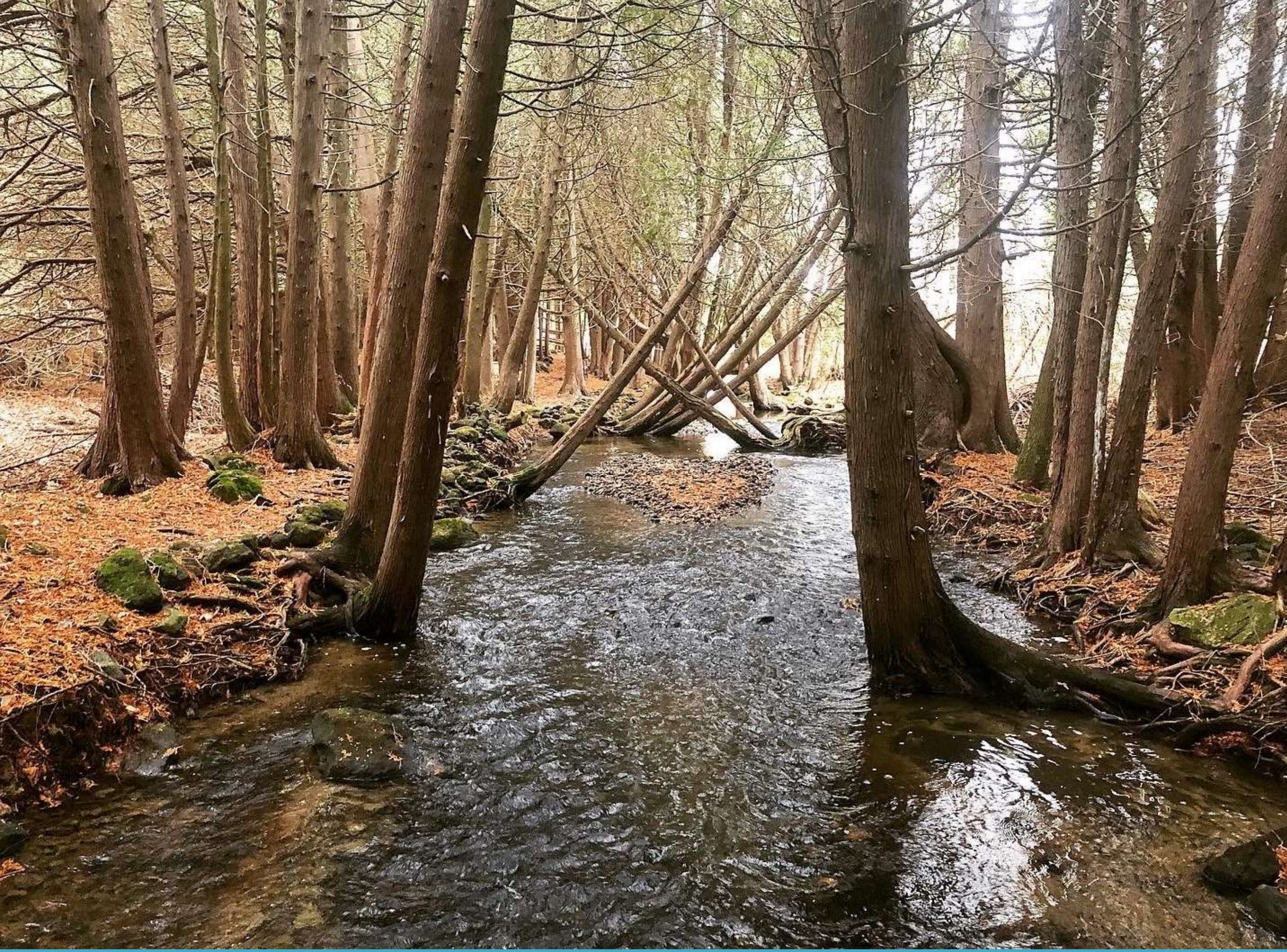

Water Temperature Data Analysis

Water Temperature Metric Update 2022

Conservation Halton

March 2022

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Rationale

Water temperature is the driving force behind many processes that occur within aquatic ecosystems. It is responsible for initiating fish spawning, embryo growth and development, stress, migration patterns, general species abundance and distribution, water chemistry and quality, nutrient loading, and ice dynamics (Caissie 2006; Prowse 2001a, Prowse 2001b). Monitoring water temperature can provide an indication of which fish communities and species may be present, ground water influences, and how other environmental and anthropogenic features are affecting stream temperatures. Water temperature is influenced by environmental factors such as yearly and seasonal weather trends, latitude and longitude of the area, and upstream channel features such as on-line ponds, SWM ponds, increased impervious cover, and lack of riparian shading. These influences are what caused a further investigation into other water temperature metrics, and how those metrics should be incorporated into our past and present water temperature data.

Conservation Halton (CH) has been monitoring water temperature since 2005. Throughout this time, both the Stoneman (1996) and Chu (2009) classification systems have been used to classify stations and stream reaches into specific thermal regimes. The Stoneman classification has three thermal classifications (Cold, Cool, Warm) and uses water temperatures at 16:30 hours when air temperatures are above 24.5°C during the months of July, August and the first week of September. In contrast, the Chu method consists of five thermal classifications (Cold, Cold-Cool, Cool, Cool-Warm, Warm) and uses water temperatures between 1600-1800 hours when air temperatures are above 24.5°C during the months of July and August. The Stoneman classification system was originally used by Conservation Halton staff, but when the Chu classification system was developed in 2009 it was adopted as it is better able to identify potential thermal stress through the use of transitional thermal zones.

There are many factors that influence water temperature, such as anthropogenic impacts (urbanization, agriculture, stream realignment, dams), climactic trends (wet versus dry years), riparian vegetation, ground water sources, water taking, and so on. Because water temperature can be impacted by a wide variety of activities, it is helpful to examine additional metrics beyond the standard thermal classification systems current in use. This will allow for a better understanding of how water temperatures are changing over time and capture fine scale changes that may not be seen using the classification system. The purpose of this document is to provide context and reasoning for the changes made to water temperature analysis within the Monitoring Ecology group. This document will also cover protocols used for comparing pre and post restoration data. Going forward, reporting will consist of one reference classification (Aquatic Ecosystem Classification) with three main reporting metrics (Thermal Classifications, Thermal Guilds and July Maximums). Additional metrics (Rate of Change, Species Specific Metrics and Days over 30°C) are also identified and will be used based on project scope and deliverables.

