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STOCHASTIC AND MODIFIED SEQUENT PEAK ALGORITHM FOR RESERVOIR PLANNING ANALYSIS CONSIDERING PERFORMANCE INDICES

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by

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Dedicated to My Dear Parents

Esmaeil Saket Oskoui and Nahid Azari

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LIST OF ABBREVIATIONS

AR	Auto Regressive
ARMA	Auto Regressive Moving Average
BL	Broken Line
CDF	Cumulative Distribution Function
CP	Critical Period
DF	Degrees of Freedom
DID	Department of Irrigation and Drainage
DP	Dynamic Programming
DRI	Drought Risk Index
F	Failure
FGN	Fractional Gaussian Noise
FM	Figure of Merit
ISM	Indexed Sequential Method
LP	Linear Programming
MA	Moving Average
MAF	Mean Annual Flow
MLE	Maximum Likelihood Estimates
NLP	Non-Linear Programming
PDF	Probability Density Function
PPCC	Probability Plot Correlation Coefficient
RMSE	Root Mean Square Error
RNG	Random Number Generator
S	Success

SC	Storage Capacity
SD	Standard Deviation
SE	Standard Error
SPA	Sequent Peak Algorithm
SPSS	Statistical Package for Social Sciences
SROC	Spearman Rank Order Correlation
WMO	World Meteorological Organization

LIST OF SYMBOLS

A	Coefficient matrix of (MN×N) in the V-S model
AR(1)	auto regressive model of 1 order
AR(p)	autoregressive model of p order
ARMA(p, q)	autoregressive moving average models
A_c	regression coefficient for modeling the critical period
A_s	regression coefficient for modeling the storage capacity
A_k	Kirby parameter for modifying Pearson type III reduced variate
A_t	reservoir water surface area at the beginning period t
A_{t+1}	reservoir water surface area at the end of period t
a	parameter, linearized slope of the area-storage curve for the reservoir
B	Coefficient matrix of (MN×MN) in the V-S model
B_c	regression coefficient for modeling the critical period
B_s	regression coefficient for modeling the storage capacity
B_k	Kirby parameter for modifying Pearson type III reduced variate
B_0, B_1, B_2	specific coefficients for autoregressive model
b	parameter, reservoir water surface area at the dead storage level
Cov	Covariance
CP_E	critical period for English systems
CP_I	critical period for Iranian systems
$CP_{(Johor)}$	critical period for Johor system
$CP_{(Melaka)}$	critical period for Melaka system
$CP_{(Muar)}$	critical period for Muar system
$CP_{(3\ Systems)}$	critical period for the three study systems together

C_V	coefficient of variation
c	minimum fraction of target demand to be guaranteed in a failure period
D	demand expressed as a ratio of mean annual flow
Demand	annual demand from the reservoir as a ratio of mean annual flow
D_w	a window width of a given duration in moving window method
E[ ]	Expectation function
EP_t	depth of evaporation from reservoir surface in period t
EV_t	volumetric storage-dependent fluxes during period t
EV_t^{sys}	net evaporation losses of the system during period t
$e^{()}$	exponential function employed for modeling the storage capacity
e_i	independent zero mean and unit variance normal random variable
$\bar{e}$	the average of independent zero mean and unit variance normal random variables
en_t	net evaporation (i.e. evaporation minus rainfall) in period t
F-stat	*F*-statistic
f_s	the number of continuous sequences of failure periods
f	total number of failure periods
f	annual risk i.e. 1-f is the annual time-based reliability
G_k	Kirby parameter for modifying Pearson type III reduced variate
g	skewness of Pearson type III variable corrected for serial correlation
g_0	original sample skewness
H_k	Kirby parameter for modifying Pearson type III reduced variate
H_0	the null hypothesis
h	Hurst coefficient
I_t	volumetric inflow into reservoir during period t

