A. PROJECT MANAGEMENT

A1. Title Page

Quality Guidance for the Great Lakes Observing System
Observing Activities

January 01, 2011

Great Lakes Observing System (GLOS)
229 Nickels Arcade
Ann Arbor, MI 48104

A2. Table of Contents

A3. Distribution List

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A4. Project Organization

The Great Lakes Observing System (GLOS) is a bi-national non-profit organization with a mission to advance the coordination of the extensive Great Lakes regional observing network of people, processes and technology that work together to maximize access to critical, real-time and historical information about the Great Lakes and St. Lawrence River system for use in managing, safeguarding and understanding these immensely valuable freshwater resources. More information about GLOS organizational structure can be found in the GLOS Quality Management Plan.

Project Staff and Partners

Program Management and Quality Assurance

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A5. Problem Definition/Background

GLOS was established as a response to the need to increase and better coordinate the collection of critical information regarding the Great Lakes ecosystem. Several U.S. federal agencies including the National Oceanographic and Atmospheric Administration (NOAA) and related collaboration initiatives, such as the Great Lakes Regional Collaboration, have identified this need and recognize GLOS as the Regional Association of the Integrated Ocean Observing System (IOOS) responsible for developing the framework for a coordinated observing system for the Great Lakes that enhances and improves existing observing activities by leading the integration and development of interoperable, easy to access data, products, and related services. The mission of GLOS is to *advance the coordination of the extensive Great Lakes regional observing network of people, processes and technology that work together to maximize access to critical, real-time and historical information for use in managing, safeguarding and understanding the Great Lakes and St. Lawrence River system.*

In serving the role as a regional data coordinating entity, it is important that GLOS develop where needed and provide guidance on standards, protocols, and processes that facilitate a consistent and effective quality management system. Following EPA's QAPP format, this document will provide background information on the quality systems, protocols and procedures employed by GLOS observing partners to serve as guiding standards for observing operations.

As new standards are formalized and adopted by IOOS and GLOS, this document will be updated and made available for reference via the GLOS website: www.glos.us.

A6. Project Description

Critical information needs for the four focus areas highlighted in the GLOS strategic plan, *A Blueprint for Great Lakes Decision Making*, will be addressed in part by implementation of an array of integrated observations including moorings, sensors, AUV/glider technologies, cross-lake ferry instrumentation, and satellite remote sensing products. GLOS has sponsored the following observing activities which serve as the baseline for developing observing quality systems. Where possible, this document will identify the common standards, processes, and protocols for ensuring GLOS sponsored observing operations are conducted in a consistent manner and that quality systems are transparent.

Table 1: Observing activities Sponsored Under NOAA 2010 Cooperative Agreement

Site	Lead	Observing System and Sensors
Lake Michigan		
Milwaukee	UW-Milwaukee	Buoy: Temp profile, meteorology, currents, water chemistry
Little Traverse Bay	U. Michigan	Buoy: Temperature, meteorology, waves
Ludington	U. Michigan	Buoy: Temperature, meteorology, waves, currents
Upper Grand Traverse Bay	U Michigan	Buoy: Surface temperature, meteorology, waves.
Lower Grand Traverse Bay	U Michigan	Buoy: /Temperature profiles, meteorology, waves.
Cross-lake transects	UW-Milwaukee	Vessel: Surface Temperature, meteorology, water chemistry
Lake Superior		
Duluth	UMD	Buoys: Temperature profiles, meteorology, water chemistry
Nearshore transects	UMD	Glider: Temperature profiles, meteorology, currents, water chemistry
North entrance to Keweenaw Waterway	MTU	Buoy: Temperature profiles, meteorology, waves, currents, water chemistry
South entrance to Keweenaw Waterway	MTU	Buoy: Temperature profiles, meteorology, waves
Cross-lake transects	MTU	Vessel: Surface Temperature, water chemistry
Lake Huron		
Alpena	GLERL	Buoy: Temperature profile, meteorology, currents, waves
Lake Erie		
Cleveland	GLERL	Buoy: Temperature profile, meteorology, currents, waves, water chemistry
Buffalo	GLRC-Buff State	Buoy: Temp record, meteorology
Lake Ontario		
Oswego	GLRC- ESF	Buoy: Temp record, meteorology, currents, water chemistry
Cross-lake transects	GLRC- ESF	Vessel: Surface Temperature, water chemistry

GLERL: NOAA's Great Lakes Environmental Research Laboratory, UMD: University of Minnesota-Duluth, MTU: Michigan Tech University, GLRC: SUNY's Great Lakes Research Consortium working with SUNY-ESF and Buffalo State

Table 2: Observing Activities Sponsored Under EPA GLRI-I.E.7 Enhanced Tributary Monitoring

