OPEN TECHNOLOGIES BASED TANK MANAGEMENT MODEL FOR FLOOD RISK REDUCTION

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Abstract

Analysis of climate induced phenomenon is data intensive and the data collected from very sparse network of professional weather stations have become incapable to estimate the magnitude of the climate induced events. Manual stations, offline data, low spatial and temporal resolution of data, high cost of modelling software and state-owned stations' data, unavailability of pre-determined parameter values, lack of trust on technology and lack of expertise knowledge, are the barriers exist in most developing countries, which evade inclusion of hydrological modelling approaches for tank / reservoir water release decisions. Presently, in Sri Lanka, the reservoir water is released once it reaches to a particular threshold. The public is informed few hours prior to the opening of reservoir gates. This current practicing way of releasing water from the reservoirs increases the potential for dam failures and public outrage, and thus strains reservoir operators to open the spill gates during emergency periods. Therefore, for a low-income country, a total open-source solution, combined with low-cost open-source hardware, free and open-source software and open standards was seen as the only possible way to overcome the flood risk associated with reservoirs. Thanks to the 4ONSE (4 times Open and Non-conventional technologies for Sensing the Environment) project, a dense open-source sensor network has been deployed in Deduru Oya watershed following a new deployment approach. Deduru Oya reservoir was chosen to develop the tank management model, as it is the main player of controlling the floods in the lower basin. The tank management decision support system presented in this research is supported by a hydrological model developed from SWAT open-source tool, fed with 4ONSE big data. Further, this research introduces a novel approach to find the dominant parameters and their values at any spatial and temporal scale. The calibration and validation results have revealed the potential of the open technologies-based tank management approach in controlling the reservoir floods.

Keywords:

4ONSE, reservoir flood control, Deduru Oya, open-source technologies, hydrological modelling

DEDICATION

This thesis is dedicated to the memory of my beloved father.

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LIST OF ABBREVIATIONS

Abbreviation	Description
4ONSE	4 times Open and Non-conventional technologies for Sensing the Environment
ALPHA_BF	Baseflow alpha factor
ALPHA_BNK	Baseflow alpha factor for bank strorage (days)
ARMA	Autoregressive Moving Average Model
AAT	All-at-a-time global sensitivity analysis
AWS	Automated Weather Stations
CANMX	Maximum canopy storage
CeNSE	Central Nervous System for the Earth
CFSR	Climate Forecast System Reanalysis
CH_D	Depth of main channel from top of bank to bottom (m)
CH_K(1)	Effective hydraulic conductivity in tributary channel alluvium
CH_K(2)	Effective hydraulic conductivity in main channel alluvium
CH_L(1)	Longest tributary channel length in sub-basin
CH_L(2)	Length of main channel (km)
CH_N(1)	Manning's "n" value for the tributary channels
CH_N(2)	Manning's "n" value for main channel
CH_S(1)	Average slope of tributary channels
CH_S(2)	Average slope of main channel along the channel length
CH_W(1)	Average width of tributary channels
CH_W(2)	Average width of main channel at top of bank

CN	Curve Number
CN2	Initial SCS runoff curve number for moisture condition II)
CNCOEF	Plant evapotranspiration curve number coefficient
DEEPST	Initial depth of water in the deep aquifer
DEM	Digital Elevation Model
EPCO	Plant uptake compensation factor
ERA5	ECMWF Reanalysis 5th Generation
ESCO	Soil evapotranspiration compensation factor
EVRCH	Reach evaporation adjustment factor
FAO-UNESCO	Food and Agricultural Organization - United Nations Educational, Scientific and Cultural Organization
FFCB	Initial soil water storage
FREEWAT	Free and Open Source Software for Water Resources Management
GAML	Green and Ampt Mein Larson
GIS	Geographic Information System
GSMB	Geological Survey and Mines Bureau
GW_DELAY	Ground water delay time
GW_REVAP	Groundwater “revap” coefficient
GW_REVAP	Groundwater “revap” coefficient
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur
HBV	Hydrologiska Byråns Vattenbalansavdelning
HBV-D	Hydrologiska Byråns Vattenbalansavdelning-D

HEC-HMS	Hydrologic Engineering Center - Hydrologic Modelling System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HP	Hewlett-Packard
HRU	Hydrological Response Unit
HRU_SLP	Average slope steepness
HYMOD	Hydrological MODel
IBM	International Business Machines
IFAS	Integrated Flood Analysis System
IHACRES	Identification of unit Hydrographs And Component flows from Rainfall, Evaporation and Streamflow data
IHDM	Institute of Hydrology Distributed Model
INSAT	Indian National Satellite System
IoT	Internet of Things
iRIC	International River Interface Cooperative
ISBA	Interaction Sol-Biosphère-Atmosphère
istSOS	Instituto scienze della Terra Sensor Observation Service
IWMI	International Water Management Institute
LAT_TTIME	Lateral flow travel time
MIKE-SHE	MIKE System Hydrologique European
MSK_CO1	Muskingum coefficient for normal flow
MSK_CO2	Muskingum coefficient for low flow
MSK_X	Weighting factor for wedge storage

NCEP	National Centers for Environmental Prediction
NN	Neural Networks
NSE	Nash-Sutcliffe Efficiency
OGC-SOS	Open Geospatial Consortium – Sensor Observation Service
OV_N	Manning's "n" value for overland flow
OAT	One-at-a-time local sensitivity analysis
PAWS	Process-based Adaptive Watershed Simulator
PCR-GLOBWB	PCRaster Global Water Balance
PET	Potential Evapotranspiration
PIHM	Penn State Integrated Hydrologic Modelling System
PRMS	Precipitation-Runoff Modelling System
QGIS	Quantum GIS
RCHRG_DP	Deep aquifer percolation factor
REVAPMN	Threshold depth of water in the shallow aquifer for percolation to the deep aquifer to occur
SCS	Soil Conservation Service
SHALLST	Initial depth of water in the shallow aquifer
SHE	System Hydrologique European
SUFI-2	Sequential Uncertainties Fitting Version 2
SLSOIL	Slope length for lateral subsurface flow
SLSUBBSN	Average slope length
SLURP	Semi-distributed Land Use-based Runoff Processes
SOL_ALB	Moist soil albedo

SOL_AWC	Available water capacity of the soil layer
SOL_BD	Moist bulk density
SOL_CRK	Potential or maximum crack volume of the soil profile expressed as a fraction of the total soil volume
SOL_K	Saturated hydraulic conductivity
SOL_Z	Depth from soil surface to bottom of layer
SRTM	Shuttle Radar Topography Mission
SURLAG	Surface runoff lag coefficient
SWAT	Soil and Water Assessment Tool
SWAT-CUP	SWAT-Calibration and Uncertainty Procedures
SWIM	Soil and Water Integrated Model
TOPMODEL	Topography based Hydrological Model
TRNSRCH	Fraction of transmission losses from main channel that enter deep aquifer
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WEAP	Water Evaluation and Planning System
WMO	World Meteorological Organization
WUDEEP	Average daily water removal from the deep aquifer for the month
WUSHAL	Average daily water removal from the shallow aquifer for the month