Appendix I – Quality Assurance Project Plan for Sediment Monitoring Study – Revision 2

Northfield Mountain Station
99 Millers Falls Road
Northfield, MA 01360
Ph: (413) 659-4489
Fax: (413) 659-4459
Internet: john.howard@gdfsuezna.com

John S. Howard
Director- FERC Hydro Compliance

August 14, 2013

Toby Stover
US EPA Region 1-New England
5 Post Office Square
Boston, MA 02109-3912
Tel: 617-918-1604

Re: Northfield Mountain Pumped Storage Project (FERC No. 2485)
Sediment Management Plan – QAPP Revision 2

Dear Toby:

FirstLight Power Resources Services, LLC submits the enclosed Revised Quality Assurance Project Plan ("QAPP Revision 2) on behalf of FirstLight Hydro Generating Company (FirstLight) for the Northfield Mountain Pumped Storage Project (Project No. 2485), located along the Connecticut River near Northfield, MA.

On February 15, 2012 FirstLight filed with FERC the revised Sediment Management Plan (Plan) for the Northfield Mountain Project. On March 28, 2012 FERC issued its Order Approving the Plan. By way of comments filed February 16, 2012, the USEPA required FirstLight to develop a Quality Assurance Project Plan (QAPP) prior to conducting suspended sediment sampling. Following review and discussion of the initial draft(s) of the QAPP, FirstLight filed QAPP Revision 1 with the USEPA, MADEP, and FERC on October 19, 2012. From June-December 2012 FirstLight conducted continuous suspended sediment concentration (SSC) monitoring at the Route 10 Bridge in Northfield, MA and at the Northfield Mountain Powerhouse. On November 30, 2012 FirstLight filed its Sediment Management Plan – 2012 Summary of Annual Monitoring with the USEPA, MADEP, and FERC.

As a result of experience gained during the 2012 monitoring efforts, combined with the recommendations of the sediment monitoring equipment manufacturer, FirstLight modified certain aspects of the methodology outlined in the QAPP Revision 1 for the 2013 monitoring season. At a meeting on June 24, 2013, FirstLight presented these changes to the USEPA and MADEP. At that meeting, USEPA requested that QAPP Revision 1 be updated to reflect the modifications put in place for 2013 and subsequent monitoring seasons. Also at the June 24 meeting, FirstLight advised USEPA and MADEP that it is considering extending the sediment monitoring program, which was scheduled to conclude in 2014 for an additional year. Following further internal discussion, FirstLight has decided to extend field data collection into the 2015 field season.

Enclosed please find the updated QAPP Revision 2 for your review. This revision reflects the changes discussed at the June 24, 2013 meeting and outlines in detail the components of the 2013 monitoring program. After reviewing the updated QAPP Revision 2, if you have any questions or concerns, please contact me at 413-659-4489.

Sincerely,

John Howard
Director – FERC Hydro Compliance

cc: Nora Conlon, USEPA
Robert Kubit, MADEP Division of Watershed Management
Mark Wamser, Gomez and Sullivan Engineers
Adam Kahn, Foley Hoag

Attachment

Quality Assurance Project Plan
for Sediment Monitoring Study- Revision 2

Prepared by:
Gomez and Sullivan Engineers, P.C.
41 Liberty Hill Road
PO Box 2179
Henniker, NH 03242

Prepared for:
FirstLight Power Resources Services, LLC
c/o FirstLight Hydro Generating Company
99 Millers Falls Road
Northfield, MA 01360

Date: October 19, 2012 (Original)
August 14, 2013 (Revision 2)

1 Title and Approval Page

John Howard — Date
FirstLight, Director – FERC Hydro Compliance, Northfield Mountain Station

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Mark Wamser — Date
Gomez and Sullivan Engineers, P.C. - Project Manager

Jason George — Date
Gomez and Sullivan Engineers, P.C. - QA Officer

George Harding, P.E. — Date
USEPA, Environmental Engineer Water Enforcement Unit

Nora Conlon — Date
USEPA, QA Representative

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List of Tables and Figures

List of Abbreviations and Acronyms

ºC	degrees Celsius
cm	centimeter
ESRI	Environmental Systems Research Institute
EWI	equal-width-increment method
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Power Resources Services, LLC on behalf of FirstLight Hydro Generating Company
GIS	Geographic Information Systems
Gomez and Sullivan	Gomez and Sullivan Engineers, PC
GPS	Global Positioning System
LISST-HYDRO	Laser In Situ Scattering and Transmissometry Hydro Particle Size Sensor
LISST-100X	Laser In Situ Scattering and Transmissometry Particle Size Analyzer
LISST-StreamSide	Laser In Situ Scattering and Transmissometry StreamSide Flow-through Particle Size Sensor
m	meter
MADEP	Massachusetts Department of Environmental Protection
MassGIS	Massachusetts Geographic Information System
m/sec	meters per second
µ	microns
µl/L	microliters per liter
mg/L	milligrams per liter
MW	mega-watts
PSD	particle size distribution
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SOP	Standard Operating Procedures
SSC	Suspended Sediment Concentration
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VC	Volume Concentration

3 Distribution List

The following individuals will receive a copy of this Quality Assurance Project Plan (QAPP) upon approval.

Ralph Abele
US EPA Region 1-New England
5 Post Office Square
Boston, MA 02109-3912
617-918-1629
Abele.ralph@epa.gov

George Harding
US EPA Region 1-New England
5 Post Office Square
Boston, MA 02109-3912
617-918-1870
Harding.george@epa.gov

Toby Stover
US EPA Region 1-New England
5 Post Office Square
Boston, MA 02109-3912
Tel: 617-918-1604
stover.toby@epa.gov

Gerry Sotolongo
US EPA Regional 1-New England
New England Regional Laboratory
11 Technology Drive
North Chelmsford, MA 01863-2431
617-918-8311
sotolongo.gerry@epa.gov

Nora Conlon
US EPA Regional 1-New England
New England Regional Laboratory
11 Technology Drive
North Chelmsford, MA 01863-2431
617-918-8335
conlon.nora@epa.gov

Robert McCollum
Program Chief
MassDEP
Wetlands & Waterways
Western Region
Springfield, MA 01103
413-755-2138
Robert.j.mccollum@state.ma.us

Robert Kubit
MassDEP
Division of Watershed Management
627 Main Street
Worcester, MA 01608
508-767-854
Robert.kubit@state.ma.us

Mark Wamser
Gomez and Sullivan Engineers, P.C.
41 Liberty Hill Road
PO Box 2179
Henniker, NH 03242
603-428-4960
mwamser@gomezandsullivan.com

Jason George
Gomez and Sullivan Engineers, P.C.
41 Liberty Hill Road
PO Box 2179
Henniker, NH 03242
603-428-4960
jgeorge@gomezandsullivan.com

John Howard
FirstLight
99 Millers Falls Road
Northfield, MA 01360
413-659-4489
John.howard@gdfsuezna.com

4 Project and Task Organization

FirstLight Power Resources Services, LLC on behalf of FirstLight Hydro Generating Company (collectively "FirstLight") owns and operates the Northfield Mountain Pumped Storage Project (Project), located along the Connecticut River near Northfield, MA. The Project is licensed with the Federal Energy Regulatory Commission (FERC) as Project No. 2485.

This document is a site-specific QAPP that describes the quality assurance measures that will be adhered to during sampling and analysis of data collected under FirstLight's revised Sediment Management Plan.

On July 15, 2011, FirstLight filed with FERC a Sediment Management Plan (Plan) for the Project which was developed in consultation with the US Environmental Protection Agency (USEPA) and the Massachusetts Department of Environmental Protection (MADEP). The Plan contained proposed methods to assess sediment dynamics in the Project's Upper Reservoir and Turners Falls Impoundment (Connecticut River) from 2011 through 2014.

The main components of the Plan included conducting annual bathymetric surveys in the Upper Reservoir, collecting turbidity and total suspended solids (TSS) data routinely from the Project area, and reporting requirements. FirstLight began implementing the Plan in 2011 and, on December 1, 2011, filed a report with FERC summarizing the bathymetric survey and sediment monitoring data collected during 2011. In the 2011 report, FirstLight also stated that it is in the process of making technical improvements and revisions to their sediment sampling methodology. Specifically, FirstLight proposed to continuously measure Suspended Sediment Concentration (SSC) in lieu of using turbidity measurements as a surrogate for TSS.

On December 6, 2011, FERC acknowledged receipt of the 2011 report and specified that FirstLight should file the revised Plan by February 15, 2012 after consultation with the MADEP and USEPA. A draft of the revised Plan was provided to the MADEP and USEPA by letter dated December 22, 2011. The MADEP submitted comments on the Plan to FirstLight on January 17, 2012.

The revised Plan was filed with FERC on February 15, 2012. The USEPA Region 1 submitted comments on the revised Plan to FirstLight on February 16, 2012. The comments primarily relate to the technical nature of the sampling equipment and USEPA's requirement that a Quality Assurance Project Plan (QAPP) be developed by FirstLight prior to sampling. FERC approved the revised Plan on March 28, 2012. FirstLight provided an initial draft of the QAPP to the USEPA on June 28, 2012. The USEPA provided comments to FirstLight on July 31, 2012. FirstLight addressed the USEPA's comments and submitted Revision 1 of the QAPP to USEPA, MADEP, and FERC on October 19, 2012.

As a result of experience gained during the 2012 monitoring efforts, combined with the recommendations of the SSC monitoring equipment manufacturer, FirstLight is presenting further revisions to the QAPP, which are contained in this document (herein after referred to as QAPP- Revision 2).

This study is a combined effort of FirstLight and Gomez and Sullivan Engineers, PC (Gomez and Sullivan). The following is a list of individuals and organizations involved with this project, showing their respective roles and responsibilities. Figure 1 displays the organization flow chart for this study. See Section 3 for contact information.

FirstLight Director of FERC Hydro Compliance for Northfield Mountain Station
John Howard, FirstLight

Responsibilities
Responsible for reporting to FERC, USEPA and MADEP.

Gomez and Sullivan Project Manager
Mark Wamser, Gomez and Sullivan

Responsibilities
Responsible for ensuring the Plan and QAPP are executed properly.

Gomez and Sullivan QA Officer
Jason George, Gomez and Sullivan

Responsibilities
Responsible for managing field data collection, review of findings, quality assurance, and reporting.

Technical Advisor to FirstLight
Bob Simons, Simons and Associates

Responsibilities
Responsible for serving in a technical advisory role to provide guidance and review of sampling methods, data analysis and interpretation.

USEPA Project Manager
George Harding, USEPA

Responsibilities
Review and concurrence with sampling plan.

USEPA Quality Assurance Representative
Nora Conlon, USEPA

Responsibilities
Review and concurrence with sampling plan.

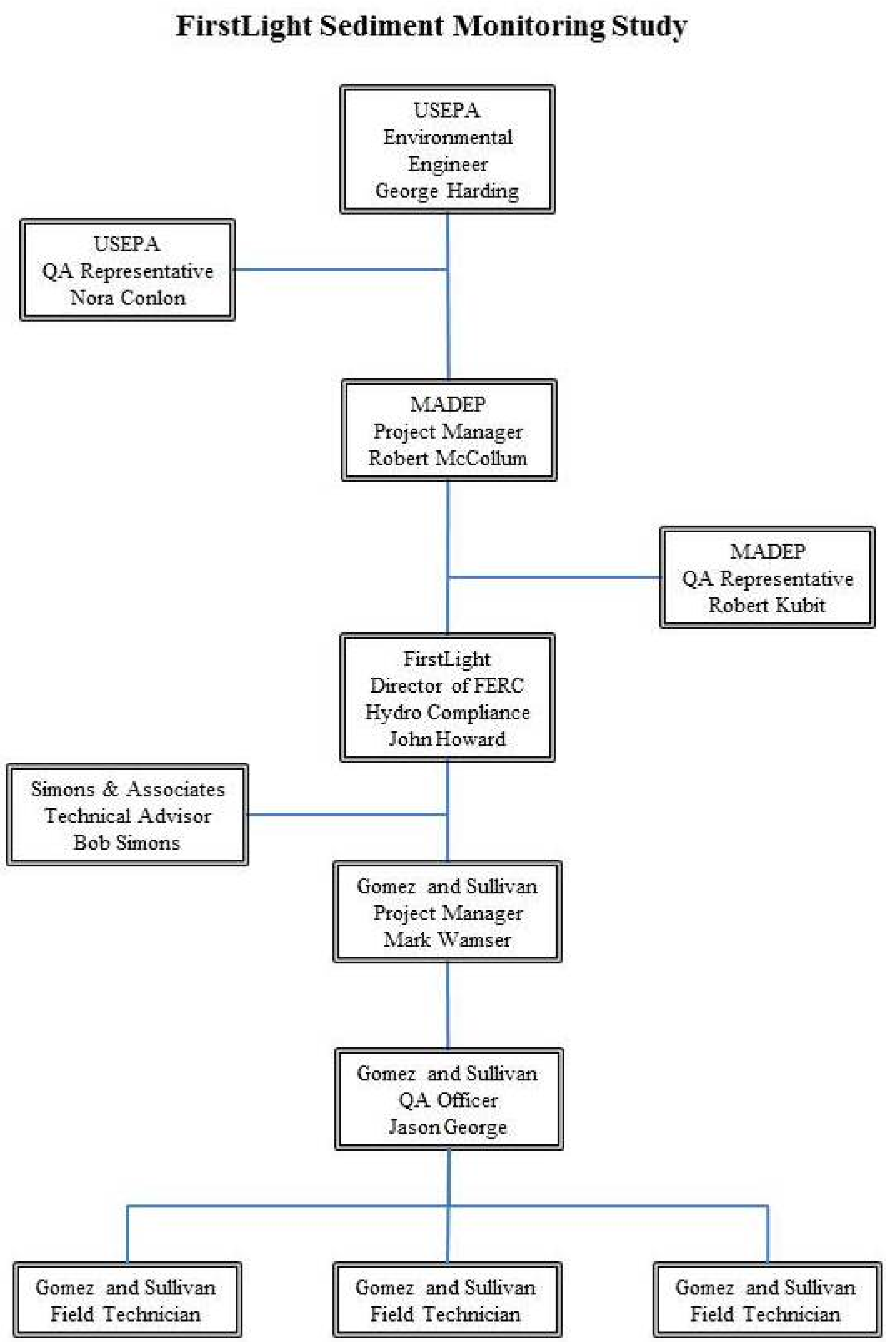
MADEP Project Manager
Robert McCollum, MADEP

Responsibilities
Review and concurrence of sampling plan.

MADEP Quality Assurance Representative
Robert Kubit, MADEP

Responsibilities
Review and concurrence with sampling plan.

