Water Temperature Monitoring Study Near the Waterford Solar Power Site: Year 1 Report

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INTRODUCTION

A 16.78 MW solar energy facility that will have nearly 46 thousand solar electric panels located at 117 Oil Mill Road in Waterford and owned by CF Waterford LLC, a subsidiary of Greenskies Clean Energy LLC, was approved for construction and operation by the Connecticut Siting Council (CSC) on November 9, 2020 (see https://portal.ct.gov/CSC/3_Petitions/Petition-Nos-1341-1350/Petition-No-1347a-GRE-GACRUX for details). A local environmental organization, Save The River-Save The Hills (STR-STH), was an intervener in the CSC proceeding and objected to this development for several reasons. Among these was the potential for stormwater detention basin discharges (Fig. 1) from this development cleared of previously forested vegetation to impact two trout streams, Stony Brook (SB) and Oil Mill Brook (OMB), both located just outside and adjacent to the solar site (Fig. 2). Cole (2016) and Connecticut Department of Energy and Environmental Protection (CT DEEP), which may be accessed via https://cteco.uconn.edu/projects/fish/viewer/ index.html, each reported brook trout (*Salvelinus fontinalis*) present in both streams and also brown trout (*Salmo trutta*) in OMB. The potential impacts were increased sedimentation due to clearing of the formerly forested site (Fig. 3), which would affect trout spawning, and increases to stream water temperature due to both forest clearing and retention and discharge of precipitation from the site stormwater system. SB and OMB are also tributaries to the nearby Niantic River, an estuary located off Long Island Sound in Waterford and East Lyme (Fig. 2).

During the CSC proceedings, subsequent changes to the solar facility site plan made impacts to OMB far less likely, but not to SB or an un-named stream located to the east of the Eversource electric sub-station, which is located on Parkway North near Oil Mill Road. This stream also drains into the Niantic River. Following CSC approval of the solar project, the Niantic River Watershed Committee (NRWC) in conjunction with STR-STH decided to place long-term water temperature monitors into the streams near this site to determine if any changes in ambient water temperature occurred from project construction and operation. The supposition for a potential water temperature increase was based on a similar long-term water temperature study conducted by the NRWC in Cranberry Meadow Brook (CMB), which is a also a cold-water trout stream located in the Niantic River watershed in East Lyme. CMB receives stormwater discharges from a smaller (5.0 MW, 16,874 panels) solar energy project. This study, completed by the senior author of this report, found that an un-named tributary to CMB receiving stormwater drainage from the East Lyme solar field underwent a small, but significant increase in water temperature following forest clearing, construction, and operation of this solar energy facility.

This report is a summary of the first year of study for what we hope will be a long-term effort in examining any effects to these ecologically significant trout streams in the Town of Waterford.

METHODS AND MATERIALS

Tidbit Placements

We used ONSET® Brand TidbiT® v2 data loggers (henceforth referred to as "Tidbits") to record stream water temperatures that were made available to us by the Millstone Environmental Laboratory (MEL). We calibrated the Tidbits and deployed them using standards given in CT DEEP (2012). We note that the water temperature data collected during this study is periodically forwarded to the CT DEEP as part of the Department's Volunteer Stream Monitoring Program.

Initially, with landowner permission we placed Tidbits into four streams (five stations) near the Waterford solar site on December 11, 2020 (Table 1; Fig. 4). At each station, we recorded the Tidbit serial number, location latitude and longitude, the time of placement, and other information on the CT DEEP Volunteer Stream Monitoring Program Stream Temperature Data Logger Installation/Retrieval Form. We took photos of the area where each Tidbit was placed (Fig. 5). The stations included SB a few feet upstream of the culvert taking the stream underneath Parkway North (SB_Culvert); in SB about 0.5 mi upstream of Parkway North (SB_Up); a tributary to SB running parallel to Parkway North approximately 50 yards west of SB_Culvert (SB_Trib); an un-named stream just east of the Eversource electric sub-station near the junction of Parkway North and Oil Mill Road about 10 yards north of its Parkway North culvert (UNS); and in OMB on the property of 82 Oil Mill Road (OMB_1), about 135 yards downstream of the OMB confluence with Willy's Meadow Brook. We view the OMB station serving as an undisturbed reference location with respect to other stations potentially impacted by the solar field clearing and stormwater discharges.

As suggested in CT DEEP (2012), we tethered Tidbits inside PVC tubes and attached these to relatively heavy sash or plate-like weights using tie-wraps. We placed the Tidbit arrays either under rocks or tie-wrapped them to tree roots or branches in locations ensuring that they would not be in direct sunlight or out of the water should stream flow volume be reduced. We set the Tidbits to record water temperature values (^{o}C) at 1-hour intervals. There were slight (<10 min) differences among the hourly times the Tidbits were set to record water temperature, which we considered to be trivial in any subsequent data analysis.

Water Temperature Data Collection

We made the first data retrieval on June 11, 2021, about 6 months after the initial Tidbit placements. All Tidbits remained where initially placed. Using a device known as an optical reader that was supplied by the MEL, we uploaded water temperature data to a laptop computer in the field. We concluded that each Tidbit provided reliable water temperature data over the initial 6-month data collection period. During this deployment we realized that the SB_Up station, which we initially thought would serve as an upstream reference station, was in an area that could possibly be affected by stormwater runoff from the solar site. Thus, we placed another Tidbit about 0.25 mi farther upstream in SB at the SB_Far station on June 11, 2021 (Fig. 4). This far upstream location is outside of any influence from the solar facility.

Most of the northeast region, including locally in New London County, received considerable rainfall from Tropical Storm Ida on September 1-2, 2021. According to the September 2 edition of *The [New London] Day*, the National Weather Service reported that East Lyme received 7.36 in of rain from

