

Standard Operating Procedure #11:

Data Entry and Management

Version 1.0

In Monitoring Protocol for Wadeable Streams of the Great Lakes Network

Prepared by

Richard Damstra, Joan E. Elias, Mark Hart, and David D. VanderMeulen*

National Park Service

Great Lakes Inventory and Monitoring Network

2800 Lake Shore Drive East

Ashland, Wisconsin 54806

* *Contact author:* david_vandermeulen@nps.gov

December 2017

Please cite this publication as:

Damstra, R., J. E. Elias, M. Hart, and D. D. VanderMeulen. 2017. Standard operating procedure #11: Data entry and management. *In* D. D. VanderMeulen, J. E. Elias, S. Magdalene, R. Damstra, and J. Glase. 2017. Monitoring protocol for wadeable streams of the Great Lakes Network, version 1.0. Natural Resource Report NPS/GLKN/NRR—2017/1567. National Park Service, Fort Collins, Colorado.

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Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this standard operating procedure will promptly notify the project manager and/or the Great Lakes Network (GLKN) data manager about recommended and required changes. The project manager must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the header of the document file. For complete instructions, please refer to Procedure for Revising the Protocol, SOP #16.

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

Acknowledgements

We relied primarily on the Great Lakes Network's data management plan (Hart and Gafvert 2005) in writing this document. Standard operating procedures for the entry and management of data written by other networks also provided guidance.

11.0 Introduction

Water quality data collected under the wadeable streams water quality monitoring protocol must be entered, quality-checked, documented, managed, and made available to others for a variety of purposes, such as management decision-making, research, and education. The National Park Service (NPS) Water Resources Division (WRD) developed a database application called the Water Quality Database Template, or NPSTORET, to facilitate management of water quality data. NPSTORET facilitates the importing of water quality data into a copy of Earthsoft's EQuIS database maintained by WRD. From the EQuIS water quality data is imported into the National STORET (STORage and RETrieval) Data Warehouse administered by U.S. Environmental Protection Agency (EPA), as required by the water quality component of the Natural Resource Challenge (NPS 1999), NPS-75, and NPS Reference Manual 77. NPSTORET is best suited for water quality data that comes from discrete sampling during individual site visits.

To better accommodate continuous or time-series data that are generated from automated data loggers, as well as streamflow data, WRD adopted Aquatic Informatics' Aquarius system for storage and visualization of continuously monitored water quality data. The Network will utilize a version of Aquarius hosted by WRD for remote data entry, analysis and visualization.

This standard operating procedure outlines data stewardship roles and responsibilities, and provides specific instructions and references for entering, quality checking, and managing water quality data.

11.1 Data and Records Management for Fieldwork

Good data management begins in the field, therefore all the following steps will be completed by field crews:

- Hand-written field sheets should be reviewed for completeness prior to leaving the site. Make photocopies as soon as possible and file them appropriately. Make electronic scans of data sheets at the end of the sampling season and archive in the GLKN office according to the data management plan (Hart and Gafvert 2006).
- Ensure that field forms, field notebooks, and other hardcopy records are secure, organized, and available for viewing, reproduction, or transfer upon request and/or at the end of each field season.
- Schedule and perform regular data transfer and backup. Data will be protected from loss or damage by daily backup, when possible, or on a feasible schedule approved by the project leader and the data manager. Ideally, raw data are backed up off-site as soon as a sampling trip is completed.
- Record and verify observed or measured data values. Complete paper forms and enter data into NPSTORET and/or other electronic databases.

- Results of macroinvertebrate identification and enumeration will be organized in a database, and will include the species name, order, family, tolerance value (an index based on the pollution tolerance of each taxon), functional feeding group, and whether reference specimens or digital photos are available.
- A ‘Memo-to-file’ will be used to document any decisions or corrections that are made. This memo will include the date, name of author, site or sample referred to, a description of the problem or error, and a statement describing the decision made or action taken. The memo will be archived with the appropriate site data and files.
- Data validation, the process by which data is proven or disproved to be accurate, involves the review of the results of all measurements, samples, and QC samples.

