Hydrologic Processes at the Residential Scale

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Problem

Population and economic growth have resulted in the conversion of rural areas into urban landscapes. Although the same physical principles are applicable to both urban and rural areas, the hydrologic regime in urban areas and rural areas are different. In California, city mangers, citizens, and environmental scientists regularly face problems with polluted runoff, flooding, and water shortages. Although solutions have been successfully applied at the regional scale (e.g., large retention/detention basins, climate-controlled irrigation scheduling for golf courses), there is growing interest in microscale applications that eliminate runoff and conserve water at the source.

Storm runoff in Los Angeles County has had a detrimental effect on the lives of many of the county's inhabitants. It has caused extensive property damage and carried pollutants to ocean beaches. These pollutants pose a threat to the environment, to human health, and to aquatic life. At the same time, the demand for water has rapidly increased. Proposed engineering solutions include increasing the height of parapet walls and bridges along the Los Angeles river to maintain the runoff in the channel, importing water from other regions, and de-salting seawater. None of these is cost-effective. An alternative solution from environmental scientists is the implementation of Best Management Practices (BMPs). These BMPs would cause further changes in the hydrologic processes of the urban ecosystem. Hence, there is a need to study these changes and the role of BMPs in storm runoff control and water resources management.

Goal and objectives

The goal of this project is to better understand hydrologic processes at the parcel scale. Objectives are to:

- Measure hydrologic processes.
- Develop and validate a parcel scale hydrologic model.
- Examine how BMPs effect storm runoff and landscape irrigation water use.

Study site

The two adjacent, single-family residential sites are located in the Crenshaw district of Los Angeles. The dimensions are the same for these two parcels. Four types of BMPs installed on the treatment site in 1997 were a cistern, retention/detention basins, drywell, and swales. No BMPs were installed on the control site, nor was the control site's landscape modified in any way. The cistern receives and stores filtered roof runoff and is used for summer irrigation.

The retention/detention basins (front and back yard lawns) retain roof runoff. The runoff infiltrates, evaporates, or overflows to the retention basin or to the street. The swale retains runoff from the retention/detention basin. The drywell infiltrates runoff from the driveway and overflow is recharged into the retention/detention basin.

Field measurement

Field measurements were conducted during 2001-02. The measurements included microclimate, irrigation water use, soil moisture, and surface runoff to the street. Both soil core samples and storm water were collected for laboratory analysis of soil properties and water quality. The laboratory water quality analysis included general water quality parameters such as pH, total dissolved solids (TDS), total suspended solids (TSS), electronic conductivity (EC), and hardness. Nutrients (TKN, NH4-N, NO3-N) and the concentration of metals were also measured. Water storage capacities of different plants surfaces were directly measured for each tree, shrub, forb, vine, and turfgrass species.

Numerical modeling

A physically based hydrologic model was developed to better understand hydrologic processes at the parcel scale and the interaction of these processes among different BMPs. This model calculates all hydrologic fluxes using an hourly time step for a full year or a selected storm event. Rainfall interception by trees is simulated from the time they are planted until they are 40-years old at five- year intervals (Figure 1). The model was calibrated using the data measured from field site.

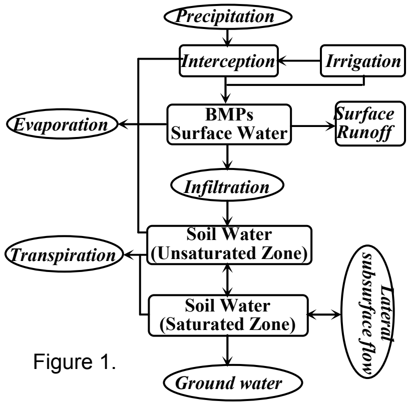
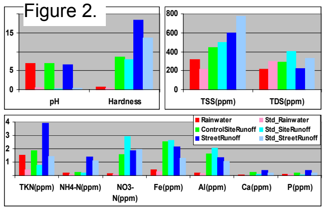


Figure 1.

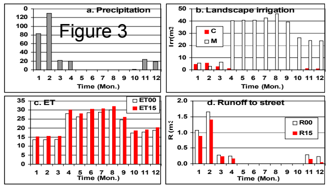
Results

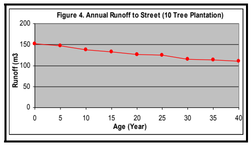
Field measurements and laboratory analysis results.

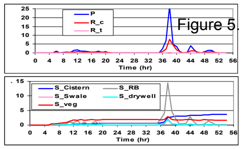
- Both sites are situated on deep sandy loam soil. The infiltration rate of the sandy soil is greater than 50 yr flood event rate.
- All storm runoff was retained on site at the treatment site. The driveway interceptor that redirects runoff to the drywell, and the berm around the lawn edge provide benefit for storm runoff reduction. The cistern storage provides about 4% of annual water required to irrigate the landscape given current irrigation practice. At the control site, runoff from half of the roof and the driveway was discharged to street.
- Figure 2 shows the quality for rainwater, runoff from the control site, and runoff from the street. Rainwater contains considerable TKN and TSS. When compared with the quality of runoff from the control site, the quality of the street runoff was much lower. The level of pollutant deposited on the street is greater than at the control site.

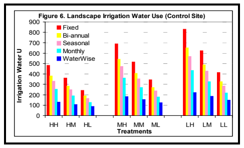


Numerical simulation Meteorological data for a typical weather year and a 50-year storm event were used to simulate effects of BMPs on annual storm runoff reduction and landscape irrigation water use, and BMPs responses to runoff reduction for large storm events. Based on numerical simulation, more than 97% of annual storm runoff to the street could be eliminated with the installation of low-cost BMPs (i.e., rain gutters that direct roof runoff to lawn retention basins, driveway interceptor that directs runoff to drywell in the lawn retention basin). The driveway interceptor was the most effective BMP for storm runoff reduction (65%), followed by the rain gutter installation (28%), and the lawn converted to a retention basin (12%). Figure 3 presents the monthly change in precipitation, landscape irrigation, ET, and runoff to street. An 11 m^3 cistern did not substantially reduce runoff, but provided 9% of annual irrigation demand. Infiltration and surface runoff processes were particularly sensitive to the soil's physical properties and its effective depth. Replacing the existing loam soil with clay soil increased annual runoff discharge to the street by 63% when climate and landscape features remained unchanged. A simulation of ten trees planted at the control site indicate that 38% of the annual runoff to the street was reduced through canopy interception after these trees were mature (Figure 4). For a 50-year storm event, runoff discharge to street is 42% of precipitation from the control site but only 1% from the treatment site (Figure 5). Landscape irrigation water use for different irrigation practices is shown in Figure 6. Here both irrigation efficiency (High, Moderate, Low) and plant water required (High, Moderate, Low) is shown in x-axis. Simulated landscape irrigation use was reduced 53% by increasing distribution uniformity, using a drip system for shrubs, and adjusting application rates monthly based on ET water demand. Irrigation water use can be further reduced (73%) when "waterwise" irrigation and low water consumption plants were selected.









Conclusions

- Storm runoff was retained on site by BMP installation.
- Rainwater had relatively high TKN and TSS.
- Pollutants in runoff are mostly resulted from street contact.
- Rain gutter, driveway interceptor, combined with lawn retention basin can retain most runoff on the sources.
- Irrigation water use was reduced from municipal water supply. It could further reduced through best irrigation management.

Partners

- Dept. LAWR, University of California Davis
- Center for Urban Forest Research, USDA FS
- TreePeople of Los Angeles

Further information

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