V PRESENTATION AND DISCUSSION OF RESULTS

5.1 General Viewpoint

This chapter presents the results of calibration and verification periods for Thubon basin from 1979 to 1984. The NAM model's estimated parameters application to two basins, Tamky and Lung, were considered as a special case before going to other ungaged basins.

Comparison of computed and observed water balance agreement, peak daily flows and time of peak, and simulation of baseflow are attended in the discussion of the results. The model performance was considered to be acceptable within a relative error of 10% because most of the rainfall-runoff models provide results within this limit. However, the results presented should be evaluated in the light of the uneven distribution of rainfall stations. The rainfall in tropical region is usually characterized by local showers. So, five rainfall stations in and out of Thubon basin and one out of Tamky basin can not represent the real average areal rainfall in the basins. It may cause some errors in model simulation. On other side, when only a few rainfall stations are in or near a great basin and the topography variation is different between the plain and the mountain areas, some flood peak simulations may be found not very coincident with the observed one.

A study of the sensitivity of the model parameters was undertaken. Comments on the results of parameter sensitivity and relationship of parameters to sub-basins are also made.

5.2 Calibration of the Model

It is not possible to determine the values of the NAM model parameters on the basis of soil physical measurements, as most of the parameters are of an empirical nature. Therefore, trial and error parameter method for calibrating the model is normally applied and used in this study.

The NAM parameters can be determined by comparing the simulated and observed discharge in a calibration. During the calibration stages, evaporation from the surface storage and the lower zone storage can be increased a little by increasing U_{max} and L_{max} and vice versa. The peak flow events and volumes are controlled by CQ_{OF} and it has a linear effect on the overland flow. The parameter TOF mainly effects the starting time of the overland runoff after relatively dry periods. The baseflow is dependent on the other streamflow components. It can be increased by decreasing the overland flow and interflow and vice versa. The shape of the overland can be steered through CK_2.

5.2.1 Model Parameters: Normally, NAM's parameters such as maximum water content in surface and root zone storages, overland runoff coefficient, time constants for routing inter- and over flow, and so on are not available, and it is difficult to get these parameters exactly by field measurements and need calibration process. For the first trial, values were assumed from the previous experiences with the NAM model. Then the output runoff hydrograph from the model was compared with recorded one. A careful observation, judgment and realization of various flow components, such as overland flow, interflow and baseflow, guided for the next trial values. This process was continued until a good fit and as much resemblance as possible between the observed and simulated hydrographs was obtained. The final values of the model parameters are presented in Table 5.1.

Observed and simulated hydrographs of both calibration and verification stages are shown in Appendix A and B (from Fig. A.1(a) to Fig. A.6(h) and from Fig. B.1(a) to Fig. B.2(d)).

5.2.2 Initial Conditions: Model calibration is completed by reasonable estimation of the initial water contents in surface and rootzone storages, the initial values of overland flow and interflow and the initial groundwater depth at the start of the simulation. Various trial values were used to simulate the basin behavior. The set of values for which the model output fitted the actual output in the beginning of simulation was considered as final.

5.3 Application of the Model to Ungaged Basin

As mentioned before the main objective of this study is to predict the continuous streamflow for ungaged basin. In this study, Tamky and Lung basins were selected as "ungaged" test-basins with data available of period one year, 1978, for Tamky and six months, from Nov. 1989 to Apr. 1990, for Lung. The problem about ungaged basin is how to select the approximate parameters for basins as input of the model. The selection of parameters can be done as follows :

(a) Transfer from the gaged basin
(b) Recalibration
(c) By adjustment of time constants

5.3.1 Transfer from the gaged basin: As first trial, the model parameters of gaged Thubon basin were used as input of the model simulation for ungaged basins. The application were done without any calibration.

The results of model response based on these parameters as shown in Fig. B.1(a) of Appendix B. These figures show that the simulation of flows give a poor result i.e. under-estimate. This may be due to incorrect in the time parameters selection. Because gaged Thubon is a large basin, its time contains should be longer than a small one's although their topographical and geological conditions are almost the same.

5.3.2 <u>Recalibration:</u> Recalibration, that means all of the gaged model parameters were changed as well as calibration process in order to look for a certain improvement. So, by visual judgment, the later hydrographs for this case were not satisfactory (see Fig. B.1(b)).

5.3.2 <u>By Adjustment of Time Constants:</u> Due to the basic difference in area, another way to test the capability of the model to simulate the ungauged basin, i.e the parameters have been determined according to the gaged Thubon basin's parameters after adjusting time constants of the model parameters such as CK_{IF}, CK_1, CK_2, and CKBF with the assumption that they have a linear relationship with the ratio of the area of ungaged basin and Thubon gaged basin. This process can be considered as a combination of the two above presented ways.

Comparing the results between (a), (b), and (c) as expected the adjustment of time contains gives a better result. The obtained results (see Fig. B.1(c) and B.1(d)) show that this assumption may be accepted and its parameters may be used for small ungaged basins that lie inside Thubon.

5.4 <u>Simulation of Water Balance</u>

To be objective, a model must be able to estimate the annual flow within acceptable limits. Relative errors of calibration and verification periods are presented in Table 5.2 . During calibration period, model was able to simulate in the yearly flows with relative error of less than 10% - within a range of 0.80% to 8.47% - for THUBON 1979, 1980, and 1981, however, the model could not do better for THUBON 1982 with relative error of 32.50%. The annual flow was well simulated for THUBON 1983, and 1984 during verification period. The annual flow was under estimated for TAMKY (1978) and LUNG (Nov.1989 - Apr.1990) with relative error of 16.15% and 16.38%, respectively. It may be due to inaccurate measurement or rough initial assumption.

Cumulative water balance as a function of time are plotted in Fig. A.1(c) through A.6(c) and B.1(e) and B.2(c) (Appendix A and B) for the corresponding years of hydrograph comparison.

