IOOS in the Great Lakes Region: 2021-2025

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PEA Statement: This project complies with the IOOS Programmatic Environmental Assessment (PEA) and specifically the Project Design Criteria referenced here:
https://cdn.ioos.noaa.gov/media/2017/12/IOOS_PEA-with-Appendices_FINAL_June-2016.pdf

PROJECT SUMMARY
TITLE: IOOS in the Great Lakes Region, 2021-2025

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Partners: A full list of partners is included in the Appendix. GLOS maintains an ongoing working relationship with the primary organizations listed and, based on funding availability, will assess appropriate partnership, contract, or grant opportunities with these and others during the annual "descope" process. *Primary partners:* NOAA's Great Lakes Environmental Research Laboratory (GLERL); Cooperative Institute for Great Lakes Research (CIGLR); SpinDance; RPS Group; IOOS Association

Project Summary

The Great Lakes Observing System (GLOS) will serve the Great Lakes region as the IOOS-certified Regional Information Coordination Entity. In this role, GLOS will share data and information on the physical, chemical, biological, and atmospheric attributes of this vast freshwater resource. The political and geographic nature of the Great Lakes with a coastline of nearly 11,000 miles, holding 5,439 cubic miles of freshwater (20 percent of the world's supply), home to 44 million American and Canadian residents and managed by eight U.S. states and two Canadian provinces, presents both challenges and opportunities in providing easily accessible data and information. The work conducted under this proposal will help meet those challenges and opportunities.

GLOS provides data and information for the region's priority needs, including a) ecosystem health, b) public health and water security, c) maritime operations, and d) climate adaptation. These programmatic priorities are directly connected to the regional economy, health, and resiliency of the Great Lakes. GLOS proposes a dynamic action plan and new business strategy to fill its mission, "Provide end-to-end data services that support science, policy, management and industry in the Great Lakes." The successful implementation of the proposed work plan will achieve the following three goals and the vision outlined in GLOS' 2020-2025 Strategic Plan, "Smart Great Lakes":

Goal 1: Improve the operational structure of GLOS in support of strategic engagement of partners/stakeholders.
Goal 2: Expand GLOS Data Management and Cyberinfrastructure (DMAC) capabilities and supporting technology solutions that address gaps in the data-to-information supply chain.
Goal 3: Support and enhance the Great Lakes observing network to address critical data needs.

GLOS will coordinate these projects, tasks and activities, through additional grant competitions, as part of a comprehensive effort to grow the GLOS network and partnerships, establish and implement business practices that support this growth, and ensure GLOS supported activities are meeting the data and information needs of the region's stakeholders.

BACKGROUND

The Great Lakes Observing System (GLOS), a 501c3 based in Ann Arbor, MI, has served as the IOOS Regional Association for the Great Lakes since 2008 with a mission to provide end-to-end data services that support policy, science, management, and industry in the Great Lakes. In 2016, GLOS was successfully certified[1] as a Regional Information Coordination Entities (RICE) under the authority of the Integrated Coastal and Ocean Observation System Act of 2009 (ICOOS Act).

The Great Lakes Observing System is unique among the Integrated Ocean Observing System (IOOS) Regional Associations. The largest surface area of freshwater in the world and the source of drinking water for tens of millions of people, the Great Lakes region hosts a complex, bi-national network of stakeholders. The network of partners engaged with GLOS has evolved and grown over time to a system currently supporting over 40 institutional data providers, 250 observing assets, and serving an average of over 250,000 data users that are distributed throughout the region's eight U.S. states and two Canadian provinces and visit GLOS sites nearly 2 million times per year.

Due to the large geography of the region and multi-jurisdictional structure, it has been difficult to sustain observations, maintain adequate geographic coverage, and respond to emerging monitoring needs for the region. For this reason, GLOS has made a strategic choice to use IOOS resources as leverage to enhance and grow the existing observing infrastructure in the region while developing our information technology (IT) infrastructure to build capacity for partners across the region to share their data online. As GLOS matures over the next five years, it will continue to serve this role and remain flexible in its approaches to provide the essential coordination and management efforts needed to bring together an otherwise disparate network of observing and data initiatives.

GOALS AND OBJECTIVES

This proposal builds upon this coordination strategy by working to meet the following goals and objectives:

1. Improve the operational structure of GLOS in support of strategic engagement of partners/stakeholders.

- Maintain and mature administrative and business operations to ensure organizational competencies, impactful programming, and high-quality services to partners and stakeholders.
- Leverage partnership opportunities, such as the Smart Great Lakes Initiative (SGLi), to identify priority information needs and extend the impact of GLOS services.

2. Expand GLOS Data Management and Cyberinfrastructure (DMAC) capabilities and supporting technology solutions that address gaps in the data-to-information supply chain.

- Establish and demonstrate GLOS' IT platform, Seagull, as an IOOS-compliant resource for the development of efficient regional/national technology solutions for data management and sharing.
- Scale and grow Seagull functionality and data services to meet stakeholder needs for data sharing, access, and interoperability.
- Support partner efforts to utilize the GLOS IT platform as a tool for data analysis and delivery applications that meet stakeholder information needs.

3. Support and enhance the Great Lakes observing network to address critical data needs.

- Invest in observing assets, leveraging and enhancing partner capabilities, to meet critical data needs efficiently and effectively.
- Cultivate a community of practice to serve data providers to advance their capabilities, enrich

[1] https://ioos.noaa.gov/about/governance-and-management/certification/

applied research, and improve their ability to meet stakeholder information needs.
- Adapt the coordinated regional observing strategy to support emerging needs, opportunities, and priorities.

CONNECTION TO USERS/STAKEHOLDERS AND BENEFITS

The Great Lakes is an expansive and heterogeneous freshwater ecosystem, with nearly 11,000 miles of total coastline (U.S. and Canada) and a watershed that spans eight U.S. states and two Canadian provinces. According to a report[2] based on 2018 economic data, the Great Lakes region has more than 1.3 million jobs generating $82 billion in wages that are directly connected to the lakes. The complex history of existing treaties and agreements between the U.S. and Canada influence the way the IOOS program is implemented in the Great Lakes. Investments and activities for observing and data management are driven by the leading policy and management issues in the region, e.g., the Boundary Waters Treaty (1909), the Convention on Great Lakes Fisheries (1955), the Great Lakes Water Quality Agreement (1972, 1978, 1987, 2012), and the Great Lakes Restoration Initiative (2010). The need for regional data integration continues to grow as Great Lakes management policies evolve. GLOS plays a pivotal role by addressing emerging data and information needs and responding to new challenges as they arise. GLOS makes sure that the Great Lakes community is coordinated with other relevant national and international programs and strategies directed towards observing, data management, and information sharing policies and best practices.

