



THESIS APPROVAL
GRADUATE SCHOOL, KASETSART UNIVERSITY

Doctor of Engineering (Water Resources Engineering)

DEGREE

Water Resources Engineering

FIELD

Water Resources Engineering

DEPARTMENT

TITLE: Dynamic Decision Support System for Reservoir Operation

NAME: Mr. Eakawit Jornpradit

THIS THESIS HAS BEEN ACCEPTED BY

THESIS ADVISOR

(Associate Professor Suwatana Chittaladakorn, Ph.D.)

THESIS CO-ADVISOR

(Mr. Somkiat Prajumwong, Ph.D.)

THESIS CO-ADVISOR

(Mr. Thongplew Kongjun, D.Eng.)

DEPARTMENT HEAD

(Assistant Professor Napaporn Piamsa-nga, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON _____

DEAN

(Associate Professor GunjanaTheeragool, D.Agr.)

THESIS

DYNAMIC DECISION SUPPORT SYSTEM FOR RESERVOIR
OPERATION



EAKAWIT JORNPRADIT

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Doctor of Engineering (Water Resources Engineering)
Graduate School, Kasetsart University
2013

Eakawit Jornpradit 2013: Dynamic Decision Support System for Reservoir Operation. Doctor of Engineering (Water Resources Engineering), Major Field: Water Resources Engineering, Department of Water Resources Engineering. Thesis Advisor: Associate Professor Suwatana Chittaladakorn, Ph.D. 137 pages.

The reservoir operation problem which counts on water usage change and climate change needs the solution tool to approach the new update reservoir operational rule influenced by the dynamic climatic data and mechanized by the dynamic decision support system. The new proposed solution is the guidance as the ideological line that additionally enhance the conventional rule curve which inform as the prohibitive limited line to be the promoted line to suggest that the water kept in the reservoir should be placed on the amount of storage capacity that will be the most appropriate at any time. The methodology was designated the components which comprise three computerized modeling processes i.e. the data synthesis, the long-term operational rule in acquisition, and the periodical short-term in operation. The case study area adopted the update secondary data from Sirikitti Reservoir, Uttaradit province and Papayom Reservoir, Phatthalung province, Thailand, to simulate for the population set of the optimal result of the long-term operational rule. Subsequently, the periodical short-term operation was demonstrated by using the most likely line, MLL line in short, of the optimal operational rule as a guideline.

The result of the data synthesis was shown that the population of the daily synthetic data is able to imitate from the sample daily archetype data on the statistical acceptance. By using the data in the simulation model with the optimization process, the MLL line was acquired for the long-term operational rule. For the wet and the dry year conditions, the input data were sorted by ordinal amount to half divide it into the greater than and lesser than normal data. The most likely line on the wet year data or MLLW and the most likely line on the dry year data or MLLD were attained. The periodical short-term operation was exhibited by using the MLL for the normal year, the MLLW for wet year, and the MLLD for dry year conditions. By complying with the water release rate suggestion, the line of storage volume was converged to the most likely line on the periodical decision and to keep close the best ideal of the operational rule which mean the risk of flood and drought could be alleviated.

Student's signature

Thesis Advisor's signature

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my advisor, Assoc. Prof. Dr. Suwatana Chittaladakorn, for the continuous support of my doctoral study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my doctoral study.

Besides my advisor, I would like to thank Dr. Jirawat Kanasuta who served as a chairman of the committee and the rest of my thesis committee: Dr. Somkiat Prajumwong, Dr. Thongplew KongJun, for their encouragement, insightful comments, and hard but valuable questions. Inevitably, I have a great thank to Asst. Prof. Dr. Sanit Wongsu whom is the external expert from King Mongkut's University of Technology Thonburi (KMUTT) who has a full spiritual mind of the instructor on his kind commentary.

I thank my fellow laboratory mates and officer whom work in department of Water Resources Engineering, Kasetsart University, Bangkhen campus, for the stimulating discussions, for the sleepless some nights while we were working together before deadlines, and for all the fun we have had in the last four or five years may I say. Also, I thank the hard problems about reservoir operation at my previous office, Phatthalung Provincial Irrigation Project, which enlightening me the first glance of research for these problems.

Last but not the least important, I would like to thank my family: my wife, Missis Nuntawan Jornpradit, my daughter, Miss Natthakorn Jornpradit, my sons, Mister Sartratorn Jornpradit and Mister Tissatorn Jornpradit, for giving great inspiration to me since at the first attendance my course and supporting me spiritually throughout my life.

Eakawit Jornpradit

March 2013

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LIST OF ABBREVIATIONS

a	=	the limit of random variable in function
a	=	the value of a quantity notation
a	=	the constant used in Gumbel Distribution function
a	=	the parameter notation
a_n	=	the alternative of n amount
A	=	the event of A
b	=	the Limit of Random Variable in Function
b	=	the value of b quantity notation
b	=	the constant used in Gumbel Distribution function
B	=	the event of B
B	=	the bias limit of Uncertainty
B	=	the constant used in Beta Distribution function
$B(t)$	=	the amount of fluid property function at t of the time moment
dV	=	the derivative of the volume V
dx	=	the derivative of x
D_t	=	the amount of the water demand of the time period t
$e^{(x)}$	=	the Napierian exponential function of x
$\exp(x), \exp^{(x)}$	=	the decimal exponential function of x
EV_t	=	the amount of evapotranspiration of the time period t
$f(x)$	=	the function with x as a dependent variable
F	=	the Fisher Statistic score test notation
I_t	=	the amount of the inflow runoff of the time period t
k	=	the number of measurements in Uncertainty
k	=	the degree of error at k value
$k+1$	=	the next number of measurements in Uncertainty
$k+1$	=	the degree of error at $k+1$ value
$\ln(x)$	=	The Napierian or natural logarithm function of x
m	=	the integer constant used in the Erlang Distribution function

LIST OF ABBREVIATIONS (Continued)

<i>max.</i>	=	the maximum value of the optional parameter notation
<i>min.</i>	=	the minimum value of the optional parameter notation
MLL	=	the Most Likely Line operational rule
MLLW	=	the Most Likely Line operational rule for Wet Year
MLLD	=	the Most Likely Line operational rule for Dry Year
<i>n</i>	=	the discrete constant used in the Binomial Distribution function
<i>N</i>	=	the total number of measurements in Uncertainty
<i>p</i>	=	the parameter notation
p_{mn}	=	the payoff at matrix <i>m</i> , and <i>n</i> or the end node
P(A)	=	the probability that an event A will occur
P(AB)	=	the probability that events A and B will both occur (A and B) is equal to P(BA)
P(A B)	=	the probability that events A will occur if B occur (A given B), but does not equal to P(B A)
$P(\tilde{A})$	=	the probability that events A will not occur (not A), equal to 1-P(A)
P_{mn}	=	the probability at matrix <i>m</i> , and <i>n</i>
P[X]	=	the probability of X set of events
PP_t	=	the amount of precipitation on the reservoir catchment area of the time period <i>t</i>
QF_t	=	the amount of inflow into the reservoir of the time period <i>t</i>
$\text{sech}^2(x)$	=	Hyperbolic sine identity or Pythagorean trigonometric identity, equal to $1 - \tanh^2(x)$
R_t	=	the amount of the water release of the time period <i>t</i>

LIST OF ABBREVIATIONS (Continued)

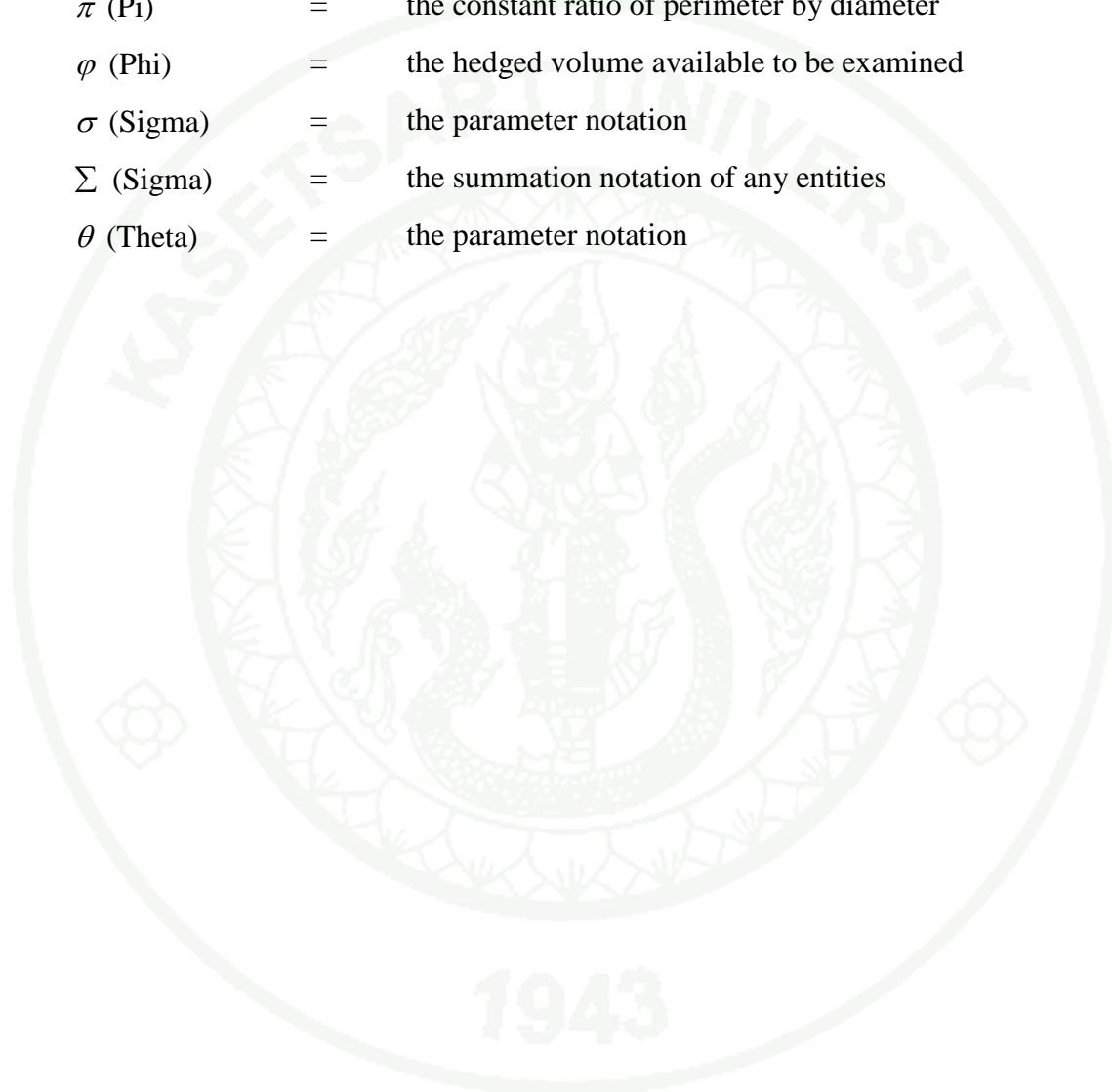
S_{max}	=	the retention storage volume or the maximum storage volume
S_{min}	=	the dead storage volume or the minimum storage volume
S_n	=	the states of nature of n amounts
S_o	=	the initial state of the storage
$S(n)$	=	the n state of the storage
$Sh(t)$	=	the shortage volume of a time period t
$Sp(t)$	=	the spillage volume of a time period t
SP_t	=	the amount of seepage and loss during the time period t
ST_t	=	the storage volume of a moment time t
ST_{t+1}	=	the storage volume at the end of the next time interval
ST_{t-1}	=	the storage volume at the end of the previous time interval
t	=	the time steps (second, minute, day, month)
t	=	the time of the moment t
Δt	=	the time of constant interval
U	=	the estimate error quantity for Uncertainty
U_X	=	a given measurement of a physical quantity for uncertainty
V_I	=	the volume of water in the system at enters
V_{II}	=	the volume of water in the system at the remains
V_{III}	=	the volume of water in the system at leaves
x	=	the value of x quantity notation
x	=	the random Variable of function $f(x)$
X	=	the amount of X events
X	=	the reading of a variable in Uncertainty

LIST OF ABBREVIATIONS (Continued)

X_k	=	the value of quantity X with the error k
X_{true}	=	the value of quantity X at its true value
\bar{X}	=	the sample mean
z	=	the variable used in the Gumbel Distribution function
Z	=	the Z Statistic score test notation
Z_n	=	the ordinal number n of the objective function
α (Alpha)	=	the parameter notation
α (Alpha)	=	the rejection region
α_1 (Alpha)	=	the parameter notation
α_2 (Alpha)	=	the parameter notation
β (Beta)	=	the bias error of Uncertainty
β (Beta)	=	the parameter notation
δ (Delta)	=	the total error of Uncertainty
χ^2 (Chi)	=	the Chi square Statistic score test notation
δ_k (Delta)	=	the error at k value
δ_{k+1} (Delta)	=	the error at $k+1$ value
ε (Epsilon)	=	the precision error of Uncertainty
ε (Epsilon)	=	the compensated value available to be estimate
ε_k (Epsilon)	=	the precision error at k value
ε_{k+1} (Epsilon)	=	the precision error at $k+1$ value
λ (Lamda)	=	the parameter notation
λ (Lamda)	=	the discrete parameter notation
μ (Mu)	=	the population means
μ (Mu)	=	the parameter notation
μ (Mu)	=	the alternative in expected value of the water release notation in the short-term operation

LIST OF ABBREVIATIONS (Continued)

μ_{mn} (Mu)	=	the consequences of the matrix m , and n
π (Pi)	=	the constant ratio of perimeter by diameter
φ (Phi)	=	the hedged volume available to be examined
σ (Sigma)	=	the parameter notation
Σ (Sigma)	=	the summation notation of any entities
θ (Theta)	=	the parameter notation



DYNAMIC DECISION SUPPORT SYSTEM FOR RESERVOIR OPERATION

INTRODUCTION

Reservoir Operation is a support activity to a certain discipline of Water Resources Development. In general, water resources development can be classified the phase into planning & construction, operation & management which aimed to approach the solutions in water resources usage problems. Flood, drought, is in term of water quantity problems and saline, polluted water, and poor dissolved oxygen concentration, are in term of water quality problems. Considering in the sources of water occurrence by the nature of water quantity in any time intervals, it occurs in the manner of Pareto traits, evermore it is in the short-term and always lies less in the long-term of yearly period, and by association with the nature of uncertainty. For those reasons, the need of water reservation, by the purpose of storage device construction such as reservoir, on water resources development planning phase is a major obligatory mission.

The difference between planning & construction and operation & management phase is the assumption on water budget balancing between demand side and supply side. Meanwhile in the planning & construction phase, the assumption in the water budget balancing both demand side and the supply side is fixed on some criterion. Yet while in the operation & management phase, the assumption in the water budget balancing both demand side and the supply side is dynamically on their current uncertainty features. Therefore, the dynamic management problem is also a big deal in decision making for every time interval of the reservoir operation.

The past few decades, the decision support system or DSS in short is additionally applied in reservoir operating system to take the advantages on the best and risk saver of the decision making. This system basically comprises three procedure bases. First is the input procedure as the “Data-Base”. Second is the process procedure as the “Model-Base”.

Last is the output procedure as the “Dialog-Base” or the decision maker interface. The decision support system is the principal system which aims to research and invents the new alternative ways of the reservoir operation.

Conventional tool for reservoir operation is the operative rule. It mostly graphically illustrates only for long-term operation and almost provide in the rule of two curves, Upper and Lower guidance curves, as the operating guideline normally called rule curve. The gap between two guidance lines is the uncertainty effect space to keep as alternatives for decision in controlling the storage in the reservoir.

In case of the high uncertainty period, the gap locates more space which more hard to make the decision. For the short-term operation, the operator mostly makes the subjective decision based on his experience consideration by the daily data support which flow in records. For that reason, the need for appropriate long-term and short-term operational rule obtaining is at this research point of interest. Furthermore, the need of operational rule improvement by the DSS system to adapt to the dynamic change in both demand side and supply side along with global weather, climate condition, and El Niño – La Niña phenomenon is the direction of this research and the new innovation creation.

Resources Management Philosophy

Inferring from the philosophy of sufficiency economy given by His Majesty King Bhumibol Adulyadej, the King of Thailand, that any resource management philosophy can be divided into three precepts;

“The values of the useful resource are the ability to control, management, and access to the resources”,

“The coverage usable resources that should be a fully suitable service will result in maximizing the usage of resources called sufficiency”,

And “The resources which insufficiency usage that be used steadily will result in sustainable resources”.

Water resources are renewable resources that occur as a hydrologic cycle passing through the periodic year. Considering the resources that are endless occurred. If we notice the happening of water resources at any one point in the year. It is found to occur intermittently, uncertainties, and seasonally. It has overabundant in the rainy season and few or sometimes none. Utilization of water resources is limited to quantity in each period of time. Mankind is always thinking how to storage the water resources and to use the water resources on the requirement while does not depend on the season by reservoir construction. Opposite the main purpose of the reservoir is depleting the water from reservoir for flood protection or keeping the water into the reservoir to alleviate the water scarcity.

Therefore, valuable water is the manageability water, especially the controllable water resources. The reservoir is an artificially constructed storage that plenty versatile. In addition to the main objectives, it has the more benefits such as hydro power, navigation, irrigation, industry, fishery, forestry, environmental conservation, sports, recreation and community development basis for the prosperity of the country. Beyond the population growth, affect the water needs to be further increased demand both in quantity and variety of activities likely more complicated. Therefore, water management for benefits in any primary or any subsidiary, the local authorities have higher level involve in decision making for water usage strategies which decision support system for the reservoir management approaching the above requirements is more necessary as well.

Subsequently, for the decision making together is somewhat tool to create a shared understanding of all parties involved in water management time. The scenarios image suggests that if a decision such as how to manage, what is the movement in the reservoir system happens continuously until next year. Only if the benefits transpire from management, it will be the results from the joint decision

makers. On the contrary, if there are some damages from the management of the blame, it would be shared by the group's decision maker to share responsibility.

Accordingly, in the future, involvement in decision making in water usage is more significant. A decision support system for reservoir management that develop in this research topic of “Dynamic decision support system for reservoir operation” to meet the above requirements is closer to the human being that expected for the need to happen in the future and it is very interesting to study.

The query leads to research work

On ambiguous answer on the simple query such as “How much the water release should be released from the reservoir today?” This leads the author to have this research work. Considering the factors which involved in this query may be separated in common kind of the obvious factors those are:

- The water release should be released on the water requirement at that considering time or on the demand side.
- It should be released on the limit of the water available which has not exceeded the storage at that considering the time.
- It should be released on the reason above and left of the rule of the water available which need to share for water use in all term of the year round.
- It should be released on the limit of the hydraulic and the hydrodynamic ability of water control structure i.e. spillway channel, river outlet capacity, downstream channel capacity etc.
- It should be released over the minimum rate of the downstream need for the environmental water request.
- It should be released on the participatory decision of the water stakeholders.

In practice on the most reservoirs, the operational rule which commonly uses across the world is the Rule Curve. The Rule Curve is a rule of the reservoir operation. It comprises two limit guidance lines: the upper rule curve or URC in short

used for guiding the maximum limit of the water storage should be controlled in the reservoir and the lower rule curve or LRC in short used for guiding the minimum limit of the water storage should be controlled in the reservoir. These curves are reasoning its characteristic range on the supply side by wet and dry year.

In Thailand, the author has never found any reservoir which did not use the rule curve guidance. Every reservoir has a unique rule curve individually. But, many reservoirs were found that it seems to use the rule curve as guidance not harmonizes with the better manner that it should be. For instance, the certain rule curve has a wide range between upper and lower curve which it does not helpful in decision guidance for a suitable storage such as Lam Ta Khong Reservoir and Mool Bon Reservoir as shown in Figure 1 and Figure 2 respectively.

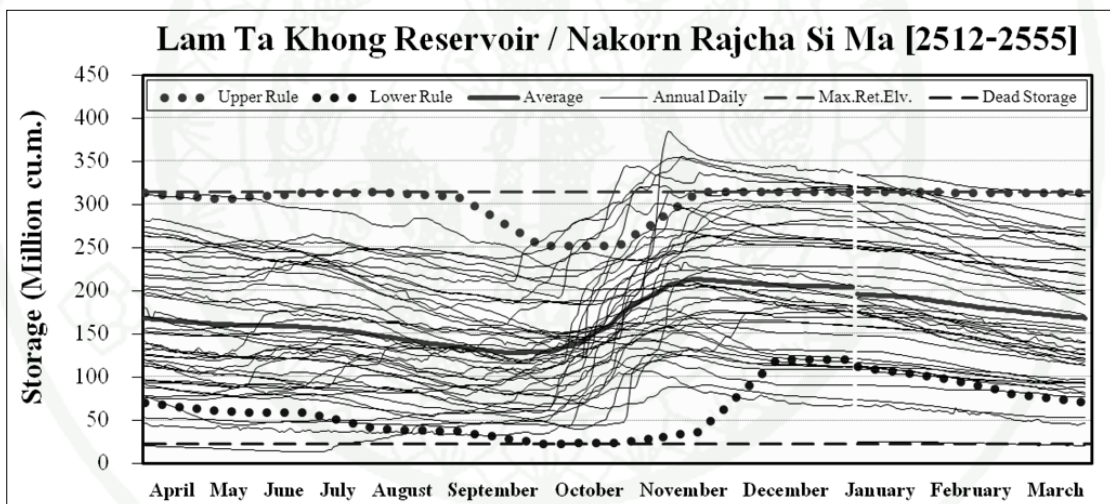


Figure 1 The certain rule curve has a wide range between upper and lower curve such as Lam Ta Khong Reservoir

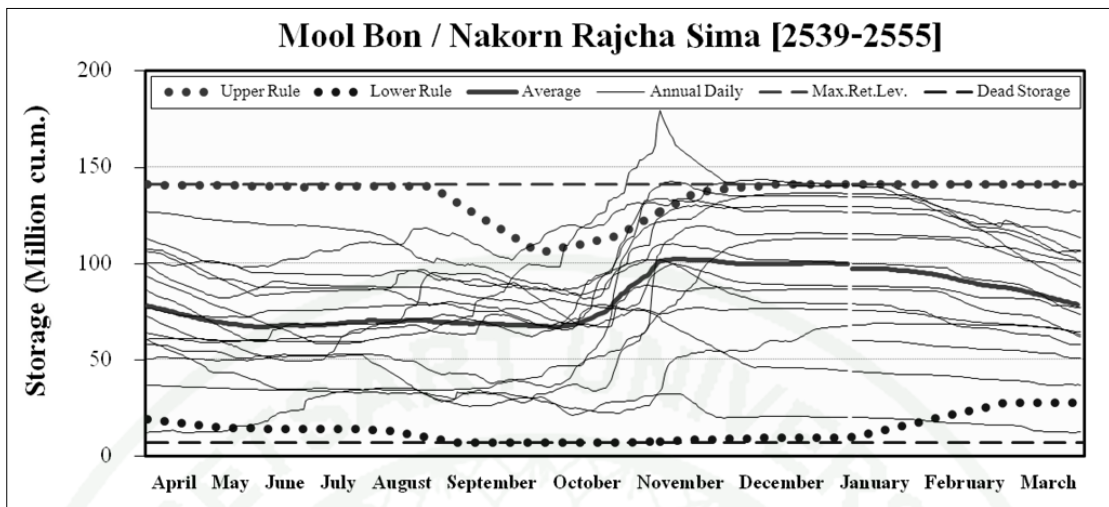


Figure 2 The certain rule curve has a wide range between upper and lower curve such as Mool Bon Reservoir

The certain rule curve has a narrow range between upper and lower curve which it's hard to control the suitable storage bound in the guidance such as Sirintorn Reservoir as shown in Figure 3.

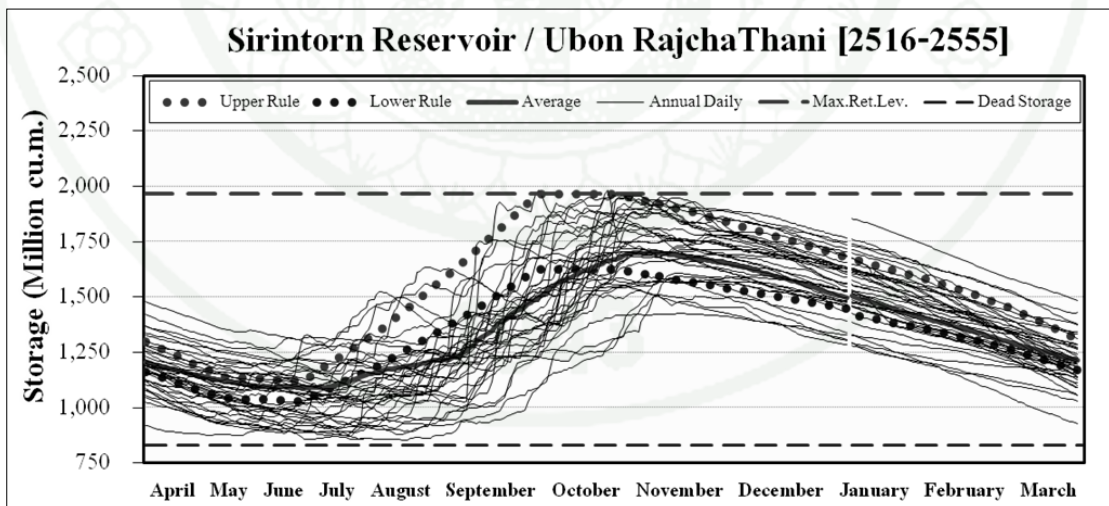


Figure 3 The certain rule curve has a narrow range between upper and lower curve such as Sirintorn Reservoir

The certain rule curve was located higher than normal such as Racha Pra Pha Reservoir as shown in Figure 4.

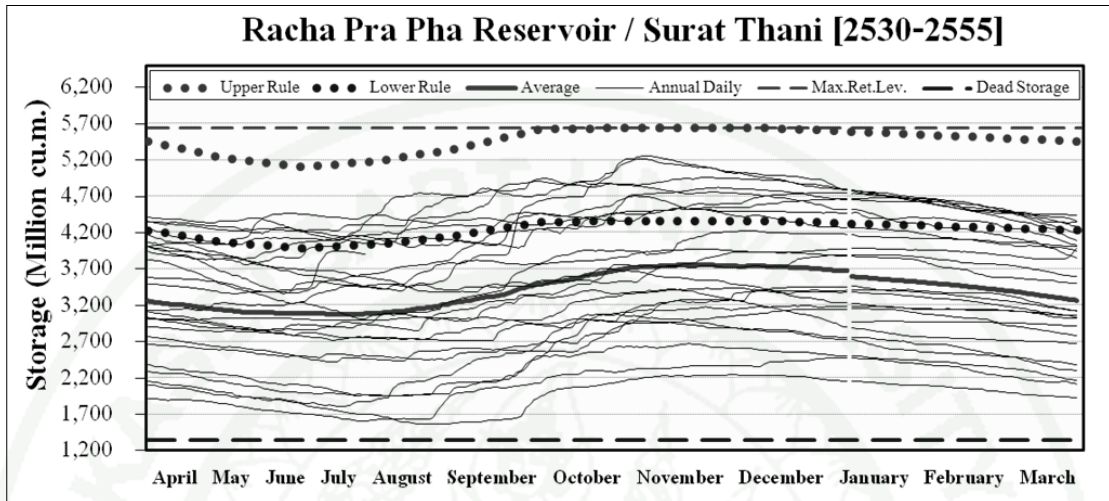


Figure 4 The certain rule curve was located higher than normal such as Racha Pra Pha Reservoir

The certain rule curve was located lower than normal such as Nong Phla Lai Reservoir as shown in Figure 5.

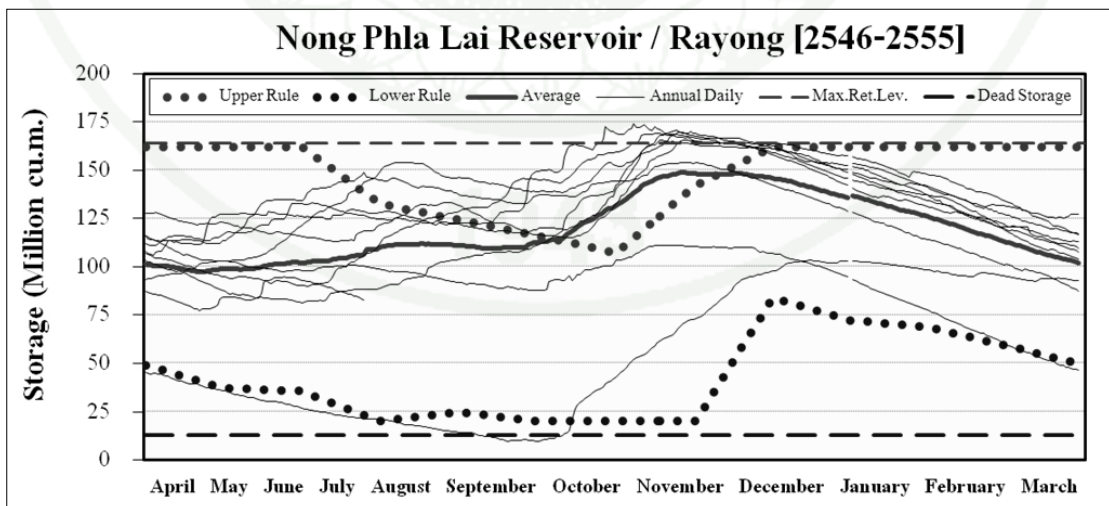


Figure 5 The certain rule curve was located lower than normal such as Nong Phla Lai Reservoir

The certain rule curve was shifted away more than normal season such as Nam Une Reservoir and Lam Sae Reservoir as shown in Figure 6 and Figure 7 respectively.

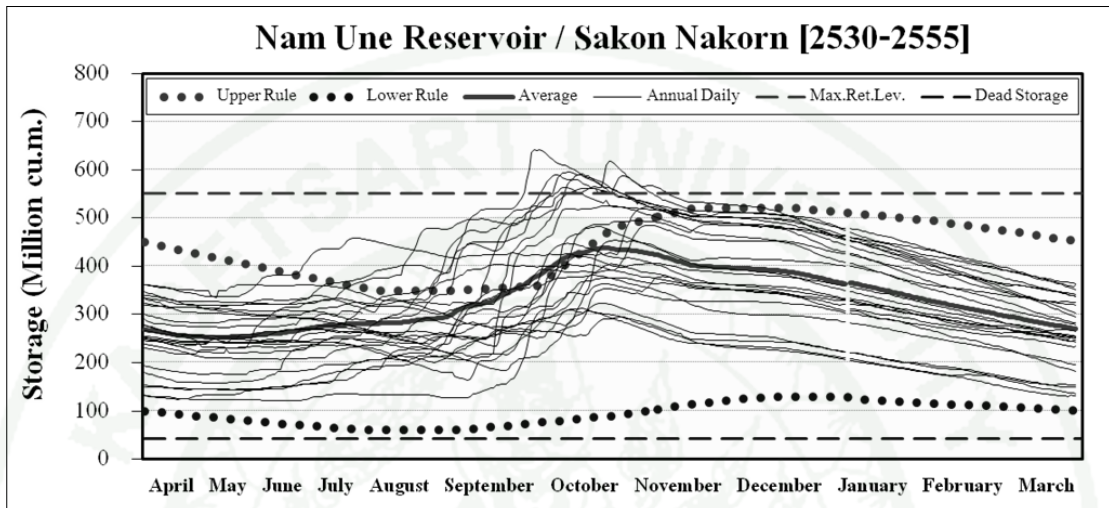


Figure 6 The certain rule curve was shifted away more than normal season such as Nam Une Reservoir

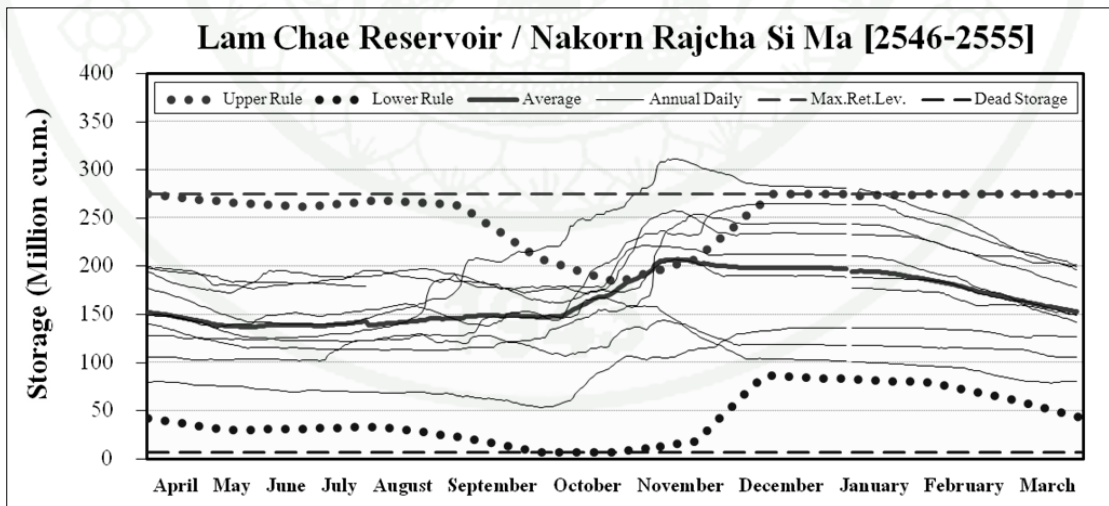


Figure 7 The certain rule curve was shifted away more than normal season such as Lam Chae Reservoir

I. Summary of the Problems Statement

This research hopes to fulfill the problem's solution in the area of water resources management. The problems discernment is classified into following six issues:

A. Non-conform to planning & construction phase and operation & management phase in assumptions

There is the non-conform assumption between planning & construction phase and operation & management phase which may be take effects of the operational rule as shown its contrary assumptions in Table 1.

