Chapter 3

Data and Program Calibration

In this work, the present historical data and calibration model method of Nam Ngum-1 hydropower plant are selected. The Nam Ngum-1 hydropower plant's historical data consist of the data of two types such as: hydrological data and physical data. The hydrological data are time series data collection for input to model such as: water inflow, water outflow, head water level and energy production. These data are separated into three cases as: wet case, drought case and normal case, the main data by using data collection from 2003 to 2012, all data are converted from excel files to dss files by using HEC-DSSVeu2.0 software to support with the model. The physical data are parameter data such as: relationship elevation-storage-area data, evaporation data, turbine discharge data, tail water data and spillway discharge data. These data are very important and required to develop for reservoir management of hydropower plant. In addition, this study presents the calibrate model method. There are two steps, as first step is water data calibration model and second step is the power data calibration model. All are demonstrated below.

3.1 Nam Ngum-1 hydropower plant general data

Nam Ngum river is one of the major rivers in the Lao People's Democratic Republic, and offers a hydropower potential to 1,600 MW from various possible sites. The Nam Ngum-1 hydropower plant is located at Sengsawang village, Keo Ou Dom district, Vientiane province, about 90 km to the north of Vientiane Capital. The project has an installed capacity of 150 MW. In the years 2003-2004, the Rehabilitation project of Unit No.1 and No.2 was implemented and increased from 15 MW to 17.5 MW each. At present, the Nam Ngum-1 hydropower plant has an installed capacity of 155 MW. Nam Ngum-1 hydropower plant has average energy production of 1,025 Gwh per year, it is the main source for energizing energy for domestic consumption and export energy to Thailand and also Nam Ngum-1 hydropower plant is very important to manage water for demand and other activities of downstream. The annual energy production, water inflow and outflow data are shown in the Table 3.1[2].

Table 3.1 Energy generation data of Nam Ngum-1 HPP from 2003 - 2012

Year	Production (kWh)	Water outflow (cubic meters)	Water inflow (cubic meters)
2003	919,852,300	9,728,084,196	9,194,676,876
2004	1,046,389,400	11,144,463,264	12,497,560,901
2005	1,127,283,800	11,728,612,728	14,342,973,710
2006	1,013,778,100	10,770,826,896	10,710,446,813
2007	852,942,700	9,217,630,764	9,075,568,314
2008	1,145,778,900	11,294,054,784	14,239,805,215
2009	1,009,485,600	10,119,091,572	9,731,572,972
2010	833,004,400	8,630,931,660	7,774,698,909
2011	1,160,659,800	12,147,113,925	15,002,756,394
2012	1,073,988,450	10,501,486,992	10,391,111,624
Average	**1,018,316,345**	**10,528,229,678**	**11,296,117,173**

3.2 Hydrological data of Nam Ngum-1 hydropower plant

Nam Ngum-1 hydropower plant's historical data consist of water inflow, water release, net evaporation, head water level, tail water level and energy production. These data are required to develop or manage for reservoir and hydropower plant. There are three cases as: wet case, drought case and normal case which the water inflow of Nam Ngum-1 reservoir are main data by using data from 2003 to 2012 due to these data's reliability. The analyzing methods of three cases have following items:

- If the water inflow is less than 9,730 MCM , this case is called drought year case (e.g., in years : 2003, 2007 and 2010).
- If the water inflow is from 9,730 to 10,800 MCM, this case is called normal year case (e.g., in years : 2006, 2009 and 2012).
- If the water inflow is more than 10,800 MCM, this case is called wet year case (e.g., in years: 2004, 2005, 2008 and 2011).

Therefore, the detail data are below:

Average the water inflow data from 2003 to 2012 and separate into three cases such as data of 2003, 2007 and 2010, this case is called drought year case; data of 2006 , 2009 and 2012, this case is called normal year case; data of 2004, 2005, 2008 and 2011, this case is called wet year case, the detailed data are below in the Figure 3.1 and Appendix D.

