Scientific Research Publishing

Journal of Water Resource and Protection, 2026, 18(3), 153-167
https://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

Contribution of Hydrological Modeling to the Management of Water Level Regulation Structures: The Case of the Bango Reservoir, Senegal

Dior Diallo[1,2], Mahecor Diouf[1], Mamadou Salif Diallo[3], Abib Ndiaye[4], Mame Fatou Konteye[1], Joost Wellens[2], El Hadji Bamba Diaw[5], Bernard Tychon[2]

[1]Ecole Nationale Supérieure d'Agriculture (ENSA), Thies, Senegal
[2]Unité Eau Environnement et Développement, Université de Liège, Arlon, Belgique
[3]University Alioune Diop de Bambey (UADB), Bambey, Senegal
[4]Office des Lac et cours d'eau (OLAC), Saint-Louis, Senegal
[5]Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE, Ouagadougou), Ouagadougou, Burkina Faso
Email: agromahec@gmail.com

How to cite this paper: Diallo, D., Diouf, M., Diallo, M.S., Ndiaye, A., Konteye, M.F., Wellens, J., Diaw, E.H.B. and Tychon, B. (2026) Contribution of Hydrological Modeling to the Management of Water Level Regulation Structures: The Case of the Bango Reservoir, Senegal. *Journal of Water Resource and Protection*, **18**, 153-167.
https://doi.org/10.4236/jwarp.2026.183009

Received: January 2, 2026
Accepted: February 27, 2026
Published: March 2, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

In a context marked by climate variability and increasing pressure on the Bango water reservoir, the rational and sustainable management of water resources has become a major concern. Indeed, the Bango Reservoir plays a vital role in supplying water to various users (drinking water supply, agriculture, and industry). Today, this reservoir faces the proliferation of aquatic plants and a progressive decline in water levels. Its inflow, mainly ensured by the Lampsar River through a set of regulation structures, strongly depends on the management mode applied to these structures. Thus, the objective of this research is to contribute to the optimal management of the regulation structures of the Bango Reservoir. The methodological approach is based on the development of a numerical model aimed at understanding the hydraulic behavior of the reservoir. The modeling results show that the overlay of the reservoir land cover layer and the flow velocity contour maps indicates an absence of aquatic vegetation in areas where flow velocity exceeds 0.014 m/s. They also show that operating the Ndiol structure at 80% capacity would provide the reservoir with a volume of 19,208,592 m^3 and a surface area of 11,403,943 m^2. Therefore, opening four gates (out of five) of the Ndiol structure with a discharge of 19 m^3/s could be considered in order to increase water availability in the reservoir while limiting the development of aquatic vegetation, up to an area of 139.7 hectares.

Keywords

Reservoir, Regulation Structures, Flow Velocities

1. Introduction

Water resources have become a critical issue today, particularly in Sahelian regions where climatic, demographic, and economic pressures exacerbate water scarcity. In Senegal, this challenge is even more pronounced as water availability, both in terms of quantity and quality, has tended to decline since the 1960s due to climate variability and the continuous increase in water demand [1]. The country's main rivers, notably the Senegal and Gambia rivers, play a decisive role in meeting domestic, agricultural, industrial, and environmental water needs. In the Senegal River delta, hydraulic developments carried out over several decades, including the Diama and Manantali dams, have profoundly altered the hydrological and ecological functioning of the area, fostering agricultural development while also generating new challenges for water resource management [2].

It is within this strategic area, characterized by high water demand and multiple competing uses, that the Bango Reservoir is located. This freshwater reservoir is essential for supplying drinking water to the city of Saint-Louis, irrigation, livestock watering, and other economic activities. Its water supply mainly depends on the Gorom-Lampsar axis, a major channel in the delta extending nearly 95 km, whose operation relies on a series of regulation structures. The optimal management of these infrastructures has therefore become a key issue to ensure the sustainable availability of water in the reservoir and to meet the growing needs of populations and users.

However, despite its strategic importance, the Bango Reservoir faces numerous constraints that threaten its ability to sustainably satisfy the various associated uses. In recent years, a significant decline in water levels has been observed, despite filling operations carried out from the Bango dam [3]. This situation is exacerbated by the expansion of irrigated areas, the establishment of new agricultural schemes, the increase in drinking water demand linked to population growth, as well as the proliferation of aquatic plants that reduce water availability. Moreover, the Gorom-Lampsar axis, particularly the downstream Lampsar, is subject to substantial abstractions for irrigation purposes, which may affect the volumes diverted toward the reservoir. It is therefore necessary to exploit this resource in a rational and equitable manner, within a sustainable development perspective [4].

The performance of this axis largely depends on regulation structures such as the Ndiol-Savoigne Bridge, the Mboubène Bridge, the Ndiawdoune Bridge, and the Bango dam, whose management conditions the conveyance of water to the reservoir. However, malfunctions or inappropriate management practices may reduce the efficiency of these structures and compromise the water supply to the reservoir. Consequently, it becomes essential to assess the functioning of all these infrastructures, analyze their management modalities, and identify their actual contribution to the filling of the Bango Reservoir.

