December 1, 2014

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 2014 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 2014. Specific components of the Plan implemented during this reporting period

[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
Director FERC Compliance
Chief Dam Safety Engineer

FirstLight Power Resources, Inc.
99 Millers Falls Road
Northfield, MA 01360
Tel. (413) 659-4489/ Fax (413) 422-5900/
E-mail: john.howard@gdfsuezna.com

include: 1) 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) measuring SSC and particle size distribution (PSD) at three locations in the Project area, 4) developing a computational fluid dynamics model of the Upper Reservoir, and 5) 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: 2014 Summary of Annual Monitoring

Sediment Management Plan - 2014 Summary of Annual Monitoring

NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT
FERC NO. 2485-058

DECEMBER 1, 2014

Prepared for:

FirstLight Power Resources
GDF SUEZ

Prepared by:

GOMEZ AND SULLIVAN ENGINEERS

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2-D	Two Dimensional
ADCP	Acoustic Doppler Current Profiler
Alden	Alden Research Laboratory, Inc.
ASTM	American Society for Testing and Materials
CFD	Computational Fluid Dynamics Model
CY	cubic yards
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Power Resources Services, LLC
ft	feet
Gomez and Sullivan	Gomez and Sullivan Engineers, DPC
ISR	Initial Study Report
LISST	Laser In Situ Scattering and Transmissometry
MA	Massachusetts
MADEP	Massachusetts Department of Environmental Protection
mg/L	milligrams per liter
msl	mean sea level
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NMPSF	Northfield Mountain Pumped Storage Facility
QAPP	Quality Assurance Project Plan
Project	Northfield Mountain Pumped Storage Project
PSD	Particle Size Distribution
RSP	Revised Study Plan
SM	Standard Method
SSC	Suspended Sediment Concentration
the Commission	Federal Energy Regulatory Commission
the Plan	Sediment Management Plan
TIN	Triangulated Irregular Network
TSS	Total Suspended Solids
µl/L	microliters per liter
USEPA	United States Environmental Protection Agency

1. Background

FirstLight Power Resources Services, LLC (FirstLight), as an agent for FirstLight Hydro Generating Company, an affiliate of GDF SUEZ Energy North America, Inc., owns and operates the Northfield Mountain Pumped Storage Project (Project), a 1,143 MW pumped storage project constructed in 1972 along the Connecticut River near Northfield, MA. The project consists of an underground powerhouse, four reversible pump-turbine generators, an underground pressure shaft, four unit penstocks and draft tubes, and a mile-long tailrace tunnel connecting the powerhouse to a 20-mile-long reach of the Connecticut River known as the Turners Falls Impoundment, which serves as the lower reservoir. The manmade Upper Reservoir was formed with four earth-core rockfill embankment structures and a concrete gravity dam.

By letter dated January 20, 2011, Federal Energy Regulatory Commission (FERC, the Commission) staff requested a plan to avoid or minimize the entrainment of sediment into the Project works during reservoir maintenance drawdowns. FirstLight filed its Sediment Management Plan (the Plan) on July 15, 2011. The Plan was developed in consultation with the US Environmental Protection Agency (USEPA) and the Massachusetts Department of Environmental Protection (MADEP). The Plan contained proposed methods to assess sediment dynamics in the Project's Upper Reservoir and Turners Falls Impoundment (Connecticut River) from 2011 through 2014. The main components of the Plan included conducting annual bathymetric surveys in the Upper Reservoir, collecting turbidity and total suspended solids data routinely from the Project area, and reporting requirements. The Plan specified that a report summarizing the bathymetric survey and sediment monitoring data would be provided to MADEP, USEPA Region 1, and FERC by December 1 of the year in which the sediment monitoring was conducted.

FirstLight's first sediment monitoring report was submitted to MADEP, USEPA and the Commission on December 1, 2011. Based on the results of initial suspended sediment sampling efforts, FirstLight determined that technical improvements and revisions to the original plan were necessary. FirstLight proposed to continuously measure Suspended Sediment Concentration (SSC) and Particle Size Distribution (PSD) in lieu of turbidity to provide a more accurate measure of sediment load in the river. The Commission accepted FirstLight's 2011 report by letter dated December 6, 2011 and requested that a modified plan be filed after consultation with the MADEP and the USEPA. Following review of 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 of Approval on March 28, 2012.

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 USEPA provided FirstLight with comments pertaining to the QAPP on July 31, 2012 which FirstLight addressed. FirstLight submitted revision 1 of the QAPP to USEPA on October 19, 2012.

As a result of experience gained during the 2012 monitoring efforts, combined with the recommendations of the sediment monitoring equipment manufacturer, FirstLight modified certain aspects of the methodology outlined in QAPP revision 1 for the 2013 monitoring season. Due to these modifications, FirstLight submitted QAPP Revision 2 to the USEPA on August 14, 2013. A meeting was held at USEPA offices on June 24, 2013 with USEPA and MADEP personnel to discuss these proposed modifications. Following this meeting, FirstLight announced that sediment monitoring activities would be extended for an additional year through the fall of 2015 due to equipment malfunctions experienced during the first three field seasons (2011-2013). USEPA and MADEP did not provide further comment on QAPP Revision 2.

Also in 2013, as part of the FERC Relicensing of the Turners Falls Hydroelectric and Northfield Mountain Pumped Storage Projects (currently underway), USEPA requested that FirstLight incorporate the Plan into its relicensing studies. As such, the Plan was included in the FERC Revised Study Plan (RSP) as Study No. 3.1.3. On September 15, 2014 FirstLight filed with FERC an Initial Study Report (ISR) titled *Relicensing Study 3.1.3 Northfield Mountain Project Sediment Management Plan Initial Study Report Summary* in accordance with FERC relicensing requirements.

FirstLight is required by the Revised Plan to submit a report summarizing sediment monitoring activities of the past calendar year to the MADEP, USEPA, and FERC by December 1 of the year in which the sediment monitoring was conducted. Previous annual summary reports were submitted to the agencies in December of 2011, 2012, and 2013. The enclosed report provides a summary of sediment monitoring activities that occurred within the Project area during 2014. Components of the Plan applicable to this reporting period include: 1) conducting an annual bathymetric survey in the Upper Reservoir, 2) collecting SSC and TSS samples from the Project area, 3) continuously measuring SSC and PSD at three locations in the Project area, and 4) reporting requirements. In addition, FirstLight contracted Alden Research Laboratory, Inc. (Alden) to conduct engineering studies of sedimentation at the Project during the reporting period. The results of these studies are discussed later in this report.

2. Bathymetric Surveys

Upper Reservoir bathymetry surveys have been conducted in 2011, 2012, 2013, and most recently in 2014 (Figure 2.0) as part of the Plan. In 2014, FirstLight contracted SeaVision Underwater Solutions, Inc. to perform a bathymetric survey of the Upper Reservoir. This survey was completed October 11-12, 2014.[1] Deliverables for the hydrographic survey included a contour plan and a sounding plan which were generated from the 2014 survey data (See Appendix A).

2.1 Methods & Analysis

A bathymetric survey of the Upper Reservoir was performed using a Norbit WBMS 455 kHz wideband precision multibeam echosounder in accordance with the U.S. Army Corps of Engineers Survey Manual EM 1110-2-1003. The multibeam echosounder collected depth data with an accuracy of ±0.03 ft (±0.1% of depth) and a resolution of 0.1 ft. Horizontal and vertical positioning during all survey operations was recorded utilizing a SBG Systems Ekinox Inertial Navigation System/GNSS Global Positioning Satellite Receiver System with Real-Time Kinematic (RTK) GPS corrections, which provided vertical control near 0.2 ft during all survey operations. All horizontal positions were referenced to the North American Datum of 1983 (NAD 1983) Massachusetts (Mainland) State Plane, US Survey Feet. All vertical elevations were referenced to the Northfield Mountain Pumped Storage Facility (NMPSF) vertical datum, which was previously calculated +0.398 ft to the North American Vertical Datum of 1988 (NAVD 88). Hypack 2014 Hydrographic Survey software was used to collected all data and monitor vessel navigation and survey progress.

All bathymetric data post-processing was performed using the Hypack 2014 software package. The Hypack software was used to create a 3-ft by 3-ft grid of data such that each grid cell represented the average of all soundings collected inside that cell. The grid cells were then used to create a Triangulated Irregular Network (TIN) to generate color-shaded relief imagery, contours and decimated grids with soundings spaced every 10, 25, and 50 ft. The generated TINs were then compared to 2012 and 2013 TIN surfaces to calculate changes in volume and bed elevations of the intake channel.

In addition to the multibeam survey, gravity cores were utilized at six locations within the intake channel to better ascertain the sediment thickness in this area. A gravity core with a four 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 4 foot barrel was pre-marked with black electrical at the 2 ft elevation mark so that once the sampler had been lowered to the reservoir bottom and driven into the sediments the ROV could be deployed to identify the degree of penetration into the bottom sediments (Figure 2.1).

2.2 Summary

Intake channel volume calculations based on the multibeam survey found that from 2012 to 2014 there was a net accumulation of 16,077 cubic yards (CY) of sediment (20,203 total CY accumulation, 4,126 CY total loss).[2] This measurement is consistent with observed sediment thickness within the intake channel

[1] Results from the 2014 bathymetric survey are preliminary as final data QA is still underway.

[2] The 2012 and 2014 bathymetry surveys were conducted using a multi-beam echosounder while the 2013 survey used a single beam instrument. After reviewing the data, FirstLight believes that the most appropriate comparison

as collected by the gravity cores ranging from 2.0 to 2.5 ft. Given the approximate surface area of the intake channel, and assuming 2.0 feet of sediment thickness, it can be estimated that approximately 15,566 CY of sediment accumulated at the bottom of the intake channel. If it is assumed that the intake channel experienced minimal accumulation prior to the 2012 survey (following the 2010 intake channel dewatering and cleaning) the net accumulation of 16,077 cubic yards of sediment as determined by the multibeam bathymetric survey is supported by the empirical approximation derived by the gravity cores.

In addition to volume calculation, detailed bathymetric maps were developed to illustrate the present bed elevations of the Upper Reservoir and intake channel. Figure 2.0 shows regions within the intake channel where sediment accumulation and loss occurred between the 2012 and 2014 surveys. Appendix A depicts present bed elevations for the entire Upper Reservoir.

is between surveys conducted using the same equipment. For that reason, this report focuses primarily on the comparison of the 2012 and 2014 surveys where multi-beam instruments were used.

Figure 2.0: Comparison of the Upper Reservoir Intake Channel TIN surfaces from the 2012, 2013, and 2014 hydrographic surveys.

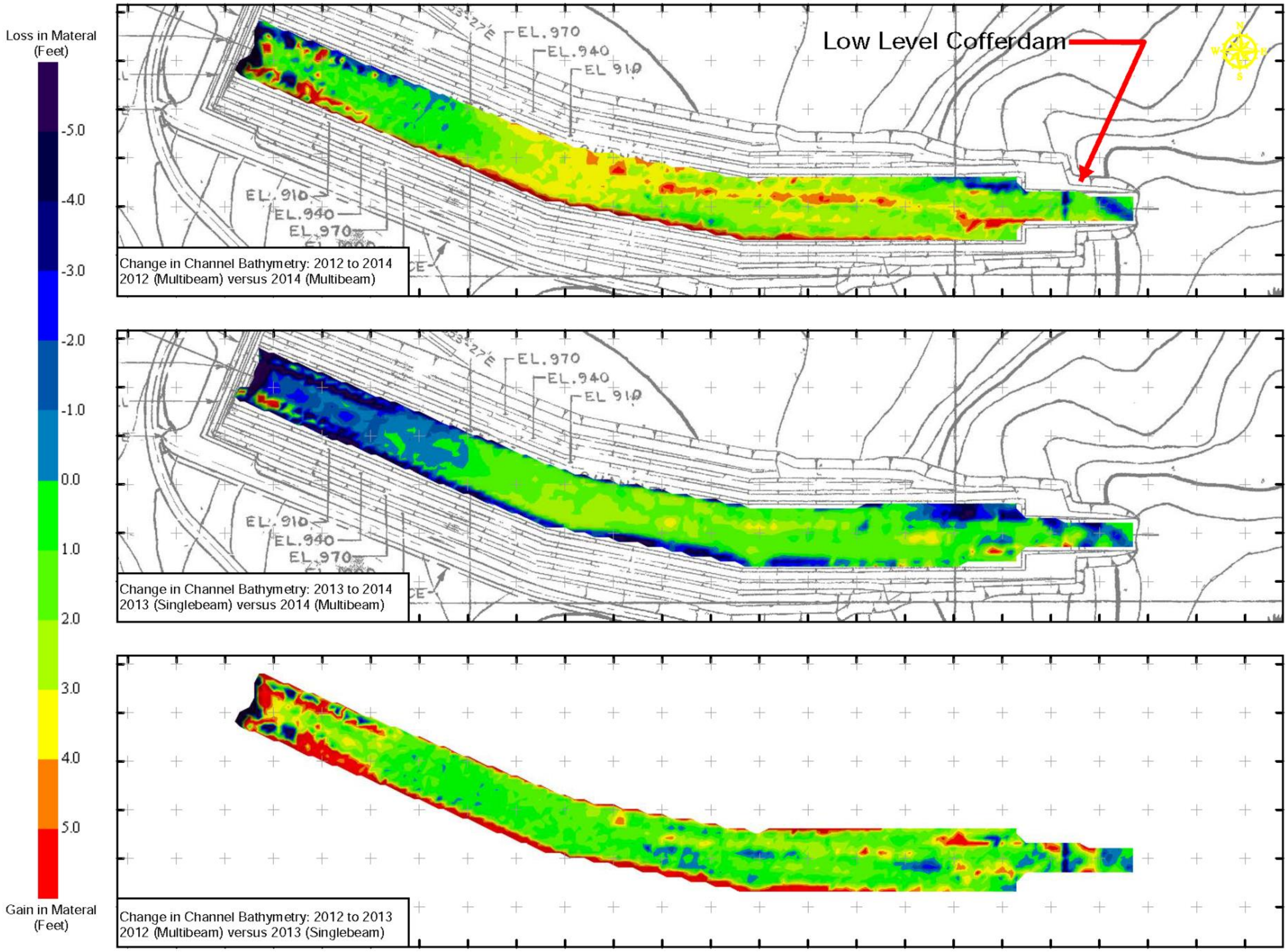
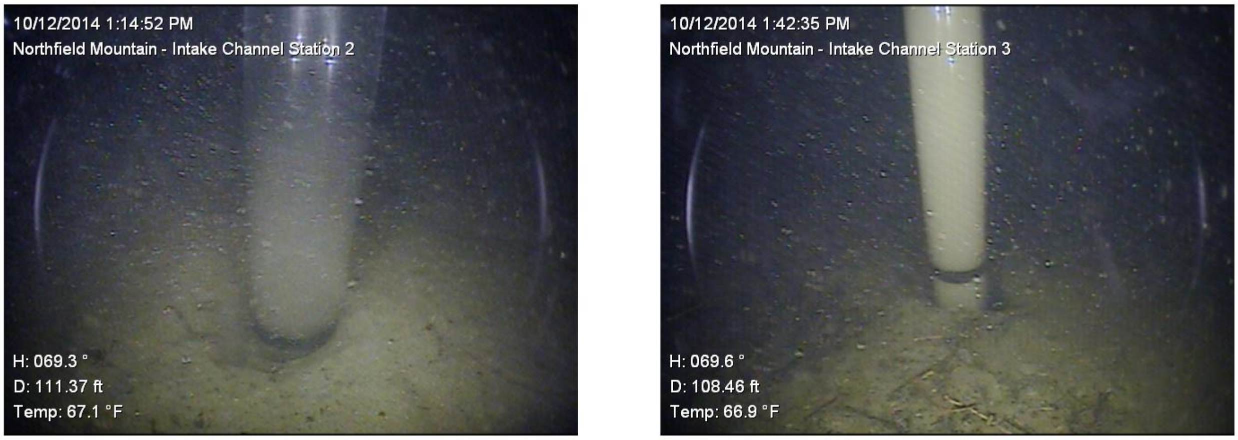


Figure 2.1: Gravity core sample depicting the barrel penetrating into sediment.



3. Suspended Sediment Monitoring

FirstLight operated continuous suspended sediment monitors at three locations in the Project area during the 2014 field season (Figure 3.0). A Laser In-Situ Scattering and Transmissometry (LISST) StreamSide instrument (Sequoia Scientific, Inc.) was installed April 1, 2014 upstream of the Route 10 Bridge in Northfield, MA. The purpose of this instrument was to provide continuous data on suspended sediment transport in the Turners Falls Impoundment over a range of flows. In addition, two LISST HYDRO instruments (Sequoia Scientific, Inc.), LISST HYDRO North and South, were installed on March 27 and April 4, 2014 at the Northfield Mountain Tailrace, respectively (Figure 3.1). The HYDRO instruments continuously monitored SSC moving into and out of the Upper Reservoir during Project Operations. The StreamSide and HYDRO instruments were removed for the season on November 7, 2014 due to freezing temperatures and safety considerations.

In addition to the continuously monitoring equipment, FirstLight also collected grab samples for laboratory analysis of SSC and Total Suspended Solids (TSS) from the outflow hoses of the LISST StreamSide and LISST HYDROs over the course of the sampling period.

3.1 Methods

LISST StreamSide

The LISST StreamSide instrument was installed on the bank of the Connecticut River upstream of the Route 10 Bridge in Northfield, MA (Figures 3.0, 3.2, and 3.3). The sampler was connected to a pump installed at a fixed location in the Connecticut River approximately 15-20 feet offshore and suspended approximately 2 feet from the river bottom. Water was pumped from the Connecticut River through the instrument where PSD and SSC were measured using laser diffraction technology. After flowing through the instrument, the water was released through a drain hose. A water sample was not retained except for periodic grab samples that were collected. All data were stored on the instrument's internal memory until they were manually downloaded to a computer.

Samples were collected on 60-minute intervals with the average sampling duration lasting 60 seconds. Each sample consisted of a 60-second clean water flush, 300-second intake flush (river water from the pump), and a 20-second post sample clean water flush. Clean-water background readings were taken from distilled water and stored every three samples to automatically "zero" the instrument by subtracting the measurement of light scattering in clean water from that resulting from the turbid sample water.

The instrument was serviced on a weekly schedule during which time the data were downloaded, the clean water tank was refilled, the optical cells were cleaned, the battery voltage was checked, and, if necessary, the connectors, casing, and hoses were cleaned and/or replaced.

LISST HYDRO

Two LISST HYDRO instruments were installed in the Northfield Mountain Tailrace on the south and north banks (Figures 3.1 and 3.4). Each sampler was connected to a pump installed at a representative location within the tailrace. These locations were chosen in order to continuously monitor SSC and PSD data that may be transported through the intake channel to the Upper Reservoir during pumping operations or transported from the Upper Reservoir to the Connecticut River during generation. Two samplers were utilized in this location to account for the potential variability of suspended sediment laterally across the tailrace and/or vertically within the water column depending on Project operations.

By installing two samplers and pumps at different horizontal and vertical locations a more representative SSC and PSD dataset can be developed.

SSC and PSD were measured 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 were visually inspected regularly to ensure proper working order and clean the optic cells. Data download was not necessary because each HYDRO instrument transmitted the data directly to FirstLight's historian computer system.

Grab Samples for Laboratory Analysis

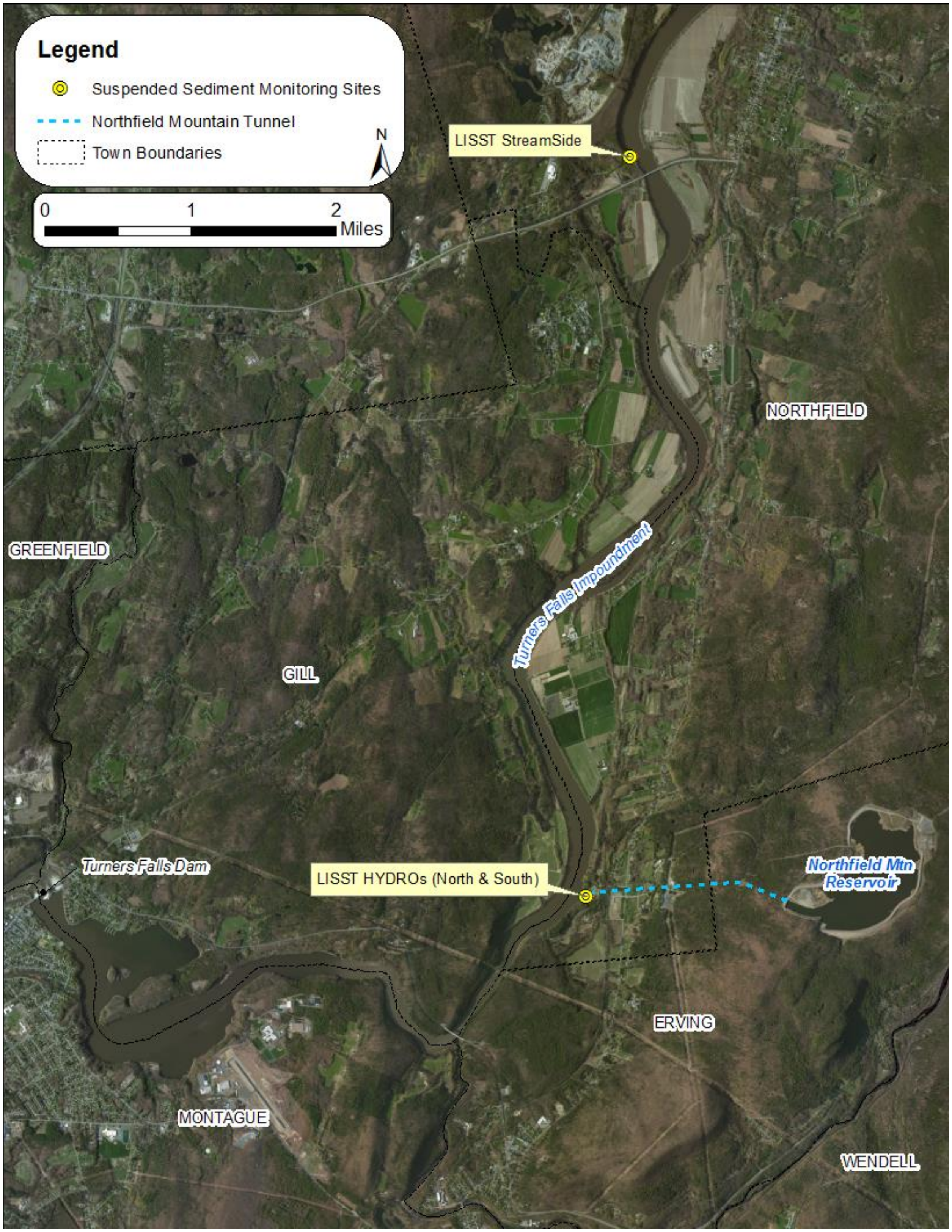
FirstLight collected grab samples during the 2014 sampling period from the outflow hoses of the LISST StreamSide and LISST HYDRO instruments as well as from in-line service water taps installed within the Powerhouse. Grab samples from the LISST instruments were collected during a corresponding LISST sampling event. All grab samples were collected in 1-liter sterile white polyethylene bottles and were analyzed for SSC and TSS by an independent laboratory (Sterling Analytical, Inc.) using ASTM D3977 and SM 2540D, respectively. The standard reporting limit for both methods was 0.5 mg/L. Sample containers were marked with identification labels that were matched to the identification information on the field datasheets. All samples were transported in a cooler on wet ice to the independent laboratory under chain of custody; average holding time from when the sample was collected and when it was analyzed was 12 days.

An overview map of the sampling locations is provided in Figure 3.0; while Table 3.0 provides descriptions of each location.

Table 3.0: Monitoring Location Descriptions

Site	Description
Powerhouse North	In-line service water taps within Northfield Mountain Powerhouse
Powerhouse South	In-line service water taps within Northfield Mountain Powerhouse
Northfield Mountain Station Tailrace (LISST HYDRO North)	Northfield Mountain Station tailrace, from the LISST-HYDRO on north bank outflow drain hose
Northfield Mountain Station Tailrace (LISST HYDRO South)	Northfield Mountain Station tailrace, from the LISST-HYDRO on south bank outflow drain hose
LISST StreamSide	Upstream of the Rt. 10 Bridge in Northfield, MA from the LISST-StreamSide outflow drain hose

Figure 3.0: Suspended Sediment Sampling Locations



3.2 Data Results

LISST StreamSide

The LISST StreamSide collected continuous (hourly) SSC and PSD data from April 2 until November 7, 2014. The initial configuration of the StreamSide is shown in Figure 3.2. Provisional data collected from the StreamSide are shown in Figure 3.5. Preliminary review of the data suggest that suspended sediment concentrations in the river were relatively low (provisional overall median concentration = 7.8 µl/L), with the occasional peak during high flow events, especially spring freshets.

Table 3.1 presents a monthly summary of total concentration and flows at the LISST instruments during the study period. Monthly median total concentration was highest (13.2-61.6 µl/L) when median flows in the Impoundment were greater than 20,000 cfs. As indicated by the flow duration curve for the study period, presented in Figure 3.6, flows greater than 20,000 cfs were equaled or exceed approximately 23% of the time during the study period. It was observed that flows exceeding 20,000 cfs generally occurred in April and early-May during the spring runoff period. During the low flow months (June through November), median total concentration of sediment ranged from 2.2 to 8.5 µl/L, when flows in the Impoundment were typically less than 12,000 cfs. Flows less than 12,000 cfs were equaled or exceed 41% of the time during the study period.

Although occasional equipment malfunctions or electrical issues were experienced during the data collection period, in general, the instrument operated well and collected a large number of data points. The instrument functioned normally from April 1 until mid-May during which time SSC and PSD data measured during the spring freshet were collected. In mid-May equipment malfunctions were observed. Multiple diagnostics were performed at which time it was determined the intake pump required replacing. The intake pump was replaced on May 21, 2014.

From late-May to mid-June the instrument experienced issues with optical transmission, potentially affecting the accuracy of the measurements. Working with the manufacturer it was determined that air bubbles were becoming entrained within the optical cell and that shortening the drain hose would resolve that problem. Based on the manufacturer's recommendation FirstLight shortened the drain hose. Flow conditions during this time were observed to be relatively low resulting in low SSC and PSD values. Data collected during this period was flagged and will be reviewed closely by FirstLight and the manufacturer to ensure it passes QA/QC protocols before being accepted in the final dataset.

In mid-June it became apparent that the two solar panels and batteries powering the instrument were insufficient for powering the electrical inverter that regulates the voltage to the unit and pump. Coupled with decreasing daylight and increasing shading from trees this resulted in periodic outages. In order to keep the StreamSide operational FirstLight replaced the existing batteries with newly charged batteries on a semi-weekly basis until a permanent solution could be implemented. Even with the periodic outages experienced during this time a large number of data points were still captured. On October 23, 2014 the trees that were shading the solar panels were removed and new panels and batteries were installed (Figure 3.3).[3] Since the installation of the new panels and selective tree removal the unit has been charging normally and collecting continuous data with no problems.

[3] Prior to removing the trees that were shading the solar panels FirstLight had to obtain permission from the abutting landowner and permitting from the local Conservation Commission. Obtaining these permissions took several months.

LISST HYDRO

The LISST HYDRO units (North and South) collected continuous SSC and PSD data in 20-minute even intervals from April until November 7, 2014. The typical configuration of the HYDRO cabinets is shown in Figure 3.4. Provisional data collected from the HDYROs are shown in Figure 3.7. As observed in Figure 3.7, data collected at the HYDROs followed similar patterns overall for total concentration during the sampling period. Provisional median concentrations for the North and South instruments were 2.2 µl/L and 1.5 µl/L respectively. Occasional spikes were observed during high flow events.

Table 3.1 presents a monthly summary of total concentration and flows at the LISST instruments during the study period. Monthly median total concentration of sediment followed a similar pattern at the North and South LISST instruments. Higher median monthly concentrations were observed mostly in April during the spring runoff period, while lower monthly median total concentrations were observed over the remaining study period. During the spring runoff period in April, monthly median total concentrations ranged from 22.0 and 19.2 µl/L at the North and South locations, respectively. The median flows in the Impoundment during this time at the North and South instruments were 31,524 and 33,339 cfs (Table 3.1). Over the duration of the study period flows ≥31,500 cfs was equaled or exceed approximately 8% of the time (Figure 3.6).

Over the course of the sampling period brief intermittent outages were experienced at both LISST HYDRO locations, mostly as a consequence of little to no clean water in the clean water tank. Preliminary examination of the data suggests that the North unit collected duplicate data (indicative of an outage) and suspicious values from the end of May to early July. This period of time will undergo a more rigorous QA/QC process. In early July the North HYDRO pump controller box malfunctioned and was sent to the manufacture for repair. On July 18, 2014 the pump controller box was reinstalled and the North LISST HYDRO resumed sampling. The North unit then operated normally until mid-October when periodic outages occurred as a consequence of the shortening day length affecting the solar panels ability to sufficiently recharge the batteries that powered the equipment.

The South HYDRO sampled normally from April 4 until mid-May when an outage occurred that lasted until early June. After working with the manufacturer it is still unclear what caused the outage, however, it is believed the outage was the result of low water flow to the unit. In late-July the pump installed at the South HYDRO failed. On July 31, 2014 the pump was replaced and the unit returned to service. From August until mid-October the unit operated normally until periodic outages occurred as a consequence of the shortening day length affecting the solar panel's ability to sufficiently recharge the batteries that power the equipment.

Grab Samples

At the request of the USEPA, 1L grab samples were collected from the LISST HYDRO and StreamSide drain hoses as well as from service water taps installed in-line in the Powerhouse (North and South). The samples within the powerhouse were collected on a near-daily basis, while grab samples from the LISST units were collected weekly from the end of July through the end of October; however, instrument outages prevented samples from being collected at times. Once collected, the grab samples were submitted to an independent laboratory (Sterling Analytical, Inc.) and analyzed for SSC (mg/L) and TSS (mg/L). Each test produced the same SSC and TSS measurement for 97% of the samples analyzed.

Table 3.2 provides a summary of the grab samples collected during the 2014 sampling season at the in-line water taps within the powerhouse. Overall median SSC and TSS at the Powerhouse North and South locations were 6.1 and 5.7 mg/L, respectively. The highest median SSC and TSS concentrations (>38 mg/L) at both powerhouse locations were observed in April during the spring runoff period when median flows in the Impoundment were approximately 31,500 cfs. Figure 3.6 presents a flow duration curve of the Turners Falls Impoundment during the study period. Flows of 31,500 cfs were equaled or exceeded 8% of the time over the study period.

Table 3.3 provides a summary of the laboratory analyses of the grab samples collected at the three LISST instruments. All grab samples collected from the three LISST instruments were collected during the low flow season. The overall median SSC and TSS measurements among all three LISST instruments ranged from 1.5 to 2.6 µl/L. The median flow during this time was <7,100 cfs.

The higher SSC and TSS values in the powerhouse samples can be attributed to the greater number of samples which encompassed the spring freshet, a greater range of flows, and range of operating conditions whereas the LISST samples captured relatively low flows over a shorter sampling duration.

Given that the SSC measurements collected by the LISST HYDRO and StreamSide equipment are in units of µl/L (volume) LISST data and grab sample results cannot be directly compared. Although a direct comparison is not possible, the grab samples still serve two important purposes: 1) they provide an independent dataset from the LISST equipment to gain a better understanding of SSC levels in the Connecticut River and 2) they can be used to convert volume concentration (LISST data) to a mass concentration by determining the effective density of sediment.

Effective density values will be calculated by dividing the mass concentration (mg/L) of the laboratory grab sample by the volume concentration (µl/L) at each LISST instrument drain hose (measured at the same time as the grab sample). The effective density is then multiplied by the volume concentrations measured by the LISST instruments to convert SSC values from volume (µl/L) to mass (mg/L). Due to the fact that this conversion requires a mass and volume concentration measured at the same time, data from grab samples used to calculate effective density is limited to those for which there is an associated LISST measurement.

Table 3.1: Monthly Summary of the Suspended Sediment Concentration (µl/L) of the Turners Falls Impoundment Measured by the three LISST Instruments

Parameter[†]	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Overall
LISST StreamSide									
No. Samples	474	327	275	386	241	244	494	102	2,536
Median Total Conc. (µl/L)	61.6	13.2	6.2	6.2	2.2	2.2	7.2	8.5	7.8
Range Total Conc. (µl/L)	10.6-717.6	0.0-591.1	1.8-24.2	1.3-98.3	0.6-45.0	0.2-76.6	0.0-156.0	0.0-178.8	0.0-717.6
Median Flow (cfs)	33,339	23,705	11,466	10,111	5,625	2,092	6,715	6,030	11,161
Flow Range (cfs)	18,446-70,976	5,424-36,409	2,111-23,746	2,190-23,746	1,959-13,296	1,822-19,983	1,720-26,544	1,720-26,544	1,720-70,976
LISST HYDRO North									
No. Samples	2,063	1,419	–	965	2,099	1,981	838	–	9,365
Median Total Conc. (µl/L)	22.0	5.8	–	2.8	1.6	0.8	0.9	–	2.2
Range Total Conc. (µl/L)	0.0-346.2	1.4-70.0	–	0.5-7.0	0.1-57.5	0.0-101.5	0.1-3.0	–	0.0-346.2
Median Flow (cfs)	31,524	18,825	–	8,577	5,733	2,057	2,330	–	8,683
Flow Range (cfs)	18,436-71,478	5,424-36,793	–	2,740-28,414	1,769-19,593	1,800-19,983	1,720-10,619	–	1,720-71,478
LISST HYDRO South									
No. Samples	1,569	514	1,512	1,203	1,771	1,563	294	–	8,426
Median Total Conc. (µl/L)	19.2	2.9	1.6	2.2	1.0	0.5	0.4	–	1.5
Range Total Conc. (µl/L)	0.0-217.8	0.0-65.4	0.0-236.1	0.0-215.9	0.0-37.0	0.0-20.9	0.0-1.6	–	0.0-236.1
Median Flow (cfs)	35,324	20,173	9,873	8,603	5,549	2,057	4,044	–	8,656
Flow Range (cfs)	18,436-71,478	5,495-32,369	1,914-30,530	2,190-26,289	1,769-19,593	1,800-19,983	1,967-10,619	–	1,769-71,478

[†]Flow data are of the Turners Falls Impoundment from April 1 through November 7, 2014. "–" indicates data are unavailable. All data are provisional.

Table 3.2: Laboratory Analyses Summary of the 2014 Grab Samples Collected from the In-line Water Taps within the Powerhouse

Parameter†	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Overall
					Powerhouse North					
No. Samples	5	49	47	49	41	33	37	44	15	320
Median SSC (mg/L)	15.1 (3.4-71.9)	46.4 (8.6-336.0)	13.9 (1.7-85.0)	6.3 (2.1-106.3)	7.3 (1.0-371.8)	2.3 (0.6-36.9)	2.3 (1.2-4.2)	1.6 (<0.5-55.2)	1.9 (0.9-5.0)	6.1 (<0.5-371.8)
Median TSS (mg/L)	15.1 (3.4-71.9)	46.4 (8.6-337.0)	13.9 (1.7-85.0)	6.3 (2.1-106.3)	7.3 (1.0-371.8)	2.3 (0.6-36.9)	2.3 (1.2-4.2)	1.6 (<0.5-55.2)	1.9 (0.9-5.0)	6.1 (<0.5-371.8)
Median Flow (cfs)	25,795	30,920	24,089	9,027	8,574	4,767	2,019	2,673	2,746	8,652
Flow Range (cfs)	2,913-30,689	18,573-68,585	5,494-33,432	2,010-25,840	2,408-25,444	1,886-18,862	1,812-10,138	1,784-23,451	2,507-6,020	1,784-68,585
Operating Scenario Range	1-3 Gen 2 Pump	1-3 Gen 1-3 Pump	1-3 Gen 1-3 Pump	1-4 Gen 1-4 Pump	1-3 Gen 1-4 Pump	1-4 Gen 1-4 Pump	1-4 Gen 1-4 Pump	1-3 Gen 1-4 Pump	1-4 Gen 1-4 Pump	1-4 Gen 1-4 Pump
					Powerhouse South					
No. Samples	5	53	47	51	45	35	41	44	15	336
Median SSC (mg/L)	6.9 (3.7-205.0)	38.6 (10.0-660.0)	12.4 (3.2-53.7)	5.6 (0.9-80.6)	6.7 (1.8-225.4)	2.5 (0.7-46.0)	2.2 (0.7-5.0)	1.4 (<0.5-31.2)	2.0 (0.7-5.9)	5.7 (15.1-660.1)
Median TSS (mg/L)	6.9 (3.7-205.0)	38.6 (10.0-660.1)	12.4 (3.2-53.7)	5.6 (0.9-80.6)	6.7 (1.8-225.4)	2.5 (0.7-47.6)	2.2 (0.7-5.0)	1.4 (<0.5-31.2)	2.0 (0.7-5.9)	5.7 (15.1-660.0)
Median Flow (cfs)	28,054	31,167	23,885	8,906	8,574	4,767	2,001	2,673	6,020	8,652
Flow Range (cfs)	2,913-30,689	18,580-68,585	5,494-33,432	2,010-25,840	2,408-25,444	1,889-18,862	1,812-10,138	1,784-23,451	2,507-6,020	1,784-68,585
Operating Scenario Range	1-3 Gen 2 Pump	1-3 Gen 1-3 Pump	1-3 Gen 1-3 Pump	1-4 Gen 1-4 Pump	1-3 Gen 1-4 Pump	1-4 Gen 1-4 Pump	1-4 Gen 1-4 Pump	1-3 Gen 1-4 Pump	1-4 Gen 1-4 Pump	1-4 Gen 1-4 Pump

†Flow data are of the Turners Falls Impoundment from March 29 through November 12, 2014. All data are provisional and subject to revision.

