December 1, 2015

**VIA EMAIL**

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Northfield Mountain Pumped Storage Project (FERC No. 2485)
Sediment Management Plan – Report of 2015 Activities

Dear Secretary Bose:

FirstLight Power Resources Services, LLC (FirstLight), as an agent for FirstLight Hydro Generating Company, an affiliate of GDF SUEZ Energy North America, Inc., submits the enclosed report for the Northfield Mountain Pumped Storage Project (Project No. 2485), located along the Connecticut River near Northfield, MA.

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.[1] Following initial field efforts and comments from the agencies, FirstLight revised its initial Plan and filed its revised Plan with the Commission on February 15, 2012. FERC issued its Order approving the Plan on March 28, 2012.

The Revised Plan specifies that a report summarizing sediment monitoring activities of the past calendar year be provided to the MADEP, USEPA, and the Commission by December 1 of the year in which the sediment monitoring was conducted. As such, the enclosed report provides an overview of sampling efforts conducted in 2015. Specific components of the Plan implemented during this reporting period include: 1)

[1] Although the original and revised plans called for sampling activities to occur from 2011 through 2014 due to equipment malfunction issues during the first few years of this study FirstLight extended monitoring efforts through 2015.

**John S. Howard**
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Chief Dam Safety Engineer

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conducting an annual bathymetric survey of the Upper Reservoir, 2) collecting Suspended Sediment Concentration (SSC) and Total Suspended Solids (TSS) grab samples from the Project area, 3) developing a computational hydrodynamic sedimentation model of the Upper Reservoir, 4) developing a computational fluid dynamics model of the Northfield Mountain Project Tailrace, 5) developing a physical model of the study area, 6) conducting an Upper Reservoir pilot dredge in the vicinity of the intake channel, and 7) reporting requirements.

Following review of this report, if you have any questions or concerns please contact me at (413) 659-4489 or john.howard@gdfsuezna.com.

Sincerely,

John Howard

Cc: Joseph Enrico, FERC NYRO
Brian Harrington, MADEP Western Regional Office
George Harding, USEPA Region 1
Toby Stover, USEPA Region 1
Nora Conlon, USEPA Region 1
Ralph Abele, USEPA Region 1
Mark Wamser, Gomez and Sullivan Engineers
Julia Wood, Van Ness Feldman
Mike Swiger, Van Ness Feldman
Adam Kahn, Foley Hoag

Attachment: 2015 Summary of Annual Monitoring

# Relicensing Study 3.1.3

# Northfield Mountain Pumped Storage Project

# Sediment Management Plan

# 2015 Summary of Annual Monitoring

## Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

*Prepared for:*

FirstLight
GDF SUEZ

*Prepared by:*

Gomez and Sullivan Engineers

**DECEMBER 2015**

# EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

Prior to initiation of the FERC relicensing process, the U.S. Environmental Protection Agency (USEPA) issued an Administrative Order dated August 4, 2010, which requested a report identifying measures to prevent discharges of sediments associated with draining the Northfield Mountain Upper Reservoir. Subsequently, by letter dated January 20, 2011, FERC staff requested a plan to avoid or minimize the entrainment of sediment into the Project works during Upper Reservoir maintenance drawdowns. On July 15, 2011 FirstLight filed the *Northfield Mountain Pumped Storage Sediment Management Plan* (the Plan) in response to the USEPA and FERC requests.

The Plan was developed in consultation with the USEPA and Massachusetts Department of Environmental Protection (MADEP). The Plan contained proposed methods to assess sediment dynamics in the Project's Upper Reservoir and the Connecticut River (Turners Falls Impoundment) from 2011 through 2014. Furthermore, FirstLight committed to propose management measures to minimize entrainment of sediment into the Project works and Connecticut River at the conclusion of the data collection and assessment efforts.

During the study plan development phase of the Project relicensing, the USEPA requested that FirstLight integrate the *Sediment Management Plan* into the FERC relicensing process. FirstLight agreed and designated the Plan as relicensing Study No. 3.1.3 *Northfield Mountain Project Sediment Management Plan* (Study No. 3.1.3). FirstLight also committed to extending data collection efforts pursuant to the Plan an additional year, through 2015. FERC approved the Plan as Study No. 3.1.3 in September 2013. As required by the FERC approved Revised Study Plan (RSP), FirstLight is obligated to file: 1) annual reports with FERC, USEPA, and MADEP summarizing the previous year's monitoring activities by December 1 of the year in which the monitoring occurred, 2) an Updated Study Report to be filed with FERC based on the information it has collected to date, and 3) a report to be filed with USEPA, MADEP and FERC, which would include any additional field data collected after September 2015.[1]

Study No. 3.1.3 contains various field studies and data collection efforts which have occurred from 2011-2015. The results of these efforts will be used to inform management measures to minimize entrainment of sediment into the Project works and discharge to the Connecticut River during drawdown or dewatering activities. Once all ongoing tasks have been completed and reviewed, FirstLight will present its proposed sediment management measures to the USEPA, MADEP, and FERC. The proposed management measures will be discussed in the final report for Study No. 3.1.3, which FirstLight expects to complete by September 1, 2016.

[1] As required by FERC and the USEPA, FirstLight filed an Updated Study Report for Study No. 3.1.3 on September 14, 2015. The September 2015 report provided a status update of all study tasks, data results and analyses for completed tasks, and a high level overview of the ongoing tasks. This submission updates the September 2015 Updated Study Report to reflect additional data collection and analyses which have occurred between September and November 2015.

# TABLE OF CONTENTS

**1 INTRODUCTION ........ 1-1**

**2 FIELD STUDIES AND DATA COLLECTION ........ 2-1**

2.1 Upper Reservoir Bathymetry Surveys ........ 2-1

2.2 Suspended Sediment Monitoring ........ 2-5

2.2.1 LISST Equipment ........ 2-7

2.2.2 Grab Sample Collection ........ 2-17

2.3 Modeling ........ 2-21

2.3.1 Computational Hydrodynamic Sedimentation Modeling of the Upper Reservoir ........ 2-21

2.3.2 Computational Fluid Dynamics Sediment Modeling of the Northfield Mountain Project Intake/Tailrace ........ 2-21

2.3.3 Physical Model of the Project Area ........ 2-25

2.4 Upper Reservoir Pilot Dredge ........ 2-32

**3 DATA ANALYSES ........ 3-1**

3.1 Upper Reservoir Bathymetry Surveys ........ 3-1

3.2 Suspended Sediment Monitoring ........ 3-5

3.2.1 QA/QC of data ........ 3-5

3.2.2 Conversion of Volume Concentration to Mass Concentration ........ 3-8

3.2.3 Analyses 3-12

**4 RESULTS & DISCUSSION ........ 4-1**

4.1 Upper Reservoir Bathymetry Surveys ........ 4-1

4.2 Suspended Sediment Monitoring ........ 4-14

4.2.1 Comparison of Point and Continuous Measurements to Flow and Operations ........ 4-14

4.2.2 Comparison of Cross-sectional Data - Rt. 10 Bridge and Northfield Mountain tailrace ........ 4-33

**5 LITERATURE CITED ........ 5-1**

# LIST OF TABLES

Table 2.1-1. Summary of Upper Reservoir Bathymetric Data Collection ....2-3
Table 3.2.3-1 Cross-sectional Data Collection – 2013 and 2015....3-14
Table 4.2.1-1 Seasonal Range of Flows and SSC (2013-2015)....4-17
Table 4.2.2-1 Summary of LISST-100X Data Collected at the Rt. 10 Bridge (2013)....4-35
Table 4.2.2-2 Summary of Rt. 10 Bridge Cross Section Grab Samples (2015)....4-35
Table 4.2.2-3 Summary of LISST-100X Data Collected at the Northfield Mountain Tailrace (2013) ...4-35

# LIST OF FIGURES

Figure 2.1-1 Northfield Mountain Upper Reservoir and Tailrace ....2-4
Figure 2.2-1 Continuous Suspended Sediment Monitor Locations ....2-6
Figure 2.2-1-1 Location of StreamSide and Rt.10 Bridge ....2-11
Figure 2.2.1-2 LISST StreamSide Equipment Cabinet Configuration....2-12
Figure 2.2.1-3 LISST-HYDRO Cabinet Configuration (typical) ....2-13
Figure 2.2.1-4 LISST HYDRO and Tailrace Cross-section Locations....2-14
Figure 2.2.1-5 LISST-100X Collection from barge at the Northfield Mountain Tailrace....2-15
Figure 2.2.1-6 LISST-100X Configuration....2-16
Figure 2.2.2-1 Configuration of Rt.10 Bridge Grab Sample Collection....2-19
Figure 2.2.2-2 Grab Sampling Locations....2-20
Figure 2.3.2-1 Tailrace/intake CFD Model – Sediment Exclusion Alternative 1....2-23
Figure 2.3.2-2 Tailrace/intake CFD Model – Sediment Exclusion Alternative 2....2-24
Figure 2.3.3-1 Extent of Physical Model ....2-27
Figure 2.3.3-2 Location of Supplemental Data Collection Efforts Related to the Physical Model ....2-28
Figure 2.3.3-3 Approximate Location of Physical Model Deflection Structure....2-29
Figure 2.3.3-4 Physical Model of Northfield Tailrace Area- Looking Downstream toward Tailrace....2-30
Figure 2.3.3-5 Physical Model of Northfield Tailrace Area- Bend in River is at the Tailrace....2-31
Figure 2.4-1 Location of Upper Reservoir Pilot Dredge Activities....2-33
Figure 2.4-2 Dredge Equipment Setup ....2-34
Figure 2.4-3 Geotube Dewatering System....2-35
Figure 3.1-1 2014 Upper Reservoir Intake Channel Gravity Core Collection (2014)....3-4
Figure 3.2.2-1 StreamSide Unit Conversion Equation....3-9
Figure 3.2.2-2 HYDRO North Unit Conversion Equation ....3-10
Figure 3.2.2-3 HYDRO South Unit Conversion Equation ....3-11
Figure 4.1-1 Upper Reservoir Intake Channel Bathymetric Survey – 2012 to 2014 Change....4-4
Figure 4.1-2 Upper Reservoir Intake Channel 2014 Multi-beam Bathymetric Survey Results and Core Sample Locations ....4-5
Figure 4.1-3 General Condition 2014 Multi-beam Survey - Color Shaded Relief ....4-6
Figure 4.1-4 General Condition 2014 Multi-beam Survey - Soundings....4-7
Figure 4.1-5 General Condition 2014 Multi-beam - Survey Contours ....4-8
Figure 4.1-6 Upper Reservoir Intake Channel Bathymetric Survey – 2014 to 2015 Change....4-9
Figure 4.1-7 Upper Reservoir Intake Channel 2015 Multi-beam Bathymetric Survey Results and Core Sample Locations ....4-10
Figure 4.1-8 General Condition 2015 Multi-beam Survey - Color Shaded Relief ....4-11
Figure 4.1-9 General Condition 2015 Multi-beam Survey – Soundings ....4-12
Figure 4.1-10 General Condition 2015 Multi-beam - Survey Contours ....4-13
Figure 4.2.1-1 Turners Falls Impoundment SSC vs. Vernon Discharge (2013-2015)....4-18
Figure 4.2.1-2 Flow Duration Curve for the Turners Falls Impoundment....4-19

Figure 4.2.1-3 2013 Spring Freshet – SSC vs. Flow (StreamSide)....4-20
Figure 4.2.1-4 2014 Spring Freshet – SSC vs. Flow (StreamSide)....4-21
Figure 4.2.1-5 2015 Spring Freshet – SSC vs. Flow (StreamSide)....4-22
Figure 4.2.1-6 Typical Summer Period – SSC vs. Flow (StreamSide)....4-23
Figure 4.2.1-7 Typical Fall Period – SSC vs. Flow (StreamSide)....4-24
Figure 4.2.1-8 Impoundment SSC Values as Related to a Typical Vernon Peaking Sequence....4-25
Figure 4.2.1-9 Northfield Mountain Tailrace High Flow Scenario (April 7-14, 2014)....4-26
Figure 4.2.1-10 Northfield Mountain Tailrace High Flow Scenario (April 14-21, 2014)....4-27
Figure 4.2.1-11 Northfield Mountain Tailrace Moderate Flow Scenario (April 21-28, 2014)....4-28
Figure 4.2.1-12 Northfield Mountain Tailrace Low Flow Scenario (August 1-11, 2014)....4-29
Figure 4.2.1-13 Northfield Mountain Tailrace Low Flow Scenario (August 11-21, 2014)....4-30
Figure 4.2.1-14 Northfield Mountain Tailrace Low Flow Scenario (August 21-31, 2014)....4-31
Figure 4.2.1-15 Paired Northfield Mountain Tailrace Grab Samples....4-32
Figure 4.2.2-1 SSC Isopleth from Rt. 10 Bridge - April 18, 2013 (LISST-100X)....4-36
Figure 4.2.2-2 Turners Falls Impoundment Hydrograph - Rt. 10 Bridge Grab Sample Data Collection 4-37
Figure 4.2.2-3 Rt. 10 Bridge Cross-section Grab Sample Data (April 14, 2015)....4-38
Figure 4.2.2-4 Rt. 10 Bridge Cross-section Grab Sample Data (April 17, 2015)....4-39
Figure 4.2.2-5 Rt. 10 Bridge Cross-section Grab Sample Data (April 20, 2015)....4-40
Figure 4.2.2-6 Rt. 10 Bridge Cross-section Grab Sample Data (April 28, 2015)....4-41

## LIST OF APPENDICES

APPENDIX A – UPPER RESERVOIR BATHYMETRY SURVEY MAPS (2011-2013)
APPENDIX B – SUMMARY OF 2015 CORRESPONDENCE & MANUFACTURER CERTIFICATION LETTER
APPENDIX C - CONTINUOUS SSC, FLOW, AND PROJECT OPERATIONS TIMESERIES PLOTS – MG/L (2013-2015)
APPENDIX D – GRAB SAMPLE SSC, FLOW, AND PROJECT OPERATIONS TIMESERIES PLOTS MG/L (2015)
APPENDIX E – LISST-100X ROUTE 10 BRIDGE & NORTHFIELD MOUNTAIN TAILRACE CROSS-SECTION PLOTS (2013)
APPENDIX F – SUSPENDED SEDIMENT MONITORING DATA (2013-2015)

# LIST OF ABBREVIATIONS

| | |
|---|---|
| 2-D | Two Dimensional |
| 3-D | Three Dimensional |
| ADCP | Acoustic Doppler Current Profiler |
| CFD | Computational Fluid Dynamics |
| cfs | cubic feet per second |
| CHA | CHA Consulting, Inc. |
| CY | Cubic yard |
| EOW | Edge-of-water |
| EWI | Equal Width Increment |
| FERC | Federal Energy Regulatory Commission |
| FirstLight | FirstLight Hydro Generating Company |
| ft. | feet |
| $ft^2$ | Square foot |
| Gomez and Sullivan | Gomez and Sullivan Engineers, DPC |
| GIS | Geographic Information System |
| HYDROs | LISST Hydro North and HYDRO South |
| ILP | Integrated Licensing Process |
| km | kilometer |
| LISST | Laser In-situ Transmissometry |
| MADEP | Massachusetts Department of Environmental Protection |
| Mg/L | milligrams per liter |
| $mi^2$ | Square mile |
| msl | Mean Sea Level |
| NAD83 | North American Datum of 1983 |
| NAVD88 | North American Vertical Datum of 1988 |
| NGVD29 | National Geodetic Vertical Datum of 1929 |
| NOI | Notice of Intent |
| Northfield Mountain Project | Northfield Mountain Pumped Storage Project |
| Ocean & Coastal | Ocean and Coastal Consultants, Inc. |
| PAD | Pre-Application Document |
| PSP | Proposed Study Plan |
| PSD | Particle Size Distribution |
| QA | Quality Assurance |
| QAPP | Quality Assurance Project Plan |
| QC | Quality Control |
| ROV | Remotely Operated Vehicle |
| RSP | Revised Study Plan |
| Rt. | Route |
| RTK GPS | Real-Time Kinematic Global Positioning System |
| SeaVision | SeaVision Underwater Solutions |
| SSC | Suspended Sediment Concentration |
| SD1 | Scoping Document 1 |
| SD2 | Scoping Document 2 |
| SPDL | Study Plan Determination Letter |
| StreamSide | LISST StreamSide |
| Study No. 3.1.3 | Northfield Mountain Pumped Storage Project Sediment Management Plan |
| TC | Total Concentration |
| the Commission | Federal Energy Regulatory Commission |

| | |
|---|---|
| the Plan | Northfield Mountain Pumped Storage Project Sediment Management Plan |
| the Project | Northfield Mountain Pumped Storage Project |
| TIN | Triangular Irregular Network |
| TSS | Total Suspended Solids |
| Turners Falls Project | Turners Falls Hydroelectric Project |
| µl/L | microliters per liter |
| USEPA | U.S. Environmental Protection Agency |
| V | Volts |
| Vernon | Vernon Hydroelectric Project |
| VY | Vermont Yankee Nuclear Power Plant |

# 1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the Northfield Mountain and Turners Falls Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

Prior to FirstLight initiating the FERC relicensing process for the Northfield Mountain and Turners Falls Projects, the U.S. Environmental Protection Agency (USEPA) issued an Administrative Order dated August 4, 2010, which requested a report identifying measures to prevent discharges of sediments associated with draining the Northfield Mountain Upper Reservoir. Subsequently, by letter dated January 20, 2011, FERC staff requested a plan to avoid or minimize the entrainment of sediment into the Northfield Mountain Project (the Project) works during reservoir maintenance drawdowns. In response to these requests, FirstLight filed the *Northfield Mountain Pumped Storage Sediment Management Plan* (the Plan) on July 15, 2011.

The Plan was developed in consultation with the 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 the Connecticut River from 2011 through 2014. These proposed methods included conducting annual bathymetric surveys in the Upper Reservoir to determine annual changes in sediment volume and collecting turbidity and total suspended solids (TSS) data routinely at the Route (Rt.) 10 Bridge (spanning the Connecticut River) and at the Northfield Mountain Project.

In its letter of February 16, 2012, the USEPA provided several comments related to the scope of the sampling and requested that FirstLight develop a Quality Assurance Project Plan (QAPP). In response, FirstLight agreed to develop a QAPP in cooperation with the USEPA; the initial draft of which was submitted on June 28, 2012. The initial draft of the QAPP included several modifications to the original Plan, most notably the addition of continuous suspended sediment monitoring equipment to be installed upstream of the Rt. 10 Bridge and at the Northfield Mountain Project. The USEPA provided FirstLight with comments pertaining to the initial QAPP on July 31, 2012, which FirstLight addressed. FirstLight submitted revision 1 of the QAPP to the USEPA on October 19, 2012.

In 2013, as part of the study scoping process associated with the relicensing of the Northfield Mountain and Turners Falls Projects, the USEPA requested that FirstLight incorporate the *Sediment Management Plan* into its relicensing studies. As such, FirstLight included the *Sediment Management Plan* in the RSP as Study No. 3.1.3 *Northfield Mountain Project Sediment Management Plan* (Study No. 3.1.3).

In accordance with the *Sediment Management Plan* and Study No. 3.1.3 RSP, Upper Reservoir bathymetry surveys have been conducted annually (starting in 2011) and suspended sediment has been monitored continuously in the vicinity of the Rt. 10 Bridge and at the Northfield Mountain Project (2012 – mid-2015). In addition, grab samples have been collected throughout the study area during this time (2012-2015). Over the course of this time period, the continuous monitoring program was modified several times due to technical challenges encountered with the monitoring equipment. In 2013, following a status update meeting with USEPA and MADEP personnel, FirstLight announced that sediment monitoring activities would be extended for an additional year through the fall of 2015 due to these technical challenges.

Also in 2013, FirstLight expanded the scope of Study No. 3.1.3 to include various modeling components. Modeling efforts implemented as part of this study include the development of a Computational Hydrodynamic Sedimentation model of the Upper Reservoir, a Computational Fluid Dynamics (CFD) sedimentation model of the Project tailrace, and a physical model of the Project area. Furthermore, in 2015 FirstLight commissioned a pilot dredge of the Upper Reservoir. As of the date of this report, the pilot dredge has been completed while the modeling efforts are still ongoing.

At the conclusion of these efforts, the results of all components of this study (i.e. modeling, dredging, annual bathymetry surveys, and suspended sediment monitoring) will be used to help inform sediment management measures that will avoid or minimize the entrainment of sediment in the Project works and the Connecticut River. Given that a number of tasks are still ongoing at the time of this filing, this report will be limited to a discussion of available results from 2011 through November 2015 and will include a high level overview of the ongoing tasks. Due to the expansion of the study effort and the ongoing nature of several of the study tasks it is anticipated that the final report, including FirstLight's proposed sediment management measures, will be completed by September 1, 2016.

Available information which will be discussed in this report includes: 1) a general overview and status update of all study components (including those tasks that are currently ongoing); 2) analyses and results pertaining to the annual Upper Reservoir Bathymetry Surveys (2011-2015); and 3) analyses and results of the suspended sediment monitoring efforts (2013- 2015). Report sections relevant to this discussion include:

- Section 2: Field Studies and Data Collection;
- Section 3: Data Analyses;
- Section 4: Results and Discussion; and
- Various Appendices (A-F)

# 2 FIELD STUDIES AND DATA COLLECTION

Various field studies and data collection efforts associated with this study occurred from 2011 to 2015. These efforts included:

- Annual Upper Reservoir bathymetry surveys (2011-2015) – Section 2.1;
- Continuous suspended sediment monitoring upstream of the Rt. 10 Bridge and at the Northfield Mountain Project (2012-2015) – Section 2.2;
- Periodic cross-sectional suspended sediment monitoring at the Rt. 10 Bridge and Northfield Mountain tailrace boat barrier buoy line (2013) – Section 2.2;
- Grab sample collection upstream of the Rt. 10 Bridge, across the Rt. 10 Bridge, and at the Northfield Mountain tailrace (2012-2015) – Section 2.2;
- Development of an Upper Reservoir Computational Hydrodynamic Sedimentation model (2013-2014) – Section 2.3;
- Development of a Northfield Mountain tailrace CFD Sedimentation model (2014) – Section 2.3;
- Development of a physical model of the Northfield Mountain tailrace and surrounding area (2015) – Section 2.3; and
- A pilot dredge of the Upper Reservoir (2015) – Section 2.4

This section provides an overview of each study component listed above. In depth discussion pertaining to data analysis and results of the annual bathymetry surveys and suspended sediment monitoring can be found in Sections 3 and 4, respectively.

## 2.1 Upper Reservoir Bathymetry Surveys

Northfield Mountain Upper Reservoir bathymetry surveys have been conducted annually since 2011 to approximate the sediment volume accumulated in the Upper Reservoir, and more specifically the amount of sediment accumulated in the intake channel. Figure 2.1-1 shows the Northfield Mountain Upper Reservoir, including the intake channel, where the surveys occurred. Table 2.1-1 provides a summary of the relevant information from each survey including which firm collected the survey data, the vertical datum of the survey, whether a single or multi-beam echosounder was used, and relevant notes (if any).

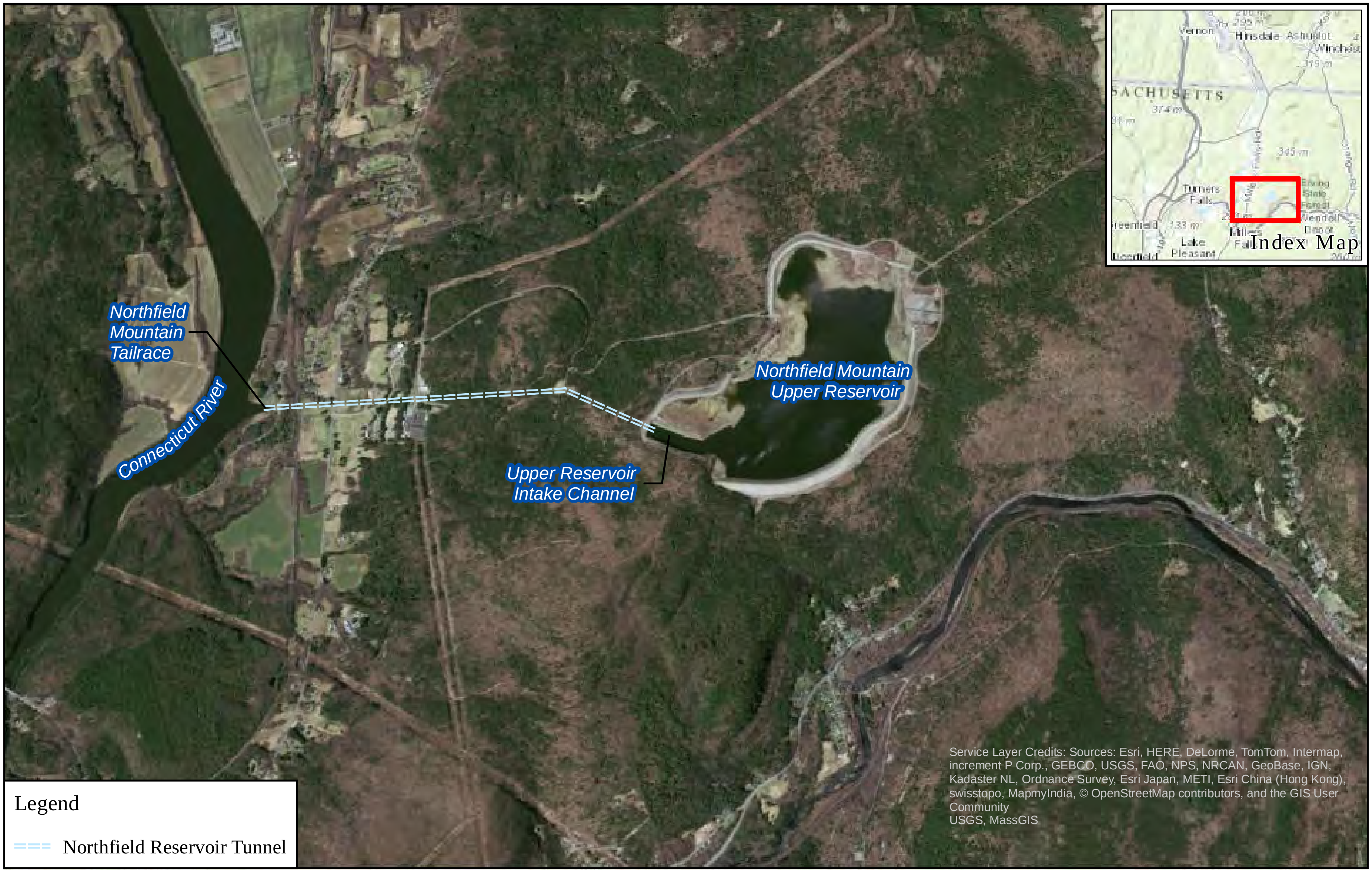
For each survey a vessel was equipped with either a single or multi-beam echosounder used to record the reservoir water depth. The echosounder was linked to a Real-Time Kinematic Global Positioning System (RTK-GPS) which was used to record the vertical and horizontal positioning of the echosounder during all survey operations. All horizontal positions were referenced to the North American Datum of 1983 (NAD83) Massachusetts Mainland State Plane, U.S. Survey feet coordinate system while all vertical positions referenced the Northfield Mountain Pumped Storage Facility vertical datum or the National Geodetic Vertical Datum of 1929 (NGVD29).

At the conclusion of each survey, the bathymetric data were used to create a Triangular Irregular Network (TIN) which depicted Upper Reservoir bed elevations. The TINs were then used in "cut-fill" and "raster-minus" operations to determine the sediment volume change between each year as well as the relative changes in bed elevation. A contour plan and sounding plan were created for each annual survey (Appendix A).

Additional information pertaining to the data analysis and results for each bathymetry survey can be found in Section 3.1 and 4.1, respectively.

**Table 2.1-1. Summary of Upper Reservoir Bathymetric Data Collection**

| Date of Bathymetric Survey | Bathymetry Collected by | Vertical Datum | Single or Multi-beam Echosounder | Comments |
|---|---|---|---|---|
| November 5, 2011 | Ocean and Coastal Consultants Inc., with SeaVision Underwater Solutions | Northfield Mountain Pumped Storage Facility vertical datum | Single beam | |
| September 29-30, 2012 | Ocean and Coastal Consultants Inc., with SeaVision Underwater Solutions | Northfield Mountain Pumped Storage Facility vertical datum | Multi-beam | Multi-beam surveys collect larger swaths of sounding data which allows for greater resolution |
| October 5-6, 2013 | CHA Consulting, Inc. | Northfield Mountain Pumped Storage Facility vertical datum | Single beam | |
| October 11-12, 2014 | SeaVision Underwater Solutions | Northfield Mountain Pumped Storage Facility vertical datum | Multi-beam | In addition to the multi-beam survey, gravity cores were utilized at six locations within the intake channel to better ascertain the sediment thickness in this area. |
| October 3-4, 2015 | SeaVision Underwater Solutions | Northfield Mountain Pumped Storage Facility vertical datum | Multi-beam | In addition to the multi-beam survey, vibracores were collected at six locations within the intake channel to better ascertain the sediment thickness in this area. Note that the bathymetry survey was conducted after initiation of the pilot dredge study. |




FirstLight GDF SUEZ

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***Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)***

Study No. 3.1.3
Northfield Mountain Pumped Storage Project
Sediment Management Plan

0 0.25 0.5 1 Miles

Figure 2.1-1 Northfield Mountain Upper Reservoir and Tailrace

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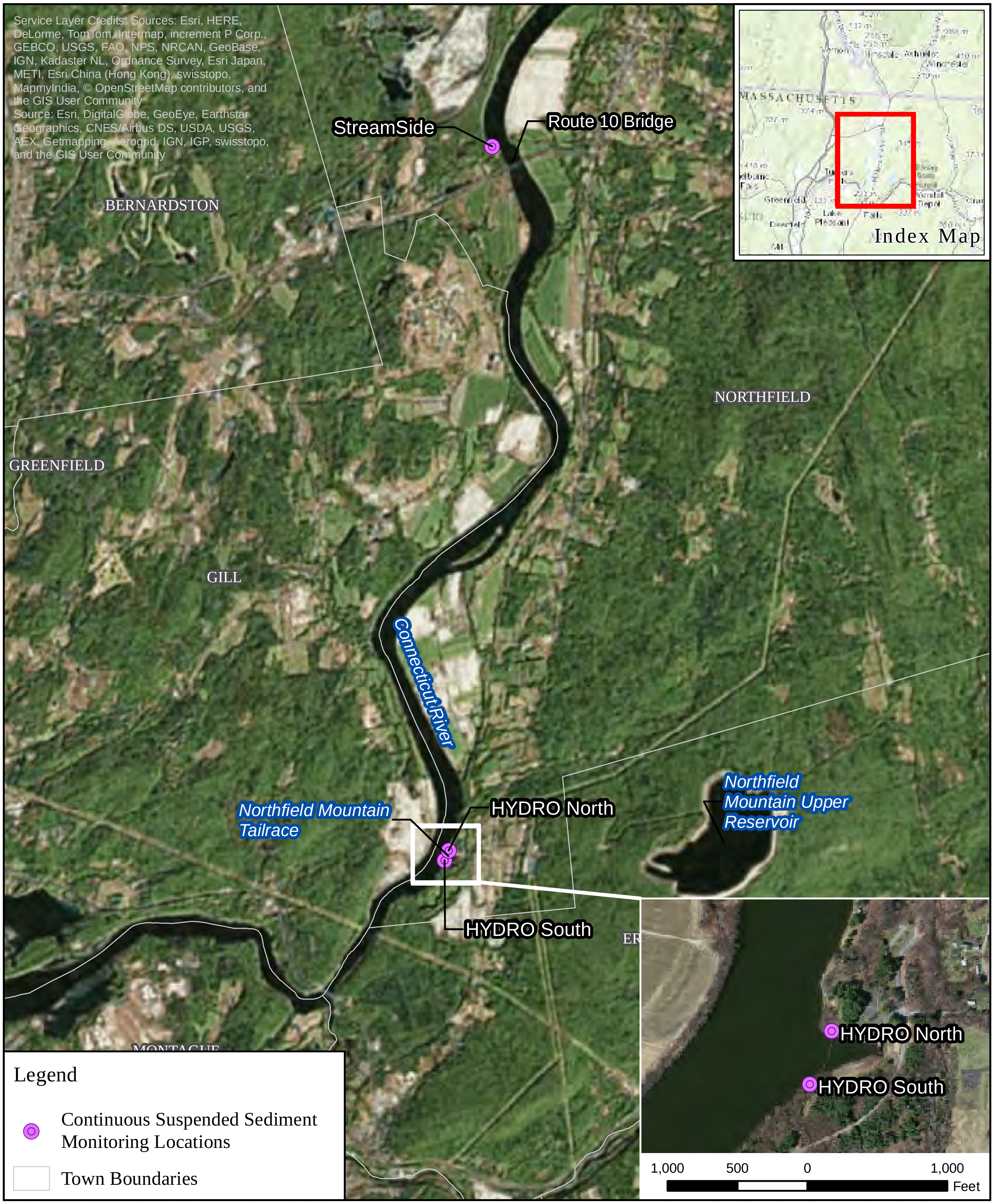
## 2.2 Suspended Sediment Monitoring

From 2012 to 2015, FirstLight operated continuous suspended sediment monitors at three locations in the Project area (Figure 2.2-1), except during the winter period (freezing temperatures). Continuous suspended sediment monitoring equipment used as part of this study included two Laser In-situ Scattering Transmissometry (LISST) HYDRO units (HYDROs) and one LISST-StreamSide (StreamSide) unit. The LISST HYDROs were installed at the Northfield Mountain Project (initially in the powerhouse and then relocated to the tailrace in 2013) while the StreamSide was installed just upstream of the Rt. 10 Bridge in Northfield, MA. Additional LISST equipment that was utilized during this study included the LISST-100X which was used to collect cross-sectional data at the Rt. 10 Bridge and Northfield Mountain tailrace boat barrier buoy line in 2013.

In addition to the LISST instruments, grab samples were taken from the drain hoses of the HYDROs and StreamSide (2012-2015), from the edge-of-water at each LISST instrument (2015), and across the Rt. 10 Bridge (2015).

This section provides a detailed discussion of each of the suspended sediment monitoring methods employed as part of this study.




FirstLight GDF SUEZ

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***Northfield Mountain Pumped Storage Project (No. 2485)***
***and Turners Falls Hydroelectric Project (No. 1889)***

Study No. 3.1.3
Northfield Mountain Pumped Storage Project
Sediment Management Plan

0 0.5 1 2
Miles

Figure 2.2-1
Locations of Continuous Suspended Sediment Monitors

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#### *2.2.1 LISST Equipment*

*LISST-StreamSide*

Starting in 2012, a continuous suspended sediment monitor (LISST-StreamSide) was installed in a secure closet on the right bank of the Connecticut River (Turners Falls Impoundment) upstream of the Rt. 10 Bridge in Northfield, MA. Figure 2.2.1-1 shows the location of the instrument relative to the Rt. 10 Bridge. The StreamSide was installed annually (2012-2015) by April 1 (or as soon as flow conditions allowed) and remained in place until late November when it was removed for the season. Figure 2.2.1-2 depicts the cabinet setup which housed the StreamSide.

The StreamSide was connected to a pump installed at a fixed location in the river approximately 10-15 feet offshore and suspended about 2 feet from the river bottom. Water was pumped from the river through the instrument where particle size distribution (PSD) (microns) and total concentration (µl/L) values were measured using laser diffraction technology. After flowing through the instrument the water was returned to the river; a water sample was not retained. Prior to each measurement, distilled water was run through the instrument to automatically "zero" it prior to the next recorded measurement. All data were stored on the instrument's hard drive until they were downloaded to a computer by field technicians.

Measurements were typically recorded at the top of every hour with the average sampling duration lasting 60 seconds. Each measurement consisted of a 60 second clean water flush, 300 second intake flush (river water from the pump), and a 20 second post measurement clean water flush.[2] Clean water background readings were taken and stored every three measurements by subtracting the measurement of light scattering in clean water from that resulting from the turbid sample water. The instrument then compared the field recorded clean water background with the manufacturer preset clean water reading. For the device to be working properly, these readings should be similar.

The StreamSide was serviced on a weekly schedule during which time the data was downloaded, the clean water tank was refilled (this occurred twice a week), the optical cells were cleaned, the battery voltage was checked, and, if necessary, the connectors, casing, and hoses were cleaned.

Over the course of the study, StreamSide data collection efforts were affected by equipment malfunctions and electrical issues which resulted in sporadic data gaps. Instrument issues ranged from electrical malfunctions, pump malfunctions, and instrument failures which resulted in the instrument being taken offline and shipped to the manufacturer for repairs. Limited usable data were collected in 2012 as a result of these instrument issues. As such, data analysis and results presented in this report focus on the 2013-2015 period. Following the challenging 2012 season, FirstLight and the equipment manufacturer worked closely to troubleshoot the equipment malfunctions. Modifications were made to the electrical components, instrument settings, and closet which housed the instrument. At the request of FirstLight, the equipment manufacturer visited the site during the 2013 field season to review and certify the instrument setup (Appendix B).

In spite of the equipment manufacturers certification that the instrument was properly installed, equipment malfunctions and electrical issues continued to plague data collection efforts during the 2013, 2014, and 2015 field seasons resulting in sporadic data gaps. FirstLight continued to work closely with the equipment manufacturer, however, instrument issues continued to persist. Following a major equipment malfunction in early 2015 which resulted in the instrument being taken offline, shipped to the manufacturer, and rebuilt, and following consultation with USEPA FirstLight curtailed continuous suspended sediment monitoring at the StreamSide.

[2] These settings represent the final data settings used during the 2014 and 2015 field seasons. The final instrument settings were refined during the 2012 and 2013 field seasons and determined in collaboration with the equipment manufacturer.

Discussion pertaining to the StreamSide data analysis and results can be found in Section 3.2 and 4.2, respectively.

*LISST-HYDROs*

To monitor SSC moving into and out of the Northfield Mountain Upper Reservoir, two continuous suspended sediment monitors (LISST-HYDROs) were installed in the Northfield Mountain powerhouse in 2012. The HYDROs were installed directly inline to two separate 30-inch service water lines using available service water taps. The 30-inch service water lines tie into the draft tube area which contains the same water that is flowing through the pump/turbines. The LISST Hydro North instrument was installed to monitor Units 1 and 2, while the LISST HYDRO South was installed to monitor Units 3 and 4. The goal of the powerhouse HYDRO configuration was to measure SSC and PSD values observed during Project pumping and generating cycles via laser diffraction technology.

Data collection inside the powerhouse 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 HYDROs to adequately record measurements and that maintaining the configuration in the powerhouse was not going to yield sufficient usable data. Following extensive investigation by FirstLight and the equipment manufacturer it was determined that relocating the HYDROs to the banks of the Project tailrace would allow for representative measurements to be recorded during pumping and generating cycles without the difficulties encountered in the powerhouse.

Starting in 2013, the HYDRO instruments were relocated to the left (HYDRO South) and right (HYDRO North) banks of the Project tailrace where they have remained in place through 2015. These locations allow for representative measurements to be recorded 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 while during generation, the water that is being discharged from the Upper Reservoir back to the river may similarly contain sediment. Due to the fact that suspended sediment may vary laterally across the tailrace and/or vertically within the water column depending on Project operations two HYDROs were utilized at the tailrace. By installing HYDROs on either bank of the tailrace, combined with cross-sectional data collected by the LISST-100X, a representative dataset was developed. Figure 2.2.1-3 shows a typical cabinet setup used to house the LISST HYDRO instruments while Figure 2.2.1-4 depicts their locations at the tailrace.

HYDRO instruments, and their associated equipment, were installed annually (2013-2015) by April 1 (or as soon as flow conditions allowed) and remained in place until mid to late November when they were removed for the season. Each HYDRO instrument was connected to a pump installed at a representative location within the tailrace. The HYDRO North and South pumps was installed approximately 50 ft. from each shore (far enough offshore so as to be in the intake channel) and approximately 2 ft. off the bed.

Total concentration (µl/L) and PSD (microns) were measured at each location using laser diffraction technology at 20-minute intervals. After flowing through the instrument, the river water was released through a drain hose. A water sample was not retained except for periodic grab samples that were collected. Clean-water background readings were taken from filtered potable water and stored prior to each sample to automatically "zero" the instrument by subtracting the measurement of light scattering in clean water from that resulting from the turbid sample water. The instruments operated on a 30-second clean water flush, a 300-second pre flush, a 30-second clean water flush and automatic optical lens cleaning.[3]

The instruments were visually inspected and cleaned on a weekly basis to ensure proper working order and clean optic cells. Data downloads from the instruments were not necessary because each HYDRO

[3] These settings represent the final data settings used during the 2014 and 2015 field seasons. The final instrument settings were refined during the 2013 field seasons and determined in collaboration with the equipment manufacturer.

instrument transmitted the data directly to FirstLight's historian computer system. Data was downloaded from the historian computer system on a weekly basis.

Similar to the StreamSide, HYDRO data collection efforts from 2012-2015 were affected by repeated equipment malfunctions and electrical issues which resulted in data gaps. No useable data were collected in 2012 when the instruments were located inside the powerhouse. As such, data analysis and results presented in this report focus on the 2013-2015 period. After relocating the HYDRO instruments to the tailrace in 2013 FirstLight requested the manufacturer visit the site during the field season to review and certify the instrument setup (Appendix B).

In spite of the equipment manufacturers' certification that the instruments were installed properly, equipment malfunctions and electrical issues continued to affect data collection efforts during the 2013, 2014, and 2015 field seasons resulting in sporadic data gaps. FirstLight continued to work closely with the equipment manufacturer, however, instrument issues continued to persist. Following a major equipment malfunction in early 2015 which resulted in the instrument being taken offline, shipped to the manufacturer, and rebuilt, and following consultation with USEPA FirstLight curtailed continuous suspended sediment monitoring at the HYDRO locations.

Discussion pertaining to the HYDRO data analysis and results can be found in Section 3.2 and 4.2, respectively.

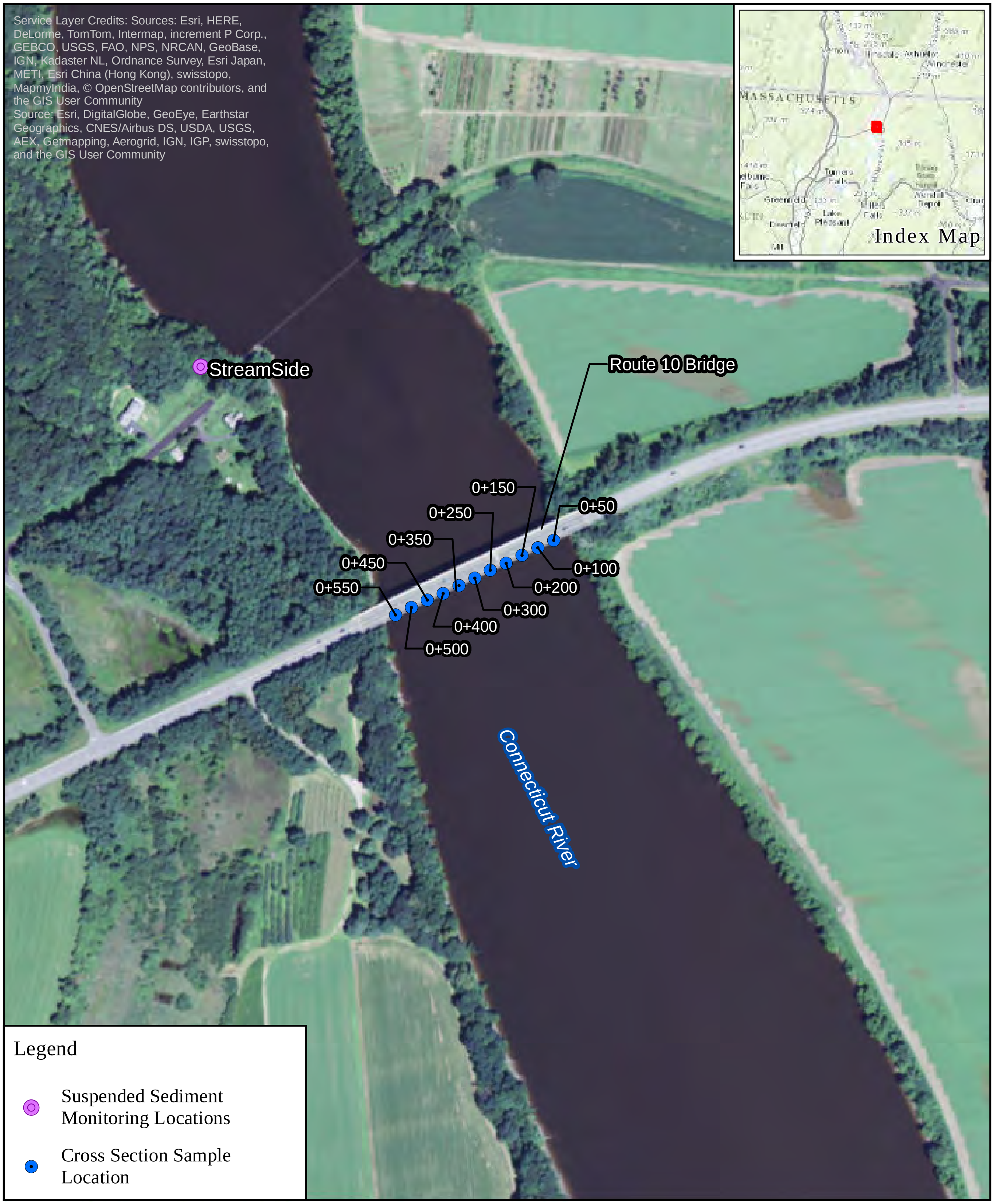
*LISST-100X*

Cross-sectional data at the Rt. 10 Bridge and the Northfield Mountain tailrace boat barrier buoy line were collected via a LISST-100X in 2013 over a range of flow and operating conditions. The cross-sectional data were collected for a variety of reasons, including: 1) to determine total concentration and PSD variation across the cross-section over a range of flow and operating conditions, 2) to determine total concentration and PSD variation throughout the water column over a range of flow and operating conditions, 3) to determine if the StreamSide and HYDRO pumps were installed at locations representative of the cross-section, and 4) as a check on the data collected at the StreamSide and HYDROs.

Data were collected using a crane and reel setup from the Rt. 10 Bridge and from a barge at the Northfield Mountain tailrace. Figure 2.2.1-5 shows the configuration of the barge at the tailrace while Figure 2.2.1-6 shows the configuration of the LISST-100X. As observed in Figure 2.2.1-6, a sounding weight with fins was attached to the LISST-100X to orient the instrument against the current and hold it in a constant position. Sampling stations were identified at evenly spaced intervals using the Equal-Width Increment Method (EWI) along transects at each location prior to sampling. Eleven (11) stations, spaced at 50-foot intervals, and 9 stations, at ~30-foot intervals, were identified at the Rt. 10 Bridge and the Northfield Mountain tailrace boat barrier buoy line, respectively (Figures 2.2.1-1 and 2.2.1-4). Total concentration (µl/L) and PSD (microns) measurements were collected via laser diffraction technology at the surface and 5-foot depth intervals at each increment until approximately one foot from the bottom was reached. At each station, the instrument was held in place for a minimum of 60 seconds with a measurement being recorded every second. Clean-water backgrounds were collected using distilled water before and after sampling at each transect to "zero" the instrument. Following completion of a transect, the data were downloaded to a computer. The instrument did not require maintenance except for regular cleaning of the optical lenses.

Over the course of the study it was observed that each LISST instrument (StreamSide, HYDRO North, HYDRO South, and LISST-100X) was unique, given that each contained its own unique lenses for measuring laser scatter. As a result of this, preliminary analyses revealed different total concentration measurements between the LISST-100X and the other LISST instruments. After discussion with the manufacturer, it was determined that the values provided by the LISST-100X were not directly comparable to the other LISST instruments due to limitations in instrument capability. Essentially, each instrument could measure particles from the same water and provide a different value. The only way to standardize the data would be to convert the LISST measurements to mg/L using grab sample data. This conversion was not performed for the LISST-100X due to the fact that too few laboratory samples were collected that corresponded to the cross-sectional sampling effort. Although the LISST instruments were not directly comparable, general patterns observed at each instrument were comparable. Therefore, the LISST-100X data were only used to describe general cross-sectional patterns rather than quantitative comparison against the other LISST instruments.

Discussion of the LISST-100X data analysis and results can be found in Section 3.2 and 4.2, respectively.

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***Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)***

Study No. 3.1.3
Northfield Mountain Pumped Storage Project
Sediment Management Plan

N

0 200 400 800 Feet

Figure 2.2.1-1
Location of StreamSide and Route 10 Bridge

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**Figure 2.2.1-2 LISST StreamSide Equipment Cabinet Configuration**

**Figure 2.2.1-3 LISST-HYDRO Cabinet Configuration (typical)**


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0 100 200 400 Feet

Figure 2.2.1-4
LISST HYDRO and Tailrace Cross-section Locations

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**Figure 2.2.1-5 LISST-100X Collection from barge at the Northfield Mountain Tailrace**

**Figure 2.2.1-6 LISST-100X Configuration**

### *2.2.2 Grab Sample Collection*

In the original *Sediment Management Plan* filed July 15, 2011, FirstLight proposed a four-year sediment monitoring study in which turbidity and TSS data were to be collected quarterly and during targeted periods of high flow in various locations throughout the Impoundment and the Northfield Mountain Upper Reservoir. TSS and turbidity grab samples were collected on two occasions during 2011 in accordance with the original plan.

Based on the data collected in 2011, and in order to accomplish the study goals, FirstLight proposed changing the data collection methods and protocols to rely on the LISST continuous suspended sediment monitors in place of periodic grab samples starting in 2012. These proposed modifications were discussed in the *Updated Sediment Management Plan* and *QAPP Revision 1*. At the request of the USEPA, periodic grab samples continued to be collected during the 2012-2015 monitoring periods to supplement the continuous suspended sediment data. From 2012-2014 grab samples were collected periodically over a range of flow and operating conditions from the StreamSide and HYDRO drain hoses. The grab sample program was expanded in 2015 to include LISST drain hose samples, edge-of-water samples collected in the vicinity of the LISST pumps, and cross-section samples collected at the Rt. 10 Bridge and Northfield Mountain tailrace boat barrier (if safely possible). Data collected as part of the expanded 2015 grab sampling program includes:

- Daily grab samples were collected from the LISST drain hoses (StreamSide and HYDROs) from April 7, 2015 until the continuous suspended sediment monitoring portion of the program was discontinued in June. Drain hose grab samples were collected at the same time as a LISST measurement, when possible. Samples were not collected when the instrument was offline due to various equipment malfunctions.

- Daily grab samples were collected from the edge-of-water in the vicinity of the LISST pumps (StreamSide and HYDROs) starting April 7, 2015 until October 30, 2015 at which time the program was discontinued.

- Cross-section grab samples were collected via a Kemmerer at predetermined stations (equal-width, 50 foot interval) across the Rt. 10 Bridge on four occasions over a range of flows during the spring freshet (20,000-60,000 cfs). Cross-section stations used in 2015 were identical to the stations used in 2013 for the LISST-100X data collection effort. Samples were collected following the EWI method at three depth increments at each station (~1 ft. below the surface, middle of the water column, and ~2 ft. from the bed). Each individual sample was submitted to an independent analytical laboratory for analysis. Figure 2.2.2-1 shows the configuration of the Kemmerer used to collect the samples. One cross-section composite was also collected and submitted to the laboratory for analysis.

- FirstLight intended to collect grab samples across the Northfield Mountain tailrace during the spring freshet; however, flow and operating conditions deemed this effort to be unsafe. As such, 2015 cross-section data were not collected at this location.

Figure 2.2.2-2 shows the grab sampling locations. All grab samples collected during this study were submitted to an independent analytical lab for analysis of TSS (SM 2540D) and Suspended Sediment Concentration (SSC) (ASTM D3977).

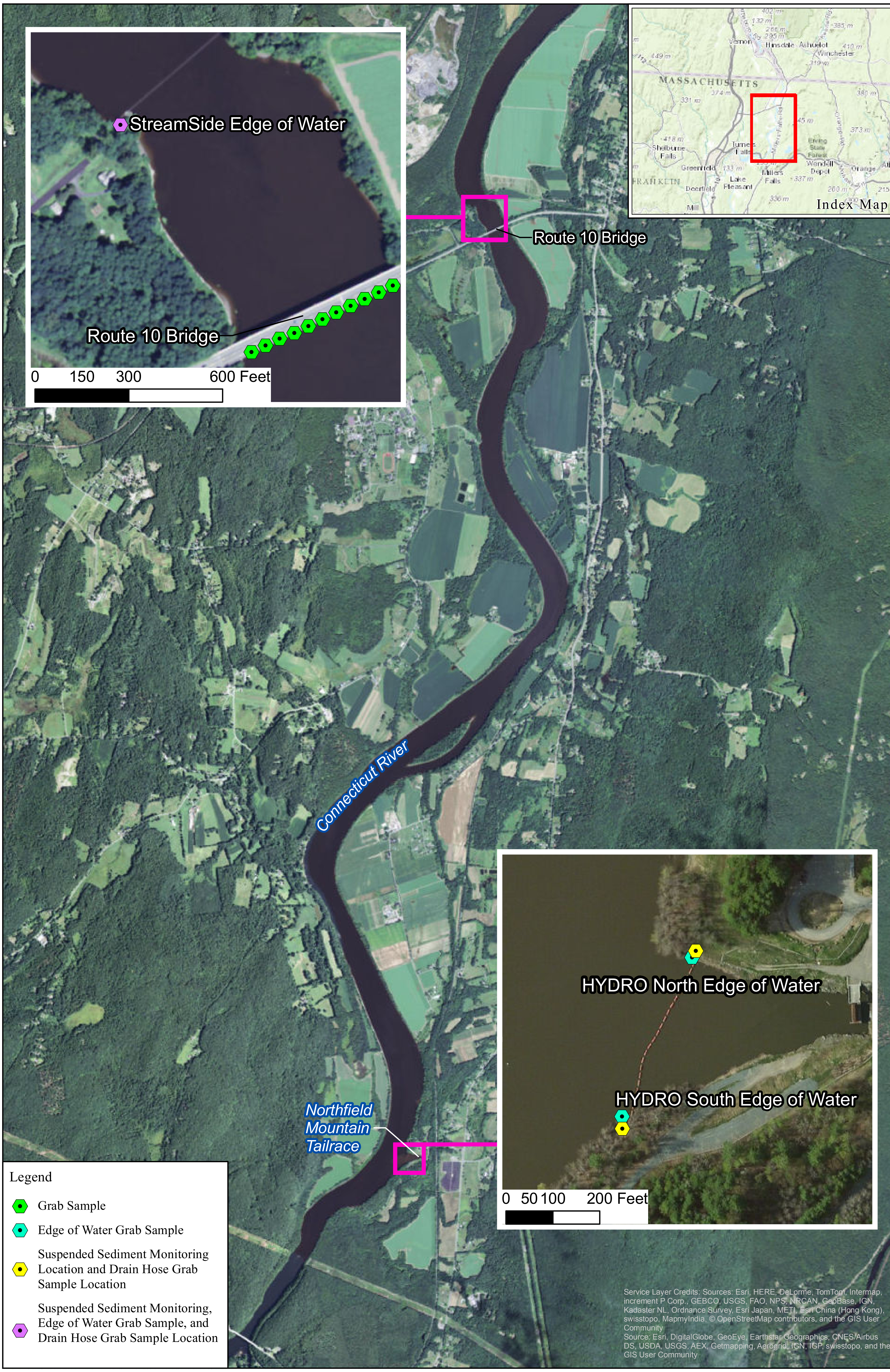
Although not directly comparable with the LISST measurements[4], the grab sample data serve two important purposes, 1) to develop a quantitative dataset over a range of flow and operating conditions to complement

[4] Total concentration (TC) measurements collected by the LISST instruments are in units of µl/L (volume) while the SSC grab sample results are in units of mg/L (mass). These datasets cannot be compared unless the LISST data is converted to mg/L.

or supplement the LISST data, and 2) to develop a correlation between the LISST data and grab sample data to either confirm or adjust the LISST data.

Discussion pertaining to the grab sample data analysis and results can be found in Section 3.2 and 4.2, respectively.

**Figure 2.2.2-1 Configuration of Rt.10 Bridge Grab Sample Collection**

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0 0.25 0.5 1 Miles

Figure 2.2.2-2
Grab Sampling Locations

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## 2.3 Modeling

In 2013, Study No. 3.1.3 was expanded to include several modeling efforts to better understand suspended sediment dynamics in the study area and to determine how operational or structural modifications could affect the entrainment of sediment in Project works and the Connecticut River. Specific modeling components developed as part of this study included a Computational Hydrodynamic Sedimentation model of the Upper Reservoir (Section 2.3.1), a CFD sedimentation model of the tailrace and surrounding areas (Section 2.3.2), and a physical model of the tailrace and surrounding areas (Section 2.3.3).

As of the date of this report the results of the Upper Reservoir and tailrace models are still being reviewed while efforts associated with the physical model are still ongoing. Once all three modeling components have been completed, the results will be reviewed collectively and combined with the other data collection efforts associated with this study to help evaluate potential sediment management measures. Given that the results and conclusions of all three models are linked it is inappropriate at this time to discuss partial or incomplete findings until all modeling has been completed. As such, discussion pertaining to the modeling efforts in this report is limited to the high level overview found in this section. A complete discussion of the modeling analyses, results, and conclusions will be presented in the final study report.

### *2.3.1 Computational Hydrodynamic Sedimentation Modeling of the Upper Reservoir*

In late 2013, FirstLight contracted with Alden Research Laboratory, Inc. (Alden) to study suspended sediment dynamics in the Upper Reservoir. As part of this effort, Alden developed a 2-dimensional (2-D) Computational Hydrodynamic Sedimentation model to understand the process of sedimentation in the Upper Reservoir and to evaluate long-term sediment management alternatives in that area. The model Alden used was the commercially available MIKE21C (DHI) 2-D numeric model. The main objective of the modeling was to determine if a modification in Upper Reservoir intake channel geometry or lowering the Upper Reservoir elevation below its current lower limit of elevation 938 feet (mean sea level (msl)) [5] could reduce sediment accumulation in the future.

The 2-D model was field validated using an Acoustic Doppler Current Profiler (ADCP) to document flow field patterns induced in the Upper Reservoir during both pumping and generating operating conditions. The field collected data were then compared to the model output.

Model runs were executed using: 1) the current FERC operational drawdown limit of the Upper Reservoir of 938 feet msl, 2) lowering the Upper Reservoir drawdown to 928 ft. msl, 3) lowering the Upper Reservoir drawdown to 920 feet msl, and 4) physically reducing the intake channel width, with the goal of increasing intake channel velocities during generation. The May 2014 Alden report describing the modeling was submitted on December 1, 2014 as part of the *Sediment Management Plan – 2014 Summary of Annual Monitoring.*

As of the date of this report, the results of this modeling effort are still under review in conjunction with other study efforts. A detailed discussion pertaining to the modeling analyses, results, and conclusions will be presented in the final study report.

### *2.3.2 Computational Fluid Dynamics Sediment Modeling of the Northfield Mountain Project Intake/Tailrace*

FirstLight also contracted with Alden to study the suspended sediment dynamics in the Northfield Mountain intake/tailrace area. The tailrace modeling effort focused on the entrained sand and fine material from the Connecticut River which is transported to the Upper Reservoir during operational pumping phases as well as potential solutions in the tailrace to reduce sediment transport to the Upper Reservoir.

[5] NGVD29 is commonly referred to as mean sea level. For the purpose of this report those two datum's should be considered identical.

The ultimate objective of this modeling effort is to determine if physical modifications to the Northfield Mountain tailrace intake area could reduce sediment entrained to the Upper Reservoir during pumping operations and hence reduce sediment accumulation in the Upper Reservoir. To accomplish this objective, Alden developed a 3-Dimensional (3-D) Computational Fluid Dynamics (CFD) model of the Northfield Mountain tailrace and surrounding area (500 feet upstream and downstream from the tailrace). The 3-D model was developed, validated, and used to simulate sediment mobilization under a range of Connecticut River discharges, Impoundment water levels, and operational pumping schemes (1, 2, 3, or 4 pumps moving water to the Upper Reservoir). A series of three CFD sediment simulations were used to compute sediment uptake under the existing configuration and to quantify the effectiveness of a convex sediment exclusion structure (Alternative 1) and a longer concave sediment exclusion structure (Alternative 2) both of which were positioned outside the exclusion zone. Figures 2.3.2-1 and 2.3.2-2 denote the location of the modeled sediment exclusion structures 1 and 2, respectively.

As of the date of this report, the results of this modeling effort are still under review in conjunction with other efforts. A detailed discussion pertaining to the modeling analyses, results, and conclusions will be presented in the final study report.

**Figure 2.3.2-1 Tailrace/intake CFD Model – Sediment Exclusion Alternative 1**

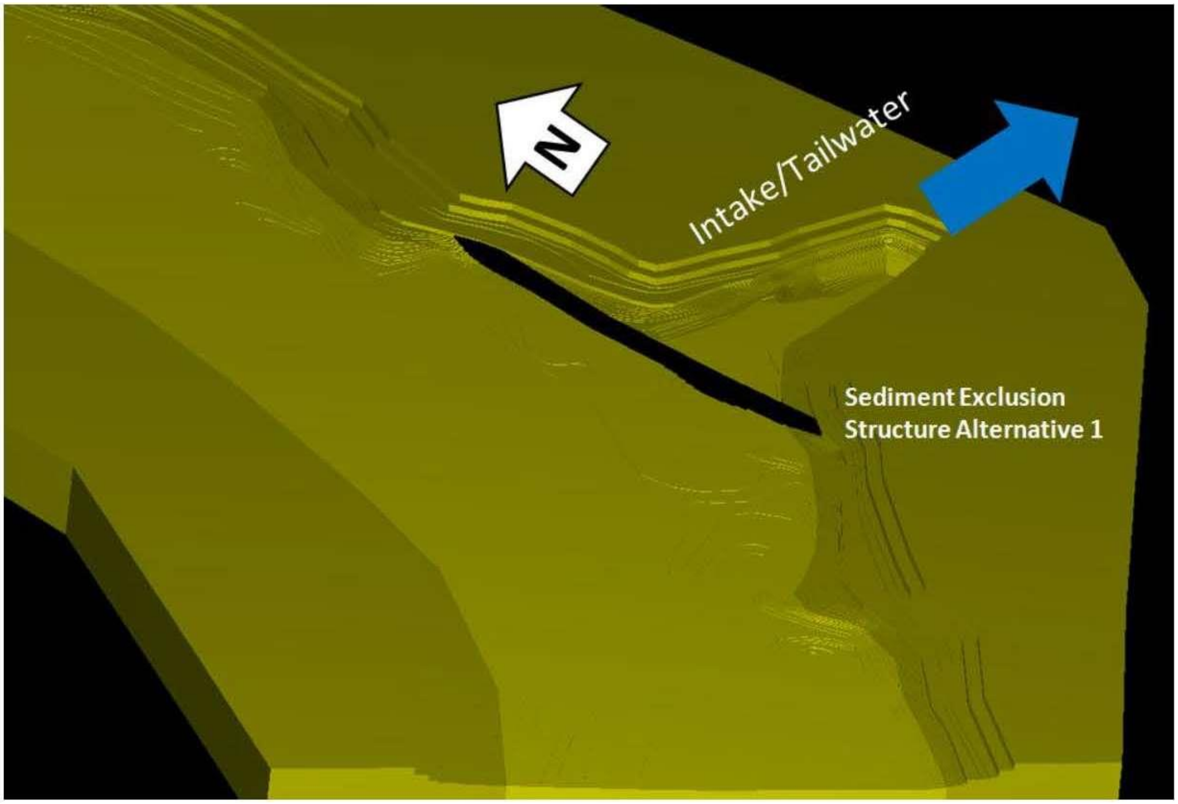
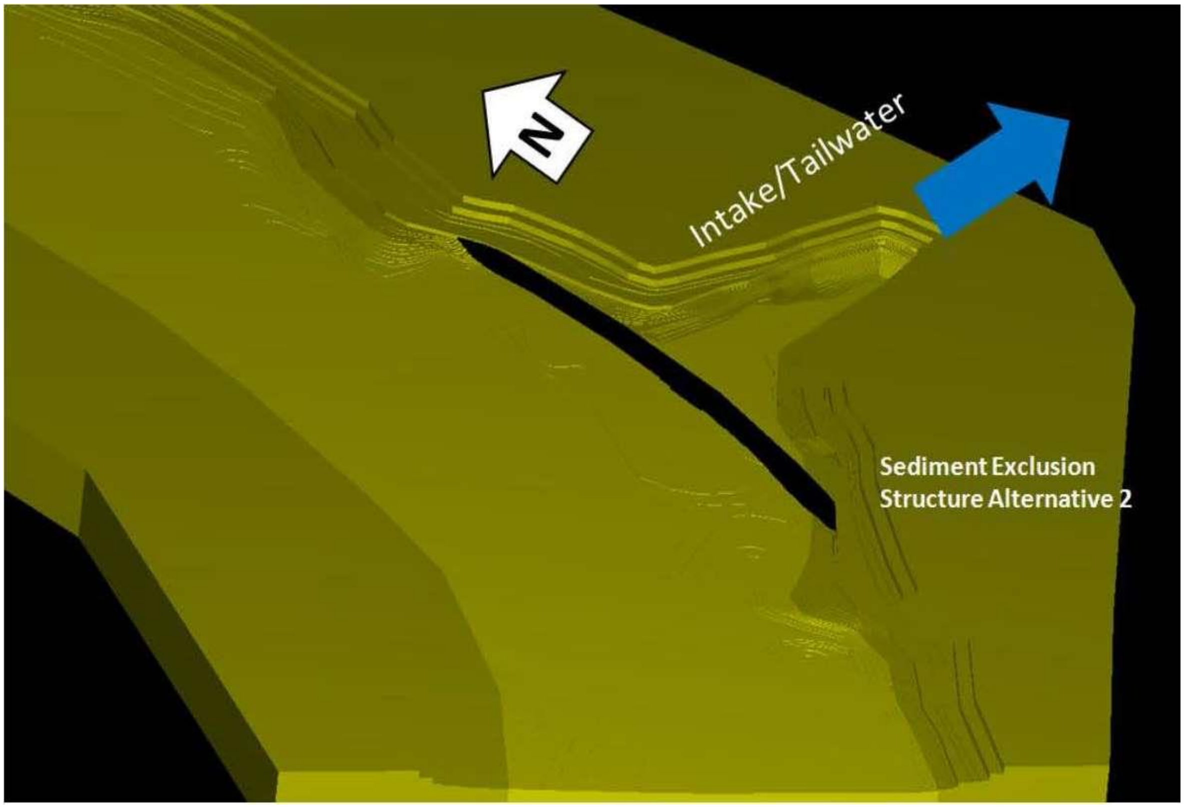


**Figure 2.3.2-2 Tailrace/intake CFD Model – Sediment Exclusion Alternative 2**



### *2.3.3 Physical Model of the Project Area*

In 2015, FirstLight expanded the modeling component of Study No. 3.1.3 to include the development of a physical model of the Northfield Mountain tailrace/intake and Connecticut River in the vicinity of the tailrace. The purpose of the physical model is to reproduce the river conditions (flows, currents, sediment load) in the study area and to investigate new civil works that could be constructed at the existing Project tailrace/intake structure.[6] The goal of the modeled intake structure upgrade would be to significantly reduce the intake of sediment during the pump cycle at the Project. FirstLight again contracted with Alden for this effort. As of the date of this report, this effort is still ongoing.

Tasks associated with the development of this model included: 1) the collection of relevant data and information (including topographical, hydraulic, operational, and sediment data); 2) the construction and calibration of the physical model based on existing conditions; 3) the modeling and testing of the new intake structure; and 4) reporting. If successful, the model will allow for:

1. The ability to reproduce steady state water surface profiles (calibration process with no operation);
2. The ability to reproduce sediment transport through the intake during pump operations; and
3. The investigation of the effect of changes in the intake structure on sediment transport.

The physical model represents the Northfield Mountain tailrace/intake area as well as the Connecticut River in the vicinity of the tailrace. Specifically, the physical boundary conditions of the model are:

- Upstream section approximately 3.2 km from the intake following the river centerline;
- Downstream section approximately 0.8 km from the intake following the river centerline;
- Approximate total river length of 4.0 km following the river centerline, which corresponds to an approximate North-South length of 3.7 km and East-West length of 1.2 km; and
- The Northfield Mountain tailrace and intake structure

Figure 2.3.3-1 depicts the extent of the physical model.

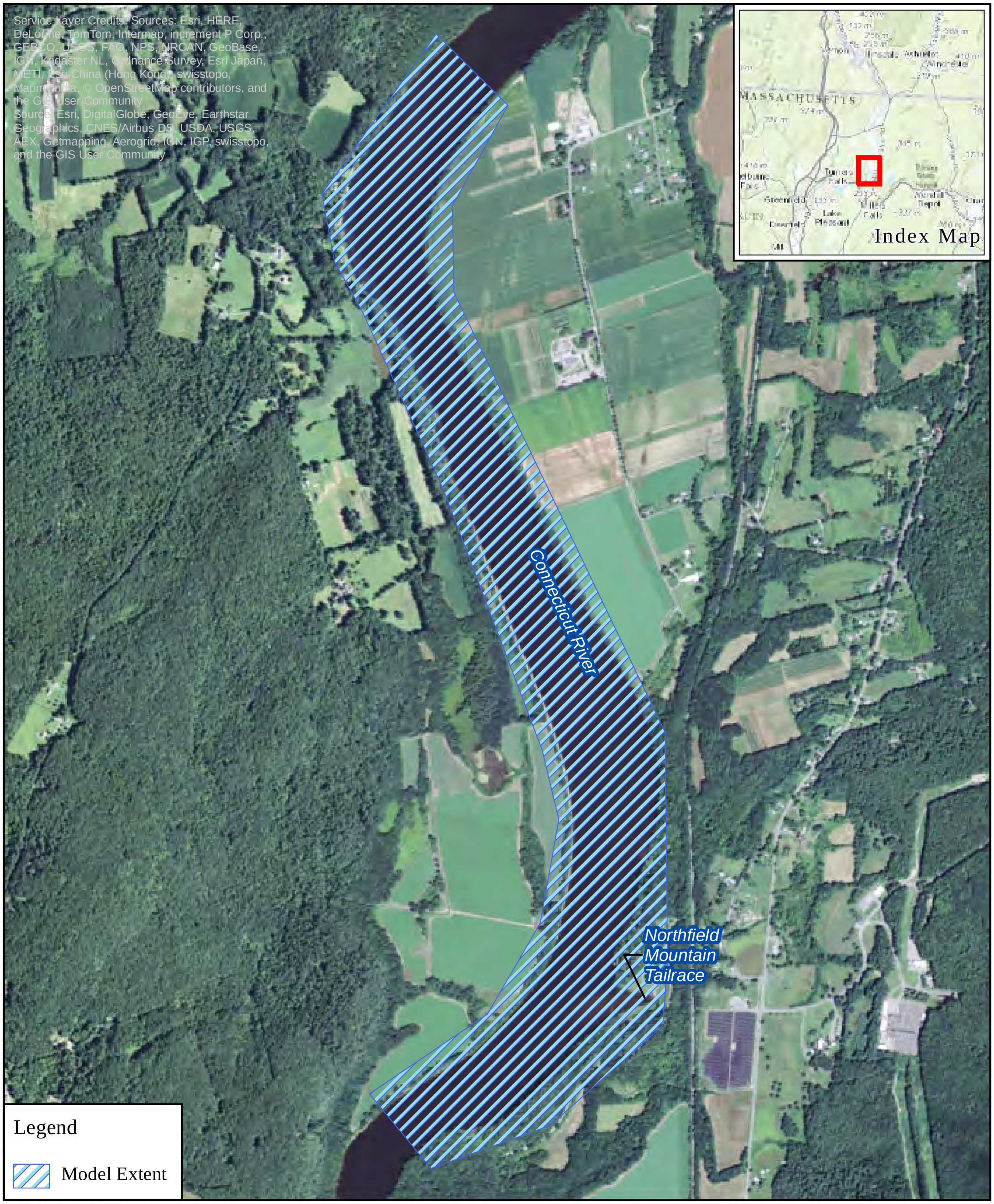
Prior to the development of the model FirstLight provided Alden with multiple datasets to support the modeling effort. These datasets included: bathymetric data for the Impoundment (including the Northfield Mountain tailrace), tailrace/intake drawings, flow and water elevation data, Project operations data, and suspended sediment data collected throughout the Impoundment. In addition to the data provided by FirstLight, Alden collected supplemental data in 2015 including: 1) the installation of a water level logger on the east bank near the intake, 2) additional bathymetry at the tailrace/intake, 3) collection of water samples for analysis of suspended sediment in the river, and 4) collection of bed material samples in the Upper Reservoir and the river at predetermined locations. Figure 2.3.3-2 depicts the locations where supplemental field data were collected.

The physical model is used to compare sediment intake associated with any modeled intake structural modifications to the existing intake structure. The modeled change to the existing intake structure is expected to consist of a deviation/deflection structure upstream of the existing intake structure to mobilize the river secondary currents and divert the sediment away from the intake structure. Figure 2.3.3-3 shows the preliminary general layout of the deflection structure. The modeled structure is designed to allow free

[6] Intake structure modifications referred to herein will be designed and constructed for the physical model only. At this time FirstLight is still evaluating the mitigation measures to minimize the entrainment of sediment in the Project works and Connecticut River.

overflow toward the existing intake with a weir level set at an elevation where most of the coarse sediments are not present (lower depths). Figures 2.3.3-4 and 2.3.3-5 depict the physical model as of early August 2015. As of the date of this report, construction of the model has been completed and simulations are currently underway.

The results of the physical model will be one more tool at FirstLight's disposal when identifying mitigation measures to minimize the entrainment of sediment into the Project works and Connecticut River. Given that these efforts are still ongoing discussion pertaining to the physical model in this report is limited to this section. Further discussion related to the physical model will be included in the final study report to be filed with FERC.

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Sediment Management Plan

N

0 750 1,500 3,000 Feet

Figure 2.3.3-1
Extent of Physical Model

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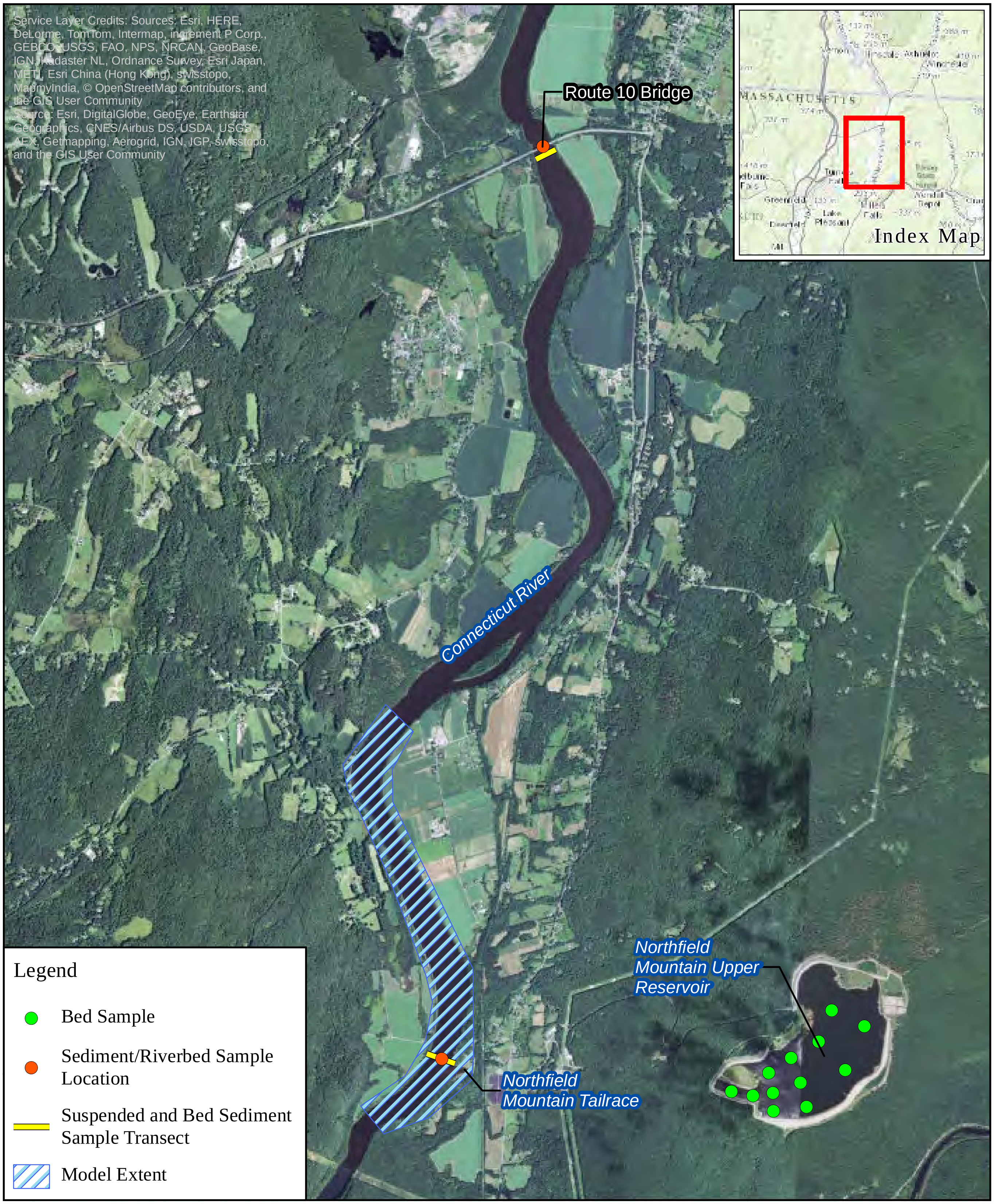


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0 0.375 0.75 1.5 Miles

Figure 2.3.3-2
Location of Supplemental Data Collection Efforts Related to the Physical Model

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0 150 300 600 Feet

Figure 2.3.3-3
Approximate Location of Physical Model Structure

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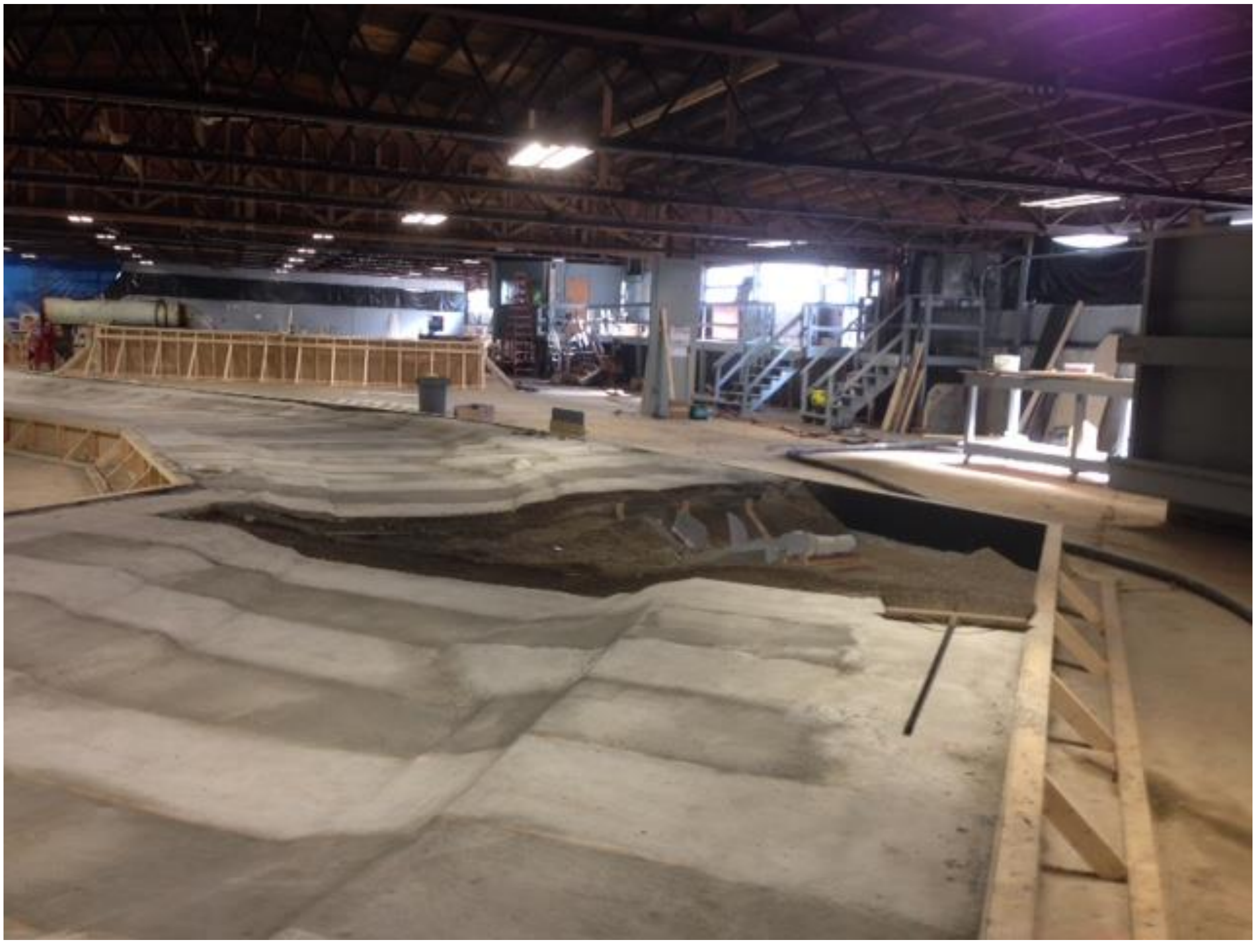
**Figure 2.3.3-4 Physical Model of Northfield Tailrace Area- Looking Downstream toward Tailrace**

**Figure 2.3.3-5 Physical Model of Northfield Tailrace Area- Bend in River is at the Tailrace**



## 2.4 Upper Reservoir Pilot Dredge

As part of FirstLight's continued assessment of sediment management techniques for the Project, FirstLight retained Dredge America, Inc. to assess and perform limited dredging of the Upper Reservoir starting in April 2015. Physical activities associated with the pilot dredge were completed in early November 2015. The pilot dredge was conducted to assess whether deep water hydraulic dredging is a viable option for removing excess accumulated sediment in the Upper Reservoir. The periodic removal of excess accumulated sediment could reduce the entrainment of accumulated silt into the Project works and the Connecticut River at harmful levels during drawdown or dewatering activities. Use of marine deep water hydraulic dredging is not proven in pumped storage facilities, which is why FirstLight conducted a pilot or a test dredge.

One of the potential advantages of deep water hydraulic dredging appears to be that it can occur while the Project is available for generation or pumping allowing for removal of sediments without the need for the Project to be offline. In contrast, other mechanical means of sediment removal may require dewatering of the Upper Reservoir and would likely require an extended outage. The technology employed by Dredge America also inherently avoids disturbance of sediments outside the small area undergoing active dredging.

Pilot dredge program activities occurred within and immediately upstream of the intake channel. Figure 2.4-1 depicts the approximate location of the dredging activities. The pilot dredge affected about 4.5 acres (1.6%) of the 274 acre Upper Reservoir. At the onset of this effort, up to 45,000 cubic yards (CY) of material were anticipated to be dredged out of the Upper Reservoir as part of this pilot program. Upon completion of the pilot program, ~46,000 CY were removed.

The pilot dredging project consisted of a boat-mounted deep water dredge as the main platform. The unit utilized a special Ellicot 370 horsepower dredge. Approximately 80 feet of additional flotation was added to the front of the dredge in order to extend the ladder line to a maximum depth of 120 feet. This depth of dredging required an underwater pump to lift the slurry off the bottom of the reservoir. The power unit was set on a second dredge platform positioned next to the main dredge. Figure 2.4-2 depicts the dredge setup.

The hybrid dredge setup ran from a static cable spanning the Upper Reservoir and anchored on opposing shores. The dredge rode along the cable and slowly suctioned an area approximately 8 feet wide per pass. The dredge made passes back and forth across the limited dredging area similar to a lawn mower cutting the grass within a large field. The depth of the suction was limited to approximately 3 feet so that the sediment on the reservoir bottom remained stable.

The dredged slurry mixture was incorporated with a polymer additive while being pumped into the Geotube dewatering system, which was located adjacent to the Upper Reservoir. Sediments from the sediment-water mixture were substantially captured in the Geotubes, with the filtered effluent flowing back into the Upper Reservoir at a controlled flow rate. Figure 2.4-3 shows the Geotube dewatering system.

As of the date of this report, the pilot dredge has been recently completed and a full review of the results has not yet occurred. As such, discussion pertaining to the pilot dredge in this report is limited to this section. Relevant findings from the pilot dredge will be included in the final study report to be filed with FERC in September 2016. For additional information regarding the pilot dredge please refer to FirstLight's February 24, 2015 filing with FERC.



***Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)***

Study No. 3.1.3
Northfield Mountain Pumped Storage Project
Sediment Management Plan

Figure 2.4-1
Location of Upper Reservoir
Pilot Dredging Activities

Legend

- Approximate Limit of Dredging Operations
- Staging Area
- Temporary Sediment Basin - 10 ft Deep

N

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Content may not reflect National Geographic's current map policy.

0 100 200 400 Feet

1 inch = 200 feet

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Path: W:\gis\studies\3_1_3\maps\Figure_2_4-1.mxd

**Figure 2.4-2 Dredge Equipment Setup**

**Figure 2.4-3 Geotube Dewatering System**

# 3 DATA ANALYSES

This section provides a detailed discussion of the data analysis methods used for the annual Upper Reservoir bathymetry surveys and the suspended sediment monitoring efforts discussed in Section 2. Section 3.1 discusses the data analysis methods associated with the Upper Reservoir Bathymetry Surveys. These methods typically included the creation of Triangular Irregular Networks (TINs) and cut/fill calculations to estimate the total sediment volume flux within the reservoir. Section 3.2 discusses the data analysis methods associated with suspended sediment monitoring efforts, including data collected at the StreamSide, HYDROs, LISST-100X, and grab samples. Data analysis protocols typically followed three steps: 1) Quality Assurance (QA)/Quality Control (QC) of all data, 2) conversion of the LISST volume concentration (µl/L) to mass concentration (mg/L) using available grab sample data, and 3) analysis of results.