It is within this broader framework that the present research is undertaken, with the objective of contributing to the optimal management of the regulation structures of the Bango Reservoir through the use of numerical modeling tools.

2. Materials and Methods

- **Presentation of the Study Area**

The Bango freshwater reservoir is located in the lower estuary of the Senegal River, less than ten kilometers from the northeastern exit of the city of Saint-Louis. It is naturally supplied by the Gorom-Lampsar system through several regulation structures, including the Mboubène structure located at the northeastern entrance of the reservoir. The reservoir corresponds to the downstream reach of the Gorom-Lampsar-Djeuss system, which consists of a series of secondary branches of the Senegal River.

The reservoir extends over a 12 km reach between the Mboubène, Bango, and Ndiawdoune structures and is bounded as follows:

- To the north by the Bango dyke, on which the Bango structure is located;
- To the east by the departmental road D401B linking Saint-Louis to Diama, on which the Mboubène structure is located;
- To the south by National Road No. 2 (RN2);
- To the west by the villages of Sanar and Bango.

Figure 1 shows the location of the study area.

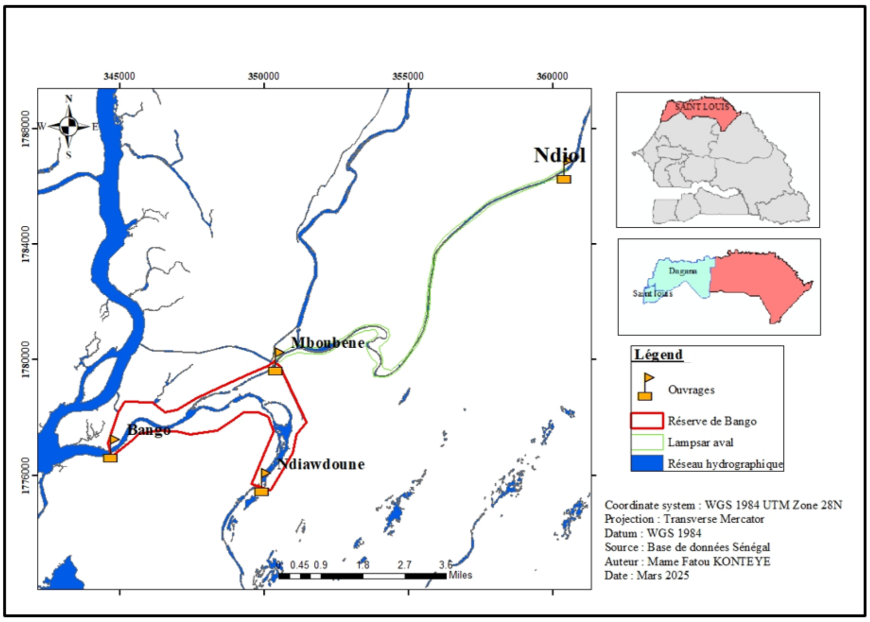

Figure 1. Location map of the study area.

- **Materials**

For the proper conduct of the study, the following materials were used (see Figure 2):

Figure 2. Equipment used (differential GPS, handheld GPS, ADCP flow meter).

1) **Differential GPS:** In this study, the Leica Viva GS14 differential GPS (with an 8 km range) was used for topographic surveys of the Ndiol-Savoigne, Mboubène, Ndiawdoune, and Bango structures.

2) **ADCP Flow Meter:** Using the boat method, the ADCP is guided across the cross-sections with a rope to measure the average flow velocity and water depth. It was used to determine the discharge of the Ndiol-Savoigne, Mboubène, Ndiawdoune, and Bango structures. Configuration is performed automatically via Bluetooth to a laptop, and the WinRiver software provides the user with all relevant information (flow profile, discharge, velocity, etc.).

3) **Handheld GPS:** Used for recording coordinates.

- **Method:**

○ *Presentation of HEC-RAS Software*:

Developed and made freely available by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers, HEC-RAS is software dedicated to simulating flows in rivers and channels. It accounts for hydrodynamic aspects, as well as concentration and temperature transport. Thus, it allows:

- Modeling of steady-state flow;
- Modeling of unsteady (transient) flow;
- Calculation of sediment transport;
- Analysis of pollution processes and water quality.

Up to version 5.0, HEC-RAS used a one-dimensional (1D) modeling approach, which limited the direct representation of hydraulic variations induced by changes in cross-sectional geometry, bed curvature, or other phenomena typical of two- or three-dimensional flows. Since version 5.0, the software allows 1D and 2D simulations, offering a more realistic representation of flows in rivers and floodplains.

HEC-RAS is widely applied in free-surface, maritime, or river hydraulics:

- Study of the impact of constructed structures (bridges, weirs, groynes);
- Dam break analysis;
- Flood studies;
- Transport of chemical tracers or pollutants.

