EXPERIMENTAL INVESTIGATION OF FLOOD WAVES FROM OPEN-CHANNEL LEVEE BREACH

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Introduction

- The main purpose of levee is to prevent flooding and inundation of the adjoining areas
- Levees were constructed over 3,000 years ago in ancient Egypt along the left bank of River Nile for more than 1,000 kilometers stretching from Aswan to Nile Delta
- Recently, levee systems have been built along the Mississippi and Sacramento Rivers in the U.S. and Rhine, Loier, Vistula, Scheldt and Danube Rivers in Europe.

Levee Breach

2011 levee breach on Weber County

2011 levee breach on Noba Canal in Egypt

2011 levee breach on Mississippi River in Missouri

Levee breaches have been encountered often lately all round the world leading to catastrophic events

2011 levee breach on Black River in Missouri

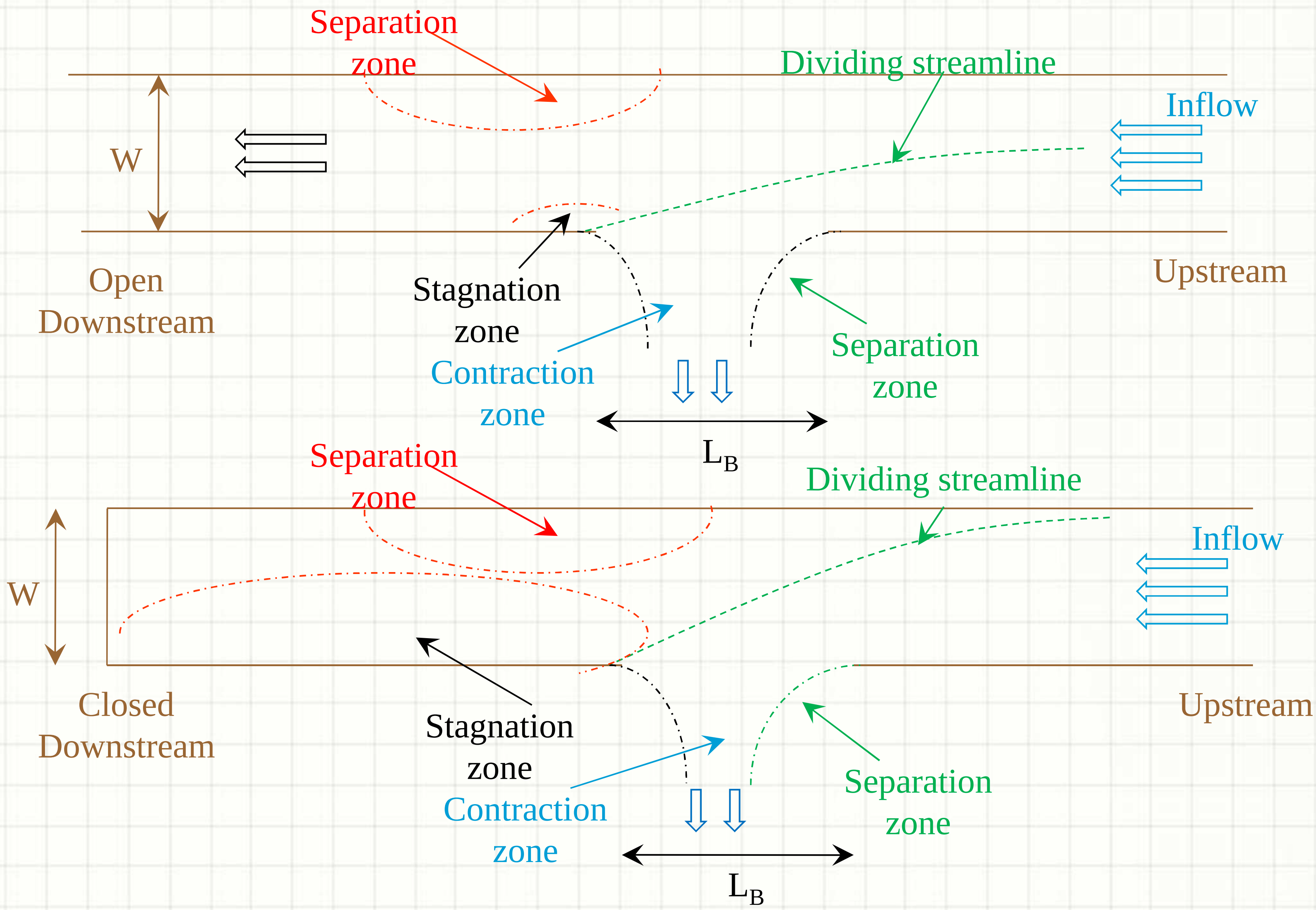
2010 levee breach in Vendee in France

2004 Levee failure on the Upper Jones Tract in California

Levee Breach Hydraulics

- Understanding hydraulic aspects is important to help devise mitigation measures and to decrease the adverse impacts on surrounding areas
- The levee breach is hydraulically similar to dividing open channel flow and dam break flow;
  - Separation zone in the main channel after the breach location
  - Stagnation zone near the downstream corner of the breach
  - Contracting flow region with free overfall conditions of dam-break similar waves

