FISH CREEK WATERSHED PLAN

Town of Gibraltar, Door County, Wisconsin, September 2017

Vision for Fish Creek:

A Healthy Stream Ecosystem that Supports the Environmental and Economic Interests of the Community

Prepared for the Town of Gibraltar by Nancy Turyk
Center for Watershed Science and Education
University of Wisconsin-Stevens Point

Many people contributed to the development of this plan. We acknowledge the following people and agencies for their leadership and assistance.

- Linda Merline for written and photographic contributions in this plan and coordination of the grant and planning processes.
- Data collection by the Fish Creek Watershed Study Volunteers.
- Funding and support provided though the Town of Gibraltar and Wisconsin Dept. of Natural Resources.
- Donated expertise by Dr. Paul McGinley.

The Fish Creek Watershed Plan was adopted by the Town of Gibraltar on:

The Fish Creek Watershed Plan was approved by the Wisconsin Dept. of Natural Resources on:

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

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Vision for Fish Creek:

A Healthy Stream Ecosystem that Supports the Environmental and Economic Interests of the Community

Fish Creek is the namesake for the local community and it provides the backdrop for many rich memories and stories. The creek is appreciated by residents and visitors, with many having spent countless hours near and in Fish Creek, enjoying its cooling waters, wildlife, and natural beauty.

Fish Creek Plan Development

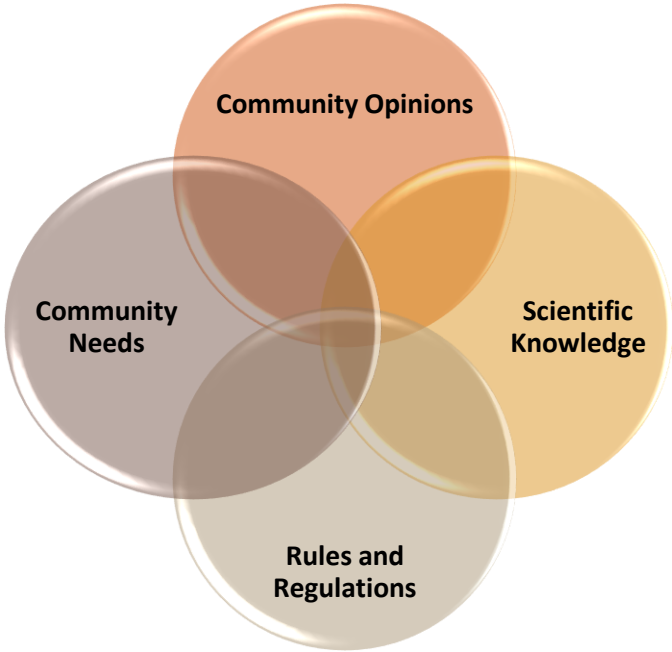
The development of this plan was initiated by the Fish Creek Watershed Study Volunteer Leaders and developed by the Town of Gibraltar Planning Commission and Town Board, with the intent of compiling and interpreting existing data to inform discussions about the protection and restoration of Fish Creek.

Community members gathered at two public discussions to learn about the creek and identify attributes worth protecting and problems that exist. Participants included watershed residents and enthusiasts, Town officials and planning commissioners, county professionals, and state biologists and experts. The gatherings were held in April and May 2017 at the old Gibraltar Town Hall in Fish Creek.

The goals and steps identified in this plan are based on the best available science and consider the opinions and needs of the community while remaining consistent with local, state, and federal guidance and rules. Flow data was non-existent; therefore, the flow model and recommendations could be refined by collecting data and updating the model in the future.

Whose plan is this?

Many partners are needed for the care and restoration of Fish Creek. The lead partners have been identified in the steps laid out in this plan; however, many additional individuals or groups may participate in the implementation of the actions needed to accomplish the shared vision for Fish Creek. Updating each other annually about plans and accomplishments will help to achieve the goals for Fish Creek and keep this plan fresh. The Town of Gibraltar Planning Commission will be the keeper of this plan.



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Fish Creek Planning Participants

Tom Blackwood, Plan Commissioner
Mary Ann Blahnik, resident
Digger DeGroot, Plan Commissioner
Dwayne Daubner, Town Board Supervisor
Tony Fiorato, Fish Creek Watershed Study, citizen scientist
Mary Ann Gieffers, resident
Steve Gomoll, resident
Brian Hackbarth, Plan Commissioner and Town Board Supervisor
Beth Hagen, Town Clerk, Treasurer, Administrator
Andrea Jauquet, resident
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David Lea, Fish Creek Watershed Study, citizen scientist
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Marise Redmann, resident
Coleen Riley, resident
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Ken Smith, resident
Steve Sohns, Town Board Supervisor, County Board Supervisor
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Bill Wettig, President, Fish Creek Sanitary District
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Susan Zielke, resident

Fish Creek Professional Participation and Assistance

Greg Coulthurst, Door County Soil and Water Conservation Dept.

Erin Hanson, Door County Soil and Water Conservation Dept.

Kari Hagenow, Door County Invasive Species Team, The Nature Conservancy

Nick Legler, Fishery Biologist, WDNR

Paul McGinley, UW-Stevens Point

Tom Meronek, Fishery Biologist, WDNR

Matt Scheve, Bureau of Environmental Analysis and Sustainability, WDNR

Jackson Parr, Reporter, Peninsula Pulse

Goals

Based on the information exchanged during the planning meetings, the following goals were identified by planning participants to protect and improve Fish Creek and its watershed. Greater details related to these goals can be found in the respective chapters of this plan. ** Indicates priorities.

GOAL 1. PREVENT THE DEGRADATION OF SURFACE AND GROUNDWATER QUALITY IN FISH CREEK AND ITS WATERSHED

OUTCOME 1.1: INCREASES IN THE GENERATION OF RUNOFF, NUTRIENTS, SEDIMENT, AND OTHER POLLUTANTS FROM DEVELOPMENT ADJACENT TO FISH CREEK WILL BE MANAGED ON SITE. **

Who: Property owners, Door County Planning and Zoning, Town of Gibraltar, Door County Soil and Water Conservation Dept.

What: Impervious surfaces associated with development and the expansion of roads creates more, often warm, runoff that carries sediment, nutrients, and other pollutants to Fish Creek. In areas with karst, small onsite basins such as raingardens are preferred to larger basins. Minimizing the amount of impervious surfaces on a development will reduce the amount of runoff requiring management.

When: As needed.

Indicators of Success: Water quality and hydrology in Fish Creek and its watershed are not altered.

OUTCOME 1.2: CONTROL FOR FLOODS, WATER LEVELS, WATER QUALITY, AND HABITAT ARE PROVIDED BY ALLOWING WETLANDS IN THE FISH CREEK WATERSHED TO REMAIN INTACT. **

Who: Door County Planning and Zoning, Door County Soil and Water Conservation Dept., Town of Gibraltar, Wisconsin and Door County Highway Depts., Dept. of Natural Resources

What: Development in the Fish Creek watershed will not interfere with the wetlands. Should alterations to the wetlands occur, mitigation should take place in the Fish Creek watershed.

When: As needed.

Indicators of Success: The integrity and area of wetlands is not impaired by development in the Fish Creek watershed.

GOAL 1. PREVENT THE DEGRADATION OF SURFACE AND GROUNDWATER QUALITY IN FISH CREEK AND ITS WATERSHED

OUTCOME 1.3: DIRECT DRAINAGE TO FISH CREEK FROM NEW OR EXPANDED ROADS WILL BE MITIGATED TO REDUCE IMPACTS TO THE FLOW AND WATER QUALITY IN FISH CREEK. **

Who: Town of Gibraltar, Wisconsin and Door County Highway Depts., Door County Soil and Water Dept.

What: When possible, manage runoff from roads draining towards Fish Creek to remove sediment and pollutants, including thermal pollution, and to regulate flow. Seek advice from the Door County Soil and Water Conservation Dept. on a case-by-case basis.

When: As needed

Indicators of Success: Water quality and hydrology are not altered in Fish Creek and its watershed.

OUTCOME 1.4: ERODING SHORELANDS ARE STABALIZED TO REDUCE SEDIMENTATION IN THE BAY AND IN-STREAM WATER DEPTH AND HABITAT IS INCREASED.

Who: Shoreland property owners, Door County Soil and Water Conservation Dept., WDNR River Protection grants, Great Lakes grants, consultants

What: Develop site specific plans to address shoreland erosion using a combination of biologs, native vegetation, riprap, regrading, and other stabilization techniques. Approach will depend on the location, adjacent land use, bank height, type and extent of erosion, water velocity, and property owner's preference. The majority of these sites are located downstream of the Highway 42 crossing.

When: Ideally, erosion repairs downstream of Highway 42 would be done in conjunction with or following corrections to the Highway 42 culvert.

Indicators of Success: Shorelands will be intact and Fish Creek will have a narrower and deeper channel.

OUTCOME 1.5: SHADING FROM SHORELAND VEGETATION WILL HELP TO MAINTAIN COOLER TEMPERATURES IN FISH CREEK.

Who: Town of Gibraltar, volunteers

What: Replace ash trees lost to disease along the creek corridor on town land. Choose replacement shrub and tree species that are likely to thrive in predicted future climatic conditions. Town will review the grant that was used to purchase the property to be sure restoration is allowable.

Indicators of Success: Temperatures in Fish Creek remain sufficiently cool for anadromous spawning fish and their young.

GOAL 1. PREVENT THE DEGRADATION OF SURFACE AND GROUNDWATER QUALITY IN FISH CREEK AND ITS WATERSHED

OUTCOME 1.6: DEGRADATION OF WATER QUALITY AND REDUCTION OFFLOW IN FISH CREEK WILL NOT OCCUR BECAUSE BEST MANAGEMENT PRACTICES ARE USED ON AGRICULTURAL LAND IN THE FISH CREEK WATERSHED.

Who: Watershed property owners, Door County Soil and Water Conservation Dept., Natural Resource Conservation Services (NRCS), consultants

What: On agricultural lands, best management practices (BPM) targeted at controlling runoff, maintaining the natural hydrology, and minimizing the use of nutrients and pesticides on the landscape will lessen impacts to flow and ecological impacts in Fish Creek. County and NRCS staff are available for consultation on site-specific recommendations and funding options, if necessary. Ensure property owners recognize they are in the Fish Creek watershed and inform landowners that rent their land for agricultural use about working with the renters to use BMPs.

When: Ongoing

Indicators of Success: Water quality and flow in Fish Creek remain the same and drinking water is not negatively impacted.

OUTCOME 1.7: SUFFICIENT WATER QUANTITY DATA FROM FISH CREEK IS AVAILABLE TO UNDERSTAND RELATIONSHIPS WITH STORM EVENTS, SEASONALITY, AND CHANGES IN LAND USE. **

Who: Fish Creek citizen science monitoring team, Gibraltar Ecology Club

What: Install monitoring wells at the locations identified in the Fish Creek Water Monitoring Strategy and measure water levels in the wells and stream flow.

When: Water level measurements from the monitoring wells should be collected throughout the year, with weekly water level measurements made between spring and fall during year 1. Stream flow measurements and monitoring well water level measurements should coincide with water quality monitoring events.

Data should be used to refine the models developed in this planning process to improve their application.

All results should be submitted to the WDNR SWIMS database for storage and use.

Indicators of Success: A reliable dataset will be available to make informed management decisions, evaluate the success of creek and land use improvements, and understand current conditions and trends.

GOAL 1. PREVENT THE DEGRADATION OF SURFACE AND GROUNDWATER QUALITY IN FISH CREEK AND ITS WATERSHED

OUTCOME 1.8: CURRENT WATER QUALITY CONDITIONS AND TRENDS WILL BE KNOWN AND USED TO MAKE DECISIONS. **

Who: Fish Creek citizen science monitoring team, Gibraltar Ecology Club, other researchers

What and When: Water Action Volunteer (WAV) Level 2 Monitoring should be conducted annually following the program's protocol. Thermistors should be placed in the stream from spring to fall to record temperature.

Samples for lab analysis should be collected at least twice per year; in the spring during runoff and during low flow in late summer. Analyses should include: nitrate ($N0_2$+NO_3-N), NH_4, total Kjeldahl nitrogen (TKN), total phosphorus (TP), chloride, and alkalinity.

Monitors should undergo WAV training and refreshers to ensure good quality data is collected.

All water quality data results should be submitted to the WDNR SWIMS database for storage and use.

Use the data to update models and recommendations.

Indicators of Success: A reliable dataset will be available to make informed management decisions, evaluate the success of implementation of the strategies in this plan, and understand current conditions and trends.

GOAL 2. PROTECT AND IMPROVE FISH AND WILDLIFE HABITAT

OUTCOME 2.1: IMPEDIMENTS TO THE ACCESS OF FISH CREEK BY FISH AND WILDLIFE ARE REDUCED. THE HIGHWAY 42 CULVERT WILL NOT BE A BARRIER TO FISH PASSAGE. **

Who: Town of Gibraltar, WDNR Fishery Biologists, WDOT Bureau of Structures, consultants, state or federal grants

What: Evaluate options to reduce the difference in height between the downstream creek bed and the culvert below Hwy 42. Options may include the replacement of the culvert with a full-span bridge and restoration of the creek bed, installation of downstream gradient controls, or the extension of a cement apron. The evaluation should identify choices that also narrow the creek to increase water depth such as, adding concrete at the sides of the concrete apron to narrow the flow when the water is low, allowing for passage of wildlife and people below Hwy 42, are within reasonable costs, and fundable by grants. Options should address which fish species will benefit from changes and the likelihood of success.

When: Begin planning in 2017

Indicators of Success: Fish can move freely in Fish Creek from the bay to the headwaters.

OUTCOME 2.2: IMPEDIMENTS TO THE ACCESS OF FISH CREEK BY FISH AND WILDLIFE ARE REDUCED. BARRIERS AT REDMANN DAM, PREVENTING FISH FROM REACHING THE IMPORTANT HEADWATER WETLANDS, WILL BE REDUCED. **

Who: Town of Gibraltar, shoreland property owners downstream from the Redmann Dam, consultant, WDNR River Protection Grant, Great Lakes grants

What: Work with an engineering firm to obtain designs to allow fish to pass between Fish Creek and the small pond and if feasible, create the connection. If this is not feasible, explore options, such as fish ladders, to allow fish passage through the pond formed behind the Redmann Dam and into the headwaters. In addition, consider the possibility of regulating the flow of water from the dam or the removal of the dam.

When:

Indicators of Success: Migratory fish will have access the Fish Creek headwater wetlands that provide critical habitat for spawning and young of the year fish will be able to travel to the bay from the headwater wetlands.

GOAL 2. PROTECT AND IMPROVE FISH AND WILDLIFE HABITAT

OUTCOME 2.3: FISH AND WILDLIFE HABITAT WILL BE ENHANCED BY ALLOWING WOODY STRUCTURE TO REMAIN IN AND NEAR FISH CREEK, HELPING TO IMPROVE THE HABITAT BIOTIC INDEX (HBI).

Who: Town of Gibraltar, shoreland property owners

What: Tree falls that occur near Fish Creek that do not create hazardous conditions or preclude fish passage should remain in and near Fish Creek. The woody structure provides cover for young fish, aquatic insects, birds, turtles, amphibians, and other animals. It can also help to narrow and deepen the creek, providing respite for small fish during periods of low flow. In sections where the creek had been straightened, woody structure will help to reestablish meanders.

When: Ongoing

Indicators of Success: Fish Creek will have sufficient woody habitat, enhancing fish and wildlife use and reproductive success. Meanders and pools will form.

