METHODOLOGIES

GIS Based Modeling

The MIKE-URBAN SWMM model works within ArcGIS and can simulate runoff, open channel flow, pipe flow, and water quality. The program is used to model the Los Altos storm drain system because of its capabilities with overland flow, weirs, and pipe networks; the incorporation of the SCS Curve Number hydrology method; and the overall stability of the model. Though the models were developed using the proprietary MIKE-URBAN, the final models are compatible with the public domain version (V13) of EPA SWMM5.

Operation

Two separate calculations are performed by SWMM for the City of Los Altos models: a stormwater runoff calculation that determines the amount of water entering the storm drain system from a specific rainfall event; and a pipe flow calculation that replicates how the storm drain system will convey those flows to outlets. Flows resulting from the runoff calculation are used as inflows for the subsequent pipe flow calculation.

SWMM has three infiltration methods: Horton, Green-Ampt, and Curve Number. Los Altos storm drain models use the Curve Number method. The runoff simulation duration is set equal to the design storm duration or some lesser duration depending on the period of interest; a 24-hour storm is used in Los Altos.

The SWMM pipe flow model offers a choice of three flow description approximations: Steady State, Kinematic Wave, and Dynamic Wave; each is distinguished based on the set of forces that each takes into account. The Los Altos storm drain model uses the most comprehensive flow description, Dynamic Wave, which incorporates the effects of gravitational, friction, pressure gradient and inertial forces. Because it accounts for all forces affecting flow conditions, this method allows the model to accurately simulate fast transitions and backwater profiles. Water above the node rims is simulated by using an artificial basin above the ground level. The area of the storage above the node is set between 1,000 and 3,000 square feet, based on location, replicating the effects of street storage during storm events. 3,000 square feet was only used at the upstream node in the each system to simulate additional upstream watershed storage. Water stored in the artificial basin begins to re-enter the system when system capacity allows. The pipe flow simulation can be executed using either a constant or variable time step, and can be run for any portion of the time interval specified by the input rainfall time series and corresponding calculated runoff hydrograph. A time step range of 1 to 10 seconds is used for models within Los Altos with an adjustment factor of 1.5. These values are based on model stability and computation time.

Input and Output

SWMM pipe flow calculations require network data, operational data, and boundary data as input. Network data consists of the pipe network elements including nodes (manholes, outlets, and storage nodes) and links (pipes, culverts, and open channels). Parameters required to describe nodes include *x* and *y* coordinates of the node, a unique name, node type (junction, outlet or basin), depth and invert levels, and water levels at outlets.

Parameters required to describe links include the name of upstream and downstream nodes, shape and dimensions, material, and upstream and downstream inverts. Structural system elements including gates and weirs are all modeled as functional relationships connecting two nodes in the system, or associated with one node in the case of free flow out of the system. Operational data consists of parameters which describe how these elements function in the network. Boundary data for the pipe flow computation can include any external loading, inflow discharges, water levels at interaction points with receiving waters; as well as the results of a run-off calculation.

Output from the pipe flow computation includes the calculated water level at each node, weir discharges, water level in network branches, discharge in network branches, water velocity in network branches, water volume in the system and time step data. Output is viewed using GIS, SWMM or the MIKE URBAN program. Results may be displayed in plan view or as a profile for a selected network section, and may be viewed as a temporal animation or at maximum or minimum values. Additional outputs which can be derived from SWMM pipe flow results using GIS include: water depth, flooding level, pressure in closed conduits, percentage pipe filling, the flow calculated for each link, and model stability and numeric continuity.

Runoff Estimation

A design storm is used in lieu of a single historic storm event to ensure that local rainfall statistics (i.e. depth, duration and frequency) are preserved. When combined with regional specific data for land use and loss rates, the model should produce runoff estimates that are consistent with frequency analyses of gauged stream-flow in the Santa Clara County area. In other words, the ten-year design storm pattern used for SWMM modeling creates results consistent with a ten-year storm runoff event.

