Suspended sediment distribution under varied currents in the largest river-connected lake of China

Hua Wang, Yijun Zhao, Fengnian Zhou, Huaiyu Yan, Yanqing Deng and Bao Li

ABSTRACT

Poyang Lake was selected as the research area. Based on laboratory experiment, field investigation and numerical simulation, the spatial distributions of suspended sediment (SS) under the gravity-flow, jacking-flow and back-flow patterns were quantitatively analysed. An annular flume experiment was conducted to determine the critical starting shear stresses of the sediments in the flood and dry seasons. By numerical experiment, the SS transport under different flow patterns was explored. Several results stand out. (1) The critical starting shear stresses of the sediments in the flood and dry seasons were 0.35 N·m⁻² and 0.29 N·m⁻², respectively. (2) Due to the strongest flow disturbance and scouring effect, SS under the gravity-flow pattern was characterized by the highest loads. The lowest SS was observed during the jacking-flow pattern, which could be attributed to the lowest water level gap between the lake and external rivers. The loads ranged from 0.053 kg·m⁻³ to 0.068 kg·m⁻³. (3) Under the back-flow pattern, SS in the north lake was evidently influenced by the Yangtze River, and the mean value was approximately 0.12 kg·m⁻³. With the gradually weakened back-flow impact, the SS load was decreased from the north to the middle of the lake.

Key words | model, numerical simulation, Poyang Lake, starting shear stress, suspended sediment

INTRODUCTION

A series of river-connected lakes are distributed in the middle and lower reaches of the Yangtze River in China, e.g., Poyang Lake in Jiangxi Province, Jinshan Lake in Zhenjiang City, Huangshan Lake in Jiangyin City and Jiyang Lake in Zhangjiagang City. Unlike the isolated lakes such as Lake Taihu and Lake Tana (Li et al. 2013; Dessie et al. 2015), this type of lake is always characterized by more complicated hydrodynamic conditions and environmental processes due to its connection to the external Yangtze River. Suspended sediment (SS) is a fundamental factor that always has important consequences for many environmental processes in a lake. It not only acts as an independent water quality parameter but also has important impacts on the aquatic ecosystem by its adsorption of nutrients, heavy metals and toxic organic pollutants. Due to the fluctuation of external inflow and the varied lake terrain conditions, the SS in river-connected lakes is always observed with evident and uneven spatial distribution. An investigation on SS transport could have a great effect on exploration of water quality variation, bio-geochemical cycling and eco-environment evolution in a river-connected lake (Cheng et al. 2013; De Girolamo et al. 2015). Poyang Lake, which is the largest freshwater lake in China and the most typical river-connected lake, is characterized by marked intra- and inter-annual variations of SS load. Some researchers have conducted a few studies regarding SS in Poyang Lake. However, most of these studies have been focused on the total volume of the exchanged SS between Poyang Lake and the external rivers and little attention has been paid to the influence of flow patterns on the spatial SS distribution. In...
the present work, we focused on SS transport under varied flow conditions in Poyang Lake. Through an annular flume experiment, the critical starting shear stresses of sediments in the flood and dry seasons were determined. A 2-D coupled water–sediment model was developed and calibrated against the field measured data in the framework of the finite volume method. By numerical experimentation, the SS transport under three typical lake currents (i.e., gravity-flow, jacking-flow and back-flow), in a common-water year was simulated and the spatial distribution of SS was quantitatively analysed.

