DOI: 10.2478/jwld-2019-0023

JOURNAL OF WATER AND LAND DEVELOPMENT
2019, No. 41 (IV–VI): 19–30
PL ISSN 1429–7426, e-ISSN 2083-4535

Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld; http://journals.pan.pl/jwld

Received 14.06.2018
Reviewed 10.12.2018
Accepted 02.01.2019

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

The application of global experiences in evaluation of mining zone: Case study the Zohreh River

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For citation: Azarang F., Shafaei Bejestan M., Jafari G., Karami M. 2019. The application of global experiences in evaluation of mining zone: Case study the Zohreh River. Journal of Water and Land Development. No. 41 (IV–VI) p. 19–30. DOI: 10.2478/jwld-2019-0023.

Abstract

The materials mining from rivers have a variety of negative and positive effects. Currently, one of the most important issues in river engineering is the proper management of materials mining. In this research, global experiences and international standards for managing sand and gravel mining have been applied to evaluate the mining area in the Zohreh River in Khuzestan province (Iran). One of the evaluation methods in this field is the river matrix method. In this method, which is defined on the basis of river pattern, river characteristics such as river size, site location of materials, associated channel and type of deposit are being considered. In this research, a segment of the Zohreh River between Sardasht Zeydun bridge and Mohseniyeh village in which has good potential for gravel mining was selected and evaluated for river characteristics, mining potential and application of river matrix method. The study indicates that the Zohreh River has a braided pattern in the range. The volume of sediment materials in the target area is about 10 000 m^3, the length and width of the mining area are 125 and 80 m respectively, and surface extraction with a maximum depth of 1 m was recommended for extraction of materials. At the end of the research, management solutions and solutions for mining of river materials were presented using various standards.

Key words: *global experiences, sand and gravel mining, river matrix method, Zohreh River*

INTRODUCTION

Water is one of the most important factors in human life and plays a crucial role in human life and agriculture [GHOLAMREZAI, SEPAHVAND 2017]. Rivers are considered to be the most important sources of water any country, so it is important to protection and operation them properly. Soil erosion and sediment transport by water in rivers are an important issue strongly deteriorating environment and requiring remedial actions [RYBICKI 2017]. The sediment transport is a complex phenomenon by its intermittent nature, randomness and by its spatio-temporal discontinuity [BERGHOUT, MEDDI 2016]. Bottom sediment, if they meet the relevant requirement, can be used to fertilize light soils as well as to remediate degraded areas [WÓJCIKOWSKA-KAPUSTA *et al.* 2018]. Any change in water flow discharge or sediment transported can changes in the river system which increase environmental and morphological damage and cause more attention and sensitivity of the water and environmental authorities to the nature of the factors and the side effect of such changes. Currently, in the world and in Iran, with the grow of population, urban development has progressed, and following this growth, the use of river materials such as sand and gravel, for use as building and road construction projects, urbanization, construction of industrial projects has increased. In other words, sand and gravel for various civil engineering projects are considered as inevitable in development affairs [ASHRAF *et al.* 2011]. On the other hand, the simplicity of access to river materials and the lack of acceptance of other resources, such as mountain materials, have exacerbated this problem. The extraction and use of river sand is one of the most important research topics and projects in the river system and has various impacts on the hydraulic, environmental and morphological conditions of the channels. The materials mining from the rivers by changing the hydrological and hydrological regime of the flow of the channel leads to fluctuations in the sediment transport load and erosion of the river banks and as a result of morphological changes [WALLING, FANG 2003]. In other words, sand and gravel mining affects the sediment balance of the downstream river banks and causes extensive changes in the channel morphology system [LEEUW *et al.* 2010]. In addition to the impacts expressed have wide environmental impacts in the river system, and today one of the environmental concerns is the extraction problems of sand and gravel from river mines, which has a great impact on the river ecosystem [MATTAMANA *et al.* 2013]. Unstudied and extensive sand and gravel from the rivers causes the bed of the river to fall, and these conditions have physical and a large environmental impact on the river system [PADMALAL *et al.* 2007]. Also, materials mining from the rivers causes erosion of the coasts and banks, development of meanders, extending the bed and scouring the bridges, floodwalls, and threats to agricultural fields. On the other hand, the mining of river sand and gravel has caused changes in the flow regime and the transfer of sediment loads [WARNER, PICKUP 1975]. It creates holes and pits at the site of mining and, over time, moves upstream and downstream of the mining area and causes a lot of destructive effects [AMINI, SALEHI NEYSHABOURI 2001; KONDOLF *et al.* 2002]. Contributing to river training, increasing the discharge capacity of the channel, and preventing meander swirling can be among the positive effects of river sand and gravel mining [RICHARDSON *et al.* 2001]. MELTON [2009] investigated the effects of sand and gravel mining from the Rio Tigre River in Costa Rica. He found that non-principled removal from the river or damage to the armor layer would affect its stability. Also due to the mining of sand and gravel, the velocity increases which results in river bed erosion and widening of the river bed. MADYISE [2013] examined the Gaborone River in South Africa. He stated the defects and advantages of sand and gravel mining on the region's environment and ecology and showed that destruction of the river bank and its erosion are the negative impacts of non-principled removal of river material. He emphasized that observing the principles associated with material mining and use of the related manuals and standards could help in reducing the undesirable impacts of material mining. BAYRAM, NSOY [2015] believed that sand and gravel mining without taking into account the extraction principles, causes change in the channel geometry and river bed depth and could result into flow diversion, accumulation of sediments and formation of deep pits. GAVRILETEA [2017] has proposed some recommendations for alleviating the environmental damage when operating the sand and gravel mines through collecting data from various resources:

– regulation and execution of the environmental laws and principles and associated standards related to the process of river bed material mining;
– issuing permit for operation of sand and gravel mining from rivers;
– supervising and inspection of areas where material removal has taken place.