Tropical Storm Ida and likely a similar amount fell in Waterford. Extremely heavy flooding occurred in the study streams, and we discuss the effect of this storm on water temperatures later in this report. After visiting the streams, we found extensive damage to riparian areas, including fallen or damaged trees and deposits of sediments, relatively large stones, and other debris. Within the streams, we observed considerable movement and deposits of sediments, including stones up to the size of softballs, and downed trees and tree limbs. Despite the flooding we found that most of the Tidbits had remained in place. However, the tree to which the SB_Trib Tidbit was attached was uprooted with the attachment root holding the Tidbit array broken off. This small stream was greatly modified with considerable erosion and many large stones deposited onto its bed, particularly downstream towards mainstem SB. We could not locate this Tidbit but based on the heavy weight to which it was attached it may have been buried somewhere in the small reach of this tributary stream above SB proper. We remain hopeful that we can locate it sometime in spring of 2022. The OMB_1 Tidbit was also attached to a small tree rootwad in this stream (see Fig. 5). This tree was severely damaged and the rootwad with the attached Tidbit washed away. The property owner noted that this rootwad had been in place for some decades before this flood. He told us that he routinely searches the OMB streambed and banks for historical artifacts uncovered by significant flooding events. After the flooding from Tropical Storm Ida subsided, he walked along OMB downstream as far as the I-95 crossing, but never saw our Tidbit array. As such, we presumed it was lost and unrecoverable, despite the array having a relatively heavy anchor. Therefore, on October 1, 2021, we placed a new Tidbit into OMB at OMB_2, which is located about 100 yards farther upstream in a more protected spot than the initial placement (Fig. 2). OMB_2 is upstream of the confluence of OMB and Willy's Meadow Brook (Fig. 1), whereas the original location was downstream. This has unknown consequences for the water temperature data, but we believe any water temperature differences will be slight, based on the apparent greater stream flow volume in OMB and the similar environmental conditions affecting both streams, which are relatively close together.

We planned a second data retrieval in early December 2021, about a year after the initial deployments. However, we found the that the optical reader available from the MEL was not working. A new reader was purchased, and we subsequently uploaded water temperature data at all stations (except for the missing SB_Trib Tidbit) on January 6, 2022. On this date, we again found that all Tidbits were in good condition, had remained in place, and appeared to have reliable water temperature data recorded. We moved the UNS Tidbit about 5 yards farther upstream to a more secure location along the bank as Tropical Storm Ida flooding had altered the stream in this area very close to its Parkway North culvert.

Data Analyses

Water temperature data were retained in Microsoft® Excel® spreadsheets, which also provided the statistical software we used to perform data summaries and analyses and plots of data. Statistical tests, including analysis of variance (ANOVA) and t-tests, were used to determine significant differences ($p \leq 0.05$) in water temperature among or between stations. We also determined correlations (r) of water temperature records among the stations. Stream discharge volume (cfs) before, during, and after Tropical Strom Ida were available from the U.S. Geological Service (USGS) gage in East Lyme's Latimer Brook. In addition to Excel®, we also used the DeltaGraph 4.0 graphics package for plotting some streamflow data.

RESULTS AND DISCUSSION

Comparison of Tidbits Used in this Study

Following their calibration and before deployment in the field, the Tidbits were contained together, so all were experiencing a common air temperature environment during portions of December 10 and 11, 2020. This enabled us to compare them statistically to ensure that none would provide biased (+ or -) water temperature data in comparison to any of the others. During the time before deployment in the field, air temperatures (^{o}C) were recorded every 15 minutes, with a total of 70 observations available. We performed a one-way ANOVA, which indicated that there were no significant differences in temperature among the Tidbits to be used in the field study (Table 2).

Initial Water Temperature Data Extraction (11 December 2020-11 June 2021)

We found water temperature data recorded at all stations during the initial deployment to be highly correlated with $r > 0.99$ for most comparisons (Table 3). The SB_Trib station was slightly less ($r = 0.975$-0.981) correlated with the two SB stations and OMB than it was with the other small flow volume stream, UNS ($r = 0.990$). This may be due to both small streams responding more similarly to air temperature fluctuations and precipitation events than SB or OMB, which have much larger watersheds of 2.86 mi^2 and 5.73 mi^2, respectively (Cole 2016).

We compared station water temperature data recorded from December 11, 2020 through June 11, 2021 using a one-way ANOVA to determine if there were any significant differences among the stations. This is important to know if we are to attribute any future increases resulting from the installation and operation of the Waterford solar energy facility. The ANOVA using data from all stations showed highly significant differences (Table 4). Mean water temperatures over this period ranged from 6.828^{o}C at UNS to 8.023^{o}C at SB_Trib. Although water temperatures at these two stations were highly correlated (Table 3), apparently there was a consistent difference of about 2^{o}C in these two small streams. An interesting finding was that SB_Trib had smaller variance in the data than the other stations. Not having a multiple range test available to examine for significant differences among the means, we made a series of statistical analyses, dropping the station with the highest mean temperature in successive tests. After deleting SB_Trib, the second ANOVA also showed highly significant differences in water temperature among the four remaining stations (Table 5). Since OMB_1 had the second highest mean temperature of 7.695^{o}C with the other three stations having means ranging between 6.828 and 6.986^{o}C, we dropped OMB_1 for the next test. We found the three remaining stations, SB_Culvert, SB_Up, and UNS, to have non-significantly different water temperatures (Table 6). Finally, we compared the two stations with the highest mean temperatures, SB_Trib and OMB_1 (Table 7). A t-test indicated that SB_Trib was significantly warmer than OMB_1, which, in turn, was significantly warmer than the other three stations as was demonstrated in a previous ANOVA (Table 5).

Water Temperature Data Through the Second Data Extraction (11 December 2020-6 January 2022)

Due to the loss of Tidbits and water temperature data at SB_Trib and in OMB for much of this period, we compared the data collected at the three stations having nearly 13 months of continuous water temperature data (Table 8; Fig. 6). The one-way ANOVA indicated no significant differences found among SB_Culvert (mean water temperature of 10.776^{o}C over the period), SB_Up (10.744^{o}C), and UNS

(10.583°C). This result was the same as found for the first 6 months of this study (Table 6), with the statistically similar mean water temperatures ranking in the same order by station.

As we established the SB_Far station on June 11, 2021, we wanted to see how water temperatures at this station compared with the nearest downstream station, SB_Up. A t-test indicated that the SB_Far station (mean = 13.765°C) had significantly cooler water temperatures than SB_Up (14.037°C) during this period (Table 9). This was not surprising as SB_Far is located closer to the headwaters of SB.

