The Effects of Hurricanes and Tropical Storms on Stormwater Runoff and Maryland's Streams

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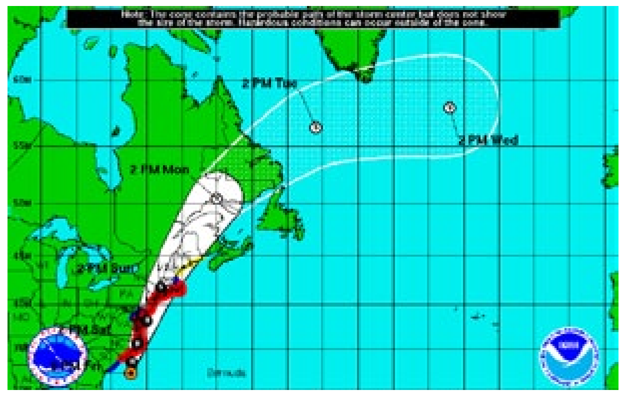
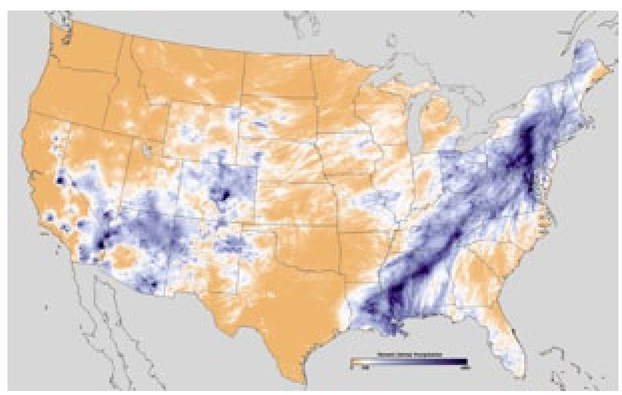
Freshwater streams are dynamic aquatic systems. They experience periodic floods (and droughts) as part of seasonal and annual variations in weather patterns. The fish, insects, crayfish, mussels, and other aquatic organisms that live in freshwater streams are adapted to survive in these dynamic habitats. Stream-dwellers can usually deal with frequent small to moderate stormwater runoff events. They can also tolerate less frequent but intense and high flow events like Maryland recently experienced during Hurricane Irene (August 28, 2011) and Tropical Storm Lee (September 5-9, 2011).



Track of Hurricane Irene from NOAA

When the natural frequency and magnitude of floods (or droughts) change dramatically in response to urbanization (and as projected by climate change models) and stream-dwelling organisms are exposed to more frequent and/or larger magnitude floods (or more frequent and longer-lasting droughts), their innate abilities to respond, adapt, and recover from these variable flow events may be compromised.



During Irene and Lee, Maryland received up to six times (the darkest blue) its normal precipitation. (Courtesy of NOAA)

Stormwater is a product of nature. There's nothing inherently bad about stormwater. It is simply water that comes from rain or snow or ice melt. Stormwater is a part of the natural cycle---part of the constant movement of water from sky to earth and back again. Left to her own devices, Nature is adept at managing stormwater. So where and how does something so natural turn into a problem?

The cascade of ecological effects associated with runoff associated with intense and/or prolonged rainstorms on a freshwater stream is influenced by topography, plant cover, soil type, moisture content of the soil, and land use/land cover. Collectively, these factors control how much and how fast stormwater soaks in versus how much and how fast it runs off into a stream.

The same drainage before and during a rain event. Large amounts of impervious surface can lead to high flows during even moderate intensity storm events, with several detrimental effects.

Stormwater runoff is not usually an issue of concern in forested watersheds. During low to moderate intensity rain events, the forest floor acts like a huge sponge, a living filter, that typically absorbs most of the rainwater — thereby minimizing the amount that runs off the land and into streams. Only if the soils under forested watersheds are completely saturated with water does a large percentage of the rainfall fail to infiltrate and instead runs off.

Stormwater becomes an issue of concern when the forests are cut and the land gets developed. Then a watershed's ability to absorb rainfall is severely compromised. Urban-suburban areas are covered with lots of hard, not spongy, surfaces like roads, sidewalks, driveways, parking lots, and roof tops. Most of the rainfall landing on these impervious areas is not absorbed, but instead runs off. Such was the case when Hurricane Irene dumped up to 10 inches of rain on parts of Maryland in only a few hours. Then Tropical Storm Lee arrived about a week later, stalled over the mid-Atlantic region, and produced rain steadily for five days.

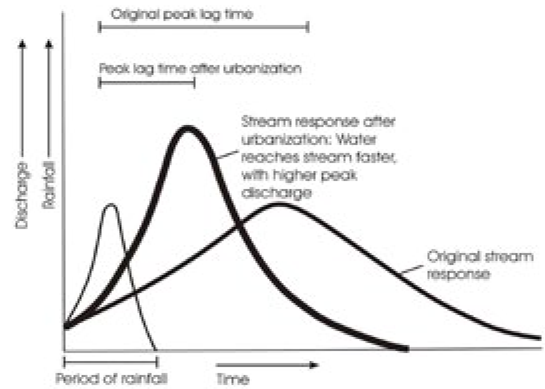
Brook trout are extremely sensitive to increases in impervious surface in watersheds that drain to their streams.

