

## RESEARCH ARTICLE

## HYDROMECHANICAL ASSESSMENT OF RIVER SEDIMENT CHARACTERISTICS IN TURBID STREAM: A CASE STUDY OF SOKHSAI

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## ARTICLE DETAILS

## Article History:

Received 26 January 2026  
Revised 20 February 2026  
Accepted 25 February 2026  
Available online 10 March 2026

## ABSTRACT

In foothill rivers, large volumes of river sediments, derived from erosional processes, move along with the water. The sediment concentration increases during the high water or flood periods of rivers, and their sizes range from 0.01 mm to 200 mm. Sedimentation tanks are used to draw water from the river to prevent silting of irrigation canals. The size of sedimentation tanks depends on the physical and hydromechanical properties of river sediments, along with stream hydrological parameters. This article studies the hydromechanical properties of river sediments based on the results of field research conducted in the right-bank sedimentation tank, which is part of the Kokand hydrocomplex. Laboratory analysis of field studies showed that sediment concentrations in the Sokhsoi stream varied seasonally within a range of 1.02 to 5.04 kg/m<sup>3</sup>, and the average particle size is medium gravel (4 mm). As theoretical part of the research, the dependence of fall velocity on the shape and size of river sediments and the dependence of viscosity on concentration were studied. The higher the concentration, the lower the rate of decline of sediment. The results show that the value of the hydraulic size of sediments entering the right-bank tank fluctuated between 189 and 429 mm/sec, influenced by the concentration and shape of the sediment. The results of this study are of great importance not only for the design of sedimentation tanks but also for the study of the characteristics of mudflows.

## KEYWORDS

mudflow, river sediments, hydraulic size, falling velocity, sedimentation tank, irrigation canal

## 1. INTRODUCTION

A large amount of sediment, consisting of mineral fertilizers and raw materials, moves with the water in the river flow (Arifjanov, Samiev, and Akmalov, 2019). However, hydraulic structures such as sedimentation tanks designed to regulate river sediments do not always function properly (Arifjanov, Samiev, Apakhodjaeva, et al., 2019). As a result, these river sediments spread along irrigation canals, which are the arteries of agriculture, reducing the hydraulic efficiency of these structures (Fatxulloev et al., 2023).

In scientific literature, a turbidity currents are usually characterized as a water-saturated flow of erosive material, such as river sediments (Basson et al., 2009). In the context of hydromechanics, these processes are also referred to as two-phase flow, that is, the interaction of water and solid particles (Haan et al., 1994). According to laboratory analysis of sedimentary particles, they consist of organic and inorganic compounds formed by primary and secondary erosion processes (Arifjanov, Samiev, and Akmalov, 2019). Turbidity currents are one of the well-known natural processes. Generally, it is almost impossible to observe pure water (not containing sediment particles) in nature. Pristine water is only available at specific places and in specific circumstances (Harr, 2006). Due to the complexity of research related to natural processes, there is currently no equation that provides an absolute mathematical representation of sediment movement (Vandekerckhove et al., 2020).

The rate of flow turbidity depends on the amount of river sediments in the stream. Sedimentation tanks, which accumulate sediment of about 0.01–

200 mm in size, in wet seasons, winter and spring, are used to pump water from mountain rivers into irrigation canals (Schuerch et al., 2006). The role of sedimentation tanks is particularly important for capturing river sediments that may settle along the irrigation network, as well as for collecting raw materials from bottom sediments for construction purposes (Mingzhou et al., 2007). The size, density, concentration, and nature of the sediment flow entering the structure play an important role in determining the size of sedimentation tank structures (Schleiss et al., 2016). The efficiency of sedimentation tanks (percentage of suspended solids removal) is directly dependent on tank shape and the flow (Li et al., 2017). And also, physical properties of sediment and water are quite important to provide efficiency of sedimentation tanks (Allayorova et al., 2025).

The hydromechanical properties of river sediments are of great importance in studies of open-channel processes, river mechanics and sedimentology (Fatxulloev et al., 2023). In hydraulics, the parameter that is defined above is fall velocity. In projecting hydraulic structure, like sedimentation tank, this is very important that understanding it depends on particle size, shape, density, fluid viscosity, and turbulence (Olsson et al., 2011). The first studies of the fall velocity of solid particles were carried out by Stokes (Rizayev et al., 2023; Van Rijn, 1984), who studied the process of movement of spherical particles at very low speeds in liquids. The fall velocity, or in other words 'Hydraulic size' ( $W$ ) of river sediments are not only influenced by particle size ( $d$ ), shape ( $\theta$ ), density ( $\rho_0$ ), viscosity ( $\nu$ ), and flow behavior ( $Re$ ), but the turbidity concentration ( $s$ ) of the mixture is also quite important to calculate it (Eq.1).

