STATISTICAL ANALYSIS OF TWO TIME SERIES
(stat_q.exe 1/30/04)

A. Overview

The program (STAT-Q) was first designed to calculate statistical comparison between simulated and observed hourly discharge time series. Now it can be used to conduct statistical analysis between any two time series in same type as long as the time series are in the OH datacard format and the data are arranged in one column. It has similar capabilities as to STAT-QME operation in mcp3 with several expanded options. This program can compute statitics on specific events.

B. History of Updates

- (Modified on 2/15/02)
  Add Nash-Sutcliffe Coefficient (***Nr***) next to ***R***
- (Modified on 3/26/02)
  Add standard deviation and coefficient of variation output; Add modified correlation coefficient for whole period and selected flood events
- (Modified on 5/10/02)
  1. Can process rainfall time series. The total rainfall for an event then can be compared to total discharge (described in the next item) for the same event.
  2. Calculate event total discharge in depth (mm). This requires an area value be given.
- (Modified on 7/15/02)
  Overall flood and peak statistics based on Victor's suggestions are included

C. Summary of Analysis Options:

1) It reads two time series in single-column OH Datacard format. The allowable time steps are 1, 2, 3, 4, 6, 8, 12, and 24 hours. **(NOTE: The discharge data should be in CMS and rainfall data should be in MM. The temperature data can be either in DEGC or DEFG and they can be different)**. Both time series must have the same time step in this version.

2) It can calculate statistical comparison between two time series (simulated and observed flows, for example) for a time step defined by a user (option @**T**) as long as the defined time interval is greater or equal to the larger time step of the two time series and is divisible by both time steps defined in the data files.

3) It outputs a summary of multi-year statistics, yearly statistics, and monthly statitics including percent bias, absolute percent bias, mean values, standard deviation, coefficient of variation, rms, correlation coefficient, Nash-Sutcliffe coefficient, modified correlation coefficient, coefficients *A* and *B* in the best line fit equation $Q_{obs} = A + B*Q_{sim}$.

4) It outputs a table of 25 largest differences between the two data series. This table contains

25 records with simulated and observed values, their difference, and percent difference.

5) It calculates statistics for a given number of evenly divided flow intervals (option @**D**). The output for each flow interval includes number of cases, percent bias, absolute percent bias, mean values, root mean squared error (rms), correlation coefficient.

6) It calculates statistics similar to operation **D** for flows that are greater than given threshold values (option @**E**).

7) It calculates statistics similar to operation **D** for given flow intervals (may not be necessary equally divided) (option @**F**).

8) It can calculates statistics for different events defined by a user (option @**G**). The output related to this option includes percent bias, absolute percent bias, mean values, rms, correlation coefficient, Nash-Sutcliffe coefficient, modified correlation coefficient, total volume of each case (in depth of mm) and their percent differences. It is followed by a table of center of mass (in terms of timing) for given events. The calculations include center of mass for two time series and their time difference. A table of peak/maximum values and corresponding time for two time series, their time difference, and value ratio is presented. The overall bias, flood bias, flood RMS, overall peak error, peak time bias, and peak time error based on Victor's equations are also calculated. Statistics are also calculated when the simulated peak times are aligned to observed ones. If -o option was given when one ran the program, the side-by-side output of time series for each event will be created and named as ***event.dat***.

9) The program can find peak flows for a given threshold value (peaks to be found are greater than this threshold value) and within a given time window (option @**H**). For any found peak flow in the observed data, if no peak found for simulated time series, it will be indicated. Otherwise, the peak values, time of peak, peak time differences, percent value differences as well as peak flow ratios will be included in the output. A summary of statistics for this option is also presented. It includes total number of observed peaks (greater than a given threshold value), total number of matched simulated peaks within the same time window, mean value of peak time difference, mean value of peak flow difference, standard deviation of peak time difference, and standard deviation of peak flow difference.

11) The program can also calculate accumulated flow depth and error for given time period in month and the basin's area (option @**I**).

12) The program stops when the option @**Q** is read in a control file.

D. Instructions on each option within the control file

All options and their required arguments can be put in a single control file. Each option starts with the symbol @ followed by a specific letter (except for file name and directory entry). Any line starting with # is treated as a comment line. A comment line can be added at any line except between the operation letter and its arguments.

@ – Option for defining input and output file names as well as analysis period. There are three

file names after @ with each occupying a single line. These names are the observed file name, simulated file name, and output file name, in that order. Either full path names or local path names can be provided. The analysis period can only be specified for files with a complete month or more of data. The analysis period given in the fourth line is start month (mm), start year (yyyy), end month (mm), and end year (yyyy) with space between. When negative values are given, the program will determine the analysis period. In the fifth line, a basin area (in km^2) has to be given if discharge time series are analyzed. If time series are rainfall data, then any negative value should be used (no need to give real area value). Whether this value is negative or positive will determine (by the program) what data type is assumed (discharge vs. rainfall).

Example:

@
/fs/awips/rfc/nwsrfs/calb/data/area_ts/oper/abrfc/keywebb/bluo2/bluo2.obs
bluo2.sim
stat.out
6 1993 5 2000
1233.5

@T – Option to process data files for a specified time step other than what is specified in the time series data files. This option can only be used after all input and output files have been defined and before any other option is chosen.