Precipitation frequency analyses are based on concepts of probability and statistics. Engineers generally assume that frequency (probability) of a rainfall event is coincident with frequency of direct storm water runoff, although runoff is determined by a number of factors (particularly land use conditions in the basin) in addition to the precipitation event. The frequency of occurrence for precipitation (and by assumption, runoff) is ten years to evaluate storm drain performance for this master plan.

Runoff ***Characteristics*** *and Design Storm*

The Santa Clara County manual provides the total rainfall depth for each MAP and storm frequency using the following equation:

$$x_{T,D} = A_{T,D} + (B_{T,D}\,MAP)$$

Where: $x_{T,D}$ = precipitation depth for a specific return period and storm duration (inches), T = return period (years), D = storm duration (hours), $A_{T,D}$, $B_{T,D}$ = coefficients from Tables B-1 and - 2 (dimensionless), MAP = Mean Annual Precipitation (inches).

The precipitation intensity, iT,D is given by:

$$i_{T,D} = \frac{x_{T\,D}}{D}$$

The Mean Annual Precipitation (MAP) range within Los Altos is 14-inches to 22-inches based on the MAP figure in the County manual (Figure A-2).

The 10-year storm intensity graph for a MAP of 18-inches is shown in Figure D-1.

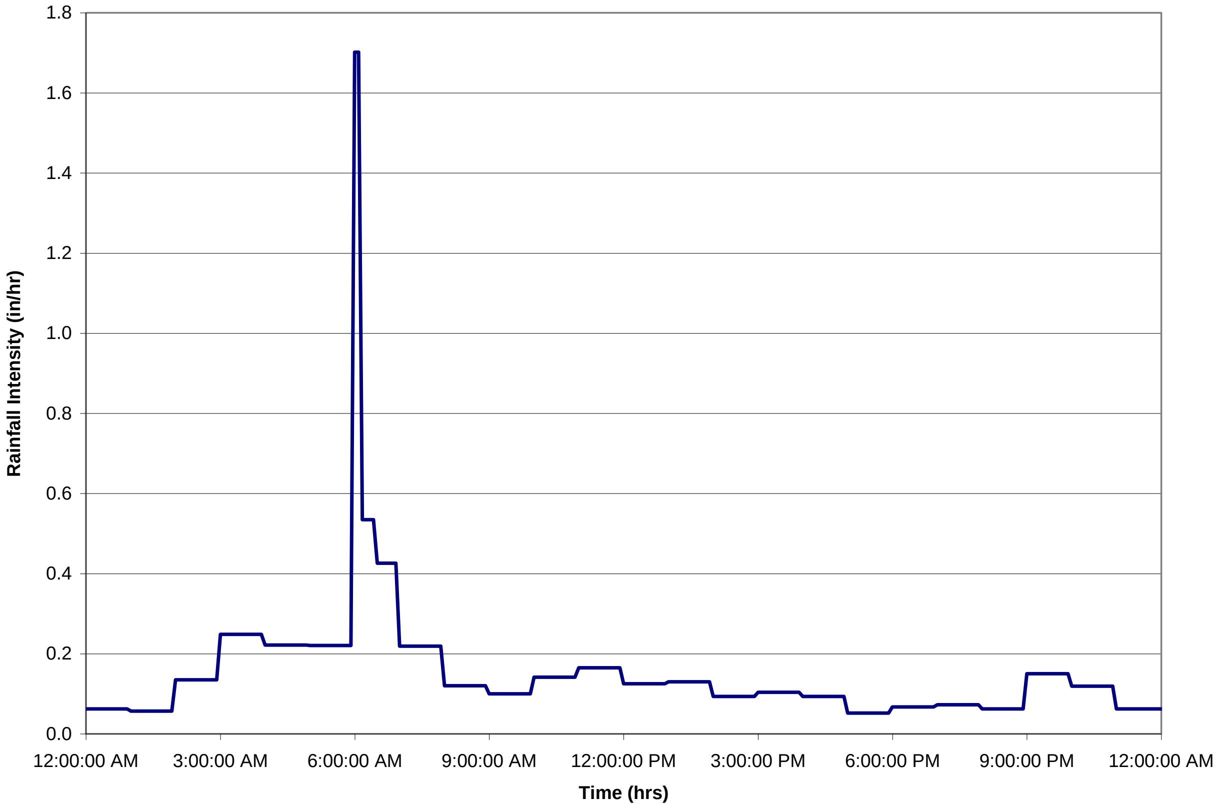

Figure D-1*:* Santa Clara County 10-Year Storm Intensity Graph (MAP 18")