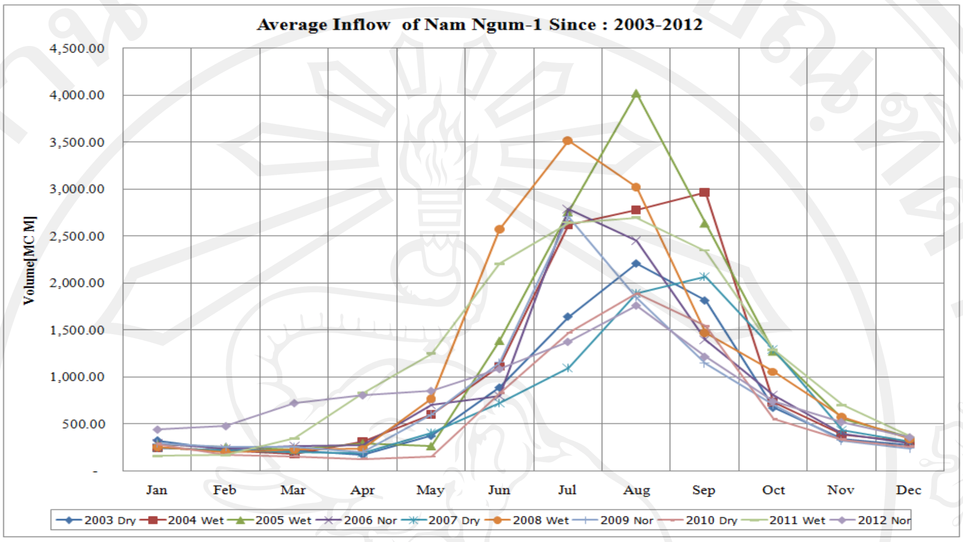

Figure 3.1 Average inflow of Nam Ngum-1 reservoir

Average the water turbine flow data from 2003 to 2012 and separate into three cases such as data of 2003, 2007 and 2010, this case is called drought year case; data of 2006, 2009 and 2012, this case is called normal year case; data of 2004, 2005, 2008 and 2011, this case is called wet year case, the detailed data are below in the Figure 3.2 and Appendix D.

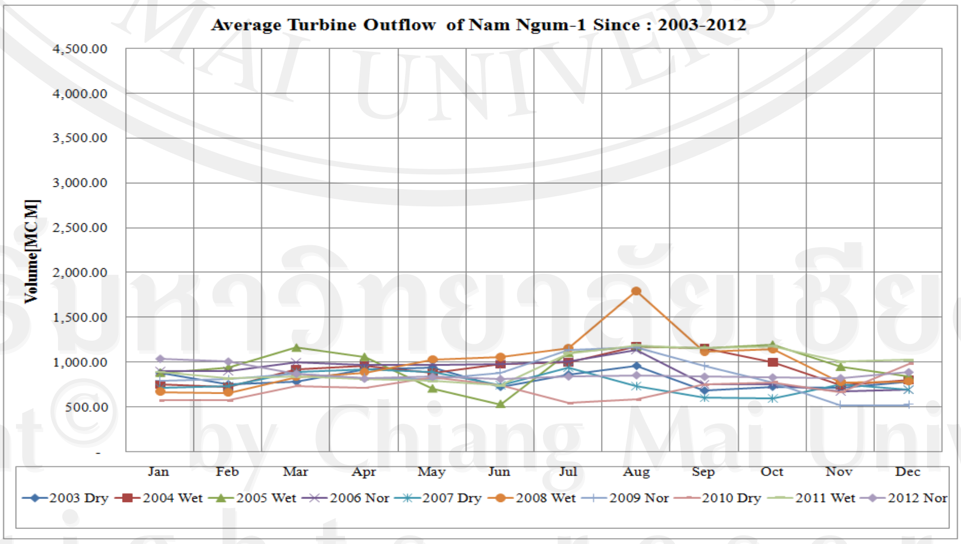

Figure 3.2 Average turbine release of Nam Ngum-1 reservoir

Average the spillway discharge data from 2003 to 2012 and separate into four years such as, data of 2004, 2005, 2008 and 2011, these years is called spillway discharge, the detailed data are below in the Figure 3.3 and Appendix D.

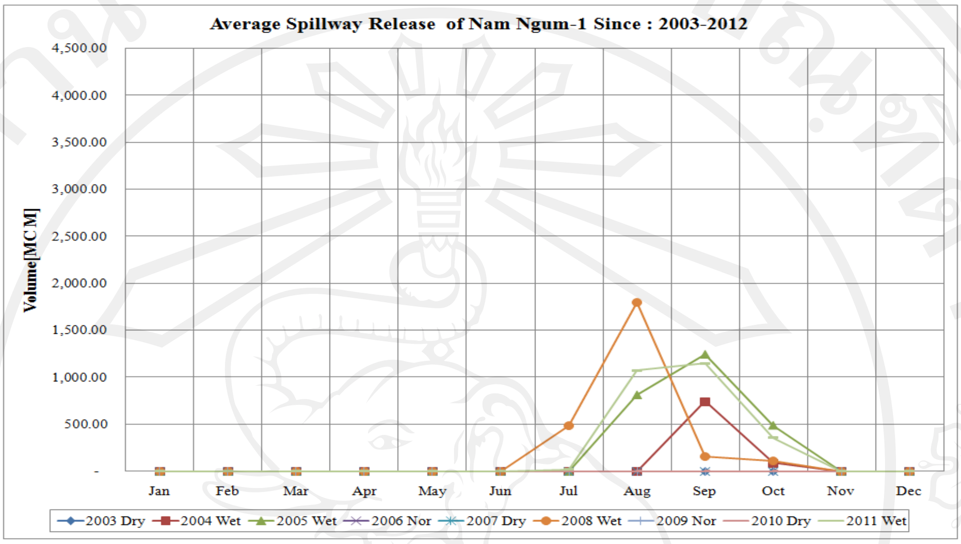

Figure 3.3 Average spill release of Nam Ngum-1 reservoir

Average the energy data from 2003 to 2012 and separate into three cases such as data of 2003, 2007 and 2010, this case is called drought year case; data of 2006, 2009 and 2012 this case is called normal year case; data of 2004, 2005,2008 and 2011, this case is called wet year cases, the detailed data are below in the Figure 3.4 and Appendix D.