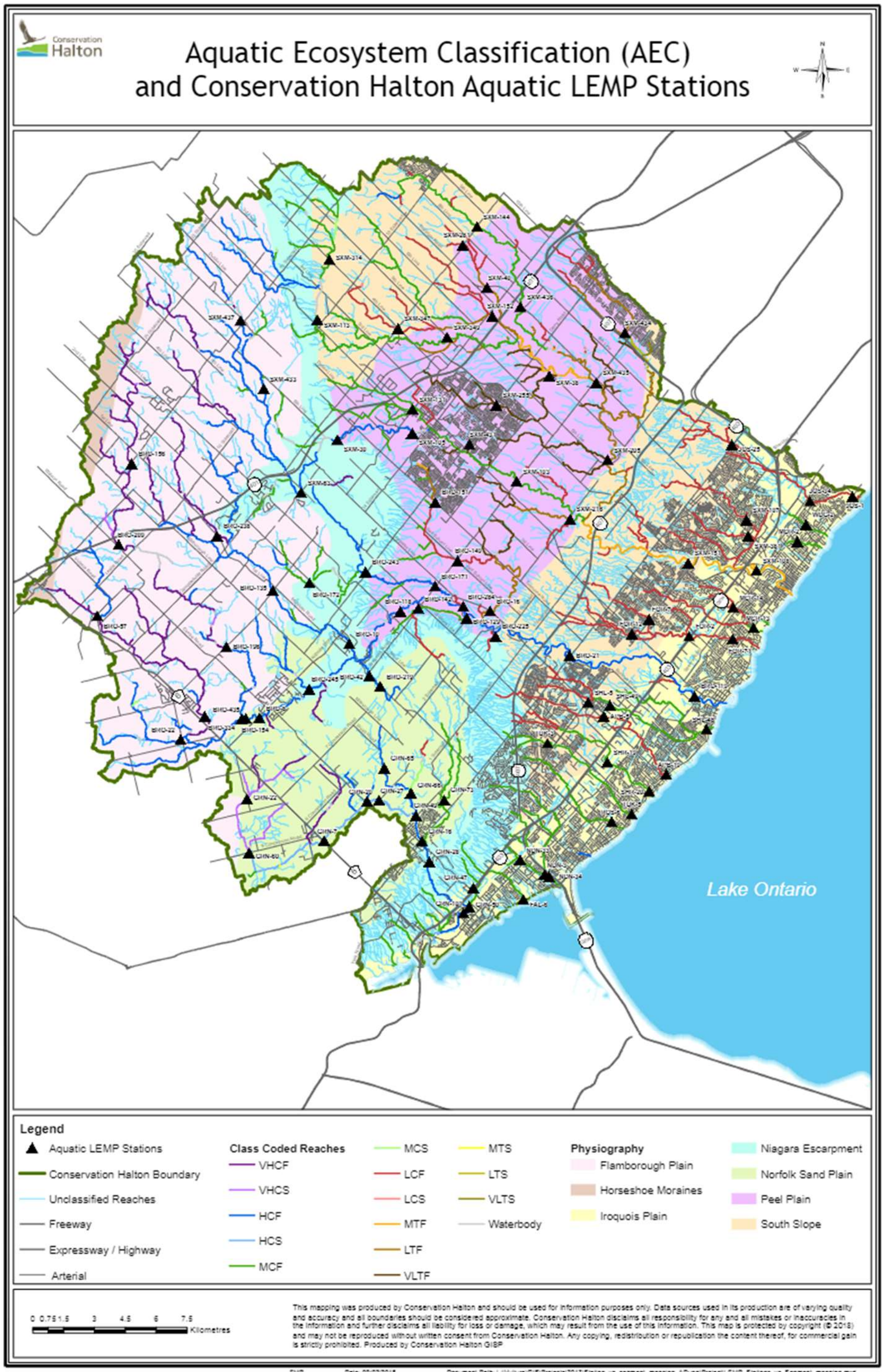
Reference Condition

Aquatic Ecosystem Classification

The Aquatic Ecosystem Classification (AEC) is a thermal stream classification, created in 2019 (Version 1), by Jones and Schmidt, and encompasses all Ontario streams. It is a science-based tool which classifies streams and rivers based on physical elements such as water temperature, and watershed traits such as upstream drainage area, physiography, soils etc. Version 2 was released in 2022.Both versions include Ontario Integrated Hydrology from 2014 as the primary spatial source data and a 30-year climate model data set from agencies across Ontario. The AEC is to be utilized as a resource management tool to inform inventory and monitoring efforts, identify habitat of highly valued species (such as species at risk and invasives species), and aids with park development and land use planning

(Jones and Schmidt 2022). It is widely used throughout Ontario by various agencies and will act as a reference point when analyzing temperatures and trends within Conservation Halton's monitoring sites. The Aquatic Ecosystem Classification will be used as a reference guideline of what streams characteristically (in theory) 'should' resemble.

Each water temperature monitoring site within the CH jurisdiction has an assigned AEC classification found in Appendix 2.



Accompanying Considerations: Climactic Variation

Temperature data provides a greater understanding of localized impacts and stream condition. It is important to compare water temperature data with local weather conditions such as precipitation and air temperature as these can both have an influence on the variability in the temperature data.

In 2019, all thermal monitoring sites were assigned to specific Conservation Halton climate stations. A list of sites with assigned gauges can be found in Appendix A.

It is important to characterize the influence of annual variations in air temperature/precipitation and stream discharge as they affect watershed conditions on an annual basis. The most logical way would be to look at archived metrics from local weather and flow gauging stations.

Metrics that would be useful to look at include the following:

1) Monthly and annual precipitation

The total yearly precipitation will be analyzed to identify if that specific year would be considered to be a dry year, normal year or wet year. This could help to understand annual variation with thermal regimes for individual sites. For instance, dry years may show some sites as being colder due to having more ground water inputs than rainfall contributions.

Spring and summer (March–August) precipitation can also be analysed for a more direct influence on summer flow regime than above. These calculations will be analysed to see the effects of rainfall accumulation on the temperature of the stream. Therefore, as mentioned above, could help identify wetter or dries than usual springs and summers, will help to further understand the thermal regime variation fluctuations, and the way in which each site individually responds.