Example:

@T 1

@A – Option for displaying the first specified lines of data. It should be followed by the number of lines you wish to display. This operation is for the purpose of checking whether the two times series are read correctly or not.

Example:

@A 10

@D – Option for producing statistics in equal flow intervals. User should provide the number of intervals desired.

example:

@D 5

@E – Option for calculating statistics for cases that are greater than specified values. This option takes 2 arguments. The first is the number of specified values desired, followed by values (number of values depends on the number of specified before the values).

example:

@E 2 250.5 350.0

@F – Option for calculating statistics of given flow intervals. The option takes two arguments. The first is the number of flow intervals desired, followed by **pairs** of values defining the intervals. (Note: each interval has two values).

example:

@F 3 5.0 15.5 250.0 380.0 390.0 500.0

@G -- Option for calculating statistics for events. It takes two set of arguments. The first is the number of events desired followed by time period definition (contains start and end time) for each event. The time should in the form/order of '**hour month day year(yyyy)**'. Note that hours are from 0 to 23.

example:

@G 2
11 7 7 1996
11 10 8 1996

0 9 10 1997
23 12 7 1997

@H – Option to calculate statistics for events found above a given threshold value within a given time window. It takes two arguments. The first should be the desired threshold value. The second should be the desired length of the window (in hours as an integer). The time window works as follows. As the program sequentially reads through the observed time series file, at a time the flow rises above the threshold, the window begins and the program continues to look for the next peak. A peak is detected if there is a decrease in the flow. If the window is large, the program may identify more than one peak in the window and will choose the maximum of these peaks. If the window is small, the program may not find a peak in the defined window (i.e. the hydrograph is rising throughout the window). In this case, the program will choose the first peak that occurs after the window. The effect of the window is to include or exclude consideration of double peaks. The same logic is used for the simulated time series data; however, it may be that the corresponding peak in the simulated time series does not exceed the selected threshold. The first time series (usually observed time series) dictates the peak values.

example:

@H 155.5 240

@I – Operation to compute accumulated flow (in millimeters) for entire time period covered by data files. The arguments should be the desired partition (given in months from 1 to 12).

example:

@I 3

@Q – Indicator the end of processing, the program will not stop until it sees this command.

example:

@Q

E. Program Execution

To run the program, issue the name of executable stat_q.exe followed by a control file. If control file was not given, then the program will prompt a user to type a control file name. If successful, a user can check all results in an output file defined in the control file. The executable program stat_q.exe is located at /fs/hydro/rms/bin. The instructions and a sample control file are located at /fs/hydro/rms/doc.

Appendix I: Mathematical Calculations

1. ***Percent Bias, P.B. (%)***

It is a measure of total volume difference between two time series. It does not measure the differences in timing.

$$P.B.= \frac{\sum_{i=1}^{N}(S_i - O_i)}{\sum_{i=1}^{N} O_i}(100)$$

where S_i is the simulated discharge for each time step, and O_i is observed value. N is total number of values within the time period of analysis.

2. ***Absolute Percent Bias***, ***A.P.B. (%)***

It is a measure of the timing difference between the two time series besides the volume difference. For example, if the percent bias measure between two time series is small and at the same time, the absolute percent bias measure is large, then one can say the two time series have close total volume but their timing are not as close. A good agreement between the two requires both percent bias and absolute percent bias are small. The absolute percent bias is always greater than or equal to percent bias.

$$A.P.B.= \frac{\sum_{i=1}^{N}\left|S_i - O_i\right|}{\sum_{i=1}^{N} O_i}(100)$$

where S_i, O_i and N have same meaning as above.

3. ***Simulated Mean,*** $\overline{S}$

$$\overline{S} = \frac{\sum_{i=1}^{N} S_i}{N}$$

4. ***Observed Mean,*** $\overline{O}$

$$\overline{O} = \frac{\sum_{i=1}^{N} O_i}{N}$$

5. ***RMS, or Percent RMS Error, % RMS. E.***

$$\%RMS.E. = \frac{\sqrt{\frac{\sum_{i=1}^{N} (S_i - O_i)^2}{N}}}{\overline{O}}(100)$$

6. ***Correlation Coefficient, R***

$$R = \frac{N \cdot \sum_{i=1}^{N} S_i \cdot O_i - \sum_{i=1}^{N} S_i \cdot \sum_{i=1}^{N} O_i}{\sqrt{\left(N \cdot \sum_{i=1}^{N} S_i^2 - \left(\sum_{i=1}^{N} S_i \right)^2 \right) \cdot \left(N \cdot \sum_{i=1}^{N} O_i^2 - \left(\sum_{i=1}^{N} O_i \right)^2 \right)}}$$

7. ***Nash-Sutcliffe Coefficient, Nr***

$$N_r = 1 - \frac{\sum_{i=1}^{N} (S_i - O_i)^2 / N}{STD_{obs}}$$

8. ***Line of Best Fit*: *O = A + B ·S***

$$B = \frac{N \cdot \left(\sum_{i=1}^{N} S_i \cdot O_i \right) - \sum_{i=1}^{N} S_i \cdot \sum_{i=1}^{N} O_i}{N \cdot \sum_{i}^{N} S_i^2 - \left(\sum_{i=1}^{N} S_i \right)^2}$$

$$A = \overline{O} - B \cdot \overline{S}$$

9. ***Standard Deviation, STD***

$$STD = \sqrt{\frac{\sum_{i=1}^{M} S_i^2 - \frac{\left(\sum_{i=1}^{M} S_i\right)^2}{M}}{M-1}}$$

where M is the number of data samples, S_i is any type of data values.

