

# Water level management in the Great Lakes: a study of an integrated optimization algorithm based on Taboo search and genetic control

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**Abstract.** This article presents a single-objective Taboo search optimal water level model designed to satisfy the needs of different stakeholders, including shipping and energy interest groups, environmental and ecological protection groups, and recreational and cultural interest groups. In order to optimize the water level of the lake, the article establishes an optimization model for comprehensive satisfaction and describes in detail the calculation method and constraints of satisfaction. Through the Taboo search algorithm, the optimal water levels of five large lakes in each month were obtained after five repeated experiments. In addition, an enhanced elite conservation control model based on a genetic algorithm is presented to satisfy different stakeholder needs by adjusting the water level of the Great Lakes as well as minimizing the time required for the adjustment. Genetic algorithm parameters include probability, population size, and number of termination generations. The superiority of the algorithm is verified through the sensitivity analysis of the control algorithm and the evaluation of real data. The final results show that after adjusting the water level, the stakeholders are more satisfied with the actual water level.

**Keywords:** Water Level Management; Satisfaction; Taboo Search Algorithm.

## 1. Introduction

In balancing the competing interests surrounding environmental conservation, economic activities, and recreational pursuits in the Great Lakes region, optimizing water levels becomes paramount. Stakeholders across diverse sectors, from shipping and energy to environmental and leisure groups, express varying concerns regarding water levels, river flows, and lake velocities [1-2]. To address these multifaceted preferences effectively, sophisticated modeling techniques and optimization frameworks are essential. The focal point of this study lies in optimizing water levels across the Great Lakes region to maximize stakeholder satisfaction [3]. Stakeholders' ideal requirements, ranging from shipping companies to environmentalists and recreational users, drive the need for a comprehensive approach that considers water level adjustments, flow velocities, and historical data constraints. This complex system demands a refined optimization model that not only meets stakeholder demands but also minimizes adjustment times and operational inefficiencies.

To tackle this intricate optimization challenge, a multi-faceted strategy integrating Single Target Taboo Search and Enhanced Elite Retention Genetic Control models is developed. Leveraging Taboo Search methodology, the first sub-model optimizes water levels iteratively to enhance stakeholder contentment while avoiding local optima. Subsequently, the Enhanced Elite Retention Genetic Control model delves into the dynamic system interactions of environmental factors and control dams, aiming to fine-tune water levels promptly and methodically [4-6].

The modeling framework encompasses intricate relationships between environmental factors, stakeholder demands, and system dynamics, paving the way for precise water level adjustments across the Great Lakes. By employing innovative optimization techniques and robust algorithms, this



study seeks to harmonize stakeholder interests, improve operational efficiencies, and enhance overall satisfaction within the intricate ecosystem of the Great Lakes.

## 2. Sub-model I: Single Target Taboo Search Optimal Water Level Model

### 2.1. The Description of Stakeholder

This article considers three types of stakeholders:

Shipping and Energy Interest Group: Shipping companies, hydroelectric power generation companies, and port managers [7].

Environmental and Ecological Conservation Group: Residents living along the river, environmentalists.

Leisure and Cultural Interest Group: Recreational boaters, fishing boat users.

In the Lake Ontario subproblem, stakeholders are particularly concerned about the water level of the lake, the flow velocity of the lake, and the flow velocity of the river. Therefore, this paper has defined the ideal requirements of these stakeholders for these three factors, as table 1:

**Table 1.** the Ideal Requirements of Stakeholders

stakeholder	water level of lake	flow of lake	flow of river
shipping companies	high	low	low
port managers	low	mid	mid
residents living along river	low	mid	mid
environmentalists	seasonal high/low	mid	mid
recreational boaters	mid	mid	mid
fishing boat users	mid	mid	mid
power generation companies	high	mid	high

Next, this paper quantifies the three factors at different levels. To simplify the problem, this paper considers factors at the same level as having the same value, as Table 2:

**Table 2.** the quantified result of three factors at three levels

factor	low	mid	high
water level of lake	0.8Mean	Mean	1.2Mean
flow of lake	0.8Mean	Mean	1.2Mean
flow of river	0.8Mean	Mean	1.2Mean

Where "Mean" represents the average value of the historical data.

