RUNOFF STUDIES OF KALLUVODDUHALLA PROJECT (KARNATAKA)

A DISSERTATION

submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

HYDROLOGY

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled "RUNOFF STUDIES OF KALLUVODDUHALLA PROJECT (KARNATAKA)" in partial fulfilment of the requirement for the award of the Degree of Master of Engineering in Hydrology, submitted in the School of Hydrology of the University, is an authentic record of my work carried out during a period from 16th October, 1983 to 16th May, 1984 under the supervision of Dr. B.S.Mathur Reader, School of Hydrology and Dr. D.K. Srivastava, Reader, School of Hydrology, University of Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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SYNOPSIS

The role of runoff is one of the basic hydrologic data and plays an important role in design aspect of Hydrology and reservoir operation studies in all water resources systems. In several water resources projects it is required to predict the characteristics and quantity of stream flow sequences. Many existing irrigation projects had been designed on the basis of scanty hydrologic data. Even some of the incoming projects are also being designed with available hydrological data.

Kalluvodduhalla project in Karnataka State is a tank Irrigation project, proposed for construction under World Bank Aid Scheme. The project is proposed across Kalluvodduhalla and no stream gauging data were available at the time of finalisation of the project. The project authorities finalised the hydrology of the project based on the available rainfall data of the catchment rainfall and the adjacent catchment rainfall. Thirty years catchment rainfall was calculated and the yield of runoff was worked out based on Strange's Table. The project was designed for 50% dependability of the flows , and was tested by 5 years continuous working Tables.

At present three years historical river flow data is now available at the site.

The aim of the present study is as follows:

(a) To generate the monthly volume of flows at the site for a period of 30 years by (i) Regression Analysis (ii) Modified Thomas Fiering Model.

(b) To study the feasibility of the project by reservoir operation for a cycle of 30 years for the 50%, 60% and 75% flow dependabilities.

(c) To work out the comparative benefit cost ratio of the project for different dependabilities.

The above study reveals that the flow generated by the regression analysis vary widely as compared to the historical flow and therefore were not considered for ~~res~~ reservoir operation. Where as the flows generated by Strange's table and the modified Thomas-Fiering Model resemble very much with the historical flows, and hence the flows generated by these two methods were used for reservoir operation. The flows generated by Modified Thomas Fiering Model are smaller than as compared with the flows generated by Strange's Table.

The 50% dependable flow scheme is feasible on the basis of reservoir operation criteria as well as on the basis of benefit cost-ratio criteria.

CHAPTER 1

INTRODUCTION

Kalluvodduhalla Project is situated in Shikaripura Taluk, Shimoga District of Karnataka State. Karnataka State is in southern part of India. Kulluvoduhalla project is taken up for construction under Tank Irrigation projects under World Bank Assistance.

Karnataka State has a total area of 1,91,773 sq.km. The total irrigation potential available in the State is about 5.5 million Hectares. About 54% of the States Geographical area is drought prone as compared to 16% of the total area in India. The State has created only about 18% of area under Irrigation as against the national average of 30%. Therefore expansion of Irrigation facility is one of the highest priorities for agricultural development plan.

In the State, tank Irrigation, is the traditional form of Irrigation. The Irrigation Department of Karnataka, has 25,150 minor Irrigation Works irrigating about 0.81 million Hectares.

To increase the irrigation potential, the State Government has identified 160 tanks irrigation projects under the assistance of World Bank Aid. Kalluvodduhalla project is one among those identified under World Bank Aid.

Kalluvodduhalla project envisages the construction of Earthen dam with flank spillway across the stream Kalluvodduhalla. It is proposed to irrigate 1450 Hectares of land to utilise 17.549 Mm^3 of water. The cost of the project works out to Rs.484.8 lakhs.

The stream gauging data of the halla were not available at the time of finalisation of the project. Hydrology of the project is finalised by using catchment rainfall and adjacent catchment rainfall statistics.

Rainfall data in the catchment is available for 11 years. By making use of rainfall data of the adjacent catchment, 19 years rainfall data in the catchment in built up by correlation analysis. In all 30 years rainfall data in the catchment is built up and the runoff is calculated by Stange's Table.

In case of Karnataka, hydrologist principally use the strauge's table for calculating runoff in case of the catchments having no stream flow data.

In the project report, 50% dependable flow is considered for design aspect and for reservoir operation studies, to see the feasibility of the project.

India has ultimate irrigation potential as estimated at 107 million ha. So far in the country, total area irrigated is of the order of 50 million ha, of which nearly 30 million ha. are accounted for by major and medium projects. The scope for constructing new Irrigation projects to provide Irrigation facilities is rather limitted, since most of the sites suitable for construction of storage reservoirs have already been developed. Even in case of relatively few sites which are considered feasible of being developed with the present level of technology available, the cost of Irrigation is much higher than in the projects already constructed. In some cases, it is possible that the system had to be designed with practically no observed data, relaying purely on empirical runoff estimates based on strauge's rainfall runoff tables or other similar methods. Considerable methods are now available to provide a more realistic basis for assessing the availability and variability of river supplies. Techniques of mathematical modelling coupled with digital computer facilities available in the country to provide powerful tools for testing the adequacy of a storage volume and evolving suitable operation schedules so as, not only to regulate available river flow to match a pattern of demand, but also to optimise the results of such regulation. In this context the possibility of improving the efficiency of the existing irrigation system as well as future coming projects, so as to use the water and thereby intensity or extend irrigation under these projects calls for urgent modernisation of reservoir operation.

Water is one of the most important natural resources on earth. All human being, animal and plant life requires water for their survival. Besides this water is also required for domestic use, municipal water supply, business establishments, industries mining, hydro-electric projects, agriculture, production of stream, refrigirator cooling system, recreation centres, fishing ponds, forming pools, and lakes. It is generally assumed that domestic water supply has the highest priority of all types of water utilisation, possibly followed by industrial and agricultural requirement. But irrigation is necessary to meet the rising demand of food and fibre for the ever rising population of the world.

Whether or not irrigation is an alternative proposition in a certain region of which the following are the most important. First of all, the political, social and economic environment. Second, the suitability of the land form. Third, availability of water in the region.

Because of the elimination of the havoc caused by drought period, the economy of the region and [illegible] to give assured supply of water for irrigation to poor with marginal land holding farmers, construction of irrigation project is more necessary than just the benefit schemes so that the economy of the region is stabilised.

1.2 BRIEF DETAILS OF THE PROJECT

1.2.1 Location

Kalluvodduhalla is a tank project situated in Shikaripura Taluk, Shimoga District of Karnata State. It is located at Latitude $14^{\circ}13' 0''$ and Longitude $75^{\circ}14' 30''$. It lies in the western part of Karnataka State in Shimoga District shown in Fig. 1.1.

1.2.2 Project

The project envisages construction of earthen dam with flank spillway across Kalluvodduhalla. It is a storage reservoir to irrigate 1450 Hectare of lands in Shikaripura Taluk, served by two canals. Shown in Fig.1.2.

1.2.3 Catchment Area

Catchment Area of the project is 41 sq.kms. This halla rises from Balundur State forest at an altitude of about 700 M. The lowest river bed level at the site is about 614 m. Upper most catchment area is hilly and thickly forested and lower reaches are in moderate country. Kalluvodduhalla stream is one of the tributary in sub-basin of Kumudvati river, which in turn is a tributory to Tungabhadra river. Catchment area shown in Fig.1.2.

1.2.4 Climate

The climate of the area is described as fairly moderate and tropical. The temperature varies from $14^{\circ}C$ minimum to $35.9^{\circ}C$ maximum. This area receives maximum rainfall during the south-west monsoon (Jun. to September) and minimum rainfall during north-east monsoon (Oct.to Dec.) The average rainfall in the area is about 1305 mm per year.

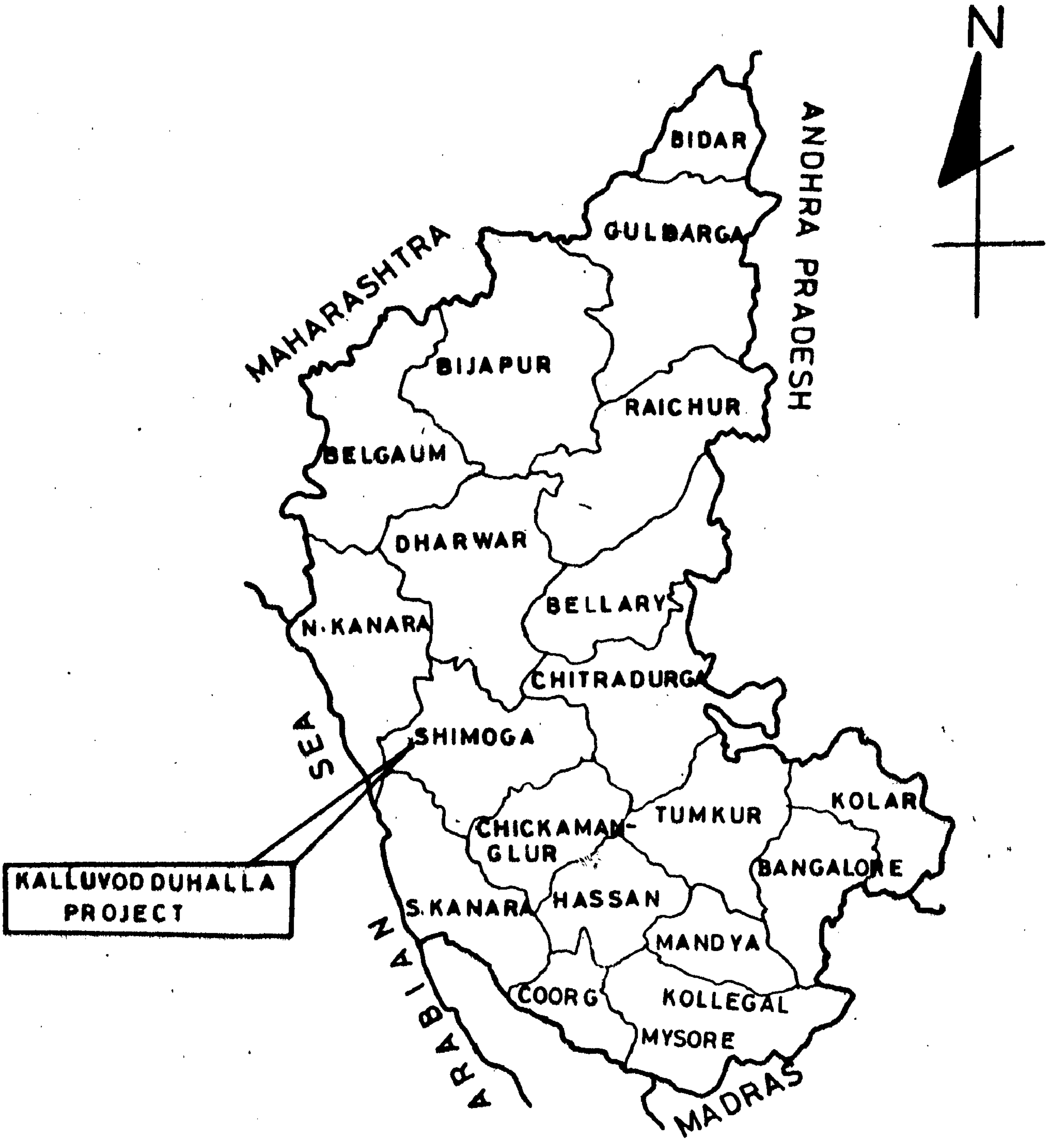


FIG. 1.1 LOCATION MAP

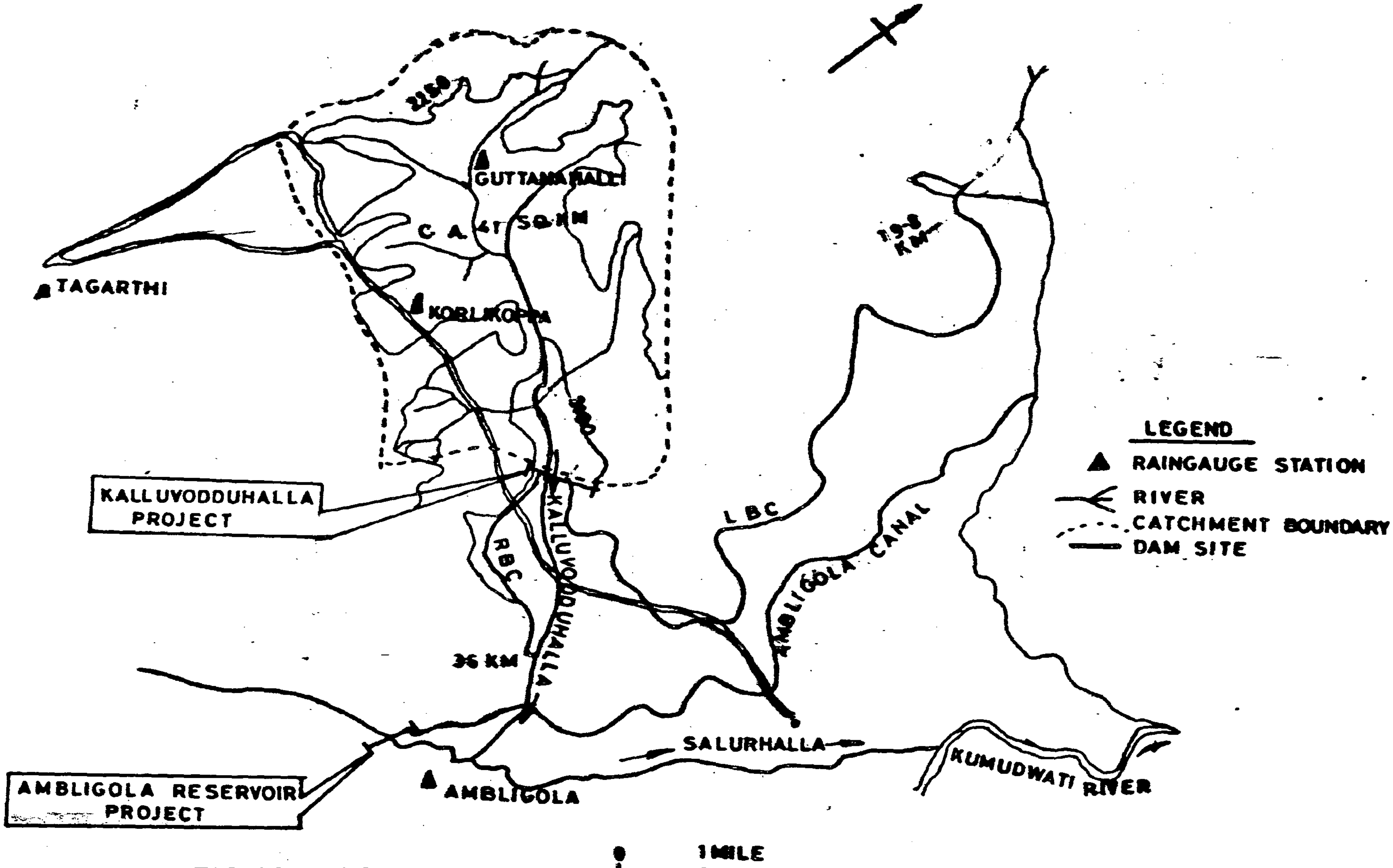


FIG-1·2 INDEX MAP

1.2.5 HYDROLOGY of the Project

Two rain gauge stations are available in side the catchment, namely Guttanahalli, and Korlikoppa stations. Shown in Fig. 1.2. Rainfall data for 9 years are available as shown in Table 1.1.

Runoff series of the project is finalised by using long term rainfall series based on strauge's table value.

Hydrological data available:

1. Catchment Area map 1'' = 1 mile
2. Rainfall data of Guttanahalli 1971-1979
3. Rainfall data of Korlikoppa 1971-1979
4. Rainfall data of Ambligola 1950-1969 and 1971-1979.
5. Area capacity Table and curve.
6. Existing and Proposed cropping pattern
7. Monthwise crop water demand.
8. Evaporation values
9. Historical stream flow data for 3 year from 1981-1984.

19 years rainfall data of the catchment is built up by using the rainfall data of adjacent catchment.

Ambligola raingauge station shown in Fig.1.2, is situated in the adjacent eatchment and fairly long term rainfall record is available shown in Table 1.2.

Ratio of 1.196 is calculated by using the concurrent period rainfall data of catchment rainfall to that

Table 1.1 : Catchment Rainfall Data (All figures are in inches)

Year	Months							
	May	June.	July	August	September	October	November	Total
				GUTTANAHALLI STATION				
1971	0.57	18.39	12.22	4.78	3.07	-	-	39.03
1972	4.48	19.23	20.27	9.25	1.20	1.06	0.16	55.65
1973	0.63	20.78	19.93	16.28	0.33	0.35	-	58.30
1974	-	3.18	18.23	11.31	4.66	3.51	-	40.89
1975	1.39	16.40	14.48	15.12	8.75	6.45	6.00	68.59
1976	-	2.74	12.81	9.31	2.32	0.48	7.25	34.91
1977	3.53	8.39	18.75	5.79	6.87	2.38	5.11	50.82
1978	6.23	19.13	17.05	16.17	3,89	3.15	2.25	67.87
1979	-	13.31	8.26	14.50	0.78	0.40	0.71	37.96
				KARLIKOPPA STATION				
1971	0.69	21.63	15.50	4.76	2.71	2.07	0.36	47.72
1972	6.57	6.11	23.15	6.71	5.13	2.86	0.67	51.20
1973	2.80	14,84	21.07	14.63	1.39	3.35	0.12	58.20
1974	2.96	5.36	18.96	13.04	5.28	3.87	-	49.47
1975	2.46	26.07	15.16	15.43	10.62	6.48	7.23	83.45
1976	-	4.54	14.07	7.58	2,97	2.90	7.93	39.99
1977	2.86	9.10	14.87	4.85	7.40	4.86	3.65	47.59
1978	4.15	13.26	22.95	15.86	3.58	4.09	2.00	65.89
1979	-	-	13.04	-	1.79	-	-	-

Table:1.2 : Rainfall Data of Ambligola(Figures are in Inches)

Year	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Total
1950	1.70	6.14	32.25	7.90	7.12	5.42	1.27	61.80
1951	5.70	7.19	14.86	3.92	4.55	8.95	-	45.17
1952	-	-	8.13	6.20	5.00	6.62	-	25.95
1953	-	16.70	6.60	16.9	-	-	-	40.20
1954	1.61	10.85	19.90	9.21	2.71	4.60	-	48.88
1955	8.55	8.36	4.32	10.19	7.36	8.40	-	47.24
1956	2.46	14.85	20.23	11.07	6.22	7.09	3.14	65.06
1957	7.66	10.38	14.53	7.47	3.29	10.94	5.05	59.25
1958	3.22	9.53	25.16	9.87	4.86	5.69	0.32	58.65
1959	4.87	15.76	34.66	7.75	10.41	1.10	3.25	71.80
1960	1.95	5.81	16.09	9.81	8.97	6.13	1.91	50.67
1961	18.35	13.87	32.12	9.24	3.73	2.09	-	79.40
1962	4.32	3.13	21.33	22.14	8.06	7.06	0.33	66.37
1963	5.58	3.56	10.24	12.42	0.95	5.02	2.37	40.14
1964	0.60	6.20	10.08	19.52	3.38	4.25	2.56	46.99
1965	2.30	6.65	18.24	7.09	1.96	1.90	-	38.14
1966	6.35	1.74	16.61	1.34	5.68	7.15	4.10	42.97
1967	3.45	6.75	22.45	10.80	1.60	1.00	-	46.05
1968	0.30	8.70	27.00	2.90	4.10	-	1.30	44.30
1971	1.27	12.89	10.79	3.74	4.60	1.73	-	35.02
1972	3.94	8.35	13.86	3.50	3.89	3.43	0.63	37.60
1973	0.51	10.31	16.77	9.93	0.55	2.59	0.48	41.14
1974	2.60	3.74	16.26	10.51	6.02	5.52	-	44.65
1975	2.98	15.02	12.24	12.92	7.24	5.63	4.66	60.69
1976	-	3.88	13.04	5.73	3.69	0.63	6.24	33.20
1977	2.50	8.00	12.00	2.96	8.26	7.36	1.68	42.76
1978	3.90	8.07	23.36	11.09	2.70	4.09	3.16	56.37
1979	-	10.95	8.99	14.34	1.04	-	1.24	36.90

of Ambligola rainfall, shown in Table 1.3.