Open Channel Levee Breach

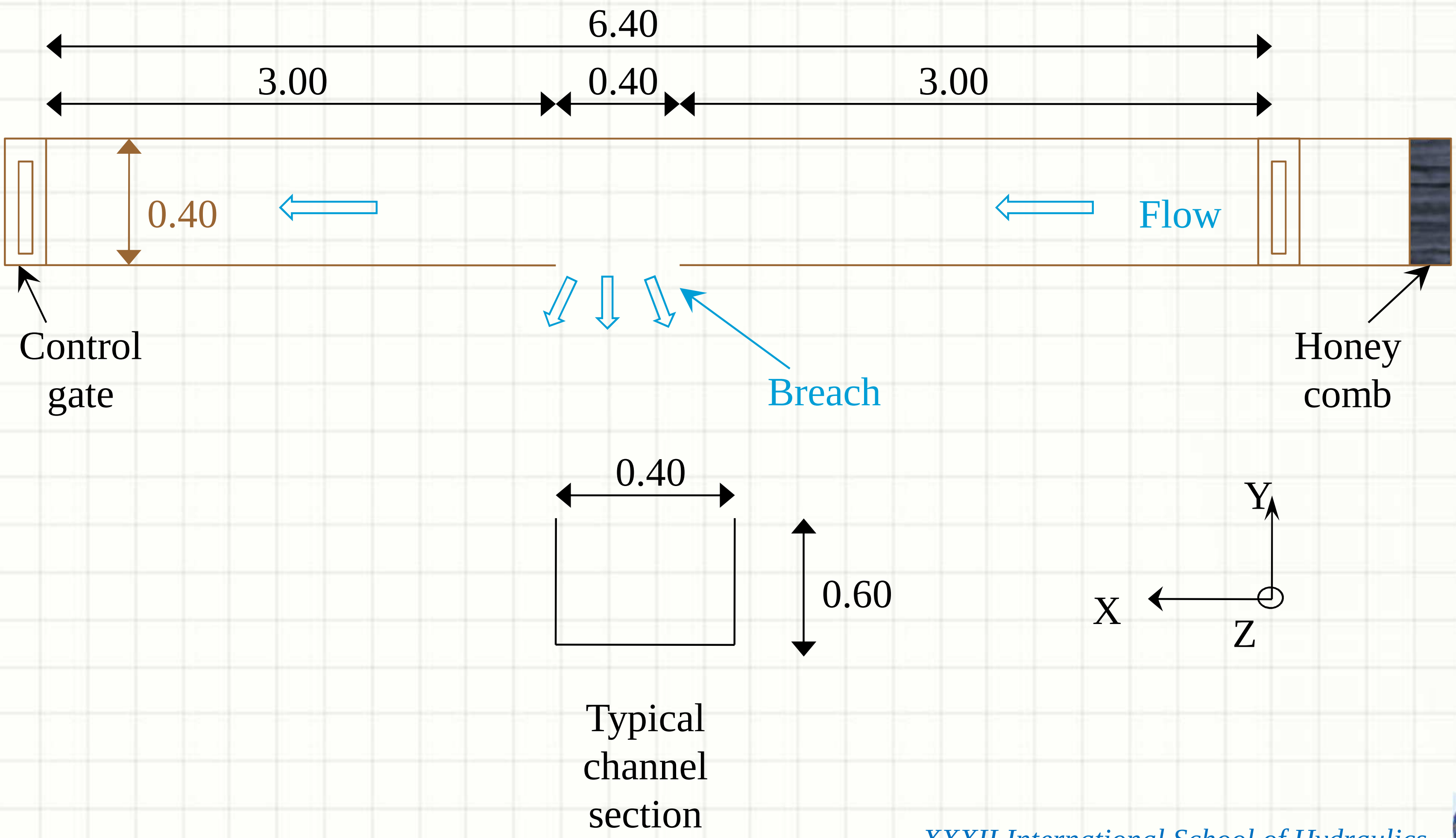


Main objective

1. Present experimental results for some of the hydraulic characteristics of rectangular open channel levee breach in 3D especially in regions of secondary currents and during highly turbulent flow events and at sharp water surface gradients
2. Develop preliminary equations for choice of sandbags for breach closure during flood events

Experimental Setup

The experiments are performed in a straight flume, which is constructed in 11.6 x 6.7m basin at the Irrigation & Hydraulics Department at Cairo University