To this end, GLOS contributes reliable data that meets stakeholder and scientific needs. The real-time observations and data products developed by GLOS support various Great Lakes "Blue Economy" sectors (e.g., shipping, fishing, water treatment, water technology development, tourism, etc.) as well as regional governments in identifying challenges to Great Lakes water quality and ecosystems health. Through various needs assessments with stakeholders, GLOS has identified four priority issue areas that are: a) ecosystem health, b) public health and water security, c) maritime operations, and d) climate adaptation. These programmatic foci are directly connected to the regional economy, health, and resiliency of the Great Lakes. In what follows, their connection to regional stakeholders and benefits is described.

a. Ecosystem health: The health of the Great Lakes was most recently assessed in the 2019 State of the Great Lakes report[3] The assessment indicated that the level of nutrients required to support a healthy aquatic food web is too low in the offshore region of Lakes Michigan, Huron and Ontario, and too high in Lake Erie and some nearshore regions in the western and central basin of Lake Ontario, Saginaw Bay in Lake Huron, and Green Bay in Lake Michigan. Nutrient associated eutrophication leads to the formation of hypoxic areas and harmful algal blooms (HABs), which negatively impact fishing, municipal drinking water, tourism, and recreational activities. The increase of HABs has negatively impacted the phytoplankton communities in Lake Erie, and changes in the phytoplankton and zooplankton communities in Lakes Michigan, Ontario, and Huron are changing the aquatic food web. Furthermore, almost all coastal wetlands in Lakes Erie and Ontario are impared due to nutrient over enrichment and/or sedimentation hindering their ability to filter water and sustain populations of

[2] Rau, E., Riseng, C. Vaccaro, L., Read, J. 2020. The Dynamic Great Lakes Economy: Employment Trends from 2009 to 2018

[3] State of the Great Lakes 2019 -Highlights Report: https://binational.net/wp-content/uploads/2020/05/May-4.2020-2019-SOGL-FINAL.pdf

native species. The problem is further compounded by aquatic invasive species capable of filtering phytoplankton and small zooplankton.

Information from the Great Lakes observing network helps evaluate HABs, hypoxia, and other water quality issues via the integration of water quality measurements from various platforms and the use of numerical models. GLOS will work to improve integrated monitoring of HABs and hypoxia-prone areas of Lakes Michigan, Erie, Huron, and Ontario by expanding the observing network to include additional platforms and biogeochemical sensors. A healthy environment is key to the subsistence of the Great Lakes fishing industry, which according to the Great Lakes Fishery Commission[4] contributes more than $7 billion annually to the regional economy while supporting over 75,000 regional jobs. Accordingly, GLOS continues to work to incorporate environmental observations and forecasts to produce tools that can contribute to safer and more efficient fishing.

b. Public health and water security: The Council of the Great Lakes Region found that the Great Lakes drive 15% of tourism-related revenues.[5] Beach health is important for public safety and key to local economies but can be impacted by extreme water levels, HABs, and bacterial contamination. GLOS will continue to prioritize water quality and water levels data to help inform warning and alerts.

   According to the Great Lakes Commission[6] over 48 million Americans and Canadians get their drinking water from the Great Lakes. The operations of regional water treatment plants (WTPs) can be severely impaired by the formation of HABs. GLOS is working with water utilities in highly impacted regions of Lake Erie to improve their access to critical HABs and hypoxia monitoring data to help them make informed decisions. GLOS has strategically expanded in-lake monitoring capabilities by installing water quality sondes in the water wells of a number of utilities. Furthermore, in partnership with NOAA GLERL, Environmental Sample Processors (ESPs) are being deployed to provide near-real time, in-situ microcystin toxin measurements in close proximity to water intakes. These data streams along with NOAA's forecasting models can improve the ability to detect and forecast HABs. GLOS is developing the Lake Erie Early Warning System (EWS) capable of issuing alerts consistent with criteria set by WTP managers. GLOS will continue to work to improve understanding of the distribution, composition, and nature of algal blooms.

   Significant progress has been made in the region to reduce the threat of toxic chemicals. However, they still pose a threat to human health and the environment. GLOS, in partnership with NOAA GLERL, has developed a spill model tool for the Huron-Erie Corridor, an important Great Lakes industrial hub that is vulnerable to potential hazardous spills. This tool is important to natural resource managers, WTPs, government agencies, and the public at large. GLOS will work to improve and expand this type of tool to other areas around the Great Lakes and the tributaries.

c. Maritime operations: According to a 2018 economic impacts study[7] over 250 million short tons of cargo, valued at $77 billion, were moved on the Great Lakes-St. Lawrence River Waterway and supported over 320,000 jobs and over $45 billion in economic activity. According to the Great Lakes Boating Federation, there are 4.3 million registered boaters in the Great Lakes, and a recent report

[4] http://www.glfc.org/

[5] Great Lakes-St. Lawrence Region Tourism Trends and Statistics (2017), Council of the Great Lakes Region

[6] https://www.glc.org/lakes/

[7] Economic Impacts of Maritime Shipping in the Great Lakes – St. Lawrence Region (July 2018), Martin Associates

names the Great Lakes region as the one with the largest concentration of registered boats per household for the 15th consecutive year.[8]

Improved marine forecasts and warnings can reduce the loss of life as well as damage to property and the ecosystem. Currents, waves, water levels, ice-coverage, weather observations, and forecasts are provided by GLOS and used by commercial and recreational vessel operators for safe operations and planning. However, not all that data is currently provided year-round due to ice formation. which requires seasonal recovery of much of the observing network. GLOS is working to add to the network to address this important gap.

Starting in 2021 GLOS will also provide high-frequency radar (HFR) current data for a portion of the Straits of Mackinac where the currents can be quite fast and change direction frequently. The data will aid navigation through the area and help inform U.S. Coast Guard (USCG) search and rescue missions. GLOS will explore the potential incorporation of year-round HFR data on the USCG Search and Rescue Optimal Planning System.

HFR continuous current mapping of the Straits of Mackinac is of great interest not just to the shipping industry but also to municipal managers, government agencies, environmentalists, and the scientific community. The data can aid not only with the validation of hydrodynamic models but also with the response to potential hazardous spills in the area. GLOS will assess whether there is merit to expanding HFR or other surface current mapping capabilities in the region.

Meteotsunamis, meteorologically-driven waves that propagate with periods ranging from a few minutes to a couple of hours, can generate unexpected rip currents that pose unpredictable and dangerous beach hazards. Since 2010 there have been 935 drownings in the Great Lakes, 97 of which happened this year alone. The National Weather Service (NWS) provides Hazardous Weather Outlooks and Lakeshore Hazard Messages based on nearshore observations when there are moderate or high risks of rip currents. However, capturing meteotsunamis is difficult because it requires real-time high frequency data. GLOS will work to improve the regional observing network's ability to collect this data.

d. Climate adaptation: Changing climate trends across the Great Lakes region continue to aggravate vulnerabilities that can have direct social and economic impacts. The analysis of time series data from various observing platforms can provide insights into inter-annual variations of temperature, water levels, meteorology, and water quality. The observed higher frequency and intensity of precipitation events calls for better monitoring, forecasting, and early warnings of storm surges to help residents in the Great Lakes basin react to and prepare for dangerous storm events and potential flooding.

   To help address climate-related information needs, GLOS has historically supported the development of information products from groups like the Great Lakes Integrated Sciences and Assessments Center and monitoring programs such as the Great Lakes Evaporation Network to provide the most accurate climate and lake evaporation information available for stakeholders. GLOS will continue to explore potential partnerships with stakeholders such as coastal and city managers and support observing data, future model projections, and data tool development to address these information needs.

[8] U.S. Recreational Boating Statistical Report (2019), National Marine Manufacturers Association

WORKPLAN

This proposal outlines a high-level overview of the GLOS workplan for 2021-2025, integrating traditional IOOS subsystem elements: 1) Governance and Management, 2) Observing, 3) Data Management and Cyberinfrastructure, 4) Modeling and Analysis, and 5) Stakeholder Engagement to meet the needs of the Great Lakes region.

