International Journal of Civil Engineering and Infrastructure
Vol. 5, No. 1, March 2025

# APPLICATION OF GENETIC ALGORITHM TO OPTIMIZE WATER DISCHARGE AT BATU TEGI DAM

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Received October 08, 2024 | Accepted November 10, 2024

***ABSTRACT***

*Water is the largest natural resource in Indonesia and it is easy to use in its utilization. Water that can be utilized directly from the river or by collecting rainwater in a tando pond or reservoir and then flowing it to turn a turbine. To utilize the available water resources, the government always builds and maintains its facilities and infrastructure, including by building dams. Unpredictable rain intensity, especially in the Lampung area, can cause a lack of optimal water release. If the release of water is not optimal, then the need for water will not be obtained optimally, but the presence of water in the reservoir cannot always be fulfilled when it is needed. The Batu Tegi Dam is an important dam for the needs of the surrounding watershed and Tanggamus. When building a system, optimization is an important component. System design can reduce processing time, among others through optimization. Mathematical functions are usually used to describe optimization problems. The process of maximizing or minimizing the objective function while taking into account the existing constraints is known as optimization. This calculation uses the Microsoft Excel 2021 application. By analyzing the optimal release discharge, as well as displaying the optimal discharge value in 2022 using the Genetic Algorithm method. This method is the expertise of flexibility and accuracy when maximizing complex systems. The results of this study obtain optimal discharge before and after using the Genetic Algorithm (GA) method with a time series of 2018 to 2022, making a discharge discharge curve in 2022.*

***Keywords:*** *Genetic Algorithm, Dam, Release Optimization*

## 1. PRELIMINARY

The Batu Tegi Dam is the largest dam in Southeast Asia. Has an area of approximately 3,560 hectares. To meet the needs of water, optimal release is required properly.

In utilizing the Batu Tegi reservoir with erratic weather intensity. Therefore, discharge rules are necessary for truly optimal use of reservoir water. One of the stochastic programming methods, namely the Genetic Algorithm method model, will be used in this study. A search method in computer science known as a genetic algorithm is used to predict solutions to optimization and search problems. Genetic algorithm is part of the evolutionary algorithm that uses methods such as inheritance, mutation, natural selection and recombination derived from evolutionary biology.

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To get an idea of the flexibility and effectiveness in optimizing the system at the Batu Tegi Dam. This will be designed to optimize the outflow of the reservoir and maximize the flow of the Batu Tegi discharge so as to minimize water shortages in the reservoir.

Genetic Algorithm (GA) Method, GA is a part of the approach that looks very promising because it uses natural systems to get the best results. This approach has the advantage of being adaptable and efficient in optimizing complex systems. GA is a stochastic optimum value search method based on the genetic theory of natural selection.

The release of reservoir water must pay attention to caution in its utilization. Apart from the high cost of building dams, there are also many needs that must be met for the survival of humans and the environment. An organized effort to select the best element from a set of existing elements is optimization. This optimization can be expressed mathematically as a methodical attempt to determine the minimum or maximum value of a function. In other words, optimization is the process of finding the optimal value based on the specified objective function. Actually, metaheuristics is an approach method based on heuristic methods. so the heuristic optimal or near optimal solution. (Budi Sentosa 2017).

Water is the largest natural resource in Indonesia and it is easy to use in its use, one of the ways to utilize it

is a hydroelectric power plant. Because it uses water as its main power source, hydropower is one of the most environmentally friendly power plants because it converts potential energy into mechanical and electrical energy. The water used can be directly from the river or from a tando pond or reservoir which first collects rainwater before being channeled to turn turbines.

By minimizing the shortage of water in the reservoir, it will also affect the performance of the turbine engines in the hydropower plant. If the reservoir often experiences drought, the engine will often stop working, and if the engine stops working frequently, it will break down quickly. Many optimization methods have been used to get the best outflow from the reservoir. This approach has the advantage of being adaptable and efficient in optimizing complex systems. (Lani rohaeni, Deni Saepudin, Aniq Atiqi 2016).

