

## Appendix A

# QUALITY CHECKING AND SELECTION OF RAINFALL DATA

## A1 QUALITY CONTROL

Initially, length of record is the most important criterion for selection. Many stations have only short records or are newly established. They add little information on the long-term variability of rainfall. From the 245 stations in the database, 94 were selected as having more than 5 complete years of data.

Records from these 94 stations were subject to quality control tests. These tests included:

- checks for monthly and annual totals outside the range expected, either on statistical grounds or by comparison with records from neighbouring stations;
- checks for unexpected zero values on the same grounds;
- checks for data repeated on successive days or on the same day in the following year;
- checks for repeated months of daily data, either in consecutive months or for the same month in consecutive years;
- some checks on repeated data between stations.

A monthly summary of data from the 94 stations was produced to help in the interpretation of the quality checks described.

These tests revealed a number of cases of repeated data, some months and in some cases years where zero rainfall is entered when the data should be entered as 'missing', and a few cases of unexpected zero rainfall and extreme or unrealistically high values. One result was to highlight stations where the time-series is unrealistic in the sense that recent years have consistently much higher rainfall than earlier years. The most obvious case of this is Ibb where in recent years annual totals of 3500mm are claimed. This record and one other were rejected completely; others were corrected as far as possible, usually by omitting particularly questionable data by months or years.

It must be stated that the modifications made to the data at this stage are an attempt to clean the data set for use in this project. They are not a substitute for the essential task of reviewing and evaluating the national database of rainfall in Yemen. That this task is essential is beyond doubt given the results of this preliminary review of the daily data.

During this review of the daily rainfall data, one further and highly significant feature became obvious. At some stations it is clear that rainfall is recorded less frequently and in greater amounts than in earlier years at the same station. The most likely explanation is that rainfall (or the lack of it) is not recorded every day and that falls are allowed to accumulate until the gauge is read at irregular intervals of several days or even weeks.

This finding is of some importance to the analysis of storm rainfall. It directly affects any analysis of the probability distribution of daily falls, and it means that rainfall ascribed to a particular day could have fallen in any of the days since the gauge was last read. This affects the linkage of rainfall events to observed floods. It also affects attempts to carry out rainfall runoff modelling on a daily time scale, where runoff generation is directly affected by the sequence of rainfall. A few high rainfalls at intervals of several days will give a quite different result to a true daily sequence of correctly measured values.

A test was devised to check for years when accumulations of rainfall are suspected. A reasonably effective test is to compute the ratio of days with less than 15mm (excluding all zero or missing records) to days with more than 15mm recorded. An example of the time series of this ratio is shown in Figure A1 for station 717 Wash'ha. The series of values around 0.5 are typical of the early years when diligent reading of the gauge is assumed. In the later years, the ratio becomes unacceptably high, and reference to the record itself confirms the absence of the lower rainfalls that should be expected.

This test identified 137 station-years from 31 stations affected by this process of rainfall accumulation between gauge readings, mainly years in the 1990s indicating a general deterioration in the quality of rainfall measurement in recent years. A threshold of 0.75 for the ratio was used as a criterion for rejection. All years of record with a ratio exceeding this value were removed from the active data set.

## **A2 A REVIEW OF THE DIFFERENCES BETWEEN MANUAL AND AUTOMATIC STATIONS**

The finding that quality of daily records has been deteriorating in recent years has some bearing on the choices for future monitoring and the flood warning system.

As the historical records derive from a number of sources, usually past projects, there are records from recording as well as manual stations throughout the last three decades. Significant differences might be seen when the stations are segregated according to their type. In recent years NWRA have installed and are continuing to install recording stations based on solid-state technology.

Four sets are used in this comparison:

- a 37-station set using all years of data - all manually read stations
- a 37-station set after censoring years with suspicious accumulations
- a 17-station set of automatic modern stations (with more than 1 complete year of data)
- a 25-station set of automatic historical stations with more than 3 complete years of data.

For each set a frequency table was compiled giving the number of days when rainfall was recorded in intervals of 5mm. The results are accumulated as a frequency of exceedence and plotted in Figure A2a.

The results from the two sets of recording stations are reasonably comparable. Some differences might be expected as the records from the recording stations are short and cover different periods. The result for the 37-station set plots significantly to the right indicating a higher proportion of larger rainfalls in the data from these manual stations, even though this set includes many station-years of good quality data. The results for the censored set lie between the extremes indicating that the censoring has been partially successful.

Closer examination suggests that the main issue is the recording of rainfalls of less than 5mm. This has been noticed before [TSHWC 1992]. Re-working of the data to omit rainfalls (raindays) of less than 5mm results in Figure A2b where it can be seen that the censored set now gives results that are comparable with the recording stations. It is clear that all frequency analysis should not include rainfall from years when accumulations of rainfall are suspected.

Regarding future rainfall monitoring, higher quality data are likely to result from recording rainfall stations (tipping bucket gauges with solid-state recording devices). There is a down-side to this. It is noticeable that none of the historical recording stations have produced as much as ten years of complete data. Also the data return measured in terms of complete data as a percentage of the nominal period of operation of the station is only about 75% for the recording stations compared with about 95% for the manual stations.

### **A3 SELECTION OF DATA**

Two main types of analysis are envisaged:

- one is concerned with the statistical characteristics of daily rainfall - the probability distribution of daily falls and the relationships between number of days of rain and the monthly and annual totals;
- the second for analysis of the regional variation in rainfall across the country on a monthly or annual time-scale.

The first requires data of a higher standard than the second. The monthly and annual totals are less affected by the accumulation of rainfall in the gauge whereas the statistical characteristics of the daily data are rendered meaningless if the records are not a true record of daily rainfall.

Different criteria were adopted to define data sets for these purposes. For the statistical analysis, a minimum of 10 years of complete data are desirable, exclusive of years rejected as having suspiciously large accumulations of rainfall. 37 stations met this criterion out of the 94 stations included in the quality checking procedure described above.

For the regional analysis, the records for years of suspicious accumulations were included and the 94-station set used for quality checking was reduced to 68 stations - partly by rejecting stations that are in areas not relevant to the catchment areas of the main wadis, and partly as a result of unacceptable data revealed by the quality checks.

Table A1 summarises these 68 stations, indicates which are included in the 37-stations set, and indicates their position and mean monthly rainfall.

