REGULATION OF WATER

IN THE

MAHAWELI PROJECT SYSTEMS

BY

R.T.C. PEIRIS B.Sc. (Eng.)

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING.

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
UNIVERSITY OF MORATUWA.

FEBRUARY - 1985

This dissertation has not been previously presented in whole or part, to any University or Institution for a higher degree.

R.T.C. PEIRIS.

February 1985.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOTATIONS

A,B	Constants
A_M	Catchment area at site M in basin M
A_N	Catchment area at site N in basin N
C	Coefficient of tunnel loss
C_A	Catchment area at A
CA_k	Net catchment area at K
CA_r	Net catchment area at R
CA_v	Net catchment area at V
C_B	Catchment area at B
CEE	Efficiency of turbine and generator
CRIRC	Coefficient of reduction in irrigation area for C
C01	Virgin flow at inflow point 01
$C01^*$	Tentative flow at inflow point 01
C02	Virgin flow at inflow point 02
C03	Virgin flow at inflow point 03
C04	Virgin flow at inflow point 04
C05	Virgin flow at inflow point 05
C06	Virgin flow at inflow point 06
C07	Virgin flow at inflow point 07
C09	Virgin flow at inflow point 09
C10	Virgin flow at inflow point 10
C41T	Virgin flow at inflow point 41T
C51	Virgin flow at inflow point 51
C101	Virgin flow at gauging station 101
C102	Virgin flow at gauging station 102
C103	Virgin flow at gauging station 103
C104	Virgin flow at gauging station 104
C105	Virgin flow at gauging station 105

C106	Virgin flow at gauging station 106
C110	Virgin flow at gauging station 110
C151	Virgin flow at gauging station 151
DA	Demand of discharge from reservoir A
DAB	Demand of discharge from reservoir A and B
DIRB	Water demand for perimeter B
DIRC	Water demand for perimeter C
DIRD	Water demand for perimeter D
DIR(J,M)	Water requirements for irrigated area (J) in time step (M)
DR	Diversion requirements
DSC	Dead storage
DTAB	Total discharge from reservoirs A and B including the previous releases
E	Overall efficiency
E_a	Farm efficiency
E_c	Water conveyance efficiency
E_N	Energy component
F_A	Factor for catchment characteristics for losses for A
F_a	Actual irrigation area of the system
F_B	Factor for catchment characteristics for losses for B
F_M	Flow at site M in basin M
F_N	Flow at site N in basin N
FRIRC	Factor for reduction in irrigation area for C
FRIRD	Factor for reduction in irrigation area for D
FRIR(J)	Restriction coefficient
f	Reduction factor
f_M	Flow at M in equivalent rainfall over the basin M
f_n	Flow at N in equivalent rainfall over basin N
f_1	Constant

C106	Virgin flow at gauging station 106
C110	Virgin flow at gauging station 110
C151	Virgin flow at gauging station 151
DA	Demand of discharge from reservoir A
DAB	Demand of discharge from reservoir A and B
DIRB	Water demand for perimeter B
DIRC	Water demand for perimeter C
DIRD	Water demand for perimeter D
DIR(J,M)	Water requirements for irrigated area (J) in time step (M)
DR	Diversion requirements
DSC	Dead storage
DTAB	Total discharge from reservoirs A and B including the previous releases
E	Overall efficiency
E_a	Farm efficiency
E_c	Water conveyance efficiency
E_N	Energy component
F_A	Factor for catchment characteristics for losses for A
F_a	Actual irrigation area of the system
F_B	Factor for catchment characteristics for losses for B
F_M	Flow at site M in basin M
F_N	Flow at site N in basin N
FRIRC	Factor for reduction in irrigation area for C
FRIRD	Factor for reduction in irrigation area for D
FRIR(J)	Restriction coefficient
f	Reduction factor
f_M	Flow at M in equivalent rainfall over the basin M
f_n	Flow at N in equivalent rainfall over basin N
f_1	Constant

