Event Mean Concentrations and First Flush Phenomena for Highway Runoff using Monitoring and Modeling

Lee-Hyung Kim* · Michael K. Stenstrom**

* Dept. of Civil and Environmental Engineering, Kongju National University, 182 Shinkwan-dong, Kongju-si, Chungnam-do, 314-701, Korea
** Dept. of Civil and Environmental Engineering, University of California, Los Angeles, California, 90095-1593, USA

1. Introduction
The United States has made tremendous advances in the past 30 years to clean up the aquatic environment by controlling pollution from point sources such as industries and sewage treatment plants. Although point source discharges have decreased during recent years, many water bodies or rivers are still impacted and are either eutrophic, with excess algae biomass and episodes of toxic algal blooms, or oxygen depleted (Horan 1990; Parr et al. 1998 Larsen et al. 1999). Non-point sources (NPSs) are the cause of many of the problems. Non-point source pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is widespread because it can occur at any time in any type of landuse. Agriculture, forestry, grazing, septic systems, recreational boating, urban runoff, construction, physical changes to stream channels, and habitat degradation are potential sources of NPS pollution. Careless or uninformed household management also contributes to NPS pollution problems. As the runoff moves, it picks up and carries away natural and anthropogenic pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even underground drinking water sources (EPA 1994; Jefferies et al. 1999; Smullen et al. 1999).

Many water bodies in developed countries remain polluted, in spite of the billions of dollars that have been spent on clean-up of municipal and industrial point pollutant sources. Non-point source pollution remains a major cause of degradation of receiving waters. NPS pollution in developing countries presents new challenges to the environmental and legal professions. Recent emphasis in the United States is to manage NPS. The United States Environmental Protection Agency (USEPA) developed Nationwide Urban Runoff Program (NURP) to expand knowledge of urban runoff pollution by instituting data collection and applied research projects in selected urban areas throughout the United States (Driscoll et al. 1990; EPA 1994, 1995, 1996). The realization that significant quantities of nutrients, pesticides, herbicides and heavy metals are contained in runoff caused the U.S. EPA to require that regional planning agencies develop programs to reduce pollution from urbanized areas under section 208 of the Clean Water Act. Best Management Practices (BMPs), which refers to education, regulatory procedures, treatment systems and other methods to control pollutants in runoff were required (Jefferies et al. 1999; Smullen et al. 1999).

Generally the sources of urban runoff pollution originate from wet and dry atmospheric deposition, street refuse, including litter, street dirt, vegetation and organic residues and vehicle emissions. Construction debris and road deicing materials are also pollutant sources. Paved areas such as highways and streets in urban areas are “stormwater intensive” land uses since they are highly impervious, and have high pollutant mass accumulation from
vehicular activity. Regulatory approaches to control NPS are institutionally difficult. It is not clear who “owns” the stormwater. Runoff from one property may discharge through a second property to a third property, accumulating pollutants as it travels. The final discharge into receiving water contains emissions from all land uses, and there is no clear responsibility to manage the runoff. Regulation becomes difficult to enforce due to the confusion about the source.

Therefore, methods to estimate pollutant emissions from different types of landuse are popular research and development topics. More recently methods to estimate pollutant accumulation over dry days and emissions during storm events are being developed and used to evaluate the impacts of urbanization. The methods are being used for analysis of existing conditions as well predictive tools for planners.

The term first flush in stormwater management refers to emissions of pollutant that occur mostly at the beginning of a rainfall or storm event. It has been defined in various ways in the past. Several previous researchers have defined it has specific fraction of the mass of the selected contaminated being discharged in a specific but smaller fraction of the total runoff volume. The existence of a first flush is only of academic interest unless the first flush provides an opportunity for enhancing best management practices (BMPs) or reducing their cost. The existence of first flush is debated and many defining criteria exist (Bertrand-Krajewski et al., 1998). Thornton and Saul (1987) defined the first flush as the initial period of storm flow during a storm event. Geiger (1987) defined a first flush as occurring when the slope of normalized cumulative mass emission plotted against normalized cumulative volume is greater than 45%. Later many investigators have also used this definition (Gupta and Saul, 1996; Larsen et al., 1998; Sansalone et al., 1998). Vorreiter and Hickey (1994) proposed using only the first 25% of runoff volume in defining first flush. Deletic (1998) used standard statistical methods including a multiple regression model, and restricted first flush to the first 20% of runoff. Saget et al. (1995) and Bertrand-Krajewski et al. (1998), defined a first flush as occurring when at least 80% of the pollutant load is emitted in the first 30% of the runoff volume. First flushes have most often been observed in small watersheds, particularly if imperviousness is high such as paved areas. Large watersheds may have long time of travel, so that the early runoff from areas far from the sample location is mixed with later runoff from areas adjacent to the sample location.

In this research we investigate the existence of first flush as a function of site-specific variables as well as stormwater characteristics. The watersheds or sites are small, and avoid problems associated with time of travel in large watersheds. The objective of the paper is to give meaningful definition of First Flush.

2. Methodology

Study Area

Rainfall, runoff flow rate and runoff quality were monitored at 8 freeway sites in Southern California. The stations were equipped with a flow meter for measuring rainfall intensity, flow velocity, level and flow rate, and automatic water sampler for taking composite water sample. The first sample was collected at the very beginning of runoff. Additional samples were collected each hour until the end of runoff. General EMCs were calculated by integrating