**Table A.1 Rainfall stations selected for daily, monthly and annual analysis**

NWRA station ID		First year	Last year	Years of record		Position (km)	
				nominal	complete	E	N
58	Kudayhah	1981	1992	7	6	330.4	1493.0
60	Habashi	1982	2000	15	11	368.3	1496.5
65	Hajdah	1980	2000	13	11	370.2	1502.0
68 **	Taizyard	1974	1990	13	11	394.4	1502.3
81 **	Al-Udein	1977	1997	14	14	401.0	1542.4
82	Ibb-1	1981	1991	11	5	413.6	1544.2
87 **	Addalil	1980	2000	17	16	411.8	1560.8
89 **	Aljirbah	1969	1992	18	15	330.9	1564.9
94 **	Rihab	1969	2000	28	27	411.9	1571.9
96 **	Alqahmah	1978	2000	18	15	331.0	1577.8
99	Madaf	1982	1991	10	5	480.7	1580.9
101 **	Almahatt	1978	2000	18	16	316.6	1581.6
104 **	Basat	1978	2000	19	18	323.8	1585.2
109	Ashshaqb	1975	1985	10	6	444.0	1588.0
110	Mishrafa	1978	2000	15	10	345.4	1588.8
111 **	Addimnah	1978	2000	19	17	331.1	1588.9
113	Alkhadra	1981	1992	12	6	471.0	1590.3
115 **	Khabar	1976	1993	18	12	481.4	1590.4
118 **	Rada'	1976	1992	17	12	482.4	1594.0
120 **	Sanaban	1976	1988	13	13	463.6	1594.5
124	Habaka	1981	2000	14	11	361.7	1597.9
125 **	Samah	1975	1988	13	11	444.2	1601.1
127	Azzuwab	1980	1994	14	7	480.6	1603.1
134 **	Dhamar-1	1975	1988	14	10	435.5	1607.7
136 **	As-Sanam	1978	2000	19	16	421.0	1608.7
139 **	Maram	1975	1989	15	14	457.8	1612.8
141	Addarb	1976	1984	8	7	430.1	1613.5
146 **	Masna'ah	1975	2000	22	15	415.6	1619.8
148 **	Ashshirq	1981	2000	15	12	388.7	1618.0
149	Dafrd	1978	1990	13	9	428.0	1626.3
151 **	Al-Hamal	1979	2000	18	14	387.0	1631.0
158	Rizwa	1975	1987	13	8	409.8	1634.7
159 **	Aldabira	1981	2000	15	14	369.1	1634.7
161	Gumischa	1972	1977	6	5	293.4	1637.7
165	Maghreba	1981	1992	7	7	335.0	1644.2
169 **	Dhaf	1975	1988	13	11	422.3	1646.8
173	Alfowara	1981	1991	7	7	408.6	1658.5
174 **	Al-Amir	1979	2000	18	17	360.2	1662.4
183 **	Al-Haima	1979	1999	18	16	381.8	1667.9
185	Asal-A	1986	2001	10	6	455.5	1669.6
192	Qadam-A	1984	2000	15	5	352.0	1671.9
217	Khamis-A	1978	1992	11	7	340.2	1679.3
222	Khamlu-A	1984	2000	14	8	330.3	1692.3
238	Addahi-A	1984	1992	9	7	290.8	1682.3
243	Assalf-A	1978	2000	19	7	385.8	1683.4
255	Yusuf-A	1984	1997	12	7	373.4	1685.4
280	Mind	1972	1979	7	5	399.7	1690.3
288	Zuhaif-A	1984	1992	9	8	329.4	1692.3
298	Ghamr-A	1984	2000	16	7	344.6	1695.4
371	Mayan-A	1984	2000	17	5	381.5	1709.1
384	Sana'a	1974	1979	6	5	416.7	1711.2
389	Mahwit	1974	2000	18	11	344.4	1710.5
436	Darwan	1972	1979	7	6	401.0	1719.8
469 **	At-Tur	1974	2000	22	18	326.7	1723.6
485 **	Hajjah	1974	2000	20	13	350.0	1734.4
505 **	Khamir	1972	2000	20	13	389.4	1769.2
679 **	Milh	1974	2000	20	17	266.0	1733.3
717 **	Wash'ha	1975	2000	18	13	327.2	1797.3
721	Zuhrah	1972	1992	15	7	287.4	1736.8
722 **	Shibam-T	1975	2000	19	16	383.8	1715.8
724 **	Shamiri	1979	2000	16	12	322.6	1657.2
725 **	Wallan	1980	1999	16	15	421.2	1671.4
726 **	Waqir	1979	2000	17	15	315.3	1646.2
727 **	Zinqah	1979	2000	17	14	331.6	1662.6
728	Sukhnah	1979	2000	17	13	331.4	1638.7
729 **	Wadi-Har	1975	2000	20	17	417.4	1605.0
730 **	Yarim	1969	2000	25	24	433.5	1581.0
731 **	Zabid	1969	2000	27	22	321.9	1568.6
720 **	Saqayn	1975	1992	12		343.8	1865.4

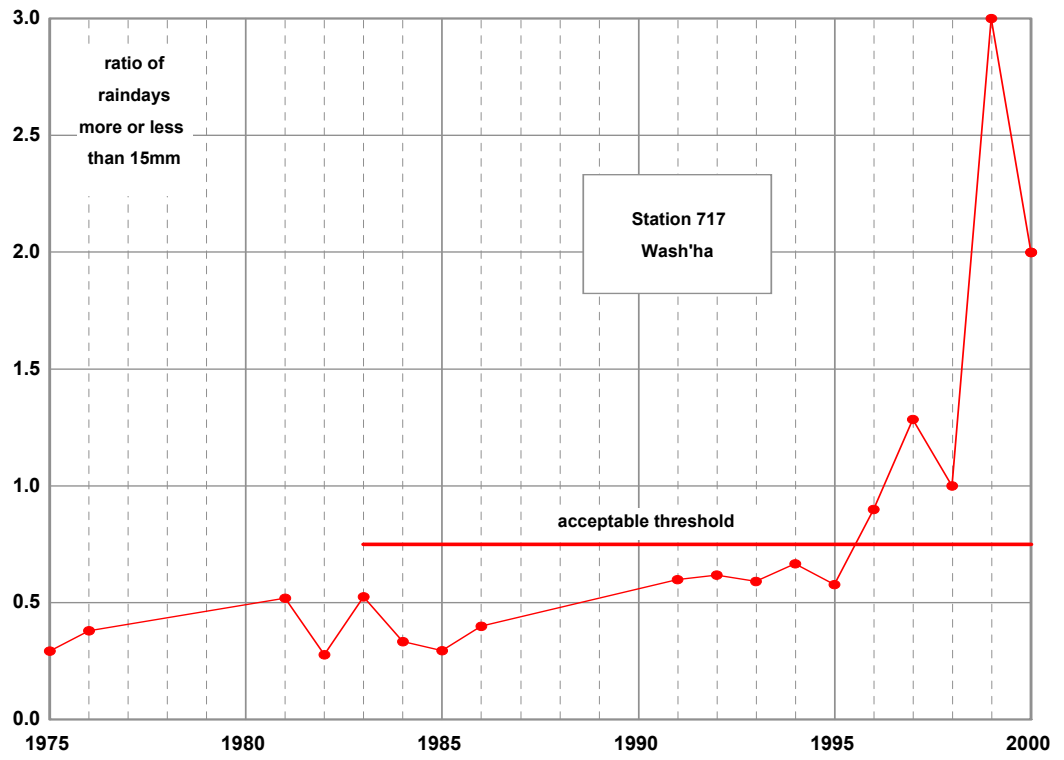
Notes: \*\* indicates the station is included in the 37-stations set  
station 720 is included in the 37-station set but not in the 68-station set

