Understanding Stormwater Runoff and Low Impact Development (LID)

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Every storm starts with one raindrop but ends up with millions. Together they can be beneficial, troublesome or even disastrous depending upon the choices that people have made about managing and using the land. When only a few people live up gradient of you, their choices probably will have little impact. However, if there are thousands living up gradient of you they can easily do things that increase the chances of flooding and downstream water-quality contamination.

Stormwater runoff is created when precipitation from rain and snowmelt flows over land or impervious surfaces and does not infiltrate into the ground. As the runoff flows over the land or impervious surfaces such as paved streets, parking lots, and rooftops, it accumulates debris, chemicals, sediment and other pollutants that can adversely affect water quality. Traditionally in Oklahoma communities, the storm sewer system collects stormwater runoff from rain and snowmelt events. The storm sewer system then discharges all the stormwater, and its accumulated pollutants, directly into our ponds, creeks, streams and lakes.

What is LID?

Low Impact Development (LID) is a stormwater management approach which seeks to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store and evaporate stormwater runoff at or close to its source. Unlike traditional stormwater infrastructure that solely conveys runoff through a large system of underground pipes and above-ground concrete channels, LID addresses stormwater runoff through a variety of landscape practices and designed systems which preserve natural drainage features and infiltrate or capture stormwater runoff. LID can be applied to new development, redevelopment, or as retrofits to existing development. LID has been adapted to a range of land uses from high density ultra-urban settings to low density development (U.S. EPA 2007).

The LID concept began in 1990 in Prince George's County, Maryland as an alternative to traditional stormwater best management practices installed at construction projects. Prince George's County Department of Environmental Resources (PGDER) found that traditional practices such as detention ponds and retention basins were not cost-effective and the results did not meet water quality goals (PGDER 1997). Today there are case studies available from across the country which reflect the acceptance and viability for using these types of practices.

Oklahoma Cooperative Extension Fact Sheets are also available on our website at:
http://osufacts.okstate.edu

The following are short descriptions of common LID practices:

Rain Gardens and Bioretention Cells are essentially excavated areas in the landscape that are filled with porous media and planted with water and drought tolerant plants that allow infiltration of stormwater runoff into the subsoil.

Rainwater Harvesting is the practice of capturing stormwater runoff, often from rooftops, and storing the water for later use for such activities as irrigation, livestock watering, flushing toilets, or washing clothes.

Pervious Pavement utilizes pavers, pervious concrete, or pervious asphalt to allow water to infiltrate through the pavement instead of running off and washing off pollutants into surface waters.

Natural & Engineered Wetlands are similar to bioretention cells, but with poorer draining subsoil which causes more ponding and growth of plants capable of flourishing in wet conditions.

Green Roofs are vegetated layers that sit on top of the conventional waterproofed roof surfaces of a building.

More information on each of these practices can be found in OSU fact sheets BAE-1753, BAE-1754, BAE-1755, BAE-1756 and BAE-1757 and on the OSU LID web site, LID.okstate.edu.

Urbanization & Water Quality

As cities become more urbanized, the amount of area where water cannot soak in (also known as impervious area) increases. This occurs as cropland, pastureland and forests are converted to housing developments, shopping centers and business districts. The result is that natural surface cover such as trees, grass and plants is replaced by rooftops, roads and parking lots. Undeveloped areas allow stormwater to infiltrate the soil, while developed areas have far less trees and grass for the stormwater to infiltrate. Therefore, to prevent flood-

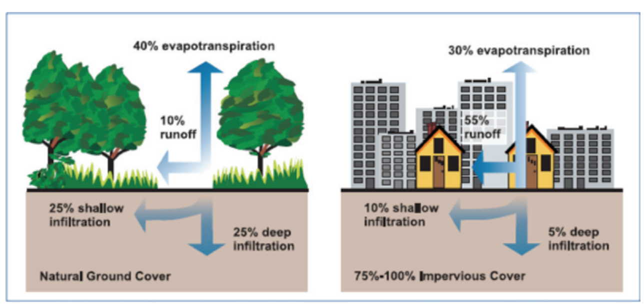

Figure 1. Runoff diagram comparing natural ground cover to 75-100% impervious cover. (U.S. EPA, undated)

ing, cities must provide a collection system for the increased stormwater runoff. Figure 1 is a general illustration of how land development, on average, can increase stormwater runoff over five times.

