Hydro13A v.22 Users Guide

RUNOFF METHODS

Per ALDOT GFO 3-45, *Acceptable Methods for Estimating Peak Runoff for an Unregulated Watershed*, the rational method is used to predict runoff for up to 200 acres for both urban and rural areas. USGS regression equations are used to estimate peak runoff for both urban and rural drainage areas larger than 200 acres. The first sheet titled "Flow Chart", shows the steps needed to follow these methods.

RATIONAL METHOD

The rational method multiplies drainage area (acres) by the intensity of the rainfall (in./hr) to estimate total rainfall; which, although dimensionally is acre-inch/hour, converts to 1.00833 cfs of rainfall. This product is then multiplied by a runoff coefficient, C, to get the projected peak runoff (cfs). A careful selection of C is essential to obtain good results for the peak flow.

Kirpich time of concentration, t_c

The FHWA's *Urban Drainage Design Manual*, HEC 22, defines the time of concentration, t_c, as *the time for runoff to travel from the hydraulically most distant point in the watershed to a point of interest within the watershed. This time is calculated by summing the individual travel times for consecutive components of the drainage system*. The hydraulically most distant point is not necessarily the same as the most distant point to the drainage divide as is often assumed. The t_c depends on the flow path length, type of flow, difference of elevation, surface geometry and cover. Three or four check paths are sometimes needed to discover the one with the longest flow time.

The Kirpich time of concentration, t_c, calculation spreadsheet is provided to facilitate the flow time calculations for the different types of overland (sheet) and channel flows based upon the Kirpich formula with pertinent modification factors. This worksheet has computational blocks for up to four different flow paths from the periphery of the drainage area to the basin outlet. Each block has columns for up to five different flow path segments if needed. Each segment flow time is calculated on a vertical column. The basic Kirpich formula flow time is computed for each path segment, which then is multiplied by a modification factor to get the modified segment flow time. The modified segment flow times are summed horizontally on the bottom line to get the total time of concentration for that flow path. Overland flow is considered to last a maximum of 300 feet unless the surface is paved or cannot erode. The longest flow time from the periphery is the t_c for the entire drainage area. Note that the t_c is a time and not a length.

Sometimes the longest path flow time is through a lake or swamp. The velocity can be estimated by the wave equaton $V_w = (g \times D_m)^{0.5}$ where V_w is ft/sec, g = 32.2 ft/sec^2 and D_m is the mean depth, ft, of the lake or reservoir. This equation can be used for a swamp except where vegetation or debris is so thick so that there if less than 25 % open water; otherwise, the Manning's equation may be more applicable. Generally V_w will be from 8 to 30 fps. For example, for a 700' thalweg through a lake with an average depth of 10', the V_w is $(g \times 10)^{0.5}$ or 17.9 fps. The flow time through the lake is 700/17.9 which equals 39 sec or 0.65 minute. The time of concentration, t_c, sheet does not have a computation for a flow path through a lake, but this time is added to the t_c for the rest of the flow path to give the total t_c through that path.

Impervious area, IA

An impervious area is an area impenetrable to water. The Impervious Area, IA, spreadsheet is provided for the computation of impervious area, IA, (acres) for use with the runoff coefficient C computation. Since all natural drainage areas are different, this sheet is generic and can be customized for a specific drainage area. The impervious area is the sum of areas of roofs, roads, sidewalks or rock outcrops which can be field measured or scaled off photographs. Permanent water covered surfaces should be considered as impervious areas with a C value of at least 0.95 and preferably 1.00 since the infiltration rate at the bottom of the stream, pond or lake will not be noticeably affected by direct rainfall.

Composite C value

The Composite (weighted) C value sheet has three parts. The first is general project information at the top. The second is part is Part A. On Part A, the C value for each major soil subarea of the drainage area or AOI (Area of Interest on the web soil survey) is estimated, and the spreadsheet computes the composite Soil C (See *Determination of Runoff Coefficient C with the Web Soil Survey* on the Hydraulic

Group Design Resources intranet website for further information, and also see the Flow Chart).

On the third part, Part B, the impervious area is subtracted from the total AOI to get the pervious soils area. The impervious area, acres, typically has a high runoff coefficient C such as 0.85 to 0.95. The spreadsheet then multiplies the impervious area C times the impervious area and separately the pervious soils C by the major soils subareas' sums, adds the two C x A products and divides the sum by the total of the major soils' subareas. The quotient is the composite C for the drainage area.

Rational Method Runoff Values Worksheets

Each of the 23 selected weather stations has a separate rational method runoff spreadsheet already set up with three unique coefficients for each of its seven intensity equations. The nearest pertinent weather station to the project site should be used for the intensity equations. The worksheet should be identified with the project data and date. This is important data because without this information the project location might be unidentifiable by the time several months have passed. To obtain the peak flow runoff the drainage area, A, runoff coefficient, C, and time of concentration, t_C, are entered directly on the selected rainfall station sheet, and the intensities and peak runoff values are shown below.