Figure 1: Project Organization Chart



5 Problem Definition / Background

FirstLight owns and operates the Northfield Mountain Pumped Storage Project (Project), a 1,119.2-MW pumped storage hydroelectric project constructed in 1972 along the Connecticut River near Northfield, MA. The Project consists of an underground powerhouse, four reversible pump-turbine generators, an underground pressure shaft, four unit penstocks and draft tubes, and a mile-long tailrace tunnel connecting the powerhouse to an approximate 20-mile-long reach of the Connecticut River known as the Turners Falls Impoundment, which serves as the Lower Reservoir (Figure 2). The manmade Upper Reservoir was formed with four earth-core rock fill embankment structures and a concrete gravity dam.

The Northfield Mountain station planned a dewatering outage for May 2010 as part of routine operations and maintenance to maintain protection against powerhouse flooding, and perform preventative long term maintenance programs. The dewatering plan consisted of draining the water from the Upper Reservoir through the pressure shaft and penstocks, powerhouse, and tailrace tunnel, enabling inspection and maintenance of the Project.

On May 1, 2010 FirstLight began the planned three-week dewatering outage with the intent of undertaking various capital projects. On May 3, 2010 FirstLight became concerned that the ongoing dewatering operation had a higher level of silt than previously expected and notified the USEPA Region 1 office accordingly. Upon further investigation, it became evident that the upper reservoir intake channel silt had dislodged and migrated into the water conveyance tunnels. The silt was deposited at multiple locations, including a large quantity in the mile-long tailrace tunnel. Dewatering through normal means ceased on May 5, 2010 when all equipment and machinery was shut down and an assessment of the extent of the problem commenced.

FirstLight received an Administrative Order from the USEPA regarding the silt release on August 4, 2010 and requested a report identifying measures FirstLight would adopt to prevent discharges of sediments to the Connecticut River associated with draining the Upper Reservoir. Similarly, on August 10, 2010, the Federal Energy Regulatory Commission (FERC) requested FirstLight to file a plan and/or procedures designed to avoid or minimize the entrainment of silt into the Project works during future Upper Reservoir drawdowns.

To address USEPA and FERC's concerns, FirstLight developed an initial Plan in consultation with the USEPA, and the MADEP. FirstLight began executing the Plan in 2011 resulting in a December 2011 filing with FERC. However, for various reasons shared with MADEP, USEPA and FERC, FirstLight developed a revised Plan on December 22, 2011, for review by the MADEP, and USEPA.

On February 15, 2012, FirstLight filed a revised Plan with FERC to minimize and avoid entrainment of sediment during reservoir maintenance drawdowns at the Project.

The main objectives of the revised Plan include:

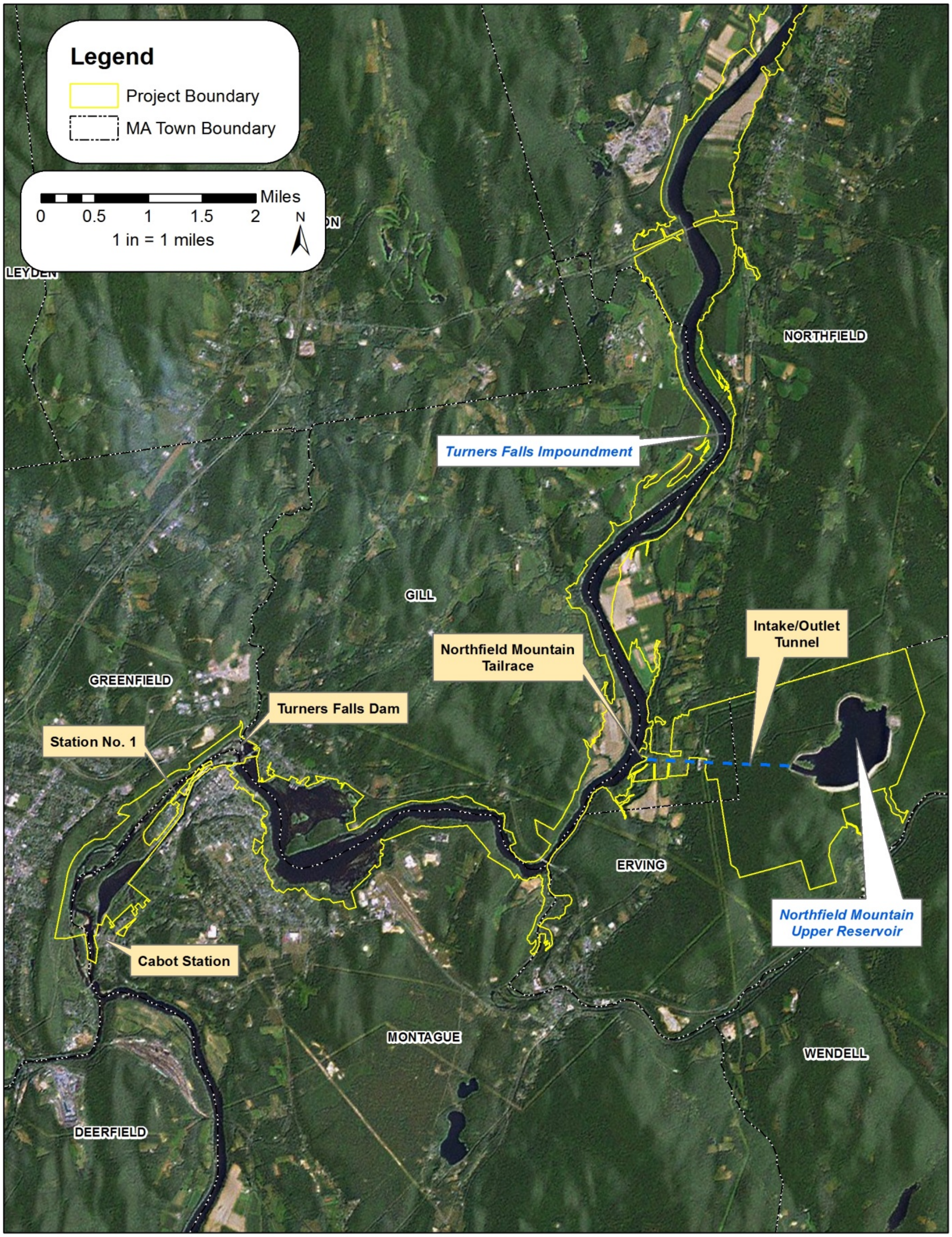
- Monitor suspended SSC and particle size distribution (PSD) in the Project intake and discharge under a range of operating and ambient river conditions;
- Monitor SSC and PSD in the Turners Falls Impoundment (at the Route 10 Bridge) under a range of flow and water level elevation conditions; and
- Conduct bathymetric mapping in the Upper Reservoir annually to estimate sediment accumulation over the period 2011-2014

On March 29, 2012, FirstLight and USEPA met to discuss the revised Plan and the need for a QAPP. All parties at this meeting understood that due to the essence of time, the sediment monitoring equipment would be installed prior to having a finalized QAPP. In May-June 2012 continuous SSC monitors were installed at three locations as described in Section 6. Continuous SSC data collection occurred with limited success from June-September 2012. A report summarizing the results of all 2012 sediment monitoring activities was submitted to the USEPA, MADEP, and FERC on November 30, 2012.

As a result of experience gained during the 2012 monitoring efforts, combined with the recommendations of the SSC monitoring equipment manufacturer, FirstLight is presenting further revisions to the QAPP, which are contained in this document. The modifications to the QAPP were orally presented to USEPA and MADEP at a meeting on June 24, 2013.

Based on the data gathered through the Plan and outlined in this QAPP- Revision 2, FirstLight's goal is to propose management measures to address entrainment of sediment into the Project works during Upper Reservoir drawdown or dewatering activities to prevent future sedimentation events.

Figure 2: Northfield Mountain Pumped Storage Hydroelectric Project



6 Project / Task Description

In the original Plan, dated July 2011, FirstLight proposed a four-year sediment monitoring study (2011-2014) in which turbidity and total suspended solids (TSS) data were to be collected routinely as well as during targeted periods of high flow in various locations within the Turners Falls Impoundment and the Upper Reservoir. TSS and turbidity grab samples were collected on two occasions during 2011 in accordance with this plan.

Based on the data collected in 2011, as summarized in the December 1, 2011 report to FERC, FirstLight proposed changes to the data collection methods as described herein. In order to achieve the study objectives, it was proposed that rather than quarterly monitoring at various locations over the four years of study, a more rigorous sampling approach be implemented. As part of this approach the following field collection methods will be employed: 1) continuous SSC and PSD data will be collected from the Turners Falls Impoundment at the Route 10 Bridge, 2) continuous SSC and PSD data will be collected from the Project intakes, both when generating and pumping, and 3) point sample data will be collected from the Turners Falls Impoundment at the Route 10 Bridge as well as at the Project for comparison purposes.

The purpose of the continuous monitoring is to understand suspended sediment levels in the Connecticut River and in the water used for Project operations over a range of river flow conditions and pumping/generating cycles. Continuous monitoring of SSC and PSD will occur at least hourly; this will provide a larger data set more representative of conditions experienced over varying rivers and a range of Project operational cycles (as opposed to four quarterly data points from each station, which provides only a snapshot in time).

In May-June 2012 continuous SSC monitoring equipment was installed as described above. Data was collected from June-September 2012 at the Route 10 Bridge and in the Northfield Mountain Powerhouse. Due to a variety of factors, as discussed in the November 30, 2012 filing with FERC, 2012 continuous monitoring activities did not achieve the level of success that was anticipated. As a result of the 2012 experience, combined with the recommendations of the equipment manufacturer, FirstLight has implemented a variety of changes to the sediment monitoring program. These changes are outlined below.

2013 and Subsequent Year Continuous Monitoring Program

The continuous monitoring program for 2013, 2014, and 2015 will consist of: 1) one LISST-StreamSide instrument installed on the Connecticut River just upstream of the Route 10 Bridge; 2) two LISST-HYDRO devices installed in the Northfield Mountain Tailrace in locations capable of collecting data during pumping and generating cycles; 3) point and transect sample data collected at the Route 10 Bridge and Northfield Mountain Tailrace using a LISST-100X device (2013 and 2014 only); and 4) water sample collection for laboratory analysis of Total Suspended Solids (TSS) and Suspended Sediment Concentration (SSC) over a range of flows and river conditions. Figure 3 and Figure 5 denote pertinent sampling locations.

In accordance with FERC's Order Approving Sediment Management Plan (March 28, 2012), FirstLight will file an annual report with the USEPA, MADEP, and FERC no later than December 1 of each sampling year summarizing the previous calendar years monitoring results.

LISST-StreamSide – Connecticut River – Route 10 Bridge

Sampling in the vicinity of the Route 10 Bridge (Figure 3) will provide sediment transport data in the Turners Falls Impoundment. A continuously recording sampler will be installed to measure SSC and PSD (Figure 4). The sampling interval will be set to a minimum of one sample per hour. The sampler will pump river water from a single fixed location in the Connecticut River at which time PSD (microns) and volume concentration (µl/L) will be measured.

Since SSC is known to vary laterally across the river and vertically with depth above the river bed, point sample data will also be collected (described in more detail below) to develop a correlation over a range of flow conditions between the overall suspended sediment transport through the entire cross-section compared to the continuous sampling at the single, fixed location. The combination of a single fixed location to provide sediment concentrations coupled with sampling of the entire cross-section through a range of flow conditions over a relatively short period of time provides the best combination of data to develop a good understanding of both the temporal variations in sediment transport from the fixed sampling location, along with the lateral and vertical distribution of sediment transport through the cross-section so a coefficient can be applied to the temporal data. This is an acceptable method described by the United States Geological Survey (USGS) (Edwards and Glysson, 1999).

The point sampling will also serve as an independent comparison of the continuous data collected. Sampling equipment proposed for the fixed location sampler at the Route 10 Bridge is the LISST-StreamSide sediment sensor. Information on this sampler is provided in Appendix A.

LISST-HYDRO – Northfield Mountain Tailrace

To monitor SSC moving into and out of the Upper Reservoir, two continuous samplers will be installed at the Northfield Mountain Project Tailrace (Figure 3). One HYDRO device will be installed on the North side of the tailrace while the other will be installed on the South side (Figure 5). These locations will allow for representative samples to be collected during both pumping and generating cycles. During pumping, the water within the tailrace may contain sediment that is pulled into the system from the Connecticut River through the intake. During generation, the water that is being discharged from the Upper Reservoir back to the river may similarly contain sediment.

In May-June 2012 the HYDRO devices were installed inside the Northfield Mountain Powerhouse directly inline on Project Service Water intake/discharge piping systems using available service water taps. Data collection was attempted from June-December 2012 with limited success. After extensive troubleshooting by FirstLight and the equipment manufacturer it was determined that the pressure from the service water line was too great for the HYDRO devices to adequately collect samples and that maintaining the configuration proposed in the QAPP Revision 1 was not likely to yield sufficient usable data. Following extensive investigation it was determined that installation of the HYDRO devices in the Project tailrace would allow for representative samples to be taken during pumping and generating cycles without the difficulties related to high pressure experienced in the Powerhouse.

Once installed, the LISST-HYDROs will pump river water from a single fixed location (one location/pump per HYDRO) in the Northfield Mountain Tailrace at which time PSD (microns) and volume concentration (µl/L)[1] will be measured. The sampling interval will be set to a minimum of once every 30 minutes. Information on this sampler is provided in Appendix B.

[1] The LISST-HYDROs collect SSC data as a volume concentration (µl/L), however, the instruments are programed to then automatically convert the volume concentration to a mass concentration (mg/L) based on an assumed standard density (2.65 g/cm^2). As a result the HYDRO output is in units of mg/L. Given that the effective density in the study area may or may not be 2.652.65 g/cm^2, this conversion will introduce error into the data. In order to

Additionally, point and transect sample data will also be collected at the Northfield Mountain Tailrace to develop a correlation over a range of flow conditions and pumping and generating cycles between the overall suspended sediment transport through the entire cross-section compared to the continuous sampling at the LISST-HYDROs (described in more detail below).

LISST-100X – Connecticut River – Route 10 Bridge and Northfield Mountain Tailrace

To account for the variation of SSC and PSD both vertically in the water column and laterally across the river, FirstLight will collect data at evenly-spaced points across the river to develop a relationship between the LISST-StreamSide and HYDRO continuous samplers and the overall sediment transport through the study reaches. To determine the relationship between the data collected by the automatic pumping-type samplers and the overall SSC through the cross-sections, concentrations determined from the pumping samplers will be compared with the corresponding concentrations determined from a complete depth integrated cross-section sample over a wide range of flows. This relationship will then be used to adjust the pumped sample results, if necessary. In addition, adjustments to the continuous sampling locations in the water column may occur to more accurately reflect the concentration across the cross-sections.

