Supplementary Information

Runoff in the Whittier, NC watershed was calculated using the Rational Method because each subwatershed has an area (A) sufficiently small (<200 acres) to warrant using this hydrologic method.

$$Q = C_f CIA \quad (1)$$

Where Q is the peak flow rate of a storm in a subwatershed. The runoff coefficient (C) is assumed to be 0.25 due to the watershed being in a predominantly wooded area [1]. When a storm has a return period between 25 years and 100 years, the Charlotte-Mecklenburg Stormwater Design Manual dictates that a frequency factor (C_f) must be applied to the rational formula. The average time of concentration for all subwatersheds was approximately 6.3 minutes. Assuming storm duration is equal to the time of concentration, the data in [2] can be used in conjunction with NOAA Atlas 14 precipitation intensity data to interpolate an appropriate intensity for a 6.3-minute storm.

The rainfall intensity (I), which is portrayed in units of inches/hour, is determined from Intensity-Duration-Frequency (IDF) curves. These curves represent parameters that were combined into the following empirical equation.

$$Intensity\ (I) = \frac{a}{(t+b)^n} \quad (2)$$

In equation 2, t represents the extent of rainfall (minutes), which is equal to the time of concentration for each subwatershed. The variables a, b, and n are empirically determined storm-fitting parameters enumerated in Charlotte-Mecklenburg Stormwater Design Manual. Time of concentration was calculated using the Kirpich equation.

$$t_c = (0.0078 * (\frac{L^{0.77}}{S^{0.385}})) * 2 \quad (3)$$

Equation 3 is multiplied by 2 because the overland flow is occurring over predominantly grassed surfaces.

The Charlotte-Mecklenburg Stormwater Design Manual was used for hydrological calculations in the Whittier, NC watershed because it is the most comprehensive hydrology manual of any large city near Whittier. It is also assumed that the terrain in Charlotte is hydrologically similar enough to Whittier for the formulae and their respective variables to be valid.

The second watershed, Leadville, CO, is much larger and is located near Turquoise Lake in Colorado with an area of 113 sq. miles (292.67 sq. km) and 69 sub watersheds (Fig 3). Two of the watershed's major streams flow through the town of Leadville. Additionally, there are 6 flood-susceptible utility poles across three locations. This entire watershed stream network ultimately drains into the Arkansas River.

Each subwatershed has an area greater than 200 acres and requires the "Natural Resource Conservation Service (NRCS) Curve Number Loss and Dimensionless Unit Hydrograph Method" to accurately calculate the peak flow of each sub watershed [3]. The City of Colorado Springs Drainage

Criteria Manual Vol I was used because Leadville and surrounding areas are not densely populated and do not have established hydrology/drainage manuals.

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad (4)$$

In equation 4, Q is the accumulated runoff (in) and is calculated with the accumulated rainfall depth (P) and approximate soil retention (S). The variables P and S are both expressed in units of inches. The equation for approximate soil retention is conveyed as:

$$S = \left(\frac{1000}{CN}\right) - 10 \quad (5)$$

A spatially averaged curve number was developed for each subwatershed by synthesizing NRCS land use and Soil Survey Geographic database (SSURGO) soils data, following the methodology introduced in [4]. The majority of subwatershed curve numbers were within the 60-70 range. This methodology for determining spatially averaged curve numbers was used in the Leadville, Colorado and London, Arkansas watersheds.

Peak flow in a sub watershed is expressed as:

$$Q_P = QAQ_p \quad (6)$$

Where Q_P is the unit peak discharge (cfs/mi^2), which is calculated using the following formula.

$$Q_p = \frac{(484) * AQ}{(0.67 * t_c)} \quad (7)$$

The constant, 484, is the unit hydrograph peak rate factor. This factor remains constant in equation 7. In the NRCS method, the time of concentration (t_c) is equal to the sum of the concentrated flow travel time (T_t) and the overland flow time (T_i).

Concentrated flow travel time is determined from the following equation.

$$T_t = \frac{L}{(3600 * V)} \quad (8)$$

L is the length of the flow path, V is velocity (ft/s) and 3600 is a conversion from seconds to hours. The equation for overland flow time is written as follows.

$$T_i = \frac{0.007(nL)^{0.8}}{P^{0.5}\, S^{0.4}} \quad (9)$$

In equation 9, n is the manning's roughness coefficient, which is assigned based on the material the channel is made from. Since it is assumed all channels in the Leadville Colorado watershed are natural, a manning's roughness coefficient of either 0.15 for "short prairie grass", 0.24 for "dense grass", or 0.8 for "dense underbrush" was used based on observations made using google earth and guidelines provided in the City of Colorado Springs Drainage Criteria Manual. The precipitation depth for a 2- to 500-year storms (P) is also used in equation 9. S is the slope of the hydraulic grade line of the channel.

The final watershed, located in Arkansas, discharges into the Arkansas River, near the town of London. Encompassing an area of 537 sq. mile (1390.82 sq. km), this watershed stretches across a portion of the Ozark National Forest and has a major stream flowing through the town of Hagarville (Fig 4). In this watershed, there are only 61 subwatersheds, despite being larger than the Leadville Colorado watershed. There are also 3 utility poles deemed to be flood susceptible. Like the second study area, the NRCS method was used to calculate the runoff for each of the subwatersheds, using nearly the exact same formulae and methodology. In this instance, the unit peak discharge is not used to calculate peak flow. Instead, the result of Equation 4 is converted to feet, multiplied by the subwatershed area, and then divided by 24 hours. The NRCS methodology for the London, Arkansas watershed was performed in accordance with the City of Fayetteville Drainage Criteria Manual [5].

References

1. Charlotte-Mecklenburg Stormwater Services. Charlotte-Mecklenburg Storm Water Design Manual Chapter 2. Charlotte Chamber Design Manual Task Force. 2014. Available online: https://charlottenc.gov/StormWater/Regulations/Documents/SWDMC/SWDMChap2Final12312013.pdf (accessed on 27 January 2021).
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3. City of Colorado Springs. Drainage Criteria Manual Vol I. 2014. Available online: https://coloradosprings.gov/sites/default/files/images/dcm_volume_1.pdf (accessed on 27 January 2021).
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