By using the ratio of 1.196, the catchment rainfall data is built up for 19 years. In addition to the 11 years available catchment rainfall total 30 years catchment rainfall is shown in Table 1.4. 3 Years historical flow data is shown in Table 1.5.

1. Runoff by Strange's Table

Stream gauging data of the stream was not available. The project authorities have finalised the runoff yield by using strange's table [illegible]

In most parts of Karnataka, except in coastal areas, the use of Strange's Table for ungauged streams, is generally accepted. In Strange's Table, the yield of runoff is given for good, average and bad catchments. Use of Strange's Table requires careful classification of catchment. The project authorities have considered the catchment as ''average'' by studying the available data of rainfall and runoff data of the adjacent catchment. 30 years runoff yield is calculated by considering the catchment as ''average''. Monthwise runoff yield calculated by Strange's Table is shown in Table 1.6.

Table 1.3: Computation of Ratio of Catchment Rainfall to Ambligola Rainfall.

Year	Guttanahally 9.60 Sq.Miles		Karlikoppa 6.23 Sq.Miles		Weighted average inches	Rainfall of Ambligola Raingauge Station
	Rainfall inches	Precipitation in Sq.Miles inches	Rainfall inches	Precipitation Sq. Miles inches		
1971	39.03	374.69	47.72	297.30	42.45	35.02
1972	55.65	534.24	51.20	318.98	53.90	37.60
1973	58.30	559.68	58.20	362.59	58.26	41.14
1974	40.89	392.54	49.47	308.20	44.27	44.65
1975	68.59	657.60	83.45	519.14	74.38	60.69
1976	34.91	535.14	39.99	249.14	36.91	33.21
1977	50.82	487.87	47.59	296.49	49.55	42.76
1978	67.87	651.55	65.89	410.49	67.09	56.37
1979	37.96	364.42	-	-	37.96	36.96
				464.77/388.40 = 1.196	464.77	388.40

Table 1.4 : Catchment Rainfall-30 years

Sl No.	Year	Rainfall Data of Ambligola	Catchment Rainfall (Built up 1950-1968) Col.3 * 1.196	Catchment Rainfall in Decending Order	
1	2	3	4	5	
1	1950	61.80	73.93	94.96	
2.	1951	45.17	54.02	93.05	
3.	1952	25.95	31.04	79.38	
4.	1953	40.20	48.08	77.81	
5.	1954	48.88	58.46	74.38	
6.	1955	47.24	56.50	73.98	
7.	1956	65.06	77.81	70.86	
8.	1957	59.25	70.86	70.15	
9.	1958	58.65	70.15	67.09	
10.	1959	77.80	93.05	61.48	
11.	1960	50.67	60.60	60.60	
12.	1961	79.40	94.96	58.46	
13.	1962	66.37	79.38	58.26	
14.	1963	40.14	48.01	56.50	
15.	1964	46.99	56.20	56.20	50% dependability
16.	1965	38.14	45.62	55.68	
17.	1966	42.97	51.39	54.02	
18.	1967	46.05	55.68	53.90	
19.	1968	44.30	54.95	53.86	
20.	1969		53.86	52.98	
21.	1970		61.48	51.39	
22.	1971		42.45	49.55	
23.	1972		53.90	48.08	
24.	1973		58.26	48.01	
25.	1974		44.27	45.62	
26.	1975		74.38	44.27	
27.	1976		36.91	42.45	
28.	1977		49.55	37.96	
29.	1978		67.09	36.91	
30.	1979		37.96	31.04	

50% Dependable Yield = 56.20'' = 54.565 * 15.81

= 862.67 Mcft.

= 24.42 Mm^3

Table 1.5 : Historical Flows (All figures in Mm^3)

Sl. No.	Month	1981	1982	1983
1.	January	0.0	0.0	0.0
2.	February	0.0	0.0	0.0
3.	March	0.0	0.0	0.0
4.	April	0.0	0.0	0.0
5.	May	0.12	0.0	0.0
6.	June	0.10	0.37	0.154
7.	July	0.876	1.163	6.551
8.	August	13.053	13.041	11.288
9.	September	1.196	1.012	1.188
10.	October	0.438	0.600	3.210
11.	November	0.0	0.425	1.707
12.	December	0.0	0.0	0.0
	Total	15.783	16.611	24.098

Table 1.6: Runoff Data Based on Strange's Table (All figures in ... in Mm^3)

Sl. No.	Year	Jun.	Jul.	Aug.	Sept.	Oct.	Nove.	May	Total
1.	1950-51	0.28	17.11	8.20	1.60	1.54	0.71	0.11	29.55
2.	1951-52	1.08	6.54	2.67	3.56	8.54	-	-	22.39
3.	1952-53	-	0.31	1.27	1.77	3.30	-	-	6.65
4.	1953-54	2.33	2.86	12.31	-	-	-	-	17.50
5.	1954-55	1.08	9.83	7.91	2.71	5.09	-	0.36	26.98
6.	1955-56	2.05	1.78	6.05	6.00	8.50	-	-	24.38
7.	1956-57	2.55	12.53	11.24	1.29	1.89	1.77	0.26	31.53
8.	1957-58	2.56	8.21	6.27	3.20	4.68	2.82	-	27.74
9.	1958-59	1.15	14.25	9.93	0.86	1.30	0.18	0.06	27.73
10.	1959-60	3.83	21.88	4.35	5.85	0.62	1.83	-	38.36
11.	1960-61	0.27	5.20	6.40	7.98	6.63	0.05	2.96	29.49
12.	1961-62	7.77	20.14	5.19	2.09	1.17	-	0.04	36.40
13.	1962-63	0.20	8.17	18.14	1.30	3.96	0.19	0.10	32.06
14.	1963-64	0.34	2.92	7.12	0.70	4.07	2.16	-	17.31
15.	1964-65	0.18	2.22	12.05	3.03	4.22	2.76	0.01	24.47
16.	1965-66	0.41	6.97	4.97	1.61	1.65	-	0.15	15.76
17.	1966-67	0.16	5.64	0.76	3.73	5.84	3.92	0.02	20.07
18.	1967-68	0.59	10.51	9.57	1.68	1.07	-	-	23.42
19.	1968-69	0.42	13.36	2.54	3.92	-	1.31	-	21.55
20.	1969-70	0.04	6.12	4.62	4.46	5.98	1.13	0.10	22.45
21.	1970-71	1.07	5.03	14.14	7.21	0.48	-	-	27.93
22.	1971-72	2.43	5.64	2.76	1.88	0.55	0.10	0.05	13,41
23.	1972-73	2.11	9.81	5.97	2.27	1.51	0.34	-	22.01
24.	1973-74	2.32	9.59	12.30	0.69	1.48	0.05	-	26.43
25.	1974-75	0.09	3.12	5.91	3.00	2.51	-	-	14.63
26.	1975-76	2.97	6.74	10.98	5.85	1.55	1.57	-	29.66
27.	1976-77	1.48	2.69	1.06	0.64	3.93	-	-	9.80
28.	1977-78	0.57	5.18	2.73	4.33	2.34	3.53	0.05	18.73
29.	1978-79	3.00	9.73	13.06	1.14	1.08	0.71	-	28.72
30.	1979-80	0.75	2.01	6.44	0.46	0.22	0.44	-	10.32

1.2.7 Dependable Flow

The project is designed for 50% dependability. Usual practice of dependable flow is 75% for major projects. It is a tank irrigation project and hence the 50% dependable flow is considered for design purposes as per staff apprisal report of Karnataka State. Yield of runoff for 30 years are arranged in decending order. The 50% dependable yield works out to 24.42 Mm^3 shown in Table 1.6. 50% dependable flow year working table enclosed in Table 1.7.

1.2.8 Evaporation Values

Daily evaporation values of the project area is enclosed in Table 1.8. Total evaporation for the 50% dependable flow year works out to 1.881 Mm^3. Shown in Table 1.7.

Table 1.7 : 50% Dependable Flow Year Working Table

Gross Storage = 12.176 Mm^3 Minimum drawdown storage = 1.222 Mm^3

Dead Storage = 0.874 Mm^3

Item	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1. Opening Balance	5.477	1.290	2.664	12.176	12.176	12.176	12.176	11.674	10.796	8.916	6.675	6.183	
2. Inflow Mm^3	0.180	2.220	12.050	3.030	4.220	2.760	-	-	-	-	-	0.01	24.470
3. Total ''	5.657	3.510	14.714	15.206	16.396	14.936	12.176	11.674	10.796	8.916	6.675	6.193	
4. Cropwater Demand Mm^3	4.280	0.796	1.318	2.498	2.600	0.929	0.347	0.700	1.701	2.032	0.298	0.050	17.549
5. Balance	1.377	2.714	13.396	12.708	13.796	14.007	11.829	10.974	9.095	6.884	6.377	6.143	
6. Mean Capacity	3.427	2.002	8.030	12.176	12.176	12.176	12.003	11.324	9.946	7.900	6.526	6.163	
7. Evap.Values Mm	110.4	95.4	97.50	100.8	101.1	98.6	92.1	164	152	137	127	124	
8. Water Spread Ha.	80	52	138	171.25	171.25	171.25	168	108.5	117.8	152.9	152.8	144.7	
9													
9. Evap.Losses	0.087	0.05	0.135	0.173	0.173	0.169	0.155	0.178	0.179	0.200	0.194	0.179	1.881
10. Closing Balance Mm^3	1.290	2.664	12.176	12.176	12.176	12.176	11.674	10.796	8.916	6.675	6.183	5.964	
11. Surplus ''			1.085	0.359	1.447	1.662	-						4.553
12. Shortages													

Opening Balance = 5.477 Mm^3
Inflow = 24.470 ''
29.947 Mm^3

Irrigation Issues = 17.549 Mm^3
Evap. Losses = 1.881 ''
Surplus = 4.553 ''
Closing Balance = 5.964 ''
29.947 Mm^3

Table 1.8 : Daily Evapotranspiration Values(Modified Penman Method)

Station : Shimoga.

Unit mm

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Daily Evapotranspiration Values in mm/day	3.50	4.21	4.93	5.09	4.67	3.68	3.07	3.15	3.36	3.26	3.29	2.97

1.2.9 Cropping Pattern

The existing crop pattern is enclosed in Table 1.9. The proposed cropping pattern is enclosed in Table 1.10. Monthly crop water requirement of the project is enclosed in Table 1.11. Crop water demand works out to 17.549 Mm^3.

1.2.10 Reservoir Elevation-Area Capacity Relations

The relation between Elevation-Area-Capacity Table is enclosed in Table 1.12. The Area capacity curve is enclosed in Fig. 1.3.

1.2.11 Topography and Soil Classification of the Command Area

Topography of the command area is plain in most part of the project area, but undulating in few places. General slope of the area varies from 0 to 3%. command area survey is done by the State Agricultural Department and has identified two soil series, shown in Table 1.13.

Amptekoppa Soil series are moderately fine to fine textured soils with medium depth and are under-laid by gravelly murrum and the land is quite suitable for irrigation.

Hagaravalli soil series are deep fine textured soils with moderately slow to slow permeability and the land is suitable for irrigation with care.

Table 1.9 : Existing Crop Pattern in the Command Area

Sl. No.	Crop	Session	Present Crop in Percent
1.	Paddy	Khariff	83.60
2.	Maize	Khariff	0.90
3.	Ragi	Khariff	6.10
4.	Pulses	Khariff	0.10
5.	Chillies	Khariff	3.80
6.	Groundnut	Khariff	0.60
7.	Seasamum	Khariff	0.60
8.	Niger	Khariff	0.60
			96.30
9.	Pulses	Rabi	7.60
10.	Cotton	Two Seasonal	2.20
11.	Sugarcane	Perennial	0.60
			106.70

Table 1.10 : Proposed Crop Pattern

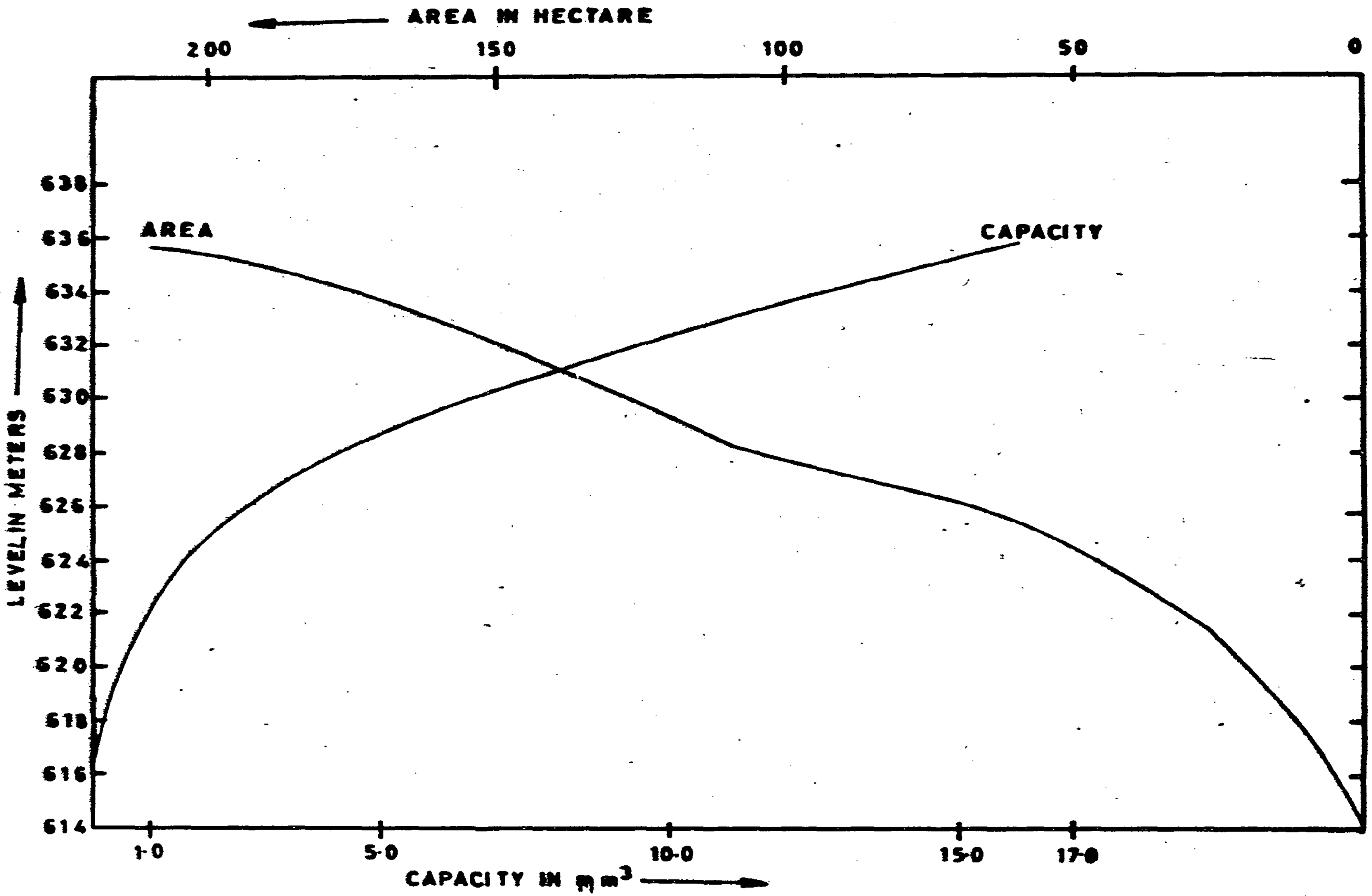
	Crop	Percentage	Crop Duration	Yield in Tonnes per Hectare
	KHARIFF			
1.	Paddy	90	June II to Nov. I	5
		90		
	RABI			
2.	Paddy	5	Oct. I to Feb. I	6
3.	Pulses	50	Nov. I to April II	1.5
4.	Wheat	4	Nov. I to April II	1.8
5.	Groundnut	9	Nov. I to April II	2.5
		63		
	PERENNIALS			
6.	Sugarcane	2	Oct. I to Sept. II	100.0
		160		

Table 1.11 : Monthly Crop Water Requirement, in Mm^3 Irrigation Area - 1450 Hactares

Period	% Irrigation	Area in Hactare	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1. Kharif Paddy	90%	1305	4.280	0.796	1.318	2.498	2.271	0.666							11.829
2. Rabi Paddy	5%	72					0.329	0.239	0.202	0.208	0.057	-	-	-	1.035
3. Rabi Semi-dry	63%	914							0.110	0.448	1.590	1.964	0.236	-	4.348
4. Perennial Sugar-cane	2%	29						0.024	0.035	0.044	0.054	0.068	0.062	0.050	0.337
Total	160%	2320	4.280	0.796	1.318	2.498	2.600	0.929	0.347	0.700	1.701	2.032	0.298	0.050	17.549

Table 1.12: Reservoir-Elevation Area-Capacity Relations

Sl. No.	Elevation in m.	Reservoir Capacity in Mm^3	Reservoir Area in Hectare
1.	614.17	-	-
2.	615.361	0.008	2.02
3.	617.495	0.114	8.90
4.	619.623	0.393	17.81
5.	621.760	0.873	27.52
6.	622.865	1.222	36.18
7.	623.985	1.638	45.32
8.	624.810	2.007	52.61
9.	626.029	2.773	62.73
10.	628.162	4.592	110.48
11.	630.296	7.155	131.52
12.	631.515	8.826	144.47
13.	632.429	10.193	154.99
14.	632.734	10.661	159.44
15.	633.495	12.176	171.18
16.	634.563	13.804	182.51
17.	635.325	15.255	198.29
18.	635.782	16.197	210.43



FIG·1.3 RESERVOIR ELEVATION AREA CAPACITY RELATION

Table 1.13 : Statement Showing the Morphological Characteristics of the Soils Coming Under the Command Area.

Sl. No.	Characteristics.	Amtekoppa Series.	Haragavalli Series.
a)	Physiography	Plain	Plain
b)	Slope	1 to 3%	0 to 1%
c)	Parent material	Schist and Quartzite	Schist and Quartisties.
d)	Colour	Yellowish brown to reddish brown	Yellowish brown to reddish brown
e)	Texture		
	i) Surface	Silty loam	
	ii) Sub-surface	Silty clay loam to gravelly clay loam	Silty clay loam clay to clay loam
f)	Soil depth	Deep	Very deep
g)	Lime status	-	-
	i) Surface	-	-
	ii) Sub-surface	-	-
h)	Sub soil drainage	Well drained	Well drained
i)	i) Land irrigability Class	Class-I.	Class-II
j)	Mapping Unit	Amk-s=1-d4 B-e2	Hgv-c1-d5 A-e1

1.2.12 Salient Feature of the Scheme

1.	Name of the Project	Kalluvodduhalla Project
2.	Name of the Stream	Kalluvodduhalla
3.	Location	Latitude 14°-13'-0''
		Longitude 75°-14'-30''
4.	Purpose	Irrigation
5.	Catchment Area	41 Sq.Km.
6.	Rainfall	1305 mm (Mean Annual)
7.	Yield at 50% Dependability	24.46 Mm^3
8.	Lowest River bed level	614.17 m
9.	Dead Storage level	621.76 m
10.	Full Reservoir level	633.495 m
11.	Top of Dam	637.155 m
12.	Dead Storage capacity	0.874 Mm^3
13.	Minimum drawdown capacity	1.222 Mm^3
14.	Gross storage capacity	12.176 Mm^3
15.	Submersion Area	198.29 Hectares
16.	Type of Dam	Earthen Dam with flank spillway
17.	Height of dam(Maximum)	22.985 m
18.	Gross command area	1882 Hectares
19.	Culturable command area	1450 Hectares
20.	Crop water requirement	17.549 Mm^3
21.	Length of left bank canal	19.80 Kms.
22.	Length of right bank canal	3.60 Kms
23.	Total cost of the Scheme	Rs.484.8 Lakhs
24.	Cost per Hectare	Rs.33,359
25.	Cost per M^3 of water utilised.	Rs.2.76

1.2.13 Reservoir Operation for 50% Dependable Year

In the report reservoir operation for 5 years have been done which includes 50% dependable year. Out of 5 years, 3 years are successful and 2 years are failure years.