10. ***Coefficient of Variation, Cv***

$$Cv = STD / Mean$$

11. ***Modified Correlation Coefficient,*** ***Rm*** (Based on R. McCuen & W. Snyder, 1975)

$$R_m = (A/B)\cdot R = R \times \frac{\min\{STD_{sim}, STD_{obs}\}}{\max\{STD_{sim}, STD_{obs}\}}$$

or

$$R_m = (A/B)\cdot R = R \times \sqrt{\frac{\min\{\quad}{\max\{}$$

where A/B should be < 1 and R is correlation coefficient.

12. Overall Statistic Equations for Flood Events

- Flood Overall Bias, ***B***, %

$$B = \frac{\sum_{i=1}^{N} B_i}{Y} 100$$

- Flood Bias, $\boldsymbol{B_{avg}}$, %

$$B_{avg} = \frac{\sum_{i=1}^{N} |B_i|}{N \cdot Y_{avg}} 100$$

- Flood Root Mean Square Error, $\boldsymbol{RMS_{avg}}$, %

$$RMS_{avg} = \frac{\sum_{i=1}^{N} RMS_i}{N \cdot Q_{avg}} 100$$

- Peak Error, $\boldsymbol{E_p}$, %

$$E_p = \frac{\sum_{i=1}^{N} \left| Q_{p,i} - Q_{ps,i} \right|}{N \cdot Q_{p,avg}} 100$$

- Peak Time Bias, $\boldsymbol{B_p}$, hrs

$$B_p = \frac{\sum_{i=1}^{N} \left(T_{p,i} - T_{ps,i} \right)}{N}$$

- Peak Time Error, $\boldsymbol{B_{p,avg}}$, hrs

$$B_{p,avg} = \frac{\sum_{i=1}^{N} \left| T_{p,i} - T_{ps,i} \right|}{N}$$

Notation:

$\boldsymbol{B_i}$ is runoff bias per i-th flood event, mm,
$\boldsymbol{Y}$ is a total observed runoff of all selected floods, mm,
$\boldsymbol{Y_{avg}}$ is an average observed flood event runoff, mm,
$\boldsymbol{RMS_i}$ is a root mean square error per i-th flood, cms
$\boldsymbol{Q_{avg}}$ is an average observed flood event discharge, cms,
$\boldsymbol{Q_{p,i}}$ is an observed peak discharge of the i-th flood event, cms,
$\boldsymbol{Q_{ps,i}}$ is a simulated peak discharge of the i-th flood event, cms,
$\boldsymbol{Q_{p,avg}}$ is an average observed peak discharge, cms,
$\boldsymbol{T_{p,i}}$ is an observed time to the i-th peak, hrs,
$\boldsymbol{T_{ps,i}}$ is a simulated time to the i-th peak, hrs, and
$\boldsymbol{N}$ is a number of selected floods.

Appendix II: Sample Output

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                      DATA INFORMATION
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OBSERVED DATA:
  file: /fs/hsmb/nwsrfs/calb/data/area_ts/oper/dmip/bluo2/bluo2.mod
  It covers the time period from 10/1992 to 3/2001 in 1 hr intervals

SIMULATED DATA:
  file: /fs/hsmb/nwsrfs/calb/data/area_ts/oper/dmip_subm/bluo2/cal7_sqin.ohd
  It covers the time period from 6/1993 to 8/2001 in 1 hr intervals

   Analysis will be conducted for data between 4/1994 and 7/2000

   Total hours of data have been read are 55536
   Total lines of data read from observed data 55536
   Total lines of data read from simulated data 55536

   There are 53338 hours of good data.
   Total 2198 hours of data were missing.

 -----> BASIN AREA IS 1233.00 KM^2 <-----
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 -----> Maximum value of flow: 482.988 (cms) <-----
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 ============================================================================================================
                                        MULTI-YEAR STATISTICS
            Abs.
      %      %       Obs.    Sim.    Obs.   Sim.   Obs.  Sim.    %      RMS         Nash-S.  Modi.
    Bias    Bias    Qmean   Qmean    std    std     Cv    Cv    RMS    (CMS)    R      r       Rm
 ------------------------------------------------------------------------------------------------------------
   12.307  50.290   8.927   10.03   24.03  24.47  2.692  2.441  139.0  12.41  0.870  0.733  0.855

  Best line fit:  Qobs = A+B*Qsim:  A--> 0.358 (cms)  B--> 0.855


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YEARLY STATISTICS

Year	Percent Bias	Absolute Percent Bias	Absolute Error (CMS)	Observed Qmean	Simulated Qmean	Percent RMS	RMS (CMS)	R	Nash-S. r
1994	-11.34	45.43	5.701	12.55	11.13	124.8	15.67	0.842	0.701
1995	-26.86	38.87	5.477	14.09	10.30	94.48	13.31	0.913	0.814
1996	2.323	42.74	4.487	10.50	10.74	143.1	15.02	0.889	0.773
1997	44.65	57.61	5.041	8.750	12.66	131.6	11.52	0.877	0.586
1998	35.94	44.28	3.817	8.619	11.72	113.0	9.740	0.944	0.836
1999	89.55	103.5	3.941	3.808	7.218	310.2	11.81	0.686	-0.851
2000	108.1	114.2	2.493	2.184	4.545	276.7	6.044	0.784	-7.22

