International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 13 (2015) pp 33197-33201
© Research India Publications. http://www.ripublication.com

Optimization operation of bening reservoir to maximize irrigation allocation

Rispiningtati[1], **Rudy Soenoko**[2]
[1]Brawijaya University, Water Resources Department, Engineering Faculty, 65145, Malang Indonesia
[2]Brawijaya University, Mechanical Engineering Department, Engineering Faculty, 65145, Malang Indonesia
rispiningtati@ub.ac.id

Abstract- On this study, an operation of Bening Reservoir has been observed. The observation was directly done on the Bening reservoir location, which is located in Lamongan, East Java, Indonesia. As the Indonesian Government decided that water resources development in Indonesia is one program to target the supply water needs, where water resources development used for irrigation is an important aspect. One of other advantages on the use of water as irrigation is the electric power hydro generation. There is a need for a water optimization capacity and reservoir operation system for the anticipation of surface water resources water restriction and a higher cost of hydraulic structures to intensify the need for an optimum capacity and an effective operation for reservoir systems. It is a must that allocating the water use as efficient and effective as possible. An optimization system model was then erected on this study. As mentioned above that the case study for this observation selected was the Bening reservoir in Lamongan. The optimization analysis result would give a lot of information for the water allocation for every objective function. The Basic Irrigation Allocation Optimization is based on the yearly reservoir data. The reservoir yearly data is the reservoir data which could reserve water during the rainy season and could support the activities on the dry season. On this type of reservoir, that should be understood, is that the water reservoir inflow quantity has a different water outflow quantity.

The methodology used in this study is concentrating on the water irrigation allocation optimization. The result of this optimization could be used as the rule curved pattern to design the basic of reservoir operation. The rule curve considered the irrigation outflow water optimization discharge, the head and the hydro electrical power energy prediction.

Keywords- Irrigation, Allocation, Outflow, Optimization.

Introduction

For Indonesia it is necessary to develop the water resources, where water resources could be develop to fulfill many water needs for human needs. Water needs taking account are water needs used for irrigation, water flow or water flow rate or water head for hydro electrical power generation, probably water needs to support industry, water needs for recreation and some more water need for daily human needs. The significant aspect of water resources developments are used for rice field irrigation. To supply water for irrigation, there should be a different elevation level so that water could flow from a high level to a lower level where the irrigation object is the target of the water irrigation. This water level difference could also be used to generate electricity from a hydroelectric power plant. Water use for Irrigation also hydro electrical power could give more advantages because it would decrease the use of gasoline as an energy source [1]. The restriction of using surface water resources and a higher cost of hydraulic structures intensify the need for an optimum capacity and operation for reservoir systems [2]. Thus, it was needed to allocate the water use as efficient as possible. To reach this target, it was needed to make a system model for water use optimization. An optimization analysis would give more information for the water allocation of each water use objective function [3]. The optimization result could be used to regulate the optimal reservoir flow.

Material and Methods

Before making the optimization process some collecting data are needed to carry out the optimization instead of the study location map, the reservoir location map and the reservoir discharge, other reservoir data such as the reservoir inflow and reservoir outflow and the irrigation area [4]. The data analysis was included for the water need for the rice field irrigation. The irrigation allocation optimization was carried out under a yearly reservoir data. Yearly reservoir was the reservoir which could reserve water during the rainy season than it was used in the dry season [5]. For this kind of reservoir, the inflow water flow rate was not the same as the outflow water flow rate.

There are many tools to solve operation research problems. One of them is the linear programming system, where linear programing is a mathematical tool used to solve some operation research studies. As the basic solver of developing operation research, linear programing is very powerful [6]. Linear programing is known as a deterministic tool because all parameters used in this program was determined accurately and certainly [7]. In fact, there was never seen a certain case, so that linear programming was used as an analysis tool of post optimization for making decision [8]. The mathematical modeling development should start by answering the three questions as follows [9]:

1. What would be devoted by the model? In the other words what variables are needed for this case?
2. What are the constraints to involve the boundary of the system?
3. What was the objective function for reaching the optimized feasible solution?

The step by step to carry out the linear programming is as follow [10]:

a. Create optimization models
b. Determine the resources which would be optimized for this case study it is irrigation
c. Calculate the input and output quantities for every kind of the unit activity
d. Lastly built the mathematical modeling.

