REVIEW ARTICLE

Enhancing baffle columns' performance to mitigate sedimentation at intake structures

Wail A. Fahmy[1] · Abdelazim M. Ali[2] · Mohamed N. El-Bahlol[2] · M. M. Ibrahim[1] · Abeer Samy[1]

Abstract

The improvement and capacity increasing of hydropower stations have brought attention to the intake structures of water-cooling systems, which suction water from alluvial channels. The accumulation of sediment in the vicinity of these intake structures poses significant operational challenges, such as strong vortices, and irregular flow distribution at pump intakes. One effective approach is the implementation of a sediment deflector system using baffle columns as avoided wall (L-Shape profile) with specific dimensions and arrangement to allow water to go through while preventing sediment ingress into the power station intakes. L-Shape profile means double voided walls, one of them parallel to flow direction while the other wall perpendicular to the flow direction in the upstream of the intake structure. The objective of this study is to optimize the performance of the baffle columns of the deflector system in mitigating sedimentation in front of the intake structures. To achieve this, an undistorted physical model with scale 1:50 is utilized to analyze the impact of a defined angle between the two voided walls of the deflector system. Three trials by changing the angle of the double voided walls (L-Shape profile) from 90° to 120°,135°, and 150°. The results of this study indicate that as the inclination angle of the deflector system increased to 150°, it resulted in uniform flow efficiency in the direction of the flow, less accumulative sedimentation ingress the intake.

Keywords Baffle columns · Deflector system · Physical model · Sedimentation

Introduction

Water intakes were established on river sides to achieve the task of water abstraction and diversion (Dereja 2003; Erbisti 2005). The management of sediment flow within a river channel relies on three primary factors: competence, capacity, and sediment supply (El Saeed et al. 2016). The morphological changes in the bathymetry of alluvial channels, resulting from water suction through intake structures, necessitate investigations to identify sedimentation areas and quantities that obstruct water flow into the intake. Various approaches have been proposed to mitigate sediment accumulation near intake structures. Initially, dredging was employed as a temporary solution for intake structure maintenance (Bosman et al. 2002). However, continuous suction forces at the intake led to sediment accumulation, rendering dredging ineffective. Submerged vanes and groins were found to be effective in reducing sediment (Emamgholizadeh et al. 2008). Despite their effectiveness, submerged vanes' crest levels could obstruct navigational channels, and localized scour and sediment deposition between the vanes necessitated additional dredging efforts, as reported (Abdelazim et al. 2007). Using oblique vanes with angle 40° decreased the sedimentation ingress of the intake structure by 40% to 75% (Fahmy et al. 2008a, b). However, the triple vane rows of that were evaluated under the considered conditions are reduced the sediment by 50–90%, while for case of double rows of vanes reduced the sediment by 50–85%. Numerous

✉ Mohamed N. El-Bahlol
  mohamednabil.mn673@gmail.com

  Wail A. Fahmy
  wael.ahmed@feng.bu.edu.eg

  Abdelazim M. Ali
  azim1@hotmail.com

  M. M. Ibrahim
  mohamed.ibrahim@feng.bu.edu.eg

  Abeer Samy
  abeer.samy@feng.bu.edu.eg

1 Civil Engineering Department, Shoubra Faculty of Engineering, Benha University, Shoubra, Egypt

2 Hydraulics Research Institute, National Water Research Center, Cairo, Egypt

attempts have been made to mitigate the adverse effects of vanes on channel bathymetry (Mahgoub 2013).

Basser et al. (2014) suggested a spur dikes system to address control flow direction and negative effects from the resulting scour zone. A combined system with skimming walls and spur dikes was proposed to enhance flow rates toward the intake and reduce sediment accumulation. However, the system had weaknesses, including local scour around spur dikes and the inclination angle of skimming walls, leading to undesired effects on the alluvial channel's bathymetry.

To address these challenges, (Abdellatif 2017) investigated a novel approach involving baffle columns to reduce or eliminate vortex activities near intake structures without impeding regular dredging of the sedimentation basin. This approach also ensures that the operation and maintenance of the intake structure remain unaffected (Ansar and Nakato 2001; Keichler 2004). Numerous researchers have sought to enhance pond efficiency by adjusting elements such as pond layout, inlet and outlet design, deflector islands, floating treatment wetlands, and baffles (De Oliveira et al. 2011; Nighman and Harbor 1997; Shabayek 2010). The baffle columns system includes the placement of posts on the top of the upstream side and the offshore long side of the sedimentation basin of the intake structure with specific dimensions, length, height, angle, and arrangement, to prevent sediment from entering the power station's intakes to be used effectively to act as anti-vortex devices (Gogus et al. 2016). The porous baffles improved the pond's hydraulic performance, regardless of their characteristics. Solid baffles also enhanced retention times and hydraulic efficiencies to some extent but were notably less effective than porous baffles due to increased water velocity resulting from reduced flow areas over the baffles (Farjood et al. 2015). The optimal shape for the baffle columns deflector system, consisting of two L-shaped walls, was identified through numerical and physical modeling (Khater and Ashraf 2017). Through numerical and physical modeling, the dimensions were carefully determined, considering various alternatives. This process resulted in identifying the optimal dimensions that minimize sediment accumulation in front of the intake structures by 67% from the calibrated physical model conclusion, however the sedimentation volume in front of the intake structure reduced by 76% by using validated numerical model (Gamal et al. 2020a; b). However, the sharp angle formed by the L-shaped walls can induce local scour zones (Radwa 2021).

The primary objective of this study is to explore methods for mitigating the adverse effects of sharp edges on the stability of the deflector system caused by scour zones around the right angle of the voided wall. Additionally, the research aims to reduce sediment activities in the vicinity of the intake structure. To achieve these goals, a physical undistorted movable bed model at a scale of 1:50 is employed to simulate flow patterns and morphological changes near the intake structure using different alternatives for the baffle columns. The aim is to minimize sediment ingress into the intake while considering the morphological aspects of the channel.

Materials and methods

The methodology and the criteria that are adopted to improve the performance of baffle Columns System consist of the following steps as shown in (Fig. 1).

In the initial phase, data are collected on the bed morphology, spatio-temporal flow, and sediment quantities. Subsequently, a preliminary analysis is conducted to gain initial insights and identify data patterns and trends. As clarified in the introduction section, which covered the review of previous research addressing the issue of sedimentation in front of intakes and the stages experienced until reaching the system of baffles. The discussion then focused on how to develop the form and dimensions of this system until we arrived at the shape we are currently developing in this study.

The next phase, data collection and bathymetric surveys are conducted for a specific area. Sediment analysis is then performed to quantify sediment types and quantities, analyzing sediment transport dynamics.

Moving into the modeling and simulation phase, a physical model is developed based on the collected data. The behavior of the river with baffle columns is simulated to understand its dynamics.

Results are evaluated to assess the effectiveness of baffle columns and compare them with the initial analysis. Finally, the findings are summarized, and conclusions are drawn based on the analysis.