Governance and Management

Through its bylaws and standard operating procedures, GLOS satisfies the criteria for disbursing funds and entering into agreements, establishes measures for ensuring accountability and liability, and maintains a governing board that oversees funding priorities. The board appoints the Chief Executive Officer, currently Kelli Paige, who, in turn, hires and supervises all other staff. GLOS staff provide oversight and management of projects, and work with partners to cultivate integrated projects that meet stakeholder needs and support the growth of the GLOS network. GLOS network activities, such as observing, data management, modeling or outreach, may be partially or fully supported by GLOS with direct funding or through in-kind services, such as group facilitation or data access. In acknowledgement of the reality of funding limitations, GLOS has updated to operating as a service-based organization, moving away from a traditional non-profit membership structure and towards a more business-oriented partner structure, engaging partners and stakeholders in four broad categories: partners, grantees, clients, and subscribers. This structure is primarily organized by how partners relate to and use the GLOS information technology platform, recognizing that IOOS funding provides base capacity support and GLOS will need to rely on leveraged resources from client and subscriber services to enhance and extend the full suite of observing and data management resources we are able to provide to the Great Lakes region.

GLOS currently has a couple of unfilled positions in the organizational chart and anticipates other possible changes to the organizational structure depending on funding levels and leveraged opportunities. In addition to fulfilling staffing needs, GLOS will support the IOOS Association efforts to increase the diversity of the IOOS workforce pipeline and access to ocean, coastal and Great Lakes data and information by underserved or underrepresented communities. Staff will support IOOS/IOOS Association projects, committees and initiatives.

PLANNING AND PRIORITIZATION: GLOS uses an adaptive planning process to prioritize projects and coordinate partner engagement, stakeholder outreach, strategic planning, project management, program evaluation, and response to regional priorities. Integrated into this process are: 1) formally organized direct engagement activities including meetings, workshops, webinars, focus groups, and online surveys, 2) indirect assessment of users, behaviors, and preferences via web analytics, contact management systems, and service performance statistics, 3) broad, macro-level engagement with Great Lakes stakeholders through the Smart Great Lakes Initiative, a collaborative consortium established in 2019 to organize the region's technology ecosystem and network of partners around common policy goals to improve monitoring, data management and analysis, advance research, and spur technology innovation. More information about the planning process and GLOS programmatic goals and strategies are described in the 2020-2025 GLOS strategic plan.

Recognizing that our ability to implement projects will be subject to annual funding levels and emerging opportunities to leverage partnerships or other funding, we have elected to characterize our workplan as an overview of the needs and priorities that address the requirements of the IOOS NOFO and will utilize mechanisms such as requests for proposals, mini-grant awards, specialized project design collaborations,

and innovation competitions to refine the scope and select appropriate partners to assist in implementing the activities described.

Observing

Currently, GLOS fully or partially funds the operation of an extensive network of 1) instrumented buoys, subsurface moorings, water quality sondes, meteorological and evaporation stations, 2) one high-frequency radar system, and 3) several mobile observing platforms, all yielding quality-controlled datasets. Aligned to meet stakeholder needs and focused on the four priority areas mentioned previously, GLOS' goal is to sustain and evolve the observing subsystem towards a robust, smart sensor-driven network that translates into customizable high-quality outputs and easy to understand data products. To that end GLOS proposes to include new observing equipment, monitoring approaches, and regional projects as follows:

NEAR AND OFFSHORE MOORING NETWORK:: The existing observing network consisting of nearshore moorings and sondes, as well as offshore surface and subsurface moorings, is operated through the major boating season from April through early November. These assets report all real-time data to GLOS and, starting in March 2021, they will be reporting data to NOAA National Data Buoy Center (NDBC) via GLOS. The configurations and parameters measured by these platforms vary. These assets complement data from other Great Lakes platforms—primarily those from NOAA GLERL's Great Lakes Real-Time Meteorological Network and Real-Time Environmental Coastal Observation Network (ReCON), NDBC, and Environment and Climate Change Canada (ECCC)—to serve the recreational boating and fishing community, commercial fishing and shipping, water treatment plant managers, coastal managers, and the scientific community, among others.

Sustaining the existing network while, at the same time, supporting its growth presents a financial challenge. To meet it GLOS proposes to prioritize the allocation of funds for both the procurement of new assets and the maintenance or upgrades of existing assets via grant mechanisms subject to available funding. GLOS recognizes the need to 1) minimize the spatial limitations of moorings by deploying additional mooring/sensor arrays and integrating data across various platforms, and 2) include more biogeochemical sensors at various depths and optical and acoustic sensors to observe marine organisms, consistent with the National Strategy for Sustained Network of Coastal Moorings.[9] GLOS proposes to expand the current observing network by prioritizing the addition of:

a) Ecosystem moorings and the incorporation of biogeochemical observations to existing moorings especially for Lakes Superior, Michigan, Huron and Ontario, not only to inform hypoxia and bloom dynamics, but also to help uncover processes driving ecosystem variations. This is consistent with the International Joint Commission Science Advisory Board priorities for science (2020-2022). The observational coverage of ecosystem properties in the western and central Lake Erie basins have been expanded in the past years to provide critical HABs and hypoxia-related information in support of water treatment and beach monitoring. Nonetheless the addition of nutrient, genomic, and optical imaging sensors for real-time detection of toxins, and food-web members is of interest in all Lakes. Some of these are costly technologies, and consequently, their incorporation might only be possible initially at key demonstration sites.

[9] National Strategy for a Sustained Network of Coastal Moorings: https://cdn.ioos.noaa.gov/media/2018/01/NationalStrategyforSustainedNetworkofCoastalMoorings_FINAL.pdf

b) Newer technologies that can support movable networks of sensor arrays connected acoustically to a central surface buoy to transmit real-time data via cellular or satellite communications. These systems can combine several arrays to cover large areas.

c) Low-cost wave buoys that provide the minimum level of accuracy required for an IOOS wave observing system, consistent with recommendations of The National Operational Wave Observation Plan,[10] to serve navigation needs in poorly observed areas. The requirements for deployment/retrieval of these assets can easily be met with small boats, significantly reducing maintenance costs. Wherever appropriate to meet recreational user needs, GLOS will team up with charter boats, angler, and/or sailing organizations for deployment and retrieval needs.

d) High-frequency barometric pressure sensors on weather buoys for the purpose of detecting atmospheric precursors of meteotsunamis that have the potential of endangering lives and property. Special consideration will be given to buoys located close to beaches and marinas. GLOS will also explore the option of adding shore-based sensors.

The current Great Lakes buoy network does not collect year-round observations, as the buoys are seasonally operated. Scarce data in late fall, winter, and early spring impacts commercial shipping and fishing, but also the calibration and validation of numerical hydrodynamic models, and the development of ecological forecasts. To address this important data gap GLOS proposes to:

a) Establish year-round permanent observing systems by leveraging existing GLERL ReCON sites on Lake Superior and on northern Lake Huron. These cabled observatories will measure physical characteristics like waves, currents, and temperature profiles, will include biogeochemical observations and will be designed to enable future system and sensor expansions. This effort will be conducted in partnership with federal and academic partners.

b) Support the development of an open-source, low-cost, Lagrangian drifter buoy. A prototype is being designed by GLOS partners to measure currents, waves, water quality, air and water temperatures, and will provide options for including additional sensors both on and below the buoy. This type of platform can easily be deployed at scale, and at a relatively low cost, to help fill the data gap that currently exists in the Great Lakes during the shoulder and winter season. The possibility of deploying the system on-ice will be explored, as well as swarm technology applications.

c) Deploy additional non-real time, short-cabled observatories at strategic locations in the vicinity of some of the existing surface buoys in Lake Superior and Northern Lake Michigan and Huron. This data, though only available on a semi-annual or annual basis, will still be of great importance to the modelling community since it is currently lacking during winter months.

