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MONTHLY STREAMFLOW SIMULATION IN BOLIVIAN BASINS WITH A STOCHASTIC MODEL

ENDE EMPRESA NACIONAL DE ELECTRICIDAD

MONTHLY STREAMFLOW SIMULATION IN BOLIVIAN BASINS WITH A STOCHASTIC MODEL

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The cover photo shows the spillway of the Corani reservoir.

Photo: C. Ambjörn

SMHIs tryckeri, Norrköping 1987.

Table of contents December 1986

		Page
1.	Introduction	1
2.	Stochastic simulation of hydrological time series	3
2.1	Description of the stochastic model	3
2.2	Methods of calculation	3
3.	Description of the basins and input data	4
3.1	Corani	5
3.2	Locotal, S:a Isabel	6
3.3	Miguillas	7
4.	Results	7
5.	Conclusions	13
6.	References	13
7.	Manual	14
Appendix:	1. Input data, all basins	17
Appendix:	2. Output data, Corani	

1. INTRODUCTION

The purpose of this project is to introduce new and efficient methods for hydroelectric studies in Bolivia through the use of mathematical modelling techniques. It is a collaboration project between Empresa Nacional de Electricidad, ENDE in Bolivia and the Swedish Meteorological and Hydrological Institute, SMHI in Sweden.

This report deals with the transfer of a stochastic model for simulating monthly streamflows and training in the handling of the model. The other part of the project, which is reported in Application of the HBV model to Bolivian Basins, ref (1), deals with the transfer of a conceptual model, called the HBV model. The HBV model extends daily discharge time series by using precipitation data from periods without discharge observations.

A personal computer, PC, is purchased and installed for this purpose at ENDE, Cochabamba.

The project started in March 1986. In May a SMHI-consultant went to Bolivia to collect data. In August two engineers from ENDE came to SMHI for two months in order to get "on the job training" on the stochastic model. The SMHI-consultant went back to ENDE in November 1986 for installing and testing the system.

The collaboration project is partly financed by the Swedish Agency for Technical and Economic Co-operation, BITS, Stockholm, Sweden. ENDE in Cochabamba, Bolivia has also contributed economically to the project.

ENDE was established by the Bolivian Government in 1965 and is responsible for the electrical power production in Bolivia. At present hydroelectric power accounts for about 70% of all generated electricity in Bolivia. This is planned to increase to 85% by the year of 2000.

The Country

The national territory of Bolivia covers approximately 1 100 000 km^2 and sustains a population of about 5 millions (1986). From west to east, three great physiographic units can be observed: the Andean plateau, the valleys and yungas, and the eastern plains (Fig 1). The Bolivian plateau occupies the southwestern part of the country and has a mean altitude of about 3800 m. Undulations and several lesser ranges disturb the plateau, and some mountain peaks reach nearly 7000 m altitude. This is a cold region with a mean annual temperature of about 10^{o}C. Daily temperature variation is typically 20^{o}C but may reach 35^{o}C. Precipitation varies between 100 and 900 mm/year. The plateau encloses nearly 15% of the total area of the country and sustains 43% of the population. Ref (2).

The valleys and yungas represent the transition from the Andean plateau to the eastern plains. Owing to their mountainous nature, local climate conditions are variable. Regions of 1800 to 3000 m altitude are called valleys, whereas the so-called "yungas" belong to the 600 to 1800 m stratum and are subject to a warmer climate and greater humidity.

Annual precipitation in the valleys may vary between 500 and 900 mm, but in the yungas it increases to 1500 mm, with a simultaneous increase in temperature and humidity. The valleys and yungas cover approximately 30% of the total area and contain 46% of the population.

The plains extend over the northern and eastern part of the country and have a mean altitude of less than 600 m. Temperature is uniform with extreme annual means between 22°C and 27°C. Precipitation varies from 600 mm to more than 2500 mm. The streams originating in the mountain regions cross the plains and are collected by the great river systems of the Amazon and the Rio de la Plata. The eastern plains cover approximately 55% of Bolivia but sustain only 11% of the population.

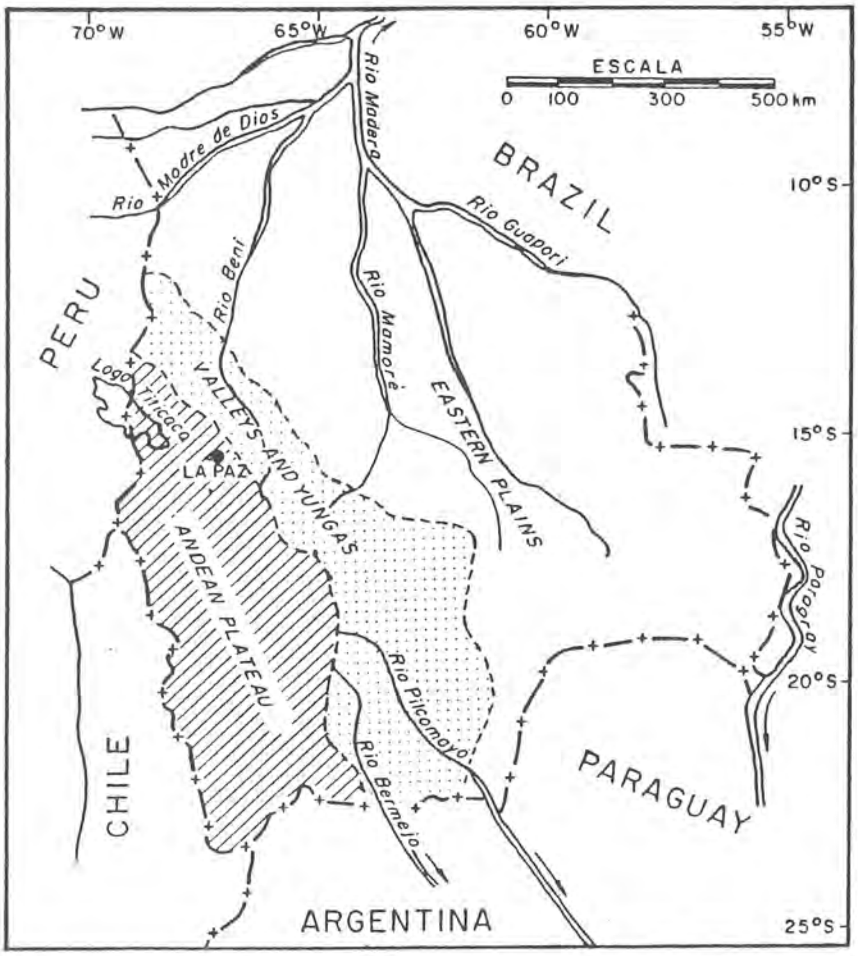


Figure 1. Main Physiographical Regions of Bolivia

2. STOCHASTIC SIMULATION OF HYDROLOGICAL TIME SERIES

For various water management problems including planning and optimal design of storage reservoirs long records of monthly streamflow are essential. Usually only short records are available, and there is a need for methods to simulate long records.

Stochastic streamflow modelling is a means to simulate long streamflow records. Stochastic models could be seen as a working tool to solve water management problems.

There are different types of stochastic models available for simulation of monthly streamflow data. The model applied here is HEC-4 developed at the Hydrologic Engineering Centre, US Army Corps of Engineers in USA. With the long records of monthly steamflow simulated with the HEC-4 program it is possible to examine critical periods of time and to study cumulative departures from the mean flow, which could be used in designing for instance optimal regulation rules for water management systems.

2.1 Description of the stochastic model

The model analyses monthly streamflows at a number of stations to determine their statistical characteristics and will generate a sequence of hypothetical streamflows of any desired length having those characteristics. It will reconstitute missing streamflows on the basis of concurrent flows observed at other locations and will obtain maximum and minimum quantities for each month and for specified durations in the recorded, reconstituted and generated flows. The length of the observed time series should be 20 years, if possible. Often monthly data are available for longer periods than daily.
The conceptual HBV model can be used as an efficient complement in this analysis. The monthly discharge data will be produced from daily precipitation data during periods when discharge data are not available or reliable. In this project, the conceptual model has been very valuable in filling gaps in the time series.

