

CHAPTER 3

HYDROLOGY



NOTE: For trunkline projects, direct questions and comments to the Hydraulic Unit Supervisor, Environmental Services Section.

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Table of Contents

3.1	INTRODUCTION/PURPOSE.....	3-4
3.2	DEFINITIONS.....	3-5
3.3	POLICY	3-8
3.3.1	EGLE	3-8
3.4	HYDROLOGIC ANALYSIS	3-9
3.4.1	Data Collection and Evaluation of Runoff Volume and Peak Discharge Factors.....	3-9
3.4.2	Rainfall Data and Recurrence Interval	3-9
3.4.3	Hydrologic Flood Flow Development	3-10
3.4.4	Documentation.....	3-10
3.5	HYDROLOGIC METHOD SELECTION.....	3-11
3.5.1	Hydrologic Analysis Procedure Flow Chart.....	3-11
3.5.2	Rainfall Distribution.....	3-12
3.5.3	Ponding Factors.....	3-14
3.6	DESIGN GUIDANCE AND PROCEDURE.....	3-15
3.6.1	Rational Method.....	3-15
3.6.1.1	Application.....	3-15
3.6.1.2	Rational Method Equation	3-15
3.6.1.3	Parameters.....	3-16
3.6.1.3.1	Time of Concentration (T_c).....	3-16
3.6.1.3.2	Common Issues Related to T_c	3-17
3.6.1.3.3	Rainfall Intensity (i).....	3-18
3.6.1.3.4	Runoff Coefficient (C).....	3-18
3.6.2	Rational Method Procedure	3-19
3.6.3	Rational Method – Example Problem.....	3-19
3.6.4	Other Hydrograph Methods	3-21
	References.....	3-23

Figures

Figure 3-1.	Representation of Hydrograph, Hyetograph, and Rainfall Excess	3-6
Figure 3-2.	Hydrologic Selection Method Flow Chart	3-12
Figure 3-3.	MSE3 and MSE4 distributions (Watkins et al., 2026).....	3-13
Figure 3-4.	Rainfall distribution zones in Michigan (Watkins et al., 2026)	3-13

Tables

Table 3-1. AEP and ARI Relationship	3-9
Table 3-2. K Coefficient Based on Flow Types	3-17
Table 3-3. Runoff Coefficients for Rational Formula.....	3-18
Table 3-4. Weighted C Values	3-20
Table 3-5. Computation of Weighted C Values	3-20
Table 3-6. T _c Calculations	3-20
Table 3-7. Other Hydrograph Methods.....	3-22

Appendices

Appendix 3-A	Symbols and Acronyms
Appendix 3-B	MDOT Rainfall Intensity-Duration-Frequency Development
Appendix 3-C	Wetland Hydrology – The Water Budget
Appendix 3-D	Flood Hydrograph Development

If you require assistance accessing this information or require it in an alternative format, contact the Michigan Department of Transportation's (MDOT) Americans with disabilities Act (ADA) coordinator at Michigan.gov/MDOT-ADA

3.1 INTRODUCTION/PURPOSE

Hydrology is defined as a science dealing with the interrelationship between water on and below the Earth's surface and in the atmosphere. For this manual, hydrology is defined as estimates of flood magnitude as the result of precipitation. In the design of highway drainage structures, floods are considered in terms of peak runoff or discharge in cubic feet per second (cfs) and hydrographs are considered in terms of discharge versus time. For structures designed to control the volume of runoff, such as detention storage facilities (Chapter 8, Stormwater Storage Facilities for Flood Control) or where flood routing through culverts is used, the discharge hydrograph is needed. Wetland hydrology for the design of weather water budgets is addressed in **Appendix 3-C**.

The analysis of the peak runoff rate, runoff volume, and time distribution of runoff flow is fundamental to the design of drainage facilities. Errors in the analysis result in a structure that is either undersized, causing more drainage problems, or is oversized, costing more than necessary. However, a hydrologic analysis is only an approximation. The relationship between the amount of precipitation into a drainage basin and the amount of runoff from the basin is complex and too little data are available on the factors influencing the rural and urban rainfall-runoff relationship to expect exact solutions.

3.2 DEFINITIONS

Annual Exceedance Probability (AEP) - The probability that the magnitude of the random variable (e.g., annual maximum flood peak) will be equaled or exceeded each year, often expressed as a percentage.

Annual Recurrence Interval (ARI) - The average time interval between occurrences of a hydrologic event of a given or greater magnitude, usually expressed in years. The ARI is the reciprocal of the AEP of a hydrologic event.

Antecedent Moisture - Water stored in the watershed prior to the start of rainfall.

Base Flow - Normal or dry weather flow in an open channel or stormwater system.

Depression Storage - The natural depressions within a watershed which store runoff.

Design Discharge - The peak rate of flow (in cubic feet per second) for which a drainage facility (bridge, culvert, pipe, storage facility, etc) is designed and expected to accommodate without exceeding the adopted design standards.

Design Storm - A selected storm of a given frequency (expressed as an AEP event) and duration used for designing features of a storm system including storm sewers, open channels, culvert, bridge, pump station, storage facilities, etc.