Location	Platforms (number)	Observations
St. Louis River/Estuary	Shore-based monitoring stations (3)	Currents, turbidity, temperature, and fluorometric measurements will allow assessment concentrations of cyanobacteria, CDOM (Colored Dissolved Organic Matter) and Chlorophyll-A.
Green Bay	AUV missions	Mapping wide spread hypoxic conditions including parameters such as phosphate, oxygen, turbidity, thermal structure, and currents
	Buoy (1)	Nutrients, carbon, persistent toxics (PCBs)
Saginaw Bay	AUV missions	Benthic habitat and algal growth, turbidity, dissolved oxygen, temperature, conductivity, Chlorophyll-A, CDOM and phycocyanin. Spatial surveys for source contributions, fate and transport of benthic muck using side-scan sonar and underwater video. Mapping water quality and water chemistry, producing full three-dimensional maps of the physical, chemical and biological structure of the Bay waters.
	BathyBoat-Autonomous survey vessel	Larval fish counts and sizes using fishery acoustics.
Maumee River	Moored station (1)	Continuous real-time observations of dissolved reactive phosphorus concentrations, light intensity, turbidity, chlorophyll, phycocyanin, CDOM, dissolved oxygen, temperature, and conductivity.
	Field data	Along with conductivity, temp, depth (CTD) profiles at each sample site, field samples will be analyzed for TP, SRP, TSS, chlorophyll, phycocyanin, dissolved organic carbon, Microcystis abundance, and microcystin concentration.
Genesee/ Rochester	Shore based (hut/pump) system (1)	Basic water quality parameters and real time phosphate and nitrate sensors.
	Buoy (1)	Thermistor string, along with epilimnetic sensors for conductivity, turbidity, and chlorophyll, meteorological data, monitor the movement of water, surface water plume and the resulting plunging of the Genesee River.
	AUV missions	Map the outflow of the river in regards to the spring thermal bar and the resulting spread of the plume, monitor for *Cladophora* distribution.
All Locations	Remote sensing	Synoptic maps of lake chlorophyll (chl), dissolved organic carbon (doc), suspended sediment (sm) values offshore of the AOCs, monthly average of optical attenuation, weekly ice cover maps, daily surface wind speeds, and mapping of harmful algae blooms (HABs).

A7. Data Quality Objectives and Criteria

The main objective of this component is to increase the observing capacity to improve wave forecasting, circulation modeling and monitoring of lake heat and water balances. Continuous in situ observations will be conducted through a variety of platforms and sensors including Moored structures and buoys, autonomous vehicles, and underway systems on vessels of opportunity. The goal of the program is to collect as much in-lake, or over-lake, time-series data from the selected observing systems outline in Table 1 in a manner that will allow the data to meet the data quality standards outlined below. However, we recognize that there are clear limitations in the ability to verify the data quality criteria on a continuous basis and the inherent limitation that in situ based observations are generally not more accurate than laboratory determined values, are often surrogate measures of a variable of interest, and are prone to impacts of biofouling and drift which will degrade the quality in between service intervals.

Fundamentally we will rely on the strict adherence of the standard operating principles defined herein, and adherence to manufacturer recommendations on calibrations, operations, and maintenance to ensure that the physical and chemical data collected by all observing systems meet the quality objectives outline in this section. To the extent possible we will use measures of accuracy, precision, completeness, representativeness, comparability and detection limits to assess data quality.

Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference or true value. Where possible, the accuracy of field time-series data will be assessed against certified standards provided by sensor manufactures in the laboratory through the comparison of observed values from the sensor and the true value from the standard. This comparison will be done prior to the deployment of the sensor and immediately upon retrieval. Care will be taken to keep the sensor in its existing state during retrieval and transport to the lab and exposed to standards at the soonest possibility. The frequency of these accuracy checks will be dependent on the sensor type, system design, and resource required for retrieving, testing, and re-deploying.

The percent difference (%PD) between the true value and measured value will be calculated as follows:

$$\%PD = \frac{(C_s - C_u)}{C_s} x\, 100$$

where C_s = concentration of CRM, standard, or discreet sensor.
C_u = measured concentration of CRM, standard, or deployed sensor.

If the percent difference falls outside of the DQO's, the previous month of data for that parameter will be flagged as necessary. If accuracy criteria are not being met, an evaluation will be conducted to identify the cause and actions will be taken to bring the criteria into compliance. Variables to be included in the evaluation of accuracy compliance will be sensor drift, sensor power, sensor malfunction, and sensor biofouling. Corrective actions could include conducting repairs to the sensors, platform systems, modifying frequency of sensor servicing for cleaning and re-calibration.

