stormwater management

Stormwater Management

Stormwater management is the term broadly applied to how runoff from human-disturbed landscapes is collected, treated, and conveyed. Its focus is typically in urban and suburban areas, where changes to natural hydrologic processes are commonly severe and their consequences are most problematic. Most commonly, stormwater management is accomplished through constructed facilities, of which those designed to accomplish water-quantity reduction address the most difficult, costly, and critical stormwater-management issues.

Peak-discharge control

Facilities designed for water-quantity reduction generally seek to achieve one of two common goals. The first is a classic approach to stormwater management called peak-discharge control (or conveyance control). Its guiding principle is to hold postdevelopment peak discharges to their predevelopment peak discharges for a given rainstorm (the "design storm"). If such a goal is met, areas adjacent to downstream conveyances (be they natural streams or constructed pipes or channels) should experience no more frequent episodes of flooding. However, the duration of any given peak discharge will normally increase, because the total volume of stormwater increases after development. If peak-discharge control is successful, the only way to release that additional runoff volume is by increasing the time over which it occurs. Thus flooding, when it does occur, will persist for much longer than under predevelopment conditions. Sediment transport in natural downstream systems, and consequently stream channel erosion and deposition, will also be more vigorous because transport conditions will persist for longer; as a result, channel morphology may change substantially.

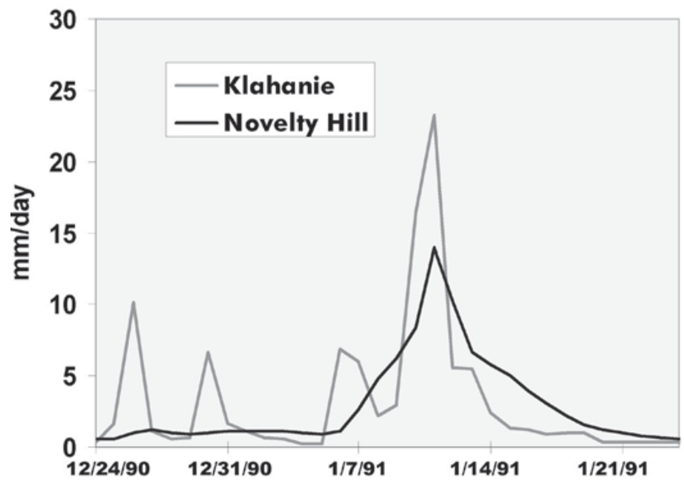
Duration control

Alternatively, a more complete suite of discharges can be targeted. The goal of such "duration controls" is to hold the aggregate durations of moderate (and larger) postdevelopment flows to their corresponding predevelopment durations, as determined over a long (and continuous) record of rainfall and runoff. Note, however, that only the aggregate durations are analyzed. In other words, there is no guarantee that a specific rainstorm will meet this criterion in isolation. Rather, when we consider the accumulated period of time that the stream's flow exceeded a chosen value, over all storms in the rainfall record, the postdevelopment time does not exceed the predevelopment time. This requires a hydrologic analysis that uses a continuous rainfall record, not a discrete design storm "event." The advantage of this goal is that it achieves all of the benefits of peak-discharge control, and it should maintain the overall pattern and magnitude of sediment transport in the downstream channel. However, the timing and pattern of sediment-transporting events, particularly their seasonality, will differ in the pre- and postdevelopment conditions (with potential consequences for instream biota). This goal also requires substantially larger stormwater facilities than for conveyance control, because a much greater volume of runoff must be managed for a much longer period.

Example of a detention pond in central King County.

Detention ponds

Achieving either of these water-quantity performance goals requires a method to manage the greater volume of stormwater that accompanies urban development. The most common approach is a constructed detention pond, designed to release runoff from a developed area more slowly than it is produced off the land surface. Because the intended outflow is less than the inflow, an excess volume of runoff is present which must be (temporarily) stored and subsequently released at a controlled rate—this is why a "pond" is needed. The release rate is determined by the size of the contributing watershed area and the chosen goal of the detention (peak-discharge or duration control). The pond can function in that fashion, however, only for as long as its total volume is not exceeded. Once flows spill over the top of the pond, no runoff control is possible and damaging downstream flows are normally assured. Thus pond volume is the ultimate determinant of performance, as the "excess" water input must be stored while awaiting (delayed) release. The outflowing discharge can always be changed by simple adjustment of the pond outlets, but the pond volume (i.e., the depth and footprint of the facility) can almost never be changed after construction. Ponds are easy to construct and maintain and can be accommodated on almost any site. However, ponds release all of the catchment's runoff as surface flow at a single point of discharge, which does not necessarily mimic the predevelopment pattern of runoff delivery to downstream watercourses. Standard detention ponds also provide minimal water-quality benefits.



Actual hydrographs from nearby developed ("Klahanie") and undeveloped ("Novelty") catchments for a series of storms in 1990-1991 (data courtesy of Mark Wigmosta, PNW National Laboratory).

Infiltration ponds

Infiltration (also known as retention) ponds and trenches form a second broad category of water-quantity control facility. Their principle is to reintroduce runoff from developed areas back into the ground by infiltration. As with detention ponds, however, the rate of infiltration from the pond area is almost always slower than the rate at which runoff is produced from the developed area and so the excess must be (temporarily) stored. Infiltration ponds can be combined with detention ponds (in sequence, or as part of the same facility) to allow some surface discharge of large runoff volumes together with infiltration of lesser volumes. As a partial or total water-quantity approach, infiltration ponds largely mimic predevelopment runoff processes in humid climates where subsurface flow predominates, and they can provide substantial water-quality benefits. They are not well-suited everywhere, however, because their performance is very soil-dependent and they are easily clogged, especially by construction-related sediment. Moreover, they require careful site evaluation, design, and attentive maintenance after construction. Although the water quality of the runoff is generally improved by these facilities, infiltrating surface-water contaminants may compromise the water quality of the groundwater. A recent variant on formal, centralized infiltration facilities is the distribution of infiltration sites and small-scale facilities across the developed landscape. In combination with a more opportunistic site design that takes advantage of intrinsic features such as infiltrative soils, existing watercourses, and mature native vegetation, these runoff-management strategies are collectively known as Low-Impact Development.

Bypass pipelines

Water quantity can also be managed by routing some fraction of the runoff collected from developed areas around a flood-prone or otherwise sensitive stream reach, normally via pipeline, to an eventual discharge in a much larger water body (such as a major river, lake, or ocean) that is unaffected by the relatively modest additional input of untreated runoff. Bypass pipelines reduce total post-development runoff volume in non-infiltrative soils and can provide nearly fail-safe reductions of peak flows and/or flow durations. Depending on their design, however, bypass pipelines may alter the predevelopment flow regime by leaving small and moderate discharges from paved surfaces nearly unaffected, or conversely they may eliminate all baseflow once contributed from now-paved upland areas. As with detention ponds, they also provide no water-quality benefits and release all runoff as surface flow at a point discharge.

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