**Table A.2 Mean monthly and annual rainfall for the selected stations (mm)**

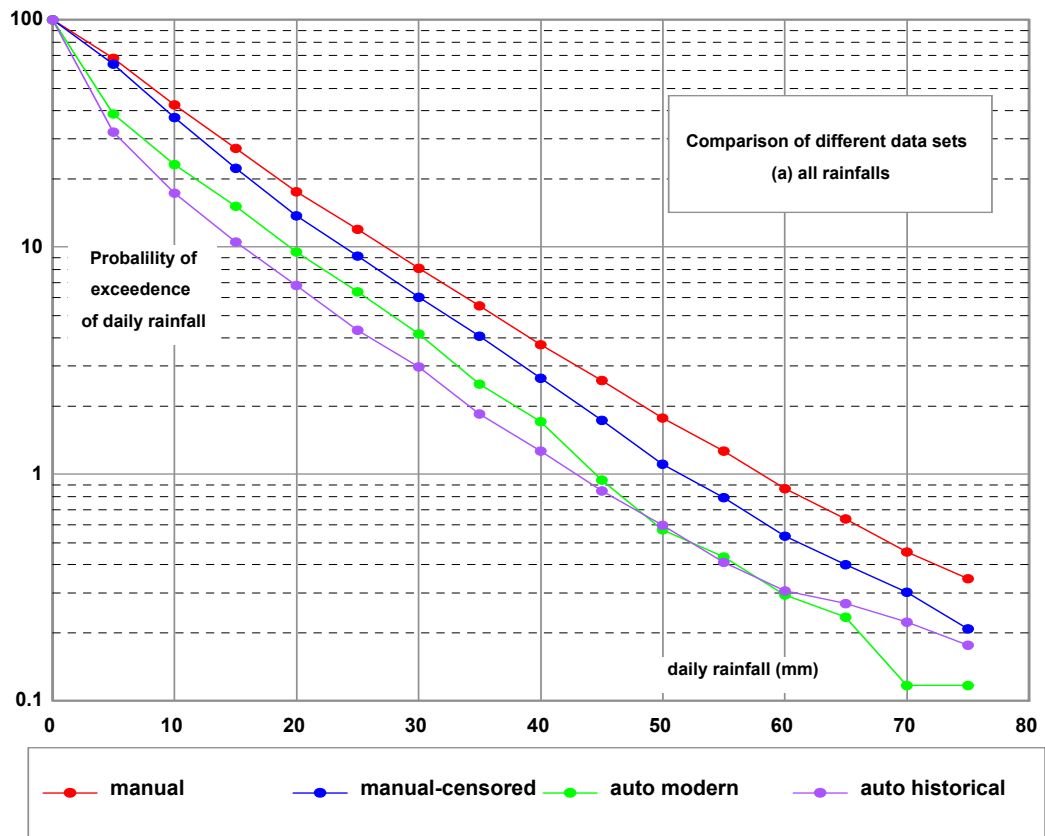
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Sum
58	13	10	9	28	33	5	4	11	28	16	14	4	181	175
60	7	9	20	75	111	83	58	76	118	45	26	6	646	634
65	2	9	23	46	43	40	33	33	50	20	4	1	295	304
68	7	15	38	79	99	71	62	84	106	83	10	5	676	659
81	6	19	51	113	124	104	133	109	90	67	25	9	850	850
82	9	11	46	79	116	125	163	157	104	21	17	2	854	850
87	6	7	55	92	97	76	105	126	63	32	21	6	691	686
89	4	11	12	21	46	6	38	66	110	52	5	1	377	372
94	5	9	34	75	98	46	91	118	55	32	14	3	582	580
96	8	7	19	11	50	14	40	60	80	33	9	2	324	333
99	4	9	23	34	21	4	8	29	3	0	2	2	129	139
101	10	5	14	8	28	11	20	44	44	24	11	4	229	223
104	7	7	14	8	44	23	32	56	90	50	14	4	352	349
109	1	3	24	23	24	11	30	46	16	14	1	3	169	196
110	21	14	37	33	70	18	53	50	46	31	17	9	447	399
111	8	1	14	22	65	22	46	58	77	64	20	12	422	409
113	4	14	46	42	22	2	22	38	9	2	4	2	211	207
115	13	11	39	42	22	3	23	46	6	6	3	2	234	216
118	13	14	53	32	24	4	22	35	7	6	4	2	218	216
120	3	12	40	32	23	3	22	33	7	14	3	0	192	192
124	5	7	20	36	41	28	67	90	16	14	3	0	342	327
125	3	6	34	48	32	1	40	68	18	11	3	2	246	266
127	5	15	26	35	26	10	12	21	3	3	3	1	206	160
134	2	16	45	66	53	5	61	117	14	11	7	3	403	400
136	10	21	62	77	32	25	46	74	27	14	6	8	405	402
139	4	11	43	44	30	3	28	60	4	7	6	2	228	242
141	6	9	80	44	46	23	58	76	18	6	25	10	390	401
146	8	12	52	63	44	24	53	78	35	22	18	16	430	425
148	13	38	31	94	89	52	56	125	47	42	17	14	582	618
149	7	14	50	52	29	6	43	65	6	4	3	7	299	286
151	5	5	45	80	83	45	62	117	39	31	7	5	529	524
158	2	5	64	87	50	10	24	44	10	8	14	5	265	323
159	11	6	23	42	34	19	21	39	16	19	2	6	239	238
161	2	3	11	13	1	0	3	11	12	16	6	0	76	78
165	20	50	112	107	78	16	53	100	48	25	54	15	676	678
169	2	7	59	84	40	2	29	63	7	7	5	5	296	310
173	24	19	83	52	37	25	21	33	7	2	5	3	312	311
174	9	8	49	94	94	22	76	84	27	25	25	8	509	521
183	4	8	38	65	49	25	53	74	18	15	4	3	356	356
185	2	6	28	60	2	1	22	19	10	12	0	3	158	165
192	1	4	6	42	60	15	52	57	20	13	7	3	288	280
217	1	7	5	48	54	29	57	83	48	6	2	6	352	346
222	1	5	7	30	48	24	36	87	42	19	6	5	326	310
238	0	5	2	12	12	1	7	39	32	16	1	4	130	131
243	4	10	48	109	38	14	105	120	15	14	14	18	442	509
255	2	4	16	77	71	61	99	114	36	13	10	5	495	508
280	4	1	20	41	57	6	56	66	41	9	2	2	291	305
288	10	13	18	70	81	35	54	106	47	18	14	13	481	479
298	2	5	26	74	60	33	33	74	31	25	17	6	378	386
371	3	9	25	58	29	13	35	51	3	4	3	10	254	243
384	6	3	24	43	38	3	47	44	8	19	7	1	239	243
389	12	19	33	106	96	42	80	140	68	49	23	8	631	676
436	4	1	10	31	41	4	44	60	4	10	2	2	227	213
469	3	4	17	48	86	55	64	107	78	52	17	2	467	533
485	0	10	46	90	68	31	62	88	30	12	8	12	501	457
505	1	1	37	60	31	24	36	42	2	7	1	2	209	244
679	8	3	2	4	9	1	4	13	2	8	11	6	72	71
717	14	9	31	74	77	24	46	62	24	39	16	17	422	433
721	6	4	3	13	27	2	20	27	27	43	5	17	176	194
722	5	8	41	77	54	28	78	129	11	14	8	1	461	454
724	5	3	8	29	74	29	43	86	124	53	26	7	492	487
725	2	8	46	58	34	11	17	54	7	17	9	5	273	268
726	3	9	7	21	37	28	39	71	74	65	16	2	389	372
727	1	2	21	32	50	46	72	106	74	22	14	1	455	441
728	9	8	17	43	80	46	58	101	90	54	30	6	571	542
729	5	16	46	66	68	34	90	80	35	19	19	1	475	479
730	8	21	57	82	87	47	95	159	43	16	10	5	630	630
731	11	4	7	9	19	3	20	34	49	35	6	0	193	197

Note: The column marked 'Sum' shows the sum of the monthly averages for each station. When there is much missing data, this is usually a better estimator of the mean annual rainfall than the mean of the totals for complete years.

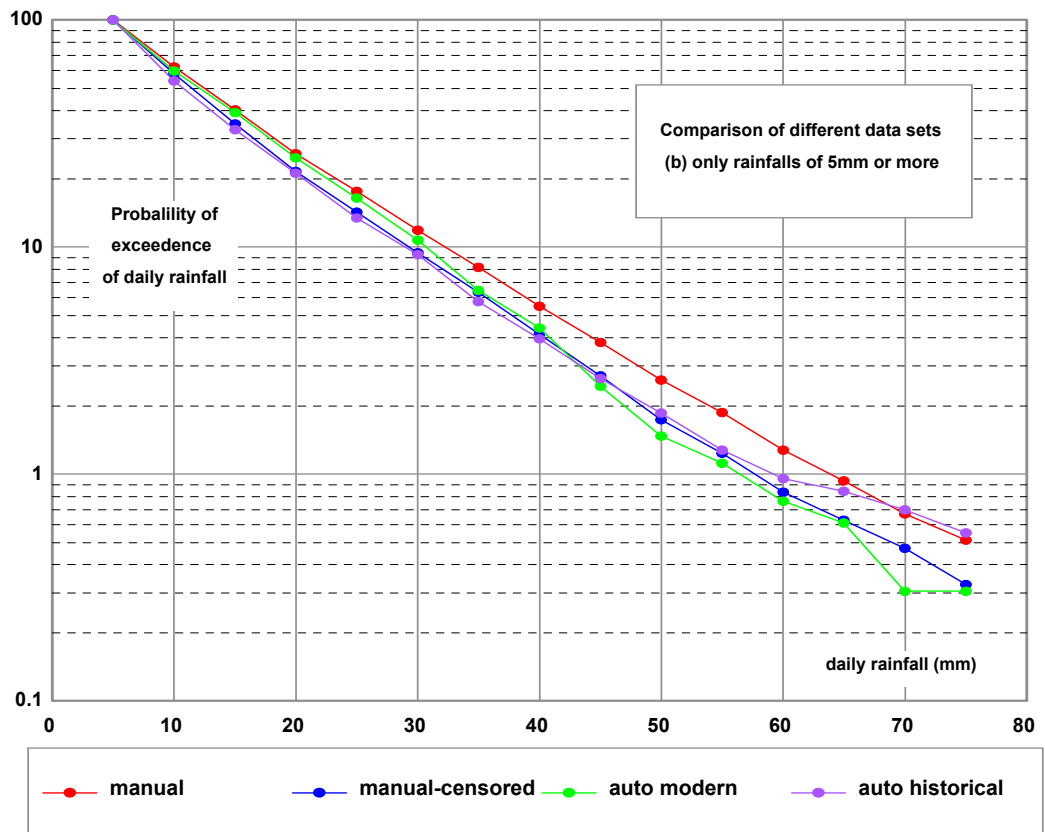
**Figure A1**      **Deterioration in quality of daily rainfall records**