2) Average or mean of the daily maximum July-August air temperatures

Daily maximums will be analyzed to see how each site reacts and responds to fluctuating air temperatures. These temperatures may show us when air temperatures reach a certain point, how the stream reacts, if critical thermal maximums are met and if there are refuge areas upstream or downstream depending on proximity to other sites. These air temperatures can also be compared to the minimum/maximum/average water temperatures, to see how they compare to each other, and the creeks response to the fluctuating air temperatures.

3) Number of days over 30°C

The number of days in July and August with air temperature over 30°C will be analyzed to see the effects of extreme heat days over time. Tracking the number of days greater than 30°C over time can help identify stress periods within our streams. This could help in highlighting thermal hot-spot areas within our streams that could benefit from restoration work to mitigate increased water temperatures (increased riparian plantings, online pond removals etc.).

Review Process

A literature review was completed to examine thermal classifications and analysis done by other organizations. Additionally, meetings were held with both internal staff and external agencies to discuss different thermal monitoring methods. Review of the program focused on protocol updates/changes, analytical tools, metrics, and interpretation. The review primarily focused on:

1) Temperature Nomograms

2) Thermal Guilds

3) July and August Minimum/Mean/Maximum

Calculations

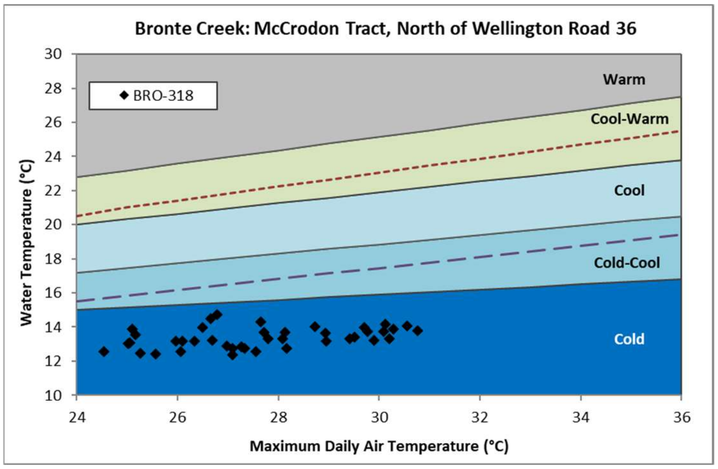
Primary Reporting Metrics

Three different metrics will be calculated for each water temperature monitoring station. These include a thermal classification, a thermal guild, and July mean. These metrics will be reported on internal and external documents. Story maps will consist of thermal classifications only, to be consistent with previous years. Other documents such as internal communications with the Landowner Outreach Restoration (LOR) team, will have all three metrics reported on. Municipality based documents will use a combination of the three metrics depending on scope and deliverables that best suite the needs of the individual municipality or project.

Thermal Classification

Since Conservation Halton began regular temperature monitoring as part of its Long-term Environmental Monitoring Program (LEMP), analysis of the results was based on the Stoneman and Jones (1996) spot temperature methodology, which classified temperatures using a thermal nomogram. Classifications are based on water temperature readings from July 1st to September 7th on days where air temperature is greater than 24.5°C at 't 4:30pm. Classification from this methodology results in three categories (Cold, Cool, Warm). Updates to the Stoneman and Jones methodology were completed as part of Chu et al. (2009), which was then incorporated in 2009 as the main analytical tools for the temperature data analysis. This method classifies each stream site into 5 different categories: Cold, Cold-Cool, Cool, Cool-Warm, and Warm and better reflects thermal transitional zones, absent from Stoneman and Jones. To complete the analysis, a modified nomogram was created using the formulas derived from the y-intecept/slope with the dashed lines representing the Stoneman and Jones (1996) classification and the colour blocks representing Chu et al. (2009). This format allows for both methods to be quantified if needed, based on the same data. To assign classifications using the nomograms, the number of data points that fall within each category are counted and then it is classified based on the category with the highest number of data points within it.

Figure 1: Nomogram of site BRO-318



While thermal classifications are important for the overall understanding of the conditions within a stream reach, it provides little detail as to the specific impacts or stressors that may be occurring at a more local scale. As a result, further evaluation beyond the stream classification is needed to clearly understand conditions at a site.

Analysis of thermal classifications is recommended at all monitored sites.

Thermal Guilds

Thermal classes (temperature preferences of all fish species) from Coker et al. (2001) were incorporated into the analysis. These preferences will be used to determine an overall thermal guild classification, which can be used to summarize suitability when using data from June 1 to August 31, the most thermally stressful period of the year for aquatic communities. Thermal guilds are categorized as Cold (<19°C), Cool (19-25°C) and Warm (>25°C). It should be noted that this method pertains to fish species thermal preferences) and uses the more traditional 3 class system. This is reported as a proportion of data that can be categorized into each thermal guild classification (Cold, Cool, Warm).

These ranges indicate the percent of time that a station would support fish species requiring each of the three guilds. For example, in the chart below, SXM-95 was in the Cold guild 100% of the time and would support coldwater species throughout the monitored period. SXM-93 was within the Cold guild 10% of the time and would only support coldwater species for a very short part of the monitoring period. The difference between these two sites, which are from a property where stream restoration is scheduled to take place, demonstrates the need to take the online pond, offline. Using thermal guild charts, like those below, add more of a robust statement when it comes to proving where restoration efforts are needed.

The calculations are done by sorting all data collected in the specified time frame (June 1 to August 31) into their categories (cold/cool/warm) and dividing the number of records in each thermal class by the total number of records of all three classes (excluding null values) and multiply by 100 to get a percentage of each class.

Analysis of thermal guilds is recommended at all temperature stations.