### 2.2. The Establishment of the Optimization Model

For a given month, this paper considers the water level that maximizes the comprehensive satisfaction of the lakes. Therefore, this paper formulates the objective function as follows:

$$\max W = \sum_{i=1}^5 \alpha_i \times Zat_i \quad (1)$$

Where W represents the comprehensive satisfaction for the month, Sati is the satisfaction for each lake, and  $\alpha_i$  is the weight for each lake.

$$Zat_i = \sum_{j=1}^7 \beta_j \times P_{ij} \quad (2)$$

Where  $P_{ij}$  denotes the satisfaction of the  $j$ -th stakeholder towards the lake  $i$ , and  $\beta_j$  is the weight for each stakeholder.

The definition of  $P_{ij}$  is given by:

$$P_{ij} = M_{ij} + N_{ij} + L_{ij} \quad (3)$$

This paper divides the satisfaction of each stakeholder for each lake into three parts, defined as follows:

$$M_{ij} = 1 - \frac{H_i - A_{ij}}{A_{iMax} - A_{iMin}} \quad (4)$$

$M_{ij}$  represents the satisfaction of the  $j$ -th stakeholder towards the water level of the lake  $i$ . Here,  $h_i$  is the water level of the lake  $i$ ,  $A_{ij}$  is the expected water level of the lake  $i$  for the  $j$ -th stakeholder,  $A_{iMax}$  is the historical maximum water level for the lake  $i$  in the given month, and  $A_{iMin}$  is the minimum.

$$N_{ij} = 1 - \frac{Vl_i - Q_{ij}}{Q_{iMax} - Q_{iMin}} \quad (5)$$

$N_{ij}$  represents the satisfaction of the  $j$ -th stakeholder regarding the flow velocity of the lake  $i$ .  $Vl_i$  is the water flow velocity of the lake  $i$ ,  $Q_{ij}$  is the expected velocity for the  $j$ -th stakeholder in the lake  $i$ ,  $Q_{iMax}$  is the historical maximum flow velocity for the lake  $i$  in that month, and  $Q_{iMin}$  is the minimum. The definition of  $Vl_i$  is as follows:

$$Vl_i = \frac{Vr_{i-1} + Vr_{i+1}}{area_i} \quad (6)$$

$Vr_i$  is the downstream river flow velocity of lake  $i$ , and  $area_i$  is the area of the lake  $i$ .

$$L_{ij} = 1 - \frac{Vr_i - U_{ij}}{U_{iMax} - U_{iMin}} \quad (7)$$

$L_{ij}$  represents the satisfaction of the  $j$ -th stakeholder regarding the downstream river flow velocity of the lake  $i$ .  $U_{ij}$  is the expected downstream river velocity for the  $j$ -th stakeholder in the lake  $i$ ,  $U_{iMax}$  is the historical maximum flow velocity of the downstream river for the lake  $i$ , and  $U_{iMin}$  is the minimum.

As the lakes are interconnected by rivers, once the water level of Lake 1 is known, the water levels of other lakes and the flow velocities of rivers can be determined. The procedure is as follows:

The water level of a lake determines the flow velocity of its downstream river, and the flow velocity of the river determines the water level of its downstream lake. Functions  $F_i$  and  $G_i$  can be approximated as follows:

$$\begin{aligned} Vr_i &= F_i(H_i) \quad i = 1,2,3,4,5 \\ H_{i+1} &= G_{i+1}(Vr_i) \quad i = 1,2,3,4 \end{aligned} \quad (8)$$

Constraint on lake water levels:

$$A_{iMax} \leq H_i \leq A_{iMin} \quad (9)$$

Constraint on lake flow velocities:

$$Q_{iMax} \leq Vl_i \leq Q_{iMin} \quad (10)$$

Constraint on river flow velocities:

$$U_{iMax} \leq Vr_i \leq U_{iMin} \quad (11)$$

So, the model for this problem is:

$$\begin{aligned} \text{Maximize } & W = \sum_{i=1}^n \alpha_i \times Z_{at_i} \\ \text{s.t. } & \begin{cases} A_{iMax} \leq S_i \leq A_{iMin} & i = 1, 2, \dots, 5 \\ Q_{iMax} \leq Vl_i \leq Q_{iMin} & i = 1, 2, \dots, 5 \\ U_{iMax} \leq Vr_i \leq U_{iMin} & i = 1, 2, \dots, 5 \end{cases} \end{aligned} \quad (12)$$