**Figure A2a** Effect of data source on rainfall frequency analysis



**Figure A2b** Effect of data source on rainfall frequency analysis



## Appendix B

# FLOODSIM THE FLOOD AND BASEFLOW SIMULATION MODEL

This Appendix describes how to use the program and what steps to take in setting and testing parameter values. It does not explain why the program is the way it is. That has been described in the main report, primarily Chapter 4.

## B1 BACKGROUND

*FloodSim* is a stochastic model that can generate sequences of flood volumes, baseflows and hydrographs from parameters that together describe the statistical features of these variables. For example, if we know that the historical record of flood volumes can be described as a statistical distribution - the normal distribution perhaps - and that they appear as a random sequence with no tendency for large floods to follow large floods or small floods to follow small ones, it follows that we can generate a possible sequence of flood volumes by drawing values randomly from that distribution. All we need to know (in the case of the normal distribution) is the mean and the standard deviation. A similar procedure can be followed when assigning the flood volumes to months of the year and days in the month. Provided that we can specify the statistics of the distribution of floods in time, we can generate a realistic time series from the statistical description.

It follows that no two generated sequences will be the same (unless the random number generator is constrained), just as in reality there are variations in the statistics of floods over all time scales.

Models of this type are different from conceptual models that attempt to describe the process of flood formation from known rainfall patterns, catchment characteristics and hydrological knowledge about how the transformation from rainfall to floods can be described. Those models are limited in their application by the rainfall data available, although it is possible to use generated rainfall sequences when local data are inadequate. They normally produce a flood sequence that is only as long as the records of rainfall. A stochastic model of the kind presented here is not limited in this way. A large number of short or long sequences can be generated, all of which have the same underlying statistical properties.

The choice of model depends on the data available and whether the model parameters can be regionalised or transferred to areas where direct model fitting is impossible because there are insufficient data to calibrate or verify any kind of model. We have discussed in Chapter 4 the reasons for adopting the stochastic approach. This Appendix is concerned with the practical issues of how to use the model - specifically the *FloodSim* program that has been developed for this project - and how to choose parameter values and test the results.

The output in hydrograph form, is intended, primarily, as an input to the SMM and use of the hydrographs for spate management is described elsewhere.



## Program form

The program comprises three parts: A Visual Basic applications program that provides a user-interface, a Fortran program that carries out the number-crunching, and an Access database that stores parameter values from previous and current runs of the model. Only the VB screens are available at run time. The Fortran program is available as a dynamic linked library file (dll) and the Access database can be interrogated independently in the normal way.

This appendix covers model operation using the VB screens and the setting of options and parameter values.

## Model components

The simulation procedure is in three main parts:

- 1 a generator for flood events and their days of occurrence;
- 2 a generator for monthly baseflow;
- 3 a procedure for deriving 15-minute flood hydrographs for the flood events.

In addition there are procedures for computing statistics of the simulated sequences for comparison with the known or expected values.

Part 1 can be used in isolation, and this is a recommended first step when applying the model to a new wadi basin.

Part 2 requires Part 1 because baseflow is believed to be defined to some degree by the volume of flood runoff.

And Part 3 requires Parts 1 and 2, although it is possible to generate flood hydrographs alone, in which case Part 2 can be ignored and the baseflow will be shown as zero.

## B2 INSTALLING THE PROGRAM

The installation program is on the CD "FloodSim".

Run *Setup.exe* and when asked for the install location enter **D:\FloodSim**

After installation, set up the following directory structure:

```

D:
|..... FloodSim
|..... Fortran
|..... Working
|..... Data

```

Move the following files into Fortran: **FloodSim.dll**

Move the following files into Data: **Log.dat**

Move the following files into Working: **Floods.mdb**, and all the remaining **.dat** files

The program expects the Access database **Floods.mdb** to be in the directory Working. The internal program links are specified in code and cannot be changed externally.

The VB screens will fill the display if the monitor display setting is set to 1024\*768 pixels and if the font size is set to 'small fonts' on the Windows Display\Settings\Advanced menu.

## **B3 RUNNING THE PROGRAM - OVERVIEW**

Start the program by double-clicking **FloodSim.exe** or by using the Run procedure in Windows or the program icon on the desktop.

Click 'Start' on the opening screen to give access to the main screen.

The program can now be used in three ways, which are illustrated in Pictures 1 to 3 in the following pages.

- 1 Picture 1 shows the main screen on first opening. The identifier (ID) of all previous runs is shown on the left side of the screen, and by selecting an ID from the list, all the control information and parameter values can be reviewed.
- 2 Picture 2 shows the main screen after clicking on the 'Prepare a new simulation' button. The ID and control information and any of the parameter values can now be changed and the simulation can be run for this data set by clicking on the 'Run the program' button.
- 3 Picture 3 shows the screen that is available on clicking the 'See the file Browser' button on the main screen, either when working in review mode (Picture 1) or to see the output of the current simulation (Picture 2). A split screen facility is provided to enable comparison between output of two simulations.

Any of the output files for all completed runs are available for review. The choice is described in section B6 below.

The parameters for each ID are automatically entered into an Access database called Floods.mdb whenever they are saved or when the simulation is run. The output files are labelled with the run ID and saved as text files in the Working sub-directory. The use of these files in model fitting, transfer of hydrographs to the SMM, and to provide general statistical information is described in later sections of this Appendix.

All output files can be regenerated from the control information and parameters values saved in the Floods.mdb database.

## B4 SETTING THE PROGRAM CONTROL INFORMATION

The Program control part of the Main screen looks like Picture 4 when the program is first started.

Picture 4

The *Simulation identifier*, (ID) uniquely defines a set of control variables and parameter values. It comprises a 2-character code defining the wadi, ZD for Zabid for example, and a 3-digit number.

If the *Status of the parameter set* is ‘locked’, it means that this data set has already been used for a simulation and that there are results available. This ID cannot be used again.

If the *Status of the parameter set* is ‘open’, it means that this data set has been saved temporarily during editing and that it has not yet been used for a simulation.

The *Random number seed* controls the starting value of the random number generator during the simulation. A value of 9999999 ensures that the simulation uses a seed chosen randomly by the computer. In this case each simulation carried out with the same parameter set would give a slightly different result. Any other value for the seed (integer up to 7-characters) will give a repeatable result.

A *Description of the simulation* is a short note written by the user to describe the purpose of the simulation that might otherwise be forgotten. It is stored with the data set in Floods.mdb.

The *Model version* refers to the parameter description of the variability of monthly flood events. It is described in more detail in section B5.

*Number of years* refers to the length of the simulation of flood events. The maximum allowed is 1000 years. Use of a long period reduces the sampling variance of the statistics derived from the simulated sequence of floods, but can produce large output files.

The section labelled *Derive a 15-minute hydrograph* can be used in several ways. When ‘No’ is selected, the simulation provides only the characteristics of flood events (volume, peak and so on) and no hydrographs are computed.

When 'Yes' is selected, the program derives hydrographs for the full sequence and computes various statistics based on the full period of simulation. However, details of these hydrographs are not sent to an output file unless the *number of years* is greater than 0. The *start year* identifies the first simulation year for which hydrographs are sent to the output file.

The lower part of the screen provides a reminder of the location of the output files and of the units used for the parameters and within the program. Where different units are used on the output files, these are identified in the files themselves.

