

# Control of Weir Flow by Changing Geometry

## Team

Laxman Desai	Sarthak Bhardwaj	Sagar Yadav	Krutarth Dhaduk
190020066	190040106	19D180026	19D170012

## Problem statement

We will try and understand how height of fluid over weir affects the flow rate of water across the weir in laminar and turbulent conditions.

## Assumptions

1. Fluid is water at 25 degrees.
2. Surface tension modeling is done by the continuum method ( $\sigma = 0.072 \text{ N/m}$ )
3. For the calculation of Reynold's number, flow is approximated to that over a flat plate. Transition from laminar to turbulent assumed at  $Re = 5 \times 10^5$

## Properties

### Dimensions

- Fixed:
  1. Dimensions of mesh:  $25 \times 6$
  2. Width of weir:  $L = 1 \text{ m}$
  3. Distance of weir from inlet:  $l = 15 \text{ m}$
- Variables:
  1.  $H_w$  = Height of weir
  2.  $H_s$  = Height of the stream
  3.  $H = H_s - H_w$  = Height of the stream above the weir's crest

### Flow

- Laminar:
  1.  $v = 5 \cdot 10^{-3} \text{ m/s}$
  2.  $Re = \frac{\rho \cdot v \cdot l}{\nu} = \frac{996 \times 5 \times 10^{-3} \times 15}{0.85 \times 10^{-3}} = 8.79 \times 10^4$
- Turbulent:
  1.  $v = 5 \text{ m/s}$
  2.  $Re = \frac{\rho \cdot v \cdot l}{\nu} = \frac{996 \times 5 \times 15}{0.85 \times 10^{-3}} = 8.79 \times 10^7$

### Mesh

- Divisions per unit length in the mesh = 2.

### Solver

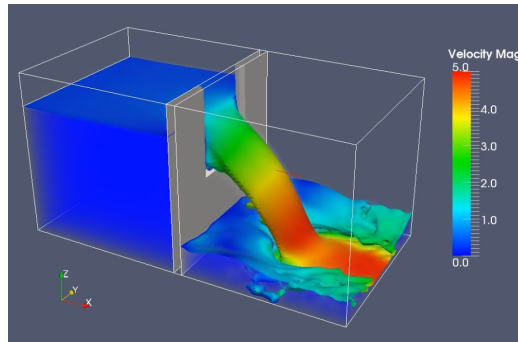
- K-epsilon turbulence model (2 equations) used.
- Volume ratio used is modified high resolution schemes for interface capturing (HRIC).
- Time step size = 0.05 s
- Number of steps = 200