### 2.3. The Solution of the Optimization Model

Taboo Search is a heuristic search algorithm for solving target optimization problems in a large search space. It avoids local optimal solutions by maintaining a Taboo table, and guides and controls the search process by introducing Taboo strategies. The main idea of Taboo search algorithm is to maintain a Taboo table during the search process to record the searched solutions or specific moves in the solution space, so as to avoid choosing these moves again in the subsequent search. This helps the algorithm to jump out of the local optimal solution and explore more widely in the solution space. The following is the pseudocode of the Taboo search algorithm [8-9].

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#### Algorithm 1 Taboo Search algorithm

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**Input:** Stakeholder parameters

**Output:** Optimal water level for the Great Lakes

- 1: Randomly generate a solution  $i$ , and evaluate its fitness  $f(i)$
  - 2:  $s = i; k = 0; H =$
  - 3: **while** not stop **do**
  - 4:   Generate the neighbors of solution  $i$
  - 5:   based on the Taboo list  $H$
  - 6:    $A = N(i, H)$
  - 7:    $i = \text{SelectBestSolution}(A)$
  - 8:   Update the Taboo list  $H$
  - 9:   **if**  $f(i) < f(s)$  **then**
  - 10:      $s = i$
  - 11:   **end if**
  - 12:    $k = k + 1$
  - 13: **end while**
  - 14: **return** Decode the results and visualization
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Due to the randomness of the Taboo search algorithm, this paper repeated the experiment five times, took the average value of each result, and obtained the best water level of the Great Lakes in each month, as shown in the table 3.

**Table 3.** Best monthly water level in the Great Lakes

<i>Month</i>	<i>Superior</i>	<i>Michigan and Huron</i>	<i>St.Clair</i>	<i>Erie</i>	<i>Ontario</i>
Jan	183.47	176.47	175.19	174.94	74.62
Feb	183.54	176.76	174.92	174.90	74.87
Mar	183.13	177.05	175.07	175.01	74.28
Apr	183.96	176.76	175.70	175.12	75.41
May	183.98	177.79	175.18	175.20	75.86
Jun	183.42	177.02	175.82	175.27	75.76
Jul	183.92	176.23	174.62	175.29	74.19
Aug	183.76	175.73	174.81	175.25	73.53
Sep	183.53	175.32	174.75	175.17	73.85
Oct	183.04	177.42	174.75	175.06	76.05
Nov	183.25	177.65	175.66	174.98	74.72
Dec	183.63	176.71	175.05	174.98	74.39

### 3. Sub-model II: Single-target Enhanced Elite Retention Genetic Control Model

#### 3.1. The Establishment of Single Objective Optimization Model

The water level of lakes is a complex outcome of the interaction of various environmental factors. This paper categorizes the influences of the environment into two types: one includes factors such as rainfall, evaporation, and winter snow accumulation that directly affect the water level of lakes, and the other involves factors like ice blockage and reservoir policy that directly impact river flow [10]. Based on this, this paper establishes the following comprehensive inflow-outflow model for the Great Lakes:

$$\begin{aligned}
area_1 \frac{dH_1(t)}{d(t)} &= -\beta_1(t)\beta_2(t)k_1(t)Vr_1(t) + e_1(t) + e_2(t) + e_3(t) \\
area_2 \frac{dH_2(t)}{d(t)} &= \beta_1(t)\beta_2(t)k_1(t)Vr_1(t) - \beta_1(t)\beta_2(t)Vr_2(t) + e_1(t) + e_2(t) + e_3(t) \\
area_3 \frac{dH_3(t)}{d(t)} &= \beta_1(t)\beta_2(t)Vr_2(t) - \beta_1(t)\beta_2(t)Vr_3(t) + e_1(t) + e_2(t) + e_3(t) \\
area_4 \frac{dH_4(t)}{d(t)} &= \beta_1(t)\beta_2(t)Vr_3(t) - \beta_1(t)\beta_2(t)Vr_4(t) + e_1(t) + e_2(t) + e_3(t) \\
area_5 \frac{dH_5(t)}{d(t)} &= \beta_1(t)\beta_2(t)Vr_4(t) - \beta_1(t)\beta_2(t)k_2(t)Vr_5(t) + e_1(t) + e_2(t) + e_3(t)
\end{aligned} \tag{13}$$

Expressing it in differential form, as follows:

$$\begin{aligned}
area_1 \Delta H_1 &= \Delta t_1 [-\beta_1(t)\beta_2(t)k_1(t)Vr_1(t) + e_1(t) + e_2(t) + e_3(t)] \\
area_2 \Delta H_2 &= \Delta t_2 [\beta_1(t)\beta_2(t)k_1(t)Vr_1(t) - \beta_1(t)\beta_2(t)Vr_2(t) + e_1(t) + e_2(t) + e_3(t)] \\
area_3 \Delta H_3 &= \Delta t_3 [\beta_1(t)\beta_2(t)Vr_2(t) - \beta_1(t)\beta_2(t)Vr_3(t) + e_1(t) + e_2(t) + e_3(t)] \\
area_4 \Delta H_4 &= \Delta t_4 [\beta_1(t)\beta_2(t)Vr_3(t) - \beta_1(t)\beta_2(t)Vr_4(t) + e_1(t) + e_2(t) + e_3(t)] \\
area_5 \Delta H_5 &= \Delta t_5 [\beta_1(t)\beta_2(t)Vr_4(t) - \beta_1(t)\beta_2(t)k_2(t)Vr_5(t) + e_1(t) + e_2(t) + e_3(t)]
\end{aligned} \tag{14}$$

$\beta_1(t)$  and  $\beta_2(t)$  represent the factors influencing river flow due to ice jams and climate at time  $t$ , with values ranging from 0 to 1.  $e_1(t)$ ,  $e_2(t)$ , and  $e_3(t)$  represent the factors at time  $t$  related to rainfall, evaporation, and winter snow accumulation directly affecting lake water levels, measured in cubic meters per second ( $m^3/s$ ),  $k_1(t)$ ,  $k_2(t)$  is the opening levels of the dams.

In the description of the problem, it is mentioned that a normal variation of two to three inches in water level can significantly impact stakeholders. This paper assume that the range of water level adjustment does not exceed three inches:

$$-0.0762 \leq \Delta H_i \leq 0.0762 \quad (15)$$

Constraint on the opening levels of the dams:

$$0 \leq k_1(t), k_2(t) \leq 1 \quad (16)$$

This paper has two objectives: one is to adjust the water level as close as possible to the determined optimal water levels, and the other is to minimize the time required for the adjustment.

$$\min z_1 = ||H_i + \Delta H_i - HM_i||^2 \min z_2 = \Delta t_1 + \Delta t_2 \quad (17)$$

Weights are assigned to the two objectives to transform the multi-objective problem into a single-objective problem. Therefore, the overall model for this problem is:

$$\begin{aligned} \text{Minimize } Z &= \gamma_1(\| H_i + \Delta H_i - H_i \|^2) + \gamma_2(\Delta t_1 + \Delta t_2) \\ \text{s.t. } \begin{cases} \text{area}_1 \Delta H_1 &= \Delta t_1 [-\beta_1(t)\beta_2(t)k_1(t)Vr_1(t) + e_1(t) + e_2(t) + e_3(t)] \\ \text{area}_2 \Delta H_2 &= \Delta t_1 [\beta_1(t)\beta_2(t)k_1(t)Vr_1(t) - \beta_1(t)\beta_2(t)Vr_2(t) + e_1(t) + e_2(t) + e_3(t)] \\ \text{area}_3 \Delta H_3 &= \Delta t_1 [\beta_1(t)\beta_2(t)Vr_2(t) - \beta_1(t)\beta_2(t)Vr_3(t) + e_1(t) + e_2(t) + e_3(t)] \\ \text{area}_4 \Delta H_3 &= \Delta t_1 [\beta_1(t)\beta_2(t)Vr_3(t) - \beta_1(t)\beta_2(t)Vr_4(t) + e_1(t) + e_2(t) + e_3(t)] \\ \text{area}_4 \Delta H_3 &= \Delta t_2 [\beta_1(t)\beta_2(t)Vr_4(t) - \beta_1(t)\beta_2(t)k_2(t)Vr_5(t) + e_1(t) + e_2(t) + e_3(t)] \\ -0.0762 &\leq \Delta H_i \leq 0.0762 \quad i = 1, 2, \dots, 5 \\ \alpha_1 + \alpha_2 &= 1 \\ 0 &\leq k_1(t), k_2(t) \leq 1 \end{cases} \quad (18) \end{aligned}$$

### 3.2. The Solution of Single Objective Optimization Model

This paper uses the single objective enhanced elite retention Genetic algorithm (SEGA) to solve the above single objective optimization problem. Genetic algorithms rely on chromosome selection, crossover and variation to complete the evolutionary process. The genetic algorithm of enhanced elite retention in this paper is just to modify the selection operator. The classical genetic algorithm selects only once, that is, the crossed and mutated individual is unconditionally eliminated from the paternal individual. This approach has certain disadvantages, because it may eliminate the better father, resulting in slower convergence. To this end, this paper adds business retention strategy to improve the genetic algorithm. The specific algorithm steps are as follows.

**Initialize Population:** Randomly generate a set of candidate solutions as the initial population.

**Evaluate Fitness:** Calculate the fitness value for each individual based on the objective function of the problem to measure its quality.

**Selection Operation:** Statistical analysis of the current population was performed to record the optimal individual and average fitness. If the termination criteria are met, stop, otherwise continue.

**Extraction of parent:** N mothers were independently drawn from the current population.

Crossover Operation: Apply crossover operations to the parent individuals, generating new offspring. Crossover involves exchanging chromosome segments of parent individuals to introduce diversity.

Mutation Operation: Apply mutation operations to the newly generated offspring, introducing random perturbations to enhance exploration capability in the search space.

Population consolidation: A population of  $2N$  individuals was obtained by merging the parent population with the cross-mutated population.

Elite selection: According to the elite selection strategy,  $N$  individuals are selected from  $2N$  individuals to get a new generation population.

Repeat Steps 2 to 8: Iterate through these steps until reaching the termination conditions (such as a specified number of iterations or a fitness threshold).

The following is a description of the parameters involved in genetic algorithm:

$P_c$ : The probability of crossover occurrence

$P_m$ : The probability of mutation occurring

$M$ : population size

$G$ : The algebra that terminates evolution

$T_f$ : If the fitness function of any individual produced by evolution exceeds  $T_f$ , the evolutionary process can be terminated

The pseudocode for the control algorithm derived from the combination of genetic algorithm and this model is as follows.

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**Algorithm 2** Single objective enhanced elite retention genetic control algorithm

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**Input:**  $\beta_1(t), \beta_2(t), e_1(t), e_2(t), e_3(t), O_i(t), I_i(t)$

**Output:**  $k_1(t), k_2(t), \Delta t_1, \Delta t_2, \Delta H_i$

1: Initializes the algorithm parameters:  $P_c, P_m, M, G, T_f$

2: Generate the initial population

3: **while**  $t < G$  **do**

4:  $F = \text{getFitness}(k_{j1}(t), k_{j2}(t))$

5: The optimal individual and average fitness were recorded

6:  $N$  populations are extracted

7: Generate new solution by crossover and mutation

8: Crossover with a crossover probability  $P_c$

9: Mutate with a mutation probability  $P_m$

10: Accept the new solutions if their fitness increase

11: Merge the population to get a population of  $2N$  individuals

12: Select  $N$  individuals as the new generation population according to the elite selection strategy

13: Update  $t = t + 1$

14: **end while**

15: **return** Decode the results and visualization

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## 4. Comprehensive Evaluation of Control Algorithms

### 4.1. The Sensitivity of the Algorithm to The Water Output of Two Control Dams

Since the solution of the control algorithm is a heuristic algorithm, the result is not necessarily the optimal solution every time, and may hover around the optimal solution. This paper takes the input-output data of the lake and river in January 2017, and analyze the sensitivity of the algorithm to the outflow of the two control DAMS by controlling the dam influence factors  $k_1$  and  $k_2$ .

