GREENIDGE GENERATION LLC
THERMAL CRITERIA STUDY

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EXECUTIVE SUMMARY

The Greenidge Generating Facility (GGF or the Facility) is located on the western shore of Seneca Lake in Dresden, New York (Yates County). The Facility is a steam electric generating station consisting of one gas-fired boiler and one turbine generator, designated Unit 4, with a rated maximum generating capacity of 107 MW. The Facility draws water for its cooling system from Seneca Lake, and discharges to the Keuka Lake Outlet (KLO) 700 ft from Seneca Lake.

The State Pollution Discharge Elimination System (SPDES) permit for the Facility (NY-0001325) requires a study to assess compliance of the thermal components of the cooling water discharge with the relevant New York water quality thermal criteria (the "Study"). The plan for the Study was approved by the New York State Department of Environmental Conservation ("NYSDEC") in January 2021.

Consistent with the NYSDEC-approved plan, the Study was conducted over 12-months from May 2021 through April 2022, using temperature recorders in the GGF discharge, 7 locations in KLO, and at surface, mid-depth, and bottom at 8 locations in Seneca Lake. Each sensor recorded temperature to <0.1 °F at 5-minute intervals.

Additionally, tri-axial (longitude, latitude, depth) temperature surveys were conducted in 2021 on June 25 and 26, and August 13 and 14, and in 2022 on March 29 and 30, and April 25 and 26. On each date, surface temperature, time, and location were recorded along 6 transects radiating from the mouth of KLO. Additional transects along the north and south shore of the KLO were added beginning with the August 13 study. Each transect extended to a point where temperature had declined to the ambient lake temperature. At each drop of 1 °F of surface temperature, a full vertical temperature profile was recorded.

Ancillary data on GGF operation, KLO flow, atmospheric conditions, Seneca Lake currents, water surface elevation, and temperatures at the north end of the lake were also recorded or obtained from data collection sources.

Assessment of the thermal discharge with respect to the NYSDEC thermal criteria was conducted for both the empirical data, and by hydrothermal modeling of actual and hypothetical conditions that are more extreme than were encountered during the study.

The GGF thermal discharge was found to meet most of the relevant criteria throughout the year, however there were some criteria that were not met at all times:

When criteria are not met an additional study to demonstrate that the standard is met may be conducted. For example, the same criteria that this Study found were not met, were also not met when GGF had four generating units that discharged approximately twice as much heat as it does presently; therefore, the prior owners of GGF submitted a demonstration using data collected from Seneca Lake and KLO demonstrating that the standard of a balanced, indigenous population of shellfish, fish and wildlife was met. Based on the information on the biological communities in KLO and Seneca Lake contained in the demonstration, NYSDEC defined a mixing zone as the lower 700 ft of KLO downstream of the GGF discharge, and 230 acres in Seneca Lake. This mixing zone which was found to meet the requirements contained in Section 704.3 is currently still in effect.

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1. INTRODUCTION

The Greenidge Generating Facility (GGF or the Facility) is located on the western shore of Seneca Lake in Dresden, New York (Yates County). The Facility is a steam electric generating station consisting of one gas-fired boiler and one turbine generator, designated Unit 4, with a rated maximum generating capacity of 107 MW. The Facility draws water for its once-through cooling system from Seneca Lake, and discharges to the Keuka Lake Outlet (KLO) 700 ft. from Seneca Lake.

New York State Department of Environmental Conservation (NYSDEC) renewed the State Pollution Discharge Elimination System (SPDES) permit for the Facility (NY-0001325) on October 1, 2017. Additional requirement 9 of the permit obligated GGF to submit an updated schedule for the Thermal Discharge Study Plan that was originally submitted on January 27, 2011 and approved by NYSDEC. The same Thermal Discharge Study Plan, with a revised schedule, was resubmitted on December 27, 2017. Comments on that Thermal Discharge Study Plan were provided by NYSDEC in a letter (Peter Maier to Kenneth Scott) on October 12, 2018. A revised study plan (precursor to this document) was submitted to NYSDEC on September 3, 2020, and comments were received from NYSDEC on November 4, 2020. In response to NYSDEC comments GGF submitted a revised study plan on December 29, 2020,(Study Plan) with the following significant changes:

- In-situ monitoring in Seneca Lake was extended to year-round to reflect current Department ambient monitoring methodology to encompass critical winter periods.
- The number of tri-axial surveys was increased from three to eight, and spread throughout the year to encompass both anticipated high and low KLO flow conditions.
- In-situ temperature sensor monitoring frequency was increased to once every five minutes.

This revised Study Plan (ASA 2020) was approved by NYSDEC on January 29, 2021.The Study was conducted consistent with the NYSDEC-approved Study Plan in 2021-2022.

This Study Report includes the technical material obtained in the study and provides all assumptions, calculations, and models used in deriving the Daily Maximum Discharge Temperature and sizing of the mixing zone.

2. GREENIDGE GENERATING FACILITY

2.1 DESCRIPTION

The GGF previously had four generating units that came online between 1938 and 1953. The cooling systems for all four units withdrew water from Seneca Lake at a maximum rate of 131,500 gpm and had a generating capacity of 215 MW. The Facility currently has only one generating unit (Unit 4) with a generating capacity of 107 MW and maximum cooling water withdrawal of 68,000 gpm.

The cooling water flow for Unit 4 is obtained from Seneca Lake through a 7-ft diameter intake pipe elevated on wood pilings that extends from the pumphouse to a point 650 ft offshore (Figure 2-1). At the end of the pipe, the lake is approximately 11 ft deep. The intake pipe opens facing downward and is surrounded by a 27 ft by 27 ft steel structure composed of 3/16- inch bars, 6 inches on center. The Unit 4 intake relies on suction to convey water from the lake, through the elevated intake pipe, and on to the circulating water pumps.

Unit 4 has three cooling water pumps with a combined capacity of 68,000 gpm. Two pumps are used throughout most of the year and the third pump is operated as needed during the summer months or used as back-up for the rest of the year. As required by the SPDES permit issued in 2017, variable-speed drive (VSD) units were installed on two of the three pumps in the summer of 2019. Station service water is drawn through the Unit 3 intake system but adds only minimally to the total flow (2%) and heat load.

The Unit 4 condenser, manufactured by the Westinghouse Electric Corporation, has 50,000 ft^2 of cooling surface made up of 9098 3/4" O.D. No. 18 BWG Admiralty metal tubes. The tubes have an effective length of 28 ft. The condenser has parallel upper and lower chambers that can be operated independently. Each tube bank is approximately circular in cross section, with the tubes arranged in radial lines, and is entirely surrounded by a zone of exhaust steam. The air off-take is located at the center of the condenser so that steam will flow radially inward from the exhaust steam zone to the central core which is connected to the air ejector. The circulating water inlet manifold is fitted with two motor operated backwash valves to permit the water flow through the tubes to be reversed as necessary to maintain efficient operation. At full generating load and flow, the design temperature rise across the condenser (ΔT) is approximately 14 °F.

After passing through the Unit 4 condenser, cooling water discharges into a common 54" diameter steel pipe which connects to a concrete tunnel 41" x 61" in cross-section which extends to the north wall of the turbine room basement. At this point the tunnel divides into two 42" diameter steel pipes connecting to the temperature activated circulating water backwash valves. Water then flows through a 7 x 10-ft tunnel to the discharge canal. The discharge canal, which is approximately 900 ft long, empties into the Keuka Outlet (KLO), a class C(T) designated water, about 700 ft upstream from Seneca Lake (Figure 2-2). Within a radius of one mile of the mouth of KLO, Seneca Lake is designated class B(T), and most of the lake more distant from the outlet is class AA(TS).

As defined in Part 701.7, the best usages of Class B waters are primary and secondary contact recreation and fishing. These waters shall be suitable for fish, shellfish, and wildlife propagation and survival. Similarly, Part 701.8 defines the best usage of Class C waters as suitable for fishing and shall also be suitable for fish, shellfish and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes. The symbol (T), in accordance with 701.25 means that the classified waters are trout waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout or trout waters applies to these waters.[1]

Figure 2-1 Unit 4 withdraws water from an elevated 7-ft diameter conduit that extends 650 from the west shore of Seneca Lake.

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[1] The two trout species are expected to use KLO are Brown Trout (*Salmo trutta*) and Rainbow Trout (*Onchorynchus gardneri*). Based on a literature review of thermal tolerance data for these species Nevada Division of Environmental Protection recommended chronic temperature tolerance values of 62.6 °F for Brown Trout, and 66.2 °F for Rainbow Trout, and acute temperature tolerance values of 75.2 °F for both species. Therefore, despite the best use designation of C(T), the natural temperature regime of KLO, regardless of the GGF discharge, renders the KLO unsuitable for both species during summer months, during which they would seek cooler waters in Seneca Lake. For both species the principal use of KLO would be for spawning, Brown Trout in the fall, and Rainbow trout in the spring. Without any contribution from KLO, Seneca Lake's Brown Trout fishery is sustained by stocking of hatchery-reared fish, while the Rainbow Trout fishery is sustained by natural spawning, primarily in Catherine Creek and its tributaries at the southern end of the lake (https://www.dec.ny.gov/outdoor/25574.html).

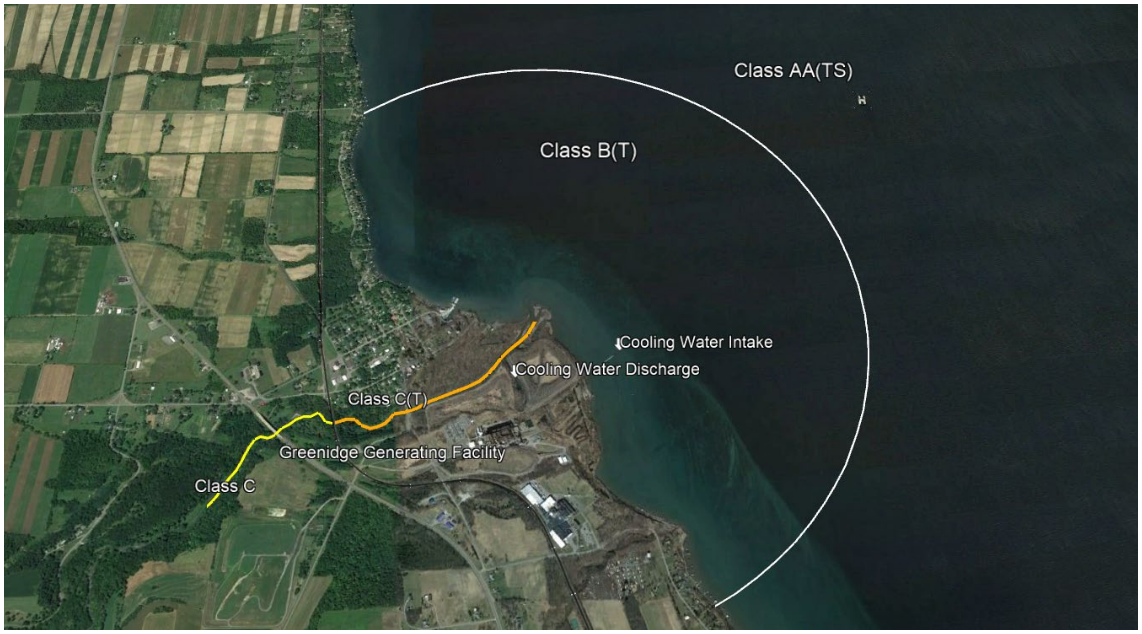

Figure 2-2 Location of Greenidge Generating Facility, its cooling water intake and discharge, water quality classification of surrounding waters.

2.2 SUMMARY OF PREVIOUS THERMAL STUDIES

The only prior thermal studies of the GGF discharge were done to support a CWA § 316(a) demonstration submitted in 1977. The extensive 316(a) demonstration included a physical description of the thermal plume on six dates, and examination of the biotic categories of phytoplankton, zooplankton, macrobenthos, aquatic macrophytes, and fish through spring, summer, and fall seasons. During the years prior to and during the studies, all four generating units were operable and operating, so that the heat load to the KLO and Seneca Lake was much higher than at present with only one unit (Unit 4) operating. From 1966 through 1975 heat rejection to Seneca Lake was approximately 6000 billion BTU annually (Figure 2-3).

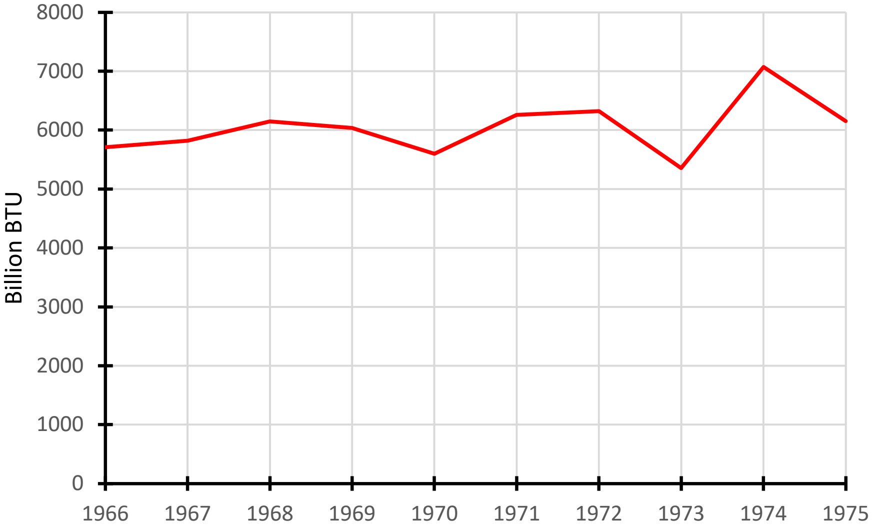

Figure 2-3 Temporal trend in annual heat rejection (Billion BTU) to Seneca Lake at the Greenidge Generating Facility from 1966-1975.

2.3 § 316(A) DEMONSTRATION

The three-dimensional structure of the thermal discharge plume was mapped on six dates from March 19 to December 9, 1976. These surveys demonstrated that surface temperatures in part of Seneca Lake at times, were raised more than 3 °F, and that the area and volume of the thermal plume (area or volume of water with raised temperature) varied with KLO flow, wind speed and direction, and ΔT of the discharge (Table 3-1). On the first four of the surveys, winds were from W, N, SW, and SW, and the plume was directed eastward into Seneca Lake with area within a 2 °C ΔT (3.6 °F) isotherm ranging from 1.5 to 40.8 acres. On the last two surveys, winds were from the NE, which directed the plume southward along the shore, with areas of 71.5 and 40.6 acres. The demonstration used the Ashbury-Frigo model[2] to estimate the maximum area of the plume with greater than 3 °F ΔT of 230 acres.

The demonstration also showed that the temperature rise in the lower 700 ft of KLO would at times exceed 2 °F.

Biological data collected on the biotic categories of phytoplankton, zooplankton, macrobenthos, aquatic macrophytes, and fish over spring, summer, and fall seasons showed no appreciable harm as a result of these criteria being exceeded.

2.4 REGULATORY ACTION

The thermal study component of the § 316(a) demonstration showed exceedances of thermal criteria for more than a 2 °F rise in temperature of a designated trout stream, and more than a 3 °F increase in the surface temperature of Seneca Lake. However, because no harm to the balanced indigenous communities or biotic categories was observed, NYSE&G requested, and NYSDEC approved, a variance from the criteria and a defined mixing zone consisting of the entire width of the KLO downstream of the confluence with the discharge canal, and an area of 230 acres of Seneca Lake around the mouth of Keuka Lake Outlet.

Table 2-1 Physical and plant operational characteristics, and thermal plume dimensions during thermal surveys conducted at Greenidge Generating Facility in 1976.

Date	Flow (cfs)		ΔT (°F)	Billion BTU/hr	Average Wind		Plume Characteristics		
	Station Discharge	Keuka Lake Outlet			Speed (mph)	Direction (°)	Centerline Distance (ft)	Max Width (ft)	Surface Area (acres)
19-Mar	162	572	9.2	0.39	3.9	244	520	180	1.5
6-May	293	316	14.6	0.78	3.5	360	1100	1250	22.4
1-Jul	249	104	14.8	0.75	4.2	215	1450	436	9.2
5-Aug	293	52	13.3	0.96	3.8	203	2050	1746	40.8
2-Sep	205	43	13.0	0.61	10.9	45	5820	798	71.5
9-Dec	249	84	18.5	0.60	4.4	61	4400	450	40.6

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[2] The Ashbury-Frigo model is a simple equation to predict the area of a thermal plume within a particular ΔT limit as a function of the total heated inflow (Q_T) and the initial temperature difference (ΔT_0): Area = $a \cdot Q_T \cdot (\Delta T/\Delta T_0)^b$. For cases when the thermal plume extended outward into Seneca Lake, fitted values were a = 0.00345 (incorrectly stated in NYSE&G 1977 as 0.0345) and b = -2.310; when the thermal plume extended along the shoreline, fitted values were a = 0.0167 and b = -2.322. The variable inputs used were Q_T = 293 cfs (GGF flow 293, KLO flow 0) and ΔT_0 = 15.8 °F. These inputs produce predicted plume areas within 3 °F ΔT of 47 acres when the plume extends into the lake and 230 acres when it extends along the shoreline.

3. THERMAL CRITERIA STUDY

The goal of this thermal criteria study is to determine whether the current GGF thermal discharge meets the criteria in 6 NYCRR Part 704.2, and if not to establish a mixing zone consistent with Part 704.3. To support this goal, the thermal monitoring program was conducted to map the temperature conditions around GGF's cooling water discharge in Keuka Lake Outlet and Seneca Lake during various lake and meteorological conditions over the course of an annual thermal cycle. In addition, a hydrothermal model was used to analyze the potential thermal effects of the GGF discharge at critical lake and discharge conditions, and to develop projections at increased ambient air temperatures.

3.1 EXISTING DATA COMPILATION AND REVIEW

The existing data and information concerning operations of the GGF and Seneca Lake information were compiled and reviewed as part of the lake temperature study and also to guide the modeling approach (i.e., extent of the modeling domain, computational grid resolution, selection of critical conditions for model projection scenarios, and development of model inputs). The following data were reviewed:

- Plant discharge/intake structure design
- Current plant generating loads, intake/discharge flows, and temperature
- Lake water level from the USGS gage on Seneca Lake at Watkins Glen (#04232400)
- Keuka Lake Outlet discharge data from USGS gage (#04232482)
- Lake bathymetry, ambient temperature and current data
- Previous thermal plume monitoring studies
- Meteorological data measured at the Northeast Regional Climate Center (Penn Yan, NY)
- Meteorological and lake temperature data at the Clarks Point buoy
- Lake temperature and water quality data collected during 2005-2006 studies

3.2 TEMPERATURE MONITORING

Temperatures were assessed through both moored *in-situ* recording temperature sensors, and during eight (8) tri-axial plume mapping surveys. This combination of temperature data allowed assessment of thermal criteria and to define a mixing zone, if necessary.

3.2.1 Moored *in-situ* temperature monitoring

From May 14, 2021, through completion of the final plume surveys on April 26, 2022, HOBO MX2204 temperature sensors (accuracy +/- 0.36 °F) were deployed at seven (7) locations in Keuka Lake Outlet (KLO). Initially the sensors were attached to rebar pounded into the substrate. After high flow events and tampering resulted in some lost instruments, the sensors were attached to a length of heavy chain at the end of a metal fence stake (Figure 3-1). (Appendix A contains the Final Interim Report which documents the details of setting of instruments and data downloads.) Locations within KLO are indicated in Figure 3-2. One additional location (P) in the north mouth of KLO was added on August 14. Completeness of the data record from the KLO sensor stations is provided in Figure 3-3. Temperature was recorded at 5-minute intervals. Initially,data were downloaded monthly, and then recorded biweekly when flow in KLO was low enough to safely retrieve the instruments, i.e. approximately 200 cfs or lower. Several very high flow events occurred during the study period, documented in Appendix A, which resulted in lost sensors. The sensors were replaced as soon as possible when suitable flow conditions occurred.

From May 14, 2021, through completion of the final plume surveys on April 26, 2022, HOBO MX2204 temperature sensors were deployed at seven (7) locations in Seneca Lake (SL) using a deployment system consisting of a weighted anchor, line, and buoy. Three sensors were deployed at each station: attached to the anchor at the bottom; to the line at mid-depth; and at the bottom of the buoy. Initially, the line was shortened so that the buoy was approximately 2 ft below the water surface[3]. Tampering resulted in some lost instruments and loss of data (Figure 3-1). (Appendix A contains the Final Interim Report which documents the details of setting of instruments and data downloads.) Locations within KLO are indicated in Figure 3-4. Additional monitoring locations O (surface only) and Q were added on July 23 and August 14, respectively. Temperature was recorded at 5-minute intervals.

In addition to the temperature sensors, an Onset meteorological monitoring station (W) was established on the GGF intake structure (Figure 3-5). The station recorded air temperature, wind speed, wind direction, solar radiation, and relative humidity at 5-minute intervals.

Figure 3-1 Attachment of HOBO sensor to chain and metal fence post.

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[3] Surface buoys in Seneca Lake must be permitted by the NYS Office of Parks and Recreation (NYSOPR). The permit for surface placement was approved on November 3, 2021 and buoys were moved to the surface at the next data download on December 8, 2021.

Figure 3-2 *In-situ* temperature recording locations in GGF discharge and Keuka Lake Outlet.

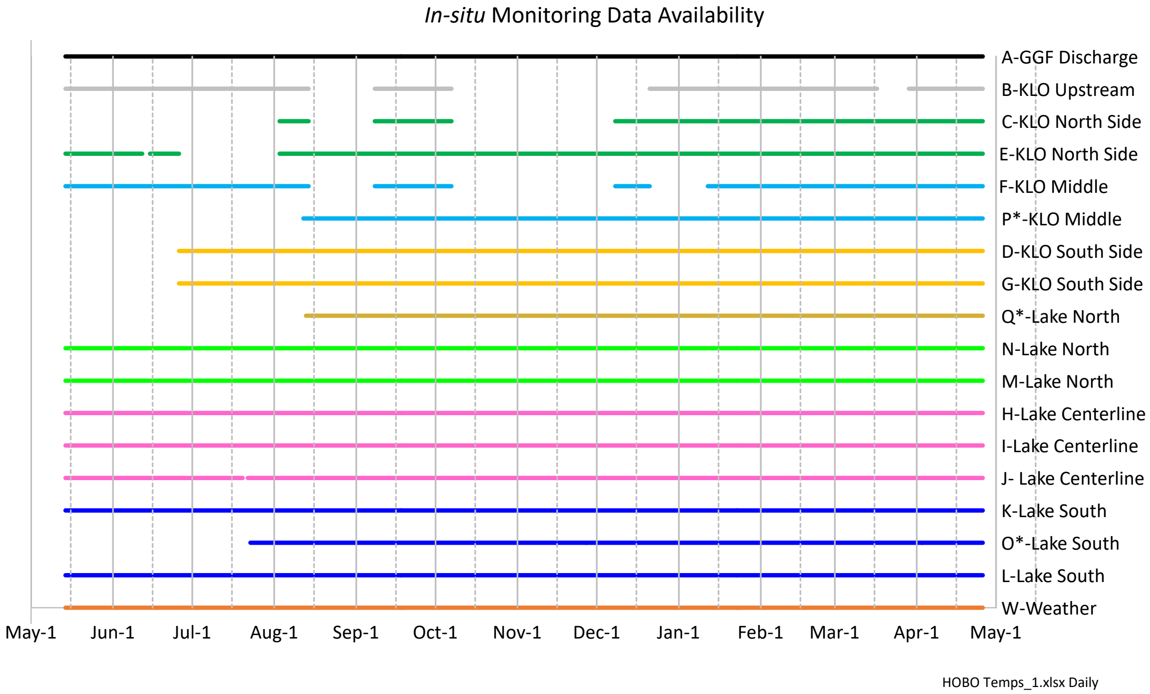

Figure 3-3 Data completeness from temperature recording stations in KLO and Seneca Lake, May 14, 2021 to April 26, 2022. Stations O, P, and Q were added after the study was initiated.

Figure 3-4 Locations for *in-situ* temperature monitors in Seneca Lake.

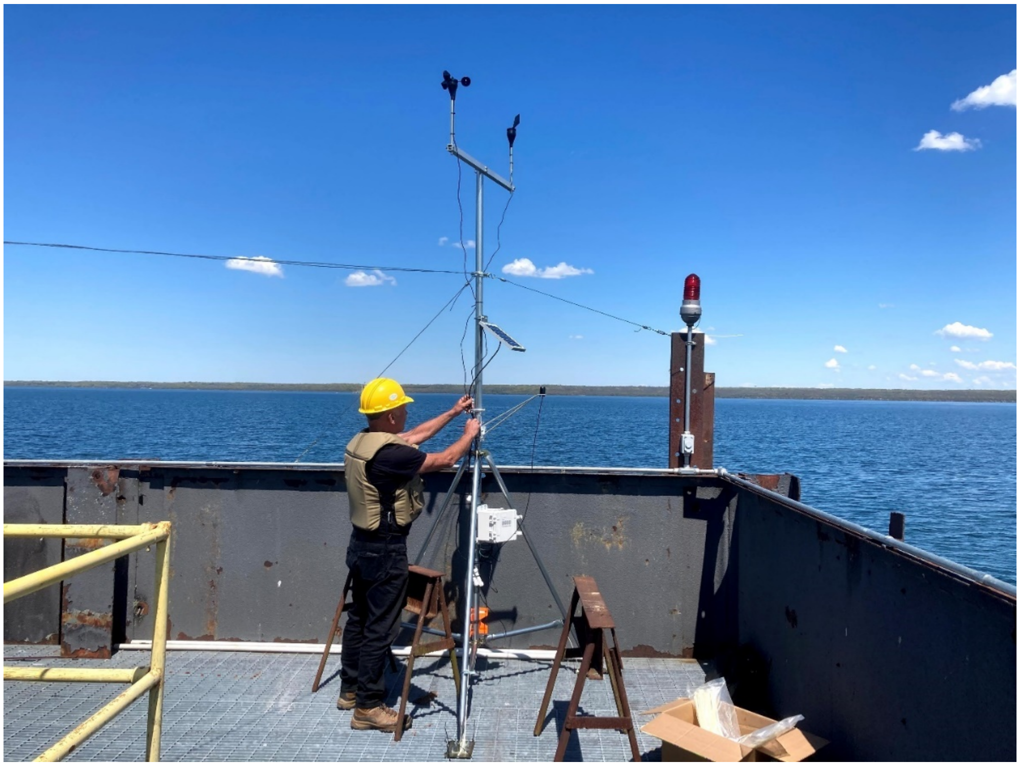

Figure 3-5 Meteorological station deployed at Greenidge cooling water intake structure on May 14, 2021.

3.2.2 Tri-axial plume mapping

A tri-axial plume mapping effort was conducted eight (8) times during the study: June 25 and 26, 2021; August 13 and 14, 2021; March 29 and 30, 2022; and April 25 and 26, 2022. The events scheduled for February 2022 were delayed until March due to high flows in KLO and weather conditions that made sampling unsafe.

During each event, surface temperature was measured along transects radiating from the KLO mouth (Figure 3-6). Temperatures were measured by towing a Valeport miniCTD-DR fast-response recording sensor (accuracy +/-0.02 °F) at the surface, coupled with a Lowrance HDS-9 chartplotter and antenna to record exact location of each measurement. Transects extended from the KLO mouth to a point at which the temperature rise above ambient was less than 1 °F. At each 1 °F drop in temperature above ambient, a full vertical temperature profile was recorded using a Valeport fastCTD profiler.

A Nortek Aquadopp Profiler (ADCP) unit was located offshore from the KLO mouth (location Z) to record prevailing current velocity and direction (Figure 3-6). During each of the plume mapping events, velocity and flow were measured across each channel of the KLO mouth using a Hach FH950 current meter, and a bathymetric survey of the area of Seneca Lake that is classified B(T) was done during the August sampling event using the Lowrance HDS-9 and a Lowrance TotalScan 455/800kHz transducer.

Figure 3-6 Transects A-F for tri-axial survey events. Near-shore transects north and south of GGF were added for the August and subsequent surveys. Z indicates location of the ADCP unit.

3.2.3 Calculations and Criteria

For comparison of the *in-situ* monitoring data to thermal criteria, the values at 5-min intervals were used to calculate hourly average values. Data for Stations B and Q were used as the ambient temperatures for KLO and Seneca Lake respectively. When data were not available for B, a cosine wave function fit to the available data was used to estimate the temperature:

$$T_{BJ} = 20.43 * \cos(2\pi[J - 212.52]/365.25) + 53.98$$

where

T_{BJ} = temperature at Station B on Julian day J

When data were not available for Station Q before it was initially set on August 13, daily average Station Q surface temperature was predicted from the uppermost temperature measurements at the Finger Lakes Institute's Clark's Point water quality buoy (CPB) using a linear regression derived from periods when Q and CPB were both deployed (August 13 through November 3):

$$T_{QsJ} = 0.9581 \times \overline{T}_{CPBsJ} + 2.661$$

where

T_{QsJ}= temperature at Station Q at the surface (s) on Julian day *J*

$\bar{T}_{CPBsJ}$=average temperature at CPB at the surface (s) on Julian day *J*

Thermal criteria were met when the observed hourly temperature at a station (generic station denoted as“X”) is less than the criterion temperature:

$$T_{X,h} < \{T_{Amb,h} + \Delta T_{Crit}\}$$

where

$T_{X,h}$= temperature at station *X* in hour h

$T_{Amb,h}$=ambient temperature in hour h. $T_{Amb,h}$ based on Station B for KLO, and Station Q for Seneca Lake

ΔT_{Crit}= maximum change in temperature allowed by a criterion

Water temperature data collected by the towed miniCTD sensor[4] and GPS track data collected during each of the 8 thermal surveys were imported into program R (R Core Team 2022) and merged based on the timestamps recorded in each dataset. After inspection of the data, spatially redundant observations were removed by averaging values recorded at each pair of latitude and longitude coordinates sampled during each survey. To avoid oversampling certain regions of the survey area (e.g., when the boat was stopped to collect vertical profiles of water temperature), a subset of temperatures spaced a minimum distance of 20 ft apart from one another was selected. This subset of the data (model subset) was used to model water temperatures within the survey areas using spatial interpolation techniques available in the gstat R package (Pebesma 2022). The remaining temperatures not selected for modeling were retained for later testing of the spatial model (validation subset). For each survey, a theoretical variogram[5] was fit to the empirical variogram and ordinary kriging was used to estimate temperatures within a raster grid[6] of the survey area. Interpolated temperatures were validated by comparing modeled temperature values to actual values from the validation subset. After ensuring the models yielded appropriate predictions, isotherm contour lines were drawn at 1°F intervals starting at ambient temperature using the rasterToContour function in the raster R package (Hijmans 2021). The spatial models of water temperature were imported into ESRI™ ArcGIS Desktop software for mapping.

For each survey, the surface area of water exposed to temperatures greater than 3°F above ambient temperature[7] was calculated by multiplying the number of grid cells with temperatures 3°F above ambient temperature by the modeled grid cell area. After unit conversion, surface area estimates were reported in acres.

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[4] During the June 25 and 26, 2021, surveys, the towed sensor was mounted at a fixed depth of approximately 2.5 feet below the water surface. For the remaining surveys, the sensor was mounted at a depth of approximately 1 foot below the water surface.

[5] Spherical, exponential, Gaussian, and Matern theoretical variogram models were fit to the empirical variogram for each survey with the best fitting model selected for kriging interpolation.

[6] Grid cell sizes varied depending on the amount of data collected and area surveyed. A 5-foot × 5-foot cell was used for the June 25, June 26, August 13, and August 14, 2021, surveys. A 10-foot × 10-foot cell was used for the remaining surveys.

[7] Ambient temperatures were determined based on temperatures recorded by the HOBO temperature logger deployed at the top of the water column at Lake Station Q during times of surveying. Because Station Q was not deployed until August 13, 2021, ambient temperatures during the June 25 and June 26, 2021, surveys were based on values observed and recorded in the field during the surveys.

3.2.4 Quality Assurance

Quality of the data was assured by the use of equipment that is both accurate and precise in measurement of temperatures, times, and locations (Appendix C), through the experience and training of the personnel conducting the study, through the application of Standard Operating Procedures, and through statistical analysis of the data to identify and filter out any clearly erroneous values that are not within appropriate limits, and by completion of and adherence to the approved Quality Assurance Project Plan (QAPP). Data from outside sources (USGS data for KLO flows, Finger Lakes Institute Clark's Point Buoy data on Seneca Lake water temperature and atmospheric data, New York State Canal Corporation data on Seneca Lake water level, GGF data on station operations) were examined for erroneous and/or obvious outlier values.

3.3 THERMAL PLUME MODEL

3.3.1 Model Selection

The RMA-10 model was used as specified in the Study Plan. RMA's quadratic, finite-element formulation accurately simulates irregular shoreline configurations and bathymetry using a moderately spaced mesh, and any section of the model's mesh may be modified locally without changing other areas of the mesh. The bathymetry of the confluence between Keuka Outlet and Seneca Lake was adapted into RMA-10's finite-element framework using very small grid elements to simulate small-scale velocity variations, and associated water temperature variability.[8] The monitoring data provide boundary conditions for water temperature and flow at the Keuka Lake Outlet mouth.

A more complete description of the model and its use is provided in Appendix D.

3.3.2 Far-Field Model Adaptation and Calibration

The RMA-10 model was adapted to the Seneca Lake environment, and was then used to simulate the GGF's thermal discharge plume under operating and environmental conditions encountered in the 2021 and 2022 field surveys, which allowed for calibration of the model through comparisons with the observations collected during these surveys.

For model adaptation, RMA-10 requires: (1) bathymetry data and shoreline boundary coordinates; (2) time-series input data (water surface elevations, boundary temperatures, tributary inflows/temperatures and meteorological variables); and (3) "tuning" parameters such as bottom friction and turbulent exchange coefficients.

3.3.3 Model Discretization

The computational mesh developed for this study is illustrated in Figure 3-7. The mesh extends from the northern to southern ends of Seneca Lake and contains a total of 2,214 nodes and 967 elements. The finest mesh spacing is provided near the mouth of the KLO, with minimal midpoint/end-point nodal separations of approximately 5 ft. To resolve vertical variability, the computational mesh contains 3 vertical layers. Each layer contains upper nodes, lower nodes and mid-side nodes, which results in 5 vertical computational points in the finite-element interpolation scheme. Water depths at each node were gleaned from available National Oceanic and Atmospheric Administration (NOAA) navigation charts, and supplemented with a new hydrographic survey conducted in this study.

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[8] In the study plan, CORMIX was specified as the model for the KLO outflow, but the adaptability of RMA-10 allowed this area to be incorporated into the model domain and conduct all modeling with a single model.

3.3.4 Boundary Conditions

For preliminary model calibration to 2021 and 2022 conditions, Seneca Lake elevation and water temperature were retrieved from available data collected during the study.

3.3.5 Tributary Inflows

Seneca Lake has two main tributaries, Keuka Lake Outlet located near the center of the Lake's western shoreline; and Catherine Creek at the southern end of Seneca Lake.

Flow in KLO is measured at a USGS station (USGS 04232482) at Dresden, approximately one mile upstream from the GGF thermal discharge. At this point, KLO drains 207 square miles. Average monthly discharges for the summer of 2021 were 92.9 cfs.in June, 206.7 cfs in July, 407.2 cfs in August, and 80.0 cfs in September. Catherine Creek flow is measured at Montour Falls (USGS 04232200) where it drains approximately 39.4 square miles. Observed mean daily stream flows for the Summer of year 2021 were 24.4 cfs.in June, 126.6 cfs in July, 85.8 cfs in August, and 30.0 cfs in September. Since the entire Seneca Lake watershed covers approximately 457 square miles the two stations cover approximately 45% and 9% of the entire Seneca Lake watershed.

3.4 MODEL CALIBRATION

Following model adaptation and model input assembly, model calibrations were performed. In this iterative procedure, representative model parameters were adjusted and the adapted model was run repeatedly until discrepancies between observed and simulated data (e.g., elevations, currents, water temperatures, etc.) were minimized. In this case, the model required little adjustment to reproduce some of the observed temporal variations in water temperature.

3.5 MODEL VERIFICATION

For verification the model calibrated to the June tri-axial surveys, was applied to simulate conditions prevailing during August tri-axial surveys. This provided a test of the model's ability to resolve temperature variability over a range of time scales (hourly, daily, weekly, etc.) at different stations in Seneca Lake. To do this model output was plotted as surface temperature distribution maps simulated at specific times for comparison with observed surface temperature mappings prepared from the shipboard survey data.

3.6 MODEL PROJECTION SCENARIOS

There were eight preliminary model scenarios defined in the NYSEDC-approved Study Plan, covering various sets of flow and ambient condition. As indicated in the Study Plan, these scenarios were refined after consideration of initial results and data availability. The final set of modeled scenarios is provided in Table 3-1.

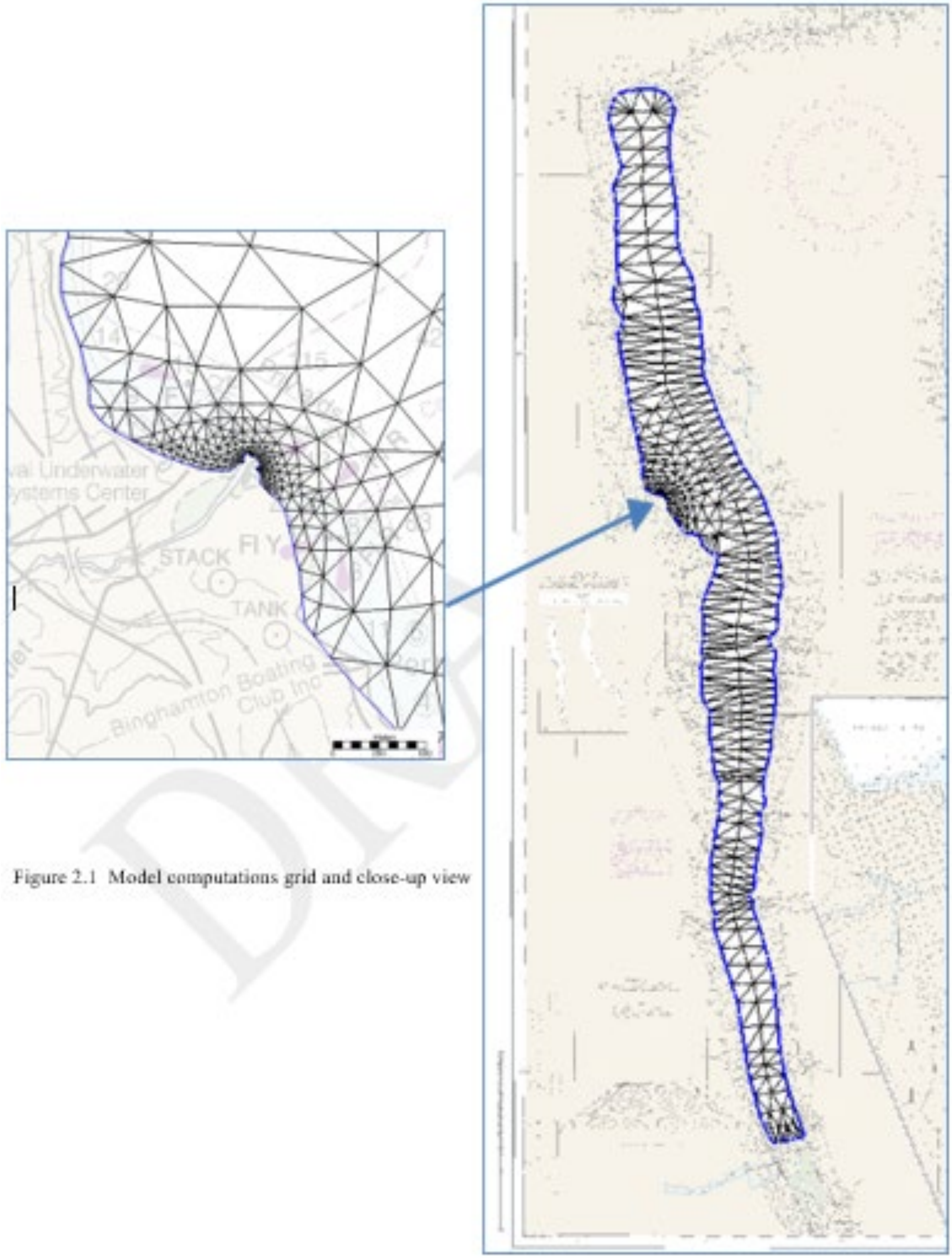

Figure 3-7 Model computation grid and close-up view at KLO mouth

Table 3-1 Scenarios projected using the RMA-10 model for the Thermal Criteria Study.

Scenario	GGF Operation	KLO Flow	Seneca Lake Temperature	Meteorological Conditions
1A Summer	107 MW; 502 MBTU/hr 3 pumps ΔT 14.7 °F	28 cfs	77.1 °F	Solar radiation, wind, humidity, elevation, air temperature during 90th
1B Summer	107 MW 502 MBTU/hr 2 pumps ΔT 17.6 °F	28 cfs	77.1 °F	Solar radiation, wind, humidity, elevation, air temperature during 90th
2 Summer	107 MW 502 MBTU/hr 2 pumps ΔT 17.6 °F	14 cfs	77.8 °F	Solar radiation, wind, humidity, elevation, air temperature during 95th
3 Shoreline plume	107 MW 502 MBTU/hr 2 pumps ΔT 17.6 °F	28 cfs	77.8 °F	Solar radiation, wind, humidity, elevation, air temperature during 95th Wind from NE.
4A Winter	107 MW 502 MBTU/hr 3 pumps ΔT 14.7 °F	147 cfs	44.9 °F	Solar radiation, wind, humidity, elevation, air temperature during typical winter conditions
4B Winter	107 MW 502 MBTU/hr 2 pumps ΔT 17.6 °F	147 cfs	44.9 °F	Solar radiation, wind, humidity, elevation, air temperature during typical winter conditions.
5 Winter	107 MW 502 MBTU/hr 3 pumps ΔT 14.7 °	35 cfs	40.0 °F	Solar radiation, wind, humidity, elevation, air temperature during extreme winter conditions.
8 Summer (+6)*	107 MW 502 MBTU/hr 2 pumps ΔT 17.6 °F	28 cfs	77.1 +2 °F	Solar radiation, wind, humidity, elevation, air temperature during 90th +6 °F air temperature

* The +6 °F air temperature scenario was run and provided no significant increase in plume size, negating the need to assess +2 °F and +4 °F scenarios.

4. COMPLIANCE WITH THERMAL CRITERIA

4.1 EMPIRICAL DATA

The empirical data collection effort of the thermal criteria study documented the temperature of Seneca Lake water as it is withdrawn by GGF, the temperature increase that occurs across the condensers, the temperature of the water as it is discharged into the Keuka Lake Outlet, temperature as Keuka Lake Outlet empties into Seneca Lake, and temperatures at various locations within Seneca Lake. Monthly averages of temperatures at several of the key points in the process are provided in Table 4-1.

Across the entire period of the study from May 2021 to April 2022, the monthly average inlet temperature of water withdrawn from Seneca Lake varied from 39.5 °F in February to 74.8 °F in August, averaging 55.5 °F for the year. The monthly average temperature differential varied from 9.4 °F to 13.6 °F. Maximum temperature differential each month ranged from 16.3 °F to 18.6 °F.

As the water was discharged into Keuka Lake Outlet, it had cooled slightly during October-April, approximately 1 °F, but during the warmer months it was nearly the same temperature as when it exited the GGF condenser. Monthly average temperature of the GGF discharge as it entered KLO varied from 49.1 °F in February to 86.7 °F in August, averaging 65.7 °F over the study.

Downstream of the confluence of the GGF discharge with KLO, during the study period the KLO was configured in a way that created three channels. Although channel configurations change over time, in the present configuration when KLO flow from upstream is low, the GGF discharge dominates the flow and mixing is substantial after the discharge enters the south side of KLO. When KLO flow is higher, above approximately 200 cfs, the GGF discharge remains concentrated on the south side of KLO. Station P, where KLO flow exits to the north, and Station G, the south exit, had distinctly different temperatures. Station P flow averaged 54.1 °F for the year (August-April), while Station G averaged 62.0 °F for the whole year (June-April), and 57.9 °F for the same months as at Station P. Approximately 60% of KLO flow exits through the north mouth, and about 33% through the south mouth.

The combined KLO and GGF flows enter Seneca Lake and mixes with the upper layers of water in the lake. At the closest station to the KLO outflow, Station H, average monthly temperatures ranged from 38.1 °F (February) to 75.1 °F (August), with annual mean temperature of 58.1 °F. At Station Q, 6500 ft north of the KLO mouth, average monthly temperatures ranged from 38.1 °F to 75.4 °F (August), with a mean over the months the station was used (August to April) of 51.9 °F. Notably, the mean temperature for these same months at Station H was also 51.9 °F.

Table 4-1 Monthly temperature (°F) statistics for Greenidge operation parameters, discharge to KLO (Station A), KLO discharge to Seneca Lake (Stations B, P and G), and Seneca Lake stations (H and Q) during thermal criteria study, May 2021-April 2022. Recorded temperatures are averaged over each hour, and then days.

Month	Greenidge Operating Data					Greenidge Discharge		Keuka Lake Outlet			Seneca Lake	
	Condenser Inlet Average	Condenser Outlet Average	Condenser Outlet Max	ΔT Average	ΔT Max	Station A Average	Station A Max[d]	Station B Average	Station P[a] Average	Station G Average	Station H Average	Station Q[a] Average
May	54.8	64.2	77.2	9.4	17.4	63.9	77.8	61.9	No Data	No Data[b]	54.3	No Data
Jun	63.8	75.0	87.8	11.1	18.4	75.1	81.2/87.5	69.8	No Data	80.4	63.5	No Data
Jul	72.7	84.3	94.4	11.6	18.4	84.3	89.7/93.9	72.6	No Data	81.2	73.0	No Data
Aug	74.8	86.7	96.2	11.8	17.5	86.7	91.0/96.0	72.9	77.9	81.9	75.1	75.4
Sep	71.2	82.3	89.8	11.1	18.6	81.7	89.6	67.5	76.8	79.9	71.4	71.1
Oct	64.8	75.4	85.1	10.6	17.6	73.0	84.6	62.5	67.1	69.7	64.1	64.4
Nov	54.3	65.1	73.3	10.8	17.1	64.1	72.9	No Data	52.7	56.3	52.8	53.9
Dec	45.8	56.7	63.6	10.9	16.3	55.6	62.5	40.2	44.3	50.2	44.3	45.0
Jan	41.2	54.8	60.1	13.6	18.2	53.2	59.7	33.9	40.6	48.1	39.0	40.4
Feb	39.5	50.4	56.3	10.9	16.3	49.1	54.7	34.2	38.3	42.1	38.1	38.1
Mar	40.6	51.0	58.5	10.4	16.4	49.9	58.1	37.0	38.8	41.3	39.3	38.6
Apr	43.0	53.3	60.9	10.3	16.3	52.2	60.2	48.1	50.1	51.4	43.2	40.4
Average[c]	55.5	66.6	75.3	11.1	17.4	65.7	73.5	54.6	54.1	62.0	54.8	51.9

[a] Station was not part of initial study design. It was established in August 2021.

[b] Sensor at the station was not retrieved. No data available for May 2021.

[c] Average of available monthly values.

[d] When only a single value is given the maximum hourly average is the same as the maximum instantaneous temperature. When two values are given, the first is the maximum hourly average and the second is the maximum instantaneous temperature.

4.1.1 Natural Seasonal Cycle Retained

Criterion: §704.2(a)(1) The natural seasonal cycle shall be retained.

The natural seasonal cycle in both KLO and Seneca Lake is typical of the northern hemisphere temperate zone climate, and follows the seasonal air temperature cycle. Most of the flow in KLO comes from the surface waters of Keuka Lake at the regulated outlet in Penn Yan. Maximum temperatures typically occur in late July or August, with minimum temperatures in January or February. The natural seasonal cycle for KLO is described by Station B temperatures, just upstream of the confluence with the GGF discharge (Figure 4-1). Minimum observed temperature was 32.1 °F on several days in January, and maximum temperature observed was 79.3 °F (August 13). Due to the data loss that occurred at Station B resulting from high flow events washing out or burying the sensor and theft of the sensor, a cosine wave was fitted to the data to better describe the seasonal cycle. The combined observed and predicted Station B temperatures indicate that KLO, independent of any influence of the GGF discharge, would be unsuitable for trout due to temperatures above their chronic threshold from June through September, when they would not be found in KLO but would be in cooler water within Seneca Lake.

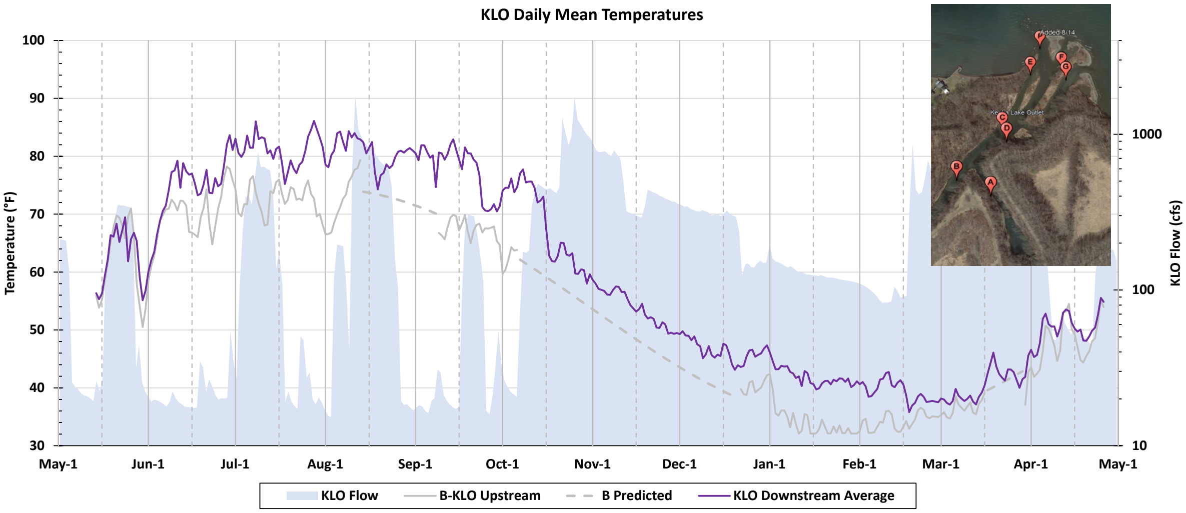

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Figure 4-1 Annual seasonal temperature cycle in KLO upstream of the GGF discharge (B), and at monitoring locations downstream of the discharge.

Average daily temperatures for stations along the south shoreline of KLO (D and G), the north shoreline (C and E), and the midchannel (F and P) all showed similar seasonal cycles to Station B, but with temperatures elevated by the GGF discharge. During periods of low KLO flow, the downstream temperatures are more uniform from shoreline to shoreline as the GGF discharge dominates the flow. During periods of higher KLO flow (generally above 200 cfs), there is less mixing of the GGF discharge with the KLO flow and the flow from GGF tends to stay closer to the south side of the stream. Under those conditions, south side temperatures (D and G) are closer to the discharge temperature, north side temperatures (C and E) are closer to the upstream KLO temperature (B), and the midchannel temperatures (F and P) are intermediate.

Seneca Lake temperatures exhibited a similar seasonal pattern, except that differences among stations were far less distinct (Figure 4-2). Station Q, farthest from the KLO mouth, had depth-averaged temperatures varying from 37.0 °F (Feb 26) to 77.5 °F (Aug 31). Daily mean temperatures at the stations closer to the KLO mouth were typically within 2 °F of those at Station Q.

The criterion that the natural seasonal temperature cycle is retained is met by the GGF discharge.

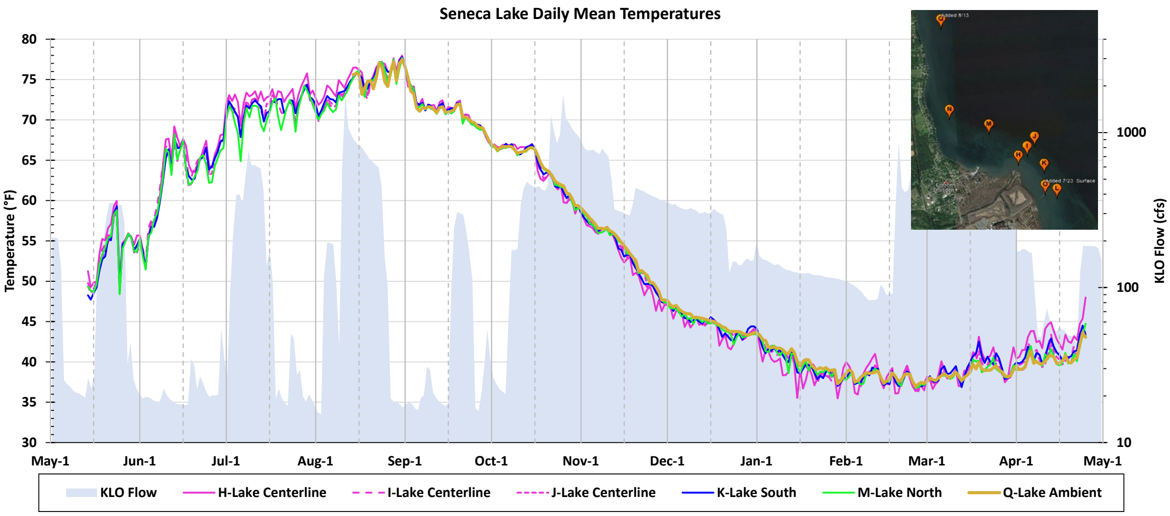

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Figure 4-2 Annual seasonal temperature cycle in Seneca Lake outside the influence of the GGF discharge (Q), and at monitoring locations closer to the discharge.

4.1.2 Spring and Fall Temperature Changes Gradual

Criterion: §704.2(a)(2) Annual spring and fall temperature changes shall be gradual.

The transition between maximum summer temperatures and minimum winter temperatures in the plume-affected areas of both KLO (Figure 4-1) and Seneca Lake (Figure 4-2) is similar to the gradual transition in areas not affected by the plume.

The criterion that spring and fall temperature changes are gradual is met by the GGF discharge.

4.1.3 Large Day-to-Day Temperature Fluctuations Shall Be Avoided

Criterion: §704.2(a)(3) Large day-to-day temperature fluctuations due to heat of artificial origin shall be avoided.