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DOI:  
10.26480/jcleanwas.01.2026.16.21

$$W = f(\theta, d, \rho_0, \nu, R_e, s) \quad (1)$$

This paper investigates the fall velocity of river sediments based on samples collected from a study area. The objective of this research is to assess the hydromechanical properties of river sediments, taking into account the physical characteristics of two-phase flow in foothill rivers.

## 2. METHODS AND MATERIALS

The research is based on the analysis of field and laboratory studies as well as the use of commonly used field research methods in hydraulics. Methodological and structural frame of this study is shown in figure 1.

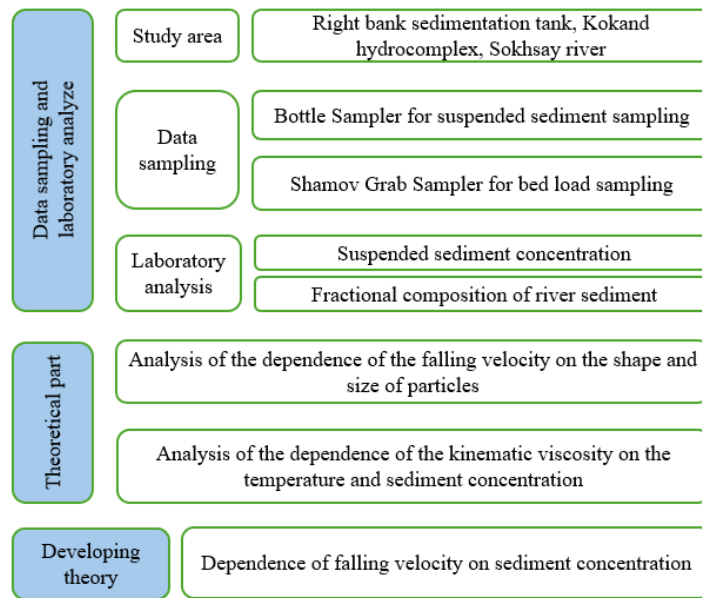


Figure 1: Methodological frame of the study.

### 2.1 Study area

In this study, the right-bank sedimentation tank (40.6553° N 70.7340° E),

which is part of the Kokand hydrocomplex constructed to regulate the flow of the Sokhsai River, was chosen to investigate the hydromechanical properties of river sediments (Figure 2).

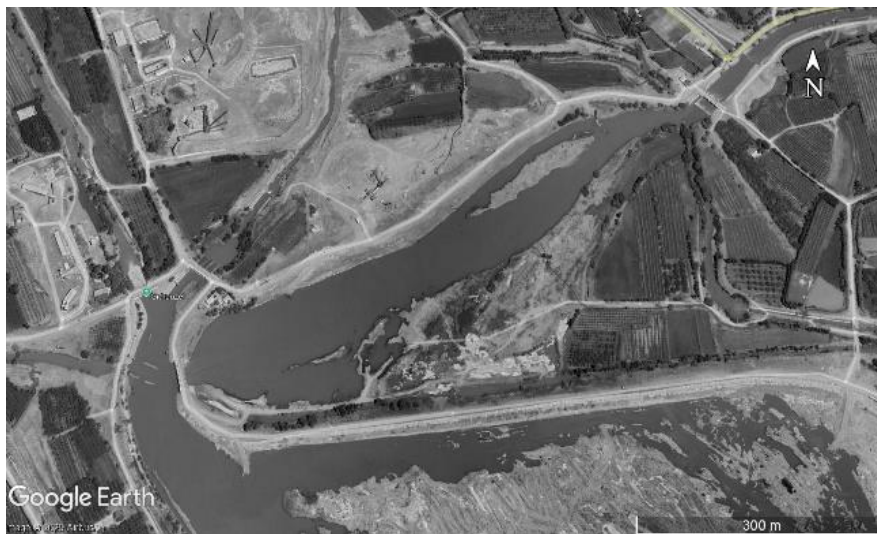


Figure 2: Bird's-eye view of study area.

The right-bank sedimentation tank is used to pump purified, sediment-free river water into irrigation canals supplying agricultural fields in the Uchkoprik, Buwayda and Baghdad districts of Fergana region, Uzbekistan. Research in the right-bank sedimentation tank showed that there is a large variation between seasonal changes in the amount of river sediment at the outlet (0.7–5.0 kg·m<sup>-3</sup>), and, therefore, the efficiency of the tank is 10–15% (Fatzulloev et al., 2023).