ICRIT	the time period corresponding to the end of the critical period
ICY	current critical period
IOVF	the time period corresponding to the beginning of the critical period
i	time / rank of observation values
K	reduced variate or frequency factor
K_a^*	minimum active storage capacity obtained by the modified SPA
K_{t-1}	volumetric sequential storage deficits at the beginning of period t
K_t	volumetric sequential storage deficits at the end of period t
K_a, K'_a	capacity estimates during any consecutive iterations for modified SPA
K_e	reduced variate of Gumbel distribution
K_g	reduced variate of Pearson type III distribution
K_g^m	modified Pearson type III reduced variate developed by Kirby (1972)
K_i	i^{th} order reduced variate or frequency factor
K_n	reduced variate of the standard normal distribution
K_O	over-year storage capacity expressed as a ratio of Mean Annual Flow
K_T	total (i.e. over-year plus within-year) storage capacity
k	continuous failure period
L_e	the length of streamflow data
LN2	the two-parameter log-normal distribution
LN3	the three-parameter log-normal distribution
LP3	the log-Pearson type III distribution
L_t	other losses during period t in the SPA
M	the total number of seasons per year in the V-S model
MA(1)	moving average model of order 1

m	standard demand parameter / standardized demand parameter
$\max(sh_k)$	maximum shortfall during the k^{th} continuous failure period
N	the length of the observed data record
N	the total number of sites in the V-S model
N_s	the number of independent samples or replicates
n	the number of the data
n_u	the total number of data / the number of years of data
n_1	the number of successes in the randomness test
n_2	the number of failures in the randomness test
P	cumulative probability
P_i	the cumulative probability of i^{th} ordered data observations
P_t	depth of rainfall on reservoir surface in period t
P3	Pearson type III distribution
p	annual reliability
$\bar{q}$	historical mean annual flow
R	the total number of the runs in randomness test
R	the range of cumulative departures of annual flows from the mean
R_e	the time-based reliability
R_t	release of the reservoir system during period t
R_t^{sys}	release of the system during period t
R^*_t	target demand of the reservoir system during period t
R_t^{*sys}	target demand of the system during period t
R^2	Coefficient of determination for the regression analysis
r ( )	lag-zero cross-correlation function for the V-S model

round { }	is a function that rounds to the closest integer number
ru_i	the rank of time series value during i period
S	standard deviation of annual flows
Skew	Skewness
SN	normalized storage capacity
Storage	active storage capacity
S-Y-P	storage-yield-performance
S-Y-R	storage yield relationships
$SN_{(Johor)}$	normalized storage capacity for Johor system
$SN_{(Melaka)}$	normalized storage capacity for Melaka system
$SN_{(Muar)}$	normalized storage capacity for Melaka system
$SN_{(3\ Systems)}$	normalized storage capacity for the three systems together
S_t	active storage for the reservoir at the beginning of period t
S_{t+1}	active storage for the reservoir at the end of period t
S_K	the coefficient of skewness for annual flows
S_x	standard deviation of the observed data
S_{xx}	The matrix of (MN×MN) in the V-S model
S_{xz}	The matrix of (MN×N) in the V-S model
S_{zz}	the covariance matrix of (N×N) in the V-S model
S_0	the covariance matrix of (N×N) in the V-S model
sh_k	shortfall during the k-th continuous failure period
T	total number of time periods in the record or inflow sequence
T	one divided by cumulative probability
T-F	Thomas-Fiering

t	time period
tr	the coefficient of the trend for trend test
t_u	the value of the test statistic for the trend test
tu_i	time of occurrence of time series data
$t\alpha_{t/2}$	value of trend test limit at α_t significance level
u	observed data record
u^*	a bootstrap sample
u_i	time series data during i period
Var	variance
V-S	Valencia-Schaake
V_i	the vector of (MN×1) independent standard normal random variables
V_u	Vulnerability
$\overline{X}$	mean of the observed data
X_i	the vector of (MN×1) transformed normally distributed seasonal flows at i year
X_i, X_{i+1}	annual flows for the i^{th} and $(i+1)^{th}$ years, respectively
X_{mi}^{n}	streamflow for season m, year i and site n in the V-S model
X_{j}^{n}	flows of season j at the site n in the V-S model
X_{l}^{k}	flows of season l at the site k in the V-S model
x_i	i-th ordered data observations
x_{max}	the largest observation
x_{med}	sample medium
x_{min}	the smallest observation
x	streamflow data