Precision

Precision is the degree of agreement between two or more measurements. The precision of field time-series data will be assessed in the laboratory through the use of repeated sequential measurements by individual sensors in known certified standards. Precision checks will be performed in conjunction with accuracy checks, namely prior to deployment and immediately upon retrieval. Sensors will be placed in a reference solution and two sequential measurements will be taken within 60 seconds of each other. The relative percent difference (RPD) between the replicate measurements will be calculated as follows:

$$RPD = \frac{(T_1 - T_2)}{0.5\,(T_1 + T_2)}\,x\,100$$

where T_1 = measured concentration of time point 1
T_2 = measured concentration of time point 2

If precision criteria are not being met, an evaluation will be conducted to identify the cause and actions will be taken to bring the criteria into compliance. Variables to be included in the evaluation of precision compliance will be sensor drift, sensor power, sensor malfunction, and sensor biofouling. Corrective actions could include conducting repairs to the sensors, platform systems, modifying frequency of sensor servicing for cleaning and re-calibration.

Completeness

Completeness is a measure of the amount of valid data obtained from a given observing system compared to the amount of data that were expected. Expected data is all data obtained while the sensors were deployed and expected to be operational. The amount of expected data is dependent to individual sensors and observing platforms based on manufacturer and design recommendations. Valid data is all obtained data that was within accuracy and precision criteria. The percent completeness (%C) will be calculated as follows:

$$\%C = \frac{M_v}{M_p}\,x\,100$$

where M_v = number of valid measurements
M_p = number of planned measurements

A completeness objective of 75% has been set for any given observing system within the project, however, we expect meteorological and physical-based in situ measurements to be able to have a much higher degree of completeness than chemical-based in situ measurements due to their proven history and lower impacts of biofouling. If criteria are not met, corrective actions could include more frequent sensor maintenance, modifying biofouling protection equipment, or replacing individual sensors or system components that are unreliable.

Representativeness

Representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Overall, field data representativeness will be satisfied by following the QAPP design, utilizing proper measurement techniques, and following manufacturer operating procedures and recommendations. Field duplicate analysis will also assist in determining representativeness. Representativeness criteria will only apply to the specific temporal and spatial scales at which any given observing system are operating. This limitation does not impact the project objectives or use of the data for any subsequent modeling or trend analysis since these secondary uses would be expected to assign the specific temporal and spatial attributes associated with any data. Necessary details of time and space stamps, measurement approaches, and data quality criteria will be included in metadata files for each observing system.

Comparability

Comparability is a measure of the confidence with which one data set can be compared with another. This parameter is important for comparing between sampling locations and over time. Field and laboratory data comparability will be ensured by following the QAPP. Standard methods will be used where possible, sampling and analytical methods will be followed consistently, and required detection limits will be achieved. Using the same sensors, where duplicate sensors are available, will assist the comparability of data sets.

Table 3: Continuous monitoring data quality assessment and objectives.

Assessment	Type of Evaluation	Data Quality Objectives
Accuracy	Comparison of readings from *in situ* sensors and 1) duplicate discreet multiparameter sondes, or 2) certified standards from sonde manufacturer	See Table 4a
Precision	Closeness of repeated sequential readings from *in situ* sensors	See Table 4b
Completeness	Comparing number of expected and valid data points in the time-series data set.	75%
Representativeness	Daily checks of time-series data, Auto-notification of problems, Visual inspection of reject spikes	
Comparability	Use SOPs and same equipment at each depth	

Table 4a: Field time-series data quality objectives

Observing System	Sensor	Parameter	Accuracy (%R) Objective	Precision (RPD) Objective
Buoys	Thermistor string	Water Temperature		
	RM Young 09106	Wind		
	RM Young 41283VC	Air Temperature		
	RM Young 41283VC	Relative Humidity		
	RM Young 61202V	Barometric Pressure		
	Li-Cor Li-199	Solar Radiation		
	Li-Cor Li 200	PAR		
	CSI 107	Water Temperature		
	Nortek Z-Cell	Current Velocity Profile		
	Nortek Z-Cell	Current Direction Profile		

	IWS	Wave Height		
	IWS	Wave Period		
Moorings	WETLabs CycleP	Dissolved PO4	± 25%	15%
	Turner Designs Cyclops 7	Chlorophyll	± 25%	15%
	Turner Designs Cyclops 7	Phycocyanin	± 25%	15%
	Turner Designs Cyclops 7	Phycoerythrin	± 25%	15%
	Turner Designs Cyclops 7	CDOM	± 25%	15%
	Turner Designs Cyclops 7	Turbidity	± 25%	15%
	YSI 6600 Sensor#	Temperature	± 25%	15%
	YSI 6600 Sensor#	Conductivity	± 25%	15%
	YSI 6600 Sensor#	Dissolved Oxygen	± 25%	15%
AUV	YSI 6600 Sensor#	Temperature	± 25%	15%
	YSI 6600 Sensor#	Conductivity	± 25%	15%
	YSI 6600 Sensor#	Dissolved Oxygen	± 25%	15%
	YSI 6600 Sensor#	CDOM	± 25%	15%
	YSI 6600 Sensor#	Chlorophyll	± 25%	15%
GLIDER	Seabird CTD	Conductivity	± 25%	15%
	Seabird CTD	Temperature	± 25%	15%
	Seabird CTD	Depth	± 25%	15%
	Wetlabs ECO puck	CDOM		

