPA, local governments Duration -1 year 2014., Total project funds- $15,500
Potential Thermal Pollution from Runoff Water in Urban Areas
Cooperators- USGS. Duration- two years, Total project fund- $160,000 (US EPA, Washington DC and USGS partial match).

- Relationship of Ecological Landscapes and Land Use to Small Stream Nutrient Loads

. Cooperators- University of Wisconsin-Madison. Duration- 2 years. Total project funds- $160,000 (US EPA Region V).

- Occurrence of Pathogens in Urban Streams

Cooperators- USGS, Great Lakes Institute. Duration- 2 years. Total project funds- Approx. $300,000

- New Methodologies for Low-Impact Urban Development (P.I. only)

Cooperators- University of Wisconsin-Madison, USGS. Duration- 2 years. Total project funds- $860,000 (US EPA, Washington D.C.)

Relevant reports and publications

IOCCG (2018). Earth Observations in Support of Global Water Quality Monitoring. Greb, S., Dekker, A. and Binding, C. (eds.), IOCCG Report Series, No. 17, International Ocean Colour Coordinating Group, Dartmouth, Canada.

Rose, K.C., S. R. Greb, M. Diebel and M. G. Turner. 2016. Annual precipitation as a regulator of spatial and temporal drivers of lake water clarity (accepted). Ecological Applications.

Gyawali, R., Greb, S. and Block, P. (2015). "Temporal Changes in Streamflow and Attribution of Changes to Climate and Land Use in Wisconsin Watersheds." Journal of American Water Resources Association (JAWRA), 51(4), 1138-1152.

Greb, S.R., S. Hook, J. Austin, E. Hestir , Z. P. Lee, J. Lenters, J. Melack, C. Mouw, C. O'Reilly, B. Schaeffer, G. Schladow, J. Schott, L. Smith R. Stumpf, M. Wang. 2015. Key Decadal Survey White Paper Challenges for Inland Water Ecosystems. National Academies of Sciences.

Mouw, C.B., S. Greb, D. Aurin, P. DiGiacomo, Z. Lee, M. Twardowski, C. Binding, C. Hu, R. Ma, T. Moore, W. Moses, S. Craig (2015) Aquatic color radiometry remote sensing of coastal and inland waters: challenges and recommendations for future satellite missions, Remote Sensing of Environment, 160:15-30

Greb, S.R. The GEOSS Water Strategy-From Observations to Decisions. Chapter 6. Existing and Planned Observational Systems for Priority Water Quality Variables. 2014. R. Lawford, editor. JAXA press.

Lee Z, Pahlevan N, Ahn YH, Greb S, O'Donnell D. Robust approach to directly measuring water-leaving radiance in the field. Appl Opt. 2013 Mar 10;52(8):1693-701. doi: 10.1364/AO.52.001693

O'Donnell D., S. W. Effler, M. Perkins, C.Strait, Z.Lee, S. Greb. 2013. Resolution of optical gradients and pursuit of optical closure for Green Bay, Lake Miichigan Journal of Great Lakes Research Volume 39, Supplement 1, Pages 161-172

Water Clarity Monitoring of Lakes in Wisconsin, USA using Landsat. 2009. Greb, S.R., A. A. Martin and
J. W. Chipman. Proceeding of International Symposium on Remote Sensing of the Environment 2009. Strasa, Italy.

Evaluation of the Multichambered Treatment Train, a Retrofit Water-Quality Management Practice. S.R. Greb, S.R. Corsi, R.T. Bannerman, and R.E. Pitt. Water Environment Research. 2000. Vol.72, no.2, p. 207-215.

Water Quality Impacts of Small Impoundments: A pilot study including the evaluation of a landscape-scale temperature model. 1999 S.R. Greb, J.A. Pike and D.J. Graczyk. Final Report to US EPA Region V. 32pp.

Hydrology, Water Quality, and Yields from Near-Shore Flows to Four Lakes in Northern Wisconsin, 1999-2001.

D.W. Graczyk, R.J. Hunt, S.R. Greb, C.A. Buchwald, and J.T. Krohelski. 2003. US Geological Survey. Water-Resource Investigations Report 03-17.

Freshwater Water Quality Monitoring by Remote Sensing; Current and Potential Applications and Needs Assessment. 2003. S.R.Greb A report to the Integrated Global Observing Strategy (IGOS) Water Cycle Committee, United Nations Environmental Programme. 22pp.

Community Involvement
Town of Dunn Plan Commission 1987-present, Chair 1990-2000.
Town of Dunn Town Board 2000-present
Volunteer Firefighter/EMT, Oregon Area Fire/EMS District