Wisconsin's 2010-11
Citizen-Based Monitoring Partnership Program
and
Trout Unlimited Driftless Area Restoration Effort (TUDARE)

TUDARE Stream Monitoring Protocols for Evaluating Stream Restoration Benefits, Including Resilience to Climate Change:

Assessment of Pre- and Post-Restoration Temperature and Habitat Conditions

Document Prepared By:

Jeff Hastings, TUDARE Project Manager, Trout Unlimited
Kent Johnson, Kiap-TU-Wish Chapter, Trout Unlimited
Matthew Mitro, Coldwater Fisheries Research Scientist, WDNR

September 2011

TUDARE Stream Monitoring Protocols for Evaluating Stream Restoration Benefits, Including Resilience to Climate Change:

Assessment of Pre- and Post-Restoration Temperature and Habitat Conditions

Table of Contents

Table of Contents
(Continued)

List of Appendices

List of Figures

Project Background:

Each year, private entities, county, state, and federal governments, and non-governmental organizations (NGOs) spend millions of dollars on stream restoration projects in the Upper Midwest Driftless Area, for the primary purpose of improving the Driftless Area's coldwater streams for brook and brown trout. Past fisheries surveys have demonstrated that stream restoration projects improve trout numbers and often upgrade streams from Class II (some natural reproduction but not enough to utilize available food and space, with stocking sometimes required to maintain a desirable sport fishery) to Class I (sufficient natural reproduction to sustain populations of wild trout). Due to stream restoration efforts, the Wisconsin Department of Natural Resources (WDNR) has upgraded the status of many miles of coldwater streams during the past several years.

There has been an assumption among professional stream ecologists that stream restoration projects may reduce stream temperatures, thereby providing an improved temperature regime for trout (Mitro, Lyons, and Sharma, 2011). This assumption is based on several premises: (1) Stream restoration projects stabilize eroding stream banks and flush out fine, dark streambed sediments that may absorb heat and transfer it to the water (fine, dark sediment is more absorbent than a light, reflective gravel bed); (2) A pre-restored shallow and wide stream with reduced current velocity is more apt to absorb heat than a post-restored deep and narrow stream with increased current velocity; and (3) Tree removal from the stream corridor during restoration is not a thermal detriment, because Driftless Area streams typically have adequate spring flow to compensate for the loss of shade.

Both brook and brown trout are sensitive to stream temperature, with optimum feeding temperatures ranging from 13 to 16° Celsius (C). Streams may become thermally unsuitable for trout when the maximum daily mean temperature exceeds 23° C and the June-August mean temperature exceeds 19° C.

Climate Change Impacts on Coldwater Resources:

Wisconsin is recognized for its abundance of coldwater streams, including over 10,000 miles of classified trout streams that provide fisheries for brook trout and brown trout. In addition to over 10,000 miles of managed trout streams, another 22,000 of Wisconsin's 54,000 stream miles may be suitable for coldwater species such as the mottled sculpin (Mitro, Lyons, and Sharma, 2011).

According to the Wisconsin Initiative on Climate Change Impacts (WICCI) Coldwater Fish and Fisheries Working Group (Mitro, Lyons, and Sharma, 2011), expected climatic changes in air temperature and precipitation patterns across the state may threaten the viability of Wisconsin's inland trout resources. Climate change will likely cause reductions in all coldwater habitats and fish species in Wisconsin. Increases in air temperature will negatively affect thermal conditions required for the persistence of coldwater fishes. Changes in the amount and distribution of precipitation across the state may ameliorate or exacerbate the reductions in coldwater habitat and fishes. The magnitude of the reductions in coldwater fishes will therefore depend on the type and location of the habitat, the particular fish species that live there, and the nature and severity of the climate change that occurs.

Long-term (decadal or greater) stream temperature data sets for Wisconsin are rare, but those that are available suggest a warming trend in stream temperatures. Mitro, Lyons, and Sharma (2011) analyzed 1992-2009 stream temperature data from four coldwater stream sites on the Kinnickinnic River and a tributary stream (Rocky Branch Creek) in Pierce and St. Croix Counties. Long-term monitoring of stream temperature at these sites is being conducted by the Kiap-TU-Wish Chapter of Trout Unlimited. The 1992-2009 temperature data for the four Wisconsin stream sites suggest that a warming trend in water temperature has been occurring (Figure 1), consistent with the observed warming trend in Wisconsin air temperature for the same time period, during which summer night-time temperatures have become warmer (Kucharik and Serbin, 2008). These data suggest that to date the warming in stream temperature has not necessarily occurred in short term peaks, as measured by the maximum daily mean temperature, but rather as increases in maximum average daily mean temperature measured over broader lengths of time (up to 63 days) during summer.

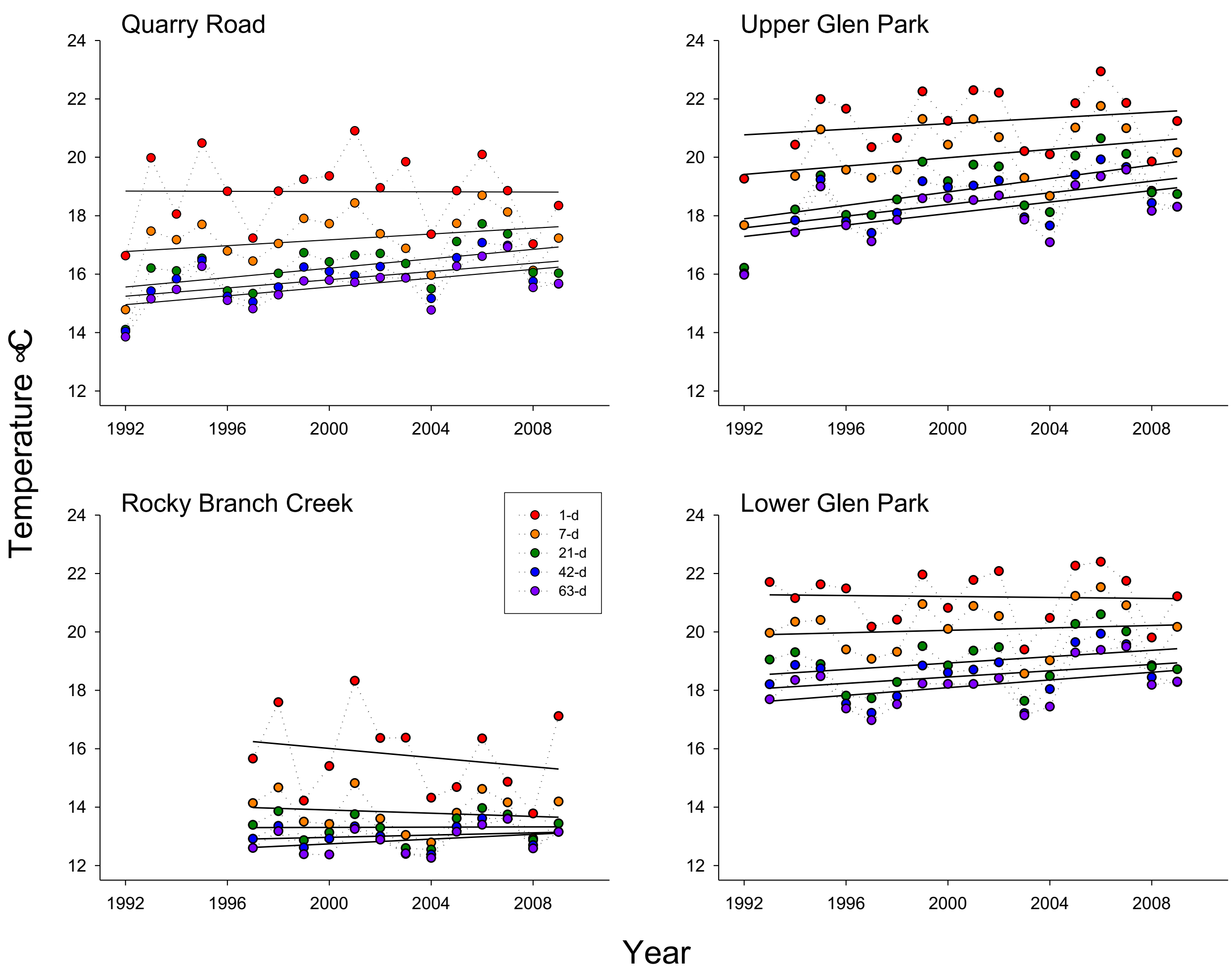


Figure 1. Maximum average daily mean temperature for five exposure periods (1, 7, 21, 42, and 63 days) by year at four stream sites (Quarry Road, Upper Glen Park, and Lower Glen Park in the Kinnickinnic River and Rocky Branch Creek, a tributary entering the Kinnickinnic River downstream of the Upper Glen Park site). Regression lines (solid lines) are shown for each exposure period at each site.

Generally, increasing air temperatures and longer periods of warm weather will cause coldwater species to disappear, and changes in precipitation amount and pattern may ameliorate or exacerbate these reductions (Mitro, Lyons, and Sharma, 2011). Human-induced land-use changes in conjunction with climate change also have the potential to dampen or amplify losses of coldwater species. Generally, more intensive human land use alterations to the landscape, such as increasing urban sprawl or expanded row-crop agriculture, degrade coldwater resources and will worsen climate change impacts, whereas the implementation of best-management practices to minimize environmental impacts of agriculture and urban development or the conversion of disturbed lands to natural vegetation will usually benefit coldwater resources and may partially offset climate change impacts.

Mitro, Lyons, and Sharma (2011) conducted ecological modeling exercises to predict the changes in coldwater habitat that might occur under three climate change scenarios. The three scenarios included (Lyons et al. 2010): (1) a "best case" scenario, in which summer air temperature increased by slightly more than 1°C and water temperature by 0.8°C; (2) a "moderate case" scenario, in which air temperature increased by 3°C and water temperature by 2.4°; and (3) a "worst case" scenario, in which air temperature increased by 5°C and water temperature by 4°C. For streams, climate change impacts on three coldwater species were considered: brown trout, brook trout, and mottled sculpin. Modeling results indicated that climate change could lead to major declines in the occurrence and distribution of coldwater fish species in Wisconsin streams (Figures 2-4). Under current conditions, mottled sculpin were predicted to be the most widespread species and brook trout the least, with brown trout intermediate. For all three climate-change scenarios, all three species declined, with brown trout declining the least and brook trout declining the most. Under the worst-case climate-change scenario, brook trout were predicted to be extirpated from Wisconsin streams, with mottled sculpin reduced in distribution by 95% and brown trout by 88%. Habitat losses were expected to occur evenly across the state and were not noticeably concentrated in any particular geographic region. The model results clearly indicate that climate change has the potential to cause major declines in coldwater fishes in streams, including the possible extirpation of species.

Coldwater fishes are an integral part of Wisconsin's natural legacy, and coldwater fisheries are a core part of the state's culture and identity. The restoration of native fisheries to Wisconsin waters is a stated goal of the state agencies entrusted to manage these resources. Anglers also make a significant contribution to our local and state economies in their pursuit of trout and other coldwater fishes. In the face of changing climate conditions, it is important to assess the potential impacts to coldwater fish and fisheries and to implement adaptive management strategies that ameliorate climate change impacts on Wisconsin's coldwater streams and their fisheries (Mitro, Lyons, and Sharma, 2011).

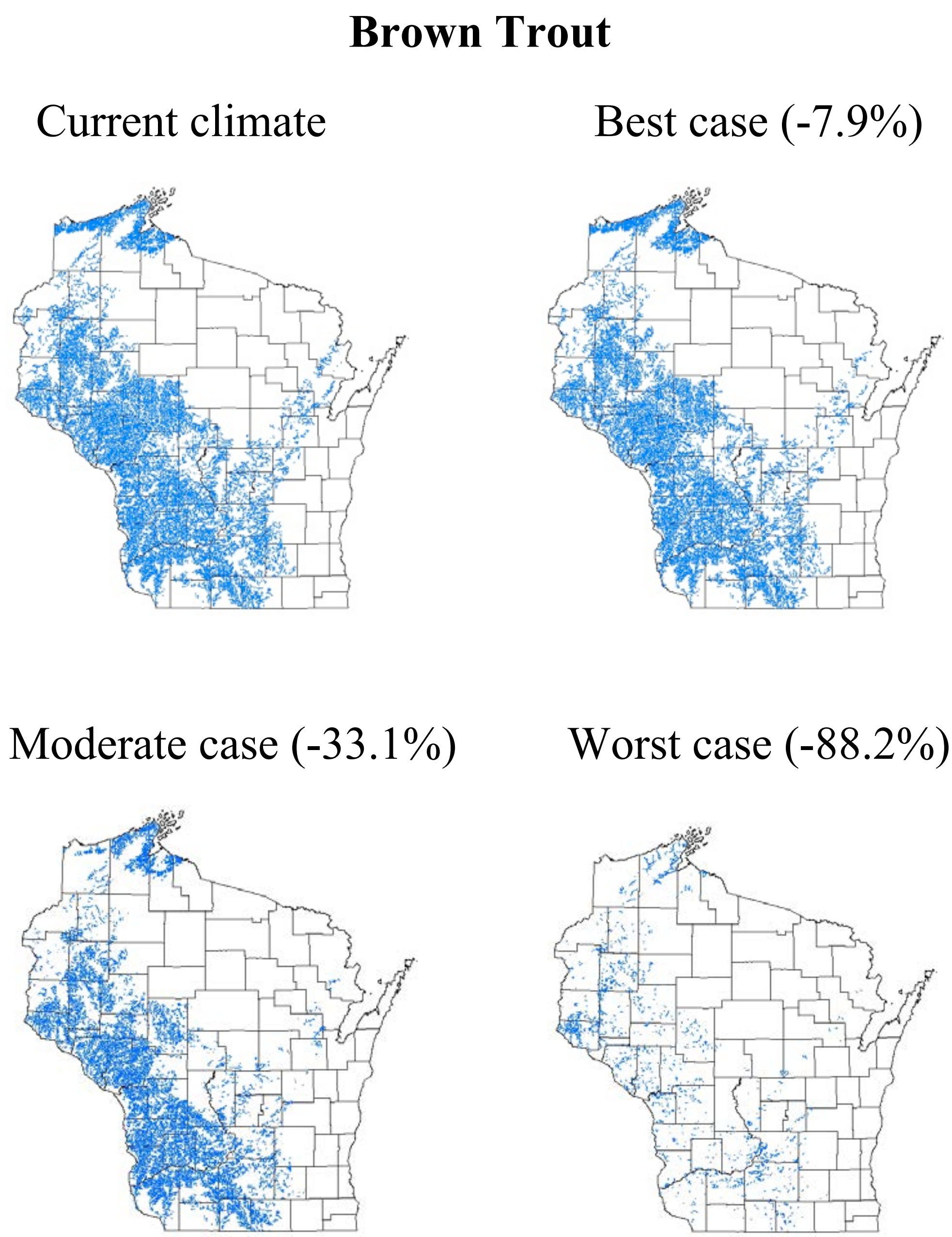


Figure 2. Predicted distribution of brown trout in Wisconsin streams under current climate conditions and three climate-warming scenarios.