MATERIALS AND METHODS

Study area

Poyang Lake (28°25′–29°45′ N, 115°50′–116°44′ E) is located on the south bank of the middle-lower Yangtze River in Jiangxi Province, China (Figure 1). As the largest river-connected lake in China, Poyang Lake has been designated on the UN list of internationally important wetlands and plays a large role in maintaining regional water balance and ecological safety (Ji et al. 2012; Zhang et al. 2012; Han et al. 2015). It hosts millions of birds from over 300 species, and is particularly vital for the conservation of the endangered Siberian crane as more than 95% of its world population congregates here during the winter. The lake can be divided into southern and northern areas. The northern part, which is directly connected to the Yangtze River, is evidently narrower than the southern main lake of which the size is 40 km in length, 3–5 km in width, and 2.8 km at its narrowest point. The size of the main lake in the south is approximately 133 km in length and 74 km at its widest point. The lake covers many districts, including Nanchang, Xinjian, Jinxian, Yugen, Boyang, Duchang, Hukou, Jiujiang, Xingzi, De’an and Yongxiu. It receives water from five rivers (the Gan River, Fu River, Xin River, Rao River and Xiu...
River) and drains into the Yangtze through a narrow outlet to the north. Due to the river–lake interaction, Poyang Lake is characterized by marked intra- and inter-annual variations of lake area and water level. Based on continuous data over 50 years, the eigenvalues are shown in Table 1. The total water transported from the Gan River, Fu River, Xin River, Rao River and Xiu River into the lake was 9.16 × 10¹¹ m³, which accounts for 87.1% of the total inflow water to Poyang Lake, and the ratios are 47.1%, 10.8%, 12.4%, 8.2% and 8.6%, respectively (Liu & Rossiter 2008; Volpe et al. 2011; Cui et al. 2015). The SS in Poyang Lake is mainly derived from the five rivers upstream, backflow water from the Yangtze River, blown sand and bank caving. Based on the data from 1956 to 2005 (Xiong 1990; Min et al. 2011), the mean SS load transported by the Gan River, Fu River, Xin River, Rao River and Xiu River into the lake was 9.16 × 10⁶ t, 1.43 × 10⁶ t, 2.12 × 10⁶ t, 0.99 × 10⁶ t and 0.80 × 10⁶ t, respectively, in a year. Due to the high water level of the Yangtze River, a certain amount of SS will flow back into Poyang Lake during flood seasons. According to the monitored data at Hukou Station, located at the lake–river joint, the annual amount of SS flowing back into Poyang Lake is approximately 151 × 10⁶ t, which is mainly concentrated from July through September. The maximum load of backflow SS was 699 × 10⁴ t (observed in 1963).

Table 1 | The eigenvalues of Poyang Lake

<table>
<thead>
<tr>
<th>Characteristic parameters</th>
<th>Value interval</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest water level at Hukou</td>
<td>5.9 m</td>
<td></td>
</tr>
<tr>
<td>Lowest lake area</td>
<td>146 km²</td>
<td>February 6, 1963</td>
</tr>
<tr>
<td>Lowest lake volume</td>
<td>4.5 × 10⁸ m³</td>
<td></td>
</tr>
<tr>
<td>Highest water level at Hukou</td>
<td>22.59</td>
<td></td>
</tr>
<tr>
<td>Highest lake area</td>
<td>4,500 km²</td>
<td>July 31, 1998</td>
</tr>
<tr>
<td>Highest lake volume</td>
<td>3.4 × 10¹⁰ m³</td>
<td></td>
</tr>
<tr>
<td>Minimum intra-annual water level gap</td>
<td>9.59 m</td>
<td></td>
</tr>
<tr>
<td>Maximum intra-annual water level gap</td>
<td>14.04 m</td>
<td></td>
</tr>
<tr>
<td>Minimum SS concentration</td>
<td>0.036 kg·m⁻³</td>
<td></td>
</tr>
<tr>
<td>Maximum SS concentration</td>
<td>0.185 kg·m⁻³</td>
<td></td>
</tr>
<tr>
<td>Mean SS concentration</td>
<td>0.120 kg·m⁻³</td>
<td></td>
</tr>
</tbody>
</table>

