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Experimental study on appropriate location of river material mining pits regarding extraction and utilization

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Abstract

River bed sand and gravel are utilized more than mountain materials due to their availability and closeness to the transit roads and sites of usage. Excessive and non-technical extraction of gravel and sand bring a kind of interference in them, leading to many negative consequences. Therefore, presenting solutions to reduce these impacts and infilling mining pits are essential. In this research work, through an experimental work, locating two consequent river bed mining pits in the form of the distance between them and also their distance from the walls for the purpose of infilling and extraction management was investigated. The results obtained showed that movement of the downstream pit did not significantly affect the infilling volume and migration of the upstream pit but by movement of the pit towards the wall, the infilling volume of the upstream pit was reduced by up to 25% compared to the channel center. Concerning the downstream pit, the impact of the distance between pits depended on their distance from the wall so that if the pit was close to the channel center, the infilling volume was increased, and if it was located close to the wall, the infilling volume was increased up to a distance equal to 9 times the flow depth, and after that the infilling was reduced. In case the pits were excavated towards the channel center and the downstream pit was excavated at a distance equal to 12 times the flow depth, the best state of infilling and pit migration did occur.

1. Introduction

Today all around the world, diverse types of river bed materials like gravel, sand, rubble, and finely-grained materials are implemented in civil activities and industrial applications, and every day thousands of tons of these kinds of materials are extracted from different river beds and walls. The river gravel and sand are desirable sources of materials, and, on the other hand, being available and close to the transportation roads, which ultimately enhance their economic value, are among the reasons for their increased daily usage. The excessive and non-technical extraction of gravel and sand from rivers, which is a kind of interference in them, brings about many negative consequences. Extraction of river bed materials creates pits in the bed, and by unbalancing the river sediments, increases the sediment transport at the downstream of the pit and river degradation, and this change alters the parameters like bed slope and flow depth. Figure 1 shows an example of excessive extraction of the river bed materials. Therefore, presenting some solutions to reduce the negative impacts and infilling of the mining pits seems to be essential.

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Figure 1. Excessive extraction of river bed materials.

Lee et al. [1] performed an experimental investigation on a rectangular mining pit migration with uniform grading. The results obtained showed that at the diffusion stage, the maximum scour depth decreased with passage of time, and also the maximum scour depth occurred at the end of the convection period.

Erskine et al. [2] conducted a field research on Hunter River in Australia by sampling and estimating the bed load in five stations on this river. They concluded that sand and gravel extraction in this river ruined armored gravel layer and reduced the bed height and that the amount of extraction from this river exceeded the estimated annual sedimentation.

Farhadzadeh and Salehi Neishabouri [3] conducted an experimental study on the pit movement due to gravel and sand extraction from the bed of a straight channel. They investigated the effects of pit length and width on the pit migration velocity. The results obtained showed that any increase in the pit width decreased the pit migration velocity and the pit length increase brought about opposite results. Also increasing the pit length and width decreases the rate of infilling, and here, the effect of width is more evident.

Salehi Neishabouri et al. [4] conducted a laboratory and field study on the mining pit movement. In their field study, they excavated a number of pits in Gavrood River located in Kurdistan (Iran) and recorded the changes in these pits. In the laboratory study, the effects of pit length and depth and also flow rate on their movement were investigated. The results obtained showed that the pit movement velocity had a direct relation with the flow rate, while it had an inverse relation with the pit depth. Among the mentioned parameters, the pit depth had the greatest impact on movement.

Boudaghpour and Hashemi [5] conducted a field study on the environmental impacts of over-extraction of sand and gravel in Chesmeh-kil River in the north of Iran, and concluded sand and gravel mining results in clay and silt settlement leading to the formation of an impermeable layer, and this matter prevented drainage to ground water aquifer.

Padmalal et al. [6] investigated the effect of gravel and sand extraction in the rivers in India. Through field measurements, they concluded that extraction of materials led to a decrease of 7-15 cm in the bed level. Also the volume of the extracted materials was estimated to be 40 times more than the permitted limit.

Bruce Melton [7] conducted a field study on the effects of gravel and sand extraction from Rio Tigre River in Costa Rica. He concluded that material extraction disturbed river stability due to ruining the armored layer. On the other hand, if gravel and sand extraction increased the depth of the bed, the flood was less spread over the flood plain, and it increased flow velocity in the river and the consequent bed erosion.

Amiri and Azizian[8] investigated appropriate locations for extraction of river bed materials using the Hec-RAS.04 numerical model. They performed this study through field measurement in Safaroud River and defined two scenarios: the first scenario was material extraction from the river bed with 1, 2, and 3 m depths, and the second one was material extraction from the river banks with 15, 30, and 45 m widths. The model results in determination of the shear stress for 2- and 5-year floods showed that the effect of deepening was much greater than widening, and led to more intense shear stress.

Ashraf et al. [9] studied a field research on Selangor River in Malaysia by sampling from 4 gravel and sand mines in this river and utilizing a sediment transport mathematical model. They found that gravel and sand extraction reduced bed load at the mining location, and as a consequence, increased the transport power of the flow at downstream and caused upstream erosion and changed the amount of turbidity and also size and type of the transported sediments. Li et al. [10] performed an experimental and numerical investigation on the mining pit migration. The tests were performed on two cases of clear water and live bed with a triangular-shaped mining pit. The results obtained showed that in the case of clear water, the pit was not moved but the materials reposed angle since the upstream and downstream edge erosion was reduced and it led to infilling of the pit bottom. In the case of live bed, head cutting occurred but due to the incoming bed load, the pit upstream slope was filled with an angle equal to the repose angle but erosion occurred downstream.

Madyise [11] performed a field investigation on the rivers of Gaborone in South Africa. They measured the length, width, depth, and other pit characteristics, and stated the advantages and disadvantages of gravel and sand mining on the environment and ecology by sampling from a field including three different mining areas. They concluded that destruction of the river wall and its erosion were among the most critical negative impacts of material extraction.

Ghafouri Azar & Namaee [12] investigated the capability of a 3D CFD program in modeling a mining pit based on the experimental data. They found that the numerical model was helpless to simulated algorithm of filling and pit migration due to the lack of sediment transport equation.