REGRESSION EQUATIONS

10-85 % Slope sheet

The 10-85 % channel slope is needed to compute lag times for the regression equations that fit within the minimum and maximum area limits shown on each of the three regresson equation spreadsheets. This worksheet takes 10 % and 85 % of the distance from the outlet to the periphery of the drainage area and computes the channel slope between those points as ft/mile.

Lagtimes

Lagtimes are necessary for hydrograph generation (but not for peak flows' estimation). Lagtime for the regression equations is the time, in hours, from the centroid of the rainfall excess to the centroid of the resultant runoff hydrograph. For the rational method it is the time of concentration from the start of the rainfall to the peak of the rational method hydrograph.

Lagtimes for the regression equations are computed by equations from the 1988 USGS report *Estimating Flood Hydrographs and Volumes for Alabama Streams*, Water Resources Investigations Report 88-4041. This is the only report used to estimate both rural and urban lagtimes. This report uses impervous area (IA) for the urban equations' lagtime. Note that the later USGS reports use percent developed (P D) for peak urban streamflow. Lagtime computations are at the bottom of the regression equations' spreadsheets.

The fall line represents the farthest distance vessels could navigate up the rivers before locks and dams were built. The fall line separates the coastal plain from the other four physiographic provinces of the state and is approximately the southern and western boundary of flood region 1. The fall line is shown specifically on Figure 1 of the Flood Regions spreadsheet.

The rural regression equations' sheets have lagtime computations available for locations both north and south of the fall line, but for the opposite location relative to the fall line used for the peak streamflows, lagtimes and USGS estimated volumes are meaningless. To deselect the unapplicable lagtime computations and the associated USGS estimated volumes, leave the DA for the lagtime computations blank.

The urban regression equations' lagtimes and USGS estimated volumes are statewide except for flood region 3 as shown on Figure 2 of the Flood Regions sheet. Rural equations should be used for urban sites located in flood region 3. The location of the fall line is irrelevant for urban regression equations.

All the rural regression equations' lagtimes depend upon drainage area (sq mi) and the 10-85 % channel slope S (ft/mile). The urban regression equations' lagtimes additionally depend upon the percent imperviousness, IA.

The USGS estimated flood volume as inches depends on peak flow and is indirectly generalized from a family of hydrographs which is a function of peak flow, lagtime and drainage area, and is shown as inches at the bottom of each regression equation spreadsheet for each return period. The standard error of estimate is plus or minus 23.2 percent. To convert inches to cubic feet, the inches are divided by 12 and multiplied by the square feet of the watershed.

Rural Regression Equations' Regions

For large and small rural streams the equations from *Magnitude and Frequency of Floods in Alabama*, *2015*, USGS Scientific Investigations Report 2020-5032 are used. The report divides the state into four flood regions which are shown on the right side of the Flood Regions Sheet. Each region has its own equations and area range with recurrence intervals of 2, 5, 10, 25, 50, 100, 200 and 500 years. The flood regions used for the rural regression equations are slightly different from the earlier regions shown by the older *Magnitude and Frequency of Floods in Alabama, 2003*: USGS Scientific Investigations Report 2007-5204; one streamgage was moved from region 1 to region 2, and another was moved from region 4 to region 3. These new regions are shown on the right side of the Flood Regions sheet as the Magnitude and Frequency of Floods in Alabama, 2015. These new regions have no effect on the Small Rural Regression peak flow equations since the small rural peak flow equations are statewide.

2020 Large Rural Regression Equations.

The lower area limit for the large streams' regression equations is five square miles because that is where they become more applicable than the small rural streams regression equations. The upper area limit for each region is different and is listed on the spreadsheet. The drainage area (DA) as sq mi is the only parameter needed to compute peak streamflows for a region. These equations should not be used where dams, detention or channelization have a significant effect on peak streamflows. The percent developed (P D) must be less than 20 per cent.

To use the spreadsheet the project data is entered which is similar to the rational method spreadsheets. The region is determined from the 2015 Regions map on the Flood Regions sheet (the map on the right side of on the Flood Regions sheet). The drainage area as square miles is entered, and the peak flow column for the applicable region then shows the peak streamflows for eight recurrence intervals from 2 to 500 years (the flows shown for other regions do not apply to the region of concern).

The location of the fall line shown on Figure 1 of the Flood Regions sheet is necessary for the rural regression equations' lagtime computations, USGS estimated flood volumes, and hydrograph generation. The rural regression lagtimes depend on the drainage area, the 10-85 % slope, and the location north or south of the fall line.

At the bottom part of the sheet are lagtime results for locations either north or south of the fall line and the USGS generalized estimated volume of runoff. To deselect the lagtime computation for the unapplicable location relative to the fall line, leave its drainage area blank under lagtime equations.

Percent Developed, P D sheet

Development could be any pavement, manmade structure or land disturbance that would cause an increase of runoff for a local area. This includes yards, roofs, pavement, etc. covered by subdivisions, downtown areas, industrial areas, or recently cleared land areas. This sheet is used to calculate the P D for the urban regression equation's peak streamflows and lagtime.

