Synthetic Rainfall Generation Model for Evaluating Potential Erosion
at Highway Construction Sites

A Thesis
Presented to
the Faculty of the Interdisciplinary Graduate Program
in Environmental Engineering
University of Houston

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in Environmental Engineering

by
Gang Qiu
May 1997
Synthetic Rainfall Generation Model for Evaluating Potential Erosion
at Highway Construction Sites

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ABSTRACT

An easy-to-use and space-saving synthetic rainfall generation (SRG) model is constructed to generate 15-minute rainfall forecasts (in a probabilistic sense) for the rainfall-runoff-solids generation model, which allows a highway engineer to evaluate the planned temporary sediment controls (TSC) that may be part of the Storm Water Pollution Prevention Plan (SW3P) required for the highway construction project. An arrival time model based upon zero and nonzero raindays is used to generate arrival time series. A four-parameter rainday convolution model is used to mimic the total precipitation and shape of historical rainday events. A Texas GIS (Geographic Information System) map is constructed to find the distances between a highway construction site and selected rainfall stations. The final rainfall sequence at a highway construction site is generated by combining rainfall sequences at three nearby rainfall stations through an inverse distance algorithm. A user-friendly interface is also built to facilitate the use of the SRG model. The statistical test approach is performed to evaluate the SRG model.
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1.1 Research Background

This research is part of the project funded by Texas Department of Transportation, titled “Evaluation of the Impacts, Performance, and Costs of Storm Water Pollution Prevention Plans (SW3P) as Applied to Highway Construction Activities”.

The Clean Water Act (CWA) regulates stormwater discharge from construction sites that disturb 5 or more acres (this value may change to 1 or more acres). General permit requirements that apply to construction activities were published in the Federal register, Volume 57, Number 175 on Wednesday, September 9, 1992.

Permittees must provide a site description, identify sources of contaminants that will affect stormwater, design appropriate measures to reduce pollutants in stormwater discharges, and implement these measures. The appropriate measures are further divided into four classes: erosion and sediment control, stabilization practices, structural practices, and stormwater management. Collectively the site description and accompanying measures are known as the facility Storm Water Pollution Prevention Plan (SW3P). The focus of SW3P is on erosion control and prevention of suspended solids leaving a construction site.

The permit contains no specific performance measures for construction activities, but states that "EPA anticipates that stormwater management will be able to provide for the
removal of at least 80% of the total suspended solids (TSS)." In terms of reducing solids load to a receiving stream, the emphasis on solids control is well supported by past studies. In an early study of TSS as a function of land use in Virginia, highway construction areas, varying from less that 1% to more than 10% of the basin contributed 85% of the sediment load. The sediment yield of the highway construction area was 10 times that of cultivated land, 200 times that for grassland, and 2000 times that of forest land. (Vice, 1969). Other investigators found that runoff from highway construction sites causes a temporary degradation of stream water quality with respect to turbidity and suspended solids (Hainly, 1980; Embler and Fletcher, 1981; Helm, 1978).

The goals of this project are to gather, analyze, and interpret existing data to infer the effect of sedimentation on receiving water ecosystems, infer the effects of SW3P on sediment transfer, determine the types and quantities of contaminants associated with highway construction activities, develop useful predictive tools to be used for cost/benefit analysis, and document all activities so that TXDOT can maintain, update and operate database and models as new information becomes available.

1.2 Rainfall-Runoff-Solids Generation Model

One tool under development is a rainfall-runoff-solids generation model to calculate the mass loadings to receiving stream, and identify the effectiveness of SW3P techniques, especially temporary sediment controls (TSC). The model considers two components: detachment and transport by rainfall and detachment and transport by overland flow. The rainfall induced surface erosion, in general, is a power function of rainfall intensity.
The sediments scoured in the overland flow are also assumed to be a power function of the overland flow rate. During a runoff producing storm, the user will be able to predict sediment mobilization and the effects of manmade controls on sediment transport using these modeling tools.

This thesis is the very first step of the model, that is to design a rainfall model which can generate 15-minute rainfall sequence for a highway construction site, which will be used in runoff and solids transport model.

1.3 The Organization of This Thesis

This thesis begins by considering the background of the research. The second chapter reviews the literature of rainfall models and concludes that there is no appropriate rainfall generation model for highway engineers to evaluate effect of SW3P on highway construction sites. Chapter 3 clearly states the problem to be addressed in this thesis.

Chapter 4 presents the synthetic rainfall generation (SRG) model and bootstrapping method development procedure. Model application and limitations are illustrated in Chapter 5. Three assumed highway construction sites, near Austin, Houston and Lubbock, are used to perform the model and statistical test. The effect of number of construction days and number of repeats of SRG model on evaluating mean value of precipitation from statistically generated 15-minute model rainfall sequences is test. Fifteen-minute rainfall sequences from SRG model and bootstrapping method is tested for their likeness and compared for their sediment production.
Chapter 6 presents the conclusions and limitations. Finally Visual Basic and FORTRAN programs source code for the SRG model are attached as appendices as well.
Chapter 2  Literature Review

A rainfall sequence is a type of time series where rainfall depths are recorded in time. The sequence is unidimensional, hydrologic, stochastic process (Yevjevich, 1972). A stochastic process is defined as a mathematical abstraction of a process that can be characterized by statistical properties. The stochastic process is considered as being mathematically described through three steps: a) distribution functions are postulated, b) parameters of distribution functions are estimated, c) proper statistical tests of hypotheses are performed. The number and kinds of stochastic models applicable in rainfall generation are nearly unlimited.

Haan (1977) stated that synthetic rainfall from a model that is based solely on historical record of rainfall is but one realization of a stochastic time series and the future realizations will resemble the historical record only in a statistical sense. Stochastic rainfall is neither historical rainfall nor predictions of future rainfall, but a representative of possible future rainfall in a statistical sense.

Pattson (1964) states that stochastic rainfall model implies a repetition in the future of the historical events and in some cases that these future occurrences will take place in the same order as that which has occurred historically. This assumption becomes more valid and the estimates are improved as the length of the historical record is increased.
Haan (1977) describes a purely random stochastic model, which the rain and no-rain events are assumed to occur at discrete times with constant time interval. The events at any time are independent of the events at any other time. The time between storms might be modeled as an independent Poisson process and the amount of rain might be modeled as a gamma variable.

Rodriguez-Iturbe et al. (1984) used a compound Poisson model to analyze the parameter estimation problems for the aggregation of rainfall at hourly and daily scales. This model considered rainfall events in the form of instantaneous burst in time. The occurrence times of the bursts are modeled by a Poisson process. Then to each burst occurrence time an independent rainfall amount is attached. This results in a compound Poisson process for the rainfall amounts in time.

Chang et al. (1984) proposed various models from discrete autoregressive moving average (DARMA) family and applied these models to occurrence of daily rainfall data of Indiana. The most popular approach of these approaches is to consider the precipitation occurrence process to be described by a finite state (typically a value of 2, a day is wet W or dry D) Markov Chain (MC) with seasonally (or time-varying) transition probabilities.

The transition probabilities from transitions (i.e., WW, WD, DW, DD) between the two states (W or D) are estimated directly from the data through a counting process. If the probability law that governs the future development of the process at some point
depends only on that point and not on the prior evolution of the process, such a process is called a first-order Markov chain. If, however, the probability law depends on the current state and also on the immediately preceding state then it is called a second-order Markov chain. Chains of Nth-order are defined in the same way. They concluded that the DARMA family of models can preserve various desirable statistical properties of the daily rainfall process.

Roldan and Woolhiser (1982) proposed a wet-dry spell approach for daily precipitation occurrence. This approach is called the alternating renewal model (ARM). No transition to the same state is possible for this approach. An advantage of this approach is that it allows direct consideration of a composite precipitation event, rather than its discontinuous truncation into arbitrary daily segments. Spell length is modeled by a geometric or a negative binominal distribution.

Slade (1936) was the first to fit a continuous probability distribution to rainfall data. He made use of a logarithmic transformation of the normal to fit the annual rainfall amounts.

Skees and Shenton (1974) noted that annual and monthly rainfall were successfully modeled as random variables with gamma, normal, and logarithmic normal distributions. For shorter intervals (weeks, days, hours), satisfactory distributions were more difficult to obtain.
The S-curve is used in hydrology to model an infinite sequential series of fixed duration storms, which is a step response process (Bras, 1990). This curve is the infinite summation of unit amount of the given duration. The S-curve is obtained by adding corresponding unit hydrograph, each lagged by one unit time.

Dempster (1993) states that a time course fitting procedure can be implemented by defining a suitable step response function for single channel currents. A channel opening can be represented by the sum of an opening step $S(t, t_0)$ and a closing step represented by an inverted form $(1 - S(t, t_0 + \tau))$, where $S$ is the amount, $t$ is time, $t_0$ is starting time, $\tau$ is delay time. The equation of this form is called a convolution equation, and parameters in this equation can be evaluated by optimization method and user-defined criteria.

McCuen (1986) described three types of parameters used to define the distribution of time series as location, scale and shape parameters (i.e., parameters of a distribution control the geometric characteristics of the distribution). Location parameter means location of center. Scale parameter indicates various fractiles of the distribution. Shape parameter is geometric configuration of a distribution, used to distinguish one from another in a family of distributions.

The WEPP USER Requirement (Foster and Lane, 1987) suggested that the maximum information required to represent a design storm consist of the following: (a) storm
amount, (b) average intensity, (c) ratio of peak intensity to average intensity, and (d) time to peak intensity.

Tabios and Salas (1985) examine several commonly used spatial interpolation techniques for point annual precipitation at 29 stations located in North Central continental United States. The techniques considered were the followings: Theissen, polynomial, inverse distance, multiquadratic, Gandin, and Kriging. The comparison is based on the following criteria: the mean and variance of the observed and interpolated annual precipitation, the sum of square errors between the observed and interpolated values of annual precipitation, the proportion of the variance accounted for by the interpolator, the coefficient of determination between the observed and interpolated values and the standard deviation of the error of interpolation.

The result from this study shows that the optimal-interpolation and Kriging techniques are the best among all techniques analyzed considering various performance criteria used by the study. The inverse distance method is not as good as Kriging and optimal-interpolation techniques, but is better than the Theissen and multiquadratic methods.

There exist many rainfall models, but very rarely is the hydrologist interested in rainfall as an isolated phenomenon. Evaporation, transportation and the antecedent moisture are always considered in a model. Also considered are pertinent characteristics of the basin itself, such as its geology, topography etc. For example the Stanford Watershed Model
(Pattison, A, 1964) and the USDA WEPP model (Foster and Lane, 1987) consider all these features.

From the literature reviewed, one concludes that there are many stochastic models based upon historical data to generate a rainfall sequence, but there is no rainfall generation model that meets the requirement for this project: generate 15-minute sequences, economical data storage so the entire state of Texas can be stored, and easy to use for highway engineers (user-friendly).

The subject of this thesis is the design of an easy-to-use synthetic rainfall generation model for a highway engineer to generate 15-minute rainfall sequences which can preserve total volume of precipitation and some characteristics of intensity of historical data.
Chapter 3 Problem Statement

EPA requires a Storm Water Pollution Prevention Plan (SW3P) to be in effect for highway construction activities. SW3P focus on erosion control and prevention of suspended sediments leaving construction sites.

Sediments produced by storms from highway construction activities effect water body ecosystems by both its sedimentation and as a medium of transporting contaminants. Simplified models to infer effects of sedimentation and SW3Ps on sediment transfer are desired. The first step of these models is a simulation model to relate rainfall to runoff and total suspended solids generation, which allows a highway engineer to evaluate the planned temporary sediment controls (TSC) that may be part of the Storm Water Pollution Prevention Plan (SW3P).

Many stochastic models exist, but most of them use rainfall data with time space equal or larger than 1 hour, involve information other than just rainfall, and are not easy to use. Furthermore there is no specific synthetic rainfall generation model for highway construction activities in Texas.

The purpose of this synthetic rainfall model is to generate rainfall forecasts (in a probabilistic sense) for the rainfall-runoff-solids generation model. This model uses historical daily and 15-minute rainfall data to predict the precipitation during a highway construction period in a probabilistic sense. Some features of this model will be the
following: generation of 15-minute sequences for the whole proposed construction period, economical data storage so the parameter for the entire state of Texas can be stored, and easy-to-use information for highway engineers (user-friendly).

Occurrence of rainfall events in each station is modeled by a sequence of days of zero rain and nonzero rain properties through a statistical distribution function. Each rainday is modeled by a step response function focusing on the volume, intensity, duration and overall shape of precipitation. A final rainfall sequence at highway construction site is generated from three nearby stations by spatial interpolation. A user-friendly Visual Basic Interface for SRG model was generated. Model tests and hypothesis tests are performed to check if this model is valid and what the suggested procedures are to use this model.
Chapter 4 Model Development

The SRG model development was divided into three steps: Geographic Information System (GIS) mapping of rainfall stations in Texas and development of a distance finding procedure, analysis and reduction of historical records into a database, and design of an interface that allows a user to access the data base.

The first step was the construction of a GIS map for rainfall stations in Texas. One hundred and nine out of 206 stations in Texas were selected to build a network of rainfall stations so that there are always some nearby stations around any possible highway construction site in Texas. The distance between the highway construction site and the rainfall stations can be found from this map, and this distance information is used in the SRG model to combine synthetic 15-minute rainfall sequences for each station to generate a 15-minute rainfall sequence for the highway construction site by spatial interpolation.

The second step was daily and 15 minute rainfall data analysis and database construction. Actual daily rainfall data files were analyzed to create empirical cumulative arrival time function (ECATF) parameter data files. Actual 15-minute data files were analyzed to create rainday parameter data files for use in a convolution equation. These parameter data are one option in the SRG model to generate synthetic 15-minute rainfall sequences for each station. Another option in the model is to resample the original data (bootstrap).
The third step was to develop a Visual Basic interface to allow the user to access the data files and generate rainfall sequences.

4.1 Construction of GIS Map and Distance Finding

In order to easily select three nearby stations and find the distances between stations and highway construction site, a Geographic Information System (GIS) (Strategic Mapping Inc., 1994) computer program was used to construct a map of Texas so that both rainfall stations and highway construction site can be viewed in the map and the distances between them can be calculated automatically.

The map was constructed by selecting 109 out of 206 stations from the original rainfall database using the following criteria:

1) All stations around major cities are available on the map.
2) Stations far away from cities are selected so that there are always at least three stations within 100 miles around any possible HCS site in Texas.
3) Choose existing stations with a longer historical record.

The longitude and latitude data of rainfall stations are extracted from the original database and are formatted so that rainfall stations can be displayed on the GIS map. Figure 4-1 shows the GIS map for the 109 selected rainfall stations in Texas. On this map, counties, major cities, and interstate highways are displayed so that a location is
easy to find. Each rainfall station is represented by a cross flag. A user can zoom in on a map section to see more detail as needed.
Figure 4-1  GIS Map Showing Rainfall Stations in Texas
Distances between rainfall stations and highway construction sites are computed in the GIS using the calculate column algorithm (Appendix A2). These distances are used in subsequent calculations.

A spatial interpolation method is used to generate a 15-minute time series for the HCS by averaging 15-minute time series from the three nearby stations using an inverse distance algorithm,

\[
Z_{\text{HCS}} = \frac{\sum_{i=1}^{n} \frac{Z_i}{(d_i)^2}}{\sum_{i=1}^{n} \frac{1}{(d_i)^2}},
\]

(4-1)

where \(Z_{\text{HCS}}\) is precipitation at the HCS, \(Z_i\) is precipitation at each rainfall station, and \(d_i\) is distance from the HCS to each rainfall station.

The inverse distance method belongs to a family of weighting techniques, that instead of simple averaging of the rainfall data applies more weight to the rainfall data that from the stations closer to the highway construction site.

4.2 Daily and 15-Minute Rainfall Data Reduction

The historical daily and 15-minute rainfall data were obtained from EarthInfo, Inc. (EarthInfo, Inc., 1995). The length of records varied from 10 to 50 years at the different stations.

The procedure of data treatment is depicted in Figure 4-2. Actual daily and 15-minute data (the upper left box) are first extracted from original database and then formatted
by manually deleting bad records and changing the data files into the proper format (the upper right 3-D box). For both daily and 15-minute rainfall data, there were up to 10% missing or improperly formatted records. These “bad” records were deleted manually so that the data files are readable by FORTRAN programs. Finally parameter generation (the lower middle 3-D box) programs are used to generate daily and 15-minute parameters (model data) represented by the lower right box.

A typical portion of an original daily rainfall record set for one particular year is illustrated in Figure 4-3. The separation mark between records is “|”. The first record is the station ID (“428”), and the second record is the record year (“1942”). This particular record set has too many missing records (indicated by consecutive “||”), so it is entirely deleted from the database.

```
428|1942
```

Next, data sets that are completed, such as the example in Figure 4-4, are reformatted to remove the separation marks, and to have a four-character station ID. Figure 4-5 illustrates how a completed, reformatted data set appears.

A similar procedure is applied to the 15-minute rainfall records in these data files. Figure 4-6 shows a typical “bad” data set. Separation marks are “||” for 96 rainfall records, and “|” for other supplementary records. The first record is the state ID (“TX” for Texas), the second record is the station ID (“8531”), and the fifth record is the date (“01/02/1984). The mark “---“ indicate a missing records. The character “A” after the number (“1.07”) indicates that 1.07 is an accumulative rainfall record from an unknown time interval (not 15-minute interval). The character “I” after the number (“1.07”)
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</table>

Figure 4-5  A Typical Reformatted Daily Data Set
indicates that 1.07 is an accumulative rainfall record for the whole day. This particular day has too many missing data, so it is deleted entirely from the database.

Figure 4-6  A Typical “Bad” Original 15-min. Data Record Set

Figure 4-7 illustrates an acceptable day for data from rainfall station 8531 near Austin.

This data set is reformatted by replacing the separation marks “||” and “|” with two spaces and replacing “.” (an abbreviation for 0.00) with “0.00”. Figure 4-8 illustrates the result of reformattting.
After the data are reformatted, the database is analyzed to construct rainfall data parameters and 15-minute data parameters.

