# Investigation of Impacts of Chevron as a River Training Measure on River Hydraulics

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***Abstract*****—**It is well known that attainment of equilibrium conditions for alluvial streams is quite often complicated by variability of sediment load along with its size distribution. Mostly the alluvial streams can only attain a state of dynamic equilibrium. This river behavior throws a big challenge to maintain the navigation channel depth. Using maintenance dredging for removal of sediments from the bed has involved large amount of cost and also involves problem related to disposal area.

In the above context a recent technique called chevrons has been innovated for the purpose of maintaining navigation channels especially near harbor areas. It is located in the shoaling area of navigation channel. Mostly built in series, it induces the bed degradation and promotes better alignment along the main channel. In this research, lab experiments are conducted on the significant design parameters and Performance of chevron is represented by Channel Deepening Factor (CDF).

***Keywords*****—**Chevrons, bed degradation, navigation, river training

## I. Introduction

IN the navigation channel, the main problem generally occurs related to shoaling due to sedimentation process. Generally, sedimentation occurs at locations where the sediment transport capacity of the hydraulic system is reduced due to decrease of steady (currents) and oscillatory (waves) flow velocity and related turbulent motions [8]. One of the area with this criterion is the flow separation zone with the uneven flow distribution between the main channel and side channel. Flow in the main channel has a less portion than side channel and at times, less than 50% [4]. This creates a hindrance in the transportation through the main channel, making the navigation difficult. For this purpose maintenance dredging is also being adopted but it has proven to be a costly method as it had to be done frequently and the disposal of the dredge material is also a serious problem. So to deal with this problem, chevron has been designed.

### *A. What Is A Chevron?*

This structure is one of innovative design developed by US Army Corps of Engineer mainly for fairway improvement in maintaining navigational depth with reducing maintenance dredging and better alignment of thalweg with sensitive approach to environmental aspects. The structures has an ellipse shaped head and two legs that extended downstream, parallel to flow and serve as both channel improvement structures and permanent dredge disposal holding areas [1].

### *B. Potential applications*

Creating navigation channel- Excessive sediment deposition in navigational infrastructure leads to a reduction of depth for the safe maneuvering of vessels, thus impeding such structures to perform at designed conditions. Situation that leads to a series of measures that obstruct the development of navigation and its economic benefit, port operators are forced to reduce the draft, to limit navigation in period of high tide, decrease the load capacity or particular cases to prevent the access of ships. Currently, the traditional solution to these problems is the use of maintenance dredging to remove the deposited sediment from the bed and to dispose it out of the system. as it helps in deepening of the channel on both sides,

Channelization of river- with the use of chevrons, the river waterway is not only constricted but it also gives the river to flow in a predefined manner.

Flood moderation- by providing desired waterway and alignment for flow of the river, it also helps in controlling of the flood.

Channel stabilization- by providing a definite path for flowing of the stream, it helps to control the process of silting of the river bank and bed, making it stable.

At present, there is no scientific design methodology approach for chevrons could be found in the literature. In this paper, an attempt has been made to develop design parameters of chevron to achieve better results for field application by evolving an objective design approach.

## II. Development Of New Design Parameters And Dimensionless Indices For Performance Evaluation Of Blunt Nosed Chevron

### *A. Construction of chevron*

Material- rock structure built using standard “A” graded stones or quarry run stones

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Shape- typical trapezoidal section with side slopes 1 V to 1.5 H [2].

Due to the elliptical shape of chevron flow separation takes place dividing the flow to pass through main channel n side channel, but the transition of flow velocity is smooth apparently without turbulence ensuring the stability and integrity of the structure [2]. Due to this main channel conveyance is increased by the scouring action at the bottom whose rate mainly depends upon the velocity of flow.

Scouring takes place along the boundary of the chevron and in the shadow area behind it due to the boundary effects on the local sedimentation patterns. This scoured area even serves as a short term dredging disposal area and as suggestion by Davinroy et.al (1996) that the further downstream placement of the material at each structure will enhance the development of ultimate desired bed configuration.

