STORMWATER TREATMENT NORTHWEST©

Last month we presented the first half of a proposal that your editors made with Herrera Environmental Consultants to the Water Environment Research Foundation (WERF) in 2006. Although the proposal was not selected, several members of the selection committee saw considerable merit in what was proposed. We therefore decided to share our concepts with our readers. Please refer to the May 2007 newsletter (Vol. 13, No. 2) for the first part of the discussion on these stormwater quality modeling ideas. Some information from the May newsletter is repeated for clarity.

WERF PROJECT GOAL

The overall goal of the WERF research project 06-SW-1 was stated as:

> This research will help link stormwater BMP control effectiveness for specific pollutants and flow to receiving water loadings, impacts and water quality objectives in order to help stormwater managers in the selection of design of BMP systems.

The RFP stated that stormwater program managers need appropriate methods and tools that can **explicitly** address the inherent uncertainty of BMP performance and receiving water quality. With scientifically based easy to use tools, stormwater program managers should be able to identify appropriate BMP selection and design characteristics having the highest likelihood of solving specific water quality problems. The RFP also stated that research should focus on the development-level scale (say 5-300 acres) but another desired outcome will be in defining how site-level methods and tools may be scaled up to a watershed (say 10-100 square miles or more).

PWR / RPA / HERRERA APPROACH

Our approach, whose technical details will be presented herein, keyed on the words “explicit” and “scientifically based.” Webster’s New Collegiate Dictionary defines “explicit” as “Clearly developed with all of its elements apparent.” The same dictionary defines “scientific” as “Agreeing with, or conducted or prepared strictly according to, the principles and practice of exact science.” And finally, “science” is defined as “A branch of study concerned with observation and classification of facts.” So to be explicit and scientifically based, the stormwater management tool should be clear with all of its elements apparent and their relationships to each other well understood. And it should agree with the stormwater quality observations that have been made and the facts that have been discovered to date.

To be explicit and scientifically based, the desired stormwater management tool must be able to simulate long-term continuous hydrographs rather than single-event peaks or just small storms. At the highly desired site scale, the tool should appropriately consider shallow subsurface flow or interflow, which has been shown to be important in the accurate estimation of flow. At the watershed scale, the tool should be able to simulate interflow and baseflow to the receiving water also on a continuous basis.

To be explicit and scientifically based, the desired stormwater management toll must be able to simulate the flow reductions associated with site specific LID practices proposed for a land development or a retrofit. The tool must be able to simulate the appropriate buildup and washoff from each of the significant source areas found throughout the urban environment like streets, parking lots, rooftops, driveways, landscaped areas and areas of special activities like construction sites or gas stations.

To be explicit and scientifically based, the stormwater management tool must be able to simulate the day-to-day and storm-to-storm interaction of and pollutant removals from BMPs that are specifically designed for each of these important source areas. The tool must be able to simulate the complex interaction of stormwater solids and other pollutants being transported from one source area to another like the way wet weather washon from adjacent landscaped or paved area impacts the solid accumulations on and eventual stormwater quality from streets or parking lots that are located down slope.

For these and other reasons, we proposed to abandon the modeling focus on land use itself since it has been shown to be a very poor indicator of stormwater quality. Instead, we proposed to focus on source areas because they relate directly to generation of pollutants and the application of both LIDs and BMPs. (Refer to the June 2007 newsletter for more discussion on these topics.)

Effective stormwater management also requires both water quality and quantity controls for minimizing watershed hydrology. Studies of urbanized watersheds repeatedly show that streams are adversely impacted by increased wet weather flows and altered dry season base flows. Stormwater conveyed via pipes to streams and wetlands increases runoff volume and rate while eliminating infiltration and groundwater recharge. Consequently, channels are scoured deeper and wider, reducing channel diversity and lowering in-channel water depth needed for aquatic species survival and riparian vegetation. Preserving historic watershed hydrology is critical to long-term health, viability and quality of receiving waters. The tool we envisioned must include effective stormwater quantity mitigation design options like low impact development (LID) techniques, which will in turn provide significant water quality benefits.