It should be noted that the percentages shown in Figure 1 are generalizations. In Oklahoma the climate and soils vary from West to East. As a result, the percentage of water that goes to each portion of the water budget varies as well. This is demonstrated in Table 1 using data adapted from the Water Atlas of Oklahoma for data from 1970-1979 (the most recent summary of its kind).

Table 1. Typical Oklahoma annual water balance. [GW: groundwater] (adapted from Pettyjohn et al., 1983)

Texas County, OK		
Precipitation:	17 inches	
Runoff:	0.3 inches	2%
Evapotranspiration:	16.6 inches	97%
GW Recharge:	0.1 inches	1%
Oklahoma County, OK		
Precipitation:	33 inches	
Runoff:	4.5 inches	14%
Evapotranspiration:	27.7 inches	84%
GW Recharge:	0.8 inches	2%
McCurtain County, OK		
Precipitation:	54 inches	
Runoff:	18 inches	33%
Evapotranspiration:	28 inches	52%
GW Recharge:	8 inches	15%

This information is useful for selecting the appropriate LID practice for different parts of the state. In the western part of Oklahoma where there is less rainfall, less runoff and high evapotranspiration rates, rainwater harvesting is an ideal practice to conserve water. However, in the east, there is a large amount of runoff that would indicate that rain gardens, pervious pavement, and other practices that encourage infiltration could further benefit groundwater recharge and reduce runoff. In central Oklahoma a combination of practices would be ideal, depending on site location. It should be noted, however, that that all LID practices can be beneficial in all areas of the state. Urban developments include impervious surfaces, disturbed soils, and managed turf grass which can have multiple impacts on water quality and aquatic life. Urban development also impacts the hydrograph of urban streams (Figure 2). Compared to the pre-development hydrograph, post-development stormwater discharges can increase the runoff volume, increase the peak discharge, and decrease the infiltration of stormwater, which thereby decreases base flow into streams and aquifers. These changes to stream hydrology result in negative impacts on water quality and quantity. Common problems associated with traditional development includes streambank scouring and erosion, loss of habitat for macro-invertebrates, fish, and other non-aquatic organisms, decreased storage in lakes due to sedimentation and lost recreational opportunities.

To deal with the harmful effects of stormwater runoff, the EPA began regulating certain groups. Polluted stormwater runoff is transported through Municipal Separate Storm Sewer Systems (MS4s), from which it is discharged untreated into local water bodies. The regulatory definition of an MS4 is "a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains owned or operated by a state, city, town, borough, county, parish, district, association, or other public body" (U.S. EPA 2007). In common

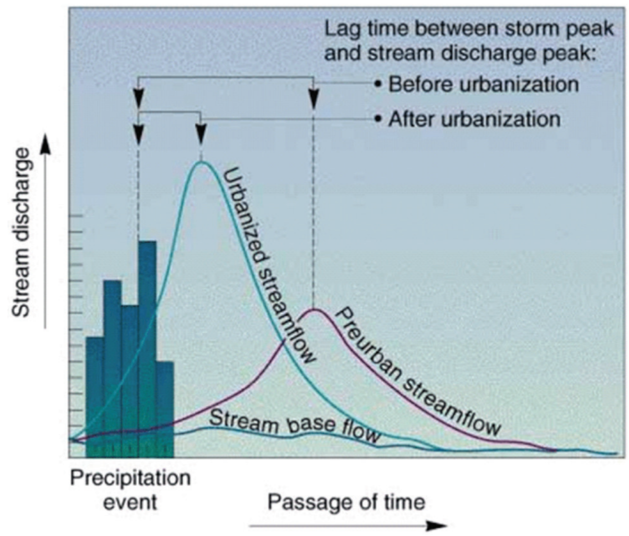

Figure 2. An idealized stream hydrograph showing the effect of neighborhoods and cities on the volume of water which must be handled by a stream over time. Note that flooding occurs due to the "flashy" runoff characteristics of urbanized areas. (from http://www.eoearth.org/article/Surface_water_management)