The concept of arrival time and an arrival time series is shown in Figure 4-9. A nonzero rainday (a day when rain occurs) is represented by a shaded box, and a zero rainday is represented by a plain box. The arrival time is defined as the number of consecutive zero raindays, and is equal to zero for a nonzero rainday. An arrival time series is a sequence of arrival times. For the daily rainfall sequence shown in Figure 4-9, the arrival time series is 0, 1, 0, 0, 3, 0, 2, 0.

Analysis of arrival times from historical real daily rainfall data for Texas indicates that arrival times appear to be Poisson distributed (Lapin, 1973). In Figure 4-10, the y-axis is the relative frequency $f(t)$ and the x-axis is arrival time $t$ in days. The relationship between relative frequency and arrival time shown in Figure 4-6 can be described by
Daily Rainfall Sequence

![Daily Rainfall Sequence](image)

Arrival Time Series

| 0 | 1 | 0 | 0 | 3 | 0 | 2 | 0 |

- rainday, or nonzero rainday
- zero rainday

Figure 4-9 Definition of Arrival Time Series

\[ f(t) = e^{-\lambda t}, \quad (4-2) \]

where \( f(t) \) is relative frequency, \( \lambda \) is the mean rate of arrival time, and \( t \) is arrival time.

Another way to represent this information is by a cumulative distribution approach as shown in Figure 4-11. The y-axis is the cumulative frequency and the x-axis is arrival time \( t \) in days. This type of distribution is described by a cumulative arrival time function, which is

\[ P = 1 - e^{-\lambda t}, \quad (4-3) \]

\[ t = \frac{1}{\lambda} \ln(1 - P), \quad (4-4) \]

where \( P \) is the cumulative probability from 0 - 1; \( t \) is arrival time in days; and \( \lambda \) is the mean rate of arrival time, 1/day. One way to interpret this distribution is in terms of exceedance probabilities. Figure 4-11 shows the probability that the arrival time of the
Figure 4-10 Relative Frequency Function of Arrival Time

Figure 4-11 Empirical Cumulative Arrival Time Function
The next nonzero rainday being less than or equal to 70 is nearly 1 (very likely).

These cumulative arrival-time function (ECATF) parameters are generated for each station by the ECATFPG model (Appendix A4). That is, a set of arrival times with a set of corresponding numbers between 0 and 1 is obtained.

To sample from these distributions a randomly generated number between 0 and 1 is associated with a corresponding arrival time. For example, if the P value is 0.6, then the arrival time is 6 days. This inverse transformation is the idea used in the random arrival time module in the SRG model to generate arrival times sequences. The simulated arrival time series is generated by adding zero raindays and nonzero raindays so that total number of days in the arrival-time sequence is equal to the number of construction days.

The mean rate of arrival time is the reciprocal of mean arrival time. Therefore a larger mean rate of arrival time is equivalent to a short arrival time, or more frequent rain events. Figure 4-12 shows the calculated mean rates of arrival times for the 109 rainfall stations in Texas. The mean rates of arrival times are larger in the east of Texas as compared to that of western Texas. In another words, there are fewer days between rain events in the eastern part of Texas than that in the western part of Texas. The shortest mean arrival time is 3.5 days near the Texas-Louisiana border, and the longest is 14.2 days near Del Rio on the Texas-Mexico border.
Figure 4-12  GIS Map Showing the Mean Rates of Arrival Times in Texas
Individual behavior on nonzero rain days are modeled using a four-parameter equation (Bras, 1990 and Dampster, 1993) that can roughly mimic overall shape, rain duration, and total precipitation of historical rain events on a daily basis. An exact fit is not expected. The equation is based on the concept of convolution where individual unit inputs are integrated to produce an overall response. The S-curve method in hydrology is an example of convolution applied to runoff hydrographs.

Figure 4-13 shows the concept of convolution. Figure 4-13(a) shows the starting of a rain event as a diffuse step response function (eqn. (4-5)) with an ultimate value of $R_0$, $t_p$ is the time for rain event to reach this value. Figure 4-13(b) shows the ending of a rain event by as the inverse response of Figure 4-13(a) with a lag time of $\tau$ (eqn. (4-6)). Figure 4-13(c) is synthesized from the sum of Figure 4-13(a) and 4-13(b).

The symbols $r_1(t)$ and $r_2(t)$ represent two step-response function:

\[
 r_1(t) = \frac{R_0}{\sqrt{4\pi S_d t}} \exp\left(-\frac{(t_p - t)^2}{4S_d t}\right), \quad (4-5)
\]

\[
 r_2(t) = -r_1(t) \text{ with a lag time of } \tau. \quad (4-6)
\]

Let

\[
 F_1(t) = \int_0^t r_1(t^*)dt^*, \quad (4-7)
\]

\[
 F_2(t) = \int_0^{-\tau} r_2(t^*)dt^*, \quad (4-8)
\]

Then, we get

\[
 R(t) = F_1(t) + F_2(t). \quad (4-9)
\]
Figure 4-13 Graphic Representation of Convolution Equation
To find $F_1(t)$, we integrate

$$F_1(t) = \int_0^t r(t^*) dt^* = \int_0^t \frac{R_0}{\sqrt{4\pi S_d t^*}} \exp\left[-\frac{(t_p - t^*)^2}{4S_d t^*}\right] dt^* \quad (4-10)$$

Let

$$u = \frac{t_p - t^*}{2\sqrt{S_d t^*}},$$

$$\sqrt{t^*} = \sqrt{S_d u^2 + t_p - \sqrt{S_d u}}, \quad (4-11)$$

$$\frac{dt^*}{\sqrt{t^*}} = 2\frac{S_d u}{\sqrt{S_d u^2 + t_p}} - \sqrt{S_d} du. \quad (4-12)$$

Then, we have

$$F_1(t) = \int_{+\infty}^{t_p-t} \frac{R_0}{2\sqrt{\pi S_d}} \times \exp(-u^2) \times 2 \times \left(\frac{S_d u}{\sqrt{S_d u^2 + t_p}} - \sqrt{S_d}\right) du, \quad (4-13)$$

$$= -\frac{R_0}{2} \int_{+\infty}^{t_p-t} \frac{2}{\sqrt{\pi S_d}} \exp(-u^2) du + \int_{+\infty}^{t_p-t} \frac{R_0 S_d}{\sqrt{\pi S_d} \sqrt{S_d u^2 + t_p}} \exp(-u^2) du,$$

$$= \frac{R_0}{2} \text{erfc}\left(\frac{t_p - t}{2\sqrt{S_d t}}\right) + \frac{R_0}{\sqrt{\pi \sqrt{S_d}}} \exp(-u^2) S_d^2 \sqrt{S_d u^2 + t_p}, \quad (4-14)$$

Let

$$w = \frac{\sqrt{u^2 S_d + t_p}}{\sqrt{S_d}}. \quad (4-15)$$

Then, we have

$$F_1(t) = \frac{R_0}{2} \text{erfc}\left(\frac{t_p - t}{2\sqrt{S_d t}}\right) + \int_{+\infty}^{t_p-t} \frac{R_0}{\sqrt{\pi}} \exp(-w^2 + \frac{t_p}{S_d}) dw, \quad (4-15)$$
Similarly, $F_2(t)$ is
\[
F_2(t) \equiv \frac{R_0}{2} \left[ \text{erfc} \left( \frac{t_p - t}{2 \sqrt{S_d t}} \right) - \exp \left( \frac{t_p}{S_d} \right) \text{erfc} \left( \frac{t_p + t}{2 \sqrt{S_d t}} \right) \right].
\tag{4-17}
\]

From eqn. (4-9), we have
\[
R(t) = F_1(t) + F_2(t).
\]
Then, $R(t)$ is equal to
\[
R(t) = \frac{1}{2} R_0 \times \left\{ \left[ \text{erfc} \left( \frac{t_p - \tau}{2 \sqrt{S_d (t - \tau)}} \right) - \exp \left( \frac{t_p}{S_d} \right) \text{erfc} \left( \frac{t_p + \tau}{2 \sqrt{S_d (t - \tau)}} \right) \right] - \left[ \text{erfc} \left( \frac{t_p - (t - \tau)}{2 \sqrt{S_d (t - t)}} \right) - \exp \left( \frac{t_p}{S_d} \right) \text{erfc} \left( \frac{t_p + (t - \tau)}{2 \sqrt{S_d (t - t)}} \right) \right] \},
\tag{4-18}
\]

where $R$ is the predicted precipitation (in.), $t$ is the elapsed time (15-minute on a daily basis, or from 15 minutes to 1440 minutes) since the beginning of the rain day, and four rainday parameters are the following: $R_0$, peak rainfall amount (in.); $t_p$, historical time to peak; $\tau$, rain duration; and $R_d$, rain dispersion coefficient.

The four rainday parameters in this model are found by minimizing the sum of squared differences between the observed and modeled rainfall values. This minimization is performed using a constrained Quasi-Newton method (Press, 1986) with the criterion that total volume of rainfall is preserved in the model. Figure 4-14 shows the results of this model approach for three different cases. The y-axis is the amount of precipitation.
inches, and the x-axis is time in minutes. As the complexity of the rainfall pattern increases in one day (From Figure 4-14(a) to 4-14(c)), the model loses the ability to simulate the real rainfall intensity, but total volume, overall shape, and rain duration are preserved. This rainday model to calculate 15-minute rainfall data from four rainday parameters is the parametric based option for generating 15-minute rainfall data in the SRG model.

Figure 4-15 shows that one benefit from data reduction is the space needed to store data in a computer is significantly reduced. For daily data, there is a reduction of the file size by a factor of 30. For 15-minute data, there is a reduction of the file size by a factor of
Figure 4-14(b) 15-minute Model vs. Real Data

Figure 4-14(c) 15-minute Model vs. Real Data
10. So after the parametric analysis, daily data files for all stations in Texas can be stored on one floppy disk. Similarly, 15-minute data all for stations around Houston can be stored on one high-density floppy disk.

![Diagram of storage space comparison](image)

**D.R.D. Treatment**

- For each station
- Real Data: 100 KB
- Model Data: 3 KB

**F.R.D. Treatment**

- For each station
- Real Data: 400 KB
- Model Data: 40 KB

Texas: from 10 to 0.3 MB

Houston: from 8 to 0.8 MB

Figure 4-15 Comparison of Storage Space for Model and Real Data

D.R.D.: daily rainfall data; F.R.D.: 15-minute rainfall data

4.3. SRG Model Interface Design

The SRG model operates on the data developed in the previous two steps. Figure 4-16 shows the flow chart of SRG model to use the 15-minute model data.

The user supplied data required for the SRG model is entered through the interface (the upper central box). These data are: number of construction days, distances from construction sites to selected stations, and station identification numbers of those...
stations. Station ID numbers are used by the SRG model to find corresponding daily and 15-minute parameter data files from the database. The model accesses these data to construct a rainfall sequence for the highway construction site being studied.

The computational sequence in the SRG model is (Figure 4-16):

1) The main module (the central upper 3-D box) will first call the random arrival time (RAT) module (the middle left 3-D box). The RAT module will read the ECATF parameters from the corresponding ECATF parameter data file (the upper left box), create a series of random numbers between zero and one according to the number of construction days; and then, generate an arrival time series (the lower left box) for each station identified in the input.

2) For those days in the generated arrival time series that are identified as raindays, the main module will call the random rainday (RRD) module (the middle right 3-D box). The RRD module will randomly select four rainday parameters from the 15-minute parameter data files (the upper right box), and produce 15-minute rainday sequence (the lower right box) from the convolution equation.

3) Finally, the main module will call the inverse distance (DIST) module (the central lower 3-D box) to generate the 15-minute rainfall sequence (the lower central box) for the construction site by combining the 15-minute rainfall sequences from the three used identified stations.
Most of the computational functionality and database information in the SRG model is coded in FORTRAN. A Visual Basic Interface is constructed to simplify the use of the SRG model. Figure 4-17 shows the relationship among user, interface and the SRG model. Instead of creating an input file and running the SRG model directly, the user (the left box) inputs the required site specific information and executes the SRG model calculations (the right box) through several labeled information boxes and command buttons on the interface (the central box).

Figure 4-18 shows the structure of the Visual Basic Interface. The main module (the left box) is used for information input and program control. From the main module, three
functions are available. The input file creation function (the right upper box) is used to create the input file for the SRG model calculations. The help function (the right central box) is available to assist the model user. The graphics function (the right lower box) is used to generate a plot of 15-minute rainfall sequence for the user to inspect.

Figure 4-18  Flow Chart of the SRG Model Interface

Figure 4-19 shows the SRG model Interface. A user enters required data in the nine boxes. The interface program checks the validity of input information, and performs calculations based upon the user’s choice of the parametric or the bootstrapping method. A user can also generate a plot of 15-minute rainfall sequence and get help using the SRG model.
Figure 4-19  SRG model Interface
Figure 4-20 shows a typical 15-minute rainfall sequence from the SRG model. The number of construction days is equal to 20. The y-axis is the amount of precipitation in inches, and the x-axis is the time in days. From these rainfall sequence diagrams, possible occurrence of rain events, rain intensity and volume of rain precipitation can be estimated.
Chapter 5 Bootstrapping Method

Bootstrapping is a generic name used to describe the process of resampling historical data. It differs from the SRG model (a parametric approach) in that it models the characteristics of a population strictly from the sample at hand, rather than by making assumptions (possibly unrealistic) about the population, distribution equations, and descriptive parameters.

At the beginning of this research, the primary concern about using bootstrapping was how to effectively resample from a huge data set. In particular, there were 10 to 50 years of historical daily and 15-minute rainfall records from the 109 rainfall stations, with a total number of rainfall data points exceeding 10 million. As many as 10% of the records were missing or irregularly formatted. The parametric SRG model was created to learn how to manage a large data set and treat missing or bad records, and change them to useable format. Once the SRG model was constructed, the bootstrapping method to resample real data was designed.

Figures 5-1(a-c) illustrate that the model preserves the overall duration, overall shape and total amount of precipitation, and does not preserve peak intensity. Alternatively, if preservation of peak intensity is emphasized, then it is impossible for any smooth and continuous curve to preserve overall duration, overall shape, and total amount of precipitation. Jilani (1997) and Liu (1997) suggest that intensity is more important than total amount of precipitation in predicting erosion. To preserve precipitation intensity
Figure 5-1(a) 15-minute Model vs. Real Data

Figure 5-1(b) 15-minute Model vs. Real Data
information, the bootstrapping method was designed and added to the model as an alternative way to generate rainfall sequences.

The bootstrapping method in this thesis selects raindays during a construction using the empirical cumulative arrival time distributions in the first step. Then the rainday behavior is modeled by selecting a historical day from the database and using the rainfall data for that day. Seasonal effects, wet/dry year effects are ignored in this method.

The computational sequence for the bootstrapping method is illustrated in Figure 5-2. The procedures is nearly identical to the parametric SRG model except for how the
rainday 15-minute precipitation values are computed.

Figure 5-2  Flow Chart of the Bootstrapping Method

The sequence of computations is

1) The main module (the central upper 3-D box) will first call the random arrival time (RAT) module (the middle left 3-D box). For each station, the RAT module reads the ECATF parameters from the corresponding ECATF parameter data file (the upper left box). Then the RAT module generates a random number between 0 and 1, and identifies the corresponding arrival time according to ECATF parameter. The RAT module repeats these steps in order to form an arrival time series (the lower left box) in which the total number of
raindays and zero raindays is equal to the number of construction days. Three simulated arrival time series (one for each station) are sent back to the main module.

2) The main module analyzes the simulated arrival time series created from the RAT module. For each rainday in the generated arrival time series, the main module will call the random rainday (RRD) module (the middle right 3-D box). The RRD module will generate a random number between 1 and the total number of 15-minute data sets for a particular station (One data set stores 96 15-minute rainfall data points for one rainday.). The module then selects the corresponding rainday from 15-minute data files (the upper right box), and reads 96 rainfall data values for that rainday (the lower right box). These rainfall data values for each rainday are returned to the main module. For each zero rainday, the main module will assign 96 zero values. The main module joins these zero and nonzero precipitation data points together on a 15-minute basis to form three rainfall sequences (one for each station) according to the order of generated arrival time series from the RAT module.

3) Finally, the main module will call the inverse distance (DIST) module (the central lower 3-D box). The DIST module will take three real rainfall data values of the same time from the three different sequences (one rainfall data value from each sequence) and calculate the rainfall data value of highway construction site from these three data values by the inverse distance
algorithm (eqn. (4-1)). Then the DIST module will join the generated rainfall data values for highway construction site one by one and form 15-minute rainfall sequence (the lower central box) for the construction site.

To illustrate the procedure of the bootstrapping method with an example, the assumed highway construction site HCS_1 near Austin is used (Figure 5-3). The required information to use the bootstrapping method is entered through the Visual Basic Interface (Figure 4-19): the number of construction days is set to be equal to 20; three stations used to perform rainfall generation for HCS_1 are 0428, 8531, and 9815; distances from HCS_1 to these three stations are 15, 18, and 25 miles, respectively.

![GIS Map Showing HCS_1 near Austin](image)

Figure 5-3  GIS Map Showing HCS_1 near Austin
Figure 5-4 shows a 15-minute rainfall sequence for the assumed highway construction site HCS_1. The y-axis is the amount of precipitation in inches, and the x-axis is the time in days.

In principle this bootstrapping method will preserve historical rainfall intensity. The pattern of Figure 5-4 is identical to that of Figure 4-20, but the intensities are greater. In fact the values in Figure 4-20 cannot even be measured using standard rain gages.
Chapter 6 Model Test

The parametric SRG model presented in Chapter 3 and 4 was tested by asking the following questions: 1) What is the effect of the number of construction days and the number of repeats on SRG model’s mean value of precipitation? 2) Is the parametric model sequence distinguishable from a rainfall sequence generated by the bootstrapping method (real rainfall sequence)? 3) If the answer to the second question is yes, then, will the model and real rainfall sequences produce the same amount of soil loss using the soil production model (Jilani, 1997)?