FLOW DURATION DESIGN MODEL (FDDM)

From several years of working for various Pacific Northwest clients, PWR has developed a powerful program that looks and feels like an EXCEL spreadsheet, but it actually executes explicit and scientifically based algorithms written in C++ code and linked with .dll files. Called the Flow Duration Design Model (FDDM), it provides the user with a flow duration response from a specific site using a continuous historic rainfall record. The user simply inputs the actual acreage of defined land cover categories that are proposed within the development site. FDDM includes six different LID practices along with extended detention. The user must input the specific design characteristics of each LID or extended detention facility being proposed. Multiple facilities can be specified and they can act in series or parallel. FDDM then explicitly simulates the flow duration response from the site. FDDM is an explicit model since a change in any of the design characteristics of any specified LID or detention would create a change in the flow duration response from the model.

As a site-based continuous hydrologic modeling tool, FDDM explicitly simulates the complex interaction of the various hydrologic processes that convert rainfall to runoff flow. FDDM is based on a continuous hydrologic watershed model known as HSPF. Various land cover categories within the watersheds where FDDM will be applied are calibrated to available gages to produce several continuous hourly time series of runoff. Each calibrated time series corresponds to a land cover category contained within the model. The user simply selects the subbasin where the site is located and the appropriate runoff time series related to land cover and underlying soil infiltration are automatically assigned. Creation of these pre-simulated runoff time series allows FDDM's adaptation to micro climate effects caused by mountains or terrain changes, for example.

With FDDM, local jurisdictions can vary their watershed management strategies at the subbasin level. While model calculations are site based, the value of aquatic resources typically varies greatly across a watershed. The ability to set targeted imperviousness at the subbasin level recognizes that high quality resources within a watershed may require greater protection than severely degraded resources. It also enables jurisdictions to balance economic needs against environmental stewardship in accordance with community values.

This tool operates quickly and efficiently using an Excel spreadsheet interface (see Figure 1). As stated previously, FDDM explicitly models several popular LID techniques for reducing runoff at the source. Currently, these include: porous pavement, amended soils, green roofs, blue roofs, planter boxes, infiltration trenches, smart cisterns and extended detention. Each LID simulation explicitly models the particular technique on an hour-by-hour basis considering inflow, storage, evaporation (if appropriate), infiltration and runoff. While FDDM can model several LID techniques at once, the tool also allows users to optimize individual LID designs.