Regression Model Comparing SB_Culvert and OMB Stations
Since we view OMB as potentially unaffected control for the other streams in this study, we thought it useful to determine the relationship in water temperature between this stream and SB, the data for which are shown in Figure 7. We selected SB_Culvert for this comparison as water temperatures there will integrate any potential thermal effects to this stream from the solar facility, which could introduce stormwater to SB through multiple points upstream. If this were to happen, then the relationship between the water temperatures of these streams might also change. We used temperature data from both OMB stations for this analysis. We proposed a simple linear regression model where:

SB_Culvert water temperature (y) =
a function of combined OMB_1 and OMB_2 water temperatures (x) ± a constant intercept

The model was highly significant ($r^2 > 0.99$; Table 10) and model results indicated:

$$SB\_Culvert_{temp} = 1.084 \times OMB_{temp} - 1.403$$

The standard errors and 95% confidence intervals for these regression coefficients were relatively small, indicating that our model was robust. We examined model residuals, which are the difference between the predicted and observed values of the dependent variable. Negative residuals mean the predicted values are too high and positive means they are too low. The largest negative residual values (maximum = -1.531°C) occurred during a 7-hour period on February 1, 2021. However, the SB_Culvert temperatures appeared to be in line with previous and succeeding water temperatures, whereas the OMB temperatures during that time frame appeared to be abnormally low and near freezing. This might have reflected a brief dewatering of the OMB Tidbit in conjunction with cold air temperatures. The largest positive residuals (maximum = +2.184°C) occurred during the afternoon of December 25, 2020, when the SB_Culvert temperatures were warmer than expected from the prevailing OMB water temperatures. Given that that were 6,685 observations of paired water temperatures, the occurrence of a few outliers in our data set did not materially affect overall model results.

Effects of Tropical Storm Ida
As we noted previously, the flooding resulting from Tropical Storm Ida, which passed through our area on September 1-2, 2021, caused damage to our study streams and the loss of two Tidbit arrays. Some effects also occurred on the solar energy site, where damage occurred to some of the stormwater basins (Fig. 8). The rapid increase in stream water volume was exemplified by the flow recorded in Latimer Brook, a tributary to the Niantic River located in nearby East Lyme (Fig. 9). Flow volume in Latimer Brook increased by about 300 times that of the discharge before the storm. Peak flow volume quickly

subsided over the next few days but remained elevated over pre-storm conditions a week later. Likely similar large increases occurred in the Waterford streams, although their watersheds are smaller in area than Latimer Brook. Besides increases in flow volume, large precipitation events can also affect stream water temperature. A plot of station water temperatures from September 1 through September 7 showed that water temperature decreased by about 3^{o}C rather quickly from the storm's high precipitation (Fig. 10). All stations had relatively similar temperatures, especially during this period of decrease during the high rainfall and flooding. Water temperature fell by about another degree over the next 2 days before rapidly recovering on September 6. SB_Culvert exhibited a slightly larger increase in temperature than did the other stations, but we cannot definitively attribute a cause for this difference and this difference decreased over time. If the SB_Trib Tidbit is recovered, its data may give further insights concerning this result. Figure 10 also shows the diurnal fluctuations in water temperature experienced by these streams, which is a normal occurrence in these relatively small volume water courses.

Do Our Study Streams Meet Temperature Criteria Established for Connecticut Trout Streams?
Even though the work of Cole (2016) and CT DEEP fisheries collections made over many years confirmed populations of brook trout exist in both SB and OMB (which also has brown trout), we examined summer (June 1-August 31) water temperatures to see where these streams fell within the steam classifications proposed by Beauchene et al. (2014). Beauchene et al. (2014) classified Connecticut streams using CT DEEP Fisheries stream survey fish collections and water temperature data during June-August as follows: cold-water streams had a mean water temperature of less than 18.2^{o}C during this period, cool-water streams were between 18.29 and 21.7^{o}C, and warm-water streams were warmer than 21.7^{o}C. These temperature ranges were demonstrated to trigger changes in stream fish communities. Two species, brook trout and slimy sculpin (*Cottus cognatus*), characterized cold-water stream fishes in the state. Warm-water streams were characterized by sunfishes and bullheads. Note, however, that the slimy sculpin has a limited distribution in Connecticut and is mostly confined to the northwestern region of the state, so is not present in southern coastal streams (Kanno and Vokoun 2008).

We were able to determine mean summer 2021 water temperatures at four stations: SB_Culvert, SB_Up, SB_Far, and UNS (Table 11). The SB_Far station Tidbit was put into placed on June 11 (Table 1), so we lacked temperature data for the first 10 days of June, a period which was relatively cooler than later during this time frame. This was exemplified by the higher minimum water temperature of 13.50^{o}C taken at SB_Far in comparison to the other three stations (10.49-11.03^{o}C). SB_Far had the smallest (1.85) standard deviation (SD) around its mean temperature, likely indicating smaller fluctuations in temperature there than at the other three stations, but perhaps this statistic was also affected the lack of data during June 1-10. The other three stations had similar SDs (2.22-2.28). The coolest mean of 18.57^{o}C was found at UNS, followed by SB_Far (18.74^{o}C), SB_Up (19.01^{o}C), and SB_Culvert (19.18^{o}C). Indeed, when water temperature data for SB_Culvert, SB_Far, and UNS were restricted to June 11-August 31, their means increased, SDs decreased, and minimum water temperatures increased (Table 12).

The station means demonstrated that water temperature in SB increases from upstream to downstream. Although having the coolest summer water temperature, the presence of any fish in the un-named stream is not known as it never has been surveyed by CT DEEP. Although we observed this stream to have lower flow volume than both mainstem SB and OMB, perhaps this stream is more influenced by cooler ground water inputs than the other, larger streams. Summer 2021 mean water temperature was not available for SB_Trib due to the loss of its Tidbit from Tropical Storm Ida flooding. However, we believe that fish (excepting perhaps the highly mobile American eel *Anguilla rostrata*) are not likely resident in this stream due to its relatively steep topography, which breaks up this small stream into a series of small pools, falls, and runs into the next pool.

The mean summer water temperatures we found showed that these streams classify as cool-water streams according to the criteria of Buchene et al. (2014). Our means, however, were less than the mid-point of their cool-water temperature range, which is about 20^{o}C. Thus, it is likely that these streams are more similar to a cold-water than a warm-water stream, which enables the persistence of trout populations. Certainly, however, the maximum summer temperatures (range of 23.14-24.03^{o}C) fell within the range of a warm-water stream, but the resident brook trout in SB and OMB apparently can either withstand warmer water temperatures for a short time or there are cooler thermal refugia to be found in these streams that allow for their persistence.

In another analysis of fish and macroinvertebrate populations found in small Connecticut streams having least human disturbances (this research did not include either SB or OMB), Bellucci et al. (2011) reported that 90% of undisturbed steams contained brook trout. They considered brook trout to be a sentinel species for smaller undisturbed streams in Connecticut. Despite Bellucci et al. (2011) noting a lack of undisturbed streams in southern coastal towns of Connecticut, SB and OMB apparently provide the necessary water temperatures and habitat features required by brook trout.