When the *Prepare for a new simulation* button is clicked, the Program control changes to that shown in Picture 5.

**Picture 5**

**Program control**

Simulation identifier:

Wadi name:

Random number seed:

Description of simulation:

Model version:  Version 1  Version 2

Number of years: length of synthetic record  years

Derive a 15-minute hydrograph?:  Yes  No

number of years:

start year:

Text files for output can be found in this folder:

Program units:  
 Flood and baseflow volume - thousand m3 (tcm)  
 Rainfall - mm  
 Area - km2  
 All parameters must be consistent with these units

It is now possible to save a new parameter set using the *Save the data* button, and to start the simulation program by clicking on the *Run the program* button. It is no longer possible to review previous parameter sets.

Previous results files can still be reviewed by clicking the *See the file browser* button.

Provided that the ID has not been used in a previous simulation, it can be used to identify the data set to be saved. If it has been used, it should be changed.

An unused data set can be saved repeatedly using an ID for an 'open' data set. This allows for time spent on editing parameters.

When the program is closed either by clicking on the *Close* button (see Picture 1) or on the normal Windows close button in the top right-hand corner of the screen, the user will be prompted to save the data set.

The data are also saved when the *Run the program* button is clicked just before the simulation starts. The data set is marked as 'locked' only when a successful simulation is completed.

In addition to the access provided by the screens, the control and parameter data sets can be reviewed or sorted in the database Floods.mdb. These data should not be edited but queries can be written to filter the data or to produce reports.

Similarly, the output files (in text format) can be accessed directly for use in spreadsheets or in reports.

## B5 SETTING THE PARAMETERS

This section defines the parameters and shows how they are represented on the main screen. A later section, B7, gives some guidance on how parameter values should be chosen, and how the parameter set can be tested.

Parameter sets are saved to the Access database Floods.mdb. For reference, Table B1 defines the field names used in that table.

### Parameters for flood events

Simulation of the floods as a sequence of individual events characterised by volume, peak and duration is the first part of the model. Picture 6 shows the complete set of parameters for this process for Version 1 of the model. The variation involved in Version 2 is described later in this section.

Picture 6

**Parameters for floods**

Mean and coefficient of variation of monthly flood events based on:  number of events  volume

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	0.11	0.06	0.94	4.56	6.33	4.39	7.33	12.22	7.06	1.83	0.39	0.17
CV	4.24	4.24	1.52	0.81	0.7	0.91	0.6	0.45	0.73	1.42	3.2	2.3

Derivation of flood duration from volume

linear  $y = a + b.x$       a:       b:

non-linear  $y = a * x^b$

Definition of exceptional flood events

mean volume	<input type="text" value="25000"/> tcm	Frequency (% of years)	<input type="text" value="1"/> March
standard deviation	<input type="text" value="5000"/> tcm		<input type="text" value="3"/> April
			<input type="text" value="7"/> May

Distribution of population of flood volumes

mean  tcm      standard deviation  tcm

Selection of flood days

random within month (non-repeating)

random within month (repeating)

Parameters in the *Distribution of population of flood volumes* box fix the mean and standard deviation of floods from which samples will be drawn. These parameters are expressed in arithmetic terms meaning that they are the normal mean and standard deviation of the series. The program transforms these parameters into logarithmic terms for use with the log-normal distribution of flood volumes that is the basis of the model.

The number of floods in each month of the year is controlled by the parameters in the *Mean and coefficients of variation of monthly flood events* box. These can be expressed in terms of the numbers of flood events or in terms of the aggregate monthly volume of events by clicking one of the options available. The mean and coefficient of variation (CV) must be entered for each month. If the value for the mean for a dry month is 0, then 0 should also be entered for the CV.

In some wadi basins exceptional events are occasionally seen in the months March to May. The frequency of these events is low - of the order of once every ten years on average - and they cannot be represented adequately by the statistical distribution of all floods. The box marked *Definition of exceptional flood events* allows these events to be specified by *mean* and *standard deviation* of volume and by *frequency* of occurrence in terms of the percentage of years that such exceptional events occur in each of the three months. For example, 3% for April means that an exceptional event will be simulated in April once every 33 years on average.

The *Selection of flood days* is not active because it is found that allowing more than one flood on the same day leads to considerable difficulties in hydrograph derivation. All simulations are now constrained to produce no more than one flood on each flood day.

Finally, the user can derive some estimate of flood duration by utilising the (moderately weak) relationship between flood duration and volume. The options in the *Derivation of flood duration from volume* box allows a 2-parameter linear or logarithmic relationship to be specified. If no relationship is to be specified the *linear* option should be selected and 0 entered for both *a* and *b*.

In the special case of Version 2, an additional parameter box will appear on the main screen. This is illustrated in Picture 6a.

**Picture 6a**

Derivation of cv of monthly number of floods

linear  $y = a + b.x$

non-linear  $y = a * x^b$

a	1.52
b	-0.408

The differences in Version 2 affect only the parameters for flood events. Version 2 is used when there is insufficient information to define adequately the CV of the number or volume of monthly floods. In this case the CV is estimated from the mean by a 2-parameter linear or logarithmic relationship.

## Parameters for monthly baseflow

Estimates of monthly baseflow are derived from rainfall, flood volumes and a persistent (constant) component as described more fully in Chapter 4. Picture 7 shows the set of parameters that define these relationships.

Picture 7

Parameters for baseflow												
Parameters for baseflow estimation												
Monthly threshold rainfall for baseflow	90	mm/month	Baseflow routing delay	20	days							
Percentage of rainfall forming baseflow	4	%	Catchment area	4632	km <sup>2</sup>							
Percentage of flood runoff forming baseflow	120	%	Added noise	0								
Persistent baseflow	1800	tcm/yr	Ceiling	10000	tcm/mon							
Mean and coefficient of variation of catchment rainfall (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	5	16	57	95	110	74	110	115	64	29	14	4
CV	1.92	1.22	0.71	0.37	0.36	0.49	0.39	0.31	0.35	1.45	1.75	1.56

It is assumed that there is a minimum monthly rainfall that contributes to baseflow and this is set in the *Monthly threshold rainfall for baseflow* box along with the *Percentage of rainfall forming baseflow*. The monthly rainfall data (mean and CV) are entered in the *Mean and coefficient of variation of catchment rainfall* box. These rainfall data should be representative of average rainfall in the wadi basin, derived from the records available.

The *Percentage of flood runoff forming baseflow* is a measure of the potential storage in the shallow alluvial deposits that appear to be replenished by flood waters. This figure can exceed 100% (as in the illustration) because the amount of the contribution is not subtracted from the flood volumes simulated. The contribution to baseflow can be thought of as additional flood flows that would occur in the complete absence of alluvial storage in the upstream basin.

The *Persistent baseflow* is a constant amount included to account for baseflow persisting through the dry season in some wadis when there is no rainfall or flood runoff to sustain baseflow directly.

The *Baseflow routing delay* accounts for the fact that an increase in baseflow following a flood event or a wet period is seen at the wadi outfall some time after the events that caused it. Although measured in days, the delay is used to proportion the baseflow between the current month and the next month (when the delay is less than 1 month), and similarly for the later months (when the delay is more than 1 month).

The parameter *Added noise* is not active. It was used during model development to try to account for the observed variability of baseflow.

The *Ceiling* parameter is used to specify the highest monthly aggregate flood volume that is taken into account in determining the contribution to baseflow from floods. This is necessary

because the alluvial storage invoked to explain the relationship seen would have a finite capacity that would be exceeded by the very high normal floods and by the exceptional floods.

## Parameters for the derivation of flood hydrographs

The methods used to transform the flood events defined by volume into a 15-minute hydrograph for input to the SMM are described in Chapter 4. Floods are perceived as being made up of a number of components. Small floods tend to be single-component floods; larger floods can have several components. Picture 8 shows the set of parameters that define this disaggregation into components and then into a hydrograph.