Field measurements and data collection

The hydraulic research institute (HRI), affiliated with the National Water Research Center (NWRC), conducted a field survey of the bathymetry along the Nile River in 2015, a hydro power station with an intake structure suitable for physical modeling. The topographic survey covered a distance of 5.0 km of the river Nile at the study area, (Fig. 2a). The topographic survey was carried out using a hand-held unit of the GPS. The location of the all-land facilities, (roads, banks, structures), were surveyed and attached to the contour maps. Bathymetric survey of the Nile River was carried out by Sounding using Echo sounder that installed on a rubber boat, (for water depth measurements), attached to a GPS unit, (for position measurements. Intensive bathymetric survey around the existing structures within the surveyed area (groins, intakes or outfalls structures, islands, etc.) was implemented. The measured data are used to develop
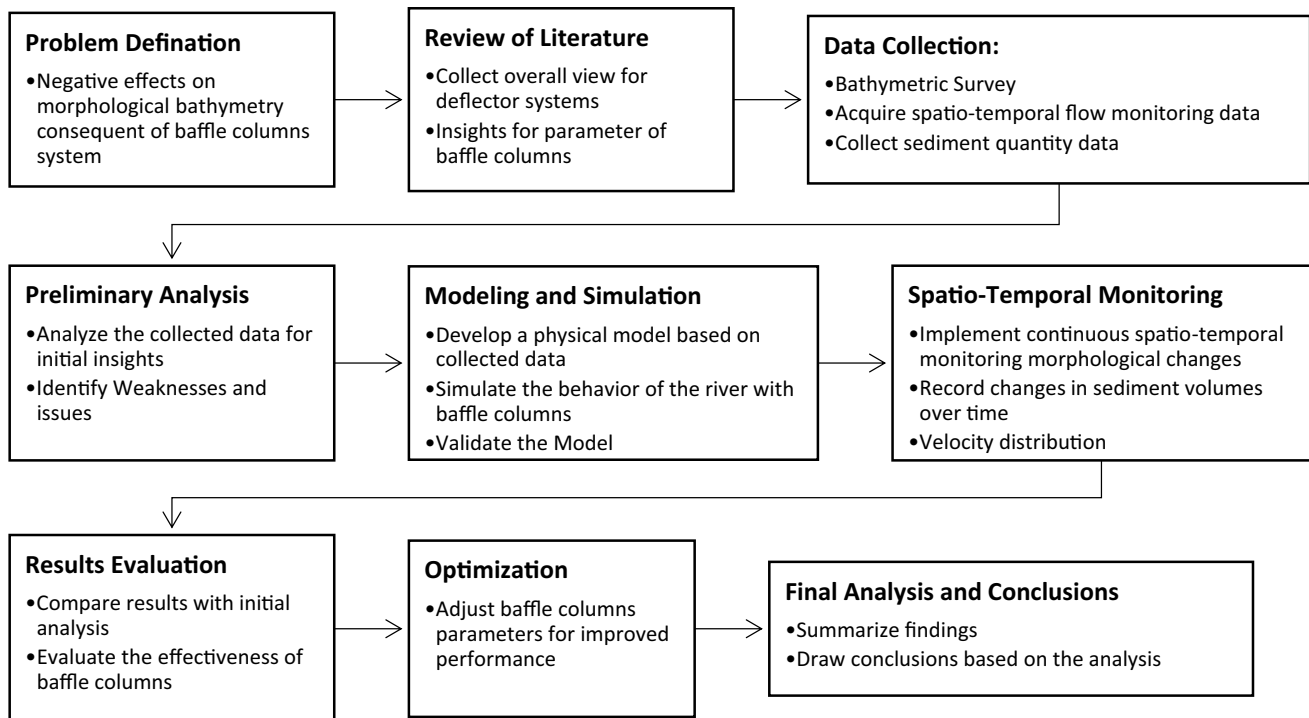
Fig. 1 Methodology flowchart

a contour map using SURFUR software. The developed contour map was produced with UTM coordinate system and 0.5 m contour step and finalized by the AUTOCAD software. Propeller current meters were used for measuring the velocity distributions at eight cross sections covering the surveyed area. Two velocity measurements were carried out to determine flow discharges for model calibration and corresponding water levels using ADCP for discharge measurements, as shown in (Fig. 2b).

Physical model

The use of physical models for simulating field conditions and predicting morphological processes enhances the accuracy and credibility of the results (Tsou et al. 1994). To ensure accuracy, an undistorted model with a constant scale ratio in all dimensions (length, width, and depth) was selected. Dynamic similarity was sought, which implies that the forces in the model maintain a fixed ratio to those in nature. In the case of free surface flow, relevant forces include inertia, gravity, buoyancy, and viscosity.

Model description

The physical model used in the study has a geometric scale of 1:50 and occupies an area of approximately 1008 m² (56 m × 18 m) within the experimental hall of the HRI. The

model represented a 2.7 km section of the Nile River. The model entrance was a shallow sloping basin, positioned at a lower elevation compared to the modeled reach. The basin floor was constructed with a brick wall covered with cement mortar, extending to a height above the highest point of the modeled reach. To control the surface water slope within the model, a flab gate measuring 12.0 m in width is installed at the end of the model (as shown in Fig. 3b).

The Froude Number, a dimensionless parameter, represents the ratio between inertia forces and gravity force and is considered as a key factor in the analysis. The value of the Froude number can be calculated from the following equation ($Fr = \frac{V}{\sqrt{gh}}$). Where, Fr: Froude number, v: average flow velocity (m/s), g: gravitational acceleration (m/s²), and h: Mean flow depth (m). As the model constructed according to the Froude similarity, then the velocity, discharge and time scale ratios are derived from the following equations:

$$n_v = n_l^{0.5} \quad n_t = n_l^{0.5} \quad n_q = n_l^{2.5}$$

With substitution in these equations by the geometric scale (n_l) was chosen to be 1:50, the following scales were obtained: The velocity scale (n_v) 1: 7.071, The discharge scale (n_q) 1: 17,677.67, and the hydraulic time scale (n_t) 1: 7.071. The sediment time scale was essentially the ratio of times in the prototype and model to build the same feature out of sediment (HRI Report 29 2017).
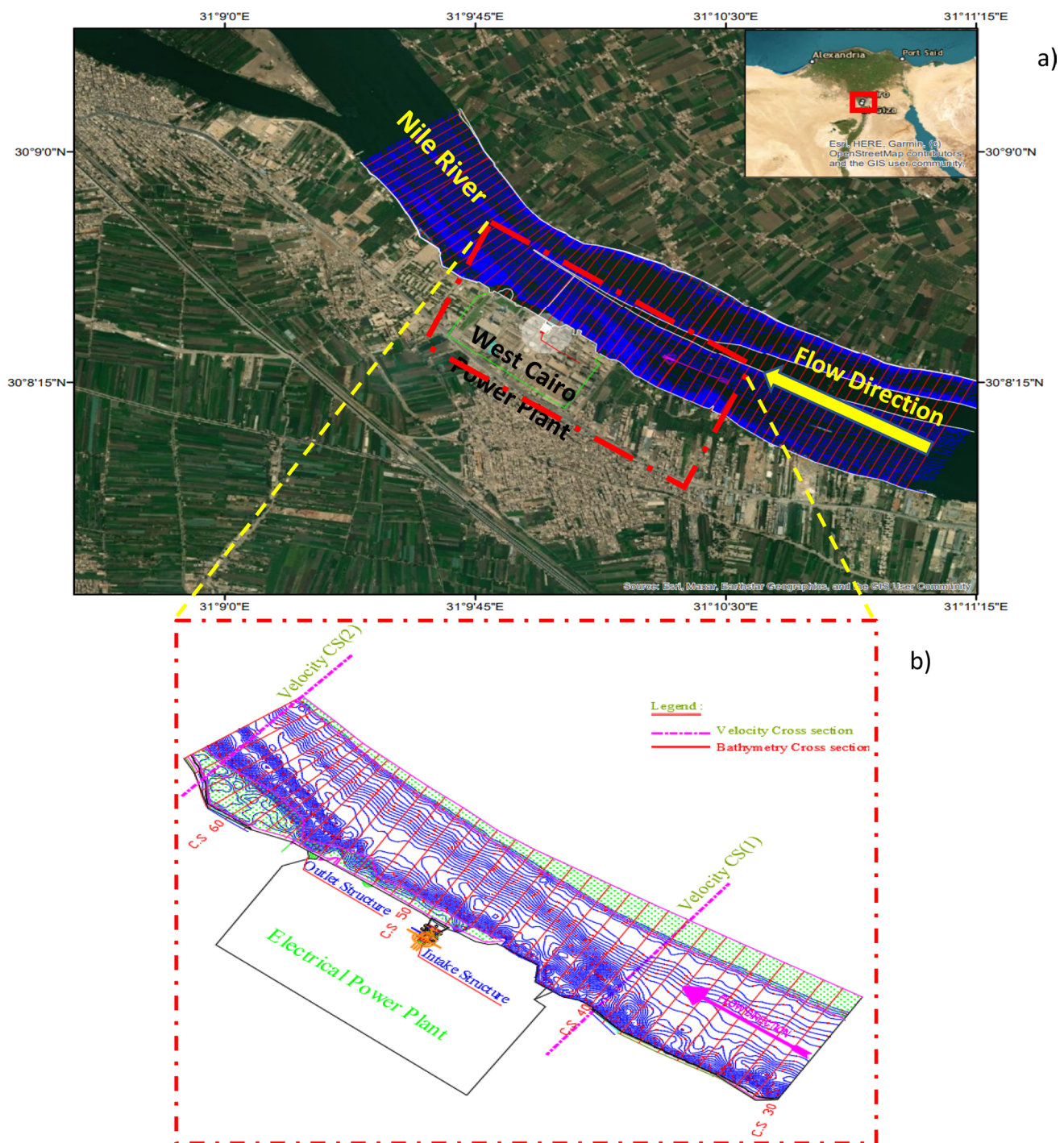
Fig. 2 General layout of the field: **a** Egypt map overview showing field survey work, and **b** Study area showing bathymetry and velocities sections locations