Table 3.3: Summary of Laboratory Analyses of the 2014 Grab Samples Collected from the LISST Instruments

Parameter[†]	Jul	Aug	Sep	Oct	Overall
LISST HYDRO North					
No. Samples	2	2	3	4	11
Median SSC (mg/L)	16.5 (2.6-30.3)	7.5 (1.0-13.9)	3.0 (2.3-4.3)	1.7 (1.1-17.6)	2.6 (1.0-30.3)
Median TSS (mg/L)	16.5 (2.6-30.3)	7.5 (1.0-13.9)	3.0 (2.3-4.3)	1.7 (1.1-17.6)	2.6 (1.0-30.3)
Median Flow (cfs)	19,320	1,832	1,971	6,983	2,457
Flow Range (cfs)	14,182-24,458	1,828-1,835	1,897-2,457	2,190-20,790	1,828-24,458
Operating Scenario Range	1-2 Gen 0 Pump	1 Gen 0 Pump	1-4 Gen 0 Pump	2 Gen 0 Pump	0-4 Gen 0 Pump
LISST HYDRO South					
No. Samples	1	1	1	3	6
Median SSC (mg/L)	6.5	2.1	3.0	2.3 (0.9-2.6)	2.5 (0.9-6.5)
Median TSS (mg/L)	6.5	2.1	3.0	2.3 (0.9-2.6)	2.5 (0.9-6.5)
Median Flow (cfs)	8,580	1,835	1,964	8,565	7,023
Flow Range (cfs)	–	–	–	5,481-13,284	1,835-13,284
Operating Scenario Range	0 Gen 0 Pump	1 Gen 0 Pump	1 Gen 0 Pump	1 Gen 0 Pump	1 Gen 0 Pump
LISST StreamSide					
No. Samples	–	2	2	4	8
Median SSC (mg/L)	–	1.0 (0.7-1.3)	2.5 (1.6-3.4)	1.7 (0.5-3.4)	1.5 (0.5-3.4)
Median TSS (mg/L)	–	1.0 (0.7-1.3)	2.5 (1.6-3.4)	1.7 (0.5-3.4)	1.5 (0.5-3.4)
Median Flow (cfs)	–	9,042	2,279	3,445	7,080
Flow Range (cfs)	–	9,042-9,042	1,897-2,661	3,445-20,797	1,897-20,797
Operating Scenario Range	0 Gen 0 Pump	0 Gen 0 Pump	1-4 Gen 0 Pump	1 Gen 0 Pump	0-4 Gen 0 Pump

[†]Flow data are of the Turners Falls Impoundment from July through October, 2014. “–” indicates data are unavailable. All data are provisional and subject to revision.

Figure 3.1: Aerial view of the Northfield Mountain Tailrace, showing LISST-HYDRO instrument locations.

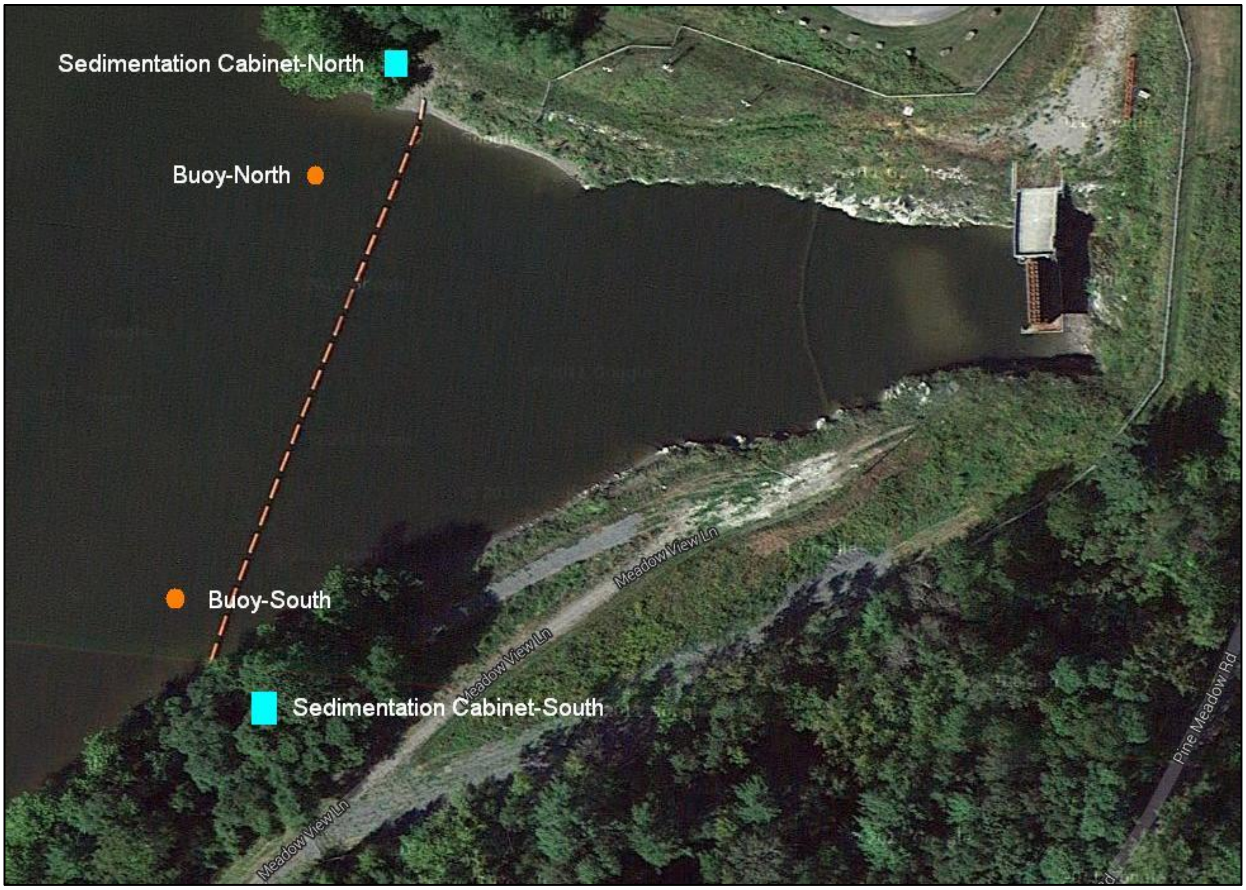
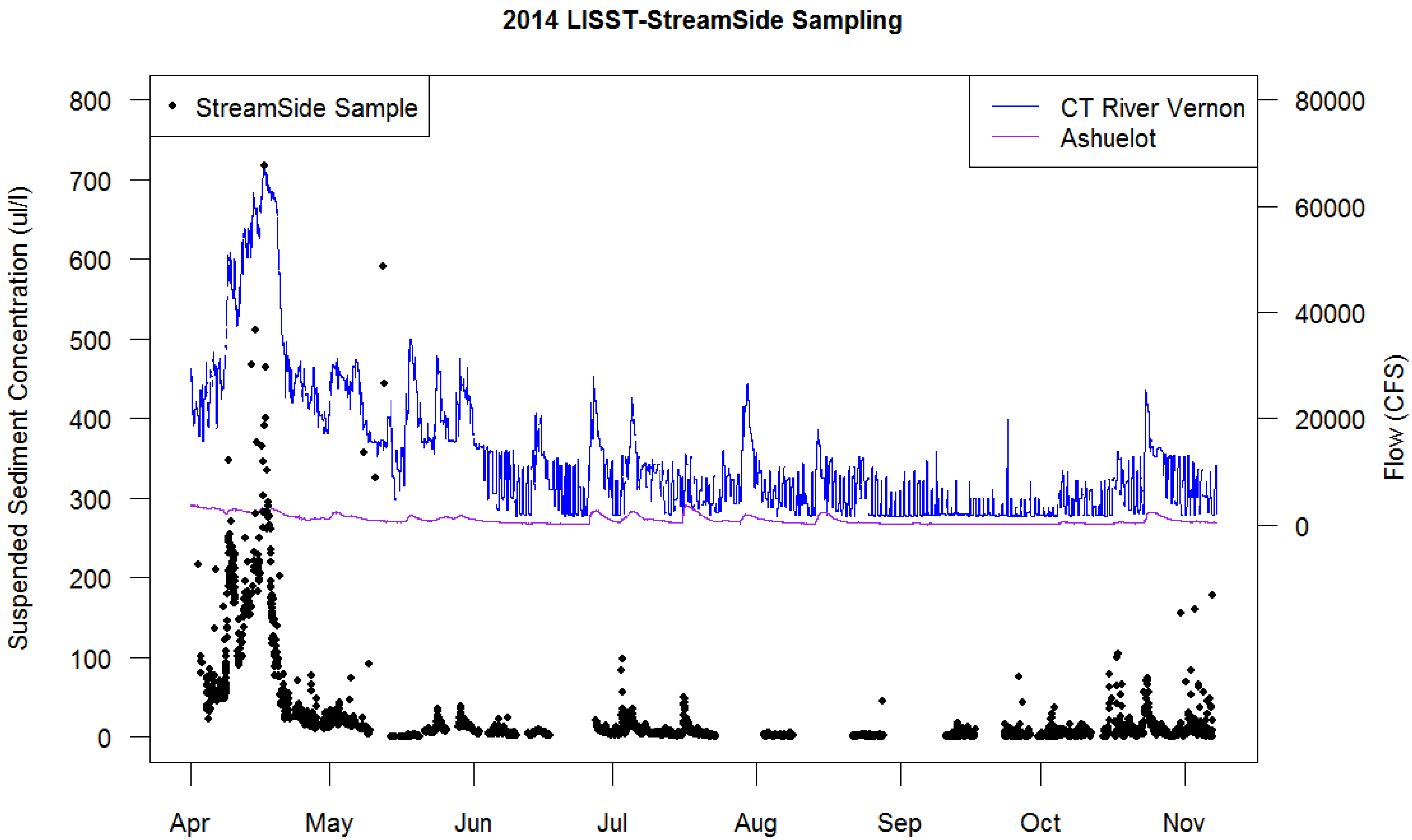


Figure 3.2: Configuration of the LISST StreamSide. The batteries were charged using solar panels.

Figure 3.3: Configuration of the LISST StreamSide from October 23, 2014 to present. The batteries are charged using solar panels.

Figure 3.4: Typical configuration of LISST HYDRO as installed at the Northfield Mountain Tailrace (North HYDRO shown). Batteries for each instrument were charged using solar panels.

Figure 3.5: Provisional LISST StreamSide Suspended Sediment Concentration (µl/L) measurements collected in the vicinity of the Route 10 Bridge during 2014.[4] All data are provisional and subject to revision.



[4] *NOTE: Periods of time where SSC data does not appear (i.e., late-June, late-July, mid-August etc.) represent intervals when the StreamSide was not in operation due to various equipment malfunctions.*

Figure 3.6: Flow Duration Curve for the Turners Falls Impoundment during the Suspended Sediment Monitoring Period. All data are provisional and subject to revision.

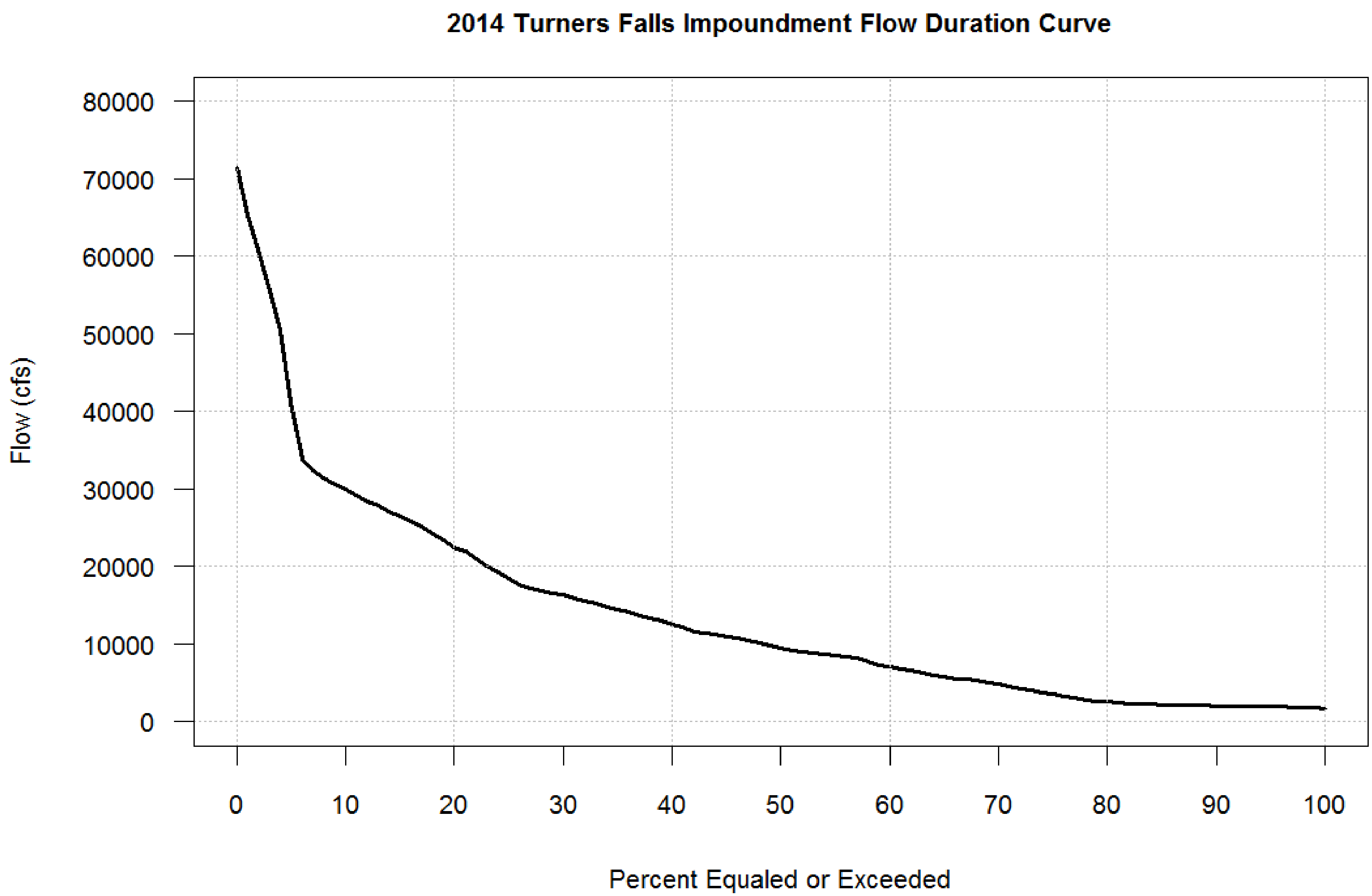
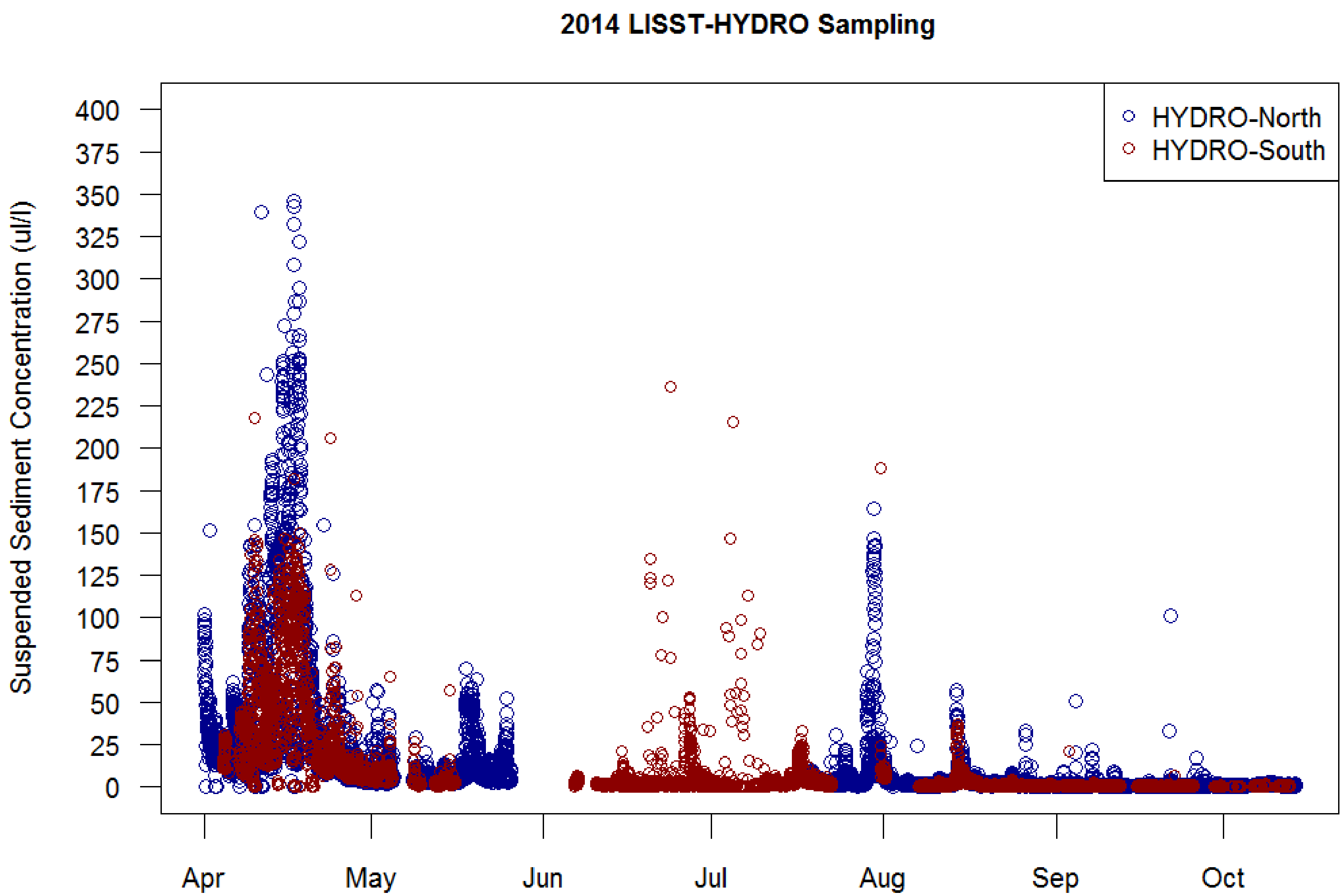


Figure 3.7: Provisional LISST HYDRO Suspended Sediment Concentration (µl/L) measurements collected in the Northfield Mountain Tailrace during 2014.[5] All data are provisional and subject to revision.



[5] *NOTE: Periods of time where SSC data does not appear (i.e., mid-May, late-July etc.) represent intervals when the HYDROs were not in operation due to various equipment malfunctions.*

3.3 Summary

The 2014 field season yielded substantially more data than any previous monitoring season. The StreamSide and HYDROs were installed and operational in time to capture SSC and PSD data for the entire spring runoff event (April 1 – May 14) with minimal to no data gaps. A strong correlation was observed between high flows (>20,000 cfs) and high suspended sediment concentrations measured during the spring runoff. Monthly median total concentration values measured during the spring runoff in April were found to be 61.6 µl/L at the StreamSide, 22.0 µl/L at the North HYDRO, and 19.2 µl/L at the South HYDRO. By comparison, monthly median total concentration values during low flow periods (June through November) were found to be 6.2 µl/L at the StreamSide, 1.25 µl/L at the North HYDRO, and 1.0 µl/L at the South HYDRO.

In general, the flows in the Turners Falls Impoundment were relatively low during the monitoring period with an average flow of 12,867 cfs from April 1 – November 7. Provisional overall median SSC values measured during the monitoring period at the StreamSide, North HYDRO, and South HYDRO were found to be 7.8, 2.2, and 1.5 µl/L, respectively.

The LISST HYDRO equipment malfunctions encountered during the 2012 and 2013 seasons were largely resolved in advance of 2014 monitoring activities. With the exception of outages at the North and South units from late May to early June the HYDROs experienced only minimal, intermittent data gaps usually due to low clean water levels in the clean water tank. Electrical issues encountered at the StreamSide starting in mid-June resulted in data gaps until a permanent solution (cutting down trees and installing additional solar panels and batteries) was implemented in October. Although the electrical problem was identified in mid-June it took several months to obtain permission from the abutting property owner and local Conservation Commission to cut down the trees.

Although the equipment issues previously identified limited the usability of some of the data collected during this past monitoring period, FirstLight was proactive in addressing all issues encountered through numerous conference calls and correspondence with the manufacturer. Equipment malfunctions were often identified right away, diagnosed, and resolved as quickly as possible.

FirstLight and its technical team are currently in the process of evaluating all LISST data collected in 2014 in conjunction with the quality control measures identified in the QAPP Revision 2 and recommended by the manufacturer. Additionally, FirstLight continues to work with the manufacturer to ensure that the data collected in 2014 were of high quality. Based on this evaluation a determination will be made by the technical team regarding the usability and reliability of the 2014 LISST data. If the data, or portions thereof, are deemed inadequate, adjustments will be made prior to the 2015 sampling effort.

Grab sample data collected during the sampling period will provide an independent, synchronous dataset that can be used to analyze levels of SSC being transported into and out of the Upper Reservoir during Project operations as well as in the Connecticut River mainstem in general. In addition, SSC laboratory results derived from the grab samples will be necessary in calculating the effective density(s) of sediment which can be used to convert volume concentrations measured by the LISST equipment to mass concentrations.

4. Computational Fluid Dynamics Sediment Modeling of the Upper Reservoir

FirstLight has contracted with Alden Research Laboratory, Inc. (Alden) to study suspended sediment dynamics in the Upper Reservoir and Project tailrace. In 2014, Alden published the report titled *Engineering Studies of Sedimentation at the Northfield Mountain Project* which presented their findings (Appendix B). The 2014 report focused on sedimentation and potential solutions in the Upper Reservoir to preclude sediment accumulation in the intake channel. A second report is expected in 2015 that will examine sediment dynamics in the tailrace area.

As part of this effort Alden developed a 2-dimensional (2-D) Computational Fluid Dynamics (CFD) sedimentation model to understand the process of sedimentation in the Upper Reservoir and to evaluate long-term sediment management alternatives in the Upper Reservoir. 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 geometry or lowering the Upper Reservoir elevation below its current lower limit of elevation 938 feet (mean sea level, msl), could reduce sediment accumulation in the future.

The 2-D model domain was represented with a curvilinear grid with each cell assigned an elevation from the 2011 Upper Reservoir bathymetric data. Using water surface level and inflow/outflow records along with Connecticut River sediment concentration and mean grain size data MIKE21C solved a set of hydrodynamic equations which describe a depth-averaged flow field throughout the model domain at a fixed time step interval (1 second time steps were used in this case). The model also solved a set of sediment transport equations which predict the amount of erosion and deposition in each computational cell during each time step. Periodically (every minute) the model updated the bed geometry based on the sediment that had deposited or scoured since the last update. As the bed evolved, the hydrodynamic flow field also changed. In this manner, MIKE21C was able to simulate the time dependent evolution of the Upper Reservoir.

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 was then compared to the model output.

Model runs were executed using: 1) the current FERC operational drawdown limit of the Upper Reservoir drawdown of 938 feet msl, 2) lowering the Upper reservoir drawdown to 928 ft., 3) lowering the Upper reservoir drawdown to 920 feet msl, and 4) physically reducing the intake channel width, with the goal of increase intake channel velocities during generation.

Under the current operational scheme the model predicted that over a period of 1 year a fan of sediment over 2 ft deep developed at the inlet throughout the intake channel reaching into the main part of the Upper Reservoir, which is consistent with, though somewhat higher than, what has been observed through the bathymetric surveys. Model runs examining different Upper Reservoir water levels (928 or 920 ft) predicted that by occasionally lowering the Upper Reservoir, the sediment deposition rate can be reduced by 4% to 5%. Finally, model runs examining physical modifications to the intake channel predicted that a similar reduction of 4% to 5% in sediment deposition would occur. In summary, it appears that changing the lower operational level of the Upper Reservoir or reducing the width of the intake channel will have a nominal effect on sediment accumulation.

5. 2014 Conclusions

Intake channel volume calculations derived from Upper Reservoir bathymetry surveys found that from 2012 to 2014 there was a net accumulation of 16,077 cubic yards of sediment (20,203 total accumulation, 4,126 total loss).[6] Observed sediment thickness as collected by the gravity cores ranged from 2.0 to 2.5 ft. Given the approximate surface area of the intake channel it can be estimated that approximately 15,566 cubic yards of sediment accumulated at the bottom of the intake channel.[7] If it is assumed that the intake channel experienced minimal accumulation prior to the 2012 survey (following the 2010 intake channel dewatering and cleaning) the net accumulation of 16,077 cubic yards of sediment as determined by the multibeam bathymetric survey is supported by the empirical approximation derived by the gravity cores.

The 2014 field season yielded substantially more data than any previous monitoring season. The StreamSide and HYDROs were installed and operational in time to capture SSC and PSD data for the entire spring runoff event (April 1 – May 14) with minimal to no data gaps. A strong correlation was observed between high flows (>20,000 cfs) and high suspended sediment concentrations measured during the spring runoff. Monthly median total concentration values measured during the spring runoff in April were found to be 61.6 µl/L at the StreamSide, 22.0 µl/L at the North HYDRO, and 19.2 µl/L at the South HYDRO. By comparison, monthly median total concentration values during low flow periods (June through November) were found to be 6.2 µl/L at the StreamSide, 1.25 µl/L at the North HYDRO, and 1.0 µl/L at the South HYDRO.

In general, the flows in the Turners Falls Impoundment were relatively low during the monitoring period with an average flow of 12,867 cfs from April 1 – November 7. Provisional median SSC values measured during the monitoring period at the StreamSide, North HYDRO, and South HYDRO were found to be 7.8, 2.2, and 1.5 µl/L, respectively. FirstLight and its technical team are currently in the process of evaluating all LISST data (StreamSide, HYDRO) collected in 2014 in conjunction with the quality control measures identified in the QAPP Revision 2 and recommended by the manufacturer. Based on this evaluation a determination will be made by the technical team regarding the usability and reliability of the 2014 LISST data as well as any potential modifications to the sampling program for the 2015 sampling season.

Based on a preliminary review of the LISST data a strong, non-linear relationship between flow and SSC was observed. In general, it was observed that moderate to high levels of SSC were present in the river during high flow conditions (>20,000 cfs). This relationship was also observed when analyzing the laboratory results derived from the grab samples. The grab sample laboratory results will also be used to calculate the effective density of sediment which can then be used to convert volume concentration to mass concentration if necessary. Data collected in 2014 will continue to be reviewed and relationships between Project operations, water levels, and flow as they relate to SSC will be examined in greater detail.

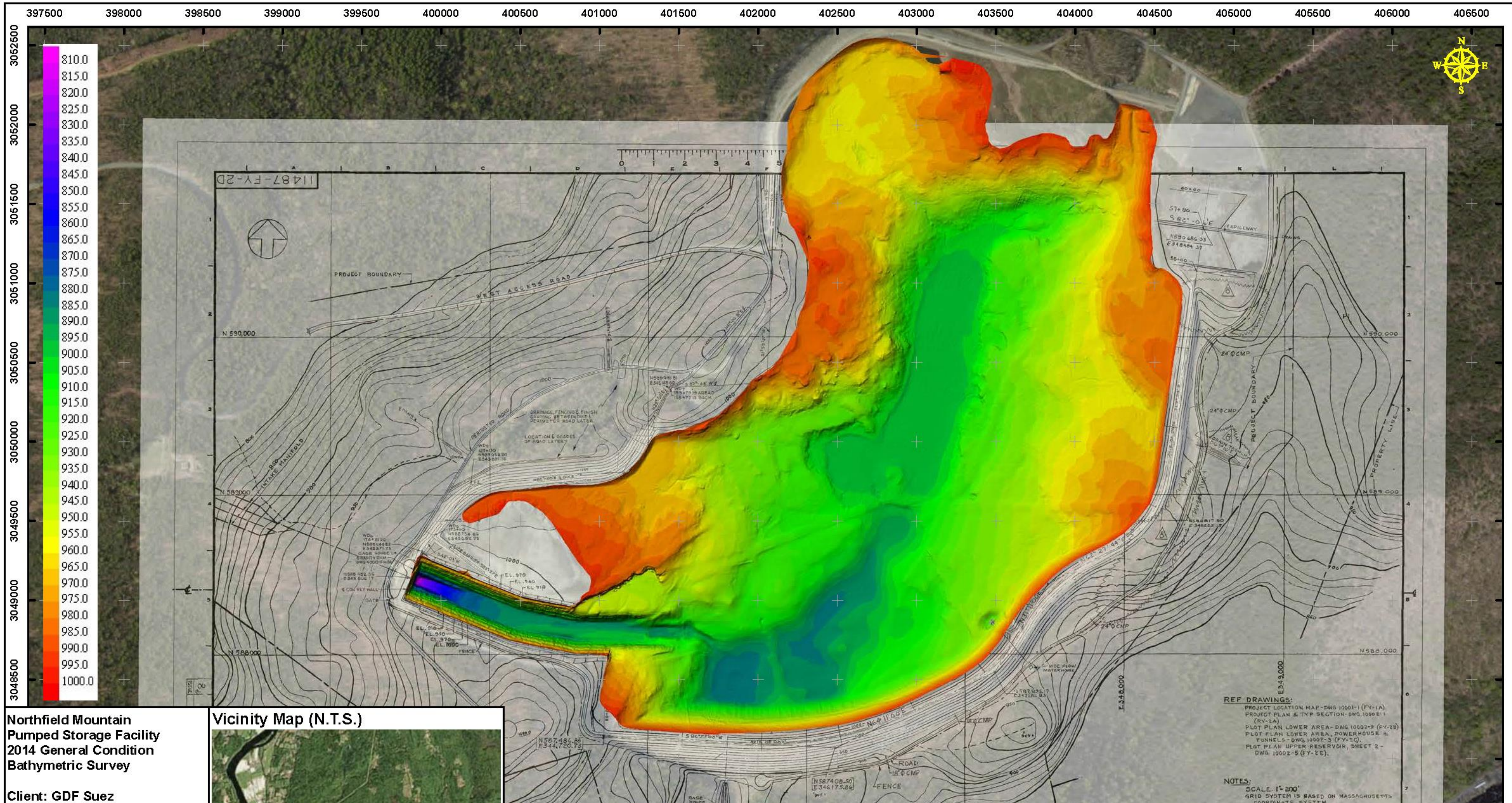
[6] The 2012 and 2014 bathymetry surveys were conducted using a multi-beam echosounder while the 2013 survey used a single beam instrument. Differences in data collected with each instrument could be attributed to the varying accuracies of the two systems; therefore, results are presented only for the 2012 and 2014 surveys where multi-beam instruments were used.

[7] The difference in intake channel sediment accumulation volumes (i.e. 16,077 vs. 15,566 cubic yards) can be attributed to the accuracy limitations of the survey equipment combined with the difference in collection methodologies.

The 2-D CFD model developed by Alden to model sediment transport in the Upper Reservoir found that, under current operating conditions, approximately 2 ft of sediment is deposited in the intake channel and portions of the main reservoir on an annual basis. Model results predicted that by occasionally lowering the Upper Reservoir, the sediment deposition rate could potentially be reduced by 4% to 5%. Furthermore, model results also found that reducing the intake channel width could potentially result in a similar reduction in sediment deposition. Neither change is expected to materially change sediment accumulation in the Upper Reservoir.

FirstLight plans to continue sampling in 2015. The data collected by FirstLight will continue to be evaluated to support the development of management measures. Management measures may include evaluating the feasibility of potentially conducting a pilot dredge of a portion of the Upper Reservoir or potentially evaluating structural modifications to address entrainment of sediment into the Project works during Upper Reservoir drawdown or dewatering activities. In addition, FirstLight expects the second phase of the Alden study to assess whether changes to the tailrace might reduce sediment accumulation in the Upper Reservoir.

Appendix A – Bathymetric Maps



Northfield Mountain Pumped Storage Facility 2014 General Condition Bathymetric Survey

Client: GDF Suez

Vicinity Map (N.T.S.)

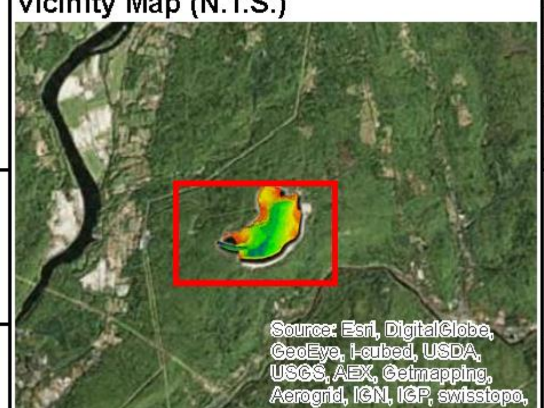


Figure 1

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.

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.

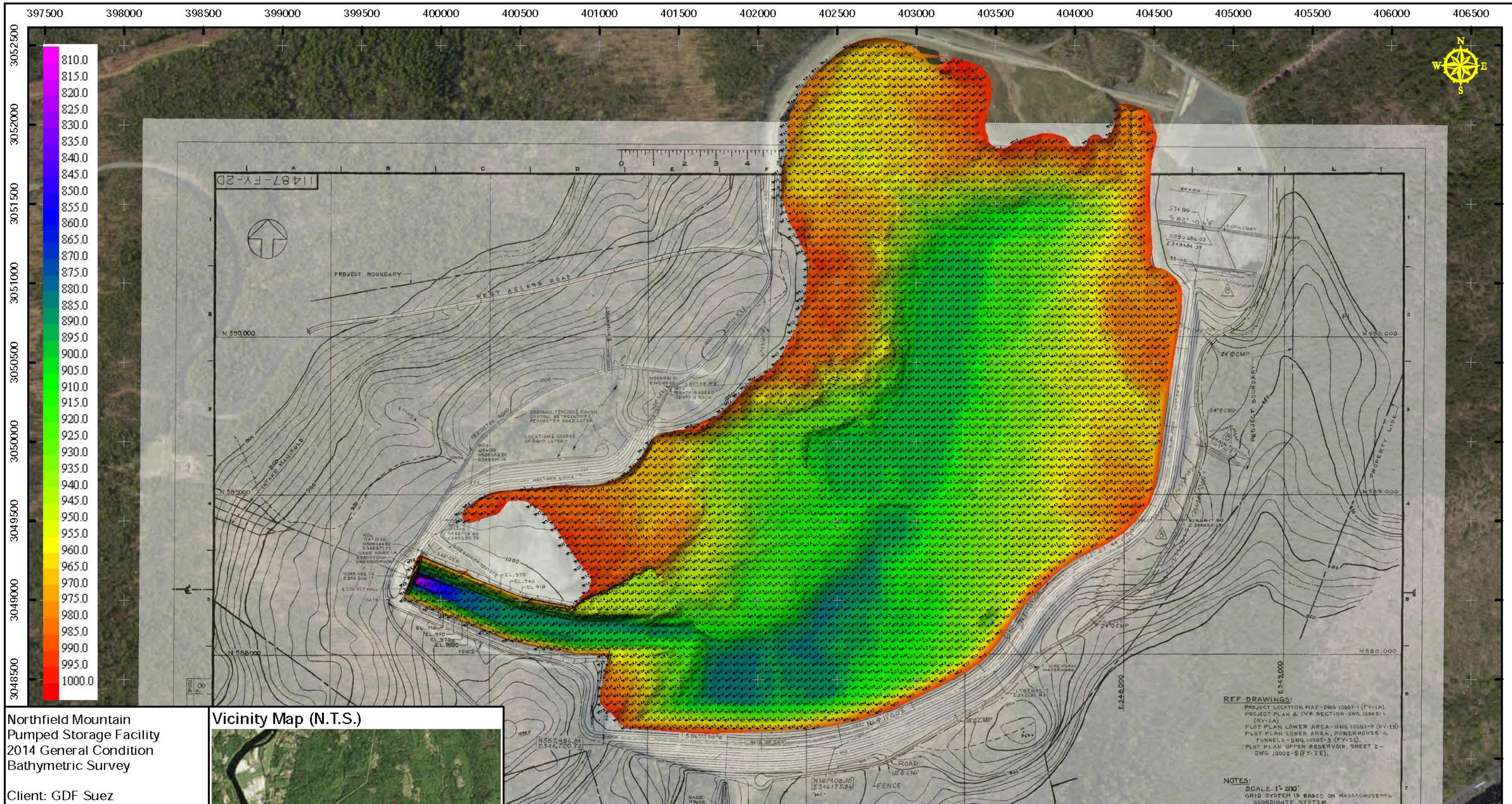
Scale

0 300 600 1,200
Feet

1 inch = 600 feet

Check Graphic Scale

SEAVISION UNDERWATER SOLUTIONS
151 Martine Street, Suite 103
Fall River, MA 02723
Phone 508-250-0650
Fax 401-633-7113
http://www.seavisionmarine.com



Northfield Mountain Pumped Storage Facility 2014 General Condition Bathymetric Survey

Client: GDF Suez

Vicinity Map (N.T.S.)

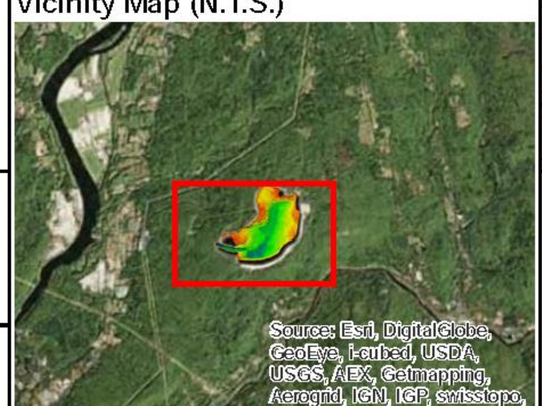


Figure 2

General Condition Multibeam Bathymetric Survey Soundings

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

Notes

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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.