One type of BUMN service, PDAM (Regional Water Supply Company), is tasked with providing safe drinking water for the general public. The manual route pattern is still used on the route pattern that has been produced by the PDAM for the installation of drinking water pipe networks. In expanding the service network, one of the most crucial considerations is paying

approach is often included in the metaheuristic approach. The complexity of the operation of the reservoir is a challenge in itself for water resources experts so that the achievement of the objectives of the construction of the reservoir/dam can be realized. Along with the times marked by increased computerization capabilities, the last 1 decade has spawned new breakthroughs or innovations for optimizing reservoirs. (Aprizal 2019).

Metaheuristics, like multi-purpose drugs, can be used to solve various optimization problems, both continuous and discrete or combinatorial, especially large ones. Heuristic or approximation is a method designed to solve a problem in systematically arranged steps without realizing optimization theories or analytical proofs.

Heuristics are interpreted to speed up computation, resulting in a decrease in the precision or accuracy of the resulting solution. The emerging metaheuristic approach to heuristic production. Metaheuristics is a computational method for solving an optimization problem by iteratively trying to improve candidate solutions by paying attention to the quality limits of the desired solution. This is held to find the

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attention to the distribution network route. In this case, the transmission pipeline design needs to be considered to achieve the best total distance (pipe length) while minimizing the overall cost.

The root of the search tree is assigned a value by the algorithm at the start. Attaching a final node to another low-level pending node is how branching is done. The search method is applied simultaneously to a number of potential solutions, or populations, in a genetic algorithm. Chromosome is the name given to individuals in a population. The solution that remains in symbol form is this chromosome. The first population is random, and the evolution of chromosomes is the second by heredity, or iteration. (Amanda Sylvia Sani 2011).

By applying the Genetic Algorithm to the dam, optimal discharge will occur with the aim of increasing its flexibility and effectiveness. Prior to AG The objective function, also known as fitness, must be used to define the problem to optimize; If a chromosome has a high fitness value it will affect the production of the next generation, thereby enabling the evolutionary process to produce a higher fitness value in each generation.

population. There are many ways to complete this step. For example, using the best individual copier or a combination of solutions for parents and children.

d. Mutations allow the creation of new individuals that are not the result of interbreeding. In the TSP problem, mutation is the appearance of a new value or an altered or replaced sequence of elements of the solution vector. Moreover, these parts are randomly selected. Consider K as the selected element for the solution vector X.

The introduction is also described become discussion in article journal.

a. Chromosomes in GA are a crucial component of the algorithm. One individual, or chromosome, represents one solution vector. These solution vectors can sometimes be coded or encoded, and other times they can be used directly in an AG implementation. By using binary numbers, coding is done to represent a solution value. Crash Duration is the shortest activity duration, when the maximum number of resources has been assigned to the activity, leading to the highest activity cost / Crash cost.
b. Fitness is used to pursue fitness as a form of self-actualization, different from other forms of self-actualization. The fitness mushroom can be combined with the target mushroom or modified in response to the target mushroom. The fitness rating system will work for most people.
c. Elitism is meant to prevent the best people from joining the population in the next iteration. In AG, the concept of elitism refers to efforts to pass on the best individuals from one generation to the next. Until the best people will continue to appear in the next

## 2. METHODOLOGI

There are a number of explanations for this research, but few are widely accepted. In order to predict and compare the outcomes of different decisions, strategies or controls, this particular strategy aims to create a scientific model of a system by combining factor measures such as opportunity and risk. Its purpose is to assist decision makers when making scientific decisions about their policies and actions. This research focuses on scientific decisions regarding the design and operation of systems, which usually involve allocating limited resources. Research is the art of coming up with bad solutions to problems that already have bad solutions.

