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Analysis of Sediment Distribution at the Intake Structure

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Abstract. As a Maritim country, most of Indonesia's population lives near the coast or estuary. The main problem felt by the community is sanitation, clean water. The utilization of groundwater is very limited in number because of the influence of seawater intrusion. On the other hand, excess freshwater from upstream is very abundant, especially around the estuary. However, the morphological condition of the river downstream or bay has a significant depth and dimension, so it requires expensive exploitation costs in using the water. One of the solutions that have been done currently to use the water as raw water for clean water is by building free intake around the estuary. Along with river utilization, problems have been found regarding intake capacity and sediment entering the intake beyond the expectation. As a result, it gives an excessive burden on the water treatment plant. This research is an experimental study conducted in the laboratory that aims to determine the distribution of sediment in free intake building. The aims of the research end up to get the most effective intake placement elevation in terms of the capacity and the amount of sediment entering the intake. As a result of this study, it can cope with the high sedimentation rates in the free intake building. The results showed that the minimum discharge to 0.5 lt/second in the intake high (h1) was 0.04 gr, while in the intake high (h3) was 0.01 gr. For the maximum discharge to 0.7 l/sec in the intake (h1) was 1.7 gr while in the intake high (h3) was 0.02 gr. The amount of sediment that comes out through the intake will be directly proportional to the fluid flow in the channel with the same slope and elevation. However, the amount of sediment that comes out through the intake will inversely proportional to the intake elevation, discharge, and the same slope.

1. Introduction

As a maritime country, most of Indonesia's population lives near the coast or estuary. The main problem felt by the community is sanitation, especially clean water. The utilization of groundwater is very limited in number because of the influence of seawater intrusion. On the other hand, excess freshwater from upstream is very abundant, especially around the estuary. However, the morphological condition of the river downstream or estuary has considerable depth and dimension, so it requires expensive exploitation costs in using the water. One of the solutions that have been done currently to use the water as raw water for clean water is by building free intake around the estuary [1].

The existence of this intake is very helpful in supplying raw water for clean water needs, especially in coastal areas. Along with the use of tenure, it was found that the existing intake capacity is far below the role of the plan. Variables affecting the function of intake are the shape and velocity of the flow in the river, river profile, and the placement of the intake pipe from the river to the intake [2]. Therefore, the application of the theory of hydraulics to the intake design can result in an appropriate real condition, and thus sufficiently rigorous for practical design [3, 4]. The previous study obtained the most effective



intake placement in terms of the intake capacity (elevation of 0.25 h) [5]. However, the current intake problem is not only a lack of intake capacity that has been planned but the rate of sediment entering the intake that exceeds the previous plan. It is one of the problems that has been facing now. As a result of the high rate of sediment entering the intake, the burden of drinking water treatment plant is also increasing. It affects the high cost of water treatment, and the quality of clean water that reaches the community is also reduced due to the high rate of sedimentation.

Based on the mentioned above, intake design in the current condition applies the principle of hydraulic flow due to the absence of previous studies conducted. So, the authors consider the need for in-depth research on the analysis of sediment distribution at the intake due to the influence of intake discharge and elevation [6].

2. Methodology

The principle of flow at the intake in a river can be said to follow the law of flow at the hole. A hole is an opening in the wall or bottom of a tank where liquid flows through it. The shape of the tunnel is a rectangular, triangular, or circular. The upstream side of the hole can be sharp or rounded. Because of its ease of manufacture, it is also commonly used in raw water intake because water is generally used in closed channels or circular pipes. According to its size, the hole is above the water surface in the tank, and such an opening called spillway. The spillway also functions as a flow measurement tool and is widely used in irrigation networks. A large size spillway is called a weir. The function of weir not only measures the discharge/debit but also to increase the water level in irrigation and raw water network. Overview hydraulic reservoirs are the same as a spillway. Spillways are usually made of plates, while weirs are made of concrete or masonry. The upstream depth is measured from the hole axis with the height of energy (head) H . In the flow through the tunnel or the spillway, the high energy can be constant or change due to an outflow. If the high energy is consistent, then the flow is steady, whereas if the high energy changes, then the flow is unsteady. Based on the principle of Bernoulli's application, the velocity or discharge is influenced by the location and hole's elevation from the surface of the water and the cross-sectional area of the hole [7]. The equation is illustrated below.