AUTONOMOUS OBSERVING PLATFORMS: GLOS proposes to maintain and operate the four existing IOOS-funded gliders to provide observations focused on HABs, hypoxia, coastal nutrient input, climate variability, and supporting year-round observations and numerical model development. Glider missions provide high vertical resolution and reasonable spatial representation, and allow for the continuous quantification of physical, chemical, and biological parameters along transects over large areas. Work will be prioritized as follows:

[10] The National Operational Wave Observation Plan:
https://cdn.ioos.noaa.gov/media/2018/01/wave_plan_final_03122009.pdf

a) GLOS partners continue to deploy gliders several times per season across various basins with GLOS support. Annual cross-lake glider surveys have been conducted in Lake Michigan since 2012 to help create an ongoing multi-year record. This data along with observations from GLERL's Long-Term Research (LTR) program in Lake Michigan, and other in-situ data is helping study inter-annual hydrometeorological and climatic variability. Glider surveys will also be conducted to support ongoing efforts to monitor and forecast toxic algal blooms in Lake Erie and western Lake Superior, hypoxia in Green Bay, and nutrient dynamics in Saginaw Bay. GLOS proposes to procure a glider to aid in HABs monitoring in Lake Ontario. Additionally, as part of the Coordinated Science Monitoring Initiative (CSMI), an annual bi-national lake-by-lake effort, longer deployments are done each year in conjunction with NOAA, USGS, and EPA.

b) The IOOS-funded gliders are maintained and operated by two organizations, one based at the Cooperative Institute for Great Lakes Research (CIGLR), and the other at the University of Minnesota-Duluth Large Lakes Observatory. In 2020, GLOS and the University of Windsor Real-time Aquatic Ecosystem Observation Network (RAEON) teamed up to collaboratively support one technician to assist with glider/AUV maintenance, resource sharing, and operations conducted by RAEON, GLERL, and CIGLR. This is consistent with the outcomes and recommendations from the "US Underwater Glider Workshop Report"[11] and the "NOAA UxS Systems Strategy."[12] Distributed glider expertise will be required to operate and maintain glider deployments in all five lakes 2-4 times a year between April and November. GLOS proposes to continue its partial support of the GLOS-RAEON glider/AUV technician position and to create a second position at a US academic institution to support the gliders operated mostly in Lake Superior and Lake Michigan and coordinate with other uncrewed system deployments conducted by other partners in those lakes. Having two IOOS-supported hubs in the region with appropriate technical support for these systems will help integrate plans to enhance efficiency and minimize costs.

c) GLOS plans to engage with and support the work that GLERL and CIGLR are conducting to further develop capabilities of uncrewed systems. GLERL and CIGLR are working to incorporate acoustic telemetry into AUVs and gliders for the purposes of tracking fish movement. Similarly, acoustic positioning could be enabled for these systems by using existing networks of acoustic sources, such as the Great Lakes Acoustic Telemetry Observation System (GLATOS). This can aid in under-ice observations where AUVs and gliders have difficulty surfacing to get position information and would be a step toward year-round observing with these assets. GLERL is also working to incorporate a hyperspectral camera into an uncrewed aerial vehicle and will contribute to the monitoring of rip currents, HABs, and submerged aquatic vegetation.

d) GLOS proposes to utilize a Saildrone during year two, and possibly year three, for deployments in early spring and late fall when only a small number of sub-surface moorings are gathering data in the Great Lakes. Saildrone, an uncrewed surface vessel, operates on a "data-by-service" basis and can collect a suite of meteorological, water surface and subsurface parameters.

[11] The U.S. Underwater Glider Workshop Report:
https://cdn.ioos.noaa.gov/attachments/2018/05/2017GliderWorkshopReportDraft2.pdf

[12] NOAA Unmanned Systems Strategy. Maximizing Value for Science-based Mission Support (February 2020)
https://nrc.noaa.gov/LinkClick.aspx?fileticket=0tHu8Kl8DBs%3D&tabid=93&portalid=0

e) "The National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone"[13] was released in June 2020 with the goals of 1) mapping the U.S. Exclusive Economic Zone (EEZ), 2) identifying, exploring and characterizing priority areas, and 3) coordinating and leveraging efforts and resources from multiple sector organizations and partnerships. The U.S. Great Lakes area occupies about 47,000 square nautical miles, and most of it is either unmapped or not adequately mapped. In 2019, GLOS partnered with regional organizations to create Lakebed 2030, an initiative that targets completion of a comprehensive, high-resolution Great Lakes map by 2030. Though the Great Lakes are not an EEZ, this effort is consistent with the targets set out by the National Strategy. GLOS proposes to support and expand regional mapping expeditions as well as the testing and/or procurement of new sonar equipped uncrewed maritime vehicles capable of producing high-resolution bathymetry, lakebed composition, imagery, and sediment representation.

VESSEL-BASED OBSERVING PLATFORMS: GLOS, in partnership with University of Wisconsin-Milwaukee, has supported a water quality system on the Lake Express, a high-speed ferry that crosses Lake Michigan several times every day between Milwaukee, WI and Muskegon, MI. This system currently provides high-resolution measurements of several parameters and, starting in 2021, will add pH, making it possibly the first device collecting high resolution pH measurements in Lake Michigan. Support for this effort, as well as the possibility of expanding this work to other vessels of opportunity will be evaluated based on available funds and partnership opportunities. Special emphasis will be given to the implementation of sensor packages that include specialized biochemical sensors. GLOS will also pursue partnerships, to support the efforts indicated in Section 2.e above, to map, explore, and characterize the Great Lakes floor using sonar-equipped ships.

SHORE-BASED OBSERVING PLATFORMS:

a) High-Frequency Radar (HFR): GLOS proposes to maintain the existing HFR system that was successfully pilot-tested against buoy data during May 2019 in the Straits of Mackinac. The original goal to have this station fully operational by 2020 was delayed until 2021 due to COVID-19. The HFR will provide real-time current maps that are not only important for maritime operations, but also for the protection of public and ecosystem health, especially in the event of a spill. Due to the unique oscillating flows through the Straits that can reverse direction approximately every 1.5 days, attaining full current coverage of the Straits would require a second set of HFR. It is proposed to wait for acquisition and installation of this second system until 2023 so that any lessons learned from the current system can be incorporated in the new system. GLOS proposes to partially support deployment of this second HFR system.

b) Smart Great Lakes Coastal Mesonet Program: Networks of automated weather stations installed close enough to one another to measure mesoscale phenomena are not new. There is a National Mesonet Program[14] and various regional mesonet programs, but none in the Great Lakes. Mesonets can provide data about local weather conditions that may be very different from the conditions of a larger-scale area. In various coastal regions along the Great Lakes, the density of weather monitoring stations is not adequate to capture strong spatial gradients in societally relevant variables. For example, the

[13] National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone, June 2020: https://www.whitehouse.gov/wp-content/uploads/2020/01/20200611-FINAL-STRATEGY-NOMEC-Sec.-2.pdf

[14] National Mesonet Program: https://nationalmesonet.us/

variability of conditions along the shoreline of the Keweenaw Peninsula in Lake Superior can be significant across distances of less than 5-10 km. This variability can have an important impact on physical lake conditions, rendering meteorological information from coarsely placed coastal weather stations and lake moorings inaccurate.