This research is also a way to make decisions that use scientific knowledge

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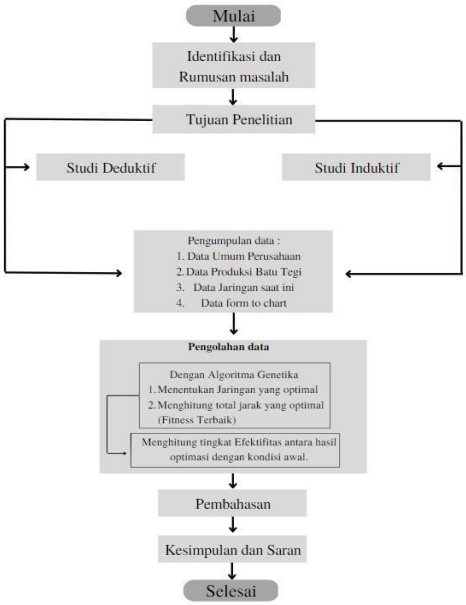
by working with groups from various fields to find out how to use limited resources. It can be understood as the application of methods, techniques and tools to problems involving system operation in a way that yields the best solution.




**Picture 1**

. Research Flowchart

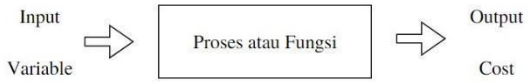
2.1. Optimization

Optimization is a method of adjusting inputs, selecting equipment characteristics, and performing mathematical procedures and tests to achieve the best possible results.

The visual representation of a network is basically a series of nodes and lines. Nodes are the points that connect one device to another. In this scenario, the line can be an arrow indicating the direction of flow from the initial or source node to the final or destination node. There are two possibilities considering the arrows indicate the current direction. The first current is one-way, while the second is bi-directional

2.3. Graph

Depending on the perspective taken, the optimization process can be considered as a minimization or maximization process.




**Picture 2.** . Optimization Function Diagram

2.2. Network models

The visual representation of a network is basically a series of nodes and lines. Nodes are the points that connect one device to another. In this scenario, the line can be an arrow indicating the direction of flow from the initial or source node to the final or destination node. There are two possibilities considering the arrows indicate the current direction. The first current is one-way, while the second is bi-directional.


**Picture 3** . a. One Way Network System; b. Two Way Network System

A graph is a collection of nodes connected to each other by edges. There are two sets in graph G: vertex set (V) and arc set (E). Arcs can also represent a number of bonds, including those between chemical bonds, flight paths, roads, telephone lines, and so on. Notation for graphs: A graph G contains two sets: the infinite set V(G), whose elements are called vertices, and the (possibly empty) set E(G), whose elements are called edges. This means that every e element in E(G) is an unordered pair of points in V(G). The set of points of G is called V(G), and the set of edges of G is called E(G). Directions and

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weights divide the graph into four sections:

a. Weighted directed graphics: Each bow has a weight and an arrow.
b. Weighted and undirected graphics: Each bow has weight but no arrows.
c. Unweighted and directed graphics: Arrows are unweighted in each arc.
d. Graphics are weightless and directionless: Each bow is weightless and has no arrows.

There are many ways to display graphs. Graph representation can be used to apply a graph in a certain way so that it can be used in various situations.

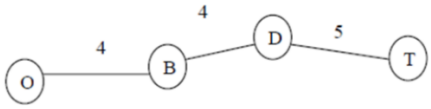
1. *Adjacency Matrix*

**Table 1.** Example of Proximity Matrix

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| A | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| B | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| C | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| D | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| E | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| F | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| G | 0 | 0 | 0 | 1 | 1 | 1 | 0 |

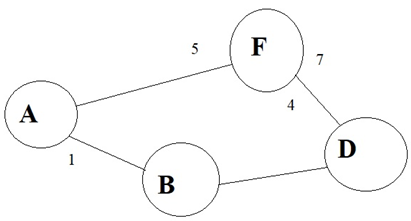
2. Adjacency list

a.



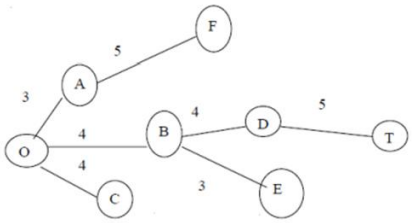

**Picture 4.** Example of a Path (from Node 0 to Node T)

b.