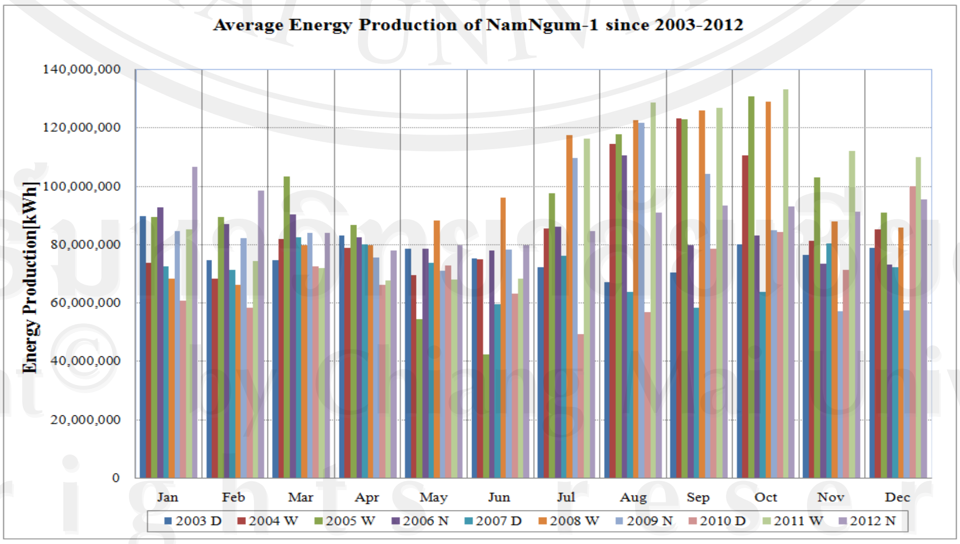

Figure 3.4 Average energy production of Nam Ngum-1 reservoir

Average the head water level data from 2003 to 2012 and separate into three cases such as data of 2003, 2007 and 2010, this case is called drought year cases; data of 2006, 2009 and 2012, this case is called normal year case and data of 2004, 2005, 2008 and 2011, this case is called wet year case, the detailed data are below in the Figure 3.5 and Appendix D.