Table 4b: Manufacturer specifications for sensor accuracy and precision. Used to set data quality criteria when comparisons against certified standards are not possible

Observing System	Sensor	Parameter	Manufacturer Sensor Specifications		
			Range	Resolution	Accuracy
Nearshore Buoys	Thermistor string	Water Temperature			
	RM Young	Wind Direction	0-360°	1 degree	±2°

	09106				
	RM Young 09106	Wind Speed	0 to 100 m/s	.1 unit	1 % of reading
	RM Young 41283VC		-50° to 50°C (V), -50° to 150°C (F)	0.1°	±0.3° at 0°C
	RM Young 41283VC	Relative Humidity	0-100%	1%	±2% at 20°C
	RM Young 61202V	Barometric Pressure	600-1100hPa	0.025% of analog scale	.05% of analog pressure range
	S2 IWS	Wave Height			
	S2 IWS	Wave direction			
	Nortek Z-cell	Currents	0-100m	n/a	1% of full scale +/-5cm

A.8. Special Training/Certification

The QA Manager will attend EPA offered training in quality management system development, review and documentation. The QA Manager will serve as a resource for all GLOS projects where QAPPs are required. Through evaluation of project proposals and review of contracts, GLOS will require project partners to ensure project staff and related sub-contract staff are well-qualified to produce project results and have completed any required training or certification. Required training for GLOS staff is expected to be limited to quality management training and staff will complete EPA offered trainings to fulfill these requirements. The QA Manager will verify that staff have completed any required training and produce a record of completion to be included in staff personnel files.

All personnel involved in the operation, maintenance, and calibration of field equipment will be trained in those areas. All analytical laboratory personnel will receive training and have proven proficiency in their designated analytical procedures. All personnel involved in generating data will be made aware of the QAPP requirements related to those duties and a sign off sheet will document that they are aware and understand these requirements.

A.9. Documentation & Records

Project specific quality documentation is the responsibility of the project manager with the project management team with oversight by the QA Manager and GLOS Executive Director. The approved QAPP and any future revisions will be distributed according to the distribution list (Section A.3). The document control information for QAPP revisions will be recorded on the title sheet and in page footers. The QAPP title page will include information on the originally dated, revision number, and revision date of the overall QAPP. Page footers will contain the date of origin or revision for the individual page. Changes to the QAPP will be recorded in the log of QAPP revisions included in the appendices. Other documentation and records anticipated from this project include:

- Raw data stream of time-series data (electronic data)
- Flagged time-series data following QC review of raw data (electronic data)
- Sensor calibration and post-calibration sheets
- Quality control check field sheets
- Laboratory analytical reports
- Instrument/sensor records
- Field Log Book
- QC summary reports
- Reports to EPA (semi-annual and final reports)

The QA Manager will be responsible for distributing the QAPP to the personnel on the distribution list. Copies will be submitted with a signature page to be returned to the QA Manager. A record of QAPP revisions and distribution will be maintained to ensure that appropriate personnel will have the most current version.

Documents generated by field activities, including field data sheets and notes, will be maintained by individual Principal Investigators. Each PI will maintain a file of raw data, instrument printouts, preparation and run logs, calibration information, analytical data, quality assurance data, and chain-of-custody forms. An electronic summary of all data will be prepared.

All original observing system records and data will be retained at individual PI institutions in a secured storage area for a period of 7 years. Electronic data will be archived on CD-ROM or other appropriate media. Time-series data from all observing systems will also be transmitted to GLOS for dissemination and archiving. All GLOS served data is also backed-up on an independently maintained server.

DATA GENERATION AND ACQUISITION

B.1. Sampling Process Design

Language to describe each individual project's sampling design is included as part of required proposal and contract scope of work documentation.

B.2. Sampling Method

As part of the QC and interpretation of the in situ sensor data, water samples will be collected for select parameters. These comparisons are not intended to directly assess accuracy, precision, or data quality objectives of the in situ measurements. Sensor readings will be empirically correlated to standard laboratory determined values to provide for a more meaningful assessment of actual water quality and ecological conditions monitored over time and space. Standard analyses will be conducted as possible for chlorophyll, total suspended solids, CDOM, dissolved oxygen, phycocyanin, and Phycoerythrin, and turbidity. During initial installation and during each field servicing interval water samples will be collected at the depth of the particular and processed according to Standard Methods or cited Standard Operating Practice manuals for a given laboratory. Water samples will be collected with either a clean VanDorn or Niskin bottle, transferred to acid washed polypropylene bottles and stored cold and dark until processed for specific analyses, with a holding time not to exceed 8 hours and if applicable frozen as soon as possible. Maximum holding time prior to analysis is 28 days.