Laboratory experiment

This experiment was conducted to provide quantitative insight into the suspension mechanisms of sediments with different sizes and optimize the parameters adopted in the numerical model. It was conducted in the Molecular Biology Laboratory of Nanjing Geography and Limnology Institute, Chinese Academy of Sciences, in September 2014. The annular flume was applied to generate the water currents. The device is composed of a flume and top lid, which can rotate independently with the control of a computer system. The flume and top lid are made of acrylic material with an outer diameter of 240 cm and inner diameter of 160 cm. The annular water channel is 40 cm in width and 41 cm in depth. There are several sample outlets set at different heights on the outer wall of the flume (Figure 2). The top lid can go up and down controlled by the computer system. The opposite rotation of the flume and top lid can generate water currents through the effect of shear stress. Due to the curvature, the rotation of the flume will bring centrifugal force outward along the radius for water flow and generate an outward secondary flow. When the top lid rotates in the opposite direction, it will bring centrifugal force inward along the radius on the water flow and generate an inward secondary flow. Since centrifugal force is related to the rotation rate, through adjustment of the rotation rates of the top lid and flume, the centrifugal forces can cancel each other out to reduce secondary flow (Li et al. 2004; Wang et al. 2011; Huang et al. 2012). Prior to the experiment, tiny sawdust was selected as a tracer indicator to calibrate the annular flume (Wang et al. 2014). Based on a certain flume rotation speed, the top lid speed was debugged to maintain a stable current for 30 min. When the tiny sawdust moved along the central line of the flume, the optimum rotation rate could be determined for eliminating the secondary flow. According to the calibration results of the rotation rate, different flow conditions could be set for the annular flume experiment. According to the sediment diameter grade, the SS in Poyang Lake is mainly composed of silt (<63 μm), and the median sizes in the flood and dry season are 33.27 μm and 24.35 μm, respectively. Thus, two groups of starting experiments were arranged. The test sediments were collected from in situ sampling. The test temperature and water depth were set at 20°C and 0.3 m,
respectively. Before the experiment, the sediment was stirred and spread evenly at the bottom of the flume, and after 1 day’s deposition, tap-water was slowly poured into the test water depth to start the experiment.

Different researchers always hold different standards for incipient sediment motion (Xiao et al. 2009). In general, the incipient motion of sediment can be divided into three levels: individual movement, ounce movement and universal movement (He et al. 2005). As universal movement is widely recognized to have better adaptability for practical application, in the present work, it was utilized as the sediment starting standard. During the test, the flow disturbance was gradually enhanced, and a small water sample was taken from the outlet to measure the SS content at each rotation speed. According to the results, the relationships between depth-averaged velocity and the SS percentage are established in Figure 3.

The results indicate that when the flow velocity was less than 0.2 m·s\(^{-1}\), the bottom sediment remained stationary and the bed surface was kept smooth with rare particle suspension. After the velocity was slightly increased to 0.2–0.3 m·s\(^{-1}\), slender striation in the flow direction was detected on the deposited sediment and a spot of sediment moved along the striation. With the flow speed increased to 0.5 m·s\(^{-1}\), eddies occurred on the sediment bed and a large amount of sediment was suspended in the eddy in smog status. The starting velocity can be used as an index to reflect the incipient sediment motion. However, it is not always convenient for practical application. Since sediment resuspension initiation is mainly dependent on the flow conditions near the surface sediment bed, it is more suitable to choose a shear stress that can more exactly describe the bottom flow disturbance as the analysis index (Yang & Wang 1995; Pang et al. 2012). Here, the following formula was used to transfer the depth-averaged velocity into critical shear stress for subsequent numerical simulation. The equations are written as follows:

\[
\begin{align*}
\tau_e & = \rho \cdot u_c^2 \\
\frac{u_c}{u_*} & = \frac{1}{k} \ln \frac{y}{k} + B_s
\end{align*}
\]
Table 2 | The critical starting shear stress of sediment in Poyang Lake