Reservoir operation table for 50% dependable flow is enclosed in Table 1.8

Dead storage capacity is fixed at 0.874 Mm^3 and the Gross storage capacity works out to be 12.176 Mm^3 to irrigate 1450 Hectares.

1.2.14 Cost of the Scheme

The scheme is proposed to irrigate 1450 Hectares of cultivable command area of Shikaripura Taluk of Shimoga District. After the advent of irrigation about 886 farming families will be benefitted. 17.549 MM^3 of water will be utilised to irrigate 1450 Hectares. The cost of the scheme works out to Rs.484.8 Lakhs.

The cost per m^3 of water utilised works out to Rs.2.76.

$$\text{Cost per } m^3 \text{ of water} = \frac{4848\ 0000}{17549\ 000} = 2.76$$

This is well within the critical limit of Rs.4.03 prescribed in the staff apprisal Report, Karnataka Government

1.2.15 Socio-economic Condition of the Project Area

The cultivators of the area are poor, backword ... and marginal land holdings. At present most of the area is under rainfed. After the advent of this project, Socio-economic conditions of this area will be improved by the assured water supply to farmers.

1.3 OBJECTIVES OF THE STUDY

Historical flows for Kalluvodduhalla were not available at the time of preparation of the project. As per staff apprisal report of Karnataka Government, for ungauged streams, the yield series are calculated from Strange's table. In Strange's Table, runoff yield is given for the catchment as 'good', Average' or 'bad'. The relationship between those classifications of catchment runoff is given by ratio of 2 : 1.5 : 1 respectively. Thus the estimates of runoff will vary significantly depending on catchment classification. It requires careful and realistic classification of the catchment. The estimated value of yields based on Strange's tables depends primarily on the duration and accuracy of the rainfall data used in deriving the average annual rainfall for each catchment.

Hence further study on the monthly volume is necessary to have realistic approaches by using available mathematical models. Number of mathematical models are available. In the present problem, the following mathematical models are used to generate the short term monthly sequences to long term monthly sequences of flow. These generated monthly sequences of flow are further used in the reservoir operation studies to check the feasibility of the report.

1.3.1 Generating Monthly Flows by Regression Analysis

In the present problem, short term historical record of 3 years are available. 3 Years historical record is generated to study the feasibility of the project. Computer programme is developed to generate flows.

1.3.2 Generation of Monthly Flows by Modified Thomas-Fiering Model.

In the present problem, zero discharges are observed during dry season. Hence modified Thomas-Fiering model is used to generate monthly flows to study the feasibility of the project.

In this study 10 years (3 years of historical record + 7 years generated flows by Strange's table) are further generated to 30 years by Modified Thomas-Fiering Model. A computer program is developed to generate flows.

These 30 years generated flows are further used in reservoir operation studies.

1.3.3 Curve Fitting for Area-Capacity Relation

In the reservoir operation table, the relation between Area and capacity is required. A third degree polynomial for

a) Area - Capacity

b) Elevation - Capacity are worked out by a computer program.

1.3.4 Reservoir Operation Studies

The reservoir operation studies are to be done for the following cases to check the feasibility of the project for different dependable flows.

(a) Yield of Runoff from Strange's Table

1. Reservoir operation for reservoir capacity obtained from 50% dependable flow year.
2. Reservoir operation for reservoir capacity obtained from 60% dependable flow year.
3. Reservoir operation for reservoir capacity obtained from 75% dependable flow year.

(b) Reservoir operation study for the flows generated from Modified Thomas Fiering Model.
Steps 1 to 3 as in (a) above.

CHAPTER 2

GENERATION OF MONTHLY VOLUMES BY REGRESSION ANALYSIS

2.1 GENERAL

Hydrologic data are the only source of information upon which quantitative hydrologic investigations are generally based, their measurements have been continiously expanding. Further more, natural hydrologic phenomena are highly erratic and commonly stochastic in nature one of the important problems in hydrology deals with interpreting a past record of hydrologic events interms of future probabilities of occurrance. This problem arises in the estimates of frequencies of floods, droughts, storages, rainfalls, and runoffs etc.

Hydrologic data can be treated as statistical variables. In statistics the whole collection of objectixx under consideration is called a population. Their characteristic are called variables. In Hydrologic phenomena, for example the variable may be the depth of rainfall is known as variate.

The characteristics of statistical parameters are many but only the important once are defined below

The Mean:- There are three kinds of means, arithmatic, geometric and harmonic.

The arithamatic mean is usually referred to simply the mean is given by

$$\bar{X} = \frac{\Sigma X}{N}$$

where, X is the variate and N is the total number of observations.

The Geometric mean is the N^{th} root of the product of N terms and is given by

$$\bar{X}_g = (X_1 * X_2 * X_3 \quad .... \; X_N)^{1/N}$$

The Harmonic mean is the reciprocal of the mean value of the reciprocal of individual values. It can be expressed as

$$\bar{X}_h = \frac{N}{\Sigma(1/X)}$$

The Median:- It is the middle value of or the variates which devides the frequencies in a distribution into two equal portions.

Mean Deviation:- It is the mean of the absolute deviations of values from their mean is called mean deviation

$$M.D. = \frac{\Sigma \; |X - \bar{X}|}{N}$$

Standard Deviation:- It is the square root of the mean-squared deviation of indivisual measurements from their mean is designated by

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N}}$$

It represents for population.

An unbiased estimate of this parameter is denoted by

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N-1}}$$

The Variance:- It is the square of the standard deviation which is denoted by σ^2.

The Range:- It is the difference between the largest and the smallest values is range.

The Coefficient of Variation:- The standard deviation devided by the mean is called the coefficient of variation and is denoted by

$$C_v = \frac{\sigma}{\mu}$$

Measures of Skewness:- The lack of Symmetry of a distribution is called Skewness and is denoted by

$$\alpha = \frac{1}{N} \Sigma (X - \mu)^3$$

This is for Population.

An unbiased estimate of this parameter is denoted by

$$\alpha = \frac{1}{(N-1)\ (N-2)} \Sigma\ (X - \bar{X})^3$$

Hydrologic models are mathematical formulations to simulate natural hydrologic phenomena which are considered as processes or as systems. Practically all hydrologic phenomena change with time.

Runoff phenomena is that part of the precipitation, as well as any other flow contributions which appears in surface streams of either Perennial or intermittent form. This is the flow collected from a drainage basin or water-shed and it appears at an outlet of the basin. Specially it is the VIRGIN FLOW which is the stream flow unaffected by artificial diversions, storage, or any other works of man made. For example, a virgin flow conditions for the period of record is considered as a stationary time series. If it is affected by man's activity in the river basin or nature's large accidental or slow modifications or histori-cal flow is a non stationary time series. Since a non-stationary processes is very complicated mathematically, hydraulic processes are generally treated as stationary.

2.2 GENERATION OF MONTHLY FLOWS BY REGRESSION ANALYSIS FOR NATURAL VALUES

The methodology for development of monthly forecasting models when the historic record is short and is described with following stages.

(a) Provisional model is postulated, accompanied by a clear statement of the assumptions made there in.

(b) Model parameters are estimated using an efficient estimation procedure. The need for such efficiency is paramount where records are short, since an inefficient estimation procedure is equivalent to throwing away some of the available data.

(c) The goodness of fit of the model is investigated, for example by close examination of the residuals x for evidance of departure from the assumption made when formulating the provisional model. If there is evidance that any assumption is invalid, the model must be modified, and stage (a) recommended.

(d) If no evidance of invalidity in the assumption is found, the model is adopted and used for forecasting.

(e) Forecasts given by the model are compared with observations.

If the deviations between forecasts and observations are satisfactorily small, then the usefulness of the model is confirmed, and it is retained.

We now consider model for forecasting monthly volume of discharge, together with some procedures for estimating model parameters and for deriving confidence limits for forecasts by regression Analysis.

A simple regression model of the form

$$Y_t = \alpha + \beta_1, \text{Cos}\,\frac{2\pi\ t}{12} + \gamma_1\ \text{Sin}\,\frac{2\pi t}{12} + \varepsilon_t$$

Where, Y_t is the volume of flow in month t. α, β_1 and γ_1 are constants to be estimated ε_t is a random variable about which the following assumptions are made.

(i) It is distributed with zero mean, and constant variance σ^2_ε

(ii) ε_t is uncorrelated with ε_{t-k} (for all k except zero)

Four parameters must therefore be estimated in the model. (α, β_1, γ_1 and σ^2_ε)

$\alpha = \bar{Y}$ (the mean of all N observations of monthly volume of discharge)

$$\beta_1 = \frac{2}{N} \sum_{t=1}^{N} Y_t\ \text{Cos}(2\pi t/12)$$

$$\gamma_1 = \frac{2}{N} \sum_{t=1}^{N} Y_t\ \text{Sin}(2\pi t/12)$$

$$\sigma^2_\varepsilon = [\sum_{t=1}^{N} (Y_t - \bar{Y})^2 - (\beta_1{}^2 - \gamma_1{}^2)/N/2]/(N-3)$$

It can then be shown that the variance of the forecast of volume of discharge at time T is

σ^2_{ε} (1 + 5/N)

So that if a third assumption is possible.

(iii) that the random variables ε_t are normally distributed then confidence limits for the forecast given by

$$= \bar{Y} + \beta_1 \text{Cos}(2\pi t/12) + \gamma_1 \text{Sin } 2\pi t/12$$
$$\pm t_{N-3} \ \sigma_{\varepsilon} \sqrt{(1 + 5/N)}$$

Where, t_{N-3} is the value, read from table of the t - statistics for the appropriate probability level, and with N-3 degree of freedom.

If the 95% confidence interval is very wide. The reason is partly the wide variation in volume of flow in the same month for different years, with the result that the variance amongst the residuals ε_t is large.

One means of circumventing this difficulty is to work with the logorithm of volume of flow, instead of the volume of flow.

Three years Historical data is to be generated to 30 years.

2.3 COMPUTATION OF MONTHLY FLOWS BY REGRESSION ANALYSIS FOR NATURAL VALUES

Step 1:- Calculate the over all mean $\bar{Y}$ and $\sum_{t=1}^{N} (Y_t - \bar{Y})^2$

Step 2:- Calculate $\beta_1 = \frac{2}{N} \sum_{t=1}^{N} Y_t \, Cos(2\pi t/12)$

and $\gamma_1 = \frac{2}{N} \sum_{t=1}^{N} Y_t \, Sin(2\pi t/12)$

$$\sigma_{\varepsilon}^2 = [\ \Sigma (Y_t - \bar{Y})^2 - (\beta_1{}^2 - \gamma_1{}^2) N/12]/(N-3)$$

and find σ_{ε}

Step 3 :- Read the value of t_{N-3} from t-statistics table for the appropriate probability level with N-3 degrees of freedom, calculate

$$t_{N-3} \ \sigma_{\varepsilon} \ \sqrt{(1 + 5/N)}$$

Step 4 :- Calculate Y_t in the regression equation for each month, with + random component and with - random component.

Computer program is developed to generate monthly flows as described above. Computer program is enclosed in Appendix -I .

In this study, 3 years Historical data are used and generated to 30 years.

2.4 GENERATION OF MONTHLY VOLUMES BY REGRESSION ANALYSIS - LOGORITHMIC VALUES

The reason is partly the wide variation in volume of flow in the same month for different years, with the result that the variance amongst the residuals ε_t is large. One means of circumventing this difficulty is to work with the logarithm of volume of flow, instead of volume of flow. Values are to transformed to logarithms to base 10. Then the model becomes

$$\text{Log } Y_t = \alpha + \beta_1 \text{Cos}(2\pi t/12) + \gamma_1 \text{Sin}(2\pi t/12) + \varepsilon_t$$

The method of calculation are same as 2.2 and 2.3 for final values, Antilogariths are to be taken and evaluated.

Computer program is developed and the following data are to be generated. Computer programme is enclosed in Appendix-II.

1) 3 Years Historical data amd to be generated to 30 years.

2.5 COMPUTATION OF MONTHLY FLOWS BY REGRESSION ANALYSIS FOR LOGARITHMIC VALUES

Here the Logcrithmic values of flows are used to generate the monthly flows.

In the present problem, some months are having zero flows. Log of zero becomes indeterminent. Hence for zero flows, it is assumed as 1 unit flows and all monthly inflows are covented into Log values.

Steps (1) to (4) same as (2.3)

Step (5) :- Take antilog for all the generated values.

Here also 3 years data is generated to 30 years.

Computer program is developed to generate monthly flows as detailed above.

Computer program is enclosed in Appendix-II.

Statement showing mean, standard deviation for observed values and for generated values are to be calculated.

CHAPTER 3

GENERATION OF MONTHLY FLOWS BY THOMAS-FIERING MODEL

3.1 GENERAL

When water resources project is planned, it is usually not possible to determine the exact sequence of hydrologic events for which the project must be designed. Correct and reliable hydrologic data of a longer record are very much useful for water resource planners.

Historical data of this project is very short. Further the recorded values of high flow, low flow and other characteristics of the record are not likely to occur during the future system. The exact pattern of flows during this historical period is extremely unlikely to occur during that period in which the proposed reservoir system will in operative.

The worst flood or drought in historical records is not the worst possibel flood or drought.

The sequencial-generation approach makes it possible to produce as many combinations of hydrologic sequences as designed for use in hydrologic analysis. This is particularly useful in the study of reservoir operation and in design of complex water resources system.

The method of generation of monthly volume of discharges depends on the type of data available. In the present study, zero flows of discharges have been observed during dry season. Hence Modified Thomas Fiering Model is used in this study to generate the monthly volumes.

Where, A is any non-negative integer and B is one of the numbers from the sequence 3, 11, 13, 19, 21, 27, 37, 53, 59, 67, 69, 77, 83, 91. The starting value of γ_o should be 10^{-P} R, where R is any integer not divisible by 2 or 5 and such that $0 < R < 10^P$.

For example, if we select P = 5, then $10^{-P/2} = 10^{-5/2}$ = 0.00316 and a possible choice for C is aquired by selecting A = 2, B = 69 so that $C = 10^{-5}(400 - 69) = 10^{-5}*331$ = 0.00331. Similarly for Selection of γ_o,

$\gamma_o = 10^{-5} * 9 = 0.00009$ (say R = 9) and starting with $\gamma_o = 0.00009$ further values of γ_i can be calculated. Further values can be calculated sequencially using

$\gamma_{i+1} = \langle 10^5 * 10^{-5} * 331 * \gamma_i \rangle$

Generation of Normally Distributed Random Numbers

It is simple to generate normal random numbers from zero mean and unit variance. If X_1 and X_2 (two sets of sequences) are variates, rectangularly distributed over the interval 0 and 1 then these can be transformed to values Y_1 and Y_2 by the following equations.

$$Y_1 = (-2 \mathrm{Log}_e X_1)^{1/2} * \mathrm{Cos}(2\pi X_2)$$

$$Y_2 = (-2 \mathrm{Log}_e X_1)^{1/2} * \mathrm{Sing}(2\pi X_2)$$

Where, Y_1 and Y_2 are normally and independently distributed with zero mean and unit variance.

3.2 GENERATION OF RANDOM NUMBERS

In generation of monthly stream flow, of any model, addition of random component is a must. This random component will take care the probability of high flow tend to follow high flow and low flows tend to follow low flows. The sequence of past historic flow give clue to the probable future flows.

Two types of generation of random number are discussed below (i) Generation (0,1) Rectangularly distributed number (ii) Generation of normally distributed random numbers.

Generation of (0,1) Rectangularly Distributed Numbers:-

The sequencial algorithm for generating the uniformly distributed pseudo-Random numbers in the interval (0,1) is given by

$$\gamma_{i+1} = \langle 10^{P} C \gamma_i \rangle$$

where, $\langle a \rangle$ denotes the fractional part of a

γ_{i+1}, γ_i being the number at ith and (i+1)th instants respectively.

P is the number of digits in the Pseudo-Random number.

C is the Constant multiplier such that $0 < C < 1$

The choice of C is as follows:

$$C = 10^{-P}(200 + B) \simeq 10^{-P/2}$$

3.3 ALGORITHM FOR THE THOMAS FIERING MODEL IS AS FOLLOWS

$$Q_{i+1} = \bar{Q}_{j+1} + b_j(Q_i - \bar{Q}_j) + Z_i S_{j+1} \sqrt{(1-\gamma_j^2)}$$

where, Q_i, Q_{i+1} are the generated volume of discharge during ith and (i+1)th month respectively.

Q_j and Q_{j+1} are the observed mean monthly discharges during the jth and (j+1)th months respectively with in a annual cycle of 12 months.

b_j is the regression coefficient for estimating volume of discharge in the (j+1)th month from the jth month

$$b_j = \gamma_j \, S_{j+1}/S_j$$

Z_i is a random normal deviate with zero mean and unit variance.

S_{j+1} is the standard deviation of discharge in the (j+1) th month.

γ_j is the correlation coefficient between flows in the jth and (j+1)th months.

Given N years of data, the calculation for the Thomas-Fiering Model is as follows

(i) For each month j = 1,2.......12

(a) the mean flow $\bar{Q}_j = \Sigma Q_{ji}/N$

$(i = j, 12 + j, 24 + j.......)$

(b) Standard deviation

$$S_j = \sqrt{[\,\Sigma(Q_{ji} - \bar{Q}_j)^2/(N-1)\,]}$$

(c) The Correlation Coefficient with flow in the preceeding month.

$$\gamma_j = \frac{\sum_i (Q_{ji} - \bar{Q}_j)(Q_{j+1,i} - \bar{Q}_{j+1})}{\sqrt{\sum_i (Q_{ji} - \bar{Q}_j)^2 \sum_i (Q_{j+1,i} - \bar{Q}_{j+1})^2}}$$

(d) The slope of the regression equation is

$$b_j = \gamma_j S_{j+1}/S_j$$

3.4 GENERATION OF MONTHLY FLOWS BY MODIFIED THOMAS FIERING MODEL

In the present problem the modified Thomas-Fiering Model is used to generate monthly flow sequences is as follows.

Suppose we have N years of data

(i) Record, for each month j(j = 1..... 12) of the year, the number of years n_j out of N for which flow was recorded let $P_j = n_j/N$

(ii) Calculate the Mean Monthly flow, and the variance of flows for each month j.

(iii) Fit a Thomas-Fiering Model.

(iv) Generation of synthetic sequences of monthly flow as follows:

(a) For month j, choose a pseudo-random number, rectangularly distributed over (0,1) if this number is less than P_j(but greater than zero) then flow to occur in month j, otherwise no flow is to occur.

(b) If no flow is to occur in month, j, repeat for month j+1

(c) If flow is to occur in month j, and it is the first month of the year for which flow is to occur, select a Pseudo random normal deviate for a distribution with mean and variance equal to the mean monthly flow and variance of flows for month j.

(d) If flow is to occur in month, j, and flow also occured in month j-1, use the regression equation of the Thomas-Fiering Model to obtain the flow for month j.