The investigated studies show that researchers in various countries have emphasized upon use of the principles and regulations associated with river material mining. This would cause reduction in the negative defects of sand and gravel mining from the rivers. An important issue in mining river materials is the proper management of the studies, implementation and operations, as well as measures related to the completion of the mining project, which is considered as important issues in river catchment management. Considering the principles of river material extraction and transported sediments by river flow in design of river structures, study of various methods to predict river sediment transport rate seem to be necessary [BALLA *et al.* 2017]. By correct management and mining operations at the proper time and place, it is possible to restore, train and reduce the negative environmental impacts in rivers. For example, in some cases it is necessary to do the materials mining process in parts of the river with the aim of directing the flow to the main channel, or helping to train and correct the channel route, is also one of the issues that the permit for the mining of sand and gravel is given in those areas. The river pattern and the type of the channel route are of particular importance in material mining issues. It is also important to have proper mining of the river according to the hydrological and morphological conditions of the river, which include scraping, dredging and mining with pit technique. The site location of materials is also one of the most important issues in the river mining project, which should always be considered. In general, materials mining can be done from locations such as terraces, active or inactive floodplains, active channels, and riverbeds. The time, period, and the number of mining operations in each river are also important issues in river sand and gravel mining projects. In the world, there are several standards and guidelines for managing the mining of river materials. Countries like India, Malaysia, the United States, Denmark, etc. have been ahead in this regard. Using global experiences, reviewing guidelines and international standards in the field of extracting materials from rivers, improving mining management and presenting new solutions are important issues. There are two manuals in the field of sand and gravel mining in Iran, the publisher number 336, entitled "Guidelines for the mining of river materials" which has been compiled and prepared by the river engineering and management approach, and the second is manual No. 563, entitled "The environmental criteria of the mining of river materials" in which the priority is environmental issues. The purpose of this present paper is to study, present and apply the proposed points and recommendations in improving the management of the mining of river materials in the form of a review of authoritative publications and guidelines in this regard. The river that is intended for this purpose is a segment of the Zohreh River in the province of Khuzestan in Iran. Considering that the important issue in management of mining of river materials is the presenting of appropriate solutions and measures to improve mining management, for this reason, such as finding suitable site locations with points with potential mining, suitable mining time, it is important to use the appropriate method for extracting sand and gravel from the river, which should be considered in any mining operation. To achieve this, using a method called the river matrix method can be useful. The river matrix method is, in fact, part of the application of global experiences in the management of mining of river materials, which is considered in this research. In this method, using the river data and characteristics, and the location of mining materials, suitable solutions can be found to improve mining management. One of the objectives of this research is to use river matrix method to evaluate the area of mining of materials in the study area. The river matrix method of assessing the area of mining of rivers was previously used by researchers in this study on the A'la River in Khuzestan province [AZARANG *et al.* 2017]. Determining the river pattern, investigating the location of mining by considering the potential, selecting the appropriate sand and gravel method, etc., is one of the items that has been evaluated in this study. Considering the problems regarding the management of sand and gravel mining in rivers and the adverse the effects of mismanagement on the morphology and river environment in this area, the necessity of this research seems very important. This research can be considered as a suitable model for using global experiences in the management of river mining management.

MATERIAL AND METHODS

To test the application of global experiences, a segment of Zohre River which have good potential for gravel mining was selected. The Zohreh River is located in the South-West of the Khersan River catchment. The river catchment is located in the southern folds of the middle Zagros Mountains. Most of them are mountainous regions. In the northern part of the White Mountain catchment with a height of 3415 m, separates the catchment area of the Zohreh River from the Karun and Marun catchments. The area of the catchment of Zohreh is about 17 150 km^2, about 14 100 km^2 of which is mountainous, and the rest of it consists of plains and mountainous foothills. The cities of Ardakan (Sepidan), Noor Abad Mamasani, Dehdasht, Gachsaran, Behbahan, Hendijan, and Mahshahr are among the most important cities of this catchment. The climatic regime of the catchment area of the Zohreh River is rainy and snowy. The river consists of two main branches called Fahlian and Kheir Abad. The first branch is called Ardakan and then renamed Fahlian. The Zohreh River enters Zeydun plain after receiving the branch of Kheir Abad. In a wetland which flows towards the ground around the hollow (low altitude). In the South of Aghajari, it is redirected to the South and passes through the Hendijan. The river finally arrives in the Persian Gulf at a location called Chatla. The length of the Zohreh River is 490 km. In the middle areas of the river to the end of the Zeydun plain, the bed becomes wider due to the slope reduction. In the end parts between the village of Dehmola and the estuarine of the river, around the Hendijan, the bed of the river is broad and the depth of it grows and finds a meandering form. The width of the river is up to 200 m and its depth is up to 3 m [AFSHIN 1994; Behan... 2010]. The range for studying the materials mining from the Zohreh River, covers the area between the downstream of Sardasht Zeydun bridge to the upstream of Mohseniyeh village. Figure 1 shows schematically the location of the catchment area of the Zohreh River in Iran (A), as well as the studied area of the Zohreh River, where the material mining area is located (B).

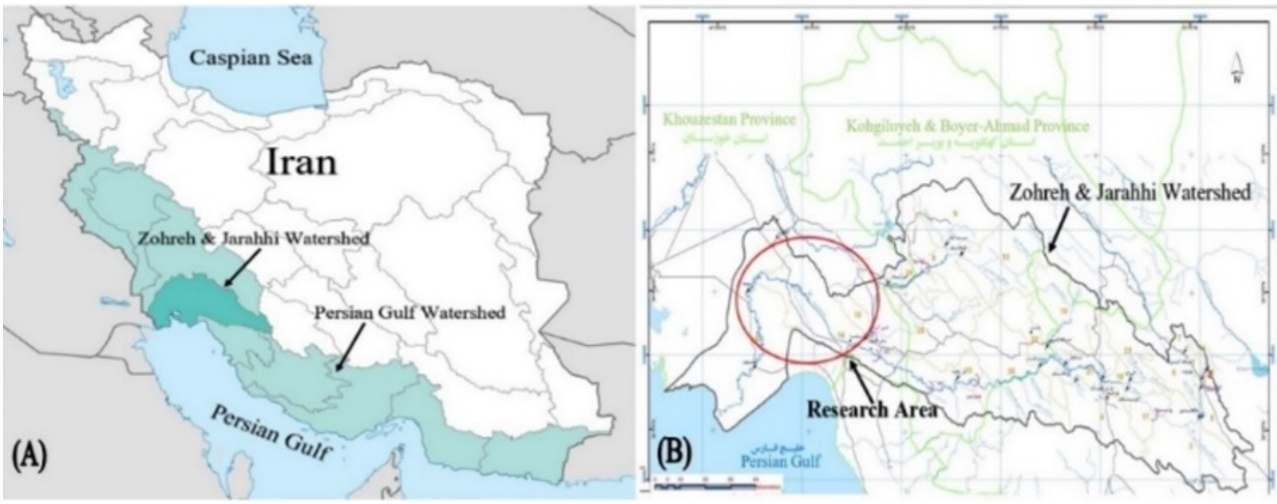

Fig. 1. Study area; A) the Zohreh and Jarahi Rivers catchment area which comprise a part of Persian Gulf and Oman Sea catchment in Iranian territories, B) studied segment of the Zohreh River where in the material mining zone is located; source: own elaboration

Fig. 2. Material mining zone along the studied segment of the Zohreh River at downstream of Sardasht Zeydun bridge; source: own elaboration

Figure 2 shows the mining area of the Zohreh River in the downstream of Stardust Zeydun bridge.