### 2.2 Data sampling and Laboratory analysis

During the study, a bottle sampler was used to determine the concentration of suspended sediments, measuring the amount of solid materials entering the sedimentation tank. Sampling was based on generally accepted field research guidelines in hydraulics. In the laboratory analysis, filter paper and a weight scale were used to analyze the turbidity concentration in the water. The samples that were taken from the right-bank sedimentation tank of the Kokand hydrocomplex has revealed that there is a seasonal fluctuation of river sediments in stream (Table 1).

Table 1: Seasonal variation of river sediments entering the structure, study area.

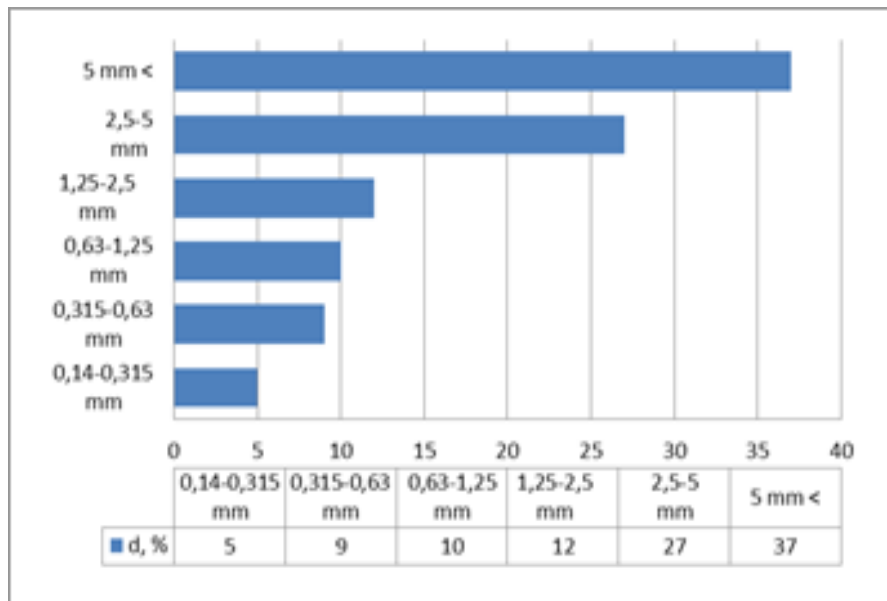
№	Sample date	Water turbidity	S, kg/m <sup>3</sup>	Concentration s, %
1	10.07.2019	3.76		0.376
2	15.07.2019	5		0.5
3	20.07.2019	5.04		0.504

**Table 1 (cont):** Seasonal variation of river sediments entering the structure, study area.

4	25.07.2019	4.94	0.494
5	30.07.2019	4.59	0.459
6	05.08.2019	3.91	0.391
7	10.08.2019	3.32	0.332
8	15.08.2019	2.66	0.266
9	20.08.2019	1.99	0.199
10	25.08.2019	1.49	0.149
11	30.08.2019	1.42	0.142
12	05.09.2019	1.02	0.102

According to laboratory analysis, the fractional composition of river sediments in the stream is as follows: 24 percent are sand in different sizes

(large, medium, and small); the others are gravel, which is up to 5 mm (Figure 3). Average diameter or medium size is equal to 4 mm: gravel.

**Figure 3:** Fractional composition of river sediment.

### 3. RESULTS AND DISCUSSIONS

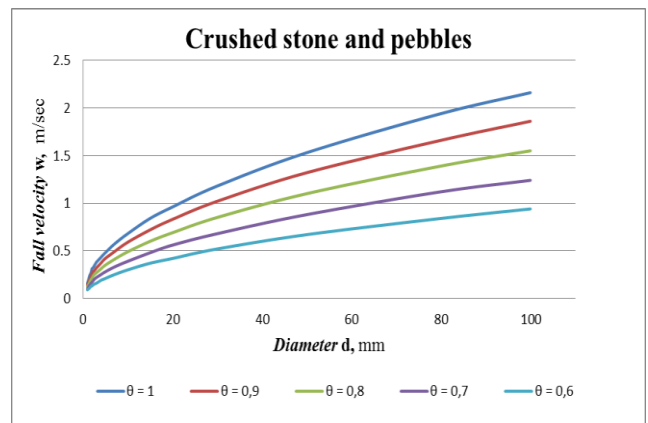
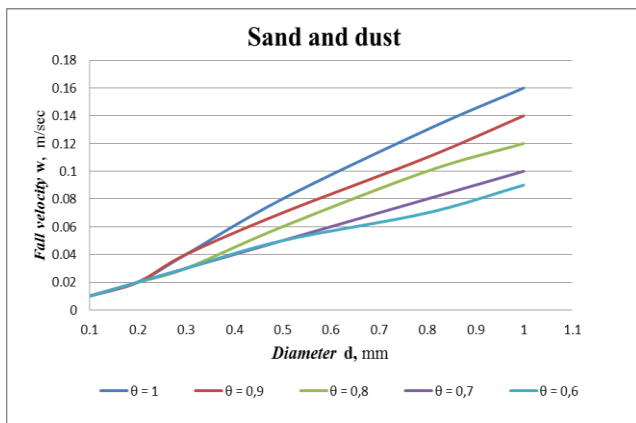
#### 3.1 Theoretical part