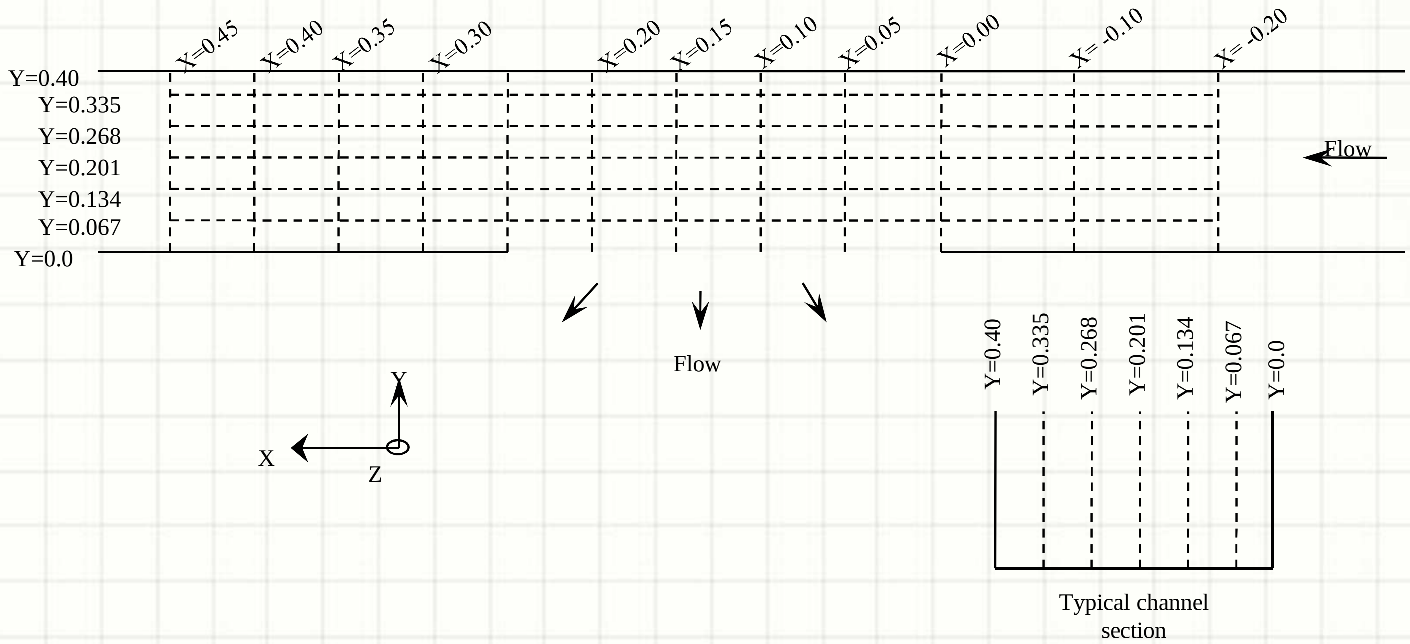
Experimental Setup

Set of experiments conducted

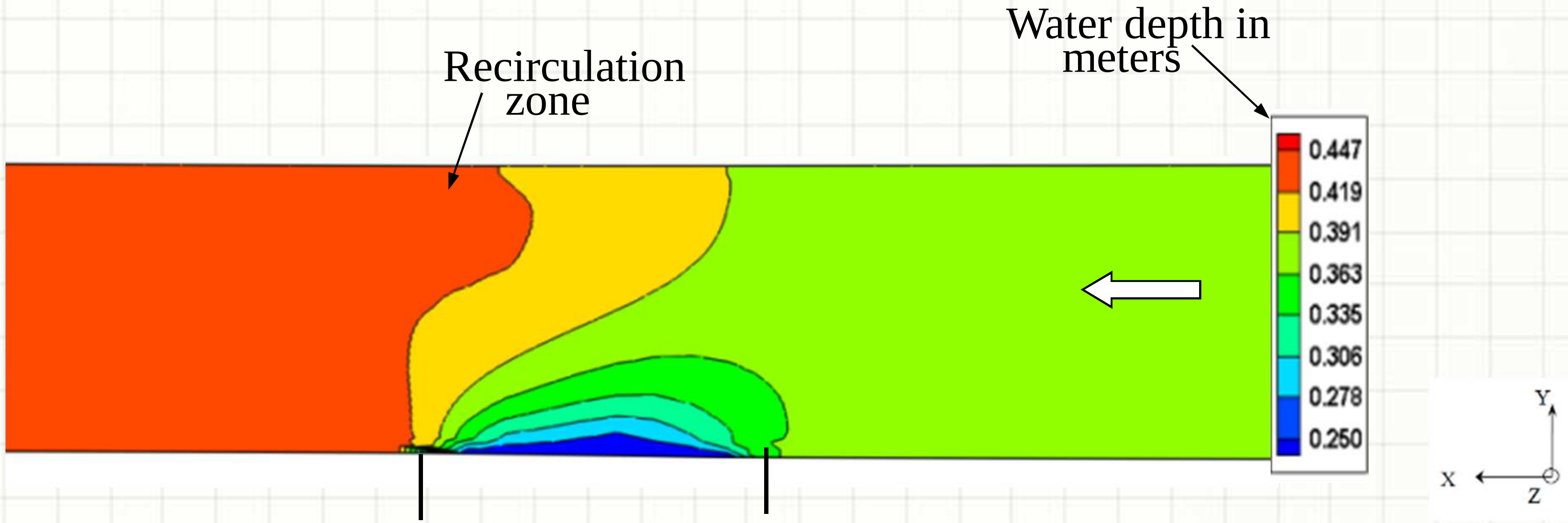
L_b =0.25m			L_b =0.40m		
Q_u (m^3/s)	Q_b (m^3/s)	Q_r	Q_u (m^3/s)	Q_b (m^3/s)	Q_r
0.16	0.16	1	0.16	0.16	1
0.16	0.1282	0.80	0.16	0.1282	0.80

Qb is the breach discharge, Qu is the main channel discharge upstream the breach and Qr is the flow ratio as defined before, and Lb is the breach width.

