UNIVERSITI TEKNOLOGI PETRONAS
energising futures

Final Year Project (FYP) Viva Presentation

Computational Fluid Dynamic Around a Pier by using LABSWE™

Presenter : Muhammad Naqib Izzuddin**(17006688)**

Supervisor : Dr. Siti Habibah

Presentation Outline

1. Introduction
2. Literature Review
3. Research Methodology
4. Results & Discussion
5. Conclusion & Recommendations

1. INTRODUCTION

Background → Problem Statement → Objectives → Scope of Study

- **Piers faces hydrodynamic load causing structural failures.**
- **The problem studied by using LABSWE™**
- **The computational analysis of flow around the piers was done to be able in understanding the behaviour against the hydraulic structure.**

LABSWE + Turbulence model → LABSWE™

1. INTRODUCTION

Background | **Problem Statement** | Objectives | Scope of Study

- Piers structural failures had become a serious problem in rural areas in Malaysia.
- Unable to picture the flow behaviour against the piers.
- Thus, it is essential to have a flow model that can provide accurate predictions.

1. INTRODUCTION

Background | Problem Statement | **Objectives** | Scope of Study

1) To derive LABSWE – Turbulence Model.
2) To perform numerical simulations using LABSWE™
3) To analyse the computational and wave hydrodynamic parameters by using a circular and square cylinder method.
4) To understand the flow behaviour comparison to piers hydrodynamic with computational analysis of velocity vectors and channel depth centreline flow.

1. INTRODUCTION

Background | Problem Statement | Objectives | **Scope of Study**

- **LABSWE – The turbulence model** is a shallow water flow model that considers the effects of turbulence around the piers.
- **Studied computational analysis environment:** flow around the circular and square cylinder.

2. LITERATURE REVIEW

Shallow-water equations.

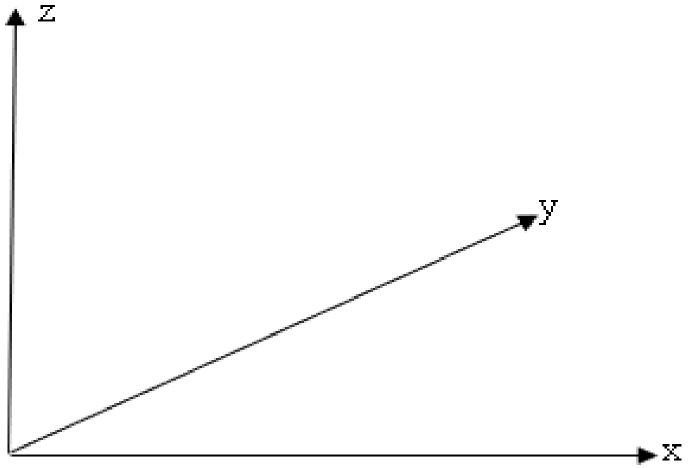
Continuity equation

$$\frac{\partial h}{\partial t} + \frac{\partial [hu_j]}{\partial x_j}$$

Momentum equation (Navier-Stokes equation)

$$\frac{\partial (hu_i)}{\partial t} + \frac{\partial (hu_i u_j)}{\partial x_j} = -g\frac{\partial}{\partial x_i}\left(\frac{h^2}{2}\right) + v\frac{\partial^2 (hu_i)}{\partial x_j \partial xi} + F_i$$

- Respect to the conservation laws
- Fluid computation to analyse natural flow which regards to shallow water.
- Continuity and Navier Stokes govern SWE.
- Widely used for solving SWE for its directness in terms of time iterations.



Cartesian of the coordinate system

Zhou, J. G. (2004). Lattice Boltzmann Method for Shallow Water Flows. Springer.

2. LITERATURE REVIEW

Lattice Boltzmann Shallow Water Equation with Turbulence Modelling (LABSWE^{TM}).

- Turbulent flows problems.
- Advantage: Accuracy and efficiency.
- Space filtered Navier-Stokes + LES + Smagorinsky SGS = LABSWE^{TM}.

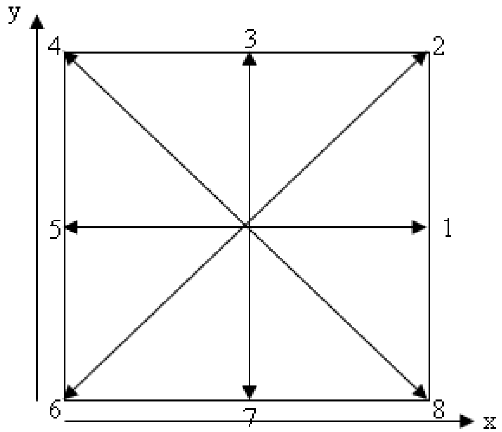


FIGURE 2.2 D2Q9 type of lattice model

$$f_\alpha(x + e_\alpha \Delta t, t\Delta t) - f_\alpha(x,t) = -\frac{1}{\tau}\left(f_\alpha - f_\alpha^{eq}\right) + \frac{\Delta t}{6e^2} e_{\alpha i} F_i$$

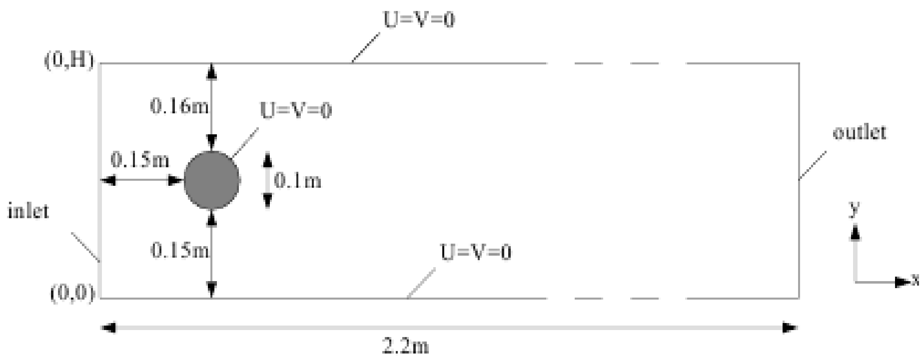
Zhou, J. G. (2004). Lattice Boltzmann Method for Shallow Water Flows. Springer.