Picture 8

Parameters for hydrograph shape							
Parameters for hydrograph definition							
Threshold volume for multi-component flood	250 tcm		Maximum number of components	2			
Rise time (hours)	minimum	maximum		minimum	maximum		
	1	1	hours	Recession constant (component 1)	1	4	hours
Delay (component 2)	0.25	2	hours	Recession constant (component 2)	4	14	hours
Delay (component 3)	0	0	hours	Recession constant (component 3)	0	0	hours
Percentage of floods starting in the following 3-hour periods (%)							
00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
25	0	0	0	0	25	25	25

The *Threshold volume for multi-component floods* defines the flood volume below which floods are always regarded as having a single component. The *Maximum number of components* is currently limited to 2.

A number of parameter are defined in terms of maximum and minimum values. The program chooses values at random between these limits for each component of each flood in the simulated sequence.

The *Rise time* defines the time between the onset of the flood and the peak discharge.

*Delay* defines the time between the onset of two components in a multi-component flood. The For example, *Delay (component 2)* defines the difference in time between the onset of component 1 and the onset of component 2. As the present model is restricted to two components, the *Delay (component 3)* is not specified.

The *Recession constant* defines the rate of reduction of discharge once the peak has passed. It is expressed as a time constant for an exponential decay.

The remaining parameters in the box marked *Percentage of floods starting in the following 3-hour periods* controls the onset time of the first component of each flood. The program chooses a start time for each flood at random within the constraints defined here.



## B6 OUTPUT GENERATED BY THE PROGRAM

A series of output files is produced for each simulation to assist with model fitting, further analysis by database or spreadsheet, and to facilitate data transfer to the SMM.

All files have the simulation ID as a prefix followed by one of the following:

Events.dat  
 EventSummary.dat  
 Baseflow.dat  
 Hydrograph.dat  
 HydrographSummary.dat  
 FrequencyTable.dat  
 AnnualFrequency.dat  
 AnnualSummary.dat

An additional file Temp.dat is used internally by the model during hydrograph generation.

### Events.dat

These files provide information on the simulated flood events. *Events.dat* lists each flood event simulated in the sequence, as partially illustrated in Picture 9. The table columns show:

Year, month and day of occurrence	[Y, M, D]
Volume and estimated duration of the event	[Vol, Dur]
Number of components to the hydrograph	[NC]
Time of onset of the flood and its rise time	[Tons, Rise]
The volume assigned to each hydrograph component	[Cvol1, Cvol2, Cvol3]
The recession constants assigned to each component	[RK1, RK2, RK3]
The time delay between onset of the components	[TG1, TG2]

Note that Cvol3, RK3 and TG2 are inactive in the current form of *FloodSim*.

Picture 9

ZD777 09 Oct 2003 at 12:09:44 100 years Seed 8888888

Simulated flood events (Units: tcm and hours)

Y	M	D	Vol	Dur	NC	Tons	Rise	Cvol1	Cvol2	Cvol3	RK1	RK2	RK3	TG1	TG2
1	4	7	156.	2.0	1	21.00	1.00	156.	0.	0.	3.94	0.00	0.00	0.00	0.00
1	4	8	600.	7.8	2	0.75	1.00	204.	396.	0.	2.81	4.97	0.00	1.26	0.00
1	4	10	253.	3.3	2	18.50	1.00	146.	107.	0.	3.44	7.98	0.00	0.68	0.00
1	4	27	93.	1.2	1	22.50	1.00	93.	0.	0.	3.57	0.00	0.00	0.00	0.00
1	5	3	453.	5.9	2	23.50	1.00	238.	215.	0.	2.90	13.81	0.00	0.35	0.00
1	5	6	2804.	36.5	2	21.50	1.00	1937.	867.	0.	2.55	11.16	0.00	0.51	0.00
1	5	10	509.	6.6	2	0.50	1.00	247.	262.	0.	3.50	12.75	0.00	0.35	0.00
1	5	13	1136.	14.8	2	21.75	1.00	846.	290.	0.	1.85	5.47	0.00	1.15	0.00
1	5	14	48.	0.6	1	23.00	1.00	48.	0.	0.	1.73	0.00	0.00	0.00	0.00
1	5	17	3454.	44.9	2	16.50	1.00	1664.	1789.	0.	3.32	11.44	0.00	0.34	0.00
1	5	29	576.	7.5	2	2.75	1.00	354.	222.	0.	1.85	12.91	0.00	0.30	0.00
1	6	1	100.	1.3	1	23.00	1.00	100.	0.	0.	2.45	0.00	0.00	0.00	0.00
1	6	21	289.	3.8	2	16.00	1.00	108.	180.	0.	3.71	7.16	0.00	0.40	0.00
1	6	24	891.	11.6	2	17.00	1.00	391.	500.	0.	2.71	5.06	0.00	0.74	0.00
1	6	25	60.	0.8	1	16.50	1.00	60.	0.	0.	1.02	0.00	0.00	0.00	0.00
1	7	7	510.	6.6	2	21.25	1.00	233.	277.	0.	2.90	6.17	0.00	1.36	0.00

## EventSummary.dat

*EventSummary.dat* shown in Picture 10 provides monthly and annual statistical information derived from the flood events simulated. These data are useful to confirm correct model operation and to provide statistics that can be compared with those derived from observed data as an aid to parameter selection and model fitting.

### Picture 10

```

ZD777 09 Oct 2003 at 12:09:44      100 years  Seed 8888888
Summary of flood volumes (Unit: tcm)
      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec   Year
av    43.   15.  442. 3387. 6801. 2936. 4398. 7492. 4759.  927.  287.   58. 31547.
sd   333.  118.  751. 3752. 9286. 3230. 2851. 3868. 4210. 1477.  908.  305. 12264.
cv    7.73  7.93  1.70  1.11  1.37  1.10  0.65  0.52  0.88  1.59  3.16  5.22  0.39

Summary of number of floods
      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec   Year
av     0.0   0.0   0.9   4.5   6.1   4.5   7.0  12.1   7.0   1.6   0.4   0.1  44.3
sd     0.2   0.2   1.1   2.8   3.6   4.1   3.8   5.4   4.7   2.4   1.1   0.3  10.8
cv     0.00  0.00  1.30  0.63  0.59  0.92  0.54  0.45  0.67  1.45  2.67  0.00  0.24

Summary of flood duration (Unit: hours)
      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec   Year
av     0.6   0.1   3.0  10.2  13.9   8.6   8.7   8.3   8.7   5.4   2.1   0.7   9.4
sd     4.3   0.8   4.2  12.6  17.6   5.6   5.4   3.7   4.8   7.1   6.6   3.9   3.5
cv     7.73  6.88  1.37  1.23  1.27  0.65  0.63  0.44  0.55  1.31  3.16  5.47  0.37

Statistics of flood volumes simulated
Number of events                4425
Sum of flood volume             3154655.
Sum of squares of volume       13060458496.
Mean flood volume               713.
Standard deviation              1563.

```

## Baseflow.dat

The file Baseflow.dat shown partially in Picture 11 lists the simulated baseflow data. A summary of monthly and annual statistics is given at the end of the file.

Picture 11

```

ZD777 09 Oct 2003 at 12:09:44      100 years  Seed 8888888
Simulated monthly baseflow (Unit: tcm)

```

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1	1239.	1239.	4247.	8551.	8056.	10475.	7719.	15749.	13221.	7034.	2881.	2276.	82686.
2	1326.	1500.	1640.	2452.	5339.	7343.	5400.	14203.	21799.	8872.	1500.	1500.	72875.
3	1622.	1866.	1866.	3197.	6080.	6815.	14477.	28441.	20128.	3556.	2193.	2182.	92424.
4	1744.	1498.	4983.	10492.	10434.	11562.	4472.	8719.	6647.	2367.	2178.	1498.	66594.
5	1689.	2070.	2089.	2666.	6017.	8775.	6984.	10790.	9441.	4659.	2070.	2070.	59320.
6	2078.	2093.	2578.	5590.	8122.	6037.	6821.	8215.	11949.	3228.	2140.	2093.	60945.
7	2102.	2120.	2316.	3817.	8906.	11631.	14974.	29482.	19115.	10949.	2120.	2120.	109651.
8	1998.	1755.	1755.	2848.	4939.	6983.	10841.	9938.	8085.	2655.	2017.	2278.	56092.
9	1581.	1233.	1233.	2285.	7527.	11057.	7204.	8773.	7256.	7952.	1593.	1233.	58929.
10	1792.	2910.	3063.	4822.	8412.	7552.	5038.	10525.	11854.	6649.	3459.	2910.	68984.
11	2922.	2947.	2947.	5458.	12121.	12698.	9831.	13486.	10290.	7931.	3932.	2947.	87511.
12	4323.	5834.	3390.	6060.	9957.	9822.	14922.	18997.	22290.	11001.	4869.	5024.	116489.
13	2265.	92.	92.	153.	3609.	7276.	2347.	5713.	8146.	5986.	1141.	92.	36913.