Table 1 The non-conform aspects to planning & construction phase and operation & management phase in the contrary assumptions

Assumption	Planning & Construction Phase	Operation & Management Phase
Demand Side	Planned / Fixed	Changeability
Supply Side	Fixed in range	Changeability
Storage Index	Keep in range	Particular point, line

The problems comprise two major issues. First, if the volumes of the actual water budget occurs more than the estimated or less than the estimated value, then the control volume is likely to mistake from the hypothesis in planning & construction phase and likely to encounter some problems. Second, if the volume of the water usage in any activity uses differs higher than the hypothesis in planning & construction phase, then the control volume is also likely to mistake from the hypothesis in planning & construction phase and likely to encounter some problems.

B. Not any system to exploit current data to improve the operational rule

There is not any system while in use to exploit current data to improve the operational rule. As the results, the operational rule could not reflect the variation characteristic of the changing climate conditions as shown the concept in Figure 8.

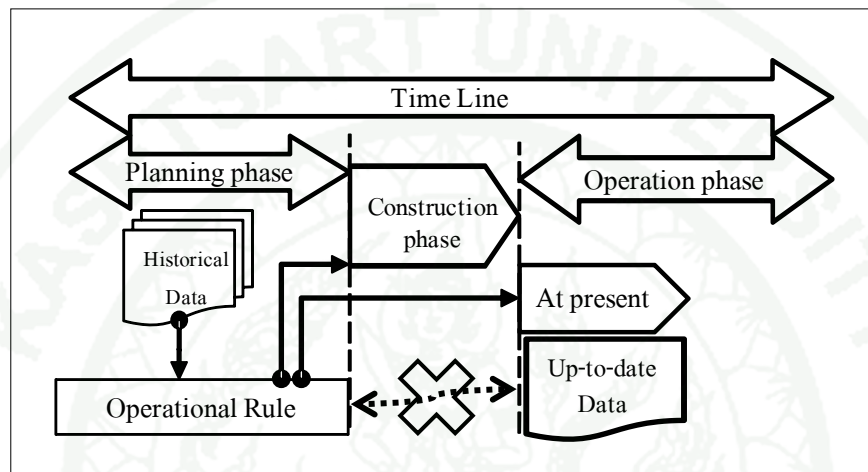


Figure 8 The concept of the need to exploit current data to improve the operational rule

The unfavorable problem is the lost opportunity to obtain the valuable information that some investors, some locations, and some cases have pour money into for this information. In other hand, is the lost of valuable information and opportunities that will indicate the options to control for reservoir operation in the better tricks of current climate condition, particularly in the case of crisis in water scarcity and deluges.

C. Need of using the uncertainties impact in climate shift & climate change to improve the operation rule

The interested problem is the error from climate assessing in the amount of water budget that will probably also be varied and increased more or depressed lower than ever in the incorrect time series. Difficulty and complication that closely

based on the uncertainty of climate shift and change needs to be attentive and intensive cared from the operating control for reservoir operating strategies. Figure 9 is illustrated for this concept.

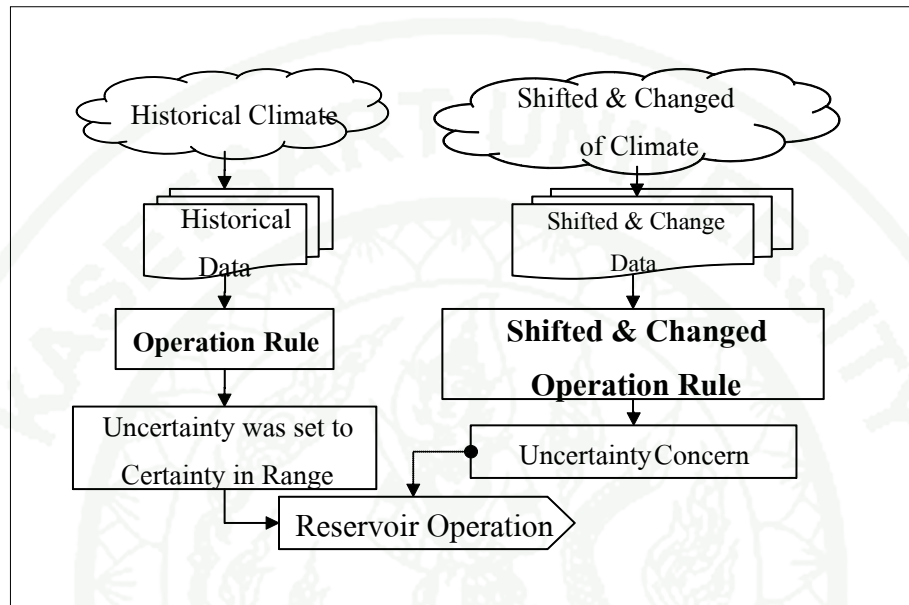


Figure 9 The need to change Operation Rule in concept by the impact of uncertainties in climate shift & climate change

D. Need of using the uncertainties impact in water management policies to improve the operation rule

In future, population is increasing. Results take effect on the higher demands for water. A variety of purposes is complex in terms of both quantity and quality time to use the water. Involve in policy decision that directs usage the water from the reservoir. Stakeholders on water usage are necessary for taking part in participants to decide. Making policies related to the use of water must be considered wisely and closely by accompanying with stakeholders in order to make a fair allocation of water, transparent to all parties and to avoid the problems of water dispute as shown in Figure 10 is the uncertainties concept in policies and decision making.

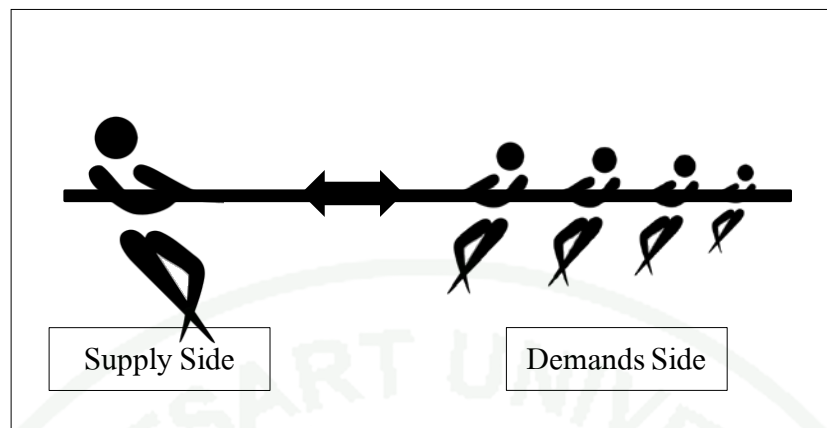


Figure 10 The uncertainties concept in policies and decision making which should be accompanied by the water master and the stakeholders

The essential problem is how to allocate the limited water budget to use in water activities perfectly, equitable, or appropriately that fair to all parties for the possible detriment which may occur occasionally.

E. Need of criteria for the antithesis strategies of storage system which execute simultaneously between scarcity alleviation and flood protection

Reservoir management strategies in any period of time, the fundamental consideration at the same time is the volume of water to retain in the reservoir for flood protection which must be measured simultaneously with the released volume or free space for water scarcity relief.

In alleviate measure for water scarcity is the restrictive measure of the water from the storage. The importance of water during flood season is a need to retain most of the occasional rainstorm in order to try or to keep the water in the reservoir which the volume of flood water in the reservoir certainly must be restricted by usage it in dry spells. But, on the other hand, the storage of water in the reservoir must also be spaced enough for a rainstorm may occur by prediction the need of available volume space. Some of water budget must be drained to support this measure instead of be stored all for upcoming usage for drought.

In flood alleviation and flood protection measure is important in late summer drought that due to storage depletion measure. The drained water needs to release out from the reservoir to match exactly with the water budget that will add to the beginning of the rainy season. When a rainstorm coming up, the depleted water from reservoir that make the storage volume become free space. The useful in curtailing the volume of flood water may flow into flooded areas located at the reservoir end. This is another benefit side of the reservoir that helping to prevent and alleviate flooding.

The concept of antithesis strategies that execute simultaneously of storage system between scarcity alleviation and flood protection was shown in Figure 11.

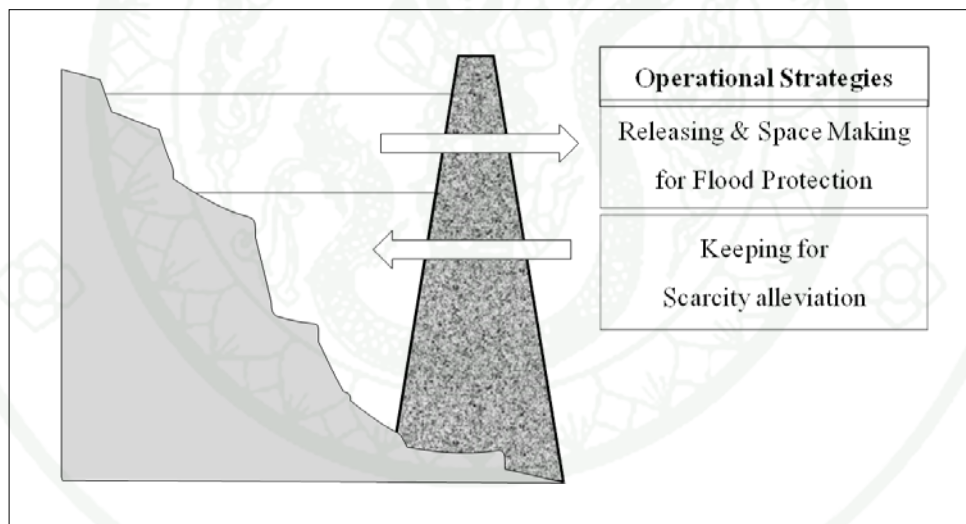


Figure 11 The concept of antithesis strategies that execute simultaneously of storage system between scarcity alleviation and flood protection

The focal problem is how to indicate any measure for the water scarcity index and flood protection and alleviation index which is contrary consideration concurrently which can be used to bring these indices appropriate for reservoir management.

F. Not any decision making interface to show the scenario of alternative results

In reservoir management, each management decision will result in both immediately and long-term period till the re-birth year-round of the water resources. The illustration in Figure 12 shows the control plan must be able to describe the status of various water management in the reservoir has to identify with all parties together with ease not only in the level of operation but in the level of the executive also.

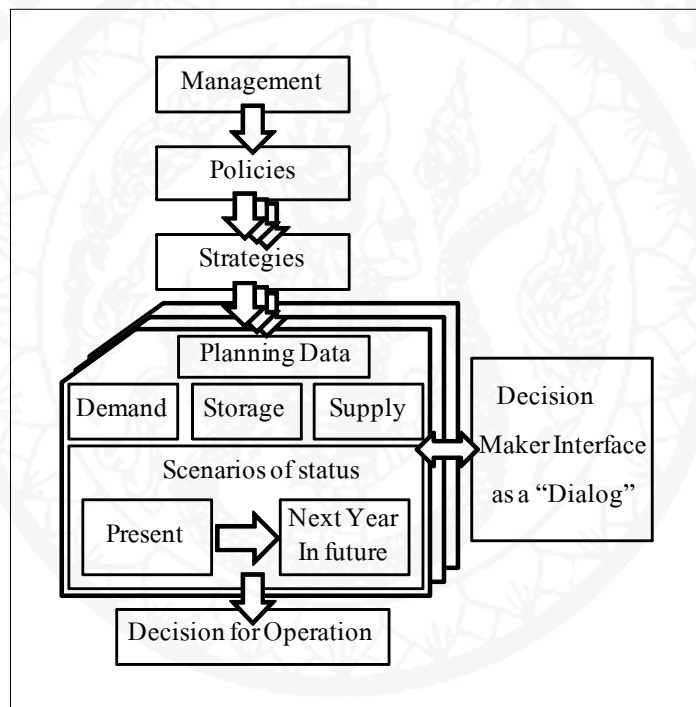


Figure 12 The concept of action plan dialog which is the decision making by the end-user in the process of the reservoir management system

The indispensable problem is what a prototype tool can be used to explain the status of reservoir management that has to understand all parties together with ease. For this reason it is essential to develop a dialog which can have immediate results when a question-oriented management can perceive evidently.

II. Purposes for solving the problems

A. Reduce the non-conform to planning & construction phase and operation & management phase in assumptions

In order to reduce the non-conform, this research purposed to get some methods which suitable for updating as the new assumption.

B. Facilitate system to exploit current data to improve the operational rule

To facilitate the system to exploit current data to improve the operational rule, this research purposed to develop some mathematical model that it is able to add the current data for the operational rule updating.

C. To change Operational Rule which influence of the impact of uncertainties in climate shifts & climate change.

The way to change the original operation rule to the better rule, this research wish to study and to take somehow the impact of uncertainties in climate shift & climate change which influence the operational rule.

D. To obtain the criteria for determining the antithesis strategies of storage system which execute simultaneously between scarcity alleviation and flood protection.

In the criteria of scarcity alleviation and flood protection determination, this research hopes to solve for compromised methods to determine an appropriate storage at any changing time that should be put between scarcity alleviation and flood protection.

E. To create the decision scenarios in the decision making alternatives particularly to use for the reservoir operation.

In the decision making process, this research aims to create the decision scenarios in the decision making alternatives particularly to use for the reservoir operation.



OBJECTIVES

The objectives of this research are the endeavor to approach the new reservoir operational rule influenced by the dynamic climatic data and mechanized by the dynamic decision support system which comprises three major issues: the data-base, the mathematical model-base, and the dialog-base for the decision maker who needs suitable information on reservoir operation in decision making, in order to achieve these following ability solutions:

- I. To conform the current operational rule that most close to its assumptions.
- II. To exploit the current data to improve the operational rule to be the up-to-date rule.
- III. The ability on demand to change the reservoir operational rule which influence of the impact of uncertainties in climate shifts & climate change.
- IV. To indicate the appropriate storage at any changing time that should be put between scarcity alleviation and flood protection.
- V. To create the decision scenarios in the decision making alternatives particularly to use for the reservoir operation.

Definition of Terminology

To correctly understand in certain terminology in this study, the following definitions are prescribed.

I. Definition of the “Long Term”

The Long Term Operation is a statement or information about the relationship between a period of time duration in monthly series and a monthly consequence of the storage of water were stored in the reservoir. It is the monthly series summarized from the daily series on the short term operation.

II. Definition of the “Short Term”

The Short Term Operation is a statement or information about the relationship between a period of time duration in daily series and a daily consequence of the storage of water were stored in the reservoir.

III. Definition of the “Demand”

The demand is the daily or monthly in time series of the water requirements rate which the water user eager to be exploited from the reservoir. It is used to guide for the water release determination in decision making. The demand included all of water need affected from source to site i.e. water consumptive uses, conveyance efficiency, and all of losses compensation.

IV. Definition of the “Release”

The release is the daily or monthly in time series of the responsive water rate which the water user should be obtained from the reservoir. It is the recommended results of the water release determination in decision making which determined by the optimization process under the water balance model with hedge operation policy described on the topic of a New Proposed Rule and Algorithms of literature review.

Scope of Research

To achieve the proposed methodologies for management of optimal reservoir operations in dynamic conditions, the following scopes are applied.

I. Considered parameters

There are two major considered parameters for inputs are water supply series, and water demand series. For output, the water release series is considered as a key parameter that it should be obtained from the optimization process in the model simulation.

II. Operational basis is only considered in attendance study

Monthly operation of the reservoir operational basis for long-term operation and daily operation of the reservoir operational basis for short-term operation is only considered in this study. All of operation quantities study only on the record meant for measuring at the point of the dam site located.

III. Data used in this study

The only secondary data are used in an every case study such as rainfall data, inflow, outflow, discharges, water level in reservoir, and others are available from study reports concerning the operation of the studying reservoir. Those reports were prepared or recorded particularly by Governmental Office.

IV. Mathematical simulation model in use

The model is used as a mathematical simulation model in this experiment is developed by researcher on spreadsheet and add-in macro on the reason of ease to modify certain aspects in particular interesting amendment. The developed model is used only for experimental research in some aspects of reservoir operation and operation rule invention. Some attributions on the developmental model are subject to trial and error procedures of the researcher. It is not for general other users. Definitely, it has not yet for professional or commercial like using.

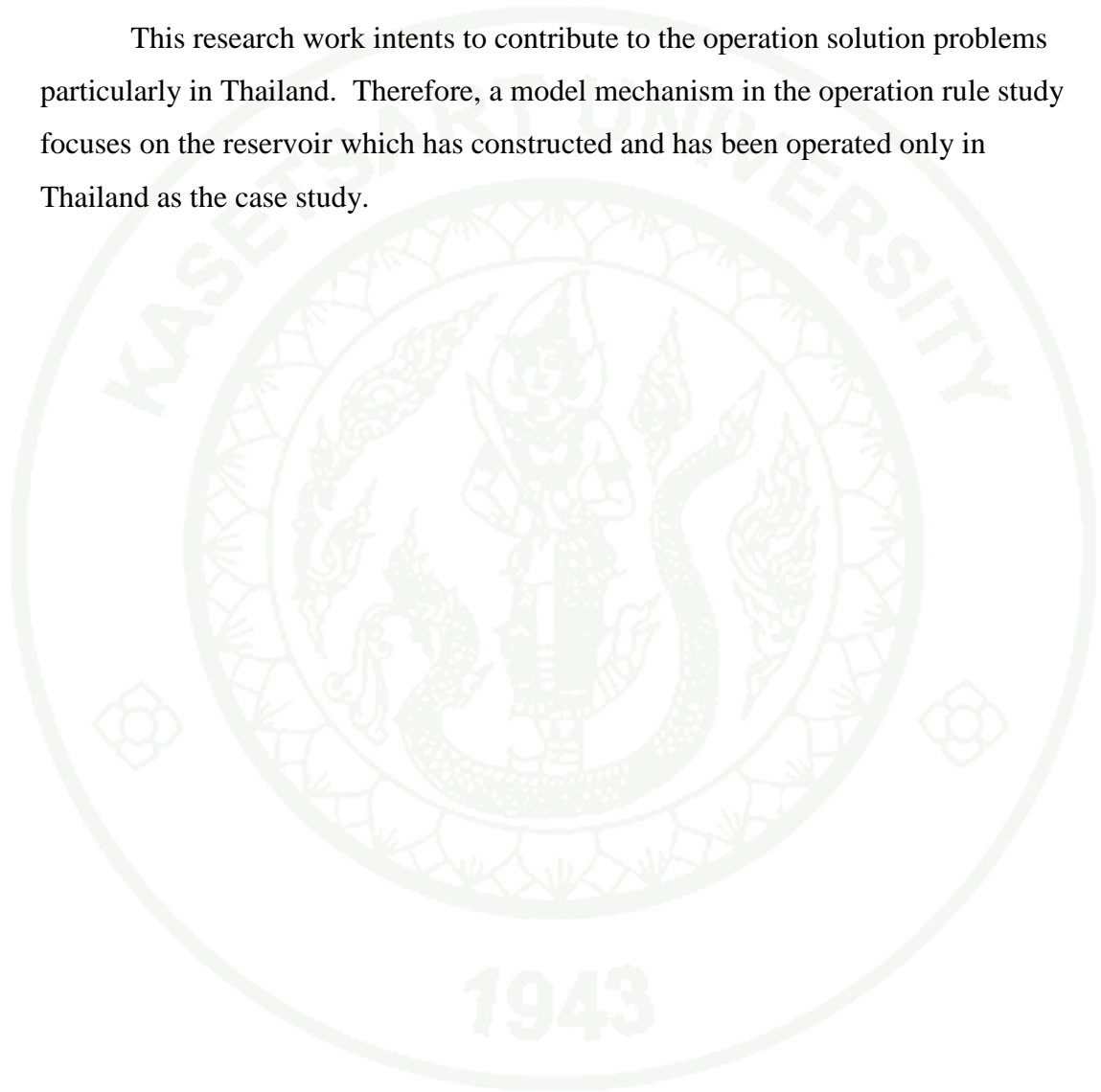
V. The interval of time step using in the model

The time step of the record data is all in daily. In synthesis process from the archetype data, the supply and demand sides of data are generated in daily interval of the time step. Yet, the model for long term optimization requires on a monthly interval of the time step by the reason of the daily interval may take the model too much complexity and unnecessarily take too much time to execute. Nevertheless for the short term operation, the periodical guidance needs to execute in daily. Therefore,

the end result of the long term operation aims to interpolate into the daily time step to use in short term operation.

VI. Reservoir's mechanism in the operation rule focused

This research work intends to contribute to the operation solution problems particularly in Thailand. Therefore, a model mechanism in the operation rule study focuses on the reservoir which has constructed and has been operated only in Thailand as the case study.



LITERATURE REVIEW

The literature review in this study comprises three major categories. First, it is the involvement theories. Second is the related research of precedent works. Lastly, it is the study area. The details in these categories are as follows.

Involvement theories

The following literature review in details of involvement theories is divided into five main topics, and it provides some background on related work and concepts in this field of study. The first topic covers the dynamic data management in term of analyze and synthesize information to support the dynamic features involved in all of this study areas. The second topic reviews pertaining to the reservoir operation techniques including their model formulation, simulation, optimization, and their application to various water resources management, particularly the area of storage problems. The third topic appraises the beneficial advantages of the various decision support systems to exploit. The forth topic assesses the decision support model both for long-term and short-term operation. Finally, the fifth topic describes and examines the technical features of the various ways to invent the dialog for the user interface.

I. Dynamic information and management

This topic of literature review covers the dynamic data management in term of analyzes and synthesizes informed of the nature of uncertainty to support the dynamic features involved in all parts of this study area. The uncertainty is focused on uncertainty information, on management under dynamic features and on adaptation matter. These sub topics were described as follows.

A. Uncertainty information

The dynamic features are the data that change over time in the real world system to naturally reflect any uncertain data. The dependent output data in

observing, it has been influenced by many factors that cause changing. Interact with some logical, some less relevant by incoming data independently as a system. Coleman and Steele (1995) consider measurements made from calibrated instruments for which all known systematic errors have been removed. Even the most carefully calibrated instruments will have errors associated with the measurement errors which assumption will be equally likely to be positive and negative. The accuracy of a measurement indicates the closeness of agreement between an experimentally determined value of a quantity and its true value. Error is the difference between the experimentally determined value and the true value. Accuracy increases as error approaches zero. In practice, the true values of measured quantities are rarely known. Thus, one must estimate error and that estimate are called an uncertainty, U . Usually, the estimate of an uncertainty, U_X , in a given measurement of a physical quantity, X , is made at a 95-percent confidence level. This means that the true value of the quantity is expected to be within the $\pm U$ interval about the mean 95 times out of 100 as shown in Figure 13.

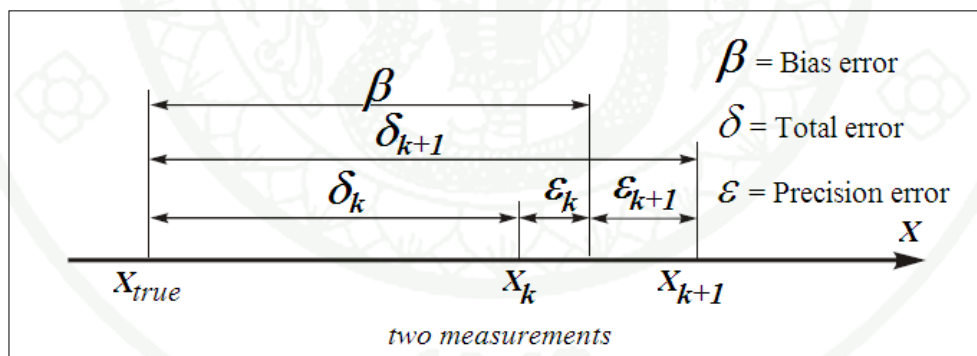


Figure 13 Bias error, Total error and Precision error by two measurements (Redraw by researcher after Coleman and Steele (1995))

The total error, δ , is composed of two components: bias error, β , and precision error, ϵ . An error is classified as a precision error if it contributes to the scatter of the data; otherwise, it is bias error. The effects of such errors on multiple readings of a variable, X , are illustrated in Figure 14.

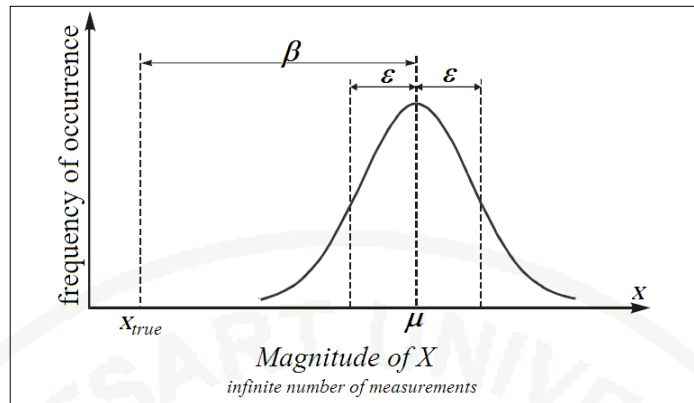


Figure 14 Bias error and Precision error by population N measurements and μ
(Redraw by researcher after Coleman and Steele (1995))

If experiment makes N measurements of some variable, the bias error gives the difference between the mean (average) value of the readings, μ , and the true value of that variable. For a single instrument measuring some variable, the bias errors, β , are fixed, systematic, or constant errors (e.g., scale resolution). Being of fixed value, bias errors cannot be determined statistically. The uncertainty estimate for β is called the bias limit, B . A useful approach to estimating the magnitude of a bias error is to assume that the bias error for a given case is a single realization drawn from some statistical parent distribution of possible bias errors. The interval defined by $\pm B$ includes 95% of the possible bias errors that could be realized from the parent distribution.

Parent distribution is the same meaning with probability mass, probability density, or a probability distribution. This function describes the probability of a random variable taking certain values. For a more precise definition investigation needs to distinguish between discrete and continuous random variables. It has also sometimes been used to denote the probability density function. In other sources, "probability distribution function" may be used when the probability distribution is defined as a function over general sets of values, or it may refer to the cumulative distribution function, or it may be a probability mass function rather than the density.

The probability density function could be configured by searching for its specific parameters. It could be used as the components of the representative function in generating the synthetic data process. In repeated data, it could do the frequency analysis, known as binning or histogram, which describes as a probability density function or a distribution function. The generic concept of the probability density function or the distribution function and the cumulative distribution function can be shown in the Figure 15 and as shown in the following equation. (Ushakov, 2001)

$$P[a \leq X \leq b] = \int_a^b f(x)dx \quad (1)$$

Where

$P[X]$ = Probability of X set of events

a, b = Limit of Random Variable in Function

x = Random Variable

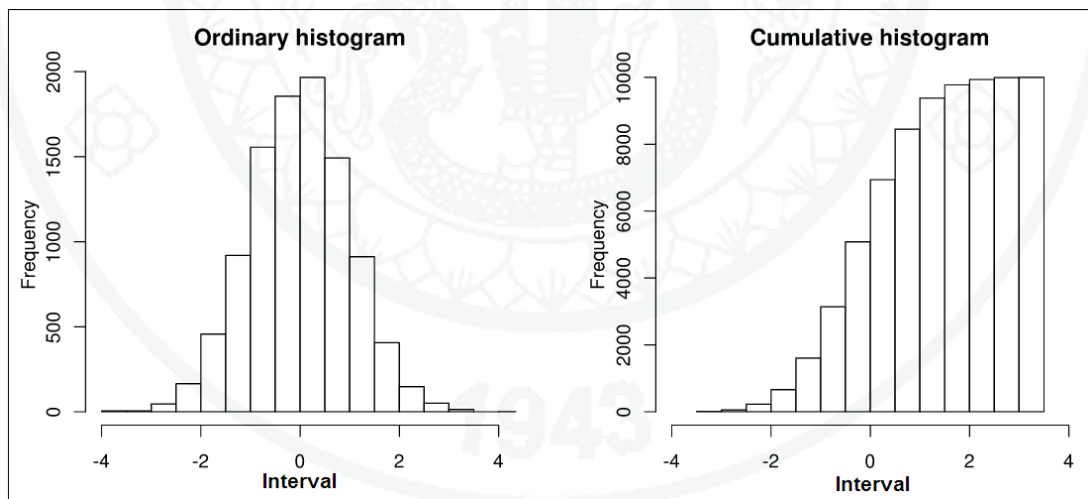


Figure 15 An ordinary and a cumulative histogram of the same uncertainty data

There are many kinds of the density function of the probability for continuous random variables. The well known functions which interested in this study for PDF equations and parameters are listed in the Table 2.

Table 2 The well known functions which interested in this study (PDF equation and parameters for continuous random variables)

Function Name	PDF equation	Parameters
Beta	$f(x) = \frac{x^{\alpha_1-1}(1-x)^{\alpha_2-1}}{B(\alpha_1, \alpha_2)}$	α_1, α_2
Erlang	$f(x) = \frac{1}{\beta (m-1)!} \left(\frac{x}{\beta}\right)^{m-1} e^{-x/\beta}$	m (Integer), β
Gumbel (Extreme)	$f(x) = \frac{1}{b} \left(\frac{1}{e^{z+\exp(-z)}} \right) \text{ where } z \equiv \frac{(x-a)}{b}$	a, b
Inverse Gaussian	$f(x) = \sqrt{\frac{\lambda}{2\pi x^3}} e^{-\left[\frac{\lambda(x-\mu)^2}{2\mu^2 x} \right]}$	μ, λ
Log-logistic	$f(x) = \frac{\operatorname{sech}^2\left(\frac{1}{2}\left(\frac{x-\alpha}{\beta}\right)\right)}{4\beta}$	α, β
Log-normal	$f(x) = \frac{1}{x\sqrt{2\pi\sigma'}} e^{-\frac{1}{2}\left[\frac{\ln x - \mu'}{\sigma'}\right]^2} \text{ with } \mu' \equiv \ln\left[\frac{\mu^2}{\sqrt{\sigma^2 + \mu^2}}\right] \text{ and } \sigma' \equiv \sqrt{\ln\left[1 + \left(\frac{\sigma}{\mu}\right)^2\right]}$	μ, σ
Pareto	$f(x) = \frac{\theta a^\theta}{x^{\theta+1}}$	a, θ
Pearson (Type III)	$f(x) = \frac{1}{\beta B(\alpha_1, \alpha_2)} \times \frac{(x/\beta)^{\alpha_1-1}}{\left(1 + \frac{x}{\beta}\right)^{\alpha_1+\alpha_2}}$	$\alpha_1, \alpha_2, \beta$
Rayleigh	$f(x) = \frac{x}{b^2} e^{-\frac{1}{2}\left(\frac{x}{b}\right)^2}$	b
Weibull	$f(x) = \frac{\alpha x^{\alpha-1}}{\beta^\alpha} e^{-(x/\beta)^\alpha}$	α, β

Source: @RISK Add-In for Microsoft® Excel Manual Document

There are many kinds of the density function of the probability for discrete random variables. The well known functions which interested in this study for PDF equations and parameters are listed in the Table 3.

Table 3 The well known functions which interested in this study (PDF equation and parameters for discrete random variables)

Function Name	PDF equation	Parameters
Binomial	$f(x) = \binom{n}{x} p^x (1-p)^{n-x}$	n (Discrete), p
Integer Uniform	$f(x) = \frac{1}{\max - \min + 1}$	max, min (Discrete)
Poisson	$f(x) = \frac{\lambda^x e^{-\lambda}}{x!}$	λ (Discrete)

Sources: @RISK Add-In for Microsoft® Excel Manual Document

1. Uncertainty on supply side

The uncertainty on supply side caused by climate change that normally happens has the changing condition of the day cycle according to the Earth's rotation that alternates the day time with the night time. When the Earth receives the sunlight, the air mass, the water mass, and the land mass is treated by radiation and the heat is transferred to enable the balanced condition. The phenomena that are close to us and we can perceive them including hot weather, cold weather, blowing wind, land breeze, sea breeze, mountain breeze, and local rainfall, etc.