Ako et al. [13] investigated a field study on the effects of sand and gravel mining in Luku, north central Nigeria. The results obtained showed that destruction of landscape, reduction of farm and grazing land, and deconstruction of river banks were the most adverse effects of sand and gravel mining.

Jang et al. [14], by laboratory and numerical investigation of the pit behavior due to material extraction in the flume, concluded that the upstream sediments settled in the pit and the pit migrated downstream with a constant slope. They demonstrated that with increase in the pit migration velocity, the pit depth decreased, and also they showed that the migration velocity depended on the incoming sediments.

Lu et al. [15] investigated sand and gravel mining in the upstream of the Yangtze River and its effects on the three gorge reservoirs, and analyzed the effects of sand and gravel mining on the deposition of the reservoir, particularly in terms of particle gradation and total amount of sediment.

Devi & Rongmei [16] investigated the impacts of sand and gravel quarrying on the stream channel and surrounding environment using remote sensing and GIS. In this study, they discovered that the negative impact caused by the quarrying activities increased more at the ongoing quarrying sites than at the banned quarrying sites.

Yuill et al. [17] documented the observed morphological evolution of a large (1·46 million m^3) borrow pit mined on a lateral sandbar in the lower Mississippi River using a time-series of multi-beam bathymetric surveys. The results obtained showed that during the 2·5-year time-series, 53% of the initial pit volume infilled with sediment, decreasing the pit depth by an average of 0·88 m yr^{-1}.

Podimata & Yannopoulos [18] described the contested *status quo* in riverbed sand-gravel mining activities with an example from Greece, as a case study. They proposed a methodology about the good governance of the mining sector that promoted a sustainable sharing of the aggregate resource by securing environment and safe-keeping revenues in the mining trade market.

Husain et al. [19] investigated the environmental impact of sand mining in Malir river bed in Karachi (Pakistan). The results obtained showed that destruction of landscape, reduction of farm grazing land, and lowering of water table were the environmental effects that were resulted due to sand and gravel mining in Malir River. It was concluded that the government developed and implemented policies designed to protect the environment around Malir sand and gravel mining areas in Karachi.

Calle et al. [20] in a field study on Rambla dela viuda in Spain investigated the morphosedimentary changes in relation to gravel mining. They found a 50% reduction in inactive section and a 20% increase in stable area and 3.5 m incision compared to the condition observed prior to gravel mining.

Sadeghi et al. [21] investigated the effects of some types of sand and gravel mining on the particle size distribution of suspended sediments in the Vaz-e-Owlya, Vaz-e-Sofla, and Alesh-Roud riverine mines located in the Mazandaran Province, northern Iran. The results obtained revealed that the level and intensity of mining activity affected the particle size distribution of the suspended sediments. Also they found that the type of mine and the level of exploitation changed the particle size distribution of the suspended sediments.

With respect to the previous studies, it was revealed that most researchers had investigated the pit migration velocity or environmental impacts of material extraction, and as so far, no research work has been done on properly locating the pits in the form of their infilling. In this research work, via an experimental study, locating mining pits was investigated and appropriate locating the pits was presented.

2. Materials and research methodology

The experiments were performed in the laboratory of Soil Conservation and Watershed Management Research Institute located in Tehran. The laboratory channel used for the test was 11 m long, 1.5 m wide, and 50 cm deep. Figure 2 shows a schematic figure of the laboratory channel.

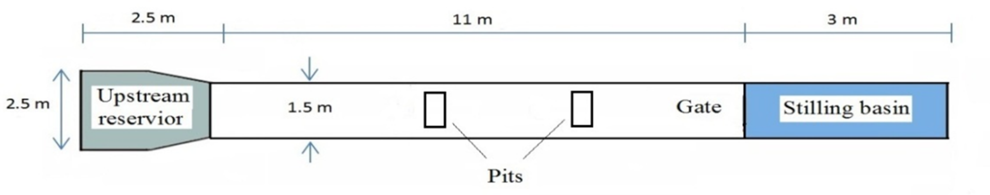


Figure 2. Laboratory flume and experimental setup.

The pit length, width, and height were taken 36, 46, and 9.5 cm, respectively, and the flow depth was taken 6 cm. The shorter dimension of the pit was put along the channel length, and the longer dimension was excavated along the channel width. Therefore, this location of the pit means a higher extraction rate across the channel width. The material used was uniform sand with an average diameter of 1 mm and the uniformity coefficient of 1.46.

A dimensional analysis was performed on the effective parameters. The effects of diverse parameters on infilling of mining pit can be shown as bellow:

$$V = f(B, S_0, L, S, V_0, l, b, C_s, U, U_c, y, d_{50}, \sigma_g, \nu, \rho, \rho_s, g) \quad (1)$$

with channel width (B), channel longitudinal slope (S_0), distance between the pits (L), distance between the pit and the wall (S), initial volume of the pit before testing (V_0), pit final volume at the end of test (V), pit length (l), pit width (b), mean flow velocity (U), incipient motion velocity of the bed materials (U_c), flow depth (y), particle average diameter (d_{50}), incoming sediment concentration (C_s), sediment mass density (ρ_s), standard deviation of material particle size distribution (σ_g), water mass density (ρ), acceleration of gravity (g), and fluid kinematic viscosity (ν).

Considering the conducted dimensional analysis of the effective variables, the following equation was obtained to investigate the influence of locating the pits in infilling:

$$\frac{V}{V_0} = f(\frac{L}{y}, \frac{S}{B}) \quad (2)$$

Using a metallic mold, two pits were created in the channel, and after regulating the hydraulic conditions for the test, the molds were removed and the experiment was begun. For more accuracy, each test was performed twice and the average of the two tests was taken as the representative result for that case, so totally 18 tests were performed. The characteristics of pits are given in Table 1. The observed incipient motion of discharge was obtained to be equal to 28.62 l/s and the flow rate in the test was taken 20% greater and equal to 34.4 l/s. Also the entrance sediment using the sediment injection device was 280 g/min, being injected from the channel upstream. The duration of the test was 60 min and changes in the bed along the centerline of each pit were measured at 18 longitudinal points at the end of the test using the PROFILER device so that the pit migration and change could be determined in terms of erosion and sedimentation. After the end of the tests, to determine the infilling rate, the pits were gridded in both the longitudinal and latitudinal directions, and the bed topography was measured.

Table 1. Properties corresponding to the location of pits in the tests.

