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Modeling Channel Response to Instream Gravel Mining

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1. Introduction

Sand and gravel on riverbeds have been considered as an attractive (high quality and low cost) source of building material for centuries (Kondolf, 1994; Gill, 1994; Rinaldi et al., 2005). Detrimental effects of in-stream mining have been documented in literature including riverbed degradation or incision (Rinaldi et al., 2005), stream-bank instability (Chang, 1987; Kondolf, 1997), destruction of bridges and channelization structures (Kondolf, 1997; Rovira et al., 2005), etc. On the other hand, removal of in-stream sediment can be beneficial, for instance, it can serve as a maintaining way of the navigation water depths (Fredsøe, 1978). To minimize the detrimental effects and maximize the beneficial impacts, channel response due to gravel mining or dredging has been studied by experiments (Fredsøe, 1978; Kornis and Laczay, 1988; Lee et al., 1993; Lee and Chen, 1996; Neyshabouri et al., 2002), field observations (Kondolf, 1997; James, 2004; Neyshabouri et al., 2002; Rinaldi et al., 2005), and simplified analytical models (Cotton and Ottozawa-Chatupron, 1990). With the rapid development of computational fluid dynamics (CFD) since late 1980s, sophisticated numerical modeling has become a practicable tool for a quantitative understanding of the channel response due to sand and gravel mining (Van Rijn, 1986; Chang, 1987; Yue and Anderson, 1990; Gill, 1994; Cao and Pender, 2004; Chen and Liu, 2009). However, the inherent complexity of sediment transport and channel changes makes the firm, specific prediction of mining effects on rivers impossible at present. For instance, sediment transport around the mining pit area behaviors a distinct non-equilibrium state due to the sharp inflection of streamlines around the upstream and downstream ends of mining pits. However, existing numerical models either choose equilibrium sediment transport formulas or bear much uncertainty due to the various parameters selection which must be introduced to close the non-equilibrium sediment transport formulas. Therefore, specific laws and regulations regarding the safe in-stream mining have not been provided for users and officials despite extensive investigation made in the past (Kondolf, 1997; Neyshabouri et al., 2002).

This paper aims to simulate the channel response to instream gravel mining. First, the feasibility of the two-dimensional depth-averaged model (CCHE2D) in modeling mining-induced bed change was examined by comparing the calculated results to the data measured in two sets of published laboratory experiments. Thereafter, the two dimensional model (CCHE2D), with appropriate non-equilibrium adaptation parameters, was applied to examine the impact of deep sand and gravel mining pits (with a depth of 10 meters) on inundated area and riverbed change of the Rio Salado, Salt River, Phoenix, Arizona. Due to the lack of field measurement, the calculated results of CCHE2D were compared to modeling results of HEC-RAS, a one dimensional hydrodynamic and sediment transport model.

2. Mining-pit evolution

The evolution of a mining pit is a complex morphodynamic process resulting from the interactions between streamflow, sediment, and movable boundaries. As water flows over a mining pit, the dividing streamlines separate and converge at the upstream and downstream ends of the pit, respectively. Streamline separation causes eddy rollers and headcut erosion at the upstream end, while streamline convergence causes bed degradation at the downstream end of the pit. Concurrently, incoming sediment from upstream is trapped in the upstream portion of the pit. (Figure 1). The overall effect is downstream migration of the gravel pit as deposition occurs at the upstream front while the tail end degrades from local scour. Such patterns have been observed in both natural streams (Chang, 1987; Kondolf, 1997; Neyshabouri et al., 2002; Rinaldi et al., 2005) and laboratory experiments (Fredsøe, 1978; Kornis and Laczay, 1988; Lee et al., 1993; Lee and Chen, 1996; Neyshabouri et al., 2002). A sketch of the flow structures and initial pit migration is shown in Figure 1. Pit geometry includes the width (B_p), length (L_p) and depth (H_p). L_u and L_d present the lengths of up- and downstream impacted reaches, respectively. Because of the asymptotic nature of the phenomenon it is difficult to fix the exact location of the endpoint of impacted reaches. A common definition is that , the bed deformation should be less than 1% of the flow depth at the end of impacted reaches at both up- and downstream of the pit.

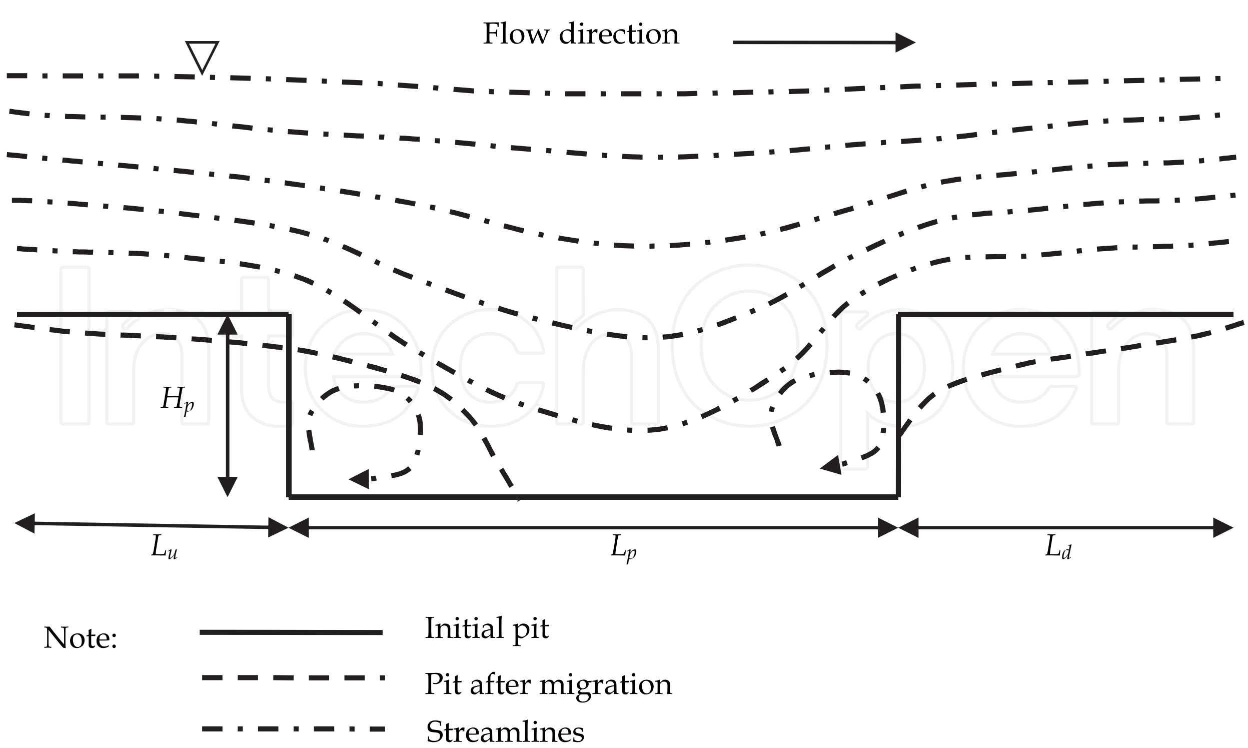


Fig. 1. Sketch of flow structure and initial pit evolution

Lee and Chen (1996) and Lee et al. (1993) conducted a series of experiments and found that the migration process of mining pits could be divided into two periods, namely convection period and diffusion period. Convection period is from beginning of deformation to the moment when the upstream boundary of the mining pit moves to the original downstream end of the pit. Diffusion period starts from that moment onward. The channel bed tends to attenuate sharp inflection on its longitudinal profile during both periods. Unlike the decreasing of scour depth during the "diffusion period", the depth of pit remains more or less constant during the "convection period" until the frontal surface of the filling sediment reach the downstream end. In this paper we continue to use names of the two periods, however, the same governing equations and non-equilibrium parameters were applied in both periods, since either convection or diffusion process of sediment transport takes import role in pit migration during both periods.