G-Anga	Diverted (observed) flow at Angamedilla
G-bow	Diverted (observed) flow at Bowatenna
G-Elah	Diverted (observed) flow at Elahera
G-Mini	Diverted (observed) flow at Minipe anicut
G-Pol	Diverted (observed) flow at Polgolla barrage
GRC	Gross reservoir capacity
G101	Observed flow at gauging station 101
G102	Observed flow at gauging station 102
G103	Observed flow at gauging station 103
G104	Observed flow at gauging station 104
G106	Observed flow at gauging station 106
G110	Observed flow at gauging station 110
G151	Observed flow at gauging station 151
HC	Level above MSL at start of time step
HCH	Net head
HDST	Bed level or river level above MSL
HF	Level above MSL at end of time step
HOUR	No. of hours per week
I1	Integer to select strategy for water release
I2	Integer to select strategy for water release
K	Multiplication factor
K_I	Factor for catchment characteristics
K_{II}	Factor for losses in basin
L_M	Losses in basin M
L_N	Losses in basin N
m	Month Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec.
PIIB	Irrigation shortgage
PIIPB	Irrigation deficit in perimeter B
PIIPC	Irrigation deficit in perimeter C

PIIPD	Irrigation deficit in perimeter D
P_N	Power component
Q_A	Flow at A
Q_B	Flow at B
Q_k	Runoff for river for which data are available
Q_r	Runoff for river for which data to be estimated
QAA	Discharge into reservoir A (flows into A)
QAE	Inflow from A (flows out)
QBE	Inflow from B (flows out)
QBL	Lateral discharge between B and A
QCE	Inflow from C (flows out)
QCL	Lateral discharge between C and B
QDE	Inflow from D (flows out)
QDL	Lateral discharge between D and E
QG_m	Flow at G in month m
QR_m	Flow at R in month m
QTR	Turbine discharge
QV_m	Flow at V in month m
R_A	Longterm mean flow for the month at A
R_A'	Solar radiation above atmosphere
R_a	Reduced irrigation area of the system
R_B	Longterm mean flow for the month at B
R_b	Net outgoing thermal radiation
R_E	Rainfall at station E
R_e	Effective rainfall
R_H	Rainfall at station H
R_M	Rainfall over basin M
R_N	Rainfall over basin N

R_s	Net shortwave radiation
R_W	Rainfall at station W
RES(J,M)	Restriction for irrigation area (J) in time step (M)
RR_m	Average longterm rainfall on CA_r in month m
RV_k	Runoff from the rainfall for catchment
RV_m	Average longterm rainfall on CA_v in month m
RV_r	Estimated runoff from the rainfall for catchment
SIR	System irrigation requirements
TWL	Depth of flow at powerplant outlet
UAE	Useful discharge from A
UBE	Useful discharge from B
UBL	Useful discharge between B and A
UCE	Useful discharge from C
UCL	Useful discharge between C and B
UDE	Useful discharge from D
UDL	Useful discharge between D and C
VA	Additional volume of water released from reservoir A for irrigation perimeter
VAB	Additional volume of water released from reservoirs A and B for irrigation
VAMA	Volume to be expected till the 18th week of the next year with a probability of 90% for reservoir A
VAMB	Volume to be expected till the 18th week of the next year with a probability of 90% for reservoir B
VCRD	Irrigation buffer
VCRDA	Volume corresponding to the rule curve for irrigation at the beginning of next week for the reservoir A
VCRE	Energy pool curve
VCREA	Volume corresponding to the energy curve for the reservoir A at the beginning of next week
VCRP	Flood protection curve

VCRPA	Volume corresponding to the flood protection curve of the reservoir A at the beginning of next time step
VCRPB	Volume corresponding tothe flood protection curve of the reservoir B at the beginning of next time step
VELB	Volume of unregulated water used in perimeter B
VELC	Volume of unregulated water used in perimeter C
VELD	Volume of unregulated water used in perimeter D
VEVPA	Volume of water evaporated from reservoir A in a week
VEVPB	Volume of water evaporated from reservoir B in a week
VIPIA	Volume released for irrigation purpose from reservoir A
VIPIAB	Volume of water released for irrigation purpose from reservoir A and B
VLPAMA	Volume discharged previously attachable to reservoir A
VLPAMB	Volume discharged previously attachable to reservoir B
VMAXB	Maximum amount of water released from reservoir A for irrigation purpose
VPA	Volume released from reservoir A for purpose of flood protection
VPAB	Volume released from reservoir A and B for purpose of flood protection
VPB	Volume released from reservoir B for purpose of flood protection
VSCA	Volume stored at the commencement of a week in the reservoir A
VSCB	Volume stores at the commencement of a week in the reservoir B
VSFA	Volume stored finally in a week in the reservoir A
VSFB	Volume stored finally in a week in the reservoir B
W_d	Total quantity of water drained from the effective root zone
W_{et}	Total quantity of water vaporized from soil and plant
W_f	Quantity of water issued to the farm