The changing condition is also the season cycle according to the Earth's axial tilt in of the sun and out of the sun that brings about the spring, summer, autumn, and winter in the cold and warm zones of the Earth. But in the tropical area, it brings about only the rainy season and summer because the heat transferred in the air mass, water mass and land mass to make the re-balanced condition in the region causes the monsoon, depression, tropical storm, and probably more severe typhoon. Moreover, the global climate change is caused in the cycle longer than the season that is the Milutin Milankovitch Cycle named after the name of a Siberian scientist who has explained the change of solar power quantity down to the Earth. Conceptual

explanation is in Figure 16. Thus, the long-term climate change is caused by these three factors described as follows:

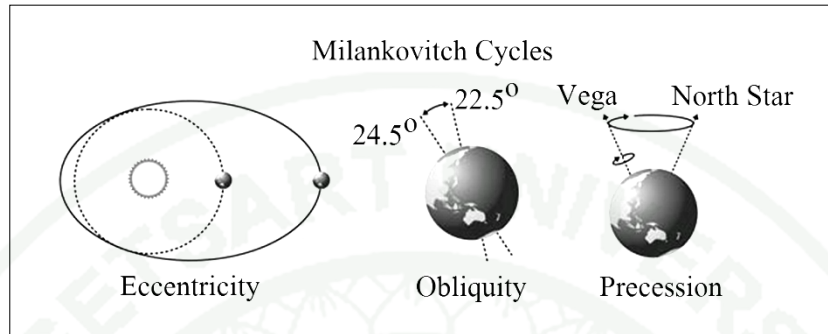


Figure 16 Conceptual explanations on Milutin Milankovitch Cycle

The first uncertainty factor is that the Earth's orbit around the sun has changed its shape from the oval nearly to the circle and reversely from the circle back to the oval again which is called the eccentricity. Each changing of the Earth's orbit shape takes the time approximately from 100,000 to 400,000 years affecting the solar power that the Earth receives. At present, the Earth is extremely far from the sun in July every year with the distance approximately 152 million kilometers whereas extremely close to the sun with the distance of 147 million kilometers in January.

The second uncertainty factor is the Earth's axial tilt. The Earth rotates around the axis drawn through the North Pole and the South Pole which is called the Earth's axis. The Earth's axis is not perpendicular to the equatorial plane of the Earth's orbit around the sun, but tilts to the line perpendicular to the equatorial plane of the Earth's orbit around the sun. The Earth's axial tilt is approximately 23.5° from the line perpendicular to the equatorial plane of the Earth's orbit. The angle is not stable with the changing degrees approximately since 21.5° to 24.5°. When the Earth's axial tilt from 21.5° and increasingly to 24.5° then tilts back to 21.5°, it is called the obliquity and takes about 41,000 years for each cycle.

The last uncertainty factor of the nature is the swinging of the Earth's rotational axis while the Earth orbits around the sun and rotates around its own axis. The Earth's axis also swings in the manner similar to the top's rotation that is going to stop. So, if any Earth's side rotates with the sun, it will get much power. At present, the Earth orbits extremely close to the sun in January when the North Pole swings out of the sun (the North Pole in winter), and extremely far from the sun in July when the North Pole points to the sun (the North Pole in summer). For approximately 11,000 years, because of the Earth's axis rotation, the North Pole swings to the sun when the Earth orbits extremely close to the sun and swings out of the sun when the Earth is extremely far from the sun, and this is called the climate procession. As a result, the northern hemisphere's summer will be the period when the Earth is extremely close to the sun, and the northern hemisphere's winter will be the period when the Earth is extremely far from the sun. In the future, the northern hemisphere may be hotter in summer and colder in winter. After that the Earth's axis will swing back to the same place. This cycle will last for approximately 21,000 years.

Nonetheless, the uncertainty climate change is caused by the human behavior that is beyond the natural normality. The world population has rapidly increased and moved to the industrial revolution, which results in the global warming. According to the 4th report of the Intergovernmental Panel on Climate Change (IPCC) (Solomon *et al.*, 2007), it has concluded that the global warming that is mostly caused by the greenhouse gases emitted from the human activities has been rapidly increasing together with the deforestation. Without sufficient air purifiers, all the greenhouse gases gather densely in the atmosphere. The solar heat that used to be sent back out of the Earth accumulates over abundantly on the Earth and causes the global temperature to increase. However, this is the natural process to help keep the global temperature not to be too cold for the living things on Earth. Usually, the Earth's surface temperature is averagely 15°. If without the greenhouse gases, the Earth's surface temperature will be -18° that the living things cannot stay alive. But what the Earth is encountering now is the over abundant greenhouse gases accumulating in the atmosphere that is called the greenhouse effect. (WMO, 2007)

So, the greenhouse gases emitted from the human activities are the problems that must be solved by everybody. During the past years, the Earth accumulates persistently the increasing amount of greenhouse gases in the atmosphere because the fuel burning in daily activities and natural disasters such as volcanic eruption causes the atmosphere to store the increasing thermal power that will result in the changing of power equity with a variety of constant effects including the environmental crisis and more severe disasters. Many countries are affected and refer to the cause of global warming as shown in the Figure 17. It is expected that the effect will further cause the anomaly of weather variability. Therefore, many scientists are seriously interested in and try to understand the atmospheric system of the Earth.

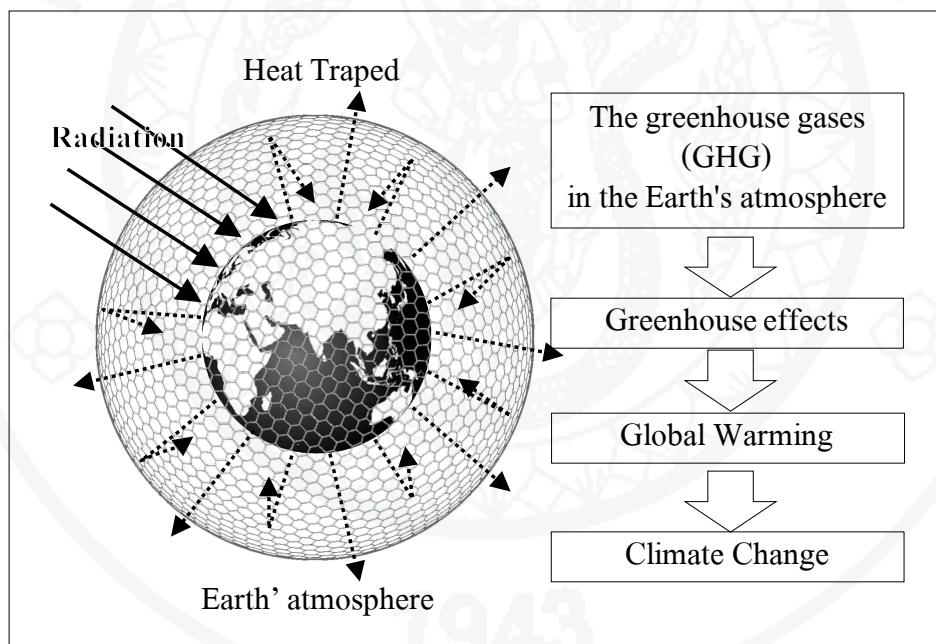


Figure 17 The global dynamic climate changing by the effect of greenhouse gas

The important approach is to foresee how the climate will change by month, year, season, decade or century in order to find ways to lessen or mitigate the severe effects of natural disaster which is unavoidable. Many countries including Thailand are aware of their responsibilities and should join hands in the campaign to lessen/mitigate the natural disaster effects in the future. The regional climate varies

occurring on the quasi-periodic climate pattern includes the El Niño-Southern Oscillation and the La Niña-Southern Oscillation (Wikipedia, 2012).

El Niño is the phenomenon of abnormal warming of sea surface temperatures across the equatorial eastern-central tropical Pacific Ocean from the average of 0.5°C upwards. This results in the occurrence of severe rainstorm that causes the flood around the coast of South America, and abnormal droughts in the countries located in the western tropical Pacific Ocean such as Australia, Indonesia, and Thailand, etc.

La Niña is the reverse phenomenon of El Niño that the sea surface temperatures across the equatorial eastern-central tropical Pacific Ocean is lower than normal by -0.5°C downwards. La Niña occurs every 2-3 years and normally will last for about 9-12 months, but sometimes, it can last up to 2-3 years. The important index used to indicate the size of El Niño and La Niña is the sea surface temperature anomaly across the equatorial central tropical Pacific Ocean. Scientists have identified 5 areas for the follow-up including Niño 1+2 ($90^{\circ}\text{W}-80^{\circ}\text{W}, 10^{\circ}\text{S}-0^{\circ}$), Niño 3 ($150^{\circ}\text{W}-90^{\circ}\text{W}, 5^{\circ}\text{S}-5^{\circ}\text{N}$), Niño 3.4 ($170^{\circ}\text{W}-120^{\circ}\text{W}, 5^{\circ}\text{S}-5^{\circ}\text{N}$), and Niño 4 ($160^{\circ}\text{E}-150^{\circ}\text{W}, 5^{\circ}\text{S}-5^{\circ}\text{N}$). The Oceanic Niño Index (ONI) is an index that is calculated from the sea surface temperature anomaly in the Niño 3.4 region covering the area of $5^{\circ}\text{S}-5^{\circ}\text{N}$ latitude and $120^{\circ}\text{W}-170^{\circ}\text{W}$ longitude. This region is shown in Figure 18. The National Oceanic and Atmospheric Administration (NOAA) use this index to predict the occurrence of ENSO phenomenon and evaluate its severity (NOAA, 2012).

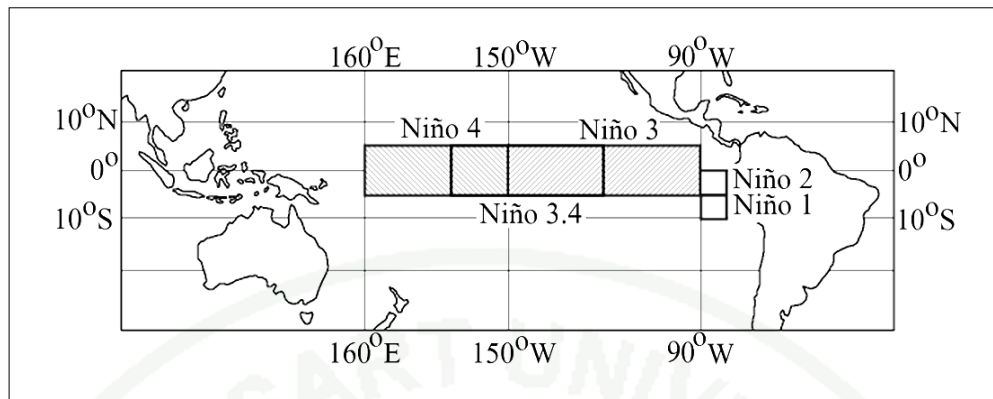


Figure 18 Niño 3.4 region where the Oceanic Niño Index is investigated

Source: IPCC redraws by researcher

a. Uncertainty on season

The uncertainty on season caused by the amount of heat energy received at any location on the globe. It is a direct effect of sun angle on climate, as the angle at which sunlight strikes the Earth varies by location, time of day, and season due to the Earth's orbit around the sun and the Earth's rotation around its tilted axis. Seasonal change in the angle of sunlight, caused by the tilt of the Earth's axis, is the basic mechanism that results in warmer weather in summer than in winter.

(Khavrus and Shelevytsky, 2010) The uncertainty of supply side data such as rainfall or inflow data is also caused by the uncertainty on the season.

b. Uncertainty of whirlwind storm

In some tropical and subtropical regions, as Thailand, it is more common to speak of the rainy (or wet, or monsoon) season versus the dry season, because the amount of precipitation may vary more dramatically than the average temperature. In other tropical areas a three-way division into hot, rainy, and cool season is used. In some parts of the world, special "seasons" are loosely defined based on important events such as a hurricane season, tornado season or a wildfire

season. The formation of tropical storm is the topic of extensive ongoing research and is still not fully understood. (Anonymous, 2006b) All mentions of this uncertainty on whirlwind storm could be affected to the uncertainty of supply side data. The whirlwind especially typhoon in Pacific Ocean tracking was recorded as shown in Figure 19.

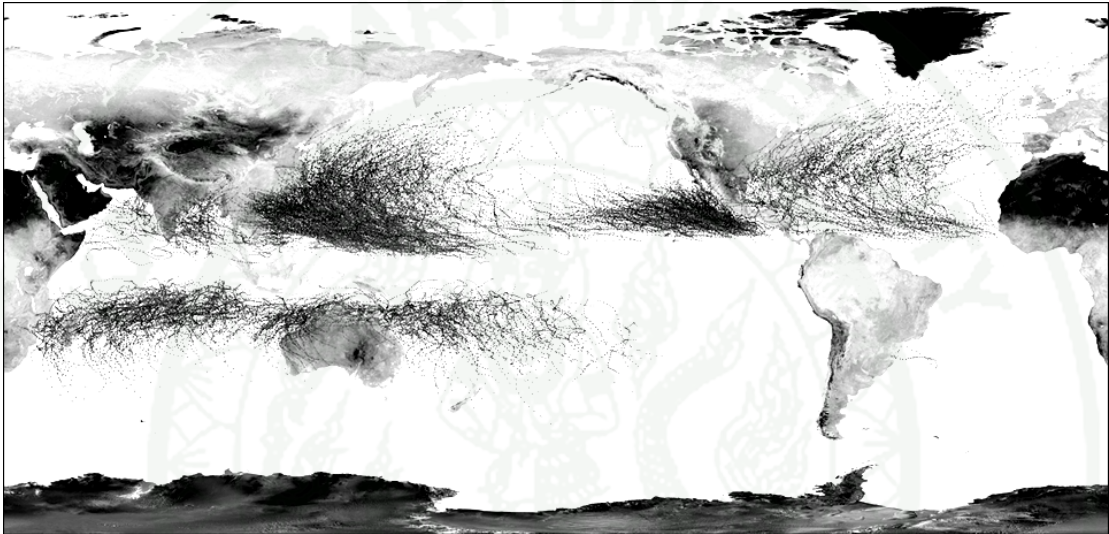


Figure 19 The trace records of the whirlwind tracking in the world.

Source: NOAA reformed by author.

c. Uncertainty on global climate change

Past hydrological data can be estimated in the modern era with the global network of precipitation gauges. Surface coverage over the oceans and remote areas is relatively sparse but reducing reliance on interpolation satellite data. It has been available since the 1970s. (New *et al.*, 2001) Quantification of climatologically variability of precipitation in prior centuries is less complete but approximated using proxies such as marine sediments, ice cores, cave stalagmites, and tree rings. (Dominic *et al.*, 2004)

Climatologically temperatures substantially affect precipitation. Thermal-driven evaporates from the oceans onto continental landmasses was low. It causes large areas of extreme desert. In contrast, the world's climate was wetter than today near the start of the warm Atlantic Period of 8000 years ago. (Adams and Faure, 1997)

Estimated global land precipitation increased by approximately 2% over the course of the 20th century, though the calculated trend varies if different time endpoints are chosen, complicated by ENSO and other oscillations, including greater global land precipitation in the 1950s and 1970s than the late 1980s and 1990s despite the positive trend over the century overall. Similar slight overall increase in global river runoff and in average soil moisture has been perceived. (Huntington, 2006)

2. Uncertainty on demand side

The uncertainty on demand side was assessed by the deterministic process in prior planning phase or construction phase of the project. For the typical assessment of demand side, it is calculated on the agricultural area and all of water requirements in order to balance the water budget which would be provided by the reservoir. Therefore, the water demand criterion which in the project consideration is initially set as the water release target while the project has been operated. This demand may say the constant quantity. But, the real demand by actual operation emerges the inherent fact that it is not really the fixed quantity. It is including the inborn uncertainty. These uncertainties are divided to the land usage changed, the cropping pattern changed, and the water requirements of certain activity change, etc. This changing aspect has been progressing from the project accomplished and beginning operates. For that reason, the dynamical evaluation should be done by the stochastic process or by using the random variables to account for the changeability of the operation rule in order to further optimal adaptation for the right water delivery on the right quantity, time, and location of water users.

a. Uncertainty on proactive or objective demand side

The uncertainty in regard to the proactive or to the objective demand side of the water user's domain may promote the project criterion on demand side concerned whether that it might respond to the originated water delivery target since the project initiated. The complied procedure by the water user practice is the restricted obedience to the water user group leader. The advantages of this practice are the ease in the water release planning for the reservoir operation. But, the disadvantage practice is the most difficult to restricted control of the amount of the water users who require various water demands by separated using in the field.

b. Uncertainty on post passive or subjective demand side

The uncertainty regard to post passive or to the subjective demand side of the water user's domain may cause the project criterion on demand side concerned whether that it would still respond to the originated water delivery target since the project initiated or not. The subjective procedure by the water user practice is none restricted regulation. The advantages of this practice are the easiest and the flexible feel free for water users in the water commanding for the reservoir operation. But, the disadvantage practice is the most difficult to optimal plan of the water release from the reservoir to ensure the water usage coverage both in the periodical short term and in all year round.

B. Management under Dynamic Features

Management under Dynamic Features is the meaning of management under uncertainty. Uncertainty is a term used in subtly different ways in a number of all fields, including physics, philosophy, statistics, economics, finance, insurance, psychology, sociology, engineering, and information science. It applies to predictions of future dynamical events, to physical dynamic measurements already made, or to the dynamic unknown. Tannert *et al.* (2007) who addressed as shown in Figure 20

that there are other taxonomies of uncertainties and decisions that include a broader sense of uncertainty and how it should be approached from an ethics perspective.

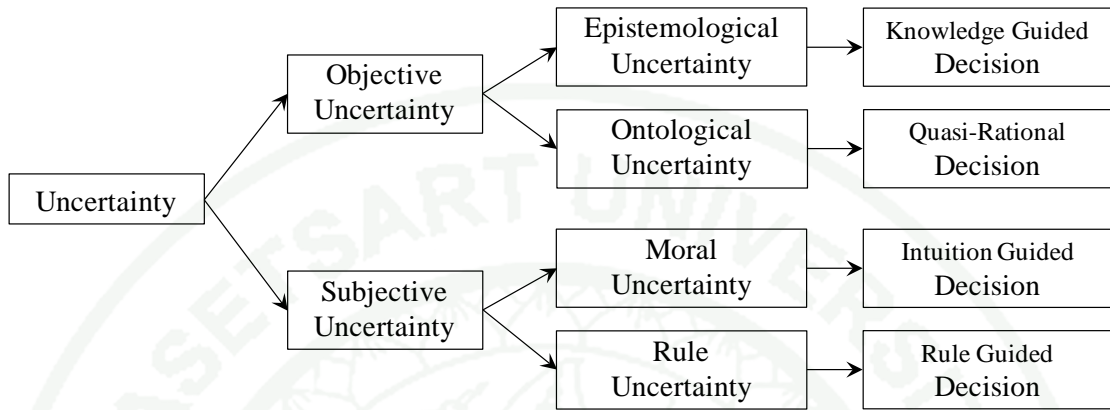


Figure 20 The taxonomies of uncertainties and decisions

Management under Dynamic Features has the measure in the decision under uncertainties which are unavoidable supported by the risk assessment. Basically, the risk is composed of the probability and the expectation or the expected value due to each individual probability relationship. David (2012) has discriminated the type of decision making that there are many types of decision making and these can be easily categorized into the following six groups: Rational, Intuitive, Combinations, Satisfying, Decision Support Systems, and Recognition primed decision making.

Rational decision making is the commonest of the types of decision making that is taught and learned when people decide that they want to improve their decision making. These are logical, sequential models where the emphasis is on listing many potential options and then working out which is the best. Often the pros and cons of each option are also listed and scored in order of importance. The rational aspect indicates that there is considerable reasoning and thinking done in order to select the optimum choice.

The second of the types of decision making is the intuitive models. The idea here is that there may be absolutely no reason or logic to the decision making process. Instead, there is an inner knowing, or intuition, or some kind of sense of what the right thing to do is. And there are probably as many intuitive types of decision making as there are people. People can feel it in their heart, or in their bones, or in their gut and so on. There are also a variety of ways for people to receive information, either in pictures or words or voices. People talk about extra sensory perception as well. However, they are still actually picking up the information through their five senses.

The third types, many decisions are actually a result of combinations of rational and intuitive processes. This can be deliberate where a person combines aspects of both, or it can occur unwittingly.

The fourth, instead of evaluating all the possible options and choosing the best, satisfying is where the decision picks the first one that will give the result. The decision making chooses an option that is “good enough”, one that satisfies our needs and sacrifices other potentially better options. Hence, it satisfies.

The fifth types, because computers can process large amounts of data quickly, they were soon put to use to help make decisions. Decision Support Systems range from a simple spreadsheet to organize information graphically, to very complex programs organizing info on international companies and including artificial intelligence that can suggest alternative options and solutions. There are various types of decision making systems depending on how many people are involved, the form of the information being processed, what type of result is required, and so on. There are pros and cons to using computers in this way, and of course, the computer is only as good as the information that it is processed which means that it still comes down to the humans.

The last type, a scientist's considerable time studying human decision making and his results are very interesting. He believes that one can make 90 to 95% of

own decisions in a pattern recognition way. He suggests that what one actually does is gather information from whose environment in relation to the decision which wants to make.

1. Risk of Luck and Risk of Hazard

Limited liability Company or LLC (2006) given risk can be seen as relating to the probability of uncertain events. In the measurement of risk sense, Hubbard (2000) uses the terms that possibility each with quantified gain probability and quantified loss probability as the risk of luck and the risk of hazard respectively.

The generally interesting definition of “Risk” address by the expert in the field of Psychology that “Risk is the conditions or situations that are empirically related to particular outcomes”. (Reddy *et al.*, 2001) In summary, the risk in quantifying measure is composed of the probability and the expected values to obtain.

2. Probability

The probability is a measure of the confidence an incident that an uncertainty event will occur. William (1968) adopts that the certainty of any event can be described in the terms of a numerical measure and this number, between 0 and 1.

3. Expectation

The good expectation may be quantified value of benefit, profit, available water budget which are called the expected value. The windfall indicates by associating with its probability that called the Risk of Luck. The bad expectation may be quantified value of harmful, damage which is called the hazard value. Sperber and William (2001) informed a hazard is any biological, chemical, mechanical, environmental or physical agent that is reasonably likely to cause harm or damage to humans, other organisms, or the environment in the absence of its control. The hazard indicates by associating with its probability that called the Risk of Hazard.

The expected values and probability used in this research in term of the payoff probability is a major component of the decision tree. (Yuan and Shaw, 1995)

4. Deterministic and stochastic process approach

The related data to the reservoir model involved uncertainty properties. The deterministic and stochastic approaches are the system of data orientation in various perspectives of advantages and disadvantages. These following literatures are a selective matter for reservoir model driven.

a. Deterministic process approach

Encyclopedia of Science (2012) informed that in mathematics and physics, a deterministic system is a system in which no randomness is involved in the development of the states of the system. A deterministic model will thus always produce the same output from a given starting condition or initial state. The reservoir operation rule can be derived from determining input data to perceptibly obtain the output. The criterion of determination setting for the data orientation was adopted in deterministic approach. For example, the acceptable extreme data usage in the best case of extreme event study, the average data usage in moderate of event estimation, and the acceptable minimal data usage in the worst case of extreme event study.

b. Stochastic process approach

In probability theory, a stochastic process or widely used a random process is a collection of random variables that is often used to represent the evolution of some random value, or system, over time. This is the probabilistic counterpart to a deterministic process or deterministic system. Instead of describing a process which can only evolve in one way, in a stochastic or random process there is some indeterminacy even if the initial condition or starting point is known, there are several directions in which the process may evolve. The basic type of a stochastic process is a random field, whose domain is a region of space, in other words, a random function whose arguments are drawn from a range of continuously changing values. One

approach to stochastic processes treats them as functions of one or several deterministic arguments (inputs, in most cases regarded as time) whose values output values are random variables such as non-deterministic quantities which have certain probability distributions. Random variables corresponding to various times or points, in the case of random fields, may be completely different. The main requirement is that these different random quantities all have the same type. Type refers to the co-domain of the function. Although the random values of a stochastic process at different times may be independent random variables, in most commonly considered situations they exhibit complicated statistical correlations. (Karlin *et al.*, 1998)

C. Adaptation

Adaptation could be a part in the field of information response or managed by the effects of dynamic features.

1. Acceptance and Rejection area

In general, the purpose of statistical tests is to determine whether some hypothesis is extremely unlikely given observed data. There are two common philosophical approaches to such tests, significance testing (Fisher, 1922a) and hypothesis testing. (Jerzy and Pearson, 1933)

a) Significance testing

Significance testing aims to quantify evidence against a particular hypothesis being true. It is recognized as testing to guide research. A certain statement may be true and want to work out whether it is worth investing time investigating it. Therefore, it looks at the opposite of this statement. If it is quite likely then further study would seem to not make sense. However if it is extremely unlikely then further study would make sense. (Fisher, 1954b)

b) Hypothesis testing

Hypothesis testing rather looks at the evidence for a particular hypothesis being true. It is recognized as a guide to making a decision. It supports the need to make a decision soon, and suspect that a given statement is true. Thus to see how unlikely is wrong, and if sufficiently unlikely to be wrong the testing can assume that this statement is true. Often this decision is final and cannot be changed. (Jerzy and Pearson, 1933)

These differences and incorrectly treat the terms "significance test" and "hypothesis test" as though they are interchangeable. A data analyst frequently wants to know whether there is a difference between two sets of data, and whether that difference is likely to occur due to random fluctuations, or is instead unusual enough that random fluctuations rarely cause such differences.

In particular, frequently the wish is to know something about the average (or mean), or about the variability (as measured by the variance or standard deviation). Statistical tests are carried out by first making some assumption, called the Null Hypothesis, and then determining whether the data observed is unlikely to occur given that assumption. If the probability of seeing the observed data is small enough under the assumed Null Hypothesis, then the Null Hypothesis is in the rejection area. Besides it is being in the acceptance area. The Figure 21 shows a conceptual diagram of acceptance area and rejection area of F-Test, χ^2 -Test, and Z-Test.

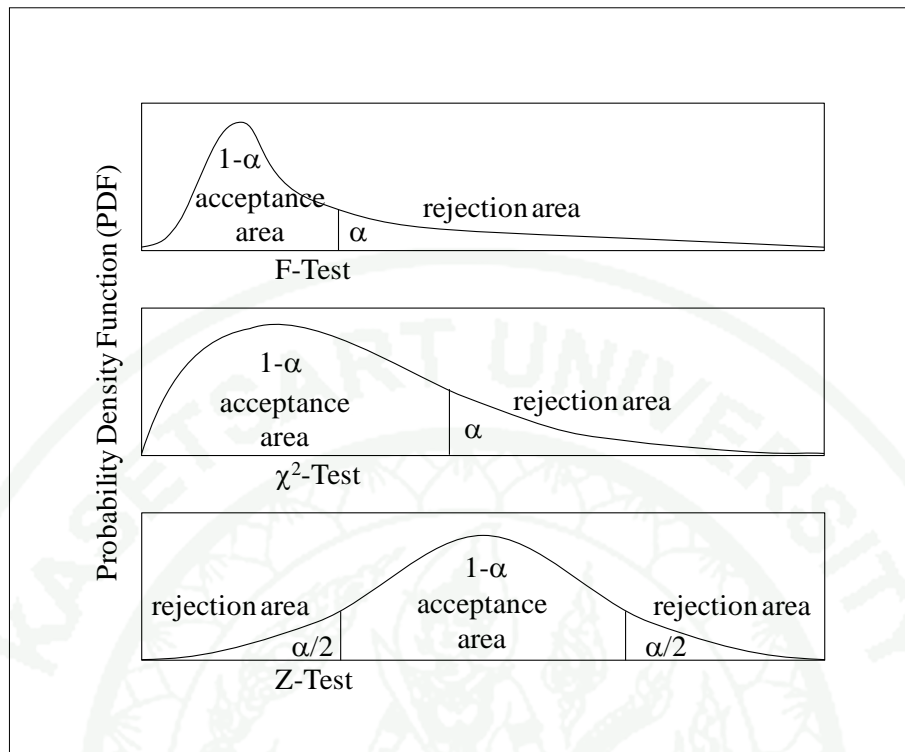


Figure 21 The conceptual diagrams of acceptance area and rejection area of F-Test, χ^2 -Test, and Z-Test.

II. Reservoir operation on systematic model techniques

The reservoir operation techniques rely on the reservoir system. The system is defined to be a collection of entities, e.g., watershed, dam, water supply side, water demand side, operator, water users, that act and interact together toward the accomplishment of some logical end. For most systems, there is a need to study model system to try to gain some insight into the relationships among various components, or to predict performance under some new condition being considered. Figure 22 below the scheme are mapped out possible different ways in which a model system might be studied. (Averille, 2007)

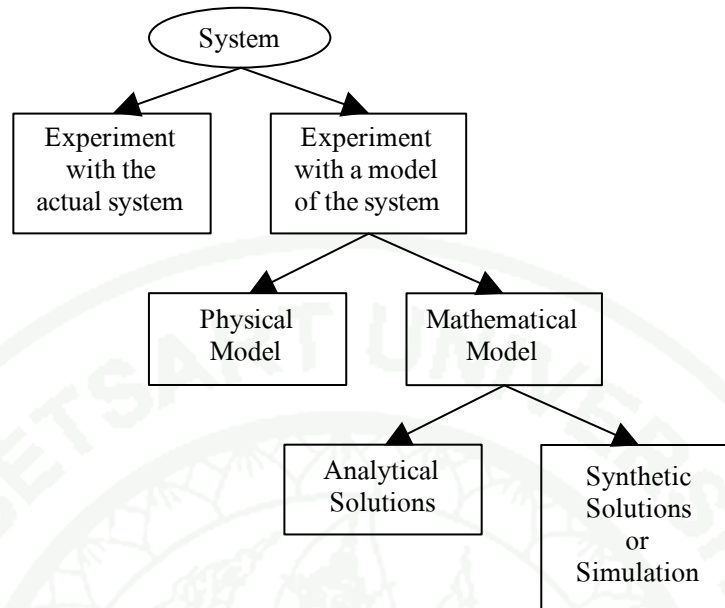


Figure 22 Maps out possibility different ways to study a model system

Experiment with the actual system versus experiment with a model of the system should be considered in the case of it is possible and cost effective to alter the system physically and then let it operate under the new conditions. It is probably desirable to do so, for in this case there is no doubt about whether what the study is valid. However, it is rarely feasible to do this, because such an experiment would often to be taken costly or too disruptive to the system.

Physical model versus Mathematical model should be considered in the case of physical model or also called iconic model has been found useful to build on the Tabletop scale model of material handling systems. But the vast majority of models built for such purposes are mathematical models, representing a system in term of logical and quantitative relationships that are then manipulated and changed to see how the model reacts, and how the system would react, if the mathematical model is a valid one. (Swart and Donno, 1981)

Analytical Solutions versus Synthetic Solutions or Simulation should be considered in the case of once we have built a mathematical model. It must then be

examined to see how it can be used to answer the questions of interest about the system it is supposed to represent. If the model is simple enough, it may be possible to work with its relationships and quantities to get an exact analytical solution. If an analytical solution to a mathematical model is available and is computationally efficient, it is usually desirable to study the model in this way rather than via a synthetic solution or simulation. However, many model systems are highly complex, so that valid mathematical models of them are themselves complex, precluding any possibility of an analytical solution. In this case, the model must be studied by means of simulation.

A. Reservoir Operation Principles

Water storage systems such as reservoirs or dams are hydraulic constructions used in some regions to improve water access in semi-arid bi-seasonal regions. They have been constructed by local governments, communities and also on private initiative. Reservoirs or dams catch water, usually surface runoff, during the rainy or wet season in order to make water available during the dry season (Liebe, 2007). One definition of a small dam, is “one whose maximum height above the lowest point in the original stream bed does not exceed 15 meters, and whose volume is not of such magnitude that significant economies can be obtained by utilizing the more precise methods of designs usually reserved for large dams”. (United States Department of the Interior Bureau of Reclamation, 1974)

More precise methods, that refer to the possibility to control the dams in their water regulative function, e.g. for generation of hydro-power. In other words, a small dam is not intended to be operated for such purposes and the operation center (if present) is not very sophisticated. The function of small dams in dry regions is, in short, to have access to water in times of drought. The dams are often referred to as having multiple purposes (or multi-purpose reservoirs), as they deliver water for multiple uses, such as domestic use, livestock watering, and predominantly small-scale irrigation. (SRP, 2003)

U.S. Army Corps of Engineer (1977) has given the detail for reservoir storage allocation as follows. Water storage systems or reservoir systems may be grouped into two general operation purposes: “conservation” and “flood control”. Conservation purposes include water distribution, low-flow augmentation for water quality, recreation, navigation, irrigation and hydroelectric power, and any other purpose for which water is saved for later release. Flood control is simply the retention or detention of water during flood events for the purpose of reducing downstream flooding.

Generally, the total reservoir storage space in a multipurpose reservoir consists of three major parts shown in Figure 23.