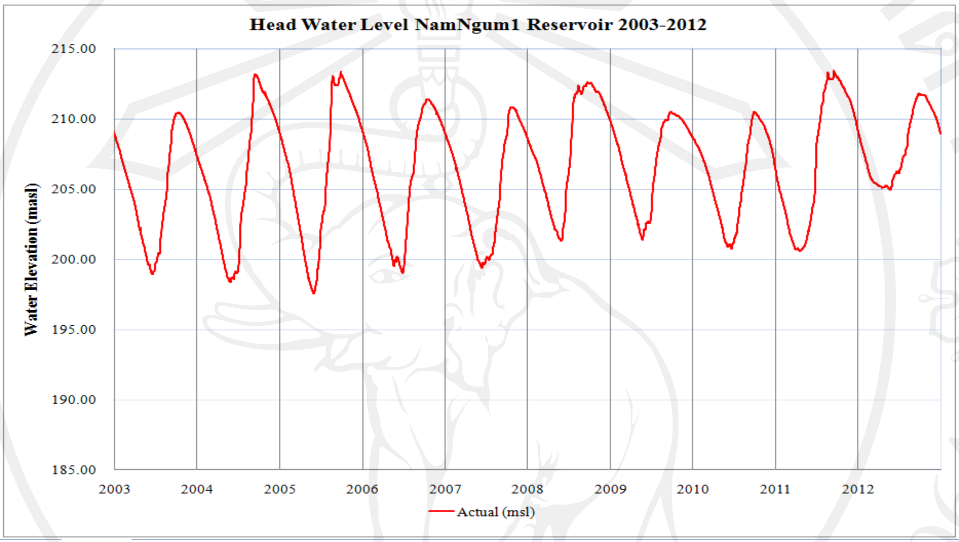

Figure 3.5 Average head water level of Nam Ngum-1 reservoir

3.3 Physical data of Nam Ngum-1 hydropower plant

The general data requirements for this model included the physical and operational characteristics of Nam Ngum-1 and hydropower reservoir. The physical reservoir data are described through the use of the elevation, storage, area curves, evaporation loss from the reservoir and the type and capacity of each outlet. The operational data includes the zone or pool level definitions along with the rules governing the operations in each zone. Nam Ngum-1 hydropower plant reservoir has three major water management zones or pools. These are the inactive zone, the conservation zone and the flood control zone. The inactive pool is often referred to as dead storage since this is the water that is below the elevation of the lowest outlet in the dam. The conservation zone holds water that is set aside for environmental release and hydropower production. The flood control zone is the storage that is set aside for the capture of inflow from precipitation events to manage potential downstream flooding. In addition to the above zones, five pool levels are fixed at 215.0 m.a.s.l (inactive level), 196. m.a.s.l (minimum operating level), 209.0 m.a.s.l (conservation level), 212.30 m.a.s.l (flood control level) and 214.0 m.a.s.l (maximum flood level) to serve as a base line data for reservoir operation of this study. The relationship between elevations, storage and area data are shown in Table 3.2 and Figure 3.6

Table 3.2 Elevation- storage-area data for Nam Ngum-1 hydropower reservoir

Elevation (m.a.s.l)	**Storage** **(m^3)**	**Area** **(ha)**
164.00	0	0
170.00	180,000,000	600
180.00	268,000,000	4,400
190.00	1,198,000,000	14,200
195.00	2,100,000,000	20,750
196.00	2,296,000,000	21,900
197.00	2,501,000,000	23,150
198.00	2,724,000,000	24,900
199.00	2,967,000,000	25,500
200.00	3,193,000,000	26,500
201.00	3,428,000,000	27,450
202.00	3,754,000,000	28,250
203.00	4,079,000,000	29,150
204.00	4,405,000,000	30,000
205.00	4,730,000,000	30,850
206.00	5,057,000,000	31,750
207.00	5,382,000,000	32,600
208.00	5,708,000,000	33,500
209.00	6,033,000,000	34,350
210.00	6,359,000,000	35,200
211.00	6,685,000,000	36,050
212.00	7,010,000,000	36,950
213.00	7,336,000,000	37,800
214.00	7,661,000,000	38,650
215.00	7,987,000,000	39,550
216.00	8,500,000,000	43,900

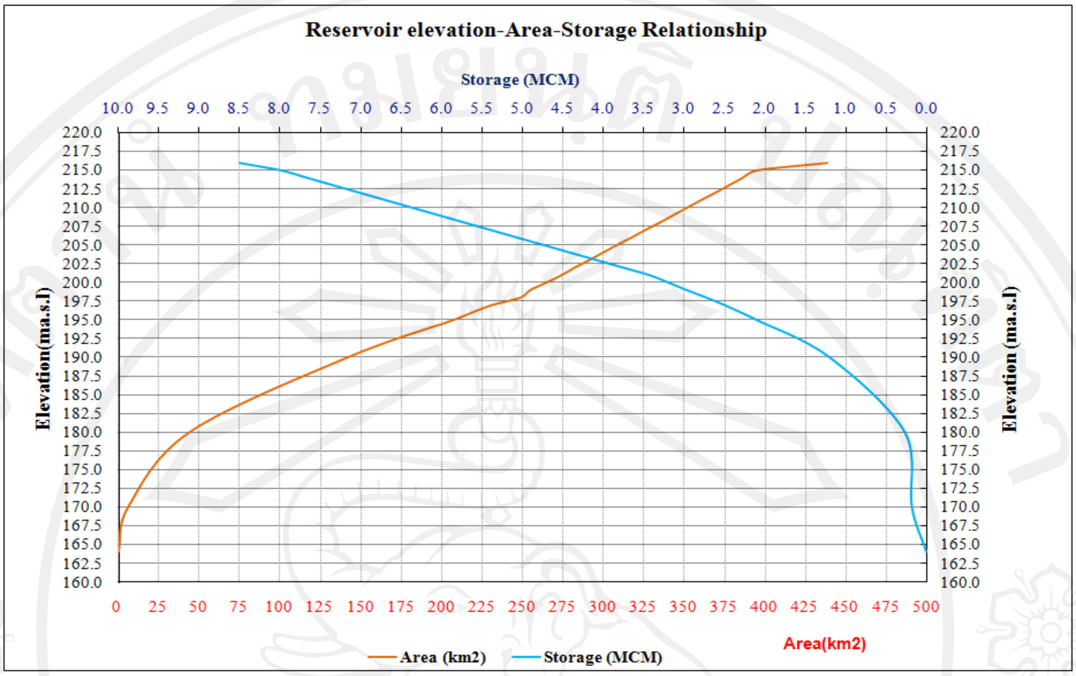

Figure 3.6 Elevation- storage-area data for Nam Ngum-1 hydropower reservoir

3.3.1 Reservoir evaporation loss

The loss of water by evaporation from the reservoir must be considered. Mean monthly evaporation data for the reservoir were obtained from feasibility study of Nam Ngum2 hydropower document and are shown in Table 3.3 [20].