## 3.1 Upper Reservoir Bathymetry Surveys

As noted in Section 2.1, Upper Reservoir bathymetry surveys have been conducted annually since 2011 as part of this study. The 2011 and 2012 surveys were conducted by Ocean and Coastal Consultants Inc. (Ocean & Coastal) with SeaVision Underwater Solutions (SeaVision). In 2013 the survey was conducted by CHA Consulting, Inc. (CHA). The 2014 and 2015 surveys were conducted by SeaVision. This section provides an overview of the data analysis methods employed for each year's survey. The ultimate goal of the data analysis was to compare the current year's survey with the previous year's survey to estimate the total sediment volume flux within the reservoir.

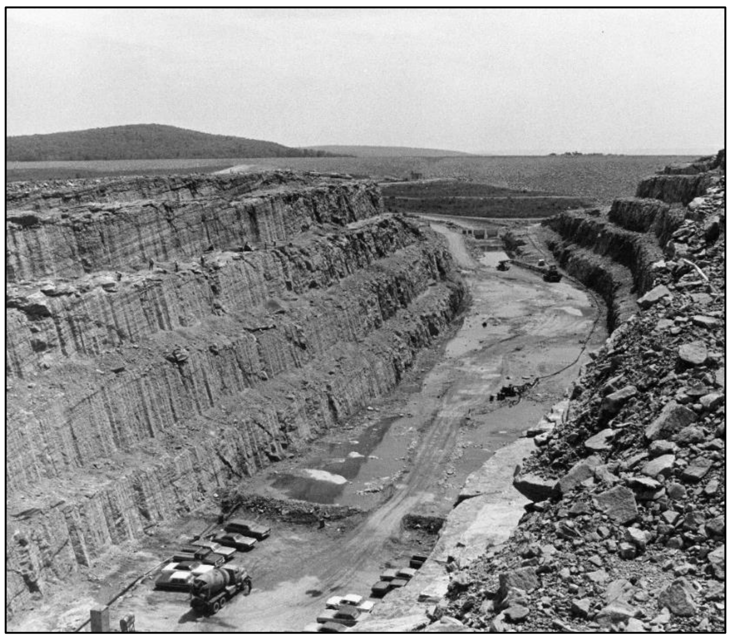
In 2011 and 2012, once all field collected data had been post processed, Ocean & Coastal and SeaVision conducted a QA/QC review of the dataset. The final QA'd data was then uploaded to a Geographic Information System (GIS) database which was used to organize and analyze the data. Once in GIS, the survey data was used to generate a contour plan of the reservoir from which a TIN was created. Cut/fill calculations were then performed by comparing the TIN created for that year's survey with the TIN(s) from the previous year(s). Differences observed between the current TIN with the past year(s) TIN(s) indicated where sediment deposition or erosion had occurred. In addition, the results of the cut/fill calculations provided net sediment accumulation or loss quantities from year to year.

In 2013, 2014, and 2015 all post processing of the hydrographic survey data was performed using the HYPACK software package. In 2013, CHA downloaded the data to an office desktop computer with the raw unedited data backed up for archival purposes. Latency test computations were performed to determine latency factors for the hydrographic survey system. Velocity corrections were made to the data from the velocity profiles observed during the field surveys. Each survey line was edited for spurious depth readings such as drop outs and spikes. All positioning data and water level corrections were reviewed for consistency. Any check lines run were compared with the sounding lines at their cross over points. Once the hydrographic data was edited, the data was sorted at a spacing of 5 ft. and 10 ft. and exported to ASCII data files for further processing.

Volume calculations were performed to assess the amount of material deposited or eroded throughout the intake channel and entire Upper Reservoir since the 2012 survey performed by Ocean & Coastal and SeaVision. The computational process involved the following steps: 1) a 2013 existing conditions TIN was created based on the hydrographic survey performed by CHA during the planned outage on October 5 and 6, 2013, 2) a 2012 existing conditions TIN was created based on the 2012 multi-beam hydrographic survey data provided by SeaVision, 3) multi-beam data was then sampled from the 2012 TIN along the sounding lines observed during 2013 survey, 4) a TIN was then created based on the sampled data and was used for volume calculations, and 5) the 2012 and 2013 TIN's were compared and volume surface was generated using Autodesk AutoCAD Land Desktop 2009.

In 2014 and 2015, SeaVision processed the multi-beam bathymetric survey data following a four phase process. In the first phase, position, orientation, water level, and sound velocity profiles for all survey lines were loaded and reviewed for errors. In the second phase, individual survey files were reviewed in a series of sweeps (usually 50 to 200 at a time) in order to review the swath data and identify any noise, spurious points, or erroneous soundings that may exist in the data. Manual editing of stray data points, and some automatic filters that search for and remove erroneous data, were then performed on all data. In the third phase of processing, all data was delivered into a matrix and reviewed as "area-based" such that cross-sections throughout the entire survey area were reviewed simultaneously. This allowed for the review of overlaps between adjacent survey lines and to confirm that the data at the overlaps was consistent (thus building in a quality assurance step to the processing phase). At the end of the third phase of processing, the data was binned for export to a grid. In the case of this work, the data grid was generated based on 3-feet by 3-feet spacing such that the sounding assigned to each grid cell represented the average of all soundings collected inside of that cell. In the final phase of processing, the ASCII XYZ grid file (with cells sized at 3-feet by 3-feet) was subjected to a TIN surface algorithm to generate color-shaded relief imagery and contours. Additionally, the TIN network was used in order to generate decimated grids with soundings spaced at 10-feet, 25-feet, and 50-feet.

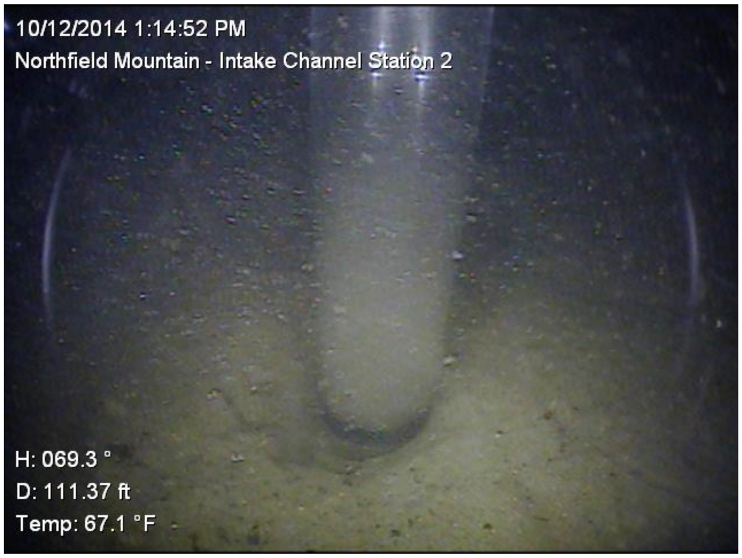
Volume calculations were then performed to assess the amount of material deposited or eroded throughout the Upper Reservoir intake channel since the 2012 survey. To define the intake channel, the original as-built drawings of the facility were referenced to define the base of the channel. It is believed that this is the most appropriate means of assessing the sediment volume behavior in the intake channel while reducing the impacts that the sheer, bounding, sidewalls (i.e. the cut rock wall faces on the north and south sides of the intake channel- see inset during original construction) can have on the survey data and thus the volume calculations. Using HYPACK, TINs were generated for the 2012-2015 surveys for comparison of surface changes to calculate volumes and to estimate the change in elevation between each surface model.



In addition to the multi-beam surveys conducted in 2014 and 2015, gravity cores (2014) and vibracores (2015) were utilized at six locations within the Upper Reservoir intake channel to better ascertain the sediment thickness in this area. The 2015 cores were not collected at the same exact locations as the 2014 cores, however, they were in the same general vicinity which allowed for indirect comparisons of sediment thickness between years. For both the gravity core and vibracore collection a similar methodology was employed. A four or six foot rigid plastic barrel was lowered to the bottom of the intake channel at each location at which time the sampling unit was deployed from the survey vessel. The rigid plastic barrel was pre-marked with black electrical tape at the 2 ft. elevation mark so that once the sampler had been lowered to the reservoir bottom and driven into the sediments a Remotely Operated Vehicle (ROV) could be deployed to identify the degree of penetration into the bottom sediments. Figure 3.1-1 depicts still video grabs showing gravity core collection at two locations in the intake channel.

Table 2.1-1 shows that the 2011 and 2013 Upper Reservoir bathymetry surveys were conducted using a single beam echosounder while the 2012, 2014, and 2015 surveys were collected using a multi-beam unit. For the purpose of this report, and to get an approximate estimate of annual deposition or erosion rates, special emphasis was placed on the results of the 2012 survey as compared with the 2014 survey given that each of the surveys conducted during those years utilized a multi-beam echosounder. The results of the 2012 to 2014 comparison were further bolstered by the use of the gravity core data collected in the intake channel. Changes in bed elevation were also analyzed comparing 2014 to 2015; however, due to the removal of ~46,000 CY of sediment during the pilot dredge the 2014 to 2015 analysis could not be used to determine annual deposition or erosion rates in the vicinity of the intake channel. Further discussion pertaining to the 2014 bathymetry analyses is discussed in Section 4.1.

**Figure 3.1-1 2014 Upper Reservoir Intake Channel Gravity Core Collection (2014)**




## 3.2 Suspended Sediment Monitoring

As previously discussed, the suspended sediment monitoring component of this program consisted of three main tasks: 1) continuous monitoring of suspended sediment at three locations within the Turners Falls Impoundment (2013-2015), 2) cross-sectional data collection from the Rt. 10 Bridge and Northfield Mountain tailrace boat barrier buoy line via the LISST-100X (2013) and grab sample collection (2015), and 3) grab sample collection at the StreamSide, HYDRO North, and HYDRO South locations over a range of flows and operating conditions (2013-2015). Once all data were collected, or laboratory results received, FirstLight conducted a thorough QA/QC review of all data. Data that did not pass the QA/QC measures were flagged or removed from the dataset. The final grab sample dataset was then used to convert the LISST data (StreamSide and HYDROs) from volume concentration (µl/L) to mass concentration (mg/L) in order to be directly comparable. Various data analyses were then conducted on the final, converted datasets in order to better understand suspended sediment dynamics throughout the study area over a range of flow and operating conditions.

This section provides a detailed discussion of the QA/QC protocols followed for the LISST and grab sample data (Section 3.2.1), the protocols followed for the conversion of volume concentration (µl/L) to mass concentration (mg/L) (Section 3.2.2), and the analyses which were then conducted on the final dataset (Section 3.2.3).

### *3.2.1 QA/QC of data*

Once all field data were collected, or laboratory results were received, each dataset went through a thorough QA/QC process before being accepted as final. Data which passed the QA/QC protocols were considered final while the remaining data were flagged and excluded from analyses. QA/QC measures performed for each dataset are described below.

*Continuous LISST Data*

The StreamSide and HYDRO instruments measured total volume concentration (µl/L) and particle size distribution (microns) using laser diffraction technology. Data were downloaded from the StreamSide on a weekly basis in .CSV format. The .CSV files were then brought into Microsoft Excel where all post processing occurred. The HYDRO instruments were programmed to automatically transmit the collected data to the Project historian computer system which was programmed to record the data in Excel format. Data were reviewed in Excel on a weekly basis.

Over the course of this study (2012-2015) previously described operational issues with the equipment were encountered which resulted in the exclusion of many measurements. Due to the challenges associated with using the continuous LISST equipment, FirstLight worked closely with the equipment manufacturer to ensure the data collected were correct and usable. Through this collaboration, the manufacturer performed QA/QC on the 2013 data and provided FirstLight with the specific QA/QC protocols to be followed when reviewing the 2014 and 2015 data. These protocols included:

1. **Review of the instrument Optical Transmission**: According to the manufacturer, the operational range of optical transmission for the LISST instruments is 0.3 to 0.98. Samples with optical transmission outside of this range were not included in analyses because resulting total concentration and mean size were likely inaccurate. The most common reason for data exclusion was high optical transmission (i.e. >0.98), which indicated that the water was too clear for the instrument to accurately measure sediment from that water sample.

2. **Review of the instrument battery voltage**: Insufficient battery power to the LISST instruments resulted in faulty data values. Samples with low battery voltage (<10 V) were not included in analyses.

3. **Review of the instrument clean water level**: The LISST instruments required occasional clean water measurements to "zero" the instrument and account for fouling on the lenses or scratches that may occur over time. If the clean water tank, which contained distilled water, was empty, adequate clean water backgrounds were not obtained. Data values taken when the clean water tank was determined to be empty were not included in analyses.

4. **Removal of the largest particle size bins due to the presence of "rising tails"[7]:** The manufacturer recommended excluding the largest size bins from the raw data due to the presence of rising tails.[8] This recommendation was based on the observed particle size distribution patterns found in the data. The values in the five largest bins were not likely attributed to the measurement of actual sediment particles, but instead resulted from laser scattering due to bubbles or thermal effects (i.e. scintillation). It was generally observed that the five largest bins were resulting in rising tails and erratic measurements. Total concentration and mean size were recalculated for all samples from the LISST instruments without including the top five particle size bins.

5. **Review of the dataset for duplicate samples**: For the LISST HYDRO instruments, data were initially stored on FirstLight's historian database, which would fill any data gaps with the last recorded measurement (e.g., if an equipment malfunction occurred and the instrument was not collecting data the historian would automatically fill this gap with the last measured value). Given that these duplicates were not actually collected during the time given by the data historian, they were not included in analyses.

6. **Review of the dataset for extreme outliers**: Occasionally, total concentration measurements were provided that were very high relative to previous and subsequent measurements, but were not flagged or excluded using the QA measures outlined above. The manufacturer suggested that these values be removed on a case-by-case basis and were likely due to an instrument issue (i.e. faulty clean water background). These measurements were relatively uncommon, typically few data points among many, and were not included in analyses if they were not within the realm of patterning observed in the dataset.

If erroneous data points were still observed, further investigation into these values via collaboration with the manufacturer occurred.[9] As an additional QA check, the final continuous LISST total concentration dataset was plotted against the grab sample dataset to determine if the general patterns observed were similar for each dataset (e.g., if the grab sample data showed a rise, peak, and fall one would expect the LISST data to show the same pattern).

*LISST-100X Data*

All LISST-100X data required post-processing and were derived using a spherical particle model, which assumes that particles within the sample that scattered light are all spheres. The manufacturer recommends a randomly-shaped model for most applications, unless comparisons with other laser diffraction instruments

[7] "Rising Tails" occur when there are an increasing number of occurrences on the ends of a sample distribution, indicating that the distribution may be multi-modal but that the entire distribution beyond the ends was not measured or apparent. From a particle size distribution perspective, it refers to higher values in the smallest or largest particle size bins. Given the indirect nature of the LISST measurements and the issues (i.e. bubbles and scintillation) encountered, it was determined by the LISST manufacturer that the largest size bins should be removed from the dataset because the values in those bins were not the result of actual sediment particles.
[8] The LISST equipment measures the particle size and concentration in a number of logarithmically spaced size classes or bins. Each size class has a manufacturer defined lower and upper size limit. Often times rising tails can occur in the smallest or largest size classes or bins.
[9] Additional investigation beyond the steps listed often resulted in FirstLight sending the data to the manufacturer for its review.

could occur. Therefore, the spherical model was chosen over a randomly-shaped model because there was the potential to compare samples from the different LISST instruments.

Clean water backgrounds were recorded in advance of, and at the completion of, field data collection efforts. During post processing, the data were processed separately using the preliminary and final clean water backgrounds at which time the backgrounds were averaged to account for biological fouling and dirty lenses. Similar to the continuous LISST monitors, and at the recommendation of the equipment manufacturer, the largest size bins were removed from the dataset due to some minor rising tails and the data were recalculated. Operational issues encountered by the continuous LISST monitors were not typically encountered by the LISST-100X; however, the absence of laboratory grab sample data corresponding to the same water that the LISST-100X measured precluded the conversion of volume (µl/L) to mass concentration (mg/L). Therefore, the use of data from the LISST-100X has been restricted to cross-section patterns and general observations, rather than quantitative comparison to the other LISST instruments.[10]

*Project Operations Data*

FirstLight records flow information at the Vernon Hydroelectric Project (Vernon) and Northfield Mountain as well as information pertaining to Northfield Mountain Project operations (e.g., number of units pumping, number of units generating, flow associated with those operations, etc.). In order to fully understand the suspended sediment dynamics in the study area, suspended sediment data collected as part of this study were analyzed against FirstLight's flow and operations data. For the purpose of this report, flow data which were utilized in the mainstem analyses focused solely on Vernon discharge and did not take into account inflow from the Ashuelot River, unless specifically noted.[11]

Gomez and Sullivan Engineers, DPC (Gomez and Sullivan) obtained 15-minute Project operations and flow data from FirstLight's historian database over the course of this study. Upon receipt of the data, Gomez and Sullivan performed a thorough QA/QC on the dataset. Each parameter was plotted and quality assured through the removal of extreme outliers and values duplicated for extended periods.[12] Erroneous data that did not pass QA/QC measures were excluded from the dataset.

*Grab Sample Data*

Over the course of the study, grab samples were collected from the drain hoses of the LISST equipment (StreamSide and HYDROs) and/or from the edge-of-water in the vicinity of each instrument's pump. In 2015, grab samples were also collected at EWI stations across the Rt. 10 Bridge. All grab samples were submitted to an independent laboratory for analysis of SSC and TSS. The goal of the grab sample data was to collect instrument-independent measurements to complement and compare to the LISST data.

Upon receipt of the laboratory results, the dataset was manually quality-assured to identify samples with missing information. If information matches could not be made to chain of custody forms, field notes, or laboratory reports, the sample was removed. The dataset was also review for any erroneous data or outliers. Few extreme outliers, possibly due to contaminated samples, were observed that were flagged and excluded from analyses.

[10] LISST-100X data was also not quantitatively comparable to the StreamSide or HYDRO instruments due to the indirect (laser scattering) nature of sampling and because each instrument measured scatter uniquely (i.e. different lenses).

[11] The Ashuelot River (drainage area ~420 $mi^2$) is a tributary to the Impoundment whose confluence is located downstream of Vernon.

[12] Duplication of data values was the result of data gaps being filled with the last measured value in the FirstLight historian database.

#### *3.2.2 Conversion of Volume Concentration to Mass Concentration*

StreamSide and HYDRO data collected from 2013-2015 were converted from volume concentration (µl/L) to mass concentration (mg/L) using conversion factors developed in 2015. Without conversion, LISST data would not have been quantitatively comparable among units due to the indirect (laser scattering) nature of sampling and because each instrument measured scatter uniquely (i.e. different lenses).

The LISST instruments measured total sediment concentration using laser diffraction technology which provided an estimate of the amount of sediment in the water as a measure of volume concentration. Volume concentration was recorded by the LISST instruments in the units of micro-liters per liter (µl/L). In order to facilitate the conversion of the dataset from µl/L to mg/L (mass concentration), as previously requested by the USEPA, grab samples were collected from the drain hoses of the LISST instruments and/or the edge-of-water in the vicinity of the LISST instrument pumps to be paired with LISST measurements. Paired sampling refers to the collection of a grab sample at the same time a measurement is recorded at the LISST instrument(s), and was recommended by the manufacturer to develop a conversion factor. In 2015, the grab sampling program was expanded to include daily collection of grab samples at both the drain hose (when possible) and the edge-of-water. Grab samples collected during the previous years of the study (2012-2014) were infrequent.

Given the variability observed among LISST measurements, and because particle density could also vary, the density conversion factor was developed using all available paired samples with linear regression. During the conversion development phase, it was noted that the LISST instruments did not reliably measure if sediment concentrations were extremely low; therefore, the y-intercept of the regression equation was set to zero and the density conversion was the slope of the line.

Due to operational issues at the StreamSide, too few grab samples were collected from the drain hose in 2015 to provide a reliable correlation; edge-of-water samples were used in place of drain samples. The results of the edge-of-water samples were appropriate to use given that they were collected in the vicinity of the StreamSide pump on a daily basis. This regression provided a strong correlation and therefore a reliable conversion factor to mass concentration for the StreamSide (Figure 3.2.2-1).

For the LISST HYDRO instruments, a sufficient number of grab samples were collected from the monitor drain hoses in 2015 such that strong correlations were observed and reliable conversion factors were developed (Figures 3.2.2-2 and 3.2.2-3).[13]

Grab samples were not available for all LISST-100X data, and the measurements from this instrument were not converted to mass concentration values. Because the LISST-100X data were primarily used for cross-sectional patterning, relative values of total volume concentration were considered sufficient.

[13] The conversion factors are instrument-specific, rather than location specific. Because the instruments were swapped and installed on different banks each year, the conversion factors were applied appropriately to the instrument.

**Figure 3.2.2-1 StreamSide Unit Conversion Equation**

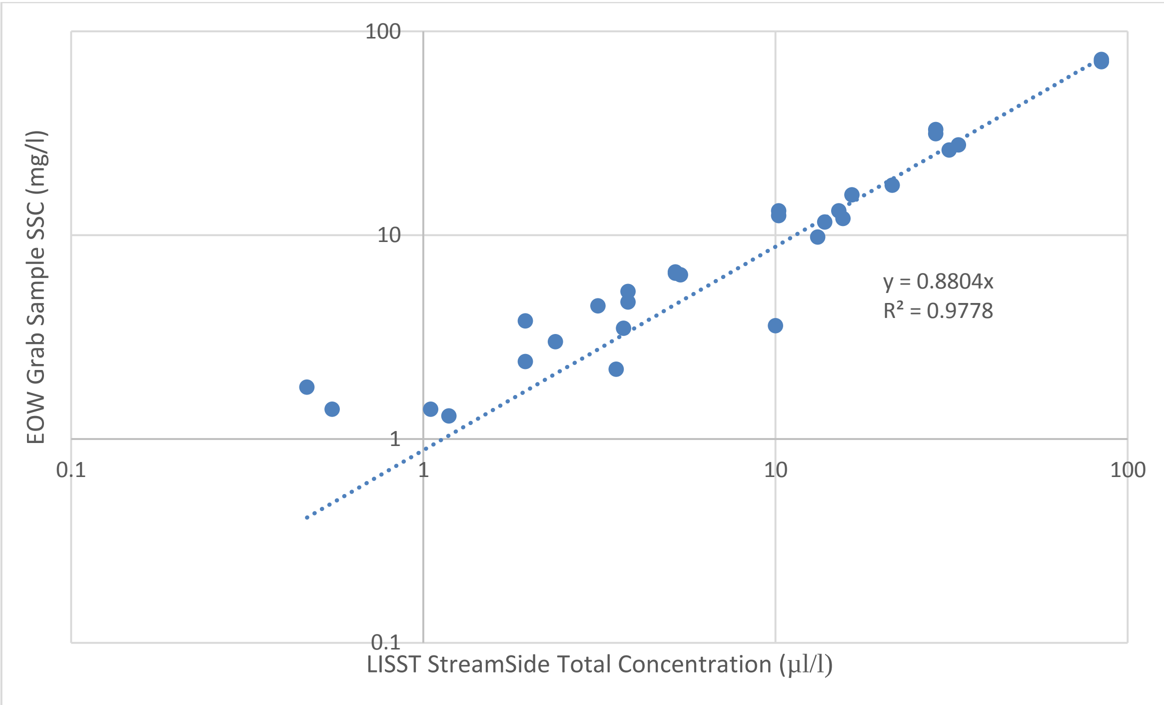


**Figure 3.2.2-2 HYDRO North Unit Conversion Equation**

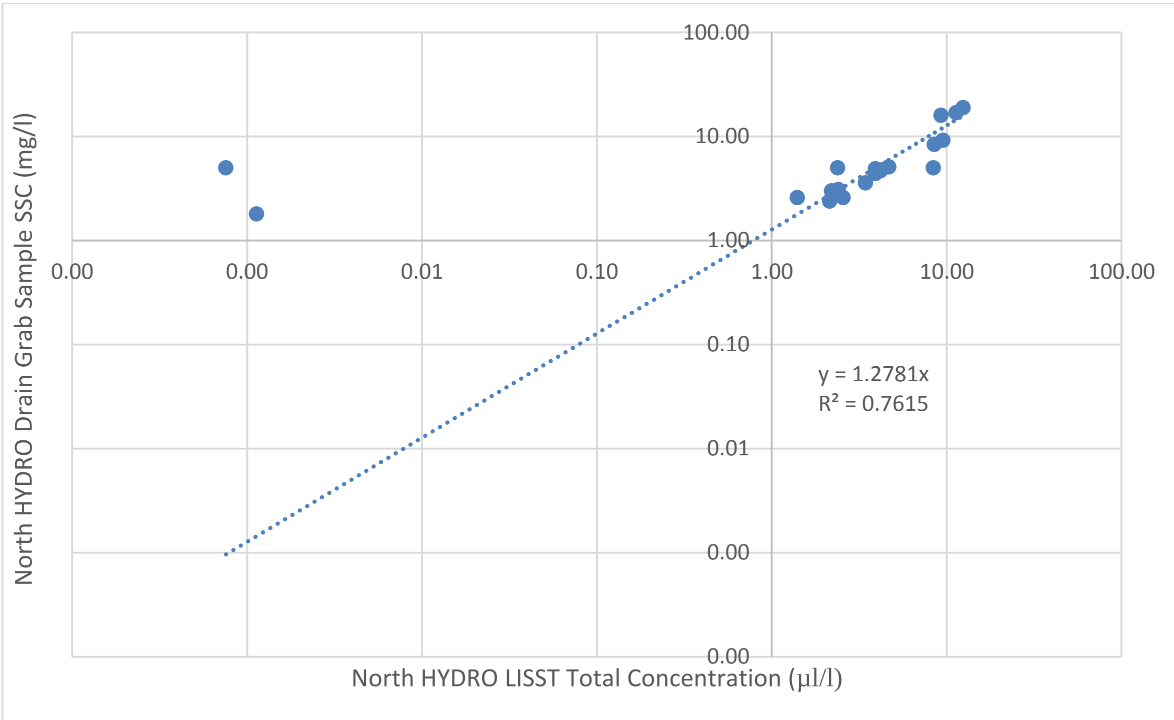
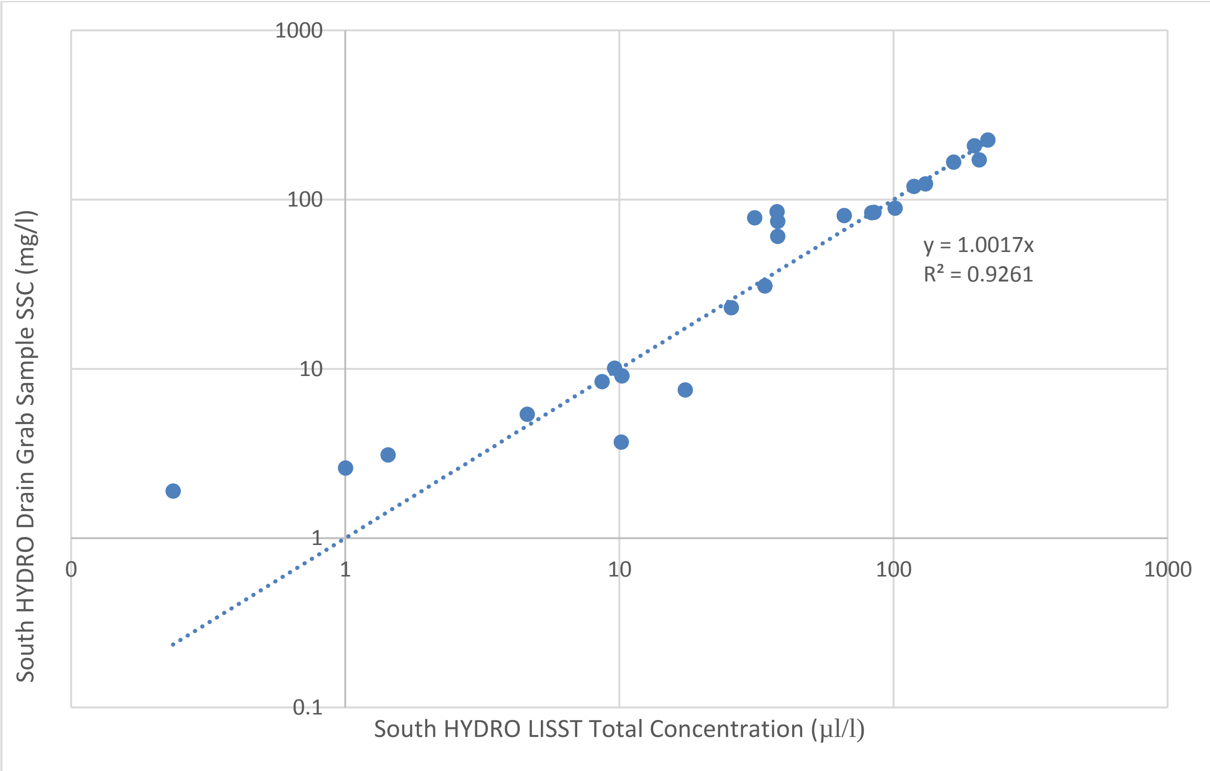


**Figure 3.2.2-3 HYDRO South Unit Conversion Equation**



#### *3.2.3 Analyses*

Following the completion of the QA processes and the conversion of the LISST data from volume to mass concentration, various suspended sediment analyses were performed.[14] Suspended sediment concentrations were compared with flow and Project operations data (Vernon and Northfield Mountain) over a range of seasonal, and operational conditions. Data collected from the Rt. 10 Bridge cross-section and the Northfield Mountain tailrace cross-section were also examined to better understand the suspended sediment dynamics across the river and tailrace, as well as throughout the water column. Cross-sectional data were also compared to the point data collected (StreamSide, HYDROs, and grab samples) to determine if the continuous sampling locations were representative of the larger cross-section and if any data adjustments would be needed. This section describes each of the analyses conducted while Section 4 discusses the results.

*Comparison of Point and Continuous Measurements to Flow and Operations*

Continuous total concentration measurements were analyzed to examine the relationships with river flow and Project operations (Vernon and Northfield Mountain). Timeseries (hourly basis) plots of SSC, river flow at Vernon Dam, and Northfield Mountain Project operational flow data were developed on a monthly or 10-day time step for the duration of the study (Appendix C and D).[15] The goals of the timeseries plots were to identify patterns of SSC on an annual, seasonal, and Project operations basis. From these analyses, several periods of interest were then identified for further analysis on a finer scale. The finer scale plots were analyzed to specifically understand the dynamics of SSC and flow in relation to the generating and pumping operations at the Project.

Time periods of interest that were examined on a finer scale included: low (2,000-12,000 cfs), moderate (12,000-20,000 cfs), and high flow (30,000-70,000 cfs) periods when Northfield Mountain was pumping and generating over a range of units (1-4). The spring freshet was also captured during the high flow period of interest. The goals of this analysis were to determine: 1) how varying SSC levels could impact the Project (i.e. sediment entrainment in Project works), 2) if an increase in SSC values were observed during pumping and/or generating conditions, 3) if an increase in SSC values were observed depending on the number of units online (1-4), 4) if there was a difference between the SSC values observed from the north bank to the south bank of the tailrace over a range of flow and operating conditions, and 5) how the SSC levels of the mainstem impacted the tailrace and, potentially, the Upper Reservoir. The results of the edge-of-water grab samples, the StreamSide, and HYDROs were used for these analyses. Section 4.2 contains a detailed discussion of these results.

*Cross-sectional Rt. 10 Bridge*

LISST-100X data were collected in 2013 over a range of flows (1,697 cfs – 31,382 cfs) in order to better understand how total concentration varied across the cross-section and throughout the water column. The LISST-100X data were also used to determine if the StreamSide pump location was representative of the cross-section or if adjustments needed to be made to the StreamSide data. Various plots depicting the LISST-100X data were developed and analyzed as part of this effort (Appendix E). However, because the LISST-100X data were not able to be converted to mass concentrations, they were not analyzed quantitatively and were only used to describe the general patterns in that area of the river.

[14] Although the LISST instruments recorded PSD measurements, given the indirect nature of the laser scattering and a lack of confidence in the accuracy of the particle size distributions provided by the LISST instruments, no analyses were performed on particle size data. As such, suspended sediment analyses were limited to suspended sediment concentration.
[15] When reviewing the plots contained in these Appendices it is important to note that the y-axis may vary from plot to plot. Additionally, in Appendix C, gaps observed in the LISST data represent periods of time when the instruments were offline due to equipment malfunctions or data that was removed from the final dataset during the QA/QC process.

In 2015, grab sample data were collected from the Rt. 10 Bridge over a range of flows (19,112 cfs – 59,700 cfs). The 2015 Rt. 10 Bridge data were plotted by depth and station in order to examine whether SSC varied across the river, with depth, or both. Flows, and any changes in flow, were also noted given that the sampling events occurred over multiple hours. Grab samples were also collected from the edge-of-water in the vicinity of the StreamSide pump before or after (sometimes both) cross-sectional data collection occurred. Measurements from grab samples taken near the StreamSide were then compared to the cross-sectional data in order to evaluate whether the StreamSide sampling location was representative of the river in that area. Results were compared to patterns from data collected in 2013 with the LISST-100X.

Table 3.2.3-1 denotes the pertinent information regarding the Rt. 10 Bridge cross-section data collection efforts of 2013 and 2015. Section 4.2 contains a detailed discussion of these results.

*Cross-sectional Northfield Tailrace*

LISST-100X data were collected over a range of operating conditions (1-3 units pumping and generating) at the Northfield Mountain tailrace boat barrier buoy line in 2013 to evaluate whether sediment concentrations differed by depth and/or station across the Northfield Mountain tailrace. The LISST-100X data were also used to determine if the HYDRO pump locations were representative of the cross-section or if adjustments needed to be made to the HYDRO data. Various plots depicting the LISST-100X data were developed and analyzed as part of this effort (Appendix E). However, because the LISST-100X data were not able to be converted to mass concentrations, they were not analyzed quantitatively and were only used to describe the general cross-sectional pattern in the tailrace.

Additionally, paired grab samples collected in 2015 from each bank were analyzed using a two sample Kolmogorov-Smirnov test, which compares the median and cumulative distribution of samples. Using this test, low p-values ($p < 0.05$) would indicate that samples from each bank differ in median, variability, or distribution. This test was performed on the complete paired dataset, along with pumping and generation subsets.

FirstLight also planned on collecting cross-sectional grab samples in 2015 at the same stations where LISST-100X data were measured in 2013 during moderate to high flow events over a range of operating conditions. Due to safety concerns associated with collecting samples from a boat at the tailrace while the Project was operating and river flows were moderate to high, this was not possible.

Table 3.2.3-1 denotes the pertinent information regarding the Northfield Mountain tailrace cross-section data collection effort in 2013. Section 4.2 contains a detailed discussion of these results.

**Table 3.2.3-1 Cross-sectional Data Collection – 2013 and 2015**

| Date | Location | Method | Flow (cfs) | Northfield Mtn. Operations | Notes |
|---|---|---|---|---|---|
| 4/18/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 33,483 | N/A – sampling point upstream of Station | Naturally Routed Flow[16] |
| 4/26/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 15,980 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 5/2/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 10,707 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 5/10/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 10,070 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 10/3/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 3,363 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 10/11/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 5,450 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 10/16/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 4,490 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 10/24/2013 | Rt. 10 Bridge | LISST-100X (EWI) | 4,278 | N/A – sampling point upstream of Station | Naturally Routed Flow |
| 10/10/2013 | NFM Boat Barrier | LISST-100X (EWI) | 6,782 | Idle | Naturally Routed Flow |
| 10/15/2013 | NFM Boat Barrier | LISST-100X (EWI) | 4,171 | 1 Unit Gen | Naturally Routed Flow |
| 10/23/2013 | NFM Boat Barrier | LISST-100X (EWI) | 4,640 | 2 Units Gen | Naturally Routed Flow |
| 10/26/2013 | NFM Boat Barrier | LISST-100X (EWI) | 4,955 | 2 Units Pump | Naturally Routed Flow |
| 10/26/2013 | NFM Boat Barrier | LISST-100X (EWI) | 4,955 | 3 Units Gen | Naturally Routed Flow |
| 4/14/2015 | Rt. 10 Bridge | Grab Sample (EWI) | 50,536-59,700 | N/A – sampling point upstream of Station | Vernon Discharge |
| 4/17/2015 | Rt. 10 Bridge | Grab Sample (EWI) | 47,970-52,591 | N/A – sampling point upstream of Station | Vernon Discharge |
| 4/20/2015 | Rt. 10 Bridge | Grab Sample (EWI) | 41,282-42,172 | N/A – sampling point upstream of Station | Vernon Discharge |
| 4/28/2015 | Rt. 10 Bridge | Grab Sample (EWI) | 20,437-19,112 | N/A – sampling point upstream of Station | Vernon Discharge |

[16] Turners Falls Impoundment Naturally Routed Flow is the sum of Vernon discharge and inflow from the Ashuelot and Millers Rivers.

# 4 RESULTS & DISCUSSION

As previously mentioned, the *Northfield Mountain Project Sediment Management Plan* has evolved into a robust study with multiple field data collection, modeling, and analysis components. The results of the various data collection and analysis efforts which have occurred from 2011-2015, and have been completed as of the date of this report, are presented in this section. Section 4.1 presents the findings of the annual bathymetry surveys including estimations of the total sediment volume flux within the reservoir. Section 4.2 discusses the findings of the suspended sediment monitoring portion of the program based on the data collected at the StreamSide, HYDROs, LISST-100X, and from the grab samples. Results discussed in that section include analysis of SSC timeseries vs. flow and Project operations (Vernon and Northfield Mountain) and review of specific periods of interest which exhibit a range of river and operations conditions.

## 4.1 Upper Reservoir Bathymetry Surveys

As mentioned in Section 3.1, the results of each annual Upper Reservoir bathymetry survey were compared against the previous year's bathymetry survey to determine the total sediment volume flux in the Upper Reservoir as well as the intake channel. TINs demonstrating the change in sediment volume (i.e. areas of deposition and erosion) from year to year were developed based on the results of the bathymetry analysis. Figures depicting the annual changes across the entire Upper Reservoir for the period 2011-2013 are included in Appendix A.[17] When reviewing the figures in the Appendix, it is important to note that these figures contain comparisons of single beam vs. multi-beam echosounder surveys. While it is possible to conduct such a comparison using GIS or CAD software, it is not appropriate to do so as the accuracy of such a comparison is unknown and could vary greatly in some areas. Similarly, it is not appropriate to compare a single beam vs. single beam period (2011 and 2013) with a multi-beam vs. multi-beam period (2012 and 2014) as the multi-beam echosounders collect data at a higher resolution. Changes in sediment volume between 2011 and 2013 depicted in the figures found in Appendix A, which are based on comparison of single and multi-beam echosounders, should be considered approximate at best.

In order to better understand the changes in sediment volume of the Upper Reservoir intake channel between surveys, in-depth data analysis focused on the results of the 2012 survey as compared with the 2014 survey. The results of these bathymetry surveys were selected for comparison given that each survey utilized a multi-beam echosounder, were conducted by the same company, and followed the same methodology. Furthermore, the results of the 2012 to 2014 comparison were checked against gravity core data collected in the intake channel in 2014 and vibracore data collected in 2015.

When comparing the results of the 2012 and 2014 bathymetry surveys it was observed that a net total of 16,077 cubic yards of sediment accumulated in the Upper Reservoir intake channel over the two year period between surveys or an average of ~8,000 cubic yards/year. As a means of comparison, the net change in sediment volume at the intake channel was also calculated based on the sediment depth observed at each gravity core location. Given that the overall area of the intake channel is approximately 210,135 $ft^2$, and the average depth of sediment accumulation was found to be approximately 2 ft. (as observed at the six gravity core locations), then the total volume of sediment at the bottom of the intake channel is approximately 15,566 cubic yards. Due to the fact that the Upper Reservoir was dewatered in 2010 and silt was mechanically removed from the intake channel, the calculated net change of 15,566 cubic yards based on gravity core data represents the net deposition over the four year period, November 2010 to October 2014, or an average of ~4,000 cubic yards/year. Based on these two calculation methods the annual

[17] Analysis of the 2014 bathymetry survey data only compared changes in sediment volume at the intake channel and not the entire Upper Reservoir. The 2015 survey was conducted after the completion of the pilot dredge program and as such is not directly comparable to the 2011-2014 results.

sediment deposition rate in the Upper Reservoir intake channel was observed to range from ~4,000 to ~8,000 cubic yards/year.

The difference between the bathymetry and gravity core comparisons could be due to a number of reasons including, but not limited to: 1) accuracy limitations of the echosounder during each bathymetry survey, 2) echosounder interference caused by the geometry of the intake channel, 3) an underestimation of the amount of sediment found in the intake channel by the gravity cores, 4) varying flow, SSC, or operational conditions from year to year, or 5) a combination of all four. Because it is not possible to definitively determine the reason for the difference in the sediment deposition rate between the two calculation methods, for the purposes of this report, the annual deposition rate is reported as a range between the two calculation methods.

Figure 4.1-1 depicts the change in sediment volume of the Upper Reservoir intake channel from 2012 to 2014. Figure 4.1-2 shows the results of the 2014 survey as well as the locations where gravity cores were collected in the intake channel. Results of the 2014 Upper Reservoir bathymetry survey for the entire reservoir are depicted in Figure 4.1-3, 4.1-4, and 4.1-5.

During the 2015 bathymetry survey vibracores were collected at six locations as a spot check against the bathymetry data collected and as a means of comparison to the gravity core data collected in 2014. Based on observations made in the field during the 2014 survey the decision was made to switch from gravity cores to vibracores in order to achieve better penetration and recovery. Comparison of the gravity core information collected in 2014 with the vibracore information collected in 2015 found that the sediment thickness at the gravity core locations ranged from 2.0 to 2.5 ft. while the vibracores ranged from 0.3 to 5 ft.[18] The low end of the range observed in 2015 represents areas where the pilot dredge occurred between surveys while the high end of the range observed in 2015 represents areas that were not dredged. The difference in the high end of the range from 2014 to 2015 may be due to: 1) differences in core collection methodology (i.e. the vibracores were able to achieve better penetration and recovery than the gravity cores), 2) cores were collected at slightly different locations in 2014 and 2015, 3) sediment deposition since the 2014 survey, or 4) some combination of all three. Based on the analysis conducted, it appears that the vibracore data collected in 2015 generally correlates with the results of the bathymetry survey comparisons made from 2012 to 2014 and the finding that the annual deposition rate in the Upper Reservoir intake channel ranges from ~4,000 to ~8,000 cubic yards/year.

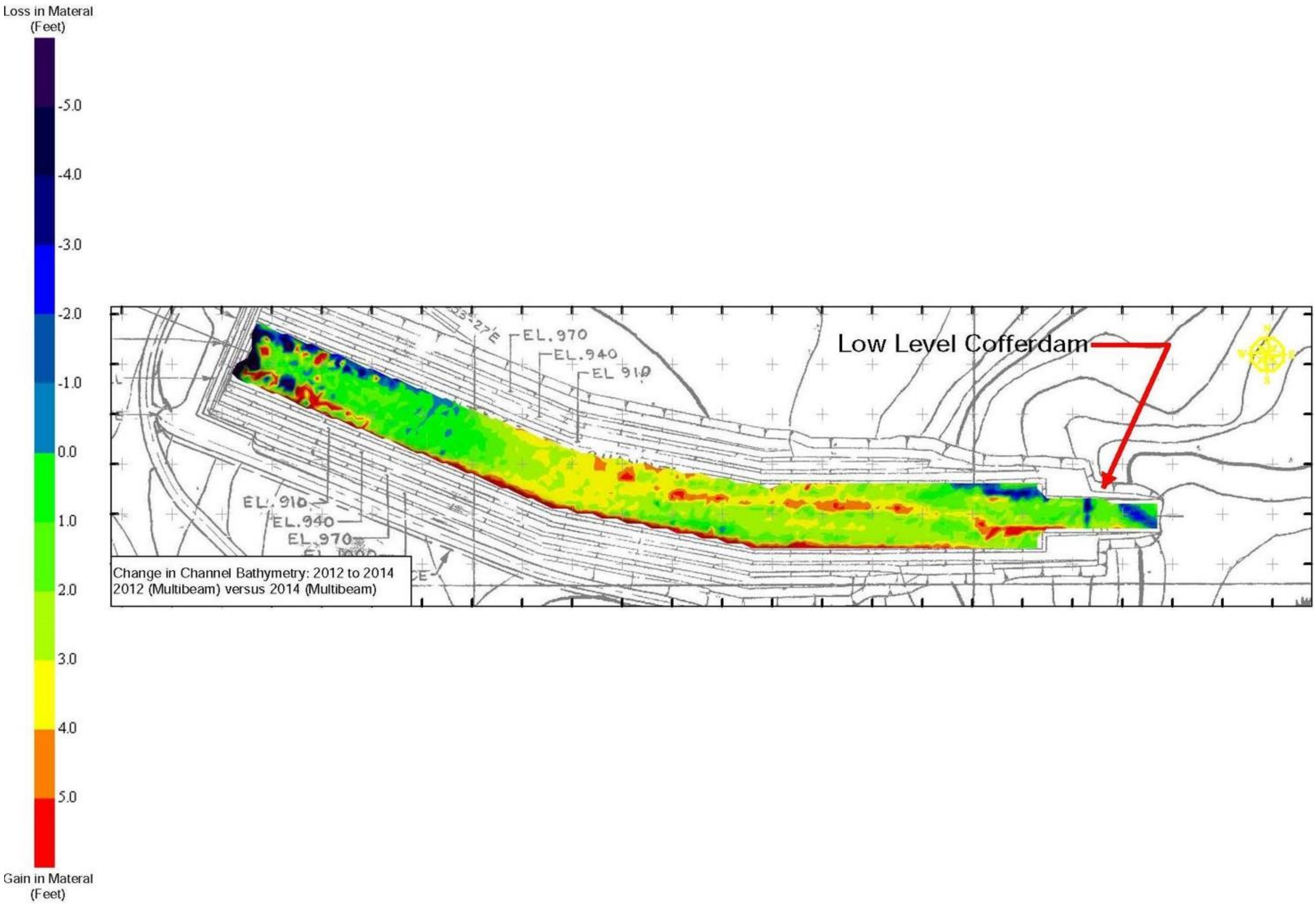
The results of the 2014 and 2015 bathymetry surveys were also compared to determine changes in the amount of sediment present in the intake channel. As previously stated, the pilot dredge occurred between surveys thus making it impossible to determine an annual deposition rate. While it was not possible to determine an annual deposition rate, calculations of the amount of sediment present in the intake channel were still possible. As stated in Section 2.4, in 2015 ~46,000 CY of sediment was dredged from within and immediately upstream of the intake channel. While the majority of the dredging activity occurred immediately upstream of the intake channel, comparison of the 2014 to the 2015 multi-beam surveys found that approximately 13,500 CY of sediment was removed from the intake channel between surveys as a result of the dredging activities.[19] Figure 4.1-6 shows the change in bed elevation at the Upper Reservoir intake channel from 2014 to 2015. The areas of net sediment loss observed in the figure are indicative of the pilot dredge.

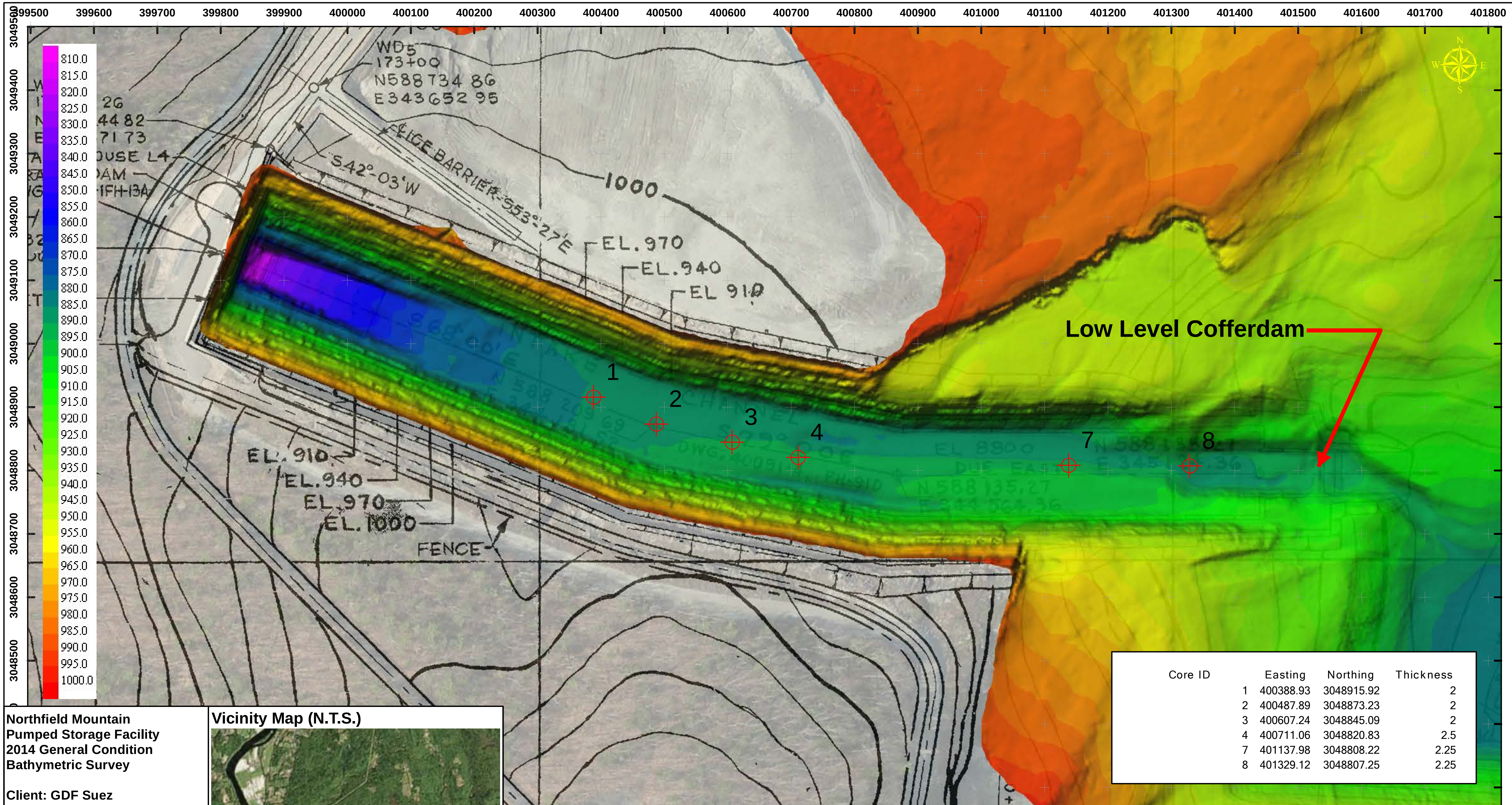
Figure 4.1-7 shows the results of the 2015 survey as well as the locations where the vibracores were collected in the intake channel. Note that the core locations are in the same general vicinity as those

[18] The 2015 cores were not collected at the same exact locations as the 2014 cores; however, they were in the same general vicinity which allowed for indirect comparisons of sediment thickness between years.
[19] This finding was checked against observations made during the dredging operation which found that approximately 15,000 CY of sediment had been removed from the intake channel.

collected in 2014. Results of the Upper Reservoir bathymetry survey for the entire reservoir are depicted in Figure 4.1-8, 4.1-9, and 4.1-10.

**Figure 4.1-1 Upper Reservoir Intake Channel Bathymetric Survey – 2012 to 2014 Change**






| Core ID | Easting | Northing | Thickness |
|---|---|---|---|
| 1 | 400388.93 | 3048915.92 | 2 |
| 2 | 400487.89 | 3048873.23 | 2 |
| 3 | 400607.24 | 3048845.09 | 2 |
| 4 | 400711.06 | 3048820.83 | 2.5 |
| 7 | 401137.98 | 3048808.22 | 2.25 |
| 8 | 401329.12 | 3048807.25 | 2.25 |

**Northfield Mountain Pumped Storage Facility 2014 General Condition Bathymetric Survey**

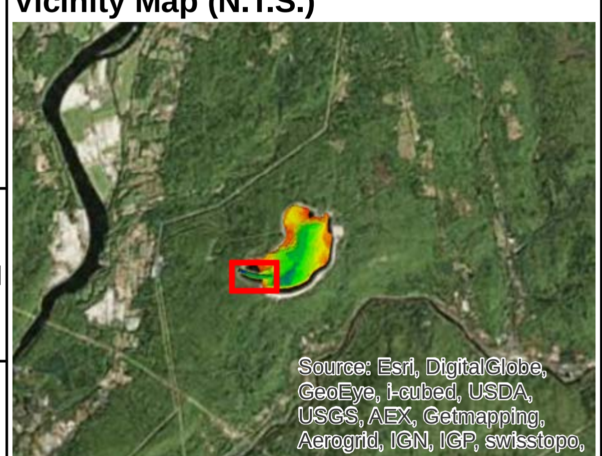
**Client: GDF Suez**

**Figure 4.1-2**

**Upper Reservoir Intake Channel Multibeam Bathymetric Survey Core Sample Locations**

SeaVision Figure 14-051-02
Drawn by: J. Snyder
Date: 11/4/2014

**Vicinity Map (N.T.S.)**




## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 12, 2014 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet). Elevations are expressed in feet and reference the Northfield Mountain Pumped Storage Facility (NMPSF) Site Datum.

4. The NMPSF Site Datum is assumed to be an elevation of +0.389 eet relative to the North American Vertical Datum of 1988 (NAVD 1988).

5. Background aerial photographs have been taken from the publicly available digital imagery available through MassGIS and from electronic drawings provided by GDF Suez / FirstLight.

**Scale**

0 75 150 300
Feet

1 inch = 150 feet

*Check Graphic Scale*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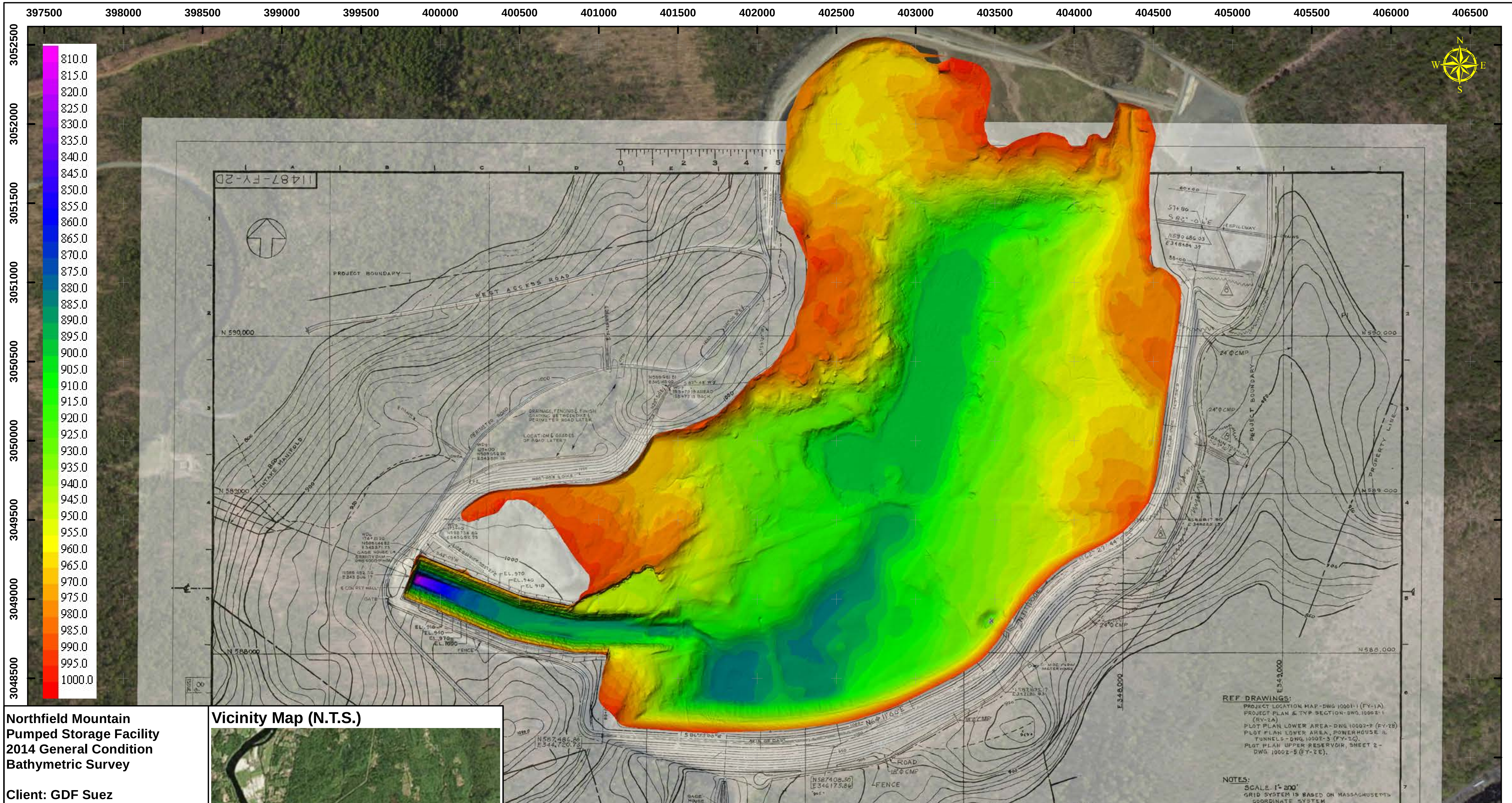


**Northfield Mountain Pumped Storage Facility 2014 General Condition Bathymetric Survey**

**Client: GDF Suez**

## Vicinity Map (N.T.S.)

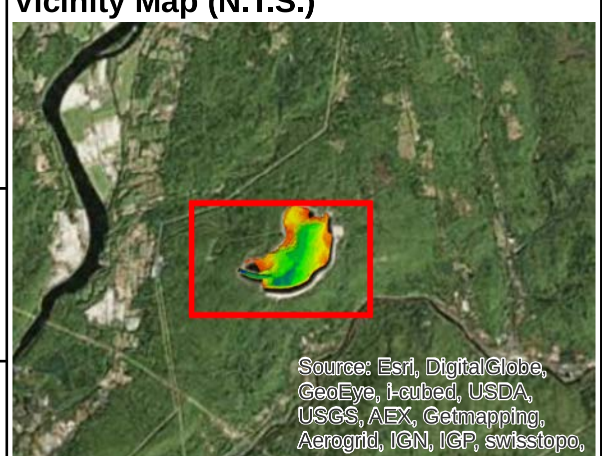


**Figure 4.1-3**

**General Condition Multibeam Bathymetric Survey Color Shaded Relief**

SeaVision Figure 14-051-01
Drawn by: J. Snyder
Date: 11/4/2014

## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 12, 2014 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

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4. The NMPSF Site Datum is assumed to be an elevation of +0.389 eet relative to the North American Vertical Datum of 1988 (NAVD 1988).

5. Background aerial photographs have been taken from the publicly available digital imagery available through MassGIS and from electronic drawings provided by GDF Suez / FirstLight.

## Scale

0 300 600 1,200
Feet

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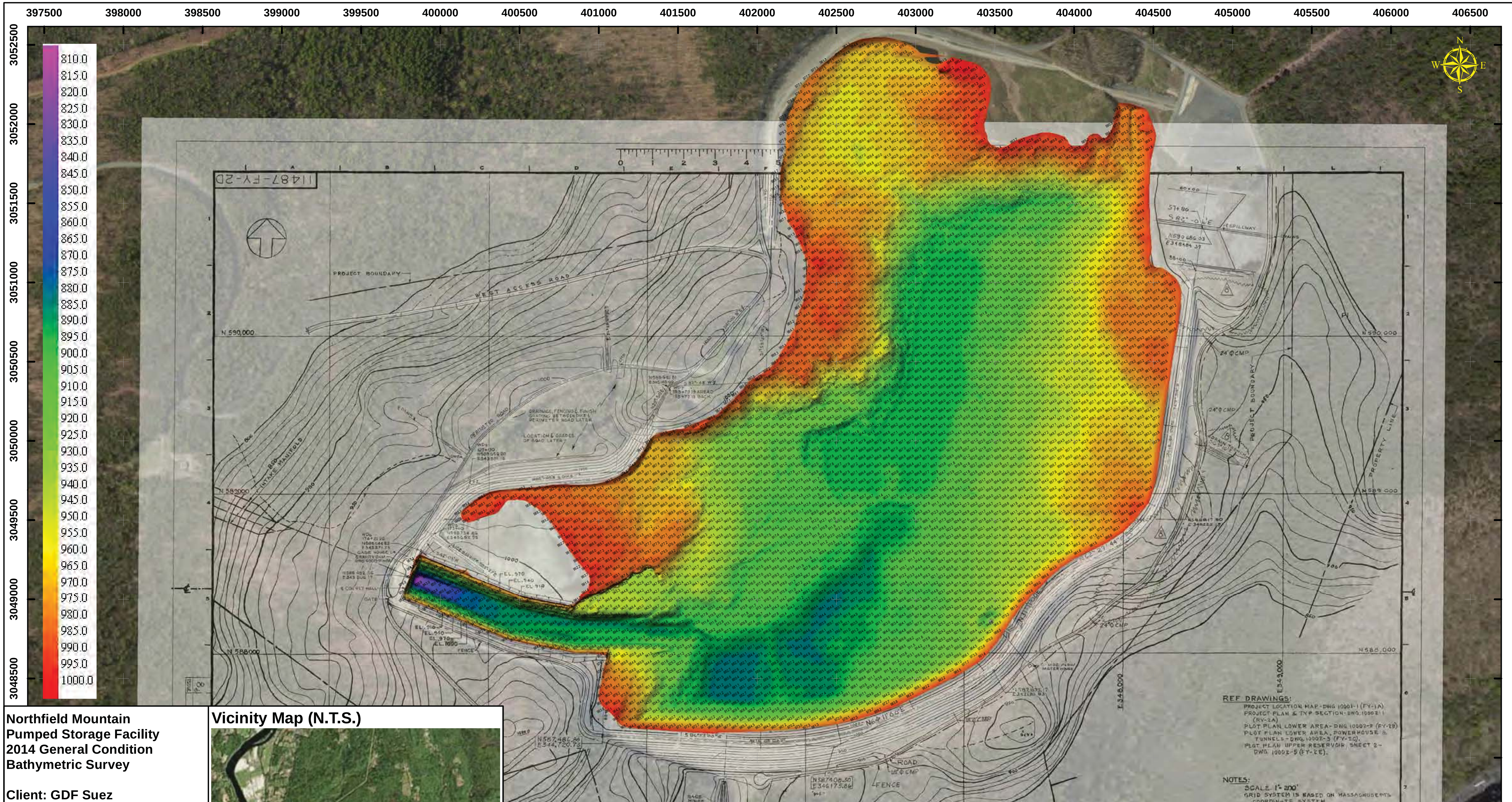



**Northfield Mountain Pumped Storage Facility 2014 General Condition Bathymetric Survey**

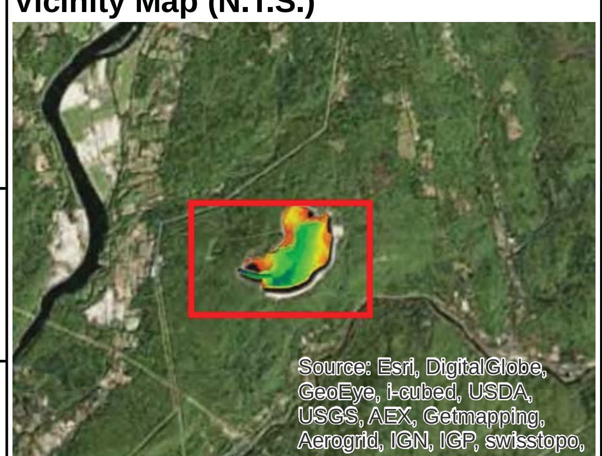
**Client: GDF Suez**

Figure 4.1-4

**General Condition Multibeam Bathymetric Survey Soundings**

SeaVision Figure 14-051-02
Drawn by: J. Snyder
Date: 11/4/2014

## Vicinity Map (N.T.S.)




## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 12, 2014 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet). Elevations are expressed in feet and reference the Northfield Mountain Pumped Storage Facility (NMPSF) Site Datum.

4. The NMPSF Site Datum is assumed to be an elevation of +0.389 eet relative to the North American Vertical Datum of 1988 (NAVD 1988).

5. Background aerial photographs have been taken from the publicly available digital imagery available through MassGIS and from electronic drawings provided by GDF Suez / FirstLight.

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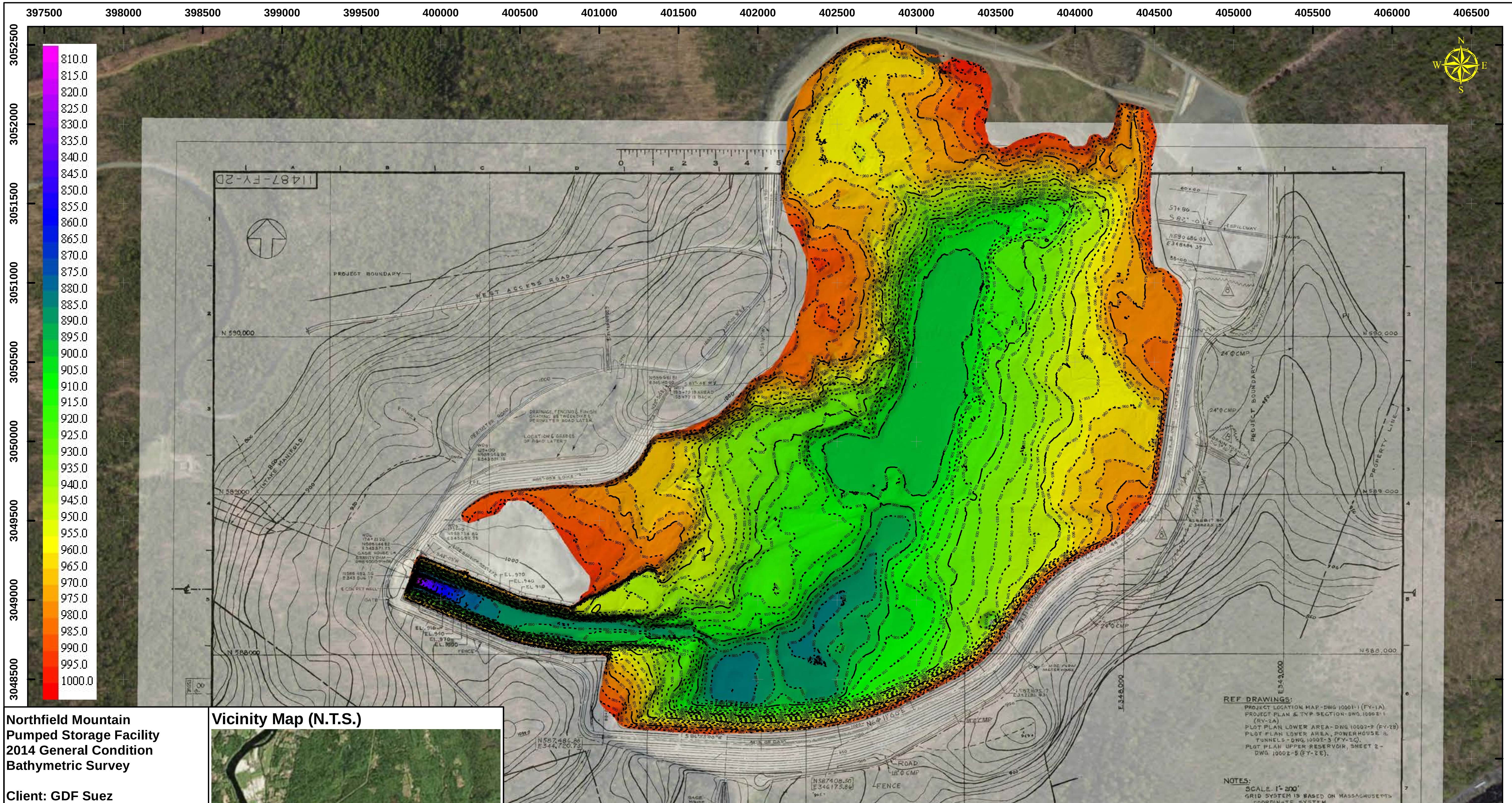



**Northfield Mountain Pumped Storage Facility 2014 General Condition Bathymetric Survey**

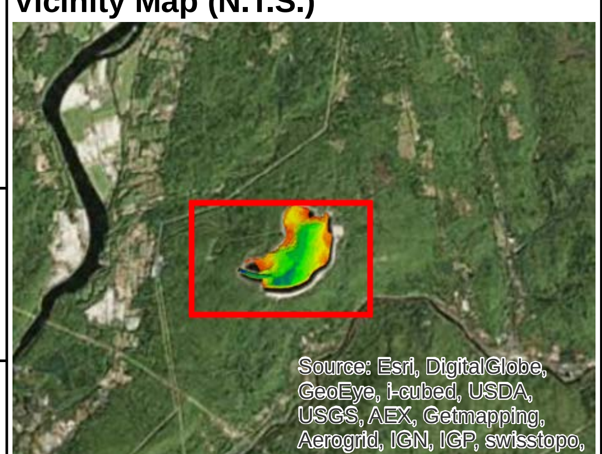
**Client: GDF Suez**

**Figure 4.1-5**

**General Condition Multibeam Bathymetric Survey Contours**

SeaVision Figure 14-051-03
Drawn by: J. Snyder
Date: 11/4/2014

**Vicinity Map (N.T.S.)**




## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 12, 2014 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet). Elevations are expressed in feet and reference the Northfield Mountain Pumped Storage Facility (NMPSF) Site Datum.

4. The NMPSF Site Datum is assumed to be an elevation of +0.389 eet relative to the North American Vertical Datum of 1988 (NAVD 1988).

5. Background aerial photographs have been taken from the publicly available digital imagery available through MassGIS and from electronic drawings provided by GDF Suez / FirstLight.

**Scale**

0 300 600 1,200

Feet

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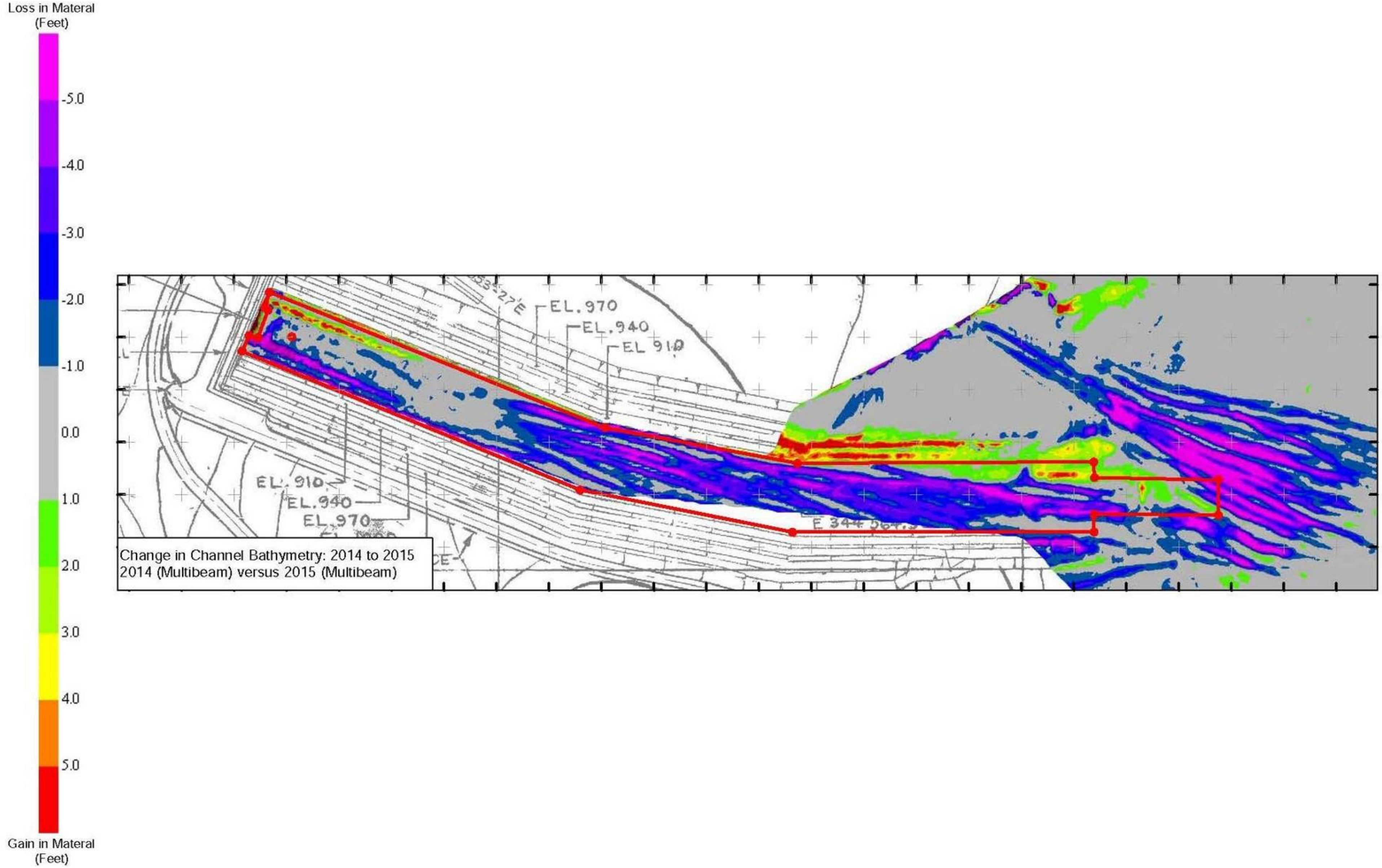
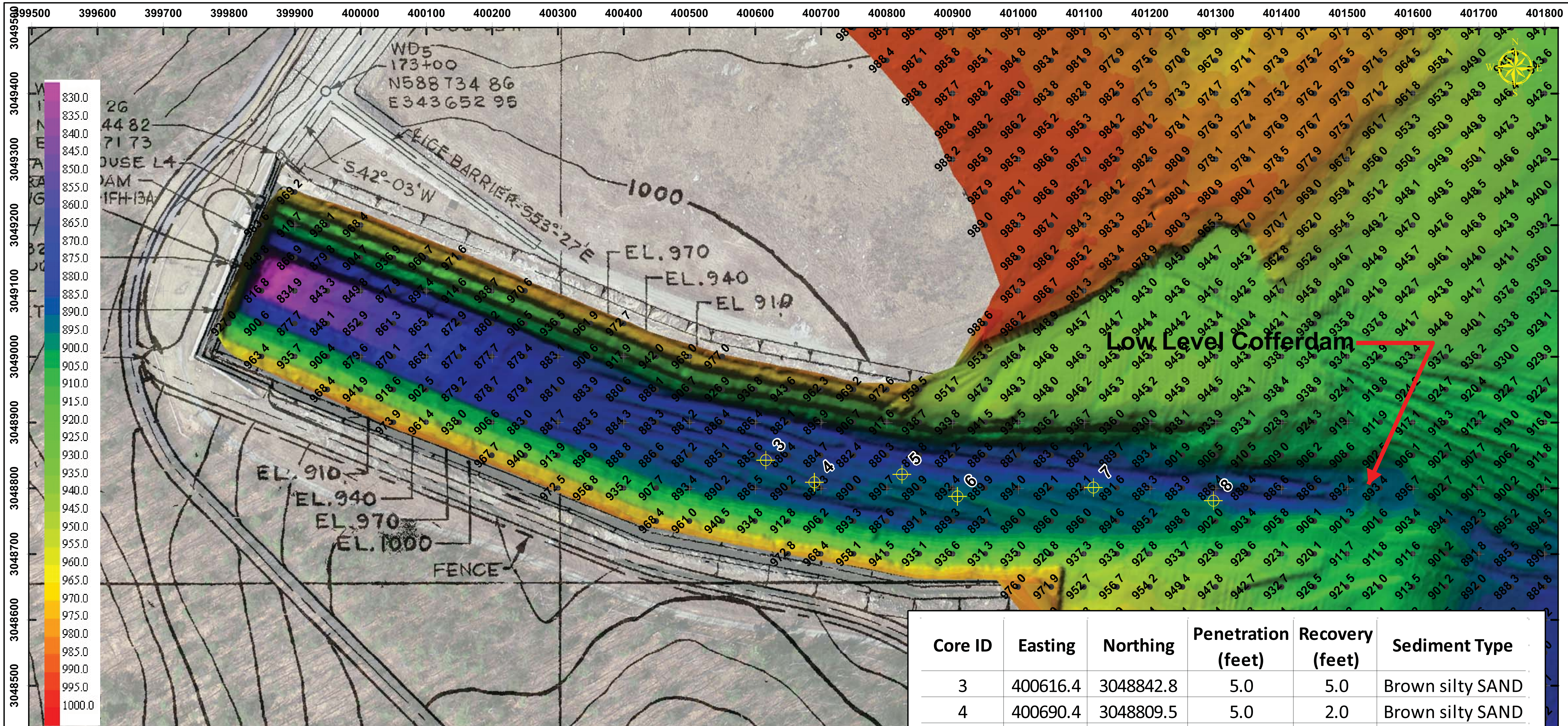
**Figure 4.1-6 Upper Reservoir Intake Channel Bathymetric Survey – 2014 to 2015 Change**






| Core ID | Easting | Northing | Penetration (feet) | Recovery (feet) | Sediment Type |
|---|---|---|---|---|---|
| 3 | 400616.4 | 3048842.8 | 5.0 | 5.0 | Brown silty SAND |
| 4 | 400690.4 | 3048809.5 | 5.0 | 2.0 | Brown silty SAND |
| 5 | 400823.3 | 3048821.3 | 3.0 | 3.0 | Brown silty SAND |
| 6 | 400907.5 | 3048787.9 | 6.0 | 4.0 | Brown silty SAND |
| 7 | 401114.1 | 3048801.3 | 6.0 | 3.0 | Brown silty SAND |
| 8 | 401296.6 | 3048781.2 | 1.0 | 0.3 | Brown silty SAND |

**Northfield Mountain Pumped Storage Facility 2015 General Condition Bathymetric Survey**

**Client: GDF Suez**

**Figure 4.1-7**

**Upper Reservoir Intake Channel Multibeam Bathymetric Survey Core Sample Locations**

SeaVision Figure 15-044-04
Drawn by: J. Snyder
Date: 11/1/2015

**Vicinity Map (N.T.S.)**


**Notes**

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 4, 2015 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet). Elevations are expressed in feet and reference the Northfield Mountain Pumped Storage Facility (NMPSF) Site Datum.

4. The NMPSF Site Datum is assumed to be an elevation of +0.389 eet relative to the North American Vertical Datum of 1988 (NAVD 1988).

5. Background aerial photographs have been taken from the publicly available digital imagery available through MassGIS and from electronic drawings provided by GDF Suez / FirstLight.

**Scale**

0 75 150 300
Feet

1 inch = 150 feet

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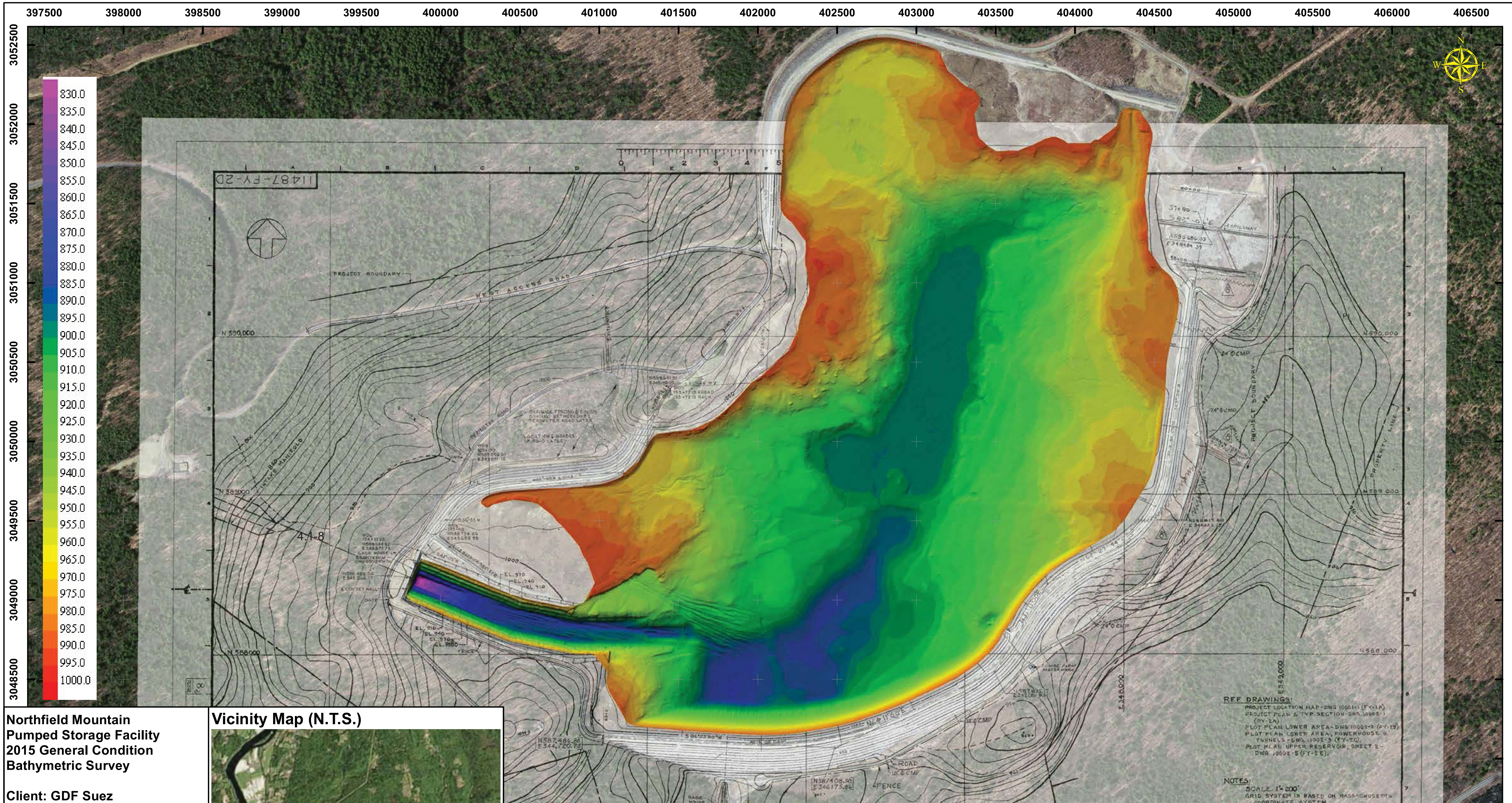


**Northfield Mountain Pumped Storage Facility 2015 General Condition Bathymetric Survey**

**Client: GDF Suez**

**Figure 4.1-8**

**General Condition Multibeam Bathymetric Survey Color Shaded Relief**

SeaVision Figure 15-044-01
Drawn by: J. Snyder
Date: 11/1/2015

## Vicinity Map (N.T.S.)


## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 4, 2015 and can only be considered to indicate the general conditions existing at that time.