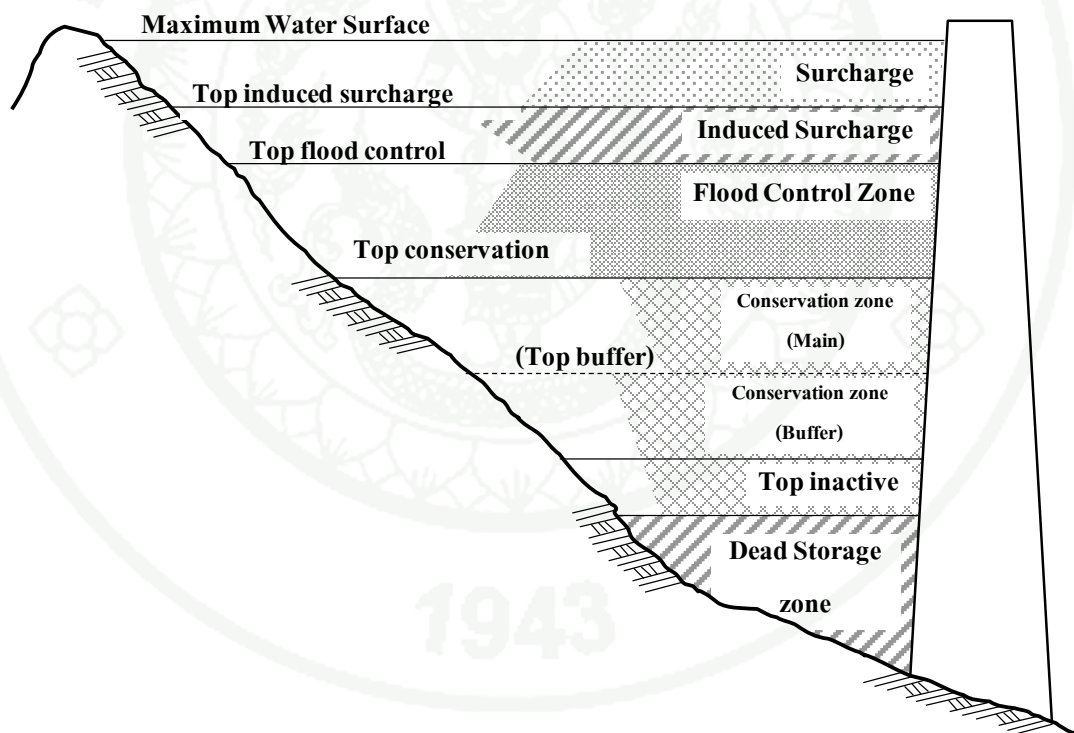


Figure 23 Reservoir allocation zones

In general, these storage spaces could be determined separately and combined later to arrive at a total storage volume of the reservoir. Larry (1996) has been suggested that the water storage system can be broadly categorized not only as

“water control systems” and “water usage systems” as shown in Table 4, but it should be noted that these systems are not mutually exclusive also. The third category of “environment restoration” has been suggested as well. The following sections present a brief overview of the design objectives in these systems.

Table 4 Main functional categories of water storage systems

Water-Control systems	Water-Usage systems
Drainage	Domestic and industrial water distribution
Flood Control	Wastewater treatment
Salinity Control	Irrigation
Sediment Control	Hydropower generation
Pollution Abatement	Environmental Restoration

The uncertainty and natural variability of hydrologic process require that most water-resource systems be designed with some degree of “risk”. Approaches to designing water-resource systems approaching to designing a water storage system are classified as either:

Frequency-Based design

Risk-Based design or Critical-Event design

In frequency-based design, the exceedance probability of the design event is selected a priori and the water storage system is designed to accommodate all lesser events up to and including an event with the selected exceedance probability. The water storage system will then be expected to fail with a probability equal to the exceedance probability of the design event. The frequency-based design approach is commonly used in designing the minor structures of drainage systems.

In risk-based design, systems are designed such that the sum of the capital cost and the cost of failure is minimized. Capital cost tends to increase and the cost of failure tends to decrease with increasing system capacity. Because any threats to human life are generally assigned extremely high failure cost, structures such as large dams are usually designed for rare hydrologic events with long return periods and commensurate small failure risks. In some extreme cases, where the consequences of failure are truly catastrophic, water storage systems are designed for the largest possible magnitude of a hydrologic event. This approach is called critical event design, and the value of the design variable in this case is referred to as the “Estimate Limiting Value” (ELV).

For the water Balance Basis, Young *et al.* (1997) addressed that a system is defined as a collection of matter of fixed identity. It may move, flow, and interact with its surroundings. In other words, a fluid system always contains the same set of mass. In contrast to a fluid system, which move around within a fluid continuum, a “*control volume*” is fixed volume in space through which fluid may flow both in and out. The “*Reynolds transport theorem*” relates the rate of change of any property in a fluid system to the rate of change of that same property in a control volume containing the fluid.

Consider the control volume in Figure 24 and define a fluid system as the fluid contained in the control volume at time t . In other words, at time t , the fluid in the control volume and the fluid in the system are the same. During a subsequent time interval, Δt , a volume V_I of fluid enters the control volume, a volume V_{II} of fluid remain in the control volume, and a volume V_{III} of fluid leaves the control volume.

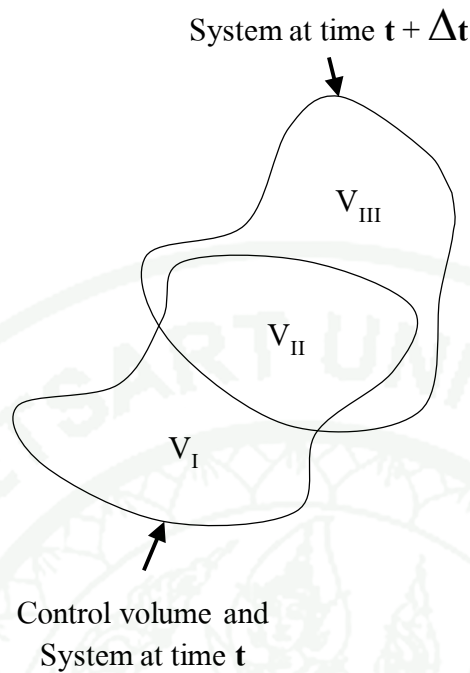


Figure 24 The inventory system and Control Volume

Defining the amount of a fluid property within the system at time t as $B(t)$, then the change in bulk; B over the time interval Δt is given by

$$B(t + \Delta t) - B(t) = \left(\int_{V_I} \rho \beta dV + \int_{V_{II}} \rho \beta dV \right)_t - \left(\int_{V_{II}} \rho \beta dV + \int_{V_{III}} \rho \beta dV \right)_{t+\Delta t} \quad (2)$$

$$B(t + \Delta t) = B(t) + \left(\int_{V_I} \rho \beta dV \right)_t + \left(\left(\int_{V_{II}} \rho \beta dV \right)_t - \left(\int_{V_{II}} \rho \beta dV \right)_{t+\Delta t} \right) - \left(\int_{V_{III}} \rho \beta dV \right)_{t+\Delta t} \quad (3)$$

It can be described that

$$B(t + \Delta t) = B(t) + \text{Inflow} + \text{control volume change} - \text{losses} \& \text{Outflow} \quad (4)$$

In application, the Water Balance Basis is the principle that becomes to Mass Balance Equation commonly used in reservoir operation and simulation shown as below.

$$ST_{t+1} = ST_t + PP_t + QF_t - R_t - EV_t - SP_t \quad (6)$$

where ST_{t+1} is the reservoir storage at the beginning of time period $t + 1$.
 ST_t is the reservoir storage at the beginning of time period t .
 PP_t is the precipitation amount on the reservoir surface of time period t .
 QF_t is the sum of inflows amount on the reservoir catchment of time period t .
 R_t is the reservoir release of time period t .
 EV_t is the evaporation of time period t .
 SP_t is the seepage and loss during time period t .

For the simplification expression, Mass Balance Equation in reservoir operation and simulation simply rewrite as:

$$ST_{t+1} = ST_t + \sum I_t - \sum R_t \quad (7)$$

where $\sum I_t$ is all of the water inflow runoff adding in at the beginning of time period t .

$\sum R_t$ is all of the water release out at the beginning of time period t .

1. Mathematical Model Formulation

The model is a structure which has been built purposefully to exhibit features and characteristics of any object. The reasons why to build a model are to improve understanding and communication, to experiment, and to standardize for analysis. The general way to construct mathematical models is the usage the variables and equations. Common features of mathematical models are abstractions which

needs enough details and need overlook, second, the computability which can the model be manipulated with ease, third, input data requirements, fourth, an uncertainty which is the inputs and the relationships between them uncertain, fifth, decision horizons, and sixth, flexibility on risk considerations. In deterministic mathematical models, there is no uncertainty. Then, the important concerns are abstraction and computability. More abstraction yields more computability which is over look at details to make necessary computations. (Metin *et al.*, 2011) However, the model formulation should be consisted of the model validation, calibration, verification and application processes.

a. Model Validation

The model is formed by the relationship between the input data and output information. That relationship is composed of a function or several functions which represent the real world characteristics in a model. Therefore, the way that the relationship naturally imitates to the right functional modeling is the process of the model validation.

b. Model Calibration

The model in term of mathematical model contains functions, parameters, variables and constants which should be represented the conditions in the data of any interesting situation. Consequently, the way that the functions, parameters, variables and the constants are investigated by the real situation testing for reliable usage in the model is the process of the model calibration.

c. Model Verification

The reliability in the model usage is examined by comparing the output between many cases in the real world situations and the output from the same cases in the same situations as in the real world situations which evaluated by the model is the process of the model verification. So, this process must be indicated the reliability by the statistics index for instance the coefficient of correlation, coefficient

of determination, etc. Nonetheless, the range of possibilities available input and reasonable output must be examined in the verification process.

d. Model Application

For the best reliable while in the model used, the validated function, the calibrated parameters, the calibrated constants used in the model, and verified condition range used in the model are the implication caution of the model applied in order to emulate the real world correctly as possible.

2. Decision Tree Model Formulation

The Decision Tree is a graphical representation of a problem describing chance events and decisions in chronological order. Events represented by a branch from their successors, making the final model look like a tree. Traditionally, decision trees begin with a decision node. Haimes (1980) has given the components of decision tree that composed of many “Alternatives”, represented by the type of node signs in a decision tree include:

□ (The rectangular sign), A Decision node has a branch extending from it for every available option.

○ (The circular sign), A Chance node has a branch for each possible outcome.

◁ (The triangular sign), An End node has no branches succeeding it and returns the payoff (p_{mn}) and probability (P_{mn}) for the associated path. At a point of the decision node extending with the branch lines lead as “State of Nature”, represented by the “Chance Node” and it also extends to the branch lines lead as “Consequences” showing in Figure 25. Therefore, the most likely to occur as a result would be affiliated with an opportunity to decide which is the earlier. Cockett and Herrera (1990) given the relationship to this possibility occurs by the chance of “reason” to the chance of “result” in term of expected values by the Bayes’ theory.

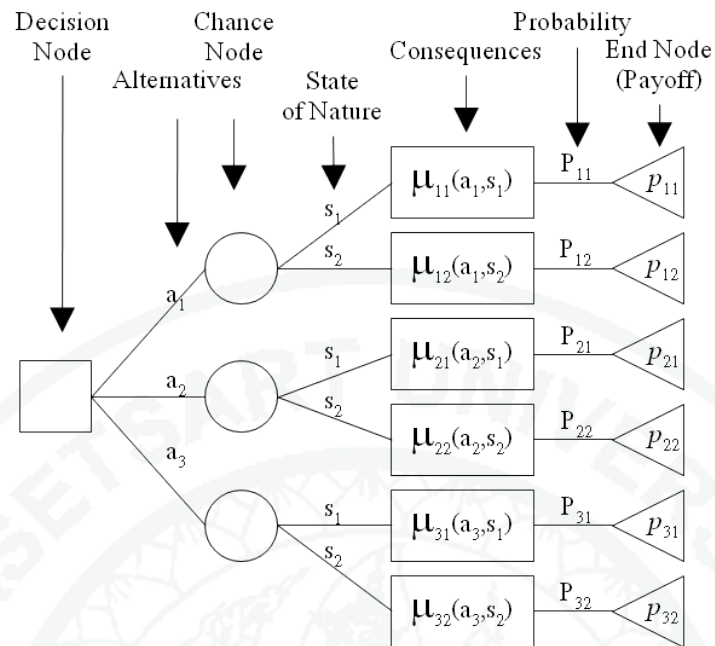


Figure 25 The typical components of the Decision Tree show consequences of the Alternatives

The Decision Tree always describes the logical relationship in a graphical picture. But another form of the same meaning can be described by a matrix notation μ_{mn} represented in the form of the alternatives matrix (m, n) showing in Figure 26 as a function of the alternative variables to a_m and s_n .

$$\begin{vmatrix} \mu_{11}(a_1, s_1) & \mu_{12}(a_1, s_2) \\ \mu_{21}(a_2, s_1) & \mu_{22}(a_2, s_2) \\ \mu_{31}(a_3, s_1) & \mu_{32}(a_3, s_2) \end{vmatrix}$$

Figure 26 The alternatives matrix (m, n) rewrite from the typical decision tree.

3. Bayes' theorem

Bayes' theorem was named after the Reverend Thomas Bayes (1702–61) who studied how to compute a distribution for the probability parameter of a binomial distribution. Bayes presented his work as the solution to a problem: Given

the number of times in which an unknown event has happened and failed [... Find] find the chance that the probability of its happening in a single trial lies somewhere between any two degrees of probability that can be named. (Bayes and Richard, 1763)

Bayesian Theory or Bay's Theorem is a theory that represents the relative value of conditional probability. The structure of the network tree represents for two events that occurred before and after. Their probability can also be calculated forward and backward called the Influence Diagram. (Oliver *et al.*, 1990) For example, there are rain gauge station at the point A and point B with the connected boundary. If there is the probability of the event at point A, and at the same time, there is the rain will fall at the point B in a certain probability event. Or vice versa, it can be implied that if there is the probability of the falling rain event at point B, then it will also have a probability in the falling rain event at point A relative as shown in the Figure 27.

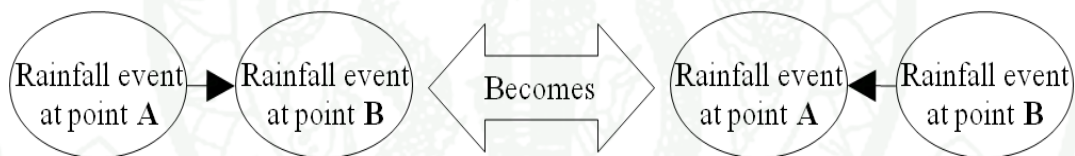


Figure 27 The Influence Diagram or logical relationship of the probability of returning forth-back to the same conditions.

This is the notation used to define the terms involved in conditional probability which is a major basis in Bayes' Theorem.

$$P(A|B) = \frac{P(B|A)P(A)}{P(B|A)P(A) + P(B|\tilde{A})P(\tilde{A})} \quad (8)$$

Where,

$P(A)$ the probability that an event A will occur.

$P(AB)$ the probability that events A and B will both occur (A and B) is equal to $P(BA)$.

$P(A|B)$ the probability that events A will occur if B occur (A given B), but does not equal $P(B|A)$.

$P(\tilde{A})$ the probability that events A will not occur (not A), equals $1-P(A)$.

B. Operational Rule

The reservoir operational rule is the storage output of the reservoir study by optimizing simulation procedure. Basically, it has an assumption on the demand side and the supply side account for the storage at any interval of a year round. The following sub topics are the concept categories on conventional rule and new purposed rule.

1. Conventional Rule

The conventional rule is assembled by the inventory account which means the water release from a reservoir is the same quantity as the water demand called the rule of the standard linear operational policy. The following sub topics and Figure 28 are its concept.

a. Rule of the Standard Linear Operational Policy (SLOP)

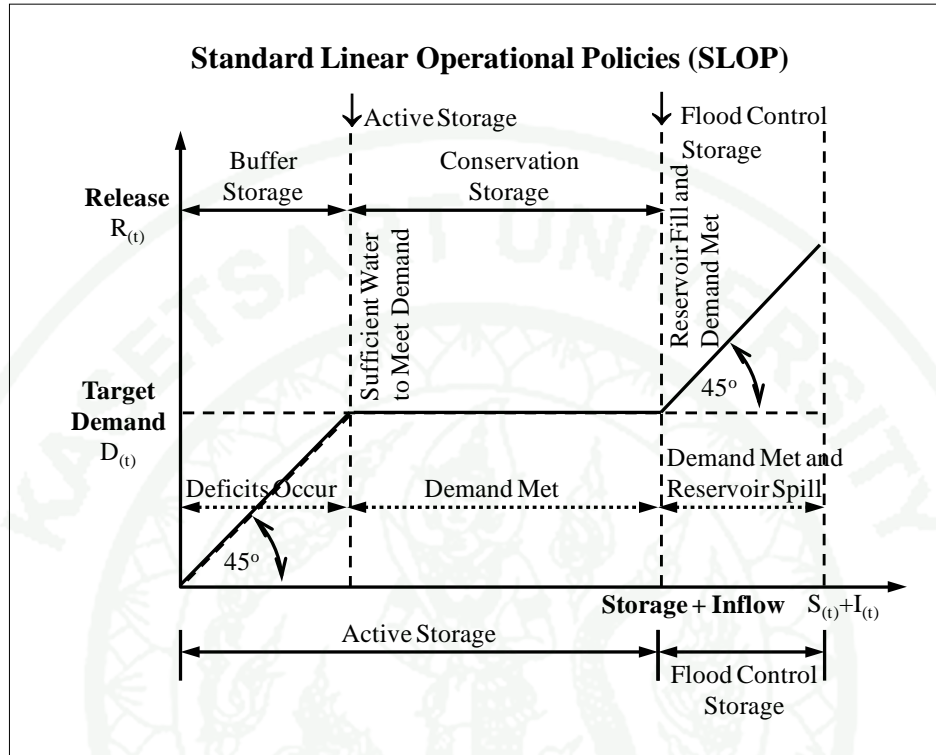


Figure 28 The concept of the rule made by the standard linear operation policy

2. New Proposed Rule and Algorithms

The new proposed rule is assembled by the optimized hedge which means the water release from a reservoir sometime is not the same quantity as the water demand called the rule of the standard linear operational policy. The water release learns to follow the water demand but does not definitely follow all time intervals. It depends on the situation of the storage and optimization process to define when to determine the water release less than, more than or equal to the water demand. (ReVelle *et al.*, 1969) The following sub topics and Figure 29 is its concept.

a. Rule of the Hedge Operational Policy (HOP)

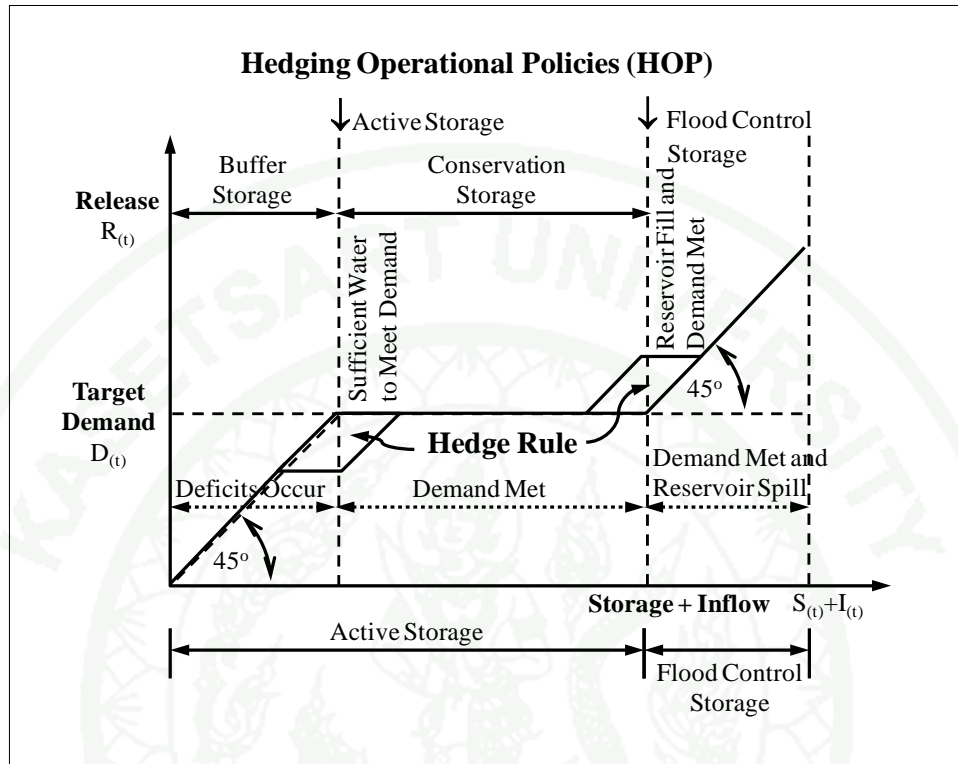


Figure 29 The concept of the rule made by the hedging operational policy

b. Hard and Soft Constraints Programming Algorithm (HSCP)

With the variations in the both sides of the supply and demand, the multi-objectives optimization is the obligatory methodology to adopt in the reservoir operation study particularly in practice or in the operation stage. In single purpose or single objective optimization provides a unique optimal solution, but in multi-purposes or multi objective optimization may not be accomplished without the sacrifice of others optimal solutions. Mays and Tung (2002) proposed the concept of non-inferiority in the multi-objective analysis that preference by choosing the most suitable solution in the set of optimal solutions is required. This approach is categorized as the aggregate approach. It commonly applies by assigning an objective function value to evaluate the dominance of solution sets when transforming the multi-objective problem into a single-objective problem. There are two common

methods to use in transforming: the constraint approach method and the weighting approach method. (Khu and Madsen, 2005)

On the other hand, Burke and Landa Silva (2006) proposed the concept of non preference or no availability of information considering before the search. This approach is not based on a single optimal value but on whether one optimal solution is dominated by others. This approach is categorized as the Pareto approach. The common concepts of multi-objective optimization approaches can be widely classified by a diagram in Figure 30. The trade-off among the different objectives is defined and presented with the set of Pareto optimal solutions or Pareto front line (Yapo *et al.*, 1998). This conceptual front can be illustrated in Figure 31.

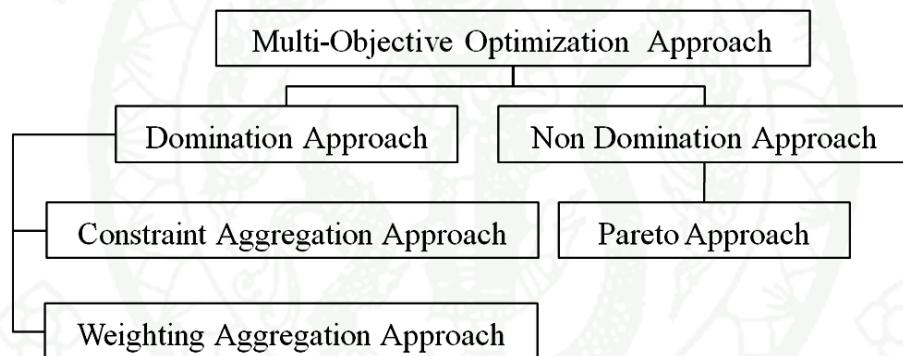


Figure 30 A diagram classified the common concepts of multi-objective optimization approaches

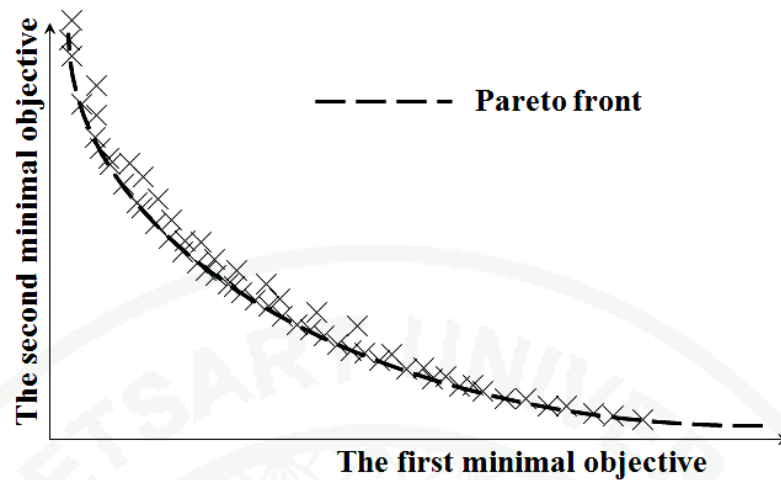


Figure 31 The generic characteristic of the Pareto front for optimization of a two objectives problem

The Pareto front forming in as a line shown above is a group of feasible multi-optimal points that sharing the priority dominance between the first minimal objective and the second minimal objective. If the first minimal objective is increasing the precedence in higher value than the second minimal objective, then the second normally must be decreasing its precedence in a lower value than the first. In opposite, if the first minimal objective is decreasing the precedence in a lower value than the second minimal objective, then the second normally must be increasing its precedence in a higher value than the first.

A kind of the programming algorithm, the Hard and Soft Constraints Programming is a well discrimination tool to approach the multi-objective optimization goal. The obvious feature is an evaluation of multi-objective in a part of optimization in the term of hard constrain and soft constraints strategy. The Figure 32 shows the main difference procedure in programming compared the traditional algorithm with the Hard and Soft Constraints Programming algorithm.

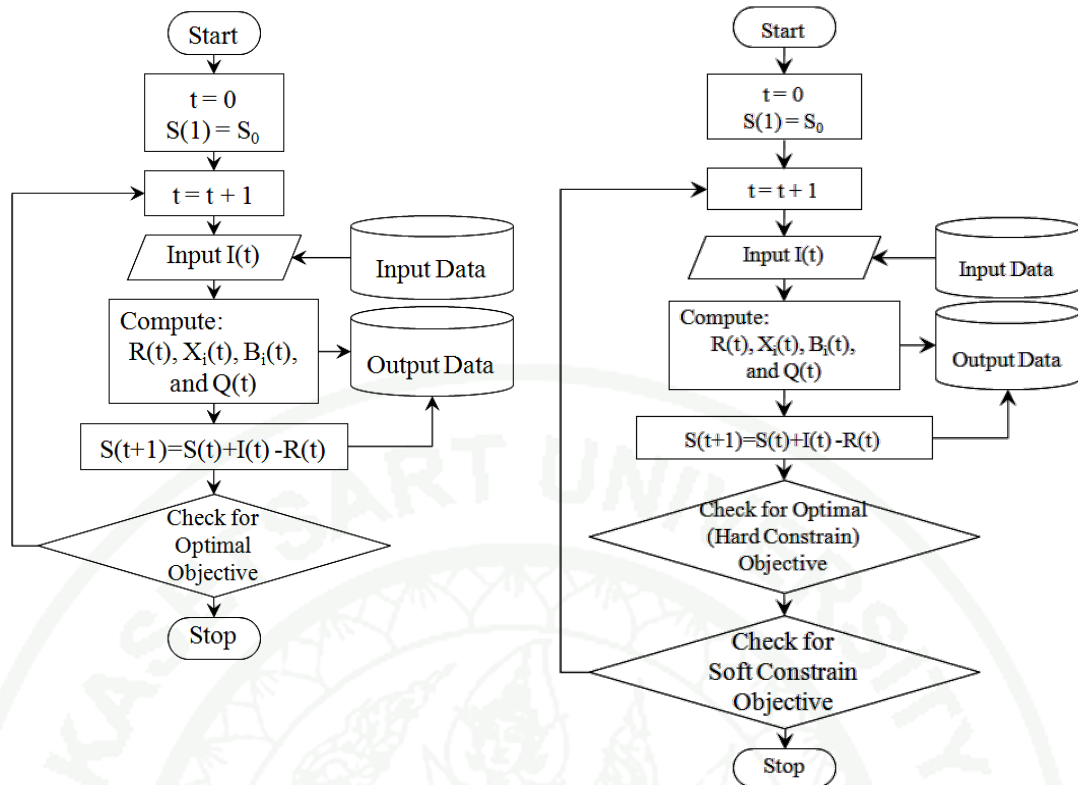


Figure 32 The additional procedure with Hard and Soft constrain objective checking in Hard and Soft Constraints Programming Algorithm (Right) compared with the traditional algorithm (Left).

C. Operational Rule for Global climate change and El Niño – La Niña phenomenon

The operational Rule for Global climate change and El Niño – La Niña phenomenon is a caution sign for consideration to use the conventional rule. If the assumption in the raw data of the supply side is subject to change more than the acceptance criteria of statistics then the rule should be considered to change. The following sub topics are the essential concerning.

1. Information on Global climate change and El Niño – La Niña phenomenon
2. Operational Rule while as El Niño phenomenon
3. Operational Rule while as La Niña phenomenon

III. Decision support system

A decision support system (DSS) is a computer-based information system that supports organizational decision-making activities. DSS serves the management, operations, and planning levels of an organization and help to make decisions, which may be rapidly changing and not easily specified in advance. Decision support systems can be either fully computerized, human or a combination of both. According to Keen (1978), the concept of decision support has evolved from two main areas of research: The theoretical studies of organizational decision making done at the Carnegie Institute of Technology during the late 1950s and early 1960s, and the technical work on interactive computer systems, mainly carried out at the Massachusetts Institute of Technology in the 1960s. It is considered that the concept of DSS became an area of research of its own in the middle of the 1970s, before gaining in intensity during the 1980s.

Decision Support Systems (DSS) is combined the word “System” and “Decision Support” that it means is to improve the quality and effectiveness of decision making. It also means of reducing the uncertainty and risk traditionally associated with decision making. (Lu and Wu, 2009)

Three fundamental components of a DSS architecture are the Data Base (or knowledge base), the Model Base (i.e., the decision context and user criteria), and Dialog Base. (the user interface) The users themselves are also important components of the architecture. (Power, 2002); (Sprague and Carlson, 1982); (Marakas, 1999)

A. Data Base Driven

The data base driven harmonizes the raw data into two processes between the data analysis process and the synthetic data process. The following sub topics are the concept.

1. Data Analysis

Analysis of data is a process of inspecting, cleaning, transforming, and modeling data with the goal of highlighting useful information, suggesting conclusions, and supporting decision making. Data analysis has multiple facets and approaches, encompassing diverse techniques under a variety of names, in different business, science, and social science domains.

2. Synthetic Data

Synthetic data are “Many production data applicable to a given situation that are not obtained by direct measurement” according to the McGraw-Hill Dictionary of Scientific and Technical Terms. (McGraw-Hill Dictionary of Scientific and Technical Terms, 2009)

3. Testing for the synthetic Data

a) Correlation, Regression, and testing for the certainty Data

i) Pearson Correlation. The correlation between two variables in the level of the Interval or Ratio Scale value is called. “Correlation coefficient”, usually is between -1.00 to 1.00. If a negative value means that the two variables are correlated in opposite directions. If the value is positive, meaning that the two variables are related in the same direction. If a value of 0 means that there is no relationship between two variables. (Anonymous, 2008a)

ii) Spearman Rank Correlation. The correlation between two variables that are in the level Ordinal Scale usually is between -1.00 to 1.00. If a negative value means that the two variables are correlated in opposite directions. If the value is positive, meaning that the two variables are related in the same direction. If a value of 0 means that there is no relationship between two variables. (Spearman, 1904)

iii) Kendall Tau Correlation

The correlation between two variables that are in the level Ordinal Scale usually is between -1.00 to 1.00. If a negative value means that the two variables are correlated in opposite directions. If the value is positive, meaning that the two variables are related in the same direction. If a value of 0 means that there is no relationship between two variables. (Kendall, 1938)

iv) Point Bi-serial Correlation

The correlation between two variables by one variable in the measurement of the Interval or Ratio Scale and another on the level Nominal Scale is divided into 2 groups typically is between -1.00 to 1.00. If a negative value means that the two variables are correlated in opposite directions. If the value is positive, meaning that the two variables are related in the same direction. If a value of 0 means that there is no relationship between two variables. (Linacre, 2008)

v) Simple Regression

To use a simple regression consists of the variable predict a criterion variable and one that should be on the level Interval or Ratio Scale both. (Kenney and Keeping, 1962)

vi) Multiple Regression Analysis

When a regression equation consists of a prediction from one or more criteria a variable by variable and should be on the level Interval or Ratio Scale. If there are any variations in the level Nominal or Ordinal Scale should be changed to a dummy variable. (Mardia *et al.*, 1979)

vii) Multivariate Regression Analysis

When a regression equation. Consists of a prediction from one or more criteria and variables with more than one variable should be on the level Interval or Ratio Scale. If there are any variations in the level Nominal or Ordinal Scale should be changed to a dummy variable. This statistic is to be used when the variables are related to each criterion. (Mardia *et al.*, 1979)

viii) Multiple Correlations

Multiple Correlations is the correlation between a set of variables in the interval or ratio scale that consists of a variable and independent variables, rather than an option.

ix) Multi-serial Correlation

The correlation between variables with one variable must be in the level Interval or Ratio Scale and a set of variables in the measurement of the Ordinal Scale.

x) Partial Correlation.

If there are multiple variables and individual variables are associated with it. To calculate the correlation for each pair value does not correspond to reality because of their relationship with other variables, thus eliminating the influence of other variables. For determining the correlation between two variables in the level of the Interval or Ratio Scale has to eliminate other variables.

xi) Path Analysis

To study the influence of different variables to determine the direct and indirect influences of variables on the dependent variable is assumed to be the cause or not. The path coefficients are values that indicate the direct influence of the variable causes another change.

xii) Z-test

Z-test was used to test the following statistics. 1. If one group of samples is the difference between the sample and the population average then to test differences between groups in proportion to population. 2. If the two samples then to test the difference of averages between two groups of samples then to test the differences in proportions between two groups of samples.

xiii) T-test

T-test was used to test the following statistics. 1. If there is one group of samples then tests differences between groups with a population average. 2. If there are two samples then test the difference between averages of two groups independently of each other and to test the differences in proportions between two groups of related samples.

xiv) Chi-Square.

