WATER SUPPLY RESERVOIR OPERATION IN THE FRAMEWORK OF CLIMATE VARIABILITY AND CHANGE

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To my beloved family…

mek
siti noor rashidah abdul rahim
muhammad nasrizal, muhammad irfan, muhammad imran
fatini, farzana
brothers, sisters, and in-laws

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ABSTRACT

The optimal planning and operation of a reservoir system is getting more crucial particularly in view of the recent awareness of potential climate change. In particular, the incorporation of hydrologic uncertainties due to climate change into reservoir operation system requires comprehensive and long-term hydrological database which rarely available in most of the conventional reservoir design. The prime objective of the study is to formulate a multiple approach on the long-term reservoir operation optimization under the scarcity of observed hydrological data and with the influence of climate change. A combined research method using IHACRES for hydrological simulation, HadCM3 for emission scenario and Statistical Downscaling Model were developed along with a Mixed Integer Linear Programming (MILP) for reservoir operation optimization. These approaches were applied to a single purpose Sg Layang Resevoir, that is one of the most prominent water supply reservoir located in Johor State, Malaysia. The climatic variables obtained from general circulation model (GCM) were downscaled corresponding to HadCM3 emission scenario and used in climate change impact analysis. The SDSM was used to produce 100 synthetic climate time-series for 90 years of the participating station, representing the climate change projection and baseline period. With respect to the baseline data, an apparent increase in temperature (1.2 degree Celsius between time periods) and rainfall was observed. The deterministic optimization exercise is performed repetitively for a number of case scenarios based on weekly reservoir's inflows derived from the projected climate change in a way to determine the optimal operation rule and policy which are based on total pumping volume and pumping cost. Corresponded to the future inflows, the pumping volume has shown an increase trend particularly during southwest monsoon, transition between seasons and autumn. Judged from the decreasing rate of the streamflows, a 34 to 40% increase in the projected monthly pumping volume is anticipated. An opposite scenario is observed during northeast monsoon season which shows a decreasing trend of 28% to 46%. At various degree of statistical reliability, the optimal operational pumping curves of the reservoir were established. These curves provide some basic information on the monthly pumping requirement from various sources of inflow to sustain the reservoir storage and demand. These operation curves are of very useful guidelines for reservoir operators in making decision to follow an optimal pumping operations schedule onsite. Such research findings were expected to generate a general awareness to the public water authorities on the potential long term effect of climate change to the reliability of reservoir operating system.

ABSTRAK

Kepentingan pengoptimuman operasi dan perancangan pengurusan sistem takungan telah meningkat terutamanya dengan kesedaran terhadap kesan potensi perubahan iklim. Khususnya, gabungan faktor ketidakpastian hidrologi disebabkan oleh perubahan iklim terhadap operasi sistem takungan memerlukan pengkalan data hidrologi yang komprehensif yang jarang terdapat dalam kebanyakan takungan konvensional. Objektif utama kajian ini ialah untuk merumuskan satu pendekatan pelbagai bagi pengoptimuman operasi takungan jangka panjang pada keadaan kekurangan data cerapan hidrologi dibawah pengaruh perubahan iklim. Gabungan kaedah kajian menggunakan IHACRES sebagai model simulasi hidrologi, senario pemancaran dari HadCM3 bagi model penurunan skala statistik (SDSM) telah dibangunkan bersama Program Integer Linear Bercampur (MILP) untuk menghasilkan operasi reservoir yang optimal. Pendekatan kajian ini diaplikasikan keatas takungan bertujuan tunggal Reservoir Sg Layang, iaitu satu takungan bekalan sumber air penting di Negeri Johor, Malaysia. Pemboleh-ubah iklim dari model peredaran umum (GCM) diturunkan skalanya selaras dengan senario HadCM3 bagi kegunaan didalam analisis impak perubahan iklim. SDSM dipilih untuk menghasilkan 100 siri data iklim sintetik bertempoh 90 tahun untuk setiap stesen pilihan yang mewakili ramalan perubahan iklim dan tempoh iklim dasar. Daripada rujukan terhadap data dasar, satu peningkatan jelas dalam suhu bagi semua musim (1.2 darjah Celsius antara sela masa) dan hujan telah ditunjukkan. Proses pengoptimuman dijalankan secara berulang bagi pelbagai kes senario dengan menggunakan siri data kadaralir mingguan yang dijanakan bagi memperolehi polisi operasi reservoir yang optimal berasaskan isipadu dan kos pengepaman. Hasil daripada aliran masuk masa depan yang dijanakan, jumlah isipadu pengepaman menunjukkan corak menaik terutama semasa monsun baratdaya, peralihan antara musim-musim dan musim luruh. Dinilai dari penyusutan kadar aliran sungai, satu unjuran peningkatan jumlah isipadu pengepaman bulanan diantara 34% hingga 40% telah dijangkakan. Sebaliknya pada musim timurlaut anggaran kadar pengepaman bulanan menurun diantara 28% hingga 46%. Dari berbagai tahap keboleh-harapan statistik, lengkung operasi optimal pengepaman ke takungan diterbitkan. Lengkung operasi ini menyediakan panduan operasi berkenaan keperluan pengepaman bulanan dari berbagai sumber aliran masuk bagi mengekalkan simpanan reservoir dan memenuhi permintaan semasa. Lengkung operasi ini juga boleh dijadikan sebagai garis panduan yang berguna kepada pengendali takungan untuk menentukan penjadualan operasi pengepaman yang optima ditapak. Hasil kajian ini dijangka mampu menjana kesedaran umum kepada pihak berkuasa bekalan air diatas potensi kesan jangka panjang dari perubahan iklim terhadap kebolehpercayaan sistem pengendalian takungan.

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LIST OF SYMBOLS

$\alpha^{(s)}$	-	Recession rate in linear module
$\beta^{(s)}$	-	Peak response in linear module
$\tau^{(s)}$	-	Slow flow time constant in linear module
ε_i	-	Modeling error
α_i	-	Weight from predictor-i (input) directly to output of skip layer connection
β_j	-	Connection weight from the *j*-th hidden node to the output node of ANN architecture
ω_{ji}	-	Bias weight in hidden layer of ANN architecture
β_o	-	Bias weight in output layer of ANN architecture
A_a	-	Area per unit active storage volume above dead storage
A_o	-	Reservoir surface area corresponding to the dead storage volume at 10m reservoir level
c	-	Mass balance parameter in non-linear module
e_t	-	Rate of evaporation
f		Temperature modulation parameter in non-linear module
h_j	-	Hidden node output of sigmoid function
Q_{in}	-	Total daily inflow
Q_t	-	Net surface inflow to reservoir during period t
t_w	-	Reference drying rate parameter in non-linear module
u_k	-	Effective rainfall
x_k	-	Streamflow
ΔS	-	Difference of reservoir storages
τ_k	-	Drying rate
ϕ_k	-	Soil moisture index

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
AOGCM	Atmosphere-Ocean General Circulation Model
DID	Malaysia Drainage and Irrigation Department
DP	Dynamic Programming
EC	Evolutionary Computation
EDA	Exploratory Data Analyses
FFNNSL	Feedforward Neural Network with skip layer connections
FFNN	Feedforward Neural Network without skip layer connections
GCM	General Circulation Model (Global Climate Model)
HadCM3	Hadley Center Coupled Model, version 3
INC	Malaysia’s Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
LAM	Limited-Area Model
LARS-WG	Long Ashton Research station Weather Generator
LP	Linear Programming
MILP	Mixed Integer Linear Programming
MMD	Malaysia Meteorological Department
NC2	Second National Communication
NCEP	National Center for Environmental Prediction
NLP	Non-Linear Programming
RCM	Regional Climate Model
RegHCM-PM	Regional Hydrologic-atmospheric Climate Model of Peninsular Malaysia
RF1	Rainfall Station at Station No 1539136
RF2	Rainfall Station at Station No. 1539134
RF3	Rainfall Station at Station No. 1538117

RF_{avg}	Average Rainfall
SDSM	Statistical Down-Scaling Model
SRES	Special Report on Emissions Scenario
T_{avg}	Average Temperature
TLFN	Time Lagged Feedforward Neural Network
T_{max}	Maximum Temperature
T_{min}	Minimum Temperature
UNFCCC	United Nations Framework Convention on Climate Change

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Urbanization processes is a continuing phenomenon not only in developing countries but also in developed countries. There has been increasing interest and concern on the use of our natural resources specifically water, that has been accorded as the highest priority in the global development agenda. Forests, plantations, grasslands and others are being continually converted into residential areas, commercial and industrial complexes, shopping centers and other facilities. One of the consequences of urbanization with which engineers, planners and decision makers should deal with is the increase demand of water supply for domestic and industrial usage that requires a greater emphasis in managing the water resources and water supply in an integrated manner.

The demand for a proper and appropriate water resources development and water supply services has increased steadily as a result of the rapid socio-economic development and environmental consciousness. As the population expands, rapid urbanization, industrial expansion and climate change, besides contributing to rising water pollution, the strains places on the earth’s natural resources also increase.

There is a strong agreement among the scientific community that the climate change is taking place with evidence from the increase in earth’s surface temperature due to greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) for instance has reported that the average global temperature increases of about 0.2°C per decade is anticipated over the next twenty years from the previous assessment of 0.6°C to 0.74°C (IPCC 2007). Changes in global climate would have significant impact on regional and local hydrological regimes in terms of key climatic variables, which in turn will affect the future water supply sources in the region. The Malaysia's Initial National Communication (INC) to the United Nations Framework Convention on Climate Change (UNFCCC) describes the quantitative impact of climate change to surface runoff. For instance, with 10% less rainfall and a 1°C increase in temperature the runoff would reduce between 13% to 35% and 14% to 43% during the wet and dry months, respectively. Similarly, when temperature rises by 3°C, the reduction in runoff ranges between 13% to 48% and 17% to 53% during the wet and dry periods, respectively (MOSTE, 2000). In the Second National Communication (NC2) report (NRE, 2010), emphasis is given to the water resources sector as a result of climate change projections that states the disruption of water supply is expected to occur in urban areas during extreme drought events.

With such climatic variation trend, it would be a great challenge for water resources managers to develop a comprehensive understanding of the expected impacts on climatic variability and change and its consequences to the water supply system. Subsequently, an optimal reservoir operation and management systems shall be planned in order to improve the management strategies for reliable water supply particularly during the long dry spells. The factors of future land used pattern and the predicted climatic conditions could be considered to accommodate the ever growing demand of freshwater supply as well as to avoid water shortages that may disrupt overall economic activities.

1.2 Statement of the Problem

As the total quantity of available water is finite with increasing demand at geometrical rates, Malaysia, a tropical country relatively rich in water resources, is not exempted from facing numerous water related problems, such as water shortages, water pollution, and floods. It is reported that 98% of the total national water resources originates from surface water which easily be affected by long dry spells. A few incidents in the past where drought caused serious water rationing and hardship to 1.8 million residents of Kuala Lumpur and other townships in Klang Valley in 1998. In similar case, Malacca state also experienced water rationing in most part of the state when the level at Durian Tunggal Dam recedes to a critical level, i.e. the main water supply reservoir of the state, reached 50% of its capacity in 1991.