5.5 <u>Simulation of Peak Discharge</u>

A comparison of the observed and simulated maximum annual peak discharge and the time of peak is shown in Table 5.3. The relative errors of peak discharge varies between 5.29% (THUBON, 1982) to 48.63% (THUBON, 1981). On a broad basis, the model has overestimated peak discharge for 6 years, as reflected by the positive sign in relative errors, and underestimated it for other years.

Most of the time to peak flows of the simulated discharge coincide with the observed periods. However, the time to peak discharge of THUBON 1983 were found later 17 days compared to the observed one, although its simulated annual flow and peak discharge were accepted. Other cases, the simulated time to peak varies between 0 - 4 days earlier compared to the actual response.

5.6 Simulation of Baseflow

The present NAM model's ability to simulate baseflow in the dry season has been investigated by comparison of monthly observed and simulated flows in the three months January, February and March. In this period, the natural runoff is well defined in the absence of the rainfall. From Table 5.4 and Fig. 5.5, the relative errors of the simulated baseflows compared to the observed one varies between 0.63 % (THUBON, M.82) to 62.19% (TAMKY, M.83). Predictive capability seems that there is no law for any month during both of the calibration and verification periods. It was found that for some years the simulated baseflow was not in good agreement with the measured one even through the relative error of annual flow was lower than 10%, such as the case of THUBON 1983.

5.7 Statistical Evaluation of the Results

In order to evaluate the performance of a developed model, some statistics that are more objective than the visual inspection of the agreement between observed and simulated discharge should be employed. The commonly used statistics such as range, mean, standard deviation, coefficient of efficiency, coefficient of correlation and root mean square error were applied in this study. The results for all these statistical parameters are shown in Table 5.5.

Generally a first requirement of a model should be the ability to reproduce the mean and standard deviation of the observed runoff. It is essential that the mean of simulation flows agrees closely with the observed record. It is evident, in Table 5.5, that 6/8 times mean is very close to the observed mean (THUBON 1979-1981, 1983-1984, and TAMKY 1978), 1/8 time it deviates more (THUBON 1982) and 1/8 time is in between (LUNG 89-90). The standard deviations are close except THUBON 1981, 1982 and LUNG 89-90. The variation in range of both series is not so high. The coefficient of efficiency E_c ranges from 0.42 (THUBON 1982) to 0.90 (THUBON 1983). Almost the values of E_c is above 0.50 (7/8). Coefficients of correlation are high ($r \geq 0.72$) in THUBON. They are equal to 0.53 and 0.59 in LUNG and TAMKY basins, respectively. The value of daily root mean square error RMS is usually used for intercomparison of models.

However, in this study, it is used to infer the hydrograph fitting during calibration and verification periods as a whole for Thubon "reference" basin. The best value fitting of RMS is for Thubon 1980.

5.8 Sensitivity Analysis

Sensitivity analysis of some parameters of the model were carried out in order to know how much effect these parameters have on the simulation results. With knowledge of parameter sensitivity, as expected the process of calibration can be done faster. Consequently, the final selection of parameters can be achieved quite rapidly. In addition the simulation results may be much better.

Sensitivity analysis is presented in this study based on the application of NAM model to Thubon basin for period 1980. The calibrated parameters value were increased and decreased by 50% in order to study the effect of each parameter on the hydrograph simulation including hydrograph component such as peak, annual flow and shape. The value of one parameter was changed at a time while keeping the values of other parameters fixed. Due to the time limitation, it is impossible to change each parameter or combination of parameter gradually. The sensitivity analysis was carried out for four most important parameters, i.e. U_{max}, L_{max}, CQ_{OF}, $CK_1 = CK_2$. The response shown by different parameters may not be the same for other basins. However, they can be used as a guide in adjusting the values of parameters. The results (see Table 5.6) obtained by successively varying these parameters are as follows :

U_{max} : U_{max} is the maximum surface storage and affects mainly overland flow, evapotranspiration, infiltration and interflow. Values of 7.5, 15.0 and 22.5 mm were studied as shown in Fig. 5.4.

Increasing the value of U_{max} from 15 mm to 22.5 mm caused a increase in relative error, simulated peak and simulated annual flow and relatively better estimate of low flows compared to the calibrated values (only for this year), Table 5.6. Decreasing the value of U_{max} from 15mm to 7.5mm reflected an increase in RE %, peak flow and low flow.

L_{max} : L_{max} is the maximum lower zone storage and represent the maximum soil moisture content in the root zone available for the vegetative transpiration. It affects mainly overland flow, infiltration, evaporation and baseflow. Values of 60, 120 and 180 mm were used and resulting hydrographs are shown in Fig. 5.5. It is evident from the study of the hydrographs and Table 5.6 that increased value of L_{max} has under-estimated the annual flow while decreased value of L_{max} has over-estimated the annual flow. In the former case peak is very fix to the observed one and low flows are close to the calibrated one. While in the latter case there is a tendency to under-estimated the low flows.

CQ_{OF} : CQ_{OF} is the overland flow runoff coefficient. It determines the extent to which excess rainfall runs off as overland flow or infiltrates. It affects mainly the amount of overland flow and infiltration. Values of 0.75, 0.50 and 0.25 were given to CQ_{OF} and resulting hydrographs are shown in Fig. 5.6.

Increased value of CQ_{OF}, means more overland flow and less infiltration, has considerably increased the magnitude of both peak and annual flow. It was observed that a decrease from 0.50 to 0.25 results in a very small peak, good estimation of annual flow. All the cases increased or decreased CQ_{OF} lead to the underestimation of low flows. It can be seen from Fig. 5.6 that increase in CQ_{OF} has resulted in a very bad recession.

CK_1, CK_2 : CK_1 and CK_2 are time constants for routing inter- and overland flow. They describe the shape of peaks in overland flow. In this study, CK_1 and CK_2 were taken in the same values. Values of 15, 30 and 45 were calculated and resulting hydrographs are shown in Fig. 5.7. Increasing these parameters will cause a decrease the values of peak flows. Other changes of annual flow and low flows arenot so much and not important. Results are presented in Table 5.6.