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Scale

0 300 600 1,200
Feet

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151 Martine Street, Suite 103
Fall River, MA 02723
Phone 508-250-0650
Fax 401-633-7113
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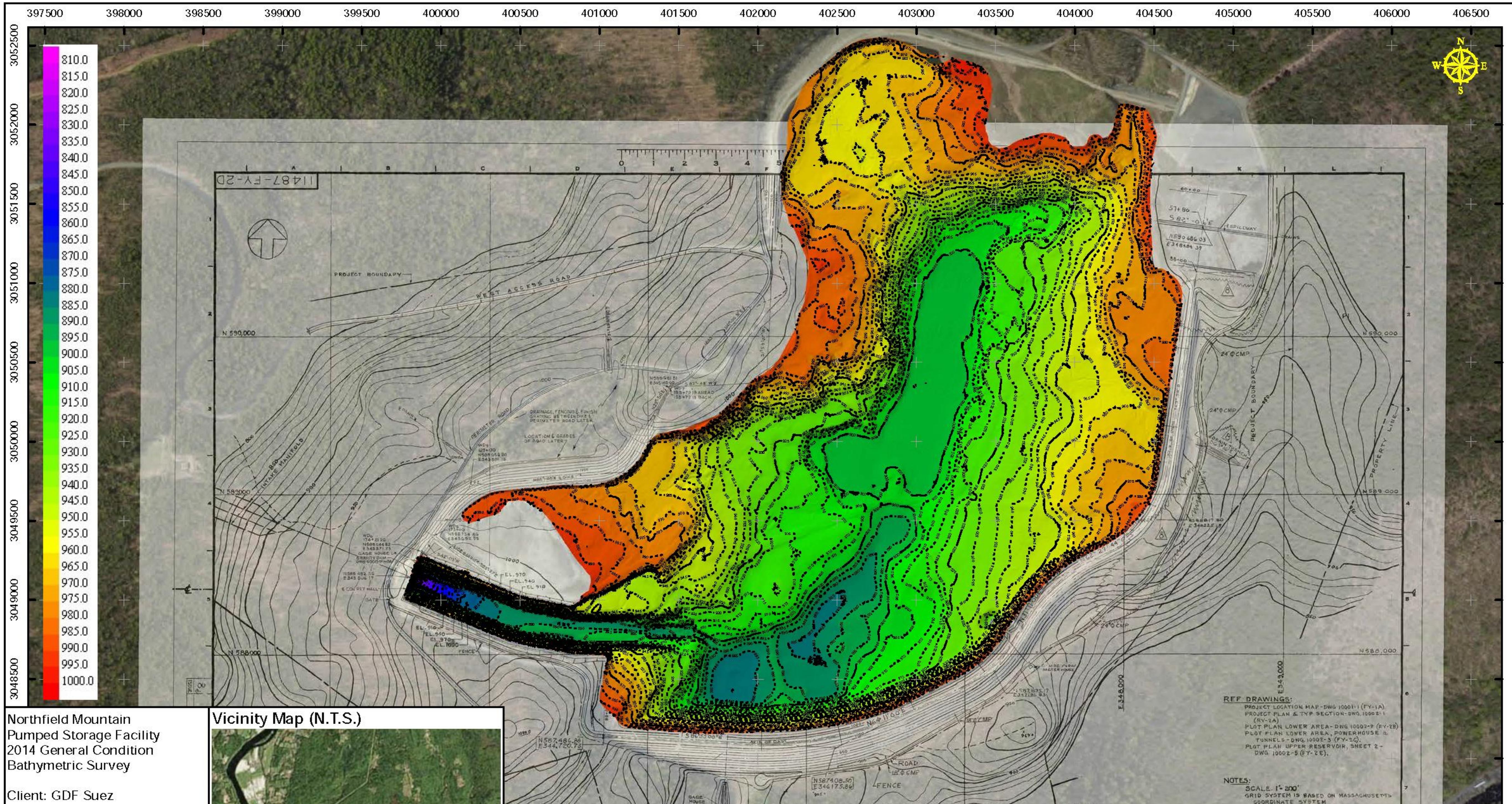


Northfield Mountain
Pumped Storage Facility
2014 General Condition
Bathymetric Survey

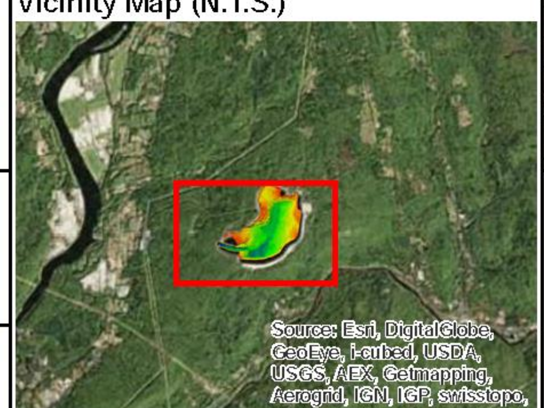
Client: GDF Suez

Figure 3

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

1 inch = 600 feet

Check Graphic Scale

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UNDERWATER SOLUTIONS
151 Martine Street, Suite 103
Fall River, MA 02723
Phone 508-250-0650
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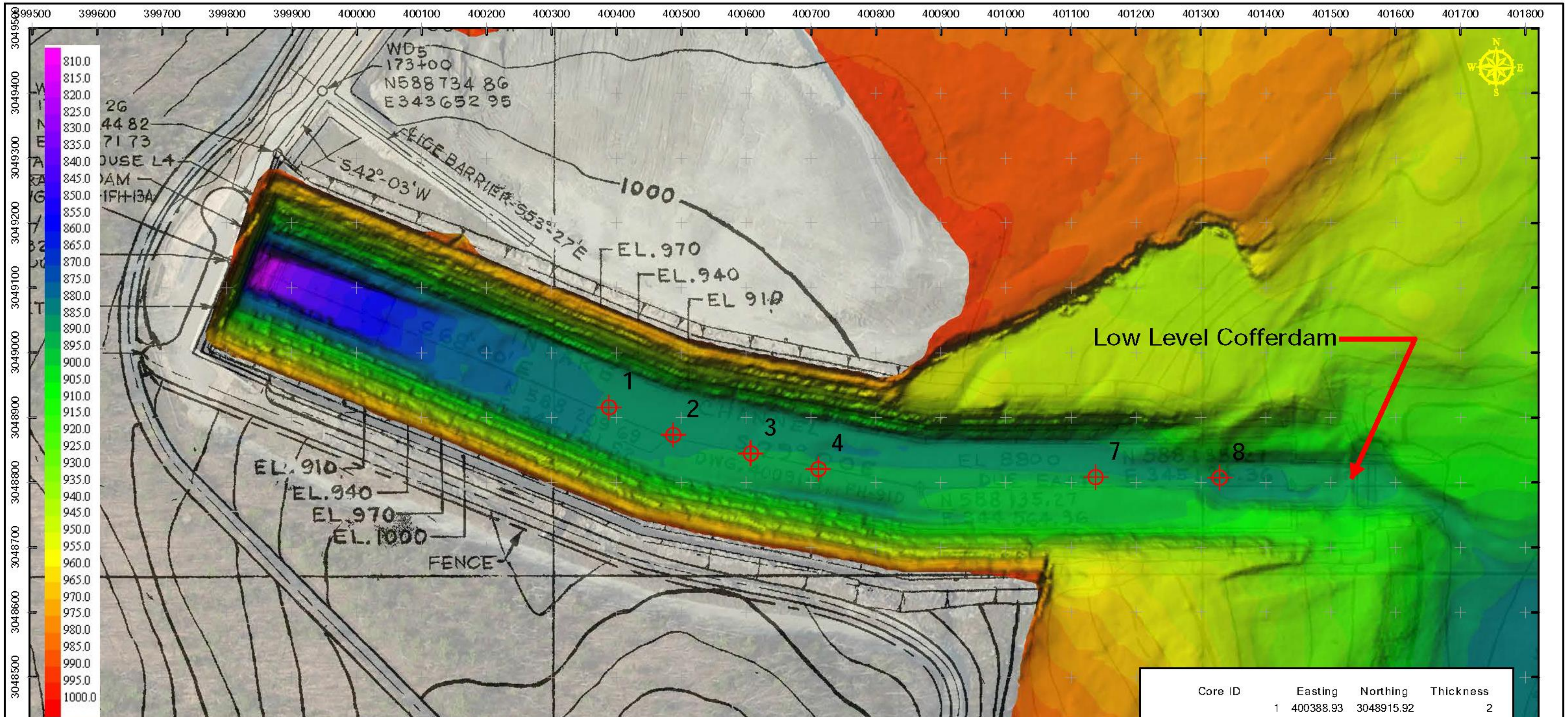


Core ID	Easting	Northing	Thickness
1	400388.93	3048915.92	2
2	400487.89	3048873.23	2
3	400607.24	3048845.09	2
4	400711.06	3048820.83	2.5
7	401137.98	3048808.22	2.25
8	401329.12	3048807.25	2.25

Northfield Mountain
Pumped Storage Facility
2014 General Condition
Bathymetric Survey

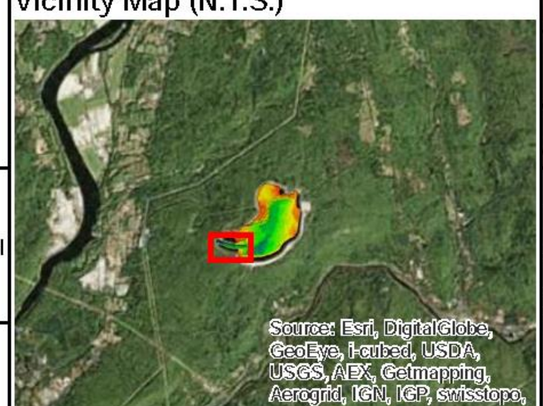
Client: GDF Suez

Figure 4

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).

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Scale

0 75 150 300
Feet

1 inch = 150 feet

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SEAVISION UNDERWATER SOLUTIONS
151 Martine Street, Suite 103
Fall River, MA 02723
Phone 508-250-0650
Fax 401-633-7113
http://www.seavisionmarine.com

Appendix B – Engineering Studies of Sedimentation at the Northfield Mountain Project – Alden Research Laboratory, Inc.

ALDEN

Solving flow problems since 1894

Engineering Studies of Sedimentation at the Northfield Mountain Project

Alden Report Number:

1135QNORTH_FINALB

Submitted to:

FirstLight Power Resources/GDF Suez N.A.
Northfield Mountain/Turners Falls Projects

May, 2014

ALDEN RESEARCH LABORATORY, INC.

ALDEN Research Laboratory, Inc.
30 Shrewsbury Street, Holden, Massachusetts 01520-1843

508-829-6000/phone • 508-829-5939/fax
info@aldenlab.com • www.aldenlab.com

EXECUTIVE SUMMARY

The Northfield Mountain Pumped-Storage Hydroelectric Project, located in the Towns of Erving and Northfield, Massachusetts, has a history of sedimentation accumulation issues. Entrained sand and fine sediment material from the Connecticut River is transported during pumping phases and accumulates in the Northfield Mountain Upper Reservoir, which may require removal. A 2-dimensional (2-D) sedimentation model was used to understand the process of sediment deposition in the reservoir and to evaluate sediment management alternatives.

Three sediment management cases were evaluated in this study in addition to an existing conditions model (Case 1). Two of the sediment management strategies considered were operational changes where the minimum reservoir level was occasionally lowered to 928 or to 920 ft (Cases 2 and 3). One management strategy considered was a physical change to the reservoir where the intake channel width was reduced (Case 4). The study findings indicate that the operational changes may be as or more effective than structural changes at reducing sediment deposition in the Northfield Mountain Upper Reservoir.

Both operational changes (Cases 2 and 3) reduce sediment deposition on the order of 4% to 5% over current operating procedures (Case 1). Narrowing the intake channel (Case 4) also leads to a 4% to 5% reduction in sediment accumulation compared to current operating procedures.

A sensitivity analysis of larger drawdowns was performed to understand how accumulated sediment can be mobilized. The results of this analysis indicate large volumes of deposited sediment lead to higher velocities within the intake channel. After a significant volume of sediment has deposited a flushing drawdown could be used to manage sediment in a controlled manner.

A combination of operational modifications and periodic reservoir flushing from this study and findings from the ongoing Connecticut River Intake Sedimentation Study may be used to further reduce sediment accumulation in the Northfield Mountain Upper Reservoir.

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ENGINEERING STUDIES OF THE SEDIMENTATION PROBLEM AT NORTHFIELD MOUNTAIN RESERVOIR

1.0 INTRODUCTION

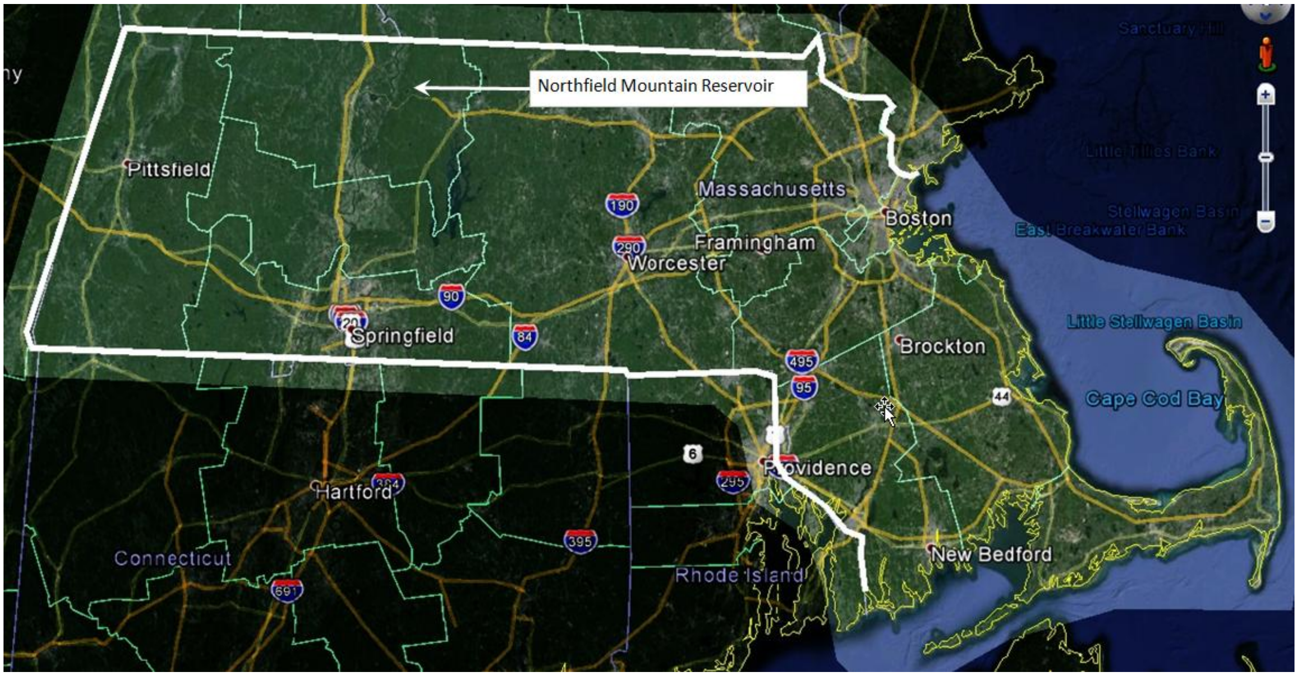
Alden Research Laboratory, Inc. (Alden) has been retained by FirstLight Power Resources (FirstLight) to provide Computational Fluid Dynamic (CFD) sediment modeling of the Northfield Mountain Upper Reservoir.

The Northfield Mountain Pumped-Storage Hydroelectric Project is located on the Connecticut River, near Turners Falls, Massachusetts (Figure 1). Figure 2 shows an aerial view of the site; the Northfield Upper Reservoir is about 2,500 ft wide and 4,500 ft long.

The reservoir is integral to the Northfield Mountain pumped-storage hydroelectric project. Water is pumped from the Connecticut River (lower impoundment) up to the Northfield Mountain Upper Reservoir usually during off-peak periods and discharged back down to the Connecticut River to generate electricity during high demand periods. The head differential between the reservoir and the river is approximately 800 ft. The reservoir has historically experienced sediment accumulation. Sand and fine sediment materials deposit in the intake channel and in the southern portion of the reservoir and this sediment accumulation requires periodic removal.

Alden has utilized a 2-dimensional (2-D) sedimentation model to understand the process of sediment deposition in the reservoir and to determine what types of measures might be taken to better manage the long-term accumulation of sediment. The ultimate objective of the modeling was to determine a modification in reservoir geometry or operational doctrine that can reduce sediment accumulation in the future. Cases explored in this report include operational changes and a physical narrowing of the intake channel to increase flow velocity during generation phases which in turn can increase mobilization of accumulated sediment back down to the Connecticut River.

Figure 1. Northfield Mountain Reservoir Location Map



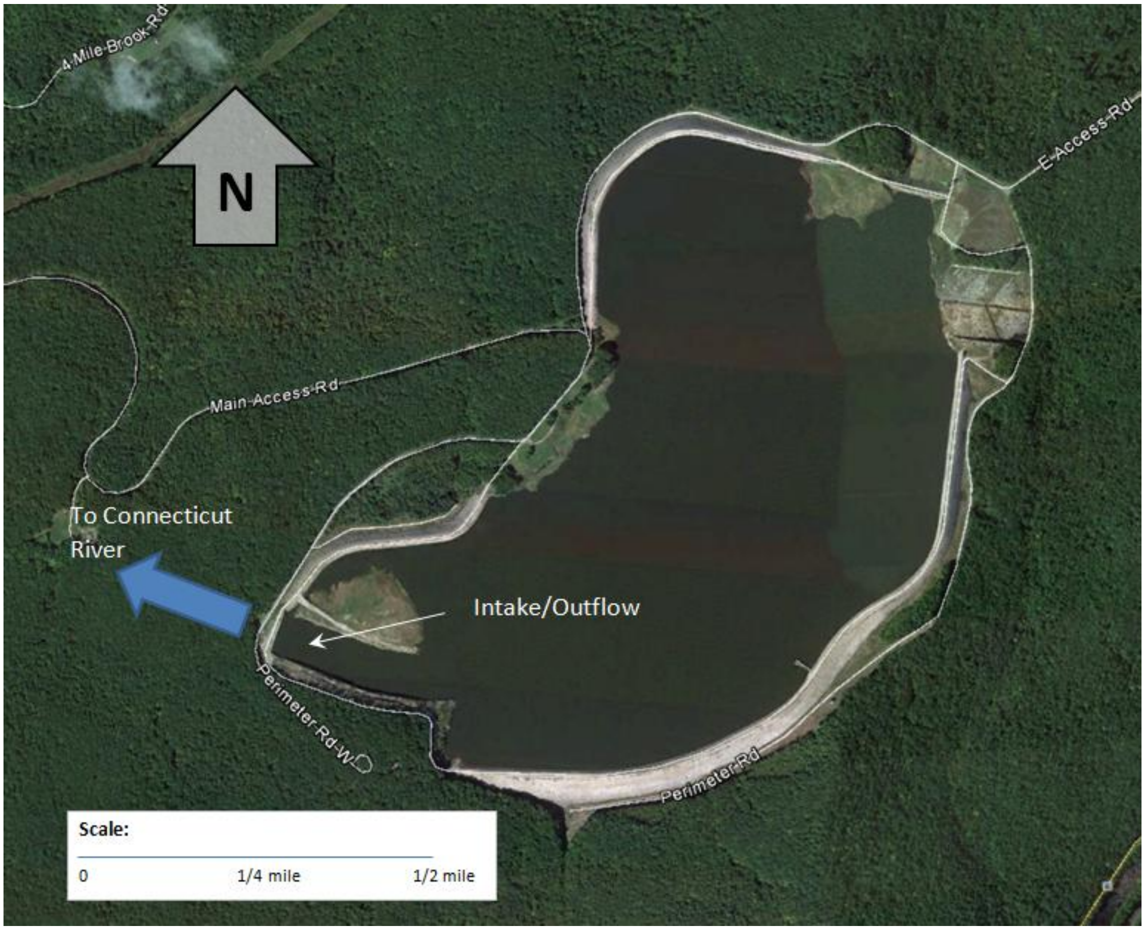
2.0 OBJECTIVES

The two main objectives of the reservoir modeling effort were to:

1. Determine the root cause of sedimentation in the reservoir. The root cause of reservoir sedimentation was investigated with a 2-dimensional numeric model which simulates long term accumulation of sediment in the reservoir (on an annual basis).

2. Investigate methods for decreasing sedimentation in the reservoir. Options considered for minimizing sediment accumulation by increasing the transport of sediment from the reservoir during generating phases included : a) operational changes – lower minimum water surface in the reservoir during generating phases, and b) a structural modification intended to manipulate reservoir currents and increase flow velocity (and sediment entrainment) in the intake channel during generating phases.

Figure 2. Overview of Northfield Mountain Reservoir



3.0 MODELING APPROACH

A variety of physical and numerical modeling approaches were considered to analyze the root cause of the Northfield Mountain Upper Reservoir sedimentation and to evaluate alternatives intended to minimize sediment deposition.

Scaled physical models have a long history of application in river sedimentation problems and to a much lesser extent have been used to model reservoirs. Physical models can have significant scaling limitations when used to evaluate local sedimentation problems especially with fine sediment (like that found in the Northfield Mountain Upper Reservoir). The sediment cannot be reduced in size by the same ratio as the model scale (e.g. sediment particles in a 1:50 scale model cannot be 50 times finer in the model than the reservoir sediment when the measured grain size is less than a millimeter in diameter. The use of plastic surrogate sediment material to balance buoyancy effects leads to transport and conveyance issues. Additionally, physical models typically lack the necessary turbulence to cause sufficient movement of sediment in suspension, which also leads to under prediction of sediment transport. As a result, physical sediment transport models are generally unable to provide quantitative results.

As a compliment to in-house physical modeling capabilities and for use on projects where physical modeling may be cost prohibitive or would not be expected to yield reasonable quantitative results (i.e. sedimentation studies with fine or small size transport material), Alden maintains a comprehensive library of 1-, 2-, and 3-dimensional Computational Fluid Dynamic (CFD) codes. For this application (especially due to time and cost constraints and fine sediment within the reservoir), Alden proposes a numeric simulation using CFD.

Several available numeric or CFD models could be used to model the sediment accumulation in the reservoir. Generally, these models can be classified as 1-, 2-, and 3-dimensional models, all of which Alden actively uses depending on the project requirements. A 1-dimensional model incorporates a cross sectional geometry approach and is useful for predicting gross changes in channel profile. This type of model is unable to predict lateral migration of sediment and is not helpful for evaluating sediment dispersion within a reservoir. Two-dimensional models are able to discretize a reservoir into computational cells in the X and Y directions. This approach allows computation of a depth averaged flow field with longitudinal and lateral components. The 2-D models can predict lateral variation in the velocity field and sediment deposition patterns. In some cases, 3-dimensional sediment transport models are used. Three-dimensional models further discretize the 2-D grid by adding cells in the vertical (or Z) direction. The 3-D models are able to develop a vertical velocity profile and predict variations in sediment concentration with depth. This type of model (3-D) is used for cases where the vertical velocity profile or sediment concentration profile can significantly affect results. The computational resources required increase with each additional dimension. Three-dimensional models are very computationally expensive. Given the large area of interest (the reservoir covers an area of almost ½ square mile) and long model run times (up to a year) required to observe sedimentation trends, a 3-D model is computationally prohibitive. Additionally, since the flow field at the reservoir intake channel is relatively deep (flow depth is on the order of 100 to 200 feet), a 3-D approach is not expected to provide additional insight beyond that provided from a 2-D model.

For this project, Alden used the 2-D numeric model MIKE21C for the sediment transport simulations. MIKE21C is commercially available software sold by DHI software. This model has been used for over 20 years with continuous updates and improvements. The curvilinear grid used in MIKE21C applies a non-orthogonal, boundary fitted mesh to the model domain, reducing the number of necessary computational elements required over that of a structured orthogonal grid. The curvilinear grid also tends to have less false numeric diffusion than triangular grids. MIKE21C uses a very robust algorithm for the wetting and drying of computational cells making it well suited for models with varying water levels, such as those at the Northfield Mountain Reservoir pump-storage facility.

MIKE21C solves a set of hydrodynamic equations which describe a depth-averaged flow field throughout the model domain at a fixed time step interval (1 second time steps were used in this case). The model also solves a set of sediment transport equations which predict the amount of erosion and deposition in each computational cell during each time step. Periodically (every minute) the model updates the bed geometry based on the sediment that has deposited or scoured since the last update. As the bed evolves, the hydrodynamic flow field also changes. In this manner, MIKE21C is able to simulate the time dependent evolution of the reservoir.

3.1 Grid, Bathymetry, Domain

The 2-D model domain is represented with a curvilinear grid with each cell assigned an elevation from the 2011 bathymetric data which was provided in the form of an AutoCAD line drawing (Reference 1, FirstLight). The 2011 survey reservoir bathymetry was selected due to more highly resolved five foot contour lines from which elevation data was extracted. The 2011 elevation contours are shown in Figure 3.

Figure 4 shows the resulting elevation map and the curvilinear grid overlay used for modeling. The grid resolution ranges from small cells approximately 12’ x 12’ at southwest corner of the model to resolve the high velocity zone within the mouth of the intake channel to about 50’ x 50’ cells at the northern end of the model. The resulting geometry encompasses 67 cells widthwise and 252 cells lengthwise for a total of 16,884 cells in the model. This grid resolution is sufficient to resolve high flow velocity in the intake channel and major flow patterns in the reservoir while maintaining a small enough cell count to allow for simulations on the order of one year. The small cells within the intake channel are shown in more detail in Figure 5. The bottom of the 55’ wide intake chamber (elevation shown in Figure 6) is represented by 5 cells at the inflow/outflow model boundary.

Figure 3. 2011 Contours (Reference 1)

Figure 4. Northfield Mountain Reservoir Model Bathymetry and Grid Resolution

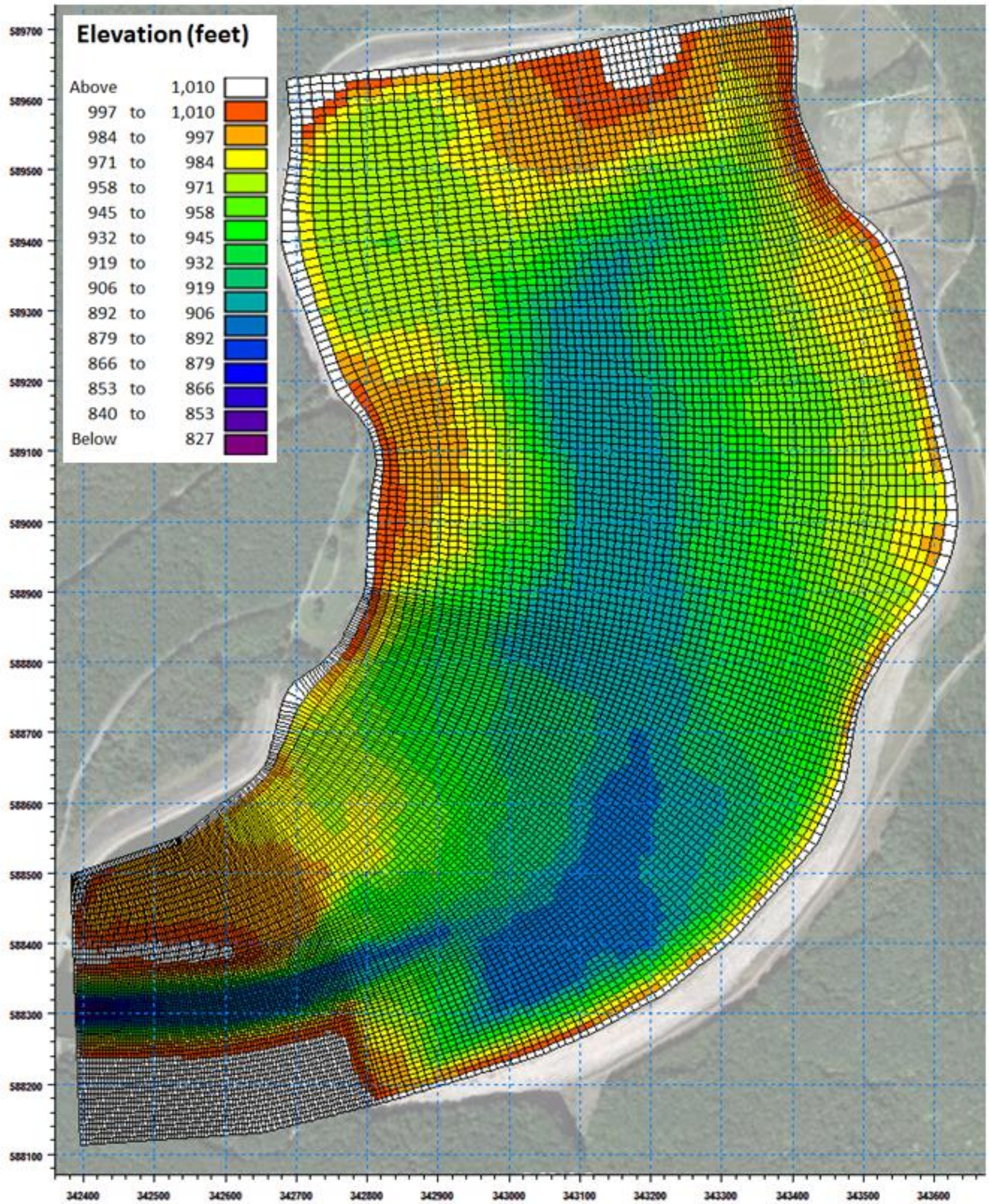
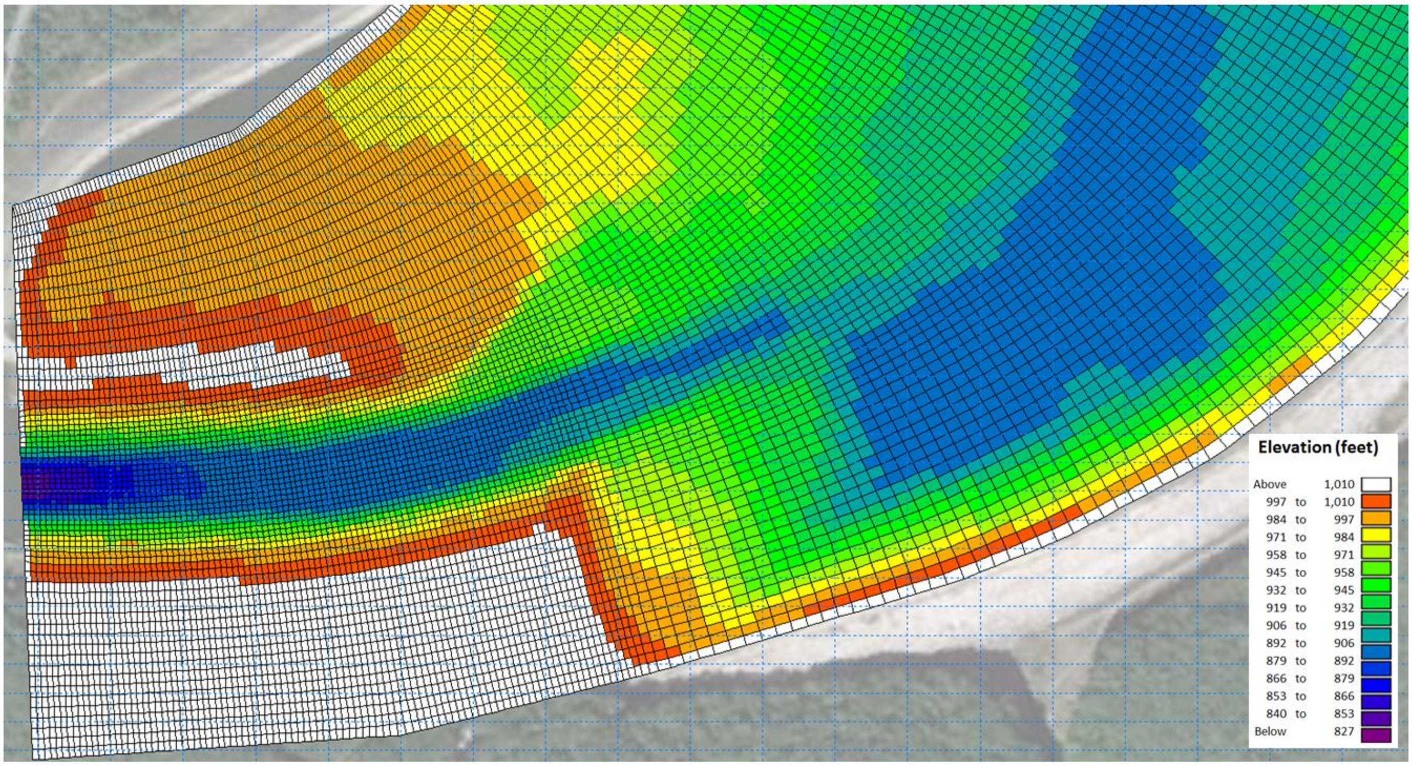


Figure 5. Intake Channel Area Detail - Model Bathymetry and Grid Resolution

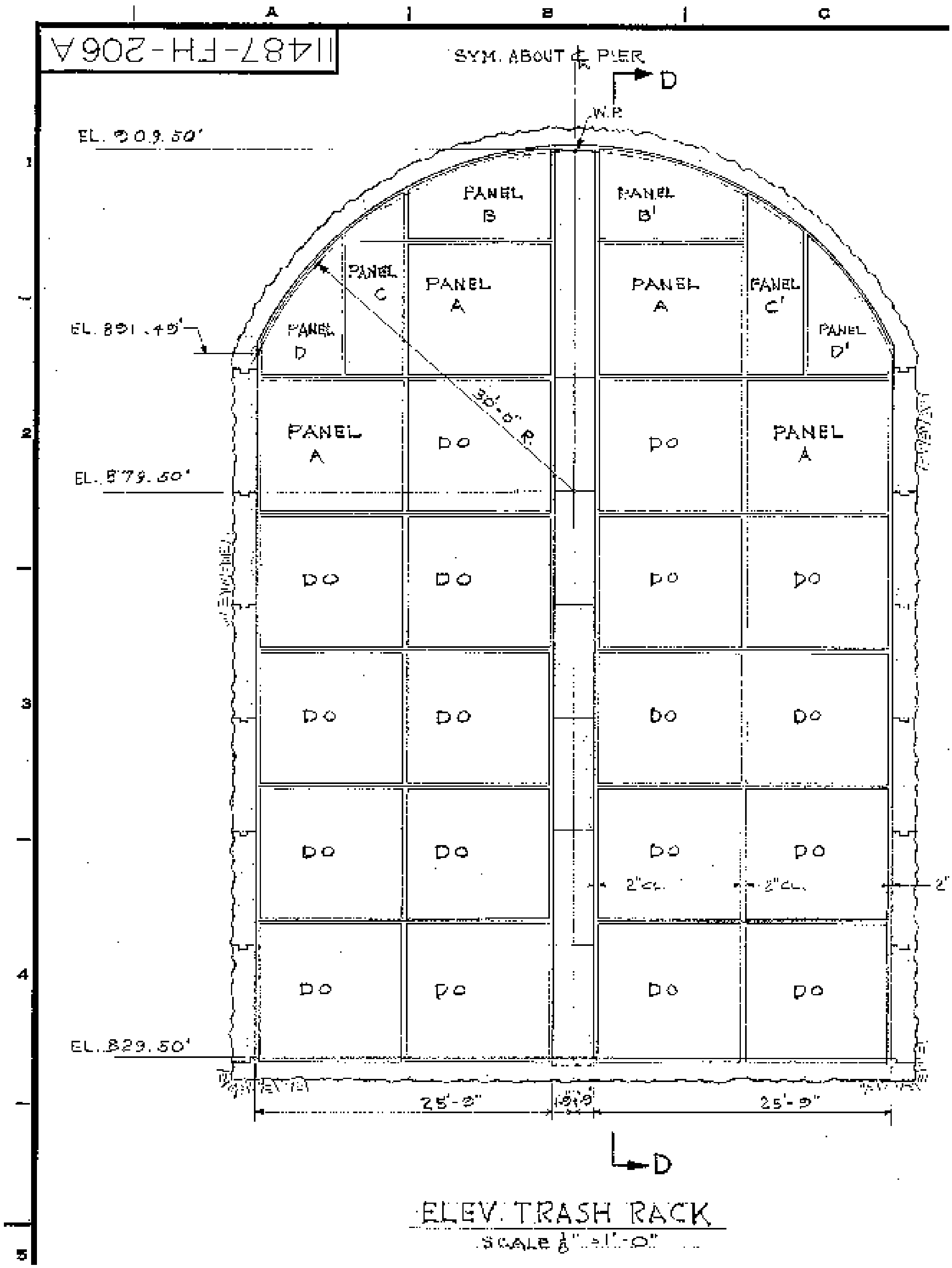


3.2 Boundary Conditions

Boundary conditions are used to define the water surface and sediment inflow for all of the 2-D model cases. Water surface level can be directly input or inflow/outflow can be used based on plant records. For the 2-D model validation, inflow/outflow was used as the downstream boundary condition. For the longer duration annual sedimentation runs, a representative water level sequence was used to drive the model. The water surface level generated by the 2-D model using observed inflow/outflow conditions during the July 31 – August 2, 2013 field data collection period is compared to observed water surface levels in Section 4.2. Water surface level boundary conditions are discussed in Section 3.3.

Computed model velocity at measured transects is compared to field data in Section 4.3. Sediment inflow used for the annual sedimentation models is described in Section 3.4, and the sediment model is described in more detail in Section 3.5.

Figure 6. Intake Chamber Elevation



3.3 Water surface elevation used for sedimentation modeling

Periodic water surface elevations for the Northfield Mountain Upper Reservoir were provided in spreadsheet form (Reference 2, Gomez and Sullivan). A plot of the historic reservoir water surface elevations from 2000 to 2009 is shown in Figure 7. To better visualize the historic reservoir water level trends, this information was broken down into a series of two year plots which are included in Appendix A (Figures A-1 through A-5). A representative operational period which includes a full range of reservoir drawdown with minimum reservoir elevations down to 938 ft was selected. Figure A-5 shows the representative sample period. The 7 week period from 2/1/2008 to 3/21/2008 was repeated several times head-to-tail to generate a typical, or representative, water surface trend for the annual sedimentation models. This boundary condition is explained in more detail for each of the annual sedimentation cases in Section 5.

A curve showing the typical occurrence of minimum water surface levels was generated based on the 2000 – 2009 water surface level data (Figure 8). Under the current plant operating scheme, the reservoir water surface level drops below 940' less than 1% of the time, and is lower than 950' only about 3% of the time. The concept operational modifications is that more frequent reservoir drawdown to lower water surface levels may allow sediment deposited along the intake channel to be re-entrained and transported back down to the Connecticut River.