Digital Elevation Model (DEM) - A representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects.

Drainage Area - The surface area draining to a given point producing runoff. Drainage area does not include non-contributing areas such as lakes, wetlands, potholes, etc.

Evapotranspiration - Surface evaporation of water and transpiration through plants.

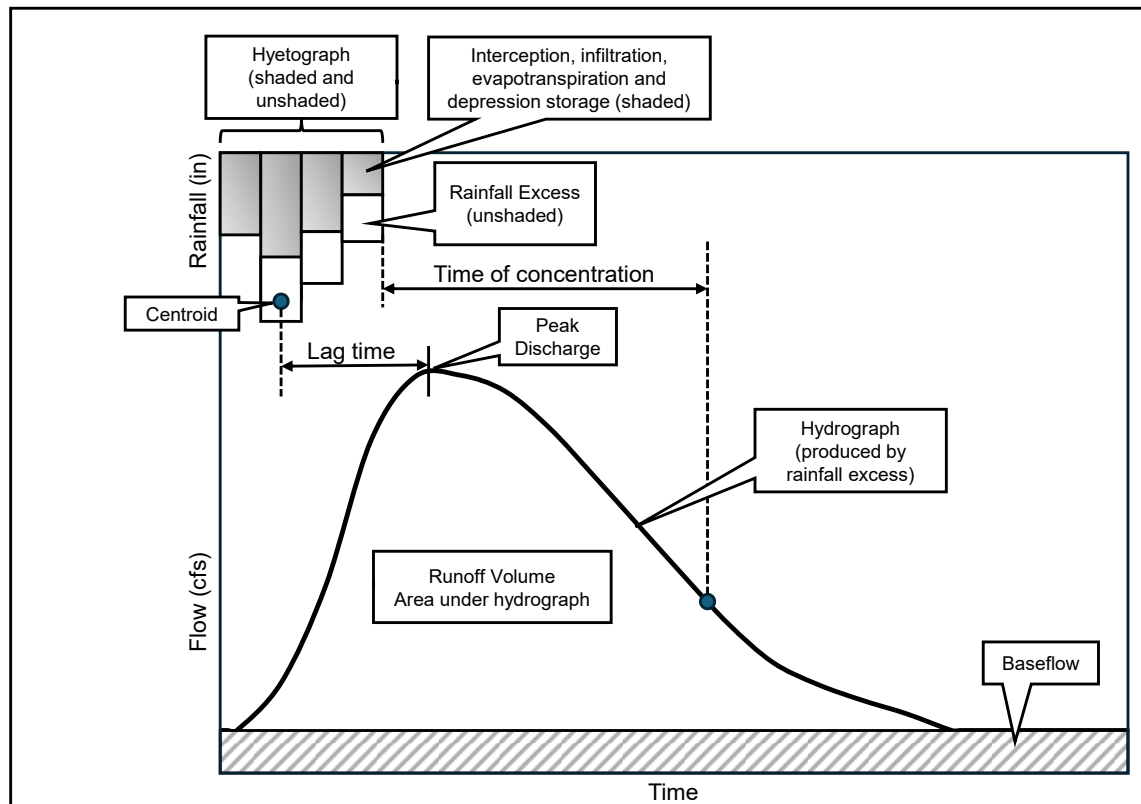
Gaged Sites - A location where instruments measure the depth and flow of the water in a stream and the stream flow record is long enough to be statistically analyzed to estimate peak discharges. Most sites in this category have tributary areas greater than two square miles.

Harmful Interference - Causing an increased stage or change in direction of flow of a river or stream that causes, or is likely to cause, any of the following: i) Damage to property, ii) A threat to life, iii) A threat of personal injury, iv) Pollution, impairment, or destruction of water or other natural resources. MCL 324.3103, R 323.1311g

Hydraulic Roughness - A composite of the physical characteristics which influence the depth and flow of water across the surface, whether natural, channelized, or in a pipe.

Hydrograph - A plot of flow versus time. Refer to **Figure 3-1**.

Figure 3-1. Representation of Hydrograph, Hyetograph, and Rainfall Excess



Hydrologic Unit Code (HUC) - A numerical code applied to watersheds delineated by USGS using a nationwide system based on surface hydrologic features.

Hyetograph - A graph of the rainfall intensity (or depth) versus time over a watershed. Refer to **Figure 3-1**.

Infiltration - The process of water on the ground surface entering the soil.

Interception - The removal of water from runoff that wets and adheres to objects above ground such as buildings, trees, and vegetation.

Lag Time - The time measured from the centroid of the excess rainfall to the peak of the hydrograph. Refer to **Figure 3-1**.

Peak Discharge - The maximum flow rate of water in cubic feet per second passing a given point as a result of a rainfall event or snowmelt; sometimes called peak flow.

Probability of Exceedance - The probability that the magnitude of the random variable (e.g., annual maximum flood peak) will be equaled or exceeded over a given time period, expressed as a percentage.