6.1 Introduction

Three assumed highway construction sites near Austin, Houston and Lubbock are selected to test the SRG model. Table 6-1 shows location information for these three sites. Figures 6-1(a), (b) and (c) show location of these sites (solid triangle enclosed by solid circle) along with selected rainfall stations for 15-minute rainfall sequence

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<th>Latitude</th>
<th>Longitude</th>
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<td>HCS_1</td>
<td>30.33</td>
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</tr>
<tr>
<td>HOUSTON No.1</td>
<td>HCS_2</td>
<td>29.83</td>
<td>95.50</td>
</tr>
<tr>
<td>LUBBOCK No.1</td>
<td>HCS_3</td>
<td>33.83</td>
<td>101.17</td>
</tr>
</tbody>
</table>
Figure 6-1(a) GIS Map Showing HCS_1 near Austin

Figure 6-1(b) GIS Map Showing HCS_2 near Houston
Figure 6-1(c) GIS Map Showing HCS_3 near Lubbock

generation (cross flag enclosed by dashed circle) on the GIS map. Also the distances from HCS to selected rainfall stations are shown on the map.

To perform a statistical test, two commonly used statistical parameters, mean and variance, will be used throughout the model test procedure. The mean is the arithmetic average of a set of data, which is defined as

\[
\mu = \frac{\sum x_i}{n},
\]  

(5-1)

where \( \mu \) is the mean value, \( x_i \) is the sample data, \( n \) is number of data points. The variance is used to define the width (spread) or variability around a central value, and is determined by

\[
s^2 = \frac{\sum (x_i - \mu)^2}{n}.
\]  

(5-2)
where $s^2$ is the variance, $x_i$ is the sample data, $\mu$ is the mean or mean value, and $n$ is number of data points.

6.2 Model Testing for the Effect on Number of Construction Days and Number of Repeats

The purpose of the first test is to determine whether the number of construction days (NCD) and number of repeated runs (NR) of the SRG model will affect the mean values of precipitation for parametrically generated rainfall sequences. The numbers of construction days used are 10, 20, 30, 60, 90 and 120, and the number of repeats are 10, 20, 30, 40, 50, and 60.

The assumed highway construction site HCS_1 and three surrounding rainfall stations are selected for this test (Figure 6-1(a)). For each NCD, a number of model rainfall sequences are generated according to NR by the SRG model. For example, if NR equals to 10, then ten sets of rainfall sequences are generated, or the SRG model is run ten times. Then the average value for each time unit (15-minute) from these rainfall sequences is computed one by one. Then these average values are connected together in the same order in time, forming the parametrically generated rainfall sequence for that NR. Table 6-2 shows the mean and variance of precipitation for the statistically generated model rainfall sequences for different NCD and NR combinations.

Figure 6-2 shows the mean values of precipitation for the parametrically generated model rainfall sequences from different NCD and NR. This figure shows that for values
of NCD less than 60 days, there is large fluctuation among mean values for different numbers of repeats. For each proposed NCD, the variances for the mean values of precipitation from different NR are calculated and are shown in Table 6-3. The variances for mean values of precipitation decrease steadily with increasing NCD. For any NCD equal to or larger than 60 days, the variances are in the order of $10^{-10}$. The reasons for this result are: 1) As sample size increases (NCD becomes larger), the mean of sample approaches the mean of population; 2) Analysis of the arrival times for rainfall events in Texas shows that maximum arrival time is around 60 days. Therefore, to run the SRG model, the NCD equal to or larger than 60 are needed so that all the probabilities of arrival times will be considered in the modeling process.

For values of NCD equal to and larger than 60, the variances of the mean values of precipitation for NR equal to 10, 20, 30, 40, 50 and 60 are calculated and shown in Table 6-4. In Figure 6-2 and Table 6-4, there exists no clear trend of variance change, and the difference in variances is within three times except for NR equal to 10. Therefore a value of NR equal to or larger than 20 is suggested to run the SRG model to get the mean value of precipitation for statistically generated rainfall sequences. The total volume of precipitation expected during a construction period can be calculated by multiplying the mean values of precipitation by duration.

Table 6-2  Result from Different NCD and NR
<table>
<thead>
<tr>
<th>Number of Construction Days</th>
<th>Number of Data</th>
<th>Number of repeats</th>
<th>Mean (in.) for Model Data</th>
<th>Variance for Model Data</th>
<th>Mean (in.) for Real Data</th>
<th>Variance for Real Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>960</td>
<td>10</td>
<td>6.16E-04</td>
<td>1.11E-06</td>
<td>4.99E-04</td>
<td>4.58E-06</td>
</tr>
<tr>
<td>20</td>
<td>1920</td>
<td>10</td>
<td>7.98E-04</td>
<td>3.04E-07</td>
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<td>2.08E-06</td>
</tr>
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<td>10</td>
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<td>2.94E-07</td>
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<td>2.31E-06</td>
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<td>3.56E-07</td>
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<td>2.15E-06</td>
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<td>6.02E-04</td>
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<td>1200</td>
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</table>
Figure 6-2  Mean Value vs. Number of Repeat

Table 6-3  Variance of Mean Values of Precipitation from Each Proposed NCD

<table>
<thead>
<tr>
<th>NCD</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2E-08</td>
<td>2.6E-09</td>
<td>4.9E-09</td>
<td>7.7E-10</td>
<td>2.2E-10</td>
<td>1.7E-10</td>
</tr>
</tbody>
</table>

Table 6-4  Variance of Mean Values from Each Proposed NR

<table>
<thead>
<tr>
<th>Number of Repeats</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance of Mean Value of Precipitation</td>
<td>7.2E-10</td>
<td>1.3E-10</td>
<td>8.6E-11</td>
<td>1.1E-10</td>
<td>6.9E-11</td>
<td>1.5E-10</td>
</tr>
</tbody>
</table>
6.3 Model Testing for Model and Real Sequences

The purpose of the second test is to determine if the model rainfall sequence is distinguishable from the real rainfall sequence generated from the bootstrapping method.

A value of NCD equal to 60 is used as input.

From Table 6-2, the variances of precipitation for the model and real rainfall sequences are quite different, and that is because an exact fit of the 15-minute real and model data on daily basis is not expected. As shown in Figure 4-14, though the model sequence preserves the overall shape and total volume of the real sequence, it produces a continuous and uniform curve for the discontinuous and spike-like real sequence on each day. Therefore the variance, which indicates the width or variability around a central value, is decreased for the model sequence.

An unequal t-test (Blaisdell, 1992) is used to test whether real and model rainfall sequences have the same mean values of precipitation. This test method is used to test whether two populations have the same mean values when their variances are different.

1. Assumptions for the test are as follows:
   a) independent random samples,
   b) each population has a normal distribution.

2. Hypothesis and test statistics are as follows:
   a) The null hypothesis (H₀) is

\[
H₀: (µ₁-µ₂) = 0,
\]  

(6-3)
where \( \mu_1 \) is the mean of precipitation for the model rainfall sequence, and \( \mu_2 \) is the mean of precipitation for the real rainfall sequence.

b) The test statistic for \( H_0 \) is

\[
t = \frac{(\mu_1 - \mu_2) - \theta}{\sqrt{s_1^2/n_1 + s_2^2/n_2}}, \tag{6-4}
\]

where \( t \) is the t-test value or t value, \( s_1^2 \) is the variance of precipitation for the model sequence, \( s_2^2 \) is the variance of precipitation for the real sequence, \( n_1 \) is the number of data points for the model rainfall sequence, and \( n_2 \) is the number of data points for the real rainfall sequence.

c) Alternative hypothesis is given by

\[
H_\alpha: (\mu_1 - \mu_2) \neq 0, \tag{6-5}
\]

where the mean of precipitation for the model rainfall sequence is not the same as that of the real rainfall sequence. The rejection region for \( H_0 \) is defined as \( t < -t_\alpha/2 \) or \( t > t_\alpha/2 \). In other words, when \( t < -t_\alpha/2 \) or \( t > t_\alpha/2 \), \( H_\alpha \) is accepted, and \( H_0 \) is rejected.

d) The degrees of freedom of the t-distribution are given by

\[
df = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}, \tag{6-6}
\]

where \( df \) is the value of the degrees of freedom, and is rounded down to the nearest integer to make a more conservative approach.

3. The test procedure is as follows:
a) Significance level is set to be 0.1.

b) The t values are calculated.

Table 6-5 shows the values of the t-test and degrees of freedom (df) for nine cases from three assumed highway construction sites. The t values vary from 0.000 to 0.354.

c) Conclusion

From a statistical table (Daniel and Terrell, 1978), for percentiles of the t distribution, \( t_{\alpha/2} (t_{0.05}) = 1.645 \), so \( t < t_{\alpha/2} \).

The null hypothesis is accepted since \( t = 0.000 \) to 0.354 does not lie in the rejection region. Thus, with \( \alpha = 0.1 \), there is sufficient evidence to conclude that the means of precipitation for the model and real data are equal.

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Trial Number</th>
<th>Mean (in.) for Model Data</th>
<th>Variance for Model Data</th>
<th>Mean (in.) for Real Data</th>
<th>Variance for Real Data</th>
<th>t value</th>
<th>df value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCS_1</td>
<td>1</td>
<td>9.13E-04</td>
<td>1.06E-05</td>
<td>9.12E-04</td>
<td>4.45E-05</td>
<td>0.010</td>
<td>8355</td>
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<tr>
<td></td>
<td>2</td>
<td>6.64E-04</td>
<td>1.10E-05</td>
<td>6.63E-04</td>
<td>9.90E-05</td>
<td>0.007</td>
<td>7023</td>
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<tr>
<td></td>
<td>3</td>
<td>3.35E-04</td>
<td>2.29E-06</td>
<td>3.35E-04</td>
<td>1.48E-05</td>
<td>0.000</td>
<td>7500</td>
</tr>
<tr>
<td>HCS_2</td>
<td>1</td>
<td>7.99E-04</td>
<td>7.15E-06</td>
<td>7.57E-04</td>
<td>7.88E-05</td>
<td>0.344</td>
<td>6796</td>
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<tr>
<td></td>
<td>2</td>
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<td>4.13E-05</td>
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<td>2.02E-05</td>
<td>4.86E-04</td>
<td>3.72E-05</td>
<td>0.000</td>
<td>10589</td>
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<tr>
<td>HCS_3</td>
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<td>1.12E-04</td>
<td>1.59E-06</td>
<td>1.12E-04</td>
<td>4.31E-06</td>
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<tr>
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<td>1.97E-05</td>
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<td>3</td>
<td>2.75E-04</td>
<td>8.49E-06</td>
<td>2.74E-04</td>
<td>1.61E-05</td>
<td>0.015</td>
<td>10511</td>
</tr>
</tbody>
</table>

6.4 Model Testing Using VISIOSED Model
The soil production model VISIOSED designed by Jilani (1997) is used to test whether the soil production from the model and real rainfall sequences are identical.

This VISIOSED model is developed from the Universal Soil Loss Equation (USLE) and calculates the mass of sediment leaving a highway construction site depending on the rainfall intensity, land slope, type of soil, type of control practice, and type of vegetation cover used to control erosion.

The field constraints entered for this model are as follows:

- Temporary sediment controls (TCS): rock filter dam vs. silt fence
- Soil type: silty clay/clay with organic contents equal to 0.5%
- Type of cover: seeding after 60 days
- Length from the point of origin of overland flow to the point where the runoff enters a defined channel: 5280 ft (1 mile)
- Average overland slope from the point of origin of overland flow to the point where the runoff enters a defined channel: 0.01
- Construction area: 2560 acres (4 sq. mile)

Six paired model and real rainfall sequences from trial number 1 and 2 in Table 6-5 for each assumed highway construction sites (HCS_1, HCS_2, and HCS_3) are used as input data for the VISIOSED model. The result is shown in Table 6-6. A statistical test is performed to see whether these six paired model and real rainfall sequences produce identical soil production in statistical sense.
Table 6-6  Soil Production from Model and Real Sequences

<table>
<thead>
<tr>
<th>TSC Type</th>
<th>Site ID</th>
<th>Soil Production from Model Rainfall Sequence (kg)</th>
<th>Soil Production from Real Rainfall Sequence (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock Filter Dam</td>
<td>HCS_1</td>
<td>243</td>
<td>243</td>
</tr>
<tr>
<td></td>
<td>HCS_2</td>
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<td></td>
<td>HCS_3</td>
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<td>55</td>
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<tr>
<td>Silt Fence</td>
<td>HCS_1</td>
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<td>399</td>
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<tr>
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<td>HCS_2</td>
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<tr>
<td></td>
<td>HCS_3</td>
<td>90</td>
<td>90</td>
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</tbody>
</table>

The same unequal t-test is performed here as the one performed in Section 6.3, except that the null hypothesis here shows the mean of soil production from six model rainfall sequences to be the same as that from six real rainfall sequences ($H_0$: $\mu_1 - \mu_2 = 0$).

The result of this test is shown in Table 6-7. From statistical table (Daniel and Terrell, 1978), for percentiles of the t distribution, $t_{\alpha/2} (t_{0.05}) = 1.645$. The null hypothesis is accepted since $t = 0.549 (< t_{\alpha/2} = 1.645)$ does not lie in the rejection region. Thus, with $\alpha = 0.1$, there is sufficient evidence to conclude that the means of soil production from the model and the real sequences are equal.

Table 6-7  Statistical Test for Soil Production

<table>
<thead>
<tr>
<th>Mean from Model Data</th>
<th>Mean from Real Data</th>
<th>Variance from Model Data</th>
<th>Variance from Real Data</th>
<th>t value</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>365</td>
<td>295</td>
<td>53206</td>
<td>43659</td>
<td>0.549</td>
<td>9</td>
</tr>
</tbody>
</table>
6.5 Conclusions from Model Tests

The first model test (Section 6.2) shows that to have a valid mean of precipitation from the SRG model, number of construction days equal to or larger than 60 and number of repeats equal to or larger than 20 are desired. The number of repeats does not show any obvious effect on the result of the SRG model except that it needs to be equal to or larger than 20 to avoid the system error problem in statistical sense.

Based on nine cases from three sites in Texas, rainfall sequences generated from the SRG model and bootstrapping method can not be distinguished from each other by their mean values for a significance level equal of 0.1. Based on six cases from three sites in Texas, the soil productions predicted by rainfall sequences generated from the SRG model and bootstrapping method are also identical to each other for a significance level equal of 0.1.
Chapter 7 Summary and Conclusions

The literature review led to the conclusion that, even though a number of models were developed to simulate rainfall, they are complicated, and difficult to use. There is no specific synthetic rainfall generation model using historical rainfall data for highway construction activities in Texas.

To evaluate the impact of the Storm Water Pollution Prevention Plans on highway construction activities, a simple-to-use rainfall generation model (the SRG model) is constructed to generate a 15-minute rainfall sequence, that can be used to evaluate the soil production and contaminant production associated with highway construction.

The Geographic Information System is used to construct a map of Texas showing all the available rainfall stations. Proposed highway construction sites can be placed on this map, and distances between highway construction sites and selected rainfall stations can be easily found. A Poisson distribution model is found to describe arrival-time distributions very well for raingage stations in Texas. A simulated arrival-time series is generated based upon this Poisson model. A convolution equation is used to generate 15-minute rainfall sequences based on four rainday parameters that preserve total precipitation amount, overall shape, and rain duration of historical data. As the duration and complexity of the historical rainfall patterns on each day increase, the fit between the model and real data deteriorates. This procedure of changing real data to model parameter data saves significant storage space in computer. For daily data, there is a
reduction of the data file size by a factor of 30. For 15-minute data, there is a reduction of the data file size by a factor of 10. An inverse distance algorithm is used to combine rainfall sequences from three nearby rainfall stations to generate the rainfall sequence for highway construction sites. A user-friendly interface is built for the SRG model so that user can easily perform data input, calculation and viewing of 15-minute rainfall sequence.

A bootstrapping method was designed to generate 15-minute rainfall sequence by resampling real 15-minute rainfall data. This option can be executed from the SRG model interface and used to faithfully produce information on intensity from historical rainfall events.

Parametrically generated rainfall sequences from three assumed highway construction sites are used to compare the effect of the number of construction days and of the number of repeats to run the SRG model on the mean values of precipitation. It is found that number of construction days equal to or larger than 60 and number of repeats equal to or larger than 20 will generate 15-minute rainfall sequences that have good statistical stability of the mean values of precipitation during a construction period.

The mean values of precipitation for rainfall sequences generated from the SRG model and bootstrapping method are indistinguishable from each other when the significance level equals 0.1. The soil productions predicted by rainfall sequences generated from the SRG model and bootstrapping method are identical for a significance level of 0.1.
References


Jilani, Nooreen (1997) *A Rainfall-soil Loss Model for Application to Highway Construction Sites*, Master’s Thesis, Department of Civil and Environmental Engineering, University of Houston, Houston, TX.


A1. Selected 109 Rainfall Stations for SRG Model in Texas

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A1. Selected 109 Rainfall Stations for SRG Model in Texas (Cont’d)

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A2. Distance Finding

To illustrate the steps a user applies to locate a station, assuming that a highway construction site the west of Austin. Let the site be named AUSTIN #1. Its site ID will be HCS_1.

A2.1. Construct location information and site location file.

i) Create a GIS file to work with

1) Start the GIS.

2) Choose FILE|OPEN to activate the Open Dialog box.

3) In the Drives list box, choose the drive that contains the directories of the GIS files for the SRG model. Typically, drive C:.

4) In Directories list box, choose the directory that contains GIS map files for the SRG model.

5) In the File Name list box, choose the map.prj project file. By default, the Files of Type list box displays the ‘Project (*.prj, *.map)’ option.

6) Click OK from the menu options.

7) Choose FILE|SAVE AS to save this map.prj as another project file that you will work with in the same target directory. For example, save map.prj as AUSTIN.PRJ.

ii) Locate the construction site and create the site location file

1) Start the Microsoft Excel™ computer program.

2) Choose File|Save As to save this site.xls as another Microsoft Excel file in the same target directory in Microsoft EXCEL version 3.0 format. For example, save site.xls as HCS_1.xls.
3) Arrange the windows for the GIS and Microsoft Excel as shown on next page.

4) Move the pointer to the proposed highway construction site and read the longitude and latitude information from the lower right corner of the GIS window (labeled as “Lon” and “Lat”, respectively).

4) Enter the following information into the Microsoft Excel spreadsheet: name of the construction site (“AUSTIN #1” under “SITE_NAME”), site ID (“HCS_1” under “SITE_ID”), whole degree portion of longitude (“30” under “LON_DEG”), fractional portion of longitude in minutes (“20” under “LON_MIN”), whole degree portion of latitude (“97” under “LAT_DEG”), and fractional portion of latitude in minutes (“55” under “LAT_MIN”). The number under the labels “LON” and “LAT” will be calculated by the EXCEL automatically.