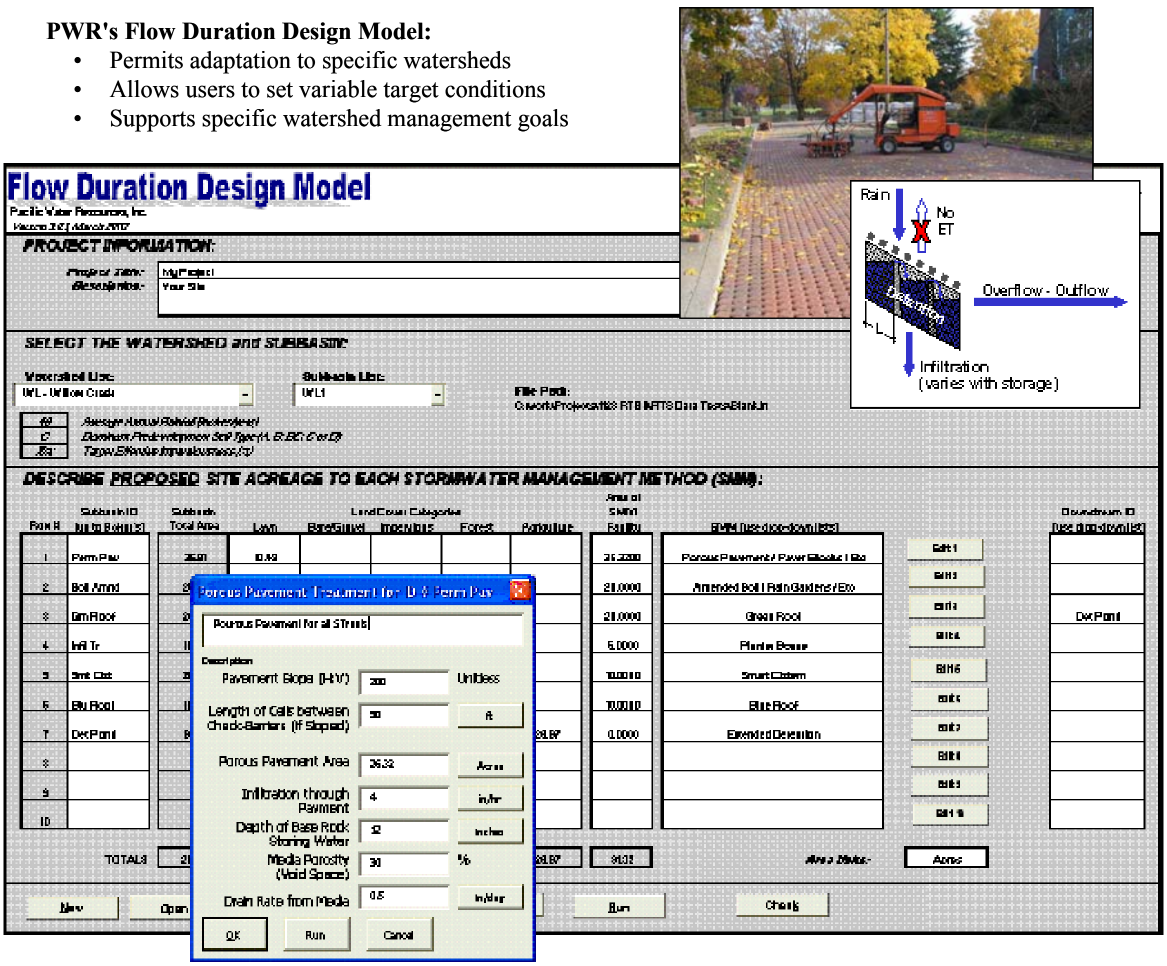

Figure 1 – FDD Input Screen with Porous Pavement Design Input Parameters Featured

Rather than a single-event, continuous multi-year hydrographs allow statistical comparisons of *flow durations* under both targeted and proposed conditions. Flow durations represent the fraction of time that a given flow is exceeded, and serve to quantify the effects (on a site basis) of proposed changes to basin hydrology. The tool presents flow durations for targeted and proposed conditions graphically, allowing designers to evaluate the impacts of design proposals quickly (see Figure 2).

A lower-limit flow duration shown on Figure 2 is set because it is neither possible nor desirable to require that design flows match a target below a certain geomorphically-based threshold. A high-limit flow duration is also set because, at some point, extreme flows are so rare and brief that it is neither practical nor cost-effective to require reducing them, especially at a site level.

Each LID element is characterized with its own distribution of contributing land surfaces discharging either offsite or to another treatment option downstream. Cascading treatments allow designers significant flexibility, which will lead to an explicit understanding of the pollutant reduction effectiveness of "treatment trains" once the stormwater management tool is expanded as described next.

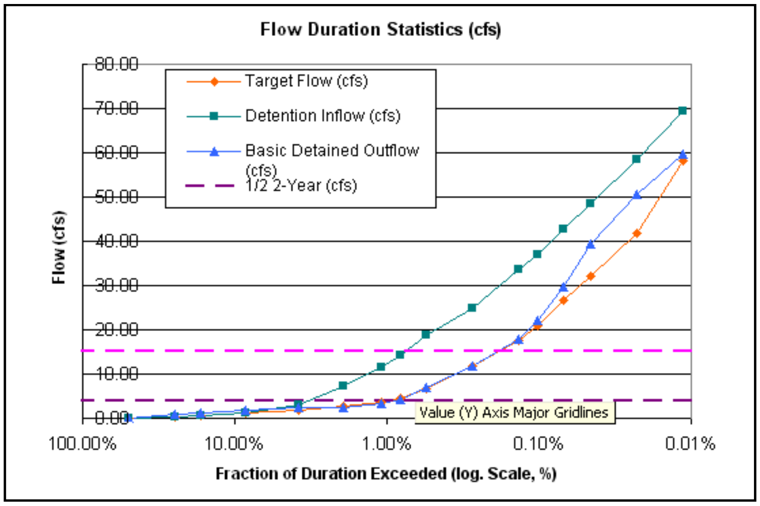

Figure 2 – FDDM Output Showing Target Flows and Design Flows for LID Practices Specified

POLLUTANT REDUCTION SPREADSHEET TOOL (PReST)

The stormwater management tool we envision will have the ability to explicitly model the pollutant reduction effectiveness of both structural and non-structural BMPs. In April 2004, PWR, in association with RPA and Dave Felstul (now with Herrera Environmental Consultants), proposed developing a similar comprehensive stormwater quality management model called the Pollutant Reduction Spreadsheet Tool (PReST) to the Oregon Association of Clean Water Agencies (ACWA). Figure 3 displays the basic elements of this previously proposed tool shown within the circle. PReST's final outputs were to be estimates of specific pollutant loadings and concentrations entering receiving waters along with the marginal costs of pollutant removal using various BMPs. The models five components would interface as shown.