OUTCOME 2.4: MORE HABITAT, DEEPER POOLS, AND REDUCED DEGRADATION DOWN STREAM WILL RESULT FROM RESTORING MEANDERS IN FISH CREEK WHERE THE CREED HAS BEEN STRAIGHTENED UPSTREAM OF HIGHWAY 42.

Who: Lead: Planning Commission. Partners may include the Town crew, volunteers, WDNR biologists, consultants

What: Work with Fishery Biologists with the WDNR to identify low-cost approaches to meander restoration using boulders, fallen trees, and other intentionally placed structures. Implement the restoration plan. See p. 56 of the Waterfront Master Plan for suggestions.

When:

Indicators of Success: Meanders are restored and deeper pools are created where the creek had been straightened.

OUTCOME 2.5: NATIVE SHORELAND VEGETATION WILL PROVIDE STABILIZATION, REDUCTION OF EROSION, AND HABITAT.

Who: Shoreland property owners, Door County Soil and Water Conservation Dept., WDNR Healthy Lakes and other state grants, Gibraltar Ecology Club

What: Inform new shoreland property owners of the importance of shoreland vegetation and the county and state ordinances that guide its protection while allowing for access. Design access to Fish Creek to provide safe entry to the water while stabilizing banks and minimizing erosion.

When:

Indicators of Success: Fish Creek shorelands will have healthy native vegetation and access will be designed to minimize streambank erosion.

GOAL 2. PROTECT AND IMPROVE FISH AND WILDLIFE HABITAT

OUTCOME 2.6: WETLANDS AND OTHER AREAS WARRANTING PROTECTION ARE ZONED ACCORDINGLY.

Who: Town of Gibraltar

What: Review the zoning in the Fish Creek watershed to verify all areas that should be in protective zoning have been properly identified. Learn about protection options from other towns and counties.

When:

Indicators of Success: Appropriate zoning is properly applied in the Fish Creek watershed.

OUTCOME 2.7: INVASIVE SPECIES IN AND ADJACENT TO FISH CREEK AND IN THE WATERSHED ARE IDENTIFIED AND CONTROLLED.

Who: The Nature Conservancy (TNC), volunteers, property owners, Gibraltar Ecology Club, Parks and Land Committee

What and When: Inform watershed property owners about opportunities to learn to identify aquatic and terrestrial invasive species through informational fliers and the Town website.

Annually monitor the creek corridor between Highway 42 and Redmann Dam. Record locations of invasive species on maps or with a GPS and record the estimated abundance. If the infestation is new or expanding, notify professionals for guidance and take steps to remove or reduce the population.

Dense populations of Japanese barberry exist along Fish Creek's shoreline. Work with TNC to develop a strategy to reduce the population. Phragmites, Dame's rocket, garlic mustard, and honeysuckle are also present in the watershed. TNC can train property owners on the proper techniques to remove these plants and reduce the spread. Once trained, volunteers should monitor annually during the growing season.

Support regional or county invasive species staff through letters of support and funding, if needed.

Indicators of Success: Invasive species will not become overly abundant in Fish Creek or on its shorelines.

OUTCOME 2.8: DEVELOP AN UNDERSTANDING OF THE USE AND REPRODUCTIVE SUCCESS OF FISH IN FISH CREEK.

Who: WDNR Fishery Biologists, other researchers, citizen scientists

What: Develop monitoring strategies to understand which fish are using Fish Creek, which sections of the creek are being used, and where improvements in habitat and passage can be made. Also, explore whether the planting of fish for imprinting should be considered.

When: Multiple years, year-to-year variability occurs.

Indicators of Success: Sufficient data exists to assess current conditions and success of improvements to Fish Creek.

GOAL 2. PROTECT AND IMPROVE FISH AND WILDLIFE HABITAT

OUTCOME 2.9: CONSERVATION EASEMENTS ARE ENCOURAGED AS A VIABLE OPTION FOR PROPERTY OWNERS INTERESTED IN PROTECTING FISH CREEK AND ITS WATERSHED.

Who: Town of Gibraltar, WDNR River Protection grants, Knowles Nelson Stewardship Fund, Conservancy trusts

What: Support property owners who are interested in placing fragile land in the Fish Creek watershed into land trusts or other protection programs.

When: As needed.

Indicators of Success: Land is protected in accordance with property owners wishes, increasing the resiliency of Fish Creek and minimizing negative impacts to surface and groundwater quality and habitat.

GOAL 3. FISH CREEK WILL BE ACCESSIBLE TO THE COMMUNITY'S RESIDENTS AND VISITORS

OUTCOME 3.1: PROVIDE SAFE PUBLIC ACCESS TO FISH CREEK.

Who: Town of Gibraltar, WDNR

What: To enjoy the land, maintain access to Fish Creek from Town land, trails, bridges, and boardwalks.

When: Ongoing

Indicators of Success: Town residents and visitors can enjoy Fish Creek and the adjacent publically owned land.

OUTCOME 3.2: PROVIDE SAFE PUBLIC ACCESS TO FISH CREEK.

Who: Town of Gibraltar, WDNR, Snowmobile bridge grant funding, Silent Sports funding

What: Explore options for people to safely access Fish Creek near Highway 42 by providing a walkway through the culvert or by replacing the culvert with an open-span bridge that would contain a multi-modal trail, providing a pedestrian footbridge that would connect the two sides of Fish Creek Park from the gazebo to the Bonnie Brooke side, and repairing or replacing the existing boardwalk crossings on the multi-modal trail in Fish Creek Park.

When:

Indicators of Success: Public can walk along Fish Creek without safety issues associated with crossing Highway 42.

OUTCOME 3.3: PROVIDE PUBLIC ACCESS AND PROTECTION: LAND FOR SALE IN THE CREEK CORRIDOR MAY BE CONSIDERED FOR PURCHASE BY THE TOWN OR OTHERS.

Who: Town of Gibraltar, WDNR River Protection grants, Great Lakes grant programs, Knowles Nelson Stewardship Funds

What: If interested, the Town will consider purchase of key parcels of land along the Fish Creek corridor and seek grant funding to assist with the purchase.

When: As the situation arises.

Indicators of Success: The public has access to various segments of Fish Creek and its adjacent land.

GOAL 3. FISH CREEK WILL BE ACCESSIBLE TO THE COMMUNITY'S RESIDENTS AND VISITORS

OUTCOME 3.4: A MULTI-GENERATIONAL PARTNERSHIP WILL SUPPORT A HEALTHY FISH CREEK.

Who: Residents, visitors, local fishing and conservation clubs, Gibraltar School, Town of Gibraltar, Door County, WDNR-Peninsula State Park, local businesses, elected officials

What: Many people and agencies are engaged in managing a healthy waterbody, especially one that is surrounded by potential threats associated with developed and agricultural landscapes. Each may have their own set of priorities, but together they are stronger. Gather at a social meeting to share ideas and discuss what might best suit the Fish Creek community. Options may include a Friend's group, an association, or a sub-committee of the Town. Identify the group's objectives to determine which type of group best suits its need. If needed, County UW-Extension staff or staff from Wisconsin River Alliance can help facilitate these conversations and decisions.

When:

Indicators of Success: The community works together to support efforts to maintain Fish Creek as healthy local resource.

OUTCOME 3.5: COMMUNICATION STRATEGIES ARE DEVELOPED.

Who: Town of Gibraltar, citizens, Friends group

What: The exchange of information will be critical to successful implementation of this plan. Consider ways to communicate with the partners involved in the development of this plan, residents and property owners, and other advocacy groups in Door County. Options include newsletters, a facebook page, local newspapers, countywide gatherings of advocacy groups, social or fundraising events, farm tours, etc.

OUTCOME 3.6: PARTNERS MEET TO DISCUSS MATTERS RELATED TO FISH CREEK. **

Who: Lead: Planning Commission, Partners: Parks and Land Committee and Watershed Volunteers and other partners

What: Partners will gather at least annually to update their progress, share information, discuss new problems, review successes, and identify components of the plan to address in the upcoming year. Formally update the plan every 5 years or sooner, if warranted. The Plan Commission will lead and manage the plan by annually holding a joint meeting of Plan Commission, Park & Lands, & Watershed Study Volunteers to determine which outcomes to pursue, which grants to apply for, and which partner should lead an effort. Strategies will be presented to the Town Board for review and approval prior to proceeding.

When: Annually

Indicators of Success: To encourage exchange of information and cooperation, all partners are aware of conditions in Fish Creek and the tasks that others are working on.

GOAL 1. PREVENT THE DEGRADATION OF WATER QUALITY IN FISH CREEK

We know how to do this. We just need the will to work together to make it happen!

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

The Fish Creek Watershed

The Fish Creek watershed is located entirely within in the Town of Gibraltar in Wisconsin's Lake Michigan basin. It occupies 7,240 acres (11.3 square miles) on the east side of the Green Bay. Fish Creek begins in a wetland complex just south of the village of Fish Creek and flows approximately 1.5 miles north to Fish Creek Harbor.

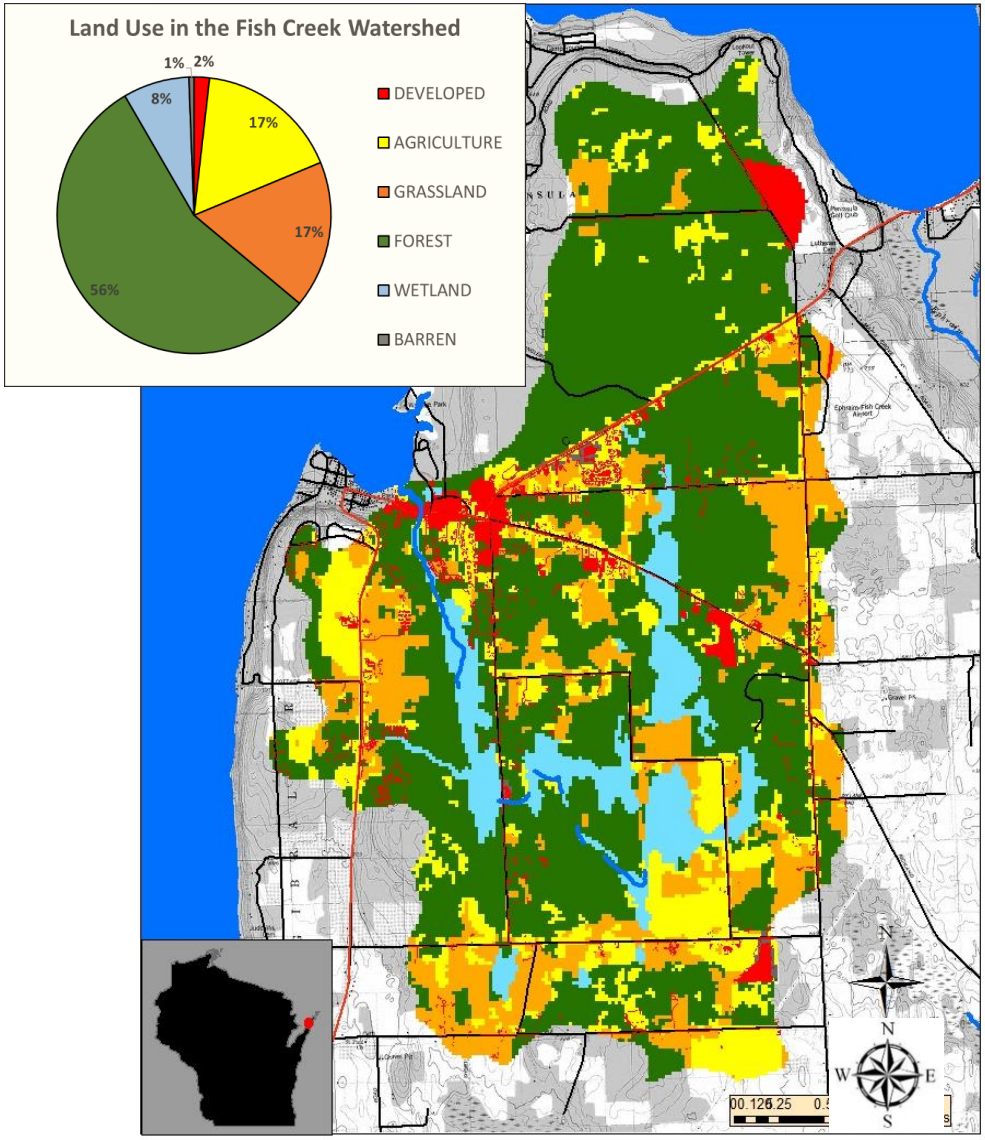
Geology dictates groundwater behavior

The Door County Peninsula is located along a geologic ridge called the Niagara Escarpment that runs from southeast Wisconsin to Ontario. The Fish Creek Watershed is located on the west side of the Door County peninsula. It is composed of resistant Silurian dolomite that formed from sediment deposited on an ancient sea floor about 430 million years ago. Multiple layers of sediment were laid down throughout the historical formations and disappearance of the ancient sea known as the Michigan Sea.

The land surface of the Fish Creek Watershed slopes generally to the southeast from a steep dolomite face that parallels the Green Bay shore and is broken at intervals by bays and coves. The rock is medium to coarse grained, mostly buff gray, and reaches a maximum thickness of 350 feet. This unit comprises the primary water supply aquifer in the area, yielding small to moderate amounts of water from vertical and bedding-plane joints. Water in the upper part of this aquifer is unconfined where vertical joints predominate (Sherrill, M.G., 1978).

Land Use and Water in the Fish Creek Watershed

Land use in a watershed has significant effects on the water that flows across the landscape and into streams. As an example, the flow of water over a landscape is slower and steadier in a mature forest with a well-developed duff layer versus a landscape that is dominated by compacted cropland or impervious surfaces, such as rooftops and roads. When surface water flow is slowed, there is more opportunity for infiltration to groundwater and less energy for erosion and mobilization of contaminants.