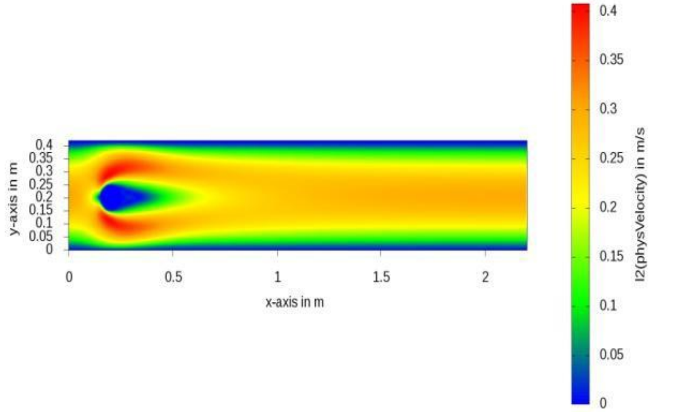
2. LITERATURE REVIEW

Computational Fluid Dynamic Flow Around Circular and Square Cylinder.

TABLE 2.1 Parameters of the computational analysis

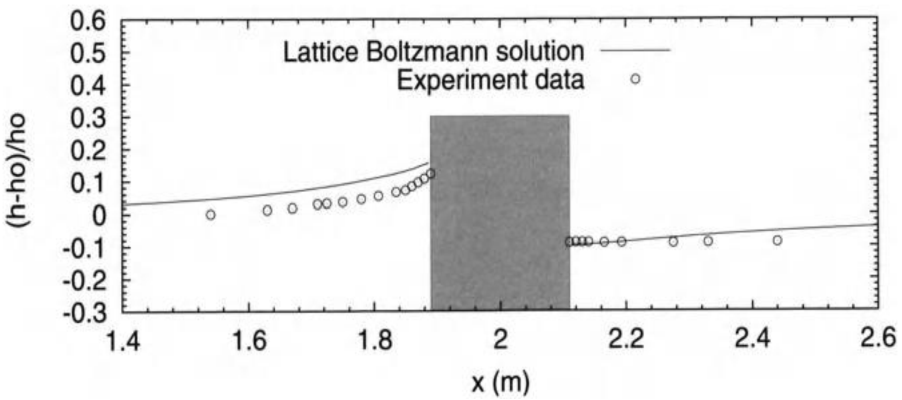
Resolution (N)	20
Characteristically pressure (N/m^2)	0
Physical density (kg/m^3)	1
Characteristically length (m)	0.1
Speed (m/s)	0.2
Lattice relaxation time	0.506
Lattice velocity	0.002
Time steps (s)	5 x 10^{-6}
Physical kinematic viscosity(m^2/s)	0.001

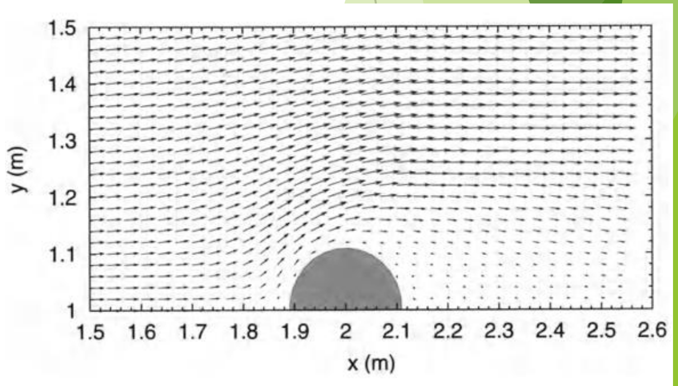




(Arumona,2018)

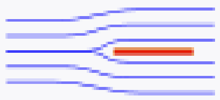
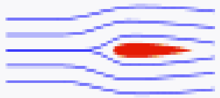
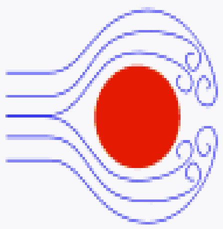
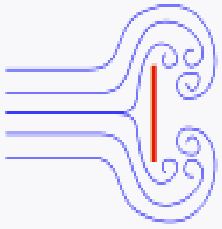
Parameters	Values
The channel dimension	4m (L) x 2m (W)
Q, Discharge	0.248 m^3/s
h0, Outflow depth	0.185m
∂_z / ∂_x, Bed slope	-6.25 x 10^{-4} (In flow direction)
Lattice	600 x 300 (Square lattice) (Model D2Q9)
L_x= L_y	0.00667m
Time, iteration	0.01, 6000 steps
tau	1.982





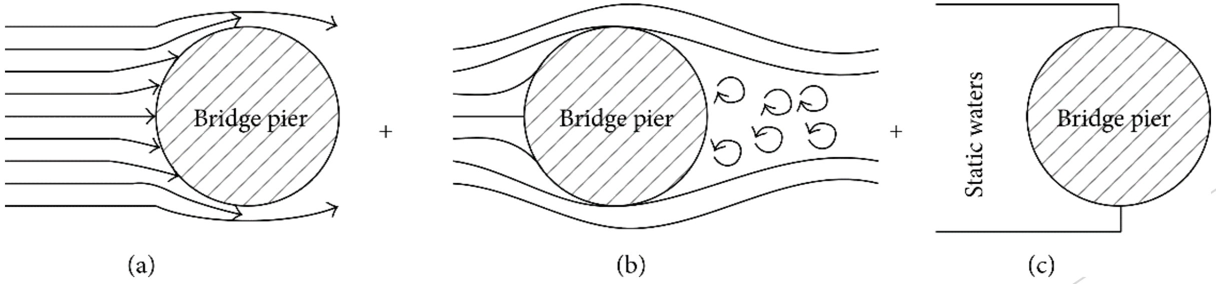
(J. G. Zhou,2004)