The sediment time scale is essentially the ratio of times in the prototype and model to build the same feature out of sediment, or to fill a certain volume with sediment. And based on studies done by SOGREAH, an empirical formula was developed from calculating the time it took for bed forms to migrate and defined volumes to fill with sediment in the construction of their physical model of the Seine River Estuary. It was found that the sediment time scale ratio is a multiplication between the time scale ratio as stated by Froude similarity laws and the submerged particle density ratio (Belleudy et al. 2000).

Fig. 3 The model configuration: **a** model entrance, **b** model exit gate, and **c** modeled bathymetry

$$N(ts) = N(T) * N(\rho s - \rho)$$

where $N(ts)$: morphological time scale, $N(t)$: hydrodynamic time scale, ρs: sediment density, ρ: density of water

The following equation is used to calculate submerged particle density scale ratio.

$$\text{Submerged particle density scale ratio}(n) = \frac{\rho p - \rho}{\rho m - \rho}$$

where ρp sediment density in the prototype, ρm sediment density in the model, ρ density of water

From the previous equation, the time duration for the model can be calculated, representing two consecutive months in prototype requires running the physical model for 8 continuous hours, which is the maximum period for flow stability, whether maximum or minimum flow.

The model features a clayey soil bed covered by a thin layer of cement mortar, topped with a layer of lightweight material to study morphological changes (as shown in Fig. 3c). The lightweight material was spherically shaped particles with specific gravities as low as 1.05 and particle sizes as small as 60 to 100 microns, which was significantly influenced by morphological changes (HRI Report 34 2015). It was characterized by its ability to interact and respond to alterations occurring in the bed of the alluvial channel.

The hydrographic and topographic surveys conducted in 2015 provided global coordinates for various cross sections within the study area. These cross sections were subsequently scaled down to match the dimensions of the model and positioned accurately based on their original coordinates. Guide wooden frames were utilized to shape the cross sections, forming the structure of the riverbed in the model.

Model calibration Velocity profiles were obtained at two cross sections within the prototype and distributed across the surveyed area. Cross section Vel (1) was positioned upstream of the intake, while cross section Vel (2) was located downstream. The model calibrated using these cross sections. Additionally, the water surface slope in the model was adjusted to match that of the prototype. The calibration process involved a river discharge of 1010 m³/s and a water level of 16.66 m + MSL, reflecting the flow conditions during the survey conducted by HRI on April 20, 2016. Velocity measurements were taken at mid-water depth in both the prototype and the model.

Following several attempts, successful calibration was achieved at the designated measuring cross sections with matching of 98% and 95% for Velocity cross Sects. (1) and (2) respectively (as mentioned in Fig. 4). The roughness of the model which is the calibration parameter was adjusted by adding some grass in the bank levels in the model to get the best matching between hydrodynamic flow conditions in both model and prototype (HRI Report 59 2016). The slope of the water level in the model was determined based on measurements of the water level surface and was found to align with the measurements obtained in the prototype.

Model test program The discharge of the model was obtained from hydrograph for Nile River flow over 10 years
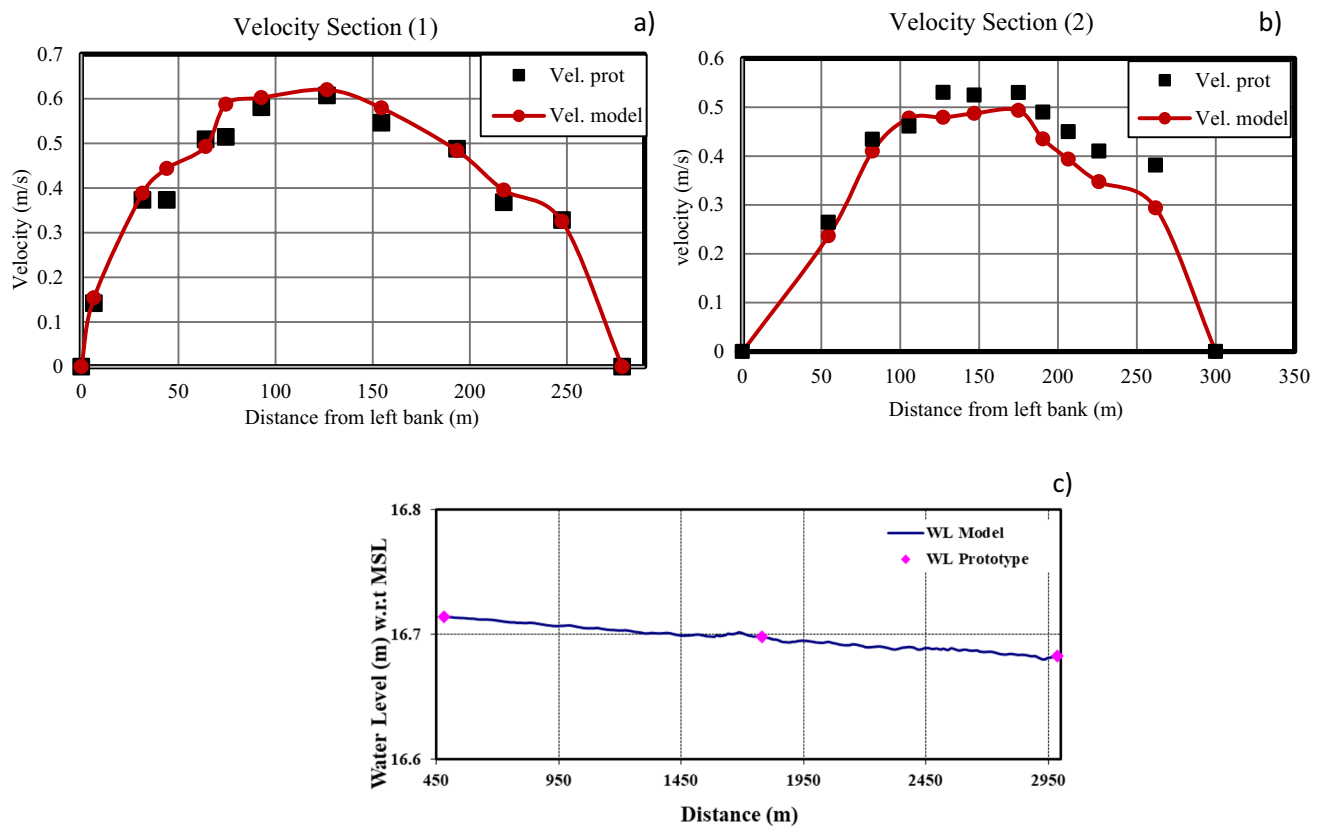
Fig. 4 Model calibration: **a** velocity cross Sect. (1) calibration, **b** velocity cross Sect. (2) calibration, and **c** water slope calibration

(from 2007 till 2017) (Gamal et al. 2020a; b). These values were 1883 m³/s for max flow with corresponding water level (WL) 16.69m, 662 m³/s for minimum flow with corresponding WL 16.50m.