In order to collect the necessary samples, a LISST-100X sensor will be utilized (Figure 6). A crane and reel for cable suspension will be used for data collection at the Route 10 Bridge; data collection at the Northfield Mountain Tailrace will occur by boat. Point samples using the Equal Width Increment (EWI) method (Edwards and Glysson, 1999) over a range of flow conditions (from low to high flow) and over a range of operating conditions (i.e. pumping and generating) will be collected (Figure 7). Measurements conducted will include PSD (microns) and volume concentration (µl/L) consistent with both the LISST-StreamSide and LISST-HYDROs. Information on this sampler and equipment is provided in Appendix C. The Plan and Revision 1 of the QAPP originally proposed that the LISST-SL would be used for this task. After further consultation with the equipment manufacturer it was determined that based on the characteristics of the Connecticut River in the vicinity of the proposed study area the LISST-100X would be a more effective solution and yield more accurate results than the LISST-SL.

Point samples will also be taken using the LISST-100X at the LISST-StreamSide and LISST-HYDRO drain hoses concurrently with a sampling event at these instruments to allow for a direct comparison of the data collected. The LISST-100X point sample will serve as an additional quality control check of the data collected at the LISST-StreamSide and LISST-HYDROs.

All LISST-100X data collection will occur in spring 2013 and fall 2013 or spring 2014 only. Data collection during these two periods will provide sufficient information to determine any variations in SSC and PSD in the water column and laterally across the river.

Laboratory Samples

Water samples will be collected for laboratory analysis of TSS and SSC from the LISST-StreamSide and LISST-HYDRO drain hoses over a range of flows and river conditions, or at a minimum of once per month. All samples will be taken concurrently with a LISST sampling event to ensure direct comparisons can be made. Results of the laboratory analysis will be used as an additional quality control check of the

eliminate this error, and maintain consistency between all LISST equipment, all output data from the HYDROs will be divided by 2.65 and stored as volume concentration.

data collected by the LISST equipment as well as for conversion from volume concentration to mass (see Section 19), if deemed necessary.

Conceptual Schedule

The two LISST-HYDRO samplers and the LISST-StreamSide sampler will continuously collect data from spring through fall when air temperatures are expected to be above freezing. Based on consultation with the manufacturer, it may also be possible to sample during the winter if freezing of sampling components can be prevented. However, FirstLight cannot commit to attempting to sample wintertime SSC because any attempts to sample during that time would be experimental and may be impractical even to attempt.

The conceptual schedule for monitoring and sample collection is as follows:

- Spring 2013: Re-install LISST-StreamSide
  - Post-installation: Weekly data download, equipment check, and cleaning
  - Collect grab samples from LISST-StreamSide drain hose during LISST-StreamSide sample collection over a range of flows and river conditions, or at a minimum of once per month

- Summer 2013: Install LISST-HYDROs
  - Post-installation: collect grab samples from LISST-HYDRO drain hoses during LISST-HYDRO sample collection over a range of flows, or at a minimum of once per month
  - Weekly review of data, periodic equipment check and maintenance

- Fall 2013 or Spring 2014: LISST-100X
  - Over the course of one month (over a range of flows and river conditions), collect weekly point and transect measurements from the Route 10 Bridge and at the Northfield Mountain Tailrace
  - Over the course of one month (over a range of flows and river conditions), collect weekly point measurements from the LISST-StreamSide and LISST-HYDRO drain hoses. Point samples will be collected at the same time as LISST-StreamSide and LISST-HYDRO sample collection to allow for direct comparisons of the data.
  - Based on river conditions and other logistical factors the LISST-100X sampling may take place in the fall 2013 or the spring 2014. LISST-100X sampling will not be conducted in 2015.

- Late Fall 2013:
  - Remove LISST-HYDRO and StreamSide samplers to avoid freezing temperatures

- December 1, 2013, 2014 and 2015:
  - File annual summary report with MADEP, USEPA and FERC

- 2014-2015:
  - Conduct additional seasons of continuous SSC monitoring following the 2013 schedule outlined above

FirstLight intends to continue sampling in 2014 and 2015 consistent with the methodology utilized in 2013. The original Plan called for 2014 to be the last year of field data collection, however, due to the technical difficulties experienced to date, as well as the proposed change in methodology, FirstLight has decided to expand field data collection to include the 2015 field season. Based on the results of the previous years sampling efforts, FirstLight may propose modifications to the sampling program. FirstLight may also propose discontinuing sampling and instead propose management measures to address entrainment of sediment into the Project works during Upper Reservoir drawdown or dewatering activities. In either event, FirstLight would consult with the MADEP and USEPA Region 1.

FirstLight is required to file a proposal for sediment management alternatives by December 1, 2015.

Figure 3: Sampling Locations

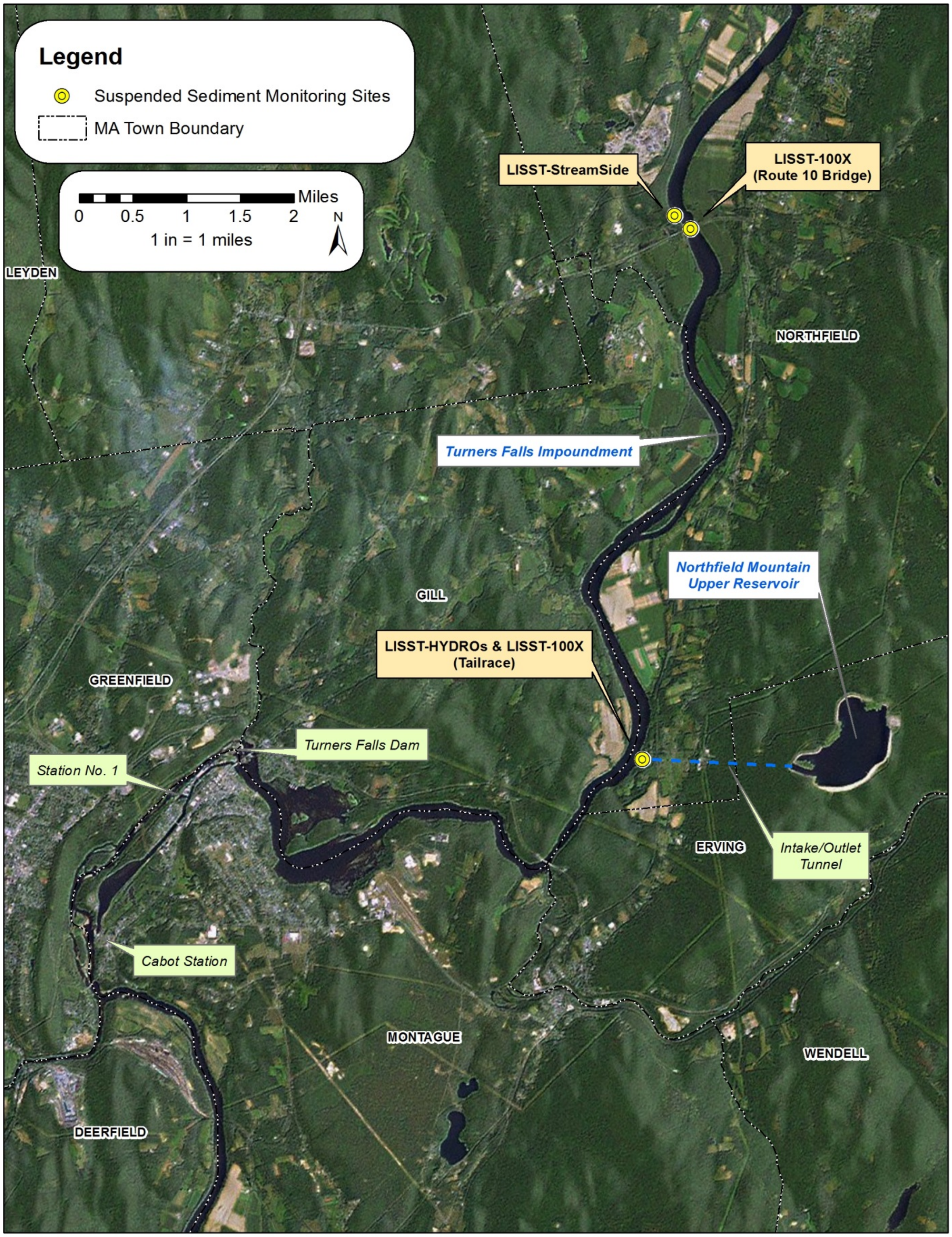
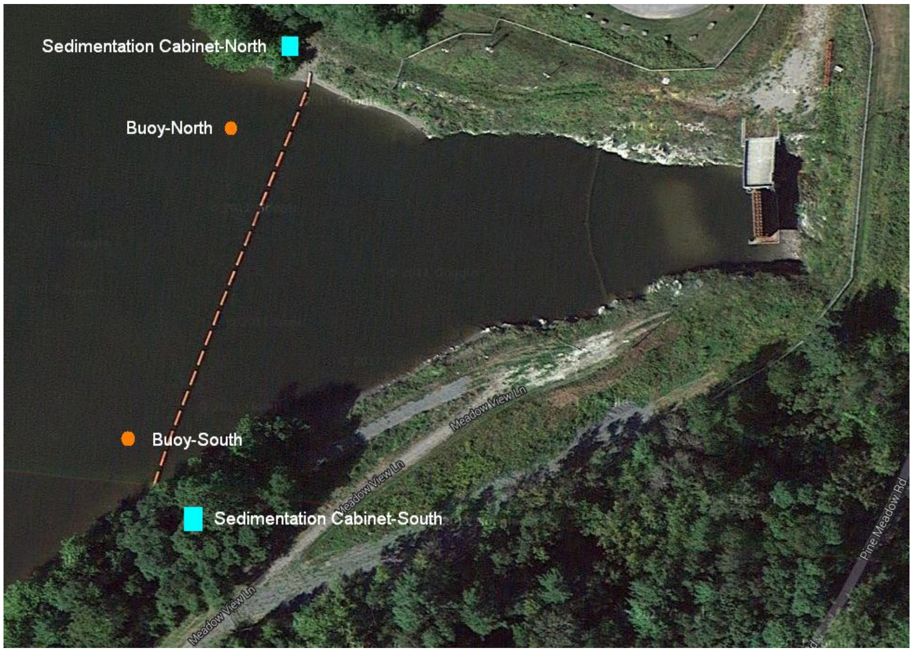


Figure 4: LISST-StreamSide Configuration Upstream of Route 10 Bridge

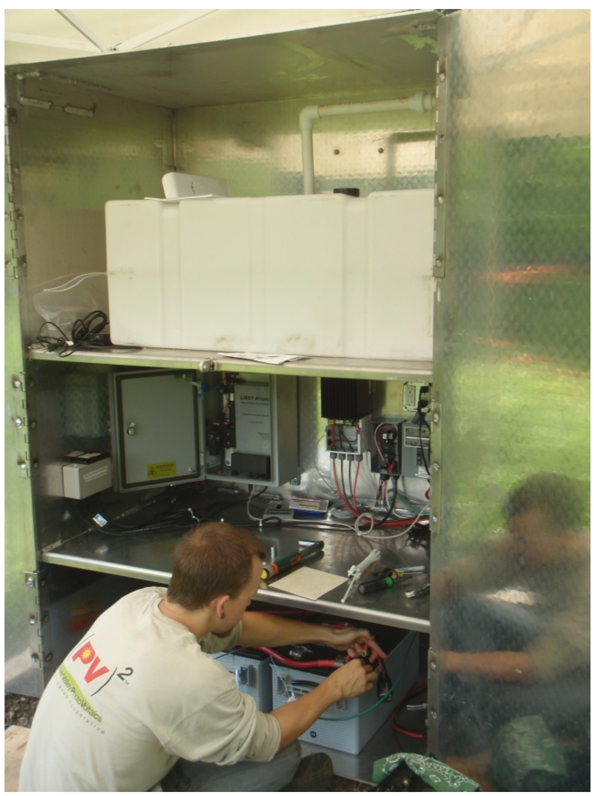
LISST-StreamSide closet upstream of Route 10 Bridge, side of Connecticut River

LISST-StreamSide Closet: clean water tank, pump controller box, StreamSide, electrical connections

Figure 5: LISST-HYDRO Configuration at Northfield Mountain Tailrace



Aerial Photo depicting LISST-HYDRO configuration at Tailrace



LISST-HYDRO Closet: HYDRO, electrical components, and clean water tank

Figure 6: LISST-100X

LISST-100X and weighted fin used for stability at Route 10 Bridge

Crane and reel used to suspend LISST-100X from Route 10 Bridge

Data Quality Objectives

The data collected during this effort will be used to assess sediment dynamics in the Connecticut River from the Turners Falls Impoundment to the Upper Reservoir and to evaluate management strategies to address the entrainment of accumulated silt into Project works during Upper Reservoir drawdown or dewatering activities.

The data collected at the Northfield Mountain Tailrace will be used in conjunction with the annual bathymetry survey of the Upper Reservoir to study the accumulation of sediment in the Upper Reservoir. The data collected at the Route 10 Bridge will be used to understand the quantity of suspended sediment being transported in the Turners Falls Impoundment upstream of the Northfield intake and the concentrations of suspended sediment under various river flow conditions.

The goal of this data collection program is to assess suspended sediments moving into and out of the Upper Reservoir and to evaluate management strategies to address the entrainment of accumulated silt into Project works during Upper Reservoir drawdown or dewatering activities. Sediment concentrations in the Connecticut River are relevant to that analysis. The sediment monitors in the tailrace may also stay in place to monitor real-time conditions during maintenance events and other operational conditions.

LISST instrumentation utilizing laser diffraction technology will be used to collect sediment data along the Connecticut River at the Route 10 Bridge and the Northfield Mountain Tailrace. The LISST-100X will be utilized to collect data on sediment concentration and sediment size distribution at various depths and stations.

Water samples will be collected at the LISST-StreamSide and LISST-HYDRO drain hoses for laboratory analysis of TSS and SSC. Results of the laboratory analysis will be used as an additional quality control check of the data collected by the LISST equipment as well as for conversion from volume concentration to mass (see Section 19), if necessary.

Equipment Specifications

The LISST-HYDRO and StreamSide samplers will continuously collect data from spring through fall when air temperatures are expected to be above freezing. Continuous data will be collected when the Northfield Project is both pumping and generating during a range of flows in the Connecticut River. LISST-100X data will be collected periodically according to the schedule above across a range of varying flow conditions in the Connecticut River. Specifications on the LISST sampling equipment are contained in Table 1 below.

Table 1: Sediment Monitoring Data Specifications.

Parameter	Units	Resolution	Range
LISST-StreamSide and LISST-HYDRO			
Sediment Concentration	µl/L[2]	<1	10-3,000 mg/L*
Sediment Size Distribution	microns	32 size classes	2.5-500

[2] The LISST-HYDROs collect SSC data as a volume concentration (µl/L), however, the instruments are programed to then automatically convert the volume concentration to a mass concentration (mg/L) based on an assumed standard density (2.65 g/cm^2). As a result the HYDRO output is in units of mg/L. Given that the effective density in the study area may or may not be 2.652.65 g/cm^2, this conversion will introduce error into the data. In order to eliminate this error, and maintain consistency between all LISST equipment, all output data from the HYDROs will be divided by 2.65 and stored as volume concentration.