Figure 2: SXM-95 Thermal Guild Chart

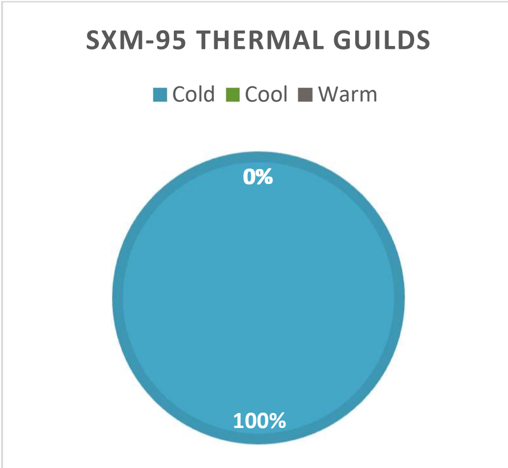
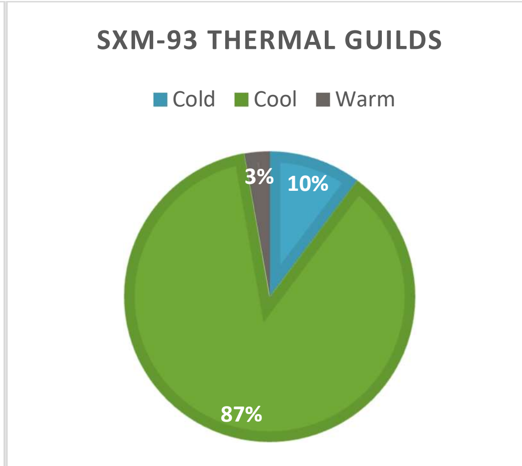


Figure 3: SXM-93 Thermal Guild Chart



July and August Minimum/Maximum/Averages

It is important to monitor thermal trends within our waterbodies, especially when it comes to stenotherm species. These species are only capable of surviving within a narrow temperature range. Examples of these species are trout, sculpins, and some cyprinid species such as Pearl and Redbelly Dace. Theses species respond to extremes in daily maximum summer temperatures, and monitoring these metrics are commonly used in describing and classifying river and stream reaches to capture this side of physiological and ecological importance. Analyzing these metrics can also tell us if there are ground water influences in the area, how air and precipitation is affecting the streams temperatures, and which lethal limits are met regarding certain fish species such as Brook Trout. July Maximums may be used at sites when thermal classifications are rising, and thermal peaks may need to be identified. These values are easily extracted from DataCurrent once data has been uploaded into the database.

Analysis of July means is recommended at all temperature stations. Associated min/max/mean data for July and August is also recommended as part of the data analysis to support future long-term analysis. This additional data is not recommended for annual reporting.

Additional Calculations

Supplementary calculations may be added depending on project scope and deliverables. These include examining the rate of change and species-specific metrics. The rate of change metric will be used for restoration sites where an online pond, weir or dam has been decommissioned. Species specific metrics will be used when a restoration project has occurred in an area where there have been historical or present records of a species at risk or sensitive species (such as American Eel, Brook Trout Silver Shiner or Redside Dace). These metrics are important to compare especially when considering compensation projects and specific grant deliverables. This data can be compared against other climate metrics such as the number of days with air temperature over 30°C. This will help to track climate variability and the associated in-stream thermal changes that can be observed as a result.

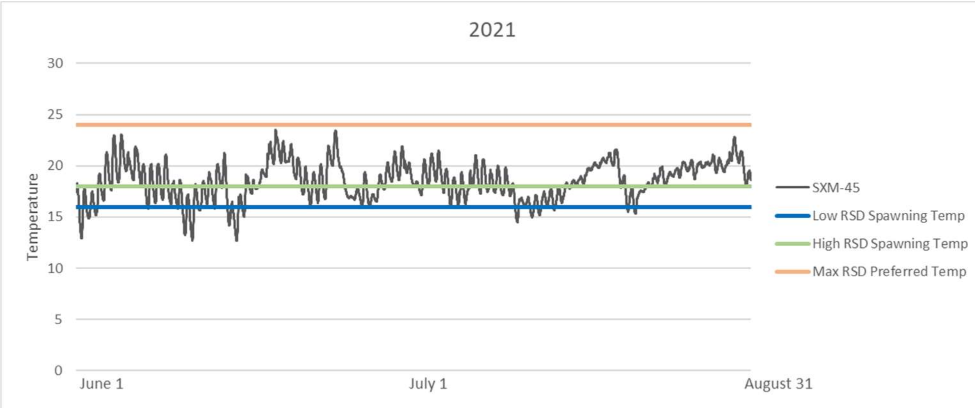
Rate of Change

The rate of change metric is used to understand how quickly temperature changes in a stream by examining the difference in water temperature from one hour to the next for a set period of time. Analyzing this thermal trend in our watershed is important to understand areas of high importance for restoration and is also a means to evaluate restoration efforts. When evaluating a restoration project such as an online pond removal, it is important to illustrate the impact that the pond is having on the stream by looking at the temperature regime upstream in comparison to the temperature regime downstream of the pond. A rate of change calculation was added to the temperature metrics so that restoration projects can be further analyzed for pre and post construction success. This calculation can also be used in regular LEMP analysis when looking at species specific sites, to observe how the creek changes, which lethal limits may be met and how fast. A stream that fluctuates frequently with high variability could affect fish species and distribution as well as reproduction, nursey success and embryo development. Literature reviewed by Metcalfe et al. (2013) found that Minor rates of change have been found to induce physiological stress which impacts metabolism (Wedemeyer 1973), slows growth rates, and increases both predation (Coutant 1973) and presence of diseases (Wedemeyer and McLealy 1981). Reducing the heating and cooling rate allows for better acclimation so that fish can adjust to the new temperature regime (McCullough 1999).

This metric is used to monitor the monthly means of daily maximum hourly rates of change for the time period in question. Analysis of the rate of change should be completed at restoration sites where impoundments to water are resulting in thermal impacts. This will help quantify the efforts over years monitored at the restoration project, and to monitor its pre and post construction effects on the stream.

Species Specific Metrics: SAR projects (American Eel, Brook Trout, Redside Dace, Silver Shiner)

All species vary with respect to temperatures, tolerances, and preferences. For this reason, species specific temperature metrics will be looked at when dealing with species specific projects. These projects could be part of restoration, ecology, or development monitoring. Aquatic species at risk of interest within Conservation Halton are: American Eel, Redside Dace and Silver Shiner. In addition, Brook Trout are an important species to monitor as they are an indicator species and are an important part of preserving our cold-water streams. Thermal preferences (e.g., low, high or max spawning temp preferences) may vary depending on life stages of development, including spawning, nursery or resident requirements. Depending on the scope of the project and target species, thermal preferences found in Appendix C should be applied. An example of evaluation of thermal preferences for Redside Dace can be seen at site SXM-45 in Figure X.