Recent local studies also suggest that due to climate change there is a likelihood of a uniform annual increase in temperature and caused the regional precipitation patterns vary considerably (Zakaria and Shaaban, 2007; Shaaban *et al*., 2011) for most of the watersheds of the country. Regarding the annual rainfall, the east coast region is expected to experience 10% increase while the west coast and southern areas may drop by 5% (Zakaria and Shaaban, 2007). Similarly, the projected increase of annual surface temperature in between 1.0°C to 1.5°C for a future period of 25 years (Salmah and Liew, 2008; Tangang *et al*., 2007) over all regions may have directly influenced the potential evapotranspiration and subsequently the quantity of the runoff component. Consequently, the availability of water resources in the region would be affected whereby in the past, many operational decisions depend explicitly on the assumptions about future climatic conditions. A few studies have been carried out to incorporate the variation of climate change factor in reservoir planning and operation (Eum and Simonovic, 2010; Karamouz *et al*., 2012). Therefore there is a need to develop an integrated approach to consider these factors on climate change impact on streamflow and derive adaptive policies for possible optimal reservoir operation.

Considering the continual growth of urbanization and industrialization and the effect of climate change, an optimal operation of a water supply reservoir demands an immediate attention to ensure a long term availability and sustainability of water supply, including the conservation of water in future.

The reliability of a water supply reservoirs system depends on the appropriate rule for optimal operation. It is presumably a function of multiple and complex factors which basically governed by hydrologic uncertainties due to both supply-demand and climatic variability and change. Such generic understanding become the impetus of the present study with primary aim is to provide detail understanding through a case study of Sg Layang Reservoir.

1.3 Objectives of the Study

The principal objective of this study is to derive more realistic and reliable operational rules for a water supply reservoir system with multi-source dependent in a way to reduce the gap between theoretical assumptions and practical implementations. The specific objectives of this study that lead to a logical progression through the thesis have been identified and are summarized as follows:

1. To generate a long-term streamflow data of the study area for climate change scenario using conceptual model

2. To generate rainfall and temperature at catchment scale for climate change scenario using statistical downscaling model by employing climate variables of Global Circulation Model (GCM).

3. To evaluate the probable reservoir inflows in a way to investigate the possible changes in water availability under the framework of future climate variability and variation in pumping operation of multi-source reservoir system.

4. To develop a reservoir optimization model based on mixed integer linear programming algorithm to produce an optimal reservoir operation rules.

1.4 Research Approach and Scope of Work

The scope of the study is focused on the development of optimization model to derive a general monthly reservoir operating policy using historical data and to account the impacts of climate change and the uncertainties of inputs arise from the random nature of the inflows to the system in addition to other various sources.

The specific aims that lead to the model development and analysis of the proposed work can be summarized as follows:

- To assess the actual performance of the current reservoir operating policy.
- To evaluate the historical trends in precipitation as the basis of selecting the local representative station
- To develop a rainfall-runoff model and model selection to simulate historical and future streamflows under current and future climate scenarios.
- To evaluate the performance of downscaling models for their ability to convert large-scale GCM outputs into finer resolution daily time series of local precipitation and temperature at local meteorological stations.
- To simulate the daily inflows to Sg Layang Reservoir for both current climatic conditions and future climate scenarios using daily rainfall and temperature time series generated from the calibrated downscaling model and the corresponding GCM predictors and analyze the inflow variation due to climate change.
- To develop a deterministic optimization model formulated based on mixed integer linear programming algorithm in order to produce an optimal reservoir operation policy of the Sg Layang Reservoir system with the overall objective is to minimize the operational pumping costs from different sources considering the peak and off-peak power prices.
- To derive an optimal reservoir operation policy based on the above optimization model that takes an account of population increase and climate change.
- To compare the operational results obtained from the simulation models with the

actual operational curve produced from historical operation of the reservoir for the evaluation of the usefulness of optimal operation policies based on performance criteria.

- To analyze the operating policy to take into account of the system maximum capacity and future increase in water demands.
- To develop reservoir pumping operating curve involving different confidence intervals and change in future demands which are more appropriate for practical applications.

1.5 Significance of the Study

Optimal operation of reservoir has been an active area of water research over the years. Various techniques have been developed and adopted for reservoir operation by incorporating the aspect of uncertainties due to stochastic nature of inflows and demands.

For a reservoir that depends not only upon catchment runoff but other sources of hydrologic inflow, the available and effective volume is subjected to numerous constraints including reservoir inflow conditions, increasing water demands, pumping, and reservoir storage. These constraints vary and may change considerably during the project life which calls for a modified operational policy.

Most of reservoirs found in Malaysia are single purpose reservoirs managed by separate authorities mainly either for the purposes of hydropower generation, water supply, flood control or irrigation. They are operated based on the skill and experience of the reservoir managers that generally provides operation strategies in the form of general operating curve for reservoir releases and pumping according to the current reservoir level, hydrological conditions and water demands. Such operating practices, however, were found not adapted well to changing in hydrologic and climatic conditions. In addition, due to the lack of information on inflows into the reservoir various hydrologic variables, a more systematic and acceptable approach is crucial to establish for optimization of the operation.

One of the most prominent water supply reservoirs found in the southern region of the country is Sg Layang Reservoir. The general annual water supply-demand analysis of the Sg Layang reservoir system characteristics has shown that in general, the current supply exceeds the demand, which could be due to an excessive pumping during the unsuitable period. If we were based on the current supply trend the future demand could be increased by 40%. As such, the current practice must be enhanced by considering the followings:

- optimizing pumping operation with respect to the demand
- developing a specific reservoir operation technique by incorporating the factor of uncertainties due to stochastic nature of inflows and demands
- developing an optimal operation rule of the reservoir in response to both nonclimatic and climatic changes

Considering the need of future reservoir system expansion, analysis based on annual averages with the upper bound supply level, the current demand can probably be extended by 1.56 times of the present system characteristics. However, monthly variations due to pumping restrictions, river depth, lower reservoir uncertainties, and inflow from watershed, the pumping cost could reduce significantly. Therefore, there is an opportunity to investigate and optimize the water supply reservoir operation in the framework of climate variability and change to establish a more reliable reservoir operating policies for utilizing water of desired quantity over the operational period.

1.6 Thesis Outline

The thesis is organized in six chapters (including the introduction as Chapter 1) as follows;

Chapter 2 presents a summary of the available literatures which are relevant to the development of the optimal operation of reservoir system in the framework of climate variability and change. It briefly introduces a review of rainfall-runoff models, downscaling methods and model selection for assessing climate change impacts on reservoir systems, and mathematical programming related to the optimization of reservoir systems. Emphasized is given to climate change and downscaling methods, describing advantages and limitation of each method and highlighting several comparative studies and models applications that are related to the current study.

Chapter 3 provides a description of study area and availability of data. A comprehensive data collection includes the historical hydrometeorological data for the hydrological and climate downscaling models calibration and analysis, and climate scenario predictor variables consisting of re-analysis data and large-scale atmospheric variables used for statistical downscaling model input.

Chapter 4 describes the methodology used to select the hydrological modeling approach to simulate inflows to the study reservoir, evaluate the downscaling models, develop future climate change scenarios, and derive an optimal operation policy for the reservoir.

Chapter 5 provides the results of a comprehensive assessment of uncertainty for the selection of the best downscaling model to generate the possible future scenarios of local meteorological variables of precipitation and rainfall at representative local station. The results of climate downscaling become the inputs to the calibrated hydrologic model to generate daily streamflow for the investigation on how changes in water availability under future climate scenarios will effect the optimal operation of pumping of multi-source reservoir system.

Chapter 6 concludes the major findings of the work described in the thesis and recommendations for future study.

REFERENCES

Abbott, M.B., J.C. Bathurst, J.C., Cunge J.A., O'Connell, P.E., and Rasmussen, J. (1986). An introduction to the European Hydrological System-Systéme Hydrologique Européen "SHE". 1: History and philosophy of a physically based distributed modelling system, *Journal of Hydrology*. 87, 45-59.

Ahmed, I., Lansey, K.E., (2001). Optimal operation of multi-reservoir systems under uncertainty. In: Phelps D, Shelke G (eds) *Proceedings of world water and environmental resources congress*. EWRI, ASCE

Allamano, P., Hutchinson, D., Whitfield, P.H. (2006). Preliminary Indications of the Transferability of IHACRES Model Parameters in Mountainous Rainfall Driven Rivers. *iEMS Summit on Environmental Modelling & Software*. July 2006. Vermont (USA).

Allen, R.B., and Bridgeman, S.G. (1986). Dynamic programming in hydropower scheduling. *Journal of Water Resources Planning and Management*. 112(3), 339-353.

Allen, G.R., and Liu, G. (2011). IHACRES Classic: Software for the Identification of Unit Hydrographs and Component Flows. *Ground Water*. 49(3), pp 305-308.

Andersen, J., Refsgaard, J.C., and Jensen, K.H. (2001). Distributed hydrological modelling of the Senegal River Basin - model construction and validation. *Journal of Hydrology*. 247, 200-214.

Andreassian, V., Perrin, C., Michel, C., Usart-Sanchez, I. and Lavabre, J. (2001). Impact of imperfect rainfall knowledge on the efficiency and the parameters of watershed models. *Journal of Hydrology*. 250, 206-223.

Archibald, T.W., McKinnon, K.I.M., Thomas, L.C. (1997). An aggregate stochastic dynamic programming model of multireservoir systems. *Water Resources Research*. 33(2), 333–340.

Archibald, T.W, McKinnon, K.I.M., Thomas, L.C. (2006). Modeling the operation of multireservoir systems using decomposition and stochastic dynamic programming. *Naval Research Logistics.* 53(3), 217–225.

Arnell, N.W. (1992). Factors controlling the effects of climate change on river flow regimes in a humid temperate environment. *Journal of Hydrology.* 132, 321–42.

Arnell, N.W (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environ Change*. 14, 31 – 52

Arora, V. (2001). Streamflow simulations for continental-scale river basins in a global atmospheric general circulation model. *Advances in Water Resources.* 24, 775-791.

Baede, A. P. M., Ahlonsou, E., Ding, Y., Schimel, D., Bolin, B., and Pollonais, S. (2001). Climate Change 2001: The Scientific Basis, Contribution from Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. *The Climate System: an Overview.* J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, K. Dai, K. Maskell, and C. A. Johnson (eds.). Cambridge University Press, Cambridge, United Kingdom.

Bardossy, A., Stehlik, J., and Caspary, H.J. (2002). Automated objective classification of daily circulation patterns for precipitation and temperature downscaling based on optimized fuzzy rules. *Climate. Research*. 23(1), 11–22.

Barros, M.T., Tsai, F., Yang, S.L., Lopes, J., Yeh, W. (2003). Optimization of large-scale hydropower system operations. *Journal of Water Resources Planning and Management*. 129(3), 178–188.

Barrow, E.M., Semenov, M.A. (1995). Climate change scenarios with high spatial and temporal resolution for agricultural applications. *Forestry*. 68, 349–360.

Barrow, E., Hulme, M., Semenov, M.A. (1996). Effect of using different methods in the construction of climate change scenarios: examples from Europe. *Climate Research*. 7,195–211.

Barrow, E., and Lee, R. J. (2000). Climate Change and Environmental Assessment Part 2: Climate Change Guidance for Environmental Assessments. *Canadian Environmental Assessment Agency.* Victoria, B.C. (www.ceaa-acee.gc.ca).

Bates, B.C., Kundzewicz, Z.W., Wu, S., and Palutikof, J.P. (2008). *Climate Change and Water*. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Bathurst, J.C. (1986). Physically-based distributed modelling of an upland catchment using the Systéme Hydrologique Européen. *Journal of Hydrology*. 87, 79-102.

Bellman, R. (1957). *Dynamic programming.* Princeton University Press, Princeton.

Bergstrom, S., Forsman, A. (1973). Development of a conceptual deterministic rainfall–runoff model. *Nord. Hydrol*. 4, pp 147–170.

Beven, K. J. and Kirkby, M. J. (1979). A physically based variable contributing area model of catchment hydrology. *Hydrol. Sci. Bull*.,24, pp. 43-69.