Original bathymetry tested to get a reference result to compare with the results of using deflector system. The model test was depending on the variability of the rotational angle of the two walls of (L-shape profile) (Khater and Ashraf 2017). The alternatives of the right angle ($\theta = 90°$) of these walls were at angle $\theta = 120°$, $\theta = 135°$ & $\theta = 150°$ (obtuse angle) to get the least amount of sedimentation and uniform flow distribution to avoid or minimize vortex activities (as shown in Fig. 5).

The general dimensions for the deflector system obtained by physical model as shown in Fig. 4. These dimensions were the spacing between posts equal the width of the post ($Ls = b_b$), the far distance of the parallel wall equal the width of intake ($d = W_{Intake}$), the rotational angle of the post with respect to flow direction $\theta = 90°$ for the parallel wall but for the perpendicular wall the posts are parallel to the flow direction (Gamal et al. 2020a, b). The tested Columns dimensions were 50 cm width (b_b) and 100 cm depth (W_b) concluded with 3 alternative physical

test (Abdellatif 2017). These alternative dimensions are derivable from the equation of the spatial density of the baffle posts) circular posts) ($B_{eff} = B$—KnD) (Ubing 2015; Julien 2002). Where, B: width of the channel (m), B_{eff}: effective width of the channel (m), K: the contraction coefficient, n: number of columns, and D: post diameter (m).

The test program was 10 scenarios, can be explained (as shown in Table 1). Test 1 & 2 are the base case without deflector system to be reference for results with minimum and maximum flow conditions with corresponding WL. The suction flow of the intake (Q_{intake}) was 50 m³/s (max value for the pump station capacity). Test 3 & 4 represent the base case in Test 1 & 2 with adding a deflector system double wall (L-shape profile) with right angle between the wall, parallel to flow direction, and the second wall perpendicular to flow direction, and the tested angle of the baffle posts is perpendicular to the flow direction for the straight wall, and parallel to flow direction for the perpendicular wall. However, tests 5 & 6 change the right angle to an obtuse angle 120° but the angle of baffle columns is fixed. Tests 7 & 8 try an angle 135°.And finally, test 9 & 10 with angle 150°.
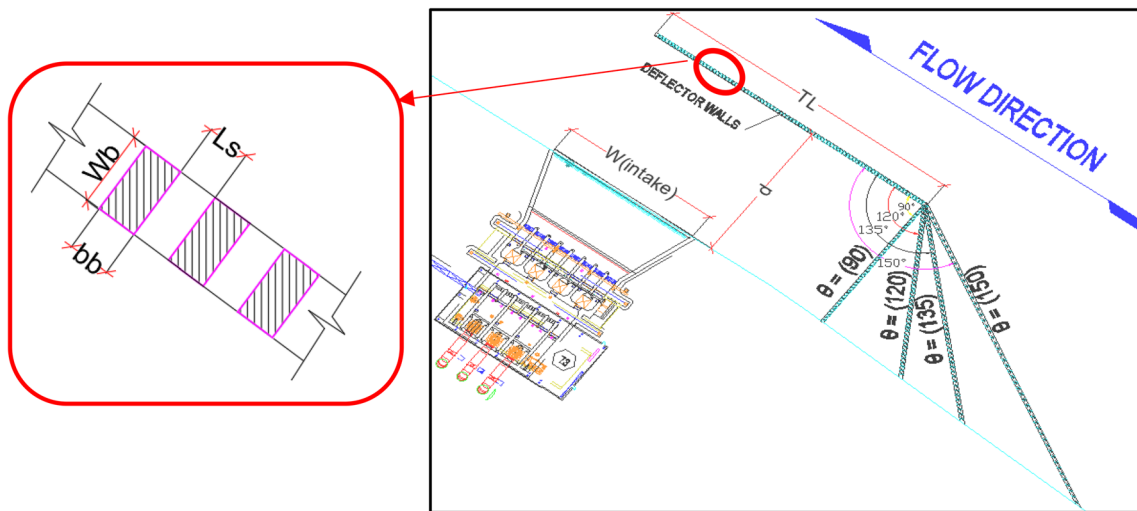
Fig. 5 Alternatives for the tested angles of the deflector walls

Table 1 Test program with variable parameters

Test No	Test name	Deflector	$Q_{channel}$ (m³/s)	Q_{intake} (m³/s)	W. L (m)	Θ
1	(Without Def., Max Q)	Without	1883	50	16.69	0
2	(Without Def., Min Q)	Without	662	50	16.5	0
3	(With Def.,90, Max Q)	With (L-shape profile)	1883	50	16.69	90
4	(With Def.,90, Min Q)	With	662	50	16.5	90
5	(With Def.,120, Max Q)	With	1883	50	16.69	120
6	(With Def.,120, Min Q)	With	662	50	16.5	120
7	(With Def.,135, Max Q)	With	1883	50	16.69	135
8	(With Def.,135, Min Q)	With	662	50	16.5	135
9	(With Def.,150, Max Q)	With	1883	50	16.69	150
10	(With Def.,150, Min Q)	With	662	50	16.5	150

Results and discussion

This section displays the results of scenarios that declare the effect of changing the tested angle between the walls of the deflector system as mentioned above.

Three governed principles that could intend to investigate the most suitable angle:

1. Morphological changes in the bed level in the vicinity of the intake.
2. Sedimentation volume at the intake.
3. Flow distribution which represents the uniform flow.

Morphological changes in the bed level

The fundamental aspect of this study centered on evaluating the scour and sedimentation zones generated by the baffle system. Consequently, the examination focused on the alterations in the riverbed bathymetry through the observation of the deflector system. Additionally, monitoring the morphological changes by the modification in the rotation angle between the two voided walls that form the baffle columns system.

At the outset, Test No. 1 and test No. 2 were conducted without using any deflectors to determine the sedimentation

quantity forming in front of the intake. Subsequently, Test No. 3 and test No. 4 were executed to investigate the impact of employing the deflector system (L-shape profile with right angle), as recommended by previous studies to reduce sedimentation in front of the intake. Indeed, there was a decrease in the sedimentation ratio, but scour and sedimentation zones appeared around the right-angled deflector. Therefore, Tests 5, 7, and 9 were carried out to mitigate this effect by varying the right-angled deflector's orientation for the maximum flow condition. Additionally, Tests 6, 8, and 10.

Figure 6 illustrates a comparison in the morphological changes in bed levels for the different alternatives in terms of maximum flow (tests numbers 1, 3, 5, 7, and test 9).