terms, MS4s can include municipalities and local sewer districts, state and federal departments of transportation, universities, hospitals, military bases, and correctional facilities (U.S. EPA 2007). The Stormwater Phase II Rule added federal systems, such as military bases and correctional facilities by including them in the definition of small MS4s. Polluted stormwater can also be in agricultural areas or in small communities that are not designated as MS4's.

To prevent harmful pollutants from being washed or dumped into an MS4, operators must obtain a National Pollutant Discharge Elimination System (NPDES) permit and develop a stormwater management program. The NPDES program is a requirement under the Clean Water Act. The NPDES MS4 permits provide more detailed requirements that MS4s must meet. In response to these permit requirements, MS4s create Stormwater Management Plans that describe the measurable goals and activities that the MS4 must meet to stay in compliance with their permit. Some states also have developed post-construction standards and/or stormwater guidance manuals to implement the stormwater regulations. Within the program, there are currently two types of regulated communities, Phase I & Phase II entities:

- Phase I, issued in 1990, requires cities or certain counties with populations of 100,000 or more to obtain NPDES permit coverage for their stormwater discharges.
- Phase II, issued in 1999, requires regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges.

An urbanized area is a land area comprising one or more places, central place(s), and the adjacent densely settled surrounding area, urban fringe, that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile (U.S. EPA 2007). The MS4 Program contains six required elements called Minimum Control Measures (MCMs) that, when implemented, should result in a significant reduction in pollutants discharged into receiving waters. These MCMs include:

- Public Education and Outreach

- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping

Each of the MCMs except for illicit discharge detection and elimination have aspects that are relevant to LID implementation or education. Since the inception of the NPDES Program regulated communities across the country are increasingly viewing stormwater management as an opportunity to improve the environment, create attractive public and private spaces, engage the community in environmental stewardship, and remedy inadequate stormwater controls.

Oklahoma Climate

"Oklahoma lies entirely within the drainage basin of the Mississippi River. The two main rivers in the state are the Arkansas, which drains the northern two-thirds of the state, and the Red, which drains the southern third and serves as the state's southern border. Principal tributaries of the Arkansas are the Verdigris, Salt Fork, Grand (Neosho), Illinois, Cimarron, Canadian and North Canadian. The Washita and Kiamichi serve as the Red's principal tributaries in Oklahoma, with the Little River flowing into the Red after it crosses into Arkansas." (Oklahoma Climatalogical Survey 2002).

The State of Oklahoma receives an average annual precipitation of 36 inches. Although precipitation is quite variable on a year-to-year basis, average annual precipitation ranges from about 17 inches in the far western panhandle to about 56 inches in the far southeast (Oklahoma Climatological Survey 2002). As indicated by the data shown in Figures 3 and 4, the rainfall in Oklahoma is generally spread out over the seasons and does not come in only one short period of the year. Figure 5 shows the spatial distribution of annual rainfall, which decreases from east to west. LID techniques are well suited to this type of rainfall distribution. However, depending on the duration and frequency of periods of drought, watering might be needed on certain vegetative practices.

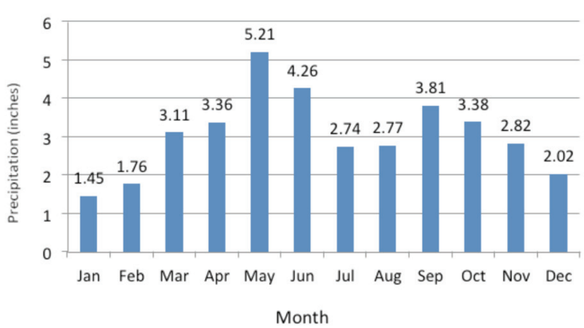

Figure 3. Average precipitation in Oklahoma by month. (from Oklahoma Climatological Survey, 2002)