Measurement Sections



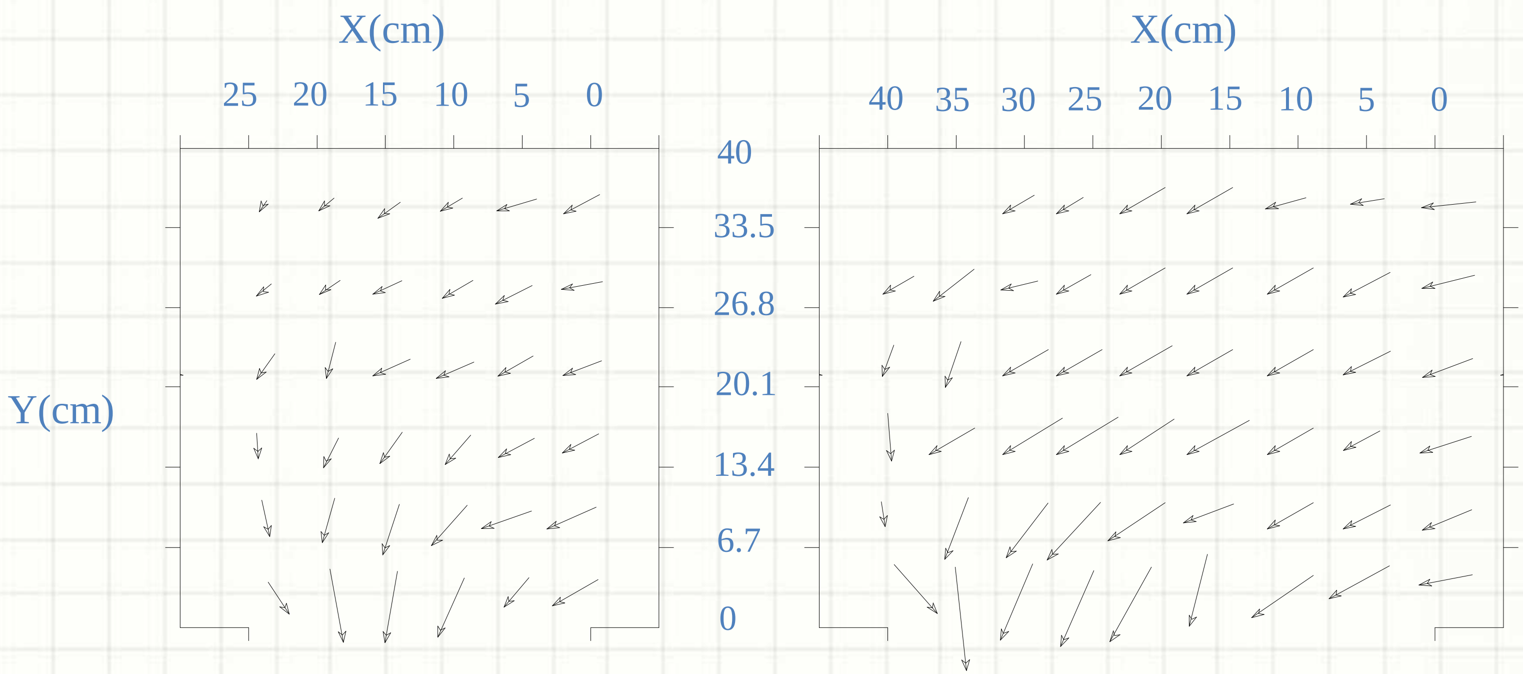
Water Surface Mapping



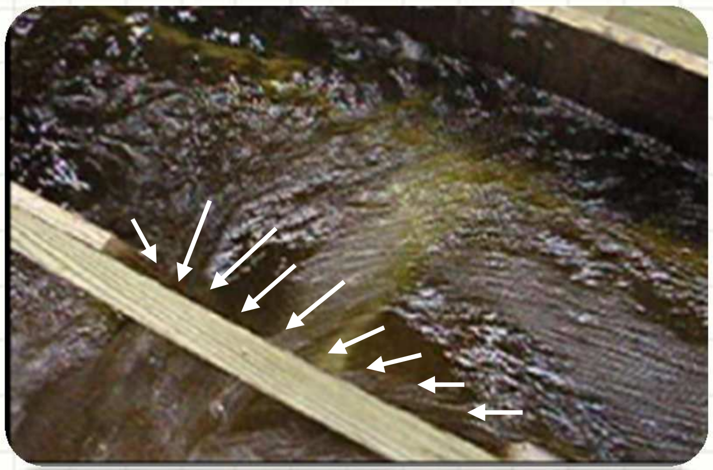
Due to the free-overfall conditions at the breach section:

1. Variations in water depth are more pronounced than in case of open channel dividing flow.
2. Rapid decrease in water depth across the channel at the breach section with velocities being the highest at breach section.