Brook Trout

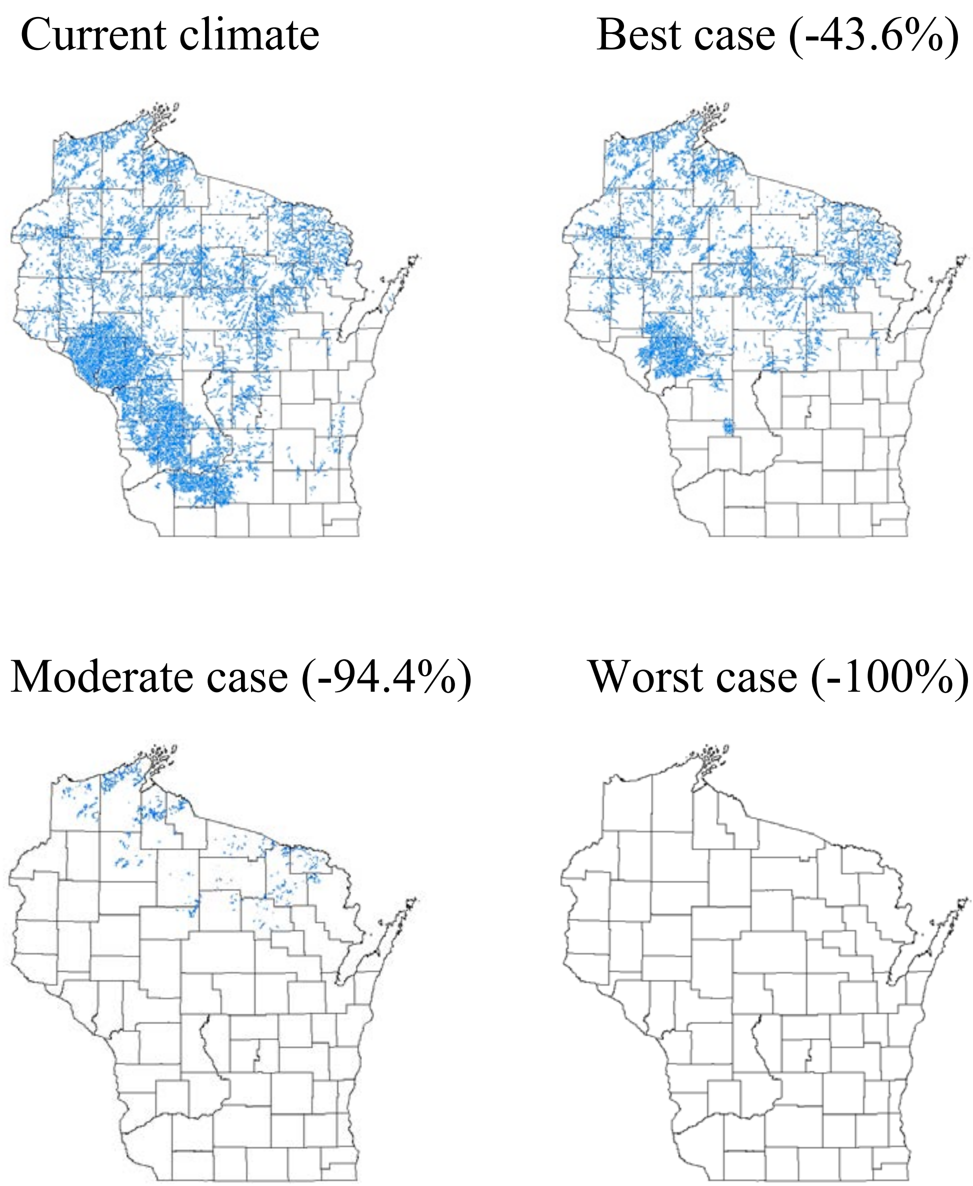


Figure 3. Predicted distribution of brook trout in Wisconsin streams under current climate conditions and three climate-warming scenarios.

Mottled Sculpin

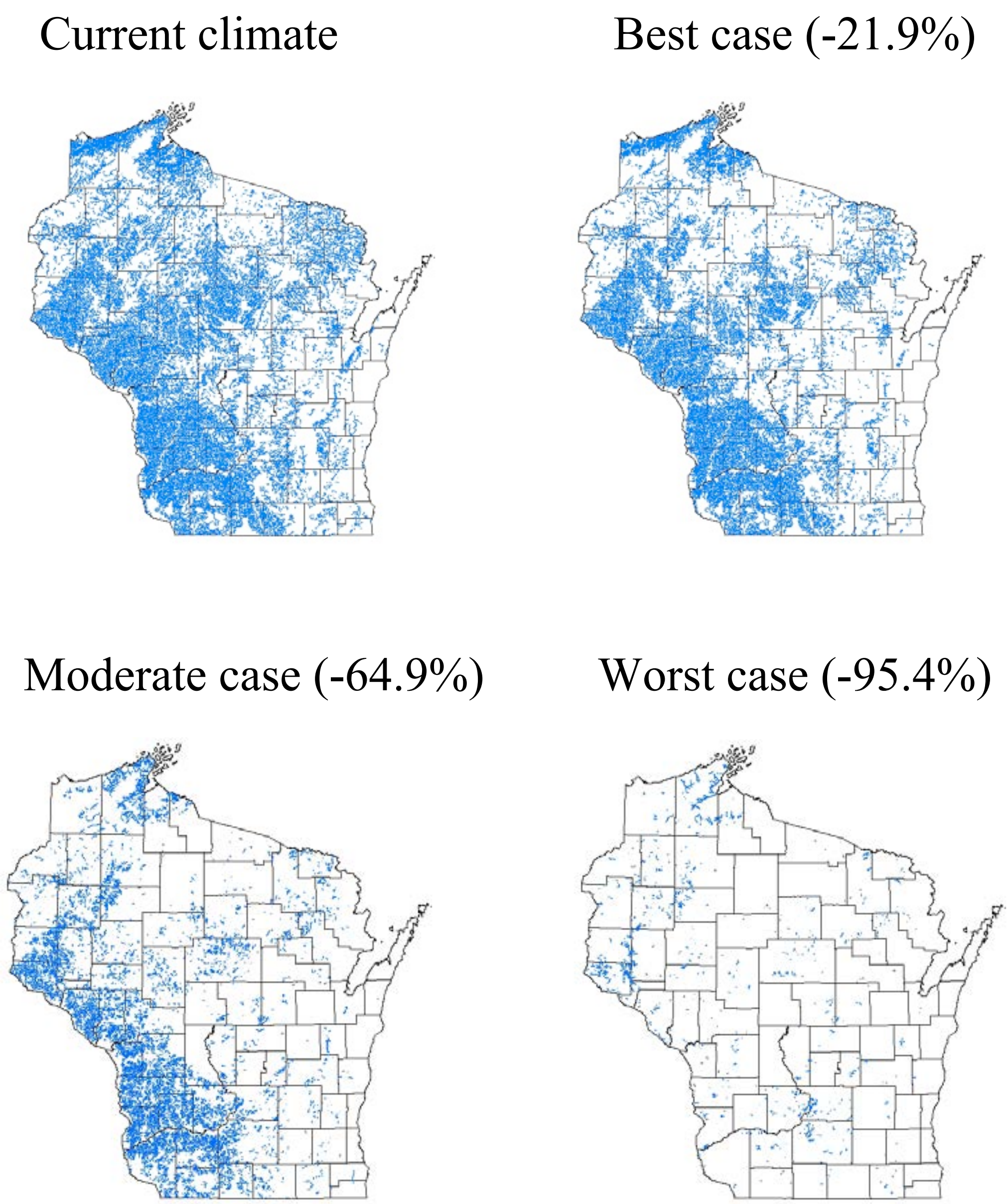


Figure 4. Predicted distribution of mottled sculpin in Wisconsin streams under current climate conditions and three climate-warming scenarios.

Stream Restoration as a Climate Change Management Strategy:

Stream restoration is an integral part of trout stream management in Wisconsin. Stream restoration generally involves the re-establishment of aquatic functions and related biological, chemical, and physical characteristics of streams that would have occurred prior to disturbance. Trout anglers fishing inland waters in Wisconsin are required to purchase a trout stamp, from which the proceeds are directed towards stream habitat restoration work. Hunt (1988) and Avery (2004) have documented a half century (1953-2000) of evaluations of trout stream habitat restoration projects in Wisconsin, and have shown how restoration has been successful at improving trout populations in terms of trout number and size (Mitro, Lyons, and Sharma, 2011).

Restoration is generally targeted at Class I or Class II trout streams. Stream restoration may take different forms, many of which can protect streams from the impacts of climate change. For example, degraded streams may exhibit wide and shallow channels, with a relatively slow current velocity. Restoration efforts typically narrow and deepen stream channels and increase current velocity, thereby helping to maintain or further cool stream temperatures during the summer. Stream banks are often sloped back to open the stream channel to the flood plain, thereby dissipating flood energy into the flood plain rather than eroding stream banks. In-stream structures may be installed, providing overhead cover and shade for fish. These structures mimic undercut banks, and are often placed on the south side of a stream, away from direct sunlight (Mitro, Lyons, and Sharma, 2011).

Beaver dam removal is another in-stream restoration tool that has been critical to the maintenance of many trout streams in Wisconsin (Mitro, Lyons, and Sharma, 2011). Beaver dams constructed on low- to moderate-gradient streams, often in excess of one per mile, may adversely affect trout populations by raising summer water temperatures and reducing stream connectivity and access to spawning sites. Avery (1991, 2002) documented reductions in water temperature and increases in trout populations in an 18-year study following the removal of beaver dams to maintain free-flowing conditions in Wisconsin coldwater streams. McRae and Edwards (1994), however, noted that the thermal effect of beaver impoundments was highly site dependent because of variation in groundwater inflow. Depending on the response of beaver to changes in climate, beaver dam removal may continue to be critical to maintaining coldwater stream habitat and trout fisheries in many Wisconsin streams impacted by climate change.

Stream restoration will continue to play a major role in trout stream management, and will help lessen any effects of climate change on coldwater streams, including warming and flooding related to changes in precipitation patterns. The WICCI Coldwater Fish and Fisheries Working Group (Mitro, Lyons, and Sharma, 2011) recommends using restoration techniques that promote colder water temperatures (e.g., narrowing and deepening stream channels) and targeting restoration efforts to streams most likely to realize these benefits under a changing climate. Stream temperature and stream fisheries models can be used to aid in site selection for future stream restoration projects.

Need for Enhanced Stream Monitoring:

Each year, NGOs, counties, and state agencies conduct monitoring to gather temperature data on a subset of coldwater streams throughout the Driftless Area. However, most monitoring efforts include only one site per stream and do not collect corresponding air temperature data on site. Also, no attempt has been made to 1) coordinate stream temperature monitoring and data collection, 2) compare pre- vs. post-stream restoration information, and 3) evaluate long-term trends in stream temperatures, as a possible consequence of climate change.

The WDNR Water Resources Policy Management Team has developed an issue brief on climate change stream monitoring (Hansis, 2010). The issue brief recommends that the WDNR Watershed Bureau should begin climate change-specific surface water monitoring. The WICCI Coldwater Fish and Fisheries Working Group has recommended adaptation strategies that may help alleviate climate change impacts on coldwater streams (Mitro, Lyons, and Sharma, 2011). One of the necessary components of an adaptation strategy is measuring the results of the chosen management activity. Since most adaptation strategies will be implemented on a decadal-scale time frame, it is imperative that measurement and monitoring programs are implemented as soon as possible. Three categories of physical monitoring should be included in WDNR stream monitoring programs: water temperature, flow, and stream channel geometry.

Stream temperature: Institute continuous stream temperature monitoring. Water temperature changes are an important impact of climate change. There are few long-term stream temperature records available to researchers. Given the long lead time necessary to develop long-term water temperature data sets, data collection should begin as soon as possible.

Flow: Fill gaps in the state's flow gauging network and emphasize long-term data gathering and analysis as opposed to short-term, project specific flow gauging. Altered precipitation patterns, including more intensive precipitation events at longer intervals, may have a profound impact on stream flow. Better measurement of these potential flow impacts is needed.

Stream channel geometry: Establish a state-wide network of stations where scientists will record stream channel geometry, sinuosity, bed forms, and sediment at recurring intervals. Altered precipitation patterns, including more intensive precipitation events at longer intervals, may have a profound impact on the size and shape of stream channels. Channel-forming flows will occur more frequently, causing channel widening and down-cutting, both of which will reduce aquatic habitat and contribute additional sediment to streams.

WDNR Long-Term Stream Monitoring Network:

Recognizing the need for enhanced monitoring to better understand and manage the impacts of climate change on Wisconsin's coldwater streams, WDNR Science Services established a network of long-term stream monitoring sites on streams located throughout southwest Wisconsin's Driftless Area (Matt Mitro, WDNR, personal communication, 2011). Establishment of this monitoring network began in 2007, with the network currently covering 20 streams in 7 counties. Continuous temperature monitoring is conducted at 30 sites on these 20 streams, with multiple monitoring sites (2-3) established on 8 streams. Continuous monitoring of water level (stage) is conducted at 20 sites on 18 streams, with multiple monitoring sites (2) established on 2 of those streams. In addition to continuous monitoring of water temperature and level on these 20 streams, trout abundance and index of biotic integrity (IBI) are being assessed in each stream on a regular basis. A list and map of the 20 streams included in the WDNR stream monitoring network are included in Appendix A.

