URBANIZED RUNOFF Let's look at an aspect of climate change at the neighborhood scale. Our present stormwater management systems were not designed to handle the heavy downpours that are expected to increase in intensity and frequency with Wisconsin's changing climate. Managing this additional stormwater is particularly important in urban areas with combined sewer and stormwater systems. Excessive runoff from urban areas can also contribute to flooding and property damage in rural areas.

Urbanization has several adverse effects on local hydrology, including increased flooding, degraded water quality, and decreased base flow in streams and rivers. All three of these result from the increased amount of runoff from the introduction of impervious surfaces and the compaction of pervious surfaces in urban areas. More runoff, coupled with the drainage "improvement" systems built to accommodate it, also increases the *rate* of runoff—which further contributes to flooding and degraded water quality.

MANAGING MORE STORMWATER

Based on a presentation by Kenneth Potter, Professor of Civil and Environmental Engineering
University of Wisconsin-Madison

Finally, the pumping of groundwater by municipal wells causes a drop in the water table that reduces the base flow of streams and the water level of lakes in the area.

This is illustrated by U.S. Geological Survey stream flow data for Spring Harbor, an urban watershed in Madison, and Garfoot Creek, a small rural watershed just outside of Madison, which are two drainage areas of similar size and hydrology. The USGS data show that runoff amounts from the same precipitation events during 1995 tended to be two to three times more in the urban watershed than in the rural one. It is notable that the base flow is zero in the urban watershed, because the spring for which Spring Harbor was named dried up after the local municipal well was installed.

CONVENTIONAL PRACTICES Conventional urban stormwater management practices are based on historical climate. Stormwater management design is commonly based on so-called “design storms,” such as a 10-year 24-hour storm, based on the maximum amount of rainfall recorded in one day in one decade. Such historical climate measures obviously will not be a good indication of future performance if the magnitude of such storms increases.

No one really knows exactly how climate is going to change rainfall patterns, and we won’t actually know how much it has changed until it has been documented with some real measurements a decade or so afterwards. Despite this uncertainty, several approaches are available to address the projected increases in rainfall intensity, especially the large events.

One potentially effective strategy is to design conservatively to hedge against possible increases in storm intensities. Two other potential strategies are to improve the performance of existing systems based on monitoring and modeling, and to introduce a capacity for real-time management.

Presently, four conventional practices for managing stormwater include:

- Conveyance (storm sewers and engineered channels)
- Storage (to control runoff peaks and improve water quality)
- Infiltration (to decrease runoff volumes and increase groundwater recharge)
- Filtration (to improve water quality)

Of these, a combination of storage and infiltration appears to be our best alternative for addressing the potential increase in storm intensities and runoff projected to occur in Wisconsin with future climate change.

CONSERVATIVE DESIGN Conservative design may be a hard sell. It means designing bigger ponds and using more developable land because climate change *might* cause rainfall intensity to increase; therefore, a conservative approach requires a logical basis for design development.

One is to regulate to the 100-year event. Madison ordinances, for example, only regulate runoff peaks to the 10-year storm event. The rationale for this is that runoff flows into the lakes, so flooding is not a concern. But that's not completely true. Part of the runoff from the Madison watershed flows into the Sugar River, and this additional runoff is increasing the 100-year flood plain along the Sugar River. A lot of communities are following Madison's lead, designing for nothing greater than the 10-year event. It's important to design for the 100-year event because to do otherwise is putting people into flood plains who weren't there previously and may not know that they are now.

Many people think that designing to the 10-year event provides a good reduction for the 100-year event. Potter described a simulation he conducted of routing a 100-year flood event through a detention pond designed according to the 10-year event, which demonstrated poor attenuation of peak flow because the storage filled up before maximum attenuation was reached. If the pond fills up before the peak is reached, it provides no benefit towards reducing the peak. This is analogous to the 1993 flood of the Mississippi River. In places where levies breached, hydrographic measures of the river's flow dropped temporarily. After those flood plain areas filled up, however, the flow basically returned to the same trajectory.

Another strategy is to use regularly updated rainfall statistics. The obvious thing to do is to look at some large events that are bigger than the design storm to ensure that the design can handle or reduce the consequences of such events. This is something to consider, especially if we expect rainfall intensities to increase.

Many stormwater management designs are still based on Technical Publication 40, or TP40, which is 40 to 50 years old now. The TP40 numbers are clearly outdated. The Midwestern Climate Center has produced a set of intensity duration frequency curves that are substantially larger. A 100-year event has gone up by a half-inch or more in most places, yet even that information is more than 10 years old now. If our climate is indeed changing, we need to adjust our intensity to frequency curves more often. However, this could be a challenge for the National Weather Service, because it doesn't have the budget to redo these frequency curves. Also, because the work takes a long time, the NWS is unlikely to recalculate them anytime soon, so stormwater designers need to pay close attention to what rainfall is doing in their region. We're fortunate to have the Midwestern Climate Center to assist us.