Table 3.3 Mean monthly evaporation data of Nam Ngum 2 reservoir(Unit : mm)

Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
127	128	161	164	145	127	123	117	116	136	135	129	1,608

3.3.2 Turbine discharge data of Nam Ngum-1 hydropower plant

The turbine discharge and water elevation data curves from designed hydropower plant. They are used for input to model. Data are shown in Table 3.4

Table 3.4 Turbine discharge data for Nam Ngum-1 hydropower reservoir

Elevation	Turbine discharge				
	Unit1	Unit2	Unit3	Unit4	Unit5
(m.a.s.l)	(cms)	(cms)	(cms)	(cms)	(cms)
198.00	46.29	46.29	101.24	101.24	101.24
198.50	47.01	47.01	101.80	101.80	101.80
199.00	48.07	48.07	103.07	103.07	103.07
199.50	47.67	47.67	102.15	102.15	102.15
200.20	48.39	48.39	107.29	107.29	107.29
200.60	48.14	48.14	107.71	107.71	107.71
201.00	48.58	48.58	108.80	108.80	108.80
201.60	49.06	49.06	109.54	109.54	109.54
202.00	49.15	49.15	110.58	110.58	110.58
202.40	49.56	49.56	111.59	111.59	111.59
203.00	49.68	49.68	111.93	111.93	111.93
203.40	50.07	50.07	112.58	112.58	112.58
204.00	49.86	49.86	113.53	113.53	113.53
204.60	50.59	50.59	115.99	115.99	115.99
205.00	50.04	50.04	114.73	114.73	114.73
205.60	51.35	51.35	115.00	115.00	115.00
206.00	51.70	51.70	115.87	115.87	115.87
206.70	51.35	51.35	116.69	116.69	116.69
207.20	51.27	51.27	117.80	117.80	117.80
207.40	52.15	52.15	118.63	118.63	118.63
208.80	50.64	50.64	115.67	115.67	115.67
209.00	51.49	51.49	118.96	118.96	118.96
209.60	51.29	51.29	121.04	121.04	121.04
209.80	51.05	51.05	121.00	121.00	121.00
211.60	49.98	49.98	117.82	117.82	117.82
212.40	49.33	49.33	119.26	119.26	119.26
212.80	49.14	49.14	118.45	118.45	118.45
213.00	50.18	50.18	119.17	119.17	119.17

3.3.3 Tail water data of Nam Ngum-1 hydropower plant

The tail water discharge and water elevation data curves from designed hydropower plant. They are used for input to model. Data are shown in Table 3.5

Table 3.5 Tail water discharge data for Nam Ngum-1 hydropower reservoir

Elevation (m.a.s.l)	Tail water Discharge (cms)
164.00	0
168.00	500.00
170.00	1,000.00
171.00	1,500.00
173.00	2,000.00
174.00	2,500.00
175.00	2,800.00
176.00	3,200.00

3.3.4 Spillway discharge data of Nam Ngum-1 hydropower plant

The spillway discharge and water elevation data curves from designed hydropower plant. They are used for input to model. Data are shown in Table 3.6

Table 3.6 Spillway discharge data for Nam Ngum-1 hydropower reservoir

Elevation (m.a.s.l)	Spillway discharge (cms)
212.30	0
213.30	405.24
214.30	788.39
215.30	1,148.50
216.30	1,484.49
217.30	1,795.16
218.30	2,079.11
219.30	2,334.74
220.30	2,560.21

3.4 HEC-DSSVue2.0 software

The Hydrologic Engineering Center's Data Storage System Visual Utility Engine (HEC-DSSVue2.0) is graphical user interface program for viewing, editing, and manipulating data in the HEC Data Storage System (HEC-DSS) database files. With HEC-DSSVue2.0, data can be plotted, tabulated and edited, as well as manipulate data with over fifty mathematical functions. Along with these functions, into a database, rename dataset names, copy data sets to other HEC-DSS files, and delete datasets. Typically, datasets will be selected from a stored / filtered list of names in a HEC-DSSVue2.0, also incorporate the standard scripting language that allow to specify a routine sequence of steps in a text format and then execute the sequence from a user defined button or a "batch" process. The main screen's software is shown in Figure 3.7 [21]

