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Technical Memorandum

City of Austin Drainage Criteria Manual (DCM) Updates Rainfall Distribution Evaluation

FREESE AND NICHOLS

Freese and Nichols, Inc.
10431 Morado Circle
Building 5, Suite 300
Austin, Texas 78759

STATE OF TEXAS
JENNIFER J. WALKER
85619
LICENSED PROFESSIONAL ENGINEER

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Contact **Watearth** Principal
Jennifer J. Walker PE, DWRE, ENV SP, CFM, QSD
TX Firm License Number #11279
106 E. Sixth Street, Suite 900
Austin, TX 78701
512.557.1028
jwalker@watearth.com

Introduction

This Technical Memorandum documents the rainfall distribution analysis performed for this project. HEC-HMS models are used to analyze *National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Point Precipitation Frequency Estimates* (*NOAA Atlas 14*) data, which includes design rainfall depths higher than those in the City of Austin's current Drainage Criteria Manual (DCM). While the Natural Resources Conservation Service (NRCS) rainfall distributions are widely used throughout the United States and the NRCS Type III distribution has historically been used within the City of Austin, these legacy distributions are being replaced by the NRCS with rainfall distributions based on *NOAA Atlas 14* precipitation frequency data (from *Design Rainfall Distributions Based on NOAA Atlas 14 Rainfall Depths and Durations* by Merkel et al., 2015).

While 24-hour rainfall data was historically available for use in the NRCS methodology such as the Type III Storm currently used for City of Austin watersheds, more detailed rainfall data was not consistently recorded for shorter duration events. Additionally, the NRCS methodology was developed to apply to a broad range of urban and rural watersheds nationwide with limited rainfall data input required. With the availability of various duration rainfall depths for a given frequency storm, other rainfall distribution methods besides recorded gauge data and the NRCS Type III Storm can be considered and tailored to local watersheds.

Given that a rainfall event of a particular frequency will vary in duration and intensity, different rainfall distributions may yield different peak flow and hydrograph results for a given precipitation depth. Incorporating the *NOAA Atlas 14* precipitation data into the *Austin Drainage Criteria Manual (DCM)* presents a unique opportunity to also evaluate the effect of rainfall distribution on HEC-HMS hydrology modeling results in terms of watershed peak flows and peak flows and detention volumes required to mitigate development and redevelopment projects.

The purpose of this analysis is to evaluate whether various rainfall distributions have a meaningful effect on the peak flows and potential required detention volumes for land development in City of Austin watersheds and ultimately to determine if and how the *DCM* should be updated with regards to rainfall distributions. Specifically, the analysis evaluates the effect of rainfall distribution on 25-year and 100-year peak flows and potential effect on detention volumes when using *NOAA Atlas 14* precipitation data. The peak flows resulting from each of the rainfall distributions are analyzed at four locations in Walnut Creek using the existing land use (EX LU) HEC-HMS model. The effect of the rainfall distributions is also evaluated for pre-development and post-development peak flows and estimated detention volumes for three actual development scenarios of different sizes: small, medium, and large. Rainfall distributions include:

- Distribution 1 – National Engineering Handbook (NEH) Distribution;
- Distribution 2 – HEC-HMS Frequency Storm Distribution;
- Distribution 3 – NRCS Type III Distribution;
- Distribution 4 - New Fixed Distribution Similar to NRCS Type III.

Methodology

This section describes the procedures used to calculate peak flows and hydrographs for the four different distributions listed above using the *NOAA Atlas 14* rainfall data. Peak flows and hydrographs are developed in HEC-HMS for all modeled distributions and the HEC-HMS Frequency Distribution and NRCS Type III Storm (Distribution 3) are developed directly in HEC-HMS. The NEH Distribution 1 is developed in Win-TR20 and Distribution 4 (New Fixed Distribution Similar to NRCS Type III) is developed in a spreadsheet based on the NEH Distribution.

HEC-HMS version 3.0.1 is used for consistency with the Walnut Creek effective HEC-HMS model obtained from the City of Austin's Watershed Protection's FloodPro website. The 25-year and 100-year, 24-hour events are modeled for all distributions for Walnut Creek and the small, medium, and large sites. Rainfall data and distributions, methodology for the four distributions, and HEC-HMS model development and reporting locations are discussed in the following sections of this memorandum.

Precipitation Data and Distributions

Precipitation Data

The rainfall distribution analysis documented in this memo was conducted concurrently with Freese and Nichols' study to produce recommended Atlas 14 rainfall depths for the City of Austin. Because the two analyses are independent of one another, the distribution analysis was based on NOAA Atlas 14 rainfall data at Austin City Hall (30.2648° N, 97.7472° W), obtained using the National Weather Service Hydrometeorological Design Studies Center Precipitation Frequency Data Server (PFDS). The 25-year, 24-hour and 100-year, 24-hour rainfall depths at this location are 8.86 inches and 12.70 inches, respectively (Table 1).

Since precipitation durations were analyzed independently in *NOAA Atlas 14*, there are cases when the precipitation intensity between successive durations does not uniformly decrease as duration increases. In developing a design rainfall distribution, this factor is of critical importance. Unsmoothed data is used for the rainfall distribution and HEC-HMS modeling analysis to maintain the integrity of the original precipitation data and limit the effect of smoothing curve/fit assumptions on the results. While unsmoothed data may result in frequency storm hyetographs with discontinuities in intensity, it is not likely to significantly affect the shape of runoff hydrographs. Additionally, smoothing of rainfall data and development of equations is being performed by Freese Nichols, Inc. (FNI) as a separate task order on this project. If necessary, smoothed data for the selected distribution will be incorporated into the analysis once selected.

The point precipitation frequency estimates for unsmoothed data for rainfall depths for the two-year through 500-year frequencies are provided in Table 1 below. While only the 25-year and 100-year frequencies are modeled, the two-year through 500-year is used for the NEH Distribution 1 to facilitate development of Distribution 4 New Fixed Distribution Similar to NRCS Type III. Tables for all four distributions are included in Appendix A and graphical illustrations of the S-Curve hydrographs are included in Figures 1 and 2 at the end of this section.

Table 1: Point Precipitation Frequency Estimates for Unsmoothed *NOAA Atlas 14* Data at Austin City Hall (Latitude 30.2648° and Longitude -97.7472°)

Duration	Rainfall (in)							
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year
5-min	0.53	0.67	0.80	0.98	1.13	1.28	1.45	1.70
10-min	0.84	1.07	1.27	1.57	1.80	2.05	2.32	2.68
15-min	1.06	1.35	1.60	1.96	2.25	2.55	2.89	3.36
30-min	1.50	1.91	2.26	2.75	3.14	3.56	4.04	4.74
60-min	1.97	2.52	2.99	3.68	4.21	4.80	5.49	6.51
2-hr	2.43	3.15	3.82	4.82	5.66	6.61	7.71	9.36
3-hr	2.70	3.54	4.34	5.57	6.64	7.86	9.27	11.40
6-hr	3.17	4.20	5.21	6.79	8.19	9.82	11.70	14.50
12-hr	3.64	4.84	6.02	7.85	9.46	11.30	13.50	16.90
24-hr	4.14	5.51	6.83	8.86	10.60	12.70	15.10	18.80

24-Hour Rainfall Distributions

Rainfall distributions play an important role in the shape of the rainfall hyetograph and resulting peak flow and time to peak for a given drainage area or watershed. The four rainfall distributions evaluated in this study use a 24-hour duration to develop the rainfall hyetograph. While 24 hours is a commonly used storm duration, this duration may be long for small watersheds or for urban watersheds that consist of highly impervious area and improved conveyance systems that efficiently convey stormwater runoff into the receiving streams. To compensate for the long duration, a short period of intense rainfall is placed in the middle of the distribution (representing a small, intense storm in the middle of the total 24-hour storm) with less intense rainfall at the beginning and end of the rainfall distribution. The resulting long duration storm with a nested small, intense storm is intended to be applicable to small, large, urban, and rural watersheds.