5) Save site.xls again in Microsoft EXCEL version 3.0 format and close this file.

Once this last step is completed, the GIS can be used to calculate distances from highway construction site to the rainfall stations.

A2.2 Finding distances in the GIS

i) Import the site location file

1) From the GIS window, choose FILE|OPEN to activate the Open dialog box.

2) In List of Files Type box, choose Excel (*.xls).

3) In the File Name list box, choose the ‘HCS_1.XLS’ Excel file.

4) Click OK from the menu options.

5) In the ‘Table Import’ dialog box, change the imported name to the table name you want. (The table created for HCS_1.XLS in the GIS format is named as
HCS_1.DBF by default.) For example, change this name to ‘HCS_1.DBF’ and choose OK from the options menu.

6) In the ‘Spreadsheet Options’ dialog box, choose OK.

7) In the Table Link dialog box:
   a) In the ‘Table Type’ menu options on the left, choose ‘Contains Points’.
   b) In the Layer Name box, enter the layer name you want for this construction site. For example, HCS_1.
   c) In the ‘Key Column’ list box, select the ‘STATION_ID’ as key column.
   d) In the ‘Longitude or X’ list box, select ‘LON’.
   e) In the ‘latitude or Y’ list box, select ‘LAT’.
   f) In the ‘Values Are’ list box, select ‘LL’.
   g) Choose OK from the options remaining in the menu.
   h) In the ‘Open’ dialog box which should state ‘File projection does not match current working set. Change file projection?’, choose OK.
   i) In the ‘Open’ dialog box which reads ‘One or more index files are missing. OK to build index files?’, choose OK.

ii) Turn on the label of the construction site

   1) Click on the right button of the mouse on the map to pop up the ‘Layers and Themes’ dialog box.
   2) In the ‘Layers’ box on the top, click ‘Label | On’ switch on the last layer, which has the ‘Order’ of ‘7’ and has the name you previously selected. This label was ‘No’ before, it should be ‘Yes’ after this step.
3) Choose the ‘Labels’ option on the left bottom of the layer of this ‘Layers and Themes’ dialog box.

4) In the ‘Label Expression’ part, click on the ‘…’ button at the end of the ‘Line 1’ text box. The ‘Expression Builder’ dialog box is then active.

5) In the ‘Columns’ list box, choose STATION_ID.

6) Choose OK on this last box and also on the ‘Layers and Themes’ dialog box.

iii) View the construction site and select three nearby stations

1) Choose ‘Zoom Out’ tool on the Tool bar.

2) Place the ‘Zoom Out’ tool on the construction site location, and select (by clicking the mouse button) the location.

3) Repeat step 2 as needed to give a detailed view of the construction site and nearly rain gage stations. The H.C.S. is marked by a solid triangle and its ID.

4) Choose the three nearest stations. For HCS_1, stations 0428, 8531 and 9815 are selected (See the Figure on next page).

iv) Calculate distances using the “Calculate Column” option.

1) Select the construction site. A solid square will mark the construction site.

2) Click on WINDOW\NEW TABLE WINDOW to activate the ‘Window Layer’ list box.

3) Choose STATIONS:station, and click OK.

4) In the Table called STATIONS:station, click on the three stations which will be used to generate the synthetic rainfall data for the construction site. The first station is selected by clicking the mouse button, the second and third stations are selected by clicking the mouse button while pressing the Shift
key.
5) Choose TABLE | CALCULATE COLUMN to activate the Calculate Column dialog box.

6) In the Table list box, choose STATION:stations.

7) In the Column to Fill dialog box, choose DISTANCE, which is the column to be filled with the calculated distances.

8) Click on the Distance to Selected Feature option button. This button is dimmed if there are no open layers with exactly one feature selected.

9) In the Layer list box, choose the layer that contains the single, selected map feature.

10) In the Rows group box, check the Selected Rows Only box.

11) Choose OK.

12) Look at the table and record the corresponding distances from the highway construction site to the rainfall stations.

The Figure on Page 71 shows the result of these steps applied to a highway construction site near Austin. The assumed highway construction site HCS_1 is marked by an solid triangle and encircled by an dashed circle and three selected rainfall stations are marked by cross flags and encircled by solid circles. The distances from HCS_1 to these stations are found to be 13, 18 and 25 miles respectively.
A3. SRG Model Calculation Source Code And Input/Output Files

A3.1 SRG model (parametric method) FORTRAN source code

A3.1.1 main.for

C SYNTHETIC RAINFALL GENERATION (SRG) MODEL
C MAIN.FOR
C CONTROL PROGRAM

C SOME ABBREVIATION USED:
C H.C.S.: HIGHWAY CONSTRUCTION SITE
C N.C.D.: NUMBER
C ECATF: EMPIRICAL CUMULATIVE ARRIVAL TIME FUNCTION
C DPD: DAILY PARAMETER DATA
C FPD: 15-MINUTE PARAMETER DATA

C DECLARE VARIABLES
C NCD: NUMBER OF CONSTRUCTION DAYS
INTEGER NCD
C INDEX_NCD: INDEX FOR HOW MANY NCD HAS BEEN CALCULATED
INTEGER INDEX_NCD
C FLAG_STATION: INDEX FOR THE STATION BEING PROCESSED
INTEGER FLAG_STATION
C ARR_TIME: SIMULATED ARRIVAL TIME SERIES
INTEGER ARR_TIME (1:5)
C FMRS_STTN: 15-MIN RAINFALL SEQUENCE AT STATIONS
REAL FMRS_STTN(1:3, 1:2000, 1:100)
C FMRS_SITE: 15-MINUTE RAINFALL SEQUENCE AT H.C.S.
REAL FMRS_SITE(1:2000, 1:100)
C RAIN_MODEL: 15-MIN RAINFALL MODEL DATA
REAL RAIN_MODEL(1:3, 1:100)

C COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ ARR_TIME
COMMON /COM_3/ RAIN_MODEL
COMMON /COM_7/ FMRS_STTN
COMMON /COM_8/ FMRS_SITE
COMMON /COM_10/ FLAG_STATION
COMMON /COM_11/ NCD

C CALL FILEIO.FOR TO GET FPD AND HPD DATA
CALL FILEIO

C A SCREEN MEMO FOR USER
WRITE (*,*) 'Program is Running, Please wait.'

C CALL ECATF.FOR TO GET ECATF PARAMETERS FOR STATIONS
CALL ECATF

C THIS CALL IS REQUIRED FOR RANDOM NUMBER GENERATOR
CALL GET_SEED

C LOOP THROUGH THREE SELECTED STATIONS
DO 3000, N = 1, 3
FLAG_STATION = N

C GET FIRST SIMULATED ARRIVAL TIME FOR RAINFALL STATIONS
CALL RAT

C IF NO RAIN IN THE WHOLE N.C.D TIME
C ARRVAL TIME > N.C.D. CASE, THEN NO RAIN
IF (ARR_TIME(N) .GE. NCD) THEN
  DO I = 1, NCD
  DO J = 1, 96
    FMRS_STTN(N, I, J) = 0.00
  END DO
  DAY = I
  END DO
  INDEX_NCD = NCD
  GOTO 3000
ELSE
  INDEX_NCD = 1
  GOTO 2200
END IF

C IF THERE ARE RAINS DURING N.C.D.
INDEX_NCD = 1
2000 IF (INDEX_NCD .LE. NCD) THEN
  GOTO 2100
ELSE
  GOTO 3000
END IF

C CALL RAT.FOR TO GET MORE GENERATED ARRIVAL TIMES
2100 CALL RAT

C IF NO RAIN DURING FURTHER DAYS
C CUMULATIVE SIMULATED ARRIVAL TIMES > N.C.D. CASE
2200 IF (ARR_TIME(N) .GE. (NCD - INDEX_NCD + 1)) THEN
  DO I = INDEX_NCD, NCD
  DO J = 1, 96
    FMRS_STTN(N, I, J) = 0.00
  END DO
  DAY = I
  END DO
  GOTO 3000
END IF

C WHEN NO RAIN FOR THESE DAYS
C ARRIVAL TIME < N.C.D. CASE AND <> 0
IF ( ( ARR_TIME(N) .LT. (NCD - INDEX_NCD + 1))
+ .AND. (ARR_TIME(N) .NE. 0) ) THEN
  DO I = INDEX_NCD, INDEX_NCD + ARR_TIME(N) - 1
  DO J = 1, 96
    FMRS_STTN(N, I, J) = 0.00
  END DO
  DAY = I
  END DO
INDEX_NCD = INDEX_NCD + ARR_TIME(N)
C CALL RRD.FOR TO RANDOMLY GENERATE MODEL RAINFALL DATA
CALL RRD
DO J = 1, 96
  FMRS_STTN(N, INDEX_NCD, J) =
RAIN_MODEL(FLAG_STATION, J)
END DO
DAY = INDEX_NCD
INDEX_NCD = INDEX_NCD + 1
GOTO 2000
END IF

C ARRIVAL TIME < NCD CASE AND ARRIVAL TIME = 0
IF ( ( ARR_TIME(N) .LT. (NCD - INDEX_NCD + 1))
+ .AND. (ARR_TIME(N) .EQ. 0) ) THEN
CALL RRD
DO J = 1, 96
FMRS_STTN(N, INDEX_NCD, J)
+ = RAIN_MODEL(FLAG_STATION, J)
END DO
DAY = INDEX_NCD
INDEX_NCD = INDEX_NCD + 1
GOTO 2000
END IF

3000 CONTINUE

C GET 15-MIN RAINFALL SEQUENCE FOR H.C.S.
CALL DIST

C OUTPUT OF SRG MODEL
WRITE (100, *) ' '
WRITE (100, *) ' '
WRITE (100, 6910) 'TIME(MIN)', 'RAINFALL'
DO I = 1, NCD
WRITE (100, 6750) 'DAY NUMBER:', I
6750 FORMAT(/ A12, I9)
6910   FORMAT (A12, A9)
DO J = 1, 96
WRITE (100, 6920) (I-1) * 1440 + (J*15),
+ FMRS_SITE(I,J)
WRITE (900, 6950) (I-1) * 1440 + (J*15),
+ FMRS_SITE(I,J)
6920 FORMAT (112, F9.6)
6950 FORMAT (112, F9.6)
END DO
END DO
6060 FORMAT (1X, F9.4)
6080 FORMAT (1X, F9.4)
CLOSE (100)
CLOSE (900)
END
C SYNTHETIC RAINFALL GENERATION (SRG) MODEL
C FILEIO.FOR
C CHECK INPUT AND OUTPUT FILES

SUBROUTINE FILEIO

C DECLARE VARIABLES

C FILEIN: INPUT FILENAME
CHARACTER*4 FILEIN
C FILEOUT: OUTPUT FILENAME
CHARACTER*11 FILEOUT
C STIE_NAME: H.C.S. NAME
CHARACTER*11 SITE_NAME
C DPD, FPD: DPD AND FPD PARAMETER FILES
CHARACTER*11 DPD, FPD
C FLAG_DPD, FLAG_FPD, FLAG_INPUT: LOGIC VARIABLES
LOGICAL FLAG_DPD, FLAG_FPD, FLAG_INPUT
C UNIT_DPD, UNIT_FPD: DPD, FPD FILE I/O CONTROLLER
INTEGER UNIT_DPD, UNIT_FPD
C T_RAIN: TOTAL NUMBER OF RAIN-DAYS
INTEGER T_RAIN(1:5)
C MAX_WTIME: MAXIMUM ARRIVAL TIME
INTEGER MAX_WTIME(1:5)
C NCD: NUMBER OF CONSTRUCTION SITE
INTEGER NCD
C DISTANCE: DISTANCE B/W H.C.S. AND RAINFALL STATIONS
INTEGER DISTANCE(1:5)

C COMMONLY USED VARIABLES IN FILES
COMMON /COM_2/ T_RAIN
COMMON /COM_5/ MAX_WTIME
COMMON /COM_6/ DISTANCE
COMMON /COM_11/ NCD

C CHECK WHETHER THE INPUT.TXT FILE AVAILABLE
INQUIRE (FILE='INPUT.TXT', EXIST=FLAG_INPUT)
IF (FLAG_INPUT .EQV. .TRUE.) THEN
   GOTO 40
ELSE
   WRITE (100,*) 'INPUT.TXT FILE CAN NOT BE FOUND.'
   STOP
END IF

C OPEN INPUT.TXT
40 OPEN(UNIT = 500, FILE = 'INPUT.TXT', ERR = 20000)
READ (500, 5100) FILEOUT
5100 FORMAT (14x, A11)

C OPEN OUTPUT FILE
OPEN(UNIT = 100, FILE = FILEOUT, ERR = 20000)
WRITE (100, 6650) 'SYNTHETIC RAINFALL GENERATION'
6650 FORMAT(A29)

C OPEN OUTPUT FILE FOR PLOT IN VISUAL BASIC INTERFACE
OPEN(UNIT = 900, FILE = 'source.out', ERR = 20000)

C READ CONSTRUCTION SITE NAME
READ (500,5610) SITE_NAME
WRITE (100, *) ' '  
WRITE (100, 6610) 'SITE_NAME: ', SITE_NAME
5610 FORMAT (14x, A11)
6610 FORMAT (A10,2X, A11)
C READ 15 MINUTE AND DAILY DATA FILE NAME
DO 3000, N = 1, 3
READ (500,5000) FILEIN
5000 FORMAT (14x, A4)
C CREATE PARAMETER DATA FILES
DPD = (FILEIN // 'D_3.TXT')
FPD = (FILEIN // 'F_3.TXT')
C CHECK INPUT FILE STATUS
INQUIRE (FILE=DPD, EXIST=FLAG_DPD)
INQUIRE (FILE=FPD, EXIST=FLAG_FPD)
IF ( (FLAG_DPD .EQV. .TRUE.) .AND.
+ (FLAG_FPD .EQV. .TRUE.) ) THEN
  GOTO 1000
ELSE
  WRITE (100, *) 'DATA FILE(S) DOES NOT EXISTS.'
  STOP
END IF
C IF STATUS OF INPUT FILES IS OK, THEN OPEN THE FILE.
1000 UNIT_DPD = N * 10 + 1
UNIT_FPD = N * 10 + 2
WRITE (100, 6710) 'STATION #', N, ':', FILEIN
6710 FORMAT (A9, I1, A1, 1X, A4)
OPEN(UNIT=UNIT_DPD, FILE=DPD,STATUS='OLD', ERR=20000)
OPEN(UNIT=UNIT_FPD, FILE=FPD,STATUS='OLD', ERR=20000)
C READ VARIABLES FROM DATA FILES
READ (UNIT_DPD, 5510) MAX_WTIME(N)
5510 FORMAT (/9X, I9 /)
READ (UNIT_FPD, 5520) T_RAIN(N)
5520 FORMAT (/9X, I9 /)
3000 CONTINUE
C READ DISTANCE FROM INPUT FILE
DO N = 1, 3
  READ (500,5530) DISTANCE(N)
END DO
5530 FORMAT (14X, I3)
WRITE (100, 5610) 'DISTANCE TO SITE:'
5610 FORMAT (A17)
DO I = 1, 3
  WRITE (100, 6660) 'STATION #', I, ':', DISTANCE(I)
END DO
6660 FORMAT(A9, I1, A1, 1X, I3)
C READ NUMBER OF CONSTRUCTION DAYS
READ (500,5540) NCD
5540 FORMAT(14x, I4)
GOTO 99999

C ERROR HANDLER
20000 PRINT*, 'ERROR HAPPENS WHEN OPENING THE FILE.'
GOTO 99999

99999 END

A3.1.3 ecatf.for

C SYNTHETIC RAINFALL GENERATION (SRG) MODEL
C ECATF.FOR
C GET ECATF PARAMETERS FROM DAILY PARAMETER DATA FILES

SUBROUTINE ECATF

C DECLARE VARIABLES

C MAX_WTIME: MAXIMUM WAITING TIME
INTEGER MAX_WTIME(1:5)
C ECATF_DATA: ECATF PARAMETERS
REAL ECATF_DATA(1:3, 0:1000)
C UNIT_DPD: DPD FILE I/O CONTROLLER
INTEGER UNIT_DPD

C COMMONLY USED VARIABLES IN FILES
COMMON /COM_4/ ECATF_DATA
COMMON /COM_5/MAX_WTIME

C READ ECATF PARAMETERS FROM DPD FILES
DO N = 1, 3
   UNIT_DPD = N * 10 + 1
   DO K = 1, MAX_WTIME(N)
   C THIS READ FOLLOWS THE READ COMMAND IN FILEIO.FOR
      READ (UNIT_DPD, 5010) ECATF_DATA(N, K)
   END DO
   ECATF_DATA(N,0) = 0.0000
END DO

5010 FORMAT (9X, F9.4)
END

A3.1.4 rat.for
SUBROUTINE RAT

DECLARE VARIABLES

RAN_DAY: RANDOM NUMBER FOR ECATF
REAL RAN_DAY

LIM_LOW, LIM_HIGH: INTERMEDIATES TO FIND ECATF
REAL LIM_LOW, LIM_HIGH

MAX_WTIME: MAXIMUM WAITING TIME OR ARRIVAL TIME
INTEGER MAX_WTIME(1:5)

ARR_TIME: ARRIVAL TIME
INTEGER ARR_TIME(1:3)

ECATF_DATA: ECATF PARAMETERS
REAL ECATF_DATA(3, 0:1000)

FLAG_STATION: INDEX FOR THE STATION BEING PROCESSED
INTEGER FLAG_STATION

TEMP1: VARIABLE USED FOR RANDOM NUMBER GENERATION
REAL TEMP1

COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ ARR_TIME
COMMON /COM_4/ ECATF_DATA
COMMON /COM_5/ MAX_WTIME
COMMON /COM_10/ FLAG_STATION

GET A RANDOM NUMBER BETWEEN 0 AND 1
CALL RANDOM(TEMP1)
RAN_DAY = TEMP1

FIND ARRIVAL TIME ACCORDING TO ECATF AND RAN_DAY
DO 2000, I = 0, MAX_WTIME(FLAG_STATION)