Before entering the solver tool in the excel program, it is neccessary to prepair a table to support the optimization process either the model constrain or the variable cell and also the optimized result cell [11].

One of the requirements of producing a model software program is that this program should be easy to use and easy to operate. Microsoft Excel has the basic features of all spreadsheets, using a grid of cells arranged in numbered rows and letter-named columns to organize data manipulations like arithmetic operations. Excel has a power of supplied functions to answer statistical, engineering and financial needs. Excel spreadsheet software is especially useful in processing information data projection, analyzing and optimizing. Microsoft Excel is a spreadsheet application developed by Microsoft for Microsoft Windows. To operate this kind of optimizing model software program, a user should have an understanding of operating a spreadsheet program. First is opening a new worksheet file and then fill the cells with data rows and columns form according to the Solver Optimization Program guidance. For the solver, two columns are needed to show the Y and X variables. For the constraints, there is no special requirement, the user could place it on every rows or columns position in accordance with the model makers plan [11].

To activate the Solver menu, activate the Tools option in the *Excel* program. Open the sheet menu then select the Solver menu, the Solver sheet would then appear. This solver sheet would seem to be filled the target value. Point the cursor on the solver until the sheets shape appears as in figure 1, which consists of a max, min and Value of option menu. From this menu, for maximizing the project objective the max option should be chosen by ticking the max option icon. Furthermore to start arranging constraints the add icon should be chosen by clicking the add icon. Rows will appear and could be filled with values according to the available constraints. Surely in compiling constraints values must tabulated, making it easy to choose and do not have to type in the column constraint anymore. It is necessary for the cell destination to have a formula in it, for example for the maximum function it should be filled do not leave empty [11].

After filling the maximize cell, the variable cell, which indicates the cell where the result of the optimization can be a column or row in the excel sheet, would automatically give a result value. The variable row or column cell value will always be change when the constraint is changed after the execution. This value in the optimization column is the final result of the optimization [11].

Examples of the use of the optimization allocation could be seen in Figure 1 as follows:

Fig 1: Changing Data Sheet optimization [11]

Steps in arranging the Solver Parameters:

1. In Set Target cell window fill up the cell target or click straight forward to the cell target on the worksheet, for example cell J23. On the target cell window appears a value of $J$23. Furthermore fill the ”Equal to” with Max or Min appropriate choice.
2. To fill the “By changing cells" fill up the column or row for the result target. For example choose cell J10 to J 22 ($J$10:$J$22).
3. Filling "Subject To Constraints" with all equation constraints written in the available window. For example: Cell J23 <= B 23, and so on.In summary the whole optimization process can be written as follows:

Optimize function:
Max Z = Max J10: J22 → Max J 23 = Max cells J10: J22
Constraints:
I10: I22> = Q → downstream cells J10: J22> = cells I10: I22
Total water allocation <= total reservoir outflow → J10 + J11 .... cells. .... .J22 <= Cell B23
Z = Target Cells J → 23

After finished filling in all the data value, click solve, and on the worksheet will appear a window as follows:

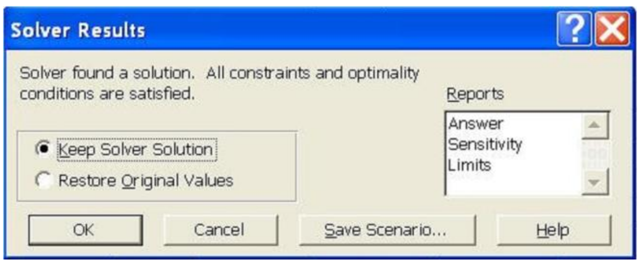

Fig 2: A successful optimization process end sheet [11]

If the result is shown as in figure 2, then process was perfectly finished and the result is optimum.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 13 (2015) pp 33197-33201
© Research India Publications. http://www.ripublication.com

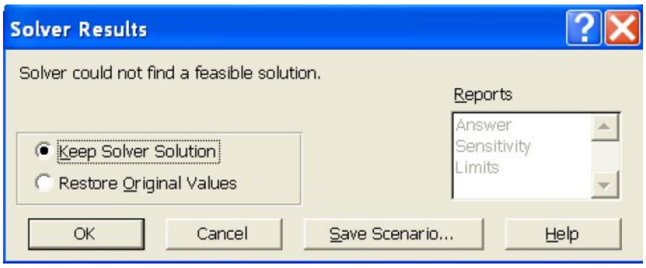

Fig 3: Solver problematic sheet [11]

If the description is shown as in Figure 3 "solver could not find a feasible solution" then the whole process could be rechecked again.