The 24-hour rainfall distribution includes the maximum rainfall distribution for all shorter durations. By using rainfall values for all durations from 5 minutes to 24 hours during development of the rainfall distribution and nesting the durations (i.e., the maximum rainfall in 5 minutes is assumed to be within the maximum 10-minute rainfall, which is within the maximum 15-minute rainfall, etc.), the result is a maximized rainfall distribution. This assists in ensuring the maximum rainfall intensity is applied to a watershed with any time of concentration less than 24 hours.

The following sections discuss development of four different rainfall distributions (NEH Distribution, HEC-HMS Frequency Distribution, NRCS Type III Storm Distribution, and New Fixed Distribution Similar to Type III). Tables of cumulative rainfall depths for the Distributions 1 through 4 for the 25-year and 100-year frequency storms are included in Appendix A. Figures 1, 2, and 3 illustrate 25-year S-Curve cumulative precipitation for the four distributions and show the entire 24-hour period, the period between 8.0 hours and 16.0 hours, and the period between 11.5 and 12.5

hours, respectively. Figures 4, 5, and 6 depict the same information for the 100-year frequency storm.

Distribution 1: National Engineering Handbook (NEH) Distribution

As mentioned previously, NRCS is replacing the use of its legacy rainfall distributions (Type I, Type IA, Type II, and Type III) with rainfall distributions based on *NOAA Atlas 14*-point precipitation-frequency data (from *Design Rainfall Distributions Based on NOAA Atlas 14 Rainfall Depths and Durations* by Merkel et al., 2015). The historical NRCS procedure was developed to derive rainfall distributions to cover the wide range of climatic conditions from tropical to arctic that occur in the United States. It is also intended to capture the maximum rainfall of any duration less than 24 hours within the 24-hour distribution, since the peak discharge for a drainage area is primarily determined by rain falling in a duration which equals the time of concentration. The newer, NEH Distribution provides regional specificity based on more detailed *NOAA Atlas 14* data.

In the NEH distribution model for the 24-hour event, the rainfall distribution has the maximum 5-minute rainfall occurring from 12.0 to 12.1 hours. The maximum 10-minute rainfall occurs between 11.9 and 12.1 hours and also includes the maximum 5-minute rainfall. This method is repeated for the entire 24-hour duration period so that shorter duration events are "nested" within longer duration events. This nesting of events allows a single rainfall distribution for 24 hours to be used for any watershed with time of concentration less than 24 hours. All durations from 1-hour to 12-hour are centered on 12 hours. For example, the 3-hour duration starts at 10.5 hours and ends at 13.5 hours with cumulative precipitation ratios of 0.2 at 10.5 hours, 0.5 at 12.0 hours, and 0.6 at 13.5 hours. The and the 6-hour duration starts at 9.0 hours and ends at 15.0 hours with cumulative precipitation ratios of 0.15 and 0.8, respectively. As shown in the figures, a significant increase in depth (and intensity) occurs at the storm center at hour 12.0 with the highest intensity 1-hour storm centered from 11.5 to 12.5 hours.

The NEH Distribution is developed using the distribution procedure described in Section 630.0403(c) and Appendix 4C of the NEH or with the WinTR-20 model. Development of the rainfall distribution is automated in WinTR-20 and can be used for both unsmoothed and smoothed rainfall data. Data entry is also automated and rainfall depth-duration values are imported directly from *NOAA Atlas 14* rainfall data. WinTR-20 is used to develop the NEH distribution for this project. Precipitation durations used for this task include the following durations: 5-min, 10-min, 15-min, 30-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, and 24-hr. NEH Distributions are developed for the two-year through 500-year frequency events for use in developing Distribution 4 for this project. The 25-year and 100-year are specifically compared to the Distribution 2 HEC-HMS frequency storm distribution as they are anticipated to match exactly.

Distribution 2: HEC-HMS Frequency Storm Distribution

The Distribution 2 HEC-HMS frequency storm distribution is developed using the same durations as the Distribution 1 NEH Distribution durations. Partial duration unsmoothed rainfall data from Table 1 is used for the 25-year and 100-year 8.86-inch and 12.70-inch events, respectively. Precipitation input data includes depth values for 5-, 10-, 15-, 30-, and 60-minute and 2-, 3-, 6-, 12-, and 24-hour durations for both the 25-year and 100-year recurrence intervals.

Except for the rainfall depths, input data into the HEC-HMS frequency storm editor matches the values contained in the effective Walnut Creek HEC-HMS model to provide consistency. The following values are used in addition to the rainfall depth data:

1. Input Type = Partial Duration
2. Output Type = Annual Duration;
3. Intensity Duration = 5 minutes;
4. Storm Duration = 24 hours;

5. Intensity Position = 50%;
6. Storm Area = 0.0 square miles (mi^2).

Note that the assumed storm area of 0.0 mi^2 does not account for the areal reduction that would typically be used for models larger than 10 mi^2. Areal reduction may be evaluated for the Walnut Creek model as part of a later revision, but is not expected to significantly affect the results of this analysis.

Distribution 3: NRCS Type III Distribution

The NRCS method contains four different distributions, labeled as Type I, IA, II, and III. The appropriate distribution is selected based on the location of the watershed being analyzed. Type I distribution is used for Alaska as well as parts of California and Type IA distribution is used for much of the West Coast. The Type II distribution covers the largest portion of the continental United States. The Type III distribution is used in portions of some southern states along the Gulf of Mexico as well as much of the East Coast. The City of Austin is in the region for the Type III distribution and Type III is used for the NRCS distribution method for this study. This Type III distribution is currently specified for use in the City of Austin DCM.

NRCS Type III distributions of the 25-year, and 100-year, 24-hr rainfall depths are developed within HEC-HMS. This distribution method can be readily used to develop a rainfall hyetograph when a rainfall pattern or distribution is not available. Data entry is design storm depth for a given frequency and the type of the storm. In this case, the City of Austin is located within an area of Type III distributions. With the SCS distribution, all storms are 24 hours in duration. A depth-area reduction can be applied to the rainfall total that is entered based on the TP-40 areal reduction curve. Models are typically run using a range of reduction areas. The final results are then interpolated using a spreadsheet. Switching to the frequency distribution would allow the area reduction procedure to be performed more easily within HEC-HMS.

Distribution 4: New Fixed Distribution Similar to NRCS Type III

Distribution 4 is a new fixed distribution like the NRCS Type III distribution. At each six-minute (0.1-hour) time step, the cumulative rainfall percentage is calculated in a spreadsheet as the average of the individual 2-yr through 500-yr NEH distributions discussed above for Distribution 1. This method standardizes the distribution of rainfall for all frequency events and avoids having a different distribution for each recurrence interval. Therefore, the 25-year and 100-year distributions are the same.

The 25-year unsmoothed rainfall depth of 8.86 inches and the 100-year unsmoothed rainfall depth of 12.70 inches are applied to each time step of Distribution 4 to obtain the rainfall hyetograph and S-Curve of cumulative precipitation for Distribution 4. Distribution 4 is incorporated into the HEC-HMS meteorological model as a specified hyetograph entered as a rainfall gage with the rainfall depth associated with each time interval for both the 25-year and 100-year events.

Comparison of Distributions 1 Through 4

Tables of cumulative rainfall depths for the Distributions 1 through 4 for the 25-year and 100-year frequency storms are included in Appendix A. Figures 1, 2, and 3 illustrate 25-year S-Curve cumulative precipitation for the four distributions and show the entire 24-hour period, the period between 8.0 hours and 16.0 hours, and the period between 11.5 and 12.5 hours, respectively. Figures 4, 5, and 6 depict the same information for the 100-year frequency storm.