This is special PC-version of the HEC-4 program, which is shorter than the original. Some facilities, found as not important for ENDE's needs, have been deleted.

2.2 Methods of calculation

The program uses monthly values as input data for one or several stations in the same run. For each month it calculates statistical characteristics such as maximum, minimum, mean value, standard deviation and skew coefficient. The maximal number of stations in a run is 10.

The stochastic model utilizes the correlation between pairs of successive months: January-February, February-March and so on. The model also calculates the correlation coefficients between all the different stations for each month.

To avoid that negative streamflow data are being generated the logaritm of the streamflow has been used.

Monthly values missing from the records of the various stations are being reconstituted using that information from the other stations, which will contribute most toward increasing the reliability of the statistics computed from the incomplete record. The missing value is computed from a regression equation, introducing a random component. New, consistent correlations are now calculated. The mean and the standard deviation are adjusted.

Generation of synthetic series are then made by computing a regression equation for each station and month and adding a random component.

Maximum and minimum values are obtained for periods of recorded and reconstituted flows as well as for the generated series. These values can, for the synthetical series, be calculated in specified parts of the total period.

3. DESCRIPTION OF THE BASINS AND INPUT DATA

The transfer of the model is made by applying it to three Bolivian basins.

Two of the basins Corani and Locotal are situated at the beginning of the Mamoré River and the other, Miguillas, is situated at the origin of the Beni River, both rivers are tributaries of the Amazon River.

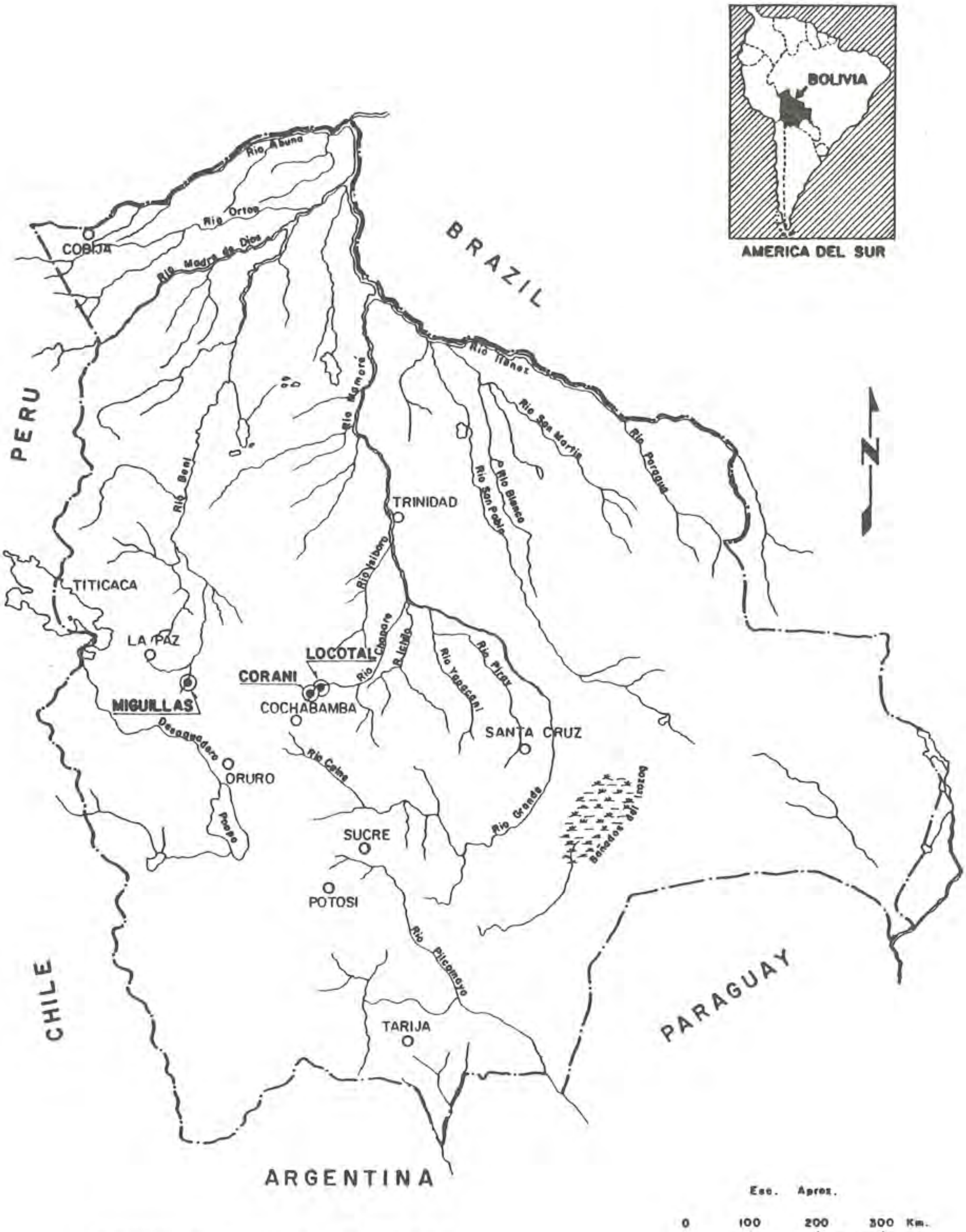


Figure 2. Map of Bolivia.

3.1 Corani

The area of the Corani basin is 287 km^2 and the elevation range is from 3200 to 4200 meters above sea level. The reservoir for the hydropower plant of Corani is situated at the outlet of the basin.

The discharge data from Corani used in the calculations consist of two different series. The first series from Sep 1952 - Mar 1966, is measured values before the reservoir was introduced. The dam was built during 1966/67. The second series is from Mar 1968 - Dec 1984, which means after the dam was built. The monthly discharge values are obtained from the daily flow through the turbines of the power plant, the reservoir levels and the spill across the reservoir spill-way. During 1982/83 the level of the dam was raised by 4 meters. No reliable data of the spill are available during that period, so zero-spill is assumed. During the total period with the dam the evapotranspiration is greater than before the reservoir was constructed, due to a larger water surface. Comparisons, of the two series though, show that this fact affects the values less than 5%. The uncertainity in the observed values is at least of the same magnitude, which means that the two series could be added to each other, which gives one long series from 1952-1984, with a gap in the middle. The length now is about 30 years, which is very good for stochastical simulations. The input values are listed in Table 1, appendix 1.

3.2 Locotal, S:a Isabel

The area of the basin of Locotal is 200 km^2. The elevation ranges from 1700 to 4200 meters above sea level.

The power plant of Corani is actually situated within the basin of Locotal, and the water from the Corani reservoir is lead to the plant through a tunnel. This means that to get runoff values from the Locotal basin, the flow through the turbines must be substracted from the observed discharges at the station in Locotal. The cross section at this station varies due to erosion and bed transport. Flow measurements are made frequently in order to get a correct stage-discharge relation, but there are still periods when the discharge values are uncertain.

The observed series is from 1967 to 1983, and the discharge values from the HBV model replace missing values in altogether 20 months. The series is 17 years long, which will be regarded as enough data for the stochastic calculations. The input values are listed in Table 2, appendix 1.

3.3 Miguillas

The area of the basin of Miguillas is 420 km , and the elevation ranges from 1950 to 5600 meters above sea level. There is snow in some parts all the year. Observed or calculated data from the station Humapalca cover the period Aug 1972 to Oct 1983, which gives about 12 years. This is quite a short period as the basis for synthetic series. We will anyhow make the calculations, bearing in mind that the results are not reliable. The input data are listed in Table 3, appendix 1.

4 RESULTS

The results from the Corani basin are described below more thoroughly.

The diagrams in Figure 3 show the observed monthly streamflow at Corani for the years 1953--1962 and one simulated time series of monthly streamflow for 10 years.

It can be seen that the simulated series shows the same general fluctuations as the observed one, but the maximum and minimum flows are somewhat more extreme.

In Figure 4 and 5 the cumulative departures from the long term average are shown for the same series as in Figure 3. These curves can be used for determining for instance the reservoir storage volume necessary for maintaining a constant flow equal to the long term mean. The required volume corresponds to the difference between the curve's maximum and minimum. It is also interesting to note that the generated cumulative curve displays a smaller difference between max and min than the observed series. This is of course due to the fact that a stochastic model does not simulate temporary fluctuations of the mean. On the other hand it is obvious from the curves in Figure 3 that the simulated series of monthly streamflow shows somewhat greater extremes than the observed flows.