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0 300 600 1,200
Feet

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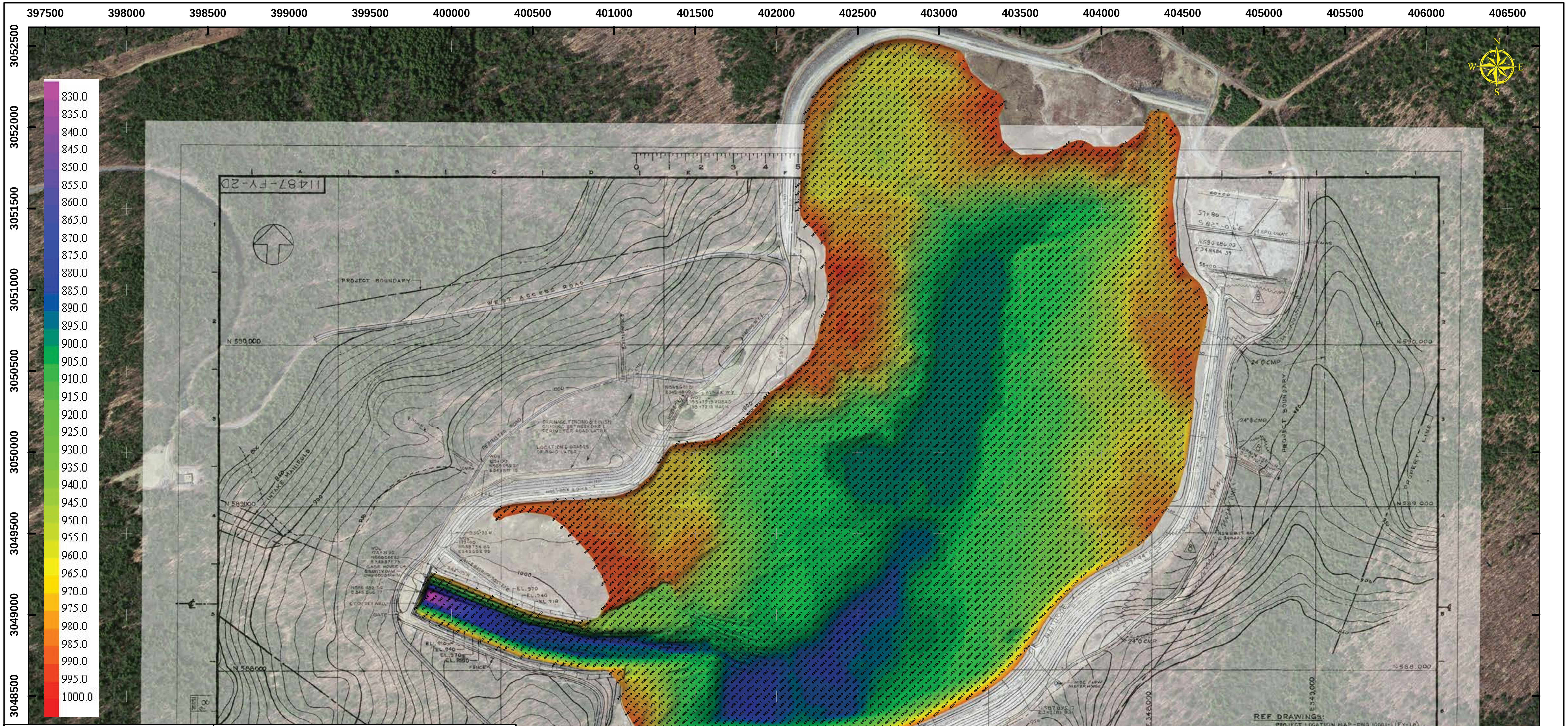


**Northfield Mountain Pumped Storage Facility 2015 General Condition Bathymetric Survey**

**Client: GDF Suez**

**Figure 4.1-9**

**General Condition Multibeam Bathymetric Survey Soundings**

SeaVision Figure 15-044-02
Drawn by: J. Snyder
Date: 11/1/2015

## Vicinity Map (N.T.S.)


## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 4, 2015 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

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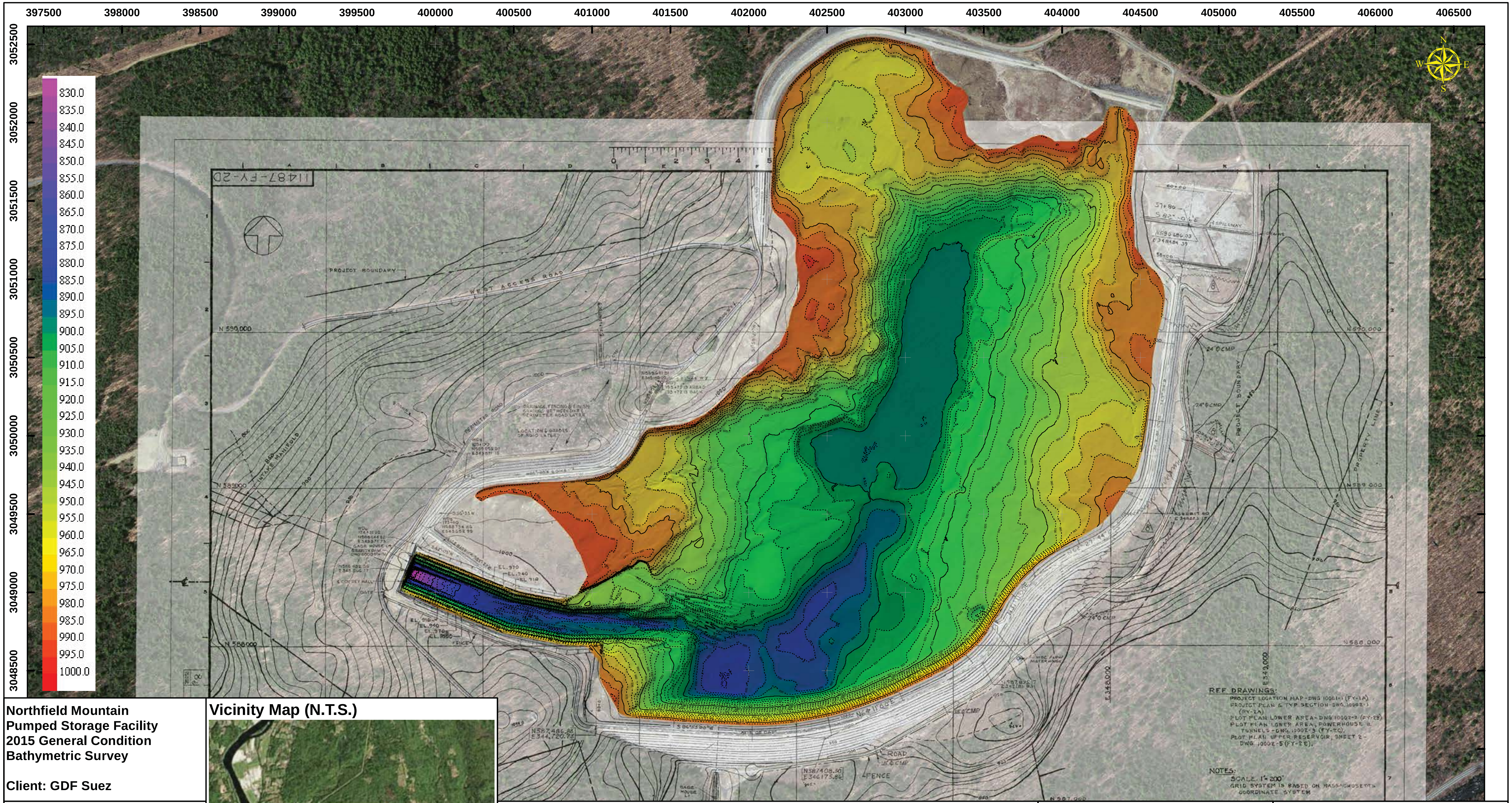


**Northfield Mountain Pumped Storage Facility 2015 General Condition Bathymetric Survey**

**Client: GDF Suez**

**Figure 4.1-10**

**General Condition Multibeam Bathymetric Survey Contours**

SeaVision Figure 15-044-03
Drawn by: J. Snyder
Date: 11/1/2015

## Vicinity Map (N.T.S.)


## Notes

1. The bathymetry depicted on this drawing represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on October 4, 2015 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a SBG Ekinox Intertial Navigation / Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Norbit 455 kHz WBMS Multibeam Echosounder to collect the data.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet). Elevations are expressed in feet and reference the Northfield Mountain Pumped Storage Facility (NMPSF) Site Datum.

4. The NMPSF Site Datum is assumed to be an elevation of +0.389 eet relative to the North American Vertical Datum of 1988 (NAVD 1988).

5. Background aerial photographs have been taken from the publicly available digital imagery available through MassGIS and from electronic drawings provided by GDF Suez / FirstLight.

## Scale

0 300 600 1,200
Feet

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## 4.2 Suspended Sediment Monitoring

Following successful QA and post processing of the suspended sediment monitoring data (continuous LISST data and grab samples) timeseries plots were developed comparing flow, Project operations (Vernon and Northfield Mountain), and SSC from 2013-2015. The timeseries plots were reviewed to identify annual, seasonal, and Project operations related patterns in SSC when compared against flow (naturally occurring), Vernon Project operations, and Northfield Mountain Project operations. From this initial review, several time periods of interest were then identified for further analyses on a finer scale. Section 4.2.1 discusses the results of these analyses.

In addition to the timeseries plots mentioned above, various plots and graphs depicting the cross-sectional data collected at the Rt. 10 Bridge (LISST-100X and grab samples) and the Northfield Mountain tailrace (LISST-100X) were developed to examine variations in SSC across the cross-section(s) and throughout the water column over a range of flow and operating conditions. Results of these analyses are found in Section 4.2.2.

### *4.2.1 Comparison of Point and Continuous Measurements to Flow and Operations*

This section presents the results of a number of analyses including:

- Seasonal SSC patterns and trends observed in relation to flow;
- SSC patterns and trends observed in relation to flow and Project operating conditions at Vernon; and
- SSC patterns and trends observed in relation to flow and Project operating conditions at Northfield Mountain

Timeseries plots for 2013, 2014, and 2015 are presented in Appendix C and D. Additional plots depicting periods of interest are presented throughout this section of the report. All suspended sediment monitoring data collected from 2013-2015 are included in Appendix F.

*Seasonal SSC patterns and trends observed in relation to flow – Connecticut River*

Suspended sediment measurements collected by the StreamSide and from grab samples collected in the vicinity of the StreamSide pump demonstrate strong correlations between flow and SSC. Over the course of the study it was observed that as Connecticut River flows increase so too did SSC. That is, the highest SSC values were observed during the highest periods of flow while the lowest SSC values were observed during the lowest period of flows. This was a consistent observation for each year data were collected. Figure 4.2.1-1 demonstrates this relationship.

As shown in Figure 4.2.1-1, SSC values were relatively low and without an apparent trend when flows from Vernon Dam were below 12,000 cfs. 95% of SSC measurements observed when flows were below 12,000 cfs were below 14.5 mg/L with a median of 2.9 mg/L. From 12,000 to 35,000 cfs, SSC values exhibited an increasing trend with a median of 12.45 mg/L. Finally, SSC values associated with flows greater than 35,000 cfs increased more quickly with flow and were significantly higher with a median of 144.61 mg/L. The results of this analysis demonstrate that three flow thresholds generally exist in the Impoundment in regard to SSC values: <12,000 cfs, 12,000-35,000 cfs, and >35,000 cfs.

Figure 4.2.1-2 depicts the flow duration curve for Vernon discharge from April through November for the years 2013-2015. As shown on the flow duration curve, flows of 12,000 cfs or less were equaled or exceeded 63% of the time, flows between 12,000-35,000 cfs were equaled or exceeded 32% of the time, while flows greater than 35,000 cfs were equaled or exceeded 5% of the time during the course of the study.

Furthermore, the hydrology of the Connecticut River in the study area is very much driven by the season. The seasonal hydrology pattern observed in the study area is defined by: 1) a spring freshet typically occurring in late March and into May when the highest annual flows are typically observed (barring a significant basin wide rain event or Hurricane in the summer or fall); 2) moderate flows throughout the early summer as the spring freshet subsides; 3) low flows throughout the summer and early fall; and 4) low to moderate flows during the fall. Significant basin wide or local rain events occasionally cause spikes in flow and SSC during the summer and fall before conditions return to a lower, more steady state. Table 4.2.1-1 denotes the range of flows observed during the course of the study broken out by season. Figures 4.2.1-3 – 4.2.1-5 depict SSC and flow values for the spring freshet's in 2013, 2014, and 2015 while Figures 4.2.1-6 and 4.2.1-7 depict a typical summer and fall period, respectively.

*SSC patterns and trends observed in relation to Vernon Project operating conditions – Connecticut River*

The Vernon Project is a peaking hydroelectric power plant located at the northern extent of the Turners Falls Impoundment approximately 9 miles upstream of the StreamSide/Rt. 10 Bridge. The hydraulic capacity of Vernon is 17,130 cfs. That is, Connecticut River discharge at or below 17,130 is regulated by Vernon while flows greater than 17,130 cfs spill through the Vernon Dam tainter gates. Figure 4.2.1-8 depicts SSC values as related to a typical Vernon peaking sequence when flows are below 17,130 cfs. Further observations of Vernon peaking operations in relation to Connecticut River SSC values can be found in the timeseries plots contained in Appendix C.

As discussed in the previous section, flows below 12,000 cfs typically corresponded to low SSC levels without an increasing trend. Apparent increases in SSC were typically not observed during peaking events. The increasing pattern of SSC between 12,000 and 17,130 cfs may have been the result of increased flow upstream of Vernon that was nearing or exceeding Vernon's hydraulic capacity.

*SSC patterns and trends observed in relation to Northfield Mountain Project operating conditions – Northfield Mountain Tailrace*

The StreamSide, HYDROs, and grab sample data were analyzed in relation to flow and Northfield Mountain operating conditions (pumping and generating) to examine the following:

- If an increase in SSC values were observed during pumping or generating cycles (or both) and if the number of units online had an effect
- How varying levels of SSC in the mainstem could impact the Project during pumping and generating cycles
- If differences existed between the SSC values recorded at the north and south banks of the tailrace over a range of flow and operating conditions

Three representative time periods were examined in detail, during which a range of flows and operational conditions were observed. These time periods included:

- A spring freshet when flows increased to a level greater than 35,000 cfs (April 7-21, 2014);
- A moderate flow period when flows were between 12,000 – 35,000 cfs (April 21-28, 2014); and
- A low flow period when flows were less than 12,000 cfs (August 2014)

During the spring freshet time period (Figures 4.2.1-9 and 4.2.1-10) mainstem SSC values (as measured at the StreamSide) increased rapidly with flow, were generally high, and followed a pattern similar to the river flow. During the same spring freshet time period, SSC measurements as recorded at the HYDROs were comparable to those measured in the mainstem (at the StreamSide) when the Project was pumping, meaning that pumping had no discernable impact on mainstem SSC levels. Alternatively, SSC values lower than those observed in the mainstem were observed when the Project was generating. This suggests that the Project was pumping more suspended sediment into the Upper Reservoir than it was transporting back to the river, which is consistent with the bathymetry results discussed in Section 4.1 indicating the accumulation of sediment in the Upper Reservoir over time. There was no clear pattern in relation to the number of units operating. When the Project was idle, or occasionally when only generating one unit, variability in the SSC levels in the tailrace can be observed; this is more likely due to changing currents in the vicinity of the tailrace than effects associated with the Project. During high flow periods, correlations between Project operations and increased mainstem SSC levels were not observed.

Review of the moderate flow scenario plot (Figure 4.2.1-10) demonstrates a similar pattern as was observed when reviewing the high flow scenario, although at lower SSC levels. SSC data measured at the HYDROs tended to be lower than mainstem SSC data measured at the StreamSide when the Project was idle or generating. During pumping operations, higher SSC values more comparable to mainstem SSC values were observed. The relatively lower measurements during generation combined with measurements similar to those observed in the mainstem during pumping suggests that suspended sediment was accumulating in the Upper Reservoir, although in lower quantities than observed during the high flow scenario. During moderate flow periods, correlations between Project operations and increased mainstem SSC levels were not observed.

During the low flow period (Figures 4.2.1-12 – 4.2.1-14), SSC values observed in the river were also very low, and differences in SSC between generation and pumping cycles were negligible, with the exception of a mid-summer rain event that occurred on August 14-15, 2014 (Figure 4.2.1-13). The effects of this rain event resulted in suspended sediment accumulation in the Upper Reservoir. The effects of this rain event lasted for approximately four days until SSC at the Project settled back into a more steady, low flow pattern. Similar to the moderate and high flow periods, correlations between Project operations and increased mainstem SSC levels were not observed.

*SSC patterns observed across the Northfield Mountain Tailrace*

Data collected at the Northfield Mountain tailrace were also compared to determine if SSC levels differed between locations (north vs. south bank) over a range of flow and operating conditions. During 2015, grab samples were taken from edge-of-water locations that corresponded to the LISST instrument locations. The paired grab samples from the north and south banks of the Northfield Mountain tailrace were then analyzed for differences in suspended sediment concentrations between both banks (Figure 4.2.1-15). For all paired samples, no significant difference was found in suspended sediment concentrations between the north and south banks (K-S test $p = 0.9592$). For paired samples that were taken during the pumping and generating cycle, no differences in suspended sediment concentration on either bank were found (K-S test $p = 0.6208$ and 0.9971 respectively).[20] Similar to cross-sectional results from the LISST-100X sampling, no differences were found from bank to bank. Based on the results of this comparison it was determined that differences between the two banks were negligible.

This differs from what was observed from the two HYDRO instruments, which were of the same design. HYDRO measurements provided were often different given that each instrument had unique lenses and the technical difficulties encountered were instrument-specific. Therefore, differences between measurements of the instruments were deemed to be due to instrumental or sampling error (i.e. indirect laser scattering measurements), rather than actual differences in suspended sediment concentration.

[20] The p-value represents the probability that the two groups of samples were collected from the same water over the course of sampling. Further discussion regarding this test can be found in Section 3.2.3

**Table 4.2.1-1 Seasonal Range of Flows and SSC (2013-2015)**

| Season | Months | Flow Range (cfs) | Median Flow (cfs) | SSC Range (mg/L) | Median SSC (mg/L) |
|---|---|---|---|---|---|
| Spring 2013 | April - June | 2,251-55,570 | 14,751 | 0.17-163.46 | 5.28 |
| Summer 2013 | July & August | 1,318-61,733 | 8,750 | 0.29-149.62 | 5.20 |
| Fall 2013 | September-November | 1,423-18,769 | 5,931 | 0.37-4.40 | 2.12 |
| Spring 2014 | April - June | 1,731-68,338 | 20,080 | 0.05-449.76 | 11.47 |
| Summer 2014 | July & August | 1,535-26,481 | 6,762 | 0.49-86.51 | 3.67 |
| Fall 2014 | September-November | 1,360-25,450 | 5,160 | 0.14-157.3979 | 6.36 |
| Spring 2015 | April - June | 1,668-66,725 | 15,340 | 2.00-43.02 | 10.68 |
| Summer 2015 | July -August | 1,346-27,042 | 4,718 | <0.5-42.7 | 1.5 |
| Fall 2015 | September-October | 1,521-32,910 | 1,949 | <0.5-61.2 | 1.6 |

**Figure 4.2.1-1 Turners Falls Impoundment SSC vs. Vernon Discharge (2013-2015)**

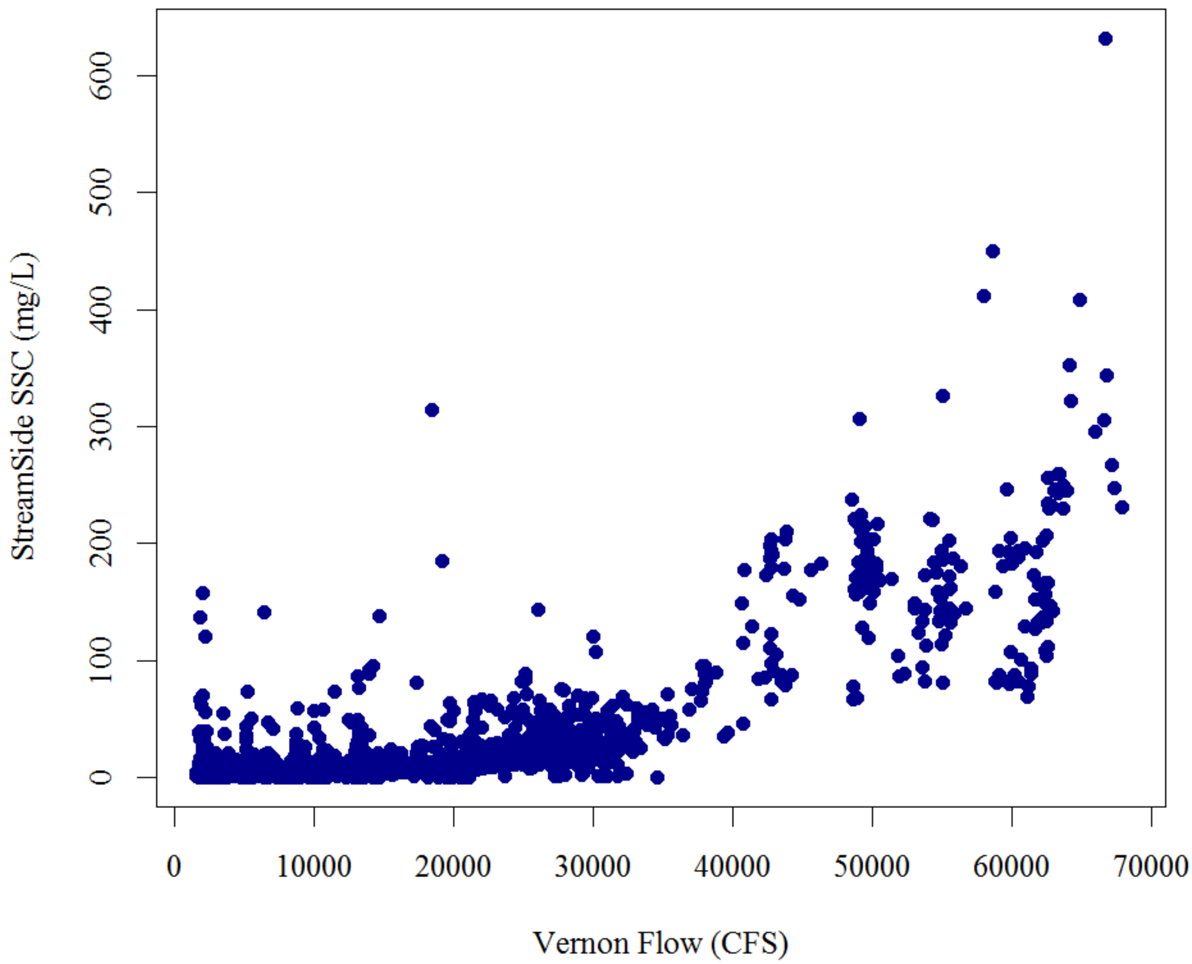


**Figure 4.2.1-2 Flow Duration Curve for the Turners Falls Impoundment**

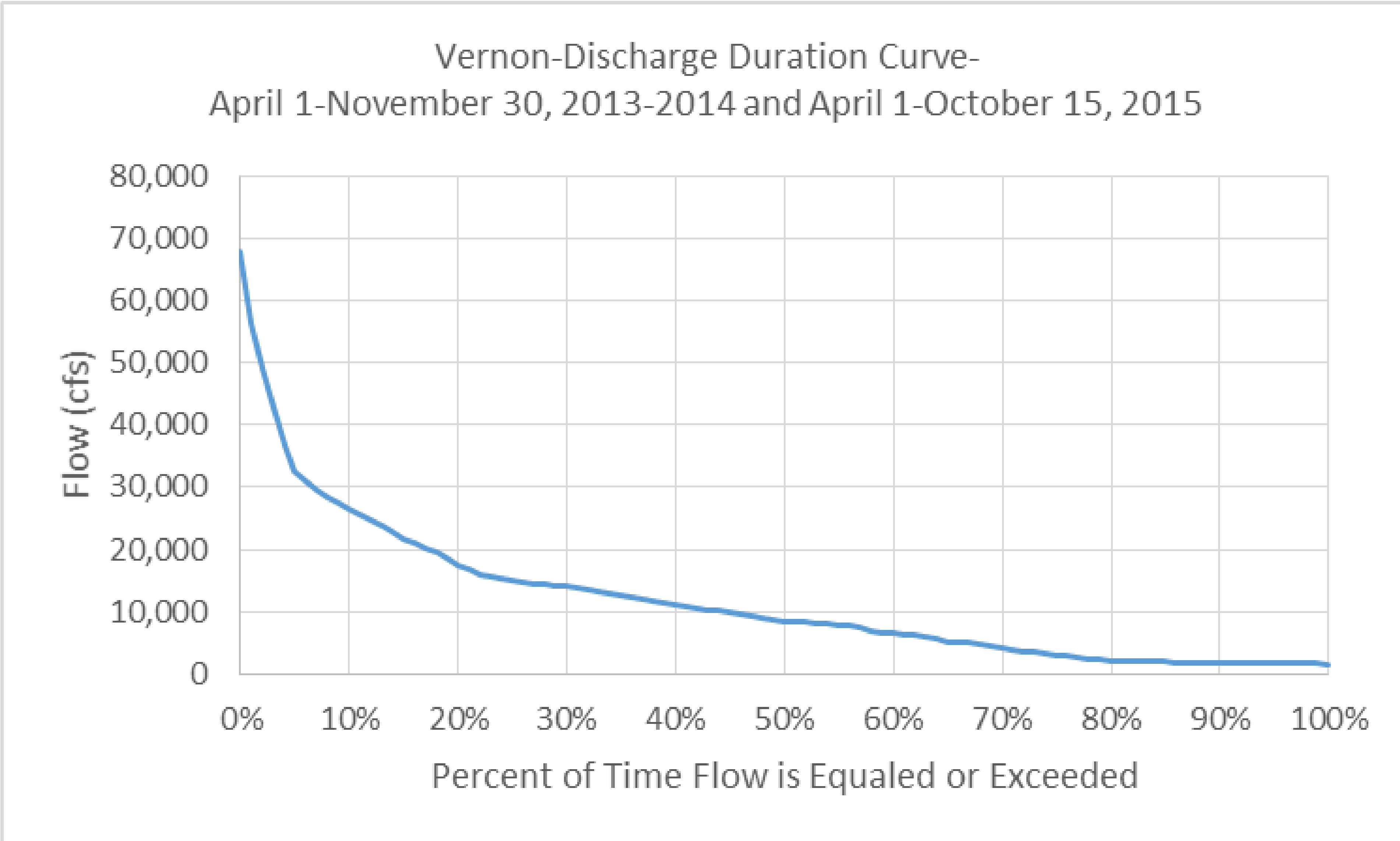


**Figure 4.2.1-3 2013 Spring Freshet – SSC vs. Flow (StreamSide)**

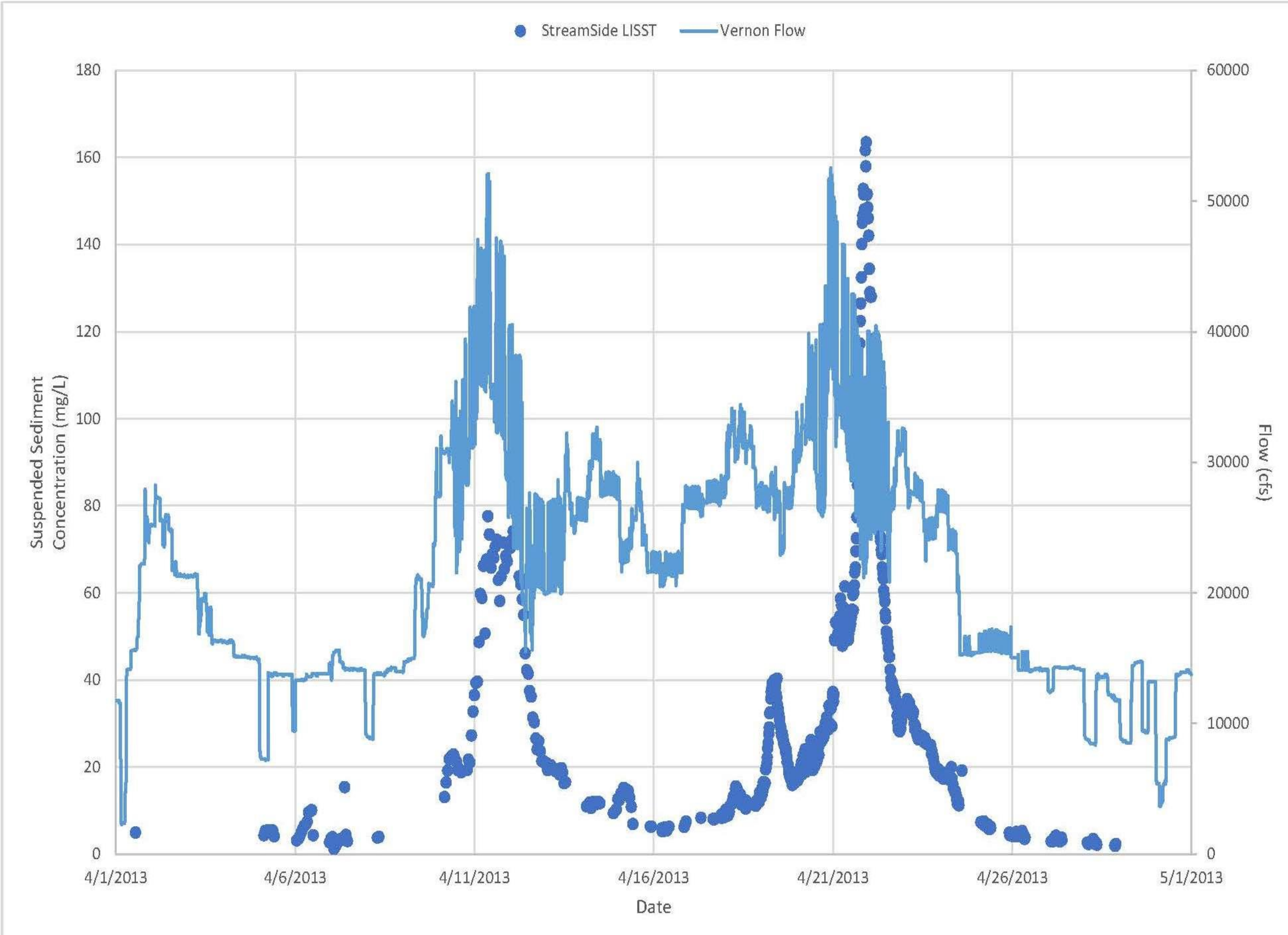


**Figure 4.2.1-4 2014 Spring Freshet – SSC vs. Flow (StreamSide)**

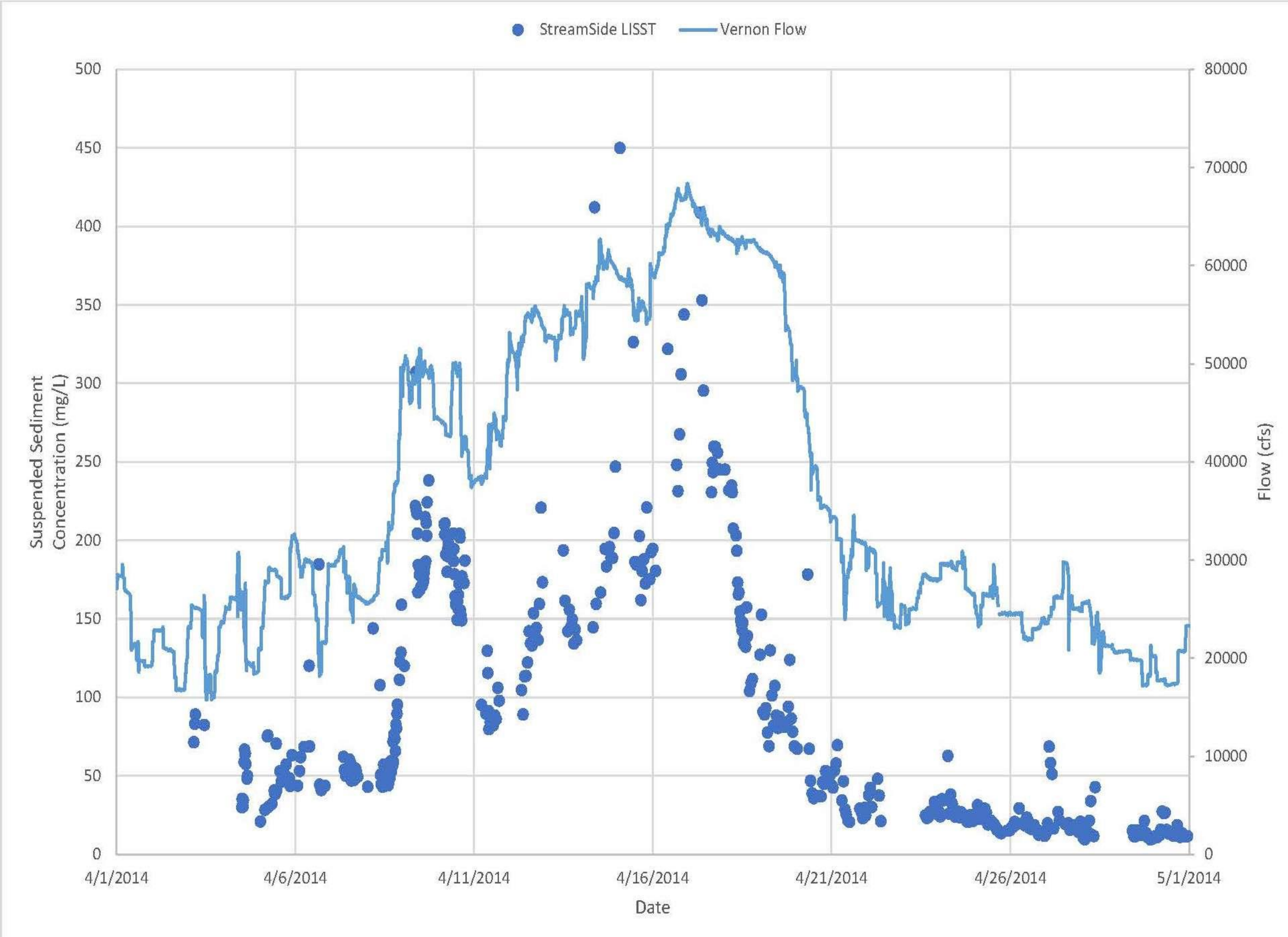


**Figure 4.2.1-5 2015 Spring Freshet – SSC vs. Flow (StreamSide)**

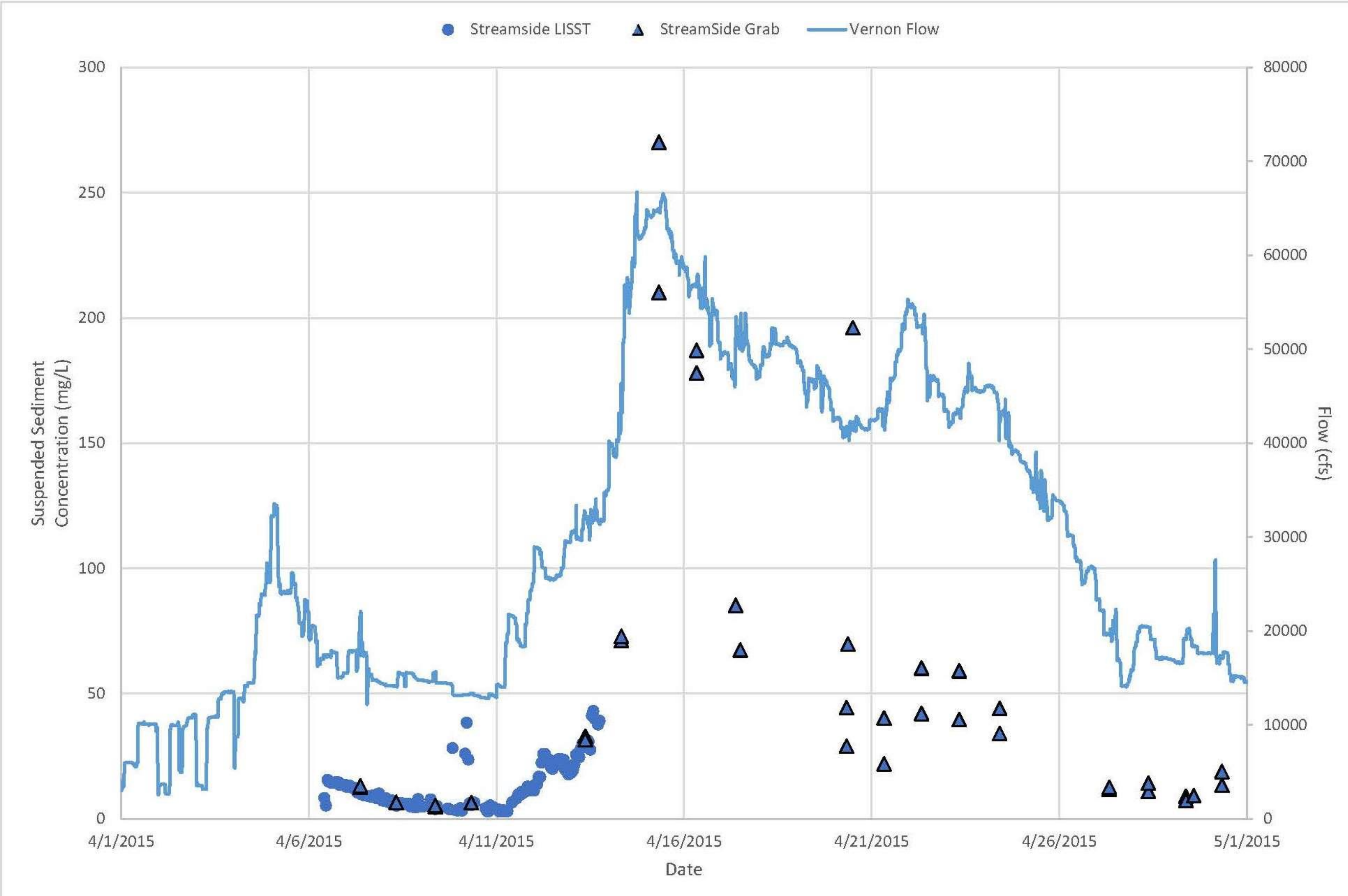


**Figure 4.2.1-6 Typical Summer Period – SSC vs. Flow (StreamSide)**

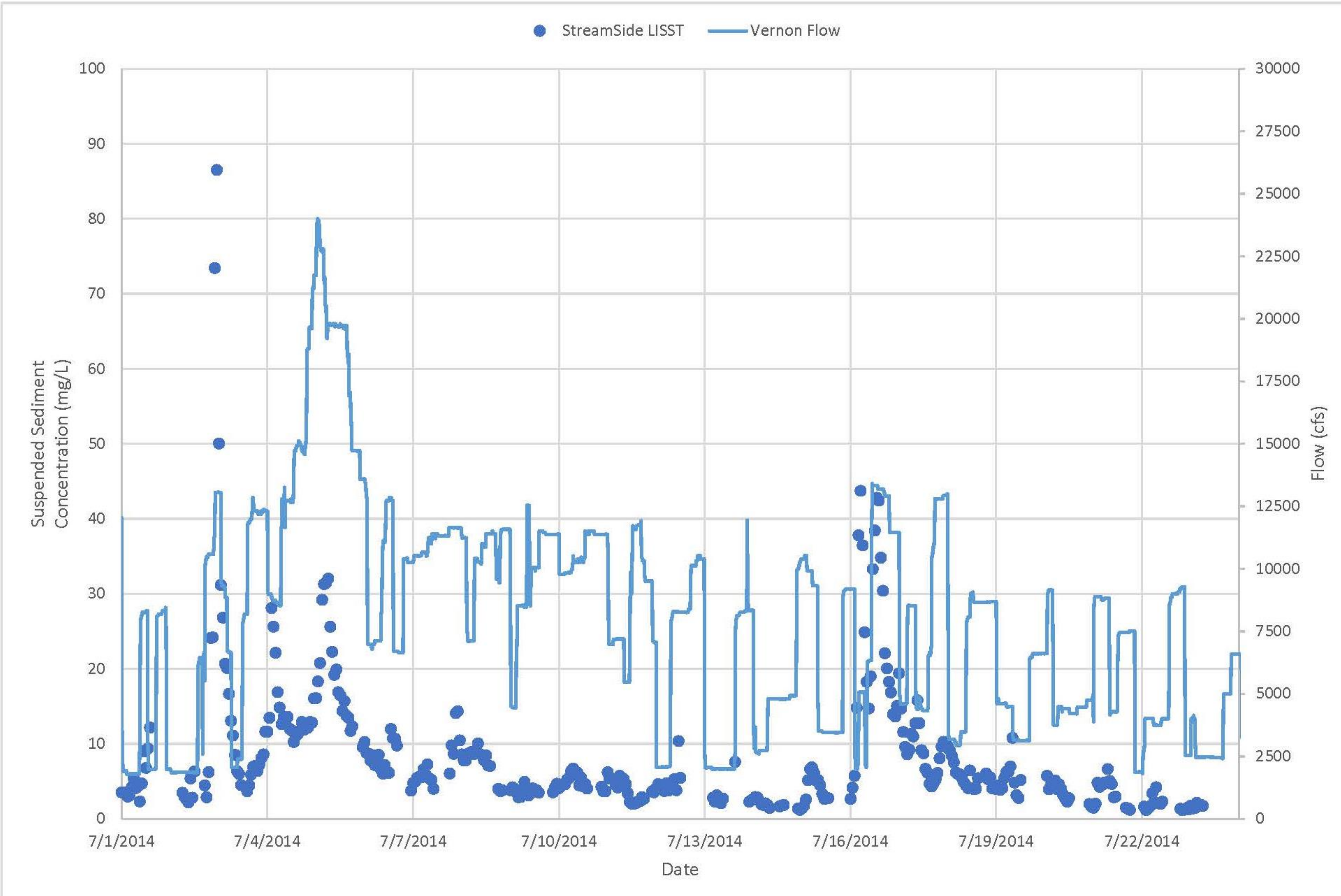


**Figure 4.2.1-7 Typical Fall Period – SSC vs. Flow (StreamSide)**

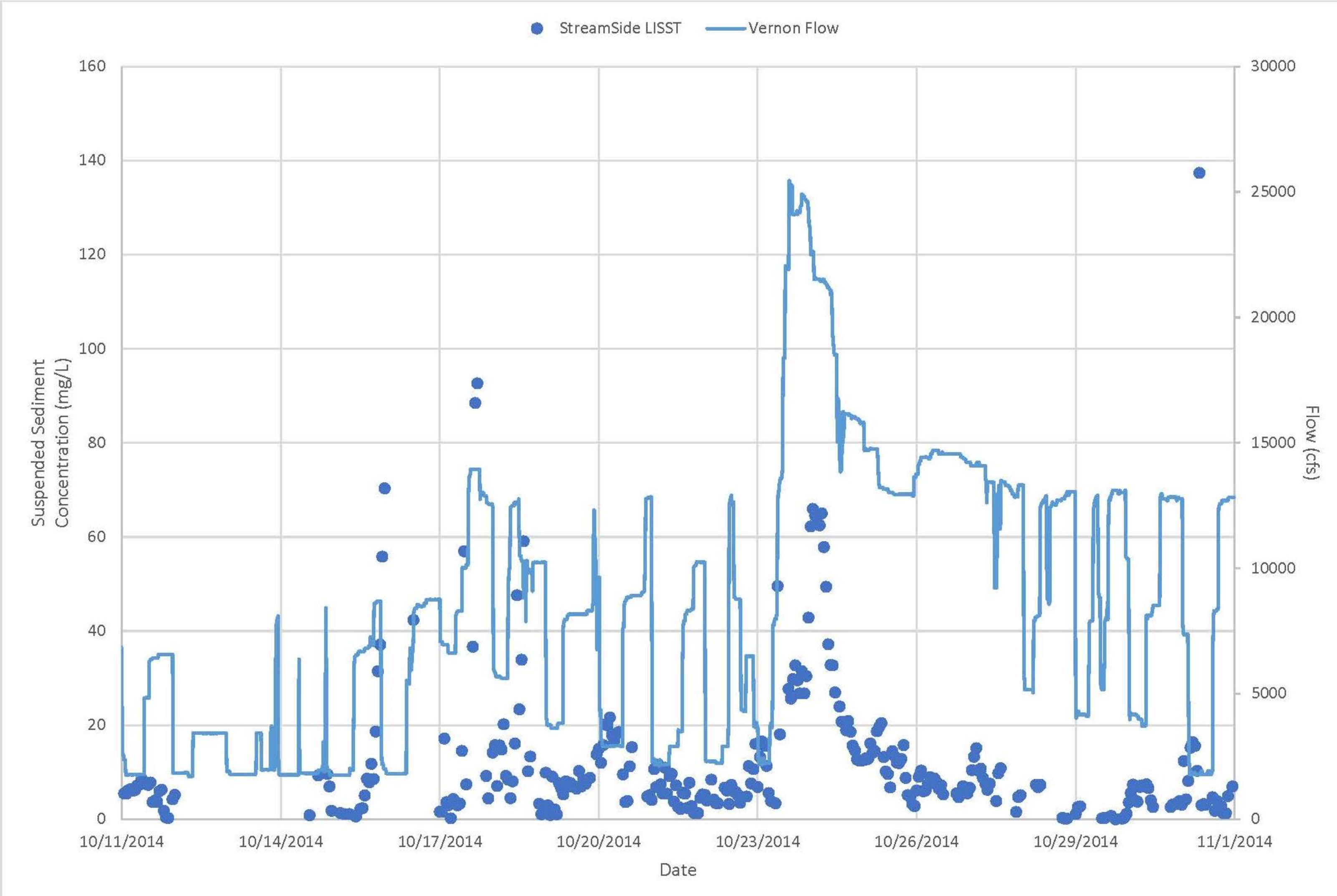


**Figure 4.2.1-8 Impoundment SSC Values as Related to a Typical Vernon Peaking Sequence**

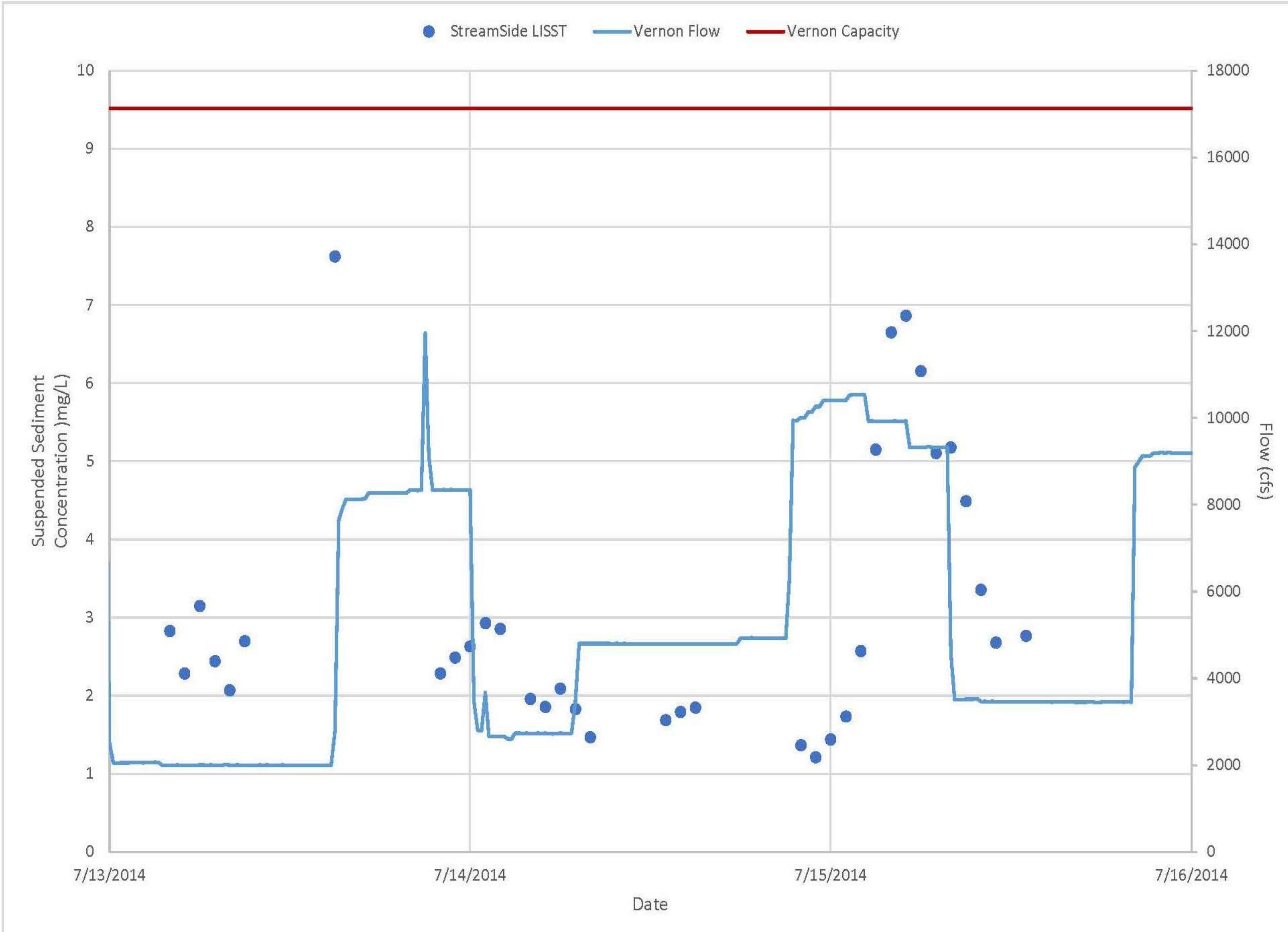


**Figure 4.2.1-9 Northfield Mountain Tailrace High Flow Scenario (April 7-14, 2014)**

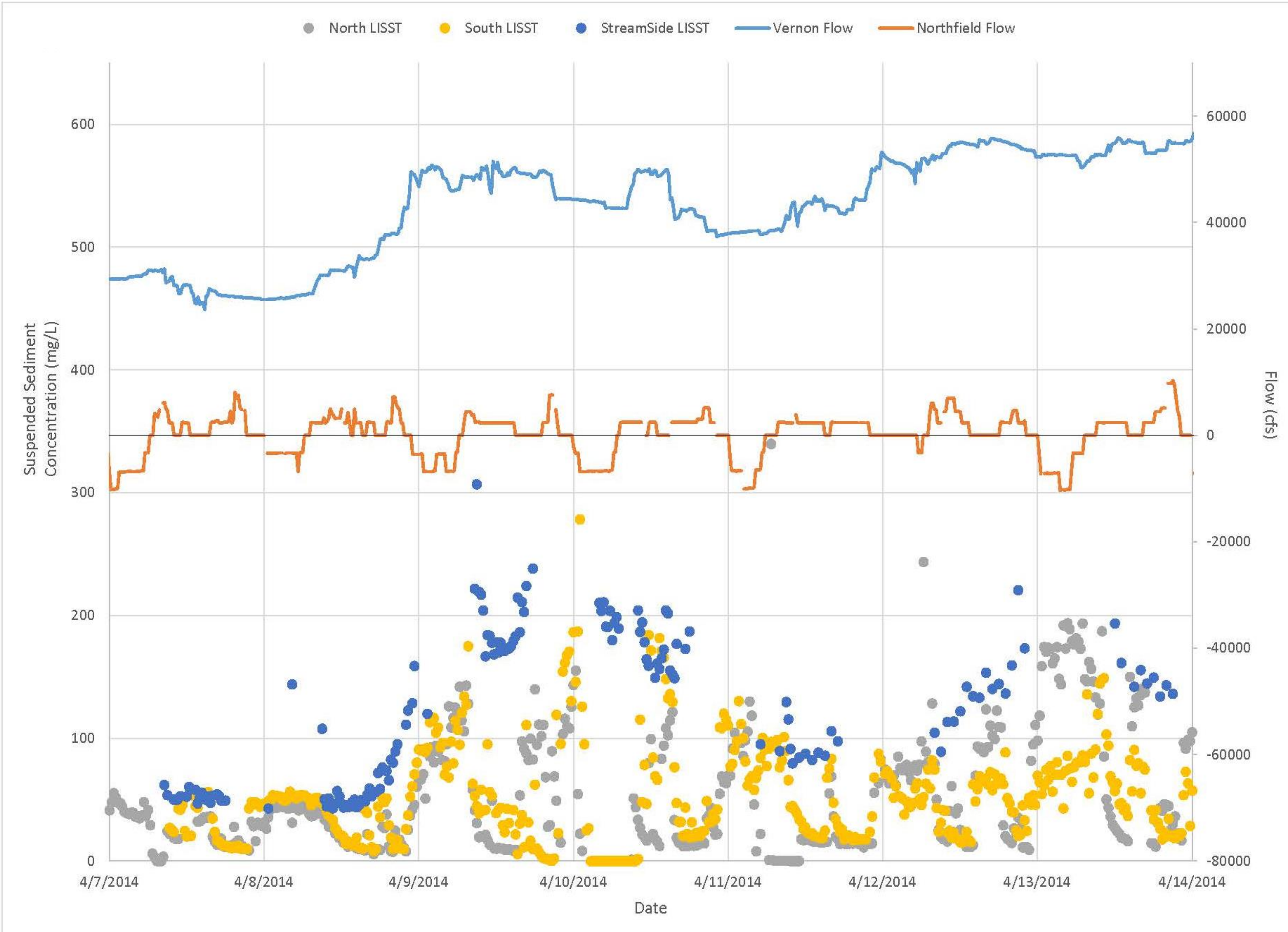


**Figure 4.2.1-10 Northfield Mountain Tailrace High Flow Scenario (April 14-21, 2014)**

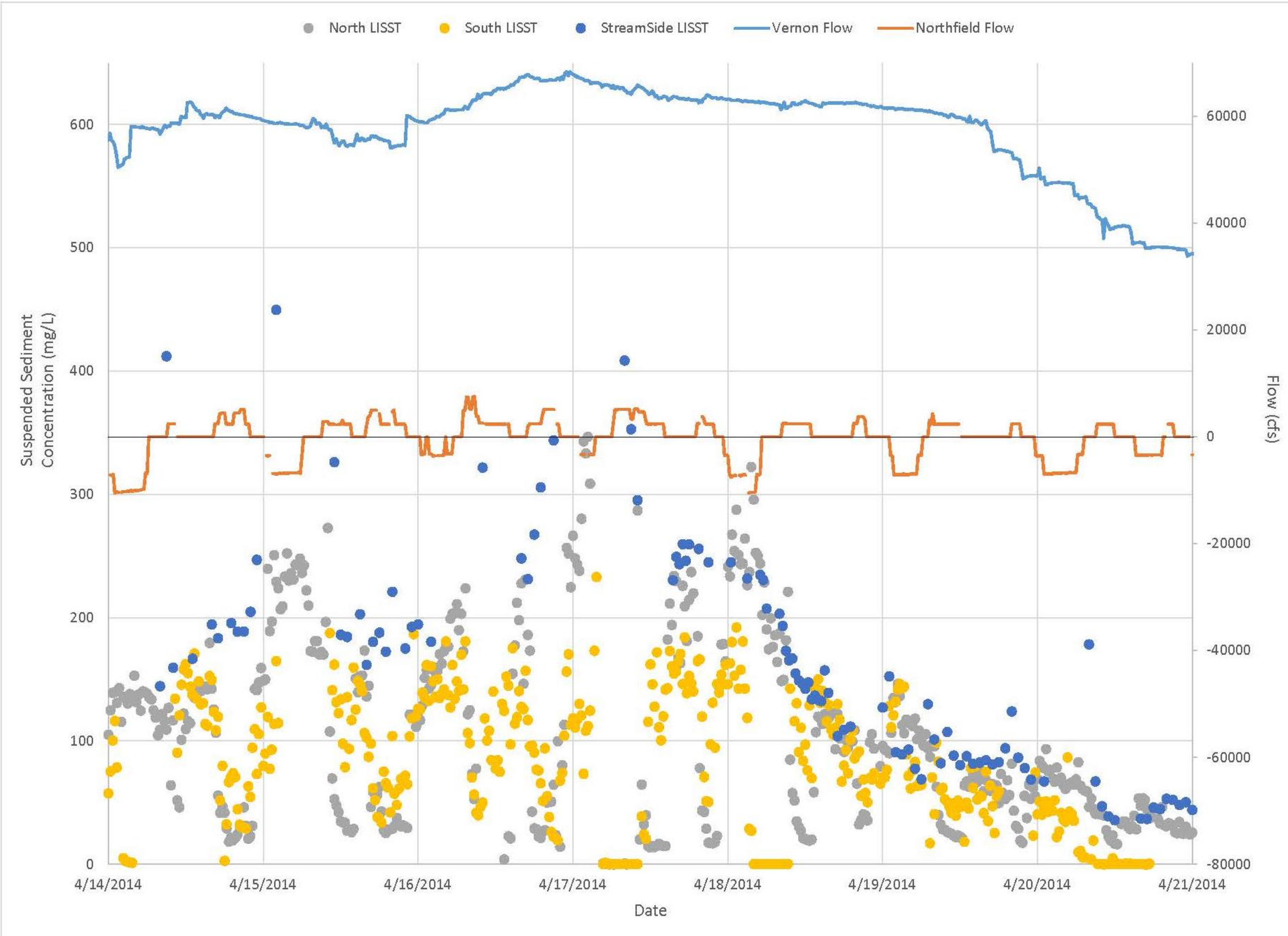


**Figure 4.2.1-11 Northfield Mountain Tailrace Moderate Flow Scenario (April 21-28, 2014)**

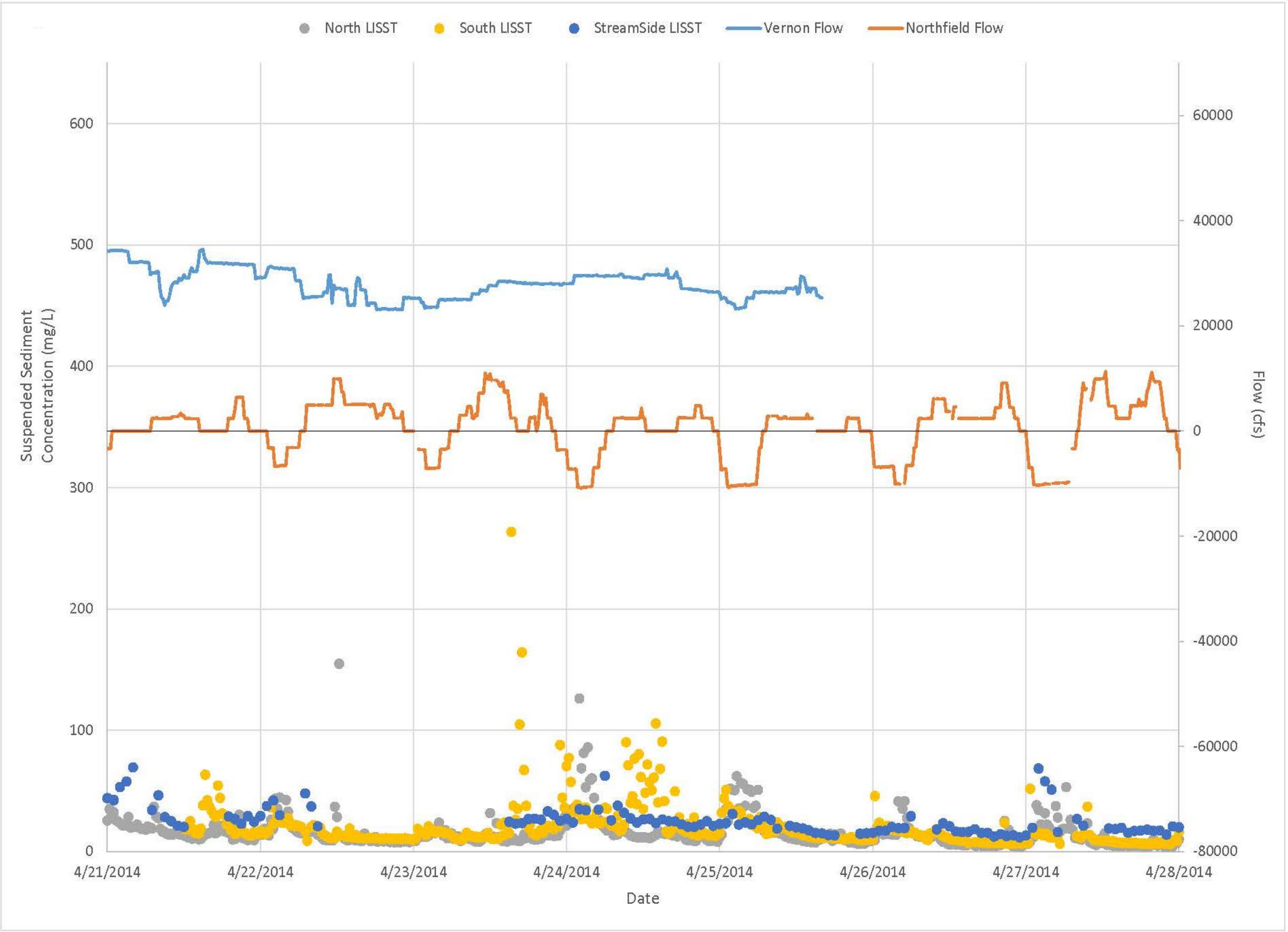


**Figure 4.2.1-12 Northfield Mountain Tailrace Low Flow Scenario (August 1-11, 2014)**

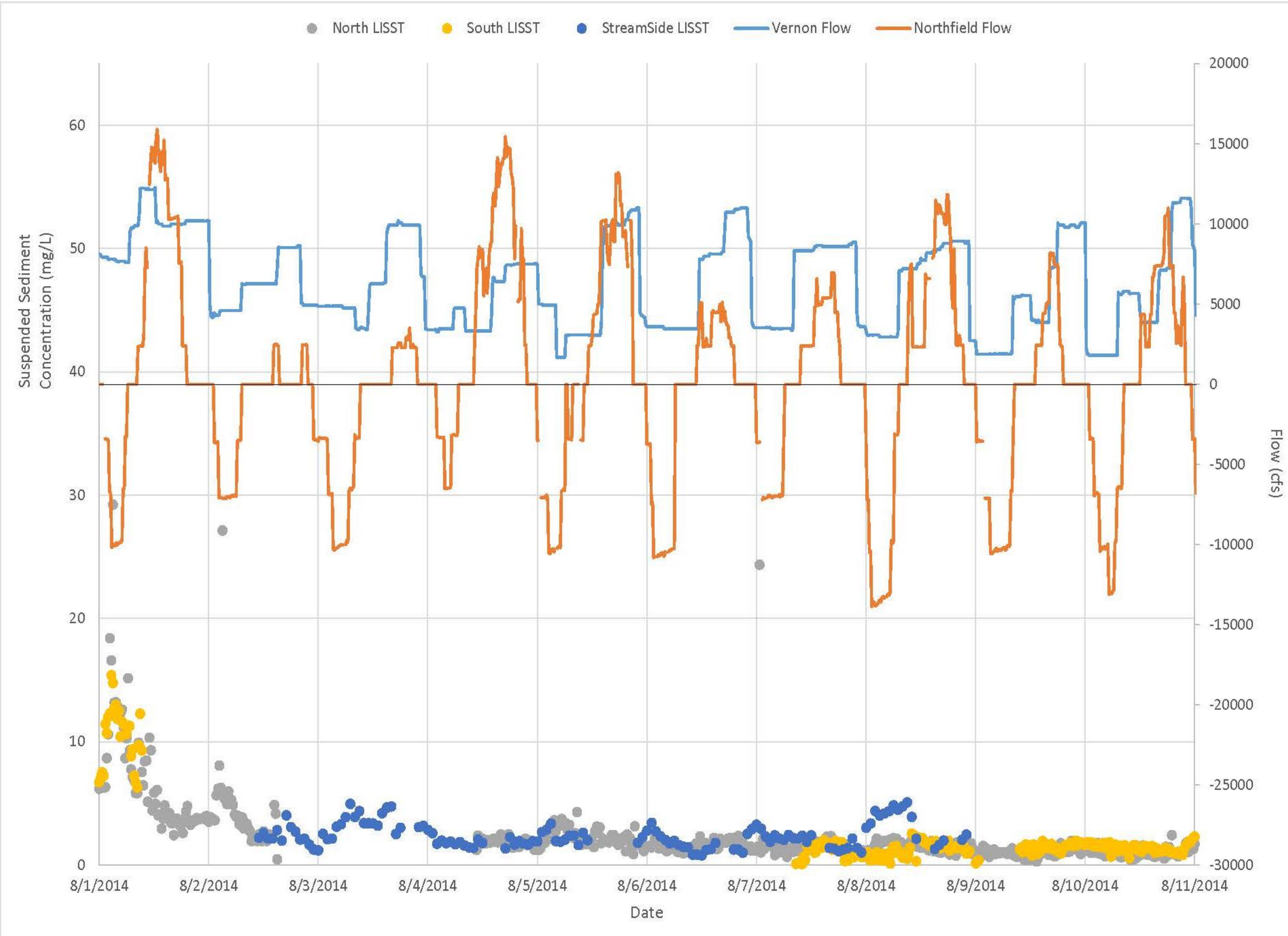


**Figure 4.2.1-13 Northfield Mountain Tailrace Low Flow Scenario (August 11-21, 2014)**

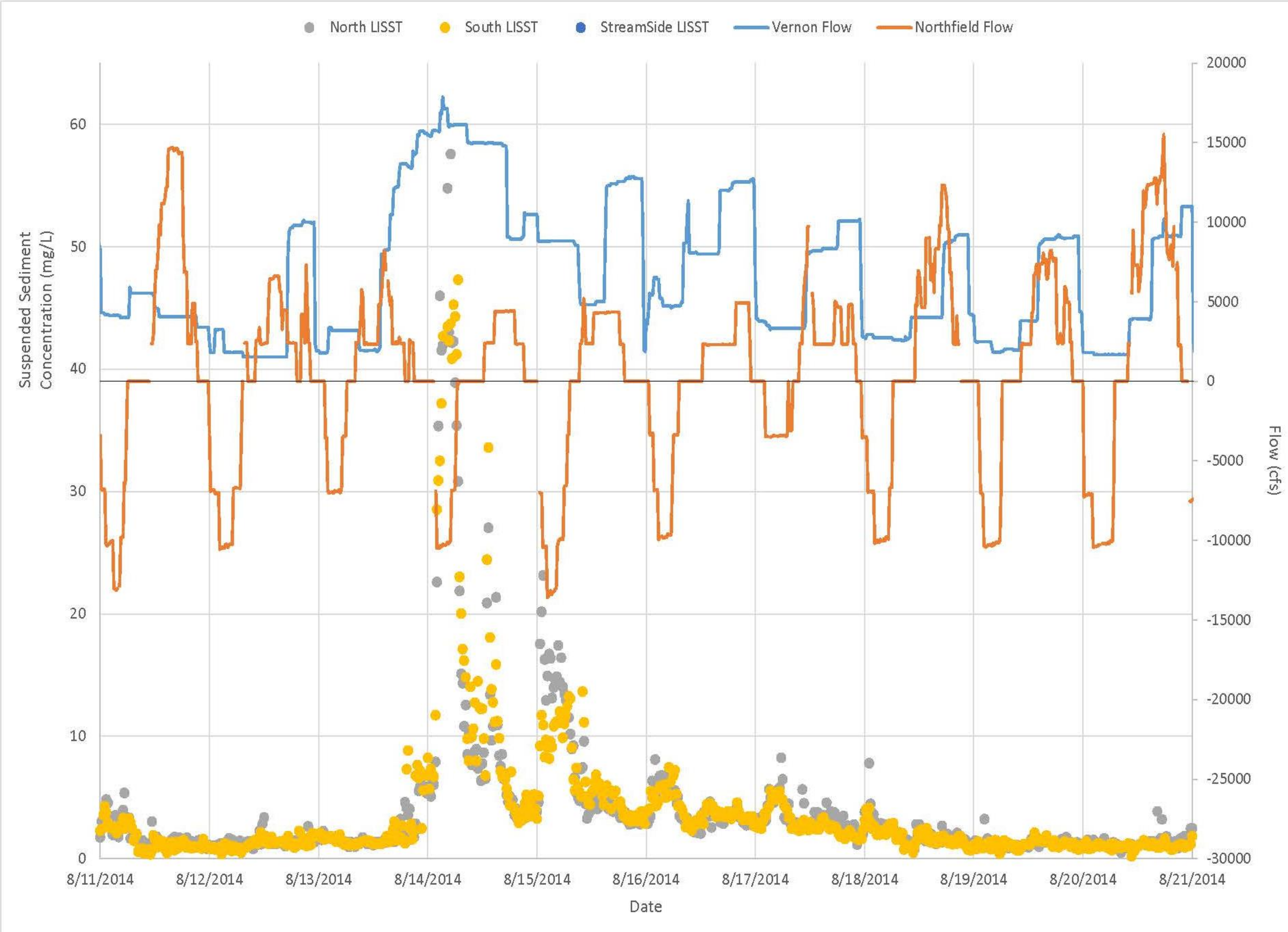


**Figure 4.2.1-14 Northfield Mountain Tailrace Low Flow Scenario (August 21-31, 2014)**

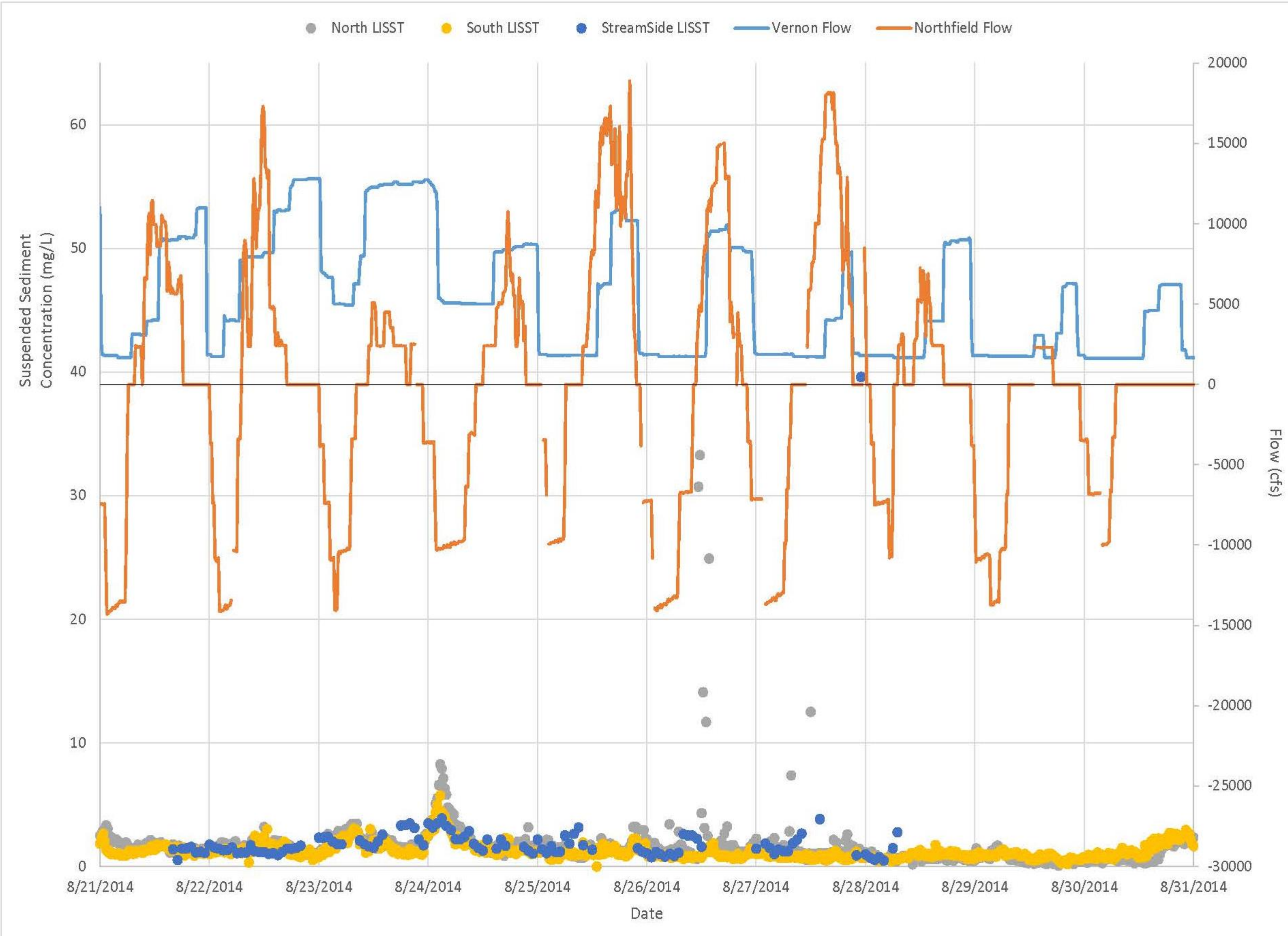
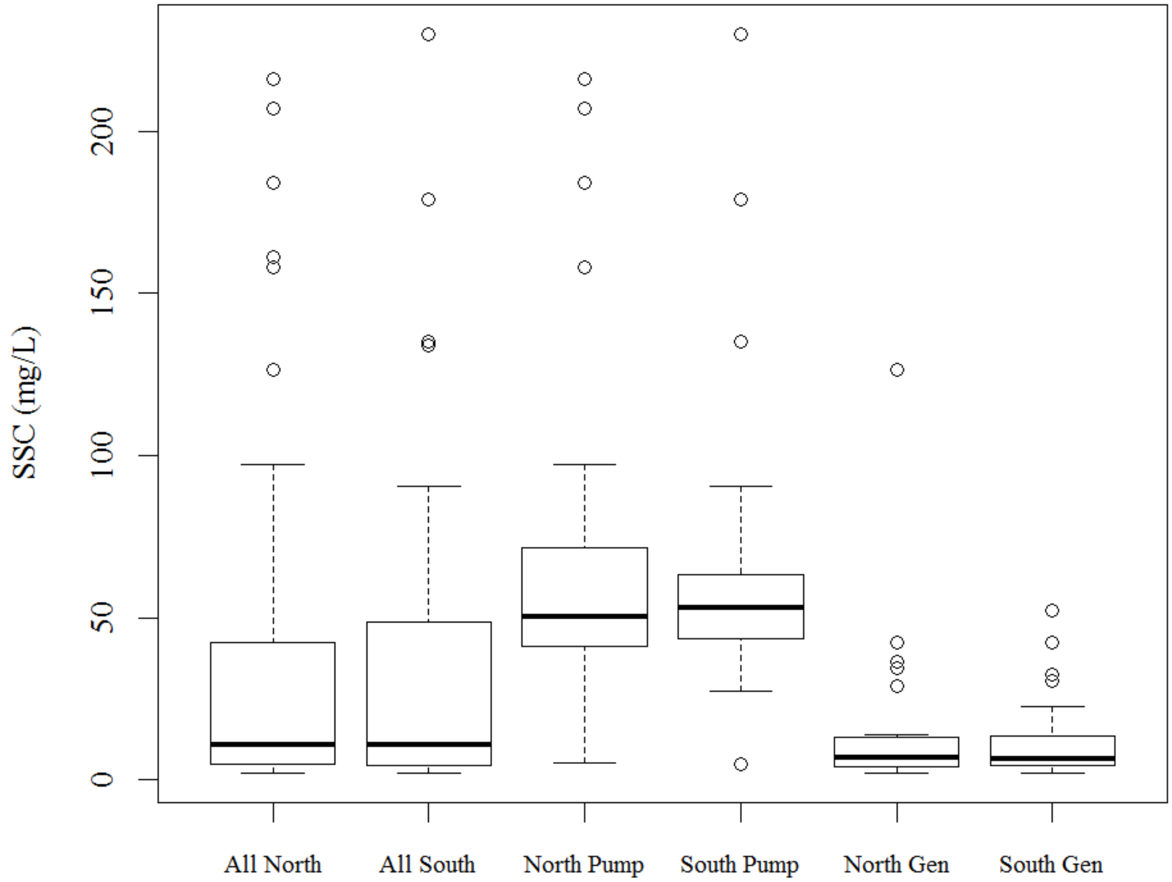


**Figure 4.2.1-15 Paired Northfield Mountain Tailrace Grab Samples**



### *4.2.2 Comparison of Cross-sectional Data - Rt. 10 Bridge and Northfield Mountain tailrace*

In 2013, cross-sectional data were collected at the Rt. 10 Bridge and Northfield Mountain tailrace boat barrier buoy line over a range of flow and operating conditions via a LISST-100X. In 2015, supplemental cross-sectional grab sample data were collected at the Rt. 10 Bridge via a Kemmerer. Data collected during 2013 and 2015 followed the EWI method. The purpose of the cross-section data was to develop a better understanding of SSC dynamics across a cross-section and with depth and to determine if the StreamSide and HYDRO pump locations were representative of cross-section conditions. This section presents the results of the cross-section data collection efforts.

*Rt. 10 Bridge Cross-section*

LISST-100X data were collected across the Rt. 10 Bridge on eight separate occasions in 2013 over a range of flows (Table 4.2.2-1). The LISST-100X data were used to identify patterns in the variation of SSC across the cross-section and with depth. Review of this dataset found that changes in SSC across the river and with depth were only observed during the highest flow event measured (Vernon discharge 31,382 on April 18, 2013). SSC values were highest on the left bank and near the bottom (Figure 4.2.2-1), though the range of measurements collected was only 5.4 µl/L. It was determined that the StreamSide pump was positioned in a location representative of the cross-section and that adjustments to the StreamSide data were not necessary. Appendix E contains various plots developed from the 2013 LISST-100X data.

Supplemental cross-section grab sample data were collected in 2015 on four separate occasions during the spring freshet (Table 4.2.2-2). Figure 4.2.2-2 depicts the hydrograph from this event as well as when grab samples were collected. Grab sampling events occurred during the rising limb, on either side of the peak, and across the falling limb. Grab samples were also collected from the edge-of-water in the vicinity of the StreamSide pump at the completion of the cross-section data collection to allow for direct comparison.

The results from the 2015 cross-section grab samples generally confirmed the findings of the LISST-100X data collection effort in 2013. SSC variation across the cross-section and with depth was not evident or was negligible during moderate flows (Figure 4.2.2-6). During higher flow, areas near the left bank exhibited slightly higher SSC values than the right bank, and SSC was often slightly higher with depth, particularly near the left bank (Figure 4.2.2-3 to 4.2.2-5). It should be noted that the cross-sectional surveys typically took approximately three hours to complete, which could also account for some of the variability. This may be particularly true of the April 14$^{th}$ and 17$^{th}$ sampling events, during which flow increased over the course of sampling.

Samples collected from the edge-of-water in the vicinity of the StreamSide pump were typically near or within the range of measurements from the cross-section. During the April 14$^{th}$ sampling event (Figure 4.2.2-3), the sample collected near the StreamSide (on the right bank) was comparable to the higher measurements observed from the cross-section near the left bank, but considerably higher than much of the remainder of the transect; this could be due to sample timing, given that flows and possibly SSC were increasing during this sampling event and the sample was collected near the StreamSide after the cross-sectional samples were collected. During the April 20$^{th}$ sampling event (Figure 4.2.2-5), SSC from the sample collected near the StreamSide was higher than expected based on the cross-sectional samples, though it was comparable to some of the higher measurements observed during cross-sectional sampling. The reason for this is unclear and could not be resolved in the absence of duplicate measurements, though potential explanations include sample timing, sample method, location, or laboratory sample issues. Samples collected near the StreamSide during the remaining two sampling events on April 17$^{th}$ and 28$^{th}$ (Figures 4.2.2-4 and 4.2.2-6) were comparable to the samples collected from the cross-section.

*Northfield Mountain Tailrace Cross-section*

LISST-100X data were collected on five occasions over a range of operating conditions across the Northfield Mountain tailrace boat barrier buoy line in 2013 (Table 4.2.2-3). Sediment concentrations did not change considerably by station or with depth, with measurements varying no more than 0.5 to 1.0 µl/L for the duration of the survey. Given these findings, it is likely that the pumps for the LISST HYDRO instruments are representative of the cross-section, and that a single instrument would suffice during the low river flow and SSC. Appendix E contains various plots developed from the 2013 LISST-100X data.

As previously reported, grab samples collected from near the surface at each bank did not differ from bank to bank under a range of flows and operational conditions, though it should be noted that tailrace sampling during higher river flows at different depths did not occur. FirstLight had proposed collecting supplemental grab sample data in 2015 at the Northfield Mountain tailrace cross-section during a moderate to high flow event (20,000-30,000 cfs). While these flow conditions did occur during the field season, sample collection did not occur due to safety concerns.

