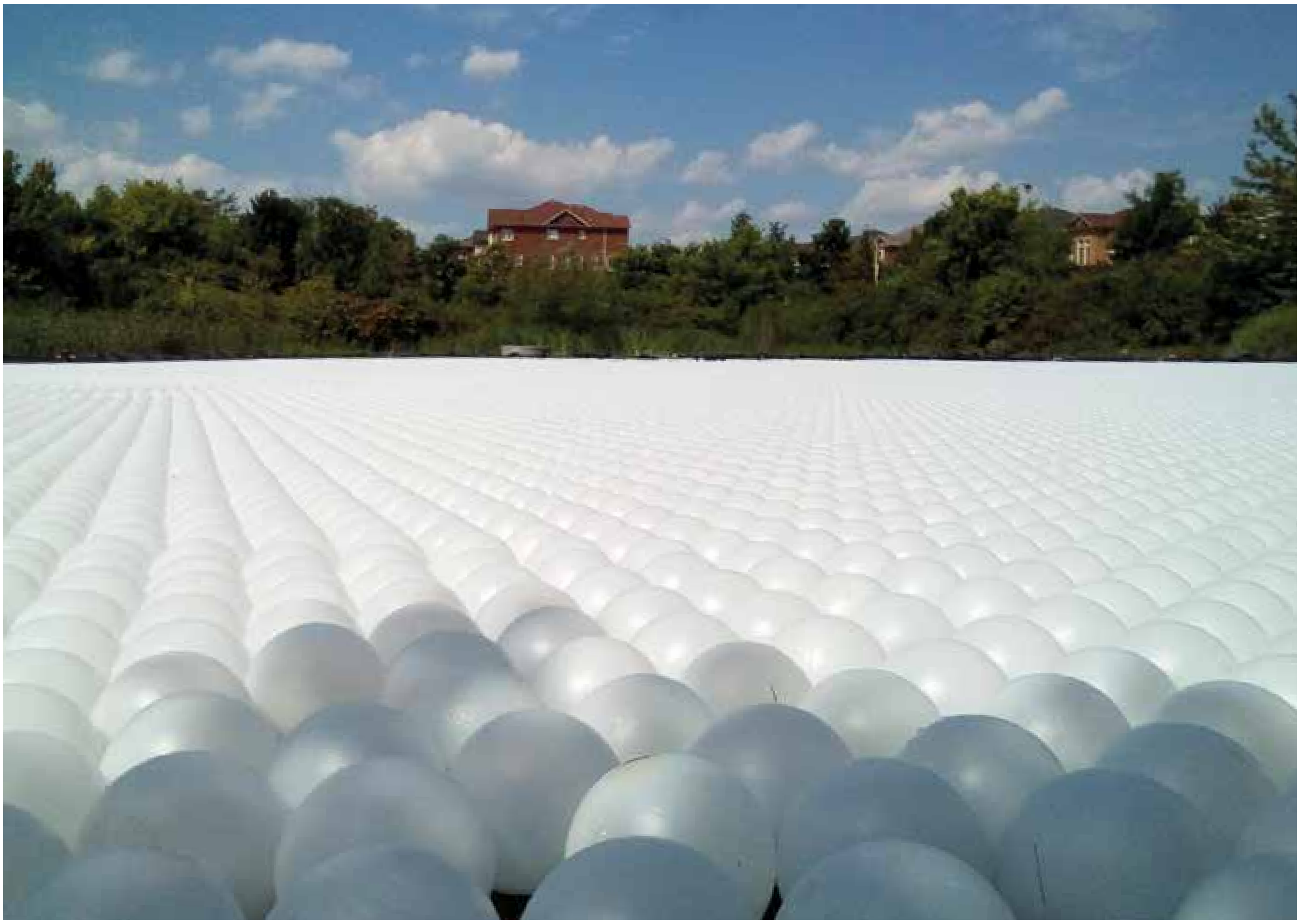

Hollow, high-density polyethylene balls cover the surface of the Esker stormwater management pond in Brampton, Ontario.

TRCA

Keeping Cool

Protecting aquatic species with thermal mitigation

BY LISA ROCHA, TIM VAN SETERS, AND ERIK JENSSEN

THE URBAN HEAT ISLAND EFFECT AND RISING summer temperatures affect more than just our air-conditioning bills. Freshwater ecosystems are at risk as well, as even small changes in water temperature can cause migration of freshwater species and population decline.