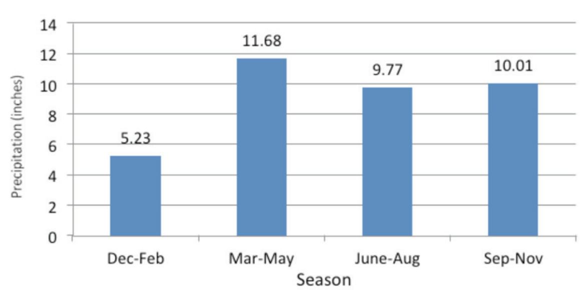

Figure 4: Average precipitation in Oklahoma average rainfall by season. (from Oklahoma Climatological Survey, 2002)

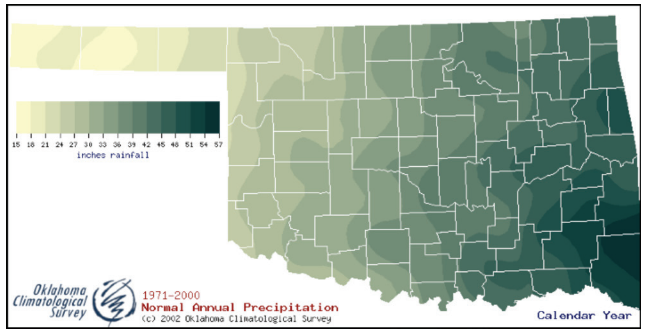

Figure 5. Average annual precipitation across Oklahoma. (from Oklahoma Climatological Survey, 2002)

How Does LID Help Oklahoma?

In recent years, many community stormwater programs across the nation have become more sophisticated and environmentally friendly by incorporating streambank protection, groundwater recharge, protection of sensitive receiving waters, control of the overall volume of stormwater runoff, and use of natural systems and site design techniques to control runoff. Since Oklahoma is regulated under the NPDES program, LID can help communities meet challenging regulations to improve water quality that are very difficult to achieve using traditional methods for handling stormwater. Table 2 lists the current regulated MS4s in Oklahoma that may benefit from LID.

Table 2. List of entities regulated as Municipal Separate Storm Sewer Systems (MS4s) in Oklahoma in 2011. (from GCSA, 2010)

Altus	Noble
Bartlesville	Nichols Hills
Bethany	Nicoma Park
Bixby	Norman
Broken Arrow	Oklahoma City
City of Catoosa	Oklahoma County
Choctaw	OK Dept. of Transportation
Claremore, City of	Oklahoma Turnpike Authority
Comanche County	Okmulgee
Coweta	Owasso
Creek County	Ponca City
Del City	Rogers County
Edmond	Sand Springs
Fort Sill Air Force Base	Spencer
Jenks	Stillwater
Lawton	The Village
McAlester	Tinker Air Force Base
Miami	Tulsa
Midwest City	Tulsa County
Moore	University of Oklahoma
Muskogee	Wagoner County
Mustang	Warr Acres
	Yukon

More specifically, some of the benefits to adopting LID practices include (from US EPA, undated unless noted):

Cost Savings – Cost savings can be achieved by using fewer materials, less labor and less land area.

Enhanced Groundwater Recharge – The natural infiltration capability of LID technologies can improve the rate at which groundwater is replenished. Allowing stormwater to infiltrate the soil and bedrock provides more water to private and public water wells.

Habitat Protection – conservation easements, riparian buffers, urban forests, wetlands and water quality improvements, achieved by decreased runoff, protects wildlife habitat.

Improved Air Quality – LID facilitates the incorporation of trees and vegetation in urban landscapes, which can contribute to improved air quality. Trees and vegetation absorb certain pollutants from the air through leaf uptake and contact removal. If widely planted or preserved throughout a community, trees and plants can even cool the air and slow the reaction that forms smog.

