CHAPTER 2

Theory and Methodology of Study

2.1 Hydrosystems Engineering

Hydrosystems is a term originally coined by V.T. Chow to describe collectively the technical areas of hydrology, hydraulics, and water resource. it includes the application of economic, optimization, probability, statistics and management. Water is a renewable resource that naturally flows the hydrologic cycle, which shown in figure 2.1. Hydrologic cycle is basically a continuous process with no beginning or end, which was shown in the hydrologic cycle system. The system can be divided into three basic sub systems. First, the atmospheric water system includes as: containing the precipitation, evaporation, interception, and transpiration process. Second, the surface water system includes as: containing the overland flow, surface runoff, subsurface and groundwater flow, and runoff to stream and ocean process. Third, the subsurface water system incluses as: containing the process of infiltration, groundwater recharge, subsurface flow, and groundwater flow.[15]

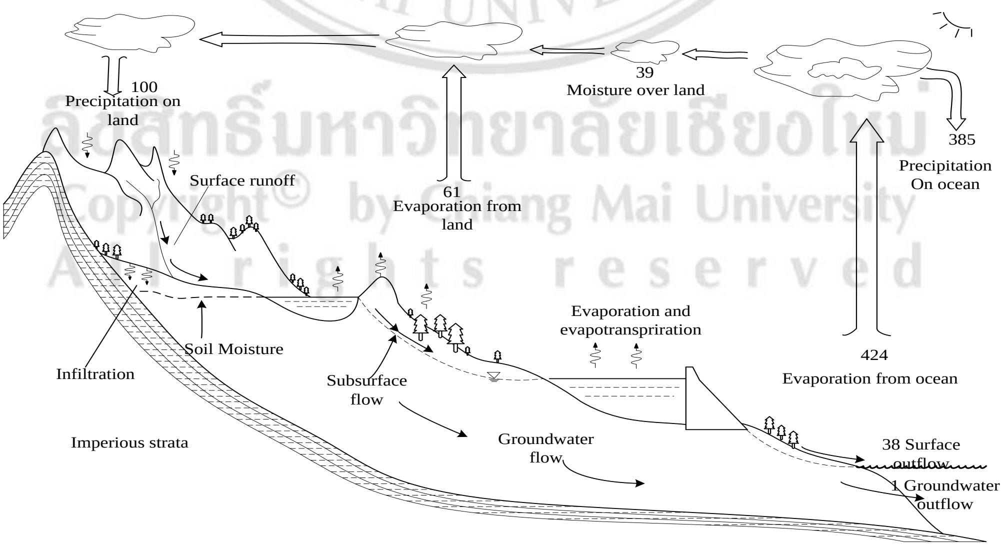

Figure 2.1 Hydrologic cycle of annual water balance

2.1.1 Hydrosystems description

Hydrosystems is included the surface water of supply system, groundwater supply system, water distribution system, urban drainage system, floodplain management system, and others. The division of subsystems within the global hydrologic system is shown in figure 2.2 as below.

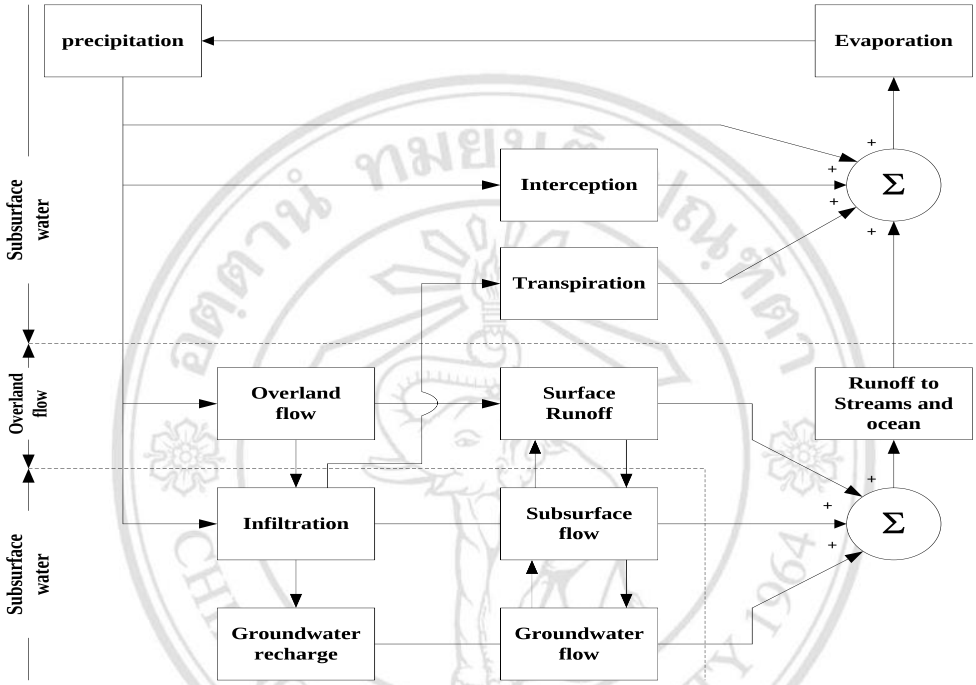

Figure 2.2 Block-diagram representation of the global hydro system.

2.1.2 Issues in hydrosystems engineering

The major types of the problems must be solved for various type of hydro system, which consists as below:

- Determination for optimal scale of development of the project,
- Determination for optimal dimensions of various components of system,
- Determination for optimal operation of the system,

If solutions to these problems are denoted as X_1, X_2, and X_3, then the benefit of these solution are:

$$B = f(X_1, X_2, X_3) \tag{2.1}$$

The objective of many hydrosystem projects to maximize the benefit, so that the problem of water resources development may be stated as:

$$\text{Maximize } B = f(X_1, X_2, X_3) \tag{2.2}$$

Constraints types is included technological constraints, economic constraints, design constraints, demand constraints, operation constraints and others.

2.1.3 Design and analysis

Hydrosystem problems manage for both design and analysis. The analysis considers for determining the behavior of existing system that is being designed. The problems of reservoirs system is to determine the size and location of reservoirs system. the analysis is process for determining operational policies of reservoirs system. Reservoir operational system is required to check the design and analysis for appropriately operation. Generally, the design is estimated and analyzed to see system. If it can performs according the specification and can satisfies all constraints. so that, the design was accepted for next operation. New design will be build, after it have been formulated and analyzed all problems of reservoirs system that better being designed.

2.1.4 Conventional and optimization procedures

Design and analysis of conventional procedures are basically processed the trial-and-error. Advantage of the conventional procedures depend on the operator, whom have knowledges, experiences, skills and intuition of the works. Therefore, conventional procedures has relationship with the persons, other factor element, which could effect to efficient works of the complex systems. Procedure is used by the simulation model for trying to arrive the optimal solution.

