DEVELOPMENT OF NRCS PEAK RATE FACTORS FOR HYDROLOGIC MODELING IN TEXAS

A Dissertation

by

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ABSTRACT

In many cases, estimation of the peak discharge is the primary goal of hydrologic modeling. We employed a dataset of 1,648 rainfall-runoff events in 104 watersheds in Texas to explore the peak rate factor (*PRF*) of 484 recommended by the Natural Resources Conservation Service (NRCS) for determining peak discharges with the unit hydrograph method, as well as the *PRF*'s dependency on watershed and storm characteristics. For each event, a unit hydrograph – assumed to follow a two-parameter Gamma distribution – was determined by deconvolving the direct runoff hydrograph with the excess rainfall hyetograph. Results showed *PRFs* reaching up to 2264 in Houston watersheds with a median of 135, and *PRFs* up to 2559 with a median of 329 for the rest of Texas. It was also found that the recommended *PRF* of 484 falls between the 75th and 90th percentile of the 1043 events analyzed in all regions except Houston, and is above the 98th percentile in all 605 events analyzed in Houston. Statistical analysis further proved that *PRFs* in Houston watersheds are significantly different from the rest of Texas.

To estimate the dependency of the *PRF* on watershed and storm parameters, regression analysis was performed, and results showed that the *PRF* is primarily dependent on the watershed's geomorphology and the main channel slope; however, its dependency on the main channel slope was largely influenced by Houston watersheds, which are characterized by flat slopes. When regression analysis only focused on non-Houston watersheds, statistical analysis only showed dependency on the watershed's geomorphology and not its slope. This dependency, however, although statistically

significant, explains only marginally the *PRF* variability. It is therefore recommended that for practical applications, and in the absence of high-quality rainfall-runoff data, constant *PRFs* of 135 and 329 be used Houston watersheds and non-Houston Texas watersheds, respectively.

DEDICATION

To my parents, for their unwavering love and support.

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NOMENCLATURE

PRF	Peak rate factor
t	Time
q_p	Peak discharge
t_p	Peak-flow time
$f(t)$	Frequency distribution
α	Dimensionless shape parameter of the two-parameter gamma distribution
β	Scale parameter of the two-parameter gamma distribution
$q(t)$	Unit hydrograph
$R(t)$	Excess rainfall hyetograph
$Q_d(t)$	Direct runoff hydrograph
A	Watershed drainage area
D	Excess rainfall depth
P	Rainfall depth
D	Excess rainfall depth
t_d	Storm duration
t_L	Lag time
i	Average rainfall intensity
CS	Main channel slope
NSE	Nash-Sutcliffe Efficiency

SSR	Sum of the square of the residuals
SF	Shape factor
L_{F-max}	Length of longest flow path
L_{E-max}	Maximum Euclidean distance to the watershed outlet
L_{E-C}	Euclidean distance from the centroid of the watershed to the watershed outlet
$\overline{L_F}$	Average of the flow distances from all points of the watershed to the watershed outlet
L_{F-C}	Flow distance from the centroid of the watershed to the watershed outlet
$\overline{L_E}$	Average of Euclidean distances from all points of the watershed to the watershed outlet
DEM	Digital elevation model
TxDOT	Texas Department of Transportation
CoA	City of Austin
HCFCD	Harris County Flood Control District
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USDA	United States Department of Agriculture
SCS	Soil Conservation Service
NRCS	Natural Resources Conservation Service

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1. INTRODUCTION

1.1. Background

Four hundred and eighty-four is a number that might seem random to the unassuming person but to the special breed of people called hydrologists, this number is pregnant with meaning. The number is an important component in the conception of the Natural Resources Conservation Service (NRCS) – formerly Soil Conservation Service (SCS) – unit hydrograph method (SCS, 1972) for determining peak discharges. This number is called the peak rate factor (*PRF*) and is the subject of this dissertation.

In the NRCS unit hydrograph method (SCS, 1972), the peak discharge for a unit excess precipitation depth [L] is:

$$q_p = \frac{(PRF)\ A}{t_p} \qquad (1\text{-}1)$$

where q_p [L^3/T] is the peak discharge, A [L^2] is the watershed area, and t_p [T] is the time to peak since the beginning of the excess-precipitation generation. If q_p is expressed in cubic feet per second (cfs), A in square miles (sq-mi), t_p in hours (hr), and the unit excess precipitation depth is one inch (in), NRCS recommends a *PRF* of 484 (SCS, 1972). The NRCS method is also adopted in the latest version of the Texas Department of Transportation Hydraulic Design Manual (TxDOT, 2019). This value was obtained empirically by Mockus (1957) by considering "a large number of natural unit hydrographs that vary widely in size and geographical locations" (SCS, 1972).

In the last 50 years, however, there has been increasing consensus that this value is not a constant, and many researchers have indicated that the *PRF* varies from watershed to watershed and from event to event. Still, it is unclear which watershed or storm parameters affect its value the most. The main goal of this dissertation, therefore, is to provide useful information regarding *PRFs* in Texas for practitioners and researchers.

1.2. Objectives

The main objective of this dissertation is to establish a guideline for estimating *PRFs* for hydrologic modeling in Texas. Specifically, this study aims to:

1. Determine the range of *PRFs* in various regions in Texas,
2. Determine which parameters affect the *PRF*, and
3. Discuss practical considerations in choosing the *PRF* for hydrologic modeling in Texas.

1.3. Contributions

The importance of accurately determining peak discharges is underscored by the fact that hydraulic structures such as bridges, culverts, levees, dams, canals, and storm sewers need to be designed to convey the appropriate design discharge. Undersized hydraulic structures would not be able to hold a certain magnitude of flow which would lead to increased risk of flooding and would jeopardize the safety of the community. On the other hand, oversized hydraulic structures would lead to unnecessary cost. The problem of overdesign is further exacerbated by the fact that pipe sizes come in increments. For example, if an erroneous design discharge that is 20% above the correct design discharge results in requiring a storm sewer pipe size of 13.15 inches, practitioners would be required to select the next higher storm sewer pipe size, which is 15 inches, resulting to a pipe that has a capacity of more than 1.2 times the needed capacity, which results in even more material and construction costs.

By directly confronting the problem associated with the lack of solid guidance in PRF estimation in Texas, this study is an important step towards accurately estimating the peak discharges in Texas using the NRCS Unit Hydrograph Method, which would lead to more accurately designed hydraulic structures. Specifically, this study makes the following contributions:

1. A comprehensive review of important concepts and literature related to *PRF* estimation was provided, which can inform practitioners and researchers interested in the same topic. The literature review includes a listing of open questions that still baffle researchers to date – some of which are answered in this dissertation but some of which are still unclear.
2. Using a comprehensive dataset of more than 1600 storms in more than 100 Texas watersheds, it was found that *PRFs* vary from event to event and from watershed to watershed. Moreover, ranges of *PRFs* in rural watersheds as well as highly developed areas such as Austin, Dallas, Fort Worth, Houston, and San Antonio were determined, which will serve as guidance to future designs of hydraulic structures. It was found in this study that the *PRFs* in Texas is lower than the NRCS-recommended value of 484. This result has economic benefits, especially in urban areas where construction is more frequent, and would be instrumental to engineering companies.
3. Geomorphological indices composed of ratio of an average length parameter and a maximum length parameter were designed and it was found that one of these ratios – the ratio of the average flow length to the maximum flow length

– significantly affects the *PRF*. It was also found that the main channel slope significantly affects the *PRF* as what other studies have pointed out. However, the variability in the *PRF* explained by these parameters were not large enough such that it might not be practical to use a regression equation in determining the value of the *PRF*. This result would give practitioners confidence to use a constant *PRF*.

4. An analysis of the effect of PRF on flood parameters such as peak discharge, flood depth, and floodplain extent considering three Austin creeks. Between a *PRF* of 100 and a *PRF* of 600 (with *PRF* of 100 taken as the denominator), the percent differences for peak flow, flood depth, and floodplain extent ranged from 427 to 483%, 80-142% and 70-100%, respectively. This result further strengthens the case for the need of accurate estimation of *PRF*.
5. While this study is motivated by the fact that existing literature on *PRF* are mostly on non-Texas locations, this study is in itself site-specific. Caution must therefore be exercised in applying the results of this study to other locations. Nevertheless, the methodologies described in this study would be useful as a template for studies in other geographical locations where there is still a dearth on studies on the *PRF*.
6. Finally, while this study is instrumental in shedding light on the *PRF* variation in Texas, more questions have come up that are not addressed in this dissertation. Thus, this study will be a springboard for future research not only on the accurate estimation of the *PRF*, but also on the broad field of hydrology.

1.4. Time and Place of Study

This study was conducted at Texas A&M University, College Station, Texas from August 2019 to June 2022.

1.5. Organization of this Dissertation

This dissertation is organized in six chapters. This chapter (Chapter 1) introduces the dissertation topic, its goals, and a summary of its contributions. In Chapter 2, a review of related literature is presented into three main headings: a review of related concepts, discussion of past related studies, and a discussion of gaps in literature and how this dissertation aims to fill some of those gaps. In Chapter 3, the study area as well as the data used in the study is discussed. Moreover, software programs that were important the analysis were also presented. In Chapter 4, the method for determining the *PRFs* as well as the range of *PRFs* in Texas are presented. Moreover, a sensitivity analysis on the effect of *PRF* on peak flow, flood depth, and areal extent of flooding is shown. In Chapter 5, methods and results for determining which parameters affect the *PRF* are shown. Finally, in Chapter 6, the dissertation ends with a summary, conclusions, recommendations, and lessons learned.

2. REVIEW OF RELATED LITERATURE

2.1. Overview

This chapter presents the literature pertinent to the study. In Section 2.2., the concepts foundational to this study are reviewed. In Section 2.3, past studies are discussed concerning the Rational Method (Section 2.3.1), advances on unit hydrograph theory (Section 2.3.2), the NRCS method (Section 2.3.3) and studies on *PRF* estimation (Section 2.3.4). Finally, in Section 2.4, a summary of gaps in literature, as well as the role of this study in filling those gaps, is presented.

2.2. Review of concepts

2.2.1. Water balance

2.2.1.1. Description

While a hydrology textbook (e.g. Dingman, 2015) is recommended for studying the basic concepts of hydrology, it is important to summarize concepts related to this study in this manuscript. The concept of peak rate factor, for example, is only significant because it is used to develop peak discharges. Streamflow discharge – or runoff – is important but it is only one component of what is called the water-balance equation. While treatment of other hydrologic concepts in this literature review would not be comprehensive, the hydrologist should be aware that surface runoff is related to these other components and an understanding of each component would be beneficial.

The **water-balance equation** describes mathematically the processes in the hydrologic cycle occurring in the troposphere:

$$P + GW_{in} - (Q + ET + GW_{out}) = \Delta S \qquad (2\text{-}1)$$

where P is precipitation, GW_{in} is groundwater inflow, Q is stream outflow, GW_{out} is groundwater outflow, ET is evapotranspiration, and ΔS is the change in storage.

In the succeeding sections, each of these terms in the water balance are discussed as well as current trends on research associated with the hydrologic process.

2.2.1.2. Storage

Storage refers to the amount of water stored in the watershed. The change in storage is the difference between the amount of water stored as groundwater and in rivers, lakes, soil, vegetation, snow and ice. In the water balance equation, it is computed as:

$$\Delta S = \frac{S_T - S_0}{T} \qquad (2\text{-}2)$$

where ΔS is the change in storage volume over a measurement period of duration T, S_0 is the initial storage, and S_T is the storage at time T.

When S_T is approximately equal to S_0, then ΔS would be negligible and water balance calculations would be simpler. For this reason, in the United States, the USGS set the beginning of the water year in October 1 on the assumption that by this time, transpiration brought about by higher temperatures in the summer have lessened and that ground-water storage is maximum (Dingman, 2015).

2.2.1.3. Evapotranspiration

Evapotranspiration refers to the processes by which water at or near earth's surface becomes atmospheric water vapor. The term includes evaporation from open water as well as evaporation from within the leaves of plants (transpiration). Evaporation that occurs in vegetative surfaces is called interception loss, where interception is the process by which vegetative surfaces catch falling water before it reaches the surface (Dingman, 2015).

2.2.1.4. Precipitation

When water vapor rises, it is cooled and eventually turns back again to liquid – a process called condensation. For condensation to occur, hydrophilic particles – called cloud condensation nuclei (CCN) – must be present to act as substrate for water. These CCN then enable droplet growth, which becomes heavy enough to fall as precipitation. For the precipitation to be significant, water vapor must continuously be important into the cloud to replace that which falls out. The processes of water falling to the earth's surface from the atmosphere is called precipitation and it includes rain, snow, hail, dew, and frost (Dingman, 2015).

2.2.1.5. Infiltration

Infiltration is the process by which water touching the soil surface enters the soil. The rate at which water infiltrates is influenced by the rain rate, the depth of ponding, the degree of saturation of the soil, and the hydraulic conductivity of the surface. One popular method of estimating infiltration rate is the Green-Ampt Loss Model, is appealing because it considers the whole process of infiltration – from the complete infiltration of rain up to the time of ponding to its decline thereafter (Dingman, 2015).

2.2.1.6. Groundwater flow

Groundwater flow comes from water that enters the soil subsurface from precipitation or from water bodies. Eventually, after infiltrating the soil layer, the water will travel in the soil surface and is eventually stored and flow slowly through geologic formations of soil, sand, rocks called aquifers. The rate at which groundwater flows is governed by Darcy's Law and is influenced by a property of the soil layer called the hydraulic conductivity (Dingman, 2015).

2.2.1.7. Runoff

To complete the hydrological cycle from evaporation from the oceans and waterbodies, water flow to a watershed and is conveyed by streams back to the oceans. The flow of water in the streams is called runoff. The watershed is then composed of a stream network that can be classified quantitatively according to Horton (1945) or Strahler (1957). In these systems, first-order streams are those with no tributaries. The confluence of two first-order streams is the beginning of a second-order stream and the confluence of two second-order streams is the beginning of a third-order stream. The order of the watershed is the order of the stream at the watershed outlet (Dingman, 2015).

An important concept in runoff generation is the **baseflow**, which is part of runoff not directly caused by a storm event. This baseflow is largely due to groundwater-surface water interactions and it is often of interest to hydrologists to remove the baseflow in hydrologic modeling so that only the direct effect of an event is analyzed. While there is no baseflow separation method based on physical laws, several methods exist such as graphical recession analysis, master recession curve, the Brutsaert approach (Brutsaert and Nieber, 1977), and the Wittenberg method (Wittenberg and Sivapalan, 1999). Despite the existence of these methods, there is still a dearth of understanding on the subject.

2.2.2. Unit hydrograph theory

2.2.2.1. Overview

An important concept in hydrology is the idea of a **watershed** (also known as catchment or basin), which is the area that – assuming water can only flow from a higher elevation to a lower elevation – appears to contribute all the water that passes through a specified cross section of a stream, called the **outlet**. The surface trace of the boundary that delimits a watershed is called a **divide** and the horizontal projection of the area of a watershed is called the **drainage area** (Dingman, 2015).

A **hydrograph** is a graph of discharge versus time at a particular point in the watershed – usually, the watershed outlet. Storm hydrographs – which are hydrographs plotted because of a storm event – may be categorized as natural hydrographs, direct runoff hydrographs, unit hydrographs, and dimensionless unit hydrographs. Natural hydrographs or total hydrographs are hydrographs that are observed in the stream. Direct runoff hydrographs are hydrographs that only represent the contribution of the storm in consideration, i.e., the hydrograph resulting only from the excess precipitation. Hence, direct runoff hydrographs are hydrographs where baseflow is removed. Unit hydrographs are direct runoff hydrographs resulting from a unit excess rainfall (e.g. one inch or one cm). Dimensionless unit hydrographs are unit hydrographs in which ordinates are divided by the peak flow and abscissas are divided by the peak-flow time.

2.2.2.2. Parts of a unit hydrograph

Figure 2-1 shows an example of a unit hydrograph. A pulse of unit rainfall (equal to one inch for English units or one centimeter for SI units) with duration t_d is depicted as a rectangular area that starts at time zero and ends at time t_d. The **lag time** t_L is the distance from the centroid of the rainfall pulse to the centroid of the watershed. The **peak discharge** $\boldsymbol{q_p}$ is the maximum value of the ordinate of the unit hydrograph. The **peak-flow time** $\boldsymbol{t_p}$ is the time it takes from the hydrograph to rise from 0 to the peak discharge. The **base time** $\boldsymbol{t_b}$ is the total time it takes for the hydrograph to rise from 0 and recede to 0. The **rising limb** is the part of the unit hydrograph from time zero to the time that it reaches its maximum ordinate (segment A to B). The **recession limb** the part of the unit hydrograph from the maximum ordinate to when it reaches zero again (segment B to C).

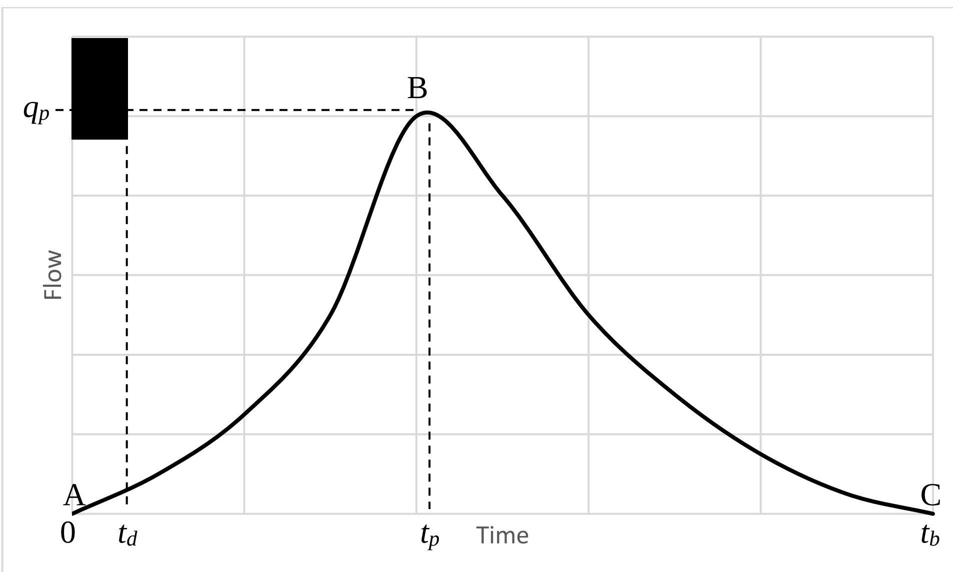


Figure 2-1. Unit hydrograph components.

2.2.2.3. Factors influencing the shape of the hydrograph

It is known the hydrographs are usually positively skewed and the main reason studied as affecting hydrograph skewness is geomorphology. In the past, descriptions of watershed geomorphology have been qualitative, until the work of Horton (1932, 1945), which paved the way for quantitative descriptions of geomorphology. Horton (1932) categorized drainage basin characteristics into morphologic factors, soil factors, geologic-structural factors, vegetational factors, and climactic-hydrological factors. He then proposed the law of stream numbers which state that "The numbers of streams of different orders in a given drainage basin tend closely to approximate an inverse geometric series in which the first term is unity and the ratio is the bifurcation ratio," where the bifurcation ratio is the "ratio of the average number of branchings or bifurcations of streams of a given order to that of streams of the next lower order. It is usually constant for all orders of streams in a given basin" (Horton, 1945). Strahler (1957) organized these variables in dimensionless groups and Shreve (1966) showed that Horton's law of stream numbers comes as a "consequence of random development of channel networks according to the laws of chance". Smart (1969) improved upon Shreve (1966) by providing a more comprehensive discussion of the statistical properties of stream lengths. Kirkby (1976) showed that the basin width influences peak discharge in proportion to the total length of streams. Rodriguez-Iturbe and Valdez (1979) postulated the concept of the geomorphological instantaneous unit hydrograph (IUH) and showed that the product of peak-flow time and peak flow increases with increasing area ratio, increasing length ratio, and decreasing bifurcation ratio. This concept was further discussed by Rinaldo and Rodriguez-Iturbe (1996).

Related to watershed geomorphology is the concept of dispersion, which motivated further research on factors that influence hydrologic response of watersheds. Robinson et al. (1995) showed that small watersheds are governed by hillslope response while large watersheds, by network response. Olivera and Koka (2004) showed that the effect of hydrodynamic dispersion decreases relative to the effect of advection with drainage area if hydrodynamic parameters are uniform. In the case of spatially varying parameters, however, the authors pointed out that the hydrologic response may be different.

To determine the factors affecting the *PRF*, it is beneficial to understand the different factors affecting the shape of a hydrograph such as main channel slope, average watershed slope, watershed shape, rainfall intensity, and rainfall duration.

A higher watershed slope and main channel slope would lead to higher runoffs, which means that a droplet would also exit the watershed faster than if runoffs were low. Hence the hydrograph would have a higher peak discharge and also a lower peak-flow time. Another factor that affects the shape of the hydrograph is the area. A larger watershed means a higher time of concentration and hence the base time of the hydrograph is also higher. It is also noted that water flows faster in the main channel than in the banks, i.e., channel flow is faster than sheet flow and overland flow. Thus, a narrower watershed also leads to a higher peak discharge and a lower peak-flow time. Land use and land cover also affect the shape of the hydrograph. The more developed (the higher %imperviousness) a watershed is, the faster the flows, and hence the peak discharge is higher and the peak-flow time is lower. Furthermore, the slopes affect the shape of the hydrograph where steeper slopes are associated with faster runoff movement and hence smaller peak-flow time. Finally, the aerial pattern of the rainfall also influences the shape of a hydrograph. When the rain is concentrated near the watershed outlet, then there will be a rapid rise (peak-flow time will be lower) and a rapid recession (base time will be lower as well). It should be noted that one of the assumptions of a unit hydrograph is a uniform rainfall distribution. This assumption is reasonable for small watersheds but as watersheds get larger and larger, this assumption becomes more difficult to be satisfied. NRCS (2007) recommends that the unit hydrograph method be applied to watersheds less than 20 square miles.

2.2.2.4. The NRCS Curve Number Method

The NRCS Curve Number Method (NRCS, 2007) is a method for estimating direct runoff given precipitation and has been ascribed to Victor Mockus (Boughton, 1980).

$$\frac{F}{S} = \frac{Q}{P} \tag{2-3}$$

where F is the actual retention of precipitation during a storm (inches), S is the potential maximum retention (inches), Q is the direct runoff (inches), and P is the total precipitation (inches). Taking into account initial abstractions – intercepted water, surface storage, and infiltration that occurred before runoff begins –

$$\frac{F}{S} = \frac{Q}{P_a} \tag{2-4}$$

Substituting $P_a - Q$ for F gives,

$$\frac{P_a - Q}{S} = \frac{Q}{P_a} \tag{2-5}$$

Solving for Q,

$$Q = \frac{{P_a}^2}{P_a + S} \tag{2-6}$$

Since $Pa = P - I_a$,

$$Q = \frac{(P-I_a)^2}{P-I_a+S} \tag{2-7}$$

Field data indicated that $I_a = 0.2S$ (Mockus), therefore,

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \tag{2-8}$$

where $Q = 0$ if $P < 0.2S$. The parameter S is related to the curve number CN by,

$$S = \frac{1000}{CN} - 10 \tag{2-9}$$

It should be noted that CN here is for average antecedent moisture conditions and that adjustments to CN must be made to account for dryer or wetter soils. Specifically,

$$CN(I) = \frac{4.2CN(II)}{10-0.058CN(II)} \tag{2-10}$$

$$CN(III) = \frac{23CN(II)}{10+0.13CN(II)} \tag{2-11}$$

where CN(II) is the curve number for average conditions, CN(I) is for dryer conditions, and CN(III) is for wetter conditions.

2.3. Past studies

2.3.1. Advances on unit hydrograph theory

2.3.1.1. Origin

The literature behind *PRF* estimation traces its roots to determining peak discharges. The earliest of the widely used methods still in use today is the *Rational Method*, which was developed by Mulvaney (1851) and Kuichling (1889) and is shown in Equation 2-12.

$$Q = ciA \tag{2-12}$$

where Q is the peak discharge, c is the runoff coefficient, i is the design rainfall intensity, and A is the drainage area.

While the Rational Method is effective for practical use in small basins, it is limited in that it does not provide information on the time parameters of this peak flow. Another method that aims to fill that gap is the hydrograph method. The concept of the **unit hydrograph** method was developed in the 1930s by Sherman (1932), with the idea that when this hydrograph is formulated for a basin, then natural hydrographs for storm duration for that basin can be derived. Moreover, watersheds with similar shape than the basin with known unit hydrograph may also be derived through their area relations: using the principle that dimensions for similar areas may be related by the square roots of their areas. Unit hydrographs have the following assumptions: 1) constant intensity of excess rainfall, 2) uniform distribution of excess rainfall over the watershed, 3) constant base time of the hydrograph, 4) direct proportionality of the ordinates of the hydrograph for a common base time, and 5) unchanging characteristics of the watershed (Chow et al., 1988). Despite these assumptions the unit hydrograph approach provides a convenient mean to estimate the direct runoff hydrographs for a given watershed from the rainfall data using linear proportions and superposition principles. Nevertheless, other limitations of the unit hydrograph prompted subsequent researchers to look for improvements on the unit hydrograph.

2.3.1.2. Snyder

One limitation of the unit hydrograph can only be generated for watersheds with gage data. Snyder (1938) sought to tackle this problem by introducing a method of developing synthetic hydrographs for drainage areas 10 to 10,000 square miles where there is no record of streamflow. This method uses the lag time between the peak discharge and center of rainfall. Thus, the peak discharge is then related to lag and after the lag is approximated for a watershed with no discharge data, the peak discharge and corresponding unit hydrograph may be developed. The following equations were therefore developed:

$$t_p = C_t(L_{ca}L)^{0.3} \quad (2\text{-}13)$$

$$q_p = \frac{640\ C_p}{t_p} \quad (2\text{-}14)$$

where t_p is the lag (hrs), L_{ca} is the distance from station where the hydrograph is to be estimated to watershed center (mi^2), L is the length of the watershed, q_p is the peak flow (cfs/mi^2), and C_t and C_p are unit conversion coefficients that ranges from 1.8 to 2.2 for C_t and 0.56 to 0.69 C_p, and where C_p approaches its larger value when C_t approaches its lower value.

2.3.1.3. Clark

One of the limitations of prior studies unit hydrograph theory is that it does not take into account the unsteady nature of storage. Clark (1945) joined concepts of routing and unit hydrograph theory to form a unit hydrograph for very short periods of initial runoff. The instantaneous unit hydrograph developed unit hydrograph (Clark, 1945) assumes that “After inflow to the water has ceased, all water which will eventually become runoff but hasn’t passed the gage is in storage” (Clark, 1945).

2.3.1.4. Hydrographs following statistical distributions

One limitation of unit hydrographs is with regards to their form and that they are limited to cases where time scales of the derived unit hydrograph are integral multiples of the time scales of the known unit hydrograph (Edson 1951). Edson (1951) derived an equation for representing the unit hydrograph as a gamma function:

$$T_m = x/y \tag{2-15}$$

$$q_m = \frac{Cy\left(\frac{x}{e}\right)^x}{\Gamma(x+1)} \tag{2-16}$$

where q_m is the maximum discharge per unit area (cfs/mi^2), T_m is the time of maximum discharge, C is a conversion constant equal to 242/9, and x is a constant specific to the watershed. He then devised a set of s-curves from which the value of x may be determined.

The justification of using Gamma distributions for unit hydrographs, as pointed out by Nash (1957), is that the form of the unit hydrograph is that of flow routed through a cascade of linear reservoirs such that the shape parameter of the gamma distribution relates to the number of linear reservoirs and the scale parameter relates to the residence time. Aron and White (1982) proposed a method for fitting a gamma unit hydrograph to synthetic unit hydrographs given peak flow and peak-flow time. Singh (2000) proposed a method for transmuting Snyder's synthetic unit hydrograph and the NRCS dimensionless unit hydrograph to gamma distributions.

It should be noted, however, that other representations of the unit hydrograph distributions are available. For example, Olivera and Maidment (1999) present a variation of the Nash's unit hydrograph in which the watershed is represented by a dendritic tree of linear reservoirs, instead of a cascade. In their model, the linear reservoirs may have different residence times, and the convolution of the reservoir responses is approximated by a first passage times distribution (Olivera and Maidment, 1999), which resembles a Gamma distribution when the reservoirs are identical and arranged as a cascade.

Moreover, Walega et al. (2014) focused on the beta and Weibull hydrographs. They compared the sensitivity of the hydrographs to input parameter changes and found the Weibull distribution is more sensitive when modeling peak discharge.

2.3.1.5. NRCS Dimensionless Unit Hydrograph

A more general approach than the unit hydrograph is the dimensionless unit hydrograph. In 1957, the dimensionless unit hydrograph was introduced by Victor Mockus and codified in the first edition of the National Engineering Handbook by US Department of Agriculture (USDA) Soil Conservation Service (SCS), which is now Natural Resources Conversation Service (NRCS) (USDA SCS, 1972). Using watersheds in Midwestern United States, the authors reported that a *PRF* of 484 is suitable for the "average watershed". This value assumed a t_r/t_p ratio of 8/3. While this value has been the basis of many state hydraulic practices, including the most recent National Engineering Handbook (USDA NRCS, 2006), subsequent authors have questioned the applicability of this value for other watersheds. In the succeeding versions of the National Engineering Handbook, more flexibility is given to the value of *PRF*, with the latest version stating that the *PRF* varies from 100 to more than 600 (NRCS, 2007).

In deriving the NRCS peak discharge equation, first equating runoff volume with the area of the triangular unit hydrograph,

$$AD = \frac{1}{2} t_b Q_p \tag{2-17}$$

Solving for Q_p,

$$Q_p = \frac{2AD}{t_b} \tag{2-18}$$

According to the experiments of Mockus (1957), $t_b = \frac{8}{3} t_p$, so

$$Q_p = \frac{2AD}{\frac{8}{3}t_p} = \frac{3}{4}\frac{AD}{t_p} \qquad (2\text{-}19)$$

If A is in square miles, D is 1 inch, and t_p is in hours, a unit conversion factor must be multiplied so that Q_p would be in cfs

$$Q_p = \frac{3}{4}\frac{AD}{t_p}\left(\frac{5280\,ft}{mi}\right)^2\left(\frac{1\,ft}{12\,in}\right)\left(\frac{1\,hr}{3600\,s}\right) = \frac{484A}{t_p} \qquad (2\text{-}20)$$

The value 484 is called the peak rate factor (*PRF*) and has been the subject of many research studies.

2.3.2. Past studies on *PRF*

Initially, Mockus (1957) did not contemplate or mention other possible *PRF* values and the *PRF* of 484 was just mentioned as a constant. Since its conception, however, many authors have sought to investigate the suitability of this value. McCuen and Bondelid (1983), working with 22 storm events in six watersheds (i.e., one each in Maryland, Virginia, and Ohio; and three in the Delmarva Peninsula), noted that the *PRF* should be less than 484 for areas with significant storage.

$$PRF = 1290.67p \qquad (2\text{-}21)$$

where p is the proportion of the area under the rising limb of the time-area curve [-].

Welle and Woodward (1989) found a *PRF* of 284 for the Delmarva Peninsula, based on an averaged unit hydrograph from seven storms in four watersheds ranging in areas from 4.63 to 60 mi^2. This *PRF* and associated unit hydrograph have been recommended for use in runoff models by the New Jersey Department of Agriculture (NJDA) (Showler, 2018).

Capece et al. (1988) considered 45 raainfall-runoff events in south Florida flatwood watersheds and employed different methods of runoff estimation. Their study results in these methods overestimating the *PRF*, and that the appropriate values should've ranged from 80 to 100, which is even less than the recommendation of Welle and Woodward (1989).

Solanki and Suau (1996) developed an empirical equation for the *PRF* considering coastal flatland watersheds in Southwest Florida. They considered the basin area and imperviousness as the main predictors of *PRF*, and not its slope as they reasoned that this parameter is already incorporated in the time of concentration. Furthermore, they found the *PRF* to increase with the imperviousness and decrease with the drainage area. Using this equation, for a full impervious surface (Imp = 100%), the *PRFs* with an area range of 1 to 20 square miles would range from 140 to 218.

$$PRF = 60\frac{Imp^{0.28}}{A^{0.15}} \qquad (2\text{-}22)$$

where *Imp* is imperviousness [%] and *A* is drainage area [mi^2].

Sheridan et al. (2002) studied eight flatland watersheds in Southeastern United States to determine an equation for the *PRF* based on the stream frequency, drainage density, channel slope, relief ratio, length-width ratio, Melton ratio, channel length, and drainage area. Using stepwise regression analysis, they found that the *PRF* depends mostly on the main channel slope and, to a lesser degree, on the drainage area.

$$PRF = 631.7 \times CS^{0.882}A^{0.264} \qquad (2\text{-}23)$$

where *CS* = main channel slope [%], measured at 10 and 85% of total main channel length, and *A* = watershed drainage area [mi^2].

Horst and Gurriell (2019) calculated site-specific *PRFs* for 26 watersheds in New Jersey for Hurricane Irene that occurred in August 2011, by assuming a range of *PRFs* to solve for peak flow, which they plugged in the following equation (taken from the National Engineering Handbook (NRCS, 2007)) to obtain the ordinates of the direct runoff hydrograph was determined. They then compared the simulated hydrographs were compared to the actual hydrograph and the *PRF* that correspond to the closest fit was selected as the solution.

$$\frac{Q}{Q_p} = e^m \left[\left(\frac{t}{t_p}\right)^m\right]\left[e^{\left(-\left(\frac{t}{t_p}\right)\right)}\right] \quad \textit{(2-24)}$$

Horst and Gurriell (2019) found *PRFs* ranging from 170 to 975; however, they did not find a correlation between *PRF* and watershed characteristics as *PRFs* that are close with each other do not seem to have the same characteristics. Furthermore, there are watersheds with the same characteristics but have vastly different *PRFs*. They remarked that it is therefore unclear how *PRFs* vary - whether watershed characteristics or storm characteristics play a more significant role in influencing the *PRFs*.

Recently, in an American Geophysical Union Fall Meeting, a couple of abstracts and poster presentations on *PRF* were presented. The first, by Zadeh and Brubaker (2021) investigated *PRFs* for 20 Maryland watersheds in response to Hurricane Sandy in October 2012 and found *PRFs* ranging from 49 to 848. They also did not find any relationship between *PRF* and watershed characteristics. The second, by Huang and Merwade (2021), considered 120 rainfall-runoff events in 30 small watersheds in Indiana and found an average *PRF* of 371. The authors also found that the main channel as a main contributor in determining the *PRF*.

The latest iteration of the NRCS National Engineering Handbook (NRCS, 2007) acknowledged that it may vary from less than 100 in flat to 600 in mountainous, steep terrain. A more detailed list of choosing a *PRF* given terrain characteristics was given by Wanielista et al. (1997), who, in their textbook on hydrology, listed a high *PRF* of 575 for urban areas with steep slopes and a low *PRF* of 100 for rural, very flat terrain.

2.3.3. Texas studies

Texas is not immune to floods and extreme rainfall, so the Government has provided manuals on hydraulic and hydrologic modeling of structures for flood mitigation. The latest hydraulic manual published by the Texas Department of Transportation was in 2019, which stipulates that in the use of the NRCS Method (NRCS, 2007), the constant of 484 is recommended for *PRF*, unless specific runoff data indicate a different value is warranted. Several federal laws and regulations are also concerned with hydraulic design: National Flood Insurance Act, Executive Order 11988 (U.S. Department of Transportation Order 5650.2), National Environmental Policy Act, Rivers and Harbors Act, Clean Water Act, 23 CFR Part 650 Subpart A, 23 CFR Part 650 Subparts C and H.

One comprehensive TxDOT project that contains comprehensive analysis of the applicability of unit hydrographs in Texas watersheds can be found in Fang et al. (2005), who considered more than 1,600 storm events in 93 watersheds and developed equations of the peak flow and of the peak-flow time as a function of drainage area, main channel slope, and maximum flow length. They reported a mean *PRF* of 370 for all the 93 watersheds. Furthermore, using regression analysis, the obtained the following equations:

$$PRF = 132.5A^{0.044}L^{-0.264}S^{-1.288} \text{ for } A<10 \text{ mi}^2 \qquad (2\text{-}25a)$$

$$PRF = 1636.19A^{0.341}L^{-0.369}S^{-0.263} \text{ for } A>10 \text{ mi}^2 \qquad (2\text{-}25b)$$

where A is drainage area [mi^2], S is main channel slope [-], and L is main channel length [mi]. They did not however, express confidence in establishing which method was suitable for which watershed; rather, they mentioned that engineering judgment should be applied in making use of the right method for *PRF* estimation.

2.4. Limitations and opportunities

In the studying the literature, several observations are worth noting. First, it cannot be denied that research on unit hydrographs and *PRF* estimation have advanced in the last century. For example, the time resolution used in Sheridan's (2002) work is six days. Data with a resolution of minutes is now available. The higher resolution of data available today makes it possible to verify past studies using better-quality data and is therefore important for future work.

Second, today's society is fortunate to have efficient access to a gamut of data sources. Many governmental agencies such that USGS and NOAA, for example, have repositories of large amounts of data that are free to the public. The availability of data presents opportunity for future work in any field of study and in the context of this literature review, in the estimation of *PRF*.

Third, there has been increasing recognition that the *PRF* for use in NRCS Unit Hydrograph Method should not be fixed to 484. For example, in the first edition of the

National Engineering Handbook (SCS, 1974), the *PRF* that was recommended was 484, with no provision for other changes. In the succeeding editions, more leeway is given. In effect, the decision of what *PRF* to use has been left to the engineer's judgment. Thus, it is important that a guideline for *PRF* be established in the future.

Fourth, while studies abound on the *PRF*, none have developed a comprehensive guideline, and specifically, for Texas watersheds. Another limitation of past studies concerns the small number of watersheds and events considered in their analysis. Furthermore, in Texas, most hydraulic manuals give much leeway to the designer instead of prescribing firm guidelines for *PRF* estimation. To avoid ambiguity among engineers, it is therefore important to establish these guidelines for localities. Moreover, while there have been reports that have dealt with *PRF* estimation in Texas, none as comprehensive is available in peer-reviewed journals. A publication based on this study is forthcoming (Lasco et al., forthcoming), which will serve to fill that gap.

Fifth, with regards to this future work, it is important to note that even though many new and more accurate methods of peak discharge estimation have been proposed, engineers still gravitate toward to simplest approach. For example, the Rational Method is still being frequently used in practice despite the availability of more sophisticated *PRF* estimation techniques. Because of this behavior, it is therefore important to keep the guidelines for *PRF* estimation as simple as possible without sacrificing accuracy.

In conclusion, despite the availability of data and research articles on *PRF* estimation for hydrologic modeling, no solid and simple guidance has been established for Texas yet. This dissertation is an effort towards narrowing these gaps by considering a comprehensive dataset involving more than 1600 events to estimate reasonable ranges of *PRF* for Texas. Moreover, 60 watersheds were considered to investigate which parameters affect the *PRF*. The comprehensiveness of this study will serve as a template for future research on *PRF*.

3. STUDY AREA, DATA, AND TOOLS

3.1. Study Area

The study area consisted of the 104 flow-gauges in central-east Texas shown in Figure 3-1, and comprises the following regions: Austin, Dallas, Fort Worth, San Antonio, Houston and Rural, where the Rural region consists of rural watersheds spread across Texas. From the map, it may be noticed that most of the sites are concentrated in East and Central Texas. While there is a lack of sites in West Texas, most of the population of Texas – according to the 2020 Census Geography (Texas Legislative Council, 2021) – are represented as can be seen in Figure 3-2. In fact, out of a population of 29,145,505, 4,731,135 or 16% are in Harris County where the Houston sites are located; 2,613,539 or 9%, Dallas County where Dallas sites are located; 2,110,640 or 7%, Tarrant County where Fort Worth sites are located; 2,009,324 or 7%, Bexar County where San Antonio sites are located; and 1,290,188 or 4%, Travis County where Austin sites are located. Including Rural areas, therefore, more than 70% of the population of Texas is represented by the USGS gages. Finally, the population in West Texas counties highlighted in Figure 3-2 is only 2,662,646 which is about 9% of the total population of Texas. Of the sites considered in the analysis, Houston, in particular, needs more attention as it is the fourth largest city in the United States and being situated in the Gulf of Mexico, is unfortunately prone to flooding more than other urban regions.

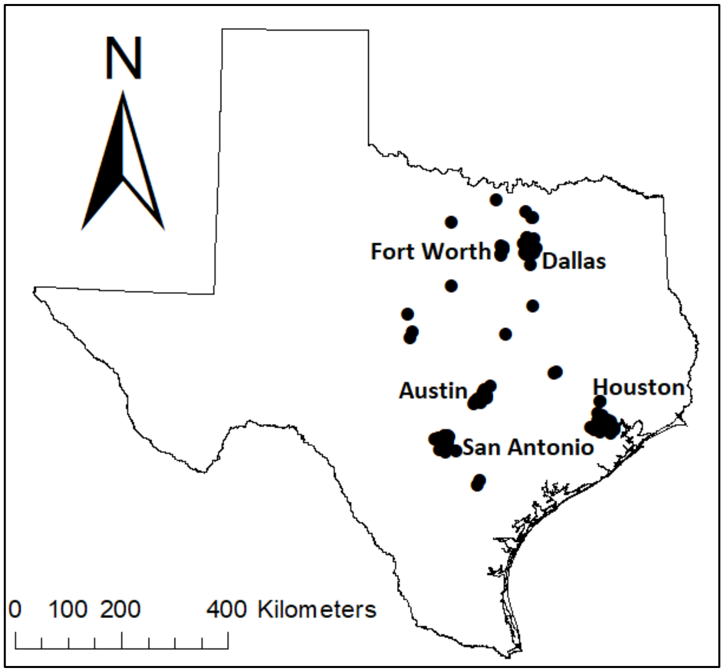


Figure 3-1 Study area.

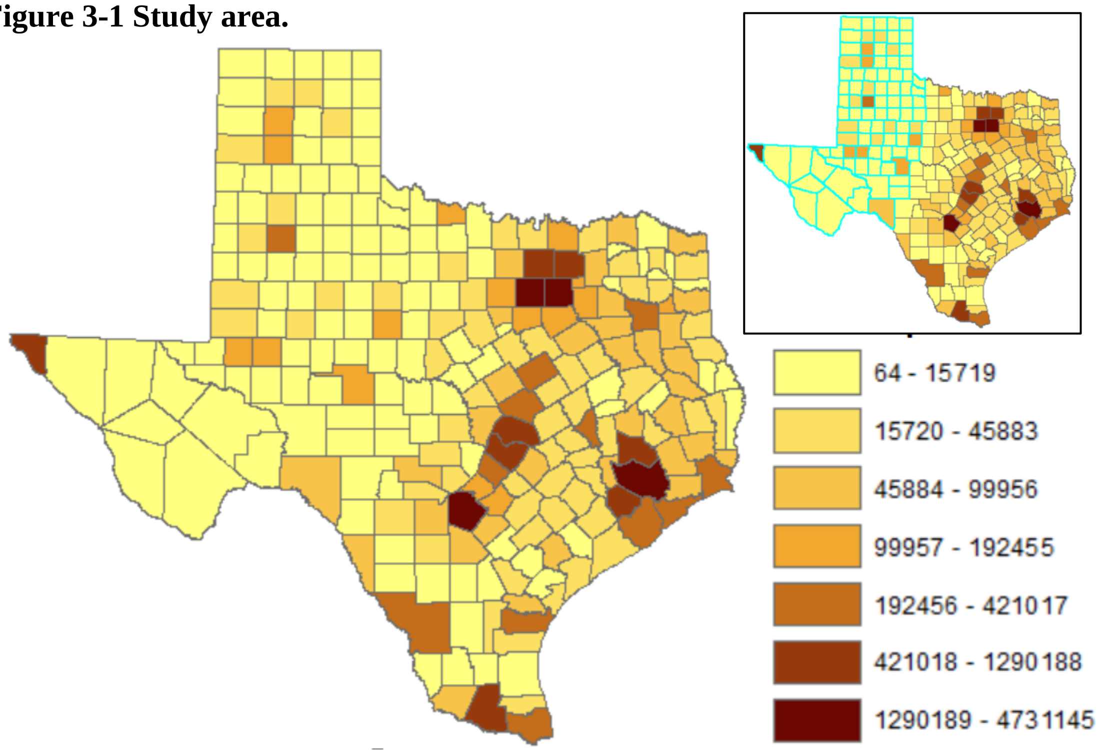


Figure 3-2. Population of Texas (as of 2020) by county.

3.2. Data

3.2.1. Description

The rainfall-runoff dataset used in the analysis was obtained from the USGS (Asquith et al., 2004; William Asquith, personal communication, 2019) and contained 2,752 rainfall-runoff events in 134 watersheds across Texas, with areas ranging from 0.13 to 182 sq-mi. Documentation of the data may be found in Asquith et. al. (2004) with some properties shown in Table 3-1.

Table 3-1. Properties of USGS historical rainfall-runoff data.

Name	USGS historical rainfall-runoff data
Units	Inches for rainfall, cubic feet per second for runoff
Start date of collection	See Asquith et al. (2004)
End date of collection	See Asquith et al. (2004)
Number of sites	134
Extent of record	1959 to 1982
Original format	Text file (.txt)
Time zone	CST/CDT
Finest resolution	5 minutes
Data documentation	Asquith et al. (2004)
Source	Printed reports from USGS (see Asquith et al., 2004)
Downloading process	Obtained directly from USGS (William Asquith, personal communication, 2019)

3.2.2. Processing

Before the rainfall-runoff data was analyzed, it must be processed in readable comma-separated values (csv) formats. The rainfall raw file, which was written in continuous line format, was formatted to csv-file with column names. The following are the fields for the output files:

MIN_PASSED_HYETO – starts with 0, which is corresponds to the start of the storm. Successive values are minutes that have passed after the start of the storm.

PRECIP – cumulative precipitation in inches

A representation of the format change is shown in Figure 3-3a. Similarly, for the runoff raw file, which was written in continuous line format, was formatted to csv-file with column names. The following are the fields for the output files:

MIN_PASSED_HYDRO – corresponds to the minutes that have passed since the beginning of the storm (time zero in the rainfall data).

RUNOFF – discharge in cubic feet per second

A representation of the format change for runoff is shown in Figure 3-3b. All data were consolidated in a folder that includes two csv files per storm event (one for rainfall and one for runoff). Each csv file is named after the event ID it represents:

rain_staUSGSID_YEAR_MMDD_HHMM.csv for rainfall or

unit__staUSGSID_YEAR_MMDD_HHMM.csv for runoff

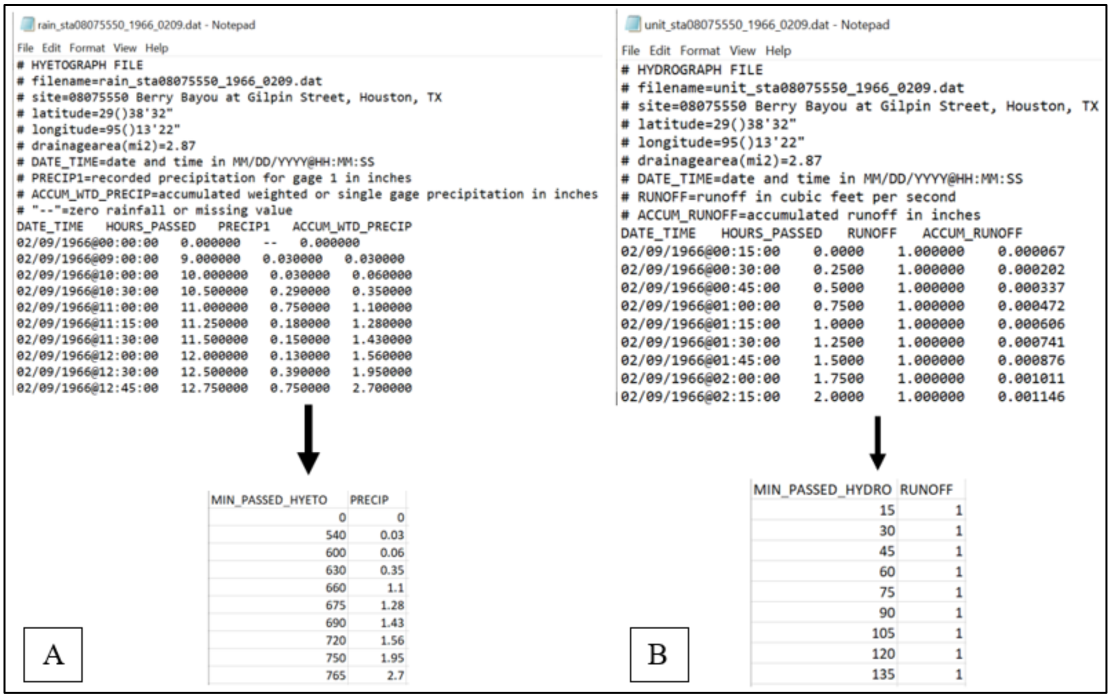


Figure 3-3. Format change for historical USGS a) rainfall data and b) runoff data.

Because the NRCS unit hydrograph is recommended only for watersheds with drainage areas less than 20 sq-mi (NRCS, 2007), all watersheds larger than that upper limit – 30 of them – were disregarded. Thus, only 104, out of the original 134 watersheds in the dataset, were considered in the analysis and only 2,106 events, out of the total of 2,752, took place on the selected watersheds. Of the 2106 events, 113 contained two or more distinct hydrographs and were split into multiple events: 93 events were split into two, 17 into three, and three into four – adding 136 more events and bringing the total to 2,242.

For each of the 104 flow gauges, its USGS ID number, region, coordinates, watershed drainage area, number of storms in the dataset, total number of storms including split events, number of storms for which *PRFs* were calculated, and number of storms for which the calculated *PRFs* were within the acceptable fit, are included in Appendix Table H2. Comprehensive documentation of the sites is available at USGS (2022).

3.3. Tools

3.3.1. Watershed delineation

ArcMap 10.6 was used for terrain analysis and geographic information systems. Terrain analysis, for stream and watershed delineation, and calculation of some of the watershed parameters was based on the 1 arc-second (i.e., approximately 30 m) DEM developed by USGS (2017).

To assemble the DEM of Texas, DEMs that cover the whole of Texas plus a buffer on the northern, western, and eastern boundary of Texas were downloaded from USGS in the following website: https://viewer.nationalmap.gov/basic/. The individual DEMs were then mosaicked and then projected to NAD 1983 Texas Statewide Mapping System (TSMS) (ArcMap tool: Data Management Tools → Raster → Raster Dataset → Mosaic to New Raster). The DEM is shown in Figure 3-4 and its properties in Table 3-2.

Table 3-2. DEM properties.

Parameter	Value
Source	USGS (https://viewer.nationalmap.gov/basic/)
Original coordinate system	North American Datum of 1983 (NAD 83)
Vertical reference system	North American Vertical Datum of 1988 (NAVD 1983)
Projected coordinate system	NAD 1983 Texas Statewide Mapping System
Cell size (X,Y)	97.255855807087 ft, 97.255855807087 ft
Uncompressed size	8.12 GB
Number of cells	2178517572

Number of NO DATA cells	1137757958

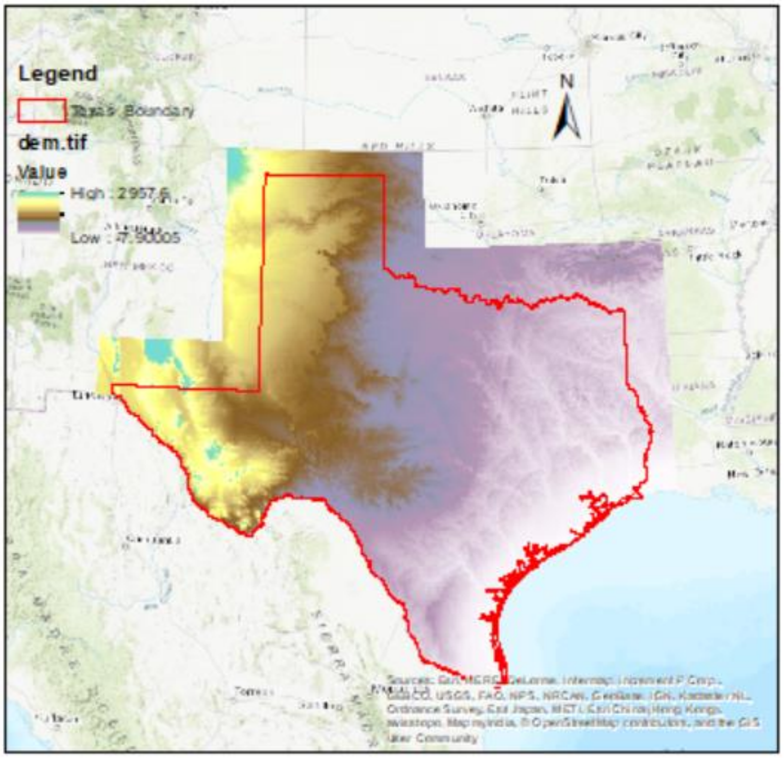


Figure 3-4. Texas DEM.

The following are the steps involved in watershed delineation in ArcMap.

Setting the environment – to ensure that there are no incongruencies in the raster files, the following settings in the ArcMap Environment were set to the projected DEM: coordinate system, processing extent, snap raster, and cell size. (ArcMap location: Geodatabase → Environments)

Pit filling – the process of filling depressions in the watershed. Pit filling is important because it prevents accumulation of flow inside the watershed and all flow drains out the watershed outlet. (ArcMap tool: Spatial Analyst Tools → Hydrology → Fill; input: projected DEM)

Flow direction – a raster with the following values representing flow direction: 1 – East, 2 – Southeast, 4 – South, 8 – Southwest, 16 – West, 32 – Northwest, 64 – North, 128 – Northeast. This flow direction that considers flow in eight directions is called the D8 flow direction algorithm. Generating flow directions is a necessary input raster for various spatial analyst tools such as flow accumulation, stream definition, flow length, and watershed tools. (ArcMap tool: Spatial Analyst Tools → Hydrology → Flow direction; input: filled DEM)

Flow accumulation – a raster where each cell value is the number of upstream cells that flow towards that cell. Generating the flow accumulation raster is important for stream definition and consequently, watershed delineation. Cells with the high flow accumulation values are likely to be streams and cells with the highest flow accumulation form the channel network. The cell with the highest flow accumulation value is the outlet of the watershed. (ArcMap tool: Spatial Analyst Tools → Hydrology → Flow accumulation; input: flow direction raster, specifying D8 as the flow direction type)

Stream definition – the process of generating a raster that defines the stream network. Streams are defined based on flow accumulation. To define the stream, a flow accumulation threshold must be used, i.e., cells with flow accumulation higher than this threshold will be considered streams. To facilitate stream definition in ArcMap, the raster calculator tool was applied wherein cells with flow accumulation values greater than the threshold were set to 1 and the other cells to NODATA. (ArcMap tool: Spatial Analyst Tools → Map Algebra → Raster Calculator; input: flow accumulation raster)

A common problem in watershed delineation is when gages snap to the wrong stream. To minimize this issue, multiple stream raster networks were generated with bins based on the reported drainage area (DA) of the watersheds. The following ranges of watershed DA were devised: 1-2, 2-5, 5-10, 10-20.

In defining the streams for each DA bin, a threshold with area that is half the lower limit of the bin was used. For example, for the DA bin of 2 to 5 square miles, a flow accumulation threshold of 1 square mile was used. The implementation in raster calculator is: `SetNull(Con("%dem_fac.tif%" > 2947, 0, 1), 1)`, where dem_fac.tif is the flow accumulation raster, 2947 is the number of cells equal to 0.5 square miles based on the map cell size (97.255855807087 ft by 97.255855807087 ft), SetNull is a function to set values to null and Con is a conditional function.

The succeeding steps in the watershed delineation process were applied separately to each of the DA bins.

Stream link – process of assigning unique values (called grid codes) to streams between intersections. Stream links form the basis of the watersheds (ArcMap tool: Spatial Analyst Tools → Hydrology → Stream Link; inputs: flow direction raster, stream raster)

Vectorization of stream raster – the process of converting the stream raster to a vector representation of the streams. In ArcMap, vector features may be represented by points, lines, or polygons. Hydrological features such as streams are represented as lines, gages are represented as points, and watersheds are represented as polygons. (ArcMap tool: Spatial Analyst Tools → Hydrology → Stream to Feature; input: flow direction raster, stream link raster, unchecking the option to simplify polylines)

Upon vectorization of the streams, opening the output attribute table may result in too many non-unique features. The duplicates were removed according to the grid code so that there is a one-to-one relationship between the grid codes and the stream lines.

Snapping of gages to stream lines – the process of situating gages exactly on the streams. The step is usually necessary because often, the geographical coordinates of the gages are such that the gages are near but not exactly right on the streams. If snapping were not done, the delineated watershed would be a very small portion than would be if the gage were place on the stream. The tool *Near* (Analysis Tools → Proximity → Near; input – projected gages) was used with the gages feature class (projected to the same coordinate system of the DEM) as input and the option *Location* checked to create the X and Y value of the points in the nearest streams to the gages. Next, the tool *Make XY Event Layer* (Data

Management Tools → Layers and Table Views → Make XY Event Layer; input – gage feature class with XY coordinates of nearest stream) was used to create a separate feature for the gage based on the X and Y coordinates.

Watershed raster – raster representing the contributing area to the gages. (ArcMap tool: Spatial Analyst Tools → Hydrology → Watershed)

Vectorization of watershed raster – the process of converting the watershed raster to a vector representation of the watersheds. (ArcMap tool: Data Management Tools → Conversion tools → Raster to polygon, unchecking the option to simplify polygons)

Dissolve – the process of combining features based on a similar attribute (in watershed delineation, this attribute is the gridcode). Dissolving the resulting feature dataset after vectorization (either of watersheds or stream lines) is important to remove duplicates (ArcMap tool: Data Management Tools → Generalization → Dissolve).

3.3.2. Calculation of watershed parameters

It is speculated that the *PRFs* depend on watershed and storm parameters. To assess this dependency, if any, statistical analysis was performed to see which parameters affected the *PRFs* and by how much. The storm parameter considered in the analysis were the precipitation depth P [L], rainfall intensity i [L/T], storm duration T [T], and excess rainfall depth D [L]. The watershed parameters considered in the analysis were the watershed drainage area A [L^2]; the watershed average slope S [-], which is the average of the slopes (i.e., rise over run) measured at a large number of points evenly distributed over the watershed; the length of the longest flow path L_{F-max} [L]; the slope of the longest flow path CS [-], which is the difference in elevation between the highest and lowest points of the longest flow path divided by its length; the watershed shape factor SF [-], which is the ratio of the area to the square of the length of the longest flow path; and a number of watershed geomorphologic indices that relate the average to the maximum distance to the outlet. When calculating the watershed geomorphologic indices, the average distance to the outlet was calculated in four ways: (1) Euclidean distance from the centroid L_{E-C} [L]; (2) average of the Euclidean distances from all points $\overline{L_E}$ [L]; (3) flow distance from the centroid L_{F-C} [L]; and (4) average of the flow distances from all points $\overline{L_F}$ [L]; where Euclidean distances are measured over straight lines, and flow distances along flow paths defined by the topography. Similarly, the maximum distance to the outlet was calculated in two ways: (1) maximum Euclidean distance L_{E-max} [L]; and (2) maximum flow distance L_{F-max} [L]. Hence, the four geomorphological parameters developed were $\frac{\overline{L_E}}{L_{E-max}}, \frac{L_{F-C}}{L_{F-max}}, \frac{\overline{L_F}}{L_{F-max}}$, and $\frac{\overline{L_E}}{L_{E-max}}$. Watershed delineation, longest flow path identification, slope and flow distance calculations were based on terrain analysis of the digital elevation model (DEM) of the study area with the eight-direction pour point algorithm (O'Callaghan and Mark, 1984).

The values of the above parameters are shown in Appendix Table H2. In what follows, the process in ArcMap for obtaining the watershed parameters are described.

Drainage area *(A)* – obtained by adding a field in the attribute table of the watershed and then calculating the area using Field Calculator.

Length of longest flow path (L_{E-max}) – obtained from generating the flow length raster (ArcMap tool: Spatial Analyst Tools → Hydrology → Flow length; input – flow direction raster, downstream). The length of longest flow path is the maximum value of the raster in the watershed, with the value of at the gage equal to zero. (ArcMap tool: Data Management Tools → Raster → Raster Properties → Get Raster Properties; input – flow length raster, Property type – Maximum)

Average slope of watershed *(S)* – the mean slope of the watershed represented in percent rise. A value equal to zero represents a flat surface while a very large value represents a vertical surface. (ArcMap tool: 3D Analyst Tools → Raster Surface → Slope, type – percent rise)

Shape factor *(SF)* – a parameter that reflects the shape of the watershed wherein a high value represents a wide watershed and a smaller time of concentration, and a low value represents a long and narrow watershed and therefore a larger time of concentration. The shape factor is calculated using the equation A/L^2 where A is the drainage area and L is the length of the longest flow path (Guo and Urbonas, 2007).

Main channel slope (*CS*) – the slope of the longest flow path, which may be computed as follows: *(elevation of the most hydraulically remote point from the gage – elevation of gage)/maximum flow length*. In ArcMap, the elevation values were obtained manually, although the Extract Multi-values to Points tool in ArcMap could have also been used.

Locating the watershed centroid – one important feature of the watershed is its geometric centroid, which is usually inside the watershed. When the centroid is outside the watershed, the watershed was not included in the analysis. (ArcMap tool: Data Management tools → Features → Feature to Point; Input features – watershed; uncheck the box named Inside)

Average flow length ($\overline{L_F}$) –arithmetic mean of the values in the flow length raster (ArcMap tool: Data Management Tools → Raster → Raster Properties → Get Raster Properties; input – flow length raster, Property type – Mean).

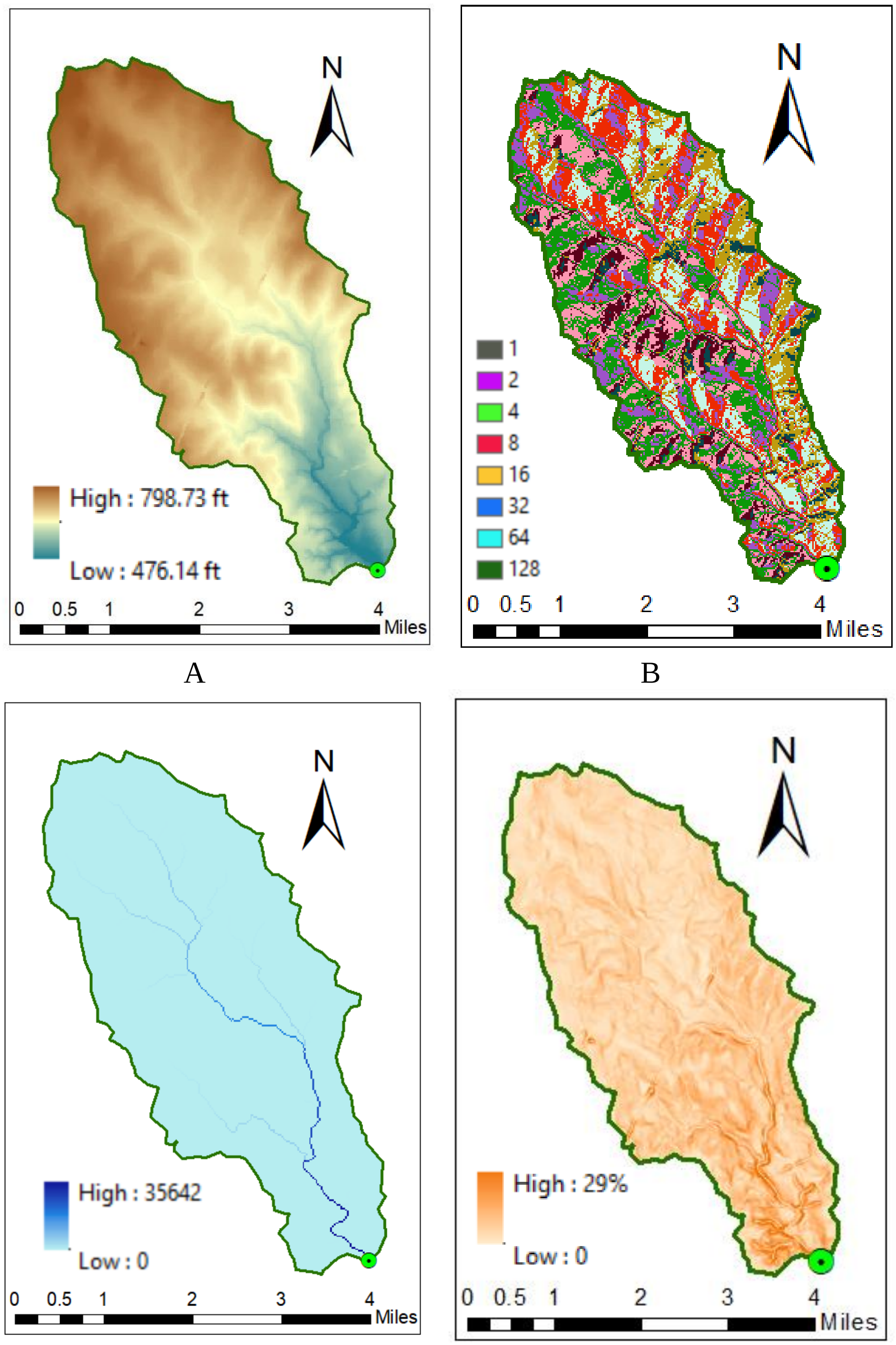
Flow length from watershed centroid to outlet (L_{F-C}) – obtained using the Extract Multi Values to Points tool in ArcMap, with the watershed centroids as the input point features and the flow length raster datasets as the input rasters (ArcMap tool: Spatial Analyst → Extraction → Extract Multi Values to Points; input point features – watershed centroids; input rasters – flow length rasters).

Maximum Euclidean distance (L_{E-max}) – obtained by applying the Euclidean Distance tool in ArcMap with the Mask and Processing extent set to the watershed and the gage set as the input raster (ArcMap tool: Spatial Analyst Tools → Distance → Euclidean Distance; Input raster or feature source data – outlet gage). Once the Euclidean distance raster has been obtained, the maximum Euclidean distance is obtained using Get Raster Properties (ArcMap tool: Data Management Tools → Raster → Raster Properties → Get Raster Properties; input – Euclidean distance raster, Property type – Maximum).

Euclidean distance from watershed centroid to outlet (L_{E-C}) – obtained using the Extract Multi Values to Points tool in ArcMap, with the watershed centroids as the input point features and the Euclidean distance raster datasets as the input rasters (ArcMap tool: Spatial Analyst → Extraction → Extract Multi Values to Points; input point features – watershed centroids; input rasters –Euclidean distance rasters).

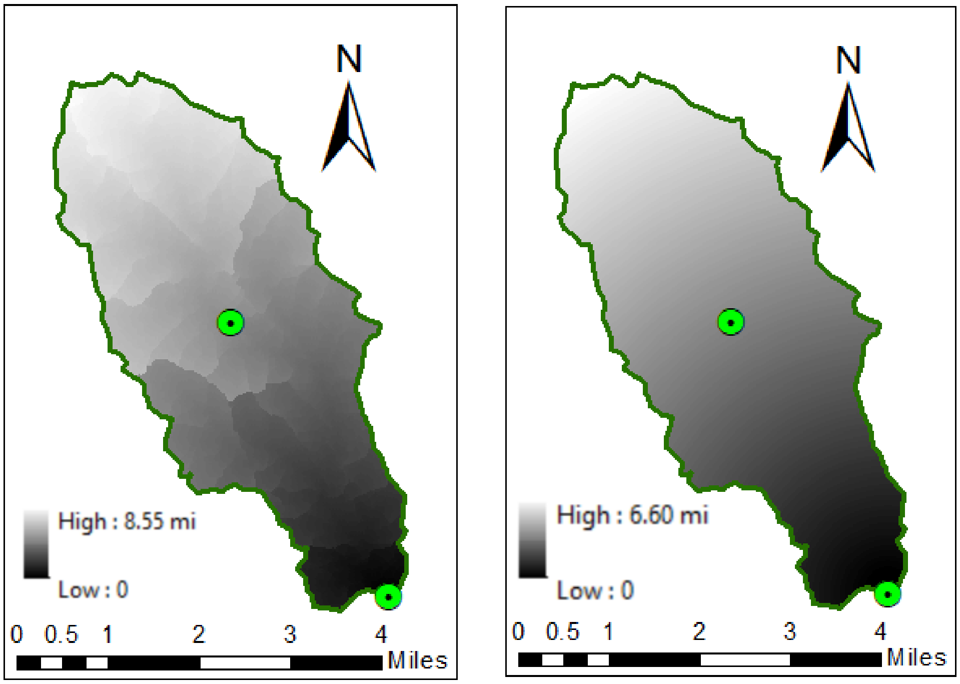
Average Euclidean Distance ($\overline{L_E}$) – It is the arithmetic mean of the values in the Euclidean distance raster (ArcMap tool: Data Management Tools → Raster → Raster Properties → Get Raster Properties; input – Euclidean distance raster, Property type – Mean).

Shown in Figure 3-5 are the DEM, flow direction, flow accumulation, slope, flow length, and Euclidean distance raster datasets for USGS 08158500.



C D

Figure 3-5. Raster datasets for USGS Gage 08158500: A) DEM, B) Flow direction, C) Flow accumulation, D) Slope, E) Flow length, and F) Euclidean distance.



E F

Figure 3-5 (continued).

3.3.3. Hydraulic modeling

Another part of the dissertation is to determine the sensitivities of peak flow, flood depth, and floodplain extent to the *PRF*. To accomplish this objective, 1D steady hydraulic modeling was employed using the United States Army Corps of Engineers' (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) was used and the cross-sections were obtained from the City of Austin Flood Pro (CoA, 2022). In this procedure, it is assumed that flow directions are unilateral along the river thalweg and that the discharge is constant throughout and calculations are based on the 1D Saint-Venant equations (USACE, 2022):

$$\frac{\partial Q}{\partial t} + \frac{\partial (QV)}{\partial x} + gA\left(\frac{\partial z}{\partial x} + S_f\right) = 0 \quad (3\text{-}1)$$

where Q is flow, t is time, V is velocity, g is the gravitational acceleration, A is the cross-sectional area, x is the distance along the stream thalweg, z is the depth, and S_f is the friction slope computed using the Manning's equation:

$$S_f = \frac{Q^2 n^2}{R^{4/3} A^2} \quad (3\text{-}2)$$

where n is the Manning's roughness coefficient, and R is the hydraulic radius equal to A divided by the wetted perimeter.

The discharges used in the model are the peak flows corresponding to different *PRFs* given watershed areas were determined. The rainfall depths for different return periods were obtained from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 Precipitation Point Frequency Estimates (NOAA, 2017) and the direct runoffs were obtained using the NRCS Curve Number Method (NRCS, 2007). The direct runoffs were then multiplied to the unit hydrographs and baseflow was added to obtain the design discharge used as input to a hydraulic model.

4. PRFS IN TEXAS WATERSHEDS

4.1. Introduction

This chapter presents the methodology for calculating *PRFs* for the rainfall-runoff dataset in Texas described in Section 3.2, determining the ranges of *PRFs* in Texas, as well as discussing the significance and implications of the results.

To calculate the *PRF* of a storm event, it is necessary to first derive its unit hydrograph. For each storm event, the unit hydrograph $q(t)$ [L^2/T] was determined by deconvolving the direct runoff hydrograph $Q_d(t)$ [L^3/T] at the watershed outlet by the excess precipitation hyetograph $R(t)$ [L/T] in the watershed, according to:

$$Q_d(t) = \int_0^t R(u)\, q(t-u)\, du = R(t) * q(t) \qquad (4\text{-}1)$$

where u [T] is a dummy variable. Because Equation 4-1 cannot be solved for $q(t)$, the deconvolution was accomplished by means of an optimization process that iterated $q(t)$ until the sum of the square of the residuals (*SSR*) between the observed and simulated direct runoff hydrographs was minimized.

The observed direct runoff hydrographs were obtained by subtracting the baseflow from the total runoff hydrographs by connecting their start- and end-points with straight lines. This approach worked well for hydrographs with clear start- and end-points; however, because the shape of natural hydrographs is often complex, each hydrograph was investigated separately and manually adjusted if needed as is the case for 24% of the events. These adjustments consisted of removing flow values that existed before the start of the event, removing precipitation records that appeared after the end of the event, extending the hydrograph recession limb if truncated, and/or splitting multiple-peak events into multiple events when deemed that one single unit hydrograph could not match multiple peaks adequately.

Event excess-rainfall hyetographs $R(t)$ were generated with the Curve Number method (NRCS, 2007). After resampling the observed rainfall into five-minute intervals, event curve numbers were used to calculate the five-minute excess-rainfall hyetographs $R(t)$. Event curve numbers were determined by matching the total excess rainfall and the total direct runoff volumes. Note that curve numbers should, conceptually, be unique for each watershed; however, our analysis indicated that it varied from event to event.

To decrease the number of variables to adjust when determining the unit hydrographs $q(t)$, it was assumed that the unit hydrographs had the shape of Gamma distributions, which have a two-parameter skewed-bell shape. Representing unit hydrographs by Gamma distributions is not new and has been done by a number of researchers in the past as discussed in Section 2.3.2. In this study, however, Gamma distribution was used, which is also the representation of the unit hydrograph chosen by the NRCS (2007).

Gamma distributions are expressed as:

$$f(t) = \frac{t^{\alpha-1}\, e^{-t/\beta}}{\beta^{\alpha}\, \Gamma(\alpha)} \qquad (4\text{-}2)$$

where *f(t)* [1/T] is the distribution frequency, *t* [T] is the value of a random variable *T* considered here as time, α is a dimensionless shape parameter, and β [T] is a scale parameter in the same units as *t*. Correspondingly, the Gamma distribution unit hydrograph, for a unit excess-precipitation depth, is represented as:

$$q(t) = \frac{t^{\alpha-1} e^{-t/\beta}}{\beta^{\alpha} \Gamma(\alpha)} A \qquad (4\text{-}3)$$

where *t* [T] is the time since the beginning of excess precipitation generation.

Figure 4-1 shows how the gamma distribution varies with α. Here, β is fixed at 20. With α equal to or less than 1, the distribution does not have a rising limb, i.e., it tends to infinity as it approaches time zero. As α increases, the distribution becomes flatter, and the peak is shifted to the right.

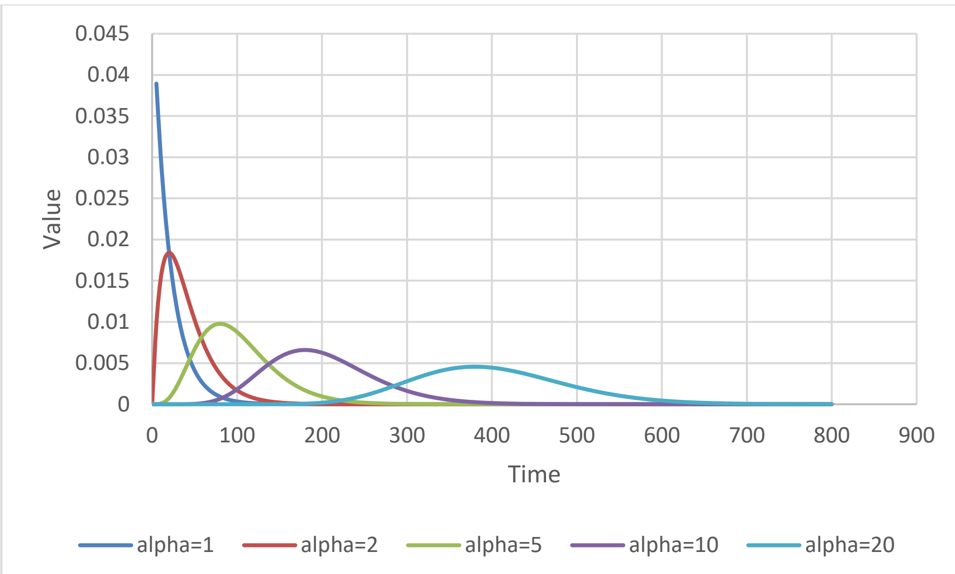


Figure 4-1. Effect of the alpha parameter in the gamma distribution.

Shown in Figure 4-2 is a plot of how the gamma distribution varies with β. Here, α is fixed at 2. As β increases, the hydrograph becomes wider, and peak is shifted downward.

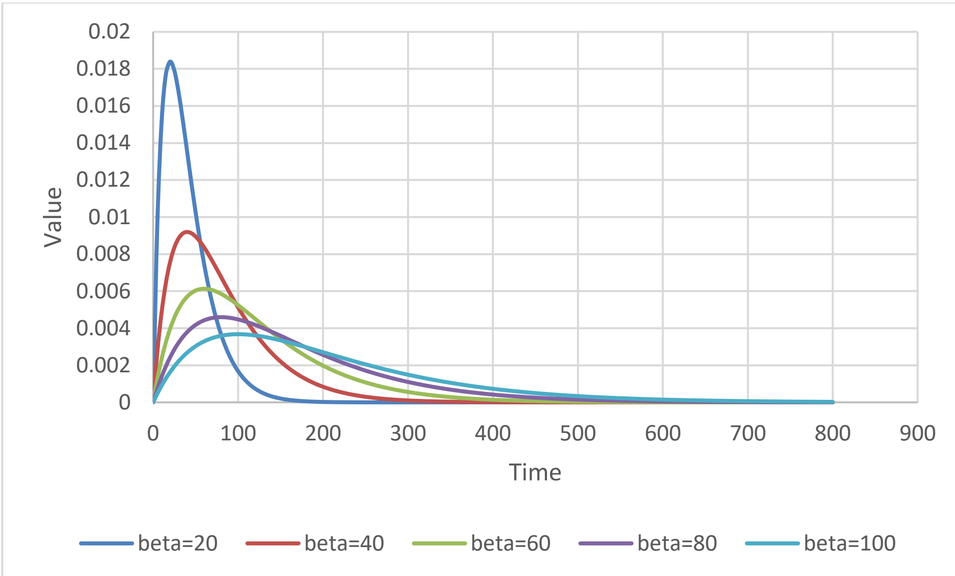


Figure 4-2. Effect of the beta parameter in the gamma distribution.

Table 4-1 contains data to be used for illustrating the steps to derive $Q_d(t)$ given $R(t)$ and $q(t)$, which is taken from watershed with USGS ID 08048550 and from an event that occurred on May 30, 1976 (event ID unit_sta08048550_1976_0530). For consistency, time units are in seconds and length units are in feet. The values of *q(t)* in the table are what would be obtained after the derivation is done. As will be explained later, *q(t)* in Table 4-1 corresponds to the optimized unit hydrograph.

Table 4-1. Hydrograph data for examples.

Time (s)	Q_d(t) (cfs)	*R(t)* (in)	*R(t)* (ft)	q(t) (cfs/ft)	Time (s)	Q_d(t) (cfs)	q(t) (cfs/ft)	Time (s)	Q_d(t) (cfs)	q(t) (cfs/ft)
0	0.00	0.000	0.0000	0.00	31800	29.15	0.10	63600	0.46	0.00
300	0.00	0.000	0.0000	3886.13	32100	27.90	0.09	63900	0.46	0.00
600	0.24	0.000	0.0000	5032.51	32400	26.64	0.08	64200	0.45	0.00
900	0.48	0.000	0.0000	5558.62	32700	25.39	0.07	64500	0.45	0.00
1200	0.72	0.000	0.0000	5752.62	33000	24.14	0.06	64800	0.45	0.00
1500	9.72	0.001	0.0001	5744.68	33300	22.89	0.06	65100	0.44	0.00
1800	18.72	0.014	0.0012	5608.71	33600	21.64	0.05	65400	0.44	0.00
2100	27.71	0.026	0.0022	5391.32	33900	20.81	0.05	65700	0.44	0.00

2400	47.21	0.008	0.0007	5123.61	34200	19.97	0.04	66000	0.43	0.00
2700	66.71	0.009	0.0007	4826.97	34500	19.14	0.04	66300	0.43	0.00
3000	81.71	0.006	0.0005	4516.38	34800	18.31	0.03	66600	0.43	0.00
3300	98.71	0.049	0.0041	4202.36	35100	17.47	0.03	66900	0.42	0.00
3600	118.71	0.064	0.0053	3892.26	35400	16.64	0.02	67200	0.42	0.00
3900	128.71	0.019	0.0016	3591.19	35700	15.80	0.02	67500	0.42	0.00
4200	138.71	0.055	0.0046	3302.55	36000	14.97	0.02	67800	0.41	0.00
4500	150.71	0.059	0.0049	3028.53	36300	14.14	0.02	68100	0.41	0.00
4800	165.71	0.028	0.0024	2770.41	36600	13.30	0.02	68400	0.41	0.00
5100	178.71	0.071	0.0059	2528.81	36900	12.47	0.01	68700	0.40	0.00
5400	203.71	0.056	0.0046	2303.87	37200	11.63	0.01	69000	0.40	0.00
5700	216.71	0.019	0.0016	2095.35	37500	11.13	0.01	69300	0.40	0.00
6000	216.71	0.000	0.0000	1902.78	37800	10.63	0.01	69600	0.39	0.00
6300	214.70	0.000	0.0000	1725.51	38100	10.13	0.01	69900	0.39	0.00
6600	202.70	0.006	0.0005	1562.80	38400	9.63	0.01	70200	0.38	0.00
6900	191.70	0.032	0.0027	1413.82	38700	9.13	0.01	70500	0.38	0.00
7200	213.70	0.240	0.0200	1277.70	39000	8.63	0.01	70800	0.38	0.00
7500	249.70	0.102	0.0085	1153.57	39300	8.13	0.01	71100	0.37	0.00
7800	283.70	0.105	0.0087	1040.59	39600	7.63	0.00	71400	0.37	0.00
8100	325.70	0.053	0.0044	937.90	39900	7.13	0.00	71700	0.37	0.00
8400	353.70	0.038	0.0032	844.70	40200	6.63	0.00	72000	0.36	0.00
8700	381.70	0.078	0.0065	760.23	40500	6.13	0.00	72300	0.36	0.00
9000	381.70	0.039	0.0033	683.76	40800	5.63	0.00	72600	0.36	0.00
9300	395.70	0.008	0.0007	614.60	41100	5.37	0.00	72900	0.35	0.00
9600	397.70	0.000	0.0000	552.11	41400	5.12	0.00	73200	0.35	0.00
9900	389.70	0.008	0.0007	495.71	41700	4.87	0.00	73500	0.35	0.00
10200	377.70	0.008	0.0007	444.85	42000	4.62	0.00	73800	0.34	0.00
10500	359.70	0.000	0.0000	399.02	42300	4.37	0.00	74100	0.34	0.00
10800	341.69	0.000	0.0000	357.74	42600	4.12	0.00	74400	0.33	0.00
11100	315.19	0.000	0.0000	320.60	42900	3.87	0.00	74700	0.33	0.00
11400	288.69	0.000	0.0000	287.20	43200	3.62	0.00	75000	0.32	0.00
11700	261.69	0.000	0.0000	257.18	43500	3.37	0.00	75300	0.32	0.00
12000	234.69	0.000	0.0000	230.21	43800	3.12	0.00	75600	0.31	0.00
12300	210.69	0.000	0.0000	206.00	44100	2.87	0.00	75900	0.31	0.00
12600	186.69	0.000	0.0000	184.28	44400	2.62	0.00	76200	0.30	0.00
12900	162.69	0.000	0.0000	164.79	44700	2.53	0.00	76500	0.30	0.00
13200	145.36	0.000	0.0000	147.32	45000	2.45	0.00	76800	0.29	0.00
13500	128.02	0.000	0.0000	131.67	45300	2.36	0.00	77100	0.29	0.00
13800	110.69	0.000	0.0000	117.65	45600	2.28	0.00	77400	0.28	0.00
14100	102.35	0.000	0.0000	105.09	45900	2.20	0.00	77700	0.28	0.00

14400	94.02	0.000	0.0000	93.85	46200	2.11	0.00	78000	0.27	0.00
14700	85.69	0.000	0.0000	83.79	46500	2.03	0.00	78300	0.27	0.00
15000	80.02	0.000	0.0000	74.79	46800	1.94	0.00	78600	0.26	0.00
15300	74.35	0.000	0.0000	66.75	47100	1.86	0.00	78900	0.26	0.00
15600	68.68	0.000	0.0000	59.55	47400	1.78	0.00	79200	0.25	0.00
15900	63.68	0.003	0.0002	53.12	47700	1.69	0.00	79500	0.25	0.00
16200	58.68	0.003	0.0002	47.38	48000	1.61	0.00	79800	0.24	0.00
16500	53.68	0.003	0.0002	42.25	48300	1.52	0.00	80100	0.24	0.00
16800	51.35	0.000	0.0000	37.67	48600	1.44	0.00	80400	0.23	0.00
17100	49.01	0.000	0.0000	33.58	48900	1.36	0.00	80700	0.23	0.00
17400	46.68	0.000	0.0000	29.92	49200	1.27	0.00	81000	0.22	0.00
17700	45.01	0.008	0.0007	26.66	49500	1.19	0.00	81300	0.22	0.00
18000	43.34	0.008	0.0007	23.76	49800	1.10	0.00	81600	0.21	0.00
18300	41.68	0.008	0.0007	21.16	50100	1.02	0.00	81900	0.21	0.00
18600	47.34	0.099	0.0082	18.85	50400	0.94	0.00	82200	0.20	0.00
18900	53.01	0.100	0.0084	16.79	50700	0.85	0.00	82500	0.20	0.00
19200	58.68	0.102	0.0085	14.95	51000	0.77	0.00	82800	0.19	0.00
19500	80.34	0.030	0.0025	13.31	51300	0.68	0.00	83100	0.19	0.00
19800	102.01	0.031	0.0025	11.85	51600	0.60	0.00	83400	0.18	0.00
20100	123.67	0.031	0.0026	10.54	51900	0.60	0.00	83700	0.18	0.00
20400	144.17	0.000	0.0000	9.38	52200	0.59	0.00	84000	0.18	0.00
20700	164.67	0.000	0.0000	8.35	52500	0.59	0.00	84300	0.17	0.00
21000	173.67	0.008	0.0007	7.43	52800	0.59	0.00	84600	0.17	0.00
21300	166.67	0.000	0.0000	6.61	53100	0.58	0.00	84900	0.16	0.00
21600	160.17	0.000	0.0000	5.88	53400	0.58	0.00	85200	0.16	0.00
21900	153.67	0.000	0.0000	5.23	53700	0.58	0.00	85500	0.15	0.00
22200	141.00	0.000	0.0000	4.65	54000	0.57	0.00	85800	0.15	0.00
22500	128.33	0.000	0.0000	4.14	54300	0.57	0.00	86100	0.14	0.00
22800	115.67	0.000	0.0000	3.68	54600	0.57	0.00	86400	0.14	0.00
23100	105.67	0.000	0.0000	3.27	54900	0.56	0.00	86700	0.13	0.00
23400	95.67	0.000	0.0000	2.91	55200	0.56	0.00	87000	0.13	0.00
23700	85.66	0.000	0.0000	2.58	55500	0.55	0.00	87300	0.12	0.00
24000	80.00	0.006	0.0005	2.30	55800	0.55	0.00	87600	0.12	0.00
24300	74.33	0.006	0.0005	2.04	56100	0.55	0.00	87900	0.11	0.00
24600	68.66	0.006	0.0005	1.81	56400	0.54	0.00	88200	0.11	0.00
24900	67.00	0.011	0.0009	1.61	56700	0.54	0.00	88500	0.10	0.00
25200	65.33	0.011	0.0009	1.43	57000	0.54	0.00	88800	0.10	0.00
25500	63.66	0.011	0.0009	1.27	57300	0.53	0.00	89100	0.09	0.00
25800	61.66			1.13	57600	0.53	0.00	89400	0.09	0.00
26100	59.66			1.00	57900	0.53	0.00	89700	0.08	0.00

26400	57.66			0.89	58200	0.52	0.00	90000	0.08	0.00
26700	55.32			0.79	58500	0.52	0.00	90300	0.07	0.00
27000	52.99			0.70	58800	0.52	0.00	90600	0.07	0.00
27300	50.66			0.63	59100	0.51	0.00	90900	0.06	0.00
27600	49.66			0.56	59400	0.51	0.00	91200	0.06	0.00
27900	48.65			0.49	59700	0.51	0.00	91500	0.05	0.00
28200	47.65			0.44	60000	0.50	0.00	91800	0.05	0.00
28500	45.82			0.39	60300	0.50	0.00	92100	0.04	0.00
28800	43.99			0.35	60600	0.50	0.00	92400	0.04	0.00
29100	42.15			0.31	60900	0.49	0.00	92700	0.03	0.00
29400	40.32			0.27	61200	0.49	0.00	93000	0.03	0.00
29700	38.48			0.24	61500	0.49	0.00	93300	0.02	0.00
30000	36.65			0.21	61800	0.48	0.00	93600	0.02	0.00
30300	35.40			0.19	62100	0.48	0.00	93900	0.01	0.00
30600	34.15			0.17	62400	0.48	0.00	94200	0.01	0.00
30900	32.90			0.15	62700	0.47	0.00	94500	0.00	0.00
31200	31.65			0.13	63000	0.47	0.00	94800	0.00	0.00
31500	30.40			0.12	63300	0.46	0.00			

The following algorithm is used to compute the $Q_d(t)$ given $R(t)$ and $q(t)$:

For i from 0 to number of elements in $q(t)$,

if i < number of elements in $R(t)$, j = i, else, j = number of elements in $R(t)$ less 1

if i=0, $Q_d(t)_i = q(t)_i R(t)_i$

if 0<i<number of elements in $R(t)$, $Q_d(t)_i = \sum_{l=0}^{j} q(t)_l R(t)_{j-l}$

if i >= number of elements in $R(t)$, $Q_d(t)_i = \sum_{l=0}^{j} q(t)_{i-j+l} R(t)_{j-l}$

In Table 4-2, the values of the $Q_{d-sim}(t)$ are obtained by using *q(t)* with gamma distribution with α = 1.55, and β = 2405 s. The values are also scaled by the area, obtained by dividing the volume of $Q_{d-obs}(t)$ with the depth (0.1405 ft). The volume of $Q_d(t)$ may be solved using Simpson's rule. In this case, the area obtained after dividing the volume by the depth is 29,749,187 ft^2. Note that this area is similar to the area delineated from the DEM; however, calculating the area from Q_{d-obs} is done to avoid round-off errors. The values of $R(t)$ are multiplied to the values of $q(t)$. The value of $R(t)$ at time zero multiplies each $q(t)$ ordinate. The value of $R(t)$ at the next time step, i.e., at 300 seconds is also multiplied in each $q(t)$ ordinate (starting from time 0) but the values are shifted one row ahead, i.e., at 300 seconds. The value of $R(t)$ at the third time step, i.e., at 600 seconds, is multiplied again in each $q(t)$ ordinate (starting from time 0) but the values are places two rows ahead, i.e., at 600 seconds. The process is repeated until the last value of $R(t)$ is reached.

Table 4-2. Computation of *Q(t)*.