Test No.	1	2	3	4	5	6	7	8	9
$\frac{L}{y}$	8	12	16	8	12	16	8	12	16
$\frac{S}{B}$	50%	50%	50%	35%	35%	35%	20%	20%	20%

3. Results and discussion

By the start of the tests, it was observed that the materials sedimented in the pits from the upstream and settled on the upstream slope and the bottom of the pit, and this caused a downward migration of the pit upstream slope. On the other hand, due to the low capacity of the sediment transport into the pit, the hungry water phenomenon occurred and the materials were eroded from the downstream edge of the pit and moved downward. Also the maximum pit depth was reduced and moved towards downstream (Figure 3).

Figure 4 shows the sediment transport pattern and infilling of the upstream and downstream pits. Regarding Figures 4 (a, c), it can be observed that for all three ratios of $\frac{L}{y}$, after 60 min, the upstream pit is completely filled and has equal deformations. However, in Figure 5e, the pit is not completely filled; therefore, distancing the downstream pit with any $\frac{S}{B}$ value would not affect the infilling of the upstream pit, and this is independent from the pit distance from the wall. However, Figure 4e shows that the wall fully affects the infilling rate and reduces it and this is true for all $\frac{L}{y}$ values.

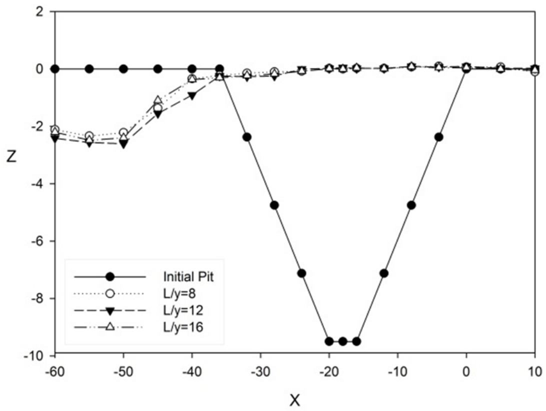
As it can be seen in Figures 4 (b, d, f), by distancing the downstream pit, both the sedimentation rate within the pit and the downstream migration of the pit are reduced for all $\frac{L}{y}$ values. This occurs due to the fact that infilling of the downstream pit is based upon the upstream pit erosion. When the downstream pit is close to the upstream one, quantitatively, higher amounts of eroded sediments from the upstream settle on the downstream pit and the sediments from the upstream pit reach earlier to the downstream pit and cause a greater downstream pit migration. Also erosion of the upstream pit leads to a fall in the filled level in the downstream pit. This occurs because of migration of the upstream pit due to the increased erosion between the two pits.

Figure 5 shows the 2D variation of the upstream pit in plan. As seen, at $\frac{S}{B} = 50\%$ and $\frac{S}{B} = 35\%$ and with passage of time, the pit is completely migrated downstream and filled entirely. By an upstream pit approach towards the wall, the infilling process is changed and turns inclined. This occurs due to the pit position and its closeness to the wall. As a matter of fact, the pit drives the incoming upstream flow to itself. This phenomenon is called the flow capture by the pit causing the flow entering the pit from the right side. This flow encounters the wall and it is diverted, resulting in the pit inclined migration.

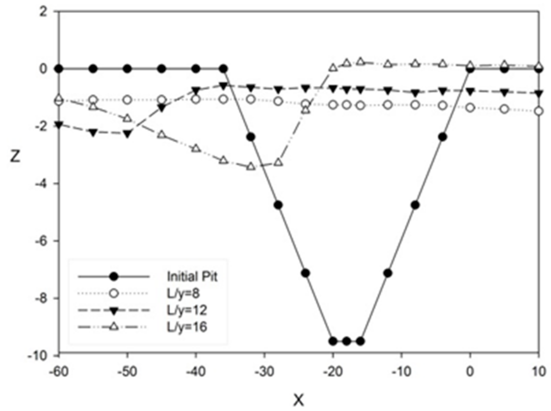
Figure 6 shows a 2D variation of the downstream pit in plan. At $\frac{S}{B} = 50\%$ and $\frac{S}{B} = 35\%$, by decreasing the distance between the pits, the bed level falls greatly within this distance, and this issue increases the incoming sediments into the downstream pit. As seen, at $\frac{S}{B} = 50\%$ and $\frac{S}{B} = 35\%$, and for $\frac{L}{y}$ =8 and 12, with the passage of time, the pit is migrated downstream and it is completely filled. At the upstream, a pit severe reduction in the bed level is clearly observed but with increase in the distance and for $\frac{L}{y}$ =16, the impact of upstream pit erosion is reduced and even sedimentation occurs (Figures 6-a-3 and 6-b-3). With increase in the distance between the pits, sedimentation is also observed at upstream of the downstream pit at $\frac{S}{B} = 20\%$.

(a) (b) (c)

Figure 3. Pit infilling at the end of the tests at $\frac{L}{y} = 12$, a) $\frac{S}{B} = 50\%$, b) $\frac{S}{B} = 35\%$ c) $\frac{S}{B} = 20\%$.



(a)



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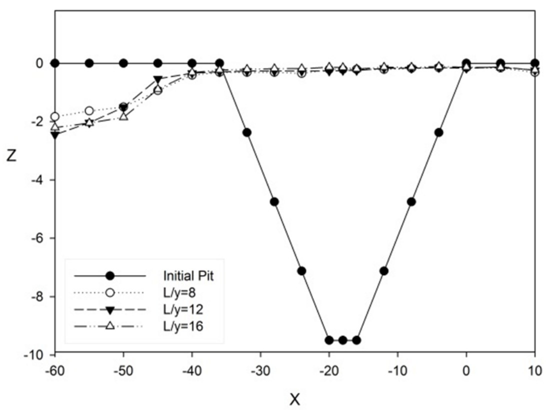
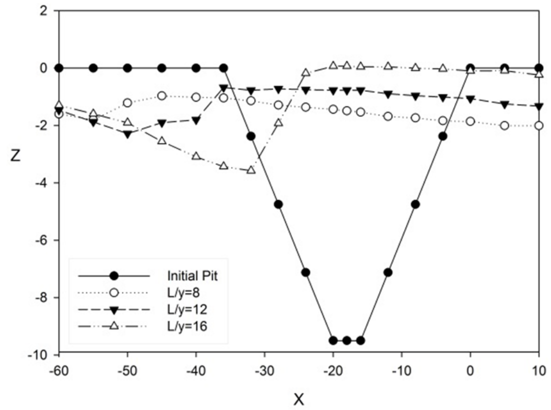
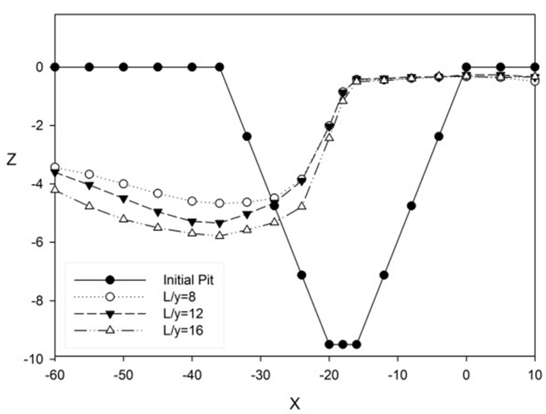