Sardasht Zeydun bridge

This bridge has a length of approximately 700 m in the upstream of the city of Sardasht near the village of Abuzar. The bridge with 26 openings and 8 m wide gauge is known as an important crossing for the transportation of light and heavy vehicles between the provinces of Bushehr and Khuzestan. Due to the presence of the bridge on the Zohreh River and changes in the flow regime, sediment load and morphology of the channel, there are favourable conditions for the formation of deposits and sedimentary masses in the downstream of the Sardasht Zeydun bridge. It can be considered as a suitable source for mining of river materials. Photo 1 shows a view of the bridge of Sardasht Zeydun on the Zohreh River.

Photo 1. A view of Sardasht Zeydun bridge on the Zohreh River at upstream of the material mining zone (phot. *F. Azarang*)

In order to control the distance of the location of materials from the hydraulic structures (Sardasht Zeydun bridge), it is necessary to use a global experience in this regard to compare the distance allowed in the standards and the distance existing at the mining site. The present distance between the sand and gravel mining site form the Sardasht Zeydun bridge is about 1000 m. To obtain the optimum distance which not affect the stability of the bridge, we found various criteria as stated in Table 1.

Table 1. Allowed distance between material mining zone and hydraulic bridge structure in different standards (Sardasht Zeydun bridge on the Zohreh River = 1000 m)

Manual name	Reference	Country or place of law	Permissible distance (m)
Standard No. 336	SALEHI NEYSHABOURI, GHODSIAN [2005]	Iran	150 (important bridge 1000)
Road Safety Law [2000]	–	Iran	1000
GMISMQSRS	YANGKAT [2011]	Sabah Province (Malaysia)	150
SSMMG	KUMAR SINGH *et al.* [2016]	India	200–500
SGMFUPAG	FULLER [2004]	United States	150
MPRSM	CHAI *et al.* [2012]	Malaysia	1000

Source: own elaboration based on cited manuals.

As it can be seen from Table 1, the required distance of a river gravel mining site from a bridge has been presented in difference standard without and consideration of the river morphology, the river hydraulic and sediment characteristics. It seem that it has been assumed that by selecting such distance, the gravel mining has no effect on bridge upstream. However as we know many factors affect such distance and it is the aim of the present study to overview the existing standards and guidelines for the mining of river materials and the following recommendations and guidelines have been presented to improve the management of river sand and gravel mining:
- appropriate locations and points for materials mining,
- season, duration and period of the mining operation in the river,
- determine the amount and timing of mining,

– various methods for extracting materials,
– specifications and geometric dimensions of the materials mining area.

To reach such goals, the matrix approaches have been applied. A corresponding matrix for evaluating the river is considered in terms of mining potential and material extraction method. In this approach many characteristics of the river should be first defined which are described in the following subsections:

River types

Braided river: a very shallow and wide river with a flow of water through the numerous channels connected to each other, separated from each other by deposits and sedimentary islands. **Split river:** split rivers have a large number of islands, the flow of water into them is divided into two channels. There are usually no more than two channels in a given range. **Meandering river:** the meander consists of a series of periodic and continuous meanders, which are joined by straight ranges. The slopes of these rivers are relatively low and their channels are unstable. **Sinusoidal river:** sinusoidal rivers have single channel and this channel in the floodplain curves forward and backward. There are few islands in these rivers. **Straight river:** generally, straight line is not a stable state in rivers, and rarely remains in nature, except in short ranges. The direct river is less curved and the sinusoidal coefficient of these rivers is less than 1.5.

Generally, each matrix has four main attributes for each of the previously grouped rivers:
– river size,
– site location,
– associated channel,
– type of deposit.

River size is one of its most important features. The area of the river catchment, its geometric dimensions, and river discharge are of factors determining the size of the river. Accordingly, rivers are divided into small, medium and large sizes. A small river, a river whose catchment area is less than 100 km^2, and the average channel width of the river are less than 15 m. The medium river, a river whose catchment area is between 100 and 1000 km^2, and the average channel width of the river are between 15 and 100 m. A large river, a river whose catchment area is more than 1000 km^2, and the average width of the channel is more than 100 m.

The site location. The location of the materials mining from the rivers can include areas such as active floodplain, inactive floodplain, or river terraces.

The associated channel. The catchment includes the active channel, the high-water channel and the abandoned channel. For a better understanding of the concepts presented, Figure 3 shows the site locations and the river channels.

Type of deposit. Deposits and sediment bars consist of river bed sediments, point or lateral bars, mid-channel bars, inside or outside meander, vegetated islands and vegetated banks [JOYCE *et al.* 1980; MESBAHI, CHITI 1998; TELVARI 2004].

According to the defined matrices for each river with a specific pattern, there is also a blank matrix (empty table)

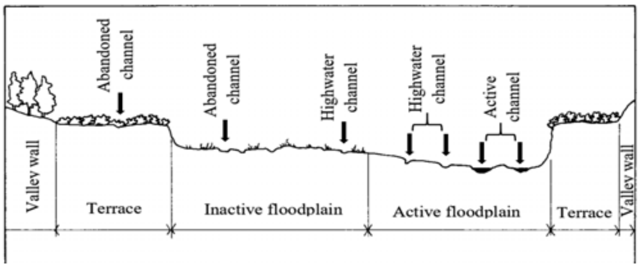

Fig. 3. Views of different parts of a material mining zone and related channel in a river system; source: JOYCE *et al.* [1980]

for completion, so that at first the type of the river studied is determined by the template, and then the matrix corresponding to it is selected and then the matrix blank table is completed for the river under study. Finally, a comparison between the matrix corresponding to the river pattern and the completed matrix is performed, based on the rows and details of the matrices, the following being specified in the case of the mining of river materials in the river to be studied:
– determine the pattern and route of the river?
– determine the size of the river, the site location, the type of channel and the type of sediment bar?
– is there a potential for sand and gravel mining from the river?
– what is the appropriate method for the materials mining?
– what are the additional recommendations and proposals to reduce the negative effects of the mining?