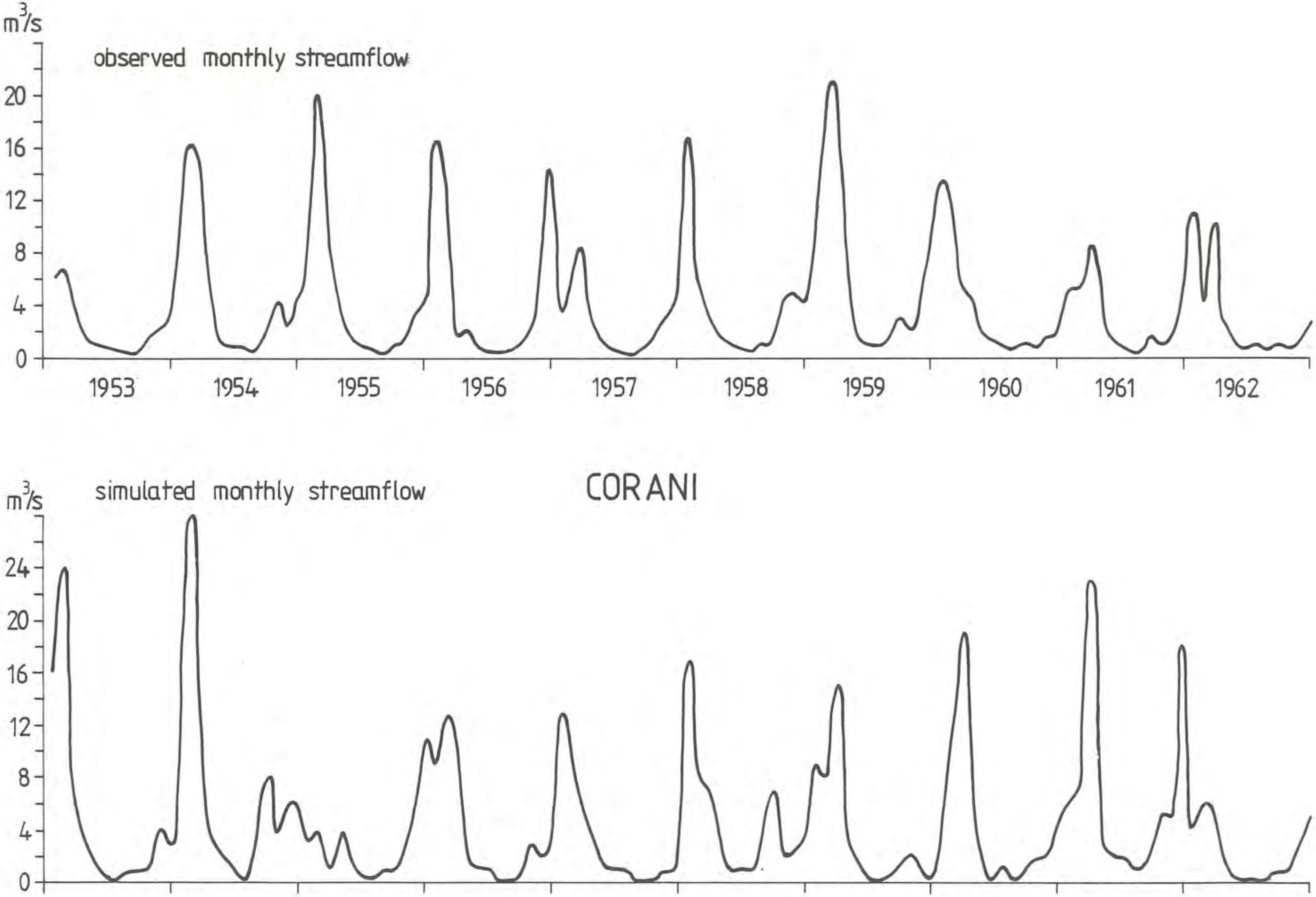


Figure 3. Observed, monthly steamflows at Corani and simulated streamflows for 10 years.

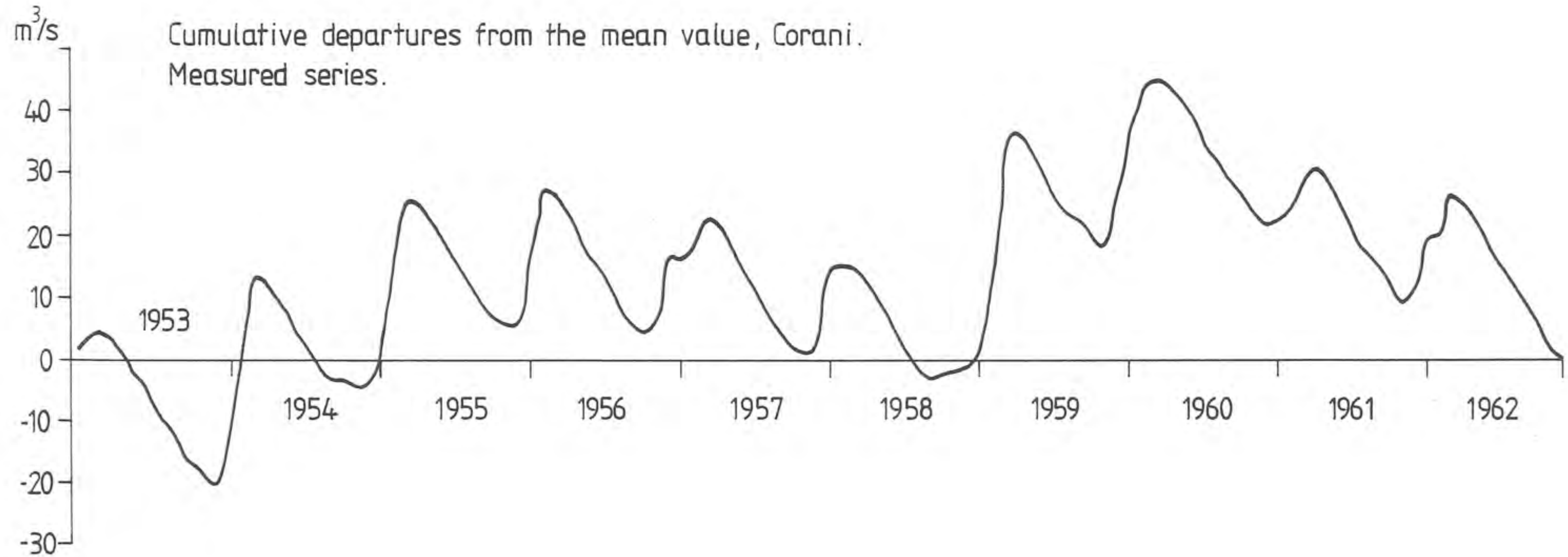

m³/s
Cumulative departures from the mean value, Corani.
Measured series.
40
30
20
10
0
-10
-20
-30
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962

Figure 4.