LISST-100X			
Sediment Concentration	µl/L	<1	1-750 mg/L*
Sediment Size Distribution	microns	32 size classes	2.5-500
Depth	cm, m	0.01 m	300m

* Approximate range, depends on grain size.

Representativeness

Monitoring sites were selected to provide an accurate representation of sediment conditions in the Connecticut River from the Turners Falls Impoundment to the Northfield Mountain Upper Reservoir over a range of flow conditions as well as during Project pumping and generating cycles. The combination of the fixed location data from the LISST-StreamSide and the cross sectional data from the LISST-100X will accurately capture SSC and PSD in the Turners Falls Impoundment.

The LISST-HYDROs will be installed in the Northfield Mountain Tailrace. This configuration will allow the LISST-HYDRO instruments to capture SSC and PSD during both pumping and generating cycles. The data collected during pumping and generating will allow for a better understanding of the relationship between water and sediment transport from the Connecticut River through the tailrace intake during varied operations of the plant. Although the LISST-HYDROs have been relocated to the tailrace from the Powerhouse, the data collected at the new locations will still be representative of that which would have been sampled in-line in the Powerhouse. During pumping cycles the water found in the 30” service water lines, which the LISST-HYDROs were originally tapped into, is pumped directly from the tailrace into the intake/outlet tunnel, through the plant, and to the Upper Reservoir. During generating the opposite process occurs. By installing the LISST-HYDROs in the tailrace at the entrance/exit to the inlet/outlet tunnel the water being continuously sampled is the same water that would have been sampled had the instruments still been installed in-line in the Powerhouse could the system water pressure been effectively regulated.

Comparability

Data will be downloaded from the LISST-StreamSide and HYDRO instruments and reviewed on a weekly schedule. Data that are downloaded will be compared to previously collected data to monitor any changes, or document any trends, that might be occurring throughout the Project. LISST-100X samples will be collected to capture data under a range of flow conditions. The weekly data will be reviewed and compared as mentioned above.

In addition to LISST instrument data collection, water samples will be taken throughout the field season over a range of flows and river conditions, or at a minimum of once per month, for laboratory analysis of TSS and SSC. All grab samples will be submitted to a certified laboratory for processing. Results of the laboratory analysis will be used as an additional quality control check of the data collected by the LISST equipment as well as for conversion from volume concentration to mass (see Section 19), if necessary.

Completeness

When it is found that data do not meet the quality objectives from this section, or do not adhere to the quality control measures described in Section 14, the Gomez and Sullivan QA Officer, with support from the Gomez and Sullivan Project Manager, will determine what corrective action(s) must be taken. Incomplete data may lead to the need for re-assessment of a particular dataset if it is found that the available data are insufficient to meet project goals.

Laboratory Analysis

USEPA has requested independent laboratory analyses of TSS on a monthly basis. Water sampling will occur at least once per month and/or over a range of flows and river conditions during the sampling period. Samples will be collected at the LISST-StreamSide and LISST-HYDRO drain hoses at the same time that a sampling event occurs at the LISST instruments.

Laboratory analysis will serve as an additional quality control check of the data and as a way to calculate an effective density value which can be used to convert sample results from volume concentration (µl/L) to mass concentration (mg/L). TSS and SSC lab results will be in units of mg/L. If a laboratory capable of analyzing these results in µl/L is found, FirstLight will submit periodic samples for analysis to allow for a direct comparison with the LISST equipment. If a laboratory with these capabilities cannot be found, the LISST-100X can be used to analyze grab samples taken at the StreamSide and HYDROs in µl/L. Based on manufacturer feedback, this is a standard method used to provide a quality check on other LISST equipment. See Section 19 for additional information on the conversion of µl/L to mg/L.

Samples will be analyzed at a certified laboratory and analyzed for TSS and SSC. TSS will be analyzed using standard method 2540D while SSC will be analyzed using ASTM D3977. Laboratory analysis will yield results as mass concentration values (mg/L). The standard reporting limit is 0.5 mg/L. A copy of the laboratory's standard operating procedure for these analyses is attached in Appendix D. The laboratory results would be used for conversion from volume concentration to mass concentration if deemed necessary by FirstLight for data analysis purposes. See Section 19 for more information on the conversion process.

7 Training Requirements

The Gomez and Sullivan Project Manager and Gomez and Sullivan QA Officer will ensure that all field technicians have current training in the operations of the sampling equipment. In addition, the Technical Advisor will provide oversight and support to the Project Manager, QA Officer, and/or field technicians when needed. There are no other specialized training or certification requirements needed to perform the tasks outlined within this QAPP.

8 Documents and Records

The Gomez and Sullivan Project Manager will establish and maintain a project file which will contain all sampling event data, records, reference materials, and other project specific information in accordance with the QAPP. Field Technicians and the Gomez and Sullivan QA Officer will ensure that all project data they receive or generate is delivered to the Project Manager for inclusion in the project file. The project file will contain, but not be limited to, the following:

- field logs and notes
- Global Positioning System (GPS) data, Geographic Information System (GIS) data, and related maps
- laboratory analytical reports
- data reports summarizing field activity and quality control for each sampling event
- miscellaneous correspondence related to sampling events
- equipment user manuals
- chain of custody forms
- quality control sample records
- the most current version of the standard operating procedures
- the most current version of the QAPP

The project file will be made available to all team members for referencing and updating throughout the duration of the project.

All continuous field collected data from LISST-HYDRO and LISST-StreamSide devices will be downloaded, compiled in spreadsheets or databases, and uploaded to secure servers. In addition, all recorded data will be left on the hard drive of the field equipment to ensure a backup of the original data exists at all times (in addition to scheduled server backups).

Samples requiring laboratory analysis will require the laboratory to prepare and submit to the Project Manager a Laboratory Analytical Summary upon completion of the analysis. The Analytical Summary will consist of analytical results, chain of custody forms, and pertinent notes.

9 Sampling Process Design (Experimental Design)

The purpose of the continuous monitoring is to understand suspended sediment levels in the Connecticut River and in the water used for Northfield Mountain Project operations over a range of river flow conditions and pumping/generating cycles. Continuous monitoring of SSC and PSD will occur on at least an hourly time step; this will provide a larger data set more representative of conditions experienced over varying river flows and a range of Project operations.

LISST-StreamSide

Sampling at the Route 10 Bridge (Figure 3) will provide data on sediment transport in the Turners Falls Impoundment. A continuously recording sampler will be installed to measure SSC and PSD on at least an hourly basis (Figure 4). The sampler will pump in river water from a single fixed location in the Connecticut River.

The settings of the LISST-StreamSide sampling interval and related information are shown in Table 2 below.

Table 2: LISST StreamSide Minimum Data Collection Settings

Parameter	Setting
Sampling Interval	60 minutes
Average Duration	60 seconds
Background Saved	Every 3 hours
Clean Water Flush	40 seconds
Post Sample Flush	20 seconds
Set Intake Flush Time	60 seconds

Since sediment concentration is known to vary laterally across the river and vertically with depth above the river bed, point sample data will also be collected (described in more detail below) so a correlation can be developed over a range of flow conditions between the overall suspended sediment transport through the entire cross-section compared to the continuous sampling at the single, fixed location. The combination of a single fixed location to provide sediment concentrations coupled with sampling of the entire cross-section through a range of flow conditions over a relatively short period of time provides the best combination of data to develop a good understanding of both the temporal variations in sediment transport from the fixed sampling location, along with the lateral and vertical distribution of sediment transport through the cross-section so a coefficient can be applied to the temporal data. This is an acceptable method described by the USGS (Edwards and Glysson, 1999). Note that FirstLight is not proposing to construct a sediment transport model. The data collected at the Route 10 Bridge will be used to understand the quantity of suspended sediment being transported in the Turners Falls Impoundment upstream of the Northfield intake and the concentrations of suspended sediment under various river flow conditions. The objective is to understand background conditions, not predictively model the sediment concentrations under various scenarios.

LISST-HYDRO

To monitor SSC moving into and out of the Upper Reservoir, two LISST-HYDRO continuous samplers (Figure 5) will be installed in the Northfield Mountain Tailrace (Figure 3). During pumping, the water may transport sediment that is being taken into the system from the Connecticut River through the tailrace intake. During generation, the water may transport sediment that is being discharged from the Upper Reservoir back to the river.

Additionally, point and transect sample data will be collected at the Northfield Mountain Tailrace to develop a correlation over a range of flow conditions and pumping and generating cycles between the overall suspended sediment transport through the entire cross-section compared to the continuous sampling at the LISST-HYDROs (described in more detail below).

LISST-100X

To account for the variation of SSC and PSD both vertically in the water column and laterally across the river, FirstLight is proposing to collect point samples to develop a relationship between the LISST-StreamSide and LISST-HYDRO continuous samplers and the overall sediment transport through the reaches. To determine the relationship between the data collected by the automatic pumping-type samplers and the overall SSC through the cross-sections, concentrations determined from the pumping samplers will be compared with the corresponding concentrations determined from a complete depth integrated cross-section sample over a wide range of flows. This relationship will then be used to adjust the pumped sample data. In addition, adjustments to the continuous sampling locations in the water column may occur to more accurately reflect the concentration across the cross-sections.

At least 10 vertical samples using the EWI method (Figure 7) (Edwards and Glysson, 1999) over a range of flow conditions (from low to high flow) will be collected using the LISST-100X (Figure 6). At each sampling increment, measurements will be collected at several depths throughout the water column. Periodic point sampling with the LISST-100X will also occur at the LISST-StreamSide and LISST-HYDRO drain hoses concurrently with sample collection at the continuous LISST monitors for comparison purposes. Sampling with the LISST-100X will yield measurements of PSD (microns) and volume concentration (µl/L) consistent with the measurements taken by the LISST-StreamSide and LISST-HYDROs.

All LISST-100X data collection will occur in spring 2013 and fall 2013 or spring 2014 only. Data collection during these two periods will provide sufficient information to determine any variations in SSC and PSD in the water column and laterally across the river.

Laboratory Analysis

USEPA has requested independent laboratory analyses of TSS on a monthly basis. Water sampling will occur at least once per month and/or over a range of flows and river conditions during the sampling period. Samples will be collected at the LISST-StreamSide and LISST-HYDRO drain hoses at the same time that a sampling event occurs at the LISST instruments.

Laboratory analysis will serve as an additional quality control check of the data and as a way to calculate an effective density value which can be used to convert sample results from volume concentration (µl/L) to mass concentration (mg/L). TSS and SSC lab results will be in units of mg/L. If a laboratory capable of analyzing these results in µl/L is found, FirstLight will submit periodic samples for analysis to allow for a direct comparison with the LISST equipment. If a laboratory with these capabilities cannot be found, the LISST-100X can be used to analyze grab samples taken at the StreamSide and HYDROs in µl/L. Based on manufacturer feedback, this is a standard method used to provide a quality check on other LISST equipment.

Grab samples will be submitted to a certified laboratory and analyzed for TSS and SSC. TSS will be analyzed using standard method 2540D while SSC will be analyzed using ASTM D3977. Laboratory analysis will yield results as mass concentration values (mg/L). The standard reporting limit is 0.5 mg/L. A copy of the laboratory's standard operating procedure for these analyses is attached in Appendix D. The laboratory results would be used for conversion from volume concentration to mass concentration if deemed necessary by FirstLight for data analysis purposes. See Section 19 for more information on the conversion process.

10 Sampling Methods

The LISST-StreamSide, LISST-HYDRO, and LISST-100X instruments use river water that is pumped/flows through the device(s) and then is returned to the source; therefore, no samples are retained during data collection. The data collection and analytical methods that will be used for these instruments come from the operation manuals which will be kept with each device. Additional information can be found in Section 13. The procedures for laboratory grab sample collection are shown in Table 3.

Table 3: Method Requirements for Laboratory Sampling

Analytical parameter	**Collection method**	**Sample volume**	**Container size and type**	**Preservation requirements**	**Max. holding time (preparation and analysis)**
SM 2540 D	Grab	1 liter	1L sterile white polyethylene	chilled to ≤ 4ºC	7 days
ASTM D 3977	Grab	1 liter	1L sterile white polyethylene	chilled to ≤ 4ºC	7 days

11 Sample Handling and Custody

LISST-StreamSide, LISST-HYDRO, and LISST-100X instruments are continuously monitoring devices that do not have samples and therefore are not relevant to this section.

For physical samples that are collected for laboratory analysis, sample containers will be marked with identification labels that will be matched to the identification information on the field data sheets. Samples requiring transport will be stored and shipped in accordance with the analytical specifications. Upon arrival at the laboratory, the person delivering the samples is responsible for documenting receipt in the form of a chain of custody form or other acceptable form as agreed to by FirstLight.

12 Analytical Methods

The analytical methods that will be used for the LISST-StreamSide, LISST-HYDRO, and LISST-100X instruments are summarized below. The printed operation manuals will be kept with each device.

LISST-StreamSide

The LISST-StreamSide will be installed at one fixed location along the Connecticut River near the Route 10 Bridge. Connecticut River water is pumped through the instrument and the detailed size distribution and volume concentration is measured using laser diffraction technology. After flowing through the instrument, the water is then returned to the Connecticut River. A water sample is not retained; therefore, no sample handling or lab processing is necessary. At a set sampling interval, distilled water is run through the sampler to flush the instrument of river water and to automatically "zero" the instrument before each measurement. Clean water backgrounds will be collected and stored at a predetermined, set interval. All data collected is stored on the instrument hard drive until it is downloaded to a computer by field technicians.

LISST-HYDRO

Two LISST-HYDRO devices will be installed at the Northfield Mountain Tailrace. The instruments will be installed on the left (south) and right (north) banks of the tailrace. During pumping, the water may transport sediment that is being taken into the system from the Connecticut River through the tailrace intake. During generation, the water may transport sediment that is being discharged from the Upper Reservoir back to the river. Using laser diffraction technology the sediment concentration and size distribution will be routinely and continuously monitored. The LISST-HYDROs will be connected directly to FirstLight servers allowing for secure storage of all data. Distilled water, or potable water filtered to 0.2 microns (as per the manufacturers recommendations), will be run through the sampler at a set interval to flush the instrument of river water and to obtain a clean water background.

LISST-100X

Since sediment concentration is known to vary laterally across the river and vertically with depth above the river bed, point sample data will also be collected at the Route 10 Bridge and Northfield Mountain Tailrace so a correlation can be developed over a range of flow conditions between the overall suspended sediment transport through the cross-sections compared to the continuous sampling at the single, fixed locations (the LISST-Streamside and LISST-HYDROs).