Taking environmental aspect into consideration, it even enhances the biodiversity of the habitat from the area of sandbars and deep-pool in middle of structure. Water is allowed to flow over the middle of structures at high water stage. Scour below the crown occurs at the bottom and provide a good environment to deep-water habitat. Chevron also provides the environmental flow for floodplain enhancement [3].

In order to develop the meaningful design criteria, design parameters of chevron geometry should be identified and investigated. Angle of flare, α, is referred as the angle between the chevron's leg endpoint and the axis normal of flow direction. The chord width of the chevron's arc is defined as the width of chevron's crown/head (WC). Width between endpoint of the chevron's leg is defined as the width of the bottom chevron (WB). Length of overall chevron is defined as the chevron leg (LC). The height of chevron (h) is taken as the distance measured from bed level surface to top of the chevron. Figure 1 illustrates the plan and elevation view of chevron.

Dimensionless design parameters have been developed by Amanda Devianty in the previous study to facilitate formulation of objective chevron performance evaluation procedure for its preliminary configuration, presented as Channel Deepening Factor (CDF). These are presented in the following.

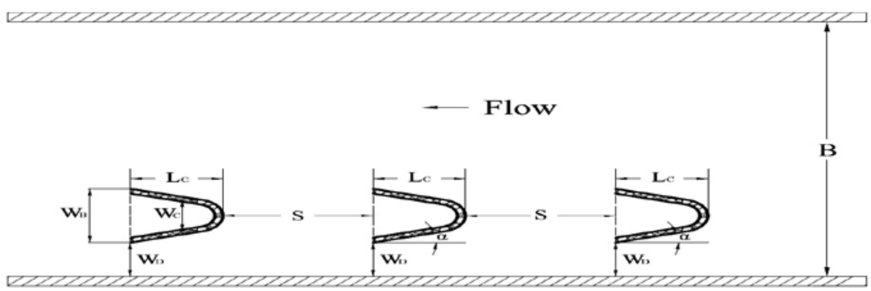


Fig. 1(a)

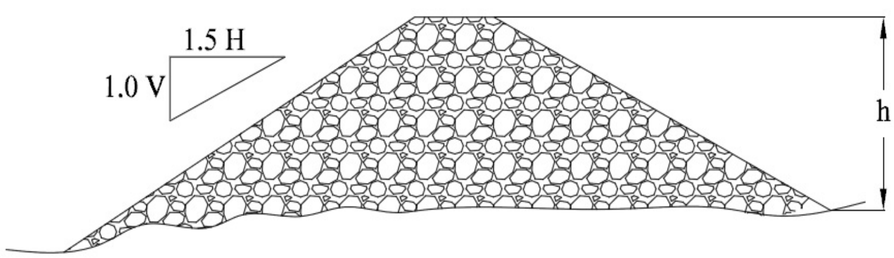


Fig. 1(b)
Fig. 1 represents Section of Chevrons; (a) Plan View; (b) Elevation View

Independent parameters input on the experimental program of geometry and layout configuration of chevrons has given results to the bed degradation that occur in the middle of the main channel. The dependent parameter already defined as Channel Deepening Factor (CDF), as the ratio of degradation depth to chevron height and bigger value of CDF indicated better performance of chevron in handling the shoaling problems. Relationship of CDF given as :

$$CDF = \frac{\Delta\,(post\ runs - pre\ runs)}{h} \qquad (1)$$

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Independent factor as the input on the experimental study are focused on the spacing between chevrons, distance from the boundary and the submergence ratio of chevron. Spacing between chevrons is formulated in relationship with chevron height, given parameter of Relative Chevron Spacing (RCS) with equation as follows :

$$RCS = \frac{s}{h} \quad (2)$$

Other layout configuration of chevron within the channel is the distance from the boundary. Proposed dimensionless parameter that relates the distance from the boundary with chevron height given as Relative Distance (RD) and the relationship given as :

$$RD = \frac{W_D}{h} \quad (3)$$

In the present study, chevron is investigated in different submergence condition to observe the hydraulic behavior in the presence of chevron. Submergence ratio is the function of chevron´s height (h) and water depth (H) with formula:

$$CSF = \frac{(H-h)}{h} \quad (4)$$

Froude number is widely used to determine the flow regime in open channel flow and represents the value given by the ratio of inertia force to the gravitational force. This dimensionless parameter also employed here as the indirect relation to velocity magnitude on bed degradation induced by chevrons.