RESULTS AND DISCUSSION

DETERMINING THE PATTERN OF THE ZOHREH RIVER AND SELECTING THE CORRESPONDING MATRIX

Various methods have been used to determine the pattern of the Zohreh River. The first method for determining the pattern of the Zohreh River is the use of maps and aerial photographs in the Google Earth software environment. In order to determine the river pattern and verification of being braided the Zohreh River, the studied area is divided into several smaller ranges. By magnifying in Google Earth software, being braided details of the river pattern and bars and several sedimentary deposits are displayed along the river channel route. Due to the presence of a large number of islands and sedimentary bars along the river flow and branching of the channel, it is clear that the pattern of the Zohreh River in this range has a braided pattern. Figure 4 shows areas of the Zohreh River in the studied range that has a braided pattern.

For more accurate evaluation of braided regions in the Zohreh River, details are given in this regard, as shown in Figure 5.

The characteristics of zones with the braided pattern of the Zohreh River in the studied period are presented in Table 2. This table summarizes the geographic coordinates of the area and the type of sediment deposited.

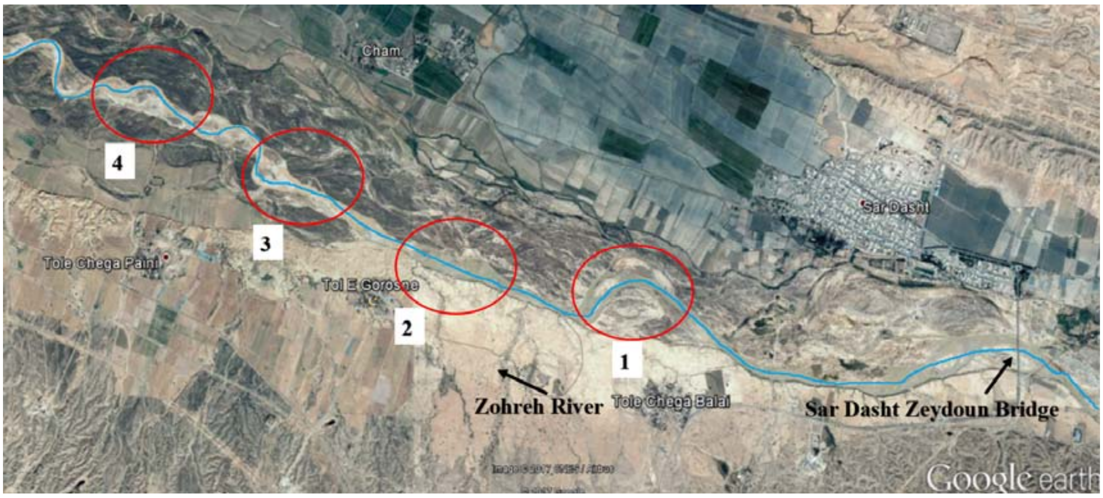

Fig. 4. Areas exhibiting braided pattern within the studied segment of the Zohreh River; source: own elaboration

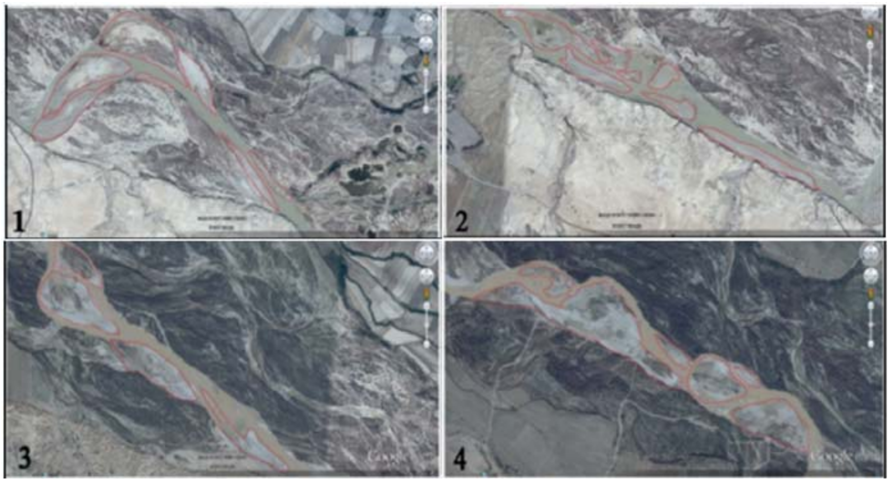

Fig. 5. A more accurate view of the areas exhibiting braided pattern along the Zohreh River; source: own elaboration

Table 2. Characteristics of sedimentary deposits exhibiting braided pattern in the studied segment of the Zohreh River

Point No	Geographical coordinates (UTM)		Type deposition of sedimentary
1	X = 422500	Y = 3354714	point bar – mid-channel bar
2	X = 420549	Y = 3354944	lateral bar – mid-channel bar
3	X = 418702	Y = 3355931	point bar – mid-channel bar
4	X = 417356	Y = 3356760	point bar – mid-channel bar

Explanation: points numbers as in Fig. 4.
Source: own elaboration.

Another method for being braided of the Zohreh River pattern in the studied period is the use of reports and documentation of study projects conducted by consulting engineering companies. In two reports titled "The morphological report of Kheir Abad and Zohreh rivers" and "Report of sediment studies on the determination of the riparian boundary and bed of the rivers of Kheir Abad and Zohreh", the Zohreh River in the range between the point of junction Zohreh and Kheir Abad rivers (upstream of Sardasht Zeydun bridge) to the Soureh area (downstream of Mohseniyeh village) have braided pattern and numerous islands along the river. Also, the river bed has been introduced in this range with sand and gravel sediments along with the banks of mixed sand and gravel layers [Sazab... 2006]. In several research papers on the Zohreh River, the pattern is considered as a braided pattern in the range between Sardasht Zeydun bridge and Saadat Abad village (upstream of Mohseniyeh village). In one of these studies, the width-to-depth ratio index has been used to prove being braided the Zohreh River and in all the cross sections considered along the Zohreh River in the above-mentioned range, the width-to-depth ratio is greater than 60. According to the Table 3, a river with a latitude greater than 60 is considered as a braided river [LEOPOLD, WOLMAN 1957].