Optimization estimated in the process of trial-and-error is the design modification for new simulation, which will change for according periods and new parameters. Furthermore, the constraints were used to define the variable limits that affect to design model. Better performance was evaluated from objective function, that consisted the optimal benefit and minimum cost. Figure 3.3 has presented the depiction of conventional procedure for the design and analysis. Advantage of the conventional procedure is depended on an engineer, whom has experience and knowledge, are used in making the concepts of the system to make or to change additional specifications. In contrast, the decision process in the conventional and optimization procedure must manage and check the procedures, which uses a mathematical method to select in the operational decision.

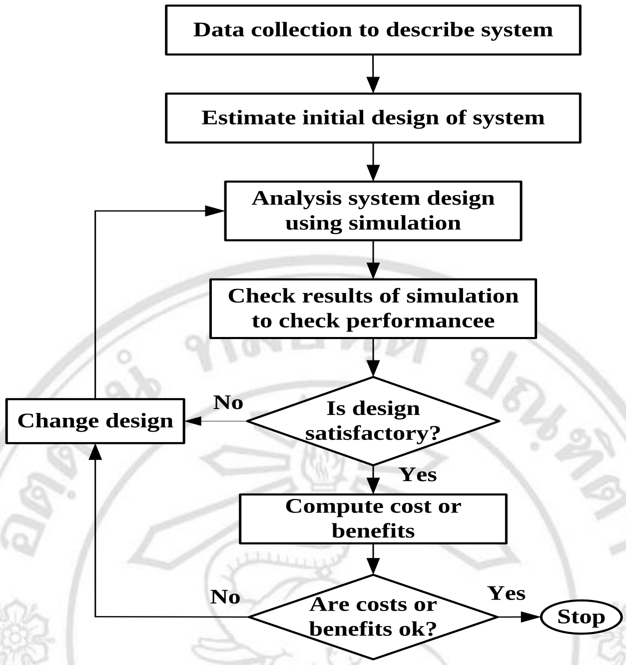

Figure 2.3 Conventional design and analysis process.

2.2 Optimization Theory

The problems in water resource of the optimization is generally formulated the main works. The works has the decision variables (x) and the objective function as:

$$\text{Optimize } f(\mathrm{x}) \tag{2.3}$$

Constraints of works

$$G(\mathrm{x}) = 0 \tag{2.4}$$

And boundary of the constraints for decision variables

$$X_{Lo} < X < X_{UP} \tag{2.5}$$

Where: X _ is a vector of *n* for decision variable ($x_1, x_2, \ldots, x_n$),

G(x) _ is a vector of m for the quastions or constraints,

X_{Lo} _ is a present the lower boundary, and

X_{UP} _ is a present the upper boundary, Problems of the optimization has divided into two parts: target or objective function and all constraints. An objectives function is explained to operate the criteria of operational system. The constraints is described the condition of operational system or the some effects that relate with operation process.

2.2.1 Optimization methodology

Optimization methodology is used for planning and managing the resources or all factors that affect to maximize benefits. The planning depend on conditions or requirements such as: resource constraints, manpower, amount of machines and other restrictions. The desired objective may be spending less, most production or both. The method is used for solving problems to optimize operational process, which is divided into three sections as.

- Decision variable and parameter variable: the decision variable is unknown variable, which is our variable wanted to find the variable value. While the other parameters refers to the relationship variables in the system.
- Constraints: constraints will reflect the physical limitations of the system, that's shown in the figure as below. Due, all constraints were taken into analysis and consideration. Then, it will appear area, which is area that can meet all constraints. This area called the area possible and apart from that area, which called the area impossible. Therefore, analysis area is the area as possible or called the feasible region, which shown detail in the figure 2.4 as below.

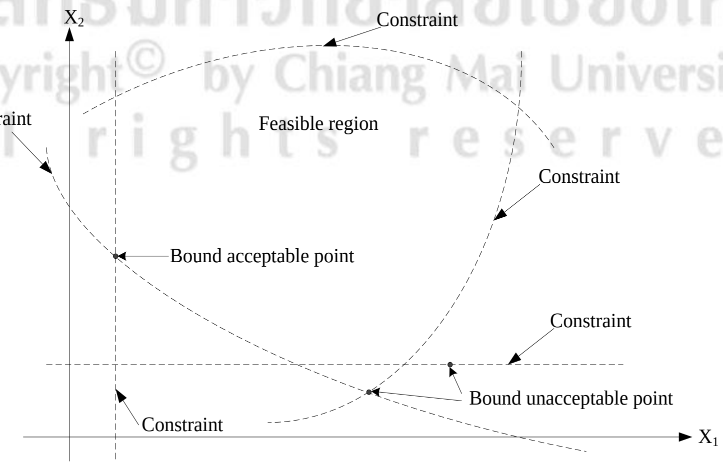

Figure 2.4 Possible area under constraints of the system.

- Objective function: is demand target for mathematical function model, in term of the decision variables. The most appropriation is answers that must be under all constraints and all regulatory requirements. At the same time, the results must be highest and lowest value of objective functions, which be under located area possible. The detail of objective function shown in the figure 2.5 for explaining the demand target as below.

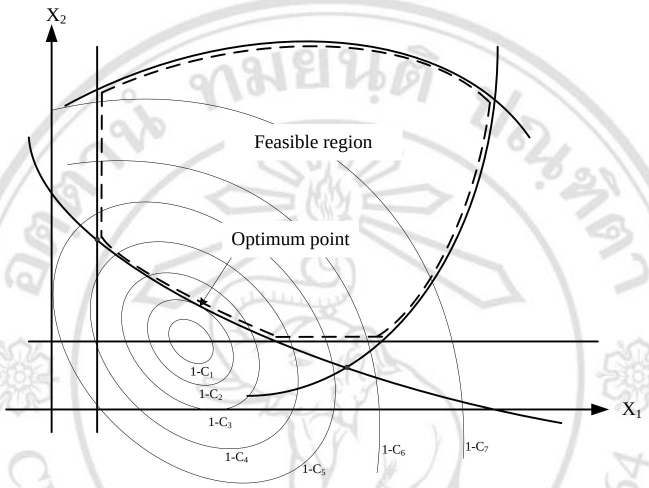

Figure 2.5 The demand target under constraints and regulation appropriate.

2.2.2 Applications of optimization in hydrosystems

The optimization is applied to more sections for application to hydrology system of engineering projects, which including as below:

- Determination for operating policies of reservoir system.
- Determination of the energy and yield to firm.
- Determination of the water inflow to reservoir and estuary.
- Determination of the flood control systems.
- Design a storage basins.
- Design an aquifer reclamation systems.
- Design an aquifer dewatering systems.
- Design of the reservoir capacity and location.
- The parameter identification for an aquifer.
- Determination of the route of water release.

- Replacement and rehabilitation of water distribution component.
- Design for the minimum cost and operation of water distribution system.
- Design for minimum cost of the sewer systems.
- Operation of regional reservoir to determine the water demand.
- Operation of the irrigation systems.
- Operation of the hydropower plants to manage systems.

2.2.3 Modelling development phases

Development phases of the optimization is divided into five major steps:

- The data collection to explain a system.
- The definition and formulation of problems.
- Model development.
- The evaluation and verification of a model.
- The interpretation and application of a model.

