Stormwater Runoff Reduction

Summary
The CITY green stormwater runoff analysis estimates the amount of stormwater that runs off a land area during a major storm, as well as the time of concentration and peak flow. The program determines runoff volume based on the percentage of tree canopy, and other landcover features, as digitized by the user in the CITYgreen view or as reported in a raster data set.

The analysis also considers a variety of localized information identified automatically by CITYgreen or entered by the user, such as local rainfall patterns, soil type, and other site characteristics.

The Stormwater Runoff program incorporates procedures and formulas developed by the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), to estimate runoff volume as well as percent changes in time of concentration and peak flow. The Urban Hydrology for Small Watersheds model, commonly referred to as Technical Release 55 or TR-55, was incorporated into CITYgreen and customized, with the help of Don Woodward, PE, a hydraulic engineer with NRCS, to determine the benefits of trees and other urban vegetation with respect to stormwater management.

Technical Methodology
CITYgreen's stormwater runoff analysis enables a user to map urban land cover features (grassland/shrub, trees, buildings and impervious surfaces) and determine percentages of each land cover feature.

Land cover percentages are then combined with average precipitation data, rainfall distribution information, percent slope, and hydrologic soil group, to estimate how trees affect runoff volume, time of concentration, and peak flow. In addition, the program estimates the additional volume of water, in cubic feet, that would have to be managed if trees were removed when comparing two scenarios. This volume estimate can be associated with an economic value since planners generally know the cost per cubic foot to build a retention pond in their municipality. CITYgreen also enables the user to model different land cover and precipitation scenarios to determine acceptable development or conservation practices.

The TR-55 model was designed to analyze runoff patterns during a 24-hour single storm-event. Engineers and non-engineers typically design stormwater management facilities for average storm events, usually 24 hours in duration, according to NRCS. CITYgreen allows the user to input values for the amount of rain that would typically fall during a typical 24-hour event observed within a 2-year span. This value is based on NRCS estimates of rainfall distributions for different regions of the country.

The user is also asked to input a slope, which can be best thought of as the estimated average slope of the site.
The following formulas are used to estimate curve numbers, stormwater runoff, time of concentration and peak flows.

Formulas used in Calculations

Curve Numbers:
CN (weighted) = Total Product of (CN x Percent land cover area) / Total Percent Area or 100
Potential Maximum Retention after Runoff begins:
$S = ((1000 / CN) - 10)$

Runoff Equation:
$Q = [P - 0.2 ((1000 / CN) - 10)]^2 / P + 0.8 ((1000 / CN) - 10)$

Flow Length:
$F = (\text{total study area acres}^{0.6}) * 209.0$

Lag Time:
$L = ((F^{0.8}) *((S + 1.0)^{0.7}) / (1900 * ((\text{slope})^{0.5})))$
Time of Concentration:
$Tc = 1.67 * L$

Unit Peak Discharge:
$\log(qu) = C_0 + C_1\log(Tc) + C_2[\log(Tc)]^2$

Peak Flow:
$Peak = (qu * Am * Q * Fp)$

Storage Volume:
$Vs = Vr *(C_0 + (C_1(qo/qi)) + (C_2 ((qo/qi) (qo/qi))) + (C_3 (qo/qi) * (qo/qi) * (qo/qi))) *$ study area acres * 43560.17 / 12

Variable Definitions
P = Average Rainfall for a 24 hour period (inches)
Am = study area acres / 640 to determine square miles
Fp = Swamp pond percentage adjustment factor
qo =Existing peak flow condition with trees
qi = Peak flow without trees
$C_{0.....}$ = TR-55 Coefficents in accordance with raintype

Output Values
Peak = Peak Flow (cfs)

Vs = Storage volume (cubic feet)
Vr = Runoff Volume (in)
CN = Runoff Curve Number (weighted)
Q = Runoff (inches)
F = Flow length (feet)
S = Potential Maximum Retention after Runoff begins (in)
L = Lag Time (hours)
Tc = Time of Concentration (hours)
qu = Unit Peak Discharge (csm / in)

TR-55 formulas are used in most engineering firms, soil conservation districts, and municipalities around the country. Over 300,000 copies of the TR-55 manual have been sold by the US National Technical Information Service as of 1994. The NRCS methods used in TR-55 are very effective in evaluating the effects of land cover/land use changes and conservation practices on direct runoff. For more information about TR-55, see the following website: *www.wcc.nrcs.usda.gov/water/quality/common/tr55/tr55.html*

The CITYgreen stormwater runoff analysis is not intended to be used to design stormwater management facilities, culverts, or ditches. The program is used to estimate the effects of vegetation, especially trees, on runoff volume and peak flow. Percent changes in runoff volume and peak flow are determined automatically by comparing two different scenarios of the same site.

References

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