11.2 Data Stewardship Roles and Responsibilities

Data stewardship is for the process of managing data and information resources that are organized, useful, compliant, available, and safe. The demand for detailed, high quality data and information about water quality requires a group of people working together to ensure that data are collected using appropriate methods, and that resulting datasets, reports, maps, and other derived products are well-managed.

The Great Lakes Network (GLKN) aquatic ecologist serves as project manager for water quality monitoring. The project manager will supervise data collection, provide project oversight, direct on-the-ground data collections, and provide cohesive links among data collection, synthesis, interpretation, and reporting.

While the project manager must act as the steward for water quality monitoring data for the Network, other project and GLKN personnel are also accountable for specific data management tasks. Table 1 lists stewardship responsibilities of personnel involved in the management of water quality data. To ensure that all project data are managed properly, individuals must understand their responsibilities, communicate with one another, and assist one another as needed.

Table 1. Data stewardship responsibilities of water quality monitoring personnel.

Personnel Role	Data management responsibilities related to water quality monitoring
Project Crew Member	Crew members collect and manage data with direction and guidance from the crew leader and/or project manager. Data collection includes calibrating and operating sampling equipment, collecting water samples, and recording measurements and observations. Crew members are responsible for quality control by following data collection and recording instructions and by promptly verifying recorded data. Crew members may also perform data entry and verification.
Project Crew Leader	The crew leader normally performs the same duties as the other crew members and ensures adherence to data collection and processing protocols, including data verification and documentation. The crew leader also works with the project manager and data manager on water quality data management in the office.
Project Manager (Network Aquatic Ecologist)	The project manager is responsible for all project operations and results, and may also participate in field operations. The project manager ensures that data management activities are conducted according to established procedures and is responsible for data validation and certification: approving the data content, quality, and documentation, as well as making decisions about data sensitivity and distribution. The project manager is responsible for evaluating project data at specified intervals, analyzing data for trends, and following reporting requirements.
Resource Specialist	The water resource specialist, who may also serve as a crew leader, works closely with the project manager in all aspects of data management. The water resource specialist collects field data, enters field and laboratory data, verifies data, and validates data.
Network Data Manager	The network data manager, together with the project manager, ensures that water quality monitoring data are organized, useful, compliant, available, and safe. The network data manager provides the most current version of NPSTORET and works with project personnel to ensure Network water quality data are received by WRD. The network data manager oversees activities related to training, user support, quality assurance, documentation, backups, archiving, and data maintenance and distribution.

11.3 NPSTORET Database

Water quality data are managed according to guidelines from the NPS Water Resources Division. In accordance with these guidelines, the desktop database application NPSTORET will be used to enter, store, document, and transfer discrete (or snapshot) water quality data. The GLKN oversees the use of NPSTORET per the Network's water quality monitoring protocols and ensures that data are transferred at least annually to the NPS Water Resource Division for upload to the EPA STORET database/Water Quality Exchange (WQX) (Figure 1).

STORET is an interagency water quality database developed and supported by the Environmental Protection Agency (EPA) to house local, state, and federal water quality data collected in support of managing the nation's water resources under the Clean Water Act. NPS Director's Order 77 indicates that the NPS should archive water quality data in STORET, and the NPS WRD mandates that any data collected as part of a WRD-funded project get archived in STORET. The NPS uses STORET as a repository of physical, chemical, biological, and other monitoring data collected in and around national park units by park staff, contractors, and cooperators. The NPS operates its own Service-

wide copy of STORET and makes periodic uploads to the EPA STORET National Data Warehouse so that data collected by and for parks will be accessible to the public.