○ ***Functionality of HEC-RAS***

HEC-RAS allows modeling of various flow regimes (subcritical, transient, and supercritical) while incorporating the effects of hydraulic structures such as bridges or weirs. It also provides the ability to simulate water quality evolution, sediment transport, floodplains, and levee breaches. Calculations can be performed under steady-state conditions (constant discharge) or unsteady conditions using hydrographs. Although its capabilities are somewhat limited, the software can also represent pressurized flow in closed conduits.

- ***Basic Equation in HEC-RAS for Unsteady Flow***

For one-dimensional unsteady flow simulation, HEC-RAS is based on the Saint-Venant equations, which model quasi-one-dimensional channel flows. This system relies on two fundamental equations: the conservation of mass and the conservation of momentum, both formulated as differential equations.

- ***Principle of Mass Conservation*** **(*Continuity Equation*)**

The principle states that the mass flow rates within a given control volume are equal to the sum of all mass flow rates entering or leaving the control volume plus the rate of change of mass within the control volume. It can be expressed as follows:

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}-ql=0$$

A = Control area (m^2);
$Q(x, t)$ = Discharge (m^3/s);
ql = Lateral flow per unit length ($m^3/m \cdot s$).

- **Principle of Momentum Conservation**

Based on Newton's second law, the principle states that any body remains at rest or in uniform motion unless acted upon by an external force that compels it to change its state. In other words, the acceleration experienced by a body in a Galilean reference frame is proportional to the resultant of the forces acting on it and inversely proportional to its mass m.

In hydraulics, only pressure, gravitational, and friction forces, as well as the net rate of momentum inflow, are considered by the software. This leads to the following equation:

$$\frac{\partial Q}{\partial t}+\frac{\partial QV}{\partial x}+A\left(\frac{\partial Z}{\partial x}+Sf\right)=0$$

A = Control area (m^2);
$Q(x, t)$ = Discharge (m^3/s);
V = Velocity (m/s);
Sf = Friction slope (calculated using Manning's equation).

- System Modeling: Steps for Constructing the HEC-RAS Model
  - Creation of Geometry

The geometry in HEC-RAS contains all the geometric information of the analyzed watercourse, including cross-sections, distances between sections, hydraulic structures, banks (bank lines, flow paths), and Manning's coefficients. These data are stored in a geometry file.

To create all the geometric data required for the HEC-RAS geometry file, the RAS Mapper component of HEC-RAS is used. This interface allows the use of satellite imagery and the import of a Digital Terrain Model (DTM). The DTM is obtained from topographic and bathymetric surveys of the downstream Lampsar and the Bango Reservoir using ArcGIS software. Figure 3 below shows the results obtained.

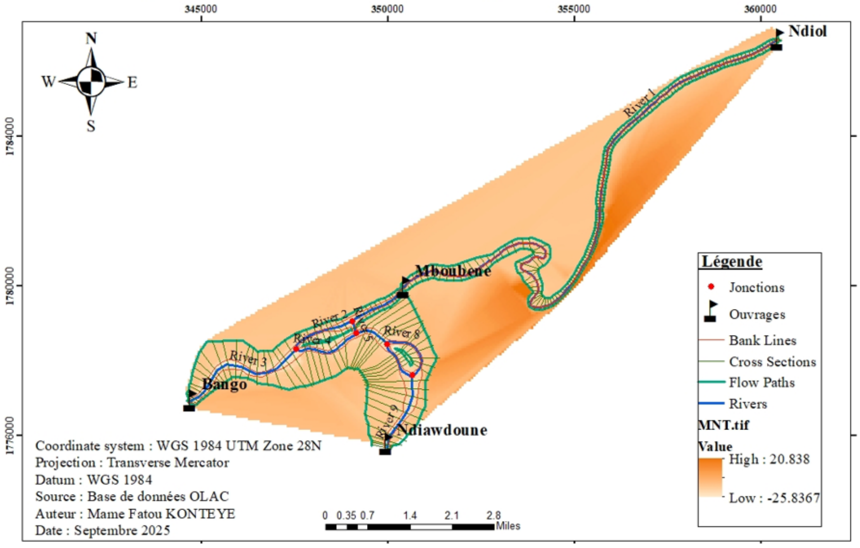

Figure 3. Overlay of the DTM and geometry components.

○ Manning-Strickler Coefficient

This parameter defines the roughness of the riverbed and helps produce a simulation that is closer to reality by accounting for the flow velocity over the riverbed and banks. It varies from one section of the channel to another depending on the physical characteristics of the material and its grain size.