Chi-Square is a statistical variable must be in the range of measurement Nominal Scale using the following test. 1. If there is one group then test the difference in variance between sample populations, and to test the differences in the expected frequency to the frequency observed, and to test data show that the distribution is normal or not (Goodness-of-fit).

b) To test the relationship between two variables are independent of each other.

xv) Phi Coefficient.

The correlation between two variables that are Measuring Nominal Scale measures are divided into two groups.

xvi) Contingency Coefficient.

The correlation between two variables that are in the level normally Nominal Scale is between 0 and 1.

xvii) Analysis of Variance.

It's the difference between the sample averages of the two groups by the dependent variable, only one is in the level and Interval or Ratio Scale ranging from 1 or more independent variables in the level Nominal Scale. If an analyst with the independent variable is called One-way ANOVA. If the analysis composed with two independent variables then called Two-way ANOVA. The analysis of the three independent variables, called the three-way ANOVA etc.

xviii) Analysis of Covariance

The difference of the average of the samples from Group 2 to the variable can have only one option in the Section level Interval or Ratio Scale variance from one or more of the level Nominal Scale and variables is posted by 1 or more in the level interval or Ratio Scale. If an analyst with the independent variable is called One-way ANCOVA. If the analysis be with two independent variables are called Two-way ANCOVA. The analysis of the three independent variables is called the three-way ANCOVA etc.

xix) Analysis of variance with repeated measures.

As a form of analysis of variance components with repeated measures are over a period of time at different times. Samples from one group to the

dependent variable, only one is in the level Interval or Ratio Scale with repeated measures over time, if a sample of a group is not independent variables.

xx) Factorial ANOVA.

If a term used to refer to statistics in the analysis of variance with ANOVA, ANCOVA and Repeated Measure the independent variables from two or more.

xxi) Discriminates Analysis.

The study predicts that any variable that can be used to classify a group of criteria in order to classify the sample into groups properly. From 1 or more predictor variables in the level Interval or Ratio Scale and variables in Section 1 of the level Nominal Scale.

xxii) Factor Analysis.

The variable is a component of the study. The variables studied can be grouped into several components. There are two types of analysis. Analysis of the survey (Exploratory Factor Analysis) to explore whether or consisting of a variable element. Analytics component verification or confirmatory factor analysis is to determine or confirm the theory that you have already discovered.

xxiii) Canonical Correlation.

This is the correlation between a set of independent variables and a set of variables. The independent variables will range from 1 or more and have more than two variables from the variable should be placed in the level Interval or Ratio Scale.

xxiv) Hotelling T. Second.

To test the difference between the two groups of samples by an independent body in the act of measurement Nominal Scale is divided into two groups and more than one variable at the level of the Interval or Ratio Scale.

xxv) Multivariate Analysis of Variance.

To test the difference between the two groups of samples from the independent variables range from 1 or more in the level and Nominal Scale has a built-in variable measure the Interval or Ratio Scale if a variable is called One-way MANOVA. The second variable is called Two-way MANOVA. The third variable is called the Three-way MANOVA etc. if a variable is called “Multivariate Analysis of Covariance”.

xxvi) Binomial Test.

This is the probability test of a Nominal Scale at the potential for a second one (Dichotomous).

xxvii) Kolmogorov Smirnov Test.

Kolmogorov Smirnov One Sample Test is to test whether the variable distribution is normal or not (Goodness of fit) variables must be measured Ordinal Scale.

Kolmogorov Smirnov Two-Sample Test is to test the difference between the two groups are independent of each other. The variables must be tested to measure the Ordinal Scale.

xxviii) Wilcoxon matched-pairs Test.

This test is to test the difference between the two groups of related samples. The information must be put to the test section to measure the Ordinal Scale.

xxxix) Sign Test.

This test is to test the difference between the two groups in relation to sample. The information must be put to the test section to measure the Ordinal Scale.

xxx) McNemar Test.

This test is to test the difference between before and after the sample group. The data were tested in the measurement of Nominal or Ordinal Scale.

xxxi) Mann Whitney U Test.

This test is to test the difference between the two groups that are independent of each other. The information must be put to the test section to measure the Ordinal Scale.

xxxii) Median Test.

This test is to test the differences between the samples from the two groups to be independent of each other. The information must be put to the test section to measure the Ordinal Scale.

xxxiii) Fisher exact test.

This test is to test the difference between the two groups that are independent of each other. The information must be put to the test in the measurement of Nominal Scale was divided into two groups.

xxxiv) Friedman Test.

The difference between the test sample, more than two groups, respectively. The information must be put to the test section to measure the Ordinal Scale.

xxxv) Cochran Q Test.

The difference between the test sample, more than two groups, respectively. The information must be put to the test in the measurement of Nominal Scale.

xxxvi) Kruskal Wallis Test.

The difference between the test samples, more than two groups independently of each other. The information must be put to the test section to measure the Ordinal Scale.

c) Testing for the uncertainty Data

i) Normality tests

Normality tests assess the likelihood that the given data set comes from a normal distribution. Typically the null hypothesis is that the observations are distributed normally with unspecified mean and variance versus the alternative that the distribution is arbitrary. A great number of tests have been

devised for this problem. The most prominent of them are outlined below: (Casella *et al.*, 2001)

1) Visual tests

Visual tests are more intuitively appealing but subjective at the same time. They rely on informal human judgment to accept or reject the null hypothesis.

- Q-Q plot

Q-Q plot is a countless-quantiles plot of the sorted values from the data set against the expected values of the corresponding quantiles from the distribution. If the null hypothesis is true, the plotted points should approximately lie on a straight line. (Henry, 2002)

- P-P plot

P-P plot similar to the Q-Q plot, but used much less frequently. This method consists of plotting the (probability-probability plot or percent-percent plot) points. For normally distributed data this plot should lie on a 45° line between (0, 0) and (1, 1). (Jean and Subhabrata, 2003)

- Wilk–Shapiro test

Wilk–Shapiro test employs the fact that the line in the Q-Q plot has the slope of standard deviation. The test compares the least squares estimate of that slope with the value of the sample variance, and rejects the null hypothesis if these two quantities differ significantly. (Shapiro and Wilk, 1965)

- Normal probability plot (rank it plot)

In statistics, its rank of a set of data is the expected value of the order statistics of a sample from the standard normal distribution the same size as the data. They are primarily used in the normal probability plot, a graphical technique for normality testing. (Chester, 1979)

2) Moment tests

- D'Agostino's K-squared test

D'Agostino's K^2 test is a goodness-of-fit measure of departure from normality that is the test aimed to establish whether or not the given sample comes from a normally distributed population. The test is based on transformations of the sample kurtosis and skewness, and has power only against the alternatives that the distribution is skewed and/or kurtic. (D'Agostino *et al.*, 1990)

- Jarque–Bera test

The Jarque–Bera test is another goodness-of-fit test of whether sample data have the skewness and kurtosis matching a normal distribution. The test is named after Carlos Jarque and Anil K. Bera. (Jarque *et al.*, 1980)

3) Empirical distribution function tests

Lilliefors test is an adaptation of the Kolmogorov–Smirnov test and the Anderson–Darling test. (Wikipedia [Normal Distribution], 2012)

B. Model Base Driven

The model base driven exploits the mathematical formulation of the workability functions to form the model and in the stochastic process it needs the input data which inherent uncertainty. The Monte-Carlo simulation plays an important role. For the reservoir operation, the simulation evaluation for the best scenario is needs the optimization process. Therefore, the section of the model base driven composing these follows.

1. Mathematical Model Development and Optimized Model Simulation for Decision Making

The main tool of the water resources engineer is the computer model, which can be classified by:

- a) Structure and function (optimization or simulation)
- b) Degree of uncertainty in system inputs (deterministic or stochastic process)
- c) Level of fluctuation in economic or environmental conditions being modeled (static or dynamic)
- d) Distribution of model data (lumped or distributed)
- e) Type of decision to be made (investment or operations/management).

Each model configuration has inherent strengths and weaknesses, and each has its proper role in water resources planning. The challenge for the water resources engineer is not to determine which is better, but which is most appropriate for a particular situation given available resources including time, money, computer

capability, and domain data. (Davis *et al.*, 1990) The involved concepts of models are shown in Figure 33.

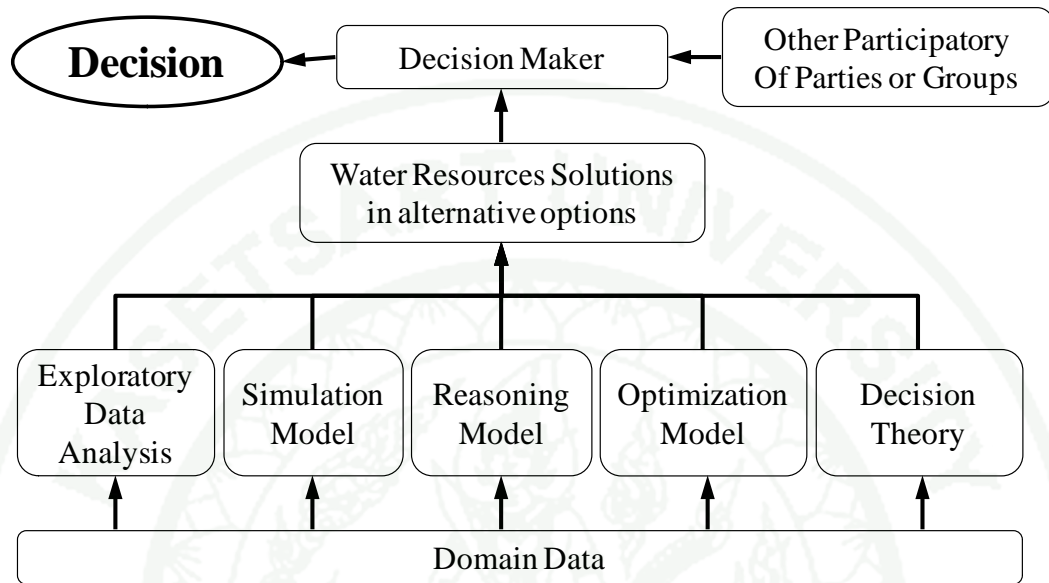


Figure 33 The water resources models have used a wide range as analytical tools and techniques to identify and evaluate alternative development plans and management strategies which is the responsibility of the decision maker.

Kuiper (1965) commended the concept in water resources model that the model should be a coherent exerted period of:

- a) Long-term operational model (A year round period in operation)
- b) Short-term operational model (Daily to weekly period in operation)

2. Monte-Carlo Simulation

Monte Carlo simulation methods are especially useful for simulating phenomena with significant uncertainty in inputs and systems with a large number of coupled degrees of freedom. Monte Carlo methods (or Monte Carlo experiments) are

a class of computational algorithms that relies on repeated random sampling to compute their results. Monte Carlo methods are often used in computer simulations of physical and mathematical systems. These methods are most suited for calculation by a computer and tend to be used when it is infeasible to compute an exact result with a deterministic algorithm. (Anderson, 1986)

3. Multi-Objectives Optimization

The complexity factors in the real world forced the modeling to be the multi-objective optimization model particularly the need for several decision variables.

a) Optimization and objective functions in Mathematical Model.

In model oriented by simulation, the optimization process needs to find out for the appropriate objective satisfaction. Therefore, any mathematical model should be formulated with the optimization.

b) Single-Objective Optimization

c) Multi-Objectives Optimization

d) Optimization Algorithms

The general global optimization is about finding the best possible solutions for giving problems by the predefined for the best smart process called an algorithm.

i) General Optimization Algorithm

The classification of the General Optimization Algorithm has shown in Figure 34.

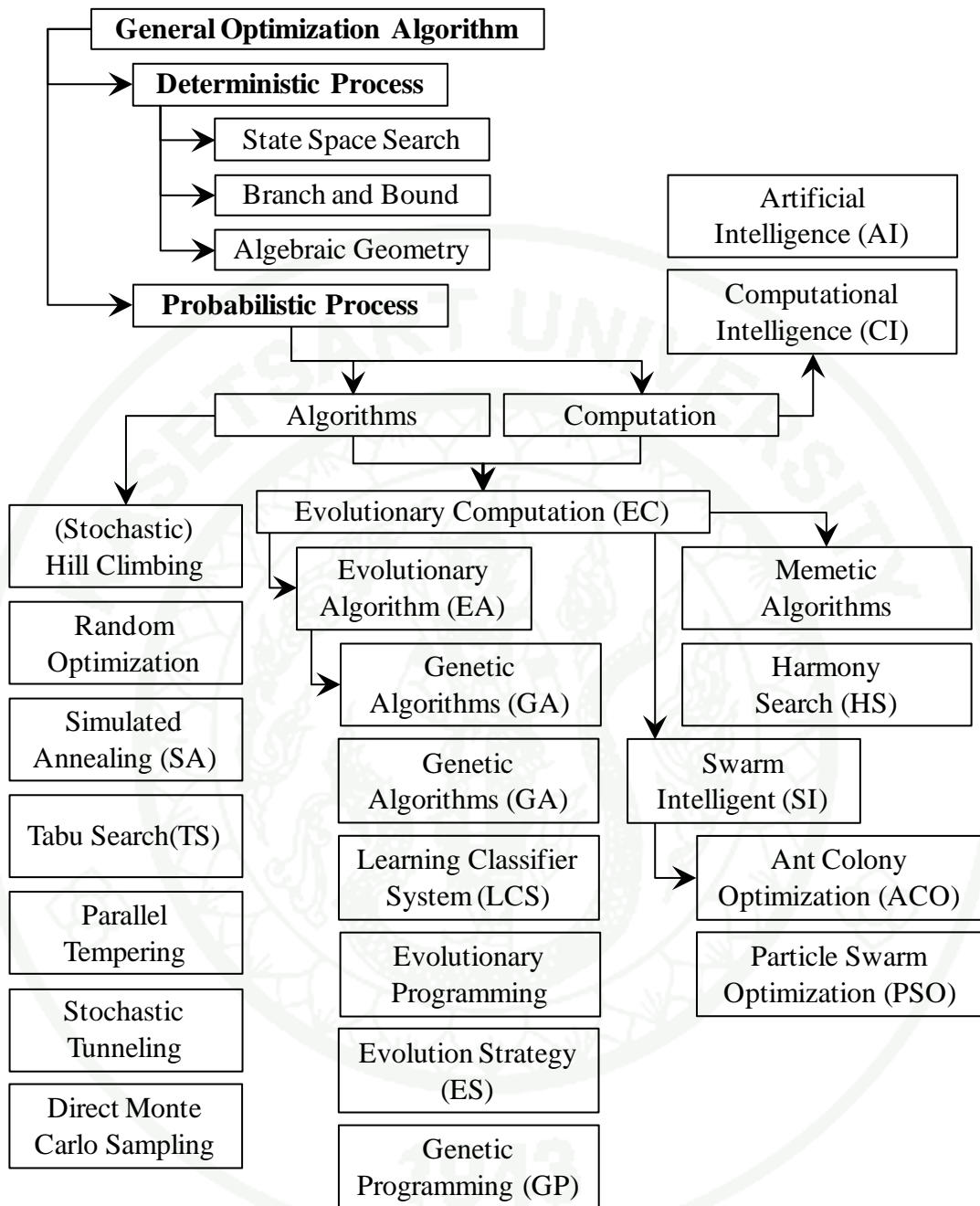


Figure 34 The taxonomy of global optimization algorithms.

ii) Evolutionary Optimization Algorithm

Evolutionary algorithms¹ (EAs) are population-based metaheuristic optimization algorithms that use biology-inspired mechanisms like mutation, crossover, natural selection, and survival of the fittest in order to refine a set of global and local optimal solution as shown in Figure 35 candidates iteratively. (Thomas, 1997)

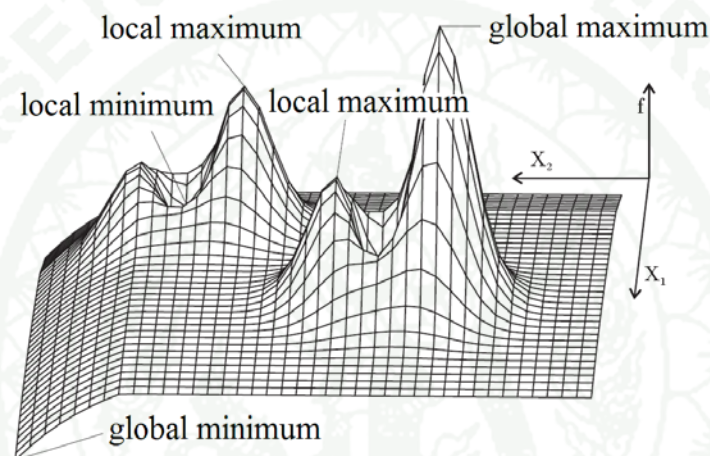


Figure 35 Global and local optima of a two-dimensional function

C. Dialog Base Driven

In the dialog base driven, Gorry and Scott (1971) defined DSS as interactive computer-based systems, which help decision makers utilize data and models to solve ill-structured problems.

1. Box-Whisker Plot for user interface

In descriptive statistics, a box whisker plot or boxplot (also known as a box-and-whisker diagram or plot) is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest

observation (sample maximum). A boxplot may also indicate which observations, if any, might be considered outliers.

Boxplots display differences between populations without making any assumptions of the underlying statistical distribution: they are non-parametric. The spacing between the different parts of the box helps indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. Boxplots can be drawn either horizontally or vertically. (Michael *et al.*, 1989)

2. Decision Making in Long-Term Operation

The decision making in long-term operation is a year round decision which making on monthly guideline of the storage. This guideline is obtained from the optimization on simulation process of the reservoir operation model in model base driven which mention in prior paragraph. By using a set of uncertainty data, the most likely line of storage as the results should be indicated the best guidance for decision making. It informs in the form of the box-whisker plot and it is also called the MLL line in this research.

3. Decision Making in Short-Term Operation

The decision making in short-term operation is the periodical decision, may be daily or every two or three day or every week, when making on the determined release volume to maintain the storage follow up for the MLL line. This release rate in decision is also obtained from the optimization on simulation process of the reservoir operation model in dialog base driven. The main driven divided into three portions of water release. First portion considering in the past stage of operation, the compensated volume of water is reviewed on the real data occurring collected in the field. Second portion considering in the present stage of operation, the volume of the water demand is determined on the basis of normal condition of the current to the future period of the climate estimation such as using an average or a most likely. The last portion considering in the future stage of operation, the volume

of the end storage is supposed by the decision tree model and optimization process for the storage converges to the MLL line.

a) Decision Tree

The decision tree model approach is the dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation. It must have the relationship in term of the Conditional Probability known as the “Bayesian Theory” and “Expect Value” between the usages of long-term operational rule such as MLL line coherent work in harmony with the short-term operation.

b) Expect Value

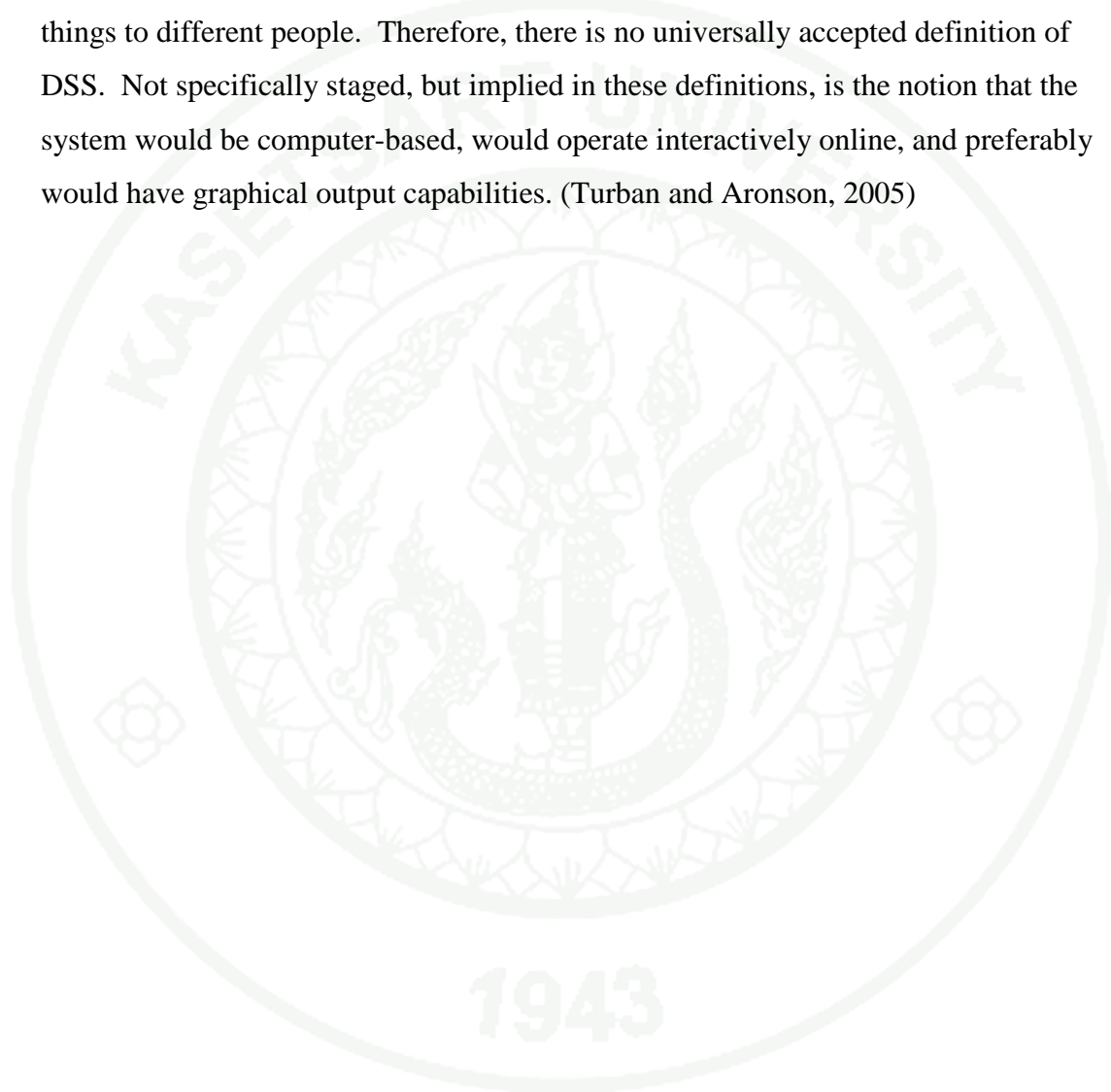
In probability theory, the expected value (or expectation, mathematical expectation, EV, mean, or the first moment) of a random variable is the weighted average of all possible values that this random variable can take on. The weights used in computing this average correspond to the probabilities in case of a discrete random variable, or densities in case of a continuous random variable. From a rigorous theoretical standpoint, the expected value is the integral of the random variable with respect to its probability measure.

c) Bayesian Theory

Bayesian Theory is one of the different interpretations of the concept of probability and belongs to the category of evidential probabilities. The Bayesian interpretation of probability can be seen as an extension of the branch of mathematical logic known as propositional logic that enables reasoning with propositions whose truth or falsity is uncertain. To evaluate the probability of a hypothesis, the Bayesian probabilistic specifies some prior probability, which is then updated in the light of new, relevant data.

IV. The dialog for decision making interface

The dialog for the decision making interface is a computer-based support system for management decision makers who deal with ill-structured problems. However, the term dialog in DSS is a content-free expression which means different things to different people. Therefore, there is no universally accepted definition of DSS. Not specifically staged, but implied in these definitions, is the notion that the system would be computer-based, would operate interactively online, and preferably would have graphical output capabilities. (Turban and Aronson, 2005)



Precedent Research Works

Recently, the amount of the precedent research works has emerged across the world still interesting and focusing in the field of reservoir operation management: optimization techniques, long term operation, short term operation, real time operation, hydropower, adaptation to climate change, etc.

For example, it is such as the paper of Andre *et al.* (2012) which presents an application of Multi-objective Differential Evolution (MoDE) algorithm for the optimal operation of a complex multipurpose reservoir system. The developed algorithm (MoDE) is compared to Genetic Algorithm (NSGA II) using a set of common test.

Wang *et al.* (2012) did the paper on title Optimizing long-term reservoir operation through multi-tier interactive genetic algorithm. Their conclusion on the optimization technique is that the Multi-tier Interactive Genetic Algorithm (MIGA) would require only very small numbers of generation number and population size to quickly reach an optimal solution. The results demonstrated that MIGA was far more efficient than the sole Genetic Algorithm (GA) and could successfully and efficiently increase the possibility of achieving the optimal solution, especially in the search of the optimal solution to a problem with a large number of variables.

Fallah-Mehdipour *et al.* (2012) did the paper on the title Real-Time Operation of Reservoir System by Genetic Programming. Their conclusion of the real time operation is the results indicate that the proposed rule based on deterministic variables is effective in determining optimal rule curves simultaneously with an inflow prediction for reservoirs.

Qiuwen *et al.* (2012) found that the optimal model allows establishing a relation between the target of fish habitat conservation and the corresponding loss of hydropower production, so as to propose compromise solutions. Its generic formulation allows applying it to a broad range of cascaded reservoir configurations.

The extensions towards cases with ecological flow requirements for more than one species are straightforward.

Hyung-II Eum *et al.* (2012) studied the research on the title Integrated Reservoir Management System for Flood Risk Assessment under Climate Change. Their conclusion is the results demonstrate that the integrated system provides optimal reservoir operation rule curves that reflect the hydrologic characteristics of future climate scenarios. Therefore, they may be useful for the development of reservoir climate change adaptation strategy.

For the precedent research works which involved the field of Decision Support System, reservoir operation, and water management in Thailand, there are some researches involved with demand side adjustment with DSS for irrigation project (Prajamwong, 1994) and DSS in multi-criteria for reservoir (Kongjun, 2003). The following descriptions provide its more details.

Prajamwong (1994) did the research in the topic of “Command Area Decision Support System for Irrigation Projects”. This work is the development of a command area decision support model (CADSM) employed to estimate the aggregate crop water requirements in agricultural irrigation systems and to determine relative crop yield. The model is a comprehensive, user-friendly, and interactive model that consists of six components: (1) description of project canal and command area layout; (2) description of general soil, crop, and climatic data; (3) generation of daily weather and field population data; (4) daily on-field water and salt balance calculation; (5) water allocation and distribution; and (6) crop yield evaluation.

The CADSM is a mathematical model which uses individual field characteristics such as field size, soil type, available soil moisture content, salt concentration, distribution efficiency, conveyance efficiency, cropping pattern, and well capacity. These field characteristics can be generated by the model from general statistical information, or they can be taken directly from measured values that are entered through the model's interface. Daily water and salt balance calculations are

performed for all fields and command areas. The soil water balance for each field is determined based on crop type and stage of development, field area, soil properties, groundwater contribution, salinity level, and several factors that take cultural practices into account.

The water requirements for each field are aggregated to estimate the potential command area water requirement, and are then totaled to determine the potential irrigation system demand. A mathematical queuing system is used to allocate and distribute available water to the respective command areas and fields. The average yield response is predicted considering crop moisture stress, salinity concentration, and effects of waterlogging. Daily weather data, including evaporation, air temperature, and reference crop evapotranspiration, can be generated using monthly statistical means and standard deviations. Model verification and calibration studies were conducted using various climatology data, cropping patterns, and simulated field conditions. The results showed an acceptable correlation and reasonableness with available field data.

Kongjun (2003) has completed research on the designation of “Multicriteria Decision Making for Multireservoir Water Allocation: A Case Study of Upper Mun Basin”, Thailand set purpose of this study to identify the water shortages by simulating the multireservoir system of the Upper Mun basin including Lum Chae, Mun Bon, Lum Phra Plerng and Lum Ta Kong reservoirs using HEC-3 with 25 years of inflow data, The ϵ -constrained linear programming was used to generate the optimum water allocation alternatives. The alternatives were selected by the analytic hierarchy process. The artificial neural network was applied to develop the simplified water allocation model. The best water allocation alternative was selected by the multicriteria decision making process. The analysis showed that the priority weight for profitability, reliability and equity were shown in percentage evidently. Multilayer Feed Forward (MLFF) and Back-Propagation (BP) neural networks were applied to develop the water allocation of two models according to the selected alternative. The determination coefficient of training and testing for artificial neural network model were used.

Study Area

I. Papayom Reservoir a case study for both long term and short term operation

Papayom Reservoir has the capacity of 20.5 million cubic meters. It locates on Songkhla Lake basin. Its catchment area is 24 square kilometers. The storage aims to serve the irrigation area while in deficit of rain. It can be illustrated in Figure 36 and schematic in Figure 37. The reservoir was fixed the retention storage at the capacity of 20.5 million cubic meters and the dead storage at the capacity of 0.8 million cubic meters.

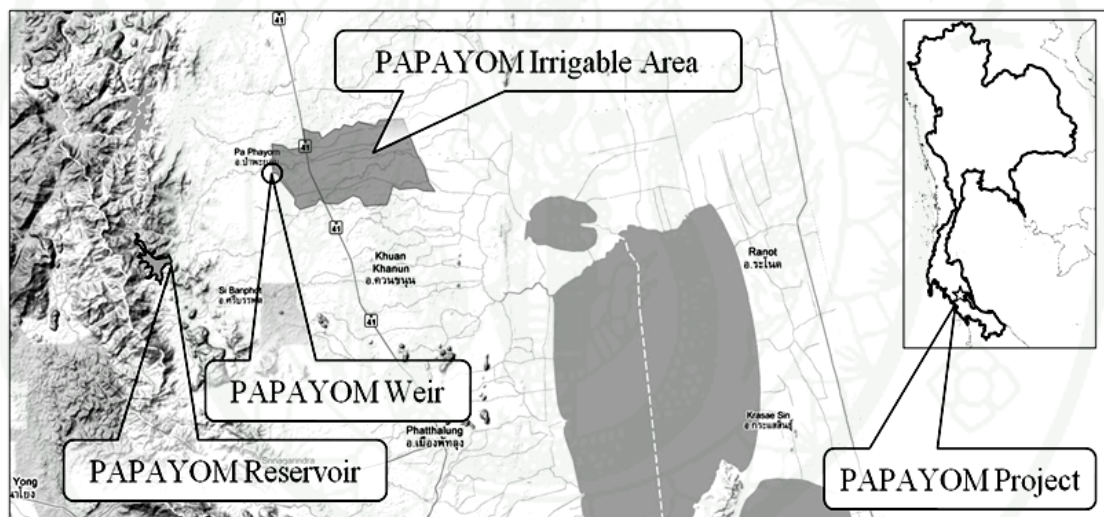


Figure 36 Location map of case study site the Papayom reservoir irrigation project, Phatthalung, Thailand.

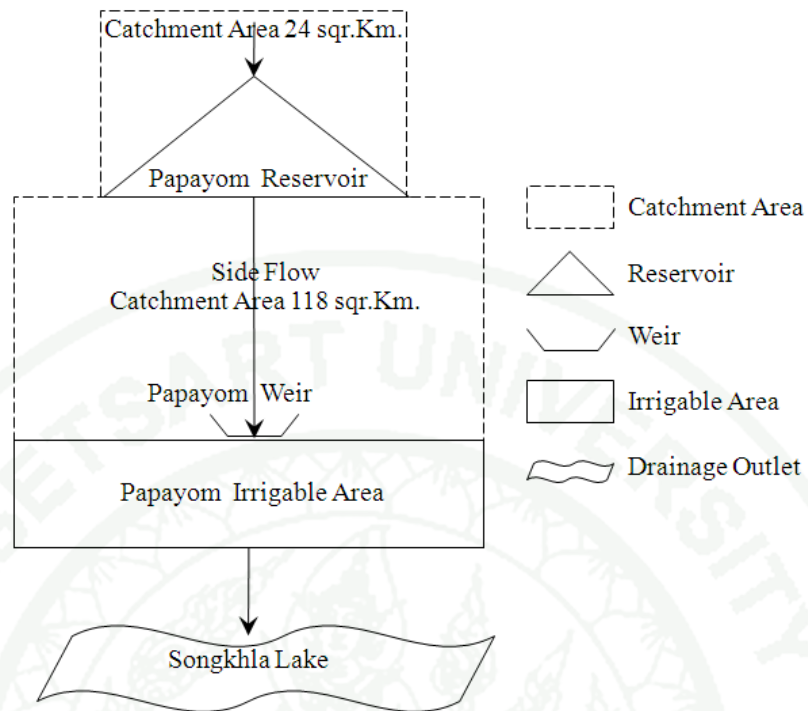


Figure 37 Schematic diagram of Papayom Reservoir showing the irrigable area and the catchment area of the reservoir and side flow

II. Sirikitti Reservoir a case study for long term operation

Sirikitti Reservoir has the maximum capacity of 10,640 million cubic meters. It locates on Nan basin. Its catchment area is 13,130 square kilometers. The storage aims to serve the hydropower and irrigation area while in deficit of rain. It can be illustrated in Figure 38. The reservoir was fixed the retention storage at the capacity of 9,510 million cubic meters and the dead storage at the capacity of 2,850 million cubic meters.