CONCLUSIONS

This report covers approximately the first year of our study, which took place during and following the clearing of trees and construction of roads and stormwater detention basins on the Waterford solar energy site after its approval by the CSC. At the time of this writing, solar energy panels have yet to be erected on the site. The water temperature data and analyses found herein serve to characterize the thermal regimes of these streams and what differences may be found among our study streams (SB, OMB, and UNS). Also examined were water temperatures at several locations within Stony Brook and one of its tributaries. We are using OMB and the farthest upstream site (SB_Far) as control stations, which will be unaffected by any stormwater discharges from the solar energy site, whether by surficial or groundwater inputs. We found some significant differences in water temperature among the streams and within SB locations, which need to be considered as this study proceeds.

We learned a valuable lesson from the passage of Tropical Storm Ida and its associated flooding. The stormwater engineering analysis for the Waterford project used 6.97 in for the 25-year storm event and 7.81 in for the 100-year storm event (VHB 2019). Total precipitation for Tropical Storm Ida was at approximately the mid-point of these modeling storm events, which are supposed to be relatively rare occurrences. This storm caused the loss of two of our Tidbit arrays and many weeks of water temperature data. Whether we can recover one of the Tidbits (SB_Trib) is yet unknown. Going forward we have slightly modified the positioning of several Tidbits to lessen the possibility of future losses or issues. This storm also caused damage to these streams by considerable sedimentation and movement of sand, gravel, stones, and wood debris. Also damaged were stormwater detention basins on the solar site, but it appears that sediments from there were not carried into SB or its tributaries but were retained in forested areas uphill from the streams.

Previous fisheries studies have demonstrated without issue that both SB and OMB are trout streams, simply based on their occurrence and persistence. Our water temperature data fully support the notion that these streams can support the year-round thermal regimes required for trout species. These two streams are important state resources as CT DEEP fisheries surveys have demonstrated that when examining Connecticut coastal towns, nearly all streams that currently support brook trout are only found within New London County (see https://portal.ct.gov/DEEP/Fishing/Freshwater/Freshwater-Fishes-of-Connecticut/Brook-Trout).

This water temperature study will continue until we can demonstrate whether the Waterford solar energy facility has impacted these streams. Thus, periodic retrieval of water temperature data and subsequent analyses will go on for at least several more years, which will include the completion of the solar facility and the first few years of its operation.

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Rondeau of the Eastern Connecticut Conservation District provided the PVC tubes, weights, and other materials needed for the Tidbit arrays. Maureen FitzGerald, Town of Waterford Environmental Planner, gave us key insights with respect to expected solar site stormwater drainage, stream conditions, location of the Tidbit stations, and helped during the data retrieval and SB_Far Tidbit placement on June 11, 2020**.** Joel Stocker supplied the GIS maps used for some of our figures. Gary and Elizabeth DeWolf, homeowners of 82 Oil Mill Road, allowed us access to their property located on OMB. Mr. DeWolf offered advice on stream conditions and Tidbit placements and kindly searched for the Tidbit lost during Tropical Storm Ida flooding. This report was reviewed by Deborah Moshier-Dunn, Steven Trinkaus, and Joel Stocker, who kindly offered suggestions and comments for its improvement.

TABLE 1. Stations and their geographic locations, Tidbit serial numbers, dates of deployments before data recovery, and remarks about the stream water temperature study underway with respect to the solar energy project in Waterford, CT.

Station/Location	Tidbit Serial Number	Deployment Dates	Remarks
Stony Brook by Parkway North Culvert (SB_Culvert) (41.3711ºN / -72.1734ºW)	10593164	11 December 2020 – 11 June 2021 11 June 2021 – 6 January 2022	Tidbit has remained in-place with no issues identified.
Stony Brook upstream (SB_Up) (41.3763ºN / -72.1714ºW)	10593166	11 December 2020 – 11 June 2021 11 June 2021 – 6 January 2022	Tidbit has remained in-place with no issues identified.
Stony Brook far upstream (SB_Far) (41.3797ºN / -72.1699ºW)	10593171	11 June 2021 – 6 January 2022	Site added as is above any influence from the solar development. Tidbit has remained in-place with no issues identified.
Stony Brook Tributary parallel to Parkway North (SB_Trib) (41.3713ºN / -72.1739ºW)	10593165	11 December 2020 – 11 June 2021	Tidbit lost from Tropical Storm Ida flooding on 1-2 September 2020. Will make further search for it in spring of 2022.
Un-named stream near Eversource sub-station (UNS) (41.3759ºN / -72.1890ºW)	10593173	11 December 2020 – 11 June 2021 11 June 2021 – 6 January 2022	Tidbit moved a few yards upstream for the second deployment. Tidbit has remained in-place with no issues identified.
Oil Mill Brook (41.3793ºN / -72.1877ºW) (OMB_1) (41.3800ºN / -72.1869ºW) (OMB_2)	10593174 10593168	11 December 2020 – 11 June 2021 1 October 2021 – 6 January 2022	Tidbit lost from Tropical Storm Ida flooding on 1-2 September 2020 and believed not recoverable. Replaced for the second deployment at a location upstream of the initial placement; now upstream of the confluence with Willy's Meadow Brook.

TABLE 2. Results of a one-way analysis of variance (ANOVA) comparing ambient air temperatures (^oC) recorded by the five Tidbits initially used in the Waterford long-term water temperature study before their placement into the streams.

Tidbit Serial Number	*Count*	*Sum*	*Mean*	*Variance*
10593164	70	1448.471	20.692	0.0942
10593165	70	1446.393	20.663	0.0935
10593166	70	1447.183	20.674	0.0935
10593173	70	1446.59	20.666	0.1170
10593174	70	1448.63	20.695	0.1111

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.0623	4	0.0156	0.1523	0.962 NS	2.398
Within Groups	35.152	345	0.1019			
Total	35.21421	349				

NS = not significant

TABLE 3. Correlations among hourly water temperatures recorded at five stations of the Waterford long-term water temperature study from December 11, 2020 through June 11, 2021 (n = 4,161 observations).

Station	SB_Culvert	SB_Trib	SB_Up	UNS	OMB_1
SB_Culvert	1				
SB_Trib	0.976	1			
SB_Up	0.995	0.975	1		
UNS	0.993	0.990	0.992	1	
OMB_1	0.996	0.981	0.993	0.995	1

TABLE 4. Results of a one-way analysis of variance (ANOVA) comparing water temperatures (^oC) recorded at five stations of the Waterford long-term water temperature study from December 11, 2020 through June 11, 2021.