B.3. Sample Handling

Field Chain of Custody and Documentation

The procedures summarized below ensure that samples will arrive at the laboratory with the chain-of-custody intact:

- The Lead Field Technician will be responsible for the care and custody of the samples.
- All collection bottles will be labeled in waterproof ink with the date, sampling location, sample number, and collector's initials.
- All collection activities will be reviewed by the Project PI and /or the QA Manager to determine whether proper procedures were used and whether additional samples are required.

All field data notes will be organized into a field logbook. Entries will be described in as much detail as possible.

Laboratory Chain of Custody and Documentation

The procedures summarized below ensure that samples maintain the chain-of-custody within the laboratory:

- A completed chain-of-custody form will accompany samples.
- Chain-of-custody forms designate the date, time, and signatures of the personnel relinquishing and receiving samples.

The sample custodian will receive the samples at the laboratory. It will be the responsibility of the sample custodian to determine the manner in which samples will be split, preserved, stored, or routed. All relevant information will also be recorded, especially the unique lab number for each sample. Samples are stored in an appropriate access-controlled location (refrigeration room or freezer) for at least 30 days after the analytical report has been written.

B.4. Analytical Methods

The analytical methods and equipment required fall into three categories: 1) buoy sensors, 2) field QC measurements using discreet sondes, and 3) laboratory analysis to guide in interpretation of in situ water quality data.

- Analytical methods for the buoy sensors in all of the GLOS observing systems are specific to the manufacturer technical design and principle of operation. Table 5 lists the sensors, general principle of measurement, and appropriate references for each parameter to be measured.
- Field QC measurements using independently maintained and calibrated sondes with the same sensor packages will be taken approximately once per month
- Laboratory analysis of comparative water samples for phosphate will be conducted using standard molybdenum blue method on a Technicon Auto Analyzer (APHA 1985)
- Laboratory analysis of comparative water samples for algal pigments; chlorophyll, phycocyanin, and phycoerythrin will be conducted using method (citation TBD)

Table 5: References for use and maintenance of instruments for in situ field observations.

Manufacturer	Parameter	Sensor	Internet Link for Manuals/Info
Nexsens	Temperature	T-nodes	http://www.nexsens.com/pdf/nexsens_t-node_manual.pdf
YSI 6600	Temperature	YSI combo	http://www.ysi.com/media/pdfs/069300-YSI-6-Series-Manual-RevF.pdf
	Conductivity		
	pH	YSI 6561	
	Turbidity	YSI 6136	
	DO	YSI 6150	
	Chlorophyll	YSI 6025	
	Phycocyanin	YSI 6131	
Turner C6	CDOM	Turner 251	http://www.turnerdesigns.com/t2/doc/manuals/C3_manual.pdf
	Chlorophyll	Turner 200	
	Phycocyanin	Turner 231	
Satlantic	Nitrates	SUNA	http://www.satlantic.com/documents/408465_SUNACom_User_Manual.pdf
LI-COR	Underwater PAR	LI-192	http://www.licor.com/env/Products/Sensors/192UW/li192_description.jsp
Li-Cor	Solar Radiation	LI-200	http://www.licor.com/env/Products/Sensors/190/li190_description.jsp
LI-COR	PAR	LI-190	http://www.licor.com/env/Products/Sensors/192UW/li192_description.jsp
Teledyne RDI	Current speed and direction	Workhorse Monitor 1200KHz	http://www.rdinstruments.com/monitor.aspx http://www.rdinstruments.com/support/documentation/cc_documents.aspx#workhorse
Nortek	Current speed and direction	Aquadopp Z-cell	http://www.nortekusa.com/lib/brochures/auqadopp-z-cell/view
LUFFT	Air temperature	WS600	http://www.lufftusa.com/pdfs/UMB2010_p5.pdf
RM Young	Wind	9106	http://www.fondriest.com/pdf/rm_young_09101_spec.pdf
RM Young	Barometric Pressure	61302	http://www.fondriest.com/pdf/rm_young_61302_manual.pdf
RM Young	Relative Humidity	41382VC/VF	http://www.fondriest.com/pdf/rm_young_41382_manual.pdf
RM Young	Air Temperature	41382VC/VF	http://www.fondriest.com/pdf/rm_young_41382_manual.pdf
MHL	Temperature	Thermistors	TBD

S2	Waves	IWS	TBD

Calibration using Secondary Standards

In many cases, true calibrations with a primary standard are not practical for In-vivo-fluorescence (IVF) applications. IVF measures the relative change in cyanobacterial biomass via pigment fluorescence and the best means of ‘calibration’ is to use a secondary standard that provides a stable signal that can be correlated to a meaningful cyanobacterial concentration through correlation. The secondary standard is used to check for instrument drift and to recalibrate if necessary. For example, in the laboratory the fluorescence of a natural water sample or cyanobacteria culture can be read using the fluorometer. Record the reading and then insert or install a secondary standard. If an adjustable secondary standard is being used, adjust until it provides the same signal level as the water sample. Then take the sample and perform a quantitative test for cyanobacteria such as cell count, taste and odor, etc. The result of the quantitative test can then be correlated to that secondary standard.