Time (seconds)	Time (seconds)	0	300	…		1500	…	Q_{d-sim} (cfs)	Q_{d-obs} (cfs)
	$q(t)$ (cfs/ft)		$R(t)$ (ft)						
		0	0	…		0.001153	…		
0	0	0.00		…			…	0.00	0.00
300	3,886	0.00	0.00	…			…	0.00	0.00
600	5,033	0.00	0.00	…			…	0.00	0.24
900	5,559	0.00	0.00	…			…	0.00	0.48
1200	5,753	0.00	0.00	…			…	0.00	0.72
1500	5,745	0.00	0.00	…			…	0.00	9.72
1800	5,609	0.00	0.00	…		0.00	…	0.47	18.72
2100	5,391	0.00	0.00	…		4.48	…	5.09	27.71
2400	5,124	0.00	0.00	…		5.80	…	15.02	47.21
2700	4,827	0.00	0.00	…		6.41	…	20.79	66.71
3000	4,516	0.00	0.00	…		6.63	…	25.75	81.71
3300	4,202	0.00	0.00	…		6.62	…	29.30	98.71
3600	3,892	0.00	0.00	…		6.46	…	46.13	118.71
3900	3,591	0.00	0.00	…		6.21	…	71.37	128.71
4200	3,303	0.00	0.00	…		5.91	…	84.89	138.71
…	…	…	…	…		…	…	…	…
94800	0	0.00	0.00	…		0.00	…	0.00	0.00

The above example shows the convolution routine for determining *$Q_d(t)$* given *R(t)* and *q(t)*. The converse problem is deriving *q(t)* given *$Q_d(t)$* and *R(t)*, that is, *q(t)* is unknown in Figure 4-3.

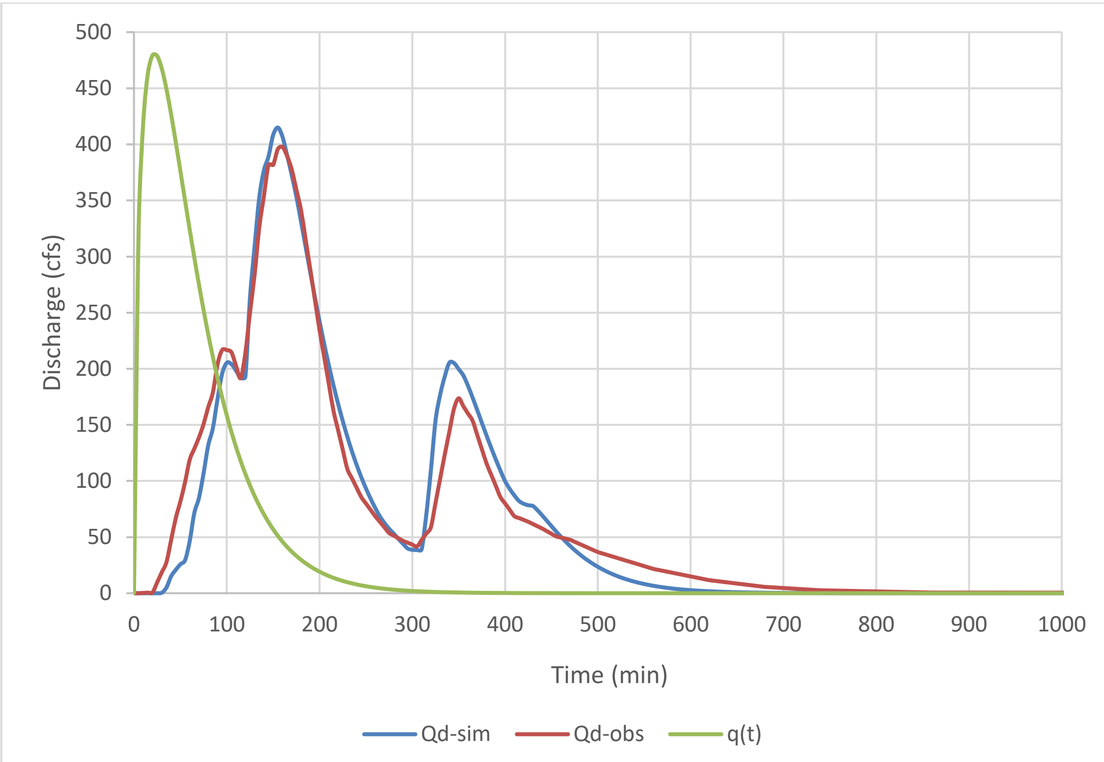


Figure 4-3. Example for deriving *Q(t)* given *q(t)* and *R(t)* (event ID unit_sta08048550_1976_0530).

For a given event, the process of determining *q(t)* consists of calculating α and β based on:

$$\text{Minimize: } \sum_i [Q_{d-obs-i} - Q_{d-sim-i}]^2$$

subject to

$$\alpha > 1, \beta > 0, \text{ and } (\alpha - 1)\beta > 300\ s$$

where $Q_{d-obs-i}$ is the observed direct runoff at time i, and $Q_{d-sim-i}$ is the simulated direct runoff at time i. Note that due to computational limitations, we set the minimum and maximum value for alpha to be 1.01 and 100, respectively. The third constraint ensures that the optimized $q(t)$ has a rising limb, and that its peak value occurs at least five minutes after the start of the event, which is the resolution of *R(t)*, and the storm duration for which the unit hydrographs were derived.

In general, for a Gamma distribution, the mode is:

$$\hat{t} = (\alpha - 1)\, \beta \qquad (4\text{-}4)$$

and its maximum frequency is:

$$f(\hat{t}) = \frac{(\alpha-1)^{\alpha-1}\, e^{1-\alpha}}{\Gamma(\alpha)\, \beta} \qquad (4\text{-}5)$$

Similarly, for a unit hydrograph, the peak time would be

$$t_p = (\alpha - 1)\, \beta \left(\frac{1}{3{,}600}\right) \qquad (4\text{-}6)$$

where t_p is in hours, β is in seconds, and 3,600 is the number of seconds in an hour; and the peak flow is:

$$q_p = \frac{(\alpha-1)^{\alpha-1}\, e^{1-\alpha}}{\Gamma(\alpha)\beta}\, A \left(\frac{27{,}878{,}400}{12}\right) \qquad (4\text{-}7)$$

where q_p is in cubic feet per second, A is in square miles, 27,878,400 is the number of square feet in a square mile, and 12 is the number of inches in a foot. Note that these values require the excess precipitation to be in inches. Combining Equation 1-1 with Equations 4-6 and Eq. 4-7 gives:

$$PRF = 645.33\, \frac{(\alpha-1)^{\alpha}\, e^{1-\alpha}}{\Gamma(\alpha)} \qquad (4\text{-}8)$$

where 645.33 is a unit conversion factor and applies only for the units indicated above. Note that the *PRF* depends only on α, the Gamma distribution shape parameter, and not on β, the Gamma distribution scale parameter. Dimensionless unit hydrographs for different *PRFs* are shown in Figure 4-4. It can be noticed that the *PRF* decreases as the skewness of the dimensionless unit hydrograph increases. Moreover, the change in shape of the unit hydrograph becomes lesser as *PRF* increases.

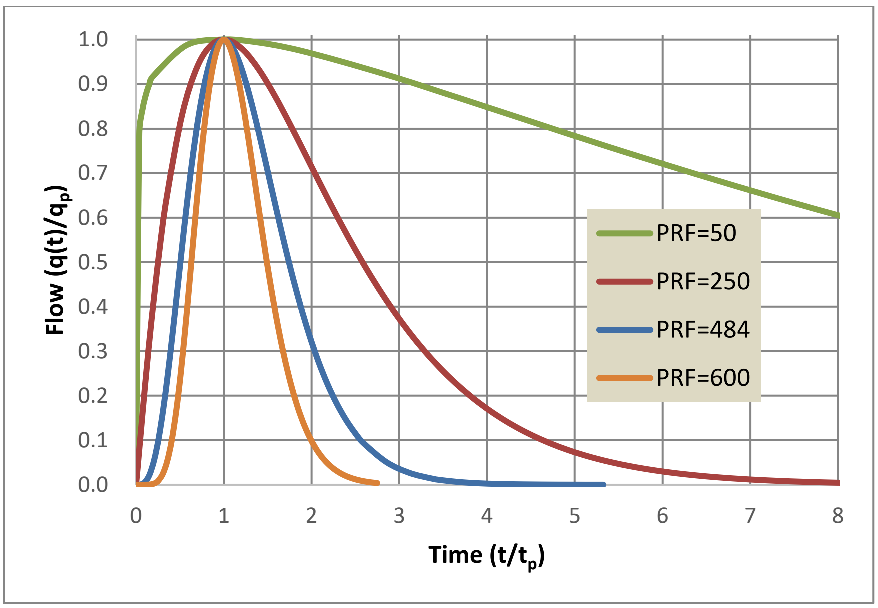


Figure 4-4. Dimensionless unit hydrographs for different *PRFs*.

To facilitate the entire process, a Python code for solving $q(t)$ is shown in Appendix A. This code also restricts the resulting $q(t)$ to where the volume of the computed DRH do not deviate from the volume of the observed DRH by more than 1%. However, when alpha is close to 1, the volume may deviate by more than 1% because the steep rising limb of $q(t)$ enlarges the error in the volume computation which is done using the Trapezoidal Rule.

The optimization algorithm used was the Sequential Least Squares Programming (SLSQP) method (Scipy, 2022). Note that this method only finds the local optimum, which means that the resulting $q(t)$ is dependent on initial seed values of the two $q(t)$ parameters. To ensure good agreement between Q_d calculated from the derived $q(t)$ and Q_{d-obs}, each $q(t)$ was investigated by plotting it along with Q_{d-sim} and Q_{d-obs}. Those which are not in agreement based on a criterion that will be discussed in the next section.

4.2. Results

4.2.1. Overview

The resulting unit hydrographs varied from those generating almost perfect matches between the observed and simulated direct-runoff hydrographs, to those generating poor matches. A Nash-Sutcliff efficiency (*NSE*) (Nash and Sutcliffe, 1970; McCuen et al., 2006) of 0.70 was considered a threshold value to discriminate between the acceptable and not acceptable hydrograph matches, where:

$$NSE = 1 - \frac{\sum_i (Q_{d-obs-i} - Q_{d-sim-i})^2}{\sum_i (Q_{d-obs-i} - \overline{Q_{d-obs}})^2} \qquad (4\text{-}9)$$

where $\overline{Q_{d-obs}}$ is the mean value of the ordinates of the observed direct runoff hydrograph and the other parameters are as defined in Section 4.1. Although this threshold *NSE* value was chosen somewhat arbitrarily, it concurred with visual inspection and corresponded to a natural break in the distribution of *NSE* values as shown in Figure 4-5.

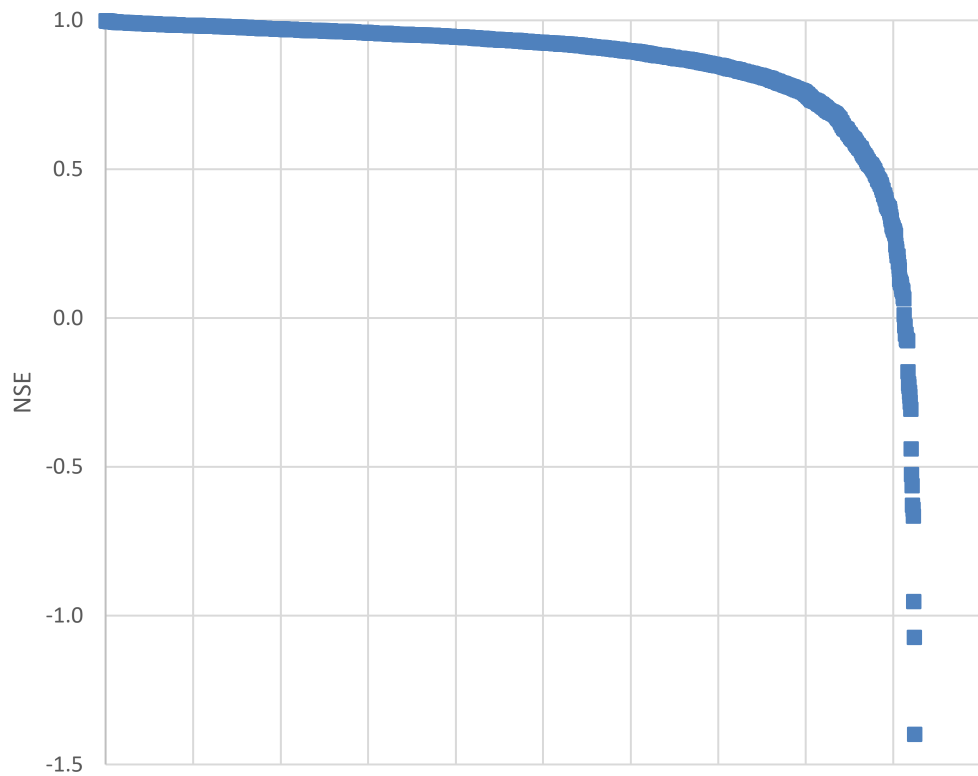
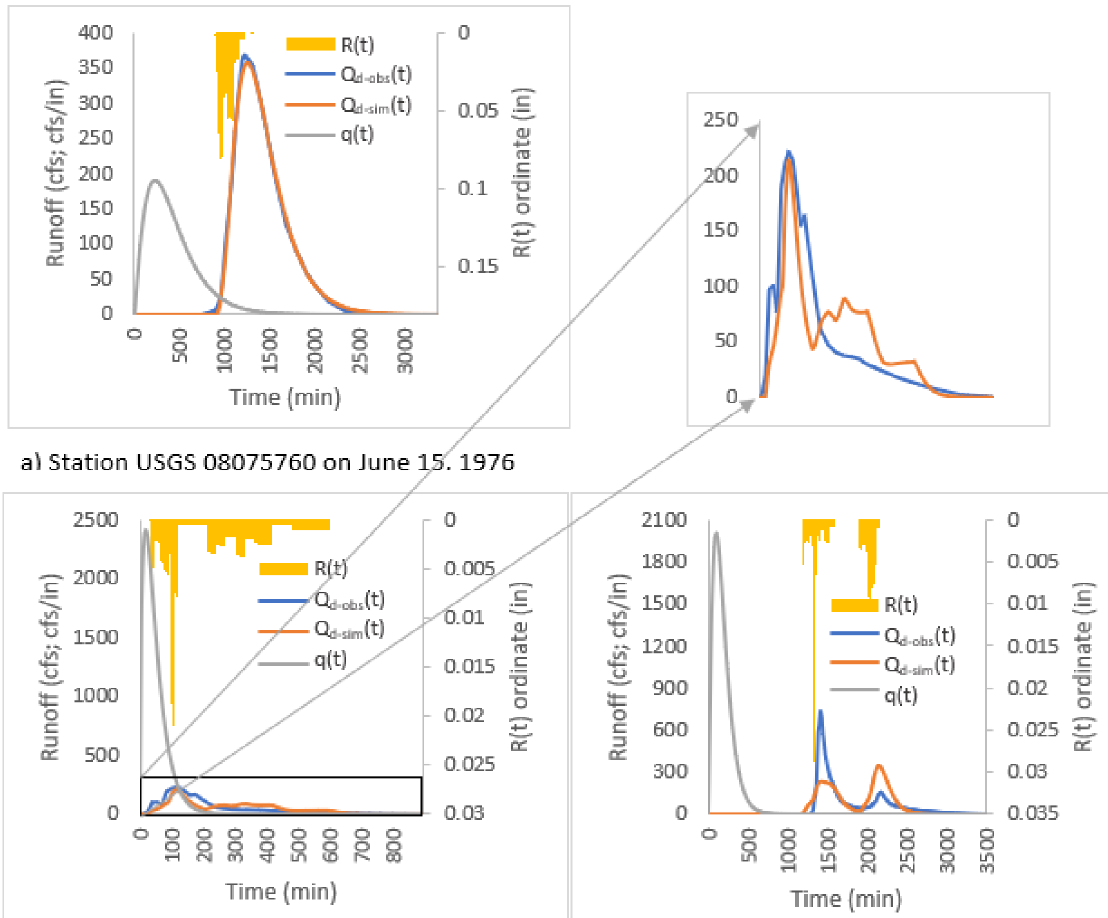


Figure 4-5. NSE ranked from highest to lowest.

Most of the mismatches between observed and simulated hydrographs were due to inconsistencies between the rainfall data and the observed hydrograph. Figure 4-6, for example, shows $R(t)$, $Q_{d-sim}(t)$, $Q_{d-obs}(t)$ and resulting $q(t)$ for three different storm events. In these graphs, time zero corresponds to the time at which precipitation starts, not the time at which *excess* precipitation starts. In Figure 4-6a, $Q_{d-obs}(t)$ almost perfectly match $Q_{d-sim}(t)$ and the *NSE* is equal to 0.999. In Figure 4-6b, there are noticeable discrepancies between the hydrographs and the *NSE* is equal to 0.702, which is barely greater than the threshold. Figure 4-6c, on the other hand, shows an example of an event that was rejected and had an *NSE* of 0.466. In this case, the volume of the excess rainfall was greater near the second peak than near the first one, although the observed flow of the first peak was greater.



a) Station USGS 08075760 on June 15, 1976

b) Station USGS 08157500 on Aug. 2, 1971

c) Station USGS 08156800 on April 19, 1977

Figure 4-6. Resulting hydrographs and excess precipitation hyetograph: a) highest *NSE*; b) threshold *NSE*; c) rejected *NSE*.

Overall, of the 2,242 events considered for analysis, those in which the *NSEs* were less than 0.70 were disregarded. Thus, the final dataset included 1,648 events. The unit hydrographs, direct runoff hydrographs from data, and simulated direct runoff hydrographs foo all 1,648 events are shown in Appendices G, H, I, J, K, and L. The raw files with which these graphs are generated may be requested from the author upon reasonable request. Histograms of all computed *PRFs* as well as *PRFs* for each region are shown in Figures 4-7 and 4-8, respectively.

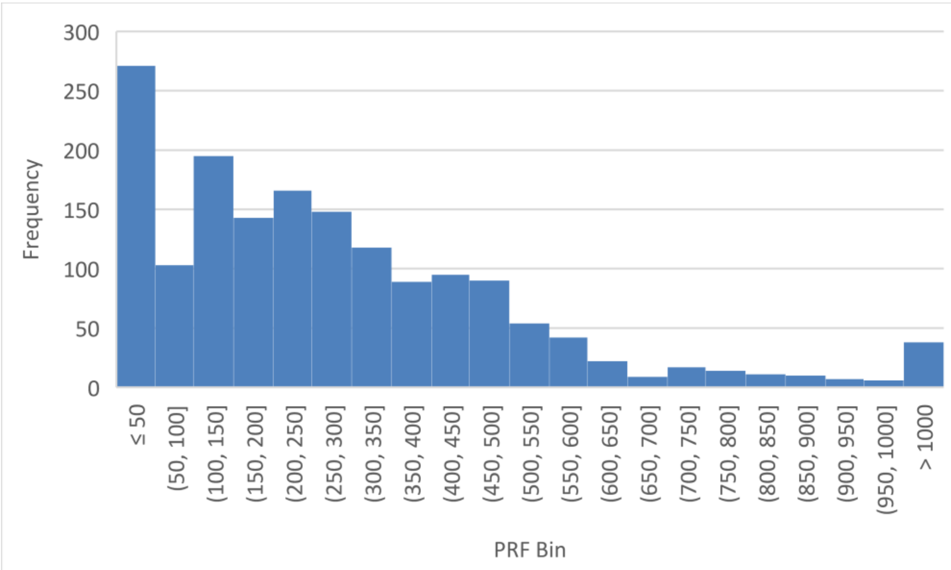


Figure 4-7. Histogram of *PRFs* for Texas.

It should be noted that as many as 271 events (i.e., 16%), out of the 1,648 considered, had *PRFs* lower than 50. Although it is recognized that storm hydrographs are typically positively skewed, *PRFs* lower than 50 had not been reported in past studies. These low-*PRF* storms have almost-instantaneous peaks and 177 of them, approximately two thirds, occurred in the Houston area. Fleischmann et al. (2016) and Collischonn et al. (2017) have appealed to hydraulics to explain hydrograph skewness. They reasoned that it is unlikely that the input hydrologic and geomorphologic parameters, while being negatively skewed, can still lead to positively-skewed hydrographs so other parameters – such as channel geometry – play a role in influencing the hydrograph shape. Still, it would be important to investigate the mechanisms behind these low-*PRF* events further. One implication of a hydrograph with *PRF* close to zero is that the principles of modeling might be similar to that of modeling dam breach or spillway release hydrographs. Knowledge of such hydrographs, as applied to storm events, would lead to a more informed hydrologic modeling process.

It is also worth noting that 146 events (i.e., 9%) had *PRFs* more than 575, which is the highest value of the *PRF* shown in Wanielista et al. (1997). As pointed out by Horst et al. (2022), the reason for these high *PRF* events might be explained by the Complacent-Violent phenomenon proposed by Hawkins et al. (2015). This phenomenon occurs in some watersheds where rain events will show almost no response to a rain event (complacent phase) until some limiting condition is met and then there will be a very rapid response (violent phase). Regions with high *PRFs* are observed more in San Antonio and Dallas watersheds.

The distribution of the *PRFs* for each region is also illustrated in the box-and-whisker plot shown in Figure 4-9. From the plot, *PRFs* in the Houston watersheds are noticeably lower than those in other regions. A plot of the *PRFs* from highest to lowest for Houston, other urban watersheds, and rural watersheds is shown in Figure 4-10. From this plot, it can also be seen that rural and urban watersheds located outside Houston have similar *PRF* distributions, while the *PRFs* of the Houston watersheds are discernibly lower than the rest.

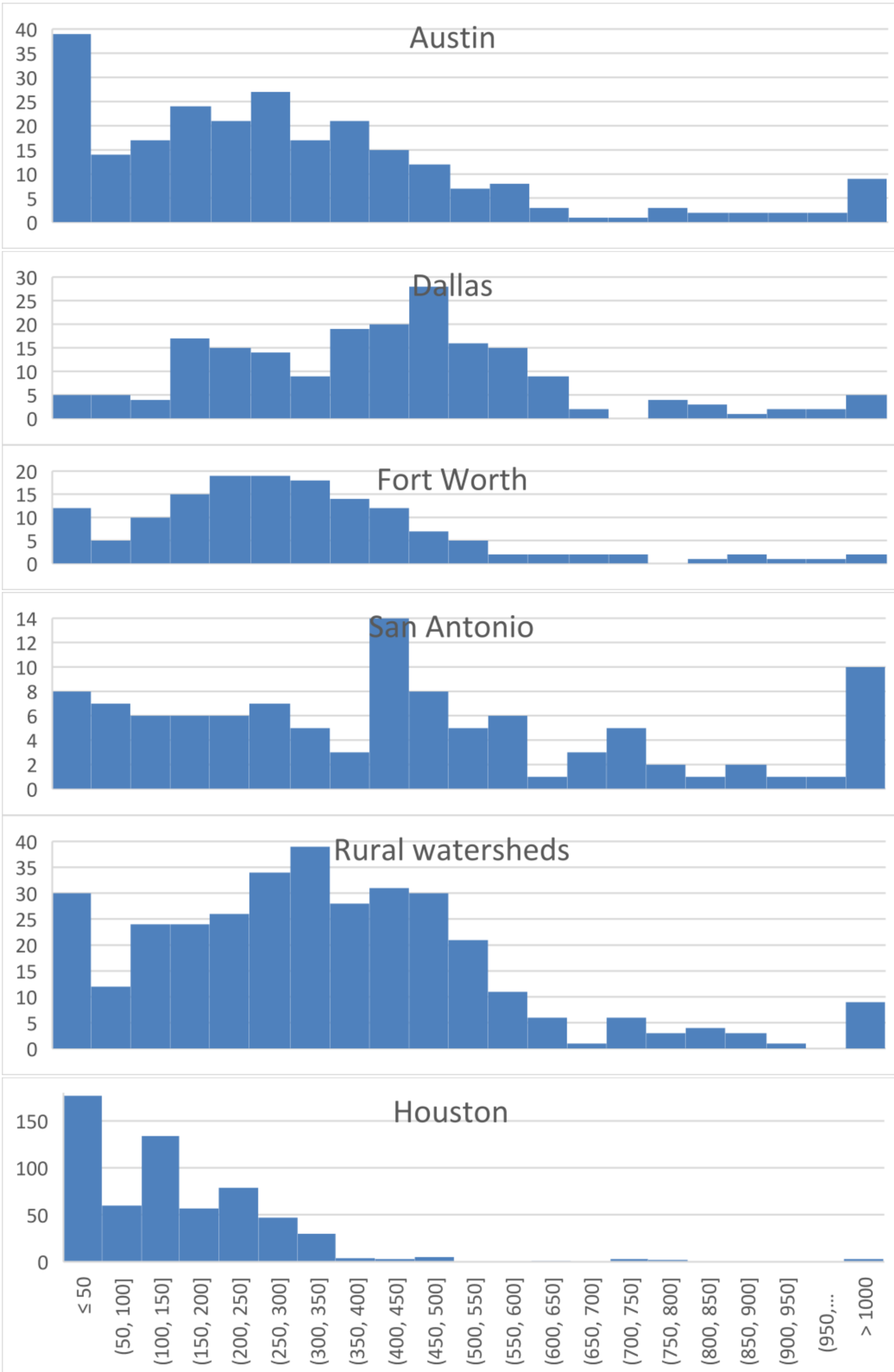


Figure 4-8. Histograms of *PRFs* for each region.

To validate this statement, the Kolmogorov-Smirnov two-sample test (Kolmogorov, 1933; Smirnov, 1944; Darling, 1957), a non-parametric test used to verify if two distributions are identical, was performed and the results show the following p-values at three significant figures: Urban (excluding Houston) *PRFs* versus Rural *PRFs*, p is equal to 0.375; Houston *PRFs* versus Urban (excluding Houston) *PRFs*, p is equal to 0.000; Houston *PRFs* versus Rural *PRFs*, *p* is equal to 0.000; Houston *PRFs* versus all non-Houston *PRFs*, *p* is equal to 0.000. Values less than 0.05 indicate that, at 5% level of significance, the *PRFs* from the two regions compared are significantly different. Therefore, it is confirmed that the *PRFs* from Houston are statistically different from those in the rest of Texas, and that *PRFs* in rural areas are not statistically different from those in non-Houston urban areas. The *PRF* mean, median, standard error for each region are shown in Table 4-3. Also included in Table 4-3 are number of events and number of watersheds included in each region. Moreover, shown in Table 4-4 are the percentiles for the PRFs in each region.

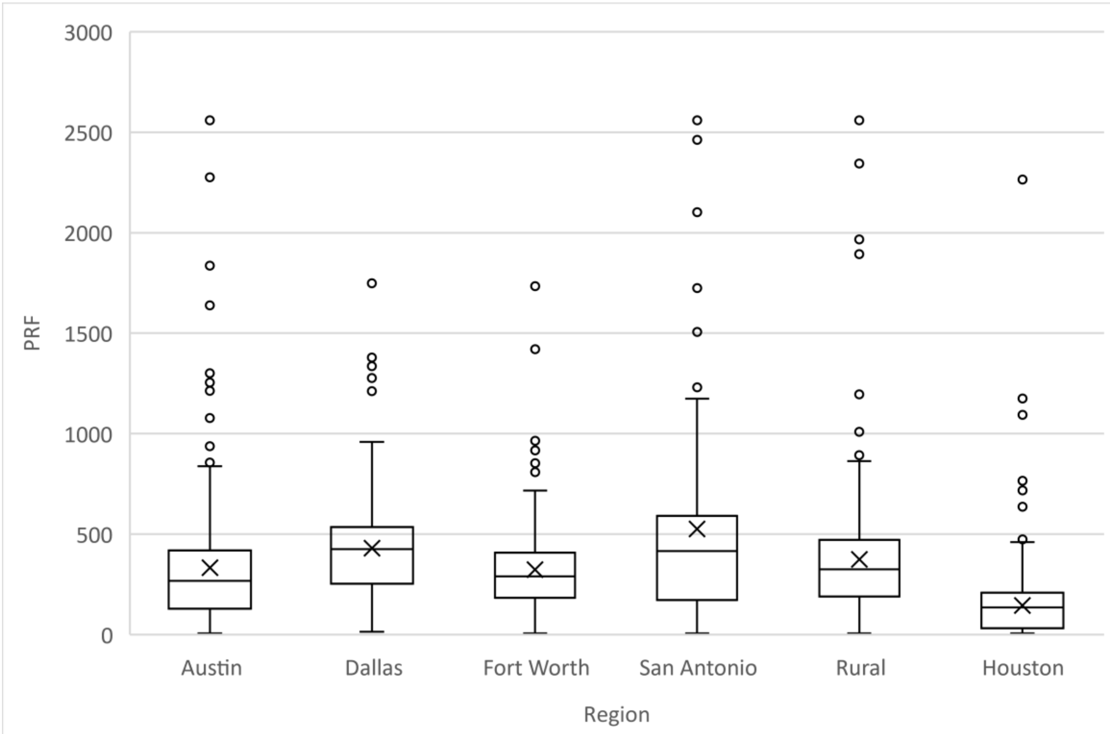


Figure 4-9. Distribution of *PRF* for each region. The lower whisker is the minimum *PRF* while the upper whisker is the 95th percentile *PRF*. *PRFs* above the upper whisker are shown as points and may be deemed outliers.

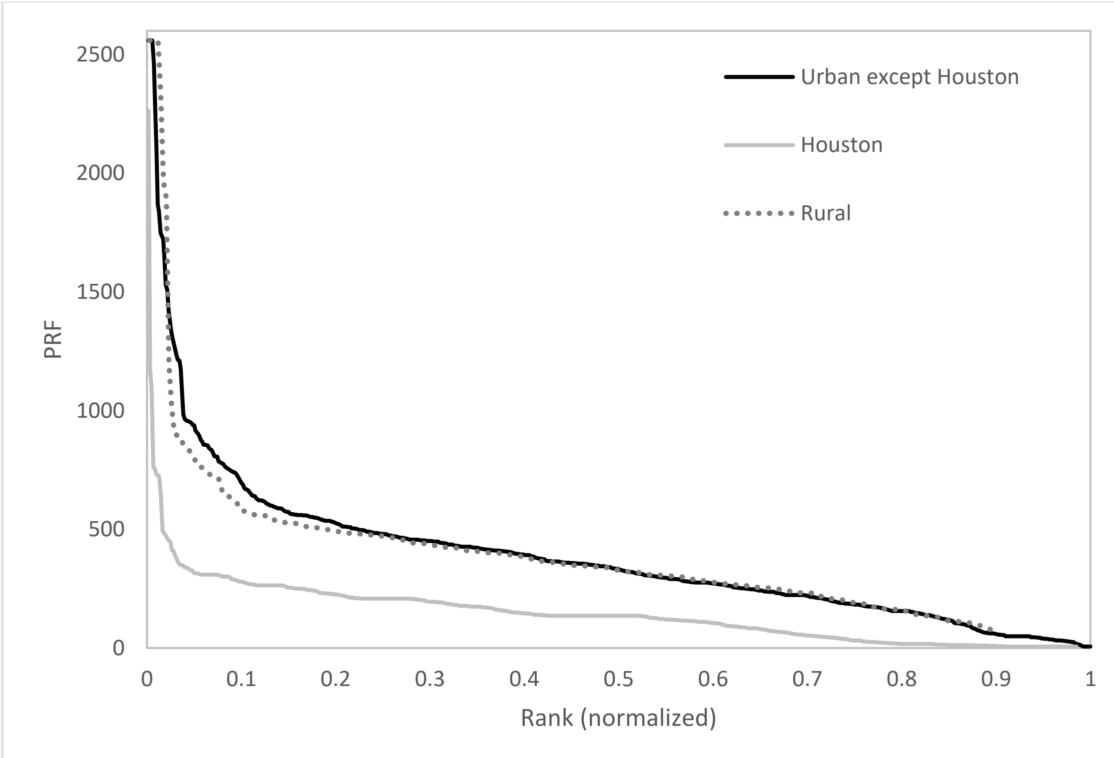


Figure 4-10. *PRF* from highest to lowest. Ranking of the events were normalized due to different sample sizes (605 for Houston, 343 for Rural, and 700 for non-Houston Urban).

Table 4-3. Descriptive statistics for *PRFs* in each region.

Region	# events	# watersheds	Mean	Standard error	Median
Austin	247	18	333	18.8	268
Dallas	195	20	430	11.9	426
Fort Worth	151	7	323	13.2	307
San Antonio	107	12	525	23.4	415
Rural	343	16	374	18.1	326
Houston	605	31	146	13.0	135
All but Houston	1043	73	383	17.8	329

Table 4-4. Ranges of *PRFs* for each region.

Percentile	All but Houston	Houston	Austin	Dallas	Fort Worth	San Antonio	Rural
0	6	6	6	14	6	6	6
1	12	6	6	32	13	31	12
2	17	6	15	49	25	32	12
3	26	6	24	64	27	37	17
4	30	6	29	96	32	44	22
5	36	6	31	102	42	49	27
6	43	6	35	120	46	49	28
7	46	6	38	144	49	52	37
8	49	6	40	156	54	57	46
9	51	6	43	162	57	62	54
10	61	8	45	173	62	67	67
11	67	10	49	177	85	73	85
12	84	11	49	185	120	78	98
13	99	12	49	187	121	90	107
14	106	12	49	190	125	104	112
15	115	13	49	198	135	135	115
16	127	15	55	205	143	138	128
17	136	17	60	210	152	139	135
18	142	17	63	215	156	146	140
19	151	17	74	223	164	147	144
20	156	17	84	223	175	153	158
21	160	20	97	223	176	159	162
22	165	22	103	236	177	164	167
23	173	25	109	241	180	170	173
24	180	27	120	251	183	173	186
25	186	32	132	255	186	189	190
26	190	37	135	266	186	211	198
27	198	42	144	275	191	218	206
28	207	45	149	277	197	227	214
29	215	49	155	290	207	235	221
30	222	52	156	298	215	244	232
31	223	56	165	303	221	251	232
32	231	64	172	314	223	259	239
33	237	67	175	320	224	266	247
34	240	72	180	344	228	271	252
35	248	80	183	349	234	273	255
36	252	83	187	354	242	282	261

37	255	87	190	356	245	294	266
38	263	92	200	358	248	312	270
39	269	98	211	364	249	328	271
40	273	105	216	366	252	337	277
41	276	110	222	370	253	346	282
42	279	113	224	379	261	352	287
43	287	115	231	393	267	360	298
44	291	118	237	394	277	365	302
45	298	120	240	398	283	394	305
46	304	124	244	402	290	408	307
47	307	130	253	411	292	409	310
48	314	135	262	414	301	410	317
49	322	135	266	422	304	415	322
50	329	135	268	426	307	415	326
51	339	135	274	427	317	423	336
52	343	135	276	430	321	426	341
53	347	135	276	436	322	427	343
54	352	135	282	443	323	433	346
55	356	135	289	448	324	441	349
56	359	135	292	450	325	445	354
57	364	135	297	453	327	449	360
58	367	138	306	454	329	451	363
59	378	141	312	456	333	456	372
60	391	146	318	458	336	472	380
61	395	149	323	461	338	486	390
62	401	156	335	465	343	489	396
63	406	161	343	472	348	493	400
64	410	170	346	479	359	495	401
65	415	174	354	481	363	496	406
66	422	175	356	482	364	521	410
67	426	178	358	484	366	526	419
68	431	185	359	489	377	535	424
69	438	192	362	496	395	536	425
70	443	195	377	500	415	540	434
71	451	202	385	507	419	556	440
72	456	206	392	511	422	564	443
73	461	208	402	511	426	571	455
74	469	208	411	524	439	585	461
75	476	208	417	536	449	590	470
76	481	208	424	539	482	596	476

77	484	208	429	547	491	634	477
78	493	210	436	550	493	679	482
79	501	216	451	559	524	694	484
80	509	225	456	560	537	720	490
81	518	230	460	561	558	733	498
82	529	235	469	567	581	740	505
83	537	244	477	573	588	745	511
84	549	251	501	577	600	749	519
85	559	254	509	589	673	772	526
86	563	263	528	600	726	783	532
87	577	263	552	617	737	820	541
88	599	263	559	622	745	871	558
89	622	268	563	627	760	883	564
90	649	278	599	641	779	934	577
91	709	288	638	658	838	1071	621
92	743	301	745	757	875	1203	648
93	772	309	779	781	908	1390	719
94	828	309	842	826	984	1523	745
95	869	315	924	846	1202	1666	769
96	942	339	955	916	1507	2011	840
97	1190	374	1162	953	1817	2397	894
98	1511	460	1328	1219	2461	2548	1307
99	2202	728	1854	1339	2559	2559	2469
100	2559	2264	2559	1749	2559	2559	2559

Appendix C contains the storm parameters for all regions and Appendix D contains all the unit hydrograph parameters for all regions. In the succeeding subsections, results for each region are elaborated by showing box plots for *PRFs* and curve numbers for each watershed in each region.

4.2.2. Austin

A total of 247 events from 18 watersheds were considered in Austin and each of the watersheds have events ranging from 2 to 41. A box-and-whiskers plot of the *PRF* for each watershed is shown in Figure 4-11. Moreover, a box-and-whiskers plot for the curve number is shown in Figure 4-12.

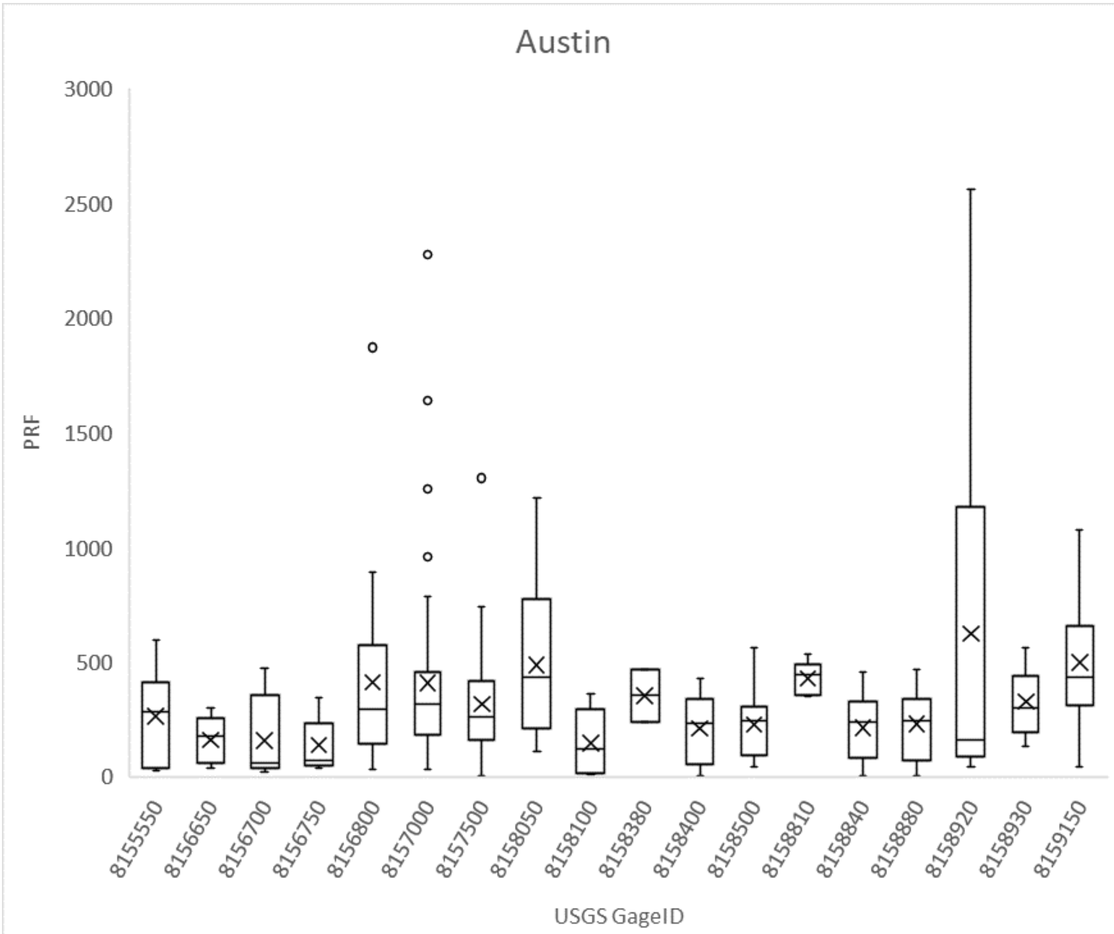


Figure 4-11. Distribution of *PRFs* in Austin watersheds.

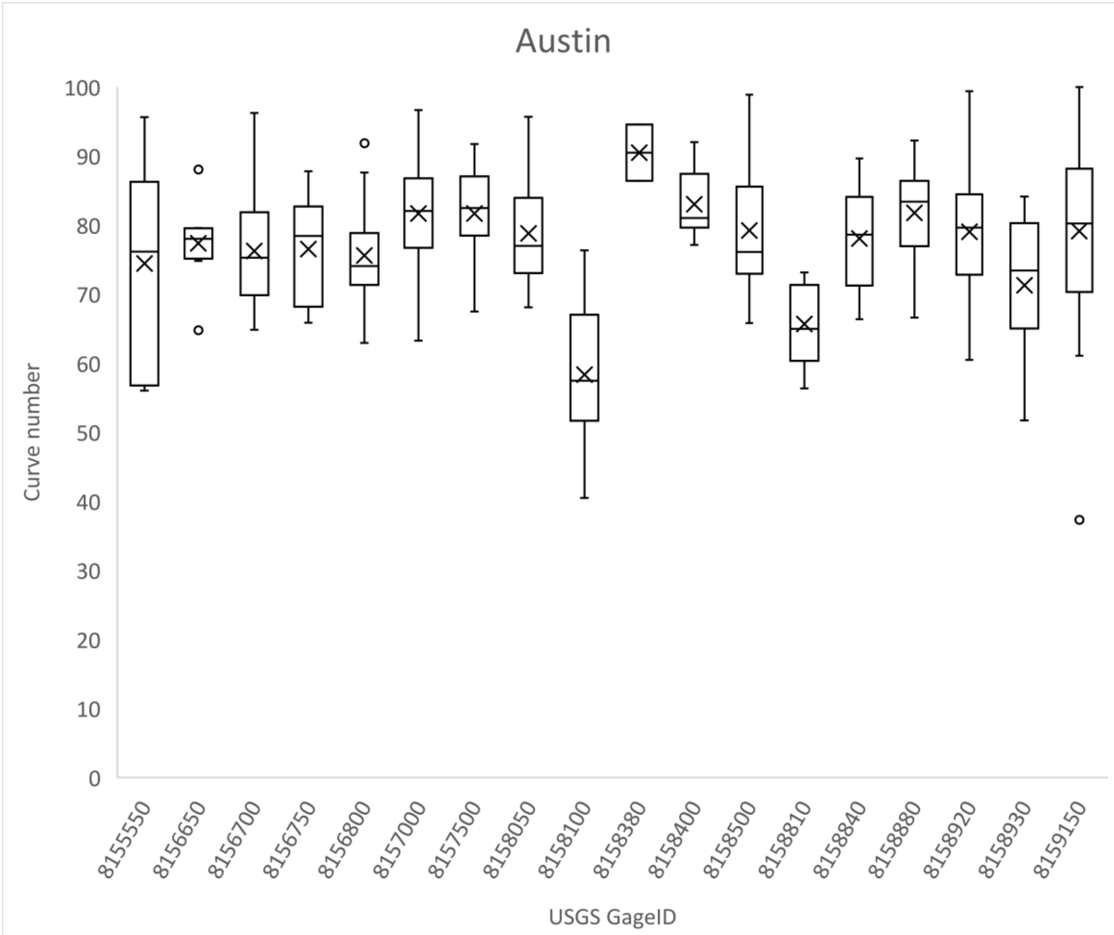


Figure 4-12. Distribution of curve numbers in Austin watersheds.

4.2.3. Dallas

A total of 195 events from 20 watersheds were considered in Dallas and each of the watersheds have events ranging from 1 to 46. A box-and-whiskers plot of the *PRF* for each watershed is shown in Figure 4-13. Moreover, a box-and-whiskers plot for the curve number is shown in Figure 4-14.

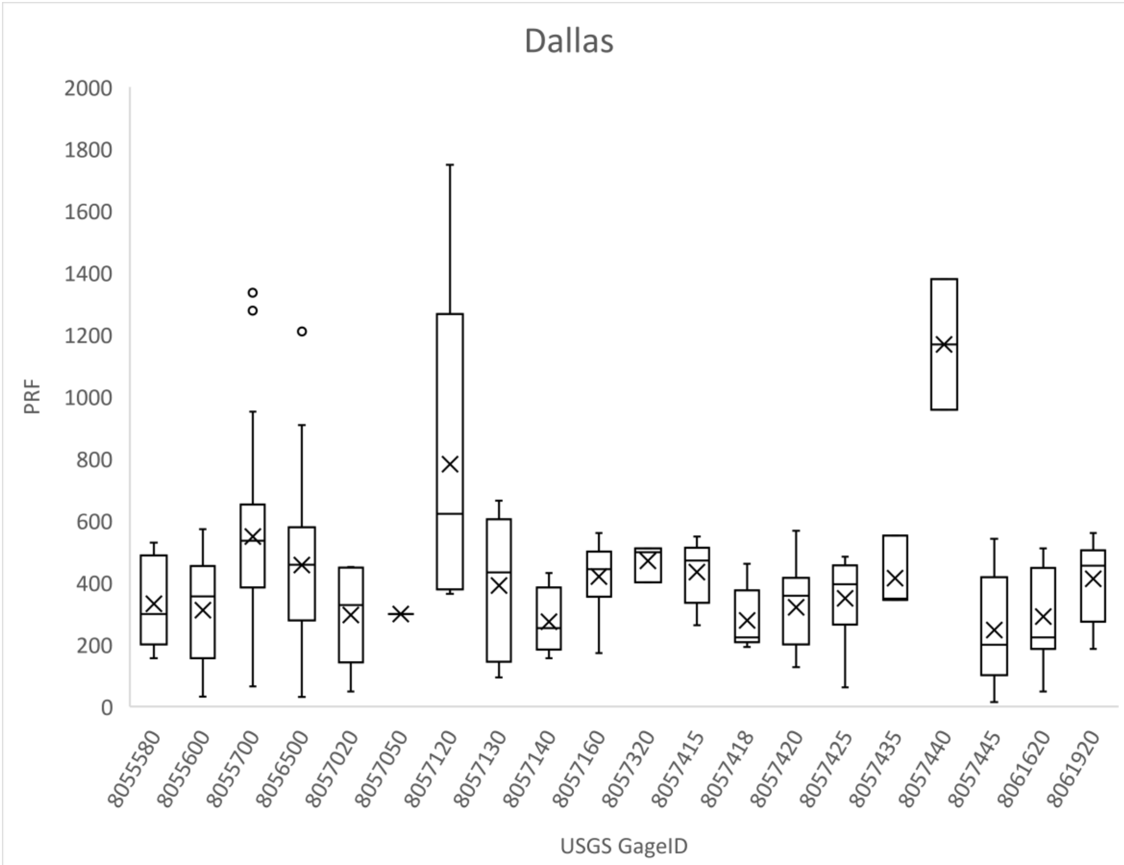


Figure 4-13. Distribution of *PRFs* in Dallas watersheds.

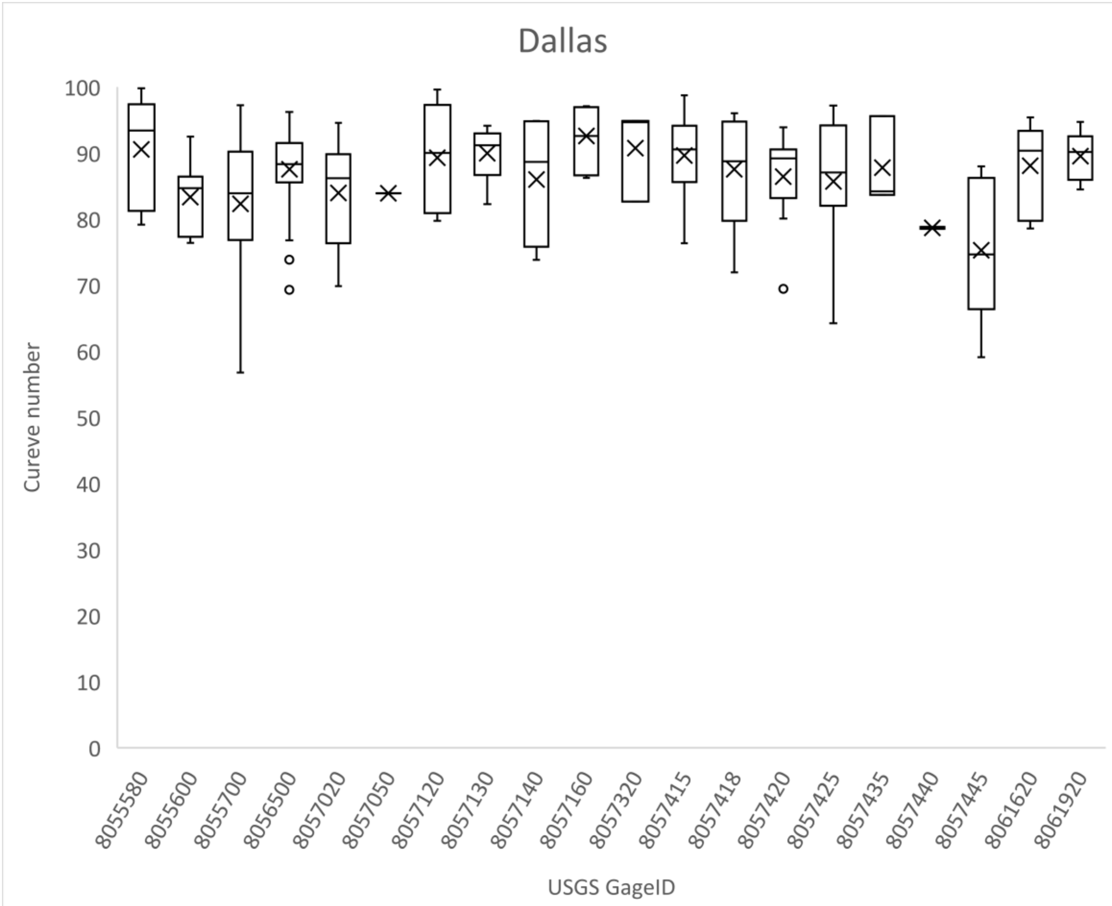


Figure 4-14. Distribution of curve numbers in Dallas watersheds.

4.2.4. Fort Worth

A total of 151 events from seven watersheds were considered in Fort Worth and each of the watersheds have events ranging from 17 to 25. A box-and-whiskers plot of the *PRF* for each watershed is shown in Figure 4-15. Moreover, a box-and-whiskers plot for the curve number is shown in Figure 4-16.

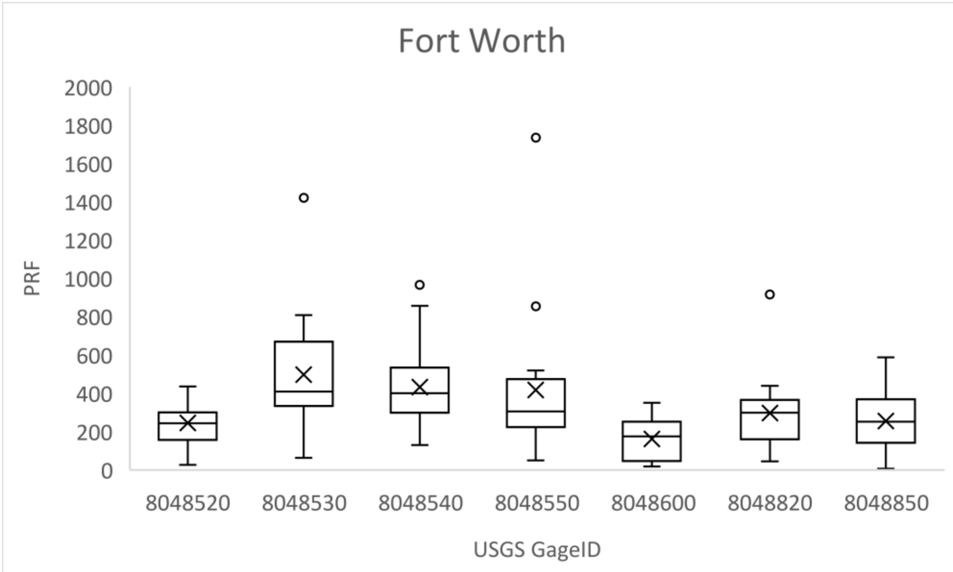


Figure 4-15. Distribution of *PRFs* in Fort Worth watersheds.

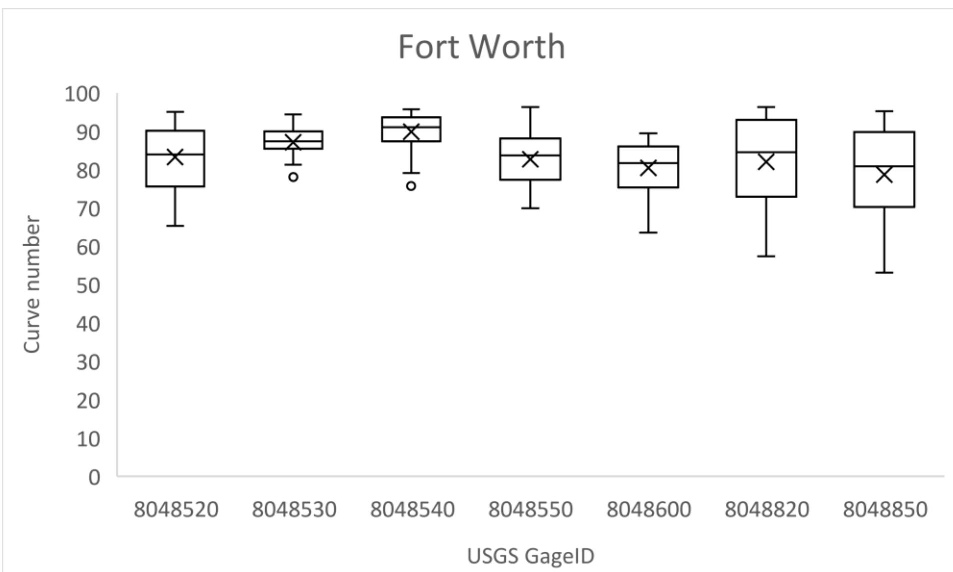


Figure 4-16. Distribution of curve numbers in Fort Worth watersheds.

4.2.5. San Antonio

A total of 107 events from 12 watersheds were considered in San Antonio and each of the watersheds have events ranging from 2 to 24. A box-and-whiskers plot of the *PRF* for each watershed is shown in Figure 4-17. Moreover, a box-and-whiskers plot for the curve number is shown in Figure 4-18.

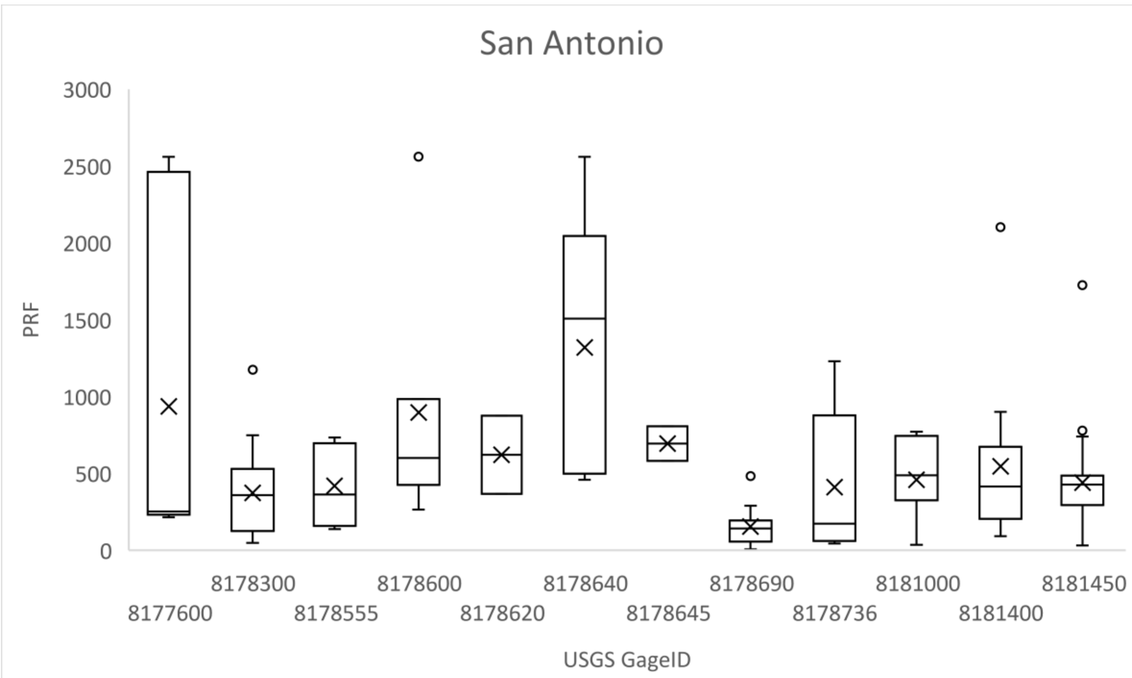


Figure 4-17. Distribution of *PRFs* in San Antonio watersheds.

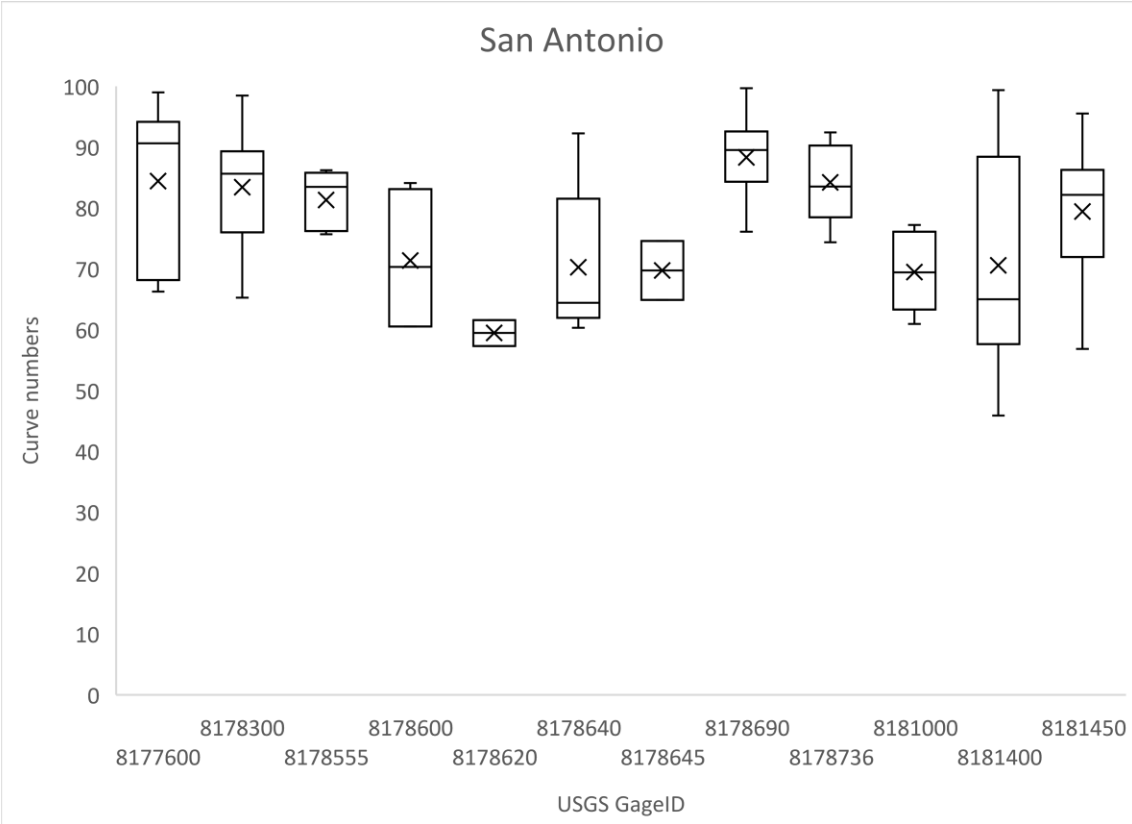


Figure 4-18. Distribution of curve numbers in San Antonio watersheds.

4.2.6. Rural watersheds

A total of 343 events from 16 rural watersheds were considered and each of the watersheds have events ranging from 6 to 39. A box-and-whiskers plot of the *PRF* for each watershed is shown in Figure 4-19. Moreover, a box-and-whiskers plot for the curve number is shown in Figure 4-20.

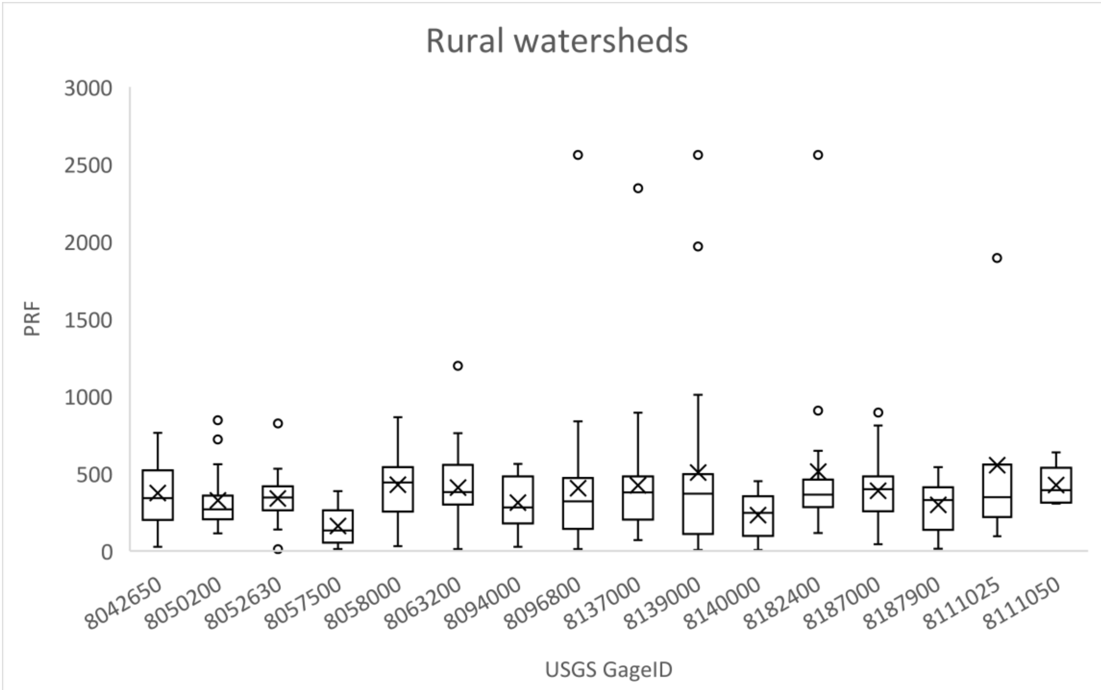


Figure 4-19. Distribution of *PRFs* in rural watersheds.

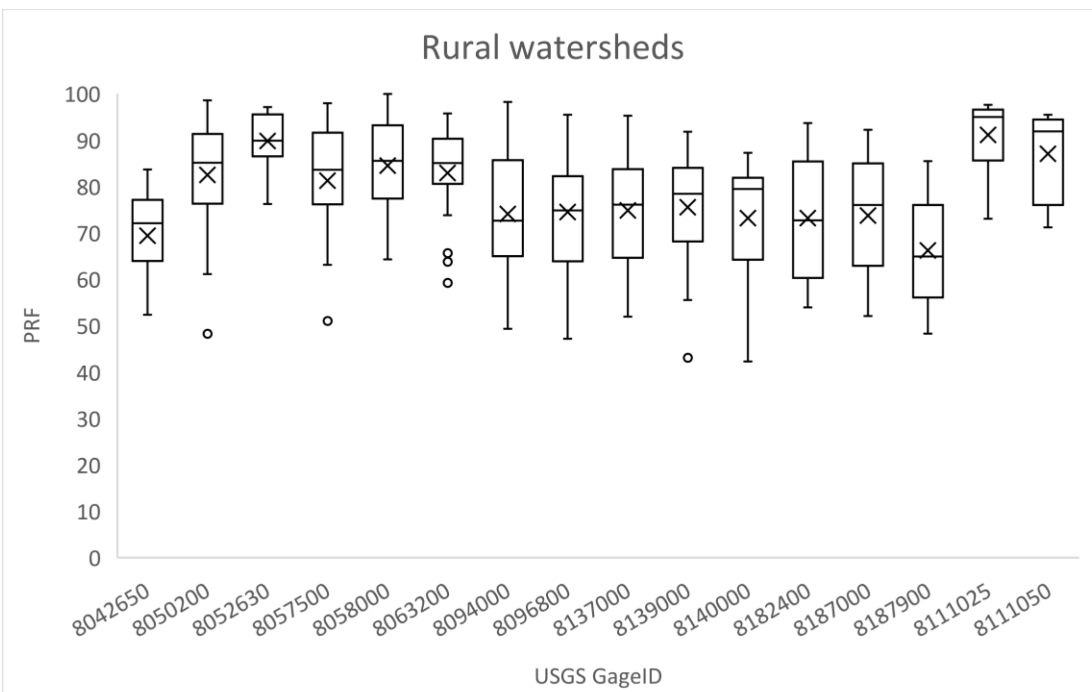


Figure 4-20. Distribution of curve numbers in rural watersheds.

4.2.7. Houston

A total of 605 events from 30 watersheds were considered in Houston and each of the watersheds have events ranging from 2 to 51. A box-and-whiskers plot of the *PRF* for each watershed is shown in Figure 4-21. Moreover, a box-and-whiskers plot for the curve number is shown in Figure 4-22.

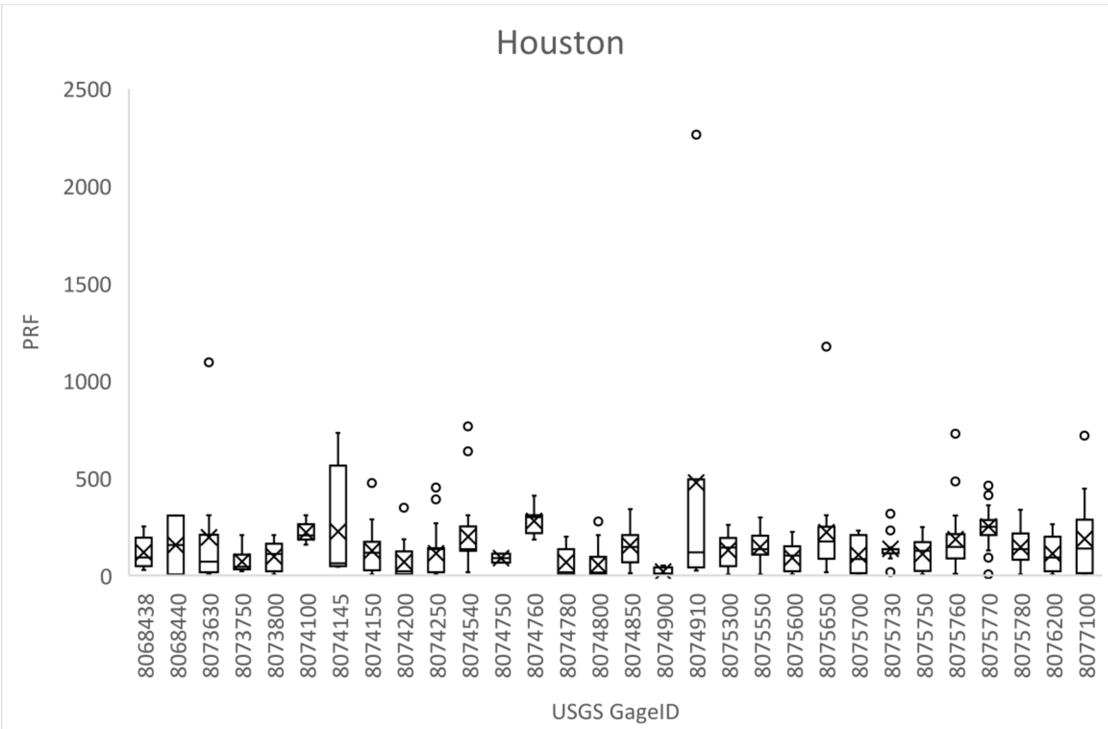


Figure 4-21. Distribution of *PRFs* in Houston watersheds.

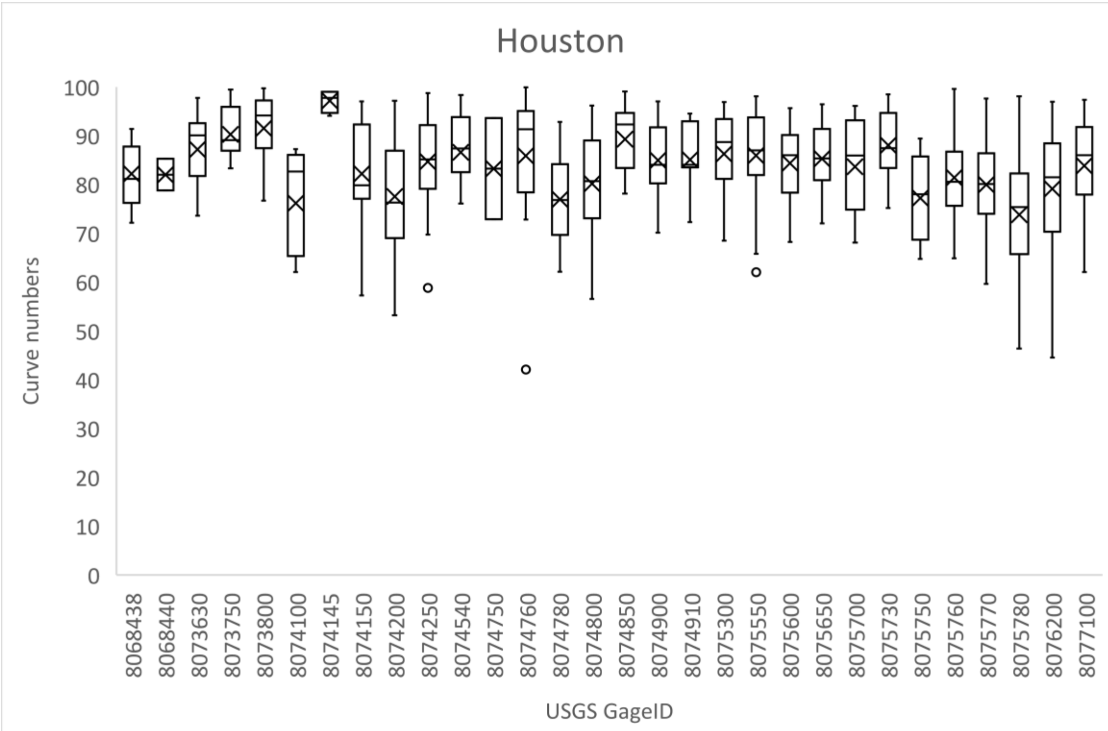


Figure 4-22. Distribution of curve numbers in Houston watersheds.

4.3. Discussion

4.3.1. Implications

It has been shown that the *PRFs* of the Houston storm events were significantly lower than those in other regions and that *PRFs* in rural areas were similar to the *PRFs* in urban areas outside Houston. It was also found that the *PRFs* in urban regions except Houston were similar to that of Rural regions; therefore, there seems to be no evidence that %imperviousness – which is a characteristic of urban watersheds – have an impact on the *PRF*, unlike what was suggested by Solanki and Suau (1996). Moreover, the NRCS-recommended *PRF* of 484 falls under the 77th percentile for non-Houston watersheds and more than 98th percentile for Houston watersheds. It seems clear, therefore, that for practical applications, the *PRF* used should be lower for all regions in Texas, and especially in Houston. Lower *PRFs* mean lower peak flows, and therefore, reduced cost of hydraulic structures.

4.3.2. Uncertainty Analysis

The importance of the accuracy of *PRF* estimates is underscored by the importance of selecting the appropriate design discharge. Since it has been shown that the *PRF* has a wide range for each region, an idea of the corresponding uncertainty in peak discharge estimates is needed. For a given watershed with known drainage area, the peak flow may be estimated according to Equation 4-8. From Equation 4-10, *PRF* only depends on α and therefore, a corresponding value of the range of alphas can be determined from the *PRF* ranges. However, in Equation 4-7, t_p is also related to α; therefore, the uncertainty on t_p must also be resolved. Furthermore, t_p is also a function of β. Thus, the following empirical equations for β in terms of α were determined. For non-Houston watersheds, $\beta = 1.62\alpha^{-0.968}$ with an R^2 of 0.32, and for Houston watersheds, $\beta = 5.32\alpha^{-0.955}$ with an R^2 of 0.15.

Substituting each to Eq. 9:

$$q_p = \left(\frac{397\alpha^{0.968}(\alpha-1)^{\alpha-1}}{e^{\alpha-1}\Gamma(\alpha)}\right)A \qquad (4\text{-}10)$$

$$q_p = \left(\frac{121\alpha^{0.955}(\alpha-1)^{\alpha-1}}{e^{\alpha-1}\Gamma(\alpha)}\right)A \qquad (4\text{-}11)$$

where Equation 4-10 is for Texas non-Houston watersheds and Equation 4-11 is for Houston watersheds. Thus, for a watershed with given area, an estimate of the uncertainty of peak flow can be inferred from the uncertainty on *PRF* (and therefore, on α). The empirical cumulative distribution function for q_p for Houston and non-Houston regions, assuming an area of 1 sq-mi, are shown in Figures 4-23 and 4-24. It may be noticed that there is a 50% probability that flow will be about 90 cfs for Houston and 323 cfs for all watersheds but Houston. Moreover, there is 90% probability that flow will about 116 cfs for Houston and 453 cfs for all watersheds but Houston.

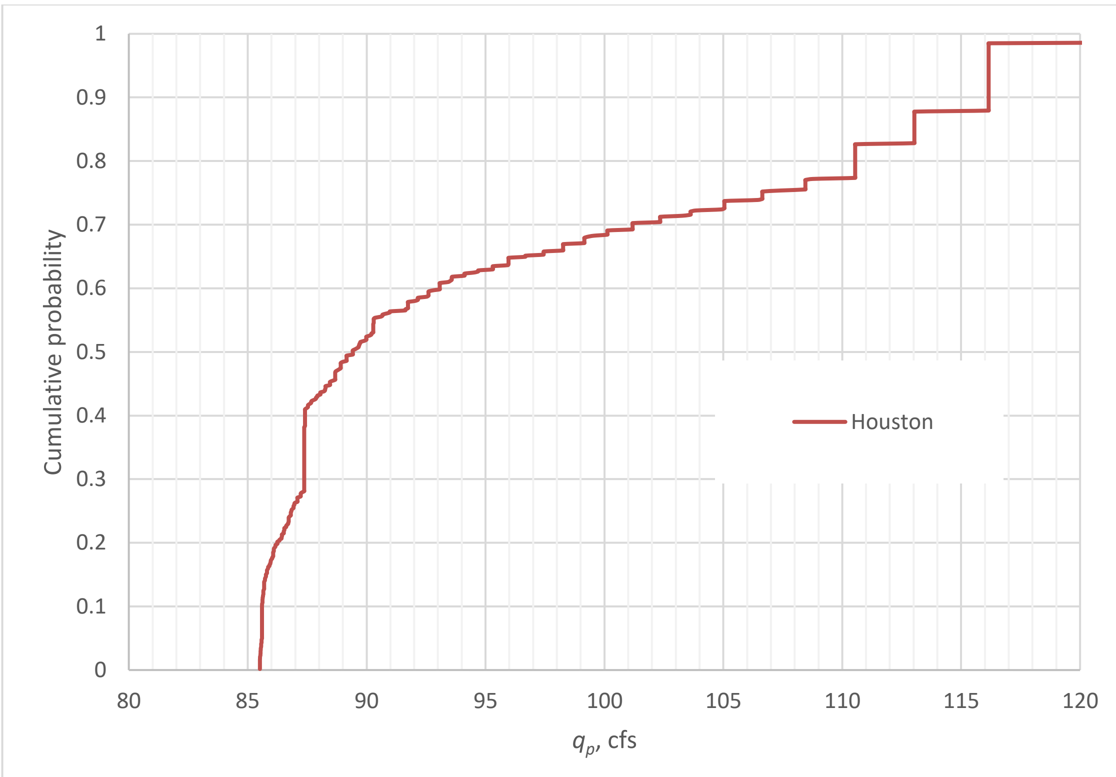


Figure 4-23. Cumulative density functions for peak flow for Houston events.

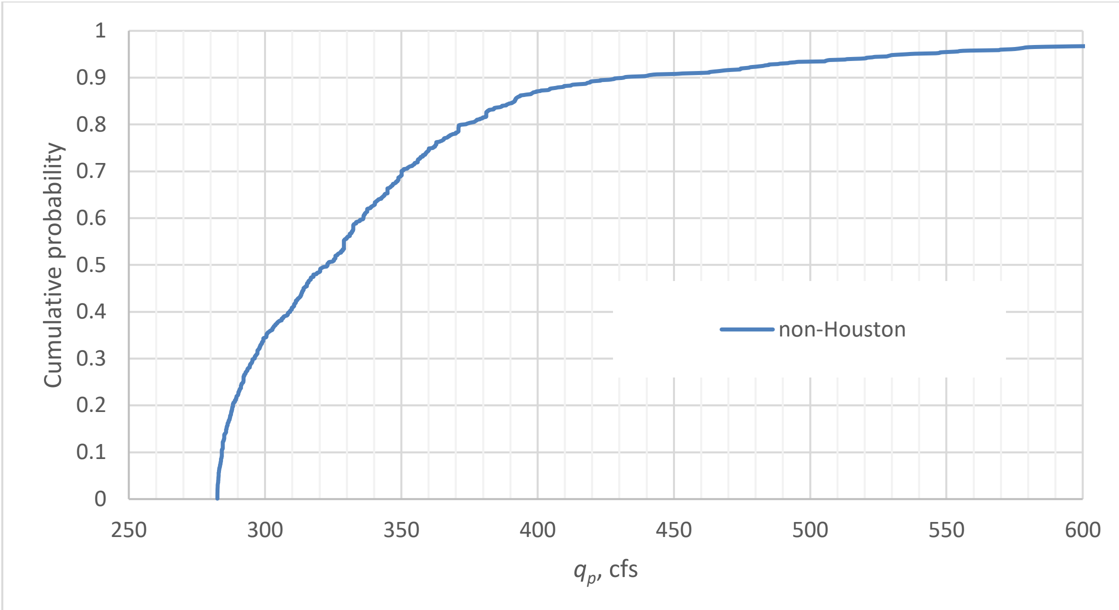


Figure 4-24. Cumulative density functions for peak flow for non-Houston events.

4.3.3. Sensitivity Analysis

The importance of flood hydrology and studying flood parameters such as peak flow, flood depth, and inundation extent is well-recognized. For instance, a simple Web of Science search with the keyword "flood extent" for example will return more than 7400 articles. Nevertheless, research concerning floods is far from saturated and some of recent efforts focus on the effects of different parameters on flood variables of interest such as peak flow, flood depth, and floodplain extent. Haque et al. (2021), for example found that including the effect of rating curve hysteresis on floodplain extent by using a 2D hydrodynamic model improved model fit with observed flood depth, discharge, and inundation extent. Gori et al. (2019) on the other hand studied the impact of urbanization on floodplain extent – using Cypress Creek in Houston, Texas as a test case – and projected that the 100-year floodplain can expand by up to 12.5% across the watershed. Sullivan et al. (2020) investigated on the effect of varying sea levels and tides on inundation extent and found that a 0.5 m increase in mean sea level will produce greater lateral inundation extent with prolonged inundation resulting to up to 23% increase. Praskievicz et al. (2020) studied the effect of Topographic resolution and Manning's roughness coefficient on model fit with inundation extend and found for their study areas of two urban watersheds in Texas and a forested watershed in Florida, the fit for the observed data was better for the higher DEM resolution for the Florida watershed but not of the urban Texas watersheds. Instead, they found that inundation extent in the urban areas were more sensitive to roughness. Wong et al. (2015) studied the sensitivity of inundation extent with on channel erosion uncertainty and found that bed elevation modifications do not significantly affect inundation extent and instead, which means consideration on channel morphology in hydraulic models are not needed unless morphological change has happened over a large number of events. Beevers et al. (2012) investigated the impact of different road development strategies on flood depth, flow velocities, and inundation duration and extent in the context of Cambodian Mekong floodplain. They found that resistance approaches necessitate higher levels of road structures, designed to higher technical specifications, whilst resilience approaches maintain the hydraulic character of floodplains but require the inclusion of well-designed flow through structures with localized scour protection. Cook and Merwade (2009), who worked with Strouds Creek in North Carolina and Brazos River in Texas, studied the effect of topographic resolution on modeled inundation extent and found that inundation extent reduces with improved horizontal and vertical resolution of the elevation model.

It is assumed that, because *PRFs* are directly related to peak flows, inaccurate determination of *PRFs* would lead to errors in assessing flood extents. The practical importance of accurate determination of the *PRF* is therefore in the sound design of hydraulic structures. Surprisingly, however, the extent of the error in design based on a wrong *PRF* is still not extensively explored. Moreover, communicating policies to authorities and decision makers who do not have an intensive background in hydrology is challenging because the significance of such policies may not be understood. Thus, it is important to answer the following question: "How serious is the problem of the lack of solid guidance for *PRF* estimation?" This question is answered by determining the effect of varying *PRFs* on the peak flow, flood depth, and floodplain extents – concepts that are understood well by the public and local government authorities.

In this section, the sensitivity of flood depths, areal extent of flooding, and peak flow to the *PRF* is investigated for segments of three creeks in Austin: Bull Creek, Shoal Creek, and Walnut Creek (Figure 4-25). The cross-sections for these creeks were obtained from the City of Austin FloodPro (City of Austin [CoA], 2022). If the lag time t_L is assumed to be one hour, and the duration t_d is assumed to be 15 minutes or a fourth of the lag time, then the corresponding peak-flow time t_p is calculated as follows:

$$t_p = \frac{t_d}{2} + t_L \qquad (4\text{-}12)$$

and is equal to 67.5 minutes.

The areas (in sq-mi) of the upstream watersheds draining to the upstream boundary of the segments considered in each creek were determined to be 7.73, 1.58, and 7.62, for Bull Creek, Walnut Creek, and Shoal Creek, respectively. Moreover, the precipitation depth corresponding to the 100-year return period (and 15-minute duration) was obtained from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 point precipitation frequency estimates (NOAA, 2017) and using a 15-minute duration (a fourth of the lag time), the value obtained for Austin was 2.55 inches. Using the average curve number for Austin watersheds of 78 (obtained from the 247 events analyzed in Austin), and the NRCS Curve Number Method (Equations 2-8 and 2-9), the corresponding runoff volume from a precipitation of 2.55 inches is 0.82 inches. Thus, the direct runoff hydrograph peak flow is obtained by multiplying the direct runoff to the unit hydrograph peak flow, and the design flow is obtained by adding the baseflow to the direct runoff hydrograph peak flow.

The peak flow is then used as the steady state design flow for HEC-RAS 1D simulation of the flood depths and floodplain extents. For *PRFs* of 100, 250, 484, and 600, results are shown in Tables 4-5 to 4-7. The water surface profiles shown in Figures 4-26, 4-28, and 4-30. Finally, the floodplain maps are shown in Figures 4-27, 4-29, and 4-31. The fact that the flood parameters vary more than 10% when using a *PRF* of 250 (which is close to the median *PRF* of 268 for Austin watersheds) compared to when using a *PRF* of 484 underscores the importance of accurate determination of *PRF* for hydrologic modeling. Note though that this analysis is done with the assumption of a constant peak-flow time.

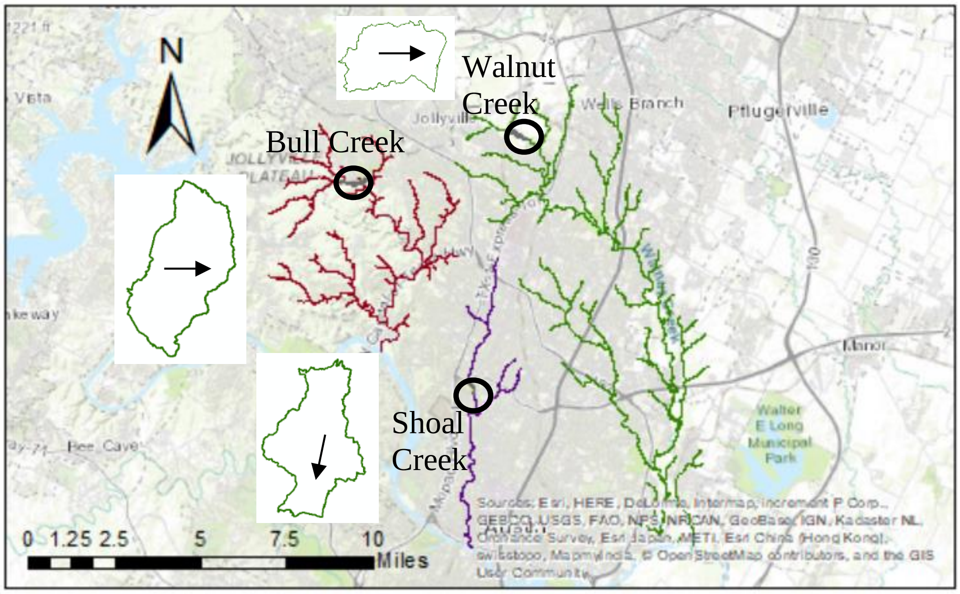


Figure 4-25. Area for sensitivity analysis (circles represent the locations of the reaches for sensitivity analysis; polygons are the shape of the watersheds draining to the reaches).

Table 4-5. Sensitivity of *PRFs* in Bull Creek to flood parameters.

PRF	Peak flow (cfs)	Max floodplain extent (mi^2)	Max depth (ft)
100	583	0.0117	4.59
250	1429	0.0199	6.54
484	2747	0.0262	8.40
600	3401	0.0283	9.18

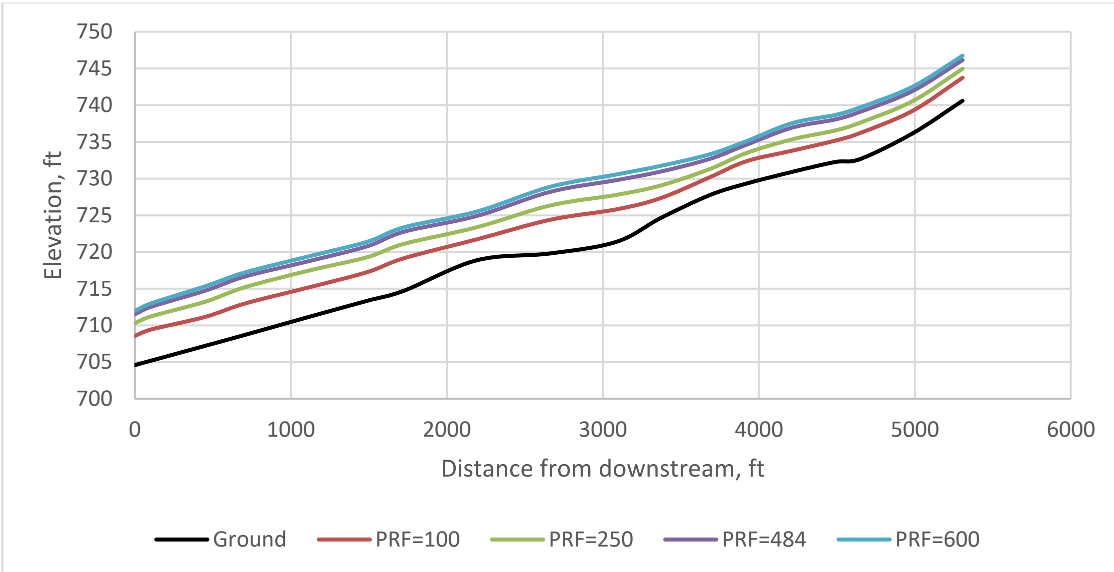


Figure 4-26. Water surface profiles for Bull Creek for different *PRFs*.

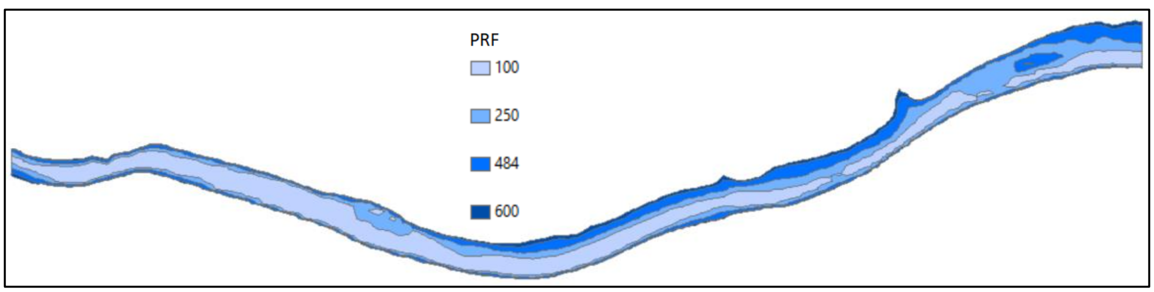


Figure 4-27. Floodplain extents for Bull Creek for different *PRFs*.

Table 4-6. Sensitivity of *PRFs* in Walnut Creek to flood parameters.

PRF	Peak flow (cfs)	Max floodplain extent (mi^2)	Max depth (ft)
100	135	0.0128	2.41
250	308	0.0171	2.95
484	577	0.0215	3.78
600	711	0.0230	4.08

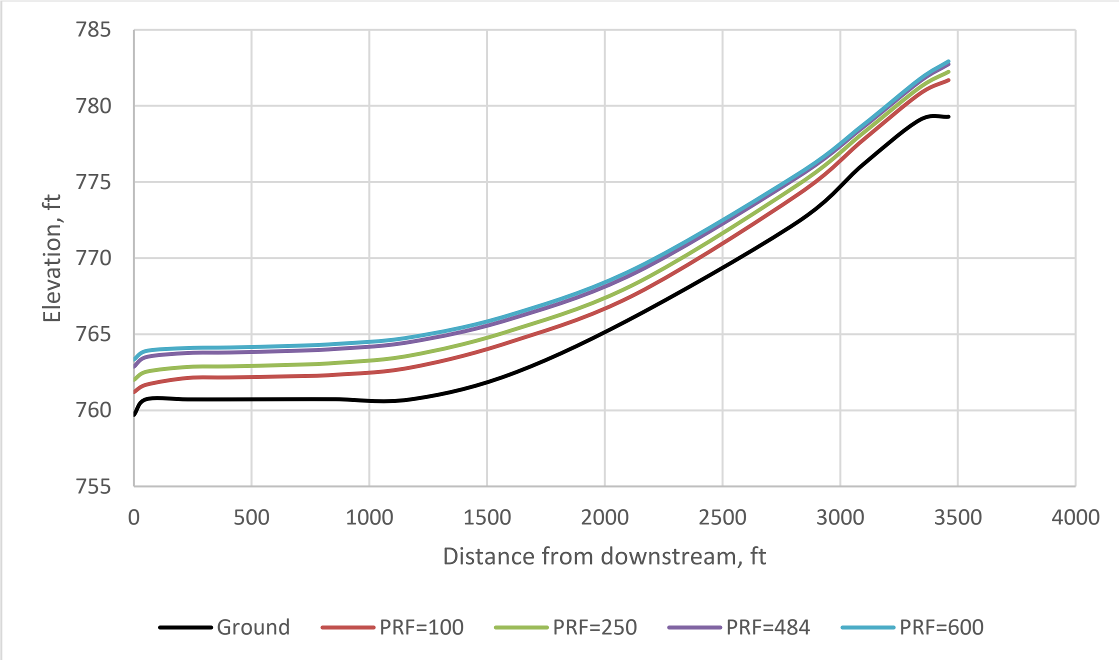


Figure 4-28. Water surface profiles for Walnut Creek for different *PRFs*.