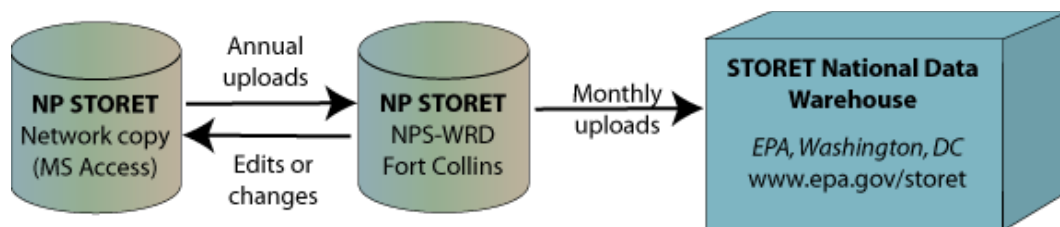


Figure 1. Schematic of data flow to the STORET database: water quality data are transferred from the Network to the national master database and ultimately to the master database. Public access to STORET is available via an online clearinghouse.

11.3.1 Database Design

The database design for NPSTORET is described in its associated documentation. Maintenance and documentation of NPSTORET is performed by NPS WRD. Because it must be compatible with the Oracle-based EPA STORET, NPSTORET is a complex MS Access implementation. The latest version of NPSTORET can be found at: <http://nrdata.nps.gov/programs/water/npstoret/>.

The Great Lakes Network will maintain one master copy of NPSTORET for each park at the Ashland office on a central server. This is the only copy of NPSTORET that can be used to export data to other locations (i.e., WRD and GLKN's SQL Server). Additional copies of NPSTORET can be used by GLKN personnel stationed at parks, but they can only be used as a conduit for data entry and the importation of data to GLKN's master version of NPSTORET. For analysis, the data from the master copy of NPSTORET, that has passed all QA/QC procedures, must be used.

11.4 Aquarius Database

Guidelines for managing time series data are being developed by NPS Water Resources and Inventory and Monitoring (IMD) divisions. For water quality monitoring personnel, data collection, management, and stewardship responsibilities for time series data are the same as those for discrete or snapshot data (Table 1). At the time of this latest SOP revision (Version 1.2), WRD and IMD are in the process of creating SOPs to use Aquarius tools to import, QA/QC, and validate and certify continuous data. A general data flow schematic for continuously collected data is shown in Figure 2.

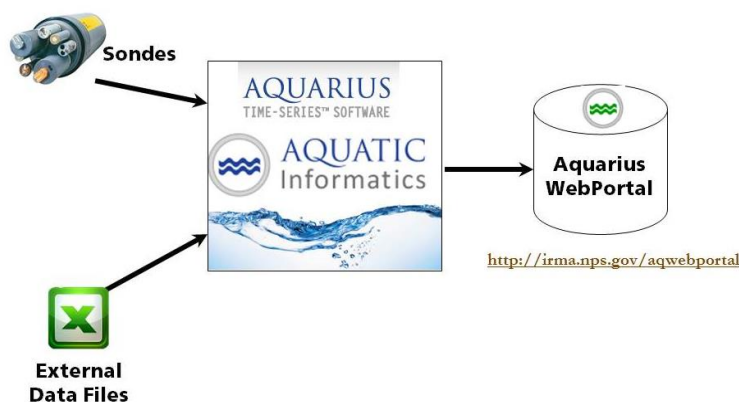


Figure 2. Schematic of data flow to the Aquarius database: water quality data from data loggers are transferred from the Network to the WRD-hosted version of Aquarius. Public access to this data is provided through the Aquarius WebPortal.

11.5 Data Management Procedures

11.5.1 Data Collection

Data values are measured, observed, or estimated according the GLKN wadeable streams water quality monitoring protocol at various monitoring locations (sample sites) and recorded on field forms (see SOP #6, Water Quality Field Measurements; SOP#7, Collection of Benthic Macroinvertebrates; SOP#8, Collection of Periphyton; SOP#9, Physical Habitat Assessment; SOP#10, Flow Measurement). Crew members are responsible for legible, accurate entries on field forms and in log books, including the calibration log. As a first step to verify data, crew members will check and double-check the recorded values on the day of data collection.

Discrete data collected with a multiparameter sonde are stored directly on a datalogger attached to the sonde and recorded on the field sheets at the time of sampling. The hard copy of the data serves as a back-up should something happen to the electronic data.