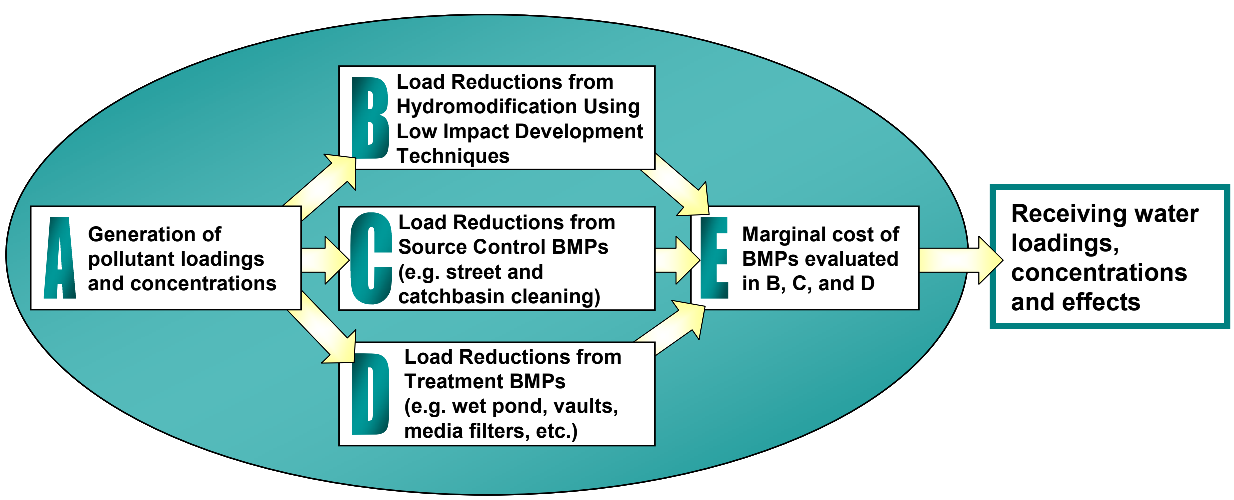

Figure 3 – Pollutant Reduction Spreadsheet Tool (PReST) Components

Four out of the five PReST components shown in the figure already exist in other established models and would only need to be integrated together. Components A and C would be based on the existing Simplified Particulate Transport Model (SIMPTM) developed by Sutherland and Jelen (1998). SIMPTM was originally developed in the early 1980s and has been used numerous times with further improvements for over two decades. The model is currently at Version 5.

Component B now exists within FDDM, as described previously. Component D would be new. Component E would be based on extensive work already performed by Sutherland and Jelen, and others like Felstul at estimating and comparing the marginal costs of maintenance practices (Sutherland and Jelen, 1997; Sutherland, Myllyoja and Jelen, 2002; Felstul, 1995).

Development of PReST was not funded and ACWA chose instead to use the existing PLOAD model, one of the "simple method" approaches discussed in the June newsletter. Ultimately, several ACWA members were disappointed in that assigning pollutant concentrations to each land use provided no direct linkage or understanding of how site-level management actions could actually affect stormwater quality. Like any stormwater tool based on any "simple method" approach, PLOAD is not designed to evaluate the explicit interaction of multiple BMPs, such as street and catchbasin cleaning, end of pipe treatment, LIDs, and extended detention. This is the key difference between our proposed stormwater management tool and those based on a "simple method" approach.

SIMPTM is the key stormwater quality model whose algorithms will be utilized by the proposed stormwater management tool. SIMPTM can explicitly simulate the physical processes of build up, washon and washoff linking actual site characteristics to storm-by-storm pollutant loadings and concentrations. SIMPTM also includes algorithms for sediment trapping in catchbasins and can simulate the explicit removal of sediments and associated pollutants as a result of both catchbasin and street cleaning practices. Associations between transported or captured particulate fractions and other pollutants of interest already exist. Since the washoff algorithms in SIMPTM are sediment transport based, they will provide a much greater understanding of the incoming stormwater characteristics that can significantly affect the design of treatment BMPs. As stated previously, this is the only component of the stormwater management tool that has not been developed.