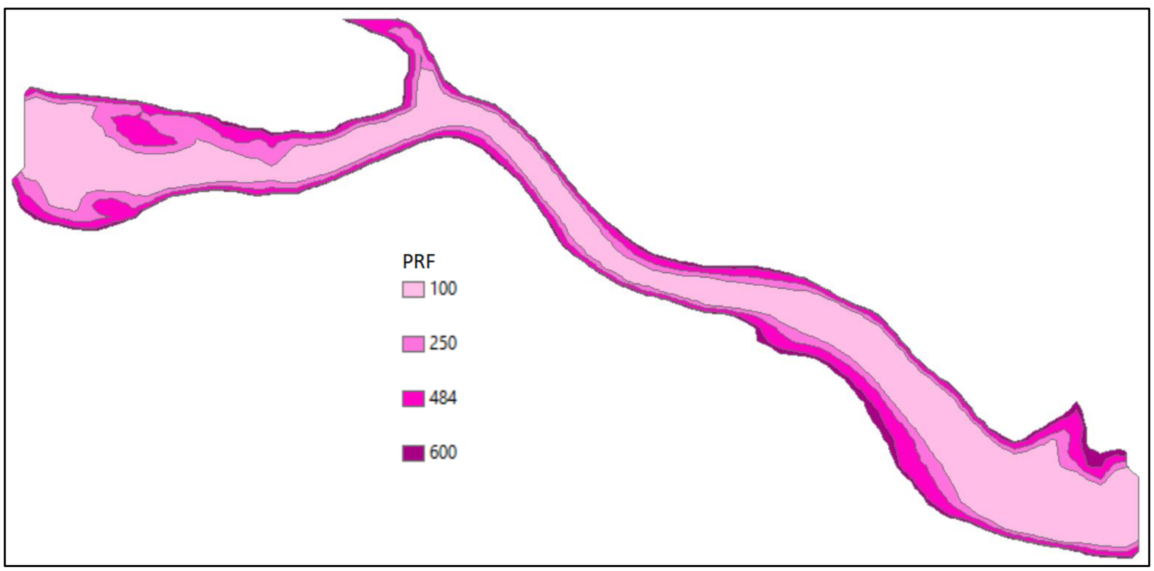


Figure 4-29. Floodplain extents for Walnut Creek for different *PRFs*.

Table 4-7. Sensitivity of *PRFs* in Shoal Creek to flood parameters.

PRF	Peak flow (cfs)	Max floodplain extent (mi^2)	Max depth (ft)
100	575	0.0049	5.61
250	1409	0.0076	7.92
484	2708	0.0093	10.09
600	3352	0.0102	10.93

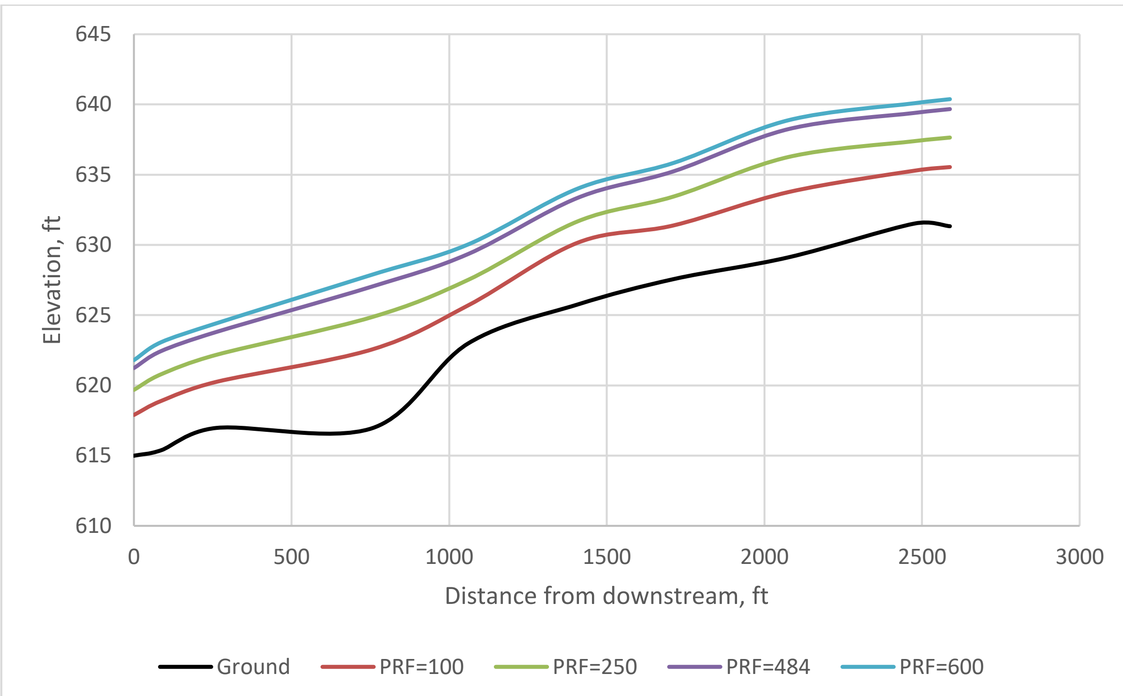


Figure 4-30. Water surface profiles for Shoal Creek for different *PRFs*.

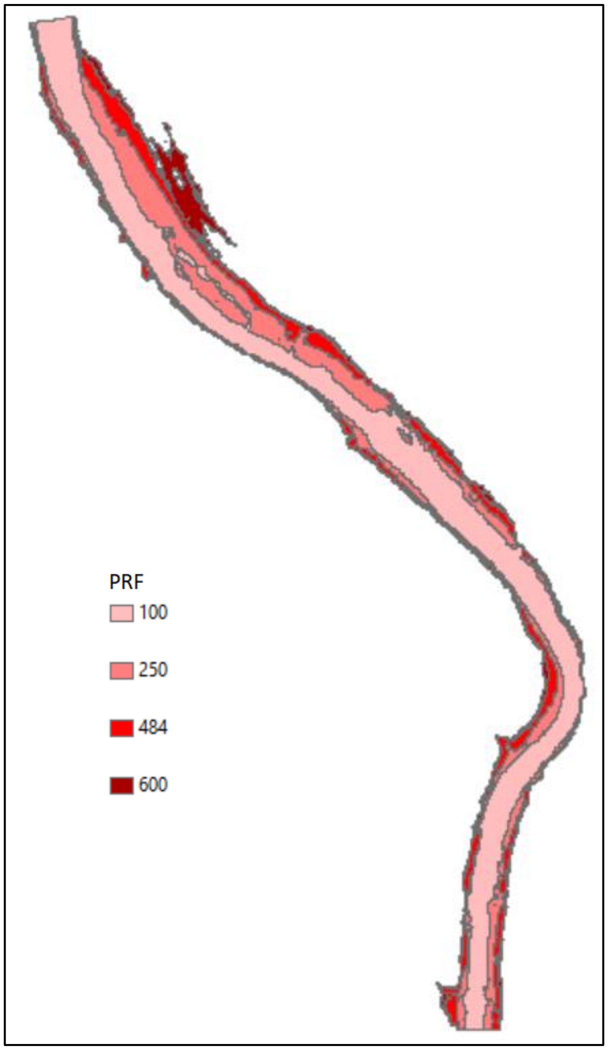


Figure 4-31. Floodplain extents for Shoal Creek for different *PRFs*.

5. PARAMETERS AFFECTING THE PRF

5.1. Overview

Chapter 3 describes the methodology for determining storm and watershed parameters that may affect the *PRF*. While the 104 watersheds were considered for determining the *PRFs*, not all of them were considered for investigating which watershed parameters affect the *PRFs* because estimation of their physical characteristics was deemed inaccurate when their delineated and USGS-reported drainage areas disagreed by more than 10%, that is,

$$\frac{|A_{delineated} - A_{USGS}|}{A_{USGS}} \times 100 > 10 \qquad (5\text{-}1)$$

where $A_{delineated}$ is drainage area delineated from the DEM and A_{USGS} is the USGS-reported drainage area. Note that 29 out of 31 Houston watersheds falls under this restriction – likely because the flat slopes that typically characterize Houston watersheds made it difficult to delineate areas the meet Equation 5-1 based on the 1-arc second DEM; therefore, to increase the representation of Houston watersheds, watersheds were generated by taking advantage of building walls based on generated watershed shapefiles from the Harris County Flood Control District (HCFCD) (Brian Edmonton, personal communication, 2021) and burning streams based on published USGS streams (USGS, 2017). Building walls is the process of raising terrain elevation to effectively confine the boundaries of flow while burning streams is the process of lowering terrain elevation to force water to flow through. In building walls, elevations across the DEM boundary are raised except for the outlet. Doing so forces flow accumulations to end up in the outlet gage.

Overall, 60 watersheds were considered for parameter analysis. The regions that make up the delineated watersheds – and the number of watersheds for each region – were as follows: Austin (14 watersheds), Dallas (12), Fort Worth (3), San Antonio (7), Houston (16) as well as eight rural watersheds – one each in Bryan, Bruceville, Elmendorf, Hubbard, Gunter, Kenedy, McKinney and Trickham. Shown in Figures 5-1 to 5-6 are watersheds. Note that for Houston, the watersheds cannot easily be resolved using the 1-arc second DEM and thus they were delineated by building walls based on the delineated watersheds from the Harris County Flood Control District (HCFCD) (Brian Edmonton, personal communication, 2021) and burning the published USGS streams (USGS, 2017). The DEM-based parameters of the 60 watersheds are shown in Table 5-1.

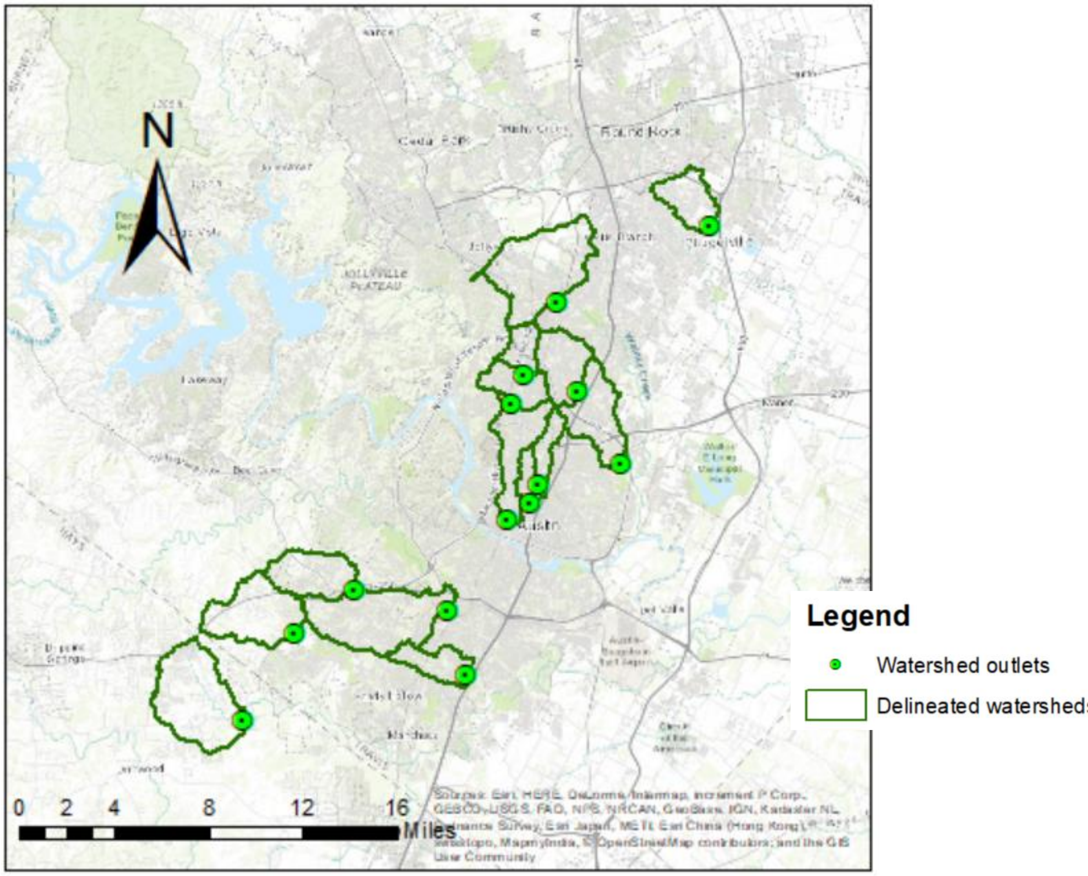


Figure 5-1. Austin delineated watersheds.

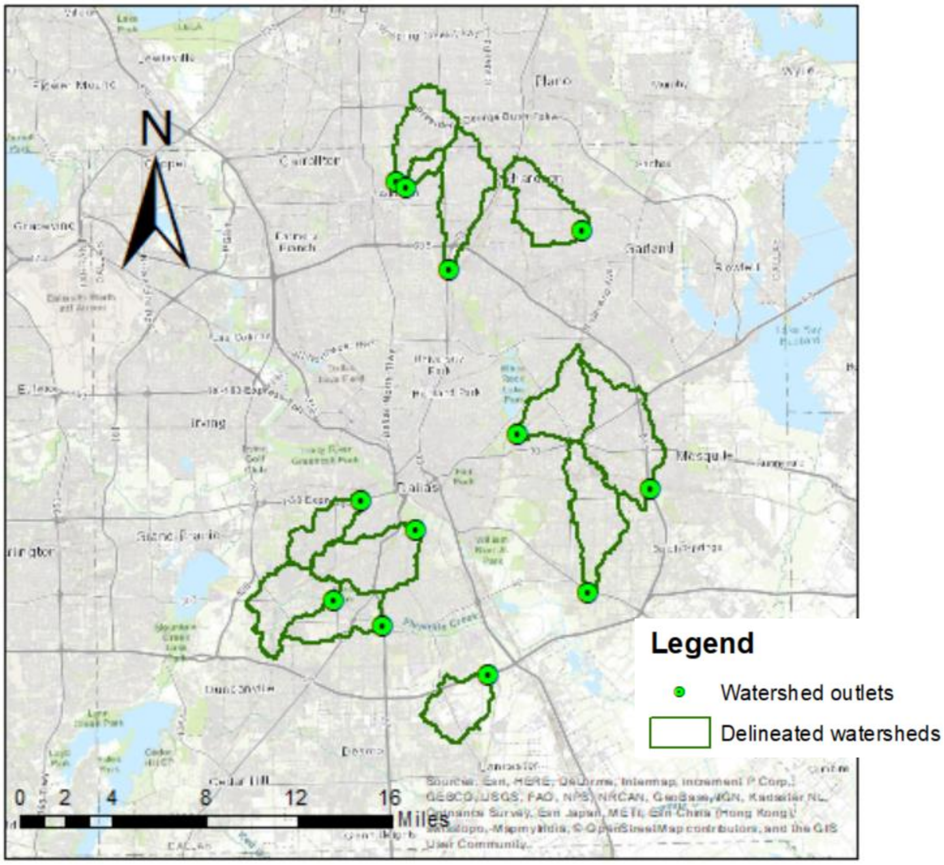


Figure 5-2. Dallas delineated watersheds.

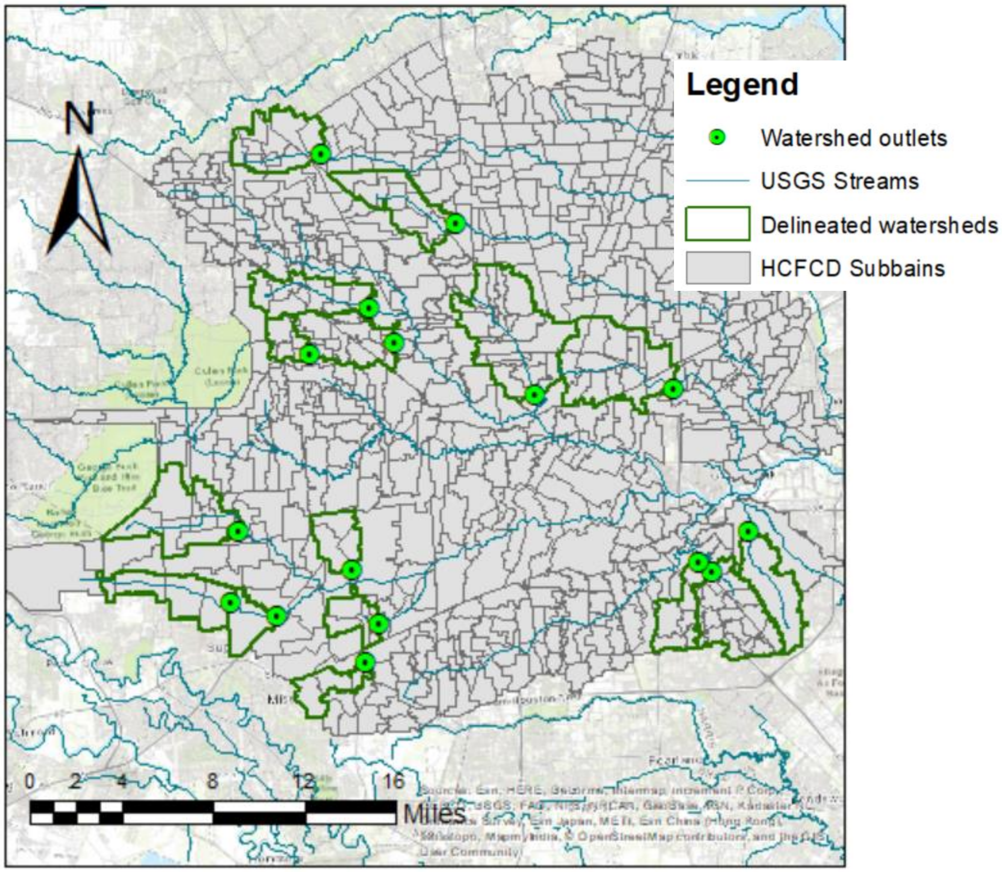


Figure 5-3. Houston delineated watersheds.

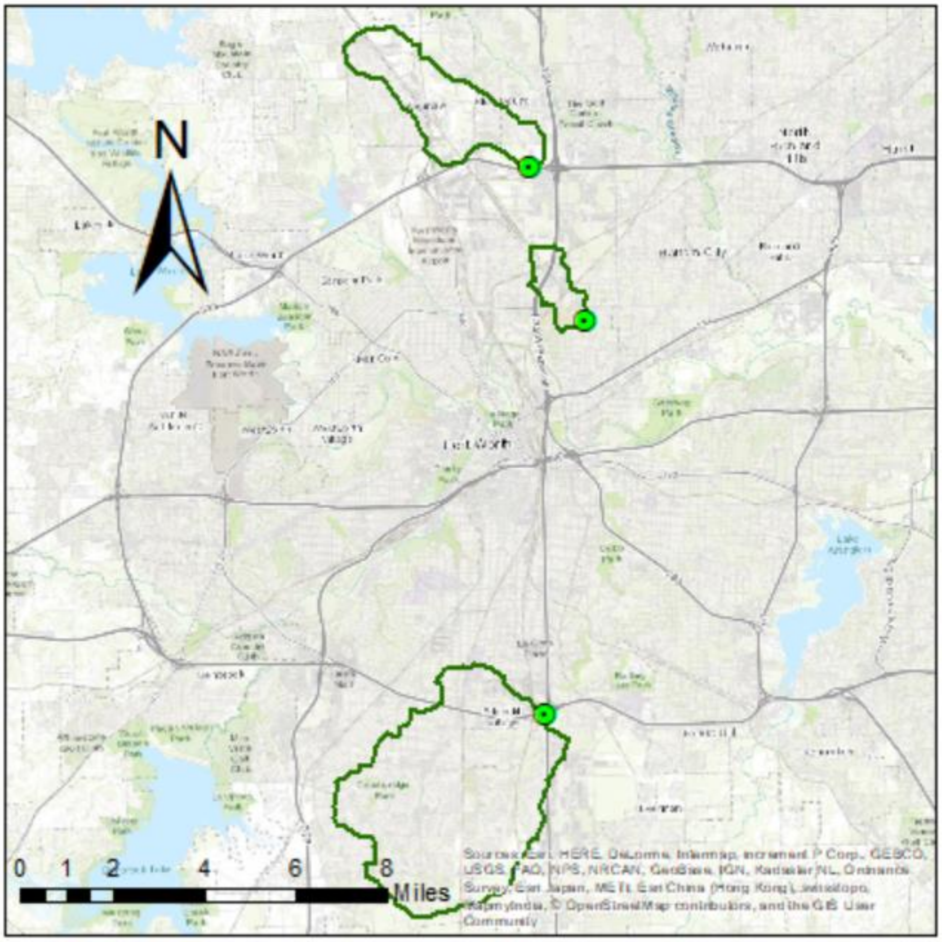


Figure 5-4. Fort Worth delineated watersheds.

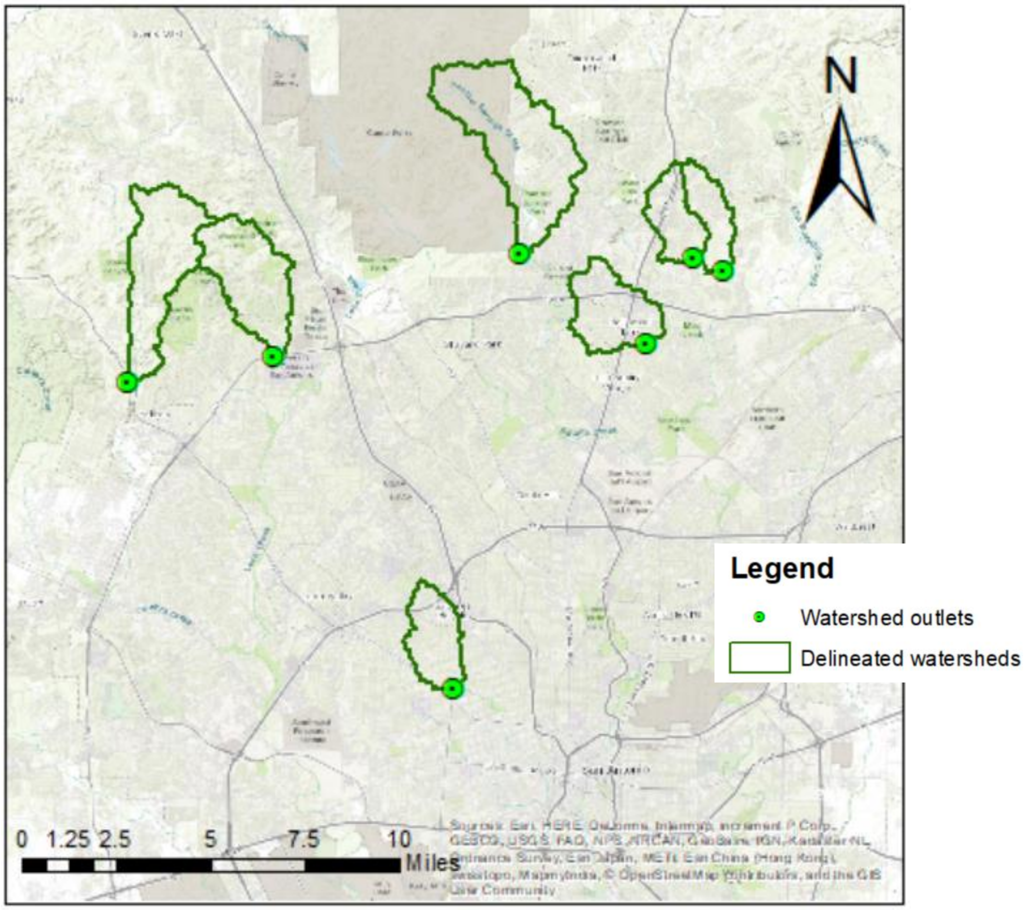


Figure 5-5. San Antonio delineated watersheds.

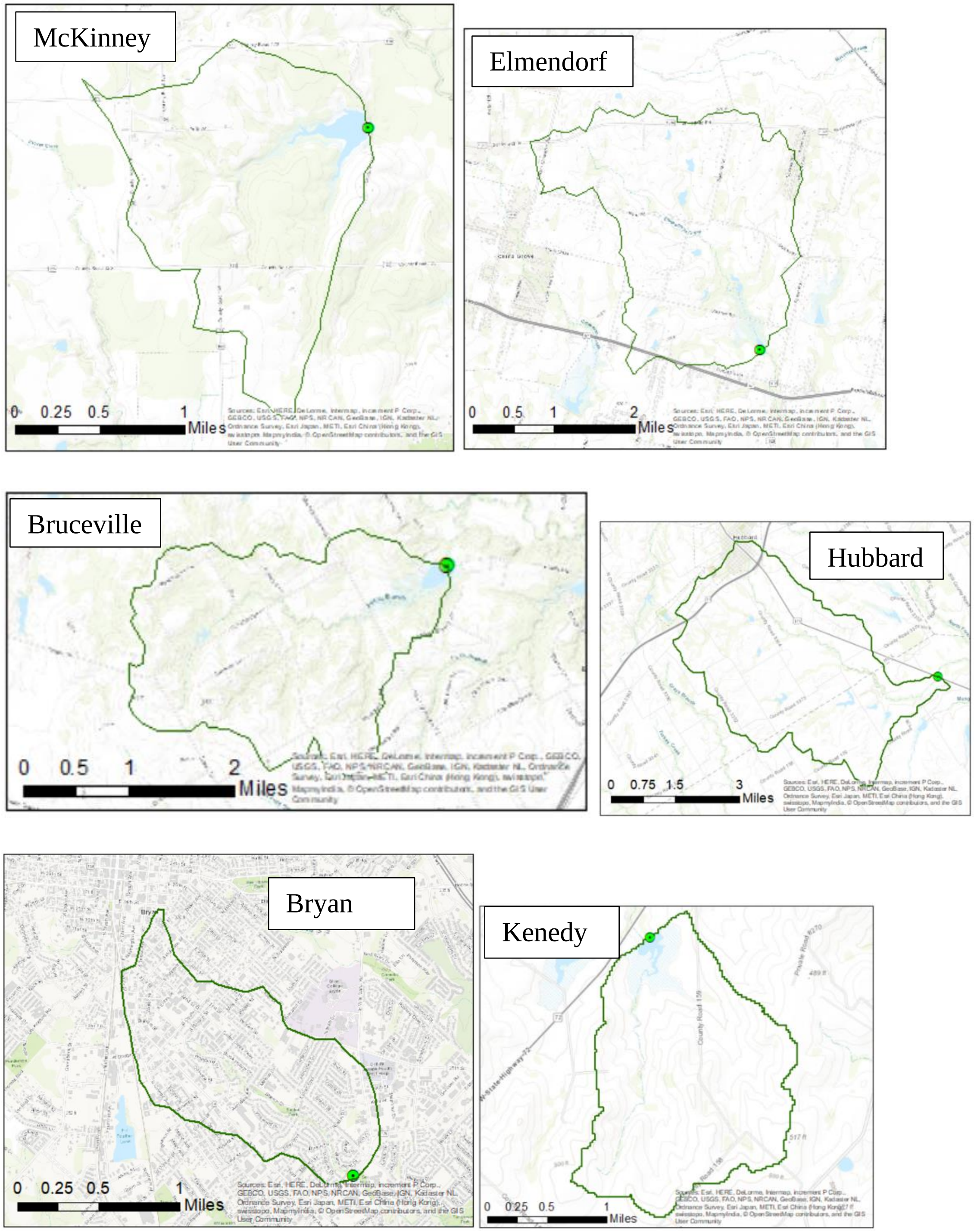


Figure 5-6. Delineated rural watersheds.

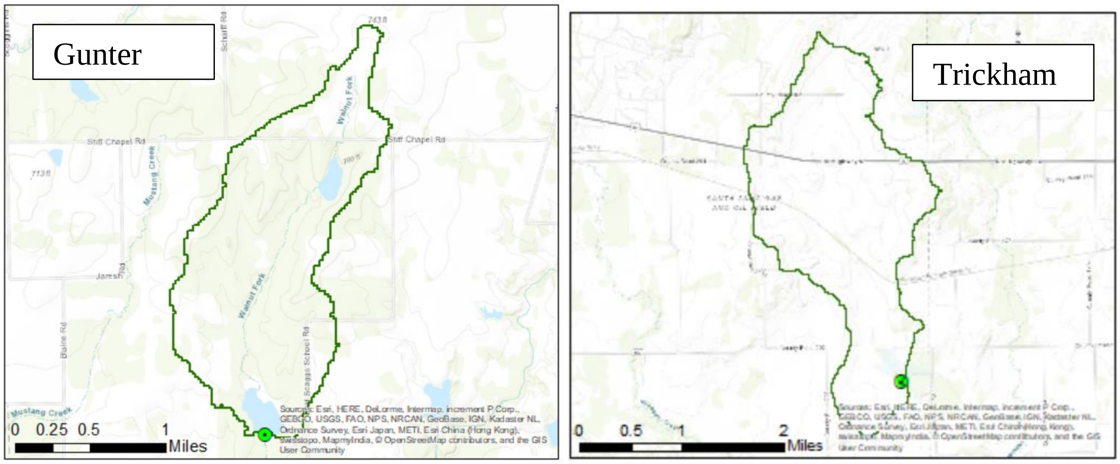


Figure 5-6 (continued). Delineated rural watersheds

Table 5-1. Watershed parameters (A in mi^2, lengths in mi).

GageID	PRF	A	L_{E-C}	L_{F-C}	$\overline{L_F}$	$\overline{L_E}$	L_{E-max}	L_{F-max}	$\frac{L_{E-C}}{L_{E-max}}$	$\frac{L_{F-C}}{L_{F-max}}$	$\frac{\overline{L_F}}{L_{F-max}}$	$\frac{\overline{L_E}}{L_{E-max}}$	SF	S	CS
08137000	379	3.9	1.68	1.96	2.21	1.77	3.51	4.16	0.48	0.47	0.53	0.50	0.22	0.023	0.0052
08048520	243	17.7	2.68	4.17	4.18	2.93	5.32	7.99	0.50	0.52	0.52	0.55	0.28	0.021	0.0049
08048550	305	1.1	0.75	0.82	0.92	0.79	1.65	1.81	0.45	0.45	0.51	0.48	0.33	0.007	0.0047
08048820	299	5.7	2.41	3.26	3.22	2.47	4.90	6.25	0.49	0.52	0.52	0.50	0.15	0.012	0.0058
08052630	344	2.0	1.20	1.44	1.55	1.25	2.80	3.33	0.43	0.43	0.47	0.45	0.18	0.026	0.0064
08057020	328	4.6	2.18	2.62	2.80	2.22	4.07	5.11	0.54	0.51	0.55	0.55	0.18	0.043	0.0097
08057050	298	9.4	2.38	3.04	3.33	2.51	4.96	6.44	0.48	0.47	0.52	0.51	0.23	0.034	0.0076
08057120	622	6.6	2.45	3.15	3.12	2.53	4.39	5.33	0.56	0.59	0.59	0.58	0.23	0.022	0.0070
08057130	433	1.3	1.10	1.33	1.40	1.13	2.18	2.67	0.50	0.50	0.52	0.52	0.18	0.015	0.0090
08057140	253	8.5	3.43	3.95	4.13	3.46	6.18	7.55	0.56	0.52	0.55	0.56	0.15	0.023	0.0056
08057320	498	7.4	2.22	2.74	2.95	2.34	4.62	5.65	0.48	0.48	0.52	0.51	0.23	0.021	0.0058
08057418	223	8.0	1.99	2.59	2.97	2.17	3.80	5.69	0.52	0.46	0.52	0.57	0.25	0.033	0.0079
08057420	358	14.3	3.22	4.08	4.49	3.35	6.00	8.46	0.54	0.48	0.53	0.56	0.20	0.037	0.0065
08057435	348	5.9	1.90	2.43	2.44	1.99	3.50	4.27	0.54	0.57	0.57	0.57	0.32	0.029	0.0093
08057445	199	8.9	3.47	4.77	4.80	3.53	6.63	8.65	0.52	0.55	0.55	0.53	0.12	0.018	0.0036
08057500	133	2.1	0.83	1.10	1.14	0.96	1.79	2.08	0.46	0.53	0.55	0.54	0.48	0.047	0.0108
08061620	223	7.7	2.08	2.72	2.83	2.20	4.43	5.39	0.47	0.50	0.53	0.50	0.26	0.012	0.0042
08061920	454	12.9	2.49	3.22	3.51	2.66	6.34	7.88	0.39	0.41	0.45	0.42	0.21	0.023	0.0039
08063200	379	18.0	3.42	4.95	5.45	3.65	6.32	9.58	0.54	0.52	0.57	0.58	0.20	0.023	0.0038
08096800	319	5.0	1.75	2.16	2.45	1.85	3.32	4.55	0.53	0.47	0.54	0.56	0.24	0.056	0.0111
08111025	346	1.3	0.96	1.17	1.24	0.99	2.03	2.60	0.47	0.45	0.48	0.49	0.20	0.020	0.0067
08156650	177	2.7	1.09	1.47	1.49	1.19	2.29	3.19	0.48	0.46	0.47	0.52	0.26	0.030	0.0110
08156700	61	6.4	1.49	1.97	2.21	1.69	3.60	4.70	0.41	0.42	0.47	0.47	0.29	0.031	0.0090
08156800	294	12.6	4.73	6.03	6.24	4.77	8.44	10.83	0.56	0.56	0.58	0.57	0.11	0.033	0.0073
08157000	314	2.2	1.72	2.19	2.16	1.74	3.44	4.20	0.50	0.52	0.51	0.51	0.13	0.023	0.0095

08158100	121	12.7	1.63	3.39	3.01	2.10	3.83	6.90	0.43	0.49	0.44	0.55	0.27	0.029	0.0085
08158380	354	5.3	1.37	1.65	1.95	1.53	3.06	3.81	0.45	0.43	0.51	0.50	0.37	0.024	0.0075
08158400	234	5.9	1.71	2.12	2.43	1.85	3.57	4.49	0.48	0.47	0.54	0.52	0.29	0.025	0.0071
08158500	246	12.1	3.47	4.73	4.78	3.52	6.60	8.55	0.53	0.55	0.56	0.53	0.17	0.035	0.0069
08158810	443	12.1	2.27	3.44	3.74	2.50	4.44	6.35	0.51	0.54	0.59	0.56	0.30	0.061	0.0108
08158840	237	8.7	1.88	2.44	2.67	2.07	4.04	5.23	0.47	0.47	0.51	0.51	0.32	0.055	0.0113
08158880	244	3.6	1.45	2.03	2.01	1.53	3.53	4.51	0.41	0.45	0.45	0.43	0.18	0.039	0.0115
08158920	160	6.2	1.89	2.28	2.50	2.00	4.01	5.01	0.47	0.46	0.50	0.50	0.25	0.064	0.0116
08159150	432	4.4	1.52	2.16	2.21	1.61	3.04	3.94	0.50	0.55	0.56	0.53	0.29	0.021	0.0076
08178300	359	3.2	1.46	2.05	1.96	1.52	3.05	3.77	0.48	0.54	0.52	0.50	0.23	0.044	0.0155
08178600	600	9.6	3.01	3.75	4.03	3.14	5.49	7.31	0.55	0.51	0.55	0.57	0.18	0.066	0.0117
08178620	621	4.1	1.30	1.76	1.93	1.43	2.79	3.51	0.47	0.50	0.55	0.51	0.33	0.033	0.0119
08178640	1507	2.6	1.19	1.60	1.60	1.27	2.60	3.11	0.46	0.51	0.51	0.49	0.27	0.058	0.0185
08178645	694	2.3	1.52	2.00	2.07	1.56	3.13	3.96	0.49	0.51	0.52	0.50	0.15	0.050	0.0149
08181000	488	5.5	2.19	3.13	3.12	2.25	3.97	5.44	0.55	0.58	0.57	0.57	0.19	0.135	0.0161
08181400	415	14.9	3.73	5.50	5.46	3.92	6.77	10.03	0.55	0.55	0.54	0.58	0.15	0.131	0.0122
08182400	364	7.1	1.78	2.10	2.51	1.93	3.86	5.01	0.46	0.42	0.50	0.50	0.28	0.026	0.0057
08187000	398	3.1	1.21	1.80	1.59	1.29	2.34	2.76	0.52	0.65	0.58	0.55	0.40	0.037	0.0098
08158930	299	18.7	3.97	5.92	5.70	4.12	8.10	10.60	0.49	0.56	0.54	0.51	0.17	0.041	0.0087
08074150	118	7.9	2.72	3.50	3.78	2.79	5.45	7.87	0.50	0.44	0.48	0.51	0.13	0.0021	0.0008
08074200	22	2.8	1.23	1.62	1.97	1.31	2.43	4.28	0.51	0.38	0.46	0.54	0.15	0.0016	0.0005
08074250	135	10.8	2.82	3.98	4.12	2.91	5.74	9.09	0.49	0.44	0.45	0.51	0.13	0.0016	0.0008
08074540	135	18.2	2.86	3.34	4.31	3.08	6.24	9.13	0.46	0.37	0.47	0.49	0.22	0.0016	0.0013
08074760	300	11.6	2.76	3.79	3.63	2.90	6.07	6.84	0.45	0.55	0.53	0.48	0.25	0.0022	0.0009
08074780	17	8.1	2.40	3.16	3.32	2.51	6.06	8.07	0.40	0.39	0.41	0.41	0.13	0.0014	0.0003
08074800	15	11.8	3.49	4.33	4.80	3.58	8.15	10.58	0.43	0.41	0.45	0.44	0.11	0.0016	0.0004
08074850	147	4.4	1.45	3.08	2.84	1.56	2.95	5.32	0.49	0.58	0.53	0.53	0.16	0.0018	0.0003

08074900	10	3.8	1.24	1.61	1.84	1.38	2.53	3.50	0.49	0.46	0.53	0.55	0.31	0.0016	0.0006
08075300	143	3.8	2.01	2.76	3.35	2.08	3.54	6.13	0.57	0.45	0.55	0.59	0.10	0.0014	0.0006
08075650	175	10.9	2.14	3.18	3.57	2.33	4.63	7.00	0.46	0.45	0.51	0.50	0.22	0.0014	0.0006
08075700	85	5.2	2.44	2.98	3.32	2.49	4.43	6.44	0.55	0.46	0.52	0.56	0.13	0.0017	0.0006
08075730	135	7.5	2.68	3.35	3.54	2.74	5.59	6.97	0.48	0.48	0.51	0.49	0.15	0.0017	0.0008
08075770	251	15.0	2.86	4.09	4.96	3.04	5.30	8.24	0.54	0.50	0.60	0.57	0.22	0.0020	0.0006
08075780	135	8.7	1.95	2.99	3.04	2.11	3.97	7.01	0.49	0.43	0.43	0.53	0.18	0.0018	0.0005
08076200	93	8.3	2.63	3.73	3.89	2.73	6.05	7.82	0.43	0.48	0.50	0.45	0.14	0.0014	0.0008

5.2. Results

5.2.1. Effect of the Watershed Characteristics on the *PRFs*

To determine which and how various watershed parameters affect the *PRFs*, multivariate linear regression of the logarithm of the median *PRFs* in each watershed and watershed parameters was conducted, which led to a relationship in the form of the product of the variables raised to different powers. The *PRFs* were averaged for each watershed to avoid giving more weight to watersheds with more events than others; moreover, the averaging procedure done was the median instead of the mean for the result to be robust to very high *PRFs*. The median *PRF* and the parameters for each watershed are also shown in Table 5-1. From the table, it may be noticed that one watershed (USGS 08178640) had a median *PRF* (1,509) that is more than five standard deviations greater than the mean median *PRF* for all watersheds (299), so it was classified as an outlier and disregarded in the analysis.

Among other requirements, multivariate linear regressions require the independent variables not to be correlated (Alexopoulos, 2010). Thus, correlation coefficients were calculated between variables and are shown in Table 5-2. Note that strong correlation was found among the different representations of the ratio of the average and maximum lengths, as well as between the watershed average slope and the main channel slope. Thus, eight regression models for the *PRF* were generated, each with four independent and uncorrelated variables: area, a length ratio, a slope parameter, and shape factor. Moreover, two other models that are similar in form to those of Sheridan et al. (2002) and Fang et al. (2004) were also generated.

Table 5-2. Correlation matrix for independent variables (correlation coefficients greater than 0.50 were considered to be high and are bolded).

log	A	$\frac{L_{E-C}}{L_{E-max}}$	$\frac{L_{F-C}}{L_{F-max}}$	$\frac{\overline{L_F}}{L_{F-max}}$	$\frac{\overline{L_E}}{L_{E-max}}$	SF	S
L_{E-C}/L_{E-max}	0.09						
L_{F-C}/L_{F-max}	0.03	**0.55**					
$\overline{L_F}/L_{F-max}$	0.06	**0.74**	**0.77**				
$\overline{L_E}/L_{E-max}$	0.14	**0.90**	**0.51**	**0.69**			
SF	-0.16	-0.19	0.12	0.20	0.10		
S	-0.08	0.18	0.44	0.37	0.24	0.37	
CS	-0.21	0.14	0.41	0.34	0.19	0.43	**0.96**

The following are the ten models that were generated:

a) $\log PRF = a + b \log A + c \log L_{E-C}/L_{E-max} + d \log S + e \log SF$

b) $\log PRF = a + b \log A + c \log L_{F-C}/L_{F-max} + d \log S + e \log SF$

c) $\log PRF = a + b \log A + c \log \overline{L_F}/L_{F-max} + d \log S + e \log SF$

d) $\log PRF = a + b \log A + c \log \overline{L_E}/L_{E-max} + d \log S + e \log SF$

e) $\log PRF = a + b \log A + c \log L_{E-C}/L_{E-max} + d \log CS + e \log SF$

f) $\log PRF = a + b \log A + c \log L_{F-C}/L_{F-max} + d \log CS + e \log SF$

g) $\log PRF = a + b \log A + c \log \overline{L_F}/L_{F-max} + d \log CS + e \log SF$

h) $\log PRF = a + b \log A + c \log \overline{L_E}/L_{E-max} + d \log CS + e \log SF$

i) $\log PRF = a + b \log A + b \log CS$

j) $\log PRF = a + b \log A + c \log L_{F-max} + c \log CS$

where *A*, the watershed area, is in square miles. Models (a) to (d) differ by the length ratio included, as is the case for models (e) to (h). Moreover, models (e) to (h) differ from models (a) to (e) by including *CS* instead of *S*. Model (i) contains predictors like those of Sheridan et al. (2002), while model (j) contains variables like those of Fang et al. (2005).

The p-values obtained using analysis of variance (ANOVA) on the residuals of the ten models (Table 5-3) were all less than 0.000 but the geomorphological parameter $\overline{L_F}/L_{F-max}$ (i.e., models (c) and (g)) produced lower p-values than the other geomorphological parameters, and that models with the *CS* variable produced lower p-value than models with the S variable. Moreover, the models that consider the same variables as those of Sheridan et al. (2002) and Fang et al. (2005) had higher p-values, which indicate that they are not the best options out of the ones considered. Instead, model (g), having the least p-value, was selected for being the one in which the watershed parameters conveyed the most information. Model (g) with the values for the coefficients is as follows:

$$\log PRF = 4.19 - 0.05 \log A + 3.31 \log \frac{\overline{L_F}}{L_{F-max}} + 0.454 \log CS - 0.214 \log SF \tag{5-2}$$

which, after rearrangement, can be expressed as:

$$PRF = \frac{15{,}354}{A^{0.05} SF^{0.214}} \left(\frac{\overline{L_F}}{L_{F-max}}\right)^{3.31} CS^{0.454} \tag{5-3}$$

Student's t-test was performed to determine the relevance of the individual variables on log *PRF*. The p-values calculated for log *A*, log $\overline{L_F}/L_{F-max}$, log *CS*, and log *SF* were 0.653, 0.002, 0.000, and 0.398 respectively, which indicates that log *CS* and, to a lesser extent, log $\overline{L_F}/L_{F-max}$ have the greatest effect on log *PRF*, while log *A* and log *SF* have lesser impact. A stepwise regression using the backward-elimination algorithm leads to the *PRF* as a function of only log *CS* and log $\overline{L_F}/L_{F-max}$:

$$PRF = 19{,}885\left(\frac{\overline{L_F}}{L_{F-max}}\right)^{3.32} CS^{0.421} \quad (5\text{-}4)$$

Table 5-3. Resulting p-values from ANOVA and t-test (Values that are bolded are less than 0.05).

Model	ANOVA p-value	t-test p-value				
		Log A	Log (Ratio)	Log (Slope)	Log SF	Log L
a	**6.10E-07**	0.653	**0.002**	**3.70E-07**	0.398	
b	**2.20E-07**	0.867	**0.011**	**4.40E-05**	0.959	
c	**6.40E-08**	0.734	**0.003**	**7.00E-06**	0.726	
d	**2.80E-06**	0.862	0.274	**1.10E-06**	0.929	
e	**4.10E-08**	0.506	**0.029**	**1.60E-07**	0.956	
f	**1.50E-08**	0.557	**0.009**	**2.50E-06**	0.665	
g	**4.00E-09**	0.653	**0.002**	**3.70E-07**	0.398	
h	**2.00E-07**	0.528	0.221	**6.50E-08**	0.556	
i	**4.10E-08**	0.859		**1.00E-08**		0.617
j	**7.80E-09**	0.494		**1.50E-09**		

A plot of actual vs predicted *PRFs*, according to Equations 5-3 and 5-4, is shown in Figure 5-7. It may be noticed that the predicted *PRFs* exhibited less variability than that of the calculated ones. For example, calculated median *PRFs* ranged from 10 to 694, but their corresponding predicted values using Equation 5-4 ranged only from 34 to 552. This result indicates that there are other variables, not considered in the analysis, that affect and explain the variability of the *PRFs*. Thus, while the model appears to capture the median *PRF*, it cannot be concluded that $\overline{L_F}/L_{F-max}$ and *CS* fully explain the PRF variance as is also implied by a modest coefficient of determination of 0.504. Note, in Fig 5-1, that Equation 5-3, which has four predictors, explains the *PRF* variability only slightly better than Equation 5-4 (R^2 = 0.497), which has only one predictor – in fact, both regression lines are almost coincident with each other.

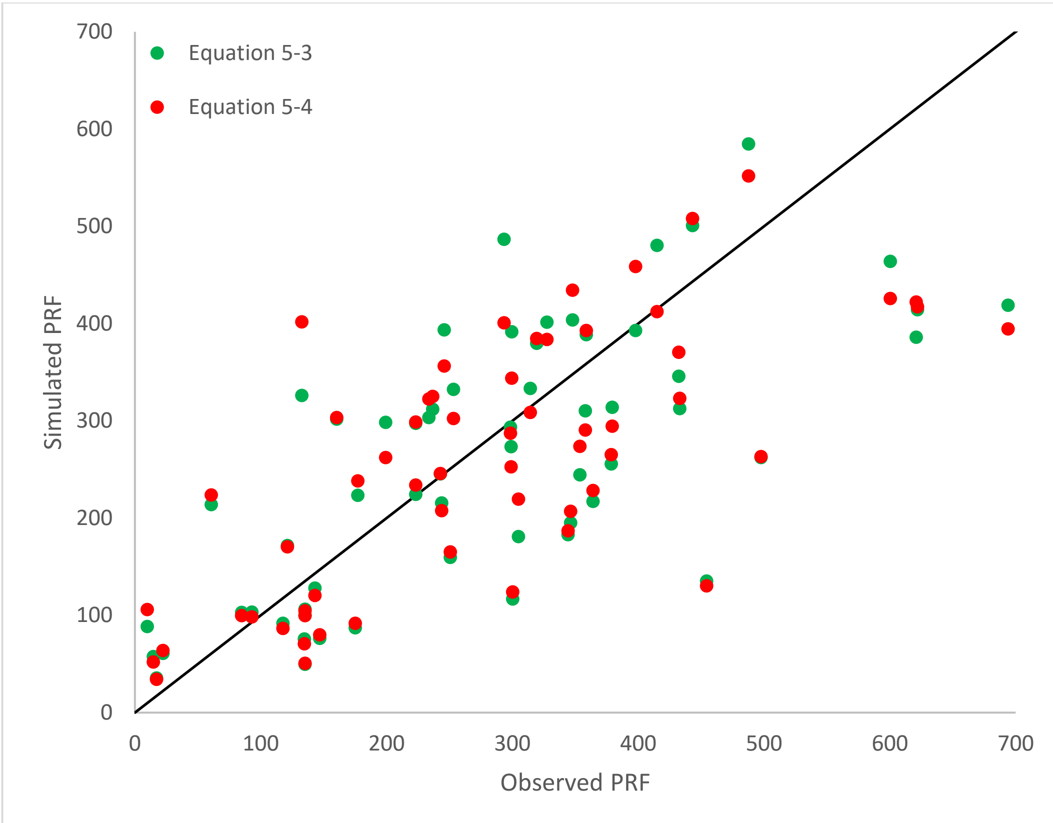


Figure 5-7. Model comparisons between Equation 5-3, which has *A*, $\overline{L_F}/L_{F-max}$, *CS*, and *SF* as predictors, and Eq. 5-4, which has only *CS* and $\overline{L_F}/L_{F-max}$ as predictors.

The final step in the analysis is to check for the regression assumptions of normality and homoscedasticity of the independent variables (Alexopulos, 2010). For a multivariate analysis, it is sufficient to only check these assumptions for the residuals. The probability plot correlation coefficient test is employed to check for normality (Filliben, 1975). A normal quantile-quantile plot – with the quantiles plotted using the Weibull plotting position – is constructed for the residuals (mean = 22, standard deviation = 113) and is shown in Figure 5-8, where the diagonal line represents a perfectly normal fit. Since the correlation coefficient (0.993) is greater than the critical correlation coefficient at 5%

level of significance (0.980 for 59 observations), there is no evidence to conclude that the distribution is not normal; therefore, the assumption of normality is satisfied. Finally, to check for the assumption of homoscedasticity, a residual plot is constructed (Figure 5-9). The absence of a clear increasing or decreasing trend of the variance in the plot indicates homoscedasticity.

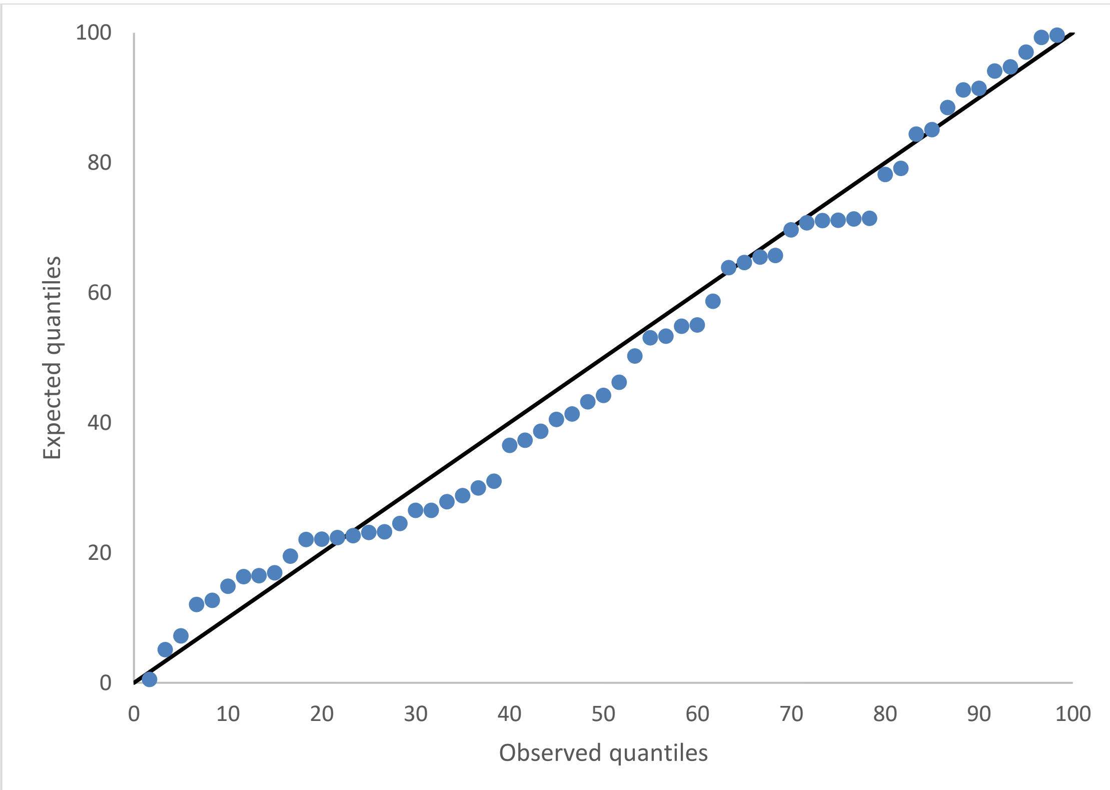


Figure 5-8. Normal Q-Q plot of residuals.

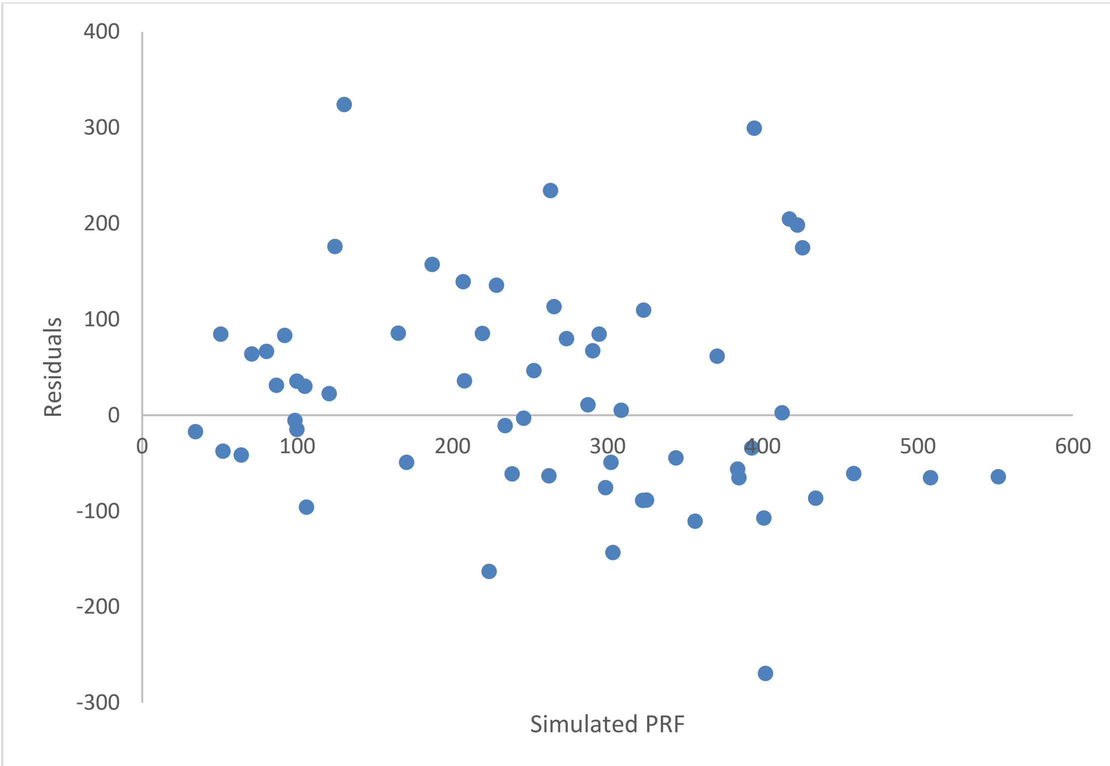


Figure 5-9. Residual plot.

5.2.2. Effect of Storm Characteristics on the *PRFs*

Using linear regression, the relationship of the *PRF* with storm characteristic for all 1,648 events was also tested using linear regression and the results are shown in Table 5-4. The low R^2 values indicate that each independent variable does not explain the variability of the *PRF*. The ranges of rainfall depth, excess rainfall depth, rainfall intensity, and duration were 0.03 to 17.08 in, 0.01 to 12.66 in, 0.001 to 3.20 in/hr, and 0.42 to 228.75 hrs, respectively. Despite the wide range of these variables, a relationship between the *PRF* and each independent variable could not be found.

Table 5-4. Regression results for investigating the influence of storm parameters on the *PRF*.

Variable	Equation for *PRF*	Correlation coefficient
Excess rainfall in inches (*D*)	$PRF = 334 - 31.6D$	0.02
Rainfall in inches (*P*)	$PRF = 369 - 27.5P$	0.03
Rainfall intensity in in/hr (*i*)	$PRF = 269 + 107i$	0.01
Storm duration in hours (t_d)	$PRF = 357 - 3.27t_d$	0.04

5.2.3. Effect of Season on the *PRFs*

The distribution of *PRFs* for each month (shown in Figure 5-10 as a box plot) was also determined to assess the effect of season on the *PRF*. From this plot, the medians seem to be not far from each other; however, application of the Kruskal-Wallis test (Kruskal and Wallis, 1952) show that at least one of the months is different from the rest, at five percent significance level, with a p-value of 0.02. Moreover, Kruskal-Wallis test yielded a p-value of 0.01 if the months were categorized according to the four seasons, where winter includes the months of December, January, and February; spring – March, April, and May; summer – June, July, and August; and, fall – September, October, and November. Hence, it can be concluded that one of the seasons have *PRFs* that are significantly different from the rest. To determine which of the seasons is different, Kolmogorov-Smirnov test was applied and the results are shown in Table 5-5. It may be noticed that *PRFs* resulting from winter storms are significantly different from *PRFs* from spring storms but are not significantly different from the other seasons. The explanation for this result might be due to higher peak-flow time resulting from a higher moisture content of soils although given the small number of events in winter relative to other seasons, it is hard to reach a definite conclusion.

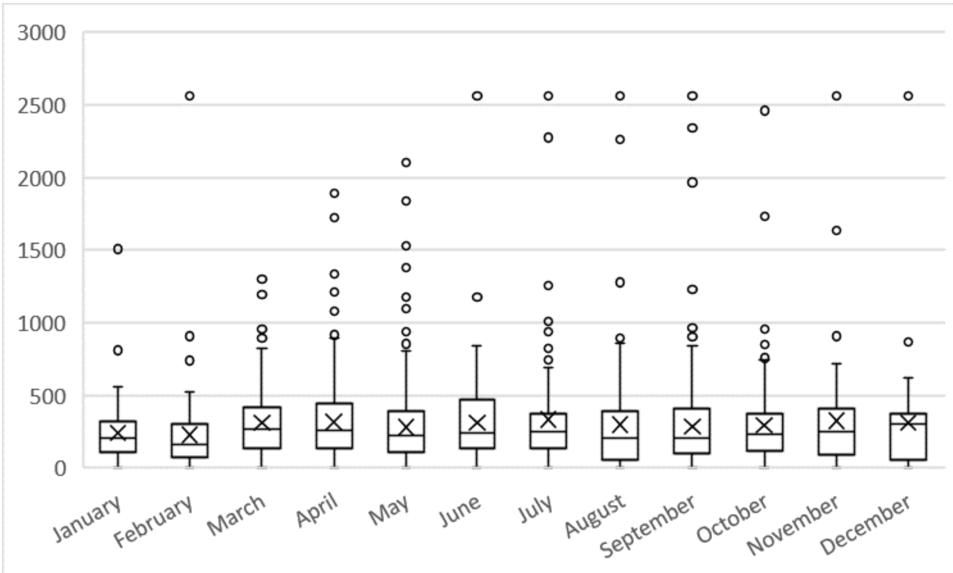


Figure 5-10. Monthly distribution of *PRF*.

Table 5-5. Comparison of *PRFs* between seasons using Kolmogorov-Smirnov test.

	Winter	Spring	Summer	Median *PRF*	Count
Winter				187	178
Spring	0.01			246	724
Summer	0.05	0.56		237	359
Fall	0.13	0.17	0.65	215	328

5.3. Discussion

5.3.1. Explanation of Results

To answer the question of which parameters affect the *PRF*, one must refer to Equation 1-1 to see that the *PRF* is proportional to the q_p, t_p and inversely proportional to the drainage area *A*. A parameter affects the *PRF* only if it has a net effect on the interaction of all the three variables. It was found that the storm parameters do not affect the *PRF* significantly, although from the results in Chapter 4, it seems clear that the *PRFs* do vary from event to event; therefore, there might be other storm parameters not tested that might have influenced the *PRF*. With regards to which watershed parameters affect the *PRF*, much of the literature (see Section 2.3.2) shows that milder watershed slopes or main-channel slopes result in lower *PRFs* and the results concur with these findings; however, it should be noted that the low slopes in the dataset were concentrated in Houston, which likely skewed the p-values towards significance. If statistical analyses were separated from Houston and non-Houston watersheds (Figure 5-11), then the equation for non-Houston watersheds considering the parameters $\overline{L_F}/L_{F-max}$ and *CS* is:

$$PRF = 2{,}184\left(\frac{\overline{L_F}}{L_{F-max}}\right)^{2.57} CS^{0.062} \qquad (5\text{-}5)$$

while the equation for that of Houston watersheds is:

$$PRF = 15{,}032\left(\frac{\overline{L_F}}{L_{F-max}}\right)^{4.18} CS^{0.937} \qquad (5\text{-}6)$$

Using t-test to test for the relevance of individual parameters on the log *PRF*, it is found that the p-values for $\overline{L_F}/L_{F-max}$ and *CS* for the model Equation 5-5 are 0.007 and 0.724, respectively, while the p-values for $\overline{L_F}/L_{F-max}$ and *CS* for the model Equation 5-6 are 0.127 and 0.164, respectively. Hence, *CS* is found insignificant when the Houston and non-Houston regions are separated. Therefore, it is still unclear if *CS* does influence the *PRF* – although it is clear that Houston *PRFs* are lower and the only defining characteristic of Houston compared to other watersheds is that it has flatter slopes. Perhaps, slope does influence the *PRF* – although it also undeniable that there are also other parameters that may have affected the *PRF*. A likely explanation for why the watershed slope and the main-channel slope may only marginally affect the *PRFs* is that not only do they affect the peak-flow value but also the peak-flow time, to a certain extent offsetting each other. Based on the *p*-values of the regression models, it was observed that *CS* was a better predictor than *S*.

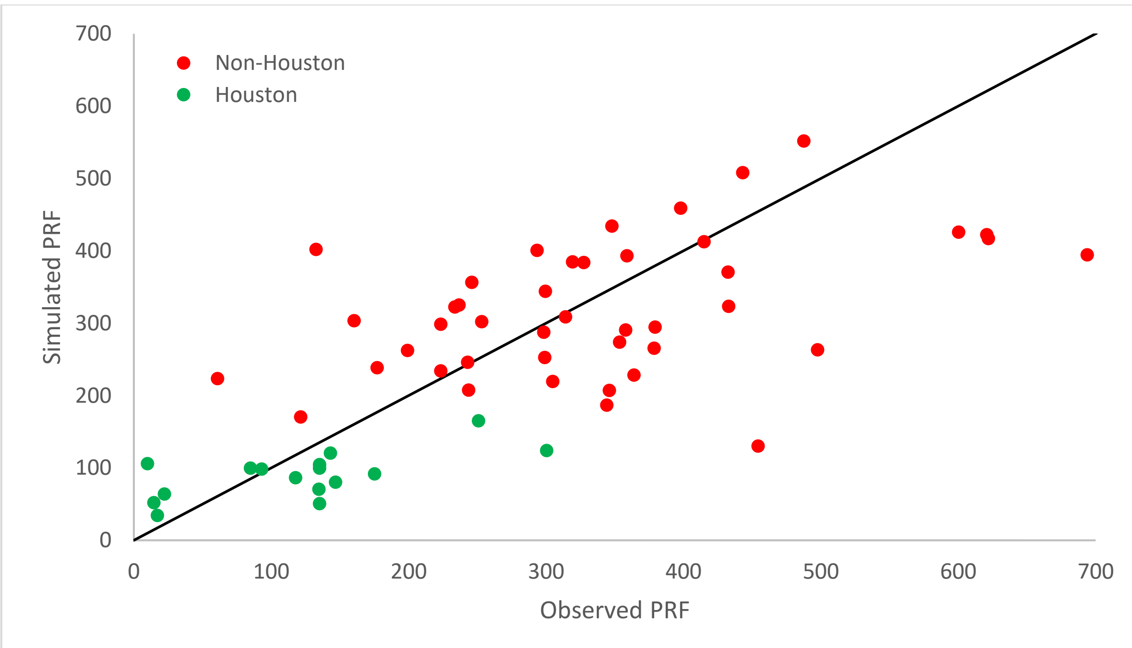


Figure 5-11. Model comparisons between Houston and non-Houston watersheds with *CS* and $\overline{L_F}/L_{F-max}$ as predictors.

With regards to the area, studies have been contradictory on its effect on the *PRF*. For example, Sheridan et al. (2004) and Fang et al. (2005) found that *PRF* increases with increasing area while Solanki and Suau (1996) concluded otherwise. The present results sided with the conclusion of Horst and Gurriell (2019) that the effect of the area on *PRF* is insignificant although it should be noted that this parameter varies in a narrow range and it is difficult to assess its importance.

Instead, there is clearer evidence that the *PRF* depends foremost on the geomorphological parameter $\overline{L_F}/L_{F-max}$. This length ratio $\overline{L_F}/L_{F-max}$ roughly describes where most of the watershed area is located with respect to the outlet. A low ratio indicates that the bulk of the watershed is concentrated close to the outlet (Figure 5-12a) and, in these cases, the unit hydrograph tends to have a positively skewed shape with a short rising limb and a low *PRF*; while a high ratio indicates that the bulk of the watershed is concentrated far from the outlet (Figure 5-12b) and, in these cases, the unit hydrograph tends to have a symmetrical shape with a rising limb as long as the falling limb and a high *PRF*. Note that since *PRF* is a function only of α (Equation 4-8), then it may be inferred that the geomorphological parameter $\overline{L_F}/L_{F-max}$ also depends on α. Moreover, from Equation 4-6, it can also be inferred that β depends on $\overline{L_F}/L_{F-max}$ and t_p, which depends on the watershed and storm parameters.

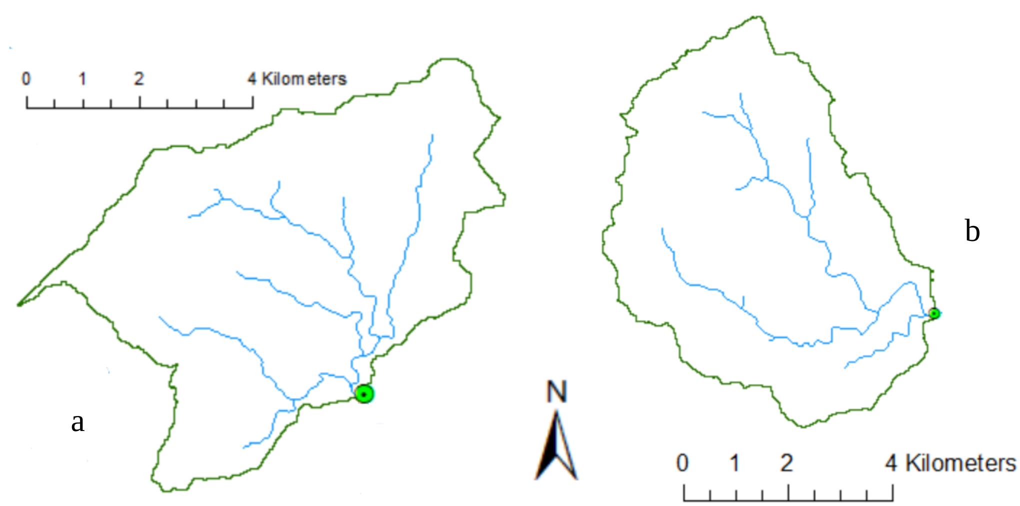
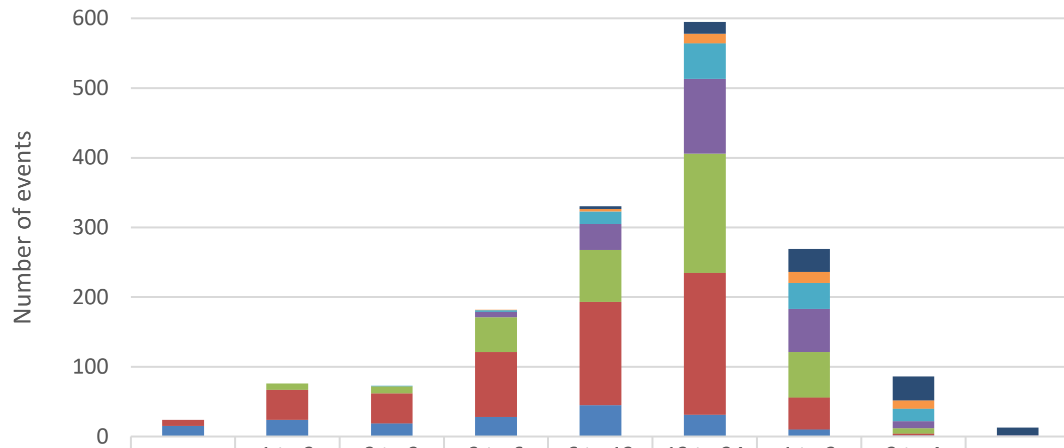


Figure 5-12. Watersheds with different length ratios: (a) USGS ID = 08158100, $\overline{L_F}/L_{F-max}$ = 0.44 and median *PRF* = 121) is bulkier near the outlet; (b) USGS ID = 08158810, $\overline{L_F}/L_{F-max}$= 0.59, median *PRF* = 443 is bulkier far from the outlet.

5.3.2. Uncertainty Analysis Statement

One source of uncertainty is the validity of the assumption of uniform rainfall, which is more frequently achieved in higher magnitude storms occurring in small drainage areas. Figure 5-13 shows the frequency of events that fall under specified ranges of time duration and precipitation depth. It may be noticed that most events (36%) fall under the 12 to 24-hour duration range and most of the events (36%) had depths between one and two inches. Accurate estimation of return periods for each event will require depth-duration-frequency curves for each gage. To make the analysis still meaningful but less tedious, the analysis only focused on urban areas and considered representative depth-duration curves for each urban area from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 point precipitation frequency estimates (NOAA, 2017) using the following coordinates (latitude, longitude): Austin (30.2646^0, -97.7466^0), Dallas (32.7834^0, -96.8018^0), Houston (29.7604^0, -95.3626^0), Fort Worth (32.7465^0, -97.3401^0), and San Antonio (29.4261^0,-98.4937^0). The depth-duration-frequency curves for each urban region as well as the depth-duration data for each event in the region are shown in Figures 5-14 to 5-18. Results show that only 23 out of 1305 (or about 2%) of urban events have return periods of more than 10 years and only two urban events had return periods of more than 100 years. It is expected that a similar result for rural watersheds would be found. The prevalence of high-frequency (low return period) events underscores the importance of having small watersheds. As mentioned, NRCS recommends watershed areas of less than 20 mi^2 but it would be interesting to investigate the validity of this limitation in a future study. Note that two storms were found to have return periods greater than 100, both occurring in Austin, but the *PRFs* calculated for those two were 151 and 363, which is within the middle 50% of the range of *PRFs* calculated in Austin (Table 4-4).

For practical purposes, in the absence of good-quality rainfall-runoff data, it is recommended to use the median *PRF* of 329 for the non-Houston areas, and 135 for the Houston area. The value of 484, which is recommended by the NRCS (SCS, 1972; NRCS, 2007), falls between the 75^{th} and 90^{th} percentile of the 1043 events analyzed in all regions except Houston, and is above 90^{th} percentile of all 605 events analyzed in Houston. While the analysis herewith used a comprehensive database of storm events in Texas, it is recognized that our sample is limited, and some parts of the state are not adequately represented. Moreover, only high-frequency events are included. Thus, this study may be improved by including more low-frequency events and more events in locations in Texas that were not represented.



	0 to 1 hr	1 to 2 hrs	2 to 3 hrs	3 to 6 hrs	6 to 12 hrs	12 to 24 hrs	1 to 2 days	2 to 4 days	> 4 days
>6 in					4	17	33	34	11
5 to 6 in				1	3	14	16	12	
4 to 5 in			1	2	18	51	37	18	
3 to 4 in				8	37	107	62	10	2
2 to 3 in		9	10	50	75	171	65	8	
1 to 2 in	9	43	43	93	148	204	46	2	
0 to 1 in	15	24	19	28	45	31	10	2	

Duration

Figure 5-13. Frequency of events with a specified precipitation depth and duration.

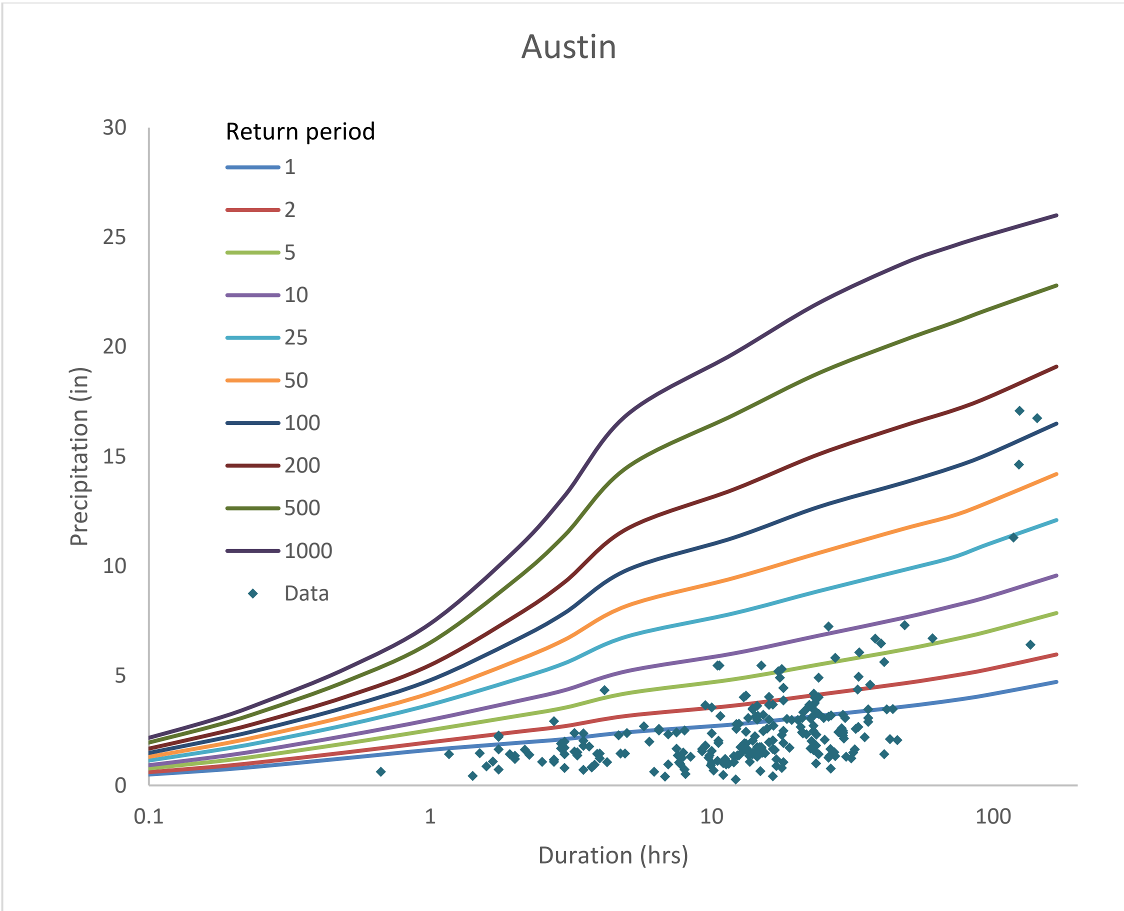


Figure 5-14. Depth-duration-frequency curves for Austin (x-axis in log scale).

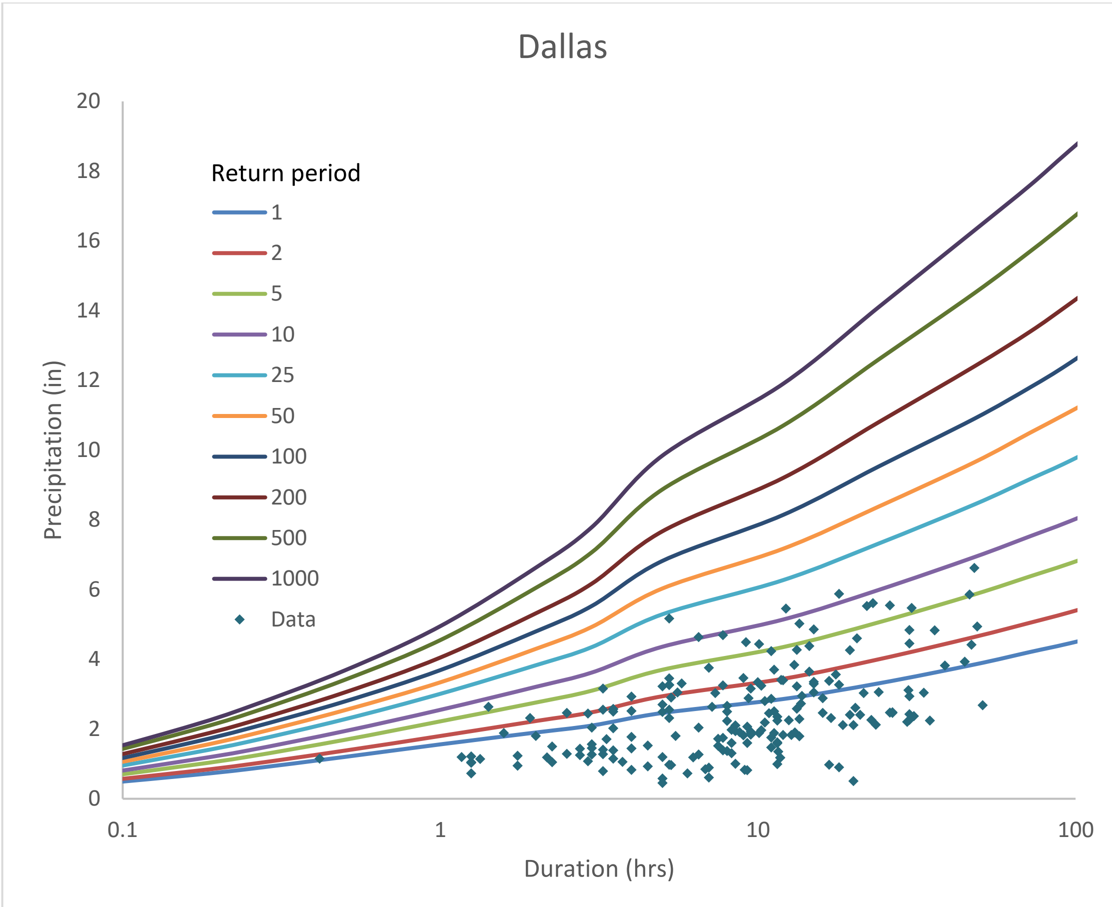


Figure 5-15. Depth-duration-frequency curves for Dallas (x-axis in log scale).

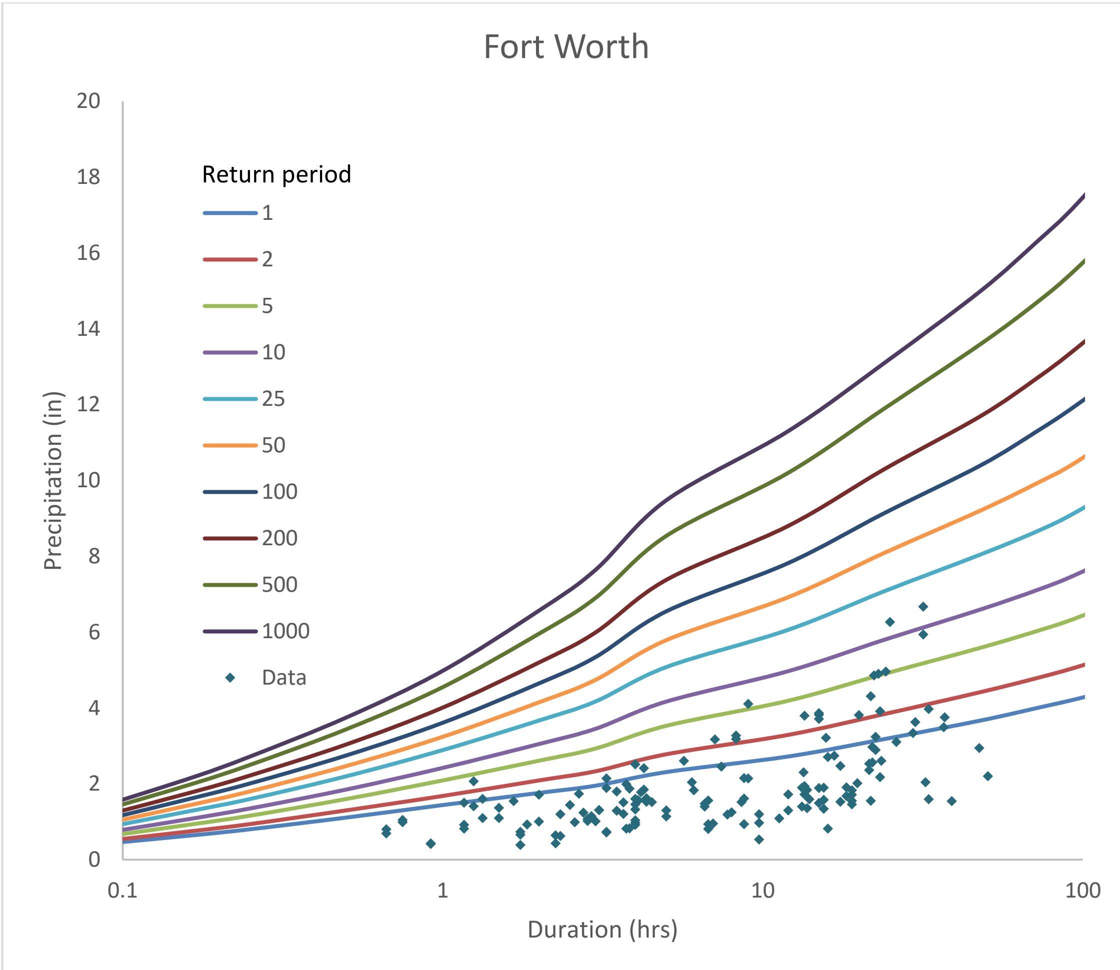


Figure 5-16. Depth-duration-frequency curves for Fort Worth (x-axis in log scale).

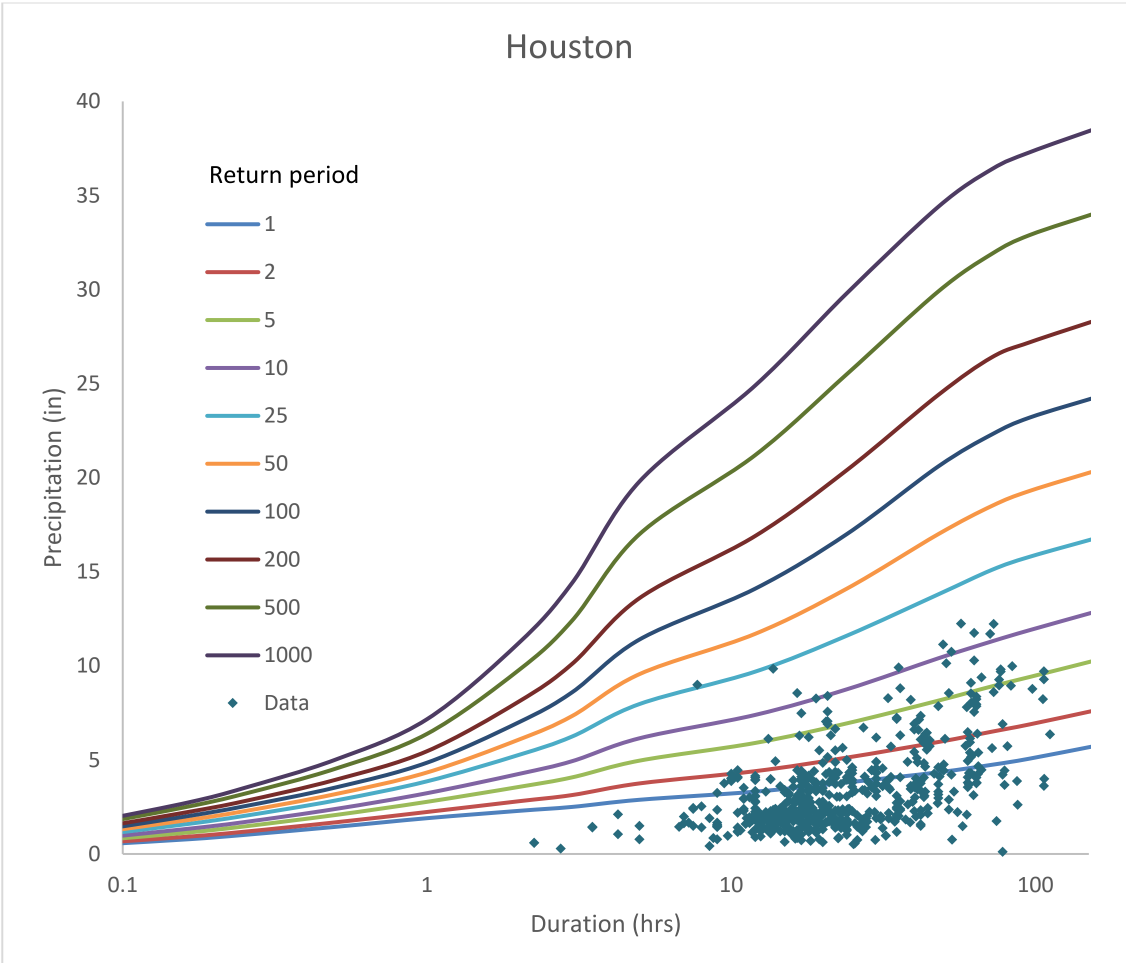


Figure 5-17. Depth-duration-frequency curves for Houston (x-axis in log scale).

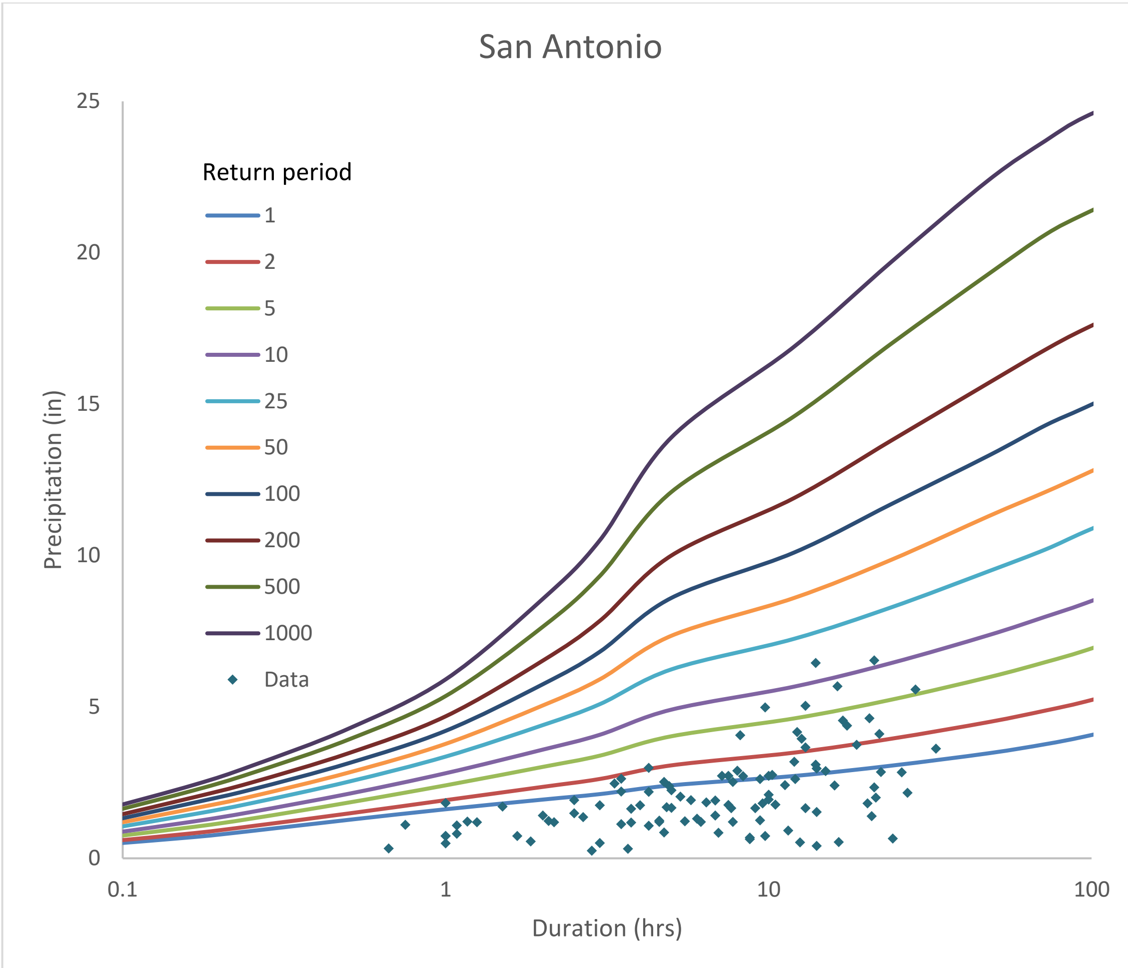


Figure 5-18. Depth-duration-frequency curves for San Antonio (x-axis in log scale).

6. CONCLUDING REMARKS

6.1. Summary

In this study, *PRFs* for 1,684 storm events in Texas were determined using the CN method for calculation of abstractions and assuming unit hydrographs with a Gamma probability distribution shape. Most of these events (i.e., 1,305 events) took place in urban areas, while 343 occurred in rural areas. The rainfall-runoff database used (Asquith, 2004; William Asquith, personal communication, 2019) included 2,752 storm events, but a number of them were excluded for different reasons including drainage area greater than 20 sq-mi, inaccuracies in the delineation of the watersheds, or mismatch between the rainfall and flow data. Statistical analyses were performed to determine the *PRF* ranges for the regions considered, and to identify the storm and watershed characteristics that most affect the *PRF* values. Models that included watershed area, shape factor, a geomorphological parameter, and a slope parameter as predictors were generated and the best model selected had the geomorphological dimensionless number $\overline{L_F}/L_{F-max}$ and the main channel slope *CS* as predictors. It was also found that among these four variables, *PRFs* depend on CS the most but there may be other variables not considered in the analysis that affect the *PRF*. Sensitivity analysis was performed on several watersheds in Austin to determine how flood depths, floodplain extents, and peak flows vary with uncertain *PRFs*. Finally, a statement on uncertainty analysis was performed to determine a typical cumulative density function for flow given the *PRF*.