Role of Volunteer Monitoring and Citizen-Based Monitoring Partnership Program Grant:

Given the need for enhanced monitoring of Wisconsin's coldwater streams in the face of climate change, and recognizing that agency resources for monitoring are limited at the local, state, and federal levels, volunteers and NGOs can play a key role to support needed stream monitoring efforts.

A rich history of volunteer monitoring exists in Wisconsin, including Water Action Volunteers (WAV) and the Citizen-Based Monitoring Partnership Program (CBMPP).

Water Action Volunteers (WAV) is a statewide program for Wisconsin citizens who want to learn about and improve the quality of Wisconsin's streams and rivers. The program is coordinated through a partnership between the Wisconsin Department of Natural Resources and the University of Wisconsin Cooperative Extension. Citizens, civic groups, 4-H clubs, students, and other volunteer groups are participating in WAV programs across the state. Citizens monitor 6 water quality parameters in streams: dissolved oxygen, temperature, transparency, flow, habitat, and macroinvertebrates. More than 450 sites are currently registered in the online database, with about 120 sites monitored annually. WAV provides citizens with assistance for setting up local stream monitoring programs, training to learn monitoring methods, written methods, data sheets, and ongoing educational programming. More information on WAV, including the monitoring protocols, can be found at: http://watermonitoring.uwex.edu/wav/.

Since 2004, WDNR and Wisconsin's Citizen-Based Monitoring Partnership Program (CBMPP) have sought to expand citizen and volunteer participation in natural resource monitoring by providing funding and assistance to high priority projects. Qualifying topics include monitoring of aquatic and terrestrial species, natural communities, and environmental components such as water, soil and air. For the 2011 fiscal year (July 1, 2010 to June 30, 2011), $100,000 of Partnership Program funding is available through the State's Conservation Segregated Fund. In April 2010, TUDARE was awarded a $4,999 CBMPP grant for their project: "**Analysis of Stream Restoration Projects on Providing Resilience to Climate Change"**. Trout Unlimited is already conducting some limited monitoring of stream restoration projects. For example, the Kiap-TU-Wish Chapter of Trout Unlimited has been conducting pre- and post-restoration monitoring of Pine Creek (Pierce County) since 2007. Kiap-TU-Wish also conducted post-restoration monitoring of Tiffany Creek (St. Croix County) in 2008. The CBMPP grant will allow TUDARE to expand stream restoration monitoring efforts and help determine whether restoration projects provide resilience to climate change. Additional TUDARE monitoring sites will also enhance WDNR's long-term stream monitoring network.

TUDARE Project Monitoring Objectives:

Key monitoring objectives for the TUDARE project: "Analysis of Stream Restoration Projects on Providing Resilience to Climate Change" are as follows:

1. Expand monitoring coverage to include more temperature data for coldwater streams throughout the Driftless Area.
2. Expand monitoring coverage to include multiple temperature monitoring sites on each stream.
3. Conduct pre- and post-monitoring of streams targeted for restoration projects, to determine if these projects are providing short-term and long-term temperature benefits.
4. Support the Wisconsin Initiative on Climate Change Impacts (WICCI) and the Coldwater Fish and Fisheries Working Group by providing long-term data to document climate change impacts on Wisconsin's coldwater streams.

A project kick-off meeting was held in Viroqua, Wisconsin on May 19, 2010. Representatives from TUDARE (Jeff Hastings), Trout Unlimited Chapters (Kent Johnson from Kiap-TU-Wish and Wally Bock and Edward Michael from Oak Brook (IL)), and WDNR (Marty Engel, Bob Hansis, Matt Mitro, and Dave Vetrano) attended the meeting. The group discussed:

1. The development and documentation of stream restoration monitoring protocols.
2. Possible streams to be monitored by this project and the responsible partners, including Creek 8-8 in Vernon County (Oak Brook Chapter of Trout Unlimited), Rocky Branch Creek in Pierce County (Kiap-TU-Wish Chapter of Trout Unlimited), and Wilson Creek in Dunn County (Clear Waters Chapter of Trout Unlimited).
3. A list of monitoring equipment needs, for purchase with CBMPP grant funding.

TUDARE Stream Monitoring Protocols:

A key project deliverable is a document that details the standardized stream monitoring protocols for determining if stream restoration projects in the Driftless Area are indeed providing resilience to climate change. This document, including the protocols for stream temperature monitoring, air temperature (and weather) monitoring, and stream habitat assessment, is provided below.

TUDARE Stream Monitoring Protocols for Evaluating Stream Restoration Benefits, Including Resilience to Climate Change:

Assessment of Pre- and Post-Restoration Temperature and Habitat Conditions

Introduction:

Definition of Stream Restoration Monitoring

Stream Restoration Monitoring: The systematic collection and analysis of data that provides information useful for measuring project performance, determining when modification of efforts is necessary, and building long-term public support for stream habitat protection and restoration (Thayer et al. 2005).

On the Need for Stream Restoration Monitoring

All parties involved with stream restoration projects, from grantor to practitioner to land manager, are vested in the outcomes of these projects and therefore benefit from feedback on project successes and failures. Documenting changes in site conditions before and after restoration project implementation is critical to determining whether a project has achieved its objectives. Planning a monitoring program in conjunction with a restoration project facilitates the development of realistic, measurable project goals and objectives and the use of suitable protocols to assess project outcomes. In addition to documenting intended beneficial effects, consistent and systematic monitoring may also highlight inadvertent effects of restoration on target ecosystems. The information obtained through monitoring provides critical feedback to project participants and grantors. Furthermore, qualitative and quantitative monitoring outcomes can help restoration professionals understand the reasons behind project successes and failures and apply those lessons to their practice. When project outcomes and the resulting lessons are presented and shared, they help fine tune restoration techniques, enhance maintenance regimes, increase the overall knowledge of stream ecosystems, and shape the growing science of stream and watershed restoration. Also, by directing the maintenance of existing projects and improving the design of future projects, such evaluation may increase the credibility of restoration efforts in the eyes of participating landowners. More formally, grant administrators are requiring an increased level of accountability from grantees, including documentation that financial resources were used for the purposes requested and that they produced the desired results (Reeve et al. 2006).

Field Reconnaissance and Site Selection:

Field reconnaissance is highly recommended before installing monitoring equipment (temperature loggers and weather station) and conducting the habitat assessment work. Field reconnaissance allows the volunteer monitor to become familiar with the stream reach that has been targeted for restoration and monitoring. A Google Earth™ map is very helpful for placing the stream restoration reach in perspective with the remainder of the stream, the adjoining riparian areas, and the larger watershed, including land uses which may impact the stream. Most stream restoration work in Wisconsin is conducted on public property or on a public easement granted by a local landowner. When accessing the stream restoration reach for field reconnaissance and monitoring work, take care to remain on public property, and respect the rights of adjacent private property owners. If stream access via private property is deemed necessary, one must first obtain permission from the property owner. A current county atlas and plat book can help identify the owners of property adjoining the stream restoration reach.

During the field reconnaissance, check for possible locations for the in-stream temperature loggers, at the upper and lower ends of the restoration reach, as well as at intermediate locations, as recommended in the **Stream Temperature Monitoring** protocol below. Candidate locations should have relatively deep water (runs are best, where the water is well-mixed and not stagnant) and suitable substrate for the anchoring devices (typically fence posts or rebar) that will secure the temperature loggers. The anchoring devices should be situated in the thalweg (main stream current), at a location that also provides potential for "camouflaging" the anchoring device and temperature logger, to prevent vandalism. While surveying the stream restoration reach, the volunteer monitor may want to check with the adjoining landowners, to see if one may be willing to "host" the weather station on his/her property (see the **Air Temperature Monitoring** protocol below). The location of the weather station on private property will help protect it from possible vandalism. The local landowner may also be willing to act as a monitoring "observer", to keep an eye on the weather station and in-stream temperature loggers while the volunteer monitor is away. The WDNR area fisheries manager could provide assistance with these landowner contacts, which also serve as an excellent opportunity to keep the adjoining property owners apprised of the restoration and monitoring work.

The WDNR area fisheries manager and other WDNR staff can provide information on any past fish survey work, monitoring, and habitat assessment work that has been conducted on the stream targeted for restoration work. This information may help guide site selection for the monitoring work to be conducted in the stream restoration reach, allowing the new monitoring work to build on past history.

Stream Temperature Monitoring:

The WDNR has established "Guidelines and Standard Procedures for Continuous Temperature Monitoring" (WDNR, 2004). These procedures are used for the continuous temperature monitoring work conducted at all sites in the WDNR long-term stream monitoring network, as described above and in Appendix A (Matt Mitro, WDNR, personal communication, 2011). The WDNR procedures, as described below, will also be used for pre- and post-restoration monitoring of stream temperature at TUDARE sites.

Temperature has an important influence on pH, density, specific conductance, the rate of chemical reactions, and solubility of constituents in water. Also, the biological activity and species composition of a stream is largely determined by water temperature. Many specific reasons illustrate how continuous temperature data can be used in stream management decisions:

- ☑ Document baseline water temperatures.
- ☑ Determine a stream's temperature category - cold, cool, or warm water.
- ☑ Aid in determination of a stream's biological potential.
- ☑ Aid in documenting and determining the effects of thermal discharges (including storm water) on aquatic biota.
- ☑ Aid in location of groundwater influence on streams.
- ☑ Document thermal impacts of structural dams and beaver dams on coldwater streams.
- ☑ Distinguish brown trout streams from potential native brook trout streams.
- ☑ Determine if winter temperatures are conducive to successful development of trout eggs.
- ☑ Document changes in stream temperatures after installation of agricultural and urban best management practices.
- ☑ Document changes in stream temperatures after stream restoration.
- ☑ Document long-term impacts of climate change on coldwater streams.
- ☑ Aid in development of a model using landscape factors to predict stream temperatures.

Stream Temperature Monitoring Site Selection and Identification

At a minimum, three continuous temperature monitoring sites should be established within the stream restoration reach:

1. At the upstream end of the stream restoration reach.
2. At the mid-point of the stream restoration reach.
3. At the downstream end of the stream restoration reach.

If the stream restoration reach is one mile or longer, it is recommended that temperature monitoring sites be established at 0.4 kilometer (0.25 mile) intervals between the upstream and downstream sites.

Each monitoring site should have relatively deep water (runs are best, where the water is well-mixed and not stagnant) and suitable substrate for the anchoring devices (see types below) that will secure the temperature loggers. A run or riffle is preferred to a pool. The anchoring devices (see **Stream Temperature Logger Deployment Methods and Anchoring Devices**, below) should be situated in the thalweg (main stream current), at a location that also provides potential for "camouflaging" the anchoring device and temperature logger, to prevent vandalism. The monitoring site should also be free of sedimentation during the period of temperature logger deployment. This is an important consideration when monitoring in low-gradient streams, or in alluvial high- and moderate-gradient streams with aggrading or shifting substrates (especially sand) that could bury the temperature logger. If possible, the monitoring site should be located in shade, to minimize any direct radiant heat from the sun. However, a deep run or riffle in the sun is acceptable, especially if no shade is present. The monitoring site should also avoid any immediate and local influences of cold or warm water inputs, such as springs, drain tile outlets, and storm sewer discharges.

The upstream and downstream temperature monitoring sites should be located slightly outside the restoration reach, so that these sites are not disturbed during the restoration work, and the temperature loggers can continue to collect data throughout the restoration period. The temperature loggers and anchoring devices at the intermediate temperature monitoring site(s) will need to be removed before restoration work commences and re-positioned at the same location(s) after restoration work is complete.

After monitoring site locations have been established, an accurate Global Positioning System (GPS) reading should be obtained for each site, for several reasons:

1. To find the temperature logger at a later date, in order to retrieve the logger and/or download the data.
2. To re-position the temperature logger and anchoring device at an intermediate site, post-restoration.
3. To record the location of the data collection point for the database.
4. To plot the monitoring site location on a map.

While a GPS unit can document monitoring site location with reasonable accuracy, an additional site marker may be helpful. For example, if the temperature logger is deployed in-stream with no fence post or re-bar extending above the water surface, it is suggested that a marker (metal fence post, electrical fence post, wire stake flag, a tree or large rock with marker paint, etc.) be placed on the stream bank, as a reference to where the logger is located in the stream. While a marker on the stream bank can be helpful for the volunteer monitor, it may also call attention to the temperature logger in public access areas with high traffic, possibly leading to vandalism or loss of the logger. Another approach is to use a tape measure to mark the location in reference to nearby landmarks. For example, a temperature monitor may be located 45m downstream of a road crossing and 2m from the left stream bank. Photo and/or video documentation of each monitoring site is also highly recommended.

Temperature monitoring sites should be named and numbered in an upstream to downstream progression through the stream restoration reach. For example, temperature monitoring sites on Wilson Creek (Dunn County) have been identified as follows: Wilson Creek_Site 1 (upstream site); Wilson Creek_Site 2 (intermediate site); and Wilson Creek_Site 3 (downstream site). The site name is used to identify the temperature logger at the site, as well as each data file generated by the logger (see **Data Management and Storage**, below).

Stream Temperature Monitoring Equipment

Individual temperature loggers, accompanying software, and other accessories are needed to continuously monitor water temperature. Purchase of equipment to deploy the temperature loggers into streams is also necessary.

Temperature loggers from the Onset Computer Corporation® are recommended for TUDARE stream temperature monitoring work. WDNR staff have been using various models of Onset® continuous temperature loggers for many years, and these loggers are currently being used at WDNR's long-term temperature monitoring sites in southwestern Wisconsin. The Kiap-TU-Wish Chapter has also used Onset® loggers extensively for temperature monitoring work on the Kinnickinnic River (St. Croix and Pierce Counties) and Pine Creek (Pierce County).

