Implementing Stormwater Management through Split-Flow Drainage Design

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Introduction

Engineers, Planners, Water Resource Professionals, Regional, State and Local Government Representatives, Land Development Professionals, Watershed and Conservation Groups are all called to be stewards of the land. We are expected to create new communities that protect and restore our natural ecosystems. At a minimum, we are asked to not harm our natural systems. However, every time we create a new impervious building, plaza, sidewalk or parking space, we increase runoff and degrade our aquatic environments. Numerous studies have identified alarming levels of degradation to aquatic ecosystems as a direct result of increased runoff. A parking lot, for example, generates almost 10 times more runoff and 16 times more pollution than a meadow. Likewise, groundwater levels continue declining as we pave over the land's adsorptive capacity. This runoff includes pollutants from a variety including; sediment, heavy metals, toxic chemicals, nutrients, grease and oils. With re-appropriation of the Clean Water Act and the National Pollutant Elimination System, thousands of municipal governments are now required to develop, adopt and implement strategies to reduce non-point source pollution directly related to new development. However, current design practices cannot meet these challenges because they approach stormwater as a waste product or hazard to be disposed of as efficiently as possible and are not intended to manage urban runoff as a natural resource. These practices have limited success in protecting aquatic environments because they are derived from centralized flood control designs and are not intended to emulating a site's natural ecology. While current detention designs are inadequate to address stormwater flow volume, quality, frequencies and duration, existing infiltration and bioretention designs are insufficient to tackle peak flow rates for different storm types. What is needed is a new stormwater design strategy that approaches runoff as a valuable resource, emulates the natural system and fulfills both our environmental goals and flood control regulations.

The Split-Flow design strategy meets prevailing environmental goals and stormwater regulations emulating the long-term hydrological processes of natural landscapes. It combines innovative site design and a new Split-Flow stormwater management concept to recreate predevelopment drainage flows, rates, quality, frequency, duration and volumes. The concept is based on preservation of the natural drainage processes. Normally rainfall has three portions – evapo-transpiration, infiltration and runoff as shown in figure 1.

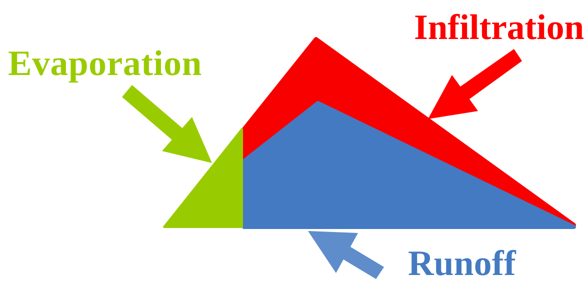

Figure 1 - Rainfall divided into evapo-transpiration, infiltration and runoff

The Split-Flow drainage strategy recreates these natural processes by managing each of these portions respectively using bioretention, recharge and downstream discharge to retain and/or infiltrate the actual runoff volume from each impervious surface. It controls peak flow rates for different storm events by maintaining runoff volumes throughout the site at predevelopment levels. Runoff from impervious surfaces is directed to water harvesting or bioretention facilities to retain the contaminated first flush and inhibit re-suspension or release of the pollutants downstream. Excess drainage is then filtered into proportional flow splitters and divided into infiltration volumes that are led into distributed infiltration facilities while discharge volumes are guided back to the natural drainage system. This self-adjusting system recreates the natural site hydrograph for each storm event.

As a result, the Split-Flow strategy recharges groundwater, prevents stream channel degradation, and decreases downstream flooding and non-point source pollution by recreating the natural site hydrology. It retains or infiltrates only the runoff from impervious areas created by development while natural flows that existed before development are cleaned and discharged downstream. A detailed explanation of the Split-Flow strategy can be found in *Split-Flow Method: Introduction of a New Stormwater Strategy*, in *Stormwater*, July/Aug., Echols, S. (2002) or online at http://www.forester.net/sw_0207_split.html.

What hydrological calculations are needed to design Split-Flow systems?