6.2. Conclusions

In Section 1.2, three specific objectives were laid down, namely: 1) determine the range of *PRFs* in various regions in Texas, 2) determine which parameters affect the *PRF*, and 3) discuss practical considerations in choosing the *PRF* for hydrologic modeling in Texas. Based on the findings, the following are the main conclusions of the study:

1. The *PRFs* of the Houston events (i.e., median = 135 and 90th percentile = 278) are statistically lower than those in the other regions (i.e., median = 329 and 90th percentile = 649); moreover, the SCS-recommended *PRF* of 484 is the 77th percentile of the *PRFs* of all events in Texas, except Houston, and is greater than 98th percentile of *PRFs* in Houston events.
2. The median *PRF* might be a function of watershed main channel slope, watershed average slope, and the ratio of the average flow length to the maximum flow length; however, it is not a function of watershed drainage area and shape factor.
3. For practical purposes, it may not be worth the effort of calculating watershed parameters to obtain the *PRF* given that only a small portion of the variance of the *PRF* is explained by the watershed parameters; rather, using the constant *PRF* values of 135 for Houston watersheds and 329 for non-Houston watersheds in the absence of reliable rainfall-runoff data, is considered sufficient. Lower *PRFs* mean lower design discharges and hence, reduced cost of designing hydraulic structures.

6.3. Recommendations

For future studies, it is recommended that the limitations of the current study are addressed. First, the scope of the data must also include watersheds in West Texas and more rural watersheds and events should be considered. Second, more events in watersheds that had less than five events need to be included to increase the reliability of statistical analysis. Third, since there has been increasing concern over hydrologic stationarity (e.g. Milly et al., 2008) – where climate variability is constant over time – more recent data need to be considered in the analysis. Climate change can potentially affect the precipitation or temperature which would lead to changes in hydrograph peaks for the same peaking time and therefore different *PRFs*. Consequently, paired rainfall-runoff data need to be recorded for Texas watersheds. Unfortunately, the maintenance of in-site gages and the unction of producing high quality paired gaged rainfall-runoff data has decreased with the advent of remote sensing (McCabe et al., 2017); hence, along with the desire to improve the quality of remotely sensed data, there must be a renewed effort in maintaining and constructing flow and rain gauges. Fourth, with regards to determining the sensitivity of flood depths, floodplain extents, and peak flows to uncertain *PRFs*, more detailed hydraulic models are recommended, especially in Houston where slopes are flat. Fifth, it has also been observed that *PRFs* in Houston watersheds are low – with a fourth below 50. Thus, future studies should investigate the mechanisms behind these low-*PRF* events. Conversely, high-PRF events were observed in all regions but more so, in San Antonio. Although the Complacent-Violent theory offers an explanation for why such cases exist, this theory is recent and needs verification. Sixth, a study on the effect of antecedent moisture conditions on the *PRF* is also warranted. The antecedent moisture condition of a watershed is reflected in its curve number and therefor the peak discharge and the *PRF*. Seventh, parameter analysis that includes watersheds smaller than one sq-mi – which would necessitate the use of a finer DEM than what was used in this study – need to be done. Finally, with regards to using the results of the study to inform engineering decisions, it must be stressed that the *PRFs* reported here are based on Gamma-shaped unit hydrographs, and care should be exercised when comparing the result with other studies that did not use Gamma-shaped unit hydrographs.

6.4. Lessons learned

To identify with the reader, I would like to end this dissertation in the first-person point of view and share the lessons that I've learned over almost three years of research. Thus, I discuss intellectual, moral, and practical lessons that I gathered from both the results of my study and the *experience* of undertaking this work.

First, I've grown to appreciate the effectiveness of mathematics to model natural phenomena. Given the complexity of the hydrologic cycle and the interconnectivity of the different processes, it is a wonder that Equation 1-1 works – that one can estimate the peak discharge solely by the area of the watershed and the peak-flow time given an appropriate peak rate factor. Indeed, as the physicist Eugene Wigner put it, "the miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve" (Wigner, 1960).

In surveying the literature as well as learning different methodologies, I've come to realized that Hydrology is not only a science, but it is also an art. Take for example, the method with which we evaluate hydrograph fit – currently, more than a hundred different criterion for evaluating hydrograph fit exist in the literature (e.g. Crochemore, 2015) and while these criteria are based on mathematical axioms, there is an art for choosing the appropriate metric. Hypothesis testing also comes in many forms – for example, one may select a parametric test such as the t-test or a non-parametric test such as the rank-sum test but when used blindly, these tests may yield p-values that are significant but don't have a sound basis in the real world. When the desire to produce significant results is high, the researcher must be guided by academic integrity. Finally, the Equation for *PRF* (Equation 1-1) is in itself based on assumptions and in this dissertation specifically, it was assumed – although with much support from past literature – that hydrographs follow a Gamma distribution, which is an idealized hydrograph of what we actually see in the field. Nevertheless, such assumptions have paved the way for much progress. Thus, while objectivity is the gold standard for scholarship and the hallmark of the scientific method, one must not deny that subjective reasoning still plays a huge role in how we do science.

I've also noticed that while the literature is replete with publications focused on improving classic methods, the methods that survive are the simplest. Take, for example, the classic Manning's formula for open channel flow that is still being widely used today despite its perceived problems such as dimensional inconsistency and at that time of its development, the "difficulty of extracting a cube root" (Yen, 1992). Indeed, Manning himself developed a second equation that sought to resolve these problems, yet history still favored that simpler version that it superseded Kutter's formula – which was the widely used formula in the mid to late 19th century (Yen, 1992). The Rational Method, for example, has underwent several iterations since its conception but most practitioners still use the original formulation. Even more, many practitioners use the method beyond its limits of applicability. The Nash Sutcliffe Efficiency criterion has undergone a lot of scrutiny in past decades, yet it is still widely used in hydrology. Perhaps there is a lesson to be learned here: that while there is an unction amongst researchers to continually improve upon methods, the methods which survive are those that are most easily understood by the majority. Of course, simplicity should not trump accurateness – but when sophistication only comes just as a marginal improvement in accuracy, then practitioners will still gravitate towards the simpler method.

Given the fact that this dissertation was completed from 2019-2022, something needs to be said as well regarding the coronavirus (COVID-19) pandemic. The pandemic will indeed be remembered to be one of the lowlights of the 21st century; however, there are still valuable lessons to be learned. First, the pandemic has forced societies to reevaluate their standard operating procedures. Majority of this dissertation, for examples, was done remotely. The data and models used, for example, were obtained online – and analysis was done only with the help of a computer. Second, the pandemic has forced people to learn how to interact remotely. Finally, the pandemic has proved that humans will continue to move forward in search of learning as evidenced by the number of scholarly works published in the literature and the number of students who have earned graduate degrees despite the restrictions brought about by the virus.

Indeed, one must not take for granted the conveniences brought about by modern technology. The amount of storage used in this dissertation, for example, is almost two terabytes – a storage capacity that was too expensive until recently but is now readily available due to advances in electronics and materials science. Moreover, computers and coding scripts have increased my efficiency by thousands of times (having more than 2000 rainfall-runoff data to work with, there are processes that are repetitive that would've taken years to process manually but was instead processed within seconds due to scripting). Furthermore, I also learned to always find for more optimal solutions than what I already know because chances are, another has already figured out a more efficient way of solving a problem.

Another lesson that I learned is with regards to the importance of being thorough in each step of the research process. When the pressure to produce results is high, one must choose the path of integrity – even to the point of redoing every step. However, one can avoid doing tasks repetitively if great care is exercised in each step. Of course, new knowledge is usually acquired in the future such that repeating some procedures may be necessary.

Probably more than half of total research hours was spent on research that was not included in this dissertation; however, the contents that did make it to the dissertation was a product of years of investigation such that research spent on methodologies that proved to be infeasible served as groundwork for the methodologies and ideas that proved to be useful. Hence, trying different approaches in solving the problem is time well-spent even though not all those approaches will be used. In research, I also learned that there are some research activities that require a lot of time but only contribute a little to the final product. Conversely, there are some activities that require less time but contribute a lot to the research. Nevertheless, both activities are required to complete everything.

Finally, the last lesson learned pertains to the scope of the research. The dissertation is a focused work on a niche method among hydrologists – the NRCS Unit

Hydrograph Method. Indeed, while this research has shed light on many issues surrounding *PRF* estimation in Texas, there are still mysteries. By extension, there are many scientific facts in this world that are still unknown, and it is impossible to learn everything; nevertheless, the possibility of learning something previously unknown to humans makes doing research worthwhile and while there are many more questions that this study did not address, another researcher might investigate on those gaps and find clearer answers.

While I hope that this dissertation will not be my most impactful scholarly work, this dissertation is most likely my third and final piece of major work as a student – the first being my bachelor's thesis (Lasco, 2013) and the second being my master's thesis (Lasco, 2017). It is often a running joke among academics that nobody ever reads one's dissertation but to the person who, for some reason, took an interest in reading this work and finished it to the end, please don't hesitate to reach out – I would be happy to buy you a coffee.

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APPENDIX A

PYTHON SCRIPTS

Baseflow removal function

```
# x is time, y is flow

def remove_baseflow(x,y):
    m=(y[len(y)-1]-y[0])/(x[len(x)-1]-x[0])
    if m > 0:
        y=[(y[i]-(y[0]+(x[i]-x[0])*m)) for i in range(len(x))]
    elif m < 0:
        y=[(y[i]-(y[0] + (x[i]-x[0])*m)) for i in range(len(x))]
    elif m==0:
        y=[(y[i]-y[0]) for i in range(len(x))]
    y=[0 if y[i] < 0 else y[i] for i in range(len(y)) ]
    return y
```

Interpolation function

```
# x is time and y is flow or precipitation

def interpolate(x,y):
    new_x=[0]*int(round((x[len(x)-1]-x[0])/5,0)+1)
    new_y=[0]*int(round((x[len(x)-1]-x[0])/5,0)+1)
    i=-1
    counter=0
    new_y[0]=y[0]
    new_x[0]=x[0]
    while i<int(len(x)-2):
        i+=1
        lower_x=x[i]
        lower_y=y[i]
        upper_x=x[i+1]
        upper_y=y[i+1]
        slope=(upper_y-lower_y)/(upper_x-lower_x)

        while new_x[counter]<round(upper_x,0):
            counter += 1
            new_y[counter]=5*slope+new_y[counter-1]
            new_x[counter]=new_x[counter-1]+5
    return new_x,new_y
```

Code for solving S in the SCS CN method

```
# P is precipitation (inches), Q is runoff depth (inches)

def solve_for_S(S):
   return P*Q + 0.8*S*Q - P**2 + 0.4*P*S - 0.04*S**2
S=float(fsolve(solve_for_S,2))
if S < 0:
   S=float(fsolve(solve_for_S,40))
if 0.2*S > P:
   S=P/0.2
```

Code for deriving the runoff hyetograph

```
#S is derived from the SCS CN method (inches), y is 5-minute accumulated weighted precipitation (inches)

sumR=[(float(i)-0.2*S)**2/(float(i)+0.8*S) if float(i)>(0.2*S) else 0 for i in y]
R=[0]+[sumR[i]-sumR[i-1] for i in range(1,len(sumR))]
```

Function for computing DRH given UH and RH

```
def compute_DRH(x_UH,y_UH,x_Hyeto,y_Hyeto):
   y_DRH=[0]*len(y_UH)
   j=-1
   for i in range(len(x_UH)):
      if i < len(y_Hyeto):
         j += 1
      if i==0:
         y_DRH[i]=y_UH[i]*y_Hyeto[i]
      elif i >= len(y_Hyeto):
         y_DRH[i]=sum([float(y_UH[i-j+l])*float(y_Hyeto[j-l]) for l in range(j)])
      else:
         y_DRH[i]=sum([float(y_UH[0+l])*float(y_Hyeto[j-l]) for l in range(j)])
   return y_DRH
```

Code for deriving the unit hydrograph

```
#filename_DRH = filename for direct runoff hydrograph in csv file format
#directory_DRH = directory where filename_DRH is located
#filename_hyeto = filename for runoff hyetograph in csv file format
#directory_hyeto = directory where filename_hyeto is located
#D = runoff depth

df_DRH= pd.read_csv(directory_DRH+'\\'+filename_DRH)
df_hyeto = pd.read_csv(directory_hyeto+'\\'+filename_hyeto)
x_DRH=list(df_DRH['MIN_PASSED_HYDRO'])
```

```
y_DRH=list(df_DRH['RUNOFF'])

x_Hyeto=list(df_hyeto['MIN_PASSED_HYETO'])
y_Hyeto=list(df_hyeto['RUNOFF_HYETOGRAPH'])

def compute_DRH(x_UH,y_UH,x_Hyeto,y_Hyeto):
    #hyetograph should be in feet
    y_DRH=[0]*len(y_UH)
    j=-1
    for i in range(len(x_UH)):
        if i < len(y_Hyeto):
            j += 1
        if i==0:
            y_DRH[i]=y_UH[i]*y_Hyeto[i]
        elif i >= len(y_Hyeto):
            y_DRH[i]=sum([float(y_UH[i-j+l])*float(y_Hyeto[j-l]) for l in range(j)])
        else:
            y_DRH[i]=sum([float(y_UH[0+l])*float(y_Hyeto[j-l]) for l in range(j)])
    return y_DRH

DRH_Volume=hydrograph_volume(x_DRH,y_DRH)   #use the function to solve
     for hydrograph volume
x_DRH=[i*60 for i in x_DRH]
A=DRH_Volume/(D/12)

if x_DRH[0] > 0:
    temp=[]
    for i in range(int(round(x_DRH[0]/300))):
        temp=temp+[i*300]
    x_DRH=temp+x_DRH
    y_DRH=[0]*(i+1)+y_DRH

y_Hyeto=[i/12 for i in y_Hyeto]    #convert hyetograph ordinates to feet

Z=np.array([1,1])

#Gamma optimization
alpha=2
beta=1000
Z0=np.array([alpha,beta])

Z= Z0

def objective_gamma(x):
```

```
    y1=y_DRH.copy()
    x1=x_DRH.copy()
    y2=[A*stats.gamma.pdf(x1[i],a=x[0],scale=x[1]) for i in range(len(x1))]
    while y2[len(y2)-1] > 0.1:
        extend = 40
        x2=[x1[len(x1)-1]+i*300 for i in range(extend)]
        y2=y2+[A*stats.gamma.pdf(x2[i],a=x[0],scale=x[1]) for i in range(len(x2))]
        x1=x1+x2
        y1=y1+[0]*(len(y2)-len(y1))
    y3=compute_DRH(x1,y2,x_Hyeto,y_Hyeto)
    result=sum([(y3[i]-y1[i])**2 for i in range(len(x1))])
    return result

bnds=((1.0001,100),(5,100000))
#objective function
solution=minimize(objective_gamma,Z0,method='SLSQP', bounds=bnds)

Z=solution.x

def get_UH(Z):
    y1=y_DRH.copy()
    x1=x_DRH.copy()
    y2=[A*stats.gamma.pdf(x1[i],a=Z[0],scale=Z[1]) for i in range(len(x1))]
    y3=compute_DRH(x1,y2,x_Hyeto,y_Hyeto)
    return x1,y1,y2,y3

x1,y1,y2,y3=get_UH(Z)
while y3[len(y3)-1] > 0.1:
    extend = 40
    y_DRH=y_DRH+[0]*(extend)
    x_DRH=x_DRH+[x1[len(x1)-1]+i*300 for i in range(extend)]
    solution=minimize(objective_gamma,Z0,method='SLSQP', bounds=bnds)
    x1,y1,y2,y3=get_UH(Z)


y2=[i/12 for i in y2]
x1=[i/60 for i in x1]

DRH_Volume=hydrograph_volume(x1,y1)
Computed_Volume=hydrograph_volume(x1,y3)
if (abs(Computed_Volume-DRH_Volume)/DRH_Volume*100 <=1):

     data_hydro=pd.DataFrame(list(zip(x1,y2)),columns=['MIN_PASSED','RUN
     OFF'])
```

```
data_hydro.to_csv('D:\\05262020 Sharif Dataset\\UHall\\'+filename_DRH)


  data_DRH=pd.DataFrame(list(zip(x1,y3)),columns=['MIN_PASSED','RUN
  OFF'])
data_DRH.to_csv('D:\\05262020                                    Sharif
  Dataset\\DRHcomputed\\'+filename_DRH)

plt.figure()
plt.plot(x1,y1,label='DRH')
plt.plot(x1,y3,label='From UH')
plt.plot(x1,y2,label='UH')
plt.xlabel('Time (min)')
plt.ylabel('Discharge (cfs)')
plt.legend(loc="upper right")
plt.savefig(filename_DRH.split('.csv')[0] +'.jpeg')

print(Z[0])
print(Z[1])
print(objective_gamma(Z))
print(rising_limb_volume(x1,y2)/hydrograph_volume(x1,y2)*1290.67)
print(abs(Computed_Volume-DRH_Volume)/DRH_Volume*100)
```

APPENDIX B

NOTES ON BASEFLOW REMOVAL

Hydrograph code	Notes
unit_sta08158500_1981_0303	applied algorithm at 555 to 1015, 1030 to end
unit_sta08158500_1981_0523	applied algorithm at 1365 to 2520, 2520 to end
unit_sta08048520_1971_1019	subtracted 22 from 0 to 60, applied algorithm at 60 to 1155, 1155 to end applied algorithm at 60 to 1155, 1155 to end
unit_sta08048520_1971_1208	tail extended manually to 14
unit_sta08048520_1971_1209	subtracted 36
unit_sta08048520_1971_1209	start from 0 with increment by 2 to 58
unit_sta08048520_1972_0429	tail extended manually to 9.4
unit_sta08048520_1973_0310	tail extended manually to 19
unit_sta08048520_1973_0603	subtracted 34
unit_sta08048520_1977_0302	tail extended to 2.7
unit_sta08048530_1970_0425	subtracted 1
unit_sta08048530_1970_0530	subtracted 0.2
unit_sta08048530_1975_0915	subtracted 2.4 0 to 115, 115 to end
unit_sta08048540_1970_0916	subtracted 0.2
unit_sta08048540_1971_0728	applied algorithm at 20 to 245, 245 to end
unit_sta08048540_1971_0814	applied algorithm at 75 to 600, 610 to end
unit_sta08048540_1971_1208	subtracted 4.9
unit_sta08048540_1973_0603	applied algorithm at 15 to 420, 435 to 1215, 1235 to end
unit_sta08048540_1974_0607	applied algorithm at 60 to 465, 480 to end
unit_sta08048540_1974_0810	applied algorithm at 30 to 420, 480 to end
unit_sta08048540_1975_0608	applied algorithm at 35 to 450, 505 to 975, 980 to end
unit_sta08048550_1971_1019	ordinate in time 1225 changed to 33, tail extended tail manually to 33
unit_sta08048550_1971_1209	tail extended manually to 32
unit_sta08048550_1974_0619	tail extended manually to 0.4
unit_sta0804880_1973_0310	tail extended manually to 1
unit_sta08048800_1975_0725	tail extended manually to 0.5
unit_sta08048820_1969_0506	tail extended manually to 99
unit_sta08048820_1971_0529	tail extended manually to 0
unit_sta08048820_1971_0806	tail extended manually to 16

unit_sta08048820_1971_1019	subtracted 19
unit_sta08048820_1971_1202	tail extended manually to 19
unit_sta08048820_1971_1208	delete 22 cfs at time 720 then applied algorithm
unit_sta08048820_1972_1021	tail extended manually to 0.1
unit_sta08048820_1974_1109	tail extended manually to 0.5
unit_sta08048820_1976_0716	tail extended manually to 0.2
unit_sta08048850_1971_0815	tail extended manually to 0.9
unit_sta08048850_1972_1021	tail extended manually to 2.6
unit_sta08048850_1973_0310	tail extended manually to 3
unit_sta08048850_1973_0715	tail extended manually to 36
unit_sta08048850_1973_1012	tail extended manually to 5.8
unit_sta08048850_1974_0826	subtracted 0.6 to 435, applied algorithm at 435 to end
unit_sta08048850_1976_1029	tail extended manually to 4.5
unit_sta08052630_1966_0423	applied algorithm at 2880, 2880 to end, tail extended manually
unit_sta08052630_1966_0427	applied algorithm at 1890, 1890 to end, cut at 300 then tail extended manually
unit_sta08052630_1969_0220	tail extended manually to 0
unit_sta08052630_1969_0506	cut at 2595
unit_sta08052630_1969_1228	cut at 2640
unit_sta08052630_1970_0430	cut at 3915
unit_sta08052630_1973_0102	tail extended logarithmically
unit_sta08052630_1973_0730	tail extended logarithmically
unit_sta08052630_1974_0924	tail extended logarithmically
unit_sta08052630_1975_0407	tail extended logarithmically
unit_sta08055700_1964_0920	applied algorithm at 660 to 3000
unit_sta08055700_1964_1117	applied algorithm at 720 to 1380, 1380 to end
unit_sta08055700_1965_0509	applied algorithm at 1020 to 1500, 1500 to end
unit_sta08055700_1965_0509	tail extended logarithmically
unit_sta08055700_1966_0209	tail extended manually to 4.4
unit_sta08055700_1966_0429	applied algorithm at 540 to 1050, subtracted 122 cfs at time 1050 to end
unit_sta08055700_1966_0429	tail extended to 34
unit_sta08055700_1966_0430	tail extended logarithmically to 44
unit_sta08055700_1966_0501	subtracted 122 to 195, 195 onwards
unit_sta08055700_1967_0420	applied algorithm at 420 to 1260, 1260 to end
unit_sta08055700_1967_0530	applied algorithm at 60 to 1200, 1200 to end
unit_sta08055700_1968_0319	applied algorithm at 75 to 1155, 1155 to end
unit_sta08055700_1970_0425	applied algorithm at 15 to 525, 525 to end

unit_sta08055700_1970_0831	applied algorithm at 225 to 1530, 1545 to 2265, 2325 to end
unit_sta08055700_1971_0814	60 to 600, 600 to end
unit_sta08055700_1971_1018	120 to 2340, 2340 to end
unit_sta08055700_1974_0607	30 to 495, 495 to end
unit_sta08055700_1974_0916	540 to 1500, 1500 to end
unit_sta08055700_1975_0407	300 to 1215, 1230 to end
unit_sta08055700_1978_0323	tail extended logarithmically to 4.8
unit_sta08055700_1978_0528	applied algorithm at 0 to 825, subtracted 4.5 from 825 to end
unit_sta08055700_1978_0804	Applied algorithm at 495 to 765, 765 to end
unit_sta08056500_1068_0513	tail extended linearly to 0
unit_sta08056500_1068_0813	tail extended linearly at 2220
unit_sta08056500_1966_0429	tail extended linearly to 0
unit_sta08056500_1966_0617	tail extended linearly to 0
unit_sta08056500_1967_0420	tail extended linearly to 0
unit_sta08056500_1967_0530	tail extended linearly to 0
unit_sta08056500_1968_0422	tail extended linearly to 0
unit_sta08056500_1969_0504	tail extended linearly to 0
unit_sta08056500_1969_0506	tail extended linearly to 0
unit_sta08056500_1969_1012	tail extended linearly to 0
unit_sta08056500_1970_0831	tail extended linearly to 0
unit_sta08056500_1971_1003	tail extended manually to 14
unit_sta08056500_1973_0423	tail extended manually to 11
unit_sta08056500_1973_0603	applied algorithm from 0 to 1260, 1275 to end
unit_sta08056500_1974_0505	tail extended linearly to 0
unit_sta08056500_1976_0525	tail extended manually to 3.4
unit_sta08056500_1978_0323	tail extended manually to 20
unit_sta08056500_1979_0503	tail extended manually to 5
unit_sta08056500_1979_0510	cut at 1125
unit_sta08057020_1979_0319	subtracted 5
unit_sta08057020_1979_0319	tail extended manually to 5
unit_sta08057120_1973_1030	tail extended to flow of 5
unit_sta08057120_1975_0628	tail extended manually
unit_sta08057130_1973_0619	tail extended hydrograph using exponential function
unit_sta08057130_1973_1030	subtracted 0.4 from 0 to 30, 30 to 440, 460 to end
unit_sta08057130_1975_0407	365 to 1380, 1420 to end
unit_sta08057130_1977_0327	applied algorithm at 0 to 1080, subtracted 1.7 from 1080 to end

unit_sta08057130_1978_0528	applied algorithm at 0 to 750, 855 to end
unit_sta08057160_1974_0917	subtracted 2.3 start to 480, applied algorithm at 480 to end
unit_sta08057160_1975_0507	subtracted 1.5
unit_sta08057320_1973_0603	applied algorithm at 90 to 390, 510 to 1290, 1320 to end
unit_sta08057320_1973_1030	applied algorithm at 0 to 405, 405 to end
unit_sta08057320_1978_0520	applied algorithm at 90 to 645, 645 to end
unit_sta08057418_1977_1011	subtracted 10
unit_sta08057445_1976_0418	tail extended manually to 3.9
unit_sta08057445_1977_0302	tail extended manually to 2
unit_sta08057445_1977_0419	tail extended manually to 3.5
unit_sta08057445_1979_0212	cut at 2460 then tail extended manually to 1.9
unit_sta08057445_1979_0330	tail extended manually to 13
unit_sta08057445_1979_0503	tail extended manually to 6.5
unit_sta08058000_1959_1215	tail extended manually to 0
unit_sta08058000_1960_0203	cut at 2700
unit_sta08058000_1960_0525	tail extended manually to 0
unit_sta08058000_1961_0106	cut at 2260
unit_sta08058000_1961_0430	cut at 1880
unit_sta08058000_1962_0423	deleted first hydro, applied algorithm until 4230, 4230 to end
unit_sta08058000_1962_0906	Applied algorithm at 1410
unit_sta08058000_1963_0530	cut at 3120
unit_sta08058000_1964_1117	cut at 3960
unit_sta08058000_1965_0527	applied algorithm until 870, 870 to end
unit_sta08058000_1966_0423	tail extended manually to 0
unit_sta08058000_1966_0427	applied algorithm until 855, tail extended manually to 0, applied algorithm at 855 to end
unit_sta08058000_1966_0430	tail extended manually to 0
unit_sta08058000_1967_0905	cut at 1620 then tail extended manually to 0
unit_sta08058000_1967_1700	cut at 1260, applied algorithm until 330,330 to 1260
unit_sta08058000_1969_0623	tail extended manually to 0
unit_sta08061620_1974_0916	applied algorithm at 420 to 1380, 1380 to end
unit_sta08061620_1979_0503	tail extended logarithmically to 6
unit_sta08061920_1973_0423	subtracted 21, 0 to 1080, 1080 to end
unit_sta08061920_1975_0131	hydrograph tail extended manually starting at 2760, then subtract 1.1 to all
unit_sta08061920_1976_0418	subtracted 10

unit_sta08061920_1978_1231	tail extended using exponential function to value of 3 (y=2440.3e
unit_sta08063200_1959_1231	tail extended manually to 0
unit_sta08063200_1960_0104	tail extended manually to 0
unit_sta08063200_1961_0617	tail extended manually to 0
unit_sta08063200_1962_0528	tail extended manually to 0
unit_sta08063200_1965_0509	cut at 1515
unit_sta08063200_1965_0509	tail extended manually to 0
unit_sta08063200_1966_0417	tail extended manually to 0
unit_sta08063200_1966_0422	tail extended manually to 0
unit_sta08063200_1967_0417	tail extended manually to 0
unit_sta08063200_1967_0611	tail extended manually to 0
unit_sta08063200_1967_1029	tail extended manually to 0
unit_sta08063200_1968_0310	tail extended manually to 0
unit_sta08063200_1968_0509	tail extended manually to 13
unit_sta08063200_1968_0602	tail extended manually to 10
unit_sta08063200_1968_0623	tail extended manually to 8
unit_sta08063200_1969_0404	tail extended manually to 0
unit_sta08063200_1969_0505	cut at 2460
unit_sta08063200_1970_0224	tail extended manually to 0
unit_sta08063200_1970_0301	tail extended manually to 21
unit_sta08063200_1970_0306	tail extended manually to 0
unit_sta08063200_1971_1210	tail extended manually to 0
unit_sta08137000_1961_0615	cut at 4005
unit_sta08137000_1961_1009	cut at 1605
unit_sta08137000_1962_0907	cut at 1650
unit_sta08137000_1962_1012	applied algorithm at 720 to end
unit_sta08137000_1963_0519	tail extended logarithmically
unit_sta08137000_1963_0616	cut at 930
unit_sta08137000_1963_1116	applied at 1185 then 2565 to end
unit_sta08137000_1964_0422	tail extended manually to 0
unit_sta08137000_1964_0424	tail extended manually to 0
unit_sta08137000_1964_0919	tail extended logarithmically, applied algorithm until 1875, 1875 to end
unit_sta08137000_1967_0512	cut at 1135
unit_sta08137000_1967_0921	cut at 3780
unit_sta08137000_1968_0118	tail extended manually to 0
unit_sta08137000_1968_0119	tail extended manually to 0
unit_sta08137000_1968_0319	cut at 1070
unit_sta08137000_1969_0603	cut at 2185

unit_sta08137000_1969_0910	tail extended manually to 0
unit_sta08137000_1971_0801	tail extended logarithmically
unit_sta08137000_1971_0813	tail extended logarithmically
unit_sta08137000_1971_0922	cut at 1260 until 2465, 2465 to end, then cut at 3680
unit_sta08137000_1971_1019	cut at 1185
unit_sta08137000_1973_0423	tail extended manually to 0
unit_sta08137000_1973_0424	tail extended manually to 0
unit_sta081516800_1975_0609	tail extended manually to 5.8
unit_sta081516800_1976_0418	tail extended manually to 0.8
unit_sta081516800_1976_0525	cut at 1275
unit_sta081516800_1976_0902	tail extended linearly to 0
unit_sta081516800_1977_0415	tail extended manually to 1.4
unit_sta081516800_1977_0416	tail extended manually to 20
unit_sta081516800_1977_0419	tail extended manually to 19
unit_sta081516800_1978_1231	tail extended linearly to 0
unit_sta081516800_1979_0521	tail extended manually to 44
unit_sta081516800_1980_0327	tail extended manually to 16
unit_sta081516800_1981_0303	tail extended manually to 3.4
unit_sta081516800_1981_0523	delete first hydrograph; start at 2595
unit_sta081516800_1981_0610	cut at 4470, tail extended manually to 61
unit_sta081516800_1982_0513	tail extended manually to 29
unit_sta081516800_1984_1007	tail extended linearly to 0
unit_sta081516800_1985_0513	tail extended manually to 16
unit_sta081516800_1986_0530	tail extended linearly to 0
unit_sta08156750_1976_0525	subtract 0.2 to all hydrographs
unit_sta08156750_1977_0415	tail extended manually to 0.8
unit_sta08157000_1967_0520_1445	applied algorithm at 15 to 345, 345 to end
unit_sta08157000_1968_0709	applied algorithm at 270 to 555, 555 to 660, and 660 to 1230
unit_sta08157000_1970_0306	tail extended logarithmically to 0.64
unit_sta08157000_1971_0803	start at 180, subtract 0.26
unit_sta08157000_1971_1117	applied algorithm at 75 to 555, 555 to end
unit_sta08157000_1972_0501	applied algorithm at 0 to 315,315 to end
unit_sta08157000_1973_0708	applied algorithm at 405 to 720, 720 to 1200, 1215 to end
unit_sta08157000_1973_1012	applied algorithm at 15 to 270, 270 to end
unit_sta08157000_1974_0823	applied algorithm at 0 to 1035, 1035 to end
unit_sta08157000_1975_0428	subtracted 0.3
unit_sta08157000_1975_0523	applied algorithm at 555 to 1740, 1740 to end
unit_sta08157000_1976_0525	applied algorithm at 55 to 1355, 1375 to end

unit_sta08157000_1976_0525	tail extended to 0.3
unit_sta081570000_1970_0307	start at 30, subtract 1.6
unit_sta08158100_1976_0525	applied algorithm at 60 to 1330, 1375 to end
unit_sta08158100_1977_0415	1175 to 4830
unit_sta08158100_1977_0419	tail extended linearly to 3.7
unit_sta08158100_1980_0327	tail extended manually to 0.1
unit_sta08158100_1981_0303	applied algorithm at 575 to 1080, 1080 to end
unit_sta08158100_1981_0303	tail extended logarithmically to 1
unit_sta08158100_1981_0610	applied algorithm at 900 to 1440, 1440 to end
unit_sta08158100_1985_0513	tail extended logarithmically to 0 (assume < 0.01 is zero)
unit_sta08158100_1986_0906	tail extended logarithmically to 16
unit_sta08158380_1986_0430	cut at 2640 then tail extended linearly to 0
unit_sta08158400_1976_0525	tail extended manually to 4.4
unit_sta08158400_1976_0525	applied algorithm at 1305 to 2580, subtracted 9 from 2630 to 2880
unit_sta08158400_1977_0415	tail extended linearly to 4
unit_sta08158400_1977_0419	tail extended logarithmically to 6
unit_sta08158400_1981_0303	applied algorithm at 340 to 1015, 1030 to end
unit_sta08158400_1981_0523	applied algorithm at 1410 to 2160, 2520 to end
unit_sta08158500_1976_0525	660 to 1905, subtracted 23 1950 to 2205
unit_sta08158500_1976_0525	tail extended manually to 6
unit_sta08158500_1977_0415	tail extended logarithmically to 5
unit_sta08158500_1977_0419	tail extended manually to 10
unit_sta08158500_1981_0303	tail extended manually to 0.8
unit_sta08158810_1980_0929	tail extended manually to 16
unit_sta08158810_1985_0605	delete first hydrograph and cut at 1750
unit_sta08158810_1985_1127	tail extended linearly to 13
unit_sta081588401980_0512	tail extended manually to 30
unit_sta081588401981_0610	applied algorithm until 3120, 3315 to 4320, 4590 to 6765, 6840 to end
unit_sta081588401982_0513	tail extended manually to 3.4
unit_sta081588401983_0520	tail extended linearly to 0
unit_sta081588401985_0223	tail extended manually to 0.9
unit_sta081588401985_0605	tail extended manually to 3.1
unit_sta081588401985_1126	tail extended manually to 23
unit_sta08158880_1981_0610	applied algorithm at 1175 to 1600, 1600 to 3360, 4905 to end; remove flow at 3360,3480,4320,4795,4905
unit_sta08158920_1980_0507	delete first hydrograph; start at 1740
unit_sta08158920_1981_0303	delete first hydrograph; start at 1170

unit_sta08158920_1981_0610	tail extended linearly to 0
unit_sta08158920_1983_0520	tail extended linearly to 0
unit_sta08158920_1984_1010	cut at 2460
unit_sta08158920_1985_0605	tail extended manually to 13
unit_sta08159150_1967_0430	tail extended logarithmically to 0.79
unit_sta08159150_1968_0517	tail extended logarithmically to 4.5
unit_sta08159150_1968_0709	delete (too small)
unit_sta08159150_1970_0306	subtracted 5.1
unit_sta08159150_1970_0306	tail extended logarithmically to 5.1
unit_sta08159150_1970_1022	subtracted 0.04
unit_sta08159150_1971_1205	tail extended manually to 0.5
unit_sta08159150_1975_0523	0 to 1710, 1740 to end
unit_sta08159150_1977_0415	tail extended logarithmically to 0.5
unit_sta08178300_1971_0613	tail extended manually to 0.2
unit_sta08178300_1972_0427	applied algorithm at 40 to 325, 330 to 780, 805 to 1240
unit_sta08178300_1973_0415	applied algorithm at until 1005, 1005 to end
unit_sta08178300_1976_0829	manually tail extended to 0
unit_sta08178300_1977_0521	tail extended manually to 0
unit_sta08178300_1977_0531	linearly tail extended to 0
unit_sta08178300_1977_0601	tail extended manually to 0
unit_sta08178300_1978_0801	manually tail extended to 0
unit_sta08178600_1971_0804	tail extended manually to 0
unit_sta08178620_1981_0612	tail extended manually to 0
unit_sta08178640_1976_0526	tail extended manually to 0
unit_sta08178640_1976_0928	tail extended manually to 0
unit_sta08178640_1976_1023	tail extended manually to 0
unit_sta08178640_1979_0110	tail extended manually to 0
unit_sta08178645_1976_0507	tail extended manually to 0
unit_sta08178645_1976_0526	tail extended manually to 0
unit_sta08178645_1976_0706	tail extended manually to 0
unit_sta08178645_1979_0110	tail extended manually to 0
unit_sta08181000_1978_1105	tail extended manually to 0
unit_sta08181000_1978_1231	tail extended manually to 0
unit_sta08181000_1979_0110	tail extended manually to 0
unit_sta08181000_1979_0320	tail extended manually to 0
unit_sta08181400_1969_0516	cut at 660 then tail extended manually to 0
unit_sta08181400_1971_0801	cut at 2280 then tail extended manually to 0
unit_sta08181400_1971_0813	cut at 1095 then tail extended manually to 27
unit_sta08181400_1973_0926	cut at 915

unit_sta08181400_1974_0912	cut at 1245
unit_sta081870001959_1003	tail extended manually to first value
unit_sta081870001960_0113	tail extended manually to 0
unit_sta081870001960_0828	tail extended manually to 0
unit_sta081870001960_1024	cut at 3240
unit_sta081870001960_1230	tail extended manually to 0
unit_sta081870001961_0205	tail extended manually to first value
unit_sta081870001962_0601	tail extended manually to 0
unit_sta081870001962_0602	tail extended manually to 0
unit_sta081870001962_1202	tail extended manually to 0
unit_sta081870001963_1127	tail extended manually to 0
unit_sta081870001963_1212	tail extended manually to 0
unit_sta081870001965_0204	cut at 825
unit_sta081870001965_0216	cut at 960
unit_sta081870001965_0511	tail extended manually to first value
unit_sta081870001965_0519	cut at 430
unit_sta081870001965_1018	tail extended manually to first value
unit_sta081870001967_0919	tail extended manually to 0
unit_sta081870001968_0507	cut at 585
unit_sta081870001969_0603	tail extended manually to 0
unit_sta081870001969_0604	tail extended manually to 0
unit_sta081870001970_0526	tail extended manually to 0
unt_sta08181000_1971_0801	tail extended manually to 0
unit_sta08075550_1966_0909	extend manually to 1
unit_sta08075550_1968_0917	extend left tail to 1
unit_sta08075550_1968_1009	extend manually to 2
unit_sta08075550_1969_0214	extend manually to 2
unit_sta08075550_1969_1030	extend left tail manually to 1; extend right tail logarithmically to 1
unit_sta08075550_1970_0521	extend manually to 1.3
unit_sta08075550_1970_0530	extend logarithmically to zero
unit_sta08075550_1970_1011	extend left tail manually to 0; extend right tail manually to 0
unit_sta08075550_1970_1023	extend left tail manually to 2
unit_sta08075550_1972_0510	extend logarithmically to 2
unit_sta08075550_1973_0416	extend logarithmically to 2
unit_sta08075550_1979_0901	extend manually to 9
unit_sta08075550_1980_0120	extend logarithmically to 2
unit_sta08075550_1981_0831	remove first hydrograph; start at 660
unit_sta08075600_1965_0522	extend logarithmically to 2
unit_sta08075600_1966_0209	extend left tail manually to 1

unit_sta08075600_1966_0328	extend logarithmically to 2
unit_sta08075600_1966_0520	extend left tail manually to 1
unit_sta08075600_1966_0909	extend left tail manually to 1
unit_sta08075600_1966_1004	extend left tail manually to 0.5
unit_sta08075600_1967_0413	extend left tail manually to 0.5
unit_sta08075600_1968_0526	extend left tail manually to 1; extend right tail logarithmically to 1
unit_sta08075600_1968_0604	extend left tail manually to 1
unit_sta08075600_1968_0917	extend left tail manually to 2; extend right tail logarithmically to 2
unit_sta08075600_1968_1009	extend left tail manually to 0; extend right tail linearly to 0
unit_sta08075600_1969_0214	remove values before 360
unit_sta08075600_1969_0315	extend left tail manually to 0; extend right tail linearly to 0
unit_sta08075600_1969_0412	remove values before 420; extend left tail manually to 0; extend right tail linearly to 0
unit_sta08075600_1969_1030	extend manually to 1.3
unit_sta08075600_1970_0530	extend left tail manually to 0.1
unit_sta08075600_1972_0510	extend to 0.2
unit_sta08075650_1965_0522	extend linearly to 5
unit_sta08075650_1965_0606	extend linearly to 10
unit_sta08075650_1966_0209	extend logarithmically to 5.3
unit_sta08075650_1966_0328	delete first small hydrograph
unit_sta08075650_1968_0510	extend left limb to 5
unit_sta08075650_1968_0604	extend manually to 5
unit_sta08075650_1968_0917	extend linearly to 5
unit_sta08075650_1969_0214	extend manually to 10
unit_sta08075650_1969_0503	extend manually to 6
unit_sta08075650_1969_1030	extend manually to 6.5
unit_sta08075550_1972_0510	extend manually to 2
unit_sta08075550_1972_1106	extend manually to 1
unit_sta08075550_1979_0725	extend manually to 2
unit_sta08075550_1979_0901	extend manually to 5
unit_sta08075550_1979_0918	removed, complicated
unit_sta08075550_1980_0120	extend manually to 2
unit_sta08075550_1981_0605	start at 285 then extend left tail to 2.1
unit_sta08075550_1981_0831	start at 660 then extend left tail to 2.1
unit_sta08075550_1981_1031	removed, complicated
unit_sta08075550_1983_0818	extend manually to 1
unit_sta08075700_1964_1209	extend manually to 1.3

unit_sta08075700_1965_0522	extend left tail manually to 2
unit_sta08075700_1966_0328	cut at 795 then extend left tail manually to 10
unit_sta08075700_1966_0414	extend left tail and right tail manually to 0
unit_sta08075700_1966_0520	extend manually to 1
unit_sta08075700_1966_0909	extend manually to 1
unit_sta08075700_1968_0604	extend left tail manually to 5
unit_sta08075700_1968_1009	extend manually to 2
unit_sta08075700_1970_1023	extend left tail manually to 8
unit_sta08075700_1972_0427	extend manually to 5
unit_sta08075730_1975_0609	extend linearly to 2.3
unit_sta08075730_1975_0731	cut at 3840 then extend manually to 8.8
unit_sta08075730_1977_0420	extend manually to 2.4
unit_sta08075730_1979_0319	extend manually to 4.4
unit_sta08075730_1979_0724	cut at 1935, extend left tail manually to 8.7
unit_sta08075730_1979_0917	removed, complicated
unit_sta08075730_1981_0830	extend manually to 1.3
unit_sta08075730_1982_0513	extend manually to 1.2
unit_sta08075730_1982_0809	extend manually to 1.7
unit_sta08075730_1983_0817	cut at 1440 then extend manually to 13
unit_sta08075730_1983_0919	cut at 840 then extend left limb to 1.5
unit_sta08075730_1985_0314	removed, complicated
unit_sta08075730_1987_0609	extend logarithmically to 30
unit_sta08075730_1987_0610	removed, complicated
unit_sta08075730_1989_0626	extend manually to 14
unit_sta08074750_1976_0615	extend manually to 0.1
unit_sta08074760_1978_0606	extend manually to 3
unit_sta08074760_1979_0419	extend manually to 3
unit_sta08074760_1979_0917	cut at 2370 then extend left manually to 25
unit_sta08074760_1979_1030	extend manually to 5
unit_sta08074760_1979_1212	extend manually to 5
unit_sta08074760_1980_0120	extend linearly to 4
unit_sta08074760_1982_0513	extend logarithmically to 6
unit_sta08074760_1982_0517	extend manually to 16
unit_sta08074760_1983_0209	extend logarithmically to 7
unit_sta08074850_1968_0814	cut at 975 then extend left limb manually to 1
unit_sta08074850_1968_0917	extend manually to 1
unit_sta08074850_1970_1022	extend manually to 1
unit_sta08074850_1972_0512	extend manually to 1
unit_sta08074850_1972_0610	extend manually to 1
unit_sta08074850_1973_0611	removed, complicated

unit_sta08074850_1974_1031	extend manually to 1
unit_sta08074850_1980_0120	removed, complicated
unit_sta08074900_1964_1119	extend logarithmically to 1
unit_sta08074900_1964_1209	removed, complicated
unit_sta08074900_1965_0216	extend manually to 2
unit_sta08074900_1965_0518	extend manually to 2
unit_sta08074900_1965_0713	extend manually to 1
unit_sta08074900_1966_0414	extend manually to 1
unit_sta08074900_1966_0806	extend manually to 1
unit_sta08074900_1966_1004	extend manually to 1
unit_sta08074900_1967_0825	extend linearly to 1
unit_sta08074900_1968_0623	extend left tail and right tail manually to 10
unit_sta08074900_1968_0725	extend manually to 1
unit_sta08074900_1968_0917	extend left and right tail manually to 1
unit_sta08074900_1969_0221	cut left tail at 345 then extend manually to 20
unit_sta08073630_1979_0719	removed, complicated
unit_sta08073630_1979_0917	removed, complicated
unit_sta08073630_1981_0830	removed, complicated
unit_sta08073630_1981_1031	cut at 1620
unit_sta08073630_1982_1102	removed, complicated
unit_sta08073630_1983_0520	removed, complicated
unit_sta08073630_1983_0616	extend left tail manually to 3
unit_sta08073630_1983_0807	removed, complicated
unit_sta08073800_1964_1209	removed, complicated
unit_sta08073800_1965_0216	extend manually to 4.4
unit_sta08073800_1966_0518	removed, complicated
unit_sta08073800_1968_0604	extend left tail manually to 1
unit_sta08073800_1968_0914	extend left tail manually to 2
unit_sta08073800_1968_0917	cut at 630 then extend left tail manually to 2
unit_sta08073800_1969_0412	removed, complicated
unit_sta08073800_1969_0919	removed, complicated
unit_sta08073800_1970_0521	extend left tail manually to 3
unit_sta08073800_1970_0705	extend left tail manually to 0.3
unit_sta08073800_1970_0830	extend manually to 10
unit_sta08073800_1970_1011	removed, complicated
unit_sta08073800_1970_1022	removed, complicated
unit_sta08073800_1972_0320	removed, complicated
unit_sta08077100_1966_0619	extend left tail manually to 1
unit_sta08077100_1966_1004	extend left tail manually to 0.2
unit_sta08077100_1968_0409	removed, complicated

unit_sta08077100_1968_0510	extend left tail manually to 2
unit_sta08077100_1968_0917	extend left tail manually to 1
unit_sta08077100_1969_1012	extend left tail manually to 0.1
unit_sta08077100_1970_1023	extend manually to 0.5
unit_sta08077100_1972_0427	extend manually to 1
unit_sta08074100_1966_0518	extend manually to 1.3
unit_sta08074100_1968_0510	removed, complicated
unit_sta08074100_1970_0530	extend left tail manually to 0.1
unit_sta08074100_1967_0413	extend manually to 1
unit_sta08074150_1965_1104	removed, complicated
unit_sta08074150_1967_0529	extend manually to 1.6
unit_sta08074150_1981_0830	extend manually to 2.3
unit_sta08074150_1984_0718	cut at 2670 then extend manually to 0.2
unit_sta08075780_1965_0122	extend manually to 5
unit_sta08075780_1968_0917	extend manually to 2.1
unit_sta08075780_1972_0510	removed, complicated
unit_sta08075780_1980_1015	removed, complicated
unit_sta08075780_1981_0831	extend left tail to 8.8
unit_sta08076200_1966_0328	extend left tail manually to 2
unit_sta08076200_1967_0921	extend left tail manually to 4
unit_sta08076200_1969_0221	extend left tail manually to 6
unit_sta08076200_1970_1023	extend left tail manually to 5
unit_sta08076200_1974_1031	extend manually to 2
unit_sta08076200_1979_0418	removed, complicated
unit_sta08076200_1980_0120	removed, complicated
unit_sta08076200_1981_0423	extend manually to 1.2
unit_sta08075750_1965_0518	extend manually to 1
unit_sta08075750_1966_0414	extend left tail manually to 3
unit_sta08075750_1966_1004	extend left tail manually to 1
unit_sta08075750_1967_0529	extend left tail manually to 1
unit_sta08075750_1970_1109	extend left tail manually to 1
unit_sta08075760_1968_1105	extend manually to 1
unit_sta08075760_1970_0515	extend left tail manually to 2
unit_sta08075760_1981_0705	cut at 2880
unit_sta08075760_1983_0510	extend logarithmically to 0.5
unit_sta08075770_1965_0216	extend manually to 2.5
unit_sta08075770_1989_0626	cut at 4140
unit_sta08074780_1974_1031	removed, complicated
unit_sta08074780_1976_0531	removed, complicated
unit_sta08074780_1978_0607	extend manually to 3

unit_sta08074800_1975_0609	extend manually to 13
unit_sta08074800_1979_0917	extend manually to 5
unit_sta08074800_1982_0715	subtract 11
unit_sta08074800_1987_0609	removed, complicated
unit_sta08075300_1965_0617	extend manually to 1.1
unit_sta08075300_1966_0414	extend manually to 5
unit_sta08075300_1966_0518	removed, complicated
unit_sta08075300_1966_0520	cut at 660 then extend left tail manually to 8
unit_sta08075300_1967_0825	cut at 675 then extend manually to 1
unit_sta08075300_1970_0501	extend manually to 1.3
unit_sta08075300_1970_0515	extend manually to 1.3
unit_sta08075300_1971_0910	extend left tail manually to 3
unit_sta08074200_1966_0414	extend manually to 0.5
unit_sta08074200_1966_0518	extend left tail manually to 2
unit_sta08074200_1970_1011	extend manually to 1
unit_sta08074200_1979_1030	extend manually to 1
unit_sta08074200_1983_0818	removed, complicated
unit_sta08074250_1965_0216	extend manually to 2
unit_sta08074250_1965_0528	extend manually to 1
unit_sta08074250_1970_0501	cut at 2880 then extend manually to 1.4
unit_sta08074250_1973_0611	removed, complicated
unit_sta08074250_1986_1123	removed, complicated
unit_sta08074540_1983_0520	removed, complicated
unit_sta08074540_1983_0615	cut at 2340
unit_sta08111025_1969_0221	run baseflow algorithm then change value at time 0 to 0
unit_sta08111025_1970_0910	run baseflow algorithm then change value at time 0 to 0
unit_sta08111050_1969_0214	extend logarithmically to 1.9, apply baseflow algorithm, then change value at time 0 to 0
unit_sta08111050_1969_0221	extend logarithmically to 0.54
unit_sta08111050_1969_0508	extend logarithmically to 1.2
unit_sta08111050_1970_0419	extend manually to 2
unit_sta08074150_1965_0216	extend logarithmically to 0.3
unit_sta08074150_1965_0922	cut at 2160 then extend linearly to 0.4
unit_sta08074150_1967_0413	extend manually to 1.1
unit_sta08074150_1968_0510	removed, too complicated
unit_sta08074150_1968_0614	extend linearly to 0.4
unit_sta08074150_1969_0221	extend manually to 21
unit_sta08074150_1970_0530	extend manually to 2.1
unit_sta08074150_1974_0119	extend manually to 9

unit_sta08074150_1977_0615	extend left tail manually to 1.5
unit_sta08074150_1979_0917	removed, too complicated
unit_sta08074150_1981_1005	start at 2460
unit_sta08074150_1983_0520	removed, too complicated
unit_sta08074150_1983_0721	extend manually to 1.2
unit_sta08074150_1988_0317	removed, too complicated

APPENDIX C

STORM PARAMETERS

Appendix Table C1. Austin storm parameters.

Code	t_d (hr)	i (in)	P (in)	CN	D (in)
unit_sta08155550_1977_0415	13.3	0.18	2.45	86	1.22
unit_sta08155550_1977_0416	7.8	0.16	1.25	96	0.83
unit_sta08155550_1979_0223	10.6	0.18	1.93	74	0.30
unit_sta08155550_1981_0523a	7.6	0.18	1.37	76	0.14
unit_sta08155550_1981_0523b	6.0	0.33	1.99	77	0.44
unit_sta08155550_1982_0513	18.0	0.25	4.45	56	0.77
unit_sta08155550_1984_1010	4.2	1.04	4.35	57	0.76
unit_sta08156650_1975_0711	3.5	0.68	2.37	75	0.57
unit_sta08156650_1976_0525b	0.7	0.93	0.62	88	0.07
unit_sta08156650_1976_0902	2.9	0.65	1.9	78	0.43
unit_sta08156650_1978_0212	13.5	0.12	1.61	78	0.29
unit_sta08156650_1978_0502	1.8	0.94	1.64	76	0.24
unit_sta08156650_1978_0511	3.9	0.37	1.44	80	0.25
unit_sta08156650_1978_1231	7.5	0.32	2.42	79	0.80
unit_sta08156650_1982_0513	10.7	0.51	5.47	65	1.95
unit_sta08156700_1976_0418	23.3	0.17	4.008	65	1.05
unit_sta08156700_1976_0902	3.3	0.45	1.51	79	0.26
unit_sta08156700_1977_0416	12.0	0.09	1.06	85	0.20
unit_sta08156700_1977_0419	26.3	0.05	1.333	82	0.25
unit_sta08156700_1978_0212	12.7	0.14	1.74	73	0.22
unit_sta08156700_1978_0502	9.5	0.19	1.79	72	0.21
unit_sta08156700_1978_0511	1.2	1.22	1.42	79	0.22
unit_sta08156700_1978_1231	21.0	0.12	2.427	70	0.41
unit_sta08156700_1979_0719	23.0	0.14	3.19	65	0.59
unit_sta08156700_1980_0512	15.0	0.12	1.75	75	0.27
unit_sta08156700_1981_0523b	26.0	0.28	7.25	86	5.62
unit_sta08156700_1981_0610a	18.0	0.25	4.44	75	2.04
unit_sta08156700_1981_0610b	6.8	0.06	0.4	96	0.14
unit_sta08156700_1982_0513	15.0	0.36	5.47	67	2.15
unit_sta08156700_1983_0510	25.3	0.08	2.08	73	0.37
unit_sta08156750_1976_0418	24.0	0.17	4.02	66	1.09
unit_sta08156750_1976_0902	15.2	0.10	1.49	78	0.24
unit_sta08156750_1977_0416	12.0	0.09	1.06	88	0.28
unit_sta08156750_1977_0419	27.5	0.05	1.34	85	0.34

unit_sta08156750_1978_0212	14.5	0.12	1.74	75	0.27
unit_sta08156750_1978_0511	3.0	0.47	1.42	79	0.23
unit_sta08156750_1978_1231	21.0	0.12	2.423	70	0.41
unit_sta08156750_1979_0719	29.3	0.11	3.22	67	0.68
unit_sta08156750_1980_0512	14.8	0.12	1.75	81	0.44
unit_sta08156800_1975_0428	13.0	0.31	4.02	63	0.92
unit_sta08156800_1975_0609	7.0	0.33	2.33	78	0.66
unit_sta08156800_1976_0418	23.8	0.17	3.98	66	1.08
unit_sta08156800_1976_0525	21.0	0.11	2.41	72	0.48
unit_sta08156800_1976_0902	3.3	0.41	1.37	75	0.13
unit_sta08156800_1977_0416	12.0	0.09	1.06	88	0.27
unit_sta08156800_1978_0502	9.5	0.19	1.82	78	0.38
unit_sta08156800_1978_0511	1.9	0.74	1.42	82	0.29
unit_sta08156800_1978_1231	21.0	0.12	2.42	78	0.72
unit_sta08156800_1979_0521	41.9	0.08	3.46	85	2.01
unit_sta08156800_1979_0719	44.0	0.08	3.48	73	1.14
unit_sta08156800_1980_0327	24.0	0.14	3.26	73	1.03
unit_sta08156800_1981_0303	29.8	0.10	3.07	74	0.95
unit_sta08156800_1981_0610	136.0	0.05	6.42	92	5.46
unit_sta08156800_1982_0513	10.5	0.52	5.47	74	2.76
unit_sta08156800_1984_1007	10.0	0.24	2.37	73	0.52
unit_sta08156800_1985_0513	3.3	0.74	2.39	69	0.39
unit_sta08156800_1986_0906	22.5	0.14	3.05	68	0.64
unit_sta08157000_1967_0520_0000	2.8	0.39	1.07	83	0.16
unit_sta08157000_1967_0520_1445	8.0	0.09	0.73	88	0.11
unit_sta08157000_1967_0817	1.8	1.30	2.27	73	0.45
unit_sta08157000_1967_0818	3.8	0.22	0.83	88	0.15
unit_sta08157000_1967_1015	14.6	0.22	3.17	73	0.97
unit_sta08157000_1968_0517	3.0	0.57	1.72	83	0.53
unit_sta08157000_1968_0527	2.2	0.75	1.63	81	0.39
unit_sta08157000_1968_0709	13.3	0.14	1.91	78	0.44
unit_sta08157000_1969_0323	10.0	0.10	1.02	86	0.22
unit_sta08157000_1969_0427	2.3	0.62	1.39	80	0.23
unit_sta08157000_1969_0508	2.0	0.68	1.35	82	0.25
unit_sta08157000_1970_0306	3.3	0.47	1.54	84	0.44
unit_sta08157000_1970_0514	3.0	0.27	0.8	87	0.13
unit_sta08157000_1970_0515	16.0	0.25	4.03	69	1.26
unit_sta08157000_1971_0621	3.5	0.52	1.81	76	0.31
unit_sta08157000_1971_0726	8.4	0.16	1.31	80	0.20
unit_sta08157000_1971_0802	9.8	0.13	1.27	86	0.33
unit_sta08157000_1971_0803	33.0	0.13	4.37	63	1.14
unit_sta08157000_1971_1117a	4.0	0.31	1.23	82	0.21

unit_sta08157000_1972_0501	12.3	0.23	2.79	80	1.08
unit_sta08157000_1972_1021	23.3	0.16	3.76	65	0.89
unit_sta08157000_1973_0708a	8.1	0.06	0.52	94	0.14
unit_sta08157000_1973_0708b	4.3	0.25	1.06	89	0.31
unit_sta08157000_1973_1011	17.5	0.28	4.91	76	2.46
unit_sta08157000_1973_1012	9.3	0.17	1.55	85	0.47
unit_sta08157000_1974_0509	23.0	0.11	2.48	79	0.82
unit_sta08157000_1975_0428	14.0	0.25	3.47	69	0.91
unit_sta08157000_1975_0523a	15.3	0.16	2.48	80	0.86
unit_sta08157000_1975_0523b	1.8	0.41	0.72	95	0.35
unit_sta08157000_1976_0418	19.3	0.16	2.99	77	1.09
unit_sta08157000_1976_0525a	21.1	0.11	2.369	81	0.83
unit_sta08157000_1976_0525b	1.4	0.30	0.43	97	0.18
unit_sta08157000_1977_0415a	9.8	0.14	1.367	85	0.35
unit_sta08157000_1977_0415b	6.3	0.10	0.62	94	0.20
unit_sta08157000_1977_0416	11.3	0.09	0.96	92	0.36
unit_sta08157000_1978_0212	13.6	0.10	1.35	85	0.37
unit_sta08157000_1978_0502	10.6	0.19	2.04	75	0.40
unit_sta08157000_1978_0511	13.7	0.08	1.08	89	0.32
unit_sta08157000_1979_0429	12.0	0.11	1.33	84	0.32
unit_sta08157000_1979_0521	41.0	0.14	5.62	73	2.79
unit_sta08157000_1980_0512	14.3	0.11	1.55	85	0.47
unit_sta08157500_1967_0520_0000	2.8	0.42	1.16	83	0.20
unit_sta08157500_1967_0817	1.8	1.26	2.21	74	0.45
unit_sta08157500_1967_0818	3.8	0.22	0.83	89	0.17
unit_sta08157500_1967_1015	14.3	0.22	3.14	73	0.93
unit_sta08157500_1968_0517	3.7	0.48	1.77	82	0.52
unit_sta08157500_1968_0527	7.5	0.22	1.67	82	0.45
unit_sta08157500_1968_0709	13.1	0.15	1.92	81	0.55
unit_sta08157500_1969_0323	7.8	0.13	0.97	85	0.16
unit_sta08157500_1969_0427	2.8	0.43	1.18	83	0.21
unit_sta08157500_1969_0508	2.0	0.61	1.21	88	0.37
unit_sta08157500_1970_0306	4.0	0.37	1.46	82	0.34
unit_sta08157500_1970_0514	3.5	0.20	0.71	89	0.12
unit_sta08157500_1970_0515	18.0	0.22	3.87	69	1.20
unit_sta08157500_1971_0621	3.5	0.58	2.03	79	0.53
unit_sta08157500_1971_0802a	9.9	0.09	0.91	90	0.27
unit_sta08157500_1971_0802c	14.0	0.15	2.03	74	0.36
unit_sta08157500_1971_1117	16.5	0.22	3.68	67	0.98
unit_sta08157500_1972_0501	12.5	0.22	2.81	78	1.02
unit_sta08157500_1973_1011	17.8	0.30	5.308	80	3.12
unit_sta08157500_1973_1012	9.3	0.18	1.65	88	0.68

unit_sta08157500_1974_0509	6.5	0.38	2.5	79	0.84
unit_sta08157500_1976_0418	20.3	0.15	2.99	77	1.06
unit_sta08157500_1976_0525	21.8	0.11	2.33	82	0.85
unit_sta08157500_1977_0416	11.5	0.09	0.98	92	0.37
unit_sta08157500_1978_0212	12.5	0.11	1.37	84	0.35
unit_sta08157500_1978_0511	7.7	0.14	1.05	89	0.32
unit_sta08157500_1979_0429	41.0	0.03	1.42	85	0.39
unit_sta08157500_1980_0512	15.5	0.09	1.465	83	0.37
unit_sta08158050_1976_0418	22.0	0.16	3.56	77	1.51
unit_sta08158050_1979_0521	27.5	0.21	5.81	77	3.27
unit_sta08158050_1979_0719	24.0	0.20	4.91	68	1.85
unit_sta08158050_1980_0425	14.0	0.11	1.48	75	0.15
unit_sta08158050_1981_0303	32.3	0.05	1.64	78	0.29
unit_sta08158050_1981_0523b	21.2	0.16	3.34	68	0.81
unit_sta08158050_1983_0604	24.0	0.06	1.43	81	0.27
unit_sta08158050_1984_1020a	17.8	0.05	0.8	94	0.33
unit_sta08158050_1984_1020b	2.5	0.43	1.08	96	0.68
unit_sta08158050_1985_0622	15.8	0.16	2.59	75	0.70
unit_sta08158100_1976_0418	23.5	0.04	0.996	40	0.30
unit_sta08158100_1977_0419	30.1	0.04	1.311	76	0.13
unit_sta08158100_1978_0410	5.0	0.48	2.39	52	0.03
unit_sta08158100_1978_1231	8.0	0.31	2.51	56	0.10
unit_sta08158100_1979_0320	26.4	0.06	1.658	67	0.08
unit_sta08158100_1980_0508	16.0	0.19	3	60	0.34
unit_sta08158100_1981_0303	36.0	0.10	3.47	55	0.34
unit_sta08158100_1981_0610a	60.9	0.11	6.702	45	1.13
unit_sta08158100_1984_1020	6.5	0.40	2.57	70	0.50
unit_sta08158100_1985_0513	3.0	0.66	1.99	62	0.08
unit_sta08158100_1985_1019	14.5	0.21	3	57	0.26
unit_sta08158380_1985_1019	14.5	0.09	1.303	95	0.80
unit_sta08158380_1986_0430	23.0	0.12	2.73	86	1.46
unit_sta08158400_1976_0418	23.0	0.16	3.687	77	1.58
unit_sta08158400_1976_0525	28.3	0.09	2.425	88	1.34
unit_sta08158400_1979_0521	21.0	0.15	3.07	81	1.37
unit_sta08158400_1979_0719	29.3	0.08	2.275	79	0.71
unit_sta08158400_1980_0327	13.5	0.23	3.07	80	1.33
unit_sta08158400_1980_0512	15.0	0.11	1.71	92	0.98
unit_sta08158400_1981_0303	36.0	0.09	3.07	85	1.64
unit_sta08158400_1981_0523	48.5	0.15	7.31	81	5.10
unit_sta08158500_1976_0418	23.0	0.15	3.468	70	0.97
unit_sta08158500_1976_0525a	20.8	0.13	2.67	74	0.72
unit_sta08158500_1977_0416	18.0	0.06	1.06	91	0.39

unit_sta08158500_1977_0419	18.0	0.11	1.93	85	0.76
unit_sta08158500_1978_0212	12.3	0.11	1.368	83	0.32
unit_sta08158500_1978_0502	16.5	0.12	2.05	76	0.43
unit_sta08158500_1978_0511	7.9	0.19	1.5	83	0.37
unit_sta08158500_1979_0521	33.3	0.15	4.949	71	2.09
unit_sta08158500_1979_0719	29.3	0.08	2.39	75	0.60
unit_sta08158500_1980_0327	18.5	0.16	3.03	74	0.91
unit_sta08158500_1980_0512	15.0	0.10	1.51	86	0.52
unit_sta08158500_1981_0303	33.2	0.08	2.661	76	0.81
unit_sta08158500_1981_0523b	17.3	0.30	5.21	99	5.07
unit_sta08158500_1981_0610	118.3	0.10	11.31	66	6.82
unit_sta08158810_1980_0512	16.5	0.10	1.66	69	0.12
unit_sta08158810_1980_0929	27.3	0.06	1.51	73	0.13
unit_sta08158810_1981_0610	123.6	0.12	14.63	56	8.21
unit_sta08158810_1982_0513	14.5	0.25	3.63	64	0.79
unit_sta08158810_1986_0509	29.5	0.07	2.146	65	0.18
unit_sta08158840_1979_0223	15.0	0.11	1.68	81	0.42
unit_sta08158840_1979_0418	45.8	0.05	2.07	87	0.95
unit_sta08158840_1980_0512	16.0	0.12	1.97	79	0.49
unit_sta08158840_1981_0303	25.0	0.12	3.07	66	0.59
unit_sta08158840_1982_0513	9.5	0.39	3.66	71	1.17
unit_sta08158840_1985_0223	10.8	0.29	3.16	77	1.20
unit_sta08158840_1985_0605	23.5	0.17	4.05	71	1.46
unit_sta08158840_1985_1126	35.0	0.06	2.19	90	1.23
unit_sta08158840_1986_0509	29.3	0.08	2.41	80	0.82
unit_sta08158880_1976_0525	23.5	0.08	1.812	78	0.38
unit_sta08158880_1977_0416	11.2	0.11	1.2	84	0.25
unit_sta08158880_1977_0919	2.8	1.06	2.92	67	0.53
unit_sta08158880_1978_0212	13.7	0.11	1.45	72	0.10
unit_sta08158880_1978_0502	16.8	0.10	1.62	76	0.23
unit_sta08158880_1981_0303	14.9	0.04	0.643	92	0.17
unit_sta08158880_1981_0524a	1.7	0.65	1.09	83	0.18
unit_sta08158880_1981_0524b	26.0	0.05	1.26	87	0.37
unit_sta08158880_1981_0610b	38.2	0.18	6.698	89	5.43
unit_sta08158880_1982_0513a	2.9	0.58	1.68	80	0.39
unit_sta08158880_1982_0513b	4.7	0.49	2.29	86	1.06
unit_sta08158880_1984_1011	26.6	0.12	3.19	85	1.77
unit_sta08158880_1985_0606	16.6	0.16	2.728	83	1.24
unit_sta08158920_1979_0223	14.0	0.10	1.43	84	0.36
unit_sta08158920_1979_0521	33.5	0.18	6.058	60	2.00
unit_sta08158920_1980_0507	31.3	0.04	1.23	77	0.12
unit_sta08158920_1981_0303	36.0	0.08	2.9	73	0.82

unit_sta08158920_1981_0610	143.4	0.12	16.749	71	12.66
unit_sta08158920_1982_0513	10.0	0.36	3.56	74	1.28
unit_sta08158920_1983_0520	12.2	0.02	0.265	99	0.20
unit_sta08158920_1985_0605	22.7	0.09	2.02	82	0.68
unit_sta08158920_1986_0509	29.0	0.09	2.61	87	1.37
unit_sta08158920_1986_0515	43.0	0.05	2.107	82	0.72
unit_sta08158930_1976_0418	23.1	0.18	4.185	66	1.21
unit_sta08158930_1977_0415	18.0	0.14	2.49	63	0.24
unit_sta08158930_1977_0416	17.0	0.07	1.19	83	0.22
unit_sta08158930_1978_0606	22.5	0.08	1.69	69	0.12
unit_sta08158930_1979_0418	29.3	0.09	2.49	75	0.63
unit_sta08158930_1979_0521	40.0	0.16	6.48	66	2.77
unit_sta08158930_1980_0507a	17.0	0.05	0.89	80	0.05
unit_sta08158930_1981_0303a	10.2	0.07	0.675	82	0.02
unit_sta08158930_1981_0303b	15.2	0.10	1.5	84	0.42
unit_sta08158930_1981_0523b	26.0	0.12	3.13	73	0.94
unit_sta08158930_1981_0610	124.3	0.14	17.08	52	9.43
unit_sta08158930_1982_0513	16.0	0.23	3.67	74	1.35
unit_sta08158930_1983_0520	18.9	0.09	1.71	74	0.22
unit_sta08158930_1985_0605	36.6	0.13	4.596	57	0.92
unit_sta08159150_1967_0430	1.6	0.55	0.87	79	0.04
unit_sta08159150_1967_0501	13.0	0.12	1.59	80	0.34
unit_sta08159150_1967_0520_1910	3.8	0.25	0.94	78	0.04
unit_sta08159150_1967_1015	14.3	0.16	2.246	63	0.17
unit_sta08159150_1968_0517	4.9	0.30	1.46	88	0.54
unit_sta08159150_1968_0527	10.0	0.16	1.57	80	0.33
unit_sta08159150_1969_0412	23.0	0.07	1.61	88	0.66
unit_sta08159150_1970_0306	4.8	0.31	1.46	88	0.57
unit_sta08159150_1970_0307	11.0	0.04	0.48	97	0.26
unit_sta08159150_1970_0515	14.0	0.25	3.51	66	0.82
unit_sta08159150_1970_1023	1.5	0.98	1.47	86	0.46
unit_sta08159150_1971_1117	16.5	0.03	0.4129	100	0.41
unit_sta08159150_1971_1205	10.5	0.11	1.12	86	0.25
unit_sta08159150_1972_0501	5.8	0.47	2.7	63	0.32
unit_sta08159150_1973_0926	26.5	0.03	0.766	37	0.47
unit_sta08159150_1973_1011	12.3	0.21	2.57	81	1.00
unit_sta08159150_1973_1013	11.0	0.09	1.01	96	0.66
unit_sta08159150_1974_1123	13.3	0.31	4.09	71	1.48
unit_sta08159150_1975_0523	32.5	0.08	2.58	77	0.81
unit_sta08159150_1975_0609	15.3	0.21	3.22	81	1.46
unit_sta08159150_1976_0418	22.3	0.16	3.665	61	0.65
unit_sta08159150_1976_0525	23.6	0.10	2.31	77	0.62

unit_sta08159150_1977_0415	17.8	0.13	2.3	69	0.34
unit_sta08159150_1977_0416	7.0	0.14	0.95	93	0.44
unit_sta08159150_1977_0419	31.8	0.05	1.49	90	0.66

Appendix Table C2. Dallas storm parameters.

Code	t_d (hr)	i (in)	P (in)	CN	D (in)
unit_sta08055580_1974_1030a	5.3	0.19	0.98	99	0.82
unit_sta08055580_1974_1030b	2.9	0.37	1.08	100	1.06
unit_sta08055580_1975_0326	6.3	0.19	1.19	93	0.63
unit_sta08055580_1976_0526	1.2	1.03	1.2	94	0.67
unit_sta08055580_1977_0612	5.3	0.44	2.32	87	1.14
unit_sta08055580_1977_0907	1.9	1.21	2.32	79	0.73
unit_sta08055580_1978_0528	13.3	0.32	4.27	79	2.22
unit_sta08055580_1979_0503	9.0	0.38	3.46	93	2.73
unit_sta08055600_1974_0920	13.3	0.24	3.22	80	1.45
unit_sta08055600_1974_1030	24.0	0.13	3.06	76	1.08
unit_sta08055600_1975_0609	1.8	0.54	0.95	92	0.39
unit_sta08055600_1976_0526	1.3	0.86	1.14	86	0.28
unit_sta08055600_1978_0528	11.8	0.29	3.41	77	1.38
unit_sta08055600_1979_0330	15.0	0.20	3.05	85	1.61
unit_sta08055600_1979_0503	10.0	0.33	3.34	86	1.93
unit_sta08055700_1964_0927	7.0	0.09	0.608	97	0.36
unit_sta08055700_1965_0509	30.0	0.16	4.84	78	2.60
unit_sta08055700_1966_0209	9.3	0.22	2.07	80	0.62
unit_sta08055700_1966_0428	5.3	0.98	5.17	95	4.60
unit_sta08055700_1966_0501	9.3	0.17	1.6	90	0.77
unit_sta08055700_1967_0420	23.5	0.09	2.12	76	0.48
unit_sta08055700_1967_0530	26.5	0.09	2.48	72	0.54
unit_sta08055700_1968_0319	33.3	0.09	3.04	88	1.87
unit_sta08055700_1968_0422	4.5	0.21	0.93	91	0.33
unit_sta08055700_1968_0512	11.8	0.10	1.18	92	0.54
unit_sta08055700_1968_0813	10.1	0.44	4.44	57	0.81
unit_sta08055700_1968_1009	1.6	1.19	1.88	77	0.38
unit_sta08055700_1969_0504	10.1	0.19	1.88	84	0.65
unit_sta08055700_1970_0425a	3.3	0.24	0.79	91	0.22
unit_sta08055700_1970_0425b	3.5	0.40	1.39	92	0.71
unit_sta08055700_1970_0831	44.8	0.09	3.93	72	1.42
unit_sta08055700_1971_0814	11.5	0.19	2.24	88	1.13
unit_sta08055700_1971_1003	30.0	0.15	4.45	70	1.62
unit_sta08055700_1971_1018	47.0	0.09	4.42	79	2.31

unit_sta08055700_1972_0712	2.9	0.84	2.44	67	0.34
unit_sta08055700_1974_0607a	2.0	0.90	1.8	81	0.48
unit_sta08055700_1974_0607b	2.8	0.45	1.25	90	0.49
unit_sta08055700_1974_0916a	13.5	0.13	1.79	83	0.54
unit_sta08055700_1974_0916b	9.5	0.20	1.92	87	0.87
unit_sta08055700_1974_1030	29.8	0.10	3.11	80	1.32
unit_sta08055700_1975_0131a	11.5	0.14	1.59	86	0.53
unit_sta08055700_1975_0131b	34.8	0.06	2.24	91	1.37
unit_sta08055700_1975_0407	31.0	0.08	2.37	85	1.07
unit_sta08055700_1976_0618	5.5	0.33	1.8	80	0.45
unit_sta08055700_1977_0326	30.5	0.18	5.47	79	3.23
unit_sta08055700_1977_0612	5.8	0.58	3.31	68	0.81
unit_sta08055700_1978_0323	3.0	0.48	1.45	85	0.41
unit_sta08055700_1978_0528	13.8	0.21	2.95	77	1.02
unit_sta08055700_1978_0804	16.0	0.18	2.88	67	0.54
unit_sta08055700_1978_0821	16.8	0.06	0.98	84	0.14
unit_sta08055700_1979_0330	7.8	0.42	3.25	91	2.34
unit_sta08055700_1979_0503	11.3	0.33	3.7	90	2.67
unit_sta08055700_1979_0717	6.5	0.20	1.27	86	0.36
unit_sta08056500_1964_1117	51.0	0.05	2.68	77	0.84
unit_sta08056500_1965_0509a	5.0	0.12	0.58	91	0.12
unit_sta08056500_1965_0509c	8.5	0.23	1.939	86	0.79
unit_sta08056500_1965_0509d	30.0	0.08	2.26	94	1.66
unit_sta08056500_1966_0209	8.0	0.28	2.23	83	0.85
unit_sta08056500_1966_0428	17.6	0.20	3.56	96	3.13
unit_sta08056500_1966_0617	11.6	0.12	1.35	86	0.41
unit_sta08056500_1967_0530a	6.0	0.12	0.73	92	0.20
unit_sta08056500_1967_0530b	7.5	0.20	1.52	86	0.50
unit_sta08056500_1968_0422	2.2	0.55	1.19	91	0.52
unit_sta08056500_1968_0513	4.0	0.36	1.44	94	0.86
unit_sta08056500_1968_0813	11.0	0.26	2.87	77	0.99
unit_sta08056500_1968_1009	4.5	0.34	1.53	85	0.46
unit_sta08056500_1969_0129b	9.3	0.09	0.82	94	0.36
unit_sta08056500_1969_0504	11.5	0.20	2.35	84	1.02
unit_sta08056500_1969_0506	23.0	0.24	5.61	89	4.31
unit_sta08056500_1969_1012	14.5	0.30	4.38	69	1.54
unit_sta08056500_1970_0831a	20.0	0.03	0.51	91	0.08
unit_sta08056500_1970_0831b	8.5	0.12	1	89	0.29
unit_sta08056500_1970_0831c	8.0	0.33	2.66	87	1.45
unit_sta08056500_1971_0814a	8.3	0.16	1.31	87	0.42
unit_sta08056500_1971_0814b	1.3	0.97	1.21	92	0.56
unit_sta08056500_1971_1003	36.0	0.13	4.83	74	2.22

unit_sta08056500_1971_1018b	12.0	0.15	1.83	95	1.32
unit_sta08056500_1973_0423	29.5	0.07	2.21	90	1.25
unit_sta08056500_1973_0511	12.8	0.14	1.83	89	0.89
unit_sta08056500_1973_0603a	4.0	0.21	0.83	90	0.23
unit_sta08056500_1973_0603b	9.5	0.20	1.87	92	1.13
unit_sta08056500_1973_0603c	5.0	0.54	2.7	94	2.07
unit_sta08056500_1973_1011	5.0	0.50	2.49	83	1.05
unit_sta08056500_1973_1030	8.8	0.22	1.91	86	0.77
unit_sta08056500_1974_0505	17.0	0.14	2.32	88	1.21
unit_sta08056500_1974_0916a	8.3	0.24	1.98	86	0.86
unit_sta08056500_1974_0916b	8.0	0.17	1.37	94	0.82
unit_sta08056500_1974_1030	16.8	0.20	3.38	84	1.87
unit_sta08056500_1975_0131b	20.3	0.13	2.61	91	1.74
unit_sta08056500_1975_0407	30.0	0.08	2.43	87	1.23
unit_sta08056500_1976_0417a	18.0	0.05	0.9	90	0.27
unit_sta08056500_1976_0417b	10.5	0.27	2.8	86	1.49
unit_sta08056500_1977_0326	22.0	0.25	5.53	78	3.21
unit_sta08056500_1977_0612	6.5	0.31	2.04	79	0.55
unit_sta08056500_1978_0323	3.0	0.42	1.27	88	0.43
unit_sta08056500_1979_0330	18.0	0.18	3.27	89	2.13
unit_sta08056500_1979_0503	11.0	0.38	4.23	87	2.86
unit_sta08056500_1979_0510a	7.8	0.18	1.39	89	0.55
unit_sta08056500_1979_0510b	11.5	0.09	0.99	95	0.56
unit_sta08057020_1973_0707	4.0	0.73	2.93	88	1.77
unit_sta08057020_1974_0920	5.3	0.66	3.45	79	1.49
unit_sta08057020_1975_0821	1.8	0.70	1.23	87	0.37
unit_sta08057020_1977_0820	7.0	0.54	3.76	70	1.16
unit_sta08057020_1979_0319	5.0	0.24	1.2	95	0.71
unit_sta08057020_1979_0330	8.0	0.31	2.5	85	1.18
unit_sta08057050_1974_0920	5.0	0.65	3.225	84	1.69
unit_sta08057120_1973_1030	6.8	0.12	0.85	100	0.80
unit_sta08057120_1975_0628	3.8	0.28	1.06	95	0.61
unit_sta08057120_1977_0414	11.5	0.14	1.62	90	0.78
unit_sta08057120_1978_0805a	1.3	0.84	1.05	82	0.13
unit_sta08057120_1978_0805b	3.3	0.43	1.405	80	0.23
unit_sta08057130_1973_0619	4.0	0.63	2.52	89	1.49
unit_sta08057130_1973_1030a	5.3	0.18	0.97	82	0.11
unit_sta08057130_1973_1030b	3.3	0.51	1.71	94	1.14
unit_sta08057130_1975_0407	26.5	0.09	2.46	91	1.61
unit_sta08057130_1976_0618	4.0	0.44	1.77	86	0.67
unit_sta08057130_1977_0327	18.0	0.33	5.88	91	4.83
unit_sta08057130_1978_0528	12.5	0.18	2.25	93	1.55

unit_sta08057130_1979_0330	10.8	0.23	2.45	93	1.70
unit_sta08057140_1973_0619	5.3	0.49	2.557	76	0.72
unit_sta08057140_1974_0607a	1.4	1.86	2.64	74	0.68
unit_sta08057140_1974_0607b	1.3	0.58	0.73	91	0.20
unit_sta08057140_1975_0529	3.5	0.33	1.15	89	0.37
unit_sta08057140_1976_0526	1.3	0.82	1.03	95	0.58
unit_sta08057140_1978_0528a	3.0	0.68	2.04	83	0.70
unit_sta08057140_1978_0528b	5.0	0.09	0.45	95	0.13
unit_sta08057160_1974_0916	8.3	0.19	1.6	97	1.29
unit_sta08057160_1974_0917	11.0	0.13	1.47	96	1.09
unit_sta08057160_1975_0529	3.3	0.39	1.28	93	0.65
unit_sta08057160_1977_0326	20.5	0.22	4.6	87	3.16
unit_sta08057160_1978_0323	3.0	0.52	1.56	86	0.54
unit_sta08057160_1979_0503	5.3	0.54	2.899	97	2.55
unit_sta08057160_1979_0715	2.3	0.67	1.5	92	0.82
unit_sta08057320_1973_1030	10.3	0.19	1.97	95	1.42
unit_sta08057320_1975_0527	18.5	0.11	2.11	95	1.57
unit_sta08057320_1977_0327	15.0	0.32	4.86	83	3.02
unit_sta08057415_1973_0310	2.5	0.98	2.46	96	2.02
unit_sta08057415_1974_0917	9.3	0.31	2.88	90	1.85
unit_sta08057415_1975_0506	2.3	0.47	1.05	91	0.38
unit_sta08057415_1976_0418b	9.2	0.49	4.49	82	2.64
unit_sta08057415_1976_0418c	9.1	0.09	0.83	99	0.69
unit_sta08057415_1977_0327	15.0	0.22	3.354	92	2.52
unit_sta08057415_1978_0805	11.0	0.16	1.76	76	0.31
unit_sta08057415_1979_0330	9.0	0.20	1.82	89	0.88
unit_sta08057415_1979_0503	7.2	0.37	2.64	92	1.80
unit_sta08057418_1976_0526	0.4	2.76	1.15	93	0.60
unit_sta08057418_1977_0326	19.5	0.12	2.41	96	1.97
unit_sta08057418_1977_0820	15.0	0.22	3.3	72	0.99
unit_sta08057418_1979_0330	13.1	0.15	1.907	87	0.86
unit_sta08057418_1979_0503	6.5	0.71	4.639	89	3.40
unit_sta08057420_1973_0707	3.5	0.73	2.57	86	1.32
unit_sta08057420_1974_0920	11.3	0.22	2.51	94	1.87
unit_sta08057420_1975_0407	26.0	0.10	2.47	89	1.44
unit_sta08057420_1976_0418a	7.0	0.13	0.89	89	0.23
unit_sta08057420_1976_0418b	13.5	0.37	5.02	90	3.87
unit_sta08057420_1976_0703	3.5	0.58	2.02	80	0.58
unit_sta08057420_1977_0326	21.5	0.14	3.03	88	1.86
unit_sta08057420_1977_0820	5.3	0.62	3.26	69	0.83
unit_sta08057420_1979_0330	9.5	0.19	1.84	91	1.05
unit_sta08057425_1973_0707	3.5	0.73	2.57	83	1.08

unit_sta08057425_1975_0527	11.3	0.17	1.885	89	0.90
unit_sta08057425_1976_0418b	12.3	0.44	5.45	96	4.93
unit_sta08057425_1976_0703	3.3	0.78	2.55	82	1.03
unit_sta08057425_1977_0820	5.3	0.62	3.27	64	0.60
unit_sta08057425_1978_0511	2.5	0.52	1.29	86	0.34
unit_sta08057425_1979_0330	7.5	0.23	1.72	90	0.86
unit_sta08057425_1979_0503	7.8	0.61	4.69	97	4.36
unit_sta08057435_1976_0530	7.3	0.41	3.03	84	1.55
unit_sta08057435_1977_0327	14.5	0.25	3.65	84	2.04
unit_sta08057435_1979_0503	7.8	0.23	1.75	96	1.29
unit_sta08057440_1976_0530	13.7	0.20	2.729	79	0.99
unit_sta08057440_1977_0327	13.0	0.30	3.84	79	1.80
unit_sta08057445_1976_0418	48.0	0.14	6.62	59	2.26
unit_sta08057445_1976_0618	3.3	0.97	3.16	69	0.76
unit_sta08057445_1977_0302	13.3	0.19	2.58	88	1.45
unit_sta08057445_1977_0326	49.0	0.10	4.94	65	1.65
unit_sta08057445_1977_0419	20.0	0.11	2.11	87	0.98
unit_sta08057445_1978_0212	21.0	0.11	2.41	75	0.61
unit_sta08057445_1979_0330	13.5	0.17	2.29	85	1.00
unit_sta08057445_1979_0503	9.5	0.33	3.16	74	1.02
unit_sta08061620_1973_0619	3.5	0.71	2.5	87	1.28
unit_sta08061620_1974_0916	26.0	0.21	5.55	80	3.35
unit_sta08061620_1974_1030	10.3	0.32	3.24	93	2.46
unit_sta08061620_1977_0326	19.5	0.22	4.26	93	3.51
unit_sta08061620_1978_0528	10.5	0.21	2.19	79	0.62
unit_sta08061620_1979_0330	12.0	0.28	3.4	90	2.38
unit_sta08061620_1979_0503	5.6	0.55	3.05	95	2.53
unit_sta08061920_1973_0423	30.0	0.10	2.94	90	1.96
unit_sta08061920_1974_0920	16.0	0.15	2.46	95	1.90
unit_sta08061920_1975_0131	38.8	0.10	3.82	93	3.06
unit_sta08061920_1975_0407	22.8	0.10	2.26	91	1.36
unit_sta08061920_1976_0418	46.3	0.13	5.86	85	4.22
unit_sta08061920_1978_0323	2.8	0.52	1.43	87	0.50
unit_sta08061920_1978_1231	11.8	0.10	1.18	90	0.44
unit_sta08061920_1979_0330	8.5	0.25	2.1	84	0.84

Appendix Table C3. Fort Worth storm parameters.