**Table 4.2.2-1 Summary of LISST-100X Data Collected at the Rt. 10 Bridge (2013)**

| Date | Vernon Discharge (cfs) | Max SSC (µl/L) | Min SSC (µl/L) | Median SSC (µl/L) |
|---|---|---|---|---|
| 4/18/2013 | 33,483 | 38.94 | 33.53 | 34.83 |
| 4/26/2013 | 15,980 | 10.54 | 10.26 | 10.42 |
| 5/2/2013 | 10,707 | 2.71 | 2.54 | 2.58 |
| 5/10/2013 | 10,070 | 4.11 | 3.73 | 3.97 |
| 10/3/2013 | 3,363 | 3.31 | 3.18 | 3.28 |
| 10/11/2013 | 5,450 | 5.40 | 4.92 | 5.02 |
| 10/16/2013 | 4,490 | 2.65 | 2.33 | 2.45 |
| 10/24/2013 | 4,278 | 3.94 | 3.73 | 3.84 |

**Table 4.2.2-2 Summary of Rt. 10 Bridge Cross Section Grab Samples (2015)**

| Date | Vernon Discharge (cfs) | Max SSC (mg/L) | Min SSC (mg/L) | Median SSC (mg/L) | StreamSide SSC (mg/L) |
|---|---|---|---|---|---|
| 4/14/2015 | 50,536 - 59,700 | 159 | 78.7 | 108 | 152 |
| 4/17/2015 | 47,970 - 52,591 | 106 | 80.3 | 89.3 | 82.1 |
| 4/20/2015 | 41,282 - 42,172 | 89.5 | 30.4 | 41.8 | 69.7 |
| 4/28/2015 | 19,112 - 20,437 | 13.5 | 6.1 | 11.5 | 12.5 |

**Table 4.2.2-3 Summary of LISST-100X Data Collected at the Northfield Mountain Tailrace (2013)**

| Date | Scenario | Naturally Routed Flow (cfs) | Max SSC (µl/L) | Min SSC (µl/L) | Median SSC (µl/L) |
|---|---|---|---|---|---|
| 10/10/2013 | Idle | 6,782 | 4.42 | 3.18 | 4.17 |
| 10/15/2013 | 1-Unit Gen | 4,171 | 2.14 | 2.08 | 2.07 |
| 10/23/2013 | 2-Units Gen | 4,640 | 2.90 | 2.28 | 2.62 |
| 10/26/2013 | 3-Units Gen | 4,955 | 3.10 | 2.63 | 2.77 |
| 10/26/2013 | 2-Units Pump | 4,955 | 3.10 | 2.25 | 2.45 |

**Figure 4.2.2-1 SSC Isopleth from Rt. 10 Bridge - April 18, 2013 (LISST-100X)**

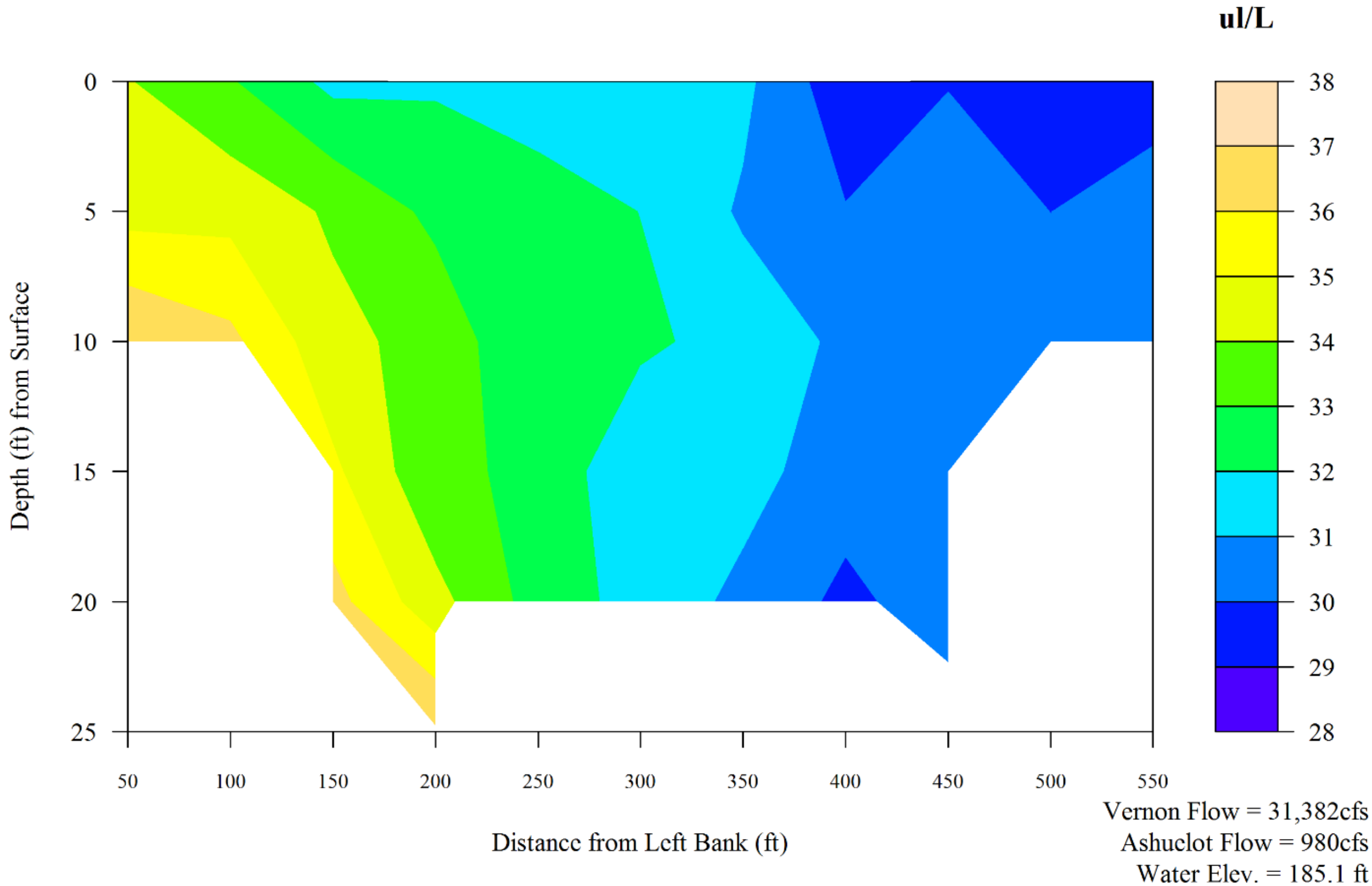


**Figure 4.2.2-2 Turners Falls Impoundment Hydrograph - Rt. 10 Bridge Grab Sample Data Collection**

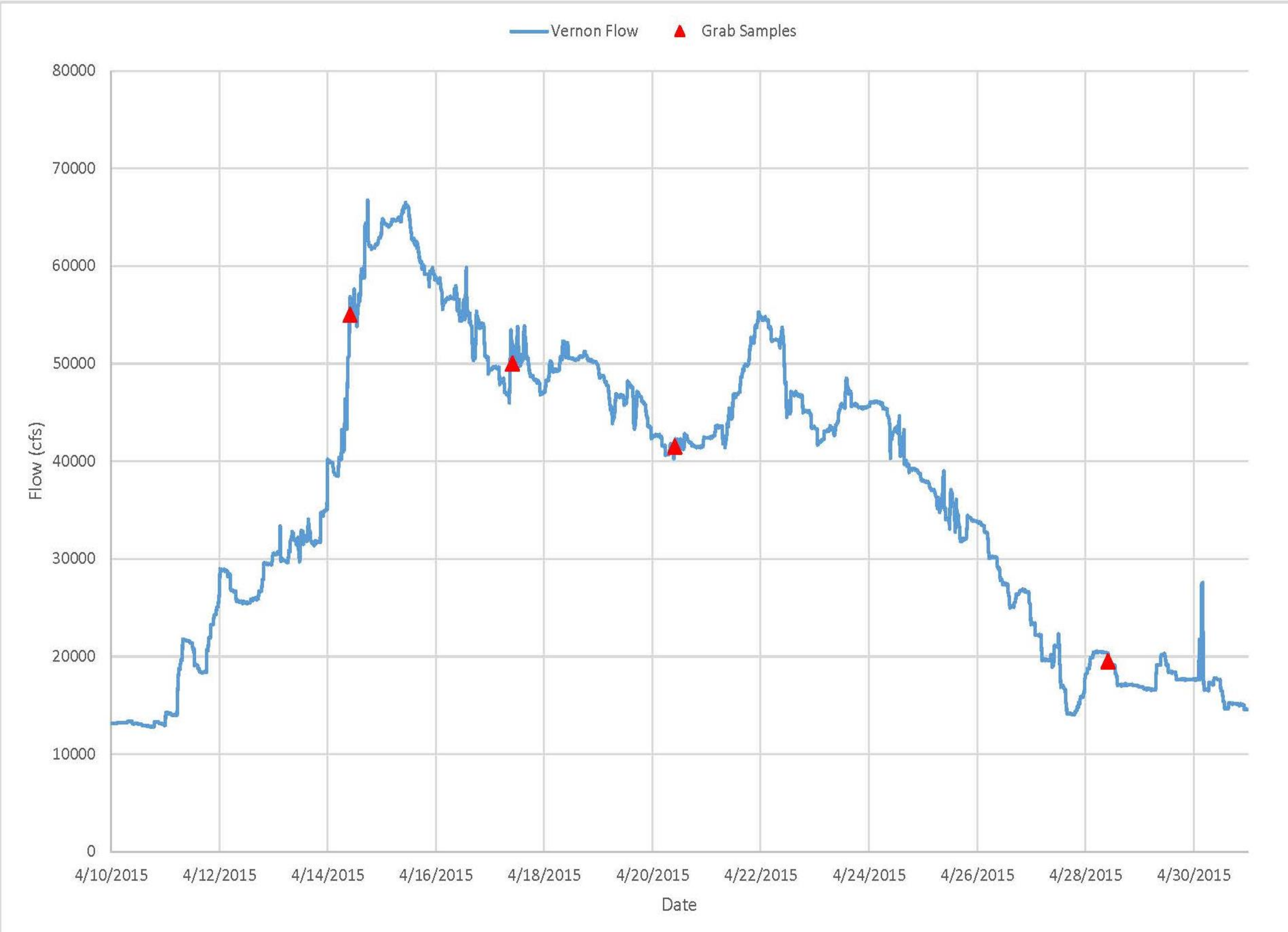


**Figure 4.2.2-3 Rt. 10 Bridge Cross-section Grab Sample Data (April 14, 2015)**

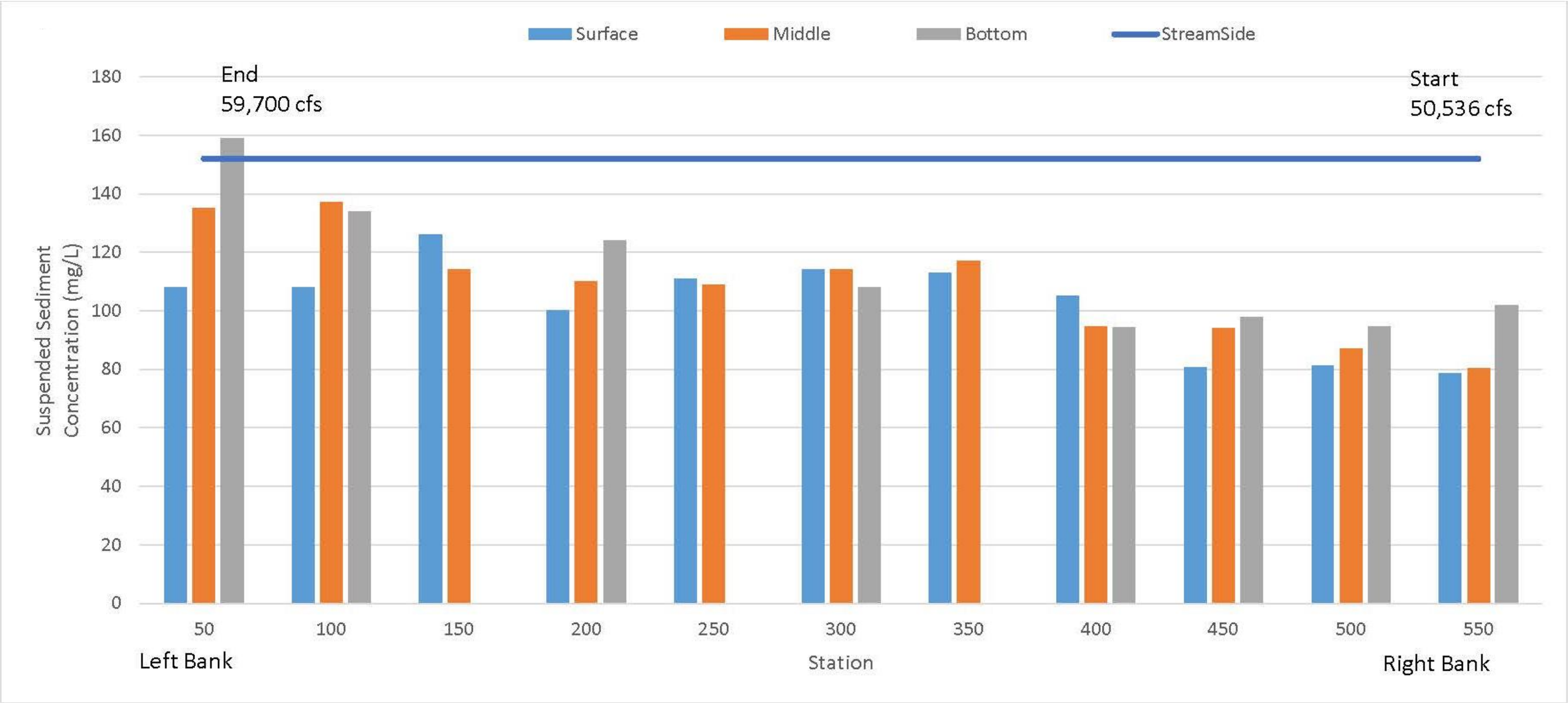
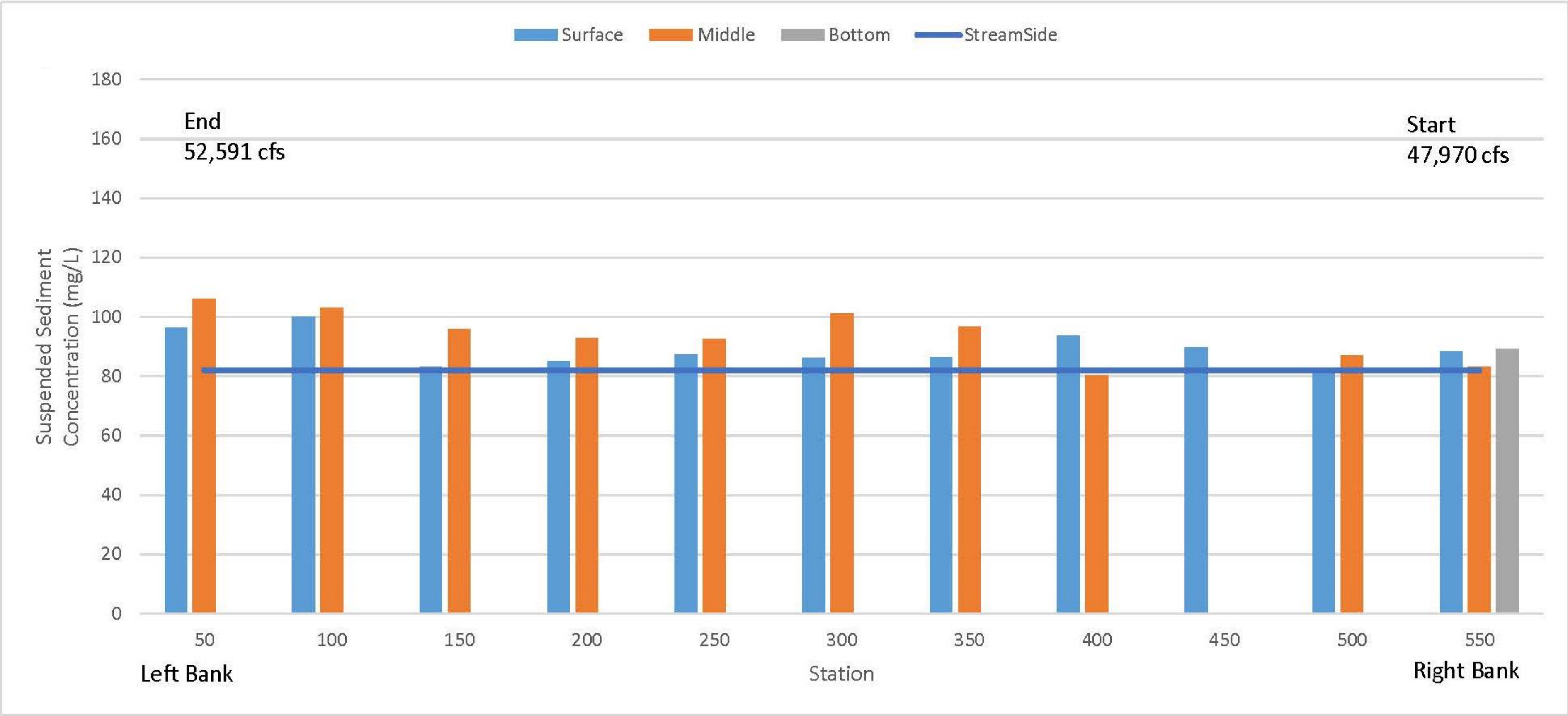


**Figure 4.2.2-4 Rt. 10 Bridge Cross-section Grab Sample Data (April 17, 2015)[21]**




[21] Bottom samples were not collected during this sampling event. The sounding weight used for sampling became detached from the Kemmerer at Station 0+550. Without the sounding weight, the Kemmerer could not reach the bottom due to the flow conditions; as such, bottom samples could not be collected.

**Figure 4.2.2-5 Rt. 10 Bridge Cross-section Grab Sample Data (April 20, 2015)**

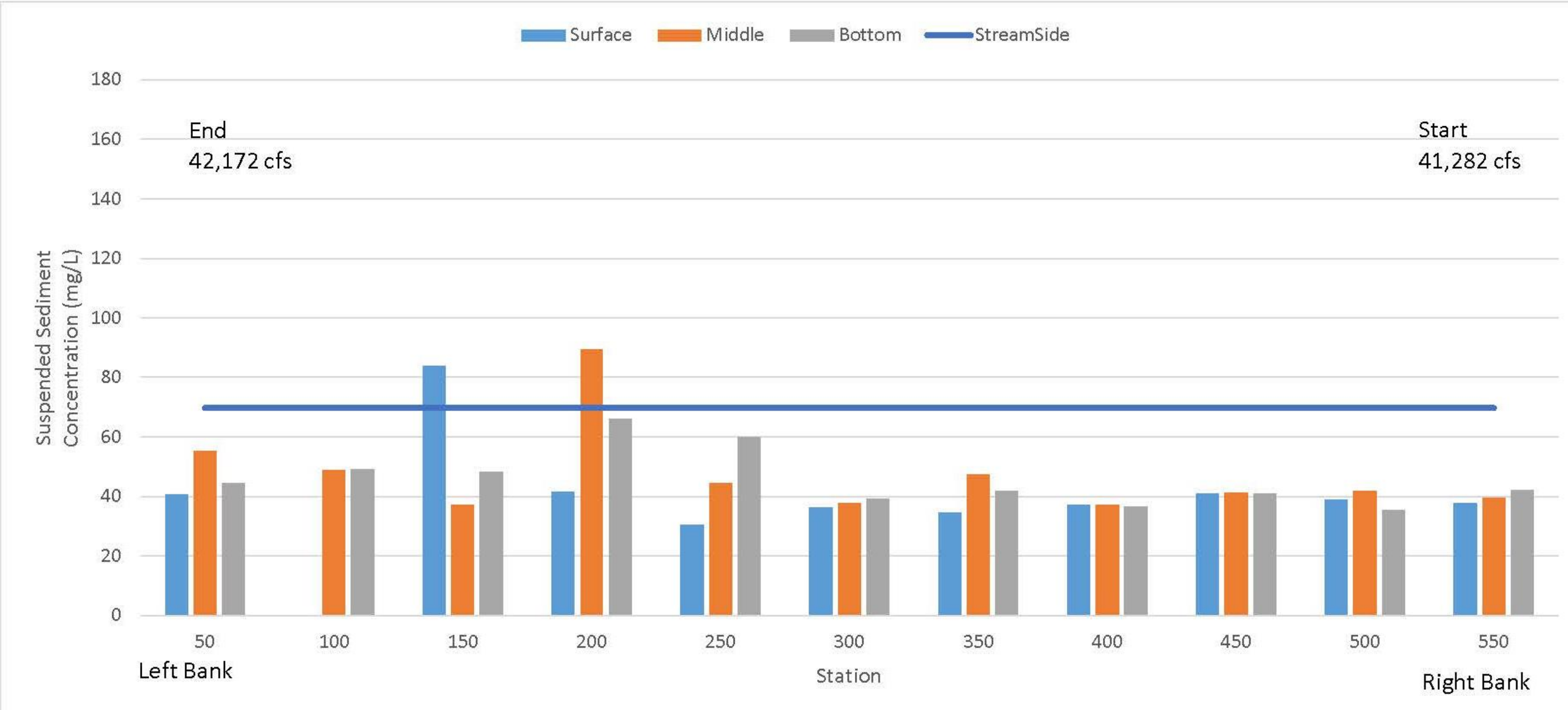
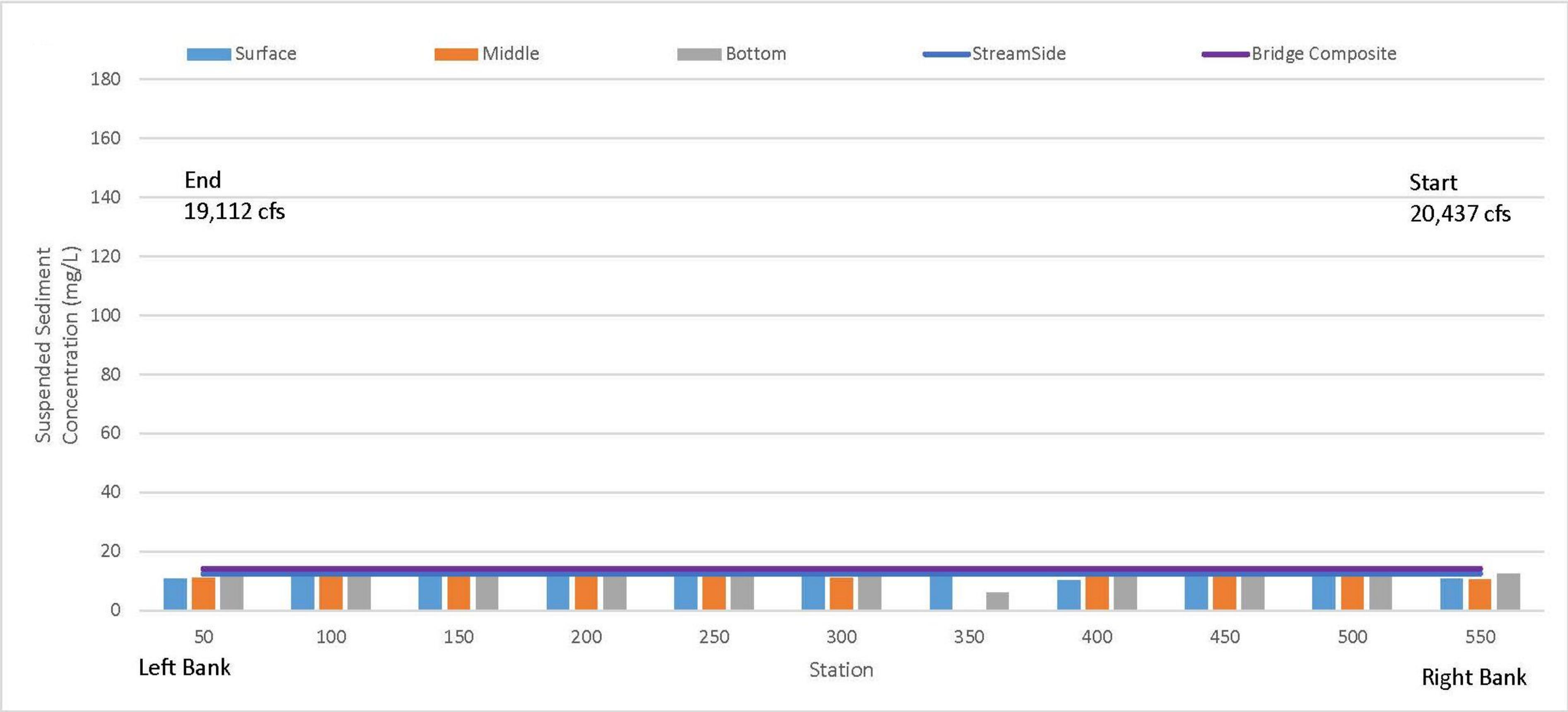


**Figure 4.2.2-6 Rt. 10 Bridge Cross-section Grab Sample Data (April 28, 2015)**



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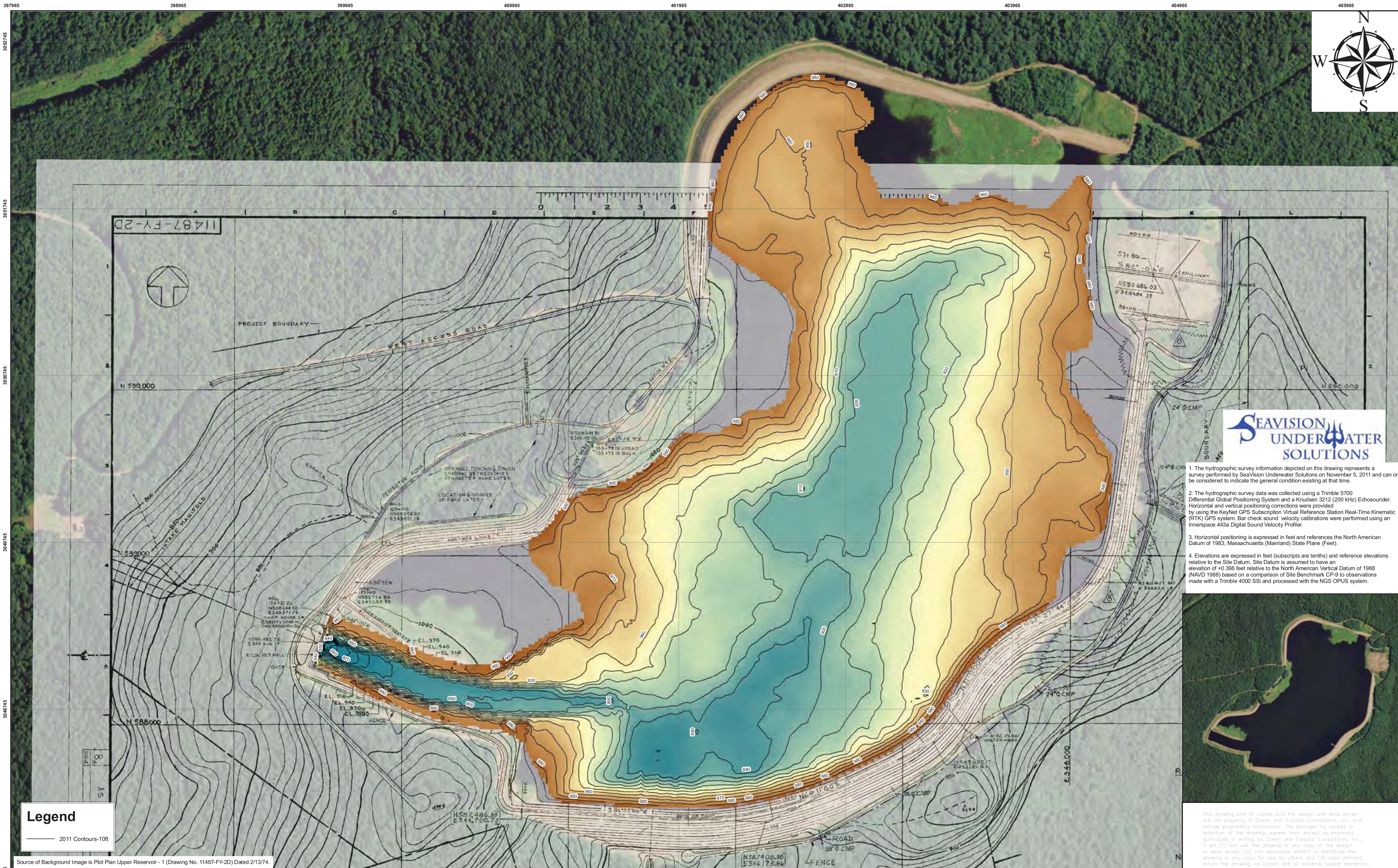
# APPENDIX A – UPPER RESERVOIR BATHYMETRY SURVEY MAPS (2011-2013)

# 2011 UPPER RESERVOIR BATHYMETRY MAPS




1. The hydrographic survey information depicted on this drawing represents a survey performed by SeaVision Underwater Solutions on November 5, 2011 and can only be considered to indicate the general condition existing at that time.

2. The hydrographic survey data was collected using a Trimble 5700 Differential Global Positioning System and a Knudsen 3212 (200 kHz) Echosounder. Horizontal and vertical positioning corrections were provided by using the KeyNet GPS Subscription Virtual Reference Station Real-Time Kinematic (RTK) GPS system. Bar check sound velocity calibrations were performed using an Innerspace 443a Digital Sound Velocity Profiler.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet).

4. Elevations are expressed in feet (subscripts are tenths) and reference elevations relative to the Site Datum. Site Datum is assumed to have an elevation of +0.398 feet relative to the North American Vertical Datum of 1988 (NAVD 1988) based on a comparison of Site Benchmark CP-9 to observations made with a Trimble 4000 SSi and processed with the NGS OPUS system.

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Tel: (508) 830-1110
Fax: (781) 834-4635

FirstLight Power Resources
GDF SUEZ

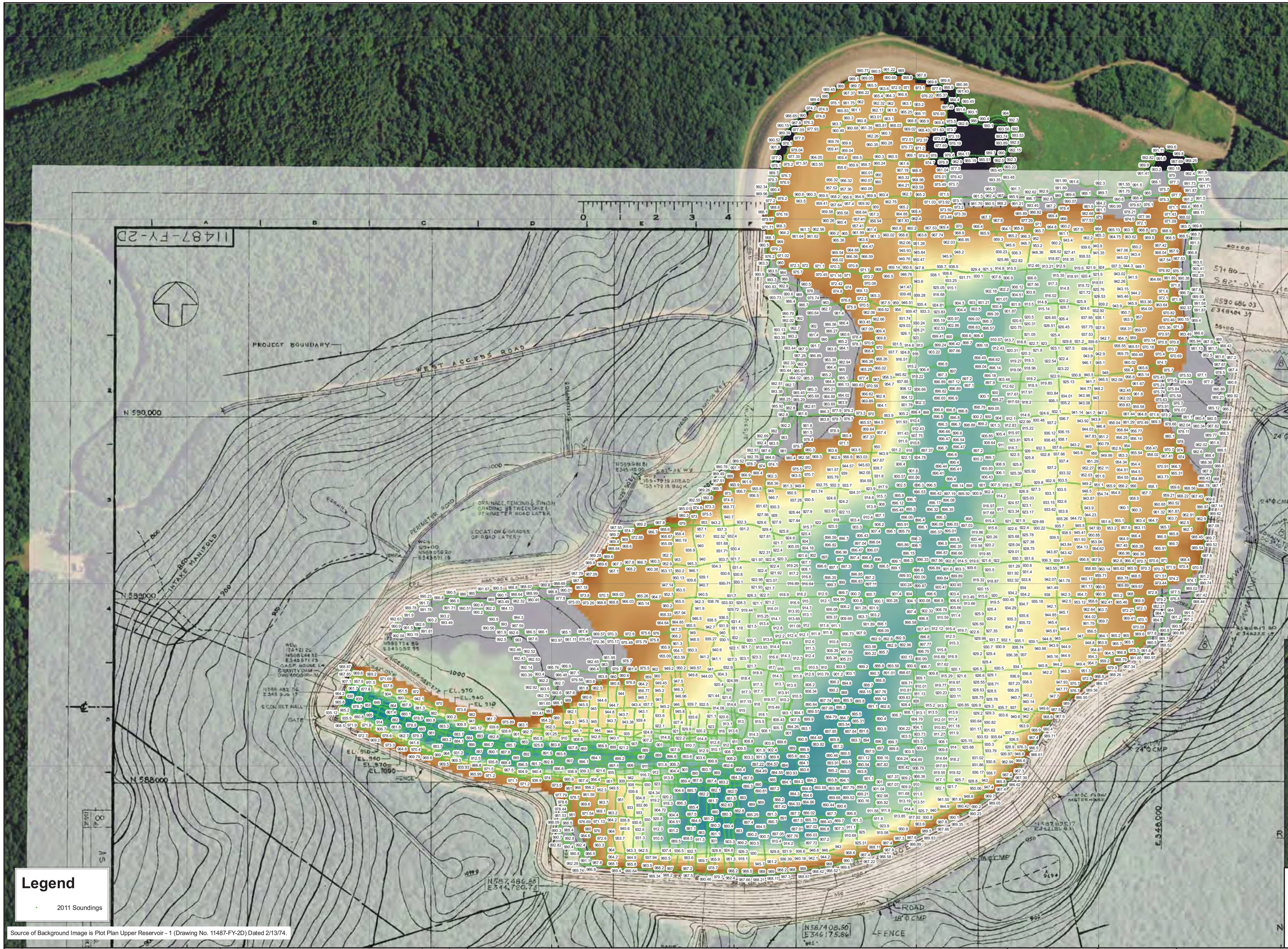
FirstLight Power
99 Millers Falls Road
Northfield, MA 01360

DESIGNED BY: EDGO
DRAWN BY: EDGO
CHECKED BY: BRJO
209080.3

NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA
HYDROGRAPHIC SURVEY

**OVERALL SURVEY - CONTOUR PLAN**

SCALE: 1:3000
DATE: 11/14/11
REVISION: 0
DRAWING NO.: 1




SEAVISION UNDERWATER SOLUTIONS

1. The hydrographic survey information depicted on this drawing represents a survey performed by SeaVision Underwater Solutions on November 5, 2011 and can only be considered to indicate the general condition existing at that time.

2. The hydrographic survey data was collected using a Trimble 5700 Differential Global Positioning System and a Knudsen 3212 (200 kHz) Echosounder. Horizontal and vertical positioning corrections were provided by using the KeyNet GPS Subscription Virtual Reference Station Real-Time Kinematic (RTK) GPS system. Bar check sound velocity calibrations were performed using an Innerspace 443a Digital Sound Velocity Profiler.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts (Mainland) State Plane (Feet).

4. Elevations are expressed in feet (subscripts are tenths) and reference elevations relative to the Site Datum. Site Datum is assumed to have an elevation of +0.398 feet relative to the North American Vertical Datum of 1988 (NAVD 1988) based on a comparison of Site Benchmark CP-9 to observations made with a Trimble 4000 SSi and processed with the NGS OPUS system.

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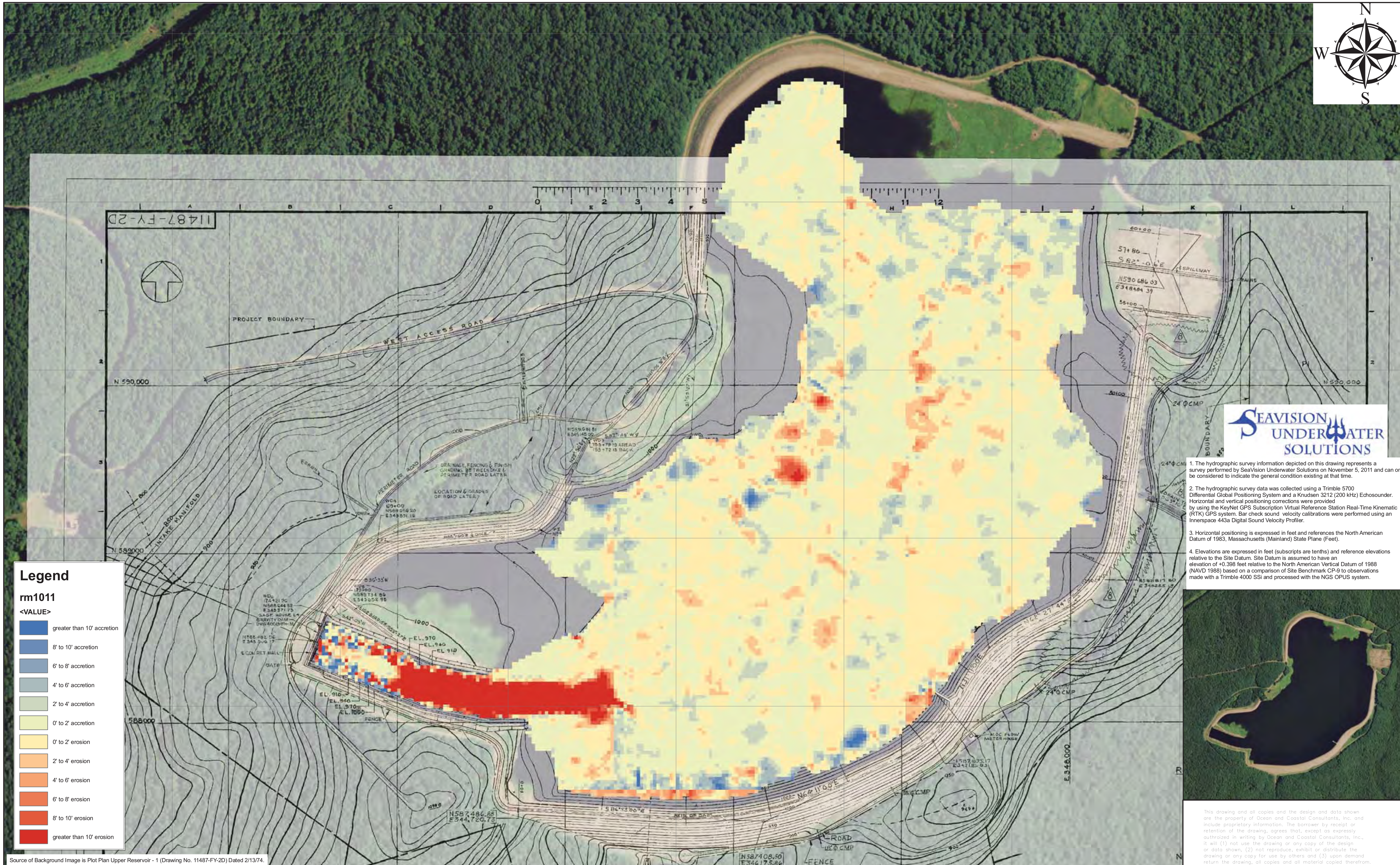
| | |
|---|---|
| DESIGNED BY: | EDGO |
| DRAWN BY: | EDGO |
| CHECKED BY: | BRJO |
| | 209080.3 |

NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA
HYDROGRAPHIC SURVEY

**OVERALL SURVEY - SOUNDING PLAN**

| SCALE | REVISION |
|---|---|
| 1:3000 | 0 |
| DATE 11/14/11 | |
| DRAWING NO. 2 | |




## Legend

**rm1011**

<VALUE>

- greater than 10' accretion
- 8' to 10' accretion
- 6' to 8' accretion
- 4' to 6' accretion
- 2' to 4' accretion
- 0' to 2' accretion
- 0' to 2' erosion
- 2' to 4' erosion
- 4' to 6' erosion
- 6' to 8' erosion
- 8' to 10' erosion
- greater than 10' erosion

Source of Background Image is Plot Plan Upper Reservoir - 1 (Drawing No. 11487-FY-2D) Dated 2/13/74.

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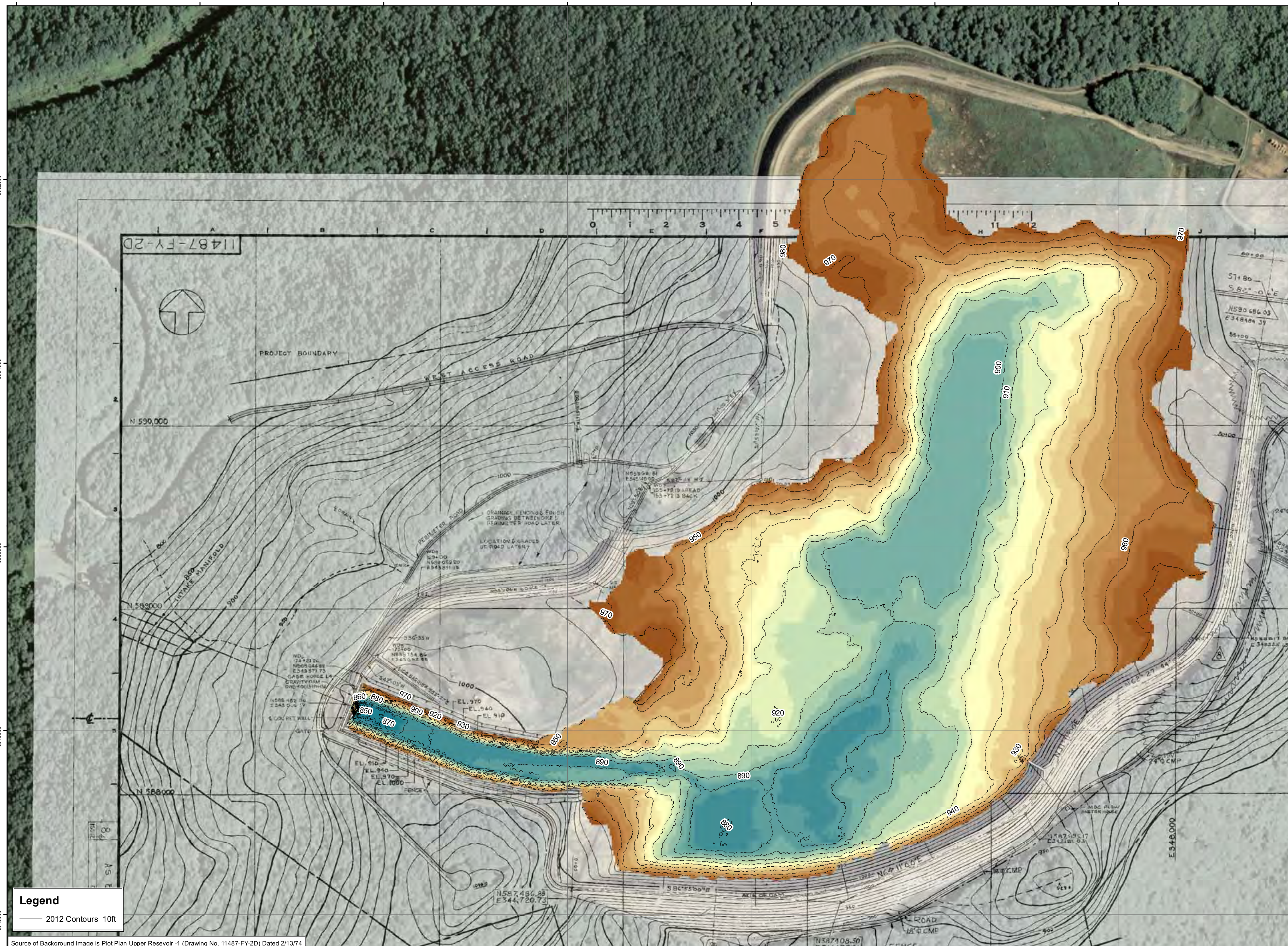
| | |
|---|---|
| DESIGNED BY: | EDGO |
| DRAWN BY: | EDGO |
| CHECKED BY: | BRJO |
| | 209080.3 |

NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA
HYDROGRAPHIC SURVEY

**OVERALL SURVEY - 2010 - 2011 ELEVATION CHANGE**

| SCALE | DATE | REVISION | DRAWING NO. |
|---|---|---|---|
| 1:3000 | 11/14/11 | 0 | 3 |

# 2012 UPPER RESERVOIR BATHYMETRY MAPS




# SEAVISION UNDERWATER SOLUTIONS

1. The bathymetry depicted on these digital products represents the results of a survey performed by SeaVision Underwater Solutions, Inc. on September 29-30, 2012 and can only be considered to indicate the general conditions existing at that time.

2. The multibeam bathymetry data was collected using a HemisphereGPS R320 Differential Global Positioning System with Real-Time Kinematic corrections transmitted from the KeyNet GPS Virtual Reference Station Network. SeaVision utilized a Teledyne Odom ES3 260 kHz multibeam echosounder, a TSS DMS-05 Motion Reference Unit, and a ComNav G4 Heading Sensor to collect the data. For sound velocity corrections, we utilized a Valeport MiniSVS Sound Velocity Profiler to collect acoustic velocity data. All data was collected and integrated using the Hypack Hysweep Software package and post-processed to the project datums to account for water level and vessel motion.

3. Horizontal positioning is expressed in feet and references the North American Datum of 1983, Massachusetts-Mainland Zone State Plane (Feet). Vertical elevations are in feet and reference the site datum, equivalent to the National Geodetic Vertical Datum of 1929.

4. Water level observations were performed in real-time using the RTK-GPS Receiver, and checked against observations from the GDF-Suez/FirstLight Power control room at Northfield Mountain.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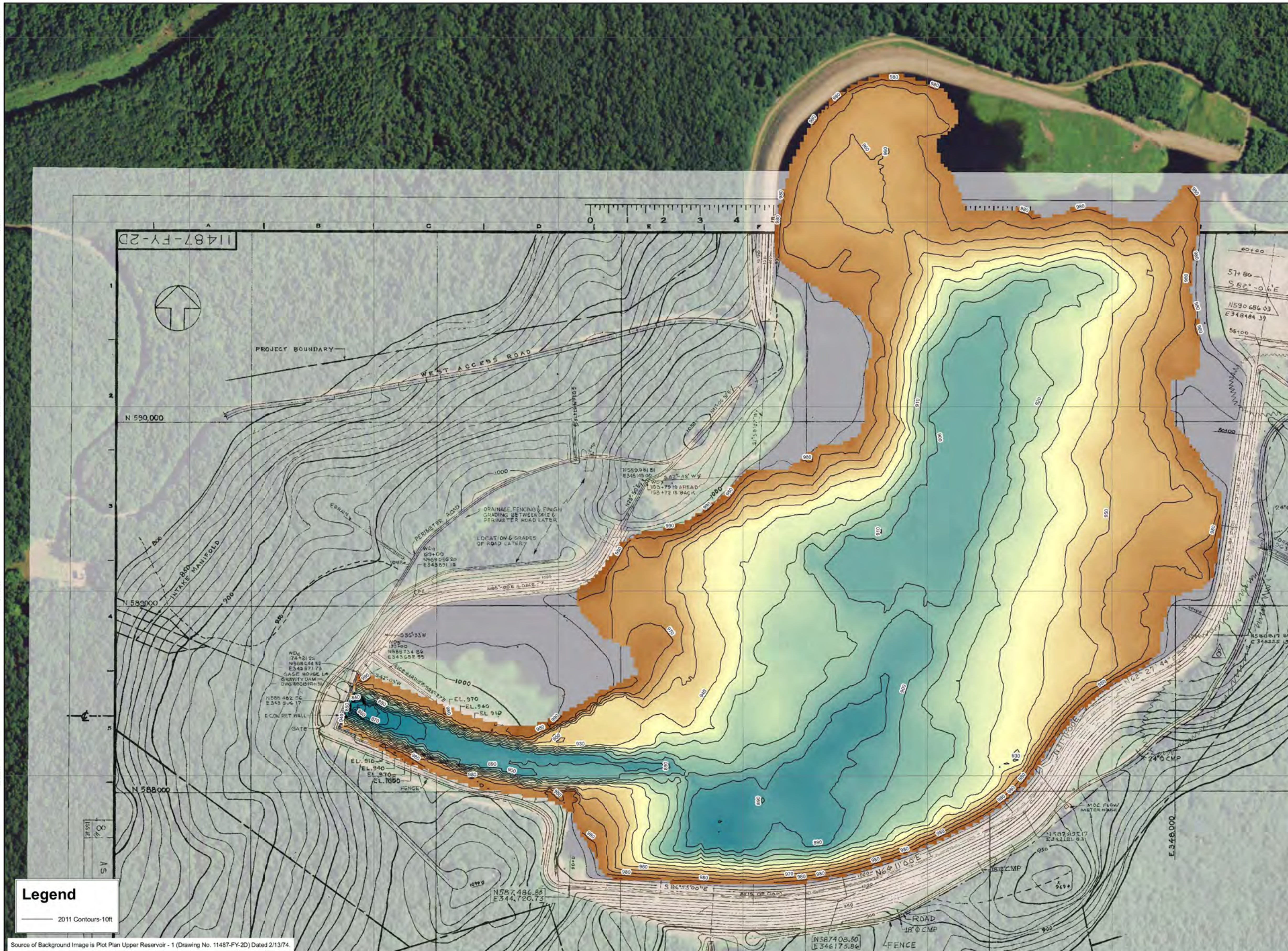
DESIGNED BY: RYAR
DRAWN BY: RYAR
CHECKED BY: BRJO
209080.3

NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA
HYDROGRAPHIC SURVEY

**OVERALL SURVEY - 2012 CONTOUR PLAN**

SCALE: 1:3,000
DATE: 9-30-2012
REVISION: 0
DRAWING NO.: 1a




SEAVISION UNDERWATER SOLUTIONS

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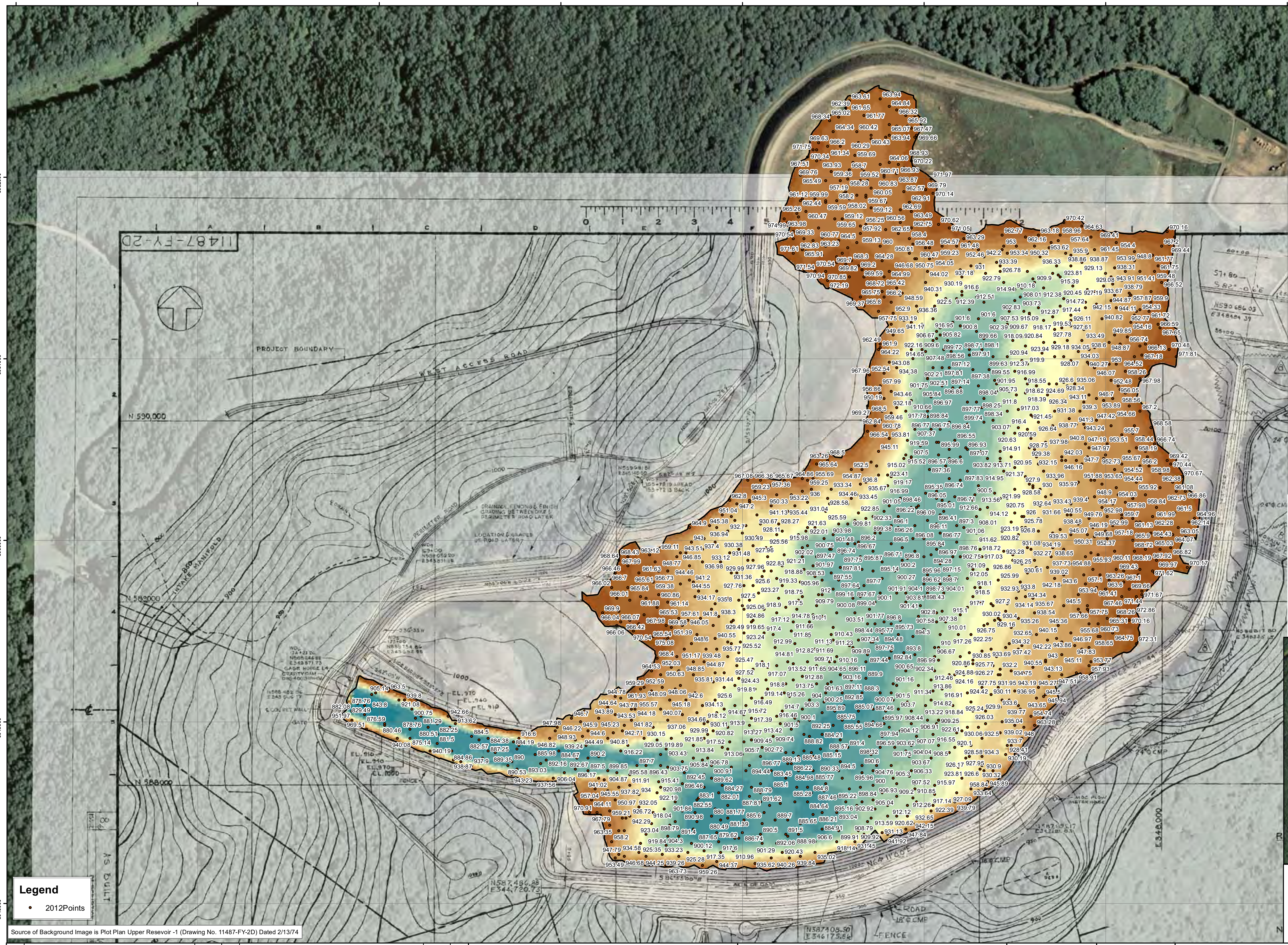
Northfield, MA 01360

NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA
HYDROGRAPHIC SURVEY

2011
**OVERALL SURVEY - CONTOUR PLAN**

1b

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4. Water level observations were performed in real-time using the RTK-GPS Receiver, and checked against observations from the GDF-Suez/FirstLight Power control room at Northfield Mountain.

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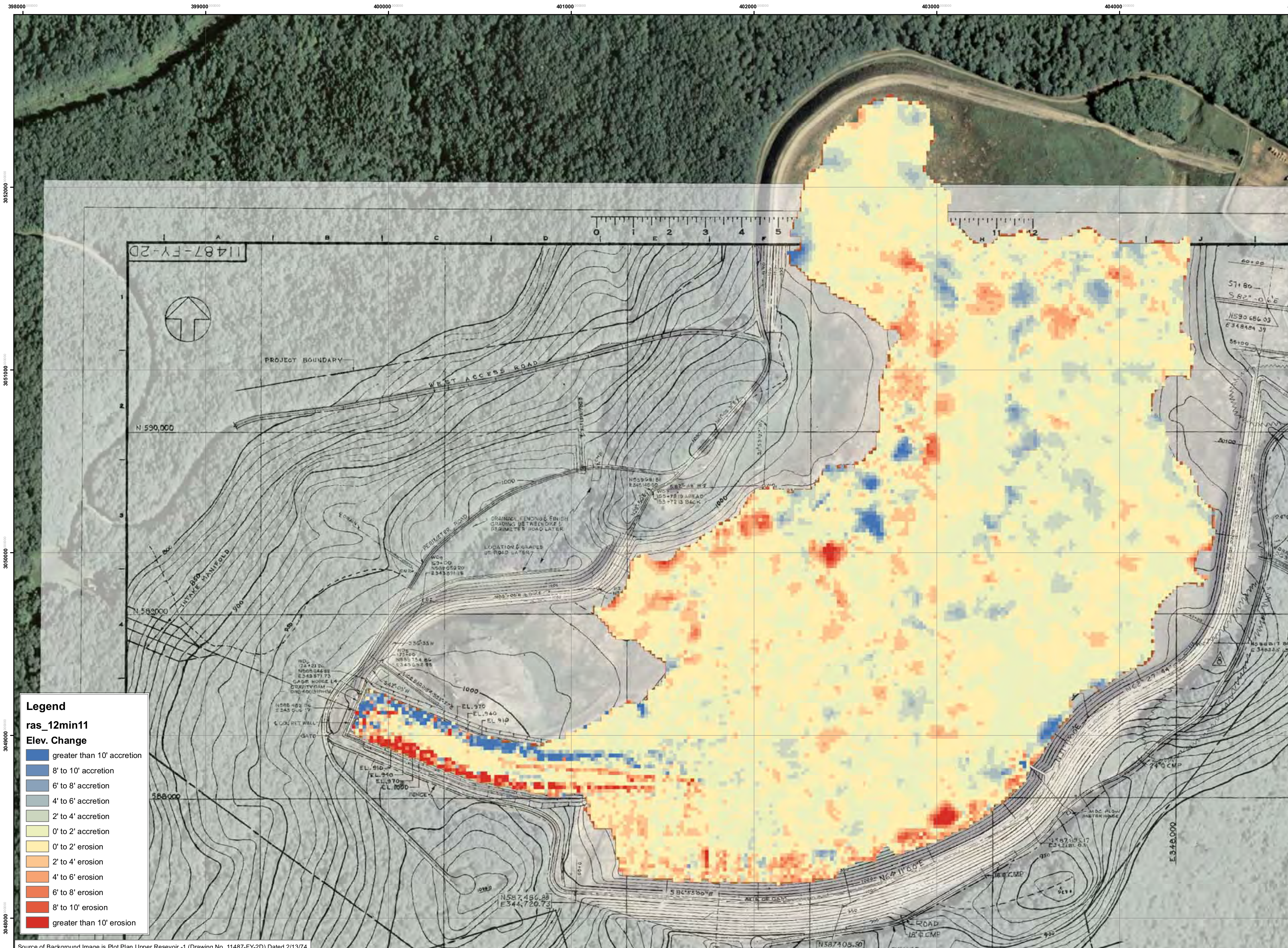
GDF SUEZ
FirstLight Power
99 Millers Falls Road
Northfield, MA 01360

| DESIGNED BY: RYAR | NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA HYDROGRAPHIC SURVEY | SCALE 1:3,000 | REVISION 0 |
|---|---|---|---|
| DRAWN BY: RYAR | | DATE 9-30-2012 | |
| CHECKED BY: BRJO | OVERALL SURVEY - 2012 SOUNDING PLAN | DRAWING NO. 2 | |
| 209080.3 | | | |

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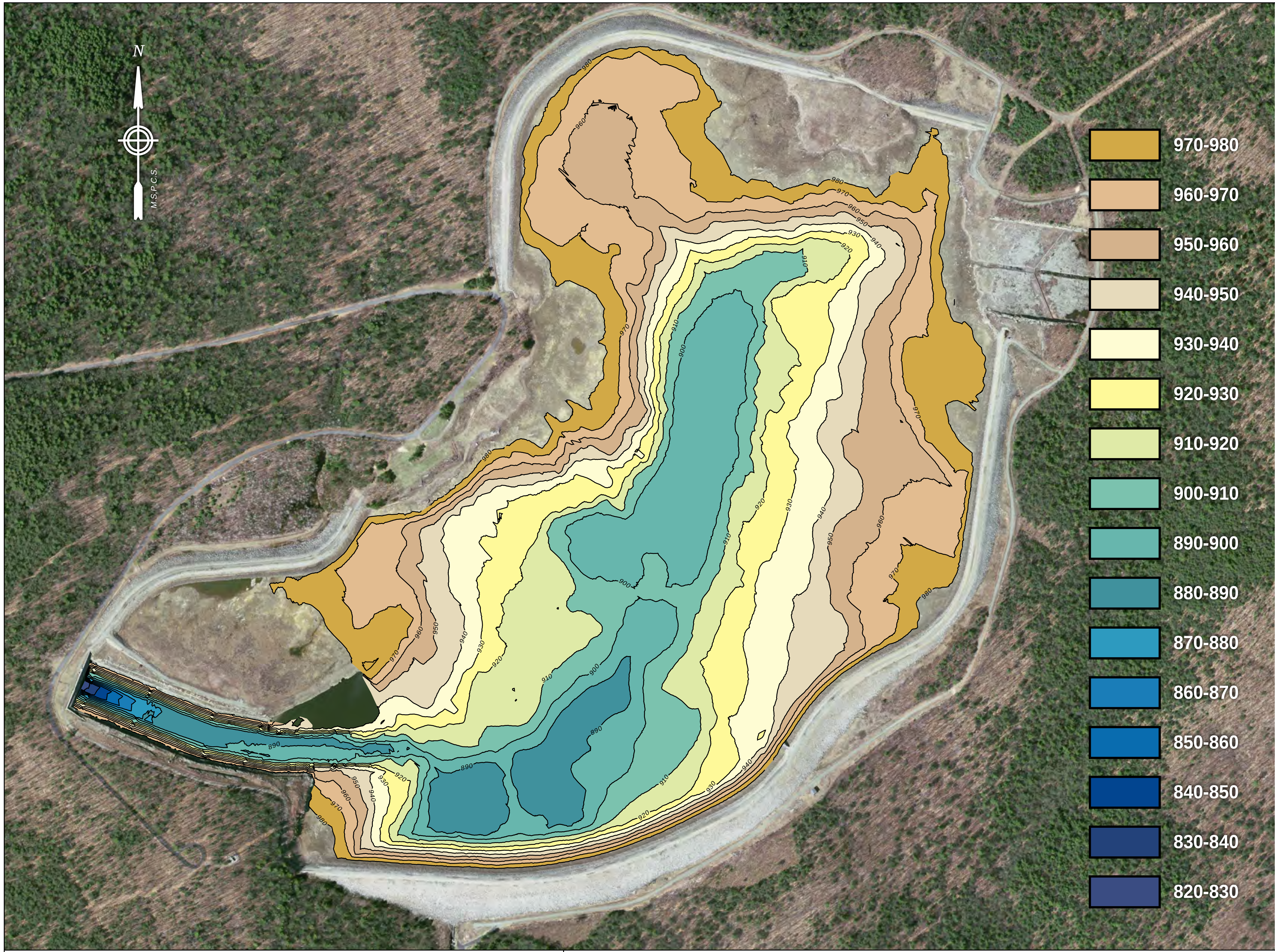
FirstLight Power
99 Millers Falls Road
Northfield, MA 01360

| | | | |
|---|---|---|---|
| DESIGNED BY: RYAR | NORTHFIELD STATION RESERVOIR, NORTHFIELD, MA HYDROGRAPHIC SURVEY | SCALE 1:3,000 | REVISION 0 |
| DRAWN BY: RYAR | | DATE 9-30-2012 | |
| CHECKED BY: BRJO | **OVERALL SURVEY - 2011-2012 ELEVATION CHANGE** | DRAWING NO. 3 | |
| 209080.3 | | | |

2013 UPPER RESERVOIR BATHYMETRY MAPS




# GENERAL NOTES:

1. CONTOURS AND ELEVATIONS PRESENTED ON THIS PLAN REPRESENT THE RESULTS OF A HYDROGRAPHIC SURVEY PERFORMED BY CHA CONSULTING, INC. ON OCTOBER 5 AND 6, 2013. REUSE OF THIS INFORMATION BY THE CLIENT OR OTHERS BEYOND THE SPECIFIC SCOPE OF WORK FOR WHICH IT WAS ACQUIRED SHALL BE AT THE SOLE RISK OF THE USER AND WITHOUT LIABILITY TO CHA CONSULTING, INC.

2. THE GRID COORDINATES ARE BASED ON THE MASSACHUSETTS STATE PLANE COORDINATE SYSTEM, ZONE 2001 (M.S.P.C.S.) AND ARE EXPRESSED IN US SURVEY FEET.

3. ELEVATIONS ON THIS PLAN ARE EXPRESSED IN FEET AND ARE REFERENCED TO THE NORTHFIELD MOUNTAIN PUMPED STORAGE FACILITY (NMPSF) SITE VERTICAL DATUM. PER THE BID SPECIFICATIONS DOCUMENT, DATED APRIL 4, 2013, THE LOCAL SITE DATUM IS CALCULATED TO BE "+0.398 FEET TO THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88)". TO CORRELATE ELEVATIONS BETWEEN DATUMS, THE FOLLOWING FORMULA SHOULD BE APPLIED:

$$EL_{NMPSF} = EL_{NAVD88} + 0.398\ FT$$

4. THE VERTICAL BENCHMARK HELD FOR THIS SURVEY IS A LEAD PLUG AND TACK LOCATED ON THE NORTH WEST CORNER OF THE CONCRETE MDC INTAKE STRUCTURE AND IS KNOWN AS CP-9 (EL=1009.94 FT. (NMPSF)).

CHA
101 Accord Park Drive
Norwell, MA 02061
Main: (781) 982-5400 • www.chacompanies.com

600 300 0 600 1200

PREPARED FOR:

FIRST LIGHT POWER RESOURCES/GDF SUEZ
99 MILLERS FALLS ROAD
NORTHFIELD, MA 01360

TITLE:

2013 HYDROGRAPHIC SURVEY - CONTOUR PLAN
NORTHFIELD MOUNTAIN UPPER RESERVOIR
NORTHFIELD, MA 01360

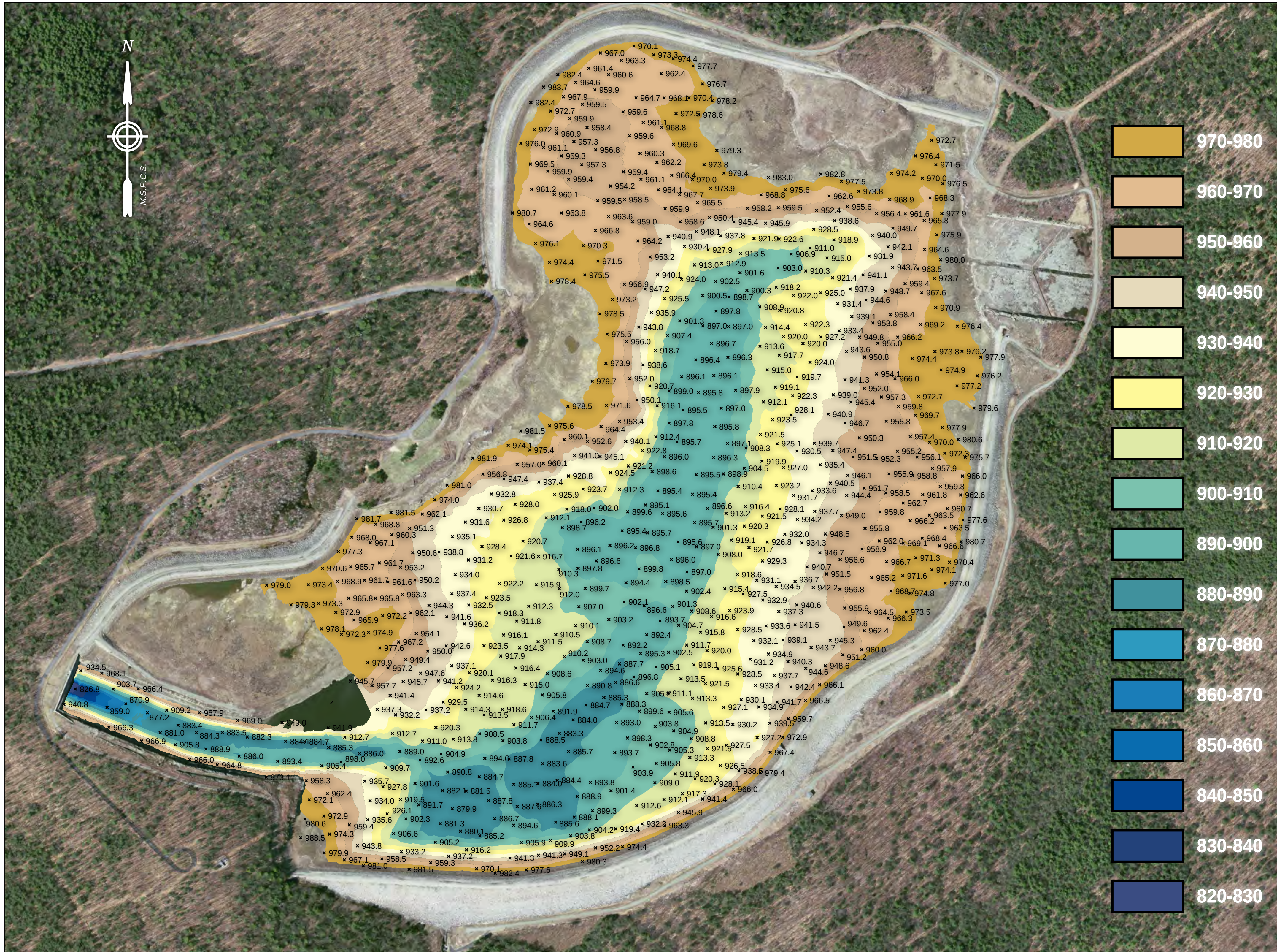
DATE: OCTOBER 31, 2013

SCALE: 1"=600'

DRAWN: AMC CHECK: EJP

DWG NAME: 26727 Upper Reservoir Hydro 2013

Fig-3

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600 300 0 600 1200

## PREPARED FOR:

*FIRST LIGHT POWER RESOURCES/GDF SUEZ*
*99 MILLERS FALLS ROAD*
*NORTHFIELD, MA 01360*

## TITLE:

*2013 HYDROGRAPHIC SURVEY - SOUNDING PLAN*
*NORTHFIELD MOUNTAIN UPPER RESERVOIR*
*NORTHFIELD, MA 01360*

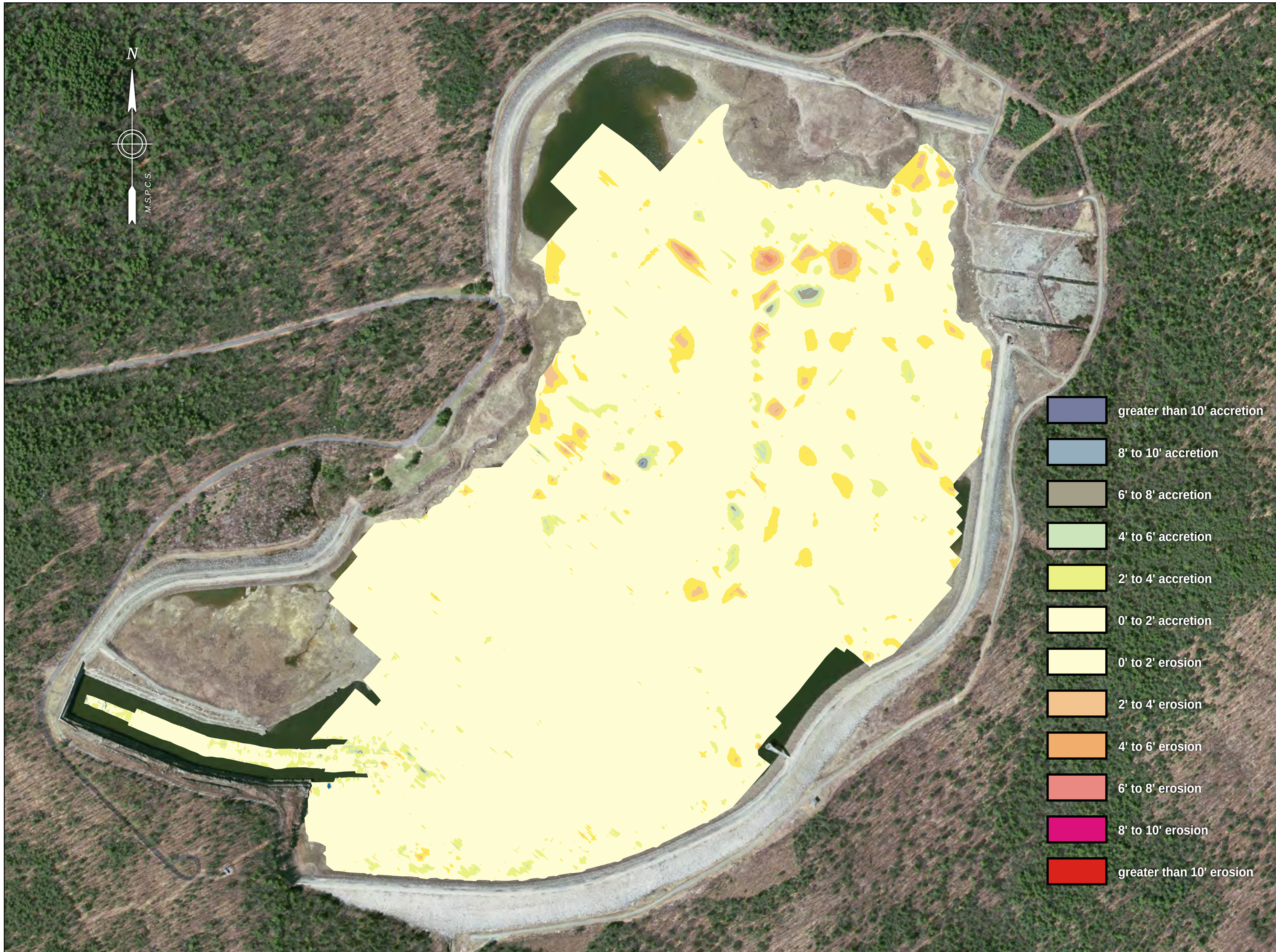
DATE: OCTOBER 31, 2013

SCALE: 1"=600'

DRAWN: AMC CHECK: EJP

DWG NAME: 26727 Upper Reservoir Hydro 2013

Fig-4

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600 300 0 600 1200

**PREPARED FOR:**

FIRST LIGHT POWER RESOURCES/GDF SUEZ
99 MILLERS FALLS ROAD
NORTHFIELD, MA 01360

**TITLE:**

2013 HYDROGRAPHIC SURVEY - ELEVATION CHANGE PLAN
2013 SURVEY vs. 2012 SURVEY
NORTHFIELD MOUNTAIN UPPER RESERVOIR
NORTHFIELD, MA 01360

DATE: OCTOBER 31, 2013

SCALE: 1"=600'

DRAWN: AMC CHECK: EJP

DWG NAME: 26727 Upper Reservoir Hydro 2013

Fig-5

# APPENDIX B – SUMMARY OF 2015 CORRESPONDENCE & MANUFACTURER CERTIFICATION LETTER

## 2015 Correspondence Summary

| Author | Distributed To | Date | Description |
|---|---|---|---|
| FirstLight | FERC | February 24, 2015 | Pilot Dredge Filing |
| USEPA | FirstLight | March 9, 2015 | Review and Comments on Northfield Mountain Pumped Storage Project Sediment Management Plan 2014 Summary of Annual Monitoring |
| FirstLight | USEPA | March 31, 2015 | FirstLight Response to EPA Comments on 2014 Summary of Annual Monitoring |
| FirstLight | FERC, USEPA, MADEP | June 24, 2015 | Northfield Mountain Pumped Storage Project Sediment Management Plan-Suspended Sediment Monitoring Equipment Status Update |
| FirstLight | FERC, USEPA, MADEP, Stakeholders | September 14, 2015 | Status update and available results report filed with the 2015 Updated Study Report |
| N/A | N/A | September 30, 2015 | FirstLight hosted Day 2 of the Updated Study Report meeting at which time the report filed on September 14, 2015 was presented to Stakeholders. |
| FirstLight | FERC, USEPA, MADEP | December 1, 2015 | Annual summary of monitoring report (i.e. updated September 14, 2015 report) |

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2700 Richards Road, Suite 107
Bellevue WA 98005 USA
425.641.0944 (T); 425.643.0595 (F)
www.SequoiaSci.com ; info@SequoiaSci.com

Thursday, November 14, 2013

Brian Sousa
FirstLight Power Resources - GDF Suez NA
Northfield Mountain Pump Storage Project - Turners Falls Project
99 Millers Falls Road
Northfield, MA 01360
Tel: (413) 659-4412

Dear Brian,

On October 9th and 10th I visited First Light's two LISST-Hydro instruments installed near the Northfield Mountain Pump Storage Project. The purpose of the visit was to review the installation and offer any suggestions for changes. The details of notes and resulting action items from my visit are documented in the "Chuck Pottsmith Site Visit Recap – 10-2103" document created by Tim Sullivan.

Both the North and South LISST-Hydro installations are well executed. The enclosure for the instruments is more than adequate, the battery and solar power chargers are well done, the clean water tank is large and has the necessary filters, and the pump is correctly mounted and its cable and hose is well protected. The installations are well within the requirements needed for proper operation of the LISST-Hydros.

During the same visit the installation of the LISST-StreamSide was also reviewed. It was also found to have an adequate enclosure, battery power and solar charging is adequate. Clean water tank is acceptable. The installation of the LISST-StreamSide is within the requirements needed for proper operation.

Please let me know if you have any additional questions. I can be reached by email at cpottsmith@sequoiasci.com or by phone at 425-641-0944 ext 107.

Sincerely,

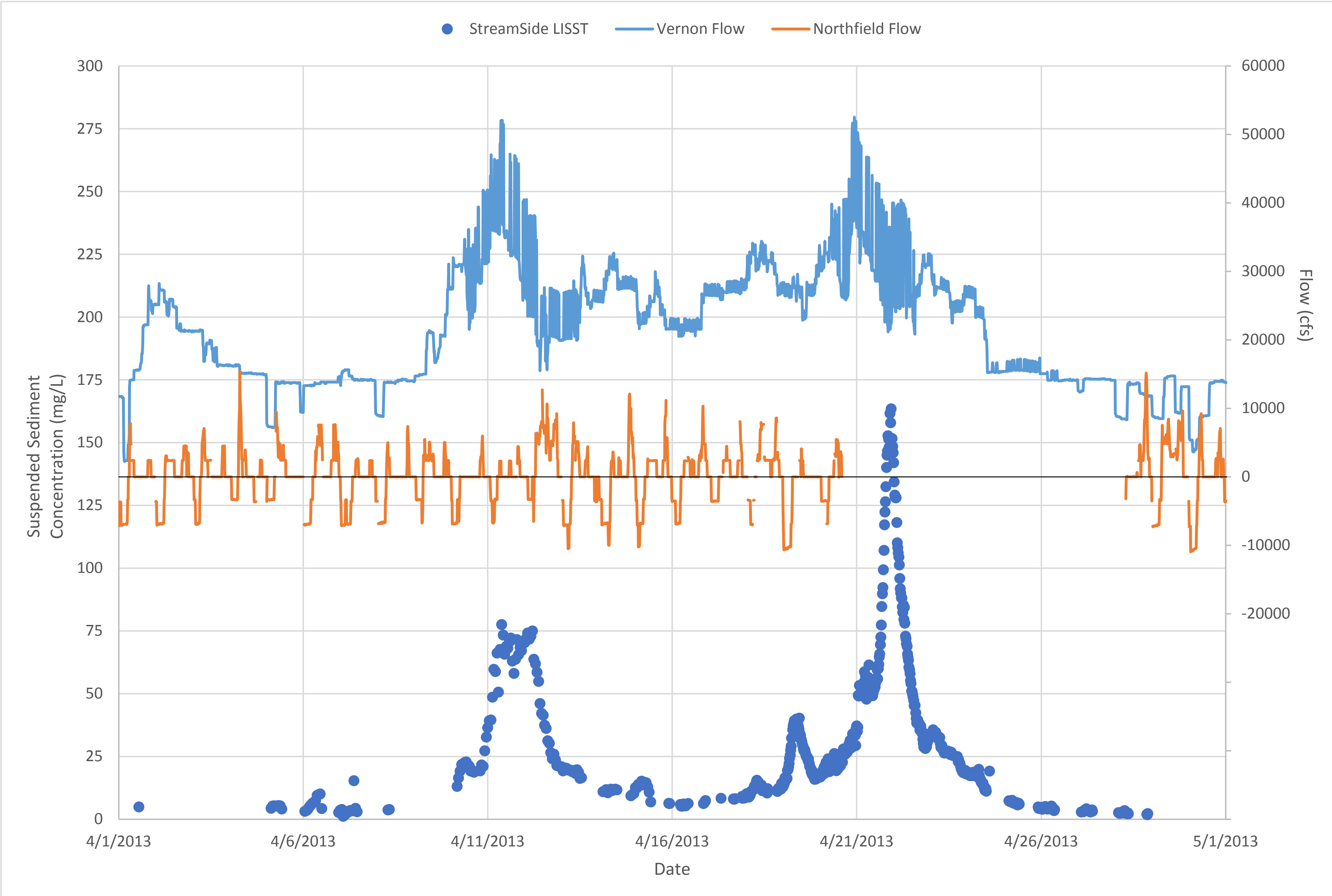
Chuck Pottsmith

Chuck Pottsmith
VP , Sales and Market Development

# APPENDIX C - CONTINUOUS SSC, FLOW, AND PROJECT OPERATIONS TIMESERIES PLOTS – MG/L (2013-2015)[22]

[22] When reviewing the plots contained in this Appendix it is important to note that: 1) the y-axis may vary from plot to plot, and 2) gaps observed in the LISST data represent periods of time when the instruments were offline due to equipment malfunctions or data that was removed from the final dataset during the QA/QC process.

# 2013 CONTINUOUS LISST INSTRUMENT TIMESERIES-MONTHLY


StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
300
275
250
225
200
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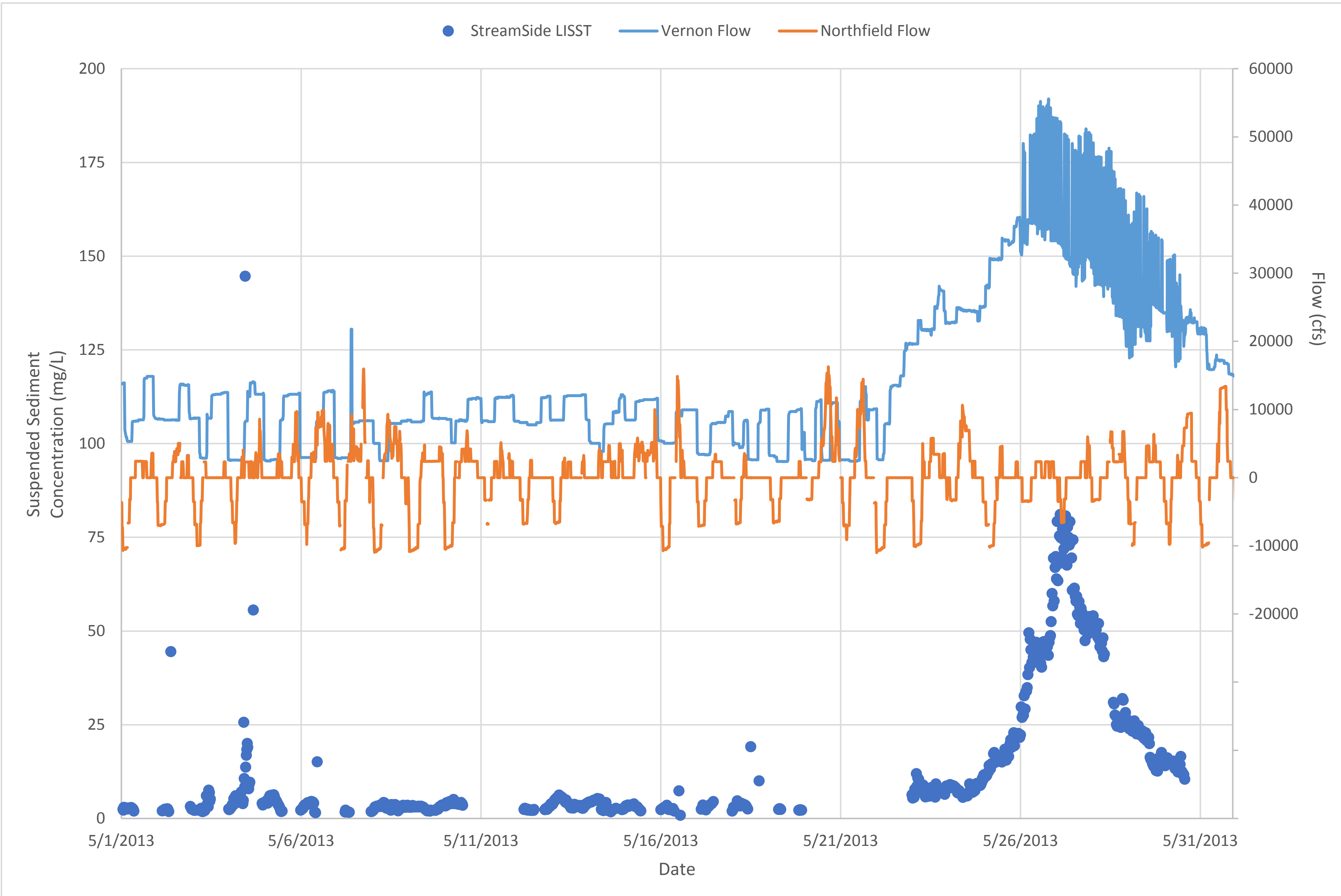
StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
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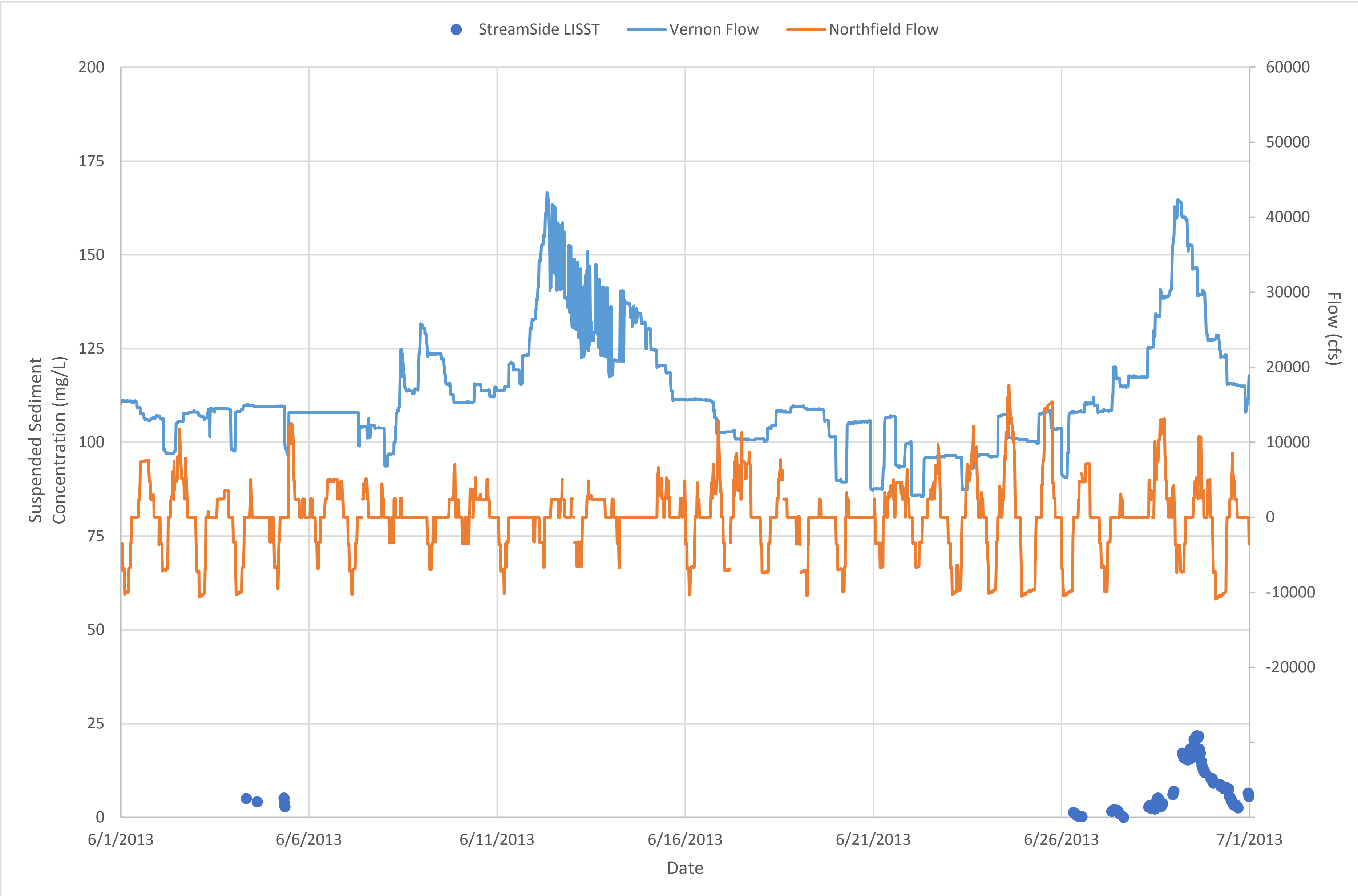

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Suspended Sediment Concentration (mg/L)
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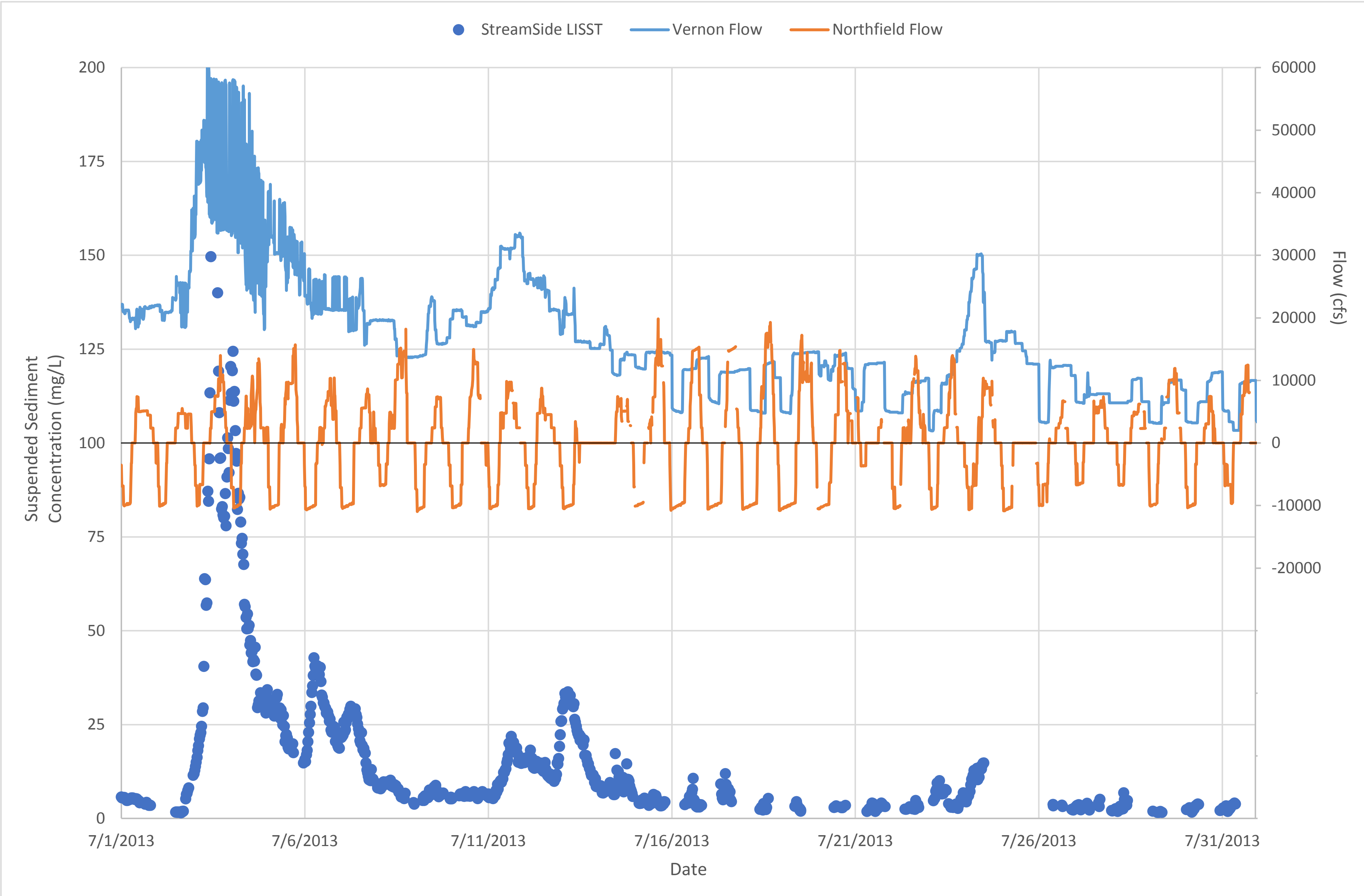