Beven, K. J. (1985). *Chapter 13, Distributed Models.* In: Anderson, M. G., and Burt, T. P. (Eds.). *Hydrologic Forecasting*. John Wiley, New York.

Beven, K., Calver, A., and Morris, E.M., (1987). The Institute of Hydrology distributed model. *Institute of Hydrology Report 98*, Wallingford, UK.

Beven, K.J. (1989). Changing ideas in hydrology - The case of physically-based models. *Journal of Hydrology,* 105**,** 157-172.

Beven, K. J. and Binley, A. (1992). Future of distributed models - Model calibration and uncertainty prediction. *Hydrological Processes*, 6, 279-298.

Beven, K.J. (1993). Prophecy, reality and uncertainty in distributed hydrological modeling. *Advances in Water Research*. 16, 41-51.

Beven, K. J. (2001). *Rainfall-runoff modelling: The Primer.* John Willey and Sons, Chichester, UK. Pp 360.

Bhaskar, N. R., and Whitlatch Jr, E. E. (1980). Derivation of monthly reservoir release policies. *Water Resources Research.* 16(6), 987-993.

Bhaskaran, B., Jones, R.G., Murphy, J.M., and Noguer, M. (1996). Simulations of the Indian summer monsoon using a nested regional climate model: Domain size experiments. *Climate Dynamics.* 12, 573-588.

Booij, M.J. (2005). Impact of climate change on river flooding assessed with different spatial model resolution. *Journal of Hydrology*. 303(1-4), pp 176-198.

Box, G.E.P., and Jenkin, G.M. (1970). *Time series analysis, forecasting and control.* Holden-Bay Inc., San Francisco.

Braga, B.P.F., Yeh, W.W-G., Becker, L., and Barros, M.T.L. (1991). Stochastic optimization of multiple-reservoir system operation. *Journal of Water Resources Planning and Management*. 117(4), 471–481.

Bras, R.L., Buchanan, R., Curry, K.C. (1983). Real time adaptive closed loop control of reservoirs with the High Aswan Dam as a case study. *Water Resources Research*. 19(1), 33-52.

Brown, M.B,. and Forsythe, A.B. (1974). Robust tests for equality of variances. *Journal of the American Statistical Association.* 69, 364–367.

Burian. S.J., Durrans, S. R., Nix, S.J., and Pitt. R.E. (2001). Training artificial neural network to perform rainfall disaggregation. *Journal of Hydrologic Engineering.* 6(1), pp. 43-51.

Burton, H. (1998). *Reservoir Inflow Forecasting Using Time Series and Neural Network Models*. M. Eng. Thesis, McGill University, Montreal.

Burnash, R.J.C. (1995). The NWS river forecast system-catchment modeling. In: Singh, V.J., (Ed.), *Computer Models of Watershed Hydrology*, Water Resources Publication, Highlands Ranch, Colorado, pp. 311–366.

Burnash, R., and Ferral, L. (1996). Conceptualization of the Sacramento Soil Moisture Accounting Model, NWSRFS Users Manual, Part II.3, *National Weather Service*, NOAA, DOC, Silver Spring, MD.

Carlile, P.W., Croke, B.F.W., Jakeman, A.J., and Lees, B.G. (2004). Development of a semi-distributed catchment hydrology model for simulation of land-use change streamflow and groundwater recharge within the Little river catchment, NSW. In I.C.Roach (ed.). *Regolith, 2004.* CRC LEME. pp. 54–56.

Capdevila, A.S., and Valdes, J.B. (2007). An alternative approach to the operation of multinational reservoir systems: Application to the Amistad and Falcon system (Lower Rio Grande/R´ıo Bravo). *Water Resources Management*. 21, 677–698.

Carter, T.R., Parry, M.L., Harasawa, H., and Nishioka, S. (1994). *IPCC technical guidelines for assessing climate change impacts and adaptions. IPCC special report to Working Group II of IPCC.* London: University College London, and Tsukaba, Japan: Centre for Global Environmental Research.

Carter, T. R., Alfsen, K., Barrow, E., Bass, B., Dai, X., Desanker, S. R., Gaffin, F., Giorgi, M., Hulme, M., Lai, M., Mata, L. J., Mearns, L. O., Mitchell, J. F. B., Morita, T., Moss, R., Murdiyarso, J. D., Pabon-Caicedo, J. D., Palutikof, J., Parry, M. L., Rosenzweig, C, Seguin, B., Scholes, R. J., and Whetton, P. H. (2007). *General Guidelines on the use of Scenario Data for Climate Impact and Adaptation Assessment. Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA) Intergovernmental Panel on Climate Change.* Finnish Environmental Institute, Helsinki, Finland.

Cavazos, T. (1999). Large-scale circulation anomalies conducive to extreme precipitation events and derivation of daily rainfall in Northeastern Mexico and Southeastern Texas. *Journal of Climate*. 12, 1506–1523.

Charles, S.P., Bates, B.C., Smith, I.N. and Hunges, J.P. (2004). Statistical downscaling of daily precipitation from observed and modelled atmospheric fields. *Hydrological Processes.* 18, 1373-1394.

Chen, L. (2003). Real time genetic algorithm optimization of long term reservoir operation. *Journal of the American Water Resources Association.* 39(5), 1157-1165.

Chen, J., Zhang, X.C., Liu, W.Z., and Li, Z. (2009). Evaluating and extending CLIGEN preciptation generation for the loess plateau of China. *Journal of American Water Resources Association*. 45 (2), 378-396.

Chiew, F.H.S., Stewardson, M.J. and McMahon, T.A. (1993). Comparison of six rainfall-runoff modelling approaches. *Journal of Hydrology,* 147, 1-36.

Chiew, F., and McMahon, T. (1994). Application of the daily rainfall runoff model MODHYDROLOG to 28 Australian catchments. *Journal of Hydrology*. 153, 383-416.

Chiu, Y.C., Chang, L.C., and Chang, F.J. (2007). Using a hybrid genetic algorithm-simulated annealing algorithm for fuzzy programming of reservoir operation. *Hydrological Processes.* 21(23), 3162–3172.

Christensen, J. H., Hewitson, B., Busuic,A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R.K., Kwon, W.-T., Laprise, R., Magana Rueda, V., Mearns, L., Menendez, C.G., Raisanen, J., RIinke, A., Sarr, A., and Whetton, P. (2007). Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In *Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

Clarke, R.T. (1973). A review of mathematical models used in hydrology, with some observations on their calibration and use. *Journal of Hydrology*. 19, pp 1–20.

Clausen, B. and Biggs, B.J.F. (2000). Flow Variables for Ecological Studies in Temperature Stream: Groupings based on Covariance. *Journal of Hydrology*. 237, 184-197.

Conover W.J. (1980). *Practical Non-parametrics Statistics*. 2nd edition, John Wiley and Sons, New York

Corte-Real, J. B., Qian, B., and Xu, H. (1999). Circulation patterns, daily precipitation in Portugal and implications for climate change simulated by the second Hadley Centre GCM. *Climate Dynamics*. 15, 921-935.

Coulibaly, P., Anctil, F., Aravena, R., and Bobee, B. (2001). ANN modeling of water table depth fluctuations. *Water Resources Research*. 37(4), 885-896.

Coulibaly, P., Yonas, B., Dibike, Y., and Anctil, F. (2005). Downscaling precipitation and temperature with temporal neural networks. *Journal of Hydrometeorology, American Meteorological Society*. 6(4), 483-496.

Crane, R.G., and Hewitson, B.C. (1998). Doubled CO_2 precipitation changes for the Susquehanna basin: down-scaling from the genesis general circulation model. *International Journal of Climatology*. *18*, 65-76.

Crawley, P. D., Graeme C., and Dandy, G.C. (1993). Optimal operation of multiple-reservoir system. *Journal of Water Resources Planning and Management*. 119 (1), 1-17.

Croke, B.F.W., W.S. Merritt and A.J. Jakeman. (2003). A dynamic model for predicting hydrologic response to land cover changes in gauged and ungauged catchments. *Journal of Hydrology*. 291, 115–131.

Croke, B. F. W. and Jakeman, A. J. (2004). A catchment moisture deficit module for the IHACRES rainfall-runoff model. *Environmental Modelling & Software,* 19, 1-5.

Croke, B. F. W., Andrews, F., Spate, J., and Cuddy, S. (2004). *IHACRES: Identification of unit hydrographs and component flows from rainfall, evaporation* *and streamflow data user guide*. iCAM Centre and CSIRO Land and Water. The Australian National University, Canberra.

Croke, B. F. W. and Norton, J. P. (2004). Regionalisation of rainfall-runoff model. In Pahl, C., Schmidt, S., Rizzoli, A.E. and Jakeman, A.J. (Eds.), *Complexity and Integrated Resources Management, Transactions of the 2nd Biennial Meeting of the International Environmental Modelling and Software Society,* vol. 3, pp. 1201-1207. iEMSs, June 2004.

Croke, B. F. W., Andrews, F., Jakeman, A. J., Cuddy, S. and Luddy, A. (2005). Redesign of the IHACRES rainfall-runoff model. *Engineers Australia. 29th Hydrology and Water Resources Symposium* 21-23 February 2005, Canberra

Croke, B.F.W., Andrews, F., Jakeman, A.J., Cuddy, S.M. and Luddy, A. (2006). IHACRES Classic Plus: A redesign of the IHACRES rainfall-runoff model. *Environmental Modelling & Software*. 21, 426-427.

Crygier, J., and Stedinger, J. (1985). Algorithms for optimizing hydropower system operation. *Water Resources Research*. 21(1), 1-10.

Cubasch, U., Meehl, G. A., Boer, G. J., Stouffer, R. J., Dix, M., Noda, A., Senior, C. A., Raper, S., and Yap, K. S. (2001). *Projections of Future Climate Change. Climate Change 2001: The Scientific Basis*. In J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, K. Dai, K. Maskell, and C. A. Johnson, (eds.), Cambridge University Press, Cambridge, United Kingdom.

Cunnane, C. (1978). Unbiased Plotting Positions - A Review. *Journal of Hydrology* 37(3/4).

Daniel W.W., (1978). *Applied Non-parametric Statistics*. Houghton Mifflin Company, Boston

DHI (Danish Hydraulic Institute). (1992). *MIKE 11 NAM Reference Manual*. Horsholm, Denmark.

DHI (Danish Hydraulic Institute). (1992). *MIKE 11 NAM User Manual*. Horsholm, Denmark.

Dankers, R., Christensen, O.B., Feyen, L., Kalas, M., and de Roo, A. (2007). Evaluation of very high resolution climate model data for simulating flood hazards in the Upper Danube Basin. *Journal of Hydrology*. 347, 319-331.

Dawdy D.R. (1983). A Review of Rainfall-Runoff Modeling. *Experiences in the development and Application of Mathematical Models in Hydrology and Water Resources in Latin America* (Proceedings of the Tegucigalpa Hydromath Symposium, September 1983). IAHS Publication .No. 152.

Dawson, C.W. and Wilby, R.L. (2007). Statistical Downscaling Model, version 4.2. Department of Geography , Lancaster University, UK.

DID (Department of Irrigation and Drainage Malaysia) (2000). *Chapter 14 – Flow Estimation and Routing*. Urban Stormwater Management Manual for Malaysia.

Department of Statistics Malaysia. (2010). Population and Housing Census of Malaysia, Preliminary Count Report. Putrajaya.

Dibike, Y. B., and Coulibaly, P. (2005). Hydrologic impact of climate change in the Saguenay watershed: comparison of downscaling methods and hydrologic models. *Journal of Hydrology,* 307(1-4), 145-163.