<table>
<thead>
<tr>
<th>Test group</th>
<th>Wet density g·cm⁻³</th>
<th>Velocity of incipient motion cm·s⁻¹</th>
<th>Friction velocity cm·s⁻¹</th>
<th>Critical starting shear stress N·m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment in flood season</td>
<td>1.19</td>
<td>55.6</td>
<td>1.87</td>
<td>0.35</td>
</tr>
<tr>
<td>Sediment in dry season</td>
<td>1.15</td>
<td>52.3</td>
<td>1.71</td>
<td>0.29</td>
</tr>
</tbody>
</table>

where \( \tau_e \) is the critical sediment starting shear stress, \( \rho \) is the water density, \( u_c \) is the friction velocity, \( u_c \) is the section averaged flow velocity, \( x \) is the Karman constant, \( y \) is 0.37 times the water depth to the bed surface, \( k_s \) is the sand roughness, which can be taken as the sediment diameter, and \( B_s \) is the dimensionless parameter of the water flow near the bed surface. The critical shear stresses of the sediment in different seasons are calculated in Table 2.

Numerical model

Governing equations

The conservation forms of 2-D water flow and SS transportation equations can be written as follows (Wang et al. 2017):

\[
\begin{align*}
\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} &= 0 \\
\frac{\partial (hu)}{\partial t} + \frac{\partial ((hu^2 + gh^2)/2)}{\partial x} + \frac{\partial (hv)}{\partial y} &= gh(s_{0x} - s_{x}) \\
\frac{\partial (hv)}{\partial t} + \frac{\partial ((hv^2 + gh^2)/2)}{\partial x} + \frac{\partial (hu)}{\partial y} &= gh(s_{0y} - s_{y}) \\
\frac{\partial (hS)}{\partial t} + \frac{\partial (huS)}{\partial x} + \frac{\partial (hvS)}{\partial y} &= \frac{\partial}{\partial x}(D_x h \frac{\partial S}{\partial x}) + \frac{\partial}{\partial y}(D_y h \frac{\partial S}{\partial y}) + F_s
\end{align*}
\]

(2)

where \( h \) is the water depth, \( t \) is time, \( u \) and \( v \) are the depth-averaged velocity components in the \( x \) and \( y \) directions, \( g \) is the acceleration of gravity, \( s_{0x} \) and \( s_{x} \) are the bed slope and friction slope in the \( x \) direction, \( s_{0y} \) and \( s_{y} \) are the bed slope and friction slope in the \( y \) direction, \( S \) is the SS concentration, \( D_x \) and \( D_y \) are the SS dispersion coefficients in the \( x \) and \( y \) directions, and \( F_s \) is the source–sink vector of SS, which is the net flux of suspension and deposition and can be expressed as follows (Asselman et al. 2003):

\[
F_s = -A_o S \left( 1 - \frac{\tau}{\tau_d} \right) + BM \left( \frac{\tau}{\tau_e} - 1 \right),
\]

\[
A = \begin{cases} 
1, & \tau \leq \tau_d \\
0, & \tau > \tau_d 
\end{cases}, \quad B = \begin{cases} 
1, & \tau \geq \tau_e \\
0, & \tau < \tau_e 
\end{cases}
\]

(3)

where \( M \) is the scouring coefficient, \( \omega \) is the deposition velocity of the sediment, \( \tau \) is the shear stress at the deposited sediment surface, \( \tau_d \) is the critical deposition shear stress, and \( \tau_e \) is the critical starting shear stress. When \( \tau \geq \tau_e \), the bottom sediment begins to suspend and the lake bed is scoured. When \( \tau \leq \tau_e \), the SS begins to settle and sedimentation is exerted on the lake bed. \( \tau_d \) is usually a bit less than \( \tau_e \) (Hu 2003), and to simplify calculation in this case, the two shear stresses were recognized as approximately the same. It was considered that the flow velocity in balanced status (non-deposition and non-eroding) was not a range (from the critical deposition velocity to the critical starting velocity) but a point, which was the critical starting velocity. The water flow and SS transport equations could be combined to be resolved, and the system of Equation (2) can be described as follows:

\[
\frac{\partial q}{\partial t} + \frac{\partial (f(q))}{\partial x} + \frac{\partial (g(q))}{\partial y} = b(q)
\]