In order to investigate the Zohreh River more accurately, in the range between Sardasht Zeydun bridge and the Mohseniyeh village, field observations from the Zohreh

Table 3. River pattern classification based on width-to-depth ratio

River type	$B : D$
Straight river	<8
Meadering river	5–15
Braided river	>60

Explanations: B = the width of the channel of the river, D = the depth of the channel of the river.
Source: TELVARI [2004].

River have also been taken and the images of these observations are presented below (Photo 2 shows sand and gravel mining in the river). It should be noted that field observations from the region also confirm the accuracy of the braided pattern of the river.

The sedimentary deposit at the upstream of Sardasht Zeydun bridge for materials mining is considered as the mid-channel bar. The geometric dimensions of the river mining area, including the length, width, and depth of the sand and gravel from the Zohreh River, are shown in Figure 6.

The characteristics of the catchment area and the Zohreh River are presented in Table 4.

Characteristics of the Zohreh River catchment acc. to Sazab… [2006] and Behan… [2010] are presented below:

River name: the Zohreh River
Main catchment: Persian Gulf and Oman Sea catchment – the Jarahi-Zohreh River catchment
Subsidiary catchment: the Zohreh River catchment
Area: 17 150 km^2
Perimeter: 1160 km
Yearly average of water supply (long term): 79.3 m^3·s^{-1}
Average slope of catchment: 20.9%
River slope: 0.7%
Main stream length: 490 km
Average height: 1217 m
Dominant height: 700 m
Compactness coefficient (Gravelius): 2.9
Sediment total load: 7.75·10^6 ton·year^{-1}
Specific sediment rate: 1146.81 Mg·year^{-1}·km^{-2}
Type of climate and meteorological conditions: semi-humid, semi-arid, semi-desert
Equivalent length of rectangular: 561 km
Equivalent width of rectangular: 23 km
Type of rainfall: Mediterranean precipitation regime
Mean annual rainfall: 486 mm
Hydrometric stations and equipment: Dehmola station – stage gauge, Cable Way
Hydraulic structures: Sardasht Zeydun bridge
Major cities: Ardakan, Noor Abad, Gachsaran, Behbahan, Hendijan, Mahshahr.

Photo 2. Field trip to the material mining zone along the Zohreh River: A) western bank of the river when viewed toward the upstream, B) deposits in sand and gravel mining zone along the Zohreh River, C) western bank of the river when viewed toward the downstream, D) machineries and equipment in the material mining workshop (phot. *F. Azarang*)

Fig. 6. Geometrical dimensions of the sedimentary deposit considered for material mining along the Zohreh River; source: own elaboration

The characteristics of material mining zone along the studied segment of the Zohreh River acc. to Sazab... [2006] and Behan… [2010] are as follow:

River name: the Zohreh River

River reach: Sardasht Zeydun bridge to Mohseniyeh Village

Geographical coordinates (UTM) of mining zone: beginning point: X = 425337, Y = 3353640; end point: X = 425124, Y = 3353560

River pattern: braided

Area of mining zone: 10,000 m^2 (1 ha)

Size of river (small-average-large): large river

Mining location (active floodplain – inactive floodplain-terrace): active floodplain

Channel of extraction location (active channel- high-water channel- abandoned channel): active channel

Type deposition of sedimentary (bed bar – point bar – lateral bar – mid-channel bar – inside meander – outside meander – vegetated island – vegetated bank): mid-channel bar

Particle size distribution: coarse size (rubble & gravel)

Removal season and time duration: summer – maximum 20 days

Type of consumption: construction site

Extraction method (scraped-dredging-pit): scraped

Extraction length: 125 m

Extraction width: 80 m

Extraction depth: 1 m

Removable volume: 10,000 m^3

Mining machinery: loader – truck

Distance of mining zone from hydraulic structures: upstream; Sardasht Zeydun bridge: 1 km

Nearby cities mine: Behbahan, Sardasht, Hendijan

Mining impacts: positive effects; river training – direct the flow into the main channel – increase the capacity of the river inflow – negative effects; sudden erosion and instant erosion and river bed achieve to the bed rock.

DETERMINING THE DETAILS OF THE MATRIX FOR THE ZOHREH RIVER

Due to the fact that the Zohreh River has a braided pattern in the studied range, it is therefore used for the braided river matrix. Table 4 shows the matrix corresponding to the pattern of the braided river. The details and characteristics of the matrix are presented in columns and rows of Table 4 as described earlier. Rows 1 to 8 in the description column of this table also provide details about the potential of mining areas, the selection of material extraction methods, and additional issues in this regard.

SUPPLEMENTARY DESCRIPTIONS OF THE RIVER MATRIX METHOD FOR A RIVER WITH A BRAIDED PATTERN

This section describes the supplementary details of rows 1–8 in Table 4.

Comment 1. Generally, the bed of an active channel should not be disturbed. If bed deposits are the only available source, the gravel should be taken only under strict work plans end stipulations.

– it is recommended that side channel (s) be mined rather than the main channel; select side channel (s) that carry less then approximately one third of the total flow during the mining period; block off upstream ends end mine by scraping operations;

– if the main channel must be mined, dredging may be an appropriate method.

Comment 2. Gravel is available by scraping gravel deposits to near the low summer flow, maintaining appropriate buffers, or no lower than the water level present during the mining operation.

Comment 3. Gravel is available by scraping such that the configuration of the channel is not greatly changed and there is not a high probability of channel diversion through the mined area.

Table 4. Special matrix for a braided river

River size			Site location			Associated channel			Type of deposit								Comments
small	medium	large	active floodplain	inactive floodplain	terrace	active channel	high-water channel	abandoned channel	bed	point bar	lateral bar	mid-channel bar	inside meander	outside meander	vegetated island	vegetated bank	
*	*	*	*			*			*								1. Gravel may be available by scraping or dredging
*	*	*	*			*					*	*					2. Gravel available by scraping
*	*	*	*	*			*	*			*	*					3. Gravel available by scraping
*	*	*	*	*		*	*	*							*		4. Generally should not be mined
*	*	*	*	*	*	*	*									*	5. Banks should not be mined
*	*	*	*	*			*	*	*								6. Gravel available by scraping
*	*	*			*		*		*		*	*			*		7. Gravel available by scraping
*	*	*		*	*			*	*		*	*			*	*	8. Gravel available by scraping or pit mining

Source: JOYCE *et al.* [1980].