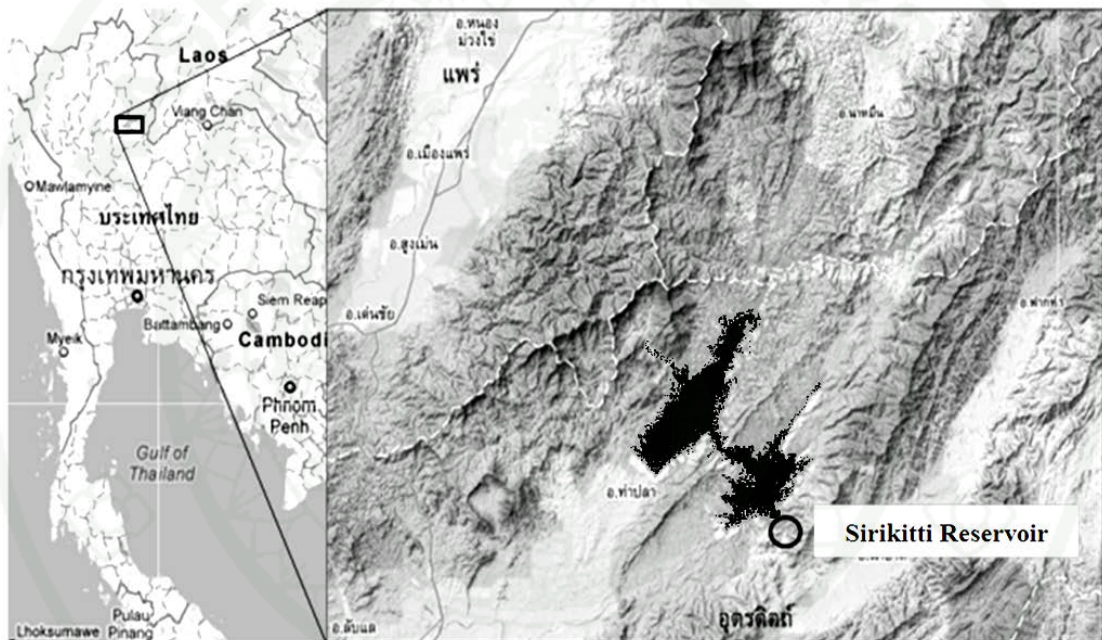


Figure 38 Location map of case study site the Sirikitti reservoir, the hydropower and irrigation project, Utaradit, Thailand.

MATERIALS AND METHODS

Materials

The Decision Support System required the following materials. The data analysis and synthesis processes were developed by using Microsoft Add-in Macro namely @RISK. The developing of reservoir operation in mathematical modeling was formulated by using personal computer CPU 2.26 GHz with 2 GB of RAM. Lastly, various official apparatus such as a printer, scanner, stationary, etc. were also required to fulfill this work.

Methods

The methodology in detail which comprises three approaches. These approaches are involved in the Decision Support System (DSS): the data approach, the model approach, and the dialog approach. In more detail, the data approach contains the uncertainty analysis on the sample data for use in synthesis the population data. The model approach constitutes the mathematical modeling which needs to obtain the Most Likely Line (MLL) of the reservoir operational rule. The dialog approach comprises the dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation. Overall processes have shown in Figure 39.

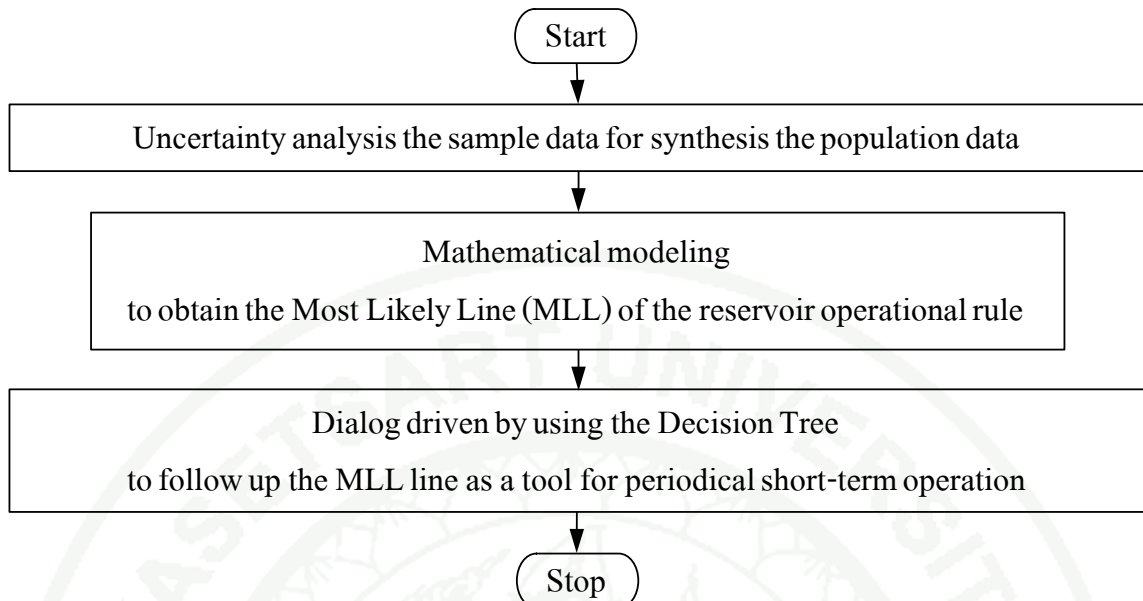


Figure 39 The overall processes expressed roughly as the DSS component.

I. The data approach

A. Uncertainty analysis the sample data for synthesis the population data

The sample uncertainty data called archetype data set is analyzed by the descriptive statistics for the results of the unique characteristic of each individual data set. Afterward, the inferential statistics are used to generate a population set which in the same similarity as archetype data set tested by Goodness-of-fit Test. The schematic diagram has shown the overall process in Figure 40.

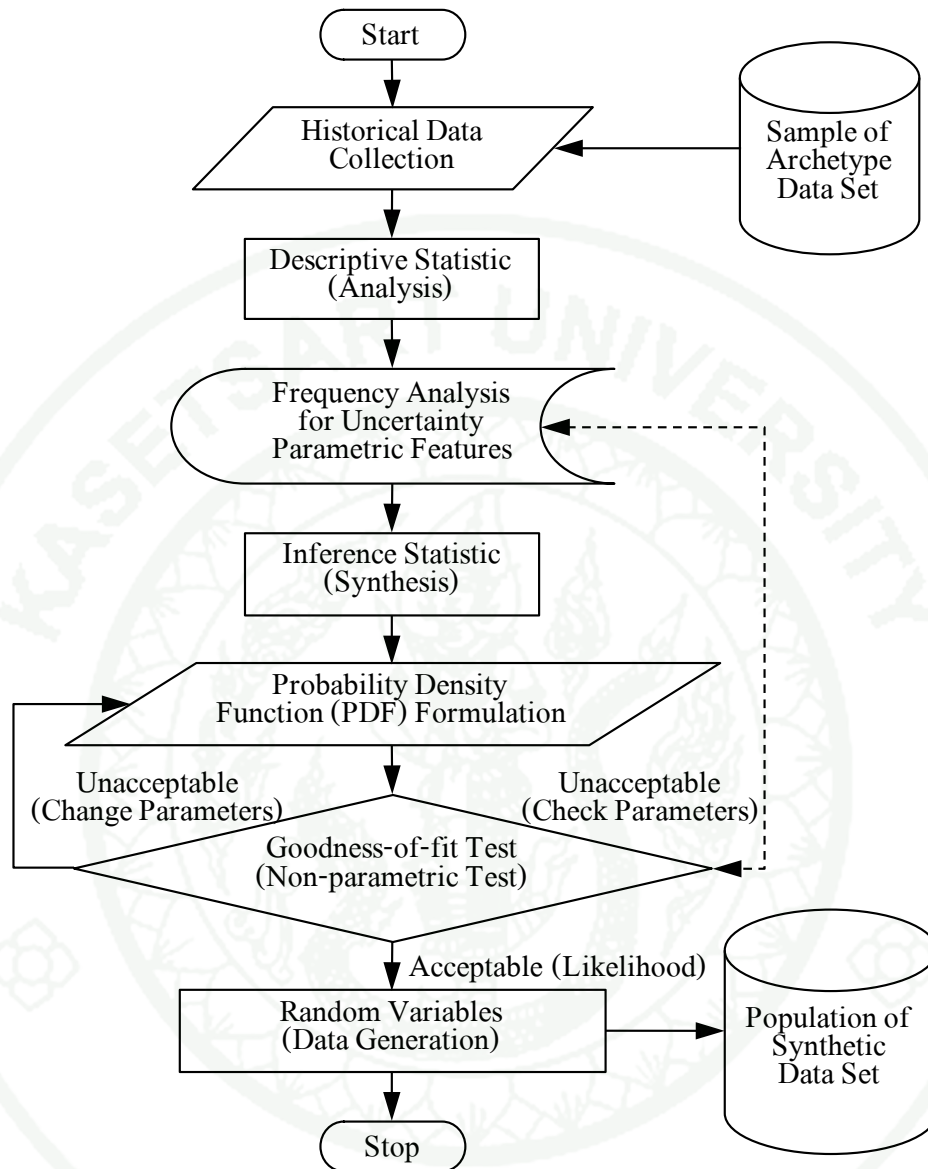


Figure 40 Uncertainty analysis the sample data for synthesis the population data

Before the imitate population of a data set is generated, the result is in the form of a distribution equation of random variables. To turn the distribution equation to be a set of generating data the process in Figure 41 shown how the uniform distribution converse to its own distribution.

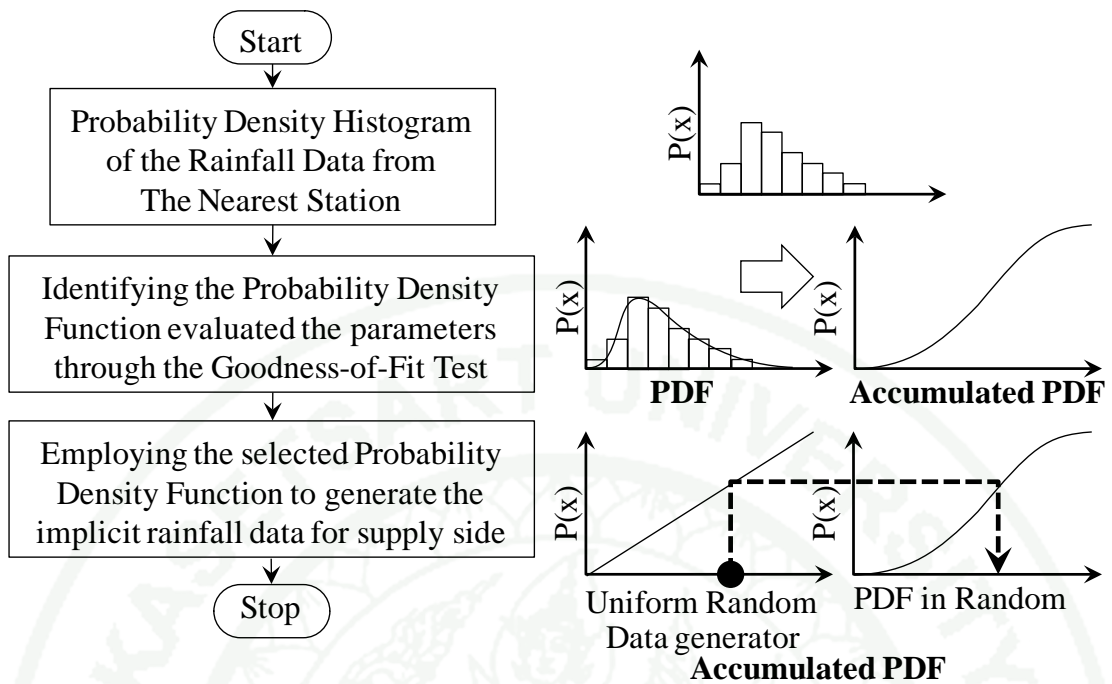


Figure 41 Schematic diagrams shown the process of a random variable is generated from a uniform distribution to the distribution of its probability density function

II. The model approach

The mathematical modeling to obtain the Most Likely Line (MLL) of the reservoir operational rule is formed by the process in Figure 42 below shown how the model on the water balance basis perform coupled with the optimization process.

III. The decision tree model approach for dialog driven

The decision tree model approach is the dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation. Figure 43 shows the process how the relationship between the uses of long-term operational rule such as MLL line coherent work in harmony with the short-term operation.

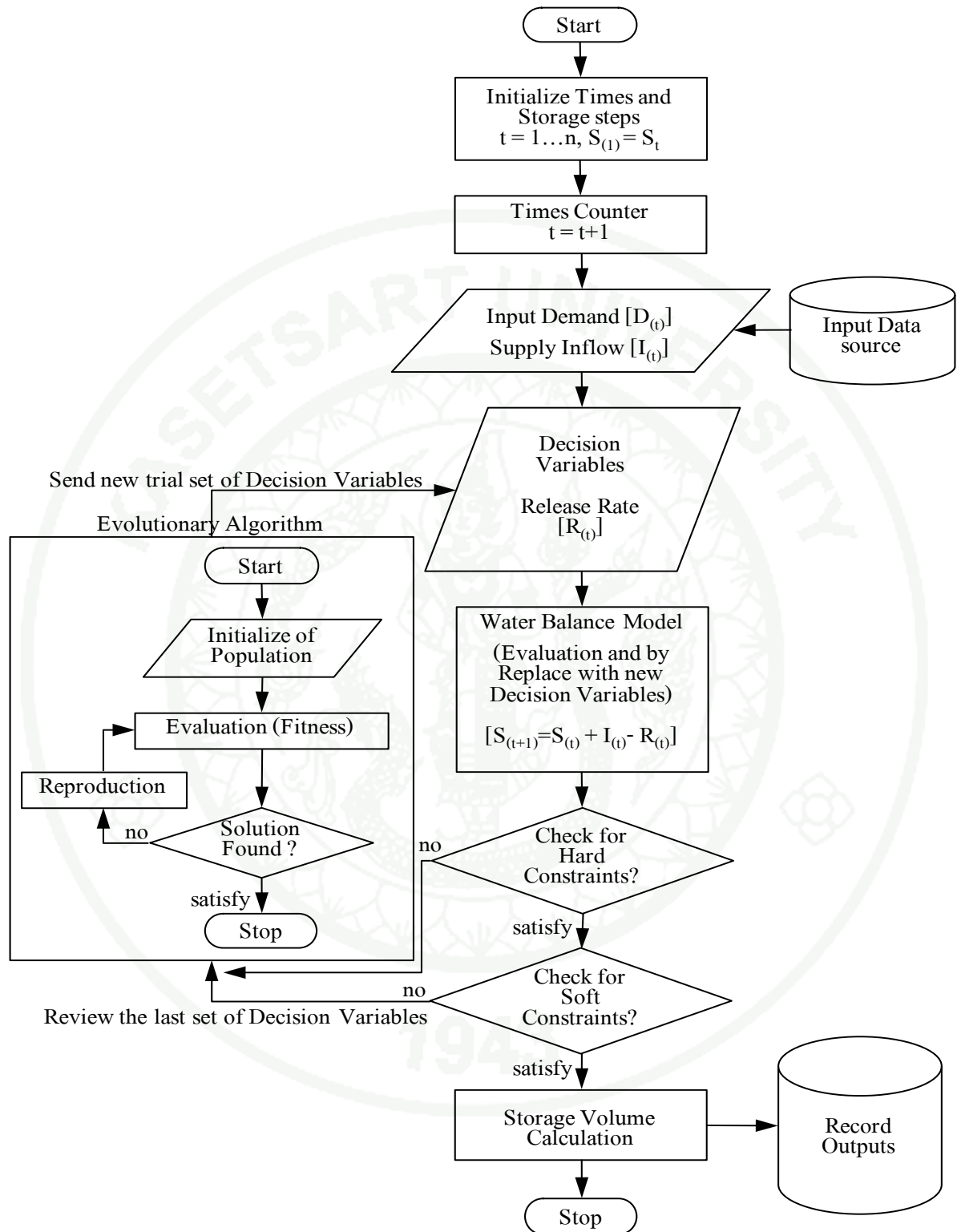


Figure 42 Mathematical modeling to obtain the Most Likely Line (MLL) of the reservoir operational rule

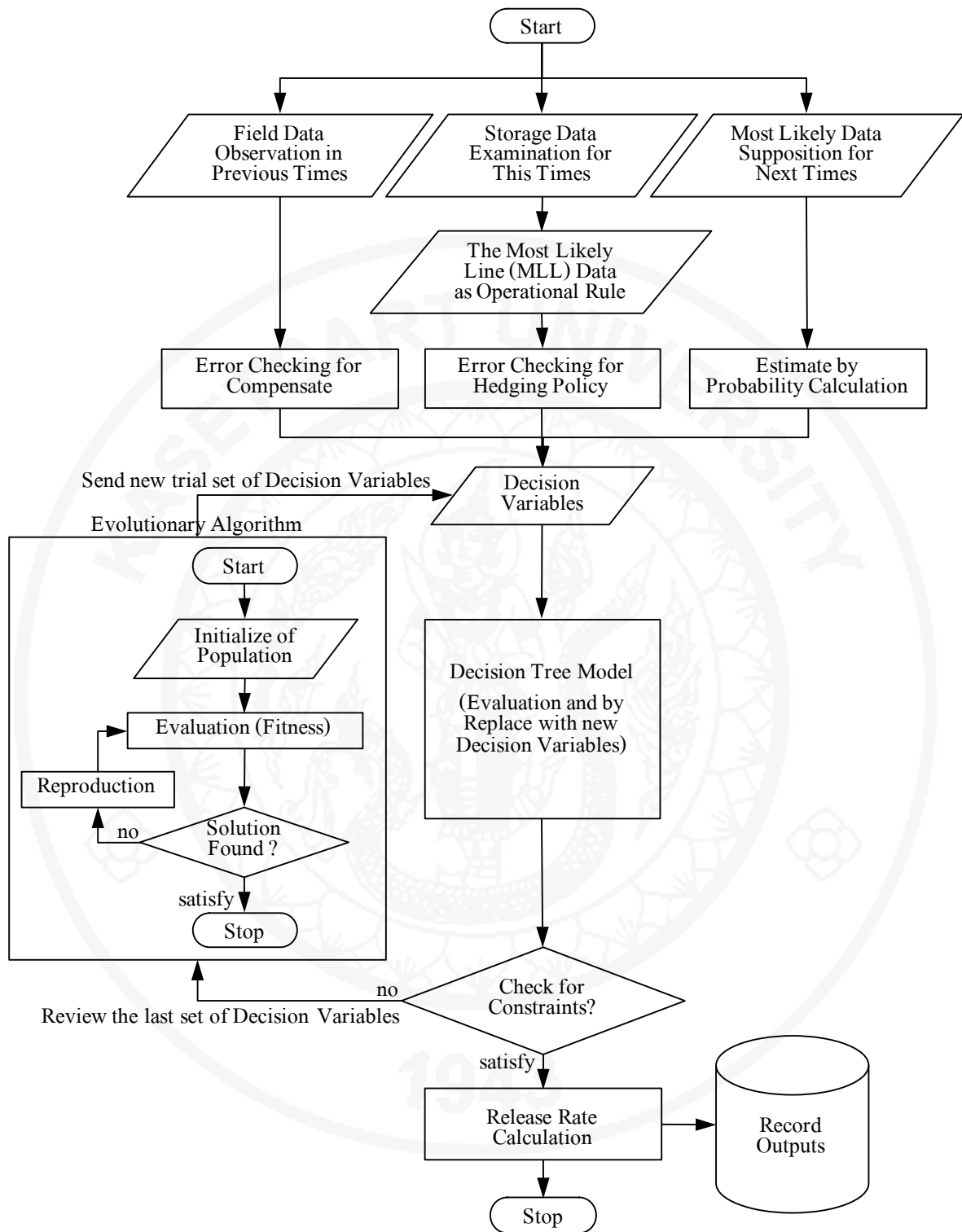


Figure 43 Dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation

A. Model formulation

1. Deterministic Model

If the usage of the data is the determined data such as the maximum, minimum, or average value then the model is figured as the deterministic model.

2. Stochastic Model

In the similar manner, if the usage of the data is the random data then the model is figured as the stochastic model. The output results must be also in the distribution of probability density function and may illustrate in the form of the Box-Whisker plot.

B. Long-term & Short-term of reservoir operation

1. The most likely line (MLL) creation for the long-term of reservoir operation

2. The periodical optimum of water delivery guide line (POD) creation for the short-term of reservoir operation

C. Results and Interpretation

1. Criterion

The methodology for interpretation on the result is a criterion of the water release decision from the reservoir in any periods in any operation. The criterion which the operator need is the amount of water release in circumstance of the dynamical change in every time steps changing. The long-term of reservoir operation is the end results to be a MLL line. It informs the appropriate water storage that should be kept in the reservoir in every time changing all the year round. It also

makes the further criteria for short-term operation which react with the climatic and water need situations which perceive via the computerized dialog.

2. Dialog limitation

The procedure of the working dialog is the data input taking and output getting. In addition, some interaction between the user and the program is necessary for the optimization simulation in being control the program running. Therefore, the limitation for dialog working is subject to the prepared data and the planned data e.g. the monthly data for the long-term operation, the daily data for the short-term operation, the more numbers of sample data for the more accurately modeling, the up to date data etc.

D. Reservoir operational rule

1. Dialog for long-term of reservoir operation

The method of the reservoir operation rule acquisition for the long-term operation is the output of the model running results as a set of the simulation optimization lines of the storage volume in each month all year round. The most frequent or the most likely line is adopted as the best ideal line for an ideal rule to use as a dialog rule for the long-term.

2. Dialog for short-term of reservoir operation

The routine of the reservoir operation rule acquisition for the short-term operation is the output of the decision tree model with the optimizing results. It interacts every time steps progress by using the progressive daily data simultaneously with the update situation data; the climatic data, the daily water needed data, the reservoir storage volume data and the ideal rule of the long-term data to identify the water release data in every time changing as a dialog rule for the short-term decision making also in the target to satisfy the water consumptions and to control the water storage volume converging to the ideal MLL line concurrently.

E. Dynamic features

1. Decision for changing the new reservoir operational rule

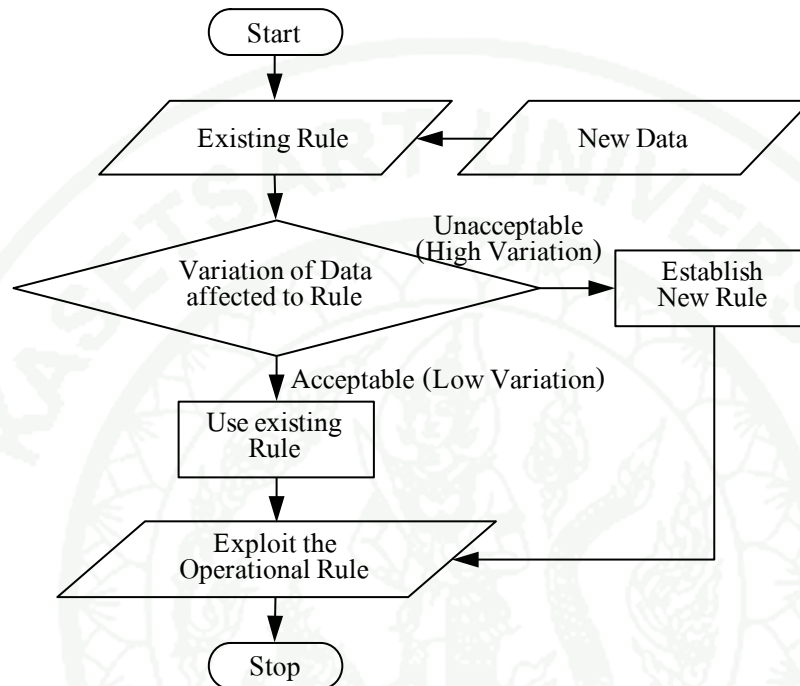


Figure 44 Schematic diagram shown the decision process for changing the new reservoir operational rule replaced the old one.

For the more details as the methodology, the process of uncertainty analysis the sample data for synthesis the population data is also comprehended in the cited paper (Eakawit and Suwatana, 2011a). The Mathematical modeling to obtain the Most Likely Line (MLL) of the reservoir operational rule is also comprehended in the cited paper in (Eakawit and Suwatana, 2011b). Lastly, the Dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation is also comprehended in the cited paper in (Eakawit and Suwatana, 2011c)

RESULTS AND DISCUSSION

In this section, the results and discussion are separated into three parts. The first part is the results for data generation of water supply and demand side. Second part, It comprises the operational rule of the reservoir storage including the results by applying the optimization model. For a sort of stochastic simulation, the results lead to show the Most Likely Line creation or MLL in short which deployed for the long-term of reservoir operation. The last part is the end results of MLL line using to operate in the short-term of reservoir operation.

Results

I. Part one of the results of Data-base Driven

Results in the first part, those are the end results in the synthesis process of water supply and demand side.

A. Input Data

The input data in this part are the daily rainfall data represented as a source of inflow into the reservoir from precipitation. It is a secondary data recorded at the nearest rain gauge station to the reservoir. Figure 45 illustrates the histogram of a sample input data which was randomly picked on one day record in which more than thirty years' data. In the case study, a set of 30 year record of daily rainfall data was shown as a sample set that there are in the pattern of natural and the ordinal of a whole set of data which can be noticed that the probabilities are intersected with two dimensions. First, it was the probability of rainfall quantity occurrence and second, it was the event in rainfall appearance.

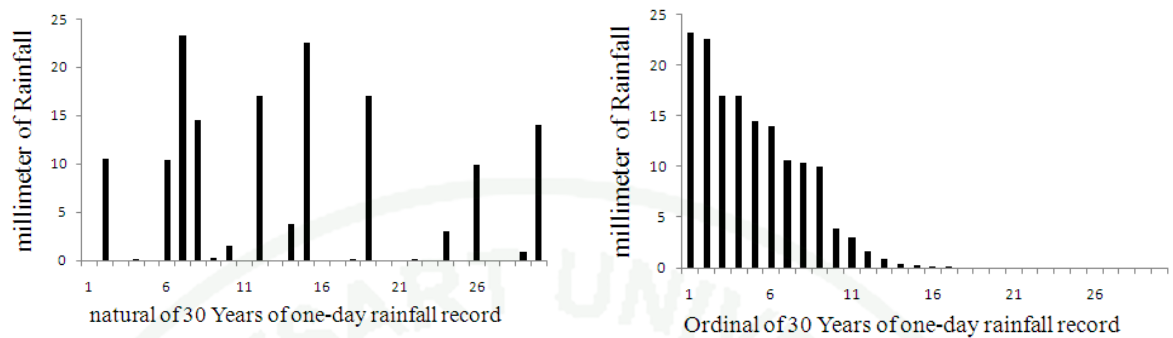


Figure 45 Graphs of natural and ordinal for 30 years of one-day rainfall record.

B. Data Process

The data process comprises four procedures. The first, the discreteness of the probability density function is identified. The second, the continuity of the probability density function is configured. The forth, is the Combination of the identified Discrete PDF with the configured Continuous PDF. And the last, the rainfall-runoff model is applied to a population set to use in the reservoir operation model. The detail was described as follows.

1. Discrete PDF identification

The result of step 1 was tested by taking the frequency analysis by binning the rain or no rain. The binning for histogram, it was selected for five year interval. Later, it obtained the observed discrete of the probability distribution (shown in line symbol).

For Binomial PDF, the optimal parameters that denote the value of n , and p are 5, and 0.62857, respectively. The Chi-Square goodness-of-fit test is less than 0.00001 of value, shown in Figure 46.

For Integer Uniform PDF, the optimal parameters that denote the value by max., and min., are 5, and 1, respectively. The Chi-Square goodness-of-fit test has also found the value less than 0.00001, shown in Figure 47.

For Poisson PDF, the optimal parameter that denotes the value by λ is 3.1429. The Chi-Square goodness-of-fit test is also less than 0.00001 of value, shown in Figure 48.

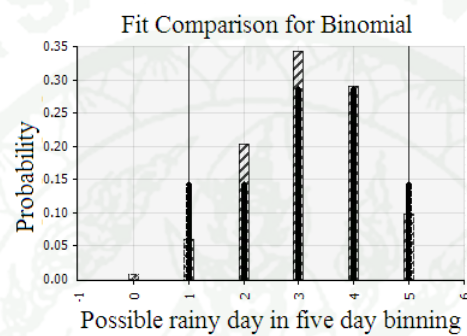


Figure 46 The graph result of fit comparison for Binomial PDF after optimization (shown in shed symbol).

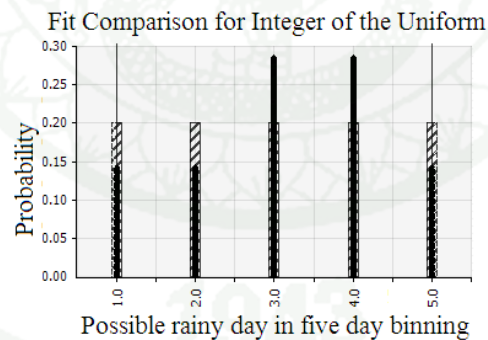


Figure 47 The result of fit comparison for Integer Uniform PDF after optimization (shown in shed symbol).

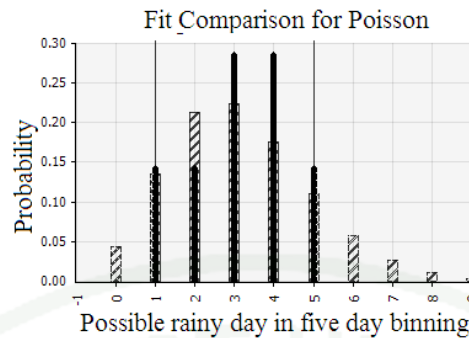


Figure 48 The result of fit comparison for Poisson PDF after optimization (shown in shed symbol).

2. Continuous PDF configures

The result of step 2 was tested by separating out the no rain data and then taken frequency analysis by binning the rainfall quantity. The result obtains the observed continuous probability distribution (shown in line symbol).

For the best goodness-of-fit with Chi-Square, it was a Beta type of probability density function. It had the value of 5.4929. The appropriate parameters that denote the value of μ , and λ are 21.666, and 158.976 respectively. It was shown in Figure 49.

For the best goodness-of-fit with K-S, it was a Rayleigh type of probability density function. It had the value of 0.1043. The appropriate parameter that denotes the value of b is 11.030. It was shown in Figure 50.

For the best goodness-of-fit with AD, it was an Inverse Gaussian type of probability density function. It had the value of 0.4829. The appropriate parameters that denote the value of μ , and λ are 21.666, and 158.976 respectively. It was shown in Figure 51.

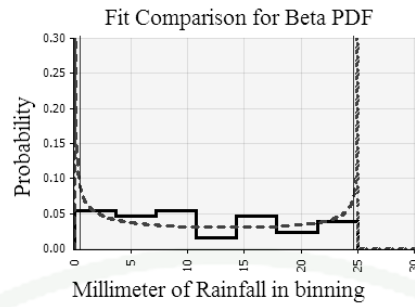


Figure 49 The result of fit comparison for Beta PDF after it was performed optimization (shown in dot line symbol).

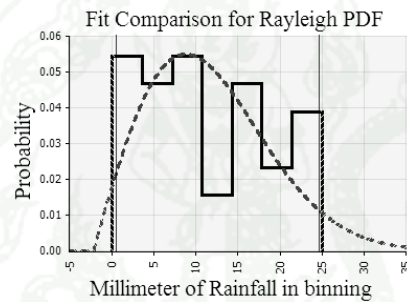


Figure 50 The result of fit comparison for Rayleigh PDF after it was performed optimization (shown in dot line symbol).

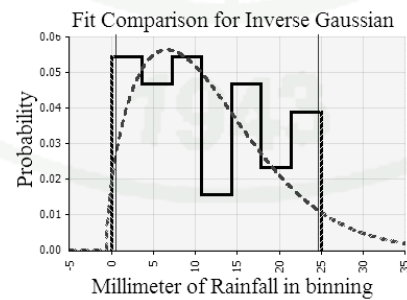


Figure 51 The result of fit comparison for Inverse Gaussian PDF after it was performed optimization (shown in dot line symbol).

In Step 3 (for discrete probability) of the application, the results indicated that it may be chosen any of three PDFs. In this study, the Poisson PDF is chosen by visual inspection. It should be noted that, whenever this function is used for generating the synthesis data, it must be divided by 5 depending on the number of binning of histogram intervals. Alternatively, it must be turned the discrete probability values $\{0, 1, 2\} = 0$ to “no rain event” and $\{3, 4, 5\} = 1$ to “it rain event” in the data generating procedure. The summary table of those results is shown in Table 5.

