

Comparison of Two Stormwater Management Paradigms: Centralized vs. Distributed

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Introduction

With the passage of the Clean Water Act, stormwater detention ordinances were promulgated. Centralized municipal stormwater basins are built to control the peak flow from the development site, and water quality improvement is carried out through the settlement of pollutants in the detention basins (DoD, 2004). The regional approach efficiently transports runoff through directly-connected curbs, gutters, roadways, and pipes, and then collects the runoff at a centralized facility. Multiple stages of outflow structures are used at the detention facilities to control the outflow at the pre-development level (VDCR; 1999; VANR, 2002). Although the regional detention facilities may be successful in reducing the peak flow rate to the pre-development level immediately downstream of the facilities, this approach may become ineffective in reducing flooding beyond some point downstream (where the total drainage is ten times the area detained) due to the aggregated increase in volume (PADEP, 2006). In comparison to the “end-of-pipe” concept in the centralized approach, the distributed approach focuses on disconnecting the impervious surfaces and treats surface runoff at the source (Debo and Reese, 2002). The distributed stormwater control practices, such as bio-retention area, green roof, and vegetation swales, has the potential to reduce the peak flow rate from post-development watershed, increase groundwater recharge, improve water quality, and protect stream channel (Clar et al., 2004). The focus of distributed stormwater control is to create a hydrologically functional landscape that mimics the pre-development watershed runoff conditions (Coffman, 2002). The concept of distributed control has been recommended by different institutions and adopted in stormwater regulations of various municipalities (Prince George’s County, 1997; Stafford County, 2003; DoD, 2004; PSAT, 2005).

The focus of this study is to quantify and compare the hydrologic behavior of distributed approach with that of the centralized approach. The comparisons are carried out using both design events and long-term simulations to understand the responses within the entire hydrological domain.

Description of Studies

The USEPA SWMM (Version 5.00.011) model was used to carry out the design storm analysis, and the comparison was conducted in a headwater subbasin of the Johnny Moore Creek Watershed, Fairfax, VA. The headwater subbasin has a total area of 676 acres, and major land uses are low intensity residential, commercial, and high-intensity residential, and open space. The overall imperviousness percentage is 10%. A centralized detention basin is used to detain runoff from the subbasin. A distributed stormwater control layout was also assumed for the headwater subbasin, in which all the rooftops

were assumed to be covered with green roof, all the parking lots were converted to porous pavement, and a total number of 20 bio-retention areas were assumed for the whole watershed. The SWMM hydrologic components of junctions, storage units, and weirs were used to represent the distributed control practices, following algorithms that were previously developed (Zhang et al., 2006). The design events of 2-year and 10-year 24-hour Type II storms were used to simulate runoff from both the centralized stormwater control layout and the assumed distributed scenario, and the peak flow and total runoff volume from the two approaches at the subbasin outlet were compared.

Long-term responses from the two stormwater control approaches were analyzed using the BMPDSS model (Cheng et al., 2006). The analysis was carried out in the Potash Brook Watershed that is located in the City of Burlington, Vermont and has about 4600 acres in area. Infiltration facilities (for example, bio-retention, vegetation swales, and infiltration facilities) were used to set up the distributed stormwater control scenario and detention facilities (for example, wet detention and dry detention) were used to set up the centralized stormwater control. A previously developed BMPDSS model for the watershed (Saravanapavan et al., 2007) was used to generate the flow duration curves from both the centralized stormwater control and the distributed scenarios for a ten year period. The flow duration statistics were further examined to understand the significance of these approaches.

Initial Results

Initial results from the Johnny Moore Creek watershed example showed that the distributed approach had lower peak flow rate and total runoff volume as compared to the regional detention approach. The hydrologic benefits were achieved through infiltration at bio-retention areas and porous pavements, which eventually contributed to groundwater recharge. Surface runoff retained in the bio-retention area and green roof also returned to the atmosphere through evapotranspiration.

In the Potash Brook Watershed example, the distributed approach yielded a flow duration curve that had lower high flow and higher low flow as compared to the regional approach. This is consistent with the findings of the Johnny Moore Creek example, in that the trend illustrates the reduction of peak flow and the increase of groundwater recharge (and thus in base flow). The study further revealed that while the centralized stormwater control approach resulted in favorable flood flow controls, it deteriorates the base flow or low flow condition. Therefore, centralized stormwater controls are inappropriate for watersheds that require substantial improvement in low flow conditions.

Conclusions

This study compared the hydrologic benefits of the distributed stormwater management practices to that from the centralized approach. The benefits were assessed using two methods: design storm and long-term continuous analysis. Initial results illustrated that while both approaches are capable of maintaining the pre-development peak flow rate, the distributed approach better mimicked the natural hydrologic condition in terms of groundwater recharge and total runoff volume reduction. With the additional

hydrological benefits from the distributed approach, it is expected that the downstream channel morphology, bio-diversity, and water quality can be better preserved.

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