Rainfall Excess - The portion of rainfall that causes direct runoff. It equals the total rainfall minus the interception, depression storage, evapotranspiration, and infiltration. Refer to **Figure 3-1**.

Runoff Volume - The area under a hydrograph minus the base flow.

Stage - The height of the water surface above a specified elevation datum at a specific location.

Time of Concentration (T_c) - The time for water to flow from the hydraulically most distant point in the watershed to the outlet or discharge point.

Ungaged Sites - Sites where no recorded stream flow data are available.

Unit Hydrograph - The direct runoff hydrograph resulting from a rainfall event that has a specific temporal and spatial distribution. A unit hydrograph lasts for a specific duration and has unit volume. When a unit hydrograph is shown with units of cubic feet per second, it is implied that the ordinates are cubic feet per second per inch of direct runoff.

Symbols and acronyms used in this chapter are listed in **Appendix 3-A**.

3.3 POLICY

Refer to Chapter 2, Policy and Procedures for Federal and State policies.

For the State of Michigan policy on floodplain management, refer to the State Executive Order 1977-4, titled “State Flood Hazard Management Plan” referenced in Chapter 2, Policy and Procedures, Appendix 2-D.

3.3.1 EGLE

For drainage areas greater than two square miles, Part 31 rules require a hydraulic analysis for highways that encroach on the floodplain, both transversely and longitudinally. The design is required to permit conveyance of floods up to and including the 1% annual exceedance probability (AEP) (100-year) flood without causing harmful interference. Refer to Chapter 6, Bridge Hydraulic Design, Appendix 6-D for more information.

3.4 HYDROLOGIC ANALYSIS

The following is a summary of components needed to complete a hydrologic analysis. For a more complete discussion of these concepts and others related to hydrologic analysis, refer to FHWA HDS 2 (2024) and *AASHTO Drainage Manual* (2014).

3.4.1 Data Collection and Evaluation of Runoff Volume and Peak Discharge Factors

For hydrologic analyses, evaluate the following factors that affect runoff volume and peak discharge:

- Drainage basin characteristics including size, shape, slope, land use, geology, soil type, surface infiltration, and storage
- Stream channel characteristics including geometry and configuration, or natural and artificial controls
- Meteorological characteristics such as precipitation amounts, type (rain, snow, hail, or combinations thereof), and time rate of precipitation (hyetograph)
- Historic flood events of the project area for the hydrology analysis and its effect on existing and proposed structures

3.4.2 Rainfall Data and Recurrence Interval

Hydrologic analysis provides estimates of flood magnitudes as a result of precipitation. The design of hydraulic facilities is determined based on the level of protection set forth in the MDOT Drainage Manual. The level of protection is expressed as a design storm that is based on the AEP. When applied to precipitation, the AEP refers to the probability that a storm of a given volume and intensity occurs within a 1-year period. It is defined as a percentage. For example, a rainfall event that has a 1 in 100 chance of being equaled or exceeded in any given year is described as the 1% AEP event. This approach can be applied to flow, flood level, etc.

AEP is related to annual recurrence interval (ARI). The ARI is the reciprocal of the AEP. The MDOT Drainage Manual uses the AEP terminology. **Table 3-1** describes the relationship between the AEP and ARI based on a 24-hour storm event.

Table 3-1. AEP and ARI Relationship

AEP	ARI
50%	2-year
20%	5-year
10%	10-year
4%	25-year
2%	50-year
1%	100-year

3.4.3 Hydrologic Flood Flow Development

Use the procedures described in this chapter to develop design flow rates and volumes for drainage areas less than two square miles. If the drainage areas are greater than two square miles, the MDOT Hydraulic Unit Supervisor submits a flood discharge request to the Hydrologic Studies Unit of EGLE, and coordinates with other agencies, as necessary, for trunkline projects. For other projects with drainage areas greater than two square miles, request flood discharges from EGLE's website at [Request a Flood Discharge](#). Refer to **Section 3.5**. Discharge estimates from EGLE may no longer be valid 1 year after issuance.

EGLE maintains a database where previous flood discharge requests can be downloaded for reference. Refer to EGLE's website at [Flood Discharge Database](#).

3.4.4 Documentation

Document hydrologic design for MDOT drainage facilities. Often, it is necessary to refer to project design files after the actual construction has been completed, therefore, fully documented results of the hydrologic analysis are required. Documentation is retained in the Hydraulic Unit file, project design file, or on the drainage map plan sheet (refer to MDOT Road Design Manual Sections 1.02.04 and 4.05.10).

Required documentation is based on the hydrologic method. Refer to Chapter 2, Policy and Procedures, Appendix 2-F for the Drainage Study Outline which includes the documentation requirements for Planisware Task 3522. Refer to Chapter 6, Bridge Hydraulic Design, Appendix 6-C for hydraulic report format and required supporting documents for Planisware Task 3520.