(4)

where \( q \) is the vector of the conserved physical quantities, \( f(q) \) and \( g(q) \) are the flux vectors in the \( x \) and \( y \) directions, and \( b(q) \) is the source–sink vector.

\[
q = (h, hu, hv, hS)^T
\]

\[
f(q) = \left( \frac{hu, hu^2 + gh^2}{2, hv, hvS} \right)^T;
\]

\[
g(q) = \left( \frac{hv, hvu, hv^2 + gh^2}{2, hvS} \right)^T;
\]

\[
b(q) = (0, gh(s_{0x} - s_{x}), gh(s_{0y} - s_{y}), \nabla \bullet (D_y \nabla (hS)) + F_s)^T
\]

For any element, the equations were solved in the framework of a finite volume method and the normal fluxes of the
variables across the interfaces between elements were calculated by the flux vector splitting scheme. Detailed mathematical processes are documented in Hu & Tan (1995) and Ding et al. (2004).

### Calibration and verification

The model was calibrated and validated against the field investigated data from January to September of 2012 at ten field investigated points in Poyang Lake (Figure 1). The calculation area included the related Yangtze River, the five upstream river inlets and Poyang Lake. Based on the topographic characteristics, the research area was divided into 7,533 nodes and 6,239 quadrilateral elements by Gambit software. The mean mesh size was 700 m × 700 m. One-tenth of the elements were given lake-bottom elevations based on field data, and the remaining bathymetry was numerically calculated by the model. The measured SS concentrations and water levels of the five upstream tributaries and the downstream Yangtze River were selected as calculation boundary conditions. The input data of the above boundaries were supplied by the Hydrology Bureau of Jiangxi Province and Bureau of Hydrology, Changjiang Water Resource Committee. The unit weights of water and suspended particles were 1.000 kg·m⁻³ and 2.650 kg·m⁻³, respectively. The kinematic viscosity coefficient was $1.0 \times 10^{-6}$ m²·s⁻¹. The roughness coefficients were arranged between 0.01 and 0.035. The wind drag coefficient and the horizontal eddy viscosity coefficient were determined as $1.0 \times 10^{-3}$ m²·s⁻¹ and $0.5 \times 10^5$ cm²·s⁻¹, respectively. The vertical and lateral diffusion coefficients were $1.0 \times 10^2$ cm²·s⁻¹ and $0.1 \times 10^2$ cm²·s⁻¹, respectively. These parameters were determined during the calibration period based on the best agreement between the predicted and observed SS concentrations. The sensitivity analysis was conducted for each parameter by keeping the others unchanged. It was observed that the sensitivity of each parameter in the sediment model varied distinctly. The least sensitivity was characterized by the horizontal eddy viscosity, and the most sensitive parameters were the vertical diffusion and roughness coefficients (Zhang et al. 2017).

During calibration it was observed that a bigger time step (1 s or 5 s) can meet the stability for the water current calculation, but it cannot simulate the SS process well. The main reason was attributed to the source–sink vector $F_s$ that was induced to generalize the vertical settlement and suspension to update the depth-averaged SS concentration. As the best agreement between predicted and observed data during the calibration period was achieved by using a small time-step, the value of 0.1 s was adopted to obey all of the stability criteria. A comparison of calculated results and field investigated data is shown in Figure 4 with the average relative error ranging from 16% to 21%. The calculated value could fit well with the field data, and the model could scientifically reflect the processes of water currents and SS in Poyang Lake.