A third strategy is to use the lowest, most conservative pre-development curve numbers that can be justified. A Soil Conservation Service (SCS) hydrology curve number is generally used to predict runoff from the selected storm event (design storm). The selection of a pre-development condition is usually specified in the local ordinance, but designers should investigate whether actual pre-development runoff rates may have been significantly less than that.

Lastly, use infiltration systems aggressively, but do not credit storage towards the peak requirement of the design. Infiltration practices like bioretention facilities or rain gardens are important approaches in a large urban area like Madison because of the large amounts of groundwater being pumped combined with the loss of groundwater recharge due to large areas of impervious surfaces. Infiltration is also important in such areas because greater runoff volume increases flooding, even with stormwater retention. Moderate development in the Lake Mendota watershed, even using everything to control the two- through 100-year peak, would still result in substantially higher peaks on the lake. Because it's a large storage site, Mendota accumulates runoff over a period of weeks and discharges water very slowly because of the downstream flow conditions. It's important to control runoff volume when dealing with sluggish natural systems like the Madison lakes.

TESTING ASSUMPTIONS Potter said he had operated under the assumption that infiltration doesn't provide much benefit when it comes to larger events. To test that assumption, he conducted an infiltration simulation using a hypothetical 160-acre development that is half impervious and applied pre- and post-development pervious surface runoff numbers. He designed a retention pond and outlet structure to hold runoff from a

100-year storm at pre-development levels and then ran the simulation a second time using the same 100-year event with 15 percent more rainfall.

The results were startling: the simulation showed that a 15 percent increase in rainfall would overwhelm the runoff control structure, doubling the rate of discharge it was designed to allow. However, when infiltration was added to the design, the rate of runoff remained at target levels or increased somewhat, depending on the type of soil used in the simulation. In the latter case, the target rate was met by increasing the bioretention area for infiltration from seven to nine percent of the total area, or nearly 14.5 acres.

This simulation showed that some benefits toward the peak can be derived from infiltration. Such aggressive infiltration may not be possible everywhere, but infiltration can be useful. However, it is essential when using infiltration that runoff storage requirements are not reduced in stormwater management designs—again, do not credit storage against the peak requirement of the design, and don't take credit towards 100-year event reductions based on infiltration. Those unused credits help keep the design conservative and provide a little excess capacity for handling more intense rainfalls in the future.

IMPROVING EXISTING SYSTEM PERFOMANCE The key to improving the performance of our stormwater management systems is to monitor individual runoff storage sites to verify the assumed storage-outflow characteristics and hydrologic parameters. Continuous simulation modeling of the system could also help identify ways to improve system performance.

When we build stormwater management systems, we *think* we know how they behave, but we really don't. The SCS hydrology curve number is just an approximation, and we can't be certain that our models or our characterization of the watershed are accurate, nor that our control and storage structures were constructed properly and are functioning as designed.

Storage performance can be monitored relatively simply with a pressure transducer in the pond and a data logger, and the stage-discharge relationship for the outlet structure can be checked by doing a few current meter measurements. Water-quality performance is especially important with some structures. Our sedimentation models assume quiescent conditions in a storage pond and don't account for resuspension due to turbulence. Unless a sedimentation pond is designed to be quiescent, it's going to be turbulent, so the kind of water-quality treatment down to the eight micron level we expect is likely not occurring.

Lake Mendota: M.F. Rothbart, UW-Madison University Communications

REAL-TIME MANAGEMENT One proposed alternative is to do as reservoir managers now do and coordinate the release of stormwater outflow for flood control. Instead of passive structures, reservoirs employ gates that can modify the amount of passing of water through the system based on real-time observations of the amount of water coming into the reservoir and the amount of rainfall predicted. When the forecast is for an exceptionally large rainfall, they open up the gates to let out enough water in advance to provide the extra storage needed to accommodate a heavy rain.

The question is whether that can be done with an urban retention pond. A simulation using the same data as before—except that some of the runoff is shunted away before reaching the retention pond—didn't significantly reduce the excessive outflow resulting from a 15 percent increase rainfall in a 100-year storm. Since engineers are unlikely to want movable gates on their ponds and performance isn't improved much anyway, this preliminary analysis indicates that real-time management of urban stormwater isn't a feasible nor effective alternative.

However, new stormwater management technologies are being developed for real-time monitoring and better forecasting, and for some systems—water quality treatment systems in particular—we may be able to optimize the performance of existing systems to accommodate better the increases in stormwater runoff that climate change is expected to bring.

Walleye: New York Department of Environmental Conservation