RAINGARDEN STUDY

BACKGROUND

As urban boundaries continue to expand into rural settings, more and more pervious land uses are converted to impervious surfaces that prevent or limit the infiltration of stormwater runoff. This can have serious effects on the groundwater recharge and the interflow to nearby streams and rivers. This effect can be too much water during and immediately following rain events and too little water during periods with little precipitation.

Infiltrating stormwater generated from impervious surfaces is one measure that can alleviate stresses to our aquifers and surface waters. As such an infiltration requirement has been codified by the State of Wisconsin in NR-151. This regulatory document requires all new development in the state, after October 1, 2004, to implement infiltration as part of the development unless restricted (primarily contamination concerns, or limited depth to groundwater).

One means of meeting this infiltration requirement that has received a great deal of national and regional attention has been the use of "Raingardens". Raingardens are typically small swales or depressions that accept runoff generated from nearby rooftops and infiltrate that water back into the soil. Typically, raingardens are planted with deep-rooted prairie plants that help keep soils loose, and increase evapotranspiration. However, the success of such devices is dependent on a number of factors including soil structure and vegetative root development.

While many groups are advocating the construction of these devices, the verified effectiveness and the guidelines for construction of raingardens are still in their infancy. As it is likely that many of the municipalities in our group will be allowing construction of rain gardens in the coming years as a means to meet the NR-151 criteria. The group believed that having some documentation on the effectiveness of these gardens was important enough to spend the groups monitoring funds on a water balance of these devices.

It was agreed that the City of Madison would act as the lead agency on this study and would find two (2) sites with room for two (2) rain gardens on each site. One garden at each site would have turf (grass) cover and the other would be planted with native (prairie) vegetation.

GOALS

The primary goal is to evaluate the effectiveness of raingardens with varying soils and differing planting types at infiltrating stormwater. Secondary objectives include, but are not limited to:

1. Measuring the vertical flux of infiltrated water beyond the root zone as well as soil moisture available for evapotranspiration
2. Measure atmospheric parameters necessary to calculate potential evapotranspiration at each location and compare to actual evapotranspiration.
3. Determine if "mounding" of infiltrated stormwater below ground may lead to lateral spreading that may cause damage to building foundations.

METHODS

The study focuses on two locations within the City of Madison where rooftop runoff was equally divided and directed into adjacent raingardens. The sites were chosen with differing soil types. The Owen Conservation Park has reasonably loose soil that has had very little disturbance over the years. The Water Utility Pumping Station on Old Sauk Road has a soil that has been compacted severely as part of construction activity and the material itself appears to be primarily made up of construction fill. Both raingardens have been constructed using existing guidelines and construction methods utilized by typical landscaper contractors as part of new construction. At each site there is one "turf" and one "native" garden.

Equipment has been installed at each location to calculate a volumetric mass balance per each raingarden based on the following equation:

$$V_{ground} = V_{in} + P - V_{out}$$

Where V_{ground} is the volume of water moving vertically through the soil column, V_{in} is the volume of water entering the raingarden from the rooftop, P is direct precipitation on the raingarden, and V_{out} is the volume of water escaping the confines of the raingarden during larger storm events. Additionally, various atmospheric conditions will be monitored to determine potential evapotranspiration (PET) rates at each test site.

Calculating V_{in}

Once each raingarden is constructed, the rooftop runoff from a nearby structure will be physically divided and routed equally to both raingardens. Runoff generated on the roof will follow its normal course through the downspout(s). If necessary, water will be concentrated from multiple downspouts into a single conveyance before entering the raingarden.

The volume of water entering each raingarden will be measured using a pre-rated, 60 degree, trapezoidal flume with attached stilling well. A submersible pressure transducer will be inserted into the stilling well to measure stage levels that can be converted into discharge.

Calculating V_{out}

A similar approach is used to measure the volume of water that may overtop the raingarden boundaries during larger storm events. Wingwalls have been inserted along the perimeter of the downstream edge of the raingarden to concentrate all excess flow into a pre-rated, 60 degree, trapezoidal flume with attached stilling well. A submersible pressure transducer will be inserted into the stilling well to measure stage levels that can be converted into discharge.

Calculating V_{ground}

Based on recorded values of volumetric water content, the movement of soil water can be calculated as a one-dimensional vertical unsaturated flux. The flux can be determined using the following equation:

$$Q = (\theta - FK)*\Delta z,$$

Where θ is the soil moisture content, FK is the field capacity of the soil, and Δz is the thickness of the soil horizon. Soil moisture content that is greater than the field capacity will result in positive fluxes (recharge). For soil moisture content less that field capacity, a negative flux (capillary rise) will occur. If integrated over time, the above equation can be used to calculate a volume of water.