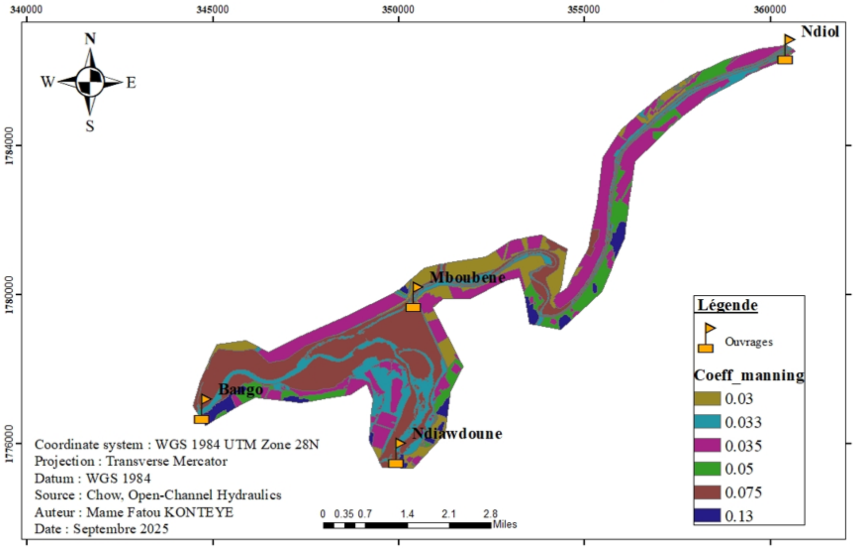

Figure 4. Map of Manning's roughness coefficient.

The coefficient can be manually entered using the **Tables** option in the Geometric Data Editor menu. Additionally, the **RAS Mapper** feature (Land Cover) allows the cross-sections to automatically adopt the Manning coefficient values corresponding to the type of substrate they traverse. Figure 4 below shows the results obtained:

○ **Insertion of Hydraulic Structures (Inline Structures)**

The downstream Lampsar and the Bango Reservoir contain hydraulic structures, and it is important to consider them in the modeling because they can significantly influence the water surface profiles.

The modeling of the Ndiol, Mboubène, Ndiawdoune, and Bango structures was performed using the **Geometry Editor**, specifying their positions, deck widths, number of gates, gate widths and heights, as well as the elevations of the channel bottom and the crest of the levee. Figure 5 below shows the results obtained.

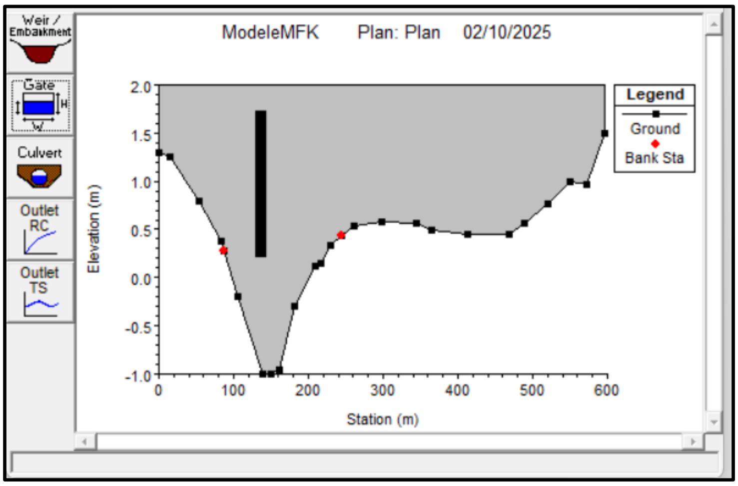

Figure 5. Editing interface for hydraulic structures.

○ **Boundary Conditions**

In hydraulic models, it is necessary to know and define the boundary conditions, *i.e.*, the hydraulic conditions of the watercourse at its limits. These can be expressed as water levels or constant or time-varying discharges. In this model, a 12-month period was considered for the study, and the input data were daily averages.

- The inflows calculated upstream of the Ndiol structure were considered as upstream boundary conditions.
- The water levels downstream of the Ndiawdoune structure and upstream of the Bango structure were considered as downstream boundary conditions.

Water level data for the Bango structure were collected from OLAC, which operates a water level monitoring system at the Bango structure. Water level data for the Ndiol and Ndiawdoune structures were obtained from SAED, which operates a remote telemetry system. Discharge data for the Ndiol structure were calculated from water level data using a stage-discharge curve.

○ **Initial Conditions**

In addition to boundary conditions, the initial conditions of the system must be established at the start of the unsteady flow simulation. Initial conditions provide information about the flow and are set using the Unsteady Flow Data Editor. They are defined as the initial water surface elevation and applied to the first section of Bank 1. In this study, the initial water level was estimated at 0.65 m, corresponding to the annual average water depth at this section.

Hydrodynamic Model Calibration

The calibration of the model in HEC RAS essentially consists of determining the appropriate Manning coefficients to reproduce the results observed in the field, as these are the parameters most sensitive to observed flow rates and water levels. However, lacking sufficient observed data to compare observed and simulated values, point flow measurements taken at the Ndiawdoune and Mboubène dams, as well as water levels observed at the Bango dam, were used as reference values for calibration. Therefore, we focused on selecting appropriate Manning coefficient values to obtain flow rate and water level ranges as close as possible to those observed. Table 1 presents the results of flow rate measurements.