$$F = \frac{V}{\sqrt{gH}}$$

### III. Laboratory Experiments On Chevron

Model of chevron has been adopted from the prototype at St. Louis Harbor in Middle Mississippi River, USA and is made of 4 mm thick steel sheet material. The scaling factor for horizontal direction is adopted as 1: 1200 and vertical as 1: 50 for vertical exaggeration factor of 24. In the present study, two geometries of the chevrons are illustrated in Figure 2.

Models are placed in the 0.50 m wide laboratory flume with height 0.4 m and bed material of sand with d50 = 0.25 mm and σg = 1.29. Sand layer on the bed has a height of 0.12 m. Slope of the flume is set at 0.0001875 and has maintained the condition of clear water flow. Flume is attached with other instruments that have flow recirculation system to provide steady uniform flow to the flume. Illustration of the flume and the recirculation system given in Figure 3.

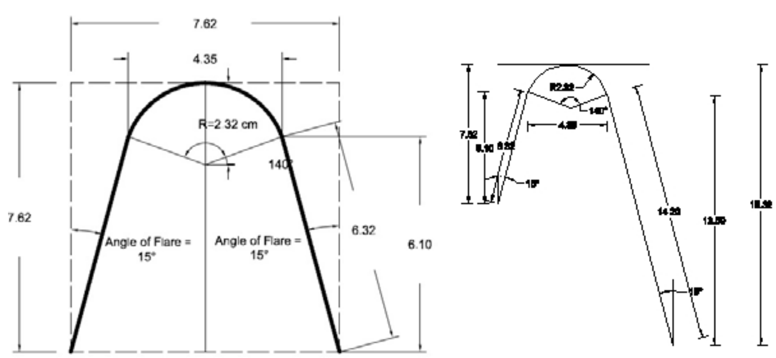


Fig. 2(a) represents 15 degree symmetric and asymmetric chevron

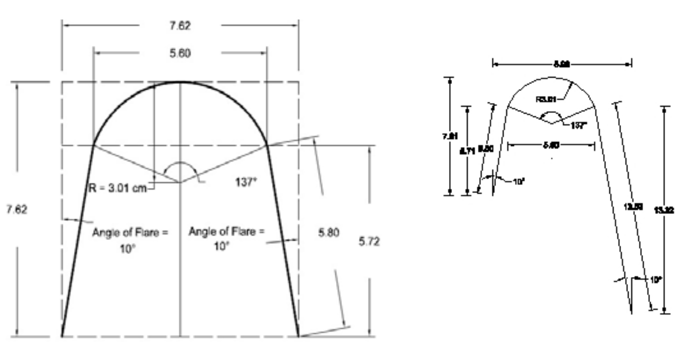


Fig. 2(b) represents 10 degree symmetric and asymmetric chevron

Fig 2 represents Blunt Nosed Chevrons Geometry; (a) Geometry 1; (b) Geometry 2

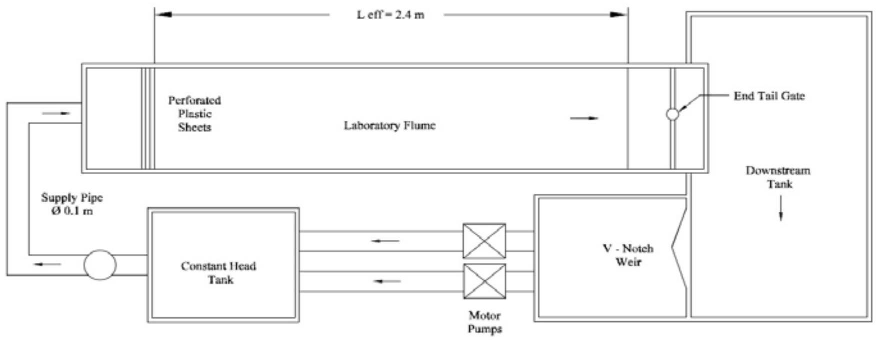


Fig. 3 represents Plan View of Experimental Set Up

Three models are configured first one of different leg length and the remaining 2 of same leg lengths for both the chevrons geometry in a straight line with constant spacing and varying distance from boundary as given in Table 1 for total 36 runs. In the present study, condition of flow submergence ratio is varied from about 0, 0.2, 0.4, and 0.6 for different water height (H). The layout configuration for chevron has been evolved as distance from the boundary, and submergence ratio. Velocity has been measured utilizing Micro ADV and measurement of bed profile after each runs has been taken using Vernier point gauge.

TABLE I
EXPERIMENTAL PROGRAM

| run no. | Geometry (m) | | | | | | S (m) | Wd (m) | H (m) | Parameters | | | | Discharge (m3/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lc (bank side) | Lc(river side) | Wc | Wb | h | | | | CSF | RCS | RD | Froude | |
| a) long leg of chevron bank side | | | | | | | | | | | | | | |
| 1 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.15 | 0 | 2 | 0.8667 | 0.065983 | 0.006 |
| 2 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.18 | 0.2 | 2 | 0.8667 | 0.060234 | 0.0072 |
| 3 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.21 | 0.4 | 2 | 0.8667 | 0.055766 | 0.0084 |
| 4 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.24 | 0.6 | 2 | 0.8667 | 0.052164 | 0.0096 |
| b) long leg of chevron river side | | | | | | | | | | | | | | |
| 5 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.15 | 0 | 2 | 0.8667 | 0.065983 | 0.006 |
| 6 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.18 | 0.2 | 2 | 0.8667 | 0.060234 | 0.0072 |
| 7 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.21 | 0.4 | 2 | 0.8667 | 0.055766 | 0.0084 |