Intense and prolonged runoff events in urban-suburban watersheds erode soil and collect pollutants as the stormwater flows down slope. This runoff can carry sediment, nutrients, oil, metals, pesticides, pathogens, road salts, and trash to the nearest stream and expose stream dwellers to a toxic brew. Reduced absorption (infiltration) of rainwater in urban-suburban watershed means less surface water flow into the shallow groundwater which, in turn, leads to low base flow levels in urban-suburban streams that can approach near-drought conditions between storms. And because much of the rainfall doesn't seep into the ground, it doesn't cool after flowing across hot pavement during the warm months. Eventually the warm runoff ends up in a stream where it can harm cool and cold-water fish and other temperature - sensitive aquatic organisms.

How a stream handles the influx of stormwater runoff will be influenced by the nature of its connection to the adjacent floodplain. If a stream channel is well connected to its floodplain and the runoff-swollen water course can easily overflow its banks (a condition usually found in streams draining forested watersheds), then the energy of the moving water can be dissipated, current velocities will be reduced, and the amount of channel scouring and downstream sediment transport will be diminished.

A deeply incised urban stream impacted by erosion of the stream channel

On the other hand, if a stream channel is deeply incised (like many streams that drain highly impervious, urban-suburban watersheds) and can't overflow its banks even during moderately-intense rain events, stormwater runoff will elevate current velocities. In turn, the stream banks and bottom are scoured and eroded, and large loads of sediment are transported downstream. Intense or prolonged rainstorms that cause channel-scouring flows in urban-suburban streams result in the transport of nutrients and toxic chemicals to downstream waters, including Chesapeake Bay.



Graph describing differences in stormwater flow (discharge) in a stream before and after urbanization

Floods associated with tropical storms and hurricanes can also displace stream-dwelling organisms downstream or they may willingly move downstream to pockets of cooler or quieter water. Man-made blockages in stream channels such as dams and road culverts can prevent later attempts by stream dwellers, particularly fish, to move back upstream after the flooding subsides and thereby keep them from re-colonizing areas from which they were displaced. Blockages can also prevent upstream re-dispersal of aquatic organisms after drought-induced downstream displacement.

Tracking the Influence of Runoff on Streams

The Maryland Biological Stream Survey, led by the Department of Natural Resources (DNR), established a Sentinel Site Network in 2000 to track the influence of floods (and droughts) on 28 streams that drain minimally-disturbed watersheds. Data from this network show us how stream conditions vary from year to year, in response to changing weather patterns. Sentinel Site data also tell us how long it takes for stream-dwelling organisms to recover after a flood or drought reduces their numbers and/or alters their distributions. Over the long run, Sentinel Site data may also tell us how global climate change is affecting Maryland's streams. For more information on the Sentinel Site Network, go to http://www.dnr.maryland.gov/streams/pdfs/2010SentinelSiteReport.pdf

The MBSS Sentinel Site Network

To better understand the effects of Hurricane Irene and Tropical Storm Lee on Maryland streams, DNR staff sampled the fish community and physical habitat at two Sentinel Sites (Baisman Run, Baltimore County, and an unnamed tributary to Swan Creek, Kent Count) in late September 2011. These two sites have been sampled annually since 2000 and were sampled before in summer of 2011, Irene and Lee passed through the area.

These two sites were selected for inclusion in the Sentinel Site Network because they are mostly undeveloped and relatively free of human influences. The watershed drained by the Baisman Run site is 56% forested, only 2% urban, with < 1% impervious land cover. The watershed drained by the Swan Creek site is more protected: 77% forested, < 1% urban, with < 1% impervious land cover.

In addition, DNR staff also re-sampled two streams (Tiber Run, Howard County, and Wheel Creek, Harford County) in late September that are the focus of restoration efforts to see how these urban-suburban streams responded to these two major rainstorms. These two streams were also sampled in early summer 2011, before the storms arrived.

In contrast to the two minimally-disturbed Sentinel Sites, the Tiber Run site is 42% urban, with 12% impervious land cover, and 31% forested. The watershed draining to the Wheel Creek site is also developed: 46% urban, with 21% impervious land cover, and 35% forested.

Post-storm sampling revealed that stream bank erosion increased at both Sentinel Sites: almost doubling in Basiman Run and increasing by almost four-fold in Swan Creek, compared to early summer, pre-storm conditions. The large, almost four-fold increase in eroded stream bank area at the Swan Creek site, that is 77% forested with < 1% impervious land cover, speaks to the rainfall amount, intensity, and duration delivered by Hurricane Irene and Tropical Storm Lee in late August and early September 2011. Even in heavily forested watersheds, prolonged storms can saturate the soils, reduce infiltration of rainfall into the shallow groundwater, and generate sufficient surface runoff to cause bank erosion in receiving streams.

In contrast, the areas of eroded banks at the two urban stream sites did not increase in response to runoff associated with Irene and Lee, presumably because bank erosion was already extensive and severe at the Tiber Run and Wheel Creek sites before these two storms swept through Maryland.

Hurricane Irene and Tropical Storm Lee appeared to have little observable effects on the fish communities, as measured by an Index of Biotic Integrity, at any of the four stream sites. However, in Baisman Run, brook trout that were present before the two storms arrived (and during every year since 2000) were absent during the post-storm sampling in late September. Will brook trout return to this Sentinel Site next year? Our annual sampling effort will find out.

Final Message

Typically, healthy streams with few stressors that drain watersheds with low impervious land cover will be more resilient to floods and droughts than unhealthy streams that are exposed to multiple stressors. The key to minimizing ecological impacts when Maryland is visited by a tropical storm or a hurricane is to ensure that our healthiest streams are protected and thereby maximize their resilience to stormwater inputs. To enhance the capability of unhealthy or impaired streams to deal with stormwater runoff, sound management actions aimed at rehabilitating these streams and reducing the amount of stormwater runoff should be taken.

For More Information...

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