Distributions 1 and 4 are very similar since Distribution 1 is based on the NEH Distribution for the individual frequency event (i.e., 25-year and 100-year), while the New Fixed Distribution Similar to NRCS Type III (Distribution 4) is based off the average of the NEH Distributions for the two-year through 500-year events. All four distributions are very similar for the 100-year event and the three distributions except the NRCS Type III Storm are similar for the 25-year event. In the 25-year event, the NRCS Type III Storm Distribution yields higher intensities and cumulative precipitation until approximately the storm center and peak intensity at hour 12.0. Between hour 12.0 and 12.5, the NRCS Type III Storm Distribution is very similar to the other three distributions, after which the intensity decreases until approximately hour 18.0 when the four curves are more similar. The NEH Distribution and Distribution 4 yield peak intensities and cumulative precipitation at hour 12.0 that is slightly lower than the HEC-HMS Frequency Storm Distribution. Otherwise, these three distributions are very similar both rainfall events.

Figure 1: 25-Year Cumulative Rainfall S-Curve for Distributions 1 Through 4

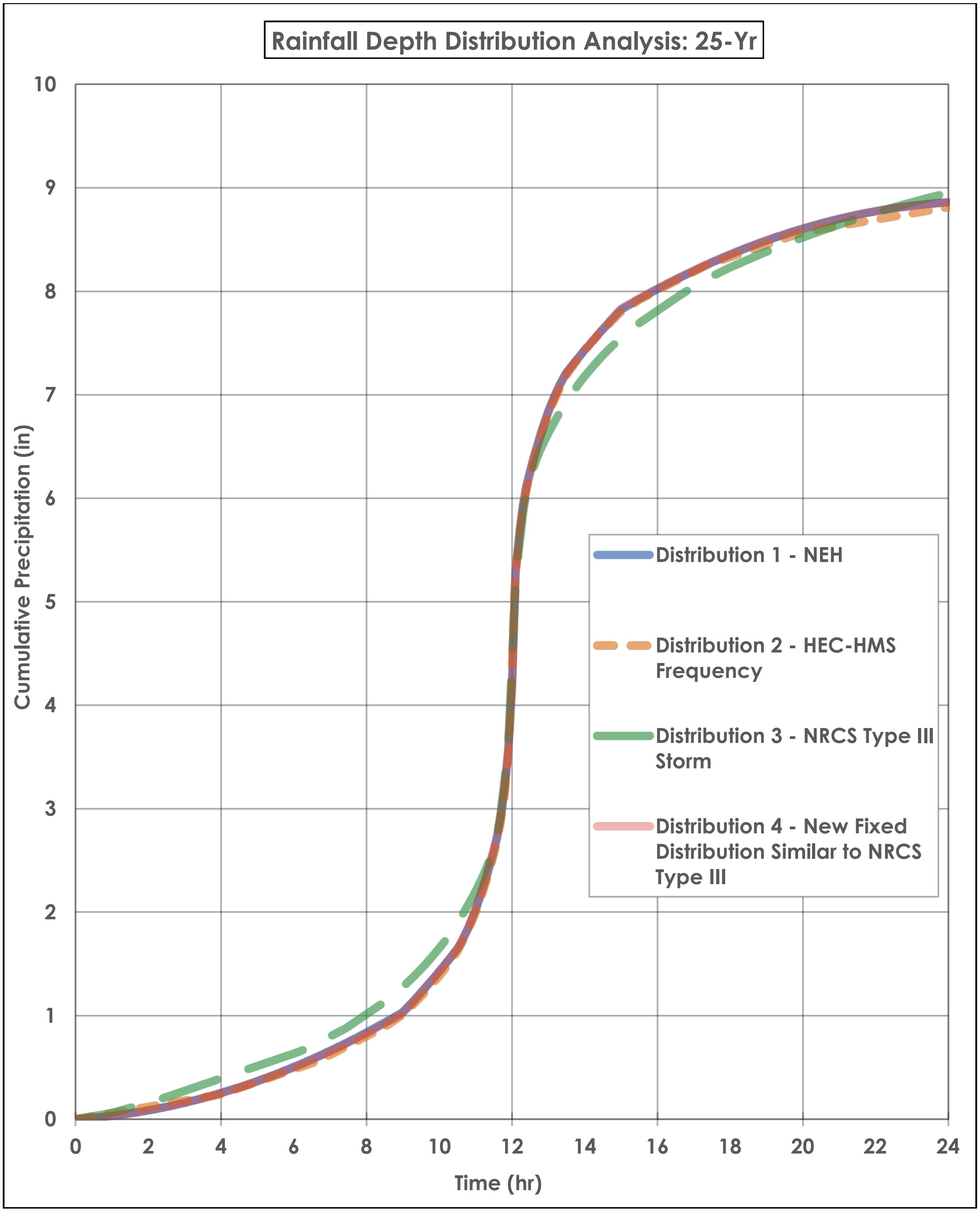


Figure 2: 25-Year Cumulative Rainfall S-Curve for Distributions 1 Through 4 at 8.0 to 16.0 Hours