The water level of each lake in January that has not been adjusted by the control algorithm is shown in the table 4.

**Table 4.** Unadjusted water levels in each lake in January

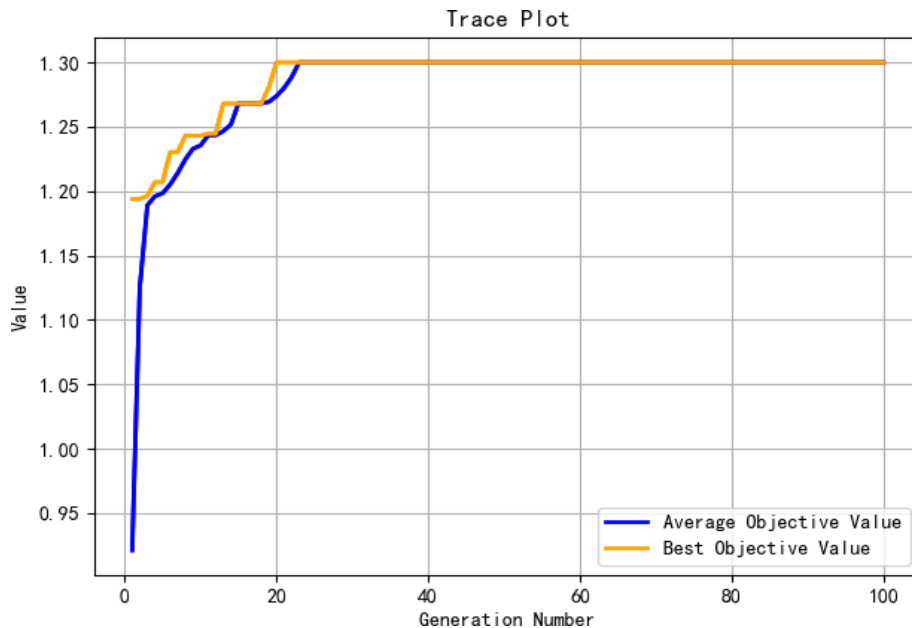
<i>Superior</i>	<i>Michigan and Huron</i>	<i>St.Clair</i>	<i>Erie</i>	<i>Ontario</i>
183.47	176.47	175.19	174.29	74.62

The flow of each river in January is shown in the table 5.

**Table 5.** River discharge in January

<i>St.Mary's</i>	<i>St.Clair</i>	<i>Detroit</i>	<i>Niagara</i>	<i>Ottawa</i>	<i>St.Lawrence</i>
2256.003	5552.933	6088.121	6320	1967	6229.706

According to the collected historical environmental data of the Great Lakes, set the environmental parameters,  $\beta_1(t) = 0.8$ ,  $\beta_2(t) = 0.9$ ,  $e_1(t)$ ,  $e_2(t)$ ,  $e_3(t)$ , and start the control algorithm. The algorithm iteration diagram is shown as figure 1:



**Figure 1.** Iterative process of genetic algorithm

The result is  $k_1 = 0.843$ ,  $k_2 = 0.238$ , and the adjusted water level is shown in the table 6.

**Table 6.** Adjusted water levels of each lake in January

<i>Superior</i>	<i>Michigan and Huron</i>	<i>St.Clair</i>	<i>Erie</i>	<i>Ontario</i>
183.52	176.53	175.33	174.65	76.55

Calculate the difference between the adjusted Great Lakes water level and the optimal water level according to the following formula.

$$S = \sum_{i=1}^5 |H_i - T_i| \quad (19)$$

Before adjustment  $S_{\text{before}} = 3.215652$ , after adjustment  $S_{\text{after}} = 0.675652$ , by changing  $K_1$  and  $K_2$ , float up and down 1%, 2%, 5%, 10%, and then find the difference between the adjusted water level of the Great Lakes and the best water level  $S$ . The results are shown in the following table 7.