Table 1. Results of flow rate measurements.

Works/sites	Speed (m^3/s)	Number of open valves	Water height (m)
Ndiol	1.47	1 et 1.2/5	
Mboubène	4.823	2/2	
Ndiawdoune	2.9	3/7	
Bango	0.079	0/6	0.85

The table below shows the results of flow measurements taken downstream of the Ndiawdoune and Mboubène dams, as well as the average water levels (in meters) observed upstream of the Bango dam. The measurement results summarized in this table served as reference values for comparing simulated and observed values. After calibration, overlaying the velocity shapefile with the land cover map reveals the velocity distribution according to land cover classes, and thus a correlation between velocity distribution and aquatic plant development.

- **Simulation**

After completing all these steps, a simulation was conducted to assess the model's behavior relative to the input data. The simulation file contains all the information necessary to run a simulation, which is defined within a Plan. This file is automatically created by HEC-RAS when a simulation is launched. Once the simulation is run, a comparison between observed and simulated values must be performed.

3. Results and Discussion

- Flow Velocity Distribution at Initial State

The HEC-RAS simulation of the downstream Lampsar and the Bango Reservoir under unsteady flow conditions allowed visualization of the flow velocity distribution within the system. Over the extent of the Bango Reservoir and the downstream Lampsar, the results show that the estimated velocity ranges from 0 to 0.159 m/s, with an average value of 0.042 m/s. Figure 6 below shows the results obtained.

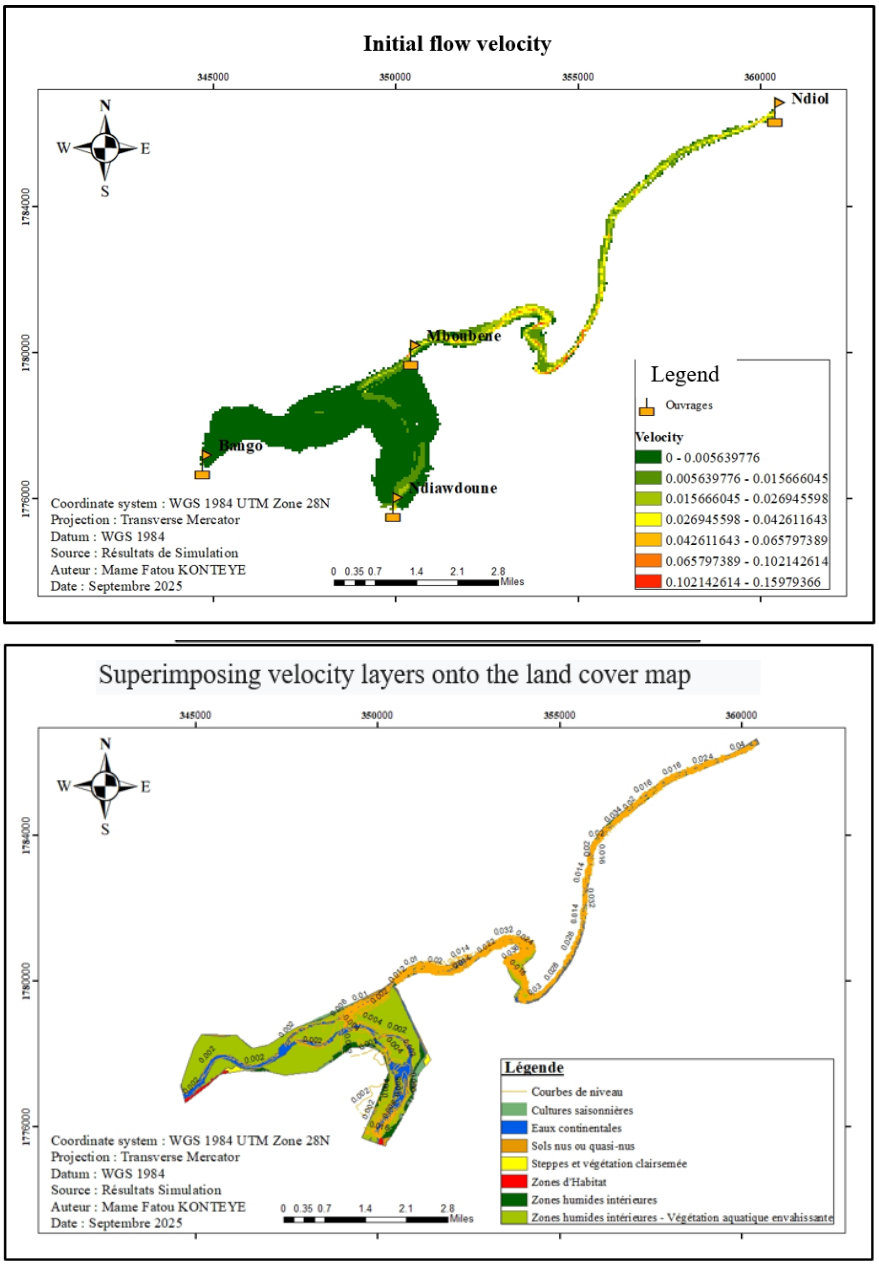

Figure 6. Flow velocity distribution at the start of the simulation—superimposing velocity layers onto the land cover map.