CASE 1: ARRIVAL TIME = 0
IF (I .EQ. 0) THEN
  IF ( RAN_DAY .LT. (ECATF_DATA(FLAG_STATION,I)/2) ) THEN
    ARR_TIME(FLAG_STATION) = 0
    GOTO 2100
  ELSE
    GOTO 2000
  END IF
END IF

CASE 2: ARRIVAL TIME = MAXIMUM WAITING TIME
IF (I .EQ. MAX_WTIME(FLAG_STATION)) THEN
  ARR_TIME = MAX_WTIME(FLAG_STATION)
  GOTO 2100
END IF

GENERAL CASE
CREATE THE PROBABILITY DENSITY RANGE
LIM_LOW = ( ECATF_DATA(FLAG_STATION,I-1) +
            ECATF_DATA(FLAG_STATION,I) ) / 2
LIM_HIGH = ( ECATF_DATA(FLAG_STATION,I) +
            ECATF_DATA(FLAG_STATION,I+1) ) / 2
C GET CORRESPONDING ARRIVAL TIME
IF ((RAN_DAY .GE. LIM_LOW) .AND. (RAN_DAY .LT. LIM_HIGH)) THEN
   ARR_TIME(FLAG_STATION) = I
   GOTO 2100
END IF

2000 CONTINUE

2100 RETURN
END

A3.1.5 rrd.for

C SYNTHETIC RAINFALL GENERATION (SRG) MODEL
C RRG.FOR
C RANDOMLY PICK A RAIN-DAY AND GENERATE MODEL RAINFALL DATA

SUBROUTINE RRD()

C DECLARE VARIABLES
C RAIN_MODEL: RAIN MODEL DATA ON DAILY BASIS
REAL RAIN_MODEL(1:3, 1:100)
C RAN_RAIN: RANDOM NUMBER USED TO PICK A RAIN-DAY; RAIN_NUM: ORDERED RAIN NUMBER IN FPD FILES
INTEGER RAN_RAIN, RAIN_NUM
C STATION_ID: STATION IDENTIFICATION NUMBER
INTEGER STATION_ID
C T_RAIN: TOTAL NUMBER OF RAIN-DAYS IN FPD FILES
INTEGER T_RAIN(1:5)
C UNIT_FPD: FPD FILE I/O CONTROLLER
INTEGER UNIT_FPD
C FLAG_STATION: INDEX FOR THE STATION BEING PROCESSED
INTEGER FLAG_STATION
C T: TIME
REAL T
C X: 4 RAIN-DAY PARAMETERS
REAL X(1:4)
C INTERMEDIATES IN CONVOLUTION
REAL*8 TERM1, TERM2
REAL*8 Y1, Y2, Y3, Y4, Y5, Y6
REAL*8 Z1, Z2, Z3, Z4, Z5, Z6
C TEMP1: VARIABLE FOR RANDOM NUMBER GENERATION
REAL TEMP1
C COMMONLY USED VARIABLES IN FILES
COMMON /COM_3/ RAIN_MODEL
COMMON /COM_2/ T_RAIN
COMMON /COM_10/ FLAG_STATION

C INITIALIZE VARIABLES
RAN_RAIN = 0
C GET A RANDOM RAIN NUMBER
CALL RANDOM(TMP1)
RAN_RAIN = 1 + INT(TMP1 * (T_RAIN(FLAG_STATION) - 1))

C READ COMMAND HERE IS JUST FOR FILE I/O READING CONVENIENT
UNIT_FPD = FLAG_STATION * 10 + 2
REWIND (UNIT_FPD)
READ (UNIT_FPD, 5610) STATION_ID

5610 FORMAT (9X, I9 //)

C READ 4 RAIN-DAY PARAMETERS FROM FPD FILE RANDOMLY
DO 100, I = 1, RAN_RAIN
   READ (UNIT_FPD, 5520) RAIN_NUM, X(1), X(2), X(3), X(4)
   IF (I .EQ. RAN_RAIN) THEN
      GOTO 1000
   ELSE
      GOTO 100
   END IF
100 CONTINUE


C GENERATE RAIN DATA BASED ON THE MODEL PARAMETERS
1000 DO 2010, I = 1, 96
   T = I * 15.0
   Y1 = X(1) - T
   Y2 = X(1) + T
   Y3 = 2 * SQRT(X(2) * T)
   Y4 = EERFC(Y1/Y3)
   Y5 = EERFC(Y2/Y3)
   Y6 = EEXP((X(1)) / X(2))
   TERM1 = 0.5 * X(4) * (Y4 - Y6 * Y5)
   IF ((T - X(3)) .LE. 0.00) THEN
      TERM2 = 0.00
   ELSE
      Z1 = X(1) - (T - X(3))
      Z2 = X(1) + (T - X(3))
      Z3 = 2 * SQRT(X(2) * (T - X(3)))
      Z4 = EERFC(Z1/Z3)
      Z5 = EERFC(Z2/Z3)
      Z6 = EEXP((X(1)) / X(2))
      TERM2 = 0.5 * X(4) * (Z4 - Z6 * Z5)
   END IF
300 IF (TERM1 - TERM2) .LE. 1E-15 THEN
   RAIN_MODEL(FLAG_STATION, I) = 1E-15
ELSE
   RAIN_MODEL(FLAG_STATION, I) = TERM1 - TERM2
END IF
2010 CONTINUE

RETURN
END

C CONDITIONAL ERROR FUNCTION
REAL FUNCTION EERFC(Q1)
REAL*8 Q1

IF (Q1 .GE. 4.0) THEN
    EERFC = 0.00
    GOTO 400
END IF
IF (Q1 .LE. -4.0) THEN
    EERFC = 2.00
    GOTO 400
END IF
IF (Q1 .LT. 0.00) THEN
    EERFC = 2.00 - ERFC(-1.0*Q1)
    GOTO 400
END IF
IF ((Q1 .GE. 0.00) .AND. (Q1 .LT. 4.00)) THEN
    EERFC = ERFC(Q1)
    GOTO 400
END IF

400   RETURN
END

C     APPROXIMATE ERROR FUNCTION
REAL FUNCTION ERFC(Q2)
REAL A1, A2, A3, A4, A5, A6
REAL *8 Q2, TEMP1, TEMP2

A1 = 0.0705230784
A2 = 0.0422820183
A3 = 0.0092705272
A4 = 0.0001520143
A5 = 0.0002765672
A6 = 0.0000430638

TEMP1=1+(A1*Q2)+(A2*(Q2**2))+(A3*(Q2**3))
+      +(A4*(Q2**4))+(A5*(Q2**5))+(A6*(Q2**6))
IF (TEMP1 .EQ. 0.00) THEN
    TEMP1 = 1.0E-2
END IF
TEMP2 = TEMP1**16
ERFC = 1 / TEMP2
RETURN
END

C     CONDITIONAL EXPONENTIAL FUNCTION
FUNCTION EEXP(Q3)
REAL Q3

IF (Q3 .LT. -100.0) THEN
    EEXP = 0.0000
    GOTO 500
END IF
IF (Q3 .GT. 85.0) THEN
    EEXP = EXP(85.0)
    GOTO 500
END IF
EEXP = EXP(Q3)
A3.1.6 dist.for

C SYNTHETIC RAINFALL GENERATION (SRG) MODEL
C DIST.FOR
C INVERSE DISTANCE METHOD

SUBROUTINE DIST

C DECLARE VARIABLES
C FMRS_STTN: 15-MINUTE RAINFALL SEQUENCE FOR STATION
REAL RATM(1:3, 1:2000, 1:100)
C FMRS_SITE: 15-MINUTE RAINFALL SEQUENCE FOR H.C.S.
REAL RATM_SITE(1:2000, 1:100)
C DISTANCE: DISTANCE BETWEEN H.C.S. AND SELECTED STATIONS
INTEGER DISTANCE (1:5)
C POWER: POWER USED IN THE INVERSE DISTANCE EQUATION
REAL POWER
C DIST_POWER: AN INTERMEDIATE IN CALCULATION
REAL DIST_POWER (1:5)
C INTERMEDIATES IN CALCULATION
INTEGER M1, M2, INDEX
C COMMONLY USED VARIABLES IN FILES
COMMON /COM_6/ DISTANCE
COMMON /COM_7/ RATM
COMMON /COM_8/ RATM_SITE
COMMON /COM_11/ NCD

C INITIALIZE VARIABLES
POWER = 2.0
N = 0
INDEX = 0
M1 = 0
M2 = 0

C CASE 1: IF EQUAL DISTANCE, TAKE AVERAGE
IF ( (DISTANCE(1) .EQ. DISTANCE(2)) .AND.
    + (DISTANCE(1) .EQ. DISTANCE(3)) ) THEN
    GOTO 200
END IF

C CASE 2: IF ONE AND ONLY ONE OF THREE STATIONS
C IS WITHIN 5 MILES OF H.C.S.,
C USE DATA FROM THIS STATION DIRECTLY.
IF ( (DISTANCE(1) .LE. 5.0) .AND. (DISTANCE(2) .GT. 5.0)
    + .AND. (DISTANCE(3) .GT. 5.0) ) THEN
    INDEX = 1
    GOTO 100
ELSE IF ( (DISTANCE(2) .LE. 5.0) .AND. + (DISTANCE(1) .GT. 5.0) + .AND. (DISTANCE(3) .GT. 5.0) ) THEN
   INDEX = 2
   GOTO 100
ELSE IF ( (DISTANCE(3) .LE. 5.0) .AND. + (DISTANCE(1) .GT. 5.0) + .AND. (DISTANCE(2) .GT. 5.0) ) THEN
   INDEX = 3
   GOTO 100

CASE 3: IF TWO AND ONLY TWO OF THREE STATIONS
IS WITHIN 5 MILES OF H.C.S.,
TAKE AVERAGE OF THESE TWO STATIONS.
ELSE IF ( (DISTANCE(1) .LE. 5.0) .AND. + (DISTANCE(2) .LE. 5.0) + .AND. (DISTANCE(3) .GT. 5.0) ) THEN
   M1 = 1
   M2 = 2
   GOTO 400
ELSE IF ( (DISTANCE(1) .LE. 5.0) .AND. + (DISTANCE(3) .LE. 5.0) + .AND. (DISTANCE(2) .GT. 5.0) ) THEN
   M1 = 1
   M2 = 3
   GOTO 400
ELSE IF ( (DISTANCE(2) .LE. 5.0) .AND. + (DISTANCE(3) .LE. 5.0) + .AND. (DISTANCE(1) .GT. 5.0) ) THEN
   M1 = 2
   M2 = 3
   GOTO 400
ELSE IF ( (DISTANCE(1) .LE. 5.0) .AND. + (DISTANCE(2) .LE. 5.0) + .AND. (DISTANCE(3) .LE. 5.0) ) THEN
   GOTO 200
END IF

MORMAL CONDITION
DO N = 1, 3
   DIST_POWER(N) = DISTANCE(N) ** (POWER)
END DO

DO 3000, I = 1, NCD
   DO 3010, J = 1, 96
      IF ( (RATM(1, I, J) .EQ. RATM(2, I, J)) .AND. + (RATM(1, I, J) .EQ. RATM(3, I, J)) ) THEN
         RATM_SITE(I, J) = RATM(1, I, J)
      GOTO 3010
   END IF
      RATM_SITE(I, J) = ( RATM(1, I, J) / DIST_POWER(1) + + RATM(2, I, J) / DIST_POWER(2) + + RATM(3, I, J) / DIST_POWER(3) ) + / ( 1.0/DIST_POWER(1) + 1.0/DIST_POWER(2) + + 1.0/DIST_POWER(3) )
3010 CONTINUE
3000 CONTINUE
GOTO 99999
C     CALCULATION OF SPECIAL CASES 1-3
100   DO I = 1, NCD
       DO J = 1, 96
           RATM_SITE(I, J) = RATM(INDEX, I, J)
       END DO
       END DO
   GOTO 99999
200   DO I = 1, NCD
       DO J = 1, 96
           RATM_SITE(I, J) = (RATM(1,I,J)+
                                RATM(2,I,J)+RATM(3,I,J))/3
       END DO
       END DO
   GOTO 99999
400   DO I = 1, NCD
       DO J = 1, 96
           RATM_SITE(I, J) = ( RATM(M1, I, J) +
                                RATM(M2, I, J) ) / 2
       END DO
       END DO
   GOTO 99999
99999 RETURN
END

A3.1.7 library.for

C     SYNTHETIC RAINFALL GENERATION (SRG) MODEL
C     LIBRARY.FOR: STORE THE FUNCTIONS NEEDED IN THE PROGRAM
C     RANDOM NUMBER GENERATOR

SUBROUTINE GET_SEED()
INTEGER MOVINGTIME
INTEGER*2 TMPHOUR, TMPMINUTE, TMPSECOND, TMPHUND
CALL GETTIM(TMPHOUR, TMPMINUTE, TMPSECOND, TMPHUND)
MOVINGTIME = TMPHOUR + TMPMINUTE + TMPSECOND + TMPHUND
CALL SEED(MOVINGTIME)
RETURN
END

A3.2 SRG_1.exe (bootstrapping method) FORTRAN source code

A3.2.1 main.for

C     SYNTHETIC RAINFALL GENERATION ADDITIONAL (SRG_1) MODEL
C MAIN.FOR
C CONTROL PROGRAM

C SOME ABBREVIATION USED:
C H.C.S.: HIGHWAY CONSTRUCTION SITE
C N.C.D.: NUMBER
C DPD: DAILY PARAMETER DATA
C FPD: 15-MINUTE PARAMETER DATA

C DECLARE VARIABLES

C NCD: NUMBER OF CONSTRUCTION DAYS
INTEGER NCD
C INDEX_NCD: INDEX FOR HOW MANY NCD HAS BEEN CALCULATED
INTEGER INDEX_NCD
C FLAG_STATION: INDEX FOR THE STATION BEING PROCESSED
INTEGER FLAG_STATION
C ARR_TIME: SIMULATED ARRIVAL TIME SERIES
INTEGER ARR_TIME (1:5)

C STTN_REAL: 15-MIN RAINFALL SEQUENCE AT STATIONS FROM REAL DATA
REAL STTN_REAL(1:3, 1:2000, 1:100)
C HCS_REAL: 15-MINUTE RAINFALL SEQUENCE AT H.C.S. FROM REAL DATA
REAL HCS_REAL(1:2000, 1:100)
C RAIN_REAL: 15-MIN RAINFALL MODEL DATA
REAL RAIN_REAL(1:3, 1:100)

C COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ ARR_TIME
COMMON /COM_23/ RAIN_REAL
COMMON /COM_27/ STTN_REAL
COMMON /COM_28/ HCS_REAL
COMMON /COM_10/ FLAG_STATION
COMMON /COM_11/ NCD

C CALL FIEEIO.FOR TO GET FPD AND HPD DATA
CALL FIEEIO

C A SCREEN MEMO FOR USER
WRITE (*,*) 'Program is Running, Please wait.'

C CALL ECATF.FOR TO GET ECATF PARAMETERS FOR STATIONS
CALL ECATF

C THIS CALL IS REQUIRED FOR RANDOM NUMBER GENERATOR
CALL GET_SEED

C LOOP THROUGH THREE SELECTED STATIONS
DO 3000, N = 1, 3
  FLAG_STATION = N
C GET FIRST SIMULATED ARRIVAL TIME FOR RAINFALL STATIONS
CALL RAT
C WRITE (100, *) ARR_TIME
C IF NO RAIN IN THE WHOLE NCD TIME
C ARRIVAL TIME > N.C.D. CASE, THEN NO RAIN
   IF (ARR_TIME(N) .GE. NCD) THEN
      DO I = 1, NCD
         DO J = 1, 96
            STTN_REAL(N, I, J) = 0.00
         END DO
      DO
      DAY = I
      END DO
      INDEX_NCD = NCD
      GOTO 3000
   ELSE
      INDEX_NCD = 1
      GOTO 2200
   END IF

C IF THERE ARE RAINS DURING N.C.D.
   INDEX_NCD = 1
2000 IF (INDEX_NCD .LE. NCD) THEN
      GOTO 2100
   ELSE
      GOTO 3000
   END IF

C CALL RAT.FOR TO GET MORE GENERATED ARRIVAL TIMES
2100 CALL RAT
C WRITE (100, *) ARR_TIME

C IF NO RAIN DURING FURTHER DAYS
C CUMULATIVE SIMULATED ARRIVAL TIMES > N.C.D. CASE
2200 IF (ARR_TIME(N) .GE. (NCD - INDEX_NCD + 1)) THEN
      DO I = INDEX_NCD, NCD
         DO J = 1, 96
            STTN_REAL(N, I, J) = 0.00
         END DO
      DO
      DAY = I
      END DO
      GOTO 3000
   END IF

C WHEN NO RAIN FOR THESE DAYS
C ARRIVAL TIME < N.C.D. CASE AND <> 0
   IF ( ( ARR_TIME(N) .LT. (NCD - INDEX_NCD + 1))
      + .AND. (ARR_TIME(N) .NE. 0) ) THEN
      DO I = INDEX_NCD, INDEX_NCD + ARR_TIME(N) - 1
         DO J = 1, 96
            STTN_REAL(N, I, J) = 0.00
         END DO
      DO
      DAY = I
      END DO
   END IF

C CALL RRD.FOR TO RANDOMLY GENERATE MODEL RAINFALL DATA
   INDEX_NCD = INDEX_NCD + ARR_TIME(N)
   DO J = 1, 96
      STTN_REAL(N, INDEX_NCD, J) =
      + RAIN_REAL(FLAG_STATION, J)
   END DO
   DAY = INDEX_NCD

90
INDEX_NCD = INDEX_NCD + 1
GOTO 2000
END IF

C ARRIVAL TIME < NCD CASE AND ARRIVAL TIME = 0
IF ( ( ARR_TIME(N) .LT. (NCD - INDEX_NCD + 1))
+ .AND. (ARR_TIME(N) .EQ. 0) ) THEN
    CALL RRD
    DO J = 1, 96
        STTN_REAL(N, INDEX_NCD, J)
    END DO
    DAY = INDEX_NCD
    INDEX_NCD = INDEX_NCD + 1
    GOTO 2000
END IF

3000 CONTINUE

C GET 15-MIN RAINFALL SEQUENCE FOR H.C.S.
CALL DIST
WRITE (100, *) 'TIME(MIN)', 'RAINFALL'
WRITE (100, 6910) 'TIME(MIN)', 'RAINFALL'
6910 FORMAT (A12, A9)