2. LITERATURE REVIEW

Shape and flow	Form Drag	Skin friction
	0%	100%
	~10%	~90%
	~90%	~10%
	100%	0%

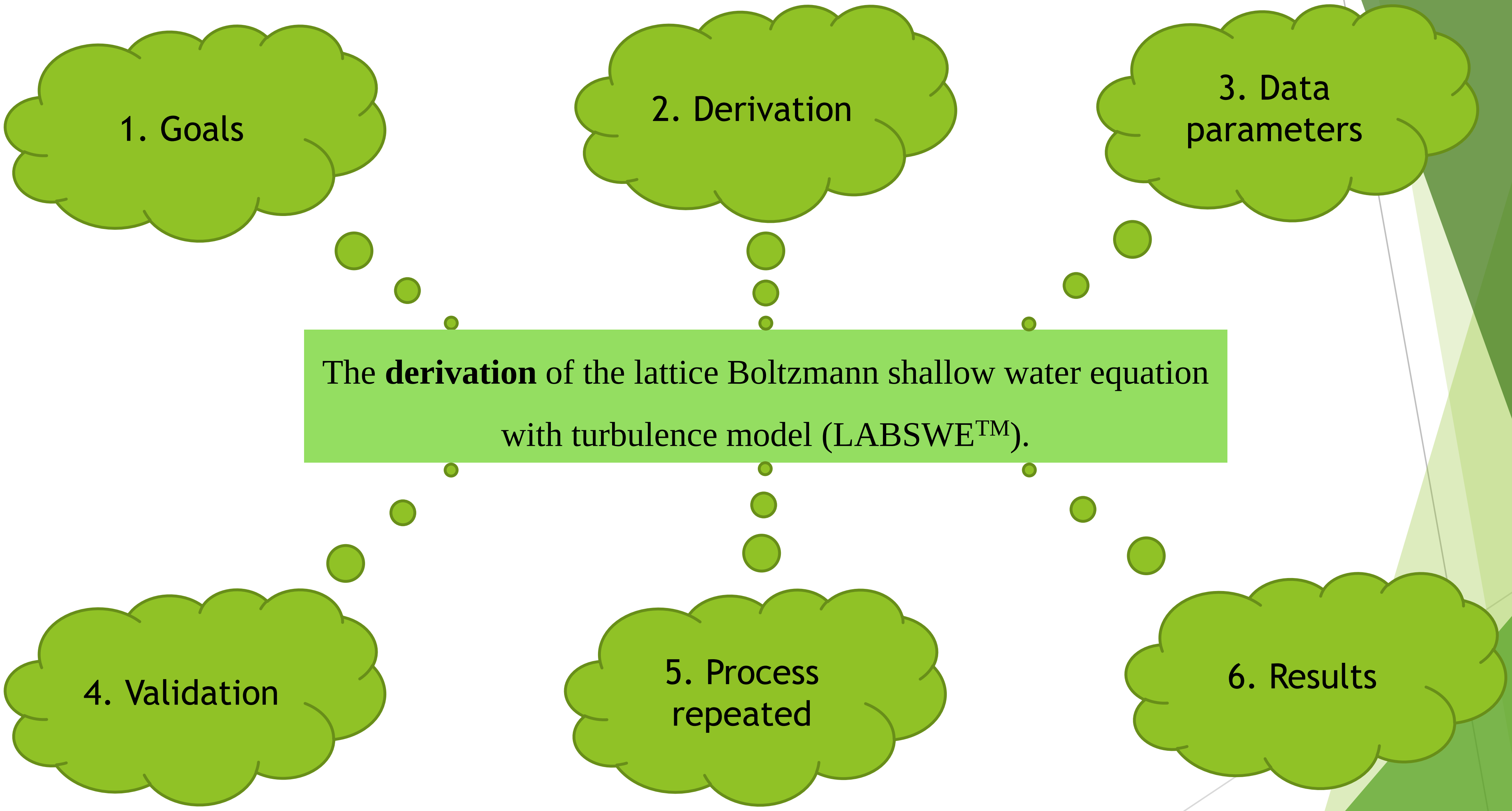
Hydrodynamic load action along the piers.

- Hydrodynamic load can be presented in many forms suited to the researcher’s goals.
- Hydrodynamic load need to be analysed in order to have a better structure
- This is because they give force or drag force to the structure which may cause structural failures if the flow is failed to be analysed.