Figure 7. Historic Reservoir Water Surface Elevations (2000 – 2009); Reference 2

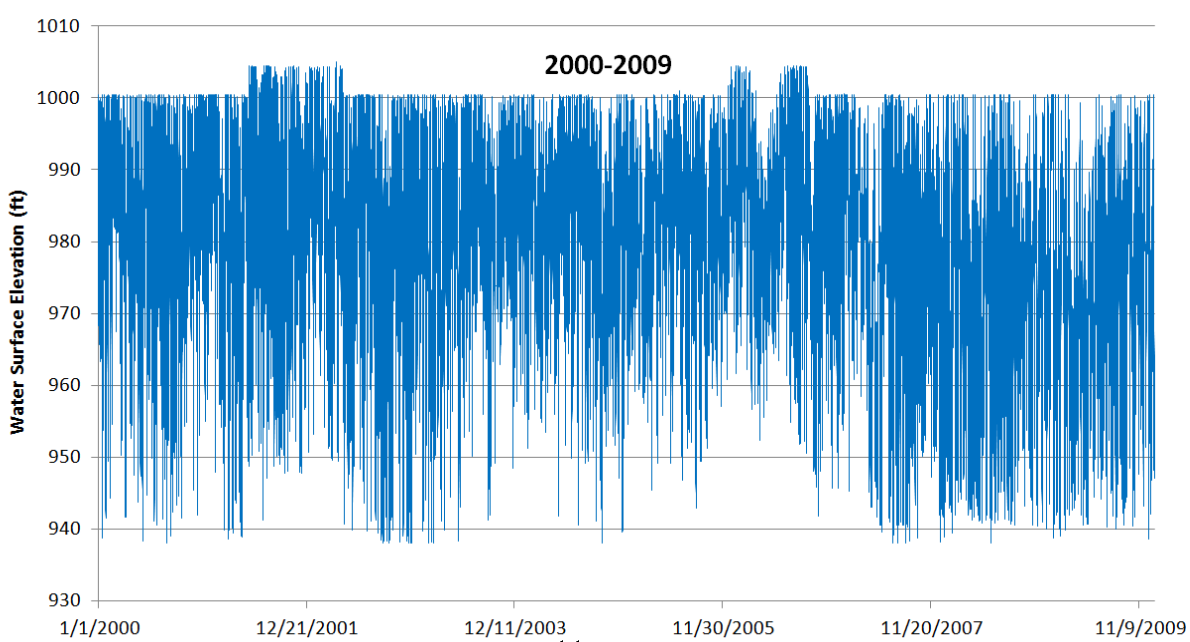
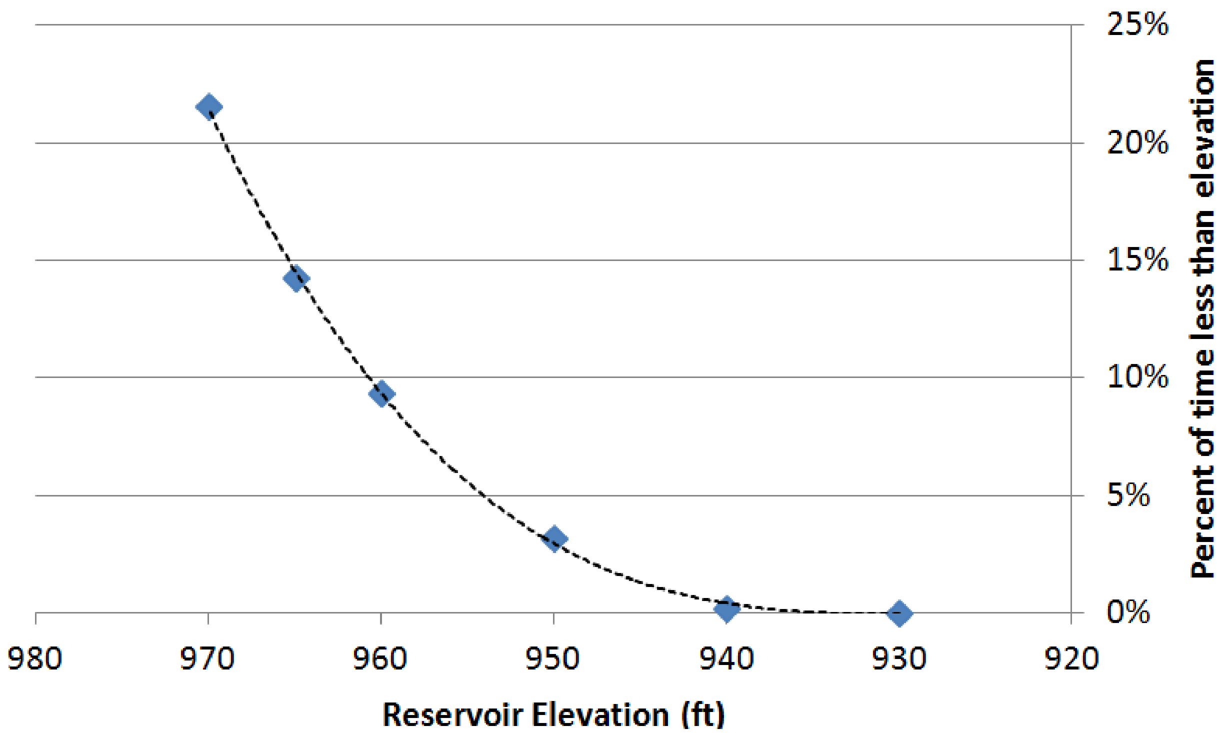


Figure 8. Minimum Reservoir Water Surface Level Exceedence



3.4 Model Sediment Size and Inflow Rate

Connecticut River sediment concentration and mean grain size were measured between September, 2012 and November, 2013. This information was provided to Alden in spreadsheet form (Reference 3, Gomez and Sullivan). Figure 9 shows the variation of sediment size in the Connecticut River sediment measurements over the 2012 - 2013 period. An average sediment size of 0.024 mm was determined from the Reference 3 data (maximum Reference 3 measured sediment size was 0.2 mm). Figure 10 shows sediment concentration in the river over the same duration. Combining river flow data with the sediment concentration information from Reference 3 yields the sediment concentration vs. Connecticut River flow plot shown in Figure 11.

Since the Reference 3 data set is representative of sediment measured in the Connecticut River and may not be entirely representative of sediment pumped to the Northfield Mountain Upper Reservoir, an additional source of information was sought for determining the inflow sediment size characteristics. Samples taken beyond the intake channel in the main part of the reservoir are broken down by size in a 2013 sediment report (Reference 4, Mineral Processing Services). Figure 12 shows the sediment sample locations for the Reference 4 report and Figure 13 shows a typical grain size distribution. Lacking data for the fines in this sample (80% of the sample is finer than a #200 sieve and is not classified), an extension of the sediment curve in Figure 13 indicates that D_{50} for the material depositing further out in the reservoir may be about 0.05 mm.

The sediment used for the annual models was broken into two classes: fine and coarse. This gradation is based on the Reference 3 dataset, the gradation curves from Reference 4, and anecdotal information indicating coarser sediment deposition within the intake channel and finer material in the main reservoir beyond the intake channel. Inflowing sediment was assumed to be made up of 70% coarse material with a grain size of 0.15 mm and 30% fine material with a 0.05 mm grain size.

The sediment inflow curve shown in Figure 11 indicates that sediment within the river exists in higher concentrations during periods of high Connecticut River flow. Although this is somewhat indicative of what the pumping operation can ingest and transport to the Northfield Mountain Upper Reservoir, it is not entirely prescriptive. Figures 14, 15, and 16 show measured bed change in the reservoir between 2010 and 2011, 2011 and 2012, and 2012 and 2013 (these Figures are from References 5, 6, and 7 - Ocean and Costal Consultants, Gomez and Sullivan, and CHA Consulting, respectively). If bed change measurement differences farther out in the main reservoir are discounted as mostly noise and possibly having to do with different measurement techniques employed in the surveys between 2011 and 2013, most of the bed change or sediment accumulation occurs in the intake channel region shown in Figure 17. A series of surface subtractions within this region of significant deposition, considering the difference between the 2011 and 2010, 2012 and 2011, and 2013 and 2012 surfaces leads to the annual deposition volumes shown in Table 1.

The 2010 to 2011 period is characterized by a decrease in material in the region of significant deposition. Sediment was manually excavated and removed from the intake channel during the 2010 dewatering. A small amount of sediment was measured as depositing in this area between 2011 and 2012 (2,700 cubic yards). The bathymetric surface comparison between the 2013 and

2012 surveys indicates 32,600 cubic yards of deposition. The 2011 to 2013 reservoir deposition may consist of two characteristically different depositional periods or maybe measurement differences leads to high or low annual deposition numbers. Considering the 2011 to 2013 period, an average of about 17,600 cubic yards of deposition per year has been observed in the Northfield Mountain Upper Reservoir.

For the annual sedimentation model inflow boundary, a representative (about 17,000 cubic yards) amount of sediment was pumped into the intake channel. This volume of sediment was pro-rated to the inflow or pumping phases by hourly water surface change (which is tied to inflow rate).

Figure 18 shows the water surface elevation boundary fluctuation for the current reservoir operations annual sedimentation model. Figures 19 and 20 show the sediment inflow used boundary condition used for the annual sedimentation models.

Figure 9. Connecticut River Sediment Size Measurements (Reference 3)

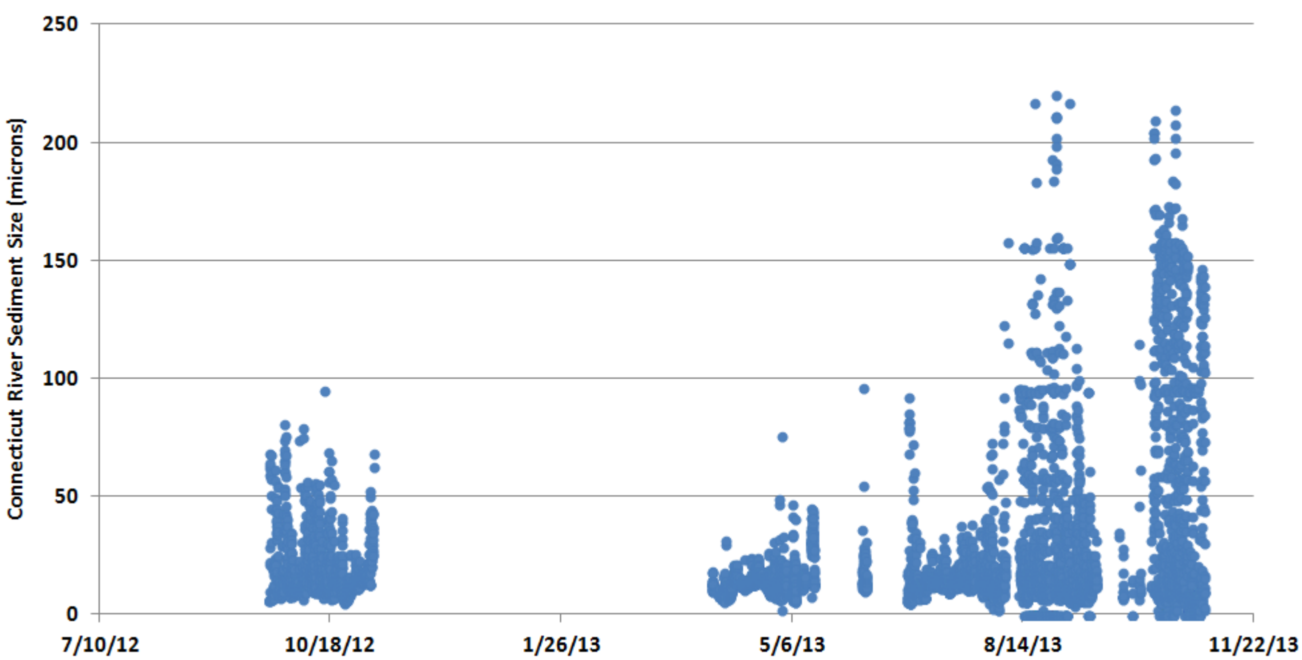
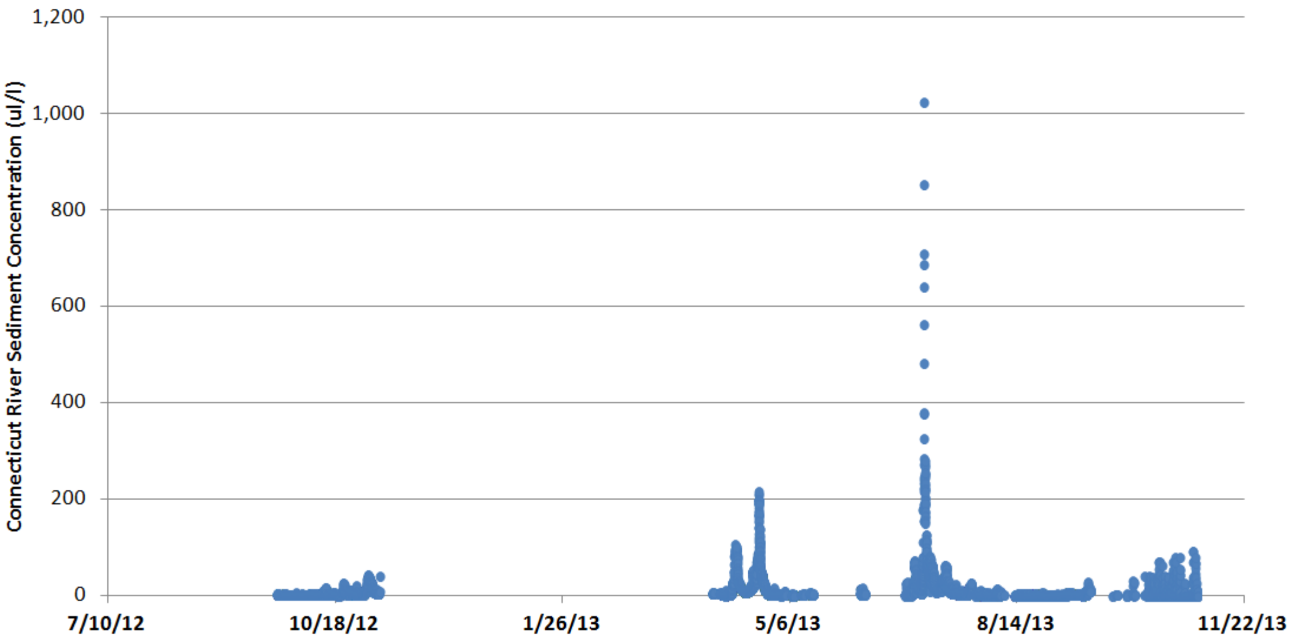


Figure 10. Event Based Sediment Concentration (9/21/2012 – 10.31/2013); Reference 3



3.5 Sedimentation Modeling Approach

Four sediment transport formulae are included in MIKE21C, along with the ability to include user developed formulas. The four included sediment formulae are as follows:

- Engelund-Hansen
- van Rijn
- Engelund-Fredsoe
- Meyer-Peter and Muller

The first two relations are applicable to fine sediments, whereas the latter two are generally bedload equations. Sedimentation in the Connecticut River and in the Northfield Mountain Upper Reservoir is best modeled using either the Engelund-Hansen or van Rijn formulation. The van Rijn formula (1984) is more recent than the work of Engelund and Hansen, is based on over 800 data sets and was developed specifically with consideration that it would be used in multi-dimensional computer models. It is best suited to particle sizes in the range of 0.1 to 0.5 mm. For coarser sands, The Engelund-Hansen formulae is based on flume experiments using four mean particle sizes ranging from 0.19 mm to 0.93 mm. For this modeling effort considering the sediment size range - 0.05 to 0.15 mm, the van Rijn formulation was used to represent the reservoir sediment.

Figure 11. Connecticut River Sediment Concentration vs Discharge (Reference 3)

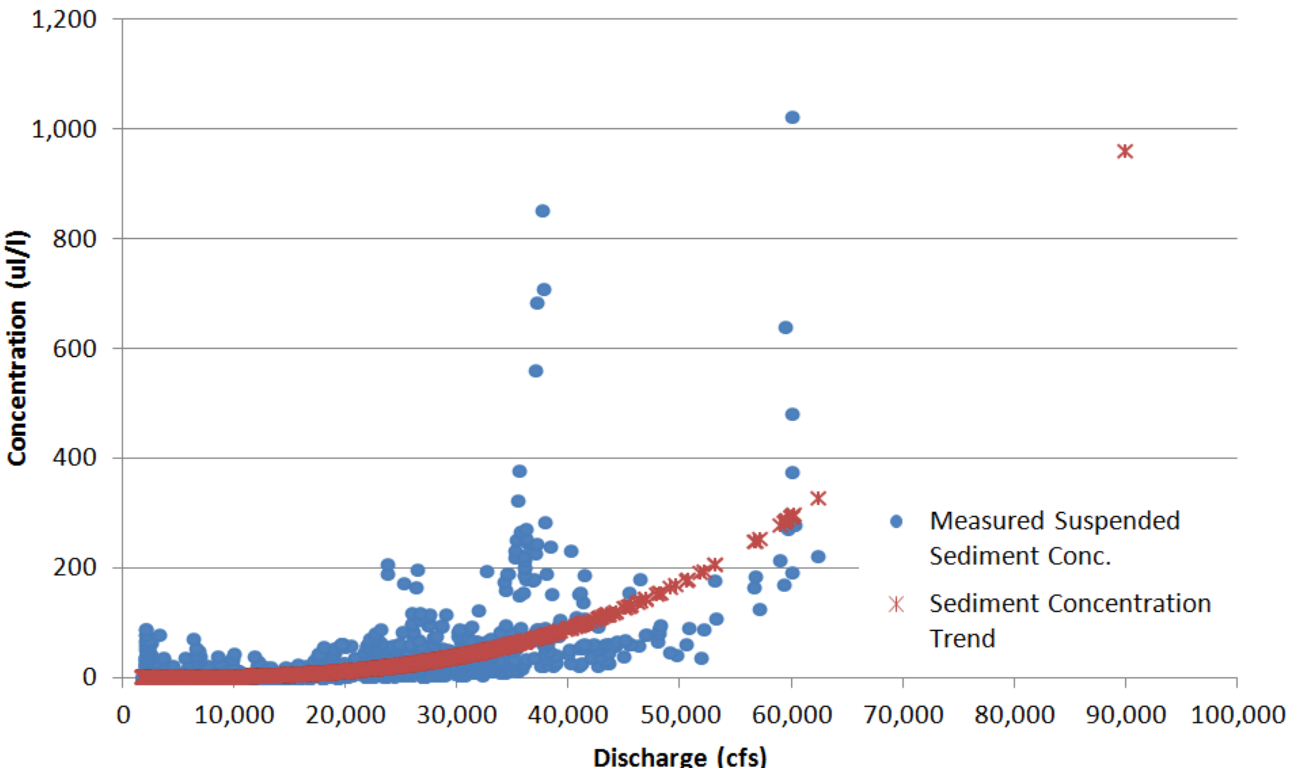


Figure 12. Main Reservoir Sediment Sampling Locations (Reference 4)

MPS – FristLight Northfield, Ma. Sediment Sampling Plan
July 30th 2013

Figure 13. Typical Sediment Gradation Within Main Reservoir (Reference 4)

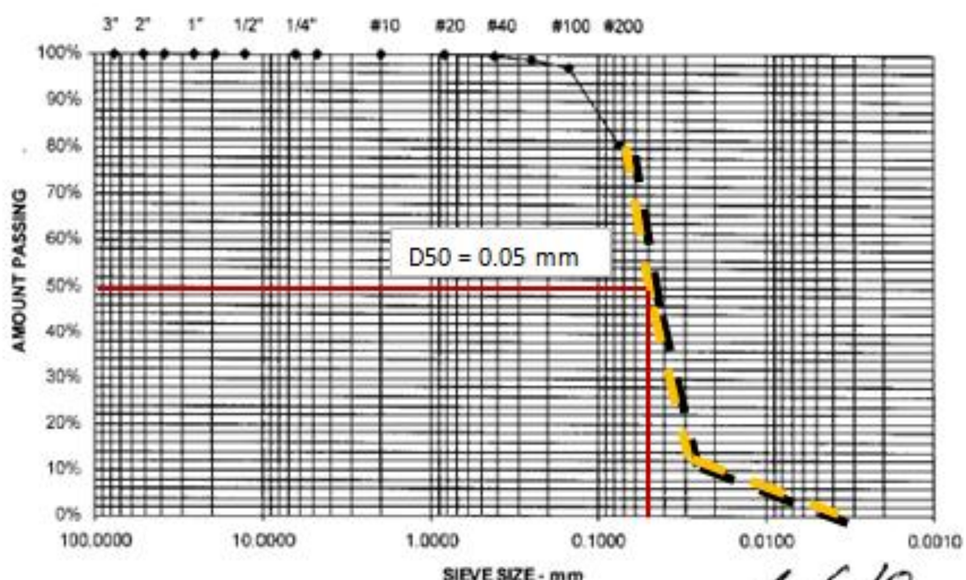
S.W.COLE ENGINEERING, INC.

Report of Gradation

ASTM C-117 & C-136

Project Name	SOUTH PORTLAND ME - FIRST LIGHT - CONSTRUCTION MATERIALS TESTING SERVICES	Project Number	13-0830
Client	MINERAL PROCESSING SERVICES LLC	Lab ID	17046G
Material Type	SEDIMENT	Date Received	8/9/2013
Material Source	ZONE 2 B	Date Completed	8/15/2013
		Tested By	JUSTIN BISSON

STANDARD DESIGNATION (mm/µm)	SIEVE SIZE	AMOUNT PASSING (%)	SPECIFICATIONS (%)
150 mm	6"	100	
125 mm	5"	100	
100 mm	4"	100	
75 mm	3"	100	
50 mm	2"	100	
38.1 mm	1-1/2"	100	
25.0 mm	1"	100	
19.0 mm	3/4"	100	
12.5 mm	1/2"	100	
6.3 mm	1/4"	100	
4.75 mm	No. 4	100	
2.00 mm	No. 10	100	
850 um	No. 20	100	
425 um	No. 40	99	
250 um	No. 60	99	
150 um	No. 100	97	
75 um	No. 200	80.9	



Comments

Roger E. Domingo

286 Portland Road, Gray, ME 04039-9586 • Tel (207) 657-2866 • Fax (207) 657-2840 • www.swcole.com

Figure 14. Elevation Change 2010 to 2011 (Reference 5)

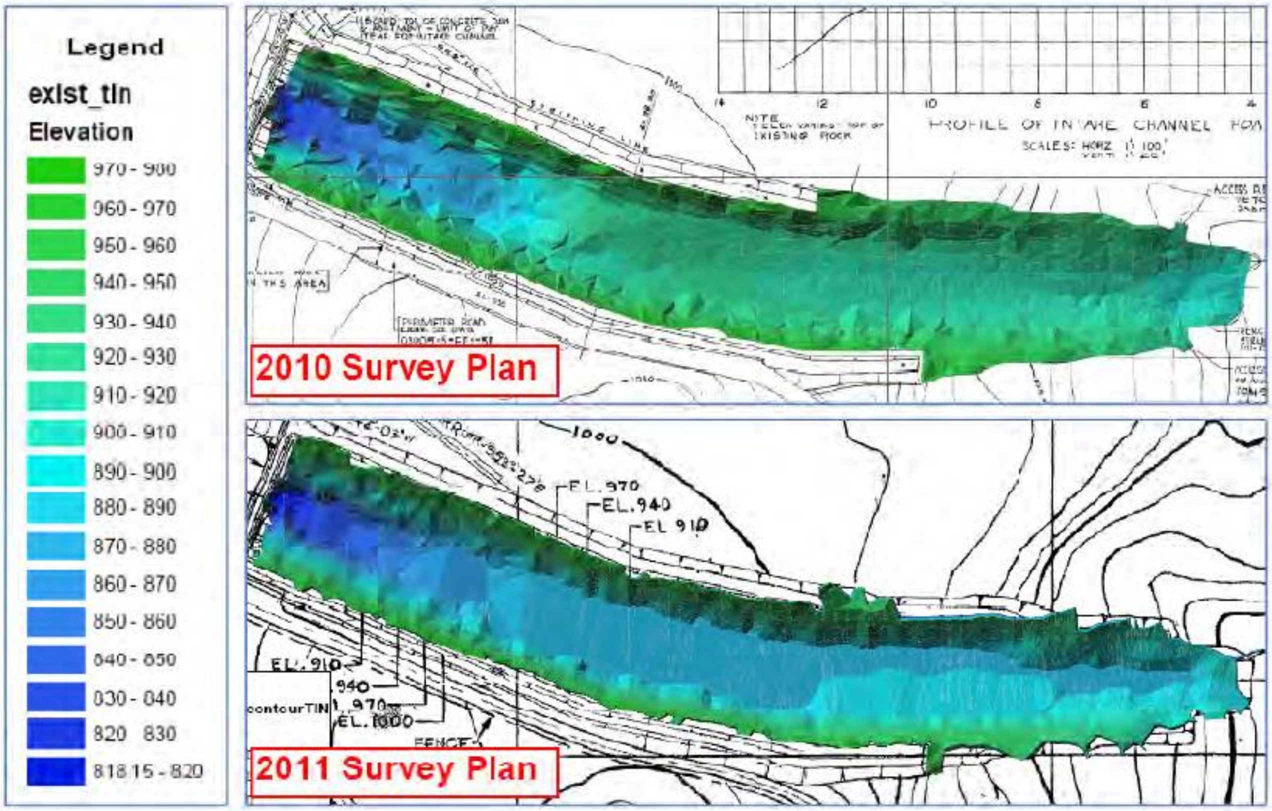


Figure 15. Elevation Change 2011 to 2012 (Reference 6)

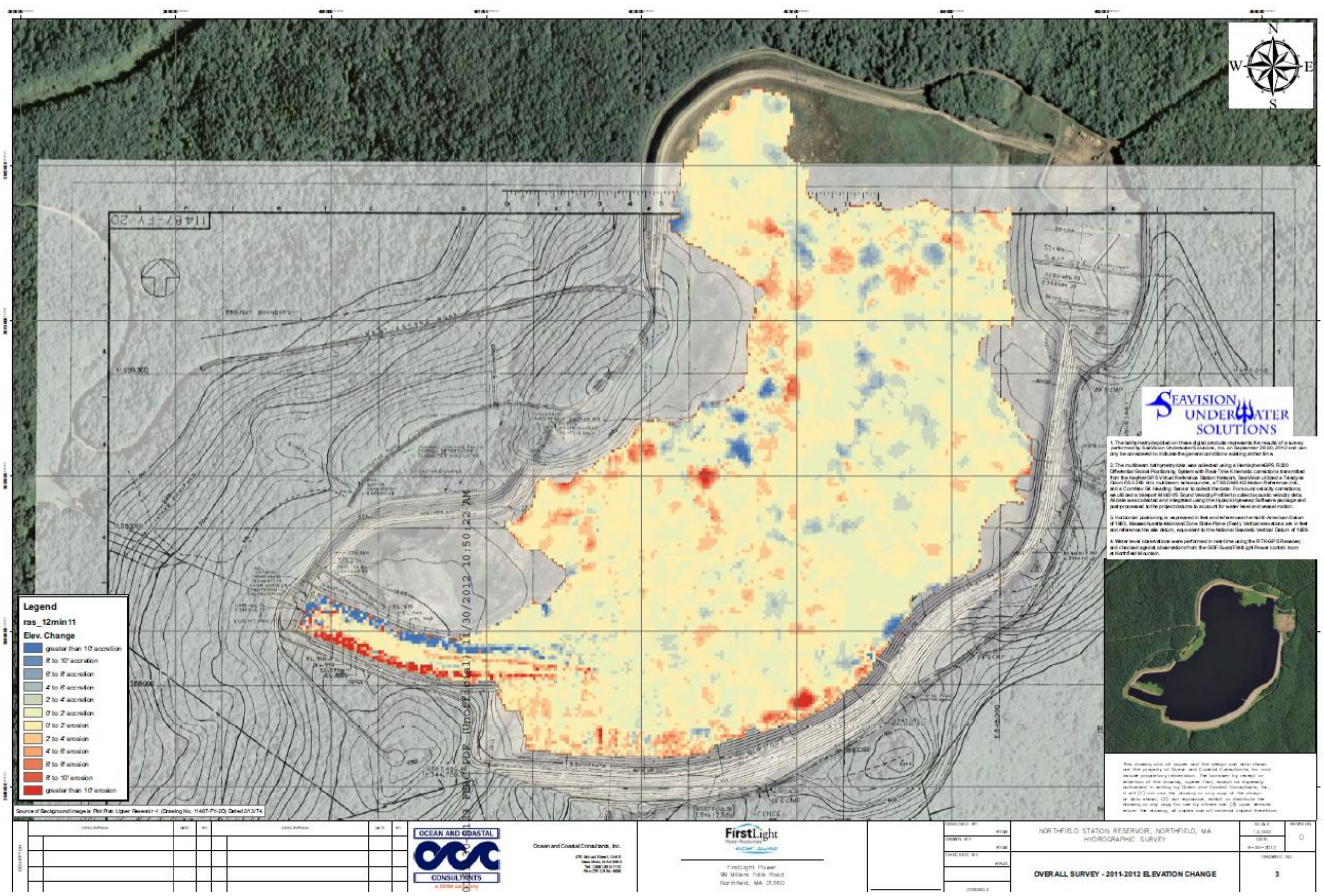


Figure 16. Elevation Change 2012 to 2013 (Reference 7)

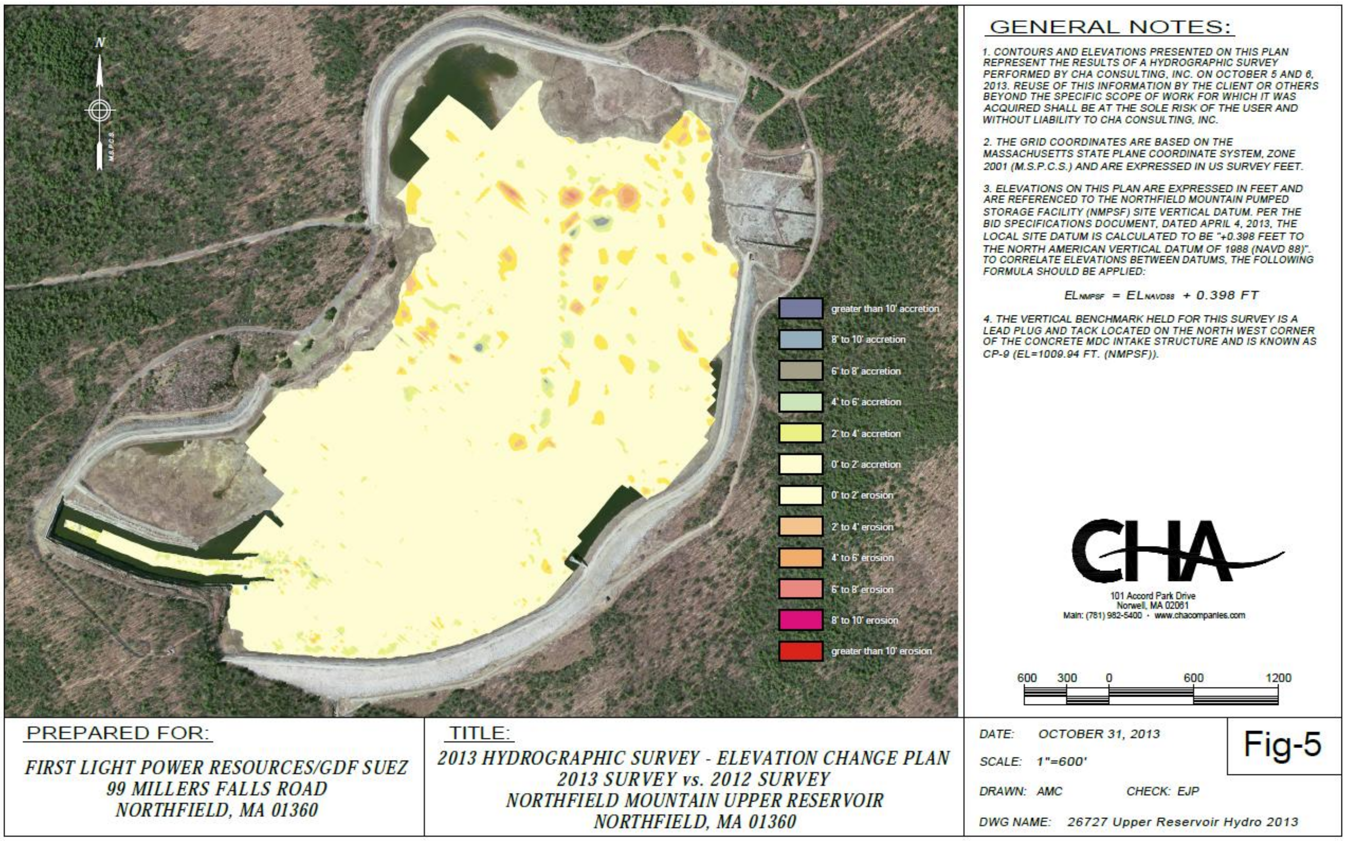


Table 1. Northfield Mountain Reservoir Sediment Volume Change (2010 – 2013)

Period	Cut	Fill	Volume Change (cubic yards) (+Depositional -Scour)	Notes
2010-2011	253,907	28,137	(225,770)	Material Excavated
2011-2012	39,201	41,917	2,716	Depositional
2012-2013	30,326	62,965	32,639	Depositional

17,678 yds deposit/yr avg

Figure 17. Region of Significant Deposition (Intake Channel and Lower Main Reservoir)

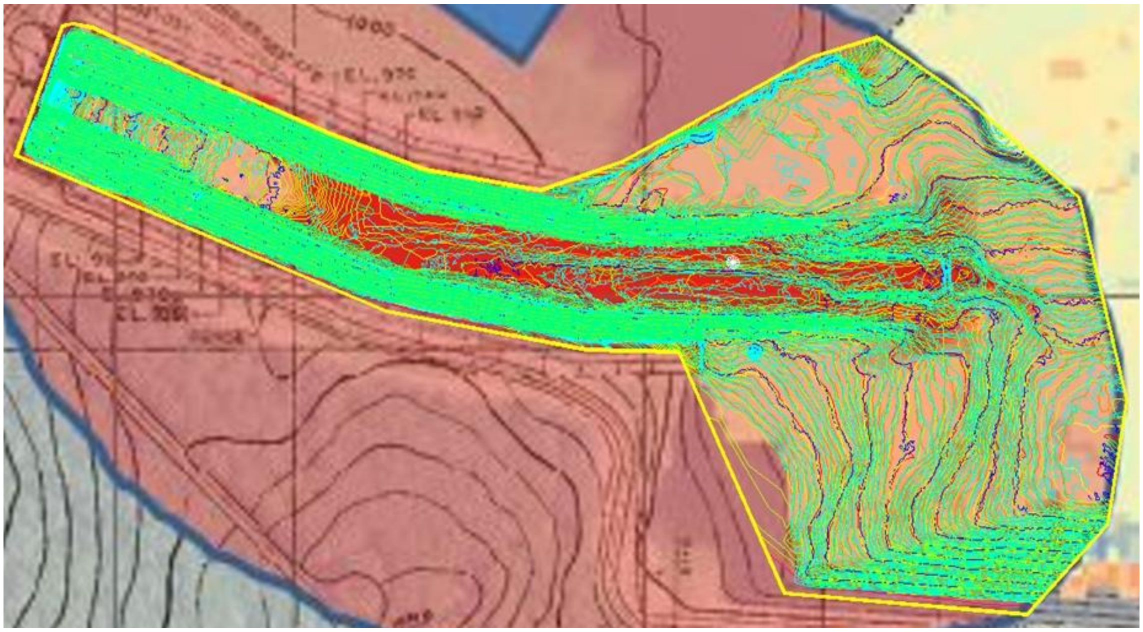


Figure 18. Water Surface Elevation for Current Reservoir Operations (Case 1 and Case 4)

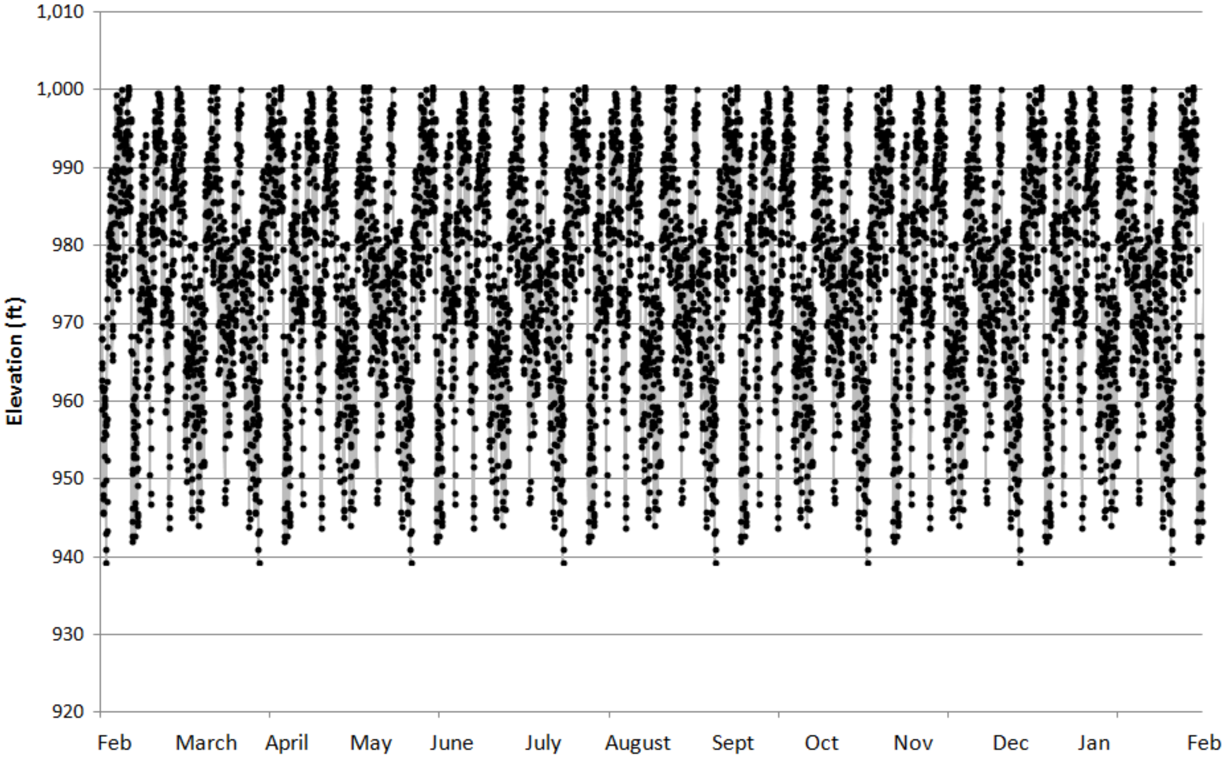


Figure 19. Coarse Sediment Inflow Curve for Annual Sedimentation Models

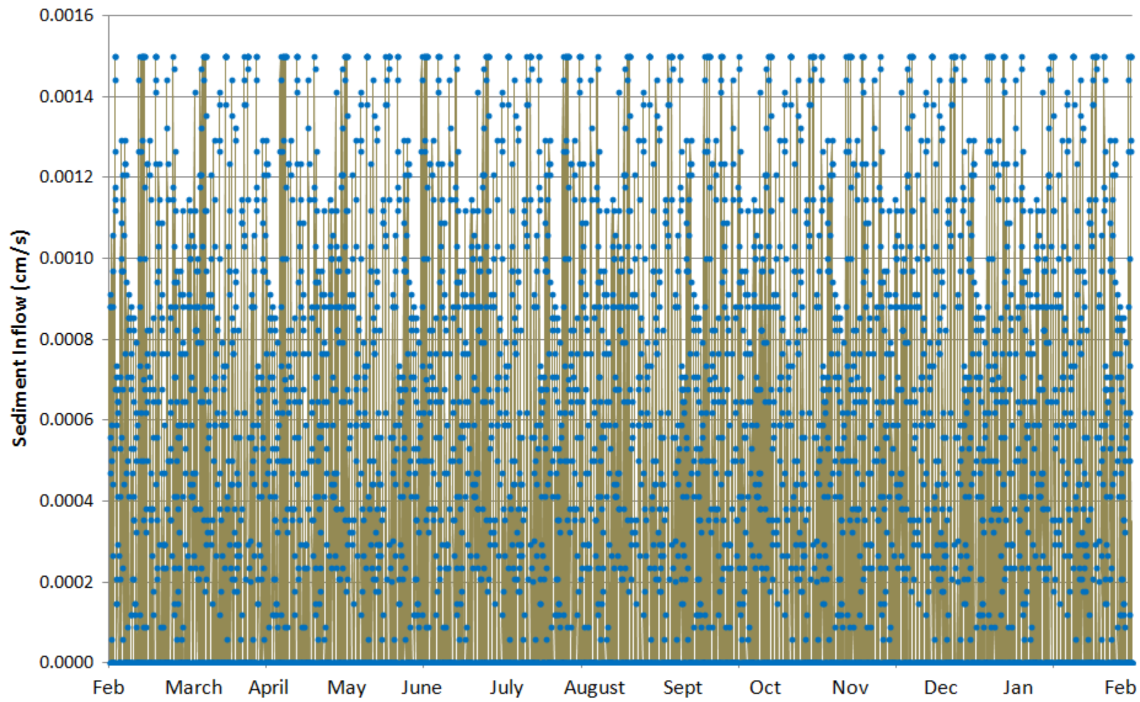
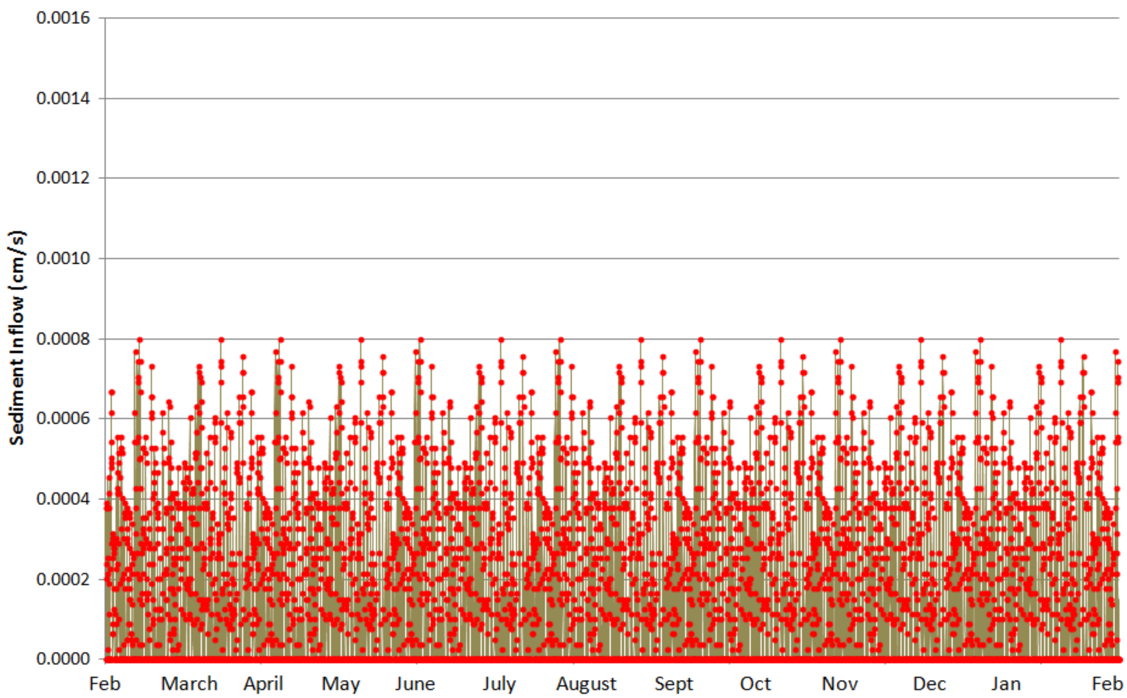


Figure 20. Fine Sediment Inflow Curve for Annual Sedimentation Models



4.0 MODEL VALIDATION

A sequence of recorded reservoir water surface elevations and transect based velocity measurements within the reservoir were used to validate the 2-D model. Section 4.1 documents the field activity required for these measurements. Water surface elevation results are compared with field measurements in Section 4.3, and velocities are compared to measurements in Section 4.3.