C OUTPUT OF SRG MODEL
DO I = 1, NCD
    DO J = 1, 96
        WRITE (100, 6950) (I-1) * 1440 + (J*15),
        + HCS_REAL(I,J)
        WRITE (900, 6950) (I-1) * 1440 + (J*15),
        + HCS_REAL(I,J)
    END DO
END DO
6950 FORMAT (I12, F9.3)

CLOSE (100)
CLOSE (900)
END

A3.2.2 fileio.for

C SYNTHETIC RAINFALL GENERATION ADDITIONAL (SRG_1) MODEL
C FILEIO.FOR
C CHECK INPUT AND OUTPUT FILES
SUBROUTINE FILEIO

C DECLARE VARIABLES
C FILEIN: INPUT FILENAME
CHARACTER*4 FILEIN
C FILEOUT: OUTPUT FILENAME
CHARACTER*11 FILEOUT
C STIE_NAME: H.C.S. NAME
CHARACTER*11 SITE_NAME
C DPD, FPD: DPD AND FPD PARAMETER FILES
CHARACTER*11 DPD, FPD_2, FPD_3
C FLAG_DPD, FLAG_FPD, FLAG_INPUT: LOGIC VARIABLES
LOGICAL FLAG_DPD, FLAG_FPD_2, FLAG_FPD_3, FLAG_INPUT
C UNIT_DPD, UNIT_FPD: DPD, FPD FILE I/O CONTROLLER
INTEGER UNIT_DPD, UNIT_FPD_2, UNIT_FPD_3
C T_RAIN: TOTAL NUMBER OF RAIN-DAYS
INTEGER T_RAIN(1:5)
C MAX_WTIME: MAXIMUM ARRIVAL TIME
INTEGER MAX_WTIME(1:5)
C NCD: NUMBER OF CONSTRUCTION SITE
INTEGER NCD
C DISTANCE: DISTANCE B/W H.C.S. AND RAINFALL STATIONS
INTEGER DISTANCE(1:5)

C COMMONLY USED VARIABLES IN FILES
COMMON /COM_2/ T_RAIN
COMMON /COM_5/ MAX_WTIME
COMMON /COM_6/ DISTANCE
COMMON /COM_11/ NCD

C CHECK WHETHER THE INPUT.TXT FILE AVAILABLE
INQUIRE (FILE='INPUT.TXT', EXIST=FLAG_INPUT)
IF (FLAG_INPUT .EQV. .TRUE.) THEN
   GOTO 40
ELSE
   PRINT *, 'INPUT FILE NOT FOUND.'
   STOP
END IF

C OPEN INPUT.TXT
40 OPEN(UNIT = 500, FILE = 'INPUT.TXT', ERR = 20000)
READ (500, 5100) FILEOUT
5100 FORMAT (14x, A11)

C OPEN OUTPUT FILE
OPEN(UNIT = 100, FILE = FILEOUT, ERR = 20000)
WRITE (100, 6650) 'SYNTHETIC RAINFALL GENERATION'
6650 FORMAT(A29)

C OPEN OUTPUT FILE FOR VISUAL BASIC GRAPHIC FUNCTION
OPEN(UNIT = 900, FILE = 'SOURCE.OUT', ERR = 20000)

C READ CONSTRUCTION SITE NAME
READ (500,5610) SITE_NAME
WRIT
E (100, '*') ' '
WRITE (100, 6610) 'SITE NAME:', SITE_NAME
5610 FORMAT (14x, A11)
C READ 15 MINUTE AND DAILY DATA FILE NAME
DO 3000, N = 1, 3
READ (500,5000) FILEIN
5000 FORMAT (14x, A4)
C CREATE PARAMETER DATA FILES
DPD = (FILEIN // 'D_3.TXT')
FPD_2 = (FILEIN // 'F_2.TXT')
FPD_3 = (FILEIN // 'F_3.TXT')
C CHECK INPUT FILE STATUS
INQUIRE (FILE=DPD, EXIST=FLAG_DPD)
INQUIRE (FILE=FPD_2, EXIST=FLAG_FPD_2)
INQUIRE (FILE=FPD_3, EXIST=FLAG_FPD_3)
IF ( (FLAG_DPD .EQV. .TRUE.) .AND. 
+ (FLAG_FPD_2 .EQV. .TRUE.) .AND. (FLAG_FPD_3 .EQV. .TRUE.)) THEN
GOTO 1000
ELSE
STOP
END IF
C IF STATUS OF INPUT FILES IS OK, THEN OPEN THE FILE.
1000 UNIT_DPD = N * 10 + 1
UNIT_FPD_2 = N * 10 + 2
UNIT_FPD_3 = N * 10 + 3
OPEN (UNIT=UNIT_DPD, FILE=DPD, STATUS='OLD', ERR=20000)
OPEN (UNIT=UNIT_FPD_2, FILE=FPD_2, STATUS='OLD', ERR=20000)
OPEN (UNIT=UNIT_FPD_3, FILE=FPD_3, STATUS='OLD', ERR=20000)
C READ VARIABLES FROM DATA FILES
READ (UNIT_DPD, 5510) MAX_WTIME(N)
5510 FORMAT (/ 9X, I9 /)
READ (UNIT_FPD_3, 5520) T_RAIN(N)
5520 FORMAT (/ 9X, I9 /)
3000 CONTINUE
C READ DISTANCE FROM INPUT FILE
DO N = 1, 3
READ (500, 5530) DISTANCE(N)
END DO
5530 FORMAT (14X, I3)
WRITE (100, 5610) ' ' 
WRITE (100, 6810) 'DISTANCE TO SITE:'
6810 FORMAT (A17)
DO I = 1, 3
WRITE (100, 6660) 'STATION #', I, ':', DISTANCE(I)
END DO
6660 FORMAT (A9, I1, A1, 1X, I3)
C READ NUMBER OF CONSTRUCTION DAYS
READ (500, 5540) NCD
A3.2.3 ecatf.for

C SYNTHETIC RAINFALL GENERATION ADDITIONAL (SRG_1) MODEL
C ECATF.FOR
C GET ECATF PARAMETERS FROM DAILY PARAMETER DATA FILES

SUBROUTINE ECATF

C DECLARE VARAIBLES

C MAX_WTIME: MAXIMUM WAITING TIME
INTEGER MAX_WTIME(1:5)
C ECATF_DATA: ECATF PARAMETERS
REAL ECATF_DATA(1:3, 0:1000)
C UNIT_DPD: DPD FILE I/O CONTROLER
INTEGER UNIT_DPD

C COMMONLY USED VARIABLES IN FILES
COMMON /COM_4/ ECATF_DATA
COMMON /COM_5/MAX_WTIME

C READ ECATF PARAMETERS FROM DPD FILES
DO N = 1, 3
   UNIT_DPD = N * 10 + 1
   DO K = 1, MAX_WTIME(N)
      C THIS READ FOLLOWS THE READ COMMAND IN FILEIO.FOR
      READ (UNIT_DPD, 5010) ECATF_DATA(N, K)
   END DO
   ECATF_DATA(N,0) = 0.0000
END DO

5010 FORMAT (9X, F9.4)

END

A3.2.4 rat.for
SUBROUTINE RAT

DECLARE VARIABLES

RAN_DAY: RANDOM NUMBER FOR ECATF
REAL RAN_DAY

LIM_LOW, LIM_HIGH: INTERMEDIATES TO FIND ECATF
REAL LIM_LOW, LIM_HIGH

MAX_WTIME: MAXIMUM WAITING TIME OR ARRIVAL TIME
INTEGER MAX_WTIME(1:5)

ARR_TIME: ARRIVAL TIME
INTEGER ARR_TIME(1:3)

ECATF_DATA: ECATF PARAMETERS
REAL ECATF_DATA(3, 0:1000)

FLAG_STATION: INDEX FOR THE STATION BEING PROCESSED
INTEGER FLAG_STATION

TEMP1: VARIABLE USED FOR RANDOM NUMBER GENERATION
REAL TEMP1

COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ ARR_TIME
COMMON /COM_4/ ECATF_DATA
COMMON /COM_5/ MAX_WTIME
COMMON /COM_10/ FLAG_STATION

GET A RANDOM NUMBER BETWEEN 0 AND 1
CALL RANDOM(TEMP1)
RAN_DAY = TEMP1

FIND ARRIVAL TIME ACCORDING TO ECATF AND RAN_DAY
DO 2000, I = 0, MAX_WTIME(FLAG_STATION)

CASE 1: ARRIVAL TIME = 0
IF (I .EQ. 0) THEN
  IF (RAN_DAY .LT. (ECATF_DATA(FLAG_STATION,1)/2)) THEN
    ARR_TIME(FLAG_STATION) = 0
    GOTO 2100
  ELSE
    GOTO 2000
  END IF
END IF
END IF

CASE 2: ARRIVAL TIME = MAXIMUM WAITING TIME
IF (I .EQ. MAX_WTIME(FLAG_STATION)) THEN
  ARR_TIME = MAX_WTIME(FLAG_STATION)
  GOTO 2100
END IF

GENERAL CASE
CREATE THE PROBABILITY DENSITY RANGE
LIM_LOW = (ECATF_DATA(FLAG_STATION,I-1) + ECATF_DATA(FLAG_STATION,I))/2
LIM_HIGH = (ECATF_DATA(FLAG_STATION,I) +
+ ECATF_DATA(FLAG_STATION,I+1) ) / 2
C GET CORRESPONDING ARRIVAL TIME
IF ((RAN_DAY .GE. LIM_LOW) .AND. (RAN_DAY .LT. LIM_HIGH)) THEN
  ARR_TIME(FLAG_STATION) = I
END IF
2000 CONTINUE
2100 RETURN
END

A3.2.5 rrd.for

C SYNTHETIC RAINFALL GENERATION ADDITIONAL (SRG_1) MODEL
C RRD.FOR
C RANDOMLY PICK A RAIN-DAY AND GET REAL RAINFALL DATA

SUBROUTINE RRD()
C DECLARE VARIABLES
REAL RAIN_REAL(1:3, 1:100)
C RAN_RAIN: RANDOM NUMBER USED TO PICK A RAIN-DAY; RAIN_NUM: ORDERED RAIN NUMBER IN FPD FILES
INTEGER RAN_RAIN, RAIN_NUM
C STATION ID: STATION IDENTIFICATION NUMBER
INTEGER STATION_ID
C T_RAIN: TOTAL NUMBER OF RAIN-DAYS IN FPD FILES
INTEGER T_RAIN(1:5)
C UNIT_FPD: FPD FILE I/O CONTROLLER
INTEGER UNIT_FPD_2, UNIT_FPD_3
C FLAG_STATION: INDEX FOR THE STATION BEING PROCESSED
INTEGER FLAG_STATION
C TEMP1: VARIABLE FOR RANDOM NUMBER GENERATION
REAL TEMP1
C COMMONLY USED VARIABLES IN FILES
COMMON /COM_23/ RAIN_REAL
COMMON /COM_2/ T_RAIN
COMMON /COM_10/ FLAG_STATION

C INITIALIZE VARIABLES
RAN_RAIN = 0
C GET A RANDOM RAIN NUMBER
CALL RANDOM(TEMP1)
RAN_RAIN = 1 + INT(TEMP1 * (T_RAIN(FLAG_STATION)-1))
C READ COMMAND HERE IS JUST FOR FILE I/O READING CONVINIENT
UNIT_FPD_2 = FLAG_STATION * 10 + 2
UNIT_FPD_3 = FLAG_STATION * 10 + 3
REWIND (UNIT_FPD_2)
REWIND (UNIT_FPD_3)
READ (UNIT_FPD_3, 5610) STATION_ID

5610 FORMAT (9X, I9 //)

C     READ 15-MIN. RAINFALL DATA FROM FPD FILE RANDOMLY
DO 100, I = 1, RAN_RAIN
    READ (UNIT_FPD_3, 5520) RAIN_NUM
    READ (UNIT_FPD_2, 5525) (RAIN_REAL(FLAG_STATION, M), M= 1, 96)
    IF (I .EQ. RAN_RAIN) THEN
        GOTO 1000
    ELSE
        GOTO 100
    END IF
100   CONTINUE

5520 FORMAT (I9)
5525 FORMAT (29X, 96(1X, F5.2), 8X)
1000 RETURN
END

A3.2.6  dist.for

C     SYNTHETIC RAINFALL GENERATION ADDITIONAL (SRG_1) MODEL
C     DIST.FOR
C     INVERSE DISTANCE METHOD

SUBROUTINE DIST

C     DECLARE VARAIBLES
C     FMRS_STTN: 15-MINUTE RAINFALL SEQUENCE FOR STATION
REAL STTN_REAL(1:3, 1:2000, 1:100)
C     FMRS_SITE: 15-MINUTE RAINFALL SEQUENCE FOR H.C.S.
REAL HCS_REAL(1:2000, 1:100)
C     DISTANCE: DISTANCE BETWEEN H.C.S. AND SELECTED STATIONS
INTEGER DISTANCE (1:5)
C     POWER: POWER USED IN THE INVERSE DISTANCE EQUATION
REAL POWER
C     DIST_POWER: AN INTERMEDIATE IN CALCULATION
REAL DIST_POWER (1:5)
C     INTERMEDIATES IN CALCULATION
INTEGER M1, M2, INDEX
C     COMMONLY USED VARAIBLES IN FILES
COMMON /COM_6/  DISTANCE
COMMON /COM_27/ STTN_REAL
COMMON /COM_28/ HCS_REAL
COMMON /COM_11/ NCD
C     INITIALIZE VARIABLES
POWER = 2.0
N = 0
INDEX = 0
M1 = 0
M2 = 0

IF (DISTANCE(1) .EQ. 0) THEN
  INDEX = 1
  GOTO 200
ELSE IF (DISTANCE(2) .EQ. 0) THEN
  INDEX = 2
  GOTO 200
ELSE IF (DISTANCE(3) .EQ. 0) THEN
  INDEX = 3
  GOTO 200
END IF

C     NORMAL CONDITION
DO N = 1, 3
  DIST_POWER(N) = DISTANCE(N) ** (POWER)
END DO

DO 3000, I = 1, NCD
  DO 3010, J = 1, 96
    HCS_REAL(I, J) = (STTN_REAL(1, I, J) / DIST_POWER(1) +
    + STTN_REAL(2, I, J) / DIST_POWER(2) +
    + STTN_REAL(3, I, J) / DIST_POWER(3) )
    + / ( 1.0/DIST_POWER(1) + 1.0/DIST_POWER(2) +
    + 1.0/DIST_POWER(3) )
  3010  CONTINUE
3000  CONTINUE
GOTO 99999

200  DO I = 1, NCD
      DO J = 1, 96
        HCS_REAL(I, J) = (STTN_REAL(INDEX,I,J))
      END DO
      END DO
GOTO 99999

99999 RETURN
END

A3.2.7  library.for

C     SYNTHETIC RAINFALL GENERATION ADDITIONAL (SRG_1) MODEL
C     LIBRARY.FOR: STORE THE FUNCTIONS NEEDED IN THE PROGRAM
C     RANDOM NUMBER GENERATOR

SUBROUTINE GET_SEED()
INTEGER MOVINGTIME

98
A3.3 input.txt

Input.txt is generated by SRG model interface and is used by srg.exe to do model calculation.

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<thead>
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<th>OPTF NAME</th>
<th>output.txt</th>
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<td>SITE NAME</td>
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<td>N.C.D.</td>
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OPTF NAME: output filename
SITE NAME: name of highway construction site
STATION #1: first rainfall station_ID
STATION #2: second rainfall station_ID
STATION #3: third rainfall station_ID
DISTANCE #1: distance from H.C.S. to first station
DISTANCE #2: distance from H.C.S. to second station
DISTANCE #3: distance from H.C.S. to third station
N.C.D.: number of construction days

A3.4 output.txt

Output.txt is generated by SRG.exe, which includes detailed 15-minute rainfall sequence.

SYNTHETIC RAINFALL GENERATION

SITE NAME: HCS_1
STATION #1: 0428
STATION #2: 8531
STATION #3: 9815

DISTANCE TO SITE:
STATION #1: 13
STATION #2: 18
STATION #3: 25

TIME(MIN) RAINFALL

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A3.5 source.out

source.txt is generated by SRG.exe, which includes 15-minute rainfall sequence for plot.exe.