It is well established that external forces, in particular hydrostatic pressure, acting on sediment particles significantly affect their surface, as a result of which the fall velocity of river sediments varies depending on the shape of the particles, despite their identical diameter (Figure 4). In

some studies, particle size is represented by a shape parameter, which is determined by the following expression (Eq.2) (Ikramova et al., 2025):

$$\theta = \frac{a^2}{a \cdot b} \quad (2)$$

where: a and b are geometric dimensions: length and width of sediment, mm; d – specified diameter of sediment, mm.

**Figure 4:** Dependence of the fall velocity on the shape and size of river sediments.

The formation of river sediments can be explained by the erosion of land surface or geological layers (rocks) over the different periods of time (Di Pietro and Mahajan, 2022). Density of river sediments will be different,

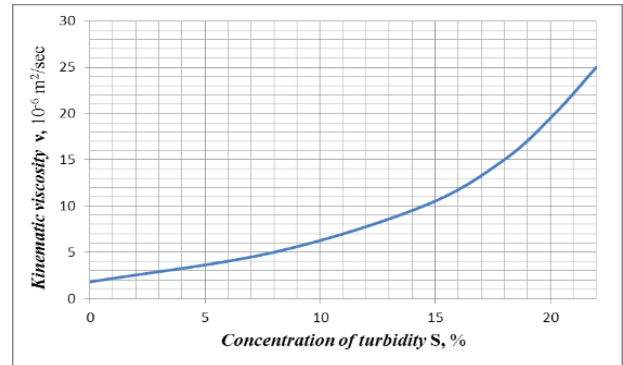
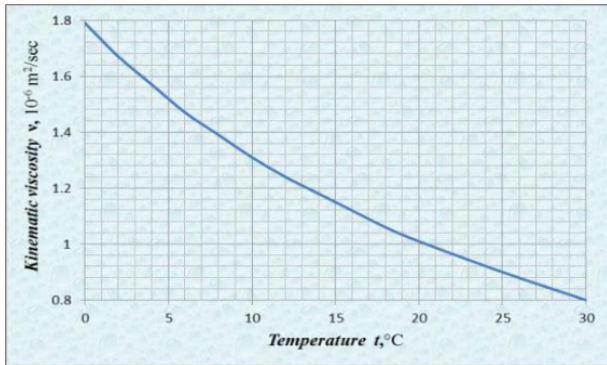
depending on the mineralogical composition of these rocks, layer (Figure 5).

**Table 2:** Density ( $\rho_0, t/m^3$ ) of river sediments with different mineralogical content

Rock type	Density $\rho_0, t/m^3$	Rock type	Density $\rho_0, t/m^3$
Limestone	2,46 - 2,84	Silicon	2,60 - 2,80
Sand	2,20 - 2,50	Granite	2,51 - 3,05
Gneiss	2,40 - 2,70	Basalt	2,70 - 3,20
Quartz sand	2,50 - 2,83	Feldspar	3,30 - 4,50

Theoretical studies of the two-phase flow dynamics indicate that the concentration of river sediments directly influences the viscosity of water, namely, the viscosity of water directly depends on its temperature and concentration of river sediments: as the temperature increases, viscosity

decreases and vice versa, as the turbidity increases, viscosity increases (Figure 5). This process shifts directly to the fall velocity of river sediments (Rizaev et al., 2023).