Test 1 (Without baffle columns system) Fig. 6a considered as the reference cases against which alternative scenarios are compared for sediment volume accumulated in the vicinity of the intake structure. Test 3 (right angle deflector L-shape profile) resulted in a substantial reduction of sediment deposition at the maximum condition by 58% in front of the intake. This outcome highlighted the positive influence of the right-angle scenario in effectively

mitigating sediment accumulation in front of the intakes. However, the right angle introduced a significant morphological change occurred due to the redirection of flow at the corner where the walls converge Fig. 6b. This leads to the development of local scour outside the right angle, which could potentially impact the stability of the deflector system. Additionally, another local scour area observed just behind the wall inside the deflector system, which is perpendicular to the flow direction, followed by local sedimentation. Test 5 (Fig. 6c) resulted in a significant 75% reduction in sediment deposition at the intake compared to the base case accumulation. Furthermore, the local scour zone that developed from the influence of the right-angle diversion during the third test was decreased by 30%. While the reduction in sediment quantity in the intake reached 68% and 71% in the 7th and 9th tests, respectively, compared to the base case.

Test 7 (Fig. 6d) achieves less local scour area with 70% compared to the right-angle scour. In Test 9 (Fig. 6e), where $\theta = 150°$, the local scour disappears by 95%, leading to a more uniform flow pattern.

Fig. 6 Bathymetry for tested angles at the maximum flow condition: **a** the base case, **b** scenario of ($\theta = 90°$), **c** scenario of ($\theta = 120°$), **d** scenario of ($\theta = 135°$), and **e** scenario of ($\theta = 150°$)
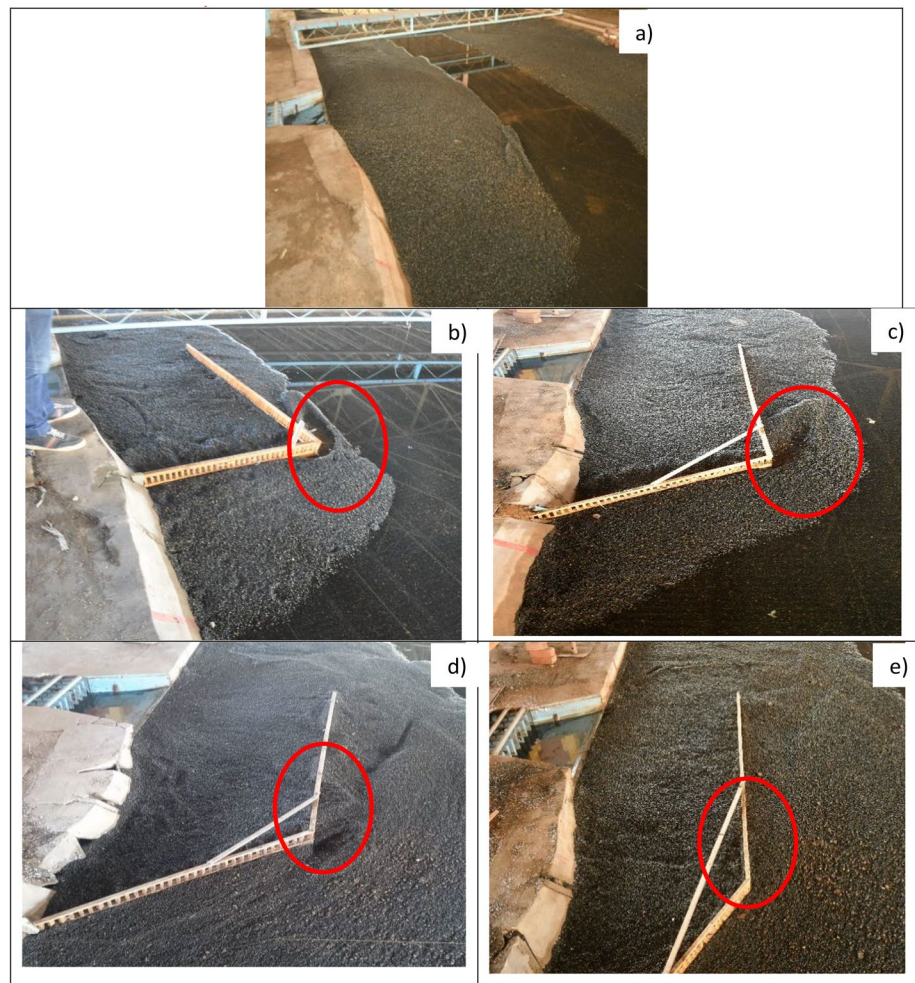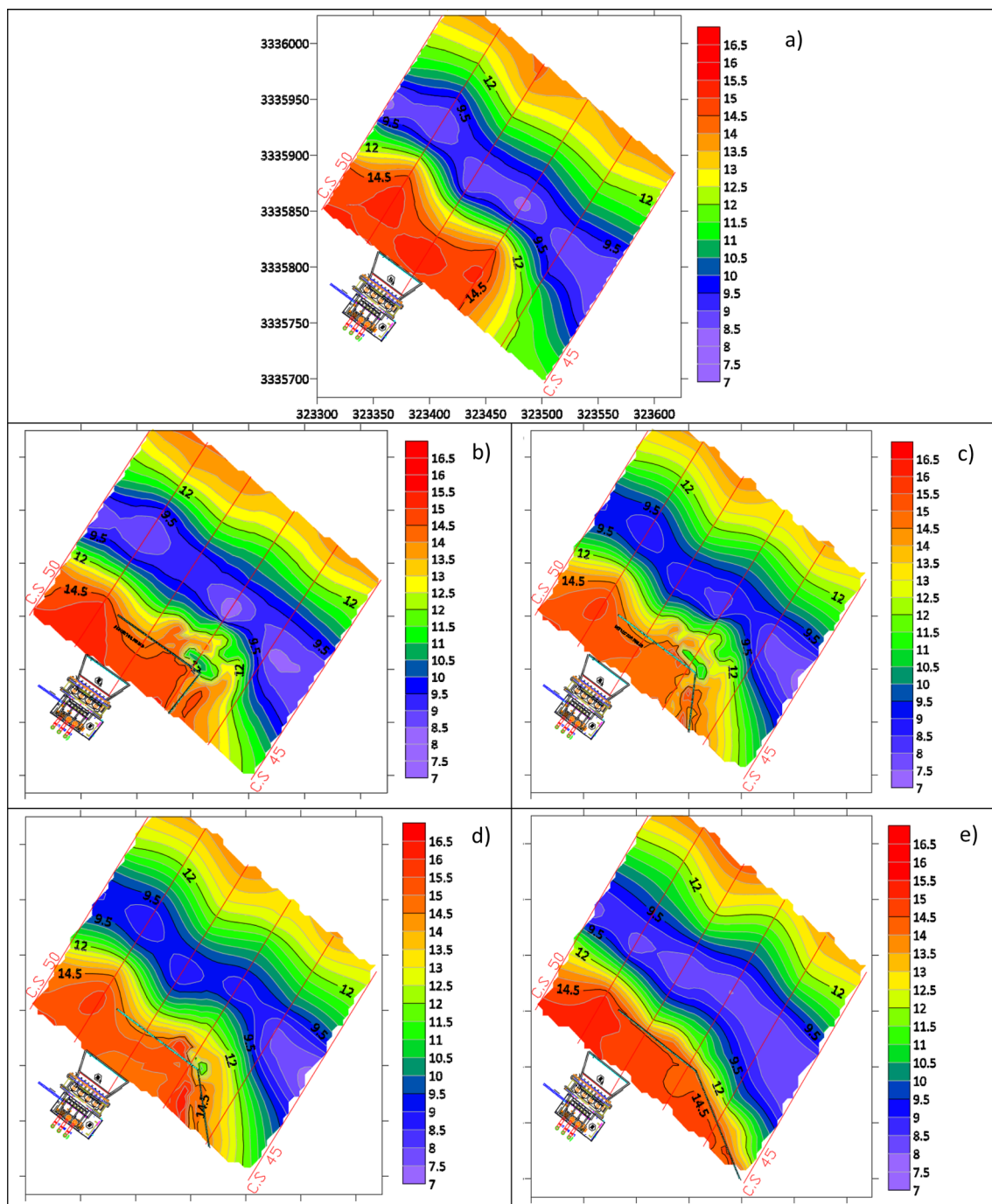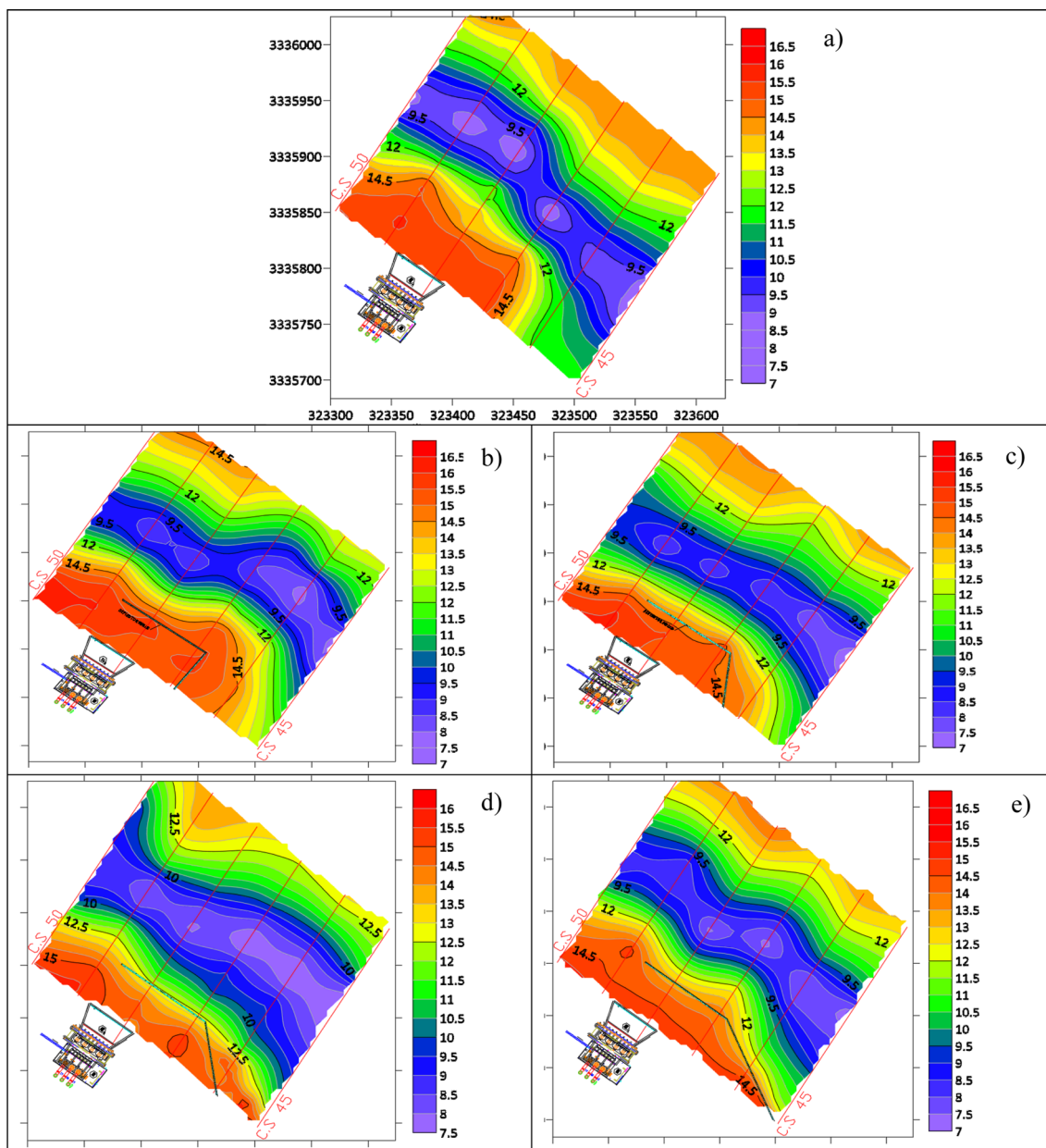
Fig. 7 Contour maps for tested angles at the maximum flow condition: **a** the base case, **b** scenario of ($\theta = 90°$), **c** scenario of ($\theta = 120°$), **d** scenario of ($\theta = 135°$),and **e** scenario of ($\theta = 150°$)