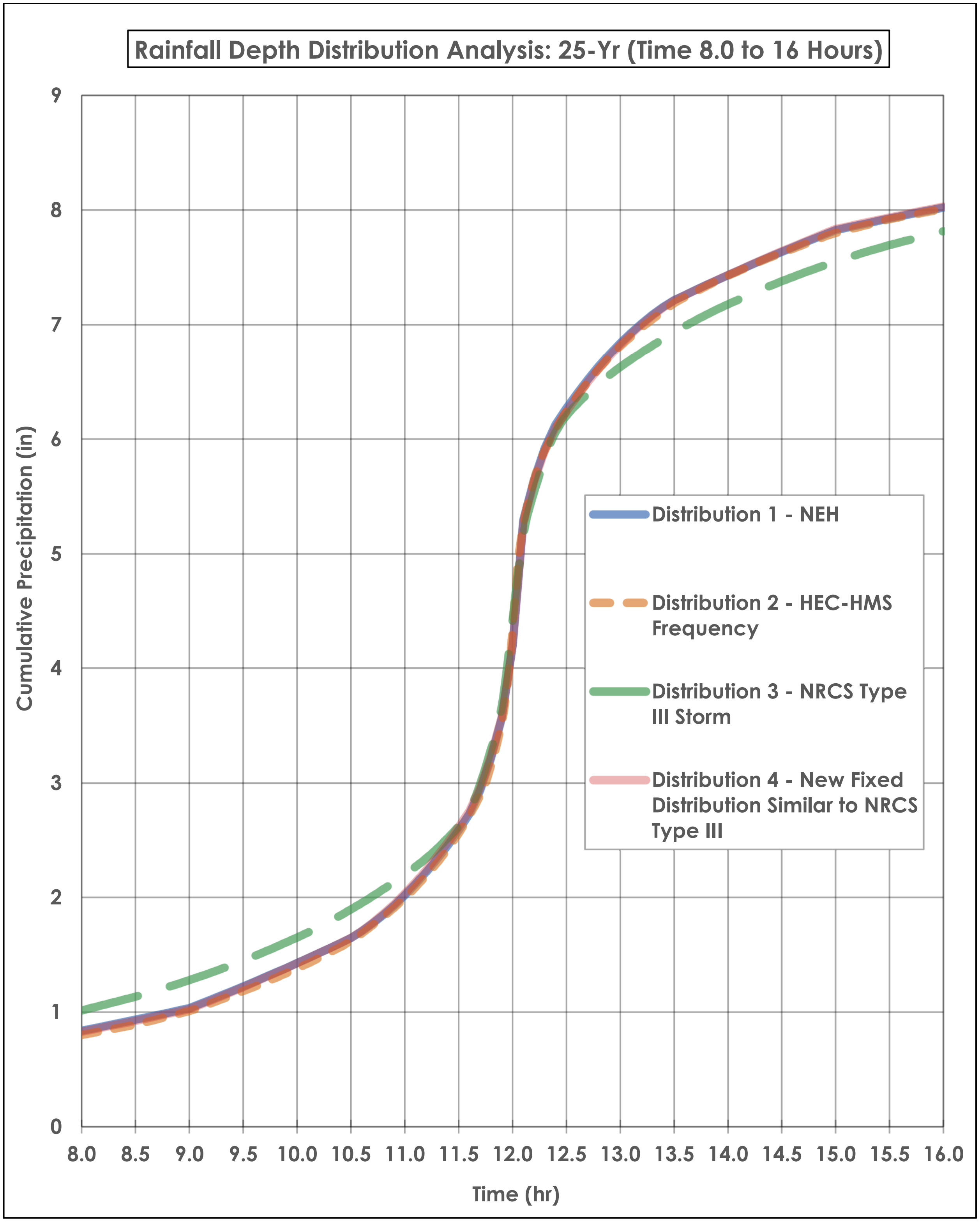


Figure 3: 25-Year Cumulative Rainfall S-Curve for Distributions 1 Through 4 at 11.5 to 12.5 Hours