Dibike, Y.B., and Coulibaly, P. (2006). Temporal neural networks for downscaling climate variability and extremes. *Neural Networks*. 19,135-144.

Dibike, Y. B., and Coulibaly, P. (2007). Validation of hydrologic models for climate scenario simulation: The case of Saguenay watershed in Quebec. *Hydrological Processes.* 21(23), 3123-3235.

Dibike, Y. B., Gachon1, P., St-Hilaire, A., Ouarda, T. B. M. J, and Nguyen, V T.-V (2008). Uncertainty analysis of statistically downscaled temperature and precipitation regimes in Northern Canada. *Theoretical and Applied Climatology*. 91, 149–170.

Dorfman, R. (1962). *Mathematical model: The multi-structure approach, in design of water resource systems edited by* A. Maass, Harvard University Press, Cambridge, Mass.

Duranyildiz, I., Önöz, B., and Bayazit M. (1999a). A Chance-Constrained LP Model for Short term reservoir Operation Optimisation. *Turkish Journal of Engineering and Environmental Science.* 23, 181-186.

Duranyildiz, I., Bayazit, M., Önöz, B., Bayazit M., Avci, I., and Oguz, B. (1999b). Optimum opearion management of the Istanbul Water supply System. *Turkish Journal of Engineering and Environmental Science.* 23, 247-254.

Dye, P. J. and Croke, B. F. W. (2003). Evaluation of streamflow predictions by the IHACRES rainfall-runoff model in two South African catchments. *Environmental Modelling & Software.* 18, 705-712.

El-Kady, A.I. (1989). Watersheds models and their applicability to conjunctive use management. *Journal of American Water Resources Association.* 25(1), pp. 25-37.

Eum, H., and Simonovic, S.P. (2010). Integrated reservoir management system for adaptation to climate change: The Nakdong River Basin in Korea. *Water Resources Management*, 24, 3397-3417.

Evans, J.P., and Jakeman, A.J. (1998). Development of a simple, catchment-scale, rainfall evapotranspiration-runoff model. *Environmental Modelling & Software*. 13, 385–393.

Evans, J., and Schreider, S. (2002). Hydrological impacts of climate change on inflows to Perth, Australia. *Climatic Change.* 55, 361-393.

Evans, J. P. (2003). Improving the characteristics of streamflow modeled by regional climate models. *Journal of Hydrology.* 284, 211-227.

Ewen, J., and Parkin, J. (1996). Validation of catchment models for predicting land-use and climate change impacts 1. Methods. *Journal of Hydrology*. 175, 583-594.

Fausett, L. (1994). *Fundamentals ofNeural Networks,* Prentice Hall, Englewood , Cliffs,N.J.

Fleming, G. (1975). *Computer simulation techniques in hydrology.* Elsevier, New York.

Fowler, H.J., Kilsby, C.G., and O'Connell, P.E. (2000). A stochastic rainfall model for the assessment of regional water resource systems under changed climatic conditions. *Hydrological and Earth Systems Science*. 4, 263-282.

Fowler, H.J., Blenkinsop, S., and Tebaldi, C. (2007). Linking climate change modeling to impacts studies: recent advances in downscaling techniques for hydrological modeling. *International Journal of Climatology*. 27, 1547-1578.

Franchini, M., and Pacciani, M. (1991). Comparative analysis of several conceptual rainfall-runoff models. *Journal of Hydrology*. 122, 161- 219.

Freeze, R.A., Harlan, R.L. (1969). Blueprint for a physically-based digitally simulated, hydrologic response model. *Journal of Hydrology* 9: 237–258.

Gachon, P., St-Hilaire, A, Ouarda, T, Nguyen, V.T.V, Lin, C, and Milton, J. (2005). *A first evaluation of the strength and weaknesses of statistical downscaling methods for simulating extremes over various regions of eastern Canada.* Subcomponent, Climate Change Action Fund (CCAF), Environment Canada, Final report, Montréal, QC 209

Gates, W.L., Mitchell J.F.B., Boer G.J., Cubasch, U. and Meleshko, V.P. (1992). *Climate modeling, climate prediction and model validation*. In Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment, Houghton J.T., Callander, B.A. and S.K. Varney (eds). Cambridge University Press. Cambridge, United Kingdom.

Georgiou, P. E., Papamichail, D. M., and Vougioukas, S.G. (2006). Optimal irrigation reservoir operation and simultaneous multi-crop cultivation area selection using simulated annealing. *Irrigation and Drainage*. 55(2), 129–144.

Giorgi, F., Brodeur C., Shields and G.T. Bates. (1994). Regional climate change scenarios over the US produced with a nested regional climate model. *Journal of Climate.* 7, 375-399.

Giorgi, F., B. Hewitson, J. Christensen, C. F, Jones, R., Hulme, M., Mearns, Von Storch, L., H., and Whetton, P. (2001). *Regional climate information evaluation and projections, in Climate Change: The scientifc basis*. In Houghton, J. T., *et al.*, (Eds.), Cambridge University Press.

Gordon, C, Cooper, C., Senior, C.A., Banks, H., Gregory, J.M., Johns, T.C., Mitchell, J.F.B., and Wood, R.A. (2000). The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. *Climate Dynamics* 16 (2–3), pp 147–168.

Govindaraju, R. S. (2000). Artificial Neural Networks in Hydrology. *Journal of Hydrologic Engineering.* 5(2), 115-137.

Grayson, R.B., Moore, I.D., and McMahon, T.A. (1992). Physically based hydrologic modeling 1. A terrain-based model for investigative purposes. *Water Resources Research*. 28(10), pp 2939-2658.

Grotch, S.L, and MacCracken, M.C. (1991). The use of general circulation models to predict regional climatic change. *Journal of Climate.* 4, 286–303.

Hall, W. A., Butcher, W.S., and Esogbu, A. (1968). Optimization of operation of a multiple-purpose reservoir by dynamic programming. *Water Resources Research*. 4(3), 471-477.

Hanson, C.E., Holt, T., and Paluikof, J.P. (2004). An Integrated Assessment of the potential for change in storm activity over Europe: Implications for insurance and forestry in the UK. *Tyndall centre for climate change research technical report l2*, pp 10-11.

Harpham, C., and Wilby, R. (2005). Multi-site downscaling of heavy daily precipitation occurrence and amounts. *Journal of Hydrology*. 312, 235-255.

Harun, S., Kassim, A.H. and Nguyen, V.T.V. (1997). Inflow Forecasting with Neural Network and ARIMA Models. *Proceedings of the 2nd Int. Conf on the App. Of Num. Method in Eng., June* 1997. Serdang, Malaysia, pp. 540-550.

Hashmi, M.Z, Shamseldin, A.Y, and Melville, B. (2009). Statistical downscaling of precipitation: state-of-the-art and application of bayesian multi-model approach for uncertainty assessment. *Hydrological and Earth System Sciences*. 6, 6535–6579.

Hay, L.E., and Clark, M.P. (2003). Use of statistically and dynamically downscaled atmospheric model output for hydrologic simulations in three mountainous basins in the western United States. *Journal of Hydrology*. 282, 56-75.

Hay, L.E., McCabe, G.J., Wolock, D.M. and Ayers, M.A. (1991). Simulation of precipitation by weather type analysis. *Water Resources Research.* 27, 493–501.

Haykin, S. (1994). *Neural Networks: A Comprehensive Foundation.* Maxwell Macmillan International, NY, USA.

Haylock, M.R., Cawley, G.C., Harpham, C., Wilby, R.L., and Goodes, C.M. (2006). Downscaling heavy precipitation over the United Kingdom: a comparison of dynamical and statistical methods and their future scenarios. *International Journal of Climatology*. 26(10), 1397-1415.

Hellstrom, C., Chen, D., Achberger, C., and Raisanen, J. (2001). Comparison of climate change scenarios for Sweden based on statistical and dynamical downscaling of monthly precipitation, *Climate Research*. 19, 45-55.

Hickey, J.T. and Diaz, G.E. (1999). From Flow to Fish to Dollar: An integrated approach to water allocation. *Journal of American Water Resources Association.* 35(5), 1053-1067.

Hiew, K. (1987). *Optimization algorithms for large scale multi-reservoir hydropower systems.* PhD dissertation, Dept. of Civil Engineering, Colorado State University, Fort Collins, Colo.

Houghton, J.T. (2001). *Climate change 2001: the scientific basis: contribution of working group I to the third assessment report of the intergovernmental panel on climate change (Houghton, J. T.,Ed.).* Cambridge: Cambridge University Press.

Houghton, J.T., Callander, B.A., and Varney, S.K. (1992). *Climate Change 1992: The IPCC Supplementary Report*. Cambridge University Press.

Hsu, K., Gupta, H.V., and Sorooshian (1995). Artificial Neural Network Modeling of the Rainfall-RunoffProcess. *Water Resources Research.* 31(10), 2517-2530.

Huang, W.C., and Yang, F.T. (1998). Streamflow estimation using Kriging. *Water Resources Research*. 34(6), 1599–1608.

Hughes, J.P., Guttorp, P., and Charles S.P. (1999). A non-homogeneous hidden Markov model for precipitation occurrence. *Applied statistics*, 48, 15-30.

Hung, N.Q., Babel, M.S., Weesakul, S., and Tripathi, N.K. (2009). An artificial neural network model for rainfall forecasting in Bangkok, Thailand. *Hydrology and Earth System Sciences*. 13, 1413-1425.

Huth R, Kliegrova S, and Metelka, L. (2008). Non-linearity in statistical downscaling: does it bring an improvement for daily temperature in Europe? *International Journal of Climatology*. 28, 465-477.

Imrie, C.E., Durucan, S., and Korre, A., (2000). River flow prediction using artificial neural network: generalisation beyond the calibration range. *Journal of Hydrology* 233, 138-153.

IPCC-TGCIA: (1999). *Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment.Version 1*. In Carter, T. R., Hulme, M., and Lal, M., Intergovernmental Panel on Climate Change, Task Group on Scenarios for Climate Impact Assessment, 69 pp.

IPCC. (2000). *Special Report on Emissions Scenarios, A Special Report of Working Group III of the Intergovernmental Panel on Climate Change,* Cambridge University Press, New York.

IPCC (Intergovernmental Panel on Climate Change). (2001): *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. In J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, (Eds.). Cambridge University Press, Cambridge, 1032 pp

IPCC. (2001). *Climate Change 2001: The Scientific Basis. Contribution of the Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, United Kingdom.

IPCC (Intergovernmental Panel on Climate Change). (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Summary for Policymakers, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Millers, (eds.). Cambridge University Press, Cambridge, United Kingdom.

Jakeman, A. J., Littlewood, I. G. and Whitehead, P. G. (1990). Computation of the instantaneous unit hydrograph and identifiable component flows with application to two small upland catchments. *Journal of Hydrology*. 117, 275-300.

Jakeman, A.J. and Hornberger, G.M. (1993). How Much Complexity is Warranted in a Rainfall-Runoff Model?. *Water Resources Research.* 29(8), 2637-2649.

Jakeman, A.J., Hornberger, G.M., Schreider, S.Y., and Ye, W. (1994). Assessing the Impacts of Climate Variability and Climate Change on Water Resources using Rainfall-Runoff models. In Jakeman, A J and Pittock, A. B. (Eds), *Climate Impact Assessment Methods for Asia and the Pacific,* Australian International Development Assistance Bureau, Canberra.

Jakeman, A.J., Post, D.A., and Beck, M.B. (1994). From data and theory to environmental model: the case of rainfall runoff. *Environmetrics*. 5, 297–314.