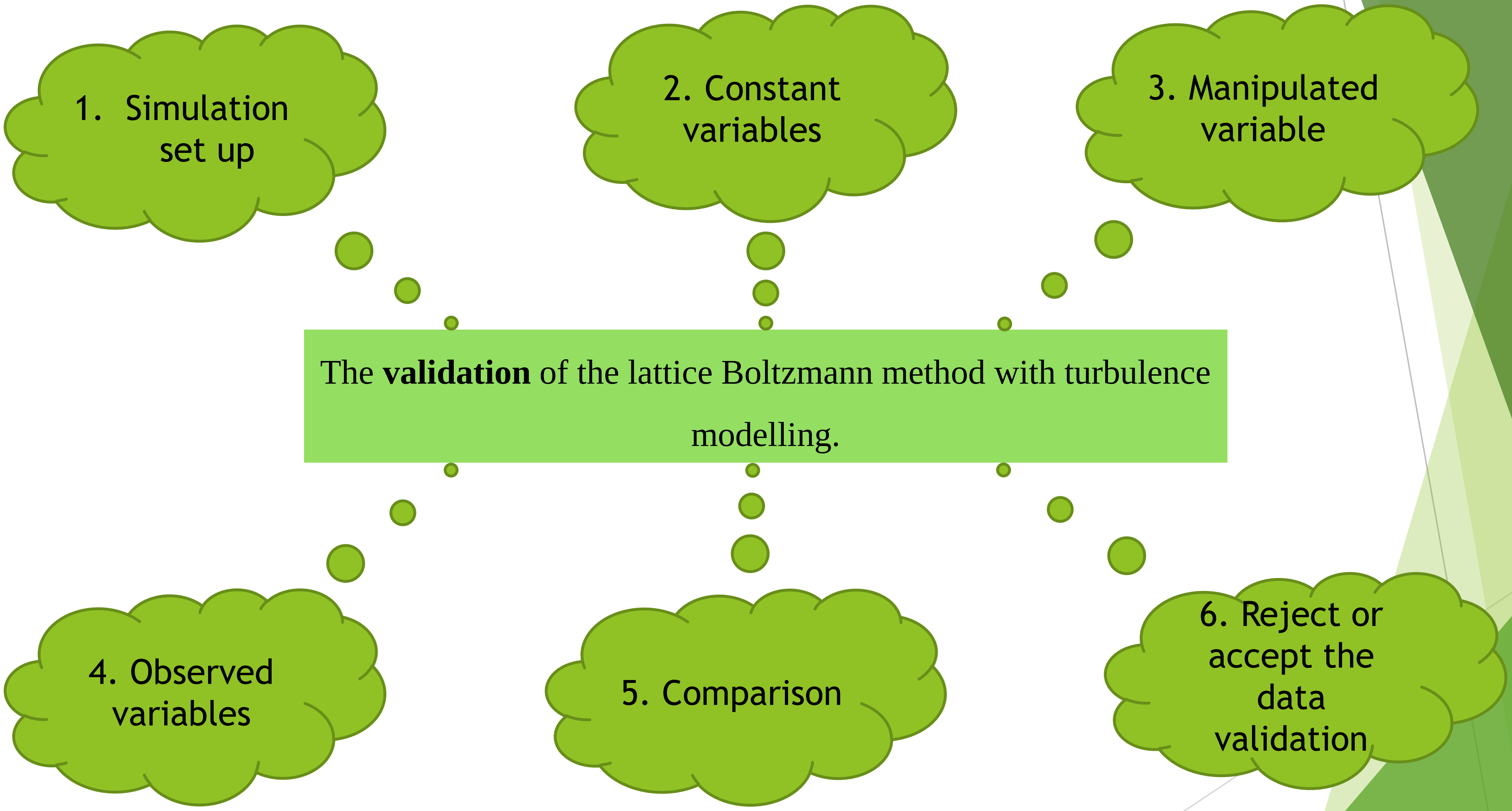


Zhou, J. G. (2004). Lattice Boltzmann Method for Shallow Water Flows. Springer.

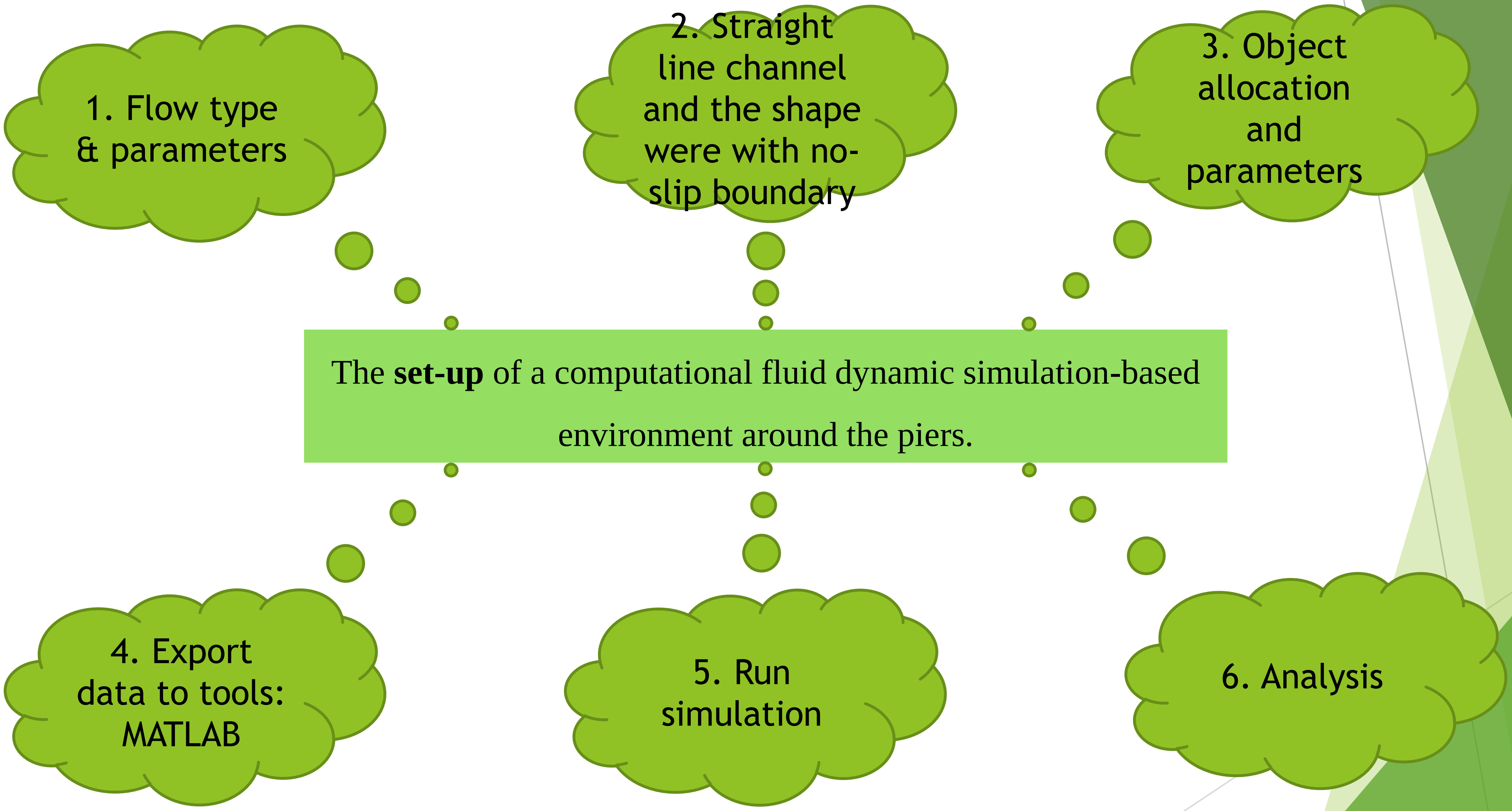
3. RESEARCH METHODOLOGY



3. RESEARCH METHODOLOGY



3. RESEARCH METHODOLOGY



3. RESEARCH METHODOLOGY

1. Goals
2. Derivation
3. Data parameters

The computational **analysis** of the flows along with the cylinder and square piers.