5.9 Discussion

One of the key problems of the hydrologist has always been that of estimating the flow of ungaged streamflows or of extending the records on gaged streamflows. Given precipitation and evaporation records which are longer than the available streamflow records, a prediction streamflow can be estimated. The NAM model calibration process involved an initial assumption of parameter values, a trial simulation on a test period, a comparison of observed and simulated flows for the calibration period, and an adjustment of parameters to yield a more correct simulation was carried out. Application of simulation to ungaged basins requires that parameters be estimated from one or more gaged basins outside or nearby. In this study, Thubon and Tamky are the two basins that have been chosen to estimate the NAM model's parameters. These parameters could then be used as determined or adjusted subjectively for application to the ungaged basins. For this procedure to be effective, parameters should have physical significance so that there is some reasonable basis for adjustment. Field investigation has shown that the change on topographic and vegetation cover one this place to another is small. With this physical similarity, we can assume that, in small basins, the routing process employed is linear with calibrated basin.

The rainfall surface over basin is almost always a complex warped surface. In fact, the distribution of rainfall stations of large Thubon basin which in this study were very important, due to all rainfall stations in those small basins were not reliable and adequate representation of the mean rainfall.

Generally and theoretically the daily runoff variable is the most promising. This has been accomplished objectively in this study and systematic evaluation of the model application was carried out considering the adoptability for low flows, peak flows and annual flows which has been further justified by performing the statistical analysis in Table 5.6.

A comparison of the observed and predicted flows has revealed that the NAM model can provide reasonably accurate representation of the basin response under both wet and dry conditions while fairly simulating the annual flow in Thubon within 10% relative error for most of the years, except 1982. In verification, less than 10% relative error of annual flow in Thubon has been predicted. In the domain of application of the model, it will not be doubtful to say that the model has tremendous potential for simulating the annual flows although the model has given 16.15% and 16.38% relative error of annual flow in Tamky and Lung, respectively.

Although the model both underestimated and overestimated peak discharge values, the sensitivity analysis showed that the model has the capability of closely simulating peak flows by means of the parameter CQ_{OF}. Model can simulate both baseflows and peak flows with some limitations. The time of peak usually was found to be close.

It is not possible for an individual to see the difference between the individual daily flow values from the plot of the observed and simulated hydrographs in assessing the performance of the model. This would only be possible by plotting the difference between observed and simulated daily flow values and this has been done in the present study (see Appendix A and B). As it was not possible to estimate the model parameters from functional relationships of basin slope, main channel slope, drainage density, soil type,landuse, etc. However, parameter sensitivity was studied by successively varying U_{max}, L_{max}, CQ_{OF}, and CK_1 & CK_2. This analysis has provided useful information for any future study.

5.10 Sources of Errors

All simulation models are essentially simlifications of reality and, as such , will be subjected to uncertainty and errors. Intricate problems encountered in the way of realistic development of rainfall - runoff relationships are due to the unrealiability of the input data. There is an upper limit of goodness of fit. So it is note worthy to consider the probable avenues of errors and lack of inadequate data.

Sources of errors were found in this study, generally due to inadequacies in the field measurements to be in collecting hydrological data. These may be in the form of errors in reading and recording and malfunctioning of the device or readjustment of gages. Besides, the meteorological data set in analysis may not be representative of the entire basins. In tropical regions rainfall usually occurs in the form of local showers. Accordingly, several rainfall stations in the basin are required to have a good estimate of the areal rainfall. Most rainfall stations are found in the plains where infect rainfall is heaviest in the mountains.

Potential evapotranspiration has been calculated by "piche" evaporation method and transferred to pan evaporation method by empirical coefficient of crop seasons. Surely there is still that possibility that it may not be as close to the actual values as desired if the stations were located within basins.

All the above mentioned factors cause random and systematic errors in the input data to the model. There may be random and systematic errors in the discharge data used in comparison to the simulated output. Some errors may be due to the inappropriate model structure. The previous experiences with the NAM model show that unexpected results are due to insufficient and inadequate input data rather than to the inappropriate model structure.

Another factor is the selection of NAM model parameters. Because the parameters were calibrated by trial and error, the final values chosen basically depend on the user. Thus the calibrated set of the model parameters may not be optimal values. There may be another set which would provide better results.

Table 5.1 NAM Model Parameters

Model Parameters		BASIN						
		Thubon	Tamky	Truong	Lung	Khang	Tranh	Namnim
Basin Area	(Km^2)	3130	236	392	27	568	236	1116
U_{max}	(mm)	15	15	15	15	15	15	15
L_{max}	(mm)	150	150	150	150	150	150	150
CQ_{OF}		0.5	0.5	0.5	0.5	0.5	0.5	0.5
CK_{IF}	(hrs)	800	60	100	7	145	60	285
TOF	(mm)	30	30	30	30	30	30	30
TIF	(mm)	20	20	20	20	20	20	20
CK_1	(hrs)	30	2.3	3.8	0.3	5.4	2.3	10.7
CK_2	(hrs)	30	2.3	3.8	0.3	5.4	2.3	10.7
TG	(mm)	25	25	25	25	25	25	25
S_y		0.1	0.1	0.1	0.1	0.1	0.1	0.1
CKBF	(hrs)	1000	75	125	9	181	75	356
$GWLBF_o$	(m)	5	5	5	5	5	5	5
$GWLFL_1$	(m)	0	0	0	0	0	0	0

Seasonal variation of max. groundwater depth causing baseflow

Maximum depth : 5.0 meter   Minimum depth : 2.0 meter

jan.	0.80
feb.	0.95
mar.	1.00
apr.	0.80
may	0.65
jun.	0.40

jul.	0.25
aug.	0.10
sep.	0.10
oct.	0.00
nov.	0.40
dec.	0.65

The monthly values are given relative to the difference between max. and min., i.e. 1.0 for max., 0.0 for min.