4.1 Field Data Collection

During the period of July 31 to August 2, 2013, Alden conducted a current velocity mapping program on the Northfield Mountain Upper Reservoir. The goal of this data acquisition effort was to document flow field patterns induced in the reservoir during both pumping and generation operating conditions. A real-time vessel-mounted acoustic Doppler current velocity profiler (ADCP) was used to measure the reservoir flow velocities. This field investigation was designed to provide supporting velocity and flow data for use in validation of the 2-D numerical model.

<u>Fieldwork Summary</u>

To collect high quality site specific velocity data within the reservoir, Alden implemented an integrated velocity survey using an RD Instruments 600 kHz Sentinel Acoustic Doppler Current Profiler (ADCP), and a Hemisphere Crescent RS110 High Precision Differential GPS positioning system (which was interfaced with a HYPACK MAX PC-based hydrographic software package). Velocity data was collected at the project site July 31 to August 2, 2013. Four transects arching across the reservoir were surveyed: Transect 1 having a radius of 2,500 ft and being about 200 ft away from the inlet/outlet channel, Transect 2 having a radius of 3,500 ft and being about 900 ft away from the inlet/outlet channel, Transect 3 having a radius of 4,500 ft and being about 1,900 ft away from the inlet/outlet channel, and Transect 4 having a radius of 5,000 ft and being about 3,000 ft away from the inlet/outlet channel. Figure 21 shows the relative location of each of the velocity transects. An Onset U20 pressure gauge was used to monitor changes in pool elevation and to record Northfield Mountain Upper Reservoir water surface elevations.

Table 2 shows the data collection activity log and notes the beginning and ending time for each of the velocity transects as well as reservoir water surface levels during the transect surveys. Figure 22 is a graphic representation of the data collection timeline.

Table 2. Field Data Collection Activity Log

Day 1 - Wednesday July 31, 2013

Site Setup & Reconnaissance

10:15 Hrs	Arrive at FirstLight, clear security and meet local personnel
10:45 Hrs	Site-specific safety training
11:30 Hrs	Reconnaissance of the upper reservoir
12:00 Hrs	Vessel rigging and setup
13:30 Hrs	Install the water level monitoring gauge
16:00 Hrs	Complete on-site work and secure vessel and equipment for the day
17:00 Hrs	End of work day

Day 2 - Tuesday August 1, 2013

Generation mapping

09:30 Hrs	Arrive at FirstLight, clear security
10:00 Hrs	Site-specific safety training
11:00 Hrs	Vessel rigging and setup
11:00 Hrs	* 2 units generating
11:57 Hrs	Start Generation Mapping #1
12:19 Hrs	* Pool elevation 992.0
12:54 Hrs	* 1 unit generating
13:16 Hrs	End Generation Mapping #1
13:27 Hrs	Start Generation Mapping #2
14:08 Hrs	* Pool elevation 989.3
14:36 Hrs	End Generation Mapping #2
14:47 Hrs	Start Generation Mapping #3
15:51 Hrs	End Generation Mapping #3
15:58 Hrs	* Pool elevation 986.5
16:00 Hrs	Generation Mappings completed. Deliver crew to shore.
16:20 Hrs	Anchored in northern end of reservoir.
17:00 Hrs	End of work day.

Day 3 - Tuesday August 1 - Wednesday August 2, 2013

Pumping mapping

23:00 Hrs	Recover crew from shore.
23:10 Hrs	* Pool elevation 985.2
23:34 Hrs	* 1 unit pumping
23:36 Hrs	Start Pumping Mapping #1
00:23 Hrs	* Pool elevation 985.9
00:23 Hrs	* 2 units pumping
01:11 Hrs	End Pumping Mapping #1
01:24 Hrs	Start Pumping Mapping #2
01:24 Hrs	* Pool elevation 988.1
03:07 Hrs	End Pumping Mapping #2
03:18 Hrs	Start Pumping Mapping #3
04:34 Hrs	* Pool elevation 994.4
05:02 Hrs	End Pumping Mapping #3
05:02 Hrs	* Pool elevation 995.7
05:02 Hrs	Pumping Mappings completed.
05:19 Hrs	Recover the water level monitoring gauge.
05:40 Hrs	All data downloaded and backed up.
06:30 Hrs	Vessel de-rigging and recovery.
07:30 Hrs	End of work day, Depart site.

Field Observations & Data Conclusions

During the Generation mapping the weather was cool and overcast. At noon time, the beginning of the mapping two units were running, within an hour they dropped down to one unit operations. The average measured flow velocity was less then 0.1ft/s, such low velocities are not ideal for acoustic current profilers, leading to a fairly high level of noise in the data sets. The general flow patterns were documented with possible recirculation near shore.

During the Pumping mapping the weather was cool with intermittent showers. At the beginning of the mapping one unit was operating and within an hour a second unit began pumping. The average flow velocity measured was less then 0.1ft/s, again such low velocities are not ideal for acoustic current profilers, leading to a fairly high level of noise in the data sets. The general flow patterns were documented with possible recirculation near shore.

Figure 21. Velocity Transect Locations

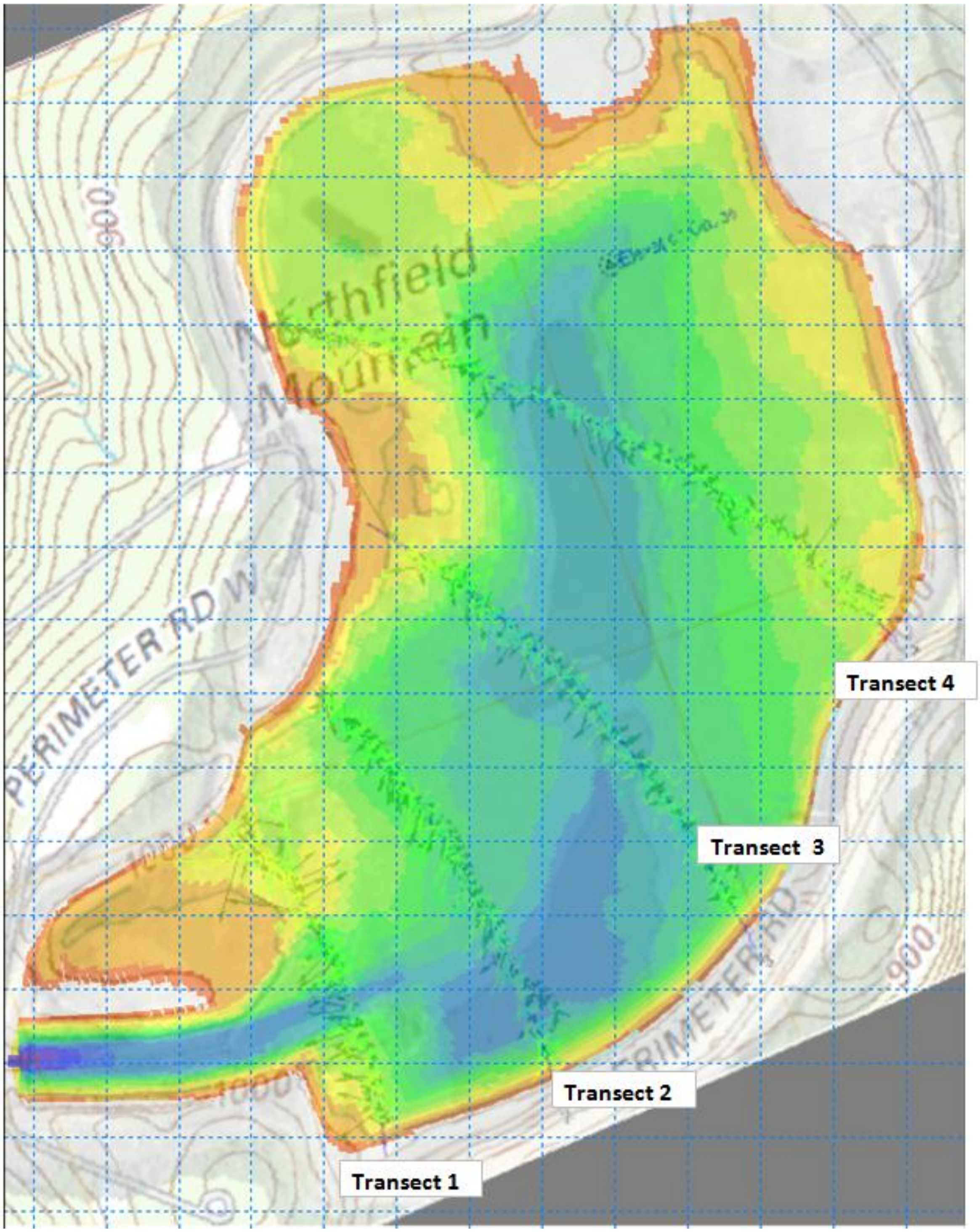
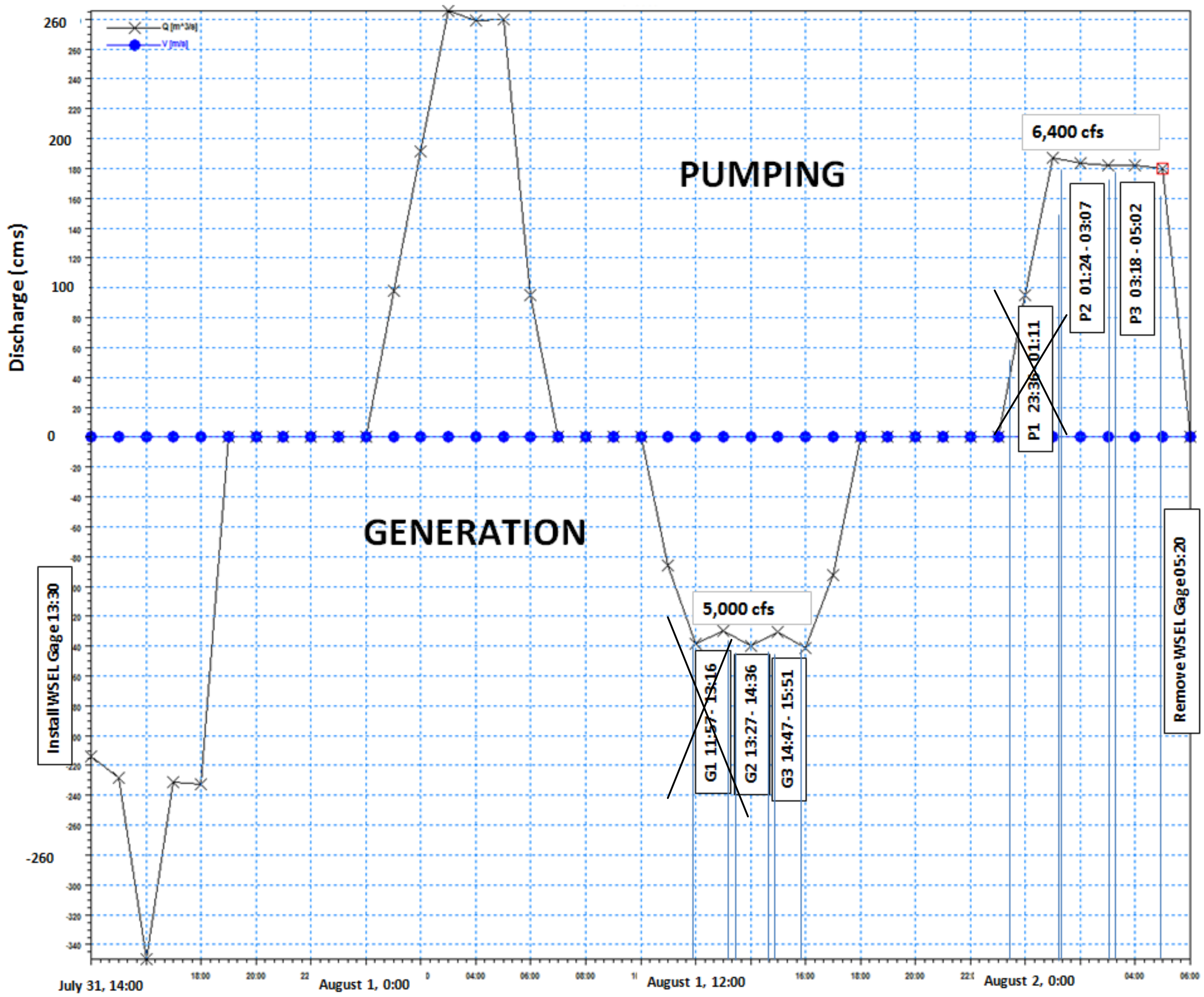


Figure 22. Data Collection Timeline

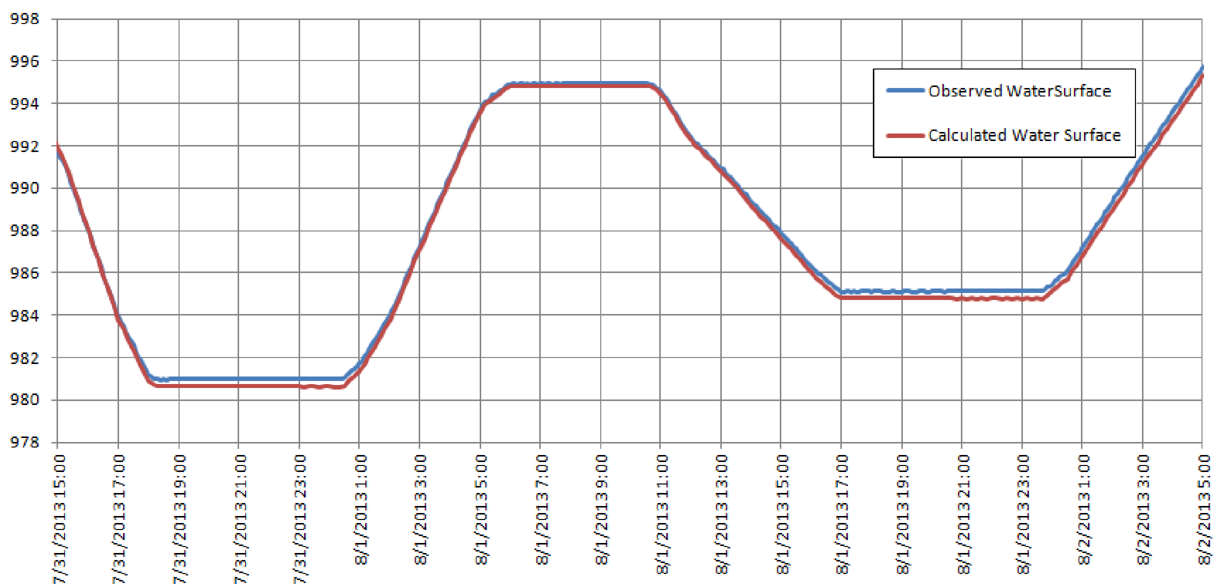


Note: ADCP Surveys taken during flow field establishment periods (G1 and G2) were omitted from the validation process and are crossed out in the above figure.

4.2 Water Surface Elevation Comparison

The first part of the Northfield Mountain Reservoir 2-D model validation is a comparison of computed reservoir water surface level trend with observed water surface elevations based on the July 31 to August 2, 2013 field data. The 5 minute pumping/generating (inflow/outflow) data was provided in spreadsheet format (Reference 8, FirstLight) and directly input into the 2-D model as the downstream boundary condition. The model was run for the data collection period (13:30 July 31 to 05:20 August 2) and the computed water surface levels were compared to measured levels from the field deployed Onset U20 pressure gage. Figure 23 shows the agreement between calculated and observed water surface levels. The proximity of the red (calculated) and blue (observed) lines indicates that the model reservoir inflow/outflow and water level/reservoir volume relationships are very similar to site conditions. The close agreement between field measurements and model results indicates that the reservoir geometry/bathymetry and boundary conditions were accurately incorporated into the 2-D model.

Figure 23. Water Surface Level – Observed and Modeled



4.3 Velocity Comparison

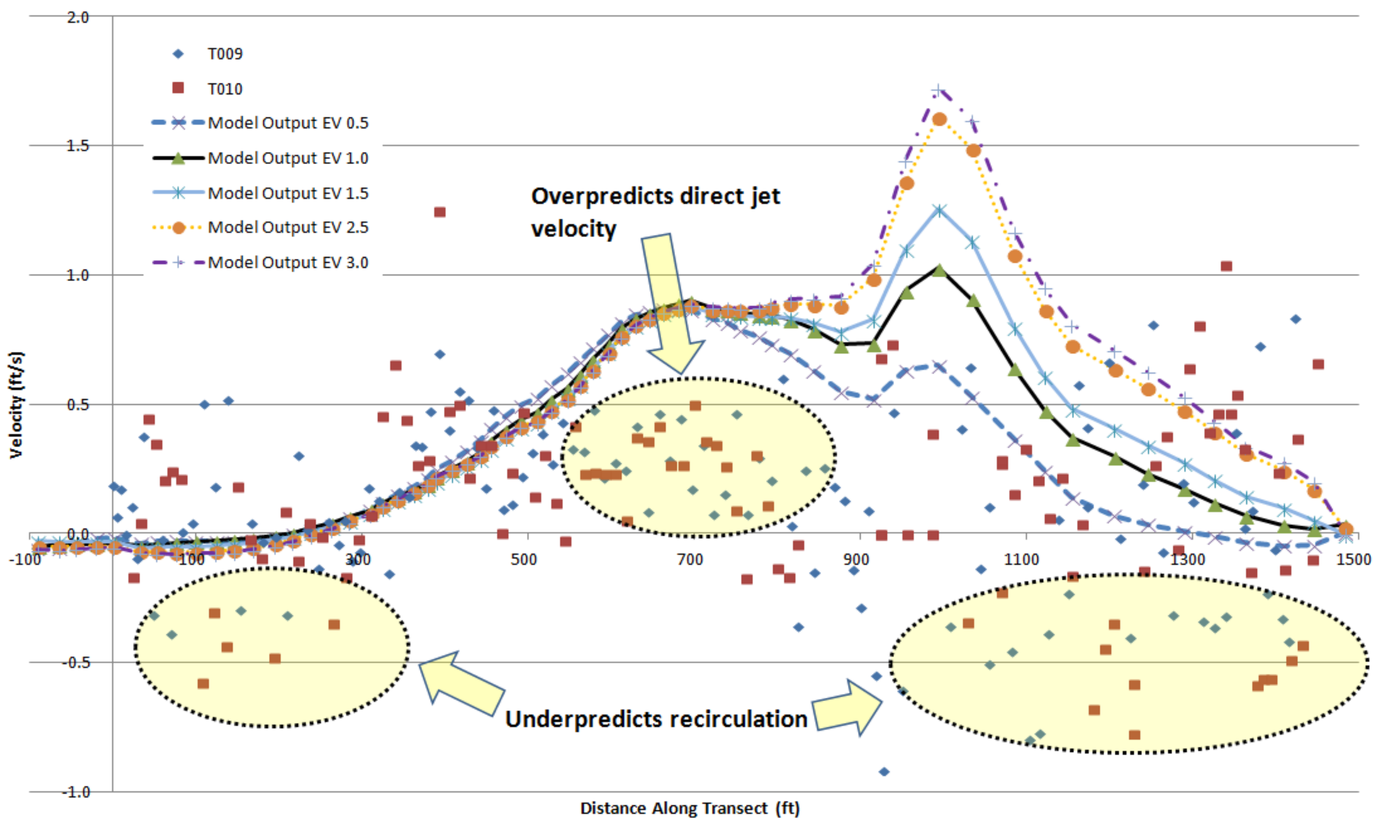
Velocity data from Transects 1, 2, and 3 under pumping and generating phases are shown in Appendix B. Each transect was surveyed twice (once from north to south, then again from south to north), and all four transects were surveyed three times under generation and then three times under pumping. Transect 4 was omitted from the Appendix due to very low observed velocities (less than 0.1 ft per second) since it is so far from the intake channel. Pumping 1 and Generating 1 were not included since they reflected the beginning of a pumping or generating phase and flow fields were still developing (not clearly established). The times of ADCP transect surveys are marked on the data collection timeline in Figure 22.

In the Appendix B velocity transect figures, model velocity output is represented by green triangles. The red squares and blue diamonds represent the measured velocities from both ADCP transect passes. As was mentioned in the Field Observations and Data Conclusions at the end of Section 4.1, low velocities can lead to a high degree of scatter with the ADCP velocity measurements. Transect 2 and 3 measurements tend to be in better agreement with the model results. In general, the generating phase (with lower flow velocities than the pumping phase) tended to have good agreement between the observed and modeled velocities.

Within MIKE21C, surface resistance (somewhat analogous to 1-D model roughness or Manning's *n*) and eddy viscosity are the main parameters used for calibration and validation. The surface resistance was set to a value of 30 which corresponds to a Manning's n value of 0.033 (this value is typical for natural channels and reasonable for the sand bed intake channel and reservoir). Eddy viscosity is normally around 1.0 but can be adjusted to change the magnitude of turbulent effects within the model. The eddy viscosity sensitivity analysis is shown in Figure 24. The data sets with solid or dashed lines represent model results with eddy viscosity (EV) ranging from 0.5 to 3.5. All of the model results at Transect 1 tend to over predict the flow velocity in the center of the transect and tend to under predict the recirculation observed on the north and south edges of Transect 1. An optimal model EV of 1.0 was selected; this is a typical value. Reducing the EV to 0.5 led to numeric stability issues with the annual sedimentation models and was not a practical approach. It should be noted that although some of the measured data appears to show a recirculation trend at the north and south edges of Transect

1 under pumping conditions, the many positive ADCP velocity measurements lead to a net zero flow across the north and south edges of that transect. Model underestimation of negative velocity within weak circulation zones in this area is not expected to significantly impact sedimentation trends within the intake channel.

Figure 24. Eddy Viscosity Sensitivity on P2 Transect 1



5.0 RESERVOIR SEDIMENTATION MODELING RESULTS

Three alternative cases in addition to existing conditions were modeled in the Northfield Mountain Reservoir Sedimentation Study. Beyond the model validation, an existing condition or current operating scheme model (Case 1) was developed. Changes in sedimentation volume for the remaining alternatives (Cases 2, 3, and 4) were compared to the existing condition - current operating scheme model (Case 1). Two lower drawdown/reservoir water level management strategies were investigated (Cases 2 and 3) and one physical change to the system (Case 4) was evaluated. Additionally a sensitivity analysis was performed to understand the amount of drawdown necessary to mobilize deposited sediment from the intake channel.

5.1 Case 1: Current Operational Scheme Sedimentation Model

A representative period of hydrologic record and sediment inflow was applied to the 2-D model to understand the root cause of sedimentation in the reservoir. Boundary conditions described in Section 4 including the model geometry were used for this model. Inflow/outflow hydrology from Figure 18 (reservoir level varies from 1,000 ft to about 938 ft) was applied to the model with respective sediment concentrations from Figures 19 and 20 (coarse and fine sediment, respectively). The model was run for a representative annual period (described in Section 3.3 and shown in Figure 18). Model output is presented in Figures 25 and 26.

For each of the model cases, a snapshot of the reservoir hydraulics (velocity contours and vectors) was taken at a minimum reservoir water surface elevation under power generation. The initial theory was that lowering the operating reservoir water surface level should result in higher outflow velocities which might serve to clean the intake channel (transport accumulated sediment back to the river). Figure 25 shows velocity contours and vectors for the existing condition - current operating scheme model (Case 1). Low velocities in the body of the reservoir (dark blue and cool colors) indicate that sediment which is transported out to this part of the reservoir is unlikely to flush back out during a generating phase. Higher velocity regions (yellow and red colored zones) show that velocity increases in intake channel and is maintained for the most part through to the reservoir inlet. Figure 26 shows the resulting bed change (deposition) for the representative annual period. After 1 year, a fan of sediment over 2' deep at the inlet has developed throughout the intake channel and reaches into the main part of the reservoir.

Figure 25. Velocity Contours and Vectors for Current Operating Scheme Model

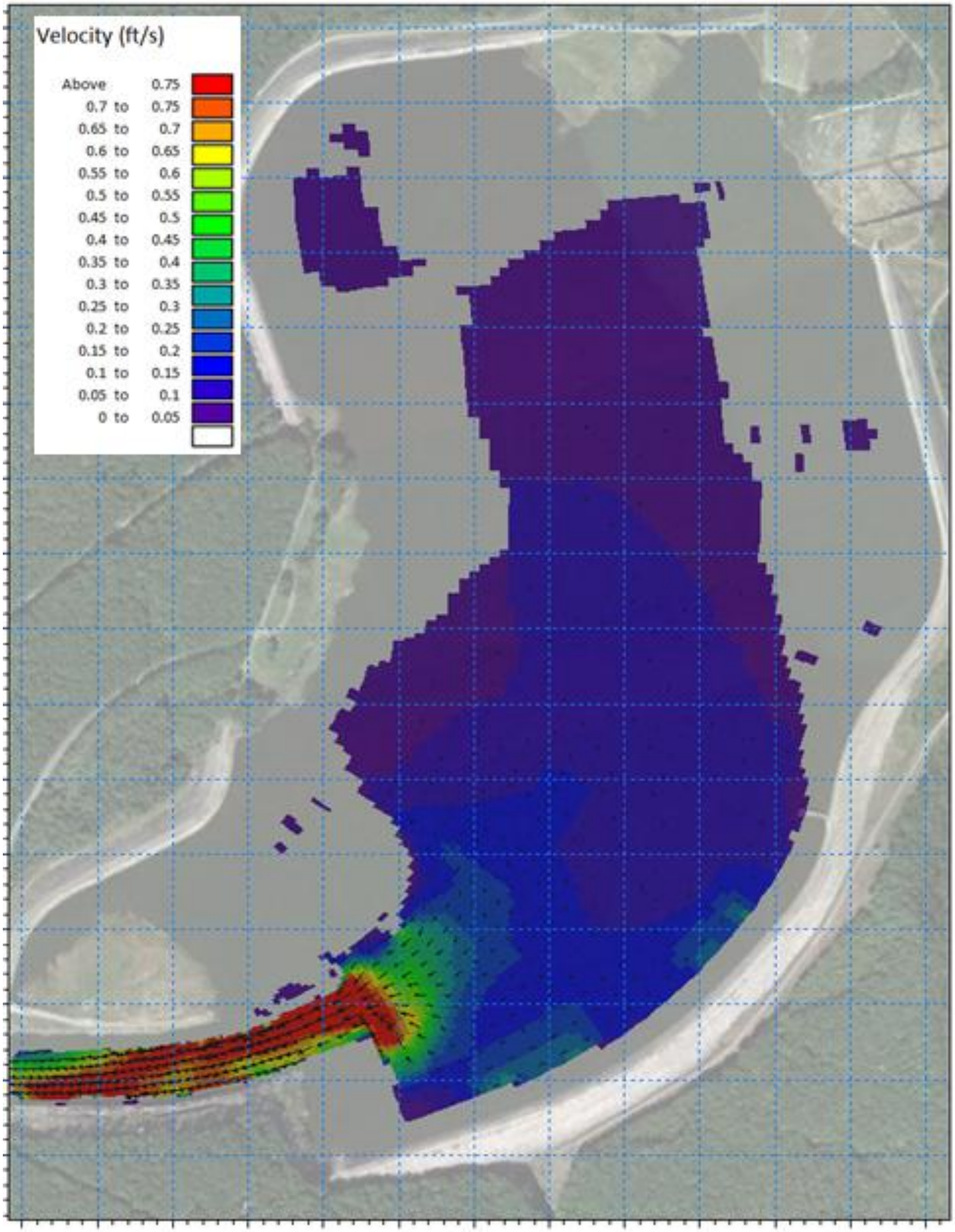
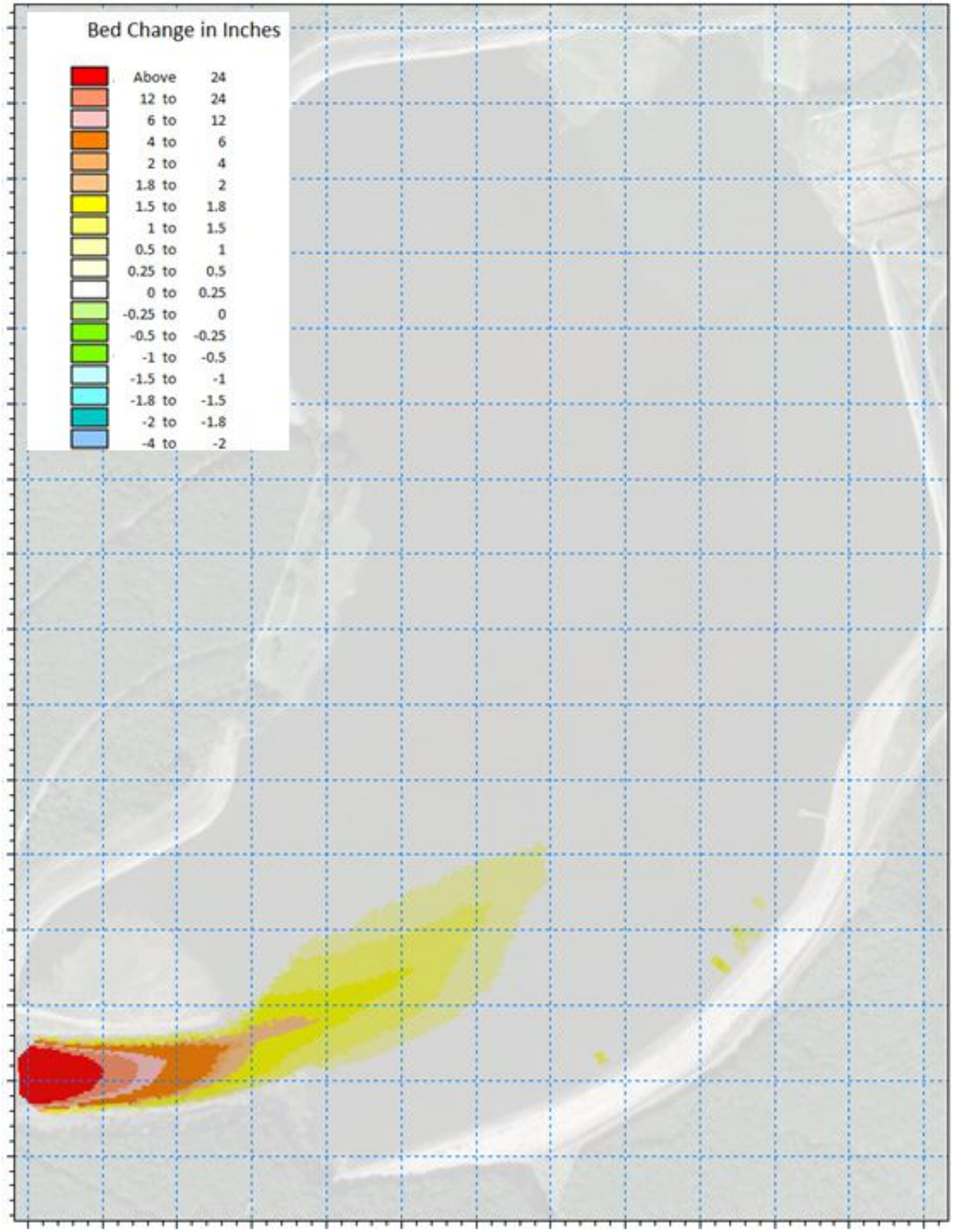


Figure 26. Bed Change for Current Operating Scheme Model



5.2 Case 2: Modified Reservoir Operations – 930 ft Minimum Reservoir Level

With a benchmark or existing condition established in Case 1, the alternative models were developed and executed; results are summarized in each of the following sections. The second model was identical to Case 1 (existing condition) with the exception of lower operational water surface levels in the reservoir. Figure 27 shows the inflow/outflow hydrograph which was essentially shifted 10 feet down in elevation from the current operating scheme model input.

Comparing Figures 25 and 28, the reservoir end of the intake channel has consistently higher velocities with a 930’ minimum reservoir water surface (Case 2) and velocities through the west end or inlet to the intake channel are generally higher under this operational scheme.

Direct comparison of the annual sedimentation for the 930’ minimum reservoir level model (Figure 29) to the existing conditions model (Figure 26) is difficult, so Figure 30 was included to better understand the difference in deposition between Cases 1 and 2. The colored regions represent the difference in annual bed change between the two cases. Looking at Figure 30, it is clear that most of the impact (lessening of sediment deposition) is at the reservoir inlet. Case 2 tends to have higher velocities at the reservoir inlet and this condition helps to re-entrain and flush a portion of reservoir sediment out of this area.

Considering the lower reservoir volume comparison zone shown in Figure 31 (including the intake channel and lower portion of the reservoir), the model output indicates about a 4.9% reduction in annual sediment deposition with Case 2; the reduction is localized to the inlet area. Case 2 leads to a 4.2% overall reduction in sediment over Case 1 if the entire reservoir is considered.