| 8 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.13 | 0.24 | 0.6 | 2 | 0.8667 | 0.052164 | 0.0096 |
| c) long leg of chevron bank side | | | | | | | | | | | | | | |
| 9 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.15 | 0 | 2 | 1.0000 | 0.065983 | 0.006 |
| 10 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.18 | 0.2 | 2 | 1.0000 | 0.060234 | 0.0072 |
| 11 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.21 | 0.4 | 2 | 1.0000 | 0.055766 | 0.0084 |
| 12 | 5 | 0.01532 | 0.0762 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.24 | 0.6 | 2 | 1.0000 | 0.052164 | 0.0096 |
| d) long leg of chevron river side | | | | | | | | | | | | | | |
| 13 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.15 | 0 | 2 | 1.0000 | 0.065983 | 0.006 |
| 14 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.18 | 0.2 | 2 | 1.0000 | 0.060234 | 0.0072 |
| 15 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.21 | 0.4 | 2 | 1.0000 | 0.055766 | 0.0084 |
| 16 | 5 | 0.0762 | 0.01532 | 0.0435 | 0.0896 | 0.15 | 0.3 | 0.15 | 0.24 | 0.6 | 2 | 1.0000 | 0.052164 | 0.0096 |
| e) long leg of chevron bank side | | | | | | | | | | | | | | |
| 17 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.15 | 0 | 2 | 0.8667 | 0.065983 | 0.006 |
| 18 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.18 | 0.2 | 2 | 0.8667 | 0.060234 | 0.0072 |
| 19 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.21 | 0.4 | 2 | 0.8667 | 0.055766 | 0.0084 |
| 20 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.24 | 0.6 | 2 | 0.8667 | 0.052164 | 0.0096 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f) long leg of chevron river side | | | | | | | | | | | | | | |
| 21 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.15 | 0 | 2 | 0.8667 | 0.065983 | 0.006 |
| 22 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.18 | 0.2 | 2 | 0.8667 | 0.060234 | 0.0072 |
| 23 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.21 | 0.4 | 2 | 0.8667 | 0.055766 | 0.0084 |
| 24 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.13 | 0.24 | 0.6 | 2 | 0.8667 | 0.052164 | 0.0096 |
| g) long leg of chevron bank side | | | | | | | | | | | | | | |
| 25 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.15 | 0 | 2 | 1.0000 | 0.065983 | 0.006 |
| 26 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.18 | 0.2 | 2 | 1.0000 | 0.060234 | 0.0072 |
| 27 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.21 | 0.4 | 2 | 1.0000 | 0.055766 | 0.0084 |
| 28 | 0 | 0.01332 | 0.0762 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.24 | 0.6 | 2 | 1.0000 | 0.052164 | 0.0096 |
| h) long leg of chevron river side | | | | | | | | | | | | | | |
| 29 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.15 | 0 | 2 | 1.0000 | 0.065983 | 0.006 |
| 30 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.18 | 0.2 | 2 | 1.0000 | 0.060234 | 0.0072 |
| 31 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.21 | 0.4 | 2 | 1.0000 | 0.055766 | 0.0084 |
| 32 | 0 | 0.0762 | 0.01332 | 0.0435 | 0.0969 | 0.15 | 0.3 | 0.15 | 0.24 | 0.6 | 2 | 1.0000 | 0.052164 | 0.0096 |