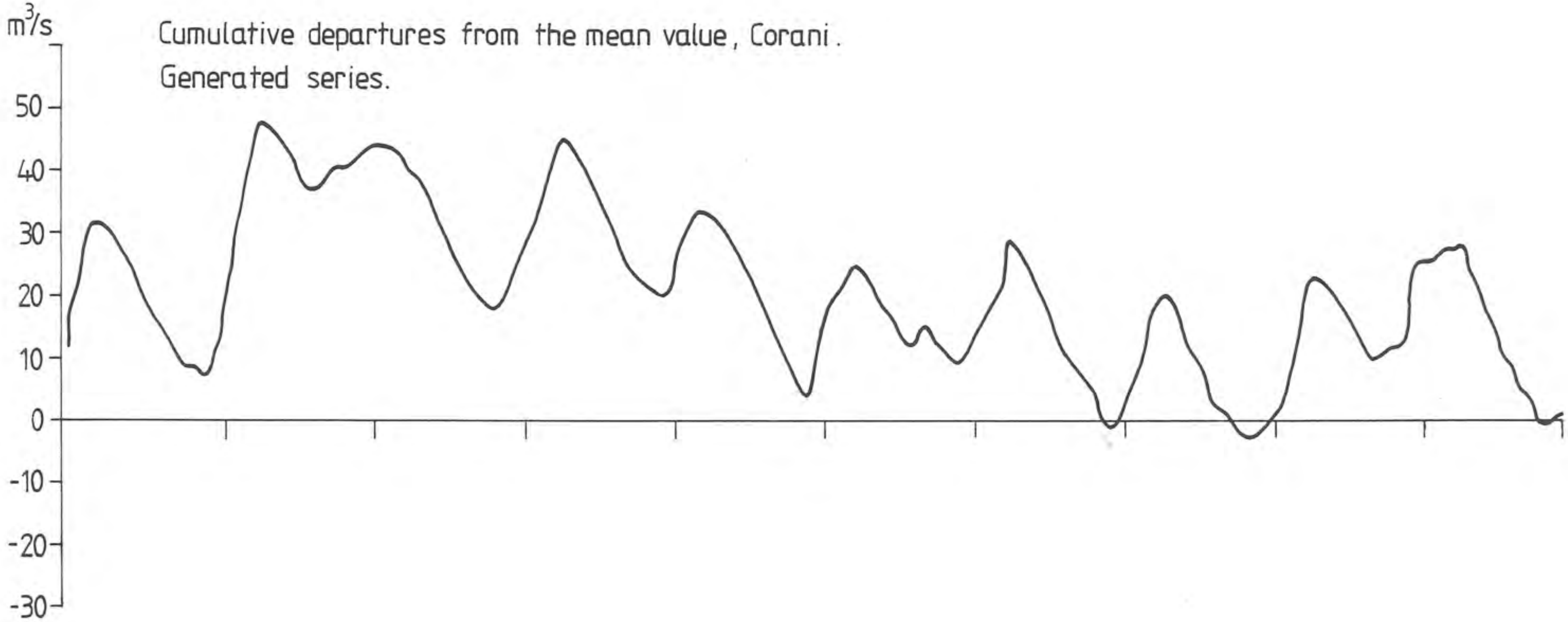
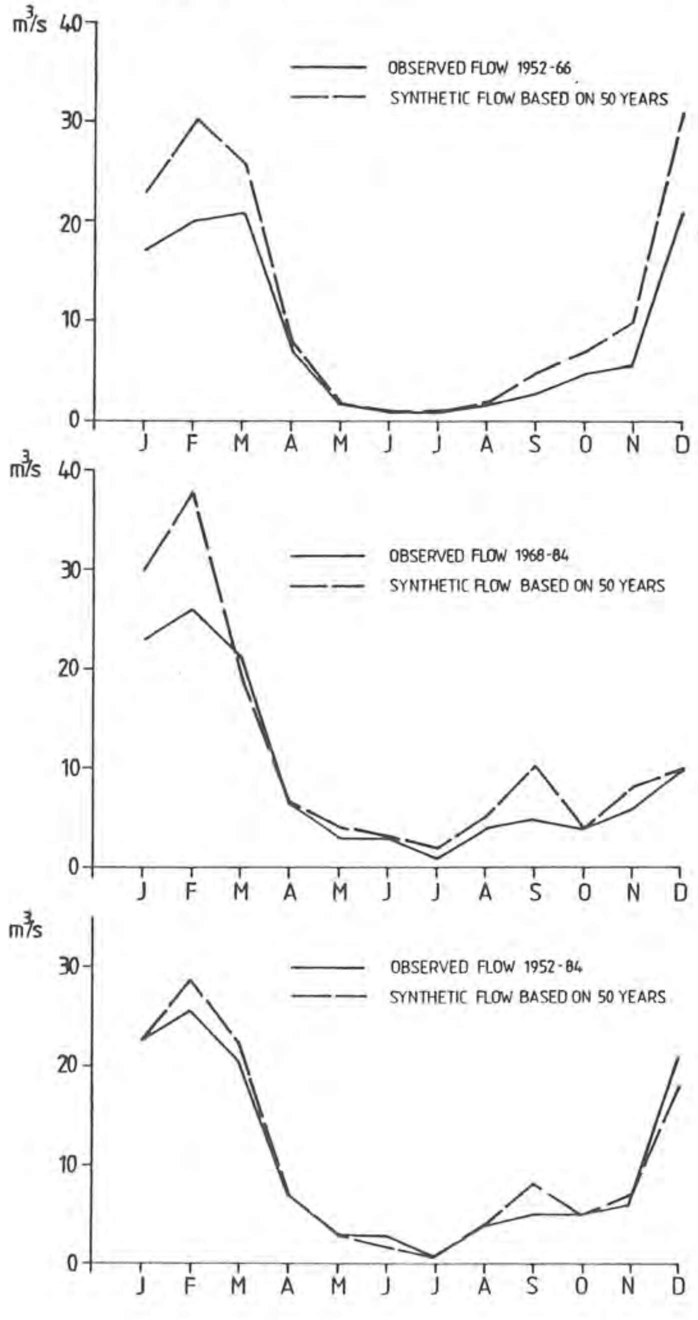

m³/s
Cumulative departures from the mean value, Corani.
Generated series.
50
40
30
20
10
0
-10
-20
-30

Figure 5.

Some comparisons of the maximas are made between the two different parts of the total observed series and the total series itself as well as between different generated synthetic flows. The maximum value for each month is regarded. These values are plotted below. Figure 6 a-c show a) the maximum streamflow for the period 1952-66 and the maxima of its synthetic series, b) the maximum streamflow for the period 1968-84 and the maxima of its synthetic series and c) the maximum streamflow for the total period and the maxima of its synthetic series.

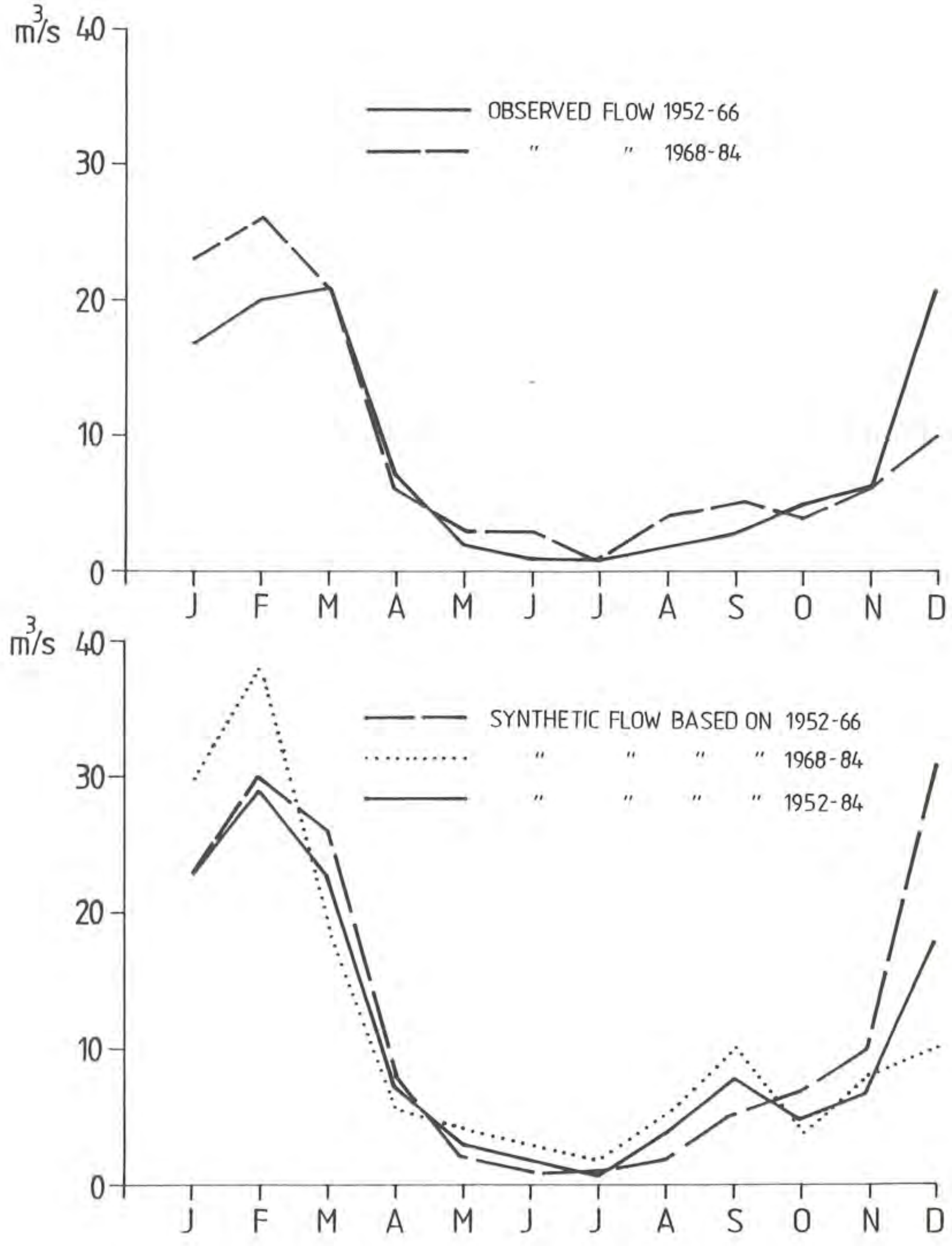
It's interesting to see, that the maximas in the synthetic series based on the long period 1952-84, 33 years, deviate very little from the observed maxima for each month. The short periods though give great differences in the synthetic values compared to the measured ones. Here, of course, the uncertainity is much bigger, because the series are too short for accurate stochastic simulation.