Groups	*Count*	*Sum*	*Mean*	*Variance*
SB_Culvert	4361	30467.826	6.986	33.817
SB_Trib	4361	34988.718	8.023	14.516
SB_Up	4361	30327.965	6.954	30.107
UNS	4361	29776.651	6.828	26.408
OMB_1	4361	33558.790	7.695	28.858

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	4882.803	4	1220.701	45.648 **	2.99914E-38
Within Groups	582961.244	21800	26.741		
Total	587844.047	21804			

** = highly significant

TABLE 5. Results of a one-way analysis of variance comparing water temperatures (^oC) recorded at four stations of the Waterford long-term water temperature study from December 11, 2020 through June 11, 2021.

Groups	*Count*	*Sum*	*Mean*	*Variance*
SB_Culvert	4361	30467.826	6.986	33.817
SB_Up	4361	30327.965	6.954	30.107
UNS	4361	29776.651	6.828	26.408
OMB_1	4361	33558.79	7.695	28.858

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2012.044	3	670.681	22.508 **	0.000	2.605
Within Groups	519671.564	17440	29.798			
Total	521683.608	17443				

** = highly significant

TABLE 6. Results of a one-way analysis of variance (ANOVA) comparing water temperatures (^{o}C) recorded at three stations of the Waterford long-term water temperature study from December 11, 2020 through June 11, 2021.

SUMMARY

Groups	*Count*	*Sum*	*Mean*	*Variance*
SB_Culvert	4361	30467.826	6.986	33.817
SB_Up	4361	30327.965	6.954	30.107
UNS	4361	29776.651	6.828	26.408

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	61.242	2	30.621	1.017 NS	0.362	2.996
Within Groups	393850.603	13080	30.111			
Total	393911.84	13082				

NS = not significant

TABLE 7. Results of a t-test comparing water temperatures (^{o}C) recorded at two stations of the Waterford long-term water temperature study from December 11, 2020 through June 11, 2021.

	SB_Trib	OMB_1
Mean	8.023	7.695
Variance	14.516	28.858
Observations	4361	4361
Hypothesized Mean Difference	0	
df	7861	
t Stat	3.288 **	
P(T<=t) one-tail	0.001	
t Critical one-tail	1.645	
P(T<=t) two-tail	0.001	
t Critical two-tail	1.960	

** = highly significant

TABLE 8. Results of a one-way analysis of variance (ANOVA) comparing water temperatures (^{o}C) recorded at three stations of the Waterford long-term water temperature study from December 11, 2020 through January 6, 2022.

SUMMARY

Groups	*Count*	*Sum*	*Mean*	*Variance*
SB_Culvert	9379	101064.296	10.776	50.012
SB_Up	9379	100767.670	10.744	47.329
UNS	9379	99260.246	10.583	44.177

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	199.556	2	99.778	2.12 NS	0.121	2.996
Within Groups	1327147.754	28134	47.172			
Total	1327347.310	28136				

NS = not significant

TABLE 9. Results of a t-test comparing water temperatures (^{o}C) recorded at two stations of the Waterford long-term water temperature study from June 11, 2021 through January 6, 2022.

	SB_Up	*SB_Far*
Mean	14.037	13.765
Variance	38.994	36.057
Observations	5015	5015
Pearson Correlation	0.997	
Hypothesized Mean Difference	0	
df	5014	
t Stat	37.351 **	
P(T<=t) one-tail	0.000	
t Critical one-tail	1.645	
P(T<=t) two-tail	0.000	
t Critical two-tail	1.960	

** = highly significant

TABLE 10. Regression model predicting water temperature (^{o}C) at SB_Culvert as a function of the water temperature recorded at the two OMB stations. Data used were from the Waterford long-term water temperature study from December 11, 2020 through June 11, 2021 and October 1, 2021 through January 6, 2022.

Regression Statistics	
Multiple R	0.997
R Square	0.993
Adjusted R Square	0.993
Standard Error	0.459
Observations	6685

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	200681.743	200681.743	952874.9**	0
Residual	6683	1407.484	0.211		
Total	6684	202089.227			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.403	0.011	-131.435**	0	-1.424	-1.382
OMB	1.084	0.001	976.153 **	0	1.082	1.086

** = highly significant

TABLE 11. Mean, minimum, and maximum water temperature (^{o}C), standard deviation of the mean, and number of observations at four stations of the Waterford long-term water temperature study during June 1 through August 31, 2021.

	SB_Culvert	SB_Up	SB_Far	UNS
Mean temperature	19.18	19.01	18.74	18.57
Minimum	11.03	10.86	13.50	10.49
Maximum	23.55	24.03	23.14	23.30
Standard deviation	2.22	2.28	1.85	2.24
Observations	2208	2208	1957[a]	2208

[a] Data collection began at SB_Far on June 11, 2021.

TABLE 12. Mean, minimum, and maximum water temperature (^{o}C), standard deviation of the mean, and number of observations at three stations of the Waterford long-term water temperature study during June 11 through August 31, 2021.

	SB_Culvert	SB_Up	UNS
Mean temperature	19.45	19.35	18.90
Minimum	13.83	13.38	13.16
Maximum	24.03	24.03	23.30
Standard deviation	2.00	2.10	1.99
Observations	1957	1957	1957

FIGURE 1. Stormwater detention basins located within the Waterford solar energy site.