3. Models and approach

3.1 Flow and sediment transport models

Flow hydraulics, sediment transport, and channel morphological changes were simulated using CCHE2D and HEC-RAS. CCHE2D is an integrated software package for two-dimensional simulation for analysis of river flows, non-uniform sediment transport, morphologic processes, coastal processes, pollutant transport and water quality developed at the National Center for Computational Hydro-Science and Engineering at the University of Mississippi. These processes in the model are solved using the depth integrated Reynolds equations, transport equations, sediment sorting equation, bed load and bed deformation equations. The model is based on Efficient Element Method, a collocation approach of the Weighted Residual Method. Internal hydraulic structures, such as dams, gates and weirs, can be formulated and simulated synchronously with the flow. A dry and wetting capability enables one to simulate flows with complex topography. There are three turbulence closure schemes in the model, depth-averaged parabolic, mixing length eddy viscosity models and k-ε model. The numerical scheme can handle subcritical, supercritical, and transitional flows (NCCHE, 2011). Sediment transport formulas by Wu et al. (2000) were selected for all the calculations. A detailed description of the model was not included in this paper but can be found in the manual of CCHE2D (Jia and Wang, 2001; Wu, 2001). The feasibility of CCHE2D in simulating mining-induced bed change was discussed in Section 4.

HEC-RAS program was developed by Hydraulic Engineering Center (HEC) of U. S. Army Corps of Engineers. The latest HEC-RAS model provides a module for sediment transport analysis. This model was designed for modeling one-dimensional sediment transport, and can simulate trends of scour and deposition typically over periods of years or alternatively, for single flow events. For unsteady flow events, it segments the hydrograph into small time periods and simulates the channel flow for each time interval assuming a steady state flow in the whole channel. The non-equilibrium sediment transport approach included in the module makes the sediment transport process more realistic. The sediment transport potential is computed by grain size fraction so that the non-uniform sediment can be represented more accurately. The model can be used for evaluating sedimentation in fixed channels and estimating maximum scour during large flood events among other purposes (USACE, 2002). The HEC-RAS sediment transport module provides the option of several different sediment transport functions, thus users can select the most appropriate function according to the site conditions. The one-dimensional model offered a quick simulation although it could not provide accurate information other than the longitudinal direction.

The applicability and limitations of one- and two-dimensional models in modeling channel response to mining were discussed in Section 7.

3.2 Non-equilibrium sediment transport mode

Streambed deformation was calculated using various forms of the sediment continuity equation. The channel bed tends to be adjusted to re-meet the flow capacity, for instances, incision may propagate up- and downstream of the mine and deposition may occurs inside the mine. However, those processes could not be done instantaneously, i.e., the flow requires a finite length of bed to erode or deposit sufficient bed material to satisfy its equilibrium transport capacity. Wu (2008) stated that the assumption of local equilibrium transport is usually unrealistic and may have significant errors in the case of strong erosion and deposition. Bell and Sutherland (1983) conducted a series of experiments and concluded that the predictions of mathematical models are poor in the local scour region if an equilibrium transport formulation is used. Therefore, it is necessary to introduce non-equilibrium sediment transport schemes when modeling mining-pit migration (Yue and Anderson, 1990; Guo and Jin, 1999; Wu, 2008).
CCHE2D implements a non-equilibrium transport model for bed-material load including suspended-load and bed-load (Wu, 2001):

$$(1-P)\frac{\partial Z_c}{\partial t} = \alpha\omega_s\left(C - C_*\right) \tag{1}$$

$$(1-P)\frac{\partial Z_c}{\partial t} = \frac{1}{L}\left(Q_s - Q_{s*}\right) \tag{2}$$

where Z_c = calculated bed elevation (m); P = porosity of bed material; ω_s = settling velocity of suspended sediment (ms^{-1}); C = depth-averaged volumetric suspended-load concentration; C^* = equilibrium depth-averaged volumetric suspended-load concentration; Q_s = volumetric bed-load transport flux per unit width (m^2s^{-1}); Q_{s*} = equilibrium volumetric bed-load transport flux per unit width (m^2s^{-1}); α = adaptation coefficient for suspended load; and L = adaptation length for bed-load (m).
The non-equilibrium adaptation length L characterizes the distance for bed-load to adjust from a non-equilibrium state to an equilibrium state; while α represents, theoretically, the ratio between the near-bed and depth-averaged suspended sediment concentrations. Coefficient α can also be represented by defining an equivalent adaptation length, L_s, as (Wu, 2001):

$$L_s = \frac{q}{\alpha\omega_s} \tag{3}$$

where q is the flow rate per unit width (m^2s^{-1}).
Both L and α are related to not only flow strength, sediment size and non-uniformity but also to the "extent of non-equilibrium", i.e., the difference between sediment load and the sediment transport capacity of flow. Researchers have reported a wide range of values for L and α. Bell and Sutherland (1983) investigated non-equilibrium sediment transport by discontinuing sediment supply at the upstream end of their flume. They found that the

length for bed-load sediment to adjust from a non-equilibrium state to an equilibrium state was about the length of the first occurrence of a sand dune or scour hole, although the sand dune or scour hole extended and migrated progressively downstream throughout the experiment. Soni (1981) also found that *L* was related to flow condition and it changed with time in an experimental case of bed aggradation. Galappatti and Vreugdenhil (1985) found that the adaptation length for which the mean concentration approaches the mean equilibrium concentration is depended on sediment size and Chézy coefficient. Armanini and di Silvio (1988) also indicated that *L* should vary with sediment size and flow characteristics (flow depth, Chézy coefficient, etc.). In the experiments conducted by Wang (1999), the adaptation length was determined by the so-called "bed inertia", which represents the difference between sediment load and the sediment transport capacity of flow. In modeling practice, Phillips and Sutherland (1989) and Wu et al. (2000) adopted the non-equilibrium adaptation length as the averaged saltation step length of bed material particles approximated as a hundred times d_{50} for bed-load. Rahuel et al. (1989) gave much larger values by estimating *L* as two times the numerical grid length when dealing with natural channels. As for the parameter α, Han et al. (1980) and Wu and Li (1992) suggested α is 1 for strong scour, 0.25 for strong deposition; and 0.5 for weak scour and deposition.