Comment 4. Vegetated islands are often a limited habitat in these systems and should generally be excluded from the work plan. Exposed deposits should be considered before vegetated island deposits. If deposits in feasible alternative locations are not sufficient, and vegetated islands are abundant in the particular reach in question, up to about 10 to 20 percent of this habitat may be removed from about a given 5-km length of the floodplain.

Comment 5. Vegetated river banks of both active end high-water channels should not be disturbed because of biological and hydraulic alterations. These should be removed from work plans.

Comment 6. Gravel is available by scraping within the channel, but the general configuration of the channel should be maintained.

Comment 7. In these systems it is recommended to scrape exposed deposits in the active floodplain. If sufficient gravel is not available in the preferred deposits, gravel may be available by scraping in these locations, but the general configuration of the channel should be maintained.

Comment 8. In these systems it is recommended to scrape exposed deposits in the active floodplain. If sufficient gravel is not available in the preferred deposits, gravel is available in these locations by either pit or scrape methods. Generally, pits should only be considered when more than 50,000 m^3 are required [JOYCE *et al.* 1980].

In this part of the research, a blank matrix should be completed based on the characteristics of the Zohreh River at the site of materials mining (Tab. 5). In the discussion and conclusion section, the reasons and the way to complete the details in Table 5 are stated. Accordingly, in each part of the main columns (size of the river, site location, the corresponding channel and the type of deposit) and their subset columns, a star is completed as the site location in the Zohreh River in which at the end of the work, the corresponding row is extracted from the special matrix of the braided river and its descriptions will be the work basis.

LOCATIONS AND POINTS FOR MATERIALS MINING

In general, the mining of river materials from the floodplain (active or inactive) or river terraces takes place. Depending on the conditions of the river, sediment yield and evaluation of post-mining effects, extraction operations are carried out in one of these areas. In the Zohreh River, according to the sedimentation site, mining operations are carried out in the active floodplain of the river.

The extraction of materials should be made from sites where appropriate sedimentary redevelopment exists. In Zohreh River and the desired area for mining, due to the sediment yield of the river, the existence of the hydraulic structure of the bridge in the upstream of the mining area and the formation of the mid-channel sedimentary bar in the flow route seems to have been well-established and can be a good source of sand and gravel mining. The mining from this sedimentary bar in the Zohreh River can help to train the river channel, increase the drainage capacity, reduce the roughness coefficient and direct the flow to the main channel.

It is generally recommended in international standards that the mining of sand and gravel be done from the large rivers, braided rivers, barriers and sedimentary bars, the inner banks of bends, upstream of dams and deviations and bridges due to the size of the river, their braided pattern and presence of sedimentary bar, and it is clear that a mining area is a suitable option for the extraction of river materials.

Large rivers due to more sedimentary yield (relative to small and medium rivers) are less effective than morphological changes due to sand and gravel mining. Therefore, the Zohreh River with an extraction potential in the mining area is considered.

Braided rivers have a high potential in sand and gravel mining due to the dynamics and variability in the formation of islands and sedimentary barriers in their routes. Therefore, the Zohreh River in the studied area, due to the braided pattern, were suitable for sand and gravel mining.

In international guidelines, it is recommended that in order to train the river, decreasing the roughness coefficient, increasing the flow capacity and dredging of the sand and gravel route from the bars in the river route, in the Zohreh River and in the downstream of the Sardasht Zeydun bridge, the mining from the desired area, which is a mid-channel bar, can produce positive effects of the mentioned materials mining.

SEASON, DURATION AND PERIOD OF MATERIALS MINING IN THE RIVER

In different standards, it is recommended that mining be carried out at appropriate times and season, and for a limited period of mining, in other words, mining during June to October is the appropriate time for mining, and the maximum allowed time for the license is considered one month (at Khuzestan Water and Power Authority). This is considered in the Zohreh River, and the mining was carried out in the summer or in the low-water of the river, and the duration of the license was up to 20 days by the contractor (the operator).

Table 5. Completing the initially blank matrix for the material mining zone along the Zohreh River

River size			Site location			Associated channel			Type of deposit									
small	medium	large	active floodplain	inactive f loodplain	terrace	active channel	high-water channel	abandoned channel	bed	point bar	lateral bar	mid-channel bar	inside meander	outside meander	vegetated island	vegetated bank
		*	*			*						*				

Source: own study.

In general, materials mining is prohibited in the rainy season, during the period of fish and aquatic animals spawning, as well as during the hours of the night, and in the case of the Zohreh River, the observance of the above mentioned is considered.

DETERMINE THE AMOUNT AND TIMING OF THE MINING

There are two important indicators for estimating the amount of materials mining from the river, the first indicator of sediment yield of the river and the second indicator of deposits and sedimentary bars from the past periods. Regarding the Zohreh River in the area, these two indicators can be mentioned. That is, the Zohreh River has deserved sedimentary yield, and islands and sedimentary bars have been created in the direction of the channel that can be considered as a suitable resource for river materials, according to the expert's investigation.

In all standards in the management of sand and gravel of river, it is pointed out that extraction of materials should not exceed the amount of river sediment renewal, as it causes destruction and erosion of the river bed, in other words, the mining with a great depth can reach the rocky bed at that section of the river. Regarding the Zohreh River, considering this approach and preventing excessive destruction and erosion of the river bed, mining with a maximum depth of 1 meter is considered for materials mining. By applying this kind of mining and depth, there will be no possibility of destruction, excessive erosion and be reaching the rocky bed of the Zohreh River.

TYPES OF MINING METHODS

In different guidelines, there are three methods for extracting sand and gravel from rivers, which include: pit drilling, surface or scraped method, and dredging method.

In the Standard number 336 of the Ministry of Energy, based on the mining area, three methods for extracting the river's materials are drilling of pits in the inactive floodplain and terrace, dredging of active channels of large and medium rivers, and scraping in the active and inactive floodplain, and terrace. Considering the location of mining in the active floodplain, the morphological conditions of the river, sediment yield, etc., the scraped method was considered as the mining operation in Zohreh River.

Technical recommendations in different standards of the countries state that the use of a pit drilling method in the main river channel should not be carried out, and in this area of the river a scraped method should be performed. In the Zohreh River, according to the issues mentioned, the deep mining and pit drilling is forbidden.

SPECIFICATIONS AND GEOMETRIC DIMENSIONS OF THE MATERIALS MINING AREA

The geometric dimensions of the materials mining area, including depth, latitude, and longitude are considered as the most important geometric parameters to be studied in the sand and gravel project of river, and any irregularity and inaccuracy of those values cause damage and the negative effects will be on the river's morphological and environmental systems.