X-Y Velocity Field

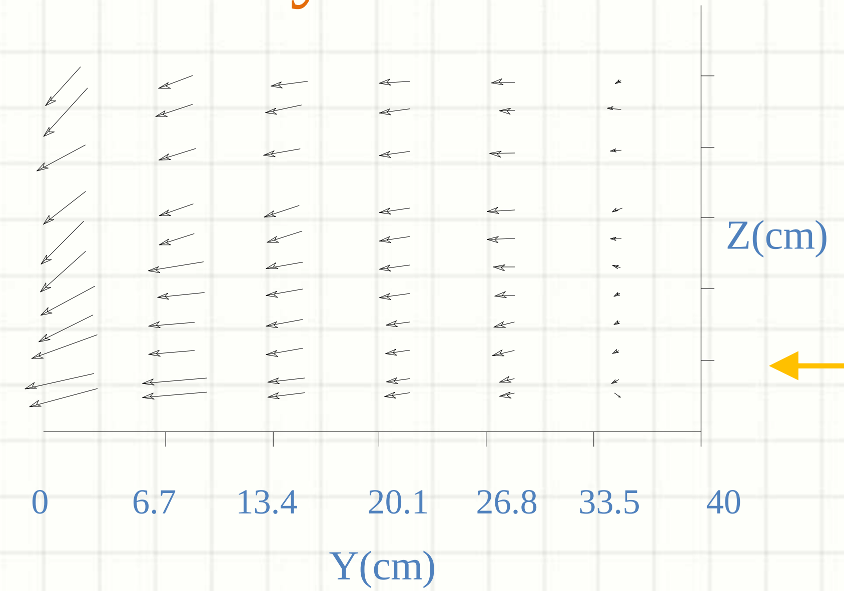


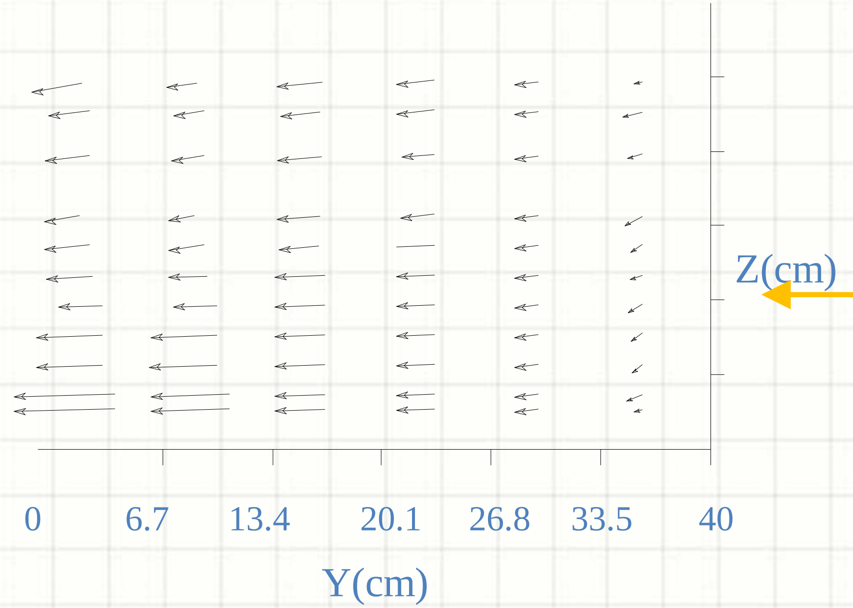
X-Y vector velocity field around the breach, Q_u =0.16m^3/s, Q_r =1, Z=0.15m for a) L_b=0.25m, and b) L_b=0.40m

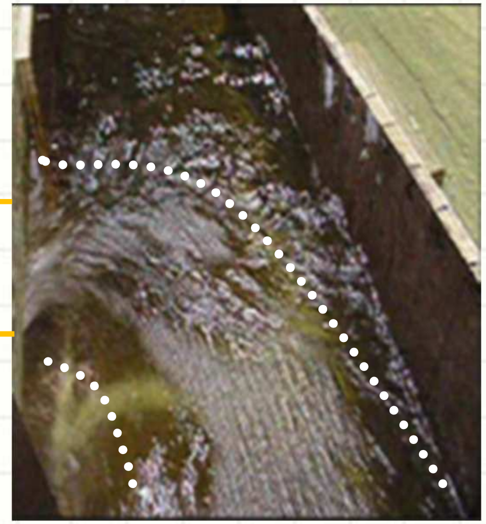


Streamlines direction and rough relative velocity at exit section at flume side breach, Q_u =0.16m^3/s, Q_r =0.8, $Z=Z_{surface}$

Y-Z Velocity Field







Q_u =0.16m^3/s, Q_r =1, for L_b=0.25m, at a)