**Picture 5.** Cycle Example

c.




**Picture 6.** Example of a tree-shaped network

2.4. Genetic Algorithm

The genetic algorithm process is adapted from natural selection. The Genetic Algorithm procedure creates a random population from a solution. Chromosome is the name given to each person in the population, which refers to the solution.

When it comes to solving complex unsolvable optimization problems, genetic algorithms are an excellent choice. A direct genetic algorithm usually consists of three operations, similar to the natural process of evolution: reproduction operations, crossover operations, and mutation operations.

The general structure of the genetic algorithm consists of the following stages:

1. Select the starting population at random.

2. Use the three operations in a way that is iterative enough to generate a new generation with enough chromosomes to represent the new solution.

3. Development of a solution that will calculate the fitness value of each chromosome to evaluate each population until the stopping criteria are met. will result in the formation of a new generation if the dismissal criteria are not met. Repeat steps

4. Some of the most frequently used criteria for quitting are:

- Focus on a specific generation.

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- After several generations of values, the highest or lowest fitness (by problem) remains constant.

- Stop if no higher or lower fitness values are obtained for the next n generations.

Optimization problem solving algorithms usually consist of asymptotically focused series of computation steps. A number of traditional optimization techniques construct a sequence of computation rules based on the trend of the objective function or final strength.


**Picture 7.** Genetic Algorithm Processing Steps

2.6. Main Elements of Genetic Algorithms

a. Coding Techniques
The process of encoding genes from chromosomes is known as coding technique.

Usually, one variable is represented by one gene. Genes can be described in the following ways: real numbers, bits, rule lists, permutation elements, program elements, or any other representation that can be used to implement the genetic operator is an example. The solution to the current problem is required for this coding method.

b. Generating Initial Population

2.5. Difference between Ordinary Optimization and Genetic Algorithms

approaches taken at one location in the search space. Through increasing iterations, this point is then increased along the decreasing or increasing depth. If it reaches the local optimum point, the approach from one point to another is unprofitable and unprofitable. The AG maintains a population of tried solutions to perform a multidirectional search. To avoid local optimum results, a population-by-population approach is used. With each generation, the population moves through simulated evolution, with the good settlements being reproduced and the bad completions being discarded or ignored. AG applies the probability switching rule, removing dead chromosomes from the investigation space while retaining reproducible good chromosomes (Gen and Cheng 1997).

The process of forming a number of people randomly or systematically is called population initialization. population size in relation to the problem at hand and the type of genetic operator to be used in the genetic algorithm. Population initialization is generated when the population size has been determined.

c. Selection
Individuals are selected through selection for crossover and mutation processes. In addition, to get a quality prospective parent. A good mother will give birth to good children." A person's chances of being selected increase with his or her fitness score.

d. Crossover
An operator of the genetic algorithm known as crossover involves two

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parents creating new chromosomes. A new point in the quest space is created by crossover, and is now ready to be tested. This procedure is not always performed on every living person. Individuals with a Pc between 0.6 and 0.95 are randomly selected to cross. The parental value will be passed on to the children (offspring) if the cross is not carried out.

Crossover is the process of creating a new person by performing genetic (swapping, arithmetic) operations on the genes of two parents.

e. Mutation
This operator is involved in replacing genes that were removed from the population as a result of a selection process that allows genes that were not present during the initialization of the population to reappear. The resulting chromosome is started by adding a very low probability random value. The percentage of a population's genes with mutations is referred to as the mutation probability (Pm). The number of new genes that will be presented for evaluation is controlled by the probability of mutation.

2.7. Research sites

This research is located in the Batu Tegi Dam (Figure 8.) located in the Tanggamus district, Lampung Province. On March 8, 2004, Mrs. Megawati Soekarnoputri, the fifth president of the Republic of Indonesia, laid the first stone for this dam. In addition, this dam has a capacity to withstand a water discharge of 9 million m3. It also functions as a source of electricity for up to 2x14 MW PLN in Lampung.