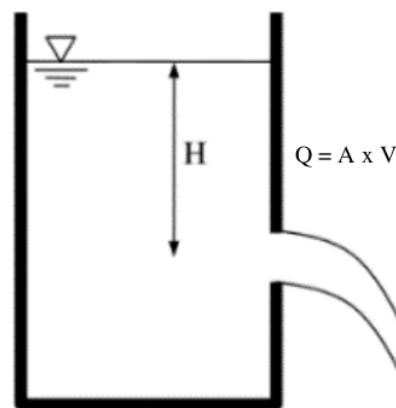


Figure 1. The principle of flow in a tank or hole

Based on Bernoulli flow principle above, the magnitude of flow velocity can be written as in the following equation:

$$V = \sqrt{2gH} \quad (1)$$

so that the amount of water flowing through the intake is:

$$Q = A \times \sqrt{2gH} \quad (2)$$

where:

- Q = Flow discharge at the intake (m³/s)
- V = velocity of bursts of water at the hole or intake (m/s)
- H = height of water above the hole (m)
- g = Acceleration of gravity (m/s²)
- A = Cross-sectional area of the hole (m²)

The flow in the tank is influenced by water height above the hole, while other flow parameters also affect the amount of water flow at the intake. The benchmark includes water flow in the river, the slope, and even the distance between weirs and intake. The flow discharge is affected by the water level. As height as the level of the surface water, the higher the discharge occurs. The increase of downstream surface water is followed by the rise of the release through the rectangular spillway. In other words that the changes in square spillway flow discharge are also accompanied by the changes in the surface water level at the upstream. A water level with flowrate, better known as the curve of release curved. The magnitude of the increase in water level downstream is not significant to changes in discharge flow. On the other hand, the flow velocity is not the same along the river. It depends on the shape, the roughness of the river canal and river patterns. The most significant velocity is located in the middle and upper part of the deepest part of the river, which is far from the frictional drag on the walls and bottom [8]. The maximum velocity in the channel usually occurs below the free surface as deep as 0.05 to 0.25 times its depth. The closer the edge, the deeper the velocity reaches the maximum [9]. The velocity distribution in the channel cross-section also depends on other factors, such as the unusual shape of the cross-section, channel roughness, and bending. Wide, swift, and shallow currents or very slippery channels, the maximum velocity often occurs on a free surface. The presence of intake in the river does not significantly affect changes in the velocity distribution in the river [5]. It is shown that the highest velocity remains located around the center of the channel and tends to fall towards the surface of the water, as shown in the following figure:

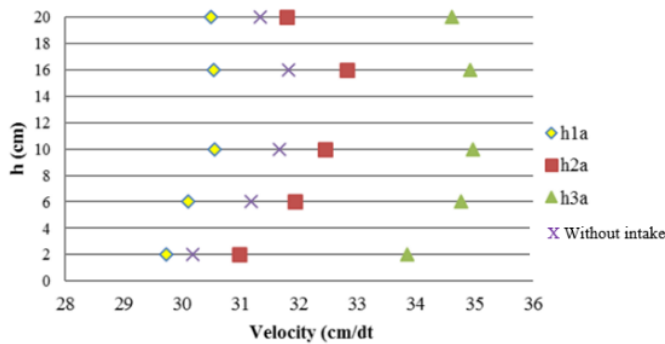


Figure 2. Distribution velocity without intake and with intake

On the other hand, the sediment transport capacity on the cross-section of the river is the magnitude of the sediment passing through the cross-section within a particular time unit. Scouring, sedimentation, and experiencing balanced transport needs to know the quantity of sediment transported in the process. The river is called balance condition when the capacity the sediment comes through the cross-sectional river is equal to the capacity sediment goes out the river. Sedimentation occurs when the sediment capacity comes in more significant than balanced sediment capacity in units of time. However, the crushing condition occurs when the capacity of sediment comes in smaller than stable sediment capacity in units of time. Riverbed material that floats in the stream consists of fine grains of sand floating above the riverbed. As a result, it is always pushed up by the turbulence of the flow. Sediment particles still