Sand Bags for breach Closure

One of the most efficient and economic ways

New Orleans Levee breach

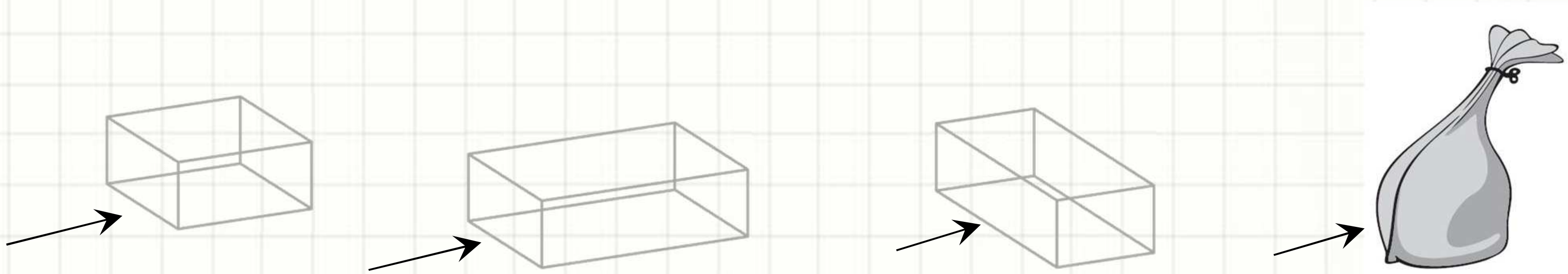
Missouri levee breach

Sand Bags for breach Closure

Size of the dumped sand bag has to be chosen such that the breach flow velocity will not sweep it away

↓ ↓ ↓

Therefore a new set of experiments is conducted on incipient motion of sand bags using sewed cloth bags containing 1.85g.cm3 sand



Prism-1- Prism-2- Prism-3- Spherical

Critical Velocity for Incipient Motion

Assuming that vertical velocity distribution along each breach section roughly follows the sixth power law; the following can be used to relate critical velocity causing the instability of sandbags dumped in running flow;