4. Model feasibility

The feasibility of the two-dimensional depth-averaged two-dimensional hydrodynamic and sediment transport model, CCHE2D, in simulating mining-induced bed change was examined by comparing the calculated results to the data measured in two sets of published laboratory experiments: 1) a set of experiments by Lee et al. (1993); and 2) a set of experiments by Delft Hydraulics Laboratory (Galappatti and Vreugdenhil, 1985; van Rijn, 1986; Guo and Jin, 1999). Both experiments were conducted with steady flow and uniform rectangular cross sections except near the artificial mining areas. The two sets of experiments were chosen as representative of bed-load-dominated and suspended-load-dominated cases.

4.1 Experiments by Lee et al. (1993)

Lee et al.'s (1993) experiments were conducted using a 17 m long by 0.6 m wide recirculation flume. The rectangular pit was 54 cm long and 4 cm deep, with the upstream end located about 9.5 m from the flume entrance. The width of the pit was equal to the width of the flume i.e., 0.6 m. No sediment was supplied from upstream. Most of the sediment movement was in the bed load transport mode and no significant bed forms occurred. The flow conditions were subcritical flow. Flow parameters used in the flume study (Lee et al., 1993) and in the present modeling study are summarized in Table 1. *Q* is flow rate; *h* is flow depth; *U* is velocity; F_r is Froude Number; H_p and L_p are the depth and length of the mining pit, respectively. Since no sediment was supplied from upstream, the experiments were conducted in a non-equilibrium condition. The present model simulated bed-load transport only and the adaptation length *L* = the length of a numerical grid, i.e., 2 cm. Comparison of computed and measured bed change due to gravel mining is shown in Fig. 2. As can be seen from this chart, the numerical results agree with the experimental results, and the R^2 value for predicting bed elevation after 2 and 5 hours are 0.74 and 0.77, respectively.

4.2 Experiments by DHL

The present model is also applied to a flume experiment carried out by Delft Hydraulics Laboratory (Galappatti and Vreugdenhil, 1985; van Rijn, 1986; Guo and Jin, 1999). The experiment produces a uniform flow over a gentle-sided (1:10) trench in a 30 m-long, 0.5 m-wide, and 0.7 m-deep flume. The trench was 0.16 m deep initially. The mean flow velocity and the flow depth were 0.51ms^{-1} and 0.39m, respectively. The bed consisted of fine sand (d_{50} = 0.16mm). Only suspended sediment transport was simulated and the non-equilibrium adaptation coefficient, α, is calculated as 4.5 by Arminini and de Silvio's (1988) method:

$$\frac{1}{\alpha}=\frac{a}{h}+(1-\frac{a}{h})\exp\left[-1.5\left(\frac{a}{h}\right)^{-1/6}\frac{\omega_s}{u_*}\right] \tag{4}$$

where *h* is the flow depth (m); *a* is the thickness of bed-load layer. Table 2 shows the flow parameters used in the DHL flume study (Galappatti and Vreugdenhil, 1986) and the present model. The width of the pit was set the same as the width of the flume, i.e., 0.5 m. Since the pit has a side-slope 1:10, both upper and bottom lengths of the pit are shown (6.2 m and 3.0 m, respectively) in Table 2. Comparison of computed and measured bed change due to gravel mining is shown in Fig. 3. The agreements are quite satisfactory - the R^2 value for predicting bed elevation after 7.5 and 15 hours are 0.92 and 0.94, respectively.

Based on sections 4.1 and 4.2, the two-dimensional model, CCHE2D, is capable in simulating mining-induced bed change as long as the non-equilibrium parameters, i.e., *L* and α, being appropriately selected. Applicability of CCHE2D for our study reach, the Oeste reach of Rio Salado, has been proved by Chen and Liu (2009) and Chen et al. (2008; 2007). Sensitivity analysis of L and α in modeling pit migration was performed by Chen et al. (2010).

	Q (m3/s)	h (cm)	U (m/s)	Fr	H_p (cm)	L_p (cm)	d_{50} (mm)	L (cm)
Experiment	0.031	10.6	0.501	0.500	4	54	1.4	-
Model	0.031	10.0	0.519	0.518	4	54	1.4	2

Table 1. Flow condition in the experiments (Lee et al., 1993) and the present model

	Q (m3/s)	h (cm)	U (m/s)	Fr	H_p (m)	L_p (m)	d_{50} (mm)	α
Experiment	0.09945	39.0	0.51	0.26	0.16	6.2/3	0.16	-
Model	0.09945	38.4	0.62	0.32	0.16	6.2/3	0.16	4.5

Table 2. Flow condition in the DHL experiments (Galappatti and Vreugdenhil, 1986) and the present model

5. Application to the Rio Salado

5.1 Study reach

The Salt River (Rio Salado in Spanish) drains 14,500 square miles of mountainous desert terrain in central and eastern Arizona and is the largest tributary to the Gila River in Arizona. The river originates in eastern Arizona and flows westward to its confluence with

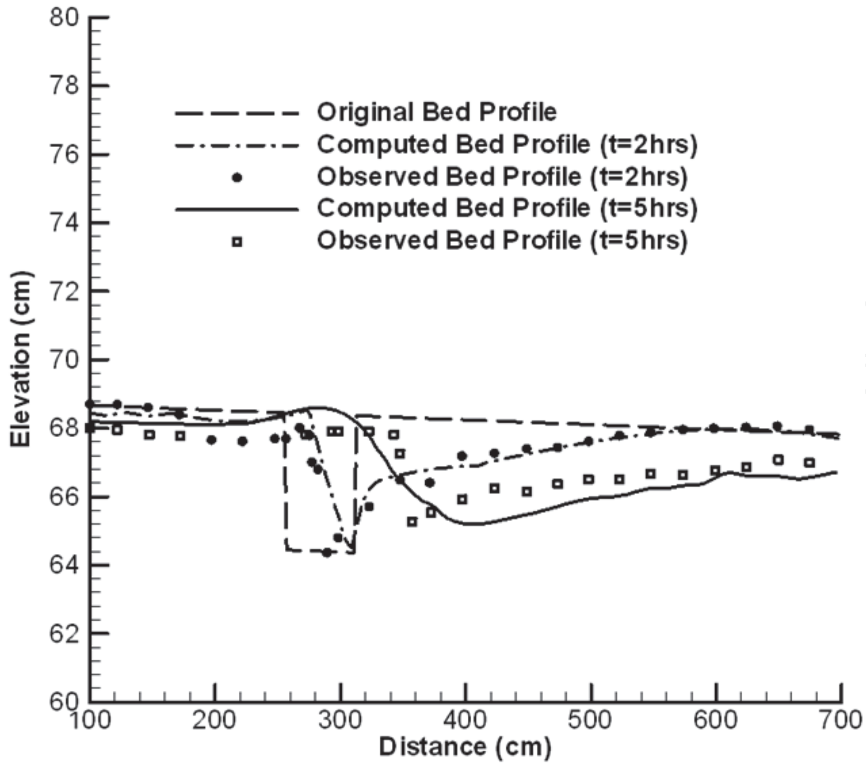


Fig. 2. Simulation results of bed change due to gravel mining (bedload transport only, observed data from Lee et al., 2003)