The parameters measured by the LISST-100X are: SSC and PSD as a function of depth, depth of the instrument at any time, and water temperature. The LISST-100X sampler will be used to collect data at a number of verticals laterally across the channel and at range of depths within each vertical to define the vertical and lateral variation in SSC.

Field personnel will utilize the EWI method for cross sectional data collection using the LISST-100X (Figure 7). The instrument will be lowered from the Route 10 Bridge (LISST-StreamSide) or from boat (LISST-HYDROs) using a crane. Figure 8 shows the conceptual location of each LISST –100X measurement at the Route 10 Bridge cross-section. Weights with fins below the body of the device will orient the unit to maintain a consistent position once in the river. Diffracted light is measured by the unit within an optical path, and the data are stored within the memory of the device. The data will be downloaded to a laptop by field technicians for processing, yielding the size distribution and volume concentration. In addition to sediment concentration and mean particle size, depth, and temperature are stored with each sample.

Laboratory Grab Samples

Grab samples will be analyzed for TSS and SSC. TSS will be analyzed using standard method 2540D while SSC will be analyzed using ASTM D3977. The standard reporting limit is 0.5 mg/L. A copy of the laboratory's standard operating procedure for these analyses is attached in Appendix D.

Figure 7: Equal Width Increment (EWI) Sampling Technique.

FIELD METHODS FOR MEASUREMENT OF FLUVIAL SEDIMENT

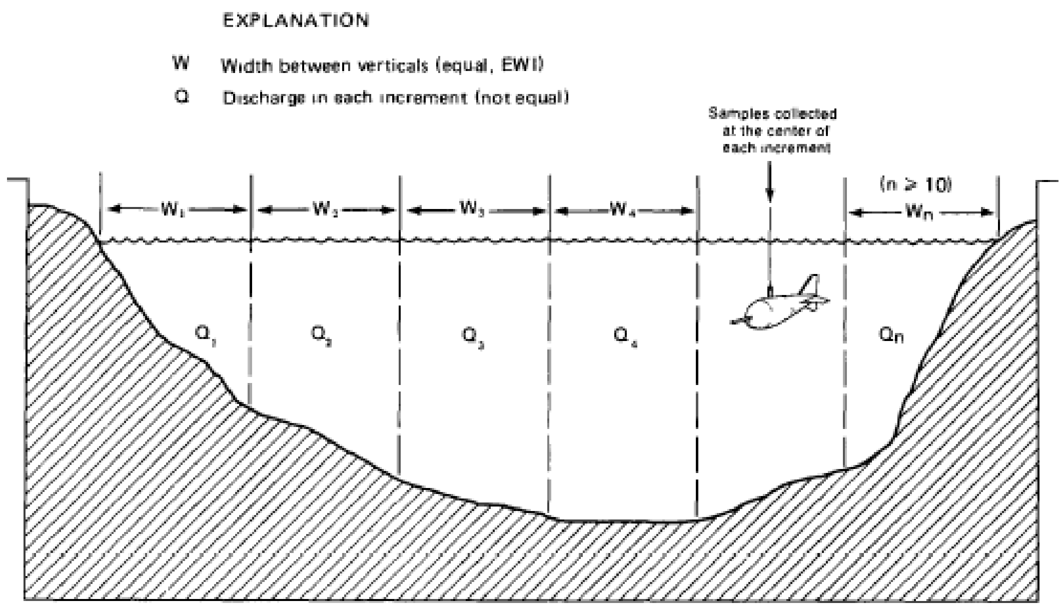
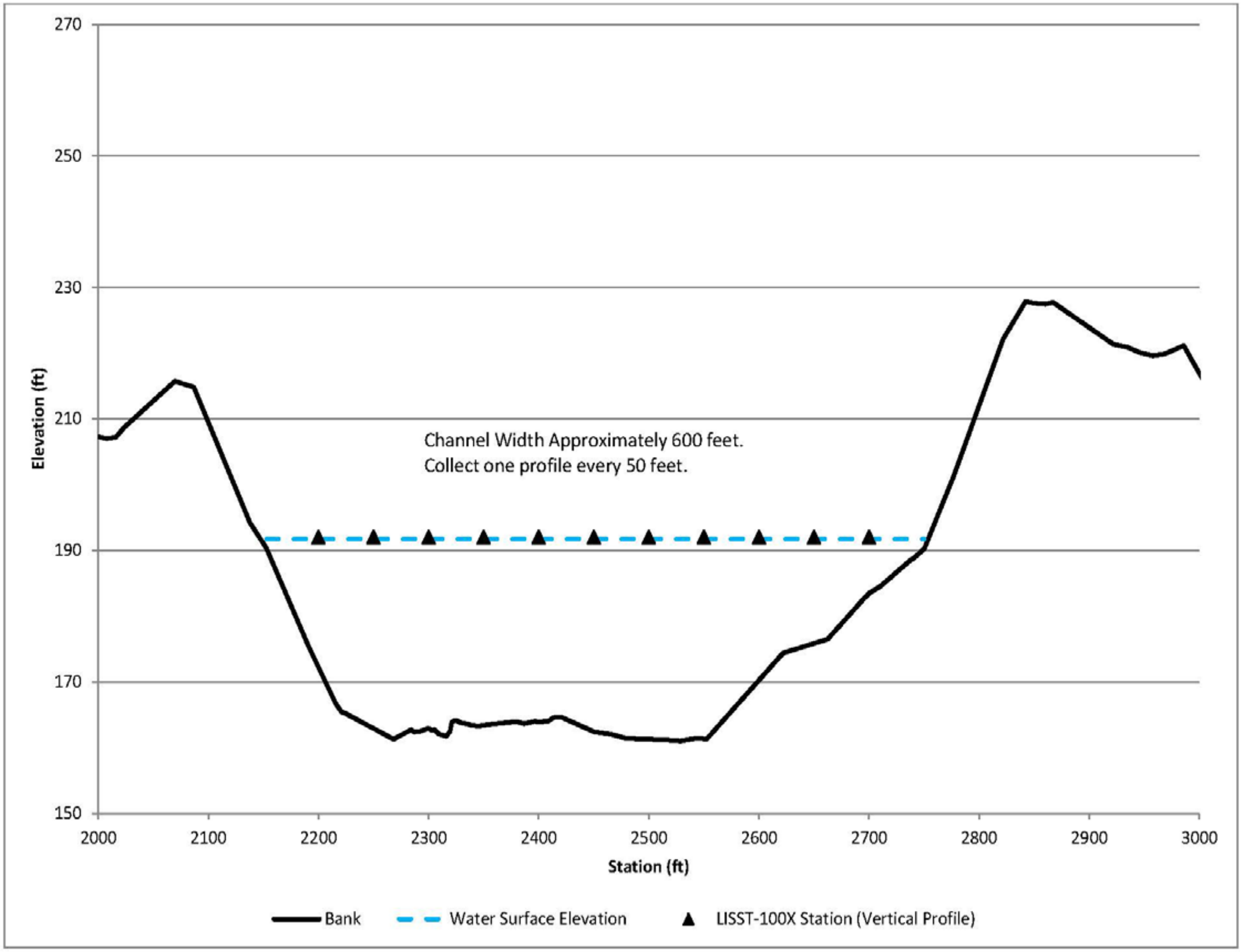


Figure 8: Conceptual Location of LISST –100X Measurements at the Route 10 Bridge



13 Quality Control

All LISST instrumentation (LISST-StreamSide, LISST-HYDRO, LISST-100X) have been factory calibrated prior to purchase or rental by FirstLight. According to the manufacturer, factory calibration is good for the life of the equipment assuming proper handling and maintenance. All equipment and instrumentation, as well as instrument settings, will be reviewed prior to initial deployment/installation, before, during, and after data collection, and during each weekly site visit. Based on this visual inspection, if necessary, the instruments will be reset to meet factory recommended settings to ensure QA/QC objectives are met.

All downloaded data will be analyzed and double checked in the field by technicians to ensure data accuracy and completeness. If the data does not appear acceptable, the equipment will be reset to ensure proper data collection. Once field collected data is transferred to secure servers and uploaded to Microsoft Excel spreadsheets or Microsoft Access databases, plots will be created to analyze quality control (detailed below). The Gomez and Sullivan QA Officer and the Technical Advisor will be responsible for reviewing and analyzing the results of these plots and resolving any data anomalies or errors.

LISST-StreamSide & LISST-HYDRO

Given that both the LISST-StreamSide and LISST-HYDRO instruments are continuous monitoring devices, the majority of the Quality Control will occur following data download.

Data quality control for the LISST-StreamSide and LISST-HYDRO focuses on three main indicators. These indicators are: 1) Optical Transmission Record, 2) Rising Tails, and 3) records of the clean water level. The first step in quality control is to plot the optical transmission. It is physically impossible for the optical transmission to exceed a value of 1. If transmission values >1 are found in the record, this indicates that the size and concentration data associated with this measurement should be used with caution. If readings above 1.0 are reported, this means the sample is clearer than the background or that some interference is affecting the background measurement. The background clean water source should be checked.

In the event that Quality Control issues arise, including optical transmission data >1.0, the FirstLight technical team will review the data and the cause and make appropriate adjustments. Erroneous data will be flagged. Periodic reports to USEPA, MADEP, and FERC will contain a section on data quality, noting any significant issues that were encountered.

The quality of the data obtained via laser diffraction can be affected negatively by particles outside the size range covered by the ring detector; however, rising "tails" in the plot of the size bins (Table 4) can give information as to whether or not the data quality was strongly affected. These tails occur due to the natural size distribution of particles in water systems. Often, instead of falling into one narrow size band, sediment particles will have a size distribution depicted by strong representation in one band and weaker representation that tapers off in the surrounding bands. Thusly, if the data starts trending upwards towards the limits of the detectable sizes, it can be inferred that the trend continues outside of the detectable range and that the data quality could be affected. Note that a rising tail is not an absolute indicator of a significant amount of undetected sediment.

To check for rising tails the ratio of size bin #1/size bin #2 and the ratio of size bin #32/size bin #31 will be plotted. Values larger than 1 indicate that particles smaller or larger than the size range were present during sampling and thus the computed mean size might be skewed.

If rising tails are observed, the data will be flagged as suspect and further quality control will be completed by observing the adjacent data points to determine if the rising tails data point is an outlier, or if the pattern continues throughout the data series. In the event that Quality Control issues arise, FirstLight technical team will review the data and the cause and make appropriate adjustments. Erroneous data will be flagged. Periodic reports to USEPA, MADEP, and FERC will contain a section on data quality, noting any significant issues that were encountered.

The records showing the clean water level over the sampling interval will be reviewed to ensure that the instrument was properly purged of the previous sample. To analyze water level indicators, a plot of the time history of the water level will be created. If the water level is at 0%, the data associated with these measurements should be disregarded.

LISST-100X

The LISST-100X does not require any calibration. In order to ensure the device is working properly and to correct for inherent scatter from the unit (i.e. lens scratches), a background measurement is taken before and after samples are collected. A background measurement is a comparison of factory preset clean water background analysis with pre and post sample clean water background analysis. All clean water background analyses utilize distilled water, poured directly into the instrument. Prior to taking the pre-sample clean water background, the lenses of the LISST-100X should be cleaned thoroughly. Upon obtaining a pre-sample background measurement, a comparison is made of the factory preset value with the field collected value. This can be done by comparing the red line on the instrument display (showing the Factory background) to the blue bars on the instrument display (showing the current background measurement). These two values should be relatively close in order for the background measurement to be considered acceptable. If the factory preset background and pre-sample background (red lines and blue bars on the instrument display) are not close, or scattering on the middle rings occurs, this is more than likely the result of dirt or scratches on the instrument windows. In the event this occurs, the windows should be thoroughly cleaned and the pre-sample background should be taken again. Sampling will commence once an acceptable background measurement has been recorded.

Following data collection, a post-sample background will be collected. The post-sample background will be used as is (i.e. no cleaning to improve the background) to correct data for any fouling that occurs during sampling. For more information on this process refer to the user's manual.

Once the data have been collected, plots will be created analyzing the optical transmission record and rising tails as discussed previously to determine quality control.

Laboratory Grab Samples

The laboratory will perform quality control as detailed in Section 9 of their SOP attached in Appendix D.

Table 4: LISST Particle Size Bins.

	Sizes (microns)		
Size Bin #	Lower	Upper	Median
1	1.90	2.25	2.07
2	2.25	2.65	2.44
3	2.65	3.13	2.88
4	3.13	3.69	3.40
5	3.69	4.35	4.01
6	4.35	5.14	4.73
7	5.14	6.06	5.58
8	6.06	7.15	6.59
9	7.15	8.44	7.77
10	8.44	9.96	9.17
11	9.96	11.8	10.8
12	11.8	13.9	12.8
13	13.9	16.4	15.1
14	16.4	19.3	17.8
15	19.3	22.8	21.0
16	22.8	26.9	24.8
17	26.9	31.8	29.2
18	31.8	37.5	34.5
19	37.5	44.2	40.7
20	44.2	52.2	48.0
21	52.2	61.6	56.7
22	61.6	72.7	66.9
23	72.7	85.7	78.9
24	85.7	101	93.1
25	101	119	110
26	119	141	130
27	141	166	153
28	166	196	181
29	196	232	213
30	232	273	252
31	273	322	297
32	322	381	350

14 Instrument and Equipment Testing, Inspection, and Maintenance

All LISST instrumentation and equipment will be maintained in accordance with the manufacturer's recommendations. Visual inspections of the instruments will occur at the beginning of, during, and at the end of each use (LISST-100X) or during each site visit (LISST-StreamSide and LISST-HYDRO). The visual inspection will then determine what testing and maintenance actions should occur, if any.

LISST-StreamSide

Maintenance falls into six main areas, 1) cleaning the optical cell, 2) cleaning the hoses, 3) filling the water tank with distilled water, 4) checking the battery voltage, 5) keeping the casing and touch panel clean, and 6) keeping the connectors clean and free from corrosion. The equipment will be visually inspected during each weekly site visit and, if deemed necessary, will be serviced accordingly. The flow rate from the pump will be measured monthly to ensure that the pump is not faulty or clogged. If flow rates become low or power consumption by the pump becomes high, the pump will be removed from the water and cleaned or replaced. Pump cleaning/replacement may also occur at the end of a sampling season if deemed necessary.

LISST-HYDRO

LISST-HYDRO maintenance is focused on cleaning the windows and optics of the unit. This should be done after the unit has been disconnected from the turbid water supply using a cotton swab as per the manufacturers' recommendations. Field technicians will visually inspect the instrument on a regular basis to determine if cleaning is necessary. If it is found that the optics require cleaning the field technician will follow the steps as outlined in the user manual. The flow rate from the pump will be measured monthly to ensure that the pump is not faulty or clogged. If flow rates become low or power consumption by the pump becomes high, the pump will be removed, inspected, and cleaned or replaced as required. Pump cleaning/replacement may also occur at the end of a sampling season if deemed necessary.