According to studies by ([1] [5] [6]), this situation is explained by the shallow depth of the Bango reserve, the lack of water demand (drawdown) both upstream and downstream, and the constraints related to the required water levels to be maintained downstream. Furthermore, the bed slope—comparable to that of the river delta—remains extremely low, at approximately 0.006‰ during average water periods and reaching 0.01‰ during high floods. This justifies the low velocities observed despite the imposed flow rates and conditions. An overlay of the Velocity layer and Land Cover data highlighted the distribution of flow velocity according to land cover classes. In this figure, Typha is represented by inland wetlands and invasive aquatic vegetation. The development of these invasive plants is observed in areas where velocities are very low, ranging between 0 and 0.004 m/s. The analysis of the figure shows the absence of Typha in areas where flow velocities exceed 0.014 m/s. Indeed, these results corroborate those of [7] and [8], who state that the absence of Typha is noted in areas where the minimum water flow velocity is greater than or equal to 0.014 m/s.

○ **Model Application:**

The model was applied by performing simulations while adjusting the gate opening heights of the Ndiol structure through an increase in upstream discharge, in order to analyze the effect of structure regulation on the horizontal distribution of flow velocity and on water availability in the reservoir, taking into account withdrawals by various users. Six scenarios were considered:

Scenario 1: In the first scenario, the regulation structures are present along the watercourse but are not actively used to modify the flow. The gates are set so that the incoming discharge automatically finds the required hydraulic section to continue its natural path. For the newly defined boundary conditions at these structures, the "Rule-Based Regulation" option is used. This consists of a set of rules allowing the operational management and automatic control of a hydraulic structure (gates, dams, weirs, or connections to a storage area) based on measured or calculated variables, such as discharges, water levels, time, or cumulative values.

In Scenario 1, the upstream calculated discharge at each structure is used, and the rule consists of adjusting the gate opening to pass this discharge without affecting the flow downstream.

Scenarios 2, 3, 4, 5, and 6: For the other five scenarios, user withdrawals are considered, and the Ndiol structure is opened at 20%, 40%, 60%, 80%, and 100% for respective upstream discharges of 6 m^3/s, 10 m^3/s, 14 m^3/s, 19 m^3/s, and 25 m^3/s.

- The gates of **the** Mboubène structure are opened to a height of 2.3 m;
- The gates of the Ndiawdoune structure are opened to a height of 0.9 m (4 gates out of 7);
- The gates of the Bango structure are opened minimally;
- Normal depth slope is set at 0.001 for all scenarios.

Withdrawals are implemented using the "uniform lateral inflow hydrograph" option, which is used as an internal boundary condition. This option allows a flow hydrograph to be applied and distributed uniformly along the river reach between two specified cross-section locations.

- **Simulation Results of the Scenarios**

○ Flow Velocity Contours (CN 0.014 m/s):

The flow velocity contours for the different scenarios are shown in **Figure 7**.

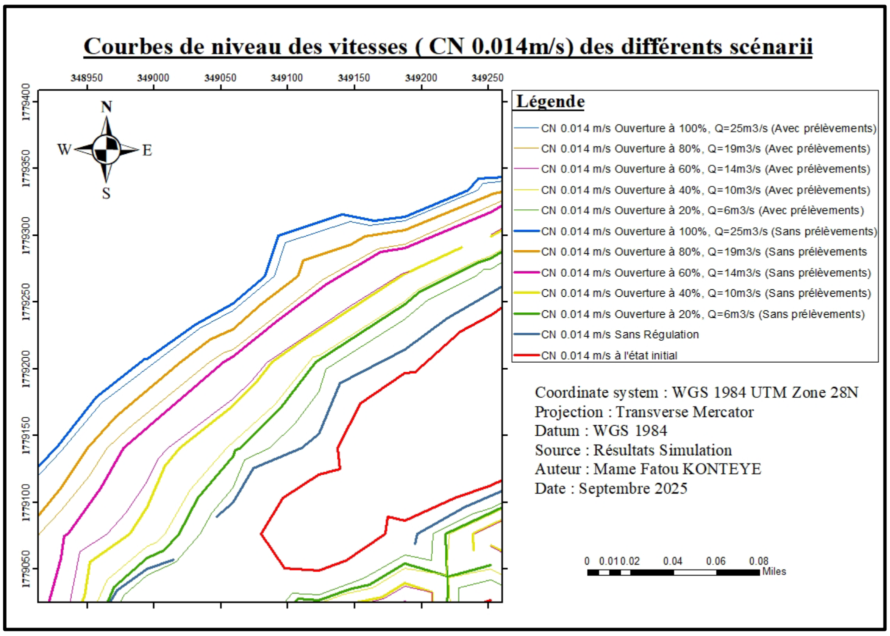

Figure 7. Flow velocity contour plots (CN 0.014 m/s) of the different scenarios.