Despite the fluctuations that occurred in GGF thermal output as generation load varied within a day and across days, the day-to-day fluctuations in KLO temperatures downstream of the GGF discharge (Stations C, D, E, F, G, P) were not greater than those upstream (Station B) (Figure 4-3). Upstream of the GGF discharge, approximately 46% of day-to-day changes were within +/- 1 °F, 72% within +/- 2 °F, and 88% within +/- 3 °F. For the downstream stations within KLO, the corresponding metrics ranged from 45%-57% within +/-1 °F, 71%-85% within +/- 2 °F, and 87%-94% within +/- 3 °F. Overall, downstream KLO temperatures were less variable on a day-to-day basis than KLO temperatures upstream of the GGF discharge.

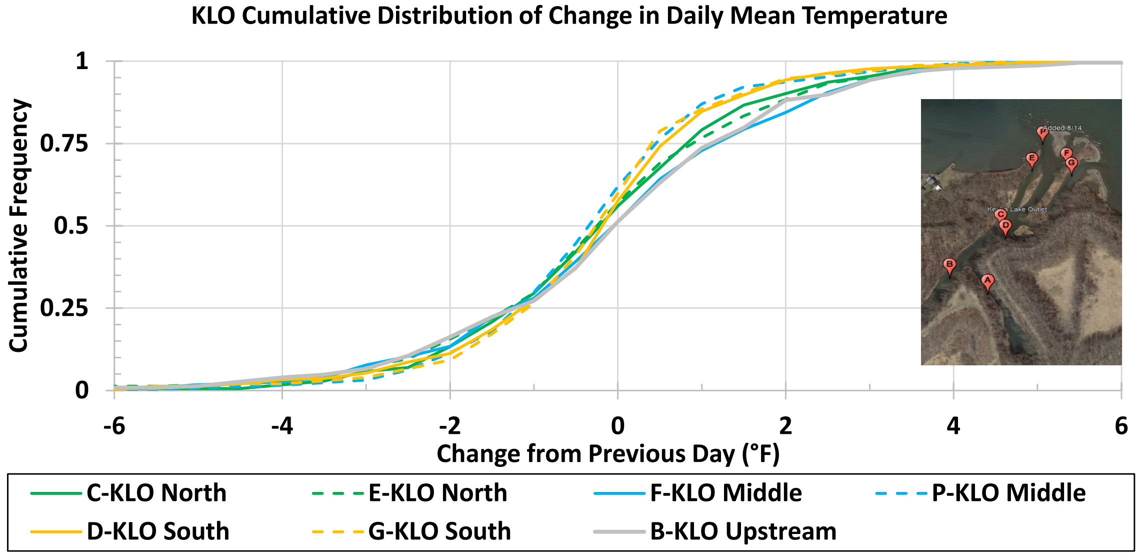

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Figure 4-3 Cumulative distribution of change in mean daily temperature at upstream KLO (B), and downstream KLO stations (C,D,E,F,G,P).

Within Seneca Lake, temperature is far more stable and changes from day to day are typically smaller due to the buffering capacity of the extremely large volume of the lake (Figure 4-4). At Station Q, 57% of day to day changes in depth-averaged ambient lake temperature were within +/- 0.5 °F, 87% within +/- 1 °F, and 98% within +/- 2 °F.

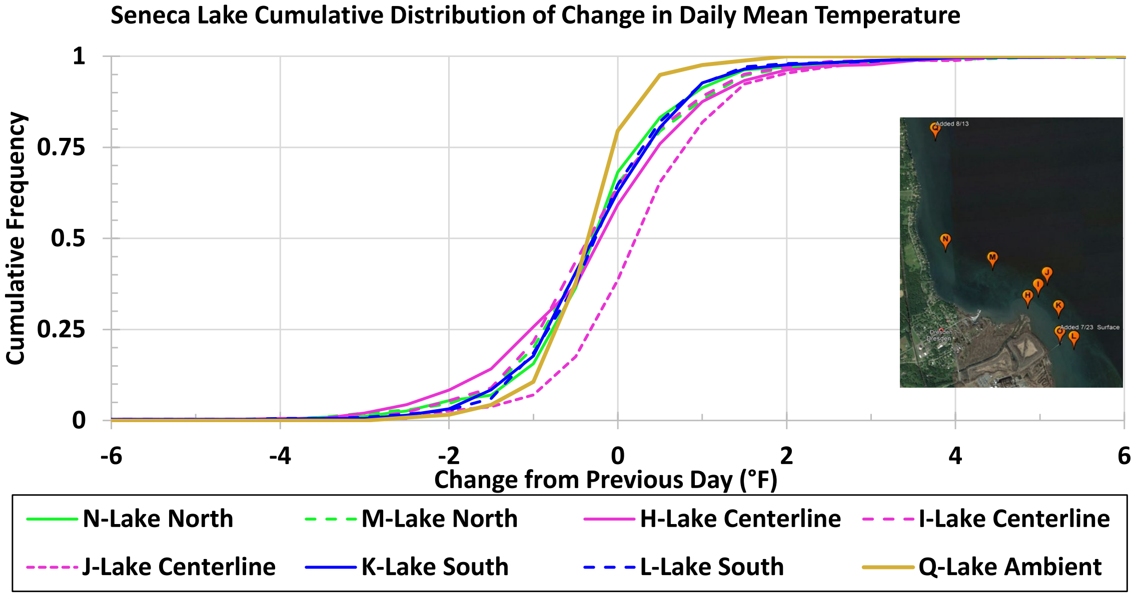

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Figure 4-4 Cumulative distribution of change in mean daily temperature at Seneca Lake outside the influence of the GGF discharge (Q), and at stations influenced by the discharge (N,M,H,I,J,K,L). All stations are based on daily average across surface, mid, and bottom measurements.

At the Seneca Lake stations closer to the KLO outlet (H through N) day-to-day variations in mean temperature were within ± 0.5 °F 37% to 47% of the time, ± 1 °F 62% to 76% of the time, ± 2 °F 88% to 95% of the time. At all of the Seneca Lake stations, day-to-day variations were within the range of -3 °F to +3.5 °F at least 98% of the time.

The criterion that large day-to-day fluctuations shall be avoided is met by the GGF discharge.

4.1.4 Development or Growth of Nuisance Organisms Shall Not Occur

Criterion: §704.2(a)(4) Development or growth of nuisance organisms shall not occur in contravention of water quality standards.

This criterion is biological rather than physical, and thus was not a subject of this Study.

4.1.5 Discharges which would lower receiving water temperature shall not cause a violation of water quality standards

Criterion: §704.2(a)(4) Discharges which would lower receiving water temperature shall not cause a violation of water quality standards and section 704.3 of this Part.

The GGF discharge does not lower receiving water temperature, therefore this criterion does not apply.

4.1.6 Routine Shut Down Shall Not be Scheduled December through March

Criterion: §704.2(a)(6) For the protection of the aquatic biota from severe temperature changes, routine shut down of an entire thermal discharge at any site shall not be scheduled during the period from December through March.

The GGF SPDES Permit contains Additional Requirement 10.

10. Because of the possible attraction of fish to the warmed water in the Keuka Lake Outlet, and the possibility of inducing cold shock to these fish in the event of rapid plant shutdown during the period between November 1 and April 30, the following operational requirements shall be instituted relative to normal plant operation and plant shutdown.

   a. When the unit is taken off line, cessation of cooling water flow will become part of the shutdown procedure and should occur no sooner than 10 hours after generation ceases.

   b. By October 15 of each year, the permittee will submit to the fisheries manager in Avon the schedule for all outages for the coming period. If no outages are planned, the permittee will so state.

GGF follows these permit requirements, therefore the criterion is being met.

4.1.7 No Discharge Over 70°F to Stream Classified for Trout

Criterion: §704.2(b)(2) Trout waters (T or TS).
(i) No discharge at a temperature over 70 degrees Fahrenheit shall be permitted at any time to streams classified for trout.

The lower 0.6 mile of KLO is designated C(T), with the GGF discharge affecting the lower 700 feet of the stream. During five months (June through October) of the study, the GGF discharge typically exceeded 70 °F (Figure 4-6). However, during the three month period from June to August, daily average temperatures of the KLO were naturally above 70 °F upstream of the GGF discharge. Moreover, water temperature in KLO would naturally increase further due to solar warming in the shallow water of the lower part of KLO (Figure 4-1).

Thus, while the GGF discharge continued to meet permit limits, and the KLO temperatures upstream from the GGF discharge were above 70°F the criterion that a discharge over 70 °F is not permitted to a trout water was not satisfied from May through October.

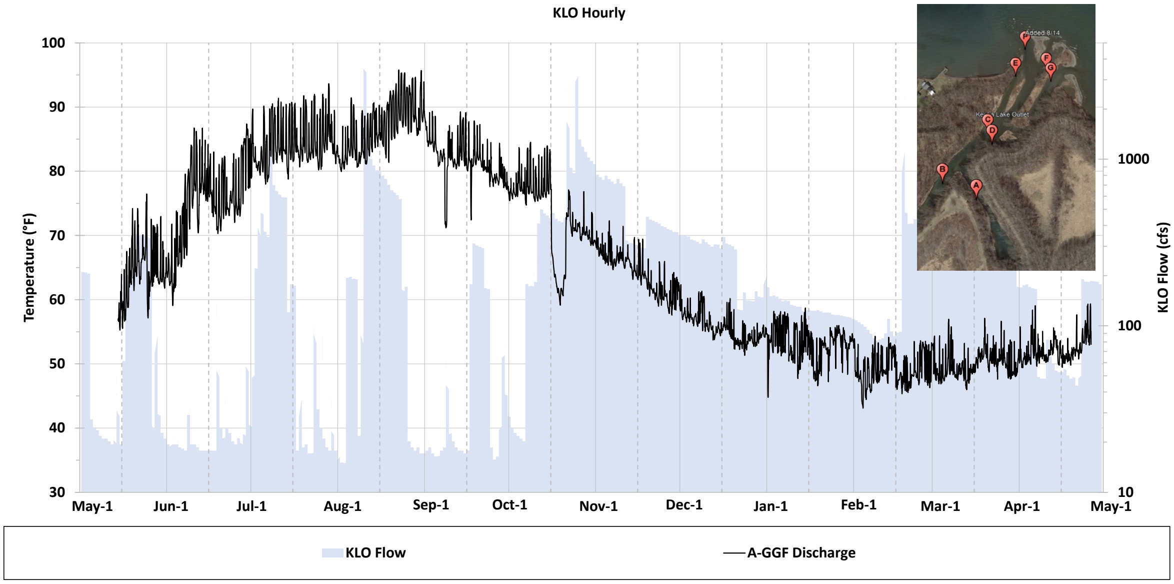

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Figure 4-5 Observed hourly GGF discharge temperature at Station A.

4.1.8 From June through September No More than 2°F to Rise in Stream Classified for Trout

Criterion: §704.2(b)(2) Trout waters (T or TS)
(ii) From June through September no discharge shall be permitted that will raise the temperature of the stream more than two Fahrenheit degrees over that which existed before the addition of heat of artificial origin.

The lower 0.6 mile of KLO is designated C(T), with the GGF discharge affecting the lower 700 feet of the stream. Due to the presence of the GGF discharge there was more than a 2 °F temperature increase in at least part of KLO from June through September (Figure 4-7). During periods of very high flow within KLO prior to the juncture with the GGF discharge, there were times when the north side of KLO was within 2 °F of ambient.

The criterion of maximum increase in stream temperature of 2 °F from June through September is not met by the GGF discharge.

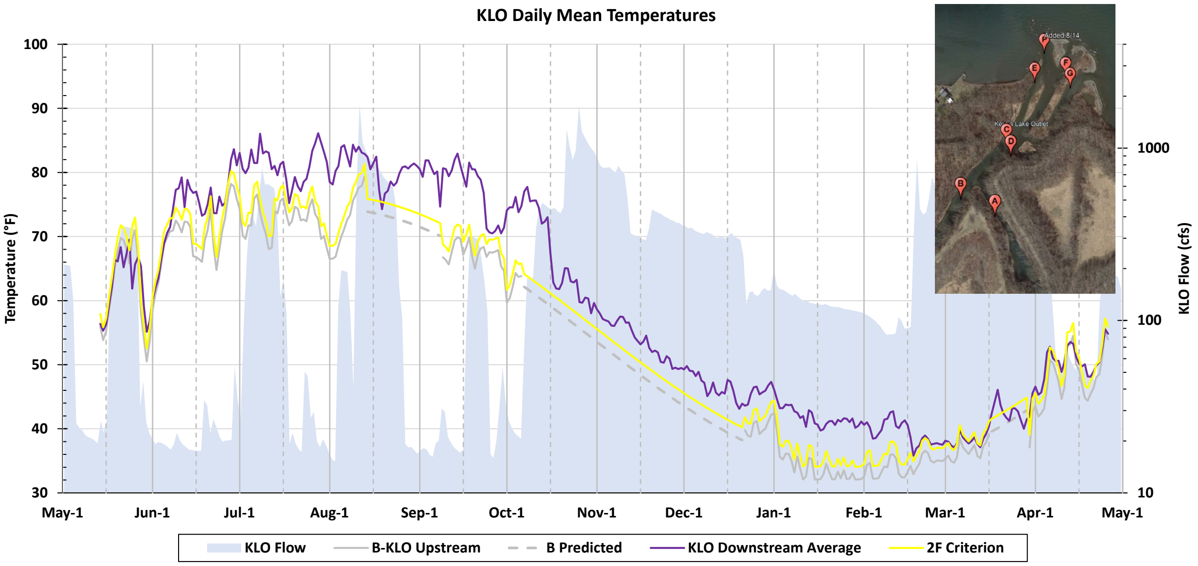

Figure 4-6 Hourly temperature observed in KLO (Stations C,D,E,F,G, and P) downstream of the GGF discharge. Yellow line indicates criterion for temperature rise (2°F June-September, and minimum of 50°F or 5°F rise October-May). Limit based on predicted Station B temperature when data from the station were unavailable.

4.1.9 From October through May Trout Stream Temperature Rise No More than 5°F or to 50°F Maximum

Criterion: §704.2(b)(2) Trout waters (T or TS)
(iii) From October through May no discharge shall be permitted that will raise the temperature of the stream more than five Fahrenheit degrees over that which existed before the addition of heat of artificial origin or to a maximum of 50 degrees Fahrenheit whichever is less.

The lower 0.6 mile of KLO is designated C(T), with the GGF discharge affecting the lower 700 feet of the stream. Parts of lower KLO were above the limit nearly continuously from July through February (Figure 4-7).

The criterion of maximum increase in stream temperature of 5 °F or stream temperatures raised above 50 °F from October through May is not met by the GGF discharge.

4.1.10 From June through September Trout Stream Temperature May Not Decrease More than 2°F

Criterion: §704.2(b)(2) Trout waters (T or TS).
(iv) From June through September no discharge shall be permitted that will lower the temperature of the stream more than two Fahrenheit degrees from that which existed immediately prior to such lowering

The GGF discharge does not cause a decrease in stream temperature, therefore this criterion is met.

4.1.11 Lake Surface Temperature Rise No More Than 3°F

Criterion: §704.2(b)(3) Lakes.
(i) The water temperature at the surface of a lake shall not be raised more than three Fahrenheit degrees over the temperature that existed before the addition of heat of artificial origin.

4.1.11.1 In-situ monitoring

The *in-situ* temperature sensors provide one data set with which to evaluate the 3°F surface temperature rise criterion; however the approved Study Plan did not include a station far enough from the KLO mouth to ensure that the data would be uninfluenced by the thermal plume. This was rectified in August when Station Q was added. From the start of the study in May until August, the uppermost twice-daily temperature measurement at the Finger Lakes Institute Clark's Point Buoy can be used to predict ambient lake surface temperature at Station Q[9].

Despite this limitation, the in-situ data demonstrate that there are times, primarily April-September when the rise in surface temperature did not meet the 3°F criterion during the study (Figure 4-8). The criterion was not met more frequently when KLO flow was low, and much less frequently during periods of high KLO flow.

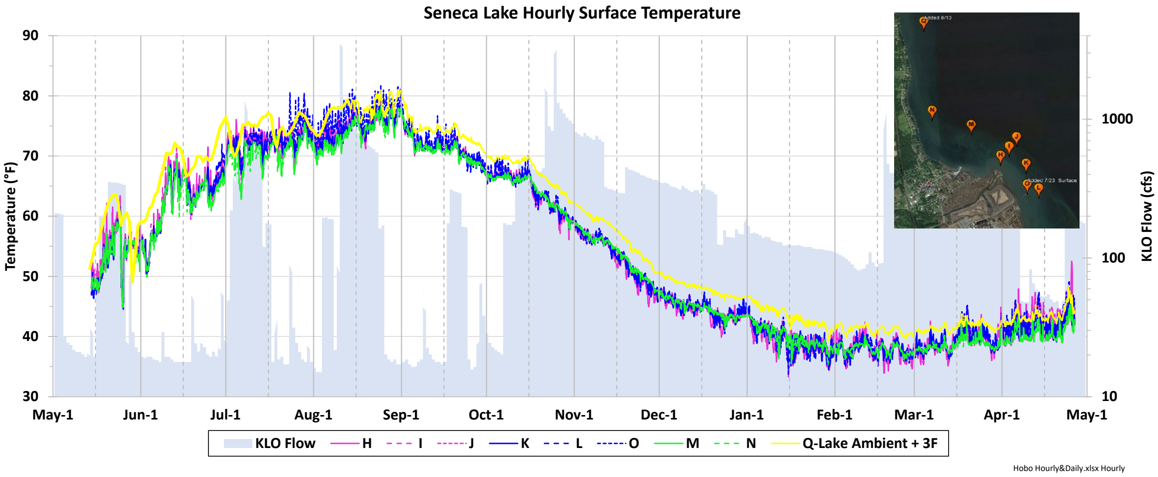

Figure 4-7 Hourly temperature observed by top HOBO sensor in Seneca Lake (Stations M,N,H,I,J,K,O, and L) and regulatory criterion of 3°F rise above lake ambient temperature predicted from the CPB data (May- August) or from Station Q (August-April).

4.1.11.2 Tri-axial mapping

Each of the 8 tri-axial surveys also provides a means to address the 3°F rise in surface temperature criterion. For each daily survey, the surface temperature measurements along the 6 (or 8 for the final 6 surveys) radial transects were interpolated to estimate the surface isotherms, and the areas within the boundaries of the interpolation in which the criterion is not met were calculated.

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[9] From August 13 through November 3, data are available from both Station Q and CPB. Daily mean temperature at Station Q can be predicted from CPB surface data: $T_Q = 0.9581 \times T_{CPB} + 2.661$ with $R^2 = 0.9817$.

June 25 and 26, 2021

The initial tri-axial survey on June 25 occurred during a period of generally sunny weather and variable winds of 5 to 20 mph from the South (direction 180°). Air temperatures were typically between 65 °F and 85 °F (Figure 4-9). Daily heat added to Seneca Lake by the water exiting KLO varied from 6,700 MBTU on June 24 to 7,500 MBTU on June 26.[10] KLO flow (not including GGF discharge) was low and steady below 20 cfs which resulted in minimal added heat energy. GGF heat energy varied between 200 and 400 MBTU/hr, accounting for 92% to 98% of the total net heat added by water entering the Lake from KLO.

On June 25 the area with greater than a 3 °F rise was calculated to be 38.4 acre (Figure 4-10). Because GGF was providing nearly all of the additional heat energy, the plume area is ascribable to GGF operation.

The survey conducted on the following day had very similar atmospheric, flow, and generation conditions (Figure 4-9), however the interpolated area with greater than a 3 °F rise was only 5.6 acres (Figure 4-11) indicative of a high degree of variability in plume characteristics even though environmental conditions appear to be similar.

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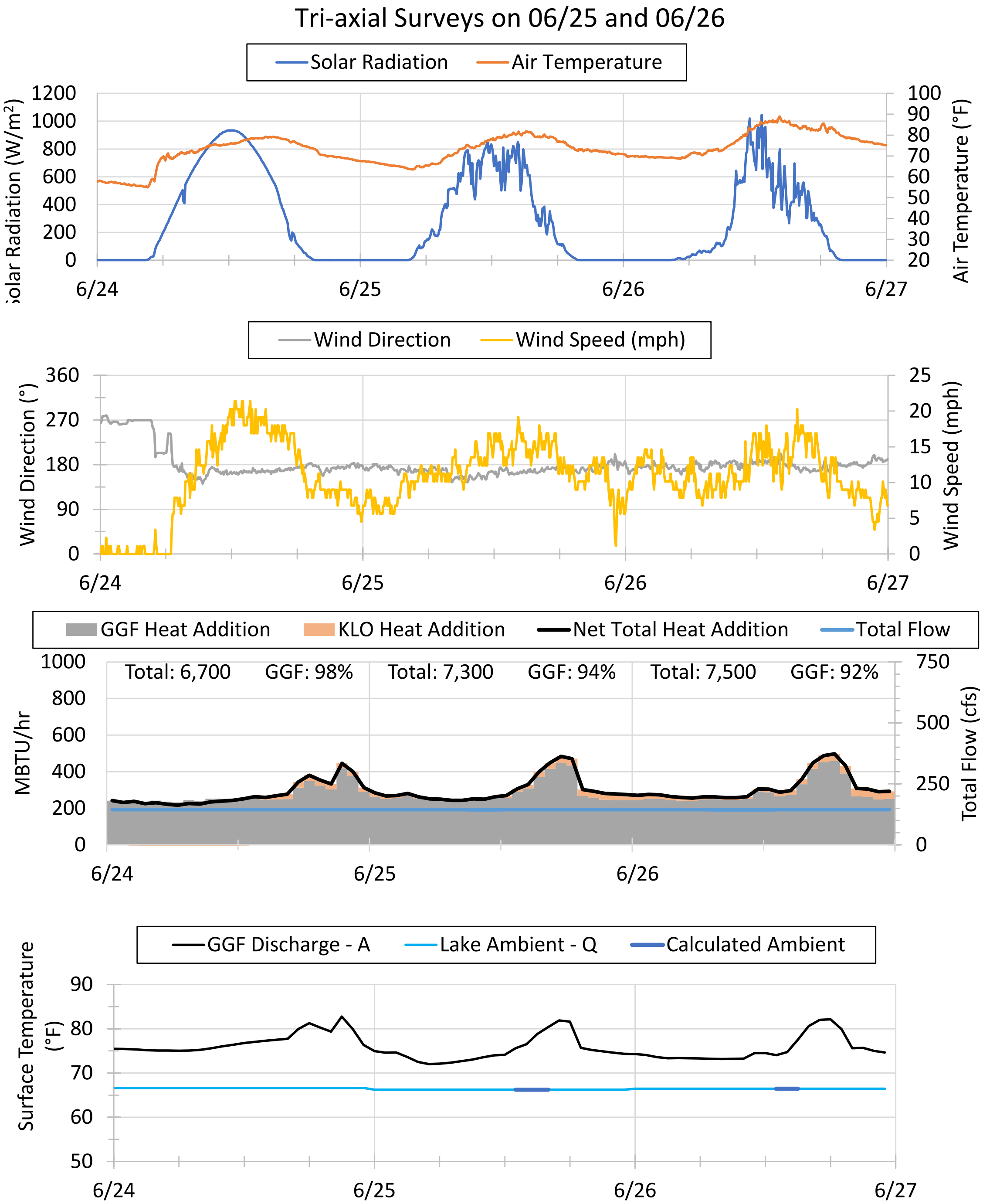
[10] Heat with potential to raise Seneca Lake temperature is added from both the natural flow of KLO and from the GGF discharge flow. Heat energy due to KLO each hour is calculated as $Heat_{KLO} = (T_B - T_Q) \times Flow_{KLO} \times 62.4 \times 3600$ where $Heat_{KLO}$ = heat energy (BTU) added from KLO, T_B = temperature at Station B, T_Q = surface temperature at Station Q, $Flow_{KLO}$ = KLO flow (cfs). Heat energy due to GGF is calculated as $Heat_{GGF} = (T_A - T_{in}) \times Flow_{GGF} \times 62.4 \times 3600$ where T_A = temperature at Station A, T_{in} = condenser inlet temperature, and $Flow_{GGF}$ = GGF flow (cfs). For this calculation, $Flow_{GGF}$ was assumed to be 57,000 gpm (127 cfs) with 2-pump operation, and 68,000 gpm (151 cfs) during 3-pump operation. When $T_B < T_Q$ the value for $Heat_{KLO}$ is negative. $Heat_{KLO}$ and $Heat_{GGF}$ are added to produce the net total heat added.



Triaxial Event Figures.xlsm Output

Figure 4-8 **Atmospheric conditions, heat addition to Seneca Lake, and Station A (GGF discharge) and Station Q (Lake ambient) temperatures prior to and during the tri-axial surveys on June 25 and June 26, 2021.**

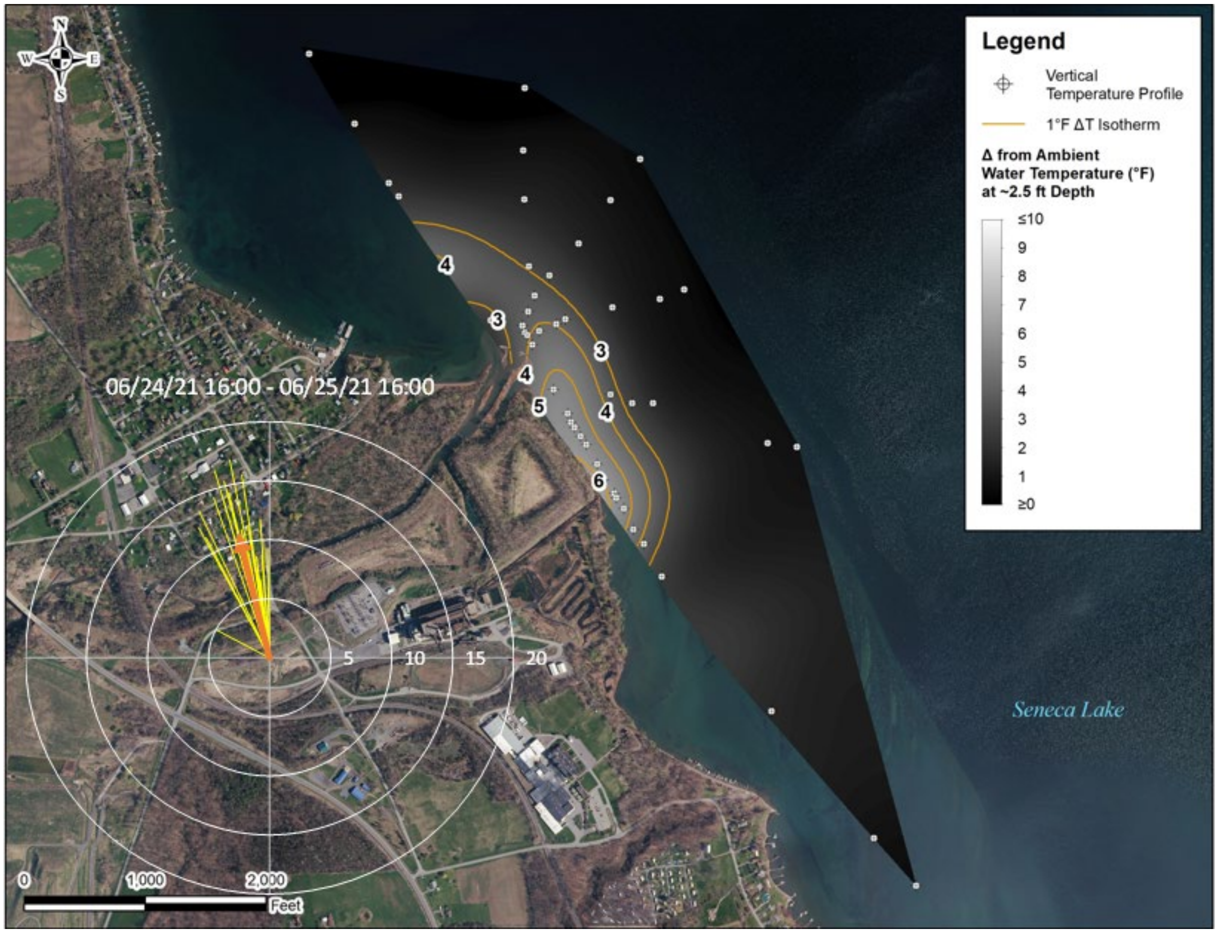


Figure 4-9 Interpolated surface ΔT isotherms from tri-axial survey conducted on June 25, 2021. Interpolated area with greater than 3°F rise in surface temperature is 38.4 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

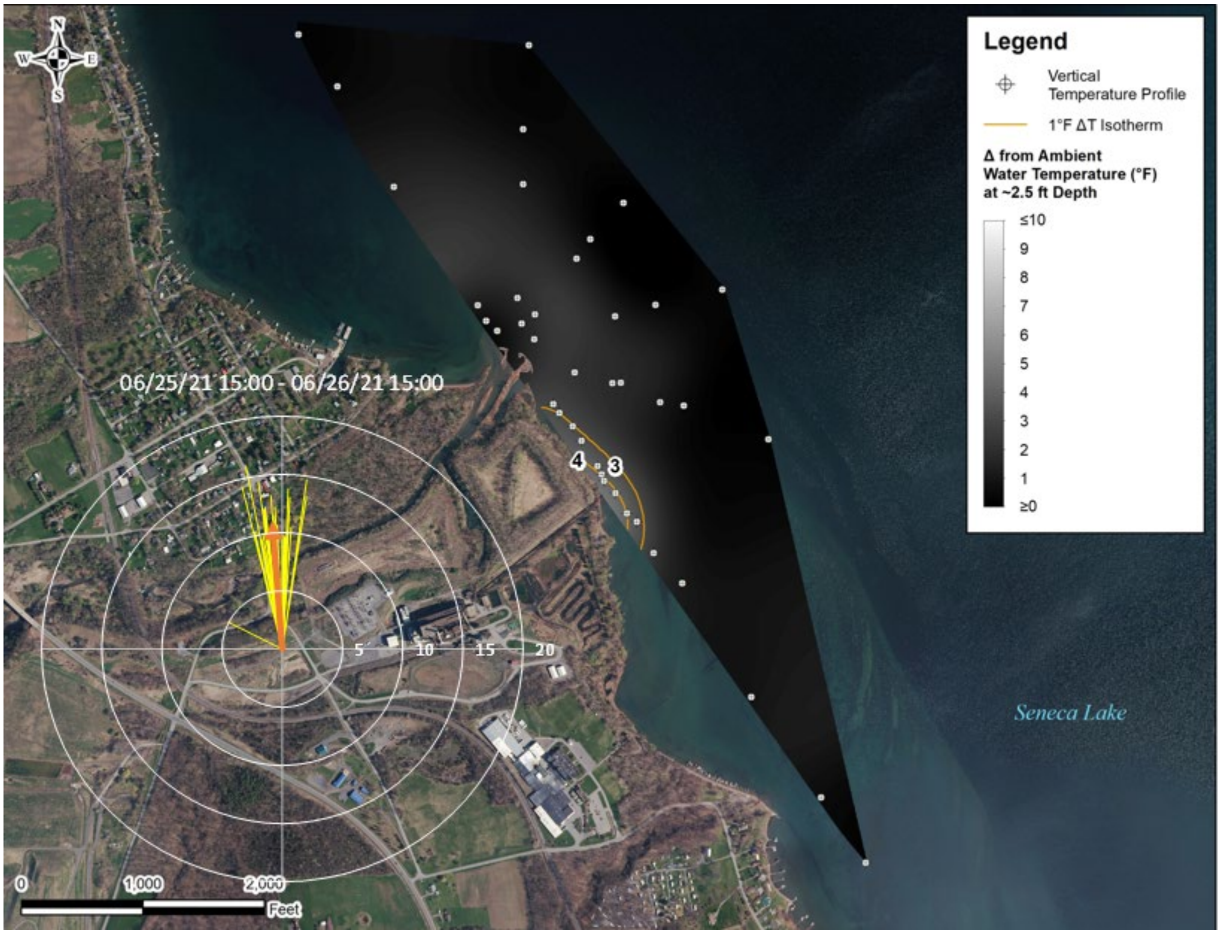


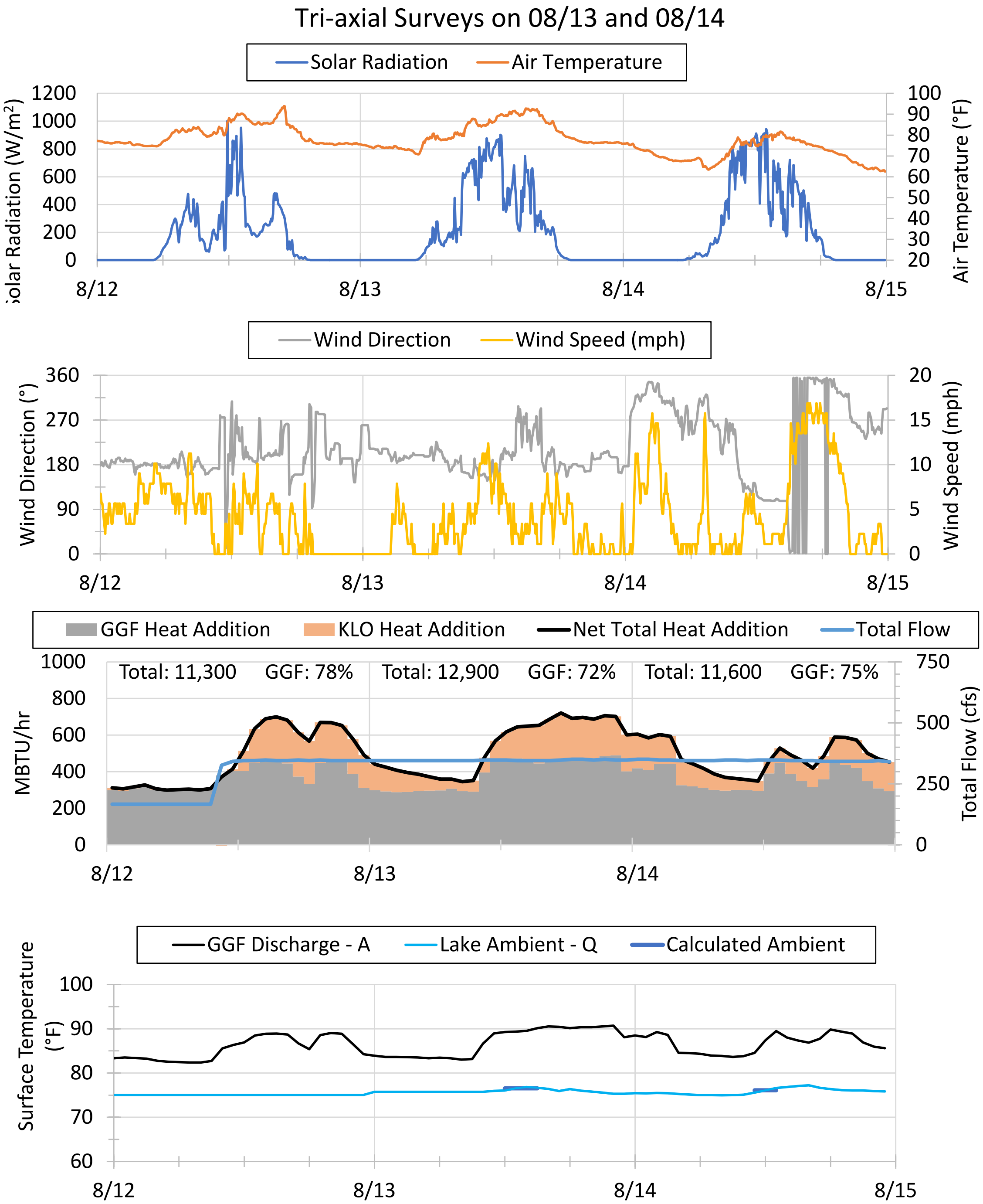
Figure 4-10 Interpolated surface ΔT isotherms from tri-axial survey conducted on June 26, 2021. Interpolated area with greater than 3°F rise in surface temperature is 5.6 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

August 13 and 14, 2021

The second set of tri-axial surveys occurred on August 13 and 14. Atmospheric conditions were partially cloudy with air temperatures reaching 90 °F on the 12th and 13th, and 80 °F on the 14th (Figure 4-12). Wind direction was from the south on the 12th and 13th, shifting to north then variable on the 14th. Generating load was variable with heat rejection ranging from approximately 300 to 500 million BTU/hr. KLO flow increased from a very low level to approximately 200 cfs mid-day on the 12th, then remained steady throughout the surveys. GGF flow was steady at 151 cfs. Total heat addition over August 12-14 was 11,300, 12,900, and 11,600 MBTU. The GGF contribution varied from 72% to 78% of the daily total net heat addition to Seneca Lake.

The area of Seneca Lake surface where the temperature was more than 3 °F above the ambient temperature was 49.6 acres. The addition of transects along the shoreline north and south of the KLO outlet allowed interpolation of isotherms nearly to the shore, however this inclusion could also incorporate solar warming in shallow near-shore areas into the interpolated plume area.

On August 14, the temperature increase of the surface water was more than 3 °F above ambient temperature was 27.5 acres (Figure 4-14), perhaps reflecting the reduction in added heat energy over the previous 24 hours relative to the survey conducted on August 13.



Triaxial Event Figures.xlsm Output

Figure 4-11 Atmospheric conditions, heat addition to Seneca Lake, and Station A (GGF discharge) and Station Q (Lake ambient) temperatures prior to and during the tri-axial surveys on August 13 and August 14, 2021.

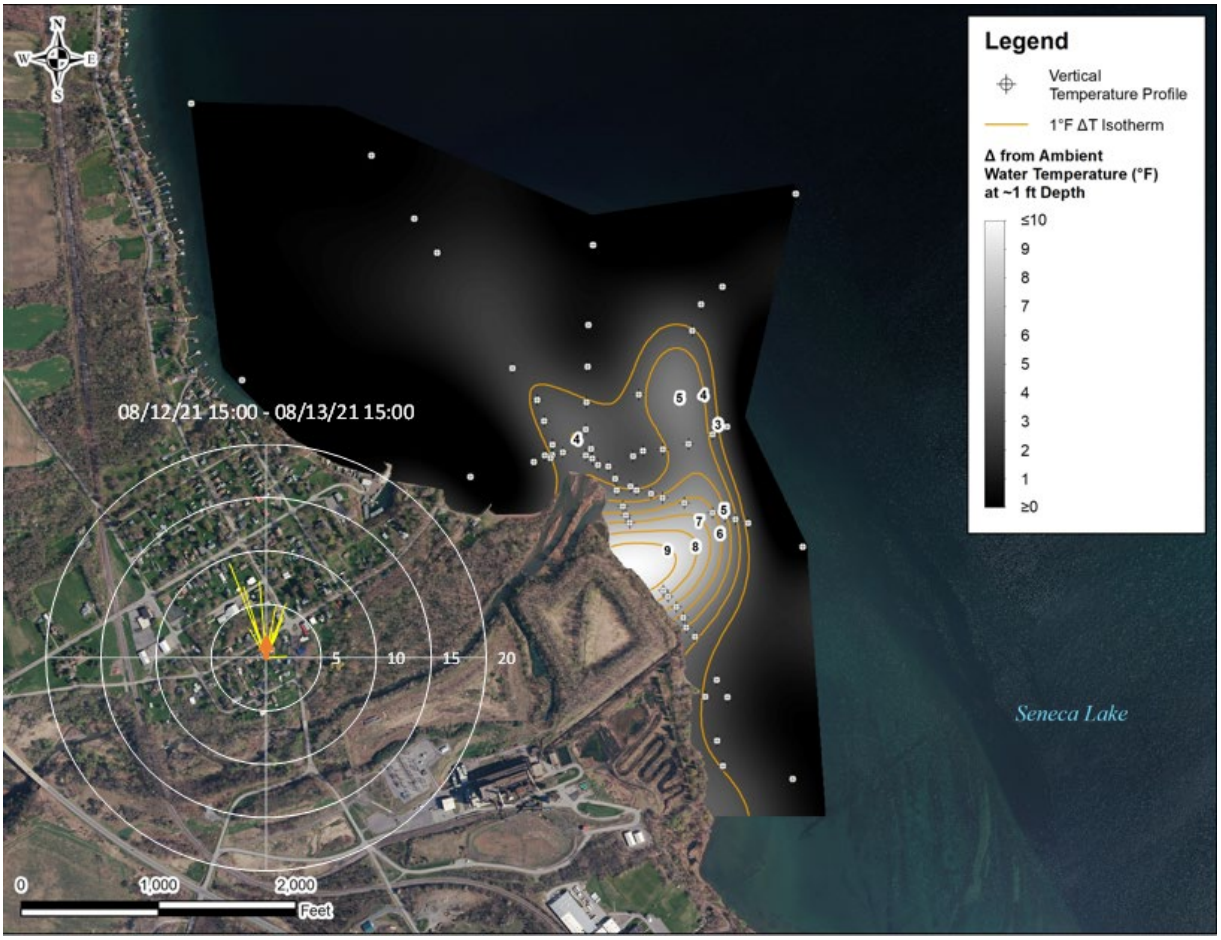


Figure 4-12 Interpolated surface isotherms from tri-axial survey conducted on August 13, 2021. Interpolated area with greater than 3°F rise in surface temperature is 49.6 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

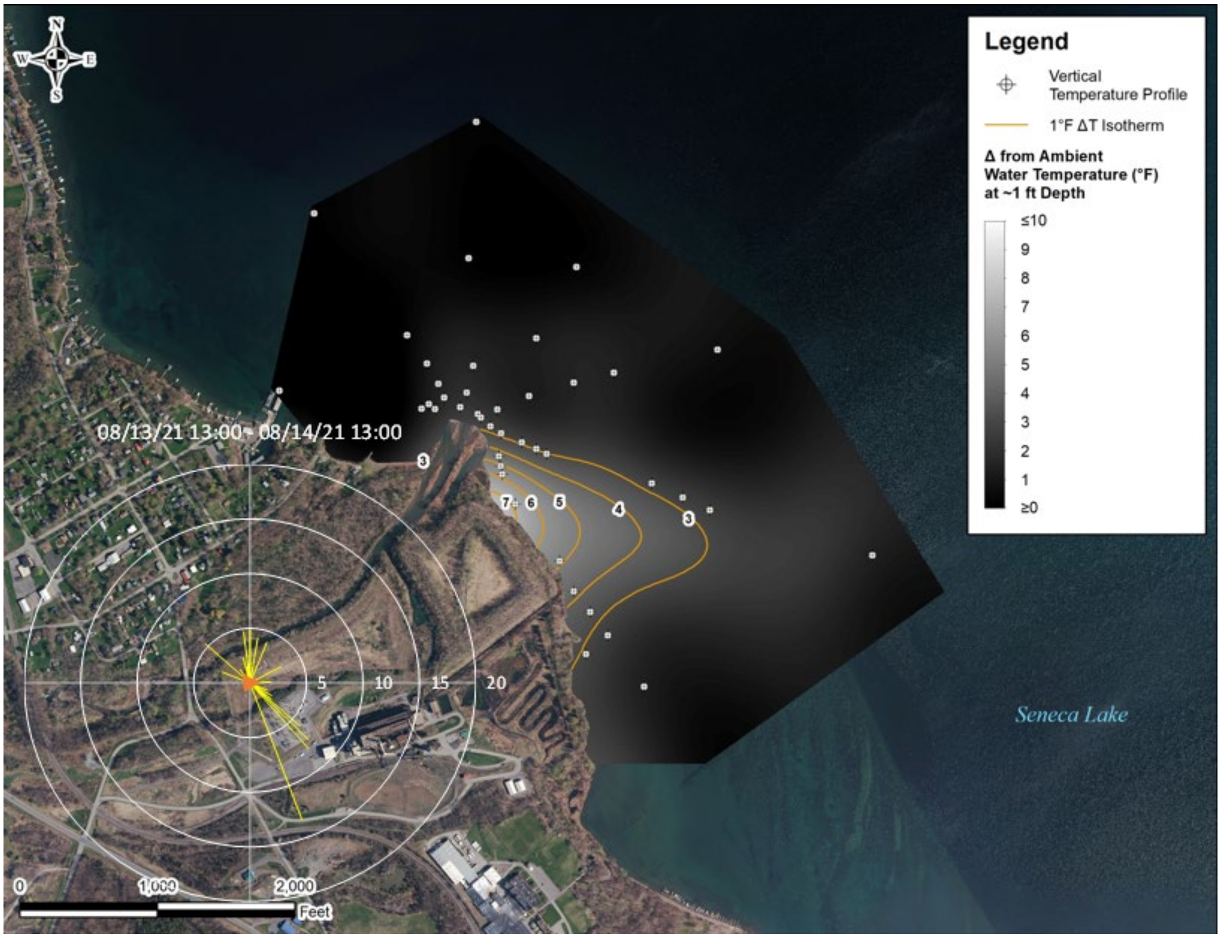


Figure 4-13 Interpolated surface isotherms from tri-axial survey conducted on August 14, 2021. Interpolated area with greater than 3°F rise in surface temperature is 27.5 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

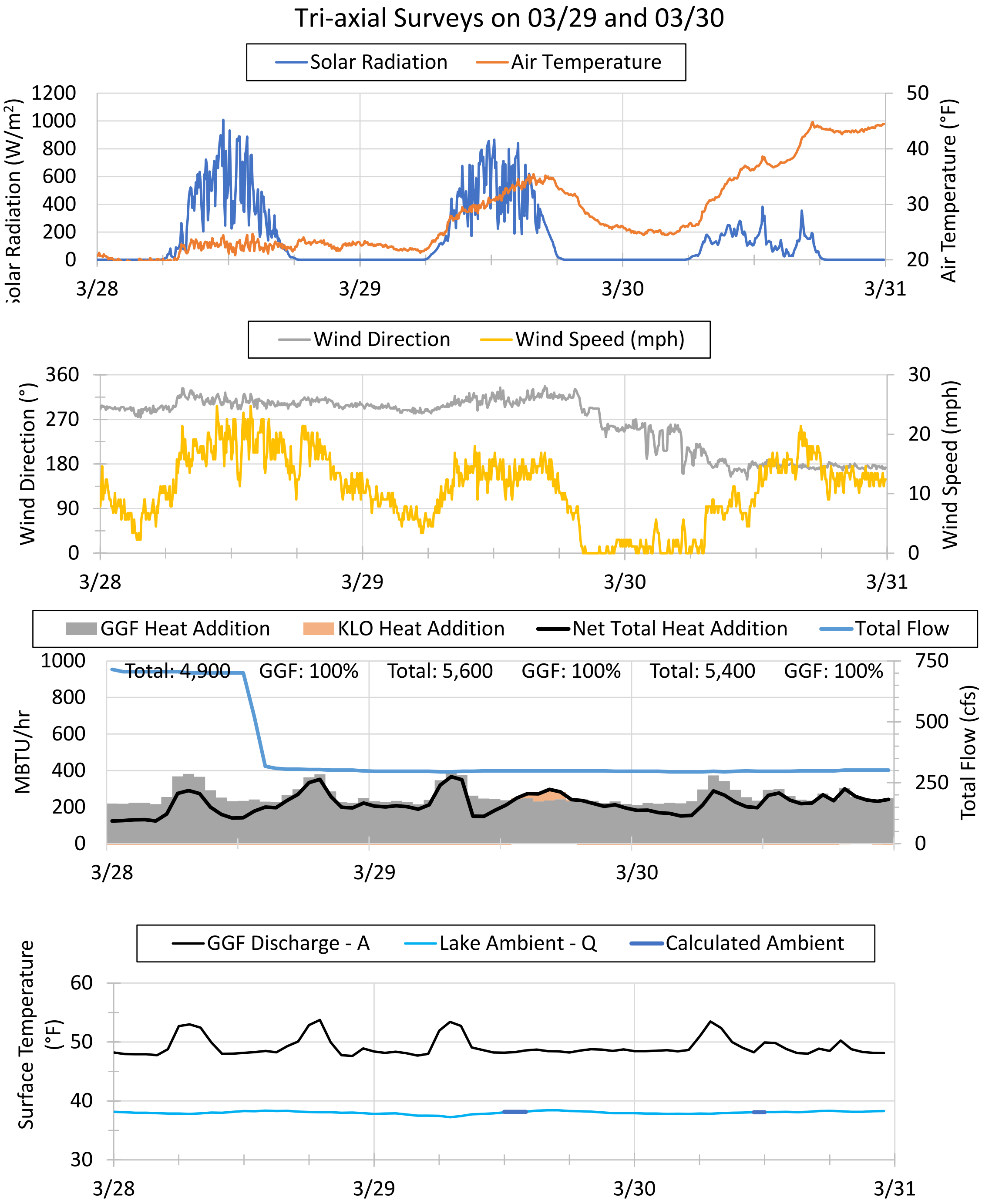
March 29 and 30,2022

The third set of tri-axial surveys were planned for February, but high KLO flows and weather conditions prevented completion of the effort at that time. From February 17 through March 27, KLO flows never dropped below 350 cfs. On March 28, gates at Keuka Lake were closed which abruptly reduced KLO flow from nearly 600 cfs to less than 200 cfs, allowing the study to be conducted.

Air temperatures were in the low 20s on March 28, and rose rapidly to mid 30s on the 29th and mid 40s on the 30th (Figure 4-15). Winds were from the northwest on 28th and 29th then turned to blow from the south on the 30th. GGF flows were steady at 127 cfs, while KLO flow from upstream was just under 200 cfs during the study. Heat rejection from GGF varied from about 200 to 350 MBTU/hr. Due to the cold air temperatures, heat addition from KLO was generally negative, i.e. colder than Lake surface temperature. The resulting daily net heat addition totals varied from 4,900 MBTU on March 28, 5,600 MBTU on March 29, and 5,400 MBTU on March 30, essentially 100% due to GGF operation.

The survey on the 29th showed only a small area of 7.8 acres above a temperature rise of 3 °F or more (Figure 4-16). This area occurred near the shore south of the KLO discharge, consistent with the wind from the NW directing the plume southward.

On March 30 interpolated area with more than a 3 °F increase was only 4.3 acres (Figure 4-17), even though the net heat addition only declined slightly from the previous day.



Triaxial Event Figures.xlsm Output

Figure 4-14 Atmospheric conditions, heat addition to Seneca Lake, and Station A (GGF discharge) and Station Q (Lake ambient) temperatures prior to and during the tri-axial surveys on March 29 and March 30, 2022.

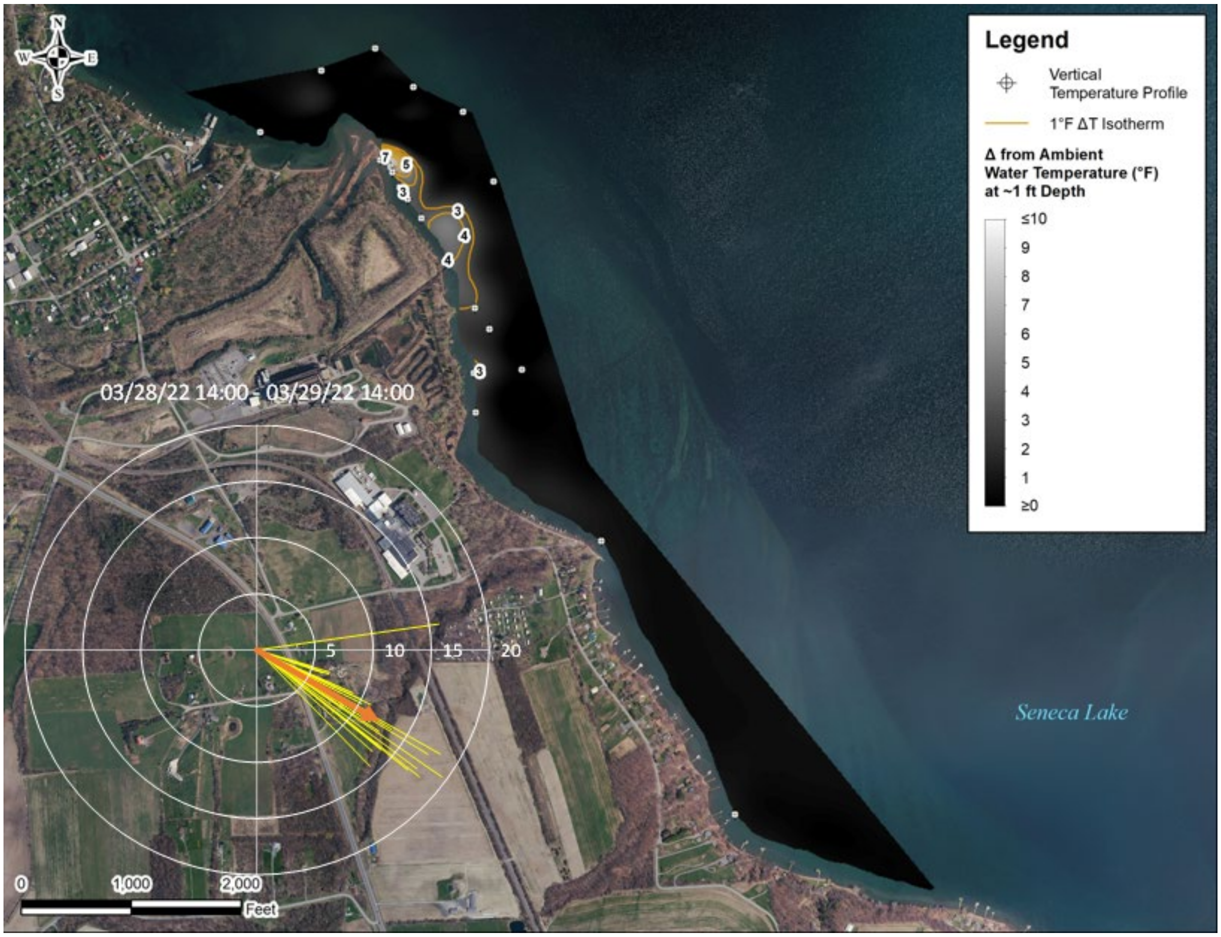


Figure 4-15 Interpolated surface isotherms from tri-axial survey conducted on March 29,2022. Interpolated area with greater than 3°F rise in surface temperature is 7.8 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

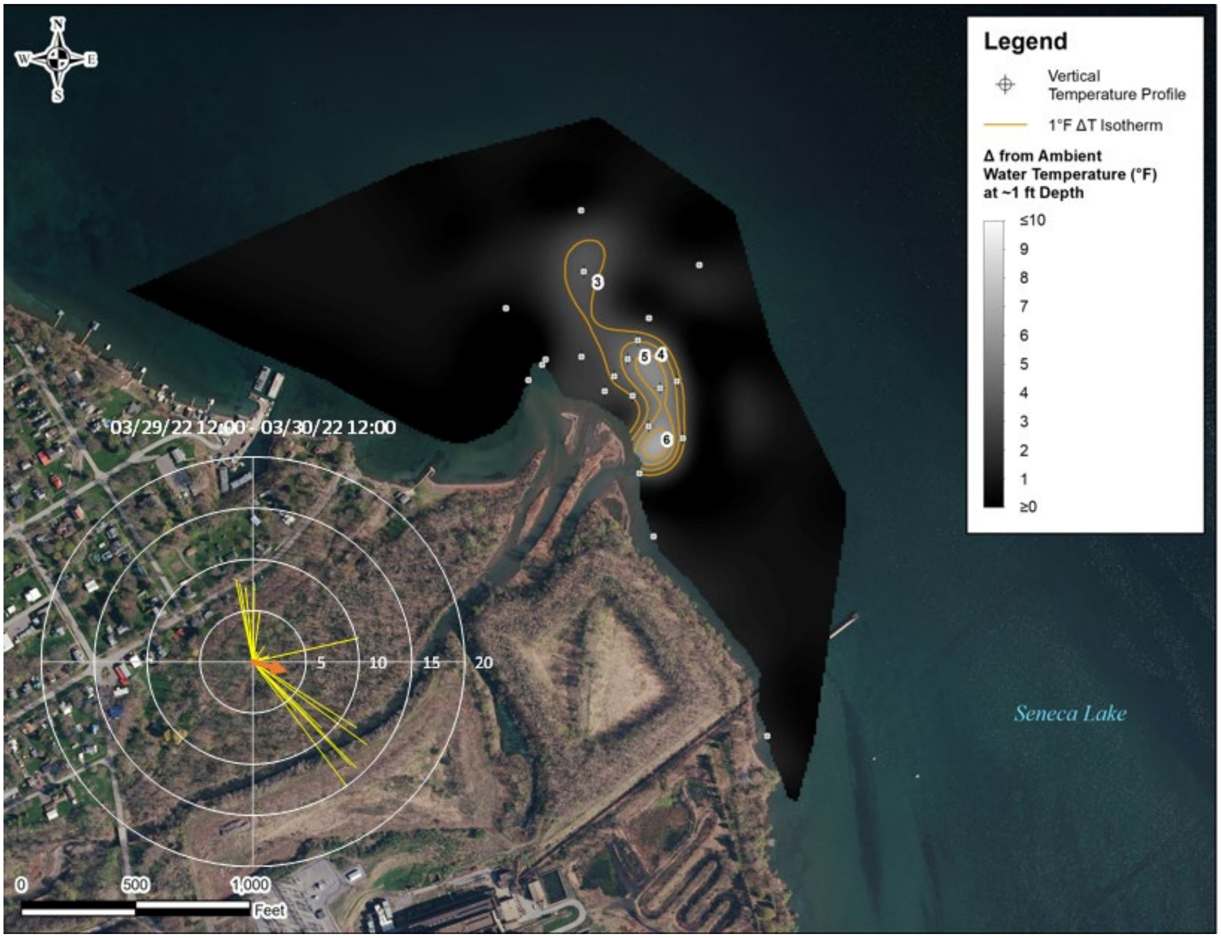


Figure 4-16 Interpolated surface isotherms from tri-axial survey conducted on March 30,2022. Interpolated area with greater than 3°F rise in surface temperature is 4.3 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

April 25 and 26, 2022

The final set of tri-axial surveys were performed on April 25 and 26, during a period of variable weather. April 24 and 25 were sunny and warm with peak air temperature in the 70s °F, while the 26th was overcast with air temperature around 50 °F (Figure 4-18). Lake ambient surface temperature at Station Q was variable during these three days ranging from 41.3 °F to 49.1 °F, indicative of substantial solar warming and subsequent cooling of the surface waters .