LISST-100X

The LISST-100X unit requires cleaning following every use, prior to storage. Standard cleaning includes rinsing the lenses with distilled water and cleaning with lens wipes. Following the lens cleaning, all other components of the unit should be cleaned in accordance with the user's manual. Because this unit does not require a flow-through pumping system, no measurement of flow rates is necessary.

15 Instrument and Equipment Calibration and Frequency

The LISST-StreamSide, LISST-HYDRO, and LISST-100X instruments have been factory calibrated prior to rental or purchase by FirstLight. Instrument settings will be reviewed prior to initial deployment/installation and during each weekly site visit. If it is determined to be necessary, the LISST-StreamSide and LISST-HYDRO samplers may be sent to the manufacturer at the end of a sampling season for re-calibration or refurbishment prior to re-installation.

16 Inspection and Acceptance of Supplies and Consumables

All supplies, including instruments and equipment, will be checked regularly before use by the Gomez and Sullivan QA Officer. In addition, during weekly site visits, field technicians will review all instruments and equipment to ensure they are functioning properly and that they have an adequate clean distilled water and power supply. For laboratory sampling, the lead field technician will ensure that sample bottles have no defects and have been prepared properly. All field analytical equipment and supplies are inspected and maintained according to methods described in Section 15 above.

17 Non-direct Measurements

USGS river gauge and Northfield Mountain Project Operations data will be used to monitor stream flow, water level, and other pertinent river characteristics. Project operations data will also be used in conjunction with LISST instrument data to analyze the variation in suspended sediment transport and concentration over time along with variation in flow. GIS and bathymetric data from a variety of sources including, but not limited to, MassGIS, USGS, and ESRI will be used to create maps and graphics as well as to support analysis.

18 Data Management

Field technicians are encouraged to use ink to document all field data and information (field measurements, station descriptions, etc.). However, documents completed with pencil or other erasable media are acceptable. Field technicians are also encouraged to correct all recording errors by placing a single horizontal line through the error, recording the new data next to or above the erroneous record(s), and initialing the correction.

<u>LISST-StreamSide & LISST-HYDRO</u>

The LISST-StreamSide and LISST-HYDRO instruments will collect continuous data throughout the duration of the study. The LISST-StreamSide will store all data on the instrument hard drive until it is offloaded by field technicians. Field technicians will visit the instrument on a weekly basis to offload the data, check on the status of the instrument, and ensure that data collection is occurring properly. All offloaded data will be transferred to a field laptop where it will be reviewed for accuracy by field technicians prior to leaving the site. The LISST-HYDRO instruments will be tied directly to secure FirstLight servers for data monitoring and storage.

Following field data download, LISST-StreamSide data will be transferred to secure Gomez and Sullivan servers for proper storage. The data will then be compiled into Microsoft Excel spreadsheets or Microsoft Access databases for use by project personnel. The computerized data will be doubled checked by at least one other person as a form of quality control. As the data are reviewed, any erroneous data will be identified, censored, and documented. Raw data from the LISST instruments will be retained in original format for long-term storage.

<u>LISST-100X</u>

The LISST-100X stores data within the instrument. Following field data collection the data is downloaded to a field laptop for processing, quality control checks, and storage. All data will be double checked by field technicians prior to leaving the site. LISST-100X data will then be transferred from the field laptop to secure servers. The data will be compiled into a Microsoft Excel spreadsheet or Microsoft Access database. The computerized data will be double checked by at least one other person as a form of quality control. As the data is reviewed any erroneous data will be identified, censored, and documented. Raw data from the LISST-100X will be retained in original format for long-term storage.

<u>Volume to Mass Conversion</u>

The LISST devices measure SSC in µl/L, which is a volume concentration (VC). All analyses will be performed on the raw data in µl/L, however, it may be deemed necessary to convert the final results to SSC in mg/L where applicable.

By default the LISST-HYDROs use a constant, assumed effective density of 2.65 g/cm^2 for all conversion from volume concentration to mass concentration. In order to better estimate the effective density of the particles, as opposed to using the assumed standard, water samples will be collected over a range of flows and river conditions, or at a minimum monthly, to measure the SSC (mg/L). Grab samples will be collected at the LISST-StreamSide and LISST-HYDRO drain hoses at the same time a measurement of the volume concentration is made by the LISST instrument(s). The laboratory grab sample (SSC) will then be divided by the corresponding LISST sample (VC). The calculation of SSC/VC will yield the effective density for that sample. The effective density of a given sample can then be used to convert the volume concentration of further results (collected under similar flows and river conditions) to a mass. Additional information on this conversion is provided in Appendix E.

Although it is possible to convert volume concentration to mass concentration, given that 1) all LISST instruments collect measurements of volume concentration and therefore are all directly comparable; 2) potential error can be introduced when determining effective density or converting volume concentration to mass concentration; and 3) it is unknown how much the effective density changes over varying flow and river conditions (which could introduce further error to the conversion), FirstLight will avoid converting suspended sediment data to mg/L unless deemed necessary for specific data analysis purposes.

Laboratory Analysis

Results from all laboratories are submitted to the Gomez and Sullivan QA Officer for review and entry into the project database.

19 Assessments and Response Actions

Attention to quality is a primary consideration of the project. The Gomez and Sullivan Project Manager will formally review the performance of the field technicians at times during the sampling season to ensure proper data collection. All personnel associated with the project will ensure that the standard operating procedures be followed closely. Training, calibration, maintenance and laboratory records will be filled out in a timely manner. Refresher courses for the field technicians will be conducted for each new season and as needed if it is determined that the field technicians are not sampling correctly.

To ensure data quality, the Gomez and Sullivan QA Officer will accompany the field crew at least once during the sampling period for (1) water sample collection, (2) operation of equipment, and (3) data documentation.

Equipment errors may occur and must be accounted for by reporting them to the Gomez and Sullivan Project Manager. If the error is identified before sampling takes place, the equipment will be labeled as broken and repaired or replaced by properly working equipment, if available. If malfunctioning equipment affects the data, the equipment will be recorded as such on the field data sheet and immediately reported to the Project Manager.

The Gomez and Sullivan Project Manager is ultimately responsible for oversight of all activities of the data collection process. The Gomez and Sullivan QA Officer will ensure that field technicians are performing all data collection as prescribed by the QAPP. All field activities may be reviewed and project sites may be visited by MADEP and USEPA quality assurance officers as requested.

20 Reports to Management

Upon completion of data collection, the Gomez and Sullivan Project Manager will prepare a final report. The final report will include a summary of activities performed, all of the accepted data, explanations for unaccepted data, a complete analysis, recommendations for the upcoming field season, and any other pertinent information.

The data will be used to provide a profile of the type of sediment that is present at various river conditions. The data collected in the vicinity of the Route 10 Bridge will be used to understand the quantity of suspended sediment being transported in the Turners Falls Impoundment upstream of the Northfield intake, and the concentrations of suspended sediment under various river flow conditions. The data collected at the Northfield Mountain Tailrace will be used in conjunction with the annual bathymetry survey of the upper reservoir to estimate how much sediment is being accumulated in the upper reservoir.

21 Data Review, Verification, and Validation

All field and laboratory data will be reviewed by the Gomez and Sullivan QA Officer to determine if the data meet QAPP objectives. The data will be scrutinized in the context of the data quality objectives. A decision will then be made whether to accept, qualify, or reject the data. Decisions to reject or qualify data will be made jointly by the FirstLight Station Manager, Gomez and Sullivan Project Manager, and Gomez and Sullivan QA Officer. For additional information refer to Section 14.

22 Verification and Validation Methods

The Gomez and Sullivan Project Manager, Gomez and Sullivan QA Officer, and field technicians will perform the following tasks to ensure validity of all data associated with the program.

Field Data Verification
Data downloaded from LISST-StreamSide and LISST-100X instruments will be double-checked by field technicians at the time of download, prior to leaving the site. LISST-HYDRO data uploaded directly to FirstLight servers will be reviewed weekly. Data that does not meet acceptable standards will be flagged and the LISST instrument settings will be reviewed and, if necessary, reset to ensure proper continuous data collection.

For point sampling collection from LISST-100X and laboratory samples, field data sheets and field collected data will be double-checked by another member of the sampling team. If errors are found, the sampler will be contacted and the errors corrected before computer data entry begins. If consistent errors are found, re-training on the particular issue will occur before the next sampling session.

Field collected data will be submitted to the Gomez and Sullivan Project Manager and Gomez and Sullivan QA Officer. The Gomez and Sullivan QA Officer will review all field data for completeness and make sure that any questionable data is verified by speaking to the field technicians, reviewing the field logbooks, or noting any unusual or anomalous data in the project files. Any decisions made regarding the usability of data will be ultimately left to the Gomez and Sullivan Project Manager; however, the Gomez and Sullivan Project Manager may consult with the Gomez and Sullivan QA Officer, project personnel, MADEP QA staff, or with personnel from USEPA.

Equipment Inspection
Equipment inspections will occur regularly to ensure that equipment is in proper working order, as detailed in Section 15.

23 Reconciliation with User Requirements

Calculations and determinations for precision, accuracy, and completeness will be made following each sampling season. If these data quality objectives are not met, the data will be tagged and subsequent corrective actions (taken in the next sampling season) will depend on the nature of the incident. Generally, the qualitative observations performed by the field technicians will be accepted with proper verification.

In situations where the equipment has been shown to be faulty, it will be replaced or another method will be found. If it is shown that better training is required, the Gomez and Sullivan Project Manager may request additional support from the Technical Advisor and Gomez and Sullivan QA Officer to ensure that training has been completed properly.

Limitations in field collected data will be clearly defined for potential end users in all reports produced. If the project objectives from Section 7 are met, the user requirements have been met. If the project objectives have not been met, corrective actions, as discussed above, will be initiated by the Gomez and Sullivan Project Manager.

If failure to meet project specifications is found to be unrelated to equipment, methods, or sample error, specifications may be revised for the next sampling season. Revisions will be submitted to MADEP and USEPA quality assurance officers for approval.

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Appendix A: LISST-StreamSide Specifications

LISST-StreamSide

A pumped in-line Sediment Sensor for continuous monitoring of shallow streams and rivers

• Particle Size Distribution • Sediment Concentration

The LISST-StreamSide from Sequoia Scientific, Inc. is a laser particle sizer specifically designed for monitoring shallow rivers, streams, or ponds. It is a flow-through instrument for use in field environments. Water is pumped through the instrument and the detailed size distribution and volume concentration is measured and stored on board. A water sample is not retained - after flowing through the instrument the water is simply returned to the source or other appropriate drain. Therefore no sample handling or lab processing is required. Sampling protocols are easily programmed using a touch panel display. A built-in clean water background system allows for automatic "zeroing" of the instrument before each measurement or on a fixed schedule. This automatic re-calibration of the instrument allows the instrument to compensate for fouling of the optics, for example due to biological growth. Communication with the instrument is through a standard serial link that is compatible with many wired and wireless remote data transfer devices.

SEQUOIA

LISST-STREAMSIDE Pumped in-line Sediment Sensor

FEATURES

- Small-angle forward laser light scattering (laser diffraction) - compliant with ISO-13320-1 standard
- Records detailed size distribution and concentration in 32 size classes - computed using state-of-the-art random shape inversions
- Standard 5mm optical path for high concentrations
- Built-in Clean water delivery system for automatic clean water background collection
- 5.1” touch panel display, 320 × 240 pixels (3.4” W × 4.5” H), 16-bit color
- Built-in Compact Flash memory (128MB standard, expandable to 4GB)
- All data-processing is performed on board and the data stored in ASCII-format – no post-processing necessary
- Nominal 12VDC power (110VAC or 220VAC optional)
- Sealed NEMA-4X housing with clear cover
- Specially designed 12V sealed pump is available and recommended for use with the LISST-StreamSide
- Outputs: Total volume concentration, mean size, standard deviation, optical transmission, size distribution, battery voltage, clean water tank level

SPECIFICATIONS (subject to change without notice)

Sediment concentration range

- 10-3,000 mg/l @ < 1mg/l resolution (actual range is grain-size dependent)

Size range

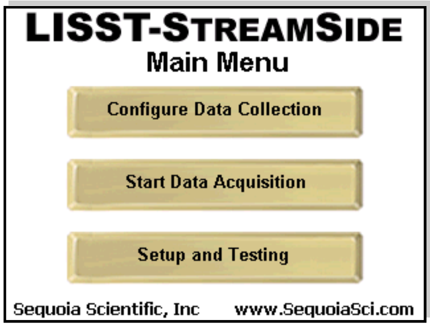
- 2.5-500 μm in 32 log-spaced size classes

Sample Acquisition Time

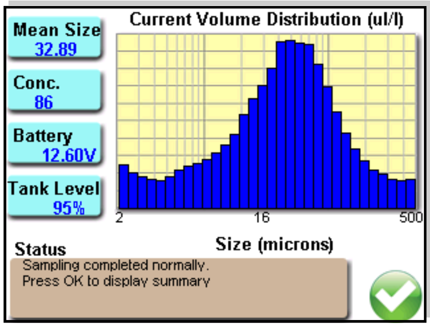
- 1 sec for 30 measurement average
- Typical maximum sample rate is 1 size distribution every 5 minutes
- Number of measurements per average and sample rate is programmable

Mechanical and electrical

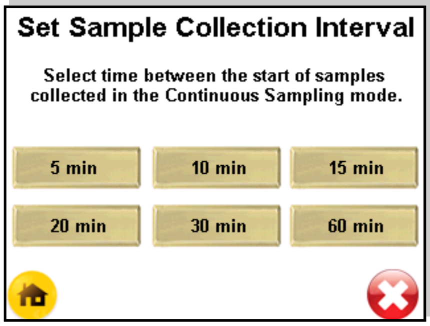
- Dimensions: 30 cm (11.8”) × 18 cm (7.1”) × 25 cm (10”) [H×D×W]
- Data storage: Standard 128MB (max 4GB) flash card is capable of storing 75,000 size distributions and associated sample information
- Power: 6-15VDC, 500mA max during sampling (excluding pump)
- Communications: RS-232 @ 9600 baud



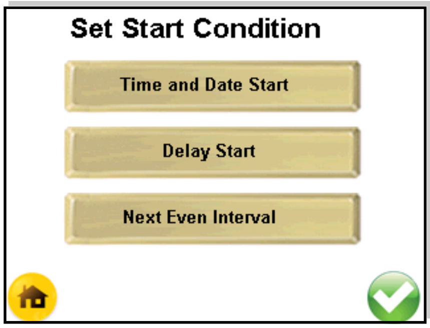
Touch panel screenshot of Main Menu



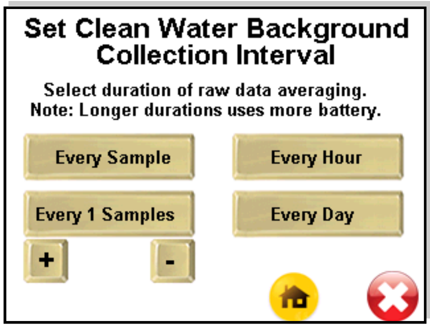
Size distribution screenshot



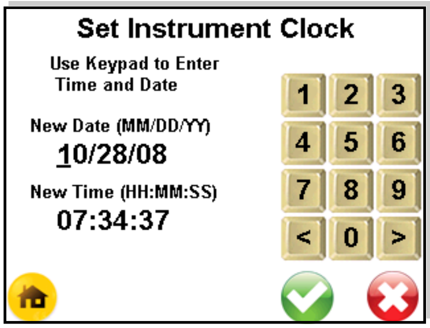
Sample Collection Interval Menu



Start Condition Menu



Background Collection Interval Menu

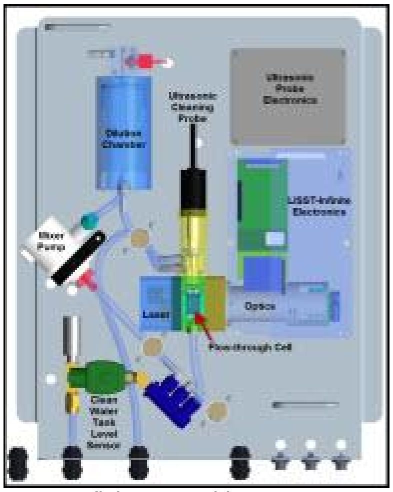


Instrument Clock Menu

Sequoia Scientific, Inc.
2700 Richards Road, Suite 107, Bellevue, WA 98005 USA
Tel 425.641.0944 **Fax** 425.643.0595 **email** info@SequoiaSci.com
www.SequoiaSci.com

Appendix B: LISST-HYDRO Specifications

Sediment (Silt) Monitoring for Turbine Erosion Prevention in Run of River Hydro Power Plants Using LISST-Infinite and LISST-Hydro.