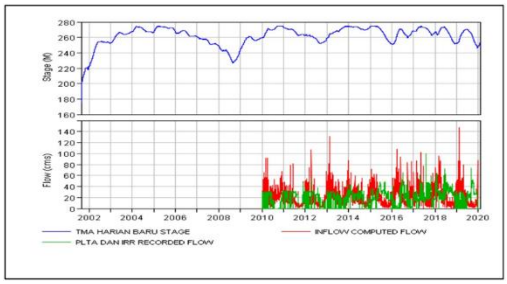

**Picture 8** . Batu Tegi Dam Map

2.8. Reservoir Characteristics

The Batu Tegi Reservoir has an initial gross storage of 687.8 million $m^3$ at a normal water level of + 274.00 m. The catchment area of the reservoir is 429 $km^2$, with an inundation area of 21 $km^2$ at El. Overflow Peak 274.0 m. The minimum elevation for power generation is +226 m and for irrigation +208 m and an effective reservoir capacity of 664.4 million $m^3$. The Dam Peak Elevation is at 283 m and the Flood Water Level is at 281.5 m.

2.6. Characteristics of Discharge

In the Batutegi Dam watershed there is only a water measuring post which reads the Water Level (TMA) in the reservoir once a day at 7:00 am. Besides that, there is outflow data at the intake for irrigation and hydropower. All data obtained from UPB Batutegi is made graphically as shown in Picture 9.




**Picture 9.** Data series of TMA Reservoir, Inflow and Outflow Batutegi

## 3. RESULT

One of the influential factors in the operation of the reservoir is the amount of inflow into the reservoir. In preparing the reservoir operation plan, it is necessary to estimate the amount of available river flow that can be utilized by the reservoir. The magnitude of the inflow will depend on the seasonal conditions during the operation of the reservoir.

To estimate the inflow that will enter the reservoir, the most important thing is to

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determine the level of probability of occurrence (or probability of exceeding) the inflow. The probability of an event is generally represented by a percentage value which indicates the probability that an event will occur (or be exceeded).

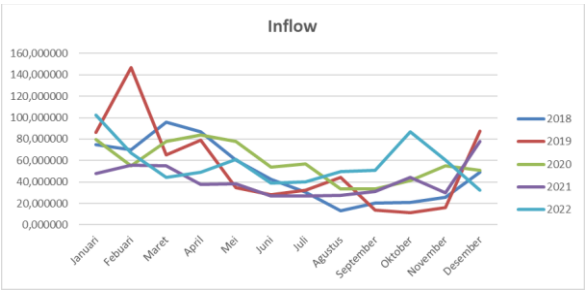
### 3.1. Data processing

This data is collected in order to organize data, in order to determine maximum results it is necessary to analyze the time series with the specified time. The purpose of data analysis in time series is to find the relationship between the magnitude of events and the frequency of events in a given year.

**Table 2** . *Inflow time series* 2018-2022

| Tahun | Bulan | | | | | |
|---|---|---|---|---|---|---|
| | Januari | Febuari | Maret | April | Mei | Juni |
| 2018 | 74,907188 | 70,193229 | 95,670529 | 87,056951 | 60,189411 | 42,647168 |
| 2019 | 86,330743 | 146,977617 | 65,271534 | 79,008348 | 34,415633 | 28,264371 |
| 2020 | 79,900671 | 55,251383 | 78,015751 | 83,562514 | 77,568988 | 54,061405 |
| 2021 | 47,741289 | 55,654537 | 55,298529 | 37,772345 | 38,209921 | 27,052886 |
| 2022 | 102,147217 | 66,937035 | 44,090850 | 49,043953 | 61,074017 | 38,725824 |

| Tahun | Bulan | | | | | |
|---|---|---|---|---|---|---|
| | Juli | Agustus | September | Oktober | November | Desember |
| 2018 | 30,432806 | 12,997111 | 20,145716 | 20,826715 | 25,689563 | 49,183673 |
| 2019 | 32,320281 | 44,473606 | 13,687139 | 11,575081 | 16,047981 | 87,183455 |
| 2020 | 56,632209 | 33,580841 | 33,580841 | 41,109971 | 55,063791 | 51,016540 |
| 2021 | 27,194618 | 27,572768 | 31,381815 | 44,052444 | 30,037777 | 77,750185 |
| 2022 | 40,123814 | 49,497628 | 51,057976 | 86,583635 | 60,461879 | 32,482000 |