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Vernon Flow
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Suspended Sediment Concentration (mg/L)
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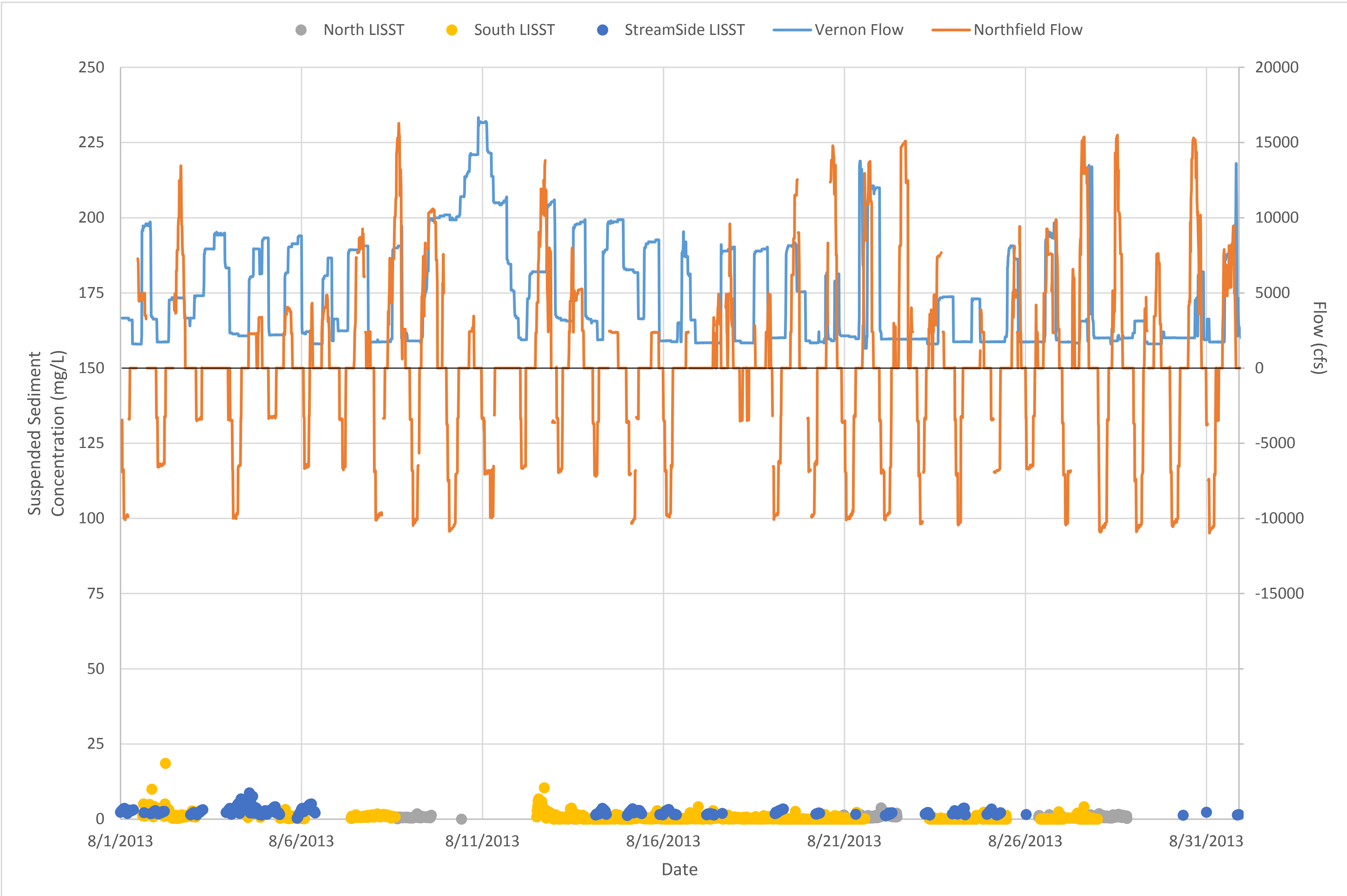
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StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
Flow (cfs)
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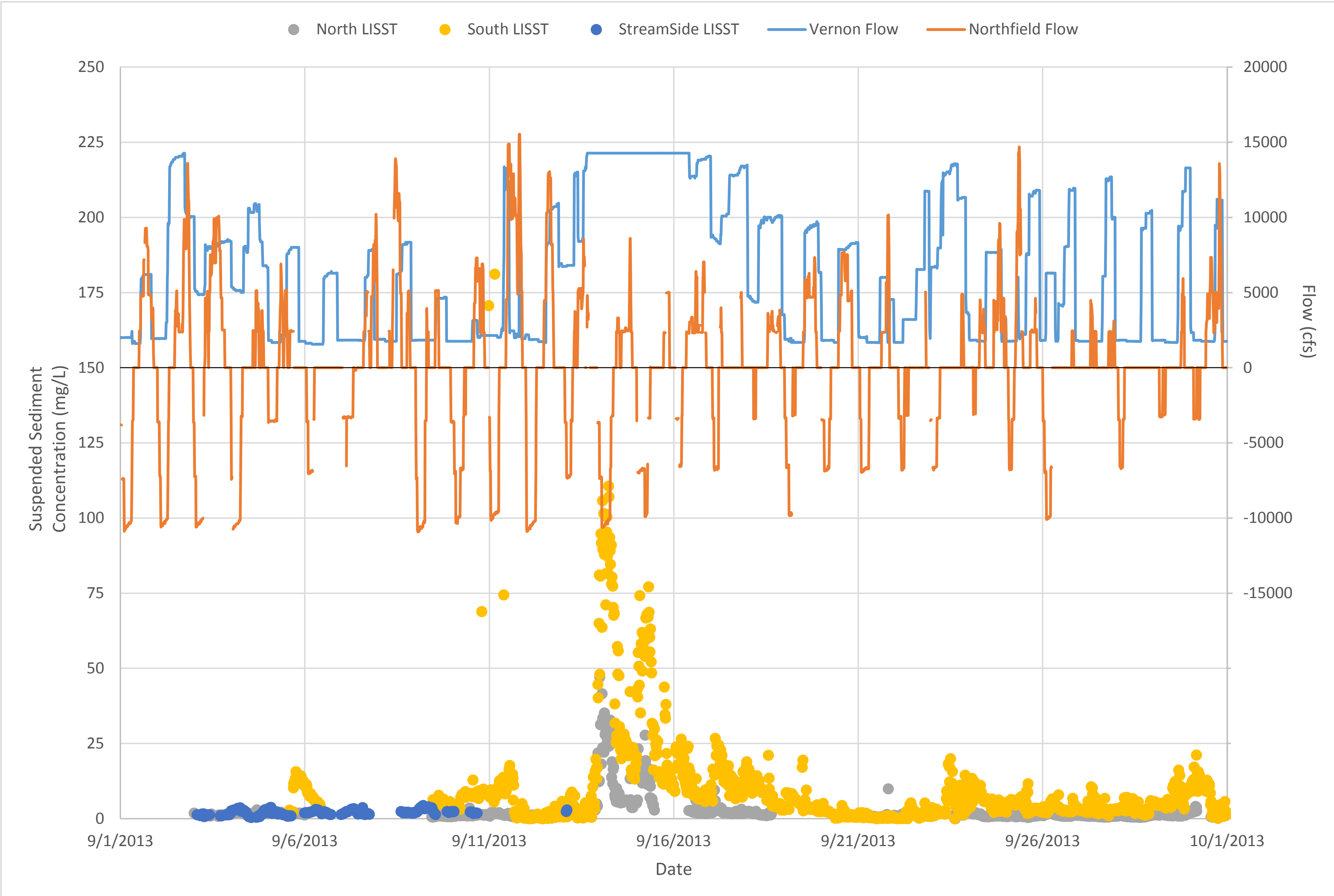

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Suspended Sediment Concentration (mg/L)
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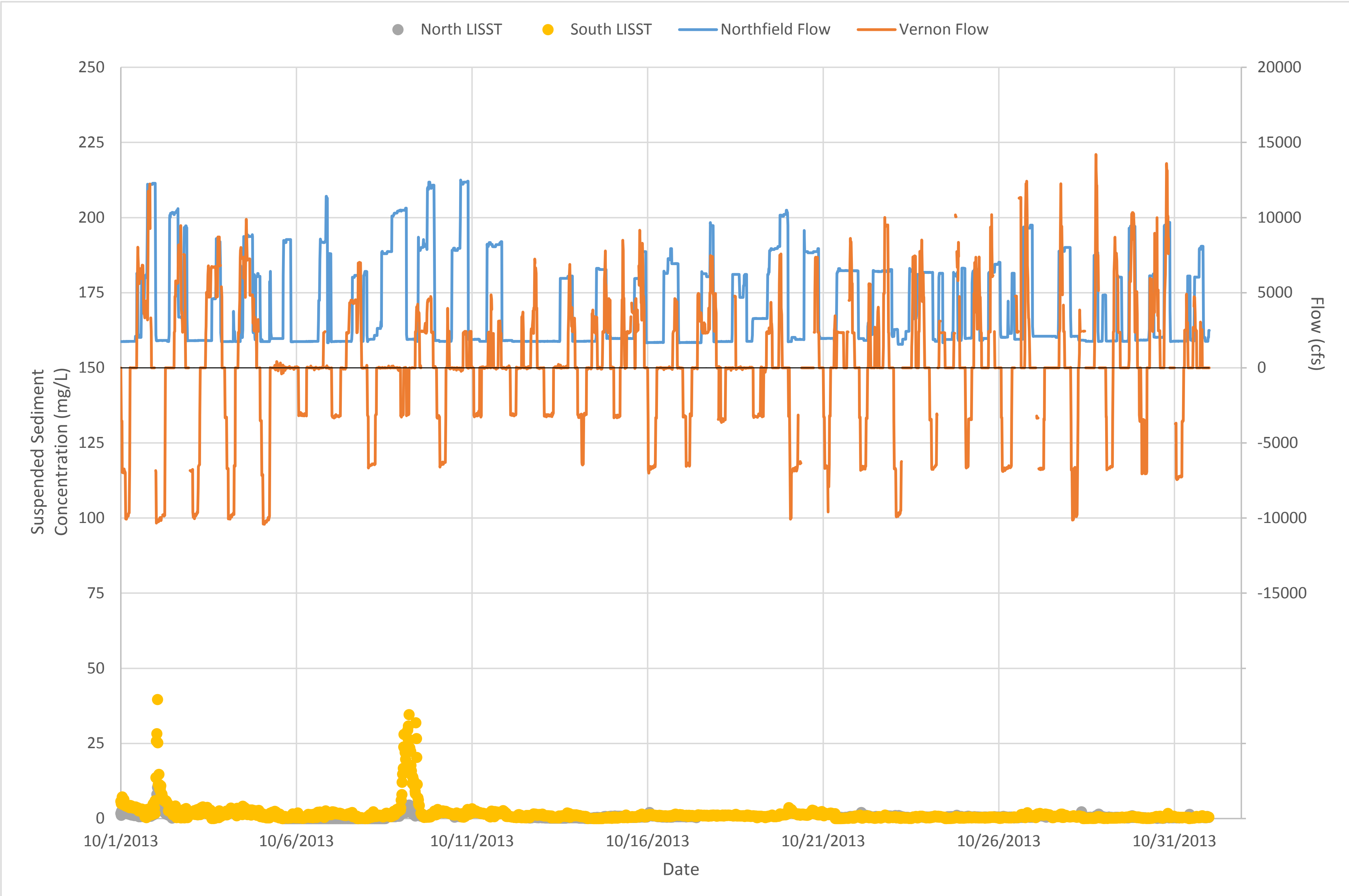
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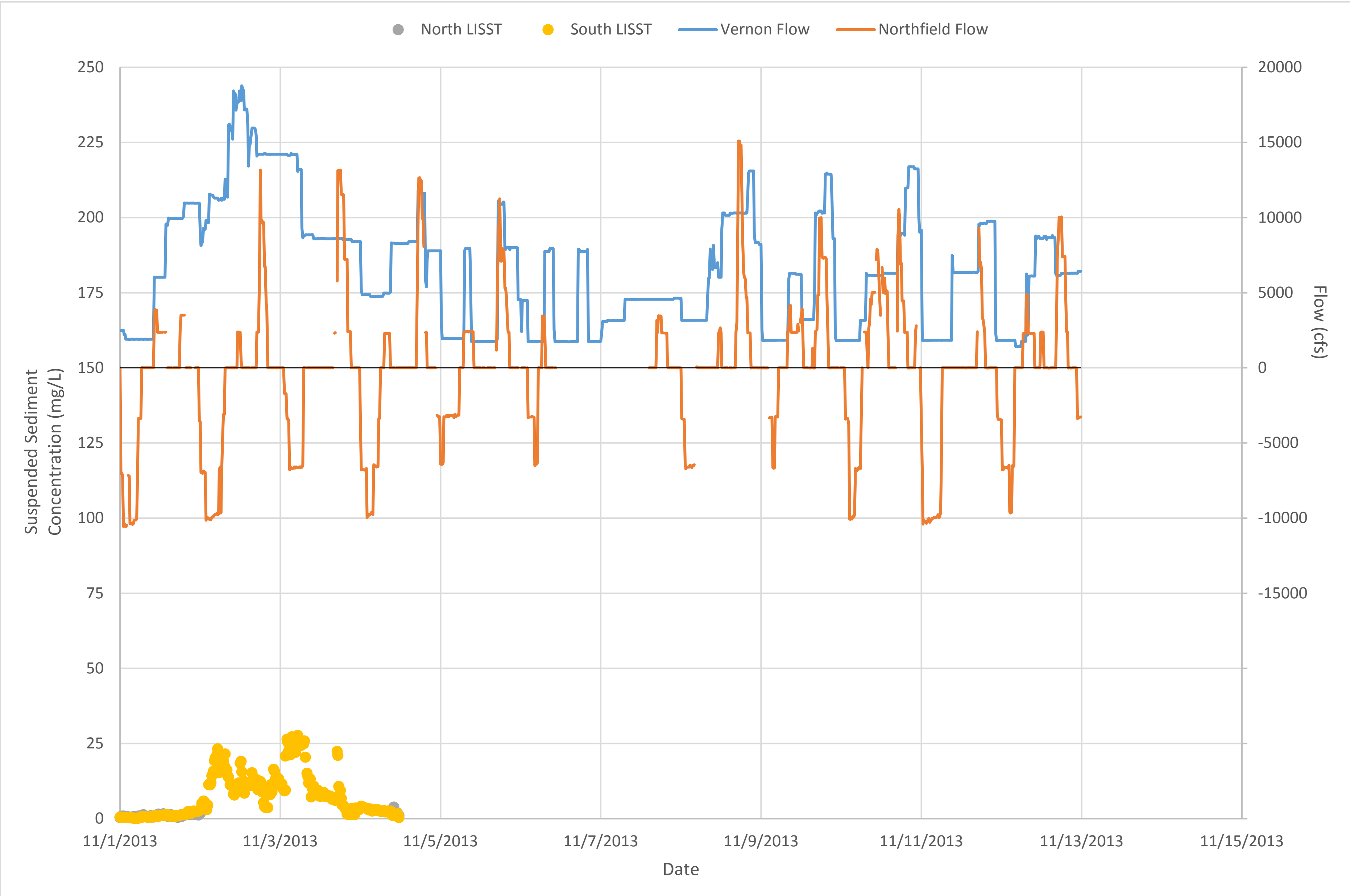
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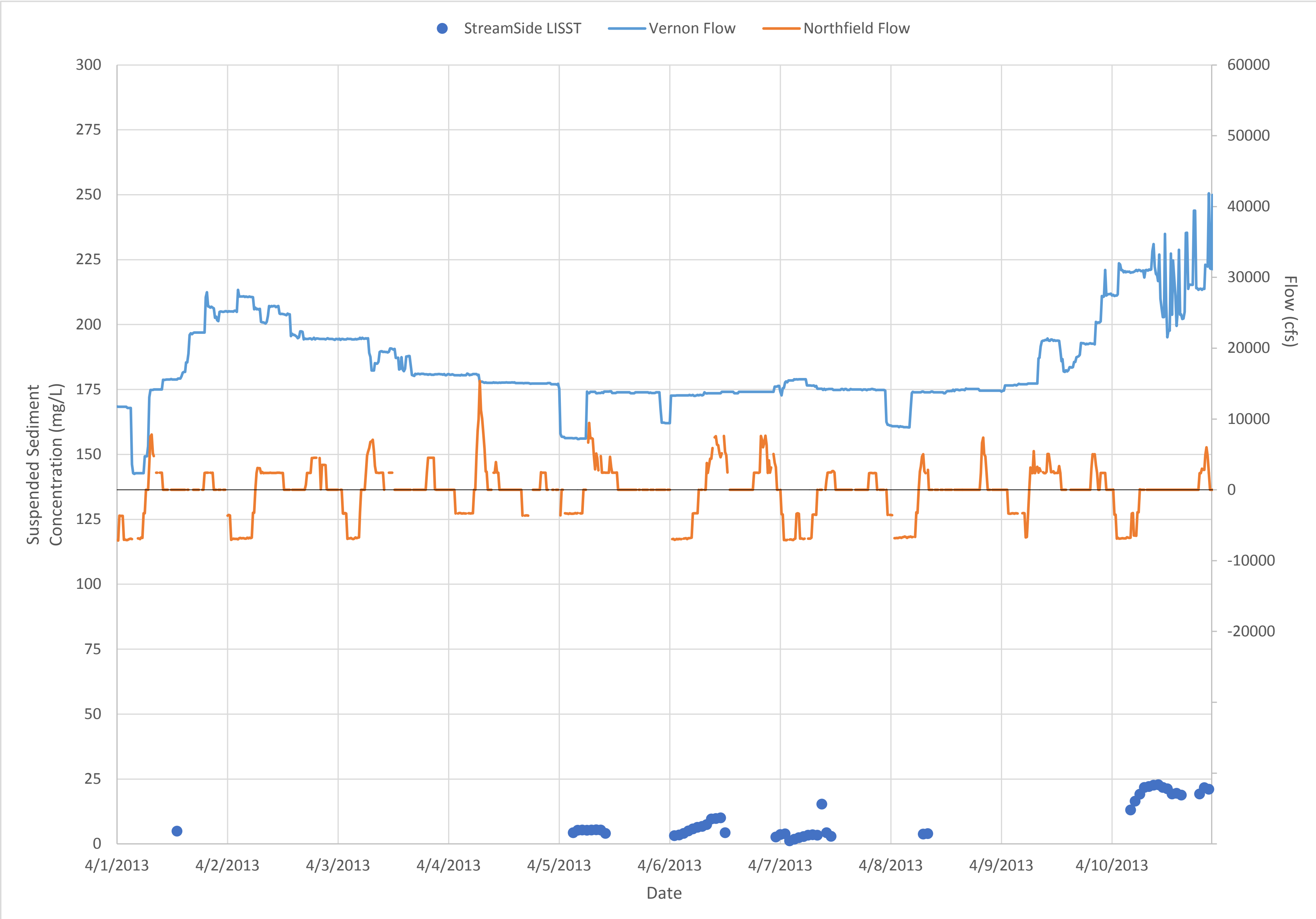
2013 CONTINUOUS LISST INSTRUMENT TIMESERIES-10 DAY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Vernon Flow
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Suspended Sediment Concentration (mg/L)
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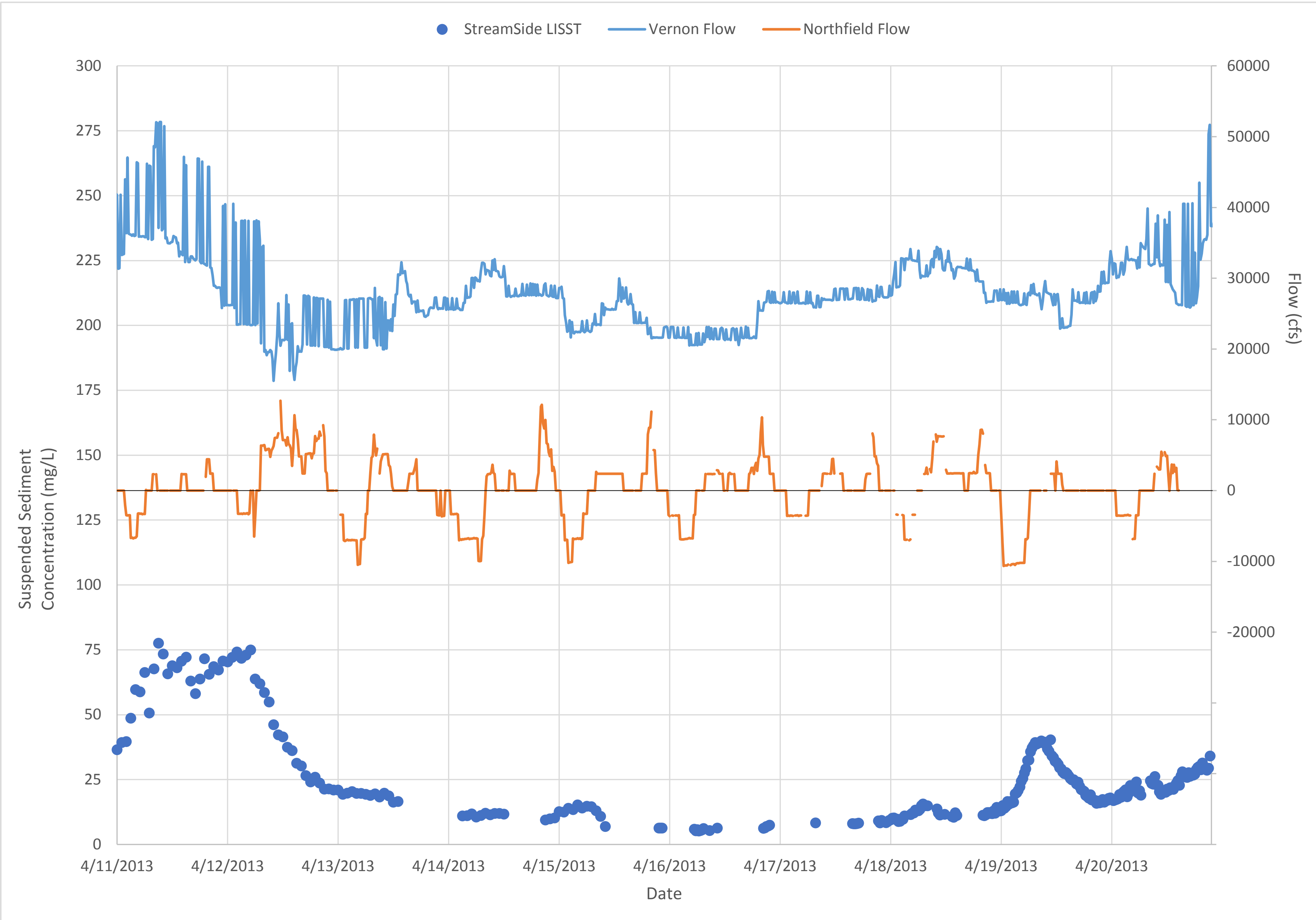

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Vernon Flow
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Suspended Sediment Concentration (mg/L)
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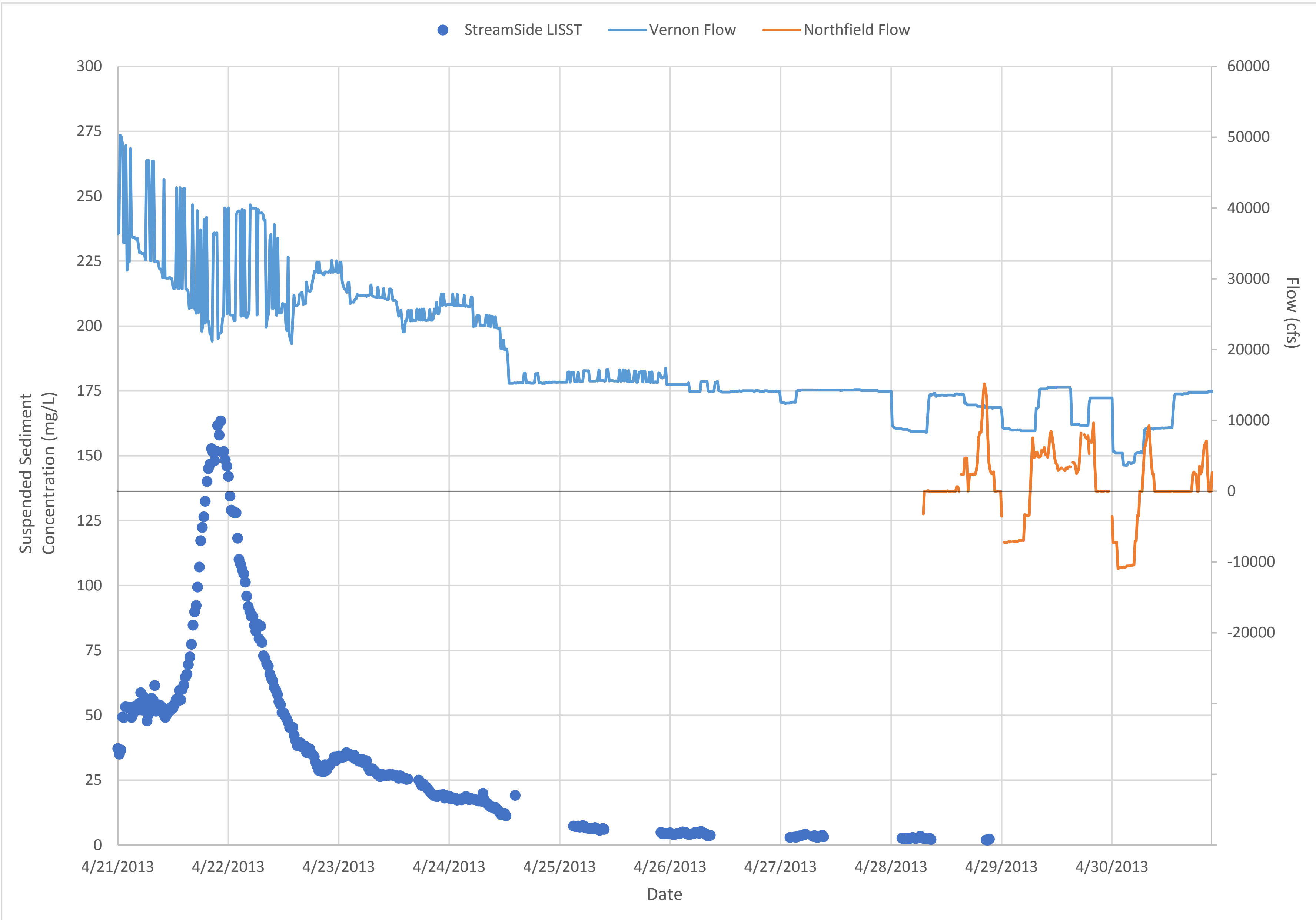
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Suspended Sediment Concentration (mg/L)
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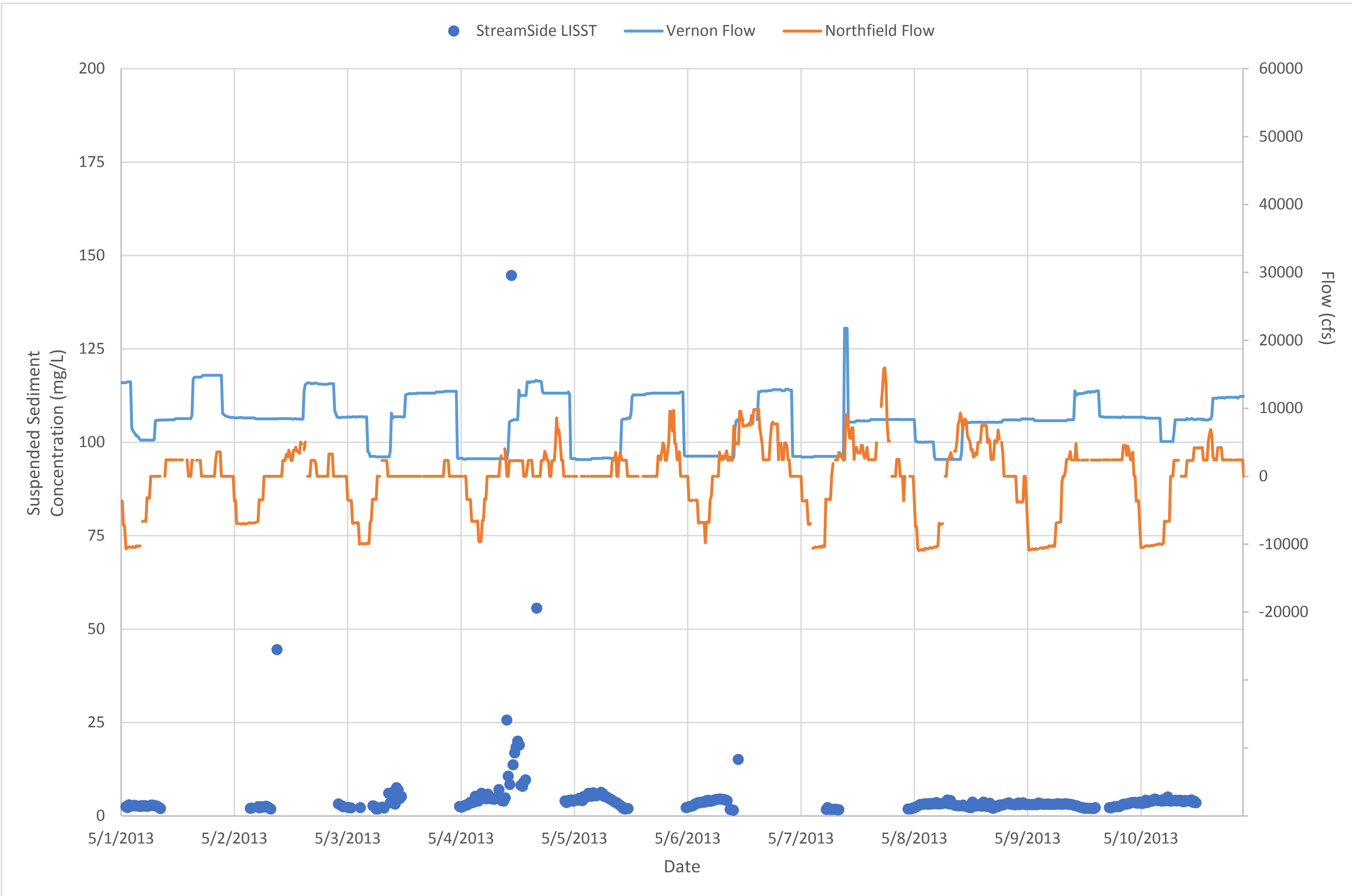

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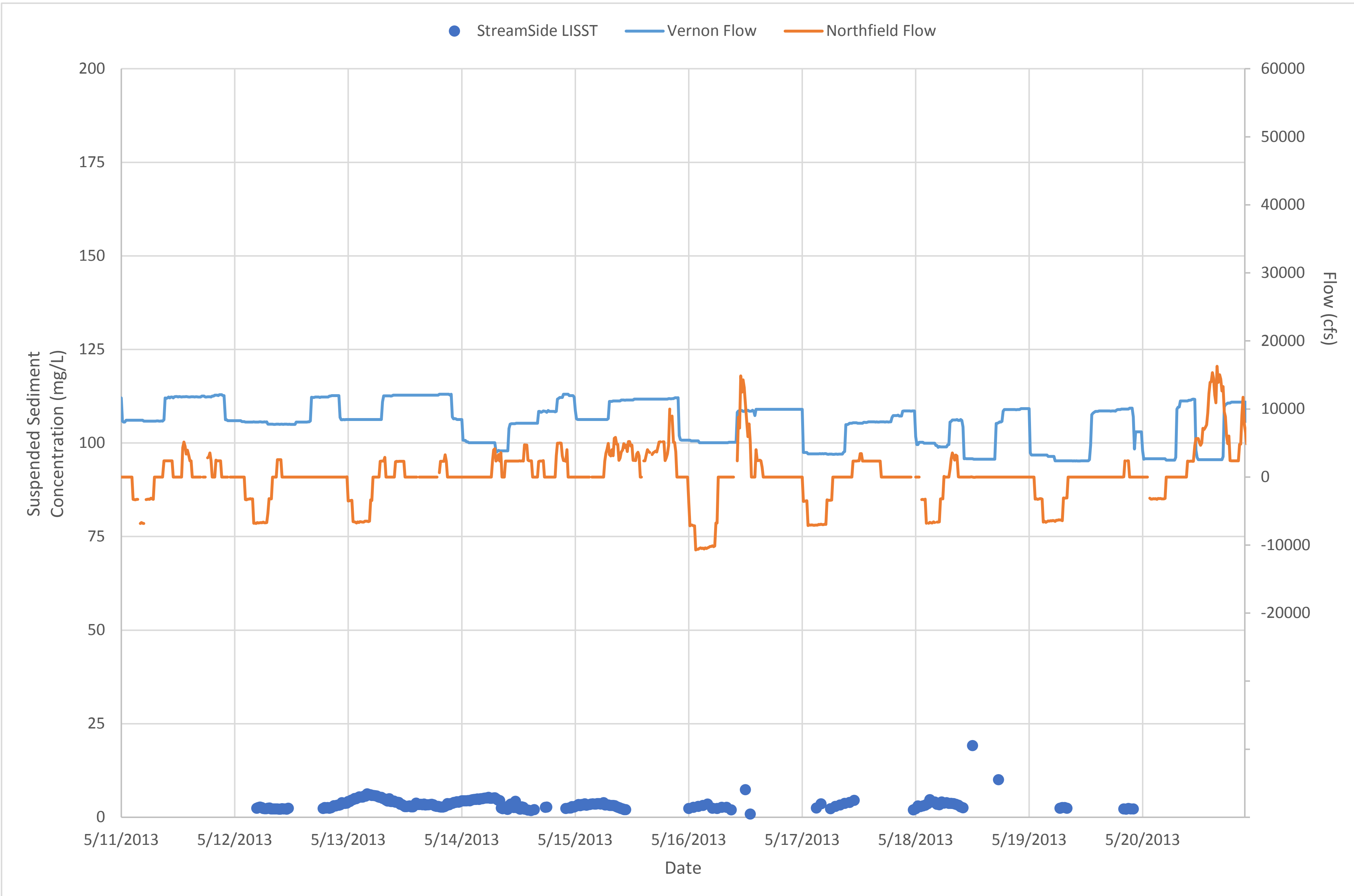

StreamSide LISST
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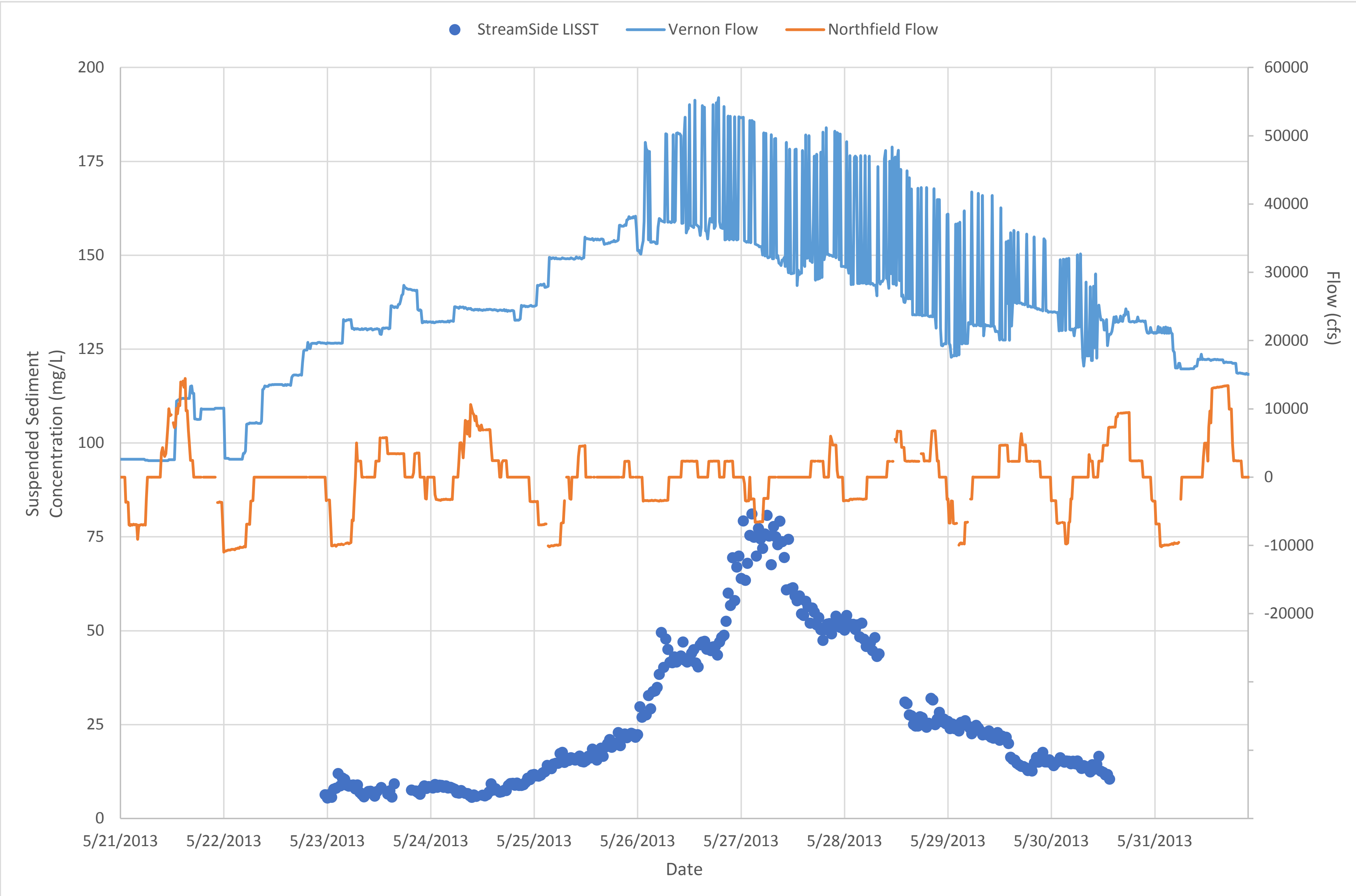
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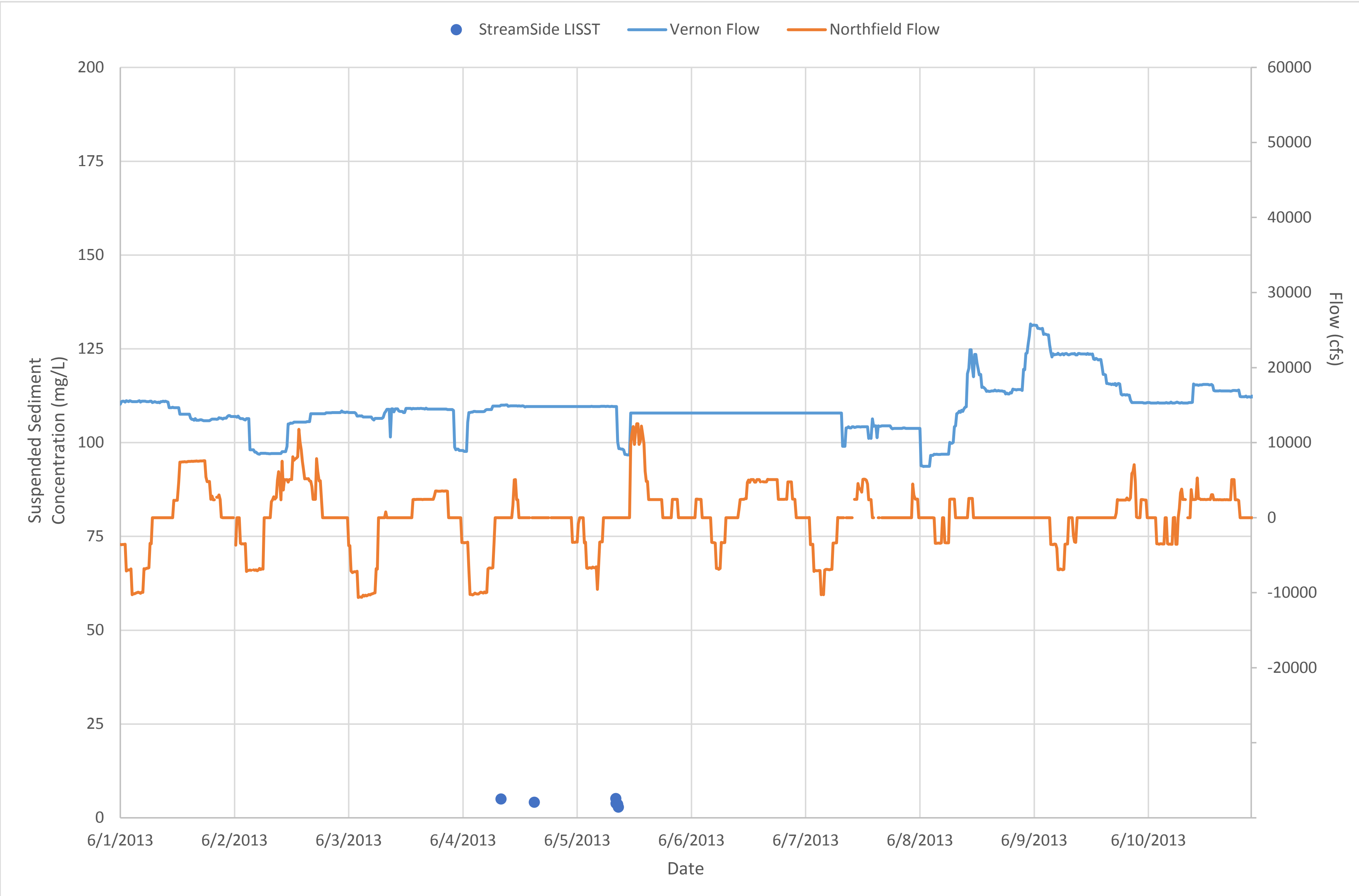

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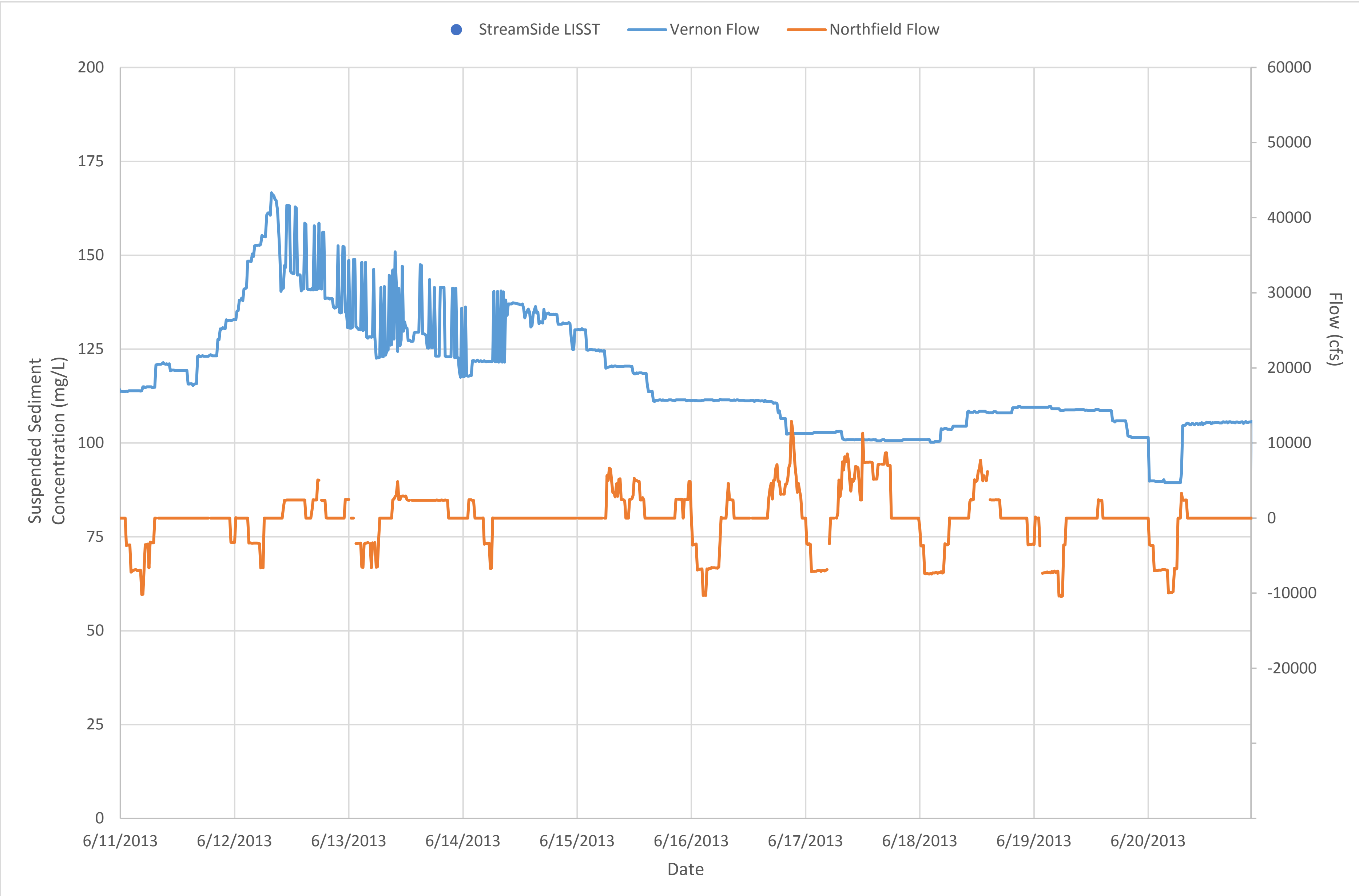

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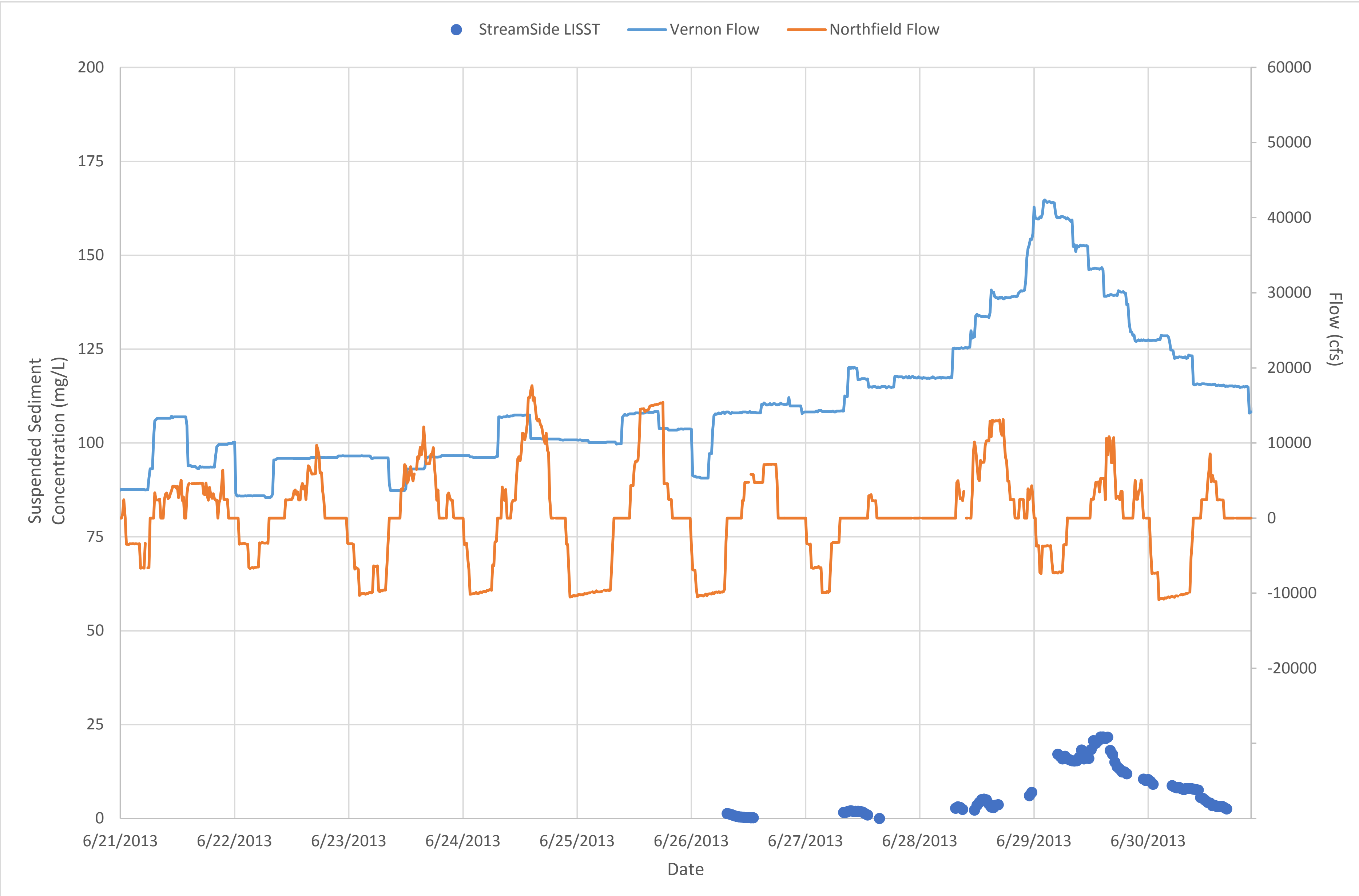

StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
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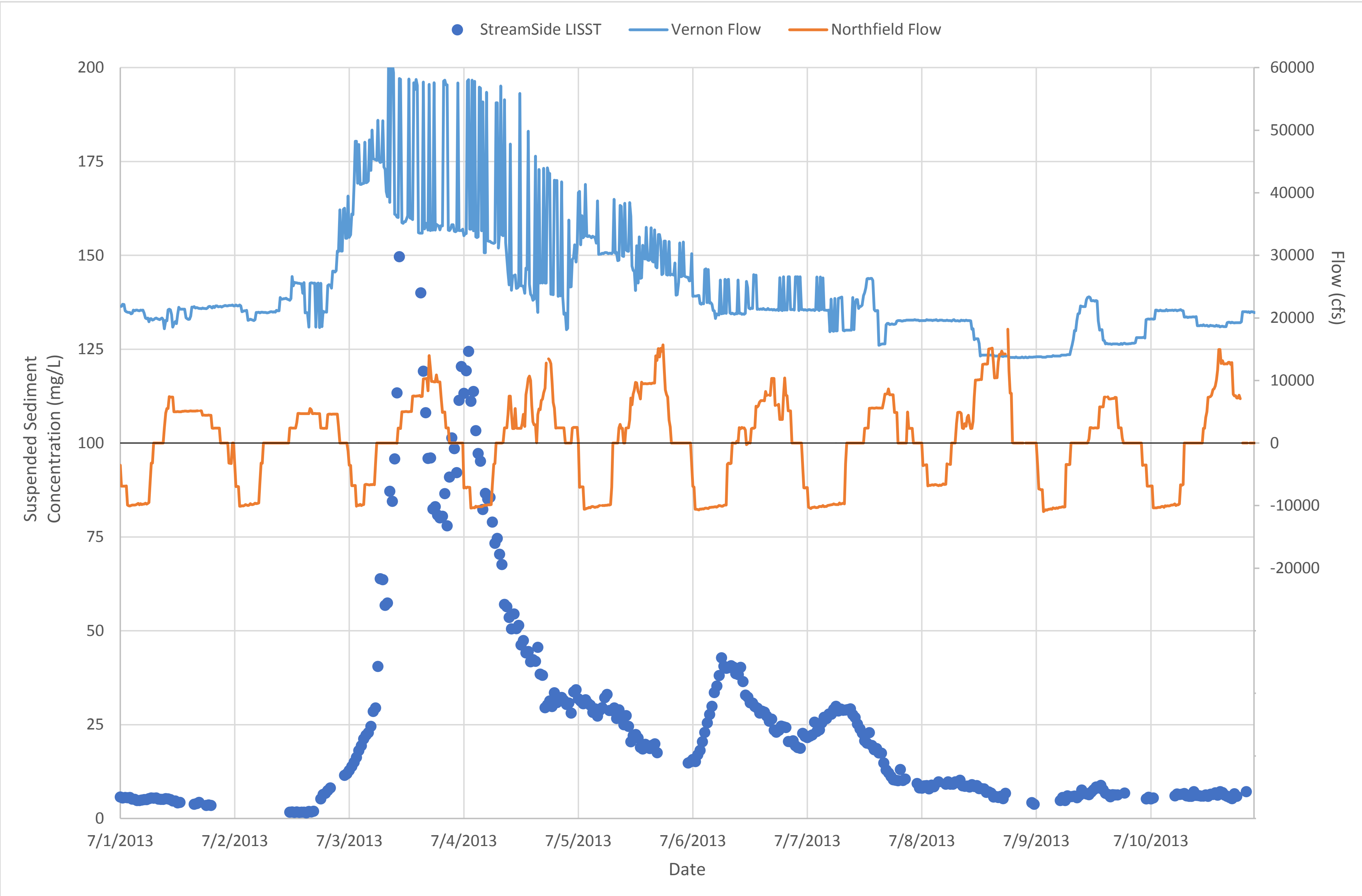

StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
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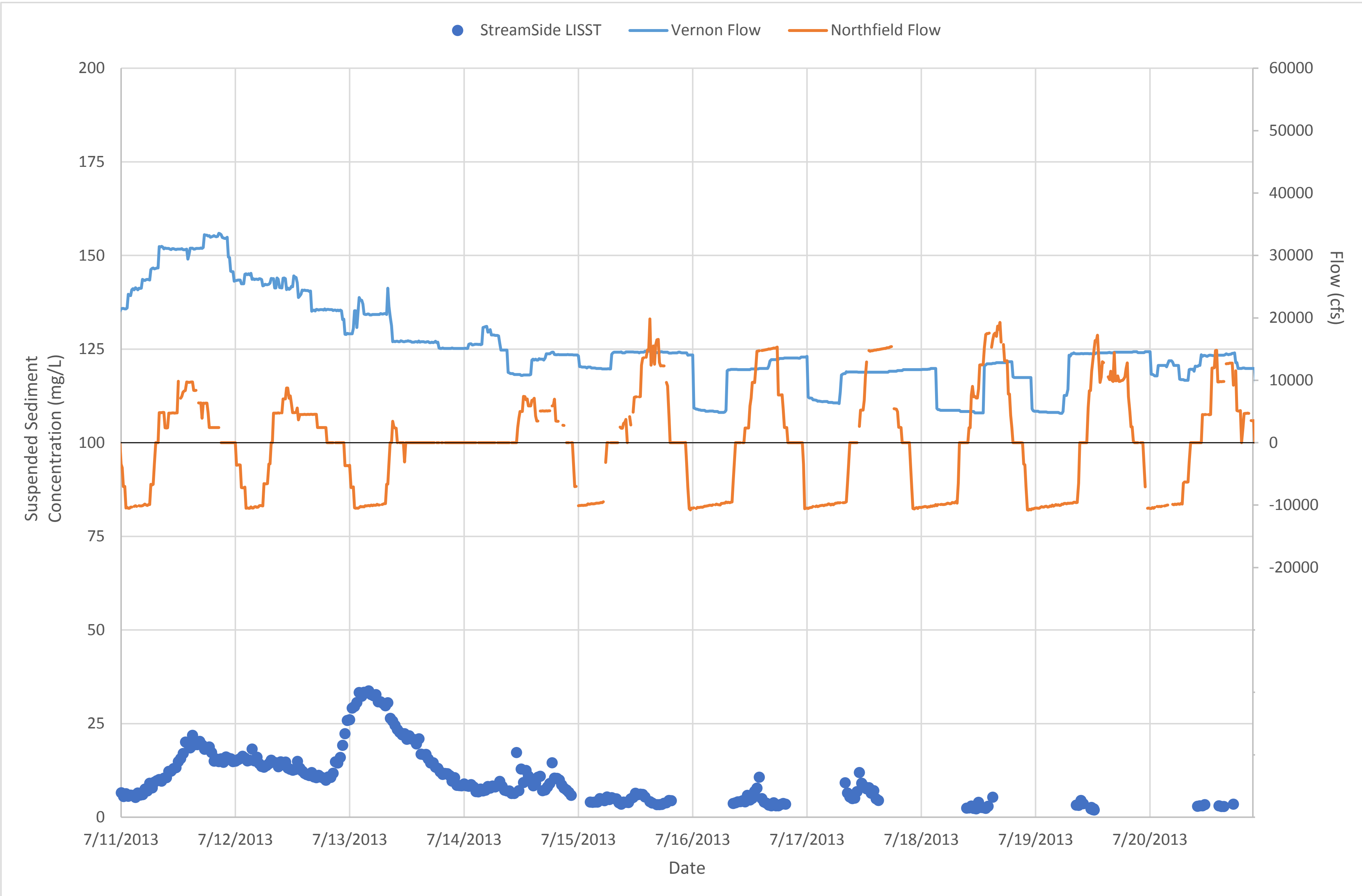
StreamSide LISST
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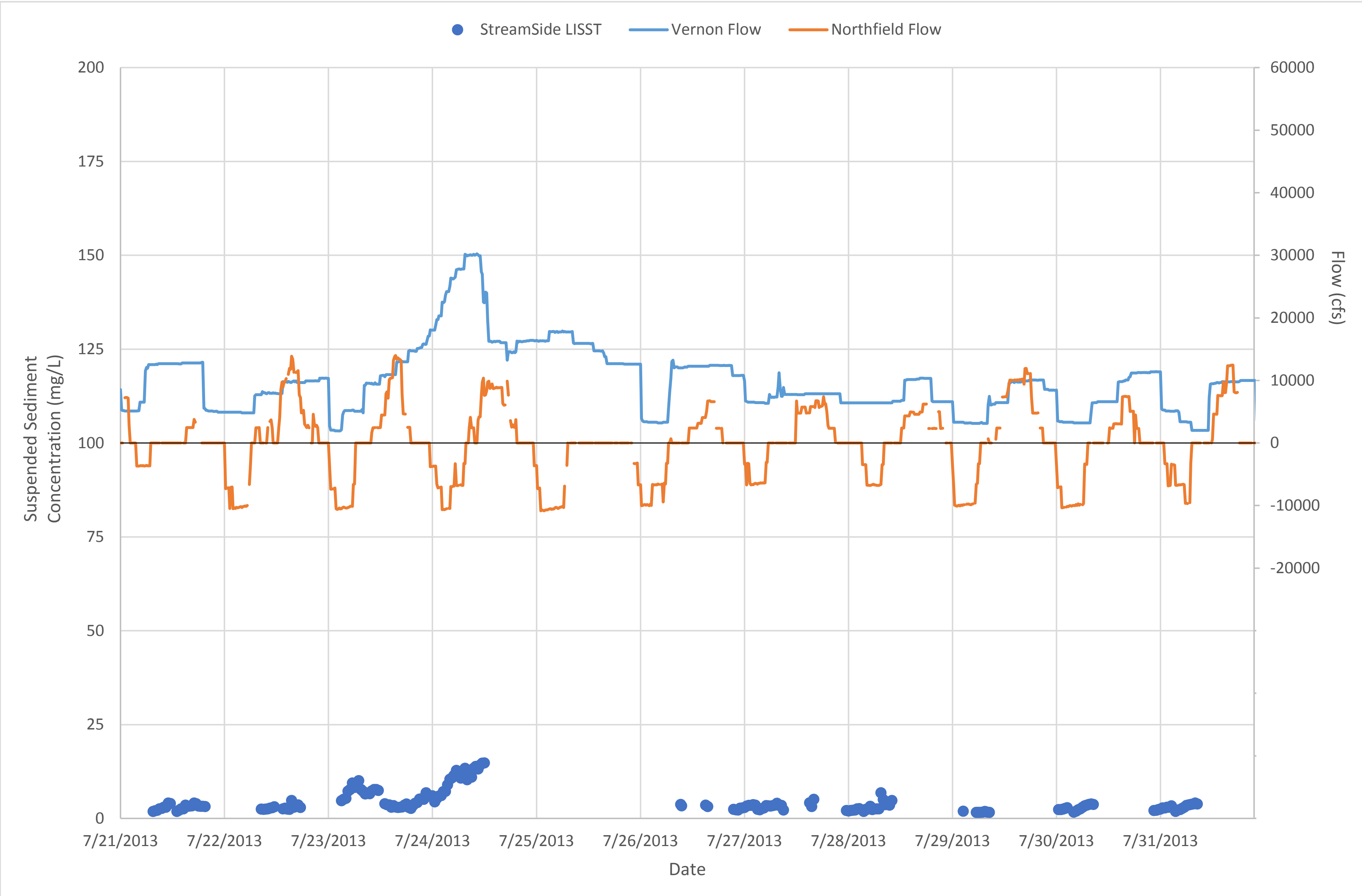

StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
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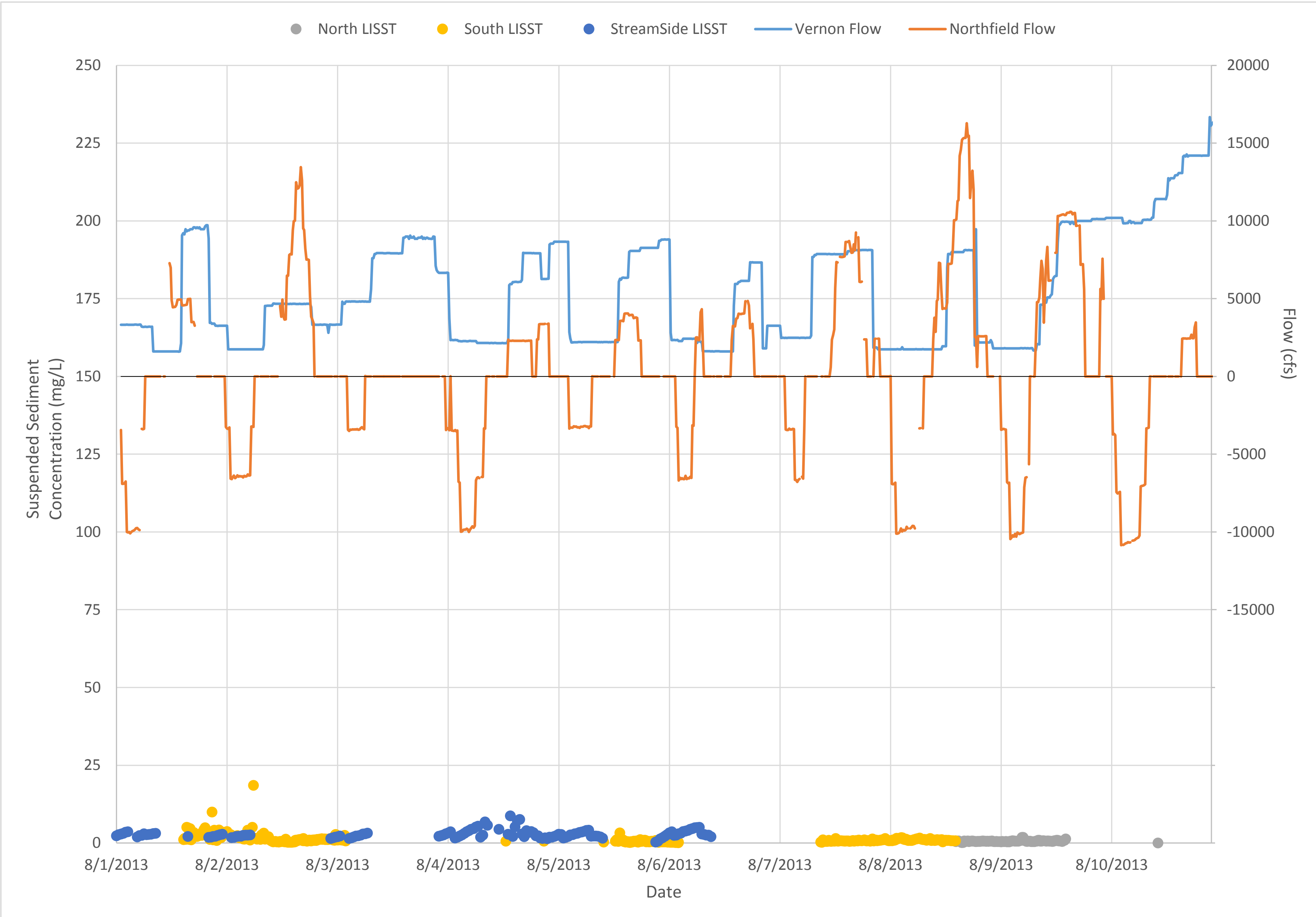

North LISST
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Vernon Flow
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Suspended Sediment Concentration (mg/L)
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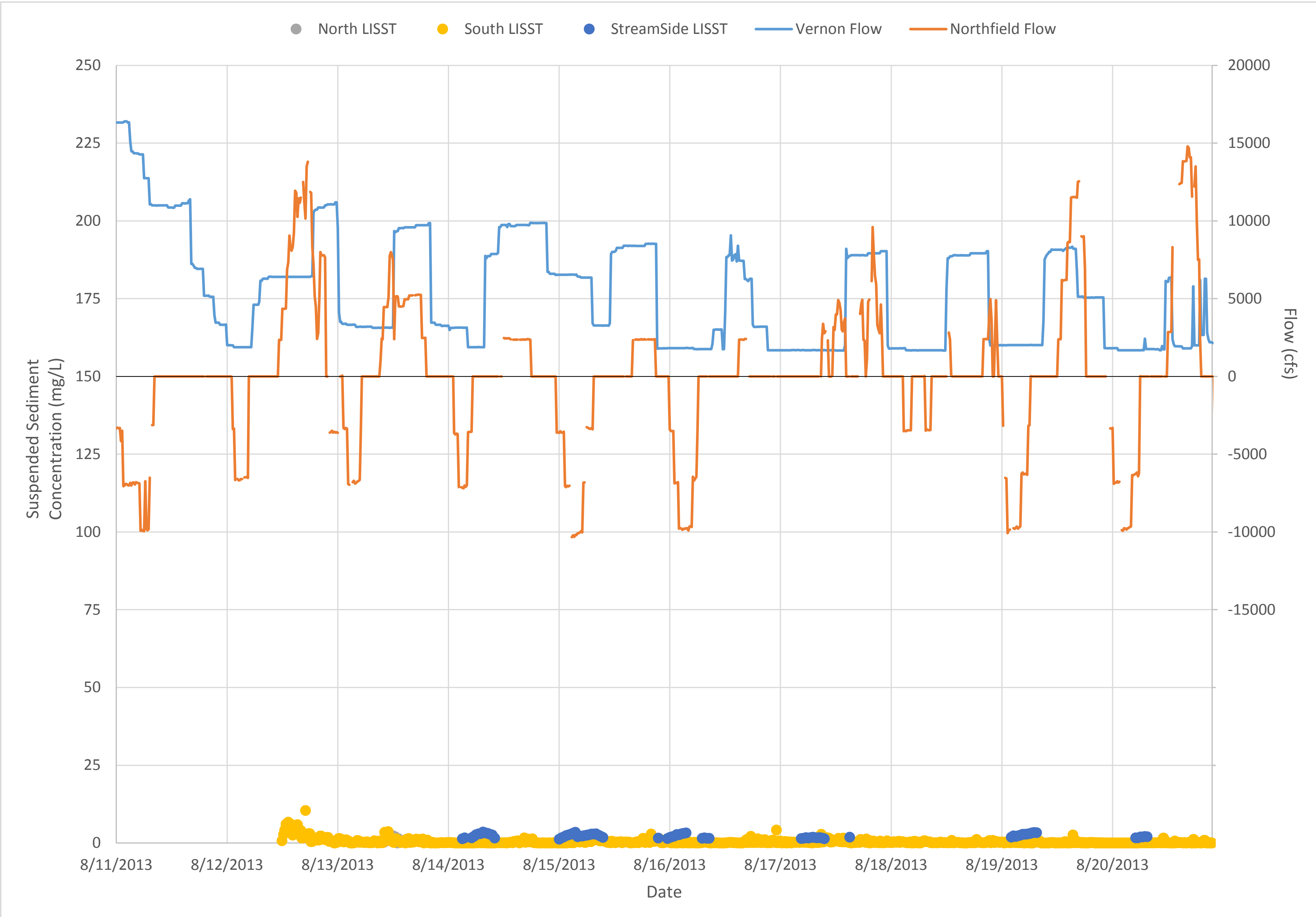

North LISST
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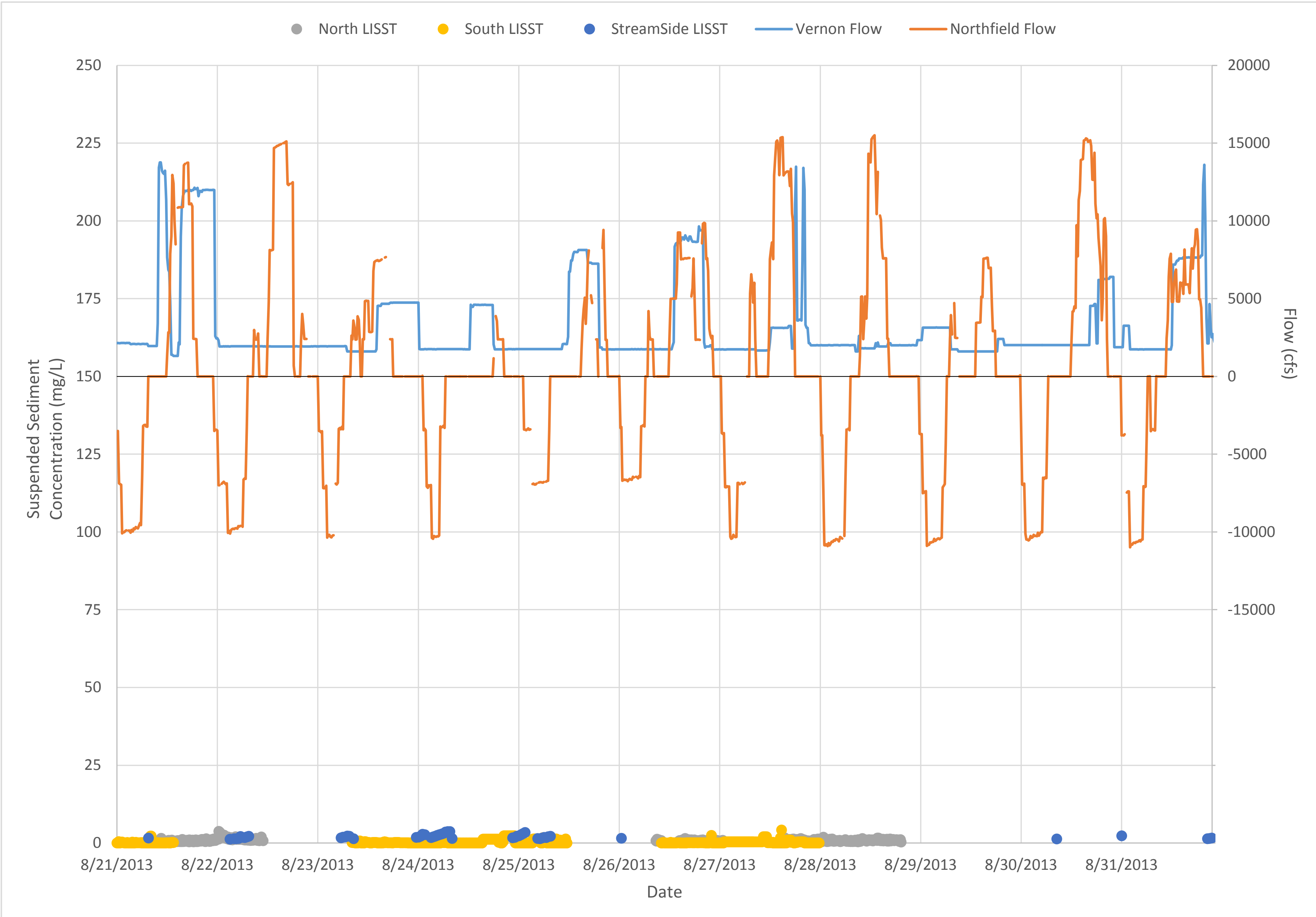

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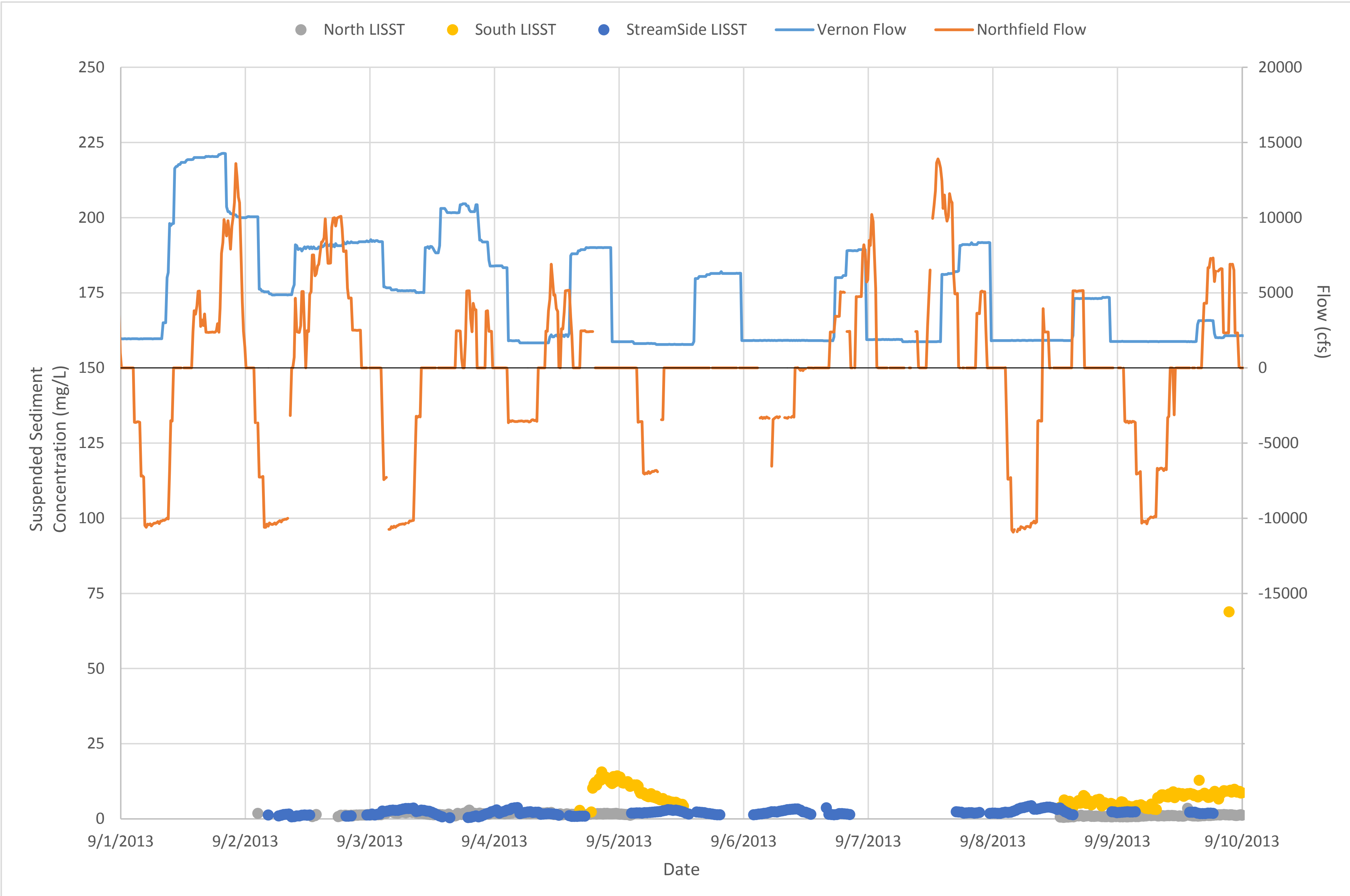

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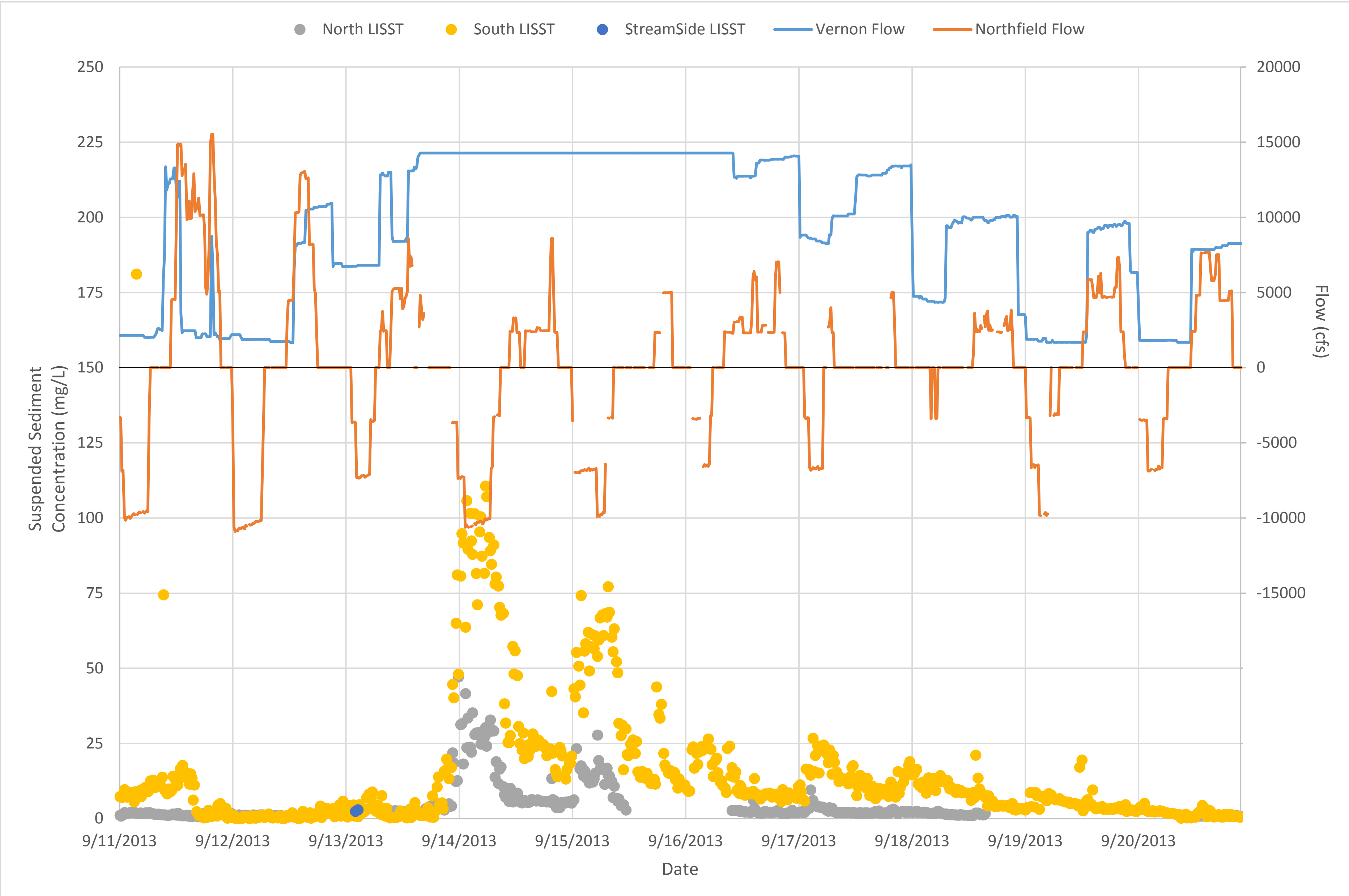
North LISST
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Vernon Flow
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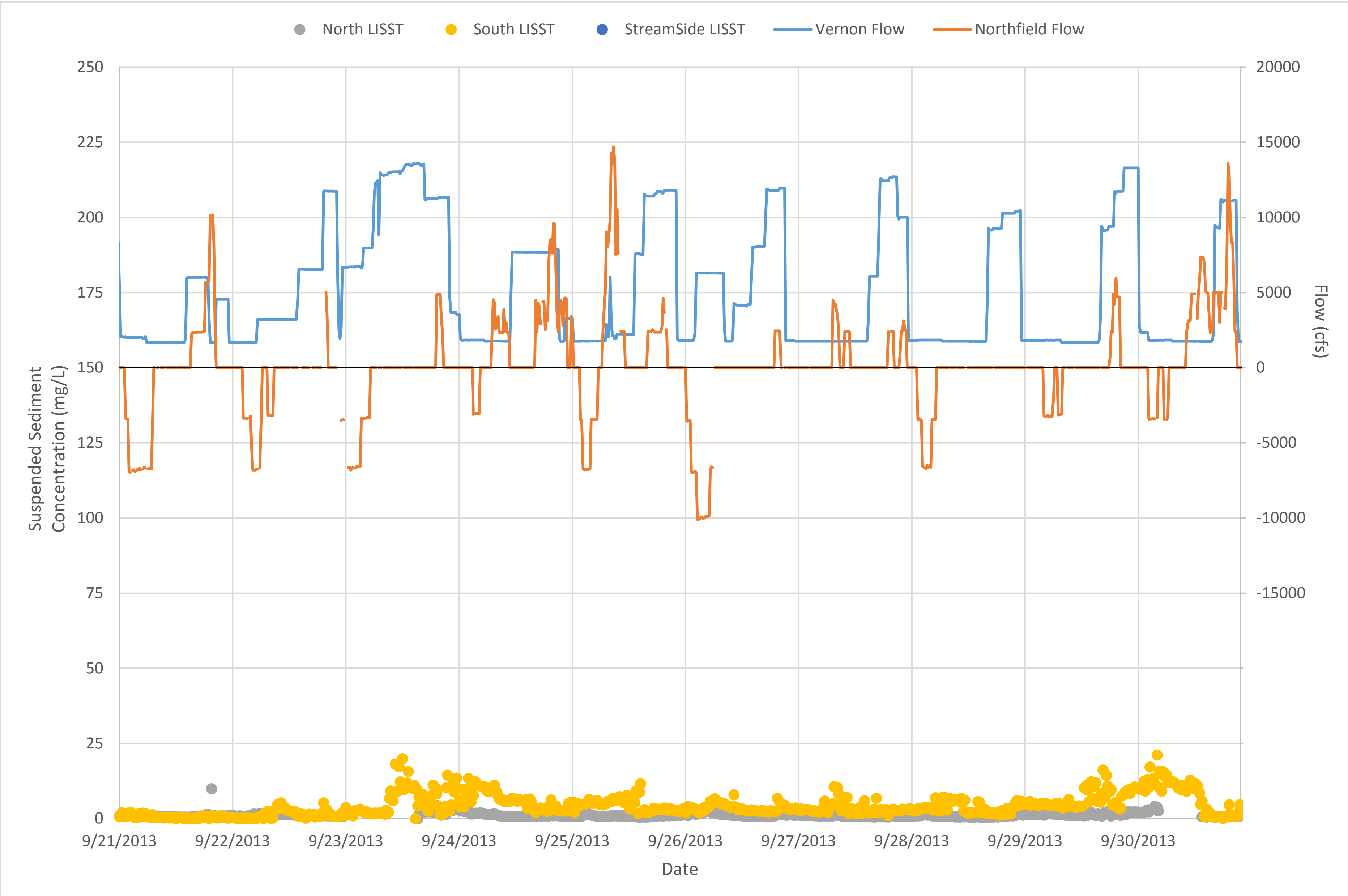