$$V_{cr} = C_I \sqrt{2gD(\rho_s - \rho_w / \rho_w)}$$

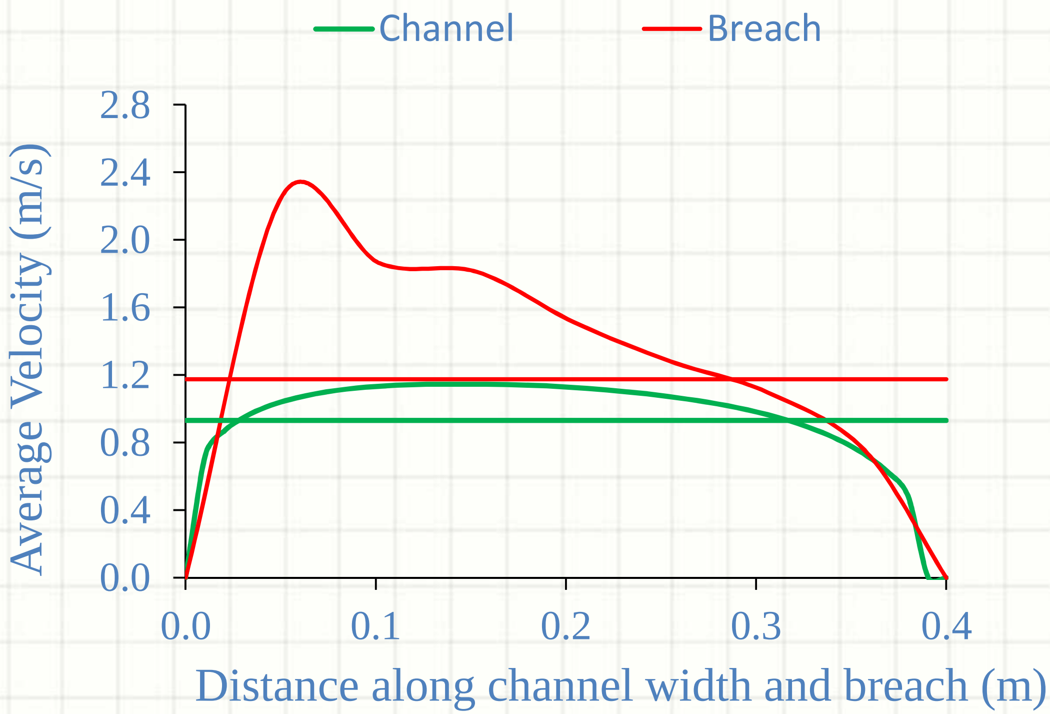
Izbash (1936) for spherical sand bags

$$V_{cr} = C_{II} (H/b)^{\frac{1}{6}} \sqrt{gb(\rho_s - \rho_w / \rho_w)}$$

Zhu et al. (2004) for prism shaped sand bags

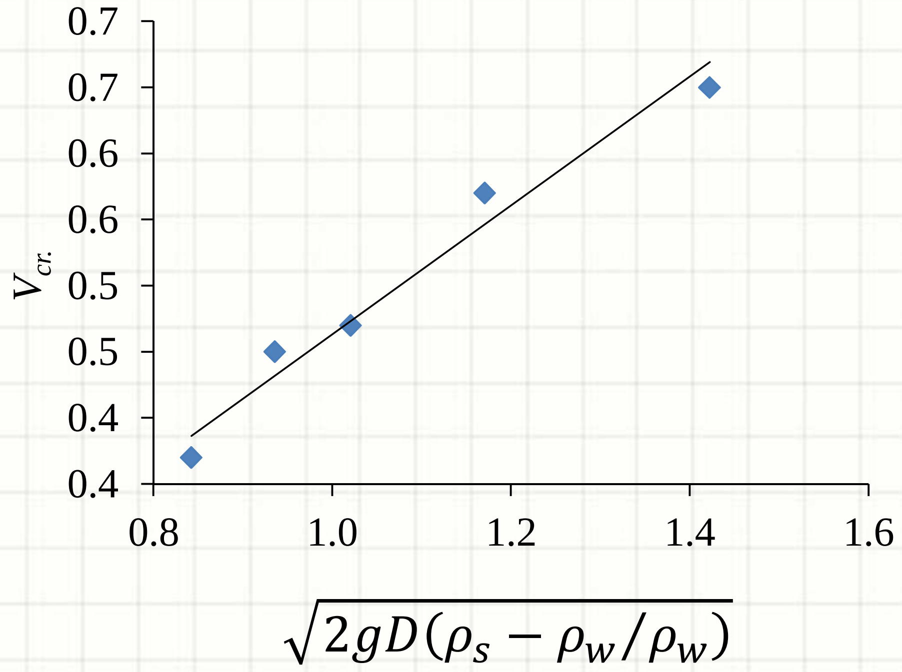
where V_{cr} is the critical velocity; D is the sandbag diameter, b is the height of the sandbag as defined before, ρ_s is the sand density and ρ_w is the water density; H is the water depth above the sandbag; and C_I, C_{II} are