4. run-up simulation
5. Validation & Analysis
6. Results

3. RESEARCH METHODOLOGY

main_program.m | solid_values.m

```matlab
%    !Calculation of parameters!
dx=length/Lx; dy=dx;Ly=width/dy;
e=dx/dt;
%u0=Qin/(h0*(Ly-1)*dy);  % h0 should be changed to net h
nu_m=(2*tau-1)/6; % molecular viscosity
nu=e^2*dt*(2*tau-1)/6; % kinematic viscosity
mu=nu*1000;  % dynamic viscosity of water
nermax=(Lx-1)*(Ly-1);
Ly=Ly+2;
Xs=1;Xe=Lx;Ys=1;Ye=Ly;
%    !determine solid values!
solid=solid_values(Lx,Ly);
%    bed data and slope calculation
[zb]=bed_data(Lx,Ly,dx,dy);
[Sx,Sy]=bed_slope(zb,Lx,Ly,dx,dy);
%    !initialize the depth and velocity field!
for y=1:Ly
    for x=1:Lx
        if solid(x,y)==0
          h(x,y) = 0.173;
          u(x,y)=0.43; v(x,y) = 0;
        else
          h(x,y) = 0; u(x,y) = 0; v(x,y) = 0;
        end
    end
end
ui=u;vi=v;hi=h;
[fb]=fb_distribution(Lx,Ly,dx,dy,h,gacl);
area0=0;
for y = 1:Ly-1
   area0 =area0+0.5*(h(1,y)+h(1,y+1))*dy;
end
[ex,ey]=setup(e); % calculate ex and ey
feq = compute_feq(Lx,Ly,h,u,v,e,ex,ey,gacl,solid);  % initial feq
f=feq; % set initial feq to f
fcon=feq;
iteration=0;

%     main loop
time=0;
for time=0:dt:6000*dt;
```

Command Window

main_program.m | solid_values.m

```matlab
%    !determine cylinder solid values!

function solid=solid_values(Lx,Ly)

for i=1:Lx
    for j=1:Ly
        if (i-25)^2+(j-35)^2<10.5^2
            solid(i,j)=1;
        else
            solid(i,j)=0;
        end
    end
end


% solid(1:81,1:23)=1; solid(100:Lx,1:23)=1;
solid(1:Lx,Ly)=1;solid(1:Lx,1)=1;
return
square

%    !determine solid values!

function solid=solid_values(Lx,Ly)

for i=1:Lx
    for j=1:Ly
        if max(abs(i-120),abs(j-35))<4.5
            solid(i,j)=1;
        else
            solid(i,j)=0;
        end
    end
end


% solid(1:81,1:23)=1; solid(100:Lx,1:23)=1;
solid(1:Lx,Ly)=1;solid(1:Lx,1)=1;



return
```

Command Window

3. KEY PROJECT MILESTONE

Key Project Milestone				
Week 1-2	**Week 3-7**	**Week 8-16**	**Week 17-24**	**Week 25-28**
• Identifying and resolving project-related issues. • Define the study's problem statements and objectives. • Read relevant academic papers and books for more information.	• Researching hydrological concerns. • Reading related research articles and reference books. • Conducting a literature review and critical analysis.	• To comprehend LABSWE™, deduce LBM, LABSWE, Navier Stokes, Large Eddies, and Turbulence flow. • Simulations should be run with the changed model. • Understanding the requirements for exporting parameters in MATLAB.	• Choosing parameters to include in the simulation based on data. • Use linear extrapolation to process and analyse the data.	• Write the FYP thesis to summarise the entire investigation. • Discuss the findings and make recommendations for future research in this sector.

3. FYP I GANTT CHART

FYP I												
TASK/WEEK	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Topic discussion with SV	■											
Highlighting problems	■	■	■	■	■	■	■	■	■	■	■	■
Highlighting objectives		■	■	■	■	■						
Gather references		■	■	■	■	■						
Study literature review							■					
Submit extended proposal						■	■	■	■			
Conceptualise research in reports								■	■			
Familiarise with LABSWE™				■	■	■	■	■	■	■	■	■
Simulate conceptual design in MATLAB						■	■	■	■	■	■	■
Interim report draft submission											■	
Finalise proposal defence report												■

3. FYP II GANTT CHART

FYP II												
TASK/WEEK	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Discuss with SV												
Design lattice Boltzmann with turbulence modelling												
Refer literature review												
Gather Intel on do simulation												
Analyse the factor of flow												
Analyse the piers chosen												
Submit draft report												
Finalise report												
Simulate conceptual design in MATLAB												
Submission of report												
Viva												

4. RESULTS & DISCUSSION

Derivation | Simulation | Validation | Analysis

The Discussion of the Derivation of the LABSWE – The turbulence modelling.

- LBM

  - to enable in understanding the dynamic behaviour of fluids flow directly meaning it can run independently.

- Navier – Stokes equation

  - an equation which able to be derived in simulating expected flow

- Large Eddy Scale

  - to enable twirl or turbulence flow in the simulation scale

- Standard Sub Grid-Scale (flow turbulence)

  - total relaxation time and local equilibrium distribution function (collision)

  - particle velocity & force term (streaming)

- Chapman- Enskog expansion

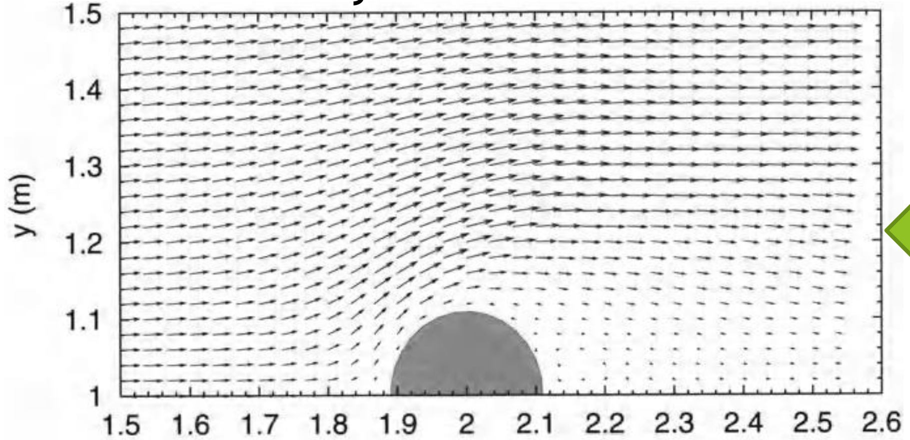
  – to recover macroscopic equation for SWE