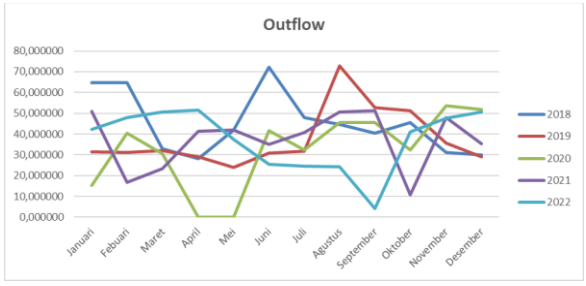



**Picture 10** . *Inflow time series* 2018-2022

**Table 3** . *Outflow time series* 2018-2022

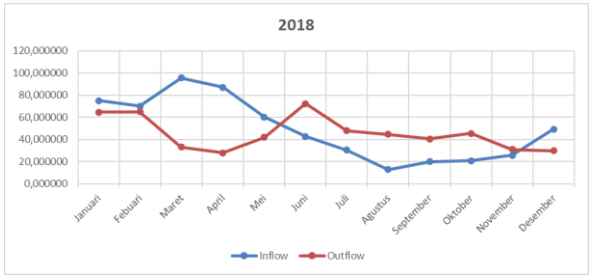
| Tahun | Bulan | | | | | |
|---|---|---|---|---|---|---|
| | Januari | Febuari | Maret | April | Mei | Juni |
| 2018 | 64,724537 | 64,784722 | 33,094118 | 28,045139 | 42,003571 | 72,310185 |
| 2019 | 31,585648 | 31,161538 | 32,033333 | 29,018519 | 24,092593 | 30,814815 |
| 2020 | 15,355556 | 40,390000 | 30,563333 | 0,000000 | 0,000000 | 41,551353 |
| 2021 | 50,857639 | 16,700000 | 23,332176 | 41,469907 | 42,032407 | 35,189815 |
| 2022 | 42,353009 | 47,797454 | 50,540509 | 51,388889 | 37,537037 | 25,385417 |

| Tahun | Bulan | | | | | |
|---|---|---|---|---|---|---|
| | Juli | Agustus | September | Oktober | November | Desember |
| 2018 | 47,936343 | 44,652778 | 40,453704 | 45,470238 | 31,041667 | 29,851852 |
| 2019 | 31,701389 | 72,952857 | 52,654000 | 51,278935 | 35,680556 | 28,951389 |
| 2020 | 32,340278 | 45,576389 | 45,576389 | 32,449074 | 53,581019 | 51,754630 |
| 2021 | 40,866667 | 50,708333 | 51,310185 | 10,910880 | 47,967593 | 35,497685 |
| 2022 | 24,668981 | 24,326389 | 4,078704 | 40,916667 | 47,597222 | 50,586806 |