3.5 COMPUTATION OF MONTHLY FLOWS BY MODIFIED THOMAS FIERING MODEL

The most modern model is proposed by Modified Thomas-Fiering model particularly with respect to the zero flows observed in some months.

In this study, 10 years data (3 years Historical flows + 7 years strange's table flows) are to be generated to 30 years to study the reservoir operation.

Step 1:- Calculate Mean, Standard - Deviation of the flows.

Step 2:- In generating the sequence of a given stream flows, it is generally considered that the flows are the out come of random process. Generate (0,1) Directangulary distributed numbers. It is possible to generate through computer the sequence of Pseudo random numbers, carefully constructed to mountain the important properties of truely random numbers

Step 3 :- Generation of stream flow by using Modified Thomas Fiering Model is applied to the problem.

Using the 10 years data and calculating the statistical parameters like mean, standard deviation correlation coefficient of the data used.

Generate rectangularly distributed pseudo random numbers and transform then into normally distributed random numbers in the interval(0,1)

Step 4:- The model may generate negative flows. When this occurs, the negative value is to calculate the next flow after which it is set to zero.

Generate 30 years data using the Model in natural series computer program is prepared to generate random numbers, to calculate the mean, standard deviation, correlation coefficient and to generate the monthly flows.

Computer program is prepared to generate monthly flows is enclosed in Appendix-III.

The statistical properties such as mean, standard deviation of the data used, and for the generated flows are to be calculated.

CHAPTER 4

RESERVOIR OPERATION STUDIES

4.1 IRRIGATION PRACTICES IN INDIA ABOUT DEPENDABLE FLOWS

India is one of the major Irrigating countries in the world. The ultimate irrigation potential in the country has been estimated at 107 million ha., the scope for constructing new irrigation projects to provide irrigation facilities is rather limited, since most of the suitable sites have already been developed. In view of this, the modern technology in planning and designing the irrigation projects is highly required.

Hydrologic phenomenon are highly erratic. Not only the inflow pattern of a river varies very widely from year to year, but distribution of flows in a year also is very uneven.

As the annual inflows of all rivers fluctuate very widely from year to year, 75% dependable flows are at present considered in the planning, design and operation of river valley schemes for harnessing the water resources. This means in a cycle of four years, water deficit is not allowed by more than one year. But there are two short comings in this way of adopting 75% dependable flows both for harnessing and for utilising the river water through storage reservoir.

One is, great portion of surplus flows released in all the good water years, which are great many in number, go unutilised and there is the full utility value of the schemes get reduced proportionately in the bad water years. In other words, not only the harnessing of waters gets restricted to 75% dependable flows, but the contemplated utilization of these 75% dependable flows harnessed in turn, also gets reduced to 75% dependability.

At present the scope of various types of projects is generally designed in relation to the available yield over a course of years, such that they operate at following dependabilities

(i)	Water supply projects	.... 100% dependability
(ii)	Hydel project	.... 90% dependability
(iii)	Irrigation projects	75% to 50% dependability

The project authorities of Kalluvodduhalla reservoir have designed the project at 50% dependability and tested the feasibility of the reservoir with 5 years continious working Tables and have found it feasible.

4.2 OPERATION OF RESERVOIR WITH CONVENTIONAL METHOD

The feasibility of a project depends upon the extent to which it can serve the required purpose of the project. The performance of the project can be tested by preparing working Tables using conventional operations as discussed below:

In the present study reservoir operation studies are made based on the principles of conventional operation.

The basic concept for conventional reservoir operation are shown in Fig.4.1.

i) The basic operation criteria with conventional method may be expressed in terms of simple continuity equation

$$S_t + I_t - E_t - R_t = S_{t+1}$$

Where, S_t is the reservoir storage at the begining of the month t

S_{t+1} is the storage at the begining of the month t+1

or

the reservoir storage at the end of month t

I_t is the inflow into the reservoir during the month

E_t is the Evaporation from reservoir during the month

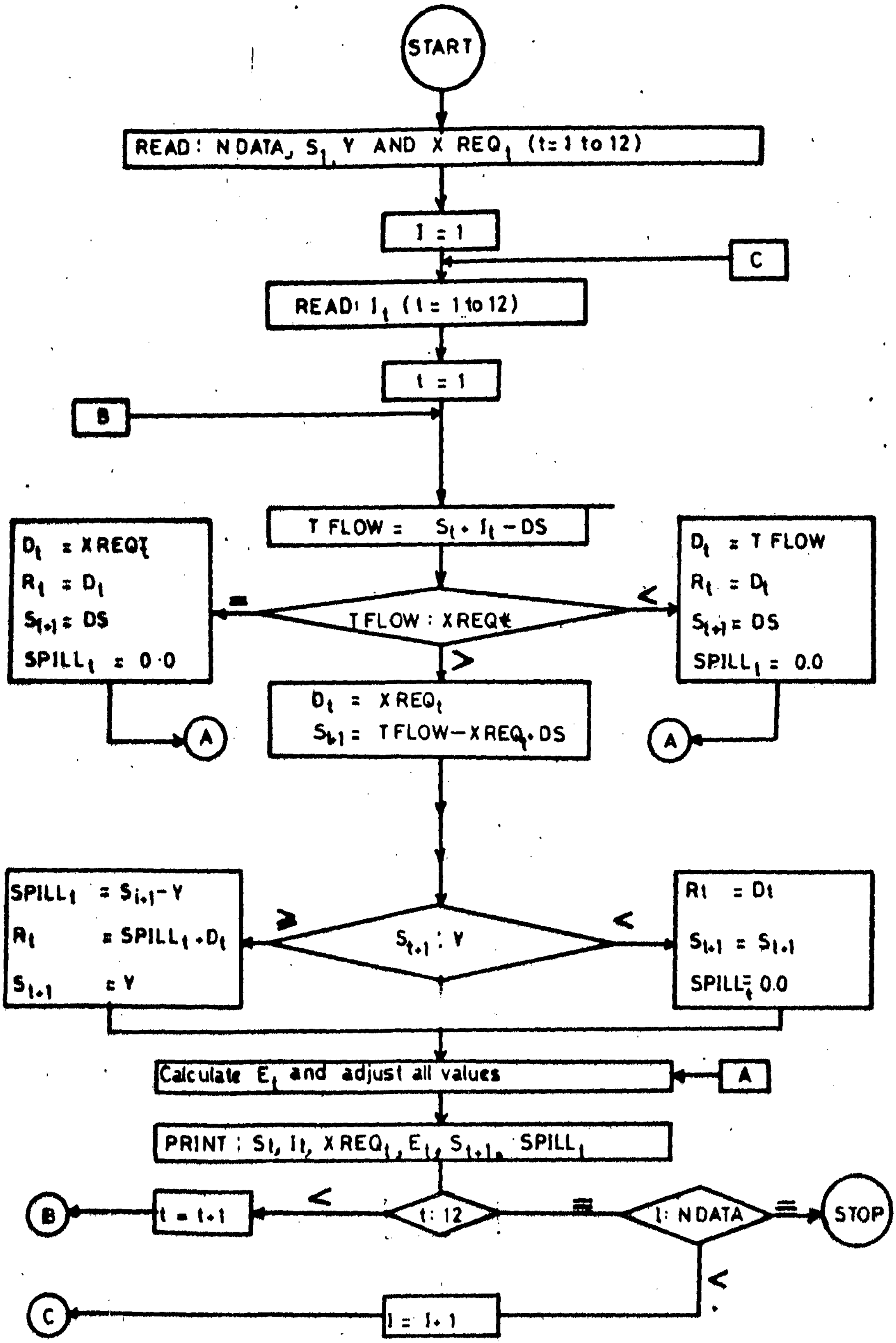


FIG.4.1 FLOW CHART FOR CONVENTIONAL RESERVOIR OPERATION

(ii) Constraint of the minimum storage and the reservoir capacity Y are as follows

$DS \leq S_t \leq Y$

Where, DS is the Dead storage capacity of reservoir, Y is the Reservoir Capacity.

(iii) With the help of above stated operation equation, the simplest operating rule is to supply all the water demand, if available. This is expressed as

$R_t \leq S_t + I_t - E_t$

The reservoir will be operated in such a manner that the amount of water released is equal to the irrigation requirement.

A computer programme is prepared and reservoir operation for different alternatives are carried out. Computer programme is given in Appendix-IV.

Data used in Reservoir Operation.

The reservoir operation starts from June month.

1) Monthly Inflow into the Reservoir
2) Monthly Crop water demand
3) Monthly Evaporation Values.
4) Reservoir Area - Capacity curve
5) Maximum Reservoir Capacity
6) Minimum Drawdown Capacity.

4.2.1 Reservoir Operation Procedure

Thirty years rainfall are available in the report. The reservoir operation starts from June month and ends in May. The reservoir operation is done for 30 years. The operation procedure is shown in Fig. 4.1 for different dependabilities considered for the study. Computer program based on the flow chart shown in Fig. is prepared and appended in Appendix IV . The operation steps is as follows:

(i) Inflow data for 30 years, Irrigation requirement are available in the project report, are used in the operation.

(ii) Minimum drawdown capacity is fixed at 1.222 Mm^3 and used in operation.

(iii) Gross storage capacities for different dependabilities are fixed by trial and error for dependable flow years and these values are used in operation.

iv) Initial storage for the first month, for first year is so assumed, that, the final storage at the end of the first month should not go below minimum drawdown capacity, after fulfilling the irrigation demand and evaporation loss of that month.

(v) Compute the total flow for the month considered as the sum of inflow during that month flow (I,J) and the initial reservoir S(J) content minus Dead Storage DS

TFLOW = S(J) + FLOW(I,J) - DS

(vi) If the total flow (T FLOW) more than the monthly irrigation requirement XREQ(J) release thefull irrigation requirement and compute new reservoir content S(J+1)

S(J+1) = FLOW - XREQ(J) + DS

If the new reservoir content S(J+1) is more than the Gross storage capacity Y compute spill

SPILL = S(J+1) - Y

A counter is provided to count the number of times the reservoir spilled.

(vii) If the total inflow TFLOW, is less than the monthly irrigation XREQ(J) requirement, then release will be made upto the dead storage capacity DS, and set the new initial storage S_{t+1} equal to DS and deficit is accounted. S(J+1) = DS

A counter is provided to count the number of times the deficit is accounted

(viii) If the total inflow TELOW is equal to monthly irrigation requirement XREQ(J) then release full irrigation requirement

S(J+1) = T FLOW - XREQ(J) + DS

(ix) Now compute Average storage X which is required for computation of monthly Evaporation, Values EVAPO(J). Average Storage X is the average of initial storage S(J) and new storage S(J+1).

X = (S(J) + S(J+1))/2.0

(x) Compute area AREA(x) with reference to the storage X with the polynomial Equation.

(xi) Monthly evaporation values are EV(J) given in the booket. Comput monthly Evaporation losses EVAPO(J)

EVAPO(J) = EV(J) * AREA(X)

((xii) Thex final storage S(J+1) is calculated as follows

S(J+1) = S(J+1) - EVAPO(J)

(xiii) Print the following data and results

1. Number of years of data available NDATA
2. Initial Reservoir Storage S(1)
3. Gross Storage Capacity Y
4. Dead Storage Capacity DS
5. Inflow into the Reservoir FDOW(I,J)
6. Irrigation Release D(J)
7. Evaporation Losses EVAPO(J)
8. Reservoir Release Including Spill R(J)
9. Final Storage SF(J)
10. Spill about the Crest Spill(J)
11. Number of Times the Reservoir Deficit IDEF(J)
12. Number of times the Reservoir Spilled over the Crest. ISPILL(J)
13. Number of time the Reservoir capacity goes below dead storage capacity. IEMPTY(J)

4.3 FITTING A POLYNOMIAL CURVE FOR RESERVOIR AREA-CAPACITY

A polynomial curve for two variables (Area-Capacity) is fitted by Least Square Method. The method of curve fitting may be graphical or analytical. The currently analysed analytical method of fitting curve to scattered points is to minimise the sum of squares of departures $Y_i = Y_i - Y$ where for a given X_i, the value of Y is determined from the fitted curve, and Y_i is the observed point. This is called Least Square Method.

For example, the fitting of a quadratic parabola of the form

$$Y = a + bx + c\,x^2$$

Normal Equations for the above

$$\Sigma Y_i = a\,N + b\,\Sigma\,X_i + c\,\Sigma\,x_i^2$$

$$\Sigma X_i Y_i = a\,\Sigma x_i + b\,\Sigma\,x_i^2 + c\,\Sigma\,x_i^3$$

$$\Sigma X_i^2 Y_i = a\,\Sigma\,X_i^2 + b\,\Sigma\,X_i^3 + c\,\Sigma\,X_i^4$$

With the summations taken from i = 1 to N. The solution of these three equations gives a, b, c

Computer programm for solving the above equation by Least Square Method is developed and the equation obtained for Relationship between Area-Capacity, is used in Reservoir operation program.

A third degree polynomial curve is fitted with maximum correlation coefficient as 0.9989.

Area = 0.2532318 E + 01 + 0.2978964 E + 02 X - 0.2116531 E + 01 X^2 + 0.6622052 E - 01 X^3

Where Area is area of submersion of the Reservoir in million square meters, corresponding to the reservoir capacity X in million cubic meters.

The water spread Area is calculated with reference to the capacity of the Reservoir. This water spread area is multiplied by the monthly evaporation values to arrive at the evaporation losses.

Monthly evaporation values during the operation period of 30 years are calculated. The computer program is given given in Appendix - V .

4.4 PERFORMANCE OF THE PROJECT - FROM STRANGE'S TABLE GENERATED FLOWS

4.4.1 Dependable Flows From Strange's Table Values

Thirty years yield of Runoff is calculated from Strange's Table vide Table . These flows are arranged in descending order and different dependable flows are calculated as described below

Dependability = m/n+1

Dependability = Dependability under - consideration

m = Sl.No. of the order

n = total no. of years considered.

i) For 50% dependability

50% = m/30+1 = 1/2

$m = \frac{30 + 1}{2} = 15.5$

say 16th year (1967)

.˙. 50% dependable yield is 23.42 Mm^3

ii) For 60% dependability

60% = m/30+1

m = (30+1) * 60% = (30+1) * 0.6

m = 18.6 , say 19th year (1969)

.˙. 60% dependable yield is 22.45 Mm^3

iii) For 75% dependability

75% = m/30+1

m = (30+1) * 75% = (30+1) * 0.75

m = 23.25, say 24th year (1963)

75% dependable yield is 17.31 Mm^3

4.4.2 Reservoir Operation for 50% Dependability

Fifty percent dependable flow works out to 23.42 Mm^3 minimum drawdown capacity is kept at 1.222 Mm^3. Irrigation requirement is taken as 17.549 Mm^3 to irrigate 1450 Hectares.

Gross storage capacity is worked out by trial and error for period of five years which includes the 50% dependable year by the project authority. Gross storage capacity works out to 12.176 Mm^3.

Reservoir operation is doen by computer program for a period of 30 years as per 4.2 and 4.2.1.

4.4.3 Reservoir Operation for 60% Dependability

Sixty Percent dependablity flow works out to 22.45 Mm^3 minimum drawdown capacity is kept at 1.222 Mm^3. Irrigation requirement is considered as 17.549 Mm^3 to irrigate 1450 Hectares.

Gross storage capacity of 14.963 Mm^3 is fixed by trial and error for the 60% dependable year.

Reservoir operation is done by computer program (Appendix - IV) for a period of 30 years as per 4.2 and 4.2.1.

4.4.4 Reservoir Operation for 75% Dependability

Yield of 17.31 Mm^3 is worked out for seventy five percent dependability. 1.222 Mm^3 is kept as minimum draw down capacity 17.549 Mm^3 is the irrigation requirement considered to irrigate 1450 Hectares.

Gross storage capacity of 16.197 Mm^3 is worked out by trial and error for the 75% dependable year.

Reservoir operation is done by computer programme for a period of 30 years as per 4.2 and 4.2.1.

4.5 RESERVOIR OPERATION FOR GENERATED FLOWS FROM MODIFIED THOMAS FIERING MODEL

From 10 years data, 30 years data are generated from Modified Thomas Fiering Model.

These inflows are used to operate the Reservoir for 30 years. The Dead Storage, Irrigation requirement and Evaporation values are used as per project report.

The operation is same as described in 4.2 and 4.2.1 The same computer program enclosed in Appendix - IV is used for reservoir operation.

CHAPTER 5

BENEFIT COST RATIO

5.0 GENERAL

The benefit cost-ratio analysis plays an important role in project evaluation. Benefit of water resources project may be divided into direct benefit and indirect benefits. Direct benefits are the immediate results of project, such as assured water supply system, production of Agricultural products, power supply, prevention of flood damage and navigation benefits. Indirect benefits are the production of loss of life as a result of flood control measures, the enhancement of scenic values due to stabilising the lake levels, recreation centre and improve the socio-economic condition of the region.

The benefit cost ratios of 1 indicates feasibility of the project. The higher the benefit cost ratio, the more the feasibility of project. But this can be relaxed in case of projects taken up in the area such as drought affected areas, backward and most needy areas.

5.1 BENEFIT-COST RATIO OF THE PROJECT

Cost of the project for 50% dependable flow was calculated by project Authority. In the present problem the project has been tested for 50%, 60% and 75% dependability for 30 years. The costs estimates for 60% and 75% dependability have been now worked based on the cost estimate of 50% dependability. After working out cost estimates, benefit cost have been worked out and the results obtained are as follows:

	Dependability	Benefit Cost Ratio at 10% interest
1.	50% dependability	1.087
2.	60% dependability	1.013
3.	75% dependability	0.992

The benefit cost ratio for 50% and 60% dependability are more than 1. But 75% dependability works out to 0.992 which is below one.

Benefit cost ratio of 50% dependability works out 1.087 and it is feasible.