Different values for geometric specifications of the mining area have been provided for this purpose, in the United States [FULLER 2004], for example, it is allowed up to a depth of 0.3 m from the riverbed, or in Malaysian guidelines, the allowed depth for materials mining in the main channel of the river is 1.5 m. Also, in this guideline, in the scraped method of sediment bars, the depth of mining is in the range of 0.3 to 0.6 m, and the maximum depth is 1 m. In Indian standard, the depth of 3.0 m is considered as the maximum depth of the materials in the river bed. The Malaysia standard has also considered the allowed depth of the river bed to be 1.5 m [CHAI *et al*. 2012; KUMAR SINGH *et al*. 2016].

In different countries due to different climatic conditions, discharge and sediment yield of rivers and, in general, different hydraulic, sedimentary and morphological conditions of rivers, different values for geometric dimensions, in particular depth of mining (the most important geometric variable parameter in mining operation) have suggested. In the Zohreh River, according to the surveys carried out and consulted with the experts of the River Engineering and Water Resources Administration of Khuzestan and Water Resources Administration of the province, the maximum allowed depth for the intended area is considered to be 1 m. The length and width of the materials mining site were determined by considering field observations and determining the sedimentary bar and studying maps and aerial photographs of 125 and 80 m respectively.

THE RESULTS OF RIVER MATRIX METHOD IN EVALUATING THE MATERIALS MINING AREA OF ZOHREH RIVER

River size. When the river catchment area is more than 1,000 km^2, the river is placed in the large river group; the catchment area of the Zohreh River covers an area of more than 17,000 km^2. Therefore, the Zohreh River is considered as a large river. Also, if the river has a channel width of more than 100 m, it is in the group of large rivers, according to the maps of Google Earth, available reports, and documentation, the Zohreh River has a latitude more than 100 m. For this reason, the size of the Zohreh River is a large river. The first column of Table 5 has been completed for the Zohreh River.

Materials site location. According to the definition, active floodplain is part of a floodplain of river that is often floodplain. This part of the floodplain is composed of channel with river natural flow, high-water channels and adjacent sedimentary deposits. This area has little or no vegetation, which corresponds to the specifications of the mining area in the Zohreh River. Also, due to field observations, the study of Google Earth maps and aerial photographs, an area of the Zohreh River that has the potential for mining and intended for materials mining in river, is considered in the active floodplain of Zohreh River (column 2 of Table 5).

The corresponding channel. The channel used to mine the river's materials is active because the area in which the mining is carried out is located in the main channel of the river and the river flows through it. In fact, this channel cannot include a high-water or abandoned channel. According to Figure 3, we can consider the concept of active channel, high-water and abandoned channels and compare it with the conditions of mining area in the Zohreh River. In fact, the active channel is part of the active floodplain in the river system (column 3 of Table 5).

Typs of sedimentary deposit: mid-channel bars, deposits and sediments that exist along the river (usually in the middle of the channel). According to field observations, maps and aerial photographs, it is determined that the intended deposits for materials mining in the Zohreh River should be taken into account as part of the mid-channel bars, since they are located almost in the mid-channel of the Zohreh River and the river flows through the surrounding area (last column of Table 5).

CONCLUSIONS

According to the comparison of the matrix completed for the Zohreh River with the special matrix of the braided rivers, it was determined that the studied area in terms of materials mining of river has the potential for sand and gravel extraction and the scraped method is the most appropriate method for materials mining from this area of the Zohreh River. The points to be taken into account in the supplementary descriptions of the river matrix method are that in sand and gravel extraction operation using the scraped method should mine the materials deposits in the summer (low-flow season) and consider the appropriate buffer zones.

In general, based on the results of this applied research, it was found that the use of global experiences and international guidelines in the management of river mining, in particular, the use of river matrix method in the accurate assessment of the river mining area, could be a useful method to provide solutions and arrangements for improving the management of sand and gravel mining from rivers.

REFERENCES

AFSHIN Y. 1994. Iran rivers. Ministry of Energy. Jamab Consulting Engineering. [In Persian].

AMINI A., SALEHI NEYSHABOURI A.R. 2001. Field study on mining-pit migration. International Conference of Hydraulic Structures. [In Persian].

ASHRAF M.A., MAAH M.J., YUSOFF I., WAJID A. 2011. Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. Scientific Research and Essays. Vol. 6. No. 6 p. 1216–1231.

AZARANG F., JAFARI G.H., KARAMI M., SHAFAEI BEJESTAN M. 2017. Protecting river environment through proper management of material mining by river matrix method (case study of A'la River in Iran). Civil Engineering Journal. Vol. 3. No. 12 p. 1301–1313.

BALLA F., KABOUCHE N., KHANCHOUL K., BOUGUERRA H. 2017. Hydro-sedimentary flow modelling in some catchments Constantine highlands, case of Wadis Soultez and Reboa (Algeria). Journal of Water and Land Development. No. 34 (VII–IX) p. 21–32. DOI 10.1515/jwld-2017-0035.

BAYRAM A.O., NSOY H. 2015. Sand and Gravel mining impact on the surface water quality: a case study from the city of Tirebolu (Giresun Province, NE Turkey). Environmental Earth Science. Vol. 73 p. 1997–2011.

Behan Sad Consulting Engineering Company 2010. Immediate updating of the water comprehensive plan of country. Hydrologic Report of Jarahi and Zohreh Catchment. Ministry of Energy. [In Persian].

BERGHOUT A., MEDDI M. 2016. Sediment transport modelling in wadi Chemora during flood flow events. Journal of Water and Land Development. Vol. 31. Iss. 1 p. 23–31. DOI 10.1515/jwld-2016-0033.

CHAI J., FRACHISSE J., GOLINGI T., KU F., LIM W. 2012. Management plan for river sand mining in Sg. Papar and Sg. Kimanis. Environment Protection Department. DHI Water & Environment Malaysia. pp. 95.

GAVRILETEA M.D. 2017. Environmental impacts of sand exploitation, analysis of market. Sustainability. Vol. 9: 1118 p. 1–26. DOI 10.3390/su9071118.

GHOLAMREZAI S., SEPAHVAND F. 2017. Farmers' participation in water user association in western Iran. Journal of Water and Land Development. No. 35 p. 49–56. DOI 10.1515/jwld-2017-0067.

J.E. Fuller Hydrology & Geomorphology Inc. 2004. Sand and gravel mining floodplain use permit application guidelines. Phoenix, AZ. Flood Control District of Maricopa County (USA) pp. 61.

