CARFFFG System Design and Theoretical Background: GIS and Threshold Runoff

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Objective of the Presentation

- Describe process for delineation of flash flood-scale watersheds. These are used for defining physical properties in CARFFG System.
  - model parameterization
  - model computations
  - product displays

- Describe Threshold Runoff theory and estimation for CARFFG.
GIS Processing to Delineate Small Flash Flood Watersheds

- GIS processing of digital elevation data to define watersheds
- GRASS GIS software utilized
- Estimate watershed characteristics (A, L, S) used in calculations

SRTM 90-m DEM
- satellite-observed
- near global
- quality controlled
GIS Processing to Delineate Small Flash Flood Watersheds

- Why GRASS?
  - freeware
  - Collaboration with developer of delineation routine, \textit{r.watershed} (1980s)
  - Evaluations of \textit{r.watershed} results found superior in representing hydrologic properties of watershed.
  - (Also included / linked with Quantum GIS (QGIS) software)

- Routine \textit{r.watershed} defines flow path and watersheds boundaries based on digital elevation data (DEM/DTM)
GIS Processing to Delineate Small Flash Flood Watersheds

- \textit{r.watershed} determines streams and boundaries based on DEM
CARFFG Basin Delineation

- r.watershed parameter defines minimum headwater stream size
- Our target: average local area of ~150km²
- Result:
  - 34,700 basins defined
  - Average A = 120km²
  - 5650 w/ $A_{\text{accum}} > 2000km²$
  - 29050 w/ $A_{\text{accum}} \leq 2000km²$
CARFFG Basin Delineation

Output is digital stream network and watershed boundaries.
Basin geometry features used to compute threshold runoff, a watershed characteristic and input to flash flood guidance.
Basins Geometric characteristics
For Accumulated Drainage Area < 2000km²
Validation of Delineation Results

(a) HRC-internal review
   comparison with Digital Chart of the World (DCW) stream database
   comparison with GoogleEarth Satellite Imagery

(b) Within-Country review
   GIS layers provided to NMHSs for evaluation and comments
Watershed delineation is based on topography only

- Represents *natural* drainage system
- SRTM “sees” top of canopy
- Known difficulties in very mildly sloping regions and regions with small terrain undulations.

Large regions require multiple “processing windows”, which are “patched” together to complete regional GIS file.

Watersheds defined throughout region. Soil/snow models applied throughout. FFG computed only for watersheds with cumulative area < 2000km².
Threshold Runoff is defined as the amount of effective rainfall of a given duration falling over a watershed that is just enough to cause bankfull conditions at the outlet of the draining stream.
Threshold runoff represents the storage capacity of the stream to accept runoff at a level of minor flooding.
Assuming *linear response* of basins to rainfall excess, threshold runoff may be calculated under the following equality:

\[ Q_p = q_{pR} R A \]

- \( Q_p \) is the bankfull flow at the watershed outlet (cms) – Can be solved by Manning eqn.
- \( q_{pR} \) is the peak of the unit hydrograph of duration \( t_R \), normalized by catchment area (cms/km²/mm) – can be estimated by GIUH
- \( A \) is the catchment area (km²) – GIS Delineation
- \( R \) is the rainfall amount over the duration \( t_R \), or the *threshold runoff* (mm)

*Carpenter et al, J. Hydrology, 1999*
Comments on Bankfull Flow

- Channel cross sections are not resolved with current (e.g., 90-m) DEM.
- Bankfull condition may be identified using morphological field evidence during local stream surveys.
- Use local survey data to develop regional relationships between cross-sectional dimensions and catchment properties (e.g., A).
Bankfull cross-section dimensions (width, depth) vary with catchment size.

$$B_b = \alpha A^\gamma \quad D_b = \varepsilon A^\lambda$$

- Use regional relationships to estimate cross-section at each outlet
- Bankfull flow is a conservative measure of flooding (little damage).
Impact of Regional Relationships

Threshold Runoff (eq.1)

\[ R = \frac{Q_p}{\{q_p R A\}} \]

Bankfull Flow:

\[ Q_p = \frac{1}{n} B_b D_b^{5/3} S_c^{0.5} \]
Relationship of Threshold Runoff to FFG

Threshold Runoff is a characteristic (non-varying) of the watershed. This is a **one-time** calculation for a given watershed. TR is computed for rainfall durations of 1-, 3-, and 6-hour to compute the 1-, 3-, and 6-hr FFG.

FFG is computed on a **real-time** basis considering up-to-date soil water content. Soil water content greatly influences FFG.
Delineation of flash flood watersheds for CARFFG based on GIS processing of 90-m SRTM DEM.

**Threshold Runoff** (TR) is defined in a physically-based manner with hydrologic principles.

TR employs *bankfull discharge* as flow associated with flooding conditions, and *geomorphologic unit hydrograph* to obtain characteristic peak catchment response to uniform rainfall of given duration.

TR formulated in terms of catchment properties (A,L), and cross-sectional dimension (Bb, Db), which are estimated based on regional relationship with catchment properties.