The contour maps provided in Fig. 7 described the variations in the depth of the scour at different tested angles. The depth of scour was about 3.5 m in the case of a right-angle configuration, decreasing to. 2.0 meters at ($\theta = 135°$) angle with a smaller scour area, and further reduced to 0.50 m at a ($\theta = 150°$) angle. The deeper the scour depth, the more it affected the stability of the wall system.

The minimum conditions varied slightly among the alternative scenarios, as shown in Fig. 8, governing the selection of the most favorable scenario. The minimum scenario exhibited a negligible influence on morphological changes, with no scour areas forming around the angles. However, there was a minor decrease in levels by approximately 1.00 m compared to the base case levels, and a reduction of up

Fig. 8 Contour maps for tested angles at the minimum flow condition: **a** the base case, **b** scenario of ($\theta=90°$), **c** scenario of ($\theta=120°$), **d** scenario of ($\theta=135°$), and **e** scenario of ($\theta=150°$)

to 94% for ($\theta=150°$) in the accumulation of sediment at the intakes. This reduction is due to the redirection of flow by the deflector walls.

Sedimentation volume at the intake

Collection of the sedimentation was the main indicator for the influence of the different alternatives for angle variation. Intake vents could be specified as shown in Fig. 9 that shown number of each opening (From number 1 to number 8) the

space in front of the intake structure divided into three zones to accurate description for the sedimentation.

Figure 10 shows that scenario (1) of the base case at the maximum condition without deflector system had the most quantity of sedimentation that form barrier of sedimentation in front of the intake vents (1, 2, 3, 4, and 5) which indicate the main flow go through vents 7&8 specially in zone 3 as the outer curve of suction flow in the intake structure and the sedimentation concentration at zone 1 as the inner curve of the suction flow, where vortices occurred with small sediment particle velocity.
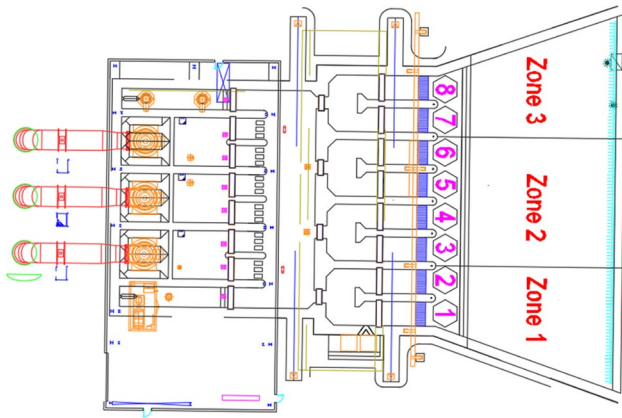
Fig. 9 Numbering the intake vents

The deflector system decreased the sedimentation ingress the intake and converted the flow path from zone 3 to uniform flow through zone 2&3.