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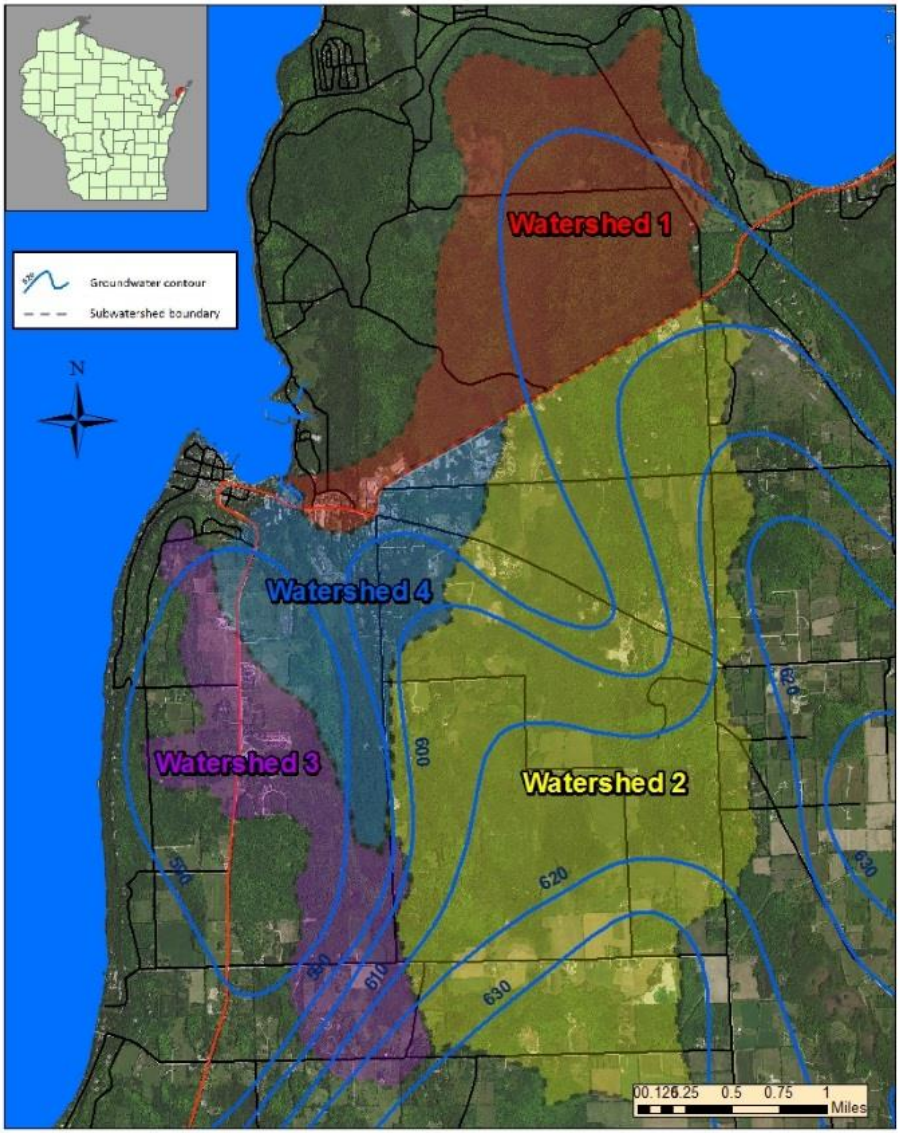
In part of the watershed, changes in land cover, and land uses in the Fish Creek watershed have likely altered the rate and amount of surface water runoff from the land that resulted from snow melt and rain events. In undeveloped areas of the watershed, some of the runoff moves slowly over the land to drainage ways. Tree leaves and branches reduce the impacts of raindrops on the ground, and the thick organic layer of decaying leaves and moss on the soil surface acts like a sponge that slows and filters the runoff. Water collects in shallow depressions, creating wetlands, and the forest canopy can provide shade that helps keep runoff water cooler. The upper reaches of Fish Creek run through a wetland complex of over 100 acres.

For the purposes of the water model constructed for this plan by UWSP, the Fish Creek watershed was broken into four sub-watersheds. The mix of land use varies in each of the sub-watersheds. Some of the sub-watersheds retain many of their natural characteristics; the Peninsula State Park sub-watershed (1) is dominated by forests (80%), the Nature Conservancy East sub-watershed (2) is characterized by 49% forests and 20% grasslands, the Nature Conservancy West subwatershed (3) is comprised of 50% forests and nearly 30% grasslands, and the Lower Fish Creek sub-watershed (4) includes 50% forests and 16% grasslands. Boundaries for these sub-watersheds are shown on the map to the right. A full list of the percentages of land use in each sub-watershed can be found in Appendix B.

The community of Fish Creek comprises a major portion of the Lower Fish Creek sub-watershed (4). Like other parts of the Fish Creek watershed, this sub-watershed is predominated by forests; however, the primary difference is the concentrated urban development near the creek's mouth. Impervious surfaces that are directly connected to Fish Creek are estimated to be 9 acres of the 910 acre sub-watershed. Left unmitigated, a larger quantity of storm water is generated from this land, which drains to the storm sewer network. This is the only part of the watershed with a network of storm sewers. These sewers discharge either directly to Green Bay or into the lower reaches of Fish Creek. Runoff across the hard surfaces readily picks up sediment, oil, leaves, animal droppings, litter, and other pollutants and

Fish Creek Subwatersheds - Door County, Wisconsin



N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

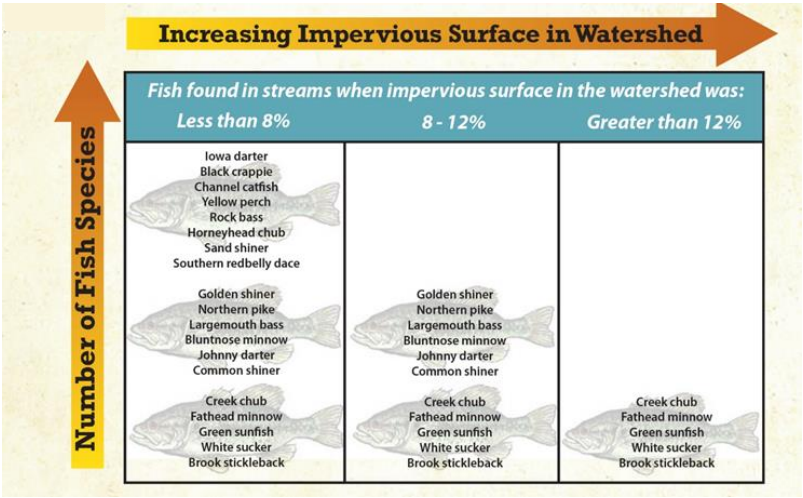
discharges them to the creek and bay. During the summer, the runoff coming off warm pavement and rooftops tends to be warmer than runoff from vegetated land. In large storms, the warm runoff can increase the temperature of the creek.

Stream Temperatures

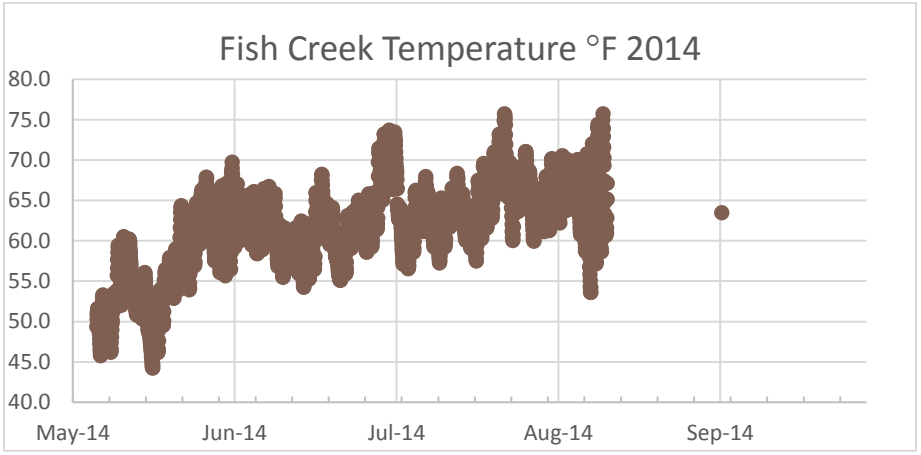
The range and variation of stream temperatures in Fish Creek is critical to its ability to support fish populations. To support healthy fish populations, it is desirable for the creek to maintain a cool, steady flow of water, which helps to provide sufficient dissolved oxygen. In some reaches of the creek, groundwater feeding it delivers cool water.

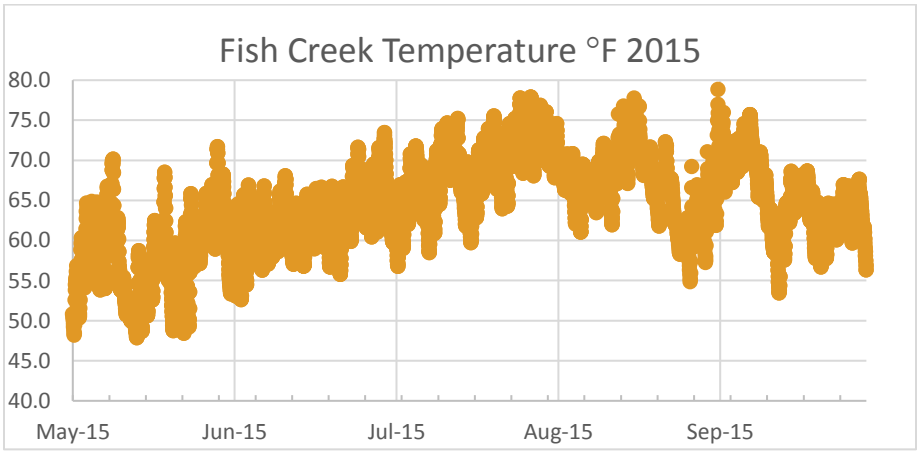
Numerous activities on the landscape can result in warmer stream temperatures during the summer. Impervious surfaces, particularly pavement, can warm the runoff which in turn results in warmer creek temperatures. The removal of shrubs and trees near the creek reduces shade. Reduction of cool groundwater inflow to the creek can also result in warmer stream temperatures and lower volumes of water.

Studies reveal that the amount of impervious surface near a waterbody affects the fish community by increasing the water temperature and turbidity.



The graphs illustrate water temperatures in Fish Creek measured just upstream of the Highway 42 crossing during spring and summer 2014 and 2015. By definition, July temperatures for a cold-water fishery average less than 63.5°F (Lyons et. al. 2009). Average temperature measured in Fish Creek in July 2014, 2015, and 2016 were 61.2, 68.9, and 71.8, respectively. Shallow water depths, warm runoff and air temperatures all contribute to these increased temperatures.





N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

Water Flow and Water Quality

Data Collections

Much of the water quality data collected from Fish Creek began in 1999. Since then, citizen scientists have collected field measurements of water temperature, water depth, dissolved oxygen, conductivity, pH, and transparency and water samples have been analyzed in the lab for alkalinity, phosphorus, nitrogen, coliform and E. coli bacteria, and transparency, Samples were collected from four sites in the watershed since 1999, with more recent measurements taken at two sites since 2002.

Advocate photo by Heidi Hodges
Town of Gibraltar Supervisor Mike Burda collects a sample of surface water from Fish Creek. He is one of several volunteers who will take water samples as part of a watershed study approved by the Town Board last month.

A map of the sampling locations and summary of the results can be found in Appendix C. As would be expected, water quality was variable between sampling sites. This is due to differences in the land cover, land use practices, and amount of flow and groundwater inputs at the different locations. The water quality results did not indicate any chronic problems; however, individual occurrences of elevated concentrations of nitrogen, phosphorus, and bacteria (e. coli) were observed periodically.

Fish Creek's Water Flow

As part of the development of this plan, a model was created to develop a first step towards understanding the hydrology of Fish Creek and exploring the potential impact of land use change on the health of the creek. This was a preliminary hydrologic analysis since it was largely based on the results of simulation modeling rather than measured flow data. The analysis applied a relatively simple tool to start to understand the hydrology of Fish Creek and its sensitivity to development in the watershed. The objectives of this model were to:

1. Develop a hydrologic model for streamflow and concentration in the Fish Creek watershed;
2. Use observations of stream depth and concentration measurements from volunteer monitoring and measurements of flow elsewhere in Door County to calibrate the model;
3. Use the model to explore how future land changes in the watershed might influence streamflow characteristics and stream chemistry.

The hydrologic modeling performed for this project was to assist in beginning to understand the biology and chemistry of the stream now and after land use change. The modeling did not perform analysis of hydraulics and the study should not be used to evaluate the implications of large stream flow events or downstream flooding.

Flow measurements have not been reported for Fish Creek; therefore, creek flow was estimated using precipitation records. The model can be improved and updated by incorporating flow data generated by following the water monitoring plan described in this chapter. The complete report of modeling results can be found in Appendix G.

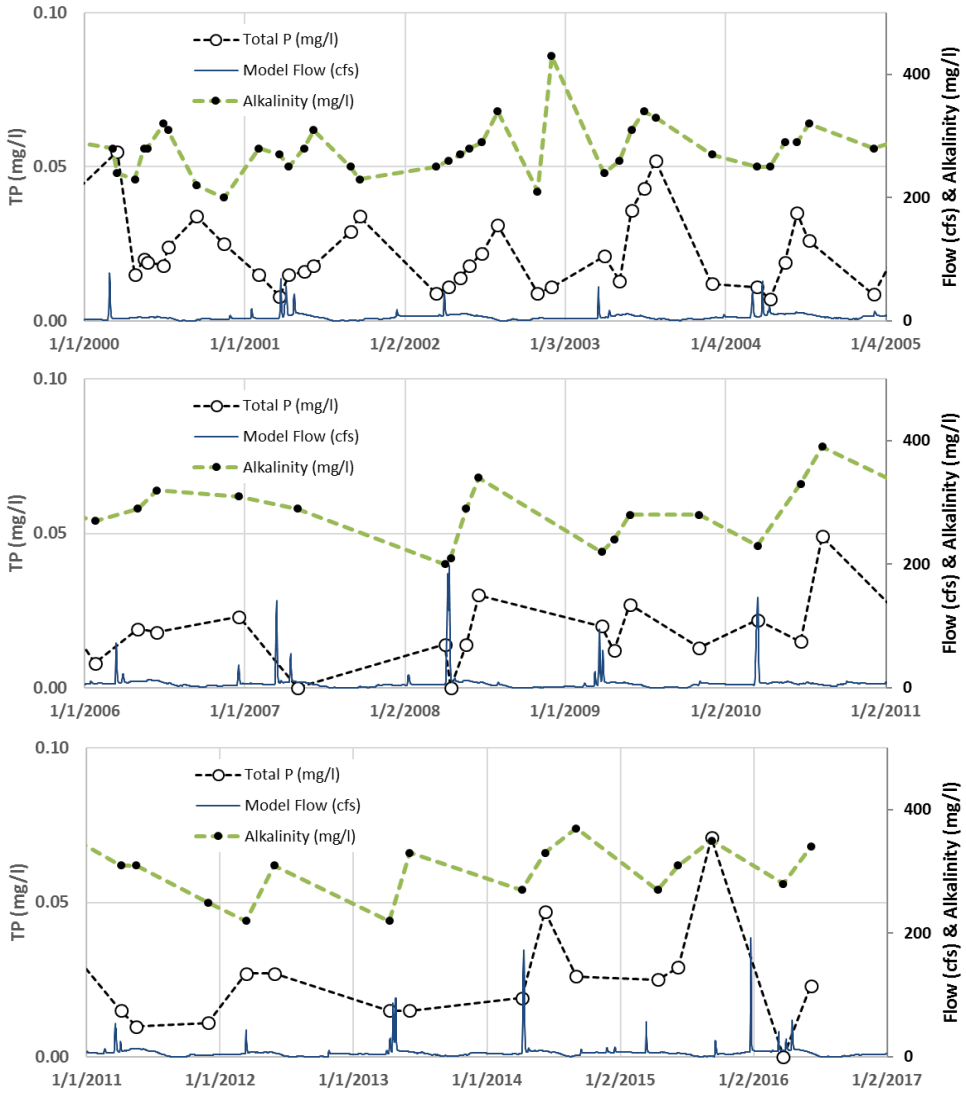
Water Quality

Phosphorous and alkalinity were included in the model. Phosphorus is a nutrient that helps algae and aquatic plants to grow. It can occur naturally, but some sources can be controlled through how land and runoff are managed. The controllable sources include erosion, runoff, fertilizers, and manure. The primary source for alkalinity in Fish Creek is from dissolved limestone carried to the creek with groundwater.

Once the model's simulation of flow was developed, phosphorus and alkalinity were graphed with the estimated flow to understand their

relationships. In general, the highest phosphorus concentrations occurred during the low flow periods of the summer and the lowest concentrations were observed during the high flow periods of the spring. This pattern is not typical of many Wisconsin streams. One explanation is, during the high flows in spring, large groundwater inputs act to dilute runoff and in-stream phosphorus concentrations. Alkalinity concentrations are low because much of the groundwater flow is through rapid transit pathways that convey snowmelt and recharge. During the low flow summer periods, stream phosphorus concentrations may be influenced by small runoff events because the overall streamflow is so low. The streamflow often has higher alkalinity during the summer, which could be the result of longer groundwater flow pathways and more contact with the carbonate bedrock. However, when small runoff inputs are added to this small groundwater flow, the relatively high concentration of phosphorus in the runoff could lead to increases in measured phosphorus.