B5. Quality Control

Quality control activities have been developed for the various GLOS observing systems based on manufacturer’s operating procedures and recommendations, current practices of existing continuous monitoring systems, and professional judgment. Sensors on the various observing system platforms will be initially calibrated prior to deployment, and at the completion of the deployment cycle. The duration of this deployment cycle will vary depending on sensor type and system platform. Most *in situ* water quality (chemical and biological) measurements will be internally logged and only processed once the sondes are being serviced and replaced on an approximately monthly sequence. Meteorological data and physical measurements of temperature and waves will be transmitted to local PI receiving stations and the data stream will be downloaded to GLOS and other internet sources for access by users within minutes of the hourly interval. Any distributed hourly data will be marked as “provisional” until further quality control checks are performed. Archived data (15 minute data) will be available to users at a later time that will have undergone a more thorough quality control evaluation.

Tier 1 Quality Control (Daily)

Incoming near-realtime data is evaluated automatically using software that allows for alarms to be set for each parameter with minimum and maximum limits. When activated, the user-defined action will occur which can include sending an email message, creating a text file, or sending a text message to a cell phone. Also, the measurements that are outside of the limits will be automatically flagged using a user-defined label. The alarms will notify the local PI immediately of a potential problem with a sensor or the occurrence of a “significant” event in the lake. Automatic flagging will allow external users to be aware of a potential problem with the data quality. Due to the automatic nature of this flagging, tolerance levels will be generous. However, tolerance will not be given to levels outside a sensor’s measurement range.

Every 1-2 days, the data stream will be reviewed for noticeable spikes and trends in the data and a determination will be made as to the acceptability of the data based on experience and professional judgment. Rejected data will be flagged with appropriate codes, such as unknown spike, blocked optic, negative value, or no data. A list of codes will be developed over time and included in future QAPP revisions.

Tier 2 Quality Control (Monthly)

At approximately monthly servicing intervals, performance checks will be made on sensor packages at fixed moorings and buoys. Duplicate freshly-calibrated sondes will be lowered into the water adjacent to the deployed sensors. The number of matched sampling timepoints will vary depending on sampling frequency. Comparisons between the data from 2 discreet sensor packages will ensure that the deployed sensor is reading each parameter within the acceptance criteria shown in Tables 3 and 5. Data will be recorded on a site visit sheet and compared to DQO's. After the comparative readings are completed, designated sensors will be retrieved for cleaning and re-calibration as specified by the manufacturer. This is also described later in Section B.7 (Instrument/Equipment Calibration and Frequency). Records of re-calibrations for each sensor will be maintained and will include pre- and post-calibration data. Differences between pre- and post-calibration data will be compared to DQO's (Tables 3 and 5) and manufacturer specifications.

The data from any sensor that failed the performance check will be subjected to careful scrutiny to observe a point in the data stream where an obvious change occurred or if the data drift is linear across the service interval. Rejected or modified data will be flagged with appropriate codes. A list of codes will be developed over time and included in future QAPP revisions. The primary reason for a sensor to fall outside of the DQO's is likely to be fouling; however, signal drift and sensor malfunction can also occur. If fouling and drift result in a linear trend in the data during the prior two week period, a variable correction may be used to correct the data for all or a portion of that period.

B6. Instrument/Equipment Testing

All sensors will be tested, inspected, and maintained according to manufacturer's instructions. In some cases, routine servicing or re-calibrations are performed by the manufacturer. If possible, all routine servicing will be performed after the buoy system is retrieved in the Fall. A sensor service log will be maintained by each PI for their own platforms to track preventive maintenance, problems, and corrective actions for each sensor, and copies of the logs will be provided to the Observatory Manager. Each sensor will be identified by a unique number to assist the tracking process. Where available, diagnostic software provided by manufacturers will also be used to check the status and functionality of sensors.

Critical spare parts will be identified, and, if possible, kept in stock to reduce sensor down time. In particular, parts related to biofouling protection will be kept in stock. Most biological and chemical sensors used on our observing systems have some type of biofouling protection that may need frequent replacement of parts such as wipers or brushes

B7. Instrument Calibration & Frequency

Calibration procedures will be performed as prescribed by the individual sensor manufacturer within the reference manual. Instruments will be calibrated prior to deployment and immediately upon retrieval as part of the accuracy checks. Types of calibration procedures and available standards are defined below in Table 6.

