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LAND INFORMATION Bulletin

from the National Consortium for Rural Geospatial InnovationS

Great Lakes, University of Wisconsin–Madison

Protecting cold water streams

GIS tackles thermal loading in urban watersheds

Cold water streams are susceptible to a growing problem in rapidly urbanizing areas: thermal loading from heated water that runs off of streets, roofs, and parking lots. A new Dane County, Wisconsin ordinance is aimed at managing thermal loading, along with other stormwater and soil-erosion concerns. Using geographic information sys - tems (GIS) and other digital tools, Dane County landowners, developers, and conser - vationists can now identify land parcels that drain into vulnerable watersheds, and predict thermal impacts from runoff. With this information at hand, they can design temperature-reducing features that control thermal loading. This strategy could be used by other communities concerned about the effects of development on their cold water resources.

Every new residential or commercial development contributes to an often-overlooked environmental impact: heated water that flows into surrounding creeks and rivers. Impervious surfaces—street pavement, parking lots, and rooftops—typically absorb and store more of the sun's energy than natural surfaces. During summer afternoon thunderstorms, the solar-heated surfaces transfer energy to the water that gathers on them. This heated water quickly moves through drainage ways to nearby streams, with little chance to cool (see figure at left). Accordingly, streams in urbanized watersheds often show increased maximum summer temperatures compared to streams in less-developed areas.

Just add water: Runoff from a summer storm will empty directly from solar-heated roads and rooftops into this cold water feeder stream.

Increased water temperature can have significant impacts on aquatic life, particularly in small cold water streams. Healthy cold water streams are able to support cold water fish (such as trout) that typically require temperatures below 21°C. To protect aquatic life in cold water streams, a new ordinance in Dane County Wisconsin—the Erosion Control and Stormwater Management Ordinance—includes a "thermal control" section, one of the first legislative attempts in the nation designed to control heated runoff from impervious surfaces. The implementation of the thermal-control section of the ordinance offers a model for other communities that are committed to protecting their cold water streams from the thermal impacts of urbanization.

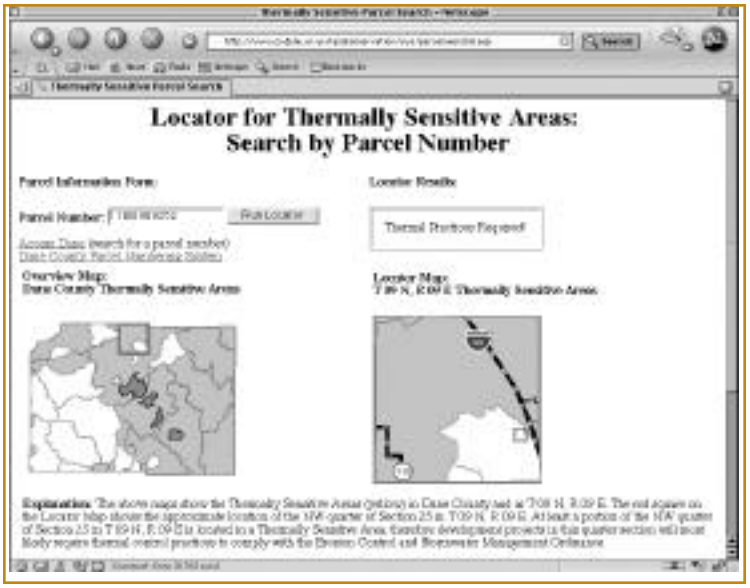
Defining Boundaries

Watershed delineation

A considerable area in Dane County drains to cold water streams and is therefore affected by the ordinance. The first step in enforcing thermal-control regulations is identifying the affected watersheds. Although field hydrologic surveys provide accurate information, the area in question is too vast for on-the-ground surveys. Instead, automated watershed delineation methods use digital elevation models (DEMs) of the areas in question.

Digital Elevation Models are raster (cell-based) representations of topography, in which each cell corresponds to an approximately square area on the earth's surface. Algorithms determine the direction of water flow for small groups of cells and then aggregate these flow directions to determine the overall drainage patterns for an entire landscape. These derived drainage patterns are used to determine watershed boundaries.

Although automated watershed delineation from a DEM is very effective in high-relief landscapes, low-relief landscapes that have been glaciated—common in southern Wisconsin—are more problematic. Automated methods used to produce DEMs can result in elevation errors that affect derived drainage patterns. For example, DEMs may inaccurately portray sinks—depressions that trap water as it moves over the landscape, preventing it from traveling over the land surface to lakes and streams. Sometimes sinks in a DEM represent legitimate landscape features that are internally drained, rather than errors. Determining which representations are actual sinks and which are errors can pose problems.



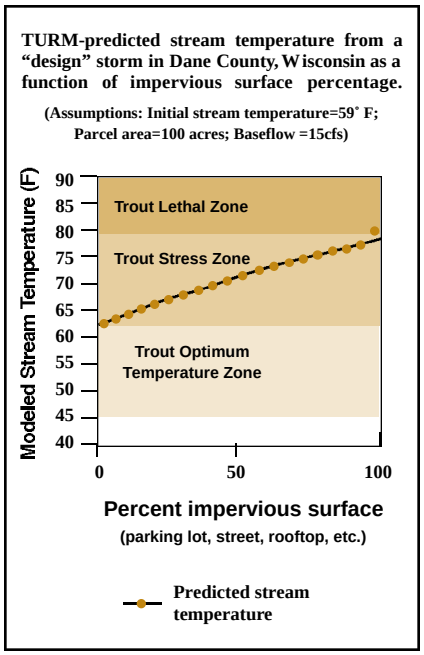
Locator tool: The image at left, located on the Dane County, Wisconsin locator Website, shows an actual parcel identified as thermally sensitive.