Continuous data collected by temperature sensors are stored directly on the sensors, downloaded to a data transfer device (e.g., a Hobo Shuttle), and transferred to a computer. Hard copies of continuous

temperature and stage data do not exist, although electronic data are stored in multiple locations and backed-up daily.

Digital images of sample sites are acquired during site establishment and periodically as sites change (SOP #4). Crew members are responsible for proper settings and use of digital camera equipment and should refer to the user manual for details specific to the camera.

GPS coordinates are stored as waypoints if using a recreational GPS unit, or as features if using a mapping-grade unit with a data dictionary, and recorded on the field sheets. When possible, the GPS data will be differentially corrected to improve the accuracy of location coordinates. See SOP #3 for more information on using a GPS unit.

11.5.2 Data Entry, Verification, and Documentation

Requirements for data entry into NPSTORET are detailed in the documentation for users. We present a summary of data entry below, and refer staff to the most recent NPSTORET documentation for the specifics.

On a regular schedule approved by the project manager and data manager, the crew leader gathers the field data collection forms and verifies the completeness, accuracy, and legibility of each form. Following each round of sampling, the crew leader will make a photocopy of each field form and ensure each copy is legible; one copy will be placed in the site binder kept at the park, and the original will be archived in the GLKN office. Upon receiving the data sheets, the project manager will proofread them, making sure that they have been filled out completely. All data sheets should have been reviewed for completeness while in the field, however some deficiencies in data recording may not be identified until all data sheets have been reviewed as a group.

Project staff enters site establishment data in the NPSTORET Station Entry Template as soon as possible following the initial site visit to each sample location. This prompt action is a good data management practice and an NPSTORET requirement that enables parameter data entry. Linking digital images of sample sites to stations in NPSTORET is required as part of this data entry process.

File size for digital images linked to stations in NPSTORET should normally be at least 100kb and less than 300kb. Project staff will reduce the size of image files larger than 300kb and copy images to a file folder named “images” for the appropriate park. Original ‘raw’ images can be stored in the Images folder (see Folder and File Organization below) if project staff determine it is important to keep higher resolution images.

Electronic data from the multiparameter sonde are downloaded from the datalogger to a computer in an MS Excel spreadsheet or text file at the end of each sampling day or as soon as feasible after sampling, and verified for accuracy. Likewise, at the end of each sampling day or as soon as feasible after sampling, all digital images will be downloaded to a computer and labeled with date, location, and subject matter. Import data from the MS Excel spreadsheet into NPSTORET following the guidelines.

Any notes taken in the field regarding collection of data with the sonde are transcribed to NPSTORET in a field for comments and notes. Results of laboratory analyses typically are sent to the project manager in a MS Excel spreadsheet and on hard copy forms. The project manager will verify both sets of data and follow-up with the contract laboratory if any discrepancies are noted or any questionable results are reported (see SOP #15 on QA/QC for more details). Project staff will import the verified data into NPSTORET.

Non-electronic field data recorded on hard copy data sheets are manually-entered into a MS Excel spreadsheet. At the end of the season when all data are entered, the project leader will perform or coordinate a check of 100% of this manually-entered data prior to import into NPSTORET.

A random check of 3% of all electronically transferred data (GPS, multiprobe, and laboratory data) is also performed after it is imported into NPSTORET, to ensure no problems occurred during data transfer. For electronically transferred or manually-entered data, the project leader resolves errors according to established procedures. See SOP #15 for additional QA/QC details.

Data verification starts with the QA/QC steps that are detailed in SOP #12. As data are entered into NPSTORET, either by keyboard or using an import routine, a suite of QA/QC procedures exist that compare the entered data with expected formats and accepted data value ranges or domains. If the entered data do not pass a form-based QA/QC test, NPSTORET prompts the user to make corrections and re-enter the data. For most of the form-based tests, the NPSTORET database will not accept out-of-bounds data, and correction is mandatory; for some range tests, out of bounds data are accepted after a user prompt, but are flagged accordingly. The QA/QC procedures on imported data perform similar tests, but exceptions that do not pass QA/QC are presented to the user and must be reconciled before the record or dataset can be accepted by NPSTORET.