- **Simulation without Withdrawals**

The results of Scenario 1 show a displacement of the 0.014 m/s velocity contour (CN 0.014 m/s) by approximately 30 m on either side of the initial minor channel of the Bango Reservoir. This operation could therefore help limit the spread of Typha over an area of approximately 159 ha within the Bango Reservoir. Table 2 presents the results of the different scenarios:

Table 2. Results of the different scenarios.

Scenario	Q (m^3/h)	CN 0.014 m/s displacement (m)	Affected area (ha)		
			Bango water Reservoir	Downstream Lampsar	Total area
1	0	30	159	249	408
2	6	50	76	268	344
3	10	50	98	322	420
4	14	79	145	348	493
5	19	116	189	355	543
6	25	163	225	343	568

The results of Scenario 2 show a displacement of the 0.014 m/s velocity contour (CN 0.014 m/s) of approximately 50 m on either side of the initial minor channel of the Bango Reservoir. This operation could therefore help limit the spread of Typha over an area of approximately 75.9 ha within the Bango Reservoir.

The maximum displacement is observed in Scenario 6, with the CN 0.014 m/s moving 163 m on either side of the initial minor channel of the Bango Reservoir. This operation could potentially limit Typha growth over an area of approximately

225.2 ha. The displacement of the CN 0.014 m/s relative to the minor channel of the downstream Lampsar is not very significant. Consequently, the impacted areas for Scenarios 1, 2, 3, 4, and 5 vary between 249 and 343 ha.

The results of Scenario 1 also indicate that the water volume in the reservoir ranges between 11,535,990 and 19,046,600 m^3, with an average value of 15,727,172 m^3. The corresponding planimetric surface area ranges between 7,154,935 and 11,415,388 m^2, with an average value of 9,979,047 m^2. This operation could therefore allow an increase of 719,250 m^3 compared to the initial state.

For Scenario 6 (Ndiol operating at 100% and $Q = 25$ m^3/s), the water volume of the reservoir ranges between 20,359,320 and 22,258,860 m^3, with an average value of 20,739,726 m^3. The corresponding planimetric surface area ranges between 11,561,912 and 11,818,017 m^2, with an average value of 11,603,001 m^2.

- **Simulation with Withdrawals**

The results of Scenario 2 show a displacement of the 0.014 m/s velocity contour (CN 0.014 m/s) of approximately 33 m on either side of the initial minor channel of the Bango Reservoir. This operation could therefore help limit the spread of Typha over an area of approximately 56 ha within the Bango Reservoir. This would reduce the impacted area by 26% compared to the initial scenario. Table 3 shows the impact of water velocity on the development of aquatic plants.

Table 3. Impact of water velocity on the development of aquatic plants.

Scenario	**Q (m^3/h)**	CN 0.014 m/s displacement (m)	Affected area (ha)	Difference in displaced area	Reduction of impacted area	**Variation (%)**
2	6	33	56	17	20	26
3	10	57	62	22	36	37
4	14	88	82	28	63	43
5	19	127	139	13	49	26
6	25	153	203	10	22	10

For Scenario 3, the CN 0.014 m/s velocity contour is displaced by approximately 57 m on either side of the initial minor channel of the Bango Reservoir. This operation could thus help limit the spread of Typha over an area of approximately 61.9 ha within the Bango Reservoir, representing a 37% reduction in the impacted area compared to the initial scenario.

The maximum displacement is observed in Scenario 6, with the CN 0.014 m/s moving 153 m on either side of the initial minor channel of the Bango Reservoir. This could limit the spread of Typha over an area of approximately 203.4 ha, corresponding to a 10% reduction in the impacted area compared to the initial scenario.

The simulation results for the various scenarios considering withdrawals show that the average water volume of the reservoir ranges from 14,106,137 m^3 in Scenario 2 to 20,476,055 m^3 in Scenario 6. The corresponding average planimetric surface area ranges from 9,187,858 m^2 to 11,574,688 m^2. For Scenario 2, this operation would reduce the average water volume by 4.4% and the average surface area by 4.64% compared to the initial scenario.

The analysis of Scenario 1 showed that the behavior of the downstream Lampsar and the Bango Reservoir, in the absence of pre-defined management rules for the structures, roughly reproduces the natural state of the river without the structures. In this case, saline water intrusion could extend up to 3.74 km upstream of the Bango structure.