Figure 27. Case 2 Water Surface Elevation– 930 ft Minimum Reservoir Level

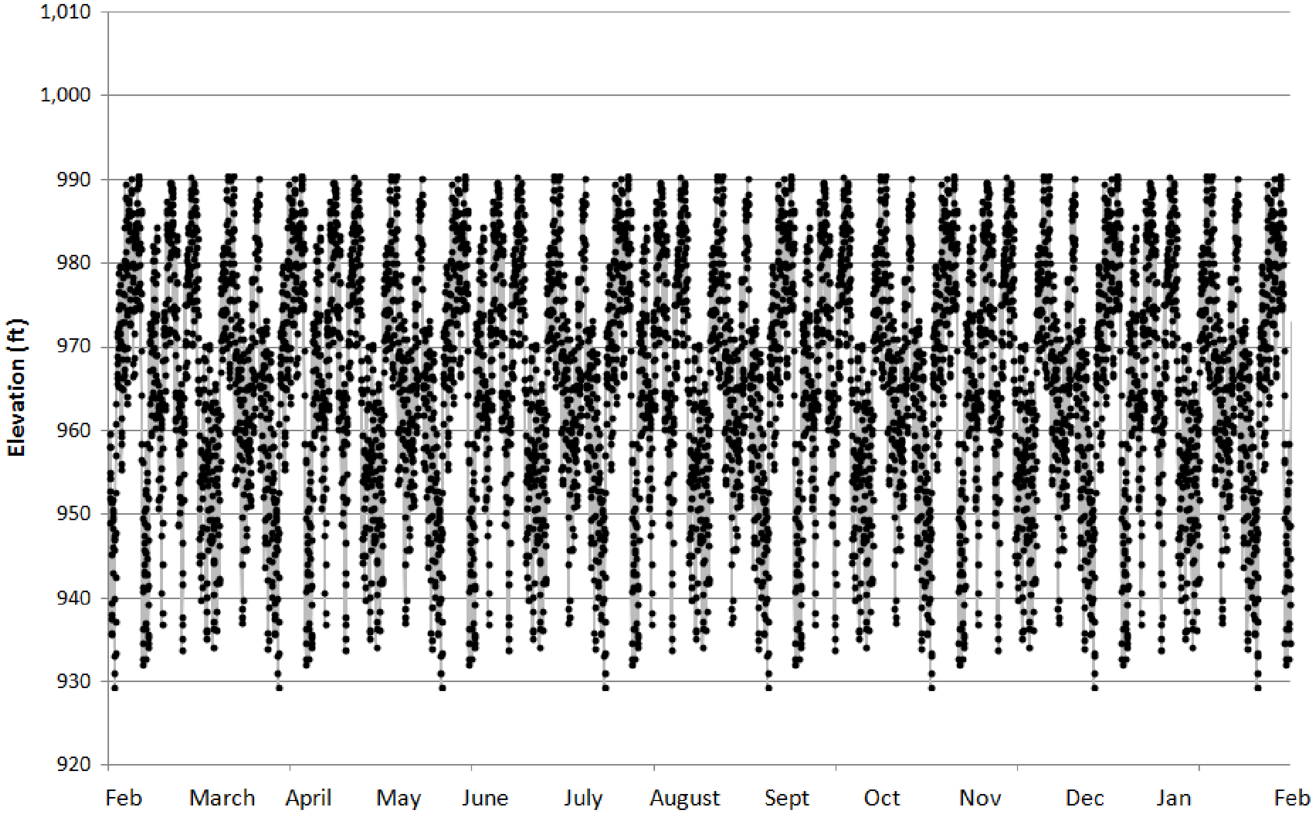


Figure 28. Velocity Contours and Vectors for 930 foot Minimum Reservoir Water Surface

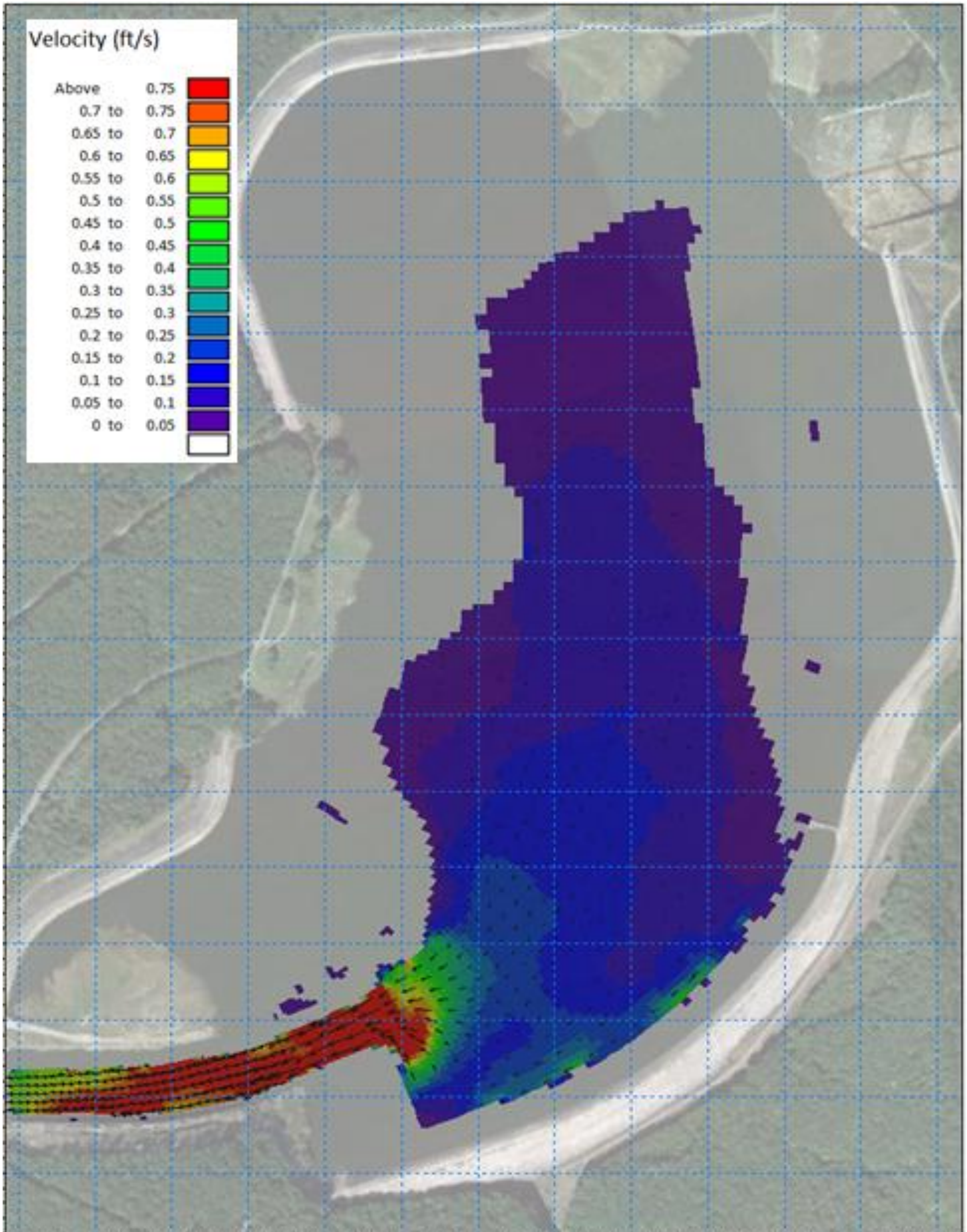


Figure 29. Bed Change for 930 foot Minimum Reservoir Water Surface Level Model

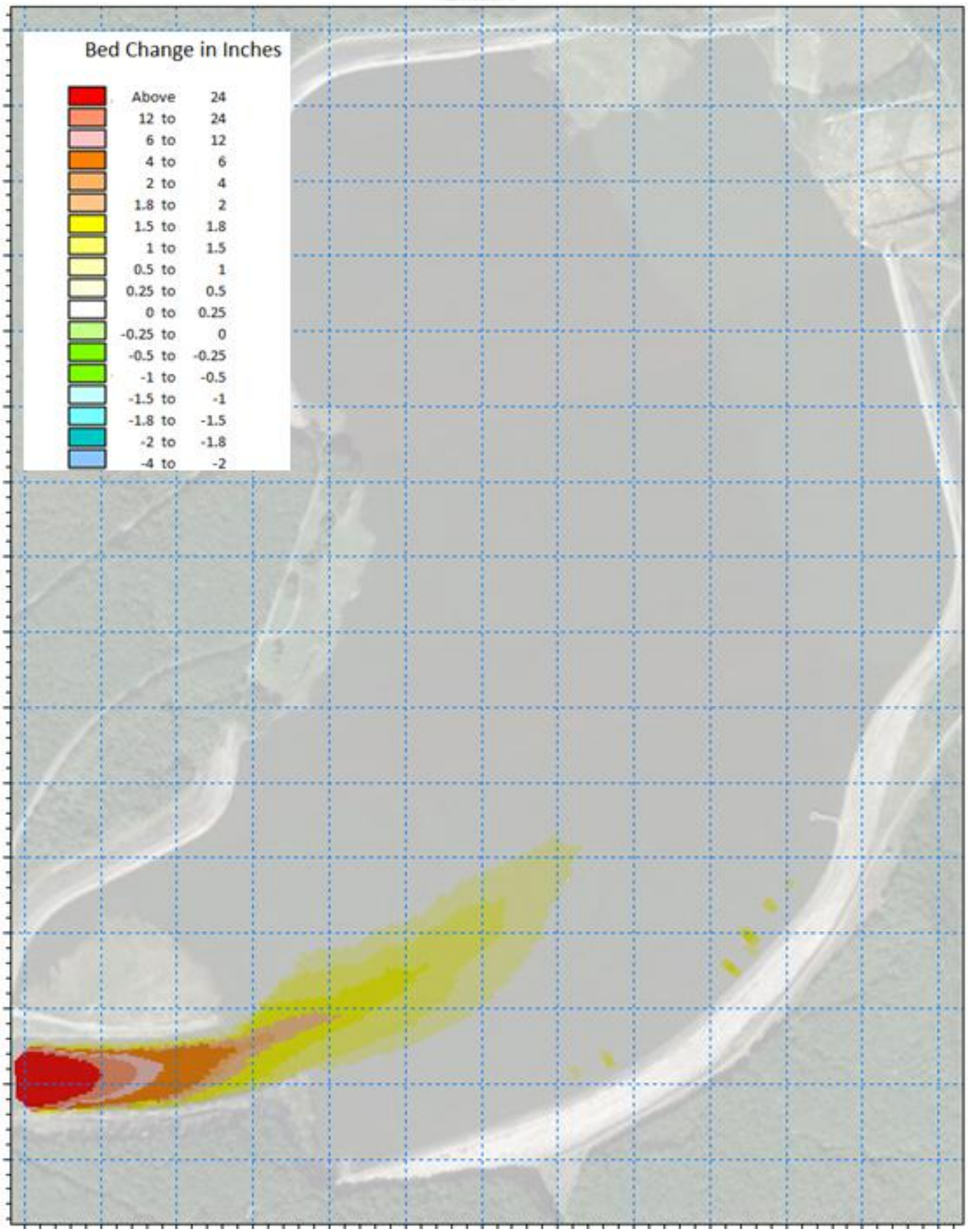


Figure 30. Difference in Bed Change Compared to Existing Conditions – 930' Min Level

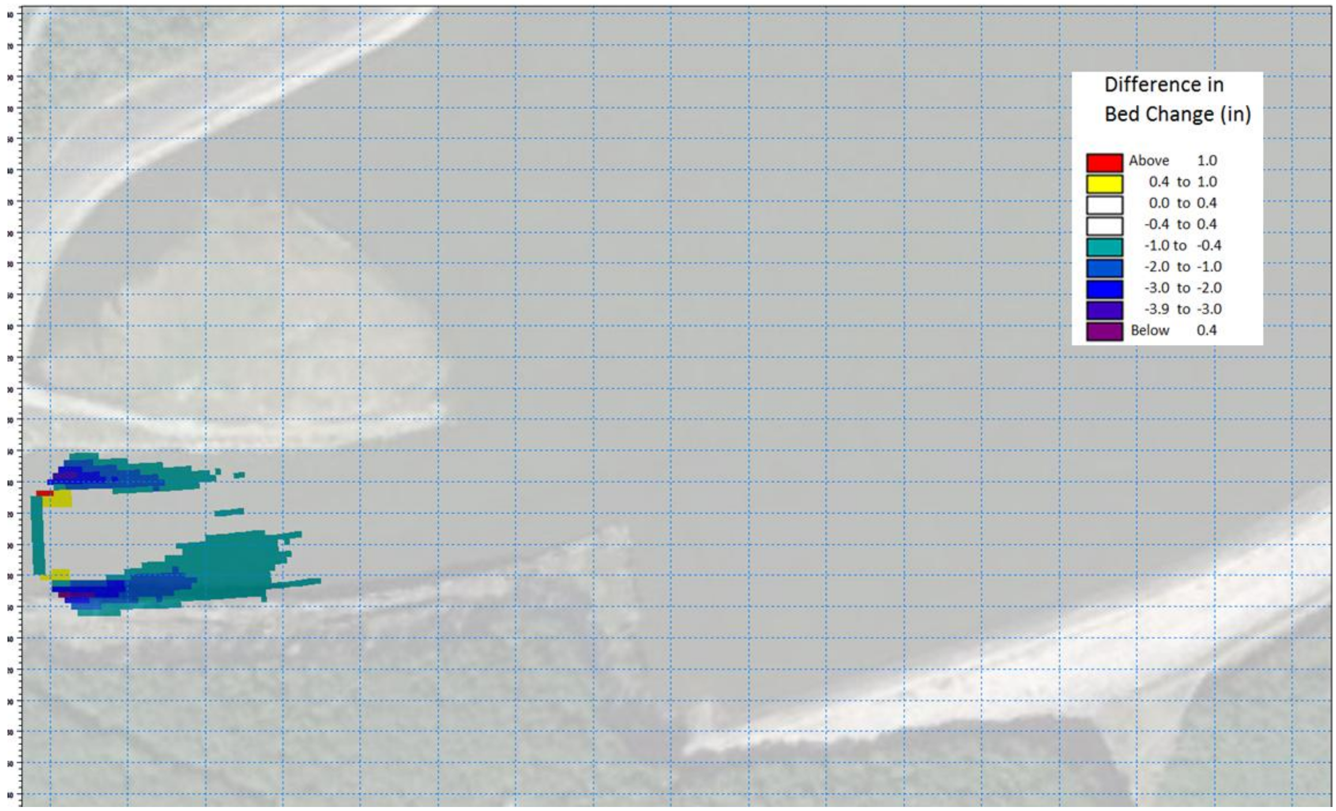
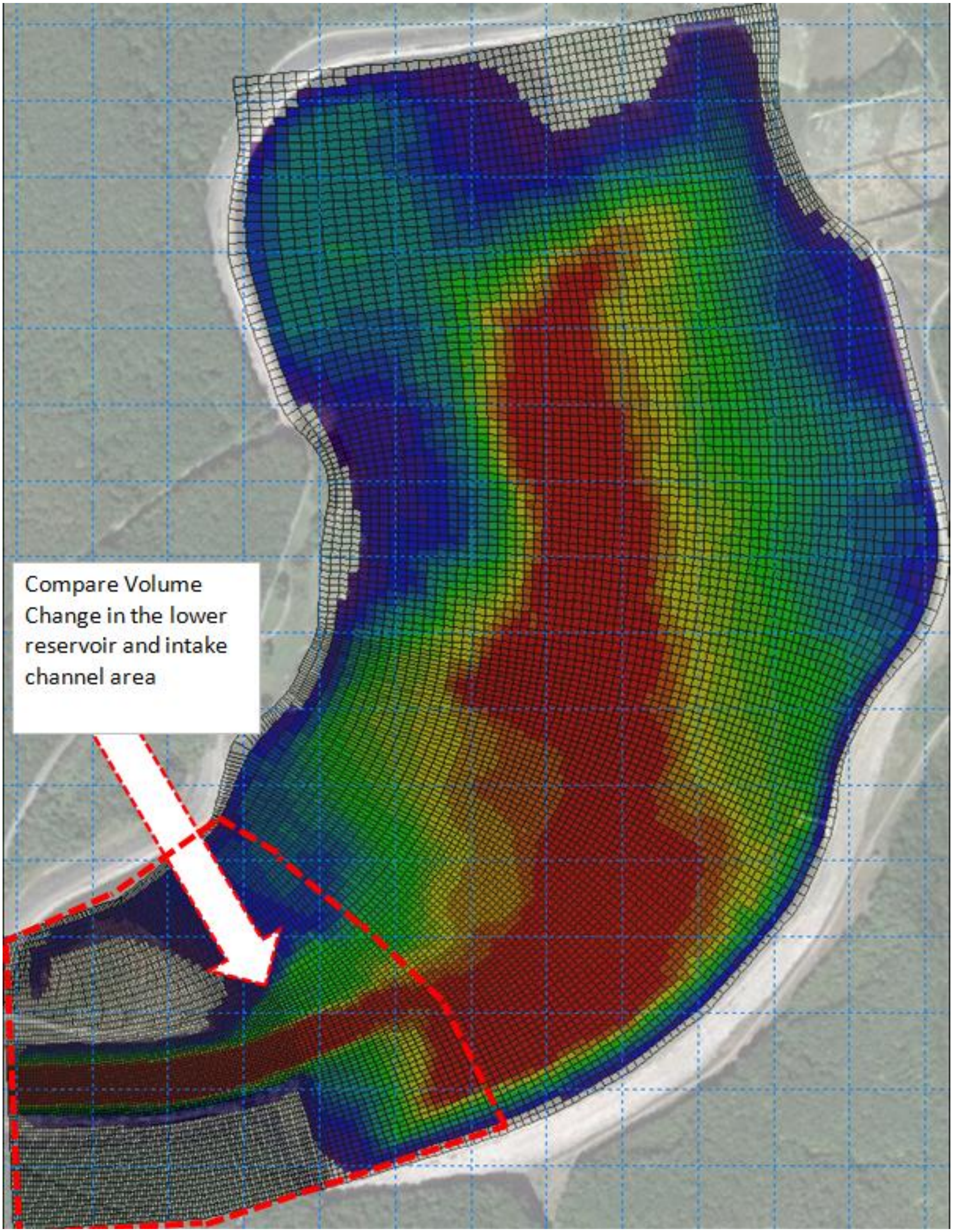


Figure 31. Intake Channel and Lower Reservoir Volume Calculation Zone



5.3 Case 3: Modified Reservoir Operations – 920 ft Minimum Reservoir Level

Case 3 is a continuation of the Case 2 concept with additional lowering of the operational reservoir water surface level down to a minimum of 920 feet. This concept is similar to legacy reservoir level operational limits and was considered to further investigate the effects of higher flow velocity in the intake channel resulting from lower minimum reservoir levels under generation phases. Figure 32 shows the inflow/outflow hydrograph for Case 3, it is essentially the same as the Case 2 hydrograph with eight annual drawdowns to 920 feet.

Figure 33 shows consistently higher velocity contours and vectors for Case 3 when compared to Case 1 and Case 2. Again the developed sediment plume in Figure 34 looks similar to the Case 1 and Case 2 sediment deposition output (Figures 26 and 29). As with Case 2, the dark colors in Figure 35 indicate a tendency for the intake channel to clean sediment near the inflow chamber under generating phases when compared to the current operational scheme.

Again considering the intake channel/lower reservoir volume comparison zone, the Case 3 model output shows about a 5.1% reduction in annual sediment deposition and a 4.4% overall reduction in sediment deposition when compared to Case 1 over the entire reservoir.

Figure 32. Case 3 Water Surface Elevation– 920 ft Minimum Reservoir Level

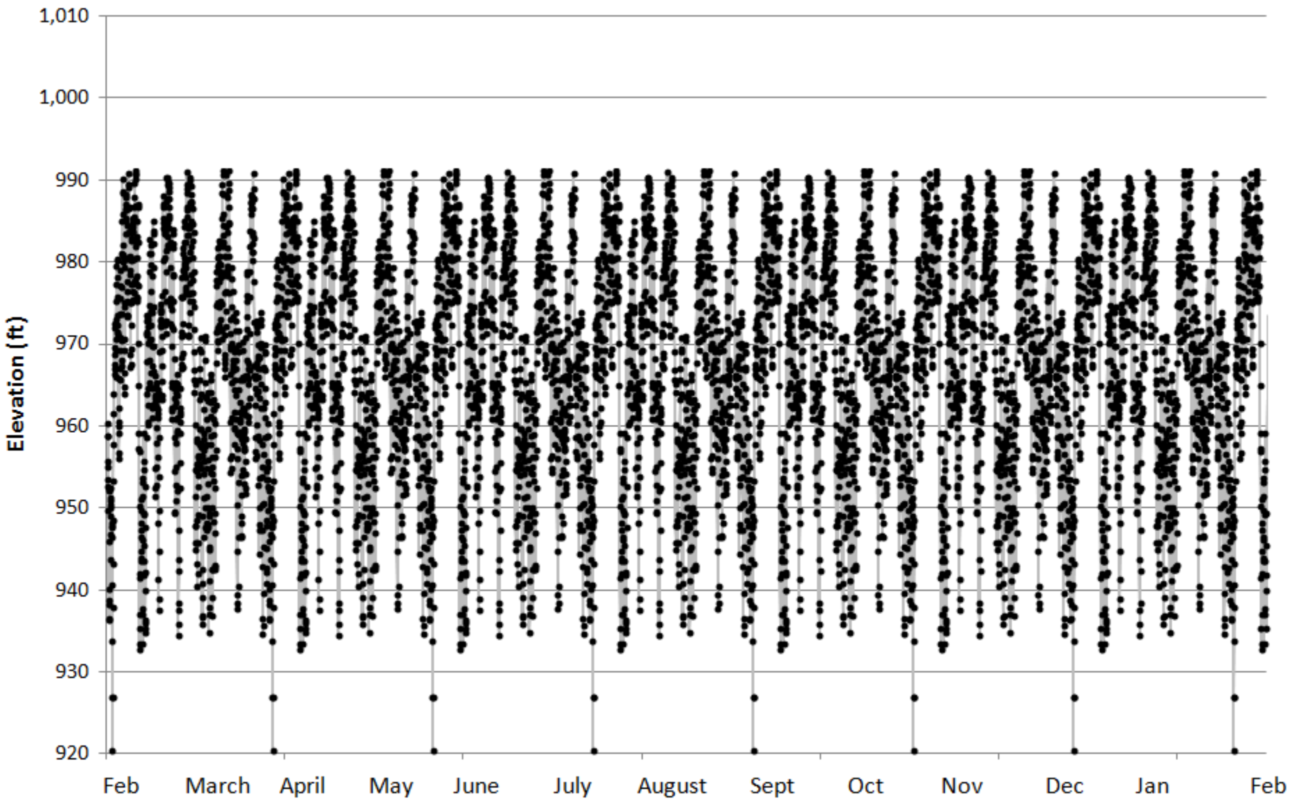


Figure 33. Velocity Contours and Vectors for 920 foot Minimum Reservoir Water Surface

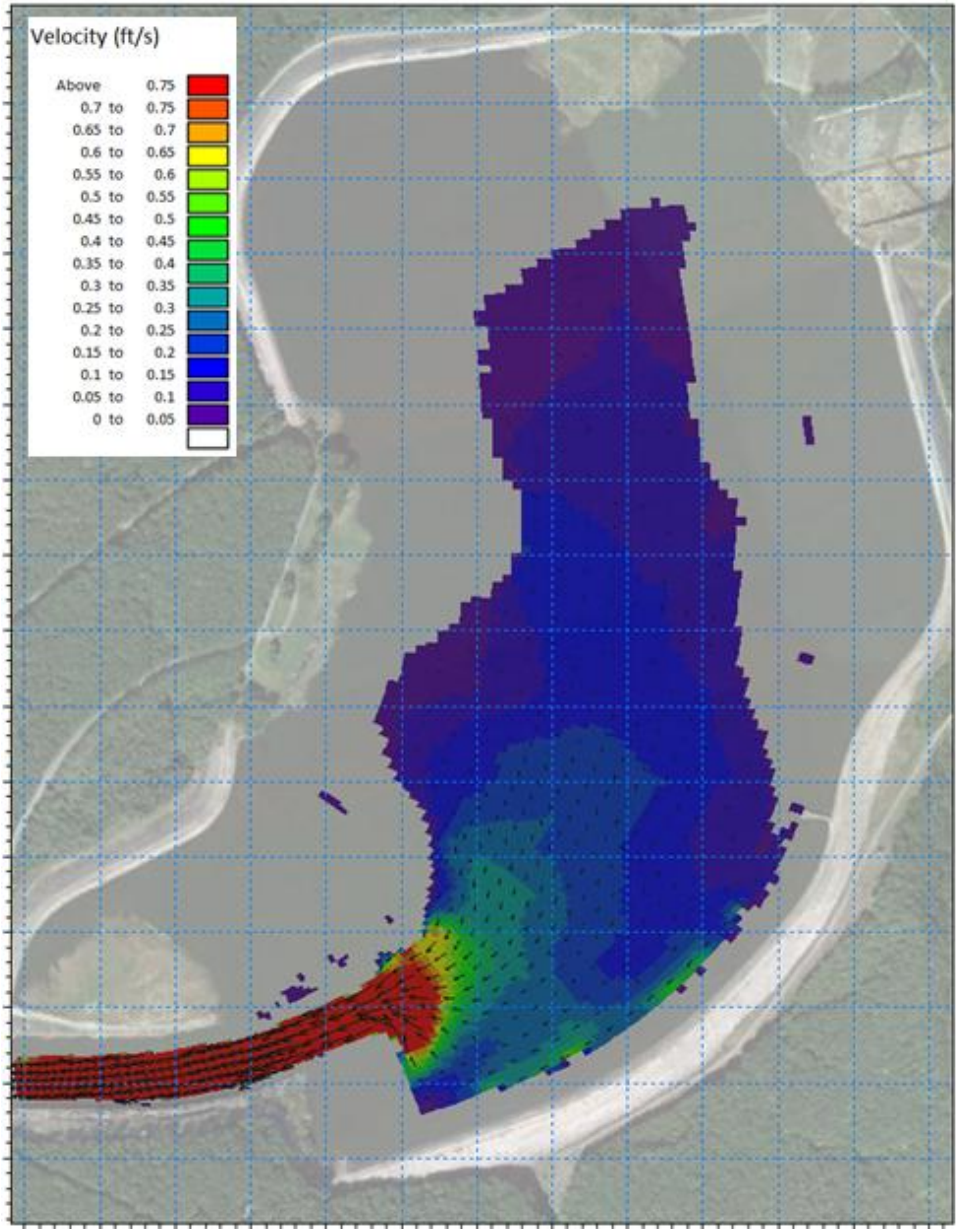


Figure 34. Bed Change for 920 foot Minimum Reservoir Level Model

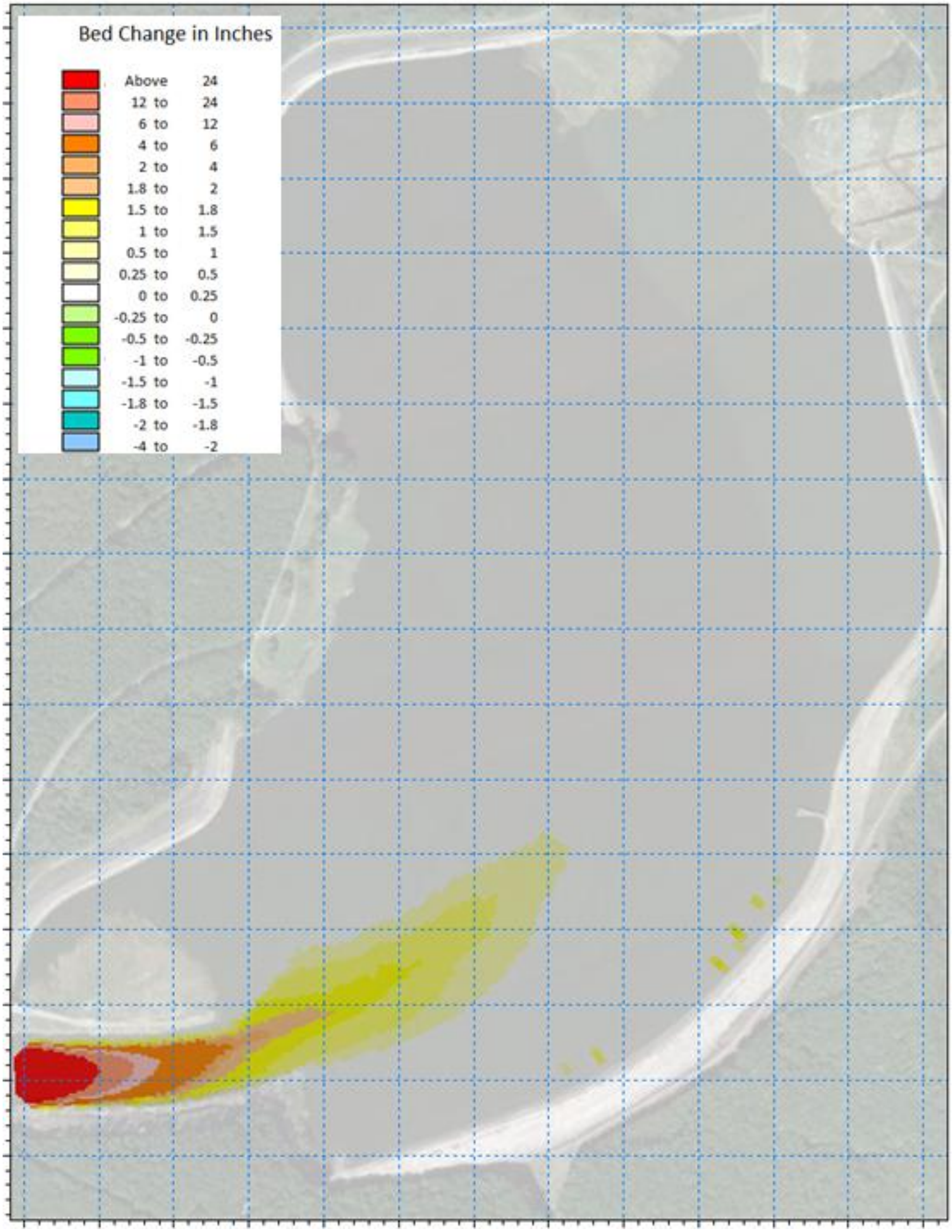
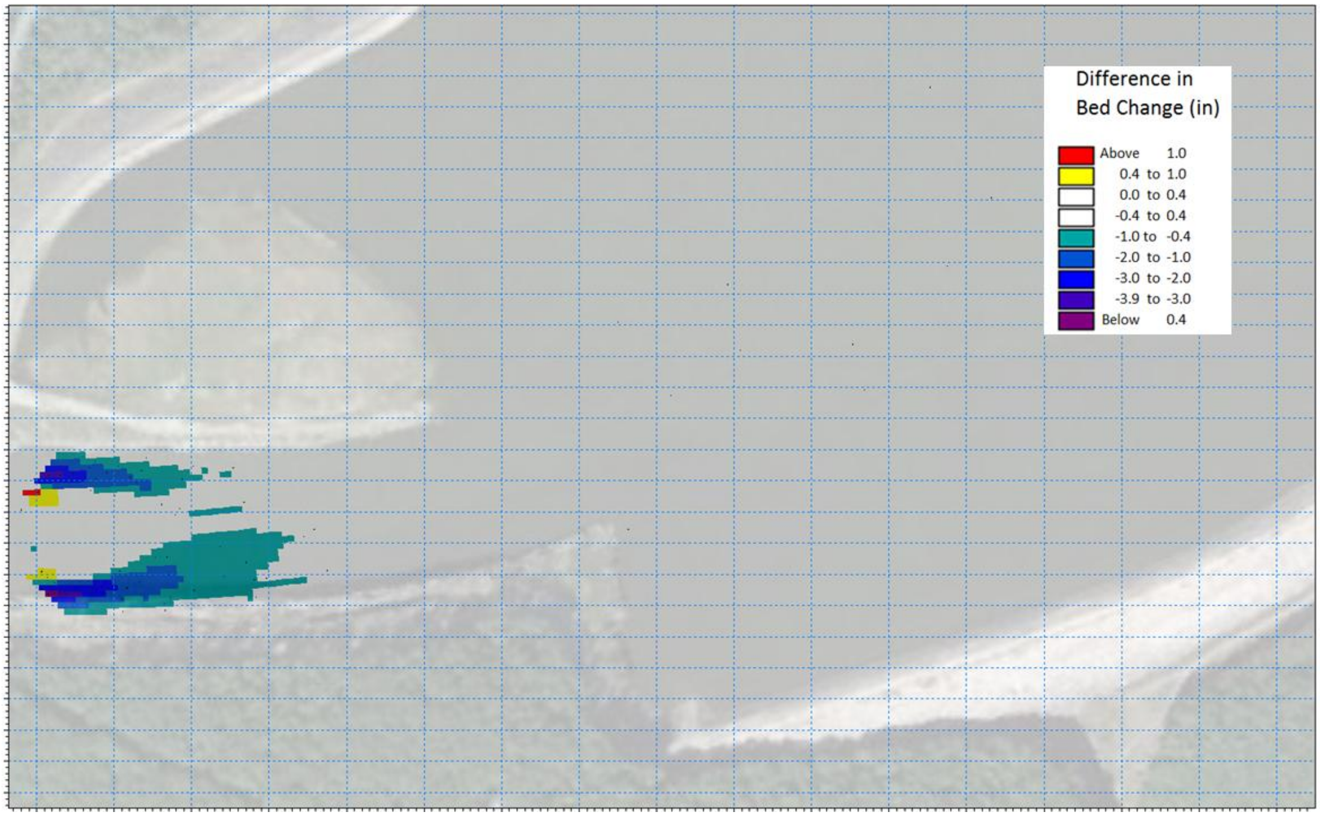


Figure 35. Difference in Bed Change Compared to Existing Conditions – 920' Min Level



5.4 Case 4: Physical Reservoir Modification

The physical modification concept (Case 4) was that by narrowing the intake channel, flow velocities would be higher and sediment material may not settle in the intake channel during pumping phases and/or might more efficiently flush out during generation phases. A section of about 700 feet on the south side of the intake channel was narrowed by 50 feet as shown in Figure 36. The current operating conditions hydrograph (reservoir water level ranging from 938 to 1,000 feet – Figure 18) was used for this case.

The velocity contours and vectors in Figure 36 are uniformly higher in the intake channel and slightly higher at the intake than the Case 1 results. The sediment plume in Figure 37 follows the same trend as with other cases, except that it is narrower due to the physical blockage of the south side of the intake channel. Figure 38 shows that deposition is reduced along the narrowed section and in the northwest corner of the intake channel (dark colors). Some parts of the middle of the intake channel experience more deposition in Case 4 (yellow and red colored areas) than in Case 1.

Narrowing the intake channel reduced deposition within the intake channel/lower reservoir volume comparison zone by 4.9% when compared to Case 1. The Case 4 model output shows about a 4.1% reduction in annual sediment deposition over Case 1 throughout the entire reservoir

Figure 36. Velocity Contours and Vectors for Narrow Intake Channel Model

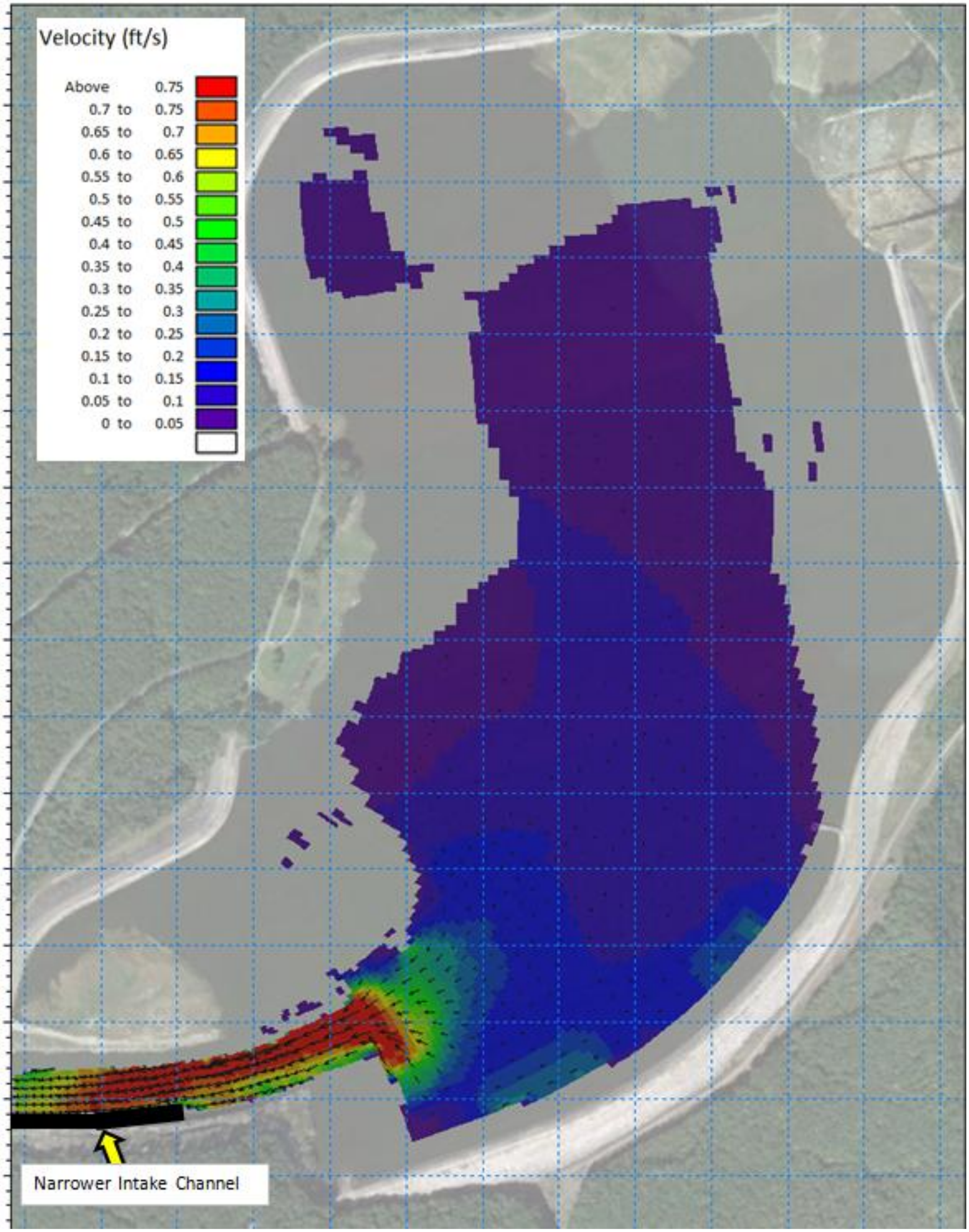


Figure 37. Bed Change for Narrow Intake Channel Model

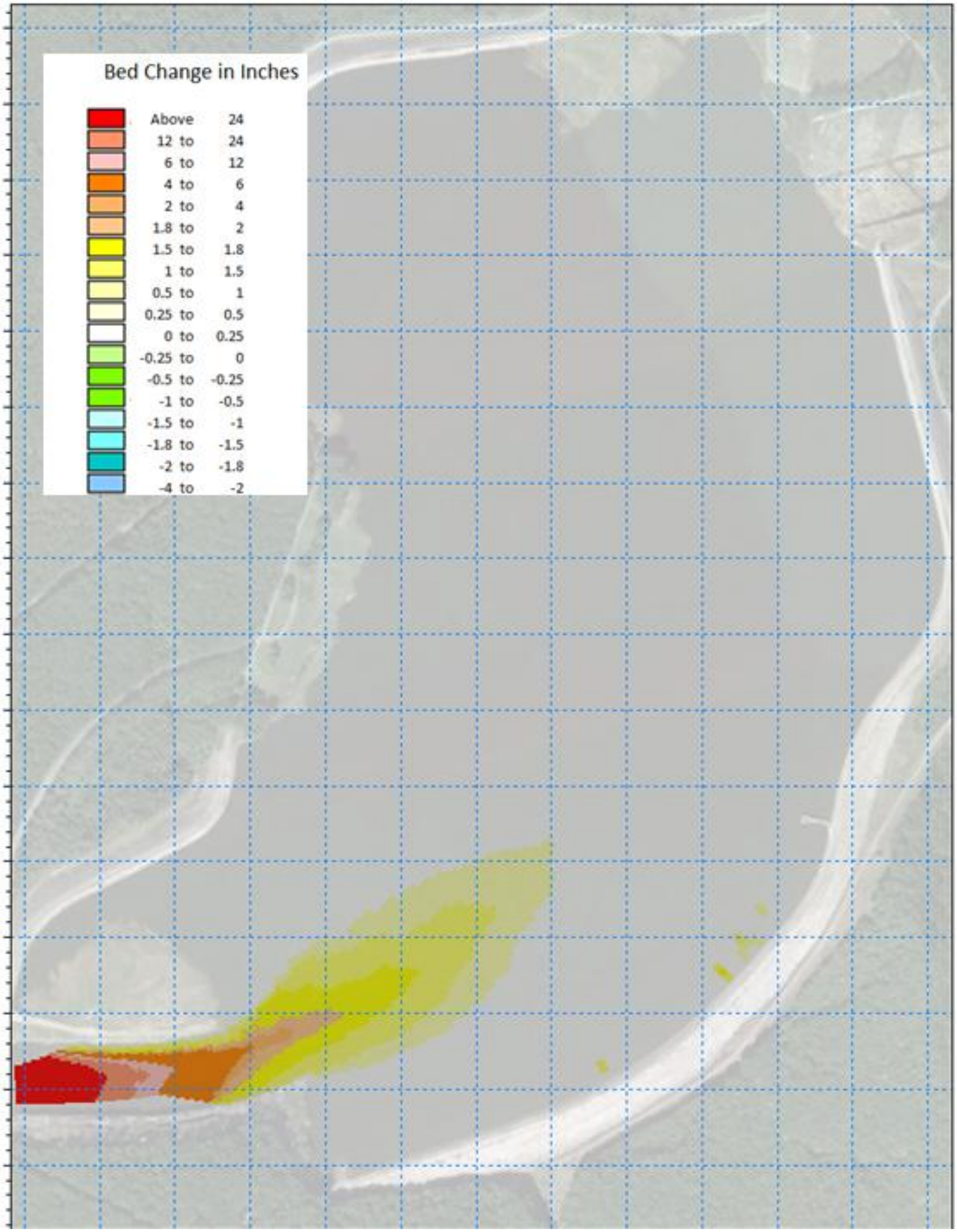
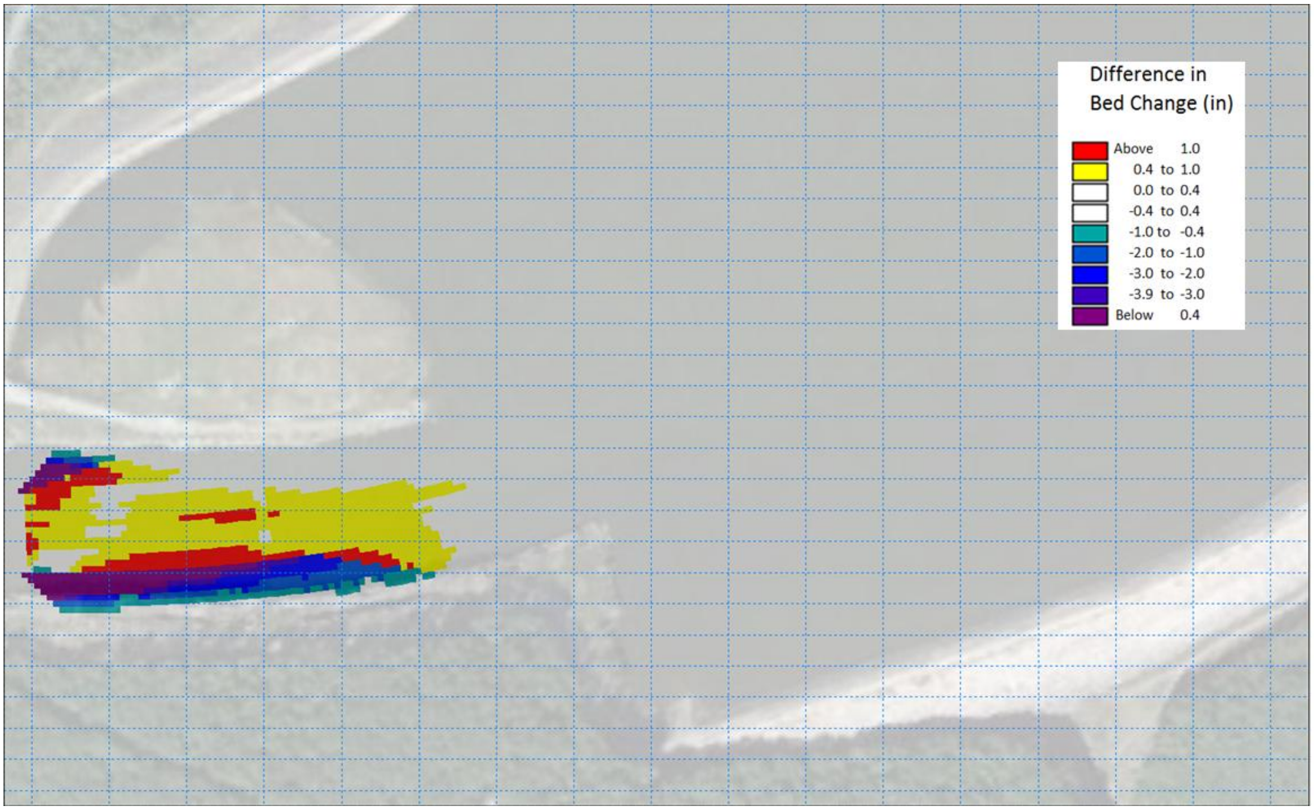


Figure 38. Difference in Bed Change Compared to Existing Conditions – Narrow Intake



5.5 Sediment Mobilization Drawdown Sensitivity

In 2010, a drawdown resulted in sediment mobilization. Figure 39 shows the sediment deposition within the intake channel after the subsequent 2010 dewatering.