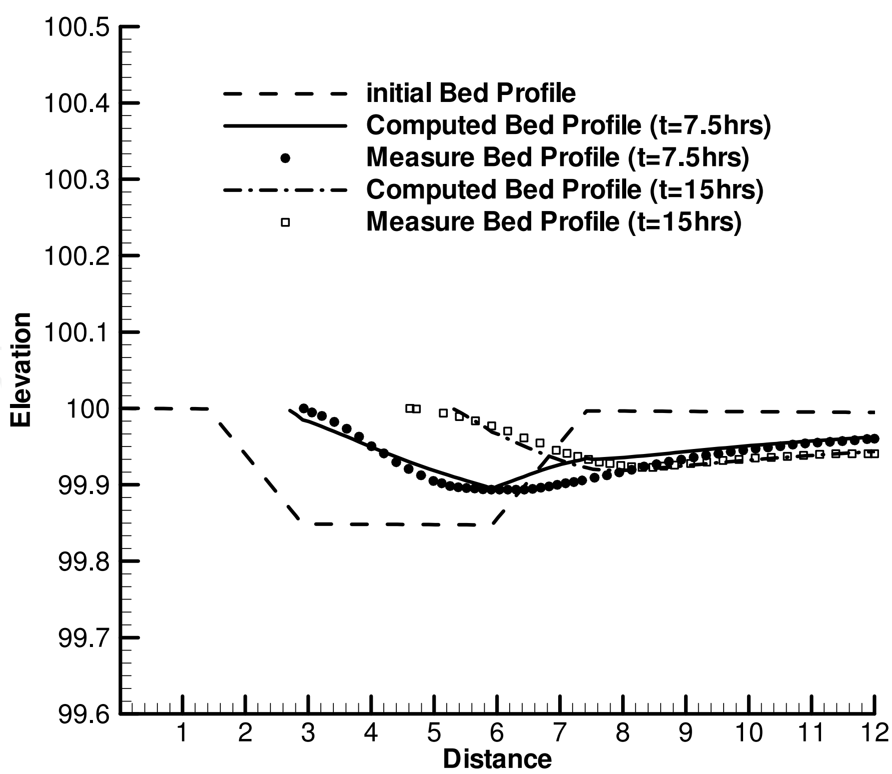


Fig. 3. Simulation results of bed change due to sand mining (suspended load only, observed data from Galappatti and Vreugdenhil, 1986)

the Gila River west of downtown Phoenix (Figure 4). Prior to agricultural development and urbanization of the Phoenix metropolitan area, the Rio Salado was a perennial stream fed by snowmelt from mountains in eastern Arizona. Flow in the river had a distinct seasonal pattern, with highest flows occurring in December and January and lowest flows in October. The yearly-averaged discharge was about 570 cfs before 1938. However, perennial flows on the Salt River have ceased due to dam and diversion construction in the early 1900s. In the early part of the 20th century, major modifications to the river system occurred as part of the Salt River Project, which placed several dams along the Salt River to allow diversions of water for agricultural and urban uses. Sand and gravel mining operations and development along the river induced additional changes to the river channel and hydrology. The materials extracted from the river have been used extensively throughout the development of the Phoenix Metropolitan area. Since 1965, the channel has carried a yearly-averaged discharge of only 400 cfs, with less than 14 cfs in almost three-fifths of the years (USACE, 2005). Now the water in the channel is dominated by the releases from upstream dams. The highest recent discharge occurred on February 13, 2005, of approximately 35,000 cfs as recorded by the USGS gauge at 51st Avenue (http://waterdata.usgs.gov/az/nwis/rt).

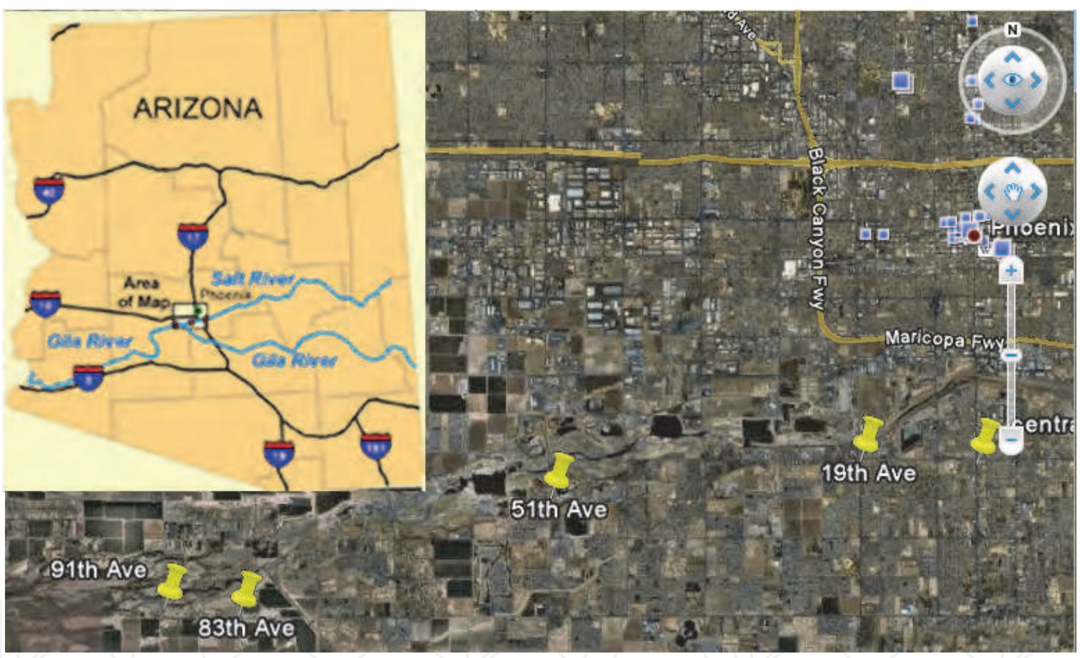


Fig. 4. Oeste reach of the Rio Salado, Salt River, Phoenix, Arizona

This study was designed to understand the impact of gravel mining on the flood zone coverage and channel geomorphology of the Oeste reach of the Salt River. The Oeste reach (study reach) is approximately 9.5 miles of the Salt River extending from 19th Avenue on the east to 91st Avenue on the west. The study area is within the boundaries of the City of Phoenix, Arizona. Previous sediment transport analyses have showed that sediment dynamics was more significant in the proximity of mining operations (USACE, 2005). Sand gravel mining has been going on in the Salt River for generations. There are numerous large mining pits in the Salt River around the city of Phoenix and the demands of more mining pits are growing day by day (shown in Fig. 4). Sand and gravel mining operations can cause changes in channel geomorphology as well as hydrology. This study was designed to understand the impacts of deep instream gravel mining pits (with a depth of 10 meters) on inundated area and riverbed change of the Oeste reach.