## Hydrograph.dat

These files are produced only if the *Derive a 15-minute hydrograph* option has been set in the control data.

Picture 12

```

50 4 18 3.25 6.7 0.7
50 4 18 3.50 6.5 0.7
50 4 18 3.75 6.2 0.7
50 4 18 4.00 6.0 0.7
50 4 18 4.25 5.8 0.7
50 4 18 4.50 5.6 0.7
50 4 18 4.75 5.4 0.7
50 4 18 5.00 5.3 0.7
50 4 18 5.25 5.1 0.7
50 4 18 5.50 5.0 0.7
50 4 18 5.75 4.8 0.7
50 4 18 6.00 4.7 0.7
50 4 18 6.25 4.6 0.7
50 4 18 6.50 4.5 0.7
50 4 18 6.75 4.4 0.7
50 4 18 7.00 4.3 0.7
50 4 18 7.25 4.2 0.7
50 4 18 7.50 4.1 0.7

```

A sample of the untitled data in *Hydrograph.dat* is shown in Picture 12.

The columns are:

Year, month and day  
Time  
Discharge in m<sup>3</sup>/s  
Baseflow in m<sup>3</sup>/s

## HydrographSummary.dat

*HydrographSummary.dat* contains the histograms of flood volume, flood peak discharge and duration as derived from the hydrographs generated from the event data. The layout is shown in Picture 13.

These statistics are produced only if the *Derive a 15-minute hydrograph* option has been set in the control data.

These data provide a further check that the hydrographs are being generated correctly. They are derived from all the events in the simulation, not just those that are selected for output in the *Hydrograph.dat* file.

### Picture 13

ZD777 09 Oct 2003 at 16:29:47 100 years Seed 8888888

#### Histograms of hydrograph characteristics

Volumes			Flood peaks			Durations					
<	50.	106	<	10.	448	<	2.	7			
50.	-	100.	436	10.	-	20.	1704	2.	-	4.	238
100.	-	200.	737	20.	-	30.	859	4.	-	6.	441
200.	-	500.	1544	30.	-	50.	846	6.	-	8.	476
500.	-	1000.	967	50.	-	100.	655	8.	-	10.	292
1000.	-	2000.	518	100.	-	200.	266	10.	-	15.	610
2000.	-	3000.	120	200.	-	300.	54	15.	-	20.	929
3000.	-	4000.	47	300.	-	400.	10	20.	-	30.	1062
4000.	-	5000.	19	400.	-	800.	17	30.	-	40.	304
>	5000.	35	>	800.	12	>	40.	71			

Histograms derived from 4425 floods

### FrequencyTable.dat

The historical data on flood hydrographs resides primarily on charts that have not been digitised. For most wadis it is not possible to derive flow duration curves without a considerable time-consuming effort to interpret these chart records.

#### Picture 14

```
ZD777 09 Oct 2003 at 16:29:47      100 years  Seed 8888888
15-min flood discharge frequency table (Unit: m3/s)

  limit  average      number
    2         1       75017
    5         4       87463
   10         8       53369
   15        13       26016
   20        18       14821
   40        30       22872
   60        50        7024
   80        70        3063
  100        90        1573
  150       125        1765
  200       175         599
  300       250         411
  400       350         154
  500       450          88
  600       550          53
  800       700          61
 1000       900          49
 1200      1100          36
 1400      1300          18
 1600      1500          12
 1800      1700           7
 2000      1900           0
 2500     2250           2
 3000     2750           1
    >    3600           0

Total non-zero intervals    294474
Zero discharge              0
```

However, some approximation to the true flow duration curve can be obtained from the simulated hydrographs.

FrequencyTable.dat derived from the full period of simulation shows the number of 15-minute intervals when the simulated discharge is in the range defined by successive limits. In this example the discharge was between 5 and 10 m3/s for 53369 intervals.

These data can be used to answer questions related to the diversion capacity needed to divert a given percentage of the long-term flood volume.

### AnnualFrequency.dat

*AnnualFrequency.dat* gives the same information but on an annual basis. These data can be used to estimate the frequency (in years) that the diversion capacity of structures within the system might be exceeded. Some allowance has to be made for attenuation, seepage losses and the cumulative effect of any upstream diversion on these statistics for point downstream within the scheme area.

#### Picture 15

```
ZD777 09 Oct 2003 at 16:29:47      100 years  Seed 8888888
Flood discharge frequency table - annual (Unit: m3/s)

limit  2    5    10   15   20   40   60   80  100  150  200  300  400  500  600  800 1000 1200 1400 1600 1800 2000 2500 3000 >3000
  1  806  887  526  251  135  237   60  28  27  24   8   0   0   0   0   0   0   0   0   0   0   0   0   0
  2  872 1009  589  305  178  276  105  16   5   9  10   0   0   0   0   0   0   0   0   0   0   0   0   0
  3  678  781  481  245  145  158   59  24   4   8   3   5   0   0   0   0   0   0   0   0   0   0   0   0
  4  589  690  394  184   82  124   19   9   3  12   4   1   0   0   0   0   0   0   0   0   0   0   0   0
  5  541  635  393  221  106  148   58  22  19  11   8   2   0   0   0   0   0   0   0   0   0   0   0   0
  6  566  699  428  220  115  146   29  13  11  14   5   2   2   3   1   0   0   0   0   0   0   0   0   0
  7  727  819  474  241  128  199   61  31  15  10   6  10   0   0   0   0   0   0   0   0   0   0   0   0
  8  833  972  554  250  151  263   80  39  14  10   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

## AnnualSummary.dat

The annual summary is useful when checking that the simulation has produced acceptable and expected results. It also simplifies the selection of characteristic years for which a full hydrograph might be generated for use with the SMM.

### Picture 16