The development steps is shown in the figure 2.6. The collection of data may be used a long time. But, the important steps was building the model process. The availability (amount) and accuracy of data can be greatly managed to affect upon the structure and detail of a model, which is ability formulation to evaluate and verify of the model.

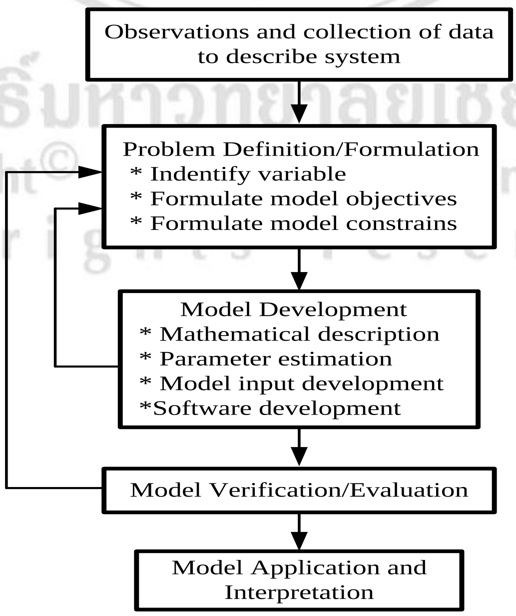

Figure 2.6 Modelling development phases.

The determination and formulation of the problems consist of the phases as: an analysis of decision variables, objective(s) function for determining, and all constraints to effect to model process. The phases operation should be performed follow as below.

- Should be identified the major elements that relate with problem.
- Degree formulation of accuracy that required in a model.
- Potential determination for using a model.
- Evaluation of complexity and structure of a model.
- Formulation number, independent variables, equations for describing the system, and number of unknown parameters.

Model development is included the mathematical explanation, input system, and software development. The development steps is iteratively made in many steps and many cases may be required for returning the definition and formulation steps. The evaluation and verification of process is checked from total model. The testing is required all testing for the individual elements of model, which should be operated out early for making in the model process. In many cases of model building must checks the mathematical relationship, which is described the actual system appropriately.

The analysis should be operated to test the model for inputing parameters. The procedure of evaluation and verification is iteratively processed. Sometime may be required for returning the problems to define and formulate the steps, which follow by development steps of the model that shown in figure. 2.6. The model validation is included the behavior validation, the validation of the model assumptions, and the logic validation.

2.3 Reservoir Operation Management

Presently, energy demand continually increased to consumption. Differently, energy resource is decreased continually. So, hydropower is a good choice for renewable energy in currently. Lao PDR has policies for developing hydropower electric to supply the energy demand. However, constraints of hydropower development initially has several conditions such as: high investment, environmental-society impacts and other conditions. Reservoir management is an important role for optimal electricity production and reservoir management for efficiency and sustainability. Presently, hydropower construction is difficulty, which has several constraints to dam construction. Because, Dam construction depend on many factors such as: land limitation, impacts, investment and policy etc. Therefore, Electricite Du Laos (EDL) will be planed for managing the among hydropower plants to optimum benefit and sustainability in the future.

2.3.1 Reservoir management

Water regulation is to manage reservoirs at downstream and upstream. management target is different of each locations. in this case is to optimize multi-reservoir operation system for optimizing electricity production, which the choice of objective functions is depend on the target and operational period. Multi reservoir operation in same river is an important problem, which has constraints and benefit together of those hydropower plants. long-term operation of among hydropower is to optimum electricity production, to guarantee in energy demand and water demand on dowstream river. The figure 2.7 is described the operational guideline for generally procedure. Reservoir operation consists of many constraints for producing electricity such as: water inflow, water storage, energy and water demand, and others. The better operational management will be helped to optimize development for balancing between electricity production and water resource, to economic benefit and eco-systems protection. [16]

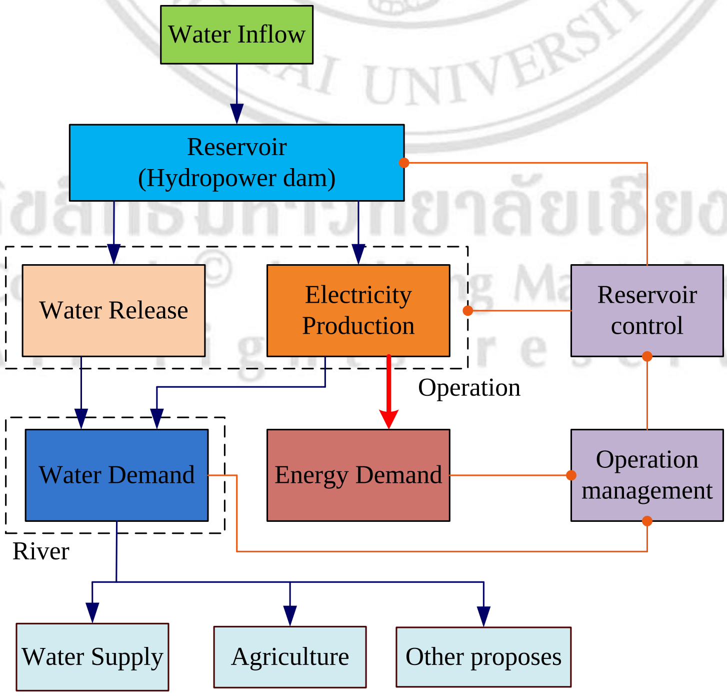

Figure 2.7 Block-diagram of reservoir management planning.

2.3.2 Reservoir operation for electricity production

Problems of power generation is water resource management, which has important role to save an energy or water storage in reservoirs. Maximum water storage is to produce energy in dry season. This paper is studied multi-reservoir management for optimizing electricity production of Namkhan 2 and 3 hydropower plants. The reservoirs operation is analyzed of both reservoirs relationship, which has coordination in water management to appropriate between both reservoirs. The objectives of Namkhan 3 reservoir management divided two objectives as: water released to supply water on downstream area in the dry season and electricity production. The coordination between both hydropower plants to optimum benefit together and to avoid damages that affected to hydropower plants and downstream namkhan areas.