GLOS will support creation of the Great Lakes Mesonet Program (GLaMP) to collect scale-relevant environmental data by using strategically deployed mesonet testbeds. The first testbed would stretch from Big Bay, MI to Ontonagon, MI with low-cost stand-alone weather stations distributed at less than 10 km separation. This site is a target of opportunity because it would build off 1) existing Great Lakes Evaporation Network (GLEN) sites to help with validation exercises and 2) an existing network of wave buoys.

REGIONAL INITIATIVES AND OTHER MANAGEMENT PROGRAMS:

a) Smart Green Bay Pilot Program: GLOS proposes to support the work that an extensive group of partners have laid out to create a Smart Great Lakes network in Green Bay, WI that integrates linked eutrophication, hydrodynamic, HAB, and dissolved oxygen sensor networks. The Fox-Wolf basin is one of the four EPA-designated algae bloom hotspots in the Great Lakes, and the Lower Green Bay and Fox River is one of the International Joint Commission-designated Areas of Concern. The infrastructure proposed will set up Green Bay as one of the most technologically advanced National Estuarine Research Reserves (currently under designation), and it will create the backbone to develop broader real-time and forecasting capacity in the area.

b) Smart Lake Erie Testbed Pilot Program: As an outcome of the October 2020 IOOS-OAR Great Lakes workshop, a pilot program in Lake Erie is proposed to establish better mechanisms for regional communication and collaboration between GLERL, CIGLR, and GLOS, in the process of advancing and facilitating transition of research capabilities to operational use. This effort will be accomplished by refining forecasting capabilities based on, among other things, improved HABs monitoring and year-round observations. The Lake Erie pilot program will also serve as a testbed for new technologies, such as CIGLR's proposed acoustic positioning for AUVs and gliders for year-round deployments. Lastly, processes will be developed for coordinated date integration between GLERL, CIGLR, and GLOS for the diversity of the datasets gathered from this project via different platforms.

c) Testing of Smart Technologies: GLOS proposes to coordinate the testing of new technologies in partnership with regional organizations at existing Great Lakes platforms and/or test beds. For example, the Marine Autonomy Research Site (MARS), supported by the Smart Ships Coalition of which GLOS is a member, is a Great Lakes test bed for autonomous surface and underwater vehicles, and other related technology.

<u>Data Management and Cyberinfrastructure</u>

The GLOS Data Management and Cyberinfrastructure (DMAC) has evolved significantly since GLOS' inception in 2008. The GLOS DMAC is a major part of the new GLOS Strategic Plan that outlines the inclusion of new data, a novel approach to data management services, and principally, the development of a new technology platform. GLOS intends to continue to grow and support diverse user groups not only through the provision of access to great technology, but also for the discovery, access, analysis, and comprehension of Great Lakes data and information. The GLOS DMAC system can support the management of Great Lakes data and information throughout its entire lifecycle via a carefully coordinated balance of inputs from data managers, standardized processes, governance policies, and information technology.

PERSONNEL/DATA MANAGERS: Data managers at GLOS include three full-time staff with plans to increase to 5 staff, dependent on funding levels. A 'data services manager' is responsible for providing evaluation and coordination of the GLOS data management team of staff and contractors, manages GLOS data management services, serves as the GLOS representative for IOOS DMAC responsibilities, and assists in GLOS' strategy in developing the next generation IT platform. As an IOOS DMAC representative, the data services manager actively participates in regional and national DMAC meetings, collaborates with other individuals at IOOS regional associations and interfaces with federal and non-federal groups supplying and consuming data provisioned by GLOS. The Geospatial Analyst serves as the central geospatial data expert at GLOS. They are tasked with supporting the observation, data management and cyberinfrastructure, and communications teams. This position is responsible for the collection, management, and maintenance of the GLOS geospatial data needs.

The Chief Information Officer at GLOS is responsible for leading the overall vision and strategy for the planning and execution of the DMAC infrastructure, software development via employees and contractors, related initiatives applications, technology platforms, and supporting technical development. GLOS is committed to supporting the data services manager, the CIO and others, to participate in IOOS DMAC meetings, collaborate with other regional associations, and share technology and information where possible with other interested parties.

Increasing the headcount of data managers at GLOS will enable more hands-on management of the information technology platform and ultimately save money for the organization. A "DevOps" resource would reduce dependency on contract vendors and increase responsiveness to organizations and individuals requiring customized, configured, or advanced technology resources. Additional desired technical resources include a developer/modeler and/or a data scientist with computer science backgrounds to enable the rapid onboarding of new data formats, observation assets, data communication channels, and improved visualization capabilities.

STANDARD PROCESSES AND GOVERNANCE POLICIES: GLOS is an innovator when it comes to developing new standardized processes that data contributors, researchers, and consumers of GLOS data interface with. Although GLOS already supports ERDDAP and THREDDS servers and is compliant with these standards, GLOS is looking to the future. Examples of this include developing advanced and streamlined processes for on-boarding observation assets and capturing IOOS-compliant metadata and providing model and observation data easily via ERDDAP and THREDDS services. These processes for ingesting data, processing it, and publishing via IOOS protocols would be available to other regional associations and the broader IOOS community, which is a challenging task with the current infrastructure. The GLOS approach to data and metadata policy is evolving and reflects the needs of the research, academic, government and IOOS communities. Furthermore, GLOS publishes the standards processes and best practices for all data contributors, users and collaborators to encourage compliance and interoperability with other data systems. GLOS is looking to better manage these processes in the future and intends to explore lineage, traceability, and credibility through blockchain technology.

GLOS typically leverages contractor vendors to assist with DMAC responsibilities. However, as in-house capabilities continue to grow, GLOS anticipates authoring, maintaining and evolving the standards processes and governance policies with respect to data, metadata, web services and asset tracking as an IOOS certified regional association and in partnership with appropriate federal, academic, Canadian, and other regional partners. Contract vendors will continue to play a role, however, as GLOS will rely on their expertise and diverse work forces to tap into a wide range of skills to develop and support our growing

information ecosystem. Indeed, contract vendors will comprise the bulk of the DMAC budget, particularly in the areas of supporting information technology development and to lesser extents, standardized processes and governance policies. GLOS manages these relationships tightly and follows strict protocols that are aligned with IOOS and other federal agencies.

Underpinning the efforts of the data managers, standardized processes and governance policies is information technology. Of the five goals that IOOS integrates across, information technology directly supports each of them in different ways. The GLOS DMAC information technology platform supports core and emerging capabilities of observation through the provision of cloud-based resources to connect observation assets and their data in an efficient and secure manner. The data management and cyberinfrastructure goal is met by the development, maintenance, and promotion of a comprehensive platform that connects users to data whether contributing or consuming. Furthermore, modeling and analysis is supported by empowering researchers with the tools to query, visualize, and run numerical models on data within the technology platform. One of the GLOS DMAC goals is to provide users of all types intuitive application products that increase their rapid access to the information and data they require. These products will be intentionally designed to increase efficiency and decrease complexity for users.

The GLOS DMAC information technology strives to improve upon the organizational enterprise excellence through three principle tenets. First, the strategic approach of the information technology is meant to not only support the data types and users of the platform, but to be in a position to scale in depth and diversity of use cases, user personas and data content. Second, the information technology of the GLOS DMAC follows a structured implementation methodology that includes the entire organization, initiatives, and programs. Finally, the information technology within DMAC adheres to an inclusive people-engagement strategy.