W_r	Quantity of water issued from the sluice
W_s	Quantity of water applied to the root zone of soil
W_z	Irrigation water applied to soil
W-106	Tentative flow at gauging station 106
X	Actual flow at station x
Y	Estimated flow at station y
α	Constant factor
Δt	Time interval
ΔW_s	Change in soil water content

ACKNOWLEDGEMENT

The author is obliged to the Mahaweli Development Board for allowing him to participate in the Systems Analysis study as the Sri Lanka counterpart in the Netherlands and for permitting him to use all the relevant data required for this study.

Sincere gratitude is expressed to Professor V.N. Kulandaiswamy of the UNESCO for providing valuable guidance in the development phase of the study.

Thanks are also due to the academic staff of the M.Eng. Course of study, Civil Engineering Department of the University of Moratuwa, Sri Lanka for providing guidance with regard to this study.

The author is obliged to Mr. Sam Ratnasamy for typing the manuscript, and deeply thankful to his wife, Nimala, for her continued support and encouragement during all stages of the study.

ABSTRACT

Regulation of water resources systems has become increasingly complex during the recent decades and there is evidence that the process will become more so in future. In the Mahaweli Project Systems, especially in a country short of natural resources this task will call for sophistication in planning the system for the future with consideration being given in complete allocation of available resources for maximization of area under cultivation and generation of electrical energy. However, the average planner and the decision maker has been provided with very few new tools and techniques to compensate for the added complexities.

Once the water is made available for irrigation of lands, its use is limited unless water management aspects at field level are not implemented. In order that the results be successful, careful consideration of every aspect of water management including the cultural practices is necessary. In arriving at acceptable management practices, a brief review of ancient irrigation systems management practices are discussed in order to establish continuity with past traditions.

The specific objective is the determination of the most efficient use of the water resources of Mahaweli and adjacent river basins within the limits of constraints, fixed with regard to the priority to meet certain demands. This lays emphasis on minimizing the loss due to water deficits as regards the water demands for irrigation and energy and capacity requirements for hydro-power during the dry years and making a balance between water demands and flood control during wet years.

A large number of components, variables and relationships define the system. In order to regulate water in such a system to achieve this specific objective a technique that is adequate to consider all the complexities has been devised. The method of System Analysis is used in this investigation to determine the most efficient use of the limited water resources available within the Project Systems. Systems Analysis in a sense, is a method of integrated thinking, and conceptually there is very little difference between mental and mathematical models. Systems analysis cannot replace experience, in fact, it augments it.

The water balance study used to determine the availability of water to meet the demands within the system, necessitated the reviewing and processing of hydrological data for INFLOWS and factors affecting the consumptive use for DEMANDS. The basic sub-systems used to build up the Macro System of water use and allocation are described in detail. The methodologies used include basic operational rules, priority for irrigation of certain areas, rule curves, probability criteria for inflows, trial and error process and successive approximations.

A rather detailed review was made of the crop water requirements and the diversion requirements for irrigated perimeters. The efficiencies of the irrigation applications, cropping patterns etc. are based on past experience as described herein. As the storage reservoirs are operated for energy generation the other river systems which generate major portion of electrical energy outside the Mahaweli Basin are also considered.

The model was prepared to simulate the integrated operation of all the hydraulic structures and power stations using available input data for INFLOWS, DEMANDS, and POWER TARGETS. The model is run for each year in a historical hydrologic period of 28 years with time step as one week for specified system characteristics and selected operational rules.

This is repeated for different combination of reservoirs, power stations, irrigated perimeters and different operational rules.

Sensitivity calculations were done to ascertain the validity of the assumptions and limitations of the analysis. Further studies and investigations are recommended based on the results of these calculations. The results of the water balance study are presented for different combinations of reservoirs and irrigation areas. Study reveals that the total area that can be successfully cultivated without any reservoirs to be about 150,000 ha. of land while the development of all the reservoirs will make it possible to cultivate about 350,000 ha. of land. The total annual energy production will be about 2650 GWh.