Total energy generation of all hydropower plants will equal to the energy generated summation of all hydropower plants. The electricity production of each hydropower plants is depended on operation periods and size of power installed capacity. annual energy generation of hydroelectric depended on resource (water inflow), reservoir storaged capacity of those hydropower plant. therefore, Total energy generation can be written the formulation as below:

$$\boldsymbol{E} = \begin{bmatrix} (\boldsymbol{P_1}\Delta_{t1} + \boldsymbol{P_1}\Delta_{t2}+\ldots+\boldsymbol{P_1}\Delta_{tn}) + (\boldsymbol{P_2}\Delta_{t1} + \boldsymbol{P_2}\Delta_{t2}+\ldots+\boldsymbol{P_2}\Delta_{tn})+\ldots \\ +(\boldsymbol{P_N}\Delta_{t1} + \boldsymbol{P_N}\Delta_{t2}+\ldots+\boldsymbol{P_N}\Delta_{tn}) \end{bmatrix}$$

Or can be written solution of equation as:

$$\boldsymbol{E} = \boldsymbol{max} \sum_{j=1}^{n} \sum_{i=1}^{N} \boldsymbol{P_{i,j}} \Delta_t \qquad ; \qquad \boldsymbol{n} = \boldsymbol{T}/\Delta_t \qquad (2.6)$$

Where: E The total energy generation,

Δ_t The time step (months),

n The number of time steps during the operational period,

T The length of the operational period (months),

N The number of hydroelectric power plants, and

$P_{i,j}$ The main output of the (i) hydropower plant during the (j) time step,

The water storaged equations equal to water flow-in summation minus water flow-out summation. The water balance equations of water storaged in the first time equal to water storaged in the end time, which not changed of reservoir level. The water flow-in is water inflow to reservoir in operation preiods. The water flow-out consists water discharged turbine, water released to control the reservoirs level. The water balanch equation can be written as below.

Water balance equation:

$$V_{i,j+1} = V_{i,j} + \left(Q'_{i,j} - Q_{i,j} - Sp_{i,j}\right) \Delta_t \tag{2.7}$$

Where: $V_{i,j+1}$ Water storaged end time while electricity production,

$V_{i,j}$ The initial storage volume of (i) reservoir during (j) time step,

$Q'_{i,j}$ The inflow of (i) reservoir during (j) time step,

$Q_{i,j}$ The discharge turbine of (i) reservoir during the (j) time step,

$Sp_{i,j}$ The discharge from spillways of (i) reservoir during (j) time step, and

Δ_t The time step (months),

The electricity production of each hydropower plants were different, which cause from the features and conditions difference. Generally, the electricity production will have efficiency of power generation during 80%-100% of power installed capacity. Furthermore, the electricity production is considered from the optimal area that related between the power output and rate head of the turbine efficiency. This efficiency was explained in figure 2.8 for showing the optimal area of power generation system.

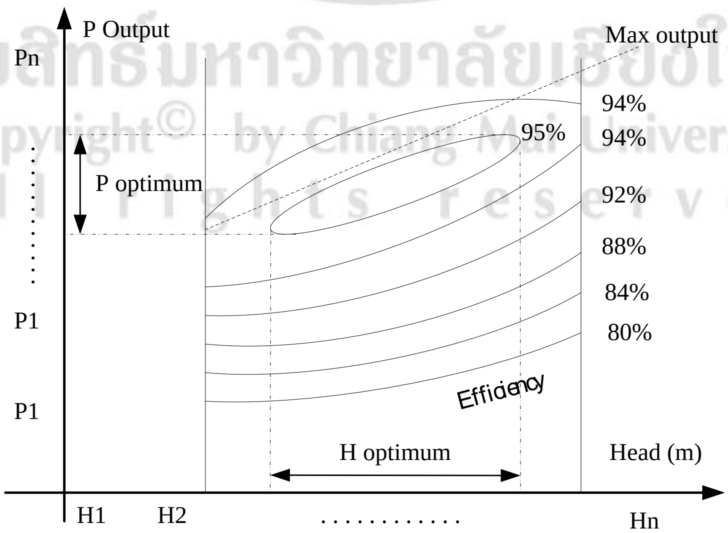

Figure 2.8 Expected hill diagraim of prototype turbine.

Hydraulic turbine is an important piece of the equipment, which transforms energy from water energy into the mechanical energy to rotate the hydroelectric generator.

$$P_G = \eta \rho g Q H \qquad (2.8)$$

where P_G is hydropower installation (W), ρ is water density (kg/m^3), g is gravitational acceleration (m/s^2), Q is water volumetric flow rate (m^3/s), H is gross head (m) and η *is* power plant efficiency.

Power plant efficiency is the ratio between the electrical power output of generator and input power from turbine of hydraulic power. Power output was measured at the generator terminals, which measure horse-power or kilowatts.

2.3.3 Reservoir operation management to water balance.

The basic computational outline of IPSO algorithm is based for the long-term operation of the multi-reservoir system. The reservoir storage volume is importance variable for designing operation of Namkhan 2 and 3 hydropower plants. The schematic representation of Namkhan 2 and 3 reservoirs is shown in the figure 2.9. it consists four hydropower plants in figure but this study case specially considered the Namkhan 2 and 3 hydropower plants only. Because, Namkhan 1 and NamMing hydropower projects not construct yet, which just planed for power development in the future.

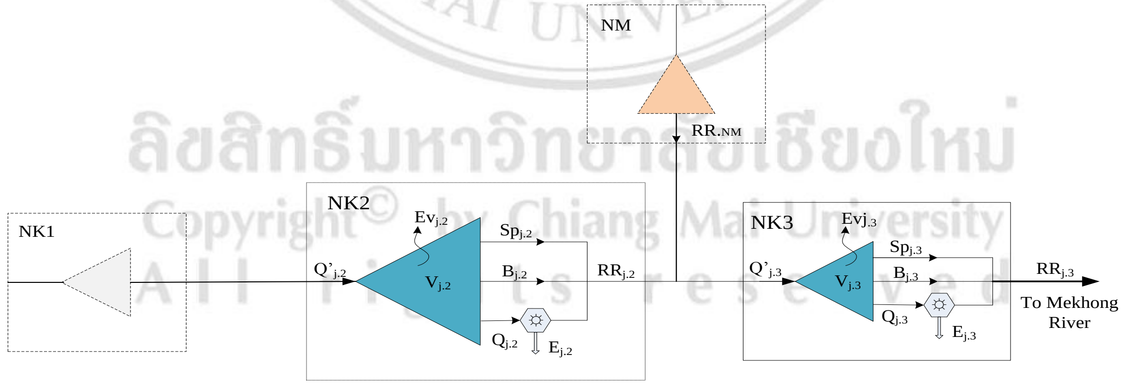

Figure 2.9 Schematic representations of Namkhan 2 and 3 reservoirs.

According to the above figure 2.9, equations can be wirtten the reservoir operation as flowing:

a) The Namkhan 2 hydropower plant has built at upstream of the Namkhan 3 hydropower plant. Water storaged depend on water inflow and water outflow (electricity production). The reservoir storaged volume in the end time equal to the water storaged volume in the first time plus the water inflow. Then, deletes the water outflow summation such as: water discharge turbine, water released through spillway, water released through bottom tunnel and evaporation net. The water storaged volume is unchanged, if water inflow equal to water released.