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A4. ECATFPG model source code and input/output files

A4.1 ECATFPG model FORTRAN source code

A4.1.1 main.for

C     ECATFPG MODEL
C     MAIN.FOR
C     PROGRAM CONTROL AND GENERATE ECATF PARAMETERS

C     DECLARE VARIABLES
C     STATION_ID: STATION IDENTIFICATION NUMBER
INTEGER STATION_ID
C     MAX_ARRTIME: MAXIMUM ARRIVAL TIME
INTEGER MAX_ARRTIME
C     MYEARS: MAXIMUM POSSIBLE NUMBER OF YEARS
INTEGER MYEARS
C     NYEARS: COUNTER OF YEARS
INTEGER NYEARS
C     ACTUAL NUMBER OF YEARS IN DAILY RAINFALL DATA
INTEGER YEARS
C     RAINYEAR: YEAR RECORD OF DAILY RAINFALL DATA
INTEGER RAINYEAR(1:100)
C     RAINDATA: DAILY RAINFALL DATA
REAL RAINDATA(100,1:400)
C     NDAYS: NUMBER OF DAILY RAINFALL RECORDS
INTEGER NDAYS(1:5000)
C     N_RAIN: NUMBER OF WAITING EVENT WRT ARRIVAL TIME
INTEGER N_RAIN(1:1000)
C     N_RAIN_NORM: NORMALIZED N_RAIN BY NDAYS
REAL N_RAIN_NORM(1:1000)
C     INDEX_WTEVT: COUNTER and INDEX FOR WAITING EVENTS
INTEGER INDEX_WTEVT
C     ECATF PARAMETERS
REAL ECATF_1(1:1000)
C VARIABLE INITIALIZATION
MYEARS = 100
NYEARS = 1

C CHECK INPUT AND OUTPUT FILES
CALL FILEIO

C INPUT AND OUTPUT OF STATION_ID
READ(11, 5010) STATION_ID
WRITE(12, 6010) 'STN_ID', STATION_ID
5010 FORMAT(I4)
6010 FORMAT(A9, I9)
REWRITE(11)

C FIND NUMBER OF YEARS IN RAINFALL DATA FILE
DO 1020 I=1, MYEARS
READ (11, 5020) RAINYEAR(I)
IF (.NOT. EOF(11)) THEN
   NYEARS = NYEARS + 1
ELSE
   GOTO 1050
END IF
1020 CONTINUE
1050 YEARS = NYEARS
5020 FORMAT (7X, I4)
REWRITE(11)

C GET DAILY RAINFALL DATA FILE
DO 300, J=1, YEARS
READ(11, 5100) (RAINDATA(J,K), K=1, 366)
300 CONTINUE
5100 FORMAT (11X, 366(1X, F6.2), 3X)

C SORT OUT WAITING EVENTS FROM
INDEX_WTEVT = 0
DO 500 I = 1, YEARS
   DO 600 J = 1, 366
      C A ZERO RAIN-DAY
      IF (RAINDATA(I,J) .EQ. 0.00) THEN
         C A STARTING POINT OF WAITING EVENTS
         IF (RAINDATA(I,J-1) .NE. 0.00) THEN
            C TOTAL NUMBER OF WAITING EVENTS INCREASE BY ONE
            INDEX_WTEVT = INDEX_WTEVT + 1
         C FOR A NEW WAITING EVENT, ARRIVAL TIME INCREASE BY ONE
         NDAYS(INDEX_WTEVT) = NDAYS(INDEX_WTEVT) + 1
         GOTO 600
         ELSE
            C FOR A OLD WAITING EVENT, ARRIVAL TIME INCREASE BY ONE
            NDAYS(INDEX_WTEVT) = NDAYS(INDEX_WTEVT) + 1
            GOTO 600
         END IF
      ELSE
         GOTO 600
      END IF
600 CONTINUE
500 CONTINUE

C FIND MAXIMUM ARRIVAL TIME
DO 1610, I = 1, INDEX_WTEVT
   IF (MAX_ARRTIME .GE. NDAYS(I)) THEN
GOTO 1610
ELSE
  MAX.ARRTIME = NDAYS(I)
END IF
1610 CONTINUE

C FIND NUMBER OF WAITING EVENTS FOR EACH ARRIVAL TIME
DO 1220, J = 1, MAX.ARRTIME
  DO I = 1, INDEX_WTEVT
    IF (J .EQ. NDAYS(I)) THEN
      N_RAIN(J) = N_RAIN(J) + 1
    END IF
  END DO
1220 CONTINUE

C OUTPUT FILE TITLES
WRITE(12, 6040) 'M.ARRTIME', MAX.ARRTIME
6040 FORMAT (A9, I9)
WRITE(12, 6050) 'ARR_T', 'ECATF'

C GENERATE NORMALIZED WAITING EVENTS
DO 800, I = 1, MAX.ARRTIME
  N_RAIN_NORM(I) = FLOAT(N_RAIN(I)) / FLOAT(INDEX_WTEVT)
800 CONTINUE

C GENERATE ECATF PARAMETERS
DO 1710, I = 1, MAX.ARRTIME
  IF (I .EQ. 1) THEN
    ECATF_1(1) = N_RAIN_NORM(1)
    GOTO 1720
  END IF
  ECATF_1(I) = ECATF_1(I-1) + N_RAIN_NORM(I)
1720 WRITE(12, 6060) I, ECATF_1(I)
1710 CONTINUE

6050 FORMAT(A9, A9)
6060 FORMAT(I9, F9.4)

CLOSE(11)
CLOSE(12)
END

A4.1.2 fileio.for

C ECATFPG MODEL
C FILEIO.FOR
C CHECK INPUT AND OUTPUT FILES

SUBROUTINE FILEIO

C DEFINE VARIABLES
C     FILEIN: INPUT DAILY DATA FILE IDENTIFICATION NUMBER
CHARACTER*4  FILEIN
C     FILEOUT: OUTPUT FILE NAME
CHARACTER*11 FILEOUT
C     DAILY DATA FILE NAME
CHARACTER*11 DPD
C     VARIABLE TO TAKE RESPONSE FROM USER
CHARACTER*1 ANSWER1
C     LOGICAL VARIABLES TO CHECK INPUT AND OUTPUT FILES
LOGICAL FLAGIN, FLAGOUT

C     ASK FOR THE STATION ID
10  PRINT *, 'PLEASE ENTER STATION ID (4 DIGIT ONLY):'
READ (*,5000) FILEIN
5000  FORMAT (A4)
C     CREATE INPUT FILE NAME FROM STATION_ID
DPD = (FILEIN // 'D_2.TXT')
C     CHECK INPUT FILE STATUS
INQUIRE (FILE=DPD, EXIST=FLAGIN)
IF (FLAGIN .EQV. .TRUE.) THEN
   GOTO 20
ELSE
   PRINT *, 'DPD FILE DOES NOT EXIST.'
   PRINT *, 'DO YOU WANT TO ENTER THE STATION ID AGAIN?'
   PRINT *, 'PRESS Y FOR YES, OR ANY OTHER KEYS TO QUIT,'
   PRINT *, 'THEN PRESS RETURN.'
   READ (*, 5030) ANSWER1
   IF ((ANSWER1 .EQ. 'Y') .OR. (ANSWER1 .EQ. 'y')) THEN
      GOTO 10
   ELSE
      STOP
   END IF
END IF

C     IF CHECKING INPUT STATUS PASS, THEN OPEN THE FILE.
20  OPEN(UNIT=11,FILE=DPD,STATUS='OLD', ERR=20000)
C     ASK FOR OUTPUT FILE NAME
FILEOUT = (FILEIN // 'D_3.TXT')
PRINT *
PRINT *
PRINT *, 'OUTPUT FILE IS SAVED AS ', FILEOUT
C     CHECK OUTPUT FILE STATUS
INQUIRE (FILE=FILEOUT, EXIST=FLAGOUT)
IF (FLAGOUT .EQV. .TRUE.) THEN
   PRINT *, 'FILE ALREADY EXISTED. WANT TO REPLACE IT?'
   PRINT *, 'ENTER Y FOR YES, OR ANY OTHER KEYS TO QUIT,'
   PRINT *, 'THEN PRESS RETURN.'
   READ (*, 5030) ANSWER1
   IF ((ANSWER1 .EQ. 'Y') .OR. (ANSWER1 .EQ. 'y')) THEN
      GOTO 40
   ELSE
      STOP
   END IF
ELSE
   GOTO 40
ENDIF
A4.2 ECATFG model input file

The input file for ECATFG model is actual historical daily rainfall data for each station. This demo example is part of file 1429d_2.txt for station 1429.

1429 1979 0.17 0.00 0.00 0.19 0.05 0.08 0.02 0.00
0.00 1.84 0.16 0.00 0.00 0.00 0.00 0.00 0.00 0.20
0.01 0.00 0.00 0.00 0.00 0.00 0.26 0.02 0.00 0.00
0.06 0.23 0.00 0.00 0.12 0.19 0.43 0.45 0.38 0.03
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.90 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.02 0.29 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
3.16 0.75 0.50 0.38 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.10 0.22 0.08 0.07 0.06 0.03 0.00 0.00 0.04
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.38
0.02 0.10 0.33 0.56 0.00 0.00 0.00 0.00 0.00 0.00
0.00 1.72 0.00 1.56 0.00 0.02 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.24 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.53 0.13 0.00 0.00 0.00 0.00 0.00
0.14 0.00 0.19 0.00 0.70 0.27 0.00 0.00 0.83 0.04
0.00 0.00 0.03 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.35 0.00 0.66 0.00 0.00 0.00 0.00 0.00 0.11
0.00 0.89 0.05 0.08 0.17 0.00 0.00 0.00 0.00 0.00
3.56 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.83
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.52
0.14 0.64 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.77 0.18 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.55 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.13 0.00 0.00 0.17 0.27 0.00
0.24 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
A4.3 ECATFG model output file

Output file from ECATFG model is ECATFG parameters for each station. This demo example is part of file 1429d_3.txt for station 1429.

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<td>.9985</td>
</tr>
<tr>
<td>64</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

STN_ID: station identification number
M_ARRTIME: maximum arrival time
ARR_T: arrival time
ECATF: cumulative probability function values

A5. RDPG model source code and input/output files

A5.1 RDPG model FORTRAN source code

A5.1.1 main.for

C     RDPG MODEL
C     MAIN.FOR
C     CONTROL THE PROGRAM
DECLARES VARIABLES

STATION_ID: STATION IDENTIFICATION NUMBER
INTEGER STATION_ID

TOTAL_RAINS: TOTAL NUMBER OF RAIN DAYS
INTEGER TOTAL_RAINS

MDAYS: MAXIMUM NUMBER OF RAIN DAYS
INTEGER MDAYS

INDEX: A COUNTER USED IN THIS PROGRAM
INTEGER INDEX

RAINDATE: DATE OF THE RAIN EVENT
CHARACTER*10, RAINDATE(1:3000)

RAIN_REALDATA: REAL (OR ACTUAL) RAINFALL DATA
REAL RAIN_REALDATA(1:100)

COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ RAIN_REALDATA
COMMON /COM_11/ INDEX

INITIALIZE VARIABLES
MDAYS = 3650
TOTAL_RAINS = 0

CALL FILEIO.FOR TO CHECK INPUT AND OUTPUT FILES
CALL FILEIO

READ AND WRITE STATION IDENTIFICATION NUMBER
READ (11,5010) STATION_ID
WRITE (12,6010) 'STN ID', STATION_ID
REWIND(11)

CALCULATE TOTAL NUMBER OF RAIN DAYS
DO 200 J = 1, MDAYS
  IF (.NOT. EOF(11)) THEN
    READ(11,5100) RAINDATE(J)
  ELSE
    GOTO 250
  END IF
200   CONTINUE
250   TOTAL_RAINS = J - 1
REWIND (11)

OUTPUT FILE TITLE AND TOTAL NUMBER OF RAIN DAYS
WRITE (12,6020) 'T_RAINS', TOTAL_RAINS
WRITE (*, *) 'TOTAL NUMBER OF RAINS ARE ', TOTAL_RAINS
WRITE (12,6030) 'RAIN_NUM', 'RAIN_CTR', 'RAIN_DSP',
               'RAIN_DRT', 'PK_RATE'

GENERATE PARAMETERS
DO 300, I = 1, TOTAL_RAINS
  INDEX = I
  WRITE (*,*) STATION_ID, INDEX
  READ(11,5020) (RAIN_REALDATA(K), K=1,96)
  DO K = 1, 96
    RAIN_REALDATA(K) = 100.0 * RAIN_REALDATA(K)
  END DO
CALL SUBROUTINE PARA.FOR TO GENERATE PARAMETERS
CALL PARA
500    CONTINUE
300   CONTINUE
5020  FORMAT (27X, 96(1X,F5.2), 8X)
6010  FORMAT (A9, I9)
6020  FORMAT (A9, I9)
6030  FORMAT (A9, A9, A9, A9, A9)
99999 END

A5.1.2 fileio.for

RDPG MODEL
FILEIO.FOR
CHECK INPUT AND OUTPUT FILE

SUBROUTINE FILEIO

DECLARE VARIABLES

FILEIN: INPUT DAILY FILE IDENTIFICATION NUMBER
CHARACTER*4  FILEIN
FILEOUT: OUTPUT FILE NAME
CHARACTER*11 FILEOUT
FPD: OVERALL 15 MINUTE INPUT FILENAME
CHARACTER*11 FPD
VARAIBLE TO TAKE RESPONSE FROM USER
CHARACTER*1 ANSWER1
LOGICAL VARIABLE TO CHECK INPUT AND OUTPUT FILES
LOGICAL FLAGIN, FLAGOUT

ASK FOR THE STATION ID
10    PRINT *, 'PLEASE ENTER STATION ID (4 DIGIT ONLY):'
       READ (*,5000) FILEIN
5000  FORMAT (A4)

CREATE INPUT FILE NAME FROM STATION_ID
FPD = (FILEIN // 'F_2.TXT')

CHECK INPUT FILE STATUS
INQUIRE (FILE=FPD, EXIST=FLAGIN)
IF (FLAGIN .EQV. .TRUE.) THEN
       GOTO 20
ELSE
       PRINT *, 'FPD FILE DOES NOT EXIST.'
       PRINT *, 'DO YOU WANT TO ENTER THE STATION ID AGAIN?'
       PRINT *, 'PRESS Y FOR YES, OR ANY OTHER KEYS TO QUIT,'
       PRINT *, 'THEN PRESS RETURN.'
       READ (*, 5030) ANSWER1
       IF ((ANSWER1 .EQ. 'Y') .OR. (ANSWER1 .EQ. 'y')) THEN
       GOTO 10
       END
ELSE
   STOP
END IF
END IF

C  IF CHECKING STATUS PASS, THEN OPEN THE FILE.
20  OPEN(UNIT=11, FILE=FPD, STATUS='OLD', ERR=20000)

C  ASK FOR OUTPUT FILE NAME
FILEOUT = (FILEIN // 'F_3.TXT')
PRINT *
PRINT *
PRINT *, 'OUTPUT FILE IS SAVED AS ', FILEOUT

C  CHECK OUTPUT FILE STATUS
INQUIRE (FILE=FILEOUT, EXIST=FLAGOUT)
IF (FLAGOUT .EQV. .TRUE.) THEN
   PRINT *, 'FILE ALREADY EXISTED. WANT TO REPLACE IT?'
   PRINT *, 'ENTER Y FOR YES, OR ANY OTHER KEYS TO QUIT,'
   PRINT *, 'THEN PRESS RETURN.'
   READ (*, 5030) ANSWER1
   IF ((ANSWER1 .EQ. 'Y') .OR. (ANSWER1 .EQ. 'y')) THEN
      GOTO 40
   ELSE
      STOP
   END IF
ELSE
   GOTO 40
END IF
5030 FORMAT(A1)

C  IF CHECKING STATUS PASS, THEN OPEN THE FILE.
40  OPEN(UNIT = 12, FILE = FILEOUT, ERR = 20000)
GOTO 99999

C  ERROR HANDLER
20000  PRINT*, 'ERROR HAPPENS WHEN OPENING THE FILE.'
GOTO 99999

99999  END

A5.1.3 para.for

C  RDPG MODEL
C  PAPA.FOR
C  FIND INITIAL PARAMETER VALUES

SUBROUTINE PARA

C  DECLARE VARIABLES

C  P: RAIN-DAY PARAMETERS
REAL P(1:4)
FTOL: TOLERANCE OF THE CALCULATATION
REAL FTOL
FRET: GUESS OF THE MINIMUM VALUE OF THE FUNCTION
REAL FRET
LIM_LOW, LIM_HIGH: RANGE OF RAINFALL DATA IN A DAY
REAL LIM_LOW, LIM_HIGH
RAIN_REALDATA: REAL OR ACTUAL RAINFALL DATA
REAL RAIN_REALDATA(1:100)
INDEX: A INDEX OF RAIN-DAY
INTEGER INDEX

COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ RAIN_REALDATA
COMMON /COM_11/ INDEX

INITIALIZE VARIABLES
NUMBER OF PARAMETERS IN THE TARGET PARAMETER ARRAY
N = 4
FTOL = 1.0E-3
FRET = 1.0E-3

P(1): TIME TO PEAK, P(2): RAIN DISPERSION COEFFICIENT
P(3): RAIN DURATION, P(4): PEAK RATE
P(1) = 0.00
P(2) = 0.01
P(3) = 0.00
P(4) = 0.00

FIND P(4) AND P(1)
DO 820, K = 1, 96
IF (P(4) .GE. RAIN_REALDATA(K)) THEN
  GOTO 820
ELSE
  P(4) = RAIN_REALDATA(K)
  P(1) = K * 15.0
  GOTO 820
END IF
820   CONTINUE

DO J = 1, 96
IF (RAIN_REALDATA(J) .NE. 0.00) THEN
  LIM_LOW = J
GOTO 2100
END IF
END DO

2100  DO M = 96, 1, -1
IF (RAIN_REALDATA(M) .NE. 0.00) THEN
  LIM_HIGH = M
GOTO 2500
END IF
END DO

FIND P(3)
2500 IF ( (LIM_HIGH - LIM_LOW) .LE. 1.0 ) THEN
  P(3) = 15.0
ELSE
  P(3) = (LIM_HIGH - LIM_LOW) * 15.0 / 2.0
END IF
C FIND FINAL P(1)
IF ( (P(1) - P(3)/2) .LE. 0.00) THEN
  P(1) = 15.0
ELSE
  P(1) = P(1) - (P(3) / 2)
END IF

C CALL QUASI-NEWTON ALGORITHM
CALL DFPMIN(P,N,FTOL,ITER,FRET)

C OUTPUT
WRITE (12, 6040) INDEX, P(1), P(2), P(3), P(4)/100.0
END

A5.1.4 dfpmin.for

C RDPG MODEL
C VARIABLE METRIC METHODS OR QUASI-NEWTON METHOD

SUBROUTINE DFPMIN(P,N,FTOL,ITER,FRET)
PARAMETER (NMAX=50,ITMAX=200,EPS=1.E-10)
DIMENSION P(N),HESSIN(NMAX,NMAX),XI(NMAX)
DIMENSION G(NMAX),DG(NMAX),HDG(NMAX)
REAL FP

FP=FUNC(P)
CALL DFUNC(P,G)