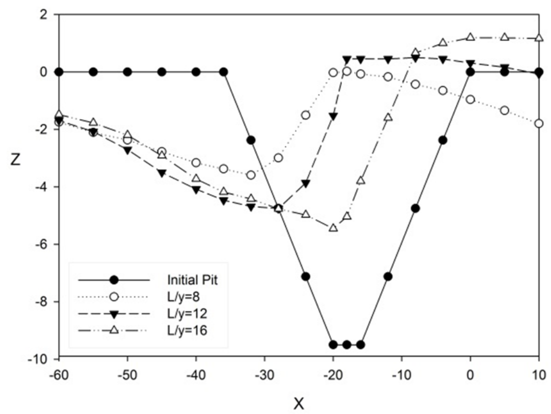
(c)



(d)



(e)



(f)

Figure 4. Sediment transport pattern a) upstream and $\frac{S}{B} = 50\%$, b) downstream and $\frac{S}{B} = 50\%$, c) upstream and $\frac{S}{B} = 35\%$, d) downstream and $\frac{S}{B} = 35\%$, e) upstream and $\frac{S}{B} = 20\%$, f) downstream and $\frac{S}{B} = 20\%$ (flow direction is from right to left).

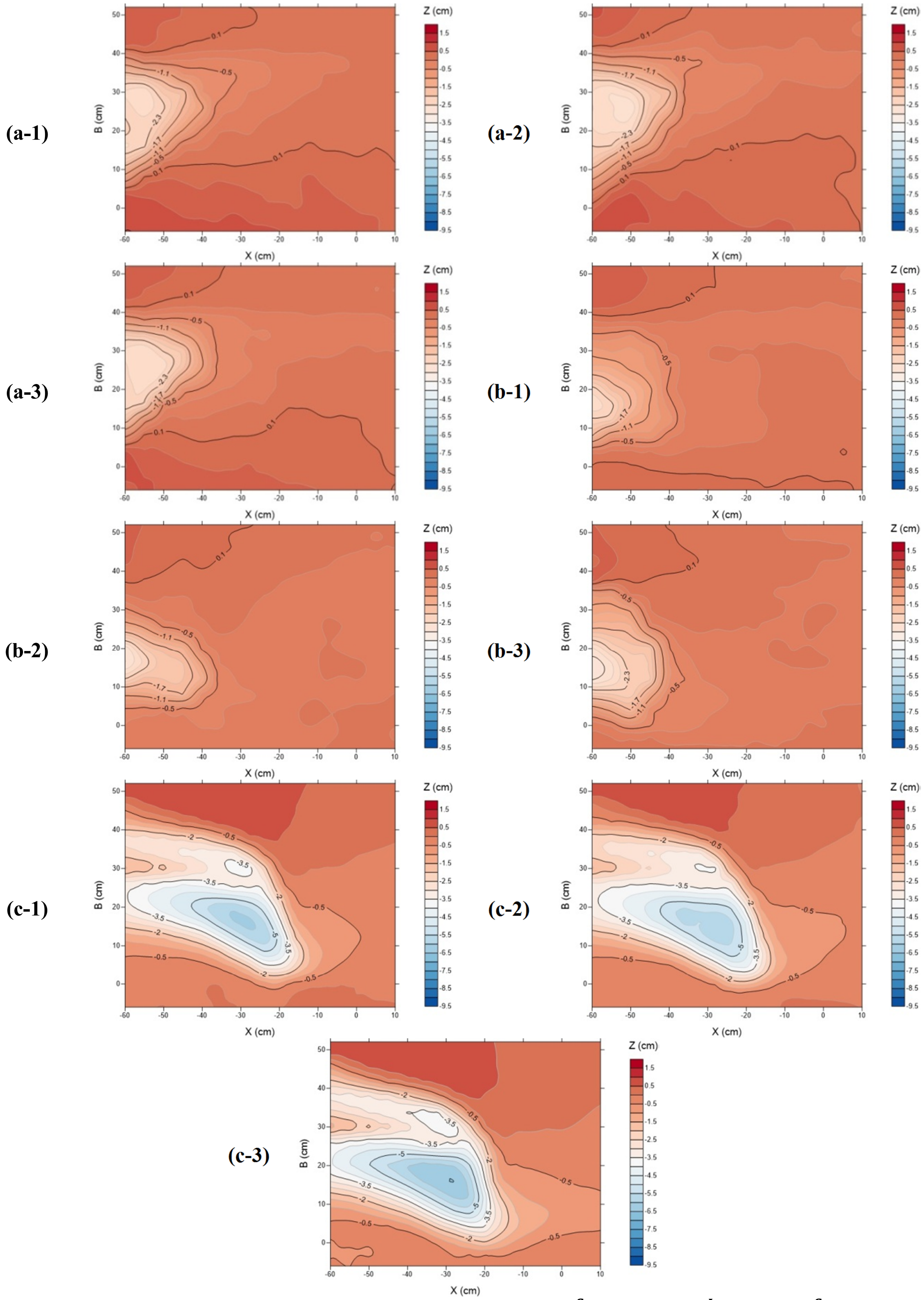


Figure 5. 2D changes in the upstream pit and its surrounding a-1) $\frac{S}{B}=50\%$ and $\frac{L}{y}=8$, a-2) $\frac{S}{B}=50\%$ and $\frac{L}{y}=12$, a-3) $\frac{S}{B}=50\%$ and $\frac{L}{y}=16$, b-1) $\frac{S}{B}=35\%$ and $\frac{L}{y}=8$, b-2) $\frac{S}{B}=35\%$ and $\frac{L}{y}=12$, b-3) $\frac{S}{B}=35\%$ and $\frac{L}{y}=16$, c-1) $\frac{S}{B}=20\%$ and $\frac{L}{y}=8$, c-2) $\frac{S}{B}=20\%$ and $\frac{L}{y}=12$, c-3) $\frac{S}{B}=20\%$ and $\frac{L}{y}=16$ (flow direction is from right to left).