INFORMATION TECHNOLOGY: The plans for information technology under the GLOS DMAC are ambitious but necessary to meet the growing needs of the IOOS community, the diverse users and rapidly scaling variety and volume of data in the Great Lakes. The rapid growth and evolution of the awareness of the criticality of Great Lakes data and information for the general public, policy-making and stability of the region lead to information technology challenges for GLOS. In order to meet these challenges head on, GLOS is developing a next generation technology platform to support a wide range of data, users, projects, partners, and potential across the Great Lakes. This new platform is part of an information ecosystem supporting the GLOS DMAC, Smart Great Lakes initiative, Lakebed 2030 initiative, and the people, processes, and governance policies related to this effort.

The five-year roadmap for Seagull, the new information technology platform, includes escalating levels of capabilities that are prioritized based on user, project, partner, stakeholder, IOOS, and GLOS needs. The platform development phase is primarily focused on building up the infrastructure required to service assets, manage data, handle processing, and serve data and information. This period will last approximately two years plus the requirements gathering, system design, and architecture development that is currently underway. Seagull will have at least three levels of application services: front end web applications (i.e., via a browser), native mobile applications, and embedded Services such as ERDDAP, THREDDS and others. In the future, Seagull may extend to the device and observation assets to improve edge processing capabilities, improve data throughput, and provide a mechanism for edge computing updates. The application development period will dominate a two-year period starting in Year 2 and, although development will never be 'done,' focus will shift after Year 3. During the scale and growth phase, Seagull will see an expansion of infrastructure capability matched with increases in data and user volume

and diversity. The purpose of this phase is to expand Seagull's overall stability, security, and capability for an increasing group of user personas, applications of Great Lakes data and use cases. Years 4 and 5 will begin an era of evolution and maintenance of the Seagull platform.

At all times during these phases, GLOS intends to share progress with other IOOS associations and interested parties. Already currently partway through the system design and architecture development, Seagull will be developed within an open framework, using open source technologies where possible and in a modularized approach. This lends itself to other organizations taking advantage of the research and development that GLOS is leading. Built on a cloud-based infrastructure, the GLOS DMAC approach for Seagull ensures that inter-regional collaboration is not only an option, but a necessity for increasing efficiencies and the sharing of information, methods, expertise, and technology across the IOOS ecosystem.

This open approach is essential to effectively manage and shepherd data through the complete data and information lifecycle. Equally important as the approach is the physical infrastructure that aggregates, manages, curates, and distributes data and information. The GLOS DMAC information technology is a cloud-based architecture built using Amazon Web Services' (AWS) global cloud-based products and third-party applications and web services. Some of these products that GLOS DMAC will leverage range from storage, databases, analytics, networking, mobile, developer tools, internet of things (IoT), security, and enterprise applications. Combined, they work in concert with each other to provide users of the platform, whether they are funded by IOOS or not, data assembly, quality control, discovery, access, and archival services for the collection, contribution, and consumption of information and data products.

Figure 1: The GLOS DMAC provides assembly, quality control, discovery, access and archival services to a range of constituents.

The data ingestion pipeline includes inputs from a wide range of data including streaming IoT, uploaded content from users, piped data via federal and non-federal application programming interfaces (APIs), research, experimental and operational model data, metadata, and existing datasets from legacy systems.

Event management is a series of services that alert internal and external processes of events that happen on the platform, such as logging new data or metadata, and communicating bi-directionally to internal and external processes.

Seagull is a platform and not an application or a system. Some of the platform services that comprise Seagull include storage, archival, user authentication, encryption, metadata management, search, social media sharing, flat file storage, database management, and extract, transform, and load (ETL) services. These services provide the direct opportunity for the GLOS DMAC to research, prototype and integrate

emerging technologies such as artificial intelligence, machine learning, edge computing, IoT, advanced automated processing and distributed computing systems and resources.

The GLOS DMAC has a long history of collecting usage data, metrics and statistics across the web and application products. Monitoring and Triage is more than just collecting metrics on a variety of parameters and publishing them for the IOOS community to observe. It is also about platform health of the many platform services running on Seagull. AWS provides an array of utilities such as AWS Cloudwatch to help the GLOS DMAC measure performance, platform health, monitor and adjust storage, CPU and throughput and log those results so that additional analytics can be assessed afterwards. Understanding and sharing these results with others benefits not only the GLOS DMAC but the entire IOOS DMAC when looking for ways to optimize the various platform services on Seagull or similar platforms.

APIs act as the primary gateways for Seagull and will be available for a wide range of activities including consumption of metadata, data, web and map services, support services, social media, user authentication, analytics, and more. Seagull will not only publish data (similar to NBDC) but consume data and information from other sources via the gateway (i.e., NCEI).

Although Seagull in its totality is considered a platform, there is an application services layer that provides the framework for applications and products. At the minimum, Seagull will have a web application that will provide the primary interface for data contributors, organizational administrators, recreational boaters, other end users, and data managers. The Seagull interface will be map-centric, portraying observation assets and spatial data in a simple-to-use application. Pending funding levels, Seagull will also add native mobile applications designed for field operations of observation assets, recreational boaters, and citizen science data collection. This sixth major component of Seagull also includes applications hosted by other servers (i.e., THREDDS, ERDDAP) that are made available to others via the application interfaces. These types of applications make it possible to access content such as the IOOS catalog, NCEI archives, and NDBC via Seagull.

SYNERGISTIC ACTIVITIES: The GLOS DMAC team is tightly integrated with the IOOS program office and several other regional associations within the IOOS community. GLOS DMAC participates in regularly scheduled DMAC workshops, meetings and ad hoc events. The team is also engaged in the promotion of the growth of the community by participating in joint projects with other regional associations, deliberately seeking new vendors and industrial partnerships and encouraging academic programs in the regions to work with GLOS data, prototype new user experiences and collaborate on innovative technologies. Examples of these efforts include the cloud data ingest project with the IOOS Program Office, RPS, NERACOOS and PacIOOS.

Modeling and Analysis

GLOS' support for Modeling and Analysis is closely coordinated with relevant Observing and DMAC activities to ensure GLOS programming adequately addresses the entire data management lifecycle as described in the Notice of Federal Funding: "from initial observations of raw data, to ingestion into the cyberinfrastructure, quality control, public dissemination, product generation, and long-term storage and archival." GLOS also enjoys a productive relationship with GLERL and CIGLR. GLERL provides GLOS with experimental and operational model data, such as the NOAA Great Lakes Coastal Forecasting System (GLCFS). This is a set of models that simulate and predict the 2-D and 3-D structure of currents, temperatures, winds, waves, ice, and more in the Great Lakes. Nowcasts and forecasts are generated throughout the day in near-real time. These predictions provide timely information to lake carriers, mariners, port and beach managers, emergency response teams, and recreational boaters, surfers, and anglers. The

GLCFS uses a modified Princeton Ocean Model, developed by GLERL and the Ohio State University, and is supported by the National Weather Service. Model output is available in a variety of formats including ascii, netCDF, Grib, and KML. Other models include those that predict real-time water levels and currents to simulate various contaminant spills in the Huron-Erie Corridor, near-real-time atmospheric observations and numerical weather prediction forecast guidance to produce three-dimensional forecasts of water temperature and currents, and two-dimensional forecasts of water levels of the Great Lakes. Researchers model persistent, seasonal harmful algal blooms in Lake Erie and beyond using remote sensing-derived products to indicate estimated chlorophyll concentrations in areas of concern, suggesting surface scum is present. Partners at NOAA help package forecast models to help predict where HABs will travel within the lakes.