Code	t_d (hr)	*i* (in)	*P* (in)	CN	*D* (in)
unit_sta08048520_1970_0430	7.8	0.15	1.19	90	0.44
unit_sta08048520_1970_0530	50.5	0.04	2.2	75	0.47

unit_sta08048520_1970_0916	21.8	0.07	1.55	76	0.20
unit_sta08048520_1971_0729	17.5	0.09	1.53	83	0.39
unit_sta08048520_1971_1019	23.0	0.21	4.9	72	2.12
unit_sta08048520_1971_1208	11.3	0.10	1.09	94	0.55
unit_sta08048520_1972_0429	1.8	0.38	0.66	94	0.24
unit_sta08048520_1973_0310	2.0	0.50	1	90	0.30
unit_sta08048520_1973_0417	13.8	0.10	1.36	91	0.62
unit_sta08048520_1973_0603	24.3	0.20	4.96	70	2.00
unit_sta08048520_1973_0728	15.8	0.20	3.21	65	0.62
unit_sta08048520_1973_1011	6.0	0.34	2.04	73	0.35
unit_sta08048520_1973_1012	12.0	0.14	1.72	85	0.59
unit_sta08048520_1974_0612	3.3	0.66	2.14	79	0.62
unit_sta08048520_1975_0523	39.0	0.04	1.54	86	0.52
unit_sta08048520_1975_0608	17.5	0.14	2.47	82	0.96
unit_sta08048520_1975_0610	4.0	0.24	0.97	95	0.54
unit_sta08048520_1976_0419	3.8	0.53	1.99	94	1.40
unit_sta08048520_1976_0530	5.0	0.26	1.3	86	0.36
unit_sta08048520_1976_0919	4.0	0.33	1.32	82	0.25
unit_sta08048520_1977_0327	22.3	0.22	4.86	89	3.62
unit_sta08048520_1977_0521	3.0	0.34	1.01	82	0.12
unit_sta08048530_1970_0530a	3.7	0.33	1.21	82	0.20
unit_sta08048530_1970_0530b	7.0	0.14	0.95	88	0.22
unit_sta08048530_1971_0527	3.8	0.22	0.83	86	0.11
unit_sta08048530_1971_0728	6.6	0.21	1.4	81	0.27
unit_sta08048530_1971_0729	4.0	0.37	1.46	87	0.52
unit_sta08048530_1971_0814a	1.8	0.42	0.73	88	0.12
unit_sta08048530_1971_0814b	0.7	1.20	0.8	90	0.21
unit_sta08048530_1971_1019b	3.8	0.49	1.87	94	1.31
unit_sta08048530_1971_1208	8.0	0.16	1.25	90	0.47
unit_sta08048530_1972_0429	2.8	0.36	1.02	86	0.21
unit_sta08048530_1973_0417	6.8	0.23	1.56	85	0.51
unit_sta08048530_1973_0603c	4.1	0.38	1.55	90	0.72
unit_sta08048530_1974_0607a	3.3	0.22	0.72	86	0.07
unit_sta08048530_1974_0607b	0.8	1.32	0.99	84	0.15
unit_sta08048530_1975_0511	4.3	0.37	1.62	78	0.29
unit_sta08048530_1975_0608a	0.9	0.47	0.43	92	0.06
unit_sta08048530_1975_0915	4.0	0.23	0.92	87	0.19
unit_sta08048530_1976_0419	3.1	0.42	1.31	93	0.68
unit_sta08048530_1976_0829	1.2	0.79	0.92	87	0.19
unit_sta08048540_1970_0425b	2.6	0.38	0.99	94	0.47
unit_sta08048540_1971_0527	8.8	0.11	0.94	90	0.29
unit_sta08048540_1971_0728	6.6	0.22	1.48	85	0.45

unit_sta08048540_1971_0729	4.0	0.40	1.6	91	0.82
unit_sta08048540_1971_0814a	2.3	0.27	0.62	92	0.15
unit_sta08048540_1971_0814b	0.7	1.04	0.69	94	0.24
unit_sta08048540_1971_1019b	4.3	0.57	2.41	96	1.95
unit_sta08048540_1971_1208a	2.3	0.19	0.43	94	0.11
unit_sta08048540_1971_1208b	3.8	0.22	0.82	96	0.45
unit_sta08048540_1971_1209	19.8	0.10	2.02	93	1.33
unit_sta08048540_1972_0429	2.8	0.38	1.07	90	0.36
unit_sta08048540_1973_0417a	3.5	0.37	1.29	89	0.46
unit_sta08048540_1973_0603b	6.1	0.30	1.83	86	0.72
unit_sta08048540_1973_0603c	4.1	0.38	1.57	91	0.82
unit_sta08048540_1973_0728	9.0	0.46	4.11	76	1.80
unit_sta08048540_1973_1011	13.4	0.17	2.302	79	0.71
unit_sta08048540_1974_0607a	3.3	0.22	0.73	91	0.19
unit_sta08048540_1974_0607b	0.8	1.40	1.05	88	0.28
unit_sta08048540_1974_0810	12.0	0.11	1.3	83	0.27
unit_sta08048540_1975_0511	4.3	0.35	1.53	84	0.42
unit_sta08048540_1975_0608a	0.9	0.45	0.41	94	0.09
unit_sta08048540_1975_0608b	1.8	0.22	0.39	95	0.10
unit_sta08048540_1975_0608c	2.9	0.39	1.15	92	0.53
unit_sta08048540_1975_0915	4.0	0.26	1.04	89	0.32
unit_sta08048540_1976_0419	3.1	0.42	1.31	94	0.74
unit_sta08048540_1976_0829	1.2	0.70	0.82	90	0.21
unit_sta08048550_1969_0416	2.7	0.65	1.736	77	0.32
unit_sta08048550_1969_0506	7.4	0.33	2.452	72	0.52
unit_sta08048550_1970_0430	3.7	0.41	1.51	81	0.31
unit_sta08048550_1970_0530	16.0	0.17	2.711	70	0.56
unit_sta08048550_1970_1023	1.3	0.83	1.1	77	0.08
unit_sta08048550_1971_0815	1.7	0.92	1.54	80	0.30
unit_sta08048550_1973_0310	1.5	0.73	1.1	84	0.19
unit_sta08048550_1973_0603a	2.3	0.51	1.2	84	0.23
unit_sta08048550_1973_0603b	15.5	0.12	1.902	84	0.70
unit_sta08048550_1973_0715	8.8	0.25	2.15	90	1.20
unit_sta08048550_1973_1012	18.3	0.09	1.68	92	0.93
unit_sta08048550_1974_0826	15.0	0.25	3.82	74	1.49
unit_sta08048550_1974_0920	1.3	1.20	1.6	93	0.97
unit_sta08048550_1975_0407	5.0	0.23	1.14	96	0.78
unit_sta08048550_1975_0724a	1.2	1.29	1.5	78	0.23
unit_sta08048550_1975_0724b	25.0	0.25	6.27	84	4.50
unit_sta08048550_1976_0530	7.1	0.45	3.17	84	1.67
unit_sta08048550_1976_0716	2.8	0.45	1.24	88	0.38
unit_sta08048600_1969_0416	4.3	0.44	1.85	86	0.74

unit_sta08048600_1969_0506	26.2	0.12	3.1	80	1.30
unit_sta08048600_1969_1012	5.7	0.46	2.61	71	0.55
unit_sta08048600_1970_0430	8.6	0.18	1.52	88	0.60
unit_sta08048600_1970_0530	16.8	0.16	2.74	74	0.73
unit_sta08048600_1970_0916	23.3	0.17	3.91	65	1.00
unit_sta08048600_1970_1023	1.8	0.51	0.93	86	0.16
unit_sta08048600_1971_0529	15.5	0.09	1.34	82	0.25
unit_sta08048600_1971_0815	2.0	0.86	1.71	81	0.43
unit_sta08048600_1971_1019a	9.8	0.10	0.97	89	0.28
unit_sta08048600_1971_1019b	4.0	0.63	2.51	81	0.97
unit_sta08048600_1971_1202	14.0	0.11	1.59	87	0.61
unit_sta08048600_1971_1209	22.0	0.12	2.56	88	1.42
unit_sta08048600_1973_0310	2.5	0.58	1.44	88	0.54
unit_sta08048600_1973_0715	9.0	0.24	2.14	86	0.94
unit_sta08048600_1973_1012	18.3	0.10	1.91	82	0.61
unit_sta08048600_1974_0826	33.0	0.12	3.97	67	1.13
unit_sta08048600_1974_0920	13.3	0.14	1.9	84	0.66
unit_sta08048600_1975_0407	22.0	0.14	2.97	80	1.22
unit_sta08048600_1975_0724	31.8	0.21	6.67	64	2.71
unit_sta08048600_1976_0716	9.8	0.12	1.2	84	0.24
unit_sta08048600_1977_0327	13.5	0.28	3.8	82	2.01
unit_sta08048600_1977_0521	1.3	1.13	1.41	81	0.27
unit_sta08048600_1977_0812	1.3	1.66	2.07	74	0.38
unit_sta08048820_1969_0416	4.2	0.43	1.78	85	0.62
unit_sta08048820_1969_0506	21.5	0.11	2.36	93	1.62
unit_sta08048820_1971_0529	13.5	0.14	1.94	78	0.44
unit_sta08048820_1971_1019	23.3	0.09	2.18	72	0.37
unit_sta08048820_1971_1202	13.3	0.11	1.4	80	0.25
unit_sta08048820_1971_1208	37.0	0.10	3.75	93	2.93
unit_sta08048820_1972_1021	30.0	0.12	3.63	60	0.59
unit_sta08048820_1973_0310	6.8	0.12	0.81	93	0.32
unit_sta08048820_1973_0715	16.0	0.05	0.82	96	0.49
unit_sta08048820_1973_1012	19.0	0.10	1.83	88	0.85
unit_sta08048820_1974_0826	15.0	0.26	3.86	57	0.57
unit_sta08048820_1974_0920	13.8	0.13	1.84	89	0.87
unit_sta08048820_1974_1109	19.0	0.08	1.55	94	0.95
unit_sta08048820_1975_0725	20.0	0.19	3.81	68	1.09
unit_sta08048820_1976_0530	8.3	0.39	3.18	74	1.01
unit_sta08048820_1976_0716	3.5	0.51	1.8	79	0.42
unit_sta08048820_1977_0211	9.8	0.05	0.53	96	0.22
unit_sta08048850_1969_0314	33.0	0.05	1.59	87	0.58
unit_sta08048850_1969_0416	4.5	0.34	1.52	90	0.70

unit_sta08048850_1969_0506	47.5	0.06	2.94	87	1.69
unit_sta08048850_1969_1228	32.3	0.06	2.04	81	0.62
unit_sta08048850_1970_0430	8.8	0.18	1.61	91	0.86
unit_sta08048850_1970_0716	21.8	0.20	4.31	53	0.57
unit_sta08048850_1971_0529	13.5	0.13	1.72	70	0.14
unit_sta08048850_1971_0815	2.3	0.28	0.64	92	0.15
unit_sta08048850_1971_1019	23.5	0.11	2.61	76	0.76
unit_sta08048850_1971_1202	15.0	0.10	1.49	84	0.42
unit_sta08048850_1971_1208	36.8	0.09	3.49	95	2.95
unit_sta08048850_1972_1021	29.5	0.11	3.34	56	0.34
unit_sta08048850_1973_0310	6.8	0.14	0.94	92	0.35
unit_sta08048850_1973_0715	15.5	0.10	1.58	92	0.87
unit_sta08048850_1973_1012	19.0	0.09	1.71	85	0.61
unit_sta08048850_1974_0826	15.0	0.25	3.71	54	0.37
unit_sta08048850_1974_0920	15.0	0.13	1.89	87	0.84
unit_sta08048850_1974_1030	21.5	0.12	2.53	90	1.53
unit_sta08048850_1975_0407	22.5	0.13	2.89	75	0.88
unit_sta08048850_1975_0724	31.8	0.19	5.94	64	2.22
unit_sta08048850_1976_0530	8.3	0.40	3.27	66	0.68
unit_sta08048850_1976_0716	3.3	0.58	1.89	71	0.22
unit_sta08048850_1976_1029	19.0	0.08	1.46	76	0.18
unit_sta08048850_1977_0327	22.5	0.14	3.24	80	1.46
unit_sta08048850_1977_0521	1.5	0.91	1.37	71	0.06

Appendix Table C4. San Antonio storm parameters.

Code	t_d (hr)	i (in)	P (in)	CN	D (in)
unit_sta08177600_1970_0526	3.5	0.75	2.63	68	0.45
unit_sta08177600_1972_0511	7.8	0.16	1.203	91	0.49
unit_sta08177600_1973_1011	2.8	0.09	0.25	99	0.16
unit_sta08177600_1974_0808	8.0	0.36	2.89	66	0.50
unit_sta08177600_1974_0830	4.8	0.18	0.85	94	0.39
unit_sta08177600_1978_0913	8.2	0.50	4.06	82	2.22
unit_sta08177600_1979_0320	6.8	0.21	1.41	91	0.68
unit_sta08178300_1969_0314	20.8	0.07	1.39	81	0.26
unit_sta08178300_1969_0503	5.0	0.45	2.25	75	0.50
unit_sta08178300_1969_0515	4.6	0.26	1.2	87	0.34
unit_sta08178300_1969_1005	10.0	0.27	2.72	68	0.49
unit_sta08178300_1970_0522	11.5	0.08	0.92	86	0.17
unit_sta08178300_1970_0528	9.8	0.08	0.74	90	0.17
unit_sta08178300_1971_0524	1.0	0.74	0.74	85	0.07

unit_sta08178300_1972_0427b	0.8	1.48	1.11	89	0.35
unit_sta08178300_1973_0926	28.5	0.20	5.573	65	2.06
unit_sta08178300_1973_1011	9.1	0.18	1.66	83	0.48
unit_sta08178300_1975_0610a	1.1	1.01	1.09	86	0.26
unit_sta08178300_1976_0506	12.7	0.31	3.95	80	2.02
unit_sta08178300_1976_0829	14.1	0.21	2.97	74	0.87
unit_sta08178300_1977_0521	1.2	1.04	1.21	89	0.42
unit_sta08178300_1977_0531	0.7	0.50	0.33	98	0.20
unit_sta08178300_1977_0601	8.8	0.08	0.68	92	0.19
unit_sta08178300_1978_0801	33.0	0.11	3.62	76	1.48
unit_sta08178300_1979_0321b	1.0	0.49	0.49	95	0.15
unit_sta08178555_1977_1101	9.4	0.28	2.62	76	0.78
unit_sta08178555_1978_0410	2.7	0.51	1.36	86	0.39
unit_sta08178555_1979_0420	5.8	0.33	1.92	76	0.36
unit_sta08178555_1979_0601	15.0	0.19	2.885	77	1.00
unit_sta08178555_1979_0605	13.0	0.13	1.659	86	0.61
unit_sta08178555_1979_0705	5.5	0.22	1.22	85	0.27
unit_sta08178555_1980_0513	2.2	0.55	1.19	83	0.23
unit_sta08178600_1969_0826	7.0	0.12	0.84	83	0.08
unit_sta08178600_1970_0526	4.3	0.52	2.19	60	0.11
unit_sta08178600_1971_1205	20.3	0.09	1.81	74	0.27
unit_sta08178600_1972_0511	18.8	0.20	3.75	84	2.16
unit_sta08178600_1973_0716	20.5	0.23	4.628	61	1.12
unit_sta08178600_1973_0926	22.3	0.13	2.85	67	0.50
unit_sta08178600_1973_1011	10.0	0.19	1.94	70	0.23
unit_sta08178620_1981_0423	10.5	0.17	1.77	62	0.04
unit_sta08178620_1981_0529	9.6	0.19	1.82	57	0.01
unit_sta08178640_1976_0526	6.4	0.29	1.85	64	0.08
unit_sta08178640_1976_0928	4.8	0.35	1.69	71	0.15
unit_sta08178640_1978_0913	8.3	0.33	2.71	64	0.36
unit_sta08178640_1979_0110	8.8	0.07	0.628	92	0.16
unit_sta08178640_1979_0601	11.3	0.22	2.422	60	0.16
unit_sta08178645_1976_0526	6.8	0.28	1.91	65	0.11
unit_sta08178645_1976_0706	5.0	0.33	1.67	75	0.22
unit_sta08178690_1969_0115	1.8	0.31	0.56	92	0.11
unit_sta08178690_1969_1005	3.0	0.58	1.753	76	0.30
unit_sta08178690_1975_0430	3.7	0.09	0.32	100	0.28
unit_sta08178690_1976_0506b	4.9	0.48	2.38	87	1.23
unit_sta08178690_1976_0818	2.1	0.59	1.23	86	0.34
unit_sta08178690_1976_1019	4.6	0.27	1.24	92	0.61
unit_sta08178690_1977_0419	22.0	0.19	4.11	93	3.30
unit_sta08178690_1977_1101	16.3	0.35	5.683	78	3.29

unit_sta08178690_1978_1126	2.5	0.77	1.92	92	1.18
unit_sta08178690_1981_0529	7.5	0.36	2.72	86	1.46
unit_sta08178736_1972_0507	12.3	0.34	4.17	74	1.75
unit_sta08178736_1973_0926	21.3	0.31	6.54	92	5.65
unit_sta08178736_1975_0508	1.0	1.83	1.83	83	0.60
unit_sta08178736_1976_0526	3.3	0.74	2.47	83	1.01
unit_sta08178736_1976_0928	3.5	0.32	1.13	88	0.34
unit_sta08181000_1970_0526	4.3	0.70	2.99	63	0.44
unit_sta08181000_1972_0506a	5.3	0.38	2.04	61	0.08
unit_sta08181000_1972_0511	26.9	0.08	2.159	77	0.54
unit_sta08181000_1973_0417	4.0	0.44	1.75	76	0.29
unit_sta08181000_1973_0716	17.0	0.27	4.547	64	1.30
unit_sta08181000_1978_1231	14.1	0.11	1.53	69	0.08
unit_sta08181000_1979_0110	9.4	0.13	1.25	75	0.09
unit_sta08181400_1969_0516	3.5	0.63	2.21	59	0.09
unit_sta08181400_1970_0523	16.0	0.15	2.41	55	0.06
unit_sta08181400_1970_0526	4.8	0.53	2.52	68	0.41
unit_sta08181400_1971_0812	10.0	0.21	2.1	57	0.05
unit_sta08181400_1971_0813	21.5	0.09	2.01	65	0.14
unit_sta08181400_1972_0507	12.5	0.04	0.529	46	0.34
unit_sta08181400_1973_0716	13.0	0.39	5.04	69	2.01
unit_sta08181400_1973_0916	16.5	0.03	0.5352	99	0.46
unit_sta08181400_1974_0912	14.0	0.22	3.097	58	0.30
unit_sta08181400_1976_0417	24.3	0.03	0.6575	99	0.58
unit_sta08181400_1976_0506	12.1	0.22	2.62	64	0.30
unit_sta08181400_1976_1023	25.8	0.11	2.84	78	0.99
unit_sta08181400_1981_0612	14.1	0.03	0.4151	99	0.34
unit_sta08181450_1969_0824	7.2	0.38	2.72	67	0.44
unit_sta08181450_1970_0514	17.5	0.25	4.38	61	1.03
unit_sta08181450_1971_0524	1.1	0.75	0.81	86	0.12
unit_sta08181450_1971_0622	1.5	1.14	1.71	81	0.45
unit_sta08181450_1972_0803	7.8	0.33	2.52	75	0.64
unit_sta08181450_1972_0926	2.5	0.60	1.49	85	0.43
unit_sta08181450_1973_0415a	6.0	0.22	1.31	86	0.36
unit_sta08181450_1973_0415b	1.0	0.74	0.74	94	0.28
unit_sta08181450_1973_0926	14.0	0.46	6.45	57	1.94
unit_sta08181450_1974_0509	6.2	0.19	1.2	85	0.27
unit_sta08181450_1974_0807a	12.0	0.27	3.19	72	0.92
unit_sta08181450_1974_0807b	9.8	0.51	4.98	72	2.19
unit_sta08181450_1974_1123	7.7	0.22	1.66	78	0.30
unit_sta08181450_1975_0508	2.0	0.71	1.41	82	0.30
unit_sta08181450_1975_1025	21.3	0.11	2.34	72	0.45

unit_sta08181450_1976_0520	4.3	0.25	1.08	89	0.34
unit_sta08181450_1976_0616	1.3	0.95	1.19	82	0.20
unit_sta08181450_1976_0928	3.8	0.43	1.63	84	0.49
unit_sta08181450_1976_1019	3.8	0.31	1.18	88	0.36
unit_sta08181450_1977_0509	1.7	0.44	0.74	95	0.32
unit_sta08181450_1977_0912	10.3	0.27	2.75	71	0.62
unit_sta08181450_1978_0907	13.0	0.28	3.66	67	0.95
unit_sta08181450_1979_0419a	3.0	0.17	0.5	95	0.19
unit_sta08181450_1979_0419b	7.5	0.23	1.76	82	0.51

Appendix Table C5. Storm parameters in rural watersheds.

Code	t_d (hr)	i (in)	P (in)	CN	D (in)
unit_sta08042650_1973_0730	11.0	0.16	1.8	79	0.41
unit_sta08042650_1973_1012	12.3	0.16	2.02	72	0.31
unit_sta08042650_1974_1030	15.0	0.19	2.88	78	1.03
unit_sta08042650_1975_0502	1.3	1.73	2.3	73	0.46
unit_sta08042650_1975_0826	5.3	0.40	2.08	64	0.13
unit_sta08042650_1976_0419	9.0	0.19	1.72	72	0.18
unit_sta08042650_1976_0919	17.5	0.25	4.44	52	0.58
unit_sta08042650_1977_0326	18.5	0.19	3.6	64	0.78
unit_sta08042650_1977_0523	1.3	1.32	1.65	75	0.23
unit_sta08042650_1978_0409	13.0	0.36	4.62	53	0.67
unit_sta08042650_1978_0805	3.0	0.40	1.19	84	0.23
unit_sta08042650_1979_0417	12.5	0.16	2.05	66	0.17
unit_sta08050200_1961_0325	10.3	0.16	1.6	85	0.53
unit_sta08050200_1962_0423	22.5	0.13	2.83	91	1.94
unit_sta08050200_1962_0618	1.1	2.12	2.3	82	0.86
unit_sta08050200_1962_0906	42.3	0.09	3.75	87	2.42
unit_sta08050200_1962_1126	24.0	0.12	2.82	75	0.87
unit_sta08050200_1963_0530	9.0	0.17	1.5	79	0.25
unit_sta08050200_1964_0915	13.8	0.04	0.513	48	0.29
unit_sta08050200_1964_0920	5.0	0.46	2.3	87	1.12
unit_sta08050200_1965_0613	10.5	0.17	1.79	75	0.30
unit_sta08050200_1965_1018	6.4	0.29	1.84	79	0.42
unit_sta08050200_1967_0530_1500	17.0	0.18	3.02	91	2.11
unit_sta08050200_1968_0118	35.0	0.05	1.89	71	0.22
unit_sta08050200_1968_0311	29.8	0.03	1	98	0.84
unit_sta08050200_1968_0320	10.0	0.21	2.08	61	0.09
unit_sta08050200_1969_0322	24.0	0.08	2.03	92	1.29
unit_sta08050200_1969_0504	4.8	0.51	2.4	90	1.42
unit_sta08050200_1969_0506	15.8	0.17	2.615	95	2.05

unit_sta08050200_1970_0418	4.0	0.38	1.5	84	0.40
unit_sta08050200_1970_0430	1.2	0.86	1	93	0.45
unit_sta08050200_1970_0925	6.0	0.25	1.5	85	0.45
unit_sta08052630_1966_0423a	19.3	0.05	1	96	0.63
unit_sta08052630_1966_0423b	8.0	0.15	1.18	89	0.40
unit_sta08052630_1966_0427	45.0	0.14	6.2	81	4.09
unit_sta08052630_1966_0830	0.5	3.20	1.6	76	0.23
unit_sta08052630_1967_0530	27.0	0.21	5.56	79	3.31
unit_sta08052630_1968_0422	0.5	2.96	1.48	88	0.57
unit_sta08052630_1968_0509	1.8	0.79	1.39	87	0.45
unit_sta08052630_1968_0510	6.0	0.25	1.49	94	0.93
unit_sta08052630_1968_0512	2.3	0.36	0.81	96	0.47
unit_sta08052630_1969_0220	32.9	0.05	1.56	96	1.12
unit_sta08052630_1969_0506	24.3	0.15	3.67	84	2.07
unit_sta08052630_1969_1228	29.0	0.09	2.483	84	1.12
unit_sta08052630_1970_0430	7.8	0.20	1.55	96	1.17
unit_sta08052630_1971_1117	2.9	0.98	2.85	87	1.61
unit_sta08052630_1973_0102	5.3	0.17	0.87	94	0.41
unit_sta08052630_1973_0730	6.3	0.28	1.73	88	0.75
unit_sta08052630_1973_0926	8.5	0.33	2.8	90	1.79
unit_sta08052630_1973_1011	5.3	0.26	1.39	95	0.95
unit_sta08052630_1973_1030	7.5	0.18	1.32	97	1.02
unit_sta08052630_1974_0924	13.0	0.09	1.23	96	0.84
unit_sta08052630_1974_1030	23.3	0.30	6.99	91	5.89
unit_sta08052630_1975_0407	23.0	0.10	2.26	90	1.31
unit_sta08052630_1975_0608	20.5	0.10	2.13	88	1.08
unit_sta08052630_1975_0609	12.0	0.19	2.31	86	1.07
unit_sta08052630_1976_0419	8.0	0.27	2.13	91	1.27
unit_sta08052630_1976_0506	4.0	0.26	1.04	94	0.54
unit_sta08057500_1960_0826	0.8	1.85	1.54	80	0.29
unit_sta08057500_1961_0106	25.0	0.07	1.64	85	0.53
unit_sta08057500_1961_0430a	1.3	1.49	1.98	76	0.41
unit_sta08057500_1961_0430b	1.3	0.96	1.28	97	1.00
unit_sta08057500_1962_0423a	27.5	0.06	1.52	81	0.33
unit_sta08057500_1962_0423b	15.5	0.09	1.46	92	0.74
unit_sta08057500_1962_0906a	11.0	0.19	2.13	63	0.14
unit_sta08057500_1962_0906b	9.0	0.08	0.76	87	0.10
unit_sta08057500_1963_0527	28.0	0.09	2.43	69	0.38
unit_sta08057500_1963_0530	11.3	0.18	2.01	89	1.02
unit_sta08057500_1964_0916	9.0	0.06	0.552	49	0.27
unit_sta08057500_1964_0920	8.3	0.61	5.05	70	2.11
unit_sta08057500_1964_1117	49.8	0.11	5.67	80	3.53

unit_sta08057500_1965_0208	26.0	0.08	2.09	92	1.33
unit_sta08057500_1966_0427	21.0	0.16	3.32	84	1.75
unit_sta08057500_1966_0429	19.0	0.14	2.64	98	2.40
unit_sta08057500_1967_0530_0700	22.0	0.21	4.54	65	1.35
unit_sta08057500_1967_0905	23.0	0.19	4.41	51	0.51
unit_sta08057500_1968_0319	26.0	0.14	3.56	86	2.19
unit_sta08057500_1968_0418	19.5	0.13	2.63	79	0.93
unit_sta08057500_1968_0516	8.0	0.19	1.53	93	0.88
unit_sta08057500_1969_0221	10.2	0.08	0.83	93	0.34
unit_sta08057500_1969_0506	20.6	0.15	3.14	87	1.88
unit_sta08057500_1969_0514	2.2	0.62	1.35	83	0.31
unit_sta08057500_1969_0517	5.2	0.41	2.14	97	1.76
unit_sta08057500_1969_0623	1.7	0.80	1.34	78	0.17
unit_sta08057500_1970_0601	5.3	0.21	1.08	89	0.35
unit_sta08058000_1959_1215	18.0	0.16	2.83	67	0.51
unit_sta08058000_1960_0203	12.0	0.14	1.68	81	0.40
unit_sta08058000_1960_0525	0.9	1.65	1.51	80	0.28
unit_sta08058000_1960_0608	1.0	1.73	1.73	78	0.35
unit_sta08058000_1961_0106	21.7	0.07	1.47	85	0.45
unit_sta08058000_1961_0430	21.7	0.16	3.51	79	1.57
unit_sta08058000_1962_0423a	21.5	0.07	1.58	85	0.51
unit_sta08058000_1962_0423b	15.7	0.08	1.22	91	0.52
unit_sta08058000_1962_0906a	7.5	0.27	2.05	74	0.39
unit_sta08058000_1963_0527	18.8	0.15	2.74	78	0.96
unit_sta08058000_1963_0530	3.3	0.58	1.87	92	1.13
unit_sta08058000_1964_0422	3.7	0.80	2.93	74	0.88
unit_sta08058000_1964_0916	10.5	0.04	0.3916	100	0.38
unit_sta08058000_1964_0920	11.0	0.43	4.77	77	2.46
unit_sta08058000_1965_0208	29.0	0.09	2.62	91	1.74
unit_sta08058000_1965_0527a	7.8	0.22	1.72	91	0.91
unit_sta08058000_1965_0527b	1.0	0.55	0.55	95	0.20
unit_sta08058000_1966_0427	20.2	0.17	3.483	93	2.73
unit_sta08058000_1966_0429	17.5	0.15	2.68	98	2.43
unit_sta08058000_1967_0530_0200	4.0	0.33	1.32	71	0.05
unit_sta08058000_1967_0530_1700	12.0	0.41	4.87	72	2.13
unit_sta08058000_1967_0905	16.3	0.22	3.657	64	0.80
unit_sta08058000_1969_0623	1.2	0.93	1.09	86	0.24
unit_sta08058000_1970_0302	8.3	0.15	1.25	96	0.84
unit_sta08058000_1970_0425	10.8	0.26	2.82	94	2.21
unit_sta08058000_1970_0430	9.0	0.12	1.08	95	0.64
unit_sta08058000_1970_0601	6.0	0.23	1.39	91	0.66
unit_sta08063200_1959_1003	31.0	0.19	5.79	66	2.26

unit_sta08063200_1959_1215	62.0	0.04	2.55	87	1.36
unit_sta08063200_1959_1231	6.5	0.18	1.17	94	0.65
unit_sta08063200_1960_0104	20.0	0.05	0.96	96	0.57
unit_sta08063200_1960_1018	7.0	0.36	2.49	81	0.95
unit_sta08063200_1960_1206	58.0	0.09	5.46	89	4.24
unit_sta08063200_1961_0215	16.5	0.09	1.56	93	0.92
unit_sta08063200_1961_0617	46.0	0.08	3.5	91	2.52
unit_sta08063200_1961_1121	24.0	0.15	3.7	88	2.49
unit_sta08063200_1962_0427	8.0	0.37	2.96	87	1.67
unit_sta08063200_1962_0528	4.2	0.60	2.5	59	0.16
unit_sta08063200_1965_0509	2.8	0.88	2.42	66	0.28
unit_sta08063200_1965_0514	8.3	0.31	2.59	82	1.05
unit_sta08063200_1965_0516	19.3	0.15	2.84	85	1.46
unit_sta08063200_1966_0417	13.0	0.29	3.79	64	0.84
unit_sta08063200_1967_0417	7.5	0.23	1.71	81	0.43
unit_sta08063200_1967_0611	7.5	0.46	3.47	74	1.21
unit_sta08063200_1967_1109	48.0	0.07	3.3	81	1.55
unit_sta08063200_1968_0310	25.5	0.08	2.09	90	1.19
unit_sta08063200_1968_0426	3.0	0.81	2.42	87	1.27
unit_sta08063200_1968_0509	19.5	0.21	4.1	88	2.83
unit_sta08063200_1968_0602	48.0	0.08	3.6	81	1.79
unit_sta08063200_1968_0623	18.0	0.17	3.02	81	1.30
unit_sta08063200_1969_0404	5.3	0.37	1.95	84	0.71
unit_sta08063200_1969_0505	6.0	0.25	1.49	91	0.75
unit_sta08063200_1970_0306	25.0	0.04	1.12	92	0.49
unit_sta08063200_1971_1210	46.0	0.07	3.42	80	1.59
unit_sta08094000_1959_1003	29.8	0.28	8.45	55	3.07
unit_sta08094000_1961_0106	31.0	0.02	0.639	49	0.23
unit_sta08094000_1961_0204	36.0	0.05	1.938	69	0.19
unit_sta08094000_1961_0709	11.0	0.14	1.5	80	0.28
unit_sta08094000_1961_1009	7.5	0.32	2.4	71	0.45
unit_sta08094000_1962_0907	22.5	0.17	3.73	66	0.91
unit_sta08094000_1962_1008	16.0	0.20	3.13	59	0.36
unit_sta08094000_1963_1108	8.0	0.49	3.9	62	0.79
unit_sta08094000_1964_0421	10.0	0.25	2.52	66	0.33
unit_sta08094000_1964_0921	10.1	0.32	3.25	82	1.58
unit_sta08094000_1965_0208	14.0	0.14	1.95	74	0.32
unit_sta08094000_1966_0430a	6.0	0.36	2.17	77	0.53
unit_sta08094000_1966_0430b	6.0	0.14	0.82	87	0.13
unit_sta08094000_1967_0916	10.3	0.10	1.01	77	0.05
unit_sta08094000_1968_0118	10.8	0.17	1.78	71	0.19
unit_sta08094000_1968_0320	4.5	0.38	1.72	91	0.94

unit_sta08094000_1968_0512	3.0	0.78	2.33	94	1.72
unit_sta08094000_1969_0412	24.0	0.11	2.69	65	0.36
unit_sta08094000_1969_1228	19.0	0.02	0.44	98	0.28
unit_sta08094000_1970_0303	3.0	0.33	1	90	0.31
unit_sta08096800_1959_1003	19.0	0.15	2.857	85	1.46
unit_sta08096800_1959_1215	10.5	0.24	2.52	73	0.58
unit_sta08096800_1960_1206	76.0	0.08	5.7	64	2.04
unit_sta08096800_1961_0205	21.0	0.11	2.23	77	0.57
unit_sta08096800_1961_0608	2.8	0.93	2.57	62	0.24
unit_sta08096800_1961_1121	16.0	0.05	0.85	82	0.07
unit_sta08096800_1962_0528	5.8	0.29	1.669	47	0.03
unit_sta08096800_1962_0601	19.3	0.06	1.15	73	0.04
unit_sta08096800_1962_0630	2.3	0.76	1.71	71	0.16
unit_sta08096800_1964_0318	10.0	0.16	1.56	68	0.08
unit_sta08096800_1964_0426	3.0	0.21	0.64	82	0.02
unit_sta08096800_1965_0121	21.8	0.13	2.81	57	0.20
unit_sta08096800_1965_0329	19.8	0.22	4.31	61	0.97
unit_sta08096800_1966_0208	17.8	0.13	2.39	74	0.54
unit_sta08096800_1966_0424_0055	12.1	0.16	1.97	74	0.34
unit_sta08096800_1966_0425	9.5	0.06	0.53	95	0.21
unit_sta08096800_1966_0520	3.8	0.43	1.64	80	0.36
unit_sta08096800_1966_0521	1.0	0.72	0.72	90	0.15
unit_sta08096800_1967_0917	0.5	1.52	0.76	78	0.01
unit_sta08096800_1967_1109	31.0	0.09	2.67	61	0.24
unit_sta08096800_1968_0623	20.0	0.11	2.12	60	0.08
unit_sta08096800_1968_0702	3.8	0.25	0.97	77	0.04
unit_sta08096800_1968_0708	5.0	0.46	2.32	70	0.39
unit_sta08096800_1969_0322	12.5	0.11	1.34	81	0.23
unit_sta08096800_1969_0412	14.5	0.15	2.18	75	0.47
unit_sta08096800_1969_0417	1.8	0.51	0.9	86	0.15
unit_sta08096800_1969_0505	6.3	0.17	1.06	86	0.23
unit_sta08096800_1970_0223	24.0	0.03	0.67	94	0.25
unit_sta08096800_1970_0306	8.0	0.15	1.21	86	0.30
unit_sta08096800_1970_0307	7.0	0.09	0.64	94	0.22
unit_sta08096800_1970_0316	7.0	0.13	0.88	90	0.24
unit_sta08096800_1971_0725	12.0	0.28	3.34	55	0.30
unit_sta08096800_1971_1117	12.0	0.30	3.552	54	0.34
unit_sta08096800_1971_1209	25.0	0.05	1.35	82	0.27
unit_sta08096800_1973_0324	6.5	0.34	2.2	78	0.58
unit_sta08096800_1973_0525	5.3	0.48	2.53	60	0.19
unit_sta08096800_1973_0603	14.0	0.19	2.64	73	0.63
unit_sta08096800_1974_1123	31.0	0.05	1.432	79	0.22

unit_sta08096800_1975_0201	42.0	0.06	2.66	71	0.59
unit_sta08137000_1961_0603	1.9	1.27	2.43	85	1.14
unit_sta08137000_1961_0605	1.8	0.62	1.13	91	0.44
unit_sta08137000_1961_0615	53.0	0.08	4.008	59	0.71
unit_sta08137000_1961_1009	14.0	0.16	2.19	58	0.07
unit_sta08137000_1962_0907	11.8	0.08	0.91	80	0.06
unit_sta08137000_1962_1012a	10.3	0.14	1.47	74	0.14
unit_sta08137000_1962_1012b	2.8	0.21	0.58	92	0.12
unit_sta08137000_1963_0530	3.5	0.41	1.44	78	0.21
unit_sta08137000_1963_0616	14.5	0.11	1.54	77	0.23
unit_sta08137000_1964_0919a	21.5	0.08	1.8	63	0.06
unit_sta08137000_1964_1116a	14.8	0.21	3.04	73	0.91
unit_sta08137000_1964_1116b	2.0	0.44	0.87	95	0.46
unit_sta08137000_1965_0509	228.8	0.04	10.04	52	3.84
unit_sta08137000_1965_1108	10.0	0.27	2.71	65	0.36
unit_sta08137000_1966_0908	3.0	0.38	1.15	83	0.20
unit_sta08137000_1966_0918	1.3	0.60	0.75	89	0.15
unit_sta08137000_1967_0512	5.0	0.45	2.24	74	0.48
unit_sta08137000_1967_0921	42.0	0.03	1.41	85	0.41
unit_sta08137000_1968_0118	11.8	0.12	1.38	75	0.13
unit_sta08137000_1968_0119	55.8	0.09	5.01	73	2.26
unit_sta08137000_1968_0319	3.6	0.45	1.63	88	0.66
unit_sta08137000_1968_0616	3.3	0.71	2.32	70	0.38
unit_sta08137000_1969_0506	13.5	0.07	0.92	82	0.09
unit_sta08137000_1969_0603	11.7	0.25	2.93	67	0.56
unit_sta08137000_1969_0910	31.3	0.15	4.55	62	1.16
unit_sta08137000_1970_0601	6.0	0.28	1.67	79	0.33
unit_sta08137000_1971_0801	19.8	0.14	2.72	60	0.25
unit_sta08137000_1971_0813	15.0	0.08	1.19	84	0.24
unit_sta08137000_1971_0922	46.8	0.16	7.55	53	2.26
unit_sta08137000_1971_1018	3.5	0.34	1.18	83	0.21
unit_sta08137000_1972_0420	2.3	0.96	2.25	65	0.21
unit_sta08137000_1973_0422	1.9	0.59	1.14	79	0.12
unit_sta08139000_1960_0104	24.0	0.07	1.66	72	0.17
unit_sta08139000_1960_1207	18.0	0.12	2.22	64	0.18
unit_sta08139000_1961_0204	20.0	0.06	1.29	74	0.08
unit_sta08139000_1962_1008	6.8	0.25	1.71	63	0.05
unit_sta08139000_1963_0517b	4.0	0.35	1.38	74	0.12
unit_sta08139000_1963_0530	3.0	0.43	1.3	78	0.16
unit_sta08139000_1964_0527	1.2	0.57	0.67	86	0.06
unit_sta08139000_1964_0528	3.4	0.71	2.43	67	0.32
unit_sta08139000_1964_0920	7.0	0.18	1.244	43	0.17

unit_sta08139000_1965_0208	14.7	0.10	1.43	80	0.24
unit_sta08139000_1965_0509b	17.7	0.14	2.55	69	0.43
unit_sta08139000_1966_0914a	1.6	0.60	0.95	82	0.10
unit_sta08139000_1966_0914b	3.0	0.35	1.05	84	0.18
unit_sta08139000_1966_0914c	7.7	0.10	0.79	88	0.14
unit_sta08139000_1967_1007	1.8	0.54	0.99	81	0.10
unit_sta08139000_1968_0409	6.0	0.21	1.23	80	0.16
unit_sta08139000_1968_0913	10.8	0.05	0.531	92	0.10
unit_sta08139000_1969_0506	6.0	0.39	2.36	77	0.66
unit_sta08139000_1969_0824	1.0	0.90	0.9	84	0.11
unit_sta08139000_1971_0726	11.0	0.59	6.5	55	1.85
unit_sta08139000_1971_0727	13.0	0.13	1.68	88	0.72
unit_sta08139000_1971_0801	11.0	0.36	3.99	79	1.92
unit_sta08140000_1960_0104	24.0	0.07	1.56	81	0.36
unit_sta08140000_1961_0204	24.3	0.08	1.88	76	0.35
unit_sta08140000_1963_0505	17.0	0.09	1.59	82	0.39
unit_sta08140000_1963_0530	2.2	0.41	0.89	81	0.06
unit_sta08140000_1963_0914	15.8	0.05	0.77	82	0.04
unit_sta08140000_1964_0527	4.3	0.55	2.32	67	0.29
unit_sta08140000_1964_0919	20.8	0.14	2.935	53	0.14
unit_sta08140000_1964_0920	7.0	0.23	1.597	42	0.10
unit_sta08140000_1965_0208	14.7	0.10	1.48	81	0.30
unit_sta08140000_1966_0914b	5.3	0.17	0.93	83	0.11
unit_sta08140000_1967_0819	1.1	0.78	0.84	83	0.08
unit_sta08140000_1967_0914	10.2	0.22	2.26	63	0.17
unit_sta08140000_1967_1007	2.0	0.53	1.05	78	0.07
unit_sta08140000_1968_0527	2.0	0.98	1.95	65	0.12
unit_sta08140000_1969_0506	11.3	0.17	1.96	80	0.53
unit_sta08140000_1969_0823	9.1	0.32	2.87	54	0.14
unit_sta08140000_1969_0824	2.2	0.29	0.62	87	0.06
unit_sta08140000_1971_0801	10.0	0.44	4.36	79	2.26
unit_sta08182400_1961_1112	16.3	0.21	3.46	56	0.35
unit_sta08182400_1963_1108	3.3	0.41	1.32	73	0.07
unit_sta08182400_1964_0130	9.0	0.24	2.12	67	0.21
unit_sta08182400_1964_0318	3.5	0.66	2.31	71	0.41
unit_sta08182400_1965_0204	19.0	0.10	1.975	60	0.06
unit_sta08182400_1965_0330	12.0	0.12	1.41	65	0.02
unit_sta08182400_1965_1202	22.8	0.13	3.06	58	0.28
unit_sta08182400_1967_1109	29.0	0.14	4.16	56	0.65
unit_sta08182400_1968_0118	6.1	0.44	2.67	89	1.62
unit_sta08182400_1968_0119	51.5	0.07	3.53	85	2.07
unit_sta08182400_1968_1126	31.3	0.11	3.31	54	0.25

unit_sta08182400_1968_1130	17.5	0.11	1.88	82	0.58
unit_sta08182400_1969_0213	23.3	0.13	3.1	63	0.47
unit_sta08182400_1969_1006	1.1	1.52	1.65	79	0.34
unit_sta08182400_1969_1012	6.0	0.20	1.22	82	0.20
unit_sta08182400_1969_1205	7.0	0.11	0.79	86	0.11
unit_sta08182400_1970_0523	9.0	0.19	1.7	81	0.43
unit_sta08182400_1970_0526	4.0	0.35	1.39	89	0.53
unit_sta08182400_1970_0528	9.8	0.14	1.34	94	0.77
unit_sta08187000_1960_0113	2.0	0.64	1.27	78	0.14
unit_sta08187000_1960_0828b	3.5	0.25	0.87	86	0.13
unit_sta08187000_1960_0828c	1.0	0.78	0.78	87	0.11
unit_sta08187000_1960_1024	36.0	0.32	11.37	63	6.51
unit_sta08187000_1961_0205	8.0	0.25	1.97	75	0.37
unit_sta08187000_1962_0601	3.5	0.62	2.183	77	0.54
unit_sta08187000_1962_0602	4.8	0.11	0.52	86	0.02
unit_sta08187000_1962_1202	2.8	0.31	0.85	85	0.11
unit_sta08187000_1963_1127	12.2	0.27	3.28	52	0.19
unit_sta08187000_1964_0318	6.3	0.27	1.71	67	0.09
unit_sta08187000_1964_0808	6.0	0.73	4.38	55	0.66
unit_sta08187000_1965_0204	8.0	0.27	2.125	67	0.21
unit_sta08187000_1965_0216	11.0	0.21	2.31	75	0.55
unit_sta08187000_1965_0511	3.3	0.80	2.68	58	0.19
unit_sta08187000_1965_0519	6.7	0.17	1.15	90	0.41
unit_sta08187000_1965_1018	4.1	0.47	1.93	63	0.09
unit_sta08187000_1967_0919	53.5	0.26	14.042	61	8.44
unit_sta08187000_1968_0507	3.0	1.43	4.29	63	1.06
unit_sta08187000_1968_0511_0030	2.4	0.59	1.42	84	0.37
unit_sta08187000_1968_0511_1155	3.8	0.20	0.76	85	0.08
unit_sta08187000_1968_0512	2.8	0.35	0.99	92	0.40
unit_sta08187000_1969_0603	2.8	0.70	1.92	65	0.11
unit_sta08187000_1969_0604	9.3	0.33	3.01	53	0.16
unit_sta08187000_1970_0526	1.7	0.59	0.98	83	0.13
unit_sta08187000_1970_0528	4.1	0.32	1.3	83	0.27
unit_sta08187000_1970_0531	1.3	1.30	1.63	85	0.52
unit_sta08187900_1962_1202	3.8	0.48	1.84	69	0.16
unit_sta08187900_1962_1220	4.8	0.35	1.68	61	0.03
unit_sta08187900_1963_0625	5.8	0.33	1.91	71	0.23
unit_sta08187900_1963_1127	12.0	0.20	2.38	54	0.05
unit_sta08187900_1964_0318	8.1	0.22	1.77	65	0.08
unit_sta08187900_1964_0808	8.1	0.14	1.165	48	0.10
unit_sta08187900_1965_0204	15.1	0.19	2.92	59	0.27
unit_sta08187900_1965_0216	20.0	0.11	2.214	73	0.41

unit_sta08187900_1965_0511	5.0	0.67	3.35	54	0.25
unit_sta08187900_1965_0519	8.5	0.32	2.7	85	1.37
unit_sta08187900_1966_0917	1.9	1.32	2.53	56	0.11
unit_sta08187900_1967_0919a	26.9	0.32	8.58	56	3.31
unit_sta08187900_1969_0504	2.0	0.85	1.7	76	0.27
unit_sta08187900_1970_0528	2.8	0.30	0.86	83	0.08
unit_sta08187900_1970_0531	1.9	0.83	1.59	83	0.43
unit_sta08111025_1968_0709	9.3	0.66	6.06	73	3.14
unit_sta08111025_1969_0214	5.5	0.28	1.52	95	1.02
unit_sta08111025_1969_0221	10.3	0.17	1.76	95	1.27
unit_sta08111025_1969_0508	5.0	0.31	1.56	95	1.06
unit_sta08111025_1970_0418	13.0	0.12	1.56	97	1.20
unit_sta08111025_1970_0910	8.0	0.49	3.88	86	2.40
unit_sta08111025_1970_0915	22.0	0.14	3.04	98	2.76
unit_sta08111050_1968_0709	7.8	0.83	6.46	71	3.29
unit_sta08111050_1969_0214	7.5	0.17	1.28	93	0.69
unit_sta08111050_1969_0221	12.0	0.11	1.33	94	0.79
unit_sta08111050_1969_0508	3.8	0.39	1.48	95	1.03
unit_sta08111050_1970_0419	15.5	0.15	2.32	90	1.41
unit_sta08111050_1970_0910	14.5	0.22	3.18	78	1.23

Appendix Table C6. Houston storm parameters.

Code	t_d (hr)	*i* (in)	*P* (in)	CN	*D* (in)
unit_sta08068438_1975_0408	13.5	0.29	3.97	81	2.11
unit_sta08068438_1981_0503	40.8	0.13	5.1	91	4.12
unit_sta08068438_1981_0831	21.3	0.30	6.303	79	3.92
unit_sta08068438_1983_0520	41.3	0.16	6.6	89	5.28
unit_sta08068438_1983_0818	20.8	0.25	5.15	86	3.62
unit_sta08068438_1984_1025	16.8	0.38	6.287	81	4.16
unit_sta08068438_1985_1124	20.8	0.40	8.4	87	6.83
unit_sta08068438_1987_0928	13.3	0.46	6.12	74	3.26
unit_sta08068438_1987_1125	7.8	1.16	9	72	5.60
unit_sta08068440_1974_1124	12.0	0.19	2.25	85	1.00
unit_sta08068440_1975_0408	13.5	0.29	3.97	79	1.92
unit_sta08073630_1979_0917	73.0	0.12	8.6	86	6.86
unit_sta08073630_1979_1212	15.2	0.13	1.995	93	1.27
unit_sta08073630_1981_0423	11.2	0.14	1.597	95	1.10
unit_sta08073630_1981_0503	61.6	0.13	8.05	78	5.48
unit_sta08073630_1981_0514	5.0	0.15	0.771	90	0.18
unit_sta08073630_1981_1031	16.5	0.12	2.06	90	1.16
unit_sta08073630_1982_0421	27.8	0.07	1.88	74	0.29

unit_sta08073630_1982_0513	33.3	0.10	3.43	91	2.46
unit_sta08073630_1983_0520a	4.3	0.49	2.1	83	0.78
unit_sta08073630_1983_0520b	2.8	0.10	0.28	98	0.12
unit_sta08073630_1984_0323	22.0	0.08	1.73	82	0.47
unit_sta08073750_1967_0921	13.8	0.17	2.35	87	1.16
unit_sta08073750_1968_0510	12.0	0.15	1.8	88	0.83
unit_sta08073750_1968_0604	8.8	0.10	0.85	90	0.23
unit_sta08073750_1968_0616	15.5	0.09	1.4	96	0.99
unit_sta08073750_1968_0914	27.5	0.15	4.107	87	2.73
unit_sta08073750_1968_0917	11.5	0.14	1.65	99	1.58
unit_sta08073750_1968_1006	6.8	0.21	1.45	83	0.36
unit_sta08073750_1968_1130	14.8	0.12	1.75	89	0.83
unit_sta08073750_1970_0521	22.0	0.18	4.05	89	2.91
unit_sta08073750_1970_0705	2.3	0.27	0.6	96	0.29
unit_sta08073750_1970_0830	9.0	0.17	1.5	88	0.58
unit_sta08073800_1965_0216	17.0	0.08	1.35	88	0.46
unit_sta08073800_1965_0805	16.5	0.07	1.1	85	0.21
unit_sta08073800_1966_0518	23.0	0.09	2.1	95	1.59
unit_sta08073800_1967_0413	12.8	0.11	1.4	90	0.63
unit_sta08073800_1967_0601	20.0	0.07	1.3	91	0.58
unit_sta08073800_1967_0824	14.8	0.12	1.7	77	0.31
unit_sta08073800_1967_0921	14.5	0.17	2.432	77	0.68
unit_sta08073800_1968_0604	9.0	0.09	0.783	87	0.12
unit_sta08073800_1968_0914	31.5	0.14	4.55	89	3.35
unit_sta08073800_1968_0917	11.5	0.16	1.871	98	1.60
unit_sta08073800_1968_1130	19.5	0.11	2.15	95	1.66
unit_sta08073800_1969_0412	26.0	0.08	2.05	96	1.62
unit_sta08073800_1970_0705	2.3	0.27	0.6	98	0.40
unit_sta08073800_1970_0830	9.0	0.18	1.658	97	1.32
unit_sta08073800_1970_1011	24.0	0.21	5	100	4.96
unit_sta08073800_1972_0320	20.3	0.12	2.4	94	1.79
unit_sta08073800_1972_1113	3.5	0.40	1.4	100	1.34
unit_sta08074100_1966_0414	10.0	0.43	4.265	83	2.49
unit_sta08074100_1966_0518	23.0	0.06	1.371	85	0.38
unit_sta08074100_1967_0413	13.8	0.14	1.885	67	0.15
unit_sta08074100_1968_0510	64.0	0.13	8.226	62	3.74
unit_sta08074100_1969_0221	17.0	0.24	4	87	2.66
unit_sta08074100_1970_0530	33.0	0.07	2.172	84	0.85
unit_sta08074100_1970_1011	24.0	0.17	4.08	64	1.04
unit_sta08074100_1970_1023	18.0	0.23	4.17	87	2.78
unit_sta08074100_1972_0320	20.8	0.33	6.9	66	3.15
unit_sta08074145_1980_0609	12.5	0.07	0.93	97	0.61

unit_sta08074145_1980_1015	18.8	0.23	4.4	94	3.72
unit_sta08074145_1981_0509	19.8	0.08	1.62	99	1.50
unit_sta08074145_1983_0209	16.0	0.08	1.22	99	1.11
unit_sta08074150_1965_0216	24.0	0.07	1.67	93	1.00
unit_sta08074150_1967_0413	14.5	0.13	1.901	73	0.27
unit_sta08074150_1967_0529	19.0	0.09	1.762	77	0.34
unit_sta08074150_1968_0510	64.0	0.12	7.963	77	5.24
unit_sta08074150_1968_0614	17.0	0.10	1.626	70	0.12
unit_sta08074150_1969_0221	17.0	0.23	3.875	97	3.53
unit_sta08074150_1970_0501	15.0	0.22	3.274	77	1.28
unit_sta08074150_1970_0515	30.0	0.11	3.325	82	1.67
unit_sta08074150_1970_0530	35.0	0.06	2.073	91	1.25
unit_sta08074150_1970_0721	17.0	0.14	2.3	78	0.68
unit_sta08074150_1970_1011	24.5	0.17	4.064	76	1.79
unit_sta08074150_1970_1023	17.0	0.24	4.12	91	3.10
unit_sta08074150_1971_0524	19.0	0.18	3.33	67	0.77
unit_sta08074150_1972_0320	20.8	0.34	7.05	78	4.53
unit_sta08074150_1973_0415	65.0	0.08	5.387	95	4.76
unit_sta08074150_1974_0119	18.0	0.11	1.907	96	1.48
unit_sta08074150_1974_0912	42.0	0.08	3.36	72	1.05
unit_sta08074150_1975_0529	43.0	0.09	4.069	97	3.69
unit_sta08074150_1975_0610	7.5	0.33	2.44	93	1.69
unit_sta08074150_1979_0917	76.0	0.12	8.958	57	3.73
unit_sta08074150_1980_0120	60.0	0.06	3.798	95	3.26
unit_sta08074150_1980_0327	60.5	0.07	4.295	80	2.30
unit_sta08074150_1981_0423	59.5	0.04	2.087	78	0.55
unit_sta08074150_1981_0503	45.0	0.13	5.732	80	3.49
unit_sta08074150_1981_0509	19.0	0.06	1.129	95	0.65
unit_sta08074150_1981_1005	52.0	0.05	2.357	74	0.52
unit_sta08074150_1981_1031	27.0	0.06	1.681	78	0.32
unit_sta08074150_1981_1129	39.5	0.07	2.764	77	0.94
unit_sta08074150_1983_0330	13.0	0.10	1.335	85	0.35
unit_sta08074150_1983_0520	43.0	0.11	4.827	79	2.66
unit_sta08074150_1983_0721	44.3	0.05	2.149	82	0.74
unit_sta08074150_1983_0818	42.0	0.14	6.089	95	5.46
unit_sta08074150_1983_0919	50.0	0.09	4.441	72	1.79
unit_sta08074150_1984_0718	29.7	0.07	2.217	82	0.81
unit_sta08074150_1986_1123	53.0	0.08	4.215	84	2.52
unit_sta08074150_1989_0517	40.0	0.17	6.923	86	5.29
unit_sta08074200_1965_0216	23.0	0.08	1.815	74	0.28
unit_sta08074200_1966_0414	10.0	0.40	4.03	64	0.98
unit_sta08074200_1966_0518	23.0	0.07	1.63	76	0.24

unit_sta08074200_1967_0413	13.8	0.13	1.805	64	0.08
unit_sta08074200_1967_0921	15.5	0.20	3.12	53	0.19
unit_sta08074200_1968_0510	64.0	0.13	8.372	67	4.48
unit_sta08074200_1968_0917	14.5	0.08	1.21	78	0.13
unit_sta08074200_1968_1006	7.0	0.23	1.625	67	0.07
unit_sta08074200_1969_0221	16.0	0.22	3.575	92	2.68
unit_sta08074200_1970_0501	15.0	0.23	3.4	76	1.28
unit_sta08074200_1970_0515	27.0	0.13	3.4	71	1.01
unit_sta08074200_1970_0721	17.0	0.14	2.3	84	0.97
unit_sta08074200_1970_1011	24.5	0.18	4.33	70	1.58
unit_sta08074200_1970_1023	18.0	0.23	4.05	82	2.21
unit_sta08074200_1971_0524	19.0	0.20	3.8	64	0.87
unit_sta08074200_1974_0119	18.0	0.10	1.787	97	1.48
unit_sta08074200_1974_0315	19.0	0.07	1.325	88	0.45
unit_sta08074200_1975_0610	7.5	0.32	2.402	87	1.21
unit_sta08074200_1975_0722	22.0	0.06	1.385	92	0.68
unit_sta08074200_1978_0606	27.3	0.25	6.72	53	1.79
unit_sta08074200_1978_0728	16.3	0.05	0.82	96	0.45
unit_sta08074200_1979_0418	52.0	0.06	2.882	85	1.48
unit_sta08074200_1979_0917	76.0	0.12	9.272	70	5.52
unit_sta08074200_1979_1030	17.8	0.13	2.323	75	0.56
unit_sta08074200_1980_0329	12.5	0.13	1.631	95	1.15
unit_sta08074200_1981_0423	17.0	0.12	2.052	83	0.74
unit_sta08074200_1981_0830	83.3	0.11	8.948	65	4.71
unit_sta08074200_1981_1031	27.0	0.07	1.824	82	0.52
unit_sta08074200_1982_0513	17.8	0.17	2.937	71	0.72
unit_sta08074200_1982_0517	31.0	0.06	2.006	71	0.28
unit_sta08074200_1983_0330	10.8	0.12	1.251	93	0.64
unit_sta08074200_1983_0721	44.3	0.06	2.44	84	1.07
unit_sta08074200_1983_0811	15.8	0.07	1.075	91	0.40
unit_sta08074200_1984_0718	20.5	0.12	2.402	77	0.67
unit_sta08074250_1965_0216	24.0	0.06	1.506	83	0.38
unit_sta08074250_1965_0528	24.0	0.05	1.232	87	0.35
unit_sta08074250_1965_0628	19.5	0.04	0.785	87	0.11
unit_sta08074250_1965_0705	20.0	0.03	0.628	95	0.24
unit_sta08074250_1966_0328	13.5	0.08	1.131	83	0.20
unit_sta08074250_1966_0414	10.0	0.39	3.87	79	1.87
unit_sta08074250_1966_0518	24.0	0.05	1.299	89	0.47
unit_sta08074250_1966_0618	15.0	0.10	1.489	78	0.23
unit_sta08074250_1967_0413	15.0	0.11	1.704	73	0.20
unit_sta08074250_1967_0825	16.5	0.08	1.275	78	0.14
unit_sta08074250_1967_0921	17.0	0.14	2.445	59	0.14

unit_sta08074250_1968_0510	64.0	0.12	7.852	81	5.65
unit_sta08074250_1968_0614	17.0	0.04	0.735	85	0.07
unit_sta08074250_1968_0917	15.0	0.08	1.199	82	0.19
unit_sta08074250_1968_1006	7.3	0.23	1.66	70	0.13
unit_sta08074250_1968_1105	23.3	0.08	1.772	70	0.16
unit_sta08074250_1969_0221	17.0	0.17	2.935	93	2.22
unit_sta08074250_1970_0501	17.0	0.18	3.142	77	1.15
unit_sta08074250_1970_0515	30.0	0.10	3.075	76	1.08
unit_sta08074250_1970_0530	35.0	0.06	1.999	86	0.84
unit_sta08074250_1970_0721	17.0	0.14	2.3	81	0.78
unit_sta08074250_1970_1011	24.0	0.16	3.946	85	2.37
unit_sta08074250_1970_1023	18.0	0.18	3.299	94	2.64
unit_sta08074250_1971_0524	19.0	0.18	3.354	73	1.09
unit_sta08074250_1972_0320	20.8	0.36	7.56	93	6.78
unit_sta08074250_1973_0611	61.5	0.14	8.528	87	6.96
unit_sta08074250_1973_0810	18.0	0.11	2.037	82	0.66
unit_sta08074250_1974_0119	18.0	0.12	2.163	94	1.57
unit_sta08074250_1974_0315	19.0	0.08	1.558	83	0.43
unit_sta08074250_1975_0529	46.5	0.09	4.26	88	2.99
unit_sta08074250_1975_0610	8.0	0.32	2.532	92	1.74
unit_sta08074250_1978_0606	36.0	0.18	6.302	71	3.10
unit_sta08074250_1978_0728	18.0	0.07	1.175	97	0.91
unit_sta08074250_1979_0418	64.0	0.06	3.758	85	2.25
unit_sta08074250_1979_0917	78.0	0.09	6.895	87	5.40
unit_sta08074250_1979_1030	19.5	0.10	1.947	78	0.47
unit_sta08074250_1980_0327a	30.0	0.06	1.901	93	1.23
unit_sta08074250_1980_0327b	4.3	0.25	1.047	99	0.91
unit_sta08074250_1980_1015	21.0	0.12	2.571	79	0.88
unit_sta08074250_1981_0830	50.5	0.12	6.126	87	4.62
unit_sta08074250_1981_1006	55.5	0.04	2.218	84	0.89
unit_sta08074250_1981_1031	38.8	0.04	1.684	85	0.56
unit_sta08074250_1982_0130	22.5	0.04	0.836	94	0.37
unit_sta08074250_1982_0513	21.0	0.11	2.283	97	1.91
unit_sta08074250_1982_0517	37.5	0.05	1.838	87	0.79
unit_sta08074250_1983_0330	13.5	0.08	1.086	93	0.54
unit_sta08074250_1983_0721	31.0	0.06	1.841	90	0.93
unit_sta08074250_1983_0811	42.0	0.04	1.584	94	0.98
unit_sta08074250_1983_0919	50.0	0.10	4.751	84	3.00
unit_sta08074250_1984_0718	24.0	0.07	1.712	90	0.88
unit_sta08074250_1989_0626	30.0	0.21	6.194	83	4.32
unit_sta08074540_1979_1030	19.5	0.14	2.746	77	0.92
unit_sta08074540_1979_1212	27.3	0.07	1.847	83	0.58

unit_sta08074540_1980_0117	15.0	0.04	0.645	89	0.09
unit_sta08074540_1981_0604	33.0	0.11	3.543	76	1.40
unit_sta08074540_1981_0705	35.5	0.07	2.315	83	0.93
unit_sta08074540_1981_0830	52.0	0.16	8.544	57	3.43
unit_sta08074540_1981_1005a	22.3	0.07	1.456	81	0.29
unit_sta08074540_1981_1005b	22.0	0.07	1.447	91	0.70
unit_sta08074540_1981_1005c	18.0	0.07	1.22	87	0.35
unit_sta08074540_1981_1031	27.8	0.05	1.426	83	0.35
unit_sta08074540_1982_0506	27.0	0.06	1.595	83	0.42
unit_sta08074540_1982_0513	18.3	0.15	2.753	88	1.59
unit_sta08074540_1982_0517	57.8	0.03	1.47	93	0.82
unit_sta08074540_1982_0622	8.5	0.05	0.42	96	0.14
unit_sta08074540_1983_0220	27.0	0.06	1.581	94	0.97
unit_sta08074540_1983_0330	16.3	0.06	1.044	95	0.59
unit_sta08074540_1983_0520b	26.0	0.06	1.447	96	1.06
unit_sta08074540_1983_0615	25.5	0.06	1.626	82	0.43
unit_sta08074540_1983_0721	29.8	0.03	0.753	95	0.38
unit_sta08074540_1983_0818	40.0	0.17	6.607	87	5.08
unit_sta08074540_1983_0919	44.0	0.13	5.535	98	5.33
unit_sta08074540_1984_0109	23.3	0.10	2.375	91	1.49
unit_sta08074750_1974_1031	34.5	0.05	1.71	94	1.10
unit_sta08074750_1976_0615	18.0	0.19	3.42	73	1.12
unit_sta08074760_1978_0606	29.0	0.12	3.536	94	2.87
unit_sta08074760_1979_0419	43.0	0.07	3.028	95	2.45
unit_sta08074760_1979_0917	78.0	0.13	10.42398	95	9.84
unit_sta08074760_1979_1030	19.0	0.10	1.83	86	0.71
unit_sta08074760_1979_1212	15.0	0.15	2.182	87	1.08
unit_sta08074760_1980_0120	60.0	0.06	3.551	100	3.54
unit_sta08074760_1981_0423	16.0	0.11	1.727	73	0.20
unit_sta08074760_1981_0503	35.0	0.03	1.174	42	0.20
unit_sta08074760_1981_1031	30.0	0.14	4.3	76	1.97
unit_sta08074760_1982_0513	19.0	0.18	3.514	90	2.43
unit_sta08074760_1983_0209	16.0	0.07	1.184	100	1.13
unit_sta08074760_1983_0919	48.0	0.16	7.863	93	7.02
unit_sta08074780_1966_0830	17.0	0.06	1.03	83	0.15
unit_sta08074780_1968_0917	11.8	0.10	1.15	84	0.23
unit_sta08074780_1974_1031	39.0	0.09	3.46	84	1.92
unit_sta08074780_1975_0804	18.0	0.13	2.25	67	0.26
unit_sta08074780_1976_0615	19.0	0.20	3.72	76	1.52
unit_sta08074780_1978_0607	14.8	0.14	2.014	73	0.33
unit_sta08074780_1979_0403	14.3	0.15	2.168	84	0.87
unit_sta08074780_1979_0419	40.5	0.10	4.011	79	1.99

unit_sta08074780_1981_0503	64.8	0.07	4.247	70	1.48
unit_sta08074780_1981_0819	15.5	0.12	1.838	79	0.43
unit_sta08074780_1981_0830	106.8	0.09	9.711	62	4.94
unit_sta08074780_1981_1129	35.0	0.05	1.902	74	0.31
unit_sta08074780_1983_0209	32.3	0.03	0.97	93	0.42
unit_sta08074780_1983_0818	41.0	0.12	4.87	77	2.50
unit_sta08074780_1983_0919	53.0	0.20	10.75	69	6.74
unit_sta08074800_1964_1209	48.0	0.08	3.708	58	0.53
unit_sta08074800_1965_0216	42.0	0.05	2.064	77	0.47
unit_sta08074800_1966_0830	17.0	0.08	1.418	85	0.39
unit_sta08074800_1970_0501	15.5	0.21	3.227	60	0.43
unit_sta08074800_1970_0521	87.0	0.04	3.879	71	1.28
unit_sta08074800_1973_0611	63.0	0.16	10.283	57	4.66
unit_sta08074800_1973_0707	23.0	0.16	3.72	70	1.16
unit_sta08074800_1974_0831	17.3	0.10	1.64	78	0.29
unit_sta08074800_1975_0609	40.0	0.14	5.43	75	2.77
unit_sta08074800_1977_0420	17.0	0.16	2.679	77	0.84
unit_sta08074800_1978_0607	14.8	0.14	2.022	80	0.59
unit_sta08074800_1979_0105	43.5	0.08	3.308	90	2.28
unit_sta08074800_1979_0403	18.0	0.12	2.183	90	1.23
unit_sta08074800_1979_0917	84.0	0.12	9.981	88	8.55
unit_sta08074800_1979_1212	42.0	0.06	2.326	72	0.43
unit_sta08074800_1980_0120	60.0	0.07	4.074	84	2.41
unit_sta08074800_1981_0423	27.0	0.04	1.205	81	0.17
unit_sta08074800_1981_0503	66.5	0.07	4.462	71	1.69
unit_sta08074800_1981_0819	15.5	0.13	2.004	80	0.58
unit_sta08074800_1981_0830	106.8	0.09	9.278	67	5.16
unit_sta08074800_1981_1129	35.5	0.06	2.019	76	0.43
unit_sta08074800_1982_0513	106.8	0.03	3.617	85	2.12
unit_sta08074800_1982_0715	53.3	0.01	0.761	91	0.19
unit_sta08074800_1982_0730	25.3	0.02	0.52	93	0.12
unit_sta08074800_1982_0808	74.5	0.02	1.751	77	0.31
unit_sta08074800_1982_1119	21.0	0.08	1.725	85	0.62
unit_sta08074800_1983_0209	32.3	0.03	0.987	96	0.63
unit_sta08074800_1983_0215	31.5	0.04	1.382	92	0.68
unit_sta08074800_1983_0220	26.0	0.03	0.744	92	0.23
unit_sta08074800_1983_0520	54.0	0.06	3.31	85	1.88
unit_sta08074800_1987_0609a	15.5	0.18	2.82	84	1.34
unit_sta08074800_1987_0609b	44.0	0.14	5.95	95	5.38
unit_sta08074800_1988_0429	24.5	0.10	2.391	86	1.17
unit_sta08074850_1968_0914	31.5	0.11	3.598	85	2.07
unit_sta08074850_1968_0917	11.8	0.15	1.79	95	1.30

unit_sta08074850_1968_1130	19.0	0.08	1.6	92	0.89
unit_sta08074850_1969_0214	8.0	0.18	1.4	94	0.82
unit_sta08074850_1969_0221	16.5	0.11	1.8	96	1.42
unit_sta08074850_1969_0503	12.3	0.17	2.05	80	0.60
unit_sta08074850_1969_0915	18.3	0.10	1.75	93	1.06
unit_sta08074850_1969_0919	20.0	0.13	2.5	83	1.05
unit_sta08074850_1970_1011	23.3	0.24	5.65	80	3.43
unit_sta08074850_1970_1022	40.3	0.07	3	95	2.45
unit_sta08074850_1972_0512	11.5	0.17	1.9	93	1.19
unit_sta08074850_1972_0610	10.5	0.39	4.1	78	1.99
unit_sta08074850_1973_0611b	18.0	0.11	2	99	1.89
unit_sta08074850_1973_0707	21.5	0.18	3.885	85	2.33
unit_sta08074850_1974_0119	10.5	0.21	2.19	93	1.49
unit_sta08074850_1974_0831	18.0	0.20	3.54	89	2.35
unit_sta08074850_1974_1031	33.0	0.06	1.88	93	1.18
unit_sta08074850_1976_0615	19.5	0.28	5.51	78	3.16
unit_sta08074850_1978_0607	12.5	0.16	1.992	92	1.20
unit_sta08074850_1980_0120c	12.3	0.19	2.275	95	1.78
unit_sta08074900_1965_0216	42.0	0.04	1.5	91	0.76
unit_sta08074900_1965_0518	19.0	0.12	2.186	82	0.76
unit_sta08074900_1965_0713	18.3	0.04	0.69	92	0.19
unit_sta08074900_1966_0328	13.0	0.14	1.839	97	1.51
unit_sta08074900_1966_0806	15.0	0.12	1.765	70	0.16
unit_sta08074900_1966_1004	21.7	0.08	1.63	82	0.41
unit_sta08074900_1967_0825	13.5	0.15	1.98	86	0.84
unit_sta08074900_1967_0921	16.5	0.17	2.815	80	1.10
unit_sta08074910_1979_0725	33.5	0.12	4.1	72	1.55
unit_sta08074910_1981_0503	32.8	0.25	8.273	84	6.37
unit_sta08074910_1981_0707	21.9	0.09	1.898	95	1.35
unit_sta08074910_1981_1031	28.5	0.08	2.25	83	0.90
unit_sta08074910_1982_0513	18.5	0.21	3.921	84	2.29
unit_sta08074910_1983_0520	13.2	0.15	2	84	0.76
unit_sta08074910_1983_0818b	20.5	0.08	1.7	93	1.04
unit_sta08075300_1966_0209	28.0	0.07	2.023	89	1.04
unit_sta08075300_1966_0414	14.0	0.35	4.935	76	2.48
unit_sta08075300_1966_0518	23.0	0.07	1.651	89	0.72
unit_sta08075300_1966_0520	17.0	0.08	1.38	97	1.06
unit_sta08075300_1967_0825	13.0	0.15	1.955	93	1.28
unit_sta08075300_1970_0501	17.5	0.22	3.863	84	2.25
unit_sta08075300_1970_0515	30.0	0.13	4.017	90	2.91
unit_sta08075300_1970_0521	21.5	0.19	4.015	94	3.36
unit_sta08075300_1971_0910	16.0	0.25	3.93	83	2.22

unit_sta08075300_1972_0510	64.5	0.10	6.4	68	2.98
unit_sta08075550_1966_0209	29.0	0.15	4.45	94	3.77
unit_sta08075550_1966_0328	14.5	0.11	1.66	79	0.33
unit_sta08075550_1966_0414	12.0	0.35	4.14	89	2.98
unit_sta08075550_1966_0520	17.8	0.09	1.66	94	1.05
unit_sta08075550_1966_0619	11.5	0.17	1.93	95	1.43
unit_sta08075550_1966_0909	22.5	0.10	2.325	78	0.69
unit_sta08075550_1967_0413	13.3	0.11	1.456	86	0.48
unit_sta08075550_1968_0119	11.0	0.27	2.96	81	1.26
unit_sta08075550_1968_0510	61.5	0.15	9.1	94	8.43
unit_sta08075550_1968_0917	12.3	0.11	1.36	89	0.51
unit_sta08075550_1968_1009	24.0	0.07	1.74	92	1.03
unit_sta08075550_1969_0214	9.0	0.16	1.45	98	1.19
unit_sta08075550_1969_0315	24.0	0.06	1.55	96	1.18
unit_sta08075550_1969_1030	16.0	0.17	2.795	80	1.11
unit_sta08075550_1970_0521	20.0	0.08	1.5	87	0.52
unit_sta08075550_1970_0530	35.0	0.07	2.4	92	1.56
unit_sta08075550_1970_1011	25.5	0.13	3.35	88	2.15
unit_sta08075550_1970_1023	18.0	0.13	2.3	86	1.06
unit_sta08075550_1972_0510	65.0	0.07	4.66	93	3.84
unit_sta08075550_1972_1106	25.0	0.09	2.28	94	1.70
unit_sta08075550_1974_0119	12.0	0.23	2.798	98	2.57
unit_sta08075550_1974_0831	18.0	0.17	2.98	95	2.46
unit_sta08075550_1978_0627	17.0	0.21	3.598	62	0.66
unit_sta08075550_1979_0725	57.0	0.21	12.246	69	8.09
unit_sta08075550_1979_0901	36.0	0.11	4.075	83	2.38
unit_sta08075550_1979_0918	49.8	0.22	11.134	84	9.09
unit_sta08075550_1980_0120	61.0	0.10	6.142	87	4.70
unit_sta08075550_1981_0503	35.5	0.28	9.919	66	5.60
unit_sta08075550_1981_0605	9.5	0.40	3.764	89	2.60
unit_sta08075550_1981_0831	20.0	0.24	4.852	85	3.22
unit_sta08075550_1982_0513	18.0	0.17	2.973	85	1.54
unit_sta08075550_1983_0818	13.8	0.72	9.84	68	5.87
unit_sta08075550_1983_0919	42.0	0.09	3.75	83	2.08
unit_sta08075550_1984_0812	16.5	0.18	3	82	1.40
unit_sta08075600_1965_0522	12.0	0.18	2.115	74	0.41
unit_sta08075600_1965_0606	14.0	0.14	2	78	0.50
unit_sta08075600_1966_0209	29.0	0.15	4.45	82	2.61
unit_sta08075600_1966_0328	14.5	0.13	1.865	77	0.36
unit_sta08075600_1966_0414	10.0	0.40	4	81	2.08
unit_sta08075600_1966_0520	17.8	0.12	2.09	96	1.63
unit_sta08075600_1966_1004	24.0	0.04	1.02	93	0.46

unit_sta08075600_1967_0413	13.5	0.11	1.509	86	0.52
unit_sta08075600_1968_0526	21.3	0.10	2.056	86	0.89
unit_sta08075600_1968_0604	10.5	0.11	1.169	88	0.35
unit_sta08075600_1968_0917	12.3	0.11	1.366	83	0.32
unit_sta08075600_1968_1009	24.0	0.07	1.781	87	0.75
unit_sta08075600_1969_0214	9.0	0.16	1.45	91	0.69
unit_sta08075600_1969_0315	24.0	0.06	1.55	93	0.92
unit_sta08075600_1969_0412	15.0	0.16	2.335	90	1.40
unit_sta08075600_1969_1030	16.0	0.14	2.27	68	0.30
unit_sta08075600_1970_0521	20.0	0.08	1.578	84	0.47
unit_sta08075600_1970_0530	35.0	0.08	2.715	77	0.87
unit_sta08075600_1972_0510	65.0	0.07	4.66	89	3.46
unit_sta08075650_1965_0522	12.0	0.16	1.882	77	0.39
unit_sta08075650_1965_0606	16.0	0.12	1.887	82	0.58
unit_sta08075650_1966_0209	29.0	0.15	4.45	96	4.04
unit_sta08075650_1966_0328	14.5	0.12	1.741	84	0.55
unit_sta08075650_1966_0909	22.5	0.10	2.31	85	1.05
unit_sta08075650_1966_1004	24.0	0.10	2.35	72	0.45
unit_sta08075650_1967_0411	14.0	0.11	1.526	80	0.31
unit_sta08075650_1967_0413	13.5	0.11	1.453	87	0.49
unit_sta08075650_1968_0526	21.3	0.10	2.212	85	0.97
unit_sta08075650_1968_0604	10.5	0.13	1.402	96	0.97
unit_sta08075650_1968_0917	12.3	0.12	1.418	86	0.44
unit_sta08075650_1968_1009	24.0	0.07	1.58	91	0.81
unit_sta08075650_1969_0214	9.0	0.16	1.45	93	0.82
unit_sta08075650_1969_1030	16.0	0.15	2.405	74	0.56
unit_sta08075650_1970_0530	36.0	0.06	2.33	84	0.99
unit_sta08075650_1970_1023	18.5	0.13	2.452	92	1.61
unit_sta08075700_1964_1104	38.1	0.07	2.626	68	0.45
unit_sta08075700_1964_1209	48.0	0.10	4.607	80	2.59
unit_sta08075700_1965_0522	12.0	0.17	2	76	0.42
unit_sta08075700_1966_0328	14.3	0.12	1.768	82	0.48
unit_sta08075700_1966_0414	12.0	0.34	4.06	95	3.50
unit_sta08075700_1966_0520	17.8	0.14	2.434	96	2.01
unit_sta08075700_1966_0909	22.5	0.10	2.3	69	0.34
unit_sta08075700_1967_0413	13.5	0.11	1.496	87	0.55
unit_sta08075700_1968_0119	11.5	0.26	3.012	86	1.67
unit_sta08075700_1968_0917	13.5	0.09	1.202	91	0.52
unit_sta08075700_1968_1009	24.0	0.08	1.835	87	0.79
unit_sta08075700_1969_0214	9.0	0.17	1.56	96	1.11
unit_sta08075700_1972_0427	21.0	0.18	3.802	74	1.43
unit_sta08075730_1975_0609	60.0	0.11	6.482	98	6.24

unit_sta08075730_1975_0731	48.4	0.09	4.12	84	2.51
unit_sta08075730_1977_0420	13.5	0.17	2.28	96	1.84
unit_sta08075730_1979_0319	22.3	0.14	3.039	94	2.42
unit_sta08075730_1979_0724	71.1	0.16	11.696	88	10.27
unit_sta08075730_1979_0917	73.0	0.17	12.23	96	11.75
unit_sta08075730_1981_0503	36.0	0.24	8.81	80	6.42
unit_sta08075730_1981_0604	33.5	0.17	5.72	92	4.83
unit_sta08075730_1981_0830	45.0	0.13	6.05	81	3.89
unit_sta08075730_1982_0513	18.0	0.16	2.824	91	1.91
unit_sta08075730_1982_0809	15.0	0.12	1.872	86	0.75
unit_sta08075730_1983_0817	51.0	0.20	10.133	79	7.50
unit_sta08075730_1983_0919	43.5	0.11	4.644	85	3.07
unit_sta08075730_1983_1130	16.5	0.05	0.84	98	0.68
unit_sta08075730_1984_0812	35.0	0.09	3.094	75	1.03
unit_sta08075730_1985_0314	30.0	0.14	4.326	87	2.98
unit_sta08075730_1985_1111	38.0	0.13	4.896	87	3.51
unit_sta08075730_1987_0609	13.0	0.25	3.306	85	1.84
unit_sta08075750_1965_0922	17.0	0.18	3.1	65	0.54
unit_sta08075750_1966_0328	13.5	0.12	1.6	82	0.41
unit_sta08075750_1966_0414	10.0	0.39	3.9	69	1.20
unit_sta08075750_1966_1004	25.0	0.14	3.564	66	0.82
unit_sta08075750_1967_0529	19.0	0.11	2	77	0.45
unit_sta08075750_1967_0921	20.0	0.18	3.5	69	0.94
unit_sta08075750_1968_0510	59.0	0.10	5.75	79	3.46
unit_sta08075750_1968_0917	11.5	0.17	1.95	89	1.01
unit_sta08075750_1969_0116	11.0	0.22	2.4	86	1.15
unit_sta08075750_1970_0515	30.0	0.16	4.9	70	1.93
unit_sta08075750_1970_0901	22.8	0.13	3.036	65	0.54
unit_sta08075750_1970_1011	25.0	0.16	3.95	74	1.58
unit_sta08075750_1970_1023	16.5	0.27	4.45	85	2.90
unit_sta08075750_1970_1027	27.5	0.12	3.4	88	2.17
unit_sta08075750_1970_1109	3.5	0.41	1.45	87	0.52
unit_sta08075750_1972_0320	20.5	0.21	4.25	84	2.63
unit_sta08075760_1965_0518	20.0	0.14	2.78	81	1.15
unit_sta08075760_1965_0918	21.8	0.09	1.945	91	1.15
unit_sta08075760_1965_0922	17.0	0.16	2.665	74	0.70
unit_sta08075760_1966_0328	14.0	0.12	1.652	95	1.15
unit_sta08075760_1966_0414	12.0	0.33	3.945	78	1.85
unit_sta08075760_1966_1004	25.0	0.17	4.288	66	1.24
unit_sta08075760_1967_0529	20.0	0.10	2.082	76	0.45
unit_sta08075760_1967_0921	20.0	0.17	3.35	70	0.94
unit_sta08075760_1968_0510	61.5	0.08	5.145	100	5.10

unit_sta08075760_1968_0908	18.0	0.11	1.93	85	0.73
unit_sta08075760_1968_0917	11.8	0.16	1.911	95	1.36
unit_sta08075760_1968_1105	24.3	0.10	2.39	77	0.68
unit_sta08075760_1969_0116	11.0	0.21	2.29	86	1.09
unit_sta08075760_1970_0515	30.0	0.16	4.9	81	2.89
unit_sta08075760_1970_0901	24.0	0.13	3.05	74	0.96
unit_sta08075760_1970_1011	25.0	0.15	3.797	80	1.90
unit_sta08075760_1970_1023	17.0	0.25	4.27	75	1.90
unit_sta08075760_1970_1109	3.5	0.41	1.423	88	0.51
unit_sta08075760_1972_0320	21.0	0.21	4.35	86	2.87
unit_sta08075760_1972_0507	14.0	0.17	2.4	90	1.42
unit_sta08075760_1973_0611	63.0	0.19	11.758	77	8.84
unit_sta08075760_1974_1031	24.0	0.09	2.142	78	0.55
unit_sta08075760_1976_0615	22.0	0.25	5.514	65	2.00
unit_sta08075760_1976_0920	22.5	0.19	4.32	78	2.14
unit_sta08075760_1978_0606	28.3	0.14	3.84	72	1.34
unit_sta08075760_1979_0901	18.0	0.34	6.2	84	4.41
unit_sta08075760_1979_0917	77.0	0.13	9.7	85	7.80
unit_sta08075760_1980_0120	60.0	0.08	4.95	86	3.46
unit_sta08075760_1980_0425	12.0	0.26	3.1	79	1.29
unit_sta08075760_1981_0503	43.0	0.14	5.9	77	3.36
unit_sta08075760_1981_0604	33.0	0.12	3.95	92	3.08
unit_sta08075760_1981_0705	35.8	0.07	2.35	93	1.67
unit_sta08075760_1981_0830	59.5	0.13	7.8	68	4.09
unit_sta08075760_1981_1005a	19.0	0.18	3.4	73	1.09
unit_sta08075760_1983_0510	11.3	0.17	1.9	83	0.65
unit_sta08075760_1983_0818	35.0	0.21	7.25	91	6.18
unit_sta08075760_1983_0919	44.0	0.15	6.45	79	4.05
unit_sta08075760_1984_0109	15.8	0.15	2.35	85	1.06
unit_sta08075770_1964_1209	48.0	0.07	3.305	67	0.74
unit_sta08075770_1965_0216	22.0	0.07	1.5	83	0.38
unit_sta08075770_1965_0922	20.0	0.13	2.605	66	0.37
unit_sta08075770_1966_0209	78.0	0.05	4.219	78	2.08
unit_sta08075770_1966_0328	14.0	0.12	1.658	79	0.33
unit_sta08075770_1966_0414	12.0	0.33	3.918	74	1.54
unit_sta08075770_1966_1004	25.0	0.18	4.453	60	0.97
unit_sta08075770_1967_0529	20.0	0.10	2.097	75	0.42
unit_sta08075770_1967_0921	20.0	0.14	2.739	68	0.51
unit_sta08075770_1968_0119	12.0	0.20	2.435	80	0.85
unit_sta08075770_1968_0510	62.0	0.08	5.255	79	2.98
unit_sta08075770_1968_0908	18.0	0.08	1.394	80	0.23
unit_sta08075770_1968_0917	11.8	0.16	1.911	85	0.75

unit_sta08075770_1968_1105	24.3	0.10	2.354	74	0.52
unit_sta08075770_1969_0116	13.0	0.17	2.228	85	0.99
unit_sta08075770_1969_0221	18.0	0.11	1.9	93	1.21
unit_sta08075770_1970_0501	17.0	0.18	3.1	75	1.02
unit_sta08075770_1970_0515	30.0	0.14	4.33	73	1.75
unit_sta08075770_1970_0901	40.0	0.09	3.548	69	0.96
unit_sta08075770_1970_1023	17.5	0.24	4.21	92	3.31
unit_sta08075770_1970_1027	28.0	0.11	3.204	90	2.14
unit_sta08075770_1970_1109	5.0	0.30	1.5	91	0.75
unit_sta08075770_1971_0909	61.0	0.10	5.926	66	2.37
unit_sta08075770_1972_0320	21.0	0.21	4.351	92	3.41
unit_sta08075770_1974_0119	18.0	0.10	1.821	91	1.02
unit_sta08075770_1975_0529	48.0	0.06	2.97	92	2.13
unit_sta08075770_1975_0609	40.0	0.09	3.69	78	1.61
unit_sta08075770_1976_0615	22.0	0.30	6.643	76	3.93
unit_sta08075770_1976_0920	22.0	0.20	4.36	72	1.74
unit_sta08075770_1978_0606	30.0	0.12	3.735	83	2.04
unit_sta08075770_1979_0917	77.0	0.13	9.816	82	7.61
unit_sta08075770_1980_0120	61.0	0.09	5.384	87	3.97
unit_sta08075770_1980_0425	12.0	0.25	3.051	81	1.34
unit_sta08075770_1981_0503	43.0	0.14	6.194	78	3.70
unit_sta08075770_1981_0603	111.8	0.06	6.366	74	3.52
unit_sta08075770_1981_0705	107.0	0.04	3.986	82	2.17
unit_sta08075770_1981_0830	63.0	0.12	7.55	61	3.13
unit_sta08075770_1982_0512	42.0	0.09	3.87	80	1.95
unit_sta08075770_1982_0517	39.0	0.09	3.456	96	2.99
unit_sta08075770_1982_0725	28.0	0.06	1.71	84	0.55
unit_sta08075770_1983_0215	25.5	0.02	0.56	94	0.17
unit_sta08075770_1983_0509	36.0	0.07	2.4	74	0.55
unit_sta08075770_1983_0818	35.0	0.21	7.181	95	6.57
unit_sta08075770_1983_0919	44.0	0.15	6.45	82	4.40
unit_sta08075770_1984_0109	15.8	0.15	2.403	82	0.92
unit_sta08075770_1986_0614	87.5	0.03	2.61	98	2.34
unit_sta08075770_1988_0317	20.8	0.08	1.716	83	0.53
unit_sta08075770_1989_0517	41.5	0.17	7.14	65	3.19
unit_sta08075770_1989_0626	66.5	0.14	9.39	79	6.83
unit_sta08075780_1965_0122	9.0	0.36	3.25	57	0.34
unit_sta08075780_1965_0216	22.0	0.08	1.75	85	0.62
unit_sta08075780_1966_0414	10.5	0.38	4.042	79	2.00
unit_sta08075780_1966_0518	63.0	0.07	4.164	87	2.75
unit_sta08075780_1967_0413	14.0	0.15	2.04	67	0.19
unit_sta08075780_1967_0921	17.0	0.44	7.48	46	1.60

unit_sta08075780_1968_0917	11.5	0.15	1.67	78	0.30
unit_sta08075780_1970_0501	14.5	0.13	1.947	70	0.22
unit_sta08075780_1970_0515	22.0	0.17	3.717	67	0.95
unit_sta08075780_1970_1011	25.0	0.18	4.613	58	0.95
unit_sta08075780_1970_1023	17.0	0.26	4.425	75	2.02
unit_sta08075780_1972_0510	60.5	0.06	3.68	72	1.24
unit_sta08075780_1973_0605	21.5	0.20	4.2	66	1.19
unit_sta08075780_1974_1031	41.0	0.08	3.43	78	1.45
unit_sta08075780_1974_1110	15.0	0.11	1.68	90	0.80
unit_sta08075780_1975_0528	64.3	0.06	3.79	79	1.83
unit_sta08075780_1976_0920	20.0	0.19	3.75	68	1.05
unit_sta08075780_1977_0420	14.0	0.17	2.39	76	0.63
unit_sta08075780_1977_0615	18.0	0.16	2.84	63	0.37
unit_sta08075780_1979_0707	62.7	0.05	3.12	66	0.62
unit_sta08075780_1980_0208	35.0	0.07	2.472	83	1.01
unit_sta08075780_1981_0304	19.0	0.07	1.302	91	0.60
unit_sta08075780_1981_0831	106.0	0.08	8.23	56	3.07
unit_sta08075780_1981_1129	79.3	0.06	4.43	74	1.91
unit_sta08075780_1982_1011	81.0	0.07	5.724	61	1.85
unit_sta08075780_1983_0520	42.0	0.17	7.34	54	2.26
unit_sta08075780_1983_0818	72.0	0.08	5.632	80	3.44
unit_sta08075780_1983_0919	48.0	0.07	3.154	81	1.40
unit_sta08075780_1984_0109	15.0	0.11	1.61	82	0.42
unit_sta08075780_1984_0212	9.8	0.10	0.96	81	0.08
unit_sta08075780_1984_0727	22.0	0.11	2.31	75	0.55
unit_sta08075780_1984_1025	16.5	0.52	8.55	66	4.40
unit_sta08075780_1985_1124	16.3	0.17	2.71	98	2.49
unit_sta08075780_1988_0811	17.5	0.14	2.52	83	1.06
unit_sta08075780_1989_0517	39.0	0.21	8.2	93	7.31
unit_sta08076200_1965_0922	17.0	0.16	2.77	57	0.18
unit_sta08076200_1966_0328	14.0	0.10	1.38	81	0.27
unit_sta08076200_1966_0414	10.5	0.42	4.459	75	2.03
unit_sta08076200_1967_0413	14.0	0.14	1.965	65	0.12
unit_sta08076200_1967_0825	15.3	0.18	2.75	58	0.19
unit_sta08076200_1967_0921	19.0	0.43	8.26	45	1.83
unit_sta08076200_1968_0917	12.0	0.11	1.3	80	0.19
unit_sta08076200_1969_0221	17.0	0.20	3.37	88	2.19
unit_sta08076200_1970_0501	14.5	0.25	3.605	70	1.05
unit_sta08076200_1970_0515	22.0	0.22	4.875	76	2.42
unit_sta08076200_1970_0530	36.0	0.08	2.81	82	1.25
unit_sta08076200_1970_1011	25.0	0.13	3.265	64	0.60
unit_sta08076200_1970_1023	17.0	0.21	3.63	79	1.69

unit_sta08076200_1972_0320	20.5	0.34	7.033	77	4.37
unit_sta08076200_1972_1118	8.5	0.22	1.9	89	0.96
unit_sta08076200_1973_1015	43.3	0.07	3.1	97	2.73
unit_sta08076200_1974_0119	17.0	0.12	2	91	1.15
unit_sta08076200_1974_1110	40.0	0.06	2.28	92	1.51
unit_sta08076200_1975_0529	32.5	0.12	3.9	88	2.60
unit_sta08076200_1975_0610	7.0	0.28	1.98	89	1.00
unit_sta08076200_1976_0418	18.0	0.20	3.553	88	2.33
unit_sta08076200_1977_0615	11.0	0.32	3.522	70	1.04
unit_sta08076200_1978_0606	30.0	0.15	4.56	77	2.23
unit_sta08076200_1979_0418	64.0	0.06	4.062	88	2.83
unit_sta08076200_1980_0120	61.5	0.07	4.301	87	2.87
unit_sta08076200_1980_0905	47.8	0.06	2.693	65	0.39
unit_sta08076200_1981_0423	16.5	0.19	3.108	70	0.79
unit_sta08076200_1981_0509	18.5	0.13	2.376	85	1.08
unit_sta08076200_1981_0830	97.8	0.09	8.77	60	3.98
unit_sta08076200_1981_1129	79.3	0.05	3.674	80	1.80
unit_sta08076200_1982_0512	7.5	0.20	1.488	83	0.38
unit_sta08076200_1982_0513	18.0	0.13	2.34	97	2.00
unit_sta08076200_1983_0323	14.3	0.15	2.11	88	1.04
unit_sta08076200_1983_0520	43.5	0.15	6.38	75	3.64
unit_sta08076200_1983_0811	40.5	0.05	1.983	92	1.21
unit_sta08076200_1984_0109	15.3	0.12	1.881	83	0.64
unit_sta08076200_1984_0212	10.5	0.11	1.206	96	0.79
unit_sta08077100_1965_0522	12.0	0.19	2.25	79	0.68
unit_sta08077100_1966_0619	12.0	0.28	3.35	62	0.55
unit_sta08077100_1966_0820	12.0	0.23	2.75	70	0.60
unit_sta08077100_1966_1004	22.6	0.04	0.873	95	0.45
unit_sta08077100_1967_0411	12.5	0.10	1.2	86	0.31
unit_sta08077100_1967_0413	13.5	0.11	1.55	90	0.71
unit_sta08077100_1968_0119	11.0	0.27	2.92	83	1.38
unit_sta08077100_1968_0409	9.0	0.26	2.35	80	0.79
unit_sta08077100_1968_0917	12.0	0.08	0.9	94	0.45
unit_sta08077100_1969_0214	9.0	0.17	1.5	93	0.84
unit_sta08077100_1969_0412	13.5	0.14	1.9	89	0.95
unit_sta08077100_1969_0503	14.0	0.13	1.82	97	1.53
unit_sta08077100_1969_1012	25.0	0.09	2.28	77	0.59
unit_sta08077100_1970_0901	15.0	0.18	2.65	69	0.50
unit_sta08077100_1970_1023	18.0	0.13	2.3	81	0.79
unit_sta08077100_1971_0909	39.0	0.09	3.62	89	2.49
unit_sta08077100_1972_0427	21.0	0.15	3.15	91	2.21

APPENDIX D

UNIT HYDROGRAPH PARAMETERS

Appendix Table D1. Unit hydrograph parameters for Austin storms.