A segmented soil moisture profiling probe will be inserted vertically into each raingarden to measure the volumetric water content of the soils at five different depths. An additional probe will be inserted vertically adjacent to the raingarden to ascertain the lateral extent of infiltrated water.

The soil underlying each raingarden will be characterized by the USGS soils laboratory in Lakewood, CO. Soils will be analyzed for bulk density, field capacity, wilting point, and percent clay/sand. A Geoprobe will be deployed to each location to retrieve several intact soil cores at varying depths.

To augment the point measurements of soil moisture, a neutron moisture probe will be used to provide a continuous soil moisture profile at selected times. Small diameter (2-inch) driven metal casings will be installed in each raingarden, from ground surface to the water table. A neutron probe can be calibrated to measure soil moisture changes on the order of 1 to 5 volume percent. This tool will help in interpreting the point soil moisture data that is collected continually in each raingarden.

Calculating PET

A weather monitoring station has been deployed at each study site to measure atmospheric conditions necessary to compute PET. Each station measures relative humidity, wind speed and direction, precipitation, temperature, solar radiation and soil heat flux. The Penman-Monteith approach will be used to calculate PET.

The Penman-Monteith approach includes all parameters that govern energy exchange and corresponding latent heat flux (evapotranspiration) from uniform expanses of vegetation. Most of the parameters are measured or can be readily calculated from weather data. The equation can be utilized for the direct calculation of any crop evapotranspiration as the surface and aerodynamic resistances are crop specific.

Data Analyses

Data analyses will be performed by the USGS and will summarize the performance of each raingarden. All runoff, precipitation, soil moisture, and atmospheric data collected will be stored in the USGS database as it becomes available. The USGS will make the data available to City and State personnel upon request.

Soil moisture data will be used to determine the volumetric water content below the raingarden at multiple depths and whether water has a positive, neutral or negative flux. Soil moisture data will be coupled with runoff data to calculate an estimated volumetric mass balance of water for each raingarden.

Data collected from each weather station will be used to predict potential evapotranspiration. Results will be compared to soil moisture data to determine if a relationship exists between potential evapotranspiration and soil moisture content.

CONSTRUCTION

The City of Madison constructed the gardens with our engineering service crews and equipment that is typically available to landscapers. Skid loaders, roto-tillers and handwork were used to construct the gardens. Generally, the scope of construction was completed in the following manner:

1) Skid loaders removed all the excess material and constructed control berms around the sites to assure that no water escaped the garden and that no runoff from areas other than the roof entered the garden.
2) Approximately 4-6" of screened compost from the Dane County Compost facility was brought in and roto-tilled into the ground at the bottom of the excavation. It should be noted here that at the Old Sauk site the ground was so compacted it was very difficult to get compost incorporated as well as would have been preferred.
3) Final grading was completed for both gardens and the turf gardens were seeded, fertilized and matted while the native gardens were planted and fertilized.
4) Construction problems – due to the drought that we experienced last caused problems with establishment of the turf gardens. The compost did not hold moisture very well and both locations get a large amount of sun. However, by the fall full turf was established in both turf gardens. The native gardens did very well almost immediately, however there too we should have put down

mulch immediately upon completion of the planting, but as we used dormant plantings rather than nursery stock this would have been difficult do to the size of the plants (very small).

OLD SAUK WATER PUMPING STATION

This site has a roof area of 1520 square feet draining to each garden. The gardens then sized to be approximately 1/3 the size of the roof area draining to them. In this case, the flat bottom of each garden is approximately 17' x 30' or 510 square feet.

OWEN PARK

This site has a roof area of 350 square feet draining to each garden. The gardens were then sized to be approximately 1/3 the size of the roof area draining to them. In this case, the flat bottom area of each garden is approximately 9' x 14' or 126 square feet.

CURRENTLY

The USGS is currently monitoring the gardens and the City of Madison will be doing some routine maintenance to the gardens this spring. This will include replacing some of the plants that did not over winter and planting new grass seed in areas as needed. We have noted that at the Old Sauk site the grass garden does hold water much longer than the native garden as evidenced in the last few photos in this package. Each site can be viewed live on the web at the following address:

Old Sauk
http://wi.waterdata.usgs.gov/nwis/uv/?site_no=430432089313401&PARAmeter_cd=00065,00060

Owen Park
http://wi.waterdata.usgs.gov/nwis/uv/?site_no=430423089291401&PARAmeter_cd+00065,00060

If you have additional questions please contact Greg Fries at 608-267-1199