5.2 Bed material gradation

Bed material gradations along the channel were obtained through a combination of Pebble Count Method and Sampling Method at five accessible locations (Chen et al, 2007). Samples were analyzed at the soil laboratory of Desert Research Institute to obtain the grain size distribution. American Society for Testing and Materials (ASTM) procedures were followed for sieving analysis as described under Standard Test Method for Particle-Size Analysis of Soils. All samples were oven dried at 105°C for 24 hours, then placed in a series of ASTM approved sieves and positioned on a mechanical shaker for a minimum of 10 minutes each. The resulting size distributions of bed surface material are plotted in Fig. 5. Based on Fig. 5, less than 0.6% surface material consists of wash load (clay and silt) whose size is less than 0.0625 mm. About 2% bed material belonged to fine sand at 19th and 91st Avenues. Bed surface material mean size D_{50} ranges from 20mm to 40mm. More than 90% of the bed surface material consists of very coarse sand and gravels. Materials at the 51st Avenue are coarser than the bed material at other locations.

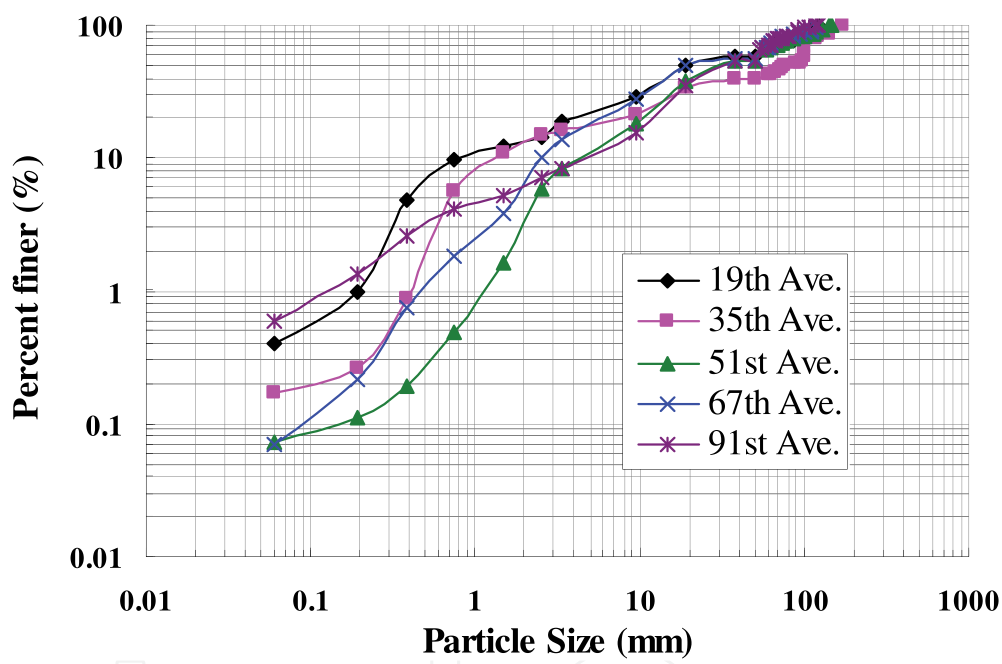


Fig. 5. Bed Surface Material Gradation in the Channel

5.3 Generation of 2-D computational mesh

A two-dimensional computational mesh was generated using the cross section data from HEC-RAS and channel topography data extracted from a digital contour map. The 2D mesh covered the entire study reach of the study site. Total of 77 cross sections extracted from the digital contour map were used to specify the bed elevations. Additional cross sections were interpolated based on these cross sections. The computational mesh had 678 cross sections with 120 computational nodes at each cross section. Fig 6 shows a part of computational mesh which includes a mining pit.

5.4 Sediment transport analysis

The sediment transport model treats suspended bed load and bed materials as mixed, grain-sized sediments and divides bed load into ten groups based on quantity and fluvial characteristics. The Wu, Wang and Jia's (2000) Formula and size distribution of substrate material are adopted in the present study. There is no field measurement of suspended load and bed load in the study reach. In the present study, we simulate sediment transport by assuming an equilibrium sediment supply at the inlet boundary which is calculated by using HEC-6T which uses Yang's (1984) Equation. In the present, we choose $\alpha = 1$ as suggested by Han et al. (1980) and Wu and Li (1992) and $L = 1000$ m (about the distance between alternative bars) based on personal discussion with NCCHE.