The results of the other scenarios indicate that an increase in upstream discharge significantly reduces the area occupied by invasive aquatic vegetation in the Bango Reservoir. Indeed, increasing the gate openings increases the discharge, which in turn raises the flow velocity. Higher velocities can delay the development of aquatic plants by preventing the sedimentation of suspended materials. Moreover, because the Bango Reservoir is a wide water body with a large floodplain, the displacement of the CN 0.014 m/s contour is very pronounced, leading to a significant increase in the impacted areas.

However, when withdrawals are taken into account, the same gate-opening scenarios result in reduced cross-sectional areas and, consequently, smaller impacted areas. In some cases, a reduction in impacted area of up to 43% was observed. This is explained by the fact that withdrawals decrease the flow, which in turn reduces the extent of areas affected by increased velocity.

An increase in reservoir capacity is also observed when the gate opening height of the Ndiol structure is increased along with a rise in upstream discharge. Indeed, water volumes of up to 20,000,000 m^3 were recorded. This is because the filling of the Bango Reservoir is largely ensured by the Lampsar, so an increase in upstream discharge positively affects the reservoir.

Overall, the analysis of all scenarios indicates that fully opening all gates of the Ndiol structure with an upstream discharge of 25 m^3/s can minimize the impact of withdrawals on aquatic vegetation development and maintain water availability in the reservoir.

For the downstream Lampsar, the configuration of the floodplain does not allow a significant increase in width, which explains the relatively minor variation in impacted areas despite increasing the gate opening height of the Ndiol structure.

4. Conclusions

The study of the management of regulation structures along the downstream Lampsar and their impact on the filling of the Bango Reservoir showed that for the Ndiol, Ndiawdoune, and Bango structures, the difference between the initial channel bed elevation and the measured elevation was almost zero. However, for the Mboubène structure, a difference of 0.26 m was observed, confirming the deterioration of this structure.

For the downstream Lampsar, maximum withdrawals by all users occur in February, reaching 2.25 m^3/s. Similarly, for the Bango Reservoir, withdrawals reach 1.74 m^3/s. Direct withdrawals by ETP represent the largest share, accounting for 41% of the total reservoir withdrawals. These results served as the basis for hydraulic modeling aimed at evaluating the impact of gate management on the operation of the Bango Reservoir.

The modeling tests showed that across all scenarios, the highest average reservoir surface area was 11,603,001 m^2, with a water volume of 20,739,726 m^3. However, when withdrawals are taken into account, reductions of 0.24% and 1.27% are observed in the average surface area and total reservoir volume, respectively.

The study also showed that operating the Ndiol structure at 80% (4 out of 5 gates) would limit the development of aquatic vegetation over an area of 139.7 ha, representing 16.4% of the total reservoir area. When withdrawals are considered, a 26% reduction in impacted area is observed. This operation results in a water volume of 19,208,592 m^3 with a surface area of 11,403,943 m^2. Therefore, opening four gates (out of five) of the Ndiol structure with a discharge of 19 m^3/s could be considered to increase water availability in the reservoir while limiting the spread of aquatic vegetation over a large portion of the reservoir.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Camara, S. and Bangoura, A. (2017) Valorisation des ressources en eau en Guinée en vue d'un développement économique et social durable. *Journal of Water and Environmental Sciences*, **1**, 106-114.

[2] Mietton, M. (2008) Le delta du fleuve Sénégal Une gestion de l'eau dans l'incertitude chronique.
https://www.academia.edu/download/70698063/Le_delta_du_fleuve_Sngal_Une_gestion_de_20210930-18786-1tcr1ic.pdf

[3] Philippe, C., Kane, A., Handschumacher, P. and Mietton, M. (1998) Aménagements hydrauliques et gestion de l'environnement dans le delta du fleuve Sénégal. In: Pratiques de gestion de l'environnement dans les pays tropicaux, PU BORDEAUX, 389-401.

[4] Diop Kane, A., Niang Diop, I., Niang, A. and Dia, A.M. (2003) Coastal Impacts of Water Abstraction and Impoundment in Africa. Cas du bassin du fleuve Sénégal. LOICZ/START AfriCat Foundation Project. Cheikh Anta Diop University.

[5] Niang, T. (2020) Etude et suivi spatio-temporelle du typha dans la zone du Bango de 2016 à 2020.

[6] Mamadou, D. (2020) Etude hydrolopgique de la réserve de Bango (essaie de modélisation du plan d'eau), Génie Rural, Thiès: Ecole Nationale Supérieure d'Agriculture.

[7] Sabo, A. (2022) Apport de la modélisation hydraulique dans la gestion de la réserve de Bango: Modélisation des écoulements avec HECRAS et impact de la vitesse du courant sur le développement de végétaux aquatiques, Génie Rural, Thiès: Ecole Nationale Supérieure d'Agriculture.

[8] Sonko, A. (2023) Modélisation de l'impact des vitesses d'écoulement et du changement

climatique sur la disponibilité et le développent des végétaux aquatiques dans la réserve de Bango à l'horizon 2100, Génie Rural, Thiès: Ecole Nationale Supérieure d'Agriculture.