Additional comparison tests will be run on data in NPSTORET to flag records that are outside the expected rate of change for a parameter based on previous records for that parameter. These suspect data points are reviewed by an expert user and can be corrected, flagged, or excluded from the dataset.

As mentioned above, NPSTORET performs numerous QA/QC checks on the data as they are entered and stored. Additionally, once the data are transferred to WRD, more QA/QC procedures are performed. The Network's water quality data records are regarded as being in provisional status until they are returned to GLKN from WRD, or are accepted by WRD without changes after the final QA/QC steps. Each individual record in the water quality dataset always has one, and only one, status flag indicating its status as provisional or final. Finalized data can still be edited and changed if errors are discovered after review in reporting and analysis, but the status of those records reverts to provisional and they must be resubmitted to the master STORET version at WRD and returned before they can be reassigned as finalized data records.

A user's identification is assigned to each aspect of data handling, from collection through the final steps of QA/QC. On data sheets, the identity of the data collector(s) is recorded and is transcribed into the data entry forms in NPSTORET. Additionally, NPSTORET records the user name (login) for

every table entry or modification. Only qualified users who have been trained and given edit permissions are allowed to edit data in NPSTORET. These procedures protect the integrity of the data and allow the history of each data record to be traced.

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The Aquarius database software used for continuous water quality data has built-in QA/QC tools specifically tailored for time series data. These features tools are particularly useful for dealing with data gaps, overlaps and out of range values, and will be utilized as part of the QA/QC process used for continuous data imported into Aquarius. At the time of this SOP development WRD and IMD are working cooperatively to create SOPs for QA/QC and data certification (see next section) for the Aquarius tool. GLKN will adopt the SOP's for these tasks when they are completed.

Executive Order 12906, mandates federal agencies to "...document all new geospatial data it collects or produces, either directly or indirectly..." using the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata. Water quality monitoring meets the definition of geospatial data and, thus, GLKN is responsible for documenting all public datasets using metadata that meets that standard. NPSTORET and Aquarius require and store a great deal of metadata at the record and project level. Metadata will be developed, using NPSTORET and Aquarius as primary sources that meet the federal standard. Consult the GLKN Data Management plan (Hart and Gafvert 2006) for additional details about metadata procedures and requirements.

11.5.3 Data Validation and Certification

Prior to distributing the data for any type of use, the project manager or other appropriate water resource specialist validates the NPSTORET and Aquarius database content in the master water quality data file according to procedures in the Quality Control and Quality Assurance SOP. The integrity of each master data file must be preserved during the validation process in cases where the person performing data validation does not have direct access to the master water quality data file. Validation is performed at least once each year after data collection and entry are complete and before data are submitted to the NPS Water Resource Division, usually by the end of each calendar year. If this annual validation does not meet scheduled reporting requirements of the Network, then the project manager may coordinate more frequent validation to meet needs, or reports can include a statement explaining that results are based on data that have not been validated. The statement should include an explanation of what significance this has for using preliminary data.

Laboratory results must be imported and validated in NPSTORET as soon as possible following receipt of the results. The project manager coordinates receiving and entering data with project staff and then performs or coordinates the validation of lab results.

Data certification will be performed annually according to policies in the Network Data Management Plan, Hart and Gafvert (2006). The certification process will take place before the finalization of the annual NPSTORET submission to WRD, and the release of data in Aquarius for public viewing.

11.5.4 Data Analysis and Reporting

Project staff will follow the procedures for data analysis in SOP #12 and data reporting in SOP #13. Data summary statistics will typically include, but not be limited to:

- Mean
- Median
- Standard deviation
- Minimum
- Maximum
- Count
- Percentiles (10, 25, 75, and 90th percentiles)
- Standard error
- Variance
- Range
- Mode
- Sum
- Kurtosis
- Skew
- Biotic indices

Some of these statistics are available through NPSTORET's query function and others can be derived from NPSTORET outputs. NPSTORET provides an export for any portion of the data in tabular format for use with the Data Analysis Toolpak. Lab results of macroinvertebrate and periphyton identification will be used to calculate various metrics, such as biotic indices, taxa richness, diversity, trophic function, dominance, or similarity indices.