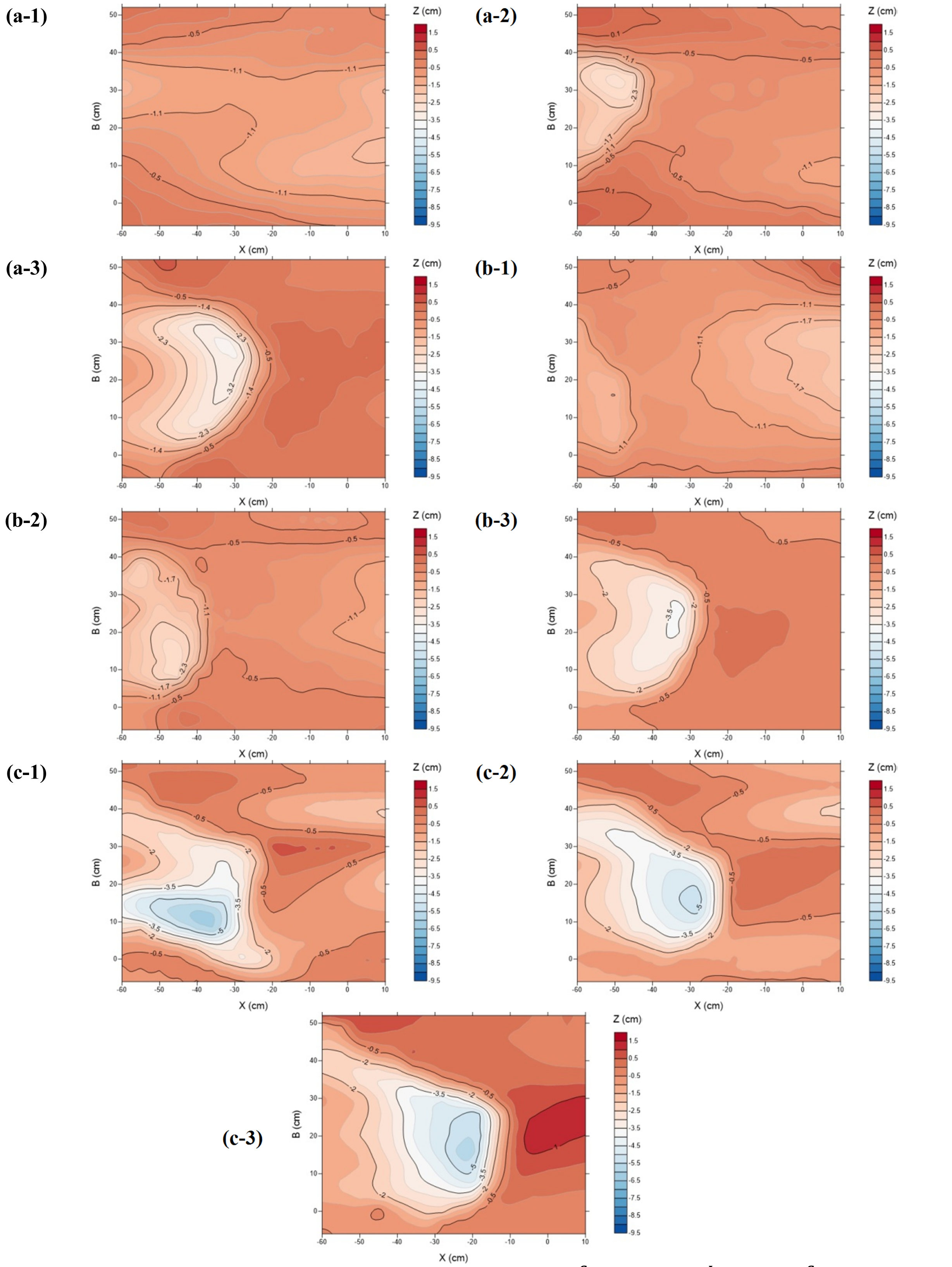


Figure 6. 2D changes in the downstream pit and its surrounding, a-1) $\frac{S}{B}=50\%$ and $\frac{L}{y}=8$, a-2) $\frac{S}{B}=50\%$ and $\frac{L}{y}=12$, a-3) $\frac{S}{B}=50\%$ and $\frac{L}{y}=16$, b-1) $\frac{S}{B}=35\%$ and $\frac{L}{y}=8$, b-2) $\frac{S}{B}=35\%$ and $\frac{L}{y}=12$, b-3) $\frac{S}{B}=35\%$ and $\frac{L}{y}=16$, c-1) $\frac{S}{B}=20\%$ and $\frac{L}{y}=8$, c-2) $\frac{S}{B}=20\%$ and $\frac{L}{y}=12$, c-3) $\frac{S}{B}=20\%$ and $\frac{L}{y}=16$ (flow direction is from right to left).

Tables 2 and 3 show a summary of the pit infilling rates for the mentioned cases.