float in the river flow if the tide is turbulent. If the flow is luminaire, the sediment concentration will decrease and eventually settle, just as if the river flow did not flow.

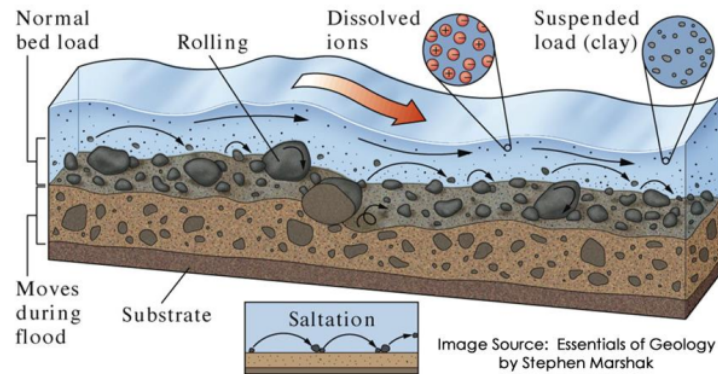


Figure 3. The movement of the sediment

This research was conducted at the Hydraulics Laboratory of the Department of Civil Engineering, Hasanuddin University. The scale model is used To describe the conditions in the field or prototypes with the model. The model is not distorted with a scale of 1:10. The flow in the river or channel uses a flume with a flume length is 9 m and a width of 0.08 m, as well as a flume height of 0.2 m. The weir or overflow height used in the flume is 0.15 m. The channel wall is installed with an intake pipe with a diameter of 7 mm to simulate the flow of water entering the intake. It is placed in 3 variations of water level, namely: $h_1 = 0.25H$, $h_2 = 0.5H$ and $h_3 = 0.75H$ from the surface water. The distance of the intake to the weir varied: $L_1 = 1$ m, $L_2 = 2$ m, and $L_3 = 3$ m. The slope of the channel is also varied 3, namely the slope of $I_1 = 0.18\%$, $I_2 = 0.25\%$ and $I_3 = 0.33\%$. There are also 3 variations of water discharge in the channel, namely $Q_1 = 0.5$ l/s, $Q_2 = 0.75$ l/s and $Q_3 = 1$ l/s.

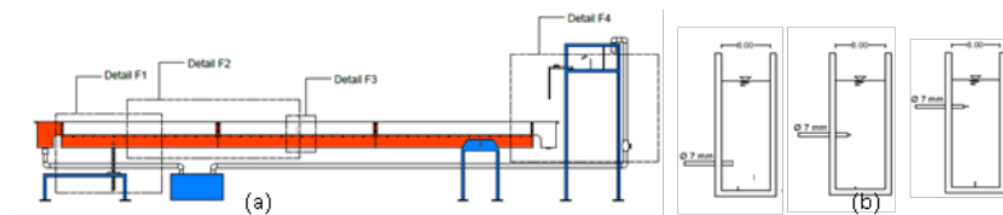


Figure 4. Research equipment a) Flume b) Elevation of intake placement

While the sedimentary characteristics used in this study are the aggregates that pass in sieve # 4 and # No.10, which are 100%. Then, the sedimentation characteristic used is 98% that pass in sieve #No.20, followed by 67.4% that pass in sieve No. 40, and filter No.60 passed 12.4%. Filter No.100 showed 3.8% passes while in filter No.200, it is 0.8%. In this test, it was found that the sample used passed filter # No. 4. This shows that the characteristics of the sample used were fine-grained, as shown in the figure below:

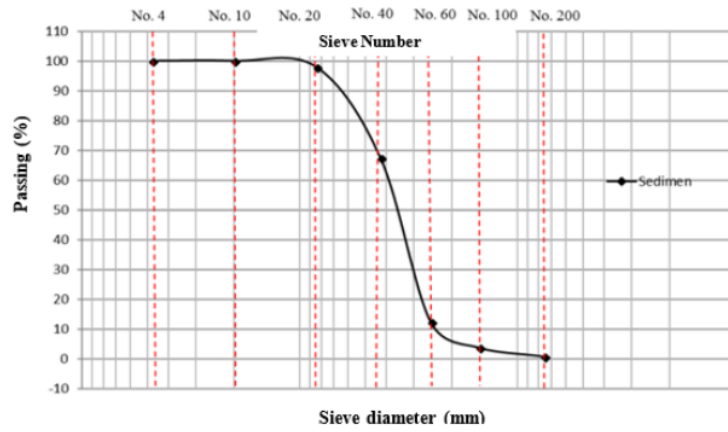


Figure 5. Sediment sample

3. Results and Discussions

3.1. Effect of Discharge on Sediment at the Intake

Based on research results, the amount of deposit that comes out due to the influence of discharge on the intake can be seen in the following:

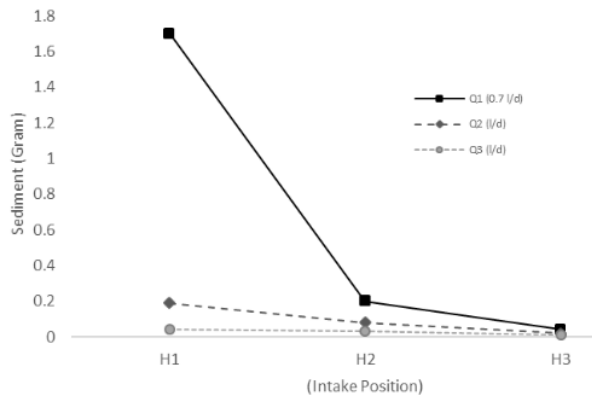


Figure 6. Comparison between sediment and water debit

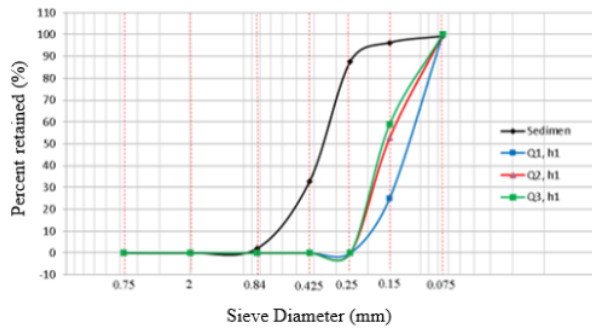


Figure 7. Sediment distribution due to changes in discharge (h1)

Figure 6 shows the relationship between sediment emitted through the intake and discharge (Q) entering the flume with slope (S) = 0.17% and elevation height (h) intake = 0.25 cm. In this experiment the three types of discharge are Q1 = 0.5 l / sec Q2 = 0.6 l / sec and Q3 = 0.7 l / sec. The value obtained from each discharge is Q1 = 0.04 gram or 5.71% and in Q2, and it increases to 0.19 gram or 27.14%, and finally, in Q3, the sediment obtained is 1.7 grams. It can be seen in the comparison graph between Q1, Q2 is 0.15 grams, and 21.43%, while in Q2, Q3 is 0.51 grams or 91.18%, respectively. It shows that with the increase in discharge in the channel, the amount of sediment that comes out at the intake will be even greater.