Code	alpha	beta (hr)	q_p (cfs)	t_p (hr)	*PRF*	*NSE*
unit_sta08155550_1977_0415	2.61	0.61	986	0.981	310	0.896
unit_sta08155550_1977_0416	6.51	0.26	1320	1.407	595	0.943
unit_sta08155550_1979_0223	2.37	0.55	1174	0.756	284	0.970
unit_sta08155550_1981_0523a	1.58	1.18	786	0.679	171	0.938
unit_sta08155550_1981_0523b	1.08	1.09	1463	0.083	39	0.928
unit_sta08155550_1982_0513	1.06	1.53	1095	0.084	29	0.772
unit_sta08155550_1984_1010	3.71	0.21	2223	0.577	411	0.953
unit_sta08156650_1975_0711	2.23	0.59	1028	0.727	268	0.956
unit_sta08156650_1976_0525b	1.82	0.59	1212	0.485	211	0.946
unit_sta08156650_1976_0902	1.82	0.62	1153	0.512	212	0.934
unit_sta08156650_1978_0212	1.44	0.69	1325	0.302	143	0.963
unit_sta08156650_1978_0502	1.14	0.61	2081	0.083	62	0.948
unit_sta08156650_1978_0511	1.12	0.70	1875	0.083	56	0.927
unit_sta08156650_1978_1231	2.49	0.32	1734	0.479	298	0.983
unit_sta08156650_1982_0513	1.08	1.21	1172	0.096	40	0.910
unit_sta08156700_1976_0418	1.08	1.11	3209	0.089	41	0.733
unit_sta08156700_1976_0902	1.09	0.91	3811	0.083	45	0.956
unit_sta08156700_1977_0416	1.07	1.20	3047	0.083	36	0.861
unit_sta08156700_1977_0419	1.67	0.74	2660	0.493	186	0.805
unit_sta08156700_1978_0212	1.07	1.12	3211	0.083	38	0.778
unit_sta08156700_1978_0502	1.50	0.28	7904	0.139	156	0.941
unit_sta08156700_1978_0511	1.41	0.51	4618	0.210	138	0.963
unit_sta08156700_1978_1231	3.06	0.26	4649	0.536	355	0.976
unit_sta08156700_1979_0719	4.51	0.15	6317	0.524	471	0.943
unit_sta08156700_1980_0512	3.48	0.18	6297	0.437	392	0.765
unit_sta08156700_1981_0523b	3.30	0.36	3181	0.832	377	0.966
unit_sta08156700_1981_0610a	1.06	1.73	2180	0.096	30	0.882
unit_sta08156700_1981_0610b	1.04	1.95	1990	0.083	24	0.957
unit_sta08156700_1982_0513	1.06	1.76	2131	0.101	31	0.772
unit_sta08156700_1983_0510	1.13	0.88	3697	0.116	61	0.905
unit_sta08156750_1976_0418	1.10	1.11	3317	0.111	49	0.817
unit_sta08156750_1976_0902	1.07	1.15	3387	0.084	38	0.970
unit_sta08156750_1977_0416	1.10	1.67	2212	0.167	49	0.943

unit_sta08156750_1977_0419	1.49	1.32	1796	0.651	155	0.726
unit_sta08156750_1978_0212	1.17	1.22	2707	0.204	73	0.797
unit_sta08156750_1978_0511	1.96	0.40	4576	0.382	231	0.948
unit_sta08156750_1978_1231	2.95	0.24	5541	0.471	345	0.963
unit_sta08156750_1979_0719	1.95	0.45	4042	0.430	230	0.926
unit_sta08156750_1980_0512	1.15	0.56	6073	0.083	67	0.881
unit_sta08156800_1975_0428	13.13	0.20	4586	2.388	891	0.897
unit_sta08156800_1975_0609	9.71	0.28	3788	2.443	752	0.949
unit_sta08156800_1976_0418	1.24	1.29	3785	0.307	94	0.895
unit_sta08156800_1976_0525	1.50	0.83	4610	0.417	156	0.920
unit_sta08156800_1976_0902	1.47	1.57	2511	0.734	150	0.838
unit_sta08156800_1977_0416	1.10	1.94	3084	0.194	49	0.982
unit_sta08156800_1978_0502	3.32	0.46	4395	1.059	379	0.971
unit_sta08156800_1978_0511	53.92	0.09	4957	4.640	1870	0.927
unit_sta08156800_1978_1231	3.10	0.56	3781	1.167	359	0.966
unit_sta08156800_1979_0521	4.01	0.36	4923	1.086	435	0.885
unit_sta08156800_1979_0719	1.06	2.51	2578	0.160	33	0.823
unit_sta08156800_1980_0327	1.59	1.25	2902	0.731	172	0.783
unit_sta08156800_1981_0303	1.54	1.33	2793	0.725	165	0.901
unit_sta08156800_1981_0610	2.62	0.85	2792	1.372	311	0.712
unit_sta08156800_1982_0513	5.87	0.30	4779	1.437	559	0.913
unit_sta08156800_1984_1007	2.30	0.56	4694	0.722	276	0.931
unit_sta08156800_1985_0513	6.95	0.24	5340	1.427	619	0.858
unit_sta08156800_1986_0906	1.31	1.34	3362	0.421	115	0.815
unit_sta08157000_1967_0520_0000	2.65	0.29	1496	0.485	314	0.960
unit_sta08157000_1967_0520_1445	1.06	1.32	922	0.083	33	0.777
unit_sta08157000_1967_0817	2.90	0.32	1271	0.618	340	0.962
unit_sta08157000_1967_0818	3.48	0.29	1269	0.713	392	0.978
unit_sta08157000_1967_1015	14.97	0.12	1301	1.698	957	0.895
unit_sta08157000_1968_0517	1.10	0.83	1351	0.083	49	0.812
unit_sta08157000_1968_0527	4.33	0.28	1150	0.919	458	0.972
unit_sta08157000_1968_0709	24.93	0.08	1531	1.894	1255	0.958
unit_sta08157000_1969_0323	5.31	0.26	1083	1.118	524	0.964
unit_sta08157000_1969_0427	3.65	0.31	1131	0.829	406	0.989
unit_sta08157000_1969_0508	10.42	0.15	1291	1.402	783	0.952
unit_sta08157000_1970_0306	3.81	0.24	1413	0.685	419	0.854
unit_sta08157000_1970_0514	1.25	0.80	1128	0.202	99	0.979
unit_sta08157000_1970_0515	1.10	0.83	1351	0.083	49	0.737
unit_sta08157000_1971_0621	1.40	0.47	1643	0.190	135	0.929
unit_sta08157000_1971_0726	1.67	0.47	1365	0.317	187	0.923
unit_sta08157000_1971_0802	2.18	0.42	1215	0.497	262	0.708
unit_sta08157000_1971_0803	2.08	0.41	1289	0.444	248	0.814

unit_sta08157000_1971_1117a	41.68	0.04	2427	1.560	1639	0.965
unit_sta08157000_1972_0501	1.90	0.28	2063	0.250	223	0.967
unit_sta08157000_1972_1021	1.10	1.11	1014	0.111	49	0.788
unit_sta08157000_1973_0708a	79.24	0.09	779	6.750	2275	0.968
unit_sta08157000_1973_0708b	2.85	0.29	1421	0.544	335	0.923
unit_sta08157000_1973_1011	2.84	0.28	1489	0.518	334	0.935
unit_sta08157000_1973_1012	2.85	0.51	827	0.934	334	0.869
unit_sta08157000_1974_0509	2.95	0.37	1092	0.728	344	0.934
unit_sta08157000_1975_0428	2.23	0.49	1022	0.604	267	0.728
unit_sta08157000_1975_0523a	1.78	0.40	1512	0.313	205	0.949
unit_sta08157000_1975_0523b	1.81	1.23	487	0.993	209	0.936
unit_sta08157000_1976_0418	1.10	1.11	1014	0.111	49	0.795
unit_sta08157000_1976_0525a	1.68	0.58	1105	0.395	189	0.884
unit_sta08157000_1976_0525b	5.88	0.22	1190	1.086	559	0.931
unit_sta08157000_1977_0415a	4.30	0.22	1474	0.715	456	0.885
unit_sta08157000_1977_0415b	1.64	0.78	845	0.500	183	0.911
unit_sta08157000_1977_0416	1.64	1.09	604	0.700	183	0.986
unit_sta08157000_1978_0212	2.57	0.45	1003	0.706	306	0.928
unit_sta08157000_1978_0502	5.06	0.17	1744	0.674	508	0.960
unit_sta08157000_1978_0511	4.56	0.18	1725	0.635	474	0.992
unit_sta08157000_1979_0429	3.42	0.23	1606	0.556	387	0.986
unit_sta08157000_1979_0521	1.27	0.66	1338	0.180	104	0.930
unit_sta08157000_1980_0512	1.96	0.58	967	0.554	232	0.742
unit_sta08157500_1967_0520_0000	2.43	0.28	2975	0.403	290	0.980
unit_sta08157500_1967_0817	1.88	0.47	2183	0.416	220	0.984
unit_sta08157500_1967_0818	3.90	0.16	3806	0.462	426	0.975
unit_sta08157500_1967_1015	2.48	0.57	1455	0.842	296	0.884
unit_sta08157500_1968_0517	1.12	0.72	2711	0.083	55	0.889
unit_sta08157500_1968_0527	1.84	0.45	2347	0.377	214	0.974
unit_sta08157500_1968_0709	2.20	0.31	2913	0.374	264	0.943
unit_sta08157500_1969_0323	26.71	0.05	4000	1.344	1301	0.867
unit_sta08157500_1969_0427	3.19	0.41	1701	0.890	367	0.985
unit_sta08157500_1969_0508	2.31	0.24	3607	0.317	277	0.946
unit_sta08157500_1970_0306	3.50	0.22	3021	0.539	394	0.813
unit_sta08157500_1970_0514	4.99	0.31	1663	1.251	503	0.963
unit_sta08157500_1970_0515	1.07	1.25	1712	0.088	36	0.795
unit_sta08157500_1971_0621	1.51	0.24	5320	0.122	157	0.968
unit_sta08157500_1971_0802a	1.63	0.49	2422	0.308	181	0.702
unit_sta08157500_1971_0802c	1.01	0.89	2840	0.009	6	0.736
unit_sta08157500_1971_1117	5.84	0.22	2118	1.085	557	0.766
unit_sta08157500_1972_0501	2.03	0.27	3549	0.281	242	0.963
unit_sta08157500_1973_1011	6.70	0.20	2148	1.164	606	0.965

unit_sta08157500_1973_1012	9.45	0.19	1938	1.579	741	0.808
unit_sta08157500_1974_0509	4.91	0.19	2730	0.754	499	0.950
unit_sta08157500_1976_0418	1.10	0.83	2416	0.083	49	0.779
unit_sta08157500_1976_0525	3.12	0.26	2663	0.560	361	0.987
unit_sta08157500_1977_0416	1.20	1.37	1268	0.267	82	0.977
unit_sta08157500_1978_0212	1.89	0.47	2177	0.422	222	0.948
unit_sta08157500_1978_0511	1.62	0.42	2798	0.265	179	0.980
unit_sta08157500_1979_0429	2.13	0.27	3389	0.310	254	0.972
unit_sta08157500_1980_0512	1.13	1.07	1772	0.144	62	0.880
unit_sta08158050_1976_0418	1.60	1.83	2085	1.100	175	0.932
unit_sta08158050_1979_0521	1.89	1.17	2783	1.042	221	0.987
unit_sta08158050_1979_0719	2.10	1.00	2986	1.100	251	0.985
unit_sta08158050_1980_0425	23.37	0.09	8118	1.958	1213	0.856
unit_sta08158050_1981_0303	3.65	0.43	4621	1.152	407	0.886
unit_sta08158050_1981_0523b	1.30	4.16	1164	1.261	112	0.909
unit_sta08158050_1983_0604	4.30	0.52	3495	1.710	456	0.907
unit_sta08158050_1984_1020a	9.95	0.25	4548	2.198	763	0.828
unit_sta08158050_1984_1020b	4.48	0.38	4660	1.319	469	0.798
unit_sta08158050_1985_0622	10.97	0.15	7267	1.453	806	0.962
unit_sta08158100_1976_0418	2.44	0.93	2736	1.344	292	0.810
unit_sta08158100_1977_0419	1.03	2.78	2600	0.083	17	0.825
unit_sta08158100_1978_0410	1.05	1.72	3984	0.083	26	0.914
unit_sta08158100_1978_1231	1.10	1.39	4423	0.139	49	0.961
unit_sta08158100_1979_0320	1.02	4.17	1789	0.083	12	0.761
unit_sta08158100_1980_0508	1.60	1.24	2966	0.744	175	0.920
unit_sta08158100_1981_0303	1.03	3.26	2248	0.083	15	0.952
unit_sta08158100_1981_0610a	1.65	2.50	1426	1.620	183	0.934
unit_sta08158100_1984_1020	3.10	0.83	2582	1.750	359	0.980
unit_sta08158100_1985_0513	1.34	1.55	2897	0.528	121	0.828
unit_sta08158100_1985_1019	3.07	0.76	2869	1.561	356	0.972
unit_sta08158380_1985_1019	2.01	0.36	3479	0.358	238	0.987
unit_sta08158380_1986_0430	4.48	0.49	1444	1.694	469	0.703
unit_sta08158400_1976_0418	1.17	1.03	2355	0.175	74	0.880
unit_sta08158400_1976_0525	1.01	1.33	2566	0.013	6	0.768
unit_sta08158400_1979_0521	1.70	0.67	2272	0.471	192	0.823
unit_sta08158400_1979_0719	1.10	0.83	3259	0.083	49	0.979
unit_sta08158400_1980_0327	2.72	0.41	2547	0.704	322	0.883
unit_sta08158400_1980_0512	2.98	0.38	2556	0.757	347	0.971
unit_sta08158400_1981_0303	3.90	0.28	2946	0.806	426	0.971
unit_sta08158400_1981_0523	2.30	0.55	2135	0.718	275	0.983
unit_sta08158500_1976_0418	1.09	1.81	3331	0.163	45	0.823
unit_sta08158500_1976_0525a	1.27	1.23	3768	0.333	104	0.939

unit_sta08158500_1977_0416	1.45	1.51	2608	0.677	146	0.993
unit_sta08158500_1977_0419	1.20	1.94	2613	0.384	83	0.798
unit_sta08158500_1978_0212	3.76	0.58	3147	1.594	415	0.980
unit_sta08158500_1978_0502	2.30	0.83	3078	1.083	276	0.974
unit_sta08158500_1978_0511	2.31	0.83	3090	1.084	277	0.981
unit_sta08158500_1979_0521	1.09	1.00	6002	0.091	45	0.943
unit_sta08158500_1979_0719	1.26	1.87	2505	0.486	101	0.839
unit_sta08158500_1980_0327	2.13	0.73	3723	0.829	255	0.808
unit_sta08158500_1980_0512	3.10	0.56	3720	1.167	359	0.938
unit_sta08158500_1981_0303	2.41	0.74	3352	1.043	289	0.924
unit_sta08158500_1981_0523b	5.95	0.42	3304	2.062	563	0.963
unit_sta08158500_1981_0610	2.00	0.95	3019	0.949	237	0.903
unit_sta08158810_1980_0512	4.12	0.68	2554	2.117	443	0.983
unit_sta08158810_1980_0929	4.20	0.94	1813	3.018	449	0.933
unit_sta08158810_1981_0610	3.03	0.42	4993	0.860	352	0.867
unit_sta08158810_1982_0513	5.43	0.27	5351	1.213	532	0.954
unit_sta08158810_1986_0509	3.12	0.58	3591	1.224	360	0.961
unit_sta08158840_1979_0223	1.99	0.97	2027	0.962	237	0.871
unit_sta08158840_1979_0418	1.10	1.67	2410	0.167	49	0.906
unit_sta08158840_1980_0512	1.44	2.76	975	1.217	144	0.907
unit_sta08158840_1981_0303	4.29	0.47	2405	1.560	455	0.926
unit_sta08158840_1982_0513	2.21	0.93	1933	1.127	264	0.962
unit_sta08158840_1985_0223	3.35	0.57	2340	1.341	381	0.730
unit_sta08158840_1985_0605	1.33	3.86	764	1.294	120	0.789
unit_sta08158840_1985_1126	1.01	11.10	456	0.111	6	0.880
unit_sta08158840_1986_0509	2.30	0.83	2096	1.083	276	0.942
unit_sta08158880_1976_0525	1.92	0.69	1277	0.635	227	0.933
unit_sta08158880_1977_0416	1.01	2.57	855	0.026	6	0.984
unit_sta08158880_1977_0919	2.02	0.27	3084	0.279	240	0.939
unit_sta08158880_1978_0212	4.42	0.41	1177	1.414	465	0.872
unit_sta08158880_1978_0502	1.12	0.71	2373	0.083	55	0.933
unit_sta08158880_1981_0303	3.07	0.78	792	1.606	355	0.960
unit_sta08158880_1981_0524a	1.21	0.99	1491	0.207	86	0.952
unit_sta08158880_1981_0524b	1.05	1.81	1084	0.083	25	0.876
unit_sta08158880_1981_0610b	2.25	0.72	1068	0.904	270	0.951
unit_sta08158880_1982_0513a	2.05	0.63	1331	0.656	244	0.977
unit_sta08158880_1982_0513b	2.73	0.48	1385	0.834	323	0.991
unit_sta08158880_1984_1011	4.04	0.28	1851	0.844	436	0.915
unit_sta08158880_1985_0606	2.30	0.56	1366	0.722	276	0.980
unit_sta08158920_1979_0223	1.54	1.48	1289	0.804	164	0.860
unit_sta08158920_1979_0521	1.50	0.83	2361	0.417	156	0.928
unit_sta08158920_1980_0507	14.90	0.42	1027	5.855	954	0.890

unit_sta08158920_1981_0303	1.08	2.58	1225	0.219	43	0.837
unit_sta08158920_1981_0610	1.48	1.06	1892	0.504	151	0.858
unit_sta08158920_1982_0513	1.10	1.94	1580	0.194	49	0.933
unit_sta08158920_1983_0520	52.02	0.06	3505	3.300	1836	0.742
unit_sta08158920_1985_0605	100.00	0.11	1437	11.222	2559	0.751
unit_sta08158920_1986_0509	1.90	0.83	1876	0.750	223	0.971
unit_sta08158920_1986_0515	1.27	1.15	2116	0.305	103	0.966
unit_sta08158930_1976_0418	3.05	0.88	3721	1.809	354	0.964
unit_sta08158930_1977_0415	4.98	0.79	3034	3.149	503	0.935
unit_sta08158930_1977_0416	2.66	1.43	2528	2.376	316	0.983
unit_sta08158930_1978_0606	1.68	2.15	2451	1.471	190	0.802
unit_sta08158930_1979_0418	5.76	0.51	4316	2.431	552	0.956
unit_sta08158930_1979_0521	1.61	1.87	2947	1.135	176	0.932
unit_sta08158930_1980_0507a	2.28	0.34	12095	0.430	273	0.942
unit_sta08158930_1981_0303a	2.36	0.41	9742	0.552	283	0.958
unit_sta08158930_1981_0303b	3.80	0.74	3851	2.065	419	0.929
unit_sta08158930_1981_0523b	5.89	0.44	4912	2.166	560	0.871
unit_sta08158930_1981_0610	3.14	0.81	3951	1.745	363	0.826
unit_sta08158930_1982_0513	2.23	1.41	2923	1.739	268	0.940
unit_sta08158930_1983_0520	1.40	1.47	4394	0.580	134	0.929
unit_sta08158930_1985_0605	1.72	1.78	2905	1.280	196	0.882
unit_sta08159150_1967_0430	18.69	0.17	1671	2.974	1078	0.952
unit_sta08159150_1967_0501	7.37	0.30	1546	1.912	641	0.946
unit_sta08159150_1967_0520_1910	2.43	1.28	736	1.819	290	0.934
unit_sta08159150_1967_1015	12.25	0.19	1893	2.087	857	0.945
unit_sta08159150_1968_0517	3.07	0.69	1141	1.437	356	0.899
unit_sta08159150_1968_0527	14.44	0.17	1877	2.305	938	0.907
unit_sta08159150_1969_0412	2.56	0.87	1032	1.363	305	0.848
unit_sta08159150_1970_0306	3.72	0.61	1136	1.673	412	0.978
unit_sta08159150_1970_0307	1.39	3.11	505	1.215	133	0.894
unit_sta08159150_1970_0515	7.89	0.24	1857	1.658	668	0.957
unit_sta08159150_1970_1023	4.76	0.48	1256	1.793	489	0.967
unit_sta08159150_1971_1117	14.71	0.12	2661	1.641	947	0.949
unit_sta08159150_1971_1205	1.38	2.05	777	0.771	130	0.903
unit_sta08159150_1972_0501	1.09	0.94	2444	0.083	44	0.916
unit_sta08159150_1973_0926	11.75	0.19	1887	2.046	838	0.837
unit_sta08159150_1973_1011	5.62	0.25	2131	1.176	543	0.970
unit_sta08159150_1973_1013	6.48	0.36	1377	1.987	593	0.989
unit_sta08159150_1974_1123	4.30	0.56	1147	1.833	456	0.972
unit_sta08159150_1975_0523	3.53	1.04	694	2.636	397	0.915
unit_sta08159150_1975_0609	2.70	0.83	1041	1.417	320	0.974
unit_sta08159150_1976_0418	5.11	0.36	1592	1.480	511	0.972

unit_sta08159150_1976_0525	3.88	0.60	1134	1.725	424	0.985
unit_sta08159150_1977_0415	3.98	0.95	707	2.818	432	0.939
unit_sta08159150_1977_0416	2.48	1.36	681	2.005	296	0.952
unit_sta08159150_1977_0419	2.93	1.20	682	2.318	343	0.856

Appendix Table D2. Unit hydrograph parameters for Dallas.

Code	alpha	beta (hr)	q_p (cfs)	t_p (hr)	*PRF*	*NSE*
unit_sta08055580_1974_1030a	3.27	0.22	1460	0.497	374	0.962
unit_sta08055580_1974_1030b	4.79	0.13	1907	0.499	491	0.987
unit_sta08055580_1975_0326	1.73	0.23	2323	0.165	198	0.960
unit_sta08055580_1976_0526	5.39	0.12	1964	0.523	529	0.934
unit_sta08055580_1977_0612	4.62	0.11	2375	0.391	479	0.951
unit_sta08055580_1977_0907	1.90	0.28	1733	0.250	223	0.985
unit_sta08055580_1978_0528	1.50	0.28	2181	0.139	156	0.965
unit_sta08055580_1979_0503	1.79	0.36	1409	0.285	207	0.714
unit_sta08055600_1974_0920	1.50	1.25	1876	0.625	156	0.851
unit_sta08055600_1974_1030	1.06	1.39	2865	0.083	32	0.756
unit_sta08055600_1975_0609	2.04	0.61	2886	0.631	242	0.978
unit_sta08055600_1976_0526	6.12	0.20	4118	1.045	573	0.983
unit_sta08055600_1978_0528	3.16	0.31	4095	0.668	364	0.988
unit_sta08055600_1979_0330	4.27	0.24	4345	0.784	454	0.875
unit_sta08055600_1979_0503	3.06	0.27	4866	0.548	355	0.785
unit_sta08055700_1964_0927	1.14	4.50	1005	0.644	65	0.931
unit_sta08055700_1965_0509	5.50	0.28	4289	1.250	536	0.944
unit_sta08055700_1966_0209	1.50	2.22	1405	1.111	156	0.920
unit_sta08055700_1966_0428	9.78	0.30	2825	2.674	755	0.926
unit_sta08055700_1966_0501	1.57	3.20	931	1.813	169	0.886
unit_sta08055700_1967_0420	4.55	0.42	3160	1.500	474	0.718
unit_sta08055700_1967_0530	6.92	0.25	4133	1.495	618	0.706
unit_sta08055700_1968_0319	3.00	0.69	2521	1.385	349	0.951
unit_sta08055700_1968_0422	6.39	0.29	3727	1.580	589	0.904
unit_sta08055700_1968_0512	3.50	0.56	2835	1.389	394	0.956
unit_sta08055700_1968_0813	1.68	1.09	2537	0.746	189	0.835
unit_sta08055700_1968_1009	3.08	0.57	2990	1.193	357	0.953
unit_sta08055700_1969_0504	2.49	0.96	2078	1.431	297	0.861
unit_sta08055700_1970_0425a	28.09	0.06	8441	1.583	1336	0.836
unit_sta08055700_1970_0425b	5.93	0.29	3941	1.426	562	0.968
unit_sta08055700_1970_0831	5.89	0.32	3585	1.561	560	0.964
unit_sta08055700_1971_0814	2.30	0.56	3816	0.722	276	0.945
unit_sta08055700_1971_1003	1.61	0.53	5528	0.318	176	0.954

unit_sta08055700_1971_1018	4.89	0.25	5064	0.981	497	0.919
unit_sta08055700_1972_0712	14.47	0.07	10002	0.939	939	0.996
unit_sta08055700_1974_0607a	11.64	0.12	6358	1.311	833	0.992
unit_sta08055700_1974_0607b	10.29	0.15	5725	1.359	778	0.993
unit_sta08055700_1974_0916a	5.70	0.24	4898	1.120	549	0.931
unit_sta08055700_1974_0916b	3.74	0.31	4804	0.861	413	0.936
unit_sta08055700_1974_1030	4.30	0.56	2488	1.833	456	0.916
unit_sta08055700_1975_0131a	3.91	0.32	4593	0.929	427	0.794
unit_sta08055700_1975_0131b	5.88	0.26	4339	1.289	559	0.955
unit_sta08055700_1975_0407	6.58	0.22	4993	1.200	599	0.970
unit_sta08055700_1976_0618	11.87	0.10	7798	1.080	842	0.975
unit_sta08055700_1977_0326	3.52	0.35	4453	0.888	395	0.976
unit_sta08055700_1977_0612	6.60	0.18	5937	1.011	600	0.993
unit_sta08055700_1978_0323	11.34	0.11	7502	1.095	821	0.983
unit_sta08055700_1978_0528	4.30	0.28	4975	0.917	456	0.989
unit_sta08055700_1978_0804	5.49	0.25	4706	1.138	535	0.938
unit_sta08055700_1978_0821	25.78	0.05	10001	1.277	1277	0.989
unit_sta08055700_1979_0330	6.19	0.26	4301	1.341	577	0.960
unit_sta08055700_1979_0503	4.70	0.28	4711	1.028	484	0.977
unit_sta08055700_1979_0717	14.83	0.08	8458	1.125	952	0.996
unit_sta08056500_1964_1117	5.67	0.29	3240	1.346	546	0.829
unit_sta08056500_1965_0509a	6.15	0.35	2549	1.800	575	0.949
unit_sta08056500_1965_0509c	12.18	0.13	4610	1.479	855	0.990
unit_sta08056500_1965_0509d	6.99	0.23	3524	1.407	621	0.948
unit_sta08056500_1966_0209	13.62	0.10	5867	1.236	909	0.893
unit_sta08056500_1966_0428	6.82	0.36	2349	2.080	613	0.817
unit_sta08056500_1966_0617	7.37	0.16	4972	1.030	642	0.872
unit_sta08056500_1967_0530a	5.10	0.32	3076	1.325	511	0.928
unit_sta08056500_1967_0530b	7.33	0.22	3591	1.421	639	0.821
unit_sta08056500_1968_0422	23.29	0.08	5302	1.823	1211	0.985
unit_sta08056500_1968_0513	5.89	0.29	3104	1.438	559	0.949
unit_sta08056500_1968_0813	3.09	0.30	4608	0.619	357	0.944
unit_sta08056500_1968_1009	2.14	0.46	3888	0.526	256	0.972
unit_sta08056500_1969_0129b	4.42	0.26	4117	0.900	465	0.980
unit_sta08056500_1969_0504	4.65	0.21	4888	0.785	481	0.966
unit_sta08056500_1969_0506	7.15	0.17	4945	1.016	630	0.977
unit_sta08056500_1969_1012	3.27	0.29	4575	0.652	374	0.707
unit_sta08056500_1970_0831a	1.06	2.38	1789	0.136	31	0.923
unit_sta08056500_1970_0831b	2.00	0.48	3955	0.478	237	0.825
unit_sta08056500_1970_0831c	1.62	0.67	3450	0.414	179	0.989
unit_sta08056500_1971_0814a	2.33	0.59	2865	0.777	279	0.972
unit_sta08056500_1971_0814b	7.00	0.20	4052	1.225	622	0.969

unit_sta08056500_1971_1003	1.74	0.39	5570	0.285	199	0.969
unit_sta08056500_1971_1018b	5.52	0.26	3718	1.154	537	0.996
unit_sta08056500_1973_0423	6.38	0.28	3139	1.495	588	0.980
unit_sta08056500_1973_0511	2.29	0.35	4789	0.456	274	0.991
unit_sta08056500_1973_0603a	1.31	0.87	3347	0.274	115	0.938
unit_sta08056500_1973_0603b	1.97	0.33	5788	0.322	234	0.989
unit_sta08056500_1973_0603c	1.84	0.44	4599	0.373	215	0.962
unit_sta08056500_1973_1011	4.98	0.18	5492	0.731	503	0.959
unit_sta08056500_1973_1030	9.85	0.17	3967	1.526	759	0.896
unit_sta08056500_1974_0505	4.22	0.25	4522	0.794	450	0.982
unit_sta08056500_1974_0916a	2.64	0.22	6991	0.358	313	0.880
unit_sta08056500_1974_0916b	3.70	0.29	4221	0.775	410	0.986
unit_sta08056500_1974_1030	6.11	0.29	3087	1.480	573	0.918
unit_sta08056500_1975_0131b	2.70	0.50	2996	0.851	319	0.973
unit_sta08056500_1975_0407	3.19	0.37	3621	0.808	366	0.945
unit_sta08056500_1976_0417a	1.81	0.53	3895	0.430	210	0.890
unit_sta08056500_1976_0417b	3.94	0.28	4189	0.817	429	0.973
unit_sta08056500_1977_0326	4.27	0.28	3928	0.923	454	0.974
unit_sta08056500_1977_0612	3.85	0.20	5870	0.574	422	0.989
unit_sta08056500_1978_0323	2.26	0.41	4221	0.512	271	0.984
unit_sta08056500_1979_0330	4.66	0.26	4054	0.948	482	0.968
unit_sta08056500_1979_0503	2.90	0.31	4670	0.581	340	0.924
unit_sta08056500_1979_0510a	4.65	0.22	4797	0.800	481	0.988
unit_sta08056500_1979_0510b	4.36	0.27	4090	0.899	461	0.948
unit_sta08057020_1973_0707	2.10	0.39	2775	0.430	251	0.957
unit_sta08057020_1974_0920	4.22	0.25	2664	0.803	450	0.963
unit_sta08057020_1975_0821	4.19	0.14	4940	0.431	448	0.984
unit_sta08057020_1977_0820	1.59	0.68	2047	0.403	174	0.926
unit_sta08057020_1979_0319	1.10	1.39	1667	0.139	49	0.939
unit_sta08057020_1979_0330	3.62	0.27	2714	0.707	404	0.869
unit_sta08057050_1974_0920	2.50	0.23	8219	0.342	298	0.915
unit_sta08057120_1973_1030	47.30	0.16	1578	7.503	1749	0.928
unit_sta08057120_1975_0628	10.48	0.29	1963	2.710	786	0.959
unit_sta08057120_1977_0414	3.16	0.74	1549	1.592	364	0.969
unit_sta08057120_1978_0805a	7.00	0.11	6403	0.658	622	0.990
unit_sta08057120_1978_0805b	3.48	0.15	7159	0.371	392	0.996
unit_sta08057130_1973_0619	1.24	1.39	348	0.338	96	0.974
unit_sta08057130_1973_1030a	2.43	0.27	927	0.383	291	0.978
unit_sta08057130_1973_1030b	1.24	1.62	301	0.382	94	0.906
unit_sta08057130_1975_0407	4.26	0.31	546	1.012	453	0.920
unit_sta08057130_1976_0618	3.73	0.16	1134	0.444	413	0.949
unit_sta08057130_1977_0327	7.84	0.08	1519	0.534	665	0.969

unit_sta08057130_1978_0528	7.54	0.09	1394	0.569	650	0.940
unit_sta08057130_1979_0330	4.44	0.25	657	0.865	466	0.833
unit_sta08057140_1973_0619	1.50	0.56	4778	0.278	156	0.984
unit_sta08057140_1974_0607a	2.53	0.34	4928	0.521	302	0.978
unit_sta08057140_1974_0607b	1.78	0.66	3394	0.514	205	0.947
unit_sta08057140_1975_0529	2.12	0.48	4017	0.536	253	0.953
unit_sta08057140_1976_0526	3.39	0.75	1827	1.790	385	0.896
unit_sta08057140_1978_0528a	3.97	0.34	3671	0.998	431	0.943
unit_sta08057140_1978_0528b	1.65	0.54	4449	0.353	184	0.926
unit_sta08057160_1974_0916	4.13	0.34	1736	1.066	444	0.974
unit_sta08057160_1974_0917	4.62	0.22	2522	0.791	479	0.974
unit_sta08057160_1975_0529	3.05	0.42	1721	0.858	354	0.976
unit_sta08057160_1977_0326	1.58	1.27	965	0.744	172	0.922
unit_sta08057160_1978_0323	3.90	0.28	2205	0.806	426	0.960
unit_sta08057160_1979_0503	4.94	0.29	1825	1.143	500	0.923
unit_sta08057160_1979_0715	5.91	0.19	2516	0.929	561	0.941
unit_sta08057320_1973_1030	4.90	0.25	3532	0.975	498	0.894
unit_sta08057320_1975_0527	3.59	0.28	3819	0.727	401	0.979
unit_sta08057320_1977_0327	5.09	0.23	3676	0.961	510	0.720
unit_sta08057415_1973_0310	3.02	0.17	1314	0.334	351	0.986
unit_sta08057415_1974_0917	5.70	0.11	1352	0.507	549	0.970
unit_sta08057415_1975_0506	5.06	0.06	2659	0.239	508	0.991
unit_sta08057415_1976_0418b	5.20	0.13	1188	0.544	517	0.944
unit_sta08057415_1976_0418c	4.78	0.11	1422	0.431	490	0.985
unit_sta08057415_1977_0327	2.70	0.15	1564	0.255	320	0.969
unit_sta08057415_1978_0805	4.04	0.07	2504	0.218	436	0.944
unit_sta08057415_1979_0330	4.51	0.10	1760	0.334	471	0.970
unit_sta08057415_1979_0503	2.19	0.22	1277	0.257	262	0.944
unit_sta08057418_1976_0526	2.42	0.43	3659	0.606	290	0.952
unit_sta08057418_1977_0326	1.70	2.97	706	2.089	193	0.728
unit_sta08057418_1977_0820	1.90	0.56	3417	0.500	223	0.949
unit_sta08057418_1979_0330	1.90	0.56	3417	0.500	223	0.984
unit_sta08057418_1979_0503	4.37	0.26	3951	0.893	461	0.976
unit_sta08057420_1973_0707	1.37	0.54	8486	0.198	128	0.959
unit_sta08057420_1974_0920	6.01	0.29	5146	1.454	567	0.943
unit_sta08057420_1975_0407	1.82	1.28	2657	1.053	212	0.955
unit_sta08057420_1976_0418a	3.59	0.35	5928	0.893	401	0.819
unit_sta08057420_1976_0418b	3.95	0.41	4745	1.196	430	0.989
unit_sta08057420_1976_0703	3.09	0.28	7935	0.595	358	0.948
unit_sta08057420_1977_0326	3.18	1.09	2038	2.370	366	0.802
unit_sta08057420_1977_0820	1.68	0.65	5664	0.441	189	0.973
unit_sta08057420_1979_0330	2.00	1.00	3134	1.000	237	0.766

unit_sta08057425_1973_0707	1.14	0.76	6972	0.102	62	0.939
unit_sta08057425_1975_0527	4.37	0.28	5690	0.932	461	0.928
unit_sta08057425_1976_0418b	4.70	0.29	5219	1.067	484	0.967
unit_sta08057425_1976_0703	3.85	0.27	6239	0.778	422	0.968
unit_sta08057425_1977_0820	2.10	0.31	8580	0.336	251	0.935
unit_sta08057425_1978_0511	2.56	0.32	6975	0.502	305	0.974
unit_sta08057425_1979_0330	3.19	0.31	6282	0.671	367	0.950
unit_sta08057425_1979_0503	4.10	0.50	3274	1.550	441	0.963
unit_sta08057435_1976_0530	2.98	0.62	1661	1.238	348	0.964
unit_sta08057435_1977_0327	2.95	0.56	1880	1.083	345	0.973
unit_sta08057435_1979_0503	5.76	0.29	2337	1.396	552	0.986
unit_sta08057440_1976_0530	29.87	0.05	2648	1.318	1379	0.863
unit_sta08057440_1977_0327	15.02	0.11	1555	1.559	958	0.970
unit_sta08057445_1976_0418	1.27	3.01	1151	0.812	104	0.879
unit_sta08057445_1976_0618	5.59	0.57	1856	2.635	542	0.989
unit_sta08057445_1977_0302	3.90	0.83	1592	2.417	426	0.959
unit_sta08057445_1977_0326	1.26	3.41	1029	0.877	100	0.816
unit_sta08057445_1977_0419	2.30	1.67	1149	2.167	276	0.950
unit_sta08057445_1978_0212	1.02	3.37	1561	0.083	14	0.965
unit_sta08057445_1979_0330	3.50	1.11	1280	2.778	394	0.976
unit_sta08057445_1979_0503	1.35	2.64	1212	0.916	123	0.809
unit_sta08061620_1973_0619	1.90	1.11	1798	1.000	223	0.928
unit_sta08061620_1974_0916	1.90	0.83	2397	0.750	223	0.939
unit_sta08061620_1974_1030	1.10	1.67	2355	0.167	49	0.959
unit_sta08061620_1977_0326	1.66	1.94	1168	1.282	186	0.933
unit_sta08061620_1978_0528	4.18	0.33	3472	1.038	448	0.970
unit_sta08061620_1979_0330	5.10	0.28	3611	1.139	511	0.940
unit_sta08061620_1979_0503	3.53	0.45	2794	1.143	397	0.920
unit_sta08061920_1973_0423	3.87	0.88	2238	2.538	424	0.955
unit_sta08061920_1974_0920	4.30	0.56	3333	1.833	456	0.951
unit_sta08061920_1975_0131	4.70	0.83	2104	3.083	484	0.963
unit_sta08061920_1975_0407	4.25	0.85	2201	2.755	453	0.971
unit_sta08061920_1976_0418	5.10	0.56	3005	2.278	511	0.947
unit_sta08061920_1978_0323	5.90	0.56	2758	2.722	560	0.987
unit_sta08061920_1978_1231	1.67	1.94	1937	1.290	186	0.876
unit_sta08061920_1979_0330	1.90	1.67	1995	1.500	223	0.996

Appendix Table D3. Unit hydrograph parameters for Fort Worth storms.

Code	alpha	beta (hr)	qp (cfs)	Tp (hr)	PRF	NSE
unit_sta08048520_1970_0430	1.50	2.50	2211	1.250	156	0.946
unit_sta08048520_1970_0530	2.47	1.34	2659	1.967	295	0.872

unit_sta08048520_1970_0916	1.38	1.11	5489	0.421	131	0.988
unit_sta08048520_1971_0729	2.63	0.61	5522	1.003	313	0.980
unit_sta08048520_1971_1019	2.30	1.11	3377	1.444	276	0.954
unit_sta08048520_1971_1208	2.30	1.67	2252	2.167	276	0.972
unit_sta08048520_1972_0429	2.08	1.15	3527	1.247	248	0.829
unit_sta08048520_1973_0310	2.08	1.22	3335	1.318	248	0.900
unit_sta08048520_1973_0417	1.50	2.22	2487	1.111	156	0.960
unit_sta08048520_1973_0603	2.00	1.78	2364	1.778	237	0.855
unit_sta08048520_1973_0728	1.05	1.33	7291	0.061	25	0.898
unit_sta08048520_1973_1011	4.02	0.35	7229	1.066	435	0.827
unit_sta08048520_1973_1012	1.50	1.94	2843	0.972	156	0.961
unit_sta08048520_1974_0612	1.35	1.98	3165	0.686	123	0.867
unit_sta08048520_1975_0523	1.50	2.78	1990	1.389	156	0.923
unit_sta08048520_1975_0608	1.90	1.94	2259	1.750	223	0.949
unit_sta08048520_1975_0610	1.90	2.78	1581	2.500	223	0.980
unit_sta08048520_1976_0419	3.47	0.86	3253	2.129	391	0.976
unit_sta08048520_1976_0530	3.84	0.52	5088	1.465	421	0.836
unit_sta08048520_1976_0919	1.90	0.83	5270	0.750	223	0.983
unit_sta08048520_1977_0327	2.27	1.08	3505	1.376	273	0.981
unit_sta08048520_1977_0521	3.41	0.50	5717	1.195	386	0.981
unit_sta08048530_1970_0530a	8.91	0.05	1794	0.387	716	0.978
unit_sta08048530_1970_0530b	7.91	0.04	2145	0.302	669	0.938
unit_sta08048530_1971_0527	31.60	0.01	4003	0.344	1420	0.964
unit_sta08048530_1971_0728	3.66	0.08	1968	0.201	407	0.957
unit_sta08048530_1971_0729	3.29	0.12	1290	0.283	376	0.990
unit_sta08048530_1971_0814a	3.02	0.18	926	0.367	351	0.729
unit_sta08048530_1971_0814b	1.66	0.20	1359	0.133	186	0.965
unit_sta08048530_1971_1019b	2.84	0.22	788	0.411	334	0.971
unit_sta08048530_1971_1208	1.14	0.60	735	0.083	63	0.787
unit_sta08048530_1972_0429	8.71	0.03	3223	0.213	707	0.948
unit_sta08048530_1973_0417	5.69	0.04	2971	0.179	548	0.848
unit_sta08048530_1973_0603c	4.03	0.16	856	0.494	436	0.883
unit_sta08048530_1974_0607a	2.52	0.11	1732	0.168	301	0.929
unit_sta08048530_1974_0607b	6.73	0.05	2049	0.288	607	0.965
unit_sta08048530_1975_0511	3.17	0.06	2960	0.120	365	0.912
unit_sta08048530_1975_0608a	4.23	0.08	1649	0.265	451	0.966
unit_sta08048530_1975_0915	11.01	0.03	2907	0.270	808	0.956
unit_sta08048530_1976_0419	2.34	0.24	845	0.322	281	0.817
unit_sta08048530_1976_0829	3.68	0.10	1533	0.258	408	0.982
unit_sta08048540_1970_0425b	1.53	0.39	1048	0.208	162	0.900
unit_sta08048540_1971_0527	4.65	0.06	2911	0.223	481	0.981
unit_sta08048540_1971_0728	2.11	0.14	2233	0.153	252	0.970

unit_sta08048540_1971_0729	2.03	0.22	1447	0.225	242	0.992
unit_sta08048540_1971_0814a	5.43	0.09	1888	0.380	532	0.726
unit_sta08048540_1971_0814b	3.46	0.10	2091	0.252	390	0.977
unit_sta08048540_1971_1019b	2.33	0.27	1065	0.354	279	0.989
unit_sta08048540_1971_1208a	2.52	0.12	2195	0.185	301	0.944
unit_sta08048540_1971_1208b	1.37	0.45	1040	0.168	129	0.865
unit_sta08048540_1971_1209	2.42	0.23	1185	0.330	290	0.792
unit_sta08048540_1972_0429	4.56	0.06	3082	0.208	475	0.969
unit_sta08048540_1973_0417a	5.80	0.05	3209	0.233	554	0.915
unit_sta08048540_1973_0603b	3.64	0.07	2838	0.193	405	0.815
unit_sta08048540_1973_0603c	5.58	0.11	1464	0.499	541	0.862
unit_sta08048540_1973_0728	3.54	0.17	1243	0.431	397	0.785
unit_sta08048540_1973_1011	3.78	0.05	3722	0.151	416	0.836
unit_sta08048540_1974_0607a	2.79	0.08	3139	0.141	329	0.881
unit_sta08048540_1974_0607b	8.04	0.05	2552	0.357	675	0.979
unit_sta08048540_1974_0810	12.22	0.02	4823	0.240	856	0.947
unit_sta08048540_1975_0511	4.50	0.05	3632	0.175	470	0.969
unit_sta08048540_1975_0608a	7.06	0.05	2666	0.317	625	0.951
unit_sta08048540_1975_0608b	3.09	0.14	1636	0.295	358	0.968
unit_sta08048540_1975_0608c	2.54	0.17	1531	0.267	303	0.975
unit_sta08048540_1975_0915	15.22	0.02	3963	0.329	965	0.980
unit_sta08048540_1976_0419	4.23	0.12	1509	0.403	451	0.888
unit_sta08048540_1976_0829	2.98	0.13	1794	0.261	347	0.985
unit_sta08048550_1969_0416	3.73	0.27	597	0.746	412	0.985
unit_sta08048550_1969_0506	1.90	0.32	838	0.288	224	0.894
unit_sta08048550_1970_0430	2.33	0.43	529	0.570	280	0.993
unit_sta08048550_1970_0530	1.90	0.35	768	0.314	223	0.979
unit_sta08048550_1970_1023	46.56	0.02	2640	0.710	1735	0.928
unit_sta08048550_1971_0815	5.23	0.20	658	0.852	519	0.978
unit_sta08048550_1973_0310	3.10	0.33	563	0.687	358	0.970
unit_sta08048550_1973_0603a	4.41	0.21	701	0.715	464	0.991
unit_sta08048550_1973_0603b	4.96	0.15	889	0.610	502	0.970
unit_sta08048550_1973_0715	2.90	0.51	381	0.964	340	0.949
unit_sta08048550_1973_1012	12.15	0.20	409	2.256	853	0.955
unit_sta08048550_1974_0826	1.10	1.11	474	0.111	49	0.978
unit_sta08048550_1974_0920	1.61	0.79	397	0.482	177	0.971
unit_sta08048550_1975_0407	2.46	0.48	455	0.699	294	0.981
unit_sta08048550_1975_0724a	2.55	0.31	674	0.488	304	0.989
unit_sta08048550_1975_0724b	2.08	0.98	255	1.049	248	0.896
unit_sta08048550_1976_0530	1.85	0.60	462	0.503	215	0.966
unit_sta08048550_1976_0716	2.56	0.25	853	0.386	305	0.990
unit_sta08048600_1969_0416	2.31	1.11	409	1.457	277	0.965

unit_sta08048600_1969_0506	2.40	0.90	493	1.253	287	0.918
unit_sta08048600_1969_1012	1.05	1.67	700	0.083	27	0.869
unit_sta08048600_1970_0430	1.64	1.23	497	0.792	183	0.952
unit_sta08048600_1970_0530	1.77	1.11	513	0.850	203	0.965
unit_sta08048600_1970_0916	1.09	0.87	1218	0.080	46	0.868
unit_sta08048600_1970_1023	2.43	0.61	717	0.871	290	0.966
unit_sta08048600_1971_0529	1.73	0.47	1239	0.341	197	0.953
unit_sta08048600_1971_0815	1.06	1.36	833	0.083	32	0.966
unit_sta08048600_1971_1019a	1.08	2.63	418	0.200	39	0.894
unit_sta08048600_1971_1019b	1.72	1.44	407	1.029	195	0.952
unit_sta08048600_1971_1202	1.03	2.78	444	0.083	17	0.964
unit_sta08048600_1971_1209	1.35	1.70	449	0.587	123	0.775
unit_sta08048600_1973_0310	1.66	1.19	505	0.792	186	0.977
unit_sta08048600_1973_0715	2.13	1.09	446	1.227	254	0.958
unit_sta08048600_1973_1012	2.87	0.62	622	1.163	336	0.966
unit_sta08048600_1974_0826	1.10	2.47	422	0.253	50	0.861
unit_sta08048600_1974_0920	2.05	0.96	521	1.007	244	0.925
unit_sta08048600_1975_0407	1.46	2.02	343	0.930	148	0.926
unit_sta08048600_1975_0724	1.55	2.64	246	1.451	166	0.882
unit_sta08048600_1976_0716	1.13	1.32	746	0.178	62	0.977
unit_sta08048600_1977_0327	1.33	2.44	317	0.811	120	0.855
unit_sta08048600_1977_0521	3.00	0.64	586	1.282	350	0.958
unit_sta08048600_1977_0812	1.05	1.67	700	0.083	27	0.770
unit_sta08048820_1969_0416	13.83	0.24	1706	3.029	916	0.931
unit_sta08048820_1969_0506	2.51	1.68	668	2.523	299	0.976
unit_sta08048820_1971_0529	1.42	4.14	452	1.748	140	0.905
unit_sta08048820_1971_1019	1.60	3.93	418	2.361	175	0.918
unit_sta08048820_1971_1202	2.63	1.76	613	2.873	312	0.992
unit_sta08048820_1971_1208	2.75	1.64	639	2.867	325	0.977
unit_sta08048820_1972_1021	1.09	3.17	887	0.282	44	0.981
unit_sta08048820_1973_0310	4.08	1.28	632	3.923	439	0.973
unit_sta08048820_1973_0715	2.93	0.96	1041	1.858	343	0.835
unit_sta08048820_1973_1012	3.17	1.66	573	3.589	365	0.988
unit_sta08048820_1974_0826	2.18	2.20	566	2.598	261	0.936
unit_sta08048820_1974_0920	1.15	3.49	729	0.508	66	0.927
unit_sta08048820_1974_1109	3.71	1.42	601	3.856	411	0.970
unit_sta08048820_1975_0725	1.90	1.01	1382	0.914	224	0.960
unit_sta08048820_1976_0530	1.93	2.27	607	2.116	228	0.988
unit_sta08048820_1976_0716	1.44	1.83	1013	0.796	143	0.981
unit_sta08048820_1977_0211	3.16	1.70	558	3.680	364	0.980
unit_sta08048850_1969_0314	3.31	1.68	1196	3.883	377	0.984
unit_sta08048850_1969_0416	2.74	1.77	1297	3.068	323	0.952

unit_sta08048850_1969_0506	2.79	1.25	1800	2.251	329	0.872
unit_sta08048850_1969_1228	6.36	1.02	1321	5.463	587	0.966
unit_sta08048850_1970_0430	3.10	1.11	1891	2.333	359	0.956
unit_sta08048850_1970_0716	1.01	6.39	1167	0.083	8	0.808
unit_sta08048850_1971_0529	2.08	2.67	1059	2.877	248	0.844
unit_sta08048850_1971_0815	1.81	0.77	4148	0.624	210	0.991
unit_sta08048850_1971_1019	1.50	1.67	2305	0.833	156	0.975
unit_sta08048850_1971_1202	2.00	2.35	1246	2.342	237	0.984
unit_sta08048850_1971_1208	3.34	1.22	1645	2.841	380	0.959
unit_sta08048850_1972_1021	1.11	2.75	2122	0.314	54	0.966
unit_sta08048850_1973_0310	1.36	3.36	1286	1.195	125	0.933
unit_sta08048850_1973_0715	4.70	0.56	2897	2.056	484	0.911
unit_sta08048850_1973_1012	2.30	2.78	939	3.611	276	0.965
unit_sta08048850_1974_0826	1.50	2.78	1383	1.389	156	0.945
unit_sta08048850_1974_0920	2.10	1.90	1477	2.089	251	0.924
unit_sta08048850_1974_1030	3.76	1.29	1434	3.562	415	0.971
unit_sta08048850_1975_0407	2.71	1.67	1378	2.865	321	0.967
unit_sta08048850_1975_0724	3.90	0.56	3253	1.611	426	0.977
unit_sta08048850_1976_0530	1.28	3.92	1196	1.079	105	0.932
unit_sta08048850_1976_0716	2.24	1.99	1336	2.475	269	0.859
unit_sta08048850_1976_1029	1.01	8.89	849	0.089	6	0.951
unit_sta08048850_1977_0327	1.90	1.27	2413	1.135	223	0.909
unit_sta08048850_1977_0521	1.12	7.70	745	0.959	58	0.818

Appendix Table D4. Unit hydrograph parameters for San Antonio watersheds.

Code	alpha	beta (hr)	q_p (cfs)	t_p (hr)	*PRF*	*NSE*
unit_sta08177600_1970_0526	1.95	0.65	122	0.623	231	0.964
unit_sta08177600_1972_0511	1.85	0.60	141	0.505	215	0.997
unit_sta08177600_1973_1011	92.56	0.05	183	4.446	2461	0.981
unit_sta08177600_1974_0808	2.11	1.17	64	1.294	252	0.830
unit_sta08177600_1974_0830	100.00	0.06	135	6.257	2559	0.950
unit_sta08177600_1978_0913	2.06	0.49	154	0.525	246	0.951
unit_sta08177600_1979_0320	6.39	0.43	83	2.327	589	0.809
unit_sta08178300_1969_0314	1.12	0.70	2202	0.083	56	0.788
unit_sta08178300_1969_0503	9.12	0.07	3990	0.593	726	0.815
unit_sta08178300_1969_0515	3.76	0.16	3040	0.446	415	0.959
unit_sta08178300_1969_1005	5.28	0.05	8235	0.207	522	0.790
unit_sta08178300_1970_0522	3.85	0.14	3444	0.400	422	0.952
unit_sta08178300_1970_0528	1.14	0.59	2507	0.083	64	0.873
unit_sta08178300_1971_0524	21.97	0.02	11188	0.342	1174	0.898

unit_sta08178300_1972_0427b	9.60	0.06	4944	0.493	748	0.964
unit_sta08178300_1973_0926	1.78	0.19	4599	0.145	205	0.932
unit_sta08178300_1973_1011	2.58	0.18	3489	0.287	307	0.968
unit_sta08178300_1975_0610a	3.71	0.11	4701	0.285	411	0.863
unit_sta08178300_1976_0506	1.87	0.24	3486	0.205	219	0.925
unit_sta08178300_1976_0829	4.88	0.13	3162	0.512	496	0.918
unit_sta08178300_1977_0521	1.45	0.58	1819	0.261	146	0.928
unit_sta08178300_1977_0531	1.10	1.67	954	0.167	49	0.896
unit_sta08178300_1977_0601	1.56	0.54	1799	0.305	169	0.847
unit_sta08178300_1978_0801	1.10	1.11	1430	0.111	49	0.709
unit_sta08178300_1979_0321b	5.77	0.14	2620	0.688	553	0.852
unit_sta08178555_1977_1101	1.41	1.90	427	0.784	138	0.882
unit_sta08178555_1978_0410	1.51	1.19	635	0.606	158	0.972
unit_sta08178555_1979_0420	6.43	0.18	1484	0.967	591	0.885
unit_sta08178555_1979_0601	3.14	0.57	721	1.222	362	0.933
unit_sta08178555_1979_0605	9.29	0.27	799	2.231	734	0.988
unit_sta08178555_1979_0705	8.46	0.25	908	1.861	696	0.950
unit_sta08178555_1980_0513	2.16	0.67	808	0.779	259	0.989
unit_sta08178600_1969_0826	100.00	0.03	8991	2.716	2559	0.904
unit_sta08178600_1970_0526	5.96	0.55	1958	2.749	564	0.856
unit_sta08178600_1971_1205	12.56	0.18	3948	2.100	869	0.898
unit_sta08178600_1972_0511	3.90	0.28	5046	0.806	426	0.935
unit_sta08178600_1973_0716	2.22	0.84	2478	1.023	266	0.725
unit_sta08178600_1973_0926	6.60	0.26	3903	1.468	600	0.947
unit_sta08178600_1973_1011	15.77	0.19	3264	2.875	984	0.912
unit_sta08178620_1981_0423	12.71	0.32	951	3.725	875	0.890
unit_sta08178620_1981_0529	3.19	0.72	947	1.569	367	0.910
unit_sta08178640_1976_0526	36.56	0.04	2548	1.473	1532	0.960
unit_sta08178640_1976_0928	100.00	0.01	4477	1.401	2559	0.852
unit_sta08178640_1978_0913	4.33	0.23	1446	0.776	458	0.973
unit_sta08178640_1979_0110	35.41	0.18	611	6.042	1507	0.987
unit_sta08178640_1979_0601	5.52	0.38	775	1.699	537	0.899
unit_sta08178645_1976_0526	10.98	0.24	779	2.412	806	0.926
unit_sta08178645_1976_0706	6.26	0.32	812	1.669	581	0.964
unit_sta08178690_1969_0115	1.53	0.24	336	0.126	162	0.987
unit_sta08178690_1969_1005	4.66	0.04	767	0.163	482	0.955
unit_sta08178690_1975_0430	1.48	1.53	54	0.732	152	0.838
unit_sta08178690_1976_0506b	1.42	0.27	317	0.114	139	0.923
unit_sta08178690_1976_0818	2.42	0.16	333	0.226	290	0.973
unit_sta08178690_1976_1019	1.01	0.91	176	0.009	6	0.913
unit_sta08178690_1977_0419	1.10	1.11	114	0.111	49	0.799
unit_sta08178690_1977_1101	1.45	0.59	143	0.266	147	0.840

unit_sta08178690_1978_1126	1.13	0.66	183	0.083	59	0.815
unit_sta08178690_1981_0529	1.16	0.54	216	0.083	69	0.837
unit_sta08178736_1972_0507	1.18	0.72	267	0.132	79	0.773
unit_sta08178736_1973_0926	1.09	2.28	99	0.196	43	0.957
unit_sta08178736_1975_0508	1.59	0.54	243	0.319	173	0.986
unit_sta08178736_1976_0526	5.34	0.15	368	0.643	526	0.974
unit_sta08178736_1976_0928	24.00	0.02	1570	0.353	1230	0.880
unit_sta08181000_1970_0526	10.15	0.15	3206	1.340	772	0.917
unit_sta08181000_1972_0506a	4.75	0.24	2964	0.916	488	0.974
unit_sta08181000_1972_0511	2.98	0.40	2447	0.791	348	0.896
unit_sta08181000_1973_0417	1.07	1.20	2409	0.083	36	0.750
unit_sta08181000_1973_0716	9.53	0.14	3366	1.232	745	0.889
unit_sta08181000_1978_1231	2.76	1.26	821	2.214	326	0.806
unit_sta08181000_1979_0110	4.84	1.04	689	3.991	493	0.952
unit_sta08181400_1969_0516	2.00	2.40	1487	2.388	237	0.978
unit_sta08181400_1970_0523	2.27	1.93	1662	2.457	272	0.970
unit_sta08181400_1970_0526	67.80	0.03	14459	2.180	2102	0.825
unit_sta08181400_1971_0812	1.41	1.71	2929	0.706	138	0.920
unit_sta08181400_1971_0813	3.64	0.86	2691	2.259	405	0.927
unit_sta08181400_1972_0507	8.35	0.25	5681	1.822	690	0.936
unit_sta08181400_1973_0716	5.50	0.28	6434	1.250	536	0.918
unit_sta08181400_1973_0916	1.23	1.96	3072	0.453	93	0.763
unit_sta08181400_1974_0912	13.40	0.18	6175	2.188	901	0.909
unit_sta08181400_1976_0417	7.64	0.26	5677	1.732	655	0.768
unit_sta08181400_1976_0506	3.76	0.48	4702	1.323	415	0.834
unit_sta08181400_1976_1023	1.59	2.19	2014	1.286	173	0.789
unit_sta08181400_1981_0612	4.78	0.50	3906	1.880	490	0.731
unit_sta08181450_1969_0824	10.32	0.22	461	2.009	779	0.887
unit_sta08181450_1970_0514	5.96	0.20	670	1.002	564	0.868
unit_sta08181450_1971_0524	9.44	0.24	436	2.020	741	0.703
unit_sta08181450_1971_0622	4.87	0.30	505	1.167	495	0.911
unit_sta08181450_1972_0803	4.21	0.40	419	1.276	449	0.926
unit_sta08181450_1972_0926	4.09	0.54	316	1.661	441	0.838
unit_sta08181450_1973_0415a	3.95	0.55	315	1.624	430	0.843
unit_sta08181450_1973_0415b	3.90	0.52	339	1.496	426	0.924
unit_sta08181450_1973_0926	1.17	1.14	450	0.197	75	0.861
unit_sta08181450_1974_0509	4.27	0.52	315	1.712	454	0.889
unit_sta08181450_1974_0807a	3.08	0.32	634	0.670	357	0.904
unit_sta08181450_1974_0807b	1.06	1.39	455	0.083	32	0.944
unit_sta08181450_1974_1123	3.68	0.85	214	2.275	409	0.859
unit_sta08181450_1975_0508	4.13	0.54	310	1.702	443	0.965
unit_sta08181450_1975_1025	2.95	0.50	417	0.984	345	0.946

unit_sta08181450_1976_0520	2.82	0.62	349	1.132	332	0.916
unit_sta08181450_1976_0616	5.48	0.40	355	1.795	535	0.832
unit_sta08181450_1976_0928	4.20	0.43	391	1.367	449	0.875
unit_sta08181450_1976_1019	2.26	1.02	250	1.285	270	0.920
unit_sta08181450_1977_0509	1.28	1.00	451	0.280	106	0.985
unit_sta08181450_1977_0912	3.68	0.40	452	1.075	409	0.868
unit_sta08181450_1978_0907	1.06	1.41	449	0.083	31	0.945
unit_sta08181450_1979_0419a	2.34	1.25	199	1.681	281	0.957
unit_sta08181450_1979_0419b	46.00	0.05	870	2.358	1724	0.865

Appendix Table D5. Unit hydrograph parameters for rural watersheds.

Code	alpha	beta (hr)	q_p (cfs)	t_p (hr)	*PRF*	*NSE*
unit_sta08042650_1973_0730	2.91	0.55	2193	1.060	341	0.830
unit_sta08042650_1973_1012	2.72	0.93	1380	1.590	322	0.989
unit_sta08042650_1974_1030	2.89	0.61	1992	1.160	339	0.898
unit_sta08042650_1975_0502	4.90	0.54	1623	2.091	498	0.962
unit_sta08042650_1975_0826	1.79	1.14	1569	0.899	207	0.871
unit_sta08042650_1976_0419	9.95	0.20	2949	1.765	763	0.763
unit_sta08042650_1976_0919	1.53	0.89	2332	0.475	162	0.927
unit_sta08042650_1977_0326	7.96	0.37	1782	2.569	671	0.915
unit_sta08042650_1977_0523	1.74	0.87	2105	0.644	199	0.967
unit_sta08042650_1978_0409	5.35	0.32	2576	1.395	527	0.920
unit_sta08042650_1978_0805	3.87	0.74	1366	2.118	424	0.852
unit_sta08042650_1979_0417	1.05	1.78	2092	0.083	26	0.719
unit_sta08050200_1961_0325	1.95	1.34	140	1.270	231	0.924
unit_sta08050200_1962_0423	11.92	0.32	188	3.462	844	0.824
unit_sta08050200_1962_0618	2.13	0.53	325	0.604	255	0.986
unit_sta08050200_1962_0906	2.98	0.86	156	1.712	348	0.870
unit_sta08050200_1962_1126	8.97	0.14	487	1.137	719	0.913
unit_sta08050200_1963_0530	3.11	0.43	305	0.910	360	0.868
unit_sta08050200_1964_0915	1.69	1.95	109	1.347	191	0.873
unit_sta08050200_1964_0920	2.00	0.72	254	0.720	237	0.951
unit_sta08050200_1965_0613	1.54	1.13	207	0.614	165	0.881
unit_sta08050200_1965_1018	1.84	0.80	247	0.670	215	0.890
unit_sta08050200_1967_0530_1500	2.40	0.60	265	0.833	287	0.822
unit_sta08050200_1968_0118	1.30	2.81	101	0.850	112	0.882
unit_sta08050200_1968_0311	5.88	0.76	116	3.709	559	0.905
unit_sta08050200_1968_0320	1.40	4.91	53	1.956	135	0.898
unit_sta08050200_1969_0322	2.90	0.42	326	0.803	340	0.943
unit_sta08050200_1969_0504	4.96	0.35	277	1.396	502	0.933

unit_sta08050200_1969_0506	2.74	0.42	337	0.740	324	0.954
unit_sta08050200_1970_0418	2.35	0.27	594	0.364	281	0.895
unit_sta08050200_1970_0430	1.75	0.93	222	0.698	201	0.876
unit_sta08050200_1970_0925	1.96	0.43	435	0.410	232	0.843
unit_sta08052630_1966_0423a	4.69	0.92	299	3.390	483	0.871
unit_sta08052630_1966_0423b	1.41	3.61	194	1.493	138	0.945
unit_sta08052630_1966_0427	2.22	1.16	396	1.414	266	0.820
unit_sta08052630_1966_0830	1.02	3.70	339	0.062	10	0.981
unit_sta08052630_1967_0530	5.42	0.15	1735	0.643	531	0.922
unit_sta08052630_1968_0422	3.68	0.60	532	1.611	408	0.878
unit_sta08052630_1968_0509	5.39	0.48	524	2.122	529	0.717
unit_sta08052630_1968_0510	3.57	0.80	410	2.048	400	0.850
unit_sta08052630_1968_0512	3.14	0.98	364	2.088	362	0.869
unit_sta08052630_1969_0220	2.29	0.85	526	1.096	275	0.912
unit_sta08052630_1969_0506	4.68	0.34	800	1.266	483	0.777
unit_sta08052630_1969_1228	1.52	2.12	305	1.103	160	0.761
unit_sta08052630_1970_0430	2.09	1.70	282	1.852	249	0.828
unit_sta08052630_1971_1117	3.19	0.45	776	0.993	367	0.875
unit_sta08052630_1973_0102	2.40	2.32	186	3.245	287	0.829
unit_sta08052630_1973_0730	11.39	0.19	856	2.019	823	0.806
unit_sta08052630_1973_0926	2.22	1.64	279	2.002	266	0.865
unit_sta08052630_1973_1011	2.26	1.81	250	2.277	271	0.958
unit_sta08052630_1973_1030	2.32	1.47	301	1.944	278	0.924
unit_sta08052630_1974_0924	2.96	1.66	223	3.261	346	0.897
unit_sta08052630_1974_1030	2.97	0.38	980	0.741	346	0.917
unit_sta08052630_1975_0407	1.59	1.83	337	1.079	173	0.841
unit_sta08052630_1975_0608	2.99	0.79	464	1.575	348	0.849
unit_sta08052630_1975_0609	1.67	1.52	386	1.022	188	0.961
unit_sta08052630_1976_0419	4.11	0.23	1283	0.724	442	0.940
unit_sta08052630_1976_0506	2.93	1.20	312	2.304	342	0.841
unit_sta08057500_1960_0826	3.08	0.49	746	1.023	357	0.776
unit_sta08057500_1961_0106	1.02	4.17	304	0.083	12	0.917
unit_sta08057500_1961_0430a	1.79	0.39	1436	0.308	206	0.877
unit_sta08057500_1961_0430b	2.53	0.30	1428	0.452	302	0.970
unit_sta08057500_1962_0423a	2.02	1.65	306	1.678	240	0.848
unit_sta08057500_1962_0423b	1.14	3.00	324	0.419	64	0.837
unit_sta08057500_1962_0906a	1.04	2.22	540	0.083	21	0.718
unit_sta08057500_1962_0906b	1.02	4.17	304	0.083	12	0.867
unit_sta08057500_1963_0527	1.10	0.83	1252	0.083	49	0.824
unit_sta08057500_1963_0530	1.17	1.13	821	0.194	75	0.965
unit_sta08057500_1964_0916	1.28	0.59	1364	0.167	106	0.901
unit_sta08057500_1964_0920	1.96	0.27	1890	0.263	232	0.910

unit_sta08057500_1964_1117	1.15	1.17	824	0.173	66	0.919
unit_sta08057500_1965_0208	3.41	2.03	169	4.877	386	0.720
unit_sta08057500_1966_0427	2.22	0.37	1256	0.454	266	0.932
unit_sta08057500_1966_0429	1.59	1.01	624	0.595	174	0.955
unit_sta08057500_1967_0530_0700	1.40	0.73	981	0.297	136	0.930
unit_sta08057500_1967_0905	1.05	1.59	727	0.083	28	0.786
unit_sta08057500_1968_0319	2.19	0.46	1027	0.546	262	0.854
unit_sta08057500_1968_0418	1.11	0.77	1335	0.083	52	0.845
unit_sta08057500_1968_0516	1.39	0.90	810	0.350	133	0.932
unit_sta08057500_1969_0221	1.29	1.36	590	0.394	109	0.960
unit_sta08057500_1969_0506	2.27	0.29	1552	0.376	273	0.950
unit_sta08057500_1969_0514	2.13	0.41	1187	0.459	255	0.964
unit_sta08057500_1969_0517	3.04	0.49	754	1.002	353	0.983
unit_sta08057500_1969_0623	1.30	0.85	929	0.258	112	0.965
unit_sta08057500_1970_0601	1.05	1.58	730	0.083	28	0.901
unit_sta08058000_1959_1215	4.12	0.44	404	1.381	443	0.932
unit_sta08058000_1960_0203	1.22	2.24	228	0.498	90	0.902
unit_sta08058000_1960_0525	2.99	0.40	545	0.806	348	0.848
unit_sta08058000_1960_0608	5.08	0.20	773	0.830	509	0.936
unit_sta08058000_1961_0106	1.85	2.01	160	1.696	215	0.958
unit_sta08058000_1961_0430	6.05	0.18	794	0.903	569	0.936
unit_sta08058000_1962_0423a	12.40	0.21	446	2.437	863	0.804
unit_sta08058000_1962_0423b	4.85	0.46	354	1.758	495	0.845
unit_sta08058000_1962_0906a	1.96	1.09	279	1.049	232	0.945
unit_sta08058000_1963_0527	3.52	0.35	568	0.877	396	0.964
unit_sta08058000_1963_0530	5.48	0.17	904	0.745	535	0.964
unit_sta08058000_1964_0422	3.08	0.29	737	0.610	357	0.982
unit_sta08058000_1964_0916	9.62	0.12	944	0.999	749	0.897
unit_sta08058000_1964_0920	4.08	0.29	620	0.894	440	0.952
unit_sta08058000_1965_0208	1.06	1.48	456	0.083	30	0.892
unit_sta08058000_1965_0527a	9.05	0.12	933	0.976	723	0.923
unit_sta08058000_1965_0527b	2.31	0.81	330	1.057	277	0.871
unit_sta08058000_1966_0427	6.71	0.14	982	0.778	606	0.925
unit_sta08058000_1966_0429	5.59	0.19	796	0.857	541	0.815
unit_sta08058000_1967_0530_0200	1.77	1.90	175	1.466	204	0.983
unit_sta08058000_1967_0530_1700	4.95	0.19	860	0.734	501	0.944
unit_sta08058000_1967_0905	1.64	2.50	143	1.609	183	0.973
unit_sta08058000_1969_0623	4.79	0.28	582	1.062	491	0.932
unit_sta08058000_1970_0302	3.59	0.35	555	0.910	401	0.858
unit_sta08058000_1970_0425	5.25	0.12	1311	0.500	521	0.945
unit_sta08058000_1970_0430	2.13	0.37	766	0.418	254	0.931
unit_sta08058000_1970_0601	6.25	0.12	1210	0.604	581	0.873

unit_sta08063200_1959_1003	8.91	0.80	1992	6.329	716	0.795
unit_sta08063200_1959_1215	5.90	1.39	1449	6.806	560	0.917
unit_sta08063200_1959_1231	3.33	2.01	1424	4.690	379	0.893
unit_sta08063200_1960_0104	3.55	2.30	1193	5.874	398	0.969
unit_sta08063200_1960_1018	3.68	1.79	1503	4.781	408	0.980
unit_sta08063200_1960_1206	5.84	1.32	1538	6.368	557	0.862
unit_sta08063200_1961_0215	5.10	1.39	1579	5.694	511	0.948
unit_sta08063200_1961_0617	6.19	1.05	1860	5.462	577	0.888
unit_sta08063200_1961_1121	4.29	1.17	2090	3.834	455	0.853
unit_sta08063200_1962_0427	4.08	1.37	1833	4.223	440	0.957
unit_sta08063200_1962_0528	2.74	2.03	1619	3.515	323	0.962
unit_sta08063200_1965_0509	2.55	2.91	1189	4.492	304	0.887
unit_sta08063200_1965_0514	3.06	2.43	1250	4.996	355	0.930
unit_sta08063200_1965_0516	1.02	4.17	2499	0.083	12	0.761
unit_sta08063200_1966_0417	1.96	3.50	1217	3.349	232	0.942
unit_sta08063200_1967_0417	1.43	10.21	570	4.345	141	0.871
unit_sta08063200_1967_0611	1.05	13.89	687	0.702	27	0.884
unit_sta08063200_1967_1109	2.13	3.86	1026	4.366	255	0.821
unit_sta08063200_1968_0310	2.53	2.75	1260	4.222	302	0.809
unit_sta08063200_1968_0426	2.51	3.45	1012	5.204	299	0.850
unit_sta08063200_1968_0509	6.14	1.03	1900	5.322	575	0.785
unit_sta08063200_1968_0602	5.06	1.42	1555	5.752	508	0.797
unit_sta08063200_1968_0623	9.88	0.69	2196	6.092	760	0.829
unit_sta08063200_1969_0404	2.91	2.95	1062	5.650	341	0.799
unit_sta08063200_1969_0505	1.30	7.71	843	2.347	112	0.867
unit_sta08063200_1970_0306	22.74	0.98	988	21.311	1196	0.717
unit_sta08063200_1971_1210	2.58	1.90	1801	3.004	307	0.757
unit_sta08094000_1959_1003	4.58	0.25	1810	0.878	476	0.907
unit_sta08094000_1961_0106	1.06	1.39	1274	0.083	32	0.863
unit_sta08094000_1961_0204	1.66	2.68	350	1.774	186	0.866
unit_sta08094000_1961_0709	4.76	0.46	945	1.726	488	0.905
unit_sta08094000_1961_1009	1.59	2.22	442	1.306	173	0.936
unit_sta08094000_1962_0907	2.07	1.46	529	1.561	247	0.747
unit_sta08094000_1962_1008	1.67	1.24	755	0.828	187	0.950
unit_sta08094000_1963_1108	2.11	0.62	1217	0.692	252	0.983
unit_sta08094000_1964_0421	4.43	0.53	850	1.829	465	0.966
unit_sta08094000_1964_0921	4.67	0.32	1384	1.164	482	0.909
unit_sta08094000_1965_0208	1.59	1.85	531	1.090	173	0.781
unit_sta08094000_1966_0430a	3.62	0.32	1589	0.849	404	0.896
unit_sta08094000_1966_0430b	1.82	1.27	678	1.040	211	0.876
unit_sta08094000_1967_0916	1.05	1.68	1078	0.083	27	0.782
unit_sta08094000_1968_0118	1.33	1.47	818	0.486	119	0.981

unit_sta08094000_1968_0320	3.57	0.44	1185	1.125	399	0.945
unit_sta08094000_1968_0512	5.47	0.26	1545	1.155	534	0.842
unit_sta08094000_1969_0412	5.14	0.42	988	1.734	513	0.975
unit_sta08094000_1969_1228	5.92	1.25	306	6.125	561	0.904
unit_sta08094000_1970_0303	2.58	1.16	559	1.839	308	0.920
unit_sta08096800_1959_1003	1.50	1.67	984	0.833	156	0.968
unit_sta08096800_1959_1215	4.32	0.18	4085	0.588	457	0.974
unit_sta08096800_1960_1206	1.02	4.17	745	0.083	12	0.709
unit_sta08096800_1961_0205	1.07	1.16	2341	0.083	37	0.969
unit_sta08096800_1961_0608	1.96	0.39	3241	0.375	232	0.984
unit_sta08096800_1961_1121	100.00	0.12	1143	11.755	2559	0.744
unit_sta08096800_1962_0528	1.03	2.78	1083	0.083	17	0.764
unit_sta08096800_1962_0601	4.51	0.22	3151	0.785	471	0.903
unit_sta08096800_1962_0630	1.96	0.65	1938	0.629	232	0.949
unit_sta08096800_1964_0318	2.62	1.05	964	1.694	311	0.953
unit_sta08096800_1964_0426	2.76	0.76	1274	1.343	326	0.835
unit_sta08096800_1965_0121	1.04	2.13	1377	0.083	22	0.846
unit_sta08096800_1965_0329	9.18	0.17	2766	1.384	729	0.910
unit_sta08096800_1966_0208	3.86	0.15	5163	0.430	423	0.930
unit_sta08096800_1966_0424_0055	4.69	0.17	3953	0.643	484	0.870
unit_sta08096800_1966_0425	2.01	1.01	1223	1.028	239	0.830
unit_sta08096800_1966_0520	1.38	0.87	2080	0.329	130	0.767
unit_sta08096800_1966_0521	1.53	0.57	2784	0.307	163	0.908
unit_sta08096800_1967_0917	4.78	0.33	2091	1.230	490	0.813
unit_sta08096800_1967_1109	1.04	2.07	1410	0.083	22	0.854
unit_sta08096800_1968_0623	1.03	2.78	1083	0.083	17	0.929
unit_sta08096800_1968_0702	4.62	0.49	1404	1.789	479	0.856
unit_sta08096800_1968_0708	11.76	0.11	3576	1.230	838	0.987
unit_sta08096800_1969_0322	3.59	0.45	1794	1.173	401	0.873
unit_sta08096800_1969_0412	2.70	0.64	1557	1.077	319	0.844
unit_sta08096800_1969_0417	1.43	1.42	1210	0.619	143	0.921
unit_sta08096800_1969_0505	1.43	1.17	1490	0.496	141	0.898
unit_sta08096800_1970_0223	100.00	0.14	962	13.970	2559	0.771
unit_sta08096800_1970_0306	1.66	0.88	1682	0.577	185	0.961
unit_sta08096800_1970_0307	1.44	1.05	1639	0.461	144	0.984
unit_sta08096800_1970_0316	1.49	0.97	1712	0.471	154	0.807
unit_sta08096800_1971_0725	3.03	0.32	2850	0.649	352	0.964
unit_sta08096800_1971_1117	3.02	0.29	3099	0.594	351	0.982
unit_sta08096800_1971_1209	1.03	2.93	1031	0.083	16	0.752
unit_sta08096800_1973_0324	3.20	0.48	1834	1.053	368	0.952
unit_sta08096800_1973_0525	4.49	0.25	2869	0.860	470	0.989
unit_sta08096800_1973_0603	5.21	0.24	2636	1.032	518	0.881

unit_sta08096800_1974_1123	3.31	0.60	1424	1.392	377	0.847
unit_sta08096800_1975_0201	3.81	0.52	1519	1.449	419	0.907
unit_sta08137000_1961_0603	10.11	0.30	1116	2.774	770	0.879
unit_sta08137000_1961_0605	2.93	1.43	498	2.767	343	0.961
unit_sta08137000_1961_0615	6.13	0.71	629	3.665	574	0.917
unit_sta08137000_1961_1009	1.16	2.25	794	0.350	69	0.948
unit_sta08137000_1962_0907	84.08	0.15	755	12.484	2344	0.920
unit_sta08137000_1962_1012a	4.59	0.46	1171	1.636	476	0.760
unit_sta08137000_1962_1012b	4.02	1.02	568	3.081	435	0.985
unit_sta08137000_1963_0530	2.69	1.47	515	2.487	319	0.950
unit_sta08137000_1963_0616	2.26	1.51	571	1.904	271	0.979
unit_sta08137000_1964_0919a	3.81	1.04	578	2.918	419	0.900
unit_sta08137000_1964_1116a	5.10	0.58	857	2.398	511	0.940
unit_sta08137000_1964_1116b	3.57	0.91	689	2.335	400	0.962
unit_sta08137000_1965_0509	2.53	1.79	443	2.741	302	0.816
unit_sta08137000_1965_1108	3.70	0.62	985	1.674	410	0.984
unit_sta08137000_1966_0908	1.72	1.37	796	0.987	195	0.979
unit_sta08137000_1966_0918	1.54	2.02	604	1.091	164	0.931
unit_sta08137000_1967_0512	2.01	1.03	920	1.045	239	0.971
unit_sta08137000_1967_0921	1.28	2.33	651	0.659	107	0.945
unit_sta08137000_1968_0118	3.26	1.37	484	3.097	373	0.939
unit_sta08137000_1968_0119	3.39	1.08	601	2.572	384	0.760
unit_sta08137000_1968_0319	5.79	0.62	749	2.972	554	0.953
unit_sta08137000_1968_0616	1.50	2.33	539	1.161	156	0.986
unit_sta08137000_1969_0506	1.87	2.09	484	1.824	219	0.963
unit_sta08137000_1969_0603	5.33	0.75	647	3.267	526	0.917
unit_sta08137000_1969_0910	4.67	0.70	757	2.561	482	0.864
unit_sta08137000_1970_0601	1.70	1.20	918	0.845	193	0.887
unit_sta08137000_1971_0801	13.22	0.19	1527	2.353	894	0.963
unit_sta08137000_1971_0813	3.64	0.99	627	2.598	405	0.926
unit_sta08137000_1971_0922	4.29	0.93	598	3.059	455	0.770
unit_sta08137000_1971_1018	2.84	2.35	311	4.321	334	0.960
unit_sta08137000_1972_0420	1.53	1.23	994	0.657	162	0.991
unit_sta08137000_1973_0422	1.21	2.84	582	0.597	86	0.968
unit_sta08139000_1960_0104	1.37	2.26	524	0.838	128	0.939
unit_sta08139000_1960_1207	1.11	0.72	2261	0.082	54	0.870
unit_sta08139000_1961_0204	1.25	2.64	509	0.657	98	0.901
unit_sta08139000_1962_1008	2.18	0.96	786	1.136	261	0.908
unit_sta08139000_1963_0517b	1.01	0.94	2242	0.009	6	0.723
unit_sta08139000_1963_0530	2.95	0.32	1863	0.633	345	0.926
unit_sta08139000_1964_0527	2.43	0.51	1360	0.730	290	0.973
unit_sta08139000_1964_0528	5.35	0.23	1832	0.983	526	0.953

unit_sta08139000_1964_0920	3.86	0.28	1790	0.808	423	0.896
unit_sta08139000_1965_0208	9.45	0.17	1816	1.396	741	0.898
unit_sta08139000_1965_0509b	1.05	1.67	1114	0.083	27	0.796
unit_sta08139000_1966_0914a	4.31	0.33	1443	1.084	457	0.938
unit_sta08139000_1966_0914b	4.62	0.20	2252	0.727	479	0.937
unit_sta08139000_1966_0914c	1.30	0.55	2302	0.167	113	0.888
unit_sta08139000_1967_1007	4.59	0.30	1505	1.083	477	0.940
unit_sta08139000_1968_0409	1.04	1.90	993	0.083	24	0.923
unit_sta08139000_1968_0913	59.54	0.10	1098	6.124	1967	0.937
unit_sta08139000_1969_0506	3.50	0.43	1244	1.082	394	0.984
unit_sta08139000_1969_0824	2.26	0.60	1230	0.753	271	0.963
unit_sta08139000_1971_0726	100.00	0.01	8133	1.076	2559	0.827
unit_sta08139000_1971_0727	16.51	0.13	1726	1.999	1009	0.899
unit_sta08139000_1971_0801	4.70	0.28	1611	1.028	484	0.982
unit_sta08140000_1960_0104	2.89	2.16	450	4.077	339	0.948
unit_sta08140000_1961_0204	1.31	3.27	606	1.026	115	0.991
unit_sta08140000_1963_0505	2.37	0.52	2170	0.706	283	0.834
unit_sta08140000_1963_0530	1.01	5.37	618	0.054	6	0.849
unit_sta08140000_1963_0914	4.12	0.29	2677	0.895	443	0.982
unit_sta08140000_1964_0527	1.20	1.76	1278	0.354	84	0.877
unit_sta08140000_1964_0919	3.89	0.23	3446	0.667	425	0.819
unit_sta08140000_1964_0920	2.50	0.91	1183	1.363	298	0.878
unit_sta08140000_1965_0208	2.82	1.04	945	1.902	332	0.951
unit_sta08140000_1966_0914b	1.02	4.17	768	0.083	12	0.881
unit_sta08140000_1967_0819	2.62	1.75	595	2.827	311	0.947
unit_sta08140000_1967_0914	1.09	5.20	513	0.490	46	0.711
unit_sta08140000_1967_1007	1.68	3.04	493	2.079	190	0.870
unit_sta08140000_1968_0527	1.78	2.91	489	2.275	206	0.867
unit_sta08140000_1969_0506	1.27	3.88	535	1.044	103	0.967
unit_sta08140000_1969_0823	3.48	0.42	2032	1.043	392	0.919
unit_sta08140000_1969_0824	1.26	2.81	744	0.738	102	0.981
unit_sta08140000_1971_0801	4.23	0.47	1594	1.531	451	0.948
unit_sta08182400_1961_1112	3.14	1.30	915	2.778	363	0.934
unit_sta08182400_1963_1108	4.05	0.89	1128	2.720	438	0.783
unit_sta08182400_1964_0130	2.35	1.15	1267	1.559	282	0.883
unit_sta08182400_1964_0318	3.99	0.70	1444	2.101	433	0.892
unit_sta08182400_1965_0204	3.16	1.19	989	2.580	364	0.890
unit_sta08182400_1965_0330	2.56	3.75	366	5.849	305	0.757
unit_sta08182400_1965_1202	100.00	0.03	5329	3.367	2559	0.913
unit_sta08182400_1967_1109	7.15	0.60	1205	3.664	630	0.880
unit_sta08182400_1968_0118	4.10	0.53	1891	1.636	441	0.879
unit_sta08182400_1968_0119	2.07	0.78	2081	0.830	246	0.873

unit_sta08182400_1968_1126	13.58	0.38	1318	4.823	907	0.816
unit_sta08182400_1968_1130	2.18	1.99	778	2.351	261	0.952
unit_sta08182400_1969_0213	1.32	2.44	1047	0.776	116	0.965
unit_sta08182400_1969_1006	7.48	0.51	1363	3.329	647	0.939
unit_sta08182400_1969_1012	2.39	1.94	744	2.697	286	0.951
unit_sta08182400_1969_1205	2.58	2.05	665	3.233	307	0.988
unit_sta08182400_1970_0523	3.61	1.09	991	2.848	403	0.902
unit_sta08182400_1970_0526	2.26	1.64	921	2.060	271	0.983
unit_sta08182400_1970_0528	4.37	0.78	1225	2.637	461	0.968
unit_sta08187000_1960_0113	11.06	0.17	1521	1.752	810	0.930
unit_sta08187000_1960_0828b	4.90	0.63	664	2.467	498	0.833
unit_sta08187000_1960_0828c	3.68	0.56	888	1.514	409	0.847
unit_sta08187000_1960_1024	1.09	0.86	1877	0.081	46	0.957
unit_sta08187000_1961_0205	3.96	0.34	1414	1.003	431	0.873
unit_sta08187000_1962_0601	4.45	0.35	1257	1.222	467	0.974
unit_sta08187000_1962_0602	7.52	0.33	1000	2.135	649	0.986
unit_sta08187000_1962_1202	6.94	0.18	1919	1.061	619	0.780
unit_sta08187000_1963_1127	1.09	1.73	950	0.151	43	0.968
unit_sta08187000_1964_0318	13.21	0.08	2944	0.999	893	0.896
unit_sta08187000_1964_0808	4.58	0.28	1550	1.010	476	0.993
unit_sta08187000_1965_0204	2.07	1.20	632	1.288	247	0.944
unit_sta08187000_1965_0216	5.32	0.26	1535	1.125	525	0.745
unit_sta08187000_1965_0511	1.09	0.97	1682	0.088	45	0.952
unit_sta08187000_1965_0519	3.88	0.32	1500	0.931	425	0.943
unit_sta08187000_1965_1018	2.11	0.44	1688	0.492	252	0.928
unit_sta08187000_1967_0919	2.50	1.14	575	1.708	298	0.788
unit_sta08187000_1968_0507	2.71	0.38	1631	0.648	321	0.949
unit_sta08187000_1968_0511_0030	2.26	0.79	896	0.995	271	0.960
unit_sta08187000_1968_0511_1155	1.97	1.05	752	1.020	233	0.952
unit_sta08187000_1968_0512	3.72	0.37	1333	1.017	412	0.938
unit_sta08187000_1969_0603	2.58	0.91	706	1.428	307	0.964
unit_sta08187000_1969_0604	2.47	1.17	566	1.718	296	0.950
unit_sta08187000_1970_0526	2.16	1.42	517	1.642	258	0.886
unit_sta08187000_1970_0528	3.42	0.59	885	1.438	387	0.917
unit_sta08187000_1970_0531	4.59	0.43	1007	1.557	477	0.950
unit_sta08187900_1962_1202	2.78	0.48	3201	0.864	328	0.731
unit_sta08187900_1962_1220	1.02	3.70	1337	0.083	13	0.779
unit_sta08187900_1963_0625	5.58	0.32	3085	1.478	541	0.962
unit_sta08187900_1963_1127	3.57	0.61	2148	1.570	400	0.950
unit_sta08187900_1964_0318	1.36	1.29	2290	0.460	125	0.869
unit_sta08187900_1964_0808	4.52	0.52	2190	1.816	472	0.974
unit_sta08187900_1965_0204	3.49	0.97	1378	2.401	393	0.966

unit_sta08187900_1965_0216	3.70	1.12	1140	3.030	410	0.978
unit_sta08187900_1965_0511	2.59	0.56	2941	0.884	308	0.948
unit_sta08187900_1965_0519	3.94	0.50	2472	1.462	429	0.820
unit_sta08187900_1966_0917	2.67	0.96	1671	1.598	317	0.862
unit_sta08187900_1967_0919a	3.26	0.50	2780	1.133	373	0.953
unit_sta08187900_1969_0504	1.52	5.48	474	2.853	160	0.857
unit_sta08187900_1970_0528	1.13	2.83	1381	0.365	60	0.966
unit_sta08187900_1970_0531	1.40	2.65	1072	1.071	136	0.890
unit_sta08111025_1968_0709	2.22	0.68	425	0.832	266	0.975
unit_sta08111025_1969_0214	1.24	0.97	548	0.229	94	0.974
unit_sta08111025_1969_0221	1.87	0.54	617	0.470	218	0.960
unit_sta08111025_1969_0508	5.02	0.24	711	0.946	506	0.946
unit_sta08111025_1970_0418	55.26	0.06	768	3.280	1893	0.988
unit_sta08111025_1970_0910	2.97	0.27	878	0.524	346	0.985
unit_sta08111025_1970_0915	5.86	0.18	866	0.856	558	0.955
unit_sta08111050_1968_0709	3.14	0.98	335	2.101	363	0.986
unit_sta08111050_1969_0214	2.57	1.96	193	3.067	306	0.988
unit_sta08111050_1969_0221	2.64	1.88	197	3.078	313	0.970
unit_sta08111050_1969_0508	3.87	0.99	288	2.851	424	0.962
unit_sta08111050_1970_0419	5.01	0.72	339	2.891	505	0.977
unit_sta08111050_1970_0910	7.28	0.44	444	2.784	637	0.983

Appendix Table D6. Unit hydrograph parameters for Houston watersheds.