MONTHLY STATISTICS

Month	Percent Bias	Absolute Percent Bias	Absolute Error (CMS)	Observed Qmean	Simulated Qmean	Percent RMS	RMS (CMS)	R	Nash-S. r
1	3.229	39.49	4.019	10.18	10.51	88.92	9.050	0.938	0.862
2	0.1340	31.35	2.523	8.046	8.057	71.96	5.790	0.957	0.911
3	10.40	43.57	5.939	13.63	15.05	94.09	12.83	0.908	0.801
4	10.72	51.50	6.558	12.73	14.10	116.3	14.81	0.797	0.539
5	2.653	46.34	7.669	16.55	16.99	116.4	19.27	0.866	0.745
6	21.81	66.77	4.504	6.746	8.217	149.0	10.05	0.712	0.437
7	38.81	65.98	1.745	2.645	3.672	212.6	5.623	0.552	-1.90
8	30.07	75.46	2.058	2.727	3.547	278.7	7.602	0.548	0.273
9	71.56	105.8	4.721	4.464	7.658	288.0	12.86	0.608	-0.223
10	16.20	65.07	3.264	5.016	5.828	227.8	11.43	0.891	0.751
11	15.70	38.89	5.414	13.92	16.11	127.5	17.75	0.922	0.807
12	6.044	55.66	4.888	8.781	9.312	139.1	12.21	0.730	0.496

25 LARGEST FLOW DIFFERENCES

Date	Observed Flow	Simulated Flow	Error (Sim-Obs)	Percent Error
8:00 11/07/1996	87.7000	385.703	298.003	339.798
9:00 11/07/1996	125.890	419.775	293.885	233.446
7:00 11/07/1996	49.5100	341.224	291.714	589.202
10:00 11/07/1996	164.080	443.646	279.566	170.384
6:00 11/07/1996	11.3200	283.386	272.066	2403.41

11:00	11/07/1996	202.271	458.292	256.021	126.573
12:00	11/07/1996	240.461	464.579	224.118	93.2035
13:00	11/07/1996	278.651	463.492	184.841	66.3342
4:00	11/15/1994	187.063	332.228	145.165	77.6022
3:00	11/15/1994	183.101	327.982	144.881	79.1263
2:00	11/15/1994	177.441	317.165	139.724	78.7439
5:00	11/15/1994	191.025	330.586	139.561	73.0590
14:00	11/07/1996	316.841	456.167	139.326	43.9735
23:00	05/10/1999	56.4530	193.718	137.265	243.149
22:00	05/10/1999	55.2830	191.432	136.149	246.276
0:00	05/11/1999	57.6320	192.874	135.242	234.665
21:00	05/10/1999	53.9060	185.578	131.672	244.262
1:00	05/11/1999	58.4810	189.471	130.990	223.987
1:00	11/15/1994	170.932	299.459	128.527	75.1919
15:00	10/22/1996	229.445	101.765	-127.680	-55.6473
16:00	10/22/1996	225.345	98.6040	-126.741	-56.2431
19:00	10/22/1996	216.502	90.5920	-125.910	-58.1565
6:00	11/15/1994	198.666	324.025	125.359	63.1004
2:00	05/11/1999	59.1630	184.121	124.958	211.210
20:00	05/10/1999	53.0390	175.962	122.923	231.760

========== Results From @D Operation ==========

STATISTICS FOR 9 FLOW INTERVALS

Flow Intervals	Number of Cases	Percent Bias	Absolute Percent Bias	Percent RMS	R	Nash-S. r
0.0000 -- 53.665:	51655	33.282	63.781	163.33	0.734	-0.6008
53.665 -- 107.33:	793	-17.337	44.642	55.911	-0.0226	-6.012
107.33 -- 161.00:	526	-21.068	32.756	41.064	0.336	-12.65
161.00 -- 214.66:	240	-5.7437	26.459	33.539	0.299	-14.11
214.66 -- 268.33:	79	-16.639	24.790	30.326	0.316	-23.21
268.33 -- 321.99:	35	6.8597	10.531	17.360	0.260	-23.38
321.99 -- 375.66:	3	-4.3993	21.528	21.733	0.674	-29.20
375.66 -- 429.32:	5	-13.536	16.906	17.630	-0.0648	-22.83
429.32 -- 482.99:	2	-15.614	15.614	15.615	1.00	-20.57

========== Results From @E Operation ==========

THE STATISTICS FOR FLOWS GREATER THAN GIVEN VALUES

Condition	Cases	Percent Bias	Absolute Percent Bias	Percent RMS	R	Nash-S. r
flow > 16.100	4519	-0.45435	42.922	59.753	0.795	0.590
flow > 154.	404	-7.15	23.3	29.9	0.614	-0.615
flow > 214.	126	-8.88	19.5	25.1	0.673	-0.659
flow > 241.	70	-3.85	14.4	19.5	0.639	-0.139