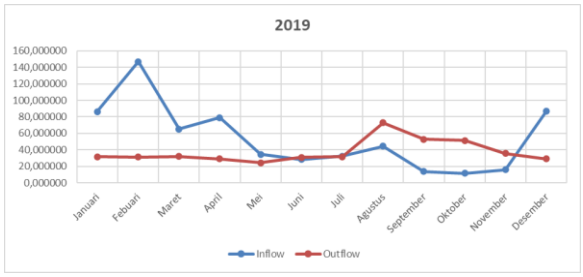



**Picture 11** . *Outflow time series* 2018-2022

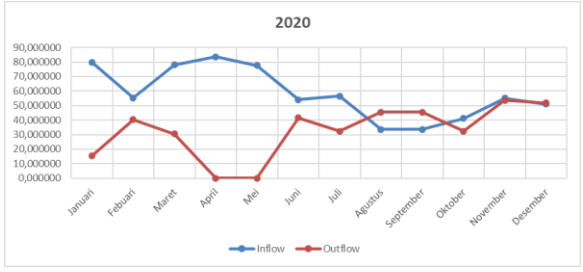
### 3.2. Annual Data in *Time series*




**Picture 12 .** *Inflow* and *outflow* of 2018




**Picture 13 .** *Inflow* and *outflow* of 2019




**Picture 14 .** *Inflow* and *outflow* in 2020

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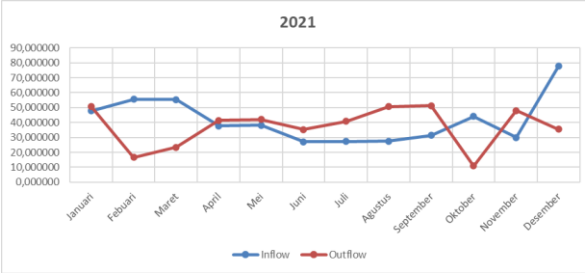
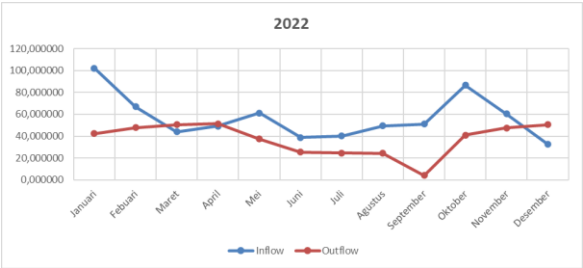



**Picture 15 .** *Inflow* and *outflow* in 2021




**Picture 16.** *Inflow* and *outflow* in 2022

3.3. In the planned year of implementing the Genetic Algorithm in 2022

**Table 4** Elevation, Inflow, Outflow in 2022

| Month | elevation | Inflow | Outflow |
|---|---|---|---|
| 1 | 269,560 | 102.147217 | 42.353009 |
| 2 | 270,020 | 66.937035 | 47.797454 |
| 3 | 269,350 | 44.090850 | 50.540509 |
| 4 | 267,450 | 49.043953 | 51.388889 |
| 5 | 267,340 | 61.074017 | 37.537037 |
| 6 | 268,080 | 38.725824 | 25.385417 |
| 7 | 267,550 | 40.123814 | 24.668981 |
| 8 | 267,470 | 49.497628 | 24.326389 |
| 9 | 269,370 | 51.057976 | 4.078704 |
| 10 | 271,040 | 86.583635 | 40.916667 |
| 11 | 270,720 | 60.461879 | 47.597222 |
| 12 | 268,040 | 32.482000 | 50.586806 |

3.4. Objective Function To Maximize Average Value

In order to maximize the average amount of energy and water released, the fitness value for a number of generation variations is the objective function.

In general, if the possibility of gene exchange is high, further research will be carried out so as not to get stuck at local optimum values.

3.5. Pattern Determination

Determining the pattern of application of the method or Genetic Algorithm (GA) is carried out by analyzing the release data in the time series and the specified year/time. The required data are:

1. Water elevation
2. Data inflow
3. Outflow data
4. Monthly average data in time series
5. The amount of inflow in the time series

Pattern application occurs in several stages to find out the optimal number.

1. Find Percentage :

$$\% = \frac{average\ in\ the\ time\ series}{total\ inflow\ in\ the\ time\ series}\ x\ 100 \quad 1$$

2. Finding optimal release using the AG method

$$AG = inflow - \left(\frac{inflow\ x\ persentase}{100}\right) \quad 2$$

3.6. Chromosome Representation

.

The representation of individual chromosomes will be determined by an artificial neural network. The number of months that will be used as process input determines the number of neurons in the input layer.

Chromosomes are a distinct set of rules for reservoir release. To convey the neurons that make up the network are finally delivered to optimal discharge.