Irrigation Optimization

On the constraint columns where the Maximum Basin Reservoir boundary with a notation of Q max (m3/sec) the basin reservoir unit in m3/sec for 1 month or S max (m3 in 1 month) in which the Basin Reservoir optimization operation must not exceed the maximum reservoir. The minimum basin reservoirs (Q min, S min) is a Q and S value, where on the optimized reservoir operation should not be smaller than the minimum basin reservoir capacity. The water demand amount is the water flow rate needed (Q need) and the minimum water storage (S need) where Q is a water flow rate required for the downstream irrigation or industry.

The Q total outflow optimal could be found on the optimization results column. On The Variable Column, O opt and I opt is also an optimization result. A variable column in this case is a column where the cell value would change according to the constraints and optimization operations performed.

The optimized model formulation for the irrigation case is as below (Cheng Yun et all 2008):

The objective function Max $I = I_1 + I_2 + I_3 + I_4 + I_5 \ldots\ldots\ldots + .I_n$

1. Subject to (constrains) are:

a. S min < Sn < S max

b. Outflow Irrigation > Q downstream

c. Total outflow 1 year = Total inflow 1 year

with

I = Monthly Outflow Irrigation (m^3/s)

Sn = monthly storage (m^3)

S min = minimal storage (m^3)

S max = maximal storage (m^3)

Q dowstream = water need in the downstream of reservoir (m^3/s)

RESULT AND DISCUSSION

The optimization of reservoir outflow was carried out by using the solver tool in MS Excel. As mentioned above that before implementing the solver tool, a table should be prepared to support the main program to be optimized. The table should contain all variables needed and all constrains for the irrigation case on this model. The optimized irrigation allocation from the solver result could be seen in Table 1.

CONCLUSIONS

The results of optimization were very important to know the optimized Irrigation Allocation as outflow optimal. The results was included the outflow from reservoir, water level at reservoir, spillway outflow, reservoir volume.

The results of optimization were very important to know the optimized Irrigation Allocation as an optimal outflow. As what seen in Table 1, the maximum outflow would occur on July with a value of 1.93m^3/sec and the minimum outflow would occur on October and November with a value of 0.00 m^3/sec. The maximum reservoir water level elevation occurs in September until November with a value of 108.60 m and the minimum reservoir water level elevation occurs in August with a value of 98.80 m. From this optimization process it is indicated that the result was really optimum, it could be seen that the water supply was maximally used for water irrigation indicated from the zero spillway outflow. The maximum reservoir volume occurs in September with a value of 26.87 x 10^6 m^3 and the minimum reservoir volume occurs in August with a value of 3.83 x 10^6 m^3.