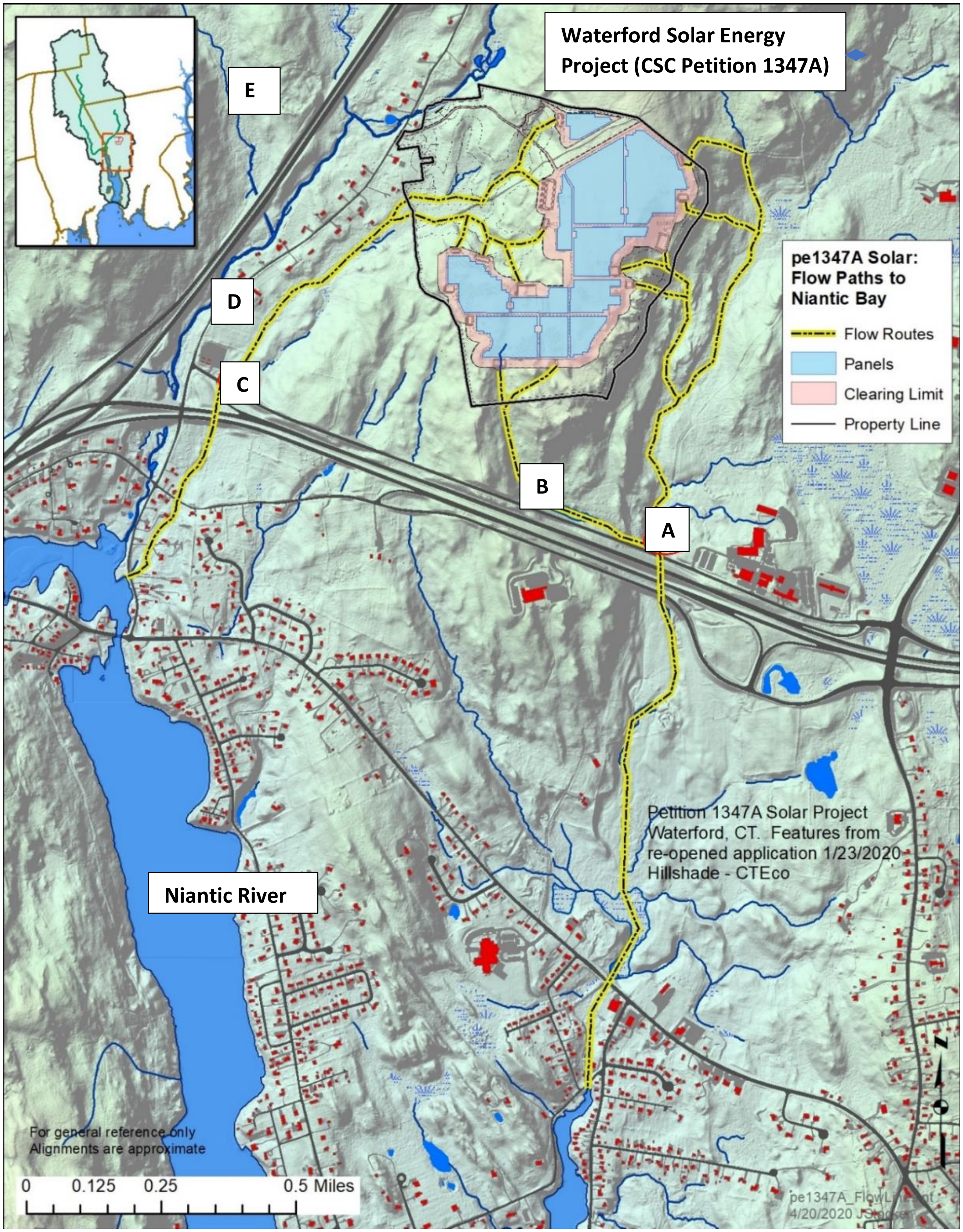


FIGURE 2. Location of the Waterford solar energy project at 117 Oil Mill Road, Waterford in relation to local water bodies: A is Stony Brook, B is the Stony Brook un-named tributary, C is the Un-named stream, D is Oil Mill Brook, and E is Willy's Meadow Brook. Yellow highlighting over black dashed lines illustrate potential routes for stormwater flows from the solar site into streams ultimately discharging into the Niantic River.

FIGURE 3. Waterford solar energy site cleared of trees and other vegetation and the surrounding forested area.

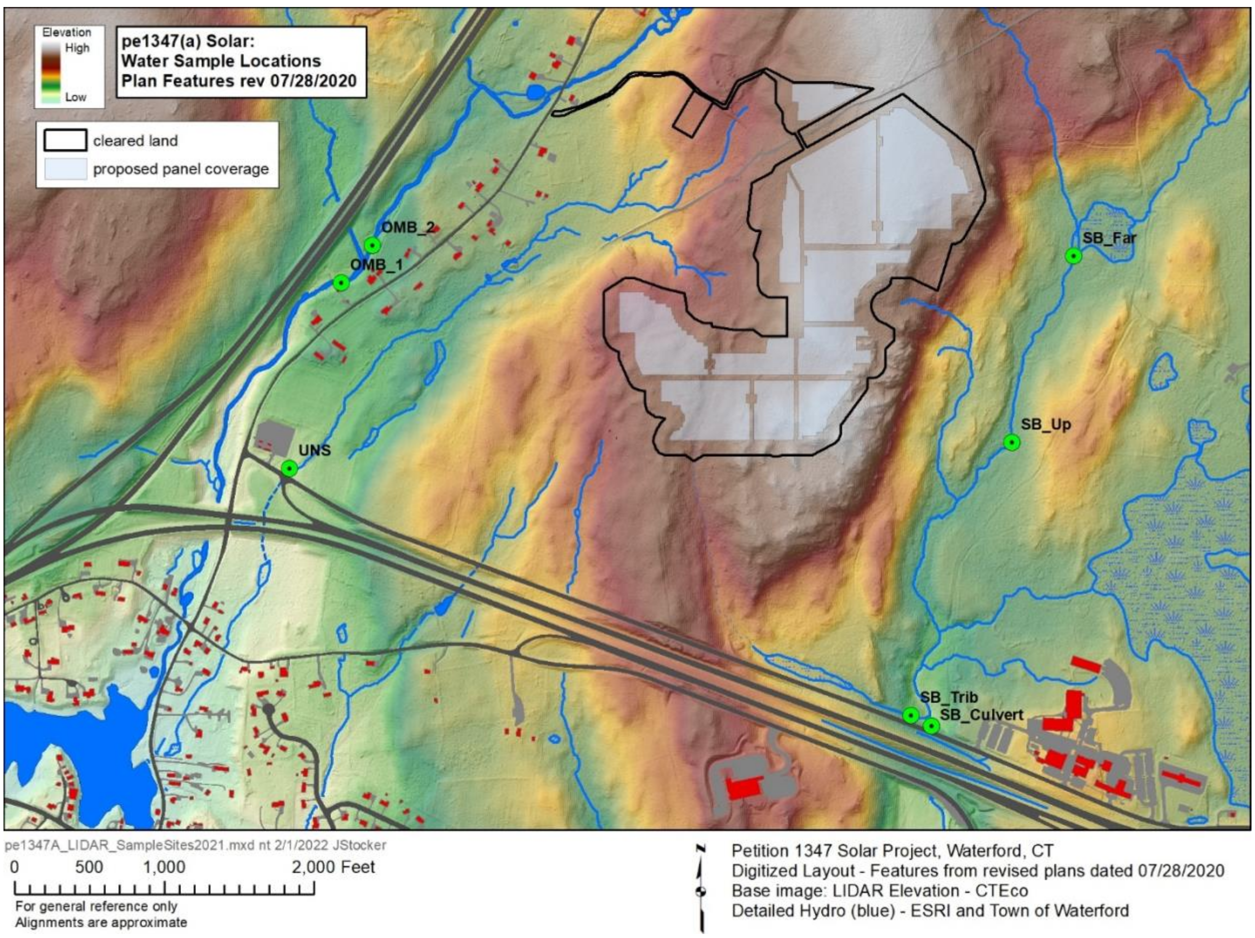


FIGURE 4. Locations of the stations used in the Waterford water temperature study: SB_Culvert, SB_Trib, SB_Up, SB_Far, UNS, OMB_1, and OMB_2.

