Modeling BMP's in Sensitive Areas with xpswmm

King's Beach Watershed Improvement Project

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INTRODUCTION

Located on the border of California and Nevada, Lake Tahoe (the Lake) is the largest alpine lake in North America. It is known for its scenic beauty and outstanding lake clarity. However, the clarity of the Lake has been declining since the mid-1960s because of the deposition of fine particles and nutrients from urban runoff and the growth of aquatic organisms that feed off the nutrients in the runoff (U.C. Davis, 2010). A program to restore the clarity of Lake Tahoe has been initiated and involves the development of numerous projects to control the quality of runoff entering the Lake.

One such project is the Kings Beach Watershed Improvement Project (WIP). The WIP includes a planning-level process that analyzes runoff patterns in the Kings Beach community at the north end of Lake Tahoe and proposes methods to treat runoff generated in the community before it reaches Lake Tahoe. Methods to collect, control, and treat Kings Beach runoff include the installation of detention basins, infiltration galleries, rock bowls, porous pavement, sediment traps, sediment vaults, and advanced treatment filter vaults connected by a network of pipes and rock and grass-lined channels that will eventually outfall into Lake Tahoe.

A comprehensive software package (xpswmm) for modeling stormwater, sanitary and river systems was selected as a tool to model the WIP, represent the complicated nature of the runoff patterns and to track suspended solids generated in rainfall events. The xpswmm program was used to simulate the routing of storm flows into Best Management Practices (BMP) before discharging to Lake Tahoe during several runoff events.

The model was run in hydrology and hydraulics modes and involves surface and subsurface conveyance features and storage facilities. The Kings Beach street system is laid out in a grid pattern with north/south streets and east/west streets intersecting and enclosing residential areas in between. By local naming convention, the north/south streets are named for mammals and the east/west streets for fish. State Route 28 passes through the lower watershed with a commercial core on both sides of the road. All of the proposed WIP drainage features function in accordance with the existing drainage patterns, facilities, and utilities in the area.

SIMULATIONS

Two types of models were developed for Kings Beach: continuous and single event. The continuous was a 10-year simulation that initially estimated the long-term performance of the facilities proposed in the WIP. As the project progressed from the concept phase to the design phase, single event simulations with the largest being a 100-yr 24-hr event, were used for sizing drainage facilities.
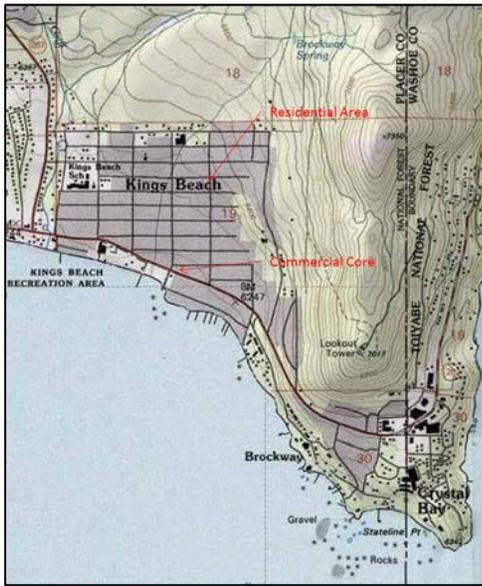
HYDROLOGY

There are over 360 hydrologic nodes in the model. Three catchments potentially drain to a given node and are represented by the fish streets, mammal streets, and the residential areas. The fish and mammal streets are impervious paved areas with unpaved shoulders. The residential areas are the rectangular areas between parallel fish and mammal streets that consist of homes (and associated impervious areas) and open spaces. A node may receive runoff from one, two, or three of these catchments. The Stormwater Management Model (SWMM) Runoff method was used to compute runoff in a catchment. Several regional databases were available to develop this model including impervious area, land use, and topography.

In the Global Data option, rainfall, infiltration, and snowmelt parameters were defined. The rainfall parameters are based off of a node's elevation in the watershed. The rainfall and temperature data that were used in the simulation were developed by Lake Tahoe agencies for the regional planning effort. The infiltration parameter considers the node's location in the watershed and is based on the Green and Ampt (used to simulate infiltration processes in hydrological models and land surface schemes) approximation. Snowmelt is defined for use in the continuous simulations.