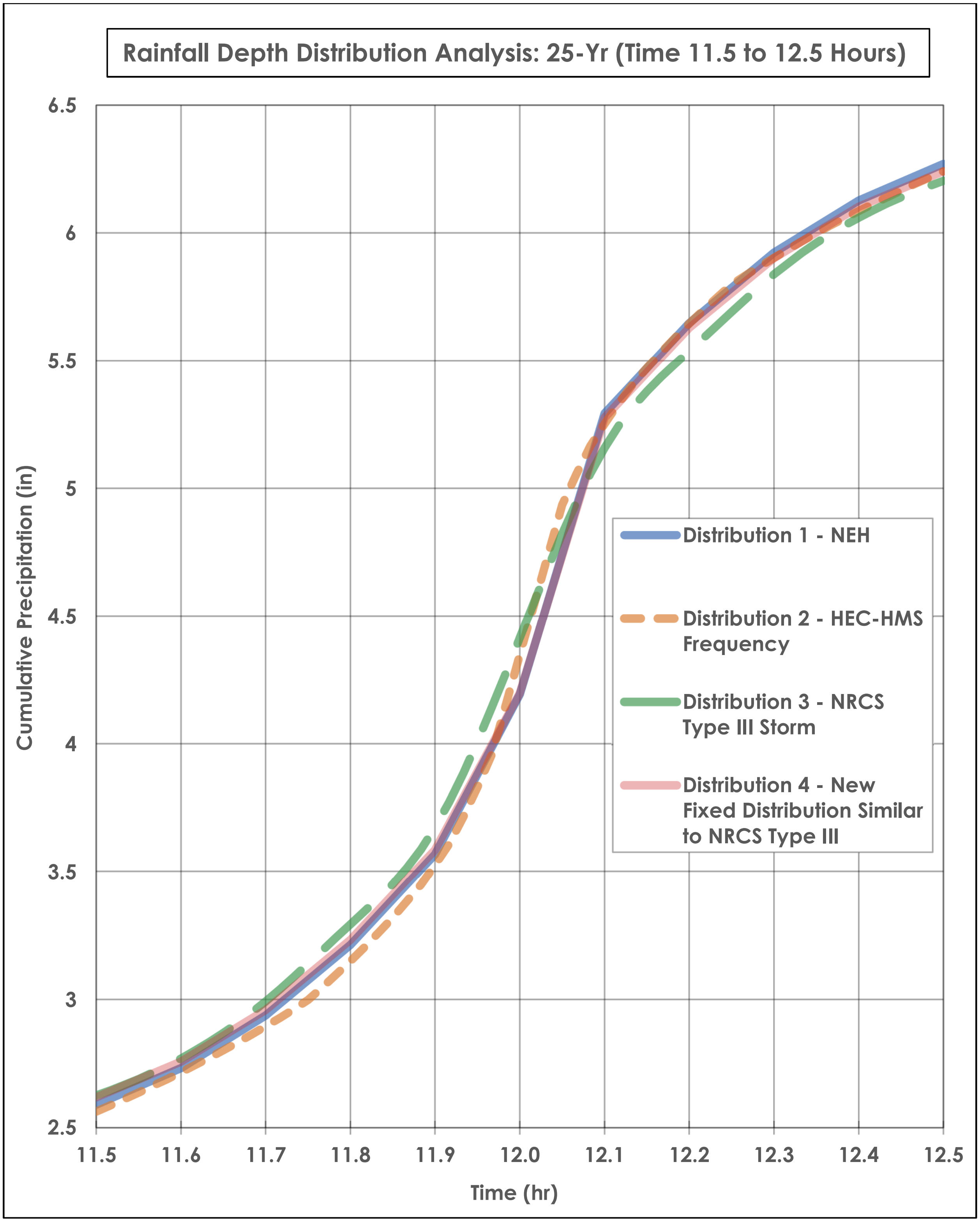


Figure 4: 100-Year Cumulative Rainfall S-Curve for Distributions 1 Through 4

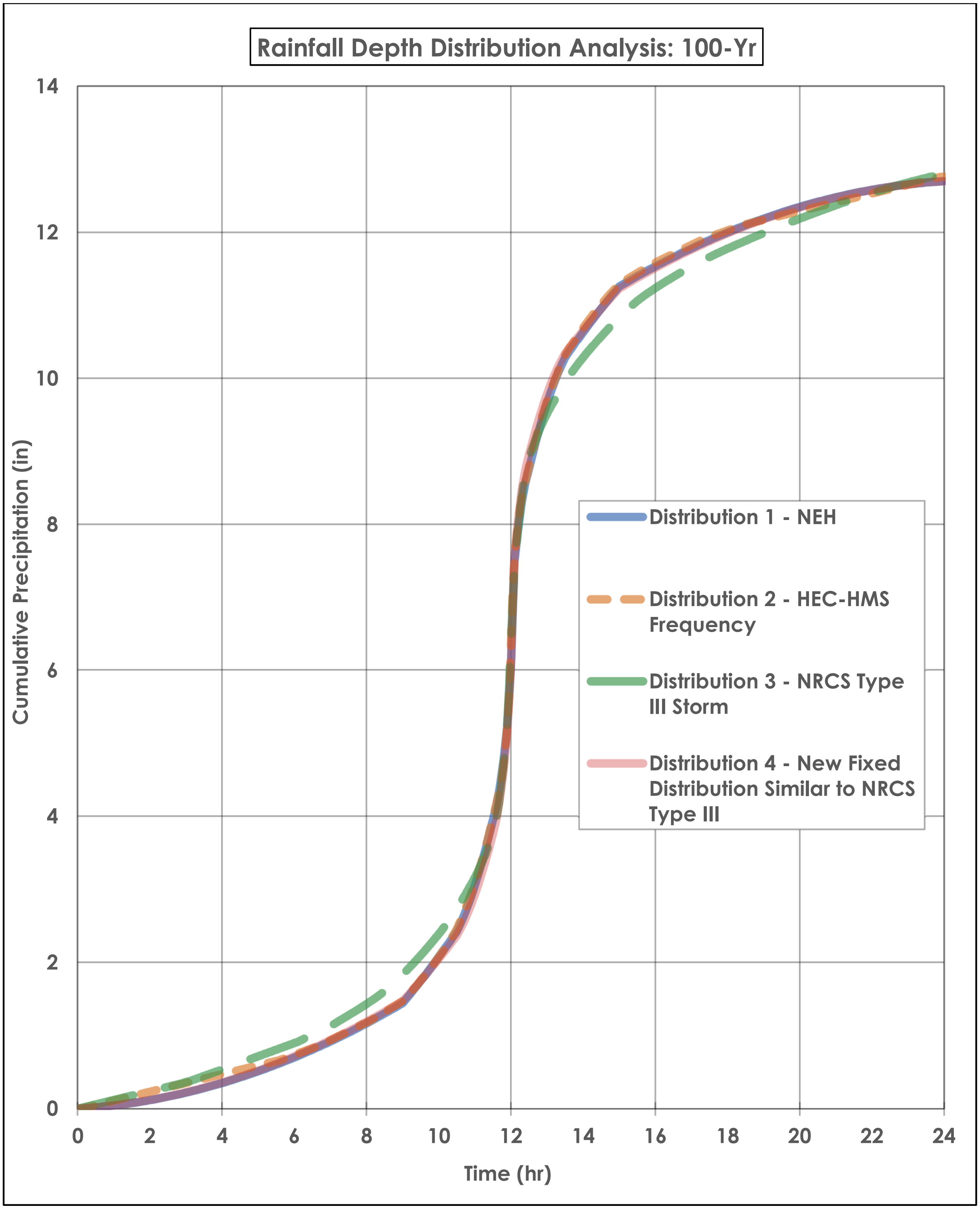


Figure 5: 100-Year Cumulative Rainfall S-Curve for Distributions 1 Through 4 at 8.0 to 16.0 Hours

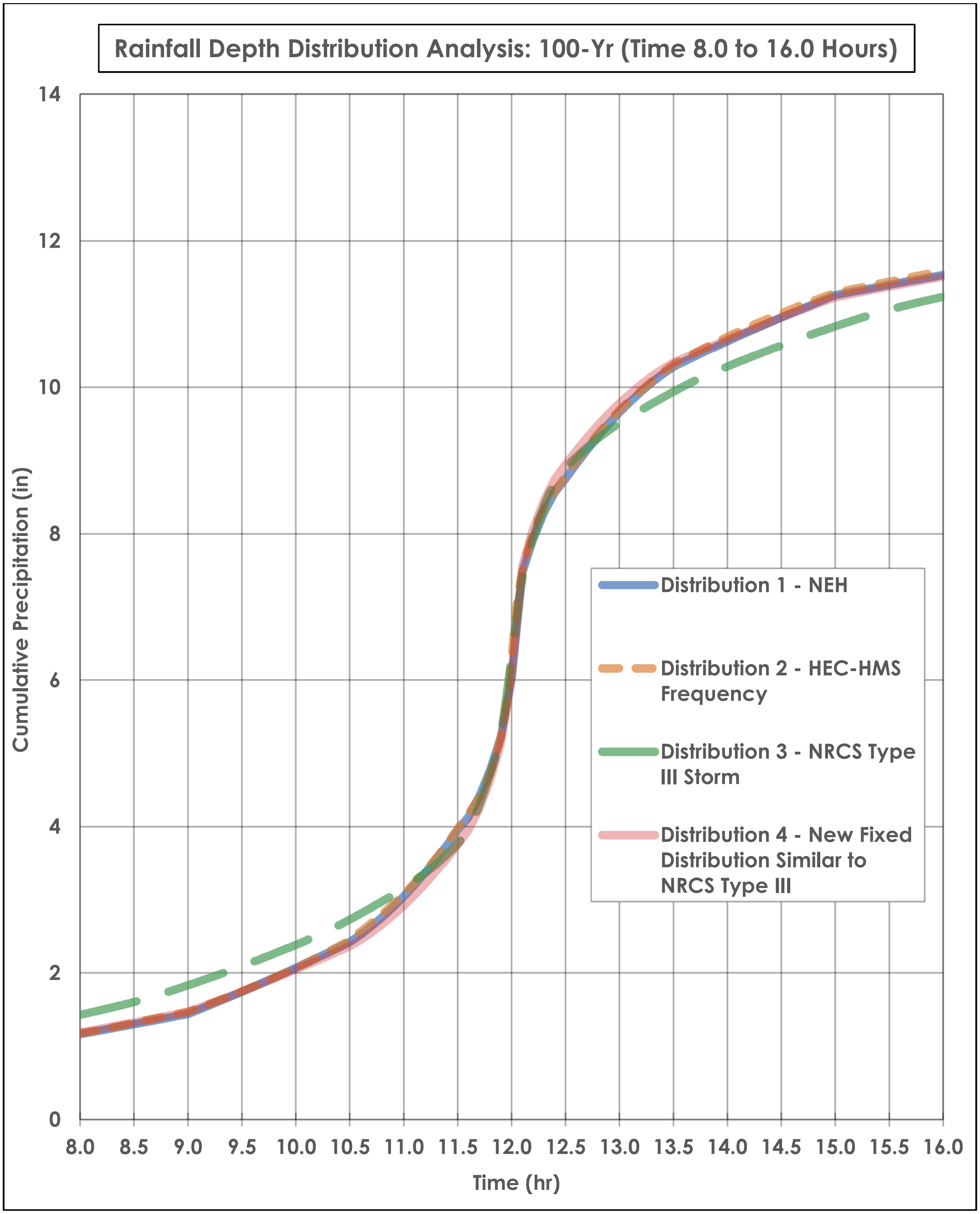
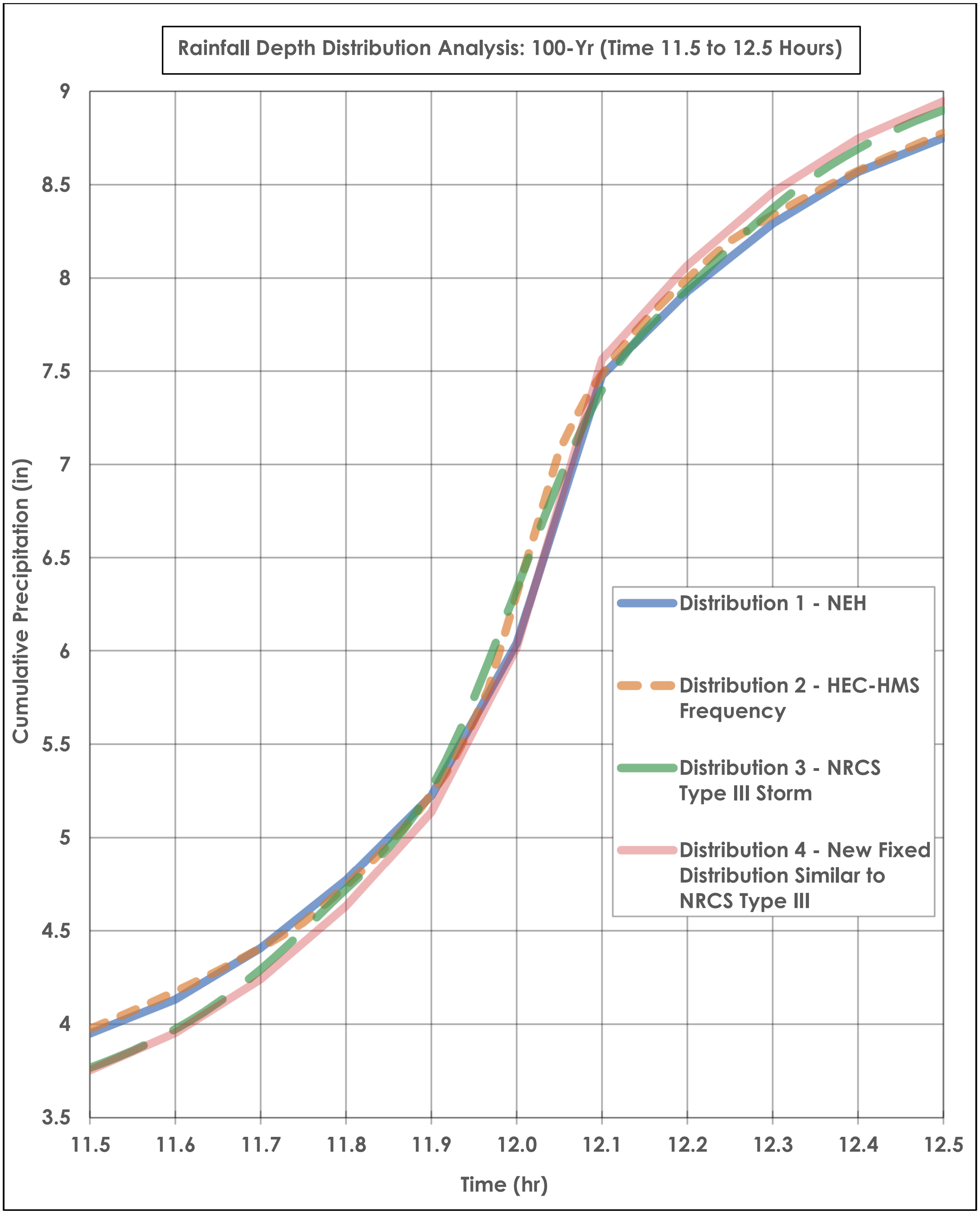