In urban areas where stormwater is managed through detention facilities like ponds, this warming effect is further exacerbated. Although these facilities enhance water quality by removing pollutants and reducing erosion and flooding issues downstream, they can also be significant contributors to thermal enrichment of streams, as the water they detain is subject to significant heating during summer months. Pond outlet temperatures are often more than 7°C warmer than inlet temperatures and well above the tolerance threshold of several cool and cold freshwater fish species across Canada.

Cold-water priority

In Ontario, this has been recognized as a concern by the Ministry of Natural Resources and Forestry, which has developed thermal targets and guidelines for development in areas that provide habitat for the endangered cold-water species, Redside dace. While protection and recovery of Redside dace populations have been the main impetus for the push toward addressing thermal enrichment of streams in the Greater Toronto Area, populations of many other cold water fish could also benefit from these measures.

One such example is the declining Brook trout, which thrive in very cold streams (< 20 °C). Today they are confined to mostly headwater areas within the Lake Ontario basin and are estimated to occupy only 21 per cent of their historic range. Modelling of future climate scenarios by Toronto and Region Conservation Authority (TRCA) in 2020 found that compared to those in warm and cool streams, cold-water fish communities are the most at risk of extirpation within the TRCA jurisdiction over the next 80 years if no adaptation measures are undertaken.

Cool strategies

Thermal mitigation refers to a range of practices that are designed to either prevent or reverse summer warming of stormwater, typically in urban and suburban areas. They can be categorized based on where in the drainage network they are applied—within the catchment area, within the stormwater pond block, or at the receiving stream – or according to the ways in which they protect streams from thermal impacts.

For example, one important technique is to release only cooler water from stormwater ponds, which can be achieved through the construction of bottom draw outlets in deeper ponds, or the installation of real-time outlet controls that only release water during the night when temperatures are lower. Other common practices like cooling trenches and vegetated outlet channels focus on cooling down pond outflows; while shading practices, like shoreline plantings and floating islands, are meant to prevent pond water from warming up in the first place. Other strategies focus on reducing total runoff volumes by enhancing infiltration and evapotranspiration, resulting in less thermally enriched water released into streams. These practices provide stormwater treatment and flow control allowing stormwater pond sizes to be reduced, and in some cases, wet ponds can even be substituted for dry ponds, which have a lower warming impact.

Over the past few decades, several of these thermal mitigation practices have been implemented and monitored in southern Ontario with results showing varying degrees of cooling effectiveness and viability with respect to operation and maintenance needs. However, finding technologies that are easy and cost-effective to implement as retrofits to existing ponds can be a challenge.

New approaches

Recognizing the limitations of existing measures, the City of Brampton partnered with the Sustainable Technologies Evaluation Program (STEP) to explore the efficacy of new thermal mitigation approaches through pilot studies. STEP is a collaborative effort involving the TRCA, Credit Valley Conservation, and the Lake Simcoe Region Conservation Authority focused on fostering broader implementation of sustainable technologies through research, guideline development, and outreach.

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Stormwater retention ponds can be significant contributors to thermal enrichment of streams.

Pilot evaluations were focused on practices that are cost-effective, easy to maintain, capable of meeting thermal targets, and can be applied either on a new site or as a retrofit to an existing facility. Two thermal mitigation technologies were selected for piloting at two different ponds in Brampton: pond surface shading with shade balls and a geothermal outflow cooling system.

Pond surface shading

In the surface shading pilot, 75 per cent of the pond's surface was covered with high-density polyethylene balls that were contained within a floating turbidity curtain barrier system. The site was monitored over three summers, during which time the pond's inlet and outlet temperatures were compared pre- and post-installation, as was a nearby pond that served as an experimental control.

Data collected showed that the shade balls did not cause a significant or consistent reduction in pond warming relative to baseline conditions or the control pond. Further investigation showed that water directly underneath the balls was warmer than water at the same depth in the unshaded area, suggesting that the balls were creating a heating effect at the pond's surface.