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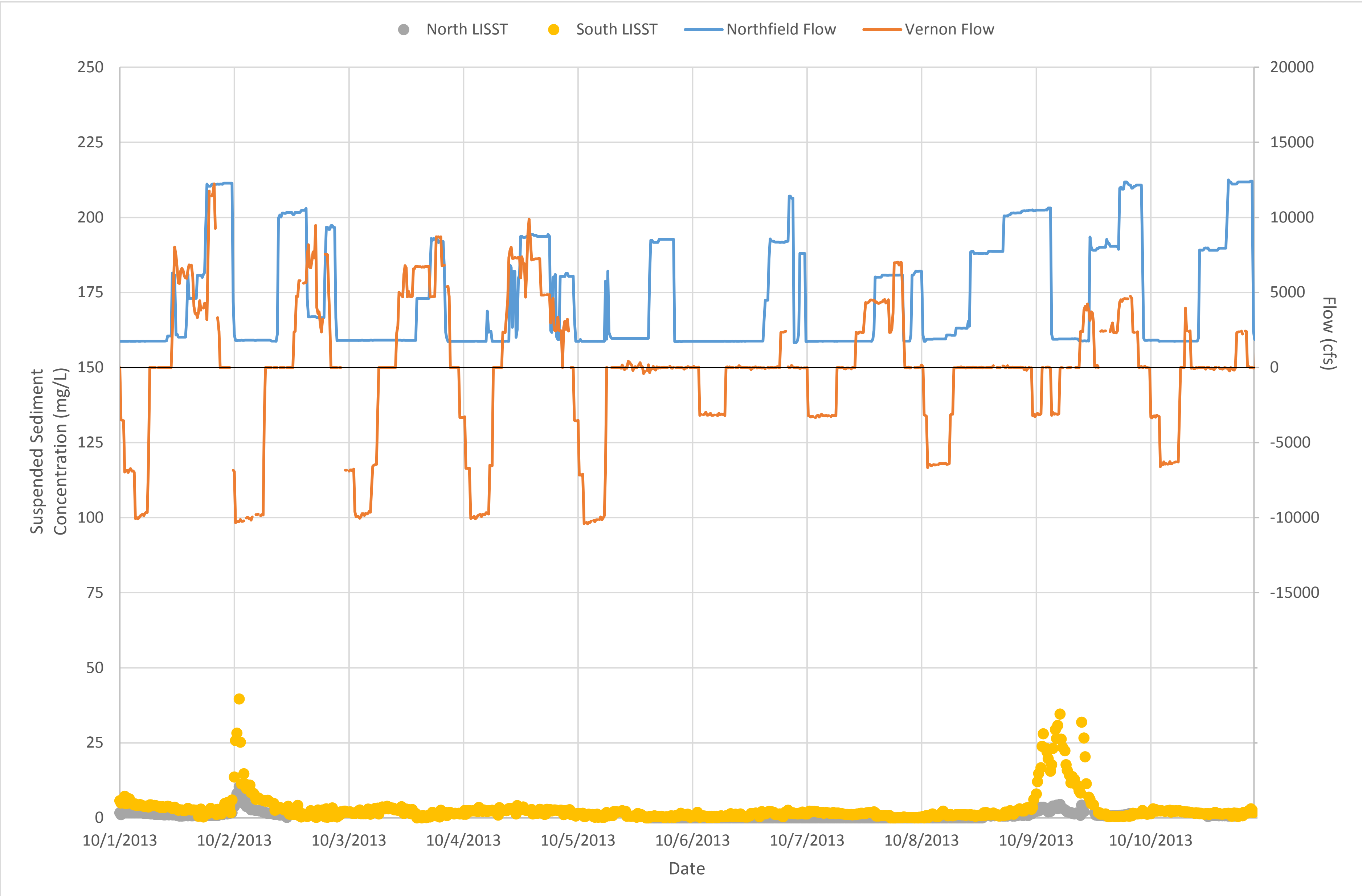
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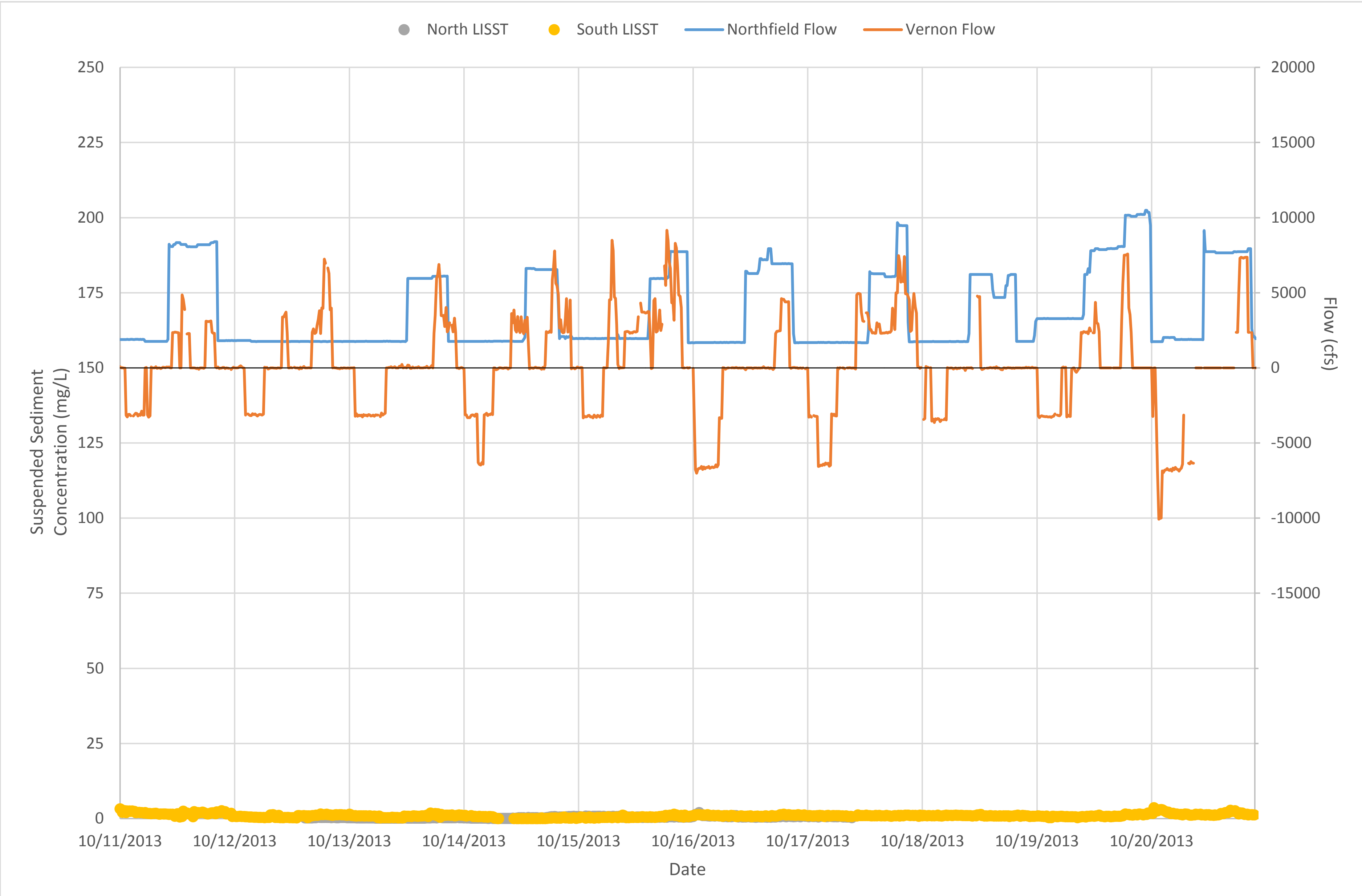
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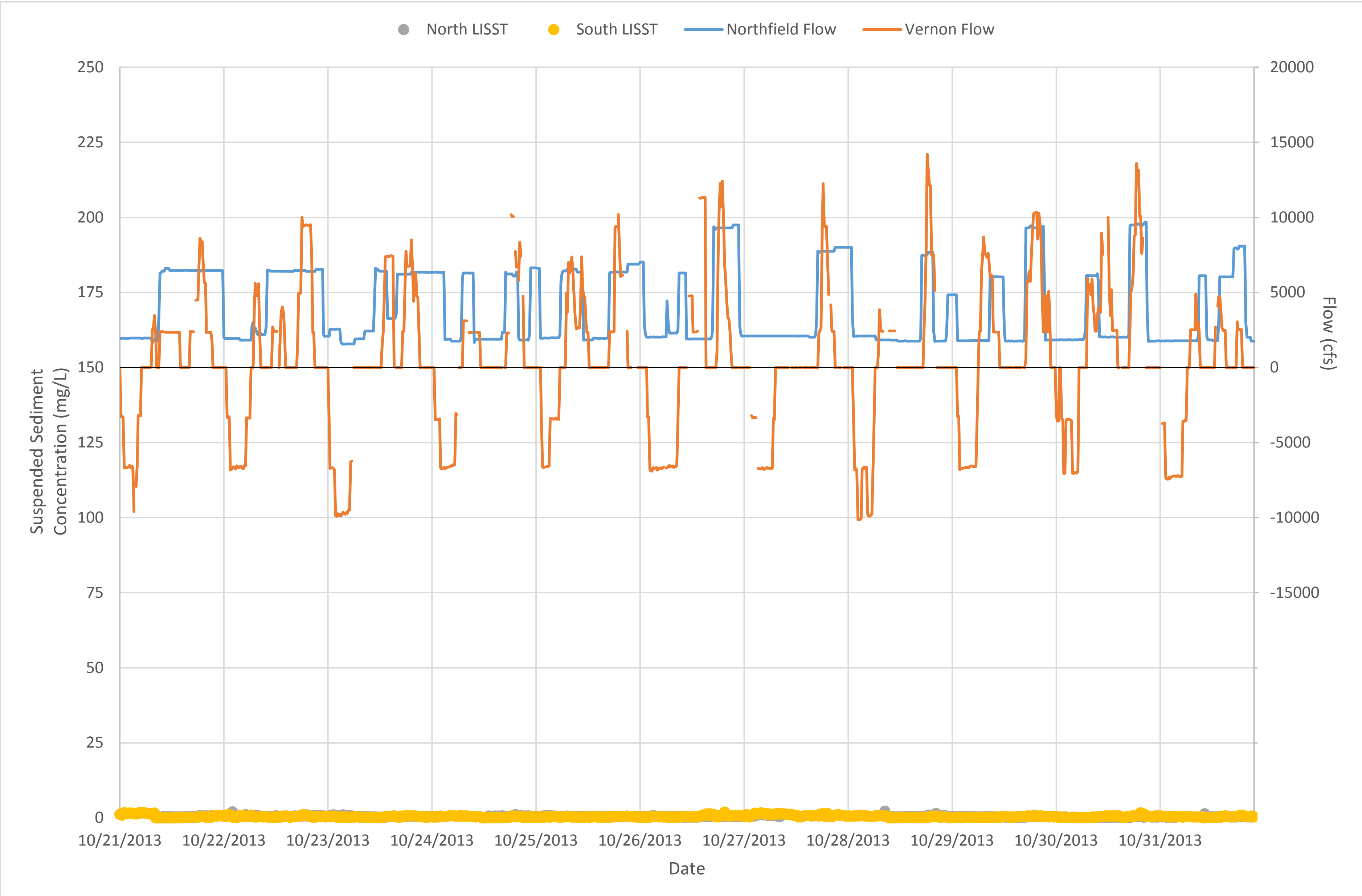
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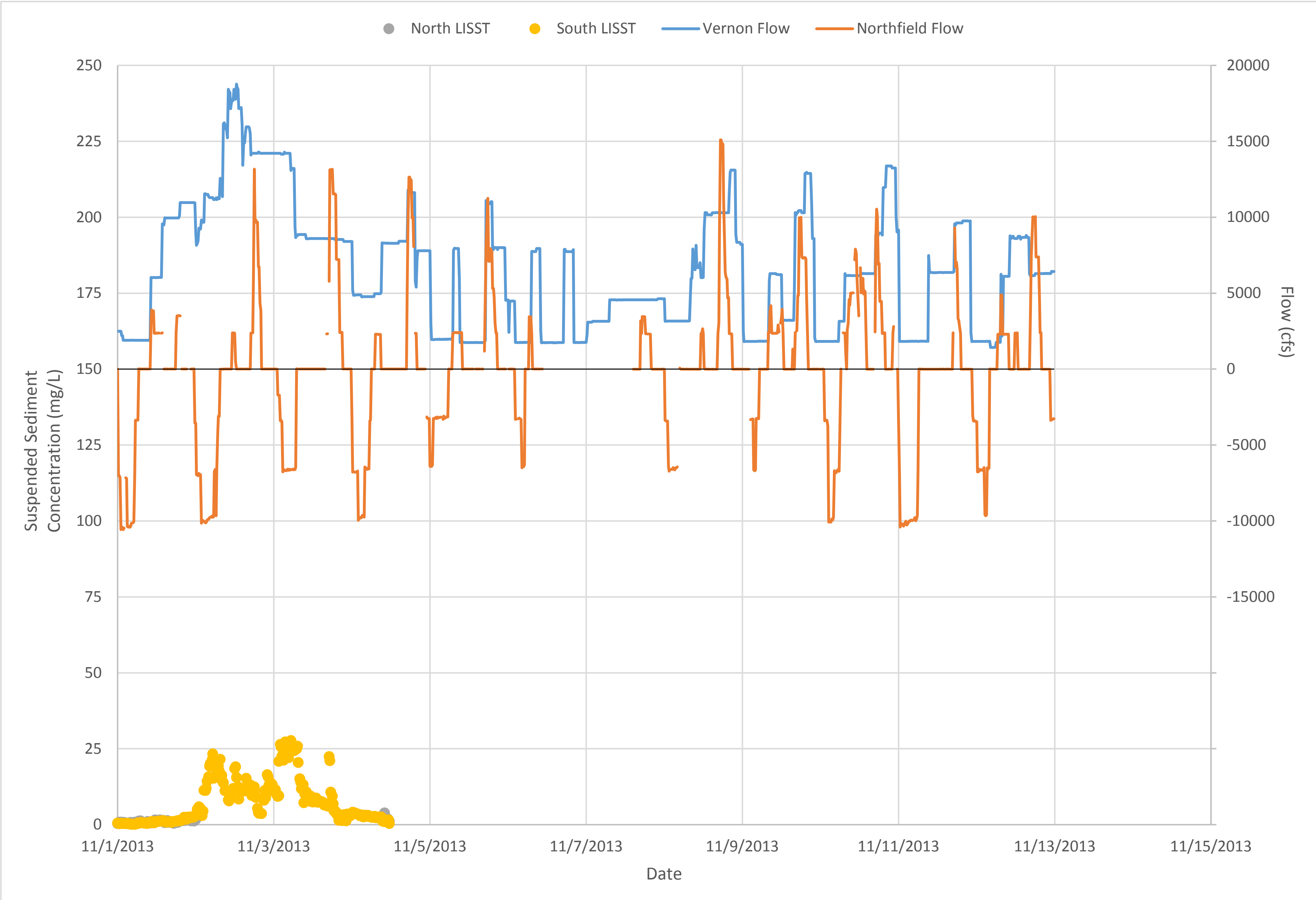
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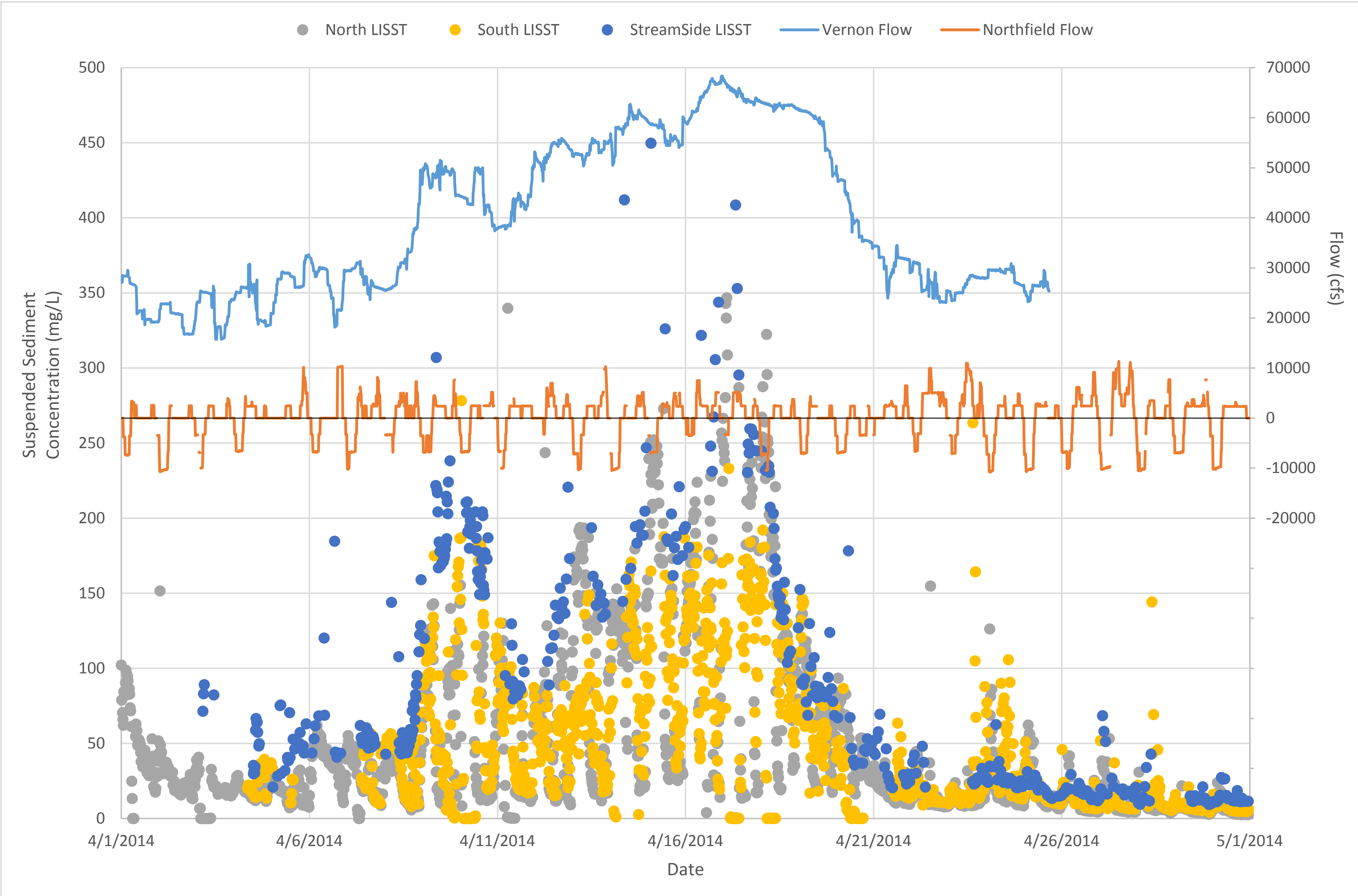
11/15/2013

# 2014 CONTINUOUS LISST INSTRUMENT TIMESERIES-MONTHLY



North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
500
450
400
350
300
250
200
150
100
50
0
70000
60000
50000
40000
30000
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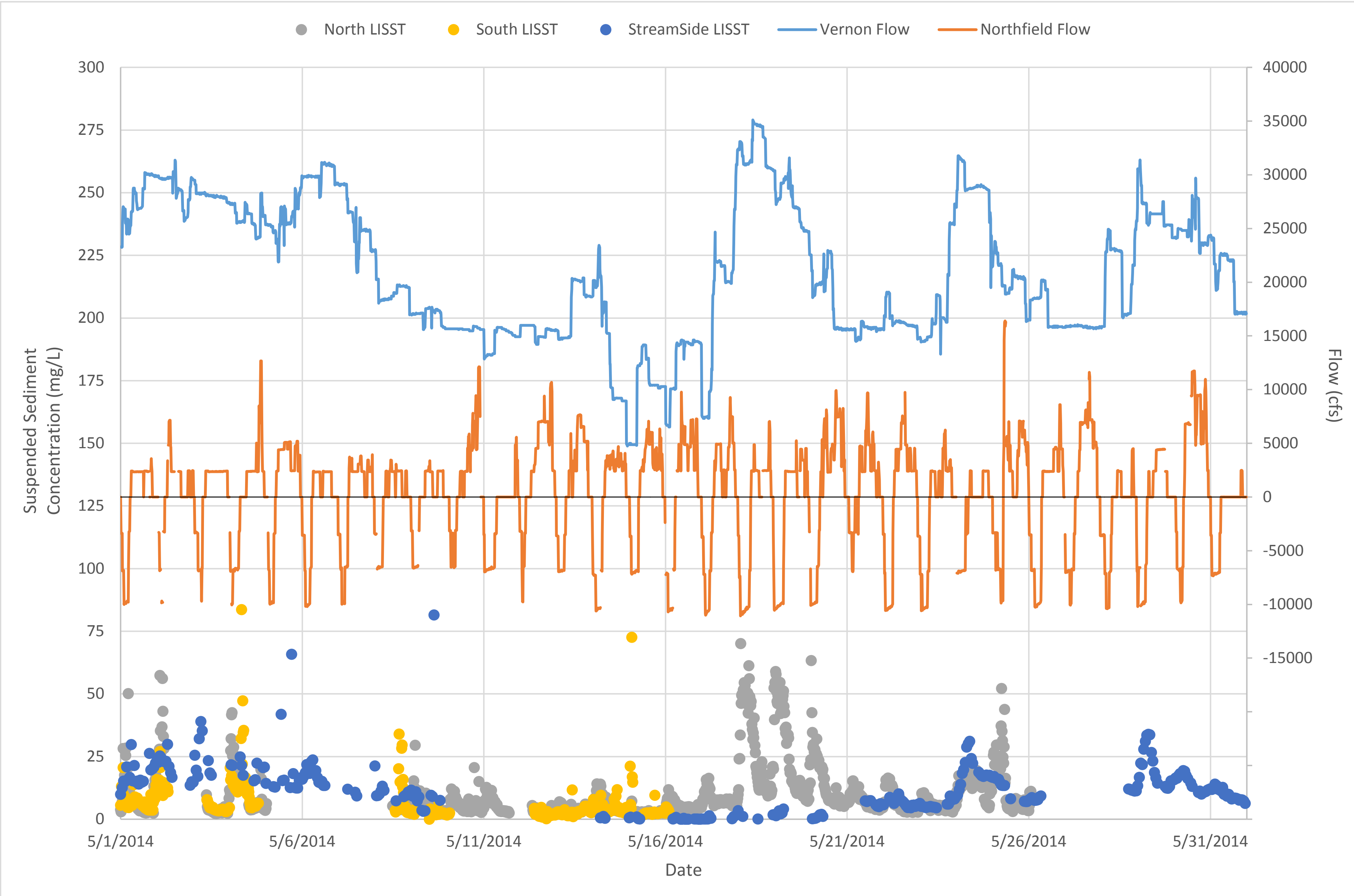
4/11/2014
4/16/2014
4/21/2014
4/26/2014
5/1/2014


North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
300
275
250
225
200
175
150
125
100
75
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25
0
Flow (cfs)
40000
35000
30000
25000
20000
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-10000
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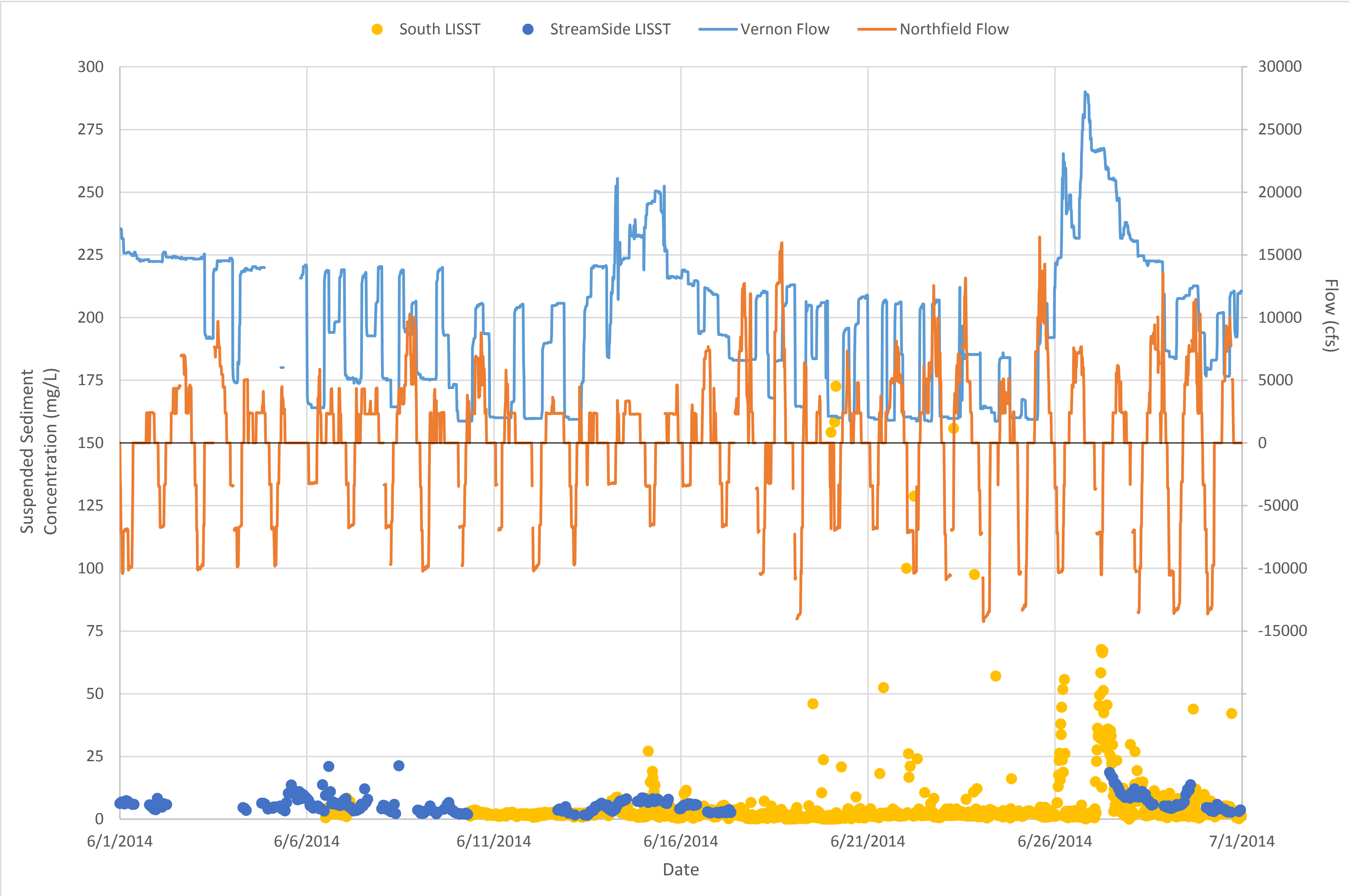
5/6/2014
5/11/2014
5/16/2014
5/21/2014
5/26/2014
5/31/2014
Date


South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
300
275
250
225
200
175
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125
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6/1/2014
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6/21/2014
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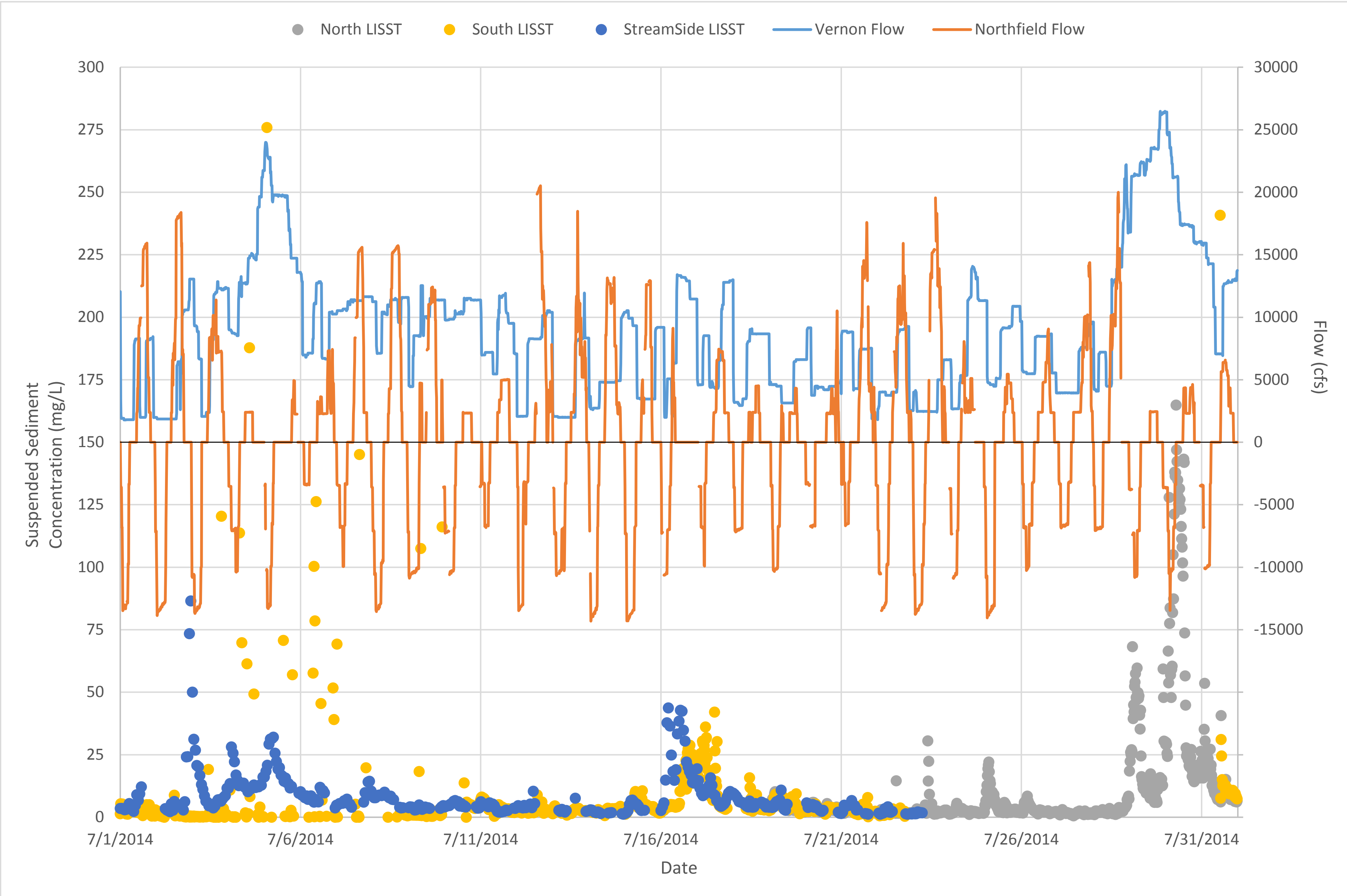
7/1/2014



North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
300
275
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225
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175
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Flow (cfs)
7/1/2014
7/6/2014
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7/21/2014
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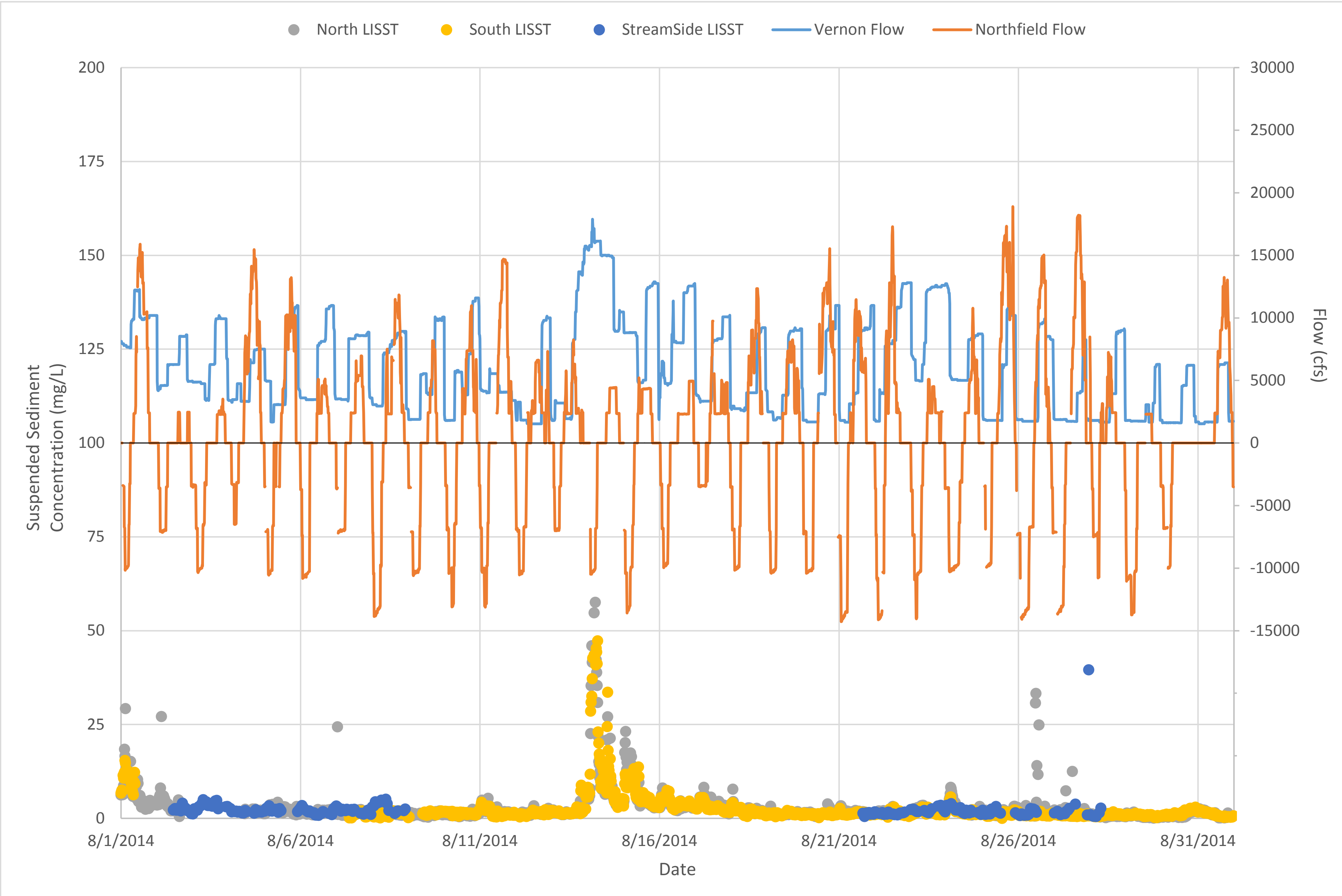
7/31/2014
Date



North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
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8/1/2014
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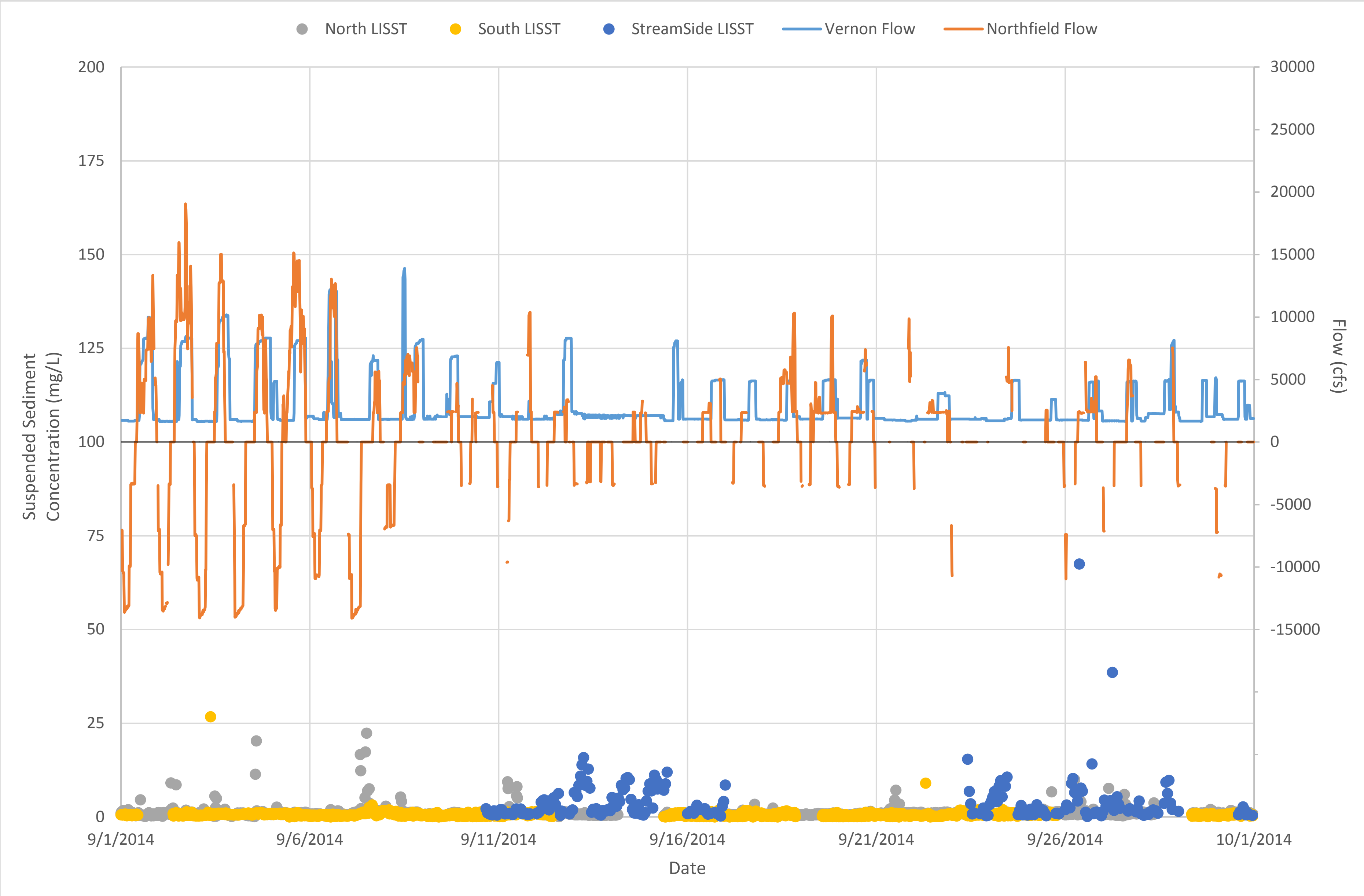
8/21/2014
8/26/2014
8/31/2014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South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
9/1/2014
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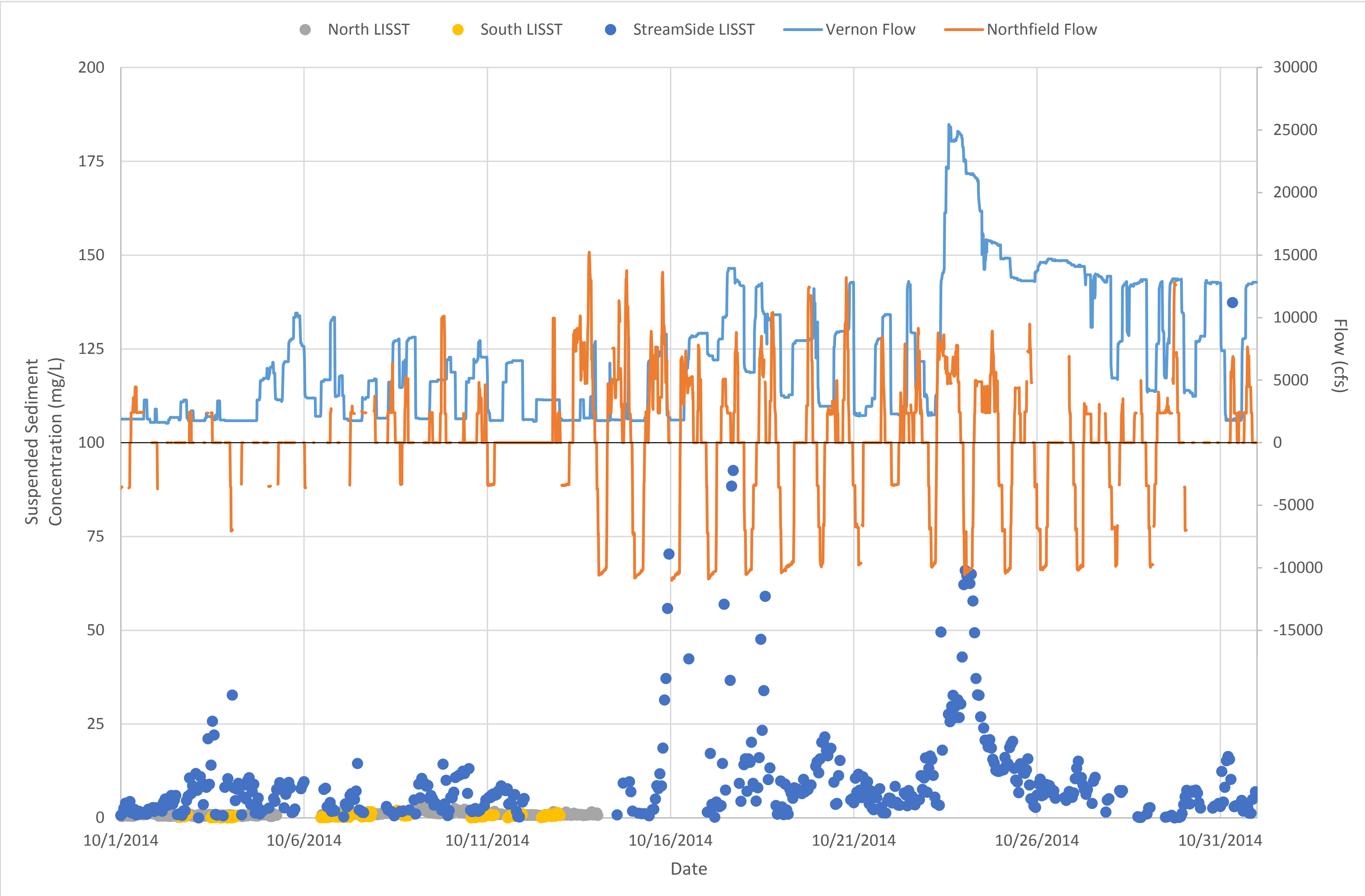
9/26/2014
10/1/2014
Date


North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
200
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150
125
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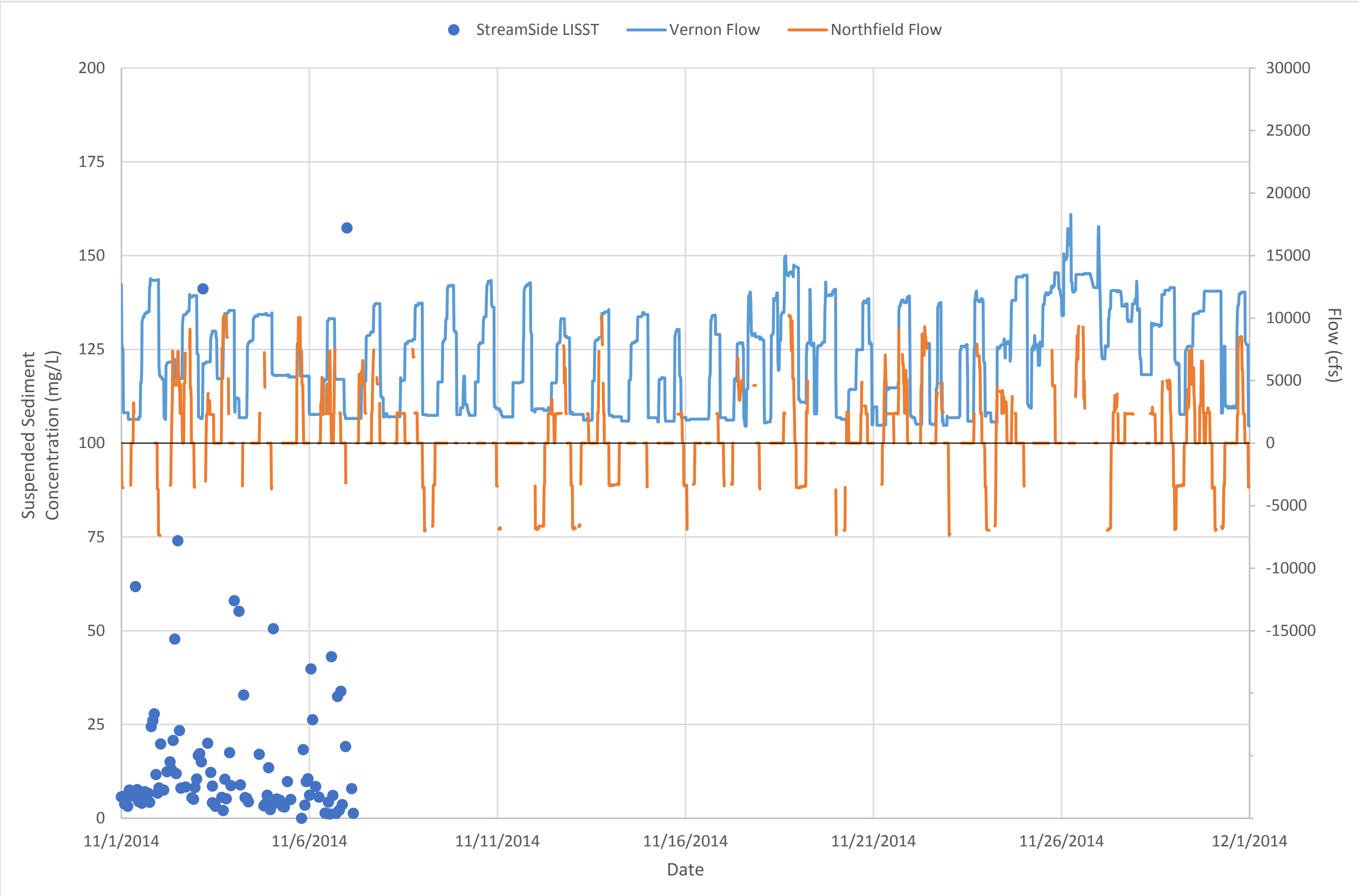
10/21/2014
10/26/2014
10/31/2014



StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
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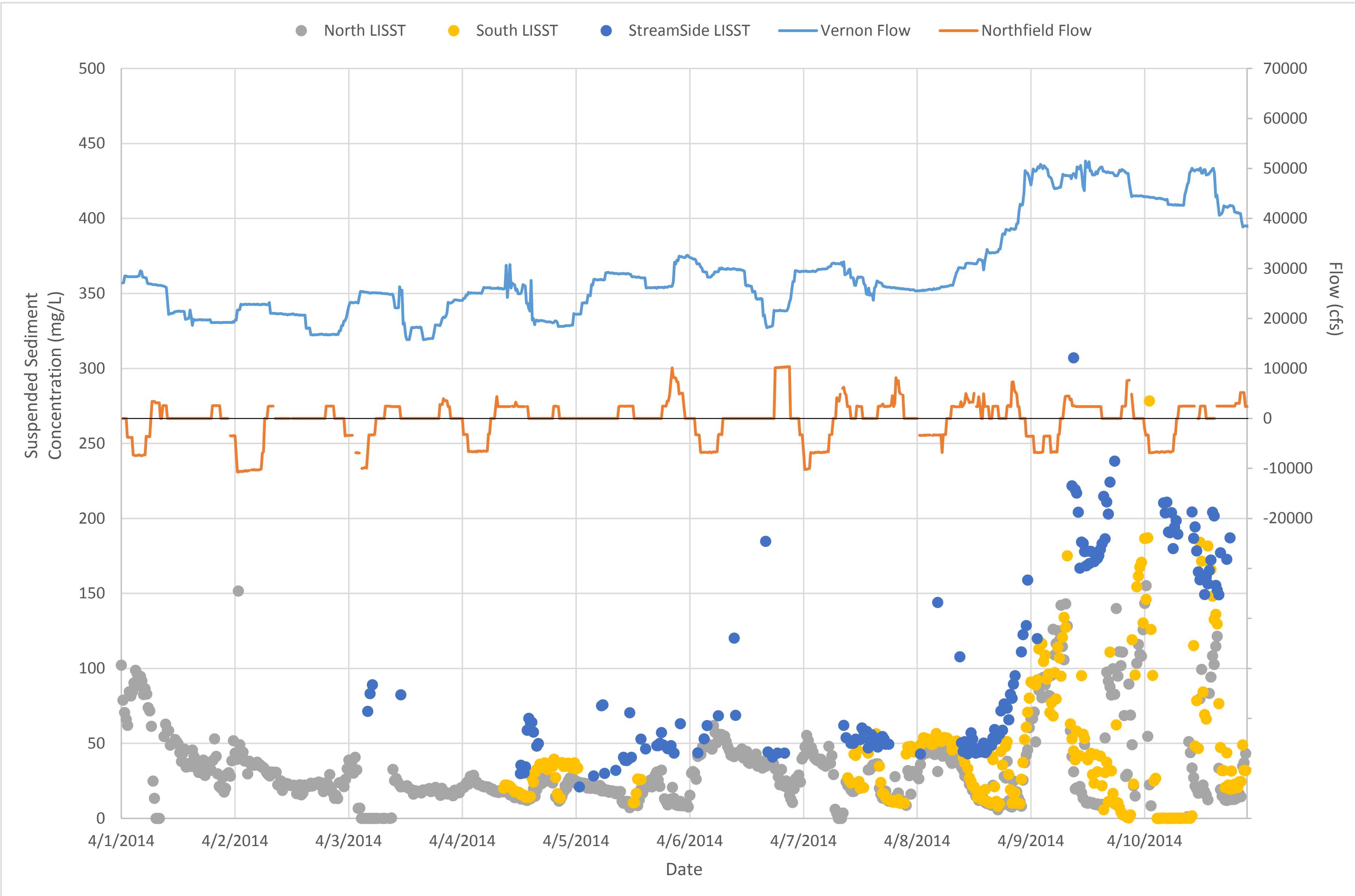
Flow (cfs)
11/1/2014
11/6/2014
11/11/2014
11/16/2014
11/21/2014
11/26/2014
12/1/2014
Date

2014 CONTINUOUS LISST INSTRUMENT TIMESERIES-10 DAY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StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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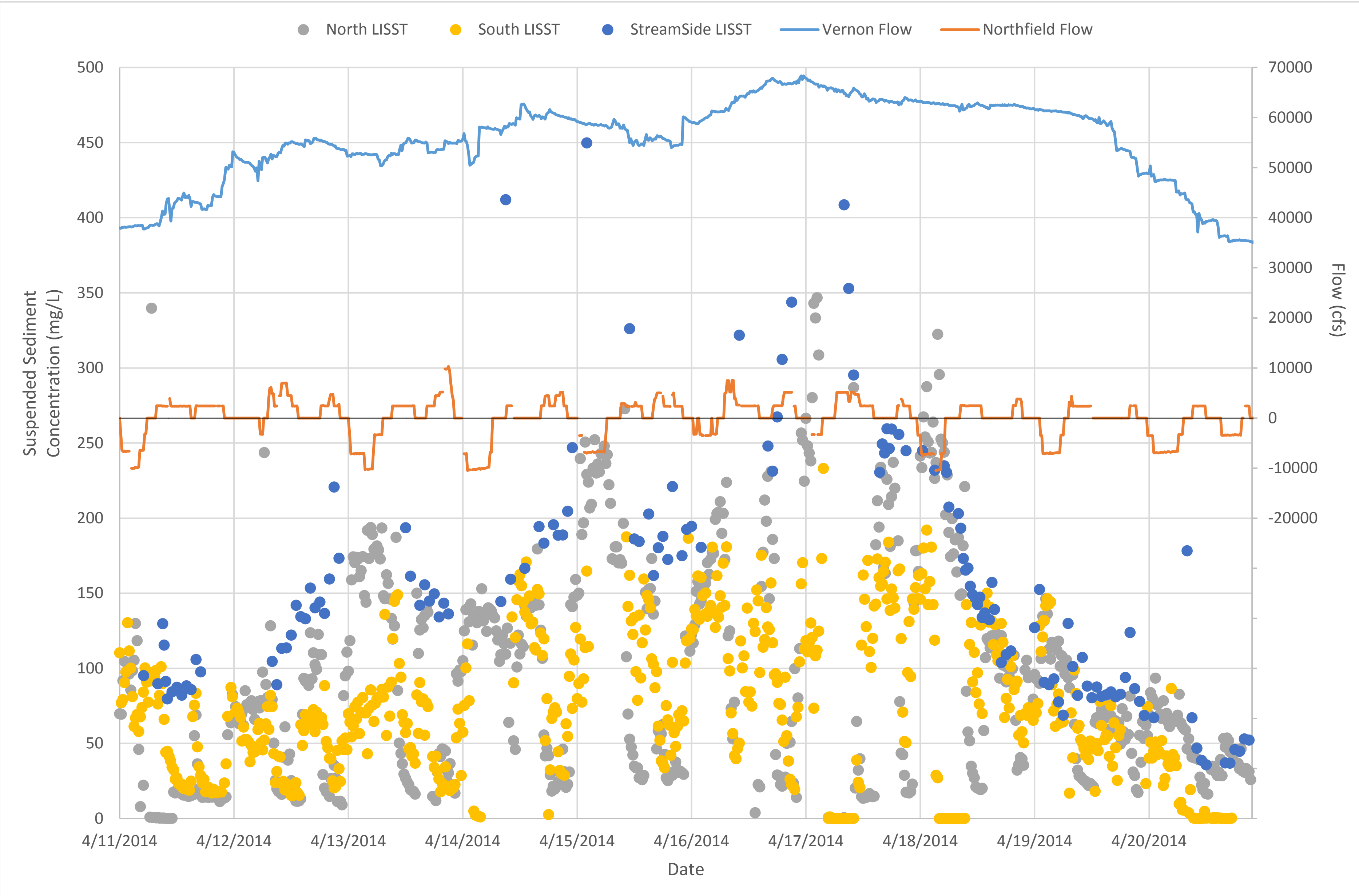
Date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South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
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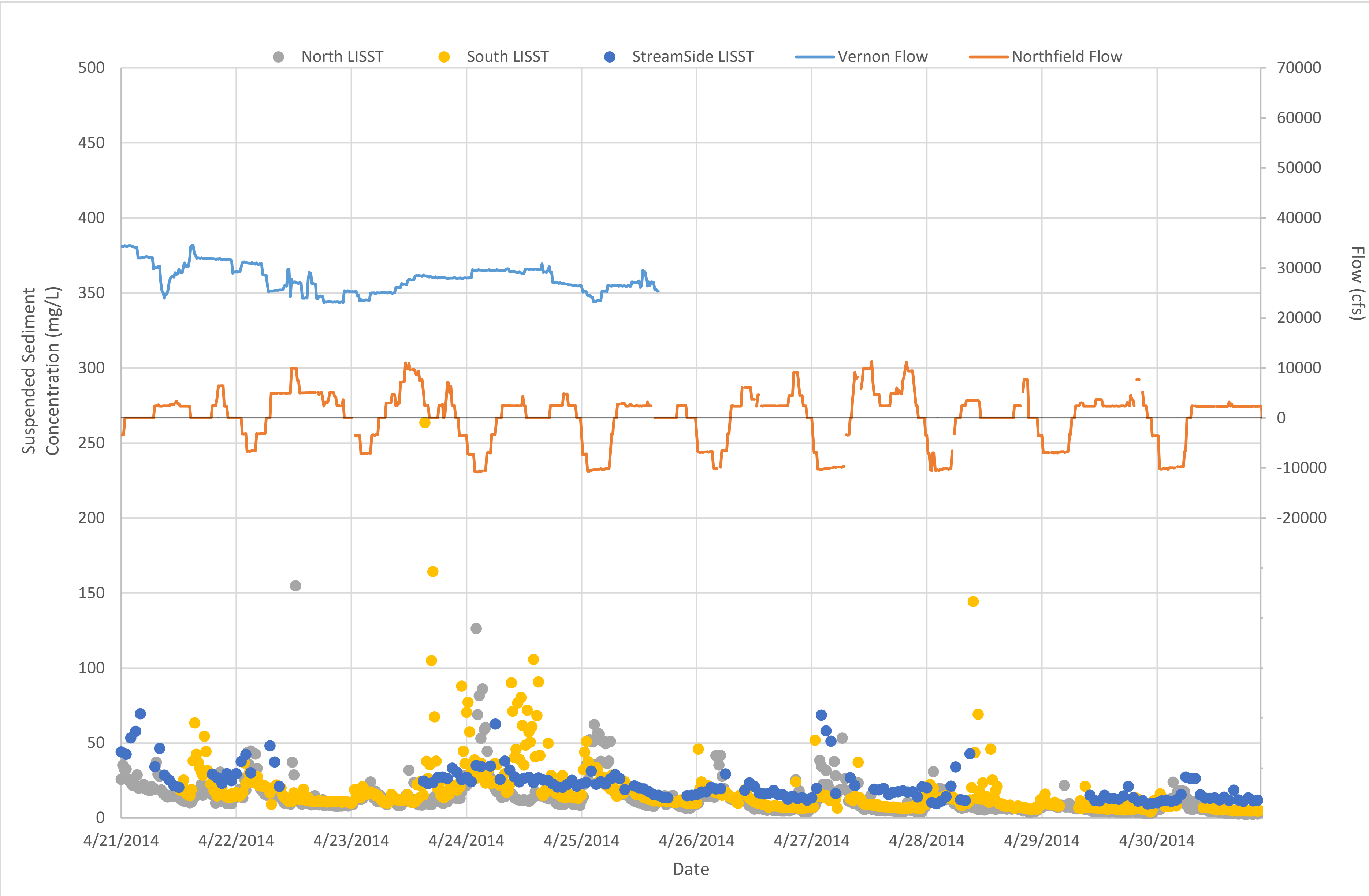

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
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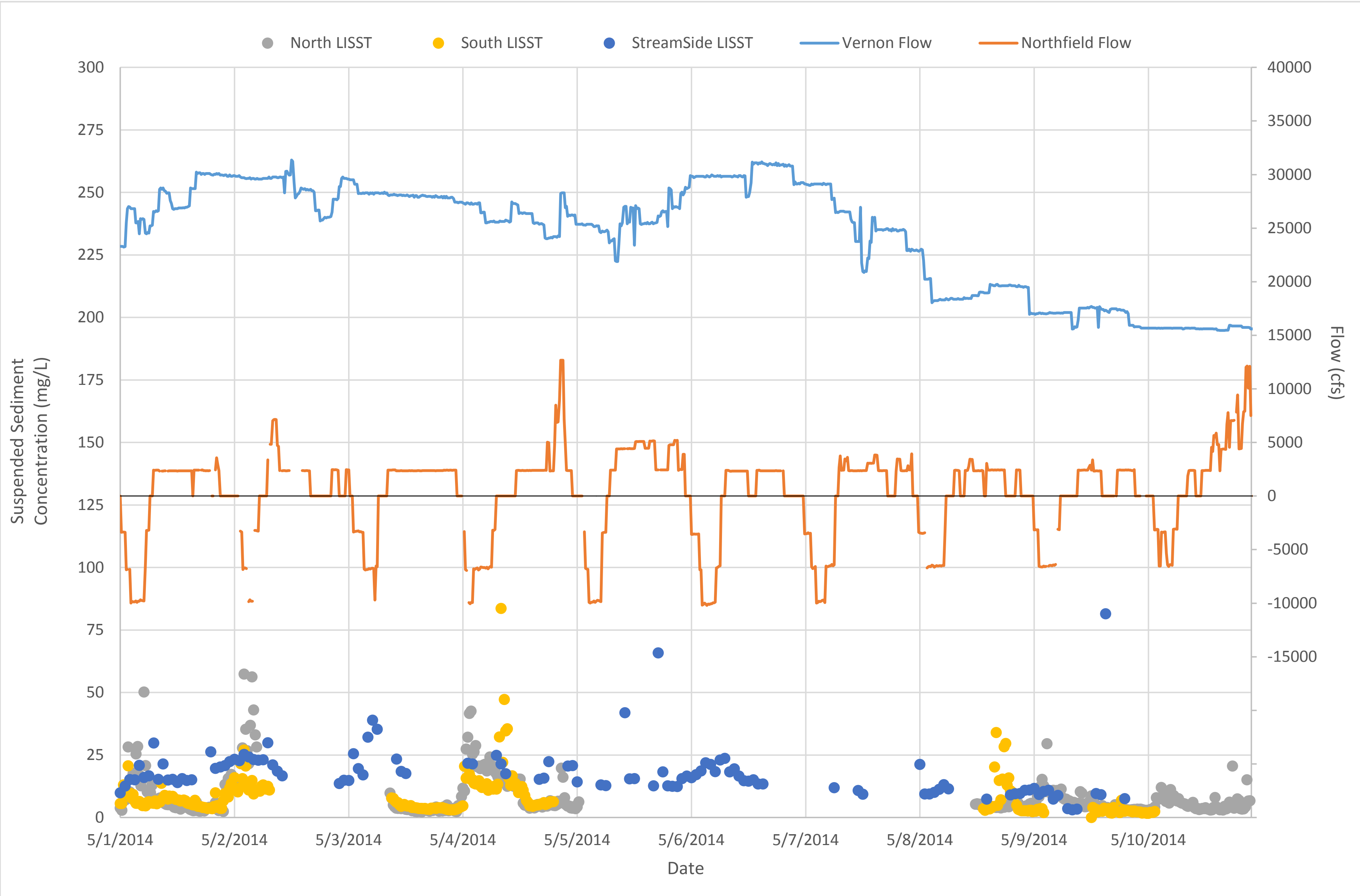
Date



North LISST
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StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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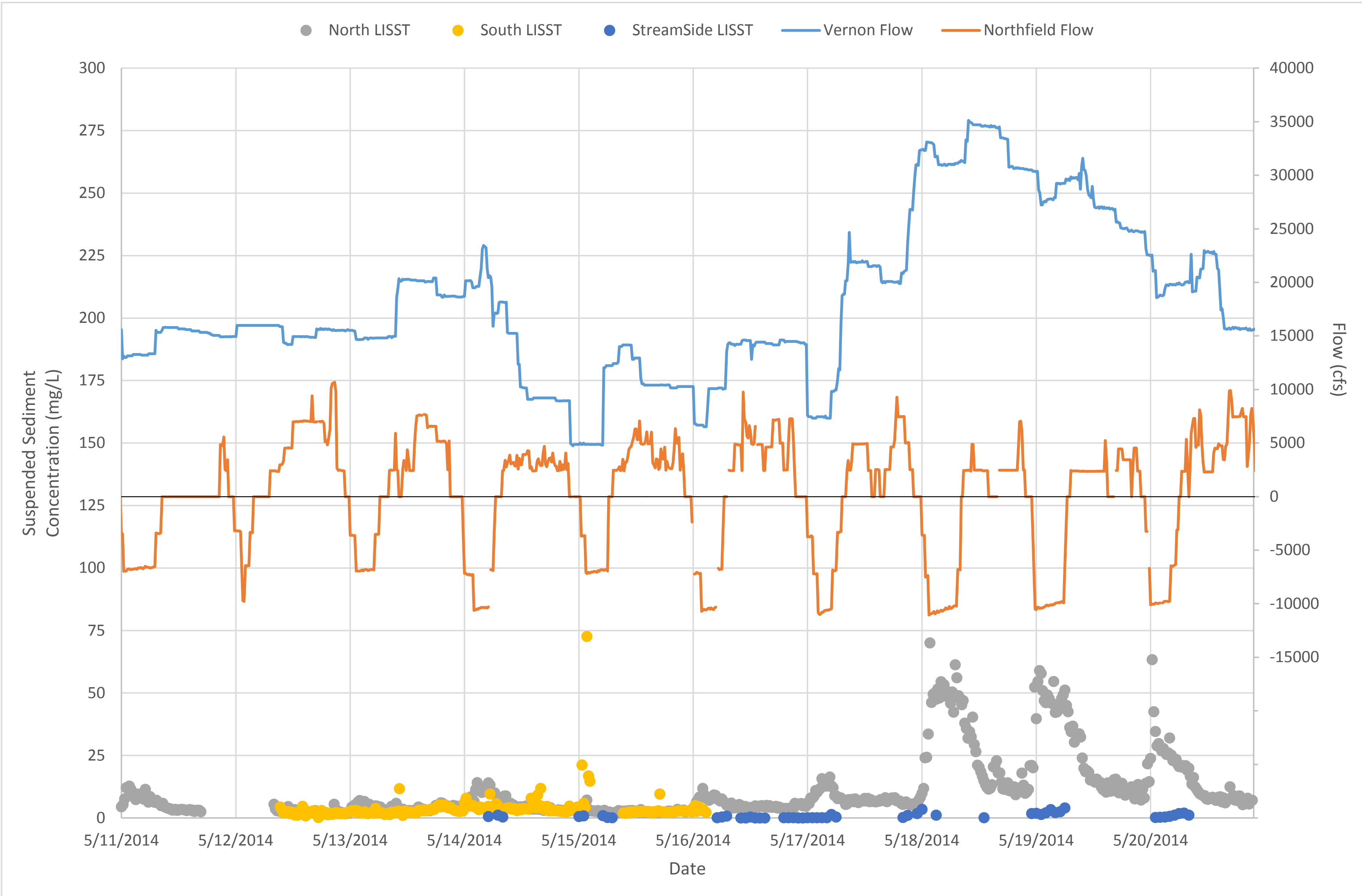

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StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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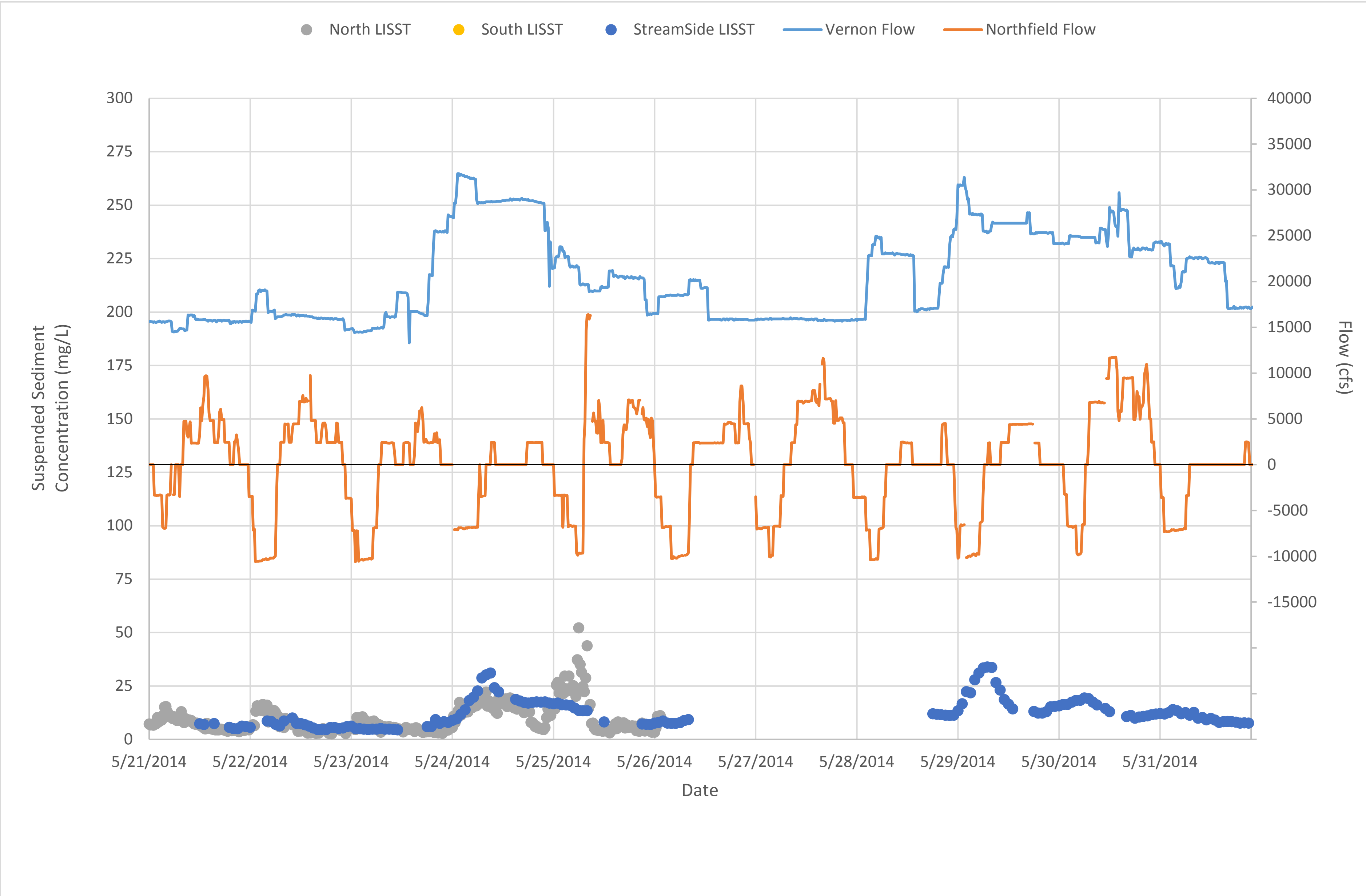

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StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
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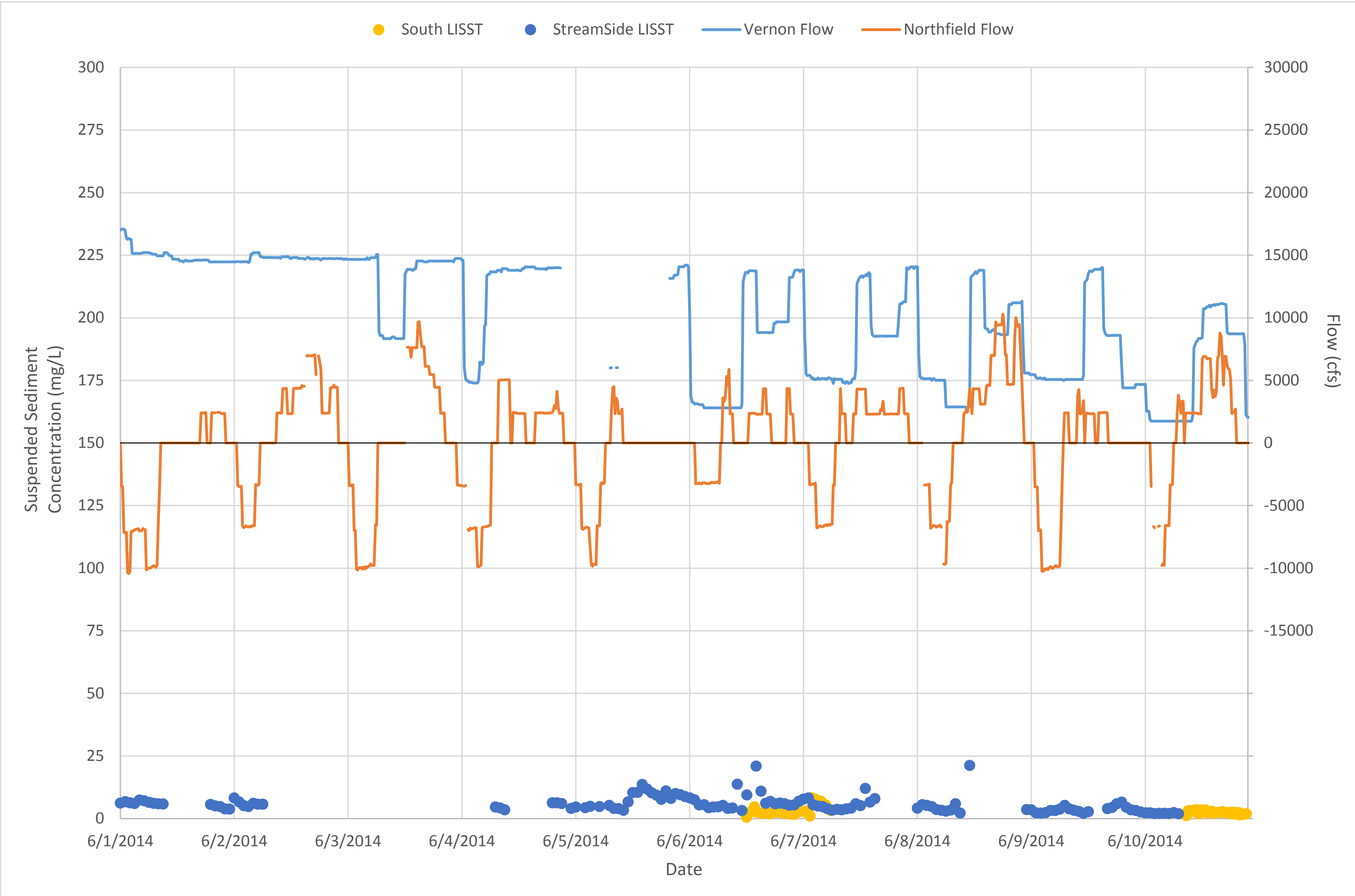
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
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Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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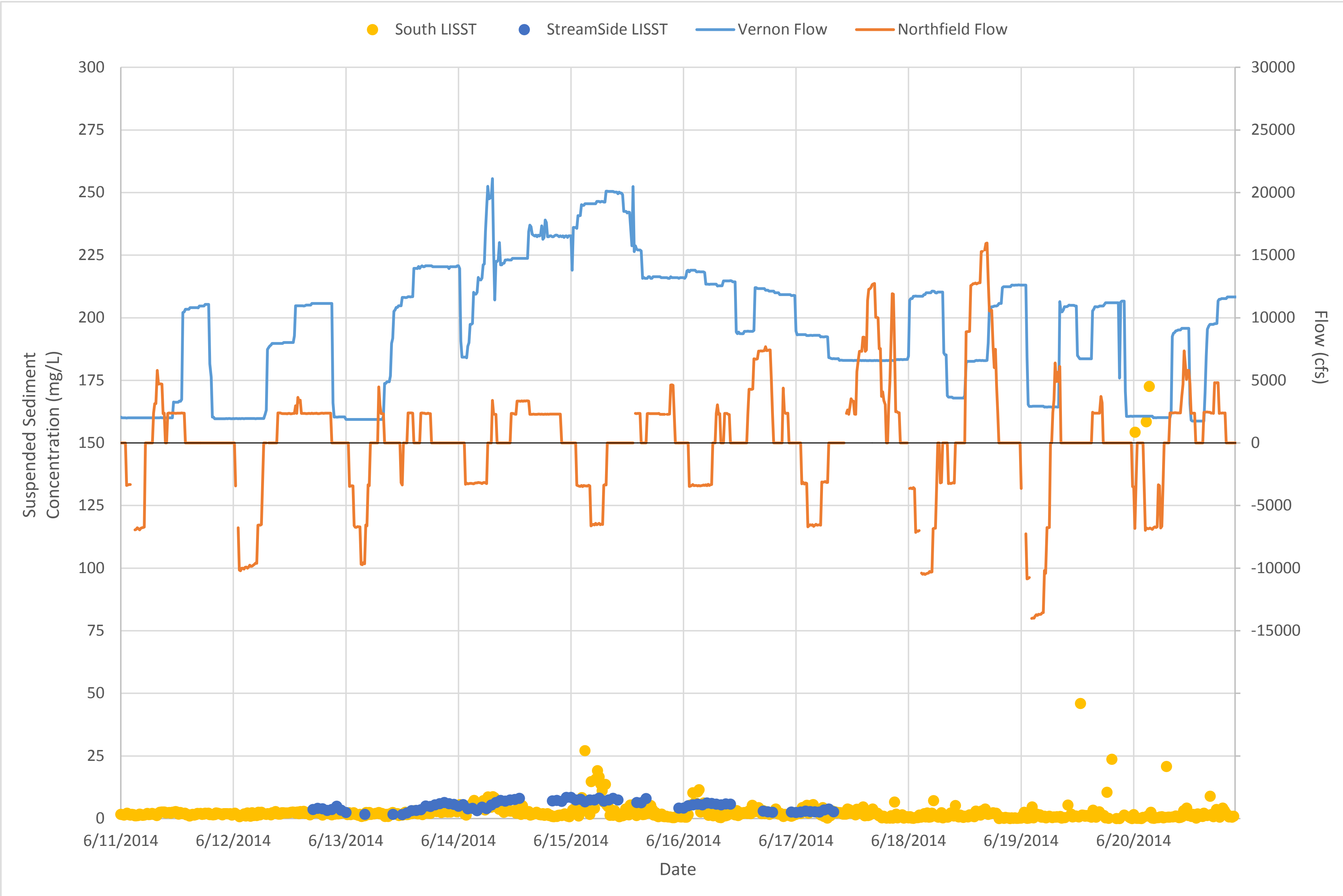
Date


South LISST
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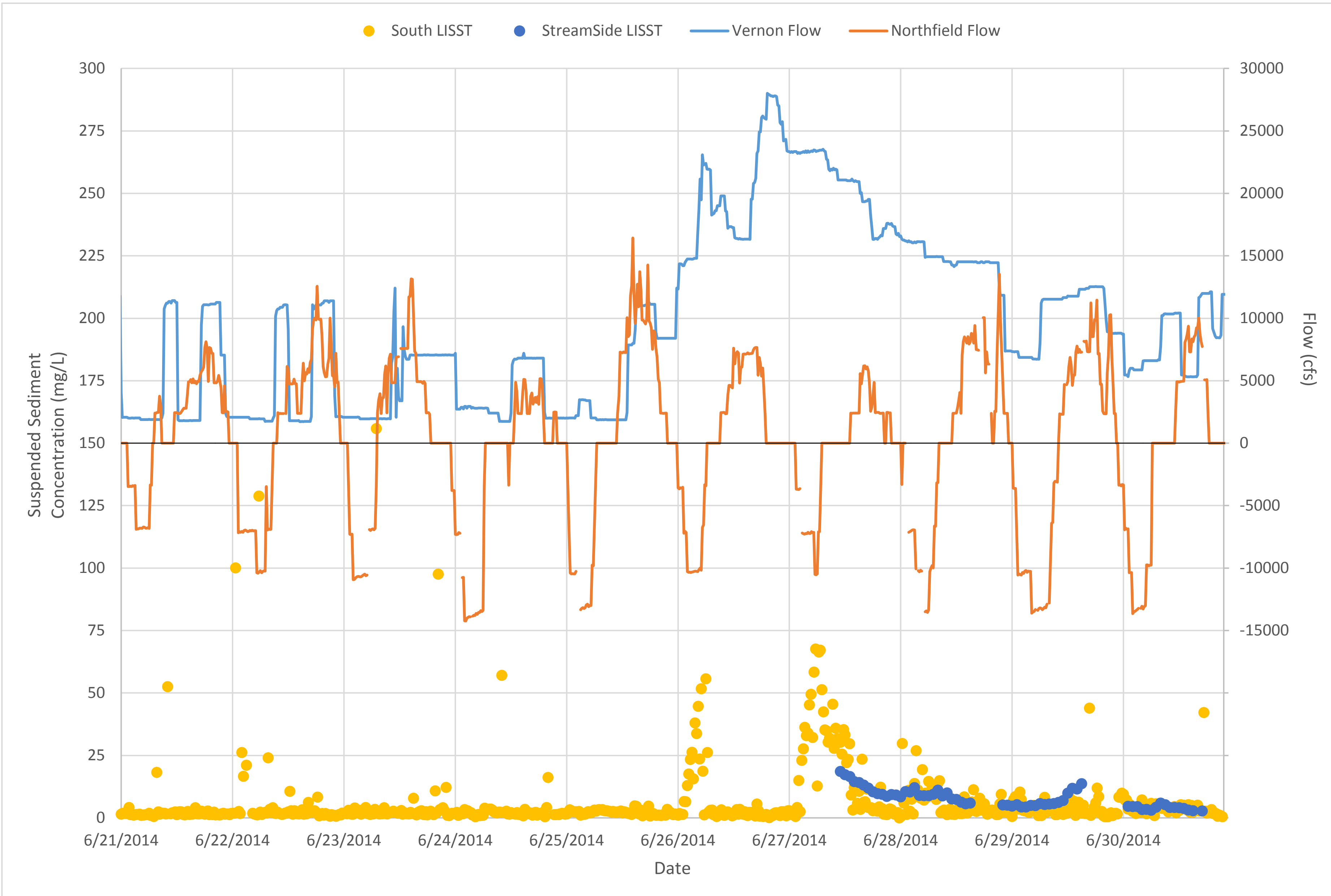
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
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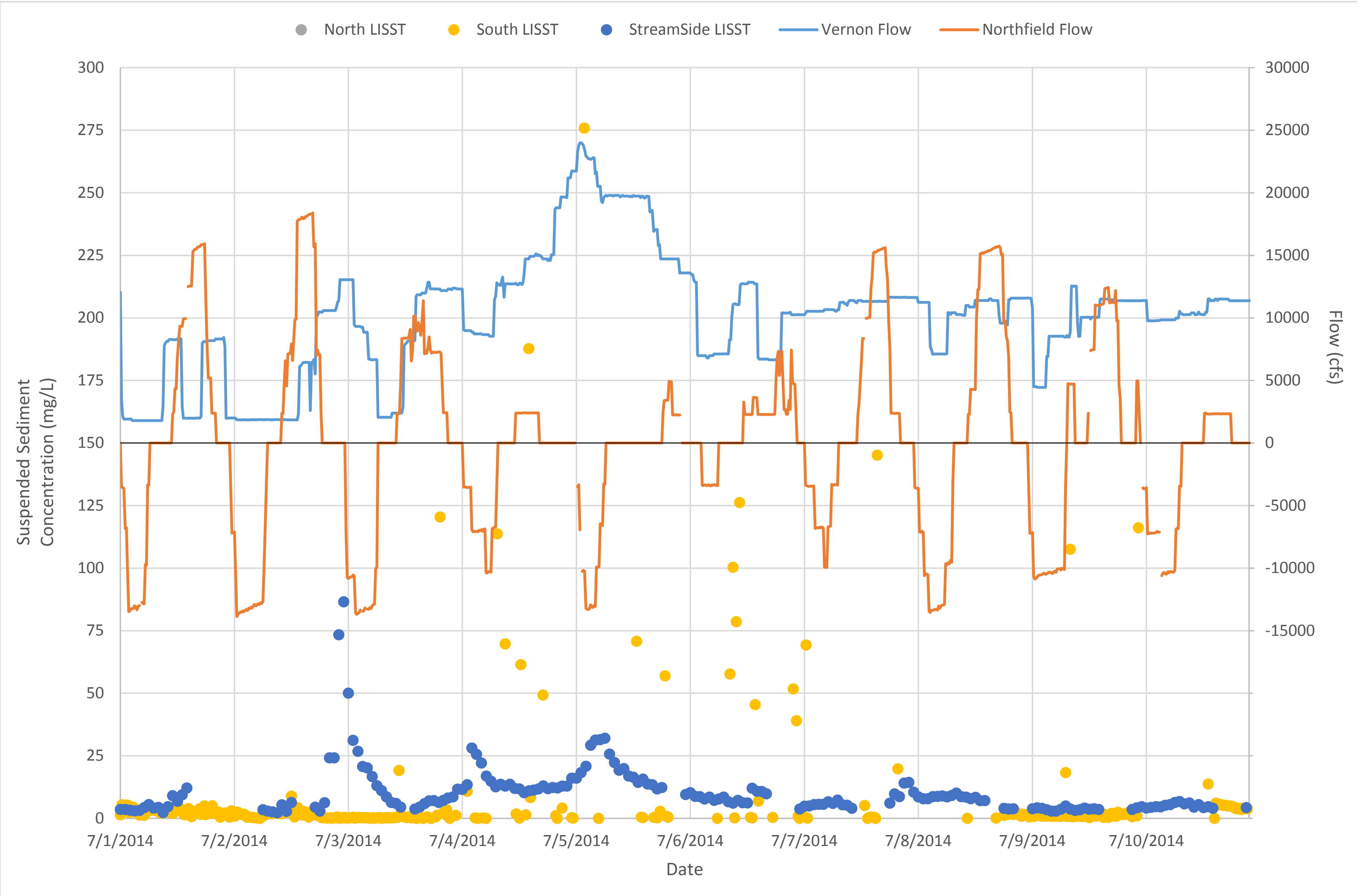

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
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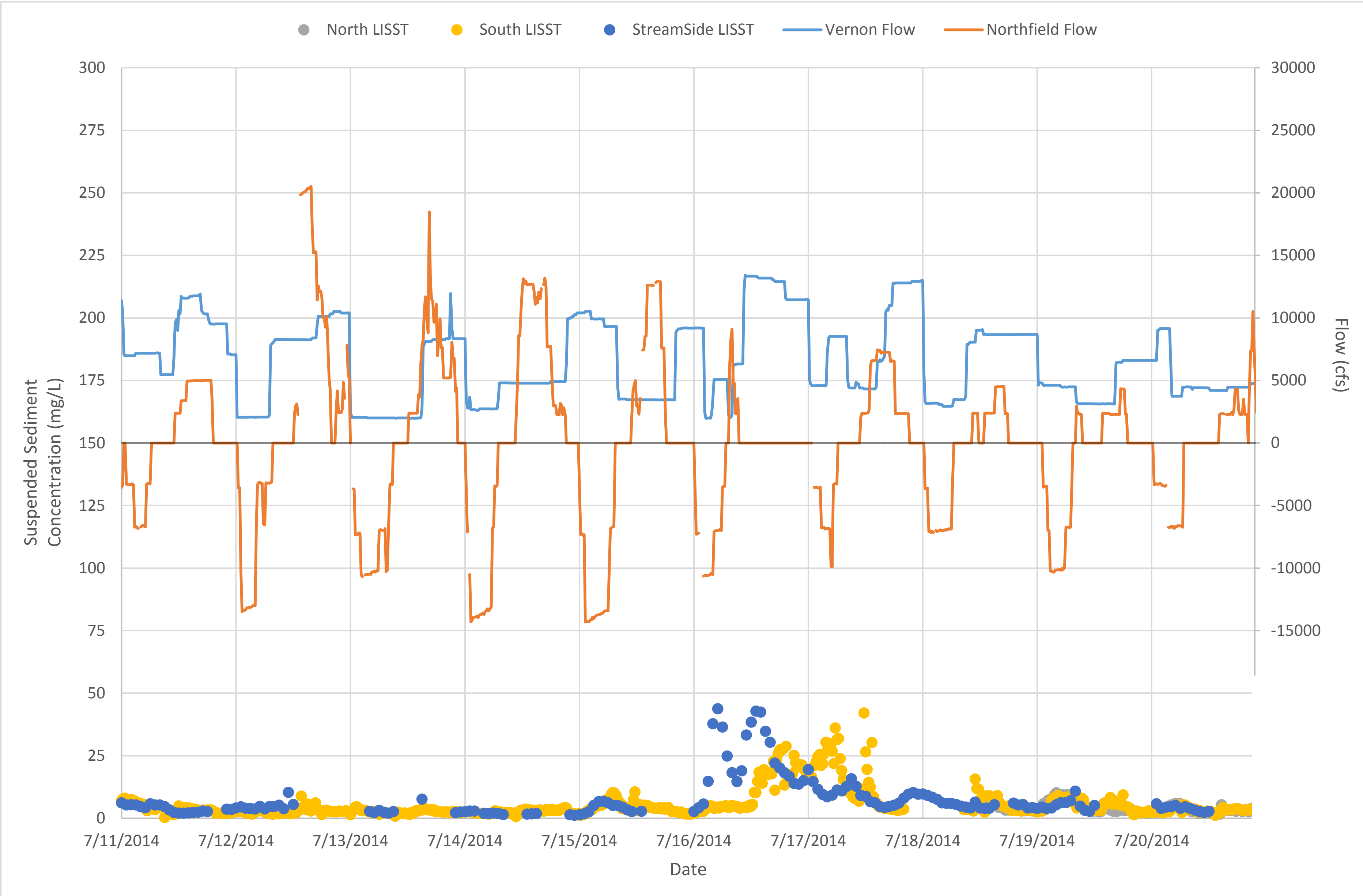
North LISST
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StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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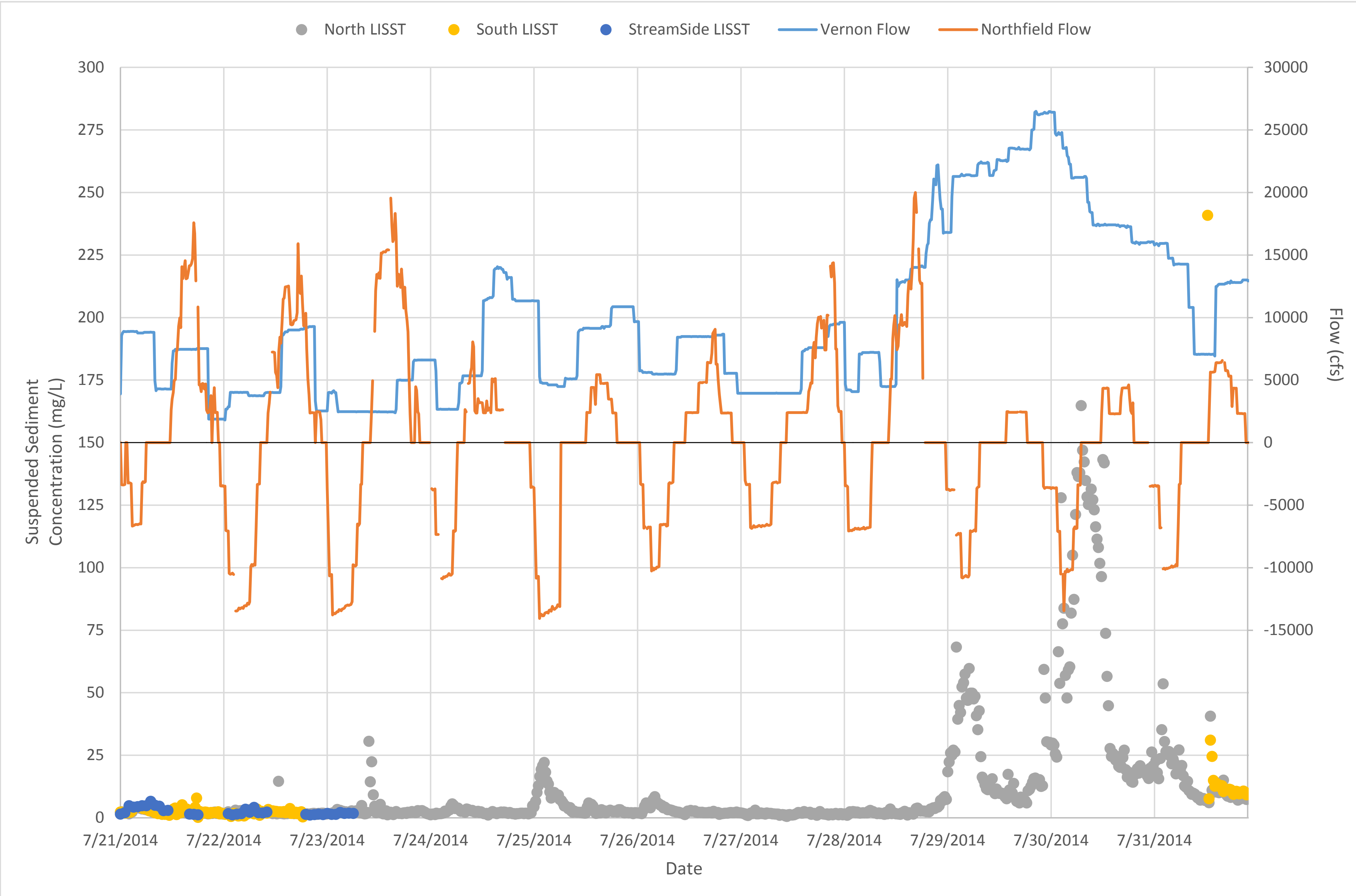