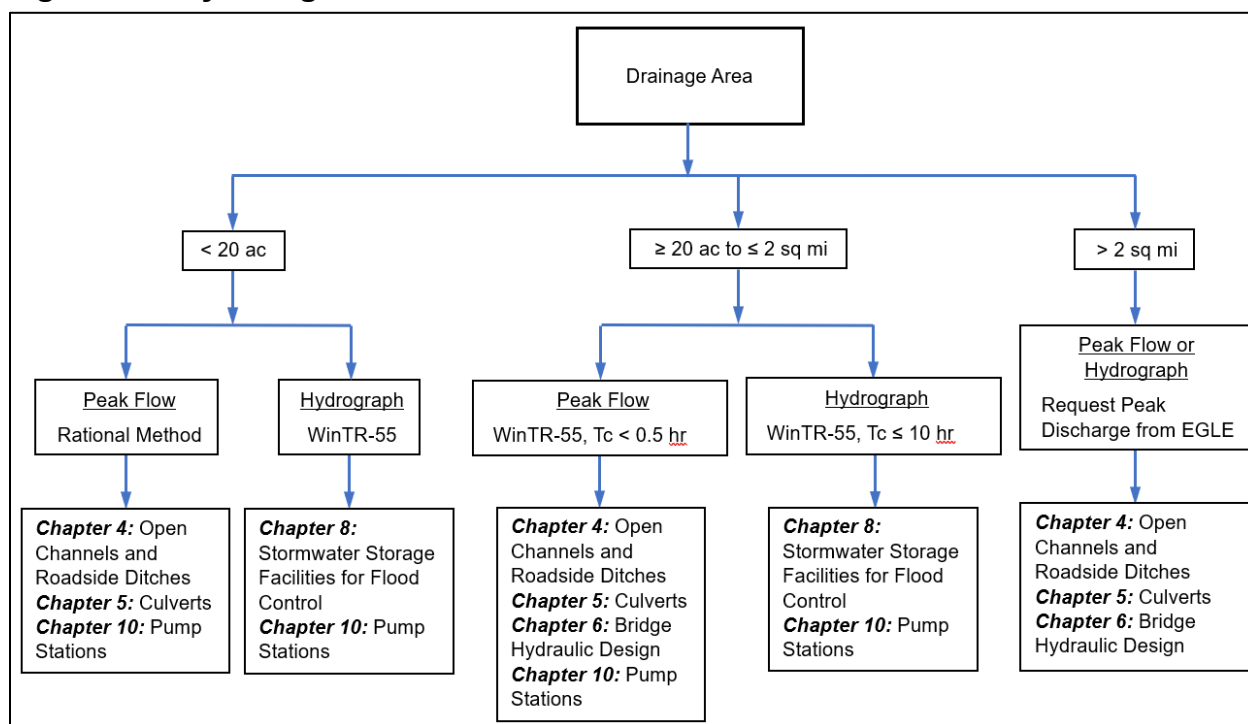
3.5 HYDROLOGIC METHOD SELECTION

Many hydrologic methods are available. The method selected depends on drainage area, time of concentration, and whether a peak flow or a full hydrograph is needed. Several methods are summarized in this section.

- Rational Method (**Section 3.6.1**) – Use Rational Method for peak flow calculations for the following conditions:
 - Pavement drainage design (refer to Chapter 7, Inlet and Enclosed Storm Drainage Systems).
 - For other drainage analysis with drainage areas less than 20 acres.
- Natural Resource Conservation Service's (NRCS) WinTR-55 – Use WinTR-55 for any size watershed. This method produces a peak discharge and flood hydrograph.
 - WinTR-55 is used for peak discharges with a time of concentration less than 10 hours.
 - WinTR-55 can be used to develop a hydrograph used for routing calculations with a time of concentration less than or equal to 10 hours. Use the standard NRCS unit hydrograph with a peak rate factor (PRF) of 300 for watersheds in the lower peninsula and eastern upper peninsula. Use a PRF of 350 for watersheds in the western upper peninsula, including the following counties: Gogebic, Ontonagon, Houghton, Keweenaw, Baraga, Iron, Dickinson, Marquette, and Menominee (Watkins et al., 2026). Refer to **Appendix 3-D** for the dimensionless unit hydrograph with a PRF of 300 and 350.
- For drainage areas equal to or greater than the regulated limit of two square miles by Administrative Rule R 323.1312(a) for Part 31 of NREPA, the design discharges are computed by the EGLE Hydrologic Studies Unit. The methods used for the regulated drainage areas include:
 - EGLE-NRCS method (maximum 20 square miles).
 - Drainage area ratio method.
 - Log-Pearson Type III probability stream gage analysis.
 - State regression equations.
- Alternative hydrologic methods are available but require the approval of the Hydraulic Unit Supervisor. Refer to **Section 3.6.4**.