Two models of Onset temperature loggers are recommended:

Onset TidbiTv2® Temperature Logger: is Onset's smallest (quarter-sized) water temperature data logger, with 12-bit resolution and a precision sensor for ± 0.2 °C accuracy in the 0-30° C temperature range. Waterproof to 300 m (1000 ft). Data capacity: 42,000 measurements. Non-replaceable battery with a 5-year life. Price $133 (2011).

Onset HOBO Water Temp Pro v2® Temperature Logger: is the size and shape of a cigar, with 12-bit resolution and a precision sensor for ± 0.2 °C accuracy in the 0-30° C temperature range. Waterproof to 120 m (400 ft). Data capacity: 42,000 measurements. Non-replaceable battery with a 6-year life. Price $123 (2011).

The Onset® temperature logger models described above can be purchased directly from the Onset Computer Corporation (http://www.onsetcomp.com/). Other scientific suppliers of Onset® temperature loggers include Ben Meadows (http://www.benmeadows.com/) and Forestry Suppliers Inc. (http://www.forestry-suppliers.com/).

While either Onset® temperature logger model is suitable for continuous monitoring, the Onset TidbiTv2® Temperature Logger is notably smaller, with the advantage of being less visible and more easily camouflaged in the stream.

See the **Stream Temperature Logger Deployment Methods and Anchoring Devices** section of this document (below) for some examples of how the temperature loggers can be anchored in place at the monitoring sites.

Protective "boots" can be purchased for both temperature logger models. The boots help shield the loggers from debris floating down the stream, and also help prevent fouling of the loggers due to silt and biofilm. The protective boots for both models are displayed below:

Onset TidbiTv2® Boots
Price: 5 for $25.00 (2011)

Onset HOBO Water Temp Pro v2® Boots
Price: $19.00 each (2011)

HOBOware Pro Mac/Win Software® is needed to communicate with the temperature logger. The software can be installed on either a laptop or desktop computer, depending on the user's preference for communicating with (activating and downloading data from) the temperature loggers. The software can be installed on a laptop computer if the loggers are to be accessed in the field, using the laptop computer with an Onset Optic Base Station®. The software can be installed on a desktop (or laptop) computer if an Onset HOBO Waterproof Shuttle® is used to access the loggers in the field and transport data back to the home or office. In addition to temperature monitor management and downloading, the software can be used for data graphing, analysis, and export.

HOBOware Pro Mac/Win Software®
Price: $89.00 (2011)

If the user's preference is to communicate with the temperature loggers in the field using a laptop computer, an Onset Optic USB Base Station® is needed. The base station provides a communication portal for accessing, programming, activating, and downloading data from the temperature loggers. Couplers for all compatible loggers, including the TidbiTv2®, HOBO Water Temp Pro v2®, and HOBO Pro v2 Temperature/Relative Humidity Data Logger (see **Air Temperature Monitoring Equipment**, below) are included with the base station.

Onset Optic USB Base Station®, with Couplers
Price: $115.00 (2011)

If the user's preference is to communicate directly with the temperature loggers in the field, rather than bringing a laptop computer streamside, an Onset HOBO Waterproof Shuttle® is needed. The shuttle provides a communication portal for accessing, programming, activating, and downloading data from the temperature loggers. The shuttle can download and re-activate multiple TidbiTv2® and/or HOBO Water Temp Pro v2® temperature loggers in one trip, with the data stored in the shuttle. When returning from the field, the logger data can be transferred from the shuttle to a home desktop or laptop computer. Couplers for all compatible loggers, including the TidbiTv2®, HOBO Water Temp Pro v2®, and HOBO Pro v2 Temperature/Relative Humidity Data Logger (see **Air Temperature Monitoring Equipment**, below) are included with the shuttle. The shuttle is also waterproof to 20 meters. If the shuttle is purchased, a USB cable ($10.00) must also be purchased with the HOBOware Pro Mac/Win Software®, since the cable will be needed to connect the shuttle to the home desktop or laptop computer.

Onset HOBO Waterproof Shuttle®, with Couplers
Price: $230.00 (2011)

Accuracy Check of Stream Temperature Loggers

Temperature Logger Accuracy Check with Certified Thermometer:

Onset® stream temperature loggers are factory-calibrated and cannot be field calibrated, unlike some field monitoring meters. However, an accuracy check over a temperature range from 0° C to approximately 25° C (the typical temperature range expected in the field) should be conducted before deploying all temperature loggers, and at one-year intervals thereafter. The accuracy check is conducted using a certified thermometer, as described in the manufacturer's documentation (see Appendix B. Onset® Stream Temperature Logger Accuracy Check).

Temperature Logger Field Accuracy Check:

Using a high quality digital field thermometer, record the water temperature of the stream when deploying, checking, downloading, or removing the temperature logger. Record the time and temperature, in conjunction with the temperature logger site and logger serial number, in the site log book or on the site field sheet (see Appendix C for an example field sheet). Remember that the field watch used to record the time and the temperature logger's internal clock (set by the computer clock at the time of launch) may be different. To avoid this difference, however, the field watch should be adjusted to the official U.S. time clock (Central Time Zone) before each field visit (see http://www.time.gov/timezone.cgi?Central/d/-6/java). After the temperature logger is downloaded, the digital field thermometer temperatures should be compared to the logger temperatures, to determine if the temperature logger has remained within an acceptable accuracy range (± 0.2° C) during the deployment period. If the temperature logger is off by more than the acceptable accuracy range, remove the temperature logger from the stream and determine the reason for error, or replace the logger.

Field Thermometer Accuracy Check:

Once per year, the digital field thermometer should be checked against the certified thermometer, preferably at the same time that the temperature loggers are checked for accuracy (Appendix B). Results should be recorded in a logbook for that particular field thermometer.

Stream Temperature Logger Deployment and Downloading

Stream Temperature Logger and Software Instructions:

Directions for accessing, deploying and downloading Onset® stream temperature loggers (both the Onset TidbiTv2® Temperature Logger and the Onset HOBO Water Temp Pro v2® Temperature Logger) are available in an instruction sheet that is provided with each temperature logger purchased. The instruction sheet includes information on:

1. Temperature logger specifications.
2. Temperature logger accessories.

3. Connecting the temperature logger to the appropriate coupler, Onset Optic USB Base Station®, or Onset HOBO Waterproof Shuttle®.
4. Operating and deploying the temperature logger.
5. Temperature logger battery life.
6. Service and support.
7. Warranty.

A user's manual for the Onset TidbiTv2® Temperature Logger can be found at:
http://www.onsetcomp.com/files/manual_pdfs/10385_C_MAN_UTBI_001.pdf

A user's manual for the Onset HOBO Water Temp Pro v2® Temperature Logger can be found at:
http://www.onsetcomp.com/files/manual_pdfs/10366-D-MAN-U22-001.pdf

In addition to the instruction sheet that accompanies each temperature logger and the on-line user's manuals, an Onset® white paper on temperature logger deployment ("Underwater Temperature Loggers: Considerations for Selection and Deployment") can be found at:
http://www.onsetcomp.com/resources/white_papers/excerpts/underwater-temperature-loggers-considerations-for-selection-and-deployment

Directions for installing and using the HOBOware Pro Mac/Win Software® accompany the software.

Stream Temperature Logger Deployment:

Prior to each communication with the temperature logger (either deploying or downloading and re-launching), it is important to ensure that the internal clock in the laptop or desktop computer has been adjusted to the official U.S. time clock (Central Time Zone). This ensures that the logger is recording an accurate time with every temperature measurement. Similarly, the volunteer's field watch should be adjusted to the official U.S. time clock (Central Time Zone) before every field visit. This ensures that times associated with all field observations are accurate, and in-stream temperature measurements with the digital field thermometer can be reliably compared to temperature logger measurements. The official U.S. time clock can be viewed at: http://www.time.gov/timezone.cgi?Central/d/-6/java.

A temperature logging interval must be selected prior to logger deployment. A 1-hour interval between temperature readings is generally adequate for acquiring necessary baseline data, including pre- and post-restoration temperature data and long-term temperature data for evaluating climate change impacts. A 1-hour interval will also allow determination of whether a stream should be considered cold, cool, or warm, as well as the temperature extremes the stream experiences during a given time period. A 15- to 30-minute interval may be necessary for small, "flashy" streams, to detect any short-term temperature changes. An interval of 15 minutes or less may be best if a stream has an immediate connection to urban storm water sources, since stream temperature changes can be very rapid in these circumstances. In any event, the temperature logging interval should be greater than the temperature logger's response time (5 minutes).

The stream temperature logger stores 64K of data, and can record approximately 42,000 12-bit temperature measurements. The temperature logging interval (above) determines the length of time that the logger can record temperature data. For instance, a 1-hour logging interval allows the logger to collect and store data for a 1,806-day period. A 15-minute logging interval allows the logger to collect and store data for a 451-day period.

Check the status of the temperature logger battery and ensure adequate battery life prior to logger deployment. Logger battery status (0-100%) can be viewed in the software deployment screen. The internal temperature logger battery is non-replaceable. Battery life of the Onset TidbiTv2® Temperature Logger is about five years. Battery life of the Onset HOBO Water Temp Pro v2® Temperature Logger is about six years. More information on battery life and the ability to detect a "bad battery" can be found in the instruction sheet that accompanies the logger.

The stream temperature logger can be deployed ("launched") instantaneously, or a delayed launch can be scheduled for a future date and time. When launching the logger from a home or office computer, the delayed launch is especially helpful, since it can allow time to transport the logger to the monitoring site before temperature logging commences. Regardless of the launch type (instantaneous or delayed), ensure that each logger is set to record temperatures on the hour (e.g. 8:00, 9:00, 10:00…..). Having all monitors recording at the same time allows for better comparison of temperature data between sites on the same stream and amongst different streams.

After the temperature logger has been launched, confirm that it is operating by checking the red LED "OK" light on the front of the logger. In brightly lit areas, it may be necessary to shade the logger to see the "OK" light blink. If the temperature logger was launched instantaneously and is actively logging data, the "OK" light will blink every one to four seconds (the shorter the logging interval, the more frequently the light blinks). If the logger was launched with a delayed start, the "OK" light blinks once every eight seconds until data logging commences.

At a minimum, the stream temperature logger should be deployed at the monitoring site throughout the "summer period" of June 1 to August 31, as defined by the WDNR continuous temperature monitoring protocol (WDNR, 2004). A monitoring period of May 1 to September 30 is even more desirable, as the months of May and September can also exhibit considerable warming, which may become more prevalent with climate change impacts. To further evaluate trout reproduction potential in a stream, temperature monitoring should be conducted from mid-September through March. Depending on site logistics and the level of volunteer commitment, a best-case scenario would be year-round temperature monitoring. Year-round data would provide the best information for assessing any long-term impacts of climate change. For a stream with multiple temperature monitoring sites, year-round deployment of a temperature logger at one of the monitoring sites (a "reference site") may be a viable option.

Stream Temperature Logger Field Visits:

Field visits should be regularly scheduled to check on the temperature loggers at the monitoring sites. During each field visit, ensure that each logger is still recording data by removing the logger from the in-stream anchoring device and checking the "OK" light. If fouling of the logger is evident due to silt and/or biofilm, the logger can be cleaned with a soft toothbrush or cloth.

The two small optical nodes on the face of the logger must be clean in order to successfully download data. After checking the temperature logger, ensure that it is enclosed in the protective boot and securely re-attached to the anchoring device before departing from the site.

Since stream channel morphometry may change dramatically after high water (runoff) events, the location of the anchoring device should be checked to ensure that representative monitoring conditions still exist (see **Stream Temperature Monitoring Site Selection and Identification**, above). If necessary, the anchoring device can be re-positioned at the monitoring site. This re-location should be noted in the site log book or on the site field sheet, and new GPS coordinates should be obtained.

Using a high quality digital field thermometer, record the water temperature of the stream during every field visit. These field temperature measurements will help verify the ongoing accuracy of the temperature logger. Record the water temperature, date, and time, in conjunction with the temperature logger site and logger serial number, in the site log book or on the site field sheet.

All field visits, including those to deploy or download the stream temperature logger, should be recorded in the site log book or on the site field sheet (see Appendix C for an example field sheet). Before departing from the monitoring site, ensure that all necessary information has been documented in the log book or on the field sheet.

Stream Temperature Logger Downloading:

While the stream temperature logger has enough data storage capacity to be deployed year-round without downloading, regular downloading is recommended. At a minimum, plan to download the logger once near the mid-point of a June-August or May-September deployment period. The temperature logger should be downloaded on a quarterly basis if it is deployed year round. More frequent logger downloading will minimize data loss in the event of logger malfunction, damage, or loss. For example, the temperature logger should be downloaded before anticipated high water events (such as spring flooding), which will prevent the loss of data if the logger becomes damaged or irretrievable. If severe flooding is forecast, it may be wise to remove the logger from the stream until flooding abates.

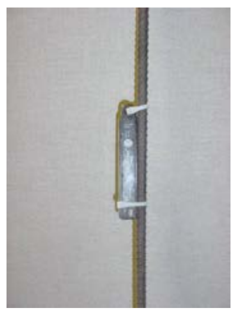
Several options exist to download data from the temperature logger. Downloading may entail removal of the logger from the stream and transport back to the home or office computer. Use of a laptop computer to download the logger at streamside is also an option. Finally, the Onset HOBO Waterproof Shuttle® allows downloading in the field with immediate re-deployment of the logger. The shuttle is then transported back to the home or office computer, for data transfer.

The HOBOware Pro Mac/Win Software® is used to download the temperature logger or the shuttle. At the outset of the downloading process, an option ("Yes" or "No") asks if data recording should stop before downloading the logger. Choose "Yes", as stopping recording clears the logger and opens more room for data collection. If data recording is not stopped and the logger is then redeployed, new temperature data are added to the data that have already downloaded, but have also been left on the logger. During the downloading process, the temperature data obtained by the logger can be immediately viewed in both tabular and graphic formats. An option exists to view the temperature data in units of degrees Celsius (°C) or Fahrenheit (°F). When the data download is complete, an Onset HOBO Datafile is created. This file stores the temperature data in units of both °C and °F. The file should be named and saved on the volunteer's computer. The file naming convention is as follows: Creek Name_Site #_Download Date. As an example, when the temperature logger at Site 1 on Wilson Creek is downloaded on July 15, 2011, the file name is: Wilson Creek_Site 1_071511. Information on file management can be found in **Data Management and Storage**, below.