Code	alpha	beta (hr)	q_p (cfs)	t_p (hr)	*PRF*	*NSE*
unit_sta08068438_1975_0408	1.72	1.98	76	1.419	195	0.953
unit_sta08068438_1981_0503	1.23	2.08	106	0.484	93	0.922
unit_sta08068438_1981_0831	2.11	0.89	140	0.989	252	0.841
unit_sta08068438_1983_0520	1.05	1.61	184	0.083	28	0.907
unit_sta08068438_1983_0818	1.71	1.42	106	1.002	193	0.955
unit_sta08068438_1984_1025	1.11	0.76	345	0.083	52	0.863
unit_sta08068438_1985_1124	1.23	1.28	173	0.291	92	0.906
unit_sta08068438_1987_0928	1.08	0.99	280	0.083	42	0.804
unit_sta08068438_1987_1125	1.34	1.10	178	0.375	122	0.955
unit_sta08068440_1974_1124	1.01	13.34	33	0.133	6	0.936
unit_sta08068440_1975_0408	2.59	2.27	61	3.605	308	0.934
unit_sta08073630_1979_0917	1.03	2.78	283	0.083	17	0.920
unit_sta08073630_1979_1212	1.01	1.70	495	0.017	6	0.955
unit_sta08073630_1981_0423	1.76	0.99	367	0.752	201	0.960
unit_sta08073630_1981_0503	2.60	1.53	173	2.444	309	0.852
unit_sta08073630_1981_0514	19.23	0.11	719	2.084	1094	0.990

unit_sta08073630_1981_1031	1.81	0.84	422	0.681	210	0.975
unit_sta08073630_1982_0421	1.62	0.62	638	0.383	179	0.869
unit_sta08073630_1982_0513	1.08	1.46	480	0.111	39	0.983
unit_sta08073630_1983_0520a	1.06	1.39	523	0.083	32	0.902
unit_sta08073630_1983_0520b	1.16	0.99	610	0.159	71	0.921
unit_sta08073630_1984_0323	1.01	1.39	605	0.014	6	0.956
unit_sta08073750_1967_0921	1.09	0.89	278	0.083	46	0.967
unit_sta08073750_1968_0510	1.28	0.76	249	0.215	107	0.974
unit_sta08073750_1968_0604	1.08	1.01	249	0.083	42	0.807
unit_sta08073750_1968_0616	1.50	0.74	211	0.371	156	0.971
unit_sta08073750_1968_0914	1.05	2.31	118	0.113	27	0.906
unit_sta08073750_1968_0917	1.15	1.39	160	0.212	68	0.890
unit_sta08073750_1968_1006	1.09	0.93	266	0.083	44	0.776
unit_sta08073750_1968_1130	1.06	1.39	191	0.083	32	0.900
unit_sta08073750_1970_0521	1.04	2.11	132	0.083	22	0.930
unit_sta08073750_1970_0705	1.80	0.74	177	0.588	208	0.920
unit_sta08073750_1970_0830	1.07	1.24	210	0.083	35	0.924
unit_sta08073800_1965_0216	1.01	7.43	229	0.074	6	0.971
unit_sta08073800_1965_0805	1.12	3.43	382	0.401	55	0.956
unit_sta08073800_1966_0518	1.02	4.17	393	0.083	12	0.863
unit_sta08073800_1967_0413	1.47	1.63	545	0.758	149	0.971
unit_sta08073800_1967_0601	1.70	1.74	438	1.213	192	0.958
unit_sta08073800_1967_0824	1.05	1.79	848	0.083	25	0.974
unit_sta08073800_1967_0921	1.07	1.17	1219	0.083	37	0.913
unit_sta08073800_1968_0604	1.72	0.88	861	0.628	195	0.965
unit_sta08073800_1968_0914	1.80	1.53	472	1.222	208	0.936
unit_sta08073800_1968_0917	1.15	2.83	439	0.422	67	0.941
unit_sta08073800_1968_1130	1.31	2.07	493	0.635	113	0.953
unit_sta08073800_1969_0412	1.33	2.51	397	0.829	119	0.984
unit_sta08073800_1970_0705	1.45	3.15	286	1.407	145	0.933
unit_sta08073800_1970_0830	1.61	1.55	517	0.947	177	0.911
unit_sta08073800_1970_1011	1.03	2.78	572	0.083	17	0.890
unit_sta08073800_1972_0320	1.03	2.78	572	0.083	17	0.917
unit_sta08073800_1972_1113	1.30	2.33	443	0.694	111	0.858
unit_sta08074100_1966_0414	2.20	4.17	371	5.000	263	0.942
unit_sta08074100_1966_0518	1.76	5.90	318	4.464	202	0.949
unit_sta08074100_1967_0413	1.70	4.01	483	2.807	192	0.940
unit_sta08074100_1968_0510	1.61	6.40	319	3.910	177	0.849
unit_sta08074100_1969_0221	2.60	4.31	317	6.889	309	0.982
unit_sta08074100_1970_0530	1.78	5.81	319	4.546	206	0.928
unit_sta08074100_1970_1011	1.81	5.08	359	4.130	210	0.963
unit_sta08074100_1970_1023	1.51	10.47	209	5.349	158	0.966

unit_sta08074100_1972_0320	2.20	4.31	360	5.167	263	0.919
unit_sta08074145_1980_0609	9.24	0.07	274	0.560	732	0.836
unit_sta08074145_1980_1015	1.09	1.99	53	0.177	44	0.852
unit_sta08074145_1981_0509	1.13	0.64	152	0.083	60	0.844
unit_sta08074145_1983_0209	1.14	0.58	163	0.083	65	0.818
unit_sta08074150_1965_0216	1.12	12.37	287	1.431	55	0.909
unit_sta08074150_1967_0413	2.41	3.23	475	4.562	289	0.909
unit_sta08074150_1967_0529	2.37	3.82	407	5.228	284	0.937
unit_sta08074150_1968_0510	1.60	6.06	361	3.647	175	0.931
unit_sta08074150_1968_0614	4.56	2.55	392	9.091	475	0.813
unit_sta08074150_1969_0221	1.78	6.50	303	5.090	206	0.992
unit_sta08074150_1970_0501	2.33	4.08	385	5.450	280	0.955
unit_sta08074150_1970_0515	1.19	8.33	383	1.546	79	0.986
unit_sta08074150_1970_0530	1.94	6.90	265	6.479	229	0.934
unit_sta08074150_1970_0721	1.54	5.36	423	2.917	165	0.978
unit_sta08074150_1970_1011	1.02	12.07	362	0.298	14	0.970
unit_sta08074150_1970_1023	1.12	15.12	233	1.846	57	0.984
unit_sta08074150_1971_0524	1.42	5.92	421	2.483	140	0.980
unit_sta08074150_1972_0320	1.01	8.61	534	0.086	6	0.985
unit_sta08074150_1973_0415	1.97	6.28	287	6.106	234	0.884
unit_sta08074150_1974_0119	1.28	8.33	341	2.339	106	0.986
unit_sta08074150_1974_0912	1.01	6.94	658	0.083	7	0.917
unit_sta08074150_1975_0529	1.01	8.33	552	0.083	6	0.867
unit_sta08074150_1975_0610	1.33	8.33	323	2.784	120	0.975
unit_sta08074150_1979_0917	1.01	15.87	290	0.159	6	0.933
unit_sta08074150_1980_0120	1.44	6.64	368	2.946	145	0.985
unit_sta08074150_1980_0327	1.28	7.74	367	2.180	107	0.902
unit_sta08074150_1981_0423	2.03	1.26	1392	1.303	242	0.926
unit_sta08074150_1981_0503	1.03	5.72	751	0.172	17	0.923
unit_sta08074150_1981_0509	1.40	3.75	676	1.500	135	0.962
unit_sta08074150_1981_1005	1.42	2.55	975	1.078	140	0.875
unit_sta08074150_1981_1031	1.32	3.39	806	1.076	116	0.978
unit_sta08074150_1981_1129	1.29	5.24	535	1.535	110	0.986
unit_sta08074150_1983_0330	1.47	2.65	907	1.236	149	0.876
unit_sta08074150_1983_0520	1.21	9.26	333	1.947	87	0.919
unit_sta08074150_1983_0721	1.23	5.47	552	1.249	92	0.778
unit_sta08074150_1983_0818	1.33	8.33	323	2.783	120	0.953
unit_sta08074150_1983_0919	1.02	4.44	998	0.089	12	0.841
unit_sta08074150_1984_0718	1.40	2.92	869	1.167	135	0.983
unit_sta08074150_1986_1123	1.02	4.17	1065	0.083	12	0.850
unit_sta08074150_1989_0517	1.01	6.03	762	0.061	6	0.951
unit_sta08074200_1965_0216	1.36	3.53	254	1.268	126	0.991

unit_sta08074200_1966_0414	1.12	8.33	145	0.989	56	0.925
unit_sta08074200_1966_0518	1.50	6.64	120	3.349	157	0.993
unit_sta08074200_1967_0413	3.29	1.14	368	2.614	376	0.915
unit_sta08074200_1967_0921	1.01	8.61	182	0.086	6	0.806
unit_sta08074200_1968_0510	1.20	7.87	136	1.562	83	0.741
unit_sta08074200_1968_0917	1.35	6.14	147	2.141	123	0.764
unit_sta08074200_1968_1006	1.11	1.95	629	0.213	52	0.951
unit_sta08074200_1969_0221	1.01	13.18	119	0.132	6	0.952
unit_sta08074200_1970_0501	1.11	13.19	93	1.412	52	0.923
unit_sta08074200_1970_0515	1.01	15.84	99	0.158	6	0.981
unit_sta08074200_1970_0721	1.01	8.33	186	0.116	8	0.949
unit_sta08074200_1970_1011	1.04	8.33	169	0.368	24	0.712
unit_sta08074200_1970_1023	1.01	12.44	126	0.124	6	0.940
unit_sta08074200_1971_0524	1.04	8.33	173	0.300	20	0.971
unit_sta08074200_1974_0119	1.20	8.33	128	1.668	83	0.952
unit_sta08074200_1974_0315	1.61	3.63	204	2.219	177	0.991
unit_sta08074200_1975_0610	1.01	10.86	145	0.109	6	0.948
unit_sta08074200_1975_0722	1.49	4.67	173	2.267	153	0.992
unit_sta08074200_1978_0606	1.02	5.16	298	0.083	10	0.771
unit_sta08074200_1978_0728	1.05	2.98	467	0.146	27	0.920
unit_sta08074200_1979_0418	1.09	5.08	250	0.459	45	0.893
unit_sta08074200_1979_0917	1.01	13.25	119	0.133	6	0.837
unit_sta08074200_1979_1030	1.03	2.50	587	0.075	17	0.951
unit_sta08074200_1980_0329	1.01	7.22	216	0.087	7	0.895
unit_sta08074200_1981_0423	2.99	0.54	831	1.073	348	0.878
unit_sta08074200_1981_0830	1.01	16.50	95	0.165	6	0.728
unit_sta08074200_1981_1031	1.67	1.76	407	1.178	187	0.942
unit_sta08074200_1982_0513	1.03	3.19	465	0.083	15	0.848
unit_sta08074200_1982_0517	1.03	1.94	755	0.058	17	0.963
unit_sta08074200_1983_0330	1.38	3.01	293	1.139	130	0.895
unit_sta08074200_1983_0721	1.01	4.43	355	0.044	6	0.949
unit_sta08074200_1983_0811	1.02	7.49	205	0.116	9	0.969
unit_sta08074200_1984_0718	1.03	2.39	604	0.083	20	0.971
unit_sta08074250_1965_0216	1.01	6.48	1067	0.083	8	0.937
unit_sta08074250_1965_0528	1.03	5.50	1188	0.165	17	0.976
unit_sta08074250_1965_0628	1.19	1.91	2517	0.365	81	0.949
unit_sta08074250_1965_0705	2.20	1.53	1638	1.833	263	0.956
unit_sta08074250_1966_0328	1.03	4.39	1489	0.132	17	0.966
unit_sta08074250_1966_0414	1.80	4.03	737	3.222	208	0.961
unit_sta08074250_1966_0518	1.46	5.81	630	2.697	149	0.975
unit_sta08074250_1966_0618	1.02	4.33	1556	0.087	12	0.876
unit_sta08074250_1967_0413	1.01	5.01	1398	0.050	6	0.942

unit_sta08074250_1967_0825	1.02	3.90	1719	0.083	13	0.900
unit_sta08074250_1967_0921	1.03	3.25	2037	0.083	15	0.870
unit_sta08074250_1968_0510	1.25	4.72	947	1.181	98	0.922
unit_sta08074250_1968_0614	3.47	1.43	1259	3.546	391	0.805
unit_sta08074250_1968_0917	1.02	3.35	1980	0.083	14	0.885
unit_sta08074250_1968_1006	1.02	4.59	1478	0.083	11	0.903
unit_sta08074250_1968_1105	1.04	1.86	3376	0.083	25	0.932
unit_sta08074250_1969_0221	1.40	4.31	895	1.722	135	0.925
unit_sta08074250_1970_0501	1.02	4.04	1673	0.080	12	0.934
unit_sta08074250_1970_0515	1.01	5.64	1218	0.083	9	0.897
unit_sta08074250_1970_0530	1.02	5.15	1327	0.083	10	0.908
unit_sta08074250_1970_0721	1.40	2.78	1387	1.111	135	0.959
unit_sta08074250_1970_1011	1.40	2.92	1321	1.167	135	0.934
unit_sta08074250_1970_1023	1.40	4.03	956	1.611	135	0.977
unit_sta08074250_1971_0524	1.42	2.80	1351	1.184	140	0.917
unit_sta08074250_1972_0320	1.40	3.89	991	1.556	135	0.978
unit_sta08074250_1973_0611	1.10	3.06	1819	0.306	49	0.919
unit_sta08074250_1973_0810	1.40	1.81	2134	0.722	135	0.989
unit_sta08074250_1974_0119	1.40	2.92	1321	1.167	135	0.946
unit_sta08074250_1974_0315	1.08	2.16	2690	0.166	39	0.951
unit_sta08074250_1975_0529	1.80	1.81	1644	1.444	208	0.942
unit_sta08074250_1975_0610	1.92	1.86	1509	1.708	226	0.909
unit_sta08074250_1978_0606	1.03	2.78	2352	0.083	17	0.854
unit_sta08074250_1978_0728	1.40	1.53	2522	0.611	135	0.987
unit_sta08074250_1979_0418	1.40	1.80	2139	0.718	135	0.894
unit_sta08074250_1979_0917	1.03	2.78	2352	0.083	17	0.944
unit_sta08074250_1979_1030	1.05	1.67	3713	0.083	27	0.908
unit_sta08074250_1980_0327a	1.41	1.84	2069	0.760	138	0.838
unit_sta08074250_1980_0327b	3.01	0.91	2185	1.829	351	0.879
unit_sta08074250_1980_1015	1.40	1.53	2522	0.611	135	0.943
unit_sta08074250_1981_0830	1.03	2.74	2370	0.087	18	0.943
unit_sta08074250_1981_1006	1.88	1.14	2505	1.003	220	0.902
unit_sta08074250_1981_1031	4.24	0.60	2630	1.958	452	0.967
unit_sta08074250_1982_0130	2.77	0.61	3479	1.071	327	0.950
unit_sta08074250_1982_0513	1.40	1.67	2311	0.667	135	0.976
unit_sta08074250_1982_0517	2.24	0.87	2832	1.082	269	0.945
unit_sta08074250_1983_0330	1.79	1.35	2204	1.072	207	0.896
unit_sta08074250_1983_0721	1.40	1.67	2311	0.667	135	0.920
unit_sta08074250_1983_0811	1.04	2.08	3049	0.083	22	0.775
unit_sta08074250_1983_0919	1.03	2.78	2352	0.083	17	0.791
unit_sta08074250_1984_0718	1.27	1.50	2913	0.405	103	0.934
unit_sta08074250_1989_0626	1.01	1.39	5037	0.014	6	0.982

unit_sta08074540_1979_1030	1.03	1.94	5335	0.058	17	0.950
unit_sta08074540_1979_1212	1.03	3.24	3178	0.104	18	0.917
unit_sta08074540_1980_0117	2.28	1.71	2255	2.196	274	0.963
unit_sta08074540_1981_0604	1.40	2.36	2591	0.944	135	0.962
unit_sta08074540_1981_0705	1.40	1.81	3388	0.722	135	0.984
unit_sta08074540_1981_0830	1.27	3.13	2226	0.832	102	0.902
unit_sta08074540_1981_1005a	1.03	2.78	3735	0.083	17	0.834
unit_sta08074540_1981_1005b	2.05	1.53	2755	1.604	244	0.972
unit_sta08074540_1981_1005c	1.60	1.53	3456	0.917	175	0.991
unit_sta08074540_1981_1031	1.43	1.77	3362	0.764	142	0.992
unit_sta08074540_1982_0506	1.40	2.50	2447	1.000	135	0.924
unit_sta08074540_1982_0513	1.40	2.92	2097	1.167	135	0.989
unit_sta08074540_1982_0517	1.80	2.08	2263	1.667	208	0.982
unit_sta08074540_1982_0622	7.29	0.41	4510	2.558	637	0.916
unit_sta08074540_1983_0220	1.72	1.85	2670	1.321	195	0.967
unit_sta08074540_1983_0330	10.00	0.54	2858	4.847	765	0.920
unit_sta08074540_1983_0520b	2.52	1.81	1973	2.760	301	0.957
unit_sta08074540_1983_0615	1.40	1.67	3670	0.667	135	0.971
unit_sta08074540_1983_0721	2.60	1.53	2290	2.444	309	0.947
unit_sta08074540_1983_0818	1.40	3.47	1762	1.389	135	0.965
unit_sta08074540_1983_0919	1.10	5.26	1689	0.506	47	0.754
unit_sta08074540_1984_0109	1.40	2.36	2591	0.944	135	0.976
unit_sta08074750_1974_1031	1.31	10.31	31	3.153	113	0.962
unit_sta08074750_1976_0615	1.15	27.78	14	4.075	66	0.969
unit_sta08074760_1978_0606	2.60	3.89	641	6.222	309	0.915
unit_sta08074760_1979_0419	1.94	4.49	700	4.218	229	0.920
unit_sta08074760_1979_0917	1.84	7.38	446	6.203	214	0.859
unit_sta08074760_1979_1030	2.53	4.78	532	7.312	302	0.934
unit_sta08074760_1979_1212	2.52	4.22	604	6.436	301	0.953
unit_sta08074760_1980_0120	1.66	8.34	436	5.477	185	0.925
unit_sta08074760_1981_0423	2.82	2.17	1085	3.946	332	0.979
unit_sta08074760_1981_0503	2.22	2.35	1200	2.855	266	0.977
unit_sta08074760_1981_1031	2.51	2.99	855	4.520	300	0.851
unit_sta08074760_1982_0513	1.80	4.31	780	3.444	208	0.920
unit_sta08074760_1983_0209	2.58	3.07	818	4.845	307	0.891
unit_sta08074760_1983_0919	3.69	1.51	1303	4.056	410	0.905
unit_sta08074780_1966_0830	1.61	4.65	537	2.845	177	0.996
unit_sta08074780_1968_0917	1.74	5.77	401	4.298	200	0.997
unit_sta08074780_1974_1031	1.01	27.71	191	0.277	6	0.764
unit_sta08074780_1975_0804	1.27	3.32	992	0.911	105	0.994
unit_sta08074780_1976_0615	1.01	25.17	210	0.252	6	0.945
unit_sta08074780_1978_0607	1.40	3.60	810	1.437	135	0.923

unit_sta08074780_1979_0403	1.01	13.01	407	0.130	6	0.863
unit_sta08074780_1979_0419	1.01	15.94	332	0.159	6	0.950
unit_sta08074780_1981_0503	1.03	6.22	795	0.187	17	0.732
unit_sta08074780_1981_0819	1.02	5.11	999	0.102	12	0.969
unit_sta08074780_1981_0830	1.01	13.99	378	0.140	6	0.881
unit_sta08074780_1981_1129	1.16	2.70	1407	0.435	71	0.853
unit_sta08074780_1983_0209	1.34	6.86	449	2.323	121	0.990
unit_sta08074780_1983_0818	1.01	7.89	670	0.083	6	0.875
unit_sta08074780_1983_0919	1.40	4.31	677	1.722	135	0.962
unit_sta08074800_1964_1209	1.01	17.99	433	0.180	6	0.946
unit_sta08074800_1965_0216	1.01	26.32	296	0.263	6	0.979
unit_sta08074800_1966_0830	1.13	11.57	511	1.462	59	0.986
unit_sta08074800_1970_0501	1.01	18.21	428	0.182	6	0.776
unit_sta08074800_1970_0521	1.01	15.83	492	0.158	6	0.916
unit_sta08074800_1973_0611	1.01	15.07	517	0.151	6	0.914
unit_sta08074800_1973_0707	1.01	18.33	425	0.183	6	0.811
unit_sta08074800_1974_0831	1.40	3.47	1236	1.389	135	0.994
unit_sta08074800_1975_0609	1.01	27.78	281	0.278	6	0.864
unit_sta08074800_1977_0420	1.60	4.45	832	2.671	175	0.902
unit_sta08074800_1978_0607	1.40	4.31	997	1.722	135	0.932
unit_sta08074800_1979_0105	1.01	16.28	479	0.163	6	0.908
unit_sta08074800_1979_0403	1.01	12.84	607	0.128	6	0.924
unit_sta08074800_1979_0917	2.32	6.82	392	8.996	278	0.791
unit_sta08074800_1979_1212	1.06	3.69	1820	0.226	32	0.962
unit_sta08074800_1980_0120	1.01	11.22	695	0.112	6	0.881
unit_sta08074800_1981_0423	1.18	3.48	1565	0.625	77	0.991
unit_sta08074800_1981_0503	1.03	5.79	1276	0.145	15	0.850
unit_sta08074800_1981_0819	1.80	2.22	1488	1.778	208	0.984
unit_sta08074800_1981_0830	1.01	9.53	818	0.095	6	0.879
unit_sta08074800_1981_1129	1.80	1.47	2247	1.178	208	0.896
unit_sta08074800_1982_0513	1.03	6.50	1120	0.195	17	0.961
unit_sta08074800_1982_0715	1.03	2.94	2472	0.088	17	0.925
unit_sta08074800_1982_0730	1.32	1.55	2990	0.492	116	0.877
unit_sta08074800_1982_0808	1.03	3.47	2096	0.104	17	0.848
unit_sta08074800_1982_1119	1.02	5.16	1476	0.083	10	0.942
unit_sta08074800_1983_0209	1.04	7.33	972	0.276	21	0.967
unit_sta08074800_1983_0215	1.01	7.97	978	0.080	6	0.975
unit_sta08074800_1983_0220	1.01	6.94	1109	0.090	8	0.826
unit_sta08074800_1983_0520	1.17	5.08	1087	0.859	74	0.911
unit_sta08074800_1987_0609a	1.02	4.17	1803	0.083	12	0.822
unit_sta08074800_1987_0609b	1.01	6.14	1247	0.089	9	0.782
unit_sta08074800_1988_0429	1.40	3.06	1405	1.222	135	0.925

unit_sta08074850_1968_0914	1.80	1.67	670	1.333	208	0.996
unit_sta08074850_1968_0917	1.40	1.94	746	0.778	135	0.987
unit_sta08074850_1968_1130	2.91	0.77	1000	1.459	340	0.952
unit_sta08074850_1969_0214	1.34	1.45	1053	0.498	122	0.994
unit_sta08074850_1969_0221	1.51	1.79	743	0.915	158	0.973
unit_sta08074850_1969_0503	1.82	1.01	1094	0.830	212	0.993
unit_sta08074850_1969_0915	1.40	1.53	949	0.611	135	0.982
unit_sta08074850_1969_0919	1.80	1.67	670	1.333	208	0.924
unit_sta08074850_1970_1011	1.63	2.12	581	1.325	180	0.905
unit_sta08074850_1970_1022	1.80	2.08	536	1.667	208	0.920
unit_sta08074850_1972_0512	1.40	1.53	949	0.611	135	0.963
unit_sta08074850_1972_0610	1.40	2.78	522	1.111	135	0.982
unit_sta08074850_1973_0611b	1.02	4.17	609	0.083	12	0.731
unit_sta08074850_1973_0707	1.03	2.56	952	0.083	19	0.955
unit_sta08074850_1974_0119	2.55	1.01	835	1.561	304	0.955
unit_sta08074850_1974_0831	1.02	4.17	609	0.083	12	0.872
unit_sta08074850_1974_1031	2.12	1.00	966	1.127	254	0.956
unit_sta08074850_1976_0615	1.06	3.33	682	0.200	32	0.915
unit_sta08074850_1978_0607	1.80	1.53	731	1.222	208	0.961
unit_sta08074850_1980_0120c	1.10	1.53	1369	0.153	49	0.966
unit_sta08074900_1965_0216	1.01	18.95	123	0.189	6	0.795
unit_sta08074900_1965_0518	1.01	18.88	124	0.189	6	0.781
unit_sta08074900_1965_0713	1.11	3.01	611	0.318	51	0.821
unit_sta08074900_1966_0328	1.01	10.77	217	0.108	6	0.836
unit_sta08074900_1966_0806	1.10	0.86	2172	0.083	47	0.907
unit_sta08074900_1966_1004	1.04	1.95	1079	0.083	24	0.966
unit_sta08074900_1967_0825	1.02	3.59	621	0.083	14	0.940
unit_sta08074900_1967_0921	1.01	9.59	244	0.096	6	0.913
unit_sta08074910_1979_0725	2.65	0.48	127	0.791	314	0.798
unit_sta08074910_1981_0503	1.05	1.85	95	0.083	25	0.980
unit_sta08074910_1981_0707	1.08	0.99	162	0.083	42	0.957
unit_sta08074910_1981_1031	4.85	0.26	161	0.982	494	0.958
unit_sta08074910_1982_0513	1.33	1.10	105	0.359	118	0.965
unit_sta08074910_1983_0520	1.18	0.90	153	0.163	78	0.961
unit_sta08074910_1983_0818b	78.48	0.08	114	6.376	2264	0.926
unit_sta08075300_1966_0209	1.67	6.48	164	4.357	188	0.971
unit_sta08075300_1966_0414	1.01	13.09	179	0.131	6	0.994
unit_sta08075300_1966_0518	1.79	6.45	155	5.088	207	0.988
unit_sta08075300_1966_0520	1.41	8.33	153	3.445	138	0.943
unit_sta08075300_1967_0825	2.17	5.48	154	6.426	260	0.967
unit_sta08075300_1970_0501	1.21	20.83	75	4.398	87	0.966
unit_sta08075300_1970_0515	1.04	23.82	89	0.964	23	0.984

unit_sta08075300_1970_0521	1.12	18.19	99	2.145	56	0.982
unit_sta08075300_1971_0910	1.46	8.10	151	3.719	148	0.951
unit_sta08075300_1972_0510	1.66	6.52	165	4.289	185	0.924
unit_sta08075550_1966_0209	1.20	5.56	215	1.111	83	0.933
unit_sta08075550_1966_0328	2.50	0.80	716	1.196	298	0.812
unit_sta08075550_1966_0414	1.40	4.31	225	1.722	135	0.992
unit_sta08075550_1966_0520	1.34	3.76	271	1.292	122	0.977
unit_sta08075550_1966_0619	1.40	3.19	304	1.278	135	0.975
unit_sta08075550_1966_0909	1.27	2.58	427	0.691	103	0.984
unit_sta08075550_1967_0413	1.60	1.79	468	1.075	175	0.990
unit_sta08075550_1968_0119	1.40	2.64	368	1.056	135	0.970
unit_sta08075550_1968_0510	1.42	6.07	158	2.524	139	0.992
unit_sta08075550_1968_0917	2.21	1.71	366	2.076	265	0.859
unit_sta08075550_1968_1009	1.62	2.84	292	1.751	178	0.976
unit_sta08075550_1969_0214	1.40	3.47	279	1.389	135	0.963
unit_sta08075550_1969_0315	1.40	3.06	317	1.222	135	0.993
unit_sta08075550_1969_1030	1.40	2.64	368	1.056	135	0.908
unit_sta08075550_1970_0521	1.32	5.43	193	1.717	115	0.980
unit_sta08075550_1970_0530	1.80	4.17	179	3.333	208	0.929
unit_sta08075550_1970_1011	1.77	3.41	223	2.608	203	0.964
unit_sta08075550_1970_1023	1.36	3.06	329	1.098	126	0.998
unit_sta08075550_1972_0510	1.80	4.03	186	3.222	208	0.952
unit_sta08075550_1972_1106	1.80	4.73	158	3.783	208	0.941
unit_sta08075550_1974_0119	1.11	6.65	208	0.700	51	0.985
unit_sta08075550_1974_0831	1.80	4.31	174	3.444	208	0.953
unit_sta08075550_1978_0627	1.20	3.33	359	0.667	83	0.935
unit_sta08075550_1979_0725	2.10	5.83	112	6.417	251	0.764
unit_sta08075550_1979_0901	1.40	4.31	225	1.722	135	0.969
unit_sta08075550_1979_0918	1.17	11.11	113	1.851	73	0.887
unit_sta08075550_1980_0120	1.40	3.61	269	1.444	135	0.954
unit_sta08075550_1981_0503	1.20	7.22	166	1.444	83	0.891
unit_sta08075550_1981_0605	1.40	3.89	249	1.556	135	0.982
unit_sta08075550_1981_0831	1.29	5.17	208	1.510	109	0.977
unit_sta08075550_1982_0513	2.23	2.09	298	2.575	267	0.964
unit_sta08075550_1983_0818	1.01	10.22	172	0.102	6	0.905
unit_sta08075550_1983_0919	1.31	3.74	282	1.163	114	0.987
unit_sta08075550_1984_0812	1.12	4.49	300	0.544	57	0.993
unit_sta08075600_1965_0522	1.06	2.25	368	0.144	34	0.980
unit_sta08075600_1965_0606	1.07	4.35	187	0.311	37	0.978
unit_sta08075600_1966_0209	1.04	3.55	249	0.134	21	0.979
unit_sta08075600_1966_0328	1.47	2.01	252	0.936	149	0.949
unit_sta08075600_1966_0414	1.39	3.50	154	1.365	133	0.943

unit_sta08075600_1966_0520	1.52	3.04	160	1.569	159	0.988
unit_sta08075600_1966_1004	1.72	1.65	261	1.183	195	0.986
unit_sta08075600_1967_0413	1.05	4.03	215	0.183	25	0.979
unit_sta08075600_1968_0526	1.02	4.56	206	0.083	11	0.979
unit_sta08075600_1968_0604	1.04	2.70	327	0.107	22	0.979
unit_sta08075600_1968_0917	1.32	2.32	248	0.744	117	0.908
unit_sta08075600_1968_1009	1.01	6.01	161	0.060	6	0.984
unit_sta08075600_1969_0214	1.02	4.83	195	0.083	10	0.991
unit_sta08075600_1969_0315	1.13	4.86	150	0.633	60	0.992
unit_sta08075600_1969_0412	1.40	4.03	133	1.611	135	0.953
unit_sta08075600_1969_1030	1.91	0.97	404	0.879	225	0.932
unit_sta08075600_1970_0521	1.52	3.08	158	1.611	161	0.994
unit_sta08075600_1970_0530	1.27	4.87	125	1.305	103	0.934
unit_sta08075600_1972_0510	1.40	4.31	124	1.722	135	0.953
unit_sta08075650_1965_0522	1.03	2.71	2258	0.083	18	0.934
unit_sta08075650_1965_0606	1.40	2.92	1240	1.167	135	0.963
unit_sta08075650_1966_0209	1.16	6.41	737	1.019	70	0.926
unit_sta08075650_1966_0328	1.40	1.81	2003	0.722	135	0.953
unit_sta08075650_1966_0909	1.40	2.50	1446	1.000	135	0.985
unit_sta08075650_1966_1004	1.80	2.08	1338	1.667	208	0.962
unit_sta08075650_1967_0411	1.06	3.66	1546	0.224	32	0.902
unit_sta08075650_1967_0413	2.20	1.53	1538	1.833	263	0.972
unit_sta08075650_1968_0526	2.60	1.53	1354	2.444	309	0.946
unit_sta08075650_1968_0604	22.00	0.72	829	15.160	1175	0.727
unit_sta08075650_1968_0917	2.60	1.53	1354	2.444	309	0.922
unit_sta08075650_1968_1009	1.70	3.47	845	2.445	193	0.958
unit_sta08075650_1969_0214	1.03	5.49	1105	0.186	19	0.989
unit_sta08075650_1969_1030	1.57	3.54	900	2.012	169	0.822
unit_sta08075650_1970_0530	1.63	4.02	760	2.553	181	0.911
unit_sta08075650_1970_1023	1.80	4.03	692	3.222	208	0.935
unit_sta08075700_1964_1104	1.02	4.99	583	0.083	10	0.910
unit_sta08075700_1964_1209	1.20	8.33	242	1.707	85	0.955
unit_sta08075700_1965_0522	1.52	4.71	317	2.467	161	0.946
unit_sta08075700_1966_0328	1.02	8.33	342	0.187	13	0.987
unit_sta08075700_1966_0414	1.95	5.69	207	5.410	230	0.947
unit_sta08075700_1966_0520	1.09	10.32	235	0.916	44	0.928
unit_sta08075700_1966_0909	1.81	3.46	365	2.794	210	0.895
unit_sta08075700_1967_0413	1.15	5.69	382	0.854	67	0.927
unit_sta08075700_1968_0119	1.80	4.31	294	3.444	208	0.976
unit_sta08075700_1968_0917	1.01	9.19	325	0.092	6	0.935
unit_sta08075700_1968_1009	1.33	7.79	224	2.597	120	0.970
unit_sta08075700_1969_0214	1.80	4.31	294	3.444	208	0.944

unit_sta08075700_1972_0427	1.01	8.33	358	0.083	6	0.944
unit_sta08075730_1975_0609	1.40	2.92	957	1.167	135	0.950
unit_sta08075730_1975_0731	1.40	3.33	837	1.333	135	0.985
unit_sta08075730_1977_0420	1.30	2.05	1504	0.606	110	0.944
unit_sta08075730_1979_0319	1.40	2.22	1256	0.889	135	0.983
unit_sta08075730_1979_0724	1.40	3.33	837	1.333	135	0.982
unit_sta08075730_1979_0917	1.45	3.33	804	1.500	146	0.955
unit_sta08075730_1981_0503	1.40	2.78	1005	1.111	135	0.979
unit_sta08075730_1981_0604	1.40	2.92	957	1.167	135	0.964
unit_sta08075730_1981_0830	1.40	2.36	1182	0.944	135	0.943
unit_sta08075730_1982_0513	1.28	2.29	1374	0.632	105	0.957
unit_sta08075730_1982_0809	1.33	1.74	1708	0.574	119	0.987
unit_sta08075730_1983_0817	1.40	2.36	1182	0.944	135	0.969
unit_sta08075730_1983_0919	1.40	1.94	1436	0.778	135	0.969
unit_sta08075730_1983_1130	2.67	0.64	2438	1.071	316	0.959
unit_sta08075730_1984_0812	1.31	1.53	1976	0.479	115	0.993
unit_sta08075730_1985_0314	1.03	2.78	1704	0.083	17	0.935
unit_sta08075730_1985_1111	1.22	2.92	1157	0.631	88	0.978
unit_sta08075730_1987_0609	1.95	1.50	1334	1.430	231	0.971
unit_sta08075750_1965_0922	1.01	1.51	489	0.015	6	0.953
unit_sta08075750_1966_0328	1.21	2.16	230	0.445	85	0.991
unit_sta08075750_1966_0414	1.02	4.44	160	0.089	12	0.857
unit_sta08075750_1966_1004	1.03	2.38	285	0.083	20	0.987
unit_sta08075750_1967_0529	1.78	1.42	222	1.107	205	0.981
unit_sta08075750_1967_0921	1.58	1.75	202	1.022	172	0.994
unit_sta08075750_1968_0510	1.40	3.03	134	1.206	135	0.962
unit_sta08075750_1968_0917	1.58	2.51	142	1.450	171	0.992
unit_sta08075750_1969_0116	1.01	4.30	171	0.043	6	0.988
unit_sta08075750_1970_0515	1.06	2.94	216	0.179	32	0.842
unit_sta08075750_1970_0901	2.05	1.57	177	1.652	244	0.752
unit_sta08075750_1970_1011	1.11	4.37	132	0.469	52	0.938
unit_sta08075750_1970_1023	2.08	2.84	97	3.064	248	0.969
unit_sta08075750_1970_1027	1.40	4.31	94	1.722	135	0.925
unit_sta08075750_1970_1109	1.33	3.17	136	1.056	120	0.963
unit_sta08075750_1972_0320	1.40	3.89	104	1.556	135	0.986
unit_sta08075760_1965_0518	4.68	1.57	229	5.788	483	0.942
unit_sta08075760_1965_0918	9.76	0.77	307	6.751	755	0.950
unit_sta08075760_1965_0922	1.30	2.79	368	0.824	110	0.935
unit_sta08075760_1966_0328	9.16	1.15	214	9.355	728	0.936
unit_sta08075760_1966_0414	1.43	2.57	353	1.103	142	0.972
unit_sta08075760_1966_1004	1.70	2.45	310	1.701	192	0.965
unit_sta08075760_1967_0529	1.45	2.53	354	1.131	146	0.967

unit_sta08075760_1967_0921	1.89	1.69	407	1.496	222	0.980
unit_sta08075760_1968_0510	1.39	5.59	168	2.173	133	0.919
unit_sta08075760_1968_0908	1.64	1.91	410	1.222	182	0.977
unit_sta08075760_1968_0917	1.72	3.29	227	2.381	196	0.953
unit_sta08075760_1968_1105	1.81	1.99	358	1.612	210	0.938
unit_sta08075760_1969_0116	1.45	2.53	351	1.150	147	0.960
unit_sta08075760_1970_0515	1.02	5.30	312	0.083	9	0.935
unit_sta08075760_1970_0901	1.02	4.44	366	0.089	12	0.862
unit_sta08075760_1970_1011	1.22	5.17	216	1.148	90	0.958
unit_sta08075760_1970_1023	2.40	4.36	129	6.110	287	0.913
unit_sta08075760_1970_1109	1.48	3.41	256	1.629	152	0.956
unit_sta08075760_1972_0320	1.40	3.89	239	1.556	135	0.990
unit_sta08075760_1972_0507	1.18	5.40	218	0.977	77	0.983
unit_sta08075760_1973_0611	2.20	3.33	181	4.000	263	0.944
unit_sta08075760_1974_1031	1.15	4.93	250	0.737	67	0.788
unit_sta08075760_1976_0615	2.20	3.19	189	3.833	263	0.999
unit_sta08075760_1976_0920	1.59	2.80	289	1.646	173	0.940
unit_sta08075760_1978_0606	2.59	1.91	280	3.029	308	0.881
unit_sta08075760_1979_0901	1.80	4.31	166	3.444	208	0.971
unit_sta08075760_1979_0917	2.20	4.31	140	5.167	263	0.977
unit_sta08075760_1980_0120	1.36	4.19	230	1.501	126	0.978
unit_sta08075760_1980_0425	1.15	4.08	301	0.623	68	0.987
unit_sta08075760_1981_0503	1.12	4.87	266	0.580	56	0.924
unit_sta08075760_1981_0604	1.44	4.17	216	1.822	143	0.994
unit_sta08075760_1981_0705	1.80	2.64	271	2.111	208	0.984
unit_sta08075760_1981_0830	1.32	3.68	273	1.159	115	0.938
unit_sta08075760_1981_1005a	1.03	3.75	427	0.094	15	0.932
unit_sta08075760_1983_0510	1.06	2.98	491	0.172	31	0.995
unit_sta08075760_1983_0818	1.80	4.17	172	3.333	208	0.977
unit_sta08075760_1983_0919	1.40	3.75	248	1.500	135	0.950
unit_sta08075760_1984_0109	1.03	3.17	503	0.083	15	0.945
unit_sta08075770_1964_1209	1.01	9.18	1076	0.092	6	0.922
unit_sta08075770_1965_0216	1.37	8.33	671	3.080	128	0.972
unit_sta08075770_1965_0922	3.12	3.04	899	6.454	360	0.956
unit_sta08075770_1966_0209	1.91	5.50	725	4.977	224	0.854
unit_sta08075770_1966_0328	1.80	3.75	1118	3.000	208	0.952
unit_sta08075770_1966_0414	2.20	4.03	878	4.833	263	0.934
unit_sta08075770_1966_1004	2.60	3.61	862	5.778	309	0.981
unit_sta08075770_1967_0529	2.43	3.93	833	5.613	290	0.997
unit_sta08075770_1967_0921	3.72	1.94	1254	5.293	412	0.982
unit_sta08075770_1968_0119	1.80	4.31	974	3.444	208	0.990
unit_sta08075770_1968_0510	1.76	4.62	925	3.530	203	0.802

unit_sta08075770_1968_0908	4.37	1.90	1157	6.412	461	0.992
unit_sta08075770_1968_0917	2.61	3.78	820	6.102	311	0.992
unit_sta08075770_1968_1105	2.89	2.99	963	5.668	339	0.993
unit_sta08075770_1969_0116	2.60	3.47	896	5.556	309	0.975
unit_sta08075770_1969_0221	2.08	4.33	852	4.699	249	0.983
unit_sta08075770_1970_0501	1.80	4.31	974	3.444	208	0.960
unit_sta08075770_1970_0515	1.80	4.31	974	3.444	208	0.950
unit_sta08075770_1970_0901	2.13	3.67	989	4.143	255	0.978
unit_sta08075770_1970_1023	2.20	4.31	821	5.167	263	0.966
unit_sta08075770_1970_1027	2.20	4.31	821	5.167	263	0.968
unit_sta08075770_1970_1109	2.28	4.35	790	5.574	274	0.993
unit_sta08075770_1971_0909	2.10	3.97	925	4.358	250	0.983
unit_sta08075770_1972_0320	2.20	3.89	909	4.667	263	0.958
unit_sta08075770_1974_0119	2.10	4.45	824	4.897	251	0.935
unit_sta08075770_1975_0529	2.10	4.45	824	4.897	251	0.946
unit_sta08075770_1975_0609	2.05	5.68	658	5.992	245	0.951
unit_sta08075770_1976_0615	1.65	6.66	684	4.326	184	0.997
unit_sta08075770_1976_0920	1.92	4.45	888	4.103	226	0.948
unit_sta08075770_1978_0606	2.20	4.31	821	5.167	263	0.970
unit_sta08075770_1979_0917	2.77	4.62	644	8.158	326	0.925
unit_sta08075770_1980_0120	2.07	4.36	853	4.650	247	0.937
unit_sta08075770_1980_0425	1.88	4.72	852	4.178	221	0.994
unit_sta08075770_1981_0503	1.80	4.03	1041	3.222	208	0.970
unit_sta08075770_1981_0603	2.20	3.47	1018	4.167	263	0.966
unit_sta08075770_1981_0705	2.33	3.47	974	4.617	279	0.790
unit_sta08075770_1981_0830	1.57	6.01	795	3.447	170	0.966
unit_sta08075770_1982_0512	2.20	4.03	878	4.833	263	0.913
unit_sta08075770_1982_0517	2.24	3.90	894	4.832	268	0.987
unit_sta08075770_1982_0725	2.65	2.95	1039	4.881	315	0.996
unit_sta08075770_1983_0215	1.23	8.38	773	1.911	92	0.770
unit_sta08075770_1983_0509	2.20	3.33	1060	4.000	263	0.983
unit_sta08075770_1983_0818	2.60	4.03	773	6.444	309	0.985
unit_sta08075770_1983_0919	1.80	4.31	974	3.444	208	0.978
unit_sta08075770_1984_0109	2.09	3.45	1067	3.761	249	0.984
unit_sta08075770_1986_0614	3.00	3.06	920	6.111	349	0.960
unit_sta08075770_1988_0317	1.86	3.95	1031	3.390	217	0.996
unit_sta08075770_1989_0517	1.60	5.00	939	3.000	175	0.856
unit_sta08075770_1989_0626	2.03	5.95	635	6.117	241	0.958
unit_sta08075780_1965_0122	1.95	7.85	267	7.478	231	0.975
unit_sta08075780_1965_0216	1.09	16.30	262	1.530	46	0.990
unit_sta08075780_1966_0414	1.60	8.33	303	4.991	175	0.956
unit_sta08075780_1966_0518	1.31	17.53	181	5.484	115	0.984

unit_sta08075780_1967_0413	2.33	4.92	370	6.519	279	0.998
unit_sta08075780_1967_0921	1.35	8.33	366	2.943	124	0.960
unit_sta08075780_1968_0917	2.39	5.60	318	7.799	286	0.988
unit_sta08075780_1970_0501	1.95	8.33	252	7.884	230	0.982
unit_sta08075780_1970_0515	1.09	20.68	207	1.892	45	0.996
unit_sta08075780_1970_1011	1.01	22.17	239	0.222	6	0.783
unit_sta08075780_1970_1023	1.33	18.27	171	5.952	118	0.971
unit_sta08075780_1972_0510	1.22	14.24	246	3.189	91	0.824
unit_sta08075780_1973_0605	1.58	8.33	308	4.793	171	0.980
unit_sta08075780_1974_1031	1.19	15.34	238	2.945	81	0.983
unit_sta08075780_1974_1110	2.01	8.33	245	8.447	239	0.908
unit_sta08075780_1975_0528	1.48	13.96	196	6.704	152	0.948
unit_sta08075780_1976_0920	1.14	21.14	186	2.978	64	0.991
unit_sta08075780_1977_0420	1.23	13.31	259	3.127	94	0.904
unit_sta08075780_1977_0615	1.01	8.33	637	0.083	6	0.837
unit_sta08075780_1979_0707	1.64	5.31	464	3.381	181	0.987
unit_sta08075780_1980_0208	1.30	8.55	377	2.539	111	0.983
unit_sta08075780_1981_0304	1.37	8.33	361	3.057	128	0.991
unit_sta08075780_1981_0831	2.12	8.33	235	9.297	253	0.925
unit_sta08075780_1981_1129	1.85	8.39	262	7.155	216	0.940
unit_sta08075780_1982_1011	1.73	8.33	281	6.059	197	0.955
unit_sta08075780_1983_0520	1.03	22.41	222	0.632	16	0.893
unit_sta08075780_1983_0818	1.32	11.03	285	3.555	117	0.980
unit_sta08075780_1983_0919	2.18	4.53	422	5.353	261	0.932
unit_sta08075780_1984_0109	1.82	5.21	428	4.285	212	0.998
unit_sta08075780_1984_0212	1.56	4.74	547	2.644	167	0.738
unit_sta08075780_1984_0727	1.03	7.72	642	0.232	17	0.971
unit_sta08075780_1984_1025	1.40	4.31	679	1.722	135	0.950
unit_sta08075780_1985_1124	2.88	3.64	427	6.836	338	0.910
unit_sta08075780_1988_0811	1.01	8.33	637	0.083	6	0.847
unit_sta08075780_1989_0517	1.60	5.00	505	3.000	175	0.927
unit_sta08076200_1965_0922	1.02	4.44	1161	0.083	11	0.956
unit_sta08076200_1966_0328	1.08	9.24	480	0.714	39	0.978
unit_sta08076200_1966_0414	1.01	14.53	367	0.145	6	0.953
unit_sta08076200_1967_0413	1.01	4.11	1296	0.041	6	0.981
unit_sta08076200_1967_0825	1.02	3.40	1488	0.083	14	0.958
unit_sta08076200_1967_0921	1.01	10.00	533	0.100	6	0.969
unit_sta08076200_1968_0917	1.21	5.77	619	1.221	87	0.964
unit_sta08076200_1969_0221	1.69	8.33	289	5.728	190	0.968
unit_sta08076200_1970_0501	1.03	8.39	594	0.252	17	0.928
unit_sta08076200_1970_0515	1.01	12.49	427	0.125	6	0.982
unit_sta08076200_1970_0530	1.20	12.26	297	2.412	82	0.980

unit_sta08076200_1970_1011	1.05	8.27	573	0.398	26	0.897
unit_sta08076200_1970_1023	1.23	12.29	283	2.859	93	0.981
unit_sta08076200_1972_0320	2.03	6.52	312	6.728	242	0.926
unit_sta08076200_1972_1118	1.01	9.29	574	0.093	6	0.982
unit_sta08076200_1973_1015	2.12	4.33	454	4.851	254	0.805
unit_sta08076200_1974_0119	1.15	10.28	381	1.497	66	0.950
unit_sta08076200_1974_1110	2.20	4.31	443	5.167	263	0.934
unit_sta08076200_1975_0529	1.95	5.14	410	4.882	230	0.810
unit_sta08076200_1975_0610	1.54	5.54	476	2.999	164	0.980
unit_sta08076200_1976_0418	2.20	4.31	443	5.167	263	0.947
unit_sta08076200_1977_0615	1.40	2.92	1007	1.167	135	0.972
unit_sta08076200_1978_0606	1.80	4.31	526	3.444	208	0.941
unit_sta08076200_1979_0418	1.07	8.92	500	0.659	38	0.950
unit_sta08076200_1980_0120	1.41	6.46	453	2.619	136	0.968
unit_sta08076200_1980_0905	1.93	1.92	1110	1.779	227	0.904
unit_sta08076200_1981_0423	1.01	5.71	918	0.083	9	0.911
unit_sta08076200_1981_0509	1.40	4.31	682	1.722	135	0.973
unit_sta08076200_1981_0830	1.80	4.31	526	3.444	208	0.939
unit_sta08076200_1981_1129	1.56	6.01	432	3.383	168	0.934
unit_sta08076200_1982_0512	1.45	4.09	688	1.850	147	0.984
unit_sta08076200_1982_0513	1.23	8.76	398	2.024	93	0.987
unit_sta08076200_1983_0323	1.80	4.17	543	3.333	208	0.955
unit_sta08076200_1983_0520	1.10	8.49	498	0.861	49	0.906
unit_sta08076200_1983_0811	1.16	7.95	480	1.302	72	0.994
unit_sta08076200_1984_0109	1.31	3.46	922	1.078	114	0.958
unit_sta08076200_1984_0212	1.50	4.60	591	2.288	156	0.954
unit_sta08077100_1965_0522	1.01	6.19	128	0.083	8	0.925
unit_sta08077100_1966_0619	1.02	4.11	189	0.083	12	0.798
unit_sta08077100_1966_0820	1.59	2.34	164	1.386	174	0.981
unit_sta08077100_1966_1004	2.64	1.19	211	1.947	313	0.954
unit_sta08077100_1967_0411	2.53	1.62	160	2.470	302	0.917
unit_sta08077100_1967_0413	1.25	3.63	141	0.911	98	0.872
unit_sta08077100_1968_0119	1.30	4.61	106	1.371	111	0.991
unit_sta08077100_1968_0409	1.02	4.17	186	0.083	12	0.963
unit_sta08077100_1968_0917	8.94	0.84	141	6.666	718	0.733
unit_sta08077100_1969_0214	1.02	4.17	186	0.083	12	0.930
unit_sta08077100_1969_0412	1.02	4.65	168	0.083	11	0.971
unit_sta08077100_1969_0503	1.40	2.36	187	0.944	135	0.940
unit_sta08077100_1969_1012	4.17	0.69	269	2.178	446	0.922
unit_sta08077100_1970_0901	1.42	2.16	202	0.903	139	0.972
unit_sta08077100_1970_1023	1.96	1.85	171	1.771	232	0.951
unit_sta08077100_1971_0909	1.83	1.72	196	1.424	213	0.956

unit_sta08077100_1972_0427	2.26	2.55	111	3.210	271	0.959

APPENDIX F

SUMMARY OF SITE INFORMATION

Appendix Table F1. Summary of site information for Austin watersheds.

GageID	Area (mi^2)	Latitude	Longitude	# of events w/o splits	# of events w/ splits	# of events (*PRF* was calculated)	# of events (accepted)
8158810	12.2	30.155	-97.94	8	8	7	5
8158050	13.1	30.263	-97.672	10	12	11	10
8158880	3.58	30.181	-97.782	14	17	13	13
8156650	2.79	30.365	-97.736	13	14	11	8
8156700	7.03	30.347	-97.745	17	20	18	15
8156750	7.56	30.339	-97.747	14	14	13	9
8156800	12.3	30.276	-97.75	24	24	21	18
8158840	8.24	30.209	-97.903	11	11	9	9
8157000	2.31	30.297	-97.727	41	46	44	41
8157500	4.13	30.286	-97.734	40	44	36	28
8158100	12.6	30.41	-97.711	15	16	14	11
8158400	5.57	30.349	-97.693	10	10	9	8
8158500	12.1	30.309	-97.668	15	17	15	14
8155550	3.12	30.264	-97.755	10	11	8	7
8159150	4.61	30.454	-97.601	29	29	26	25
8158920	6.3	30.235	-97.86	14	14	11	10
8158930	19	30.221	-97.793	18	22	17	14
8158380	5.22	30.354	-97.698	2	2	2	2

Appendix Table F2. Summary of site information for Dallas watersheds.

GageID	Area (mi^2)	Latitude	Longitude	# of events w/o splits	# of events w/ splits	# of events (*PRF* was calculated)	# of events (accepted)
8057320	6.92	32.805	-96.718	5	6	4	3
8055700	10	32.857	-96.837	41	47	41	38
8057050	9.42	32.747	-96.796	3	3	1	1
8057020	4.75	32.767	-96.835	7	7	6	6
8057140	8.5	32.909	-96.765	6	8	8	7
8061620	8.05	32.931	-96.665	8	8	7	7
8057415	1.25	32.737	-96.693	8	10	10	9
8057418	7.65	32.705	-96.859	7	7	5	5
8057420	13.2	32.688	-96.823	10	11	9	9
8057160	4.17	32.909	-96.759	8	8	8	7
8055580	1.94	32.895	-96.693	7	8	8	8
8055600	7.51	32.861	-96.874	10	10	7	7
8057435	5.91	32.655	-96.745	4	4	3	3
8057445	9.03	32.705	-96.67	8	8	8	8
8057130	1.22	32.963	-96.796	7	8	8	8
8061920	13.4	32.769	-96.622	9	9	8	8
8057120	6.77	32.966	-96.803	5	6	5	5
8056500	7.98	32.807	-96.802	42	57	49	46
8057440	2.53	32.491	-96.74	4	4	2	2
8057425	11.5	32.683	-96.823	10	11	9	8

Appendix Table F3. Summary of site information for Fort Worth watersheds.

GageID	Area (mi^2)	Latitude	Longitude	# of events w/o splits	# of events w/ splits	# of events (*PRF* was calculated)	# of events (accepted)
8048550	1.08	32.789	-97.306	25	27	19	18
8048600	2.15	32.776	-97.288	27	28	25	24
8048820	5.64	32.839	-97.323	20	20	17	17
8048850	12.3	32.809	-97.291	25	25	25	25
8048520	17.7	32.665	-97.321	24	24	24	22
8048530	0.97	32.686	-97.329	28	36	22	19
8048540	1.35	32.688	-97.32	24	38	27	26

Appendix Table F4. Summary of site information for San Antonio watersheds.

GageID	Area (mi^2)	Latitude	Longitude	# of events w/o splits	# of events w/ splits	# of events (*PRF* was calculated)	# of events (accepted)
8178300	3.26	29.458	-98.55	30	36	23	18
8181000	5.57	29.587	-98.628	10	11	8	7
8181400	15	29.578	-98.691	15	15	15	13
8181450	1.19	29.387	-98.6	30	33	28	24
8177600	0.33	29.576	-98.546	14	14	7	7
8178555	2.43	29.351	-98.492	10	10	8	7
8178600	9.54	29.625	-98.518	13	13	12	7
8178620	4.05	29.59	-98.463	3	3	3	2
8178640	2.45	29.623	-98.441	8	8	7	5
8178645	2.33	29.618	-98.428	6	6	3	2
8178690	0.26	29.527	-98.44	41	45	14	10
8178736	0.45	29.444	-98.454	12	13	5	5

Appendix Table F5. Summary of site information for rural watersheds.

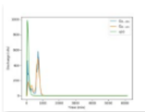
GageID	Area (mi^2)	Latitude	Longitude	# of events w/o splits	# of events w/ splits	# of events (*PRF* was calculated)	# of events (accepted)
8111025	1.33	30.647	-96.349	7	7	7	7
8111050	1.94	30.661	-96.3	7	7	6	6
8096800	5.25	31.333	-97.267	52	52	44	39
8094000	3.34	32.167	-98.342	30	31	27	20
8139000	3.42	31.29	-99.156	30	36	29	22
8140000	5.41	31.402	-99.121	31	33	25	18
8137000	4.02	31.694	-99.205	39	42	34	32
8182400	7.01	29.38	-98.293	25	25	21	19
8187000	3.29	28.778	-97.895	33	36	32	26
8187900	8.43	28.861	-97.844	20	21	18	15
8050200	0.77	33.62	-97.404	35	35	24	20
8057500	2.14	33.303	-96.689	32	35	30	27
8058000	1.26	33.306	-96.67	29	32	29	27
8052630	2.1	33.409	-96.811	30	31	29	26
8042650	6.82	33.248	-98.322	15	15	13	12
8063200	17.6	31.8	-96.717	33	33	32	27

Appendix Table F6. Summary of site information for Houston watersheds.

GageID	Area (mi^2)	Latitude	Longitude	# of events w/o splits	# of events w/ splits	# of events (*PRF* was calculated)	# of events (accepted)
8075550	2.87	29.642	-95.223	36	36	35	34
8075600	1.58	29.65	-95.247	20	20	20	19
8075650	10.7	29.676	-95.244	34	34	16	16
8075700	4.86	29.683	-95.253	15	15	15	13
8075730	8.26	29.694	-95.216	22	24	20	18
8074750	0.87	29.717	-95.661	2	2	2	2
8074760	12.9	29.711	-95.587	15	15	12	12
8074850	4.29	29.688	-95.506	24	27	22	20
8074900	3.81	29.65	-95.486	15	15	9	8
8074910	0.32	29.662	-95.486	13	14	9	7
8073630	1.37	29.776	-95.54	18	21	12	11
8073750	0.5	29.735	-95.506	17	17	11	11
8073800	2.77	29.756	-95.496	21	22	18	17
8077100	1.31	29.603	-95.278	18	18	18	17
8074100	7.05	29.857	-95.515	14	14	10	9
8074145	0.21	29.859	-95.486	19	19	6	4
8074150	7.5	29.851	-95.488	42	42	41	36
8075780	8.65	29.949	-95.519	41	41	41	35
8076200	8.69	29.902	-95.423	39	39	39	37
8075750	1.2	29.8	-95.334	20	20	18	16
8075760	2.75	29.806	-95.331	39	40	38	38
8075770	16.1	29.793	-95.268	51	51	50	49
8074780	8.63	29.665	-95.595	28	28	23	15
8074800	12.7	29.656	-95.562	50	51	47	33
8068438	0.55	30.144	-95.469	10	10	9	9
8068440	0.71	30.14	-95.476	2	2	2	2
8075300	3.81	29.626	-95.499	14	14	11	10
8074200	2.56	29.831	-95.528	39	39	38	34
8074250	11.4	29.828	-95.469	55	56	53	51
8074400	0.13	29.804	-95.434	23	23	1	0
8074540	18.1	29.793	-95.368	23	26	24	22

APPENDIX G

SIMULATION RESULTS FOR AUSTIN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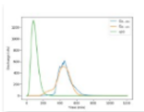
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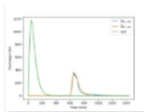
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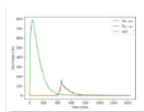
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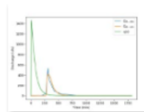
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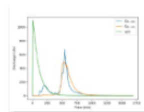
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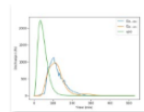
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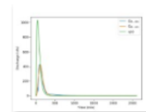
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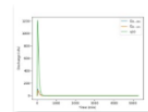
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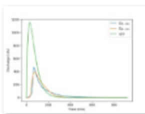
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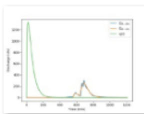
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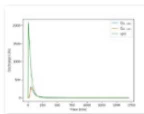
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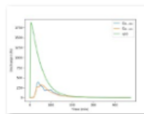
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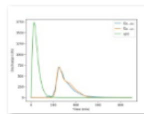
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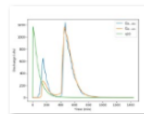
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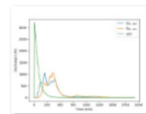
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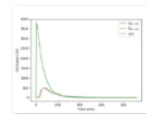
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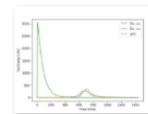
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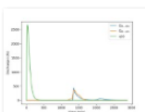
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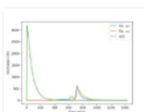
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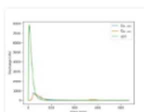
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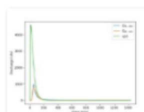
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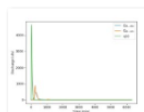
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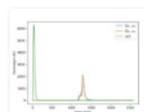
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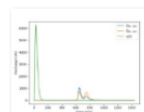
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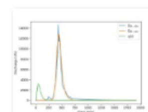
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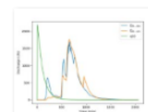
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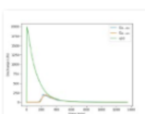
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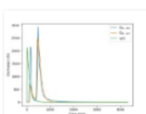
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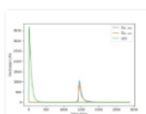
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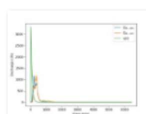
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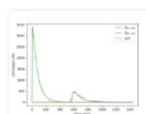
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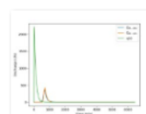
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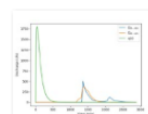
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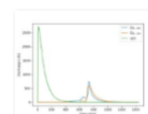
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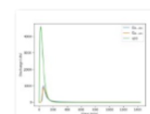
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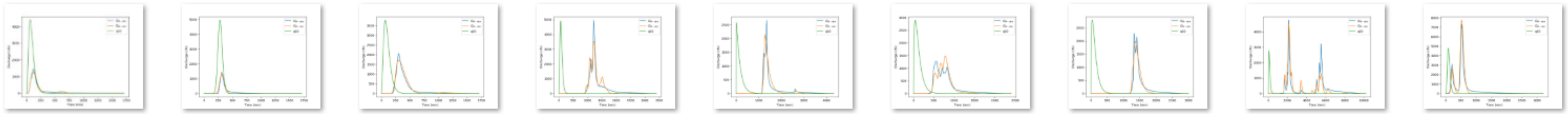

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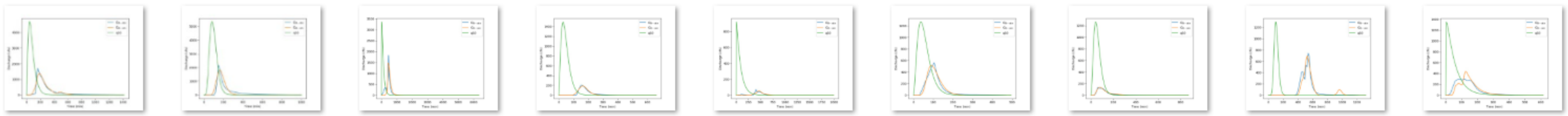

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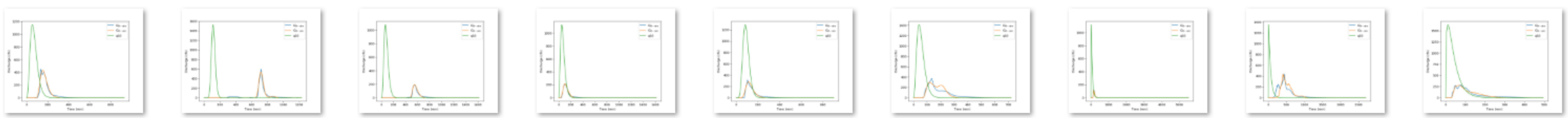

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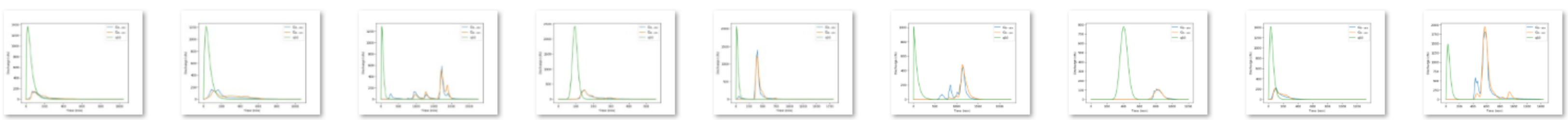

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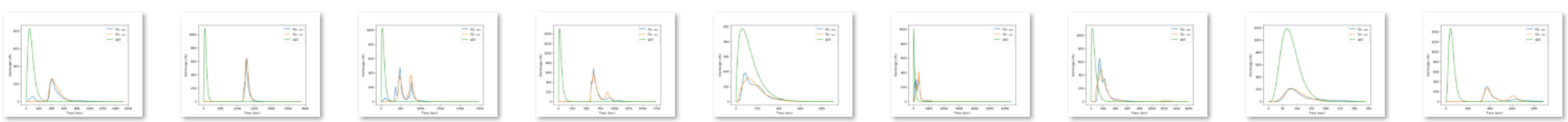

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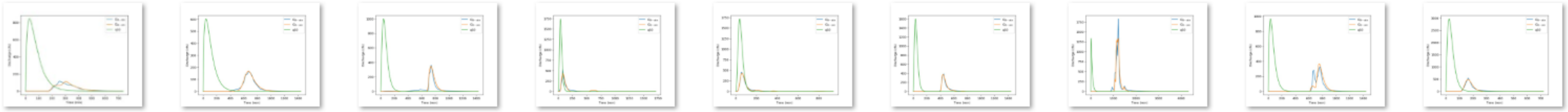

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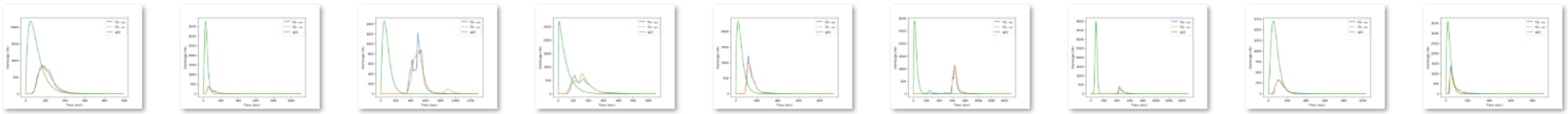

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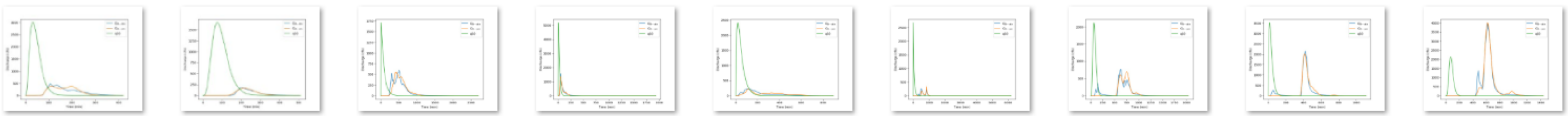

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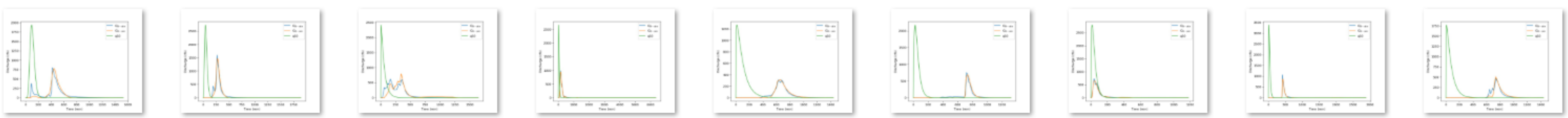

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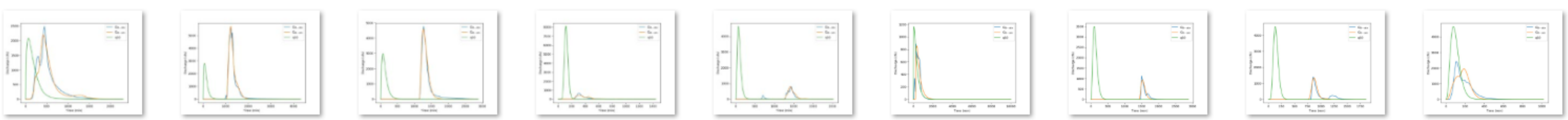

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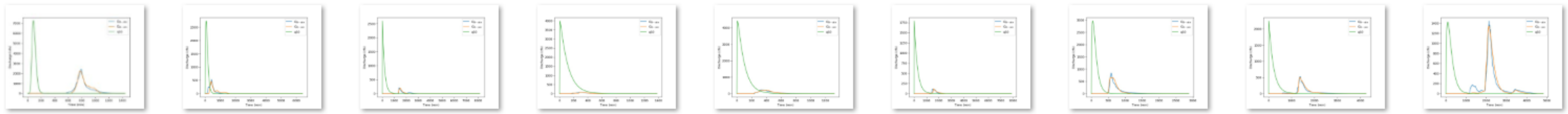

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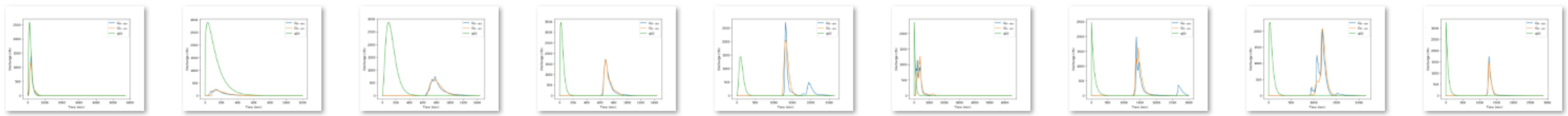

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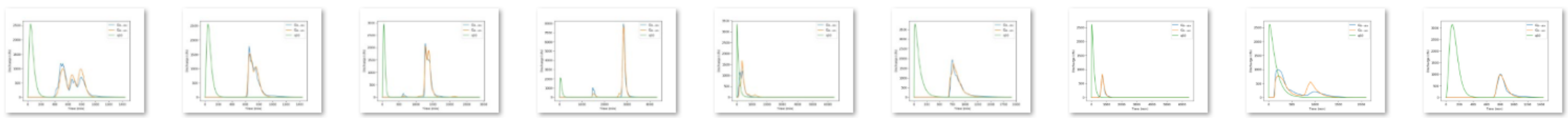

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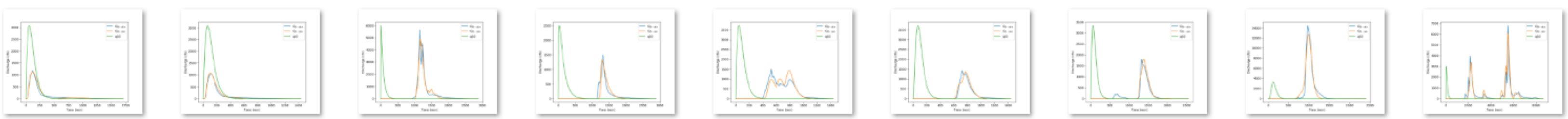

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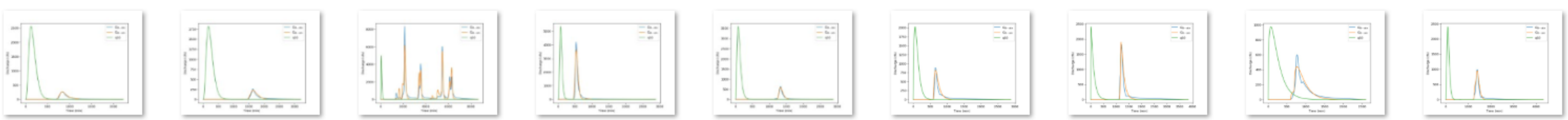

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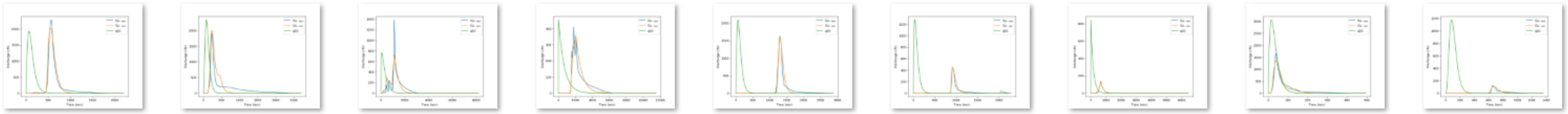

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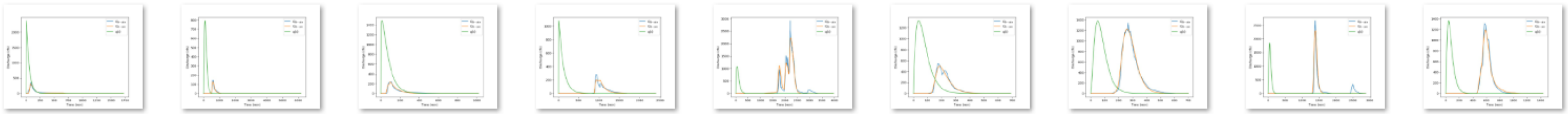

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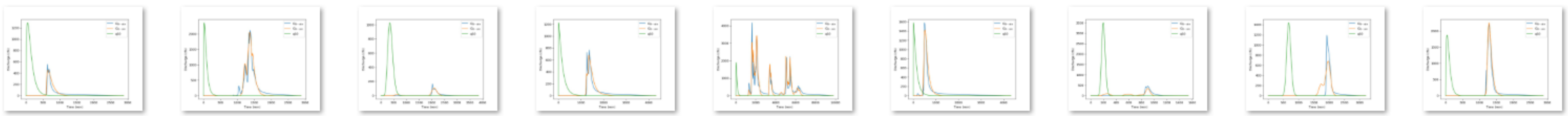

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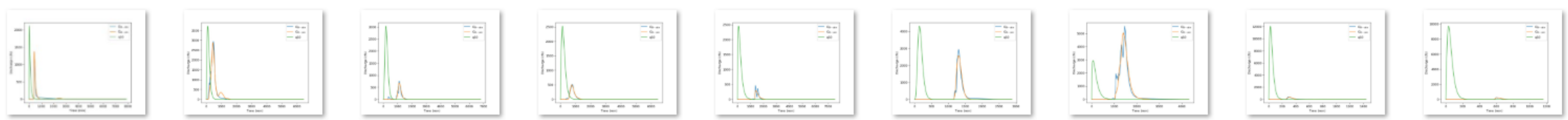

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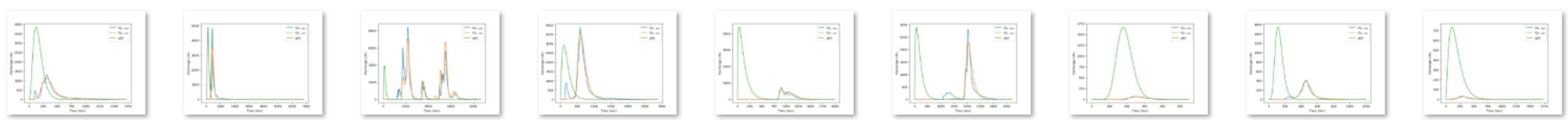

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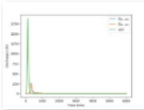

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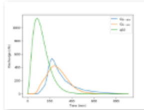

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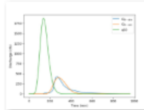

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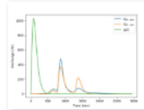

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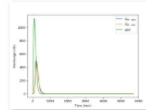

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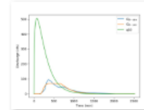

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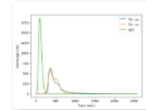

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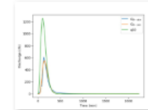

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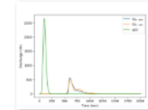

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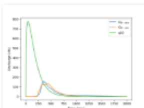

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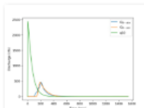

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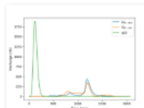

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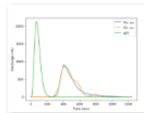

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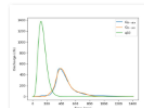

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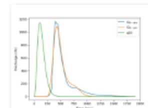

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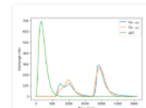

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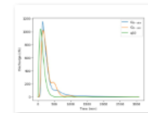

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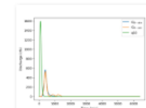

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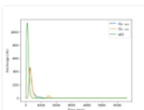

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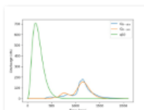

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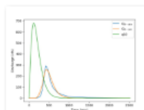

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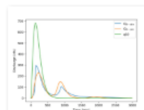

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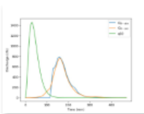
APPENDIX H

SIMULATION RESULTS FOR DALLAS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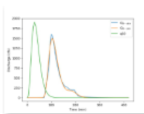
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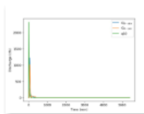
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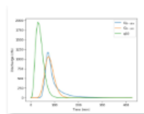
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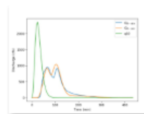
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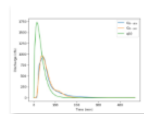
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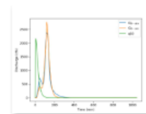
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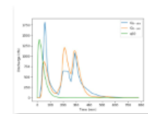
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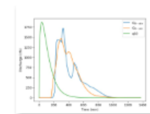
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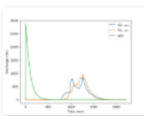
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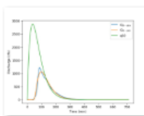
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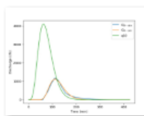
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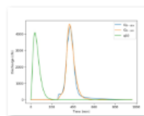
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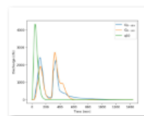
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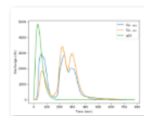
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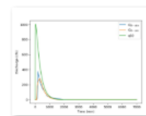
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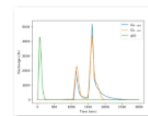
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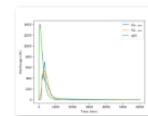
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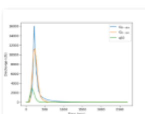
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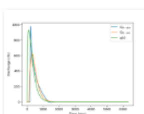
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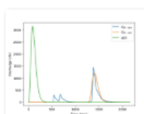
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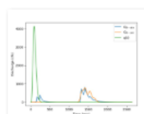
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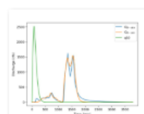
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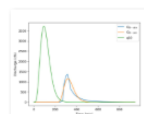
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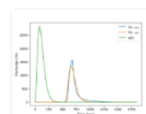
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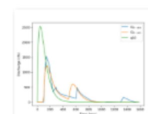
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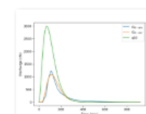
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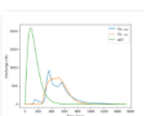
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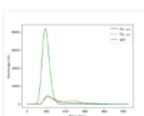
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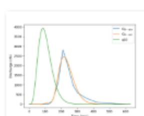
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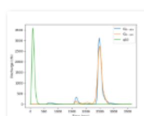
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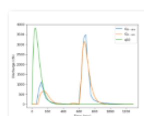
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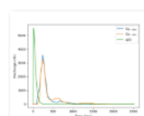
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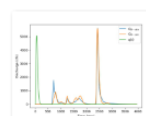
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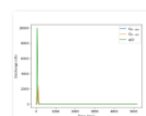
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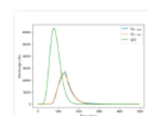
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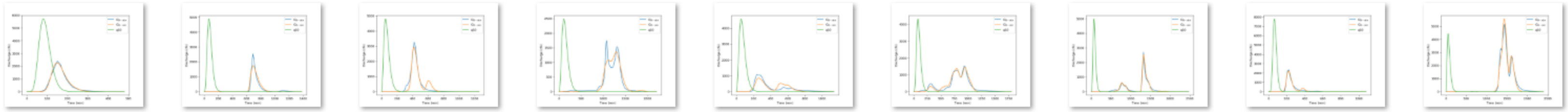

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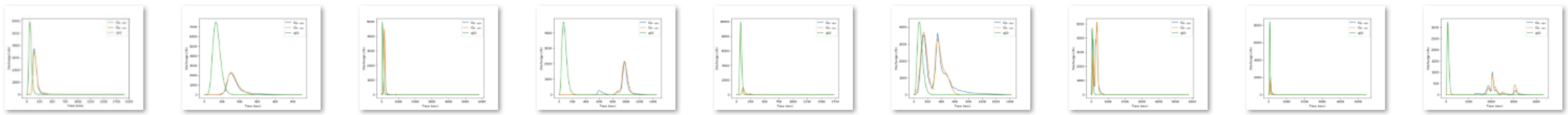

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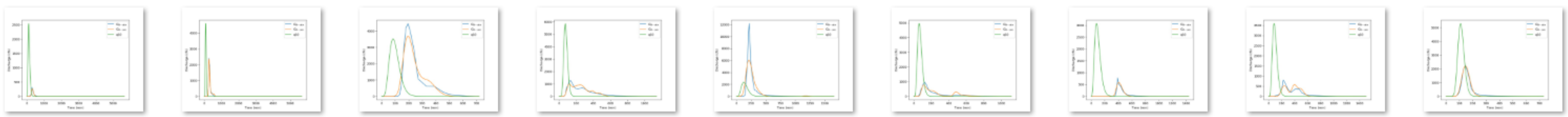

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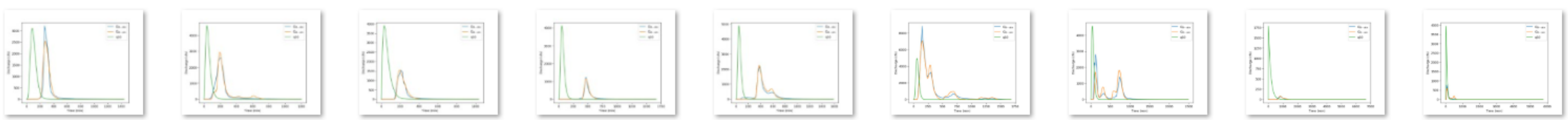

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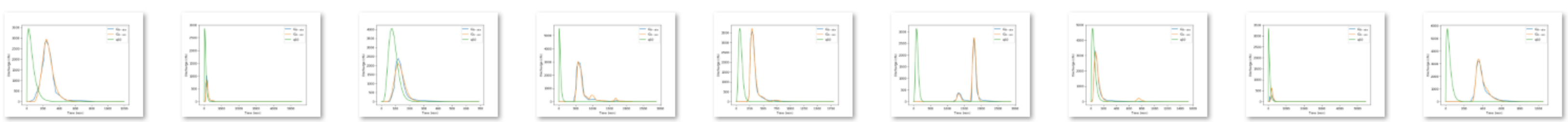

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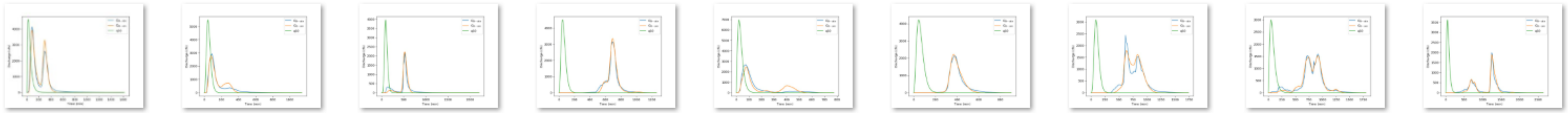

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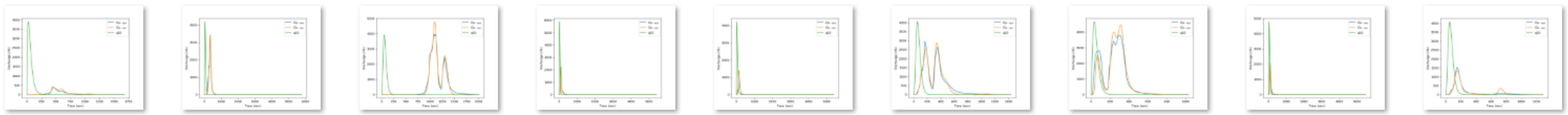

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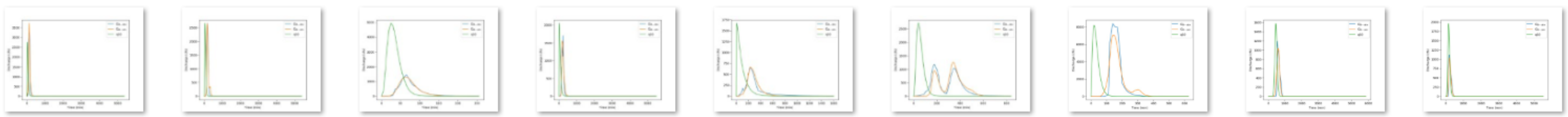

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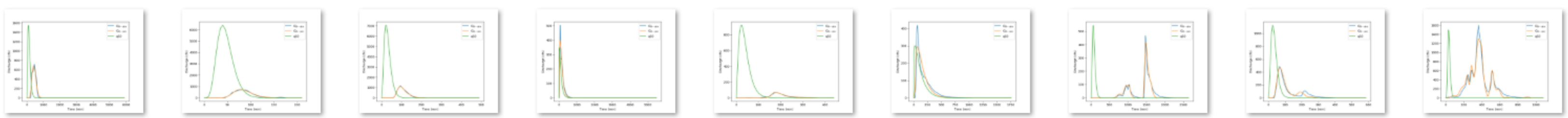

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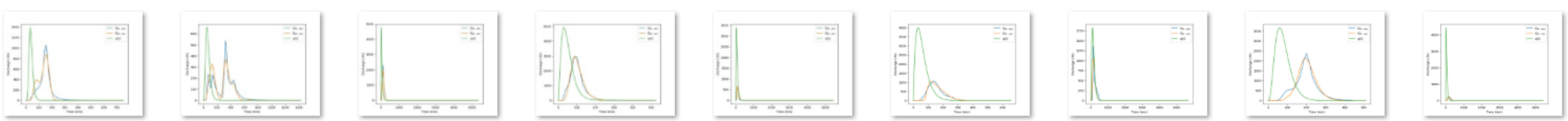

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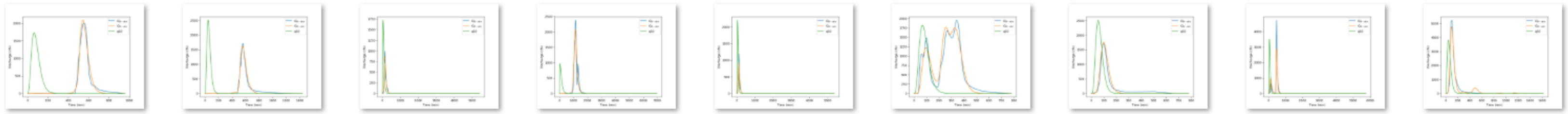

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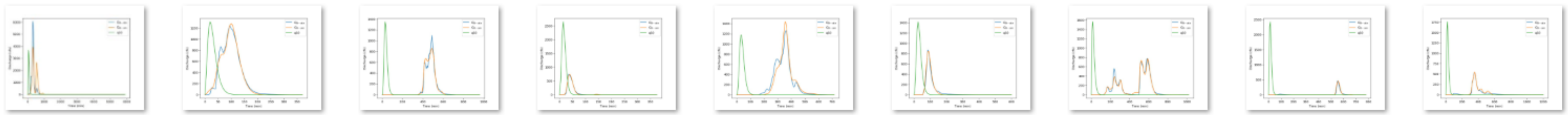

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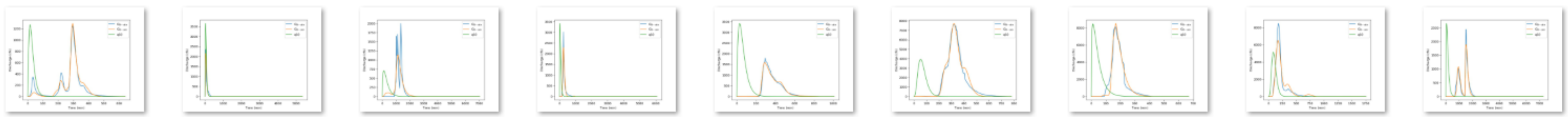

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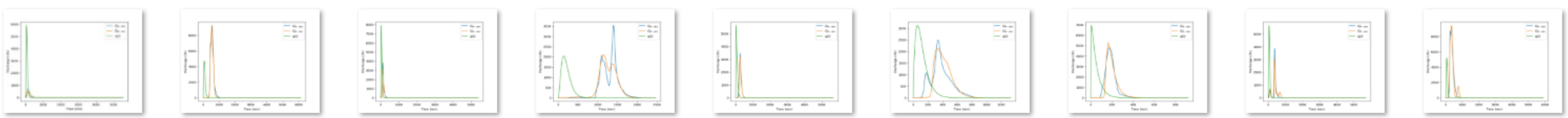

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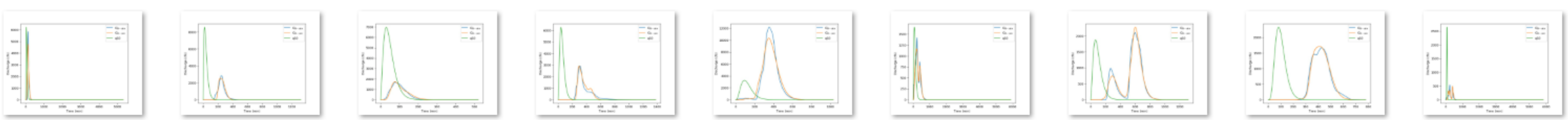