INITIAL CONDITIONS

Water content in surface storage	:	0.50	mm
Water content in root zone	:	0.50	mm
Overland flow	:	0.00	mm/hr
Interflow	:	0.00	mm/hr
Groundwater depth (meter below surface)	:	4.50	meter

Table 5.2 Comparison of Observed and Simulated Yearly Flow (mm)

Basin	Year	Calibration		Verification		Relative error RE %
		Obs.	Sim.	Obs.	Sim.	
THUBON	1979	1979.72	1913.76			- 3.33
	1980	3004.34	3028.51			0.80
	1981	3786.50	4017.32			8.47
	1982	1040.20	1541.10			- 32.50
	1983			2397.87	2605.86	8.67
	1984			2317.51	2472.64	- 6.27
TAMKY	1978 (*)			3914.92	3282.41	- 16.15
LUNG	1990 (**)			1211.26	1012.81	- 16.38

Note : (*) Calculated from 1 Jan. 1978 to 31 Dec. 1978.
(**) Calculated from 1 Nov. 1989 to 30 Apr. 1990.

Table 5.3 Comparison of Observed and Simulated Peak Discharge (m^3/s) and Time of Peak

Basin	Year	Observed Peak		Simulated Peak		Relative error REP %	Dif. days No.
		Max.	Date	Max.	Date		
THUBON	1979	2310	18 Nov.	2708	18 Nov.	17.23	0
	1980	6210	17 Nov.	6658	17 Nov.	7.21	0
	1981	4440	29 Oct.	6599	28 Oct.	48.63	1
	1982	1750	7 Sep.	1662	7 Sep.	- 5.29	0
	1983	5540	30 Oct.	4977	16 Nov.	- 9.30	17
	1984	2970	8 Nov.	3457	4 Nov.	14.09	4
TAMKY	1978 (*)	512	3 Nov.	674	30 Oct.	16.15	3
LUNG	89-90 (**)	11.85	10 Nov.	13.99	10 Nov.	18.05	0

Note : (*) Calculated from 1 Jan. 1978 to 31 Dec. 1978.
(**) Calculated from 1 Nov. 1989 to 30 Apr. 1990.

Table 5.4 Comparison of Observed and Simulated Monthly Flows (mm) during Dry Season

Basin	Mth.Yr	Observed Flow	Simulated Flow	Relative error %
THUBON	J.80 F.80 M.80	125.94 83.24 54.48	152.82 90.30 48.49	21.34 8.48 - 10.99
	Σ	266.66	291.61	10.60
	J.81 F.81 M.81	183.06 113.72 70.30	175.05 96.07 49.82	- 4.37 - 15.52 - 29.13
	Σ	369.78	302.94	- 13.20
	J.82 F.82 M.82	180.90 88.13 56.95	193.34 103.52 57.31	6.87 17.46 0.63
	Σ	325.98	354.17	8.64
	J.83 F.83 M.83	90.03 43.06 36.48	144.91 66.68 43.31	60.95 54.85 18.72
	Σ	169.57	254.90	50.32
	J.84 F.84 M.84	154.46 99.12 58.69	170.15 104.76 50.53	10.15 5.69 - 13.90
	Σ	312.27	325.39	4.20
	J.85 F.85 M.85	184.84 94.80 58.12	206.51 126.40 60.78	11.72 33.33 4.57
	Σ	337.76	393.69	16.55
TAMKY	J.78 F.78 M.78	723.70 122.05 77.88	490.15 63.08 29.44	- 32.29 - 48.31 - 62.19
	Σ	923.63	582.67	- 36.91
LUNG	J.90 F.90 M.90	215.80 143.32 103.64	146.78 128.55 115.98	- 31.98 - 10.31 11.88
	Σ	462.76	391.31	- 15.43

Table 5.5 Statistical Evaluation of the Results

Basin	Year	RQ_o	RQ_s	$\bar{Q}_o$	$\bar{Q}_s$	STD_o	STD_s	E_c	r	RMS
THUBON	1979	2273.3	2708.0	195.95	189.42	294.18	289.54	0.85	0.86	113.20
	1980	6173.6	6658.0	298.18	300.58	545.55	626.99	0.89	0.92	17.31
	1981	4409.5	6599.0	375.81	407.65	722.80	902.76	0.82	0.91	20.16
	1982	1724.4	1662.0	103.24	152.95	121.85	195.42	0.42	0.72	121.30
	1983	5435.0	4977.0	237.34	257.93	572.36	638.57	0.90	0.92	181.78
	1984	2956.0	3457.0	230.01	245.41	409.66	443.31	0.83	0.85	171.02
TAMKY	1978	508.4	674.7	29.29	24.56	54.83	57.65	0.55	0.59	36.85
LUNG	89-90	11.2	13.9	2.09	1.74	1.58	2.05	0.51	0.53	1.11

Note : 1) All units are in m^3/s except 'D'.
2) Calculations are for daily discharge.
3) For symbols see Article no. 3.6