- Reporting interval = 10

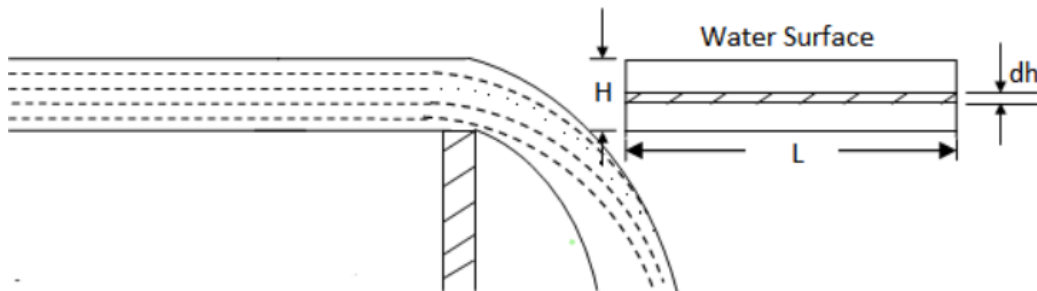
## Boundary conditions

1. No slip condition on the stream bed & the surface of weir.
2. Plug flow in the inlet stream.

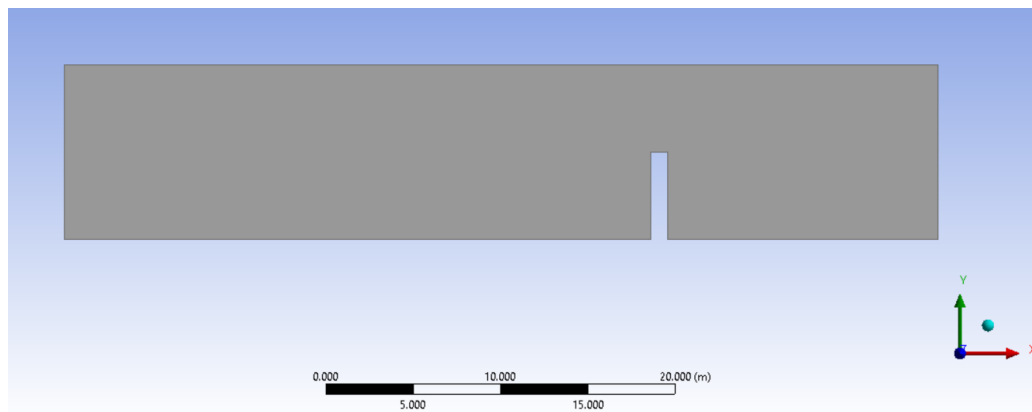
## Visualization



**Figure 1.1:** 3D geometry of flow over weir



**Figure 1.2:** Cross section view



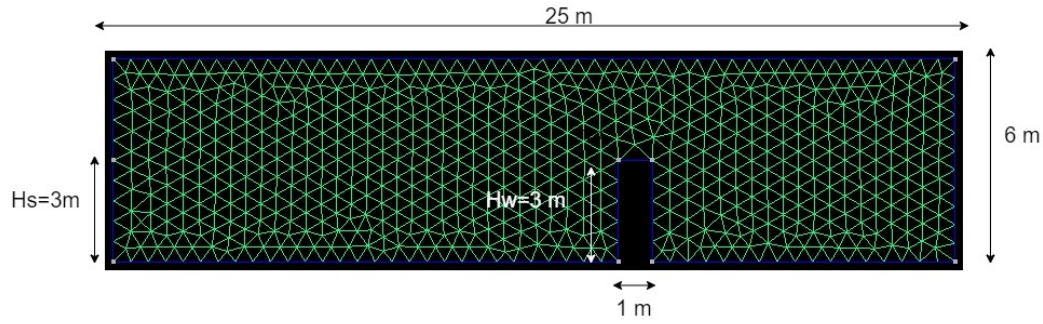
**Figure 1.3:** Mesh cross section view

## Geometry

Case 1:  $H = 0 \text{ m}$

### Properties

$$H_s = 3 \text{ m}, H_w = 3 \text{ m}$$



**Figure 2.1:** 2D mesh for case 1 ( $H=0$ )

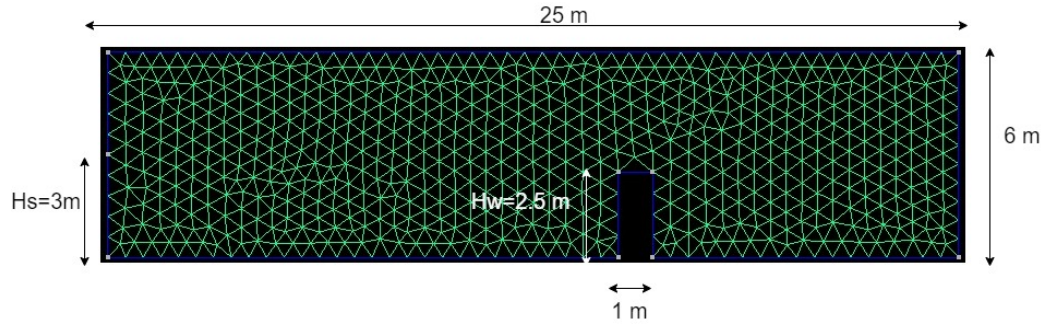
### Mesh - Gmsh .geo file

```
// Gmsh project created on Mon May 10 10:15:28 2021
SetFactory("OpenCASCADE");
Point(1) = {0, 0, 0, 1.0};
Point(2) = {15, 0, 0, 1.0};
Point(3) = {15, 3, 0, 1.0};
Point(4) = {16, 3, 0, 1.0};
Point(5) = {16, 0, 0, 1.0};
Point(6) = {25, 0, 0, 1.0};
Point(7) = {25, 6, 0, 1.0};
Point(8) = {0, 6, 0, 1.0};
Point(9) = {0, 3, 0, 1.0};
Line(1) = {1, 2};
Line(2) = {2, 3};
Line(3) = {3, 4};
Line(4) = {4, 5};
Line(5) = {5, 6};
Line(6) = {6, 7};
Line(7) = {7, 8};
Line(8) = {8, 9};
Line(9) = {9, 1};
Curve Loop(1) = {8, 9, 1, 2, 3, 4, 5, 6, 7};
Plane Surface(1) = {1};
Physical Curve("inlet", 10) = {9};
Physical Curve("outlet", 11) = {6, 5};
Physical Curve("ambient", 12) = {7};
Physical Curve("fw", 13) = {8, 1, 2, 3, 4};
Physical Surface("Area1", 14) = {1};
Transfinite Curve {7} = 50 Using Progression 1;
Transfinite Curve {6} = 12 Using Progression 1;
Transfinite Curve {8} = 6 Using Progression 1;
Transfinite Curve {9} = 6 Using Progression 1;
Transfinite Curve {1} = 30 Using Progression 1;
Transfinite Curve {5} = 18 Using Progression 1;
Transfinite Curve {2} = 6 Using Progression 1;
Transfinite Curve {4} = 6 Using Progression 1;
Transfinite Curve {3} = 2 Using Progression 1;
```