Conclusion

Monitoring stream temperature is crucial when trying to detect fish community assemblages, changes in species at risk habitat suitability, climate change trends and impacts from urbanization. When monitoring water temperature, it is best to analyze temperature data with more than one metric, for a comprehensive understanding of these thermal trends, fluctuations, and habitat restraints. To do so updates to Conservation Halton water temperature monitoring program will see the following updates:

- Create a larger understanding of climatic impacts on water temperature by completing seasonal air temperature and precipitation calculations. Annual calculations can be compared against long-term seasonal values to classify climate conditions.
- Expand LEMP monitoring to include metrics discussed in this document.
- To include metrics within this document in restoration monitoring reporting and communications.
- Continue to assess water temperature data gaps by analyzing areas where historical data is deficient, and where additional data is needed (ex for restoration projects, future development areas).
- Continue to monitor Species at Risk habitat and highlight thermal restraints, which would consequently identify restoration opportunity areas.

By implementing this new way of analyzing water temperature, we hope to provide further information as to how our streams are reacting to environmental and anthropogenic variations, in addition to highlighting areas where restoration is needed. Conservation Halton will continue to assess ways of analyzing water temperature and continue to communicate with local Conservation Authorities to ensure we are synchronous with the most recent and up to date scientific analysis.

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Appendix A: Stations locations with associated gauge stations

Station	Watershed	Easting	Northing	Station Locality	Gauge Station	After 2011	After 2016
APB-19	Appleby Creek	601856.40	4801791.96	Upstream of Lakeshore Road, east of Appleby Line between Edgecliff place and Colonial drive	Burlington Pier	Fourteen (2011)	Mainway (2016)
APB-5	Appleby Creek	598815.17	4804620.18	Downstream of Mainway Road just east of Appleby Line	Burlington Pier	Fourteen (2011)	Mainway (2016)
BRO-10	Bronte Creek	586454.01	4808161.63	~30m upstream of #8 Sideroad	Admin (2006)	Admin (2006)	Admin (2006)
BRO-118	Bronte Creek	588937.79	4809729.36	Directly upstream of pedestrian bridge on the furthest downstream end of Lowville Park	Admin (2006)	Admin (2006)	Admin (2006)
BRO-119	Bronte Creek	603223.61	4805589.19	Petro Canada Park, middle braid upstream of Rebecca Street starting at bottom of small island to the west	Burlington Pier	Fourteen (2011)	Fourteen (2011)
BRO-129	Bronte Creek	592152.50	4809404.74	~80m downstream of #4 Sideroad	Admin (2006)	Admin (2006)	Admin (2006)
BRO-135	Bronte Creek	582734.60	4810731.76	Directly upstream of Steeles Avenue- 2nd stream crossing to the west of First Line	Mountsberg (2006)	Mountsberg (2006)	Mountsberg (2006)
BRO-142	Bronte Creek	589803.08	4809856.55	Upstream side of Britannia Road, 1st crossing west of Walkers Line	Admin (2006)	Admin (2006)	Admin (2006)
BRO-149	Bronte Creek	591717.84	4812187.50	~50m downstream of Britannia Road.	Admin (2006)	Admin (2006)	Admin (2006)
BRO-151	Bronte Creek	590626.96	4815026.13	On either side of Tremaine Road, south of Derry Road	Admin (2006)	Admin (2006)	Kelso (2016)
BRO-156	Bronte Creek	575867.25	4816917.24	~65m downstream of 15th Sideroad, west of Moffat	Mountsberg (2006)	Mountsberg (2006)	Mountsberg (2006)
BRO-16	Bronte Creek	593288.89	4809738.81	Appleby Line stream crossing, north of #2 Sideroad.	Admin (2006)	Admin (2006)	Admin (2006)
BRO-171	Bronte Creek	590618.93	4810956.65	Upstream of Britannia road stream crossing, west of Appleby Line.	Admin (2006)	Admin (2006)	Admin (2006)

BRO-172	Bronte Creek	584517.64	4811105.84	~95m upstream of Twiss Road calcium pits on the west branch.	Admin (2006)	Admin (2006)	Admin (2006)
BRO-196	Bronte Creek	580475.70	4807991.96	~50m downstream of entrance to Lawson Park campground on 11th Con E, west of Milborough Line	Mountsberg (2006)	Mountsberg (2006)	Mountsberg (2006)
BRO-209	Bronte Creek	575233.00	4812979.33	~25m downstream of walking bridge behind #4135 Watson Road	Mountsberg (2006)	Mountsberg (2006)	Mountsberg (2006)
BRO-21	Bronte Creek	597156.83	4807588.66	Upstream of Dundas Road (HWY 5) stream crossing.	Lake or Admin	Fourteen (2011)	Fourteen (2011)
BRO-219	Bronte Creek	587942.88	4806079.55	Directly downstream of Cedar Springs Road at U-shaped crossing	Admin (2006)	Admin (2006)	Admin (2006)
BRO-22	Bronte Creek	578246.12	4803484.41	~80 m upstream of Brock Road, north of 8th Concession West	Admin (2006)	Admin (2006)	Admin (2006)
BRO-225	Bronte Creek	593554.99	4808500.76	~460m upstream from the confluence with main Bronte Creek, downstream of #2 Sideroad	Admin (2006)	Admin (2006)	Admin (2006)
BRO-238	Bronte Creek	580014.00	4813387.00	Upstream of First Line, downstream of CPR tracks to CPR culvert	Mountsberg (2006)	Mountsberg (2006)	Mountsberg (2006)
BRO-243	Bronte Creek	587237.69	4811644.01	~126m upstream of Derry Road east of Guelph Line. Behind old schoolhouse.	Admin (2006)	Admin (2006)	Admin (2006)
BRO-245	Bronte Creek	584494.49	4805954.19	Behind #1408 Progreston Road, down trail and around bend in creek	Admin (2006)	Admin (2006)	Admin (2006)
BRO-284	Bronte Creek	591991.00	4809958.17	~100m downstream of #4 Sideroad stream crossing.	Admin (2006)	Admin (2006)	Admin (2006)
BRO-334	Bronte Creek	579417.66	4804620.93	~160m upstream of 10th Concession East, first trib east of Highway 6.	Admin (2006)	Admin (2006)	Admin (2006)
BRO-42	Bronte Creek	587425.71	4806597.58	~115m upstream of Britannia Road just east of Cedar Springs Road	Admin (2006)	Admin (2006)	Admin (2006)
BRO-435	Bronte Creek	581226.00	4804485.00	25m upstream of blue pedestrian bridge in newly constructed (2017) channel in Courtcliffe Park, approximately 50m upstream of confluence with main Bronte	Admin (2006)	Admin (2006)	Admin (2006)
BRO-57	Bronte Creek	574196.61	4809505.90	~50m downstream of MacPherson Lane and Maddaugh Road	Mountsberg (2006)	Mountsberg (2006)	Mountsberg (2006)
BRO-8	Bronte Creek	582083.31	4804547.74	Downstream of Carlisle Road, east of Centre Road	Admin (2006)	Admin (2006)	Admin (2006)