The publication of these models through the GLOS DMAC help support the modeling and analysis subsystem. Researchers around the Great Lakes leverage GLOS web services via a THREDDS Server, Data Portal, Metadata Catalog, and the IOOS Catalog to do advanced modeling and analysis, perform numerical simulations that can lead to the generation of hindcasts, nowcasts, and forecasts.

Data does not improve science or policy unless it is collected, integrated, processed, and analyzed to serve users' needs. GLOS will focus on supporting numerical modeling, and data analyses that produce tools and enable nowcast and forecasting capabilities based on stakeholder needs. To that end, GLOS' work will focus on the following areas:

1. Consistent with NOAA's Ecological Forecasting Roadmap,[15] GLOS, in partnership with federal, non-profit, and private regional organizations, is working to improve forecast products and services in the ecological forecasting priority areas of HABs and hypoxia. Important outcomes of this work have been 1) the ESP toxicity data along with NOAA's HAB forecasting model outcomes is improving the ability to detect toxic blooms and forecast their movement and 2) the development of an early warning system (EWS) minimum viable product, expected to be operational in 2021, following lessons learned from an EWS prototype and taking into consideration stakeholder feedback. To further improve this work GLOS proposes to:

a. Assess the EWS Minimum Viable Product performance, as well as tool usage statistics, and other stakeholder recommendations by the end of the 2022 field season. GLOS will also explore alternative and improved ways of analyzing, storing, and displaying data to potentially simplify the use of this data to fulfill utilities' regulatory requirements.
b. Support the development of numerical tools to probabilistically forecast where and when toxicity levels of HABs exceed advisory concentrations for drinking water or recreational contact. The refinement of existing approaches is expected, as in-situ toxin observations at smaller spatial and temporal scales continue to increase.
c. Contribute to perform model validations by providing visualizations that allow interactive time-series comparisons between observations and model outputs at user-specified mooring locations and timeframes.

[15] A Strategic Vision for NOAA's Ecological Forecasting Roadmap: 2015-2019
http://oceanservice.noaa.gov/ecoforecasting/noaa-ecoforecasting-roadmap.pdf

2. GLOS will support partner-led regional data assimilation (DA) efforts, which is an approach consistent with the recommendations and guidance highlighted in Wilkin et al. 2017.[16] For example, NOAA-GLERL and Michigan Technological University have worked to incorporate DA into NOAA's Great Lakes Operational Forecasting System (GLOFS) to improve the thermal structure simulation of Lake Erie.[17] This is being done as a proof of concept for future GLOFS-DA forecasting systems that can be extended to all Great Lakes.

3. GLOS also proposes to support modeling efforts that help optimize the Great Lakes observing network by helping to assess its strengths and weaknesses. Observing system experiments (OSEs) could be conducted to evaluate forecasts' sensitivity to sampling frequency, types of observations, assets density, etc.

4. In partnership with the regional Sea Grant programs, NOAA's Great Lakes CoastWatch node, and NOAA-GLERL, GLOS proposes to support the development of tools informed by stakeholder surveys, to meet the information needs of Great Lakes recreational and charter fishermen. These tools would allow the users to select locations to visualize various relevant physical parameters of the surface and water column based on observing and modeled data, as well as weather forecasts.

5. GLOS will support collaborations to further develop remote sensing-based water quality products and data analytic tools, like multivariate statistical techniques, to identify water biogeochemical constituents that help discern the distribution, composition, and nature of algae blooms.

6. GLOS proposes to support University of Michigan's integrated assessment to extend their Lake Erie ecosystem evaluation to the other lakes. The work aims at 1) collecting historical publicly available time-series biological, physical, chemical, and anthropogenic/socioeconomic data pertaining to the lakes' ecosystems, 2) conducting a series of multivariate analysis and visualizations to assess the changes in the ecosystems, and 3) providing a framework for lake ecosystem-based management.

User Engagement/Outreach

A recent national survey conducted by the Middlebury Institute for International Studies titled "Center for the Blue Economy Survey on the Economic Value of Ocean Observing Systems" collected responses from users across all 11 IOOS regional associations. Early results highlight the high level of engagement from Great Lakes stakeholders as approximately half of the total responses across the entire IOOS network came from GLOS users.

Building a strong, diverse, and active partnership network is critical to ensuring that GLOS activities are relevant, proactive, and successful in addressing the observing and information needs of the Great Lakes region. This is particularly important as GLOS transitions to a service-based approach because our ability to successfully serve stakeholder information needs and leverage those services is necessary to effectively expand our impact across the region. In the 2020-2025 Strategic Plan, GLOS outlines three core values for the organization: empowerment, simplicity, and integrity. Within the details for these values is the cross-cutting commitment to diversity, equity, and inclusion. We believe diversity drives innovation and are

[16] Wilkin, J., Rosenfiel, L., Allen, A., Baltes, R., Baptista, A., He, R, Hogan, P., Kurapov, A., Mehra, A., Quintrell, J., Schwab, D., Signell, R., Smith, J. 2017. Advancing coastal ocean modelling, analysis, and prediction for the US Integrated Ocean Observing System. Journal of Operational Oceanography, 10:2, 115-126.

[17] Ye, X., Chu, P., Anderson, E., Huang, C., Lang, G., Xue, P. 2020. Improved thermal structure simulation and optimized sampling strategy for Lake Erie using a data assimilative model. Journal of Great Lakes Research 46, 144-158.

committed to building a culture where difference is valued and appropriately acknowledged in both a top-down and grassroots approach. Our approach to user engagement can be organized into three main categories:

DIRECT OUTREACH: GLOS staff routinely employ direct engagement activities including meetings, workshops, webinars, focus groups and online surveys to solicit input from stakeholders and include them in the planning, implementation, and evaluation of observing and data services. We will continue to organize, host, and/or participate in these types of direct outreach activities as needed and as possible given potential funding or travel limitations (i.e., due to COVID-19 restrictions).

DATA AS A SERVICE: Inherent in the service-based management of GLOS programming, GLOS utilizes several different tools to manage user feedback, assess user behaviors via web analytics, and track service performance statistics. As funding allows, GLOS will mature these processes to continually improve competencies, enrich services for data providers and users, and help inform/prioritize the development of new features or functionalities within Seagull.

SMART GREAT LAKES: GLOS is a co-lead of the Smart Great Lakes Initiative, a collaborative consortium established in 2019 to organize the region's technology ecosystem and network of partners around common policy goals to improve monitoring, data management and analysis, advance research, and spur technology innovation. With nearly 100 active members representing academic, tribal, state, provincial, Federal, private-sector, and non-profit interests, this consortium is currently developing a Common Strategy for Smart Great Lakes that will articulate a shared vision for advancing information technology in the region. This group has convened broad stakeholder engagement, including an ongoing effort to engage indigenous communities specifically through a "braided-river" approach[18] to develop shared goals and strategies. The consortium is also a helpful resource for identifying and prioritizing major information gaps as well as appropriate leveraging and partnership opportunities.

PARTNERS AND FEDERAL PARTNER ROLES: GLOS has traditionally partnered with an extended, bi-national, network of academic, government, and private organizations. We have been working to continually grow and cultivate the GLOS network and leverage new opportunities for partnership. A list of current partners is included in the Appendix. As part of this proposal development process, GLOS has solicited project ideas from these partners through a Request for Information (RFI). GLOS will utilize mechanisms such as Requests for Proposals, mini-grant awards, specialized project design collaborations, and innovation competitions to refine the scope and select appropriate partners to assist in implementing the activities described.