**Table 7.** Adjusted water levels of each lake in January

Change	$k_1$	$k_2$	Post – fluctuation $S$	Unfluctuating $S$	Error
-1%	0.8346	0.2356	0.6844	0.6756	1.3%
-2%	0.8261	0.2332	0.6878	0.6756	1.8%
-5%	0.8008	0.2261	0.7074	0.6756	4.7%
-10%	0.7587	0.2142	0.8107	0.6756	20%
+1%	0.8429	0.2379	0.6914	0.6756	2.3%
+2%	0.8598	0.2427	0.6946	0.6756	2.8%
+5%	0.8851	0.2499	0.7046	0.6756	4.2%
+10%	0.9273	0.2618	0.8407	0.6756	24.4%

It can be seen from the results that when the fluctuation of  $k_1$  and  $k_2$  is less than 5%, the error of the algorithm can be stabilized at about 4%. When it is more than 5%, the error of the algorithm is larger, and the result is far from the optimal value. This corresponds to the characteristics of the heuristic algorithm, and it can be seen that the overall robustness of the control algorithm is good. From this, this paper can draw a conclusion that the control algorithm is sensitive to dam outflow: when the dam outflow control parameter fluctuates within 5%, the sensitivity to dam is low, and when it is greater than 5%, the sensitivity to dam is high.

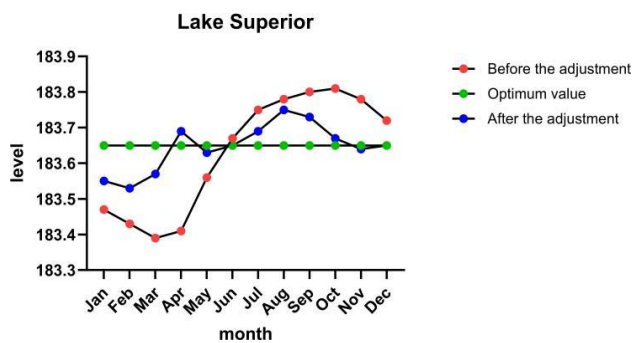
#### 4.2. Evaluation of Control Algorithms Using Real Data

Based on the data of lakes and rivers in 2017, the control algorithm is used to simulate and adjust the water level and compare the optimal water level to determine whether the actual water level will make various stakeholders more satisfied.

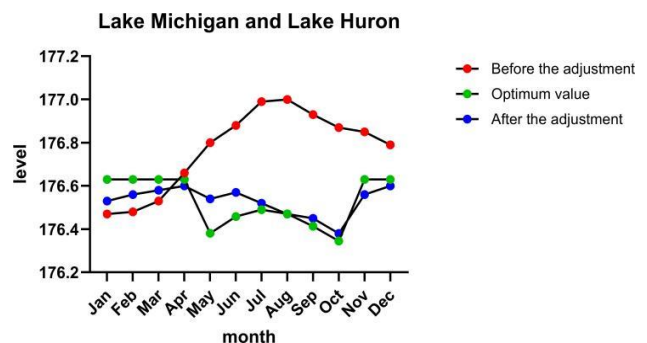
In order to describe the satisfaction degree of each stakeholder with the actual water level, this paper take the absolute value of the difference between the actual water level and the optimal water level each month, and the reciprocal of the sum is the satisfaction degree. The higher the satisfaction degree is, the more satisfied the stakeholders are with the water level.