HYDRAULICS

There are over 980 nodes and 1,000 hydraulic links in the model. The hydraulic nodes reflect manholes, junctions, drainage inlets, sediment traps, basins, vaults, and infiltration galleries. The links in the model are either single link or multi-link and reflect buried conduit, gutters, and surface channels. The surface channels in the model are varied, reflecting designed grass-lined swales or rock-lined channels, and natural dispersed overflow areas. The natural dispersed areas occur where improvements are not planned and runoff spreads according to existing topography.

During the design for each phase of the project, the model simulations were coordinated with the design engineers so that pipe conditions (size, slope, invert elevations) could be adjusted based on model results and conditions in the field. The iterative back-and-forth between the modelers and designers resulted in a best fit for field conditions and optimal flow through the pipe network during different storm events. Design was modified to avoid soffit surcharge during a 10-yr 1-hr event and manhole surcharge during a 100-yr 1-hr event. Pipe sizes were modified so that the peak flows in the pipes during a 25-yr 1-hr event did not exceed the maximum design flows.

WATER QUALITY

Water quality simulations were initiated by selecting the Water Quality function in the Runoff Job Control. In the Global Data, a pollutant TSS (total suspended solids) was defined for simulation. Other Global Data parameters were also defined including erosion, buildup/washoff, and land use. The erosion type was

defined for the water quality application based on the type of land use present. The variable parameter in the definition was the Fraction of Area Subject to Erosion. Different Erosion types were defined based on the different amount of erodible land present. The event mean concentration (EMC) was specified for the washoff of TSS. The values were selected from current research in the Lake Tahoe basin. Four different Buildup/washoff types were defined based on the assumed EMC from the type: Residential, Street, Forest, or Highway. The land use types defined in the model match the land uses in the Buildup/washoff definition.

Also, at each hydrology node, the Water Quality Data function was selected. Selecting this option requires selection of a Land use and an Erosion type. It also requires selection of Erosion Flow Distance. The flow distance was selected based on the Fraction of Area Subject to Erosion from the Erosion Global Value but also based on the amount of this area that is disturbed.
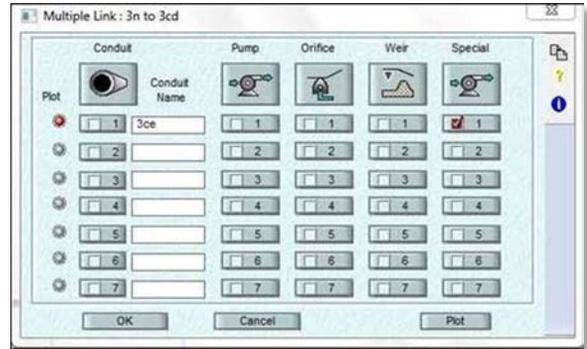
Sediment concentration and load are reported in xpswmm output. The erosion simulated in the Runoff mode was routed through the conduit and nodes in the Hydraulics mode. This resulted in some deposition and removal of TSS load in the basins, sumps, and advanced filters.

BMPs were initially simulated in xpswmm's Sanitary mode. However additions and modifications to the model made using Hydraulics mode more efficient to model the BMPs. Results contained in the hydraulic mode output file were post-processed and used to assess the TSS removal rate for the BMPs at the nodes. To accomplish this, the TSS load at the upstream end of a treatment train (a series of BMP's located between the source and the outfall) was compared against the TSS load leaving the treatment train (typically the outfall). Through the post processing, the BMP effectiveness was estimated. BMPs were not considered on an individual basis but rather based on a treatment train approach. This approach was used because no single BMP provides complete pollutant control but the cumulative BMPs can provide sufficient removal of up to 99% of the influent TSS load.

CONCLUSIONS

The xpswmm program was used to simulate a detailed system of pipes and channels with surface and subsurface flow. Within the model, treatment nodes were used to represent BMPs to simulate the removal of TSS from the system. The model proved to be a useful tool when examining the "Big Picture" of improvements throughout the Kings Beach area, and for the fine detail of design of individual phases of the project. The iterative approach provided an effective refinement of the design. Most importantly, the model allowed the entire drainage system to be modeled as an interconnected unit which would not have been possible with more traditional hydrologic techniques such as the Rational Method applied basin by basin.

To date, one phase has been constructed and another is in final plans. The model is continually updated to reflect new information on field conditions, client needs, and water quality considerations and has worked well as the initial planning-level model and eventual design model.