The graphs below show the measured total phosphorus and alkalinity concentrations over time in Fish Creek at Hwy 42 shown with simulated flow.
Note: The dotted lines were added to demonstrate connection between points, and do not imply concentrations between sample acquisition.



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Potential Changes to Fish Creek from Development

The modeling explored how increasing the quantity of impervious surface might influence the hydrology and water quality in Fish Creek. This was accomplished by increasing the directly connected impervious fraction of the downstream sub-watershed 4 from 1% to 20%. Overall, the flow appeared similar because this change only affects a small percentage of the watershed; however, this change could have an important impact on flows and flow variation during the lower flow periods of the year.

The graphs summarize changes in the maximum (peak) flow in the creek by year, with simulated increases in hard (impervious) surfaces in sub-watershed 4. As expected, more runoff resulting from more hard surfaces would increase flow in May and August. This change reflects the large addition of runoff to Fish Creek with a relatively low increase in flow during periods of low flow. As described earlier for the evaluation of stream water quality, higher phosphorus concentrations would be expected in Fish Creek during the summer with increases in hard surfaces when the resulting additional runoff is not properly managed.

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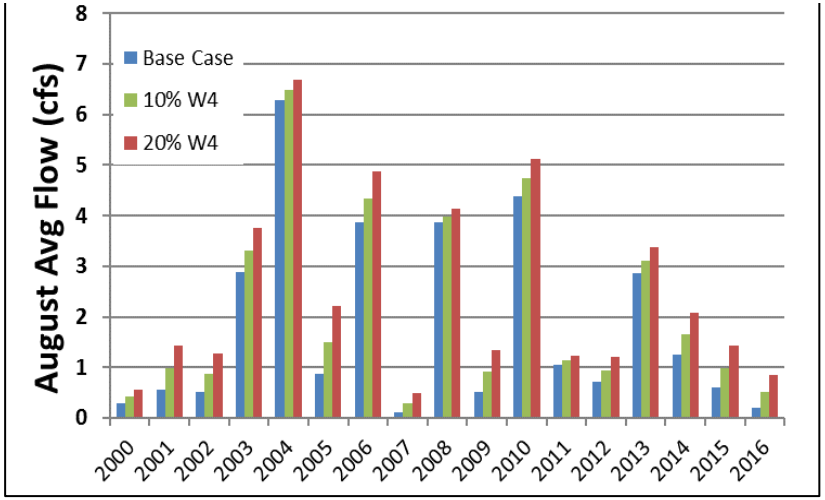
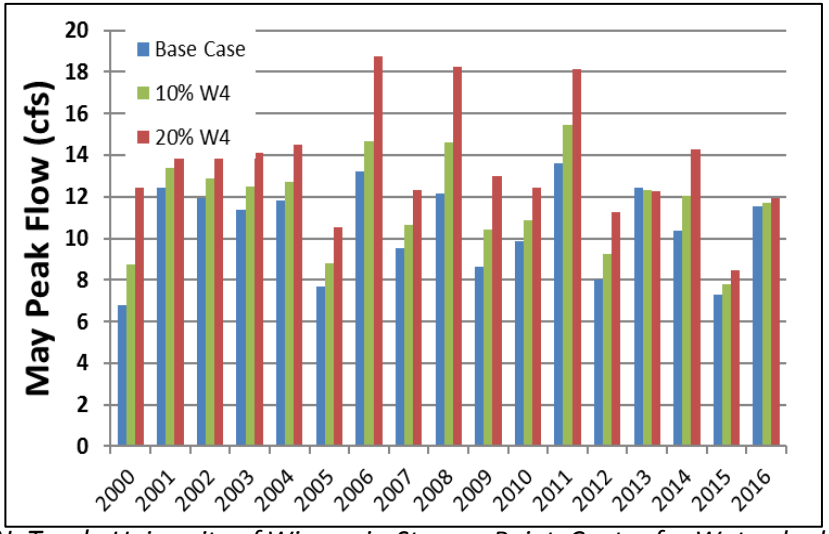
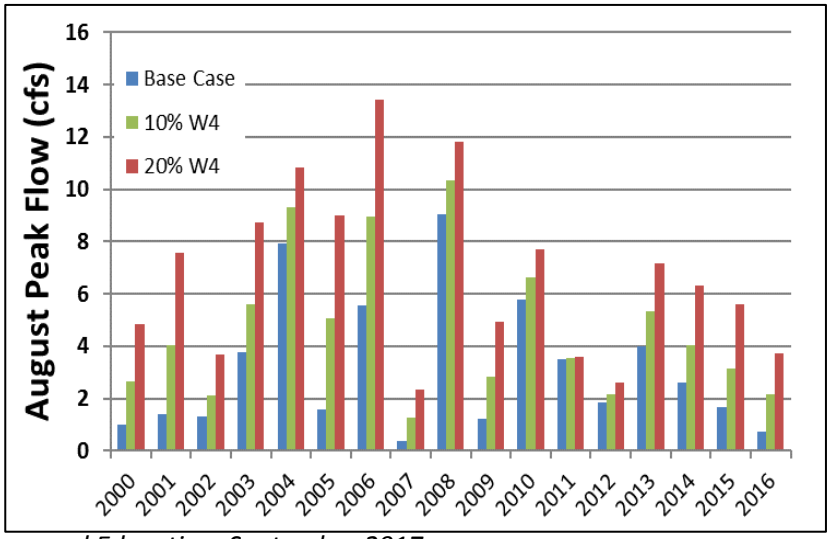
Simulated impact of changes in hard (impervious) surfaces in downstream sub-watershed 4 on peak and average annual streamflow in Fish Creek.







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Differing flows in Fish Creek upstream of the Highway 42 crossing.

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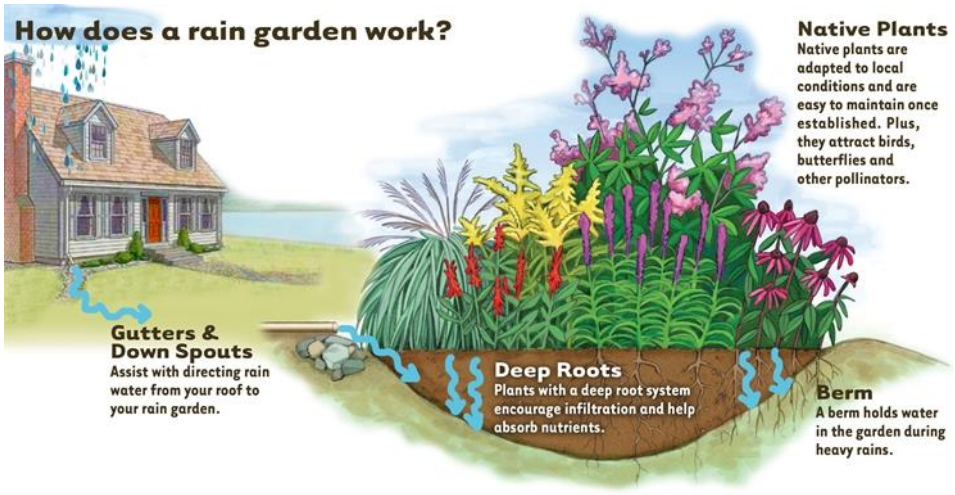
Planning for Increases in Hard Surfaces

There are a number of options to reduce (mitigate) the effects of existing and additional development in the Fish Creek watershed, especially in close proximity to the creek. The wetlands play an important role in the reduction of runoff to Fish Creek by storing the water and slowly releasing it. It is tempting to direct runoff from development to the wetlands; however, this is not an ideal solution for Fish Creek. Except for the headwaters area, wetlands fringe the creek and offer minimal retention benefits.

Retention ponds are commonly used to manage runoff in other settings; however, in karst settings it is preferable to manage runoff from roofs and pavement in smaller onsite basins. Incorporating runoff management into the landscape design can be easily accomplished using depressions in part of a parcel, properly sized raingardens, terracing, and other water collection systems. Decreasing the amount of hards surface can reduce the amount of runoff and hence, the size of an onsite basin. This can be accomplished by minimizing the impervious footprint by building up instead of out, reducing driveway size, and using pervious pavers. Swales can be used to collect and infiltrate runoff from roads.

Runoff management will benefit Fish Creek and the waterfront. There are many ways to encourage owners of developed property to incorporate runoff management into their landscape. Information about its importance is always the first step. This can be accomplished by installing or identifying demonstration sites and highlighting them with signage if they are on public property, hosting discussions at garden walks, using awards to highlight good shoreland practices, and communication about benefits in newspapers or newsletters. Competitions or participation in grant programs can also offer incentive. Designs can vary and should be appealing to the property owners.



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Fish Creek Water Monitoring Strategy

THESE WATER QUALITY AND QUANTITY MONITORING STRATEGIES HAVE BEEN DESIGNED TO COLLECT INFORMATION THAT WILL CONTINUE THE MOST RELEVANT ASPECTS OF PAST MONITORING EFFORTS AND PROVIDE THE PERTINANT INFORMATION TO ANSWER QUESTIONS ABOUT CREEK HEALTH IN THE FUTURE. TO ENSURE THE INTEGRITY OF THE DATA, DATA COLLECTION SHOULD BE DONE BY TRAINED INDIVIDUALS FOLLOWING ACCEPTED PROTOCOLS, SUCH AS THE WATER ACTION VOLUNEER (WAV) PROGRAM.

ANTICIPATED CHANGES IN LAND USE IN THE FISH CREEK WATERSHED INCLUDE INCREASES IN AGRICULTURAL LANDS AND DEVELOPMENT. DEPENDING ON HOW THE LAND IS MANAGED, THESE PRACTICES MAY HAVE MINIMAL OR SIGNIFICANT IMPACTS ON FISH CREEK AND ITS INHABITANTS.

LOCATIONS

MONITORING STATIONS SHOULD BE SITUATED IN TWO LOCATIONS IN FISH CREEK. THE UPSTREAM STATION SHOULD BE LOCATED DOWNSTREAM FROM THE PONDS, IDEALLY NEAR THE FOOT BRIDGE. THE MOST DESIRABLE DOWNSTREAM LOCATION WOULD BE IN THE TOWN PARK AT THE FOOT BRIDGE; HOWEVER, BECAUSE THE SITE JUST UPSTREAM OF THE HIGHWAY 42 BRIDGE HAS BEEN USED FOR SOME TIME, IT IS DESIRABLE TO COLLECT DATA AT BOTH LOCATIONS FOR 1-2 YEARS.

WATER QUANTITY

MONITORING WELLS SHOULD BE INSTALLED ON THE LAND ADJACENT TO THE CREEK AT BOTH MONITORING LOCATIONS. WELLS SHOULD HAVE LOCKED CASING AROUND THEM TO PREVENT UNDERSIRED TAMPERING WITH THE WELL AND PREVENT CONTAMINATION OF GROUNDWATER. THE LENGTH OF THE WELL SCREENS SHOULD BE SUFFICIENT TO CAPTURE ANTICIPATED FLUCTUATIONS IN WATER TABLE ELEVATION. WATER LEVEL MEASUREMENTS SHOULD BE COLLECTED THROUGHOUT THE YEAR, WITH THE GREATEST FREQUENCY OF WATER LEVEL MEASUREMENTS MADE WEEKLY BETWEEN SPRING AND FALL. IF POSSIBLE, THE WELLS SHOULD BE SURVEYED ANNUALLY TO IDENTIFY CHANGES IN ELEVATION.

STREAM FLOW MEASUREMENTS AND MONITORING WELL WATER LEVEL MEASUREMENTS SHOULD COINCIDE WITH WATER QUALITY MONITORING.

WATER QUALITY

WAV LEVEL 2 MONITORING SHOULD BE CONDUCTED PER THE PROGRAM'S PROTOCOL. THERMISTERS SHOULD BE PLACED IN THE CREEK FROM SPRING TO FALL TO RECORD TEMPERATURE.

SAMPLES FOR LAB ANALYSIS SHOULD BE COLLECTED AT LEAST TWICE PER YEAR, IN THE SPRING DURING RUNOFF AND DURING LOW FLOW IN LATE SUMMER. ANALYSES SHOULD INCLUDE: NITRATE (NO_2+NO_3-N), NH_4, TOTAL KJELDAHL NITROGEN (TKN), TOTAL PHOSPHORUS (TP), CHLORIDE, AND ALKALINITY.

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Watershed Communities and Management Highlights

Many local and regional plans are relevant to Fish Creek and many governmental and non-governmental organizations are tasked with aspects associated with management of Fish Creek, its inhabitants, and its watershed. Following are key plans and legislation that provide guidance; however, this list should not be treated as all-inclusive.

The Town of Gibraltar Comprehensive Plan, approved by the town board in 2003, identifies goals and objectives to improve and protect the land, water, and other natural resources of the township. Objectives that most closely related to management and restoration goals of the Fish Creek Watershed are:

- The Town of Gibraltar's natural areas and resources: land, water, and air as well as plant and animal life and habitat, are preserved, protected, conserved, restored, enhanced and maintained for future generations.
- Maintain and/or improve the quality of our water and its sources (wetlands, springs, streams and lakes) within and around the Town.
- Ensure that all growth and development will respect and preserve the unique natural environment of the Town; its woodlands, the escarpment, the shoreline, and its open spaces characterized by a variety of housing types and densities, pedestrian accessibility of neighborhoods and parks, inclusion of open green spaces within the developments, new trail ways, and environmental protection.

The Town of Gibraltar Waterfront Master Plan, developed in 2016, includes Fish Creek and its watershed. The recommendations directly related to Fish Creek are:

- Add meanders and pools
- Pre-treat stormwater before it reaches the creek
- Lower the floodplain to promote wetlands
- Appropriately size channel
- Add structure for habitat
- Restore fish passage
- Add educational signage
- Enhance multi-modal access

The village of Fish Creek owns and maintains the 27-acre Fish Creek Park.

The Door County Comprehensive Plan, adopted by the Door County Board of Supervisors on October 27, 2009, identifies goals and objectives to improve and protect the land, water and other natural resources of the county. Objectives that most closely related to management and restoration goals of the Fish Creek Watershed are:

- Protect lakes, rivers, streams, wetlands, steep slopes, wildlife habitat, and other natural features.
- Protect and enhance the county's surface and ground water quality.

The Door County Soil and Water Resource Management Plan 2011-2020 (DCLWRMP) was developed to prioritize efforts by the County and staff. Goals for the Upper Door County Watershed, which includes Fish Creek, include addressing groundwater and surface water quality issues related to agriculture through the implementation of best management practices, nutrient management, and compliance with ordinances aimed at achieving these goals, such as the manure storage ordinance. The DCLWRMP acknowledges the wetlands along the 1.5 mile Fish Creek corridor which were designated as important wildlife habitat within the Bay to Lake Wildlife Corridor in the Collaborative Community publication "A Guide to Significant Wildlife Habitat and Natural Areas of Door County, Wisconsin (2003)".

Door County Soil and Water Conservation Dept. and the Natural Resource Conservation Service (NRCS) assist landowners with conservation planning and cost-sharing to improve the productivity and ecological values of their land including the implementation of agricultural BMPs, restoration of shorelands, and protection and restoration of wetlands in the watershed.