Corani basin.

Figure 6 a-c. Monthly maximum streamflows.

Figure 7a shows the maximas of the two parts of the measured series just to give an idea of the difference between them. Figure 7b is a plot of the maximas of the three different synthetic series named above. The curve with the fully drawn line shows the reliable maximas, because they are based on the long time series. It is also clear that this one often has the smallest maximas, more moderate than those of the two others.



Corani basin
Figure 7. a) Monthly maximum observed streamflows.
b) Generated, synthetic maximas.

5. CONCLUSIONS

a) The model is installed and it works for different types of Bolivian basins.

b) Long storage reservoir records of monthly streamflows, as Corani flows, can be generated by the stochastic model HEC-4 and the output values are reliable and can be used for further studies.

c) ENDE´s staff has learned to handle the model and is now able to run it and analyze the results without further instructions.

6. REFERENCES

(1) Johansson Barbro, Persson Magnus, Aranibar Enrique, Llobet Roberto. Application of the HBV model to Bolivian basins. SMHI report No. 10, Norrköping 1987.

(2) Paredes-Acre, Leonardo E., and Klohn Wulf. Improvement of Hydrological-Services in Bolivia (1970).

* * *

ACKNOWLEDGEMENTS

Thanks are due to Mr Arne Forsman, SMHI the projectleader and Mr Ola Grahn, SMHI for valuable assistence in computer techniques.

7. MANUAL

Never make changes in the main program, and if you do, always work with a copy of the program. Language: Fortran.

Input data

File no 8.

Give the file a suitable name, such as CORANI1.DAT. The file contains general information in letters about the area, kind of data and so on.

Thereafter specific information comes; five values. Be very careful to keep the correct position (format) for each value.

1:st value: Starting year. If you have more than one station, choose the earliest year.
2:nd value: Starting month. You can start with January, which gives the value 1, if you start with October give the value 10. One reason for not choosing January is if you want to separate the rainy season from the dry season, because the model also calculates max/min in six months-periods.
3:rd value: The total length on the observation period in years, based of the earliest and the latest year on all the stations calculated.
4:th value: The amount of years for which you want to calculate the generated flow.

5:th value: You can calculate max/min of the generated flow in parts. If you generate 100 years, you can calculate max/min for 25-years-periods. Then you write 25 in this place of the data-file.

Example of the data-file no 8.

```
A  FILE 8: CORANI1.DAT     (informacion requerida)/OCT.1986
A   ANIO       MES     NoANOS  NoANOS NoANOS
A INICIAL    INIC.     OBSERV  GENER. GEN.PAR
B   1952       01        33      50      50
C
END OF FILE
```

File no 9

Give the file a suitable name, such as CORANI.DAT. The file contains station number (3 places) and year (4 places), and 12 values with the monthly streamflows. Be very careful to keep the proper positions (format) for each value. Missing values, then punch -1. in the position where the value should have been. All values are real numbers, which means that there always must be a dot, for example 12.0, 12300.0, 13.87 or 14. Never punch only 2 or 13890 and so on. Any station having less than 3 years data for any of the months is taken out of the calculation by the computer program, it then writes station xxx deleted, insufficient data. Don't forget to always finish the file with a line containing zeros in at least the first seven positions.

Example of the data file no 9 is found in appendix 1, Table 1.

Output data

There are two different output files no 4 and no 7. The first file, no 4, gives all the calculated results and the input data. The second file, no 7, gives the recorded and reconstituted time series and the generated time series for all stations.

The output in file 4 and file 7 from a calculation using only one station is shown in appendix no 2.

Compiling, linking and running the program

Compiling the HEC4A.FOR and linking HEC4A.OBJ+HEC4B.OBJ, use the HEC4.BAT which also contains the total information. Punch HEC4. In the compilation you always get a list, called for example HEC4A.LST which contains the program and the compilation errors, if there are any. On the screen you also get information if there are any 'warnings' or 'errors' in the program.

The HEC4.BAT sequence:

```
REM HEC4.BAT
REM compile and linking  sequence for stochastic streamflows
REM following two lines only compile 1st and 2nd part of the program:
REM profort HEC4A.for/L/Z >HEC4A.lst
REM profort HEC4B.for/L/Z >HEC4B.lst (it is compiled!)
REM next line link the two parts together:
REM link HEC4A+HEC4B
REM next line shows which library you must use when you link:
REM C:            \fortran\lib\profort
REM  profort HEC4A.for/L/Z >HEC4A.lst
     profort hec4b.for/L/Z >hec4b.lst
REM  link HEC4A+HEC4B,,nul,\fortran\lib\profort
     LINK HEC4A+HEC4B,,NUL,\SYS\FORTRAN\PROFORT.LIB
REM Now your executable element has the name HEC4A !!!
```

When you run a program you only punch the name of the BAT-sequence, if you for example run the Corani-basin you only write H4CORANI.

The H4CORANI.BAT sequence:

```
REM H4CORANI.BAT
REM It is enough write h4corani and the program HEC4 starts
REM HEC4 : starting sequence for stochastic streamflows for CORANI
          set fort8=corani1.dat
          set fort9=corani.dat
          set fort4=res.dat
          set fort7=out.dat
          hec4a
```