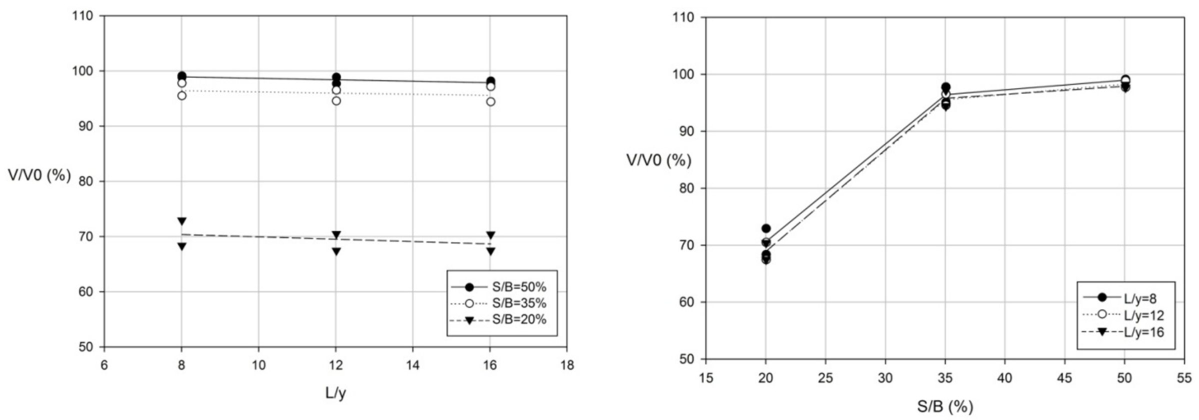
Table 2. Infilling rate of the upstream pit in percentage.

Locating	$\frac{L}{y}=8$	$\frac{L}{y}=12$	$\frac{L}{y}=16$
$\frac{S}{B}=20\%$	70.45	68.77	68.65
$\frac{S}{B}=35\%$	96.64	95.54	95.8
$\frac{S}{B}=50\%$	98.98	97.92	98.28

Table 3. Infilling rate of the downstream pit in percentage.

Locating	$\frac{L}{y}=8$	$\frac{L}{y}=12$	$\frac{L}{y}=16$
$\frac{S}{B}=20\%$	76.7	74.29	66.57
$\frac{S}{B}=35\%$	71.88	82.89	89.86
$\frac{S}{B}=50\%$	72.73	83.59	89.41

The effects of distance between pits and also their distance from the wall on changes in the upstream and downstream pit volumes are shown in Figures 7 and 8 in the form of the best fit to the points. With respect to Figure 7 a, distancing the downstream pit does not have any significant impact on the alternations in the upstream pit infilling volume for all S/B values. The results obtained show that when the pit is located close to the wall, the infilling volume is reduced by about 25% compared to being located close to the channel center. This issue is due to flow hits to the wall and its diversion causing pit infilling just from the right side. Figure 7 b shows that with movement of the upstream pit from the wall towards the channel center, the infilling rate increases but from $\frac{S}{B}=35\%$ to $\frac{S}{B}=50\%$, the slope of infilling becomes moderate, whereas from $\frac{S}{B}=20\%$ to $\frac{S}{B}=35\%$, this slope is sharp.



(a) (b)

Figure 7. Infilling of the upstream pit: a) effect of distance between pits, b) effect of distance from the wall.

It can be seen in Figure 8 that at $\frac{S}{B}=50\%$ and $\frac{S}{B}=35\%$, by increasing the distance between the pits, the infilling volume increases, but quantitatively, the infilling amount is the same since when the downstream pit is close to the upstream pit, due to the erosion of the upstream pit, it is rapidly filled but after infilling, as the upstream erosion is still continued, it causes a fall in the pit filled level, reducing the infilling volume compared to the initial state. By distancing the downstream pit, a lower amount of sediments enters the pit, and at $\frac{L}{y}=16$, the pit is not completely filled during the experiment, and in this case, sedimentation at upstream edge and over the pit increases the infilling volume. At $\frac{S}{B}=20\%$, the opposite occurs, and by increasing the distance between the pits, the infilled volume of the downstream pit is reduced because the downstream pit in this case is not thoroughly filled and the fall in the pit filled level does not occur. Regarding Figure 8 b, it is found that from $\frac{S}{B}=20\%$ to $\frac{S}{B}=35\%$, by increasing the distance between the pits, the trend of infilling volume changes so that by increasing the distance between the upstream and downstream pits within $8\leq\frac{L}{y}\leq12$, the wall has a desirable impact on the pit infilling, and according to Figure 8 a, this value is $\frac{L}{y}=9$ (at the intersection of $\frac{S}{B}=20\%$ and $\frac{S}{B}=35\%$). However, from $\frac{L}{y}=9$ on, the wall has a negative impact and the infilled volume is decreased. Movement of the pit from $\frac{S}{B}$ = 35% to $\frac{S}{B}$ = 50% does not affect the infilling volume, and this issue is independent from the distance between the upstream and downstream pits. With respect to the presented results, it could be concluded that increasing the distance between the pits does not impact the upstream pit infilling but it greatly affects the downstream pit.

Downstream migration of the pit generally results in its disappearance, and it is desirable for infilling of the pit. Therefore, migration of the pits is also important for a proper determination of extraction location. The spatial-temporal diagrams corresponding to the upstream and downstream pits knick points are shown in Figures 9 and 10, where the slope of each diagram indicates the downward migration velocity of the pit knick point. As seen in Figure 9, by increasing the distance between the pits, the upstream pit migration velocity does not change and the $\frac{\boldsymbol{L}}{\boldsymbol{y}}$ ratio is not effective. The migration velocity of the upstream pit is the same at both $\frac{S}{B}$ = 35% and $\frac{S}{B}$ = 50% and is lower at $\frac{S}{B}$ = 20%, and the pit reaches downstream with more delay.