Information needed to design a Split-Flow system includes the site's initial abstraction, the runoff amount before development, the excess runoff from impervious surfaces and a summary of the site's impervious areas. Double weirs are built using Vee-notch sizing methods, allowing them to be sized on different flow rates to control the volume difference for all storm events. The infiltration weir sized for the difference in natural and developed peak flow and directs the infiltration volume into distributed infiltration facilities. The runoff weir sized for natural peak flow and directs the cleaned runoff volume to an existing drainage outlet. The key to efficient rainwater management here is to install numerous proportional flow splitters that divide the runoff into portions that emulate the predevelopment runoff flows and the difference in predevelopment and post development flow for each impervious surface and distribute the excess runoff into individual infiltration facilities. The maximum volume of runoff infiltrated for each impervious surface is limited by the largest storm predicted to meet the acceptable level of flood risk for the site design taking into account unique site conditions.

When should Split-Flow strategies be utilized?

Split-Flow systems are most useful in locations demanding valuable aquatic habitat protection or seeking auxiliary capacity in the municipal stormwater system. The infiltrated volume regulated by flow splitters depends on natural infiltration rate of each site, crucial on sites with clay soils that allow little natural water recharges. As the amounts of rainwater retained or infiltrated in each facility is controlled and not concentrated in large quantities, peak flow rates for the entire site are controlled at preexisting levels, duration, and frequency . However, if the infiltrations are not well-distributed on the site, the system will fail owing to insufficient soil area for infiltration.

What are the costs for building Split-Flow systems?

Preliminary research shows that Split-Flow systems can lower on-site stormwater management costs and promote environmental protection. The construction costs for Split-Flow systems are comparable to detention systems depending on the design complexity. Construction of erosion and sediment control measures for this system creates additional design challenges because it does not use detention basins that are often used at temporary sediment basins. Hence, other solutions considered should include alternative controls that do not need sediment basins, temporary basins that can be converted into bioretention facilities, or sediment basins elsewhere on-site that can be removed after construction. Regardless what erosion and sediment control measures are used, Split-Flow systems should not be activated until the site is completely.

What are the best methods for integrating Split-Flow systems into site design?

Preliminary studies show that Split-Flow systems can be used for sites with up to 80% impermeable area. These systems can be designed to fit the space used for existing detention basins, however, this would not adequately distributed recharge. So development sites are best designed with distributed open spaces to locate decentralized Split-Flow systems immediately down-slope from impervious surfaces. A decentralized design that avoids large rainwater facilities allows for flexibility in site design and development planning, and for changes in the system design with future design options.

How can Split-Flow systems meet current urban drainage regulations and guide evolving urban drainage policy?

Split-Flow systems embrace the premise that the best stormwater management strategy is preserving the existing drainage by recreating predevelopment runoff rates, volume, frequency, duration, and water quality in developments. It differs from current regulations fashioned to accommodate development by quick disposal and regard rainwater as useless and unwanted and treat runoff as a flood hazard. Rainwater is a vital natural resource for streams and lakes, and recharges ground water supplies. This publicly owned natural resource has substantial economic and environmental impacts on our quality of life in both positive and negative aspects. Rainwater in properly designed developments is managed to preserve surfacewater and groundwater as well as prevent flooding. But in poorly designed developments, it continues to destroy aquatic ecosystems and flood downstream properties. The four basic objectives of Split-Flow systems are: (1) not increasing down stream flow rates; (2) reducing non-point source water pollution; (3) recharging at predevelopment rates; and (4) not polluting groundwater. Many cities have implemented fees for storm sewers and runoff treatment facilities based on the amount of impervious surface areas in each property. These regulations will hopefully promote reduction of impervious areas and responsible rainwater management practices. If the fees can be waived for preservation of the natural drainage system, developments may utilize Split-Flow systems to provide flood control and reduce non-point source pollution while lowering annual operation costs by eliminating the annual rainwater utility fees.

What benefits are gained with Split-Flow strategies?

Prevalent stormwater detention methods strive to decrease local flooding caused by storing and releasing runoff at pre-development flows rates. But they do not address certain issues like: (1) downstream flooding from combined detained flows; (2) groundwater and stream base flow depletion; (3) diminishing wildlife habitat; (4) frequent nuisance flooding caused by detention systems designed for large storms and (5) non-point source pollution. Split-Flow systems, however, are designed to preserve natural drainage rates and volumes by recreating the pre-development hydrological processes. Some of the expected benefits include following.