4. RESULTS & DISCUSSION

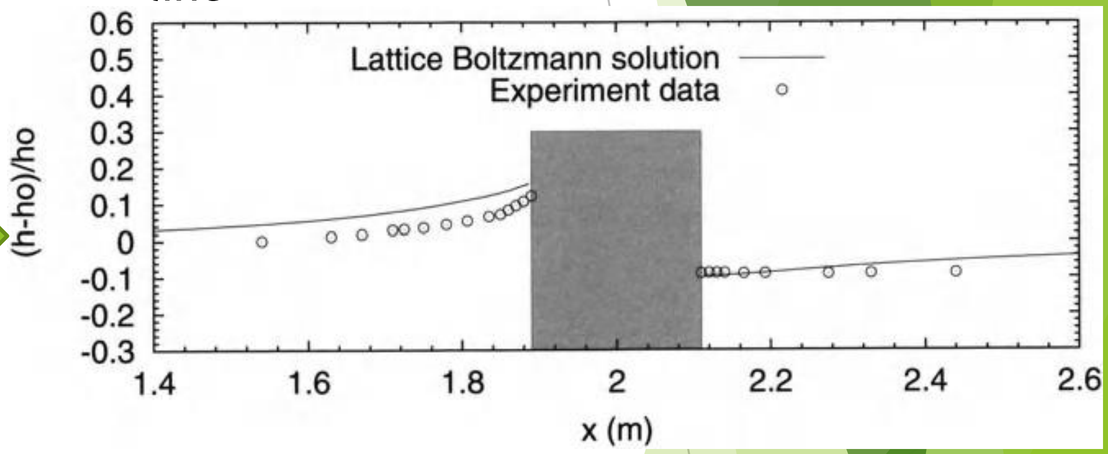
Derivation | **Simulation** | Validation | Analysis

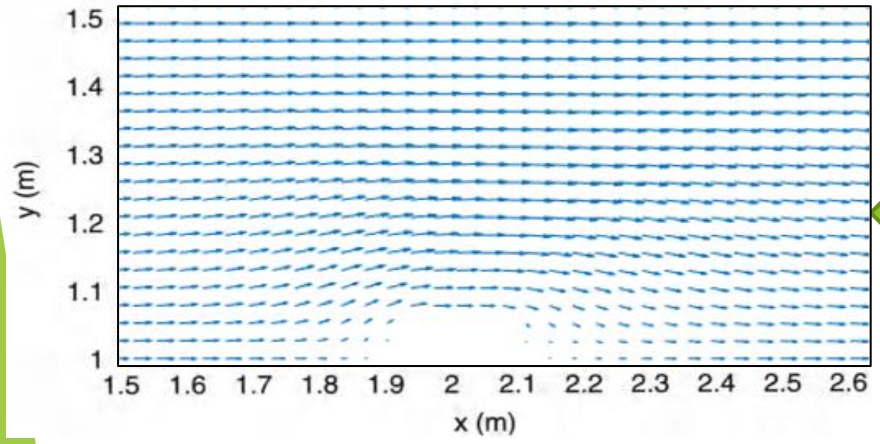
i. Plotted in quivers: observed on its velocity vectors

ii. Depth of flow along the channel centre line

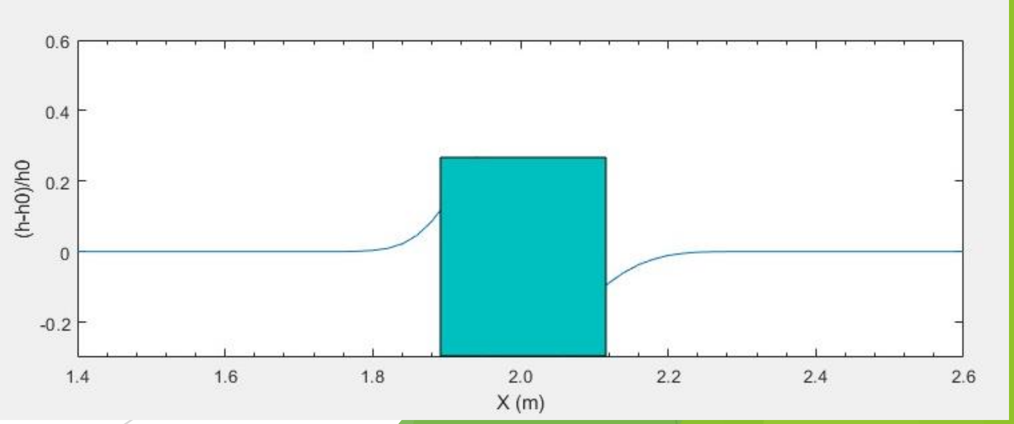


(J. G. Zhou, 2005)





Validation



4. RESULTS & DISCUSSION

Derivation → Simulation → **Validation** → Analysis

Hence, the simulation of the computational analysis of fluid dynamics along the piers by using LABSWE^{TM} with MATLAB as the medium is validated.

Data validation on flow along the piers with past data.

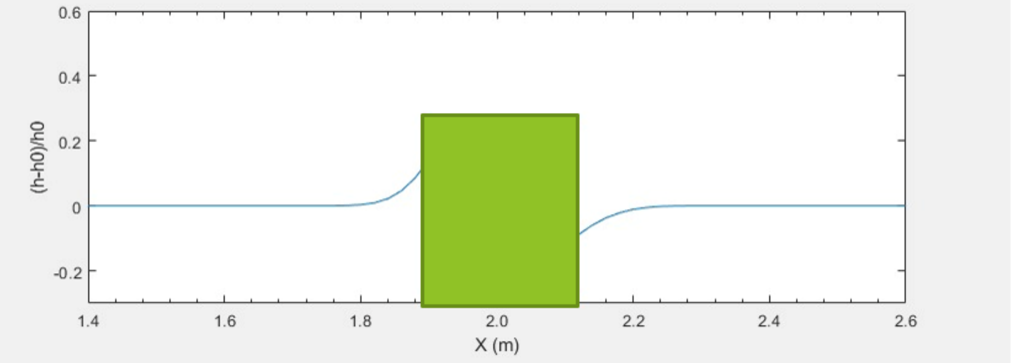
Observed	Data achieved	difference
Velocity vectors finals (x-axis)	(Past) = 2.130m (Present) = 2.135m	=0.005m =0.23%
Depth at initial and final depth level	(Past) i=0.19 (h-h0)/h0 f= - 0.12(h-h0)/h0 (Present) i=0.185(h-h0)/h0 f= - 0.14(h-h0)/h0	i=0.005(h-h0)/h0 i%= 0.02% f= -0.02(h-h0)/h0 F%= 0.16%