========== Results From @F Operation ==========

STATISTICS FOR A GIVEN FLOW INTERVAL

Flow Intervals	Number of Cases	Percent Bias	Absolute Percent Bias	Percent RMS	R	Nash-S. r
0.0000 -- 16.100:	48819	31.406	61.313	154.58	0.578	-2.115
16.100 -- 153.50:	4115	2.2961	50.966	70.257	0.584	0.1476
153.50 -- 241.00:	334	-8.2106	26.203	33.186	0.289	-6.356
241.00 -- 500.00:	70	-3.8511	14.375	19.475	0.639	-0.1392

========== Results From @G Operation ==========

STATISTICS FOR GIVEN EVENTS/TIME INTERVALS

Event Number	Period	Hrs	% Bias	Abs. % Bias	% RMS	R	Nash-S. r	Modi. Rm	Total Obs Q (mm)	Total Sim Q (mm)
1.	4/25/1994 0:00 ~ 5/08/1994 23:00	335	8.4708	38.417	56.554	0.866	0.743	0.712	59.1	64.1
2.	11/12/1994 0:00 ~ 11/27/1994 23:00	383	-2.393	34.04	71.43	0.899	0.762	0.807	43.8	42.7
3.	12/07/1994 0:00 ~ 12/13/1994 23:00	167	-60.31	60.41	99.31	0.971	0.186	0.284	22.0	8.75
4.	3/12/1995 0:00 ~ 3/20/1995 23:00	215	-24.83	26.16	40.85	0.978	0.851	0.736	30.2	22.7
5.	5/06/1995 0:00 ~ 5/21/1995 23:00	383	-2.061	21.29	37.12	0.963	0.926	0.954	71.8	70.3
6.	9/17/1995 0:00 ~ 9/24/1995 23:00	191	22.08	37.45	65.10	0.883	0.726	0.854	5.12	6.25
7.	9/26/1996 0:00 ~ 10/11/1996 23:00	383	7.936	37.89	94.19	0.918	0.842	0.830	10.6	11.5

8.	10/19/1996 0:00	11/03/1996 23:00	383	-24.36	43.33	79.04	0.924	0.727	0.559	37.4	28.3
9.	11/06/1996 0:00	11/21/1996 23:00	383	11.79	40.03	98.91	0.862	0.691	0.797	48.4	54.1
10.	11/23/1996 0:00	12/06/1996 23:00	335	29.09	31.52	46.52	0.960	0.796	0.817	62.3	80.4
11.	2/18/1997 0:00	3/05/1997 23:00	383	20.85	30.14	42.38	0.956	0.887	0.887	44.9	54.2
12.	3/25/1997 0:00	3/30/1997 23:00	143	35.12	38.13	52.84	0.935	0.721	0.840	6.14	8.30
13.	6/09/1997 0:00	6/16/1997 23:00	191	66.27	86.59	121.5	0.829	0.526	0.813	8.24	13.7
14.	12/20/1997 0:00	12/28/1997 23:00	215	27.95	45.04	54.51	0.886	0.699	0.705	22.0	28.2
15.	1/03/1998 0:00	1/14/1998 23:00	287	10.36	26.79	38.17	0.919	0.828	0.905	59.3	65.4
16.	3/06/1998 0:00	3/13/1998 23:00	191	21.51	32.40	49.52	0.936	0.846	0.900	15.8	19.2
17.	3/14/1998 0:00	3/29/1998 23:00	383	26.64	30.31	52.53	0.964	0.846	0.821	51.6	65.4
18.	1/28/1999 0:00	2/02/1999 23:00	144	82.16	82.16	111.8	0.940	-0.374	0.566	3.55	6.47
19.	3/27/1999 0:00	4/07/1999 23:00	287	11.10	41.63	74.13	0.929	0.824	0.687	17.0	18.8
20.	6/22/1999 0:00	7/06/1999 23:00	359	172.6	172.6	271.9	0.832	-7.97	0.270	5.67	15.5
21.	9/08/1999 0:00	9/24/1999 23:00	407	622.2	622.2	1106.	0.793	-98.9	0.0877	3.36	24.3
22.	12/09/1999 0:00	12/19/1999 23:00	263	168.3	168.7	350.3	0.936	-6.58	0.281	2.95	7.90
23.	2/22/2000 0:00	3/02/2000 23:00	239	51.45	63.89	105.4	0.706	-1.00	0.410	2.57	3.89
24.	4/29/2000 0:00	5/11/2000 23:00	311	136.4	137.3	261.2	0.918	-5.79	0.295	4.82	11.4
Mean Values:	----------->>		290.	59.1	81.2	141.	0.904	-4.47	0.659	26.6	30.5