Heat additions due to GGF operation ranged approximately from 240 to 440 MBTU/hr. Heat additions from upstream KLO flow were substantially higher than in the previous surveys, varying from about 125 to 570 MBTU/hr. Combined KLO and GGF daily heat addition above ambient Lake temperature varied from 11,700 MBTU on April 24, 16,900 MBTU on April 25, and 11,100 MBTU on April 26 (for the part of the day prior to and during the survey). GGF contribution to the daily heat additions due to water exiting KLO was 54%, 42%, and 48% respectively.

During the 25th, the thermal plume was mainly dispersed to the north by the southerly winds (Figure 4-19)., however there were areas of warmer water along the shoreline south of the KLO outlet These nearshore areas would have been influenced by the general warming trend due to solar radiation and air temperatures during the 24th and 25th. Notably, the Shore South transect detected increasing temperatures near the cove where outfall 002 enters, probably a result of general near-shore warming and solar warming of the outfall flow itself. Therefore, measurements for the Shore South and F transects south of Lat 42.6786 were deleted when calculating plume area because these measurements would not be representative of GGF operation. The calculated area with surface temperature more than 3 °F above ambient was 46.8 acres.

On April 26, the surface plume of warmer water was dispersed over a wide area, with only a small area of distinctly higher temperatures near the KLO mouth. The area greater than 3 °F above ambient lake temperature was calculated to be 227.5 acres (Figure 4-20).

The larger areas within which the 3 °F surface ΔT criterion was not met in these two final surveys can be attributed to the larger total heat addition as a result of relatively high KLO flows (≈200 cfs) of water warmer than the Seneca Lake surface temperature. The GGF contribution to the heat generating these larger plumes was below 50% therefore the calculated areas of 46.8 and 227.5 acres are not attributable solely to GGF operation. The extreme variability of surface temperatures at this time of year (Figure 4-21), and the way the variability affects the calculated ambient temperature for setting the 3 °F ΔT criterion value may also be influencing the area calculation. Station Q, although still on the broad shallow shelf along the west shoreline of the lake, is at a depth of 20 ft, where surface water may warm more slowly than in the shallower areas over which the plume occurs.

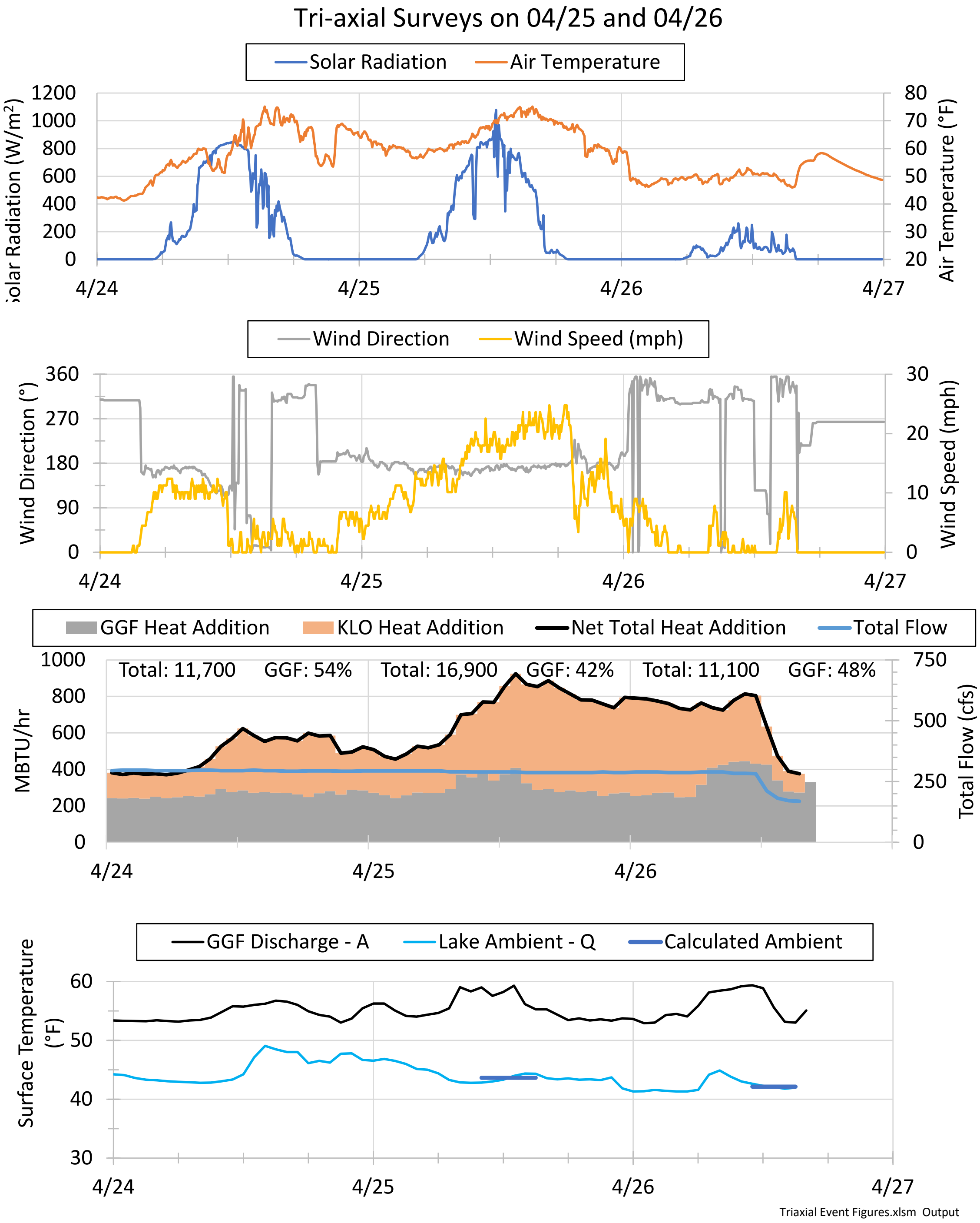


Figure 4-17 Atmospheric conditions, heat addition to Seneca Lake, and Station A (GGF discharge) and Station Q (Lake ambient) temperatures prior to and during the tri-axial surveys on April 25 and April 26, 2022.

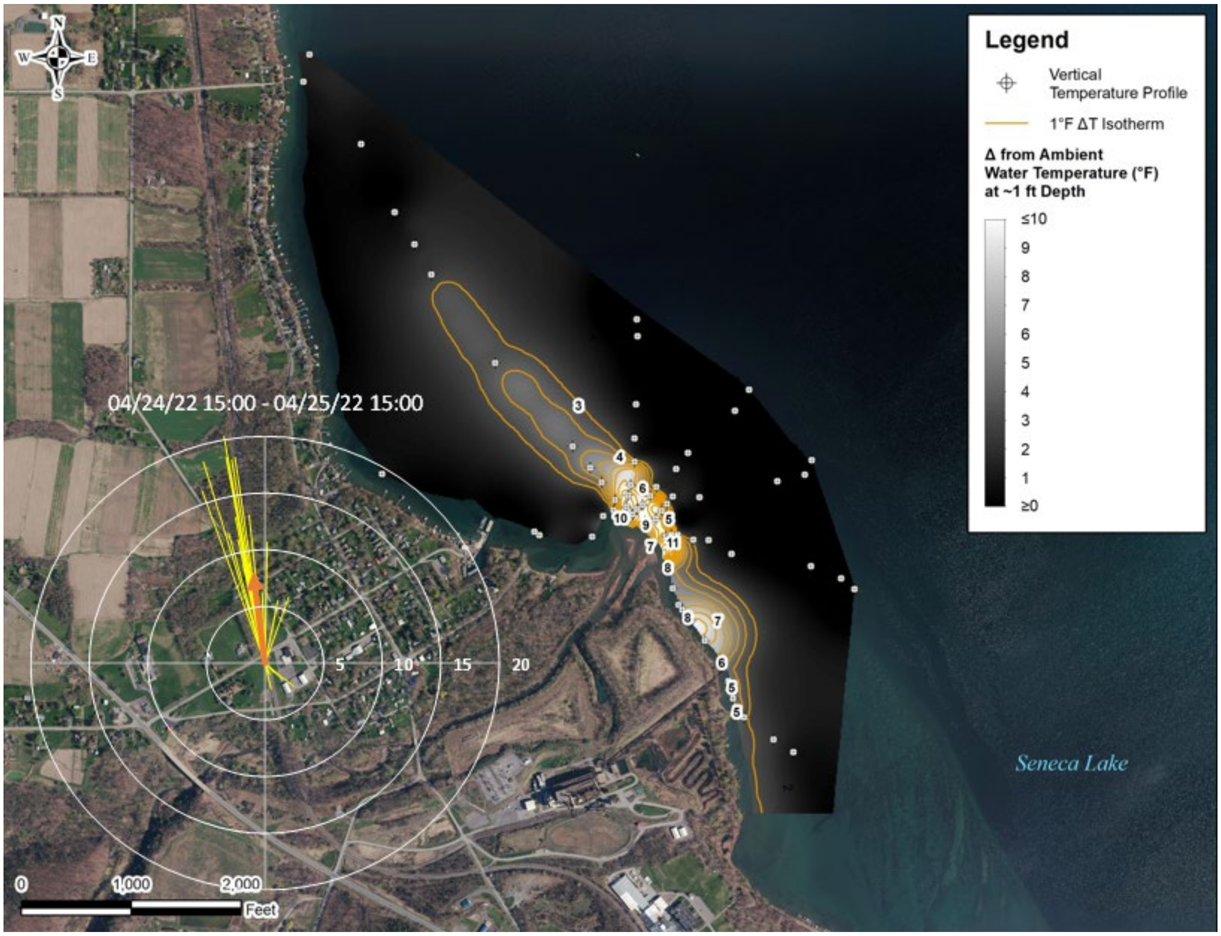


Figure 4-18 Interpolated surface isotherms from tri-axial survey conducted on April 25, 2022. Interpolated area with greater than 3°F rise in surface temperature is 46.8 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

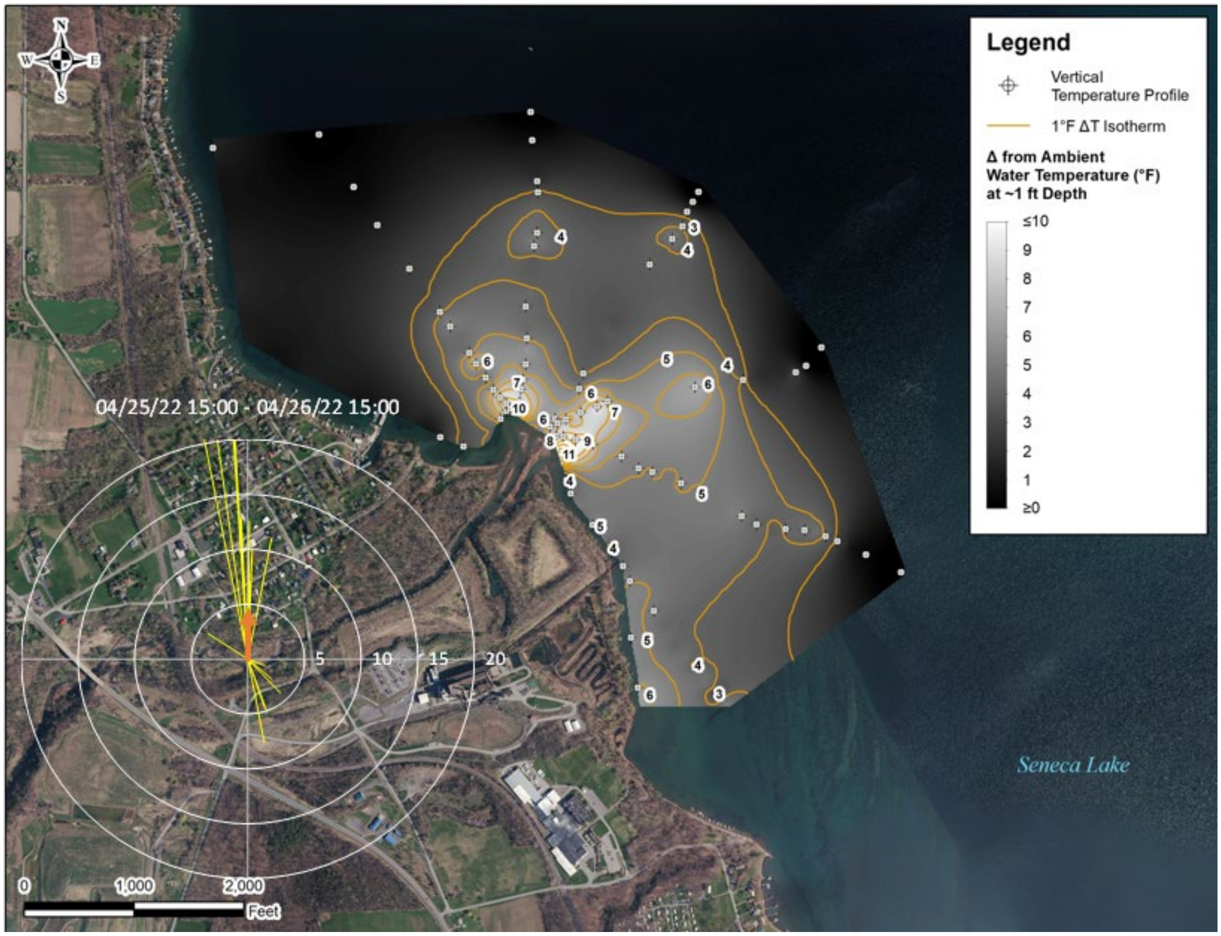


Figure 4-19 Interpolated surface isotherms from tri-axial survey conducted on April 26, 2022. Interpolated area with greater than 3°F rise in surface temperature is 227.5 acres. Wind rose shows wind velocity (mph) and direction over a 24-hour period ending with the survey.

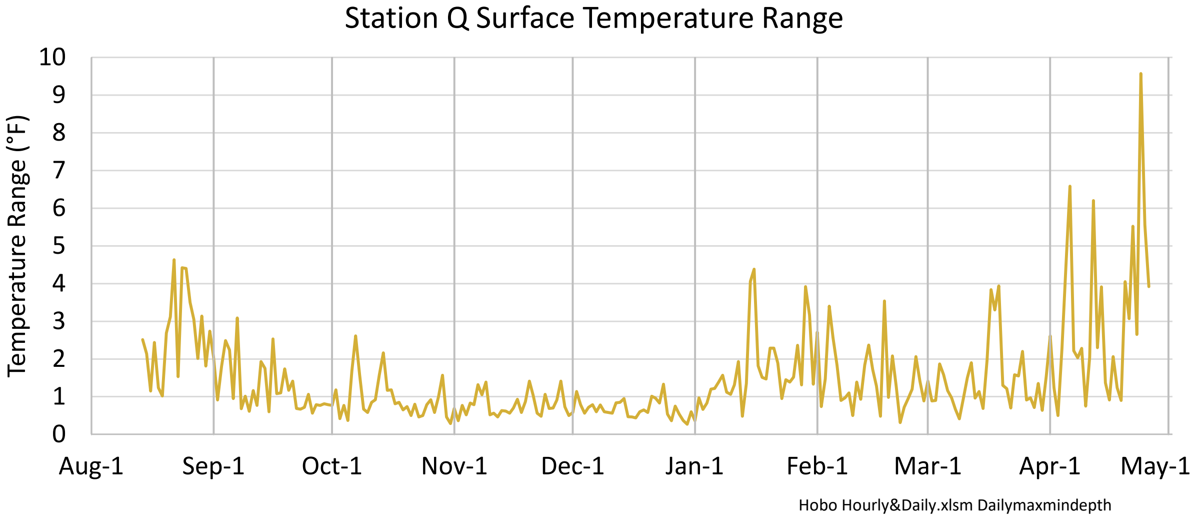


Figure 4-20 Daily range of surface temperature (°F) at Station Q from August to April.

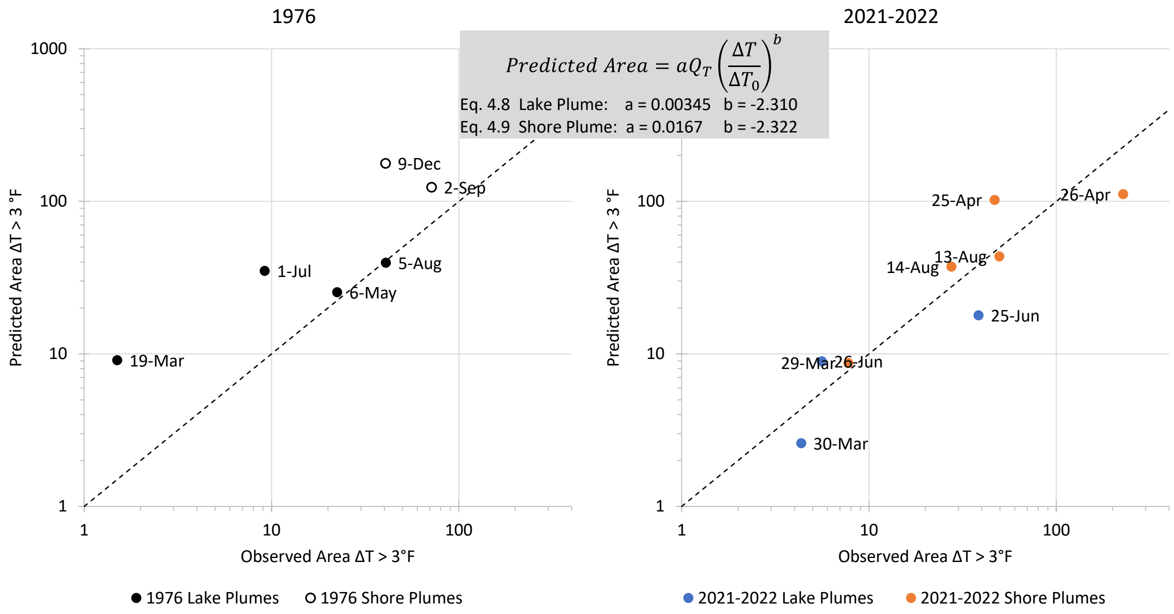
Table 4-2 Ambient surface temperatures and area exceeding 3 °F temperature rise criterion during each tri-axial survey.

Survey Date	Ambient Surface Temperature (°F)	Criterion Temperature (°F)	Total Heat Addition Prior 24 Hours (MBTU)	Area Outside Criterion (acres)
6/25/2021	63.6	66.6	7,000	38.4
6/26/2021	63.8	66.8	7,100	5.6
8/13/2021	76.5	79.5	12,300	49.6
8/14/2021	75.7	78.7	13,600	27.5
3/29/2022	38.1	41.1	5,500	7.8
3/30/2022	38.1	41.1	5,300	4.3
4/25/2022	43.6	46.6	13,800	46.8
4/26/2022	42.2	45.2	19,100	227.5

Triaxial Surveys Summary

The empirical tri-axial surveys each collected data over a period of several hours that reflect operating and environmental conditions and events that occurred over a time frame from minutes to possibly days prior. These events include large and small-scale water transport and thermodynamic phenomena such as winds, wind-driven surface currents, convection currents, radiation gains and losses, momentum variations, internal seiches, and eddies among others. These phenomena occur not only within the area being surveyed, but also at control locations used to estimate the lake ambient temperature. When thermal conditions are particularly variable, such as in spring and fall months when the lake surface is warming or cooling rapidly, it is more difficult to separate thermal plume effects from natural temperature variations. These rapidly changing conditions, particularly near-shore in shallow water, likely contributed to the large estimate of plume area for the April 25 and 26 surveys.

The results of the eight triaxial survey events conducted in 2021-2022 can be examined in the context of the Ashbury-Frigo equation, similar to the 1976 surveys. Using the same parameters for *a* and *b* that were determined in 1976, the 2021-2022 data appear to fit the model as well, or better, than the 1976 data (Figure 4-22). Predictions of the >3 °F ΔT area using current operational parameters of 127 or 151 cfs cooling water flow, and 14.7 °F ΔT_0, and assuming KLO temperature is the same as Seneca Lake, range from 5.2 to 127.0 acres Table 4-3). The largest predicted area would be a shore-attached plume with GGF operating at maximum capacity discharging approximately 127 cfs to KLO, with no natural KLO flow. As either GGF flow or KLO flow increases, the rejected heat is dispersed into the larger flow and the ΔT_0 decreases, resulting in smaller predicted areas where the ΔT is above 3 °F.



Emprical Model.xlsx Sheet2

Figure 4-21 Comparison of observed plume areas and areas predicted by Ashbury-Frigo equation from 1976 Greenidge thermal study. Left panel is 1976 result, right panel is 2021-2022 result.

Table 4-3 Ashbury-Frigo model predicted areas in Seneca Lake with more than 3 °F ΔT based on current GGF operational parameters of 127 or 151 cfs, and 14.7 °F ΔT. KLO flow is assumed to be at the same temperature as Seneca Lake.

Q_{GGF} (cfs)	Q_{KLO} (cfs)	Q_T (cfs)	Inflow ΔT_0 (°F)	Lake Plume (acres)	Shore Plume (acres)
127	0	127	17.5	25.7	127.0
151	0	151	14.7	20.5	101.0
127	100	227	9.8	12.0	58.9
127	200	327	6.8	7.4	36.4
127	300	427	5.2	5.2	25.6

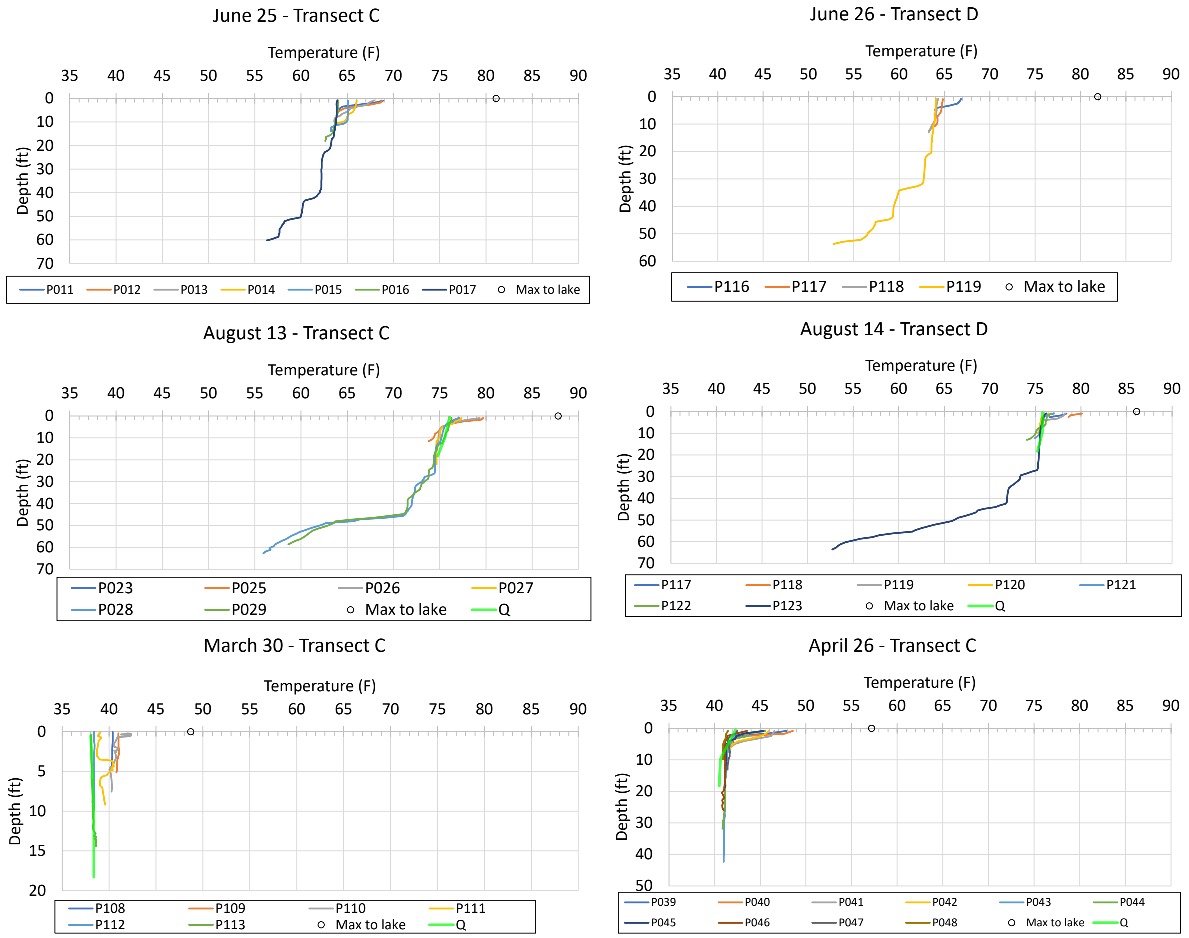
4.1.12 Discharges Which Raise Temperature to Stratified Lakes Confined to Epilimnion

Criterion: §704.2(b)(3) Lakes.
(ii) In lakes subject to stratification as defined in Part 652 of this Title, thermal discharges that will raise the temperature of the receiving waters shall be confined to the epilimnion.

Seneca Lake is dimictic, a lake which reaches nearly uniform temperature throughout the water column twice annually. This typically happens at a water column average temperature of approximately 40 °F. The periods of (nearly) uniform temperature occur in the spring as the lake begins to warm, and again in the fall when surface waters cool down. The lake has a distinct epilimnion, layer of warm low-density water near the surface, in the summer and early fall between the two dimictic events. The epilimnion lies above the thermocline, a zone where temperatures change rapidly with depth. Birge and Juday (1914) reported the epilimnion in Seneca Lake, during the time that it is present, to be the top 12 m to 15 m (39 ft to 49 ft).

The vertical temperature profiles taken at the transects that go from shallow to deeper water (C and D) during the tri-axial surveys demonstrate that the GGF thermal discharge is confined to the epilimnion. Water exits KLO near the surface. (During flow measurements at the KLO mouths, the maximum measured depth was 6.0 ft, with average depth of 1.8 ft.) The epilimnion extends to different depths on the different survey dates, but approximate depth at the bottom of the epilimnion were approximately 40 ft on June 25, 35 ft on June 26, 45 ft on August 13 and 14 (Figure 4-23). During the surveys in March and April the lake was much colder, near 40 °F, and no epilimnion had yet been established.

The criterion that, in lakes subject to stratification as defined in Part 652, thermal discharges that will raise the temperature of the receiving waters shall be confined to the epilimnion is met by the GGF discharge.



Discharge to Epilimnion.xlsx Plots

Figure 4-22 Vertical temperature profiles along transects C or D during tri-axial surveys on June 25, June 26, August 13, August 14, March 30, and April 26. Maximum daily temperature from any KLO outflow indicated in black. Temperature profile at Station Q indicated in green.

4.1.13 Discharges Which Lower Temperature to Stratified Lakes Confined to Hypolimnion

Criterion: §704.2(b)(3) Lakes.
(iii) In lakes subject to stratification as defined in Part 652 of this Title, thermal discharges that will lower the temperature of the receiving waters shall be discharged to the hypolimnion and shall meet the water quality standards contained in Part 703 of this Title in all respects.

The GGF does not discharge water that will lower the temperature of Seneca Lake, therefore this criterion does not apply.

4.2 HYDROTHERMAL MODELING

4.2.1 Lake Surface Temperature Rise No More Than 3°F

Criterion: §704.2(b)(3) Lakes.
(i) The water temperature at the surface of a lake shall not be raised more than three Fahrenheit degrees over the temperature that existed before the addition of heat of artificial origin.

Analysis of the empirical data collected during the study has shown that this criterion is at times not met by the GGF discharge, and that the area of the lake over which this occurs varies with operational and environmental conditions. The hydrothermal modelling is conducted to examine plume characteristics during conditions which may not be observed during the study and could represent more extreme yet possible occurrences. Model description, calibration, and complete results of scenarios examined is provided in Appendix D.

4.2.1.1 Scenario 1A – Summer 90th Percentile – Full Flow

Scenario 1A examined summer discharge plume characteristics under approximately 90th percentile conditions for KLO flow and Seneca Lake temperatures. This scenario assumes GGF operating continuously (i.e., baseload operation) at 107 MW and at full flow of 68,000 gpm, with a cooling water ΔT of 14.7 °F, and KLO flow at a low level of 28 cfs and Lake temperature of 77.1 °F. Model results for the entire scenario simulation period (11 days) indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 11.6 acres (Figure 4-24).

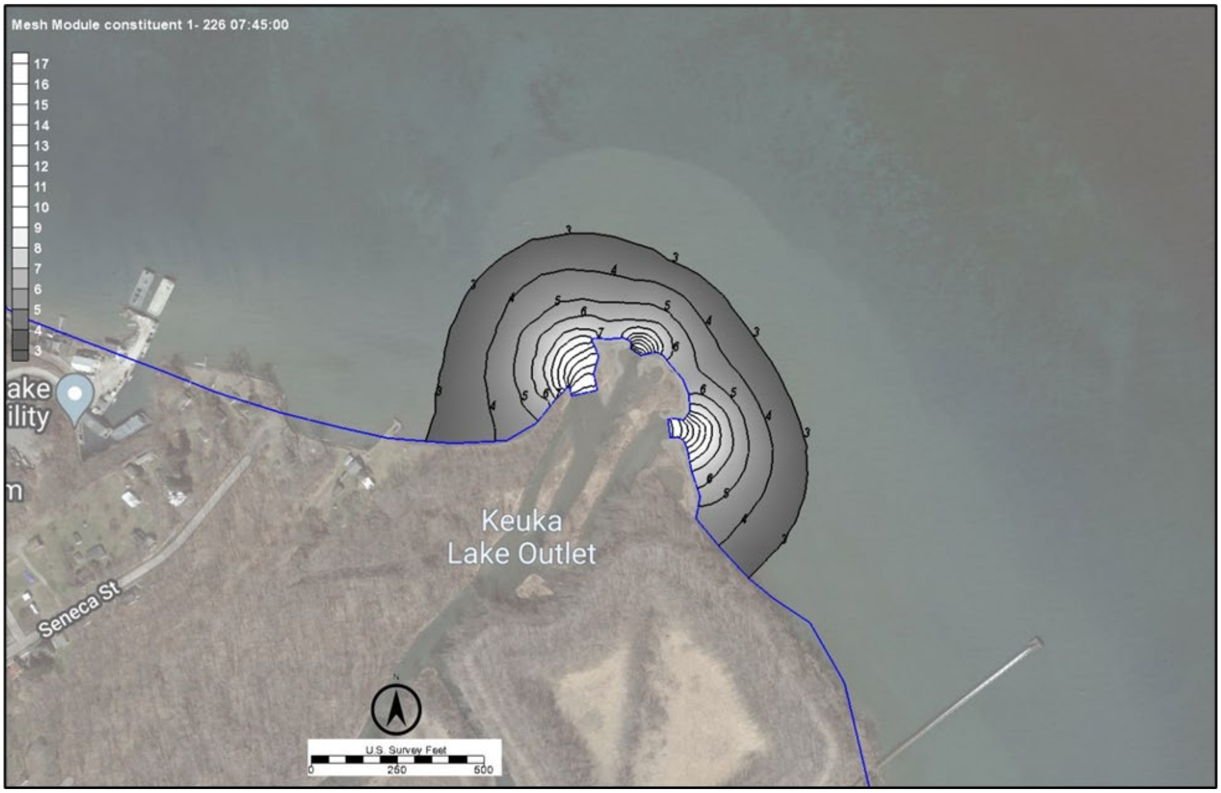


Figure 4-23 ΔT Contours for Scenario Simulation 1A at 8/14/21 07:45. The enclosed area where ΔT is ≥ 3°F is 11.6 Acres.

4.2.1.2 Scenario 1B– Summer 90th Percentile – Normal Flow

Scenario 1B used the same conditions as Scenario 1a, except that GGF flow was assumed to be a value more representative of 2-pump operation (i.e., 57,000 gpm). Also, a higher value was prescribed for the Facility's temperature rise (17.6°F). Model results for the entire scenario simulation period indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 13.5 acres (Figure 4-25).

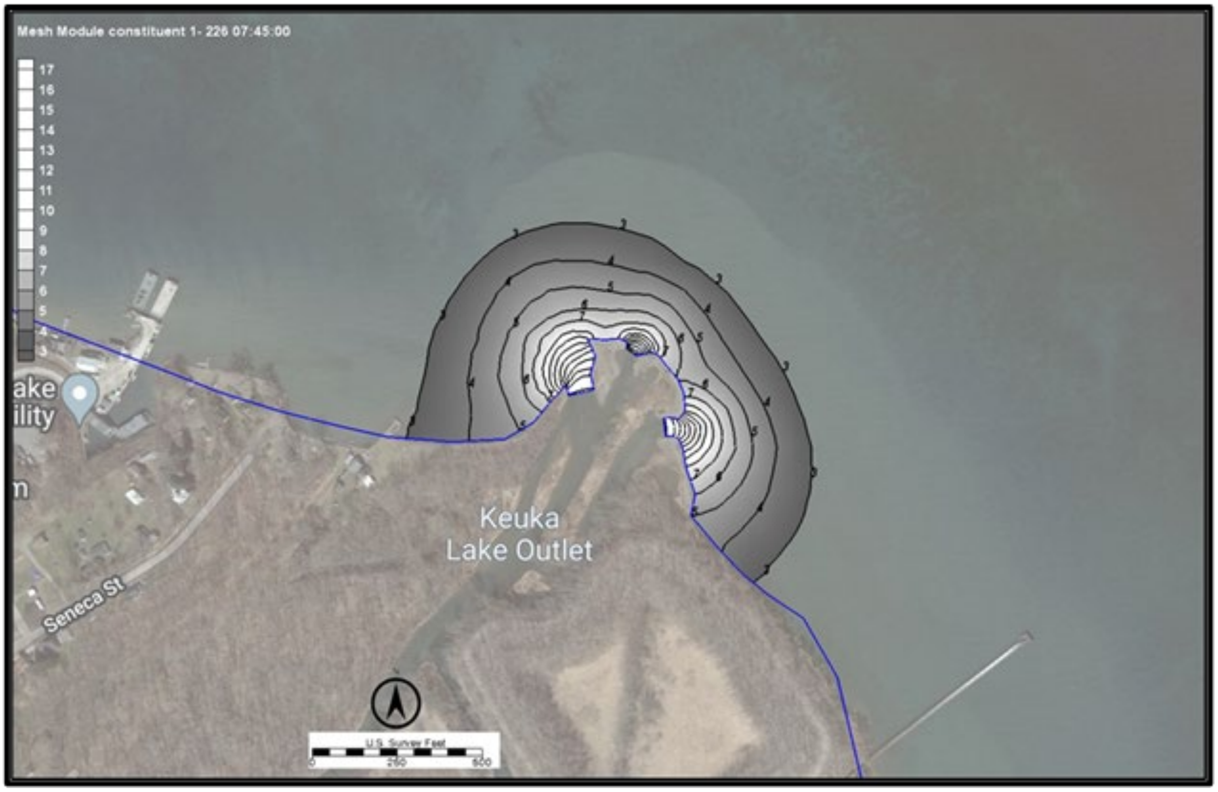


Figure 4-24 ΔT Contours for Scenario Simulation 1B at 8/14/21 07:45. The enclosed area where ∆T is ≥ 3°F is 13.5 Acres

4.2.1.3 Scenario 2 – Summer 95th Percentile – Normal Flow

Scenario 2 used more extreme conditions of approximately 95th percentiles for KLO flow (14 cfs) and Seneca Lake temperatures (77.8°F), and the lower GGF flow of 57,000 gpm, since that flow produced the more extensive plume in Scenario 1. Model results for the entire scenario simulation period (11 days) indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 16.4 acres (Figure 4-26).

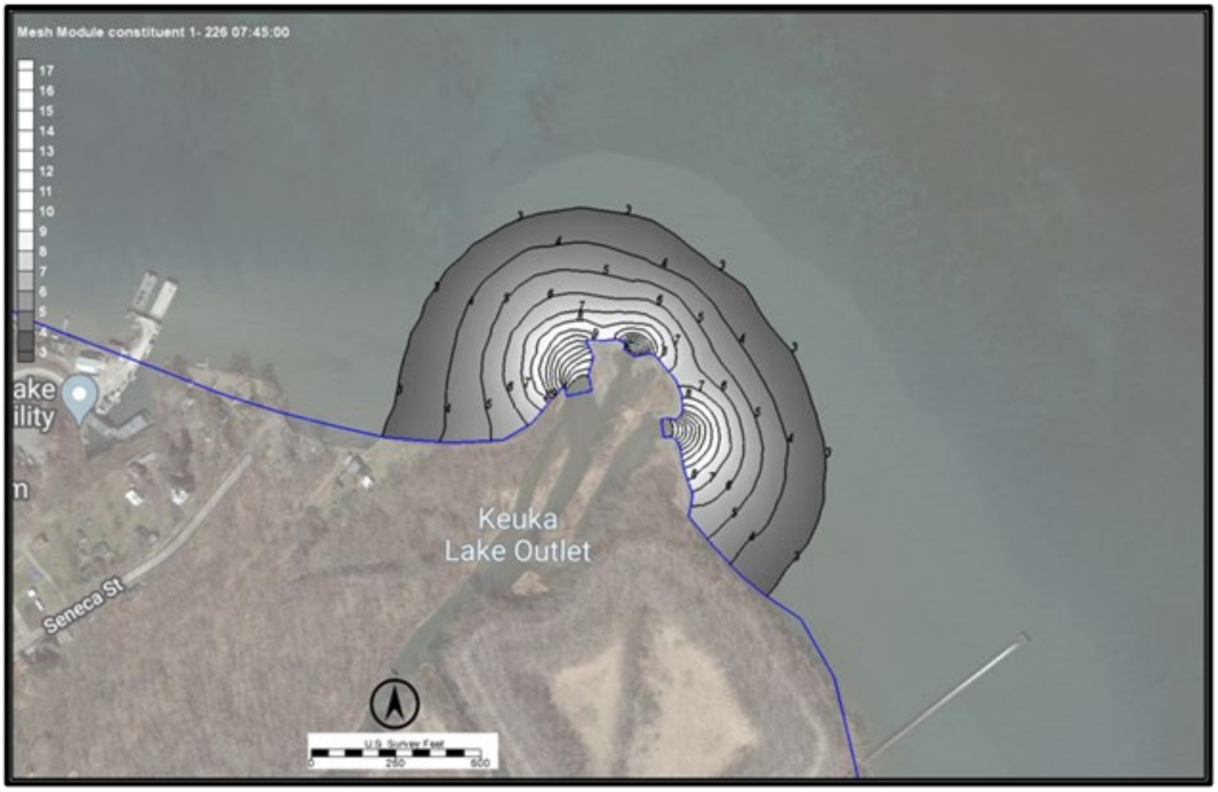


Figure 4-25 ∆T Contours for Scenario Simulation 2 at 8/14/21 07:45. The enclosed area where ∆T is ≥ 3°F is 16.4 Acres

4.2.1.4 Scenario 3 – Shoreline Plume

Scenario 3 simulated the seiche and shore attached plume effect caused by persistent wind. The wind direction was fixed at 30° (from NNE) but kept the magnitude unchanged for the 11 days simulation period. The simulation used more extreme conditions of approximately 95th percentiles for KLO flow (14 cfs) and Seneca Lake temperatures (77.8°F), and the lower GGF flow of 57,000 gpm, since that flow produced the more extensive plume in Scenario 1. Model results shows the thermal plume is compressed against the shore with the maximum area over which more than a 3°F rise in surface temperature would occur is 18.7 acres (Figure 4-27).

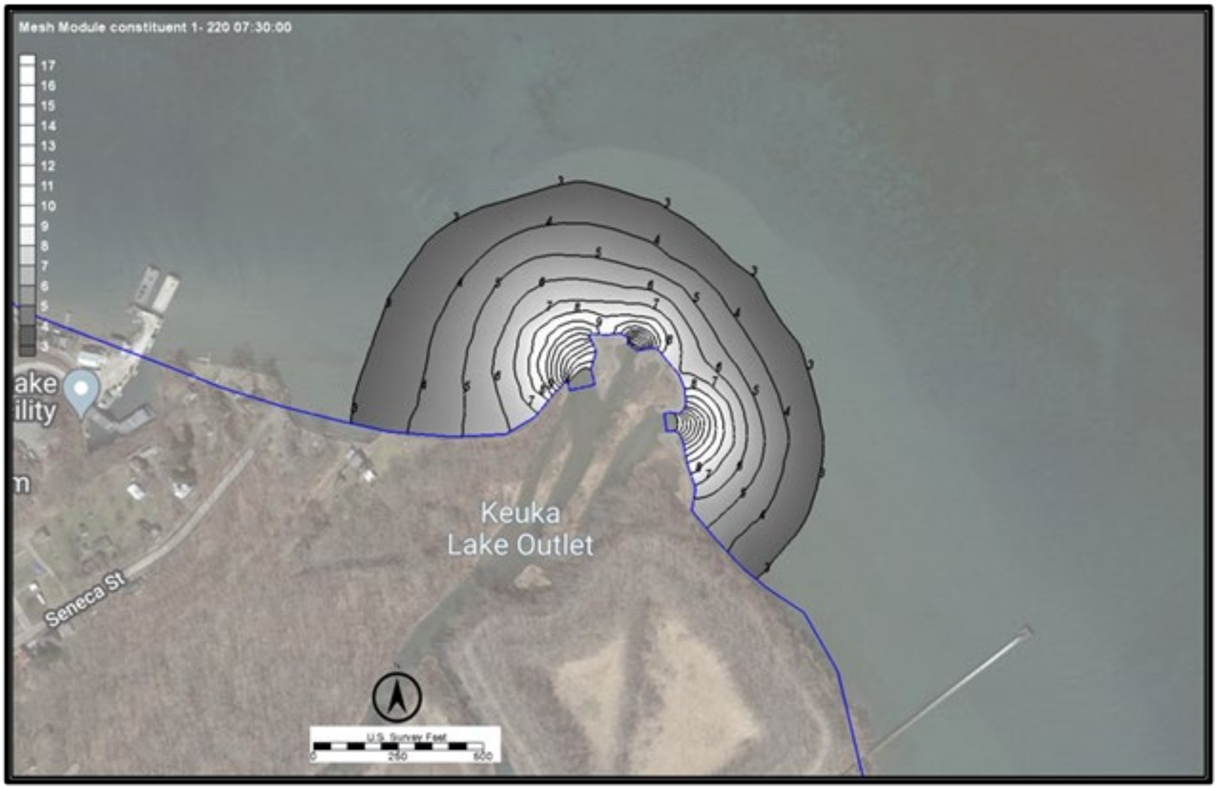


Figure 4-26 ∆T Contours for Scenario Simulation 3 at 8/14/21 07:45. The enclosed area where ∆T is ≥ 3°F is 18.7 Acres

4.2.1.5 Scenario 4A – Winter 10^{th} Percentile – Full Flow

Scenario 4A examined winter discharge plume characteristics under approximately 90th percentile conditions for KLO flow and Seneca Lake temperatures. This scenario assumes GGF operating continuously (i.e., baseload operation) at 107 MW and at full flow of 68,000 gpm, with a cooling water ΔT of 14.7°F, and KLO flow at 147 cfs and Lake temperature of 44.9°F. The model was exercised for 59 days from 1/1/2022 to 2/28/2022. Model results for the entire scenario simulation period indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 6.36 acres (Figure 4-28)

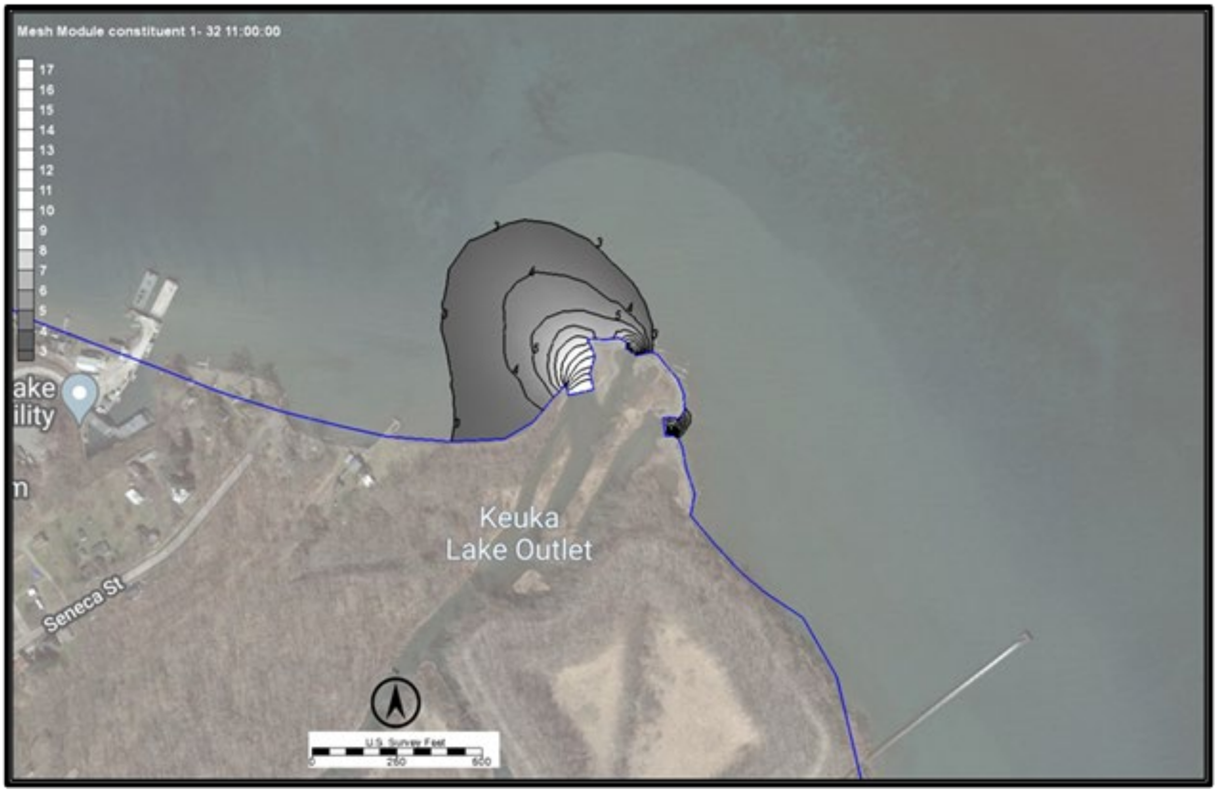


Figure 4-27 ∆T Contours for Scenario Simulation 4A at 02/01/2022 11:00. The enclosed area where ∆T is ≥ 3°F is 6.36 Acres

4.2.1.6 Scenario 4B– Winter 10th Percentile – Normal Flow

Scenario 4B examined winter discharge plume characteristics under approximately 90th percentile conditions for KLO flow and Seneca Lake temperatures. This scenario assumes GGF operating continuously (i.e., baseload operation) at 107 MW and at full flow of 57,000 gpm, with a cooling water ΔT of 17.6 °F, and KLO flow at 147 cfs and Lake temperature of 44.9°F. The model was exercised for 59 days from 1/1/2022 to 2/28/2022. Model results for the entire scenario simulation period indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 6.1 acres (Figure 4-29).

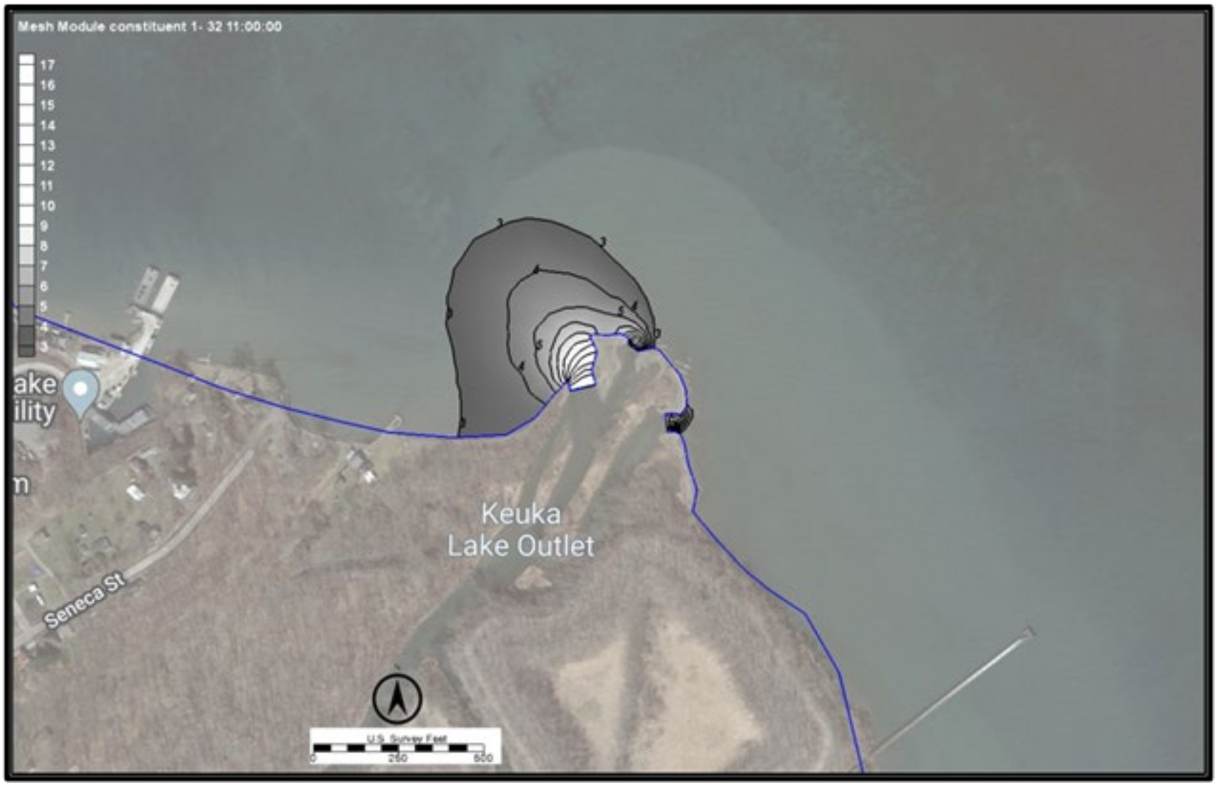


Figure 4-28 ∆T Contours for Scenario Simulation 4B at 02/01/2022 11:00. The enclosed area where ∆T is ≥ 3°F is 6.1 Acres

4.2.1.7 Scenario 5– Winter 95th Percentile – Normal Flow

Scenario 5 examined winter discharge plume characteristics under approximately 90th percentile conditions for KLO flow and Seneca Lake temperatures. This scenario assumes GGF operating continuously (i.e., baseload operation) at 107 MW and at full flow of 68,000 gpm, with a cooling water ΔT of 14.7 °F, and KLO flow at 35 cfs and Lake temperature of 40°F. The model was exercised for 59 days from 1/1/2022 to 2/28/2022. Model results for the entire scenario simulation period indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 10.0 acres (Figure 4-30).