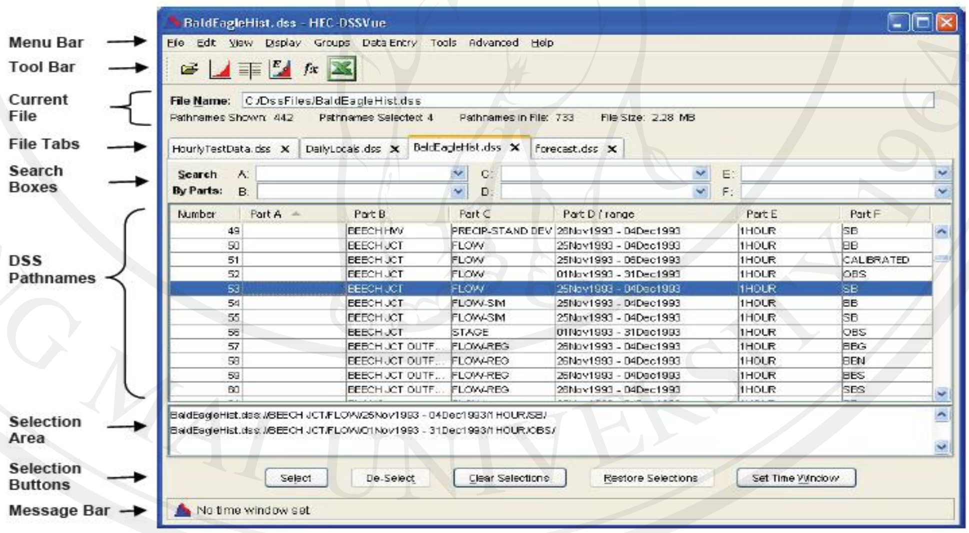

Figure 3.7 Main window of HEC-DssVue2.0 software

HEC-DSSVue2.0 was written using the Java programming language that allows it to be run under a variety of different operating systems. Fully supported systems include Microsoft Windows, Sun Solaris (UNIX), Red Had Linux and other systems.

3.5 Create data base in HEC-DSSVue2.0 software

Included within the framework of HEC-ResSim3.0 is HEC-DssVue2.0, a tool that allows to access data stored in HEC-DSS database files. With HEC-DssVue2.0, data may be plotted, tabulated, edited, and manipulated with over fifty mathematical functions. In addition to these functions, HEC-DssVue2.0 provides several utility functions, such as entering data sets into a database, renaming data sets, copying data sets to other DSS database files, and deleting data sets. HEC-DssVue2.0 can be launched from any HEC-ResSim3.0 module by choosing HEC-DssVue2.0 from the **Tools** menu. DSS files refer to time-series data by **Pathnames** representing records. **Pathnames** are separated into six parts (delimited by slashes "/") labeled "A" through "F." For "regular" time-series records, the naming conventions for describing the contents of the six pathname parts appear in Figure 3.8 [21]

A Project name

B Location or gage identifier

C Data variable, such as FLOW-IN, FLOW-OUT or ELEV-RES

D Starting date in the format 01JAN2013

E Time interval

F Additional user-defined descriptive information

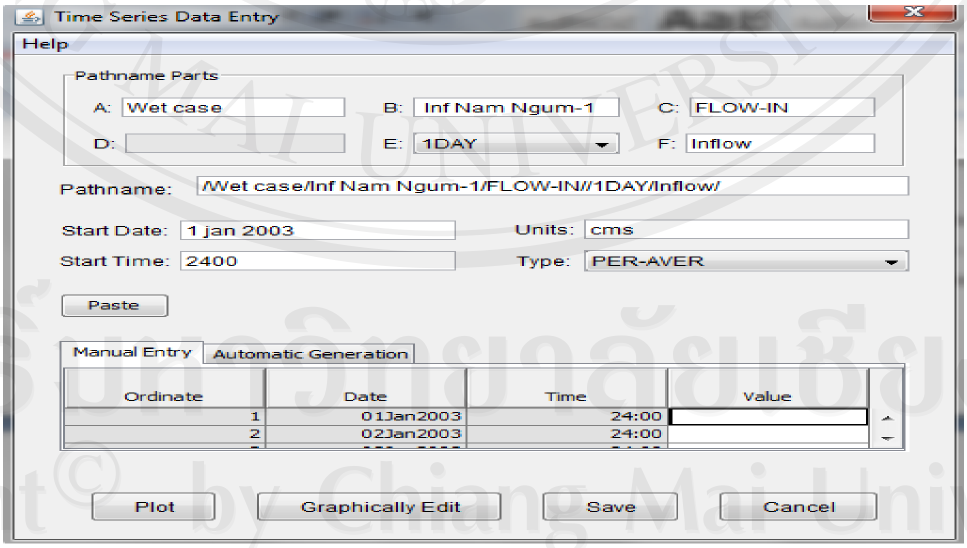

Figure 3.8 HEC-DSSVue2.0 software

3.6 Steps for create database in HEC-DSSVue2.0 software

The Nam Ngum-1 hydropower plant reservoir data are separated into three cases as: wet case, drought case and normal case. The time series data use data collection from 2003 to 2012, all data are converted from excel files to dss files by using HEC-DSSVeu2.0 software for support with the HEC-ResSim3.0 model. This work considers the data preparation steps as follows:

1. Preparation of the average time series daily data as: water inflow, water outflow and water elevation from 2003-2012 in Microsoft excel.
2. Start HEC-DSSVeu2.0 software by opening the icon on computer ‘desktop.
3. From the HEC-DSSVeu2.0 software, create the new file by selecting **New**.
4. From the HEC-DSSVeu2.0 software, select the **Data Entry** and **Manual Time series.**
5. From the HEC-DSSVeu2.0 software, it shows the window for creating new files and the six pathname parts appear as: **A**, **B**, **C**, **D**, **E** and **F**. In part **C** is very important. If the time series data are water inflow, the units is FLOW-IN only. If the time series data are water outflow the units is FLOW-OUT only and if the time series data are water elevation, the units is ELEV- RES only.
6. From the water inflow, water outflow and water elevation at the type box are PER-AVER type, the detail is shown in Figure 3.8.
7. When copy the time series data from excels files and move to the HEC-DSSVeu2.0 software by clicking the **value box** and clicking the **Paste** and **Save,** the detail is shown in Figure 3.8.
8. Finally, time series data are completed and can use input to HEC-ResSim3.o model for analyzing the optimal result.

The detail steps are shown in Appendix B.

3.7 Step of Input Data to Model

The time series data are completed by converting from excel files to dss files. This section will present data input to HEC-ResSim3.0 model for simulation which are detailed in following steps:

1. Start HEC-ResSim3.0 software by opening the icon on computer ‘desktop.
2. Select the **Reservoir Network Module**.

3. From the **Reservoir Network Module,** select **Alternative**.
4. From the **Alternative,** select **Edit** and **New**.
5. Create the new name of alternative
6. From the **Alternative,** Select the **Select DSS Path**

7. Finally, time series data are completed input to model and can use for simulation of the optimal result.

The detail steps are shown in the Appendix .B.

3.8 Step of calibration model

The main purpose of this study was to find out simulation model for reservoir management by HEC-ResSim3.0 which is developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center's Reservoir System Simulation, April 2007 to make simulation model for reservoir management and its objectives are irrigation, navigation, hydropower plant and drinking water supply.

This work is calibration model. This test uses elevation of reservoir and energy to compare with actual data by considering R^2 (Root Square), EI (Efficiency Index), RMSE (Root Mean Square Error) which are detailed as following items:

R^2 =1, the simulation test is highly reliable, EI = 100%, the simulation test is highly reliable and RMSE = 0, the simulation test is highly reliable.

From simulation model, result comparison with actual data record by using water inflow, water out flow, elevation of daily, monthly, yearly from 2003 to 2012 which are highly reliable data. The calibration method considers 2 types as: first type is water data and second types are energy data as shown below:

3.9 Water data calibration model

Use the average evaporation loss of Nam Ngum2 hydropower plant which is from design evaporation data of project construction and these data are used for NamNgum-1 hydropower plant by calculating percent, decreasing 100% to 9%, 8%,7%, respectively.

Startup water data calibration model begins. First of all, it starts from the preparation of hydropower data, geography data and hydrological data as :

Hydropower data are parameter for model include : physical data and operation data, the physical data such as: pool, evaporation, elevation of dam , length of dam, power capacity, efficiency, station used, hydraulic loss, tail rating curve and spillway rating curve data. As well the operations data are parameter for model include other zone and rule of reservoir such as: food control zone, conservation zone, inactive zone, upper and lower rule curve.

Geography data are the maps which include: location, reservoir network and shape of river, which are created by Arc View software or shape files.

Hydrological data are other flow includes: water inflow, water outflow, water elevation and evaporation.

The all time series data and parameter input to model are completed: it will go to the next step. Conduct the simulation model and the result of model can get two types such us plot result and table result. Next step, compare result of model with actual data in the Microsoft Excels and considers the R^2, EI and RMSE value. If thay are highly reliable, the model can be used for simulation of the optimal result of Nam Ngum-1 hydropower plant. This flow work is shown in Figure 3.9 and Appendix A.