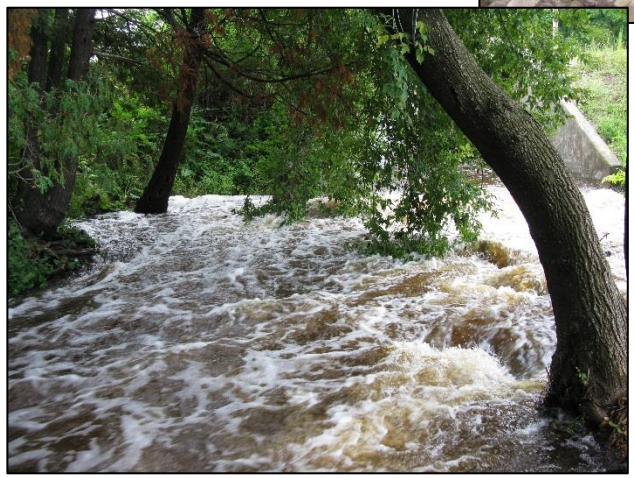
The Wisconsin's Dept. of Agriculture, Trade, and Consumer Protections (DATCP) reviews county land and water conservation plans and provides funds to Door County to assist with their implementation.

Several state agencies are responsible for watershed management. The Lakeshore Basin Plan (WDNR 2000) also identifies Fish Creek as an "at risk community" based on stormwater and runoff issues due to intensive development. Peninsula State Park is owned and managed by the WDNR. The 3,776-acre park comprises over 2,000 acres of the watershed. WDNR also has oversight of fisheries and wildlife management. Fish Creek Citizen Scientists use the WAV program protocols, co-managed by WDNR and UWEX.

As Wisconsin's primary environmental quality management agency, the WDNR works in partnership with the U.S. EPA to achieve goals of the federal Clean Water Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, Endangered Species Act, and of binational programs related to Great Lakes restoration and management.

With support from National Oceanic and Atmospheric Administration (NOAA) and the US Department of Commerce, the Wisconsin Office of Coastal Management works cooperatively with state, federal, local and tribal governments; and non-governmental organizations in managing the ecological, economic, and aesthetic resources of coastal communities, including Green Bay

The University of Wisconsin and NOAA Sea Grant programs offer research-based education in support of stewardship and sustainable use of Great Lakes resources.



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GOAL 2. PROTECT AND IMPROVE FISH AND WILDLIFE HABITAT

Assisting fish to move upstream to spawn.

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Having taught for 38 years, I would very much like to see our young people, perhaps Middle/High School students involved in the reclaiming in some way. Perhaps they could take a section and work on removing debris/help build fish ladders and pools/help with mitigating erosion problems. I think it is important that they also learn to become stewards of the land and water.

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In Stream Habitat and the Fish Community

Many local observations about the fish in Fish Creek exist. However, only several formal surveys of the fish community have been conducted by WDNR fishery biologists. Records of the 1968 survey were minimal. They stated *Surface acres = 1.0; Miles = 1.0; Gradient = 15.0 feet per mile; a small, low gradient, intermittent creek which originates in swampland and flows to Green Bay at Fish Creek. Forage species constitute the fish population. A state highway is the only road crossing this stream.* During the 1968 survey, 19 stocked rainbow trout were captured. A summer baseline survey was also conducted in 2003; no fish were captured. Water level data were not available to determine if the lack of resident fish was related to the amount of flow. A spring survey may have revealed different results including estimates of use by fish species migrating from Green Bay.

Fish stocking records for Fish Creek, Door County. Source: WDNR

Year	Species	Age Class	Number	Ave. Length
1972	Rainbow Trout	Fingerling	4,384	7
1976	Brown Trout	Fingerling	4,500	7
1977	Walleye	Fingerling	50,600	5
1982	Brown Tout	Yearling	16,800	
1982	Brown Trout	Fingerling	30,000	7
1984	Brown Trout	Fingerling	10,000	7
1990	Brook Trout	Yearling	5,000	9
1990	Brook Trout	Fingerling	9,000	3
1992	Chinook Salmon	Fingerling	19,928	3
1992	Chinook Salmon	Fingerling	10,000	4
1994	Brown Trout	Fingerling	15,000	6.8

According to the fishery biologists with the WDNR, the low water in Fish Creek limit the year-round fish community. However, improvements could be made that would allow for more use by species from Green Bay.

Correcting barriers of passage by the fish, narrowing the creek channel while increasing its depth, enhancing meanders, increasing woody habitat, and correcting erosion will better accommodate fish use.

Aquatic Insects and Stream Habitat

Knowledge of stream habitat and the aquatic insects living in a stream can provide insight about the health of the stream and its ability to support certain fish species. An aquatic insect (macro invertebrate) survey was conducted in Fish Creek by WDNR staff in 1999. Summarized habitat descriptions from the survey follow.

…mostly run, with small pools found between the runs. Habitat features ranged from 3 to 7 meters in length for pools, and 6.5 to 31.0 meters in length for runs. No riffle areas were noted. Bank erosion within 5 meters of the creek was common throughout the survey section and ranged from 10 to 60% of the stream bank. It appeared that at one time this section of creek was channelized. Fish cover was limited to large woody vegetation found in and near the pools.

A summary of the stream health and water quality based on the aquatic insects found in a stretch of stream is called the Hilsenhoff Biotic Index (HBI). The HBI scores range from 0-10; sensitive species that require high dissolved oxygen and low organic materials are assigned low scores and organisms tolerant of low oxygen or organic pollutants receive high scores. In Fish Creek, HBI scores ranged from 3.8 to 7.7.

Location in Fish Creek	HBI	Quality
Headwaters near Wandering Rd.	3.8	Very Good
Just below Redmann Pond	7.7	Very Poor
Near Highway 42	5.3	Fairly Poor

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Each species of aquatic insect has a different level of tolerance to oxygen levels and naturally occurring and added organic materials. Controllable organic materials come from eroded soil, decomposing leaves, manure, and effluent from septic systems from the surrounding landscape. Volunteer monitoring data revealed that the monitored sites in Fish Creek typically have sufficient dissolved oxygen so high HBI scores are likely a result of organic materials in Fish Creek.

Typically, most road crossings alter the quality of a stream and the streambed; therefore, moving the Highway 42 monitoring site upstream into the town park would provide a better indication of the overall health of this stretch of Fish Creek.

Fish Barriers and Habitat Issues

Upstream Wetland Habitat for Spawning Fish

According to fishery biologists with the WDNR, the wetland complexes upstream of the ponds would likely offer good habitat for spawning fish such as northern pike and young fry. However, the ponds created by dams in Fish Creek prevent most fish from accessing this habitat. Several options that could address fish access were discussed during the planning meetings. Options included: allowing fish access to the Redmann pond through the creation of fish ladders, the removal of the dam that creates the larger Redmann pond, or providing access from Fish Creek to the smaller pond. Following a considerable amount of discussion, the most desirable option for access between Fish Creek and the headwater wetlands was believed to be through the smaller pond. Benefits of the ponds were recognized as the primary reasons for keeping them intact. These benefits include providing habitat and attracting a number of inhabitants such as ducks, herons, and Blanding's and other turtles. Blanding's turtles are a threatened species. The ponds are also appreciated for their aesthetic values.

I had the privilege of spotting an otter in Claflin Pond in 2014! I have photos of extensive otter tracts in the snow covered ice on the pond.

Existing connection between Fish Creek and the smaller pond.

Redmann Pond

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

Lack of Meanders = Lack of Pools

Moving downstream from the ponds, just upstream from Highway 42, a section of the creek appears to have been straightened in the past, leaving a primary channel and small side oxbows that dewater periodically. When water is available in the oxbows, typically in spring, they provide habitat for tadpoles, macro invertebrates, and small fish. The straightening resulted in a wider creek with shallower water depths. Restoring meanders to this section would help to develop a narrower creek with deeper pools and cooler water. Reestablishing meanders could range from local volunteers adding some boulders, downed trees, and/or wing dam structures to hiring an engineer for a more formalized design. Fishing clubs regularly work with WDNR fishery biologists to develop restoration plans and install materials. Since much of this section occurs within Fish Creek Park, as the adjacent landowner, the town will need to determine which direction is most appealing.

Migration Problems: Getting Upstream of Highway 42

The crossing at Highway 42 produces a significant impediment to the fish attempting to migrate from Green Bay to spawn upstream in Fish Creek. On the downstream side of the crossing, a scour-pool exists, resulting in a difference in hieght of about 18 inches between the creek bed and the base of the culvert. The scour-pool is in part due to the loss of meanders in the stream above Highway 42 and increases in stream flow during runoff events, resulting from more runoff to the creek, which results from unmanaged runoff from hard surfaces. During higher flows, many migrating fish from Green Bay are able to move upstream to spawn, but during lower flows, without the assistance of humans, many fish are unable to access the culvert to travel upstream. During lower flows, the culvert is too high to crest and the water in the culvert can be too shallow to navigate due to the wide width of the culvert. Solutions need to attend to both of these problems. **Addressing these problems are a high priority in this plan.** The need for the replacement of this culvert was also identified in a report that inventoried problem fish barriers in Green Bay. (Diebel, 2013).

A range of options exists to correct these issues. The solution that best addresses these problems over the long-term would also be the most costly option. This option includes the replacement of the culvert with an open-span bridge, narrowing the creek, and restoring the creek bed, as well as, the development of an above-grade walkway adjacent to the creek, designed to allow for safe passage below Highway 42 during low flow by people and wildlife.

The next most viable option is the installation of downstream grade controls. A series of these controls, along with the addition of properly sized-bed materials would help to adjust the grade of the creek bed, bringing the creek bed up to grade with the bottom of the culvert. To narrow the stream when the water is shallow and allow for safe passage of wildlife and people during low flow, a concrete side sill would be created

inside the culvert. Another option is the placement of a concrete apron downstream of the culvert where the scour-pool exists; however, this option would be less aesthetically pleasing in this highly visible and visited section of Fish Creek.

Shoreland Erosion

Shoreland erosion is most prevalent downstream from Highway 42. To reduce the delivery of nutrient rich sediment to Green Bay, the erosion should be stabilized and the shorelands should be restored with deeply rooted native vegetation. In this reach, a high percentage of impervious surfaces generate runoff directly to the creek. Many practices could be put into place to reduce runoff while still allowing for access to the creek, including pervious pavement, management of roof runoff using onsite small-scale retention ponds, and shoreland plantings with native vegetation that could include shade- producing trees.

What is good about the creek is that despite it being rather a forgotten resource, it can be helped to re-establish its prominence in the village and protected for future generations.

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

The Good: Wildlife, Plant Species, and Communities

The Wisconsin Natural Heritage Inventory (NHI) identifies habitats and species. The lists include rare species and natural features. As of April 2017, the NHI has identified 47 species and natural features within the town of Gibraltar. The resulting list of rare plants and communities can be found in Appendix E. and list of rare animals can be found in Appendix F. Prior to development of land in the watershed, additional information should be acquired for a particular location to minimize disturbance of habitat for these flora and fauna. More information can be found at http://dnr.wi.gov/topic/NHI/

The Bad: Invasive Species

Invasive species came to Door County as garden plants, unwanted pets or were inadvertently transported by boats or vehicles. These plants and animals originate in different ecosystems and often lack natural predators in their new home, so they continue to propagate with little to keep them in check. In September 2009, the WDNR developed a comprehensive invasive species program and rule (NR40) to identify, classify, and control invasive species. NR40 classifies invasive species. **Prohibited** species are not found in Wisconsin with the exception of small pioneer populations. They may not be transported, possessed, transferred, or introduced. **Restricted** species are already established in the state. They may not be transported, transferred, or introduced. If they are already on private property, the landowner is encouraged, but not required, to remove them.

Some species not regulated by NR40 have invasive behavior in parts of Wisconsin or in regions of the US that are similar to Wisconsin. While it is not necessary to report these species, control of them is encouraged, but not required by law. The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) maintains a database of invasive species found in northern Wisconsin. Other species known to be present in the Fish Creek watershed but are not yet included on the GLIFWC list include phragmites, honeysuckle, garlic mustard, and dames rocket.

Invasive species listed as present in the Fish Creek watershed along with their Wisconsin classification under NR40. Source: GLIFWC

Common Name	Scientific Name	NR 40 Classification
Emerald Ash Borer	*Agrilus planipennis*	Restricted
Gypsy Moth	*Lymantria dispar*	Prohibited
Zebra Mussel	*Dreissena polymorpha*	Restricted
Reed Canary Grass	*Phalaris arundinacea*	Restricted
Japanese Barberry	*Berberis thunbergii*	Restricted

Most of the aquatic invasive species (AIS) in Wisconsin arrive in the Great Lakes in ship bilge water. The direct connection between Fish Creek and Green Bay make it impossible to prevent infestations of AIS. However, early detection and control measures can help to prevent major alterations to the Fish Creek aquatic ecosystem.

Japanese Barberry infestation displaces native vegetation.

GOAL 3. FISH CREEK WILL BE ACCESSIBLE TO THE COMMUNITY'S RESIDENTS AND VISITORS

As a young person, the creek became a classroom where we were taken often to see when the creek began running in the spring, identify fish, birds, and other critters. It was visited often.

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

History of Fish Creek

Archaeological evidence from the area indicates early use of the creek site, possibly as a seasonal fishing camp, dating back to about 600-400 B.C. Early European visitors were primarily French explorers and fur traders. Claimed by the French in the 1600s, the British claimed the territory from the French, and in 1783, the United States claimed it from the British. Under the United States government, the peninsula was first designated part of the Northwest Territory. As populations grew and shifted, the land was considered part of Indiana Territory, Illinois Territory, Michigan Territory, and Wisconsin Territory. In 1848, when Wisconsin became a state, the peninsula was designated part of Brown County.

The area was still wilderness in 1835, when Increase Claflin settled his family just north of the creek's mouth. His choice of this location to settle may have been influenced by the Menominee people he had traded with. They knew this area well and called it Ma-Go-She-Kah-ning, which meant "trout fishing". This may have given rise to the creek and the area around it being named Fish Creek. Entrepreneur Asa Thorp built the first dock in 1855, establishing the only place between Fort Howard (Green Bay) and Rock Island for ships to refuel on cordwood, and naturally, the village thrived. By 1880, no less than 60 piers had been built for the purpose of shipping lumber; some stretched over 1,000 feet into the lake (Burton 2007).

Early settlers made their living largely through the harvest of timber and fish. By 1900, over-harvesting of these resources, combined with improved Transportation, including a regular schedule of passenger steamers to the villages, led to the rise of the tourism industry. Although the land had never been suitable for farming crops such as wheat, it was discovered that fruit trees would flourish (Bremer 2010).

The community of Fish Creek surrounds its namesake. There are several points of public access to Fish Creek; most are located downstream near Highway 42. Most notable are Fish Creek Park, a 27-acre park on the east side of Highway 42 and Peninsula State Park, a 3,776-acre park to the north and west of the Highway 42 crossing of Fish Creek. Enhancing access and enjoyment of Fish Creek and the waterfront are priorities for the Fish Creek community. Strategies for these enhancements are described in the Fish Creek Waterfront Master Plan (2016). Community members support a walkway below Highway 42 to provide safe access to the creek upstream and downstream of the Highway. It is important to community members to ensure that the creek is accessible to migratory fish and that healthy habitat exists to ensure their reproductive success.

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

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APPENDICES

Appendix A: Watershed Communities and Management

Watershed Communities and Management

Many local and regional plans are relevant to Fish Creek and its watershed. In addition to general water quality improvement objectives, the Town of Gibraltar Comprehensive Plan highlights Fish Creek as one of the three named creeks draining to Green Bay in Door County. One of the numerous water quality actions identified in the plan is the development of a list of best practices for the protection of ground and surface water. The town plan also identifies the need to minimize storm water runoff into Green Bay and other surface waters. The Lakeshore Basin Plan (WDNR, 2000) also identifies Fish Creek as an "at risk community" based on storm water and runoff issues due to intensive development.