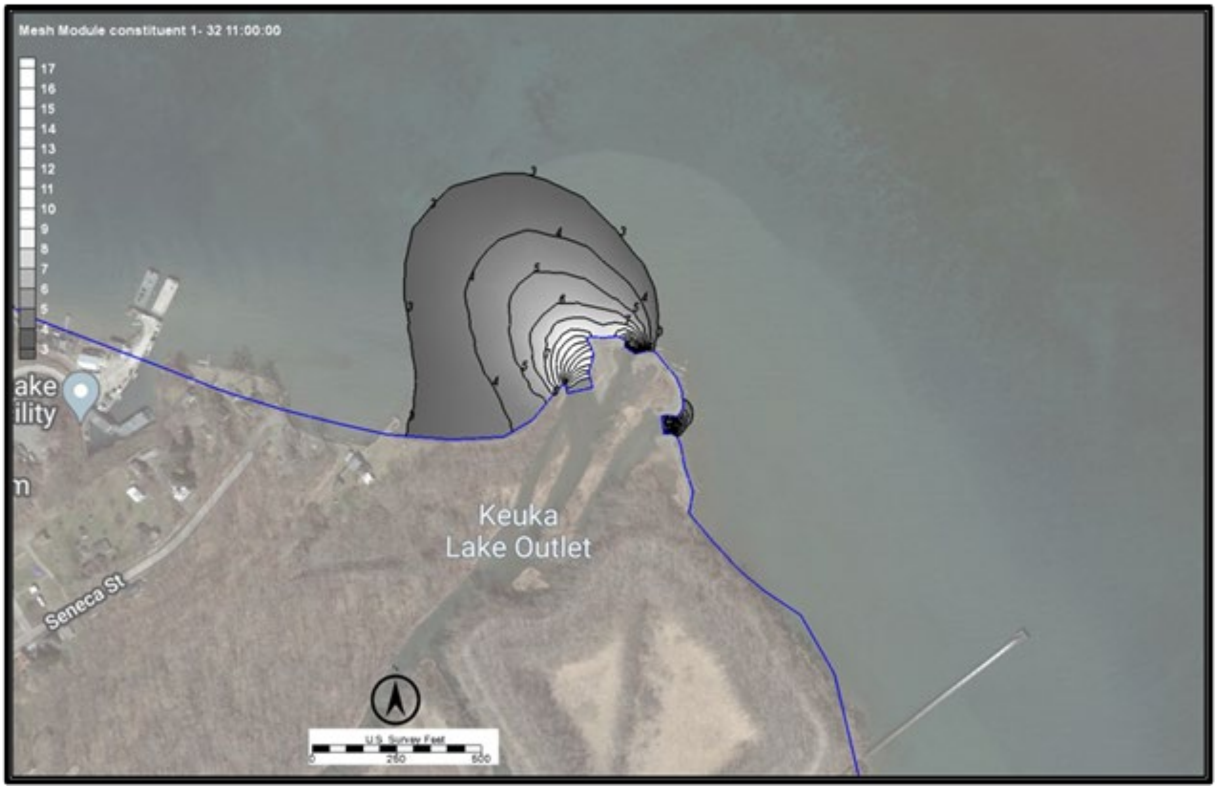


Figure 4-29 ∆T Contours for Scenario Simulation 5 at 02/01/2022 11:00. The enclosed area where ∆T is ≥ 3°F is 10.0 Acres

4.2.1.8 Scenario 8– Summer 90th Percentile – Full Flow – Air Temperature +6 °F

Scenario 8 used the same conditions prescribed for Scenario 1A, but with the ambient air temperature raised by 6°F. Accordingly, the specified increment in Seneca Lake water temperature (at the intake) is raised by 2°F (Figure 4-31). Model results for the entire scenario simulation period (11 days) indicate that the maximum area over which more than a 3°F rise in surface temperature would occur is 15.5 acres (Figure 4-32).

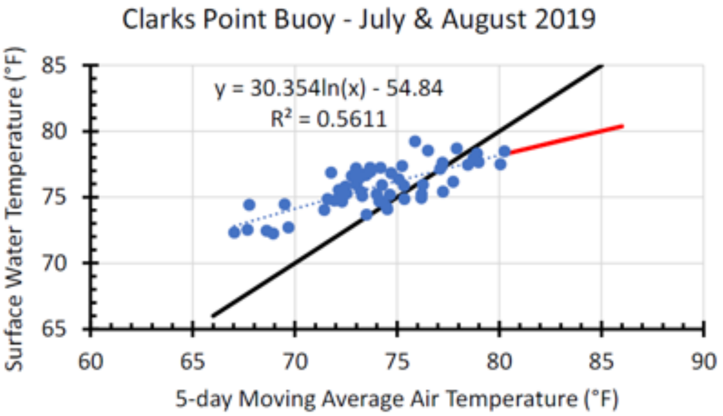


Figure 4-30 Relationship of surface layer (1 m depth) water temperature at Clarks Point buoy with mean air temperature over previous 5 days. Red line indicates predicted water temperature at mean 5-day air temperature up to 86 °F.

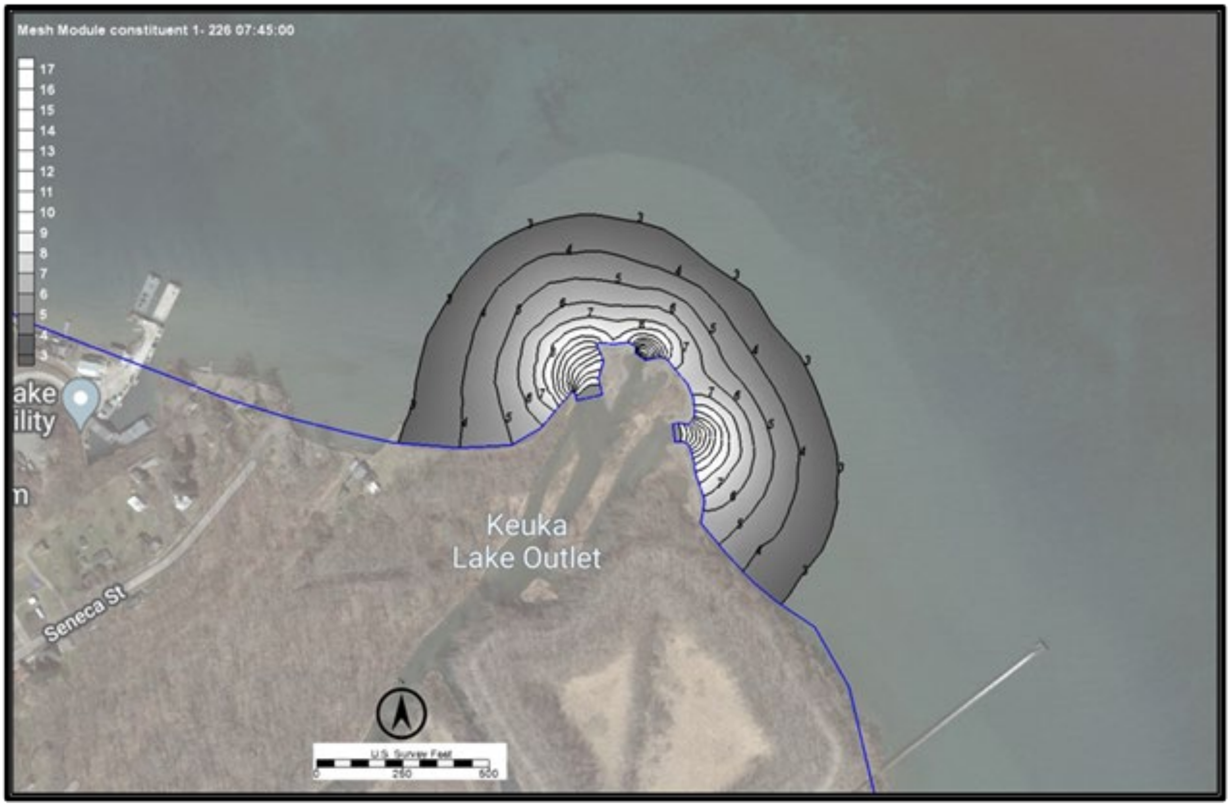


Figure 4-31 ∆T Contours for Scenario Simulation 8 at 8/14/21 07:45. (Background Air Temp also increase by 6 Degrees F). The enclosed area where ∆T is ≥ 3°F is 15.5 Acres

4.2.1.9 Scenario Summary

The hydrothermal modeling effort uses a different method of determining ΔT values than is used in the analysis of the tri-axial survey data. For the tri-axial surveys, the surface temperatures in the area of KLO entry to Seneca Lake are compared to surface temperature at a control location that is not influenced by the GGF discharge. The surface temperature data are collected over a period of several hours and thus vary in both time and space. Results can only be examined for the time span covered by the survey, but are influenced by conditions occurring prior to the survey.

The hydrothermal modeling takes a different approach to analysis of the ΔT and area within ΔT isotherms. RMA-10 calculates temperature at nodal points over the entire area and volume of Seneca Lake, at each time step used for the model. For each scenario, one model run is made without the GGF discharge to determine the base thermal state and results are stored. Then a second model run, with the GGF discharge, is made and the results of the two are compared over both space and time. Thus the thermal plume is not static, but changes through time. The ΔTs are calculated as the temperature difference for the same point in space and time between the two model runs. The isotherms depicted in the figures represent the maximum areas with more than a 3°F rise in surface temperature.

Despite these fundamental conceptual differences in the two approaches, the estimates of the area of Seneca Lake over which the 3 °F ΔT criterion would not be met are similar in magnitude. The first six of the tri-axial surveys estimated area ranged from 4.3 to 49.6 acres. The last two survey estimates of 46.8 and 227.5 acres occurred at a time when surface temperatures were in general increasing rapidly with relatively large within-day variation, which may have affected the value used for the lake ambient temperature. In addition, the amount of heat energy being added by the combined GGF and KLO flow was substantially higher than for the other surveys, and less than half of that energy originated from GGF. The area due to GGF alone cannot be separated from that for KLO using the temperature monitoring data.

The hydrothermal modeling estimates of the area over which the 3 °F ΔT criterion would not be met varied only from 6.1 to 18.7 acres (Table 4-4). Areas for the winter conditions were smaller than during summer conditions. The scenarios with a 6 °F increase in air temperature resulted in only a 2 acre increase at high GGF operating flows (8 compared to 1A). Because these increases in plume size were insignificant for the 6 °F increase, it was not necessary to model the smaller air temperature increases of +2 °F and +4 °F.

Table 4-4 Result of hydrothermal modeling for operation and environmental scenarios for GGF. For all scenarios, GGF is assumed to operate continuously at 107 MW with a heat rejection of 502 MBTU/hr.

Scenario	GGF Flow (gpm)	ΔT(°F)	KLO Flow (cfs)	Seneca Lake Temperature (°F)	Surface area with >3 °F ΔT (acres)
1A Summer	68,000	14.7	28	77.1	11.6
1B Summer	57,000	17.6	28	77.1	13.5
2 Summer	57,000	17.6	14	77.8	16.4
3 Shoreline plume	57,000	17.6	28	77.8	14.0
4A Winter	68,000	14.7	147	44.9	6.4
4B Winter	57,000	17.6	147	44.9	6.1
5 Winter	68,000	14.7	35	40.0	10.0
8 Summer (+6)*	68,000	14.7	28	77.1 +2	15.5

5. SUMMARY

5.1 SATISFACTION OF THERMAL CRITERIA

The goal of this study was to determine whether applicable thermal criteria are met by the GGF discharge of cooling water. The study was conducted over the 12-months from May 2021 through April 2022, using temperature recorders in the GGF discharge, 7 locations in KLO, and at surface, mid-depth, and bottom at 8 locations in Seneca Lake. Each sensor recorded temperature to <0.1 °F at 5-minute intervals.

Additionally, tri-axial (longitude, latitude, depth) temperature surveys were conducted in 2021 on June 25 and 26, August 13 and 14, and in 2022 on March 29 and 30, April 25 and 26. On each date, surface temperature, time, and location were recorded along 6 transects radiating from the mouth of KLO. Additional transects along the north and south shore of the KLO were added beginning with the August 13 study. Each transect extended to a point where temperature had declined to the ambient lake temperature. At each drop of 1 °F of surface temperature, a full vertical temperature profile was recorded.

Ancillary data on GGF operation, KLO flow, atmospheric conditions, Seneca Lake currents, water surface elevation, and temperatures at the north end of the lake were also recorded or obtained from data collection sources.

The GGF thermal discharge was found to meet most of the relevant criteria throughout the year, however there were some criteria that were not at times met (Table 5-1). Empirical measurements of the thermal plume in Seneca Lake estimated the area in which ΔT could be greater than 3 °F ranged from 4 to 50 acres, with one outlier estimate of 228 acres in late April when natural KLO flow was contributing more heat to Seneca Lake than was GGF. Hydrothermal model results produced areas ranging from 6 to 19 acres.

In addition to the criteria, the GGF SPDES Permit (NY0001325) also contains thermal limits relating to the GGF discharge. GGF has a daily maximum summer (May 1 through October 31) discharge temperature limit of 108 °F, maximum summer temperature difference of 26 °F, maximum winter discharge temperature of 86 °F, and maximum winter temperature difference of 31 °F. None of these limits were exceeded. Maximum instantaneous discharge temperature (Station A) in the summer was 96.0 °F, and 72.9 °F in the winter, both well below the permit limits. Maximum ΔT, measured across the condensers, was 18.6 °F in the summer, and 18.2 °F in the winter (Table 4-1), again well below permit limits.

Table 5-1 Status of Greenidge Generation facility thermal discharge with respect to New York State thermal criteria.

Criterion	Status
§704.2(a)(1) The natural seasonal cycle shall be retained.	Met in both KLO and Seneca Lake
§704.2(a)(2) Annual spring and fall temperature changes shall be gradual.	Met in both KLO and Seneca Lake
§704.2(a)(3) Large day-to-day temperature fluctuations shall be avoided.	Met in both KLO and Seneca Lake
§704.2(a)(4) Development or growth of nuisance organisms shall not occur	Not directly assessed, but no evidence observed to indicate it is not met.

Criterion	Status
§704.2(a)(4) Discharges which would lower receiving water temperature	Not applicable to the GGF discharge.
§704.2(a)(6) Routine shut down shall not be scheduled during the period from December through March.	Met in both KLO and Seneca Lake
§704.2(b)(2) (i) No discharge at a temperature over 70 degrees Fahrenheit to streams classified for trout.	Applicable in KLO only. Not met from May through October.
§704.2(b)(2) (ii) From June through September no discharge may raise the temperature of a trout stream more than 2°F.	Applicable in KLO only. Not met.
§704.2(b)(2) (iii) From October through May may not raise the temperature of trout stream more than 5 °F or above 50 °F.	Applicable in KLO only. Not met in parts of KLO.
§704.2(b)(2) (iv) From June through September no discharge shall be permitted that will lower the temperature more than 2°F..	Applicable in KLO only. Criterion is met.
§704.2(b)(3)(i) The water temperature at the surface of a lake shall not be raised more than 3 °F.	Applicable in Seneca Lake only. Criterion is not met in area of varying size.
§704.2(b)(3) (ii) In lakes subject to stratification thermal discharges that will raise the temperature shall be confined to the epilimnion.	Applicable in Seneca Lake only. Criterion is met.
§704.2(b)(3) (iii) In lakes subject to stratification thermal discharges that will lower the temperature of the receiving waters shall be discharged to the hypolimnion.	Criterion is not applicable.

5.2 MIXING ZONE REQUIREMENTS

When all temperature criteria are met, the thermal water quality standard of *§704.1* that the discharge must “assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water” is presumed to be met. In cases where this standard is met, but any criteria are not met, the State shall “specify definable, numerical limits” for a mixing zone, within which the criteria may not be met, as long as conditions in the mixing zone are not lethal to aquatic biota, and the zone does not interfere with spawning areas, nursery areas and fish migration routes (See *§704.3).* When criteria are not met, and as specified in the GGF SPDES permit, the State may require an additional study to demonstrate that *§704.1* is met despite criteria not being satisfied.

In 1977, the prior owners of GGF submitted a demonstration based on data collected from Seneca Lake and KLO. The impetus for the demonstration was that these same criteria, *§704.2(b)(2) (i), §704.2(b)(2) (ii), §704.2(b)(2) (iii)*, and *§704.2(b)(3)(i)* were not being met by the thermal discharge from four GGF generating units with maximum output of 215 MW_e and cooling water flow of 131,500 gpm (293 cfs). Heat rejection to KLO and Seneca Lake at that time was more than twice the heat rejection during this study (Figure 5-1). Total annual heat rejection in 1975 was 6,103 billion BTU, while heat rejection during the 12 months of the current study was 2,932 billion BTU.

The prior demonstration included 6 tri-axial surveys, with estimated areas more than 3 °F above ambient lake temperatures ranging from 1.5 to 71.5 acres with GGF discharge flows approximately twice the present flow rates, but similar ΔT values. The Ashbury-Frigo model was applied to these 6 observations, with the result that the largest surface area of Seneca Lake which would exceed a 3 °F ΔT was estimated as 230 acres. Upon review of the demonstration, NYSDEC defined a mixing zone as the portion of KLO downstream of the junction with the GGF discharge and 230 acres within Seneca Lake.

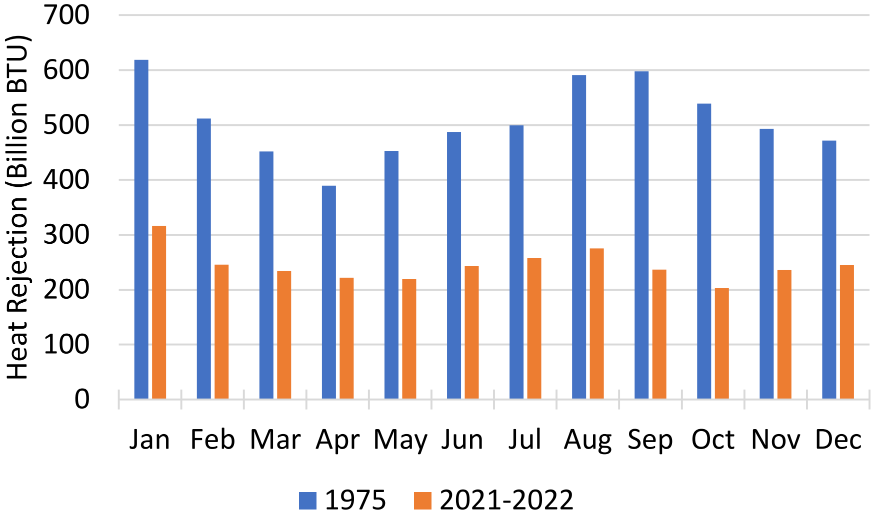


Figure 5-1 Monthly heat rejection of GGF in 1975 and during the 2021-2022 thermal criteria study.

The current study is consistent with the prior investigation, and again demonstrates that although some criteria will not be fully satisfied in the lower part of KLO and in a portion of Seneca Lake, the observable temperature effects of the GGF discharge are restricted to a small area within KLO and near its entry to the lake. When the Ashbury-Frigo model, used to estimate the prior mixing zone, is applied to current GGF operation characteristics, the largest estimated area 3 °F above ambient lake temperature is 127 acres. Although one of the eight tri-axial surveys produced an estimated area substantially larger, this event appears to be an anomaly that occurred during a period when lake conditions, particularly ambient surface temperature, were highly variable, and KLO flow was delivering more heat energy than the GFF discharge. It is probable that the mixing zone for GGF's current discharge could be significantly smaller than the 230 acres defined previously and still be effective in protecting resources in the lake.

Since some thermal criteria cannot be met by the GGF discharge, another demonstration study may be required at the Department's discretion to confirm that the standard of a balanced indigenous community in KLO and Seneca Lake is assured. This study would examine multiple community components, including zooplankton, aquatic vegetation, macroinvertebrates, and fish to assess whether the thermal discharge has caused them appreciable harm. The study would also evaluate access to spawning and nursery area for species that utilize both KLO and Seneca Lake. However, even prior to conducting a biological study, the potential significance of the GGF heat rejection on the ecology of Seneca Lake can be evaluated by comparison to the annual heat budget of the lake. Birge and Juday (1914) estimated the annual heat energy entering Seneca Lake from solar radiation (and exiting during the winter) was 68,000 cal/cm^2 in 1910 and 65,000 cal/cm^2 in 1911. The 2021-2022 heat rejection by GGF to Seneca Lake expressed in the same units is 421 cal/cm^2, which is 0.6% of the 1911 heat budget, and far less than the inter-annual variation of 3000 cal/cm^2 observed for the two years examined. Therefore, physical and ecological effects of the thermal discharge, if any, would be expected to be restricted to the vicinity of the KLO discharge.

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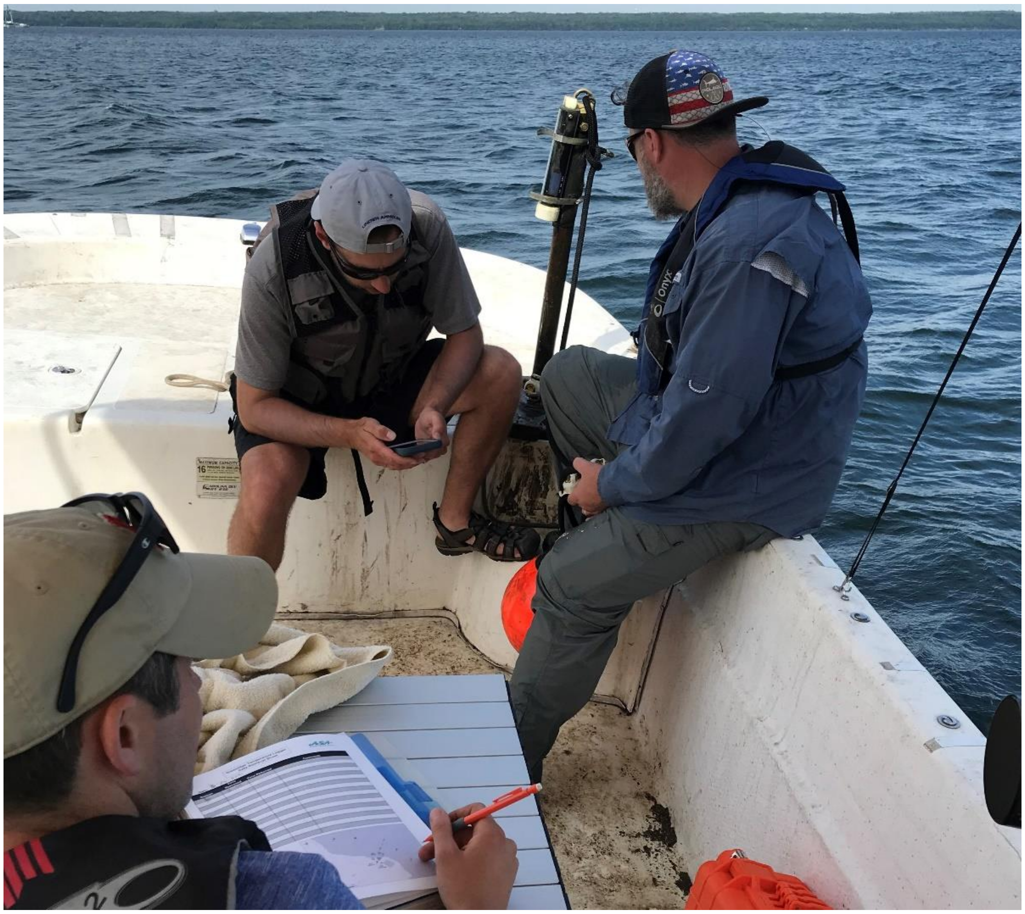
APPENDIX A – FINAL INTERIM REPORT

GREENIDGE THERMAL STUDY

FINAL INTERIM REPORT



Prepared for:

Greenidge Generation

Prepared by:

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5/25/22

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This Interim Report contains the entire previous Interim Reports, with the addition of activities conducted subsequent to the last prior report (Sections 11 through 14). Each subsequent Interim Report will follow this same format and simply add new project activities to those already reported.

1. INITIAL GEAR DEPLOYMENT

In-situ temperature monitoring equipment was deployed on May 14. KLO flow 211cfs and clear, Seneca Lake level was 446.36. Once conditions could be assessed at each location, some of the stations were moved to locations that appeared less conspicuous and/or better able to assess temperatures. These relocations were primarily for KLO monitoring stations, but Station N in Seneca Lake was moved due to an error in recording the Lat-Lon coordinates in the QAPP. Locations of sensor deployment are provided in Table 1. In addition to the in-situ HOBO sensors, the meteorological station was deployed at the cooling water intake structure (Figure 1).

Figure 1 Meteorological station deployed at Greenidge cooling water intake structure on May 14, 2021.

Table 1 Planned and actual deployment locations for Greenidge thermal study monitoring.

Parameter	Station	Location	Sensors	Planned Deployment		Actual Deployment		Difference in Deployment	Reason for Difference
				Latitude	Longitude	Latitude	Longitude		
Water Temperature	A	GGF Discharge	1	42.6824	-76.9480	42.6824	-76.9480	30 feet downstream	Access
	B	KLO	1	42.6826	-76.9789	42.6827	-76.9488	66 feet downstream	Concerns of theft/tampering
	C	KLO	1	42.6838	-76.9477	42.6836	-76.9478	60 feet upstream	Shallow water
	D	KLO	1	42.6837	-76.9474	42.6834	-7+6.9477	120 feet upstream	Shallow water
	E	KLO	1	42.6845	-76.9472	42.6849	-76.9469	186 feet downstream	Shallow water
	F	KLO	1	42.6844	-76.9469	42.6848	-76.9464	210 feet downstream	Shallow water
	G	KLO	1	42.6842	-76.9466	42.6846	-76.9463	171 feet downstream	Shallow water
	H	Seneca Lake	3	42.6861	-76.9459	42.6861	-76.9459	None	-
	I	Seneca Lake	3	42.6871	-76.9447	42.6871	-76.9447	None	-
	J	Seneca Lake	3	42.6882	-76.9437	42.6882	-76.9437	None	-
	K	Seneca Lake	3	42.6852	-76.9424	42.6852	-76.9424	None	-
	L	Seneca Lake	3	42.6824	-76.9406	42.6824	-76.9406	None	-
	M	Seneca Lake	3	42.6896	-76.9499	42.6896	-76.9499	None	-
	N	Seneca Lake	3	42.6912	-76.9573	42.6912	-76.9553	540 feet East	Planned location did not match coordinates. Too close to shoreline. Concerns of theft/tampering.
Meteorology Station	W	Seneca Lake	6	42.6829	-76.9419	42.6829	-76.9419	None	-
Current Profile	Z	Seneca Lake	1	42.6869	-76.9450	42.6869	-76.9450	None	-

Stations in KLO were constructed by a piece of steel rebar hammered into the substrate until the top of the rebar was below the water surface. One HOBO sensor was attached to the rebar by cable ties at mid-depth (Figure 2).

Figure 2 Hobo sensors deployed at Stations G (left) and C (right) on May 14, 2021.

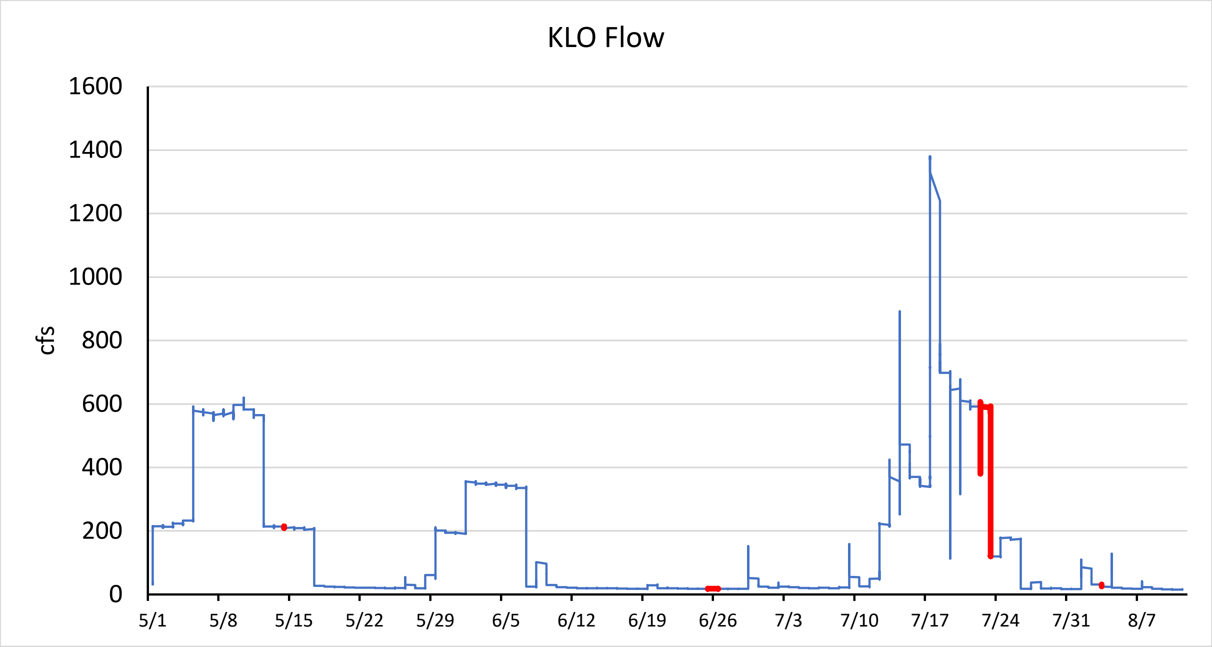


Figure 3 Keuka Lake Outlet flow from May 1 through August 11, 2021. Source: USGS Station 04232482 at Dresden, NY. Dates on which activities covered in this report indicated in red.

2. JUNE DATA RETRIEVAL

2.1 IN-SITU MONITORS

Data retrieval from the in-situ monitors was conducted on June 25-26. On the first date, KLO flow was 19 cfs and Seneca Lake level 445.94. Sensors at stations C, D, E, and G could not be located. Sensor at location E was located on June 26, but was no longer in the substrate. This is apparently the station NYSDEC crews encountered and removed temporarily in early June. Although all data were retrieved from Station E, it appears that data for June 12-15 have been compromised. A much wider swing in temperatures on those days indicates the sensor may have been out of the water during that time.

Missing sensors were replaced, and all KLO stations were reset by driving the rebar into the stream bottom, with the top of the rebar bent over, and the sensor hidden under rocks.

2.2 METEOROLOGICAL STATION

Data from the meteorological station were retrieved successfully without issue.

Table 2 Data retrieval from in-situ HOBO sensors and meteorology tower on June 25-26, 2021.

Parameter	Station	Location	Status	Data Completeness	Corrective Action
Water Temperature	A	GGF Discharge	Located and successfully downloaded.	100%	All sensors reinstalled with rebar driven and bent over, with replacement of sensors at C, D, and G. Rock cover for additional security.
	B	KLO	Located and successfully downloaded.	100%	
	C	KLO	Not Located.	0%	
	D	KLO	Not Located.	0%	
	E	KLO	Located and successfully downloaded.	~90%	
	F	KLO	Located and successfully downloaded.	100%	
	G	KLO	Not Located.	0%	
	H	Seneca Lake	Located and successfully downloaded.	100%	Reset all release timers and redeployed.
	I	Seneca Lake	Located and successfully downloaded. Buoy had released.	100%	
	J	Seneca Lake	Located and successfully downloaded.	100%	
	K	Seneca Lake	Located and successfully downloaded.	100%	
	L	Seneca Lake	Located and successfully downloaded.	100%	
	M	Seneca Lake	Located and successfully downloaded.	100%	
	N	Seneca Lake	Located and successfully downloaded.	100%	
Meteorology	W	Seneca Lake	Located and successfully downloaded.	100%	None Required

3. JUNE TRIAXIAL SURVEY

3.1 DAY 1 SURVEY – JUNE 25

ADCP deployed at Station Z at Lat 42.6869, Lon -76.9450 as planned. All transects (6) completed as planned. A total of 51 vertical temperature profiles were measured at locations where surface temperature has changed by 1° F from previous profile location.

Table 3 Data collection status for triaxial survey on June 25, 2021.

Parameter	Transect	Location	Status	Vertical Profiles	Data Completeness	Corrective Action
Water Temperature	A	Seneca Lake	Completed successfully.	5	100%	None Required
	B	Seneca Lake	Completed successfully	9	100%	
	C	Seneca Lake	Completed successfully	7	100%	
	D	Seneca Lake	Completed successfully	7	100%	
	E	Seneca Lake	Completed successfully	6	100%	
	F	Seneca Lake	Completed successfully	17	100%	
Current	W	Seneca Lake	Completed successfully	NA	100%	None Required

3.2 DAY 2 SURVEY – JUNE 26

ADCP deployed at Station Z at Lat 42.6869, Lon -76.9450 as planned. KLO flow 19 cfs and Seneca Lake level 445.98. All transects (6) completed as planned. A total of 41 vertical temperature profiles were measured at locations where surface temperature has changed by 1° F from previous profile location. Upon completion of the survey and download of the ADCP data, the data appeared invalid. Data were sent to the manufacturer and confirmed as not valid due to the orientation of the sensor being horizontal rather than vertical, after the first two hours of deployment. When the sensor was retrieved, a large fishing lure and line were snagged on the buoy line, indicating the cause of the horizontal orientation. Additional weight will be added to the tripod on future surveys to ensure orientation is not disturbed after deployment. Correlation of current speed and direction with wind speed and direction for other dates will be examined as a way to substitute for the ADCP data.

Table 4 Data collection status for triaxial survey on June 26, 2021.

Parameter	Transect	Location	Status	Vertical Profiles	Data Completeness	Corrective Action
Water Temperature	A	Seneca Lake	Completed successfully.	6	100%	None Required
	B	Seneca Lake	Completed successfully	5	100%	
	C	Seneca Lake	Completed successfully	4	100%	
	D	Seneca Lake	Completed successfully	4	100%	
	E	Seneca Lake	Completed successfully	6	100%	
	F	Seneca Lake	Completed successfully	16	100%	

Parameter	Transect	Location	Status	Vertical Profiles	Data Completeness	Corrective Action
Current	W	Seneca Lake	Completed but data after 2 hr was invalid.	NA	25%	Add additional weight to tripod to maintain orientation.

4. JULY DATA RETRIEVAL

4.1 IN-SITU MONITORS

Data retrieval occurred July 22 and 23. Seneca Lake water level 446.5. KLO flow 600 cfs and turbid. All Seneca Lake stations were located and downloaded except Station I. It could not be located, but may still be in place. Station J sensor string was removed by Yates County sheriff on July 20. Sensors were retrieved and valid data downloaded prior to removal. Surface sensors were missing at stations M and N, with evidence of vandalism (cut sensor housing) at station M.

On August 3 we returned to check sensors and complete downloads. KLO flow was 20 cfs and clear. Seneca Lake water level was 445.96. All Seneca Lake sensors were located in correct position. Station I was located and data successfully downloaded. KLO sensors A, B, D, F, and G were located in correct position and data downloaded. Station C appeared to buried under loose gravel and was not found. Replaced at same location. Station E was not found and again likely buried under loose gravel or silt. Station E was moved upstream approximately 50 yards and replaced. At Station G, a tree on the island fell into the channel, nearly on top of the sensor (Figure 4). Cameras were mounted at all stations and verified as operational (Figure 4, Figure 5, Figure 6) except E. Incorrect camera mount was sent by vendor. Correct camera mount and camera will be installed at next download.

Table 5 Data retrieval from in-situ HOBO sensors and meteorology tower on July 22-23, and August 3, 2021.

Parameter	Station	Location	Status	Data Completeness	Corrective Action
Water Temperature	A	GGF Discharge	High water in KLO (> 600 cfs). No search for sensors could be conducted. Returned on 8/3 and downloaded data	100%	A, B, D, F, & G sensors located on 8/3. C and E were replaced. Trail cameras mounted on nearby trees and will provide alerts to tampering.
	B	KLO	Downloaded on 8/3.	100%	
	C	KLO	Could not be located on 8/3. Probably buried in gravel. Replaced.	0%	
	D	KLO	Downloaded on 8/3.	100%	
	E	KLO	Could not be located on 8/3. Probably buried in gravel. Replaced. Moved station upstream to 42.68470 -76. 94714.	0%	
	F	KLO	Downloaded on 8/3.	100%	
	G	KLO	Downloaded on 8/3. Tree on island uprooted and fell into channel at the location.	100%	
	H	Seneca Lake	Located and successfully downloaded.	100%	Removed all release timers and redeployed (except I). Replaced missing sensors at M and N. Sensor at M replaced with MX2201 from GGF. Return to locate or replace I. On 8/3, checked for presence of all Seneca
	I	Seneca Lake	Not located in July, but was found on 8/3 at correct location. Data downloaded	100%	
	J	Seneca Lake	Buoy had released and was removed by Sheriff's Department on 7/20. Data prior to 7/20	90%	

Parameter	Station	Location	Status	Data Completeness	Corrective Action
			successfully downloaded.		Lake sensors. All present in correct location. L was at surface and was repositioned. All others were about 2 ft under surface.
	K	Seneca Lake	Located and successfully downloaded.	100%	
	L	Seneca Lake	Located and successfully downloaded.	100%	
	M	Seneca Lake	Buoy released. Surface sensor missing and appeared to have been tampered with.	67%	
	N	Seneca Lake	Located and successfully downloaded, except surface sensor missing.	67%	
	O	Seneca Lake	Placed two additional MX2201 sensors near surface under intake conduit.	NA	Replace with MX2204 sensors when available
Meteorology	W	Seneca Lake	Located and successfully downloaded.	100%	None

Figure 4 Tree fallen into the KLO channel at site of Station G sensor.

4.2 METEOROLOGICAL STATION

Data from the meteorological station were retrieved successfully without issue on July 23.

Figure 5 Heron photographed at Station F by security camera.

Figure 6 Kayaker photographed at Station C by security camera.

5. AUGUST TRIAXIAL SURVEYS

The August triaxial survey events and data downloads were conducted successfully during August 13 and 14. All stations within KLO and in Seneca Lake were located and were successfully recording data. Flow measurements were made at the three KLO channels on both days. ADCP data were collected successfully. Data from the weather station were downloaded successfully.

Conditions during the effort:

Seneca Lake Level: 445.9 ft KLO flow: ~190 cfs

One additional temperature sensor was added in Seneca Lake to provide data from well outside of the possible extent of the thermal plume:

Station Q: Lat: 42.70130 Lon: -76.95646

One additional temperature sensor was added just outside of the KLO north outlet channel

Station P: Lat: 42.68525 Lon: -76.95690

There are no suitable structures on which a security camera could be established for this station.

6. HURRICANE FRED

The remainder of Hurricane Fred came through the region on August 18-19. This storm resulted in heavy precipitation of nearly 4". Recorded precipitation at Ithaca on these dates was 1.87 and 2.03 inches, and at Corning was 0.95 and 2.71 inches.

This heavy rainfall resulted in a rapid increase in KLO flow from 21 cfs at noon on August 17, to 402 by noon on August 18, and to the peak of 3510 by 11:30 PM (Figure 7). Flow declined rapidly to 1310 cfs by 3:00 PM on August 20, but then only to 1110 by 9:00 AM on August 23. For the entire period of record of the USGS station at Dresden, beginning in October 1990, the August 18 peak has been exceeded only once (Figure 8).

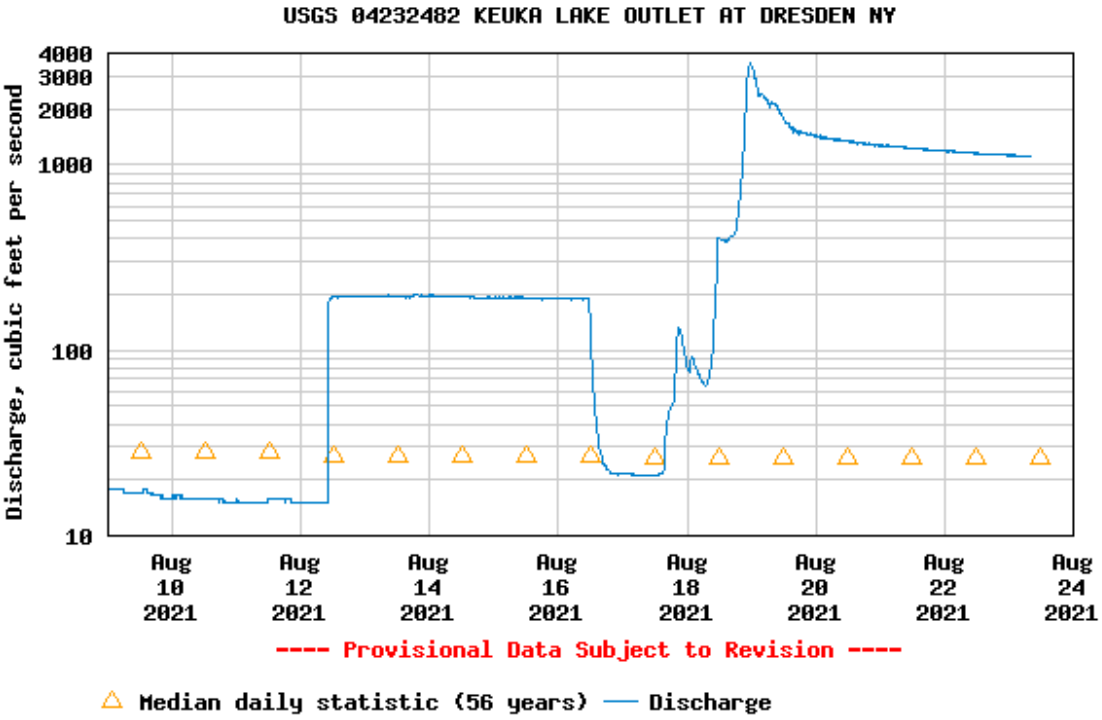


Figure 7 Keuka Lake Outlet flow from 8/13 to 8/20, 2021. Data from USGS station 04232482.

KLO flow may not decline to normal levels immediately since the level of Keuka Lake rose by more than 1 ft and is presently about 0.6 ft above the upper bound of the target elevation range. As of 9:00 AM on August 23, all discharge gates were open and flow into KLO was 895 cfs (Figure 9).

All security cameras set up at KLO stations are still operational, but the status of the temperature monitors is unknown. A data download was planned for 8/26, but that may be postponed if KLO flows remain high and turbid. Previous experience has demonstrated that the flow will have to be below 600 cfs, or possibly lower, in order to provide safe conditions for accessing the sensors. Even when access is possible, the sensors will be difficult to locate in the altered KLO morphology and influx of woody debris (Figure 10 and Figure 11).

If sensors cannot be located, they will be replaced as quickly as possible to minimize loss of data. Stations in Seneca Lake are not expected to be adversely affected, although they would be difficult to locate in present conditions due to the high Seneca Lake level (approximately 1 ft higher than during the August triaxial survey) and turbidity plume coming from KLO. The sensors have sufficient data recording capacity that a delayed data download will not result in any data loss. The Seneca Lake sensors, and triaxial surveys, are the primary data inputs to the plume modeling effort, so the potential loss of some KLO data during an extreme high flow event will not adversely affect integrity of study results.

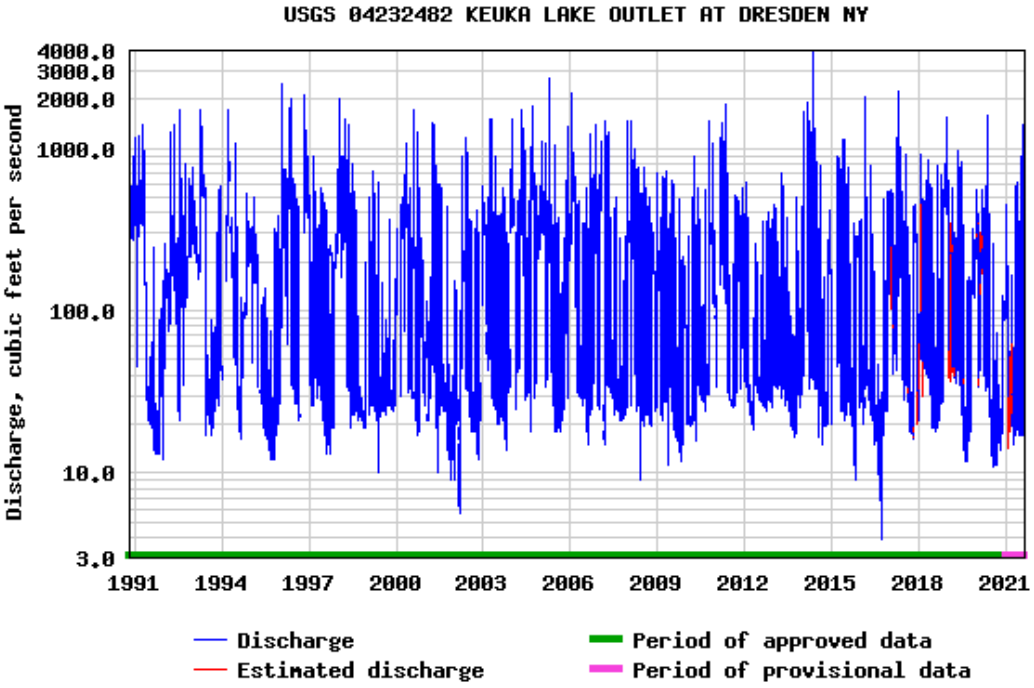
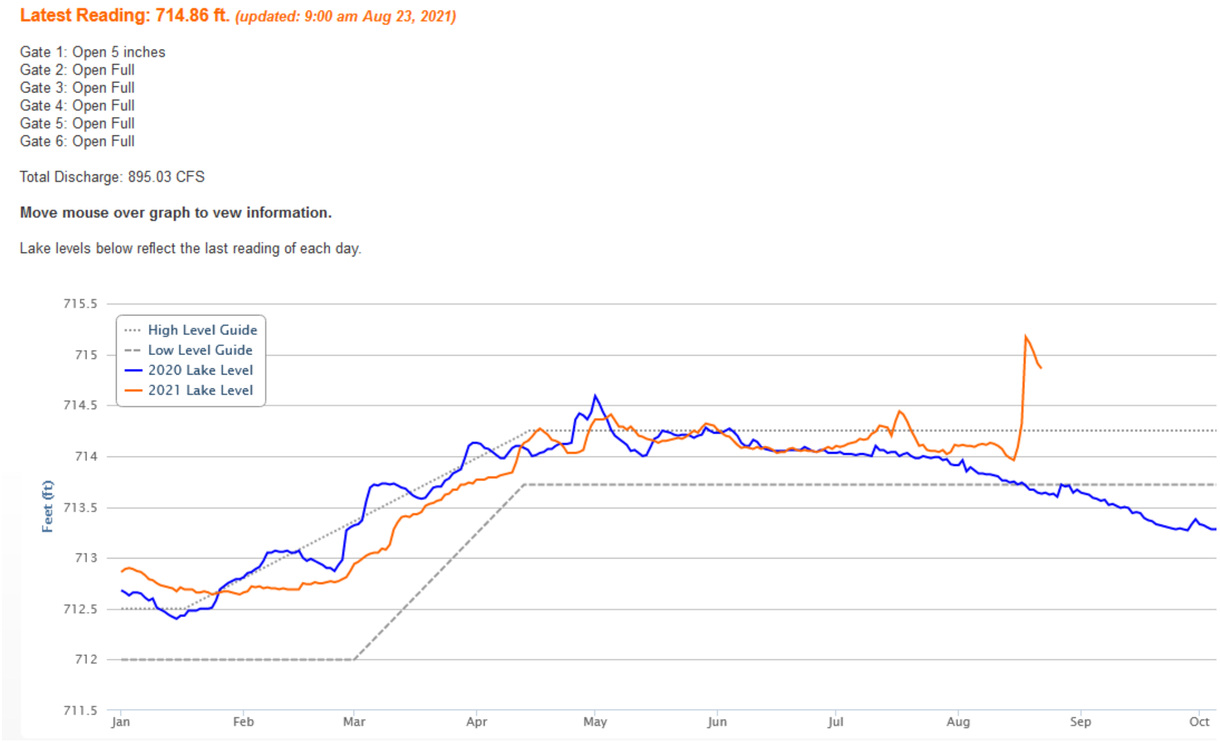


Figure 8 Keuka Lake Outlet flow from 10/29/1990 to 8/20/2021. Data from USGS station 04232482.



Latest Reading: 714.86 ft. ***(updated: 9:00 am Aug 23, 2021)***

Gate 1: Open 5 inches
Gate 2: Open Full
Gate 3: Open Full
Gate 4: Open Full
Gate 5: Open Full
Gate 6: Open Full

Total Discharge: 895.03 CFS

Move mouse over graph to vew information.

Lake levels below reflect the last reading of each day.

Figure 9 Keuka Lake surface elevation in 2020 and 2021, and target range.

Figure 10 View from security camera at Station F looking northwest across Keuka Lake Outlet channels on 8/4 (top) and 8/20 (bottom). Approximate sensor locations E and F are indicated in top panel.

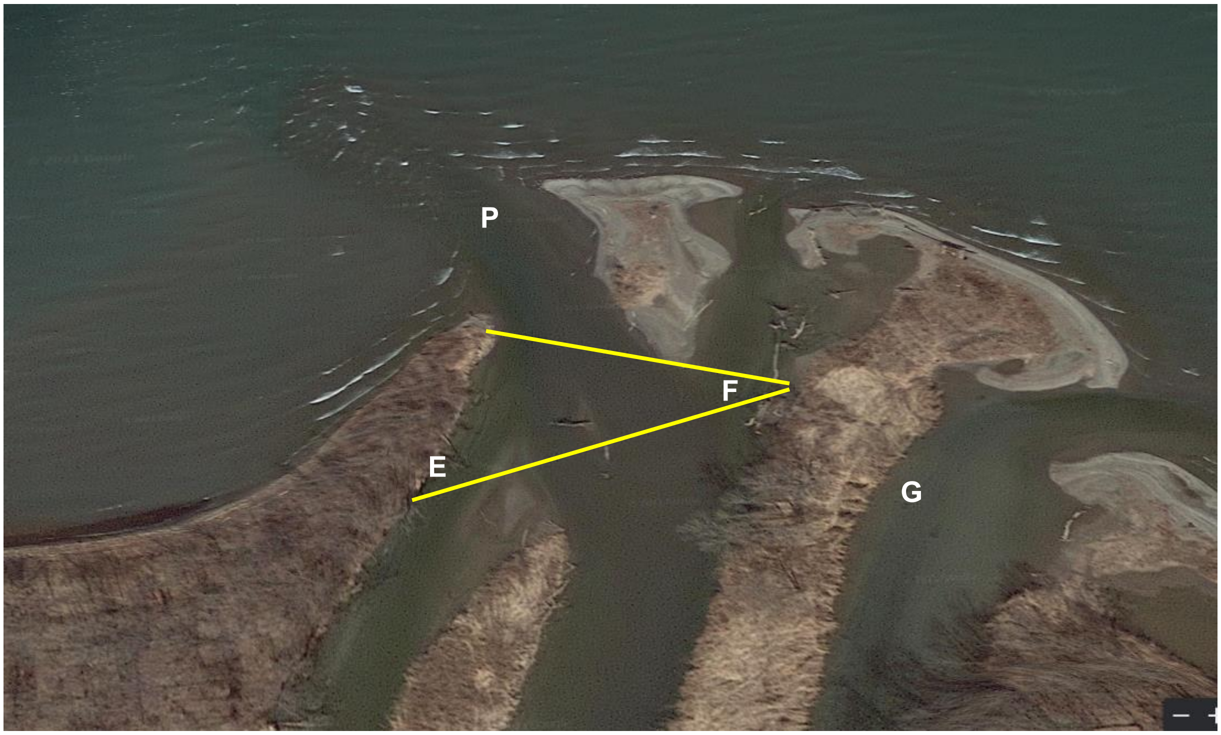


Figure 11 Aerial view of Keuka Lake Outlet delta showing approximate locations of Stations E, F, G, and new station P. Yellow lines indicate approximate field of vision of security camera at Station F.

7. SEPTEMBER 8 DOWNLOAD

Crews returned to the site to assess sensor status and download data on September 8. By that time KLO flow had declined to approximately 50 cfs with low turbidity (Figure 12).

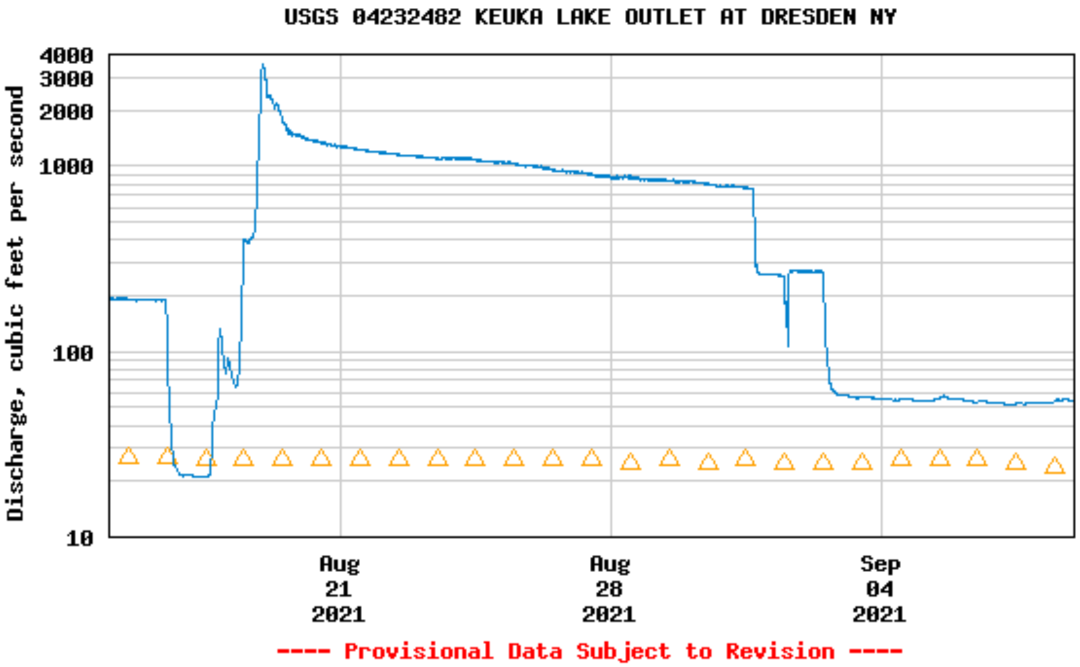


Figure 12 KLO flow from 8/15/21 to 9/8/21.