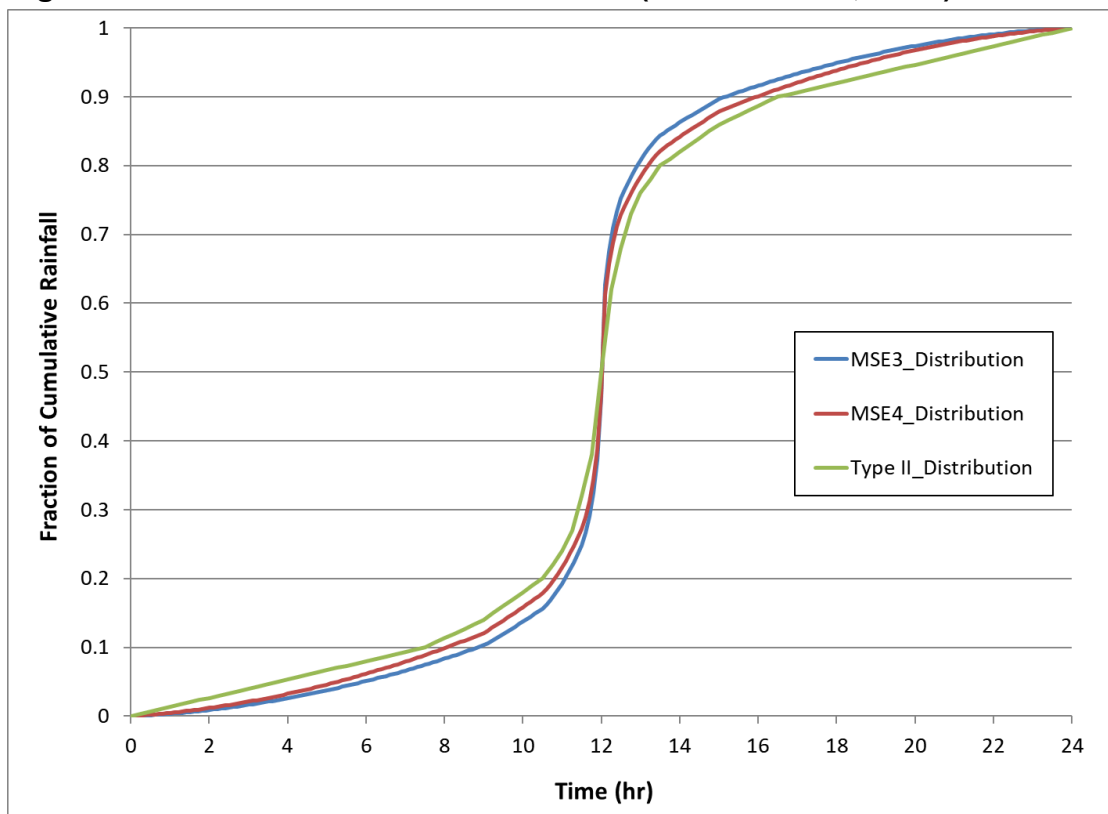
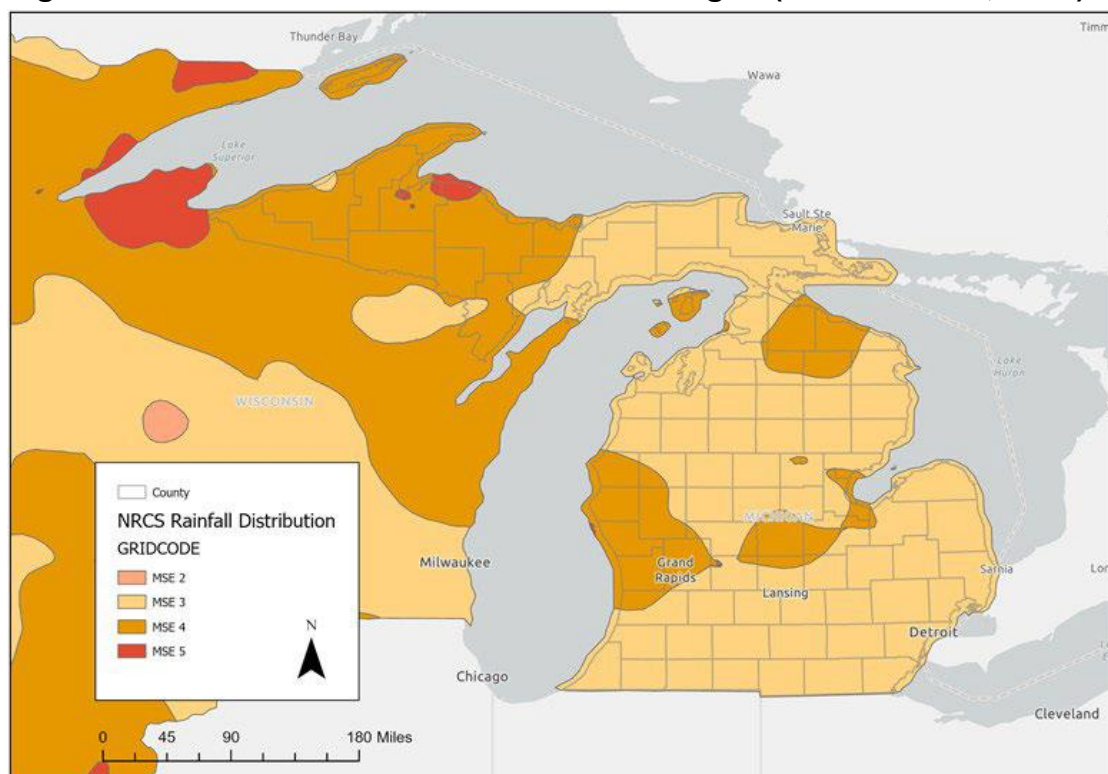
3.5.1 Hydrologic Analysis Procedure Flow Chart

The flow chart shown in **Figure 3-2** identifies the hydrologic method selected for analysis based on area, time of concentration, peak flow, and routing requirements. Document and submit the results to the Hydraulic Unit Supervisor with the Drainage Study per **Section 3.4.4**.