Aquarius has primarily been a tool used by hydrologists to compile stage and discharge data for flowing waters to construct rating curves. It can generate the same data summary statistics as NPSTORET as well as a few others, such as reports by location showing minimum, maximum, mean, and count number of data points per time series. Aquarius can also be used to calculate means

over several time scales (monthly, daily, or hourly) and to generate time series graphs. In addition to these and other analysis procedures, data can also be exported from Aquarius to flat file formats for use by other graphing or statistical software, such as R or SigmaPlot.

11.5.5 Data Folder and File Organization

All data from this wadeable streams protocol should be stored, at the earliest possibility, on the GLKN central server. A diagram of the folder structure is shown below (Figure 3).

Files should be named in accordance with the file-naming standards in the GLKN Data Management plan (see section 6.4 of Hart and Gafvert 2006). Files have a 'GLKN' prefix, a descriptive element, and finish with a date element. For example, GLKN_ISRO_Field_Data_20070605.doc contains field data from Isle Royale National Park on June 5, 2007. Do not use spaces in file names.

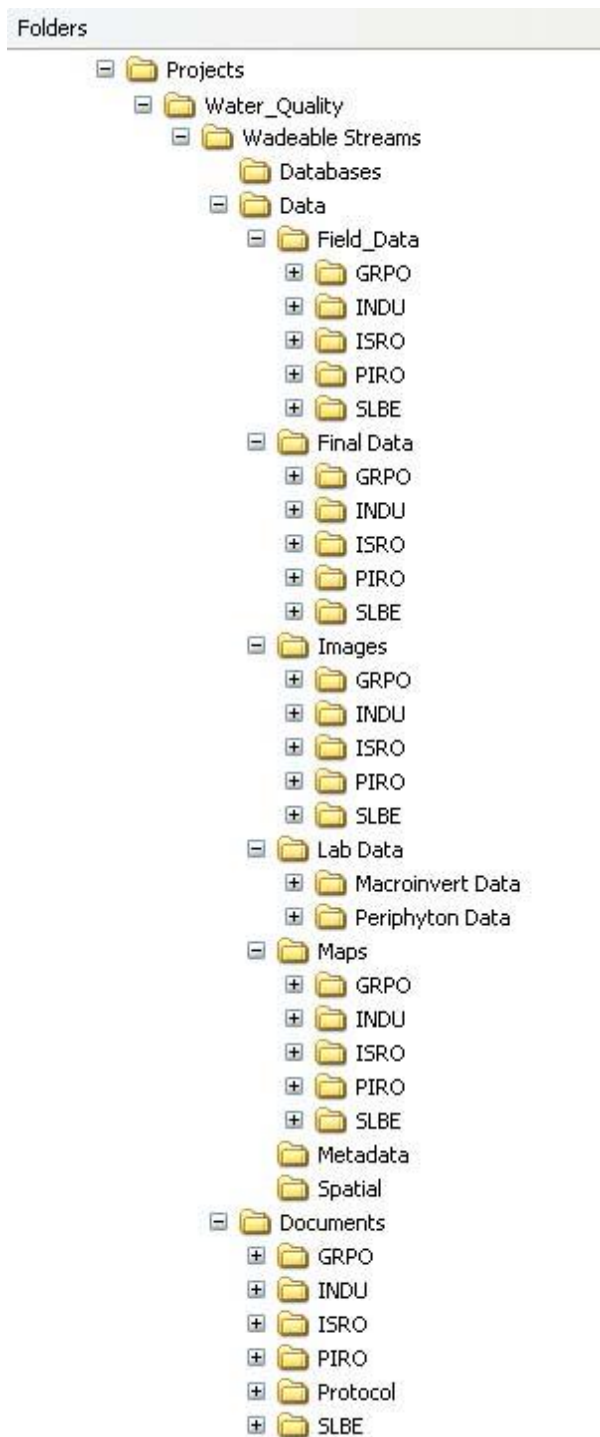


Figure 3. Great Lakes Network folder structure for information related to the protocol for monitoring wadeable streams. Data are organized in subfolders by year within each park folder.