The Town of Gibraltar Comprehensive Plan, approved by the town board in 2003, identifies goals and objectives to improve and protect the land, water, and other natural resources of the township. Objectives that most closely related to management and restoration goals of the Fish Creek Watershed are:

- The Town of Gibraltar's natural areas and resources; land, water and air as well as plant and animal life and habitat: are preserved, protected, conserved, restored, enhanced and maintained for future generations.
- Maintain and/or improve the quality of our water and its sources (wetlands, springs, streams and lakes) within and around the Town.
- Ensure that all growth and development will respect and preserve the unique natural environment of the Town; its woodlands, the escarpment, the shoreline, and its open spaces characterized by a variety of housing types and densities, pedestrian accessibility of neighborhoods and parks, inclusion of open green spaces within the developments, new trail ways, and environmental protection.
- Owns and maintains the 27-acre Fish Creek Park.

The Door County Land and Water Resource Management Plan 2011-2020 (DCLWRMP) was developed to prioritize efforts by the County and staff. Goals for the Upper Door County Watershed, which includes Fish Creek, include addressing groundwater and surface water quality issues related to agriculture through the implementation of best management practices, nutrient management, and compliance with ordinances aimed at achieving these goals, such as the manure storage ordinance. The DCLWRMP acknowledges the wetlands along the 1.5 mile Fish Creek corridor which were designated as important wildlife habitat within the Bay to Lake Wildlife Corridor in the Collaborative Community publication "A Guide to Significant Wildlife Habitat and Natural Areas of Door County, Wisconsin (2003)". In addition to water quality, plans in this project will identify strategies to restore and protect fish and wildlife habitat.

The Door County Comprehensive Plan, adopted by the Door County Board of Supervisors on October 27, 2009, identifies goals and objectives to improve and protect the land, water and other natural resources of the county. Objectives that most closely related to management and restoration goals of the Fish Creek Watershed are:

- Protect lakes, rivers, streams, wetlands, steep slopes, wildlife habitat, and other natural features.
- Protect and enhance the county's surface and ground water quality.

N. Turyk, University of Wisconsin-Stevens Point, Center for Watershed Science and Education, September 2017

Several state agencies are responsible for watershed management. Peninsula State Park is owned and managed by the WDNR. It comprises over 2,000 acres within the watershed. The fisheries and wildlife are also managed by WDNR. As Wisconsin's primary environmental quality management agency, the WDNR works in partnership with the USEPA to achieve goals of the federal clean water, clean air, and hazardous materials management programs; and of binational programs related to Great Lakes restoration and management.

With support from NOAA of the US Department of Commerce, the Wisconsin Office of Coastal Management works cooperatively with state, federal, local and tribal governments; and non-governmental organizations in managing the ecological, economic, and aesthetic resources of coastal communities. The Land and Water Conservation Board of DATCP reviews county land and water conservation plans and provides funds to assist in their implementation.

The University of Wisconsin's Extension and NOAA's Sea Grant programs offer research-based education in support of stewardship and sustainable use of Great Lakes resources.

The Natural Resource Conservation Services (NRCS) assists landowners with conservation planning and cost-sharing to improve the productivity and ecological values of their land. The NRCS provides leadership for oils mapping and also financially supports the implementation of agricultural best management practices, restoration of riparian lands, and protection and restoration of wetlands in the watershed.

The Environmental Protection Agency (EPA) provides the regulatory framework and water quality guidance in the Clean Water Act.

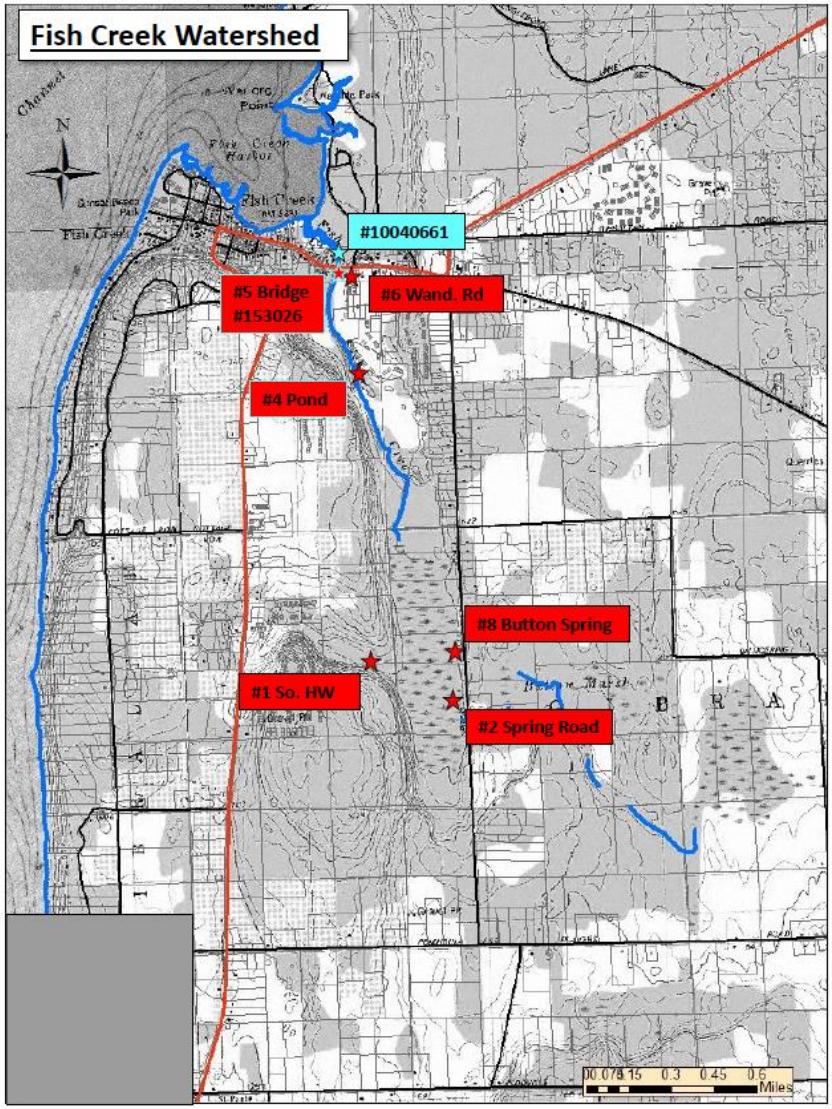
Appendix B. Land use categories in the Fish Creek subwatersheds.

Land Use	Peninsula State Park Sub-Watershed		Nature Con East Sub-Watershed		Nature Con West Sub-Watershed		Lower Fish Creek-Sub-Watershed	
	Acres	%	Acres	%	Acres	%	Acres	%
Developed	93	6.1	6	0.2	0	0	33	3.6
Agriculture	137	8.9	725	19.1	193	19.8	168	18.5
Grassland	54	3.5	771	20.3	271	27.8	148	16.3
Forest	1249	81.3	1862	49.0	483	49.6	420	46.1
Wetland	3	0.2	404	10.6	28	2.8	129	14.2
Barren	0	0	31	0.8	0	0	12	1.3
Total Acres	**1536**		**3799**		**974**		**910**	

Appendix C: Water quality sampling sites in Fish Creek watershed.

Map courtesy of Fish Creek citizen science monitoring team.

Note: testing at Spring Road was conducted upstream and east of the culvert, not west as shown on the map.



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Appendix D: Summary statistics for Fish Creek water quality results by site. 1999-2015.

Source: WDNR, Fish Creek Water Monitors

Location	pH Field	Alkalinity (mg/L)	Conductivity (umho)	NH4 (mg/L)	NO2+NO3-N (mg/L)	Total Kjeldahl N (mg/L)	Total Phosphorus (ug/L)	Total Coliform (MPN/100ml)	E. coli (MPN/100ml)	Transparency (cm)
#1 So. HW Min	7.9	180	510	LOD	0.2	0.0	LOD	72	1	98
#1 So. HW Average	8.0	308	693	0.04	0.8	0.4	19	1196	198	116
#1 So. HW Max	8.0	410	851	0.31	1.6	2.1	99	2420	2420	120
#2 Spring Road Min	7.7	150	338	LOD	LOD	0.3	LOD	61	1	108
#2 Spring Road Average	8.0	236	460	0.05	0.1	0.7	26	1215	82	117
#2 Spring Road Max	8.2	330	632	0.19	0.8	1.1	120	2420	1046	120
#4 Pond Min		200	427	0.00	0.0	0.2	LOD	187	4	90
#4 Pond Average		282	549	0.10	0.2	0.7	22	1455	100	113
#4 Pond Max		400	745	1.30	1.0	1.4	96	2420	792	120
#5 Hwy 42 Culvert Min	7.7	200	444	LOD	LOD	0.3	LOD	24	1	65
#5 Hwy 42 Culvert Average	7.9	286	571	0.06	0.3	0.7	23	1337	85	110
#5 Hwy 42 Culvert Max	8.2	430	764	0.32	3.5	1.3	75	2420	602	120
#6 Wand. Rd Min		200	405	LOD	0.1	0.1	7	75	7	-
#6 Wand. Rd Average		269	512	0.03	0.1	0.2	18	670	11	-
#6 Wand. Rd Max		290	560	0.10	0.2	0.4	36	1733	16	-

Appendix E: Sensitive habitat types and plant species in the Fish Creek Watershed

Source: Wisconsin Natural Heritage Inventory.

Common Name	Scientific Name	Wisconsin Status	Federal Status	Group
Boreal Rich Fen		NA		Community~
Emergent Marsh		NA		Community~
Great Lakes Alkaline Rockshore		NA		Community~
Hardwood Swamp		NA		Community~
Moist Cliff		NA		Community
Northern Mesic Forest		NA		Community
Northern Sedge Meadow		NA		Community~
Northern Wet-mesic Forest		NA		Community~
Southern Sedge Meadow		NA		Community~
Bird's-eye Primrose	Primula mistassinica	SC		Plant~
Broad-leaf Sedge	Carex platyphylla	SC		Plant
Climbing Fumitory	Adlumia fungosa	SC		Plant
Coast Sedge	Carex exilis	THR		Plant~
Dwarf Lake Iris	Iris lacustris	THR	LT	Plant~
Elk Sedge	Carex garberi	THR		Plant~
Few-flowered Spike-rush	Eleocharis quinqueflora	SC		Plant~
Giant Pinedrops	Pterospora andromedea	END		Plant
Giant Rattlesnake-plantain	Goodyera oblongifolia	SC		Plant
Hoary Whitlow-grass	Draba cana	END		Plant
Hooker's Orchid	Platanthera hookeri	SC		Plant
Large-flowered Ground-cherry	Leucophysalis grandiflora	SC		Plant
Limestone Oak Fern	Gymnocarpium robertianum	SC		Plant
Linear-leaved Sundew	Drosera linearis	THR		Plant~
Livid Sedge	Carex livida	SC		Plant~
Long-spurred Violet	Viola rostrata	SC		Plant
Maidenhair Spleenwort	Asplenium trichomanes	SC		Plant
Marsh Ragwort	Tephroseris palustris	SC		Plant~
Rock Whitlow-grass	Draba arabisans	SC		Plant
Slender Bog Arrow-grass	Triglochin palustris	SC		Plant~
Tufted Bulrush	Trichophorum cespitosum	THR		Plant~
Western Fescue	Festuca occidentalis	THR		Plant
WI Status Key: END = endangered; THR = threatened; SC = special concern				
US Status Key: LT = listed threatened				

Appendix F: Sensitive animal species in the Fish Creek Watershed.

Source: Wisconsin Natural Heritage Inventory.

Common Name	Scientific Name	Wisconsin Status	Federal Status	Group
Predaceous Diving Beetle	Hygrotus compar	SC/N		Insect - Beetle~
Black-crowned Night-Heron	Nycticorax nycticorax	SC/M		Bird~
Brilliant Granule	Guppya sterkii	SC/N		Snail
Caspian Tern	Hydroprogne caspia	END		Bird~
Cherrystone Drop	Hendersonia occulta	THR		Snail
Dentate Supercoil	Paravitrea multidentata	SC/N		Snail
Eastern Ribbonsnake	Thamnophis sauritus	END		Snake~
Hine's Emerald	Somatochlora hineana	END	LE	Insect - Dragonfly~
Hooded Warbler	Setophaga citrina	THR		Bird
Hubricht's Vertigo	Vertigo hubrichti	END		Snail
Red-shouldered Hawk	Buteo lineatus	THR		Bird~
Six-whorl Vertigo	Vertigo morsei	SC/N		Snail
Swamp Darner	Epiaeschna heros	SC/N		Insect - Dragonfly~
Transparent Vitrine Snail	Vitrina angelicae	SC/N		Snail

WI Status Key: END = endangered; THR = threatened; SC = special concern
SC/N = no laws regulating use, possession, or harvesting
SC/M = fully protected by federal and state laws under the Migratory Bird Act
US Status Key: LE = listed endangered

Appendix G: Preliminary Hydrologic Modeling and Analysis of Fish Creek, Door County, Wisconsin

Preliminary Hydrologic Modeling and Analysis of Fish Creek, Door County, Wisconsin

April, 2017

Ryan Haney, Nancy Turyk and Paul McGinley
Center for Watershed Science and Education
University of Wisconsin-Stevens Point

Introduction and Purpose

Fish Creek is a stream in northern Door County, Wisconsin. It flows approximately 1.5 miles before discharging to Green Bay (Door County, 2000). The stream originates in springs discharging to upstream wetland areas. The watershed is a complex karst landscape and likely similar to other areas of Door County where groundwater recharge occurs through thin soils and groundwater flow is within vertical and horizontal fractures (Sherrill, 1978, Muldoon and Bradbury, 2005). As such, the streamflow is likely to vary similar to the groundwater level in wells where there are increases after precipitation events and it is lower seasonally during periods of higher evapotranspiration.

The purpose of this Fish Creek hydrologic analysis was a "first step" towards understanding the hydrology of Fish Creek and exploring the potential impact of land use change on the health of the stream. This is a preliminary hydrologic analysis as we are largely basing it on the results of simulation modeling. The analysis applies a relatively simple tool to start to understand the hydrology of Fish Creek and its sensitivity to development in the watershed. The objectives of this project were to:

1) Develop a hydrologic model for streamflow and concentration in the Fish Creek watershed;

2) Use observations on stream depth and concentration measurements from volunteer monitoring and measurements of flow elsewhere in Door County to calibrate the model;

3) Use the model to explore how future land changes in the watershed might influence streamflow characteristics and stream chemistry.

It is important to note that the hydrologic modeling performed for this project was to assist in beginning to understand the biology and chemistry of the stream now and after land use change. The modeling did not perform analysis of hydraulics and the study should not be used to evaluate the implications of large stream flow events or downstream flooding.

Methods

Model Development. We selected the P8 model (Version 3.5, Walker, 2015) because it can explore impervious surface impacts on hydrology while also tracking groundwater flow. Also important in this study was that is provides a relatively simple model that can be used to better understand the data that has already been collected for Fish Creek. The model simulates land as impervious areas that are directly-connected to the stream, or as pervious areas that generate runoff or infiltration to groundwater. The directly-connected impervious areas allow some storage of initial precipitation as ponds or depressions, but any precipitation within an event after that storage is satisfied is

assumed to become direct runoff to the stream. The pervious areas are simulated using a Natural Resource Conservation Service (NRCS) curve number approach where runoff is a nonlinear function of event depth (NRCS, 1985). The model adjusts the curve number for rainfall that occurred in the previous five days and for frozen conditions. The model uses daily temperature to estimate snow formation, snow melting and evapotranspiration. Model inputs are hourly precipitation and daily temperature. We used precipitation and temperature records from the closest continuous recording stations we could find for the study period. We used measurements from Sturgeon Bay through 2013 and then Green Bay from 2014-2016. Where some of the hours in the Sturgeon Bay record were missing, we substituted 0.3 inches per hour, which is the closest match based on the annual precipitation totals recorded for that location.