Figure 3-2. Hydrologic Selection Method Flow Chart

3.5.2 Rainfall Distribution

Hydrologic techniques that utilize hydrographs require a design rainfall distribution. In Michigan, the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall with the Midwest and Southeast United States Type 3 (MSE3) or Type 4 (MSE4) temporal distribution as shown in **Figure 3-3** is used. Rainfall distribution zones are shown in **Figure 3-4** with each county assigned either an MSE3 or MSE4 distribution. A county rainfall distribution table is included in **Appendix 3-D**. Atlas 14 total rainfall depths are categorized by township and range (TR) scale. A table of rainfall depths for each design storm assigned to each TR is included on the MDOT website.

Figure 3-3. MSE3 and MSE4 distributions (Watkins et al., 2026)**Figure 3-4. Rainfall distribution zones in Michigan (Watkins et al., 2026)**

3.5.3 Ponding Factors

Refer to Table 10.1 from EGLE's publication "Computing Flood Discharges for Small Ungaged Watersheds" (Sorrell, 2010) for peak discharge reduction factors for ponding within each watershed.

3.6 DESIGN GUIDANCE AND PROCEDURE

3.6.1 Rational Method

Use Rational Method for peak flow calculations for the following conditions:

- Pavement drainage design
- For other drainage analysis with drainage areas less than 20 acres

3.6.1.1 Application

Considerations for using the Rational Method are the following:

- Obtain a topographic map (typically USGS 1-meter digital elevation model (DEM) or more recently collected LiDAR DEM data) and define the boundaries of the drainage area in question. A field inspection is necessary to determine if natural drainage divides have been altered.
- To determine the runoff coefficient, C , for the drainage area, consider future changes in land use that may occur during the service life of the proposed facility that could result in an inadequate drainage system.
- Restrictions to the natural flow (creating storage areas) such as highway crossings and dams that exist in the drainage area require investigation. Dams and stormwater control measures may produce conditions that are not reflected in the flows determined by the Rational Method, therefore another method may be warranted.

3.6.1.2 Rational Method Equation

The Rational Method estimates a peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and rainfall intensity for the time of concentration. The rational formula is expressed as follows:

$$Q = CiA \quad (3.1)$$

where:

- Q = peak flow, cfs
- C = dimensionless runoff coefficient (refer to **Table 3-3**)
- i = rainfall intensity for the design storm, in/hr (refer to **Appendix 3-B**)
- A = drainage area, ac

A unique aspect of the Rational Method is the units (English units). One acre-inch/hour is approximately equivalent to 1 cfs, so conversion of the units is not necessary when using the rational formula.

3.6.1.3 Parameters

Estimating peak discharge using the Rational Method is sensitive to the parameters that are used. Following is a discussion of the different variables used in the Rational Method.

3.6.1.3.1 Time of Concentration (T_c)

T_c is the time required for water to flow from the hydraulically most distant point in the watershed to the outlet or design point.

For roadway pavement drainage design, use the following initial T_c :

- 15 minutes for non-depressed roadways
- 10 minutes for depressed roadways or roadways discharging to a pump station
- 10 minutes for sag locations

For bridge deck drainage, calculate the T_c using FHWA HEC-21 (1993). The minimum T_c for bridge decks is 5 minutes.

For other Rational Method calculations, T_c is calculated by estimating the velocity through the various components of the stream network. The method presented expresses velocity in the form:

$$V = KS^{1/2} \quad (3.2)$$

where:

- V = velocity, fps
- K = coefficient depending on the type of flow (refer to **Table 3-2**)
- S = slope of the flow path, %

Three flow types are used based on their designation on USGS topographic maps.

- **Small Tributary:** Permanent or intermittent streams, which appear as a solid or dashed blue line on the topo maps. This also applies to a swamp that has a defined stream channel. Man-made channels and swales on engineering drawings should be considered small tributaries.
- **Waterway:** A travel path as shown by the curves in the contours on a USGS topographic map (such as a valley, swale, or shallow drainage course), but does not have a blue streamline denoting a defined channel. This also applies to a swamp that does not have a defined channel flowing through it.
- **Sheet Flow:** Any overland flow path which does not conform to a defined waterway. Studies have shown that after approximately 300 feet, sheet flow forms shallow concentrated rivulets that are better defined as “waterway” flow. For this reason, sheet flow reach lengths should be terminated at a maximum length of 300 feet. The remaining downstream portion of the reach should be modeled using the “waterway” velocity equation.

The K coefficient for each of these types of flow are shown in **Table 3-2**.