Stream Temperature Logger Deployment Methods and Anchoring Devices

A number of options exist for securely anchoring the stream temperature logger at the monitoring site. Examples of anchoring devices are provided below.

In slotted PVC tube



Connected to re-bar with zip ties. Re-bar is pounded into stream bottom.

Connected to railroad tie plate and protected by PVC tube

In PVC tube attached to brick

In capsule attached to fence post or re-bar and pounded into stream bottom

Connected to angle iron welded to re-bar and pounded into stream bottom

Volunteer driving a metal, U-shaped fence post that will secure a temperature logger at a monitoring site. With this anchoring device, the logger is wired directly to the fence post.

Note that some anchoring devices deploy the temperature logger near the stream bottom, while others suspend the logger off the bottom. The stream type and size may determine which deployment method and anchoring device is most likely to keep the temperature logger submerged and free of sediment during the deployment period.

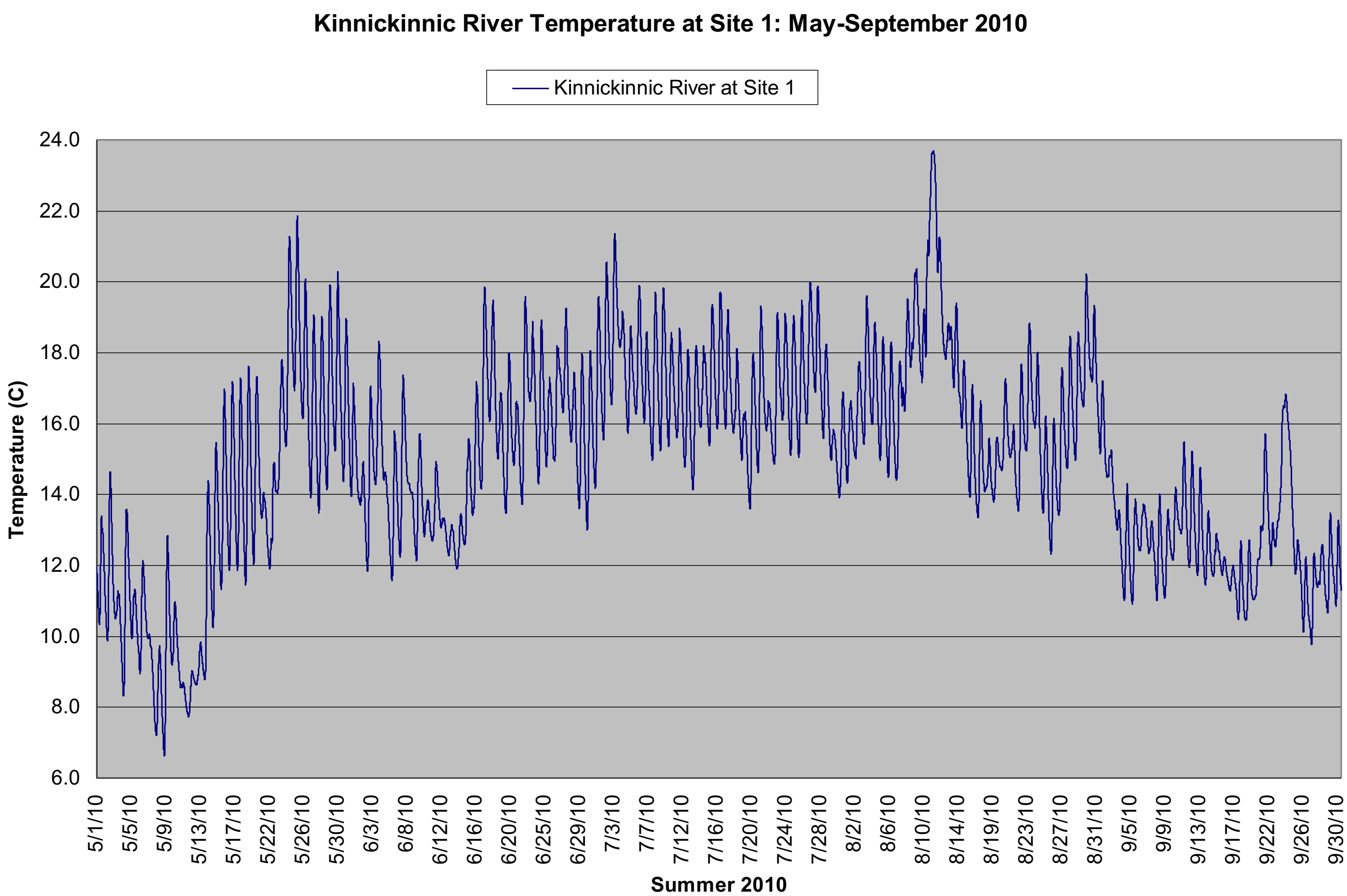
When soft substrate is present on the stream bottom, a metal, U-shaped fence post may be a preferable anchoring device. A suitable soft spot for a fence post can generally be found at a monitoring site, unless there is bedrock or large rubble. A heavy-duty 5-foot fence post or a light-duty 4-foot fence post can be purchased with pre-drilled holes, which allow the logger to be attached directly to the post with a heavy (12-gauge) solid insulated electrical wire or heavy plastic tie wraps. A sledge hammer or post driver is used to set the fence post, and a hack saw and file may be needed in the event that the post needs to be shortened. The post should be driven in the stream channel with the U-shaped trough oriented downstream. This orientation allows the logger to be fully or partially tucked into the trough on the downstream side of the post, thereby protecting the logger from damage due to debris.

When rocky substrate is present on the stream bottom, a 3- to 5-foot length of re-bar works well as an anchoring device. Multiple plastic zip ties can be used to attach the logger to the re-bar. If bedrock is present at the monitoring site, a heavy-duty concrete block can be used as an anchoring device. The logger can be wired to the interior of the block, on the center post. The concrete block should be oriented to allow water to flow through the two openings, thereby decreasing resistance on the block. If high water displaces the concrete block, the logger is protected in the interior of the block. The block can be readily retrieved and re-positioned after high water subsides. To provide additional protection and better ensure recovery of the cement block in the event of flooding, a light-gauge steel cable can be used to attach the block to a secure object (such as a tree trunk) on the stream bank. However, the visibility of the cable on the stream bank could encourage tampering or vandalism.

If desired, an identification tag can be attached to the temperature logger or the anchoring device. The tag may identify the equipment as owned by TUDARE, with the volunteer's contact information (name and phone number) provided. Since the temperature loggers will typically be deployed in a stream with public access, the best defense against vandalism is to ensure that the loggers are not visible. This can be done by camouflaging the logger and anchoring device, or by locating the anchoring device near existing natural in-stream structures such as logs and boulders. If the temperature logger is well hidden, it can be difficult for the volunteer to find it on return visits. GPS coordinates, stream bank markers, tape measurements from reference points, and pictures are helpful for re-locating the logger.

Air Temperature Monitoring:

Air temperature has a significant influence on water temperature in coldwater streams (Stewart, Mitro, Roehl, and Risley, 2006), as is evident in the Kinnickinnic River thermograph below.



Temperature of the Kinnickinnic River (River Falls, WI) at Site 1, May-September 2010

Of immediate note in these thermographs is the strong diurnal (daily) temperature pattern in the river. Although cold ground water continually feeds the river via springs along the entire riverway, the temperature of the Kinnickinnic River is greatly influenced by ambient air temperature. During the daylight hours, the river gradually warms and generally reaches a daily maximum temperature in the late afternoon or early evening (4:30-6:30 PM). At night, the river gradually cools and typically reaches a daily minimum temperature just after sunrise (7:30-9:30 AM). These diurnal temperature fluctuations in the river are natural, and the river's residents, including macroinvertebrates and trout, have become accustomed to a constantly but slowly changing temperature regime.

Also of note in the 2010 Kinnickinnic River thermograph are the relatively frequent changes in the daily minimum and maximum river temperatures and daily temperature ranges that are influenced by local weather patterns (cold fronts and warm fronts) and seasonal climate changes. During the summer 2010 period, for example, the monthly mean river temperature was coolest in May (13.1 degrees Celsius (°C)) and warmest in July (17.0° C).

Air temperature is the climate variable that best explains temporal variation in stream temperature (Mitro, Lyons, and Sharma, 2010). Because of the impact of air temperature on water temperature, it is important to monitor air temperature in the locale where stream temperature monitoring sites have been established. Local sources of air temperature data may already be available, such as the National Weather Service, colleges or universities, and state or local units of government. For instance, corresponding air temperature data for the Kinnickinnic River temperature data are obtained from a local City of River Falls weather station. However, if an existing local weather station is used, it must be able to continuously record air temperature data at the same interval as that used for recording water temperature data via the in-stream temperature loggers. For example, if the in-stream temperature loggers are recording water temperature at hourly intervals, air temperature should also be recorded at hourly intervals.

In addition to air temperature information, it is also very helpful to obtain local information on relative humidity level and dew point temperature. As a consequence of a warming climate, relative humidity levels and dew point temperatures are expected to increase along with air temperatures. Altered precipitation patterns, including increased annual precipitation (Mitro, Lyons, and Sharma, 2010) and more intensive precipitation events at longer intervals (Hansis, 2010), are a likely consequence of higher relative humidity levels and dew point temperatures. Dew point temperature is also a very good approximation of night-time stream temperature (Heinz Stefan, personal communication, February 2011).

When suitable local weather data (air temperature, relative humidity level, and dew point temperature) are not available, a weather station should be established to house the equipment needed to collect these data in the vicinity of the stream.

Weather Station Site Selection and Shelter

The weather station does not need to be located immediately next to the stream. To best prevent vandalism, a location on private property may be the safest alternative. While surveying the stream restoration reach in advance of the monitoring project (see **Field Reconnaissance and Site Selection**, above), the volunteer monitor may want to check with the adjoining landowners, to see if one may be willing to "host" the weather station on his/her property. The local landowner may also be willing to act as a monitoring "observer", to keep an eye on the weather station while the volunteer monitor is away.

Pine Creek weather station, hosted by Maiden Rock American Legion Post 158
Maiden Rock, Wisconsin

As shown above, the weather station should be situated in an open area away from buildings, parking lots, and other structures that could unduly influence air temperature. Shaded areas should also be avoided.

Several types of shelters are available for housing and protecting the air temperature monitoring equipment. The weather station shelter shown below meets National Weather Service protocols, and provides a dry, secure location for the air temperature logger (see **Air Temperature Monitoring Equipment**, below).

This weather station can be purchased from the Ben Meadows Company, as a "thermometer shelter", at a cost of $95.50 (2011) (see http://www.benmeadows.com/).

The weather station has a locking front door that provides easy access to the air temperature logger. This shelter can be readily mounted on an 8-foot, 4" x 4" treated wooden post. Use lag screws and washers to secure the shelter to the wooden post via the mounting holes provided on the upper and lower flanges of the back panel (see photo at right, above). Per National Weather Service protocol, the bottom of shelter should be 4 feet above ground level. If desired, the post can be cemented in the ground to provide additional stability. The air temperature logger should be mounted in the center of the interior back panel of the weather station (see photo at right, above), using the mounting bracket and screws that accompany the logger.

As another option for housing the air temperature logger, a solar radiation shield can be purchased from the Onset Computer Corporation® (http://www.onsetcomp.com/), at a cost of $105.00 (2011).

The solar radiation shield provides less security than the weather station shelter, but it can be easily mounted on a metal, U-shaped fence post, a round metal post, or a wooden post, using the mounting hardware provided. Per National Weather Service protocol, the solar radiation shield should be 4 feet above ground level.

If a local monitoring observer is available, he/she may also be willing to measure rainfall on a daily basis. An inexpensive rain gauge (see photo below) can be readily mounted on the post for the weather station shelter or solar radiation shield. Ensure that the top of the gauge extends above the top of the post, as shown below. The rain gauge should be capable of measuring precipitation in 0.01-inch increments.

A rain gauge can be purchased from the Ben Meadows Company, at a cost of $33.90 (2011) (see http://www.benmeadows.com/). A rain gauge can also be purchased through the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) Network (http://www.cocorahs.org/), a nation-wide volunteer precipitation monitoring network sponsored by the National Weather Service. The cost of the rain gauge via CoCoRaHS is $25.00. If possible, daily precipitation measurements should be made on a year-round basis, using CoCoRaHS protocols. At a minimum, daily rainfall should be recorded during the same time period that stream and air temperature data are being obtained. Field sheets for recording precipitation on a monthly and/or annual basis are available on the CoCoRaHS website.

If desired, a sign or identification tag can be attached to the weather station. The sign or tag may identify the equipment as owned by TUDARE, with the volunteer's contact information (name and phone number) provided.

Air Temperature Monitoring Equipment

A temperature logger from the Onset Computer Corporation® is recommended for TUDARE air temperature monitoring work. In addition to continuously measuring air temperature, this logger (as shown below) measures relative humidity and dew point temperature.

Onset HOBO Pro v2® Temperature/Relative Humidity Logger: is a weatherproof data logger with built-in temperature and relative humidity sensors. The relative humidity sensor provides superior durability in humid environments and is user replaceable. Temperature sensor accuracy is ± 0.2 °C in the 0-50° C temperature range. Relative humidity sensor accuracy is ± 2.5% in the 10-90% range. Memory is 64K, providing 21,000 temperature and relative humidity measurements. User-replaceable battery with a 3-year life. Price $163 (2011).

The Onset® air temperature logger can be purchased directly from the Onset Computer Corporation (http://www.onsetcomp.com/). Other scientific suppliers of the Onset® air temperature logger include Ben Meadows (http://www.benmeadows.com/) and Forestry Suppliers Inc. (http://www.forestry-suppliers.com/).