FAL-6	Falcon Creek	594908.56	4795705.67	Adjacent to Burlington Golf and Country Club, on west side, upstream of Northshore Boulevard.	Burlington Pier	Aldershot (2011)	Aldershot (2011)
FOR-12	Fourteen Mile Creek	600182.00	4808639.00	Upper Middle Road at Richview Golf Course.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
FOR-2	Fourteen Mile Creek	602958.57	4808517.58	Directly upstream of North Service Road (and QEW) between Bronte Road (HWY 25) and 3rd Line	Burlington Pier	Fourteen (2011)	Fourteen (2011)
FOR-7	Fourteen Mile Creek	601015.00	4809342.74	Upstream of Upper Middle Road. Most easterly tributary just east of Grand Oak Trail	Burlington Pier	Fourteen (2011)	Fourteen (2011)
FOR-71	Fourteen Mile Creek	605087.48	4808367.20	~110m downstream of Warminster Drive	Burlington Pier	Fourteen (2011)	Fourteen (2011)
GRN-101	Grindstone Creek	592000.97	4795058.24	~60m downstream of walking bridge in Hidden Valley Park, parralel to red roofed picnic paviliion	Burlington Pier	Aldershot (2011)	Aldershot (2011)
GRN-16	Grindstone Creek	589986.75	4798545.64	~104m downstream of Dundas Road, east of Mill Street	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-20	Grindstone Creek	587310.69	4800489.90	Downstream of Centre Road to below Centre Road bridge. North of Parkside Drive.	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-22	Grindstone Creek	581477.15	4800603.83	Directly downstream of Edgewood Road crossing	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-27	Grindstone Creek	587898.05	4800544.62	Upstream of 5th Concession East road crossing.	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-28	Grindstone Creek	590339.28	4797545.91	~350m downstream of Smokey Hollow falls (Waterdown falls).	Millgrove/Lake	Aldershot (2011)	Aldershot (2011)
GRN-47	Grindstone Creek	592472.45	4796271.42	Upstream of North Service Road culvert within Sassafras Woods. East of Waterdown Road.	Burlington Pier	Aldershot (2011)	Aldershot (2011)
GRN-49	Grindstone Creek	589678.98	4799781.19	Upstream of Parkside Drive to spillway on Vanderkruk Property.	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-50	Grindstone Creek	592273.11	4795350.71	Hidden Valley Park from tributary confluence, upstream to walking bridge.	Burlington Pier	Aldershot (2011)	Aldershot (2011)
GRN-60	Grindstone Creek	581583.13	4797971.60	Immediately downstream of 5th Concession. Road crossing directly below Fuciarelli property.	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)

GRN-65	Grindstone Creek	588140.09	4802101.06	Immediately upstream of Beeforth Road, between 5th and 6th Concession East	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-66	Grindstone Creek	589443.26	4800890.44	Upstream of Robson Road culvert - 1st trib North of Parkside Drive	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-7	Grindstone Creek	585223.63	4798565.18	Downstream of HWY 6, towards 5th Concession East	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
GRN-73	Grindstone Creek	591053.12	4800548.13	~40m downstream of Evans Sideroad, 2nd tributary south of parkside Drive	Millgrove (2008)	Millgrove (2008)	Millgrove (2008)
JOS-1	Joshua's Creek	610893.56	4815312.24	Upstream of Lakeshore Road east of Arkendo Road	Burlington Pier	Fourteen (2011)	Fourteen (2011)
JOS-25	Joshua's Creek	605041.76	4817834.07	North of Dundas Road and west of 9th Line	Burlington Pier	Fourteen (2011)	Fourteen (2011)
JOS-34	Joshua's Creek	608838.20	4815087.69	Directly upstream of Constance Road (~2m upstream of road)	Burlington Pier	Fourteen (2011)	Fourteen (2011)
MCR-13	McCraney Creek	606088.98	4808918.28	Upstream of Lakeshore Road across from Appleby College campus.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
MCR-14	McCraney Creek	605106.15	4809906.34	Upstream of Speers Road and Fourth Line.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
MOR-2	Morrison Creek	608230.68	4813129.81	Pinewood park downstream of footbridge.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
NDN-3	Indian Creek	595955.42	4796929.17	Upstream of intersection between Greenwood Drive and Greenwood Place	Burlington Pier	Aldershot (2011)	Aldershot (2011)
NDN-33	Indian Creek	594746.46	4797633.89	Upstream of Plains Road, west of the Fortinos Parking lot.	Burlington Pier	Aldershot (2011)	Aldershot (2011)
NDN-34	Indian Creek	596164.69	4796823.74	Downstream of Greenwood Drive, 130m downstream of the side channel.	Burlington Pier	Aldershot (2011)	Aldershot (2011)
ROS-6	Roseland Creek	599197.89	4799487.38	Dowsntream of New Street at Gary Fisher High School	Burlington Pier	Fourteen (2011)	Mainway (2016)
SHL-48	Sheldon Creek	603802.11	4803994.86	Downstream of walking bridge in Shell Park	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SHL-49	Sheldon Creek	599116.86	4805143.14	North of Mainway Drive.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SHL-5	Sheldon Creek	598057.28	4805293.63	Upper Middle Road stream crossing, east of Appleby Line. West branch.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SHR-19	Shoreacres Creek	598985.26	4802378.45	Upstream of Harvester Road	Burlington Pier	Fourteen (2011)	Mainway (2016)