Regarding the amount of sediment collected and volume measured for the tested angles, the presence of the deflector reduced the sediment accumulation by 71% in the case of maximum deflection and 94% in the case of minimum deflection as shown in Table 2. Sedimentation volume for test 9 (Scenario of θ = 150°) slightly increased, perhaps due to the distance from the deflector wall system to the intake structure caused by the angle between the angle walls, which reduced the particle movement near the deflector, and due to the increased distance, particle movement increased, resulting in a higher sedimentation rate.

The sedimentation rate decreased from 2.8 m^3/day to 0.7 m^3/day for test 5 (Scenario of $\theta = 120°$) for maximum flow

Fig. 10 Sedimentation in the intake for tested angles at the maximum flow condition: **a** the base case, **b** scenario of ($\theta = 90°$), **c** scenario of ($\theta = 120°$), **d** scenario of ($\theta = 135°$), and **e** scenario of ($\theta = 150°$)
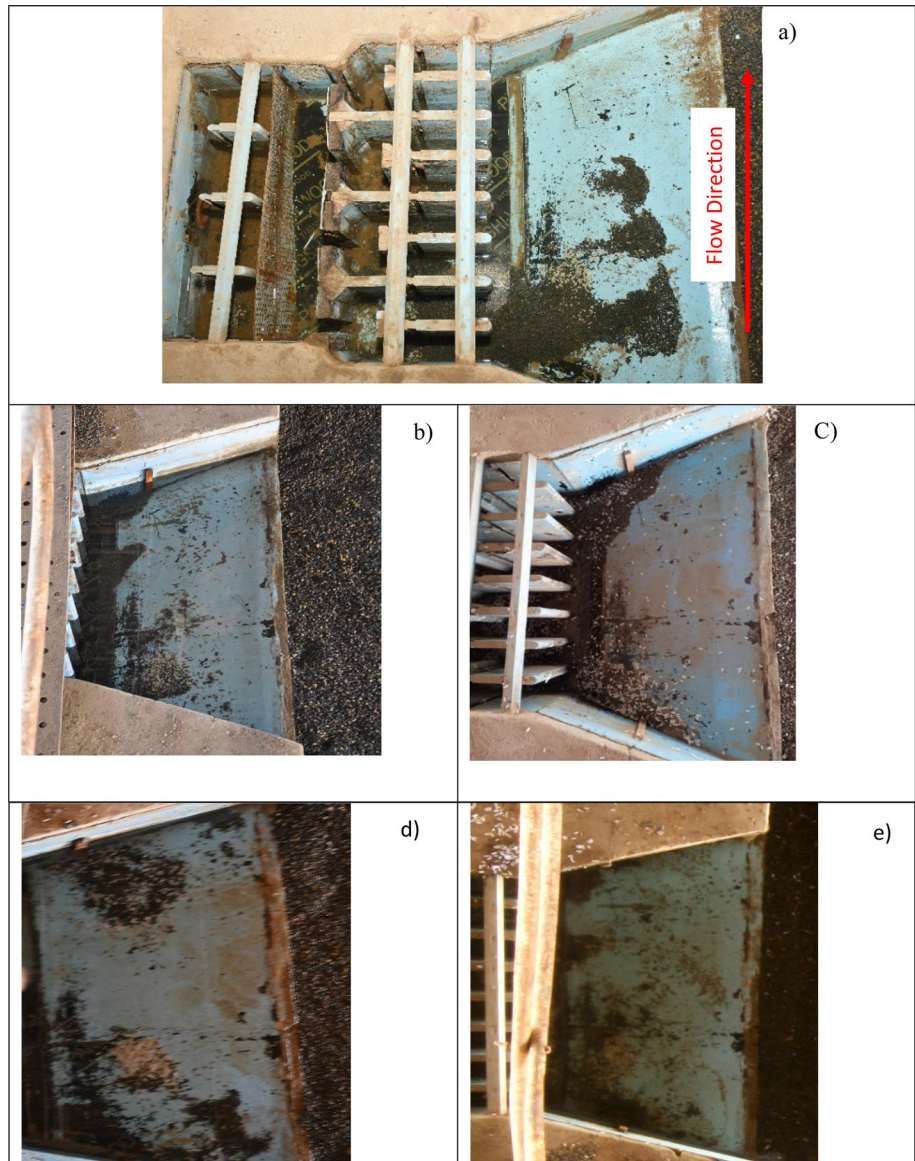
Table 2 Tests comparison for sediment rates

Test No	Test name	Total sediment volume (m³)	Percentage of sediment reduction %	Sediment rate (m³/day)
1	(Without Def., Max Q)	135.6	–	2.8
2	(Without Def., Min Q)	65.6	–	1.4
3	(With Def.,90, Max Q)	57.5	57.6	1.2
4	(With Def.,90, Min Q)	18.7	71.4	0.4
5	(With Def.,120, Max Q)	33.7	75.2	0.7
6	(With Def.,120, Min Q)	4.1	93.8	0.1
7	(With Def.,135, Max Q)	43.8	67.7	0.9
8	(With Def.,135, Min Q)	4.0	93.9	0.1
9	(With Def.,150, Max Q)	40	70.5	0.8
10	(With Def.,150, Min Q)	3.8	94.3	0.1
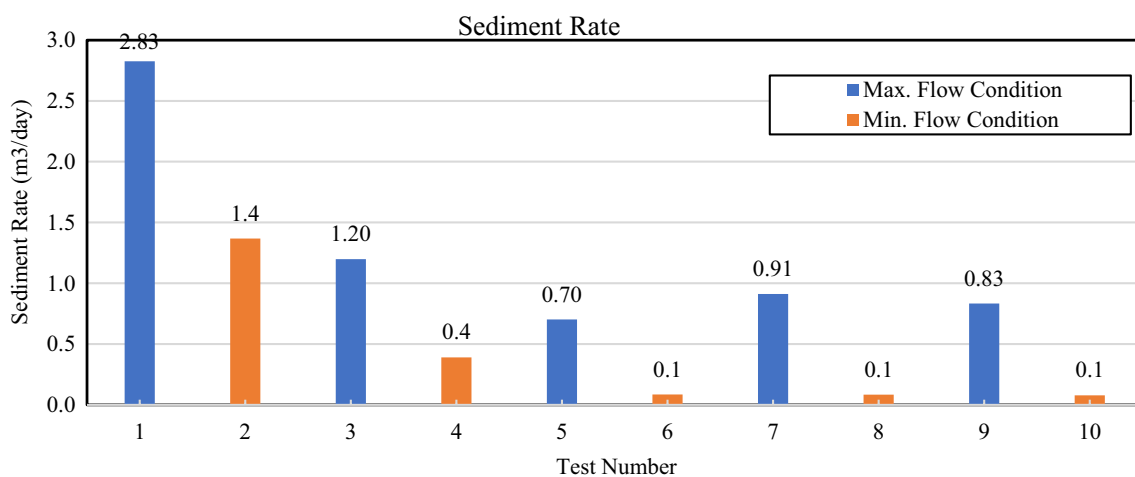
Fig. 11 Sedimentation rate for tested angles

condition. In addition to decrease from 1.4 m³/day to 0.1 m³/day for test 10 (Scenario of $\theta = 150°$) for minimum flow as shown in Fig. 11.

Flow distribution

Streamline flow is a major factor for elimination of the surface vortices that formed in the sedimentation basin. All alternatives almost had similar effect for formation of vortices as shown in Fig. 12, that indicated formation of surface vortices in the sedimentation basin at the maximum flow conditions. However, their impact on sediment movement becomes evident in the accumulated and formed sediment in accordance with the previously patterns.

The velocity distribution described the effect of deflector wall on the flow distribution. Two velocity sections chosen before and inside the intake structure, velocity Sect. (46) located in the upstream of the intake structure (perpendicular to flow direction) before the effect of the deflector system and velocity Sect. (48) inside the intake structure as shown in Fig. 13.