Overall bias, B, %	Flood bias, Bavg, %	Flood, RMS, %
14.6	24.7	68.1

CENTER OF MASS FOR GIVEN EVENTS

Event	Observed Center of Mass	Simulated Center of Mass	Time Diff. (Hr.)
1.	14:00 05/02/1994	1:00 05/02/1994	-13
2.	20:00 11/17/1994	16:00 11/17/1994	-4
3.	10:00 12/10/1994	14:00 12/10/1994	4
4.	11:00 03/15/1995	13:00 03/15/1995	2
5.	3:00 05/10/1995	8:00 05/10/1995	5
6.	10:00 09/20/1995	6:00 09/20/1995	-4
7.	18:00 09/28/1996	7:00 09/29/1996	13
8.	13:00 10/24/1996	22:00 10/25/1996	33
9.	4:00 11/11/1996	12:00 11/10/1996	-16
10.	3:00 11/28/1996	11:00 11/28/1996	8
11.	21:00 02/23/1997	15:00 02/24/1997	18
12.	0:00 03/27/1997	2:00 03/27/1997	2
13.	11:00 06/11/1997	23:00 06/11/1997	12

14.	17:00 12/23/1997	0:00 12/24/1997	7		
15.	20:00 01/07/1998	8:00 01/08/1998	12		
16.	5:00 03/09/1998	12:00 03/09/1998	7		
17.	4:00 03/19/1998	4:00 03/19/1998	0		
18.	10:00 01/31/1999	14:00 01/31/1999	4		
19.	9:00 04/03/1999	12:00 04/02/1999	-21		
20.	13:00 06/28/1999	9:00 06/28/1999	-4		
21.	17:00 09/15/1999	8:00 09/14/1999	-33		
22.	19:00 12/13/1999	3:00 12/13/1999	-16		
23.	6:00 02/26/2000	2:00 02/26/2000	-4		
24.	10:00 05/04/2000	17:00 05/03/2000	-17		

Mean value of time difference for above events --> -0.2083 (hours)
Mean value of absolute time difference for above events --> 10.79 (hours)

MAXIMUM VALUES OF FLOW FOR GIVEN EVENTS

Event	Observed Max	Date	Simulated Max	Date	Time Diff.	Max Flow Ratio	Relative Peak Error
1.	224.136	17:00 05/03/1994	201.241	15:00 04/30/1994	-74	0.898	-0.102
2.	215.080	18:00 11/15/1994	332.228	4:00 11/15/1994	-14	1.54	0.545
3.	142.349	22:00 12/09/1994	46.8340	6:00 12/10/1994	8	0.329	-0.671
4.	148.292	3:00 03/15/1995	112.777	6:00 03/14/1995	-21	0.761	-0.239
5.	288.660	23:00 05/08/1995	336.426	20:00 05/08/1995	-3	1.17	0.165
6.	46.9780	11:00 09/20/1995	49.3770	2:00 09/20/1995	-9	1.05	0.0511
7.	155.672	4:00 09/27/1996	112.306	5:00 09/27/1996	1	0.721	-0.279
8.	253.252	1:00 10/22/1996	212.096	23:00 10/21/1996	-2	0.837	-0.163
9.	482.988	17:00 11/07/1996	464.579	12:00 11/07/1996	-5	0.962	-0.0381
10.	230.001	14:00 11/25/1996	280.712	19:00 11/25/1996	5	1.22	0.220
11.	194.429	10:00 02/21/1997	175.486	10:00 02/21/1997	0	0.903	-0.0974
12.	59.9340	21:00 03/25/1997	59.2400	1:00 03/26/1997	4	0.988	-0.0116
13.	129.914	10:00 06/10/1997	102.095	15:00 06/10/1997	5	0.786	-0.214
14.	119.943	10:00 12/24/1997	100.092	14:00 12/24/1997	4	0.834	-0.166
15.	175.843	8:00 01/05/1998	197.659	10:00 01/08/1998	74	1.12	0.124
16.	118.329	9:00 03/08/1998	118.197	10:00 03/08/1998	1	0.999	-0.00112
17.	203.641	4:00 03/18/1998	267.864	1:00 03/17/1998	-27	1.32	0.315
18.	24.7870	1:00 01/31/1999	35.8970	4:00 01/31/1999	3	1.45	0.448
19.	171.607	5:00 04/04/1999	131.264	0:00 04/04/1999	-5	0.765	-0.235
20.	29.2270	10:00 06/26/1999	65.8790	17:00 06/26/1999	7	2.25	1.25
21.	16.9230	14:00 09/14/1999	92.5590	14:00 09/14/1999	0	5.47	4.47
22.	26.2660	18:00 12/12/1999	66.4170	19:00 12/12/1999	1	2.53	1.53

23.	11.0700	5:00 02/24/2000	15.3230	22:00 02/23/2000	-7	1.38	0.384	
24.	23.2110	17:00 05/02/2000	58.5700	22:00 05/02/2000	5	2.52	1.52	
				Mean value ---------->>		-2.042	1.367	0.5519

Overall Peak Flow Statistics: (for 24 events)

Peak Error, Ep, % *	Overall Peak Time Bias, Bp, hrs *	Peak Time Error, Bp,avg, hrs
24.96	-49.00	11.88