In this study, P8 simulates aquifer storage and release to the stream. In P8, groundwater release is at a rate proportional to the volume of water in the aquifer. This is a "linear reservoir" approach to simulating the groundwater hydrology. Although it is simple, it maintains the water budget and appears consistent with the annual pattern of flow. The results simulate a higher streamflow during periods of active groundwater recharge followed by low streamflow during periods of low or no recharge.

We compared the model results to measurements made in Fish Creek. One measurement of flow from the Wisconsin DNR database was available in Fish Creek on June 6, 1972. They estimated a flow of 2 cubic feet per second. More recent measurements of Fish Creek have been made as the depth of water observed by volunteer monitors. We used their measurements collected at the Highway 42 bridge (Fish Creek Site #5) (Figure 1) and converted them to an estimated flow by assuming a trapezoidal shape to the stream channel with a bottom width of 10 feet and 4 to 1 side slopes and an average velocity of 1.5 feet per second. This is a simplification as the average velocity will change with flow but it should capture the general trend in flow over time.

Figure 1. Photograph of Fish Creek Site #5 looking downstream toward Highway 42 culvert. Photo courtesy of Linda Merline.

Our model divides the watershed into four subwatersheds (Figure 2) and a stream network. Infiltration moves into the "aquifer" and enters the stream at the pond and a downstream stream points. Figure 3 is a model schematic. We assigned watershed hydrologic curve numbers and impervious percentages based on a review of soil types, GIS data, and orthophotos (Table 1). A trial and error calibration based on visual comparison of modeled an estimated measured flows was used to select a time of concentration for the aquifers of 9600 hours (400 days) and for the watershed and stream nodes a time of concentration of 24 hours.

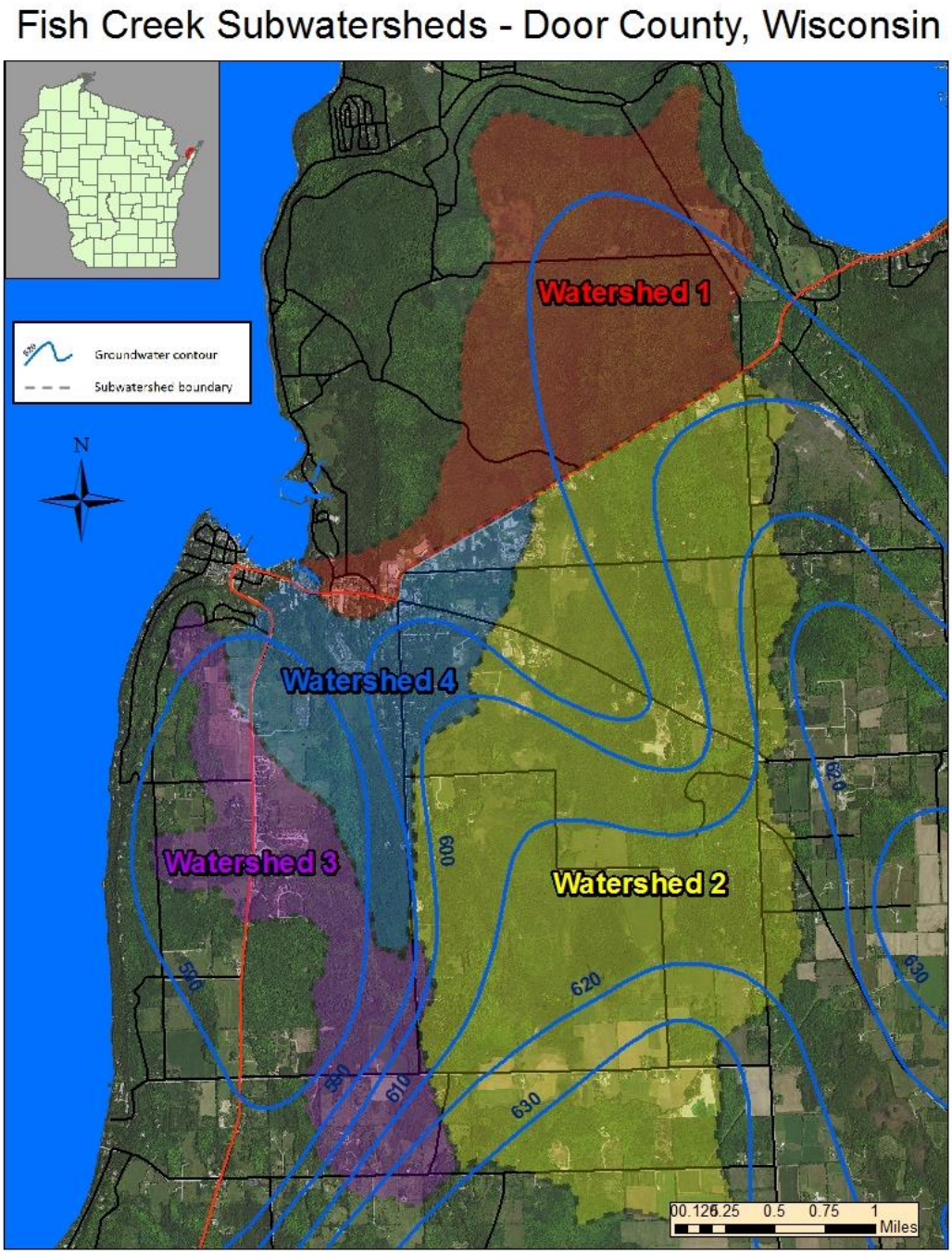

Figure 2. Fish Creek subwatersheds and groundwater contour map.

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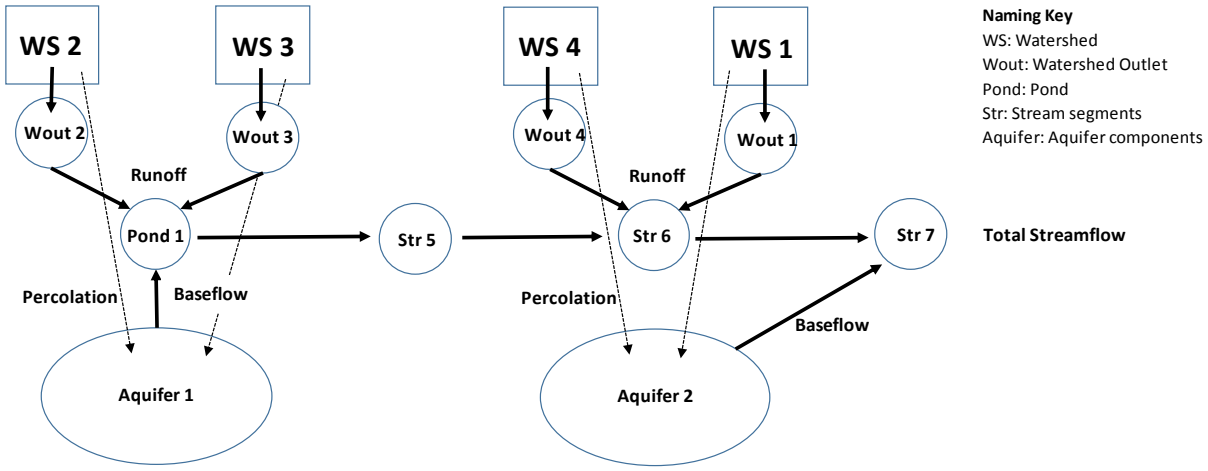

Watershed #1: Penninsula State Park, culvert coming from east under park road from bike rental
Watershed #2: Nature conservancy wetland, East side
Watershed #3: Nature conservancy wetland, West side
Watershed #4: Lower Fish Creek

Figure 3. Schematic of the P8 model configuration for Fish Creek for streamflow at monitoring point #5. Model component types identified in the Naming Key to the right.

Table 1. Watershed Characteristics for P8 Model

Subwatershed (P8 Number)	Area (acres)	% Direct Impervious	Pervious / Indirectly Connected CN
Peninsula State Park (1)	154*	0	60
East (2)	3799	0	60
West (3)	974	0	60
Lower (4)	910	1	65

**Only 10% of watershed 1 (154 of the 1540 acres) assumed to join Fish Creek prior to Monitoring Station 5.*

Results

Streamflow in Fish Creek

We used the measured stream depth at Site #5 near Highway 42 to estimate the streamflow in Fish Creek. These measurements converted to flow are in Figure 4 as the cubic feet of water per second over time. Although estimates, these flows exhibit a general trend of higher flow in late winter and early spring and lower flow in summer.

The model results for flow at Monitoring Site 5 near Highway 42 are also in Figure 4. The model simulates peak flows in the spring coinciding with snowmelt and spring recharge followed by a decrease in flow most summers and then a smaller increase in the fall. Although our flow measurements are just estimates based on the observed stream depth, the measured and model patterns are consistent with observations in monitoring wells near Sturgeon Bay in Door County (Rayne et al., 2001) and flow in Logan Creek on the east side of Door County (McGinley and Hoverson, 2006).

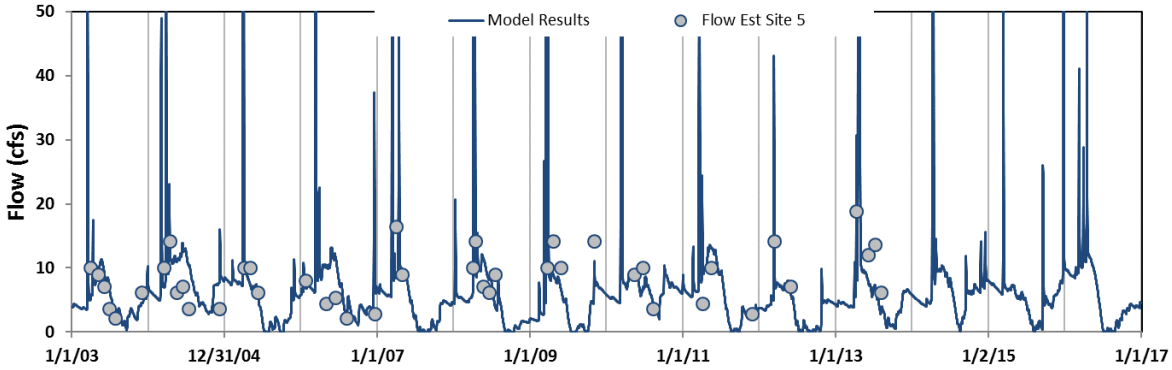

Figure 4. Comparison of estimated measured flows an model results for flow in Fish Creek at Hwy 42.

The model results were used to create an annual hydrologic budget for the Fish Creek watershed. Figure 5 shows how the annual precipitation totals lead to approximately two-thirds as evapotranspiration and one third as streamflow (groundwater recharge and runoff). That generally corresponds to observations of Bradbury and Muldoon (1992) who found approximately 9.5 inches of groundwater recharge per year. Our model results simulate this amount as varying from year to year based on the precipitation total and the timing. Precipitation totals also vary across Door County and because the only hourly precipitation records we found were in Sturgeon Bay we expect the precipitation will differ somewhat from that in the Fish Creek watershed.

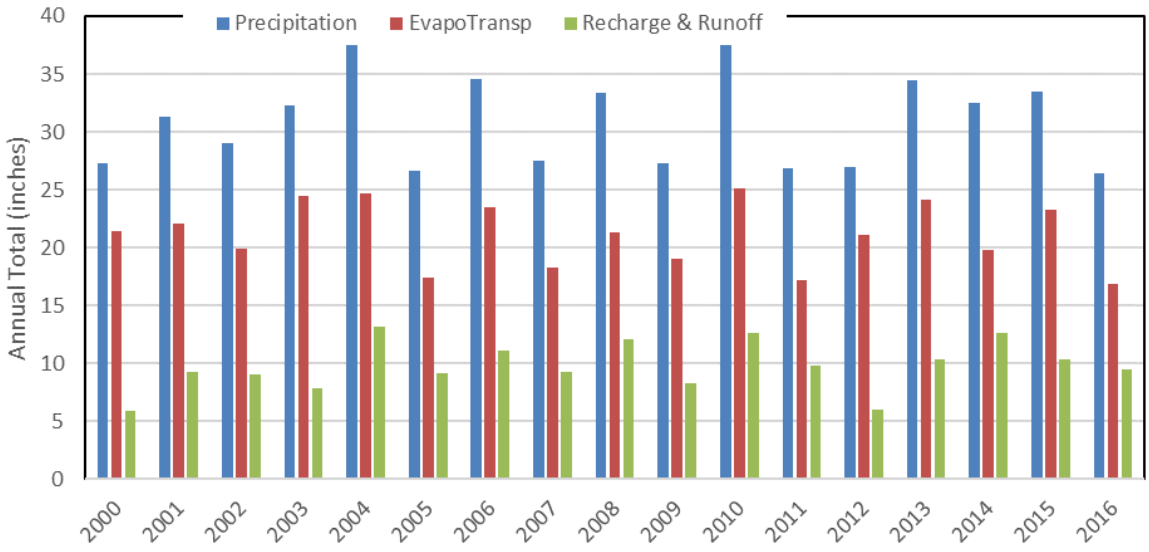

Figure 5. Simulated hydrologic budget for the Fish Creek watershed expressed as depth of water per calendar year.

Water Chemistry of Fish Creek

Monitoring since 2000 provides a useful dataset for evaluating the water chemistry of Fish Creek. One important measure of water quality is the phosphorus concentration in the stream. Phosphorus is an essential element that can influence the biological productivity and subsequently the oxygen content and biological communities in the stream. Figure 6 shows the history of total phosphorus over time in Fish Creek as open symbols and allows it to be compared with simulated streamflow and alkalinity concentrations. The alkalinity concentrations are a measure of how the streamflow has interacted with the carbonate rock in the watershed. Higher alkalinity values are consistent with groundwater and lower alkalinity values suggest either some addition of direct runoff or rapid passage through rock fractures of snowmelt or rainfall.

The relationship between phosphorus, flow and alkalinity can help evaluate controls over concentration patterns in the stream. In general, the highest phosphorus concentrations are during the low flow periods of the summer and the lowest concentrations are during the high flow periods of the spring. One explanation for these observations is that during the high flow spring period, large groundwater flows act to dilute runoff phosphorus concentrations. Alkalinity concentrations can be low because much of the groundwater flow is through rapid transit pathways that convey snowmelt and recharge. During the low flow summer periods, stream phosphorus concentrations may be influenced by small runoff events because the overall streamflow is so low. The streamflow often has higher alkalinity during the summer, which could be the result of longer groundwater flow pathways and more contact with the carbonate bedrock. However, when small runoff inputs are added to this small groundwater flow, the relatively high concentration of phosphorus in the runoff could lead to increases in measured total phosphorus.