### RESULTS AND DISCUSSION

#### Calculation condition

The water level in Poyang Lake was influenced by the combination of the five upstream rivers and the downstream Yangtze River. In typical water years, the water level in the lake can be generally divided into the following three periods: a low water level period (during the dry season), a rising water level period (during the flood season of the five upstream rivers) and the jacking-backflow period (during the flood season of the Yangtze River) (Wu et al. 2014). Here, ‘jacking’ means that Poyang Lake can receive water from five rivers (the Gan River, Fu River, Xin River, Rao River and Xiu River) but cannot drain into the Yangtze River, normally due to the high water level. During different periods, the exchanged water volume between the lake and the external rivers and the lake currents varied remarkably, which resulted in a complicated SS distribution. According to the long-range hydrology data, water currents in Poyang Lake can be generalized into the following three types. (1) Gravity-flow pattern, the primary lake current. Water flows from the south to the north in accordance with the main channel, and the flow velocity is mainly driven by the water surface slope. (2) Jacking-flow pattern, the second dominant current. It is formed when the water levels in the five upstream rivers and the downstream Yangtze River rise at the same time or at the end of the flood season of the five upstream rivers when the water level of the Yangtze River is still rising. Under this current, the...
Figure 4 | Comparison of the calculated results and measured SS concentration in Poyang Lake.
flow velocity in the whole lake is evidently decreased. (3) Back-flow pattern, mainly observed between July and September. This current is induced by the flooding of the Yangtze River. It always happens when the flood season of the five upstream rivers is finished and the water level in the Yangtze River is higher than the lake. Figure 5 shows the water level variation at Xingzi Station in 2000 and the occurrence periods of the three water current patterns.

Here, we selected the hydrological conditions in a common-water year (2000) as the calculation scheme. The three typical flow current processes were determined for numerical simulation, including the gravity-flow pattern (January 17, 2000), jacking-flow pattern (June 28, 2000) and back-flow pattern (August 17, 2000). The currents under three typical flow patterns are shown in Figure 6. During the simulation, the grid division and parameter determination were the same as that in the section ‘Calibration and verification’.

SS distribution

Based on the simulated results, the spatial distributions of SS under the three typical water currents are shown in Figure 7. This indicated the following:

(1) The gravity-flow pattern was characterized by the highest SS load attributed to its strongest disturbance. Under this current, SS concentrations in the southern and northern lakes were significantly higher than that in the middle. Due to the relatively narrow section and contribution of external rivers, the sediment carrying capacity in the southern lake was enhanced and the mean SS concentration reached 0.122 kg·m$^{-3}$. Influenced by the sediment transported by inflowing rivers, the SS concentrations at some lake inlet areas were evidently higher. For example, in the estuary area of the Fu River south branch, the SS load increased to 0.19 kg·m$^{-3}$. In the joint area of the southern and middle lakes, the mean SS concentration was approximately 0.150 kg·m$^{-3}$, which was higher than other regions in the southern lake, because the Gan River south branch, the Fu River north branch and the Xin River were integrated here and the strong water current strengthened the sediment suspension. The coccygeal end areas in the southern lake were characterized by the lowest SS load of 0.061 kg·m$^{-3}$, as a result of the weak hydrodynamic conditions and longer water exchange cycles. In the middle lake, the

![Figure 5](https://iwaponline.com/wpcontent/uploads/2018/18/3/0994/figure-5.png)

**Figure 5** | Temporal distribution of the three typical water currents in Poyang Lake.

![Figure 6](https://iwaponline.com/wpcontent/uploads/2018/18/3/0994/figure-6.png)

**Figure 6** | Water flow distribution under three typical currents in Poyang Lake.
mean SS concentration was reduced to 0.085 kg·m⁻³, which was 30.3% less than that of the southern lake because of the reduced flow intensity induced by the broad lake surface. At the regions where some external rivers flow into the lake, the SS loads were relatively higher with the mean values ranging from 0.105 kg·m⁻³ to 0.113 kg·m⁻³. In the intersection of the middle and northern lakes, the gradually reduced water section resulted in a gradually enhanced disturbance, and the SS concentration was increased from 0.081 kg·m⁻³ to 0.11 kg·m⁻³. As the exchange channel with the Yangtze River, the northern lake showed the highest SS concentration in the entire lake, which reached approximately 0.145 kg·m⁻³, 41.4% and 15.9% higher than that in the middle and southern areas, respectively.