5.2 COST ESTIMATE (FOR 50% DEPENDABILITY)

Sl. No.	Items	Cost in Rs.Lakhs
1.	Land Acquisition	23.40
2.	Earth Dam and Appertinent Works	117.20
3.	Spillway	57.00
4.	Approach Channel	
5.	Energy Dicipating Arrangements	
6.	Buildings	2.50
7.	Canals (Earth work + Structures)	62.70
8.	Canal lining	30.00
9.	Special Tools and Plant	20.50
10.	a) Field Channel(60 M/Hectare) at Rs.200/- Hectare	2.90
11.	b) Outlets 180 Number at Rs.1000/-each	1.80
12.	a) Physical Contingencies at 10% of Dam Works	19.40
	b) Physical Contingencies at 20% of Canal Works	19.20
	c) Engineering Supervision charges at 15%	58.00
	d) Add for Escalation of Rates at 10%	59.70
13.	Add catchment area protection works and rounding	10.50
	Total	484.80

5.3 COST ESTIMATE (60% DEPENDABILITY)

Sl. No.	Items	Cost in Lakhs
1.	Land Acquisition	27.40
2.	Earth Dam and Appertinent Works	124.90
3.	Spillway	
4.	Approach Channel	57.00
5.	Energy Discipating Arrangements	
6.	Buildings	2.50
7.	Canals (Earth Work + Structures)	62.70
8.	Canal lining	30.00
9.	Special Tools and Plants	20.50
10.	a) Field Channel(60 M/Hectare) at Rs.200/- Hectare	2.90
11.	Outlets 180 Number at Rs.1000/- Each	1.80
12.	a) Physical Contingencies at 10% of Dam Works	20.93
	b) Physical Contingencies at 20% of canal works	19.02
	c) Engineering Supervision Charges at 15%	58.00
	d) Add for Escalation of rates at 10%	59.90
13.	Add Catchment Area Protection Works and rounding	10.45
	Total	498.00

5.4 COST ESTIMATE (75% DEPENDABILITY)

Sl. No.	Items	Cost in Rs. Lakhs
1.	Land Acquisition	27.90
2.	Earth Dam and Appertinent Works	134.90
3.	Spillway	
4.	Approach Channel	57.00
5.	Energy Dicipating Arrangements	
6.	Buildings	2.50
7.	Canals(Earth Works + Structures)	62.70
8.	Canals ~~(Ear~~ Lining	30.00
9.	Special Tools and Plant	20.50
10.	Field Channel(60 M/Hectare) at Rs.2000/- Hectare	2.90
11.	Outlets 180 Number at Rs.1000/- Each	1.80
12.	a) Physical Contingencies at 10% of Dam Works	21.38
	b) Physical Contingencies at 20% of Canal works	19.02
	c) Engineering Supervision Charges at 15%	58.10
	d) Add for Escalation of Rates at 10%	60.00
13.	Add Catchment area protection works and rounding.	10.30
	Total	509.00

5.5 BENEFIT COST-RATIO (AT 50% DEPENDABILITY)

A - Benefits (Direct)

I.	(a)	Value of Total Agricultural Produce before advent of Irrigation	4079979
	(b)	Cost of Cultivation	2983429
	(c)	Net produce before Irrigation	1114550
II.	(a)	Value of Agricultural production after Irrigation	16416243
	(b)	Cost of Cultivation	8886688
	(c)	Net production after Irrigation	7529555
III.		Net Benefits (II - I)	6415005

B - Annual Costs

		At 5%	At 10%
a)	Interest on Capital on Rs.48480000	2424000	4848000
b)	Depreciation at 2%	696600	696600
c)	Administrative Expenses at Rs.24.71/- Hectare on 1450	358830	358830
		3479430	5903430

C - Benefit Cost Ratio

	At 5%	At 10%
Benefit Cost Ratio	$\frac{6415005}{3479430}$	$\frac{6415005}{5903430}$
	1.844	1.087

Cost Per Cubic Meters of Water Utilised $\frac{48480000}{17548000} = 2.76$

5.6 BENEFIT COST-RATIO (AT 60% DEPENDABILITY)

A - Benefits (Direct)

I.	(a) Value of Total Agricultural Produce before advent of Irrigation		4097979
	(b) Cost of Cultivation		2983429
	(c) Net produce before Irrigation		1114550
II	(a) Value of Agricultural Production after Irrigation		16416243
	(b) Cost of cultivation		8886688
	(c) Net production after Irrigation		7529555
III	Net Benefits (II - I)		6415005
	B - Annual Costs	At 5%	At 10%
a)	Interest on Capital on Rs.49800000	2490000	4980000
b)	Depreciation at 2%	996000	996000
c)	Administrative expenses at Rs.24.71/- Hectare on 1450	358830	258830
		3844830	6334830
	C - Benefit Cost Ratio	6415005 / 3844830	6415005 / 6334830
		1.668	1.013

5.7 BENEFIT COST-RATIO(AT 75% DEPENDABILITY)

A - Benefits (Direct)

I	(a)	Value of Total Agricultural Produce before advent of Irrigation	4079979
	(b)	Cost of Cultivation	2983429
	(c)	Net Production before Irrigation	114550
II.	(a)	Value of Agricultural Production after Irrigation	16416243
	(b)	Cost of Cultivation	8886688
	(c)	Net Production after Irrigation	7529555
III		Net Benefits(II-I)	6415005

	B - Annual Costs	At 5%	At 10%
a)	Interest on Capital on Rs.50900000	2545000	5090000
b)	Depreciation at 2%	1018000	1018000
c)	Administrative expenses at Rs.24.71/- Hectare on 1450	358830	358830
		3921830	6466830

	At 5%	At 10%
C - Benefit Cost-Ratio	6415005 / 3921830	6415005 / 6466830
	1.636	0.992

CHAPTER 6

DISCUSSION, CONCLUSION AND SUGGESTION

6.1 GENERAL:

Runoff studies were carried out for Kalluvodduhalla Irrigation project in Karnataka to find the water availability at the site. This was done by using various methods of river flow generation and then comparing the water availability for different dependabilities. For flow generation, strauge's table, Regression analysis and Modified Thomas Fiering Model were used. Water availabilities were compared for 50%, 60% and 75% dependabilities. Reservoir operation using conventional operation rule was also carried out to see the feasibility of the project. Reservoir capacities obtained from Strauge's table were used for reservoir operation with the Modified Thomas Fiering Model generated flows.

Yield of runoff is generated by Strauge's table vide chapter 1.2.6 .

Monthly volume of flow is generated by Regression analysis in chapter 2.0 .

Synthetic sequences of monthly volume is generated by Modified Thomas Fiering Model vide chapter 3.0 .

Reservoir operation for different dependabities for the flows generated by Strange's table and by Modified Thomas Fiering Model vide chapter 4.0 .

The Benefit cost ratio of the scheme for different dependabilities of the Strauge's table flow is worked out in chapter 5 .

6.2 DISCUSSION: For the design of Water Resources Project, the accuracy and reliability of results depend upon the availability of fairly long term period historical flows at the site and the reliability of input data. The results of computation given in tables 6.1 to 6.13.

6.2.1 Runoff from Strauge's Table:

Thirty years runoff series is built by Strauge's Table vide Table 1.4 .

In the absence of Runoff data at the site, the yield of runoff is generated by Strauge's table. It has got following limitations.

1. Binnie developed his curves in 1880 by observing a number of small catchments in Madha Pradesh. Some two years later Strauge's developed his curves using data observed in Irrigation tanks in South India.
2. The critical Weakness of Strauge's Table approach is that the rainfall runoff curve do not reflect different incidences of rainfall. The total rainfall is considered for monsoon period only.
3. Strauge's Table gives yield of Runoff up to 60" rainfall for the catchment classification of

Good, Average and bad. The relationship between these conditions is given by a ratio of 2:1.5:1 respectively. Hence classification of catchment requires careful study and reliable judgement of catchment classification. The catchment under consideration is classified as "average".

4. Accuracy of yield of Runoff depends on the reliability and availability of longer period catchment rainfall data. In the present problem the catchment rainfall data available are only for 9 years.
5. Only monsoon Rainfall is considered. The period of monsoon differs from catchment to catchment. In this problem monsoon period is from May to November.

The Mean, standard deviation of the 30 years Runoff data is given in Table 6.1 and fig 6.1. It shows that the generated flows do not vary much as compared to the historical flows.

6.3 GENERATION OF MONTHLY VOLUME OF FLOW BY REGRESSION ANALYSIS MODEL:

6.3.1 General:

Mathematical models are no replacement for field observations. Their value lies in their ability, when correctly chosen and adjusted, to extract the maximum amount of information from the available data.

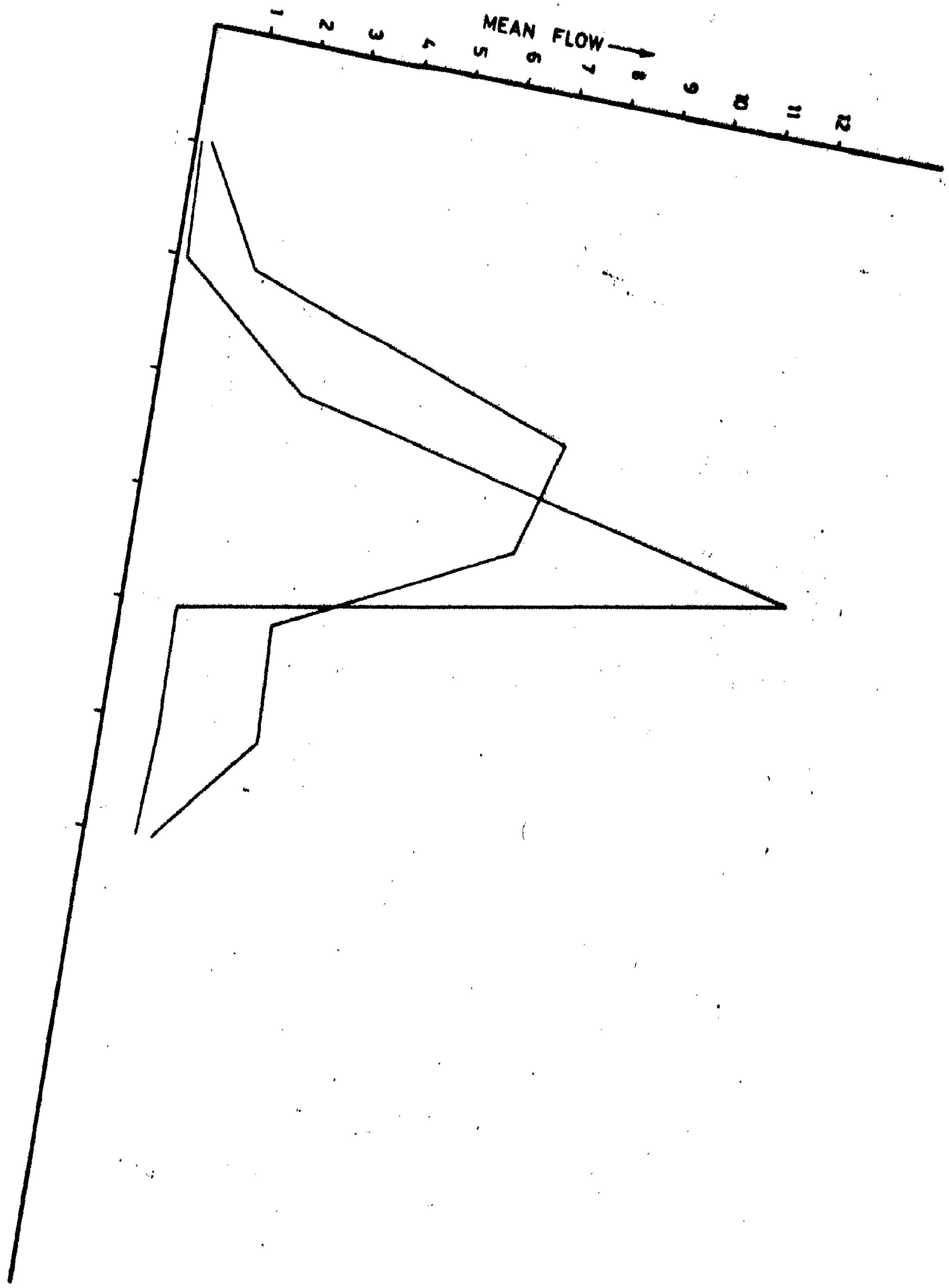
TABLE 6.1

FLOW - STATISTICS OF STRANGE'S TABLE AND HISTORICAL FLOW

Sl. No.	Months	STRANGE'S TABLE FLOW*		HISTORICAL FLOW**	
		Mean in Mm^3	Standard deviation	Mean in Mm^3	Standard Deviation
1	May	0.3984	0.7969	0.12	0
2	Jun	1.5200	1.6172	0.208	0.1428
3	Jul	7.8696	5.3972	2.8633	3.1968
4	Aug	7.2303	4.3535	12.4606	1.0155
5	Sep	2.9244	2.0666	2.132	0.1040
6	Oct	3.0607	2.3925	1.146	1.5557
7	Nov	1.3457	1.2245	1.066	0.9065

* 30 years generated data

** 3 years historical data.


MEAN FLOW
1
2
3
4
5
6
7
8
9
10
11
12

6.3.2 To Extend Records of Short Duration By Regression Analysis for Natural Values:

Where the variance amongst the total volumes of flow recorded in a particular month does not appear to bear any significant relation to the mean volume of flow (or in other words, where the variance amongst total flow volume in a particular month does not appear to vary significantly with time) then it may be satisfactory in certain circumstances to assume a simple regression model.

6.3.3 Assumptions:

The regression model is as below:

$$Y_t = \bar{Y} + \beta_1 Cos(2\pi t/12) + \gamma_1 Sin(2\pi t/12) + \varepsilon_t$$

It is explained in chapter. 2.

Here ε_t is a random variable about which the following assumptions are made.

(i) It is distributed with zero mean and constant variance.

(ii) ε_t is uncorrelated with ε_{t-k} (for all K except zero).

(iii) That the random variables ε_t are normally distributed.

This model has particular advantage as a by-product of the produce for estimating model parameters, one less than the forecast and one greater, such that there is a given probability that these values will bracket the observed value of the variable at time (t + k). Confidence limits therefore express the uncertainity, the wider apart the confidence limits the less reliable. Further the greater the lead-time k, the greater will be the width of confidence interval since the distant future is more uncertain than the immediate.

6.3.4 Results:

Three years Historical flows are generated to thirty years .

The results of Mean, standard deviation of Historical flows and the generated flows are given in Table 6.2 and fig. .

It reveals that the results of Mean, and Standard deviations of the values used and generated values vary widely The standard deviations of the generated flows are very small in many months.

The 95% confidence interval for the generated flows is more and hence these values are not considered for further study. For July in Ist year it is from 10.4616 to -2.6444.It reveals the higher 95% confidence limit.

6.4 TO EXTEND RECORDS OF SHORT DECRATION BY REGRESSION ANALYSIS FOR LOGARITHMIC VALUES:

If the value of variance amongst residuals $\mathcal{E}_t$ is large, One means of circumventing this difficulty is to work

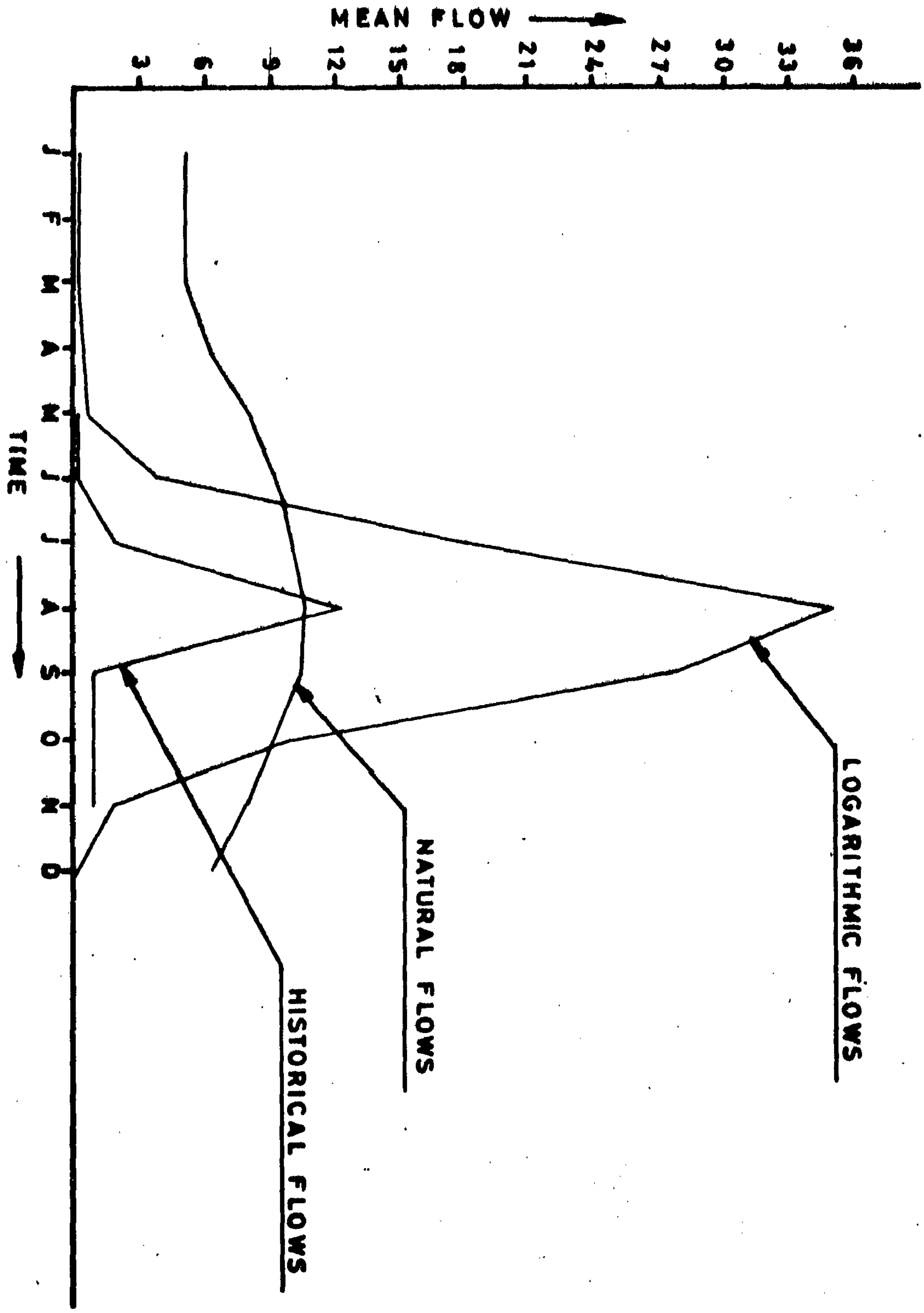
TABLE 6.2

FLOW-STATISTICS OF HISTORICAL FLOW AND GENERATED BY REGRESION ANALYSIS

Sl. No.	Months.	HISTORICAL FLOW*		GENERATED FLOWS**			
				Natural values		Logarithmic Values.	
		Mean inMm^3	Standard Deviation	Mean inMm^3	Standard Deviation	Mean in Mm^3	Standard Deviation
1.	Jan	0	0	5.7312	0.0389	0.1008	0.0045
2.	Feb.	0	0	5.3313	0.0012	0.0520	0.0005
3.	Mar.	0	0	5.6799	0.0299	0.0643	0.0017
4.	Apr.	0	0	6.6834	0.0529	0.1805	0.0103
5.	May.	0.12	0	8.0472	0.0617	0.8686	0.0626
6.	June	0.2080	0.1428	9.4753	0.0540	4.7049	0.3169
7.	July	2.8633	3.1968	10.5150	0.0318	18.2374	0.8125
8.	Aug	12.4606	1.0155	10.9131	0.0012	35.2120	0.3463
9.	Sep	1.132	0.1040	10.5628	0.0299	28.4057	0.7831
10.	Oct	1.146	1.5557	9.558	0.1529	10.1396	0.5835
11.	Nov.	1.066	0.9065	8.1682	0.0617	2.1091	0.1521
12.	Dec.	0	0	6.7660	0.0540	0.3892	0.0262

* 3 years Data

** 30 years Generated data.


MEAN FLOW
3
6
9
12
15
18
21
24
27
30
33
36
TIME
J
F
M
A
M
J
J
A
S
O
N
D
LOGARITHMIC FLOWS
NATURAL FLOWS
HISTORICAL FLOWS

with the logarithmic of volume of flow, instead of volume of flow.

Here three years Historical record is generated to thirty years.

6.4.1 Results:

Statement showing Mean and Standard deviation of the generated data are enclosed in table 6.2 and Fig. 6.2 .

It indicates wide variation between observed and generated flows.

The 95% confidance interval is more for the generated flows. For July Ist year it is 16.9109 to 0.1035 Mm^3. It reveals the higher 95% confidence limit.

Hence the flows are not considered for reservoir operation.

6.5 GENERATION OF MONTHLY VOLUME OF FLOWS BY MODIFIED THOMAS FIERING MODEL:

The Generation of stream flow data by this model have following limitations.

1. It assumes that the flow sequences are normally distributed.
2. The accuracy of results of generated series depends upon the number of historical input flow sequence.

6.5.1 Results:

Ten years data are used and thirty years generated flows are given in Tables 6.3 and 6.4.

The statement showing the mean, standard deviation of the data used and generated flows are given in table 6.5.

These generated data are further used in reservoir operation studies.

Graph showing Time verses Mean of 10 years data and generated data is shown in fig. 6.3 .

Table showing 50%, 60% and 75% dependable flows are shown in table 6.6

6.6 COMPARISION OF FLOWS GENERATED FROM STRAUGE'S TABLE AND MODIFIED THOMAS FIERING MODEL:

The 50%,60% and 75% dependable flows from the Strauge's Table and Modified Thomas Fiering Model are given in Table 6.7.