Averaged observed peak flow for all events: 145.5 CMS

STATISTICS FOR GIVEN TIME INTERVAL/EVENT WITH SIMULATED
DATA SHIFTED TO ALIGN MAXIMUM VALUES

Event	Period	Hours	Percent Bias	Absolute Percent Bias	Percent RMS	R	Nash-S. r	Total Observed Flow (mm)	Total Simulated Flow (mm)
1.	0:00 4/25/1994 ~ 23:00 5/08/1994	335	1.285	72.23	94.51	0.598	0.281	59.1	59.9
2.	0:00 11/12/1994 ~ 23:00 11/27/1994	383	-2.257	52.60	99.49	0.798	0.538	43.8	42.8
3.	0:00 12/07/1994 ~ 23:00 12/13/1994	167	-60.07	63.35	100.2	0.947	0.172	22.0	8.80
4.	0:00 3/12/1995 ~ 23:00 3/20/1995	215	-25.55	58.66	96.67	0.526	0.168	30.2	22.5
5.	0:00 5/06/1995 ~ 23:00 5/21/1995	383	-1.803	24.51	44.60	0.946	0.894	71.8	70.5
6.	0:00 9/17/1995 ~ 23:00 9/24/1995	191	21.80	44.14	65.64	0.880	0.722	5.12	6.24
7.	0:00 9/26/1996 ~ 23:00 10/11/1996	383	9.821	35.52	88.11	0.929	0.862	10.6	11.7
8.	0:00 10/19/1996 ~ 23:00 11/03/1996	383	-24.86	45.58	81.45	0.911	0.710	37.4	28.1
9.	0:00 11/06/1996 ~ 23:00 11/21/1996	383	15.00	29.09	50.17	0.970	0.921	48.4	55.6
10.	0:00 11/23/1996 ~ 23:00 12/06/1996	335	29.20	29.85	43.20	0.972	0.824	62.3	80.5
11.	0:00 2/18/1997 ~ 23:00 3/05/1997	383	20.85	30.14	42.38	0.956	0.887	44.9	54.2
12.	0:00 3/25/1997 ~ 23:00 3/30/1997	143	35.28	35.64	54.17	0.929	0.706	6.14	8.31
13.	0:00 6/09/1997 ~ 23:00 6/16/1997	191	66.48	76.91	106.2	0.887	0.637	8.24	13.7
14.	0:00 12/20/1997 ~ 23:00 12/28/1997	215	28.25	44.29	53.24	0.897	0.713	22.0	28.3
15.	0:00 1/03/1998 ~ 23:00 1/14/1998	287	-1.071	73.43	105.5	0.341	-0.314	59.3	58.7
16.	0:00 3/06/1998 ~ 23:00 3/13/1998	191	21.58	32.12	48.31	0.940	0.854	15.8	19.2
17.	0:00 3/14/1998 ~ 23:00 3/29/1998	383	26.55	82.27	134.3	0.601	-0.00492	51.6	65.3
18.	0:00 1/28/1999 ~ 23:00 2/02/1999	144	83.65	83.65	111.5	0.947	-0.366	3.55	6.52
19.	0:00 3/27/1999 ~ 23:00 4/07/1999	287	10.54	51.56	93.15	0.859	0.722	17.0	18.7
20.	0:00 6/22/1999 ~ 23:00 7/06/1999	359	172.5	172.5	264.9	0.906	-7.52	5.67	15.5
21.	0:00 9/08/1999 ~ 23:00 9/24/1999	407	622.2	622.2	1106.	0.793	-98.9	3.36	24.3
22.	0:00 12/09/1999 ~ 23:00 12/19/1999	263	168.4	168.9	350.5	0.935	-6.59	2.95	7.91
23.	0:00 2/22/2000 ~ 23:00 3/02/2000	239	51.31	60.30	96.20	0.804	-0.669	2.57	3.89
24.	0:00 4/29/2000 ~ 23:00 5/11/2000	311	136.4	137.7	260.1	0.927	-5.73	4.82	11.4

```
          Mean Values:  ---------->>        290.      58.6      88.6      150.   0.842   -4.56      26.6     30.1
```

```
======================   Results From @H Operation   ======================

            PEAK FLOW FOR GIVEN TIME INTERVAL ABOVE GIVEN THRESHOLD

                 Threshold Value = 214., Window = 120 hr(s)
```

Observed Peak Flow Qobs	Date	Simulated Peak Flow Qsim	Date	Time Difference (hour)	Percent Peak Difference 100*(S-O)/O	Peak flow Ratio S/O
224.136	17:00 5/03/1994	none found				
215.080	18:00 11/15/1994	none found				
288.660	23:00 5/08/1995	336.426	20:00 5/08/1995	-3	16.5475	1.165
253.252	1:00 10/22/1996	none found				
482.988	17:00 11/07/1996	464.579	12:00 11/07/1996	-5	-3.81148	0.9619
230.001	14:00 11/25/1996	280.712	19:00 11/25/1996	5	22.0482	1.220

```
 Summery Statistics:
----------------------

  Total number of observed peak flows above 214.0 --> 6
  Total number of matched simulated peak flows -----> 3

  Mean value of peak flow time difference ----------->  -1.000 hr(s)
  Mean value of peak flow difference --------------->   11.59 cms
  Standard deviation of peak flow time difference -->   5.292 hr(s)
  Standard deviation of peak flow difference ------->   13.62 cms
```

```
======================   Results From @I Operation   ======================

                ACCUMULATED FLOW IN DEPTH (MM)
                     FOR EVERY 1 MONTHS
```

Period	Observed	Simulated	Acc Error	Error This Period
4/1994 ~ 4/1994	21.19	27.69	6.502	6.502
5/1994 ~ 5/1994	100.8	88.57	-12.22	-18.73