## IV. Laboratory Results

As stated earlier, parameters of chevron performance have been proposed in this study. Performance of chevrons has been investigated, from the individual effect of the combined effect of geometry and layout configuration parameters. Each individual effect will be discussed separately. While from multi effect, the dominant parameter which controls the value of the CDF will be defined.

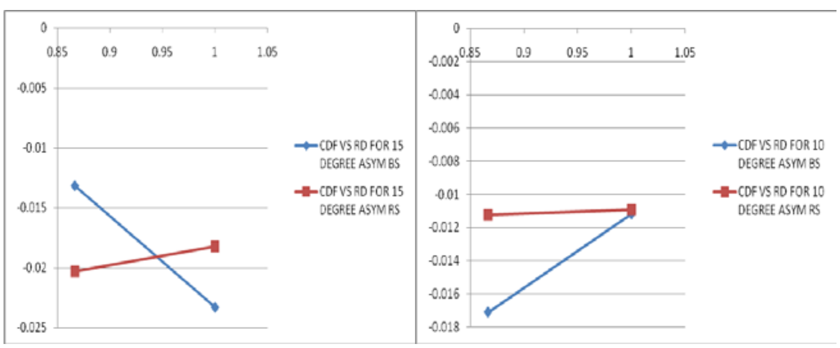


Fig. 4(a) represents placement of long leg bs means bank side and rs means river side

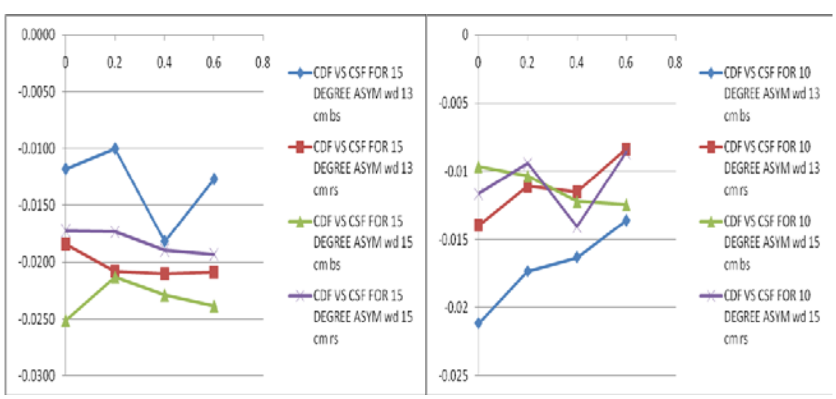


Fig. 4(b) represents placement of long leg bs means bank side and rs means river side