APPENDIX 1

Table 1

1101952	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	1.25	1.90	1.32	3.23
1101953	6.08	6.82	3.56	1.61	1.00	0.68	0.56	0.42	0.37	1.59	2.36	2.76
1101954	14.89	16.31	15.10	2.81	0.95	0.81	0.83	0.65	1.96	4.18	2.56	4.29
1101955	12.73	20.20	8.80	3.97	1.65	0.73	0.65	0.49	0.85	1.12	3.17	4.46
1101956	16.80	13.50	1.97	2.08	0.65	0.54	0.44	0.63	0.66	1.79	6.11	14.46
1101957	3.60	6.25	8.28	2.66	0.90	0.46	0.30	0.25	0.76	1.90	3.65	4.64
1101958	16.82	5.09	3.28	1.48	0.89	0.45	0.39	1.61	1.07	4.80	4.77	4.20
1101959	7.32	19.80	21.14	6.35	1.54	0.83	0.57	0.63	3.19	2.19	2.14	11.68
1101960	13.62	11.44	5.41	4.18	1.57	0.77	0.63	0.43	1.18	0.93	1.48	1.85
1101961	5.19	5.19	8.45	6.86	1.58	0.65	0.38	0.26	1.82	1.20	1.84	6.64
1101962	11.12	4.39	10.43	2.81	1.43	0.62	0.65	0.33	0.81	0.65	0.61	2.71
1101963	12.52	14.98	12.58	3.87	1.43	0.89	0.42	0.27	0.44	1.42	3.97	5.04
1101964	3.69	10.44	15.76	2.60	1.17	0.54	0.29	1.01	1.49	1.78	1.07	2.13
1101965	10.53	11.00	4.83	1.71	0.80	0.27	0.20	0.19	1.98	3.38	5.01	21.49
1101966	7.86	9.91	11.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
1101967	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
1101968	-1.00	-1.00	7.0	1.9	0.6	0.1	0.0	0.0	0.0	0.2	2.8	3.8
1101969	8.3	12.6	1.5	1.2	0.4	0.0	0.2	0.2	0.0	0.2	1.4	2.2
1101970	5.3	10.3	9.5	3.2	0.8	0.4	0.4	0.2	0.6	1.0	1.4	6.0
1101971	15.9	21.7	8.1	3.9	1.0	1.1	0.2	0.2	0.3	0.7	2.6	6.8
1101972	9.1	8.4	6.5	3.6	0.8	0.6	0.5	1.6	1.7	2.0	2.9	6.5
1101973	11.8	16.3	9.6	4.4	3.2	2.9	1.0	3.7	1.7	4.0	2.6	4.5
1101974	12.9	19.3	9.9	6.1	1.0	0.6	0.3	1.0	0.3	1.9	0.8	1.6
1101975	12.9	14.0	10.1	2.4	0.8	0.6	0.2	1.2	4.8	2.3	3.1	4.9
1101976	22.5	10.2	4.4	2.0	0.9	0.3	0.1	1.3	3.6	0.6	0.4	0.9
1101977	2.7	10.6	11.4	1.9	1.7	0.5	0.7	1.5	2.2	1.6	3.3	6.8
1101978	14.0	8.7	5.1	2.0	0.6	0.1	0.4	0.0	0.4	1.0	1.7	1.5
1101979	14.0	9.8	7.7	2.7	0.9	0.0	0.5	0.0	0.0	0.7	1.3	10.3
1101980	5.5	3.9	7.5	1.8	0.5	0.1	0.0	1.0	0.5	1.8	0.6	0.3
1101981	7.9	15.0	5.7	2.4	0.3	0.4	0.0	1.2	0.7	2.3	2.2	4.5
1101982	9.1	5.0	17.8	3.3	0.9	0.7	0.1	0.3	0.0	2.1	5.6	4.8
1101983	3.1	4.4	8.4	2.6	1.3	0.8	1.2	1.4	2.7	1.3	1.6	1.8
1101984	23.0	25.5	20.5	4.9	1.5	0.7	0.5	0.4	0.1	0.8	5.9	4.5
0 0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

CORANI.DAT

Los valores hasta marzo del ano 1966 fueron obtenidos del anexo 2.11 del informe de A. Benitez y M. Pereira. A partir marzo del ano 1968 los valores corresponden a los observados(o calculados con el modelo HBV) en base a datos diarios.

Table 2

1101967	23.6	17.3	19.7	8.6	5.1	2.8	1.9	1.6	2.5	2.7	5.7	9.8
1101968	18.8	27.3	18.9	9.0	3.8	2.4	1.6	1.5	1.4	2.8	7.1	8.4
1101969	17.2	18.9	7.8	6.1	2.6	1.7	1.0	1.3	1.2	3.3	13.8	11.7
1101970	16.7	21.5	21.3	16.4	6.8	2.5	2.3	1.4	2.3	4.0	13.1	27.3
1101971	30.3	29.3	19.4	11.2	5.9	3.7	2.5	1.8	2.2	3.7	7.4	20.2
1101972	19.2	16.7	21.3	16.0	5.7	3.3	2.4	3.1	4.5	5.3	9.1	14.7
1101973	30.3	33.2	28.5	13.5	8.1	7.1	3.1	5.0	3.7	9.2	9.1	12.2
1101974	28.4	30.9	22.8	16.9	6.2	3.6	2.7	1.9	2.5	7.0	4.6	6.4
1101975	20.4	32.6	24.8	9.9	4.1	3.1	2.1	2.1	6.0	6.4	14.7	16.8
1101976	42.1	23.9	17.6	6.8	2.9	2.0	1.5	2.2	3.6	1.8	2.2	5.3
1101977	12.7	27.8	23.3	10.3	5.9	4.3	3.3	4.1	7.4	7.8	13.8	14.7
1101978	26.7	22.9	11.6	6.0	3.2	1.9	1.3	0.8	1.6	1.2	3.9	12.5
1101979	16.2	16.3	16.6	9.3	3.7	2.5	2.7	1.2	0.8	2.9	4.9	13.3
1101980	14.6	8.8	17.2	9.8	3.7	2.0	1.4	2.1	2.5	5.9	4.8	7.1
1101981	25.3	37.6	20.5	12.2	3.1	1.0	0.4	1.3	2.0	6.0	7.7	11.7
1101982	20.8	17.0	26.2	13.5	5.0	1.8	0.7	1.5	1.2	7.2	14.6	23.6
1101983	11.9	21.3	47.0	12.1	7.7	4.0	3.4	3.5	5.4	4.0	6.9	7.6
0000000												

LOCOTAL.DAT
Los caudales de los periodos ene/67 a abr/81; dic/82; y feb/83 a dic/83 son medidos en la estacion de locotal restados los caudales de generacion de Corani y Santa Isabel.
Los periodos de may/81 a nov/82 y ene/83 fueron obtenidos con el modelo HBV

Table 3

3101971	-1.	-1.	-1.	-1.	-1.	-1.	1.6	1.3	1.4	2.6	9.2	17.4
3101972	26.9	32.2	29.8	15.6	9.5	7.1	5.5	4.4	4.6	5.5	6.7	19.9
3101973	32.1	31.1	26.2	16.6	9.8	9.8	7.9	9.3	10.1	10.9	10.9	15.8
3101974	34.2	49.2	34.5	25.2	9.9	7.2	5.9	8.4	9.1	11.3	11.1	13.2
3101975	37.7	54.4	26.2	9.5	8.1	7.1	5.7	4.9	8.2	9.1	10.2	22.9
3101976	37.2	32.8	26.5	14.0	10.4	7.3	6.3	5.6	8.4	6.2	4.9	10.3
3101977	18.6	30.1	37.9	13.4	8.9	6.7	5.6	5.7	10.4	6.6	20.2	27.1
3101978	35.1	36.3	26.7	17.1	10.7	7.1	5.7	4.8	4.8	4.7	15.0	20.4
3101979	45.4	26.5	26.6	15.2	10.0	7.5	6.0	3.1	3.2	5.7	9.1	17.9
3101980	23.7	17.7	29.4	13.9	6.6	5.2	4.9	5.1	6.2	6.1	3.7	5.2
3101981	19.7	34.6	27.7	16.7	7.6	5.2	4.1	7.5	7.7	13.2	14.8	16.3
3101982	31.6	21.5	26.9	16.6	8.5	5.4	4.2	3.7	4.8	5.4	13.2	14.8
3101983	12.0	15.4	13.8	10.0	8.3	5.6	6.3	6.6	12.6	-1.	-1.	-1.
0000000												

RIO MIGUILLAS CAUDALES MENSUALES EN HUMAPALCA
Nombre del file: MIGUILLA.DAT
Caudales de los periodos: jul/71 a jul/72; ene,mar,sep,oct,dic/75; ene a may/76; oct/77; mar a jul/79 fueron generados con el modelo HBV.