STORMWATER MANAGEMENT TOOL

We envision a stormwater management tool (SMT) with the capabilities of the previously proposed PReST but with a site based look and structure similar to FDDM. The SMT's focus would be the specific hydrologic and pollutant loading response of a proposed development site. However, the ability to vary targeted imperviousness by subbasin throughout any complex watershed where the SMT may be implemented affords the local jurisdiction the opportunity to ensure watershed based goals are being met as part of the development of a single site.

In addition to flow duration, we see another output of this stormwater management tool as *concentration duration curves and/or load duration curves* for pollutants of interest. These curves will tell users how often pollutant concentrations based on water quality standards, for example, may be exceeded during wet weather. Or, in the case of loadings, these curves will tell them how often some established TMDL may be exceeded. This output could occur either be at the site scale or at some user specified downstream point. This could eventually lead to development of realistic wet weather water quality standards and TMDLs that recognize the infrequent occurrences of high pollutant concentrations and loadings, a positive outcome of this new modeling approach.

The SMT will provide the user with the opportunity to understand the differences in pollutant concentrations and loadings due to differences in site characteristics. For example, dry weather pollutant build up on impervious surfaces could be a function of traffic volume and pavement characteristics. Wet weather washon would be explicitly simulated as transported sediments from adjacent areas that are deposited on directly connected impervious areas during recession flows. The pick-up or removal of accumulated sediments from pavement cleaning would be simulated as a function of sediment accumulations, particle size distributions and sweeper pick-up performance, which is tied to actual testing, as it is in SIMPTM today (Sutherland and Jelen, 1997).

As stated previously, we still need to develop algorithms that can describe the physical processes of the treatment BMPs to be included in the tool (i.e. see Component D in Figure 3). Considering that the simulated input to the treatment BMP algorithms will be a continuous trace of flow, pollutant concentration, and particle size distribution for the transported sediment fraction, even the most simplistic sediment and pollutant removal equations are likely to yield considerable benefits. And, as noted previously, SIMPTM already includes tested and proven catchbasin sediment trapping routines.

CLOSING

We have offered our ideas on how we could leverage decades of work developing and refining SIMPTM and more recent efforts used to produce FDDM to create an explicit and scientifically based stormwater management tool (SMT). We envision a tool that is easy to use and has the look and feel of a simple EXCEL spreadsheet but acts instead as a powerful simulation model providing the user with quick results. We envision a tool that can be used to plan the overall stormwater management strategy of an entire complicated watershed. We envision a tool that can be used to design the appropriate LIDs, BMPs, and cleaning or maintenance practices for a specific development site within that watershed that ensures the overall management strategy is being implemented. Four of the five major components envisioned for this powerful modeling tool already exist today and are ready for integration into one single program.

Imagine a stormwater management tool that can accurately estimate the flows, pollutant concentrations and loadings being discharged from a watershed and a specific site within that watershed. Imagine a management tool that can accurately estimate the flow and pollutant reduction effectiveness of both a watershed wide planning strategy and a site specific development proposal, not for just a single storm or a series of storms but for a period of time equivalent to the longest historical record of precipitation available within the region. Imagine the ability to understand how cost effective a specific stormwater management practice is in the removal of a specific pollutant at a specific location in a given watershed. Image the ability to understand how the implementation of a single BMP or multiple BMPs affect not only the mean or median concentrations of a given pollutant but the actual distribution of the entire population of pollutant concentration that would have occurred throughout the historical rainfall record. Imagine the ability to understand the variation in pollutant loadings and concentrations that result from differences in traffic volume, pavement condition, site imperviousness and other important characteristics such as those associated with the collection and transport of stormwater itself. Imagine a tool that can be used equally well in evaluating a proposed new development as a retrofit of an existing urbanized area.

We have the technology. We have the tried and tested algorithms that have been accurately calibrated to real data. We have almost all of the pieces to this complex puzzle that your editors have dedicated well over 30 years of effort each trying to assemble. What we are missing is the financial resources needed to put this puzzle together so we can finally get some answers to these very important questions.

Please contact Roger Sutherland or Gary Minton if you would like more information or have the desire to provide or help us find these resources.

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