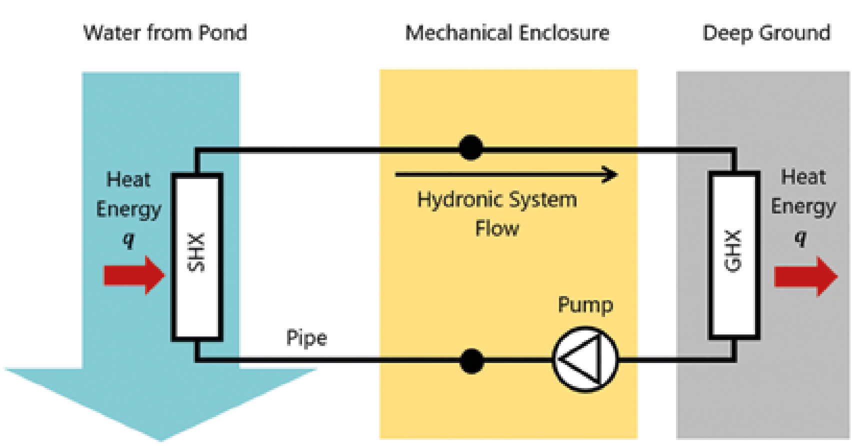
During small-scale experiments conducted as part of this study, the cooling performance of other ball colours were also investigated, including black balls and white balls that had received a coat of reflective paint. This testing revealed that the black balls kept the water beneath them coolest, resulting in median water temperatures nearly 2°C cooler than beneath the white balls.

Ultimately this pilot demonstrated that while the specific product tested wasn't effective in preventing warming, shading alternatives should still be considered as part of the toolkit of thermal mitigation best practices, albeit not as standalone measures.

Geothermal cooling

Passively cooling pond outflows using technologies like cooling trenches is a well-established thermal mitigation approach, with performance varying significantly from site-to-site. Geothermal technology takes this technology one step further by actively using the stable cold temperatures deep underground as both a source and a sink for heat energy. While typically deployed in conjunction with a heat pump to create an energy efficient heating and cooling system for a building, geothermal was applied in this pilot to passively cool warm stormwater pond outflows instead. The system consists of a 183-metre deep geothermal borehole, or ground heat exchanger (GHX), connected in a closed loop with a stormwater heat exchanger (SHX) (see Figure 1).

The SHX in this pilot were made from



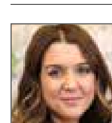
L to R: Figure 1. Schematic diagram of the pilot geothermal stormwater cooling system. The coil of high-density polyethylene pipe used as the stormwater heat exchanger (SHX) in the geothermal cooling pilot.

inexpensive coils of polyethylene pipe, installed inside a space-efficient vault downstream of the pond outlet. A heat transfer fluid is pumped continuously through the closed loop. When warm pond outflows move through the vault on their way to the stream, they pass over the coils of the SHX which absorbs heat and, via the circulating fluid, rejects it to the deep ground using the GHX. This cycle can be used to continuously cool warm stormwater outflows as they leave the pond.

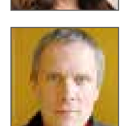
The pilot included only one borehole to provide the data that would allow for development and calibration of a system model capable of predicting how cooling performance varies based on changing design parameters. Using the model, cost optimization calculations can be undertaken to determine the lowest cost number of boreholes and length of pipe required to meet the target outflow temperature. For the pilot site, the model developed predicted that with no geothermal cooling in place, pond outflows would exceed 24°C about 50 per cent of the time from June 1 to September 15, but if a system that included four-to-six boreholes was installed, outflows would remain below 24°C for 95 per cent of that time. Geothermal systems are space- and cost-efficient, suitable for retrofit applications and visually unobtrusive, making it a great solution for thermal mitigation of stormwater pond outflows.

Creative combinations

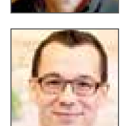
Finding creative combinations using a toolbox of approaches tailored to the unique character of each site helps optimize individual technologies, reduce cost, and improve overall effectiveness. This means seeking out opportunities across the landscape to absorb and infiltrate water, providing shade where feasible, using cool water deep in the stormwater ponds to reduce outlet temperatures, and relying on active cooling techniques to provide a final boost before water is released to streams. WC



Lisa Rocha is a project manager with the Sustainable Technologies Evaluation Program (STEP) at the Toronto and Region Conservation Authority, who specializes in sustainable water management.



Tim Van Seters manages the Sustainable Technologies Evaluation Program (STEP) at the Toronto and Region Conservation Authority.



Erik Janssen is an analyst with the Sustainable Technologies Evaluation Program (STEP) of the Toronto and Region Conservation Authority.