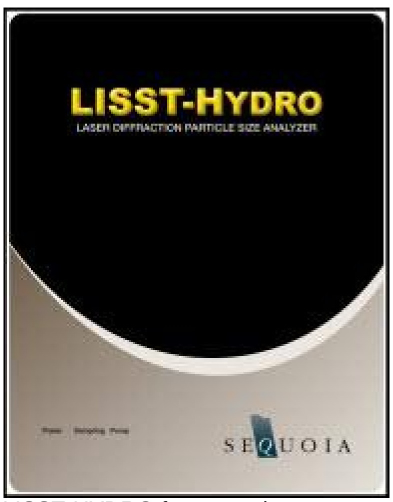


LISST-Infinite assembly

In run of river power plants, severe erosion of turbine parts can occur due to sediments carried by rivers, despite the presence of desiltation chambers. The problem is severe in power plants that are sited in the steep terrains, e.g. the Himalayan topography, or in regions with rivers carrying large amounts of sediment, e.g. South America.

Turbines, wicket gates, valves etc. can suffer severe erosion if the size of suspended sediment grains is large. Convention has it that grains >200 microns cause the most severe damage. As a result, often desiltation efficiency is described in terms of the removal of such large grains. In fact, there is no sharp cut-off in size below which grains may cause no turbine erosion. Thus, a measurement of the full size distribution of suspended sediments is needed at all times.

The erosion of turbines in Hydro Power plants is known to be a severe problem in rivers that drain the Himalayas - covering India, China, Nepal, Bhutan and other countries of East Asia. In Europe, power plants in Switzerland and Norway also are subject to such erosion and wear. In South America, power plants in Colombia, Brazil, Ecuador, Chile and Bolivia suffer from the same damages.



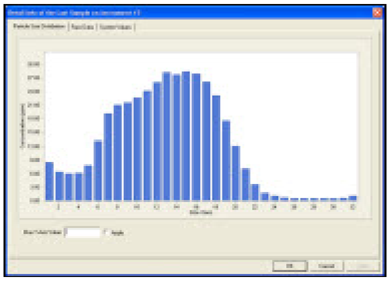
LISST-HYDRO front panel

Sequoia Scientific, Inc. has developed the world's first instrument system geared to the automated at-site MONITORING of the suspended sediment size distribution and concentration. Two different systems have been developed; one with and one without an auto-dilution system. These two systems are called **LISST-Infinite** and **LISST-HYDRO**, respectively. Using our basic laser diffraction technology the concentration and size distribution can be routinely and continuously monitored.

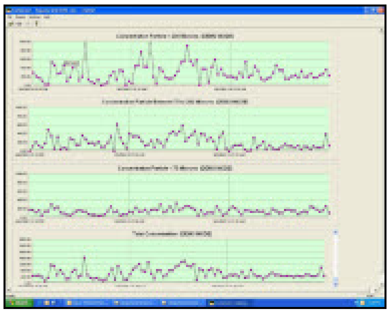
The LISST-HYDRO is quite similar to Sequoia's LISST-StreamSide instrument, but with the capability to talk to our LISST-Infinite Monitor software for displaying real-time size and concentration in a control room environment.

Both systems consists of a laser optical flow through cell. The user must provide power and clean filtered water. The instruments monitors the sediment properties on a user selected schedule. When the concentration exceeds a factory pre-set threshold, the LISST-Infinite will perform a dilution step before making a measurement of the concentration and size distribution. Typically, below about 2,000 mg/l (precise number depends on sediment size) no dilution is required. Thus, the upper range of concentration that the LISST-HYDRO can work in is around 2,000 mg/l. For the LISST-Infinite, the upper concentration limit is around 30,000 mg/l. See the article 'LISST Concentration Limits' for more information on what influences these limits.

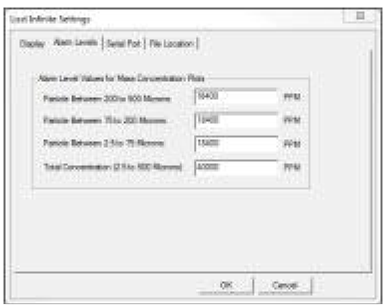
Some capabilities are shared between the LISST-Infinite and the LISST-HYDRO. The list below details these shared capabilities.



- Measurement of size distribution and concentration; the size distribution reports concentration in 32 log-spaced size classes covering the size range from 2.5 to 500 microns



- Control Room strip chart display of history and current data on a dedicated computer;



- Systems can be programmed to set off alarms at user-selected thresholds in user-selected size classes

- Data can be archived, archived and hard-wired, or archived and telemetered to a remote site via RF or satellite links.

Appendix C: LISST-100X Specifications

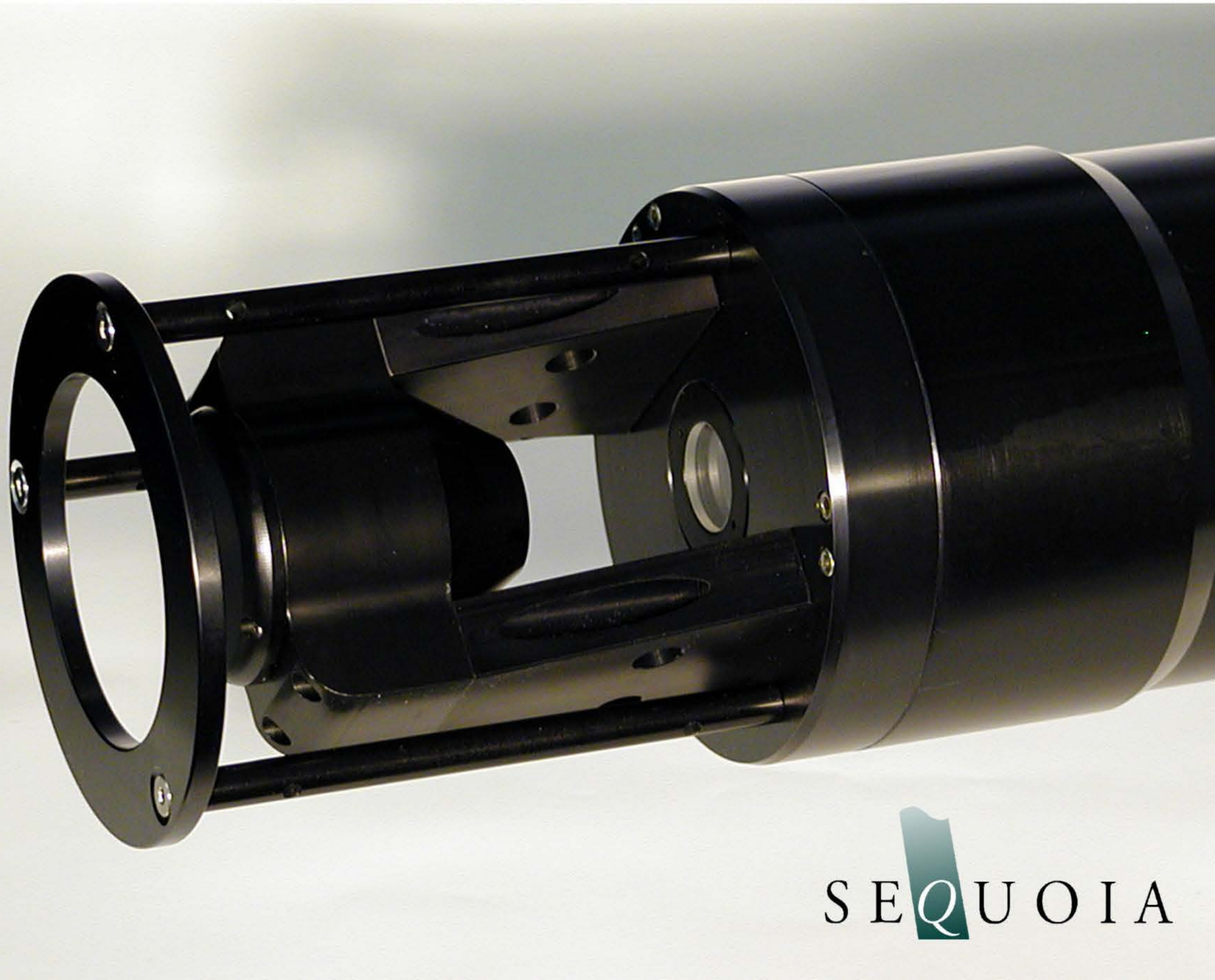
LISST-100X

Submersible Particle Size Analyzer

• Particle Size Distribution • Volume Scattering Function

• Optical Transmission • Particle Volume Concentration

The LISST-100X instrument obtains *in-situ* measurements of particle size distribution, optical transmission, and the optical volume scattering function (VSF). Using a red 670nm diode laser and a custom silicon detector, small-angle scattering from suspended particles is sensed at 32 specific log-spaced angle ranges. This primary measurement is post-processed to obtain sediment size distribution, volume concentration, optical transmission, and VSF. Temperature and depth are also recorded. Optionally, a SeaBird MicroCat 37-SI CTD can be integrated for high precision conductivity, temperature, and depth measurement. Alternatively a Campbell OBS-3+ or a Turner Designs Cyclops-7 fluorometer can be integrated upon request. Special versions with folded housing or a shorter housing with an external battery pack are available. A version for deep-ocean use (LISST-DEEP) is also available. For extended field deployment, our BioBlock anti-fouling system option is recommended.



SEQUOIA

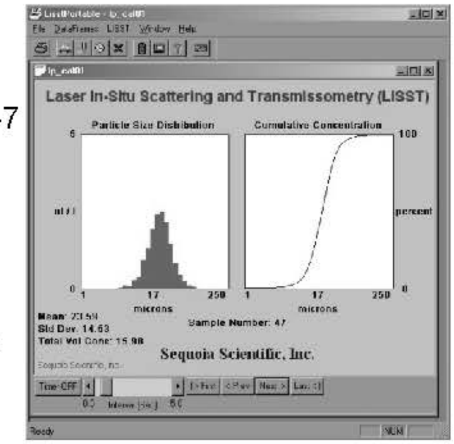
SEQUOIA SCIENTIFIC, INC.
2700 Richards Road, Suite 107
Bellevue, WA 98005 USA
Phone (425) 641-0944
Fax (425) 643-0595
www.SequoiaSci.com
info@SequoiaSci.com

LISST-100X

Submersible Particle Size Analyzer

FEATURES

- Small angle forward-scattering laser diffraction technology
- Self-contained with internal datalogger, CF memory module and alkaline battery pack
- RS232 connection to PC for real-time size distribution displays
- Programmable data collection
- Integrated BioBlock connection
- *Optional extra feature:* Can be configured to receive input from Campbell OBS-3+, Turner Designs Cyclops-7 fluorometer or Sea-Bird Micro-Cat CTD.



SPECIFICATIONS

Parameters Measured

Particle Size Distribution, Optical Transmission, Depth,
Volume Concentration, Temperature,
Volume Scattering Function

Technology

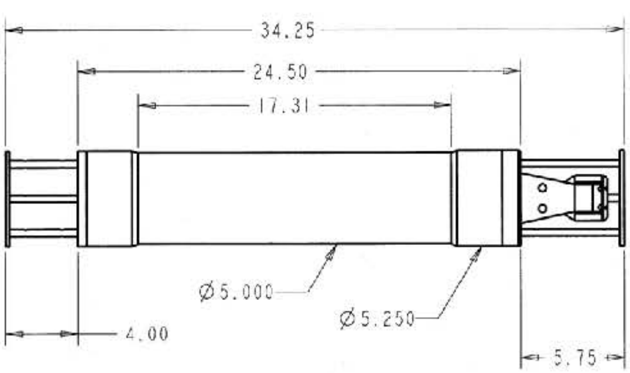
Solid State Diode Laser @ 670 nm, 1mW
Detector: 32-ring custom photodiode
Sample Rate: Programmable, up to 25 Hz internally, 1 Hz saving to datalogger
Optical Path: 50 mm standard. Bolt-on path reduction modules are available for higher concentration environments

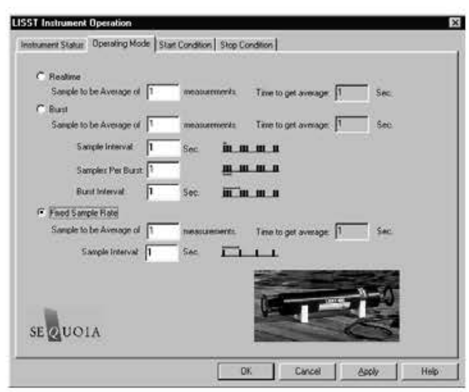
Sediment Size Distribution, Scattering Angles and Concentration

32 log-spaced size classes: 1.25-250 or 2.5-500 µm (0.08-15° or 0.04-7.5° in water)
Range: 1-750 mg/L (approximate range based on 30 µm mean size particles)
Resolution: <1 mg/L

Mechanical and Electrical

Dimensions: 5.25" (13.3 cm) ∅ x 34.25" (87 cm) L
Weight: 25 lbs (11 kg) in air; 8 lbs (3.6 kg) in water
Depth Rating: 300 meters
Serial Interface: RS232C, 9600 baud, High speed offload at 115K baud
Alkaline Battery Pack: Custom 9V nominal, 42Ah
External Power Input (optional): 12 VDC nominal, 10 to 24 VDC
CF Memory Card: 128 Mb standard (1,600,000 size distributions)
Battery Current Drain: 146 mA / 8 mA / 128 µA (measuring/quiescent/sleeping)





Appendix D: Certified Laboratory Standard Testing Methodology

SEDIMENT CONCENTRATION IN WATER SAMPLES

Standard Operating Procedure

Standard Procedure for the analysis of water and wastewater samples in accordance with ASTM Method D3977-B

Reviewed by: ________________ Reviewed Date: ________________
Department Analyst

Implemented by: ________________ Date Implemented:______________
Laboratory Supervisor

Sterling Analytical, Inc.
15 Agawam Ave. West Springfield, MA
(413) 214-6541

Sterling Analytical, Inc.