6/1994	6/1994	113.9	97.48	-16.46	-4.235
7/1994	7/1994	124.0	113.3	-10.69	5.774
8/1994	8/1994	130.0	120.9	-9.067	1.618
9/1994	9/1994	136.6	131.7	-4.895	4.173
10/1994	10/1994	146.4	144.4	-2.064	2.831
11/1994	11/1994	202.8	197.0	-5.781	-3.718
12/1994	12/1994	241.8	214.4	-27.40	-21.62
1/1995	1/1995	262.8	223.3	-39.49	-12.09
2/1995	2/1995	274.6	227.5	-47.04	-7.547
3/1995	3/1995	327.6	258.0	-69.60	-22.56
4/1995	4/1995	387.7	298.3	-89.42	-19.82
5/1995	5/1995	503.7	396.9	-106.8	-17.42
6/1995	6/1995	548.0	427.4	-120.6	-13.80
7/1995	7/1995	557.1	438.7	-118.4	2.244
8/1995	8/1995	562.4	443.7	-118.7	-0.3253
9/1995	9/1995	572.7	453.1	-119.5	-0.8105
10/1995	10/1995	577.1	458.0	-119.1	0.4412
11/1995	11/1995	580.8	462.0	-118.8	0.2874
12/1995	12/1995	586.5	466.5	-120.0	-1.201
1/1996	1/1996	593.0	471.1	-121.9	-1.892
2/1996	2/1996	595.9	473.6	-122.3	-0.4278
3/1996	3/1996	603.4	479.5	-123.9	-1.565
4/1996	4/1996	620.9	493.5	-127.4	-3.453
5/1996	5/1996	626.1	495.4	-130.7	-3.371
6/1996	6/1996	632.7	502.8	-130.0	0.7632
7/1996	7/1996	637.9	508.9	-129.0	0.9090
8/1996	8/1996	655.0	524.7	-130.3	-1.221
9/1996	9/1996	676.6	550.8	-125.8	4.422
10/1996	10/1996	712.7	576.3	-136.5	-10.61
11/1996	11/1996	818.9	701.1	-117.9	18.60
12/1996	12/1996	846.9	733.0	-114.0	3.895
1/1997	1/1997	860.5	742.4	-118.1	-4.168
2/1997	2/1997	913.7	800.7	-113.0	5.180
3/1997	3/1997	938.7	831.5	-107.2	5.738
4/1997	4/1997	974.3	895.0	-79.29	27.92
5/1997	5/1997	993.6	933.9	-59.72	19.58
6/1997	6/1997	1008.	956.5	-51.64	8.079
7/1997	7/1997	1013.	964.5	-48.44	3.197
8/1997	8/1997	1016.	974.9	-41.11	7.329
9/1997	9/1997	1016.	975.3	-40.95	0.1572
10/1997	10/1997	1018.	980.3	-37.60	3.357
11/1997	11/1997	1021.	987.4	-33.40	4.200
12/1997	12/1997	1047.	1022.	-24.75	8.646
1/1998	1/1998	1126.	1117.	-8.619	16.13

2/1998 ~	2/1998	1143.	1135.	-7.694	0.9247
3/1998 ~	3/1998	1214.	1224.	9.647	17.34
4/1998 ~	4/1998	1232.	1242.	10.57	0.9280
5/1998 ~	5/1998	1239.	1250.	10.80	0.2205
6/1998 ~	6/1998	1245.	1264.	18.56	7.760
7/1998 ~	7/1998	1247.	1267.	19.81	1.258
8/1998 ~	8/1998	1248.	1271.	22.17	2.359
9/1998 ~	9/1998	1250.	1274.	24.25	2.075
10/1998 ~	10/1998	1253.	1289.	36.14	11.89
11/1998 ~	11/1998	1256.	1299.	42.90	6.757
12/1998 ~	12/1998	1266.	1321.	54.21	11.31
1/1999 ~	1/1999	1271.	1327.	56.04	1.828
2/1999 ~	2/1999	1275.	1332.	56.97	0.9373
3/1999 ~	3/1999	1284.	1347.	63.53	6.554
4/1999 ~	4/1999	1306.	1376.	69.48	5.953
5/1999 ~	5/1999	1323.	1412.	88.77	19.29
6/1999 ~	6/1999	1334.	1438.	103.5	14.72
7/1999 ~	7/1999	1341.	1445.	104.6	1.115
8/1999 ~	8/1999	1343.	1449.	105.5	0.9059
9/1999 ~	9/1999	1348.	1475.	127.2	21.67
10/1999 ~	10/1999	1350.	1479.	128.7	1.525
11/1999 ~	11/1999	1353.	1483.	130.0	1.286
12/1999 ~	12/1999	1358.	1493.	135.8	5.841
1/2000 ~	1/2000	1361.	1501.	140.2	4.335
2/2000 ~	2/2000	1365.	1506.	141.2	1.057
3/2000 ~	3/2000	1372.	1525.	153.6	12.40
4/2000 ~	4/2000	1378.	1533.	154.9	1.285
5/2000 ~	5/2000	1385.	1547.	162.0	7.102
6/2000 ~	6/2000	1389.	1559.	170.4	8.362
7/2000 ~	7/2000	1390.	1561.	171.1	0.7089