It reveals that the flows generated from modified Thomas Fiering Model are of the Smaller values as compared to the Strauge's Table flows.

Flow-Duration Computations are shown in Table 6.8 for both the methods flow -duration curves are also shown in fig. 6.4

It reveals that the probability of that particular flow will be equalled or exceeded is less in case of Modified Thomas Fiering Model.

TABLE 6.3

TEN YEARS DATA

(3 YEARS HISTORICAL + 7 YEARS STRANGEIS TABLE FLOW), IN Mm^3

Years	May	Jun	Jul	Aug	Sep	Oct	Nov
1	0.0	0.09	3.12	5.91	3.0	2[illegible]	0.0
2	0.0	2.97	6.74	10.98	5.85	1.55	1.57
3	0.0	1.48	2.69	1.06	0.64	3.93	0.0
4	0.0	0.59	5.18	2.73	4.33	2.34	3.53
5	0.5	3.0	9.73	13.06	1.14	1.08	0.71
6	0.0	0.75	2.01	6.44	0.46	0.22	0.44
7	0.02	3.37	15.10	9.76	0.45	0.46	0.67
8	0.12	0.10	0.876	13.053	1.196	0.438	0.0
9	0.0	0.37	1.163	13.041	1.012	0.600	0.425
10	0.0	0.154	6.551	11.288	1.188	3.210	1.707

TABLE 6.4

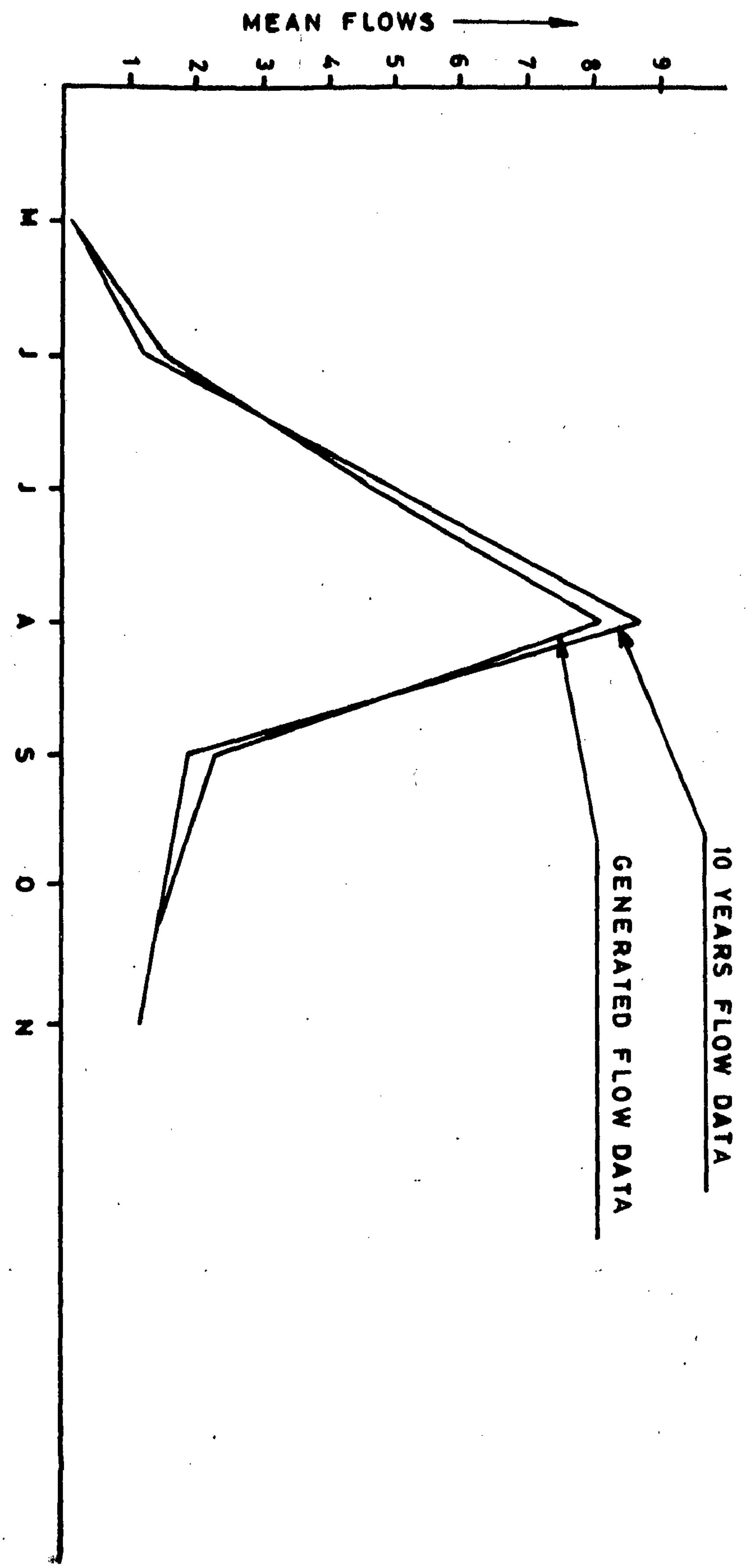
GENERATED FLOW DATA IN Mm3

Sl. No.	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
1	0.1981	0.0589	1.9591	6.3136	2.358	0.6330	0.9422	12.4629
2	0.0	1.0466	2.0773	4.6060	0.7331	0.0	0.0	8.4630
3	0.0	0.1423	1.5268	5.3135	3.1279	1.5364	0.8265	12.4734
4	0.0	0.9817	1.9869	5.1050	0.3407	0.0	0.9103	9.3246
5	0.0	2.8441	0.7888	16.1117	1.2349	1.0487	0.0	22.0282
6	0.0	1.8217	11.3005	6.3852	1.9154	0.8876	0.0	22.3104
7	0.0063	3.3241	4.6994	9.9752	4.2070	1.0486	1.2464	24.8670
8	0.0	0.0	4.8568	8.0932	4.6189	0.9392	1.5401	20.0482
9	0.1994	1.0015	6.6616	8.9307	0.0	1.0793	0.0	17.8725
10	0.0	2.9391	8.9111	6.7572	0.0	1.7938	0.0	20.4012
11	0.0871	1.7271	7.8981	13.0666	1.1543	1.9464	1.0510	26.9306
12	0.0	2.5885	8.8366	15.2047	2.8244	2.1666	0.6966	32.3174
13	0.0	1.3132	7.4829	14.8122	2.8585	2.6584	2.5874	31.7126
14	0.0	0.2069	4.1850	9.6538	0.1895	0.0	0.8127	15.0479
15	0.1043	2.2103	6.0120	9.4174	0.0305	0.6627	0.5898	19.0270
16	0.0	0.2816	0.5698	9.2944	0.9969	0.1217	1.7524	13.0168
17	0.0	0.0	2.1405	0.5749	1.9627	1.1214	0.0	5.7995
18	0.0	0.2912	0.0	7.9304	3.4209	2.2025	2.2172	15.9722
19	0.0	2.2771	7.4442	11.5478	2.6263	1.7977	1.7482	27.4413
20	0.0	1.8250	5.1640	7.5194	2.0249	1.0415	0.9091	18.4839
21	0.0	1.1164	0.6668	5.[illegible]567	3.1048	2.0524	2.2536	14.9507
22	0.0	0.0	2.9855	6.7008	3.0966	0.0	0.3176	13.0005
23	0.0	1.5317	7.6844	6.5952	1.1401	0.0	0.9378	17.9892
24	0.0	0.4005	0.0	6.8087	0.0	1.5560	0.9832	9.7584
25	0.0	2.1707	6.0390	9.7955	3.4401	4.4640	2.9270	28.8363
26	0.142	0.5190	1.9816	7.3609	2.6576	1.5128	0.8546	15.0285
27	0.0	1.2465	3.7870	3.1429	3.8186	0.9892	0.0	12.9842
28	0.0	3.7941	10.2014	8.9074	3.8441	1.3943	1.3689	29.5102
29	0.0	0.0	0.2943	10.5073	0.4860	3.5352	0.0	14.8228
30	0.0	0.0	1.2892	2.3401	2.2031	2.1305	1.2507	9.2136

TABLE 6.5

COMPARISION OF 10 YEARS FLOW AND FLOWS GENERATED FROM MODIFED THOMAS FIERING MODEL

Sl. No.	Months	10 Years Flow		Generated Flow	
		Mean in Mm^3	Standard Deviation	Mean in Mm^3	Standard Diviation
1.	Jan	-	-	-	-
2.	Feb.	-	-	-	-
3.	Mar.	-	-	-	-
4.	Apr.	-	-	-	-
5.	May.	0.0633	0.0513	0.1228	0.0736
6.	Jun.	1.2874	1.3285	1.5063	1.0636
7.	Jul.	5.3160	4.4521	4.6225	3.2202
8.	Aug.	8.7322	4.4311	8.1576	3.6099
9.	Sep.	1.9266	1.8512	2.2376	1.3005
10.	Oct.	1.6338	1.3001	1.6271	0.9340
11.	Nov.	1.2931	1.1151	1.2965	0.6692
12.	Dec.	-	-	-	-


MEAN FLOWS
1
2
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4
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M
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N
10 YEARS FLOW DATA
GENERATED FLOW DATA

TABLE 6.6

30 YEARS GENERATED FLOW

All figures in Mm^3

Sl. No.	Inflow	Inflow in decending order	
1	12.4629	32.3174	
2	8.4630	31.7126	
3	12.4734	29.5102	
4	9.3246	28.8363	
5	22.0282	27.4413	
6	22.3104	26.9306	
7	24.8670	24.8670	
8	20.0482	22.3104	
9	17.8725	22.0282	
10	20.4012	20.4012	
11	26.9306	20.0482	
12	32.3174	19.0270	
13	31.7126	18.4839	
14	15.0479	17.9892	
15	19.0270	17.8725	
16	13.0168	15.9722	50%dependable flow
17	5.7995	15.0479	
18	15.9722	15.0285	
19	27.4413	14.9507	60%dependable flow
20	18.4839	14.8228	
21	14.9507	13.0168	
22	13.0005	13.0005	
23	17.9892	12.9842	75%dependable flow
24	9.7484	12.4734	
25	28.8363	12.4629	
26	15.0285	9.7484	
27	12.9842	9.3246	
28	29.5102	9.2136	
29	14.8228	8.4630	
30	9.2136	5.7995	

TABLE 6.7

Various Dependable Flows

All figures in Mm^3

Sl. No.	Particulars	Strange's Flow.	Modified Thomas Fiering Model Flow.
1.	50% dependable flow.	23.42	15.9722
2.	60% dependable flow.	22.45	14.9507
3.	75% dependable flow.	17.31	12.9842

TABLE 6.8

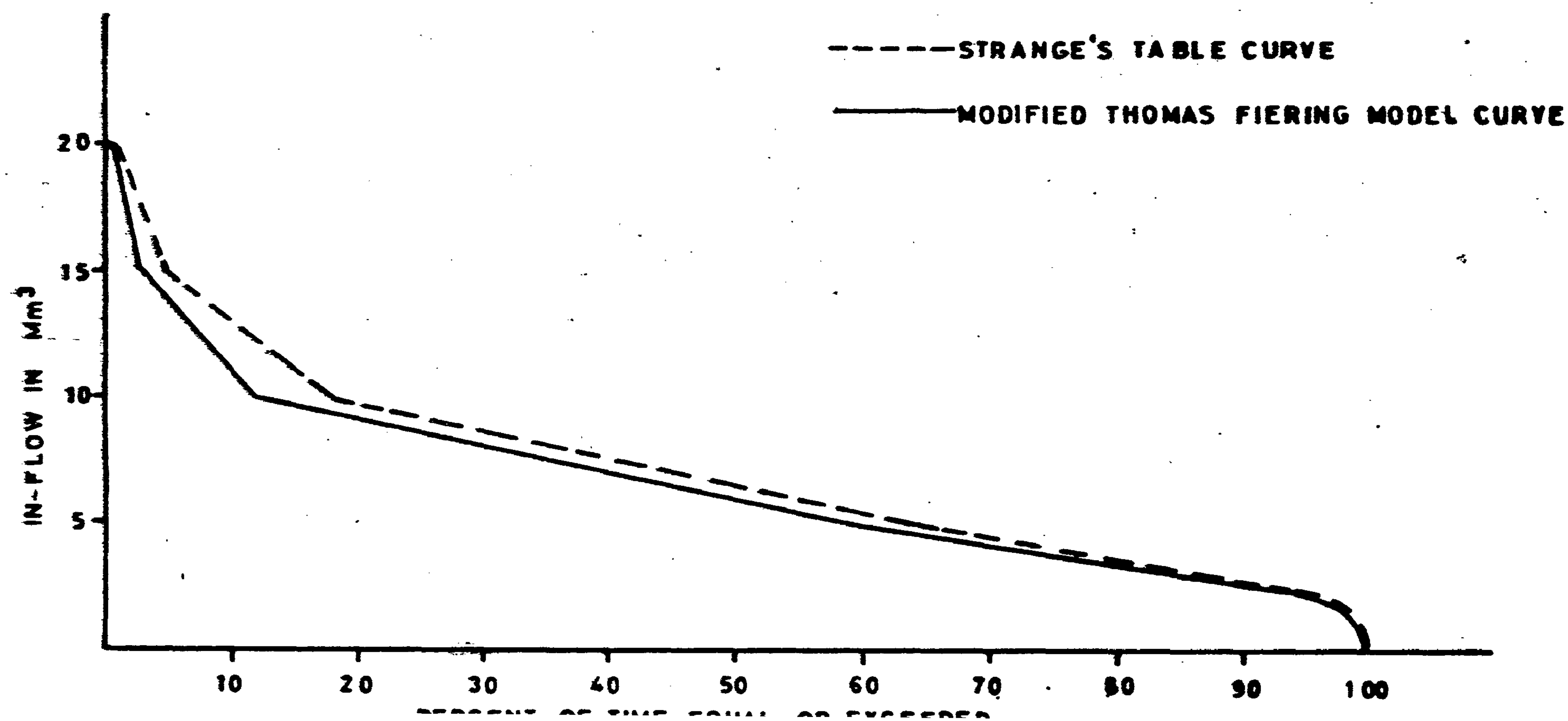
INFLOW - DURATION CURVE

A- STRANGE'S TABLE-INFLOW

Class No.	Class Inter-vals	Nos.	Cumulative nos	Prabability P(x)
I	Above 15	4	4	0.02
II	10.1-15	11	15	0.07
III	5.1-10	39	54	0.26
IV	0-5	156	210	1.00

B.-GENERATED-FLOWS

Class No.	Class Interval	Nos	Cumulative nos	Probability P(x)
I	Above 15	2	2	0.01
II	10.1-15	6	8	0.04
III	5.1-10	31	39	0.19
IV	0-5	171	210	1.00


STRANGE'S TABLE CURVE
MODIFIED THOMAS FIERING MODEL CURVE
IN-FLOW IN Mm3
5
10
15
20
10
20
30
40
50
60
70
80
90
100

6.7 RESERVOIR OPERATION STUDIES FOR CHECKING FEASIBILITY OF THE PROJECT FOR DIFFERENT DEPENDABILITIES:

Strauge's Table Flows

Reservoir operation for a cycle of 30 years with 50%, 60% and 75% dependabilities are done for finding the feasibility of the project. The results obtained are shown in Table 6.9(a) and (b). In calculating successful years, the marginal deficit is considered as successful years. 10% deficit is considered as marginal deficit.

Gross storage required for 50%,60% and 75% dependable flow are 12.176 Mm^3, 14.963 Mm^3 and 16.197 Mm^3 respectively for an annual irrigation requirement of 17.549 Mm^3. The percentage of Gross-Storage capacity for different dependabilities works out to 28%, 34.5% and 37.5%. The increase in capacity between 50% to 75% dependability is 9.5% which is considerably large. Increase in dependability, will result in increased, storage capacity, Area of Submergence and evaporation losses. Percentage of crop water deficit with total crop water demand ([illegible]) for 50% to 75% dependability are 9.8% to 4%. These are within 10% limit. Hence percentage of crop water deficit for 50% and 75% dependability are with in marginal limit.

(Storage/Capacity) verses probability that of equalled or exceeded is enclosed in Table No.6.10. It reveals that probability of a particular (Storage/Capacity) will be equalled or exceeded also increases as the dependability

TABLE 6.9(a)

RESULTS FROM 30 YEARS WORKING TABLE

Dependability in percentage	Total inflow available for 30 years in Mm^3	CROP WATER REQUIREMENT: As per design for 30 years in Mm^3	CROP WATER REQUIREMENT: %tage with total flow	CROP WATER REQUIREMENT: Water released for 30 years in Mm^3	CROP WATER REQUIREMENT: %tage with total flow	CAPACITIES: As per design in Mm^3	CAPACITIES: %tage	EVAPORATION LOSSES: Total for 30 years in Mm^3	EVAPORATION LOSSES: %tage with total flow	SURPLUS: Total for 30 years in Mm^3	SURPLUS: %tage with total flow	DEFICIT: Total for 30 years in Mm^3	DEFICIT: %tage with total flow	%tage deficit with crop demand.
						STRANGE'S TABLE FLOW								
50	697.43	526.47	75.5	475.87	68.1	12.176	28.0	47.5	6.8	174.9	25.1	51.4	7.4	9.8
60	697.43	526.47	75.5	500.27	71.7	14.963	34.5	56.3	8.1	141.2	20.2	26.2	3.8	5.0
75	697.43	526.47	75.5	505.87	72.5	16.197	37.5	60.0	8.6	133.3	19.1	20.6	3.0	4.0
						THOMAS FIERING MODEL FLOW								
50	542.09	526.5	97.0	429.1	79.0	12.176	28.0	40.0	7.4	72.9	13.0	97.6	17.7	18.5
60	542.09	526.5	97.0	449.3	82.8	14.963	34.5	46.4	8.6	48.9	9.0	79.2	14.6	15.0
75	542.09	526.5	97.0	450.5	83.0	16.197	37.5	49.2	9.0	42.9	8.0	76.0	14.0	14.0

TABLE 6.9(b)

RESULTS-30 YEARS RESERVOIR OPERATION FROM STRAUGE'S TABLE FLOW
(All Figures in Mm^3)

Sl. No.	Particulars	50% dependability	60% dependability	75% dependability
1	Gross Storage Capacity	12.176	14.9 3	16.197
2	Percentage of Storage capacity	28	34.5	37.5
3	No.of Successful years	15	19	22
4	No.of Deficit years	15	11	8
5.	No.of years Spill over	20	19	18
6.	No.of Months Spill over	42	36	33
7.	No.of Deficit Months	41	23	19
8.	Percentage of crop water requirement with inflow	75.5	75.5	75.5
9.	Percentage of water released for crop requirement with inflow.	68.1	71.7	72.5
10.	Percentage of water loss as evaporation.	6.8	8.1	8.6
11.	Percentage of water Spilled over the crest.	25.1	20.2	19.1
12.	Percentage of crop water deficit with total flow.	7.4	3.8	3.0
13.	Percentage of crop water deficit with total crop water demand.	9.8	5	4
14.	Irrigation Shortage Index.	0.031	0.008	0.004

TABLE 6-10

STORAGE DURATION VALUES- STRAUGE'S TABLE FLOW.