**Figure 5:** Dependence of kinematic viscosity on the water temperature and sediment concentration.

In the field of hydraulic engineering, to reduce the adverse effects of river sediments on irrigation canal, sedimentation tanks are commonly employed, as we summarize above. It is generally known that the efficiency of the sedimentation tank is depend on flow characteristics and the hydromechanical properties of the river sediments. In other words, the closer the flow regime is to the laminar area, the greater the efficiency. To ensure efficiency, irrigation sedimentation tanks are designed and constructed in a trapezoidal expanding shape (Figure 2). During the sedimentation process, if the influence of dynamic velocity on particles decreases, then the settling of the particle depends only on its falling velocity. In this study, when evaluating the effect of turbidity concentration on particle settling velocity, the flow in the sedimentation tank was assumed to be laminar. The dynamic velocity was not taken into account.

particle size, shape, density, and viscosity affect the fall velocity of river sediments in the stream. In addition, the extent to which sediment concentration affects water viscosity was studied (Figure 5). Therefore, since viscosity increases with increasing concentration, this also affects the hydromechanical properties of the sediment. This means that the higher the concentration, the lower the rate of decline of sediment (Eq.3).

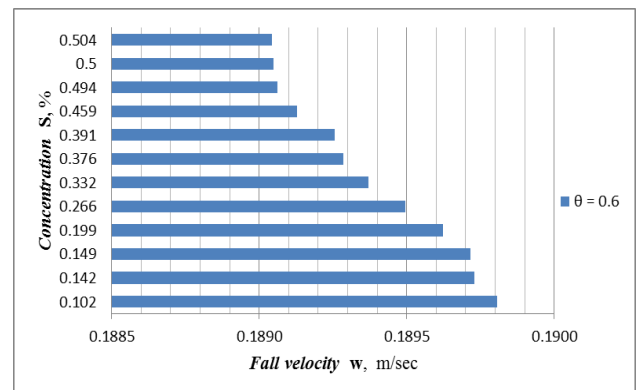
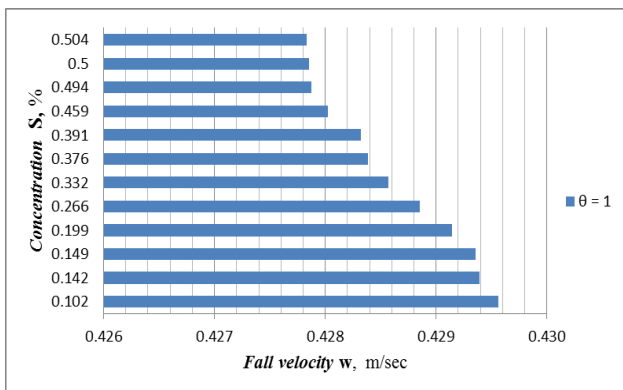
**3.2 Developing theory**

According to the above analyses, it is clear how physical properties,

$$W = W_0 \cdot (1 - s)^n \tag{3}$$

where:  $W_0$  – fall velocity of river sediment in fresh water, mm/s;  $s$  – concentration of river sediments in water.

The fall velocity of river sediments entering the right-bank sedimentation tank was reanalyzed by Eq. 3 (Figure 6). In this case, we considered cases of river sediments with an average diameter of 4 mm, which had different shapes. The results of the calculations show that the value of fall velocity drops sharply when the particle shape is different from spherical, that is, more flattened.



**Figure 6:** Dependence of falling velocity of river sediments on sediment concentration.

Results show the fall velocity of river sediments entering the right-bank tank varied in the range of 189-429 mm/sec depending on the concentration and shape of the sediment. This situation, where the probability of a particle sinking sharply decreases with a change in concentration, is usually clearly seen in mudflow (Schippa, 2020). Sediment concentrations in mudflows are typically observed to range from 50 percent to 80 percent (Cabral et al., 2021). Therefore, after a flood,

a large amount of sediment accumulates in the flooded areas. Therefore, when studying the movement of river sediments moving with mudflow, their concentration is of great importance.

**4. CONCLUSIONS**

In this study, the hydromechanical properties of river sediments were

analyzed taking into account the physical characteristics of sediments and water. The main conclusions of the study are as follows:

- During periods of high-water levels or floods, the concentration of sediment in rivers increases, and during these times, sedimentation tanks must function properly to drain water from the river into irrigation canals;
- Hydromechanical properties of river sediments, fall velocity, depend on the shape and size of river sediments and the viscosity of two-phase flow. The higher the concentration, the lower the sedimentation rate;
- Understanding the relationship between concentration and falling velocity of sediment is important not only for the operation of sedimentation tanks but also for mudflow studies.

For more comprehensive research, future investigations should concentrate to the multi-year availability of measurement data for accurate calculation of the concentration, and the degree coefficient ( $n$ ) using Eq.3 in another research.

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