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
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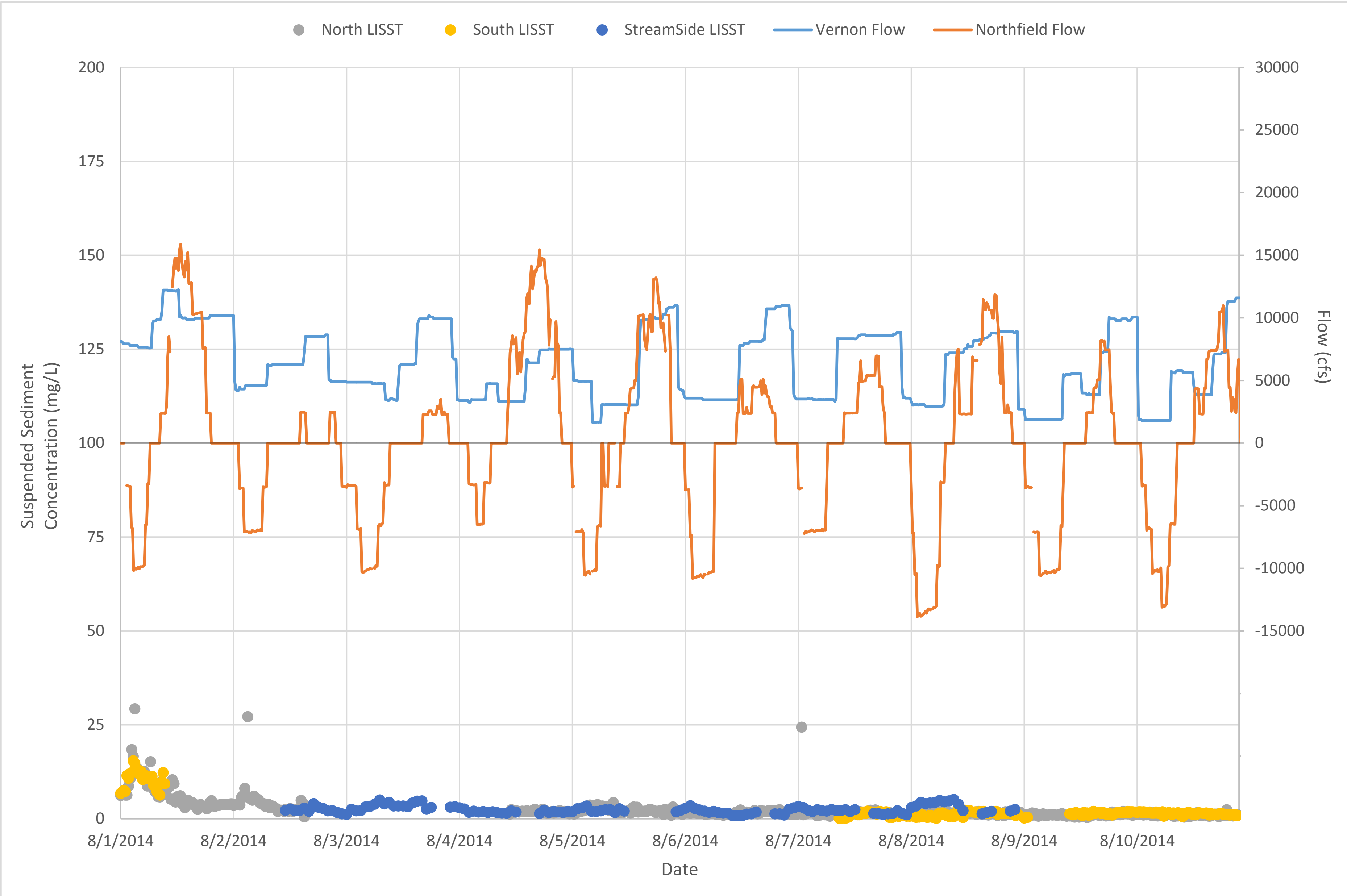

North LISST
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StreamSide LISST
Vernon Flow
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Suspended Sediment Concentration (mg/L)
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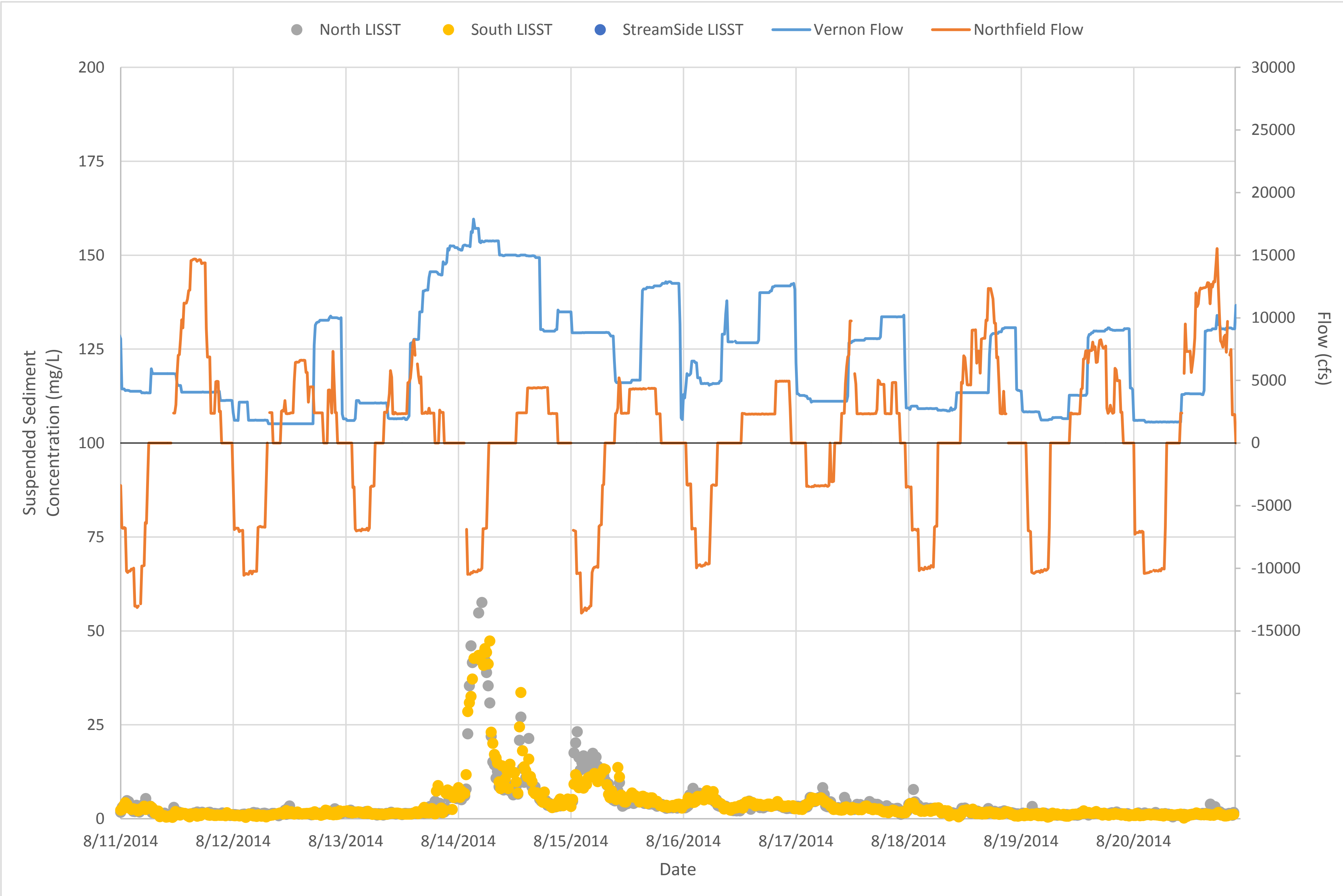
Date


North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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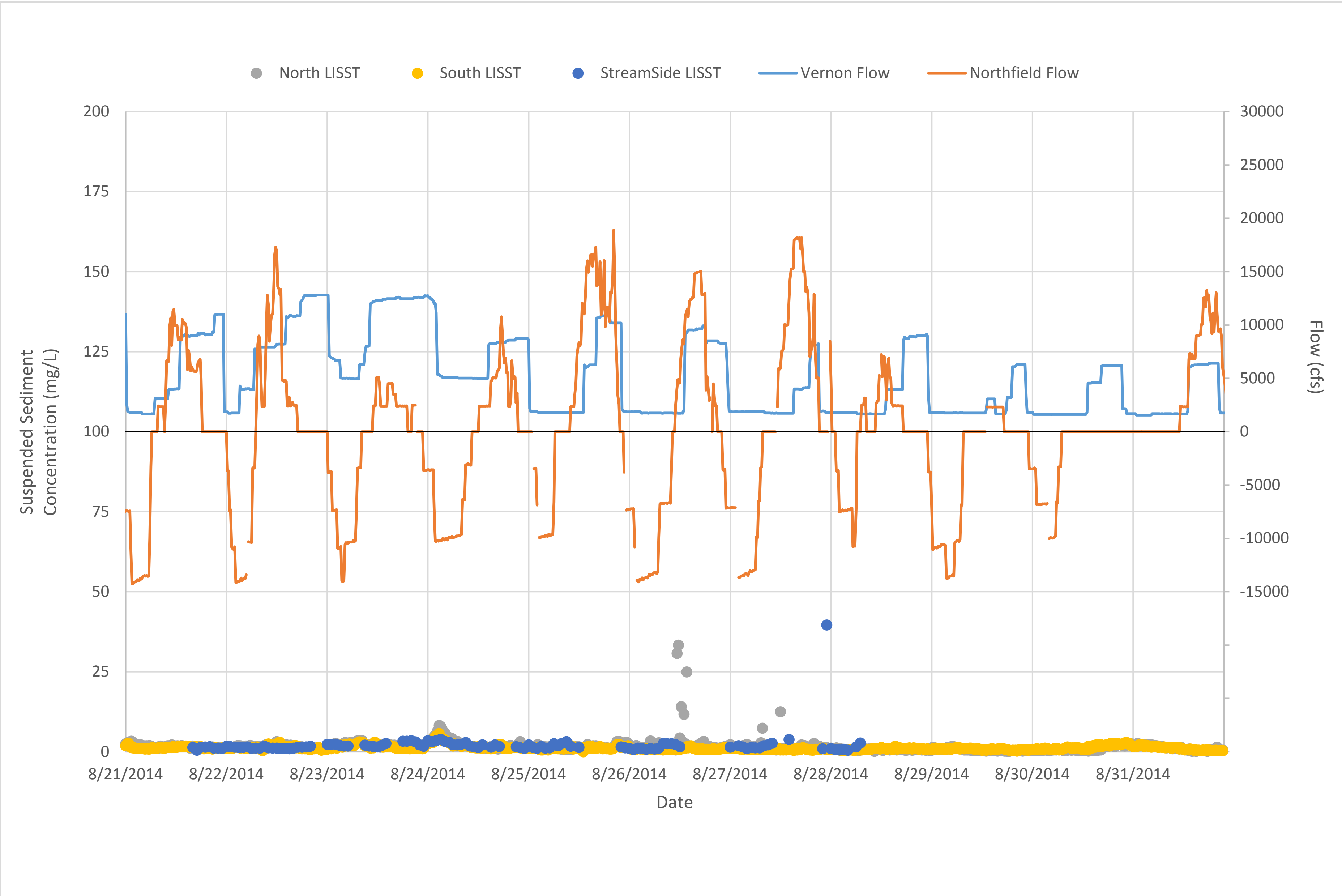

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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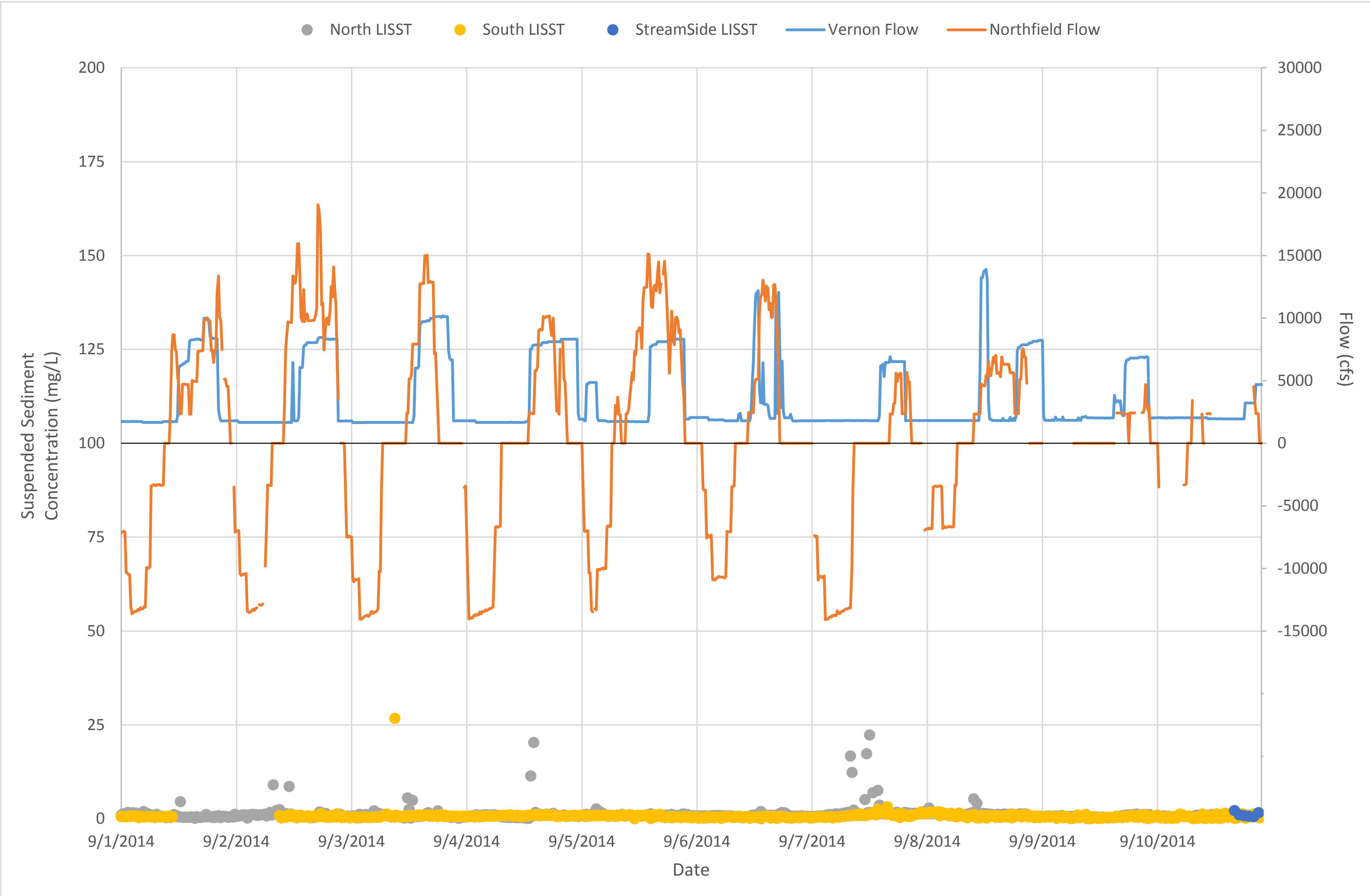
North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
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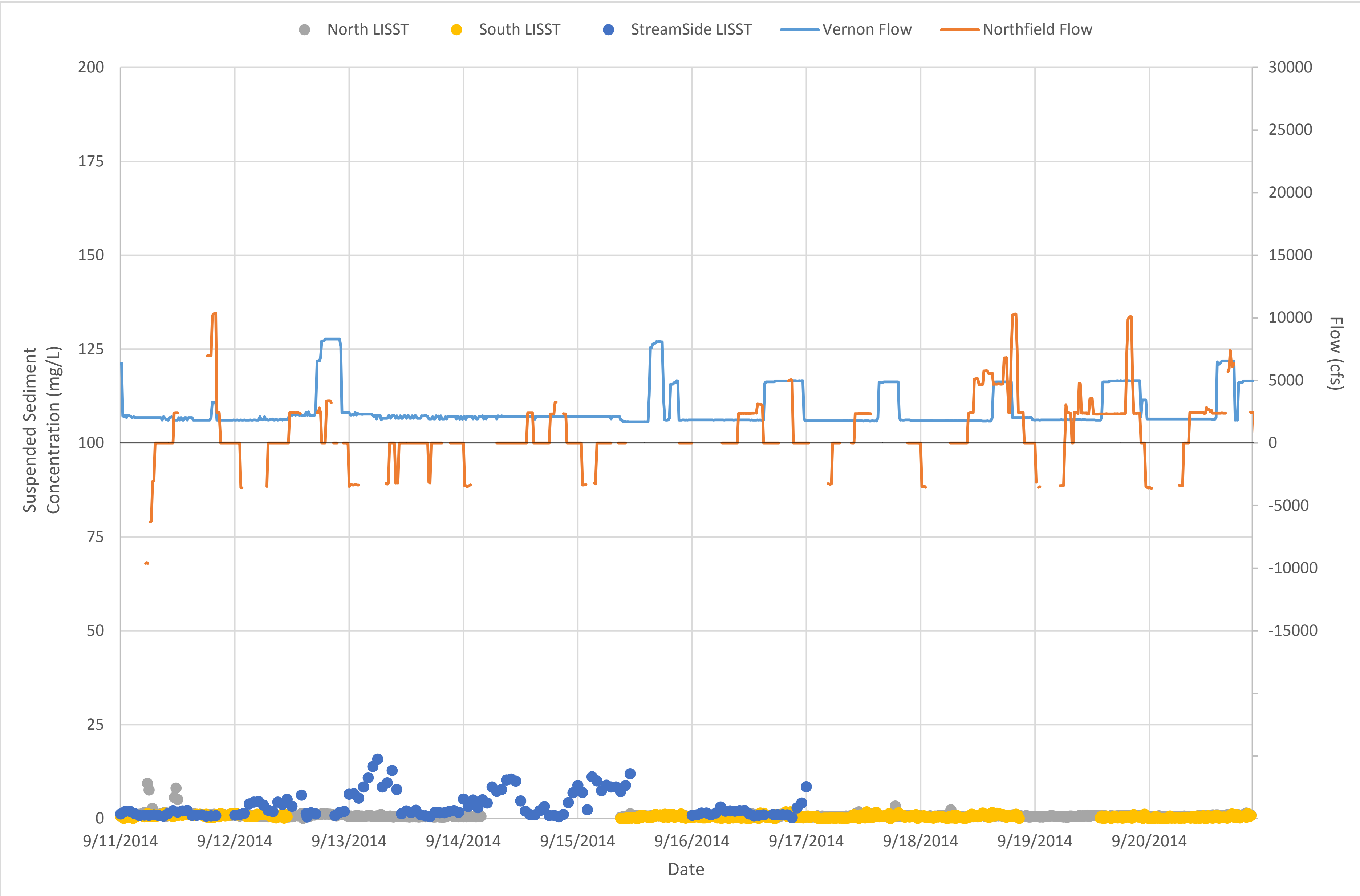

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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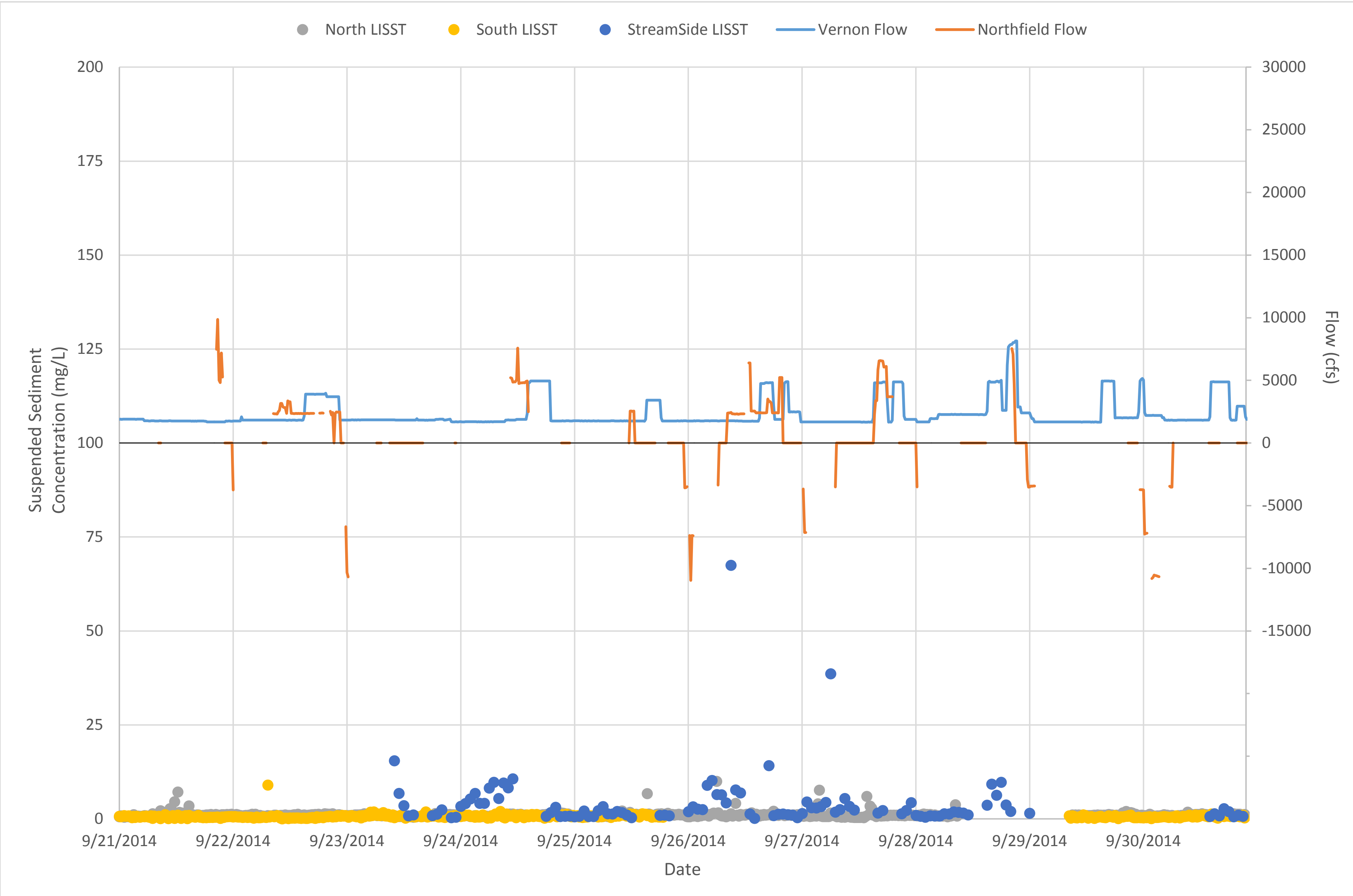
Date



North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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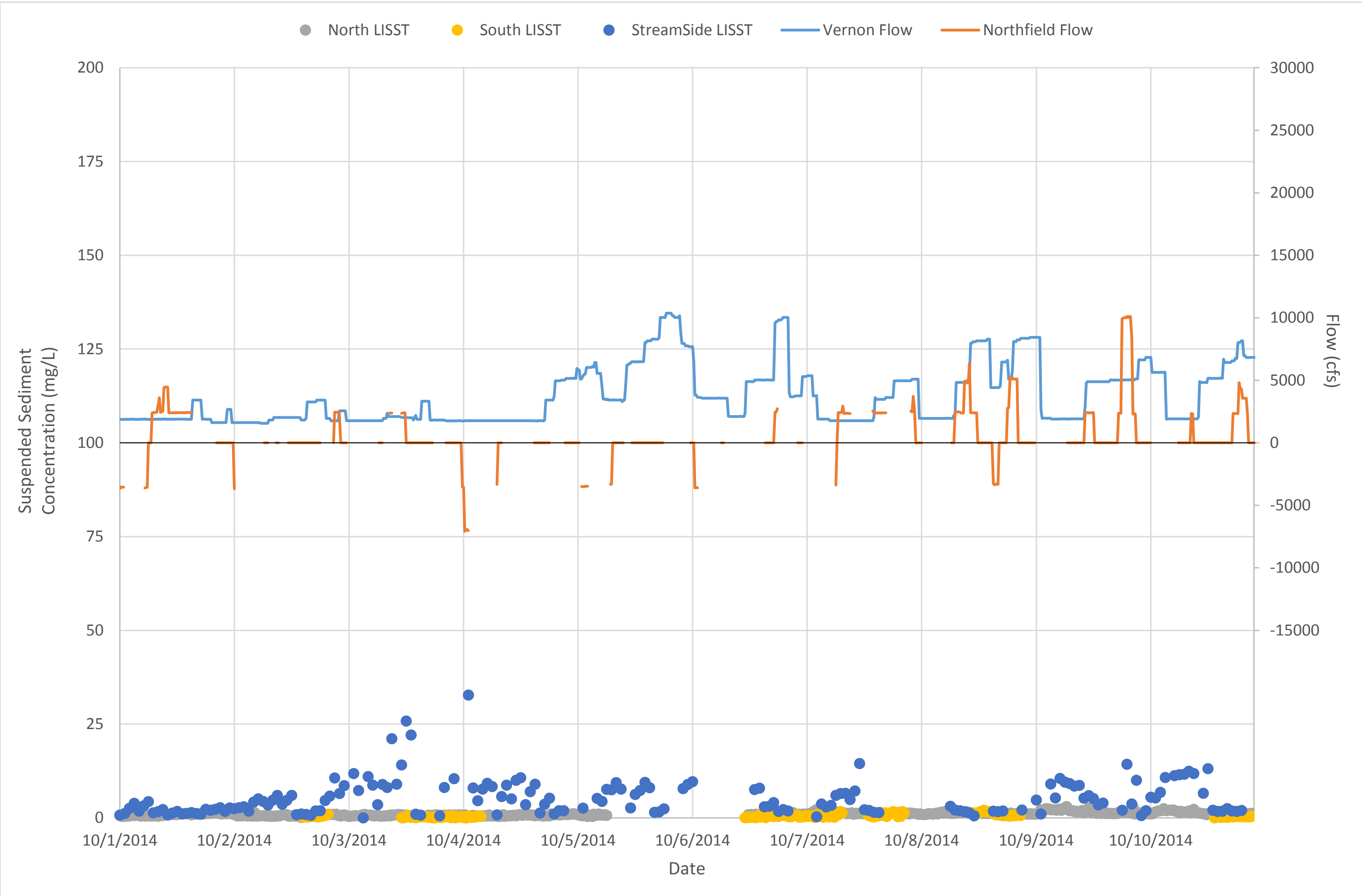

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
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Flow (cfs)
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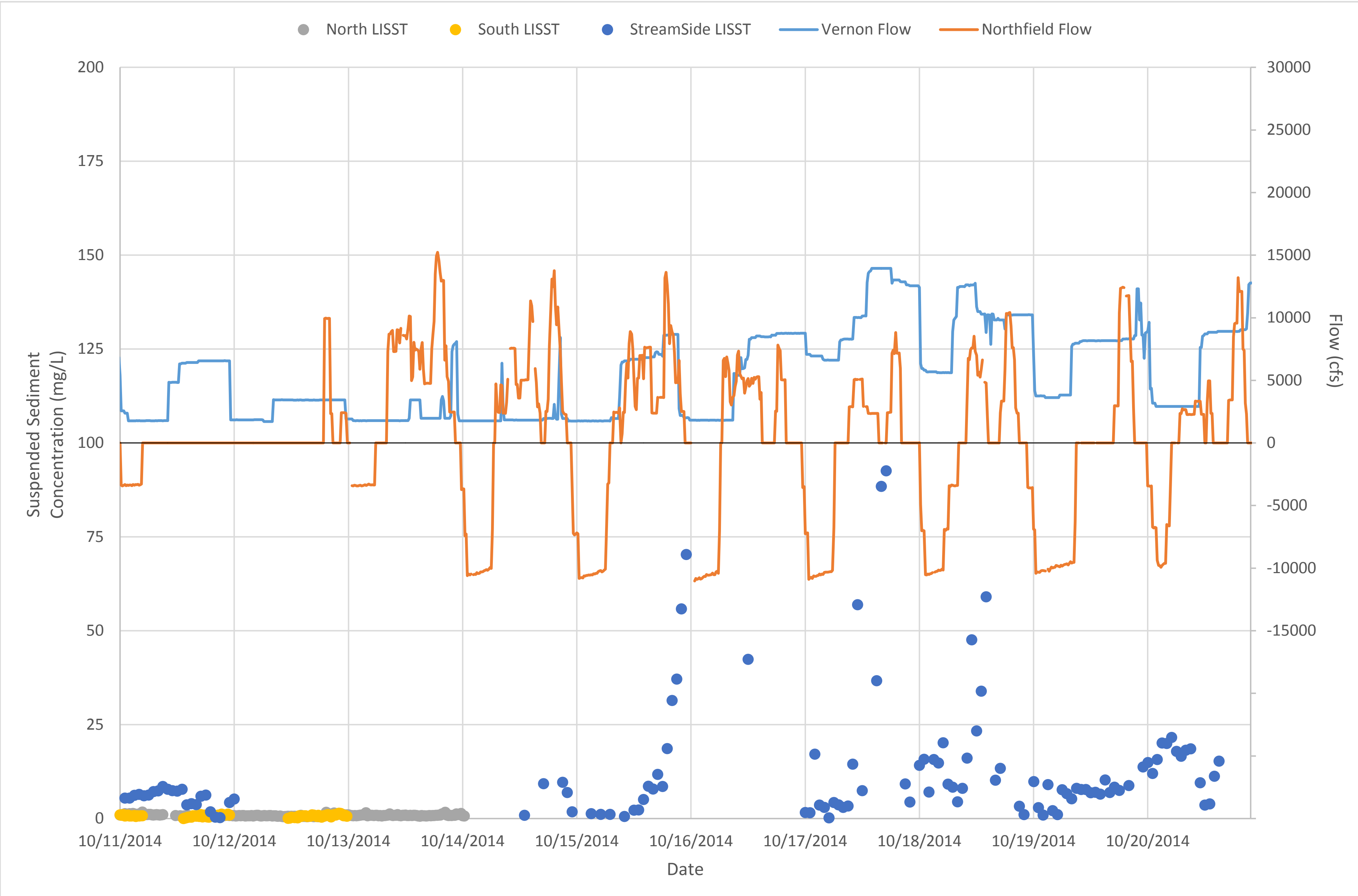

North LISST
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Suspended Sediment Concentration (mg/L)
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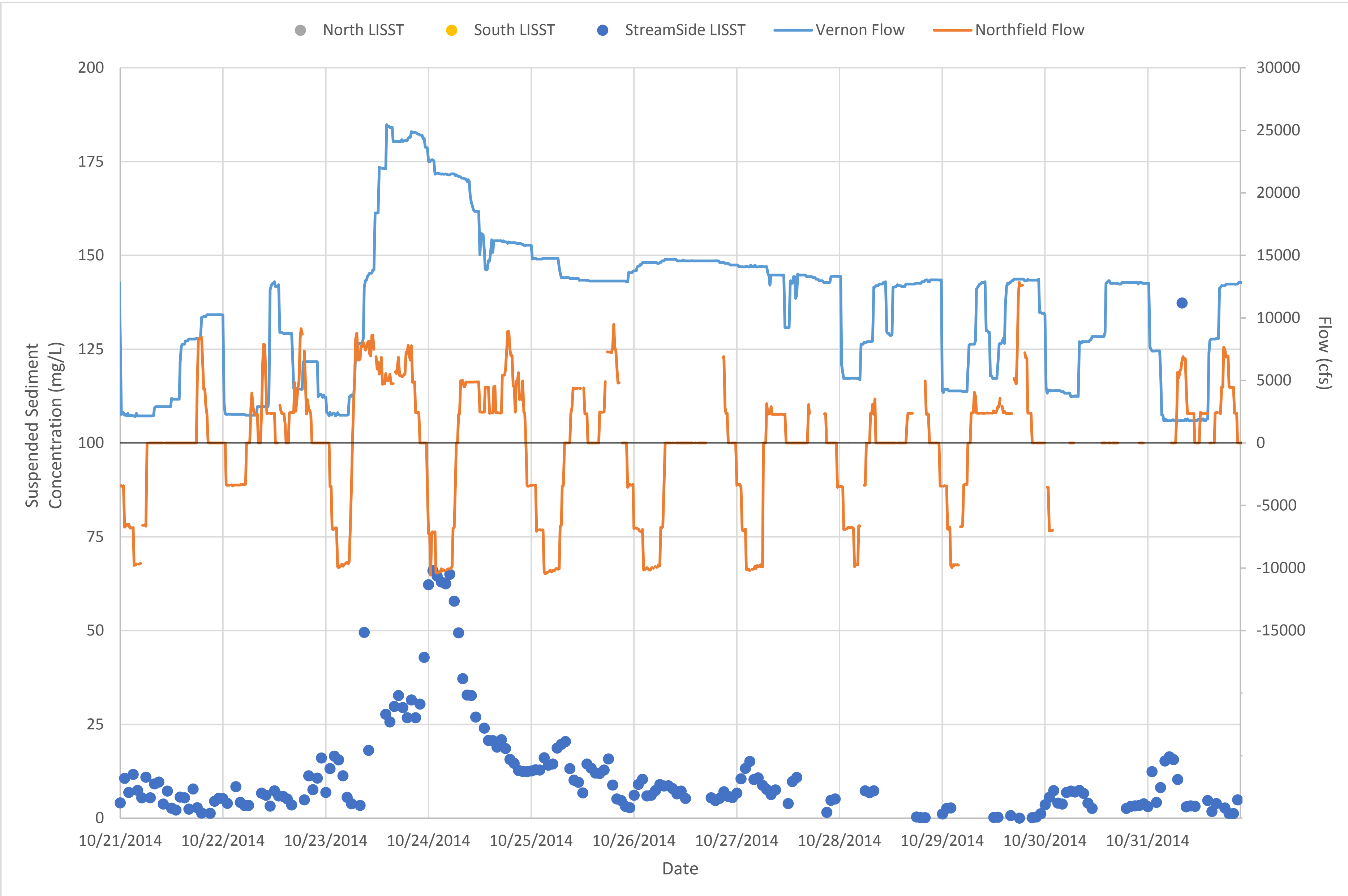
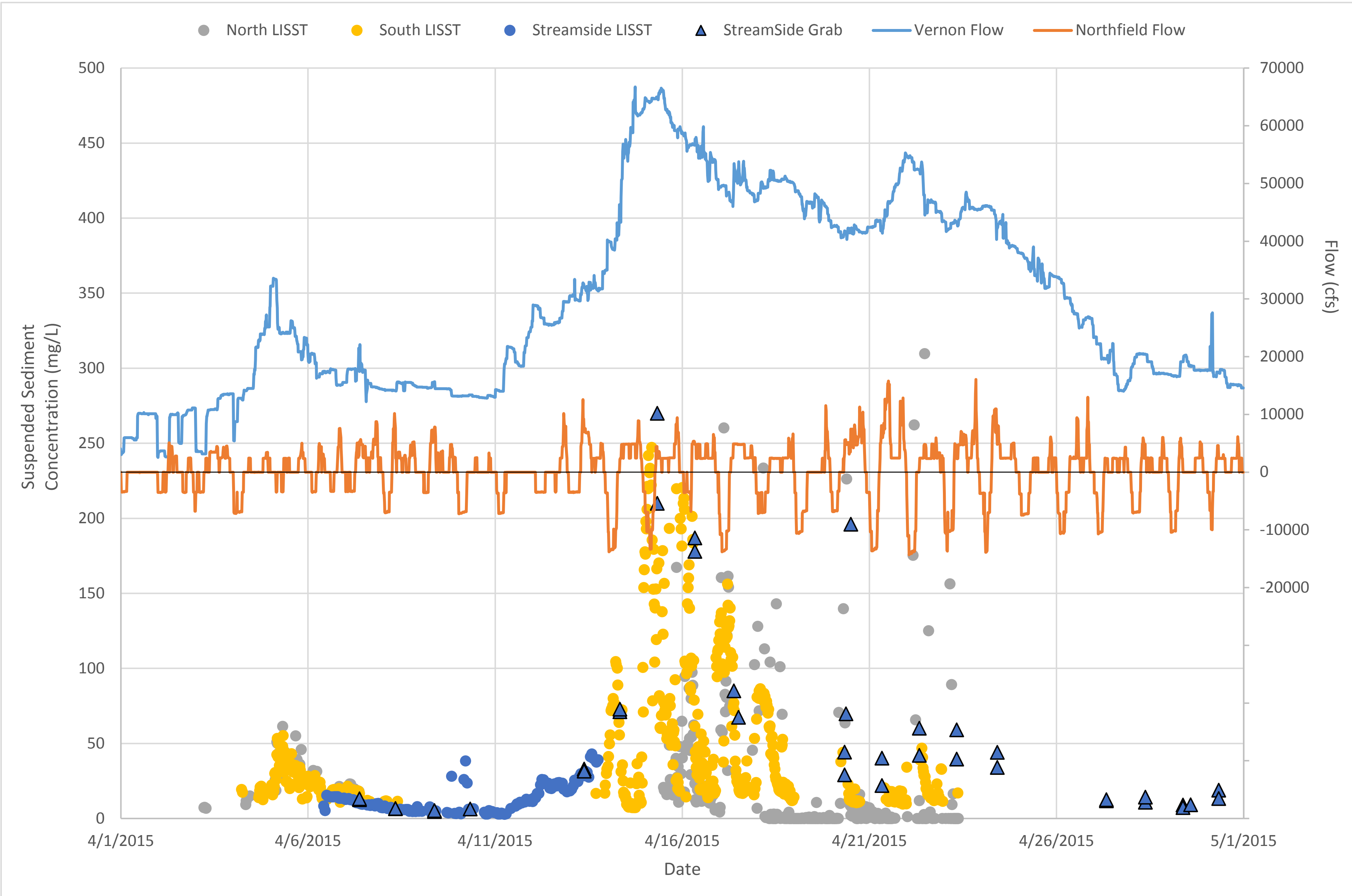
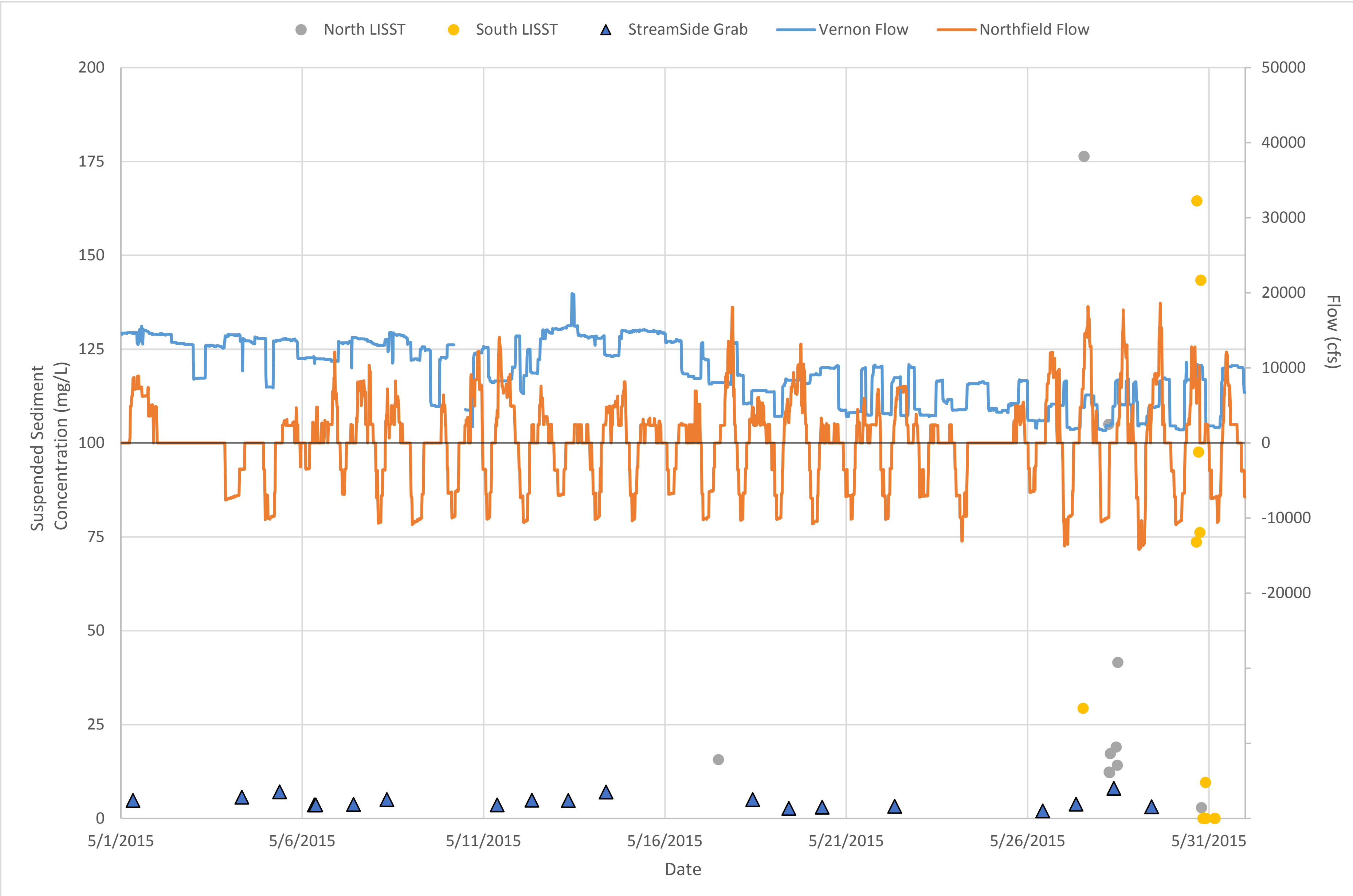
10/15/2014
10/16/2014
10/17/2014
10/18/2014
10/19/2014
10/20/2014
Date

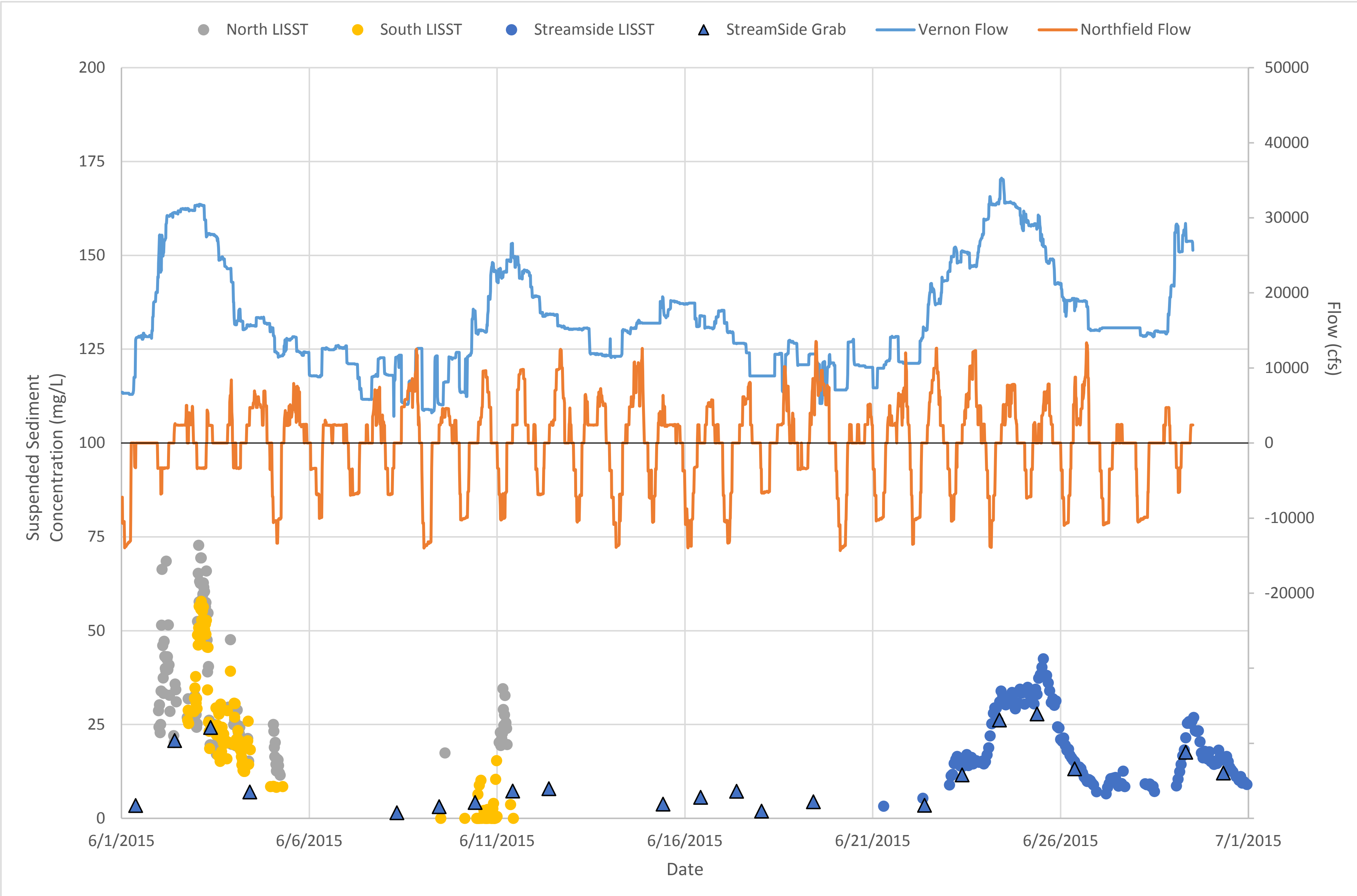

North LISST
South LISST
StreamSide LISST
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
30000
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
Flow (cfs)
10/21/2014
10/22/2014
10/23/2014
10/24/2014
10/25/2014
10/26/2014
10/27/2014
10/28/2014
10/29/2014
10/30/2014
10/31/2014
Date

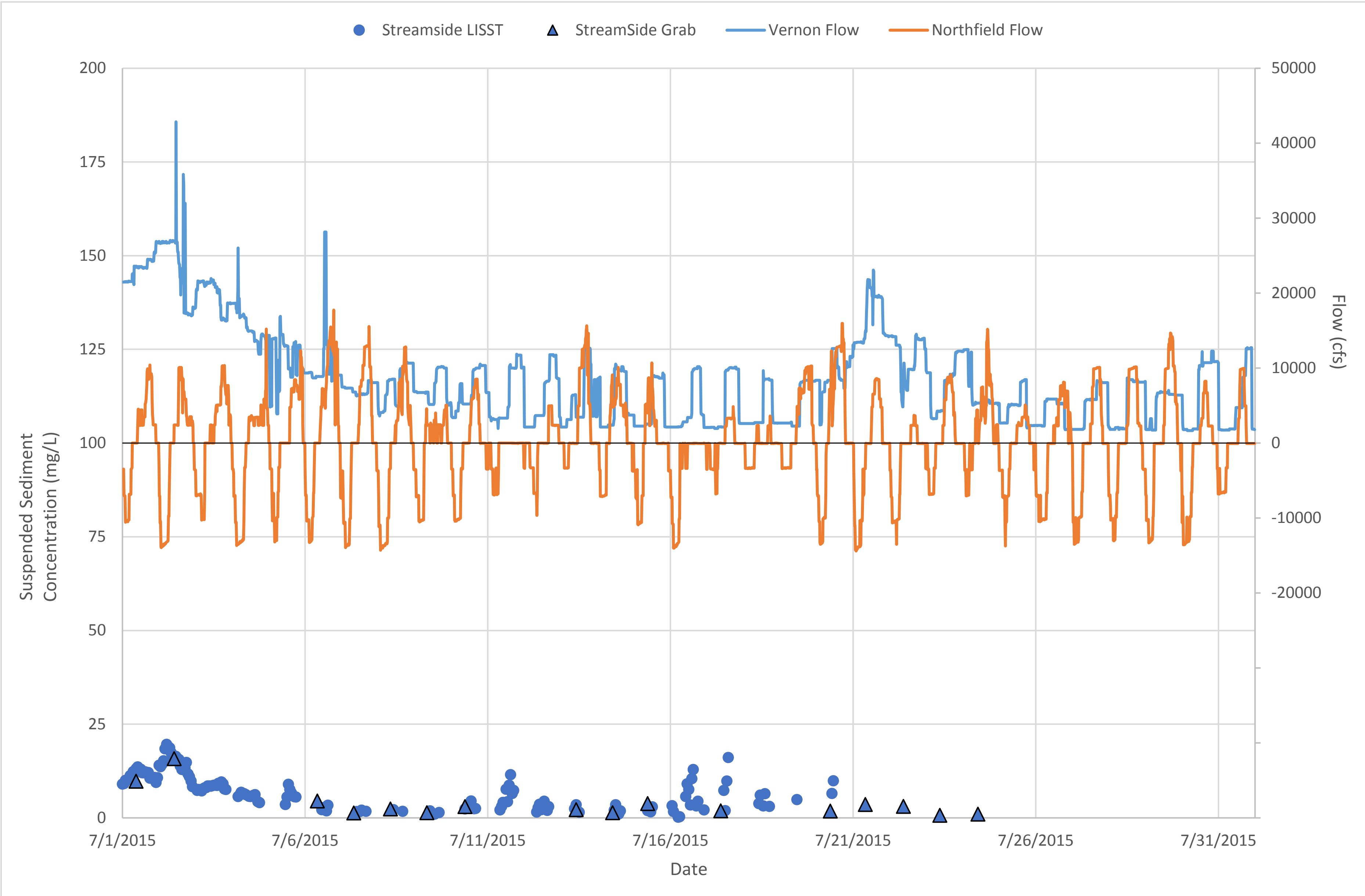
# 2015 CONTINUOUS LISST INSTRUMENT TIMESERIES-MONTHLY


North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
500
450
400
350
300
250
200
150
100
50
0
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
4/1/2015
4/6/2015
4/11/2015
4/16/2015
4/21/2015
4/26/2015
5/1/2015



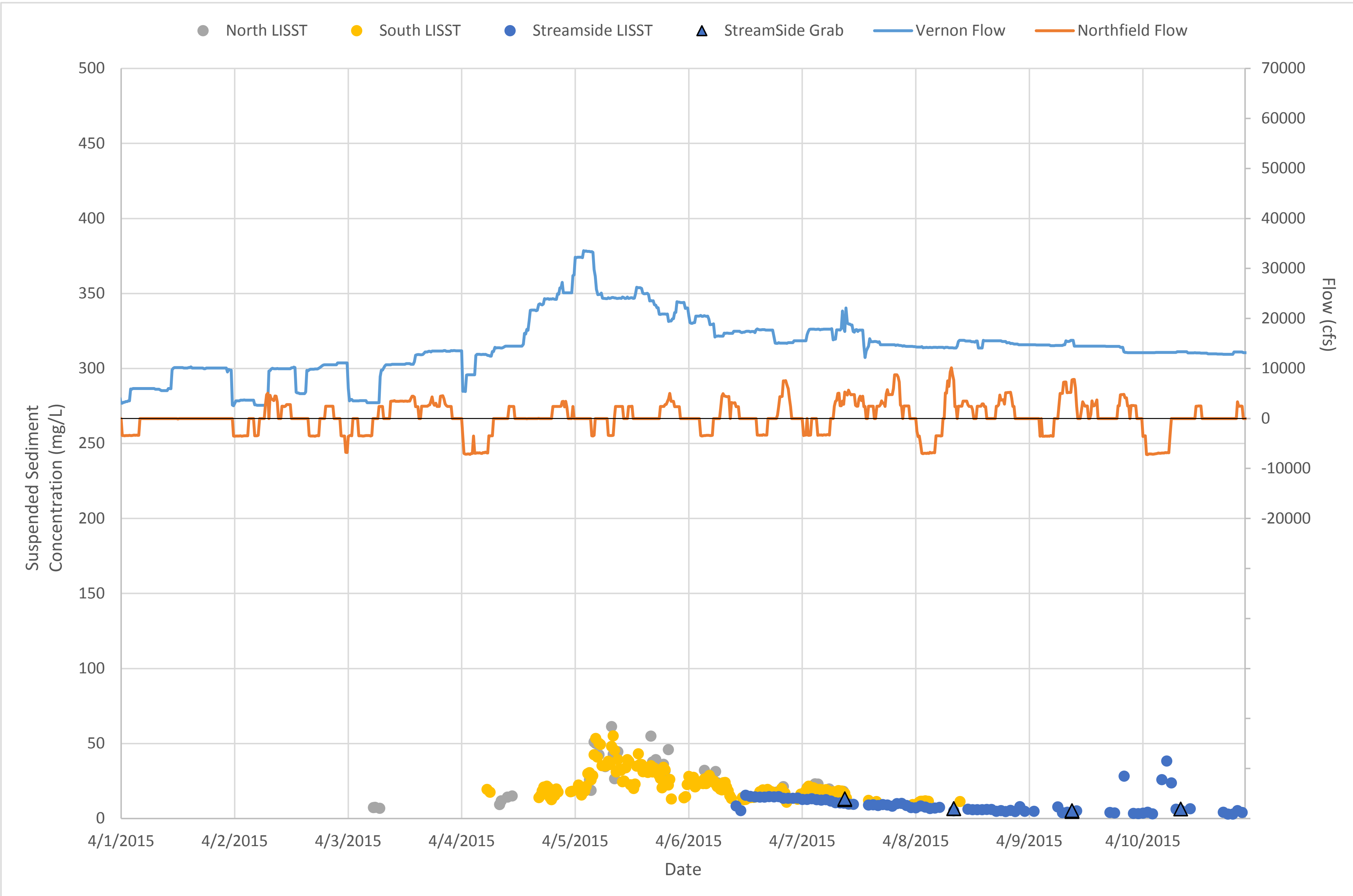
North LISST
South LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
Flow (cfs)
50000
40000
30000
20000
10000
0
-10000
-20000
5/1/2015
5/6/2015
5/11/2015
5/16/2015
5/21/2015
5/26/2015
5/31/2015
Date


North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
6/1/2015
6/6/2015
6/11/2015
6/16/2015
6/21/2015
6/26/2015
7/1/2015

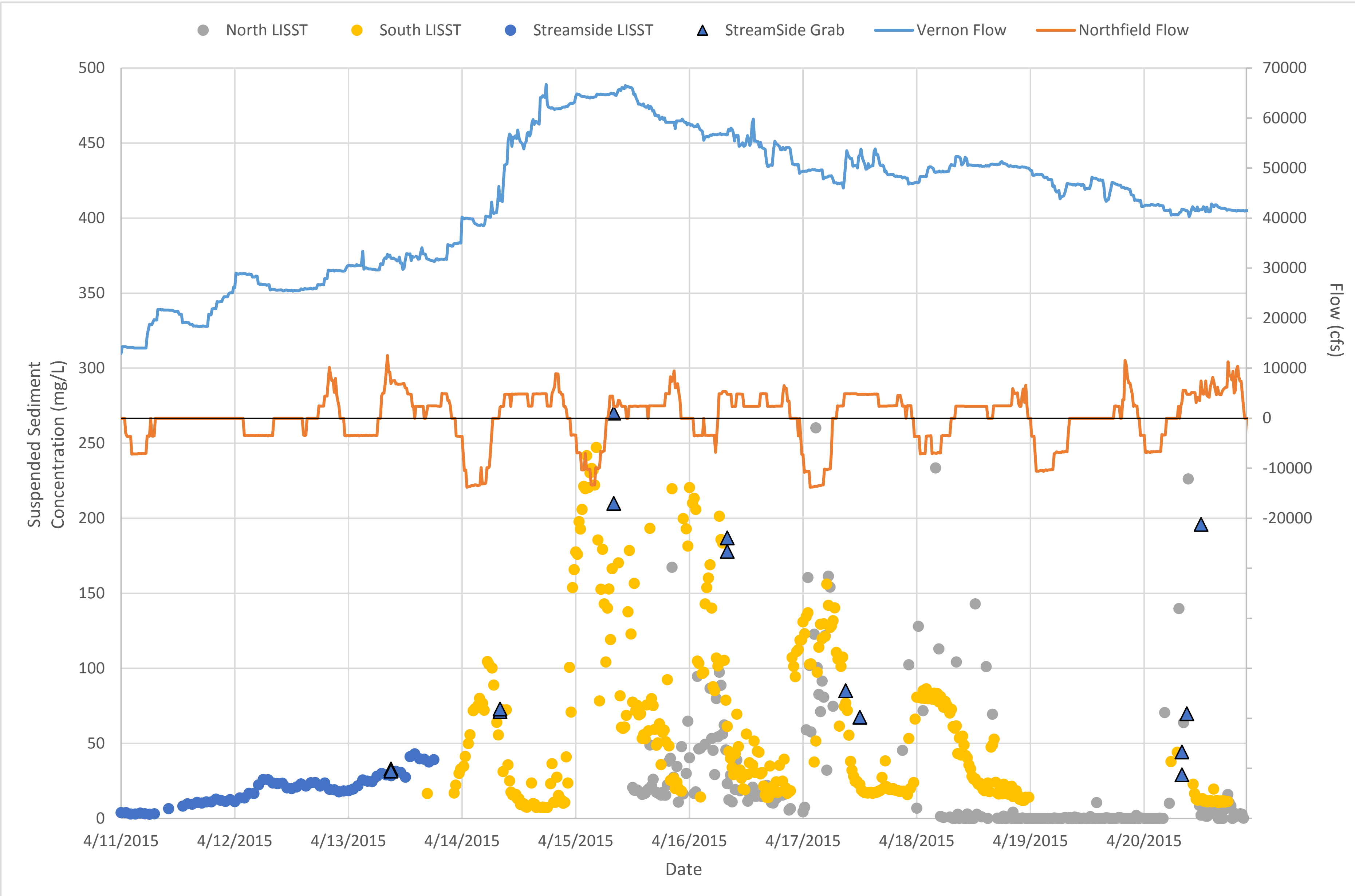


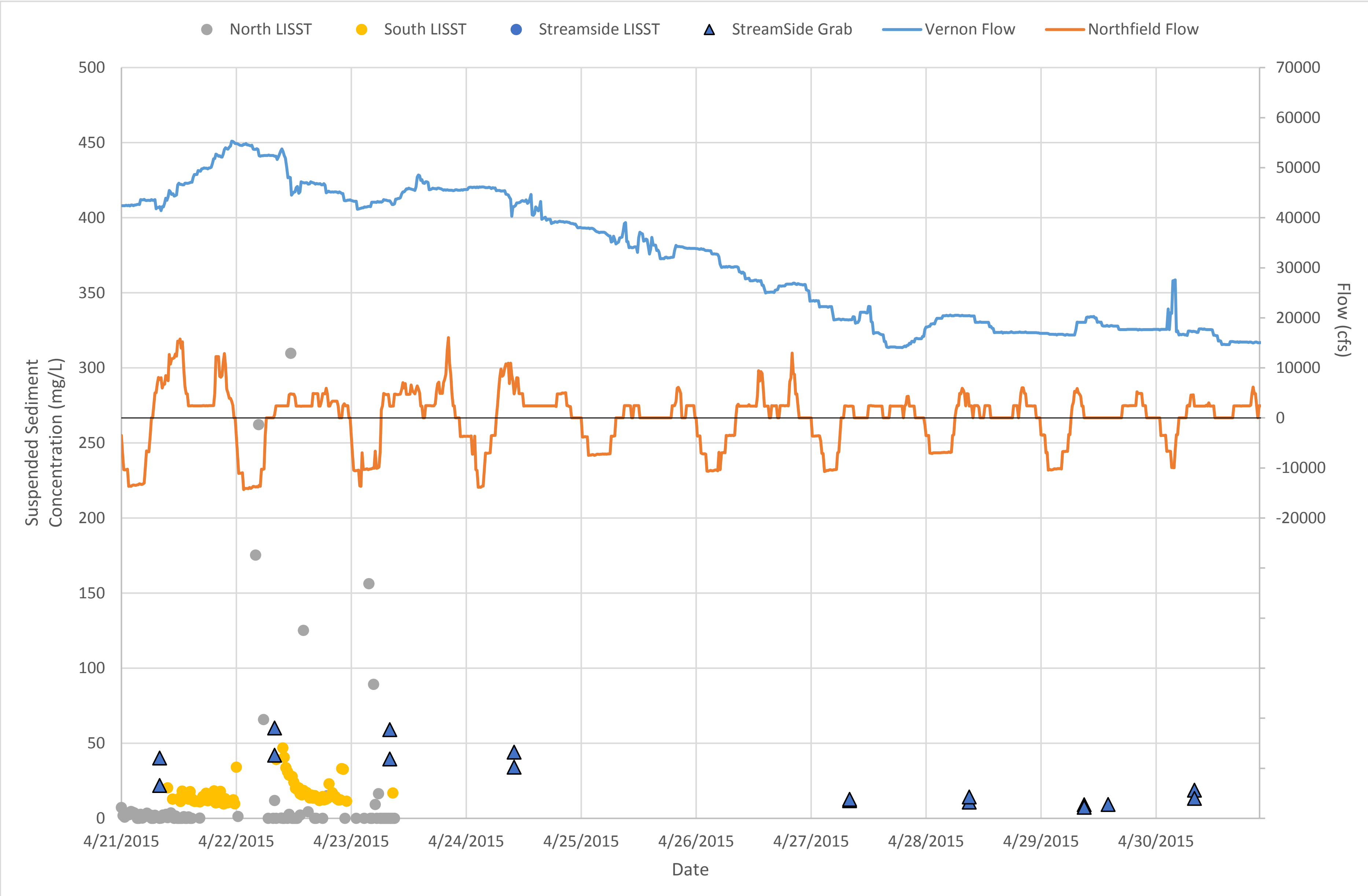
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
200
175
150
125
100
75
50
25
0
Suspended Sediment Concentration (mg/L)
50000
40000
30000
20000
10000
0
-10000
-20000
Flow (cfs)
7/1/2015
7/6/2015
7/11/2015
7/16/2015
7/21/2015
7/26/2015
7/31/2015
Date

2015 CONTINUOUS LISST INSTRUMENT TIMESERIES-10 DAY

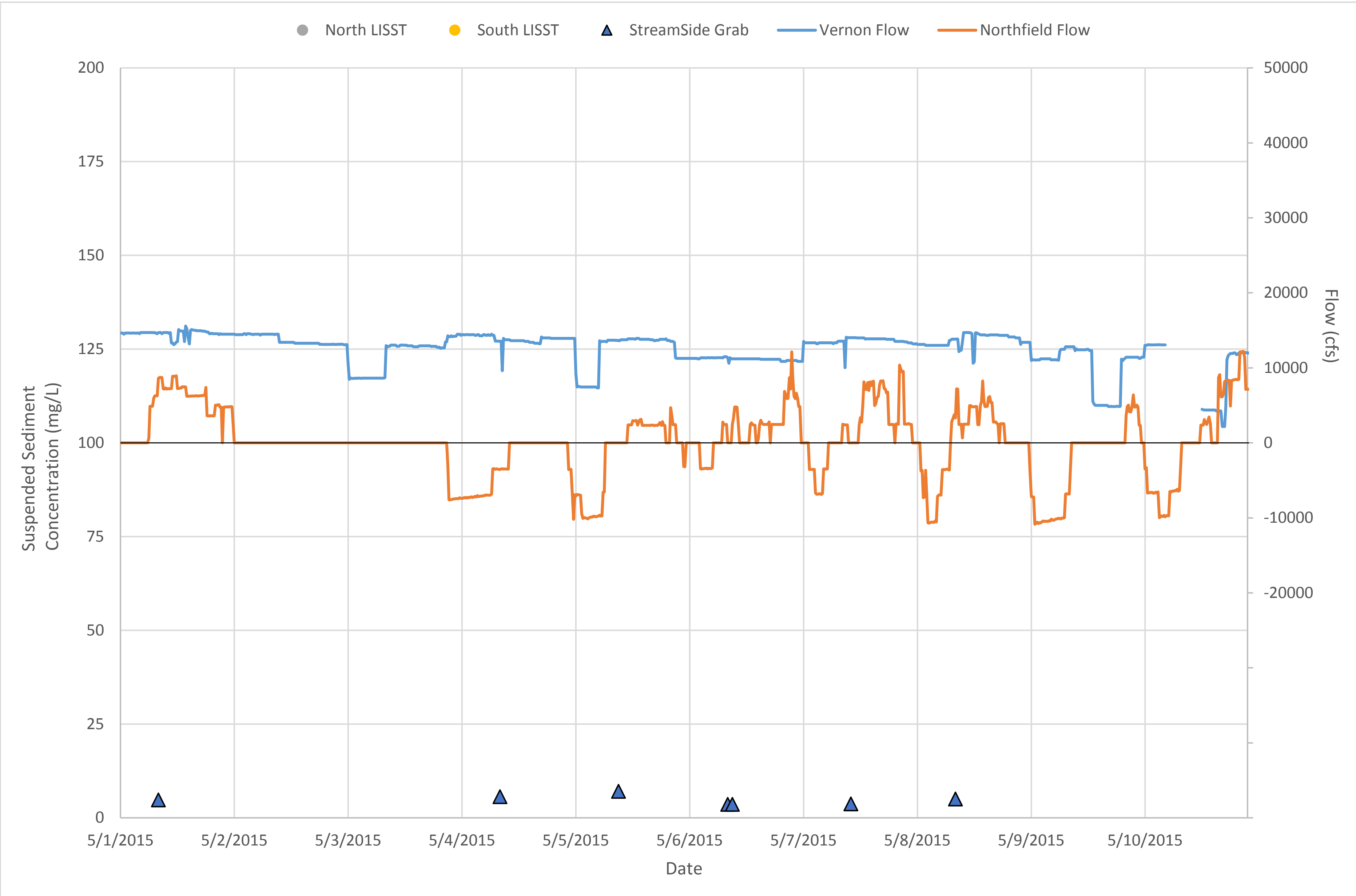


North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
500
450
400
350
300
250
200
150
100
50
0
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
4/1/2015
4/2/2015
4/3/2015
4/4/2015
4/5/2015
4/6/2015
4/7/2015
4/8/2015
4/9/2015
4/10/2015

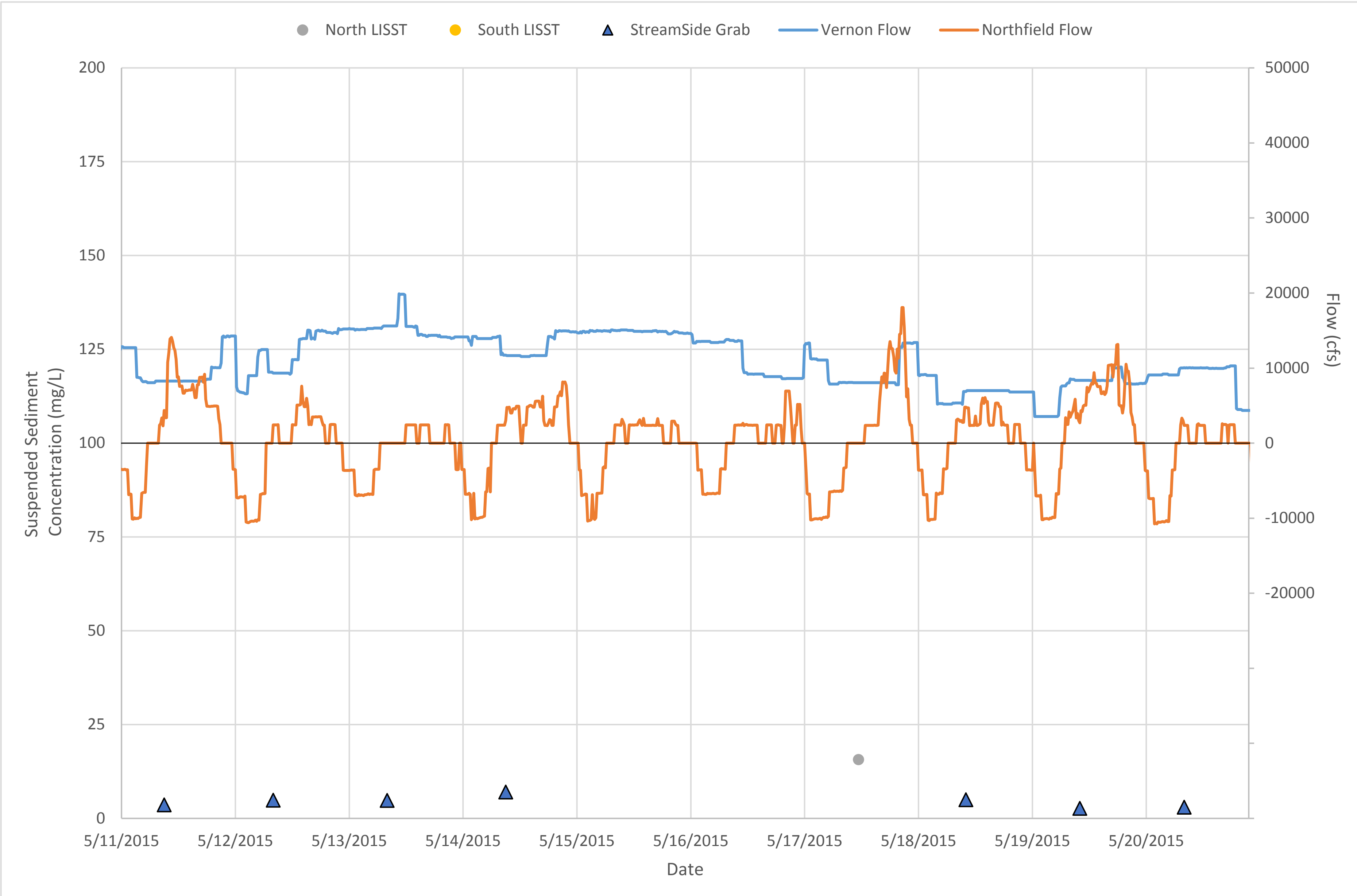

North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
500
450
400
350
300
250
200
150
100
50
0
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
4/11/2015
4/12/2015
4/13/2015
4/14/2015
4/15/2015
4/16/2015
4/17/2015
4/18/2015
4/19/2015
4/20/2015



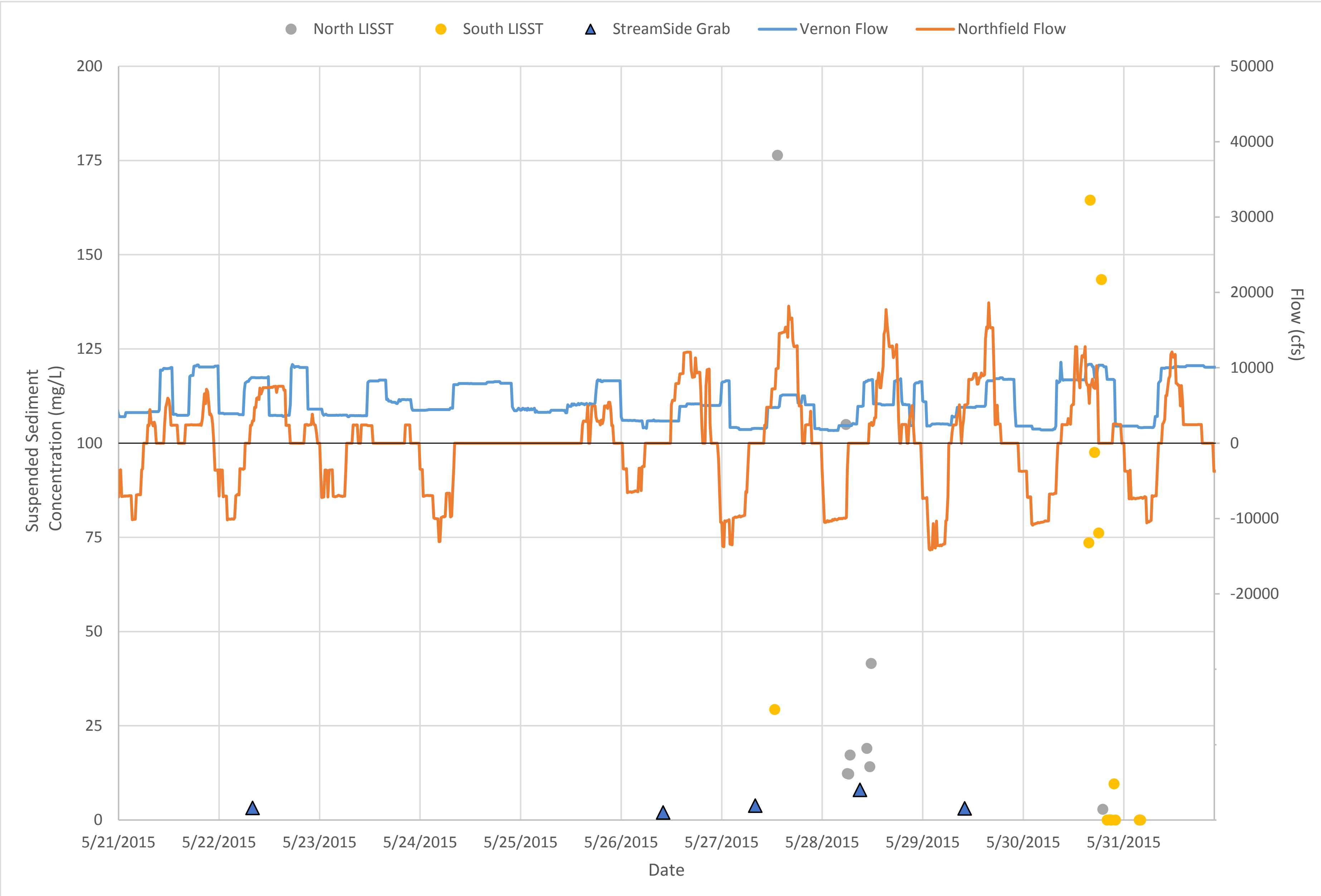
North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
500
450
400
350
300
250
200
150
100
50
0
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
4/21/2015
4/22/2015
4/23/2015
4/24/2015
4/25/2015
4/26/2015
4/27/2015
4/28/2015
4/29/2015
4/30/2015



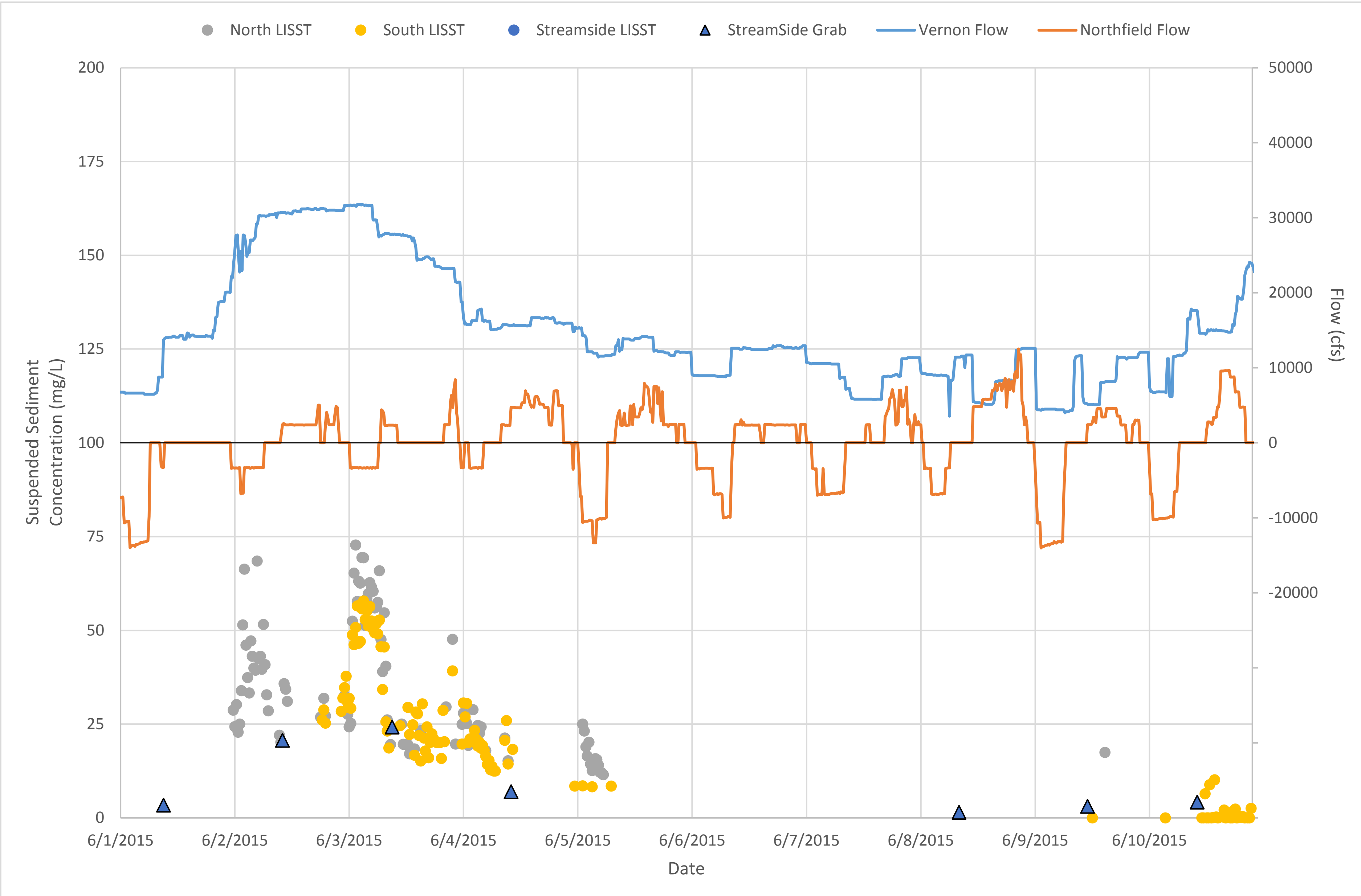
North LISST
South LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
Flow (cfs)
50000
40000
30000
20000
10000
0
-10000
-20000
5/1/2015
5/2/2015
5/3/2015
5/4/2015
5/5/2015
5/6/2015
5/7/2015
5/8/2015
5/9/2015
5/10/2015
Date



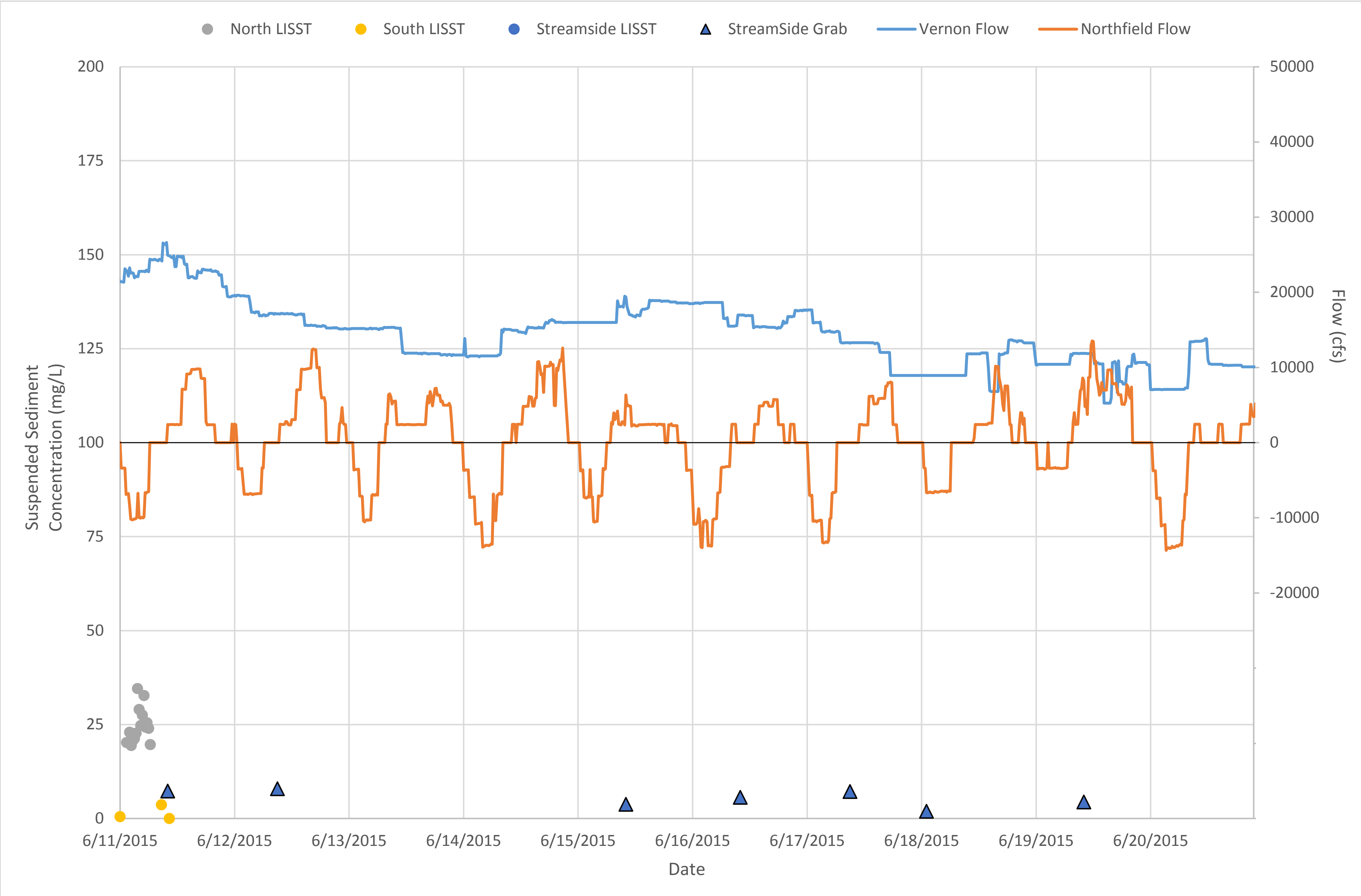
North LISST
South LISST
StreamSide Grab
Vernon Flow
Northfield Flow
200
175
150
125
100
75
50
25
0
Suspended Sediment Concentration (mg/L)
50000
40000
30000
20000
10000
0
-10000
-20000
Flow (cfs)
5/11/2015
5/12/2015
5/13/2015
5/14/2015
5/15/2015
5/16/2015
5/17/2015
5/18/2015
5/19/2015
5/20/2015
Date



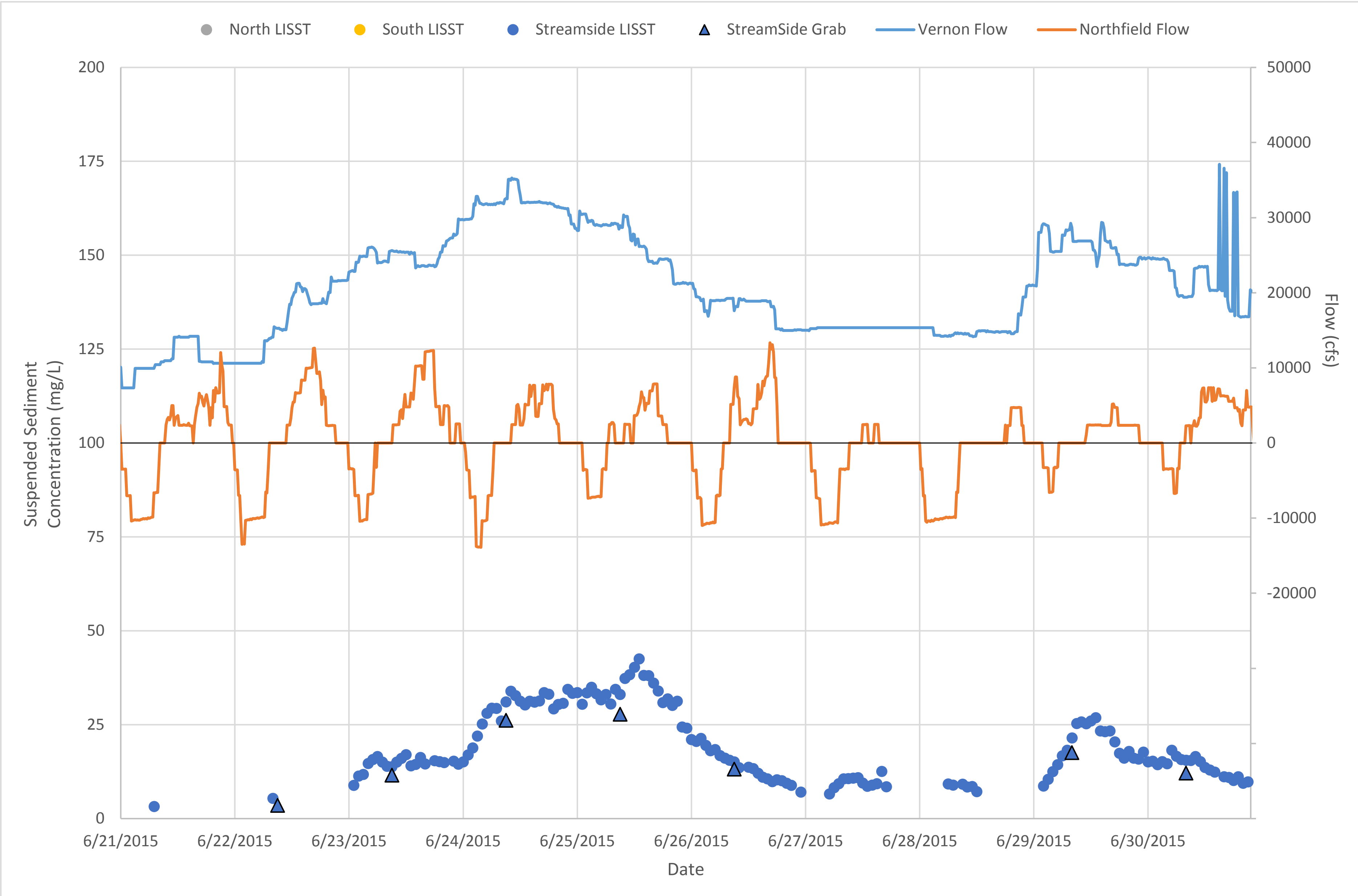
North LISST
South LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
Flow (cfs)
50000
40000
30000
20000
10000
0
-10000
-20000
5/21/2015
5/22/2015
5/23/2015
5/24/2015
5/25/2015
5/26/2015
5/27/2015
5/28/2015
5/29/2015
5/30/2015
5/31/2015
Date