JOYCE M.R., RUNDQUIST L.A., MOULTON L.L., FIRTH R.W., FOLLMANN E.H. 1980. Gravel removal guidelines manual for arctic and subarctic floodplains. U.S Fish and Wildlife Service, Woodward Clyde Consultants pp. 176.

KONDOLF G.M., PIGAY H., LANDON N. 2002. Channel response to increased and decreased bed load supply from land use change: contrast between two catchments. Geomorphology. Vol. 45 p. 35–51.

KUMAR SINGH S.M, SRIDHARAN U., LAL R.B., SINGH S. 2016. Sustainable sand mining management guidelines. Ministry of Environment, Forest and Climate Change of India pp. 101.

LEEUW J., SHANKMAN D., WU G., BOER W.F., BURNHAM J., HE Q., YESOU H., XIAO J. 2010. Strategic assessment of the magnitude and impacts of sand mining in Poyang Lake, China. Regional Environmental Change. Vol. 10 p. 95–102.

LEOPOLD L.B., WOLMAN M.G. 1957. River channel patterns; braided, meandering and straight. Washington. Geological Survey Professional Paper. U.S. Department of the Interior. U.S. Government Printing Office pp. 85.

MADYISE T. 2013. Case study on environmental impacts of sand mining and gravel extraction for urban development in Gaborone. M.Sc. Thesis. Pretoria. University of South Africa pp. 120.

MATTAMANA B.A., VARGHESE S., PAUL K. 2013. River sand inflow assessment and optimal sand mining policy development. International Journal of Emerging Technology and Advanced Engineering. Vol. 3. No. 3 p. 305–317.

MELTON B. 2009. In-stream gravel mining impacts and environmental degradation feedback associated with gravel mining on the Rio Tigre of OSA Peninsula, Costa Rica, and the proposed ADI Jimenez gravel mining concession. Austin. Melton Engineering Services pp. 24 .

MESBAHI J., CHITI M.H. 1998. Dictionary of river engineering. Ministry of Energy. [In Persian].

PADMALAL D., MAYA K., SREEBHA S., SREEJA A.R. 2007. Environmental effects of river sand mining: a case from the river catchments of Vembanad lake, southwest coast of India. Environmental Geology. Vol. 54. No. 4 p. 879–889.

RICHARDSON E.V., SIMONS D.B., LAGASSE P.F. 2001. River engineering for highway encroachments, Highways in the river environment. Hydraulic design series number 6. Washington, USA, National Highway Institute, Virginia. Office of Bridge Technology pp. 646.

RYBICKI R. 2017. Evaluation of the effects of land consolidation in the Latyczyn village in terms of land protection against erosion on the slope scale. Journal of Water and Land Development. No. 35 p. 203–209. DOI 10.1515/jwld-2017-0085.

SALEHI NEYSHABOURI A.A., GHODSIAN M. 2005. Guideline on sand and gravel mining from rivers (Standard 336). Ministry of Energy, Management and Planning Organization. [In Persian].

Sazab Pardazan Consulting Engineering Company 2006. Determine the boundaries of the rivers of the province. Ministry of Energy, Khuzestan Water and Power Authority. [In Persian].

Sazab Pardazan Consulting Engineering Company 2006. Report of sediment studies on the determination of the riparian boundary and bed of the rivers of Kheir Abad and Zohreh. Ministry of Energy, Khuzestan Water and Power Authority. [In Persian].

Sazab Pardazan Consulting Engineering Company 2006. The morphological report of Kheir Abad and Zohreh rivers. Ministry of Energy, Khuzestan Water and Power Authority. [In Persian].

TELVARI A.R. 2004. Fundamental of river training and engineering, Ministry of Jihad-e-Agriculture. Agricultural Research and Education Organization. Soil Conservation and Watershed Management Research Institute. [In Persian].

WALLING D.E., FANG D. 2003. Trends in the suspended sediment loads of the world's rivers. Global and Planetary Change. Vol. 39 p. 111–126.

WARNER R.F., PICKUP G. 1975. Estuary sand dredging: A case study of an environmental problem. New Zealand Geographical Society: Conference Series. No. 8 p. 325–333.

WÓJCIKOWSKA-KAPUSTA A., SMAL H., LIGĘZA S. 2018. Contents of selected macronutrients in bottom sediments of two water reservoirs and assessment of their suitability for natural use. Journal of Water and Land Development. No. 38 p. 147–153. DOI 10.2478/jwld-2018-0051.

YANGKAT Y. 2011. Guidelines for minimizing impacts of sand mining on quality of specific rivers in Sabah. Sabah. Environment Protection Department. Ministry of Tourism. Culture and Environment of Malaysia pp. 54.

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Zastosowanie globalnych doświadczeń w ocenie strefy wydobycia: Przypadek rzeki Zohreh

STRESZCZENIE

Pozyskiwanie materiału rzecznego niesie ze sobą wiele negatywnych i pozytywnych skutków. Obecnie jednym z głównych problemów inżynierii rzecznej jest właściwe zarządzanie wydobyciem materiałów. W badaniach wykorzystano globalne doświadczenie i międzynarodowe standardy wydobycia piasku i żwiru do oceny obszaru eksploatacji w rzece Zohreh w prowincji Khuzestan (Iran). Jedną z metod oceny jest metoda macierzowa. W metodzie tej, którą definiuje się na podstawie układu rzeki, bierze się pod uwagę takie cechy rzeki, jak: wielkość, lokalizacja materiału, kanały boczne i rodzaj depozytu. Do badań wybrano odcinek rzeki Zohreh pomiędzy mostem Sardasht Zeydun a wsią Mohseniyeh, gdzie istnieją duże możliwości wydobycia żwiru. Oceniono właściwości rzeki, potencjał wydobywczy i zastosowanie metody macierzowej. Badania wykazały, że rzeka Zohreh na badanym odcinku ma układ wielokorytowy. Objętość materiału osadowego na badanym obszarze wynosi ok. 10 000 m^3, długość i szerokość terenu wydobywczego to odpowiednio 125 i 80 m, a zalecana maksymalna głębokość wydobycia materiału wynosi 1 m. W podsumowaniu badań przedstawiono rozwiązania w zakresie wydobycia materiałów rzecznych z uwzględnieniem różnych standardów.

Słowa kluczowe: *globalne doświadczenie, metoda macierzowa, rzeka Zohreh, wydobycie piasku i żwiru*