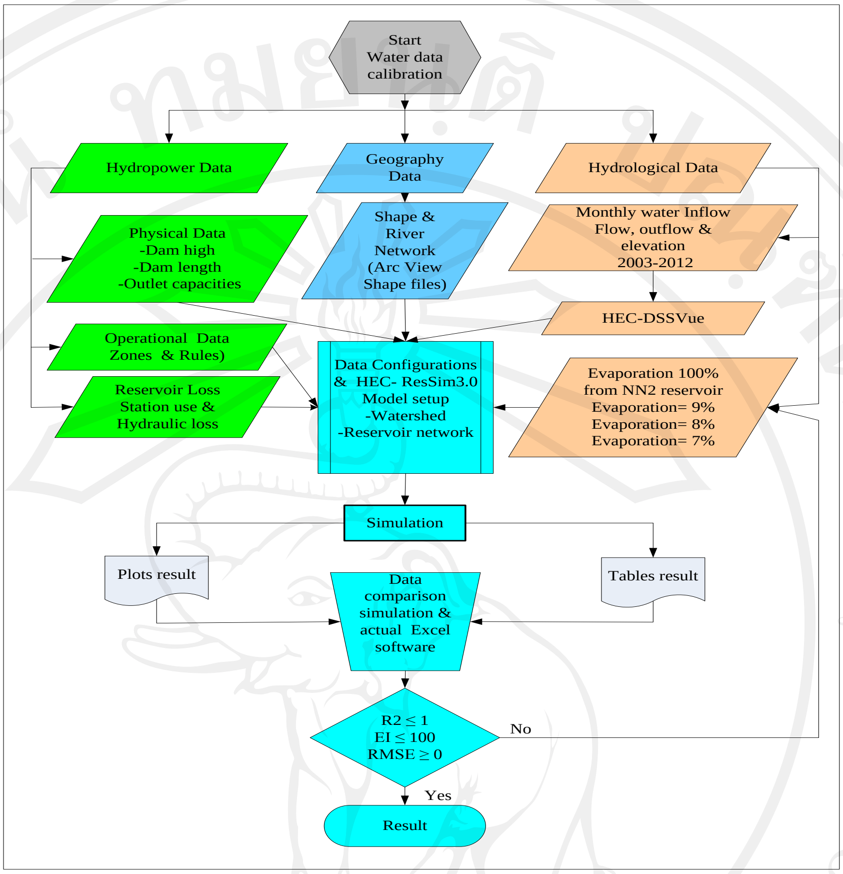

Figure 3.9 Step of water data calibration model

3.10 Power data calibration model

The study was conducted to determine calibration model. This test uses energy result from model to compare with actual data record by considering R^2 and EI. Use the data Station Use and Hydraulic loss. These data are used for NamNgum-1 reservoir loss by predicting step by step. Starting from 1.0, 1.5, 2.0 and constant efficiency 97%, the detail is shown in the Appendix. A.

First of all, it starts from the preparation of hydropower data, geography data and hydrological data into model and then the conditions and parameter, time series data are such as water inflow, water outflow, water elevation, station use and hydraulic loss, will be checked. If they are ready, it will go to the next step. By staring simulation model and the result of model can get two types such us plot result and table result. Next step, comparison of result of model with actual data in the Microsoft excels. Consider the R^2 and EI value.

If the comparison of simulation result and actual data are not highly reliable, then calibration will go in the next iteration by using hydraulic loss and station use in 1.0, 1.5 and 2.0, respectively.

If the comparison of simulation result and actual data are highly reliable, the results were at optimal point for reservoir management of Nam Ngum-1 hydropower plant. This flow work is shown in Figure 3.10 and Appendix A.

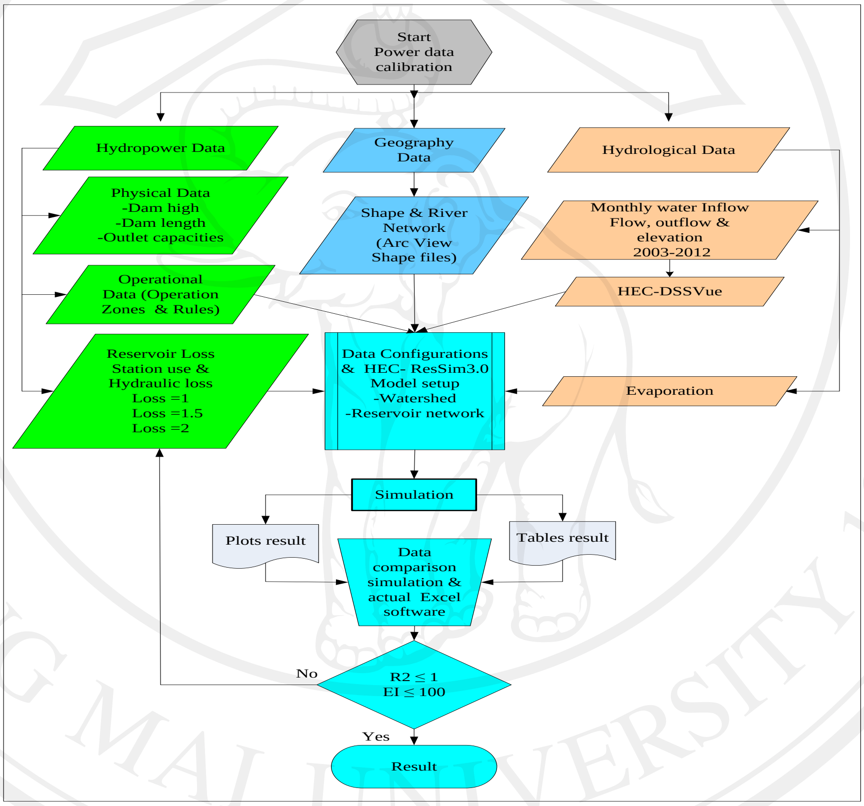

Figure 3.10 Step of power data calibration model