11.5.6 Data Archival and Distribution Procedures

Data archiving serves two primary functions: it provides a source to retrieve a copy of any data set when the primary dataset is lost or destroyed, and it provides a data record that is an essential part of the QA/QC process. Original data will be archived at the Network office. Original data for printed forms are either the physical data sheets or exact and complete digital copies of the forms that capture all entries and notations. The unedited files are the original data for digital data.

All digital data have a duplicate file created at the earliest opportunity. Digital field data that are entered directly into a field computer or collected from a data logger must be backed up to a second medium at the earliest possibility. The data files on field computers and loggers must not be erased until the integrity of these data files are verified on the duplicate storage medium. The removal of original data files from a field computer or logger must be a balance of keeping memory available for new data collection and a need to keep data in their most original form for as long as possible. Field files should only be deleted when memory space is needed for new data collection.

The Network's master version of NPSTORET and the SQL Server geodatabase are maintained on a central server in the Ashland Office that is backed up daily, and backed up off-site weekly. Complete details of the GLKN Server archiving procedure are found the Infrastructure chapter of GLKN's Data Management Plan (Hart and Gafvert 2006); the general strategy for data archiving is also described in this plan and its appendices.

Raw time series data (.hobo files and flat files created from the .hobo files) are stored on the central server at GLKN, which is backed up daily, and backed up off-site weekly. The version of Aquarius that GLKN uses is housed on a server at WRD in Ft. Collins, Colorado. For the time series data to be stored and used in Aquarius, the flat file versions are uploaded to the SQL server using the Aquarius Springboard. All Aquarius data is uploaded to this server at least annually by GLKN staff or cooperators. WRD is currently working on a public-facing web application where this time series data will be available, once the data is officially certified.

GLKN has a number of different avenues for data distribution depending on the audience served and the degree of analysis and customization needed by the end-user (see GLKN's data management plan, Hart and Gafvert [2006], for more details). The NPS IMD Integrated Resource Management Applications (IRMA) web portal is the primary tool that provides interactive access to GLKN data. Some GLKN water quality datasets are available through links to the IRMA portal on the GLKN webpages. However, due to the complexity of the NPSTORET database, providing the data in that format will not meet the needs of those users unfamiliar with that application. Network (GLKN) versions of NPSTORET are used to update a master version of STORET maintained by NPS WRD. The WRD master copy of STORET data is used to regularly update the EPA database that provides on-line access to GLKN water quality data through the EPA WQX and forthcoming Water Quality Portal. NPS IMD is also developing a web map portal to monitoring data tentatively called the NPS Data Visualizer. This will allow a user to spatial query data, including monitoring data, and retrieve the scope of interest. The pathway for this tool is via a Common View Data Template that will allow data in NPSTORET to be read by the database server supplying the Data Visualizer.

Data distribution will primarily occur through the EPA STORET portal, the NPS Data Store, Aquarius WebPortal and the NPS Data Visualizer. These tools are described previously in this document. The USGS and EPA are developing the Water Quality Portal (www.waterqualitydata.us). This will probably become the primary tool for reaching data stored in EPA STORET/WQX. For many users, the EPA tools will be the easiest way to retrieve subsets of GLKN wadeable streams water quality data.

In cases where specific data are requested that are unavailable through the public distribution methods outlined above, the project manager or appropriate water resource specialist will respond based on the nature of each request and the state of the data, for example, whether or not the data are fully qualified and documented to meet the needs of the requestor.

11.6 Literature Cited

- Hart, M., and U. Gafvert (editors). 2006. Data management plan: Great Lakes Inventory and Monitoring Network. Great Lakes Inventory and Monitoring Network Report GLKN/2006/20. National Park Service, Ashland, Wisconsin. Available at http://science.nature.nps.gov/im/units/glkn/assets/docs/GLKN_SD8_Data_Management_Plan.pdf
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