Table 3-2. K Coefficient Based on Flow Types

Flow Type	K
Small Tributary	2.1
Waterway	1.2
Sheet Flow	0.48

When detailed flow velocities are unavailable, the K coefficients, derived by Richardson (1969), are used to estimate velocities. Once the velocity is determined, time of concentration can be computed as:

$$T_c = \sum T_i = \sum \frac{L_i}{60 \times V_i} \quad (3.3)$$

Where:

- T_c = Time of concentration, min
- T_i = Travel time, min
- L_i = Length, ft
- V_i = Velocity for each flow path, fps

In most watersheds all three flow types will be present. Starting at the basin divide, the runoff may proceed from sheet flow to waterway to small tributary, back to waterway again, then small tributary, etc. The T_i for each segment should be computed and then summed to give the total T_c .

It is important that the length used to compute T_i has a uniform slope. As an example, assume a 5,000-foot length of small tributary has a change in elevation of 10.4 feet. This slope of 0.208% produced a T_i of 1.45 hours. However, if it is known that the upper 1,000 feet of this stream falls 10 feet, and the lower 4,000 feet only falls 0.4 feet, this would produce $T_1 + T_2$ for a total T_c of 5.42 hours. Therefore, it is best to sum T_i over the smallest possible contour interval using a topographic map or USGS 1-meter DEM. This interval is enlarged if a visual examination of the topographic map shows a uniform spacing between successive elevation contours.

3.6.1.3.2 Common Issues Related to T_c

Avoid two common errors when calculating T_c . In some cases, runoff from a portion of the drainage area which is highly impervious results in a greater peak discharge than would occur if the entire area were considered. In these cases, adjustments can be made to the drainage area by disregarding those areas where flow time is too long to add to the peak discharge. Sometimes it is necessary to estimate several different T_c to determine the design flow that is critical for a particular application.

The overland flow path is not necessarily perpendicular to the contours shown on available mapping. Often the land will be graded and swales will intercept the natural

contours and drain the water to the streets, which reduces the T_c . A field visit should be made to verify the information presented on the mapping.

3.6.1.3.3 Rainfall Intensity (i)

The rainfall intensity (i) is uniform over a storm time duration equal to the T_c . Obtain Atlas 14 rainfall point precipitation statistics from the NOAA website. Refer to **Appendix 3-B** for instructions to obtain Atlas 14 rainfall information for OpenRoads Designer Drainage and Utilities or hand calculations.

3.6.1.3.4 Runoff Coefficient (C)

Develop a composite C based on the percentage of different surfaces in the drainage area. Apply the composite C procedure to an entire drainage area. Ranges of runoff coefficients for various land uses are provided in **Table 3-3** (Michigan State Administrative Rules R 280.9). The runoff coefficients are used in the Rational Method.

Table 3-3. Runoff Coefficients for Rational Formula

Type of Surface	Runoff Coefficient
Concrete or Asphalt Pavement	0.8 - 0.9
Commercial and Industrial	0.7 - 0.9
Gravel Roadways and Shoulders	0.5 - 0.7
Residential – Urban (Less than 1/2-acre lots)	0.5 - 0.7
Residential – Suburban (Greater than or equal to 1/2-acre lots)	0.3 - 0.5
Undeveloped	0.1 - 0.3
Berms	0.1 - 0.3
Agricultural - Cultivated Fields	0.15 - 0.4
Meadow, Pasture, Forested Areas	0.1 - 0.4

For railroad ballast, assume the same runoff coefficient as Gravel Roadways and Shoulders. Lower runoff coefficients are selected for flat slopes, permeable soils, or pervious pavement. Higher values are selected for steeper slopes and less permeable soils or surfaces. Steep slopes are 2:1 or steeper.

3.6.2 Rational Method Procedure

The Rational Method procedure follows these general steps:

Step 1 Obtain topographic information for the entire area that is contributing runoff. Include drainage area outside of the ROW. Sources include:

- USGS quadrangle maps
- 1-Meter DEM
- County drain maps
- Construction drawings
- Other topographic maps if available

Step 2 Define the drainage boundary to the point where a flow estimate is desired.

Step 3 Define a weighted average “C” value for the tributary area

Step 4 Calculate a T_c to the point where a flow estimate is desired.

Step 5 Determine the rainfall intensity that applies to the calculated T_c and the project location (refer to **Appendix 3-B**).

Step 6 Calculate peak flow, Q , using the equation $Q = CiA$.

A detailed description for using the Rational Method for inlet spacing and storm sewer design is contained in Chapter 7, Inlet and Enclosed Storm Drainage Systems.

3.6.3 Rational Method – Example Problem

The example problem illustrates the application of the Rational Method to estimate peak discharges.

Problem: For a culvert located in Ingham County, Michigan, estimate the maximum rate of runoff to a culvert for the 1% AEP (100-year) and 2% AEP (50-year) storm events.

Step 1 Obtain topographic information
Obtain topographic map and field survey.

Step 2 Delineate the drainage boundary.
The watershed has a drainage area of 20 acres.