Tolerance in error must be below 9% (J. G. Zhou, 2004)

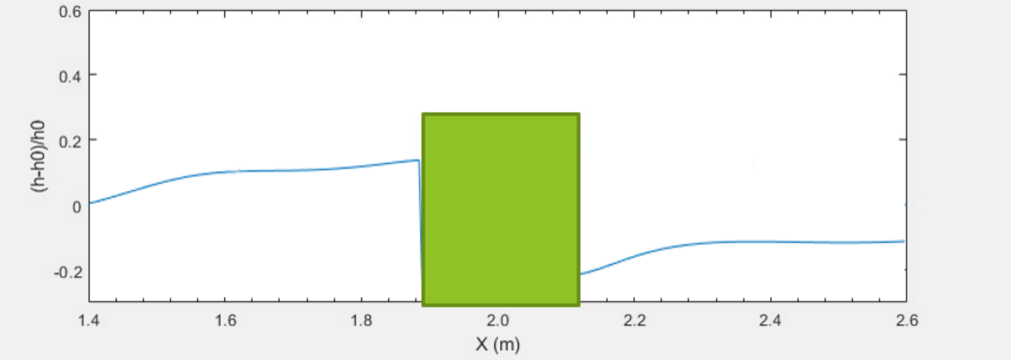
4. RESULTS & DISCUSSION

Derivation → Simulation → Validation → **Analysis**

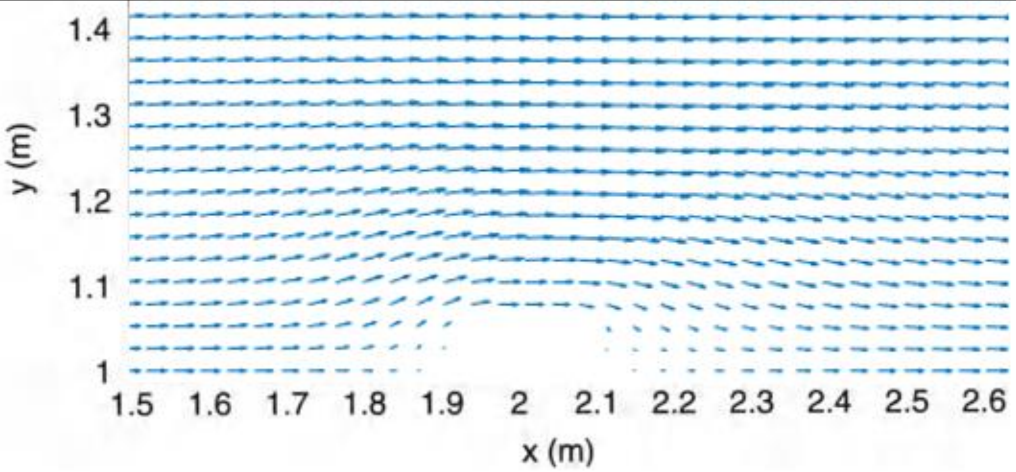
Circular cylinder validation in comparing to the simulation that was done by J. G. Zhou (2005)



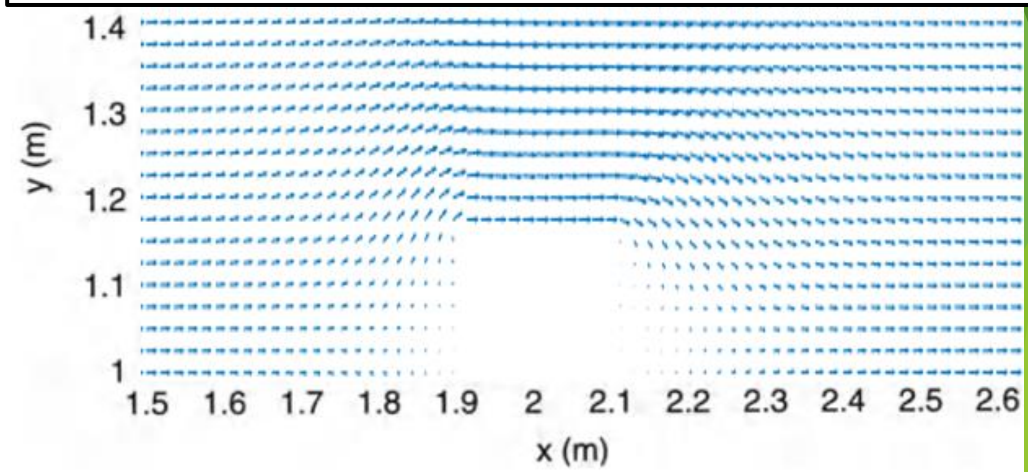
Square cylinder validation in comparing to the simulation that was done by J. G. Zhou (2005)



Cylinder validation simulation result of plotting quivers for the cylinder flow compared to J. G. Zhou (2005)



Square validation simulation result of plotting quivers for the cylinder flow compared to J. G. Zhou (2005)



4. RESULTS & DISCUSSION

Constant parameters throughout the analysis	
Parameters	Values
The channel dimension	4m (L) x 2m (W)
Q, Discharge	0.248 m^3/s
h0, Outflow depth	0.185m
∂_z / ∂_x, Bed slope	-6.25 x 10^{-4} (In flow direction)
Lattice	600 x 300 (Square lattice) (Model D2Q9)
$L_x = L_y$	0.00667m
Time, iteration	0.01, 6000 steps
tau	1.982