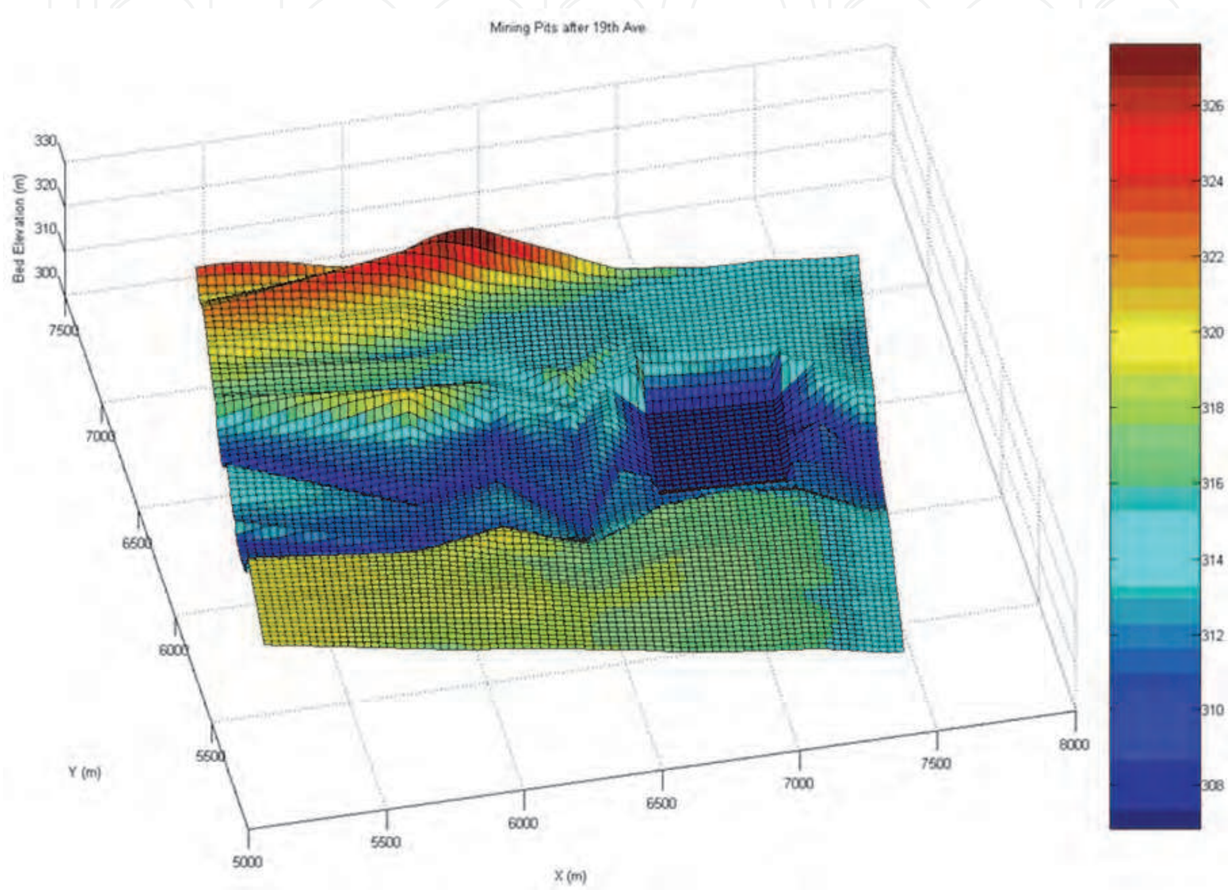


Fig. 6. Part of computational mesh including a mining pit

5.5 Hydrodynamic simulation

The effect of mining pits on inundated areas during different discharges was simulated in this study. Fig.7 provides an example of the calculated inundated areas with and without the mining pits at 500-year event. Based on Fig. 7, HEC-RAS and CCHE2D have similar calculated results which indicate that the inundated area has been reduced around the pits. However, this modification is minor comparing to the whole inundated area because the mining area only occupied a small part in the whole domain. Similar conclusions were drawn under other discharges which are not included in the report. However, our results also suggested that mining pits altered the local flow direction and magnitude. It may cause channel instability if those mining pits are close to riverbanks (Chen et al., 2008; 2007). The maximum riverbank shift has been as much as one-half mile in some locations through the area between 19th and 91st Avenues, Phoenix (USACE, 2005). However, the quantitative relation between bank erosion and gravel mining activities has not been formulated yet.

5.6 Simulation of bed elevation change

The effect of mining pits on bed elevation change was also simulated in this study. Fig. 8 and 9 show the bed topography change induced by gravel mining operation at 500-year flood event with HEC-RAS and CCHE2D models, respectively. Based on the simulation results, there was substantial erosion occurring upstream and downstream of the pits, however, the modeling results of HEC-RAS and CCHE2D model differed with each other. HEC-RAS results indicated serious head-cutting occurred upstream the pits, while CCHE2D results suggested "downstream erosion" was more noticeable. Modeling results of HEC-RAS showed the maximum bed degradation were 3.6 meters and 2.9 meters upstream of the Pit #1 and Pit #3, respectively. However, modeling results of CCHE2D exhibited the maximum bed degradation was 3.3 meters which occurred downstream the Pit #1. Besides, modeling results of CCHE2D indicated most sediment deposition was occurred in the upstream end of the mining pits. The maximum bed aggradations were 1.7 meters and 1.9 meters in the Pit #1 and Pit #2, respectively. Based on author's previous modeling study (Chen et al., 2008), the two-dimensional model was more robust in simulating flood zone coverage, non-uniform sediment sorting, and channel geomorphologic changes.

6. Conclusions

Impacts of instream gravel mining on flood zone coverage and riverbed change of the Rio Salado, Salt River, Phoenix, Arizona were simulated using HEC-RAS and CCHE2D in the present study. The capability of CCHE2D model in simulating bed changes due to mining was verified by two laboratorial cases. The following conclusions can be obtained:

a. Presence of mining pits insignificantly reduced the inundate area in the study reach, however, those pits changed the local flow directions and magnitudes which may accelerate stream bank erosion.
b. Calculated results of bed elevations of the two models differ with each other. There was substantial erosion occurring upstream and downstream of the pits, however, HEC-RAS results indicated serious head-cutting occurred upstream the pits, while CCHE2D results showed "downstream erosion" was more noticeable.
c. CCHE2D results indicated most sediment was deposited in the upstream end of the pits.

7. Discussion

The two-dimensional model was more robust in simulating the impacts of mining on flood zone coverage, non-uniform sediment sorting, and channel geomorphologic changes since one dimensional model hardly consider the information along the cross-sectional direction. The overestimation of the head-cutting by HEC-RAS was most likely caused by the improper calculation of the cross-sectional velocity upstream the pits, which is totally determined by the local water surface elevation in the one-dimensional calculation. In Figure 8b, the calculated water surface curve dropped dramatically upstream the pit #3, which is not realistic since the location of the pit is offset from the high velocity zone.

Flow structure around a deep mining pits present evident three-dimensional characteristics, however, three-dimensional sediment transport and bed deformation models are either complicate or time-consuming in preparing input data and calculation. The two dimensional model (CCHE2D) is able to examine the mining-induced bed change after appropriately determining non-equilibrium adaptation parameters. One-dimensional or vertical two-dimensional models may be applicable when the mining pit covers most area of the main flow zone.