Table 5.6 Parameter Sensitivity Analysis

Model Parameter	Value	Annual flow (mm)		RE	Peak flow (m^3/s)			Baseflow (mm) for the Month of January			February			March		
		Obs.	Sim.	(%)	Obs.	Sim.	RE %	Obs.	Sim.	RE%	Obs.	Sim.	RE %	Obs.	Sim.	RE %
U_{max} (mm)	7.5	3004.34	3044.34	1.33	6210	6657	7.19	183.06	173.66	-5.13	113.72	97.06	-14.65	70.31	51.15	-15.66
	15.0		3028.51	0.80		6658	7.21		175.04	-4.38		96.07	-15.52		49.82	-29.13
	22.5		3036.91	1.08		6659	7.23		175.89	-3.91		96.24	-15.31		48.74	-30.66
L_{max} (mm)	60	3004.34	3086.23	2.72	6210	6658	7.21	183.06	175.04	-4.38	113.72	96.03	-15.55	70.31	49.82	-29.13
	120		3028.51	0.80		6658	7.21		175.04	-4.38		96.07	-15.52		49.82	-29.13
	180		2970.83	-1.11		6658	7.21		175.04	-4.38		96.08	-15.51		49.82	-29.13
CQ_{OF}	0.25	3004.34	3021.20	0.56	6210	4325	-30.35	183.06	170.58	-6.82	113.72	106.90	- 6.00	70.31	57.28	-18.53
	0.50		3028.51	0.80		6658	7.21		175.04	-4.38		96.07	-15.52		49.82	-29.13
	0.75		3035.01	1.02		7592	22.25		186.00	-1.60		87.61	-22.95		43.84	-37.46
$CK_1 = CK_2$ (hrs)	15	3004.34	3027.29	0.76	6210	7018	13.01	183.06	177.02	-3.30	113.72	93.42	-17.48	70.31	49.81	-29.15
	30		3028.51	0.80		6658	7.21		175.04	-4.38		96.07	-15.52		49.82	-29.13
	45		3030.01	0.85		5764	-7.18		171.40	-6.37		100.42	-11.69		49.84	-29.11

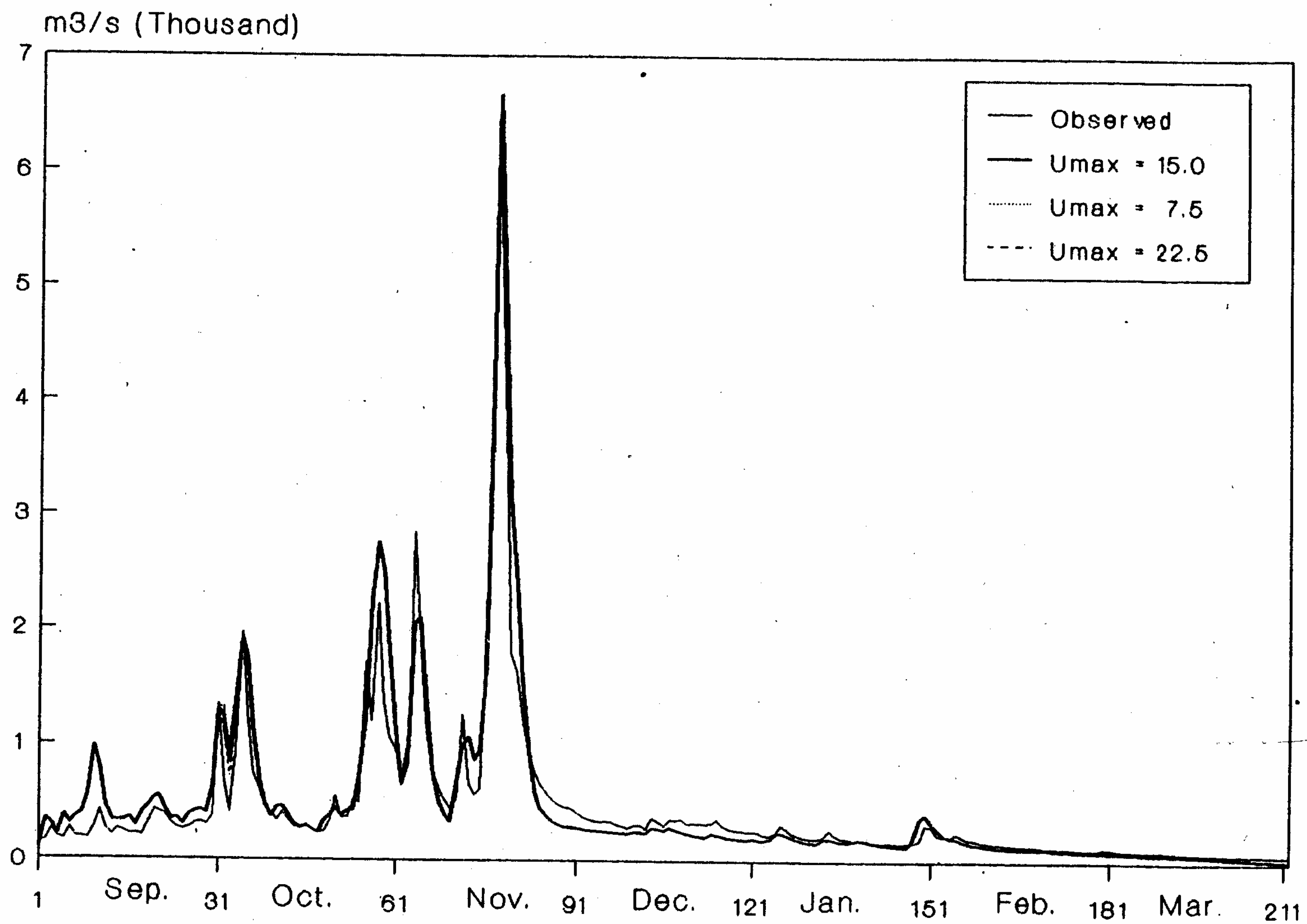

Fig. 5.1 Comparison of Qobs. & Qsim. with Variation of Umax
Thubon basin, from 1 Sep. 1980 to 31 Mar. 1981