Reducing on-site and downstream flooding – Risk of on-site and down stream flooding is reduced because distributed Split-Flow systems prevent the increase in flow rates that can often occur using standard bioretention of infiltration methods. This is because current bioretention and infiltration systems are designed to retain and infiltrate either the first flush or truncated hydrograph volume for a specific design storm. In either case, the peak flow rates for larger storms are not maintained at the predevelopment level. As a result, on-site and downstream flooding is likely to occur without the construction of additional detention facilities.

Reducing flooding caused by combining detained runoff – Risk of flooding caused by combining detained runoff is reduced because distributed Split-Flow systems prevent the increase in flow volumes that occur using detention methods. With detention methods, the increased flow volumes can combine downstream in elevated flood flows. Distributed Split-Flow systems, however, do not allow increased flow volumes, therefore, increased volumes cannot combine downstream in elevated flood flows.

Reducing site and regional rainwater systems cost – Research results suggest that the split-flow strategy can be used to lower the cost of on-site rainwater management systems and provide a higher level of environmental protection. Results also suggests that split-flow systems are less expensive to construct than truncated hydrograph systems, and that split-flow systems are comparable in construction cost to detention systems depending on the complexity of a detention system design and configuration of a site's drainage features. As a result, non-point source water pollution reduction objectives, currently achieved with either detention with first flush or truncated hydrograph systems, could be achieved cost-effectively using the split-flow strategy.

Reducing duration of peak storm flows — Detention basins extend the duration of peak storm flow with disastrous results for downstream ecosystems. Risk of extended peak storm flows are eliminated because distributed Split-Flow systems maintain existing flow volumes and hence eliminate the need for detaining increased rainwater volumes and releasing this runoff at peak storm flow levels.

Reducing downstream scouring — The prolonged elevated flows from detention systems are often at bank-full levels, which cause the stream-banks to be scoured. This scouring will widen and deepen the cross section of a stream-bank. Changes in stream channel morphology result in accelerated flow velocities, which increases stream-bank scouring. This becomes an escalating cycle that desecrates the natural stream geomorphology.

Reducing non-point pollution — Various existing best management strategies are designed to retain and/or treat the first flush of runoff from impervious surfaces. The Split-Flow rainwater strategy incorporates and adapts many of these existing techniques based on the site's natural hydrology functions. The runoff volume retained and treated in the Split-Flow strategy is based on the site's natural initial abstraction. This volume is diverted on-site for use in non-potable applications, retained for evpo-transpiration and/or infiltrated into the groundwater.

Reducing thermal pollution — Solar radiation heats both pavements and detention basins in urban areas, which in turn elevate runoff temperatures. The Split-Flow strategy solves the problem created by hot pavements by diverting the heated first flush into offline rainwater treatment facilities that do not discharge downstream, thereby retaining the heated water on-site and not affecting local streams. The problem created by solar radiation heating detention basins is eliminated with the Split-Flow strategy because detention basins are not used.

Restoring natural groundwater recharge rates — Rainfall duration, slope, soil type and existing soil moisture control the rainwater volume naturally infiltrating on a site. Existing bioretention and infiltration methods can recharge rainwater by diverting a fixed volume to recharge facilities. They do not, however, restore the natural recharge rates because they are not self-adjusting systems based on the natural hydrology.

Restoring stream base flow — Base flows provide important habitat for aquatic systems between rain events. However, when groundwater recharge is eliminated because of urban development, stream base flow is also eliminated because groundwater levels are not replenished. Split-Flow systems restore natural groundwater recharge rates, which in turn restore natural stream base flow.

Conclusion

The goals of this paper are 1) to add an additional management option that can help address currently varying rainwater management expectations, 2) to demonstrate derivation of a viable rainwater management strategy from the premise that preserving the natural hydrology is a better way to manage rainwater and 3) to show how modification of land development practices to accommodate natural systems can be more effective than the other way around. However, the Split-Flow strategy is still a theory that needs additional tests to discover the problems occurring in the design and construction processes. Notable implications that need to be addressed with potential development of the Split-Flow strategy include: rainwater policy, site design and construction practices, runoff modeling and environmental concerns. Further research may be needed as other site design and construction implications arise.