STANDARD OPERATING PROCEDURE
SEDIMENT CONCENTRATION IN WATERS
ASTM D3977 METHOD B

TABLE of CONTENTS

INTRODUCTION

It is the policy of Sterling Analytical to ensure that we carry out orders for services and analyses in a manner that is fully compliant with governmental laws and regulations as well as company policies and regulations.

1.0 SCOPE AND APPLICATION

1.1 This method is applicable to samples collected from lakes, reservoirs, ponds, streams, and other water bodies with sand concentrations less than 10,000 mg/l and clay concentrations less than 200 mg/l.

1.2 The practical range of the determination is 0.5 mg/l to 10,000 mg/l.

2.0 SUMMARY OF METHOD

2.1 A well-mixed sample is filtered through a glass fiber filter, and the residue which is retained on the filter, is dried to a constant weight at 105°C.

3.0 INTERFERENCES

3.1 Non-representative particulate should be excluded if it is determined that their inclusion is not desired in the final result.

3.2 Filtration apparatus, filter material, pre-washing, post washing and drying temperature are specified because these variables have been known to affect the results.

3.3 Samples high in dissolved solids, such as saline water may cause a positive interference.

4.0 SAFETY

4.1 Certain unknown samples may contain toxic conditions therefore use the appropriate safety equipment when doing this analysis.

5.0 EQUIPMENT AND MATERIALS

5.1 Glass fiber filter discs 1.5 um, Whatman 934-AH or the equivalent, 9.0 cm.

5.2 Buchner filter support and funnel 9.0 cm.

5.3 1 liter suction flask

5.4 Drying oven, 105°C

5.5 Dessicator

5.6 Analytical Balance Capable of weighing to 0.1 mg.

5.7 Filter Forceps

5.8 1000 ml Graduated Cylinder

5.9 10.0 cm watch glasses

6.0 REAGENTS

6.1 Reagent water, type II

7.0 QUALITY CONTROL

7.1 Duplicate analyses should be within Std. deviation of 2.8 mg/L

8.0 PROCEDURE

8.1 Preparation of glass fiber disc: place glass fiber paper, wrinkled side-up on the membrane filter apparatus. Wash disc with 20 mls distilled water successive, 3 times. Remove all traces of water by applying vacuum alter water has passed through. Remove from apparatus and place on a watch glass. Dry in drying oven at 105°C for 1 hr. Cool and store in dessicator. Repeat the drying cycle until a constant weight is obtained. (<0.2 mg weight loss). Weigh immediately before use and handle filter with forceps.

8.2 Assemble the filtering apparatus and begin suction. Place the filter against the fritted support to seat it.

8.3 Quantitatively transfer the entire sample volume to the filter by first decanting the supernate and then the remaining sediment. Flush the inner surfaces of the bottle with water if necessary. Remove all traces of water by continuing to apply vacuum after the sample has passed through.

8.4 Pour the filtrate into a graduated cylinder and record the volume.

8.5 With suction on, wash the filter, filter funnel wall and residue with distilled water from a wash bottle. Allow complete drainage between washings. Remove all traces of water by continuing to apply vacuum after water has passed through. Make sure all sediment is on the filter. The minimum total volume of wash water is 50 mls for a 9.0 cm filter. Use more if necessary.

8.6 Carefully remove filter from the filter support and place on a watch glass. Dry at least one hour at 105°C. Cool in a dessicator and weigh to the nearest 0.1 mg. Repeat the drying cycle until a constant weight is obtained.

9.0 DATA ANALYSIS AND CALCULATIONS

9.1 Determine the amount of sediment in each sample using the following equation:

$$\text{Sediment, mg/l} = \frac{(A-B) \times 1000}{C}$$

A = weight of filter and sediment in mg
B = weight of filter in mg (tare weight)
C = total volume of sample in ml

10.0 RECORDKEEPING

10.1 All readings are written with pen in a bound hardcover book. The results show the sample #, date, watch glass ID, analyst, and subsequent readings.

11.0 WASTE MANAGEMENT

11.1 The Sterling Analytical laboratory complies with all federal, state, and local regulations pertaining to waste management and disposal, as well as maintaining conservation programs to minimize waste disposal and recycle solvents whenever possible.

NON-FILTERABLE RESIDUE

Standard Operating Procedure

Standard Procedure for the analysis of drinking, surface, and saline waters, domestic and industrial wastes in accordance with Standard Methods SM 2540D

Reviewed by: ________________ Reviewed Date: ________________
Department Analyst

Implemented by: ________________ Date Implemented: ______________
Laboratory Supervisor

Sterling Analytical, Inc.

15 Agawam Ave. West Springfield, MA

(413) 214-6541

Sterling Analytical, Inc.

STANDARD OPERATING PROCEDURE
RESIDUE, NON-FILTERABLE (Total Suspended Solids)
Standard Methods SM 2540D

TABLE of CONTENTS

INTRODUCTION

It is the policy of Sterling Analytical to ensure that we carry out orders for services and analyses in a manner that is fully compliant with governmental laws and regulations as well as company policies and regulations.

1.0 SCOPE AND APPLICATION

1.1 This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes.

1.2 The practical range of the determination is 0.5 mg/l to 20,000 mg/l.

2.0 SUMMARY OF METHOD

2.1 A well-mixed sample is filtered through a glass fiber filter, and the residue which is retained on the filter, is dried to a constant weight at 103 - 105°C.

2.2 The filtrate from this method may be used for Residue, Filterable (total dissolved solids).

3.0 INTERFERENCES

3.1 Non-representative particulate should be excluded if it is determined that their inclusion is not desired in the final result.

3.2 Filtration apparatus, filter material, pre-washing, post washing and drying temperature are specified because these variables have been known to affect the results.

3.3 Samples high in dissolved solids, such as saline water may cause a positive interference.

4.0 SAFETY

4.1 Certain unknown samples may contain toxic conditions therefore use the appropriate safety equipment when doing this analysis.

5.0 EQUIPMENT AND MATERIALS

5.1 Glass fiber filter discs, Gelman type A/E or the equivalent, 4.7 cm.

5.2 Membrane filter support and funnel with reservoir, 250 ml capacity.

5.3 1 liter suction flask

5.4 Drying oven, 103° to 105°C

5.5 Dessicator

5.6 Analytical Balance Capable of weighing to 0.1 mg.

5.7 Filter Forceps

5.8 500 ml Glass Cylinder

5.9 Volumetric Pipettes in various sizes

6.0 REAGENTS AND STANDARDS

6.1 Reagent water, type II

6.2 Silica gel, 100-200 mesh (nominal)

6.3 ISS Standard (known duplicates) weigh out 100 to 500 mg of silica gel in a weighing dish. Using a funnel, carefully transfer silica gel into a 1 liter flask. Dilute to mark with distilled water. Record weight in the "Standards" book.

7.0 QUALITY CONTROL

7.1 Method Detection Limit > To establish the ability to detect Suspended Solids, the laboratory shall determine the MDL using a blank solution fortified at two to three times the estimated detection limit. To generate an MDL, seven identical aliquots are processed through the analytical method over a minimum 3-day period. The results are then entered in the MDL chart, where the actual MDL is calculated. The MDL generated must be low enough to detect suspended solids at the levels outlined in compliance monitoring regulations. This MDL is determined annually, unless a change in hardware or operating conditions occurs which would warrant re-evaluation.

7.2 Duplicate analyses should be within Std. deviation of 2.8 mg/L

8.0 PROCEDURE

8.1 Preparation of glass fiber disc: place glass fiber paper, wrinkled side-up on the membrane filter apparatus. Wash disc with 20 mls distilled water successively, 3 times. Remove all traces of water by applying vacuum after water has passed through. Remove from apparatus, place in glass petri dish cover. Dry in drying oven at 103-105^{o} C for 1 hr. Cool and store in dessicator. Repeat the drying cycle until a constant weight is obtained. (<0.5 mg weight loss). Weigh immediately before use and handle filter with forceps.

8.2 For a 4.7 cm diameter filter, filter enough sample so at least 1.0 mg of residue is captured. If the residue is less than 1.0 mg, filter more sample.

8.3 Assemble the filtering apparatus and begin suction. Place the filter against the fritted support to seat it.

8.4 Shake the sample vigorously and quantitatively transfer the predetermined sample volume to the filter using a graduated cylinder. Remove all traces of water by continuing to apply vacuum after the sample has passed through.

8.5 With suction on, wash the graduated cylinder, filter, filter funnel wall and residue with three portions of distilled water from a wash bottle. Allow complete drainage between washings. Remove all traces of water by continuing to apply vacuum after water has passed through. Make sure all residue is on the filter. The minimum total volume of wash water is 30 mls for a 4.7 cm filter. Use more if necessary.

8.6 Carefully remove filter from the filter support place in glass petri dish cover. Dry at least one hour at 103° to 105°C. Cool in a dessicator and weigh. Repair the drying cycle until a constant weight is obtained.

9.0 DATA ANALYSIS AND CALCULATIONS

9.1 Determine the amount of non-filterable residue in each sample using the following equation:

$$\text{Filterable residue, mg/l} = \frac{(A-B) \times 1000}{C}$$

A = weight of filter and residue in mg
B = weight of filter in mg (tare weight)
C = volume of sample used in ml

10.0 RECORDKEEPING

10.1 All readings are written with pen in a bound hardcover book. The results show the sample #, date, petri dish cover ID, analyst, and subsequent readings.

10.2 Sterling Analytical laboratory maintains cumulative QC data in chart form to monitor blanks, MDL and known duplicates.

11.0 WASTE MANAGEMENT

11.1 The Sterling Analytical laboratory complies with all federal, state, and local regulations pertaining to waste management and disposal, as well as maintaining conservation programs to minimize waste disposal and recycle solvents whenever possible.

11.2 Standards are prepared in volumes consistent with laboratory use to minimize the volume of expired standards to be disposed of.

Appendix E: Converting LISST Volume Concentration to Mass Concentration

Converting LISST volume concentration to mass concentrations

How do I convert the volume concentrations (VC) from the LISST to mass concentrations?

[Sequoia, March 24, 2010]

Converting volume concentration (VC) to mass concentration, total suspended solids or suspended sediment concentration requires some assumptions. First of all, the reason why the LISST does not output mass right away is that this is not what is being measured using laser diffraction. When the laser beam encounters a particle it scatters in a manner that is proportional to the particle cross-sectional area. Essentially, the laser beam encounters the cross-sectional area of the particle. Now, the ratio of particle surface area to particle volume decreases with increasing particle size (i.e. with increasing particle volume). Therefore, on a per unit volume concentration basis, the scattering is inversely proportional to the size of the particles. This is true for all laser particle sizers, not just Sequoia's LISST instruments. The only way to get mass concentration directly is by actually **weighing** the sediment in a sample – typically this means filtering it.

In principle it is very straightforward to convert volume to mass, by multiplying the volume of the particles with the density of the particles. For a suspension of fully dispersed (unflocculated) mineral grains the density of all particles will be 2.65 g/cm3 or very close to this value. In this case the VC (with units of µl/l) could simply be multiplied with 2.65 in order to yield mass concentration in units of mg/l.

Major problems arise when the density of the particles in suspension are not all the same. There are several reasons why this might be:

1. Flocculation. If particles flocculate their density decreases. The more they flocculate, the smaller the density. A floc with a diameter of a few hundred micro meters can easily have a density very close to that of water (1 g/cm3), because most of its volume *is* water.

2. Mixture of organic / inorganic particles. If the suspended particles are made up of a mixture of organic (e.g diatoms) and inorganic particles, then the densities will differ, as the organic particles tend to have (much) smaller densities than the mineral grains.

3. Different minerals. If the suspended particles in your sample are made of of minerals with varying densities, the same thing will happen.

It is possible to – occasionally – take a water sample, filter it, get the mass concentration and then compare that to the VC from the same sample, thereby getting an average density for the particles for that sample. However, if just some of the particles are flocculated, then using an average density to convert volume to mass will invariably cause an overestimation of the mass in the larger size classes, and a general overestimation of the mass concentration. (Of course, for the *exact* sample that is being used to obtain the relationship everything will be OK!).

The best way to convert VC to mass concentration is to take a water sample for mass concentration now and then, and divide the mass concentration with the volume concentration from the LISST in order to get the average density of the particles in that paricular sample. Do this over time and you will get an idea of how much the density of the particles generally varies. If the variability is small, then do an average of all the densities and use this value to for future runs. One may find a seasonal variability of the densities, with lower densities in the summer and higher in the winter (due to more organic particles in the summer), in which case it would be necessary to use a seasonally varying density to convert LISST volume to mass.

The following articles may be of interest if you are interested in learning more about this topic:

Fennessy et al (1994): INSSEV: An instrument to measure the size and settling velocity of flocs in situ. Marine Geology 117: 107-117.

Fennessy et al. (1997): Estimation of settling flux spectra in estuaries using INSSEV. In 'Cohesive Sediments' (Eds: Burt, Parker, Watts), John Wiley & Sons, pp. 87-104.

Fugate D, and Chant B (2006): Aggregate settling velocity of combined sewage overflow. Marine Pollution Bulletin 52: 427-432.

Khelifa A, and Hill PS (2006): Models for effective density and settling velocity of flocs. Journal of Hydraulic Research 44(3): 390-401.

Mikkelsen OA, and Pejrup M (2001): The use of a LISST-100 laser particle sizer for in-situ estimates of floc size, density and settling velocity. Geo-Marine Letters 20: 187-195. doi:10.1007/s003670100064

Finally, you may be interested in this article here on our website: ‘Comparing volume concentration and mass concentration.’

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Updated 2/22/2011

Questions to this application note? Email us!