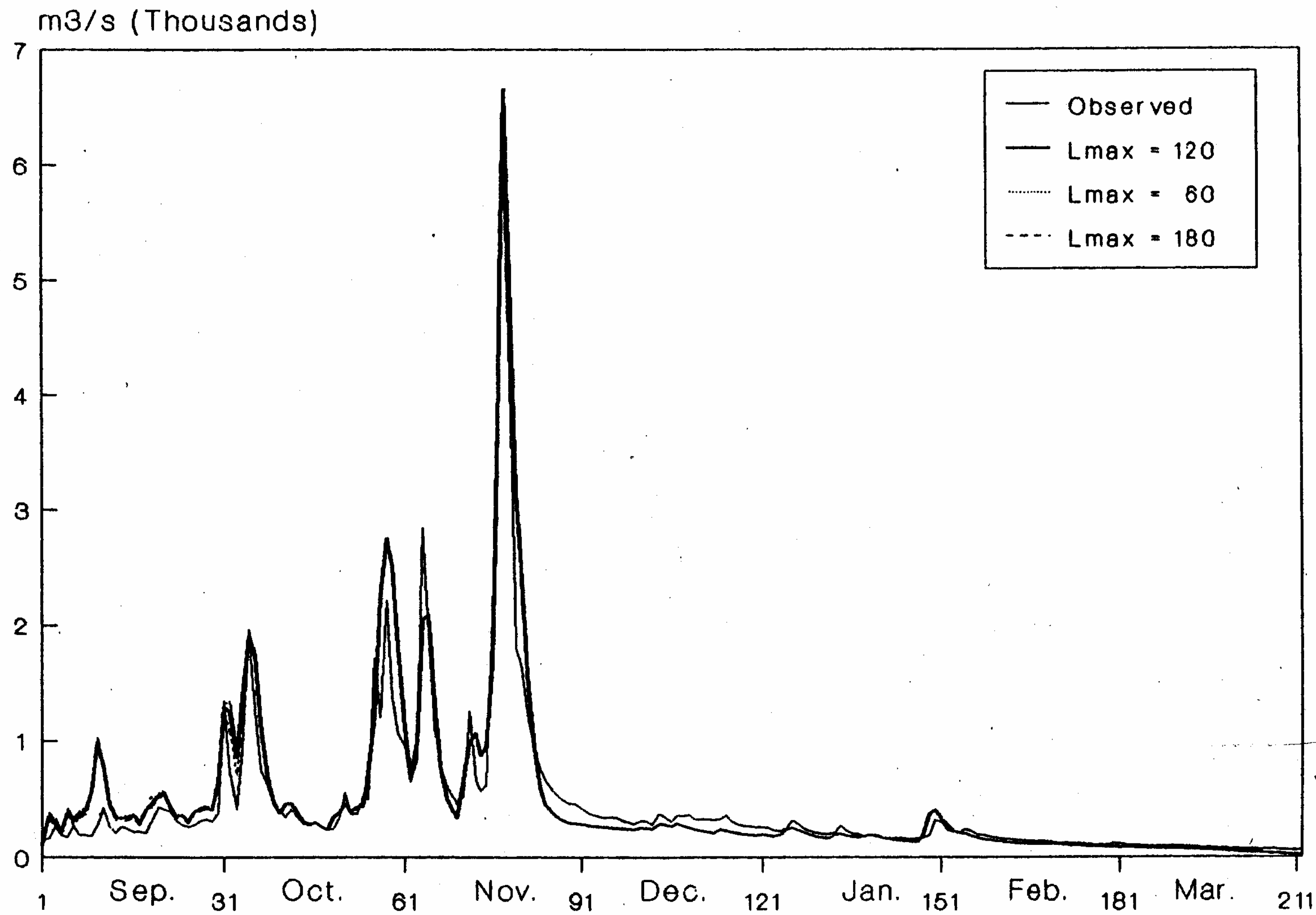

Fig. 5.1 Comparison of Qobs. & Qsim. with Variation of Lmax
Thubon basin, from 1 Sep. 1980 to 31 Mar. 1981