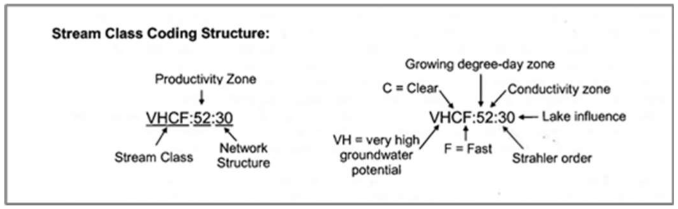
SHR-20	Shoreacres Creek	601035.13	4800968.82	~16m upstream of Lakeshore Road	Burlington Pier	Fourteen (2011)	Mainway (2016)
SXM-103	Sixteen Mile Creek	594583.42	4816058.71	Upstream of Britannia Road stream crossing. First crossing east of HWY 25 (Bronte Road)	Admin (2006)	Admin (2006)	Admin (2006)
SXM-105	Sixteen Mile Creek	589513.39	4818388.42	In channel beside Milton Mill Pond. Upstream of pond. Station begins~50m downstream of rocky ramp.	Admin (2006)	Admin (2006)	Kelso (2016)
SXM-107	Sixteen Mile Creek	605757.41	4814173.35	Down the Morrison Valley Trail entrance at Algrove Park. ~85m downstream from trail pedstrian bridge.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SXM-108	Sixteen Mile Creek	606238.78	4811708.60	Upstream of Go Train bridge at Speers Road and Cross Avenue.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SXM-113	Sixteen Mile Creek	584898.43	4823897.67	Downstream of Scotch Block reservoir and upstream of HWY 25 and #10 Sideroad	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-131	Sixteen Mile Creek	589529.81	4819543.05	Steeles Avenue east of Martin Street. Upstream of Bridge.	Mountsberg (2006)	Mountsberg (2006)	Kelso (2016)
SXM-144	Sixteen Mile Creek	592654.03	4828439.80	Directly upstream of #5 Sideroad culvert to ~45m upstream.	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-151	Sixteen Mile Creek	602917.52	4812068.97	~60m downstream of walking bridge in Sixteen Mile Valley, upstream of Upper Middle Road.	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SXM-152	Sixteen Mile Creek	593394.85	4824089.41	1st crossover ~18m downstream of emergency access gate in Hornby Park.	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-205	Sixteen Mile Creek	599008.48	4817093.36	~200m upstream of Lower Baseline adjacent to rock wall	Admin (2006)	Admin (2006)	Admin (2006)
SXM-216	Sixteen Mile Creek	597179.80	4814196.53	Directly upstream of Lower Base Line east of HWY 25	Admin (2006)	Admin (2006)	Admin (2006)
SXM-255	Sixteen Mile Creek	593590.62	4819761.60	Upstream of Derry Road, directly west of 4th Line	Admin (2006)	Admin (2006)	Kelso (2016)
SXM-281	Sixteen Mile Creek	591955.99	4827538.91	Upstream of #5 Sideroad stream crossing. 1st crossing east of Trafalagar Road and west of Eighth Line	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-30	Sixteen Mile Creek	585865.00	4818066.00	Downstream of Kelso reservoir, where creek runs adjacent to Kelso Road	Mountsberg (2006)	Mountsberg (2006)	Kelso (2016)

SXM-314	Sixteen Mile Creek	585473.45	4826829.74	Downstream of 4th Line, north of railway tracks. Crossing between 10th and 15th Sideroad	Mountsberg (2006)	Mountsberg (2006)	Plaikner (2016)
SXM-347	Sixteen Mile Creek	588810.60	4823483.47	Downstream of intersection between 4th Line and #5 Sideroad	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-349	Sixteen Mile Creek	591200.66	4823059.83	5th Line stream crossing (upstream) and north of Steeles	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-38	Sixteen Mile Creek	596177.74	4821164.65	Southern crossing on 6th Line between Derry Road and Britannia Road (upstream of road crossing).	Admin (2006)	Admin (2006)	Kelso (2016)
SXM-381	Sixteen Mile Creek	605827.66	4813390.86	Upstream of McCraney Street just west of Trafalgar Road	Burlington Pier	Fourteen (2011)	Fourteen (2011)
SXM-40	Sixteen Mile Creek	593140.98	4825467.69	West crossing downstream of Trafalgar Road north of Steeles	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-431	Sixteen Mile Creek	592292.37	4817843.16	Approximately 100m downstream of Derry Road, first trib east of Ontario.	Admin (2006)	Admin (2006)	Kelso (2016)
SXM-433	Sixteen Mile Creek	582283.12	4820560.65	Briton Tract, ~100m downstream of trail crossing	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-434	Sixteen Mile Creek	599850.08	4823263.17	Downstream of Ninth Line, north of Parkgate Road	Admin (2006)	Admin (2006)	Admin (2006)
SXM-435	Sixteen Mile Creek	598446.30	4820836.73	~78m downstream of Britannia Road, west of Trafalgar Road	Admin (2006)	Admin (2006)	Admin (2006)
SXM-436	Sixteen Mile Creek	594766.95	4824529.72	~ 100m downstream of Trafalgar Road, south of the 401	Admin (2006)	Admin (2006)	Kelso (2016)
SXM-437	Sixteen Mile Creek	581162.34	4823870.17	Downstream of Nassagaweya Townline noth of 15th Sideroad	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
SXM-63	Sixteen Mile Creek	584110.24	4815505.28	Parallel to #3 Sideroad, east of Walkers Line	Mountsberg (2006)	Mountsberg (2006)	Scotch Block (2016)
TUK-3	Tuck Creek	596075.30	4803335.10	Upstream of Headon Road, north of Upper Middle Road	Burlington Pier	Fourteen (2011)	Mainway (2016)
TUK-5	Tuck Creek	600176.47	4799857.70	Upstream of Lakeshore Road just east of Lakeview Avenue	Burlington Pier	Fourteen (2011)	Mainway (2016)
WDG-2	Wedgewood Creek	608643.70	4813947.85	Downstream of Devon Road in area between Weaver Avenue and Dalewood Drive	Burlington Pier	Fourteen (2011)	Fourteen (2011)
GRN-5	Grindstone Creek	591735.95	4794723.50	~200m downstream of Unsworth Avenue within RBG lands	Burlington Pier	Aldershot (2011)	Aldershot (2011)