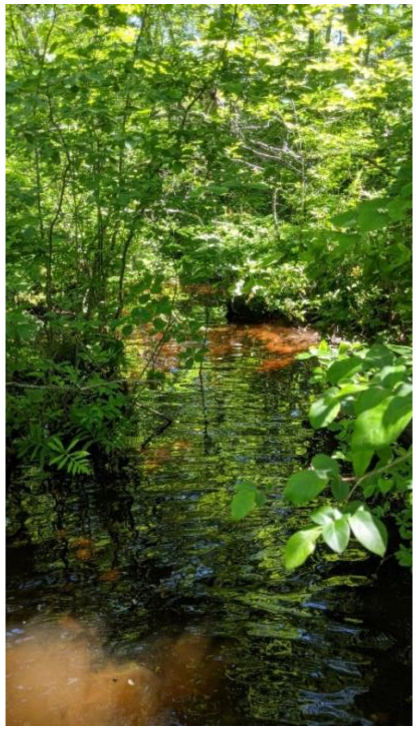
SB_Culvert

SB_Up

SB_Trib

UNS

OMB_1



SB_Far

OMB_2

FIGURE 5. Photographs of Tidbit placement locations at the stations used in the Waterford water temperature study.

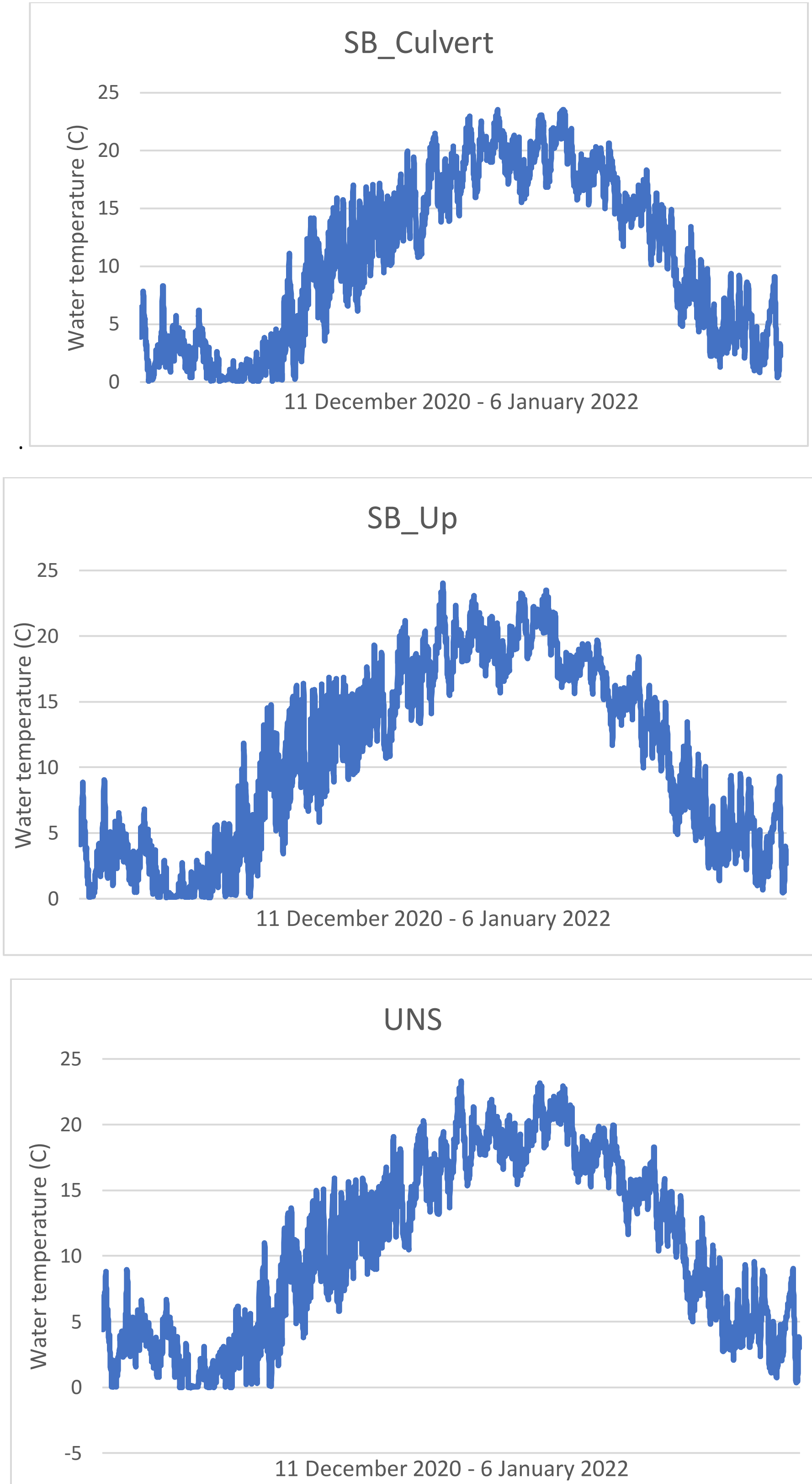


FIGURE 6. Water temperatures (^{0}C) recorded continuously at three stations used in the Waterford water temperature study from December 11, 2020 through January 6, 2022.

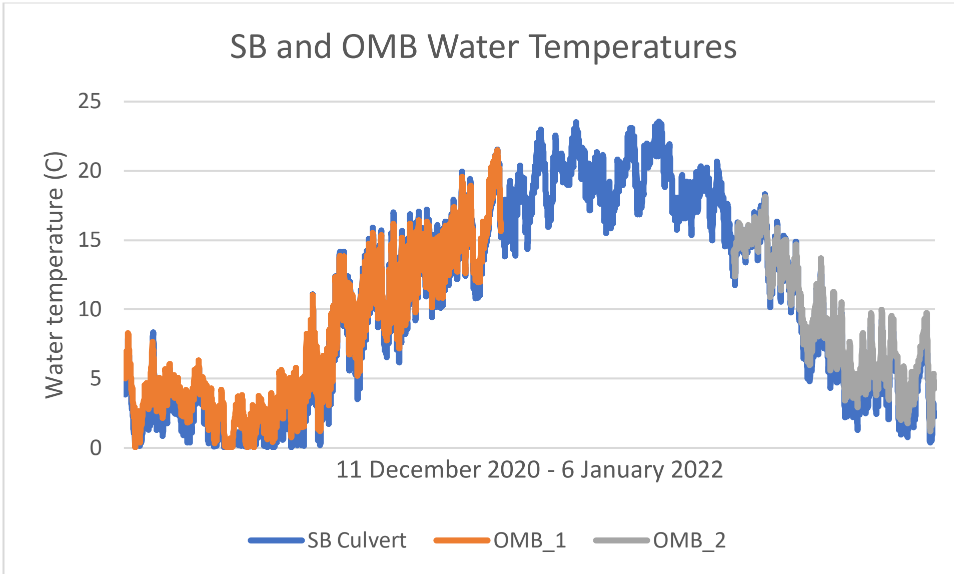


FIGURE 7. Comparison of water temperatures (^{o}C) recorded continuously during the Waterford water temperature study at SB_Culvert and OMB_1 and 2 from December 11, 2020 through January 6, 2022.