With such complicating factors, both automated and manual methods were used to delineate the boundaries of watersheds draining to cold water streams in Dane County. To improve the accuracy of these boundaries, additional information (the noted locations of true stream paths and true sinks) was incorporated into the DEM. In areas where the presence of sinks had a considerable effect on automatically-delineated watershed boundaries, watersheds were manually delineated from detailed topographic maps (2-foot contours). This fine-honing of accuracy ensured that regulations would be fairly applied, covering only the vulnerable areas.

Even without enforced runoff-temperature regulations in most communities, identifying areas that drain to cold water streams is still a worthwhile task. Cold water watersheds can be another valued data layer for planners to consider when making planning and zoning decisions related to development.

Web-based locator tool

Once the regulatory cold water-watershed boundaries are established, developers and others must determine whether a particular area of land falls within these boundaries. A geographic information system (GIS) overlay of Dane County parcels with the cold water-watershed boundaries shows which parcels are thermally sensitive. A Website, referred to as the thermal locator tool, accepts Dane County parcel information from users and determines whether or not the parcel is within a thermally sensitive area. The Website (**http://www.co.dane.wi.us/landconservation/cws/index3.html**) is maintained by the Dane County Land Conservation Department.



TURM-predicted stream temperature from a "design" storm in Dane County, Wisconsin as a function of impervious surface percentage.

(Assumptions: Initial stream temperature=59˚ F; Parcel area=100 acres; Baseflow =15cfs)

Predicting Effects

Thermal urban runoff model

The Thermal Urban Runoff Model (TURM) was developed and tested in Dane County specifically for the purpose of assessing a development project's thermal impact on the cold water stream into which it drains. Once the scope of the problem is assessed, builders can design and implement effective temperature-reduction practices. TURM uses weather data along with information about a development project in order to predict the resulting runoff and stream temperatures. It also predicts the temperature reduction achieved by using selected thermal-control practices.

TURM is a simple model that has been validated under a variety of storm conditions in Dane County. To use TURM as a predictive tool, some assumptions must be made about the typical weather conditions found prior to and during a storm with the potential for significant thermal impact in a developed area. Weather data from several stations were evaluated to determine values of weather variables for a "design" storm in Dane County. (Design storm refers to a set of storm conditions—rainfall, air temperature, relative humidity, etc.—that engineers assume when designing temperature-reduction practices). Standardizing the design-storm conditions allows users to predict the thermal impact of a particular project using a few development variables (such as parcel area and percentage of imperviousness).

Temperature reduction practices

Currently TURM is able to predict the temperature and flow rate of water exiting temperature-reduction practices, including:

1) Rock crib: a bed of rocks that receives runoff from a developed area. Heat exchange between water and rocks cools heated runoff.

2) Thermal swale: a vegetated trench that receives runoff from a developed area. A gentle slope along the bottom of the swale directs runoff toward an outlet pipe, which is at the bottom of one end of the swale. The swale reduces heated runoff mainly by controlling the rate at which heated runoff is introduced into a stream.

The ability to predict the effect of other management practices (such as detention ponds) on runoff temperature is a planned future development for the TURM model.

Above: A "dry" rock crib, which is designed to contain runoff before it enters a cold water stream.

Below: Thermal swale, designed to absorb runoff in an urban area.

Future Work

Three primary tasks, yet to be completed, can further protect cold water streams from the thermal impacts of urbanization in Dane County. First, TURM should be validated for predicting stream temperatures (currently, only runoff-temperature equations have been validated). Validation will involve comparing measured and modeled stream temperatures during various types of storms and adjusting the stream temperature equations as necessary to improve the model's accuracy. Second, TURM should encompass an entire watershed to account for the cumulative thermal impact of many developed parcels draining to the same cold water stream. Finally, more education is needed for those involved with designing, implementing, and reviewing temperature-reduction practices to ensure the effectiveness of these practices (see sidebar, p. 4). Over the long term, the new ordinance's thermal-control section can only be considered successful if the streams that it was designed to protect remain healthy cold water communities, despite significant new urban development.

About RGIS

The National Consortium for Rural Geospatial Innovations–Great Lakes is located on the campus of the University of Wisconsin–Madison. It is a USDA Cooperative State Research, Education and Extension Service (CSREES) program designed to promote the use of geospatial information and technologies by communities in rural America. RGIS is dedicated to helping communities understand the concepts and benefits of using geospatial data as well as assisting them in all aspects of GIS development.

Educational material available in Dane County

Thermal-impact educational material is available to help developers, conservationists and others not familiar with thermal-impact modeling and mitigation learn about the TURM model and how it is used with Dane County's stormwater ordinance. The material introduces important concepts about the effects of urbanization on stream temperatures.

Included are general descriptions of problems, detailed explanations of how impervious surfaces, project area, and stream-flow conditions interact to influence stream temperatures. There are descriptions of thermal-reduction practices. Tables and charts show how model factors interact and how effective control measures might be in reducing stream temperature increases caused by different land uses under varying storm conditions. This material can be downloaded (pdf format) from:

www.co.dane.wi.us/landconservation/ecswpubspg.htm.

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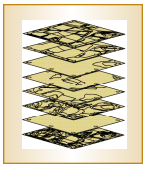

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