APPENDIX 2

FILE 4

FILE 8: CORANI1.DAT (informacion requerida)/OCT.1986

ANIO INICIAL	MES INIC.	NoANOS OBSERV	NoANOS GENER.	NoANOS GEN.PAR
1952	1	33	50	50

IYRA	IMNTH	IANAL	MXRCS	NYRG	NYMXG	NPASS	IPCHQ	IPCHS	NSTA	NCOMB	NTNDM	NCSTY	IGNRL	NPROJ	IYRPJ	MTHPJ	LYRPJ	IDEC
1952	1	1	33	50	50	1	1	0	0	0	0	0	0	0	0	0	0	2

MAXIMUM VOLUMES OF RECORDED FLOWS

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
110	23	26	21	7	3	3	1	4	5	5	6	21	26	77	275	4

MINIMUM VOLUMES

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
110	3	4	2	1	0	0	0	0	0	0	0	0	0	1	157	

FREQUENCY STATISTICS

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
110	MEAN	0.974	1.020	0.895	0.467	0.037	-0.246	-0.362	-0.225	-0.084	0.178	0.349	0.604
	STD DEV	0.245	0.225	0.262	0.187	0.187	0.311	0.290	0.389	0.478	0.288	0.282	0.345
	SKEW	-0.573	-0.282	-0.735	0.291	0.020	-0.813	-0.883	-0.311	-0.625	-0.621	-0.437	-0.567
	INCRMT	0.11	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	YEARS	30	30	31	30	30	30	30	30	31	31	31	31

RAW CORRELATION COEFFICIENTS FOR MONTH 1

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 -0.032

RAW CORRELATION COEFFICIENTS FOR MONTH 2

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.463

RAW CORRELATION COEFFICIENTS FOR MONTH 3

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.242

RAW CORRELATION COEFFICIENTS FOR MONTH 4

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.637

RAW CORRELATION COEFFICIENTS FOR MONTH 5

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.596

RAW CORRELATION COEFFICIENTS FOR MONTH 6

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.731

RAW CORRELATION COEFFICIENTS FOR MONTH 7

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.523

RAW CORRELATION COEFFICIENTS FOR MONTH 8

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.258

RAW CORRELATION COEFFICIENTS FOR MONTH 9

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.617

RAW CORRELATION COEFFICIENTS FOR MONTH 10

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.480

RAW CORRELATION COEFFICIENTS FOR MONTH 11

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.356

RAW CORRELATION COEFFICIENTS FOR MONTH 12

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.642

RECORDED AND RECONSTITUTED FLOWS

STA	YEAR	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
110	1952	12E	9E	12E	5E	2E	2E	1E	0E	1	2	1	3	50
110	1953	6	7	4	2	1	1	1	0	0	2	2	3	29
110	1954	15	16	15	3	1	1	1	1	2	4	3	4	66
110	1955	13	20	9	4	2	1	1	0	1	1	3	4	59
110	1956	17	13	2	2	1	1	0	1	1	2	6	14	60
110	1957	4	6	8	3	1	0	0	0	1	2	4	5	34
110	1958	17	5	3	1	1	0	0	2	1	5	5	4	44
110	1959	7	20	21	6	2	1	1	1	3	2	2	12	78
110	1960	14	11	5	4	2	1	1	0	1	1	1	2	43
110	1961	5	5	8	7	2	1	0	0	2	1	2	7	40
110	1962	11	4	10	3	1	1	1	0	1	1	1	3	37
110	1963	13	15	13	4	1	1	0	0	0	1	4	5	57
110	1964	4	10	16	3	1	1	0	1	1	2	1	2	42
110	1965	11	11	5	2	1	0	0	0	2	3	5	21	61
110	1966	8	10	11	3E	1E	1E	0E	0E	0E	1E	5E	4E	44
110	1967	9E	18E	3E	2E	1E	0E	1E	1E	0E	1E	2E	1E	39
110	1968	7E	15E	7	2	1	0	0	0	0	0	3	4	39
110	1969	8	13	1	1	0	0	0	0	0	0	1	2	26
110	1970	5	10	9	3	1	0	0	0	1	1	1	6	37
110	1971	16	22	8	4	1	1	0	0	0	1	3	7	63
110	1972	9	8	6	4	1	1	1	2	2	2	3	6	45
110	1973	12	16	10	4	3	3	1	4	2	4	3	5	67
110	1974	13	19	10	6	1	1	0	1	0	2	1	2	56
110	1975	13	14	10	2	1	1	0	1	5	2	3	5	57
110	1976	23	10	4	2	1	0	0	1	4	1	0	1	47
110	1977	3	11	11	2	2	1	1	2	2	2	3	7	47
110	1978	14	9	5	2	1	0	0	0	0	1	2	1	35
110	1979	14	10	8	3	1	0	1	0	0	1	1	10	49
110	1980	6	4	8	2	1	0	0	1	1	2	1	0	26
110	1981	8	15	6	2	0	0	0	1	1	2	2	5	42
110	1982	9	5	18	3	1	1	0	0	0	2	6	5	50
110	1983	3	4	8	3	1	1	1	1	3	1	2	2	30
110	1984	23	25	21	5	1	1	1	0	0	1	6	5	89

ADJUSTED FREQUENCY STATISTICS

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
110	MEAN	0.974	1.029	0.889	0.469	0.048	-0.229	-0.347	-0.228	-0.113	0.167	0.357	0.589
	STD DEV	0.235	0.220	0.265	0.185	0.186	0.312	0.282	0.380	0.480	0.285	0.280	0.345
	SKEW	-0.587	-0.354	-0.684	0.233	-0.014	-0.758	-1.001	-0.291	-0.493	-0.523	-0.453	-0.491
	INCRMT	0.11	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

CONSISTENT CORRELATION MATRIX FOR MONTH 1

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 -0.010

CONSISTENT CORRELATION MATRIX FOR MONTH 2

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.426

CONSISTENT CORRELATION MATRIX FOR MONTH 3

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.162

CONSISTENT CORRELATION MATRIX FOR MONTH 4

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.663

CONSISTENT CORRELATION MATRIX FOR MONTH 5

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.610

CONSISTENT CORRELATION MATRIX FOR MONTH 6

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.754

CONSISTENT CORRELATION MATRIX FOR MONTH 7

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.516

CONSISTENT CORRELATION MATRIX FOR MONTH 8

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.262

CONSISTENT CORRELATION MATRIX FOR MONTH 9

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.605

CONSISTENT CORRELATION MATRIX FOR MONTH 10

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.484

CONSISTENT CORRELATION MATRIX FOR MONTH 11

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.342

CONSISTENT CORRELATION MATRIX FOR MONTH 12

STA 110
WITH CURRENT MONTH
110 1.000
WITH PRECEDING MONTH AT ABOVE STATION
110 0.621

MAXIMUM VOLUMES FOR PERIOD 1 OF 33 YEARS OF RECORDED AND RECONSTITUTED FLOWS

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
110	23	25	21	7	3	3	1	4	5	5	6	21	25	77	275	4

MINIMUM VOLUMES

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
110	3	4	1	1	0	0	0	0	0	0	0	0	0	1	150	