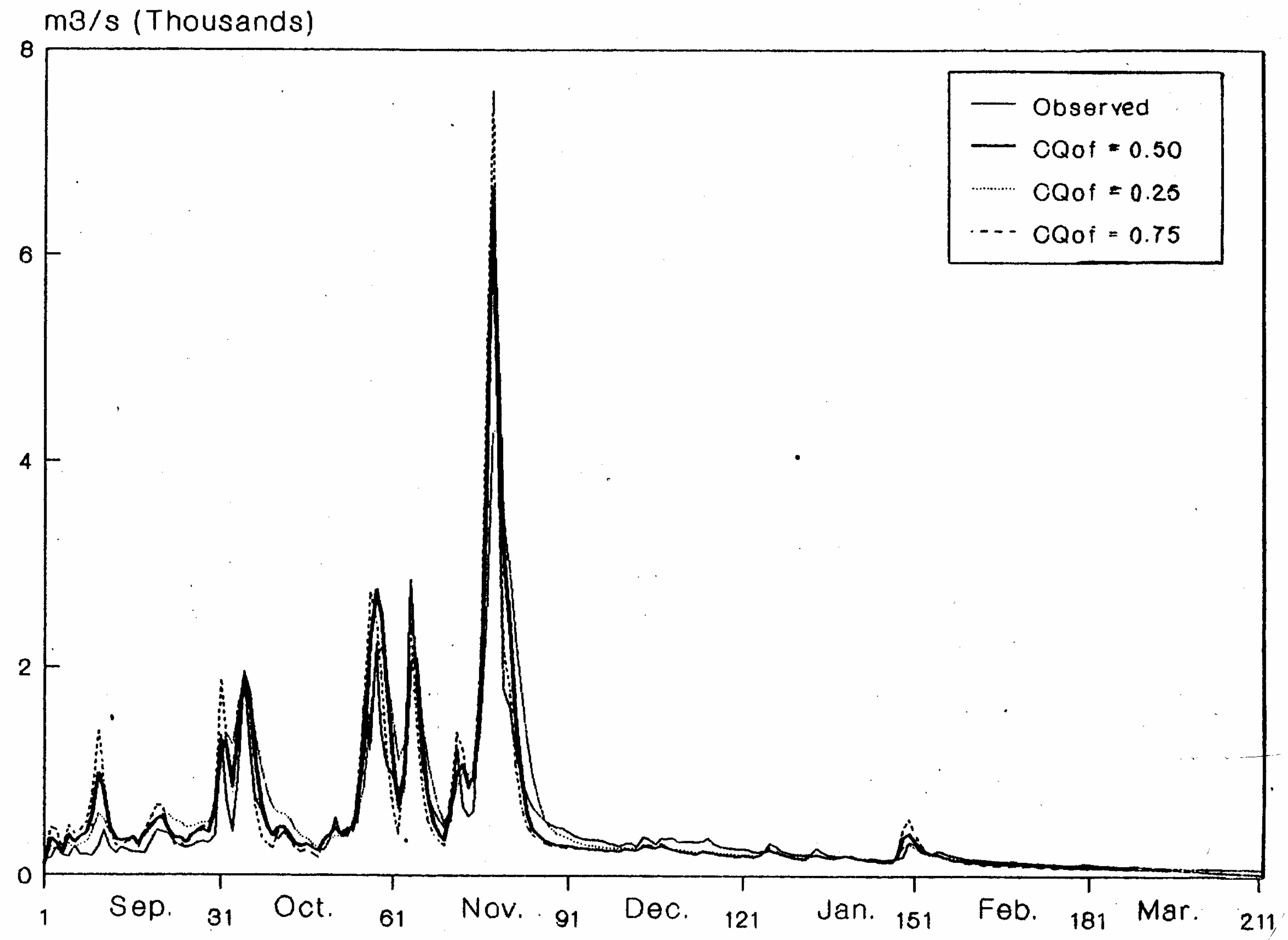

Fig. 5.3 Comparison of Qobs. & Qsim. with Variation of CQof
Thubon basin, from 1 Sep. 1980 to 31 Mar. 1981

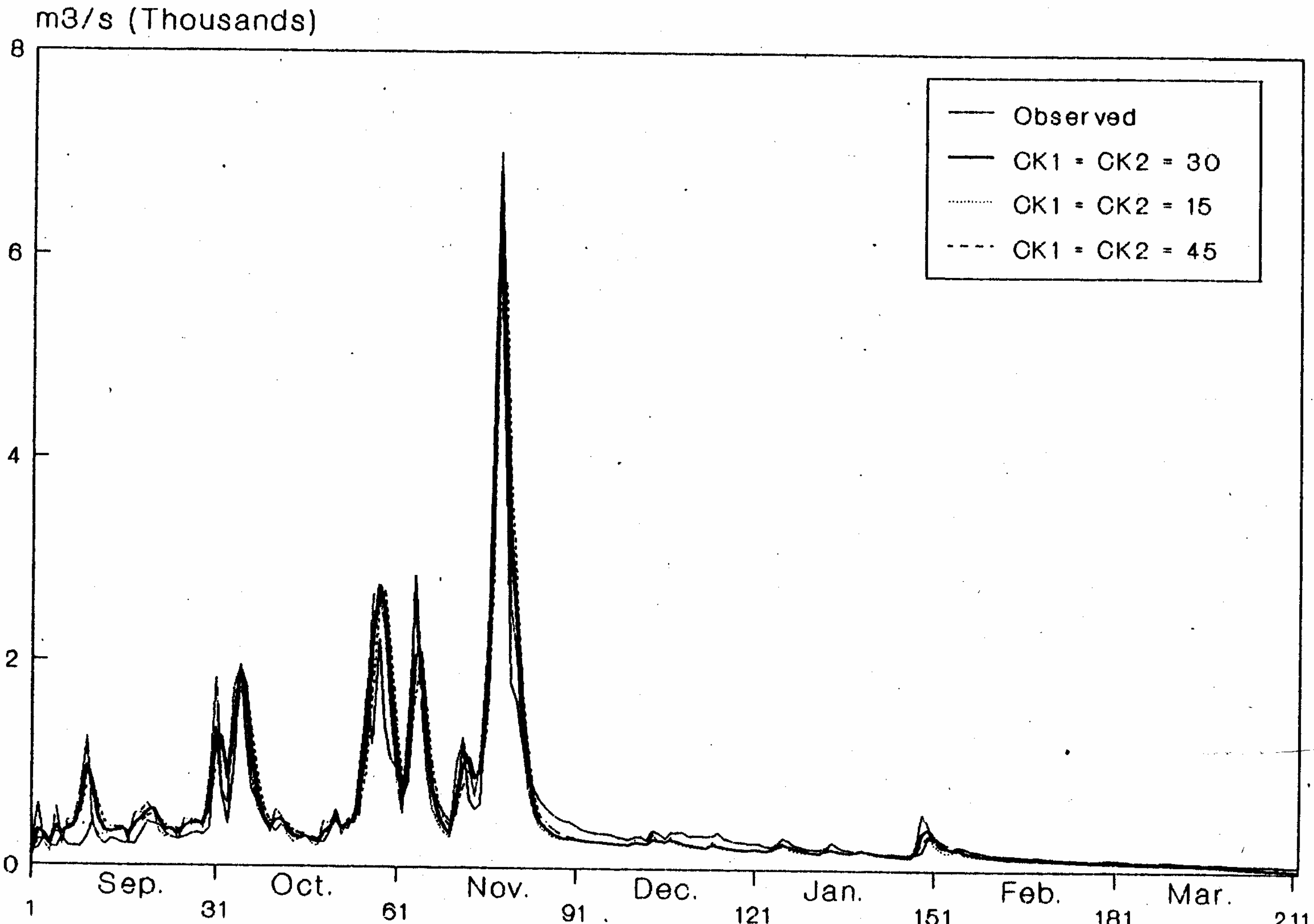

Fig. 5.4 Comparison of Qobs. & Qsim. with Variation of CK
Thubon basin, from 1 Sep. 1980 to 31 Mar. 1981