Figure 6: 100-Year Cumulative Rainfall S-Curve for Distributions 1 Through 4 at 11.5 to 12.5 Hours



HEC-HMS Model Development and Reporting Locations

The Walnut Creek model obtained from the City of Austin FloodPro website (www.austintexas.gov/floodpro/) is used as the HEC-HMS model basis for this project. The EX LU basin model is used for Walnut Creek and a Sites basin model is added to provide a platform for modeling the small, medium, and large sites rather than using multiple HEC-HMS models. Reporting locations for Walnut Creek and the three sites along with HEC-HMS model development for the three sites are discussed in the following sections. To maintain consistency with the effective HEC-HMS model, version 3.0.1 is used for all model development and analysis.

Walnut Creek Reporting Locations

In conjunction with Watershed Protection staff, four junctions are selected for reporting locations because they provide very different hydrologic conditions providing a fuller range of comparison of the effects of rainfall distribution on peak flows computed in HEC-HMS. The EX LU Walnut Creek basin model is used for this analysis.

Peak flows are reported for three junctions at the Walnut Creek/Little Walnut Creek confluence, with one for each stream before the confluence and one with both streams combined after the confluence of Walnut Creek and Little Walnut Creek. The junction analysis points are labeled JLWALN160, JWALNC267, and JWALNC270. Results are also reported for the upstream junction JWALNC070 as it represents a drainage sub-basin with an approximately one-hour time of concentration that isn't influenced by detention. As shown in Table 2, drainage areas range from 3.84 square miles (mi^2) for JWALNC070 to 50.93 mi^2 for JWALNC270 with associated effective peak flows in the EX LU model of 5,603 cubic feet per second (cfs) and 36,480 cfs, respectively. These peak flows are based on the current Austin DCM rainfall depths and the NRCS Type III distribution and are provided for scale reference only.

Table 2 Hydrologic Parameters for Ex LU Walnut Creek Reporting Locations

Junction	Description	Drainage Area (mi^2)	Drainage Area (ac)	100-Year Peak Discharge (cfs)	100-Year Time of Peak
JWALNC070	Drainage Sub-basin with Tc Around One-Hour	3.84	2,458	5,603	01Jan2001, 13:13
JWALN160	Confluence with Walnut Creek Before Combination	13.20	8,449	22,202	01Jan2001, 13:07
JWALNC267	Confluence with Little Walnut Creek Before Combination	37.55	24,031	29,687	01Jan2001, 15:27
JWALNC270	Just D/S of Confluence of Little Walnut With Walnut	50.93	32,595	36,480	01Jan2001, 13:52

Small, Medium, and Large Sites Model Development and Reporting Locations

The three site locations selected for the hydrologic analysis of small, medium, and large sites were provided by Watershed Protection and based on prior analyses performed by Crespo Consulting Services, Inc. (Crespo) as part of Volumetric Design Procedure (VDP) pilot studies for the Austin DCM. Crespo's analysis is documented in a series of memorandums and HEC-HMS models listed below:

1. *Site 1 – Analysis Summary Stormwater Criteria Updates*, dated June 17, 2015;
2. *Site 2 – Analysis Summary VDP Pilot Study #2 – Gilleland Watershed Project*, dated September 22, 2015;
3. *Site 3 – Analysis Summary VDP Pilot Study #3 – Decker Creek Watershed Project*, dated October 16, 2015.

Modeling data is readily available for pre-development and post-development conditions for all three sites as they are taken from actual projects. Additionally, the sizes range from 8.6 ac for the Small Site (Site 1) to 48.2 ac (48.1 ac in post-development) for the Medium Site (Site 2) to 155.1 ac (155.6 ac in post-development) for the Large Site (Site 3).

The pre-development and post-development hydrologic parameters for the three sites are obtained from the HEC-HMS model sub-basin data rather than the data reported in the memorandums as the models included lag time and combination of drainage sub-basins at junctions. Where sites were modeled as multiple drainage sub-areas and junctions, this methodology is maintained to provide a consistent basis for comparison. The NRCS Curve Number method is used for losses and the NRCS Unit Hydrograph Method is used for developing hydrographs. Hydrologic parameters include drainage area (square miles), Curve Number, percent impervious cover, and lag time (minutes). The specific values of the hydrologic parameters for Site 1, Site 2, and Site 3 are presented below in Table 3, Table 4, and Table 5, respectively. Muskingum-Cunge is the reach routing method and details are listed in Table 6.

Table 3 Hydrologic Parameters for Site 1 (Small Site)

Sub-basin	Area (mi^2)	Area (ac)	CN	Impervious (%)	Lag time (min)
EX	0.0134	8.6	77	0	12.6
PR-A	0.0075	4.8	74	50	11.0
PR-B	0.0021	1.3	74	52	11.4
PR-C	0.0038	2.4	74	45	10.2

Table 4 Hydrologic Parameters for Site 2 (Medium Site)

Sub-basin	Area (mi^2)	Area (ac)	CN	Impervious (%)	Lag time (min)
Ex-B	0.0753	48.2	71	0	27.2
B1	0.0660	42.2	93	0	5.0
B2	0.0091	5.8	93	0	5.0

Table 5 Hydrologic Parameters for Site 3 (Large Site)

Sub-basin	Area (mi^2)	Area (ac)	CN	Impervious (%)	Lag time (min)
EX-B1	0.1000	64.0	78	0	25.2
EX-B2	0.0891	57.0	78	10	15.6
EX-B3	0.0533	34.1	78	0	10.2
PR-B1	0.1000	64.0	78	45	17.4
PR-B2	0.0880	56.3	78	45	12.6
PR-B3	0.0447	28.6	78	30	7.8
PR-B4	0.0104	6.7	78	5	7.2

Table 6: HEC-HMS Muskingum-Cunge Routing Data for Site 3

Muskingum-Cunge Routing Parameters									
Hydrologic Element	Desc.	Downstream	Method	Length (ft)	Slope (ft/ft)	Manning's n-value	Shape	Bottom Width (ft)	Side Slope (xH:1V)
Site 3 (R_B1)	B1 to JB12	Site 3 Junction (J EX B1-2)	Muskingum-Cunge	2034	0.003	0.04	Trapezoid	100	5
Site 3 (R_B1&2)	-	Outlet	Muskingum-Cunge	1123	0.007	0.04	Trapezoid	100	4
Site 3 (R_Prop B1)	B1 to JB12	Site 3 Junction (J Prop B1-2)	Muskingum-Cunge	2034	0.003	0.04	Trapezoid	100	5
Site 3 (R B1&2)	-	Site 3 Junction (J Prop B1-3)	Muskingum-Cunge	1123	0.007	0.004	Trapezoid	100	4
Site 3 (R_B1_3)	-	Site 3 Proposed Outlet	Muskingum-Cunge	50	0.007	0.04	Trapezoid	100	3

Results

Peak flows are compared at the Walnut Creek reporting locations for the three modeled distributions and pre-development and post-development peak flows are compared for the three modeled sites. For the three sites, estimated detention volumes for the three modeled distributions are also compared. Peak flow and detention volumes estimates are discussed in the following sub-sections.