Jakeman, A.J., Green, T.R., Beavis, S.G., Zhang, L., Dietrich, C.R., and Crapper, P.F. (1999). Modelling upland and in-stream erosion, sediment and phosphorus transport in a large catchment. *Hydrological Processes.* 13(5), 745–752.

Janssen, P.H.M, and Heuberger, P.S.C. (1995). Calibration of process-oriented models. Ecological modeling 83, 55-66

Jiang, T., Chen, Y.D., Xu, C., Chen, X., and Singh, V.P. (2007). Comparison of hydrological impacts of climate change simulated by six hydrological models in the Dongjiang Basin, South China. *Journal of Hydrology*. 336, 316-333.

Jones, R.G., Murphy J.M., and Noguer, M. (1995). Simulation of climate change over Europe using a nested regional climate model. Part 1: Assessment of control climate, including sensitivity to location of lateral boundaries. *Quarterly Journal of the Royal Meteorological Society.* 121, 1413-1449.

Jothiprakash, V., and Shanthi, G. (2006). Single reservoir operating policies using genetic algorithm. *Water Resources Management*. 20(6), 917–929.

Juraj Cunderlik (2003). *Hydrologic Model Selection for the CFCAS Project: Assessment of water resources risk and vulnerability to changing climate condition.* Water Resources Research Report. Department of Civil and Environmental Engineering,The University of Western Ontario,

Kaastra, I., and Boyd, M. (1996). Design a neural network for forecasting financial and economic time series. *Neurocomputing*. 10, pp, 215-236.

Kallen, E., Kattsov, V., Walsh, J., and Weatherhead, E. (2001). Report from the Arctic Climate Impact Assessment Modelling and Scenario Workshop. *Arctic Climate Impact Assessment Modelling and Scenarios Workshop.* ACIA Secretariate, Fairbanks, Stockholm, Sweden.

Kalnay, E., Kanamitsu, R., Kistler, R., Collins, W., Deaven, L., Gandin, M., Iredell, S., Saha, G., White, J., Woollen, Y., Zhu, M., Chelliah, M., Ebisuzaki, W., Higgins, W., Janowiak, K., Mo, C, Ropelewski, J., Wang, A., Leetmaa, R., Reynolds, R., Jenne, R., and Joseph, D. (1996). The NCEP/NCAR 40-year reanalysis project. *Bulletin of American Meteorological Society,* 77, 437-471.

Karamouz M, and Houck, M. H. (1982). Annual and monthly reservoir operating rules generated by deterministic optimization. *Water Resources Research*. 18(5), 1337-1344.

Karamouz, M., Houck, M. H., and Delleur, J. W. (1992). Optimization and simulation of multiple reservoir systems. *Journal of Water Resources Planning and Management*. 118(1), 71-81.

Karamouz, M., Vasiliadis, H.V. (1992). Bayesian stochastic optimization of reservoir operation using uncertain forecasts. *Water Resources Research*. 28(5), 1221-1232.

Karamouz, M., Szidarovszky, F., Zahraie, B. (2003). *Water Resources System Analysis*. Bota Racon, Florida. Lewis Publishers.

Karamouz, M., Fallahi, M., S. Nazif, S., and Farahani, M.R. (2009a). Long Lead Rainfall Prediction Using Statistical Downscaling and Artifcial Neural Network Modeling *Transaction A: Civil Engineering, Scientia Iranica*. 6(2), 165-172.

Karamouz, M., Rouhanizadeh, B., Taheriyoun, M. and F. Emami. (2009b). Impact of Climate Change on Sediment Loads Transport in a Watershed Scale: A Case Study. *Proceedings of ICWR Conference, Malaysia*.

Karamouz, M, Moridi, A, and Nazif, S. (2010). *Urban Water Engineering and Management*. CRC Press.

Karamouz, M., Imen, S., and Nazif, S. (2012). Development of a Demand Driven Hydro-climatic Model for Drought Planning. *Water Resources Management.* 26, 329–357.

Kavvas, M.L., Chen, Z.Q., and Ohara, N. (2006). *Study of the impact of climate change on the hydrologic regime and water resources of Peninsular Malaysia*. California Hydrologic Research Laboratory, Davis, California U.S.A.

Kavvas, M.L., Chen, Z.Q., Tan, L., Soong, S.T., Terakawa, A., Yoshitami, J., and Fukami, K. (1998). A regional scale land surface parameterization based on areally-averaged hydrological conservation equation. *Hydrological Science Journal*. 43(4), 611-631.

Kelman, J., Stedinger, J., Cooper, L., Hsu, E., and Yusan, S.Q. (1990). Sampling stochastic dynamic-programming applied to reservoir operation. *Water Resources Research*. 26(3), 446-454.

Kenabatho, P.K., McIntyre, N.R., and Wheater, H.S. (2009). Impacts of rainfall uncertainty on water resources planning models in the upper Limpopo basin, Botswana. *New Approaches to Hydrological Prediction in Data Sparse Regions (Proc. Of Symposium HS.2 at the Joint IAHS and IAH Convention, Hyderabad, India).* September 2009. IAHS Publ. 333.

Kendall M.G. (1938). A new measure of rank correlation. Biometrika, 30(1-2), 81-93.

Kendall, M.G. (1975). *Rank correlation methods,* 4th ed. Charles Griffin, London.

Khan, M.S., Coulibaly, P., Dibike, Y. (2006a). Uncertainty analysis of statistical downscaling methods. *Journal of Hydrology*. 319, 357-382.

Khan, M.S., Coulibaly, P., Dibike, Y. (2006b). Uncertainty analysis of statistical downscaling methods using Canadian Global Climate Model predictors. *Hydrological Processes*. 20, 3085-3104.

Kidson, J. W., and Thompson, C. S. (1998). A comparison of statistical and model-based downscaling techniques for estimating local climate variations. *Journal of Climate*. 11, 735-753.

Kilsby, C.G., Cowpertwait, P.S.P., O'Connell, P.E., and Jones, P.D. (1998). Predicting rainfall statistics in England and Wales using atmospheric circulation variables. *International Journal of Climatology*. 18, 523-539.

Kim, Y,O., and Palmer, R.N. (1997). Value of seasonal flow forecasts in Bayesian stochastic programming. *Journal of Water Resources Planning and Management*. 123(6), 327-335.

Kistler, R., Kalnay, E., Collins, W., Saha, S, White, G, Woollen, J, Chelliah, M, Ebisuzaki, W, Kanamitsu, M, Kousky, V, Huug van den Dool, H.V.D., Jenne, R, and Michael Fiorino, M. (1999). The NCEP/NCAR 50-year reanalysis. *Bulletin of American Meteorological Society. pp 247-267.*

Kokkonen, T.S., Jakeman, A.J., Young, P.C., and Koivusalo, H.J. (2003). Predicting daily flows in an ungaged catchments: model regionalization from catchment descriptors at the Coweeta Hydrologic Laboratory, North Carolina. *Hydrologic Processes.* 17, 2219-2238.

Koren, V., Reed, S., Smith, M., Zhang, Z. and Seo, D.J. (2004). Hydrology laboratory research modeling system (HL-RMS) of the US national weather service. *Journal of Hydrology*. 291, 297-318.

Kostopoulou, E., Giannakopoulos, C., Anagnostopoulou, C., Tolika, K., Maheras, P., Vafiadis, M., and Founda, D. (2007). Simulating maximum and minimum temperature over Greece: a comparison of three downscaling techniques. *Theoretical and Applied Climatology*. 90, 65-82.

Krause, P., Boyle, D.P., and Bäse, F. (2005). Comparison of different efficiency criteria for hydrological model assessment. *Advances in Geosciences*. 5, 89–97.

Kunstmann, H, Heckl, A, and Rimmer, A. (2006). Physically based distributed hydrological modelling of the Upper Jordan catchment and investigation of effective model equations. *Advances in Geoscience*. 9, 123–130.

Labadie, J. W. (1997). Reservoir system optimization models. *Water Resources. Update (Journal of Contemporary Water Research and Education)*. 108, 83-110.

Labadie, J.W. (2004). Optimal operation of multireservoir systems: State-of-the-art review. *Journal of Water Resources Planning and Management*. *ASCE* 130(2), 93–111.

Lambert, S. J., and Boer, G.J. (2001). CMIP1 Evaluation and Intercomparison of Coupled Climate Models. *Climate Dynamics*, 17: 83-106.

Lau, L., Young, R.A., McKeon, G., Syktus, J., Duncalfe, F., Graham, N., and McGregor, J. (1999). Downscaling global information for regional benefit: coupling spatial models at varying spatial and time scales. *Environmental Modelling and Software*. 14, 519–529.

Lawless, C., and Semenov, M.A. (2005). Assessing lead-time for predicting wheat growth using a crop simulation model. *Agric for Meteorology*. 135,302–313.

Leavesley, G.H., Lichty, R.W., Troutman, B.M., and Saindon, L.G. (1983). Precipitation-runoff modeling system. User manual. *USGS water resources investigations report 83-4238*, USGS, Denver.

Lee, H., McIntyre, N.R., Wheater, H.S., and Young, A R. (2004). Selection of conceptual models for regionalisation of rainfall runoff relationships. *Journal of Hydrology*. 312(1-4),125-147.

Legates, D. R., and McCabe, G. J. (1999). Evaluating the use of‘goodness-of-fit measures in hydrologic and hydroclimatic model validation. *Water Resources. Research.* 35(1), 233–241.

Leggett, J., Pepper, W.J. and Swart, R.J. (1992). Emissions Scenarios for the IPCC: An Update. In *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment* (Eds.) Hughton, J.T., Callander, B.A. and Varney, S.K.). Cambridge University Press, Cambridge. pp.69-95.

Letcher, R.A., Jakeman, A.J., Merritt, W.S., McKee, L.J., Eyre, B.D., and Baginska, B. (1999). Review of techniques to estimate catchment exports, *Environmental Protection Authority, Sydney*.

Levene, H (1960). Robust tests for equality of variances. in Ingram Olkin, Harold Hotelling et al. *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*. Stanford University Press. pp. 278–292

Li, X. G., and Wei, X. (2008). An improved genetic algorithm-simulated annealing hybrid algorithm for the optimization of multiple reservoirs. *Water Resources Management*. 22(8), 1031–1049.

LINDO Systems Inc. (2010). *LINGO the modeling language and optimizer, user's guide*. Chicago, Illinois. LINDO Systems Inc.

Linsley, R.K. (1982). *Rainfall-runoff models – an overview in Rainfall-runoff relationship, V.P. Singh (ed.)*. Water Resources Publications, Littleton, Co. pp. 3-22.

Little, K.W., McCrodden, B. J. (1989). Minimization of raw water pumping costs using MILP. *Journal of Water Resources Planning and Management*. 115 (4), 511-522.

Littlewood, I.G. (2002). Improved unit hydrograph characterisation of the daily flow regime (including low flows) for the River Teifi, Wales: towards better rainfall-streamflow models for regionalisation. *Hydrology and Earth System Sciences.* 6, 899-911.

Littlewood, I.G., Clarke, R. T., Collischonn, W. and Croke, B. F. W. (2007). Predicting daily streamflow using rainfall forecasts, a simple loss module and unit hydrographs: Two Brazilian catchments. *Environmental Modelling & Software*. 22, 1229-1239.

Littlewood, I.G. (2003). Improved unit hydrograph identification for seven Welsh rivers: implications for estimating continuous streamflow at ungauged sites. *Hydrological Sciences Journal*. 48(5), 743-762.

Littlewood, I.G., K. Down, J.R. Parker and Post, D.A. (1997). *IHACRES: Catchment-Scale Rainfall-Streamflow Modelling Version 1.0 User Guide*. Institute of Hydrology, Centre for Ecology and Hydrology, Wallingford, Oxon, UK. pp.94.