Appendix B: Site Codes with AEC Classification and Current July Mean

Station ID	AEC Class Code	Current July Mean	Preferred Temperature (°C)	Station ID	AEC Class Code	Current July Mean	Preferred Temperature (°C)	Station ID	AEC Class Code	Current July Mean	Preferred Temperature (°C)
APB-19	LCF	21.68	21-22	**BRO-8**	HCF	21.66	21-22	**SXM-105**	HCF	20.11	>18.5 - <21.5
APB-5	LCF	22.8	>21.5	**FOR-12**	LCF	23.63	>21.5	**SXM-107**	LCF	18.76	>18.5 - <21.5
BRO-10	HCF	19.25	>18.5 - <21.5	**FOR-2**	LCF	22.08	>21.5	**SXM-108**	MTF	22.96	>21.5
BRO-118	HCF	21.83	21-22	**FOR-7**	LCF	19.07	>18.5 - <21.5	**SXM-131**	MCF	19.86	>18.5 - <21.5
BRO-119	HCF	24.07	>21.5	**GRN-184**	HCF	20.09	>18.5 - <21.5	**SXM-144**	MCF	19.86	>18.5 - <21.5
BRO-135	HCF	20.08	>18.5 - <21.5	**GRN-16**	HCF	19.51	>18.5 - <21.5	**SXM-151**	MTF	23.05	>21.5
BRO-142	MCF	19.47	>18.5 - <21.5	**GRN-20**	HCS	19.52	>18.5 - <21.5	**SXM-152**	LTF	21.32	>18.5 - <21.5
BRO-149	LCF	22.29	>21.5	**GRN-22**	VHCS	19.42	>18.5 - <21.5	**SXM-205**	LTF	22.71	21-22
BRO-154	HCF	19.83	>18.5 - <21.5	**GRN-27**	HCS	19.64	>18.5 - <21.5	**SXM-216**	MCF	21.89	21-22
BRO-16	HCF	21.94	21-22	**GRN-49**	HCF	21.42	>18.5 - <21.5	**SXM-30**	HCF	18.78	>18.5 - <21.5
BRO-171	HCF	21.01	>18.5 - <21.5	**GRN-50**	HCF	20.61	>18.5 - <21.5	**SXM-314**	MCF	17.45	<18.5
BRO-172	MCF	18.5	18-19	**GRN-60**	HCS	22.72	>21.5	**SXM-347**	LCF	18.61	>18.5 - <21.5
BRO-196	HCF	22.15	>21.5	**GRN-65**	HCF	17.99	<18.5	**SXM-349**	MCF	20.21	>18.5 - <21.5
BRO-2	VHCF	21.43	>18.5 - <21.5	**GRN-66**	HCF	18.9	>18.5 - <21.5	**SXM-38**	MTF	21.75	21-22
BRO-21	HCF	20.92	>18.5 - <21.5	**GRN-7**	HCS	18.63	>18.5 - <21.5	**SXM-381**	LCF	19.8	>18.5 - <21.5
BRO-219	HCF	20.2	>18.5 - <21.5	**JOS-1**	LCF	21.43	>18.5 - <21.5	**SXM-40**	LTF	18.44	<18.5
BRO-22	HCF	18.73	>18.5 - <21.5	**MCR-13**	MCF	17.5	<18.5	**SXM-433**	HCF	20.76	>18.5 - <21.5
BRO-238	VHCF	18.21	<18.5	**MOR-2**	MCF	18.48	<18.5	**SXM-435**	LTF	22.37	>21.5
BRO-243	HCF	17.44	<18.5	**NDN-3**	MCF	18.84	>18.5 - <21.5	**SXM-436**	MCF	20.85	>18.5 - <21.5
BRO-245	HCF	17.88	<18.5	**NDN-33**	MCF	21.13	>18.5 - <21.5	**SXM-437**	HCF	24.65	>21.5
BRO-284	HCF	22.63	>21.5	**SHL-48**	MCF	22.15	>21.5	**SXM-63**	HCF	21.29	>18.5 - <21.5
BRO-42	HCF	19.24	>18.5 - <21.5	**SHL-49**	MCF	21.25	>18.5 - <21.5	**TUK-5**	MCF	21.6	21-22
BRO-435	HCF	18.9	>18.5 - <21.5	**SHR-20**	MCF	21.29	>18.5 - <21.5	**WDG-2**	MCF	18.62	>18.5 - <21.5
BRO-57	VHCF	12.54	<18.5	**SXM-103**	MCF	21.25	>18.5 - <21.5				

LCF	Low Clear Fast
HCF	High Clear Fast
MCF	Medium Clear Fast
VHCF	Very High Clear Fast
HCS	High Clear Slow
VHCS	Very High Clear Slow
LTF	Low Turbid Fast
MTF	Medium Turbid Fast



Mean July Temperature	AEC Thermal Class
<18.5	**Cold**
18-19	**Cold-Cool**
>18.5 <21.5	**Cool**
21 to 22	**Cool-Warm**
>21.5	**Warm**

Appendix C: Species Specific Temperatures

Species	Overall Preferred Temperature (°C)	Spawning Temperature (°C)
American Eel	19	N/A
Brook Trout	16	10.7
Redside Dace	<24	16-18
Silver Shiner	8.3-27.6	14.8-23.5

Appendix D: Rate of Change Calculation

This metric is the calculation of the monthly mean of the daily maximum rates (hourly) of temperature variation that change less than 2°C, in between 2-5°C, to greater than 5°C an hour from the monthly mean of daily maximum hourly rates of temperature change obtained from the reference condition.

The degree of change can be determined as follows (Metcalfe et al 2013):

Low Rate of Change is less than 2.0°C change in an hour relative to the monthly mean of daily maximum hourly rates of temperature change

Medium Rate of Change is between 2.0°C – 5.0°C in an hour relative to the monthly mean of daily maximum hourly rates of temperature change

High Rate of Change is greater than 5.0°C an hour relative to the monthly mean of daily maximum hourly rates of temperature change.

Methods are as follows (Metcalfe et al 2013)

This procedure determines the monthly means of daily maximum hourly +/-rates of change for the period of record. The output is 24 values representing the monthly averages of all daily maximum hourly positive and negative rates of change.

1) Resample the time series by removing all records except for full hour records (e.g., 12:00:00, 13:00:00, 14:00:00). Note: Do not use hourly averages during resampling.

2) Calculate hourly rate of change value between records by subtracting the next record from the current record (e.g. record(i+1) – record(i)). Note: Positive rates represent warming rates and negative rates cooling rates.

3)Bin all rates according to their sign (2 bins: 1 positive rate bin, 1 negative rate bin). Note: Zero rates are excluded since they cannot be classified into these bins.

4)Bin the records again with the previous bins according to month (24 bins: 12 positive monthly bins, 12 negative monthly bins).

5) Calculate the average of each bin.