A sensitivity analysis was performed to understand more about the relationship between level of reservoir drawdown and mobilization of deposited sediment. Discussion with FirstLight Staff indicated that a drawdown to about 901 feet may be possible to manage sediment within the reservoir. Two models were generated to visualize sediment response to a flushing drawdown. The first model reflects the present bed geometry (2011 survey) after one year of sediment deposition as described in previous sections. The second model was used to demonstrate the mobilization of the accumulated sediment using the pre-dredging or 2010 channel geometry (after 20 years of sediment deposition). A station line along the intake channel is shown in Figure 40. Figures 41 and 42 show the intake channel profile along the station line for the existing (Post 2010) and pre-dredging (2010) conditions before (green line) and after (red line) the reservoir flushing drawdown (1000 to 901 feet).

The sensitivity modeling results indicate that a reservoir drawdown to 901 feet is not sufficient to mobilize the small amount of annual deposition in shown in Figure 41 (the green – pre drawdown and red – post drawdown lines are coincident). However sediment within the pre-dredging intake channel with 20 years of sediment deposition (Figure 42) is mobilized as the water level is drawn down to a 901 foot level. This result is consistent with the dewatered photograph in Figure 39; a sediment conveyance channel developed along the south side of the intake channel as the deposited sediment volume became unstable and failed into this area.

Figure 39. Sediment Deposition (2010)

Figure 40. Intake Channel Station Line

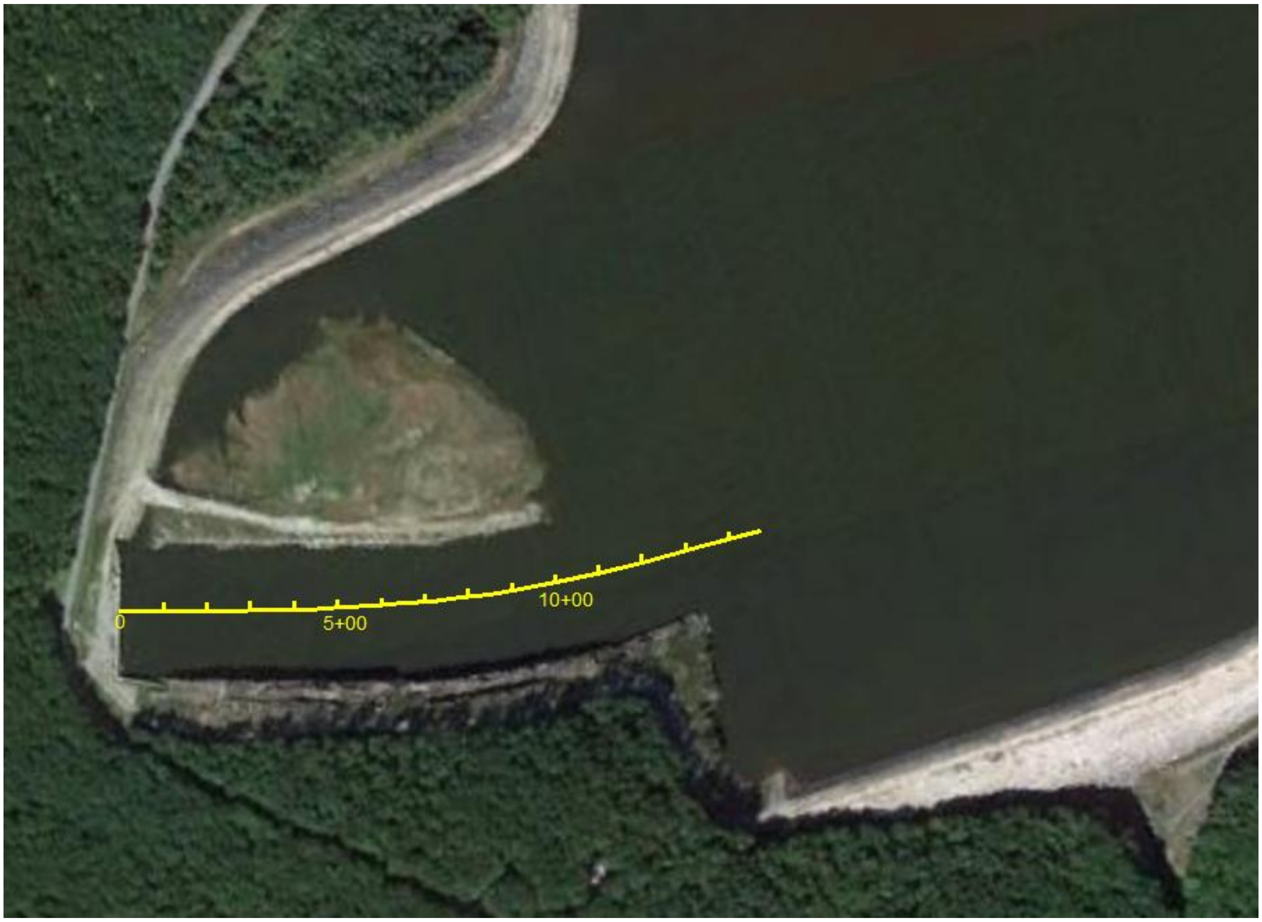


Figure 41. Sediment Mobilization Under Drawdown (Post 2010)

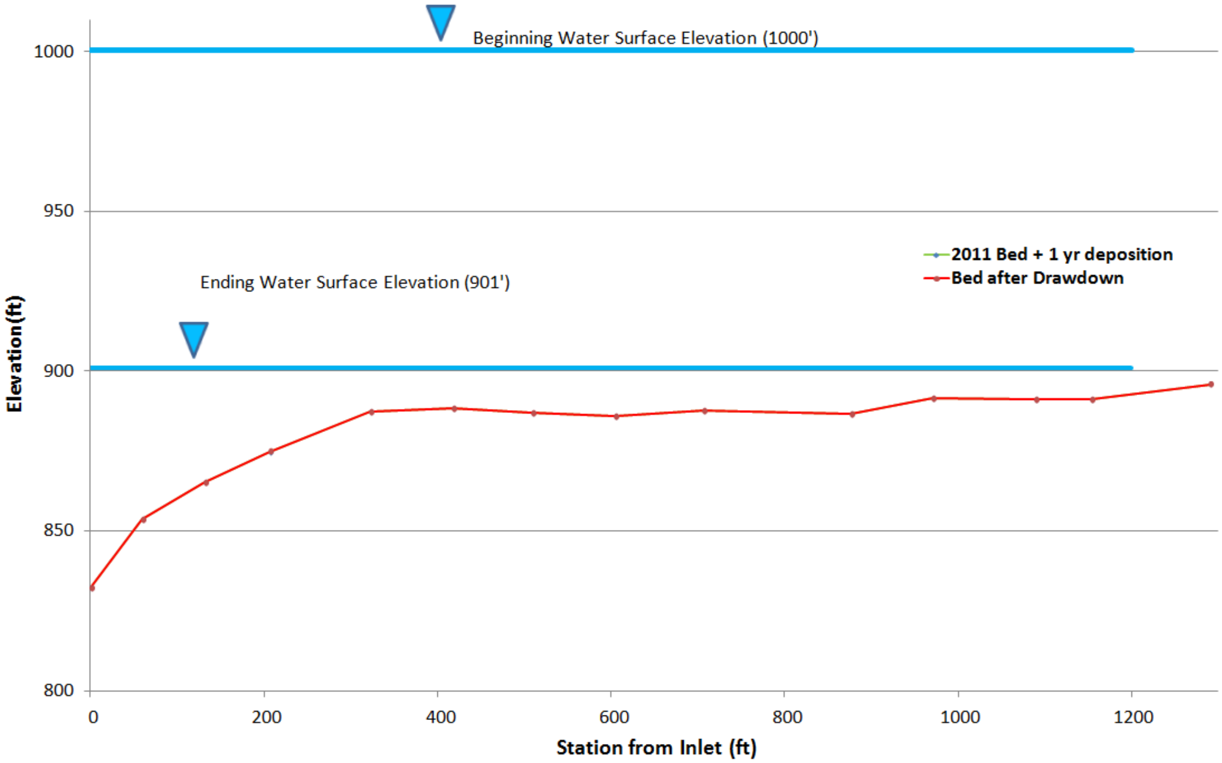
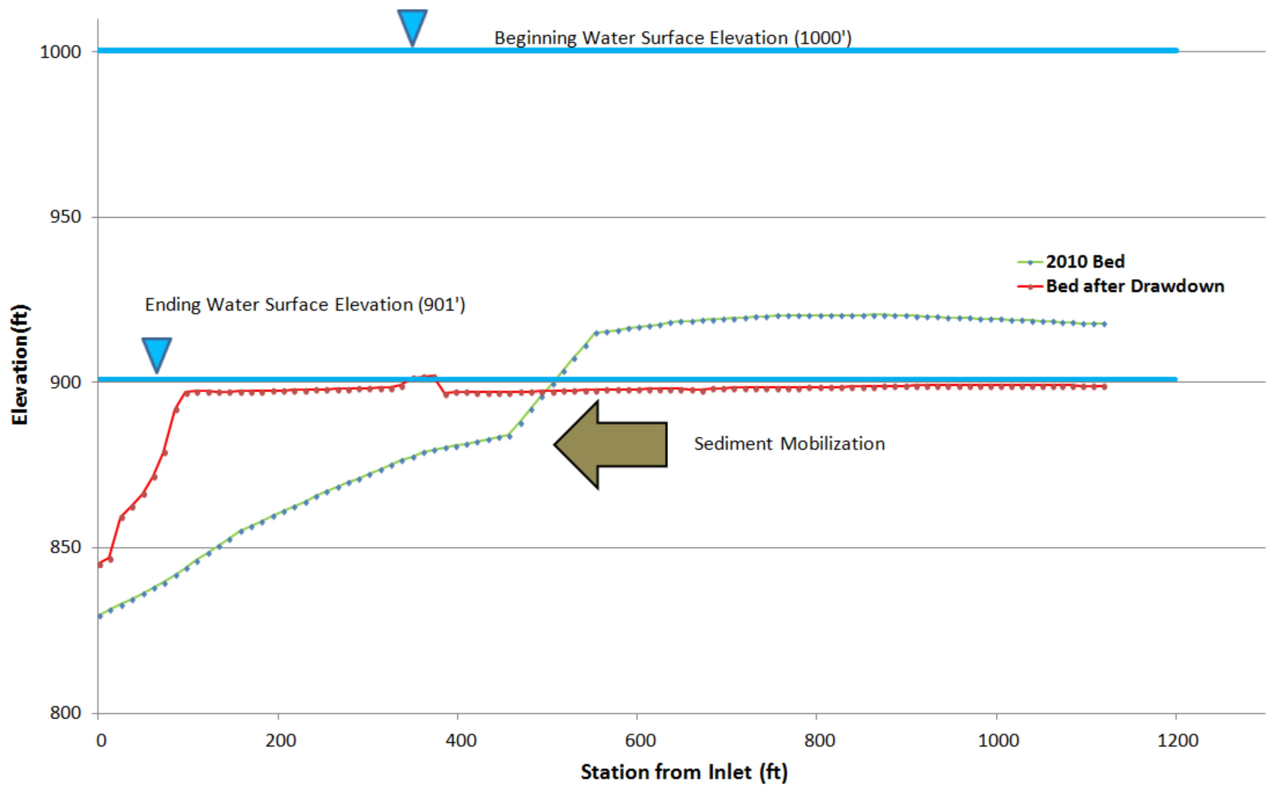


Figure 42. Sediment Mobilization Under Drawdown (2010 Channel Geometry)



6.0 CONCLUSIONS

The root cause of sedimentation in the Northfield Reservoir likely begins with relatively high concentrations of entrained bed and suspended load sediment from the Connecticut River being transported with process water under pumping phases. The water and sediment are transported at a high flow velocity through the conduit system to the upper reservoir. As the water and sediment combine with water already in the intake channel, the wider and deeper intake channel leads to a deceleration of the sediment rich pumped water and subsequent deposition of the sediment. Exit velocities are lower in the intake channel under generation than in the river intake and conduit system under pumping, so much of the deposited sediment cannot be re-entrained and flushed from the reservoir.

The cases analyzed in this study indicate that operational changes may be as or more effective than structural changes at reducing sediment deposition in the Northfield Mountain Upper Reservoir. Both operational changes (Cases 2 and 3) reduce sediment on the order of 4% to 5% over existing conditions/current operating procedures. Narrowing the intake channel (Case 4) also leads to a 4% to 5% reduction in sediment accumulation compared to current operating procedures. Table 3 summarizes the modeled reduction in reservoir sedimentation for Cases 2, 3, and 4 compared to Case 1 over a representative annual period.

A sensitivity analysis of larger drawdowns was performed to understand how accumulated sediment can be mobilized. The results of this analysis indicate that reservoir drawdown to a level of 901 feet does not generate sufficient flow velocities to mobilize small (annual) amounts of sediment. Larger volumes of sediment accumulation lead to a higher intake channel profile which in turn produces higher velocities under the flushing drawdown to 901 feet. An adaptive sediment management plan can be developed to draw down the reservoir level for flushing on a periodic basis. Annual reservoir surveys will inform this process. When significant sediment build up is observed a plan can be used to slowly draw down the reservoir to a level where some of the sediment could be released in a controlled manner.

A study is presently underway to look at sedimentation processes at the Connecticut River intake/outfall. It is expected that changes to the downstream (Connecticut River) end of the system to exclude sediment may compliment operational changes and periodic reservoir flushing. This approach may be more effective than expensive structural modifications to the reservoir intake channel in limiting sediment from the river being transported to and deposited into the Northfield Mountain Upper Reservoir.

Table 3. Potential Sediment Reduction of Cases over Current Operating Conditions

Case	Reduction in Deposition Over Case 1	Reservoir	Intake Area
2	930' Min. Reservoir	4.2%	4.9%
3	920' Min. Reservoir	4.4%	5.1%
4	Narrow Intake Channel	4.1%	4.9%

8.0 REFERENCES

1. "20111106-NorthfieldMtn-SiteDatum-Contours-5ft.dxf". Provided by FirstLight March, 2013.

2. "Northfield Upper Reservoir Elevation Data 2000-2009.xlsx". Provided by Gomez and Sullivan November, 2013.

3. "StreamSide Data for Alden.xlsx". Provided by Gomez and Sullivan November, 2013.

4. Geotube Smartfeed Dewatering Technology Testing for FirstLight Power Resources. Mineral Processing Services, LLC. September 20, 2013.

5. 2011 Upper Reservoir Hydrographic Survey. Ocean and Coastal Consultants, Inc. November 30, 2011.

6. Sediment Management Plan – 2012 Summary of Annual Monitoring, Northfield Mountain Pumped Storage Project FERC No. 2485-058. Gomez and Sullivan, November 30, 2012.

7. 2013 Existing Conditions Hydrographic Survey - Upper Reservoir Northfield Mountain Pumped Storage Facility. CHA Consulting, Inc. October 31, 2013.

8. "July 31_August 2.xlsx". Provided by FirstLight October, 2013

APPENDIX A: Reservoir Stage Record 2000 – 2009

Figure A- 1. Historic Reservior Water Surface Elevations

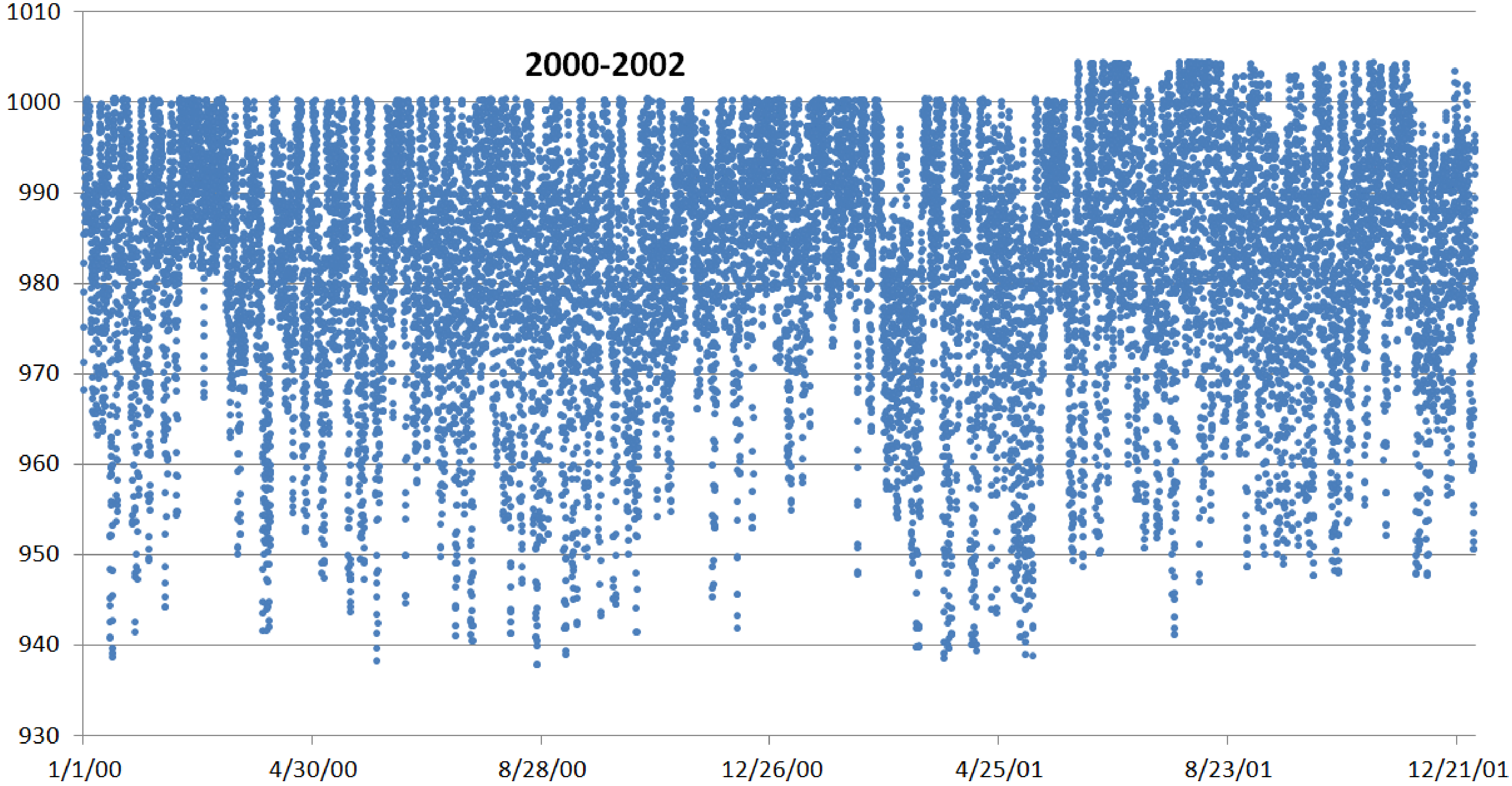


Figure A- 2. Historic Reservior Water Surface Elevations

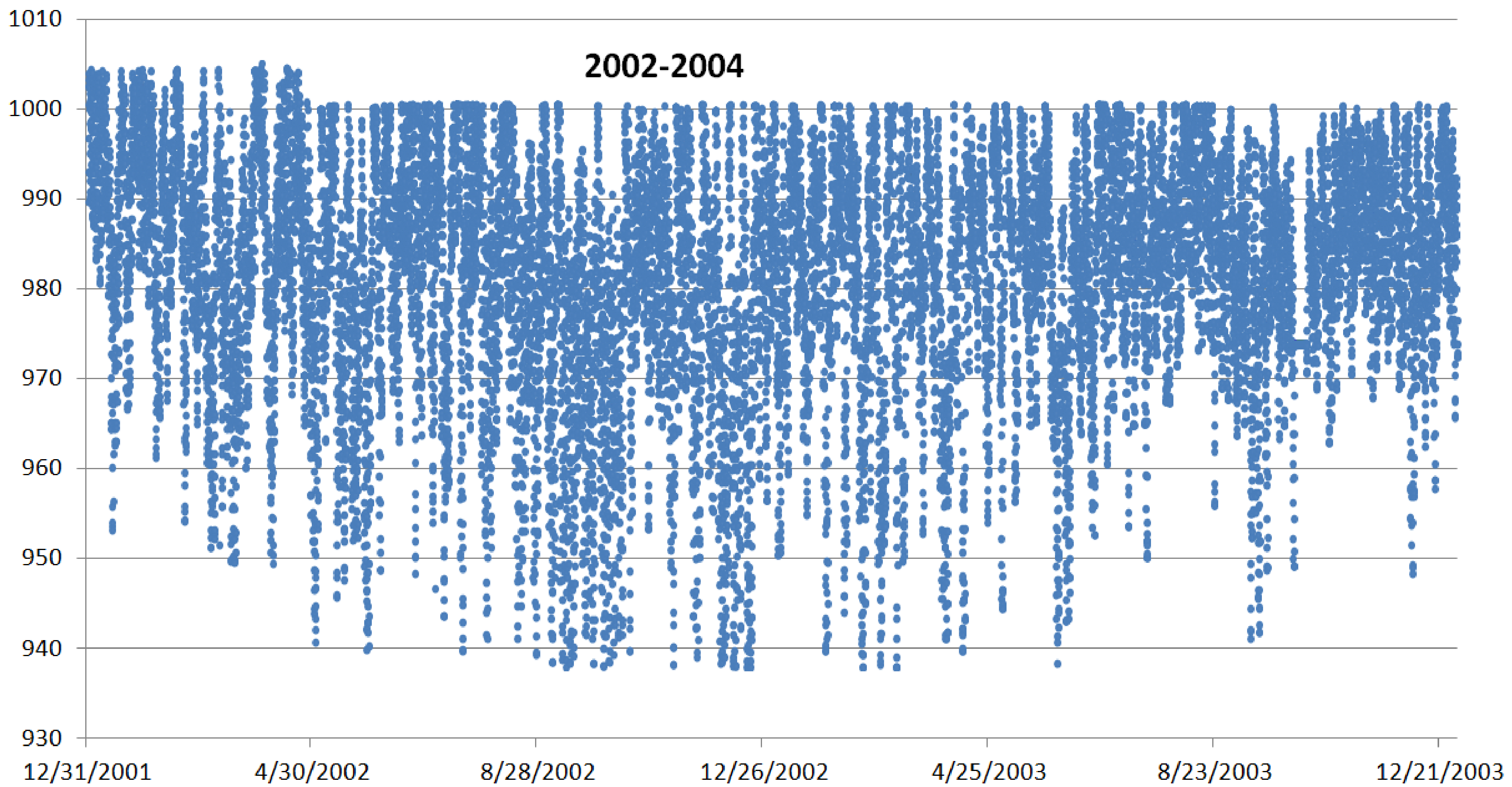


Figure A- 3. Historic Reservior Water Surface Elevations

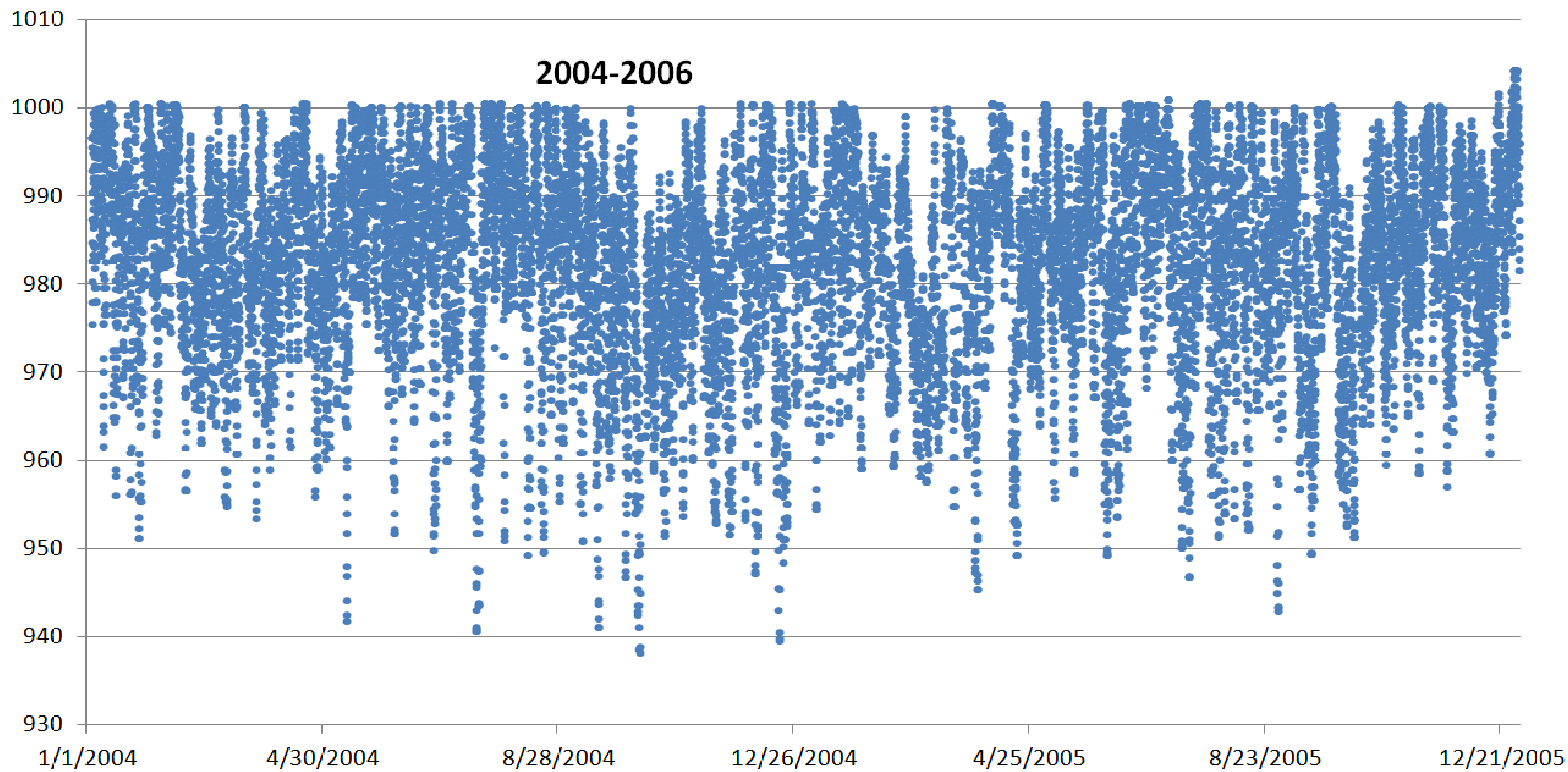


Figure A- 4. Historic Reservior Water Surface Elevations

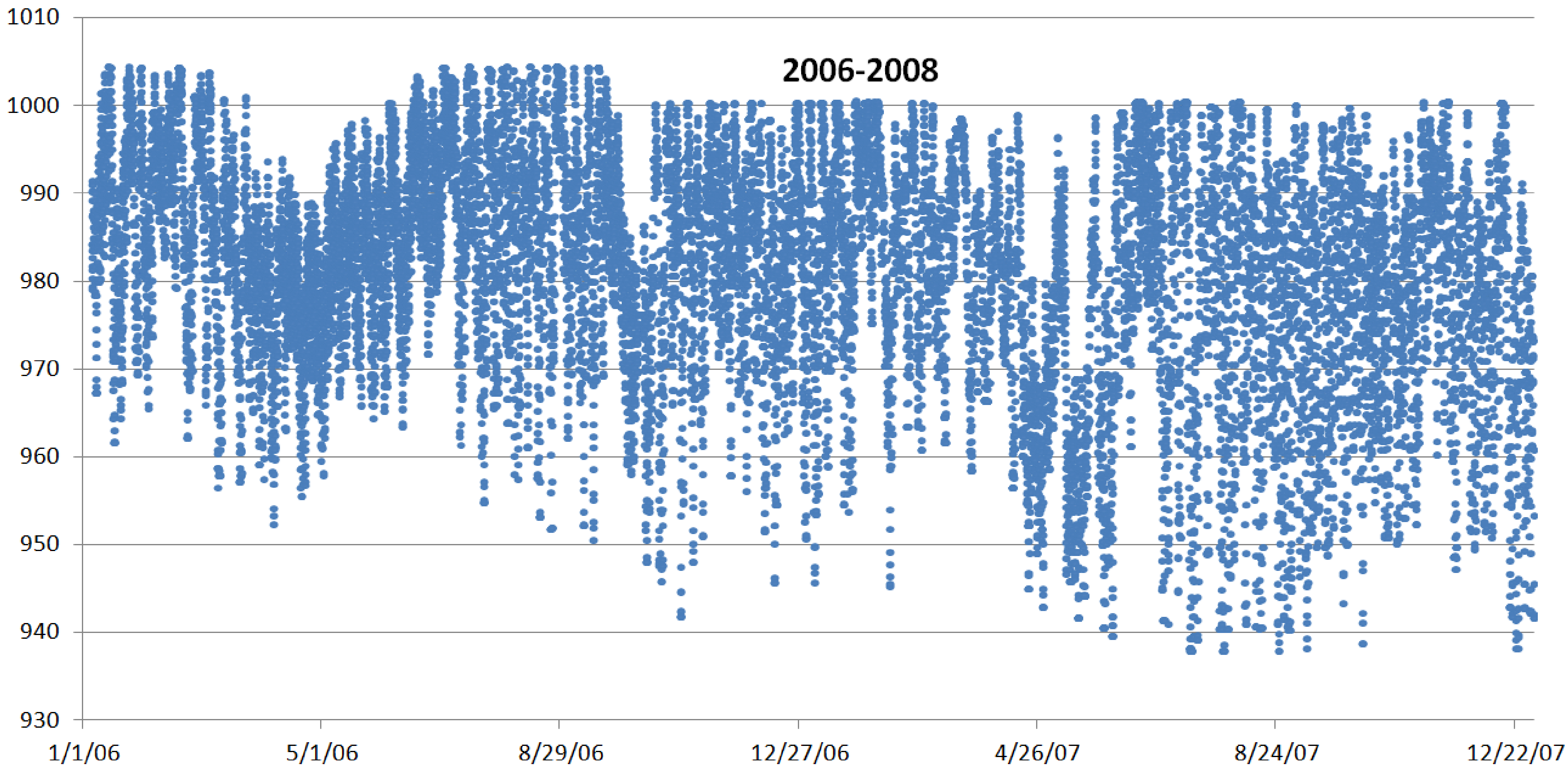
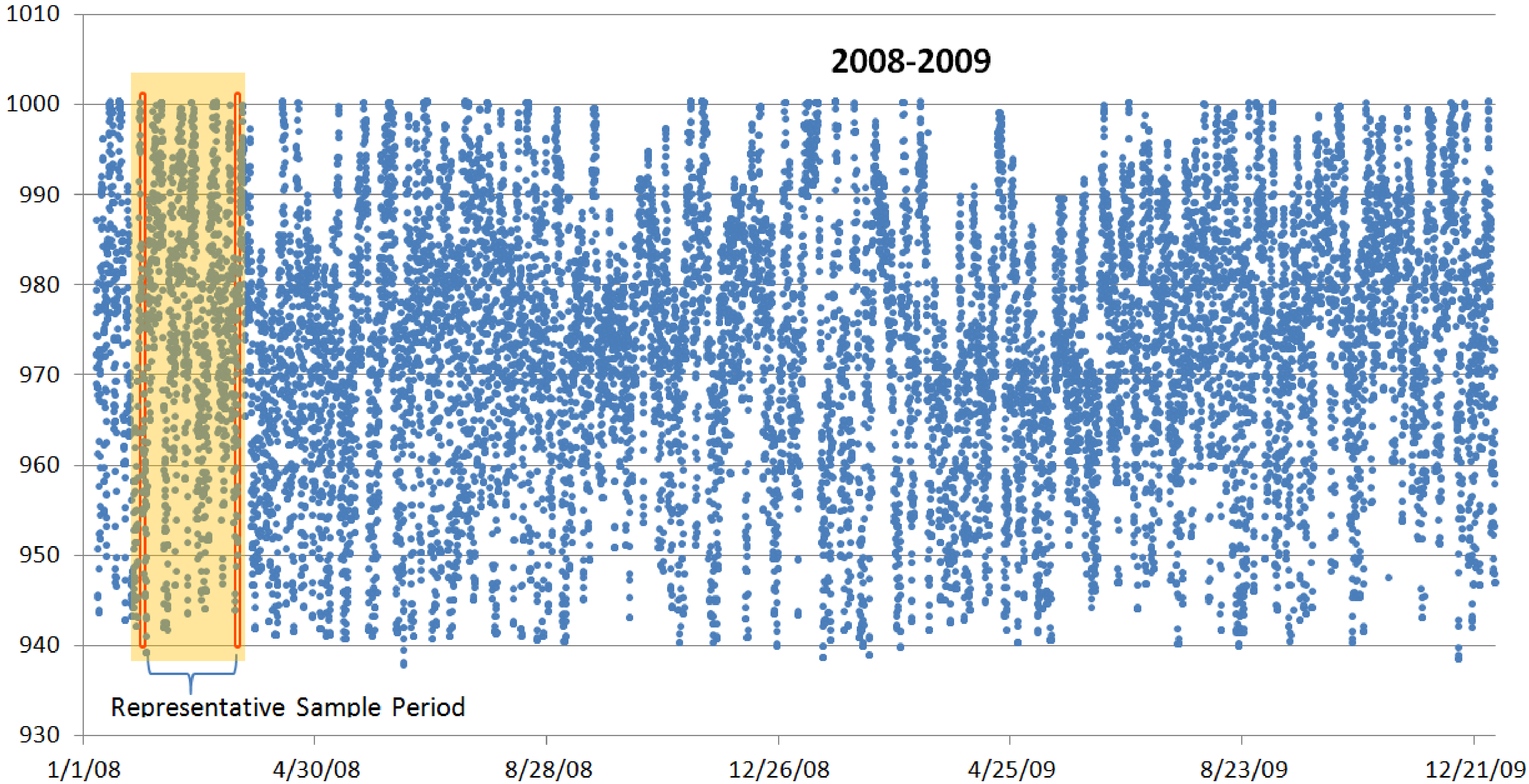