Liu, X, Coulibaly, P., and Evora, N. (2008). Comparison of data-driven methods for downscaling ensemble weather forecasts. *Hydrology and Earth System Sciences*. 12, 615-624.

Loucks, D.P., Stedinger, J.R., and Haith, D. A. (1981). *Water Resources System Planning and Analysis*. Englewood Cliffs, New Jersey. Prentice Hall

Maier, H.R., and Dandy, G.C. (1996). The Use ofArtificial Neural Networks for the Prediction ofWater Quality Parameters. *Water Resources Research.* 32(4), 1013-1022.

Malaysia Meteorological Department (2009). *Climate Change Scenario for Malaysia 2001-2099*. Malaysian Meteorological Department, Scientific Report,January 2009.. 68 pp.

Mann, H.B. (1945). Non-parametric test against trend. Econometrica, 13(3), 245-259,

Mankin, K.R., Koelliker, J.K., and Kalita, P.K., (1999). Watershed and lake water quality assessment: An integrated modeling approach. *Journal of Water Resources Association*. 35(5), 1069-1088.

Martin, Q.W. (1987). Optimal daily operation of surface-water systems. *Journal of Water Resources Planning and Management*. 113(4), 453-470.

Martin, Q.W. (1983). Optimal operastion of multiple reservoir systems. *Journal of Water Resources Planning and Management*. 19(1), 58-71.

Maurer, E.P., and Hidalgo, H. G. (2008). Utility of daily vs. monthly large-scale climate data: an intercomparison of two statistical downscaling methods. *Hydrol. Earth Syst. Sci.* 12, 551–563.

Mays, L.W., and Tung, Y.K. (2002). *Hydrosystems Engineering and Management*. Water Resources Publications.

McIntyre, N.R., and Al-Qurashi, A. (2009). Performance of ten rainfall–runoff models applied to an arid catchment in Oman. *Environmental Modelling & Software*. 24, 726-738.

Md. Hazrat Ali, Shui, L.T., Yan, K.C., and Aziz F.E. (2000). Modelling evaporation and evapotranspiration under temperature change in Malaysia. *Pertanika J. Sci. & Technology*. 8(2): 191-204.

Md. Hazrat Ali, and Shui, L.T. (2009). Potential evapotranspiration model for Muda Irrigation Project, Malaysia. *Water Resources Management*. 23:57–69.

Mearns, L.O., Rosenzweig, C., and Goldberg, R. (1992). Effect of changes in interannual climatic variability of CERES-Wheat yields: Sensitivity and 2xCO_2 general circulation model studies. *Agricultural and Forest Meteorology*. 62,159-189.

Mearns, L.O., Bogardi, I., Giorgi, F., Matyasovszky, I., and Palecki, M. (1999). Comparison of climate change scenarios generated from regional climate model experiments and statistical downscaling. *J. Geophysical Research Atmosphere*. 104, 6603-6621.

Mearns, L.O., Hulme, M., Carter, T. R., Leemans, R., Lai, M., Whetton, P., Hay, L., Jones, R.N., Katz, R., Kittel, T., Smith, R., and Wilby, R.L. (2001). *Climate Scenario Development. Climate Change 2001: The Scientific Basis.* Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai, K., Maskell, K., and Johnson, C. A. (eds.). Cambridge University Press, Cambridge, United Kingdom.

Mearns, L.O., Giorgi, F., Whetton, P., Pabon, D., Hulme, M., and Lal, M. (2004). Guidelines for use of climate scenarios developed from regional climate model experiments. *Tech. rep., Data Distribution Centre of the IPCC.*

Mehrotra, R., Sharma, A., and Cordery, I. (2004). Comparison of two approaches for downscaling synoptic atmospheric patterns to multisite precipitation occurrence. *Journal of Geophysical Research.* 109**,** D14107, doi:10.1029/2004JD004823.

Mendes, D., and Marengo, J.A. (2010). Temporal downscaling: a comparison between artificial neural network and autocorrelation techniques over the Amazon Basin in present and future climate change scenarios. *Theoretical and Applied Climatology*. 100(3-4), 413-421.

Merritt, W.S., Letcher, R.A., and Jakeman, A.J. (2003). A review of erosion and sediment transport models. *Environmental Modelling & Software*. 18, pp. 761–799.

Milly, P.C.D., Dunne ,K.A., Vecchia, A.V. (2005). Global pattern of trends in streamflow and water availability in changing climate. *Nature*. 438 (7066), 347-350.

Minitab Inc. (2010). *Minitab Version 12 Statistical Software*, State College, PA: Minitab, Inc.

Minns, A.W., Hall, M.J. (1996). Artificial neural networks as rainfall-runoff model. *Hydrological Sciences*. 41 (3), 399-417.

Montanari, G.E., and Ranalli, M.G. (2005). Nonparametric model calibration estimation in survey sampling. *Journal of American Statistical Association*. 100(472), 1429-1442.

Moradkhani, H., and Sorooshian, S. (2009). General review of rainfall-runoff modeling: Model calibration, data assimilation, and uncertainty analysis. In S. Sorooshian *et al*.

(eds.). *Hydrological Modelling and the Water Cycle. Water Science and Technology Library, Springer*. pp 1-24.

Moreda, F., Koren, V., Zhang, Z., Reed, S., and Smith, M. (2006). Parameterization of distributed hydrological models: learning from the experiences of lumped modeling. *Journal of Hydrology*. 320, 218–237.

MOSTE (Ministry of Science, Technology and Environment) (2000). *Initial National Communication (INC) to the United Nations framework convention on climate change (UNFCCC)*. Malaysia.

Mujumdar, P. P. and Vedula, S., (1992). Optimal reservoir operation for irrigation of multiple crops. *Water Resources Research*. 28(1), 1-9.

Mujumdar, P. P., and Ramesh, T. S. V. (1997). Real-time reservoir operation for irrigation. *Water Resources Research.* 33(5), 1157-1164.

Mujumdar, P.P., and Teegavarapu, R., (1998). A short-term reservoir operation model for multicrop irrigation. *Hydrological Sciences Journal*, 43 (3). pp. 479-494.

Murphy, J. (1999). An evaluation of statistical and dynamical techniques for downscaling local climate. *Journal of Climate*. 12, 2256-2284.

Nakićenović, N., Davidson, O., Davis, G., Grübler, A, Kram, A.T., La Rovere, E.L., Metz, B., Morita, T., Pepper, W, Pitcher, H., Sankovski A., Shukla P., Swart, R., Watson, R., and Dad, Z. (2000). *Emissions scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, USA.

Nandalal, K. D. W., Bogardi, J, J. (2007). *Dynamic programming based operation of reservoirs: applicability and limits.* Cambridge University Press, Cambridge.

Nash, J.E., and Sutcliffe, J.V. (1970). River flow forecasting through conceptual models. Part 1: A discussion of principles." *Journal of Hydrology*. 10(3), 282–290.

Needham, J.T., Watkins, D.W. Jr., Lund, J.R., and Nanda, S.K. (2000). Linear Programming for Flood Control in the Iowa and Des Moines Rivers. *Journal of Water Resources Planning and Management.* pp. 118-127.

Newham, L.T.H. (2002). *Catchment Scale Modelling of Water Quality and Quantity*. Ph.D. Thesis, the Australian National University

Nguyen, V.T.V, Nguyen, T.D., and Gachon, P. (2006). On the linkage of large scale climate variability with local characteristics of daily precipitation and temperature extremes: An evaluation of statistical downscaling methods. *Advances in Geosciences* Vol. 4: Hydrological Science. In Namsik Park, Eiichi Nakakita, Chilsang Yoo and R. B. Singh.(eds.) World Scientific Co., Pte. Ltd., Singapore.

Nguyen, V.T.V, Nguyen, T.D., and Cung, A. (2007). A statistical approach to downscaling of sub-daily extreme rainfall processes for climate-related impact studies in urban areas. *Water Science and Technology*. 7(2), 183-192.

Nguyen, V.T.V, and Nguyen, T.D. (2007). Downscaling methods for climate-related impact assessment studies. *Proceedings of Expert Symposium on Climate Change-Modeling, Impacts, and Adaptations and Workshop on Climate Change and Slope Stability*. National University of Singapore, 13-22.

Nicks, A. D., Lane, L.J., and Gander, G.A. (1995). Chapter 2: Weather generator. In USDA – Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation, 2.1 – 2.22. D. C. Flanagan and M. A. Nearing, eds. NSERL Report No. 10. West Lafayette, Ind.: USDA – ARS – NSERL

NRE (Ministry of Natural Resources and Environment Malaysia) (2010). *Malaysia's Second National Communication (NC2) to the United Nations framework convention on climate change (UNFCCC)*, Malaysia

Nurul Adzura Ismail (2011). *Statistical Downscaling of Precipitation for Impact Assessment on Hydrology*. PhD Thesis, Universiti Teknologi Malaysia, Skudai. Malaysia.

O'Connel, P.E., and Todini, F. (1996). Modeling of rainfall, flow and mass transport in hydrological systems: an overview. *Journal of Hydrology*. 175, 3-16.

Oliveira, R., and Loucks, D. P. (1997). Operating rules for multireservoir systems. *Water Resources Research.* 33(4), 839-852.

Palmer, R.N., Clancy, E., Rheenen, N.T.V., and Wiley, M.T. (2004). *The impacts of climate change on the Tualatine River basin water supply: An investigation into projected hydrologic and management impacts*. Department of Civil and Environmental Engineering, University of Washington. 67pp.

Pan, Z., Christensen, J. H., Arritt, R. W., Gutowski Jr., W. J., Takle, E. S., and Otieno, F. (2001). Evaluation of uncertainties in regional climate change simulations. *Journal of Geophysical Research- Atmospheres*. 106, 17735–17751.

Paola Allamano, Hutchinson, D., and Whitfield, P.H.(2006) Preliminary Indications of the Transferability of IHACRES Model Parameters in Mountainous Rainfall Driven Rivers. *iEMS Summit on Environmental Modelling & Software.* July 2006. Vermont (USA)

Parajka, J., Merz, R., and Bloschl, G. (2005). . A comparison of regionalisation methods for catchment model parameters. *Hydrol. Earth Sys. Sci.* 2, 509–542

Peng C.S., and Buras, N. (2000). Practical estimation of inflows into multireservoir system. *Journal of Water Resources Planning and Management.* 126(5), 331-334.

Post, D.A. and Jakeman, A.J. (1996). Relationships between catchment attributes and hydrologic response characteristics in small Australian mountain ash catchments. *Hydrological Processes,* 10, 877-892.

Post, D.A., Jones, J.A. and Grant G.E. (1998). An improved methodology for predicting the daily hydrologic response of ungauged catchments. *Environmental Modelling and Software*, 13, 395–403.

Post, D. A. and Jakeman, A. J. (1998). Using a Lumped Conceptual Rainfall-Runoff Model to Predict the Hydrologic Impact of Forestry Treatments. In Alila, Y. (Ed), *Proceedings of the Canadian Water Resources Association 51st Conference,* Victoria, Canada.

Post, D.A., and Jakeman, A.J. (1999). Predicting the daily streamflow of ungauged catchments in SE Australia by regionalising the parameters of a lumped conceptual rainfall-runoff model. *Ecological Modelling.* 123, 91-104.

Prudhomme, C., Reynard, N., and Crooks, S. (2002). Downscaling of global climate models for flood frequency analysis: where are we now?. *Hydrological Processes.* 16, 1137–1150.

Racsko, P., Szeidl, L., and Semenov, M. (1991). A serial approach to local stochastic weather models. *Ecological Modeling* 57, 27- 4 1.