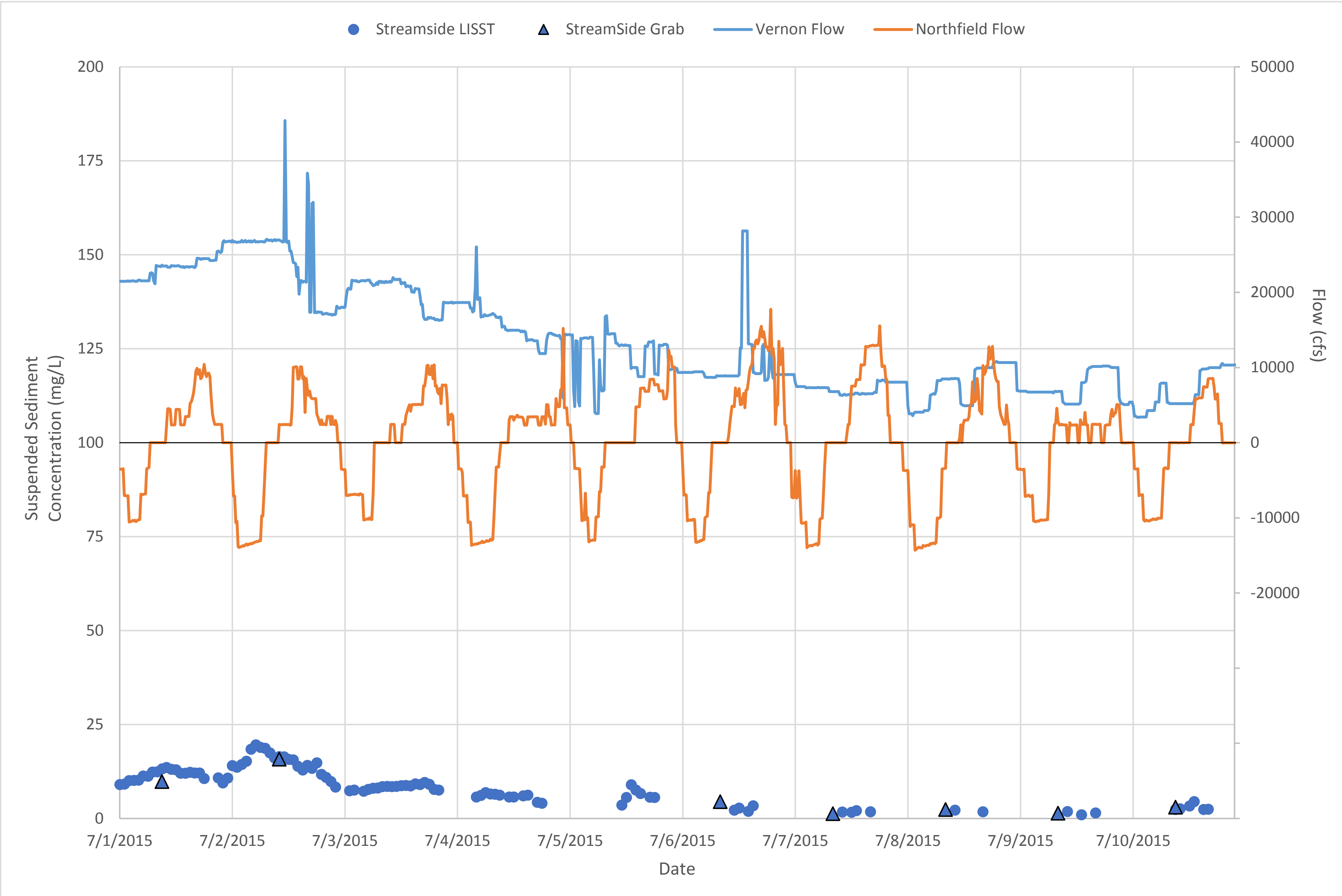
North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
Flow (cfs)
6/1/2015
6/2/2015
6/3/2015
6/4/2015
6/5/2015
6/6/2015
6/7/2015
6/8/2015
6/9/2015
6/10/2015
Date



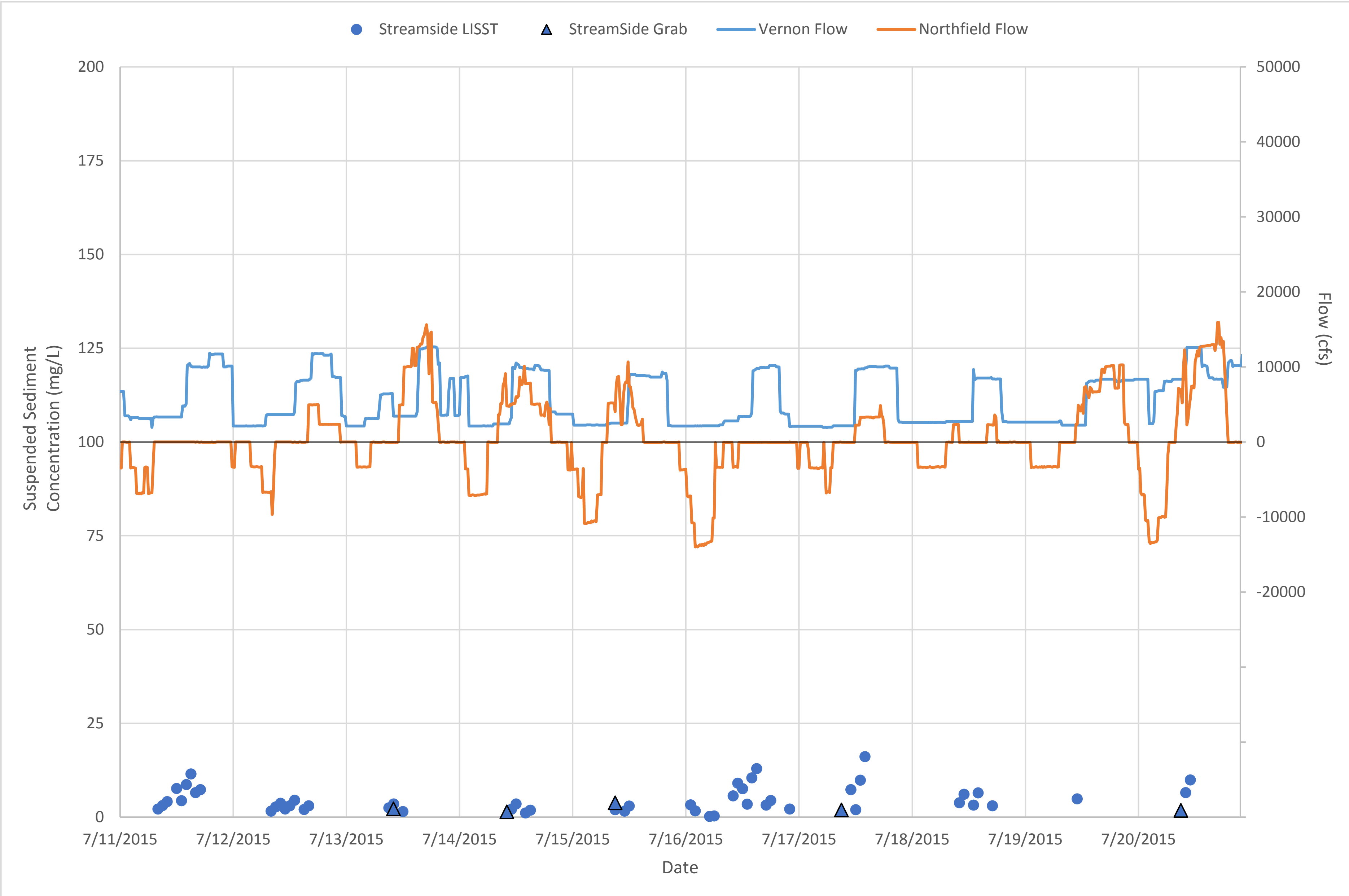
North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
Flow (cfs)
50000
40000
30000
20000
10000
0
-10000
-20000
6/11/2015
6/12/2015
6/13/2015
6/14/2015
6/15/2015
6/16/2015
6/17/2015
6/18/2015
6/19/2015
6/20/2015
Date



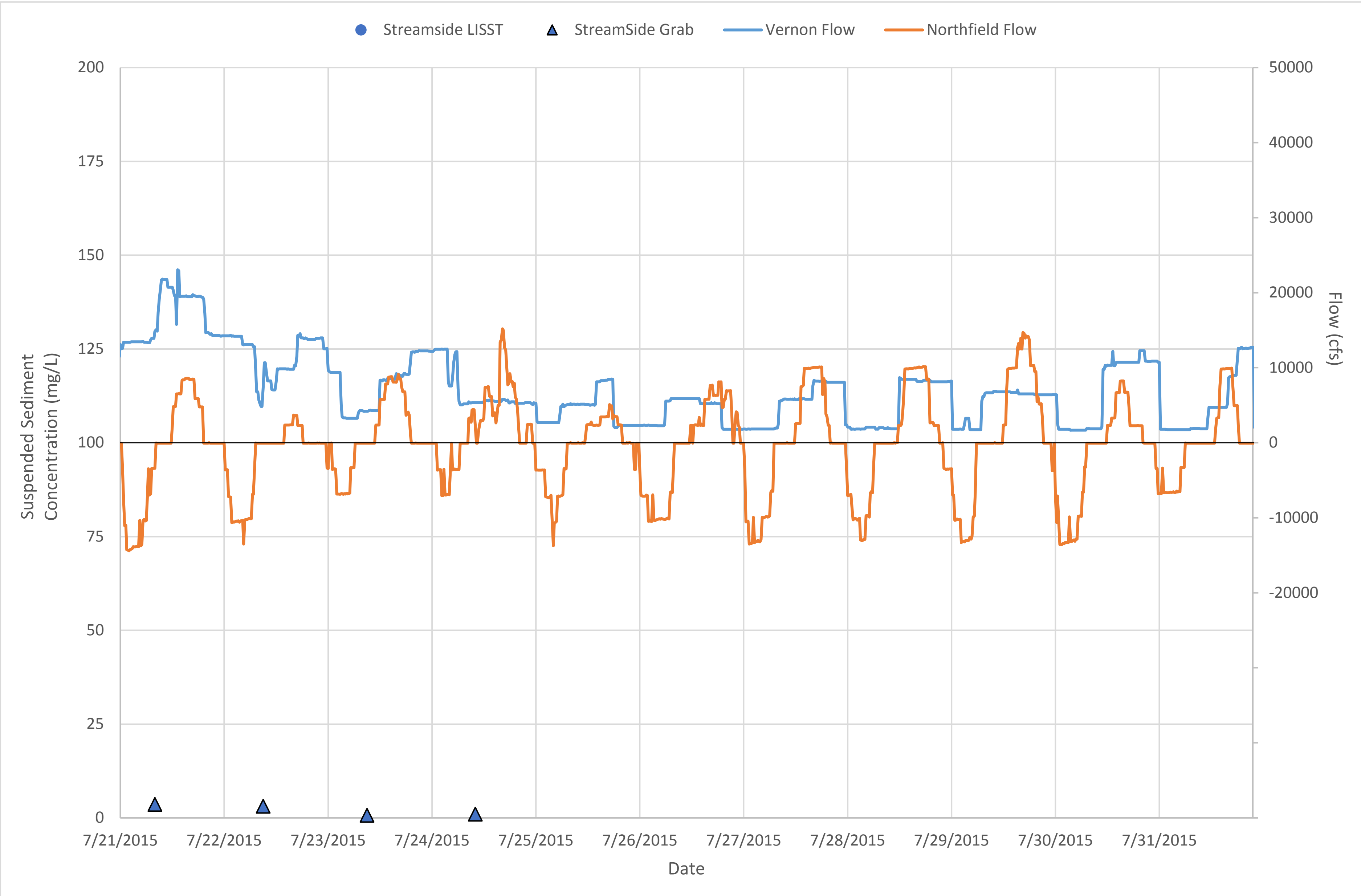
North LISST
South LISST
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
6/21/2015
6/22/2015
6/23/2015
6/24/2015
6/25/2015
6/26/2015
6/27/2015
6/28/2015
6/29/2015
6/30/2015
Date



Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
Flow (cfs)
50000
40000
30000
20000
10000
0
-10000
-20000
7/1/2015
7/2/2015
7/3/2015
7/4/2015
7/5/2015
7/6/2015
7/7/2015
7/8/2015
7/9/2015
7/10/2015
Date



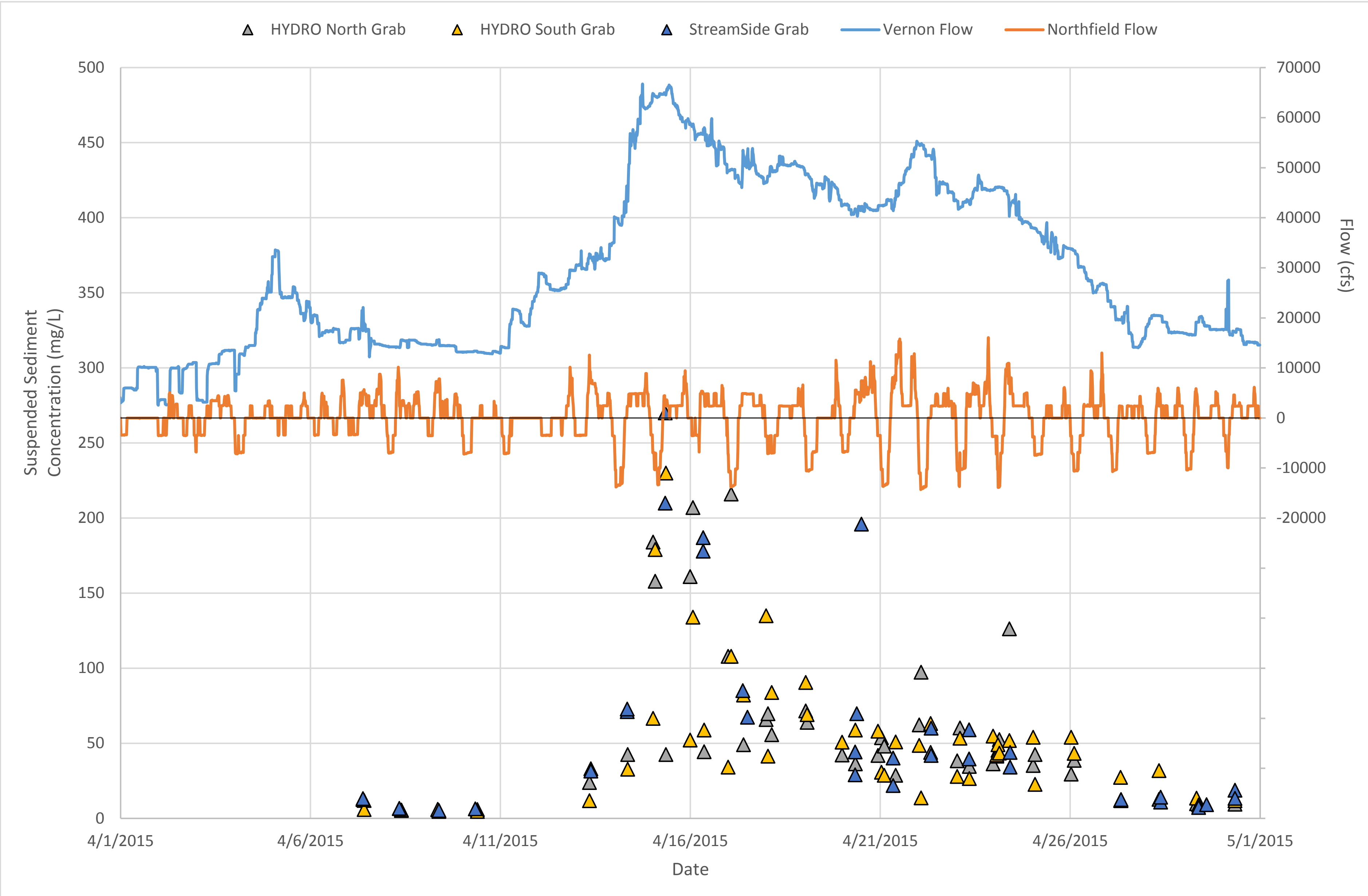
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
7/11/2015
7/12/2015
7/13/2015
7/14/2015
7/15/2015
7/16/2015
7/17/2015
7/18/2015
7/19/2015
7/20/2015



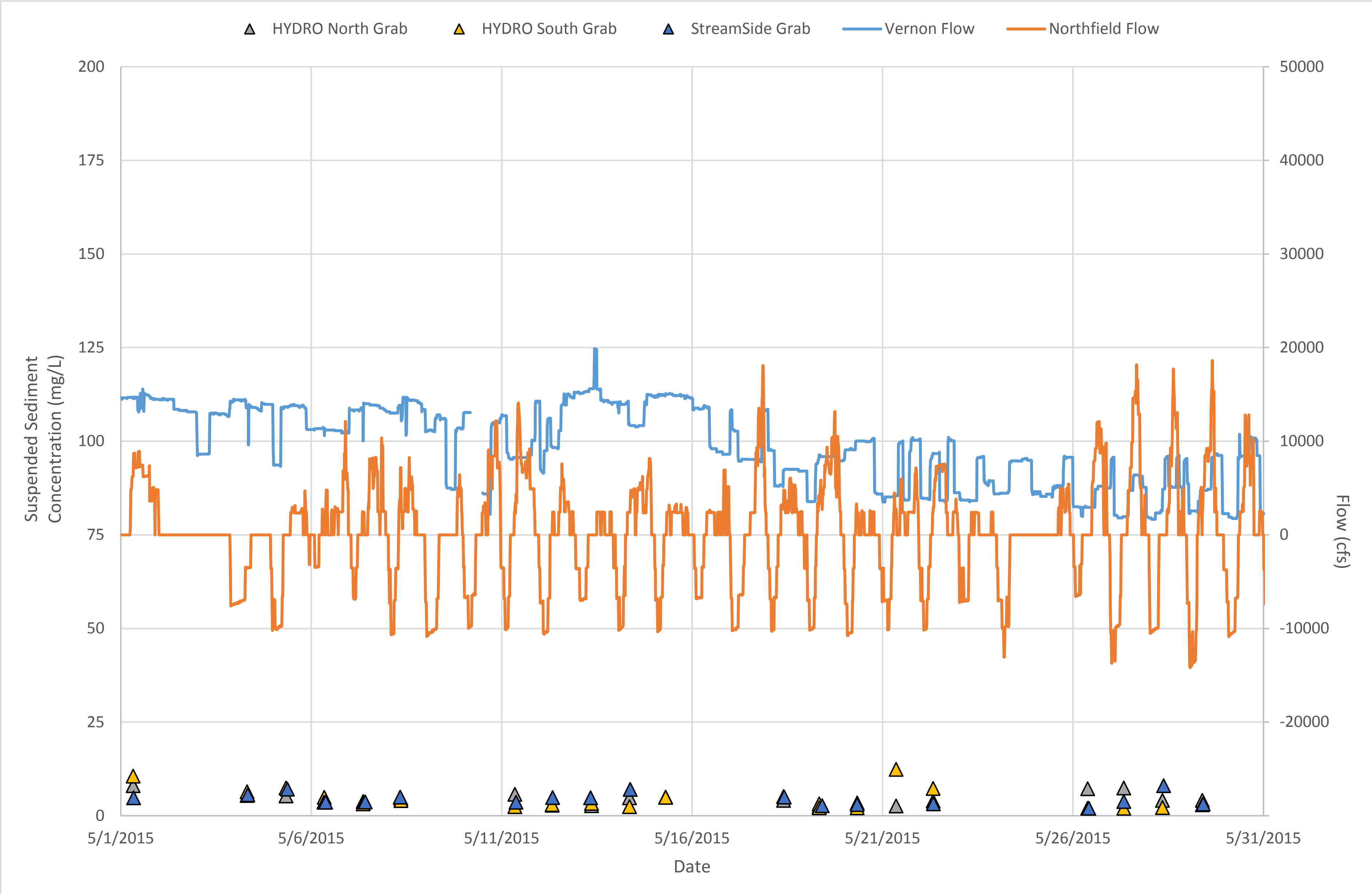
Streamside LISST
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
7/21/2015
7/22/2015
7/23/2015
7/24/2015
7/25/2015
7/26/2015
7/27/2015
7/28/2015
7/29/2015
7/30/2015
7/31/2015

# APPENDIX D – GRAB SAMPLE SSC, FLOW, AND PROJECT OPERATIONS TIMESERIES PLOTS MG/L (2015)

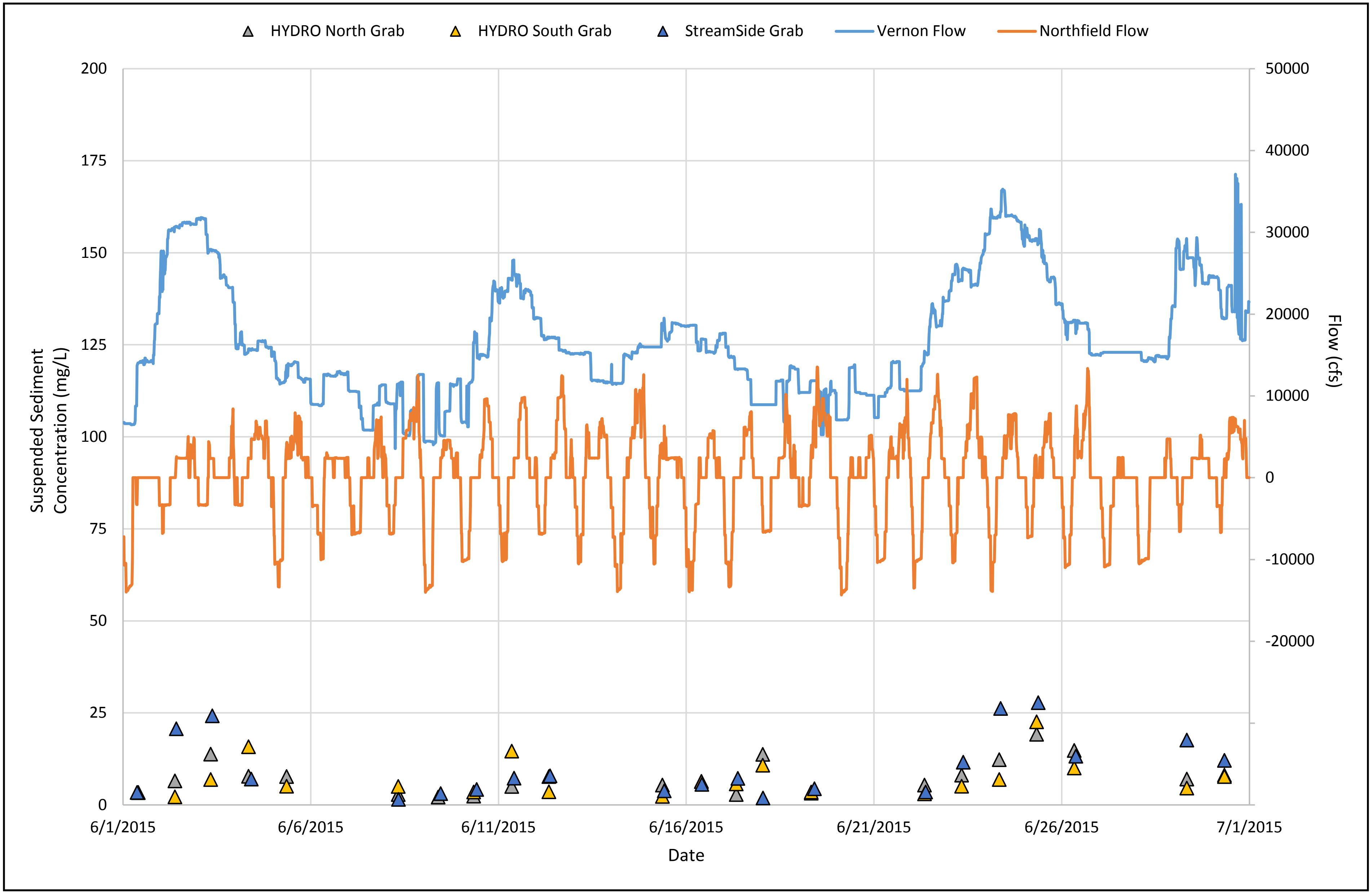
2015 GRAB SAMPLE TIMESERIES-MONTHLY



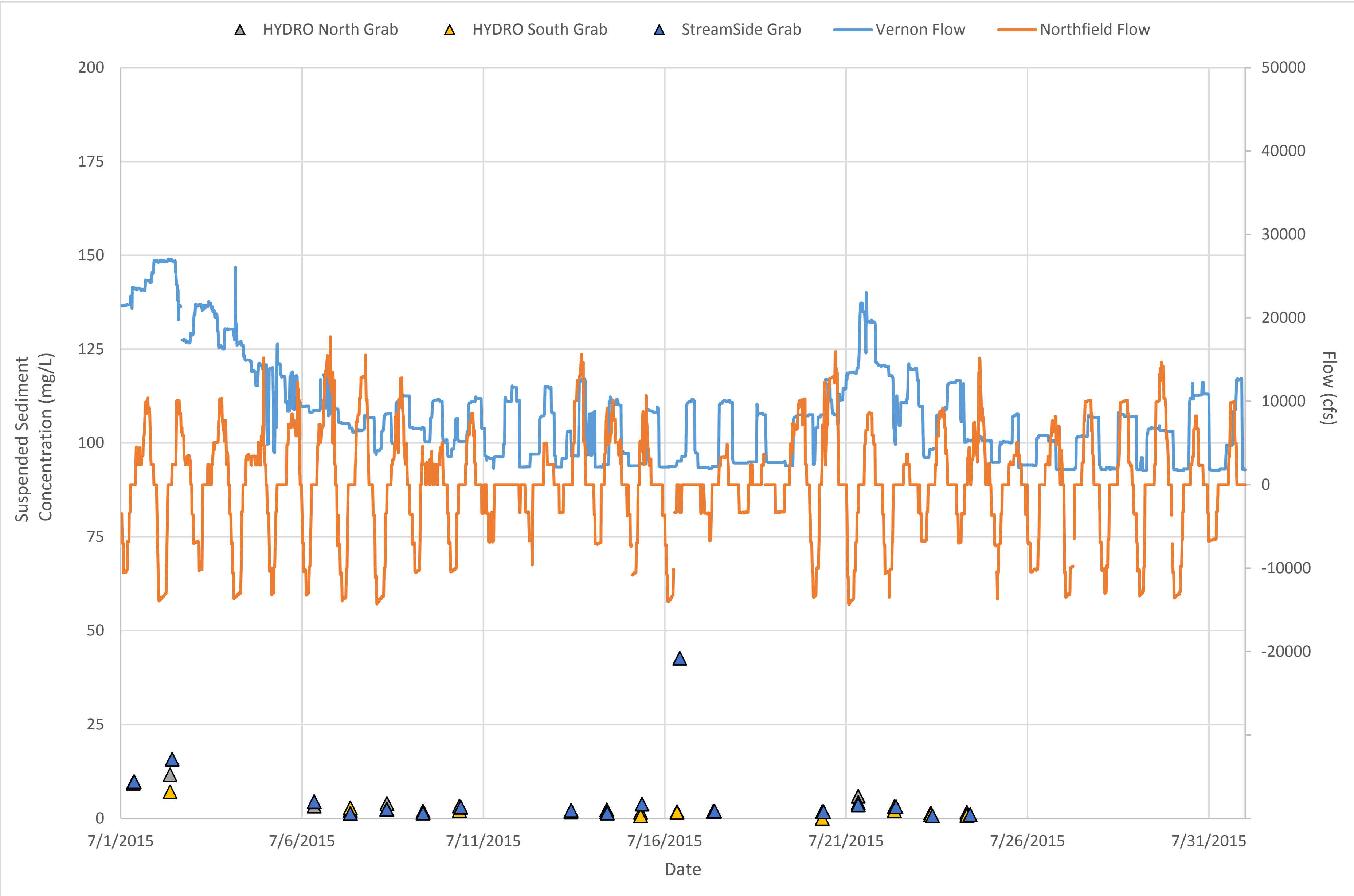
HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
500
450
400
350
300
250
200
150
100
50
0
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
4/1/2015
4/6/2015
4/11/2015
4/16/2015
4/21/2015
4/26/2015
5/1/2015



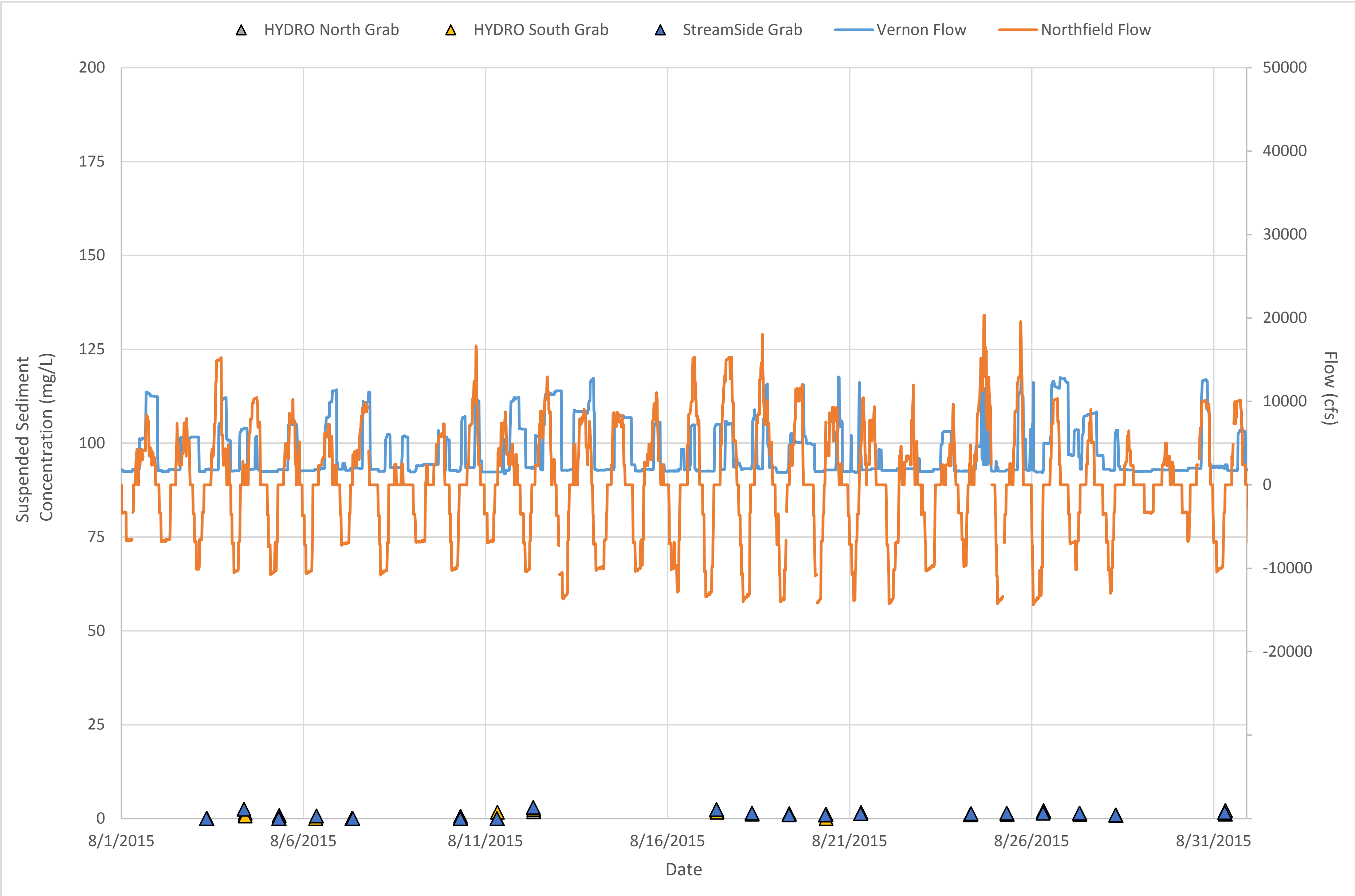
HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
0
25
50
75
100
125
150
175
200
-20000
-10000
0
10000
20000
30000
40000
50000
5/1/2015
5/6/2015
5/11/2015
5/16/2015
5/21/2015
5/26/2015
5/31/2015

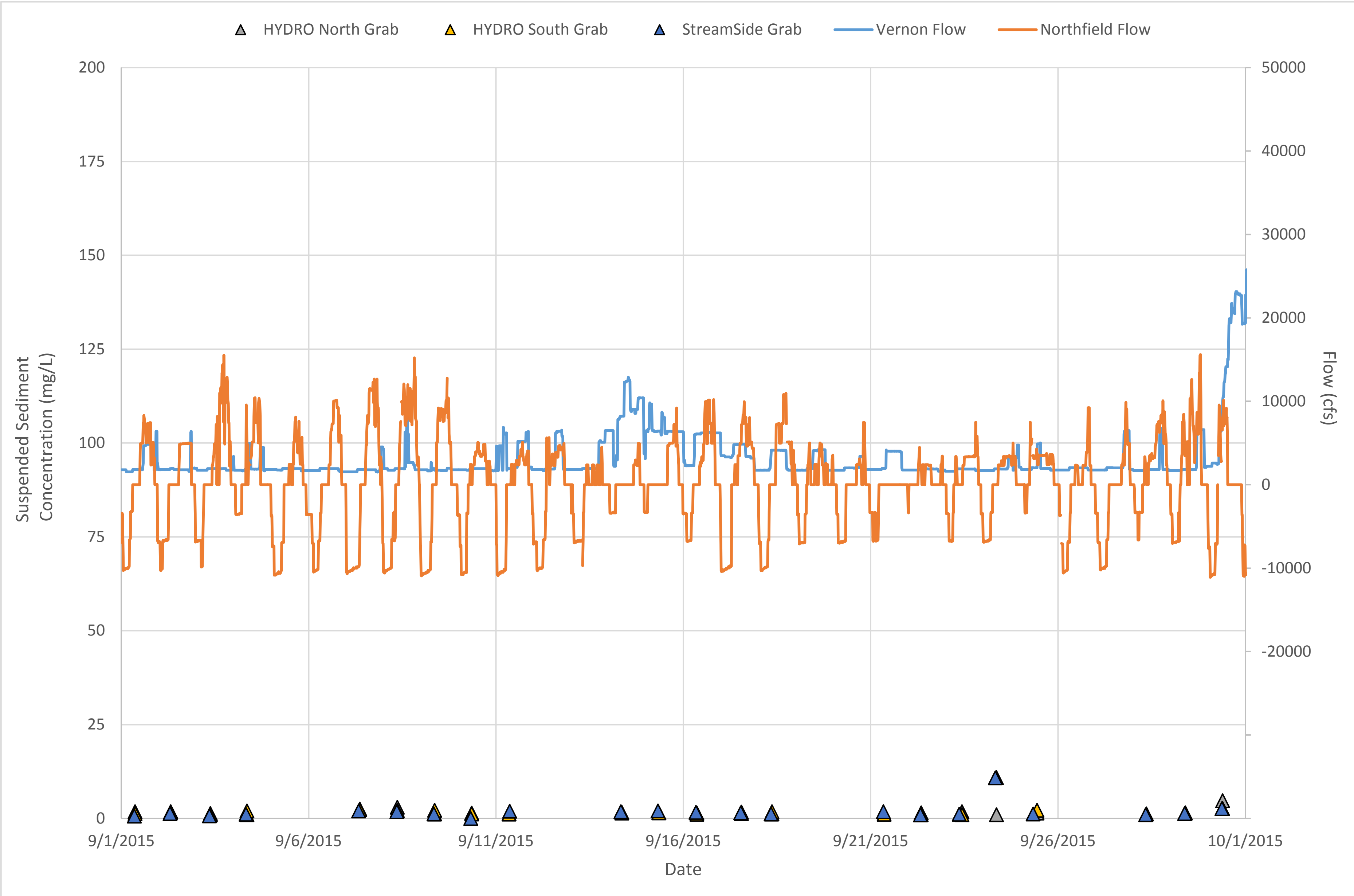


HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
0
25
50
75
100
125
150
175
200
50000
40000
30000
20000
10000
0
-10000
-20000
6/1/2015
6/6/2015
6/11/2015
6/16/2015
6/21/2015
6/26/2015
7/1/2015

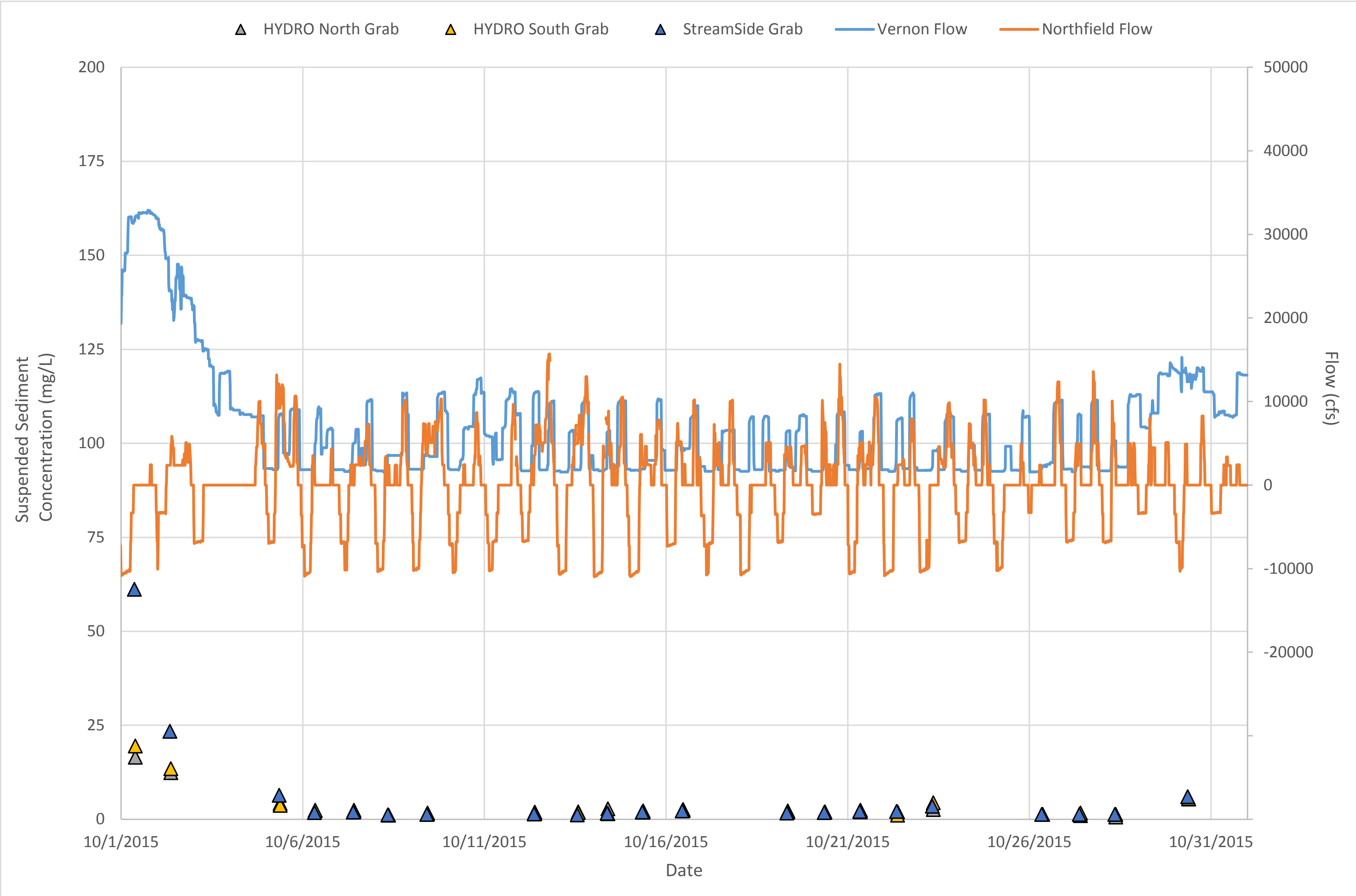


HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
0
25
50
75
100
125
150
175
200
50000
40000
30000
20000
10000
0
-10000
-20000
7/1/2015
7/6/2015
7/11/2015
7/16/2015
7/21/2015
7/26/2015
7/31/2015


HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
Flow (cfs)
8/1/2015
8/6/2015
8/11/2015
8/16/2015
8/21/2015
8/26/2015
8/31/2015
Date

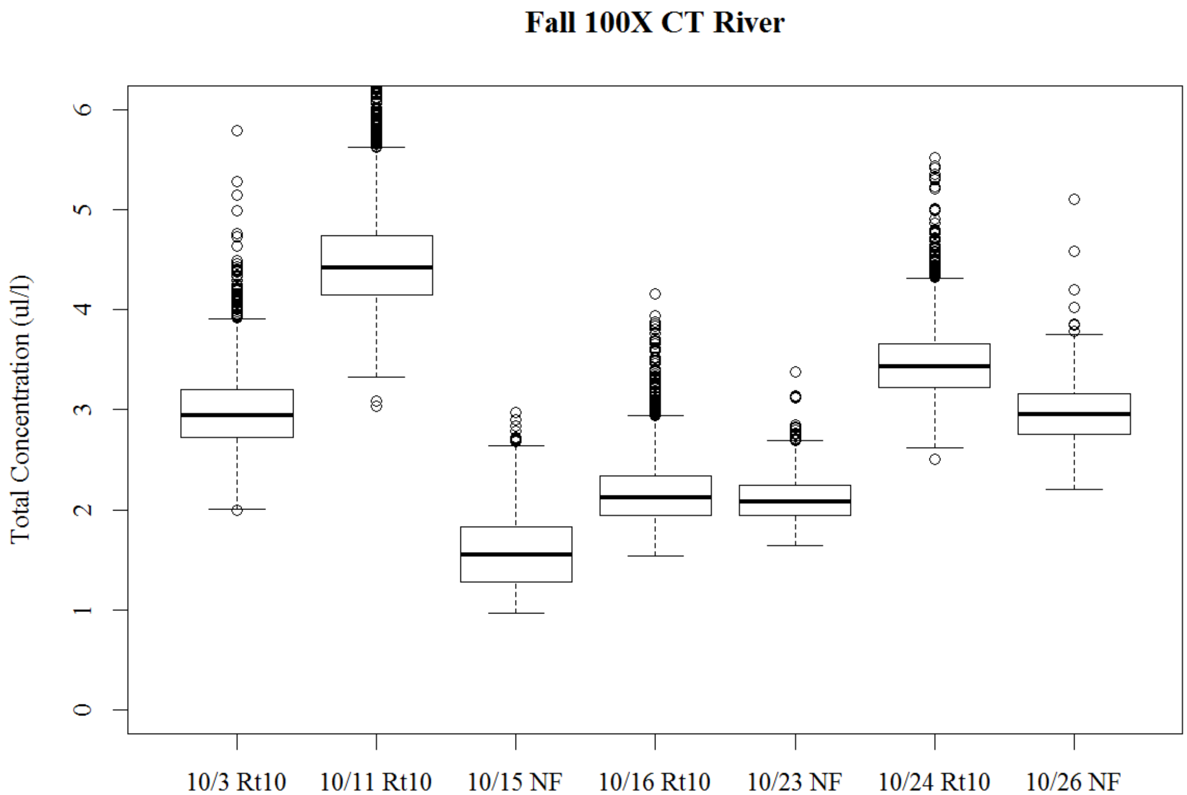


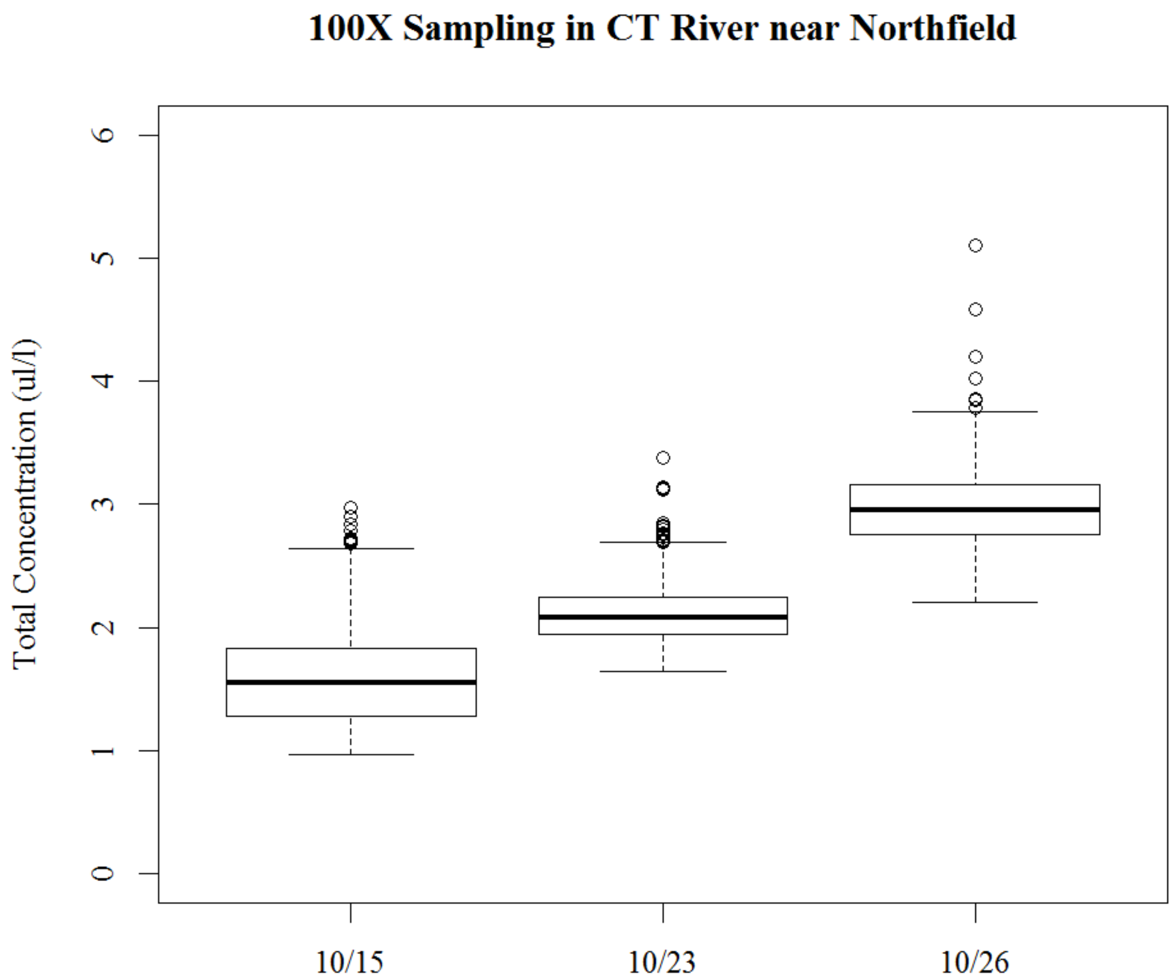
HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
200
175
150
125
100
75
50
25
0
Flow (cfs)
50000
40000
30000
20000
10000
0
-10000
-20000
9/1/2015
9/6/2015
9/11/2015
9/16/2015
9/21/2015
9/26/2015
10/1/2015
Date


HYDRO North Grab
HYDRO South Grab
StreamSide Grab
Vernon Flow
Northfield Flow
Suspended Sediment Concentration (mg/L)
Flow (cfs)
Date
200
175
150
125
100
75
50
25
0
50000
40000
30000
20000
10000
0
-10000
-20000
10/1/2015
10/6/2015
10/11/2015
10/16/2015
10/21/2015
10/26/2015
10/31/2015

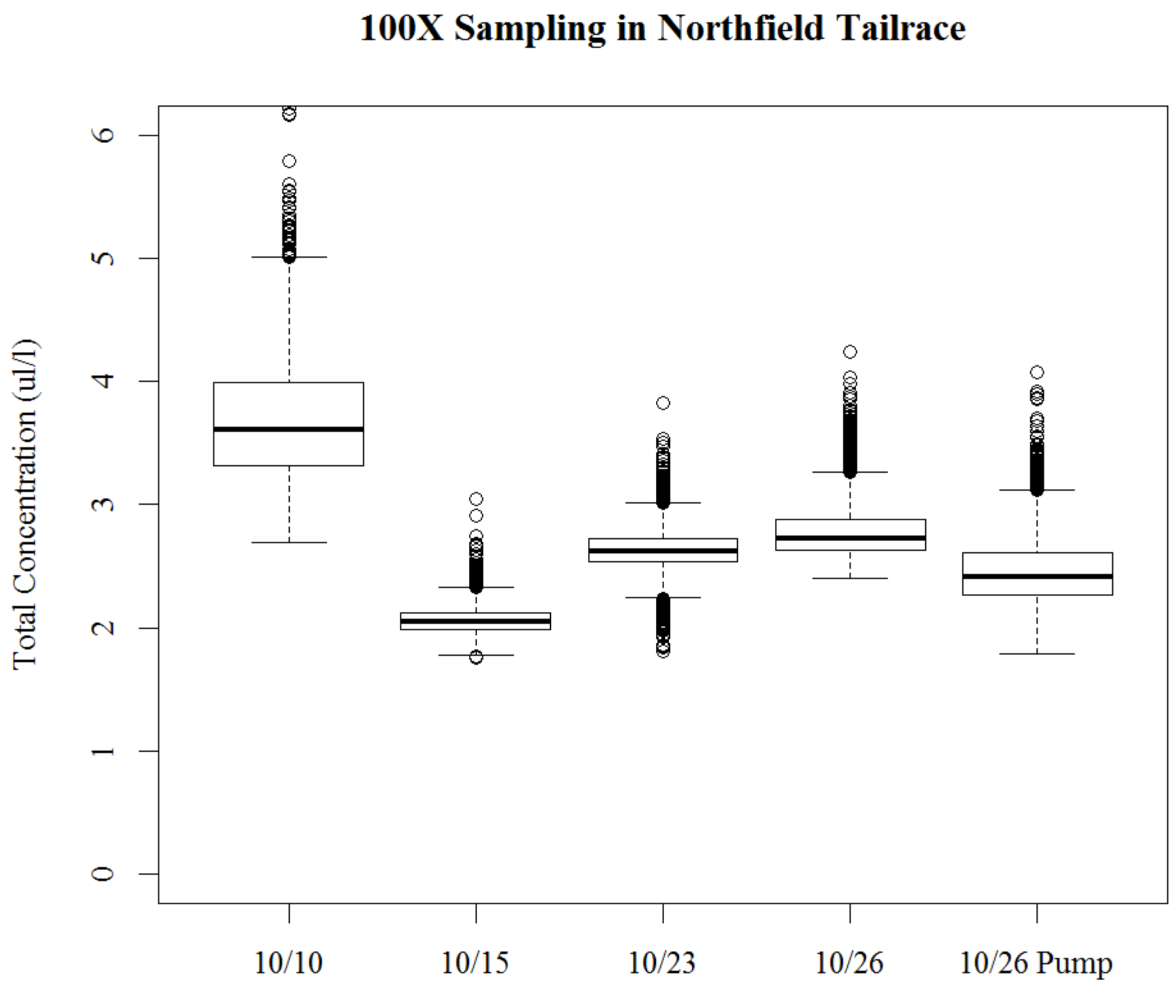
# APPENDIX E – LISST-100X ROUTE 10 BRIDGE & NORTHFIELD MOUNTAIN TAILRACE CROSS-SECTION PLOTS (2013)

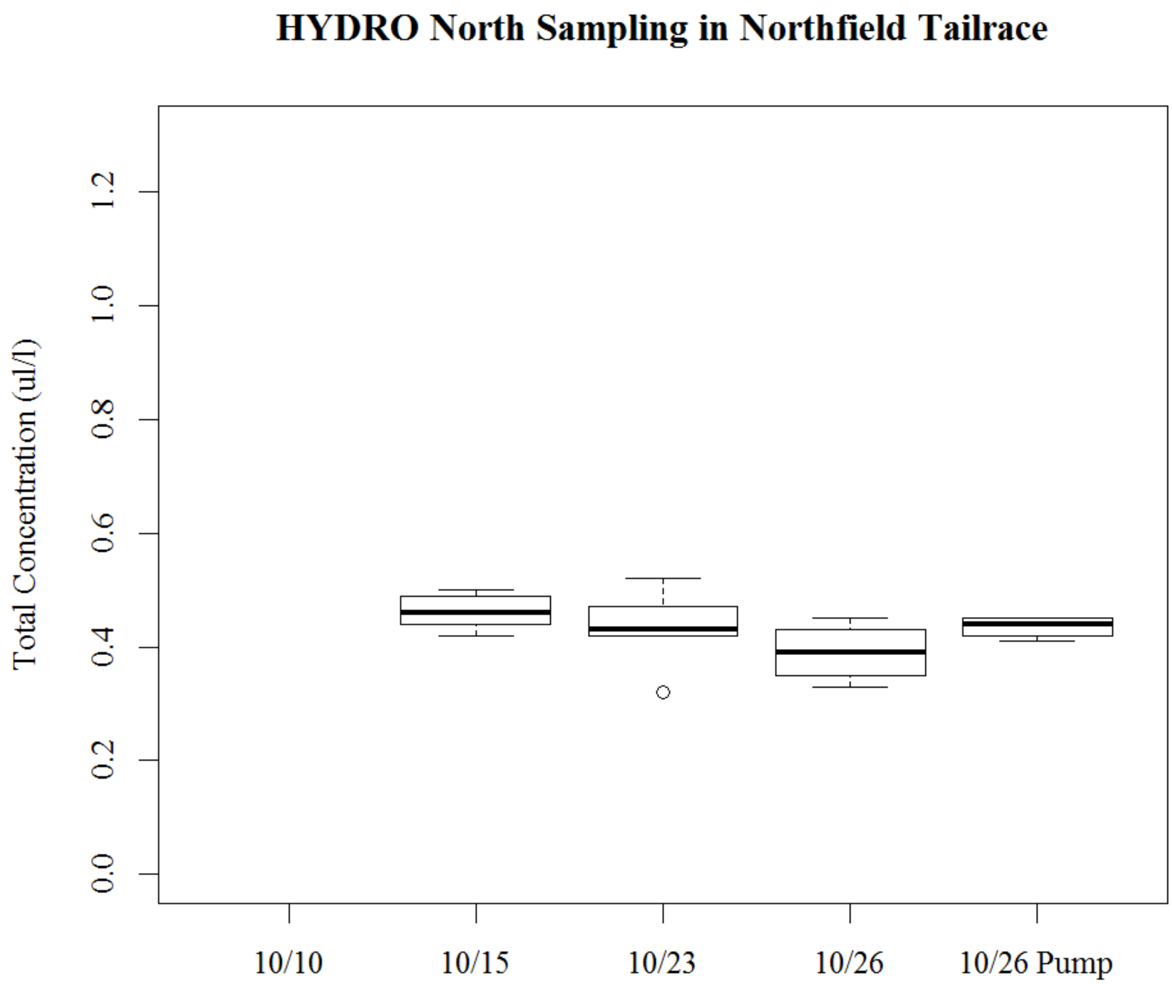
2013 LISST 100X PLOTS- HYDRO AND 100X ANALYSIS


Fall 100X CT River
Total Concentration (ul/l)
0
1
2
3
4
5
6
10/3 Rt10
10/11 Rt10
10/15 NF
10/16 Rt10
10/23 NF
10/24 Rt10
10/26 NF

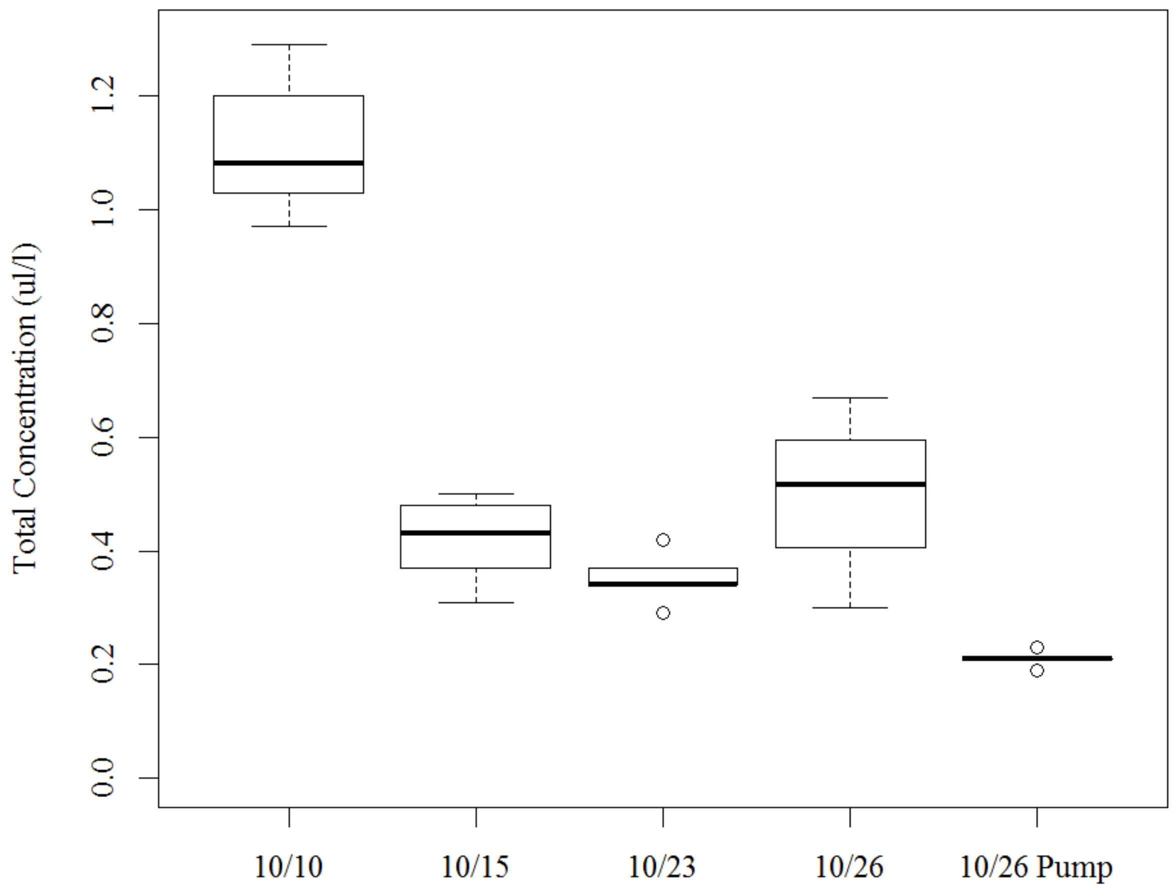


100X Sampling in CT River near Northfield
Total Concentration (ul/l)
0
1
2
3
4
5
6
10/15
10/23
10/26

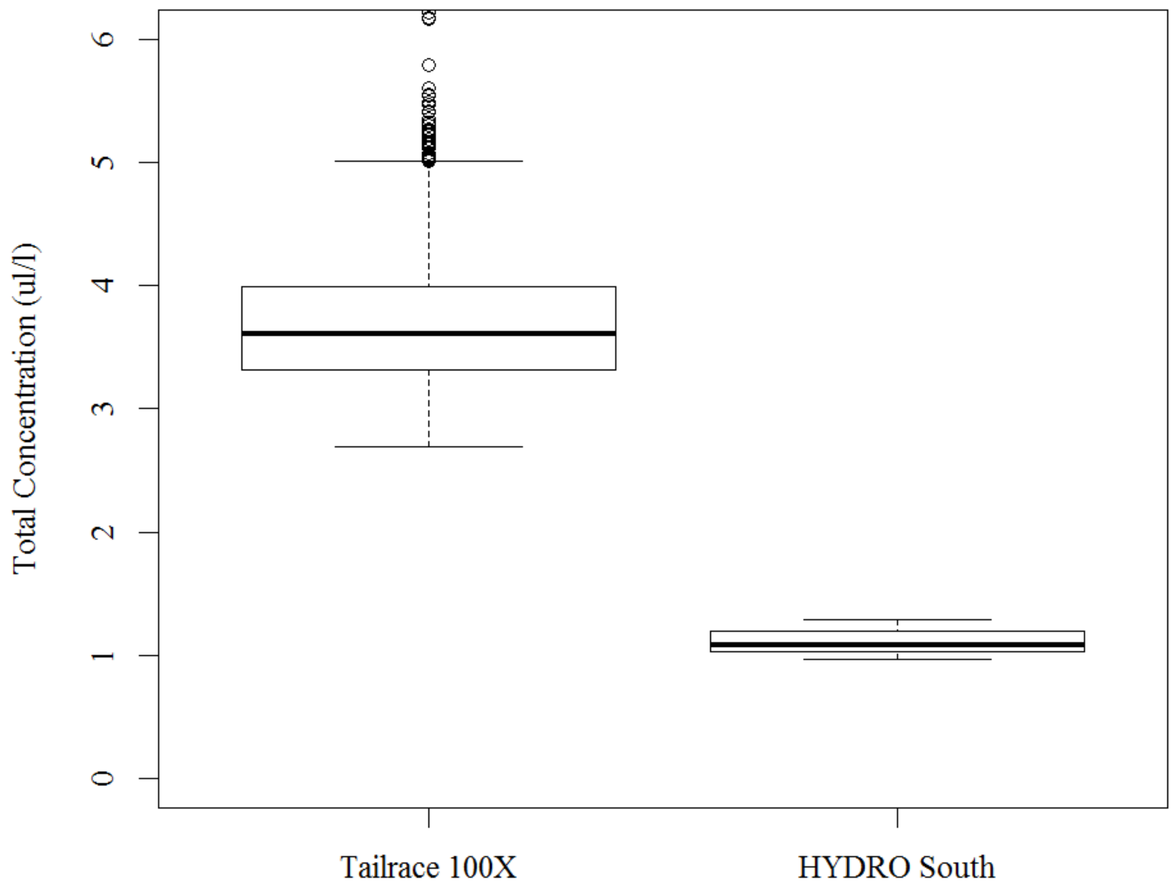

100X Sampling in Northfield Tailrace
Total Concentration (ul/l)
0
1
2
3
4
5
6
10/10
10/15
10/23
10/26
10/26 Pump


HYDRO North Sampling in Northfield Tailrace
Total Concentration (ul/l)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
10/10
10/15
10/23
10/26
10/26 Pump

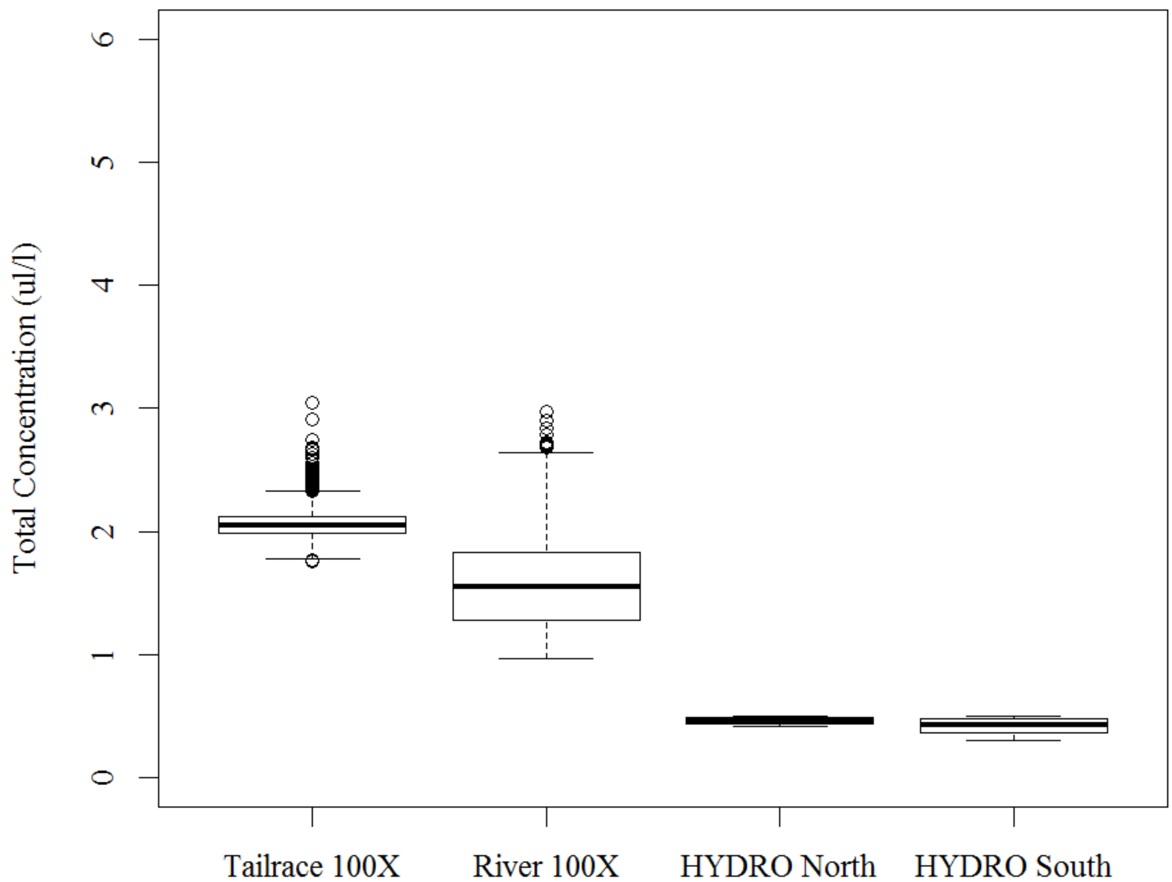
## HYDRO South Sampling in Northfield Tailrace

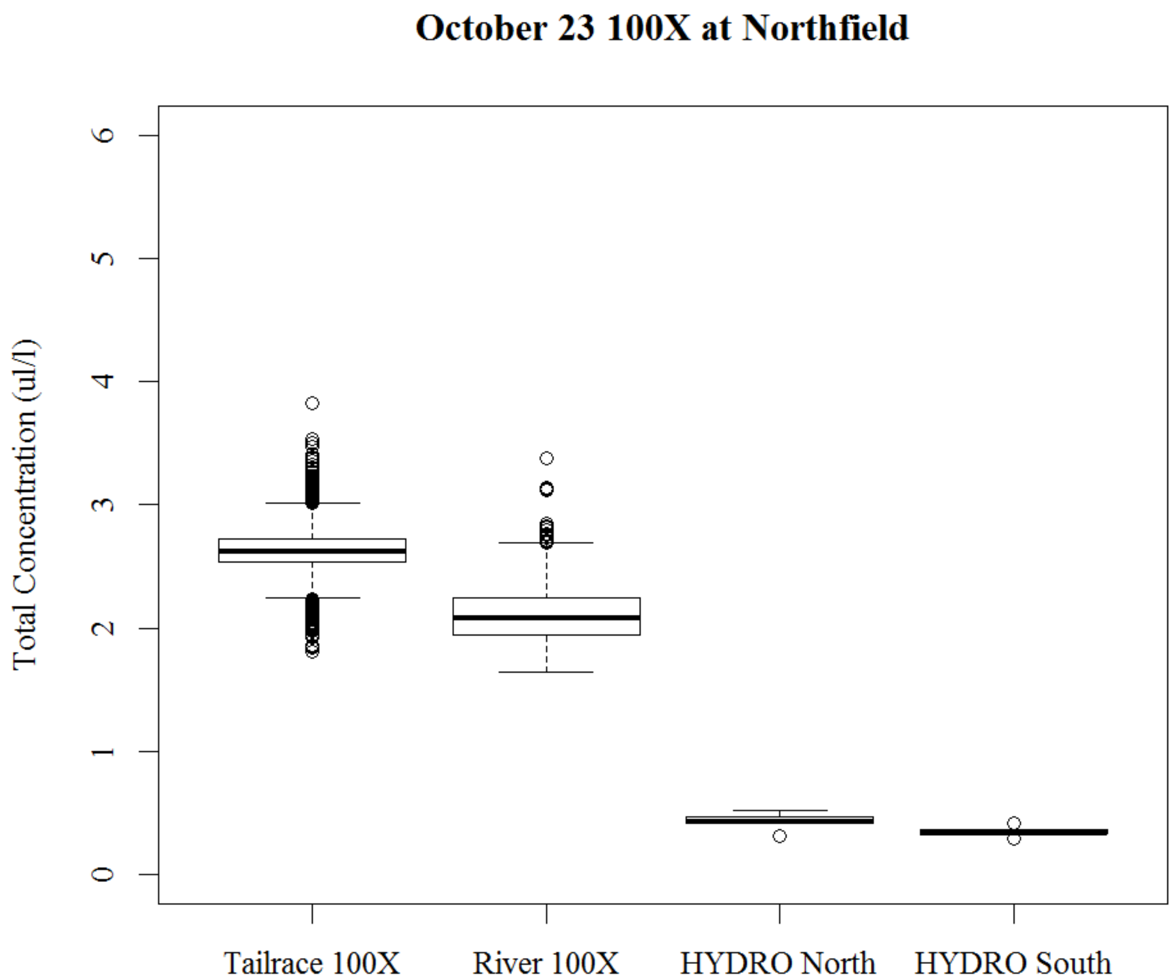


**October 10 100X at Northfield**

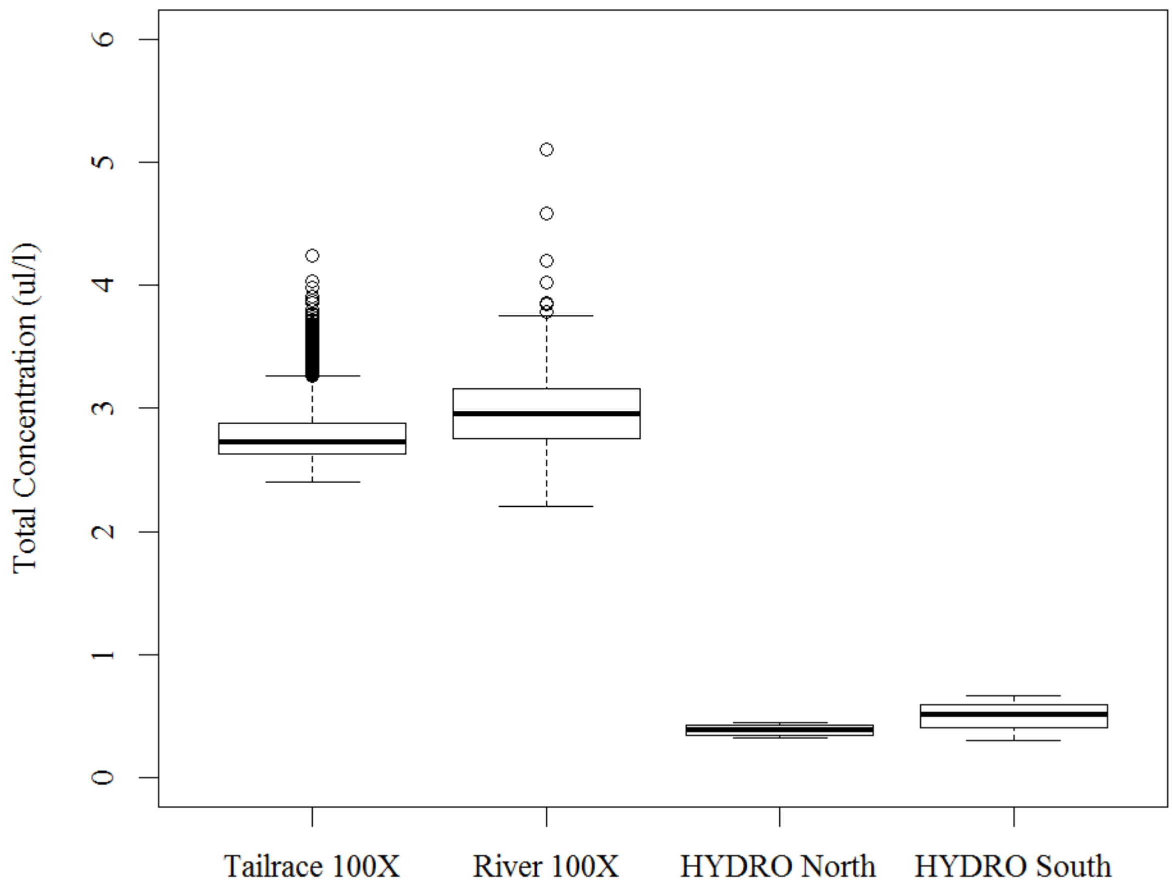


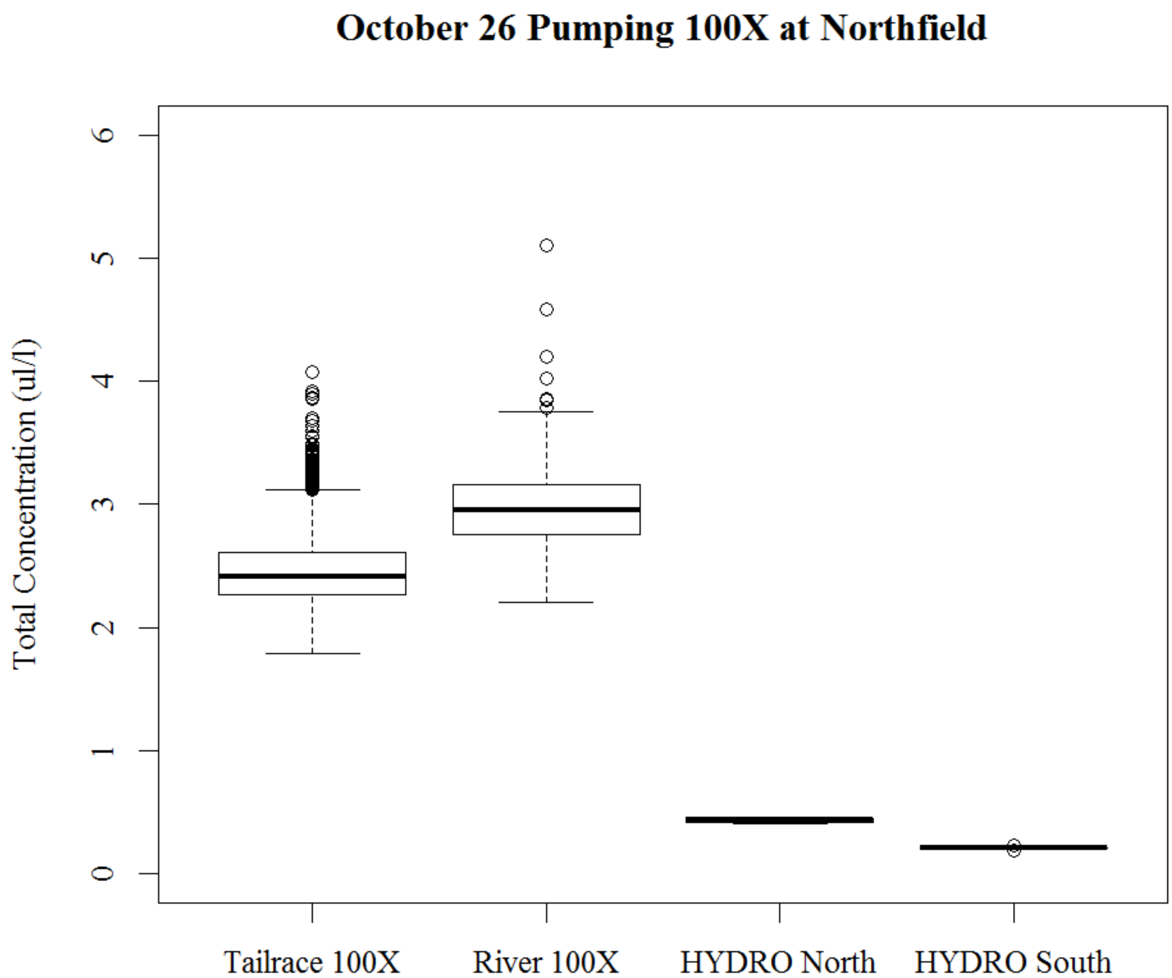
## October 15 100X at Northfield




October 23 100X at Northfield
Total Concentration (ul/l)
0
1
2
3
4
5
6
Tailrace 100X
River 100X
HYDRO North
HYDRO South

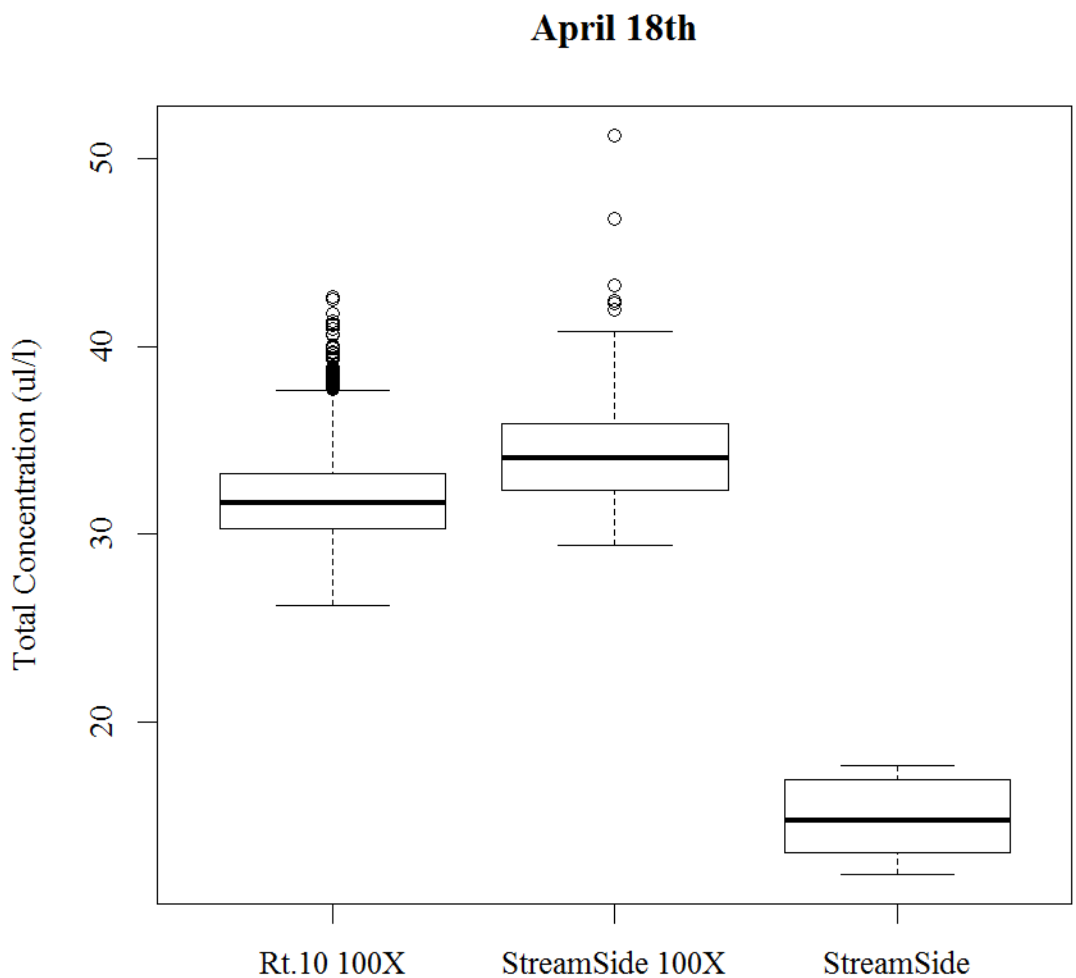
# October 26 100X at Northfield

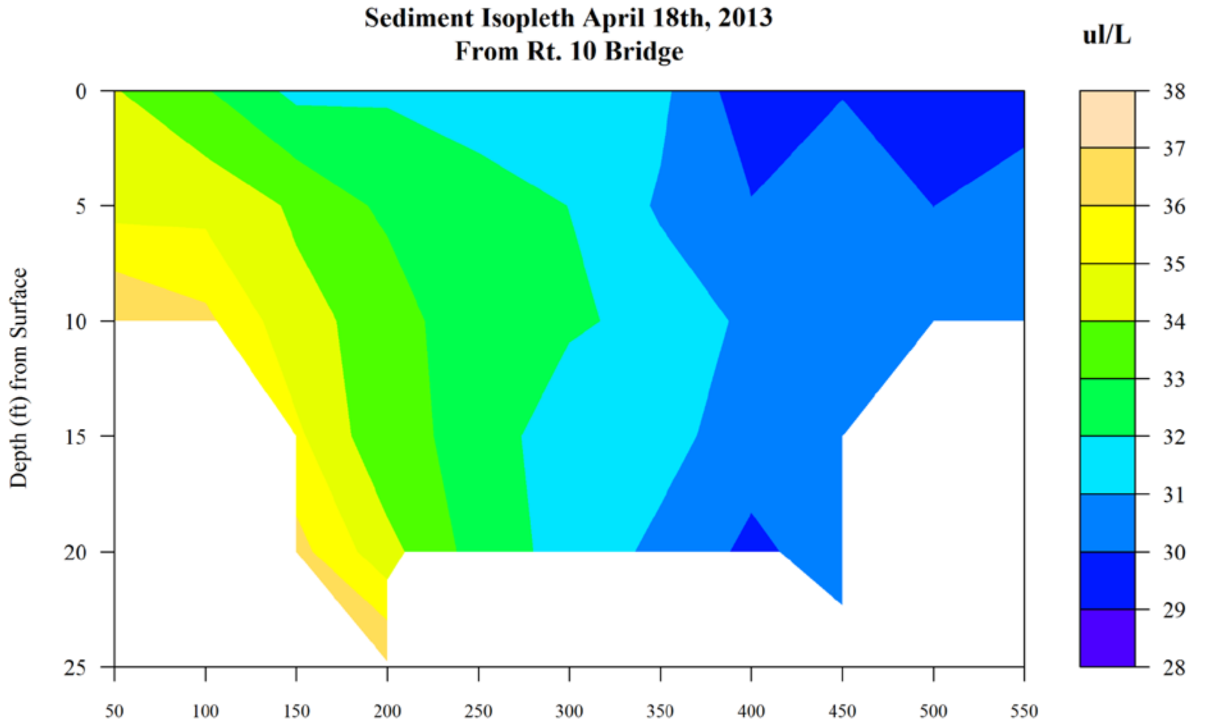




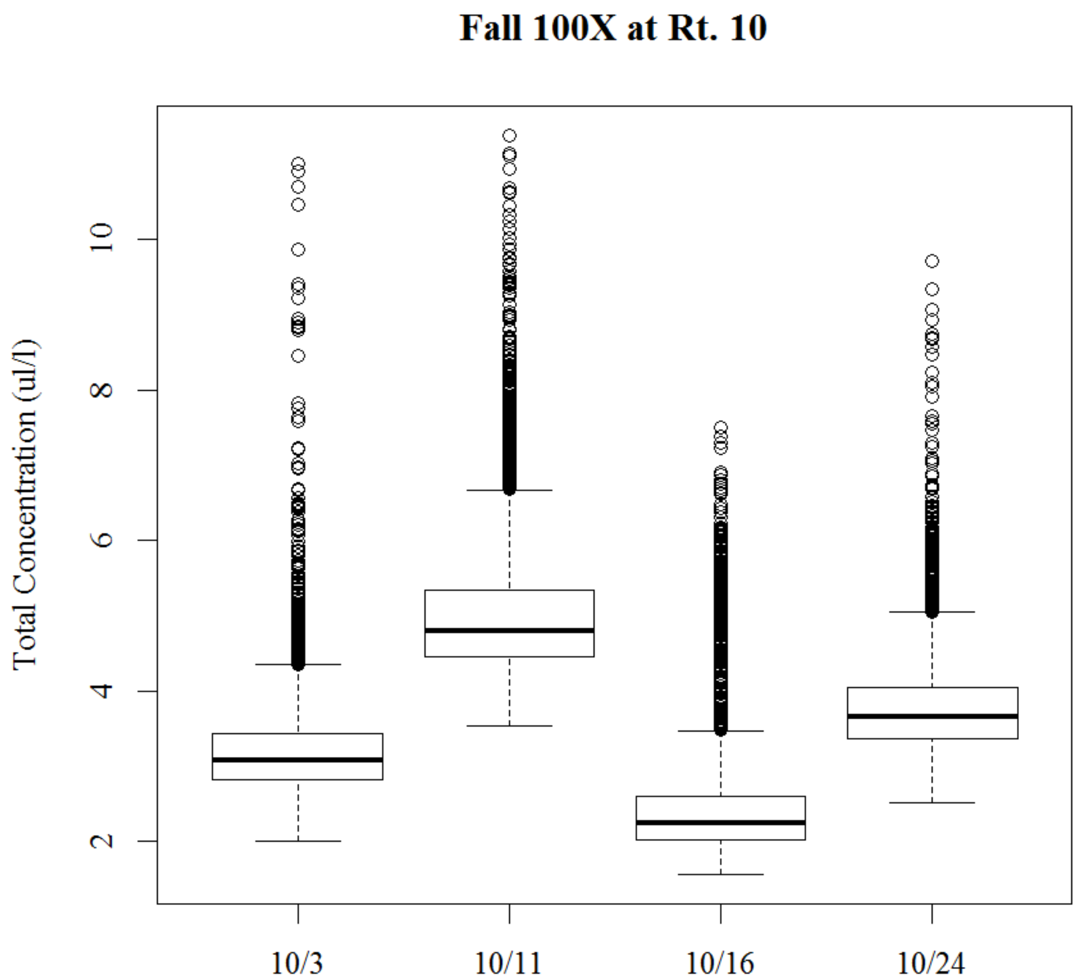
October 26 Pumping 100X at Northfield
Total Concentration (ul/l)
0
1
2
3
4
5
6
Tailrace 100X
River 100X
HYDRO North
HYDRO South

2013 LISST 100X PLOT- STREAMSIDE AND 100X ANALYSIS


April 18th
Total Concentration (ul/l)
50
40
30
20
Rt.10 100X
StreamSide 100X
StreamSide




Vernon Flow = 31,382cfs
Ashuelot Flow = 980cfs
Water Elev. = 185.1 ft


Fall 100X at Rt. 10
Total Concentration (ul/l)
2
4
6
8
10
10/3
10/11
10/16
10/24

# APPENDIX F – SUSPENDED SEDIMENT MONITORING DATA (2013-2015)

CD AVAILABLE UPON REQUEST

DATA POSTED TO RELICENSING WEBSITE AT THE TIME OF FILING