(2) In the jacking-flow pattern, the external Yangtze River and the northern lake were basically equipped with the same water level. Water in the lake could not smoothly outflow to the Yangtze River, which reduced the flow disturbance in the whole lake and resulted in a remarkable SS decrease. An uneven spatial SS distribution still existed between the northern, middle and southern lakes but was less evident than that under the gravity-flow pattern. Affected by the upstream rivers, the southern lake was characterized by the highest SS load, which was approximately 0.068 kg·m⁻³ and 20.2% less than the value of the gravity-flow pattern. Due to the external input, SS at the intersection of the southern and middle lakes was still higher than other regions with a mean value of 0.070 kg·m⁻³. Both the broad water surface and the longer hydraulic retention time resulted in the lowest SS concentration of 0.053 kg·m⁻³ in the middle lake. In the areas where some external rivers flow into the lake, the SS loads still showed a relatively higher value, which reached 0.062 kg·m⁻³ to 0.070 kg·m⁻³. Although ‘jacking’ reduced the water currents in the northern lake, the SS load here was still stronger than that in the middle lake due to the higher SS concentration of the external Yangtze River. The mean value was approximately 0.065 kg·m⁻³, which was 55.2% less than that under the gravity-flow pattern.

(3) With a water level increase of the Yangtze River, the back-flow pattern will occur especially during the flood season of the Yangtze River. The flow direction between Poyang Lake and the Yangtze River was changed, and the inflow water volume with a higher SS load evidently increased the SS concentration in the northern lake, which was approximately 0.12 kg·m⁻³ and 84.6%
higher than that of the jacking-flow pattern. In view of the whole lake, the intensity of the flow disturbance under the back-flow current generally ranged between the other two flow patterns. A distinct decreasing trend of SS concentration was detected from the northern to the middle lake and was attributed to the gradually weakened back-flow impact. In the middle lake, the SS of the area next to the north was approximately 0.095 kg·m⁻³, which was markedly higher than the mean value of 0.057 kg·m⁻³ in the central area. During the period of back-flow, the SS concentration in the southern lake was 0.073 kg·m⁻³ on average, which was 7.4% higher than that in the jacking-flow pattern but 14.1% less than that in the gravity-flow pattern. The SS concentration at the intersection of the southern and middle lakes was still characterized by a higher value of 0.10 kg·m⁻³ due to the external contribution.

CONCLUSIONS

Poyang Lake, which is the most typical river-connected lake in China, was selected as the study area. Based on laboratory experiment, field investigation and numerical simulation, SS distribution under three typical flow patterns, including gravity-flow, jacking-flow and back-flow, was quantitatively explored. A rotating annular flume was applied to conduct the sediment starting experiment, and the critical sheer stresses for the sediments in the flood and dry seasons were determined. A 2-D current-sediment coupled model was established in the framework of the finite volume method and was validated and calibrated against the field measured data. By numerical simulation, it was determined that the spatial SS distribution varied remarkably with water flow patterns. The jacking-flow pattern was characterized by the lowest SS load due to the long hydraulic retention time and the weak flow disturbance. Under the gravity-flow pattern, the flow disturbance was significantly enhanced and the SS concentration of the whole lake increased to the highest level due to the strong eroding impact. Influenced by the inflowing water from the Yangtze River, the SS concentration in the northern lake was markedly higher than the other regions. A distinct decreasing trend of the SS concentration was detected from the northern to the middle lake during the back-flow period as a result of the gradually weakened back-flow impact.

This paper presents an important basis for the in-depth study of SS in Poyang Lake and, to some extent, provides useful references for related research on river-connected lakes.

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