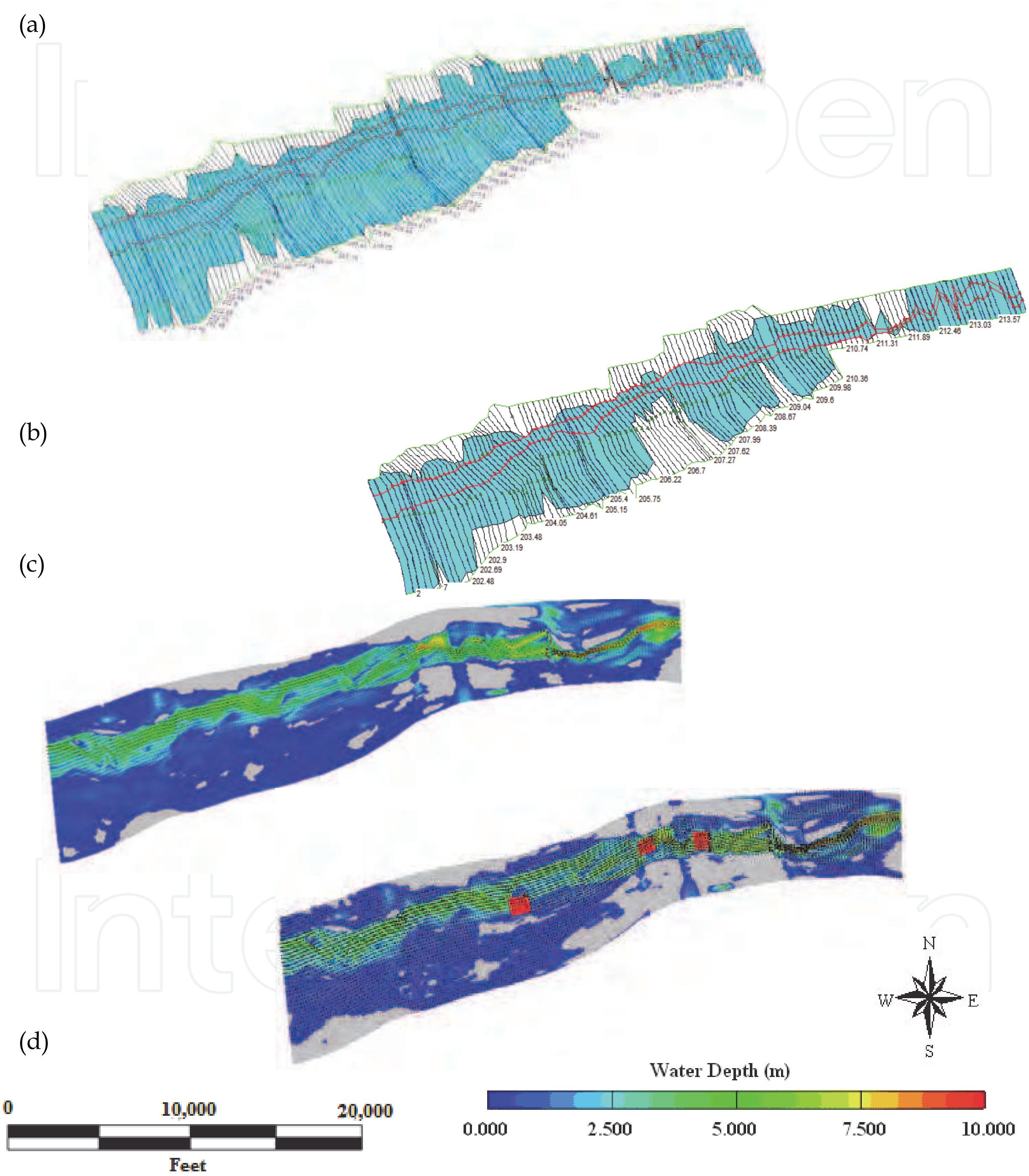
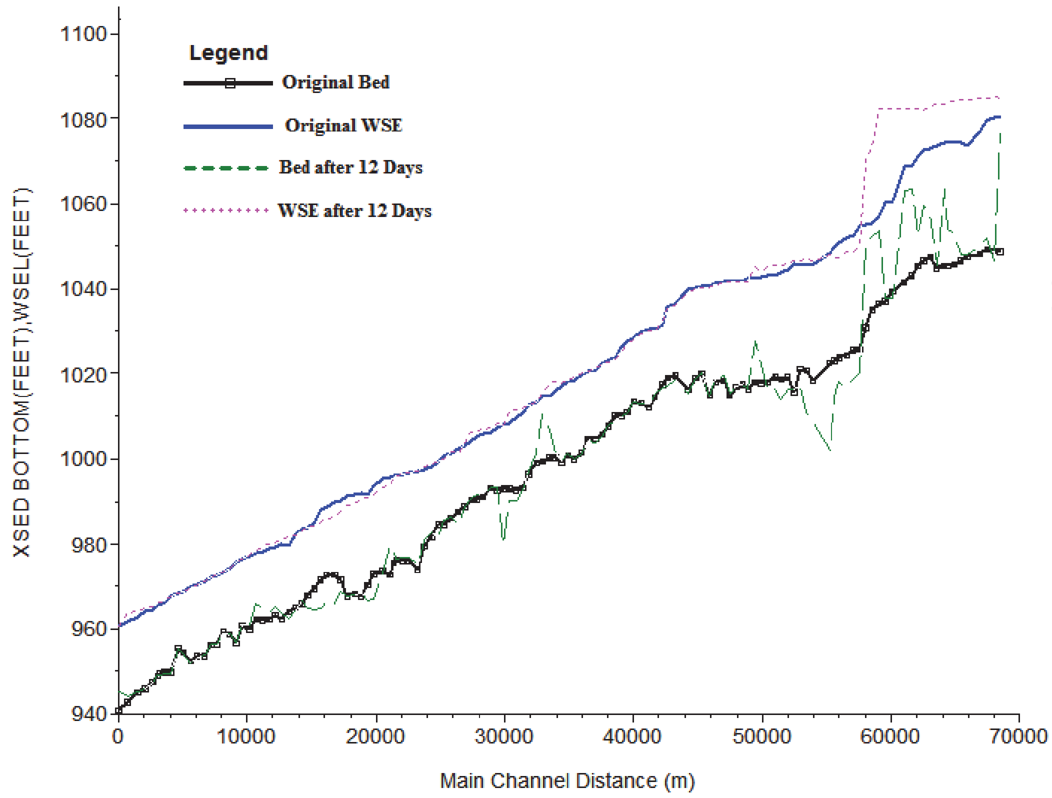
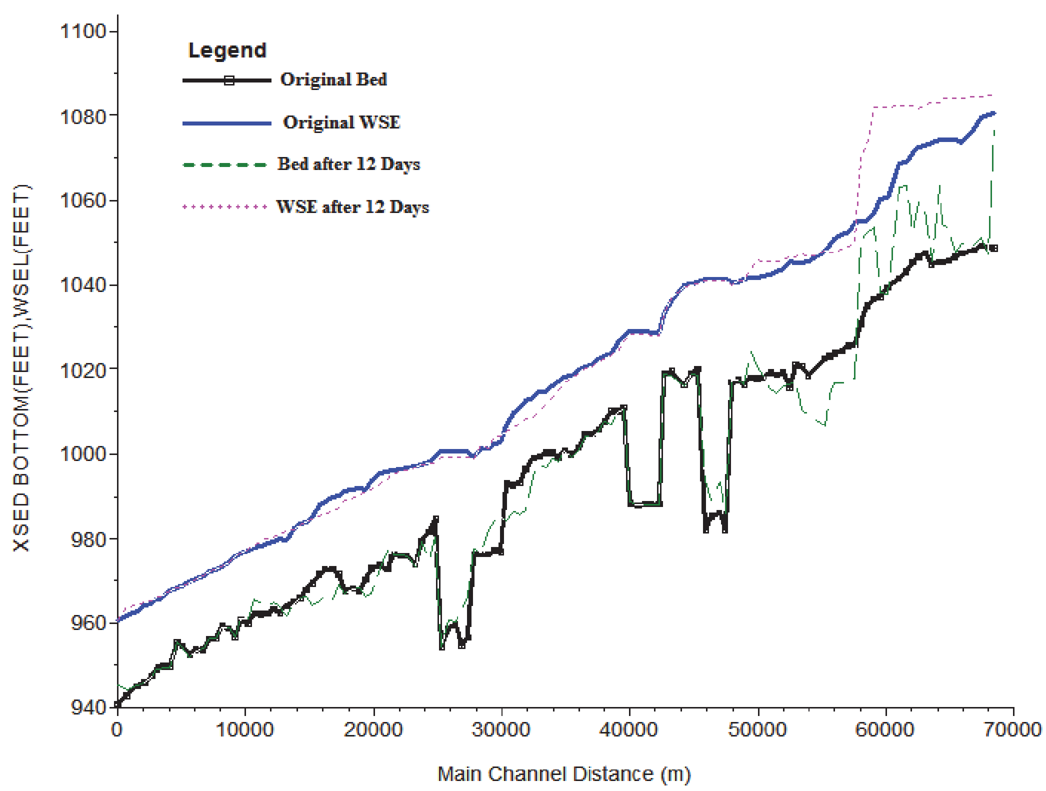


Fig. 7. Calculated inundated areas at 500-year event (a) HEC-RAS without mining pits; (b) HEC-RAS with three 10m pits; (c) CCHE2D without mining pits; (d) CCHE2D with three 10m pits