Sensors were located at Stations A, D, E, G. The sensor for Station P was found on the shoreline still attached to the T-post. Data were successfully downloaded from all of these stations.

Sensors at stations B, C, and F were not located, and had apparently either been washed out or buried under gravel moved downstream during Hurricane Fred. Station F was buried under logs and woody debris (Figure 10).

Deployment at all of the KLO stations was changed to a stake & chain method (). A 6 ft length of chain was attached to the end of a 4 ft T-post. The T-post was driven into the substrate as far as possible. Future downloads can be done by snagging the chain with a hook and raising the sensor out of the water. At Station A, the chain was attached to the boundary fence.

All Seneca Lake stations were located successfully and data were downloaded. All MX2204 sensors still in use were replaced with new MX2201 sensors.

Figure 13 Stake & chain deployment apparatus for KLO stations.

8. SEPTEMBER 23 DOWNLOAD

The download trip on 9/23 was successful in locating and downloading data from all KLO and Seneca Lake stations. During the day KLO flow increased rapidly from 17.8 cfs at 07:30 to 188 cfs at 14:30, and then another sharp increase on 9/24 to flows above 300 cfs. These rapid increases result from changes in releases from Keuka Lake.

9. OCTOBER DOWNLOADS

Data were downloaded successfully from all KLO and Seneca Lake stations on 10/7 when KLO flow was approximately 30 cfs. On 10/12 flow increased abruptly to 170 cfs when gate were opened in Pen Yan (Figure 14). On 10/16 flow increased to over 500 cfs and remained high for the remainder of the month, precluding access to the KLO sensors.

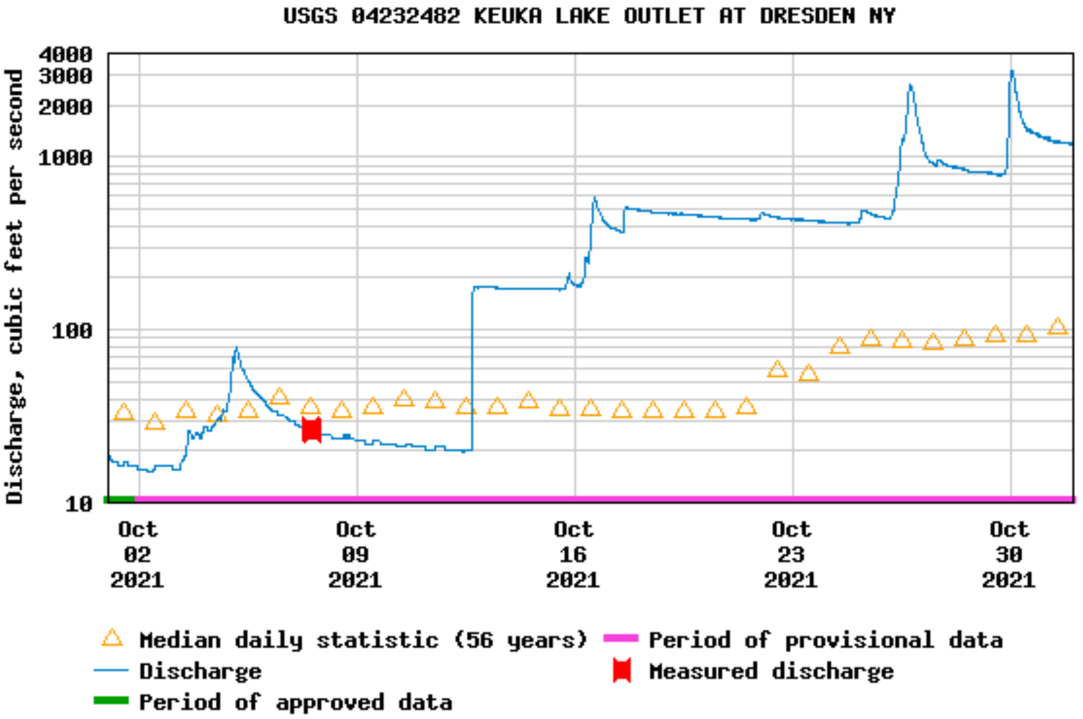


Figure 14 KLO flow during October, 2021.

10. NOVEMBER-DECEMBER DOWNLOADS

Although download events were planned for approximately 2-week intervals, after the successful downloads from all stations on 10/7, continuous high flows in KLO from mid-October through early December (Figure 15) precluded access to KLO sensors and download trips planned for late October and November were postponed. In addition, wind conditions also made potential access to Seneca Lake stations questionable.

Flows dropped below 300 cfs in early December, permitting partial access to the KLO stations on 12/8. The Floating Object Permit for the Seneca Lake buoys was approved on 11/3 and mailed. During the download event on 12/8 the buoys were repositioned to the lake surface and the sensors were checked and repositioned vertically if necessary. Permit labels were placed on the northernmost (Q) and southernmost (M) buoys. All Seneca Lake stations were accessed and downloaded.

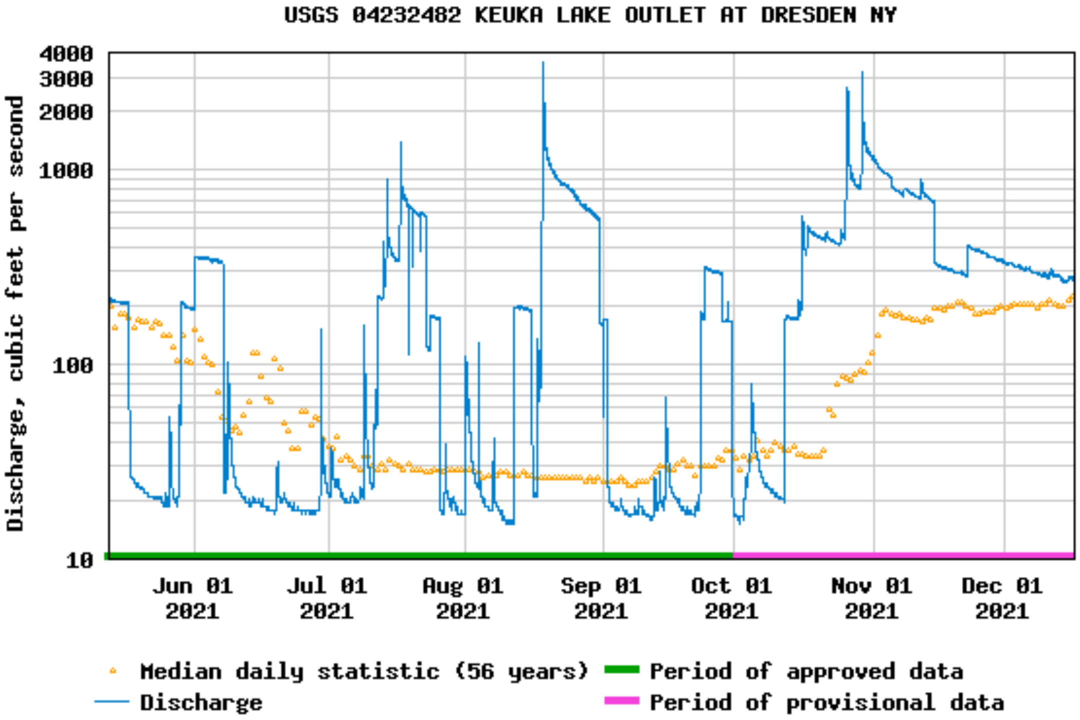


Figure 15 Flow in KLO from beginning of study in May through December 16.

Flows in the KLO at approximately 295 fps made access difficult, but possible at most of the stations. Substantial changes had occurred in the channel since the prior download on 10/7, with large woody debris (tree trunks) found at new locations (Figure 16).

Stations A, D, E, G, and P were successfully located and downloaded. Water level was too high and flow too rapid to access station B, although it is anticipated that the sensor is still there and will be accessible at lower flows. The sensor was not replaced. The sensor at Station C could not be located, although in the high and turbid flow it could have been missed. A new sensor was placed and chained to a log at the location. The sensor at Station F was buried under sediment and large woody debris. A new sensor was placed at the location and chained to a large log. Very little flow is exiting KLO through the middle channel. Most of the middle channel flow cuts across to the northern channel where temperature is monitored at Station P.

Trail cameras mounted at Stations A and C were non-functional and were removed.

Figure 16 View of KLO from approximately Station C looking east toward Station E on 12/8. The logs visible in the foreground and background were not there during prior download trip.

Data were again downloaded from all Seneca Lake stations and KLO stations A, C, D, E, F, G, and P. KLO flows were 270 cfs and precluded access to station B and searching for the previous sensor at station C. An additional sensor was deployed at station B.

Status of all download events through 12/21 is provided in Table 6.

Table 6 Status of data downloads from stations in KLO and Seneca Lake.

Station	Location	1	2	3	4	5	6	7	8	9
		6/25	7/22	8/3	8/14	9/8	9/23	10/7	12/8	12/21
A	KLO	D	H	D	D	D	D	D	D	D
B		D	D	D	D	R	D	D	H	H-R
C		R	H	R	D	R	D	D	H-R	D
D		R	H	D	D	D	D	D	D	D
E		D	H	R	D	D	D	D	D	D
F		D	H	D	D	R	D	D	R	D
G		N	H	D	D	D	D	D	D	D
P		-	-	-	I	D	D	D	D	D
H	Seneca Lake	D	D	D	D	D	D	D	D[3]	D
I		D	N	D	D	D	D	D	D[3]	D
J		D	D[1]	D	D	D	D	D	D[3]	D
K		D	D	D	D	D	D	D	D[3]	D
L		D	D	D	D	D	D	D	D[3]	D
M		D	D[2]	D	D	D	D	D	D[3]	D
N		D	D[2]	D	D	D	D	D	D[3]	D
O		-	-	I	D	D	D	D	D[3]	D
Q		-	-		I	D	D	D	D[3]	D
W		D		D	D				D	D

D: Located and downloaded.
N: Not located.
R: Not located and replaced.
H: High flow conditions prevented access.
I: Initial placement of new station.

[1] Removed by Sherriff's department on 7/20.

[2] Surface sensor missing and replaced.

[3] Buoy moved to surface and sensors repositioned vertically.

11. JANUARY 11, 2022, DOWNLOAD

Data retrieval was conducted on January 11, 2022. Average air temperature for the day was 11.4 °F, average wind speed 10.8 mph, and KLO flow was 132 cfs. In KLO, Stations A, B, C, D, E, G, and P were successfully located and data was downloaded. There was very little flow through the central KLO mouth. Station F was not able to be accessed because it was frozen in.

All Seneca Lake stations were successfully located and downloaded.

12. FEBRUARY DOWNLOADS AND TRIAXIAL SURVEY

Conditions for conducting data downloads after the January 11 event were variable and unpredictable. Low air temperatures, often below 20 °F, and average winds above 10 mph provided unfavorable conditions for open water work. After February 16, KLO flow jumped abruptly and remained above 200 cfs until March 28. Due to the environmental conditions, both data downloads and the scheduled February triaxial survey were postponed.

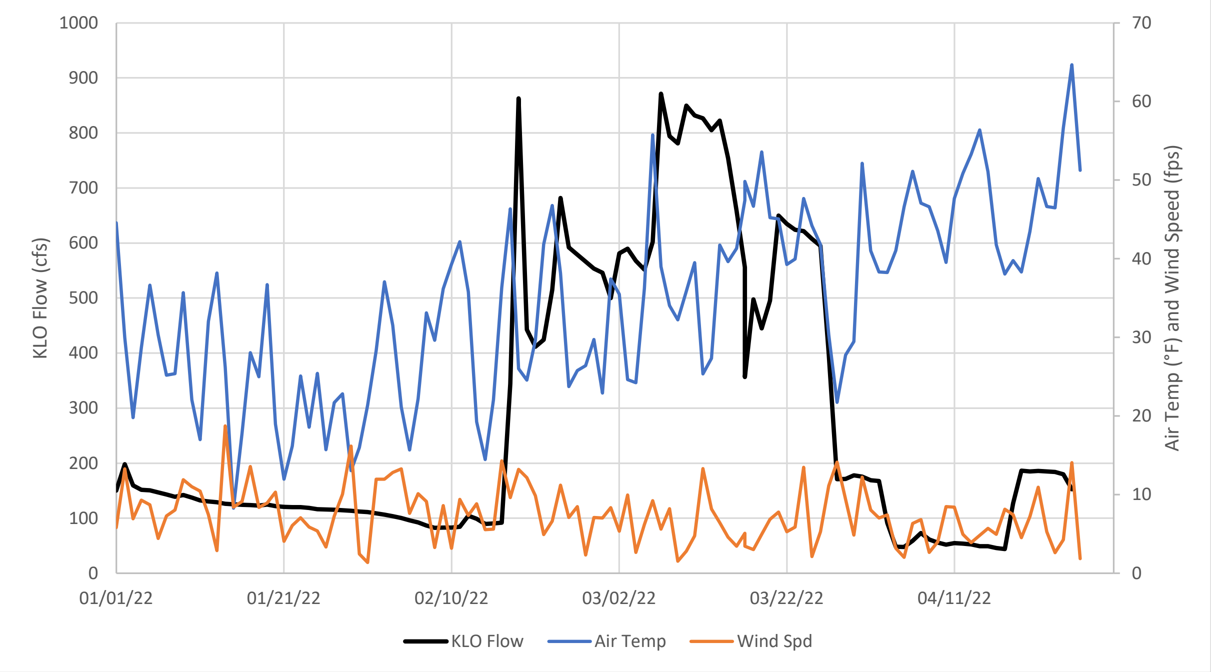


Figure 17 Daily mean KLO flow, air temperature, and wind speed from January 1 to April 26, 2022.

13. MARCH DOWNLOADS AND TRIAXIAL SURVEY

The next data download was accomplished on March 17 when average air temperature was 48 °F, average wind speed 3.2 mph, and KLO flow 427 cfs. All stations in Seneca Lake were accessed and downloaded. All KLO stations except P (in the north mouth) were accessed and downloaded. Flow was too high to access Station P.

The postponed February triaxial survey was completed on March 29 (air temperature 28 °F, wind speed 9.4 mph, KLO flow 171 cfs) and March 30 (air temperature 29 °F, wind speed 4.8 mph, KLO flow 177 cfs). All transects, vertical profiles, and other data was collected successfully.

Data download occurred on March 30. All stations except Station B (in KLO upstream of Greenidge discharge) were located and successfully downloaded. The sensor at Station B appeared to have been stolen. A replacement sensor was installed.

14. APRIL DOWNLOADS AND TRIAXIAL SURVEY

A data download was accomplished on April 12 when average air temperature was 51 °F, average wind speed 4.9 mph, and KLO flow 54 cfs. All stations in Seneca Lake and KLO were accessed and downloaded.

The final set of triaxial surveys was completed on April 25 (air temperature 65 °F, wind speed 14.1 mph, KLO flow ≈155 cfs) and April 26 (air temperature 51 °F, wind speed 1.9 mph, KLO flow ≈100cfs). All transects, vertical profiles, and other data was collected successfully.

The final data download and retrieval of equipment occurred on April 26 after completion of the transects. All stations were successfully located. Data could not be downloaded from the surface sensor at Station N so the sensor was sent back to the manufacturer for possible data retrieval. In addition, one of the replaced sensors at Station C was located, providing the possibility of retrieving some of the missing data for that location. Final status of monitoring data is provided in Table 7.

Table 7 Status of data downloads from stations in KLO and Seneca Lake for entire project.

Station	Location	1	2	3	4	5	6	7	8	9	10	12	13	14	15
		6/25	7/22	8/3	8/14	9/8	9/23	10/7	12/8	12/21	1/11	3/17	3/30	4/12	4/26
A	KLO	D	H	D	D	D	D	D	D	D	D	D	D	D	D
B		D	D	D	D	R	D	D	H	H-R	D	D	R[6]	D	D
C		R	H	R	D	R	D	D	H-R	D	D	D	D	D	D[7]
D		R	H	D	D	D	D	D	D	D	D	D	D	D	D
E		D	H	R	D	D	D	D	D	D	D	D	D	D	D
F		D	H	D	D	R	D	D	R	D	D	D	D	D	D
G		N	H	D	D	D	D	D	D	D	N[4]	D	D	D	D
P		-	-	-	I	D	D	D	D	D	D	N[5]	D	D	D
H	Seneca Lake	D	D	D	D	D	D	D	D[3]	D	D	D	D	D	D
I		D	N	D	D	D	D	D	D[3]	D	D	D	D	D	D
J		D	D[1]	D	D	D	D	D	D[3]	D	D	D	D	D	D
K		D	D	D	D	D	D	D	D[3]	D	D	D	D	D	D
L		D	D	D	D	D	D	D	D[3]	D	D	D	D	D	D
M		D	D[2]	D	D	D	D	D	D[3]	D	D	D	D	D	D
N		D	D[2]	D	D	D	D	D	D[3]	D	D	D	D	D	D[8]
O		-	-	I	D	D	D	D	D[3]	D	D	D	D	D	D
Q		-	-		I	D	D	D	D[3]	D	D	D	D	D	D
W		D		D	D				D	D		D	D	D	D

D: Located and downloaded.
N: Not located.
R: Not located and replaced.
H: High flow conditions prevented access.
I: Initial placement of new station.

[1] Removed by Sherriff's department on 7/20.

[2] Surface sensor missing and replaced.

[3] Buoy moved to surface and sensors repositioned vertically.

[4] Station hidden under ice. Sensor not accessible.

[5] Sensor not accessible due to high flows.

[6] Sensor missing. Appears to have been stolen.

[7] Prior sensor also located and downloaded.

[8] Surface sensor would not download. Sent to manufacturer for data retrieval.

APPENDIX B – HOBO DEPLOYMENT AND RETREIVAL

Waterbody	Station	Latitude	Longitude	Column Position	Serial No.	Dates Represented by Download Period														Notes
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	
KLO	A	42.68242	-76.94801	Middle	20433452	05/14-06/25														All KLO loggers moved to bottom.
		42.68242	-76.94801	Bottom	20433452		High flows	06/25-08/03	08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	03/17-03/30	03/30-04/12	04/12-04/26	
	B	42.68280	-76.94880	Middle	20643952	05/14-06/25														All KLO loggers moved to bottom.
		42.68280	-76.94880	Bottom	20643952		High flows	06/25-08/03	08/03-08/14	Lost										
		42.68280	-76.94880		21159638						09/08-09/23	09/23-10/07	High flows	High flows	Lost					
		42.68274	-76.94867		21212257										12/21-01/11	01/11-03/17	Lost			Moved to opposite side of channel.
		42.68274	-76.94867		21175418												03/29-03/30	03/30-04/12	04/12-04/26	
	C	42.68364	-76.94777	Middle	20430367	Lost														All KLO loggers moved to bottom.
		42.68364	-76.94777	Bottom	20643953		High flows	Lost												
		42.68364	-76.94777		21128287				08/03-08/14	Lost										
		42.68364	-76.94777		21159639						09/08-09/23	09/23-10/07	10/07-10/30							Logger buried in high flow event, recove
		42.68364	-76.94777		21159640									12/08-12/21	12/21-01/11	01/11-03/17	03/17-03/30	03/30-04/12	04/12-04/26	
	D	42.68359	-76.94769	Middle	20430458	Lost														All KLO loggers moved to bottom.
		42.68359	-76.94769	Bottom	20565301		High flows	06/26-08/03	08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	03/17-03/30	03/30-04/12	04/12-04/26	
	E	42.68493	-76.94693	Middle	20430368	05/14-06/26														All KLO loggers moved to bottom.
		42.68493	-76.94693	Bottom	20430368		High flows	Lost												
		42.68470	-76.94714	Bottom	21128274				08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	03/17-03/30	03/30-04/12	04/12-04/26	Small change in location.
	F	42.68489	-76.94649	Middle	20430362	05/14-06/25														All KLO loggers moved to bottom.
		42.68489	-76.94649	Bottom	20430362		High flows	06/25-08/03	08/03-08/14	Lost										
		42.68489	-76.94649		21175412						09/08-09/23	09/23-10/07	Lost							
		42.68489	-76.94649		21175417									12/08-12/21	Inaccessible	12/21-03/17	03/17-03/30	03/30-04/12	04/12-04/26	
	G	42.68456	-76.94630	Middle	20430363	Lost														All KLO loggers moved to bottom.
		42.68456	-76.94630	Bottom	20433446		High flows	06/26-08/03	08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	03/17-03/30	03/30-04/12	04/12-04/26	
	P	42.68526	-76.94690	Bottom	21128277				08/12-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	Inaccessible	01/11-03/30	03/30-04/12	04/12-04/26	
Seneca Lake	H	42.68610	-76.94590	Top	20433450	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68610	-76.94590	Middle	20643954	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68610	-76.94590	Bottom	20433451	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	I	42.68710	-76.94470	Top	20433454	05/14-06/25	Not visible	06/25-08/03	08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68710	-76.94470	Middle	20433453	05/14-06/25	Not visible	06/25-08/03	08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68710	-76.94470	Bottom	20643950	05/14-06/25	Not visible	06/25-08/03	08/03-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	J	42.68820	-76.94370	Top	20430358	05/14-06/25	06/25-07/20	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	Removed by sheriff 7/20.
		42.68820	-76.94370	Middle	20430364	05/14-06/25	06/25-07/20	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	Removed by sheriff 7/20.
		42.68820	-76.94370	Bottom	20430356	05/14-06/25	06/25-07/20	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	Removed by sheriff 7/20.
	K	42.68520	-76.94240	Top	20430361	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68520	-76.94240	Middle	20433447	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68520	-76.94240	Bottom	20430365	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	L	42.68240	-76.94060	Top	20433448	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68240	-76.94060	Middle	20430354	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68240	-76.94060	Bottom	20430369	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	M	42.68960	-76.94990	Top	20433449	05/14-06/25	Lost													
		42.68960	-76.94990		21061986			Not scheduled	07/22-08/14	08/14-09/08										Replaced with MX400 series logger.
		42.68960	-76.94990		21175409						09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68960	-76.94990	Middle	20643951	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68960	-76.94990	Bottom	20430353	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	N	42.69120	-76.95530	Top	20430357	05/14-06/25	Lost													
		42.69120	-76.95530		20430355			Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/25	Onset recovered data until failed from
		42.69120	-76.95530	Middle	20430366	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.69120	-76.95530	Bottom	20430360	05/14-06/25	06/25-07/22	Not scheduled	07/22-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	O	42.68283	-76.94223	Surface	21061991			Not scheduled	07/23-08/14	08/14-09/08										Replaced with MX400 series logger.
		42.68283	-76.94223		21175407						09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.68283	-76.94223	Top	21061990			Not scheduled	07/23-08/14	08/14-09/08										Replaced with MX400 series logger.
		42.68283	-76.94223		21175408						09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
	Q	42.70130	-76.95646	Top	20232980				08/13-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.70130	-76.95646	Middle	21128280				08/13-08/14	08/14-09/08	09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	
		42.70130	-76.95646	Bottom	21061989				08/13-08/14	08/14-09/08										Replaced with MX400 series logger.
		42.70130	-76.95646		21159637						09/08-09/23	09/23-10/07	10/07-12/08	12/08-12/21	12/21-01/11	01/11-03/17	Not scheduled	03/17-04/12	04/12-04/26	

APPENDIX C – INSTRUMENT SPECIFICATIONS

Study Phase	Attribute	Instrument	Specifications
Continuous *in-situ* temperature monitoring	Temperature	Onset HOBO TidbiT MX2204 Recording at 5-min intervals	Range -4°F to 122°F Resolution: 0.018°F Accuracy: +/-0.36°F
	Temperature	Onset HOBO TidbiT MX2201 Recording at 5-min intervals (temporary use)	Range -4°F to 122°F Resolution: 0.072°F Accuracy: +/-0.9°F
	Location	Lowrance® HDS-9 chartplotter unit equipped with a Lowrance® Point-1 external antenna.	Accuracy: 20m RMS
Triaxial Survey	Temperature	Valeport Limited miniCTD-DR temperature	Range -23°F to 95°F Resolution: 0.002°F Accuracy: +/-0.02°F Response:
	Location	Lowrance® HDS-9 chartplotter unit equipped with a Lowrance® Point-1 external antenna.	Accuracy: 20m RMS
	Depth	Lowrance® TotalScan Med/High/455/800kHz Transducer.	Accuracy: 0.17 ±0.13 m[11]
	Current	Nortek® Aquadopp Profiler Acoustic Doppler Current Profiler	Depth, direction, and velocity
Weather Station	Time	H2	±2 sec and ±5 seconds per week
	Air Temperature	S-THB-M002	Accuracy: 0.38 °F
	Relative Humidity	S-THB-M002	± 2.5% from 10% to 90%
	Barometric Pressure	HOBO S-BPB-CM50	±0.088 inHg @77°F
	Wind Speed	HOBO S-WSET-B	Accuracy:±2.4 mph or ±4% Resolution: 1.1 mph
	Wind Direction	HOBO S-WSET-B	Accuracy:±5° Resolution: 1.4°
	Solar Radiation	HOBO S-LIB-M003	Accuracy:±10 W/m^2 or ±5% Resolution: 1.25 W/m^2 Spectral range: 300 to 1100 nm Measurement range: 0 to 1280 W/m^2

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[11] Mean absolute error in depth reported by Helminen et al. 2019 for Lowrance HDS 5 and HDS 7 units with 83/200 kHz transducer.

Study Phase	Attribute	Instrument	Specifications
KLO channel discharge	KLO channel discharge	Measuring tape, measuring staff, and Hach FH950	

APPENDIX D – HYDROTHERMAL MODELING

Final Report:

HYDROTHERMAL MODEL STUDY OF THERMAL DISCHARGE FROM GREENIDGE GENERATING FACILITY

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August 2022

EXECUTIVE SUMMARY

The Greenidge Generating Facility (GGF) is a steam-electric generating facility located on the western shore of Seneca Lake in Dresden, Yates County, New York. Presently, the GGF consists of a single, gas-fired boiler and one turbine generator (designated Unit 4), with a rated maximum generating capacity of 107 MW. The facility draws water for its once-through cooling system from Seneca Lake. Heated cooling waters from this system are discharged into the lower reach of Keuka Lake Outlet (KLO) which, in turn, discharges to the adjacent Seneca Lake.

This report documents a hydrothermal model study that was conducted to characterize potential impacts of heated discharges from the GGF on the thermal regime of Seneca Lake. This study was required as a condition of SPDES permit NY0001325 for the Facility.

The last prior study of the Facility's thermal discharge occurred in 1976, when the Facility operated at a much higher capacity -- with four units operating at a combined generating capacity of 215 MW. That prior study demonstrated that some thermal criteria for the receiving waters were not being met, but no harm to the balanced indigenous community (BIC) was observed. As a result, the New York State Department of Environmental Conservation (NYSDEC) defined a mixing zone within the lowest 700 ft of KLO and extending up to 230 acres into Seneca Lake.

The basic goal of the present study was to reassess spatial and temporal distributions of temperature changes in Seneca Lake receiving waters due to the Facility's current discharge capacity. To this end, a time-varying, three-dimensional, mathematical model (RMA-10) was adapted to the study area, and verified with new sets of field data collected during 2021-2022.

The verified model was used to simulate a series of reasonable, worst-case scenarios for variables that control the overall size, shape and movement of the Facility's thermal plume. Results for all model scenarios indicate that the maximum receiving-water area over which more than a 3°F rise in surface temperature would occur is 18.7 acres. This area is significantly smaller than the corresponding areas (47 acres or 230 acres) simulated in the previous hydrothermal study. This result is consistent with the historical decreases in GGF generating capacity. The model also indicates that potential future air temperature increases will have a de minimis (~ 2-acre) impact on the extent of the 3°F area.

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1. BACKGROUND

1.1 Introduction and Objectives

The Greenidge Generating Facility (hereafter “GGF” or “the Facility”) is located on the western shore of Seneca Lake (Figure 1.1) in Dresden, Yates County, New York. The GGF is a steam-electric generating facility that presently consists of a single, gas-fired boiler and one turbine generator (designated Unit 4), with a rated maximum generating capacity of 107 MW. The Facility draws up to approximately 98 MGD of cooling water from Seneca Lake. Heated cooling waters are discharged into the lower reach of Keuka Lake Outlet (KLO) which, in turn, discharges into the adjacent Seneca Lake.

GGF’s SPDES permit NY0001325 required that a Thermal Discharge Study be performed to assess compliance with New York State thermal water quality criteria. This report documents a key component of the Study -- a hydrothermal model assessment of the Facility’s thermal plume in Seneca Lake.

A prior thermal study at GGF was conducted in 1976, when the facility operated at approximately twice its current capacity (i.e., at a plant load of 215 MW). That prior study demonstrated that some thermal criteria for the receiving waters were not being met. However, no harm to the balanced indigenous community (BIC) was observed, so a variance from the thermal criteria was granted by New York State Department of Environmental Conservation (NYSDEC) within a specified mixing zone.

The 1976 thermal study estimated the maximum areal extent of Seneca lake within which the 3°F surface temperature ΔT criterion would not be met was either: (a) 47 acres (190,202 m^2) for the case when an onshore-offshore (i.e., lakeward-directed) plume develops; or (b) 230 acres (930,776 m^2) for the case when a shore-attached plume develops. Based on the study, NYSDEC defined the mixing zone as the lowest 700 ft of KLO and 230 acres in the adjacent area of Seneca Lake.

The SPDES permit states that a model should be used to simulate the Facility’s thermal plume under critical ambient temperature conditions, when all units are operating during summer, winter or other critical climatological conditions. In accordance with the Facility’s Permit, the basic goal of the present study was to re-assess spatial and temporal distributions of temperature changes in Seneca Lake receiving waters due to the Facility’s current thermal discharges, and to account for possible effects of atmospheric temperature changes. To this end, a time-varying, three-dimensional hydrothermal model (RMA-10) was adapted to the study area, and verified with a new set of field data collected during 2021 and 2022. The validated model was used to delineate the magnitude and extent of the Facility’s thermal plume -- particularly the area in Seneca Lake with more than a 3°F rise in surface temperature -- over a representative range of environmental conditions and Facility operations -- including reasonable, worst-case (“critical”) conditions and potential atmospheric warming. This preliminary model analysis may support planning of future biothermal assessments to determine whether the Facility’s thermal discharges continue to protect the balanced indigenous community within the receiving water bodies.

Figure 1.1: Study area map (Source: U.S. Geological Survey National Map)

1.2 Facility and Site Description

Relevant background information regarding the GGF and its surroundings have been summarized previously in the report entitled “Greenidge Thermal Discharge Study Plan” (ASA Analysis and Communication, 2020). Salient and additional features are re-stated below.

The generating capacity of the GGF has decreased substantially over time. The GGF previously had four generating units that came online between 1938 and 1953, with a combined generating capacity of 215 MW. The cooling systems withdrew water from Seneca Lake at a maximum rate of 131,500 gpm (189.4 MGD). The Facility currently has only one generating unit (Unit 4), with a generating capacity of 107 MW.

Cooling water for Unit 4 is withdrawn from Seneca Lake through a 7-ft diameter, elevated intake pipe that extends from the pumphouse to a point 650 feet offshore (Figure 1.2). At the end of the pipe, the Lake depth is approximately 11 feet. The Unit 4 intake relies on suction to convey water from the Lake, through the elevated intake pipe, and on to the circulating water pumps.

Unit 4 has three cooling water pumps with a combined capacity of 68,100 gpm (90.0 MGD). Two pumps are used throughout most of the year and the third pump is operated, as needed, during the summer months or used as back-up for the rest of the year. As required by the SPDES permit issued in 2017, variable-speed drive units were installed on two of the three pumps in the summer of 2019. Service water for Unit 4 is drawn through the Unit 3 intake system, but adds only minimally to the total flow and heat load.

The Unit 4 condenser, manufactured by the Westinghouse Electric Corporation, has 50,000 ft^2 of cooling surface made up of 9098 3/4" O.D. No. 18 BWG Admiralty metal tubes having an effective length of 28 ft. At full generating load and flow, the design temperature rise across the condenser (ΔT) is approximately 14 °F.

After passing through the Unit 4 condenser, cooling water discharges into the discharge canal, which is approximately 900-feet long and empties into the Keuka Outlet, about 700 feet upstream from Seneca Lake (Figure 1.3).

1.3 Description of the Receiving Waters

Keuka Lake Outlet/ Seneca Lake are the receiving waters for the Facility's thermal discharge. The Facility's cooling water discharge empties into the lower reach of the Keuka Lake Outlet approximately 700 feet upstream from its confluence with Seneca Lake (Figures 1.3). The mouth of the Keuka Lake Outlet splits into three channels that divide and spread outflow into Seneca Lake.

Figure 1.2: Unit 4 withdrawal conduit extending from the west shore of Seneca Lake.

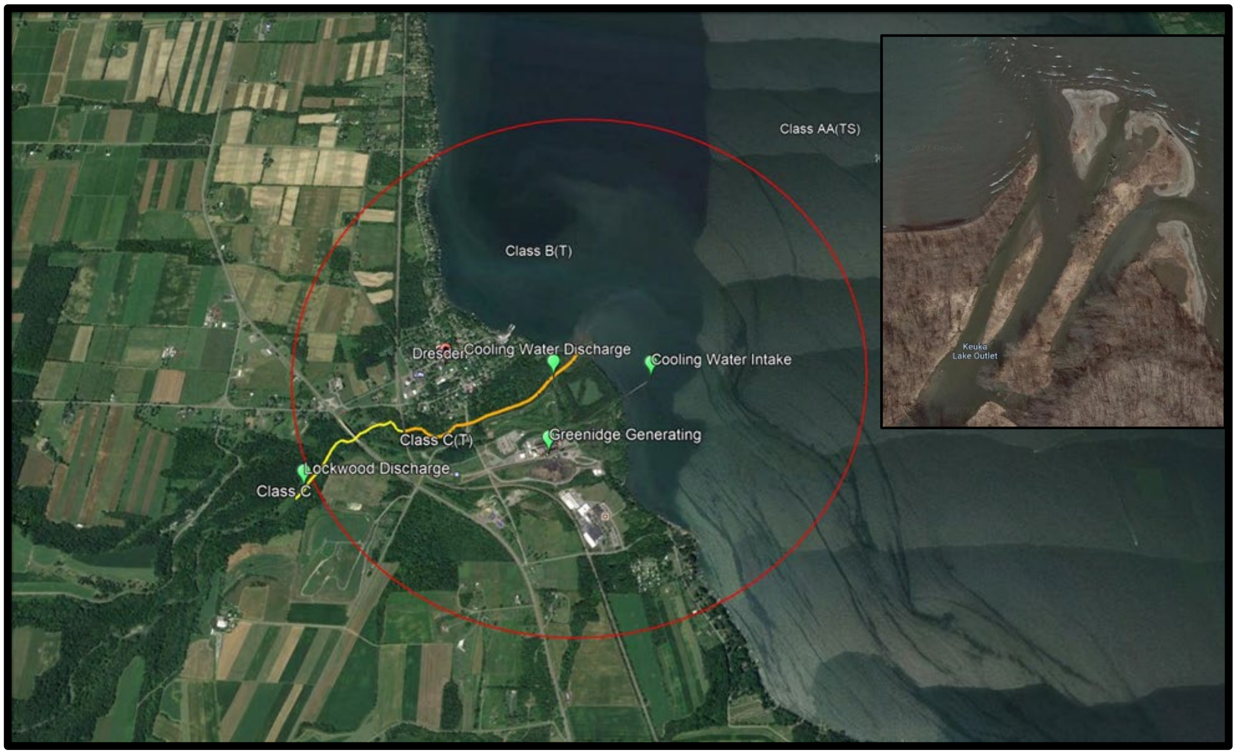

Figure 1.3: NYSDEC classifications, discharge location, and KLO mouth channels (top right)

Seneca Lake lies within New York State's Finger Lakes region. Lake depths vary laterally from approximately 0-12 feet nearshore to approximately 200 ft to 400+ ft offshore (Figure 1.4). The main axis of the Lake is aligned approximately N-S and has a maximum fetch of 38 miles. Axis-aligned wind stresses during storm events can generate relatively large surface stresses, surface waves and internal waves in Seneca Lake.

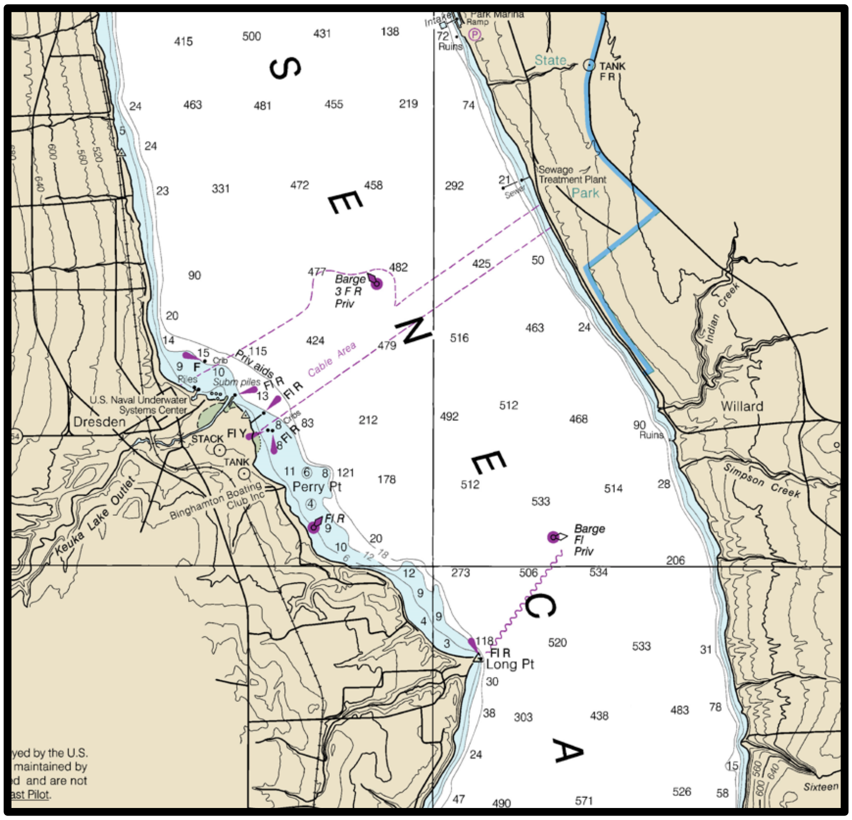

Figure 1.4: Local Bathymetry of Seneca Lake (Source: NOAA Navigation Chart No. 14791).

Previous observational studies (e.g., Hobart and William Smith Colleges, 2012) indicate that when the thermocline forms in Seneca Lake, it forms a boundary between the warmer (4 to 25°C, 39º to 77ºF), less-dense and sunlit epilimnion and the colder (4°C), more-dense, darker hypolimnion. A typical thermocline depth is reported at 66 feet (20 m); However, thermocline depth was observed to oscillate vertically in response to internal seiche activity, epilimnetic mixing by storm waves, and by season warming and cooling of the epilimnion. The NYSDEC website[1] posts a thermocline depth varying from approximately 60 feet to 125 feet (18m to 38m).

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[1] https://www.dec.ny.gov/

The Facility's thermal plume extends from the lower KLO and into Seneca Lake, where it is influenced by factors such as KLO flow, wind speed, wind direction, Lake ambient temperature, Lake turbulence, and Lake stratification. Steady winds aligned with the north-south axis of Seneca Lake, will tend to move the plume along the western shoreline. Also, wind effects may interact with KLO flow events. The variations of KLO flow and wind strength can alter the position and size of the GGF thermal plume over short time scales.

Within a radius of one mile from the mouth of KLO, Seneca Lake is designated as class B(T) NYSDEC (Figure 1.3). Class B waters are deemed suitable for fish, shellfish, and wildlife propagation and survival. The (T) sub-designation refers to the Lake's support of trout. Most of the lake more distant from the outlet is class AA(TS). Class AA(TS) waters can be used as a potable source with limited treatment. The (TS) sub-designation refers to the Lake's support of trout spawning.

1.4 Facility Power Generation

Representative patterns of recent GGS power generation are displayed in Figure 1.5. The Facility often displays a daily cycling mode of electrical generation, consisting of near-peak generation followed by an off-peak interval of near-minimum generation, as illustrated in Figure 1.6. At times, this pattern is interrupted with extended periods of reduced generation over a few days (Figures 1.5).

During June through July of 2021, GGS generation typically fluctuated between peaks of approximately 100-109 MW and troughs of approximately 43-54 MW (Figure 1.5). Interspersed within these fluctuations were some days of low-level (~ 45 MW) generation.

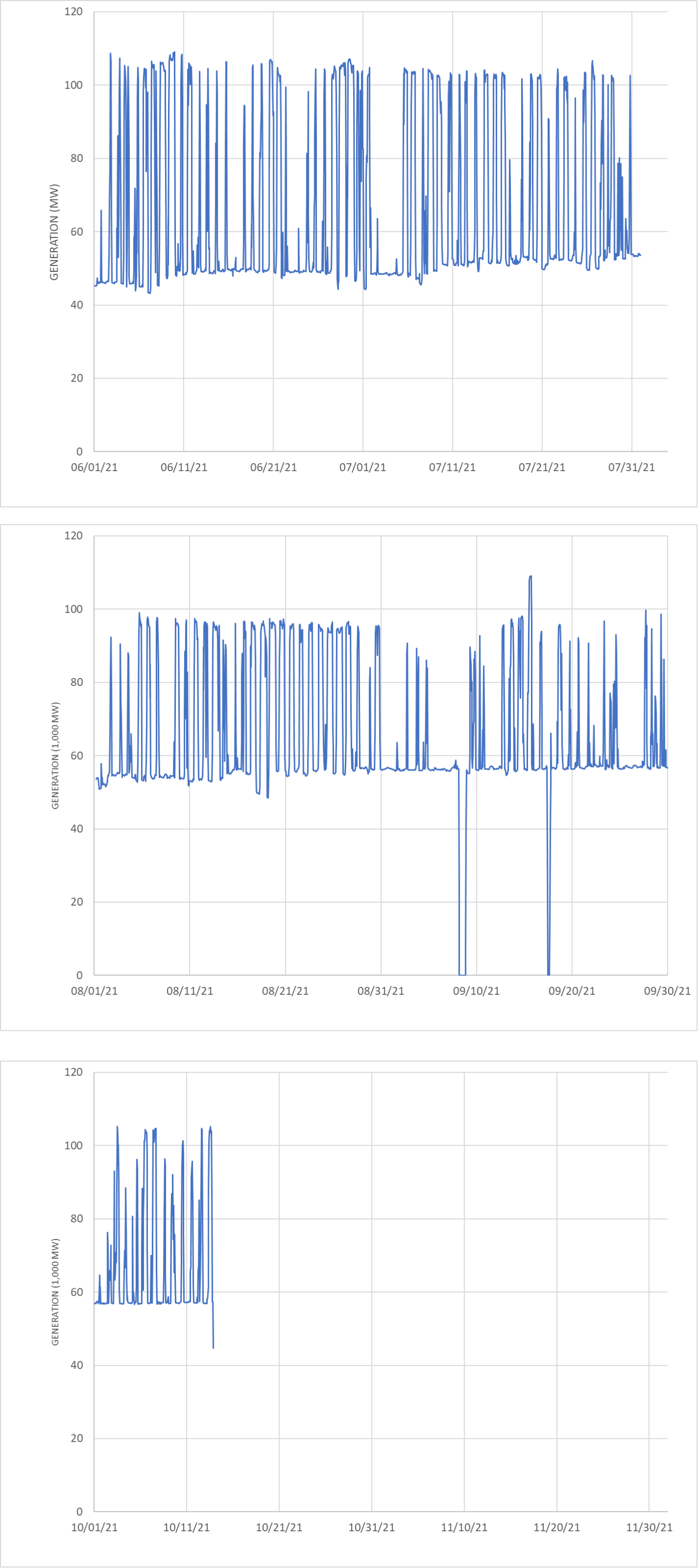


Figure 1.5: Representative patterns of electrical generation: June through November , 2021.

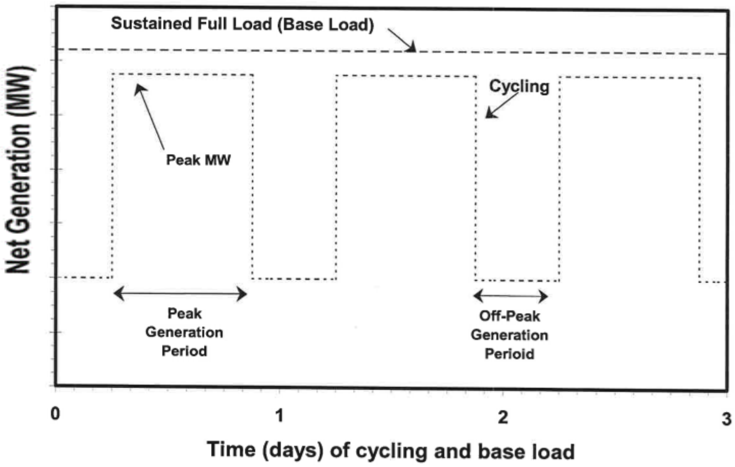


Figure 1.6 General Representation of cycling mode of electrical generation.

1.5 Facility Heat Rejection

Facility heat rejection rates are calculated according to the formula:

$$HRR = 9.704x10^6 * Q * (T_o - T_i)$$

where:

HRR = Facility heat rejection rate [Btu/day]

Q = flow through Facility [cfs]

To = condenser inlet temperature (deg C)

Ti = condenser outlet temperature (deg C).

Representative patterns of GGS heat rejection are displayed in Figure 1.7. The Facility's cycling mode of electrical generation results in a cycling pattern of heat rejection. Within most days, there is a period of near-peak heat rejection followed by a period of near-minimum heat rejection, as illustrated in Figure 1.7.

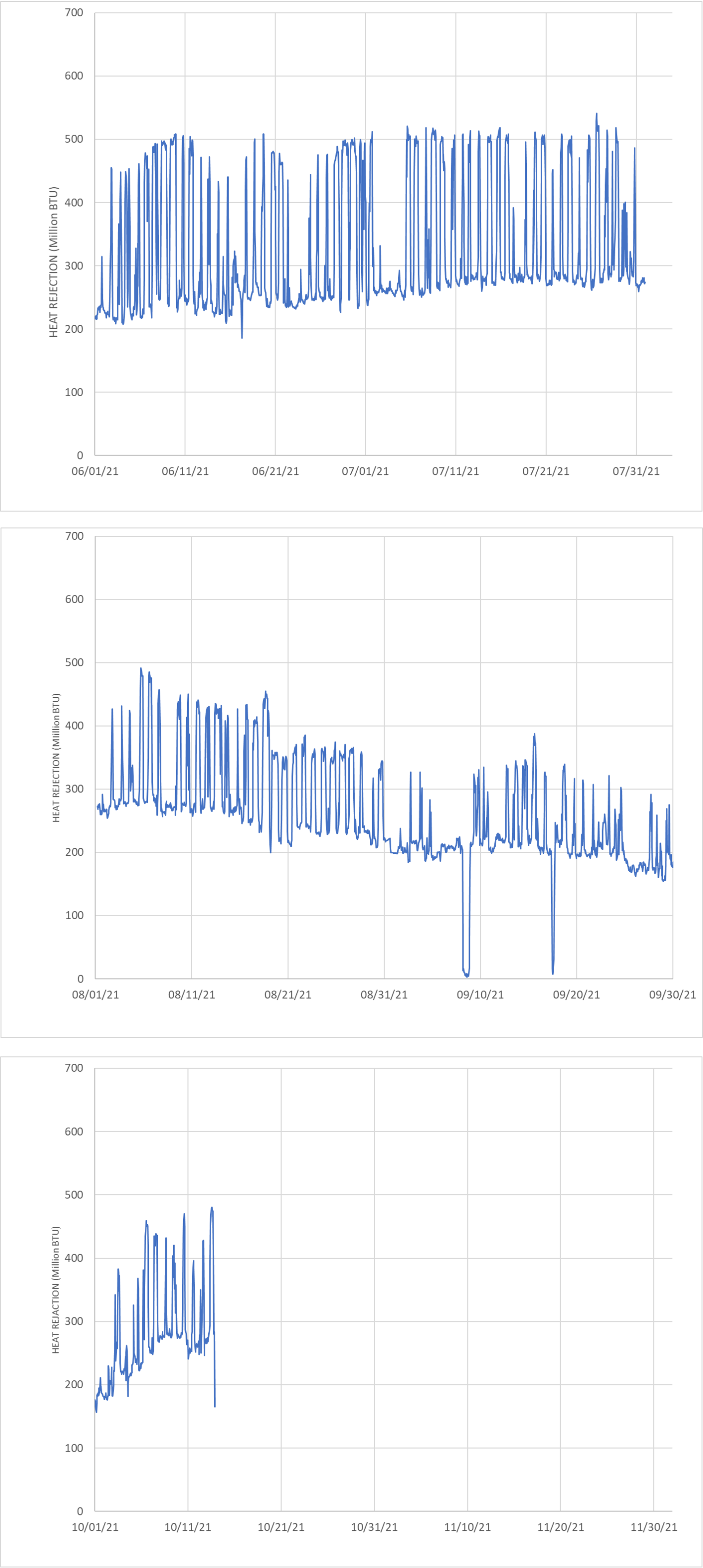


Figure 1.7 Representative patterns of GGS heat rejection: June through October , 2021. (Source: GGS)

2. FIELD DATA

Field data collected to support the present study are described in the companion study report entitled "Greenidge Generation Thermal Criteria Study" (ASA Analysis and Communication, 2022). Information that is particularly relevant to the RMA-10 modeling analysis is reproduced below.

2.1 Available Historical Data

Available information concerning operations of the GGF, and characteristics of Seneca Lake, were reviewed to guide the modeling approach (i.e., extent of the modeling domain, computational grid resolution, selection of critical conditions for model projection scenarios, and development of model inputs). The following available data were reviewed:

- Plant discharge/intake structure design
- Current plant generating loads, intake/discharge flows, and temperature
- Lake water level from the USGS gage on Seneca Lake at Watkins Glen (#04232400)
- Keuka Lake Outlet discharge data from USGS gage (#04232482)
- Lake bathymetry, ambient temperature and current data
- Previous thermal plume monitoring studies
- Meteorological data measured at the Northeast Regional Climate Center (Penn Yan, NY)
- Meteorological and lake temperature data at the Clarks Point buoy
- Lake temperature and water quality data collected during 2005-2006 studies

2.2 New Lake Temperature Survey Data

In-situ water temperatures were measured in two modes: (1) with temperature sensors deployed at fixed locations in the local receiving waters; and (2) with temperature sensor towed along prescribed radial transects in the adjacent Seneca Lake ("triaxial" surveys). This combination of fixed moorings and shipboard transect surveys characterized patterns of spatial and temporal variability in receiving water temperatures. Also, it supported the validation of the selected hydrothermal model.

2.2.1 In-situ Temperature Monitoring at Fixed Locations in KLO and Seneca Lake

Temperature sensors deployed at fixed locations in the receiving waters provide high-temporal-resolution data, but at particular locations. From mid-May 2021 through April 2022, initially 7 (and then 8) recording temperature sensors were anchored at the bottom in the KLO and the GGF discharge canal, as shown in Figure 2.1. These sensors recorded in-situ temperatures to the nearest 0.1ºF, and at 5-minute intervals. Details regarding this sampling program at these 8 KLO locations are provided in the companion report (ASA 2022).

Figure 2.1: In-situ temperature recording locations in GGF discharge and Lower KLO.

During the same period, initially 7 sets of temperature sensors were deployed in Seneca Lake surrounding the Outlet mouth (Figure 2.2) using a mooring consisting of a weighted anchor, line, and buoy (Figure 2.2). At each location, sensors were located at surface, mid-depth and bottom. The sensors recorded temperature at 5-minute intervals, and to the nearest 0.1°F. In July 2021, an additional surface sensor was installed near the intake conduit, and in August 2021 and additional multi-depth location was installed to the north. Details regarding this Lake mooring sampling program are provided in the companion report (ASA 2022).

In addition to the temperature sensors, an Onset meteorological monitoring station (W) was established on the GGF intake structure (Figure 3 5). The station recorded air temperature, wind speed, wind direction, solar radiation, and relative humidity at 5-minute intervals.

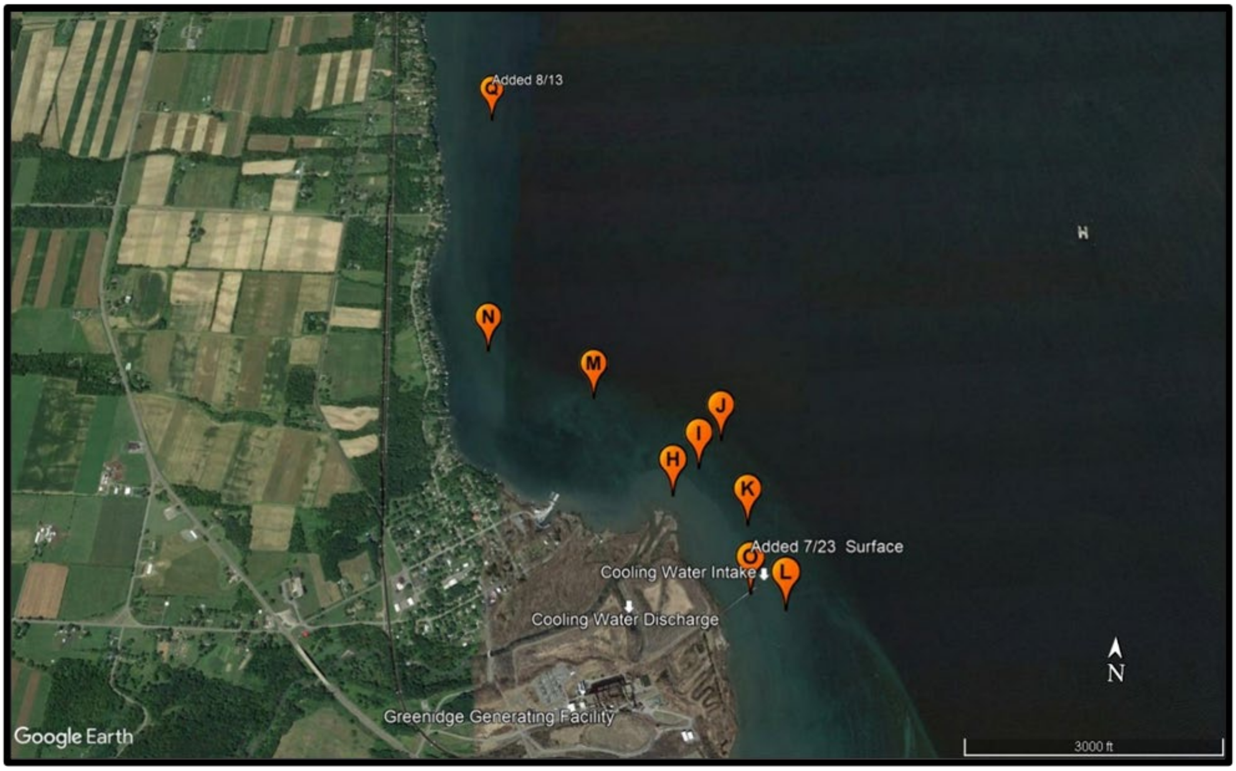


Figure 2.2: Locations for moored in-situ temperature monitors in Seneca Lake

2.2.2 Shipboard, Tri-axial Plume Mappings

Temperature sensors towed along transects ("tri-axial" surveys) provide much greater spatial resolution than moored sensor arrays, but over a limited time frame. Tri-axial plume mapping effort was conducted eight times during 4 events (in June, August, March, and April), including three (3) times during an approximate 1-month period of peak summer temperatures in 2021, between mid-July and mid-September. (The in-situ temperature sensors were placed in Seneca Lake prior to the first survey, and removed after the last survey).