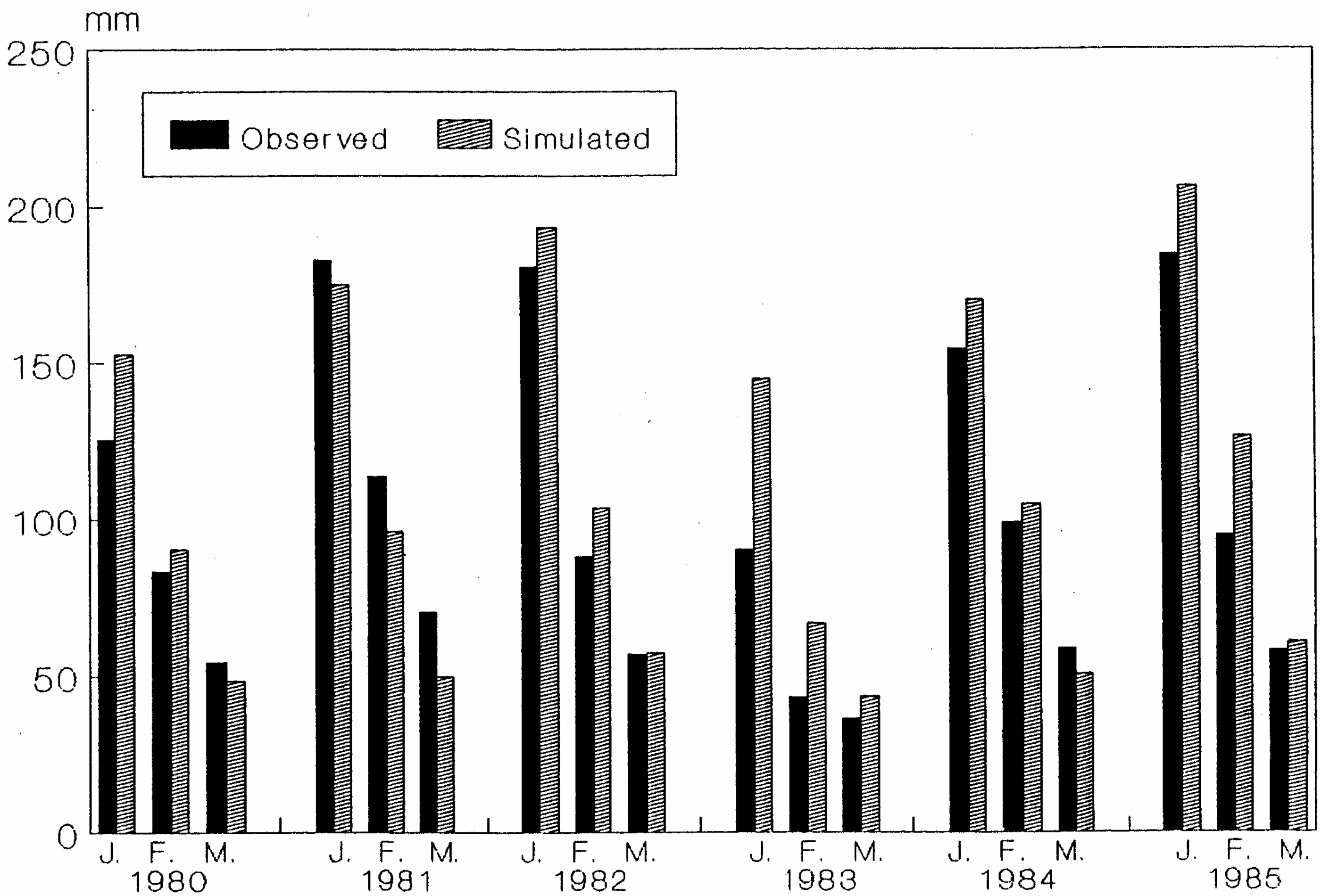

Fig. 5.5 Dry Period Flow-Depth in Thu bon basin

VI. SUMMARY AND CONCLUSIONS

As described in the previous chapters, the main purpose of this study is to estimate runoff by rainfall and runoff modeling for ungaged basins in Quangnam - Danang province, Central Vietnam. The NAM model was applied in the Thubon basin. Final values of the parameters were obtained by trial and error after careful judgment of fit between the observed and simulated hydrographs with some statistical analysis based on the calculated results of annual flows, peak flows, time to peak and baseflows. These calibrated and verificated parameters were also tested by analytical method after adjusting the routing time constants following the ratio of areas between considered and calibrated ones.

Based on the results of application of the model in this region, several conclusions can be drawn as follows :

1. The NAM model can be applied in tropical regions which have a large variability of rainfall and give a good prediction of a continuous streamflow especially annual flow, peak flow and time to peak.

2. The model can be applied and tested on gaged and ungaged basins and give a certainly satisfactory result for prediction of daily continuous runoff both on gaged and ungaged basins.

3. The baseflow simulation for both gaged and ungaged basins is not so good. However, the results can be accepted if the total dry flows are considered.

4. It was found that the typical shape of the hydrograph simulated are quite close compared with the observed one.

5. Effect of parameters U_{max}, L_{max} on the model hydrograph shapes is small if compared with CQ_{OF} and $CK_{1,2}$.

6. Parameter sensitivity analysis has shown that the model has tremendous potential for simulating annual flows, peak flows and baseflows provided the objectives for using the model is defined before hand.

7. Taking into account the simplicity of the model, investigations have demonstrated that the prospects for its applicability to small basins n tropical regions are promising. Hence, the model can be used as a tool for water resources investigation in small basins.

VII. RECOMMENDATION FOR FUTURE STUDIES

Summarizing the discussion and conclusion as well as regarding the model's applicability, the following recommendations are suggested for further study.

1. Due to the fact that NAM model is based on physical structures and equations used together with semi-empirical ones, the data about the basin characteristics should be collected as accurately as possible.

2. In order to know exactly the effect concerning the parameter on the model response, the sensitivity analysis must be done for different basins and characteristics.

3. It is necessary to organize some more hydrometeological stations in other ungaged basins as well as to continue to measure present stations. Recorded data will be used for testing the applicability of the model.

4. Finally, a search for a general parameters set for many difference regions on topography, vegetation, and flow characteristics, would be a very interesting and useful work for planning and developing water resources systems in Vietnam and others countries.

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