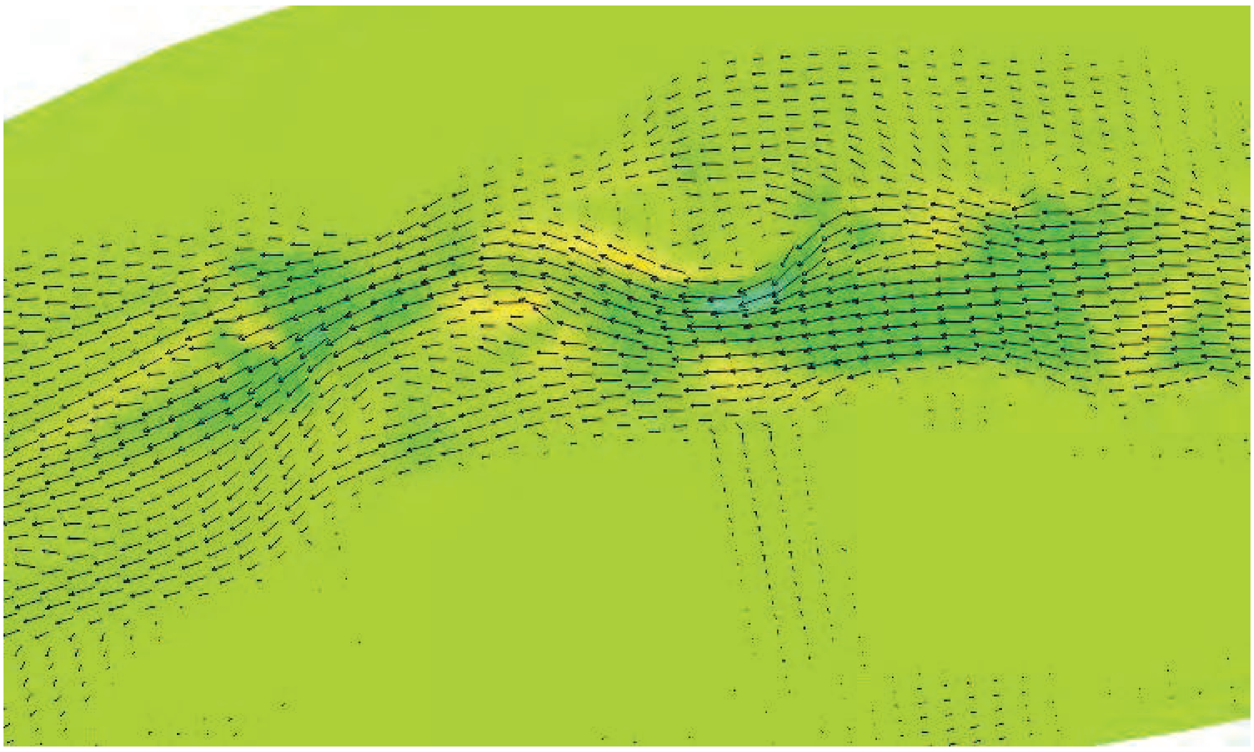


(a)

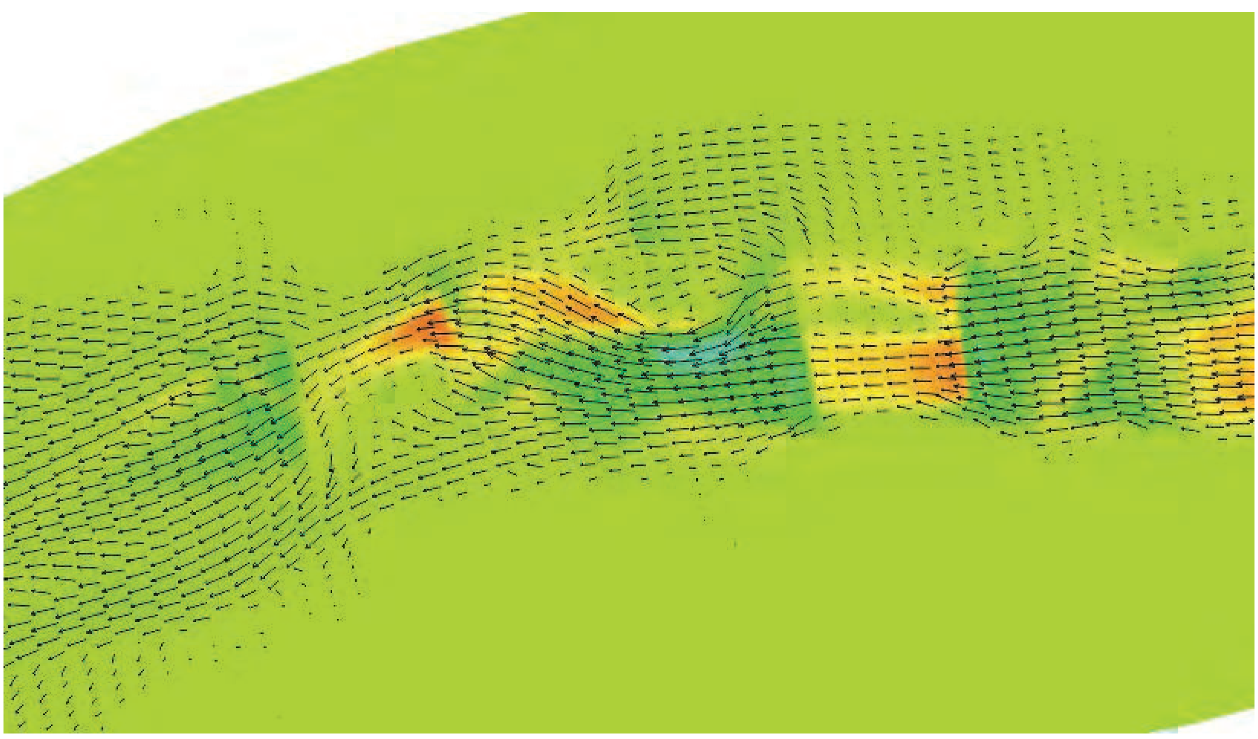


(b)

Fig. 8. Calculated bed topography change with HEC-RAS (a) without mining pits; (b) with three 10m mining pits (500-year event).



(a)



(b)

Fig. 9. Calculated bed topography change with CCHE2D (a) without mining pits; (b) with three 10m mining pits (500-year event).

8. Acknowledgement

This study was funded by US Corps of Army Engineers (USACE), Department of Defense under Urban Flood Demonstration Program of Arid and Semi-Arid Regions (UFDP). We thank the personnel of Flood Control District of Maricopa County and Phoenix district office of the USACE for their assistance in data collection and providing over view of the sites. We would also like to acknowledge the National Center for Computational Hydro-science and Engineering at the University of Mississippi for CCHE2D model.

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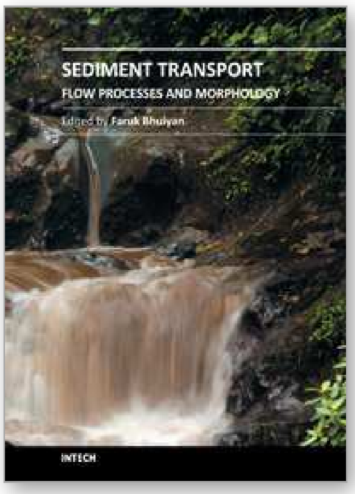

Sediment Transport - Flow and Morphological Processes
Edited by Prof. Faruk Bhuiyan

ISBN 978-953-307-374-3
Hard cover, 250 pages
Publisher InTech
Published online 26, October, 2011
Published in print edition October, 2011