Water storage equation can be written as below:

$$St_{j.2} = V_{j.2} + Q'_{j.2} - \left(Q_{j.2} + Sp_{j.2} + B_{j.2}\right) - Ev_{j.2} \tag{2.9}$$

Where: $St_{j.2}$ The reservoir storage during the (j) time step of Namkhan 2 hydropower plants,

$V_{j.2}$ The water storage in reservoir,

$Q'_{j.2}$ The water inflow during (j) time step,

$Q_{j.2}$ The water released for power generation during (j) time,

$Sp_{j.2}$ The Spillway discharge during (j) time,

$B_{j.2}$ The Button tunnel release during (j) time, and

$Ev_{j.2}$ The evaporation during (j) time,

b) The Namkhan 3 hydropower plant has built at downstream of the Namkhan 2 hydropower plant. Water storage in reservoir depend on water inflow and all water outflow (electricity production). The water storaged volume in the end time equal to water storaged volume in the first time plus the water inflow. Then, deletes the water outflow summation, which include as: water discharge turbine, water released through spillway, water released through bottom tunnel and evaporation net. If water inflow and water release is balance as well as water storage volume is unchanged.

Which can be written equation as below:

$$St_{j.3} = V_{j.3} + Q'_{j.3} - \left(Q_{j.3} + Sp_{j.3} + B_{j.3}\right) - Ev_{j.3} \tag{2.10}$$

Where $St_{j.3}$ is reservoir storage during the (j) time step of Namkhan 3 hydropower plants, $V_{j.3}$ is water storage in reservoir, $Q'_{j.3}$ is water inflow during (j) time step, $Q_{j.3}$ is water released for power generation during (j) time, $Sp_{j.3}$ is spillway discharge during

(j) time, $B_{j.3}$ is button tunnel release during (j) time, and $Ev_{j.3}$ is evaporation during (j) time (water loss).

Furthermore, if considering from total water storage of Namkhan 2 and 3 reservoirs, regulation storage capacity of Namkhan 3 hydropower plant is total water storage of both reservoirs. So that, the water volume for the electricity production of Namkham 3 HPP will equal to water storage summation of both reservoirs. Regulation storage capacity of Namkhan 2 reservoir is 229 million cubic meters, which is elevation during 465-475 masl of operational water level. Regulation storage capacity of Namkhan 3 reservoir is 48 million cubic meters, which is elevation during 343-348 masl of operational water level. Conclusion, total water volumes 277 million cubic meters can be used for producing electricd of Namkhan 3 hydropower plant.

Therefore, water storage volume of Namkhan 3 hydropower plant can be written equation total water usage as below.

$$\mathrm{St}_3 = \mathrm{V}_{\mathrm{ST2}(465-475)} + \mathrm{V}_{\mathrm{ST3}(343-348)} \tag{2.11}$$

Where: $\mathrm{St}_{\mathbf{3}}$ The total water storage volume for the water regulation of Namkhan 3 hydropower plants,

$\mathrm{V}_{\mathrm{ST2}}$ The water storage in reservoir for the water regulation (elevation 465-475 masl) of Namkhan 2 HPP, and

$\mathrm{V}_{\mathrm{ST3}}$ The water storage in reservoir for the water regulation (elevation 343-348 masl) of Namkhan 3 HPP,

The $\mathrm{RR}_{\mathrm{NM}}$ is the water liberty released during j time Namming hydro power project. The $\mathrm{RR}_{\mathrm{j2}}$ and $\mathrm{RR}_{\mathrm{j3}}$ are the water liberty release during j time of Namkhan 2 power plant, Namkhan 3 hydropower plant, respectively.

The (V_{j}) water volume change in reservoir depend on water release and water inflow. If water inflow more than water released, water storage volumes in reservoir will be increased, which can be written formula as below.

$$\mathrm{Q}'_{\mathrm{j.2}} > \mathrm{RR}_{\mathrm{j.2}}; \quad \mathrm{Q}'_{\mathrm{j.3}} > \mathrm{RR}_{\mathrm{j.3}} \tag{2.12}$$

Water storage volume in end time is more than the water storage volume in first time and water level will be increased, which can be written equations as.

$$V_{j.2}(t_2) > V_{j.2}(t_1) \quad ; \quad V_{j.3}(t_2) > V_{j.3}(t_1) \tag{2.13}$$

$$HWL_{F.2} < HWL_{E.2}\ ; \quad HWL_{F.3} < HWL_{E.3} \tag{2.14}$$

If the water inflow less than the water released, the water storage volume in reservoir is changed. Water storage volume in reservoir is decreased, which can be written formula as:

$$Q'_{j.2} < RR_{j.2}; \quad Q'_{j.3} < RR_{j.3} \tag{2.15}$$

So, water storage volume in second time is less than the water storage volume in first time, which cause the water volume and level drops:

$$V_{j.2}(t_1) > V_{j.2}(t_2) \quad ; \quad V_{j.3}(t_1) > V_{j.3}(t_2) \tag{2.16}$$

$$HWL_{F.2} > HWL_{E.2} \ ; \quad HWL_{F.3} > HWL_{E.3} \tag{2.17}$$

If the water inflow equal to the water released, the water storage volume in reservoir is not changed, which can be written formula below as:

$$Q'_{j.2} = RR_{j.2}; \quad Q'_{j.3} = RR_{j.3} \tag{2.18}$$

So, water storage volume in second time is equal to the water storage volume in first time, which cause the water volume and level is unchanged:

$$V_{j.2}(t_1) = V_{j.2}(t_2) \quad ; \quad V_{j.3}(t_1) = V_{j.3}(t_2) \tag{2.19}$$

$$HWL_{F.2} = HWL_{E.2} \quad ; \quad HWL_{F.3} = HWL_{E.3} \tag{2.20}$$

Where: HWL_F The head water level first time, and

HWL_E The head water level end time,

2.4 Reservoir Operation for Water Supply and Flood Control

2.4.1 Reservoir operation modelling

Multi-reservoir operational management can be performed by many models in reservoir operation systems for multiple objectives. Flood control is one of important objective of reservoir management. Many dams have constructed on the same river and operation policies were established to operate those reservoirs. However, these reservoirs cannot be controlled because those hydropower plants is not owned same. They have produced to be operated for their benefits. This is a reason that affects to reservoir operation, which cannot control the water released on rainy season. these problem affect risks to flood on along river the floodplains of downstream river.Control and operation of reservoir is dependent on the several factors. These factors are conditions and constraints of reservoir operation. operation management have a lot of methods, which depend on each cases. The better method should be appropriated with actually works of each locations.

This case studies especially the Namkhan 2 and 3 hydropower plants, which is series dams in same river. The objective of method is divided into two purpose as: flood control and water supply. The flood control is used for supporting in rainy season of wet year. The water supply is used for supplying water on dry season of sry year. The appropriately methodology can be helped for planning the effectively reservoirs operation. Furthermore, it can be protected risk from the flood and water shortage of downstream area river.

Multi-reservoir system has several conditions that affects to major flood conditions. Due, changed of water level is related with gate operation of water released, tributary flows, hurricane surge flows, and tidal conditions. This phenomenon cannot explain by hydrologic routing method but phenomenon must be explained by hydraulic routing method to the more accurate, which is based upon the definition and solution of problems. Best of the reservoir operation should be having a plan, managing method for supporting the operating systems.