Step 3 Calculate weighted C value for drainage area.
From existing land use maps, the land use for the drainage area is estimated to be:

Woods	= 20%
Cultivated Land	= 60%
Pasture	= 20%

Since the watershed contains different types of land uses, a weighted C needs to be estimated from the values in **Table 3-3**.

For the given land uses and average overland slope, the C for woods, cultivated land, and pasture are listed in **Table 3-4**.

Table 3-4. Weighted C Values

Land Use	C Value
Woods	0.20
Cultivated Land	0.40
Pasture	0.20

The following tabulation illustrates the computation of the weighted C.

Table 3-5. Computation of Weighted C Values

Land Use	% of Total Area	Runoff Coefficient	Weighted Coefficient
Woods	20	0.20	0.20 (20/100) = 0.04
Cultivated Land	60	0.40	0.40 (60/100) = 0.24
Pasture	20	0.20	0.20 (20/100) = 0.04

Total weighted C = 0.04 + 0.24 + 0.04 = 0.32.

Step 4 Calculate T_c .

The following lengths and slopes are measured from the topographic maps and field survey obtained in Step 1.

Length of channel flow (upstream) = 400 feet at 0.07950%
 Length of channel flow (downstream) = 600 feet at 0.07576%
 Length of waterway flow = 300 feet at 0.11364%
 Length of sheet flow = 100 feet at 0.07576%
 Average overland slope = 0.1%

The following tabulation shows the T_c calculations, based on the equations in **Section 3.6.1.3.1**.

Table 3-6. T_c Calculations

Flow Type	Length (ft)	Slope (%)	Velocity (fps)	T_c (min)
Small Tributary (upstream)	400	0.07950	0.59	11.3
Small Tributary (downstream)	600	0.07576	0.58	17.2
Waterway	300	0.11364	0.40	12.5
Sheet Flow	100	0.07576	0.13	12.8

T_c is calculated using **Equations 3.2** and **3.3** respectively for each flow type.

For the small tributary (upstream):

$$V = KS^{1/2} = 2.1 * (0.07950\%)^{1/2} = 0.59 \text{ fps}$$

$$T_c = 400 \text{ ft} / (0.59 \text{ fps} * 60 \text{ sec}) = 11.3 \text{ min}$$

For the small tributary (downstream):

$$V = KS^{1/2} = 2.1 * (0.07576\%)^{1/2} = 0.58 \text{ fps}$$

$$T_c = 600 \text{ ft} / (0.58 \text{ fps} * 60 \text{ sec}) = 17.2 \text{ min}$$

For the waterway:

$$V = KS^{1/2} = 1.2 * (0.11364\%)^{1/2} = 0.40 \text{ fps}$$

$$T_c = 300 \text{ ft} / (0.40 \text{ fps} * 60 \text{ sec}) = 12.5 \text{ min}$$

For the sheet flow:

$$V = KS^{1/2} = 0.48 * (0.07576\%)^{1/2} = 0.13 \text{ fps}$$

$$T_c = 100 \text{ ft} / (0.13 \text{ fps} * 60 \text{ sec}) = 12.8 \text{ min}$$

$$\text{Total } T_c = 11.3 + 17.2 + 12.5 + 12.8 = 54 \text{ min}$$

Step 5 Determine rainfall intensity.

The intensity used in the Rational Method is for a rainfall duration equal to the T_c . Follow the instructions in **Appendix 3-B** to obtain the intensity for a 54-minute rainfall.

Since the project location is in Ingham County, the intensities developed from the Atlas 14 – IDF spreadsheet are 2.53 in/hr for the 2% AEP (50-year) storm and 2.86 in/hr for the 1% AEP (100-year) storm.

Step 6 Calculate peak flow using the Rational Equation.

Substituting the appropriate values into the Rational Method, $Q = CiA$:

2% AEP (50-year) peak discharge:

$$Q_{50} = (0.32) * (2.53 \text{ in/hr}) * (20 \text{ acres}) = 16.19 \text{ cfs}$$

1% AEP (100-year) peak discharge:

$$Q_{100} = (0.32) * (2.86 \text{ in/hr}) * (20 \text{ acres}) = 18.3 \text{ cfs}$$

3.6.4 Other Hydrograph Methods

There are other methods available for calculating flow rates in watercourses not under EGLE's floodplain regulatory authority shown in **Table 3-7**. Other methods are useful for complex systems or where fully dynamic routing is required. The majority of these methods can be used to size or confirm sizing of storage facilities (refer to Chapter 8, Stormwater Storage Facilities for Flood Control). Contact the Hydraulic Unit Supervisor for approval prior to their use on MDOT projects.

Table 3-7. Other Hydrograph Methods

Method	Author	Typical Applications
EPA SWMM (Stormwater Management Model)	Environmental Protection Agency	• Urban watersheds • Consider effect of storage in channels, pipes, and basins • Surcharged storm drainage systems
WinTR-20	USDA	• For $T_c > 10$ hours • Urban or rural watershed • Runoff and routing
HEC-HMS	U.S. Army Corps of Engineers	• Urban or rural watershed • Consider effect of storage in channels and basins

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