constants that are assumed in the current study to be related to sandbag shape factor β, and orientation in flow.

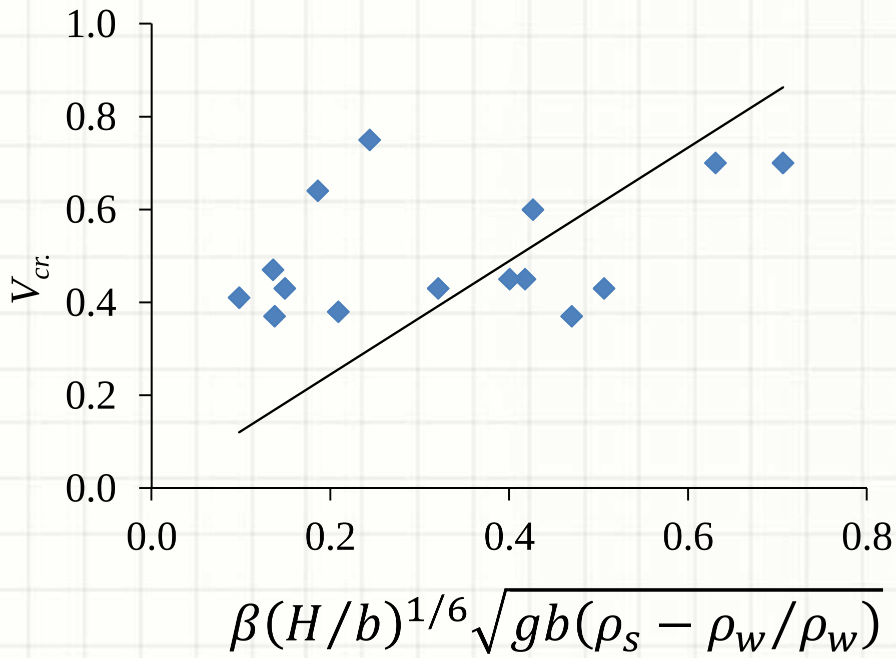
Critical Velocity for Incipient Motion



All previous studies on incipient motion of sandbags or large particles used the average channel section velocity at the initiation of the motion to determine the stability condition.

Critical Velocity for Incipient Motion





Spherical sandbags

$C_I = 0.4876$

Prism sandbags

$C_{II} = 1.222(H/b)^{1/6}$

THANK YOU FOR YOUR TIME!