Improved Human Health – A number of scientific studies conducted by faculty and graduate students at the University of Illinois at Urbana-Champaign suggest that vegetation and green space, two key components of LID, can have a positive impact on human health. Their research has linked the presence of trees, plants, and green space to reduced levels of inner-city crime and violence, a stronger sense of community, improved academic performance, and even reductions in the symptoms associated with attention deficit and hyperactivity disorders (University of Illinois at Urbana-Champaign 2010).

Increased Land Values – LID can increase surrounding property values. This is achieved by the fact that lots near a water feature, open space area or natural feature have higher values (MacMahon 2008).

Reduced Energy Demands – Trees and vegetation have a natural cooling effect. By providing increased amounts of urban green space and vegetation, LID can help mitigate the effect of urban heat islands and reduce energy demands. Trees, green roofs and other green infrastructure can also lower the demand for air conditioning energy, thereby decreasing emissions from power plants.

Reduction in Streambank Erosion – By using practices that infiltrate stormwater rather than pipe it to a creek, the runoff is reduced and therefore less stream erosion occurs. This is achieved by reducing the total water volume entering waterways.

Water Conservation – Rainwater harvesting through the use of rain barrels and cisterns can result in a decrease in municipal or well water usage.

Water Quality Improvements – When stormwater runoff is reduced, less water is available to transport pollutants in its path to nearby surface waters. Once runoff soaks into soils, plants and microbes can naturally filter and breakdown many common pollutants found in stormwater.

As Table 3 indicates, some LID practices can benefit Oklahoma through water-quantity control and by improving water quality.

Summary

As stormwater runoff occurs, pollutants are transported to our waterways resulting in impaired waterways. LID seeks to manage rainfall where it occurs instead of piping it away from sites. When stormwater is infiltrated it allows a variety of benefits to be achieved. Some of these benefits include groundwater recharge, aesthetic value, wildlife habitat, nutrient uptake and water conservation just to name a few. In Oklahoma, our climate and topography are conducive for implementation of many types of LID practices.

References

Glen, Charlotte. 2008. Brunswick County LID Guidance Manual. Available at: http://www.brunswickcountync.gov/Portals/0/bcfiles/en_Brunswick_County_LID_Guidance_Manual.pdf.

Green Country Stormwater Alliance, 2010. Permittees in Oklahoma. Available at: http://www.stormwaterok.net/permittees_in_oklahoma.htm.

Oklahoma Climatological Survey. 2002. Oklahoma's Climate: An Overview. Available at: http://climate.mesonet.org/county_climate/Products/oklahoma_climate_overview.pdf.

Pettyjohn, Wayne A., White, Hal, & Dunn, Shari. 1983. Water Atlas of Oklahoma. Oklahoma Center for Water Research.

Prince George's County Department of Environmental Resources (PGDER). 1997. Landover, MD. Low Impact Development Design Manual.

United States Environmental Protection Agency (U.S. EPA). Undated. Managing Wet Weather with Green Infrastructure. Available at: http://cfpub.epa.gov/npdes/home.cfm?program_id=298.

United States Environmental Protection Agency (U.S. EPA). 2007. Fact Sheet: Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. Available at: http://www.epa.gov/owowwtr1/nps/lid/costs07/factsheet.html.

University of Illinois at Urbana-Champaign. 2010. Landscape and Human Health Laboratory. Scientific Articles. Available at: http://lhhl.illinois.edu/all.scientific.articles.htm.

Table 3. Pollutant removal rates among low impact development practices [TSS: total suspended solids; TN: total nitrogen; TP: total phosphorus]. (from Glen, 2008)

	Quantity Control	*TSS Removal Efficiency*	*TN Removal Efficiency*	*TP Removal Efficiency*	*Fecal Bacteria Removal Ability*
Bioretention	Possible	85%	35%	45%	High
Stormwater wetlands	Yes	85%	40%	35%	Med
Sand filter	Possible	85%	35%	45%	High
Filter strip	No	25-40%	20%	35%	Med
Grassed swale	No	35%	20%	20%	Low
Restored riparian buffer	No	60%	30%	35%	Med
Infiltration devices	Possible	85%	30%	35%	High

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