GLOS also enjoys an inherent and close relationship with NOAA's Great Lakes Environmental Research Lab (GLERL) and the Cooperative Institute for Great Lakes Research (CIGLR) being co-located at GLERL's Ann Arbor facility and working collaboratively with staff from both organizations in the planning and prioritization of monitoring and research activities. Over the years, we have worked on many projects with other NOAA offices including NCCOS, Sea Grant, OCM and many of the NOAA partners engaged with NOAA's Great Lakes Regional Collaboration Team. Many of the activities featured in this proposal workplan will be planned and/or carried out in cooperation with our NOAA partners, and GLOS will consult with GLERL and CIGLR specifically, once annual funding levels have been established, to determine best opportunities for leveraging our collective workplans. GLOS also currently has a Cooperative Agreement

[18] https://thehub.swa.govt.nz/assets/Uploads/Bridging-Cultural-Perspectives-FINAL-0.pdf

with USGS and is engaged with other US and Canadian Federal agencies through the Smart Great Lakes Initiative.

MILESTOME SUMMARY TABLE

This table is a high-level summary of the milestones related to the proposed workplan. More detailed milestones for the Observing, Modeling and DMAC subsystems is provided in the Appendix.

		YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Operations in support of Great Lakes Stakeholders	Tier 1	Maintain the administration and coordination necessary to implement IOOS in the Great Lakes.	Complete Smart Great Lakes Common Strategy and promote.	Iterate and improve on user/stakeholder evaluation and reporting.	Evaluate and update GLOS Strategic Plan.	Maintain the administration and coordination necessary to implement IOOS in the Great Lakes.
	Tier 2	Plan and coordinate for new staff and programming to support Smart Great Lakes priorities.	Accelerate user/stakeholder analytics in support of advanced Seagull functionality.	Advance priority "Smart Lake" testbed projects, grow participation and coordination resources for Smart Great Lakes partners, iterate on Common Strategy to include new/emerging needs (ex. indigenous input).		Evaluate next steps for the Smart Great Lakes Initiative.
Observing and Modeling to address data needs	Tier 1	Evaluate and prioritize investment to sustain and expand the observing network and establish support for observing and modeled data providers.	Initiate projects prioritizing the maintenance and upgrade of existing moored & shore-based assets, coordination and deployments for existing autonomous platforms, and sustaining necessary technical and coordination support for existing observing and modeled data providers. As resources allow, GLOS will try to extend capacity in these areas to new data providers and extend observing coverage to fill geographic gaps.			Re-assess network needs; Prioritize investments to sustain and expand the network as possible.
	Tier 2	Plan and coordinate new observing and modeling programs to address priority gaps and needs.	Initiate projects prioritizing year-round observations; innovative monitoring technologies; and coordinated "Smart Lake" testbed programs that integrate multi-disciplinary observing platforms, modeled data products, and information outcomes coordinated with partners.			Re-assess network needs; Prioritize investments to sustain and expand the network as possible.
Data Management & Cyberinfrastructure	Tier 1	Maintain staff, infrastructure, and supporting services necessary to meet IOOS data sharing requirements. Prioritize the updates and upgrades in process to ensure efficient and reliable data services can be maintained.		Ongoing evaluation of system status/health and planning for maintenance and improvements. Development of added functionality and features to support GLOS programming and address stakeholder needs as possible.		
	Tier 2	Evaluate and plan for added functionality and accelerated growth.	Initiate development of prioritized mobile-first applications, IoT and other new data type support, and security enhancements.			Ongoing evaluation of system status/health and planning for improvements as possible.

BUDGET SUMMARY TABLE

This budget table presents a high-level summary of budget allocations at the proposed $6M/year funding level and alternative allocations at the $3M/year funding level. It reflects how proposal elements will be implemented as general percentages of our budget and how we envision those allocations changing over time. Additional details and justification are provided in our budget narrative in the Appendix. Final funding decisions, including appropriate sub-awards, contracts, and equipment purchases will be made after assessing annual funding availability.

	Year 1	Year 2	Year 3	Year 4	Year 5
PERSONNEL + BENEFITS					
Staff Salaries (6M)	$940,380.91	$1,053,592.34	$1,085,200.11	$1,117,756.11	$1,151,288.80
Fringe Benefits (6M)	$235,095.23	$263,398.09	$271,300.03	$279,439.03	$287,822.20
SUBTOTAL (6M)	$1,175,476.14	$1,316,990.43	$1,356,500.14	$1,397,195.14	$1,439,111.00
Staff Salaries (3M)	$870,380.91	$896,492.34	$923,387.11	$951,088.72	$979,621.39
Fringe Benefits (3M)	$217,595.23	$224,123.09	$230,846.78	$237,772.18	$244,905.35
SUBTOTAL (3M)	$1,087,976.14	$1,120,615.43	$1,154,233.89	$1,188,860.91	$1,224,526.73
TRAVEL	$56,000.00	$56,000.00	$56,000.00	$56,000.00	$56,000.00
EQUIPMENT					
Equipment (6M)	$177,330.05	$509,514.36	$495,972.36	$960,095.81	$419,380.88
Equipment (3M)	$121,961.60	$318,752.29	$174,156.36	$411,500.00	$123,000.00
SUPPLIES					
Staff Computers (6M)	$6,000.00	$6,000.00	$6,000.00	$6,000.00	$4,000.00
Staff Computers (3M)	$4,000.00	$4,000.00	$4,000.00	$4,000.00	$4,000.00
Office Supplies	$1,500.00	$1,500.00	$1,500.00	$1,500.00	$1,500.00
CONTRACTUAL					
CONSTRUCTION					
OTHER					
IT Services (6M)	$2,000,000.00	$1,200,000.00	$1,150,000.00	$500,000.00	$500,000.00
IT Services (3M)	$1,000,000.00	$581,644.00	$688,504.00	$250,000.00	$250,000.00
Obs Program w/o Equipment (6M)	$1,548,237.11	$1,874,538.51	$1,898,570.80	$2,218,752.35	$2,719,551.43
Obs Program w/o Equipment (3M)	$1,187,214.82	$1,402,252.29	$1,433,264.51	$1,627,499.47	$1,908,866.30
Modeling (6M)	$300,000.00	$300,000.00	$300,000.00	$125,000.00	$125,000.00
Modeling (3M)	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00
SUBTOTAL OTHER (6M)	$3,848,237.11	$3,374,538.51	$3,348,570.80	$2,843,752.35	$3,344,551.43
SUBTOTAL OTHER (3M)	$2,287,214.82	$2,083,896.29	$2,221,768.51	$1,977,499.47	$2,258,866.30
TOTAL DIRECT COSTS					
Direct Costs (6M)	$5,264,543.30	$5,264,543.30	$5,264,543.30	$5,264,543.30	$5,264,543.31
Direct Costs (3M)	$2,632,271.65	$2,632,271.67	$2,632,271.65	$2,632,271.65	$2,632,271.65
INDIRECT COSTS (13.97%)					
Indirect Costs (6M)	$735,456.70	$735,456.70	$735,456.70	$735,456.70	$735,456.70
Indirect Costs (3M)	$367,728.35	$367,728.35	$367,728.35	$367,728.35	$367,728.35
FINAL TOTAL					
Final Total (6M)	$6,000,000.00	$5,999,999.99	$6,000,000.00	$6,000,000.00	$6,000,000.01
Final Total (3M)	$3,000,000.00	$3,000,000.02	$3,000,000.00	$3,000,000.00	$3,000,000.00