$$Q = \frac{1}{\sum_{i=1}^5 \sum_{j=1}^{12} |H_{ij} - T_{ij}|} \quad (20)$$

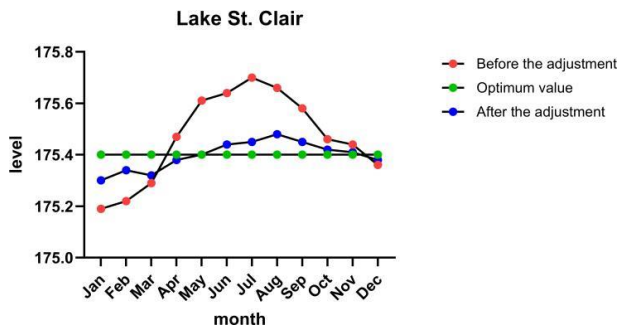
According to the control algorithm, the water level of the Great Lakes in 2017 after adjustment is obtained. The comparison figure before and after adjustment is shown figure 2 to figure 6.



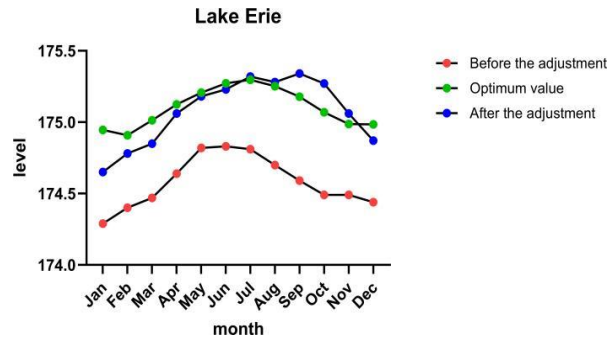
**Figure 2.** Lake Superior



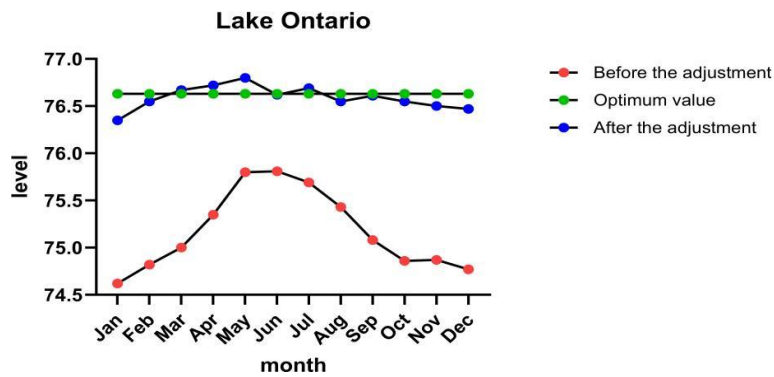
**Figure 3.** Lake Michigan and Lake Huron



**Figure 4.** Lake St. Clair



**Figure 5.** Lake Erie



**Figure 6.** Lake Ontario

Before the adjustment, the satisfaction was calculated to be 0.0321, and after the adjustment, the satisfaction was 0.275021, which increased by 7 times, indicating that after adjusting the water level using our control algorithm, all stakeholders would be more satisfied with the actual water level.

## 5. Conclusion

This paper investigates the optimization of water levels in Lake Ontario by means of a single-objective forbidden search algorithm and an augmented elite retention genetic algorithm to maximize the satisfaction of different stakeholders. Stakeholders include shipping and energy groups, environmental and ecological conservation groups, and recreational and cultural interest groups with different desired requirements for lake water levels, lake flows, and river flows.

The optimization model developed quantifies the lake and river water level and flow rate into three levels and optimizes them through a comprehensive satisfaction function, which takes into account the different weights of each stakeholder. The forbidden search algorithm was used to find the optimal lake level for each month, and the results showed that the optimal lake level varied significantly from month to month.

In addition, a single-objective augmented elite retention genetic algorithm was introduced into the study to take into account the effects of environmental factors on lake water levels and to optimize the water levels by adjusting the openings of the control dams, with the goal of keeping the levels close to the optimal values and minimizing the adjustment time. The experimental results show that the optimization algorithm can significantly improve the satisfaction of various stakeholders, and the sensitivity of the algorithm to the outflow of the control dam performs well within the fluctuation range of the control parameter, with good overall robustness.

Finally, by simulating and adjusting the 2017 Great Lakes water level and river flow data, the results show that the adjusted water level can significantly improve the satisfaction of stakeholders.

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