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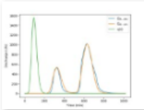
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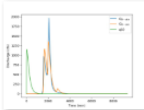
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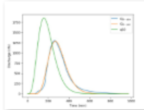
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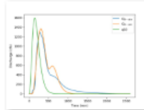
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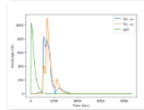
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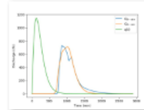
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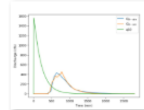
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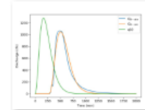
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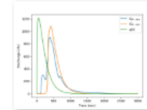
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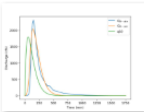
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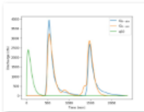
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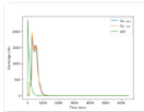
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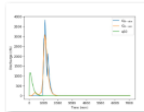
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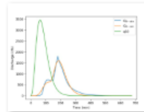
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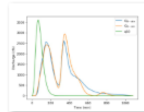
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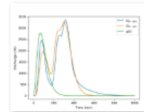
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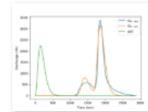
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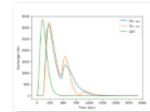
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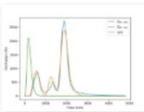
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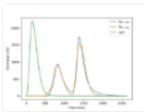
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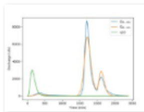
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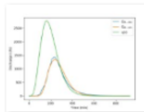
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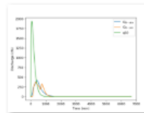
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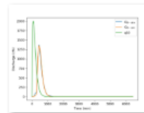
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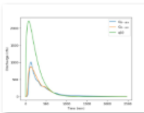
APPENDIX I

SIMULATION RESULTS FOR FORT WORTH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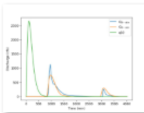
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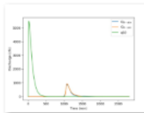
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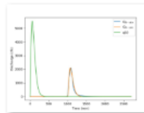
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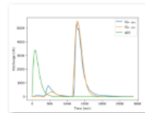
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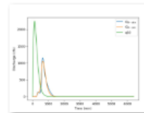
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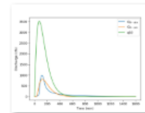
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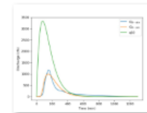
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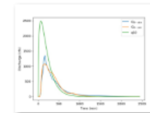
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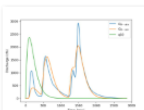
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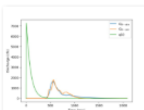
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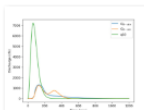
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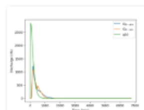
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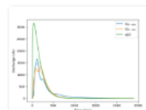
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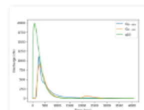
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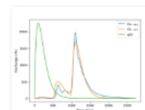
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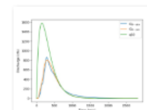
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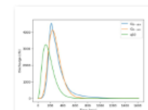
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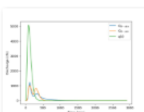
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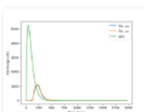
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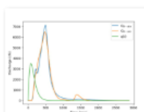
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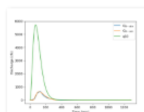
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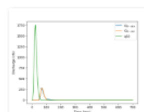
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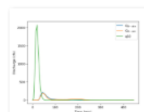
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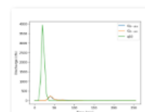
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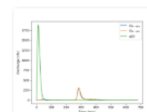
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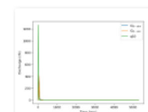
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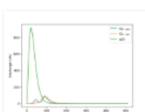
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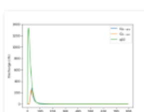
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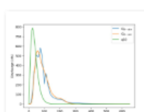
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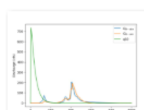
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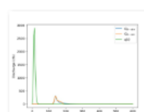
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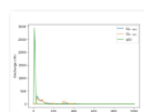
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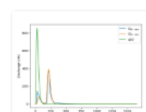
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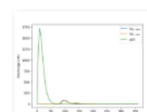
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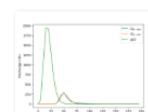
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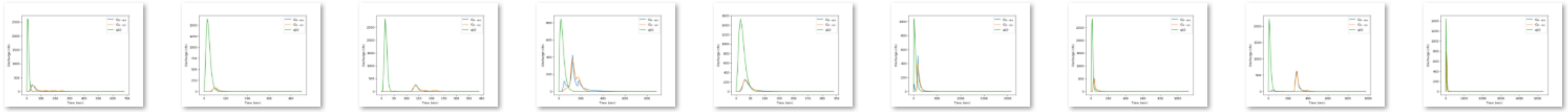

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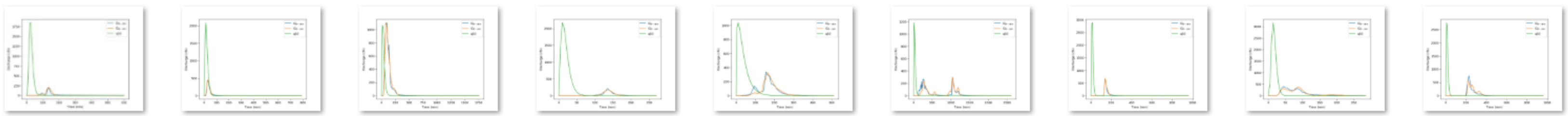

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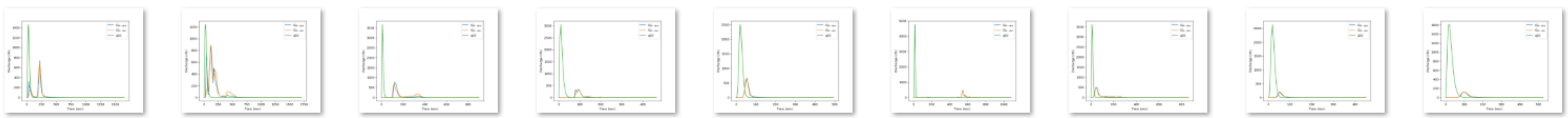

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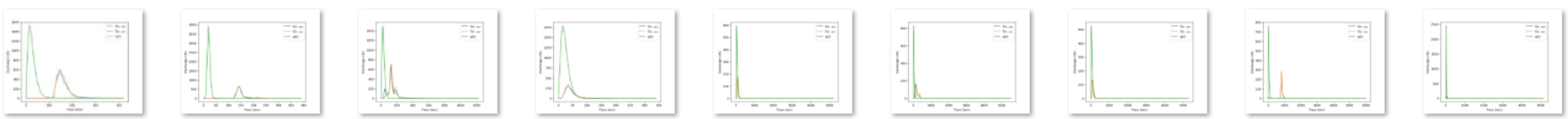

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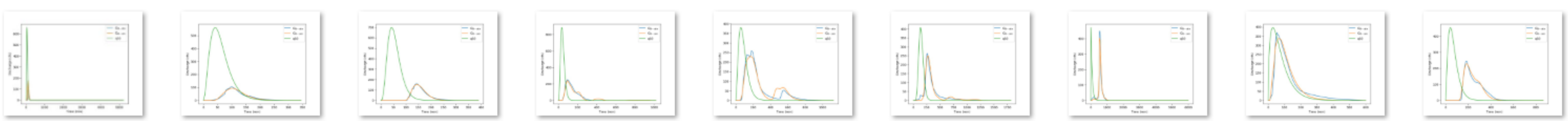

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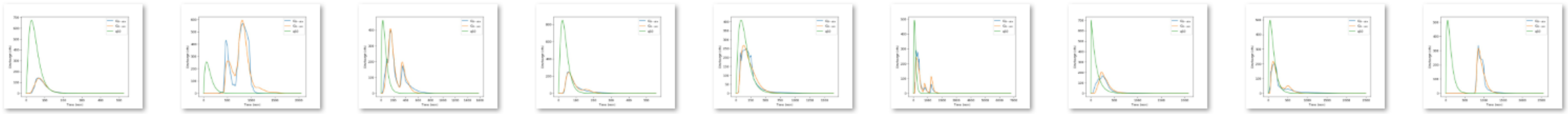

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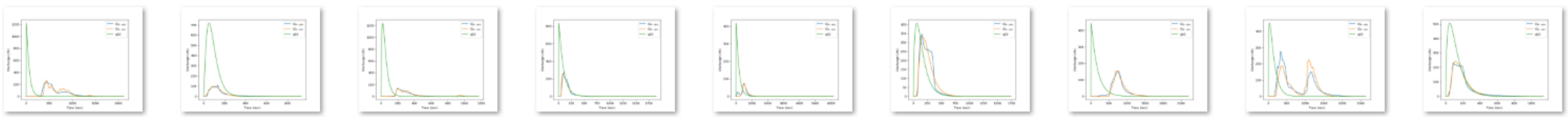

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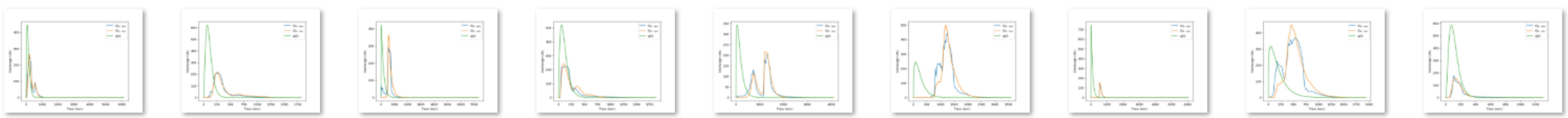

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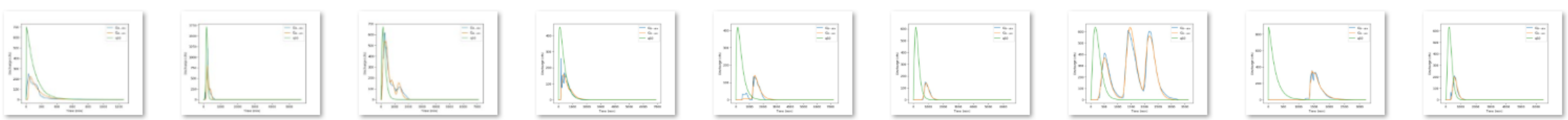

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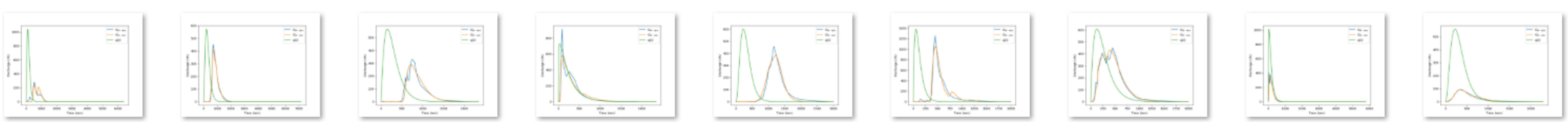

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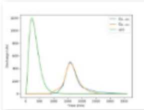

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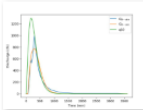

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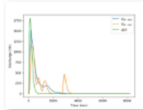

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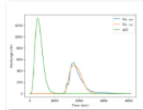

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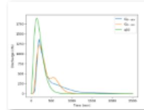

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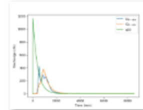

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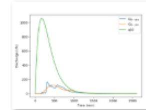

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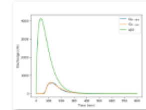

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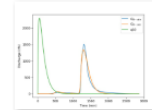

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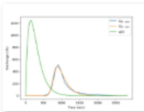

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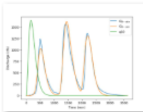

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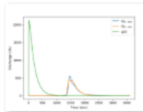

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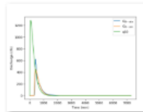

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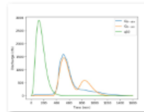

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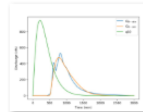

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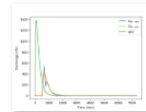

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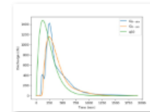

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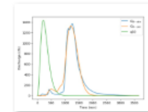

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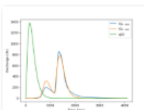

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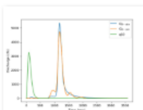

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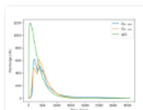

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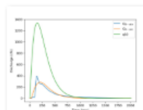

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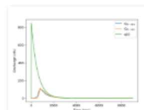

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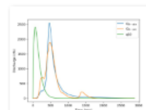

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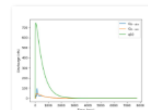

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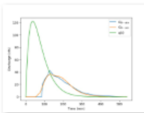
APPENDIX J

SIMULATION RESULTS FOR SAN ANTONIO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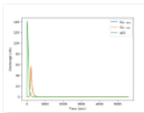
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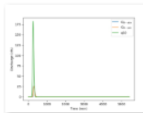
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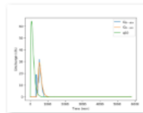
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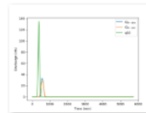
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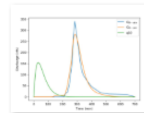
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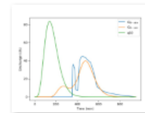
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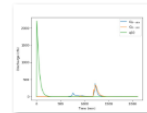
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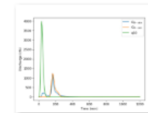
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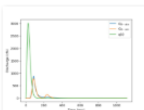
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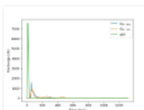
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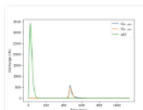
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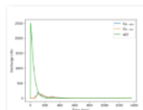
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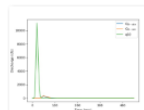
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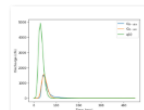
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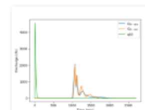
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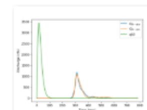
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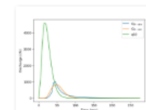
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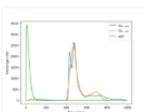
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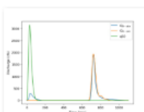
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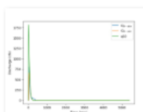
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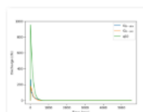
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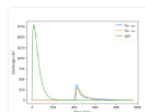
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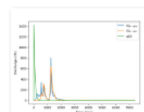
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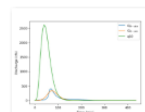
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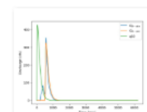
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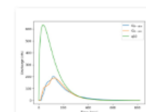
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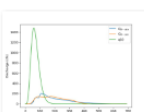
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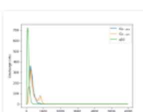
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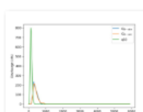
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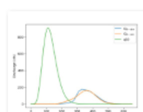
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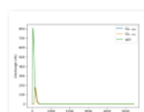
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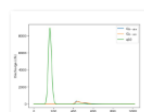
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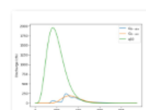
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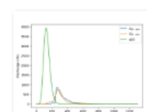
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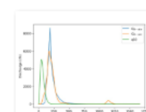
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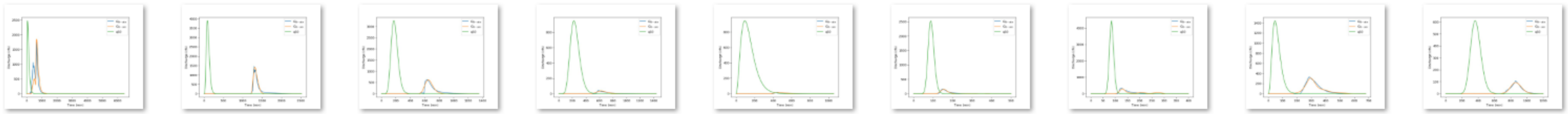

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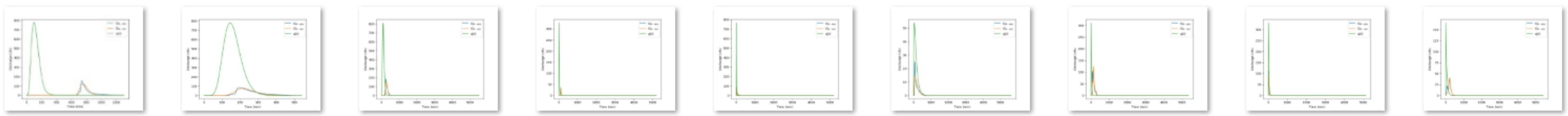

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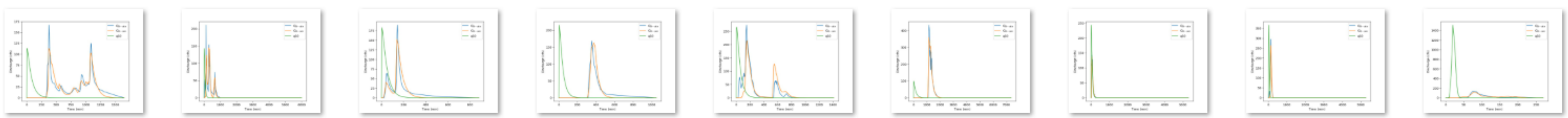

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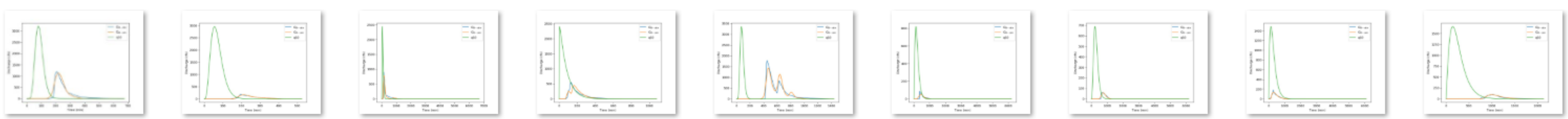

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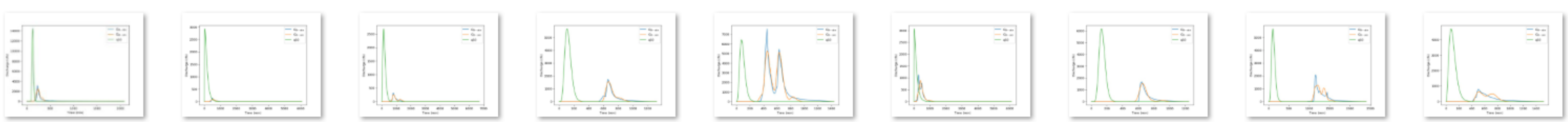

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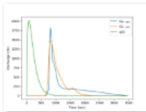

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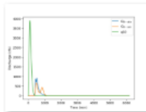

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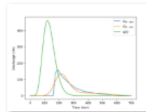

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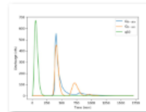

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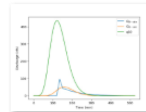

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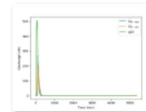

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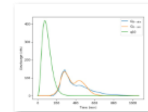

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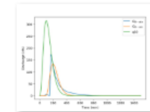

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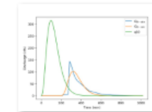

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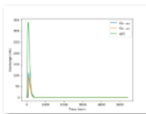

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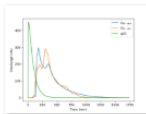

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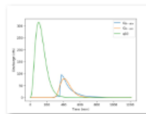

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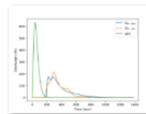

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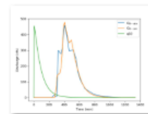

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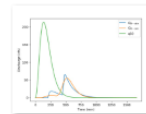

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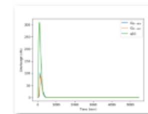

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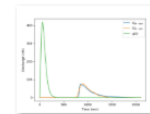

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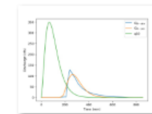

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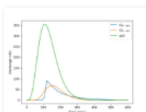

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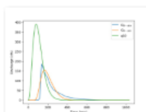

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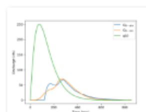

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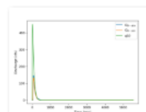

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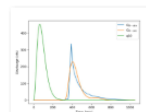

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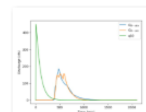

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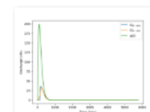

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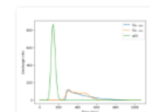

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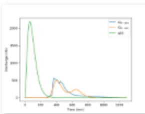
APPENDIX K

SIMULATION RESULTS FOR RURAL WATERSHEDS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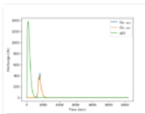
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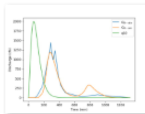
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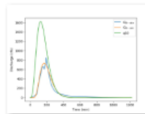
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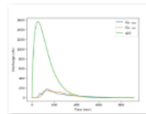
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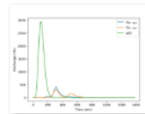
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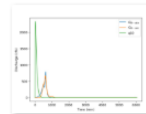
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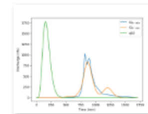
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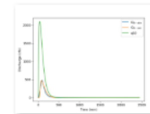
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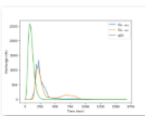
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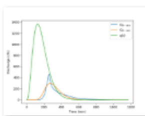
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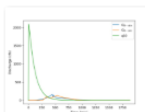
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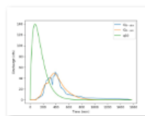
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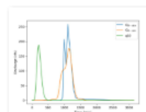
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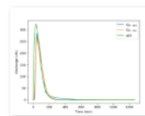
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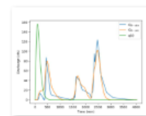
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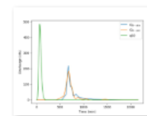
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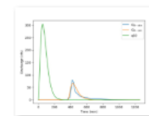
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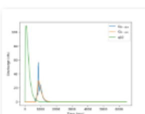
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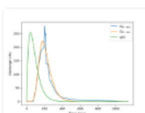
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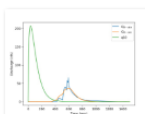
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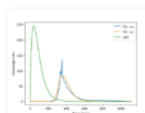
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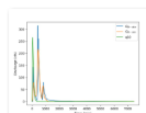
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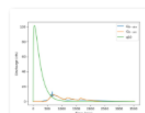
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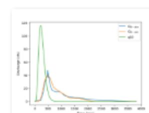
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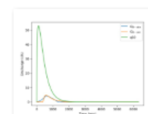
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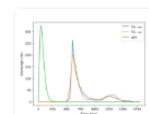
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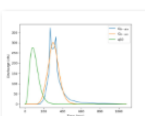
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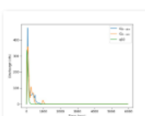
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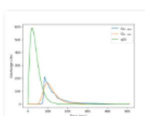
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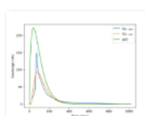
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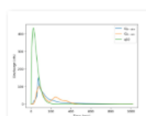
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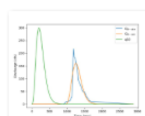
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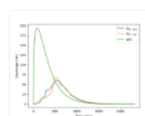
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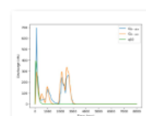
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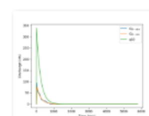
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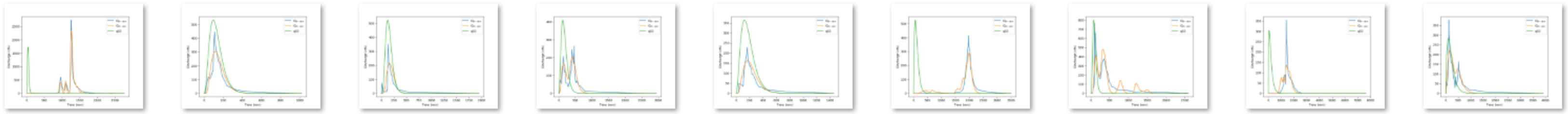

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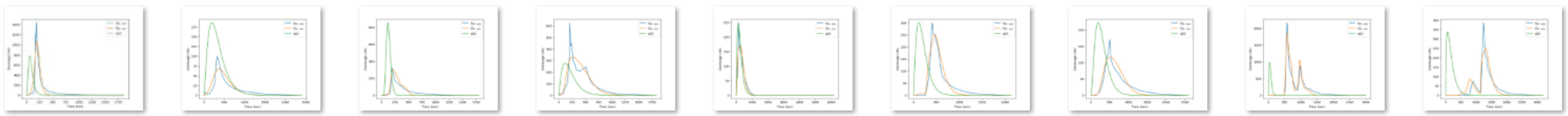

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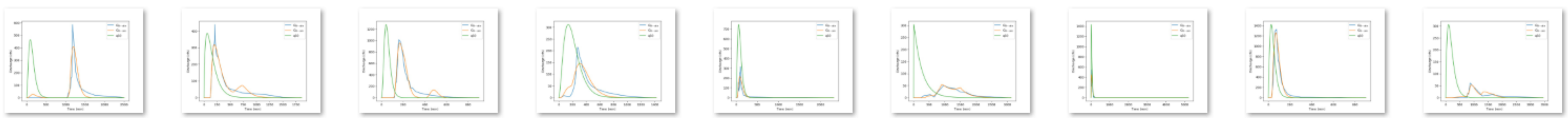

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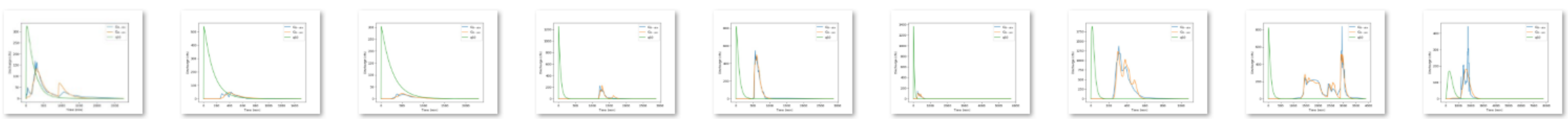

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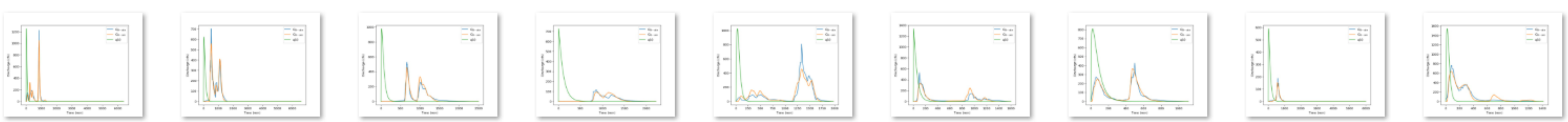

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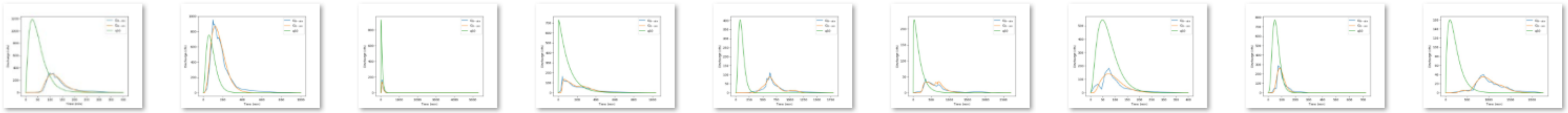

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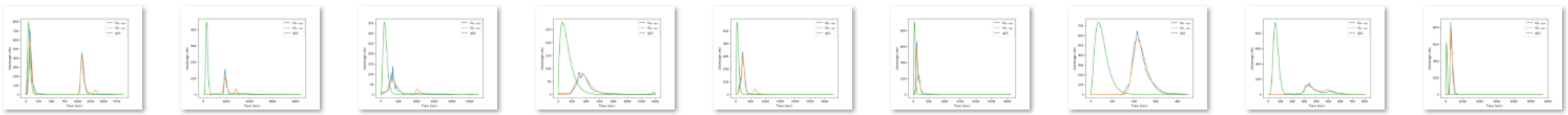

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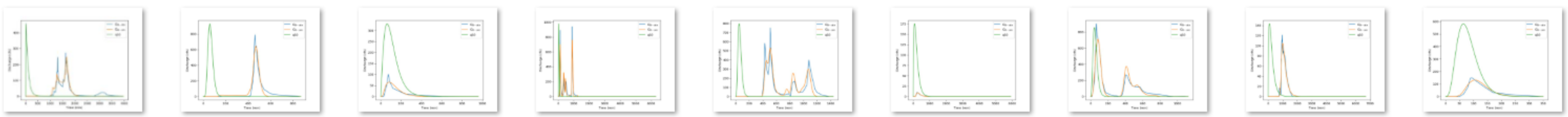

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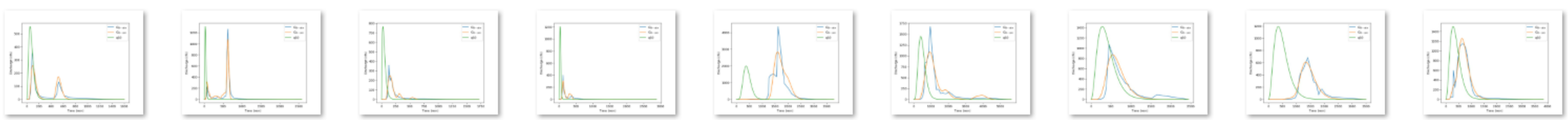

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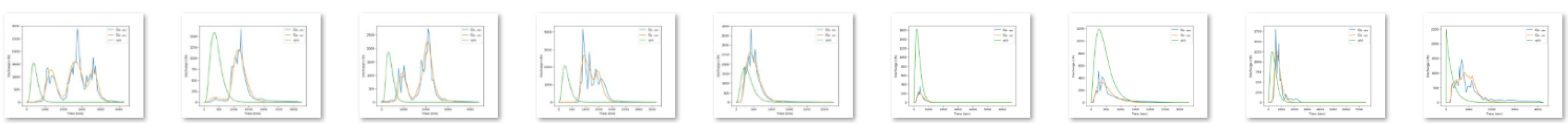

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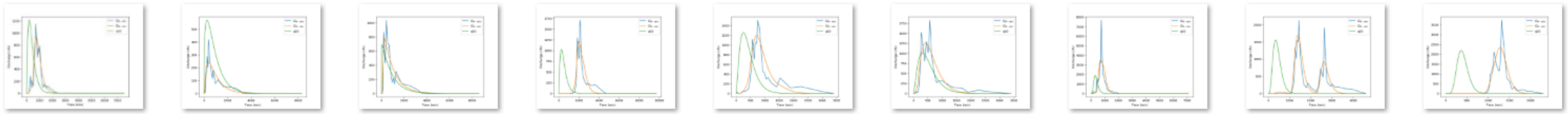

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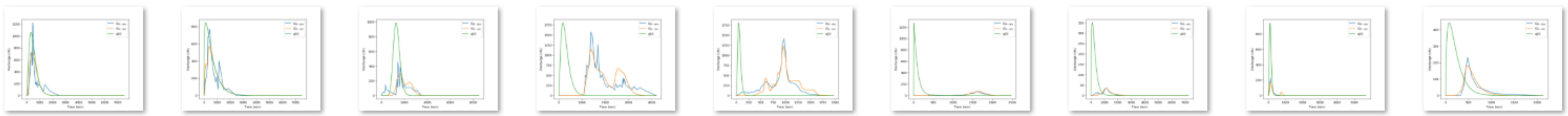

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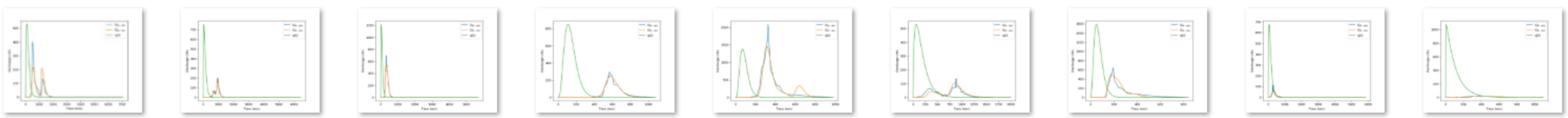

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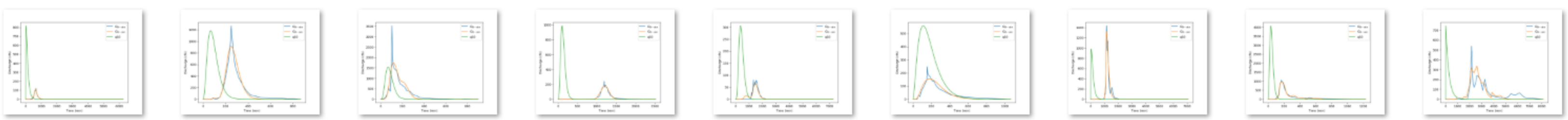

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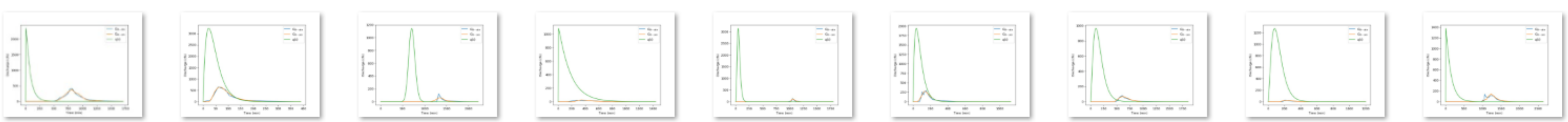

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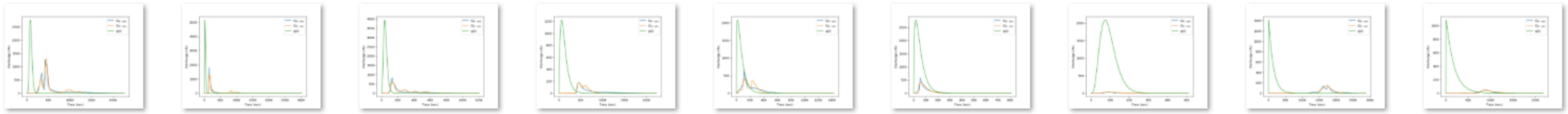

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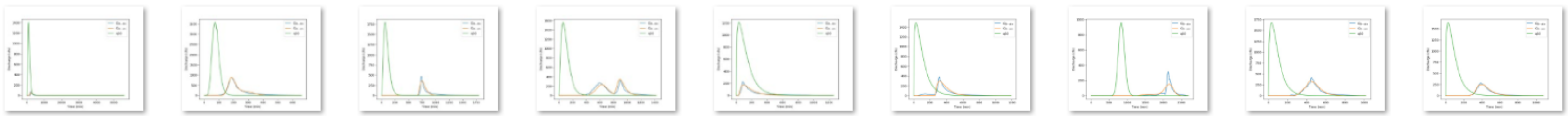

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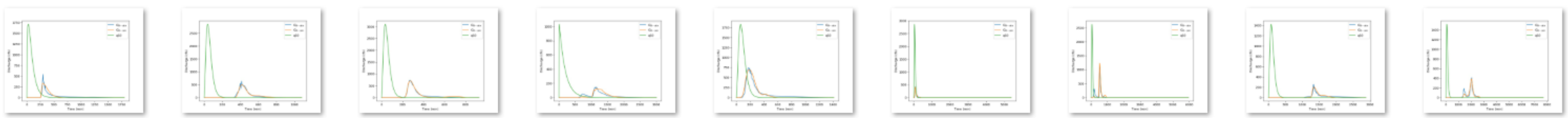

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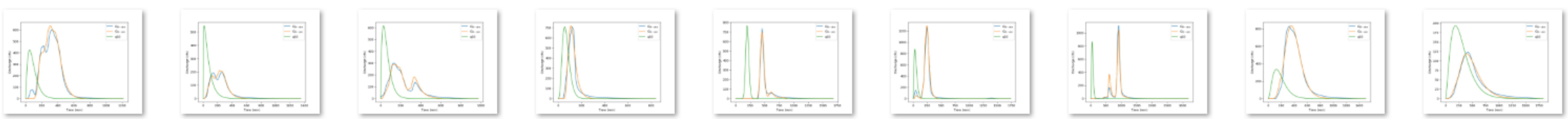

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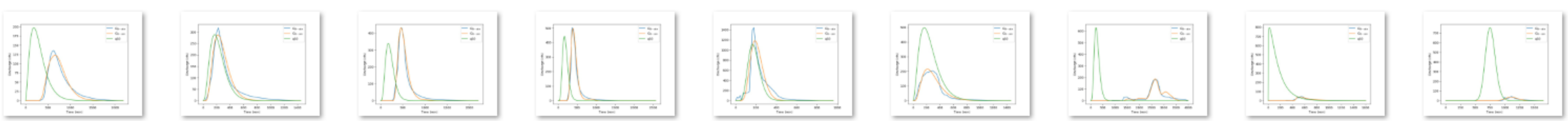

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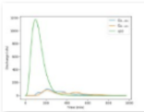
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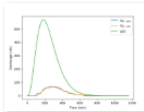
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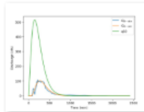
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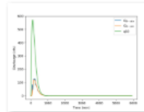
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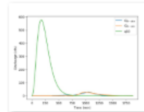
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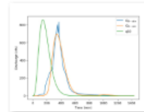
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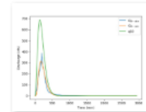
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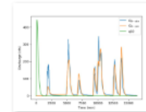
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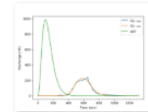
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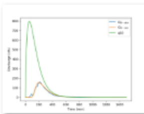
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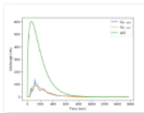
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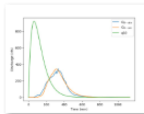
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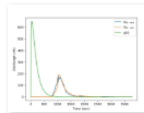
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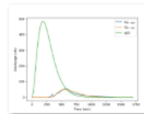
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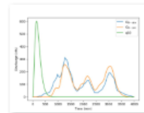
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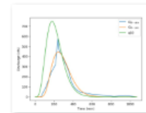
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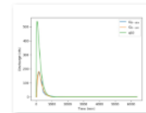
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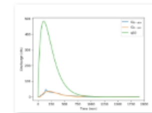
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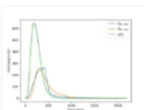
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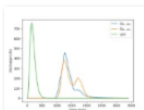
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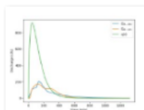
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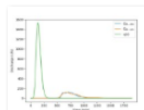
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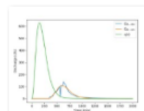
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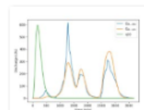
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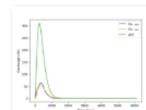
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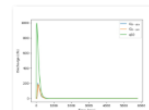
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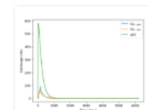
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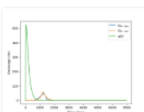
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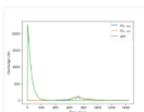
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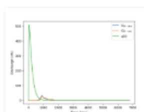
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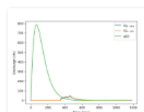
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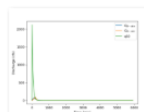
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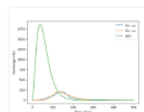
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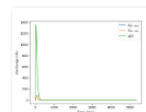
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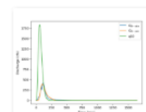
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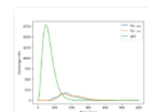
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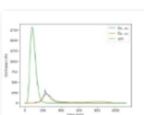
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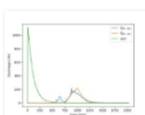
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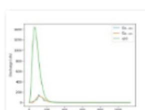
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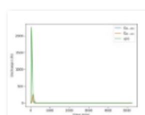
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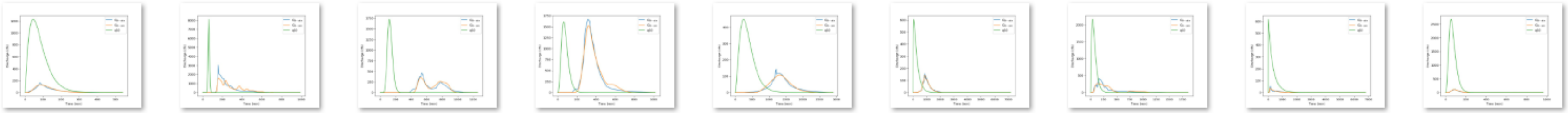

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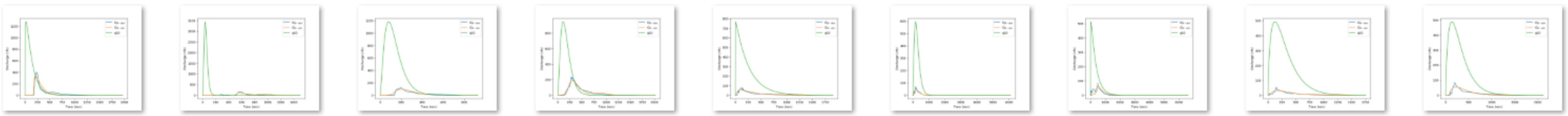

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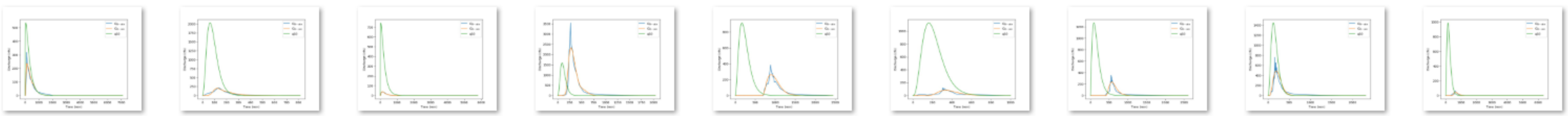

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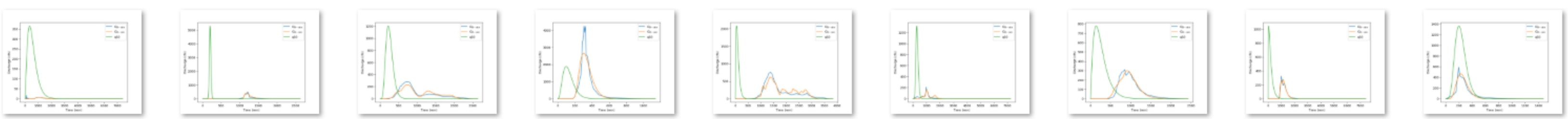

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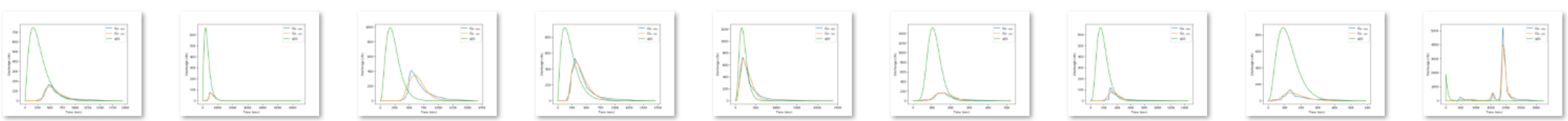

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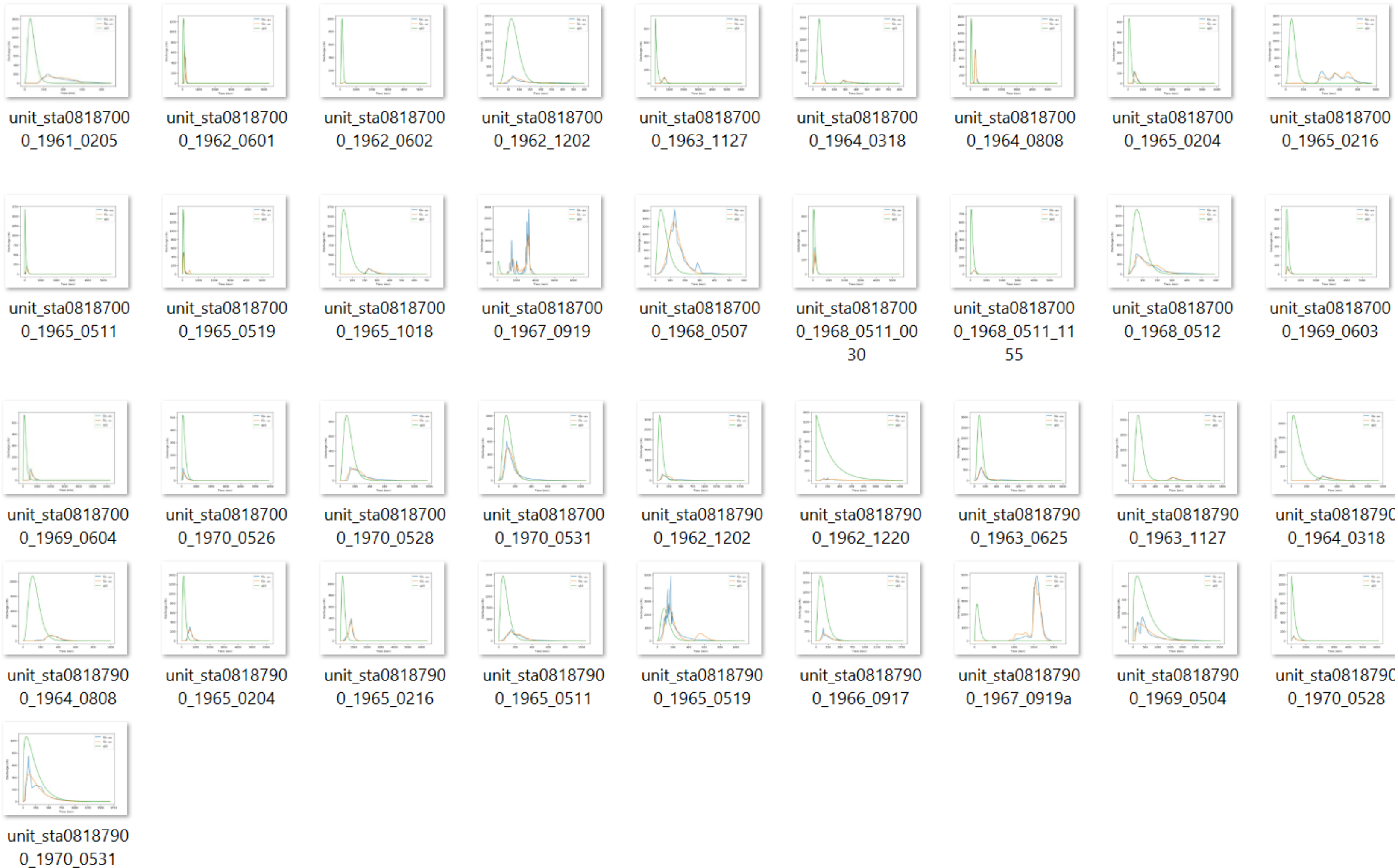
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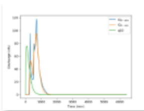
VAPPENDIX L

SIMULATION RESULTS FOR HOUSTON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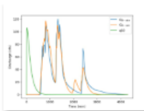
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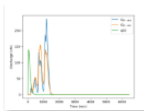
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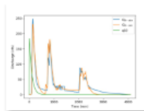
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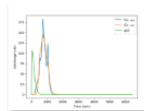
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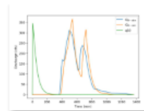
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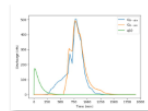
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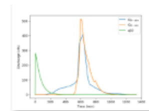
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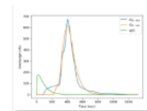
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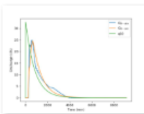
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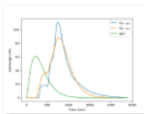
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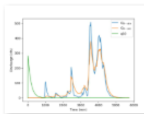
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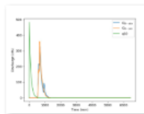
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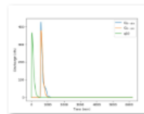
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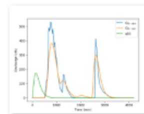
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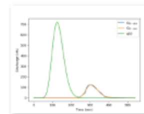
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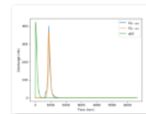
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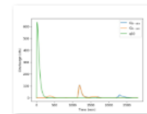
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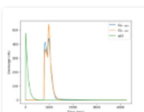
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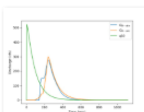
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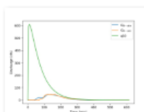
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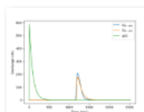
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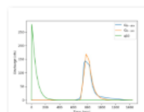
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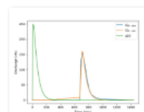
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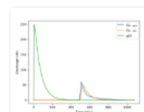
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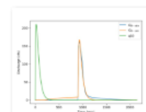
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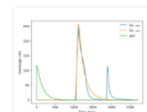
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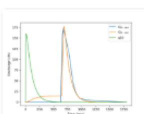
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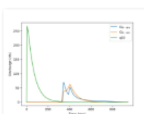
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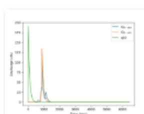
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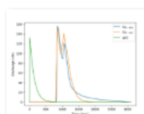
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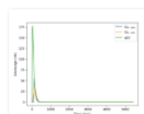
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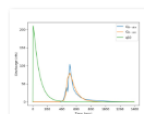
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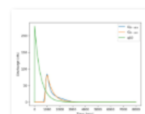
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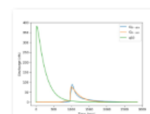
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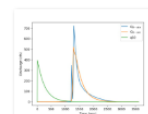
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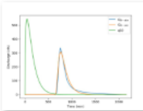
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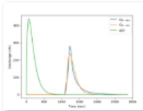
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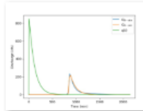
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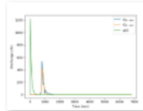
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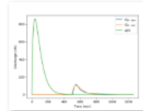
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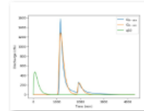
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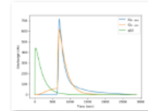
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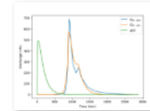
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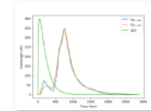
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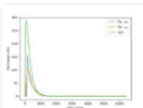
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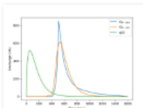
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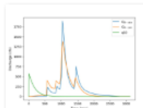
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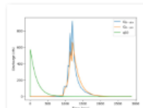
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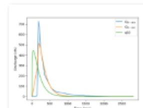
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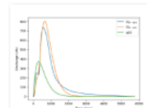
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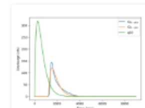
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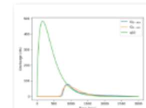
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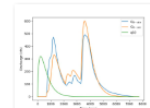
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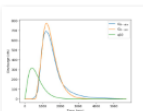
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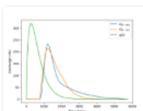
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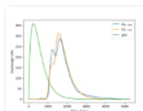
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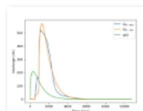
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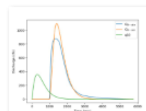
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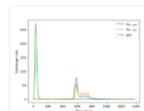
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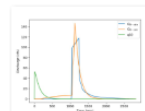
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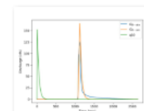
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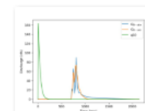
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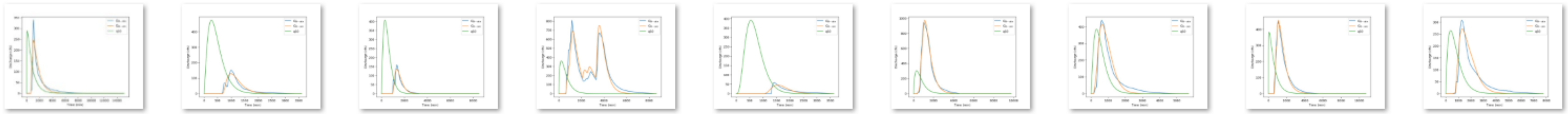

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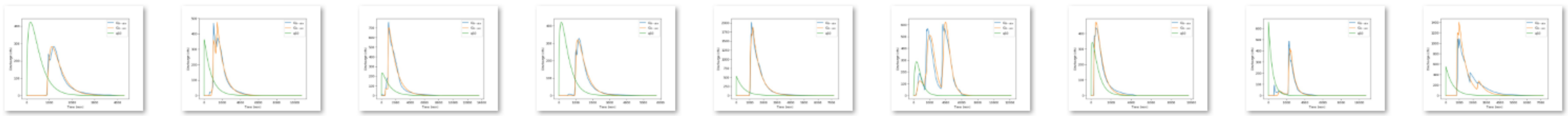

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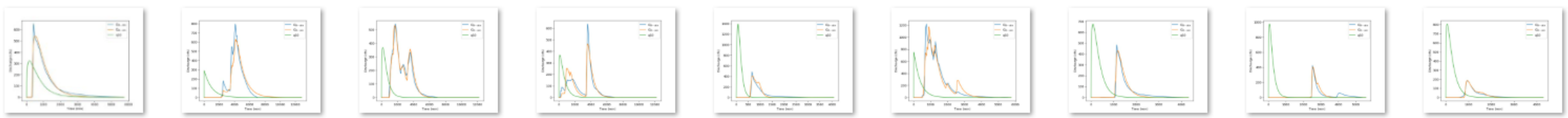

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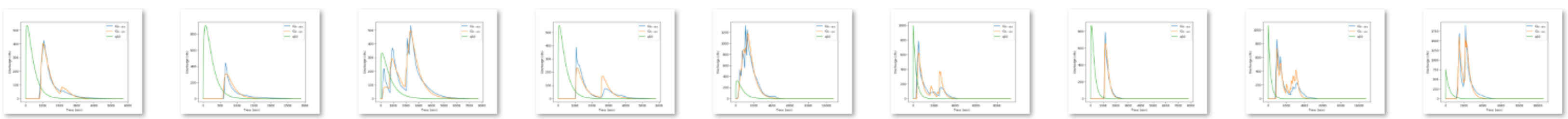

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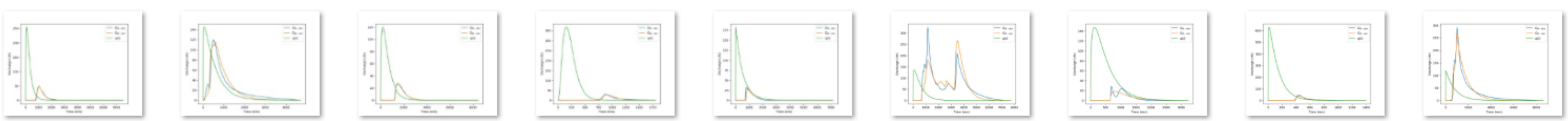

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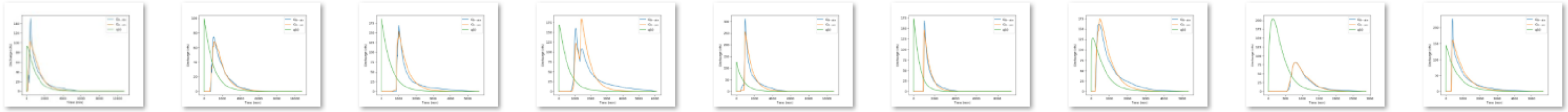

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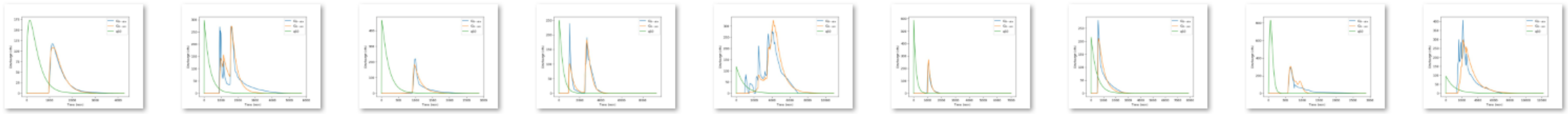

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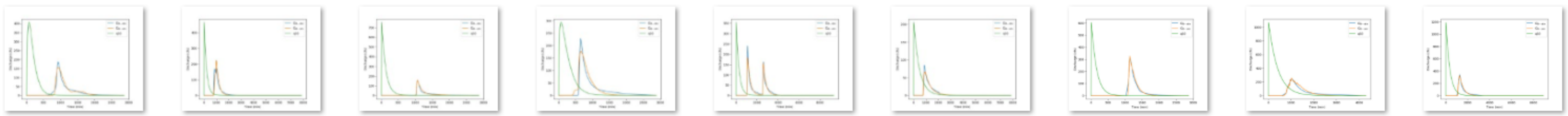

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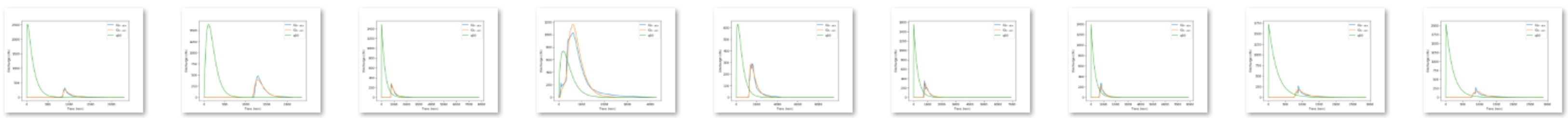

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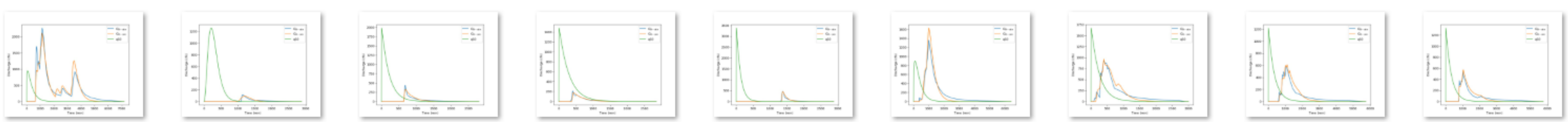

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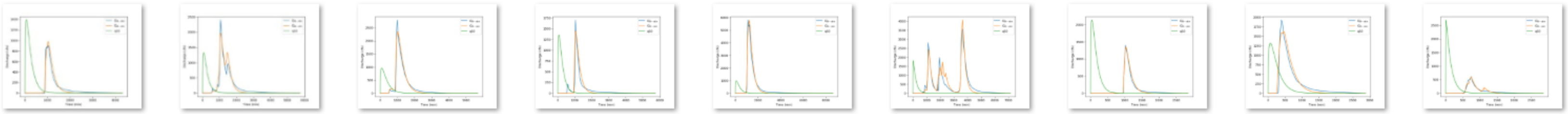

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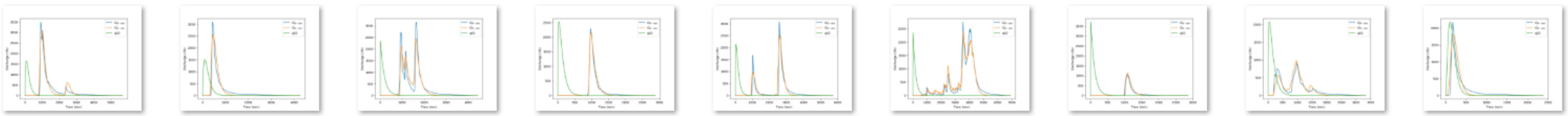

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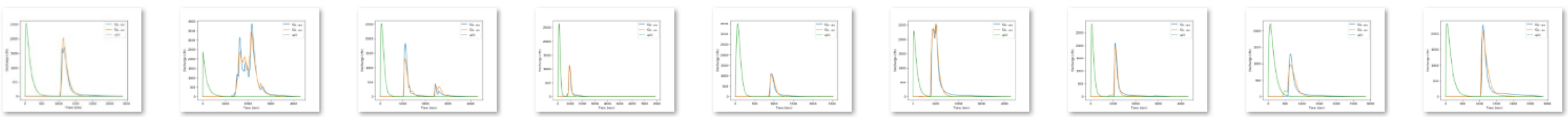

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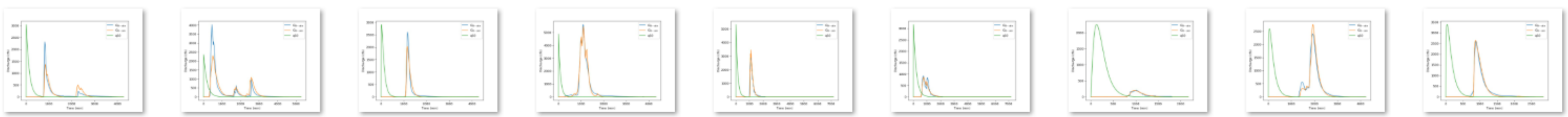

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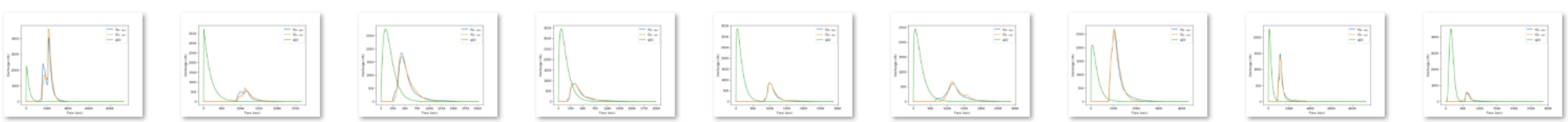

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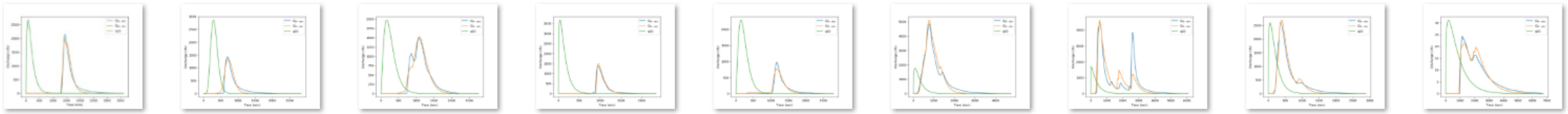

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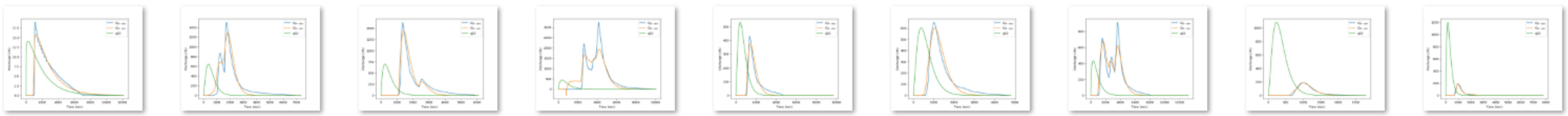

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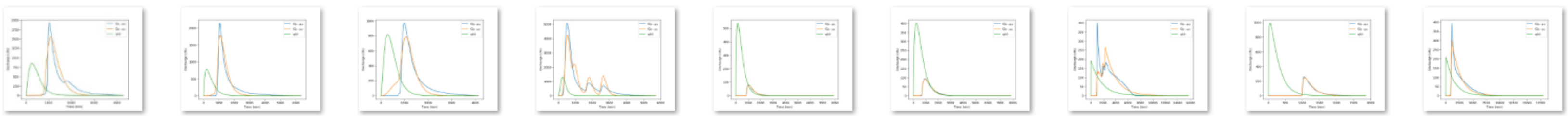

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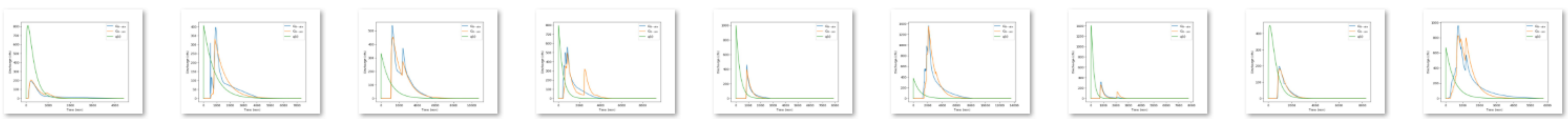

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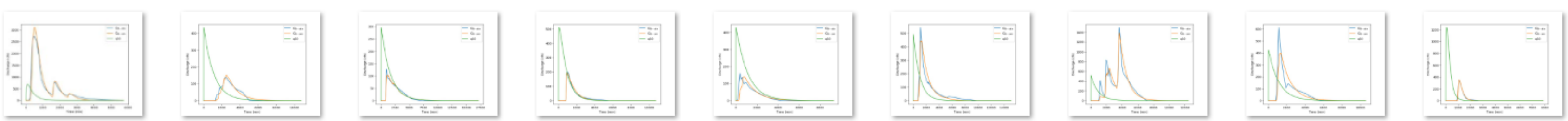

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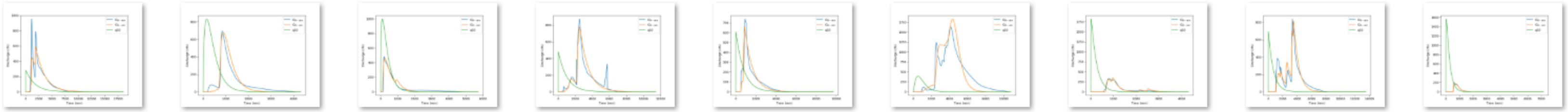
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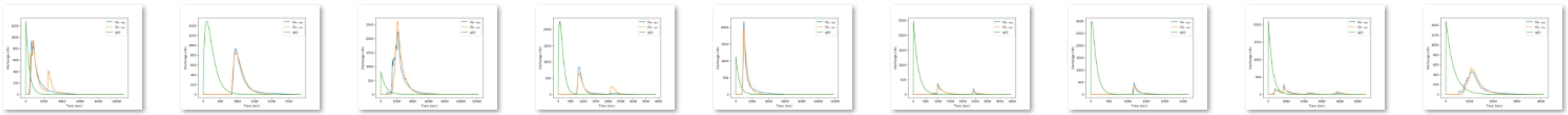
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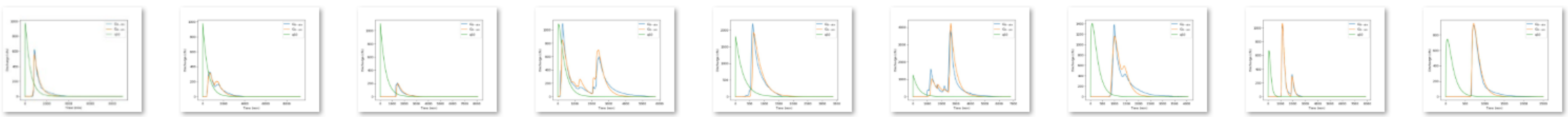
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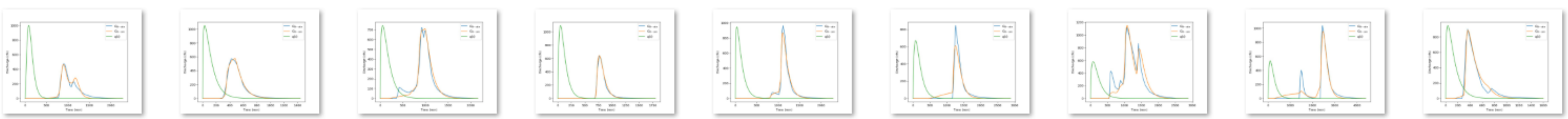
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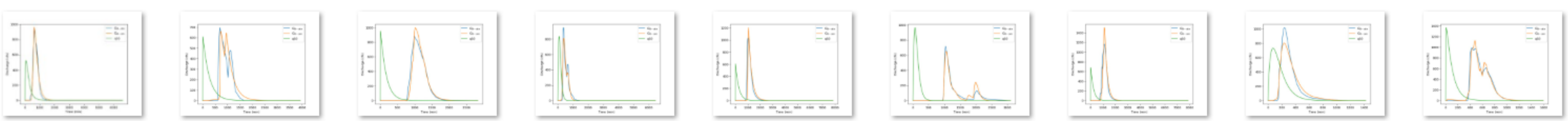
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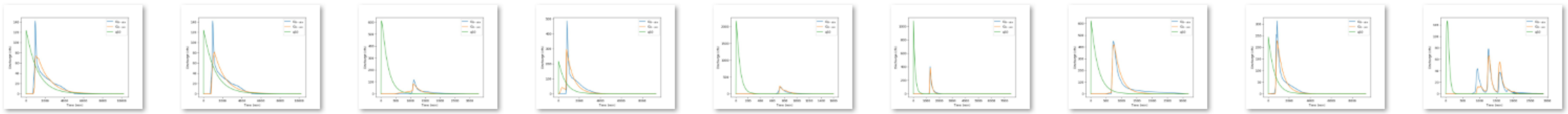

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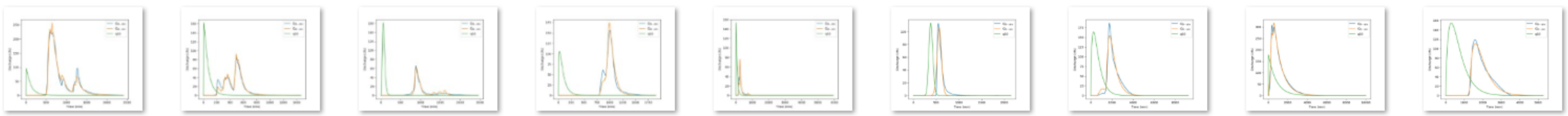

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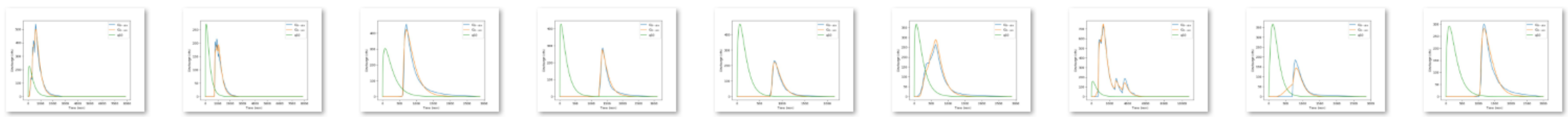

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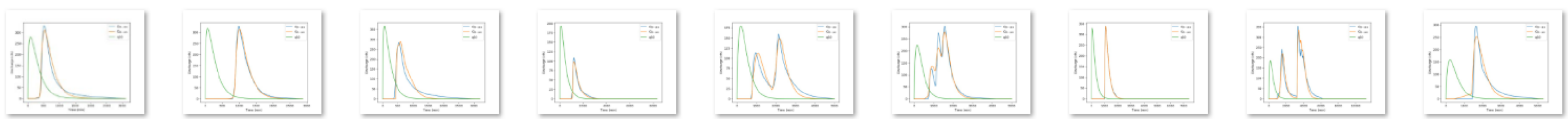

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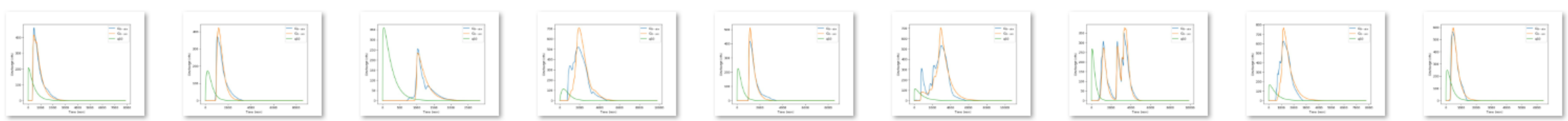

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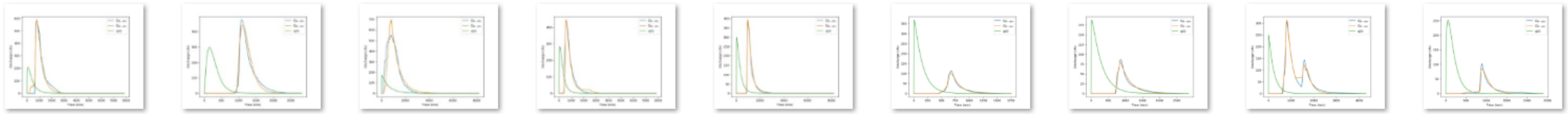

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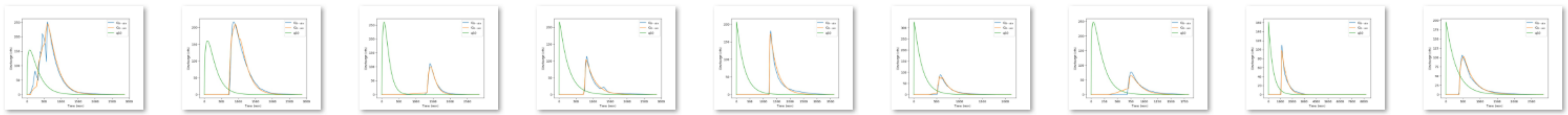

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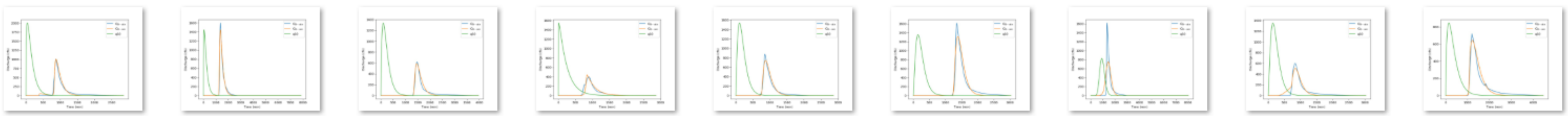

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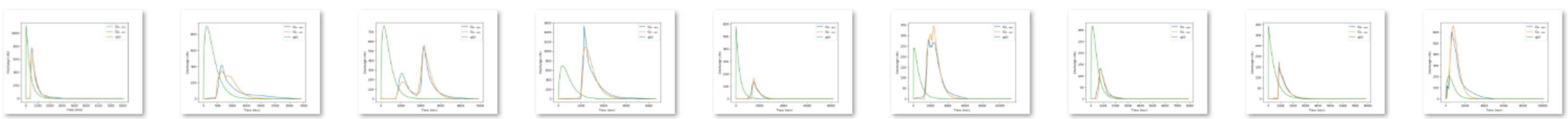

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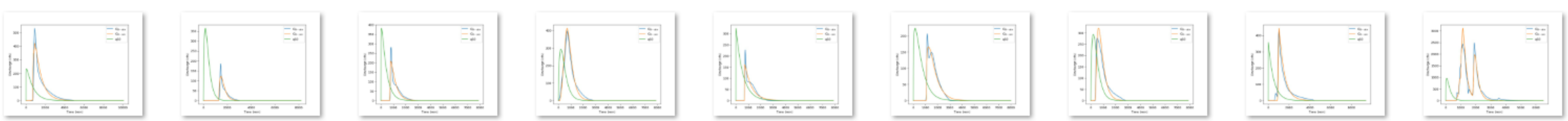

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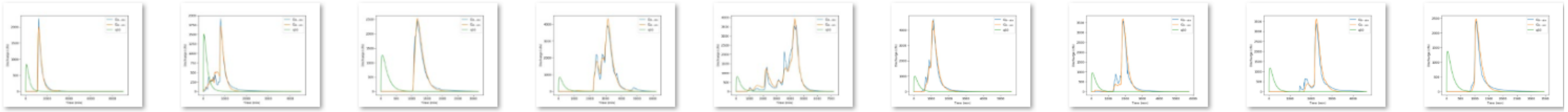

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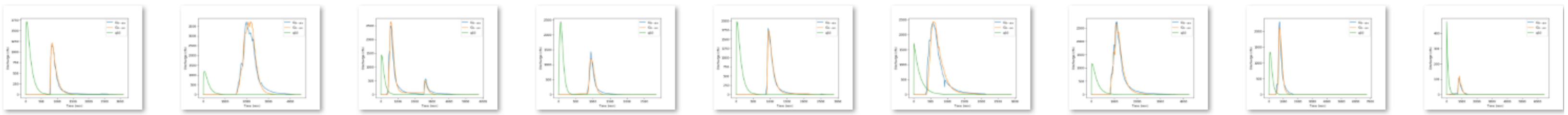

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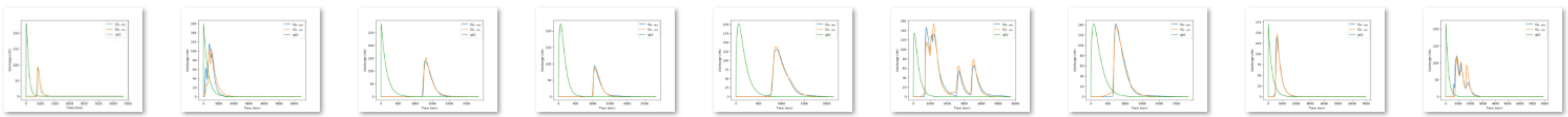

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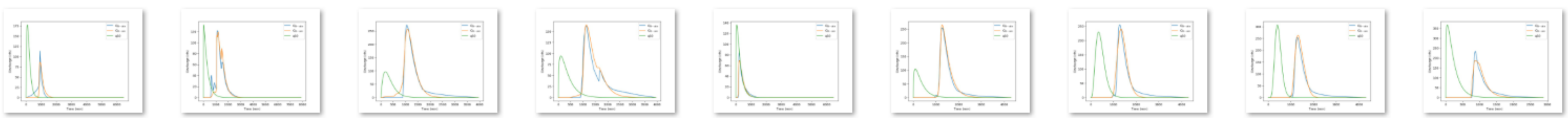

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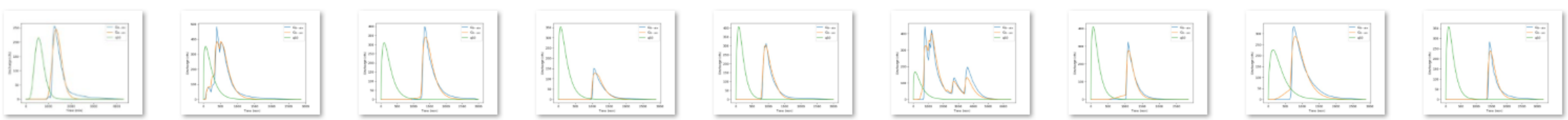

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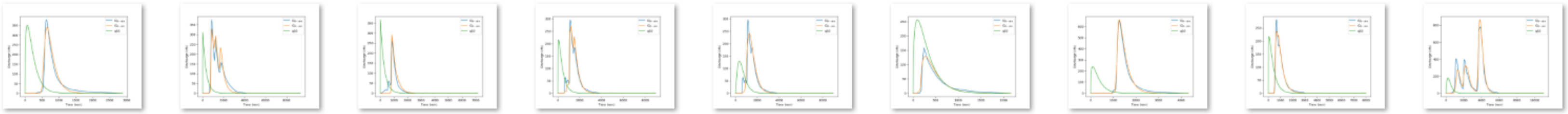

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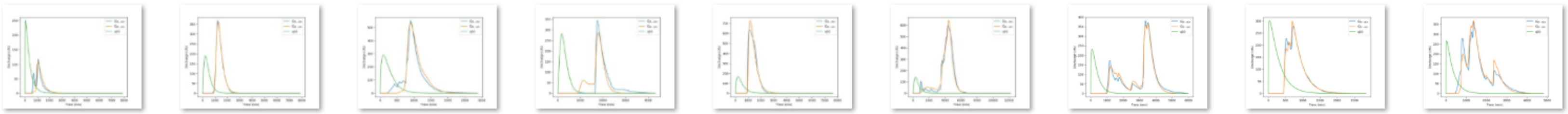

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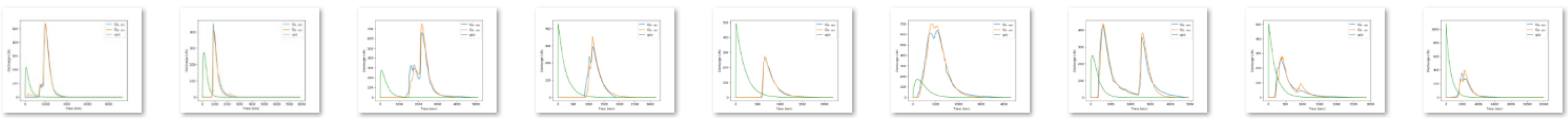

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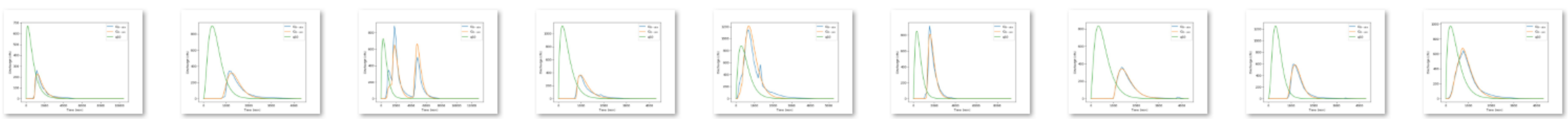

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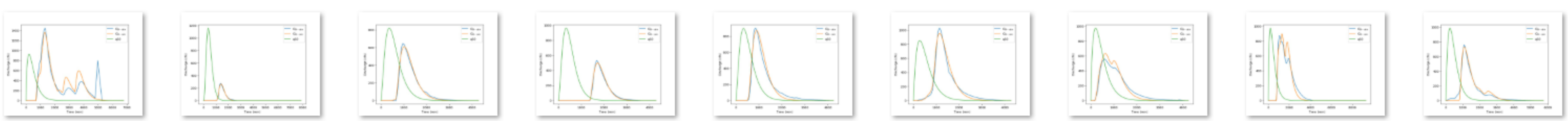

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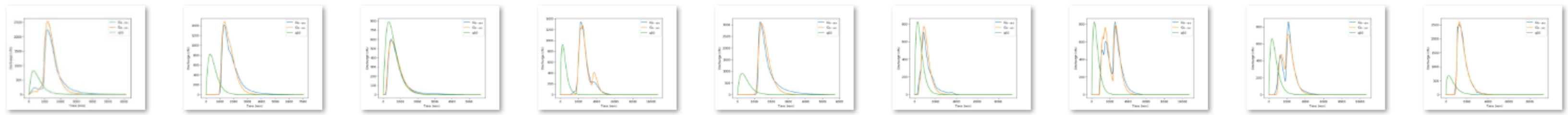

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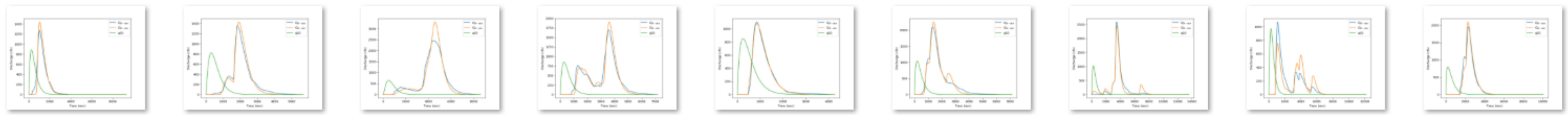

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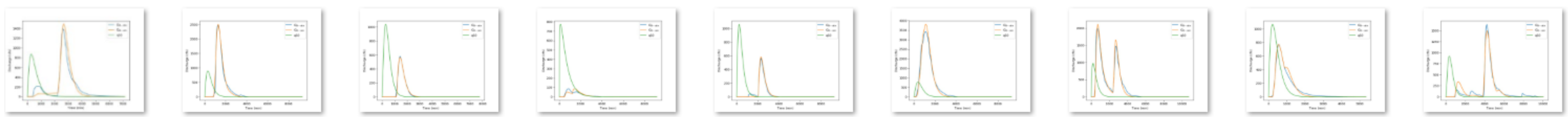

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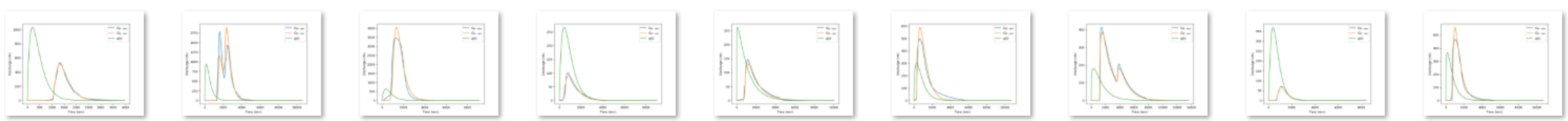

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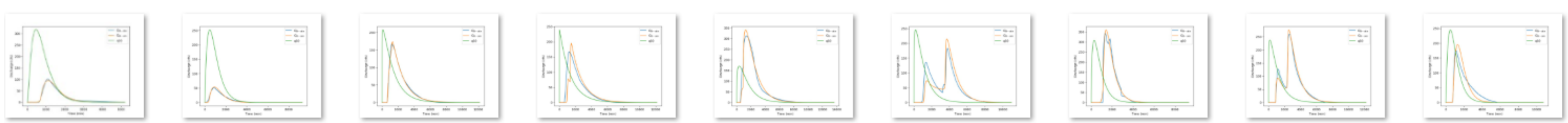

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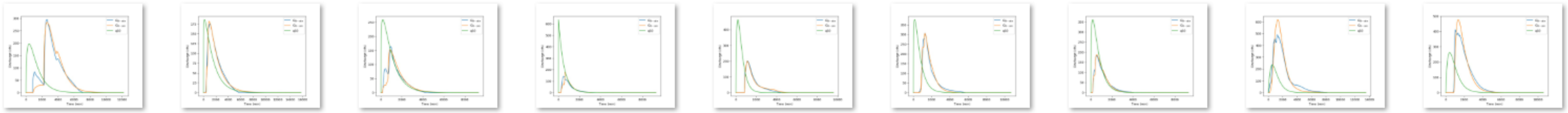

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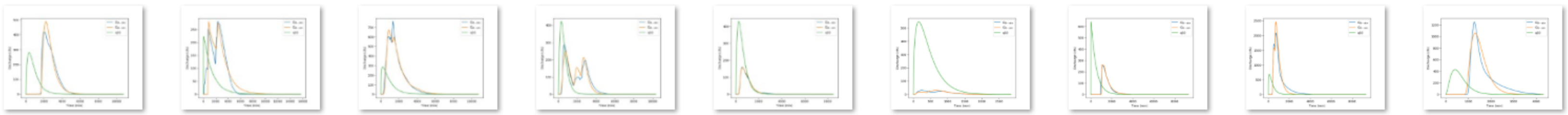

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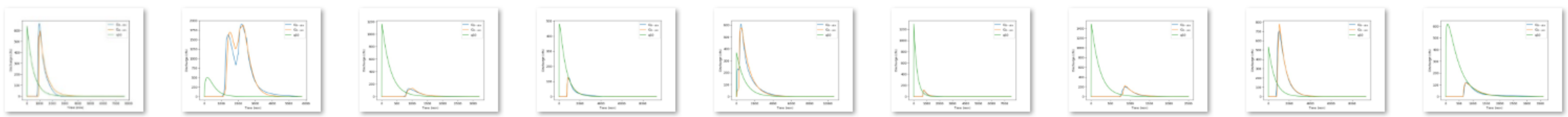

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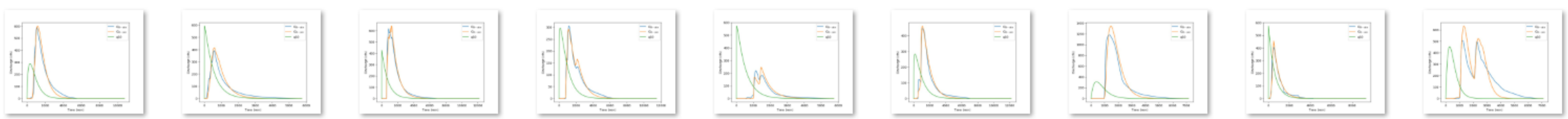

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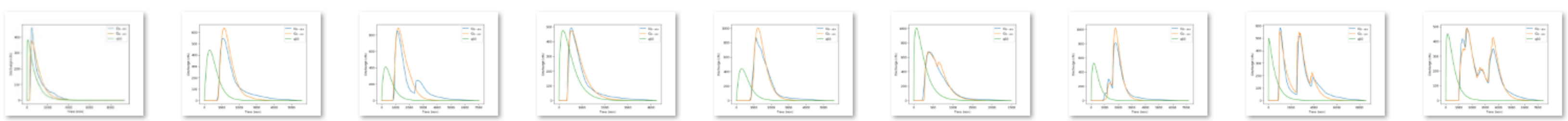

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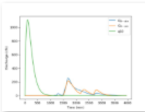
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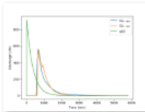
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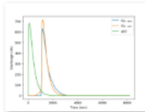
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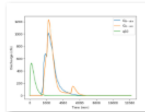
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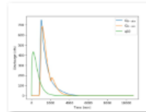
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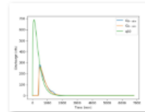
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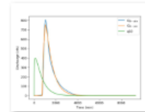
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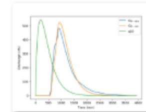
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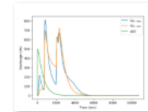
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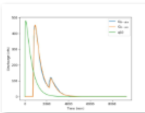
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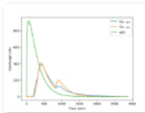
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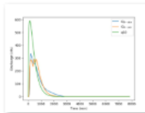
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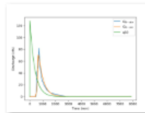
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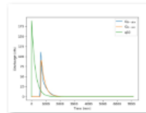
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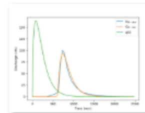
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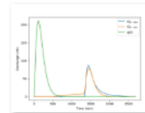
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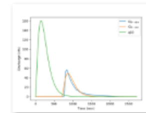
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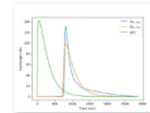
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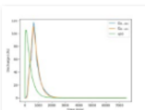
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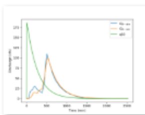
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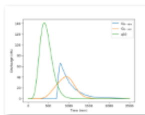
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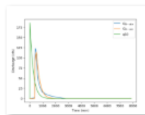
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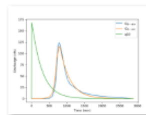
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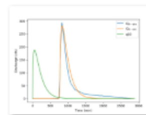
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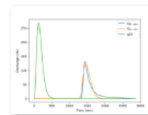
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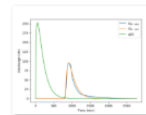
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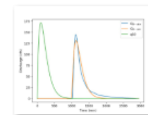
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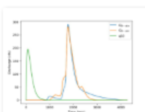
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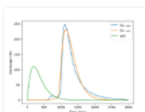
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