The data is collected from actual data, which come from the statistic to present data. For, historical data analysis is considered from the data collection to predict and plan for reservoir management. The overall model structure is shown in figure 2.10 for explaining the real time flood management system. This figure is divided into two modules as: data management module and real time flood control module. [15]

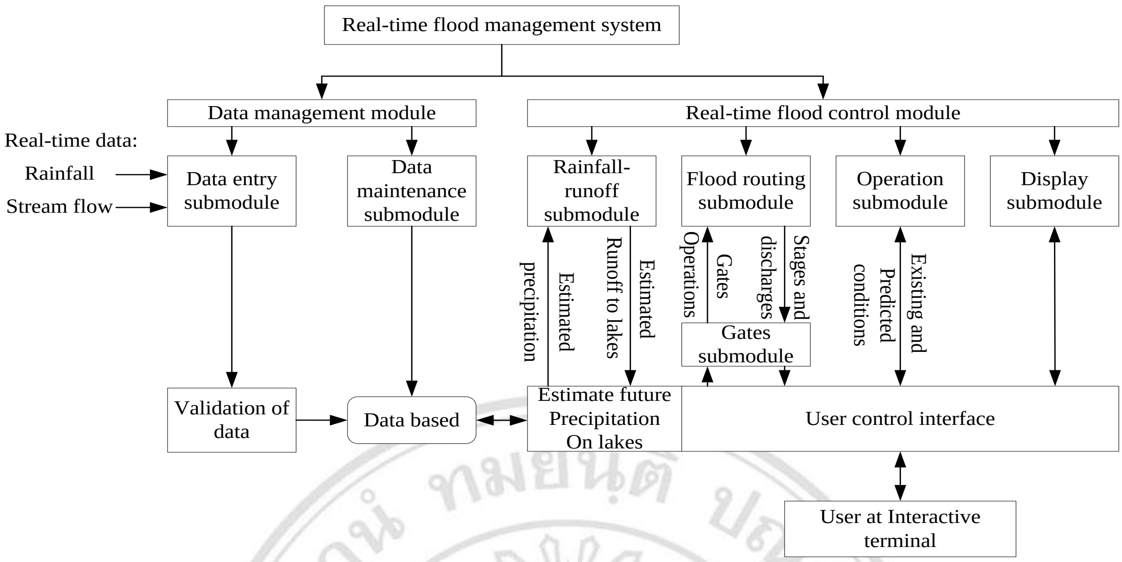

Figure 2.10 Overall structure of real-time flood management model

The data addition for forecasting is included the real-time data and the physical data of reservoir system, weather, and statistic rainfall of each zone. The physical data consists of: data describing stream the cross section and roughness relationships, characteristics of spillway gate and among tunnel that relation with reservoir, floodplain area at downstream and hydrologic parameter evaluation for rainfall-runoff. The real-time data consists of: streamflow data is included water control and uncontrolled at each dam, rainfall, subsystem data of reservoir that will be considered in the routing, and the reservoir operation.

2.4.2 Controlling and operating management of flood case

Reservoir management has important role for operating hydropower plants to protect the impact from flood in the downstream area. So, operators should know the all conditions or constraints of each dam such as: water storage capacity of reservoir, water release capacity on downstream river, technical data that relation with reservoir operation of hydropower plants. Therefore, any operation should be had the operational plan to appropriate for the each hydropower plants. The operation process of wet year case is shown in figure 2.11 for reservoir operational management. operation process is described detail as follow: Frist, operators should be checks reservoir elevation crisis that has or not, during rainy season or not. operators must be analyzed for increasing or decreasing of water level, rainfall on each months. Second, if reservoir elevation is crisis level should be opened gates to release water, which can release through spillway or bottom tunnel of each dam.

Furthermore, operation agency should be checked impacts in downstream area that impacted or not. If it has impacted, operation agency must adjust the water released to appropriate with actually. Specially, if water released but elevation continuously increased in reservoir, which should be released water to out from reservoir to control water level. However, water level control in reservoirs was most important to safety of dam body. Before, many water released should be warning to peoples whom living in downstream area. Public relations to peoples for understood and knowledge about river elevation on downstream area. Operation agency must defines the river level while open spillway gates, which aims to avoid impacts from flood, when there is many water released out.

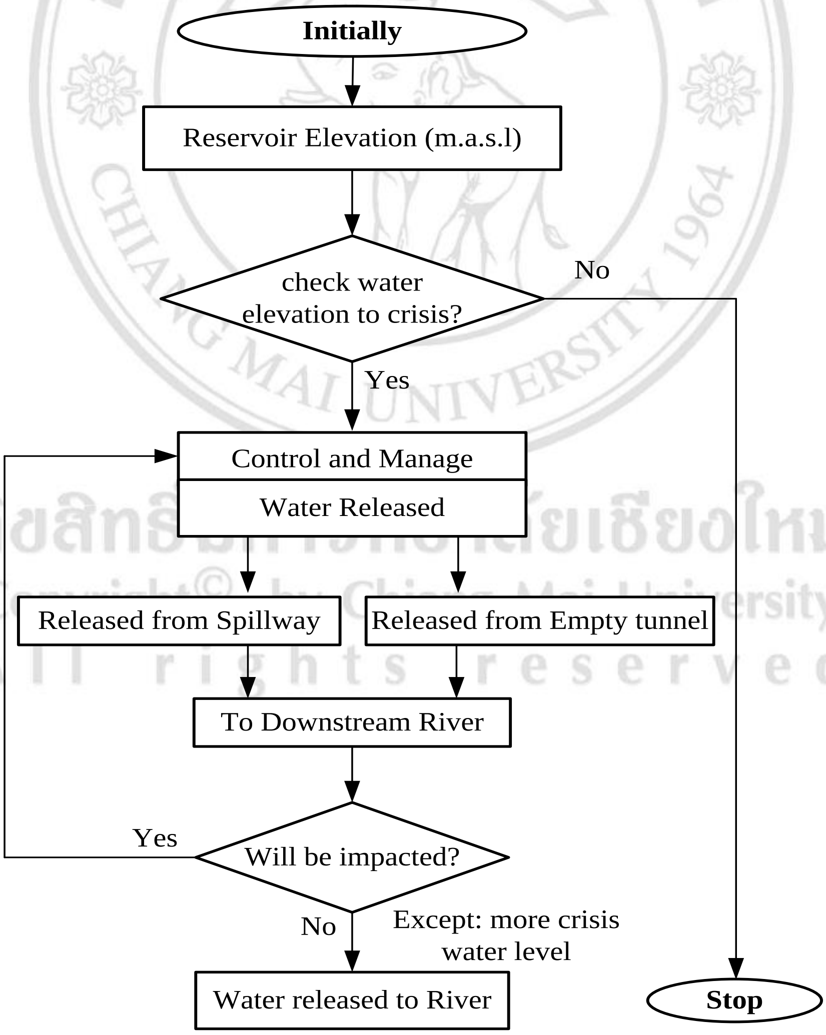

Figure 2.11 Controlling and operating management of flood case.