FIGURE 8. Damage to a stormwater basin on the Waterford solar energy site due to heavy precipitation from Tropical Storm Ida, which occurred on September 1-2, 2021.

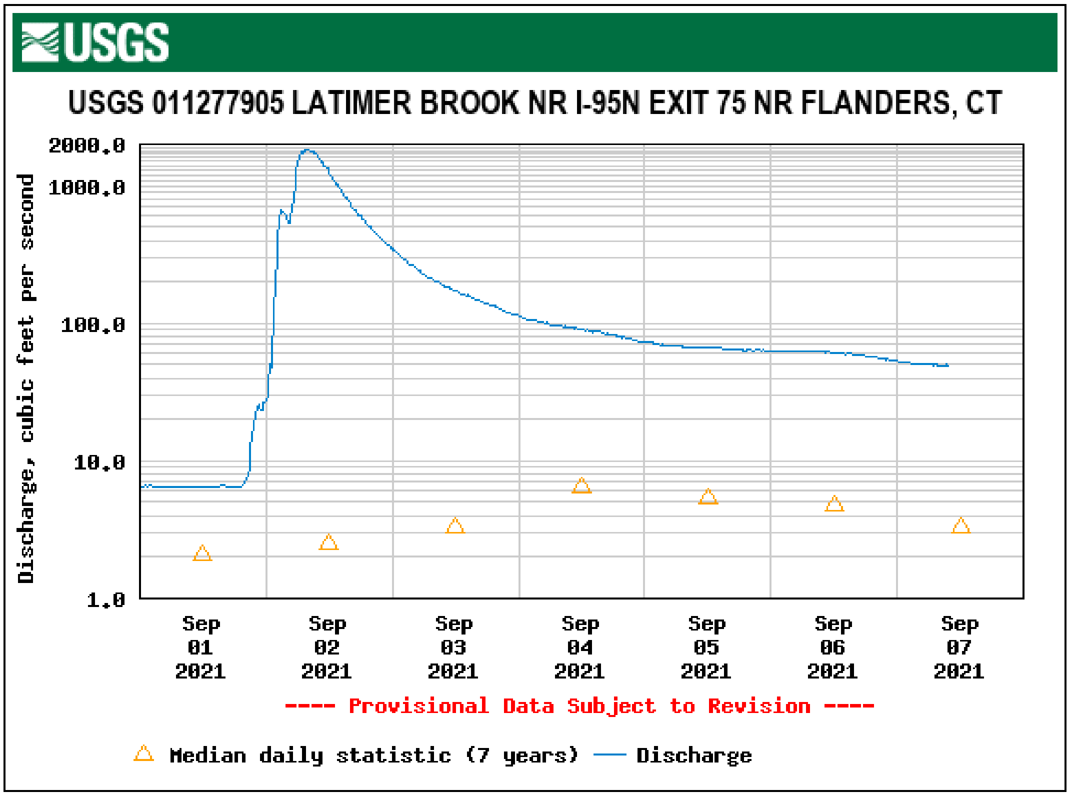


FIGURE 9. Stream discharge (cfs) as measured by the United States Geological Service water flow gage located in lower Latimer Brook below the Flanders dam in East Lyme from September 1 through September 7, 2021, the time period just before and after the passage of Tropical Storm Ida.

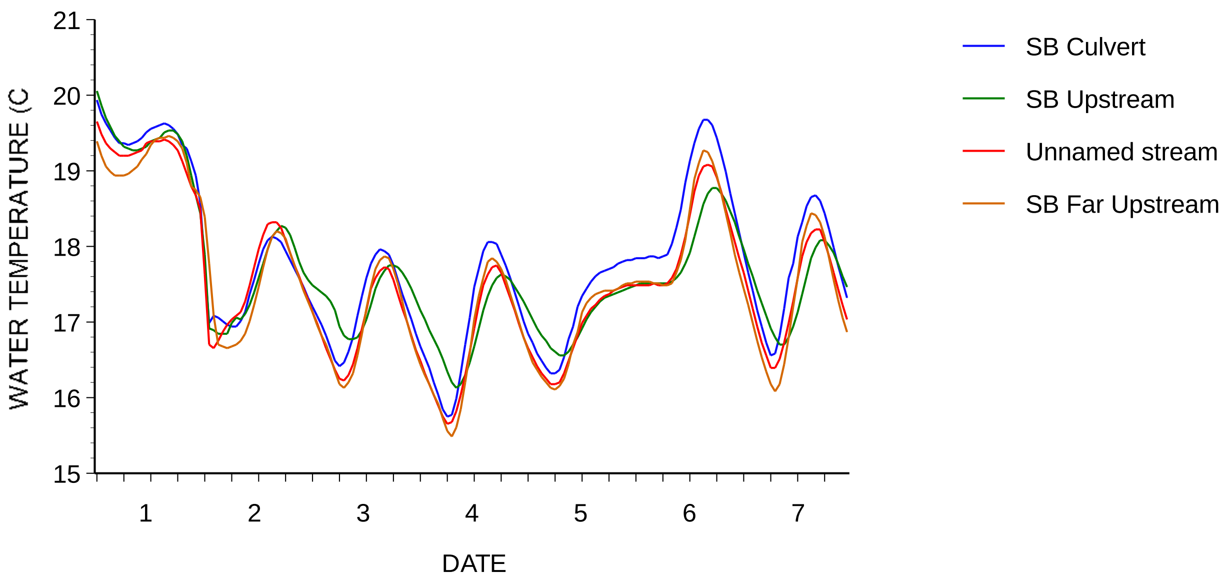


FIGURE 10. Water temperatures (°C) recorded during the Waterford water temperature study at four stations from September 1 through 7, 2021, just prior to and after the passage of Tropical Storm Ida with its associated heavy precipitation and flooding event.