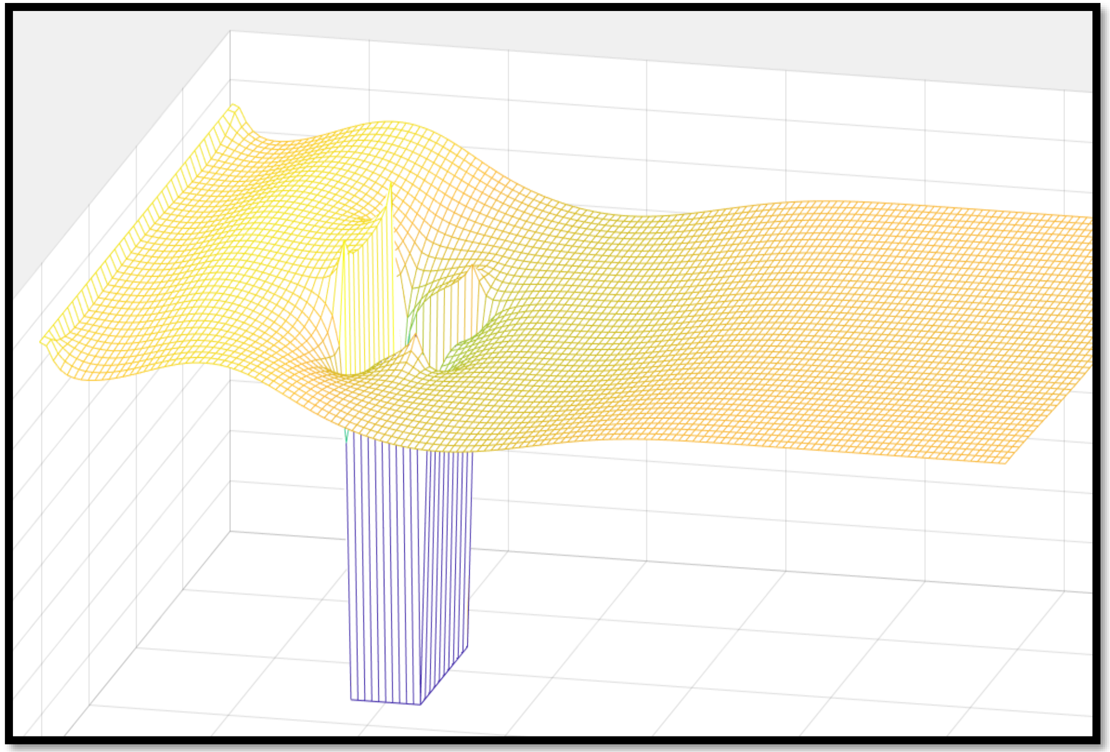
Manipulated variables throughout the analysis	
Parameters	Value
Circular piers	
Height	0.37m
Radius	0.11m
Boundary condition	No-slip
Square piers	
Height	0.37
Dimension	0.22m (W) x 0.22 (L)
Boundary condition	No-slip

4. RESULTS & DISCUSSION

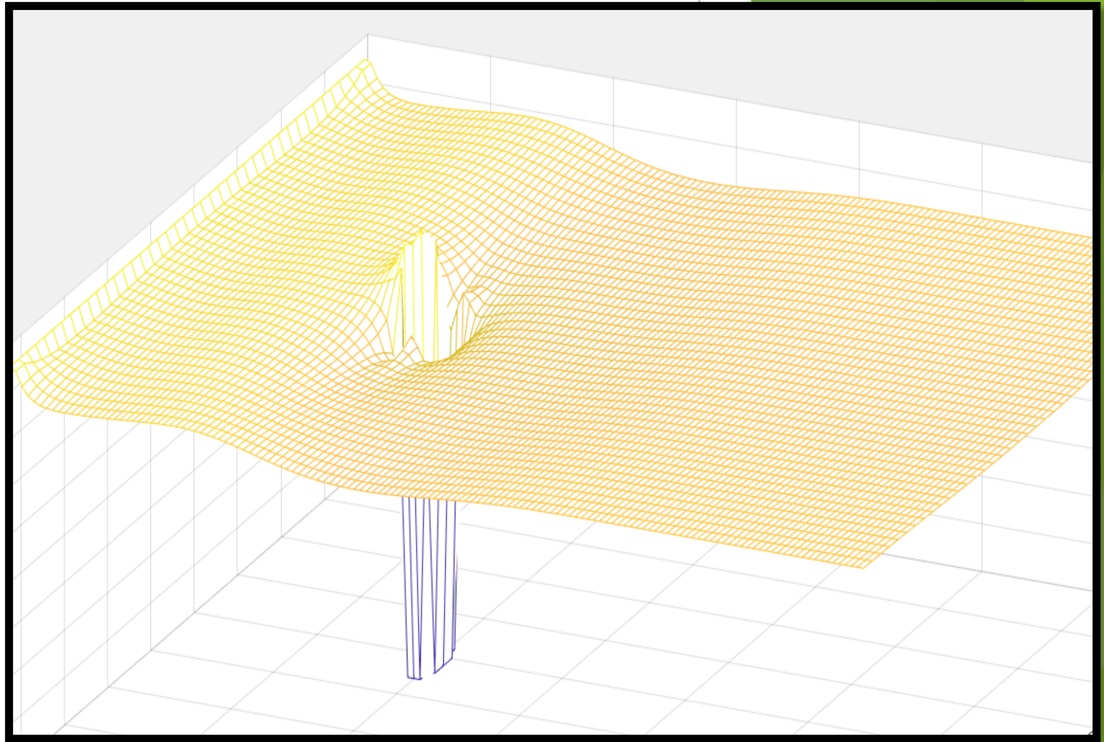
Comparison of discharge observed along the flow	
Circular piers	Square piers
The discharge seems to peak a litter when the flow passes by the piers.	The discharge seems to be higher than circular did.
Can be concluded such phenomena happens, because the simulation shows that the hydrodynamic load against the square piers is higher than circular piers.	

Comparison of Level of depth along the centreline	
Circular piers	Square piers
After the wave passes the piers the depth of centreline started at -0.1 ((h-h0)/h0)	After the wave passes the piers, the depth of centreline started at -0.155 ((h-h0)/h0)
As per hypothesis, the more not being hydrodynamic in terms of shape the deeper lower the level of depth as the flow went through. Therefore, the level will only be limited to 0.0 ((h-h0)/h0) as centreline in comparing the piers shape as the disturbance to the flow.	

3D VIEW



Square cylinder flow analysis in 3D view



Circular cylinder flow analysis in 3D view

5. Conclusion and Recommendations

- **LABSWE – Turbulence model** is able to simulate flow around the piers
- Computational analysis is able to be done and validated with previous analysis which was done by J. G. Zhou (2005).
- ***Recommendations:***
  - To grasp flow studies on it behaviour on other hydraulic structure
  - To model other turbulent debris flows
  - To produce 1D, 2D or 3D model

Presented By:

Muhammad Naqib Izzuddin(17006688)

Civil Engineering Department,

Universiti Teknologi PETRONAS.