Based on Figure 7, it can be seen that the sediment entering the intake in conditions Q1h1 is No.4, 10, and 60 all pass 100% while the condition filter No.100 that passes through is 75%. In the Q2h1 condition in filters, No.4, 10, 40, and 60 all passed 100%, while in filter No.100, that passed is 48%. In the Q3h1 condition in filters, No.4, 10, 40, and 60 all passed 100%, while in filter No.100, that passed is 40%. It shows that the increase in discharge causes more and more diameter of the sediment to pass through the No.100 filter. Increased discharge from Q2-Q1 shows a rise of 16.7%, while an increase in the diameter of the sediment that passed the No.100 filter is 56.25%. Similarly, the increase in discharge from Q2-Q3 shows a rise of 40%, while the increase in the diameter of the sediment that passed the No.100 filter is 87.5%.

Figure 6 shows the relationship between sediment released through intake and discharge (Q) with elevation height (h2) intake = 0.53 cm. The value obtained from each discharge is Q1 = 0.03 gram or 15% and in Q2 increases to 0.08 gram or 40%. Finally, in Q3, the sediment obtained is 0.2 gram, it can be seen in the comparison chart between Q1, Q2 is 0.05 gram or 25% while in Q2, Q3 is 0.12 gram or 60%. It shows that with the increase in discharge in the channel, the amount of sediment that comes out at the intake will be even higher.

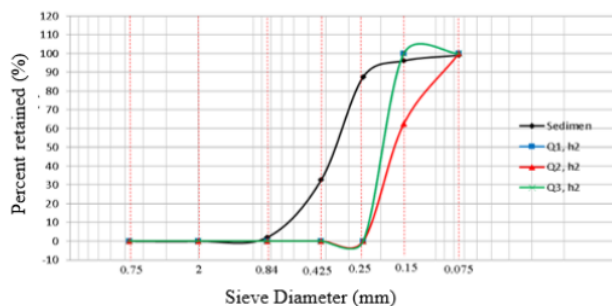


Figure 8. Sediment distribution due to changes in discharge (h2)

Figure 8 shows that the sediment that enters the intake at Q1 conditions in filters No.4, 10, 40, and 60, all passes 100%, while at filter No.100 to the pan that passes is 0%. At condition Q2 on filter No.4, 10, 40, and 60 all passed 100%, while in filter # No.100, that passed is 37.5%. In condition Q3 in filter No.4, 10, 40, and 60 all passed 100%, while in filter No.100 to the pan, that escapes is 0%. It indicates that sediment entering the intake is fine-grained sediment, while the percent held in this condition can be seen that sediment coming to the intake under conditions Q1, h2, I and Q3, h2, I in filter No. 4, 10, 40 and 60 are retained by 0%. In filters, No.100 and 200 are retained by 100%, while in conditions Q2, h1, I in filters No.4, 10, 40, and 60 are retained by 0%. In filter No. 100, it was maintained as much as 62.5% and in filter No. 200 stuck by 100%.

Figure 6 also shows the relationship between sediment emitted through intake and discharge (Q) entering the flume with elevation height (h) intake = 0.75 h. The value obtained from each discharge is Q1 = 0.01 gr or 25%, and in Q2, it increases to 0.02 gr or 50%. Finally, in Q3, the sediment obtained is 0.04 gr. It can be seen in the comparison chart between Q1, Q2 is 0.01 grams or 25% whereas, in Q2, Q3 is 0.02 grams or 50%. It shows that with the increase in discharge in the channel, the amount of sediment that comes out at the intake will be even higher.