Velocity Sect. (46) declared the effect of deflector in velocity distribution in x-direction, where the distraction of flow due to the presence of the deflector led to a 61% reduction in velocity compared to the base case without the deflector, over a distance of 75 m which represented one-third of the channel width (Fig. 13b). After that distance, the flow velocity gradually approached the base condition and followed the same upward trend. As for Sect. 48, it illustrated the impact of the deflector on the velocity distribution (in x-direction) passing through it. It showed a significant decrease in velocities just behind the deflector for the tested angles, with an almost uniform pattern observed in the case of the right angle (Fig. 13c).

For velocity in Y-direction (Vy), After studying and analyzing the results, it became evident that small variations in flow velocities were not significant.

Fig. 12 Photographs for Comparison in stream flow at maximum condition: **a** the base case, **b** scenario of ($\theta = 90°$), **c** scenario of ($\theta = 120°$), **d** scenario of ($\theta = 135°$), and **e** scenario of ($\theta = 150°$)
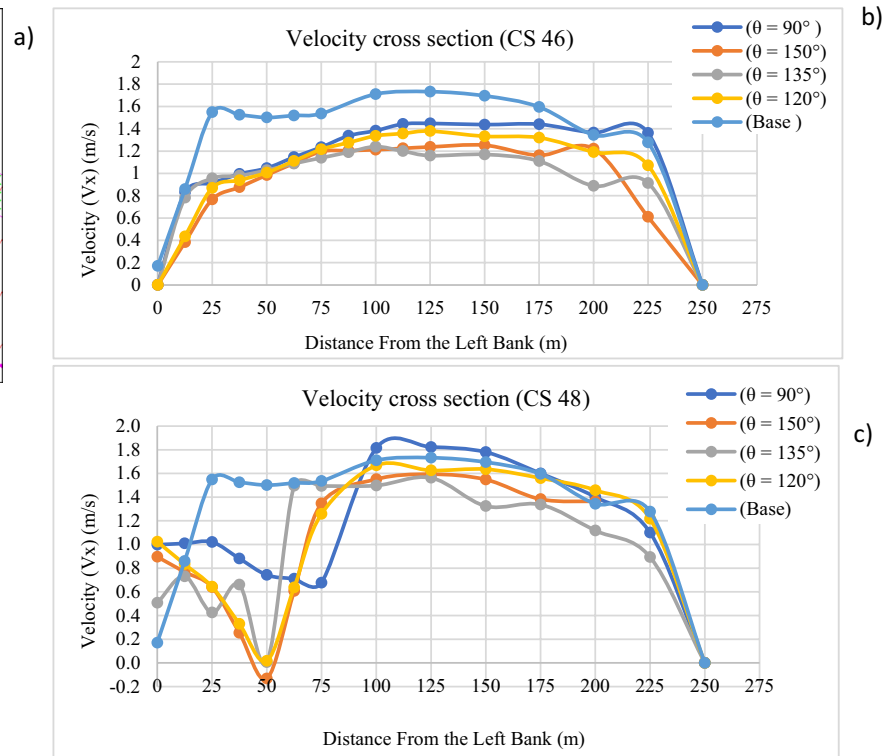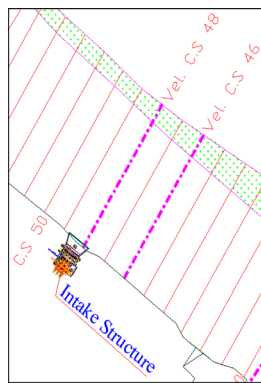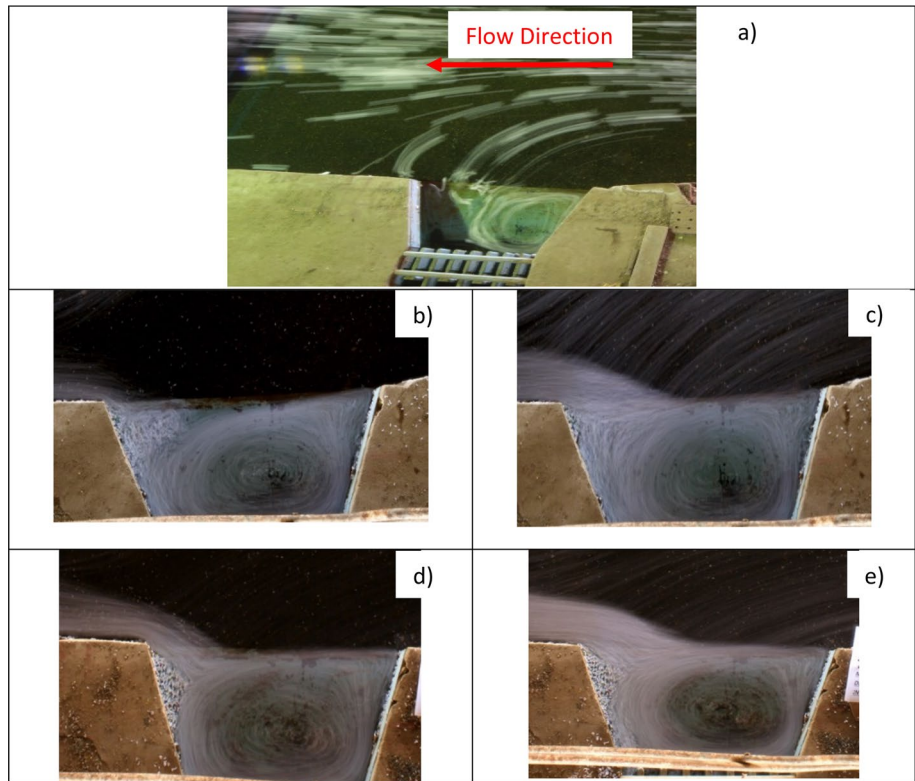

Fig. 13 Velocity (Vx) comparison in maximum flow alternatives: **a** velocity section locations, **b** velocity cross Sect. (46), **c** velocity cross Sect. (48)

The velocities in x-direction exhibit significant values, as previously explained. These velocities represent the velocity in flow direction, and accordingly, they change with variations in flow direction, which is influenced by the presence of sediment distortion systems. As for the velocity in y-direction, it represents the perpendicular velocities to the flow direction and is very small in magnitude.

Conclusion

Based on the preceding analysis and simulation of various scenarios aimed at optimizing the performance of the deflector system in reducing sedimentation that accumulated inside the intake structure, it was found that the deflector system of an angle double voided walls (known as baffle columns) yielded favorable results. The efficacy of the deflector system in mitigating sedimentation in front of water intakes had been investigated and tested by the physical model detailed in the previous research, and the outcomes were analyzed through three primary perspectives. Firstly, the assessment focused on the quantity of sedimentation accumulating in front of the intake. The right-angle deflector with voided walls system was found to decrease sedimentation by 58%. However, this angle exhibited adverse effects on the river morphology, introducing scour and sedimentation zones around the right-angled junction. Subsequent trials involved testing various angles, including 120° and 135°. The results underscored that the 150° angle produced the most favorable outcomes, effectively mitigating the scour and sedimentation issue by 95% at the maximum flow condition and reduced the accumulated sedimentation inside the intake by 71% in the maximum flow condition. Although the sediment rate was not the absolute minimum in the scenario with an angle of $\theta = 150°$ between the two walls, it was sufficient to ensure the stability of the deflector system while effectively mitigating sediment accumulation. No significant differences were found for the minimum flow condition. Furthermore, the approach fostered smoother velocity patterns and behaviors within the deflector system, contributing to improvement in its hydraulic performance.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval Not applicable.

Consent to participate Not applicable.

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