Table 6: Type of Calibration for Sensors

Manufacturer	Parameter	Calibration Type	Reference Standard
Nexsens	Temperature	Send to Manufacturer every 2 years or as needed	Check against known temperature[3]
YSI 6600/ 6920	Depth	Known Std	Atmospheric pressure
	Temperature	none	Check against known temperature[3]; replace if bad
	Conductivity	Known Std	Potassium Chloride
	pH	Known Std	Calibration buffers
	Turbidity	Known Std	Styrenedivinylbenzene copolymer
	DO	Known Std	Atmospheric O_2
	Chlorophyll	Raw RFU[1]	Check zero with ultrapure water
	Phycocyanin	Raw RFU[1]	Check zero with ultrapure water
Turner C3	CDOM	Raw RFU[1]	Check zero with ultrapure water
	Chlorophyll	Raw RFU[1]	Check zero with ultrapure water
	Phycocyanin	Raw RFU[1]	Check zero with ultrapure water
Satlantic	Nitrates	Known Std and/or Raw RSU[2]	Nitrate and/or check zero with ultrapure water
LI-COR	PAR	Send to Manufacturer every 2 years or as needed	
LI-COR	Solar Radiation	Send to Manufacturer every 2 years or as needed	
Teledyne RDI	Current speed and direction	na	
Nortek	Current speed and direction	na	
S2	IWS	Annually	Calibrate compass/ferris wheel
MHL	Thermistor	Annually	Check against known temperature[3]
LUFFT	Air temperature	Send to Manufacturer as needed, recommended annually for humidity	
	Relative humidity		
	Precipitation		
	Air pressure		
	Wind direction, speed		
RM Young	Air temperature	Send to Manufacturer as needed, recommended every two years	
	Relative humidity		

	Air pressure		
	Wind direction, speed		

[1] Relative fluorescence unit; RFUs can be converted to known quantities by calibrating sensors to known standards to obtain conversion factors.
[2] Relative Spectrophotometric Unit, RSUs can be converted to known quantities by calibrating sensors to known standards to obtain conversion factors.
[3] Checked against a known temperature using either 1) a digital NBS temperature probe, or 2) a temperature probe on a discreet sonde that has been checked against a digital NBS temperature probe.

B.8. Inspection/Acceptance for Supplies

Individual PIs will be responsible for the inspection of field supplies and consumables for their sensor platforms. Sensor calibration standards will be assigned expiration dates as necessary; no expired materials will be used for this project.

The analytical laboratory staff will be responsible for the inspection of laboratory supplies and consumables. Expiration dates for standards and reagents will be assigned based on vendor or method requirements; no expired materials will be used for this project. Method or instrument criteria for purity will be met by standards, reagents, gases, and laboratory water.

B9. Data Acquisition (Non-Direct)

GLOS sponsored projects that require the use or acquisition of data via non-direct methods are required to complete EPA QAPP or QAPP for Secondary Data Projects as appropriate. For example, remote sensing quality documentation has been developed and submitted to EPA separately by Robert Shuchman at Michigan Tech Research Institute and is not included in this document. Submission of these documents to GLOS is required in contracting and can be made available by request.

B10. Data Management

Each Principal Investigator is required through GLOS contracting to provide necessary information on individual data management systems.

C. ASSESSMENT AND OVERSIGHT

C1. Assessments & Response Actions

Assessments will be conducted to ensure that the project meets quality assurance objectives and corrective actions will be identified if necessary. These will generally consist of:

- Day to day assessments of the local PI of all project activities
- Monthly assessments of data quality by the QA Manager

A formal corrective action program will be determined and implemented when a noncompliance problem is identified in the field or laboratory. The person who identifies the problem is responsible for notifying the local PI, and QA Manager as necessary. Corrective actions will be required with any analytical, equipment, or database system problem. Action taken is dependent on the event.

The local PI will be alerted that corrective actions are necessary if QA/QC samples submitted to the laboratory do not meet criteria or if field equipment output data are suspect. The local PI is responsible for reviewing field equipment output data for QA/QC and initiating corrective action.

The local PIs and QA Managers will be alerted that corrective actions are necessary if:

- QC data do not meet accuracy and precision criteria;
- Blanks contain target analytes above acceptable levels;
- Detection limits are unusually altered;
- Deficiencies are detected by during internal/external audits or from the results of performance evaluation samples;
- Inquiries concerning data quality are received.

Corrective action is often taken at the bench level by the field or lab technician. The designated technician is continually reviewing the following for possible errors: the preparation/ extraction procedure, instrument calibration, preparation of standards, matrix spikes, matrix spike duplicates, and instrument sensitivity. If a problem persists or cannot be identified, the issue is referred to local PI. Once the problem is resolved, full documentation of the corrective action procedure is filed. Validation will consist of a review of all experimental and water quality parameters to demonstrate compliance with method performance criteria.