A total of two rainfall frequencies (25-year and 100-year), two basin models (Walnut Creek and Sites), and three rainfall distributions are run for a total of 12 model runs. Four reporting locations are used for Walnut Creek and three pre-development and three post-development reporting locations are used in the Sites model for the small, medium, and large sites. This yields 10 reporting locations. A total of 60 peak flows (ten reporting locations x two storms x three distributions) are reported and 18 detention volumes (three sites x two storms x three distributions) are reported.

Peak Flows

Peak flows for the Walnut Creek reporting locations are listed in Tables 7 and 8. Pre-development and post-development peak flows are reported in Tables 9 and 10 for the three sites for the four distributions. Detailed tables and results are included in Appendix B. The NRCS Type III Storm Distribution generally returns the lowest peak flows for the 25-year and 100-year event and the HEC-HMS Frequency Distribution and New Fixed Distribution Similar to NRCS Type III (Distribution 4) generally produce the highest peak flows for the 25-year and 100-year events, respectively.

For Walnut Creek, the maximum difference between the highest and lowest peak flows ranges from 4.7% to 8.0% for the 25-year event and 4.5% to 10.7% for the 100-year event. The maximum range of differences between peak flows produced by Distributions 2 and 4 is 1.0% for the 25-year and 6.3% for the 100-year. The NRCS Type III Distribution returns the lowest peak flows for all reporting locations for the 25-year event. The HEC-HMS Frequency Distribution returns the highest peak flows for all but one location with the New Fixed Distribution Similar to Type NRCS Type III (Distribution 4) returning the highest 25-year peak flow for the 2,458-acre watershed contributing to junction JWALNC070. For the 100-year event, the New Fixed Distribution Similar to Type NRCS Type III (Distribution 4) returns the highest peak flows for all locations. The HEC-HMS Distribution (2) returns the lowest peak flows for the two smaller watersheds contributing to JWALNC070 and JWALN160, whereas the NRCS Type III Distribution (3) returns the lowest peak flows for the two large watersheds contributing to the 24,031-acre JWALNC267 and 32,595-acre JWALNC270.

Table 7: 25-Year Peak Flow Comparison for Walnut Creek for Three Distributions

Location	Drainage Area (ac)	25-Year Peak Flows (cfs)						
		NEH Distribution 1	HEC-HMS Distribution 2	NRCS Type III Distribution 3	New Fixed Distribution 4	Difference (Distributions 2 and 1)	Difference (Distributions 2 and 3)	Difference (Distributions 2 and 4)
JWALNC070	2,458.2	4,025	3,997	3,772	3,999	-0.7%	5.6%	0.0%
JLWALN160	8,448.6	19,562	19,588	18,705	19,385	0.1%	4.5%	1.0%
JWALNC267	24,030.7	26,880	26,903	25,014	26,874	0.1%	7.0%	0.1%
JWALNC270	32,594.6	32,648	32,662	30,255	32,618	0.0%	7.4%	0.1%

Table 8: 100-Year Peak Flow Comparison for Walnut Creek for Three Distributions

Location	Drainage Area (ac)	100-Year Peak Flows (cfs)						
		NEH Distribution 1	HEC-HMS Distribution 2	NRCS Type III Distribution 3	New Fixed Distribution 4	Difference (Distributions 2 and 1)	Difference (Distributions 2 and 3)	Difference (Distributions 2 and 4)
JWALNC070	2,458.2	8,238	8,217	8,283	8,735	-0.3%	-0.8%	-6.3%
JLWALN160	8,448.6	25,438	25,453	25,567	26,602	0.1%	-0.4%	-4.5%
JWALNC267	24,030.7	42,374	42,414	39,735	42,939	0.1%	6.3%	-1.2%
JWALNC270	32,594.6	54,159	54,291	50,174	55,525	0.2%	7.6%	-2.3%

For the three sites, the maximum difference between the highest and lowest peak flows ranges from 5.3% to 40.1% for the 25-year event and 8.3% and 33.6% for the 100-year event. The maximum range of differences between peak flows produced by Distributions 2 and 4 is 6.7% for the 25-year and 8.3% for the 100-year. The NRCS Type III Distribution returns the lowest peak flows for all sites for the 25-year event and the HEC-HMS Frequency Distribution. For the 100-year event, the New Fixed Distribution Similar to Type NRCS Type III (Distribution 4) returns the highest peak flows for all sites. The HEC-HMS Distribution (2) returns the lowest peak flow for the Large Site and the NRCS Type III Distribution (3) returns the lowest peak flows for the Small and Medium Site.

Table 9: 25-Year Peak Flow Comparison for Three Sites for Three Distributions

Location	Drainage Area (ac)	25-Year Peak Flows (cfs)				
		HMS - Distribution 2	NRCS Type III - Distribution 3	New Fixed - Distribution 4	Difference (Distributions 2 and 3)	Difference (Distributions 2 and 4)
Small (Site 1)	8.6	7.8	6.3	7.3	19.9%	6.7%
Medium (Site 2)	48.2	295.5	210.9	276.4	28.6%	6.5%
Large (Site 3)	155.1	129.2	123.8	122.7	4.1%	4.9%

Table 10: 100-Year Peak Flow Comparison for Three Sites for Three Distributions

Location	Drainage Area (ac)	100-Year Peak Flows (cfs)				
		HMS - Distribution 2	NRCS Type III - Distribution 3	New Fixed - Distribution 4	Difference (Distributions 2 and 3)	Difference (Distributions 2 and 4)
Small (Site 1)	8.6	8.0	6.9	8.2	14.1%	-2.9%
Medium (Site 2)	48.2	360.2	277.5	370.6	23.0%	-2.9%
Large (Site 3)	155.1	148.5	158.0	160.9	-6.4%	-8.4%

Detention Volume Estimates

Figures 6 through 15 in Appendix D illustrate pre-development and post-development runoff hydrographs for each of the three modeled rainfall distributions for the 25-year and 100-year frequency events. As shown, the shapes of the 25-year and 100-year pre-development and post-development hydrographs are similar for all three distributions with all peaks occurring between hour 12:00 and 13:00. There is a slight difference in the NRCS Type III for 25-year and 100-year distribution which can generate the higher peak flow for the NRCS Type III discharge shown in Table 10.

A comparison of the area under the volume curve is used to estimate the required volume for each of the distributions. The approximate 25-year and 100-year detention volumes are estimated by defining the excess volume between the rising limbs of the pre- and post-development hydrographs. Detention volume estimates are computed for each time step until the first time step where the pre-development flow is greater than the post-development flow at that time step. The sum of the individual time step volumes for each frequency yields the estimated detention volume for that frequency storm.

Detention results tables for each of the three sites for each rainfall distribution are included in Appendix B. HEC-HMS models developed for this project and HEC-HMS reporting output is included in the excel spreadsheet includes as Appendix E. Pre-development and post-development peak flows and estimated detention volumes are summarized in Tables 11 and 12 for the three distributions for the three sites. For the 25-year event, the NRCS Type III Distribution produces the smallest estimated detention volumes for all sites and the HEC-HMS Frequency Distribution produces the largest estimated detention volume for all sites. For the 100-year event, the HEC-HMS Frequency Distribution produces the smallest estimated detention volumes for the Medium and Large Site and matches the Small Site results produced by the NRCS Type III Distribution. Distribution 4 (New Fixed Distribution Similar to NRCS Type III) produces the largest estimated detention volume for all three sites for the 100-year event.