Table 5 The summary table of results of the optimal parameters and types for discrete PDF configuring

Probability Density Function Types (PDF Types)	Chi-Square Test (χ^2)	Optimal Parameters of PDF.
Binomial	Less Than 0.00001	$n = 5, p = 0.62857$
Integer Uniform	Less Than 0.00001	$\max = 5, \min = 1$
Poisson	Less Than 0.00001	$\lambda = 3.1429$

Notice: The kinds of goodness-of-fit test had performed only by Chi-Square Test for discrete PDF.

In Step 3 (for continuous probability) of the application, the results indicated that Rayleigh PDF should be chosen due to its minimum goodness-of-fit value. The entire summary tables of results are shown in Table 6 to Table 8.

Table 6 The summary table of the top three results of the optimal parameters and types of continuous PDF configuring and the goodness-of-fit test by Chi-Square test.

Probability Density Function Types (PDF Types)	Chi-Square Test (χ^2)	Optimal Parameters of PDF.
Beta	5.4929	$\alpha_1 = 0.61508,$ $\alpha_2 = 0.67718$
Weibull	9.9319	$\alpha = 1.5953, \beta = 13.486$
Rayleigh	10.7001	$b = 11.030$

Table 7 The summary table of the top three results of the optimal parameters and types of continuous PDF configuring and the goodness-of-fit test by Kolmogorov-Smirnov test.

Probability Density Function Types (PDF Types)	Kolmogorov-Smirnov Test (K-S or D_n)	Optimal Parameters of PDF.
Rayleigh	0.1043	$b = 11.030$
Log Logistic	0.1056	$\alpha = -7.9312, \beta = 18.1344$
Beta	0.1057	$\alpha_1 = 0.61508,$ $\alpha_2 = 0.67718$

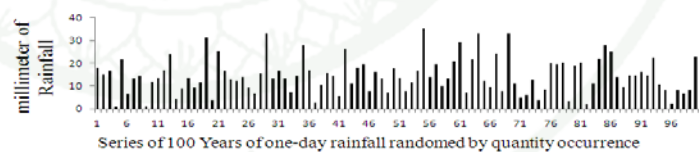
Table 8 The summary table of the top three results of the optimal parameters and types of continuous PDF configuring and the goodness-of-fit test by Anderson-Darling Test.

Probability Density Function Types (PDF Types)	Anderson-Darling Test (A-D or A_n^2)	Optimal Parameters of PDF.
Inverse Gaussian	0.4829	$\mu = 21.666, \lambda = 158.976$
Log-Normal	0.4871	$\mu = 23.652, \lambda = 7.9259$
Gumbel or Extreme Value	0.4947	$a = 7.8297, b = 6.3170$

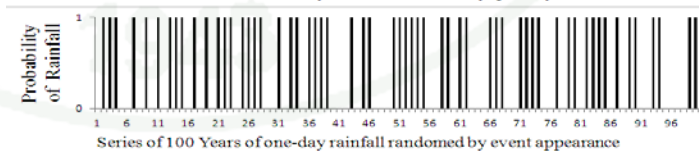
3. Combine the identified Discrete PDF with the configured Continuous PDF

Step 4 The final step, the chosen functions, the Poisson and the Rayleigh PDF, are used for generating a 100 years set of data. Later, the joint probability principle applying after the PDF has been chosen in step 3. That is “ $P(A \cap B) = P(A|B).P(B)$ ”. Three sub-figures in Figure 52 present the intersection of randomly generated data with discrete PDF and continuous PDF for a set of daily rainfall forming.

$P(A|B)$: by Rayleigh PDF



$P(B)$: by Poisson PDF



$P(A \cap B) = P(A|B).P(B)$

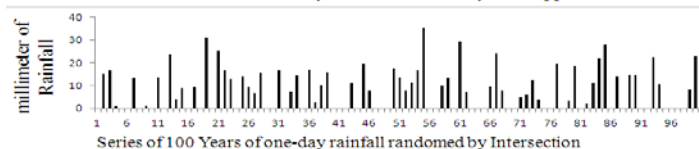


Figure 52 The intersection of discrete PDF and continuous PDF was formed as a set of 100 of daily rainfall data by randomly generating.

4. Apply to Rainfall-Runoff Model

The rainfall data plan to use is monthly rainfall data, but this study uses a thirty years set of historical daily rainfall to be a prototype for creating a set of unlimited synthetic daily rainfall, roughly expressed as a conceptual diagram in Figure 53. (Methodology) The big amounts of the synthetic daily rainfall data can be transformed into the big amounts of the daily inflow runoff in reservoir by the Rainfall-Runoff Model. The selected model in use was literally discussed in prior topic.

With the Linear Perturbation Model (LPM) applying, the daily inflow runoff has created based on the daily rainfall data and the area of the reservoir catchment area data. For the results in a year as a sample demonstrate by the case study of Papayom reservoir shown in Figure 54 below.

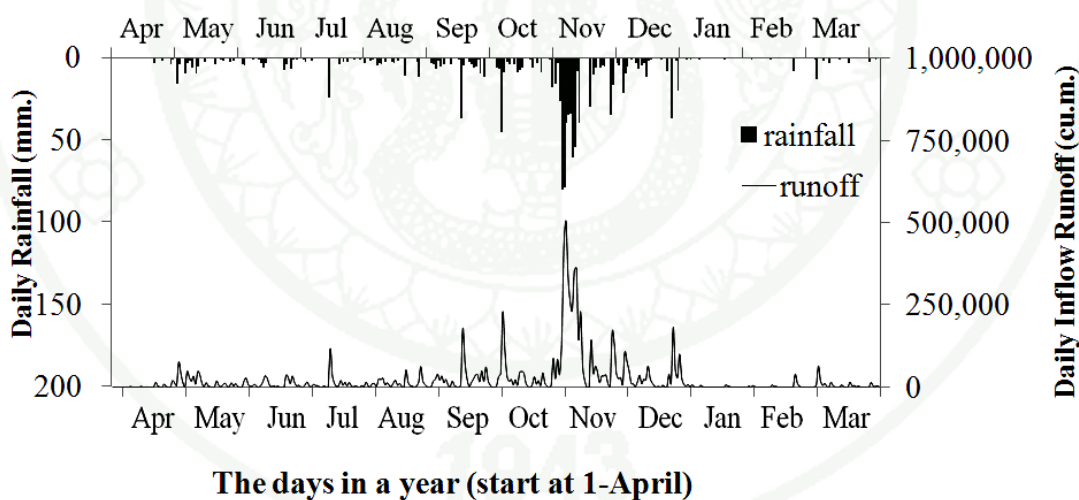


Figure 53 A sample results by applying Rainfall-Runoff Modeling for a year period

For overall a set of the daily rainfall data use as the input, a set of the daily inflow runoff data was also generated by the Rainfall-Runoff Modeling which expressed in Figure 54.

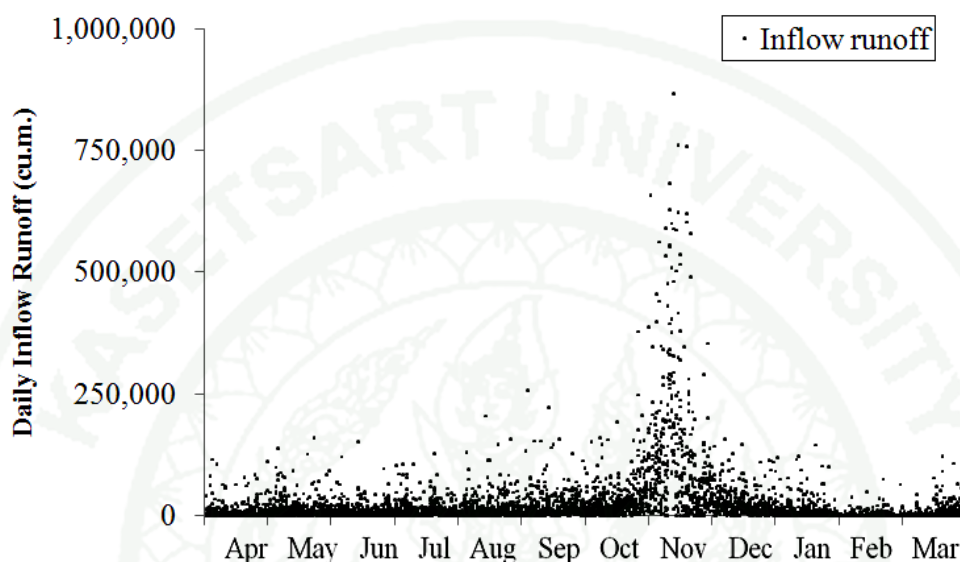


Figure 54 Source of the daily inflow runoff data which transformed from a set of the synthetic daily rainfall data by Rainfall-Runoff Modeling

II. Part two for the results of the Model-Base Driven

Results in the part two, those are the end results in the optimized modeling process for obtaining the long-term and short-term operational rules.

A. Optimized Modeling for Long-Term Operational Rule

1. Case study of Papayom Reservoir

The reservoir operation optimization requires the assistance of computer modeling tools to provide information for rational operational decisions. An effective tool is a simulation model that includes decision rules to enable a decision-maker to examine the consequences of various scenarios of an existing reservoir system. This study setup a simulation model for reservoir operation and

optimization into two categories, the deterministic reservoir operation optimization in order to obtain an operational line and stochastic reservoir simulation in order to obtain a set of operational trace lines, as following particular procedures.

The reservoir operation in term of deterministic optimization proposes optimizing process by using the balanced deterministic data both supply side and demand side with the purpose of obtaining the optimal operation guideline. The inflow into the reservoir and the water release from the reservoir are set at the average of the monthly quantity and in the equal quantity. $I(t)$ are represented as the monthly inflow series. $D(t)$ is represented as the monthly demand series. For that reason, $\Sigma I(t)$ is equal $\Sigma D(t)$.

a) Decision Variables

The monthly water release from reservoir in a set of year round, $R(t)$ is represented as the monthly release series, is a set of decision variables.

b) Multi-Objective Function Formulation

The objectives are set into two categories, a hard constraint and soft constraints. The hard constraint is to be necessarily satisfied, while soft constraints only express a preference of some solutions (those having a high or low value) over other ones (those having lower/higher value).

Hard constraints objective:

Hard constraints objective: is the minimal objective of the sum of square of relative error or the error index between monthly demand and release rate. It must be minimal in the first priority. The meaning is the responsive index of the release to demands volume.

$$\text{The first objective: } \mathbf{Min. Z_1} = \sum_{t=1}^n \left[\frac{R(t)-D(t)}{D(t)} \right]^2 \quad (9)$$

Soft constraint objective:

Soft constraint objective: a kind of statistical index, or the standard deviation of the monthly release rate. It could be as minimal as it could be. The meaning is how well in the release rate in equally sharing for all month as discussed in topic 1.2.

$$\text{The second objective: } \mathbf{Min. Z_2} = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (R_{(i)} - \bar{R})^2} \quad (10)$$

Soft constraint objective: the water excess of storage capacity, or monthly spill volume, $Sp(t)$ is represented. It could be as minimal as it could be. The meaning is how to obtain the optimal initial storage to safe the water budget by spillage.

$$\text{The third objective: } \mathbf{Min. Z_3} = Sp(t) \quad (11)$$

When $Sp(t) = S(t) - S_{max}$, and $S(t) \geq S_{max}$

Soft constraint objective: the water shortage which water demand is less than dead storage capacity, or monthly shortage volume, $Sh(t)$ is represented. It could be as minimal as it could be. The meaning is how to obtain the optimal initial storage to avoid the water deficit by shortage.

$$\text{The forth objective: } \mathbf{Min. Z_4} = Sh(t) \quad (12)$$

When $Sh(t) = S(t) - S_{min} - D(t)$, and $D(t) \geq S(t) - S_{min}$,

and $R(t) = S(t) - S_{min}$

Subject to Constraints:

The constraints are divided into four categories; the equality constraints, the inequality constraints, the conditional constraints, and the non-negativity constraints as follows:

Equality Constraints

Mass balance constraint: This equation is the same equation and the same meaning as equation (2) described in topic Reservoir Operation Principles.

$$S(t + 1) = S(t) + \sum I(t) - \sum R(t) \quad \forall t = 1, 2, \dots, T \quad (13)$$

Minimum constraint of water release rate: This rate is the water requirement for environmental support estimated by the Papayom Irrigation Project.

$$R_{min} = 0.1886 \text{ Million cu. m./month} \quad (14)$$

Maximum constraint of water release rate: This rate is the highest river outlet capability appraised by the Papayom Irrigation Project.

$$R_{max} = 2.1312 \text{ Million cu. m./month} \quad (15)$$

Minimum constraint of storage volume: This volume is the physical constraint of designing reservoir informed of the Papayom Irrigation Project.

$$S_{min} = 0.8 \text{ Million cu. m.} \quad (16)$$

Maximum constraint of storage volume: This volume is the physical constraint of designing reservoir informed of the Papayom Irrigation Project.

$$S_{max} = 20.5 \text{ Million cu. m.} \quad (17)$$

For constraints on discharge defined by the river's outlet channel limits; q_{min} , and q_{max} which is able to approximately carry the discharge 5.0 million

cu.m./month. This drainage ability takes benefit more than R_{max} . For this reason, q_{max} is not necessary to set as a constraint. However for another constraint consideration, there are not hydropower constraint, $(HP_{min}, HP(t), HP_{max})$, to consider for this project.

Inequality Constraints

There are two inequality constraints in this study those are the water release gap and the storage volume gap.

$$R_{min} \leq R(t) \leq R_{max} \quad \forall t = 1, 2, \dots, T \quad (18)$$

Conditional Constraints

Hedging Operation Policy (HOP) constraint: These conditional constraints or logical equations are the same equations and the same meaning as equation (19) described in topic modeling on the Hedging Operational Policy.

$$R(t) = \begin{cases} D(t) + S(t) + Sp(t) - S_{max}, & \text{for } S(t) + Sp(t) \geq S_{max} + D(t) \\ D(t) + Sp(t), & \text{for } S_{max} + D(t) + Sp(t) > S(t) \geq S_{min} \\ D(t) - Sh(t), & \text{for } S_{max} + D(t) - Sh(t) > S(t) \geq S_{min} \geq 0 \\ D(t) + S(t) - Sh(t) - S_{min}, & \text{for } S_{max} > S(t) \geq S_{min} - D(t) - Sh(t) \geq 0 \\ 0 - Sh(t), & \text{otherwise, } R(t) \geq 0 \end{cases} \quad (19)$$

Non-negativity Constraints

Non-negativity constraints is set for all involved constraints; monthly inflow: $I(t)$, water demand: $D(t)$, water release: $R(t)$, storage volume: $S(t)$, spill volume: $Sp(t)$, shortage volume: $Sh(t)$, and discrete value of time step: t must be non-negativity constraints.

$$I(t), D(t), R(t), S(t), Sp(t), Sh(t), \text{ and } t \geq 0 \quad (20)$$

c) Result of Reservoir Operation Model

The result is a set of the optimal lines of Papayom reservoir and Sirikitti reservoir illustrated in Figure 55 and Figure 56 respectively. The most possible can be analyzed to percent probability symbolized by the Box-Whisker plotting.

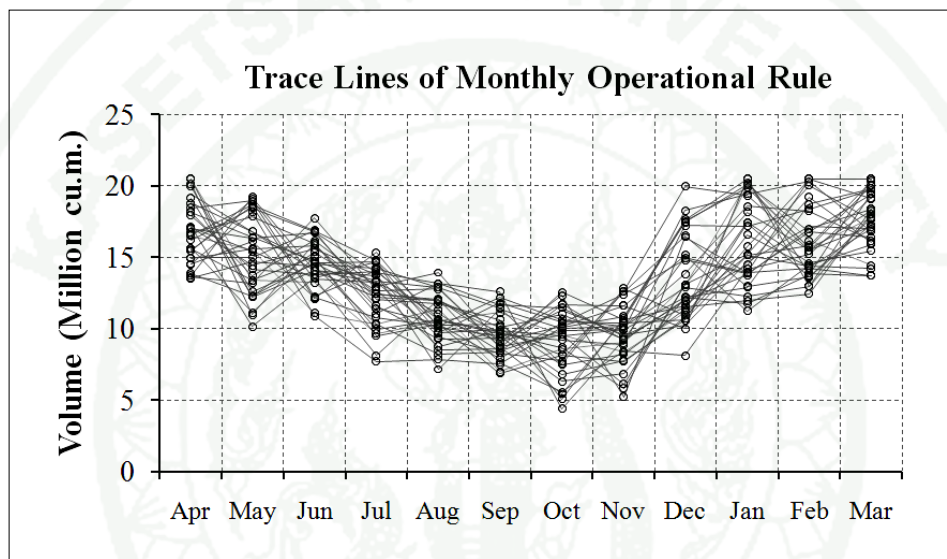


Figure 55 The set of optimal results of the monthly operational rule expresses by the trace lines the Case Study: Papayom Reservoir

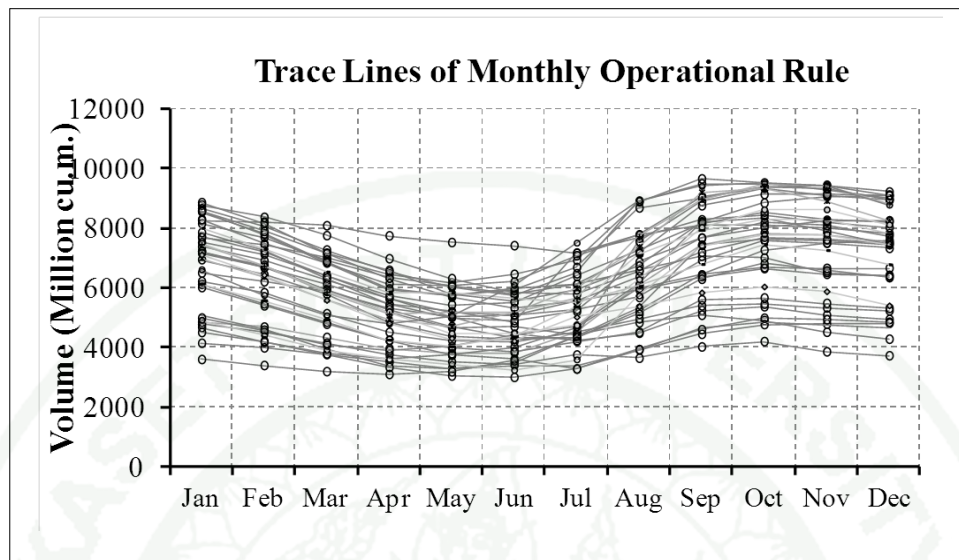


Figure 56 The set of optimal results of the monthly operational rule expresses by the trace lines the Case Study: Sirikitti Reservoir

B. Optimized Modeling for Short-Term Operational Rule

The Optimized Modeling for Short-Term Operational Rule has the detail in this following cited paper (Eakawit and Suwatana, 2011c). In briefly, this process is the identification for three parameters which are the alternative in expect value denoted by μ , the compensated water to be estimate denoted by ε , and the hedge up or down water to be examined denoted by φ . These parameters will be optimized in the decision tree with the evolutionary algorithms.

1. Case study of Papayom Reservoir

a) Result for Input data

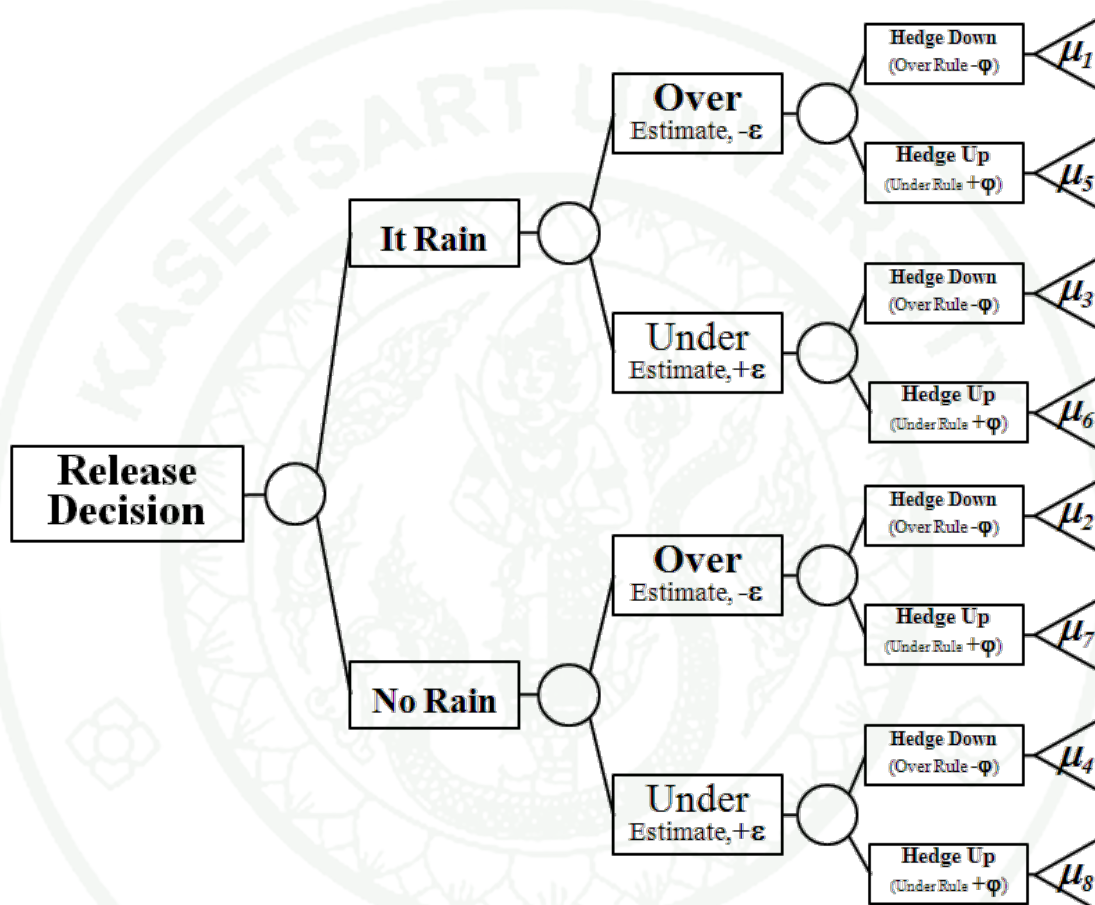


Figure 57 The Decision Tree for release decision in the short term expressed the alternative logic classified by the uncertainty events

b) Result of Decision Tree Operation Model

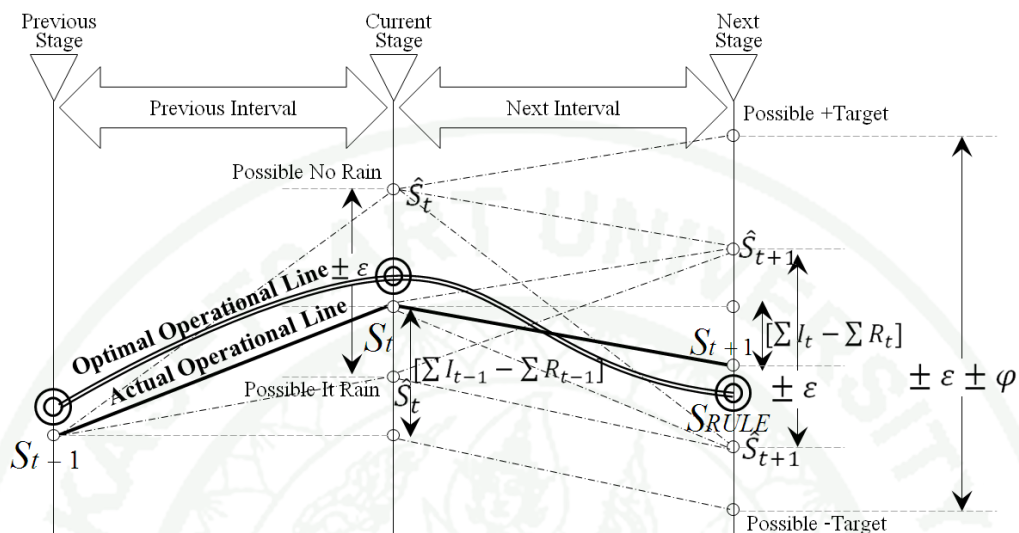


Figure 58 Diagram shows the calculation mechanism for following up the MLL line by adjusting ϵ and φ to determine the release decision.

III. Part three of the result of the Dialog - Base Driven

A. User interface output by Box-Whisker graph

1. Most Likely Line of Sirikitti Reservoir

a) Result for Input data

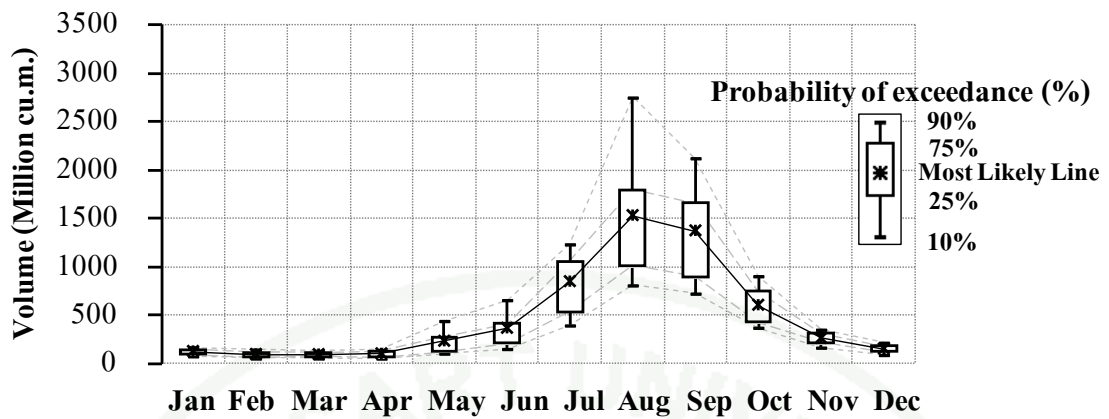


Figure 59 Box-Whisker Plot of the synthetic inflow of Sirikitti Reservoir

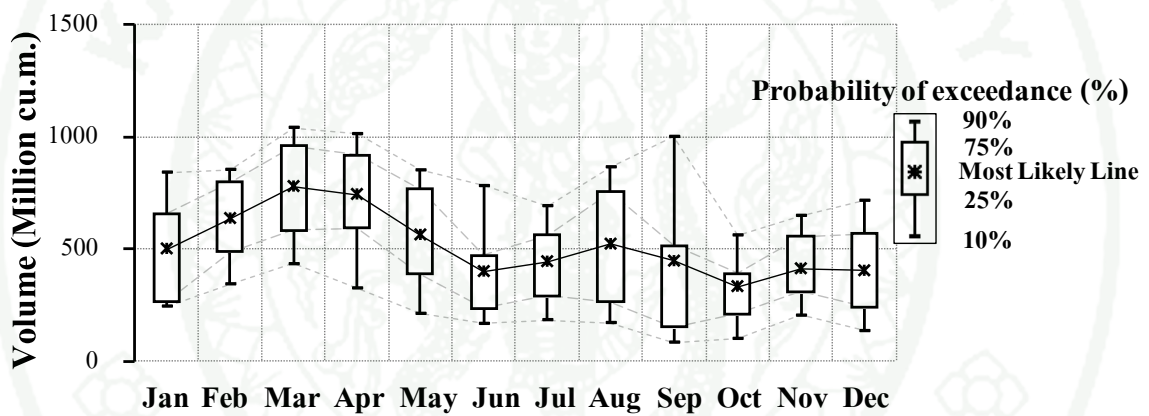


Figure 60 Box-Whisker Plot of the synthetic outflow of Sirikitti Reservoir

The results by using a set of inflow data illustrated in Figure 61 are a set of the optimal lines. The most possible can be analyzed to the percent of probability symbolized by the Box-Whisker plotting.

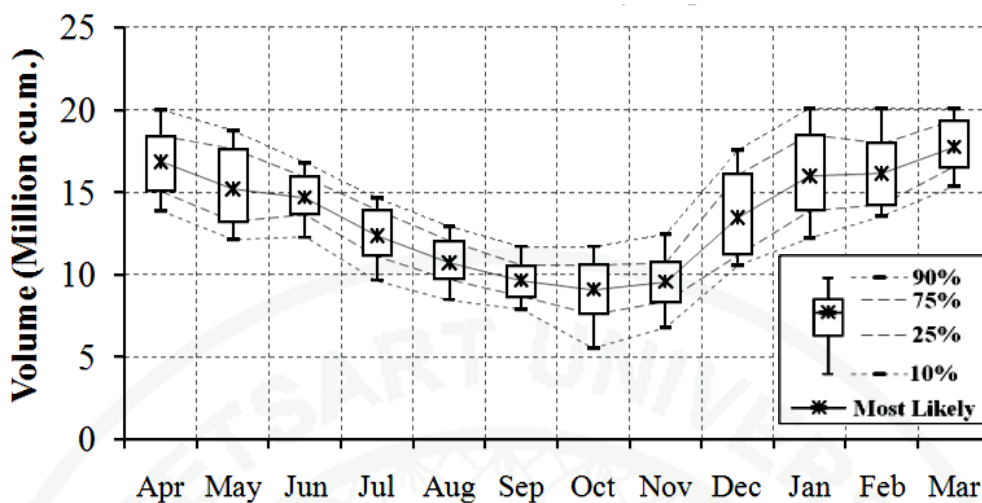


Figure 61 The set of optimal results of the monthly operational rule expresses by Box-Whisker plots for MLL line of Papayom reservoir.

2. Most Likely Line of Sirikitti Reservoir

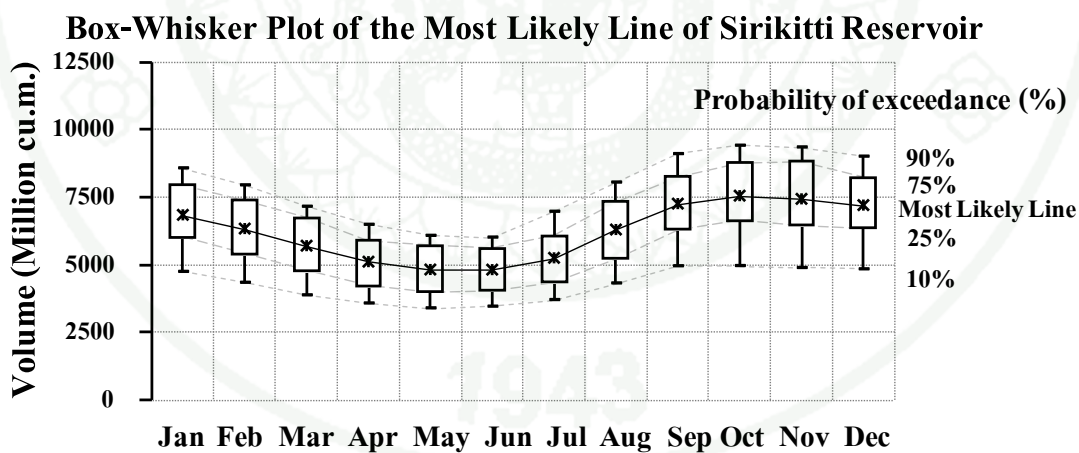


Figure 62 The set of optimal results of the monthly operational rule expresses by Box-Whisker plots for MLL line of Sirikitti reservoir.

B. User interface output by Spreadsheet Dialog

1. Decision Tree Dialog of Papayom Reservoir

The result of the decision is the performance of the operating mechanism. The decision tree model will perform its functions in searching for minimal ΔS of 8 alternatives. The optimal alternative is obtained from the optimization driven. The overall result can be shown in Figure 63 in order to satisfy an appropriate release rate for operating in the decision making.

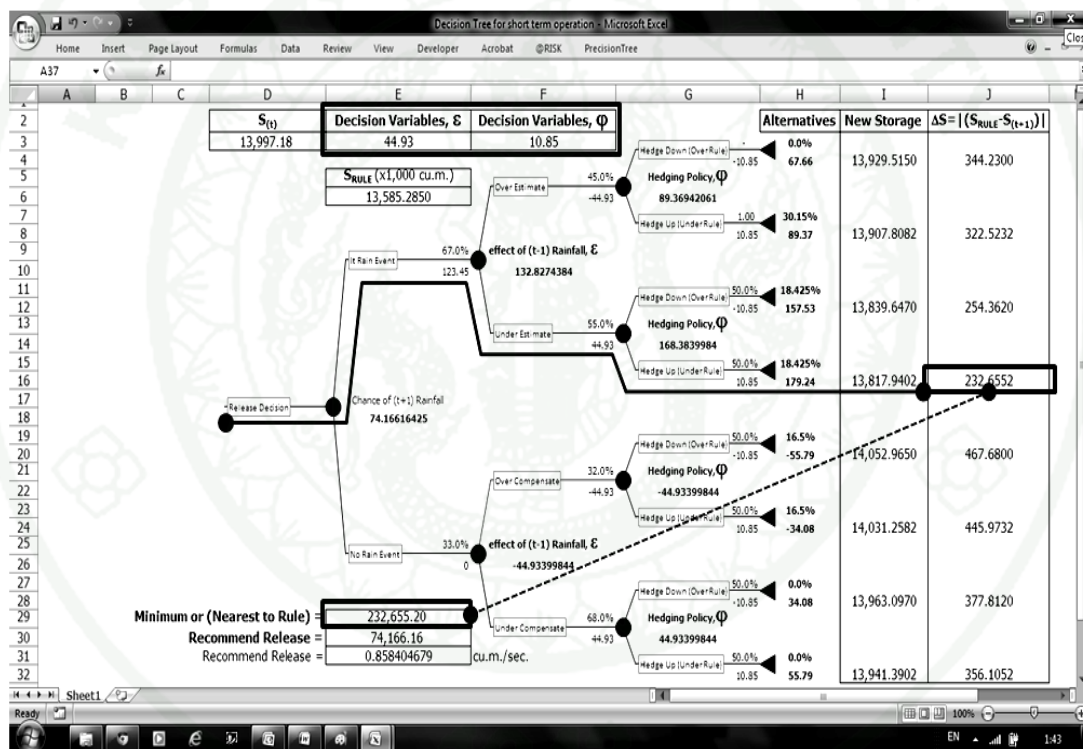


Figure 63 The minimum alternative obtained from concurrence performing by the decision tree and the optimization procedure.