GENERATED FLOWS FOR PERIOD 1

STA	YEAR	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
110	1	16	24	4	2	1	0	0	1	1	1	4	3	57
110	2	14	28	11	3	2	1	0	4	8	4	6	6	87
110	3	3	4	1	2	1	0	0	1	1	2	4	11	30
110	4	9	13	11	2	1	1	0	0	0	3	2	3	45
110	5	13	8	5	3	1	1	1	0	0	0	1	1	34
110	6	17	8	7	3	1	1	1	2	7	2	2	3	54
110	7	9	8	15	3	1	0	0	0	1	2	1	0	40
110	8	4	8	19	6	1	0	1	0	1	2	2	4	48
110	9	6	7	23	6	2	2	1	1	2	5	5	18	78
110	10	4	6	5	1	0	0	0	0	1	1	2	5	25
110	11	18	19	14	3	1	1	1	0	0	1	4	7	69
110	12	5	11	11	2	1	1	0	2	1	1	0	5	40
110	13	2	7	8	2	1	1	0	1	3	5	3	3	36
110	14	11	10	7	3	2	0	0	1	1	1	3	2	41
110	15	5	4	5	4	2	0	0	1	1	2	3	4	31
110	16	7	10	8	6	1	2	1	2	1	2	7	18	65
110	17	16	11	7	2	0	0	0	1	0	1	1	5	44
110	18	14	20	16	4	1	1	0	1	1	1	1	3	63
110	19	18	9	7	4	1	0	0	0	1	2	1	1	44
110	20	10	5	5	3	1	0	0	0	2	2	5	11	44
110	21	8	10	9	3	1	0	0	0	1	1	1	5	39
110	22	6	5	1	1	1	1	0	0	0	1	3	5	24
110	23	9	8	15	3	1	2	1	1	3	2	1	13	59
110	24	19	20	15	3	1	0	0	0	1	1	2	4	66
110	25	10	14	12	5	1	1	1	0	1	2	1	1	49
110	26	8	24	6	2	1	0	0	1	2	2	4	2	52
110	27	12	4	6	2	1	0	0	1	0	2	3	10	41
110	28	23	13	6	2	1	0	1	0	0	1	2	3	52
110	29	13	13	5	1	0	0	1	1	0	0	5	5	44
110	30	11	15	8	3	1	0	1	1	3	3	4	6	56
110	31	15	29	12	6	1	0	0	0	0	1	2	3	69
110	32	12	12	8	3	2	1	1	0	1	1	3	3	47
110	33	3	6	16	4	1	1	1	0	0	1	1	9	43
110	34	4	6	2	3	0	0	0	0	0	1	1	3	20
110	35	18	27	9	2	1	1	0	1	2	1	1	3	66
110	36	10	8	10	2	1	0	0	2	3	1	1	4	42
110	37	8	15	9	3	1	0	0	4	2	4	3	11	60
110	38	6	12	19	7	3	1	1	0	0	0	1	4	54
110	39	5	10	6	3	1	1	1	1	1	1	2	6	38
110	40	7	6	4	2	1	1	0	2	0	1	3	3	30
110	41	16	17	4	2	1	0	0	1	0	1	2	2	46
110	42	21	16	16	5	1	1	1	0	0	1	2	2	66
110	43	12	11	4	3	1	0	0	0	1	3	1	3	39
110	44	5	11	11	3	1	0	1	0	1	4	4	5	46
110	45	20	15	5	5	3	2	1	1	0	0	0	1	53
110	46	11	10	7	3	1	1	1	2	2	2	4	3	47
110	47	15	15	3	1	1	1	0	0	1	1	1	3	42
110	48	12	12	14	2	1	0	0	0	1	1	1	3	47
110	49	6	12	11	5	3	1	1	1	1	1	4	3	49
110	50	8	7	9	3	1	1	0	0	0	1	5	10	45

MAXIMUM VOLUMES FOR PERIOD 1 OF 50 YEARS OF SYNTHETIC FLOWS

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
110	23	29	23	7	3	2	1	4	8	5	7	18	29	72	269	4

MINIMUM VOLUMES

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
110	2	4	1	1	0	0	0	0	0	0	0	0	0	2	153	

ND OF FILE

FILE 7

RECORDED AND RECONSTITUTED FLOWS

1101952	12	9	12	5	2	2	1	0	1	2	1	3
1101953	6	7	4	2	1	1	1	0	0	2	2	3
1101954	15	16	15	3	1	1	1	1	2	4	3	4
1101955	13	20	9	4	2	1	1	0	1	1	3	4
1101956	17	13	2	2	1	1	0	1	1	2	6	14
1101957	4	6	8	3	1	0	0	0	1	2	4	5
1101958	17	5	3	1	1	0	0	2	1	5	5	4
1101959	7	20	21	6	2	1	1	1	3	2	2	12
1101960	14	11	5	4	2	1	1	0	1	1	1	2
1101961	5	5	8	7	2	1	0	0	2	1	2	7
1101962	11	4	10	3	1	1	1	0	1	1	1	3
1101963	13	15	13	4	1	1	0	0	0	1	4	5
1101964	4	10	16	3	1	1	0	1	1	2	1	2
1101965	11	11	5	2	1	0	0	0	2	3	5	21
1101966	8	10	11	3	1	1	0	0	0	1	5	4
1101967	9	18	3	2	1	0	1	1	0	1	2	1
1101968	7	15	7	2	1	0	0	0	0	0	3	4
1101969	8	13	1	1	0	0	0	0	0	0	1	2
1101970	5	10	9	3	1	0	0	0	1	1	1	6
1101971	16	22	8	4	1	1	0	0	0	1	3	7
1101972	9	8	6	4	1	1	1	2	2	2	3	6
1101973	12	16	10	4	3	3	1	4	2	4	3	5
1101974	13	19	10	6	1	1	0	1	0	2	1	2
1101975	13	14	10	2	1	1	0	1	5	2	3	5
1101976	23	10	4	2	1	0	0	1	4	1	0	1
1101977	3	11	11	2	2	1	1	2	2	2	3	7
1101978	14	9	5	2	1	0	0	0	0	1	2	1
1101979	14	10	8	3	1	0	1	0	0	1	1	10
1101980	6	4	8	2	1	0	0	1	1	2	1	0
1101981	8	15	6	2	0	0	0	1	1	2	2	5
1101982	9	5	18	3	1	1	0	0	0	2	6	5
1101983	3	4	8	3	1	1	1	1	3	1	2	2
1101984	23	25	21	5	1	1	1	0	0	1	6	5

GENERATED FLOWS FOR PERIOD 1

110	1	16	24	4	2	1	0	0	1	1	1	4	3
110	2	14	28	11	3	2	1	0	4	8	4	6	6
110	3	3	4	1	2	1	0	0	1	1	2	4	11
110	4	9	13	11	2	1	1	0	0	0	3	2	3
110	5	13	8	5	3	1	1	1	0	0	0	1	1
110	6	17	8	7	3	1	1	1	2	7	2	2	3
110	7	9	8	15	3	1	0	0	0	1	2	1	0
110	8	4	8	19	6	1	0	1	0	1	2	2	4
110	9	6	7	23	6	2	2	1	1	2	5	5	18
110	10	4	6	5	1	0	0	0	0	1	1	2	5
110	11	18	19	14	3	1	1	1	0	0	1	4	7
110	12	5	11	11	2	1	1	0	2	1	1	0	5
110	13	2	7	8	2	1	1	0	1	3	5	3	3
110	14	11	10	7	3	2	0	0	1	1	1	3	2
110	15	5	4	5	4	2	0	0	1	1	2	3	4
110	16	7	10	8	6	1	2	1	2	1	2	7	18
110	17	16	11	7	2	0	0	0	1	0	1	1	5
110	18	14	20	16	4	1	1	0	1	1	1	1	3
110	19	18	9	7	4	1	0	0	0	1	2	1	1
110	20	10	5	5	3	1	0	0	0	2	2	5	11
110	21	8	10	9	3	1	0	0	0	1	1	1	5
110	22	6	5	1	1	1	1	0	0	0	1	3	5
110	23	9	8	15	3	1	2	1	1	3	2	1	13
110	24	19	20	15	3	1	0	0	0	1	1	2	4
110	25	10	14	12	5	1	1	1	0	1	2	1	1
110	26	8	24	6	2	1	0	0	1	2	2	4	2
110	27	12	4	6	2	1	0	0	1	0	2	3	10
110	28	23	13	6	2	1	0	1	0	0	1	2	3
110	29	13	13	5	1	0	0	1	1	0	0	5	5
110	30	11	15	8	3	1	0	1	1	3	3	4	6
110	31	15	29	12	6	1	0	0	0	0	1	2	3
110	32	12	12	8	3	2	1	1	0	1	1	3	3
110	33	3	6	16	4	1	1	1	0	0	1	1	9
110	34	4	6	2	3	0	0	0	0	0	1	1	3
110	35	18	27	9	2	1	1	0	1	2	1	1	3
110	36	10	8	10	2	1	0	0	2	3	1	1	4
110	37	8	15	9	3	1	0	0	4	2	4	3	11
110	38	6	12	19	7	3	1	1	0	0	0	1	4
110	39	5	10	6	3	1	1	1	1	1	1	2	6
110	40	7	6	4	2	1	1	0	2	0	1	3	3
110	41	16	17	4	2	1	0	0	1	0	1	2	2
110	42	21	16	16	5	1	1	1	0	0	1	2	2
110	43	12	11	4	3	1	0	0	0	1	3	1	3
110	44	5	11	11	3	1	0	1	0	1	4	4	5
110	45	20	15	5	5	3	2	1	1	0	0	0	1
110	46	11	10	7	3	1	1	1	2	2	2	4	3
110	47	15	15	3	1	1	1	0	0	1	1	1	3
110	48	12	12	14	2	1	0	0	0	1	1	1	3
110	49	6	12	11	5	3	1	1	1	1	1	4	3
110	50	8	7	9	3	1	1	0	0	0	1	5	10

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