Figure A- 5. Historic Reservior Water Surface Elevations



APPENDIX B: Measured and Modeled Velocity Transects

Figure B- 1. Pumping 2 Transect 1

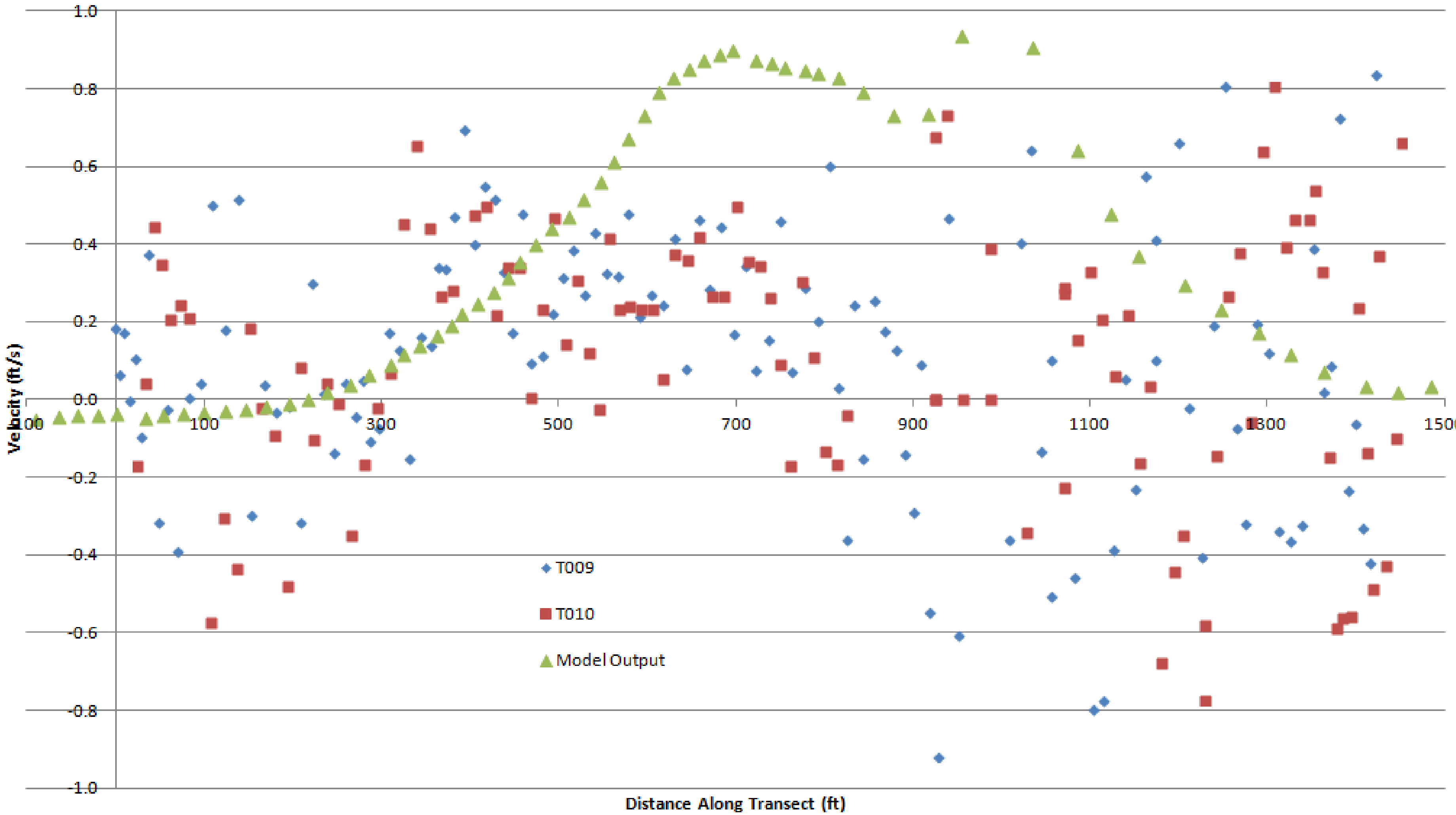


Figure B- 2. Pumping 2 Transect 2

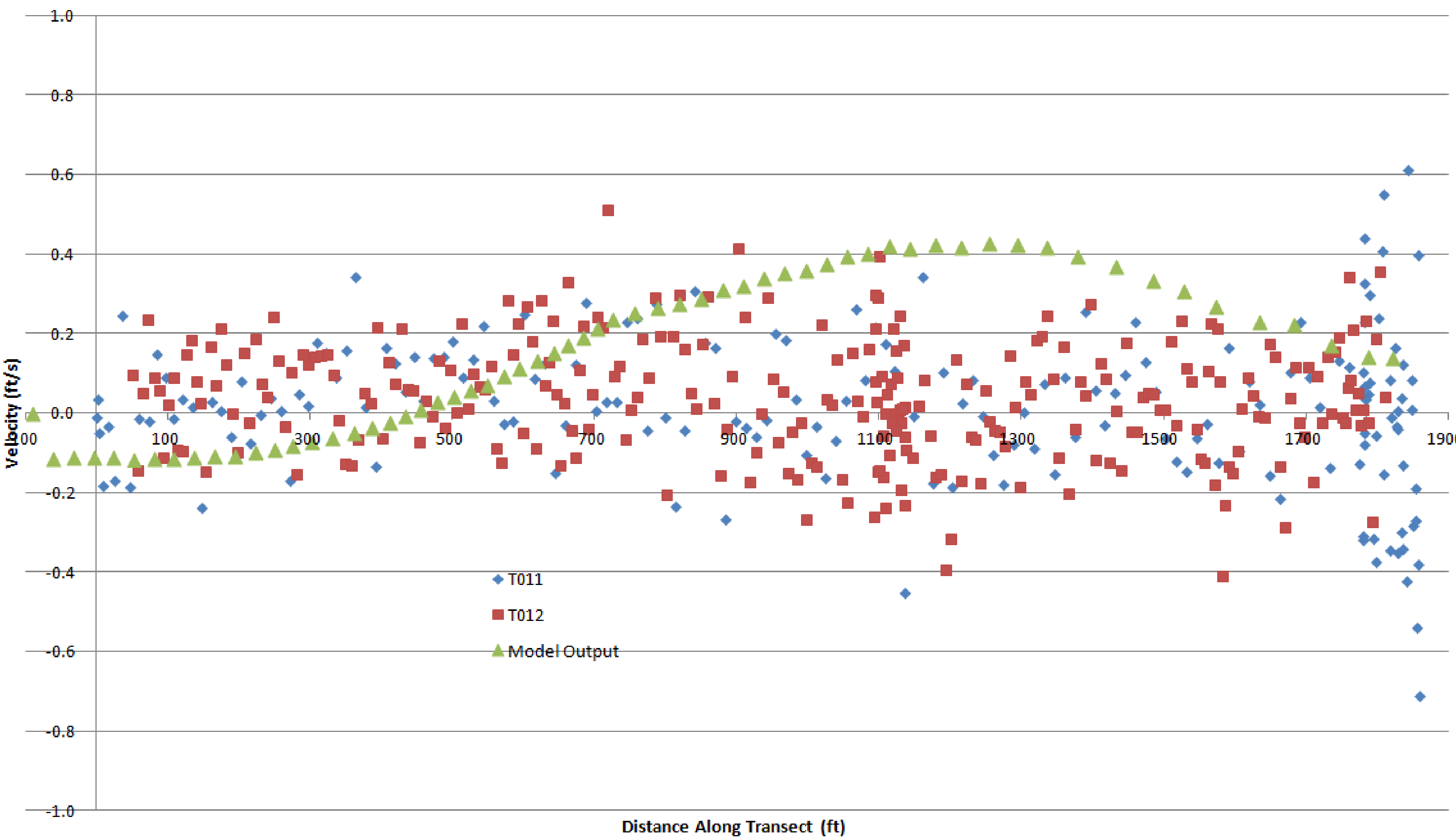


Figure B- 3. Pumping 2 Transect 3

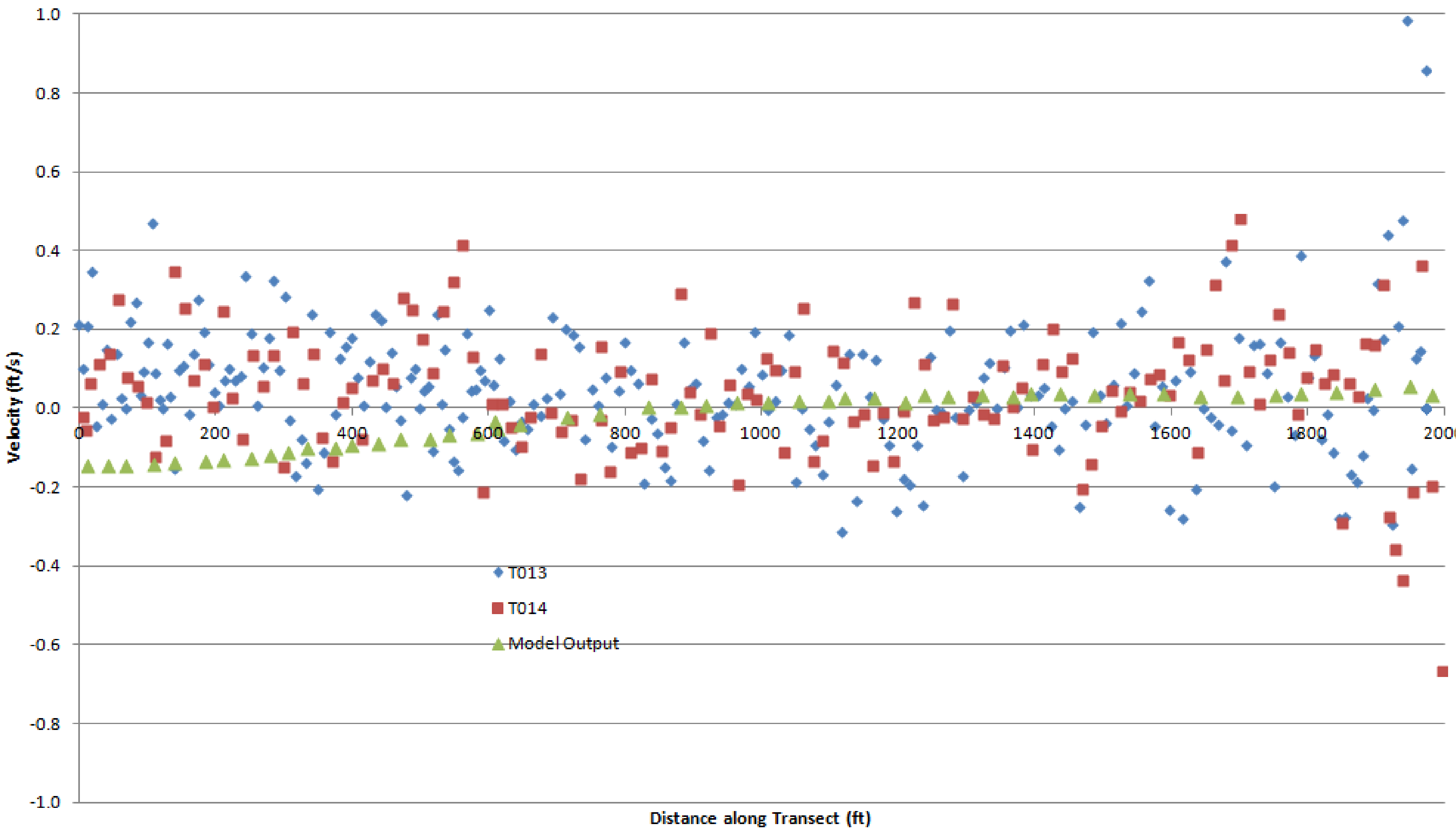


Figure B- 4. Generating 2 Transect 1

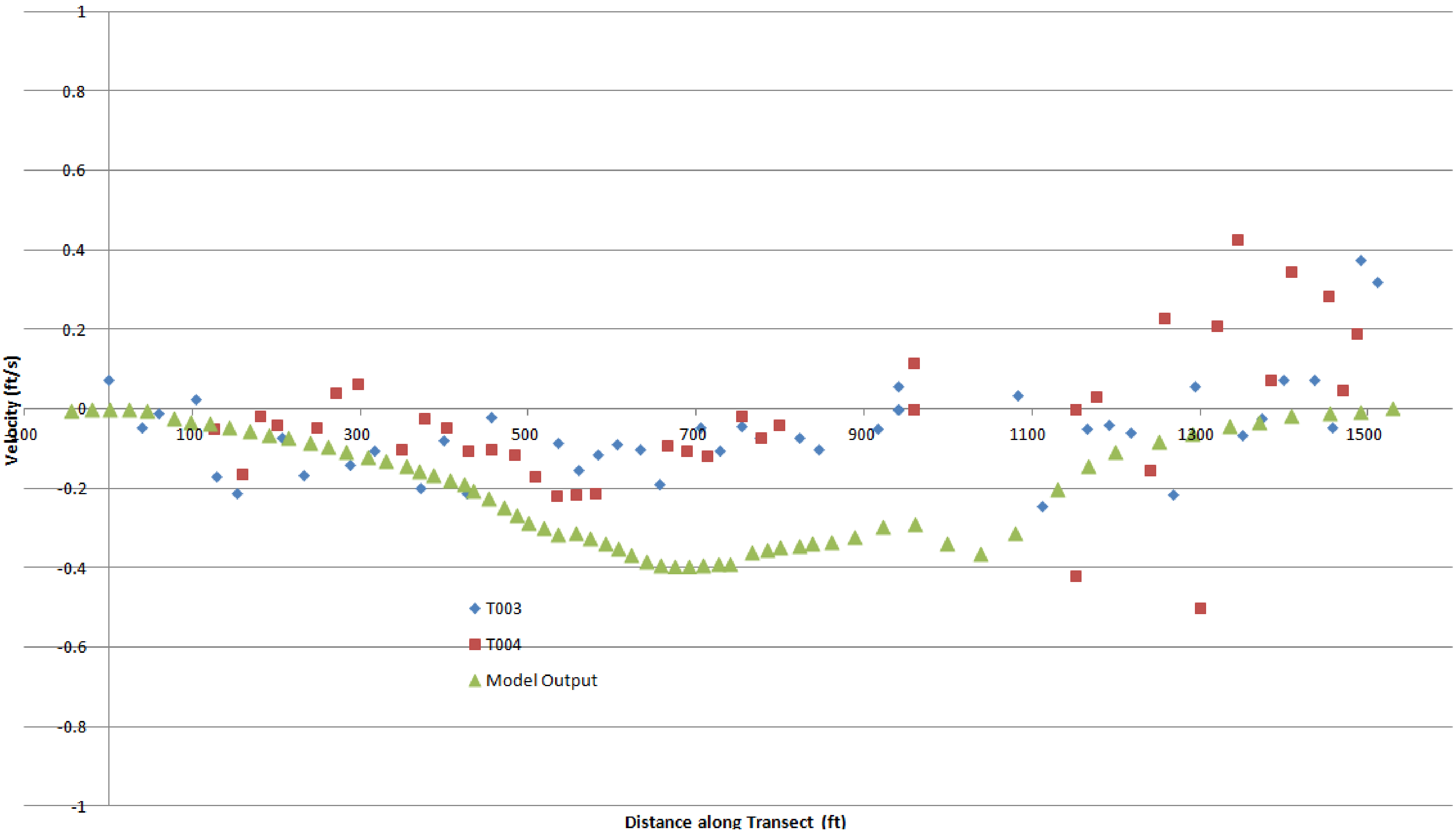


Figure B- 5. Generating 2 Transect 2

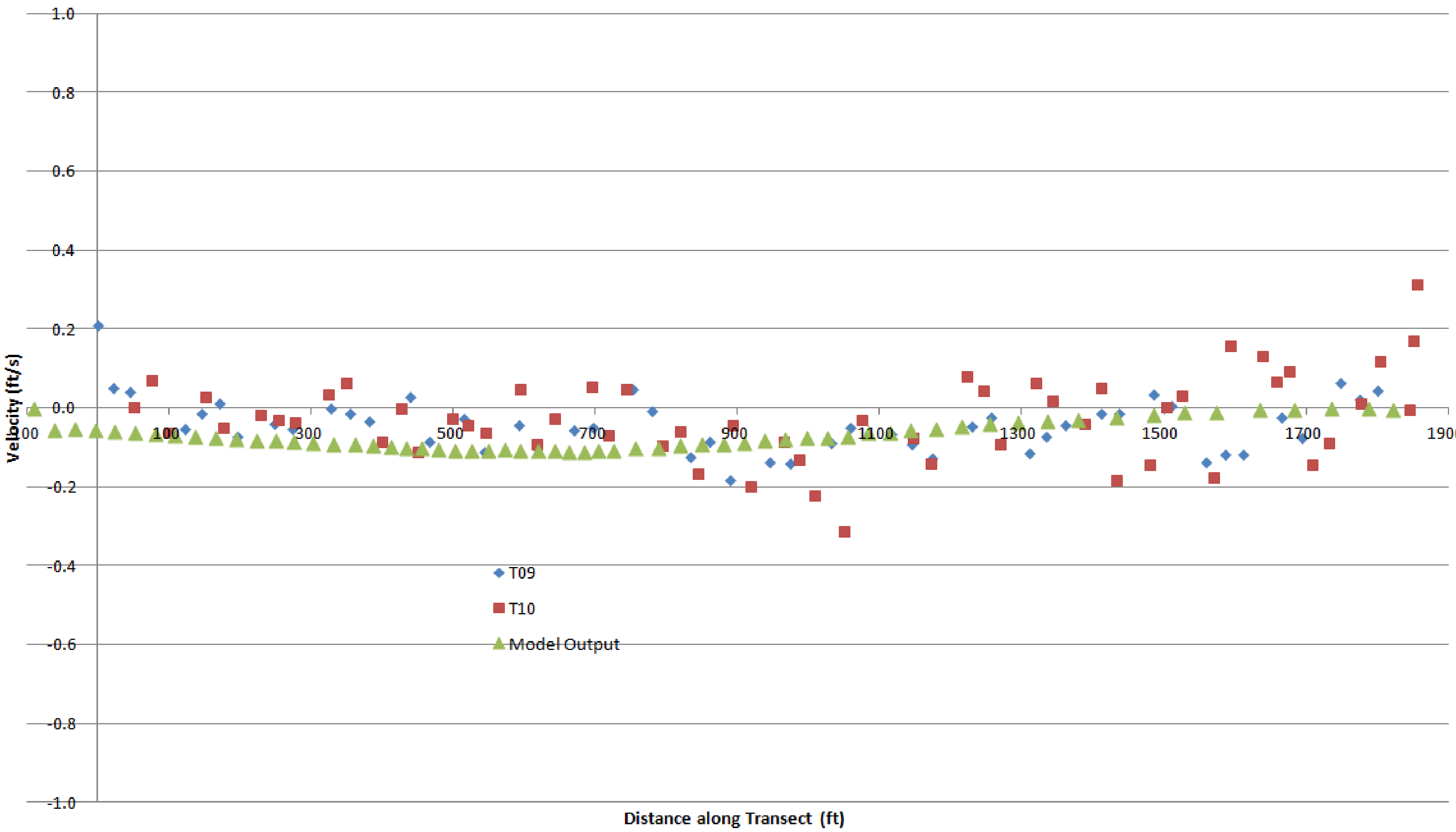


Figure B- 6. Generating 2 Transect 3

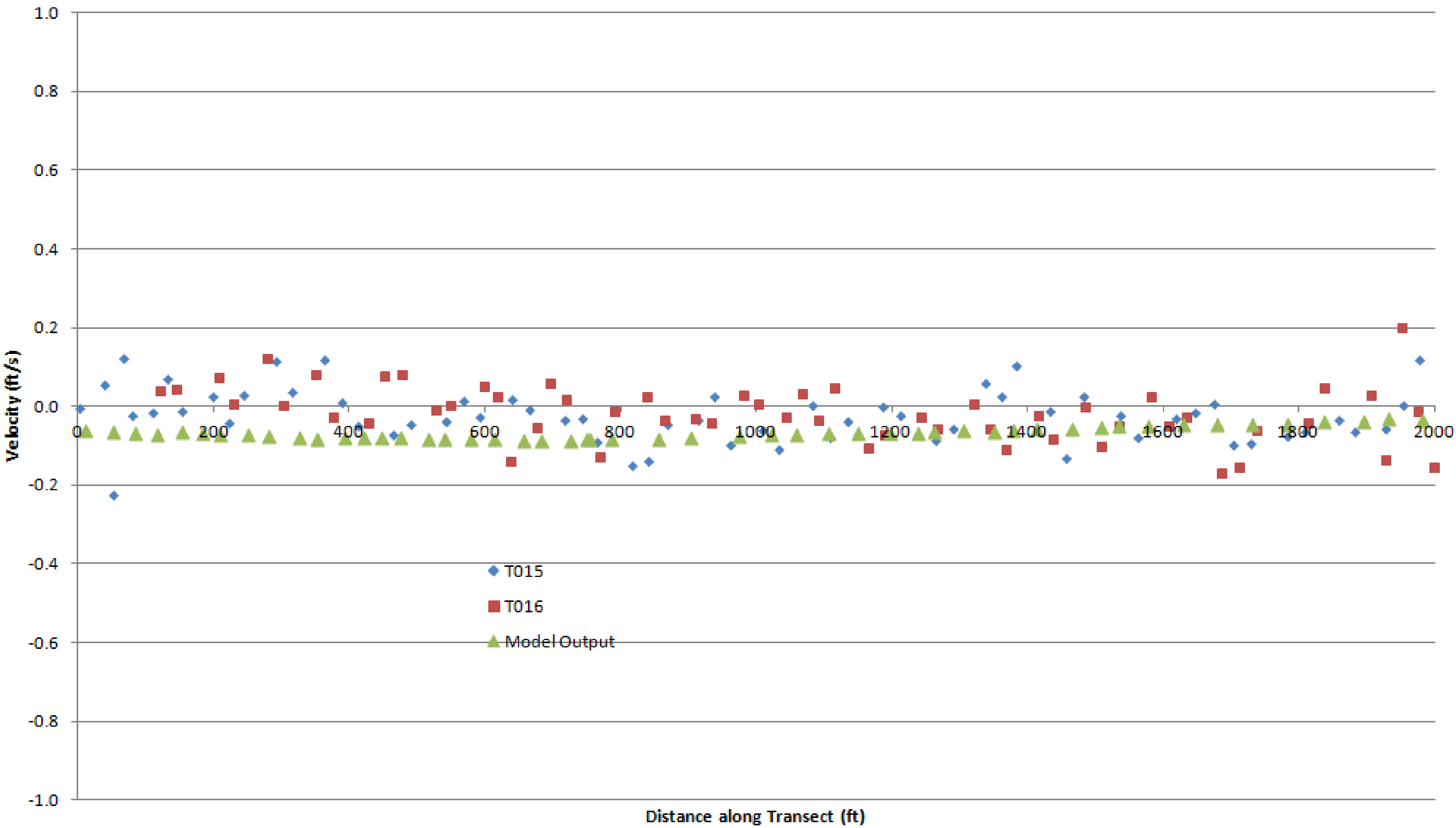


Figure B- 7. Pumping 3 Transect 1

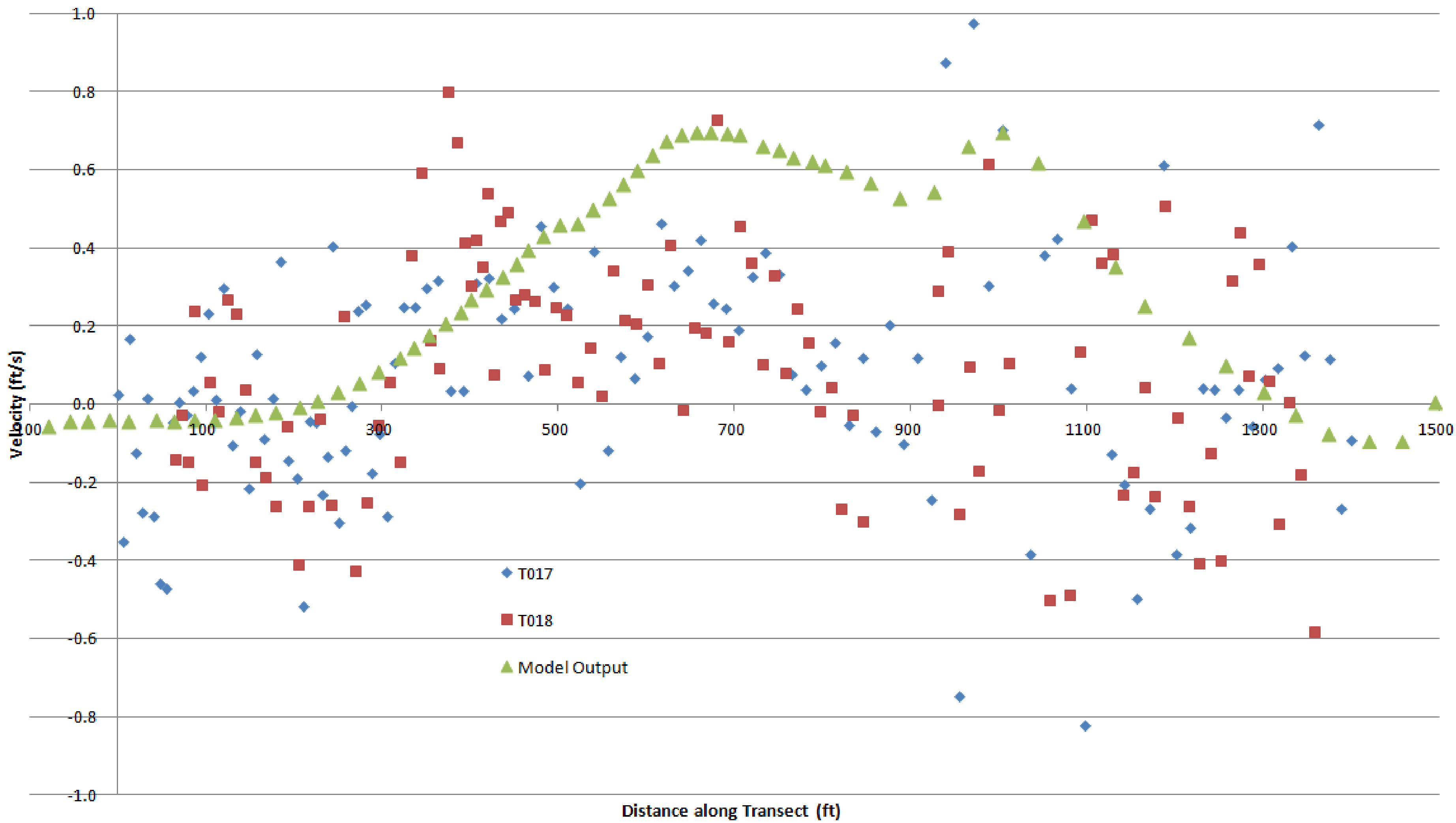


Figure B- 8. Pumping 3 Transect 2

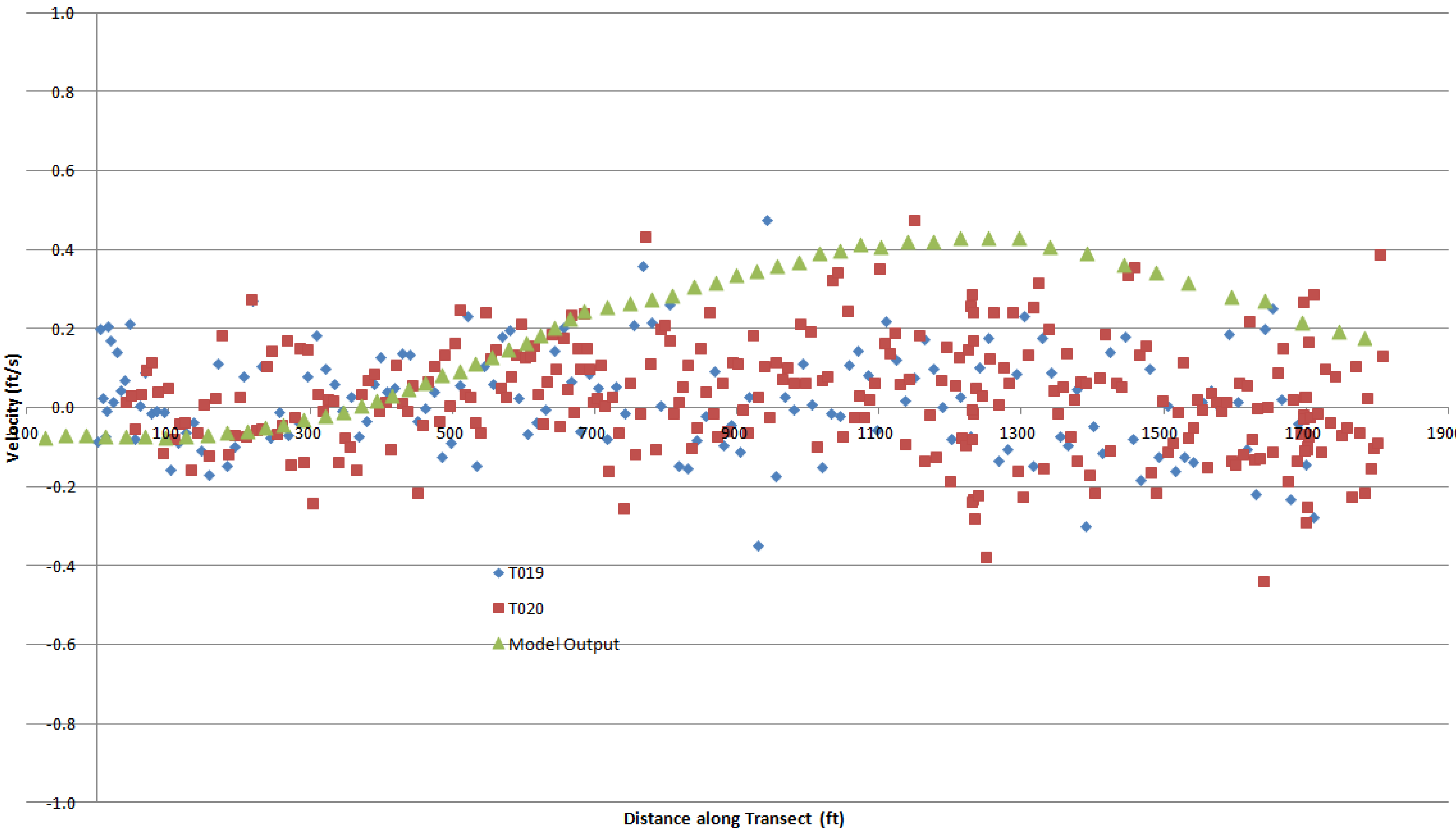


Figure B- 9. Pumping 3 Transect 3

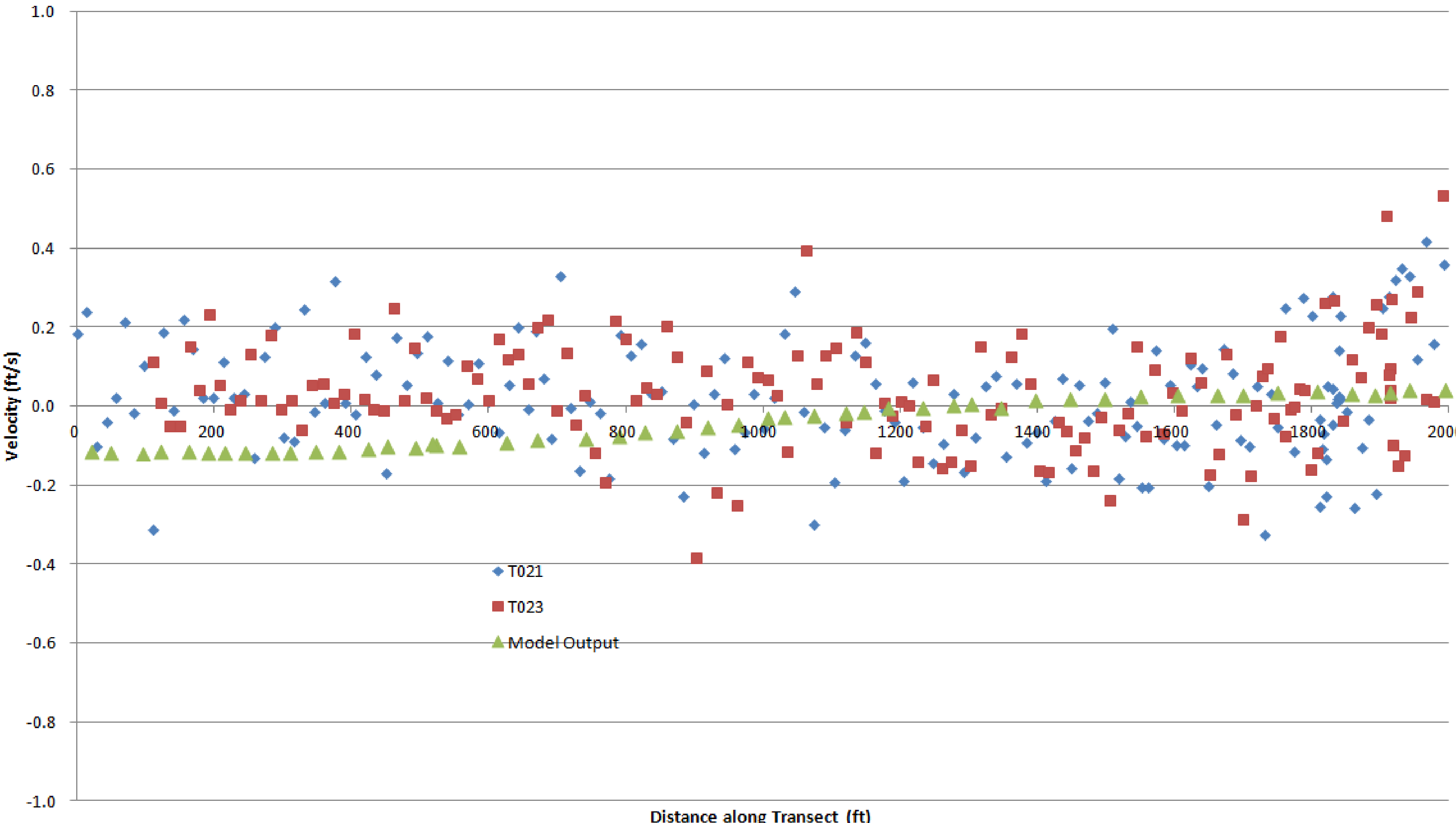


Figure B- 10. Generating 3 Transect 1

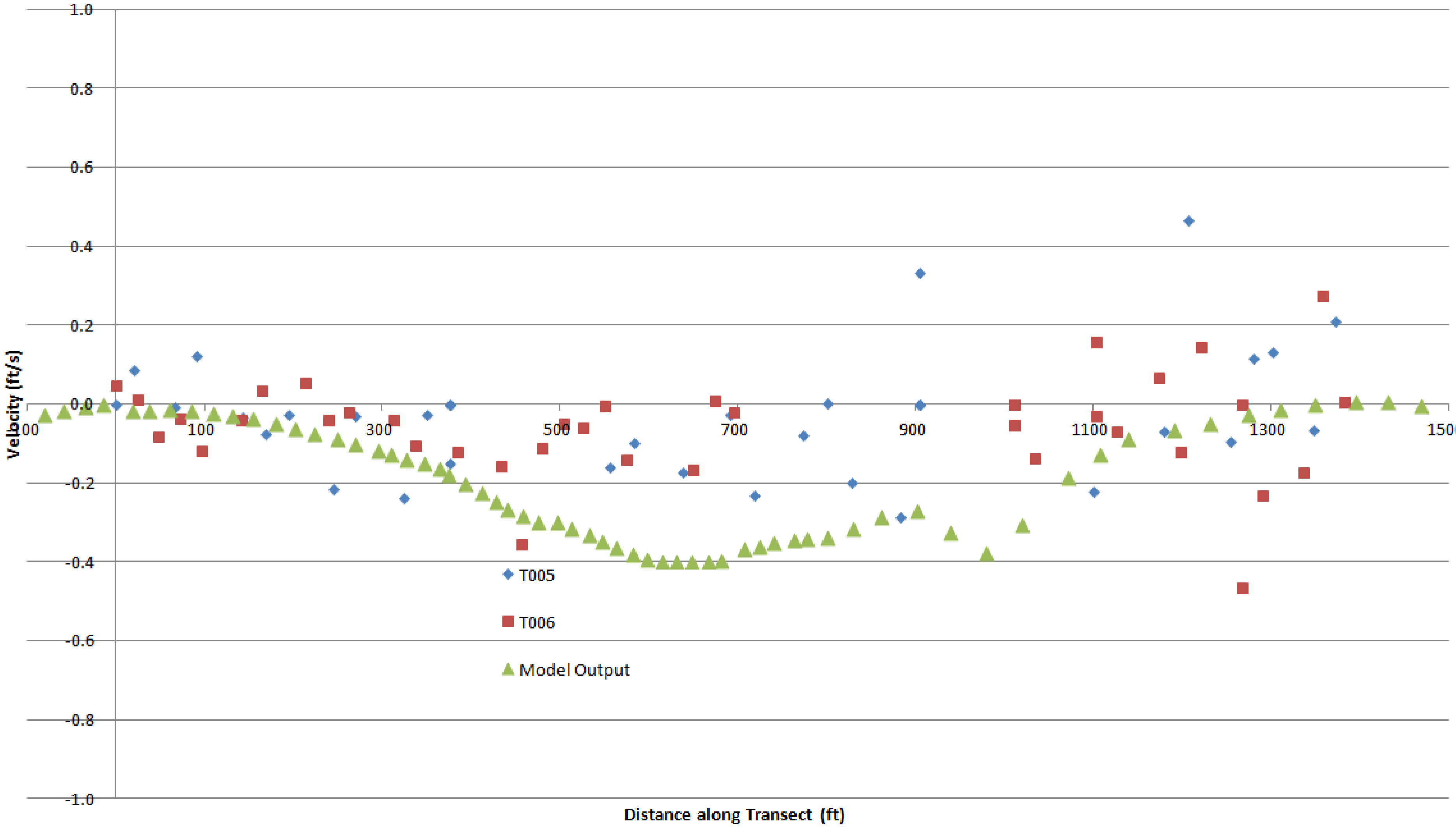


Figure B- 11. Generating 3 Transect 2

Figure B- 12. Generating 3 Transect 3