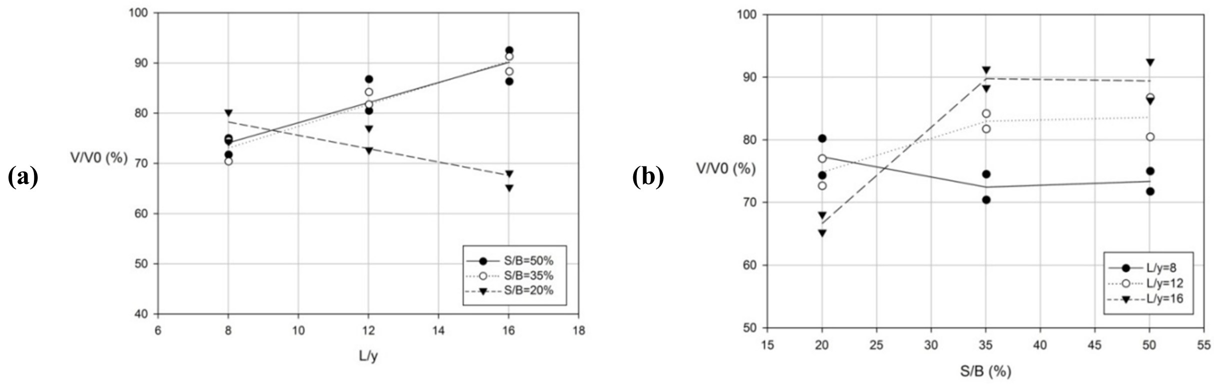
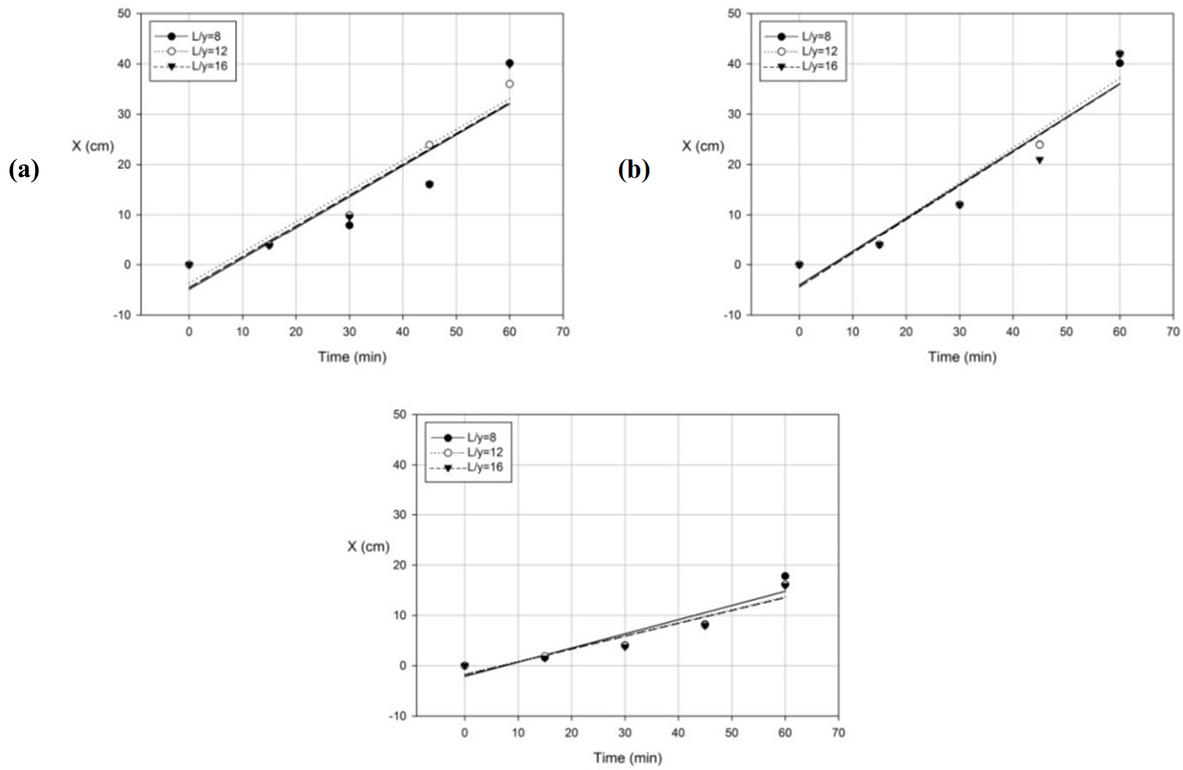


Figure 8. Infilling of the downstream pit: a) effect of distance between the pits, b) effect of distance from the wall.



(c)

Figure 9. Spatial-temporal diagram of the upstream pit nick point a) $\frac{S}{B} = 50\%$, b) $\frac{S}{B} = 35\%$, c) $\frac{S}{B} = 20\%$.

Regarding Figure 10, it is found that by increasing the distance between the pits, the downstream pit migration velocity decreases. This issue is independent from the pit distance from the wall, and it is true for all three ratios of $\frac{S}{B}$. On the other hand, when the downstream pit approaches the wall, the migration velocity decreases considerably, this is due to the effect of wall and flow diversion and a different infilling pattern.
In order to achieve an optimal state for both the upstream and downstream pits where both the infilling volume and migration velocity get better, it should be noted that for the upstream pit, whether in terms of infilling or migration velocity, the $\frac{S}{B}$= 50% ratio is appropriate but for the downstream pit at $\frac{S}{B}$ = 50%, $\frac{L}{y}$ ≥16 is appropriate for infilling volume and $\frac{L}{y}$ ≤12 is appropriate for pit migration. Thus a state should be selected wherein the pit area is entirely filled and at the same state it has an acceptable infilling volume. The optimal state is $\frac{L}{y}$ = 12 because the downstream pit has an acceptable percentage of infilling and also has an optimal filled area and migration velocity. Therefore, the most optimal state is where the pits are located at $\frac{S}{B}$= 50% and the downstream pit is excavated at $\frac{L}{y}$ = 12.