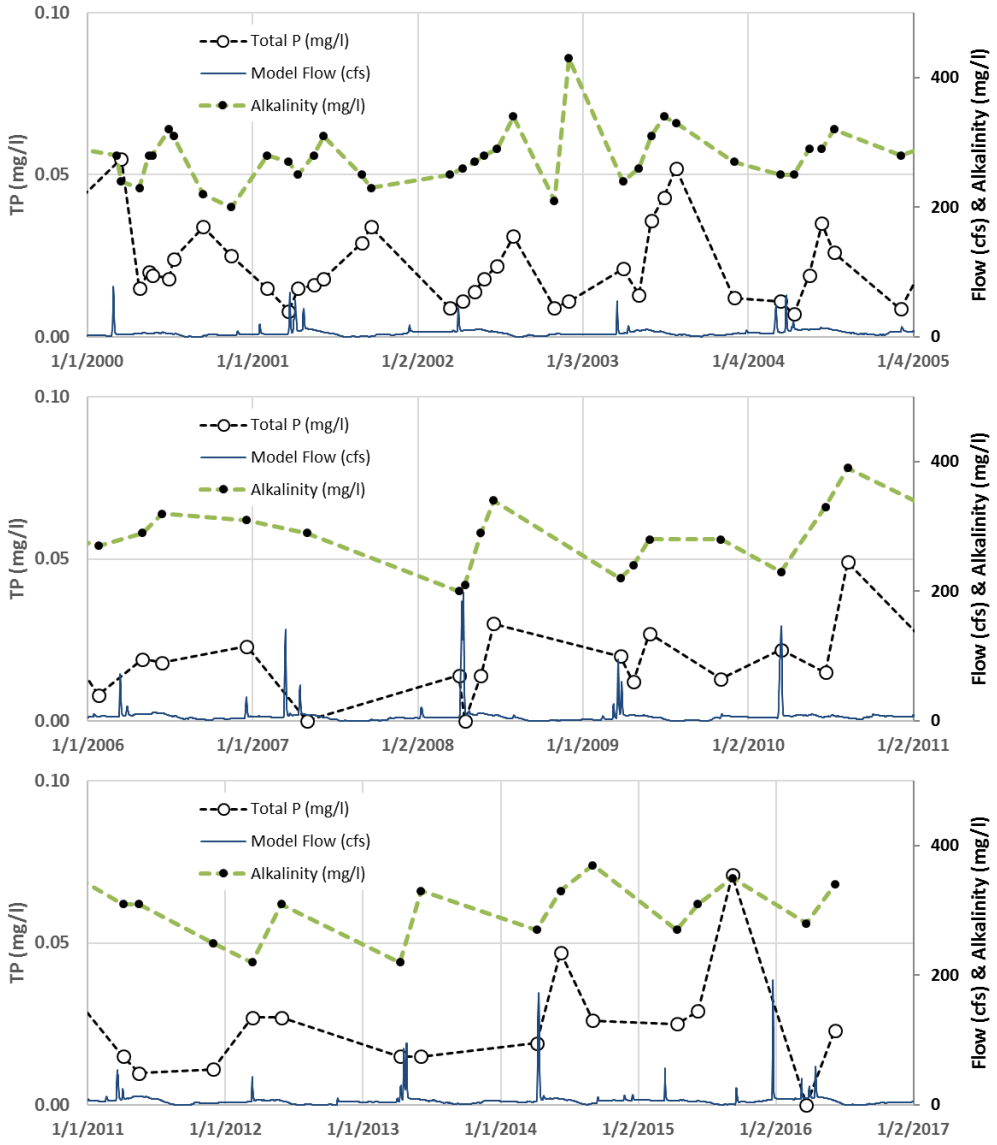

Figure 6. Measured total phosphorus concentrations over time in Fish Creek shown with measured alkalinity and simulated flow. Dotted lines added to demonstrate connection between points, and do not imply those are the concentrations between.

We explored the application of the P8 model to simulate stream phosphorus concentrations. The model simulates the stream concentration by summing the contribution of phosphorus from groundwater and runoff. We simulated the groundwater phosphorus concentration as relatively low (0.02 mg/l) and composed of dissolved phosphorus. The runoff phosphorus concentration combines the particulate and dissolved fractions. The results of total phosphorus modeling in Figure 7 show that these assumptions result in higher total phosphorus in the late winter and late summer for many years. The lowest simulated phosphorus concentrations generally occur in early summer and winter. To some extent, that simulated pattern agrees with the measured results. The model simulates the highest phosphorus during periods of very low streamflow when small runoff events with their higher phosphorus concentrations would more strongly influence the overall stream concentration.

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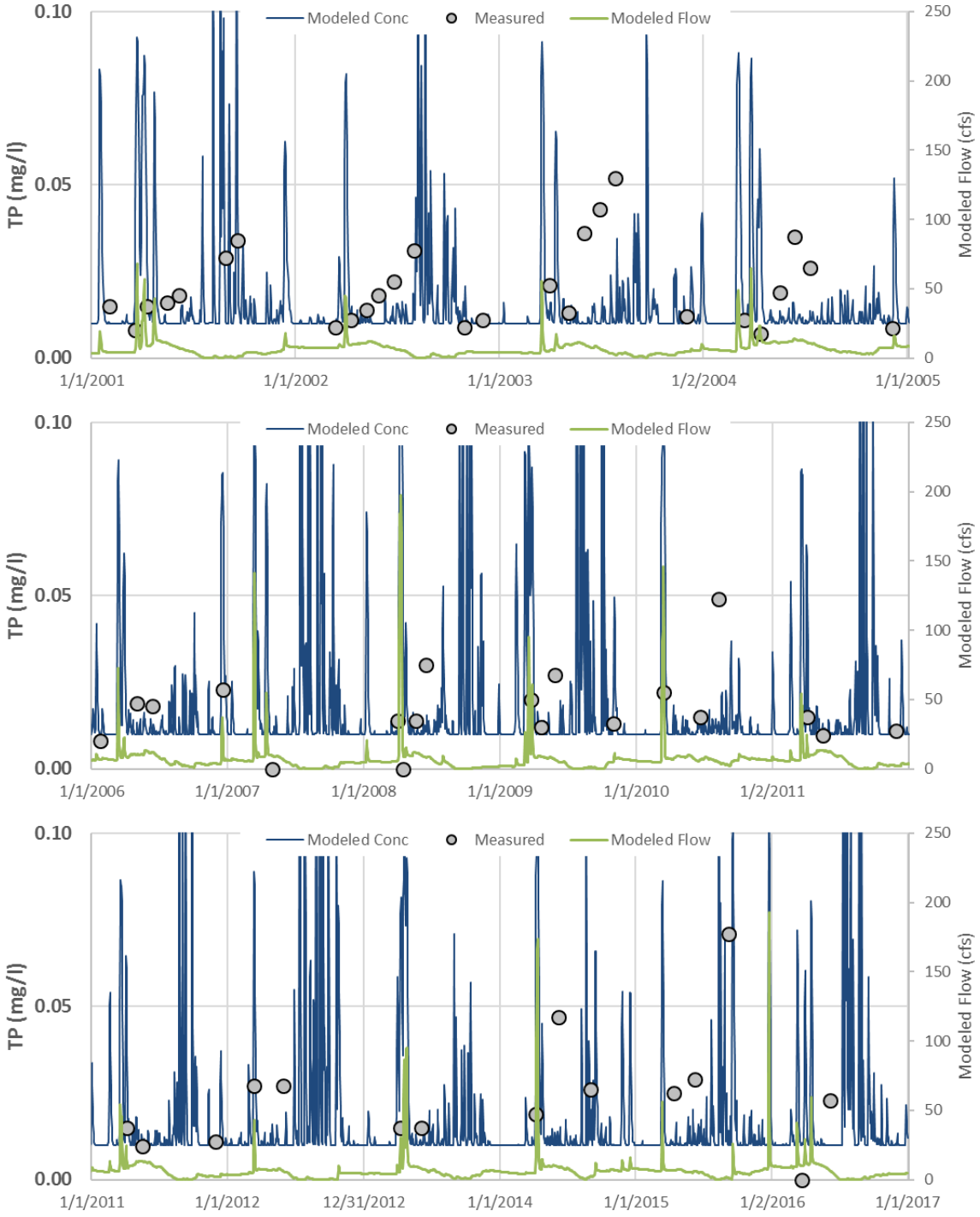

Figure 7. Comparison of measured and modeled total phosphorus concentrations in Fish Creek (left axis) shown with modeled flow (right axis).

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Potential Impact of Development

The modeling explored how increasing the quantity of impervious surface might influence the hydrology and water quality in Fish Creek. We simulated the impact of increasing the directly connected impervious fraction of the downstream Watershed 4. Figure 8 shows the overall flow that was modeled after increasing the directly connected impervious fraction of watershed from 1% to 20%. Overall, the flow looks similar because this change only affects a small percentage of the watershed, but this change could have an important impact on flows and flow variation during the lower flow periods of the year. Figure 9 summarizes changes by year in the maximum flow in the stream simulated by the changes in impervious surface in Watershed 4. As expected, a higher percentage of directly connected impervious increases flow in May and August. This change reflects the large addition of runoff to a stream with a relatively low increase in baseflow. As described earlier for the evaluation of stream concentration, this change would likely lead to a stream more closely resembling runoff water quality. For example, higher phosphorus concentrations would be expected during the summer in Fish Creek with those changes in impervious surface.

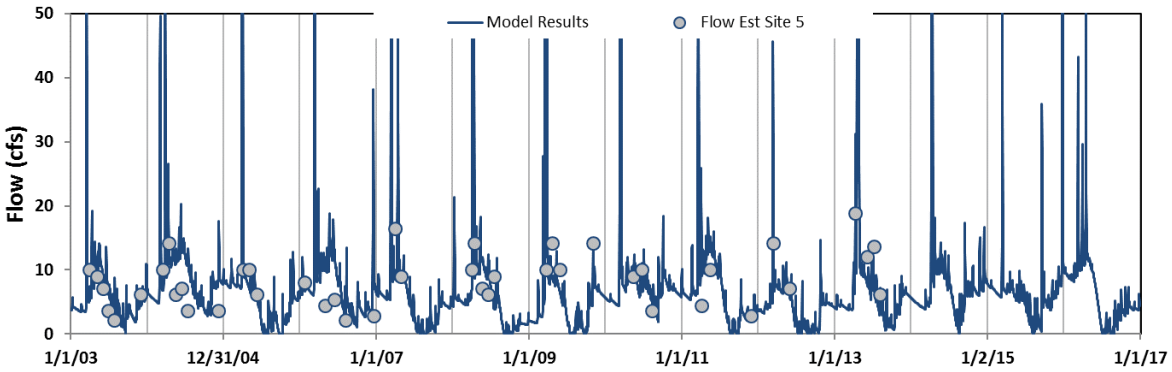

Figure 8. Simulated flow with 20% of the downstream watershed 4 as directly connected impervious area.

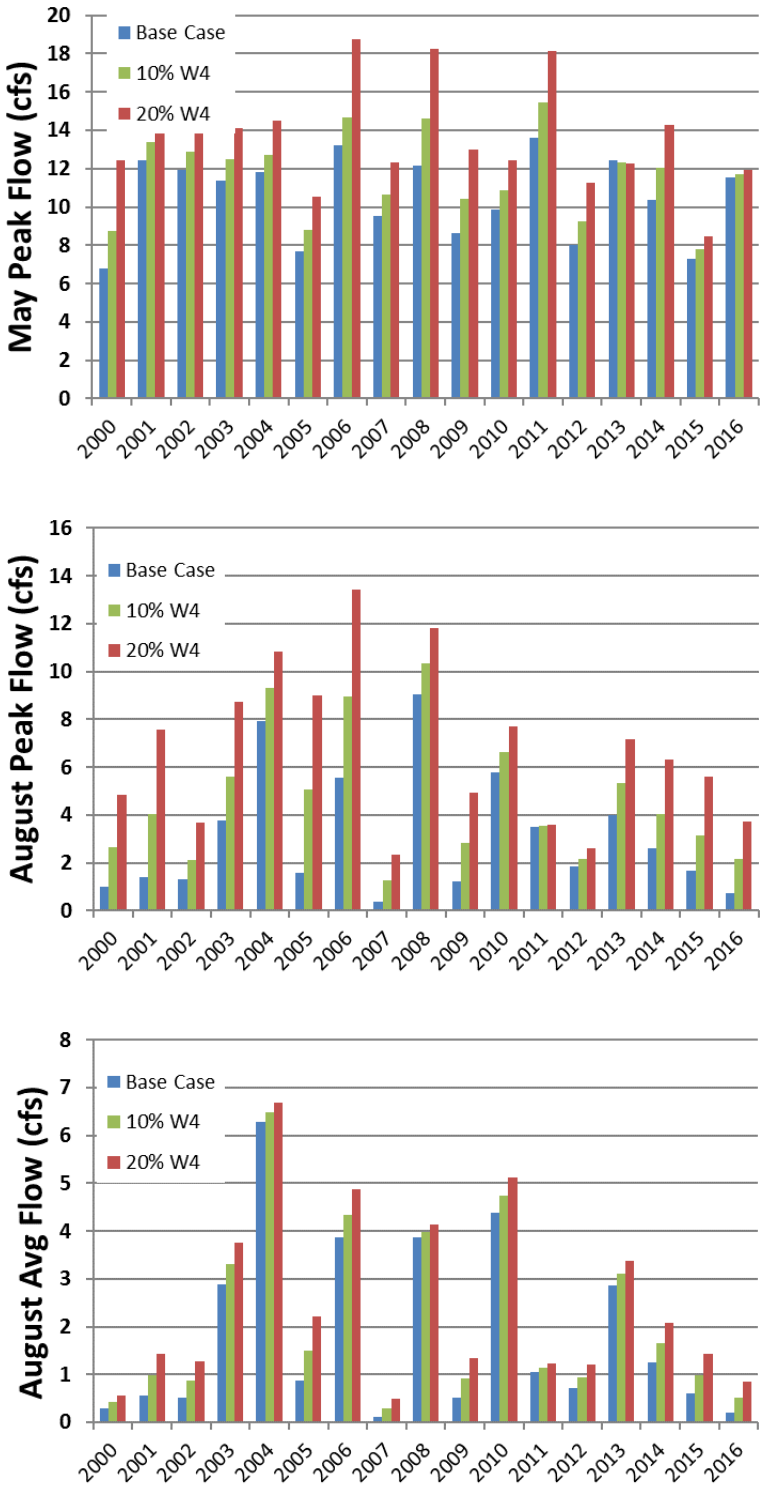

Figure 9. Simulated impact of changes in impervious surface of downstream watershed 4 on peak and average streamflow in Fish Creek.

Summary and Conclusions

This study used a simple hydrologic model to help interpret the data on stream depth and phosphorus concentration. It developed a conceptual model of watershed-stream interaction to establish a method for evaluating possible impacts of development in the watershed.

Some of the findings of this study are:

1) Flow in the stream likely reflects the rapid movement of rain and melting snow through the soil and fractured rock to the stream. Flow is likely highest in the late winter and early spring and lowest in the summer.
2) The simulated water budget shows year-to-year variation in streamflow reflecting the amount and timing of precipitation.
3) Mineral content of the water (likely dominated by hardness and alkalinity) varies during the year reflecting the extent of contact with carbonate bedrock. Phosphorus content of the water appears to follow the extent of runoff contributions and seems highest during periods of low streamflow when those runoff contributions would be largest relative to the groundwater flow.
4) The most obvious immediate impact of additional directly connected impervious in the watershed would likely be increased flow variation during the low flow periods when runoff drains directly to the stream. This will increase stream nutrient concentrations.

This study is a preliminary hydrologic analysis in that it uses a simulation model to "fill in" between measurements and build a conceptual understanding based on previous groundwater investigations in Door County. Future direct measurements of flow, particularly continuous monitoring at several locations in the stream, would be very useful in validating the interpretation provided here.

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