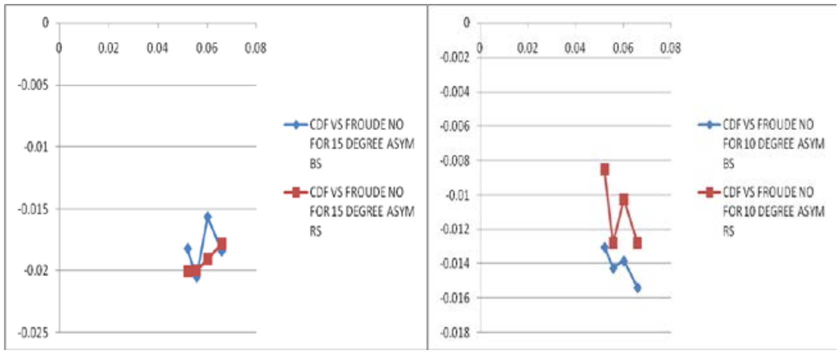


Fig. 4(c) represents placement of long leg bs means bank side and rs means river side

Fig 4 CDF as the function of chevron parameters; (a) RD; (b) CSF; (c) Froude Number

### A. Effect of Distance from Boundary

Figure 4 (b) relates CDF for both geometry of the chevron to distance from the boundary. Relative Distance (RD) is the function of distance from the boundary to chevron height. The distance also determines the width of the side channel, where partial flow is distributed flow through this area. Agreement from geometry 1 and geometry 2 of the chevron is also observed for RD in linear relation with CDF and is different for both long leg river side and bank side cases. Minimum width in main channel that facilitates waterborne traffic should be determined first, while the remaining width could be applied for side channel. Distance from boundary should be dependent on channel geometry and is to be determined by case-to-case basis.

### B. Effect of Submergence Ratio

Chevrons have been tested with various submergence conditions. As stated before, chevron allows the flow over the structure. From the experimental observation, chevrons are more effective when the water height is decreased. It relates with velocity measurement taken with Micro ADV, in which magnitude of velocity in lower submergence is higher than the higher ratio. From fig 4 (b) it can be concluded that the submergence has the inverse relation with CDF.

## REFERENCES

[1] ASCE COPRI. “Inland Navigation Channel Training Works”. Manual of Practice, New York, Headquarters of The Society, 2013

[2] Davinroy, D.R., Redington, L.S., Stauser, N.C., “Design of Blunt Nose Chevrons in The Mississippi River for Sediment Management.” Proceeding of 6th FISC, Las Vegas, NV., 1996

[3] DuBowy, J.P. ”Mississippi River Ecohydrology : Past, Present, and Future.” Ecohydrol.Hydrobiol. http://dx.doi.org/10.1016/j.ecohyd.2013.02.003

[4] Gordon, C.D. ”A Remedy for a Chronic Dredging Problem.” Engineer, Vol. 34 No. 4, p32-35, Oct- Dec 2004, US Army Corps of Engineers., 2004

[5] Julien, Y.P., Duncan, R.J. ”Optimal Design Criteria of Bendway Weirs From Numerical Simulations and Physical Model Studies.” Technical Paper, March 17, 2003, Civil Engineering, Colorado State University., 2003

[6] Lamm, M.D., Davinroy, D.R., Gordon, C.D., Riff, H.E., Brauer, J.E., Brown, L.J. “Sedimentation and Navigation Study of The Middle Mississippi River in The St. Louis Harbor River Miles 192.0 to 172.0.” Hydraulic Micro Model Investigation, Technical Report M31, Applied River Engineering Center. Hydrologic and Hydraulics Branch. Engineering Division. St. Louis District.US Army Corps of Engineer, 2004

[7] Pinter, N., Miller, K., Wlosinski, J. H., & Van der Ploeg, R. R. “Recurrent Shoaling and Channel Dredging, Middle and Upper Mississippi River, USA.” Journal of Hydrology, 290(3-4), 275–296. doi:10.1016/j.jhydrol.2003.12.021, 2004 http://dx.doi.org/10.1016/j.jhydrol.2003.12.021

[8] Van Rijn, C.L. “Estuarine and Coastal Sedimentation Problems.” International Journal of Sediment Research, Vol. 20, No.1, pp. 39-51, Elsevier., 2005