C.2. Reports to Management

Each project partner will be responsible for submitting quarterly progress report to the Quality Assurance Manager. The Observatory manager will prepare QC summary reports, addressing all quality assurance problems and solutions, which will be reviewed by GLOS QA and Project Manager. The EPA project manager will receive semi-annual and final reports which will contain QA sections that summarize data quality information from the project and will provide an overall data assessment/validation in accordance with the QAPP objectives. The project schedule provided in Table 2 shows the time-line for when semi-annual and final reports will be produced.

D. DATA VALIDATION AND USABILITY

As discussed above the primary use of GLOS observed data is for research and this QAPP has been developed under a graded or qualitative approach as outlined by EPA QA/R-5. There are many unknowns as to the performance of individual sensors under monthly to seasonal deployments periods in the lake environment, especially with respect to biofouling. As we move forward, our experiences and lessons learned should allow us to develop a revised quality plan that is more detailed and provides data that are of even higher quality.

D.1. Data Review, Validation, & Verification

All data produced by this project will be reviewed to evaluate the data against the method/procedural requirements (verification) and to determine if the data meet the data quality objectives (validation). The review process involves:

- Preliminary review of the data collected in the field and in the laboratory by all data generators;
- Secondary review of field records and analytical results to verify the data against method and SOP requirements by local PI;
- Review of the verified data and preliminary validation by the QA manager;
- Final validation by Project Manager; and
- Assessment of the data for its usability to meet project goals by Project Manager.

D.2. Validation and Verification Methods

Responsibilities for conducting verifications of all data generated by this project are shown in Table 7. The local PI will be responsible for reviewing data, conducting corrective actions if QA/QC requirements are not met, and assembling a data package that includes the flagged data, calibration records, and results of quality control check samples. The QA Manager will review each data package for completeness and compliance with project requirements and summarize the findings on the Preliminary Data Validation Checklist (Appendix 15). This checklist will be changed as necessary as the project moves forward. Based on this review, the QA Manager will be responsible for conducting the necessary corrective action, notifying the Project Manager, and documenting the outcome. Select audits of field activities will be performed by the Project Manager.

Table 7: Project operations and verification responsibilities

Operation	Responsibility
Observatory	
Sensor calibrations prior to deployment	Lead Field Technician
Buoy location as specified	Local PI
Hourly data retrievals operations	Local Data Manager
Automatic data flagging (Tier 1)	Local Data Manager
Monthly calibrations (Tier 2)	Lead Field Technician
Manual raw data flagging	Local Data Manager
Compliance corrective actions	Local PI
Data management	Local PI
Instrument inspection and maintenance	Lead Field Technician
Field chain of custody	Local PI
Assemble monthly QA summary reports	Local PI
Review monthly QA summary reports	QA Manager
Implement corrective actions based on QA summary reports	QA Manager
Field data collection audit	Project Manager
Field methods audit	Local PI
Field instrument calibration audit	Local PI
Manual data flagging audit	Local PI

Data validation focuses on the ability to use data as intended to make decisions and to address project objectives. At this time we envision assigning a qualification to flagged data points indicating the degree to which the reporting of this value deviated from performance criteria. These qualifications address overall usability, not contractual adherence. Examples of some data qualifications include:

- Analyte is not detected above the method detection limit.
- Quantity of analyte is approximate due to analysis limitations.
- Identification of the analyte is tentative.
- Identification of the analyte is uncertain (with reason given, such as interference).

The local PI will conduct a systematic review of the data for compliance with the established quality control criteria and any comparative laboratory analysis. A quarterly data summary report will be prepared by the local PI that includes data qualifiers based on QA checks, duplicate instrument measurements and lab comparisons. The QA Manager will append all the quarterly data summaries into an annual data report that will be provided to the Project Manager. The annual data summaries will be included in the final report submitted to EPA.

D.3. Reconciliation with User Requirements

Project data will be reconciled with the data quality objectives through the verification and validation process. Data that do not meet these objectives will be qualified and discussed in the final report. In addition, data qualifications will be made available to user databases.

In general, users will access the data from live display and archived database. In meeting user requirements, the initial goal is make sure that the data stream is in the required GLOS format (http://www.glos.us/obs/), NOAA’s National Data Buoy Center (http://www.ndbc.noaa.gov/), and IOOS (http://www.ioos.gov/catalog/). These portals are major access points for local, regional, national, and international data users. Each local PI will work with the GLOS management team to understand their short-term and long-term needs. Generally, archived data will be universal formatted in common data formats (e.g., ASCII), so that users can upload this data set into their particular software to manipulate the database for their specific research or outreach needs.