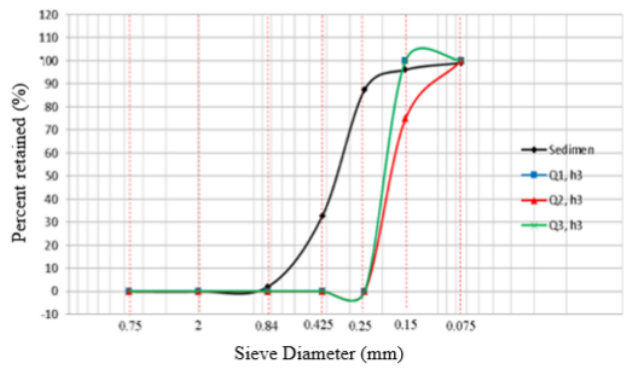


Figure 9. Sediment distribution due to changes in discharge (h3)

Based on the graph above, it can be seen that the sediment that enters the intake under Q1 conditions at the same elevation and slope, in filters No.4, 10, 40, and 60 all pass 100%, then hold in the No.100 filter to 0% pan. In the Q2 conditions in filters No.4, 10, 40, and 60 all passed 100%, then in filter No.100 that passed is 25%. In the Q3 conditions in filters No.4, 10, 40, and 60 all passed 100%, then in filters No.100 and 200, they are held 100%. It indicates that the sediment that enters the intake is fine-grained. The percent retained in this condition can be seen that the sediment that enters the intake under conditions Q1, h3, and Q3, h2 on the filters No.4, 10, 40, and 60 are retained as much 0%. In filter No.100 and No.200, it is retained by 100%. It is in Q2 conditions, h1 in filter No.4, 10, 40, and 60 are retained by 0%, while in filter No.100, it is retained by 75%, and on sieve No.200, it is held 100%.

3.2. Effect of Intake Elevation on Sediment at the Intake

Based on the results of research conducted in the laboratory that the elevation of the intake building influences the amount of sediment that comes out through the intake pipe. This can be seen in the following picture below:

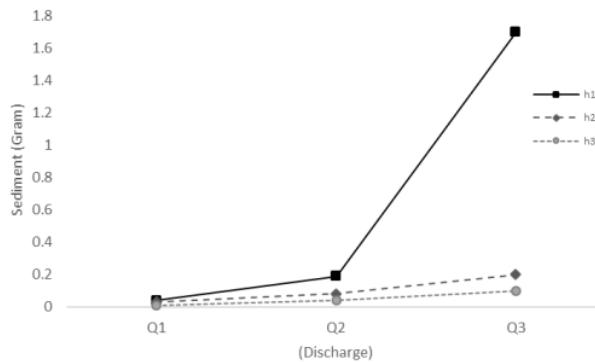


Figure 10. Comparison between sediment and water debit

A comparison between different sediments (grams) and elevation under Q1 conditions can be analyzed graphically. Figure 10 shows the relationship between sediments coming out through the intake based on intake and discharge elevations (Q) entering the flume at Q1 = 0.5 l / sec. This experiment was carried out with three types of elevation namely h1 = 0.25cm, h2 = 0.5 cm and h3 = 0.75 cm. The value obtained from each elevation is h1 = 0.04 gram, and on h2 decreased to 0.03 gram or 75%. Finally, on h3, the sediment obtained is 0.01 gram or 25%. It can be seen in the comparison chart between h1-h2 is 0.01 gram or 25%, whereas in h2 - h3 is 0.02 gram or 50%. It shows that with the increase in intake elevation in the channel, the amount of sediment that comes out in the intake pipe will be smaller.

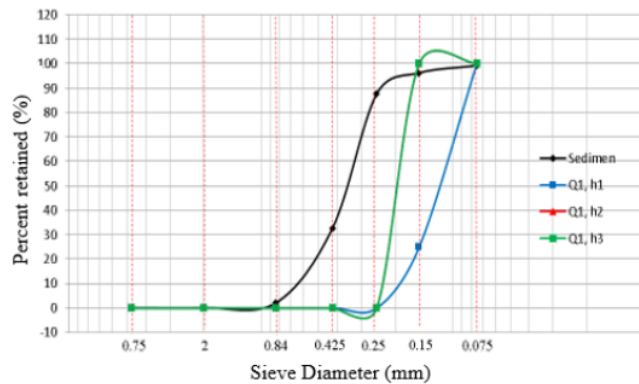


Figure 11. Comparison graph between sediment and intake elevation ($Q1 = 0.5 \text{ l / sec}$)

10
 Based on the picture above, it can be seen that the sediment is entering the intake in conditions Q1h1 and Q1h2 in filters No.4, 10, 40, and 60 are retained as much as 0%, while in filter No. 100 is retained as much as 25%. In filter, No.200 is retained as much as 100%. Meanwhile, in the Q3h1 condition is in filters No.4, 10, 40, and 60, then in filter No.100 it was retained by 52.63%, and in filter 200, it was held 100%. It indicates that the sediment that enters the intake is fine-grained sediment.