Ranatunga, K. (2008). Review of soil water models and their applications in Australia. *Environmental Modelling & Software*. vol 23, 1182-1206.

Randall, D., Cleland, L., Kuehne, C. S., Link, G. W. B, and Sheer, D. P. (1997). Water supply planning simulation model using mixed-integer linear programming “Engine”. *]ournal of Water Resources Planning and Management.* Vol. 123. (2). Pp 116-124

Rani, D., and Moreira, M.M. (2010). Simulation-Optimization Modeling: A Survey and Potential Application in Reservoir Systems Operation. *Water Resources Management.* 24, 1107–1138.

Ranjithan S., Eheart, J.W., and Garrett Jr, J.H. (1993). Neural network based screening for groundwater reclamation under uncertainty. *Water Resources Research*. 29(3), 563–574.

Reed, S., Koren, V., Smith, M., Zhang, Z., Moreda, F., Seo, D.J, and DMIP Participants. (2004). Overall distributed model intercomparison project results. *Journal of Hydrology*. 298. pp 27–60.

Reed, S., Schaake, J., and Zhang, Z. (2007). A distributed hydrologic model and threshold frequency-based method for flash flood forecasting at ungauged locations. *Journal of Hydrology* . 337, pp. 402– 420.

Refsgaard, J. C. and Storm, B. (1995). MIKE SHE. In: Singh, V. J. (Ed.) *Computer Models in Watershed Hydrology.* Water Resources Publications.

Refsgaard, J. C. and Knudsen, J. (1996). Operational validation and intercomparison of different types of hydrological models. . *Water Resources Research.* 32(7), 2189-2202.

Riad, S., Mania, J., Bouchaou, L. and Najjar, Y. (2004). Predicting catchment flow in a semi arid region via an artificial neural network technique. *Hydrological Processes.* 18, pp 2387-2393.

Richardson C.W. (1981). Stochastic simulation of daily precipitation, temperature, and solar radiation. *Water Resources Research.* 17,182-190.

Richardson, C. W. and Wright, D. A. (1984). WGEN: A model for generating daily weather variables. *US Department of Agriculture, Agricultural Research Service, ARS-8. USDA, Washington, DC.*

Rudra, R.P., Dickinson, W.T., Abedini, M.J., and Wall, G.J., (1999). A multi-tier approach for agricultural watershed management. *Journal of Water Resources Assocoaition.* 35(5), 1059-1-70.

Running, S.W. and Nemani, R.R. (1991). Regional hydrologic carbon balance responses of forests resulting from potential climate change. *Climatic Change.* 19, 349–68.

Saad M., Bigras, P., Turgeon, A., and Duquette, R. (1996). Fuzzy learning decomposition for the scheduling of hydroelectric power systems. *Water Resources Research*. 32(1), 179-186.

Sabetraftar, K. (2005). *The Hydrological Flux of Organic Carbon at the catchment Scale: a Case Study in the Cotter River Catchment, Australia*. PhD Thesis, The Australia National University.

Sajjad Khan, M., Coulibaly, P., and Dibike, Y. (2006). Uncertainty Analysis of Statistical Downscaling Methods. *Journal of Hydrology*. 319, 357-382.

Salathé, E.P. (2003). Comparison of various precipitation downscaling methods for the simulation of streamflow in a rainshadow river basin. *International Journal of Climatology*. 23, 887–901.

Salmah Zakaria and Liew Yuk San, (2008). Climate change and water resources management in Malaysia. *Second National Conference on Extreme Weather and Climate Change,* PICC, Putrajaya, Malaysia.

Savenije, H.H.G. (2001). Equifinality, a blessing in disguise? *Hydrological Processes*. 15, 2835-2838.

Schoof, J.T., and Pryor, S.C. (2001). Downscaling temperature and precipitation: A comparison of regression-based methodsand artificial neural networks. *Intternational Journal of Climatology*. 21, 773–790.

Schrage, L.E. (2009). *Optimization modeling with LINGO*. (6th ed.) Chicago, Illinois. LINDO Systems Inc.

Schreider, S.Y., Jakeman, A.J., and Pittock, A.B. (1996). Modelling rainfall–runoff from large catchment to basin scale: the Goulburn Valley, Victoria. *Hydrological Processes*. 10 (6), 863–876.

Schreider, S. Y., Whetton, P. H., Jakeman, A. J., and Pittock, A. B. (1997). Runoff Modelling for Snow-Affected catchment in the Australia Alpine Region, Eastern Victoria. *Journal of Hydrology*. 200, 1-23.

Schreider, S. Y., Jakeman, A. J., Letcher, R. A., Nathan, R. J., Neal, B. P. and Beavis, S. G. (2002). Detecting changes in streamflow response to changes in non-climatic catchment conditions: farm dam development in the Murray-Darling basin, Australia. *Journal of Hydrology*. 262, 84-98.

Schreider, S.Y., Smith, D.I., and Jakeman, A.J. (2002). Climate change impacts on urban flooding. *Climate Change*. vol 47, pp 1-23.

Scibek, J., and Allen, D.M. (2006). Modelled impacts of predicted climate change on recharge and groundwater levels. *Water Resources Research*. 42, W11405, doi:10.1029/2005WR004742.

Sefton, C. E. M., and Boorman, D.B. (1997). A regional investigation of climate change impacts on UK Streamflows. *Journal of Hydrology*. 195. pp 26-44.

Sefton, C. E. M., and Howarth, S. M. (1998). Relationship between dynamic response characteristics and physical descriptors of catchment in England and Wales. *Journal of Hydrology*. 211, 1-16.

Semenov, M. A., and Barrow, E. M. (1997). Use of stochastic weather generator in the development of climate change scenarios. *Climatic change*. 35**,** 397-414.

Semenov, M.A., Brooks, R.J., Barrow, E.M., and Richardson, C.W. (1998). Comparison of the WGEN and LARS-WG stochastic weather generators in diverse climates. *Climate Research*. 10:95-107.

Semenov M.A., and Brooks, R.J. (1999). Spatial interpolation of the LARS-WG stochastic weather generator in Great Britain. *Climate Research*. 11, 137-148.

Semenov, M.A., and Barrow, E.M. (2002). *LARS-WG: a stochastic weather generator for use in climate impact studies*. Version 3.0, user manual.

Semenov, M.A., and Doblas-Reyes, F.J. (2007). Utility of dynamical seasonal forecasts in predicting crop yield. *Climate Research*. 34, 71–81.

Semenov, M.A. (2007). Development of high resolution UKCIP02-based climate change scenarios in the UK. *Agric For Meteorol*. 144, 127–138.

Semenov, M.A. (2008). Simulation of extreme weather events by a stochastic weather generator. *Climate Research*. 35, 203-212.

Shaaban, A.J, Amin, M.Z.M., Chen, Z.Q., and Ohara, N. (2011). Regional Modeling of Climate Change Impact on Peninsular Malaysia Water Resources. *Journal of Hydrologic Engineering*. 16(12), 1040-1049.

Shamseldin, A. Y. (1997). Application of neural network technique to rainfall-runoff modelling. *Journal of Hydrology.* 199, pp 272-294.

Shamsudin, S., Ing, L.H., and Rahman, A.A. (2008). Phosphorus loading estimation using a fuzzy Vollenweider- IHACRES model, Malaysia*. Journal of Environmental Hydrology*. Vol. 16, Paper 7.

Simonovic, S.P. (1992). Reservoir systems analysis: closing gap between theory and practice. *Journal of Water Resources Planning and Management*. 118(3), 262-280.

Smith, R.E., Goodrich, D.C., Woolhiser, D.A., and Unkrich, C.L. (1995). KINEROS - A kinematic runoff and erosion model. Chap. 20 of Computer Models of Watershed Hydrology, Singh, V. J., Ed., Water Resources Publication, Highlands Ranch, Colo., pp. 697-732.*Hydrology*, Singh, V. J., Ed., Water Resources Pub., Highlands Ranch, Colo., pp. 697-732.

S-PLUS 6 for Windows Guide to Statistics, (2001). Insightful Corporation, vol. 2. Seattle, WA, USA.

Sriwongsitanon, N., and Taesombat, W. (2011). Estimation of the IHACRES Model Parameters for Flood Estimation of Ungauged Catchments in the Upper Ping River Basin. *Kasetsart J. (Nat. Sci.)*. 45, pp 917-931.

Sun, Y.H., Yeh, W. W.G., Hsu, N.S., and Louie, P.W.F. (1995). Generalized Network algorithm for water-supply-system optimization. *Journal of Water Resources Planning and Management*. ASCE, 121(5), 392-398.

Taesombat, W. and Sriwongsitanon, N. (2010). Flood investigation for the upper Ping river basin using the mathematical models. *Kasetsart J. (Nat. Sci.).* 44, 152–166.

Tang, Z., Almeida, C., and Fishwick, P.A., (1991). Time series forecasting using neural networks vs Box-Jenkins methodology. *Simulation*. 57 (5), 303–310.

Tangang, F. T., Juneng ,L., and Ahmad, S. (2007). Trend and interannual variability of temperature in Malaysia: 1961–2002. *Theoretical and Applied Climatology*. 89, pp 127–141.

Tarmizi Ismail (1997). Streamflow simulation using MIKE11 NAM model. *International Conference of Humid Tropics '97*, Penang, Malaysia

Tarmizi Ismail, Amir Hashim Mohd Kassim, and Abdullah Al Mamun. (1998). Simulation of Runoff for an Ungaged Catchment in Peninsular Malaysia: Sg Layang Catchment Case study. *1st Asia/Pacific Friend Workshop*. IHP No. 5, pp. 173-184.

Teegavarapu, R.S.V., and Simonovic, S.P. (2002). Optimal operation of reservoir systems using simulated annealing. *Water Resources Management*. 16(5), 401–428.

Teixeira, A.S., and Marino, M.A. (2002). Coupled reservoir operation-irrigation scheduling by dynamic programming. *Journal of Irrigation and Drainage Engineering*. 128(2), 63-73.

Tejada-Guibert, J.A., Johnson, S.A., and Stedinger, J.R. (1995). The value of hydrologic information in stochastic dynamic programming models of a multireservoir system. *Water Resources Research*. 31(10), 2571-2579.

TNB (Tenaga National Berhad). (2011). *Pricing and Tariff*. Retrieved on January, 23 2011, from http://www.tnb.com.my/

Todini, E. (1988). Rainfall runoff modeling: Past, present and future. *Journal of Hydrology*. 100, pp 341-352.

Todini, E. (1996). The ARNO rainfall-runoff model. *Journal of Hydrology*. 175, 339-382.

Tokar, A.S., and Johnson, P. A. (1999). Rainfall-runoff modeling using artificial neural networks. *Journal of Hydrologic Engineering,* ASCE. 4(3), pp 232-239.

Tokar, A.S., and Markus, M. (2000). Precipitation-Runoff Modeling Using Artificial Neural Networks and Conceptual Models. *Journal of Hydrologic Engineering.* 5(2), 156-161.

Trezos, T. (1991). Integer programming application for planning of hydropower production. *Journal of Water Resources Planning and Management. 117(3), 340-351.*

Trigo, R.M., and Palutikof, J.P. (1999). Simulation of daily temperatures for climate change scenarios over Portugal: a neural network model approach. *Climate Research*. 13, 45-59.

Tu, M.Y., Hsu, N.S., and Yeh, W. W.G. (2003). Optimization of Reservoir Management and Operation with Hedging Rules. *Journal of Water Resources Planning and Management.* 129 (2), 86-97.