2.4.3 Control and operation management of water shortage case

Reservoir management in dry year case is an important case to several aspects, which is a water released section to meet the water demand in downstream area. Downstream area of Namkhan 2 and 3 hydropower plants have a lot of peoples, that lives along Namkhan river. Downstream area incluldes Xiengnguen and Luangprabang districts, Luangprabang province. Namkhan river is main river for using in agriculture, water supply and others of both dictricts. In dry year, it affects to produce electricity and water released because catchment area of Namkhan 3 hydropower plant is 92.5% of total 7620 square kilometer. This research has the operation process for drought case, which shown in figure 2.12 for describing the operational produres as follow.

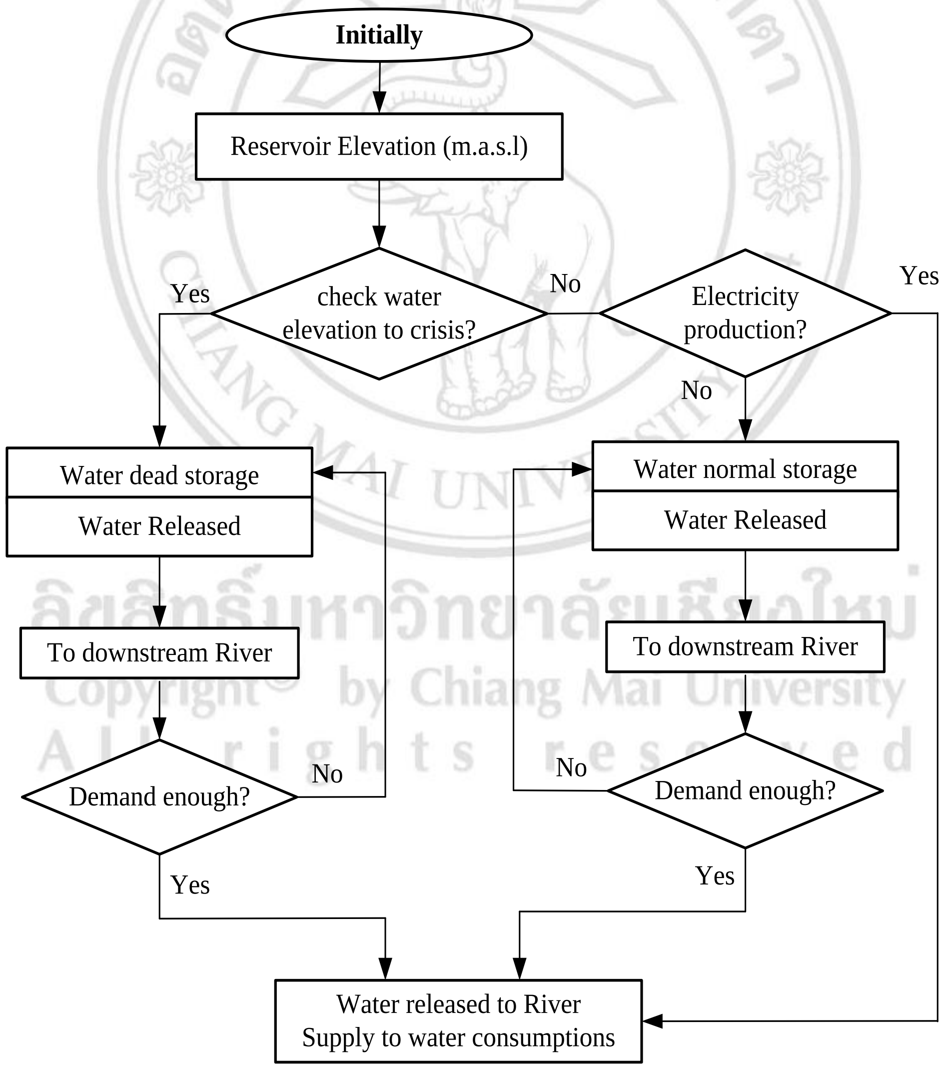

Figure 2.12 Control and operation management of water shortage case.

The above methodology explained the detail as: initially, operation agency should be checked the water storage in reservoir, that water elevation has crisis or not. If water storage in reservoir is not crisis but don't have electricity production. Operation agency shoud be studied to release water to protect environmental and to meet the water demand of peoples in downstream area. Furthermore, if water volume in reservoir is crisis level. Operators should be analyzed the dead storage to release water for solving the drought in downstream area. Water released should be released appropriately in actually conformity operation. Finally, reservoir management should be awareness and concerns in the several aspect to optimum benefit and appropriately operation.

2.5 Optimization Models for Operation Development

Operational development is one of sections for reservoir management to optimize the operation models, which can be helped to determine for planning the flood control and water shortage operation of reservoir system. The objective model is to plan and determine for operating policy (water release), which decrease the flood damage and water shortage at downstream river. Optimization model of operation development is one of among models for improving operation model. The development model is shown in figure 2.13 for improving the operation model to appropriate with actually works.

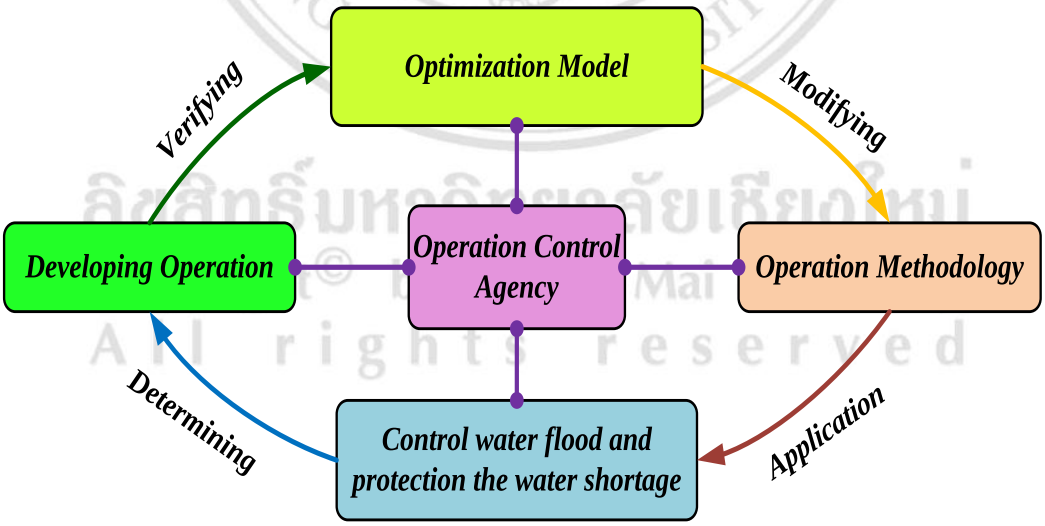

Figure 2.13 Optimization model for operation development.

The development should be considered from several parameters that relates with reservoir systems such as: water inflow, reservoir capacity, water outflow, and others. These data can be helped to analyze for finding the maximum flow (Wet year) or minimum flow (Dry year) and among problems of reservoir operation in each cases. Then, these constraints will be summarized to create the operation model for protecting and supporting those problems. In addition, operation model must depend on conditions or constraints in raw system such as: government policy, agency benefit, damage, and so on. In Figure 2.13 was shown the development cycles of the each section that relates together. The model can change and improve to meet the all conditions in conformity actually.