During each triaxial survey, water temperatures were measured in two spatial modes: (1) horizontally, by towing fast-response temperature sensors approximately just below the surface and along 6 transects that radiate from the KLO mouth (Figure 2.3) out to a distance where near ambient temperature is recorded; and (2) in vertical casts ("full water-column profile" measurements) performed at each location along the surveyed transects where surface temperatures are observed to decline by 1°F while traveling away from KLO mouth. (Note that with the August triaxial event, a nearshore transect was added to both North and South of KLO.) These transects cover shallow areas approximately 50 yd from the shore.)

During four of the plume mapping events, velocity and flow were measured at the Keuka Lake Outlet mouth, and a bathymetric survey was conducted within the area of Seneca Lake that is classified B(T). Complete details regarding this transect sampling program are provided in the companion report (ASA 2022).

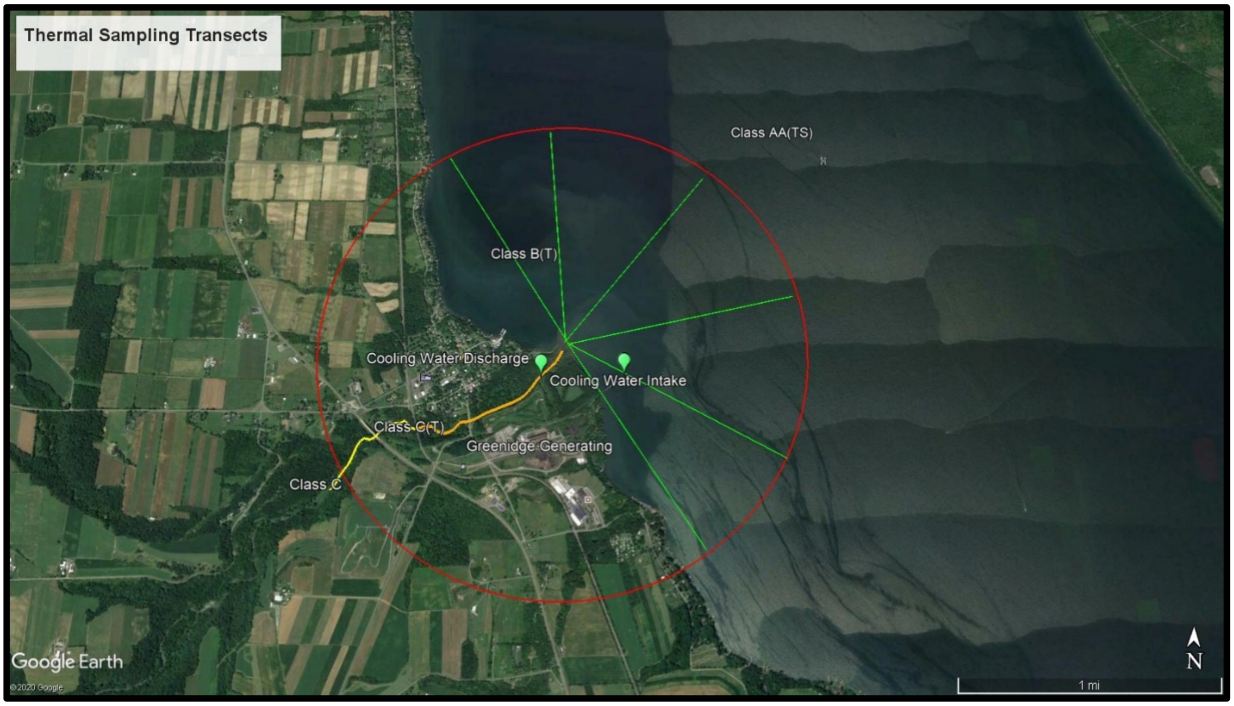


Figure 2.3: Transects used for the tri-axial plume mapping. Transects were continued to the point at which the temperature rise is less than 1 °F. Locations of transects are approximate.

2.3 Evaluation of Ambient Water Temperature

Ambient water temperatures are defined as the water temperatures that would exist without the addition of heat from the Facility and other heat sources. The actual water temperature observed near the Facility can be decomposed into the ambient water temperature plus the temperature increase due to the Facility's thermal discharges (i.e., "ΔT").

Ambient water temperatures are needed for several purposes. First, ambient temperatures are needed to address compliance with several water quality criteria. Since the receiving waters are classified as trout waters, 6 CRR-NY 704.2(b)(3) states:

(*i) The water temperature at the surface of a lake shall not be raised more than three Fahrenheit degrees over the temperature that existed before the addition of heat of artificial origin.*

Evaluation of this criterion requires comparisons of observed (and/or predicted) water temperatures to corresponding ambient temperatures. In this study, a mathematical model is developed to predict receiving-water temperatures over a range of natural conditions and Facility operations. The model is capable of simulating Lake water temperatures both with or without the GGF's thermal discharges, and ΔT.

To obtain approximate ambient water temperatures, the field monitoring program included transect ("triaxial") temperature surveys that extended to a point at which the temperature rise above "ambient" appeared to be less than 1°F.

The program also included representative, field-ambient monitoring locations. Initially HOBO station N, which is located nearshore in the far-field region and 3,300 ft north of the KLO discharge (Figure 2.2), was felt to be an appropriate location to measure ambient surface water temperature. However, in August 2021 an additional station (station Q) was added 6,500 ft from the KLO mouth (Figure 2.2). Direct water temperature measurements from this station provide a reasonable proxy for ambient surface water temperatures, since: (a) station N and Q are located outside the Facility's direct zone of influence under most conditions; and (b) the area around these stations is comparable to the shallow water environment adjacent to the KLO mouth.

3. HYDROTHERMAL MODEL ADAPTATION AND CALIBRATION

3.1 Model Selection

In the near-field region, plume mixing is caused by the momentum and buoyancy of the initial discharge, and by the interaction with the ambient current. In the far-field region, the plume is diffused primarily by Lake turbulence, and its transport is controlled primarily by large-scale circulation patterns driven by wind forcing, atmospheric heating/cooling, and tributary inflows.

In this case, the GGF discharges cooling water to a 900-foot-long canal that empties into the stream environment of KLO, then travels another 700 ft before entering Seneca Lake through one of three mouths (as currently configured). Typically, the near-field extends only a few tens of meters from these entry points, after which the heated water passively drifts with the ambient current in adjacent areas of Seneca Lake. Hence, most of the model domain is in the far-field region.

The RMA-10 model was selected as the far-field model because it can simulate the hydrodynamic/hydrothermal processes that regulate mixing and dispersion of the Facility's thermal plume. RMA-10 is a three-dimensional, time-varying, finite-element, hydrodynamic and constituent transport model. RMA-10 solves the full, nonlinear Navier-Stokes equations and incorporates the hydrostatic assumption. The model simulates temperature distributions based on the advection-diffusion equation, and the governing equations are coupled to density through an equation of state. This allows RMA-10 to simulate relevant features such as density-induced currents (i.e., circulation patterns resulting from vertical and horizontal gradients in temperature or density). Moreover, RMA-10 can accommodate local morphology of the Lake.

RMA-10, originally developed by Dr. Ian King of the University of California, Davis with the support of the U.S. Army Corps of Engineers' (COE's) Waterways Experiment Station, is well-suited to applications like Seneca Lake. Unlike finite-difference models, RMA's quadratic, finite-element formulation accurately simulates irregular shoreline configurations and channel bathymetry using a moderately spaced mesh, and any section of the model's mesh may be modified locally without changing other areas of the mesh. Also, the model's implicit solution scheme allows for use of long time steps (e.g., 15-30 minutes). Model documentation and application for the COE can be found in King et al. (1993) and King and Rachiele (1989b) and (King 2008).

Najarian Associates has previously used RMA-10 to simulate temperature increases above ambient due to a power plant discharge for numerous facilities, including several in New York State (e.g. Far Rockaway Generating Station, E. F. Barrett Generating Station, Northport Generating Station). For these applications model simulations are conducted both with and without the power plant's thermal discharge.

Since RMA-10 has a very flexible finite-element formulation, it may be applied in this case without coupling to a separate near-field model. The bathymetry of the confluence between Keuka Outlet and Seneca Lake was adapted into RMA-10's finite-element framework using very small grid elements to simulate small-scale velocity variations, and associated water temperature variability. Available field data provides boundary conditions for water temperature and flow at the Keuka Lake Outlet mouth.

3.2 Far-Field Model Adaptation and Calibration

RMA-10 was adapted to the Facility's receiving-water environment, and used to simulate the Facility's thermal discharge plume under operating and environmental conditions encountered in the 2021-2022 field surveys. RMA-10 required model input in various forms, including: (1) sounding data and shoreline boundary coordinates; (2) time-series input data (boundary temperatures, tributary inflows/temperatures and meteorological variables); and (3) initial condition water surface elevations; and (4) semi-empirical "tuning" parameters such as bottom friction and turbulent exchange coefficients. Specifications for each of these data are provided below.

3.3 Model Discretization

RMA-10 imposes a computational mesh over the model domain, in this case the entirety of Seneca Lake. This mesh contains discrete points (nodes) where initial condition and depth data are input to the model. The model then computes solutions to the governing hydrothermal equations at each of these nodes.

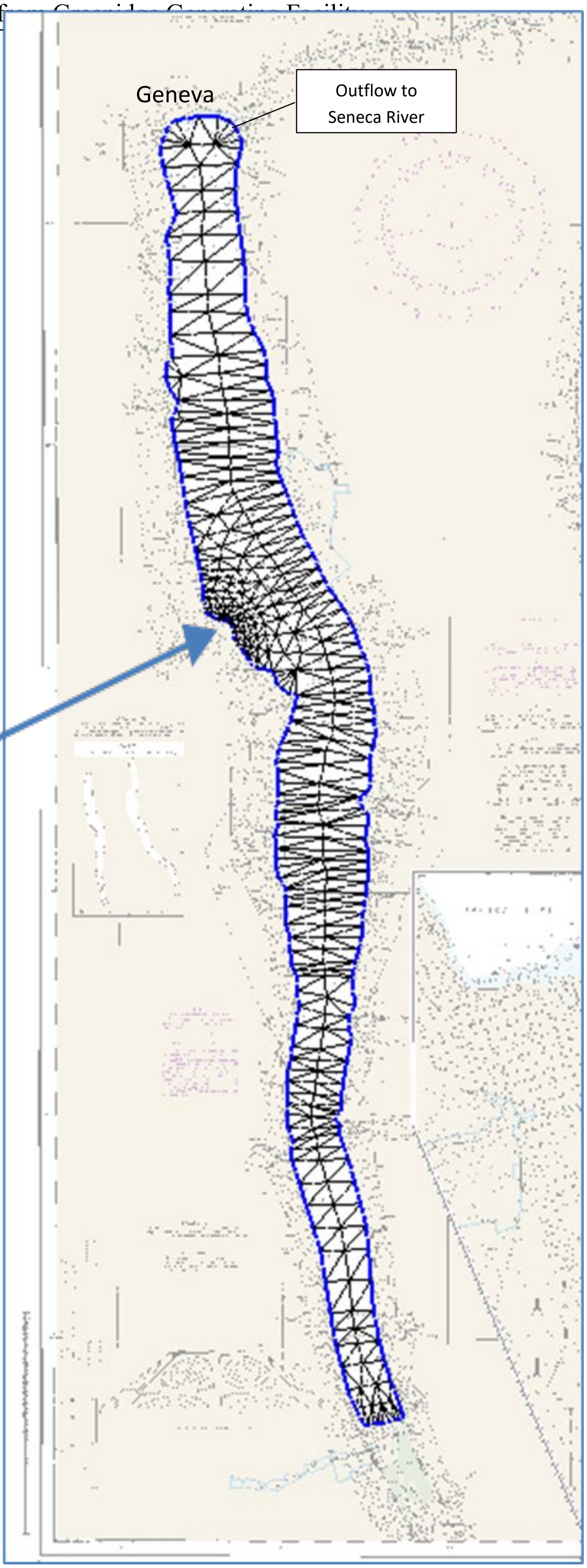
The mesh incorporated large-scale bathymetric features (deep areas, shoal areas, bed slopes, etc.) and provided finer spacing in areas of large temperature gradients near the KLO entry, thus enhancing model resolution near established field-monitoring sites.

The computational mesh developed for this study is illustrated in Figure 3-1. The finest mesh spacing is provided near the mouth of the KLO, with minimal midpoint/end-point nodal separations of approximately 5 ft. To resolve vertical variability, the computational mesh (i.e., grid) contains 3 vertical elements. As each layer contains upper nodes, lower nodes and mid-side nodes, these 3 layers correspond to 5 vertical computational points in RMA-10's quadratic, finite-element interpolation scheme.

At each nodal point, water depths are entered into the model. These depths were gleaned from available NOAA navigation charts, and supplemented with a new hydrographic survey conducted in this study. Figure 3-1 also displays the resulting model bathymetry.

3.4 Boundary Conditions

RMA-10 requires an input of representative "forcing functions" (e.g., time series of water inflows/outflows and water temperatures) at the model's boundaries, including at the mouths of Keuka Lake Outlet and at the outflow into Seneca River near Geneva at the North end of the Lake (Figure 3.1). Available data, including major tributary inflow and outflow data were reviewed as described in the flowing sections. Three boundary conditions were established: The KLO discharge into Seneca Lake through three mouths; the overflow at the North end of the Lake near Geneva; and the GGF cooling-water intake.



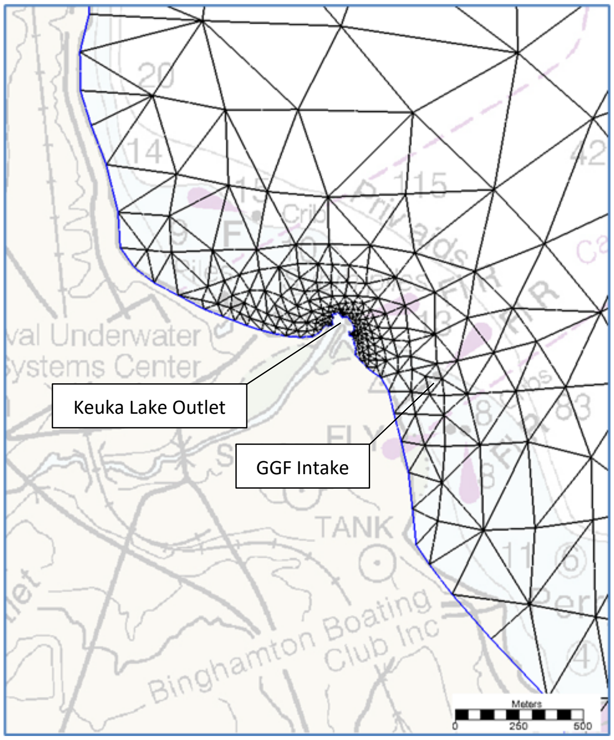


Figure 3.1 Model computations grid and close-up view

3.5 Inflow Data

The USGS maintains a gaging station (USGS 04232482) on the KLO at the Milo Street Bridge crossing in Dresden, Yates County, New York, approximately 1600 ft upstream from the Facility's thermal discharge. Here, the KLO drains 207 square miles. Most of that area drains first into Keuka Lake, and then flows into KLO through control gates at Penn Yan. The gates are regulated to maintain desired water levels in Keuka Lake so KLO flows do not closely follow local precipitation events of typical intensity.

Observed KLO mean daily stream flows for the Summer of year 2021 are displayed in Figure 3.2. Average monthly discharges for that period were 93 cfs.in June,' 207 cfs in July, 407.2 cfs in August, and 80 cfs in September. In August an extreme rain event caused a peak flow approaching 4000 cfs, followed by a prolonged period of flow above 500 cfs as Keuka Lake water level was reduced to the desired range.

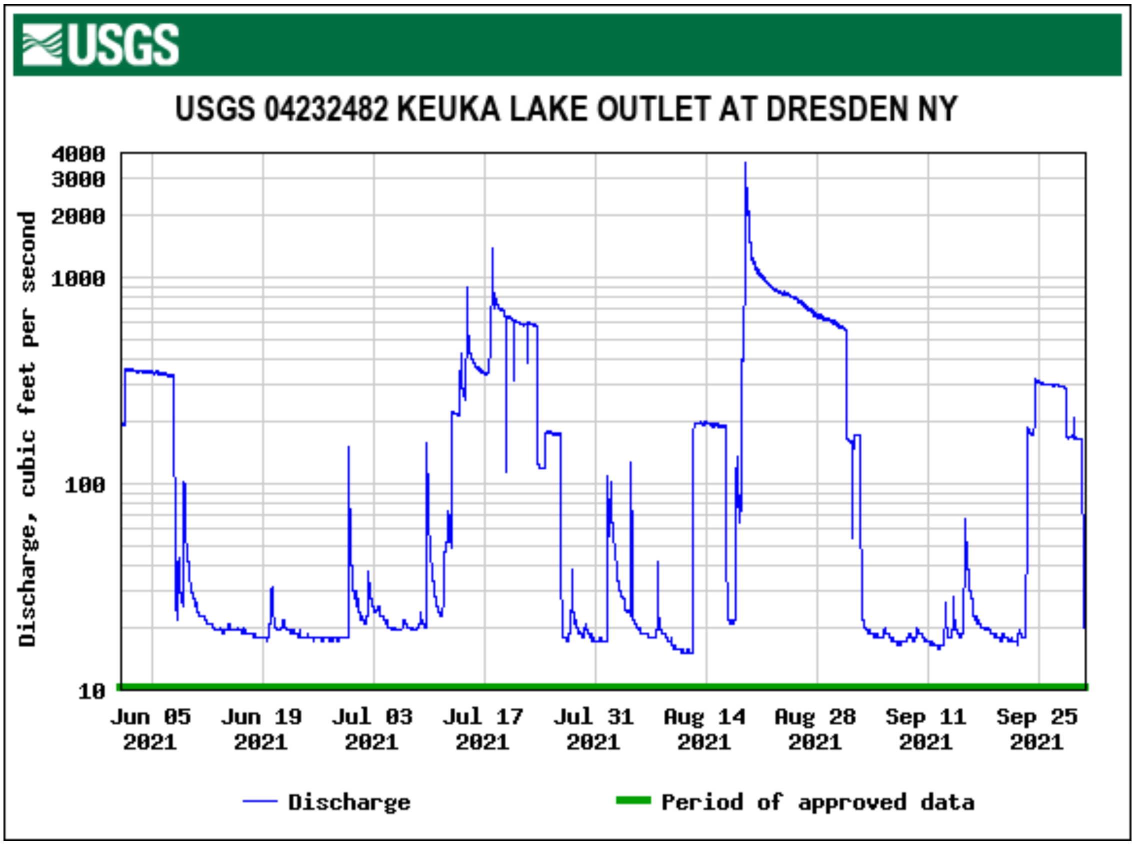


Figure 3.2: Keuka Lake Outlet Discharge at Dresden (Source: USGS)

Likewise, the USGS maintains a gage at the USGS 04232200 station at Catherine Creek, Montour Falls, NY, approximately 5 miles upstream from the confluence with the southern end of Seneca Lake. Here, the Creek drains approximately 39.4 square miles. Observed mean daily stream flows for the Summer of 2021 are displayed in Figure 3.3. . Average monthly discharges for that period were 24 cfs.in June' 127 cfs in July, 86 cfs in August, and 30 cfs in September.

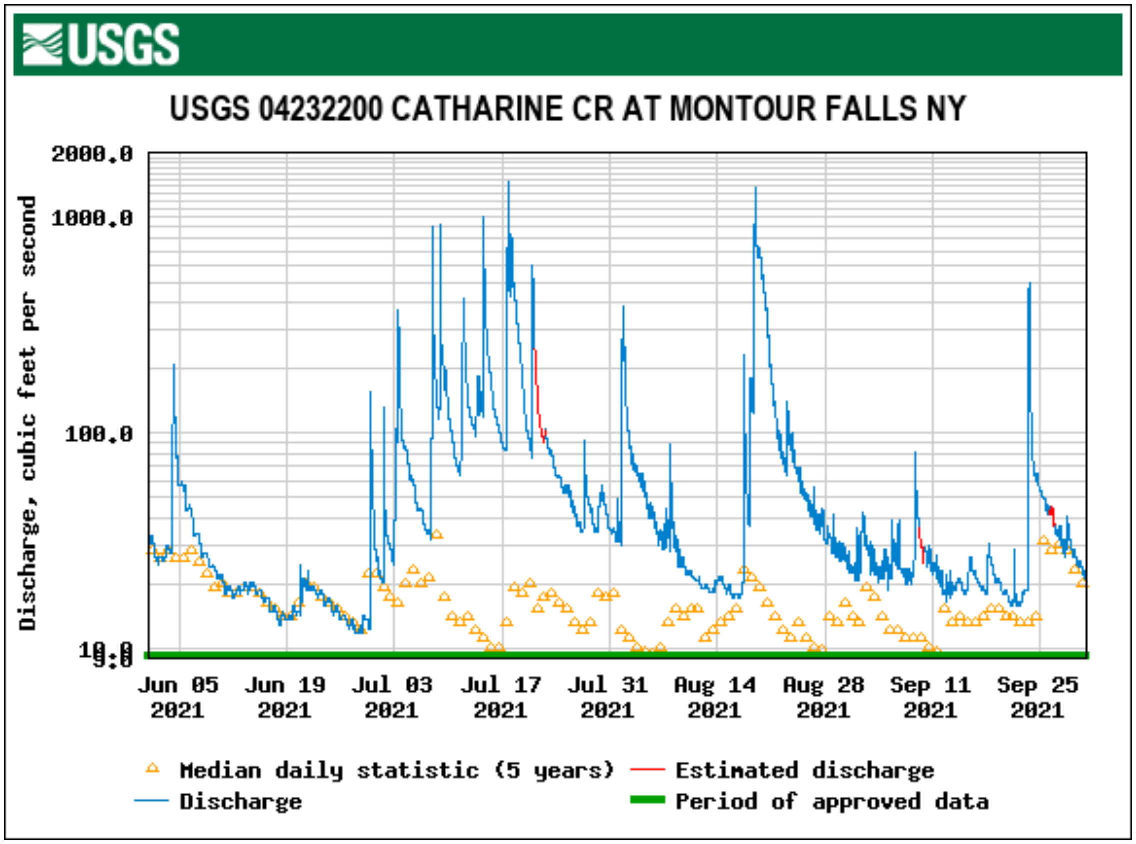


Figure 3.3: Catherine Creek Discharge at Dresden (Source: USGS)

The entire Seneca Lake watershed) covers approximately 457 square miles. (Hobart and William Smith Colleges, 2021). The gaged portion of the KLO tributary drains approximately 45% of this area; the gaged Catherine Creek drains approximately 9%.

3.6 Flow Distribution at the Mouth of Keuka Lake Outlet into Seneca Lake

The RMA-10 model requires specification of inflows, and inflow temperatures, into the receiving waters. In this case, the KLO enters Seneca Lake (Figure 2.2) generally through three channel mouths (Upper or North, Middle or Center, and Lower or South). Examination of historical aerial photographs indicates that the three channel mouths are unstable -- their shapes and locations have varied over the years, especially after major storm events. Thus, the representative KLO flows were measured and incorporated into the RMA-10 Model.

The ASA field sampling program surveyed flows through three KLO channel mouths in June and August of 2021, and in March and April of 2022. The sampled flow distributions were fairly steady during those surveys – with the upper (north) channel mouth conveying approximately 60% of the total flow, the center channel mouth conveying approximately 10%, and the lower (south) channel mouth conveying approximately 30%. These representative flow distributions were specified as inflows into the RMA-10 model for Seneca Lake.

Representative inflow temperatures specified at the channel mouths were estimated using KLO Flows, GGF discharge data and available HOBO station data. In some cases, these inflow temperatures were calculated based on a simple steady-state heat balance of the respective observed GGF effluent discharge and temperature and KLO flows and temperature.

4. Model Calibration

4.1 Hydrothermal Model Calibration Methods

After the RMA model was adapted to the study area, model calibration was performed. Model calibration consists of a series of model runs in which initial estimates for the model's semi-empirical parameters are adjusted ('tuned") to reduce discrepancies between observed and simulated data (e.g., elevations, currents, water temperatures, etc.) water temperature data. In this case, the model required several adjustments to reproduce basic trends in the temperature data recorded at most HOBO stations (Figure 4.1). The resulting set of input parameters that produce a reasonable first "fit" was then selected as the calibration parameters (Table 4.1).

Table 4.1: Selected RMA-10 Model Calibration Coefficients*

Bottom Manning's n	**Shoreline Manning's n**	**E_{xx}, E_{xy}, E_{yx}, E_{yy} (kg-sec/m^2)**	**E_{xz}, E_{yz} (kg-sec/m^2)**	**K_{xx}, K_{yy} (m^2/sec)**	**K_{zz} (m/sec)**	**Extinction Coefficient (1/ft)**
0.03	0.035	-0.5	0.01	-0.5	0.000001	1.0

- Negative sign means coefficient scaled by grid size in RMA-10's mathematical formulation

4.2 Hydrothermal Model Calibration Results

The blue curves plotted in Figures 4.2 through 4.8 are near surface, mid-depth and near bottom water temperatures observed at the in-situ mooring sites (H, I, J, K, L, M, N) during June, 2021. The red curves in these figures represent corresponding model calibration simulations at these locations.

In general, the greatest discrepancies between the model calibration results and the moored temperature sensor data occurred at Hobo Station H during June 18-22, 2021 (upper panel of Figure 4.2). Otherwise, the RMA model generally tracked the observed mid-depth and near-bottom water temperatures at most sites.

At Station H, the model simulated higher (peaking) surface water temperatures during the interval from 6/18/2021 to 6/21/2021. However, an examination of the controlling variables at this Station indicated that the model was responding as anticipated to peaking effluent and air temperatures during this interval (Figure 4.3). The muted, observed response (blue curve) to these peaks in forcing variables during this interval appears to be inconsistent with these peaks. It appears to reflect KLO temperatures rather than a balanced response to the heated effluent and KLO flow. Thus, no further adjustment was made to improve model agreement for Station H.

It should be noted that some of the sensor mounting rods may have been moved or interfered with following deployment as a result of high flow events and/or human activities. Also note that the model is simulating water temperatures at the surface, while the temperature sensor in this particular survey recorded water temperatures 4 feet below the water surface.

Figure 4.1: HOBO station locations (recording water temperature time series) during June 16, 2021 – June 28, 2021 survey

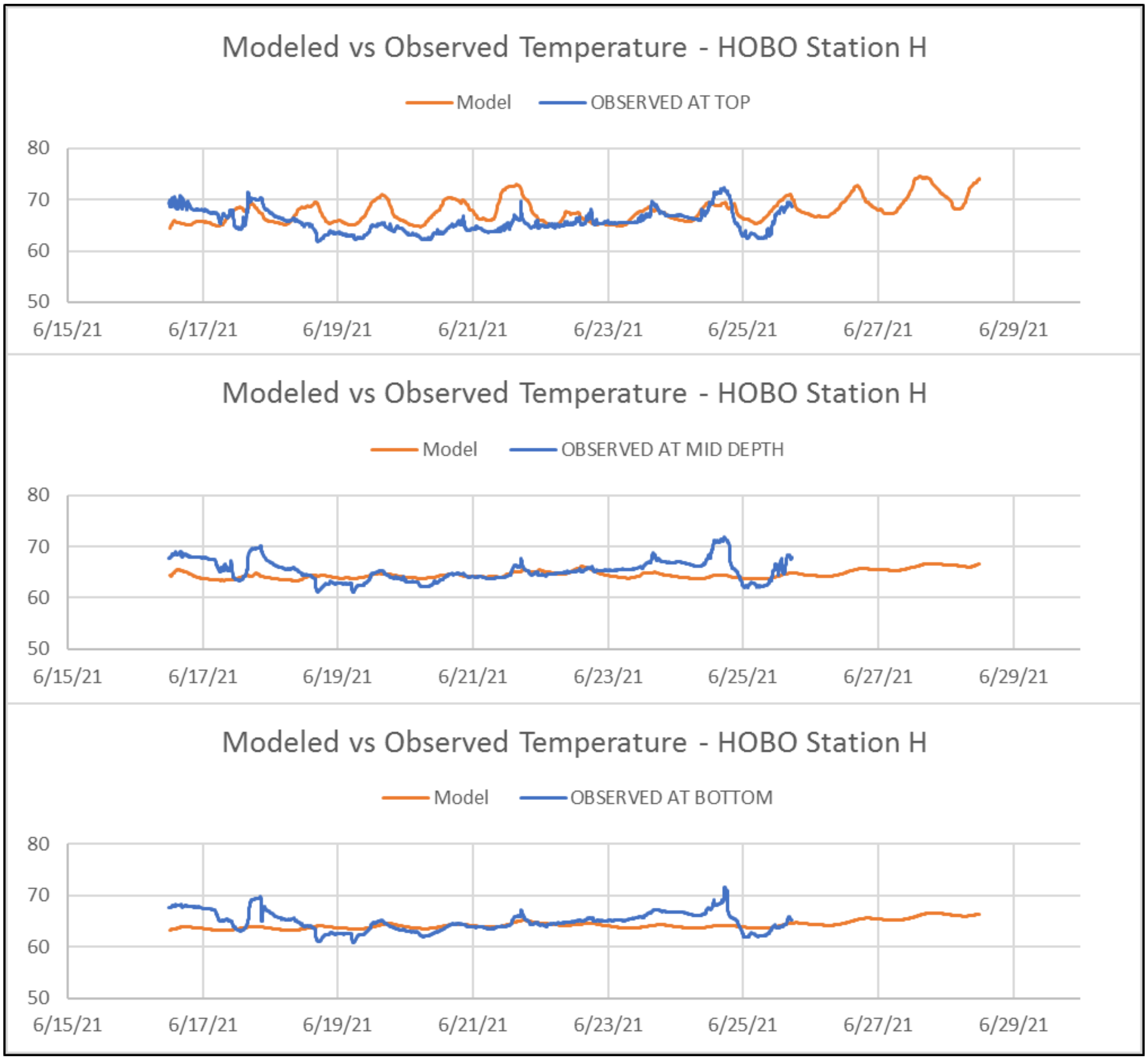


Figure 4.2: Model calibration results at HOBO Station H

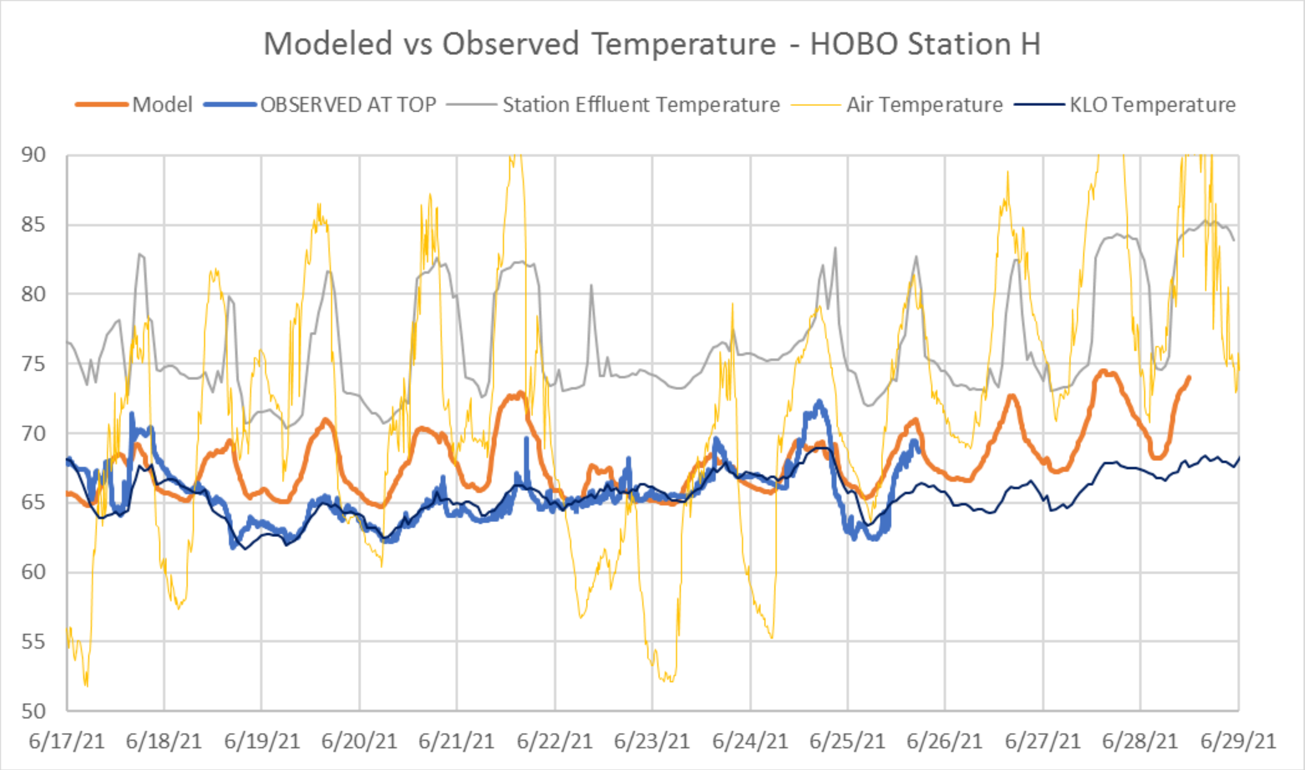


Figure 4.3: Model calibration – modeled vs. observed temperature at Station H with controlling temperature variables.

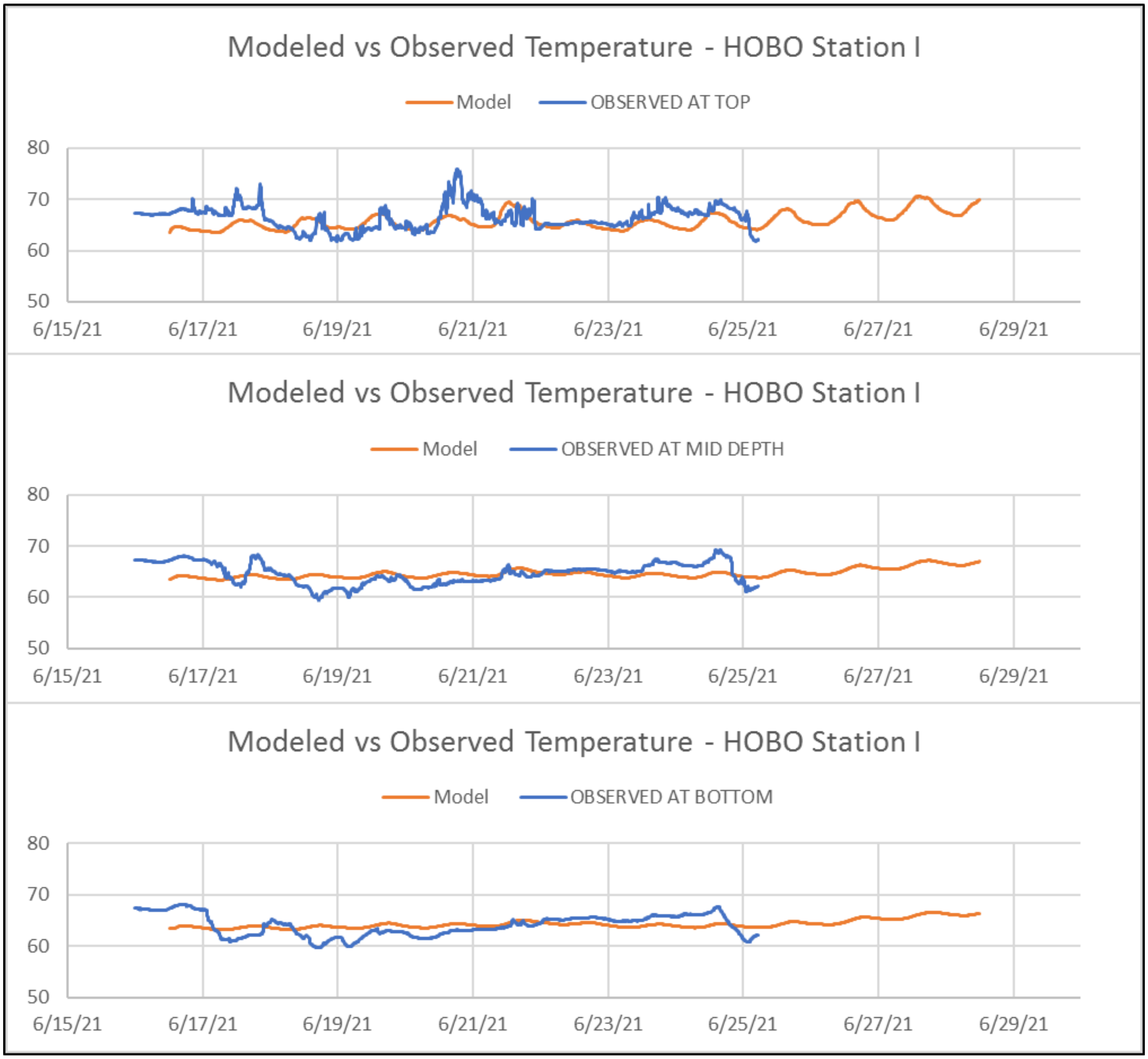


Figure 4.4: Model calibration results at HOBO Station I

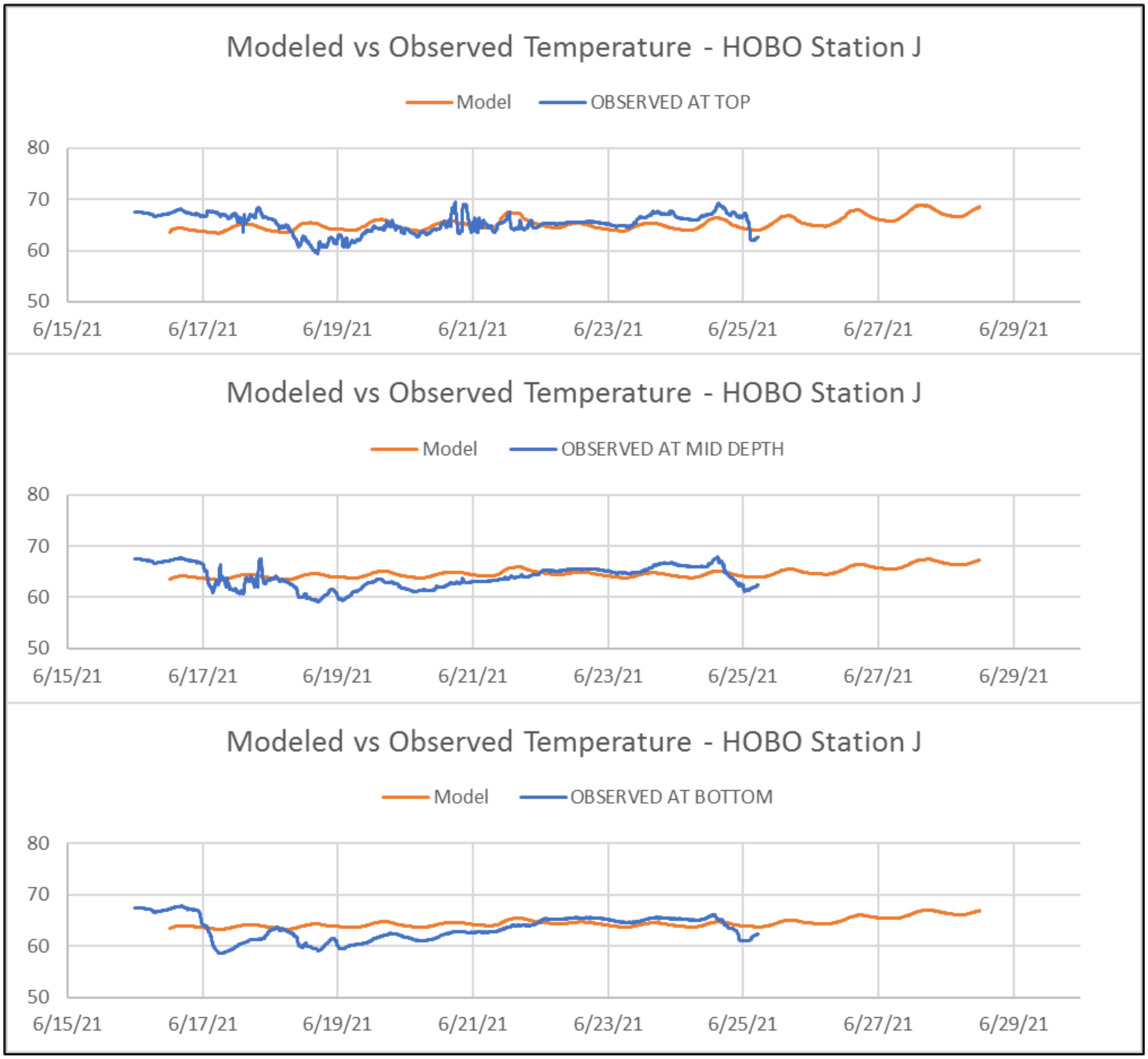


Figure 4.5: Model calibration results at HOBO Station J

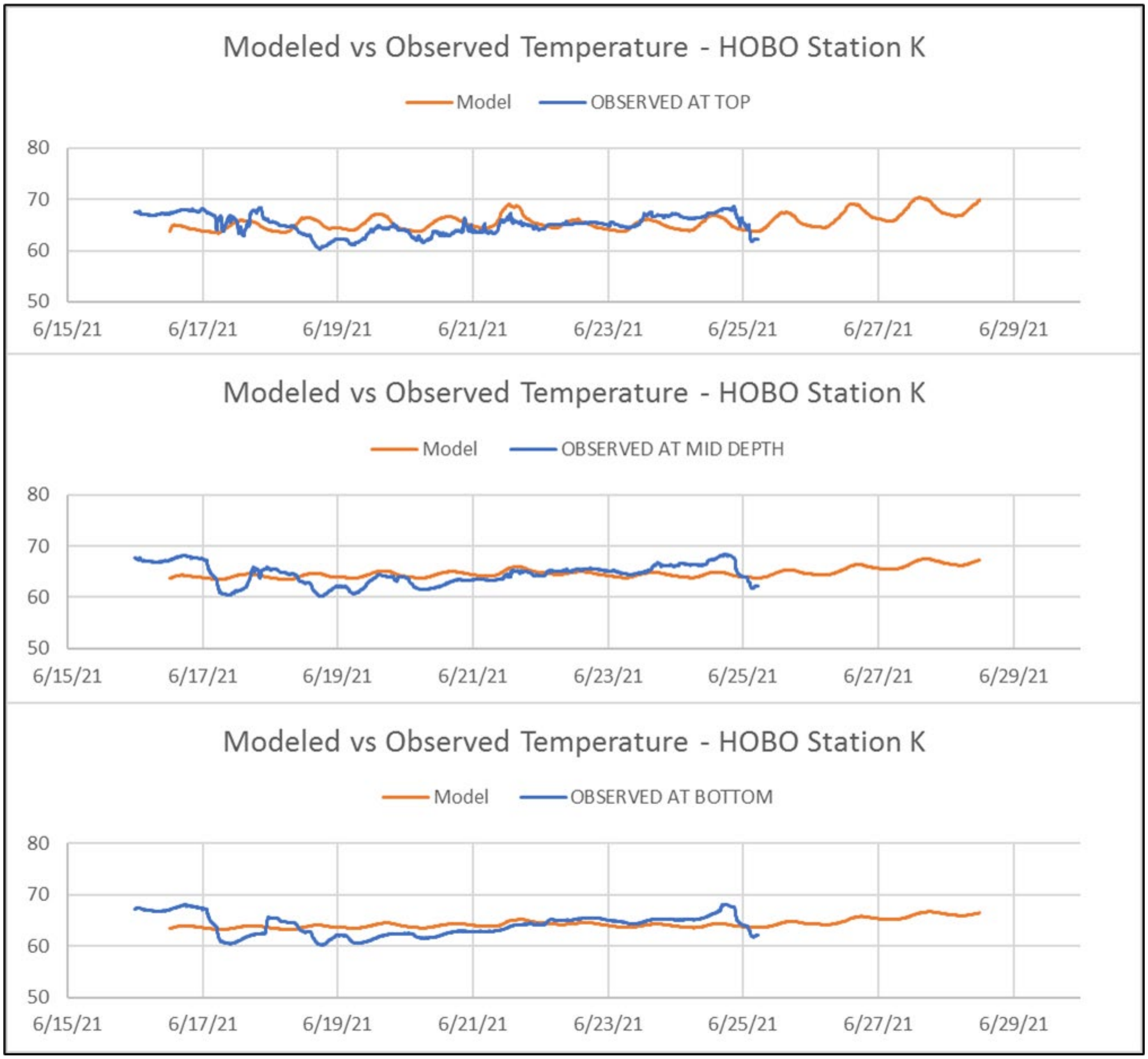


Figure 4.6: Model calibration results at HOBO Station K

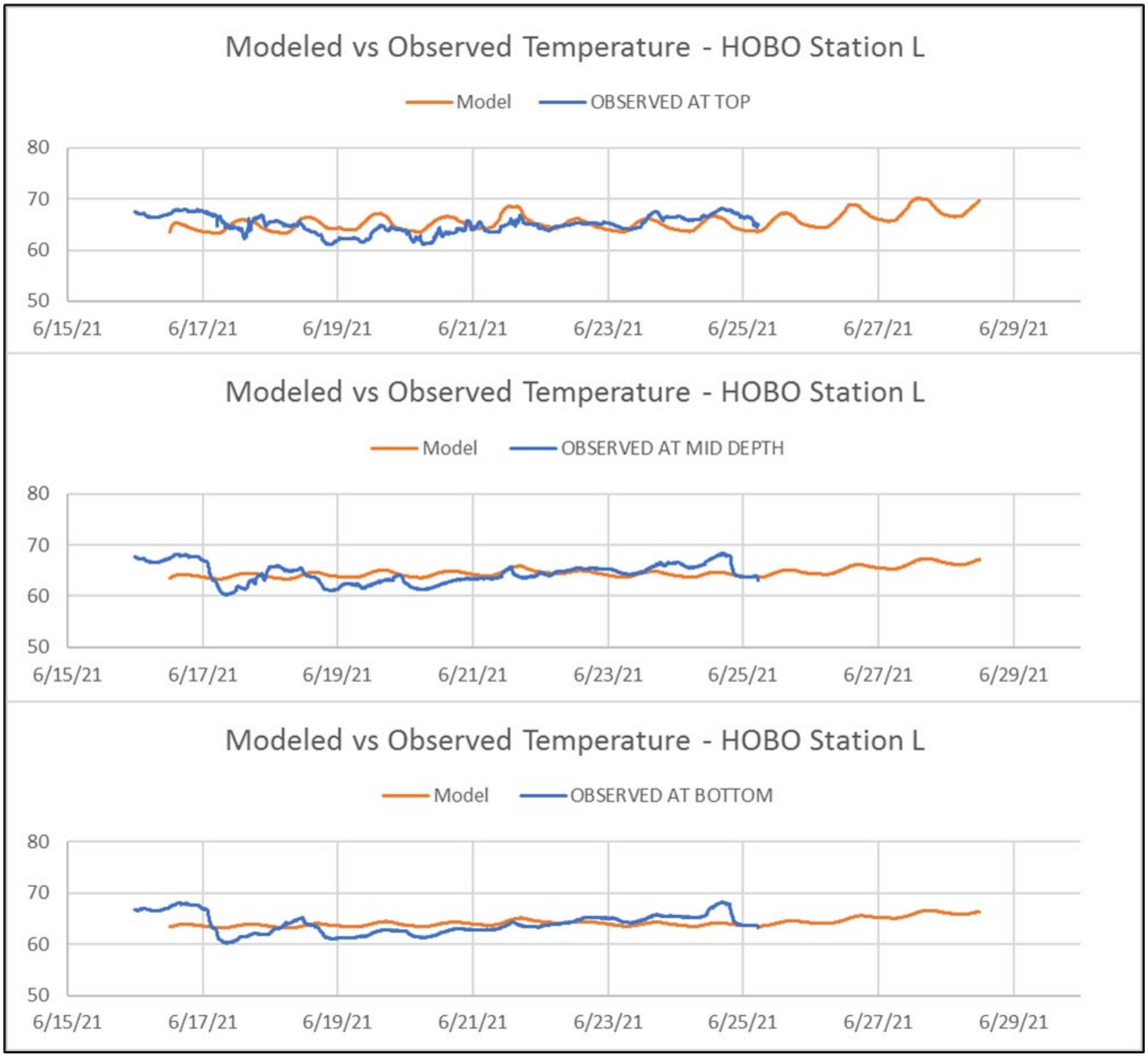


Figure 4.7: Model calibration results at HOBO Station L

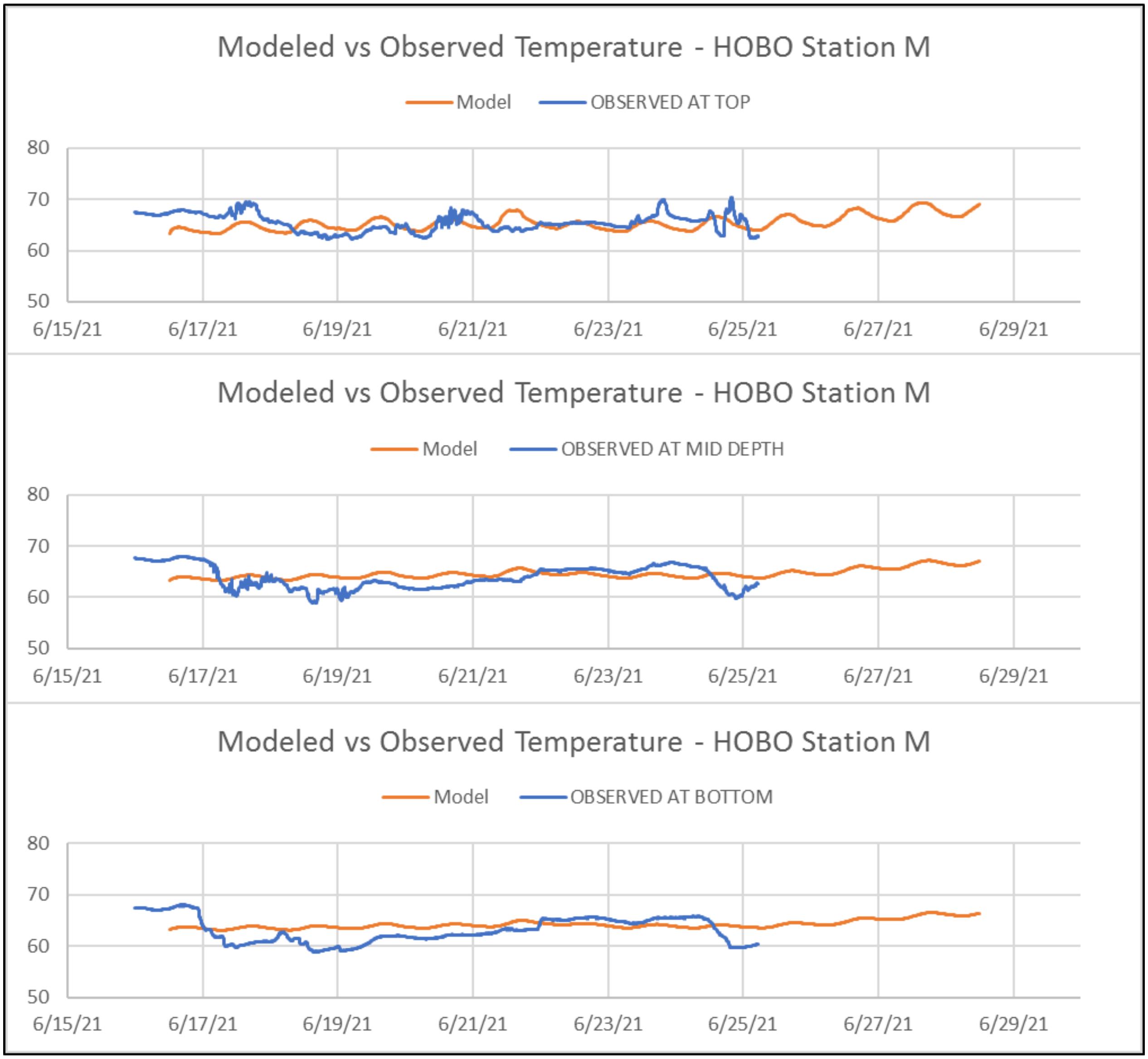


Figure 4.8: Model calibration results at HOBO Station M

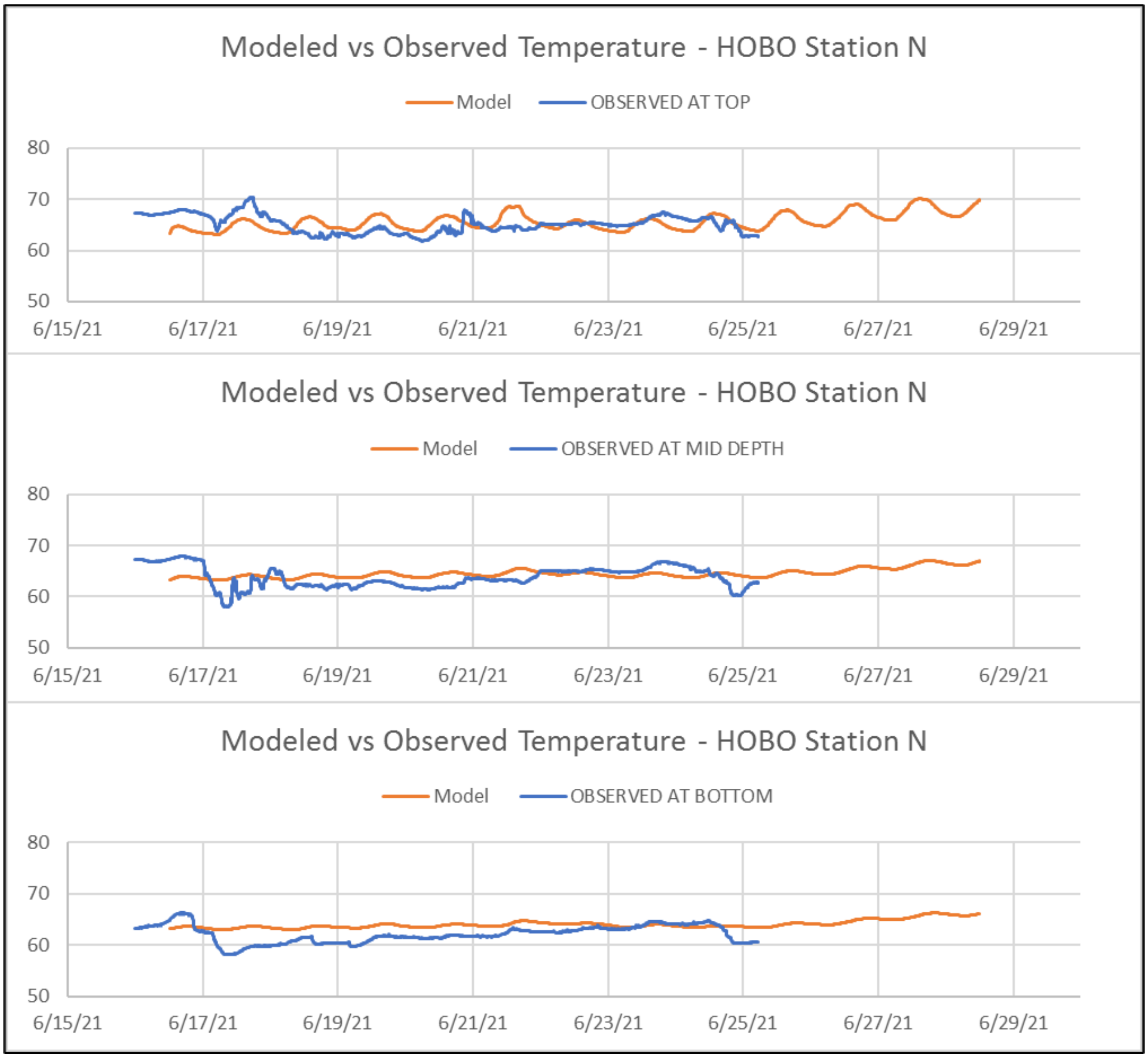


Figure 4.9: Model calibration results at HOBO Station N

The temperature mooring data described above provided a test of the model's ability to resolve temperature variability over a range of time scales (hourly, daily, weekly, etc.) at seven different mooring sites and at three depths. The semi-synoptic temperature data collected in the tri-axial surveys provide a means to assess modeled spatial variability.