*Basin **Runoff** and Loss Parameters*

SWMM includes limited hydrologic loss parameters. Basin lag, or lag time, is defined as the time elapsed between rain fall occurring within a basin and runoff occurring at an outlet point. SWMM uses basin slope (S), Manning's roughness coefficient (N), and basin width (W) to determine lag time. Slope is expressed in percent, roughness values for pervious (N-pervious) and impervious (N-impervious) are dimensionless and width is expressed in feet. SWMM does not provide detailed documentation of how lag time is calculated; furthermore, it is unclear of what exactly the W value is. The SWMM manual defines it as:

Characteristic width of the overland flow path for sheet flow runoff (feet or meters)...Adjustments should be made to the width parameter to produce good fits to measured runoff hydrographs.

It should be noted that the basin roughness factor (N) is not the same as Manning's roughness coefficient (n). Typical N values are shown in Table D-1.

Table D-1: Overland N Values

Surface	N
Smooth asphalt	0.011
Smooth concrete	0.012
Ordinary concrete lining	0.013
Good wood	0.014
Brick with cement mortar	0.014
Vitrified clay	0.015
Cast iron	0.015
Corrugated metal pipes	0.024
Cement rubble surface	0.024
Fallow soils (no residue)	0.05
Cultivated soils	
Residue cover <20%	0.06
Residue cover >20%	0.17
Range (natural)	0.13
Grasses	
Short, prairie	0.15
Dense	0.24
Bermuda grass	0.41
Woods	
Light underbrush	0.4
Dense underbrush	0.8

Although the County Hydrology Manual provides a generalized map of basin slopes, Schaaf & Wheeler has calculated basin slope using the County LiDAR data and found that a total of 65 of 661 basins had slopes greater than 5%, with a peak slope of 21.7% calculated.

Drainage System Analyses

Pipes are modeled as one-dimensional closed conduit links which connect two nodes in the models. The conduit link is described by a constant cross-section along its length, constant bottom slope, and straight alignment. Unsteady flow in closed conduits is calculated using conservation of continuity and momentum equations, distinguishing between pipes flowing partially full (free surface flow), and those flowing full (pressurized flow). The Darcy-Wiebach equation for pressure flow conditions was selected for this study. Most pipes within the Los Altos model are modeled as reinforced concrete pipe (RCP) with a Manning's '*n'* of 0.013. There are a few corrugated metal pipes (CMP), mostly outfalls, with '*n' of* 0.022.

Open Channels

Open channel within the drainage network are modeled as one-dimensional links which connect two nodes in the model. The conduit link is described by a constant cross-section along its length, constant bottom slope, and straight alignment. SWMM uses Manning's equation for open channel flow. The channels within the Los Altos model are modeled with '*n'* of 0.025.

System Extensions

Due to the City's rural street characteristics, there are numerous locations where no storm drain pipe network exists. In many cases this does not pose any significant flooding risk. There are, however, areas of the City that do experience repetitive nuance flooding due to the lack of a formal drainage system. Streets that could benefit from an extension of the pipe network are based on model results and City staff knowledge. Extensions are recommended on streets where the improved model results have a hydraulic grade line (HGL) more than 6-inches above the ground surface.

Outlet Boundary Conditions

Pipe network outlets require a water surface elevation to modeling backwater effects from receiving waters. In areas that outlet to a channel, the water surface elevation is set at the 10-year FEMA FIS level. For outlets to channel sections not studied by FEMA, an arbitrary static water level of 4 feet above the pipe invert was assumed. Adjustments were then made where the assumed static channel water level was higher than the ground elevations of upstream nodes.