```
ZD998 14 Oct 2003 at 15:24:41      10 years Seed 8888888
Summary of annual characteristics (mcm and m3/s)
```

Year	Volume			Number	Flood events			
	Total	Floods	Baseflow		Largest	Highest		
1	116.8	29.2	87.6	50	3.45	May	199	May
2	93.3	30.4	62.8	49	4.80	Sep	190	Sep
3	60.0	22.7	37.3	41	3.63	Rug	263	Rug
4	71.9	16.2	55.7	31	2.20	May	230	Rug
5	72.6	21.9	50.7	33	2.97	May	235	May
6	133.3	22.0	111.3	33	4.44	Rpr	538	Rpr
7	73.9	26.9	47.1	38	6.23	Sep	286	Sep
8	124.4	28.3	96.1	44	3.30	Rug	129	Rug
9	100.0	23.6	76.3	37	3.55	Sep	397	Sep
10	63.2	16.7	46.5	37	1.41	Sep	87	Rug

The volumes are self-explanatory as is the number of flood events. The largest flood refers to the individual flood event having the largest volume in the year. The highest flood event refers to the event with the highest peak discharge.

The peak discharge is in m<sup>3</sup>/s and the volumes are shown here in mcm.

## B7 USING THE PROGRAM

The application of this simulation methodology to Wadi Zabid has been described in some detail in Chapter 4 and the difficulties of deriving parameters for Wadi Tuban where there is much less information is described in Chapter 5.

The user is recommended to study these results before attempting to use the model for simulation on other wadis.

There are three classes of information that can be used to derive parameter values:

- historical data including records of flood volume, peak flow and duration (of the kind collated by the TDA for Wadi Zabid. These data also include representative hydrographs (most of the data are in the Hydrological database);
- knowledge of suitable parameter values from neighbouring wadis that might be expected to experience the same kind of storms and to behave in the same way;
- fragmentary information of doubtful current value such as monthly flood and baseflows for a short period of years several decades ago, hearsay evidence for the number of floods perceived by local farmers and managers of the existing schemes.

Reliable results can be expected only when the first of these classes of information is available. There will be a substantial reduction in reliability when data from the second and third class are the only data available for parameter estimation. It is probably true to say that a model cannot be adequately calibrated if the only information is that regarded here as falling in the third class.

The user is advised to fit the model in stages, deriving flood events initially, followed by baseflow

and finally by hydrograph simulation.

Parameter selection should be based as far as possible on the characteristics of the observed floods and baseflow. However, this can provide only a guide. Some parameters, particularly those relating to baseflow and hydrograph simulation can only be finalised by a process of trial and error. There is no automatic, objective way of defining an optimum parameter set. During the trial and error process, only one or a related set of values should be changed at one time so that the user can gain some understanding of the impact of the changes made.

### **Parameters for flood events**

These parameters should be based on analysis of recorded flood events such as that made in Chapter 4 for Wadi Zabid (a case where there is much useful information) and Chapter 5 for Wadi Tuban (a case where the information is much more fragmentary).

It is desirable to be able to define from historical records the statistical distribution describing the volume of individual flood events, and the monthly distribution of flood events by number or by volume as well as the variability of these measures.

If this information is not available, parameters might be assigned based on values in neighbouring basins. In this case it is essential that regional variations in the incidence of rainfall and other inter-basin comparisons are studied. Some information in this regard is given in Chapter 6.

The definition of exceptional floods is the most difficult and uncertain part of the modelling procedure. There is little information available and defining the parameters for these events should be done after the distribution of 'normal' floods is simulated realistically.

The parameters are tested by comparison between observed and simulated statistics as illustrated in Chapters 4 and 5. This means describing the variability of measures such as the monthly volume, number and duration as well as the average values of these measures.

### **Parameters for baseflow**

The genesis of baseflow cannot be adequately defined from current information. It has therefore been assumed that baseflow can be estimated from a number of variables including catchment rainfall, flood volumes and some persistent element representing long term storage of groundwater replenished by rainfall over a period longer than a year.

Further, it is assumed that the processes of baseflow formation involved storage of water that is released after the storage has been replenished. Therefore there is some delay. For example, it is possible that the storm rainfall that produces floods also replenishes shallow alluvial storage that supports baseflow over a period of months following the storm.

Parameter selection should follow some exploratory work to review the relevance of these relationships using the data available. This means preparing an index of basin rainfall from the records available. Monthly baseflow can be related to rainfall and flood volume to indicate the relative importance of these measures in predicting baseflow.

Simulated baseflow and its variability can be compared with the statistics from the observed data where possible, and parameter values adjusted by trial and error until a reasonable comparison is achieved.

## Parameters for hydrographs

The hydrographs are assumed to be made up of a number of components of the form described in Chapter 4. *FloodSim* contains a hydrograph generation procedure that randomly selects a parameter set for each flood based on the ranges of values defined by the parameters set. While the screen allows parameters for up to three components, the program is currently limited to processing a maximum of two components. This is because of difficulties in fitting parameter values given only a very limited set of hydrographs available in computerised form.

Indications of the range of values for the parameters can be gained from review of observed hydrographs abstracted from charts or from the logger data in the southern wadis. Rise time and recession constants can be defined in this way.

Additional information such as the relative number of single-peaked and multiple events and the time delay between components of multiple hydrographs can also be gained from study of the historical records.

Fitting the parameters is again a trial and error procedure, and it is recommended that comparisons be made between observed and simulated flood peaks and flood durations as a guide to parameter adjustment.

## B8 PROGRAM CRASH

This is a program under continual development and it is written for a specific purpose for limited use within the Yemen IIP. It is therefore uneconomic to spend a large amount of time testing the program under all possible conditions and providing comprehensive error trapping and help systems. Consequently, the program is likely to crash from time to time, usually when faced with parameter values that cause mathematical errors to arise (logs of negative numbers for example), or when some parameters are not set (interpreted as zero).

With experience, some of the more likely 'errors' can be identified and error traps set. Otherwise, it is a matter of trial and error to avoid parameter values that cause the program to fail.

When the program crashes, the VB application will usually close or a dialogue box will appear asking whether the program should be closed or whether it should be debugged. In the latter case, the 'close' option should be used, the VB program restarted, and the parameter values re-examined for possible errors or unrealistic values.

Because the parameter values are saved in *Floods.mdb* before the simulation is started, they will be available when the program is restarted under the relevant ID. Check the values carefully, ensuring that values have been set in all visible frames on the screen before clicking 'Run the program' again.



**Table B 1 Definition of field names in the Parameters table**

Field name	Description	Field name	Description
ID	Parameter set and simulation identifier	MRJan	Monthly average catchment rainfall
Sdat	Date parameters saved (dd-mmm-yy)	MRFeb	
Locking	1=parameter set used for simulation	MRMar	
Seed	Starting seed	MRApr	
Notes	Notes	MRMay	
Lsim	Number of years for simulation	MRJun	
Mver	Model version	MRJul	
HydYN	Detailed hydrograph (Yes/No)	MRAug	
Lhyd	Length of 15-min hydrograph	MRSep	
Lone	Start year of 15-min hydrograph	MROct	
PopAv	Population values - mean	MRNov	
PopSD	Population values - sd	MRDec	
MonNCVOpt	CV monthly flood events - option	MRcvJan	Monthl CV of average rainfall
MonNCVA	CV monthly flood events - A	MRcvFeb	
MonNCVB	CV monthly flood events - B	MRcvMar	
DSelect	Selection of days	MRcvApr	
DurOpt	Duration - lin/log option	MRcvMay	
DurA	Duration - A parameter	MRcvJun	
DurB	Duration - B parameter	MRcvJul	
NumVol	toggle for number of floods or volume	MRcvAug	
MavJan	Monthly average number of flood events or	MRcvSep	
MavFeb		MRcvOct	
MavMar		MRcvNov	
MavApr		MRcvDec	
MavMay		EEmean	Exceptional events -mean volume
MavJun		EEsd	Exceptional events - sd
MavJul		EEMar	Exceptional events - frequency % March
MavAug		EEApr	Exceptional events - frequency % April
MavSep		EEMay	Exceptional events - frequency % May
MavOct		POnset1	Prob of onset - 0-3 hours
MavNov		POnset2	Prob of onset - 3-6 hours
MavDec		POnset3	Prob of onset - 6-9 hours
McvJan	CV of monthly number of flood events or	POnset4	Prob of onset - 9-12 hours
McvFeb		POnset5	Prob of onset - 12-15 hours
McvMar		POnset6	Prob of onset - 15-18 hours
McvApr		POnset7	Prob of onset - 18-21hours
McvMay		POnset8	Prob of onset - 21-24 hours
McvJun		ThreshVol	Threshold vol for multi floods
McvJul		MaxComp	Maximum number of components
McvAug		RiseMin	Minimum rise time
McvSep		RiseMax	Maximum rise time
McvOct		RK1Min	Min recession constant - component 1
McvNov		RK1Max	Max recession constant - component 1
McvDec		RK2Min	Min recession constant - component 2
ARthres	Baseflow - annual rainfall threshold	RK2Max	Max recession constant - component 2
BFrain	Baseflow - percentage rainfall contribution	RK3Min	Min recession constant - component 3
BFflood	Baseflow - percentage flood contribution	RK3Max	Max recession constant - component 3
BFpers	Baseflow - persistent contribution	TGap1Min	Min delay - component 2
BFflag	Baseflow - baseflow lag	TGap1Max	Max delay - component 2
Area	Baseflow - catchment area	TGap2Min	Min delay - component 2
BFnoise	Baseflow - noise component	TGap2Max	Max delay - component 2
BFceiling	Baseflow - ceiling on flood contribution		
BFspare2	Baseflow - spare parameter		