To this end, near-surface (~ 2.5 ft deep) temperature data collected along radial transects over approximately a 3-hour interval (on June 25, 2021 and June 26, 2021) were plotted and contoured to produce representative average observed surface temperature distribution maps for these intervals (Figures 4.10 and 4.12). For comparison, model outputs of instantaneous Lake surface water temperatures were plotted at specific times on these days (Figures 4.11 and 4.13). While these results cannot be compared directly due to differences in timing (average vs. instantaneous) and depth (surface vs. near-surface), they both show general patterns of elevated nearshore temperatures and onshore-offshore gradients. The model also shows the simulated instantaneous current velocities distribution.

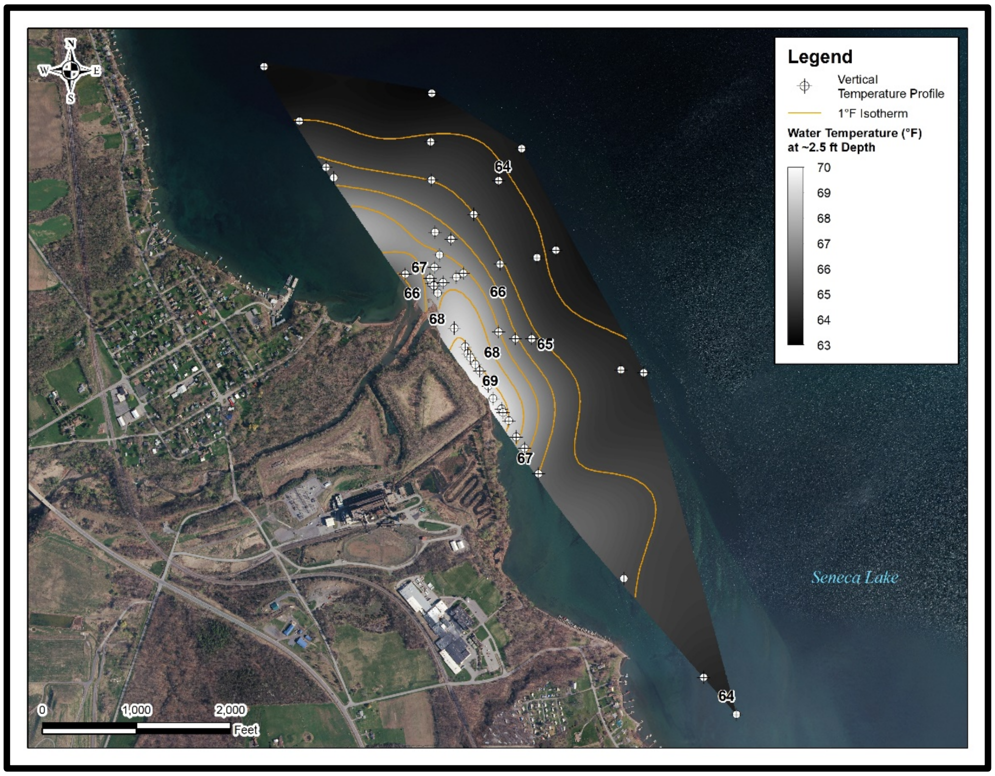


Figure 4.10: Near-surface (~ 2.5 f t depth) temperature mapping conducted from 13:09 to 16:07 on 6/25/21.

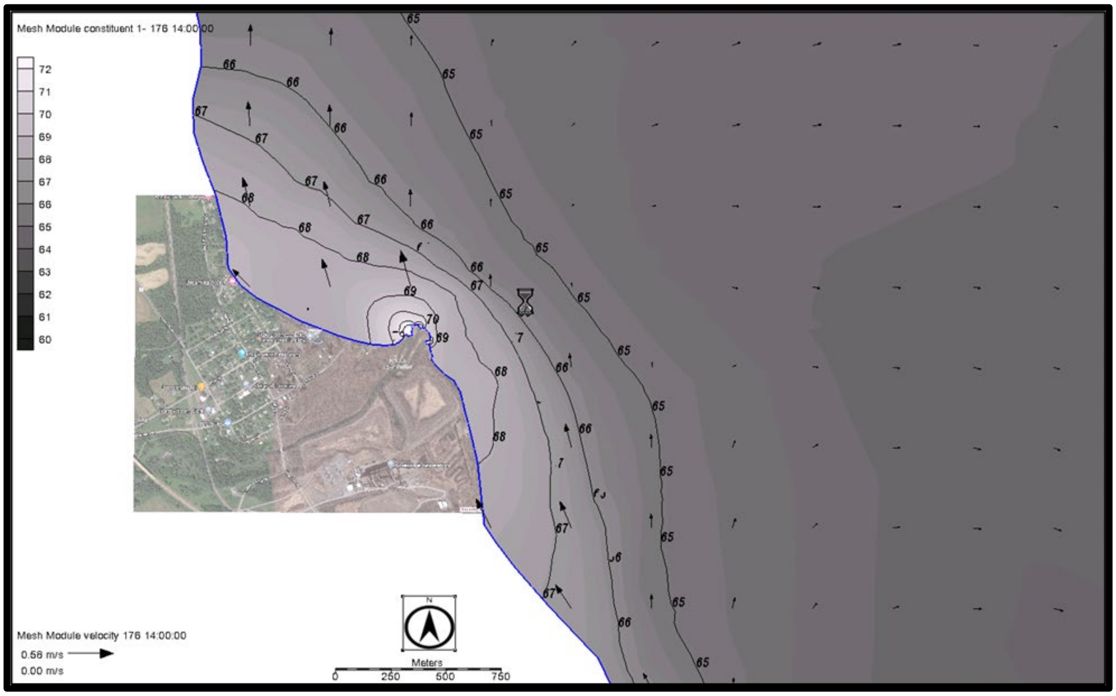


Figure 4.11: Model calibration simulation of surface water temperatures on 6/25/21 at 14:00 hours. .

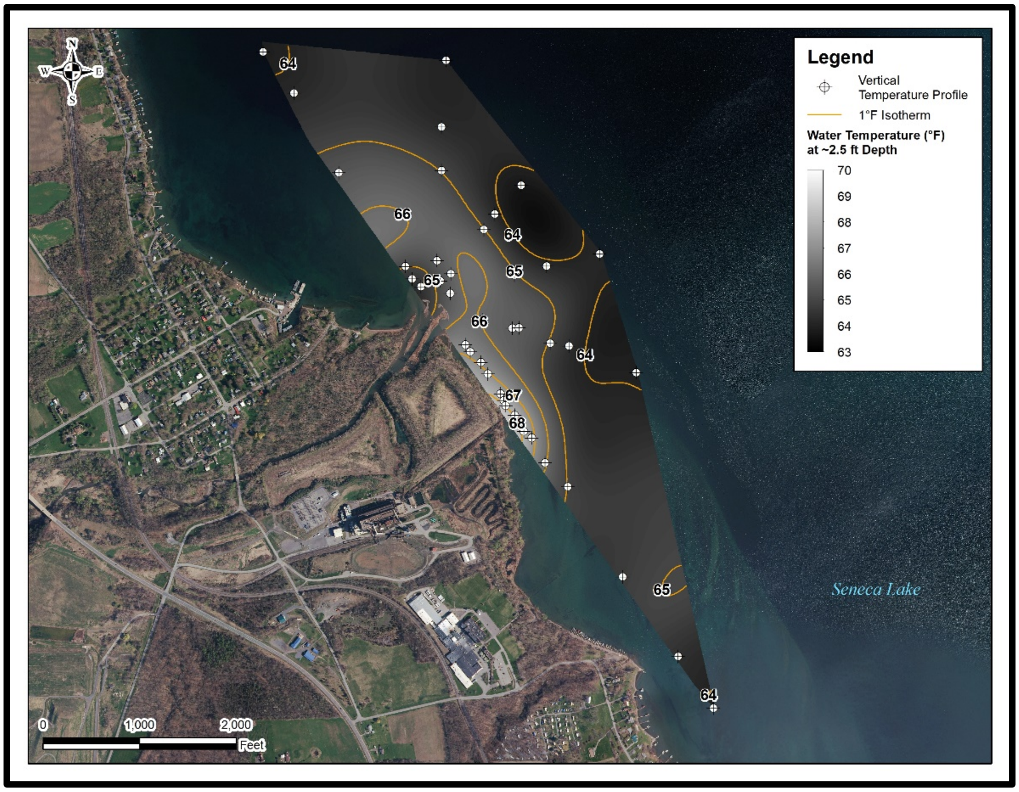


Figure 4. 12: Near-surface (~ 2.5 m depth) temperature mapping conducted from 13:09 to 16:07 on 6/26/21.

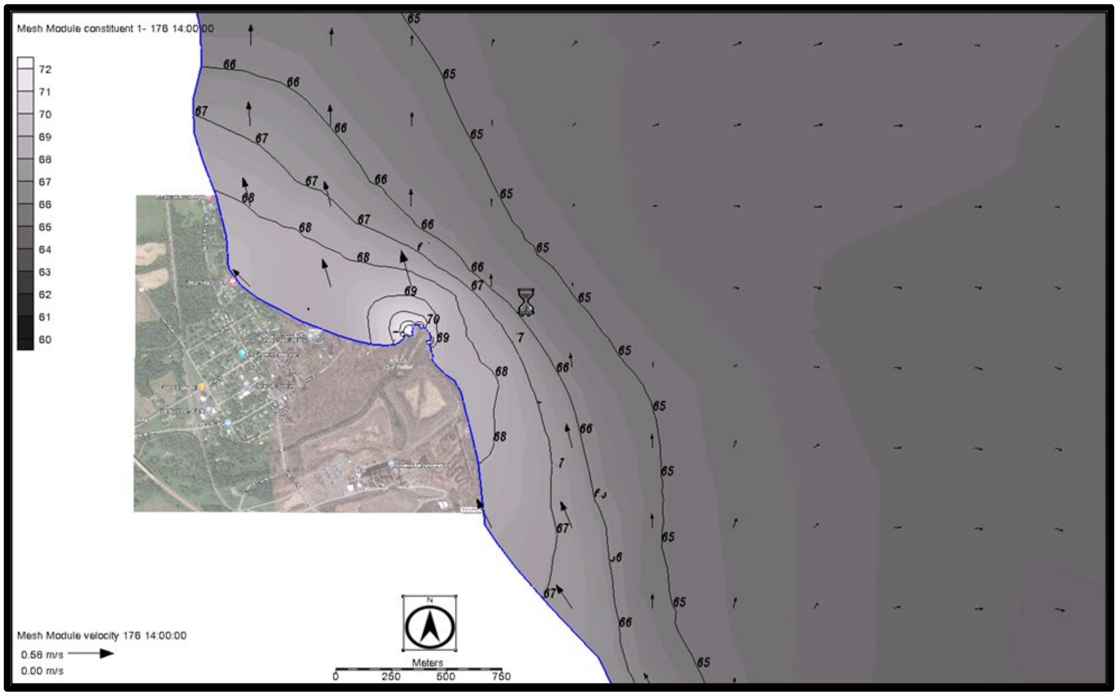


Figure 4. 13: Model calibration simulation of surface water temperatures on 6/26/21 at 13:00 hours.

5. Model Verification

Model verification is a process whereby a calibrated model is checked with a second, independent set of data. The objective is to determine how closely the adapted/calibrated model can simulate a second data set with no further adjustments to the selected model calibration parameters (Table 4-1). Accordingly, the adapted and calibrated RMA-10 model was applied a second time to simulate conditions prevailing during the 2021 Field Sampling Program.

5.1 Hydrothermal Model Verification Results

Figures 5-1 through 5-10 display observed vs. simulated water temperatures monitored at sites H through N in the 2021-2022 field program. Note that no temporal or spatial averaging was performed on the model or data in this comparison. Thus, these comparisons provide a most rigorous check on model performance. As illustrated, the model generally tracked the observed water temperature variations over time at these fixed locations.

To quantify uncertainties in this model validation, a model skill assessment was performed for mooring sites. Metrics used included the absolute error (defined as the absolute value of difference between simulated and observed value), and the percent error (defined as the average absolute error divided by the average observed temperature).

Overall, discrepancies between observed and simulated water temperatures were generally small. The average difference between observed and expected temperature were usually small. (~ 1.5 ºF) relative to prevailing summer temperatures).

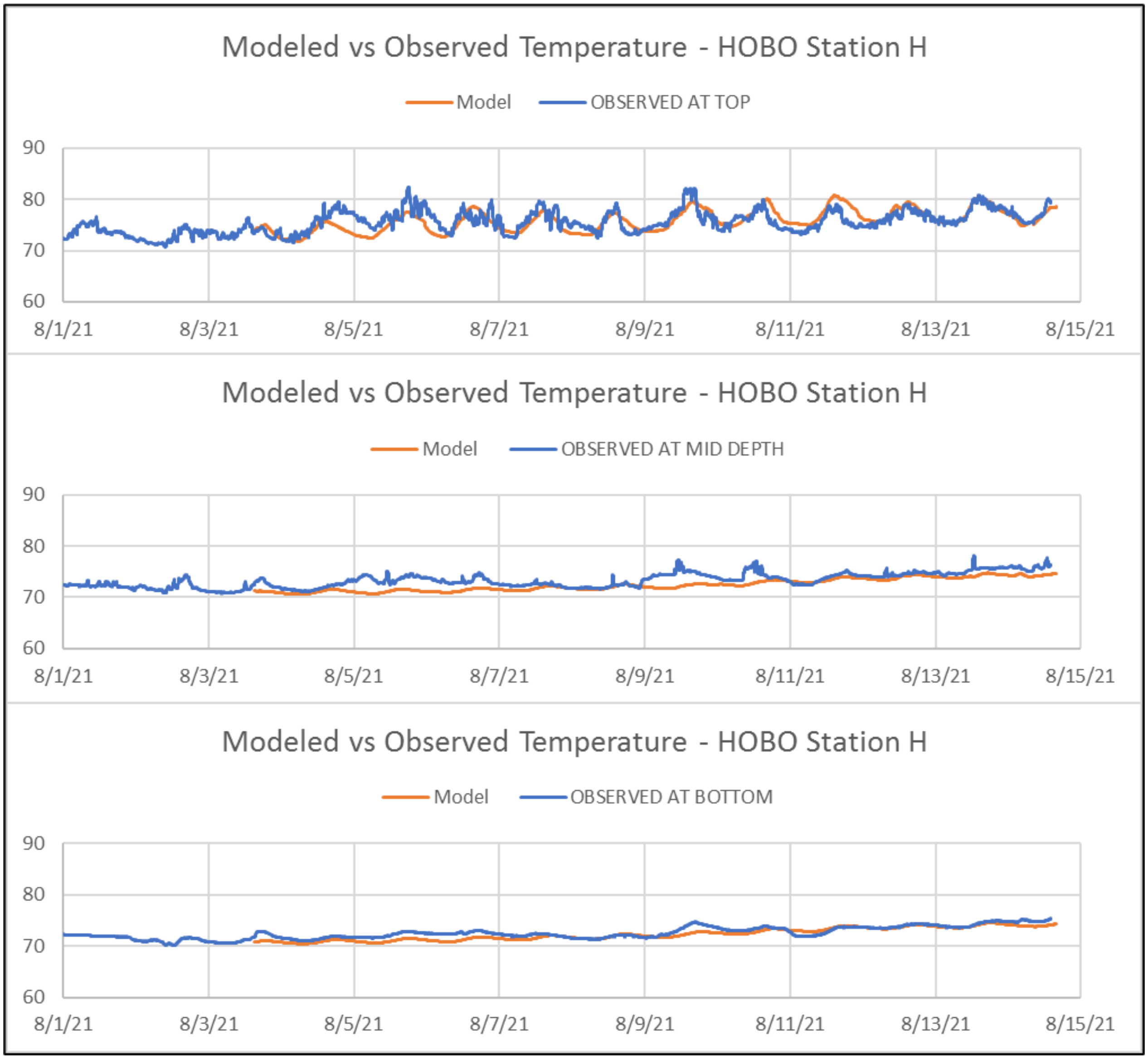


Figure 5.1: Model verification results at HOBO Station H

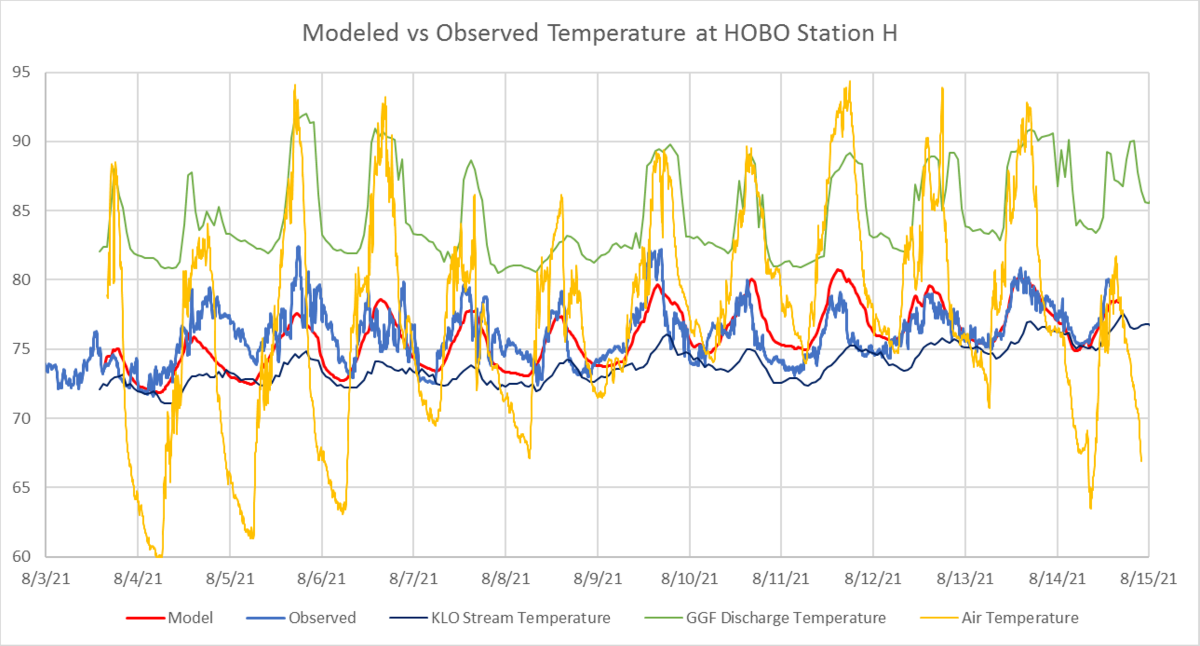


Figure 5.2: Model verification – modeled vs. observed temperature at Station H with controlling temperature variables.

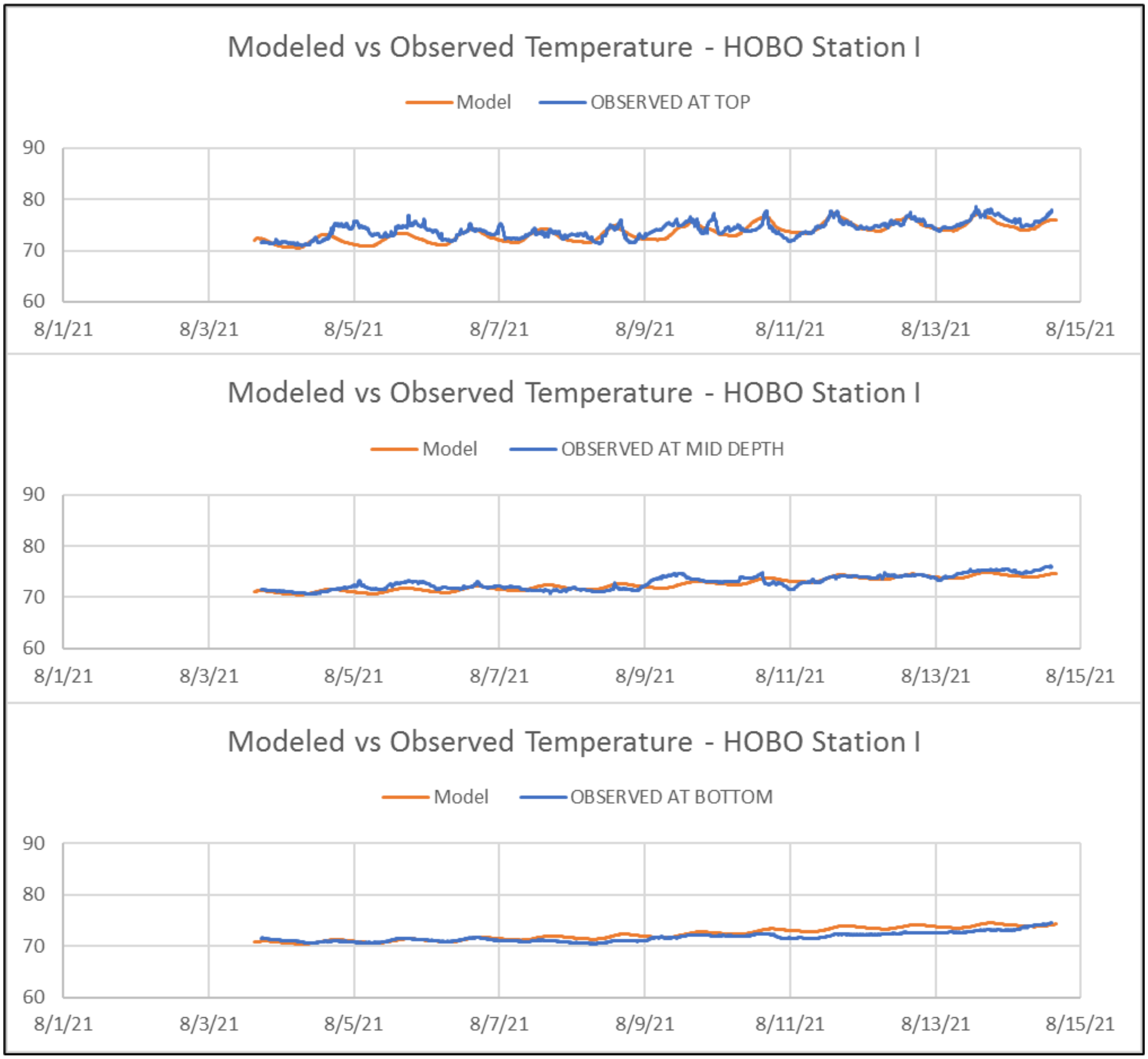


Figure 5.3: Model verification results at HOBO Station I

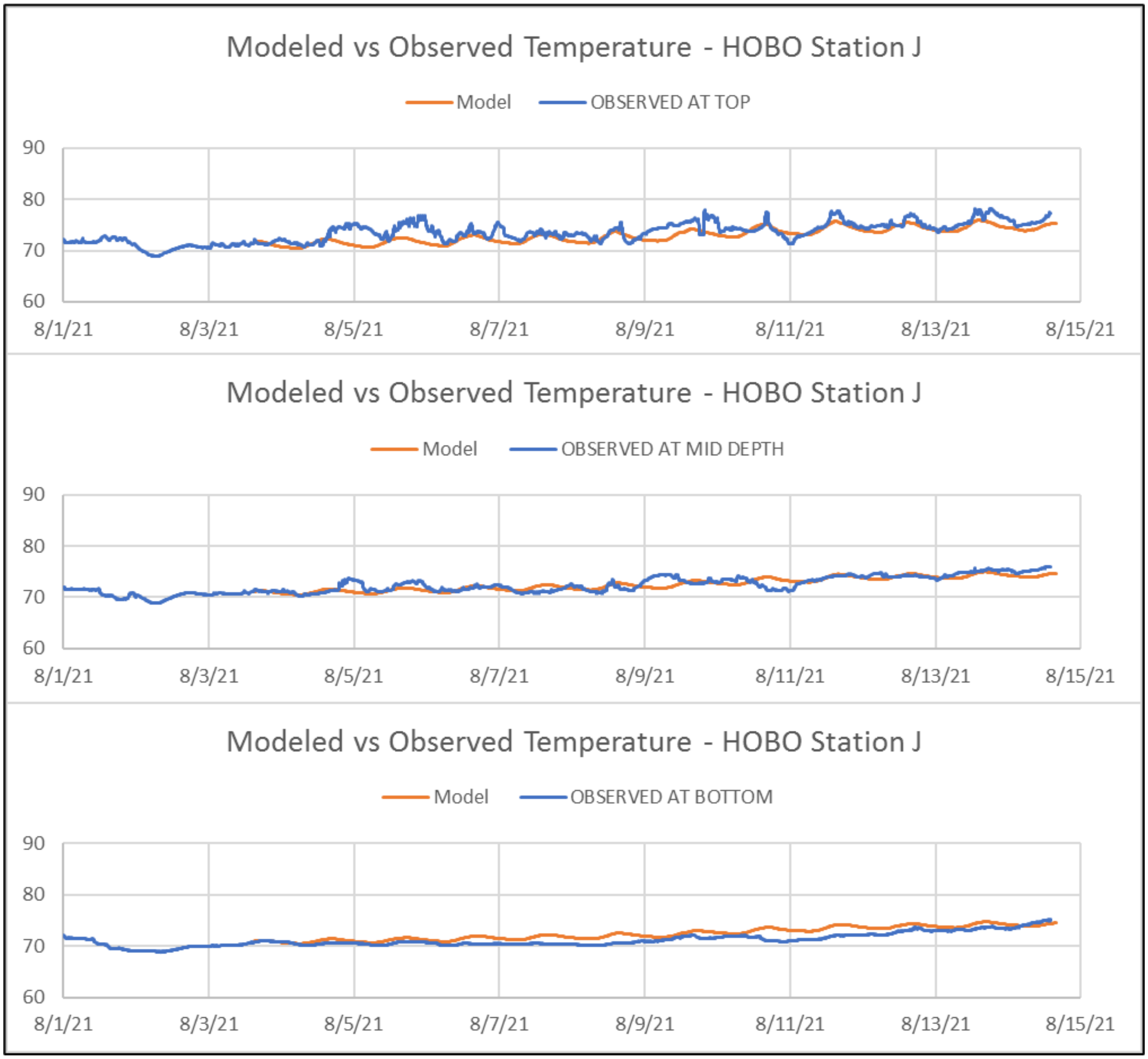


Figure 5.4: Model verification results at HOBO Station J

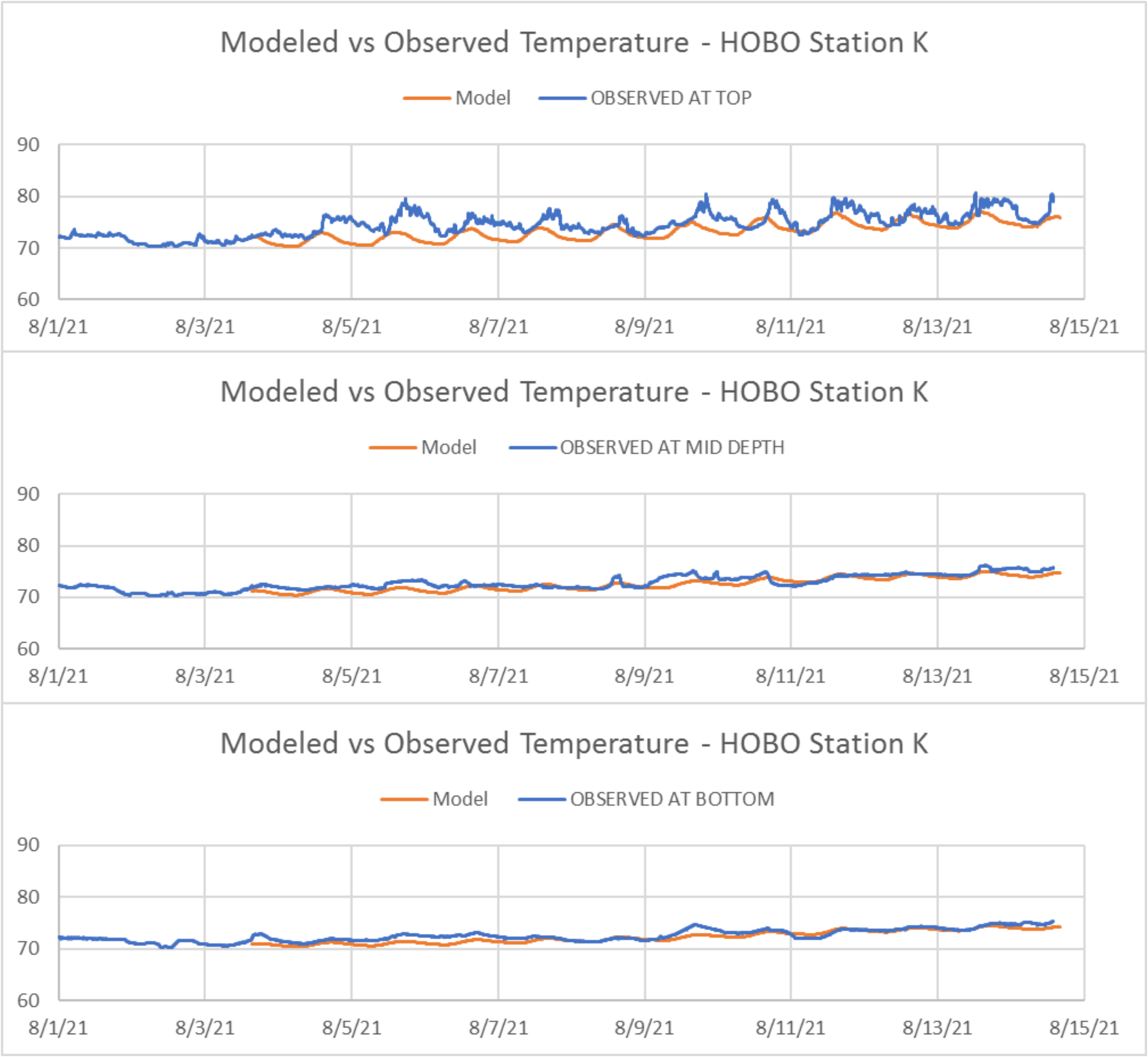
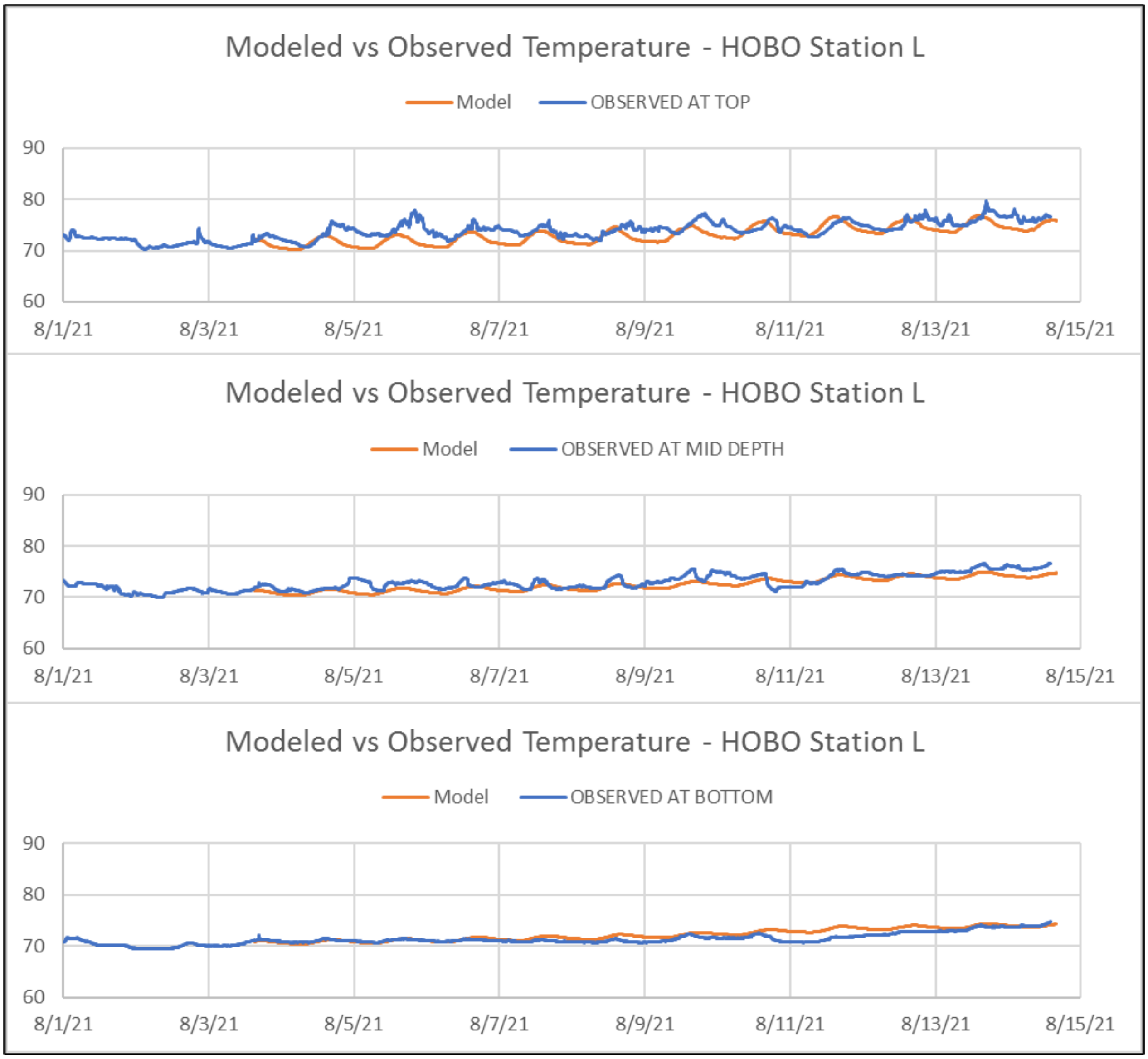


Figure 5.5: Model verification results at HOBO Station K


Modeled vs Observed Temperature - HOBO Station L

Modeled vs Observed Temperature - HOBO Station L

Modeled vs Observed Temperature - HOBO Station L

Figure 5.6: Model verification results at HOBO Station L

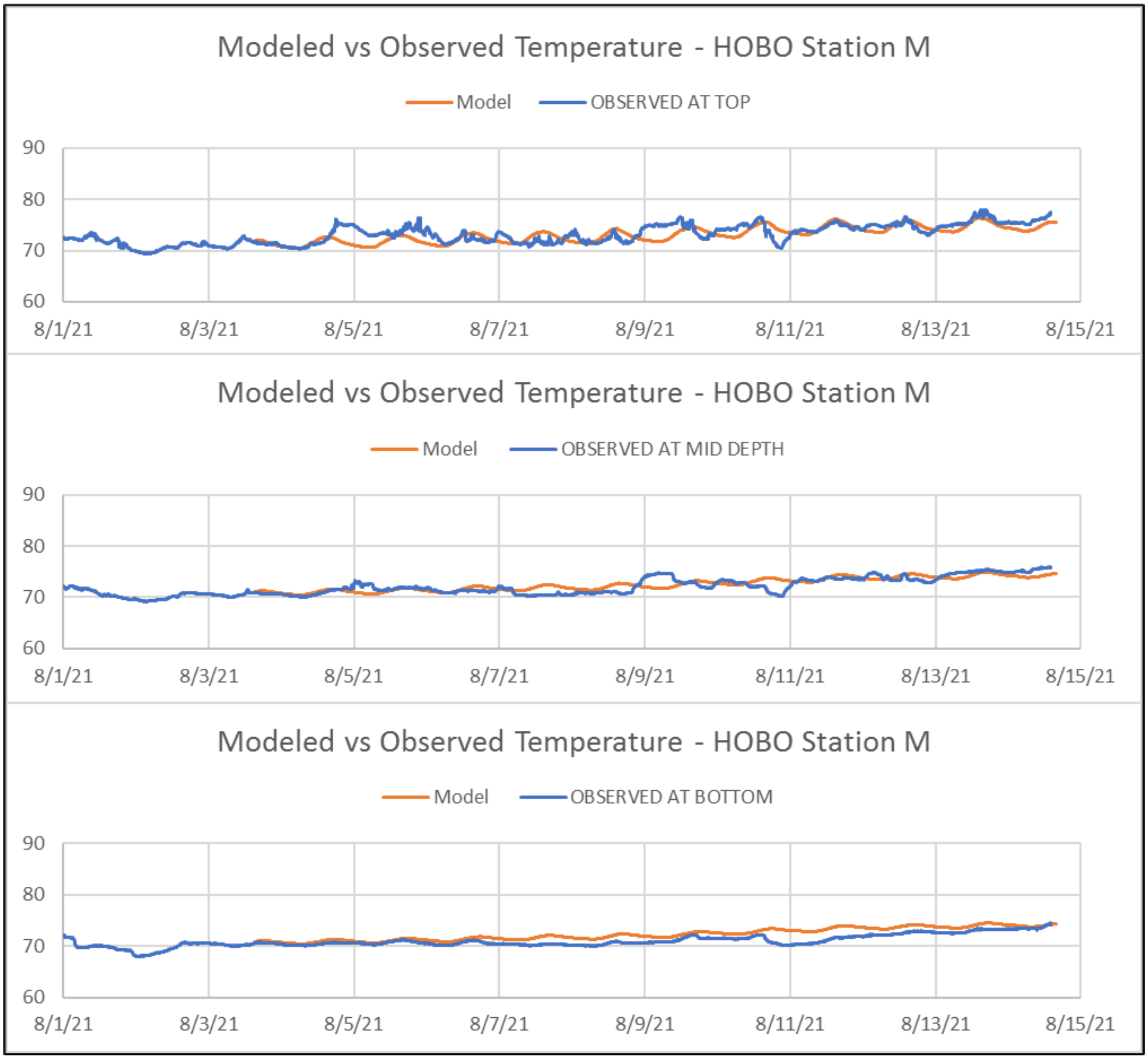
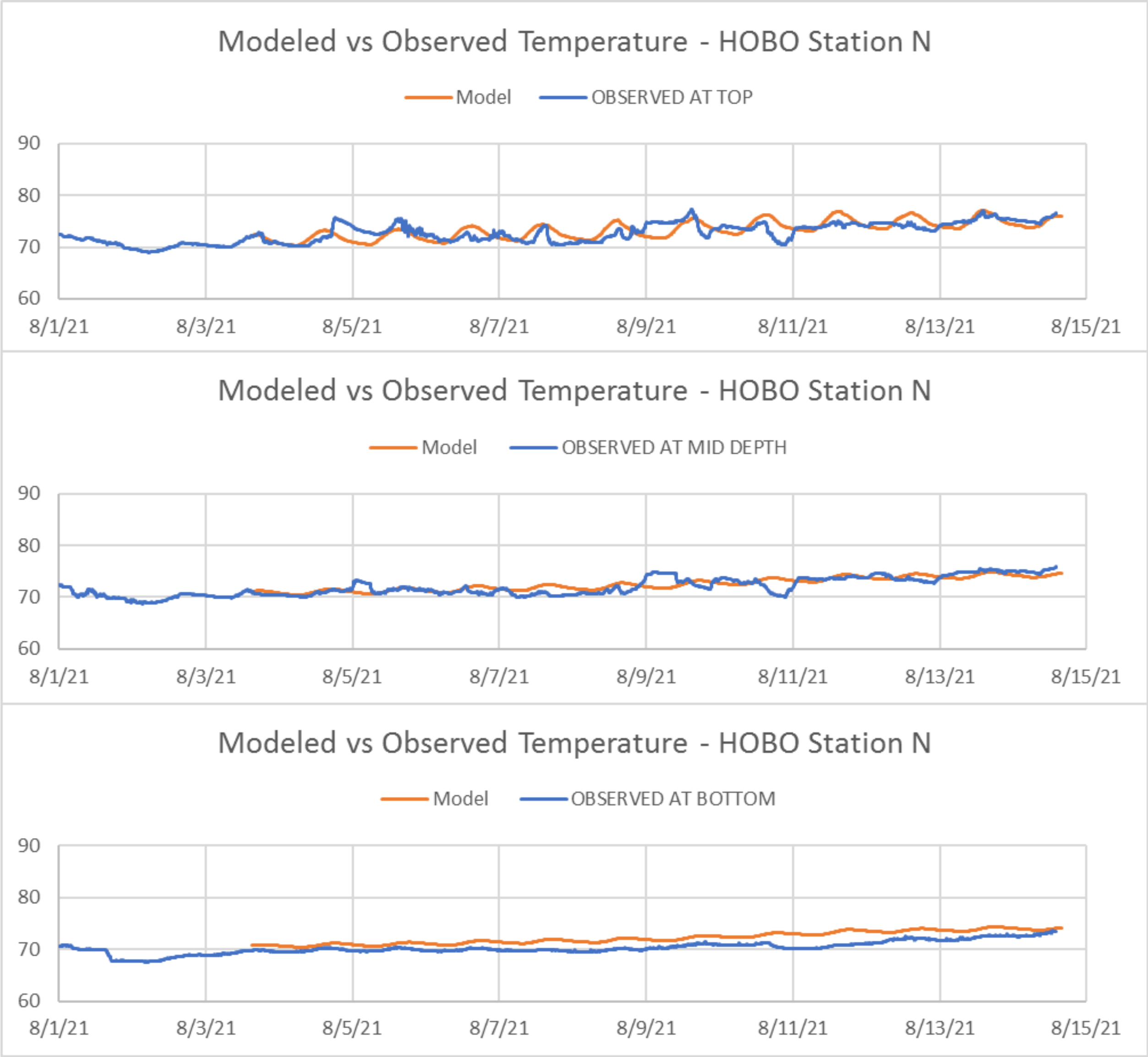


Figure 5.7: Model verification results at HOBO Station M



Modeled vs Observed Temperature - HOBO Station N

Modeled vs Observed Temperature - HOBO Station N

Modeled vs Observed Temperature - HOBO Station N

Figure 5.8: Model verification results at HOBO Station N

The temperature mooring data described above provided a test of the model's ability to resolve temperature variability over a range of time scales (hourly, daily, weekly, etc.) at seven different mooring sites. In addition, temperature mapping data collected in the tri-axial, shipboard surveys also provide a means to assess modeled spatial variability.

To this end, surface (~ 0.5 ft deep) temperature data collected along radial transects at various transect sites over 2-3 hour intervals (on 8/13/2021 and 8/14/2021) were plotted and contoured to produce representative average observed surface temperature distribution maps for these intervals (Figures 5.9 and 5.11). For comparison, model outputs of instantaneous Lake surface water temperatures were plotted at specific times on those days (Figures 5.10 and 5.12). While these results cannot be compared directly due to differences in timing (average vs. instantaneous), they both show general patterns of elevated nearshore temperatures and onshore-offshore gradients.

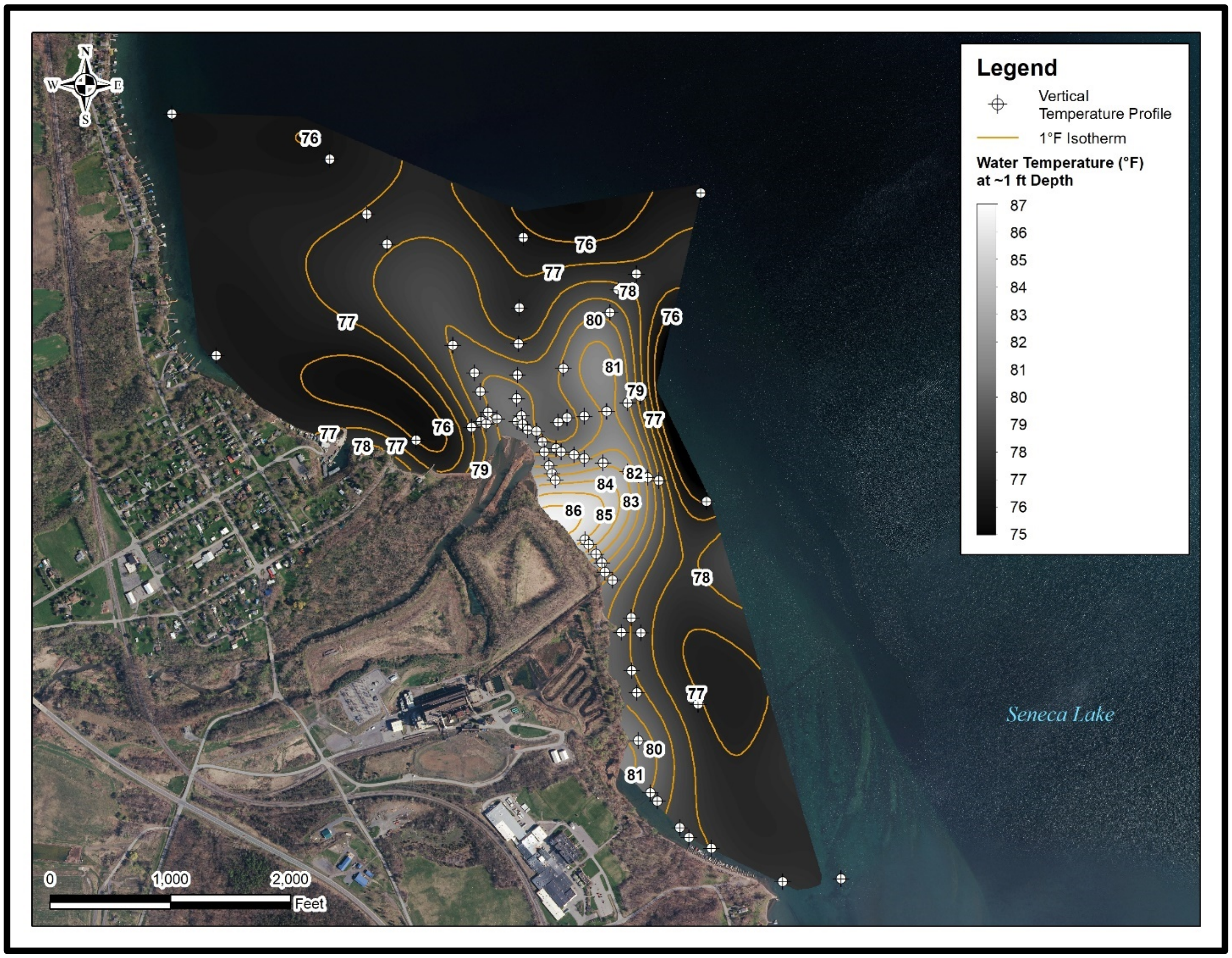


Figure 5.9: Composite water surface temperature mapping conducted on 8/13/2021 during sampling interval 12:10 through 14:49

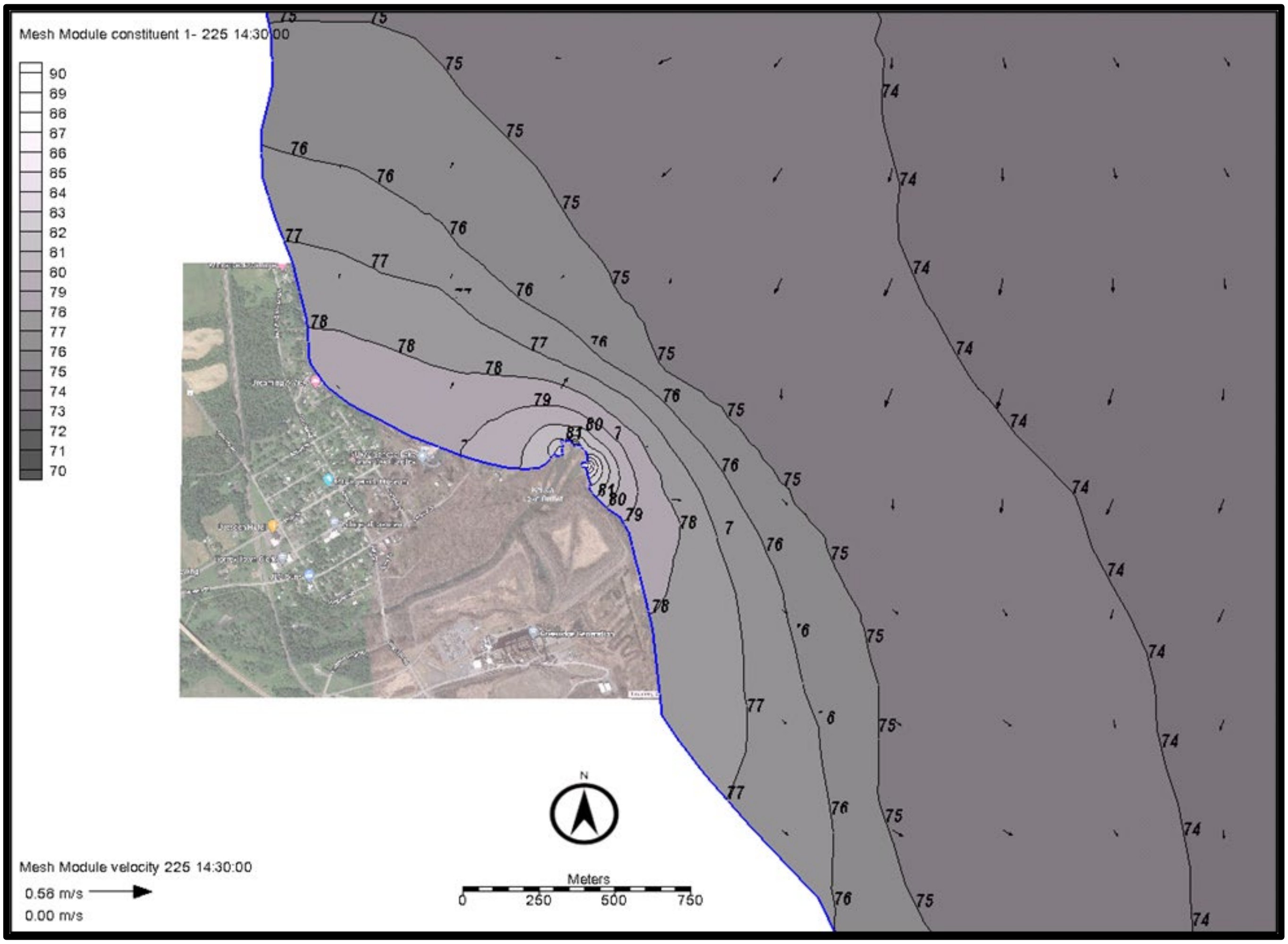


Figure 5.10: .Model verification results at surface on 8/13/2022 at 14:30 hours.