The target of reservoir management is to maximize benefit and minimize damage from reservoir operation. Figure 2.14 and 2.15 is shown operation curve for Namkhan 2 and 3 hydropower plants, respectively. Operation curve or switching curve is one of tools that can help to optimizing electricity production and multi-reservoir operational management. water level of operation curve consistes three levels as: crisis level, wary level and conservation level. For crisis level is divided two levels as: flood crisis level and drought crisis level.

The flood control level is water released level to control reservoir level, which control from water released through the spillway and bottom tunnel. The inactive level is a dead line or dead storage level of reservoir, which is water level that cannot electricity production. But this level can release water thought spillway or bottom tunnel. The wary level was divided two levels as: wary level before flood control level and wary level before inactive level, which should be followed the optimal model and specially attend for reservoir management in this level.

The operation level is reservoir conservation or operation management level that can produce electricity and reservoir management. The switching curve for reservoir management is guideline cuvre for reservoir appropriately operation of each hydropower plants. Due each hydropower plant have different constraints. Therefore, constraints affects the operation curve of each hydropower that get the switching curve differently. The operation curve is not best guideline curve but it can help operator's decision for planning and operating in actually works of among hydropower plants.

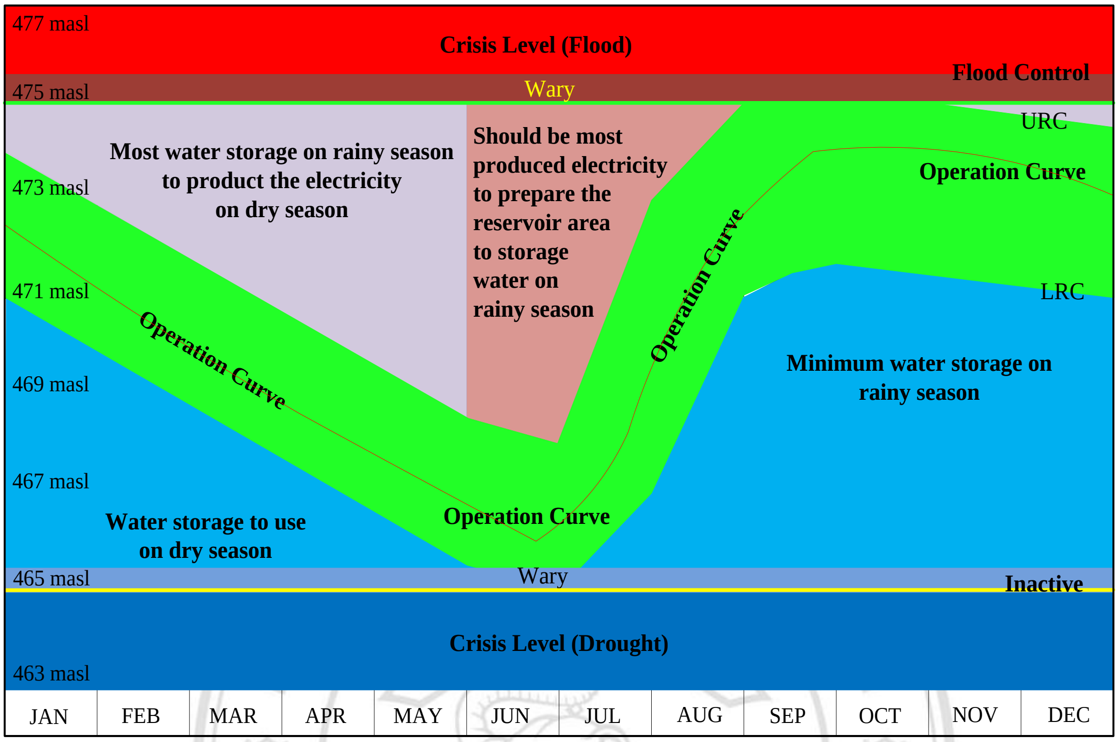

Figure 2.14 Namkhan 2 HPP’s switching curve for reservoir management.

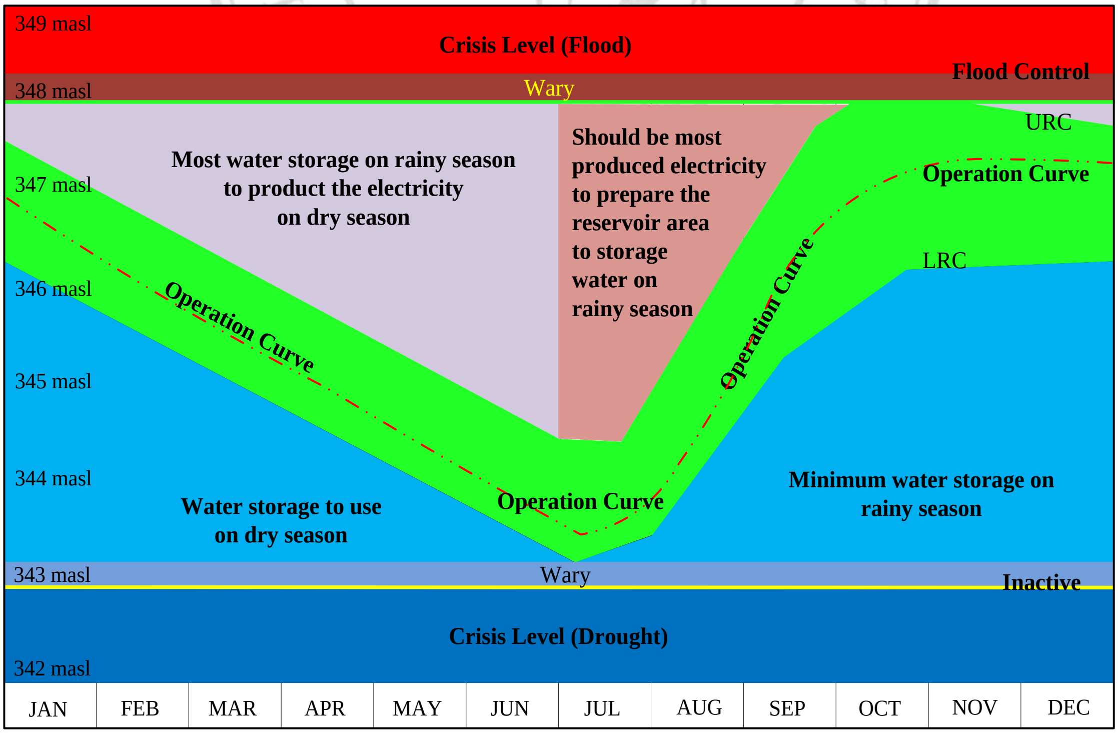

Figure 2.15 Namkhan 3 HPP’s switching curve for reservoir operation management.