Sl. No.	Storage Capacity	Nos	Cumulative Nos	Probability P(x)
		50% Dependability		
I	0-0.25	90	360	1.0
II	0.26-0.5	73	270	0.75
III	.51-.75	82	197	0.55
IV	> .75	115	115	0.32
		60% Dependability		
I	0-0.25	58	360	1.0
II	0.26-0.5	82	302	0.84
III	0.51-0.75	98	220	0.61
IV	Above 0.75	122	122	0.34
		75% Dependability		
I	0-0.25	54	360	1.00
II	0.26-0.5	81	306	0.85
III	0.51-0.75	103	225	0.63
IV	Above 0.75	122	122	0.34

of flow increases vide fig.6.5

Shortage Index: It is a measure of the number and magnitude of annual shortages. Lower shortage index indicates more adequately meeting the target requirement.

$$\text{Shortage Index} = \frac{100}{N} \sum_{1}^{N} \left(\frac{\text{Annual Shortage}}{\text{Annual requirement}} \right)^2$$

where,

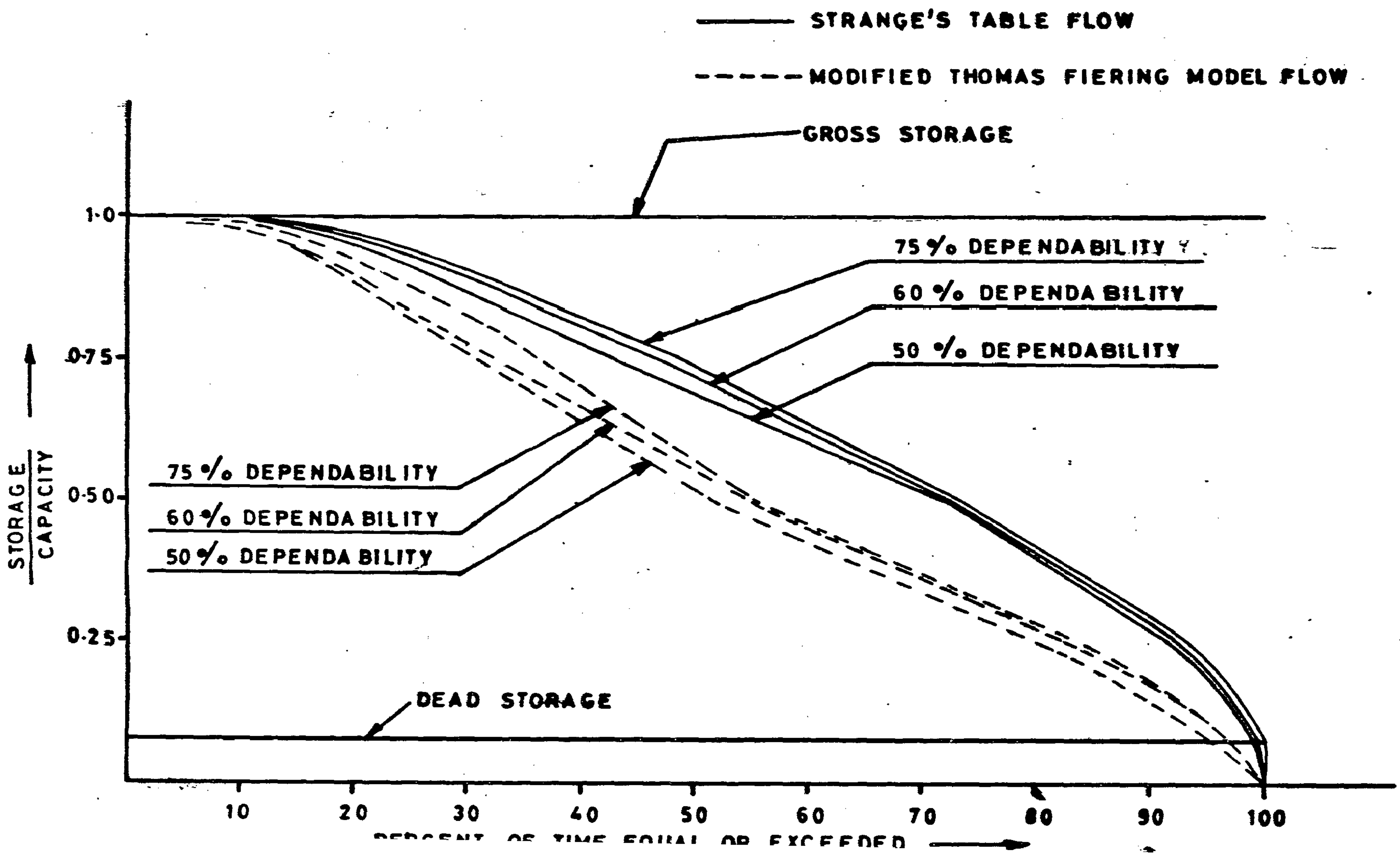
N = Period of analysis

The difference in shortage index for the three alternatives are marginal vide Table 6.9(b) .

On the basis of the above following criteria 50% dependable flow scheme is feasible.

1. Generally 60% dependability for irrigation projects is not the design creteria.
2. The increase in reservoir capacity between 50% to 75% dependability is .9.5%.
3. Successful years for 50% and 75% dependability are as per requirement of feasibility.
4. Evaporation losses for 50% dependability are less compared to 75% dependability.
5. Percentage of crop water deficit for 50% dependability is with in the marginal deficit of 10%.

6.8 RESERVOIR OPERATION STUDIES FOR CHECKING FEASIBILITY OF PROJECT FOR THE FLOWS GENERATED FROM MODIFIED THOMAS-FIERING MODEL:


STRANGE'S TABLE FLOW
MODIFIED THOMAS FIERING MODEL FLOW
GROSS STORAGE
75 % DEPENDABILITY
60 % DEPENDABILITY
50 % DEPENDABILITY
75 % DEPENDABILITY
60 % DEPENDABILITY
50 % DEPENDABILITY
DEAD STORAGE
STORAGE / CAPACITY
1·0
0·75
0·50
0·25
10
20
30
40
50
60
70
80
90
100

The reservoir capacities for different dependable flows were taken here as obtained from the Strange's Table computations and were also given in sec. 6.7. The results of operation are given in Table 6.11. Storage-duration computations are given in Table 6.12. Here also it reveals that probability that a particular (storage/capacity) will be equalled or exceeded also increases as the dependability of flows increases, fig. 6.5

On the basis of successful years none of the dependable flow schemes are feasible.

6.9 COMPARISION OF PROJECT FEASIBILITIES OBTAINED FROM STRANGE'S TABLE AND MODIFIED THOMAS FIERING MODEL FLOWS:

From the tables 6.9 and 6.11 it reveals that the number of failure years, number of deficit months, percentage of water deficit for crop demand, irrigation shortage index are more for the Modified Thomas Fiering Model from operation as compared with the Strauge's Table flow operation.

From Fig. 6.5 it also shows that probabbility that a particular (storage/capacity) will be equalled or exceeded is less in case of Modified Thomas Fiering Model flows as compared to Strauge's Table flows.

These may be due to the fact that the flows generated from the Modified Thomas Fiering Model are on the lowest side as compared with Strauge's Table flows. Secondly

TABLE 6.11

RESULTS OF 30 YEARS RESERVOIR OPERATION FROM MODIFIED THOMAS FIERING MODEL FLOW

Sl. No.	Particulars	50% dependability	60% dependability	75% dependability
1.	Gross storage capacity	12.176	14.963	16.197
2.	No.of Successfull years	11	17	17
3.	No.of deficit years	19	13	13
4.	No.of years spill over	16	14	13
5.	No.of Months Spill over	24	21	0
6.	No.of Deficit Months	65	48	47
7.	Percentage of crop water requirement with inflow	97	97	97
8.	Percentage of water released for crop requirement with inflow.	79	82.8	83
9.	Percentage of water loss as evaporation	7.4	8.6	9
10.	Percentage of water Spilled over the crest.	13	9	8
11.	Percentage of crop water deficit with total flow	17.4	14.6	14
12.	Percentage of crop water deficit with crop water demand.	18.5	15	14
13.	Irrigation shortage index	0.114	0.075	0.069

TABLE 6.12

STORAGE-DURATION VALUES-MODIFIED THOMAS FIERING MODEL

Sl.No.	Storage Capacity	Nos	Cumulative Nos	Probability P(x)
		50% Dependability		
I	0-0.25	134	360	1
II	0.26-0.50	73	226	0.63
III	0.51-0.75	78	153	0.43
IV	> 0.75	75	76	0.20
		60% Dependability		
I	0-0.25	121	360	1
II	0.26-0.50	78	239	0.66
III	0.51-0.75	85	161	0.45
IV	> 0.75	76	76	0.21
		75% Dependability		
I	0-0.25	118	360	1
II	0.26-0.50	87	240	0.67
III	0.51-0.75	76	153	0.43
IV	> 0.75	79	79	0.22

TABLE 6.13

COMPARISION OF COST AND BENEFIT COST RATIO

Sl. No.	Particulars	Cost in Rs.Lakhs	Benefit cost Ratio
1	50% dependability	484.80	1.087
2	60% dependability	498.00	1.013
3	75% dependability	509.00	0.992

the reservoir capacities for operation for the Thomas Fiering Model were taken same as obtained from Strauge's table flow for different dependabilities. To check the feasibility of the project with dependable flows of generated from Thomas Fiering Model requires further study.

6.10 BENEFIT COST-RATIO:

Benefit Cost-Ratio for 50%,60% and 75% dependable flow generated from Strauge's Table is worked out and shown in Table 6.13.

It reveals that the cost of the project increases as the dependability increases.

As the dependability increases, benefit cost ratio decreases. Benefit cost ratio of 50% dependable flow is more than 1 and that of 75% dependable flow is less than 1. Hence 50% dependable flow scheme is feasible based on benefit-cost ratio.

6.11 CONCLUSION:

Runoff-Studies were carried out for Kalluvodduhalla irrigation project.

Genration of flow done by (a) Strauge's Table (b) Regression Analysis and (c) Thomas Fiering Model. The following conclusions may be drawn.

1. Flow generated by Regression analysis vary widely **compared** to 3 years historical flows. Comparative graph showing mean versus time of three years flow, generated flow with natural values and

generated flows with logarithmic values are shown in fig. 6.2 . It reveals, that there is a wide variation between historical flows and generated flows. It is due to the reason that there is no consideration in the regression equation for the zero flows observed in any of the months,Hence these flows are not considered for further study.

2. Flow generated by the Modified Thomas_Fiering Model are of the smaller values as compared to that of the generated flow by Strauge's Table.It is due to fact that the historical flows are available only for 3 years. Thomas Fiering Model generally requires at least 10 years historical flow data.

3. From flow duration curve it is found that the probability of a particular flow will be equalled or exceeded is less in case of the flows generated by Modified Thomas Fiering Model as compared to that of Strauge's Table generated flow.

4. From Strauge's Table generated flows, gross reservoir capacity required for 50%,60% and 75% dependable flows are 12.176 Mm^3, 14.963 Mm^3 and 16.197 Mm^3 respectively, for an annual irrigation requirement of 17.549 Mm^3. The increase in capacity between 50% and 75% dependability is 9.5% which considerably large. Increase in dependability will result in increased, storage capacity,area of Submergence and evaporation losses.

8 5. From reservoir operation results for the capacities of 12.176 Mm^3, 14.963 Mm^3 and 16.197 Mm^3, the number of failure years number of deficit months, percentage of water deficit for crop index are more for the Modified Thomas Fiering Model flow operation as compared with Strauge's flow operation.

6 (a) From Storage-duration curve it reveals that the probability of a particular (Storage/Capacity) will be equalled or exceeded increases as the dependability of flow increases. This is due to the increase in reservoir capacity with the increase of dependable flow with the same annual irrigation requirement.

(b) The storage duration curve also depicts that the probability of a particular (Storage/Capacity) will be equalled or exceeded is less in case of operation with modified Thomas-Fiering Model flows as compared to Strauge's Table flow. This may be firstly due to the fact that the flows generated from the Modified Thomas Fiering Model are Smaller than the flows generated from Strauge's Table flow. Secondly, the reservoir capacities for operation for the Thomas Fiering Model were taken same as obtained from Strauge's Table for different dependabilities.

7. The 50% dependable flow scheme is feasible on the basis of reservoir operation creteria as well as on the basis of benefit cost ratio creteria.

6.12 SUGGESTION:

As a result of present work the following are the suggestions:

(a) The generation of monthly volume and reservoir operation should be carried out for longer period.

(b) A longer period historical flow data should be available for runoff studies.

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```
      DIMENSION Y(1500),G(1500),CGP(1500),CGM(1500)
      OPEN(UNIT=1,DEVICE='DSK',FILE='K3.DAT')
      Y=MONTHLY FLOW DATA
      G=GENERATED MONTHLY FLOW DATA
      CGP=GENERATED MONTHLY FLOW UPPER  CONFI LIMIT
      CGM=GENERATED MONTHLY FLOW LOWER CONFI LIMIT
      N=TOTAL NO OF DATA IN Y-SERIES
      NN=TOTAL NO OF GENERATED DATA
      TN=FACTOR FROM T-TEST TABLE FOR N-3 DEGREE OF FREEDOM
      SUM1=SIGMA(AY-AYBAR)**2.0
      GM1=GAMMA1
      BM1=BETA1
      VASQ=CONSTANT VARIANCE (SIGMA E SQUARE)
      RADV=RANDOM COMPONENT
      READ (1,2) N,NN
      READ (1,4) TN
      READ(1,4) (Y(J),J=1,N)
      PRINT 20
      PRINT 21
        PRINT*,N,NN
        PRINT*,TN
        PRINT*,(Y(J),J=1,N)
      CALL STA1(N,Y,YBAR,SUM1,STD)
      PRINT 22
      PRINT 23,YBAR,SUM1,STD
      SUM 3=0.0
      SUM4=0.0
      DO30 J=1,N
      X1=J
      X2=(2.0*3.14285*X1)/12.0
      X3=SIN(X2)
      XX1=COS(X2)
      X4=Y(J)*X3
      XX2=Y(J)*XX1
      SUM3=SUM3+X4
      SUM4=SUM4+XX2
   30 CONTINUE
      X5=N
      GM1=(2.0/X5)*SUM3
      BM1=(2.0/X5)*SUM4
      PRINT 31,GM1,BM1
      X6=(BM1*BM1)+(GM1*GM1)
      X7=(X6*X5)/2.0
```

```
      VASQ=(SUM1-X7)/X8
      PRINT 32,VASQ
      X9=SQRT(VASQ)
      A1=1.0+(5.0/X5)
      A2=SQRT(A1)
      A3=X9*A2
      RADV=TN*A3
      PRINT 33,RADV
      DO 40 J=1,NN
      B1=J
      B2=(2.0*3.14285*B1)/12.0
      B3=COS(B2)
      B4=SIN(B2)
      G(J)=YBAR+BM1*B3+GM1*B4
      CGP(J)=G(J)+RADV
      CGM(J)=G(J)-RADV
   40 CONTINUE
      PRINT 42
      PRINT 44,((J,G(J),CGP(J),CGM(J)),J=1,NN)
    2 FORMAT(2I4)
    4 FORMAT (8F10.3)
   20 FORMAT(15X,'GENERATION OF FLOW')
   21 FORMAT(5X,'DATA USED')
   22 FORMAT(15X,'STATISTICAL PARAMETERS')
   23 FORMAT(10X,'MEAN=',E16.7,10X,'SUM1=',E16.7, 'STANDARD DEVIATION
        1=',E16.7)
   31 FORMAT(10X,'GAMA1=',E16.7,10X 'BETA1=',
     1E16.7)
   32 FORMAT(10X,'VARIANCE SQARE=',E16.7)
   33 FORMAT(10X,'RANDOM COMPONENT=',E16.7)
   42 FORMAT(15X,'GENERATED DATA')
   44 FORMAT(5X,I3,10X,E16.7,E16.7,10X,E16.7)
      STOP
      END
      SUBROUTINE STA1(K,AY,YBAR,SUM1,STD)
      FOR COMPUTING MEAN AND STD-DEVIATION
      DIMENSION AY(500)
      SUM=0.0
      DO 10 J=1,K
      SUM=SUM+AY(J)
   10 CONTINUE
      AN=K
      YBAR=SUM/AN
```

```
      SUM1=0.0
      DO 15 J=1,K
      CX=AY(J)-YBAR
      CX1=CX*CX
      SUM1=SUM1+CX1
   15 CONTINUE
      BN=K-1
      CX2=SUM/BN
      STD=SQRT(CX2)
      RETURN
      END
```

```
      DIMENSION Y(1500),G(1500),CGP(1500),CGM(1500)
      OPEN (UNIT=1,DEVICE='DSK',FILE='K2.DAT')
C     Y=MONTHLY FLOW DATA
C     G=GENERATED MONTHLY FLOW DATA
C     CGP=GENERATED MONTHLY FLOW UPPER  CONFI LIMIT
C     CGM=GENERATED MONTHLY FLOW LOWER CONFI LIMIT
C     N=TOTAL NO OF DATA IN Y-SERIES
C     NN=TOTAL NO OF GENERATED DATA
C     TN=FACTOR FROM T-TEST TABLE FOR N-3 DEGREE OF FREEDOM
C     SUM1=SIGMA(AY-AYBAR)**2.0
C     GM1=GAMMA1
C     BM1=BETA1
C     VASQ=CONSTANT VARIANCE (SIGMA E SQUARE)
C     RADV=RANDOM COMPONENT
      READ (1,2) N,NN
      READ (1,4) TN
      READ(1,4) (Y(J),J=1,N)
        PRINT*,Y(J)
        DO 60 J=1,N
        Y(J)=Y(J)*100
  60    CONTINUE
        PRINT*,(Y(J),J=1,N)
        DO 50 J=1,N
        IF( Y(J)) 52,52,50
  52    Y(J)=1.
  50    CONTINUE
        DO 55 J=1,N
        A=Y(J)
        Y(J)=ALOG10(A)
   55   CONTINUE
        PRINT*,Y(J)
      PRINT 20
      PRINT 21
        PRINT*,N,NN
        PRINT*,TN
        PRINT*,(Y(J),J=1,N)
      CALL STA1(N,Y,YBAR,SUM1,STD)
      PRINT 22
      PRINT 23,YBAR,SUM1,STD
      SUM3=0.0
      SUM4=0.0
      DO30 J=1,N
      X1=J
```

```
      X2=(2.0*3.14285*X1)/12.0
      X3=SIN(X2)
      XX1=COS(X2)
      X4=Y(J)*X3
      XX2=Y(J)*XX1
      SUM3=SUM3+X4
      SUM4=SUM4+XX2
   30 CONTINUE
      X5=N
      GM1=(2.0/X5)*SUM3
      BM1=(2.0/X5)*SUM4
      PRINT 31,GM1,BM1
      X6=(BM1*BM1)+(GM1*GM1)
      X7=(X6*X5)/2.0
      X8=X5-3.0
      VASQ=(SUM1-X7)/X8
      PRINT 32,VASQ
      X9=SQRT(VASQ)
      A1=1.0+(5.0/X5)
      A2=SQRT(A1)
      A3=X9*A2
      RADV=TN*A3
      PRINT 33,RADV
      DO 40 J=1,NN
      B1=J
      B2=(2.0*3.14285*B1)/12.0
      B3=COS(B2)
      B4=SIN(B2)
      G(J)=YBAR+BM1*B3+GM1*B4
      CGP(J)=G(J)+RADV
      CGM(J)=G(J)-RADV
   40 CONTINUE
      PRINT 42
C       PRINT 44,((J,G(J),CGP(J),CGM(J)),J=1,NN)
        DO 65 J=1,NN
          G(J)=(10.**G(J))/100
        CGP(J)= (10.**CGP(J))/100
        CGM(J)=(10.**CGM(J))/100
   65   CONTINUE
       PRINT 44,((J,G (J),CGP(J),CGM(J)),J=1,NN)
    2 FORMAT(2I4)
    4 FORMAT (8F10.3)
   20 FORMAT(15X,'GENERATION OF FLOW')
   21 FORMAT(5X,'DATA USED')
```