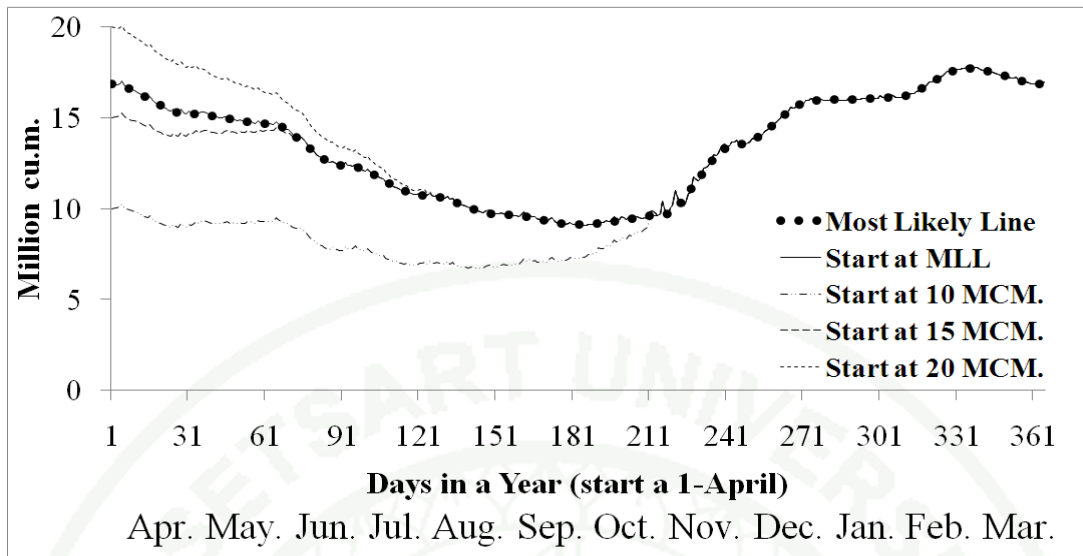


Figure 64 The convergence lines to the MLL line in several cases different initial volumes

In combination of all year round decision, the different scenario simulation result can be shown the converged lines in the MLL line in Figure 64. Those initial are at 10, 15, and 20 million cubic meters.

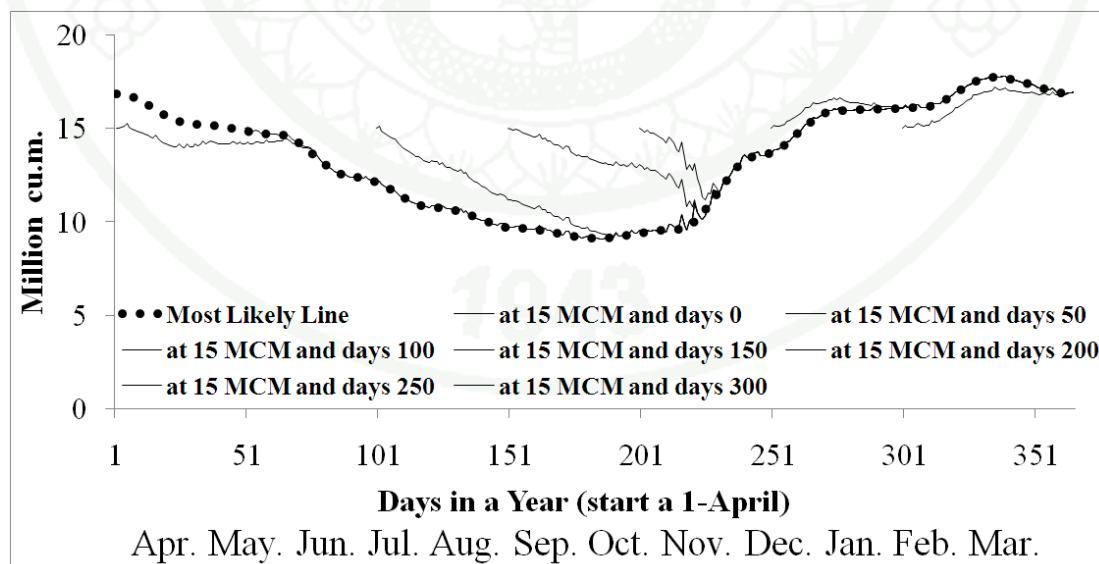


Figure 65 The convergence line to the MLL line by setting initial volumes of 15 million cubic meters at different time stages in simulation results

Likewise, in combination of all year round decision, Figure 65 shows the scenario results as converged lines in the MLL line in various initial conditions of the 15 million cubic meters storages, but at the several time stages. Those start on the day of 0, 50, 100, 150, 200, 250, and 300. The results show all scenarios nicely converging to the MLL line.

Decision Making for Short Term Operation

The finalized results of the decision making for short term operation are the determination of the optimal release rate of the water volume of the reservoir. The following up on the actual storage line to MLL line, produced by optimization simulation, is a recommendation for short term decision for the optimal operation guideline. The optimal release rate of the recommended water volume of the reservoir is the differential volume between the next estimation and the current determination at that time interval. This volume should be a preference of the decision making to the operator who controls the reservoir in practice.

IV. Part four of the additional results for Wet and Dry year conditions

In order to get the scenarios both for wet and dry year conditions, the input data are equally separated into two sets. For the wet and the dry year condition, the input data was sorted by ordinal amount to divide it into the greater than and lesser than normal data. These sets of the data are represented as the population set of the generated data on each amount of one hundred years data set. By twice input it into the model, its output are the most likely line for wet year condition so called in short as the MLLW which shows in Figure 66 to Figure 69 and the most likely line for dry year condition so called in short as the MLLD which shows in Figure 70 to Figure 73 respectively.

A. The additional results of Sirikitti Reservoir

1. The additional results of Sirikitti Reservoir for wet year condition

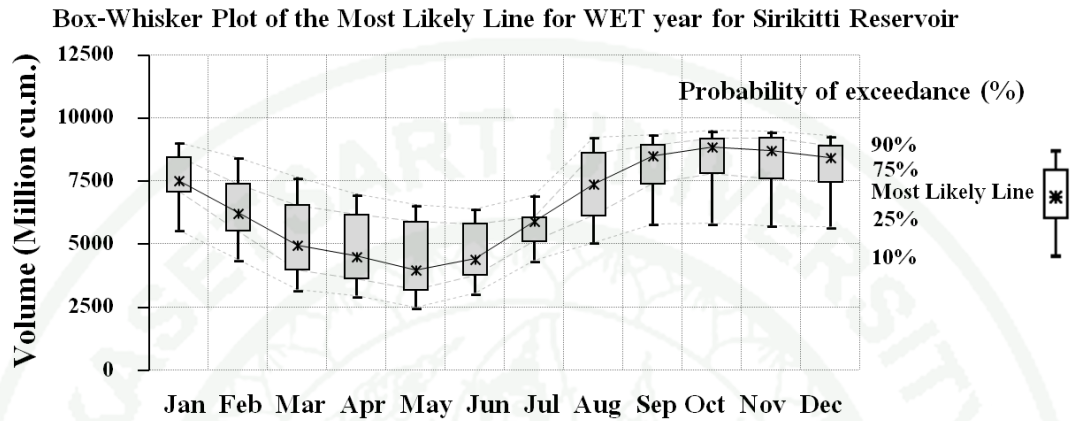


Figure 66 The MLLW line of Sirikitti Reservoir obtained from the simulation results by setting the greater than normal data of the inflow into the reservoir.

2. The additional results of Sirikitti Reservoir for dry year condition

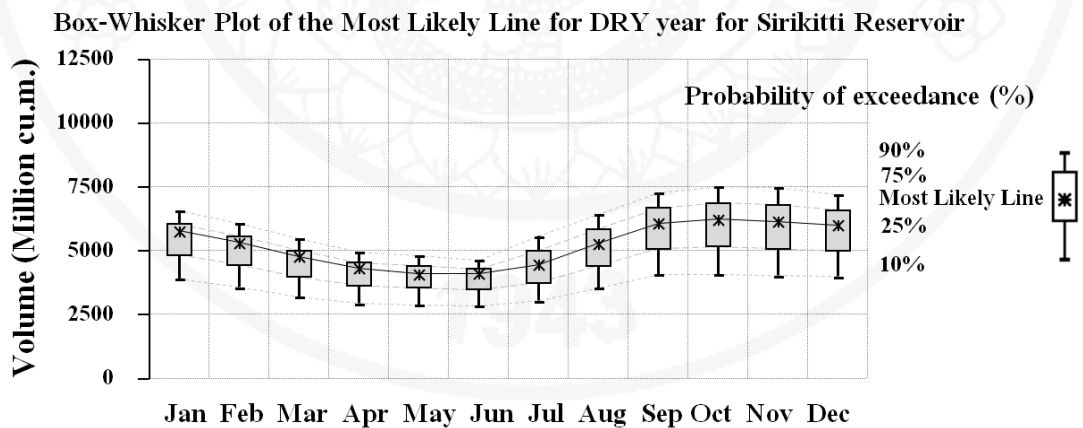


Figure 67 The MLLD line of Sirikitti Reservoir obtained from the simulation results by setting the lesser than normal data of the inflow into the reservoir.

3. The comparative results of Sirikitti Reservoir for normal, wet, and dry year condition

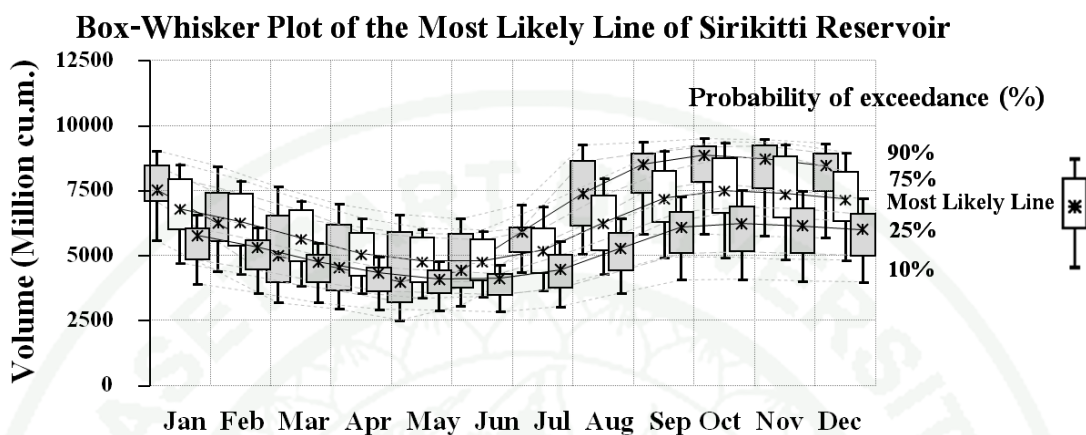


Figure 68 In comparison with the Upper Rule, Lower Rule, MLL, MLLW, and the MLLD line of Sirikitti Reservoir in the form of Box-Whisker plot

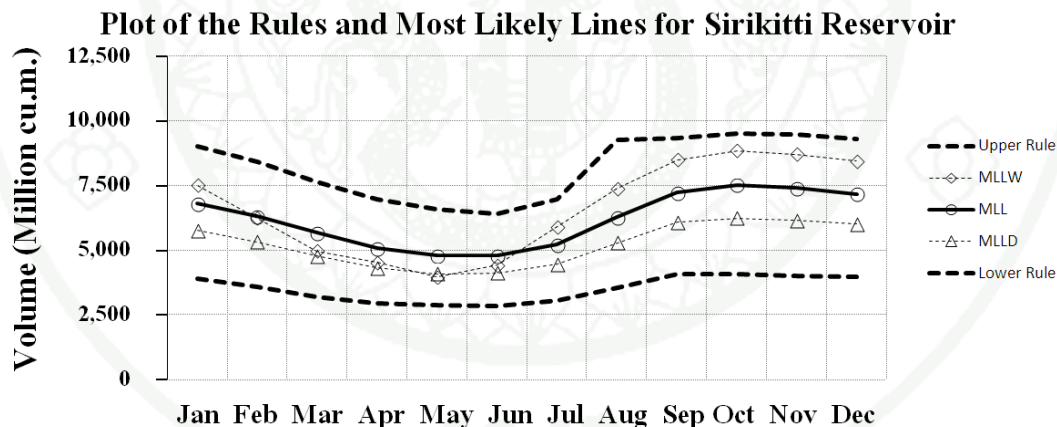


Figure 69 In comparison with the Upper Rule, Lower Rule, MLL, MLLW, and the MLLD line of Sirikitti Reservoir in the form of scatter plot

B. The additional results of Papayom Reservoir

1. The additional results of Papayom Reservoir for wet year condition

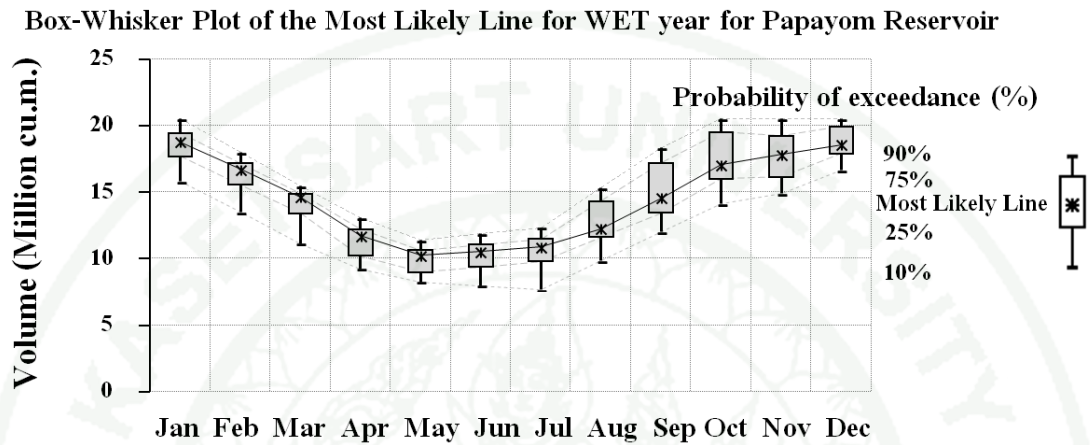


Figure 70 The MLLW line of Papayom Reservoir obtained from the simulation results by setting the greater than normal data of the inflow into the reservoir.

2. The additional results of Papayom Reservoir for dry year condition

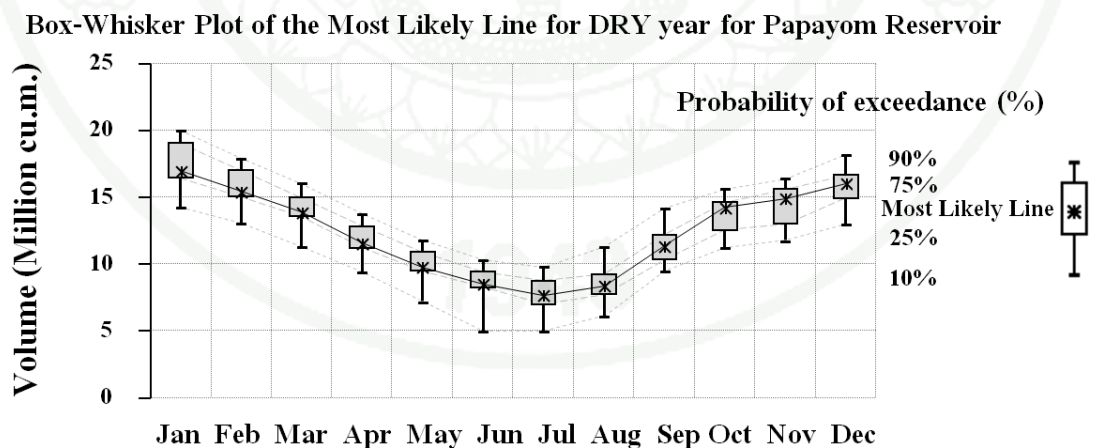


Figure 71 The MLLD line of Papayom Reservoir obtained from the simulation results by setting the lesser than normal data of the inflow into the reservoir.

3. The comparative results of Papayom Reservoir for normal, wet, and dry year condition

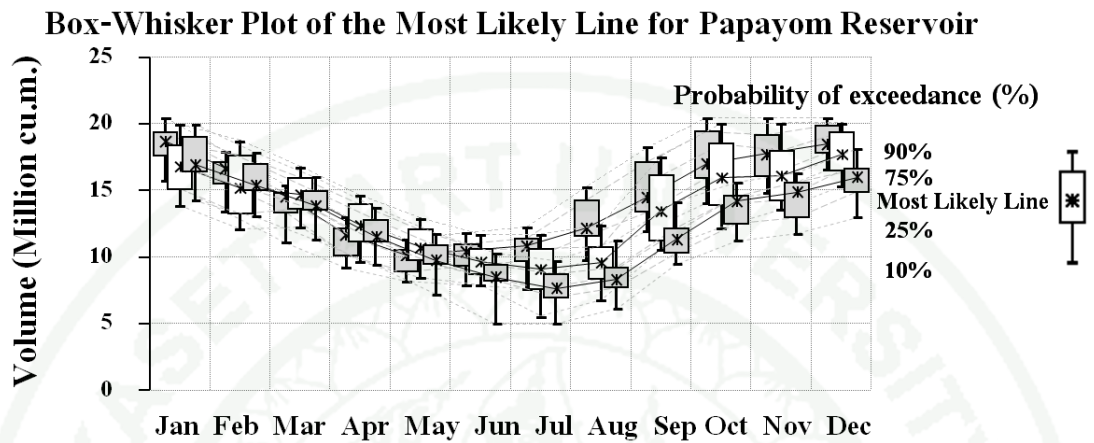


Figure 72 In comparison with the Upper Rule, Lower Rule, MLL, MLLW, and the MLLD line of Papayom Reservoir in the form of Box-Whisker plot

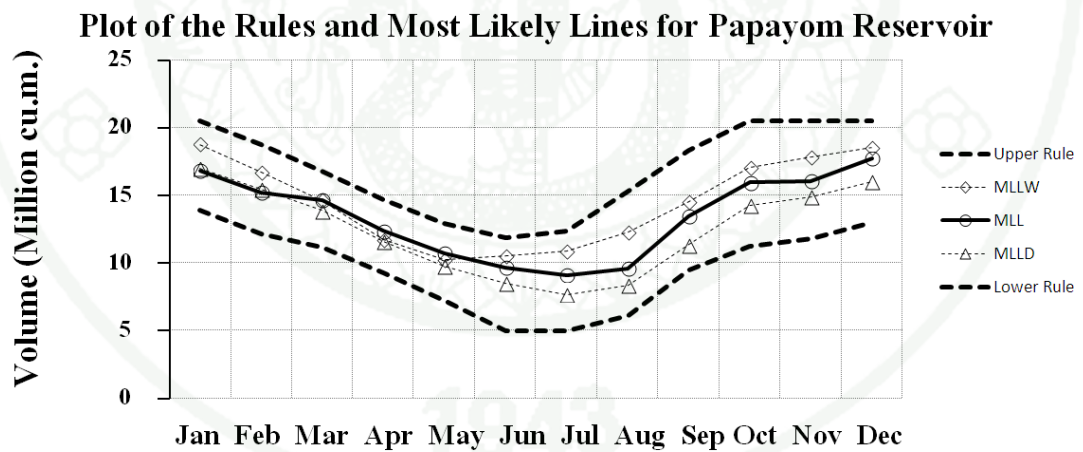


Figure 73 In comparison with the Upper Rule, Lower Rule, MLL, MLLW, and the MLLD line of Papayom Reservoir in the form of scatter plot

Discussion

For the constructive results, the discussion is placed in four major following details, the research output, the research outcome, their contributions, and their impacts.

I. Research Output

The output result is the long-term for reservoir operational rule which mean the rule that cover consideration by the period of a year. This rule comprehends a set of the possibility lines of the optimal reservoir operational rule or it is called the Most Likely Line: MLL in the form of the Box-Whisker plot. The distance from the MLL indicates that the water storage as it be will reduce the appropriate reliability. If the storage line is located upper than the MLL line, it means vulnerable risk to flooding, because there is more water retention than depletion space. Hence, if the storage line is located lower than the MLL line, it means vulnerable risk to the deficit, because there is less water retention than water usage plan.

II. Research Outcome

The useful benefit on the research outcome in the long-term of the reservoir operational rule is a guideline to control the amount of water which should be kept in the reservoir on a year round covering. This rule is in response to the uncertainty on both sides of the water resources: for water supply and the demand side can be useful in the management of water in a short-term period such as for daily, for the past three days, but should not be for more than a week.

III. Contributions

The contributions of the research for reservoir operational rule also both in long-term and short-term are to acquire new knowledge including the synthetic procedure of the daily rainfall by applying Bayesian theory and the objective function

in optimization procedure for the new technique of the long-term reservoir operation rule which subsequently contains four features.

A. The first feature is directly responsive to the changeableness of the water demand.

B. The second feature is the equity sharing of the water release from reservoir on all year round.

C. The third feature is the suitable position where located the water storage in the reservoir on each month to cope with the volume of water in a wet and dry year.

D. The fourth feature is the concept to control the amount of water in the reservoir in order to show a convergence toward the MLL line.

In addition, this research provides the new knowledge or the new approach in the short-term operation in the reservoir management by decisions making led to long-term reservoir operation rule. The MLL line is introduced in reservoir management is the most appropriate to suggest that a single line operational rule. The operators who use this rule would not hesitate in practice. On the other hand, It also can be used as an index for controlling the amount of water how keeping in the reservoir to the proper state which it should be at any time interval or at any times of the reservoir operation.

IV. Impacts

The impacts on research results of the reservoir operation by the new concepts in case of applying in practice may be discussed in these following topics.

A. The first impact is on the need for a tool improvement to collect the daily data. Due to this new concept offer the continuous data collection and its feedback from the actual work in the field. In case of the project has usual daily

routine for data collecting, this impact will not affect for additional budget and workers.

B. The next impact is affected by the complexity of the calculations which requires the computational processes, the understanding person and the interpreter for the results of the calculation. Currently, there is only a prototype for concept proving. Thus there is a need to devise a training program for practical applications.

C. Another impact is the restrictions on water use by this new concept.

To consider the demand for the water release from the reservoir is able to do in both following two cases.

1. The first case, the operator is an authorized person who projects the water release plan. The water users must follow up. This demand plan is so called Proactive Demand.

2. The second case, the water users project the water release plan. The operator must follow up. This demand plan is a so called Pre-Passive Demand.

All cases have the restrictions on water use by quantity and time constraint. Thus, the limit of water requirement is not higher than water budget which guide by this concept may effects to the water users though the water users are the planners if it appears that the demand for water exceeds the water use restrictions.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main objective of this research is the endeavor to approach the new reservoir operational rule mechanized by the dynamic decision support system (Data-base, Model-base, and Dialog-base) for the decision maker who needs suitable information or proper scenarios on reservoir operation in decision making. Therefore the tasks are integrated with: (1) Uncertainty analysis the sample data for synthesis the population data, (2) Mathematical modeling to obtain the Most Likely Line (MLL) of the reservoir operational rule, (3) Dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation. The conclusions can be drawn as follows:

I. Uncertainty analysis the sample data for synthesis the population data.

This topic introduces a new method to randomly generate the synthesis daily rainfall as a population set from a sample data set of thirty years of one-day rainfall data on the fixed date as input. Fundamentally, it has been intersected with the probability of the quantity occurrence and of the event appears. The process of disjointing between continuous and discrete probabilities is necessary in order to configure the parameters which shaping in the form of probability function. Then finally, the joining of their probabilities is carried out to complete the synthetic process. These processes are from the conditional probability. Nevertheless in this topic, the application of Evolutionary Algorithm to find the optimal parameters of PDF uses the Genetic Algorithms. The results showed its high efficiency performance in term of rapidly and accurately searching the appropriate parameter values. It would be a replacement for the conventional method of trial and error. For the types of PDF selection, the minimal value of the goodness-of-fit test was used as an index to evaluate and making the decision for selecting their types.

II. Mathematical modeling to obtain the Most Likely Line (MLL) of the reservoir operational rule.

Mathematical model a tool to obtain the Most Likely Line (MLL) of the reservoir operational rule plays the important role in this research for new strategies and tactics to improve the operational rules by up to date with response to the changes for better scenario that are necessary and need to be the dynamic feature of the reservoir operation. The Most Likely Line (MLL), the related results of the optimized simulation, is one of the ideas of the advice for the reservoir operation. This method originates by a result of the Dynamic Decision Support System (DDSS) which is applied to the water balance of the reservoir. It is used for suggestion the changes in each period of the amount of water that should be controlled for the water storage and for the water depletion.

III. Dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation.

Dialog driven by using the Decision Tree to follow up the MLL line as a tool for periodical short-term operation or the method for supporting decision on this topic is the new way to control water releasing from the reservoir in short term operation. It created by the integrated model through the decision tree algorithm on the basis of Bayes' theorem couple with an optimization technique by Evolutionary Algorithm. This method is reasonable for controlling the water storage depending on the inflow at supply side and outflow or demand side accounting for related time intervals in the past, present, and future with the uncertainty conditions. The decision making technique for following up the MLL line is for adjusting the water budget situation according to uncertainty climate condition. By this method, the operator easier control the periodic optimum of water release instead of using only the conventional method by upper and lower rule curves.

IV. Problems solving.

Six major problems as mention in the topic statement of the problems could be solved by the MLL line as a new tool. It is an additional line beside upper and lower limit guidance line with the rule curve concept and it is made on the up-to-date of the dynamical data including supply and demand side. MLL line serves for six problem's solution as follows:

A. MLL line improves the problem of non-conform to the rule curve via planning phase to the operation and management phase to be a better conform rule.

B. MLL line is made on current data adding on every rebuilt times in order to address the problem of up-to-date data using.

C. MLL line serve toward the climate change data by taking its effects through the synthetic data from the current data.

D. MLL line relies on the group of optimal storage guidance line which reflects the balance both the uncertainty on supply and demand side.

E. MLL line guides the most likely in decision making between depletion and retention policy.

F. MLL line guides cover long term and short term operation.

Therefore, the method of MLL, MLLW, and MLLD line establishment as well in long term operation and the operation procedure in practice by using these lines in short term operation as a guideline could be a new proposed method in decision support for operations to complete the dynamic effects on the reservoir operation achievement. The periodical short-term operation was exhibited by using the MLL for the normal year, the MLLW for wet year, and the MLLD for dry year conditions. By complying with the water release rate suggestion, the line of storage volume was converged to the most likely line on the periodical decision and to keep close the best

ideal of the operational rule which mean the risk of flood and drought could be alleviated.

Recommendations

The recommendation to the further study, it is very necessary and very high importance to prepare for water resources management to support though for present and for the future. Because the population growth, climate variation, unpredictable nature disaster etc. which inevitably affects of human being and to water resources. Therefore, the strongest recommend for the further research work should be continuing these following topics.

I. The MLL operational rule particularly for flood and drought conditions and periodical operation by short term operation that associate with the forecasting data and telemetering or SCADA technology in the real case should be in focus.

II. The demand side justifying in order to allocating on the basis of sufficiency and keeping it to the ground of sustainability in which adapts to the dynamical climate change condition should be in the center of attention.

III. The scenarios of water management especially of the reservoir in the condition of population growth rising up more than the natural resources is able to support should be in pre-awareness.

IV. The optimization simulation in appropriate planning of the land use change is also interesting for further research work.

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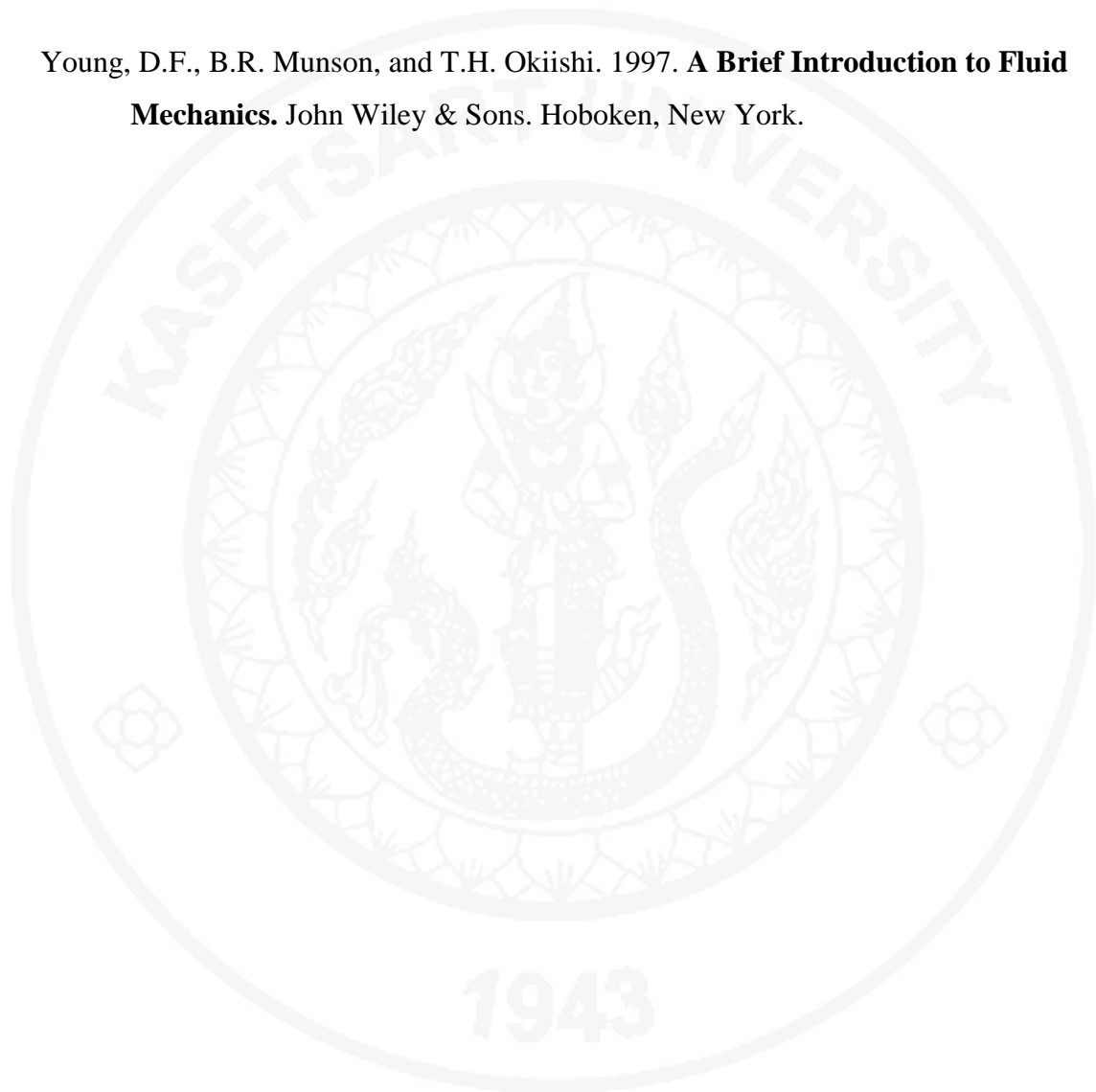
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CURRICULUM VITAE

NAME : Mr. Eakawit Jornpradit

BIRTH DATE : June 7, 1962

BIRTH PLACE : Nakhon Si Thammarat, Thailand

EDUCATION	: <u>YEAR</u>	<u>INSTITUTE</u>	<u>DEGREE/DIPLOMA</u>
	1998	Institute of Technology and Vocational Education.	B.Eng.(Civil)
	2005	Kasetsart University.	M.Eng.(Water Resources)

POSITION/TITLE : Civil Engineer/ Researcher

WORK PLACE : Working Group of Research and Development in
Engineering Discipline, Office of Research and
Development, Royal Irrigation Department,
Parkred, Nonthaburi, Thailand.

SCHOLARSHIP/AWARDS : The Commission on Higher Education,
Royal Irrigation Department,
Ministry of Agriculture and Cooperation