Tu, M.Y., Hsu, N.S., Tsai, F.T.C., and Yeh, W. W.G. (2008). Optimization of Hedging Rules for Reservoir Operations. *Journal of Water Resources Planning and Management*, Vol. 134(1). pp 3-13.

Turgeon, A, and Charbonneau, R. (1998). An aggregation–disaggregation approach to long-term reservoir management. *Water Resources Research*. 34(12), 3585–3594.

Unver, O., Mays, L. (1990. Model for real-time optimal flood control operation of a reservoir system. *Water Resources Management*, 4, 21-46.

USEPA. (2006). *Data quality assessment: statistical methods for practitioners EPA QA/G-9S*. Office of Environmental Information, Washington, D.C.

Uvo, C.B., Tolle, U., and Berndtsson, R. (2000). Forecasting discharge in amazon using artificial neural networks. *International Journal of Climatology* 20, 1495-1507.

Vasiliadis, H.V., and Karamouz, M. (1994). Demand-driven operation of reservoirs using uncertainty-based optimal operating policies. *Journal of Water Resources Planning and Management*. 120(1), 101-114.

Vemuri, V.R., and Rogers, R.D. (1994) *Artificial Neural Networks: Forecasting Time Series*. IEEE Computer Society Press, Los Alamitos, CA.

Viner, D., and Hulme, M. (1992). *Climate Change Scenarios for Impact Studies in the UK. Climatic Research Unit*. University of East Anglia, Norwich, United Kingdom.

Viner, D., and Hulme, M. (1997). *The Climate Impacts LINK Project: Applying Results from the Hadley Centre's Climate Change Experiments for Climate Change Impacts Assessment*. Climatic Research Unit, Norwich,UK. 17 pp.

Walsh, K., and McGregor, J. (1997). An assessment of simulations of climate variability over Australia with a limited area model. *International Journal of Climatology*. 17, 201-224.

Wang, J., Yuan X. and Zhang Y. (2004). Short-term scheduling of large-scale hydropower systems for energy maximization. *Journal of Water Resources Planning and Management.* 130(3), 198-205.

Wardlaw, R., and Sharif, M. (1999). Evaluation of genetic algorithms for optimal reservoir system operation. *Journal of Water Resources Planning and Management*. 125(1), 25-33.

Weiss, A., Hays, C.J., and Won, J. (2003). Assessing winter wheat responses to climate change scenarios: a simulation study in the U.S. Great Plains. *Climatic Change*. 58,119–147.

Welsh, W.D., Barratt, D.G., Ranatunga, K., and Randall, L.A. (2006). Development of national, landused-based water balance model for Australia. *Proceedings of the* *iEMSs Third Biennial Meeting, "Summit on the Environmental Modeling and Software", International Environmental Modeling and Software Society,* Burlington, USA.

Wetterhall, F., Bádossy, A., Chen, D., Halldin, S., and Xu, C.Y. (2006). Daily precipitation-downscaling techniques in three Chinese regions. *Water Resources Research*. 42, W11423, doi:10.1029/2005WR004573.

Wetterhall, F., Halldin, S., and Xu, C.Y. (2007). Seasonality properties of four statistical-downscaling methods in central Sweden, *Theoretical and Applied Climatology*. 87, 123-137.

Wheater, H.S., Jakeman, A.J., and Beven, K.J. (1993). Progress and directions in rainfall-runoff modelling. In: Jakeman, A.J., Beck, M.B., McAleer, M.J. (Eds.), *Modelling Change in Environmental Systems*. John Wiley and Sons, Chichester, pp. 101–132.

Wigley, T.M.L. and Jones, P.D. (1985) Influences of precipitation changes and direct CO_2 effects on streamflow. *Nature.* 314, 149-152.

Wigley, T.M.L., Jones, P.D., Briffa, K.R. and Smith, G. (1990). Obtaining sub-gridscale information from coarse-resolution general circulation model output. *Journal of Geophysical Research.* 95, 1943–1953.

Wilby, R.L., and Wigley, T.M.L. (1997). Downscaling general circulation model output: a review of methods and limitations, *Progress in Physical Geography. 21*, 530-548.

Wilby, R. L., Wigley, T. M. L., Conway, D., Jones, P. D., Hewitson, B. C, Main, J., and Wilks, D. S. (1998). Statistical downscaling of general circulation model output: a comparison of methods. *Water Resources Research.* 34, 2995-3008.

Wilby, R. L., Hay, L. E., and Leavesley, G. H. (1999). A comparison of downscaled and raw GCM output: Implications for climate change scenarios in the San Juan River Basin, Colorado. *Journal of Hydrology*. 225, 67-91.

Wilby, R. L., and Wigley, T. M. L. (2000). Precipitation predictors for downscaling: Observed and General Circulation Model relationships, *International Journal of Climatology*. 20, 641-661.

Wilby, R.L., Conway, D., Jones, P.D. (2002). Prospects for downscaling seasonal precipitation variability using conditioned weather generator parameters. *Hydrological Processes.* 16, 1215-1234.

Wilby, R.L., Dawson, C.W., and Barrow, E.M. (2002). SDSM - a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling Software*. 17, 147-159.

Wilby, R.L., Tomlinson, O.J., and Dawson, C.W. (2003). Multi-site simulation of precipitation by conditional resampling. *Climate Research*. 23, 183-194.

Wilby, R.L. and Dawson , C.W. (2004). *Using SDSM Version 3.1 - A decision support tool for the assessment of regional climate change impacts*, Climate Change Unit, Environment Agency of England and Wales, Nottingham, NG2 5FA, UK and Department of Computer Science, Loughborough University , Leics. , LE1 1 3TU , UK.

Wilby, R. L., Charles, S. P., Zorita, E., Timbal, B., Whetton, P., and Mearns, L. P. (2004). *Guidelines for use of climate scenarios developed from statistical downscaling methods.* Data Distribution Center of the International Panel on Climate Change, UEA, Norwich, UK, 27. *Available for download from: http://ipcc-ddc.cru.uea.ac.uk.*

Wilby, R.L., and Dawson, C.W. (2007). *Statistical Downscaling Model, version 4.2.* Department of Geography, Lancaster University, UK.

Wilcoxon, F. (1945). Individual comparisons by ranking methods. *Biometric Bulletins*. 1(6), 80-83.

Wilks, D.S. (1999). Multisite downscaling of daily precipitation with a stochastic weather generator. *Climate Research*. 11, 125-136.

Wilks, D.S., and Wilby, R.L. (1999). The weather generator game: a review of stochastic weather models. *Progress in Physical Geography*. 23, 329-358.

Willis, J.C., Bohan, D.A., Choiw, Y.H., Conrad, K.F., and Semenov, M.A. (2006). Use of an individual-based model to forecast the effect of climate change on the dynamics, abundance and geographical range of the pest slug Deroceras reticulatum in the UK. *Global Change Biology*. 12, 1643-1657.

Wood, A.W., Leung, L.R., Sridhar, V., and Lettenmaier, D.P. (2004). Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs. *Climatic Change*. 62, 189-216.

Woolhiser, D.A. (1973). *Hydrologic and watershed modeling – State of the art.* Transaction of ASAE, 16, pp. 533-559.

Woolhiser, D.A., Smith, S.E., and Giraldez, J.Y. (1996). Effects of spatial variability of saturated hydraulic conductivity on Hortonian overland flow. W*ater Resources Research* .32, 671-678.

Wurbs, R.A. (1991). *Optimization of multi-purpose reservoir system operations: a review of modeling and analysis approaches.* Research Document RD-34, US Army Corps of Engineers. Hydrologic Engineering Center, Davis, CA.

Wurbs, R.A. (1993). Reservoir-system simulation and optimization models. *Journal of Water Resources Planning and Management*. 119 (4), 455-472.

Wurbs, R.A. (1996). *Modeling and Analysis of Reservoir System Operations*, Prentice-Hall, Englewood Cliffs, N.J.

Xiaoli Liu, Coulibaly, P., and Evora, N. (2008). Comparison of data-driven methods for downscaling ensemble weather forecasts. *Hydrol. Earth Syst. Sci*. 12, 615–624.

Xu, C.Y. (1999). From GCMs to river flow: a review of downscaling methods and hydrologic modeling approaches. *Progress in Physical Geography, 23(20).* pp. 789-797.

Yakowitz, S.J. (1982). Dynamic programming applications in water resources. *Water Resources Research*. 18(4):673–696.

Yang, X., Parent, E., Claude, M., and Roche, P.A. (1995). Comparison of real-time reservoir-operation techniques. *Journal of Water Resources Planning and Management*. 121(5), 345-351.

Yarnal, B., Comrie, A.C., Frakes, B., and Brown, D.P. (2001). Developments and Prospects in Synoptic climatology. *International Journal of Climatology*. 21, 1923 - 1950.

Ye, W., Jakeman, A.J., and Barnes, C.J. (1995). A parametrically efficient model for prediction of streamflow in an Australian benchmark catchment with complex storage dynamics. *Environment Internationa.l* 21(5), 475–758.

Ye, W., Bates, B.C., Viney, N.R., Sivapalan, M., and Jakeman, A.J. (1997). Performance of conceptual rainfall-runoff models in low-yielding ephemeral catchments. *Water Resources Research*. 33, 153-166.

Ye, W., Jakeman, A.J., and Young, P.C. (1998). Identification of improved rainfall-runoff models for an ephemeral low-yielding Australian catchment. *Environmental Modelling & Software*. 13, 59-74.

Yeh, W. W.G. (1985). Reservoir management and operation models: A state-of-the-art review', *Water Resources Research.* 21(12), 1797–1818.

Yonas B. Dibike, and Coulibaly, P. (2005). Hydrologic impact of climate change in the Saguenay watershed: comparison of downscaling methods and hydrologic models. *Journal of Hydrology.* 307 (2005) 145–163

Young, P.C., and Beven, K.J. (1994). Data-based mechanistic modelling and the rainfall-flow non-linearity. *Environmetrics,* 5**,** 335-363.

Young, P.C., and Beven, K.J. (1991). Computation of the instantaneous unit hydrograph and identifiable component flows with applications to two small upland catchments-comment. *Journal of Hydrology.* 129 389-396.

Young, G. K. (1967). Finding reservoir operation rules. *Journal of Hydraulic Division, ASCE.* 93(HY 6):297–321.

Young, W., Brandis, K. and Kingsford, R. (2006). Modelling monthly streamflows in two Australian dryland rivers: Matching model complexity to spatial scale and data availability. *Journal of Hydrology.* 331, 242-256.

Zakaria, S., and Shaaban, A.J. (2007). Impact of climate change on Malaysia water resources. *NAHRIM. National Seminar on Socio-economic Impact of Extreme Weather and Climate Change* . Ministry of Science, Technology and Innovation. 21-22 June 2007, Putrajaya, Malaysia.

Zealand, C.M., Burn, D. H., and Simonovic, S. P. (1999). Short term streamflow forecasting using artificial neural networks. *Journal of Hydrology.* 214, pp. 32-48.

Zhang, M., Fulcher, J., and Scofield, R.A. (1997). Rainfall Estimation using Artificial Neural Network Group. *Neurocomputing.* Vol. 16, pp. 97-115.

Zhang, Z., Koren, V., Reed, S., Smith, M., Zhang, Y., Moreda, F., and Cosgrove, B. (2012). SAC-SMA a priori parameter differences and their impact on distributed hydrologic model simulations. J*ournal of Hydrology*. 420–421, pp 216–227.

Zhao, R. J. (1992). The Xinanjiang model applied in China. *Journal of Hydrology.* 135 (1-4), 371–381.

Zorita, E. and von Storch, H. (1999). The analog method as a simple statistical downscaling technique: Comparison with more complicated methods. *Journal of Climate*, 12, 2474-2489.