DO 12 I=1,N
  DO 11 J=1,N
    HESSIN(I,J)=0.
  11  CONTINUE
  HESSIN(I,I)=1.
  XI(I)=-G(I)
12  CONTINUE
DO 24 ITER=1,ITMAX
  CALL LINMIN(P,XI,N,FRET)
  IF(2.*ABS(FRET-FP).LE.FTOL*(ABS(FRET)+ABS(FP)+EPS))
    RETURN
  FP=FRET
  DO 13 I=1,N
    DG(I)=G(I)
  13  CONTINUE
  FRET=FUNC(P)
  CALL DFUNC(P,G)
  DO 14 I=1,N
    DG(I)=G(I)-DG(I)
  14  CONTINUE
CONTINUE
DO 16 I=1,N
    HDG(I)=0.
    DO 15 J=1,N
        HDG(I)=HDG(I)+HESSIN(I,J)*DG(J)
    15 CONTINUE
16 CONTINUE
FAC=0.
FAE=0.
DO 17 I=1,N
    FAC=FAC+DG(I)*XI(I)
    FAE=FAE+DG(I)*HDG(I)
17 CONTINUE
C ADDED CODE TO PREVENT DIVIDED-BY-ZERO
IF (FAC .EQ. 0.00) THEN
    FAC = 1.0E-15
END IF
IF (FAE .EQ. 0.00) THEN
    FAE = 1.0E-15
END IF
C ADDED CODE ABOVE
FAC=1./FAC
FAD=1./FAE
DO 18 I=1,N
    DG(I)=FAC*XI(I)-FAD*HDG(I)
18 CONTINUE
DO 21 I=1,N
    DO 19 J=1,N
        HESSIN(I,J)=HESSIN(I,J)+FAC*XI(I)*XI(J)-FAD*HDG(I)*HDG(J)+FAE*DG(I)*DG(J)
19 CONTINUE
21 CONTINUE
DO 23 I=1,N
    XI(I)=0.
    DO 22 J=1,N
        XI(I)=XI(I)-HESSIN(I,J)*G(J)
22 CONTINUE
23 CONTINUE
24 CONTINUE
PAUSE 'too many iterations in DFPMIN'
RETURN
END

A5.1.5 library.for

C RDPG MODEL
C LIBRARY.FOR
C STORE THE FUNCTION NAMED AS FUNC

REAL FUNCTION FUNC(P)
DIMENSION P(1:4)
REAL TARGET
C CALL MDLCLC.FOR TO CALCULATE FUNC VALUE
CALL MDLCLC(P, TARGET)
FUNC = TARGET
RETURN
END

A5.1.6 dfunc.for

C  RDPG MODEL
C  DFUNC.FOR
C  GET GRADIENT G(I)

SUBROUTINE DFUNC(P,G)
REAL P(1:4), G(1:4)
REAL X(1:4), X_DX(1:4)
REAL TARGET
REAL F_X
REAL F_X_FORWARD(4), F_X_BACKWARD(4)

C FUNCTION VALUE AT X
DO I = 1, 4
  X(I) = P(I)
END DO
CALL MDLCLC(X, TARGET)
F_X = TARGET

C FUNCTION VALUE AT X+DELTA_X
DO I = 1, 4
  DELTA_X = P(I)/100.0
  IF (DELTA_X .EQ. 0.00) THEN
    DELTA_X = 0.001
  END IF
  DO J = 1, 4
    IF (J .EQ. I) THEN
      X_DX(J) = P(J) + DELTA_X
    ELSE
      X_DX(J) = P(J)
    END IF
  END DO
  CALL MDLCLC(X_DX, TARGET)
  F_X_FORWARD(I) = TARGET
END DO

C FUNCTION VALUE AT X+DELTA_X
DO J = 1, 4
  IF (J .EQ. I) THEN
    X_DX(J) = P(J) - DELTA_X
  ELSE
    X_DX(J) = P(J)
  END IF
END DO
CALL MDLCLC(X_DX, TARGET)
F_X_BACKWARD(I) = TARGET
C \hspace{1cm} \text{PREVENT UNUSUAL CASE}
\hspace{1cm} \text{IF (DELTA_X .EQ. 0.00) THEN}
\hspace{1cm} \text{WRITE (*,*) 'DELTA_X IS 0.00. PRESS ANY KEY TO STOP.'}
\hspace{1cm} \text{PAUSE}
\hspace{1cm} \text{STOP}
\hspace{1cm} \text{END IF}

C \hspace{1cm} \text{GRADIENT ARRAY G(I) BY CENTRAL DIFFERENCE METHOD}
\hspace{1cm} G(I) = (F_X_FORWARD(I) - F_X_BACKWARD(I)) / (2*DELTA_X)

END DO

END

A5.1.7 mdlclc.for

C \hspace{1cm} \text{RDPG MODEL}
C \hspace{1cm} \text{MDLCLC.FOR}
C \hspace{1cm} \text{CALCULATE THE TARGET FUNCTION}

SUBROUTINE MDLCLC(X, TARGET)

C \hspace{1cm} \text{DECLARE VARIABLES}
C \hspace{1cm} X: 4 RAIN-DAY PARAMETERS
REAL X(1:4)
C \hspace{1cm} RAIN MODEL: MODEL RAINFALL DATA
REAL RAIN_MODEL(1:100)
C \hspace{1cm} RAIN_REALDATA: REAL RAINFALL DATA
REAL RAIN_REALDATA(1:100)
C \hspace{1cm} TARGET: TARGET FUNCTION
REAL TARGET
C \hspace{1cm} VOLUME_MODEL, VOLUME_REALDATA: VOLUME OF MODEL & REAL DATA
REAL VOLUME_MODEL, VOLUME_REALDATA
C \hspace{1cm} T: TIME, 15 MINUTE SPACED ON DAILY BASIS
REAL T
C \hspace{1cm} V_DIFFERENCE: VOLUME DIFFERENCE B/W MODEL AND REAL DATA
REAL*8 V_DIFFERENCE
C \hspace{1cm} TERM1, TERM2: TWO PARTS IN CONVOLUTION EQUATION
REAL*8 TERM1, TERM2
C \hspace{1cm} Y1, Y2, Y3, Y4, Y5, Y6: MIDDLE RESULTS
REAL*8 Y1, Y2, Y3, Y4, Y5, Y6
C \hspace{1cm} Z1, Z2, Z3, Z4, Z5, Z6
REAL*8 Z1, Z2, Z3, Z4, Z5, Z6
C \hspace{1cm} COMMONLY USED VARIABLES IN FILES
COMMON /COM_1/ RAIN_REALDATA
COMMON /COM_2/ RAIN_MODEL
C \hspace{1cm} X(1): TIME TO PEAK, X(2): RAIN DISPERSION COEFFICIENT
C \hspace{1cm} X(3): RAIN DURATION, X(4): PEAK RATE
C  INITIALIZE VARIABLES
TARGET = 0.0000
VOLUME_MODEL = 0.0000
VOLUME_REALDATA = 0.0000

C  CONTROL RANGE OF PARAMETERS
IF ( X(2) .LE. 0.01) THEN
  X(2) = 0.01
END IF
IF ( X(2) .GE. 1.0) THEN
  X(2) = 1.0
END IF

IF ( X(1) .LE. 15.0) THEN
  X(1) = 15.0
END IF
IF ( X(1) .GE. 1440.0) THEN
  X(1) = 1440.0
END IF

IF ( X(3) .LE. 15.0) THEN
  X(3) = 15.0
END IF
IF ( X(3) .GE. 1440.0) THEN
  X(3) = 1440.0
END IF

IF ( X(4) .LE. 0.001) THEN
  X(4) = 0.001
END IF

C  BEGIN THE CALCULATION BASED ON CONVOLUTION EQUATION
DO 2010, I = 1, 96
  T = I * 15.0
  Y1 = X(1) - T
  Y2 = X(1) + T
  Y3 = 2 * SQRT(X(2) * T)
  Y4 = EERFC(Y1/Y3)
  Y5 = EERFC(Y2/Y3)
  Y6 = EEXP((X(1)) / X(2))
  TERM1 = 0.5 * X(4) * (Y4 - Y6 * Y5)
  IF ((T - X(3)) .LE. 0.00) THEN
    TERM2 = 0.00
    GOTO 300
  ELSE
    Z1 = X(1) - (T - X(3))
    Z2 = X(1) + (T - X(3))
    Z3 = 2*SQRT(X(2)*(T - X(3)))
    Z4 = EERFC(Z1/Z3)
    Z5 = EERFC(Z2/Z3)
    Z6 = EEXP((X(1)) / X(2))
    TERM2 = 0.5 * X(4) * (Z4 - Z6 * Z5)
  END IF
300  IF ( (TERM1-TERM2) .LE. 1E-15 ) THEN
  RAIN_MODEL(I) = 1E-15
ELSE
RAIN_MODEL(I) = TERM1 - TERM2
END IF

VOLUME_MODEL = VOLUME_MODEL + RAIN_MODEL(I)
VOLUME_REALDATA = VOLUME_REALDATA + RAIN_REALDATA(I)

2010 CONTINUE
C IF MODEL DATA IS NOT GENERATED, STOP THE PROGRAM.
IF (VOLUME_MODEL .EQ. 0.00) THEN
  WRITE (*,*) 'VOLUME_MODEL IS 0.00. PRESS ANY KEY TO STOP.'
  PAUSE
  STOP
END IF
V_DIFFERENCE = ABS(VOLUME_MODEL - VOLUME_REALDATA)
+ / VOLUME_MODEL * 100

C TARGET FUNCTION
TARGET = V_DIFFERENCE
RETURN
END

C CONDITIONAL ERROR FUNCTION
REAL FUNCTION EERFC(Q1)
REAL*8 Q1
IF (Q1 .GE. 4.0) THEN
  EERFC = 0.00
  GOTO 400
END IF
IF (Q1 .LE. -4.0) THEN
  EERFC = 2.00
  GOTO 400
END IF
IF (Q1 .LT. 0.00) THEN
  EERFC = 2.00 - ERFC(-1.0*Q1)
  GOTO 400
END IF
IF ((Q1 .GE. 0.00) .AND. (Q1 .LT. 4.00)) THEN
  EERFC = ERFC(Q1)
  GOTO 400
END IF
400 RETURN
END

C APPROXIMATE ERROR FUNCTION
REAL FUNCTION ERFC(Q2)
REAL A1, A2, A3, A4, A5, A6
REAL *8 Q2, TEMP1, TEMP2

A1 = 0.0705230784
A2 = 0.0422820183
A3 = 0.0092705272
A4 = 0.0001520143
A5 = 0.0002765672
A6 = 0.0000430638

TEMP1=1+(A1*Q2)+(A2*(Q2**2))+(A3*(Q2**3))+(A4*(Q2**4))+(A5*(Q2**5))+(A6*(Q2**6))
+ (A4*(Q2**4))+(A5*(Q2**5))+(A6*(Q2**6))
IF (TEMP1 .EQ. 0.00) THEN
    TEMP1 = 1.0E-2
END IF
TEMP2= TEMP1**16
ERFC = 1 / TEMP2
RETURN
END
C
CONDITIONAL EXPONENTIAL FUNCTION
FUNCTION EEXP(Q3)
REAL Q3
IF (Q3 .LT. -100.0) THEN
    EEXP = 0.0000
GOTO 500
END IF
IF (Q3 .GT. 85.0) THEN
    EEXP = EXP(85.0)
GOTO 500
END IF
EEXP = EXP(Q3)
500   RETURN
END

A5.1.8 linmin.for
C
RDPG MODEL
LINMIN.FOR: FROM PRESS, ET AL., 1986, P 300-301.
IMPLEMENT LINE MINIMIZATION
SUBROUTINE LINMIN(P,XI,N,FRET)
PARAMETER (NMAX=50,TOL=1.E-4)
EXTERNAL F1DIM
DIMENSION P(N),XI(N)
COMMON /F1COM/ NCOM,PCOM(NMAX),XICOM(NMAX)
C
ADDED CODE BELOW TO CONTROL RANGE OF VARIABLES
IF ( P(2) .LE. 0.01) THEN
    P(2) = 0.01
END IF
IF ( P(2) .GE. 1.0) THEN
    P(2) = 1.0
END IF
IF ( P(1) .LE. 15.0) THEN
    P(1) = 15.0
END IF
IF ( P(1) .GE. 1440.0) THEN
    P(1) = 1440.0
END IF
IF ( P(3) .LE. 15.0) THEN
  P(3) = 15.0
END IF
IF ( P(3) .GE. 1440.0) THEN
  P(3) = 1440.0
END IF

IF ( P(4) .LE. 0.001) THEN
  P(4) = 0.001
END IF

C     ADDED CODE ABOVE

NCOM=N
DO 11 J=1,N
  PCOM(J)=P(J)
  XICOM(J)=XI(J)
CONTINUE

AX=0.
XX=1.
BX=2.
CALL MNBRAK(AX,XX,BX,FA,FX,F1DIM)
FRET=BRENT(AX,XX,BX,F1DIM,TOL,XMIN)
DO 12 J=1,N
  XI(J)=XMIN*XI(J)
  P(J)=P(J)+XI(J)
CONTINUE

C     ADDED CODE BELOW TO CONTROL RANGE OF VARIABLES
IF ( P(2) .LE. 0.01) THEN
  P(2) = 0.01
END IF
IF ( P(2) .GE. 1.0) THEN
  P(2) = 1.0
END IF

C     ADDED CODE ABOVE

RETURN
END

C     ADDED CODE FROM PRESS, ET AL, 1986, PAGE 301.
FUNCTION F1DIM(X)
PARAMETER (NMAX=50)
COMMON /F1COM/ NCOM, PCOM(NMAX), XICOM(NMAX)
DIMENSION XT(NMAX)
DO J = 1, NCOM
  XT(J) = PCOM(J) + X * XICOM(J)
END DO
F1DIM = FUNC(XT)
RETURN
END
SUBROUTINE MNBRAK(AX,BX,CX,FA,FB,FC,FUNC)
PARAMETER (GOLD=1.618034, GLIMIT=100., TINY=1.E-20)
FA=FUNC(AX)
FB=FUNC(BX)
IF(FB.GT.FA)THEN
  DUM=AX
  AX=BX
  BX=DUM
  DUM=FB
  FB=FA
  FA=DUM
ENDIF
CX=BX+GOLD*(BX-AX)
FC=FUNC(CX)
1 IF(FB.GE.FC)THEN
  R=(BX-AX)*(FB-FC)
  Q=(BX-CX)*(FB-FA)
  IF (2.*SIGN(MAX(ABS(Q-R),TINY),Q-R) .EQ. 0.00) THEN
    U=BX-((BX-CX)*Q-(BX-AX)*R)/1.0E-15
  ELSE
    U=BX-((BX-CX)*Q-(BX-AX)*R)/
      + (2.*SIGN(MAX(ABS(Q-R),TINY),Q-R))
  END IF
ULIM=BX+GLIMIT*(CX-BX)
IF((BX-U)*(U-CX).GT.0.)THEN
  FU=FUNC(U)
  IF(FU.LT.FC).THEN
    AX=BX
    FA=FB
    BX=U
    FB=FU
    GO TO 1
  ELSE IF(FU.GT.FB).THEN
    CX=U
    FC=FU
    GO TO 1
  ENDIF
  U=CX+GOLD*(CX-BX)
  FU=FUNC(U)
ELSE IF((CX-U)*(U-ULIM).GT.0.)THEN
  FU=FUNC(U)
  IF(FU.LT.FC).THEN
    BX=CX
    CX=U
    U=CX+GOLD*(CX-BX)
    FB=FC
    FC=FU
    FU=FUNC(U)
  ENDIF
  ELSE IF((U-ULIM)*(ULIM-CX).GE.0.)THEN
    U=ULIM
    FU=FUNC(U)
  ELSE

U = CX + GOLD * (CX - BX)
FU = FUNC(U)
ENDIF
AX = BX
BX = CX
CX = U
FA = FB
FB = FC
FC = FU
GO TO 1
ENDIF
RETURN
END

A5.1.10 brent.for
C     RDPG MODEL
C     DO PARABOLIC INTERPOLATION

FUNCTION BRENT (AX, BX, CX, F, TOL, XMIN)
PARAMETER (ITMAX=200, CGOLD=.3819660, ZEPS=1.0E-10)
A = MIN(AX, CX)
B = MAX(AX, CX)
V = BX
W = V
X = V
E = 0.
FX = F(X)
FV = FX
FW = FX
DO 11 ITER = 1, ITMAX
XM = 0.5 * (A + B)
TOL1 = TOL * ABS(X) + ZEPS
TOL2 = 2. * TOL1
IF (ABS(X - XM).LE.(TOL2 -.5*(B-A))) GOTO 3
IF (ABS(E).GT.TOL1) THEN
R = (X - W) * (FX - FV)
Q = (X - V) * (FX - FW)
P = (X - V) * Q - (X - W) * R
Q = 2. * (Q - R)
IF(Q.GT.0.) P = -P
Q = ABS(Q)
ETEMP = E
E = D
*     P.GE.Q*(B-X)) GOTO 1
IF (Q .EQ. 0.00) THEN
Q = 1.0E-15
END IF
D = P / Q
U = X + D
IF(U-A.LT.TOL2 .OR. B-U.LT.TOL2) D = SIGN(TOL1, XM-X)
11
GOTO 2
ENDIF
1       IF(X.GE.XM) THEN
      E=A-X
ELSE
      E=B-X
ENDIF
    D=CGOLD*E
2       IF(ABS(D).GE.TOL1) THEN
      U=X+D
ELSE
      U=X+SIGN(TOL1,D)
ENDIF
    FU=F(U)
    IF(FU.LT.FX) THEN
      A=X
    ELSE
      B=X
ENDIF
    V=W
    FV=FW
    W=X
    FW=FX
    X=U
    FX=FU
ELSE
    IF(U.LT.X) THEN
      A=U
    ELSE
      B=U
ENDIF
    IF(FU.LE.FW .OR. W.EQ.X) THEN
      V=W
    ELSE IF(FU.LE.FV .OR. V.EQ.X .OR. V.EQ.W) THEN
      V=U
    ELSE
    ENDIF
ENDIF
11    CONTINUE
PAUSE 'Brent exceed maximum iterations.'
3     XMIN=X
BRENT=FX
RETURN
END

A5.2 RDPG model input file
The input file for RDPG model is actual historical 15-minute rainfall data for each station on daily basis. This demo example is part of file 0428f_2.txt for station 1429.

```
TX  0428  7 in 01/01/1984  0.01  0.02  0.03  0.04  0.05  0.06  0.07
0.08 0.09 0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07
0.08 0.09 0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07
0.08 0.09 0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07
```

A5.3 RDPG model output file

The output file for RDPG model is rain-day parameters for each station on daily basis. This demo example is part of file 0428f_2.txt for station 0428f_3.txt.

```
STN ID: station identification number
T_RAINS: total number of rain-days
RAIN_NUM: rain number, index number of rain-day
```
RAIN_CTR: rain center, also called time to peak, which is the time that maximum precipitation occurs
RAIN_DSP: rain dispersion coefficient, which indicates the spread-out pattern of rainfall event
RAIN_DRT: rain duration, duration of rainfall event
PK_RATE: peak rate, maximum precipitation of a rainfall event