HOBOware Pro Mac/Win Software® is needed to communicate with the air temperature logger, along with an Onset Optic Base Station® or an Onset HOBO Waterproof Shuttle®. A description of these items and directions for their use are provided in **Stream Temperature Monitoring Equipment**, above.

Accuracy Check of Air Temperature Logger

The Onset® air temperature logger is factory-calibrated and cannot be field calibrated, unlike some field monitoring meters. Onset® provides no specific instructions for checking the accuracy of the air temperature logger. If a controlled environment is available, the logger could be checked to determine if it is recording air temperature and relative humidity within their specifications.

Air Temperature Logger Deployment and Downloading

Directions for accessing, deploying and downloading the Onset® air temperature logger are available in an instruction sheet that is provided with each temperature logger purchased. An Onset HOBO Pro v2® User's Manual can be found at:

http://www.onsetcomp.com/files/manual_pdfs/10694-H-MAN-U23.pdf

Air Temperature Logger Deployment:

Directions for deploying the air temperature logger are nearly identical to those for deploying a stream temperature logger (see **Stream Temperature Logger Deployment**, above).

An air temperature logging interval must be selected prior to logger deployment. Ensure that the logging interval and logger recording times (on-the-hour) are identical to those used for the stream temperature loggers. If water temperature is measured at 8:00 AM, ensure that air temperature is also measured at 8:00 AM. In this manner, air temperature data can be directly compared to stream temperature data.

The air temperature logger stores 64K of data, and can record approximately 21,000 air temperature and relative humidity measurements. The temperature logging interval (above) determines the length of time that the logger can record temperature and relative humidity data. For instance, a 1-hour logging interval allows the logger to collect and store data for a 903-day period. A 15-minute logging interval allows the logger to collect and store data for a 225-day period.

Check the status of the air temperature logger battery and ensure adequate battery life prior to logger deployment. Logger battery status (0-100%) can be viewed in the software deployment screen. The internal logger battery (1/2 AA 3.6 volt lithium) is user-replaceable (Onset® Part # HP-B). Battery life is about three years. More information on battery life, battery replacement, and the ability to detect a "bad battery" can be found in the user's manual.

The three dessicant packs in the logger cap should be periodically inspected. If the packs are not bright blue, dry them following the instructions in the user's manual, or replace them (Onset® Part # DESSICANT1). Instructions for replacing the relative humidity sensor are also found in the user's manual.

The air temperature logger can be deployed ("launched") instantaneously, or a delayed launch can be scheduled for a future date and time. When launching the logger from a home or office computer, the delayed launch is especially helpful, since it can allow time to transport the logger to the weather station before temperature logging commences.

After the air temperature logger has been launched, confirm that it is operating by checking the red LED "OK" light on the front of the logger. In brightly lit areas, it may be necessary to shade the logger to see the "OK" light blink. If the temperature logger was launched instantaneously and is actively logging data, the "OK" light will blink every one to four seconds (the shorter the logging interval, the more frequently the light blinks). If the logger was launched with a delayed start, the "OK" light blinks once every eight seconds until data logging commences.

At a minimum, the air temperature logger should be deployed during the same time period as the stream temperature loggers. For instance, if the stream temperature loggers are deployed during the May 1-September 30 time period, the air temperature logger should also be deployed during this time period. In this manner, air temperature data can be directly compared to stream temperature data. Since air temperature logger deployment entails minimal effort once the weather station has been established, year-round data (air temperature, relative humidity, and dew point temperature) would provide the best information for assessing any long-term impacts of climate change.

Air Temperature Logger and Weather Station Field Visits:

Field visits should be regularly scheduled to check on the air temperature logger. During each field visit, ensure that the logger is still recording data by removing the logger from the weather station or the solar radiation shield and checking the "OK" light. Make sure that the logger's communication window is clean and dry, by gently wiping it with a clean, non-abrasive cloth. If the logger is damp, wipe off any excess moisture.

Ensure that the weather station or solar radiation shield is still in good repair, and free of pests and debris. During the warm weather season, always open the weather station door or remove the logger from the solar radiation shield with care, as these types of shelters can attract nest-building wasps. On occasion, both the interior and exterior of the weather station will need to be re-painted. Always use white paint, as it reflects solar radiation and heat. Ensure that the air temperature logger is removed from the weather station prior to painting, especially if spray painting the exterior, as the paint will enter the interior of the station through the ventilation slats.

If a rain gauge is present at the weather station, check to make sure that it is good repair, and free of pests and debris, especially the conical funnel at the top of the gauge. The top of the gauge and the inner and outer cylindrical tubes can all be cleaned with water and a soft-bristled bottle brush.

All field visits, including those to deploy or download the air temperature logger, should be recorded in the site log book or on the site field sheet (see Appendix C for an example field sheet). Before departing from the monitoring site, ensure that all necessary information has been documented in the log book or on the field sheet.

Air Temperature Logger Downloading:

Directions for downloading the air temperature logger are nearly identical to those for downloading a stream temperature logger (see **Stream Temperature Logger Downloading**, above).

While the air temperature logger has enough data storage capacity to be deployed for a lengthy time period, regular downloading is recommended. More frequent logger downloading will minimize data loss in the event of logger malfunction, damage, or loss. As standard practice, plan to download the air temperature logger whenever the stream temperature loggers are downloaded.

Options for downloading data from the air temperature logger are the same as those described in **Stream Temperature Logger Downloading**, above. Data recording should stop before downloading the logger. During the downloading process, the air temperature, dew point temperature, and relative humidity data obtained by the logger can be immediately viewed in both tabular and graphic formats. An option exists to view the air and dew point temperature data in units of degrees Celsius (°C) or Fahrenheit (°F). When the data download is complete, an Onset HOBO Datafile is created. This file stores the air and dew point temperature data (in units of both °C and °F), as well as the relative humidity data. The file should be named and saved on the volunteer's computer. The file naming convention is as follows: Creek Name_WS (Weather Station)_Download Date. As an example, when the air temperature logger at Wilson Creek is downloaded on July 15, 2011, the file name is: Wilson Creek_WS_071511. Information on file management can be found in **Data Management and Storage**, below.

Stream Habitat Assessment:

Stream geomorphology plays a major role in determining the ecological condition of a coldwater resource, and can also have a significant influence on stream temperature. These geomorphic features include regional and local geology, water flow and velocity, stream channel shape, size, and slope, stream bank height, shape, and soil type, and stream bed substrate composition.

The WICCI Coldwater Fish and Fisheries Working Group (Mitro, Lyons, and Sharma, 2010) recommends using stream restoration techniques that promote colder water temperatures (e.g., narrowing and deepening stream channels) and targeting restoration efforts to streams most likely to realize these benefits under a changing climate. As such, pre- and post-restoration assessment of key geomorphic (habitat) conditions is very helpful for understanding how a restoration project has improved the temperature regime and ecological health of a coldwater stream. Furthermore, ongoing post-restoration habitat assessment at regular intervals can provide critical information on how a restoration project withstands high water (flood) events, and can also inform any needs for maintenance of the restoration reach (Johnson, 2010). On a long-term basis, post-restoration habitat assessment at regular intervals can provide information on how the restoration project withstands any climate-influenced impacts related to increasing temperature and precipitation and runoff. The WDNR Water Resources Policy Management Team has recommended that the WDNR Watershed Bureau should begin climate change-specific surface water monitoring (Hansis, 2010), including the establishment of a state-wide network of stations where scientists will record stream channel geometry, sinuosity, bed forms, and sediment at recurring intervals. Volunteer monitoring of stream restoration projects will support this WDNR recommendation.

Stream Habitat Assessment Variables

For the purpose of this volunteer monitoring program, the extent of stream habitat assessment will be limited to the measurement of four key geomorphic variables that have the greatest impact on stream temperature: stream width, water depth, water velocity, and canopy cover. Changes in these four variables from pre- to post-restoration may best explain any temperature improvement observed as a result of the restoration project. A narrower, deeper stream channel after restoration should increase water velocity and reduce travel time through the restoration reach, thereby improving the temperature regime and increasing stream resilience to climate change. However, canopy cover (shading) also influences stream temperature as water travels through the restoration reach, so pre- and post-restoration measurements of canopy cover are important to help explain any observed temperature changes.

While the four key habitat variables (stream width, water depth, water velocity, and canopy cover) are the focus of this volunteer monitoring program, other geomorphic (habitat) variables can also be measured as volunteer interest, time, and resources (including equipment availability) allow. Additional habitat variables that can be measured include: water flow, stream channel bankfull width and depth, stream bank height, depth, slope, and soil type, and stream bed substrate composition. Qualitative observations of macrophyte (rooted aquatic plants), macroinvertebrate (aquatic insects), and fish presence can also be made. Pre- and post-restoration measurements of these other habitat variables can document additional benefits of stream restoration, including reduced stream bank erosion, improved stream bed substrate for macroinvertebrates and fish (spawning), the creation of in-stream habitat structures, improved stream access to the floodplain, and improved ecological condition. In addition to improving the stream temperature regime, all of these ancillary restoration project benefits can provide increased resistance to climate change impacts.

Stream Habitat Assessment Site Selection and Identification

For pre- and post-restoration assessment of the four key habitat variables (stream width, water depth, water velocity, and canopy cover) and additional habitat variables as desired, 1-meter wide transects should be established across the stream channel at approximately 125-meter intervals along the entire stream restoration reach, starting at the upper project boundary and proceeding downstream to the lower project boundary.

Habitat transects can best be established during a field reconnaissance trip in advance of the assessment work (see **Field Reconnaissance and Site Selection**, above). If possible, the habitat assessment transects should be located in close proximity to the stream temperature monitoring sites, including those near the upper and lower project boundaries, but also those at intermediate sites. Note whether each transect location is a riffle, run, or pool. Representation of all three hydrologic features is desirable, and transect sites can be adjusted slightly to ensure a balanced representation of these stream features. Once the habitat transect locations have been finalized, note the downstream distance of each transect from the upper project boundary. The downstream distance of each transect from the upper project boundary and the approximate 125-meter distances between transects can be measured by using the length of the volunteer's walking step and/or a pedometer, or preferably, by using a measuring wheel (see below) or measuring tape, which will provide a direct, more accurate measurement of distance (in meters).

ROLATAPE® Model 415M Measuring Wheel
Price: $168.00 (2011)

A variety of measuring wheels, in a price range from $100-$200, are available for purchase from Ben Meadows (http://www.benmeadows.com/) and Forestry Suppliers Inc. (http://www.forestry-suppliers.com/). A wheel that measures in meters is preferable to one that measures in feet.

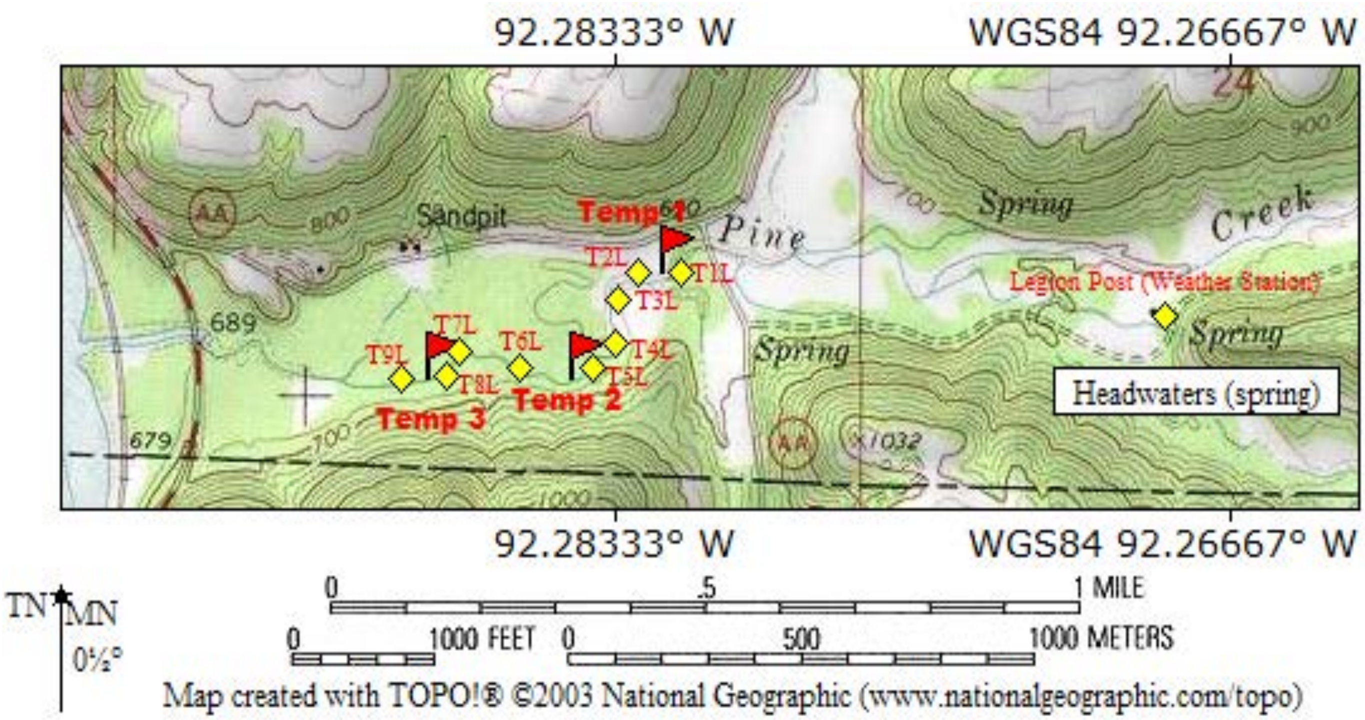
Once established, each 1-meter wide transect site should be marked with four brightly-colored survey flags: two located a meter apart on left descending stream bank, and two located a meter apart on the right descending stream bank. A meter stick can be used to position the flags on each stream bank, as pictured below.