Figure 10 shows the relationship between sediment emitted through intake based on intake and discharge elevation (Q) entering the flume at $Q2 = 0.6 \text{ l / s}$. The value obtained from each elevation is $h1 = 0.19 \text{ gr}$, and at $h2$ decreases to 0.08 gram or 42.10% . Finally in the $h3$ sediment obtained was 0.04 gram or 21.05% . The ratio between $h1-h2$ was 0.11 gram or 57.9% , whereas in $h2 - h3$ it was 0.04 gram or 21.05% . It shows that with the increase in intake elevation in the channel, the amount of sediment that comes out in the intake pipe will be smaller.

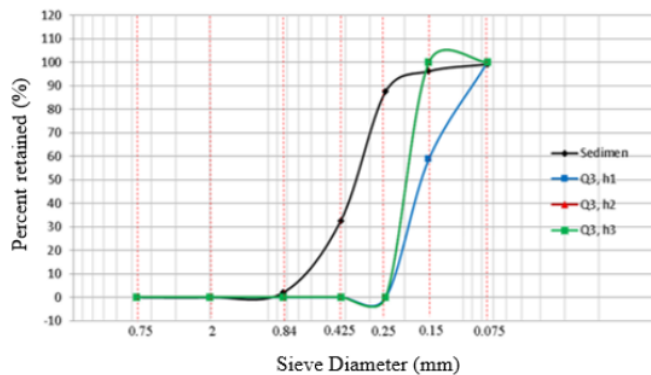


Figure 12. Sediment distribution due to changes in elevation ($Q3$)

Based on the graph above, it can be seen that the distribution of sediment entering the intake, Q3h1 and Q3h2 in sieves No.4, 10, 40 and 60, is retained by 0%, then in filter No. 100 it is maintained by 60%, while Q3h3 is retained by 0% in sieve No. 4, 10, 40, 60, and 100. It indicates that the intake elevation affects the diameter of the sediment entering the intake. The higher the intake elevation from the riverbed channel, the smaller the diameter of the sediment that enters the intake. A comparison of the elevation of the intake elevation from $h1-h2$ shows an increase in the height of 100% while the increase in sediment distribution with the diameter held in the No.100 filter is the same or 0%. Likewise, the rise in intake elevation from $h1-h3$ showed an increase in the height of 200%, while the increase in the distribution of sediment with a diameter held in the No.100 filter was only 66.7%.

4. Conclusion

Based on the results of the analysis shows that changes in intake discharge and elevation affect the distribution of sediment that enters the intake as summarized as follows:

- The amount of sediment coming out through the intake is affected by the intake discharge and elevation. The lower the elevation intake, the more sediment that will come out due to the movement of sediment that occurs under the channel that flows faster,
- The amount of sediment coming out through the intake will be inversely proportional to the intake elevation (h) with the same flow and slope channel. The minimum amount of sediment that comes out through the intake is at the highest intake elevation, $h = 0.75$ cm.
- The amount of sediment coming out through the intake is so significant compared to the discharge and other elevations of the intake. It is due to the pattern of sediment movement and discharges pressure at the highest Q3 h1 conditions and closest to the bottom of the channel
- Placement of intake elevation shows changes in sediment distribution, the closer the intake is to the bottom of the canal or river, the more varied the sediment that enters the intake. Whereas fine-grained diameter sediments will dominate the further the input from the bottom of the channel/river, the sediment entering the intake.

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