The percent developed (P D) as percent is the percentage of the drainage area covered by any kind of development. A P D of at least 20 percent is required for an area to be considered urban. The sum of the developed areas is divided by the total area and multiplied by 100 % to get the P D. The P D spreadsheet has space to list the developed areas and make and document the P D computations.

2020 Small Rural Regression Eq.

Magnitude and Frequency of Floods in Alabama, 2015, USGS Scientific Investigations Report 2020-5032 is used to estimate floods for small rural drainage areas from 0.13 sq mi (83.2 ac) up to 14 sq mi statewide. However, by GFO 3-45 the rational method is used for up to 200 acres (0.31 sq. miles), which makes 200 acres the acceptable lower limit for the small rural regression equations. The accuracy of the small rural regression equations annual exceedance probability is improved over the large rural regression equations for up to 5 sq mi so that is the upper preferred area limit for the small rural streams' equations.

A single set of peak streamflow equations with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years applies for the small rural streams statewide (all four regions). The only parameter needed to compute flows is the DA as sq mi. A small rural area has a P D of less than 20 percent, and the P D will need to be computed or estimated to make sure the small rural equations apply. Channelization and backwater must not significantly affect the stream for the small rural regression equations to apply.

To use the spreadsheet the project data is entered which is similar to the rational method spreadsheets. The P D is checked or estimated to see if the urban regression equations could apply. Drainage area as square miles is entered on the upper part of the sheet. The peak flow column then shows the peak streamflows for the eight recurrence intervals.

For lagtime computations and hydrograph generation the location north or south of the fall line is significant as it is with the large rural equations. These rural lagtimes depend on the drainage area, the 10 - 85 % slope, and the location north or south of the fall line.

At the bottom part of the sheet are the lagtime results for locations either north or south of the fall line. To deselect the lagtime computation for the unapplicable location relative to the fall line, leave its drainage area blank under lagtime equations.

The USGS estimated volume as inches is also shown for each return period.

2010 Urban Regression Equations.

Urban regression equations are used to estimate flood flows for urban drainage areas from 1 to 43 sq mi from *Magnitude and Frequency of Floods for Urban Streams in Alabama, 2007*: USGS Scientific Investigations Report 2010-5012. For practical use this lower limit is extrapolated down to 0.31 sq mi (200 acres) to the upper limit of the rational equations to compute urban flood flows. Twenty percent is the minimum P D required for the urban equations to be applicable. The equations require area as sq mi and percent developed (P D) to yield peak streamflow.

A single set of urban equations for Regions 1, 2, and 4 are used with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years. These flood regions are from the 2003 USGS report and are shown as Figure 2 (the middle chart on the Flood Regions sheet). Region 3 has no urban equations because the small and large rural equations for Region 3 give better estimates of flood flows. Flood Region 3 is basically the blackbelt region of the coastal plain which has soils that effectively seal over when thoroughly wet. The DA must not be significantly affected by dams, detention storage, hurricane storm surges or substantial tidal fluctuations

To use the spreadsheet the project data and date are entered which is similar to the rational method spreadsheets. Drainage area as square miles and the P D are entered on the upper part of the sheet. The peak flow column then shows the urban peak streamflows for eight recurrence intervals for regions 1, 2, and 4 shown on the 2003 USGS report.

The lagtime computation results are shown below the peak stream flow computations. To deselect the lagtime computations enter zero for the DA. The urban lagtime computations depend on the area, slope, and percent impervious, IA %. The impervious area IA spreadsheet used for the computation of the composite C for rational equations can be used to compute the impervious area IA %. The location north or south of the fall line is not relevant for lagtime for urban hydrograph generation since there is only one set of statewide urban lagtime equations. The generalized USGS estimated volume as inches is also shown for each return period.

Hydrograph

A spreadsheet is provided for the average statewide dimensionless Alabama hydrograph based on the 1988 report *Estimating Flood Hydrographs and Volumes for Alabama Streams,* USGS Water Resources Investigations Report 88-4041. This hydrograph is used to estimate a runoff hydrograph at an ungaged site for a specific recurrence interval. The peak flow and lagtime, L T, are required to be entered. The L T is needed to compute the time coordinates of the dimensionless hydrograph. The hydrograph is used with the computed lagtime for the regression equations, or with the time of concentration for the rational method.. .

Runoff Volume

The trapezoidal rule is the preferred method used to calculate the total volume of flow (cubic feet) under the hydrograph on the Runoff Volume sheet. Direct rainfall runoff is the volume of runoff which results from the design storm. The base flow is subtracted from the calculated total volume to obtain the direct rainfall runoff.

An estimated method for flood volume as total depth of flow is from USGS Water Resources Investigations Report 88-4041. This depth is estimated on the Runoff Volume sheet as inches which includes base flow and is estimated from the peak discharge (cfs), L T (hrs), and drainage area (square miles); however, this method has a standard error of estimate compared to observed runoff volumes of plus or minus 23.2 %. This method is also shown at the bottom of the rural and urban equations worksheets.

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