Establishing a 1-meter wide transect at Lower Pine Creek_T4L

Although very helpful for locating transects while pre-restoration habitat assessment work is being conducted, these survey flags cannot be regarded as permanent, as they are subject to subsequent loss by high water (flood) events and vandalism, and will certainly be lost when stream restoration work occurs. Therefore, GPS measurements should also be obtained at both ends of each transect, on the left and right descending stream banks. In this manner, the GPS coordinates can be used to re-establish each transect at the same location, when post-restoration habitat assessment work is conducted. The pre- and post-restoration GPS coordinates should be recorded on the field sheet for each transect (see **Stream Habitat Assessment Field Sheet**, below). In addition to obtaining GPS coordinates, it may be helpful to use a tape measure to locate transects in relation to some permanent marker or structure (e.g., bridge or tree) that will not be impacted by the stream restoration work. Pre- and post-restoration photo documentation of each transect location is also highly recommended.

Habitat assessment transects should be named and numbered in an upstream to downstream progression through the stream restoration reach. For example, if three habitat assessment transects are established on Wilson Creek (Dunn County), they would be identified as follows: Wilson Creek_T1 (upstream site); Wilson Creek_T2 (intermediate site); and Wilson Creek_T3 (downstream site).

An example of transect establishment and numbering in a restoration reach at Pine Creek (Maiden Rock, WI) is provided below.



This project map shows the locations of the three (3) temperature monitors (Temp #), weather station, and the nine (9) habitat assessment transects (T#L) in Lower Pine Creek.

Habitat indicators were measured on nine (9) 1-meter wide transects located at approximately 125-meter intervals along the 1050-meter restoration reach of Lower Pine Creek (see project map above). The nine transects were established at the following distances downstream of the upper project boundary:

T1L:	0 meters	(Run)	T4L:	351 meters	(Run)	T7L:	750 meters	(Run)
T2L:	125 meters	(Riffle)	T5L:	517 meters	(Pool)	T8L:	866 meters	(Run)
T3L:	253 meters	(Riffle)	T6L:	620 meters	(Riffle)	T9L:	966 meters	(Run)

Conducting habitat assessment work
within the 1-meter wide transect at Lower Pine Creek_T4L

All stream habitat assessment measurements should be obtained during a base flow (non-runoff) condition, since this condition primarily defines the temperature of a coldwater stream. Under a base flow condition, the stream is dominated by the groundwater inputs that provide the cold water. Hence, measurement of habitat variables under a base flow condition provides the best understanding of how these variables relate to stream temperature.

Each pre- and post-restoration habitat assessment should be conducted during a short (1-2 day) time period, if possible, to provide a "snapshot" view that is not impacted by any large intervening flood events that could change stream habitat conditions.

Pre-restoration habitat assessment should be conducted shortly before stream restoration work begins. Post-restoration habitat assessment should be conducted a year after project work has been completed, thereby providing an opportunity for the stream channel and riparian areas to stabilize. Since streams are dynamic systems, even after restoration occurs, post-restoration habitat assessment should be conducted at 3-5 year intervals after the initial post-restoration assessment has been conducted (Johnson, 2010). Regular post-restoration habitat assessment also provides an opportunity to evaluate any project maintenance needs that arise. These needs can subsequently be conveyed to the WDNR restoration project manager.

Stream Habitat Assessment Equipment

A list of the equipment needed to conduct stream habitat assessment work is provided below:

- ☑ Measuring wheel and/or pedometer
- ☑ Measuring tape (preferably 30-meter fiberglass)
- ☑ Stake(s), for anchoring end(s) of measuring tape
- ☑ Meter stick
- ☑ Brightly-colored survey flags, with flexible, narrow-gauge wire shafts
- ☑ GPS unit
- ☑ Digital camera and/or video recorder
- ☑ Velocity meter (Marsh-McBirney or similar), with instructions for use and spare batteries
- ☑ USGS-style wading rod, with instructions for use
- ☑ Floating object (an orange or tennis ball works best)
- ☑ Spherical densiometer (convex), with instructions for use
- ☑ Compass
- ☑ Field sheets (one per transect)
- ☑ Clipboard
- ☑ Pens and pencils
- ☑ Digital thermometer (°C)
- ☑ Watch, with stop-watch function
- ☑ Hand-held calculator

Stream Habitat Assessment Methods

When conducting stream habitat assessment measurements, it is important to minimize stream bottom disturbance within each 1-meter wide transect, especially if measuring other habitat variables such as stream bed substrate composition, embeddedness, and the presence of macrophytes. Since stream bed substrate composition, embeddedness, and macrophyte presence are largely based on visual inspection, these observations should be made first, before other stream channel measurements (stream width, water depth, water velocity, and canopy cover) that require wading in the transect.

Stream Width:

A wide stream has a large water surface area exposed to warm air temperatures, which warm the water. Diurnal (daily) fluctuations in stream temperature are a common occurrence, due to daily fluctuations in air temperature. However, wide, shallow, and slow-flowing streams are more subject to summer warming. Stream restoration work typically creates a narrower stream channel that maintains a cooler water temperature during the summer.

Stream width should be measured across the center of each 1-meter wide habitat assessment transect, using a 30-meter (100-foot) fiberglass measuring tape, or any other type of measuring tape with sufficient length and metric units. Extend the measuring tape from the water's edge near one stream bank to the water's edge near the opposite stream bank, as shown in the photo below. If needed, a stake can be used to anchor the end of the tape on one edge of the stream while extending the tape across the channel to the other edge. Once the tape is extended across the stream channel, ensure that it is taut and not bowed downstream by the stream current. Stream width should be measured in meters (m), to the nearest 0.1 m, and recorded on the transect field sheet (see **Stream Habitat Assessment Field Sheet**, below).

Measuring stream width and marking quarter-point locations
within the 1-meter wide transect at Lower Pine Creek_T6L

While measuring stream width at each transect location, mark the quarter-point locations across the stream channel by placing brightly-colored survey flags in the streambed, as pictured above. Quarter-points are defined as locations that are 25%, 50%, and 75% of the distance across the stream channel. If the stream width is 4.0 meters or greater, place survey flags at two additional locations that are 0.5 meter from the left and right descending banks. The quarter-point locations and two additional locations near the stream banks will be used to make measurements of water depth and velocity, as described below.

Water Depth:

A shallow stream is more subject to warming. Besides increasing the stream temperature, the shallow water provides very little habitat for trout, with few places to escape predation by herons, kingfishers, mink, and raccoons. Stream restoration work typically creates a deeper stream channel that maintains cooler water temperatures during the summer, and provides better trout habitat, especially with LUNKER structures present.

Water depth should be measured at the marked locations (see **Stream Width**, above) across the center of each 1-meter wide habitat assessment transect, using a meter stick (preferred) or measuring tape. The marked locations include the three quarter-point locations and the two additional locations that are 0.5 meter from the left and right descending banks (if the stream width is 4.0 meters or greater). While measuring water depths at the designated locations across the transect, also measure water depth at the deepest location on the transect. All water depths should be measured in meters (m), to the nearest 0.01 m, and recorded in the appropriate spots on the transect field sheet (see **Stream Habitat Assessment Field Sheet**, below). Water depths at all of the marked locations can be averaged and reported as mean water depth on the field sheet.

Water Velocity:

A slow-moving stream is subject to warming, and may not create the oxygen-rich environment associated with streams that flow quickly and tumble over coarse bottom substrate such as boulders, rubble, and gravel. As water velocity decreases, a stream is more likely to deposit any fine sediment that it is carrying, creating a silty stream bed that is unsuitable for macroinvertebrate production and trout spawning. Stream restoration work typically creates a faster water velocity that maintains cooler water temperatures during the summer, increases dissolved oxygen concentrations, reduces sediment deposition, and scours silt from the stream bed.

Several types of velocity (current) meters are available for making water velocity measurements, including the Marsh-McBirney Flo-Mate™ Model 2000 Portable Flowmeter, the SonTek/YSI Flowtracker Handheld Acoustic Doppler Velocimeter®, the USGS Price Meter, the USGS Type AA Meter, and the USGS Pygmy Meter. All of these meters are used in conjunction with a top-setting USGS-style wading rod, which can position the meter's in-stream velocity sensor at the pre-determined water depth(s) where water velocity measurements are made. Instructions for using these meters and the accompanying USGS-style wading rod are provided by the instrument manufacturers.

Velocity (current) meters are expensive, generally ranging in price from $2,000-$10,000. A USGS-style wading rod ranges in price from $400-$500. Given this expense, most volunteers and/or volunteer monitoring organizations will not have the capacity to purchase high-quality water velocity monitoring equipment. However, state and federal agencies such as the WDNR and USGS (U.S. Geological Survey) generally have this type of equipment available. Agency staff may be willing to lend the equipment to the volunteer, and/or (more preferably) assist with the water velocity measurements, since considerable expertise is required to operate the meter and wading rod.

If a velocity (current) meter is available, water velocity should be measured at the quarter-point locations (see **Stream Width**, above) across the center of each 1-meter wide habitat assessment transect, using the meter and USGS-style wading rod (see photo below). At each quarter-point location, water depth can be measured directly by using the units (in 0.1-foot increments) marked on the wading rod. If the water depth is 2.5 feet (0.75 meter) or less, water velocity should be measured at one point in the water column, located at 0.6 of the water depth below the water surface. The wading rod can be adjusted to precisely measure this location. If the water depth is greater than 2.5 feet (0.75 meter), water velocity should be measured at two points in the water column, located at 0.2 and 0.8 of the water depth below the water surface. The wading rod can also be adjusted to precisely measure these two locations. When making the water velocity measurement(s) at each quarter-point, face upstream and stand 1.5 feet downstream and off to one side of the wading rod and velocity sensor, to avoid influencing the current velocity. Ensure that the wading rod remains vertical and the velocity sensor remains oriented correctly in relationship to the oncoming current, depending upon the type of meter used. All water velocities should be measured in meters per second (m/sec), to the nearest 0.01 m/sec, and recorded in the appropriate spots on the transect field sheet (see **Stream Habitat Assessment Field Sheet**, below). If two velocity measurements are made at a quarter-point location (at the 0.2 and 0.8 depths) these two velocity measurements should be averaged and reported as one value for that location. Water velocity measurements at the three quarter-point locations can be averaged and reported as mean water velocity on the field sheet.

Measuring water velocity at a quarter-point location
within the 1-meter wide transect at Lower Pine Creek_T1L

If a velocity (current) meter is not available, water velocity should be measured at the quarter-point locations on each transect, using the Water Action Volunteer (WAV) method, as described on page 3 ("Velocity Measurement") of the "**Stream Flow**" protocol document, at: http://watermonitoring.uwex.edu/pdf/level1/FactSeries-StreamFlow.pdf). Rather than tracking the time it takes for a floating object to move through a 20-foot length of stream, as described in the WAV protocol, simply track the time it takes the floating object to travel through the 1-meter wide transect, at all three quarter-point locations. A stopwatch is necessary to make an accurate measurement of travel time. Knowing the distance traveled (1 meter) and the travel time (in seconds), calculate water velocity in meters per second (m/sec), to the nearest 0.01 m/sec. To ensure a closer approximation of the stream's true velocity, three time trials should be conducted at each quarter-point location. These three velocity measurements should be averaged and reported as one value for that quarter-point location. All water velocities should be recorded in the appropriate spots on the transect field sheet (see **Stream Habitat Assessment Field Sheet**, below). Water velocity measurements at the three quarter-point locations can be averaged and reported as mean water velocity on the field sheet.

While water depth and water velocity measurements as described above are certainly adequate, more frequent measurements are desirable. If time allows, obtain 10-20 depth and velocity measurements at fixed increments across each transect, depending on stream width. For example, if the stream is 4.4 m wide, measurements could be made at 0.3 m increments (0.3 m, 0.6 m, 0.9 m, etc.) for a total of 14 measurements.

Canopy Cover:

Canopy cover is the extent to which riparian vegetation (primarily trees and shrubs) shades the stream from sunlight. Shading can be an important factor for maintaining cooler temperatures in trout streams, and can also affect the presence and distribution of aquatic vegetation, including macrophytes. The forest canopy contributes leaves and terrestrial insects that serve as food sources for macroinvertebrates and trout. Fallen trees, submerged logs, and branches (woody debris) provide nutrients, food, and habitat for macroinvertebrates and trout. Driftless Area stream restoration practices, which promote the re-establishment of native grasses in the riparian zone, may permanently reduce canopy cover. However, a narrower, deeper channel and faster water velocity should still improve the stream's temperature regime by facilitating the transport of cold groundwater inputs. As the riparian area becomes re-vegetated after restoration work is complete, it is likely that tall, overhanging native grasses will partially shade a narrower stream channel.

An estimate of percent canopy cover should be made at the center of each 1-meter wide habitat assessment transect, using a convex spherical densiometer, which is shown below.

Spherical Densiometers (convex at left)
Price: $104.00 (2011)

Convex spherical densiometers are available for purchase from Ben Meadows (http://www.benmeadows.com/) and Forestry Suppliers Inc. (http://www.forestry-suppliers.com/).

Detailed instructions for using the spherical densiometer are conveniently provided on the inside cover of the instrument. Standing in the center of the habitat assessment transect, obtain four measurements of percent canopy cover, facing north, east, south, and west. Use a compass to ensure accurate directional orientation. Average the four measurements of percent canopy cover, and report the average percent canopy cover measurement on the transect field sheet (see **Stream Habitat Assessment Field Sheet**, below).

After all habitat assessment measurements have been obtained, the in-stream survey flags should be removed from the stream channel. If desired, the four survey flags marking the transect ends on the left and right descending stream banks can remain in place, for future reference.

Stream Habitat Assessment Field Sheet

An example field sheet for recording all stream habitat assessment measurements is provided in Appendix C. Note that the stream name can be readily changed in the header of the field sheet. A separate field sheet should be used to record the measurements obtained on each stream transect. When habitat assessment work has been completed on the transect, carefully review the field sheet to ensure that all necessary information has been accurately recorded, including ancillary information: date, start and end times, weather conditions (percent cloud cover, wind direction, air temperature (°C), and precipitation, if any), water temperature (°C), names of the field crew members, transect number, transect distance downstream (from the upper project boundary), and transect GPS coordinates (obtained on the left and right descending stream banks). Instantaneous measurements of air temperature (°C) and water temperature (°C) can be made with a digital thermometer.