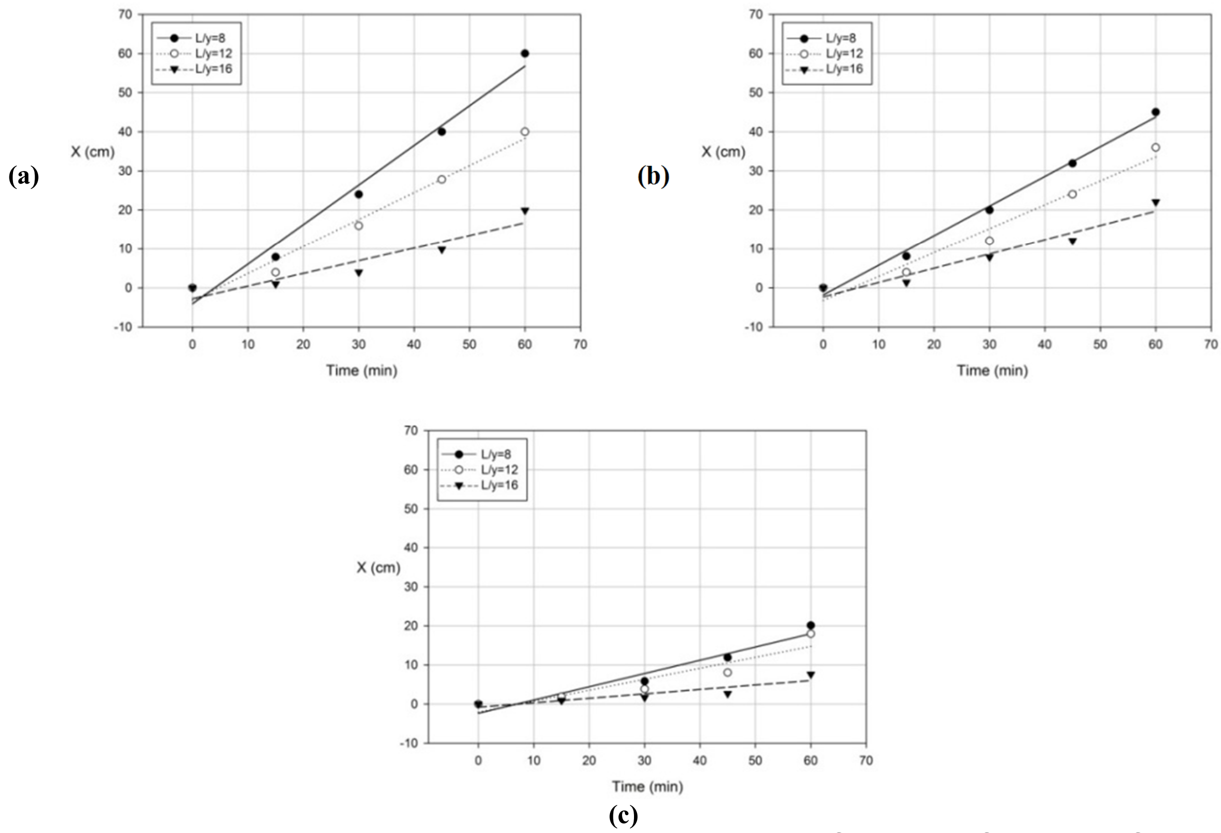


Figure 10. Spatial-temporal diagram of the downstream pit nick point a) $\frac{S}{B} = 50\%$, b) $\frac{S}{B} = 35\%$, c) $\frac{S}{B} = 20\%$.

4. Conclusions

In this experimental study, the impact of locating mining pits on their infilling rate was investigated in the form of the distance between the pits and their distance from the wall. The results obtained from the experiments showed that:

1- Movement of the downstream pit did not significantly affect the way the upstream pit was filled and also the infilling volume.

2- As the pits approached the wall, the infilling volume of the upstream pit was reduced so that the reduced volume during movement of the pit from the channel center to the vicinity of wall was about 25%.

3- For the downstream pit, the effect of distance between the pits depended on their distance from the wall. In case the pit was located at 35% ≤ $\frac{S}{B}$ ≤ 50%, with increase in the distance between the pits, the infilling volume of the downstream pit increased but at $20\% \leq \frac{S}{B} \leq 35\%$, in case the pits were located at a distance equal to 9 times the flow depth, the wall had a desirable effect on the downstream pit infilling but for distances greater than 9 times the flow depth, the wall had a negative effect and decreased the downstream pit infilling volume.

4- The distance between the pits did not affect the upstream pit migration velocity but the wall had a negative effect and reduced the migration velocity.

5- For the downstream pit, by increasing the distance between the pits, the migration velocity was reduced, and this issue was independent from the pit distance from the wall. In fact, by increasing the distance between the pits and approaching the pits to the wall, the migration velocity of downstream pit was reduced.

According to the results obtained, in order to achieve a state of an acceptable infilling percentage and also optimal total area of the filled pit and the migration velocity, the pits should be located at $\frac{S}{B} = 50\%$ and the downstream pit should be excavated at $\frac{L}{y} = 12$.

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مطالعه آزمایشگاهی مکان مناسب حفره‌های برداشت مصالح رودخانه‌ای با توجه به استخراج و بهره‌برداری

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چکیده:

شن و ماسه رودخانه‌ای منابع مطلوبی از مصالح هستند که در دسترس بودن و نزدیکی به جاده‌های حمل‌ونقل و محل مصرف از جمله دلایلی است کـه اسـتفاده روزافزون آن را نسبت به مصالح کوهی به دنبال داشته است. برداشت بی‌رویه و غیر فنی شن و ماسه از رودخانه‌ها که نوعی دخل و تصرف در آن به شمار می‌آیـد، آثار منفی فراوانی را به دنبال دارد؛ بنابراین ارائه راهکارهایی برای کاهش آثار منفی و احیای حفره برداشت مصالح ضروری به نظر مـی‌رسـد. در ایـن پـژوهش بـا مطالعه آزمایشگاهی مکان‌یابی دو حفره متوالی برداشت مصالح رودخانه‌ای در قالب فاصله حفره‌ها از هم و همچنین فاصله حفره‌ها از دیواره به منظور پرشـدگی و احیای آن‌ها برای مدیریت بهره‌برداری و برداشت مورد بررسی قرار گرفته است. نتایج نشان می‌دهد که جابجایی حفره پایین دست بر حجم پرشـدگی و مهـاجرت حفره بالادست تأثیر محسوسی ندارد اما با نزدیک شدن حفره به سمت دیواره حجم پرشدگی برای حفره بالادست نسبت به مرکز کانال ۲۵ درصد کاهش می‌یابد. برای حفره پایین دست، تأثیر فاصله بین حفره‌ها به جانمایی آن‌ها از دیواره بستگی داشته به طوری که اگر حفره در نزدیکی مرکز کانـال باشـد حجـم پرشـدگی افزایش یافته و در صورتی که در نزدیکی دیواره قرار بگیرد در فاصله‌ای تا ۹ برابر عمق جریان سبب افزایش حجـم پرشـده مـی‌شـود و پـس از آن سـبب کـاهش پرشدگی خواهد شد. در صورتی که حفره‌ها به سمت مرکز آبراهه و حفره پایین دست در فاصله ۱۲ برابـر عمـق جریـان حفـر شـود، بهتـرین میـزان پرشـدگی و مهاجرت حفره‌ها اتفاق می‌افتد.

کلمات کلیدی: برداشت مصالح، حفره برداشت، انتقال رسوب، سرعت مهاجرت.