Table 1: Optimization of Irrigation Allocation at Bening Reservoir, Indonesia

1	CONSTRAINTS									Optimization Result
2	A	B	C	D	E	F	G	H	I	J
3	m^3/sec	10^6 m^3	m^3/sec	10^6 m^3	m^3/sec	10^6 m^3	m	m	m	m^3/sec
4	Q max	S Max	Q min	S Min	Q need	S need	El.Max	El.Min	TWL	Out mean
5	7.53	19.520	10.37	4.00	1	21	108.6	96.4	80	0.86
6		$Sn = S_{(n-1)} + In - Out$			$S O = S_n - Smax$					
7		I	Sn	I - O	SO					
8		m^3/sec	m^3/sec	m^3/sec	m^3/sec	10^6 m^3	m	m	m^3/sec	m^3/sec
9	Month	Inflow	Sn	ΔS	Spill Out	S Res	Elevation	Heff	Q Down stream	Q Optimal irrigation
10	December		5.26							
11	January	2.47	7.53	2.27	0.00	19.52	108.60	28.60	0.20	0.20
12	February	2.37	7.53	2.37	2.37	19.52	108.60	28.60	0.00	0.00
13	March	2.07	7.53	2.07	2.07	19.52	108.60	28.60	0.00	0.00
14	April	1.30	7.53	0.30	0.30	19.520	108.60	28.60	1.00	1.00
15	May	0.17	6.56	-0.97	0.00	17.00	107.03	27.03	1.00	1.14
16	June	0.17	4.73	-1.83	0.00	12.25	104.06	24.06	2.00	2.00
17	July	0.13	2.93	-1.80	0.00	7.59	101.14	21.14	1.93	1.93
18	August	0.03	1.48	-1.45	0.00	3.83	98.80	18.80	1.40	1.48
19	September	0.07	10.37	-1.48	0.00	26.87	108.60	28.60	0.40	1.54
20	October	0.18	7.53	0.18	3.02	19.52	108.60	28.60	0.00	0.00
21	November	0.45	7.53	0.45	0.45	19.97	108.60	28.60	0.00	0.00
22	December	0.90	7.43	-0.10	0.00	19.26	108.44	28.44	1.00	1.00
23	Total	10.30			8.20				8.93	10.30
24	10^6 m^3	26.7	16.99	0.00	21.26				23.15	26.69
25	Average	0.86	6.56	0.00	0.68	17.03	106.64	26.64	0.74	0.86

From the result above it could be concluded that by implementing this irrigation allocation optimization, the whole water input and output could be controlled optimally. The water reservoir could be reserve yearly water normally. Hopefully the reservoir could reserve water at a lowest level in a certain month but it could still supply water minimum either for water irrigation or for electric power generation, as this Bening water reservoir functioned. Based on this irrigation allocation optimization the water level on the water reservoir could reach the maximum level but still could be controlled not be higher than this maximum level. The whole year irrigation program could be controlled optimally, either for the water allocation for rice production and other planting or for electric power generation.

The important aspect of water resources developments used is for Irrigation could be reach optimally and the other objective is generating hydro electrical power which would gave more advantage in decreasing the use of gasoline. The surface water resources restriction and a higher cost of hydraulic structures intensify could be controlled on an optimum capacity.

Acknowledgement

The author would like to thank to the Water Resources Engineering Department, Brawijaya University; The Hydraulic Laboratory Brawijaya University and the Water Resources Computer Laboratory Brawijaya University for the facilities and system supports.

References

[1] Loucks, D.P. 1985. “Water Resources Systems Planning and Analysis”, Prentice Hall, Inc. Englewood Cliffs, New Jersey, 07632

[2] Niedda, M. 1996. “Mixed Optimization Technique for Large Scale Water Resources Systems”, Research, Armidale, Australia Loose Leaf n. p.

[3] Lund, J.R. 1996. “Operating Rule Optimization for Missouri River Reservoir System”, Journal of Water Resources Planning and Management, 122(4): 287-295

[4] Major, D.C. 1998. “Climate Change and Water Resources the Role of Risk Management Methods”, Water Resources Update, USA, 112: 47-50

[5] Hunt, C.1999. “Transposing of Water Policies From Developed To Developing Countries the Case of User Pays”, Water International. 24(4): 293-306.

[6] Taha, H. A. 1996. "Operation Research", Second Edition. Department of Industrial Engineering of University of Arkansas. USA.

[7] Alfredo, A. 1987. "Probability Concepts in Engineering Planning and Design", First edition, John Wiley & Sons, Inc. USA INWRDAM, 2001.

[8] Labadie, J.W., 2001. "Reservoir System Optimization Models", Water Resources Update, USA.108: 83-110.

[9] Lasdon, L. 1998. "Microsoft Excel Solver uses the Generalized Reduced Gradient non Linear Optimization", University of Texas Austin Cleveland State University.

[10] Rispiningtati, 2014. "Irrigation Allocation Optimization of Wonorejo Reservoir", International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 9, Number 22, pp. 12871-12878

[11] Beecher, J. A. 1999. "Sustainable Water Pricing", Water Resources Update114:26-33

[12] Harald D., 1996, "Water Crisis in Developing World Misconceptions about Solution", Journal of Water Resources Planning and Management, 122(2):79-87