While detention routing with actual tailwater conditions or consideration of downstream impacts to peak flows may yield different results, this comparison conceptually represents the effect that each of the rainfall distributions may have on the required detention volume. For the 25-year event, the maximum difference in detention volume between the highest and lowest requirement ranges from 1.5% for the 8.6-acre Small Site 1 to 3.5% for the 48.1-acre Medium Site. For the 100-year event, the maximum difference in detention volume between the highest and lowest requirement ranges between ranges from 1.8% for the 8.6-acre Small Site 1 and 3.4% for the 48.2-acre Medium Site 2. The difference between the HEC-HMS Frequency Distribution and Distribution 4 is only 1.1% for the 25-year and 3.4% for the 100-year.

From a land area requirement, with an average detention depth of five feet, a difference in volume of 3.4% (maximum 100-year volume differential) for the Large Site yields an additional required area of 0.14 ac (0.09% of the 155.1-acre development) for detention. An average detention depth of ten feet, requires an additional land are of 0.07 ac (0.05% of the 155.1-acre development) for detention. Similarly, for the Small Site an additional estimated area of 0.0067 ac (0.08% of the 8.6-acre development) or 0.0034 ac (0.04% of the 8.6-acre development) is required for detention with a difference in estimated volume of 3.4%.

Table 11: 25-Year Detention Volume Comparison for Three Sites for Three Distributions

Location	Drainage Area (ac)	25-Year Detention Volume (ac-ft)				
		HMS - Distribution 2	NRCS Type III - Distribution 3	New Fixed - Distribution 4	Maximum Difference	Difference Distribution 2 and 4
Small (Site 1)	8.6	0.86	0.85	0.86	1.5%	-0.3%
Medium (Site 2)	48.1	15.34	14.83	15.18	3.5%	-1.1%
Large (Site 3)	155.6	15.79	15.49	15.71	1.9%	-0.5%

Table 12: 100-Year Detention Volume Comparison for Three Sites for Three Distributions

Location	Drainage Area (ac)	100-Year Detention Volume (ac-ft)				
		HMS - Distribution 2	NRCS Type III - Distribution 3	New Fixed - Distribution 4	Maximum Difference	Difference Distribution 2 and 4
Small (Site 1)	0.99	0.99	0.99	1.00	1.8%	1.5%
Medium (Site 2)	19.99	19.99	20.09	20.68	3.4%	3.4%
Large (Site 3)	18.95	18.95	19.18	19.44	2.6%	2.6%

Conclusions and Recommendations

1. **Peak Flows:** The NRCS Type III Storm Distribution generally returns the lowest peak flows for the 25-year and 100-year events for the range of site sizes and drainage areas contributing to the Walnut Creek reporting locations. The HEC-HMS Frequency Distribution and New Fixed Distribution Similar to NRCS Type III (Distribution 4) generally produce the highest peak flows for the 25-year and 100-year events, respectively.

   For Walnut Creek, the maximum difference between the highest and lowest peak flows ranges from 4.7% to 8.0% for the 25-year event and 4.5% to 10.7% for the 100-year event. For the three sites, the maximum difference between the highest and lowest peak flows ranges from 5.3% to 40.1% for the 25-year event and 8.3% to 33.6% for the 100-year event. This difference is most pronounced in the Medium and Small Sites. The maximum difference between the HEC-HMS Frequency Distribution and the New Fixed Distribution Similar to NRCS Type III (Distribution 4) ranges from 0% to 8%.

2. **Hydrographs:** The hydrographs from all three distributions have similar shapes and times to peak for all events and all development conditions. Both pre-development and post-development peak flows occur approximately between hour 12:00 to 13:00 with all three distribution methods.

3. **Detention Volumes:** For the 25-year event, the NRCS Type III Distribution produces the smallest estimated detention volumes for all sites and the HEC-HMS Frequency Distribution produces the largest estimated detention volume for all sites. For the 100-year event, the HEC-HMS Frequency Distribution produces the smallest estimated detention volumes for the Medium and Large Site and matches the Small Site results produced by the NRCS Type III Distribution. Distribution 4 (New Fixed Distribution Similar to NRCS Type III) produces the largest estimated detention volume for all three sites for the 100-year event.

   The differences in estimated detention volume between the highest and lowest requirements range from 1.5% in the 25-year event for the Small Site to 3.5% in the 25-year event for the Medium Site. The 100-year estimated detention volume maximum differential is 3.4% for the Medium Site. These differences translate to a minimal or just a small increase in additional land required for detention ranging from 0.04% to 0.09% of the development. This differential in land dedicated to detention could also be met through incorporation of Green Infrastructure techniques.

4. **Rainfall Distributions:** The selected rainfall distribution method is likely to have a more significant effect on the sizing of flood control and drainage conveyance infrastructure than on land area required for detention. The selection of one method may also have an effect on the base flood elevation (BFE) and associated 100-year flood plains within Austin's watersheds. Since the NRCS Type III Storm is being phased out and *NOAA Atlas 14* and future updates provide detailed data for multiple durations of a given frequency storm, we recommend that the NRCS Type III Storm not be selected as the City of Austin's rainfall distribution method.

Both the NEH Distribution and Distribution 4 produce similar results. The New Fixed Distribution Similar to Type III (Distribution 4) has the advantage of providing a consistent rainfall hyetograph and S-Curve of cumulative precipitation for all design storm events, whereas the NEH Distribution requires the use of a different rainfall hyetograph or S-Curve of cumulative precipitation for each design storm event. Both the NEH Distribution and New Fixed Distribution Similar to Type III (Distribution 4) are more complex to model in HEC-HMS requiring the use of a rainfall gage as opposed to the HEC-HMS Frequency Storm. An alternative would be to enter a "Specified Hyetograph" (which HMS allows) as a unit hyetograph and then apply a rainfall total to it.

Given the similarity of results between the HEC-HMS Frequency Distribution and Distribution 4 (New Fixed Distribution Similar to NRCS Type III), the effect of selecting one of these versus the other may not be substantial. The HEC-HMS Frequency Storm is a commonly used modern method to provide rainfall data tailored to local watersheds and is relatively simple to simulate in HEC-HMS, which provides a significant benefit. The primary benefits of the HEC-HMS Frequency Storm are: 1) it allows for simple data entry and quality control, 2) involves fewer simplifying assumptions, 3) integrates with HEC-HMS built-in areal reduction process, and 4) allows flexibility for users to generate storms with free HEC-HMS software and use resulting precipitation with other programs. For these reasons, we recommend selecting the HEC-HMS Frequency Storm as the City of Austin's rainfall distribution method in conjunction with implementation of *NOAA Atlas 14* precipitation data.

5. **Updates to Austin DCM and Models:** We recommend that the Austin DCM be updated with the NOAA Atlas 14 precipitation data as well as the selected rainfall distribution. Updates to the effective and current watershed models are also recommended as feasible to provide a better understanding of system flood control capacity and visual understanding of flood risk to residents.

We appreciate the opportunity assist FNI and the City of Austin Watershed Protection with this visionary project for the region. Updates to the DCM rainfall frequency depths and distributions is pivotal to protect residents from flooding and preserve the existing watershed health and flood control capacity.

Appendices

Appendix A – Tables of Four Rainfall Distributions

Appendix B – Summary Tables of Peak Flows and Detention Estimate Results

Appendix C – Detailed Hydrographs and Tables of Results for Detention Estimates for Three Sites

Appendix D – Hydrographs for Three Sites for Three Distributions

Appendix E - HEC-HMS Models, Win-TR20 Models, and Excel Spreadsheets of Model Results and Rainfall Distributions (Electronic)