By using the Genetic Algorithm method, the reservoir release rule is determined based on the reservoir that is considered the most optimal based on the results of the objective function and uniform alternative reservoir discharge rules in a 5 year time series.

At the completion of the operation of the Batu Tegi Reservoir in the arrangement of the chromosome shape there are 12 periods (monthly operation). This shows that there are 12 (gens) in the AG formulation. In one chromosome, all of the generated genes are bound to each other by predetermined constraints.

### 3.6.1. *Two-point Crossover*

Through several intersection points, this cross produces new chromosomes by swapping genes from one chromosome with another. The difference between two-point crossover and one-point crossover is that two-point crossover produces two random numbers as the intersection of chromosomes. In other words, one chromosome is divided into three parts and then crossed with other chromosomes.

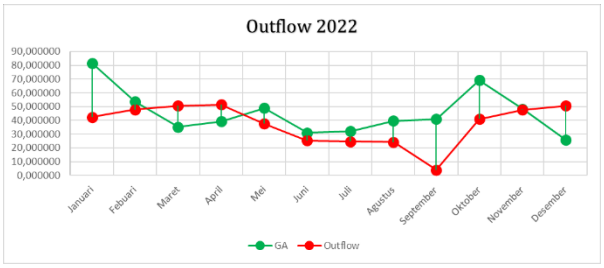
### 3.7. Analysis Results Before and After the Genetic Algorithm Method

The AG optimization process for the operation of the reservoir goes through several stages, including: the process of initialization, crossover, mutation, elitism, evaluation of fitness values, and the selection process.

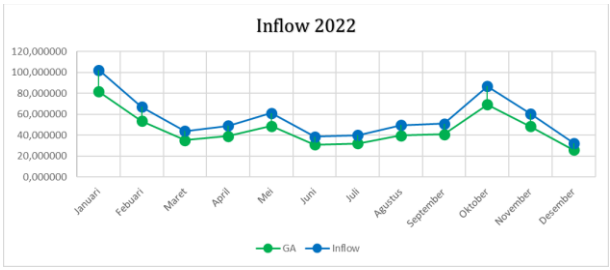
The results of applying with the 2018-2022 time series release analysis, the optimal figures can be compared/applied in the specified year.

**Table 5.** Implementation of the Genetic Algorithm in 2022

| Bulan | Elevasi | Inflow | Persentase | AG |
|---|---|---|---|---|
| 1 | 269,56 | 102,147217 | 20% | 81,717773 |
| 2 | 270,02 | 66,937035 | 20% | 53,549628 |
| 3 | 269,35 | 44,090850 | 20% | 35,272680 |
| 4 | 267,45 | 49,043953 | 20% | 39,235162 |
| 5 | 267,34 | 61,074017 | 20% | 48,859213 |
| 6 | 268,08 | 38,725824 | 20% | 30,980659 |
| 7 | 267,55 | 40,123814 | 20% | 32,099051 |
| 8 | 267,47 | 49,497628 | 20% | 39,598102 |
| 9 | 269,37 | 51,057976 | 20% | 40,846381 |
| 10 | 271,04 | 86,583635 | 20% | 69,266908 |
| 11 | 270,72 | 60,461879 | 20% | 48,369503 |
| 12 | 268,04 | 32,482000 | 20% | 25,985600 |




**Picture 17.** (Comparison of 2022 *outflow with release using the AG method)*




**Picture 18.** (Comparison of 2022 *inflow with release using the AG method)*

## 4. CONCLUSION

Given the compilation of data and analysis and exploration carried out in this method, the following results are obtained:

1. After analyzing the release of the Batu Tegi Dam, it can be used as a comparison of the optimality of the Batu Tegi Dam in 2022.
2. From the way it works, namely conveying the neurons that make up

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the network, it is finally delivered into optimal discharge.

3. After obtaining optimal results the following year can be used as a reference for BBWS in dam release.
4. Reservoir performance is more optimal in meeting the needs of the total needs. Then make the reservoir function optimally..

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