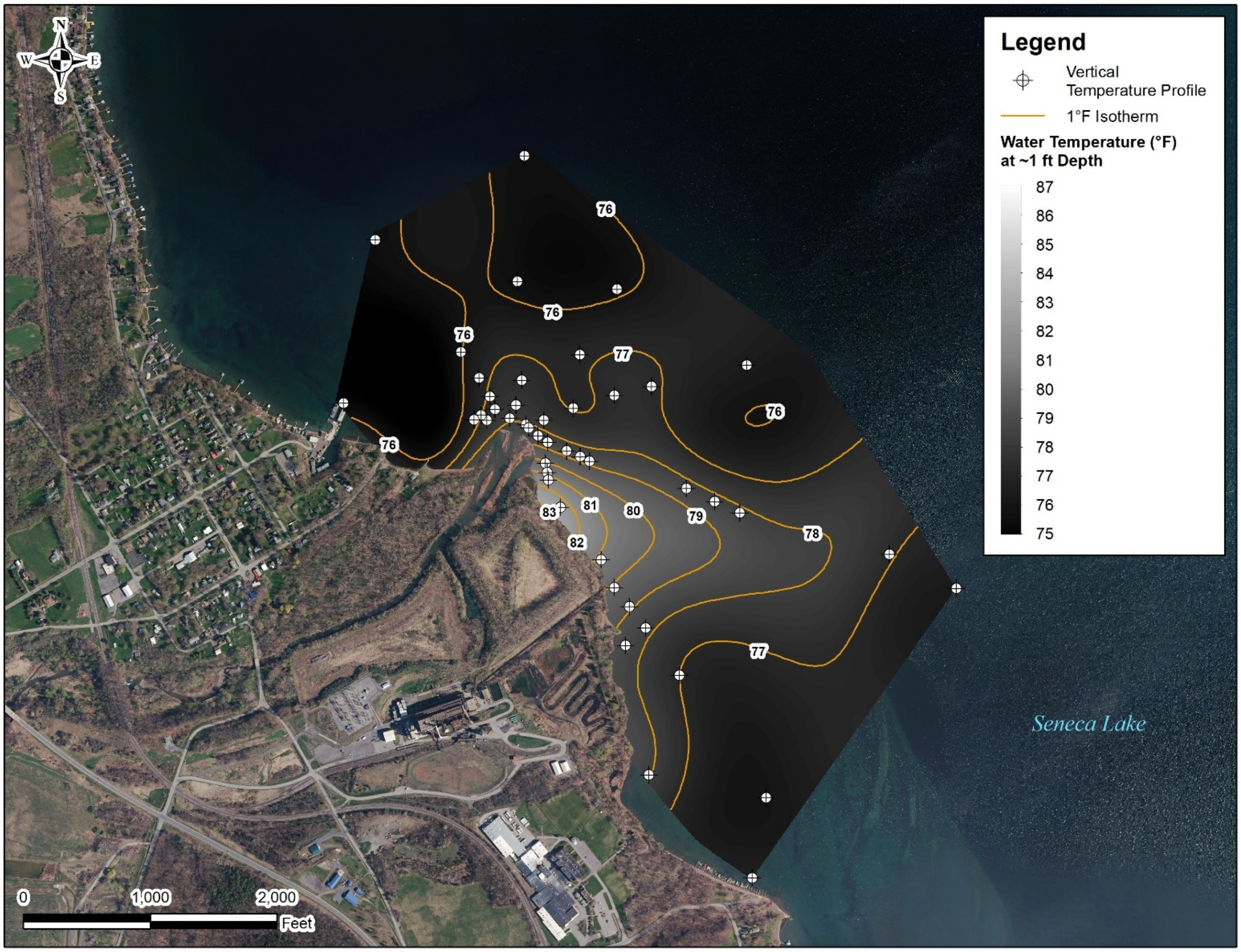


Figure 5.11: Composite water surface temperature mapping conducted on 8/14/2021 during sampling interval 10:45 through 12:53.

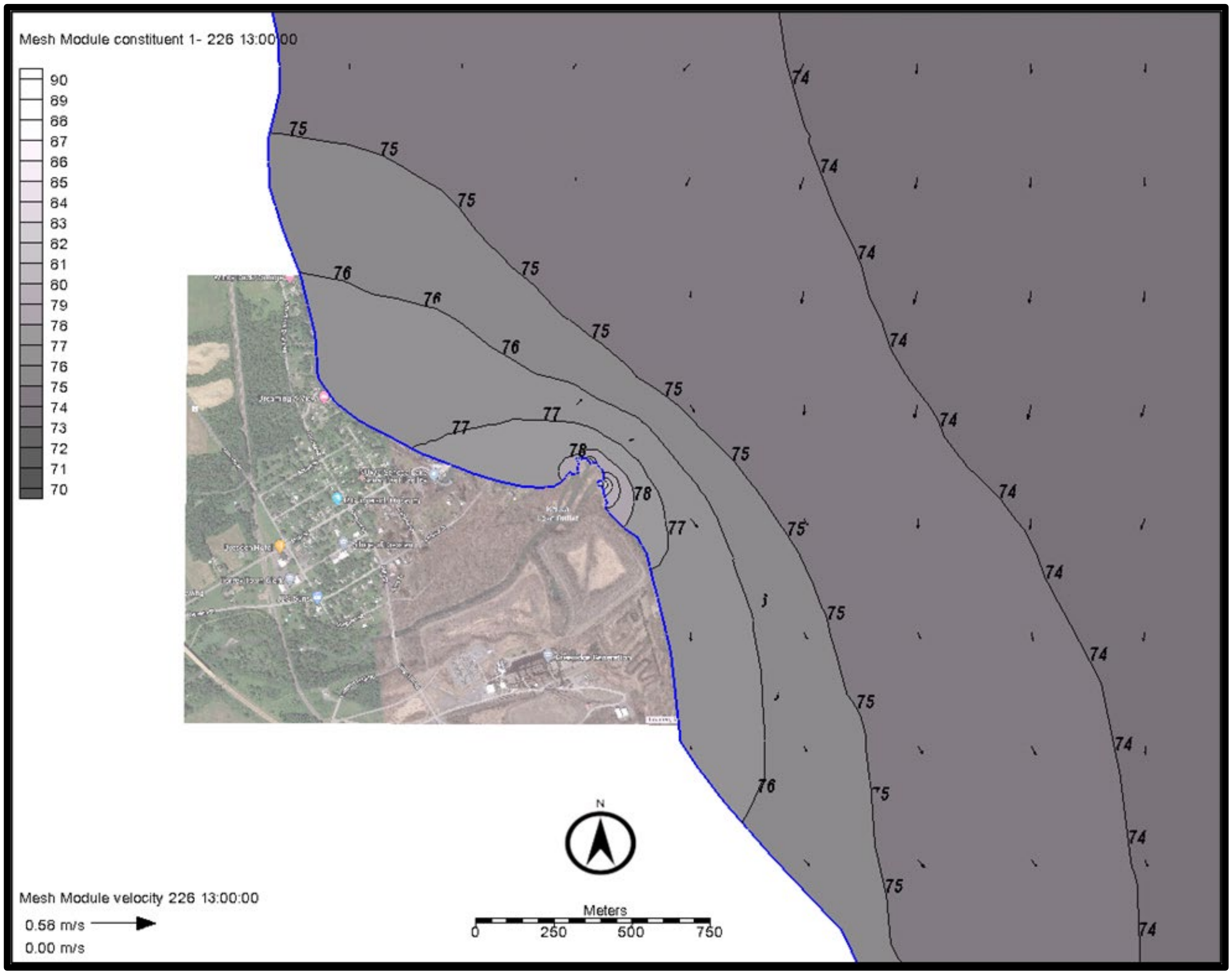


Figure 5.12: Model verification simulation results at surface on 8/14/2022 at 13:00 hours.

Average absolute temperature differences between the RMA-10 model and the field data for Stations H, I, J, K, L, M, and N ranged from 1.0 °F (I) to 2.06 °F (K) at the surface, 0.66 °F (I) to 1.64 °F (H) at mid-depth, and 0.68 °F (I, K, and L) to 1.27 °F (H) at the bottom.

Table 5.1(A): Model verification error analysis for **surface** temperatures

Station	**Number of Data Points**	**Mean Absolute Error* (°F)**	**Absolute Error as % of Mean Observed Temperature**	**r^2**
H Surface	1052	1.44	1.9%	0.42
I Surface	1044	1.00	1.3%	0.53
J Surface	1045	1.31	1.8%	0.47
K Surface	1052	2.06	2.7%	0.40
L Surface	1051	1.55	2.1%	0.41
M Surface	1054	1.18	1.6%	0.38
N Surface	1054	1.23	1.7%	0.77

- Absolute value of difference between simulated and observed value

Table 5.1(B): Model verification error analysis for **middle-**layer temperatures

Station	**Number of Data Points**	**Average Absolute Error (^oF)**	**Absolute Error as % of Mean Observed Temperature**	**r^2**
H Middle	1052	1.64	1.7%	0.50
I Middle	1044	0.66	0.9%	0.69
J Middle	1045	0.73	1.0%	0.59
K Middle	1052	0.82	1.1%	0.72
L Mid-mod.	1051	1.03	1.4%	0.64
M Middle	1054	0.85	1.2%	0.54
N Middle	1054	0.86	1.2%	0.34

Table 5.1(C): Model verification error analysis for **bottom** temperatures

Station	**Number of Data Points**	**Average Absolute Error (^oF)**	**Absolute Error as % of Mean Observed Temperature**	**r^2**
H Bottom	1052	1.27	0.9%	0.73
I Bottom	1044	0.68	0.9%	0.76
J Bottom	1045	1.03	1.4%	0.73
K Bottom	1052	0.68	0.9%	0.74
L Bottom.	1051	0.68	0.9%	0.66
M Bottom	1054	1.07	1.5%	0.70
N Bottom	1054	1.60	2.3%	0.54

6. PREDICTIVE CHARACTERIZATIONS OF THE THERMAL PLUME

6.1 Model Scenario Inputs and Scenario Development

The validated hydrothermal model was applied in a series of model scenario projections designed to characterize the thermal plume that would exist under various hypothetical operating and environmental conditions. Model scenarios were developed based on conservative combinations of variables that control the overall size, shape and movement of the Facility's thermal plume; namely: the Facility's temperature rise and heat rejection rate, KLO flows, Seneca Lake temperatures, meteorological conditions, and Lake Elevation.

For these simulations, GGF operational data were supplied by the Facility's engineer (including historical plant intake temperatures). KLO flows were obtained from available USGS gage data described above. Meteorological data were collected at 5-minute intervals from a station located at the end of the GGF intake pipe.

There were eight preliminary model scenarios defined in the NYSEDC-approved Study Plan, covering various sets of flow and ambient condition. As indicated in the plan, these scenarios were refined after consideration of initial results and data availability. The final set of modeled scenarios is provided in Table 6-1.

Each selected model scenario simulation was based on a combination of "critical" (reasonable worst-case) inputs for the controlling variables that would tend to maximize the size of the thermal plume – and have a relatively low frequency of occurrence (e.g., a few times a year). Because there are inherent uncertainties associated with model predictions, most of the model inputs were set at conservatively high values in these scenarios (i.e., 90th or 95th percentile values). Moreover, each scenarios assumed a thermal heat load associated with continuous (baseload) power generation at the Facility's full capacity (107 MW), rather than its current cycling patterns.

The selected model scenarios included two relevant biological seasons; namely: (1) summer, a period of maximum temperature; and (2) winter, a period of lowest temperatures. Model scenarios 1 and 2 simulated critical summer conditions; model scenarios 4 and 5 simulated critical winter conditions. Model scenarios 1 and 4 both included alternate combinations of GGF temperature rise and discharge rate. Here, the goal was to determine whether a discharge rate of 68,000 gpm or 57,000 gpm has a larger noncompliance zone, and to use that specification for later scenarios.

Model Scenario 3 simulated the most shore-attached plume effect caused by persistent wind from the northeast.

Table 6.1 Selected Model Scenario Projections for the Thermal Criteria Study.

Scenario	GGF Continuous (Baseload) Operation (MW – gpm)	Keuka Lake Outlet Flow Percentile	Seneca Lake Temperature Percentile	Meteorological Conditions
1 Summer 90th	107 MW - 68,000 gpm A: 107 – 68,000 501 MBTU/hr ΔT 14.7 B: 107 – 57,000 501 MBTU/hr ΔT 17.6	July-Aug 10th Constant 28 cfs	July-Aug 90th Constant 77.1 Top 4 m at CPB.	Solar radiation, wind, humidity, elevation, air temperature. Use 90th percentile values of relevant inputs. Determine whether 68,000 or 57,000 gpm has larger noncompliance zone and use that for later scenarios
2 Summer 95th	107 - 68,000 More extreme of A or B	July-Aug 5th 14 cfs	July-Aug 95th 77.8	Solar radiation, wind, humidity, elevation, air temperature. Use 95th of relevant inputs.
3 Seiche	107 - 68,000 More extreme of A or B	28 cfs	77.1	Scenario 1 plus actual or predicted wind & solar conditions during 7/3/21 through 7/17/21 or appropriate period. (This is intended to show extreme dispersion due to wind and water currents)
4 Winter 10th	107 – 68,000 A and B	Jan-Feb 10th 147 cfs	Jan-Feb 10th 44.9	Solar radiation, wind, humidity, elevation, air temperature during 10th Determine whether A or B is more extreme for winter.
5 Winter 5th	107 - 60,800 More extreme of A or B	Jan-Feb 5th 35 cfs	Jan-Feb 5th 40.0	Solar radiation, wind, humidity, elevation, air temperature during 5th
8 Summer 90th + 6°F	107 - 68,000 More extreme of A or B	July-Aug 10th 28 cfs	July-Aug 90th 77.1 + increment	Scenario 1 +6 °F air temperature
7 Summer 90th + 4°F	107 - 68,000 More extreme of A or B	July-Aug 10th 28 cfs	July-Aug 90th 77.1 + increment	Scenario 1 +4 °F air temperature. Only if Scenario 8 mixing zone exceeds that of Scenario 1.
6 Summer 90th + 2°F	107 - 68,000 More extreme of A or B	July-Aug 10th 28 cfs	July-Aug 90th 77.1 + increment	Scenario 1 +2 °F air temperature. Only if Scenario 7 mixing zone exceeds that of Scenario 1.

Model Scenarios 6, 7 and 8 were similar to Scenario 1B, but were developed to address anticipated future increases in air temperature due to climate change. These additional scenarios (with the critical conditions as described above, and incremental 2°F increases in air temperature (i.e., +2, +4 and +6°F).

To support these scenarios, an analysis was performed to establish a statistical relationship between Seneca Lake surface temperature with air temperature using the historical Clarks Point buoy data. An example of the analysis is provided in Figure 6.1 using data from 2019-2021, in which a 2°F increase in Lake surface temperature occurred. Such increases were incorporated into the model scenarios 6, 7 and 8.

In each scenario simulation, the calibrated RMA-10 model was run over a period 11 to 59 days with and without the thermal discharge. The thermal plume, areas of the lake where temperatures differed between the two conditions, was tracked through time. The largest plume areas used to determine the size and shape of the thermal plume, and the enclosed area of the plume where ΔT is ≥ 3°F for each scenario, areas illustrated below in Section 6.2.

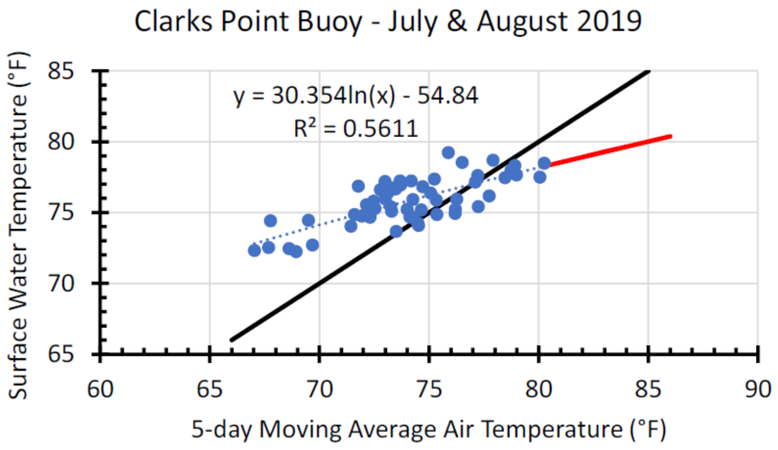


Figure 6.1: Relationship of surface layer (1 m depth) water temperature at Clarks Point buoy with mean air temperature over previous 5 days. Red line indicates predicted water temperature at mean 5-day air temperature up to 86 °F.

6.2 Model Scenario Simulations

Simulations were conducted for each model scenario using the model inputs of "MW-gpm" and KLO flow specified in Table 6-1. Also, the specified Facility ΔT was added to the specified Lake temperature to calculate the corresponding GGF discharge temperature prior to its merge with KLO.

For the summer scenarios (i.e., scenarios 1,2,3 and 8), the model was exercised for the period August 3 – August 14, 2021 (one of the warmest periods of the year). This period corresponds to a total of 1,060 15-minute time steps. The model output of surface water temperatures at every nodal point was stored for every time step, forming a "Scenario" dataset.

Likewise, the model was exercised again for the same period, but without the specified GGF discharge and Intake flow. The model output of surface water temperatures at every nodal point was stored for every time step, forming a "Natural" condition dataset.

Next, a "ΔT" results dataset was created by subtracting the "Natural" dataset temperature from the "Scenario" dataset temperature for every nodal point in the Model at each time step, as in our previous applications of this model. Finally, ΔT contours were plotted for each time step. The maximum acreage of the *"ΔT > than 3 degrees F"* contours were singled out from the maximum of the results for all 1060 time steps. Results are presented below.

A similar procedure was employed for winter scenarios 4 and 5. However, a longer simulation period (1/1/2022 through 2/28/2022) was selected to include the potential coldest period of winter.

6.2.1 Model Scenario 1A and 1B Results

Following Table 6.1, Scenario 1A examined summer discharge plume characteristics under approximately 90th percentile conditions for KLO flow and Seneca Lake surface temperatures. KLO flow was set at 28 cfs; Lake temperature at 77.1 °F. Also, Scenario 1A assumed the following combination of Facility operations: (a) GGF operating continuously (i.e., baseload operation) at 107 MW; (b) a full discharge flow of 68,000 gpm; and (c) a Facility temperature rise of 14.7 °F. Model results at each time step for the entire scenario simulation period (11 days, August 3-14, 2021) indicate that the maximum Lake area over which more than a 3°F rise in surface temperature would occur is 11.6 acres (Figure 6.2)

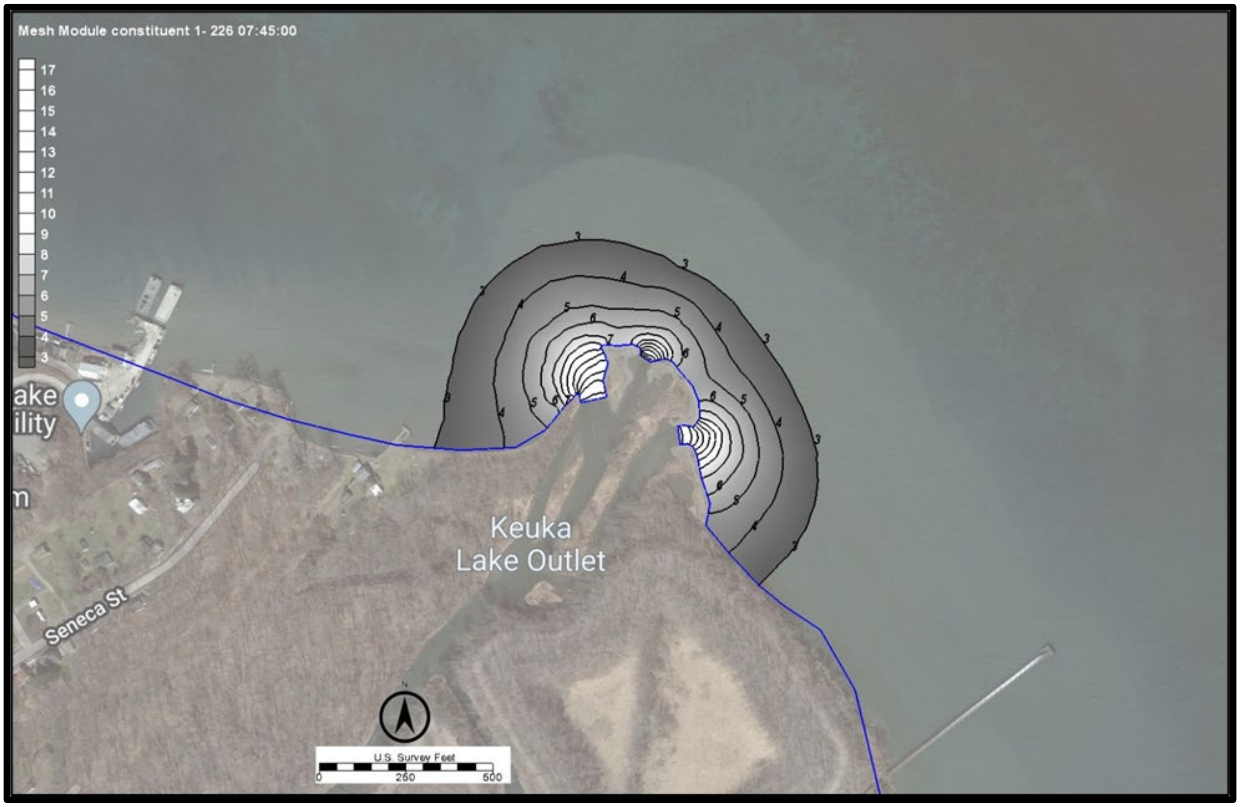


Figure 6.2: ΔT Contours for Scenario Simulation **1A** at 8/14/21 07:45. The enclosed area where ΔT is ≥ 3°F is **11.6 Acres**

Scenario 1B used the same conditions as Scenario 1A, except that GGF flow was assumed to be a value more representative of 2-pump operation (i.e., 57,000 gpm). Also, a higher value was prescribed for the Facility's temperature rise (17.6°F), corresponding to the same heat rejection as in Scenario 1A (but in a smaller volume of water). Model results for the entire scenario simulation period indicated that the maximum Lake area over which more than a 3°F rise in surface temperature would occur was 13.5 acres (Figure 6.3). Thus, Scenario 1B resulted in a slightly larger area than Scenario 1A, and is deemed more "extreme."

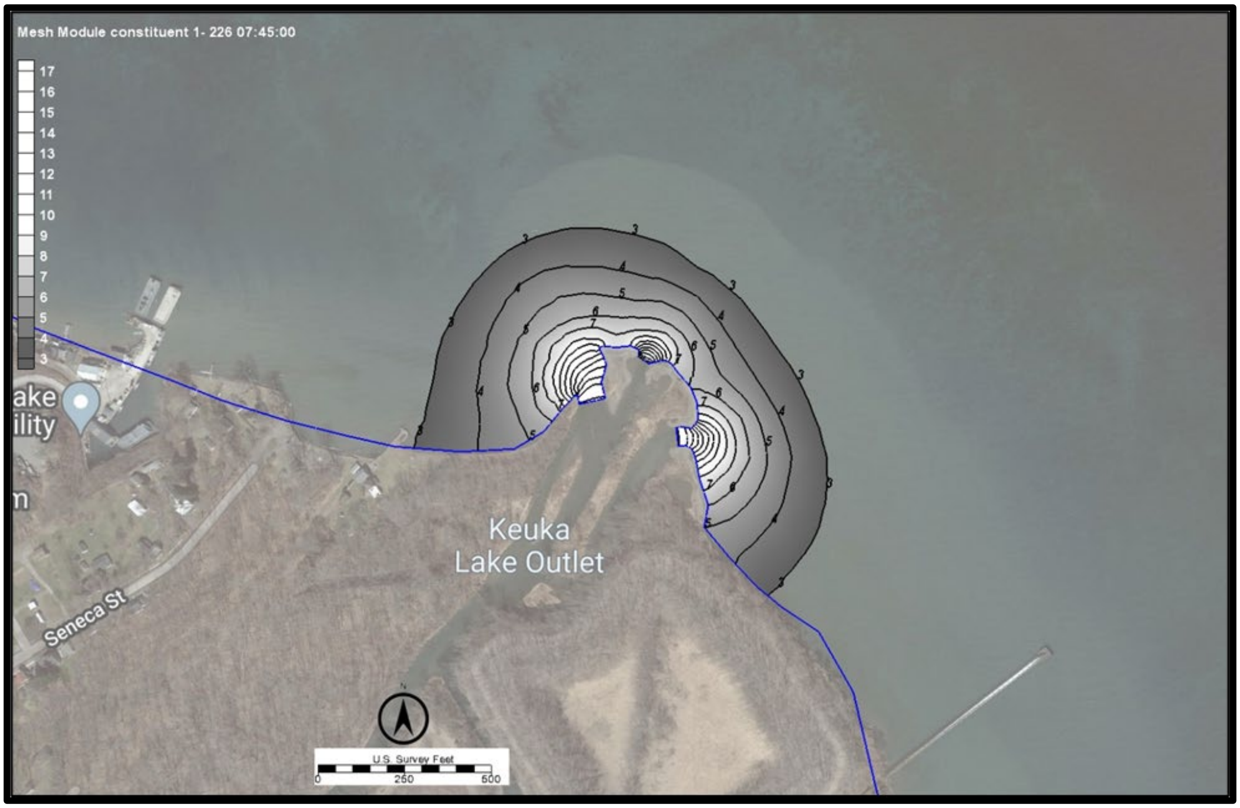


Figure 6.3: ΔT Contours for Scenario Simulation **1B** at 8/14/21 07:45. The enclosed area where ΔT is ≥ 3°F is **13.5 Acres**

6.2.2 Model Scenario 2 Results

Model Scenario 2 used more extreme conditions of approximately 95th percentile for Seneca Lake temperatures (77.8°F) and lower KLO flow (14 cfs). Also, Scenario 2 used the more extreme combination of GGF flow (57,000 gpm) and Facility temperature rise (17.6°F) that was prescribed in Scenario 1B above. Model results at each time step for the entire scenario simulation period (11 days) indicate that the maximum area over which more than a 3°F rise in surface temperature would occur was 16.4 acres (Figure 6-4).

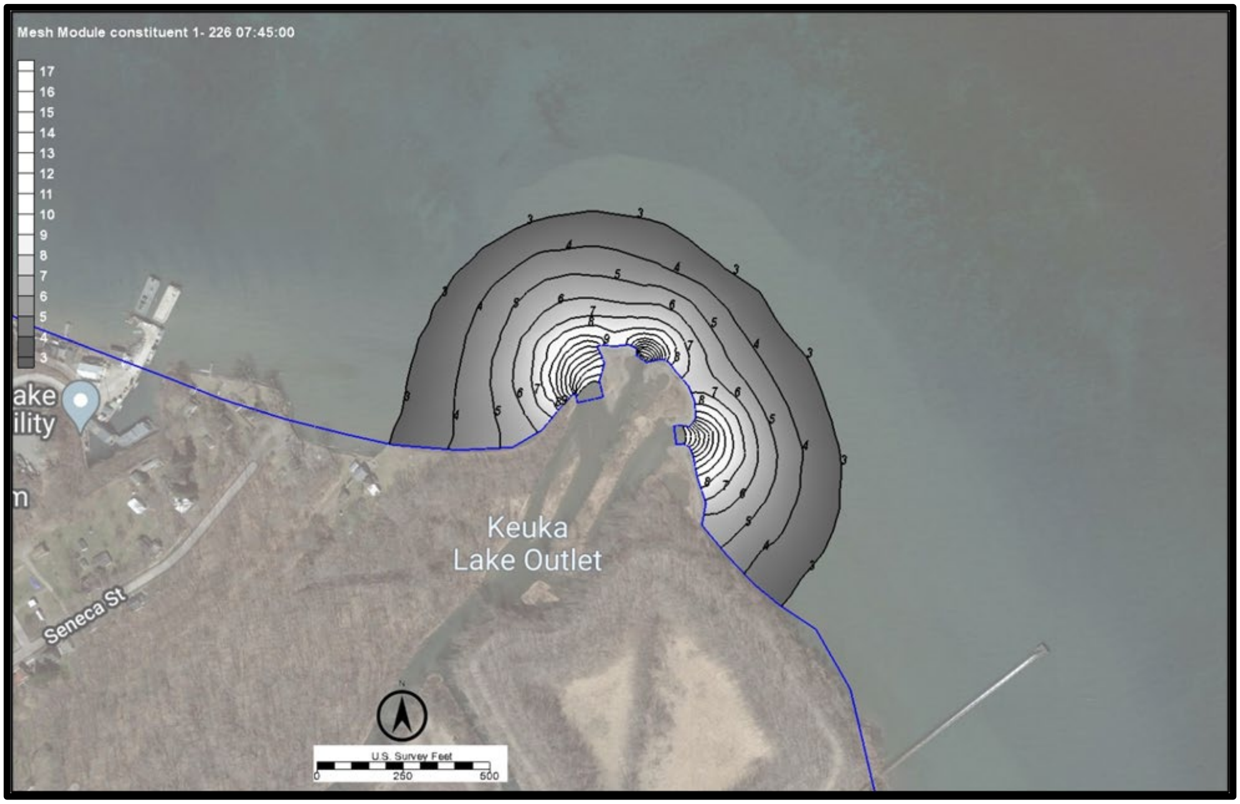


Figure 6.4: ΔT Contours for Scenario Simulation **2** at 8/14/21 07:45. The enclosed area where ΔT is ≥ 3°F is **16.4 Acres**

6.2.3 Model Scenario 3 Results

Model Scenario 3 simulated the shore attached plume effect caused by persistent onshore trapping wind. The wind direction was fixed at 30-degrees, but kept the wind speed unchanged from that observed during the 11-day simulation period. Also, like the more extreme Scenario 1B, Scenario 3 used a GGF flow of 57,000 gpm, a Facility temperature rise of 17.6ºF, a KLO flow of 28 cfs, and a Seneca Lake temperature of 77.1°F. Model results shows the thermal plume compressed against the shore (Figure 6.5).

For Scenario 3, the Model also computed that the maximum area over which more than a 3°F rise in surface temperature would occur was 18.7 acres (Figure 6-6).

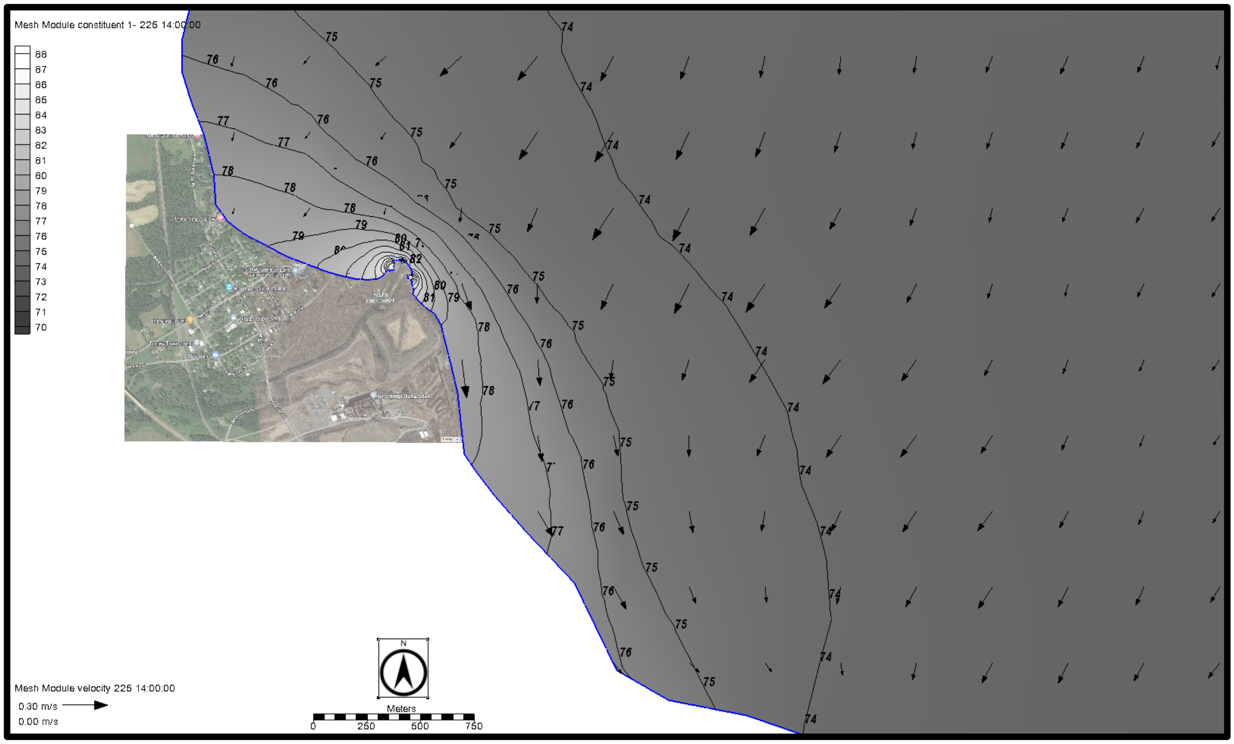


Figure 6.5: Simulated surface water temperature contours and current velocities for Scenario 3 with persistent wind directions.

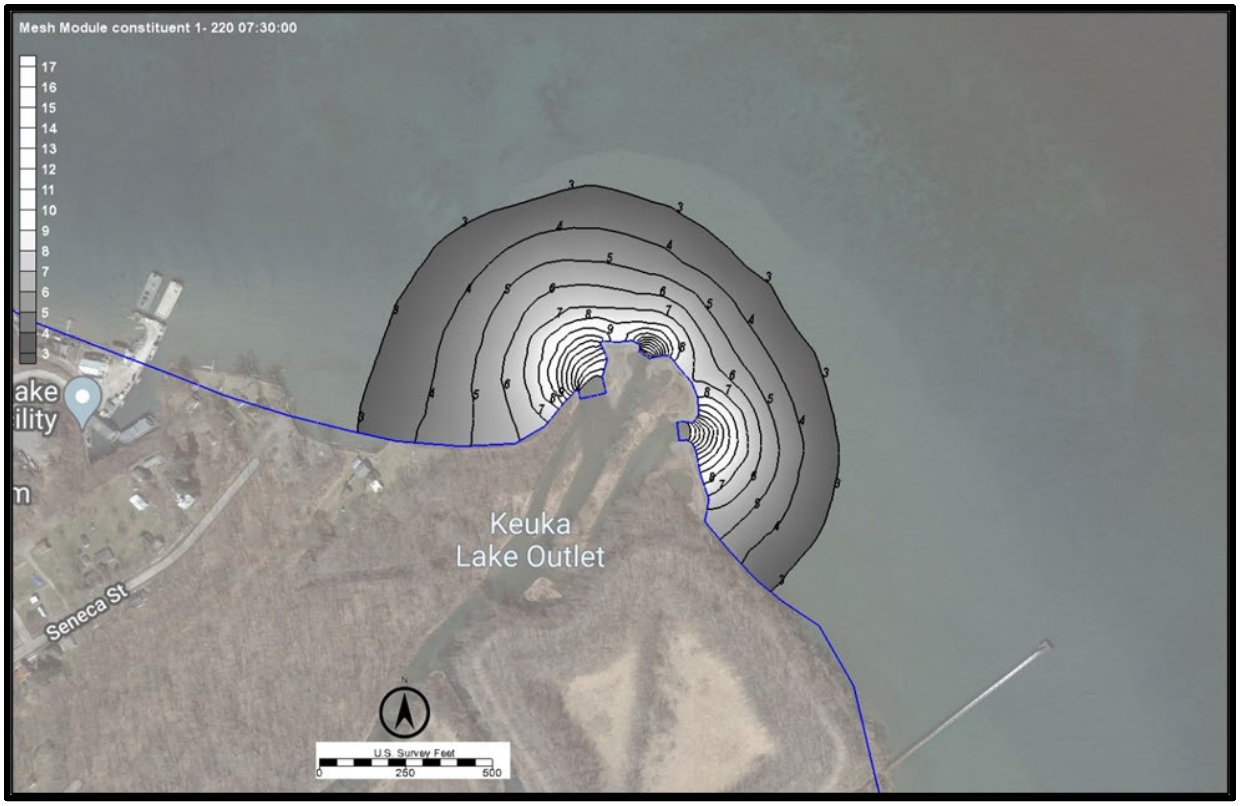


Figure 6.6: ΔT Contours for Scenario Simulation **3** at 8/8/21 07:30. The enclosed area where ΔT is ≥ 3°F is **18.7 Acres**

6.2.4 Model Scenario 4 Results

Model Scenario 4A examined *winter* discharge plume characteristics. Like summer Scenario 1A, winter Scenario 4A assumes GGF operating continuously (i.e., baseload operation) at 107 MW, a full flow of 68,000 gpm, and a Facility temperature rise of 14.7°F. Also, winter Scenario 4A assumed a representative winter KLO flow of 147 cfs and Lake temperature of 44.9°F.

After a model spin-up run during December 2021, the model was exercised for 59 days from 1/1/2022 to 2/28/2022, using observed meteorological data for this period. Model results at each time step for the entire scenario simulation period indicated that the maximum area over which more than a 3°F rise in surface temperature would occur was 6.4 acres (Figure 6.7). This maximum ΔT area was found to occur at 2/1/2022 11:00 hours. The simulated plume drifted North due to predominant northward winds during 1/31/22 and 2/1/22.

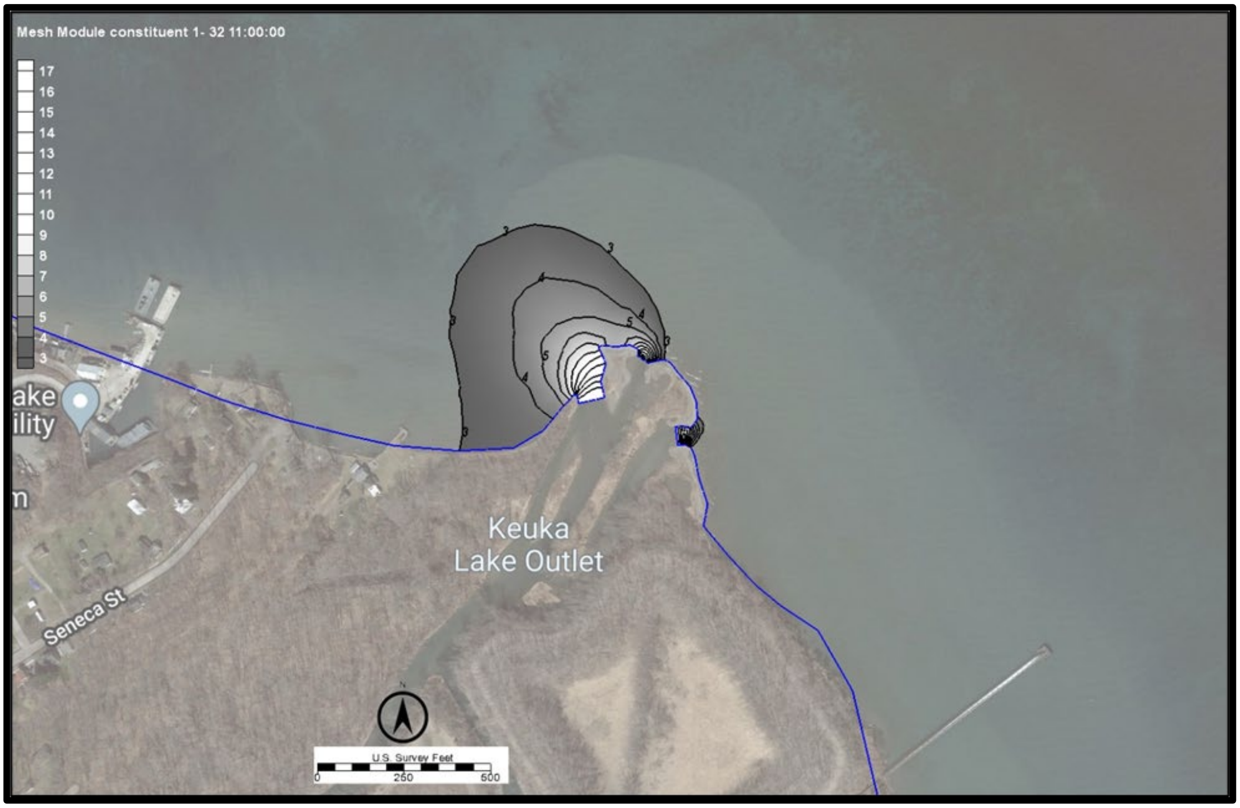


Figure 6.7: ΔT Contours for Scenario Simulation **4A** at 02/01/2022 11:00 Hours. The enclosed area where ΔT is ≥ 3°F is **6.4 Acres**

Model Scenario 4B also examined winter discharge plume characteristics. Like Scenario 4A, Scenario 4b also assumed a KLO flow of 147 cfs and a Lake temperature of 44.9°F. However, like summer Scenario 1B, winter Scenario 4B assumed that the GGF operating continuously (i.e., baseload operation) at 107 MW, at a full flow of 57,000 gpm, and with a Facility temperature rise of 17.6 °F.

The model was exercised for 59 days from 1/1/2022 to 2/28/2022. Model results at each time step for the entire Scenario 4B simulation period indicated that the maximum area over which more than a 3°F rise in surface temperature would occur was 6.1 acres (Figure 6.8). Thus, Scenario 4A conditions yielded a slightly larger area, and was deemed more extreme than Scenario 4B.

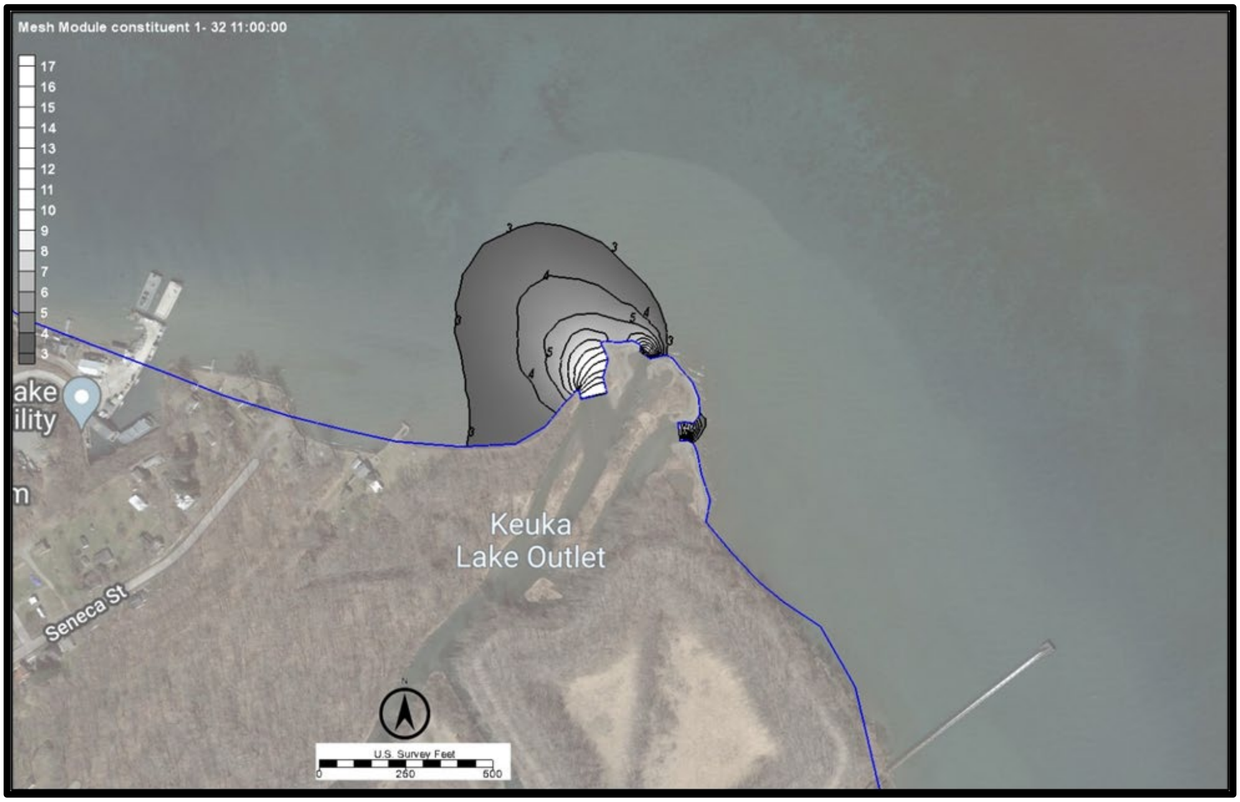


Figure 6.8: ΔT Contours for Scenario Simulation **4B** at 02/01/2022 11:00. The enclosed area where ΔT is ≥ 3°F is **6.1 Acres**

6.2.5 Model Scenario 5 Results

Scenario 5 examined alternate winter discharge plume characteristics. Like extreme Scenario 4A, winter Scenario 5 assumed GGF operating continuously (i.e., baseload operation) at 107 MW, a full flow of 68,000 gpm, and a Facility temperature rise of 14.7 °F. However, KLO flow was set at 35 cfs, while the prescribed Lake temperature was 40°F. Again, the model was exercised for 59 days from 1/1/2022 to 2/28/2022. Model results at each time step for the entire scenario simulation period indicated that the maximum area over which more than a 3°F rise in surface temperature would occur was 10.0 acres (Figure 6.9)

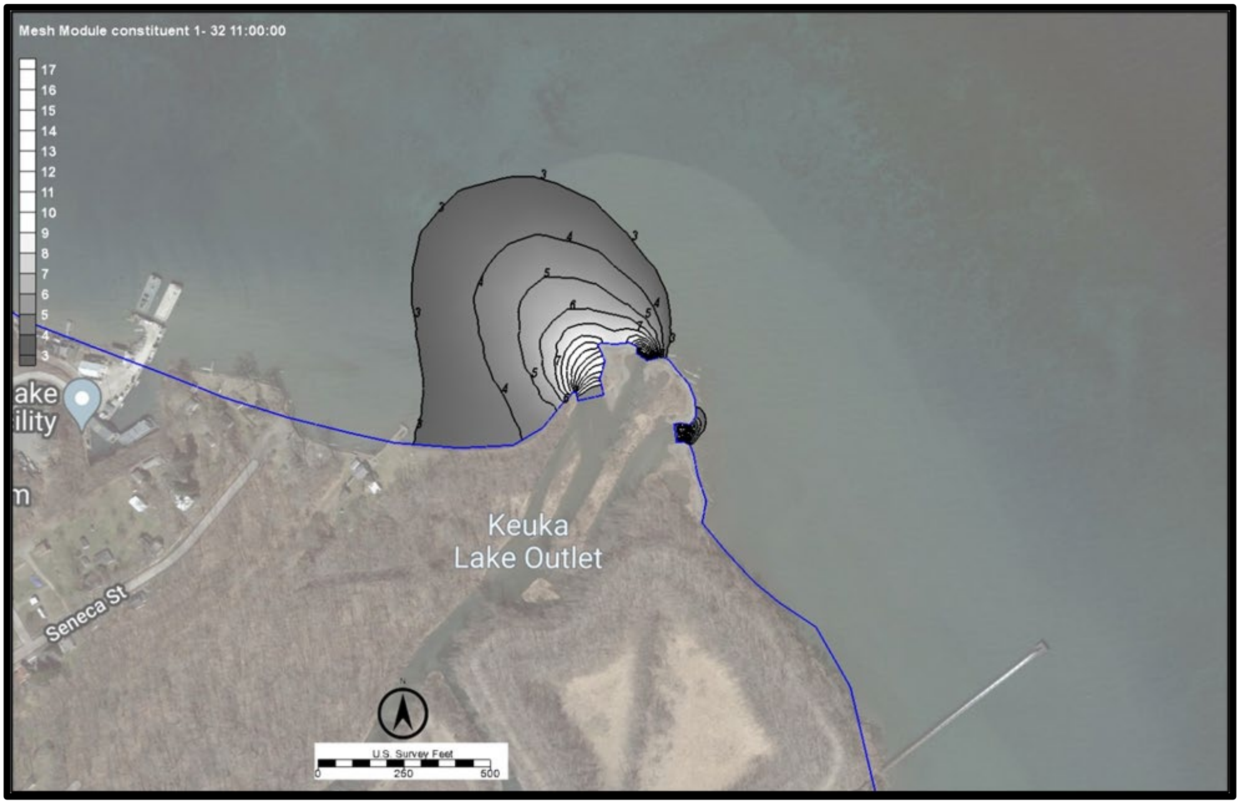


Figure 6.9: ΔT Contours for Scenario Simulation **5** at 02/01/2022 11:00 Hours. The enclosed area where ΔT is ≥ 3°F is **10.0 Acres**

6.2.6 Results for Model Scenarios 6, 7, and 8

Summer Scenario 8 used the same conditions prescribed for extreme summer Scenario 1B, but with the ambient air temperature raised by 6°F. Accordingly, the specified increment in Seneca Lake water temperature (at the intake) is raised by 2°F (*See ASA Study Plan Figure 4-4, ASA 2020*). Accordingly, this scenario assumed GGF operating continuously (i.e., baseload operation) at 107 MW and at a flow of 57,000 gpm, with a Facility temperature rise of 17.6 °F, a KLO flow of 28 cfs, and a Lake temperature of 79.1 °F. Model results at each time step for the entire scenario simulation period (11 days) indicated that the maximum area over which more than a 3°F rise in surface temperature would occur was 15.5 acres (Figure 6-10). This result was only 2 acres greater than the result for analogous Scenario 1B (Figure 6.3).

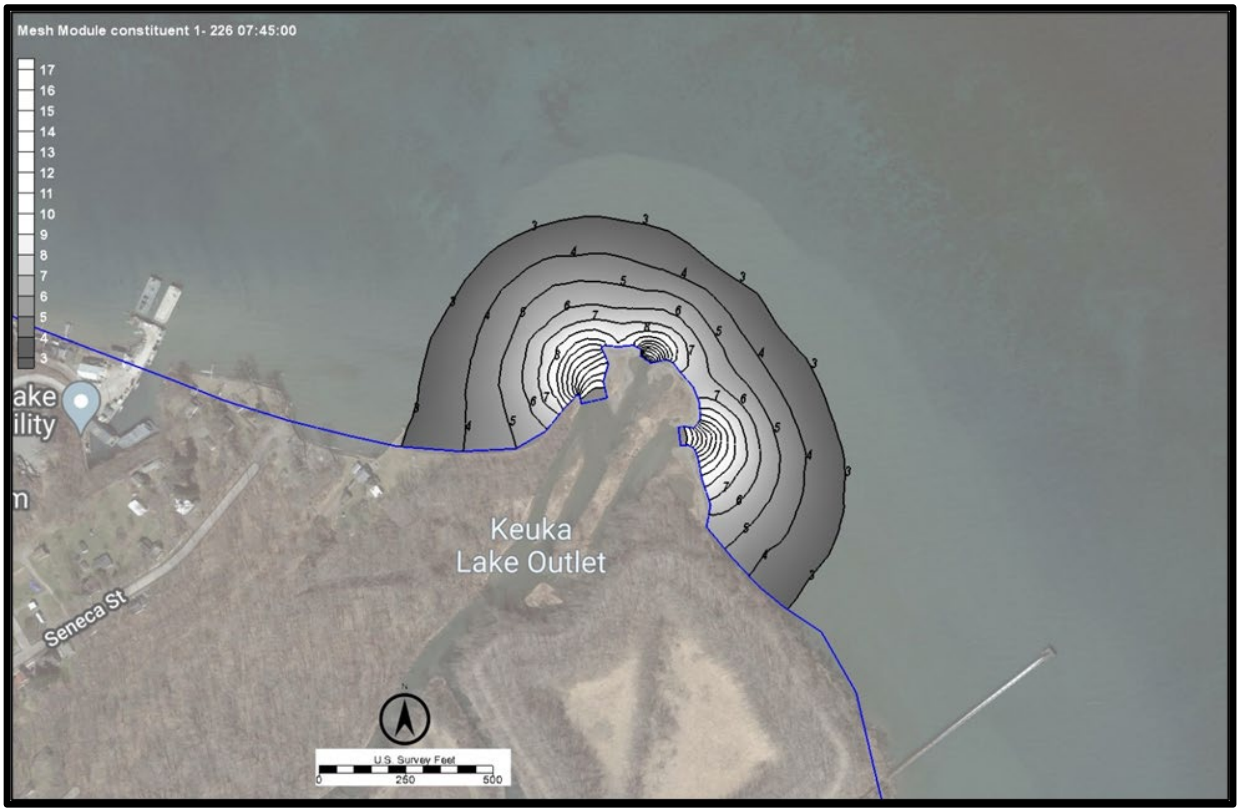


Figure 6.10: ΔT Contours for Scenario Simulation **8** at 8/14/21 07:45. (Background Air Temp also increase by 6 Degrees F). The enclosed area where ΔT is ≥ 3°F is **15.5 Acres**

Because comparable model results were obtained for scenario 8 -- and because model scenario 8 (6°F air temperature increase) was more extreme than either model scenario 7 (4°F air temperature increase) or model scenario 6 (2°F air temperature increase) -- additional model simulations were not conducted for scenarios 6 and 7.

7. CONCLUSIONS

A condition of the GGF's SPDES permit NY0001325 requires that a Thermal Discharge Study be performed to assess whether the Facility's thermal discharge meets all relevant thermal water quality criteria. This report documents a key component of the Study -- a hydrothermal model assessment of the Facility's thermal plume in Seneca Lake, where the relevant criterion is whether the surface temperature is raised by more than 3ºF. A prior hydrothermal model study at GGF was conducted in 1976, when the facility operated at approximately twice its current capacity (i.e., at a plant load of 215 MW). That study estimated the maximum area where surface temperature was raised at least 3ºF was either: (a) 47 acres (190,202 m^2) for the case when an onshore-offshore plume develops; or (b) 230 acres (930,776 m^2) for the when a shore-attached plume develops.

The basic goal of the present study was to reassess spatial and temporal distributions of added heat in Seneca Lake receiving waters due to the Facility's current discharge capacity, and to account for possible effects of atmospheric temperature increases. To this end, a time-varying, three-dimensional hydrothermal model (RMA-10) is adapted to the study area, and verified with a new set of field data collected during year 2021. The validated model is used to delineate the magnitude and extent of the Facility's thermal plume (and 3ºF ΔT area) over reasonable, worst-case ("critical") conditions. These include: (a) continuous (baseload) power generation at the Facility's full capacity (107 MW) rather than its current cycling patterns; and (b) model inputs were jointly set at conservatively high values in these scenarios (i.e., 90th and 95th percentile values).

The model scenario results indicate that the maximum receiving-water area over which more than a 3°F rise in surface temperature would occur is 18.7 acres for all 8 model scenarios. The area is significantly smaller than the corresponding areas (47 acres or 230 acres) estimated in the previous (1976) hydrothermal model study, consistent with the reduction in GGF generating capacity. The model also suggests that air temperature increases as high as 6ºF will not increase the 3ºF exceedance area significantly (only by ~ 2 acres).

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