Data Management and Storage:

The stream temperature, air temperature, and habitat assessment data obtained as a result of the pre- and post-restoration monitoring work are the desired outcome of the project. All of this information should be managed and stored with the utmost care.

All of the electronic Onset HOBO Datafiles created as a result of downloading the stream and air temperature loggers should be saved and stored on the volunteer's desktop or laptop computer. An example of a stream temperature data file is provided below:

Lower Pine Creek_L1.001.hobo

Onset HOBO Datafile for Lower Pine Creek (Site 1)

Even if field deployment periods for the stream and air temperature loggers are lengthy, Onset HOBO Datafile sizes are relatively small, typically ranging from 10-70 KB. Hence, very little computer memory is required for storage of numerous files over the lifespan of the monitoring project.

Excel is the preferred software for storing, managing, and analyzing the stream and air temperature monitoring data. Any Onset HOBO Datafile can be readily exported into an Excel spreadsheet, using the HOBOware Pro Mac/Win Software®. Ensure that all stream and air temperature data are exported into Excel spreadsheets with units of °C. This data standardization will readily allow a comparison of stream temperature data amongst streams throughout the volunteer and WDNR monitoring network, and will also allow a direct comparison of air temperature data with stream temperature data. Each Excel file should be saved using the same name as that used for the original Onset HOBO Datafile. In addition to storing the temperature monitoring data, the Excel spreadsheet provides an opportunity to include critical metadata as a part of the temperature data record. The metadata can include information such as stream name, monitoring site number, county, site GPS coordinates, temperature logger type (manufacturer and model number) and serial number, the volunteer's name, and any additional notes, as desired.

After the Onset HOBO Datafile has been imported into an Excel spreadsheet, the temperature data can be reviewed, to ensure accuracy and quality. All instantaneous stream temperature measurements obtained with the digital thermometer during the logger deployment period can be compared to the logger temperatures, to determine if the stream temperature logger has remained within an acceptable accuracy range (± 0.2° C) while deployed. In addition, any non-representative data and/or data known to be false (i.e. air temperatures recorded because the stream temperature logger was removed from the water for cleaning, downloading, and/or transported for downloading) should be eliminated from the data record.

Excel also provides an easy means for statistical analysis and graphing of the stream and air temperature data, as shown in the Kinnickinnic River thermograph (see **Air Temperature Monitoring**, above). WDNR staff are currently developing a special Excel spreadsheet that can be used to conduct multiple statistical analyses of air and stream temperature data. This spreadsheet will be available for volunteer use after it has been finalized and tested.

All pre- and post-restoration habitat assessment data can also be stored in an Excel spreadsheet, by entering all of the information recorded on the transect field sheets. Storage of the habitat assessment data in an Excel spreadsheet also allows for statistical analysis and graphical presentation of this information. An example of an Excel habitat assessment spreadsheet, with graphical presentation of the data, is provided below.

Excel spreadsheet for Lower Pine Creek habitat assessment data

All Excel files with stream temperature, air temperature, and habitat assessment data should be saved and stored on the volunteer's desktop or laptop computer.

On an annual basis, preferably at the end of each calendar year, all paper field sheets used for recording information related to stream and air temperature monitoring and habitat assessment work should be converted to Adobe Portable Document Format (PDF). Any precipitation field sheets and any field notes recorded in site log books should also be converted to PDF files. All PDF files should be saved and stored on the volunteer's desktop or laptop computer. All original paper copies of field sheets and/or field notes should be organized and stored in a dry, secure location.

Consider implementing a logical file structure for all of the electronic data stored on the volunteer's desktop or laptop computer. This will greatly facilitate data retrieval (by anyone) as needs arise. A suggested file structure is shown below:

- County
  - Stream Name
    - Raw Data Files
      - Onset HOBO Datafiles (Stream Temperature Monitoring)
      - Onset HOBO Datafiles (Air Temperature Monitoring)
    - Excel Data Files
      - Stream Temperature Monitoring Data Files
      - Stream Temperature Monitoring Field Sheets
      - Air Temperature Monitoring Data Files
      - Air Temperature Monitoring Field Sheets
      - Habitat Assessment Data Files
    - PDF Files
      - Stream Temperature Monitoring Field Sheets
      - Air Temperature Monitoring Field Sheets
      - Habitat Assessment Field Sheets
      - Precipitation Field Sheets
      - Other Field Notes and/or Site Log Books

If monitoring project data files only reside on the volunteer's desktop or laptop computer, all project data will be lost if the computer crashes. Until a central repository and/or database has been established to house all TUDARE volunteer monitoring data, it is critically important for each volunteer to back up all data files, including raw data files, Excel data files, and PDF files. All new files should be backed up as soon as they are generated. Data backup can be to a CD, floppy disk, thumb drive, portable hard drive, tape drive, network drive, or another computer. Backing up data in multiple locations is even better than backing it up in a single location, in the event of a home catastrophe such as fire or storm damage. **The importance of backing up this valuable monitoring data cannot be stressed enough.**

The WDNR's Surface Water Integrated Monitoring System (SWIMS) database is a state-wide database to store and access Wisconsin water quality data. As such, SWIMS could serve as the permanent, central repository for all of the TUDARE volunteer monitoring data generated by this project. While WDNR staff have ready access to SWIMS, it may be possible to arrange database access for TUDARE volunteers as well. The use of SWIMS for volunteer data storage and volunteer access to this database will be discussed with WDNR staff.

Additional Stream Monitoring Protocols:

Additional information on stream monitoring protocols can be found in documents prepared by the Kiap-TU-Wish Chapter of Trout Unlimited (Kiap-TU-Wish, 2007), Metropolitan Council Environmental Services (Johnson, 2010) (MCES, 2011), Minnesota Department of Natural Resources (MDNR, 2010), U.S. Forest Service (Dunham et al., 2005), and the Wisconsin Water Action Volunteers Stream Monitoring Program, at:

(http://watermonitoring.uwex.edu/wav/monitoring/index.html).

References:

Avery, E. L. 1991. Impact of beaver dam removal on summer water temperatures in a northeastern Wisconsin trout stream. Wisconsin Department of Natural Resources, Research Management Findings No. 30.

Avery, E. L. 2002. Fish community and habitat responses in a northern Wisconsin brook trout stream 18 years after beaver dam removal. Wisconsin Department of Natural Resources, Final Project Report F-95-P.

Avery, E. L. 2004. A compendium of 58 trout stream habitat development evaluations in Wisconsin - 1985-2000. Wisconsin Department of Natural Resources, Madison, WI. Research Report 187.

Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: a user's guide. U.S. Forest Service, Rocky Mountain Research Station. General Technical Report RMRS-GTR-150WWW. 15 p.

Hansis, R. 2010. Climate change stream monitoring. Wisconsin Department of Natural Resources, Water Resources Policy Management Team. Issue brief.

Hunt, R. L. 1988. A compendium of 45 trout stream habitat development evaluations in Wisconsin during 1953-1985. Wisconsin Department of Natural Resources Technical Bulletin No. 162.

Johnson, K. 2010. The role of monitoring in stream restoration. Metropolitan Council Environmental Services, Environmental Monitoring Section, St. Paul, MN. 16 p.

Kiap-TU-Wish. 2007. Pine Creek restoration project: physical and biological metrics for measuring stream restoration success. Kiap-TU-Wish Chapter, Trout Unlimited, Hudson, WI. 39 p.

Kucharik, C. J., and S. P. Serbin. 2008. Impacts of recent climate change on Wisconsin corn and soybean yield trends. Environmental Research Letters 3(3):1-10.

Lyons, J., J. S. Stewart, and M. Mitro. 2010. Predicted effects of climate warming on the distribution of 50 stream fishes in Wisconsin, U.S.A. Journal of Fish Biology 77:1867-1898.

MCES. 2011. Metropolitan Council Environmental Services quality assurance program plan: stream monitoring. Metropolitan Council Environmental Services, Environmental Monitoring Section, St. Paul, MN. 28 p.

McRae, G., and C. J. Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: implications for brook trout habitat. Transactions of the American Fisheries Society 123:641-656.

MDNR. 2010. Minnesota Department of Natural Resources stream survey manual 2.11. Minnesota Department of Natural Resources, St. Paul, MN.

Mitro, M., J. Lyons, and S. Sharma. 2011. Wisconsin Initiative on Climate Change Impacts: Coldwater Fish and Fisheries Working Group Report. 31 p.

Reeve, T., J. Lichatowich, W. Towey, and A. Duncan. 2006. Building science and accountability into community-based restoration: can a new funding approach facilitate effective and accountable restoration? Fisheries 31 (1): 17-24.

Stewart, J., M. Mitro, E. A. Roehl, Jr., and J. Risley. 2006. Numerically optimized empirical modeling of highly dynamic, spatially expansive, and behaviorally heterogeneous hydrologic systems – part 2. *In:* Proceedings of the 7th International Conference on Hydroinformatics, Nice, France. P. 1-8.

Thayer, G. W., T. A. McTigue, R. J. Salz, D. H. Merkey, F. M. Burrows, and P. F. Gayaldo, (Eds.). 2005. Science-based restoration monitoring of coastal habitats, Volume Two: tools for monitoring coastal habitats. NOAA Coastal Ocean Program Decision Analysis Series No. 23. NOAA National Centers for Coastal Ocean Science, Silver Springs, MD. 628 p. plus appendices.

WDNR. 2004. Guidelines and Standard Procedures for Continuous Temperature Monitoring (Version 1). Wisconsin Department of Natural Resources Streams Team. 11 p.

Appendix A. List of 20 streams surveyed by WDNR as temporal trend reference sites for temperature, water level, trout relative abundance, and index of biotic integrity. Trout are tagged for survival analyses in five streams indicated by * .

Stream Name	Temperature Monitor	Year	Water Level Monitor	Year
Crawford County				
Plum	1	2007-present	1	2007-present
	2	2010-present		
Rush	1	2008-present	1	2008-present
	2	2010-present		
Grant County				
Big Spring *	1	2007-present	1	2007-present
	2	2010-present		
Jackson County				
Allen	1	2007-present	1	2007-present
Levis	1	2007-present	1	2007-present
Lowe	1	2007-present	1	2007-present
South Fork Beaver	1	2008-present	1	2008-present
Vismal	1	2007-present	1	2007-present
Vosse Coulee	1	2007-present	1	2007-present
La Crosse County				
Mormon Coulee Creek	1	2007-present	1	2007-present
Monroe County				
Little La Crosse River	1	2008-present	1	2008-present
Richland County				
Ash *	1	2008-present	1	2008-present
	2	2010-present		
Elk *	1	2008-present	1	2008-present
	2	2010-present		
Vernon County				
Timber Coulee *	1	2007-present	1	2007-present
	2	2007-present	2	2008-present
	3	2008-present		
Rullands Coulee (trib to Timber Coulee)	1	2010-present		
North Fork Bad Axe River	1	2008-present	1	2008-present
	2	2008-present	2	2008-present
Springville Branch (trib to NF Bad Axe)	1	2008-present	1	2008-present
South Fork Bad Axe River	1	2008-present	1	2008-present
	2	2010-present		
	3	2010-present		
Norwegian Hollow Creek (trib to SF Bad Axe)	1	2010-present		
Spring Coulee *	1	2010-present	1	2010-present

Appendix B. Onset® Stream Temperature Logger Accuracy Check

While the Onset® stream temperature loggers cannot be calibrated, they can certainly be checked to see if they are recording within their specifications. Ideally, the accuracy check should be conducted in a controlled environment.

The following simple test can be conducted to check the accuracy of a stream temperature logger. Place crushed ice (preferably made from distilled water) in an insulated container that is large enough to hold the temperature logger(s) being tested. It is important to crush the ice to maintain as consistent and uniform a temperature as possible. Fill the container with distilled water to just below the level of the ice and stir the mixture. Submerge the temperature logger and place the entire container in a refrigerator to minimize temperature gradients. Allow 15 minutes for the temperature logger to acclimate and for the ice to melt slowly. The actual temperature in the container should settle around 0° C if the ice bath was prepared correctly. The temperature logger should be recording data, and a certified thermometer (see definition below) should be in the same ice water bath. After the 15-minute temperature equilibration period, either remove the temperature logger and certified thermometer from the ice bath and allow them to reach room temperature, or remove the container from the refrigerator and allow the ice bath to reach room temperature. Record the certified thermometer temperature at pre-determined intervals (e.g. 30 minutes, 1 hour). Download the temperature logger and plot the data on a graph with the certified thermometer data, to see if the logger data are within the acceptable accuracy range specified by the manufacturer. The temperature loggers, however, do not allow any calibration adjustment. If logger temperatures do not fall with in the acceptable accuracy range, the temperature logger must not be used. Conducting this accuracy check on all temperature loggers at once saves time, and can also reveal those loggers that may be unsuitable for deployment. Record the date, time, logger serial number, and calibration check results in a quality assurance log book for each temperature logger.

Listed below is the accuracy range expected from the temperature logger, if the calibration check was conducted correctly.

Temperature Logger	Accuracy
Onset TidbiTv2® Temperature Logger	± 0.2°C in the 0-30° C range
Onset HOBO Water Temp Pro v2® Temperature Logger	± 0.2°C in the 0-30° C range

<u>Certified Thermometer</u> - A certified thermometer is a glass and mercury thermometer with a certificate stating the temperature difference between it and a National Institute of Standards and Technology (NIST) thermometer. The certified thermometer should be returned to the manufacturer on an occasional basis, for re-certification. The cost for this service is approximately $150. The cost of a certified thermometer is approximately $350-$400.

Appendix C. Example Field Sheets

Examples of field sheets and field notes that can be used for stream temperature monitoring, air temperature monitoring, and stream habitat assessment are provided below.

Stream Temperature Monitoring:

Stream Temperature Field Sheet.xls
Example Field Sheet

Pine Creek Field Notes_Stream Tempe
Example Field Notes

Air Temperature Monitoring:

Air Temperature Field Sheet.xls
Example Field Sheet

Pine Creek Field Notes_Weather Stati
Example Field Notes

Stream Habitat Assessment:

Creek 8-8 Field Sheet.doc

Wilson Creek Field Sheet.doc