```
      22 FORMAT(5X,'STATISTICAL PARAMETERS')
      23 FORMAT(10X,'YBAR=',E16.7,10X,'SUM1=',E16.7, 'STANDARD DEVIATION
     1=',E16.7)
      31 FORMAT(10X,'GAMA1=',E16.7,10X 'BETA1=',
     1E16.7)
      32 FORMAT(10X,'VARIANCE SQARE=',E16.7)
      33 FORMAT(10X,'RANDOM COMPONENT=',E16.7)
      42 FORMAT(15X,'GENERATED DATA')
      44 FORMAT(5X,I3,10X,E16.7,E16.7,10X,E16.7)
         STOP
         END
         SUBROUTINE STA1(K,AY,YBAR,SUM1,STD)
C        FOR COMPUTING MEAN AND STD-DEVIATION
         DIMENSION AY(500)
         SUM=0.0
         DO 10 J=1,K
         SUM=SUM+AY(J)
      10 CONTINUE
         AN=K
         YBAR=SUM/AN
         SUM1=0.0
         DO 15 J=1,K
         CX=AY(J)-YBAR
         CX1=CX*CX
         SUM1=SUM1+CX1
      15 CONTINUE
         BN=K-1
         CX2=SUM1/BN
         STD=SQRT(CX2)
         RETURN
         END
```

```
      C     DISSERTATION WORK OF G.D.SHANKARAMURTHY,M.E.HYDROLOGY
      C     PROGRAM FOR GENERATION OF MONTHLY FLOW
      C     BY THOMAS FIERING MODEL (MODIFIED)
      C     COMPUTATION OF MONTHLY STATISTICAL
      C     1PARAMETERS
      C     NT=NUMBER OF MONTHS DISCHARGES
      C     1ARE AVAILABLE IN A YEAR
      C     K=NUMBER OF YEARS OF DATA AVAILABLE
              DIMENSION EPSL(1400),Q1(100 ,13)
            DIMENSION Q(50,12),QBAR(12),STD(12),R(12),B(12)
              COMMON/BLK1/EPSL
              COMMON/BLK2/QBAR,STD,R,B,Q
              COMMON/BLK3/Q1
            OPEN (UNIT=1,DEVICE='DSK',FILE='TM.DAT')
            READ(1,2) NT,K,NDATA
            PRINT2,NT,K,NDATA
            DO 10 I=1,K
            READ(1,*)(Q(I,J),J=1,NT)
            PRINT 4,(Q(I,J),J=1,NT)
         10 CONTINUE
          2 FORMAT(3I5)
          4 FORMAT(7F10.4)
            CALL STAN(  K,NT)
            DO 11 J=1,NT
            PRINT 5,QBAR(J),STD(J),R(J),B(J)
        11  CONTINUE
          5 FORMAT( 8F10.4)
              CALL RAND(NT,NDATA)
              CALL TF(NDATA,NT,K)
              PRINT* ,((Q1(I,J),J=1,NT),I=1,NDATA)
              DO 53 I=1,NDATA
              DO 53 J=1,NT
        53    Q(I,J)=Q1(I,J)
              CALL STAN (NDATA,NT)
              DO 60 J=1,NT
              PRINT*,QBAR(J),STD(J),R(J),B(J)
        60    CONTINUE
            STOP
            END
            SUBROUTINE STAN (  K,NT)
            DIMENSION Z(50,12),ZBAR(12),STD(12),R(12),NN(12),B(12)
              COMMON / BLK2/ ZBAR,STD,R,B ,Z
              DO 10 KK=1,NT
              NN(KK)=0
```

```
      DO 10 I=1,K
      IF(Z(I,KK).GT.0.)NN(KK)=NN(KK)+1
10    CONTINUE
      DO 5 KK=1,NT
      SUM1=0.
      A1=0
      DO 6 I=1,K
      IF(Z(I,KK).GT.0.) SUM1=SUM1+Z(I,KK)
6     CONTINUE
      A1=NN(KK)
5     ZBAR(KK)=SUM1/A1
C     FOLLOWING STATEMENTS FORMCOMPUTING
C     STANDARD DEVIATION OF DIFFRENT MONTHS
      DO 1 KK=1,NT
      SUM2=0.
      DO 8I=1,K
      IF(Z(I,KK).EQ.0.) GO TO 8
      IF(Z(I,KK).GT.0.) A2=Z(I,KK)-ZBAR(KK)
      A3=A2*A2
C     PRINT*,A3
      SUM2=SUM2+A3
8     CONTINUE
      AK=NN(KK)-1
C     PRINT*,AK
      SUM2=SUM2/AK
1     STD(KK)=SQRT(SUM2)
C     COMPUTATION OF CORRELATION COEFFICIENT
      DO 15 KK=2,NT
      SUM3=0.0
      SUM4=0.
      SUM5=0.
      DO12I=1,K
      IF(Z(I,KK).EQ.0.)GO TO 12
      AN1=Z(I,KK)-ZBAR(KK)
      AN2=Z(I,KK-1)-ZBAR(KK-1)
C     PRINT*,AN1,AN2
      AN3=AN1*AN1
C     PRINT*,AN3
      AN4=AN2*AN2
      SUM3=SUM3+AN1*AN2
      SUM4=SUM4+AN3
      SUM5=SUM5+AN4
12    CONTINUE
      AN5=SUM4*SUM5
```

```
      AN6=SQRT(A.5)
      R(KK)=SUM3/AN6
C     PRINT*,ZBAR(KK),STD(KK),R(KK)
 15    CONTINUE
       DO 13 KK=2,NT
       B(KK)=R(KK)*STD(KK   )/STD(KK-1)
C     PRINT*,B(KK)
 13     CONTINUE
      RETURN
      END
        SUBROUTINE RAND(NM,M)
C       PROGRAM FOR GENERATION OFRANDOM NUMBERS
C       NM = NUMBER OF MONTHS
C       M=NUMBER OF YEARS OF DATA TO BE GENERATED
C       NOS=NUMBER OF SETS OF RANDOM NUMBERS
C       R0=INITIAL VALUE
C       R1 AND R2=NEW VALUES OF R0
C       T(I)=RANDOM NUMBERS
C       N.R.NOS.(0,1) BY BOX MULLER
        DIMENSION T(1400),EPSL(1400),X(1400),Y(1400)
        COMMON/BLK1/EPSL
        READ(1,10)NOS
        PRINT 104,NOS
 10     FORMAT(3I4)
        DO 99 K=1,NOS
        LL=0
        PI=3.1415936
        READ(1,12)R1,R2
        PRINT  12,R1,R2
 12     FORMAT(2F10.8)
        NN=0
        DO100KK=1,M
        DO107 I=1,NM
        NN=NN+1
        CALL URAND(R1,R)
        U1=R
        CALL URAND (R2,R)
        U2=R
        X(NN)=U1
        Y(NN)=U2
        ARGNT=2.0*PI*U2
        T(I)=(-2.*ALOG(U1))**0.5*COS(ARGNT)
 107    CONTINUE
C     PRINT106,( T(I), I=1,NN)
```

```
              DO5  J=1,NT
              LL=LL+1
               EPSL(LL)=T(J)
      C       PRINT*,EPSL(LL)
       50     CONTINUE
       100    CONTINUE
      C     PRINT103,(X(I),I=1,NN)
      C     PRINT103,(Y(I),I=1,NN)
       103    FORMAT(6F12.7)
       99     CONTINUE
       104    FORMAT(3I4)
      C 105    FORMAT(2F10.5)
       106    FORMAT(5F10.4)
              RETURN
              END
              SUBROUTINE URAND(R0,R)
              R=331.*R0
              I=R
              XI=I
              R=R-XI
              R0=R
              RETURN
              END
              SUBROUTINE TF(NDATA,NT,K)
      C     GENERATION OF MONTHLY FLOW BY MODIFIED
      C     THOMAS FIERING MODEL
      C     Q(I,J)=OBSERVED FLOW DATA IN  I TH
      C     YEAR AND J TH MONTH
      C     Q1(I,J)=GENERATED FLOW IN I TH
      C     YEAR AND J TH MONTH
      C     QBAR(J)=AVARAGE FLOW IN J TH
      C     MONTH
      C     B(J)=REGRESSION COEFFICIENT
      C     EPSL(1)=RANDOM NUMBERS
      C     NDATA=NUMBER OF YEARS OF DATA
      C     TO BE GENERATED
      C     NT=NUMBAR OF MONTHS DISCHARGES
      C     AVAILABLE
      C     R(J)=CORRELATION COEFFICIENT
      C     STD(J)=STANDARD DEVIATION
            DIMENSION Q(50,12),QBAR(12),STD(12),B(12),R(12)
            DIMENSION EPSL (1400)
            DIMENSION Q1 (100 ,13),P(12)
              COMMON/BLK1/EPSL
```

```
      COMMON /BLK2/QBAR,STD,R,B,Q
      COMMON /BLK3/Q1
  101 FORMAT(3I4)
C     PRINT 101,NT,K,NDATA
  102 FORMAT (7F10.4)
C     PRINT 102,((Q(I,J),J=1,NT),I=1,K)
      READ(1,103)RO
  103 FORMAT(5F10.8)
C     PRINT*,(QBAR(J),J=1,NT)
C     PRINT*,(STD(J),J=1,NT)
C     PRINT*,(B(J),J=1,NT)
C     PRINT*,(R(J),J=1,NT)
C      PRINT*,(EPSL(J),J=1,NT)
      XK=K
      DO 51 J=1,NT
      P(J)=0
      DO 51 I=1,K
      IF(Q(I,J).GT.0.)P(J)= P(J)+(1. /XK)
   51 CONTINUE
        PRINT*,(P(J),J=1,NT)
      LLL=0
      DO 50 I=1,NDATA
      DO 50 J=1,NT
        Q1(I,J)=0
      CALL GRAND (RO,RANDM)
C      PRINT*,(RO,RANDM)
       IF(RANDM.LT.P(J).AND.RANDM.GT.0)GO TO 52
       GO TO 50
   52 LLL=LLL+1
      IF(J.EQ.1)Q1(I,J)=QBAR(J)+STD(J)*EPSL(LLL)
      IF(J.GT.1)Q1(I,J)=QBAR(J)+B(J   )*(Q1(I,J-1)-QBAR(J-1))+STD(J)
     1  *SQRT(1-R(J   )*R(J))*EPSL(LLL)
        IF(Q1(I,J).LT.0.)Q1(I,J)=0.
   50 CONTINUE
C     PRINT*,((Q1(I,J),J=1 ,NT),I=1,NDATA)
      RETURN
      END
```

```
C     G.....URTHY, .E. HYDROLOGY DISSERTIO. WORK
C     RESERVOIR OPERATION OF K.HALLA
C     NDATA=NUMBER OF YEARS OF DATA AVAILABLE
C     S=I ITIAL LIVE STORAGE
C     FLO =I FLO  TO RESERVOIR
C     XREQ=IRRIGATION REQUIREMENT
C     D=IRRIGATIO  RELEASE
C     SPILL=SPILL FROM RESERVOIR
C     R=TOTAL RELEASE INCLUDING SPILL
C     Y=GROSS RESERVOIR CAPACITY
C     EV=EVAPORATIO  COEFFICIENT FROM RESERVOIR
C     EVAPO=EVOPORATION FROM RESERVOIR
      DIMENSION S(13),FLO (50,12),XREQ(12),D(12),
     1SPILL(12),R(12),EV(12),EVAPO(12),SF(12)
        DIMENSION DEF(12),IDEF(12),ISPILL(12),IEMPTY(12)
      OPE  (U IT=1,DEVICE='DSK',FILE='TOP.DAT')
      READ(1,100) NDATA
  100 FORMAT(10I5)
      READ(1,101) S(1),Y,DS
  101 FORMAT(6F10.3)
      DO 12 I=1,NDATA
      READ(1,*  )(FLOW(I,J),J=1,12)
   12 CONTINUE
      READ(1,101)(XREQ(J),J=1,12)
      READ(1,102)(EV(J),J=1,12)
  102 FORMAT(6F10.8)
        DO 16 J=1,12
        DEF (J)=0.
        IDEF(J)=0.
        ISPILL(J)=0
        IEMPTY(J)=0.
 16     CONTINUE
      DO1 I=1,NDATA
      DO11 J=1,12
      TFLOW=S(J)+FLOW(I,J)-DS
      IF(TFLOW.LT.XREQ(J)) GO TO 2
      IF(TFLOW.EQ.XREQ(J)) GO TO 3
      IF(TFLOW.GT.XREQ(J)) GO TO 4
    2 D(J)=TFLOW
      SPILL(J)=0
      R(J)=D(J)
      S(J+1)=DS
      GO TO 5
    3 D(J)=XREQ(J)
```

```
      SPILL(J)=0
      R(J)=D(J)
      S(J+1)=DS
      GO TO 5
    4 D(J)=XREQ(J)
      S(J+1)=TFLOW-XREQ(J)+DS
      IF(S(J+1).GE.(Y    )) GO TO 6
      SPILL(J)=0
      R(J)=D(J)
      S(J+1)=S(J+1)
      GO TO 5
    6 SPILL(J)=S(J+1)-(Y    )
      R(J)=SPILL(J)+D(J)
      S(J+1)=Y
    5 X=(S(J)+S(J+1))/2.
      EVAPO(J)=EV(J)*AREA(X)
      IF(SPILL(J).GT.0) GO TO 7
        X=S(J+1)-DS
        IF(X.GE.EVAPO(J))GO TO 19
      D(J)=D(J)-(EVAPO(J)-X)
      IF(D(J).GT.0) GO TO 13
      D(J)=0
   13 R(J)=D(J)
        S(J+1)=(DS-(EVAPO(J)-X))
      GO TO 9
   19 S(J+1)=     DS+(X-EVAPO(J))
        GO TO 9
    7 IF(SPILL(J).GT.EVAPO(J)) GO TO 8
      X=EVAPO(J)-SPILL(J)
      D(J)=D(J)-X
      S(J+1)=S(J+1)-X
      SPILL(J)=0
      R(J)=D(J)
      GO TO 9
    8 SPILL(J)=SPILL(J)-EVAPO(J)
      R(J)=D(J)+SPILL(J)
 9     IF(J.EQ.12)SI=S(J+1)
   11 CONTINUE
      DO 10 JJ=1,12
      SF(JJ)=S(JJ+1)
   10 CONTINUE
        DO 17 J=1,12
        DEF(J)=XREQ(J)-D(J)
        IF(DEF(J).GT.0)IDEF(J)=IDEF(J)+1
```

```
      IF(SPILL(J).GT.0)ISPILL(J)=ISPILL(J)+1
      IF(SF(J).LE.DS)IEMPTY(J)=IEMPTY(J)+1
17    CONTINUE
     DO 15 J=1,12
     PRINT 200,S(J),FLOW(I,J),D(J),EVAPO(J),R(J),SF(J),SPILL(J)
 200 FORMAT(7F12.4)
  15 CONTINUE
     S(1)=SI
   1 CONTINUE
      DO 18 J=1,12
      PRINT 201,IDEF(J),ISPILL(J),IEMPTY(J)
201   FORMAT(3I6)
18    CONTINUE
      STOP
      END
      FUNCTION AREA(X)
      AREA=0.2532318E+01+0.2978964E+02*X-0.2116531E+01
    1*X*X+0.6622052E-01*X*X*X
      RETURN
```

```
C
C          LEAST SQUARE FOR CURVE FITTING
C       A=COEFFICIENT OF POLYNOMIAL
C       C=CORRELATION INDEX
C       I=    OF SIDS OF CURVE TO BE FITTED
C        =      OF POLYNOMIAL
C         =       OF POLYNOMIALS TO BE FITTED
C        =      OF OBSERVATIONS
C         =      OF POLYNOMIALS TO BE FITTED
C       X(I)=INDEPENDENT VARIABLES
C       Y(I)=DEPENDENT VARIABLES
        DIMENSION X(25),Y(25),B(25,27),C(25,27),D(26,27),CONST(26),A(26)
        DIMENSION Y1(25),  (5 ), (2 )
          OPEN (UNIT=1,DEVICE='DSK',FILE='LS.DAT')
          READ(1,100)L
        DO    L=1,L
          READ(1,1 )
  1     FORMAT (2I4)
          READ(1,1 1)(X(I),I=1, )
        PRINT 1 2
 1 2    FORMAT (1X,10HX ORDINATE,/)
        PRINT 2 1,(X(I),I=1, )
 1 1    FORMAT(3F1 .3)
 201    FORMAT(5F15.7)
          READ(1,1 1)(Y(I),I=1, )
        PRINT 1 3
 1  3   FORMAT (1X,16HYORDINATE ACTUAL,/)
        PRINT 2  ,(Y(I),I=1, )
        P      1
 1 1    FORMAT (1X,3 (1H-))
        S  1= .
        S  2= .
        DO 2  I=1,
        S 1=S 1+Y(I)*Y(I)
  2     S  2=S 2+Y(I)
        X =
        X   =S 2/
        C=SQRT((S 1-X   *S 2)/(X -1. ))
            ( ,1  )  (L )
         1=  (  )
           (  ,   )(  (I),I=1, )
C       C  3 (  I=1)
         7=  (  )
             =  , 7
```

```
              =  .
              =  (N  )
          P     2  ,  ,
   2 2    F      (  ,22  DEGREE OF POLYNOMIAL=,I3,1X,19H NO.OF OBSERVATIONS=,
         1I3/)
                  =  ,
    1     (  ,  )=  .
             =  +.
          D   2 =  ,
             2 =  ,
          J  1=  -
    2     B(I,  )=  (I)**J  1
             2=  +2
             I=  ,
    3     B(I,   2)=-Y(I)
          D  5  =1,  P1
          D      I=  ,
             J=  ,  P2
    4     C(I,  )=  (I,J)*B(I,K)
             J=1,  P2
          D(  ,J)=  .
          DO   I=1,
    6     D(  ,  )=  (K,J)+C(I,J)
    5     C    I    E
          D    I=1,  P1
    8     C    (I)=-D(I,  P2)
          CALL   I  (D,  P  )
             7  J=  ,  P1
          A(J)=  .
             7   =  ,  P1
    7     A(J)=  (J)+  (J,K)*CO  ST(K)
          P        2  5
  2 5     F      (  X,27H COEFFICIENTS OF POLYNOMIAL,/)
          P        2  3,(A(J),J=1,  P1)
  2 3     F      (      .7)
          G     =  .
                  =  ,
          Y  (  )=  (  )
           P  =  +
               2    J=  ,  P
   22     Y  (  )=  (  )+  (J)*(X(I)**(J-1))
   21     G       =     +(Y(I)-Y  (I))**2
          G=        /(        )
                        ,
```

```
      ; 9   (  ,  (•,   .')
            IF(   )   ,   ,   5
      5     (   -6)
      1  5 P    :
      1  6 F    (  ,  ATE C  C  ),/)
            P   ,( (I),I=1, )
            IF(  .  ,5),  6
      5     P  3,
      23    F   (  ,  CORRELATION INDEX=,F  ,/)
            G        7
      1  6 P   .
      1  8 F    ( ,32  CORRELATION INDEX  DETERMINATE,/)
      1  7 P     1
      1  1 F    (1X,  (1H-))
      24    C
            P
      1     F   (1X,79(1H-))
      1     C
            S
            E
            S   DETERMINATE(A, )
            DIMENSION A(26,27),B(31),C(31)
              = -1
            A(1,1)=1./A(1,1)
            D   =1,
            K= +1
            D     =1,
            B(I)=
            D  3  J=1,
      3     B(I)=B(I)+A(I,J)*A(J, )
            D=
            D    I=1,
      4     D=D+ ( ,I)*B(I)
            D=- +A(K,K)
            A( , )=1./D
            D   5 I=1,
      5     A( , )=-B(I)*A(K,K)
                  J=1,
            C( )=
            D     I=1,
      6     C( )=C( )+ (K,I)*A(I,J)
            D  7  J=1,
      7     A( , )=-C(J)*A( , )
            D     =1,
```

```
              =  ,
      8   A(I,J)= (I,J)-B(I)*( ,J)
          RETURN
          END
```