### Case 2: $H = 0.5 \text{ m}$

#### Properties

$$H_s = 3 \text{ m}, H_w = 2.5 \text{ m}$$



**Figure 2.2:** 2D mesh for case 2 ( $H=0.5$ )

### Mesh - Gmsh .geo file

```

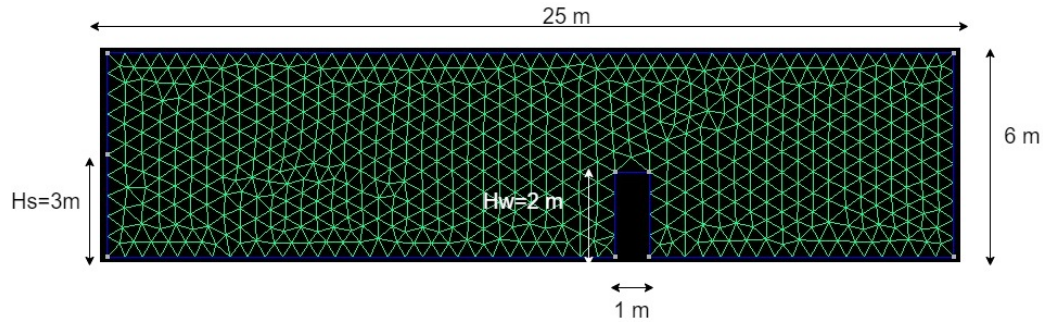
SetFactory("OpenCASCADE");
Point(1) = {0, 0, 0, 1.0};
Point(2) = {15, 0, 0, 1.0};
Point(3) = {15, 2.5, 0, 1.0};
Point(4) = {16, 2.5, 0, 1.0};
Point(5) = {16, 0, 0, 1.0};
Point(6) = {25, 0, 0, 1.0};
Point(7) = {25, 6, 0, 1.0};
Point(8) = {0, 6, 0, 1.0};
Point(9) = {0, 3, 0, 1.0};
Line(1) = {1, 2};
Line(2) = {2, 3};
Line(3) = {3, 4};
Line(4) = {4, 5};
Line(5) = {5, 6};
Line(6) = {6, 7};
Line(7) = {7, 8};
Line(8) = {8, 9};
Line(9) = {9, 1};
Curve Loop(1) = {9, 1, 2, 3, 4, 5, 6, 7, 8};
Plane Surface(1) = {1};
Physical Curve("inlet", 10) = {9};
Physical Curve("outlet", 11) = {6, 5};
Physical Curve("ambient", 12) = {7};
Physical Curve("fw", 13) = {8, 1, 2, 3, 4};
Physical Surface("Area2", 14) = {1};
SetFactory("OpenCASCADE");
Transfinite Curve {7} = 50 Using Progression 1;
Transfinite Curve {6} = 12 Using Progression 1;
Transfinite Curve {8} = 6 Using Progression 1;
Transfinite Curve {9} = 6 Using Progression 1;
Transfinite Curve {1} = 30 Using Progression 1;
Transfinite Curve {5} = 18 Using Progression 1;
Transfinite Curve {2} = 5 Using Progression 1;
Transfinite Curve {4} = 5 Using Progression 1;
Transfinite Curve {3} = 2 Using Progression 1;

```

### Case 3: $H = 1\text{ m}$

#### Properties

$$H_w = 2\text{ m}, H_s = 3\text{ m}$$

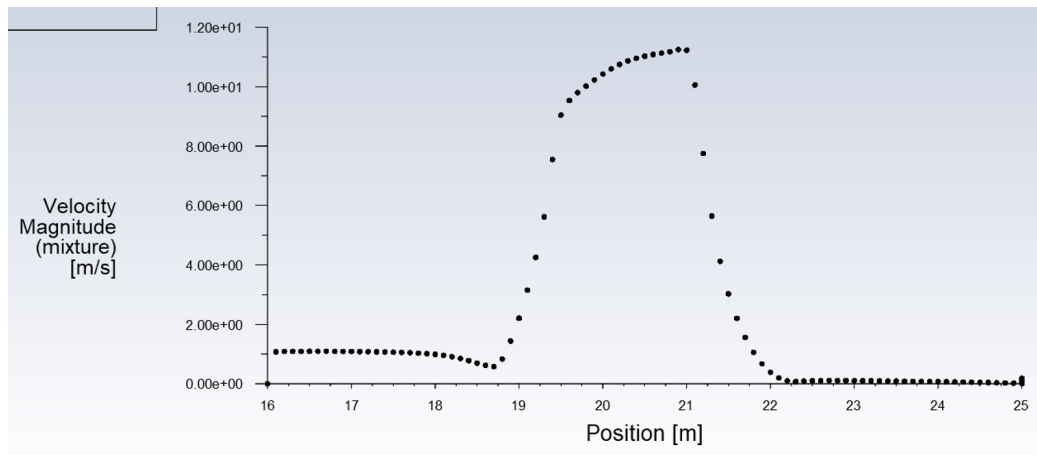


**Figure 2.3:** 2D mesh for case 3 ( $H=1$ )

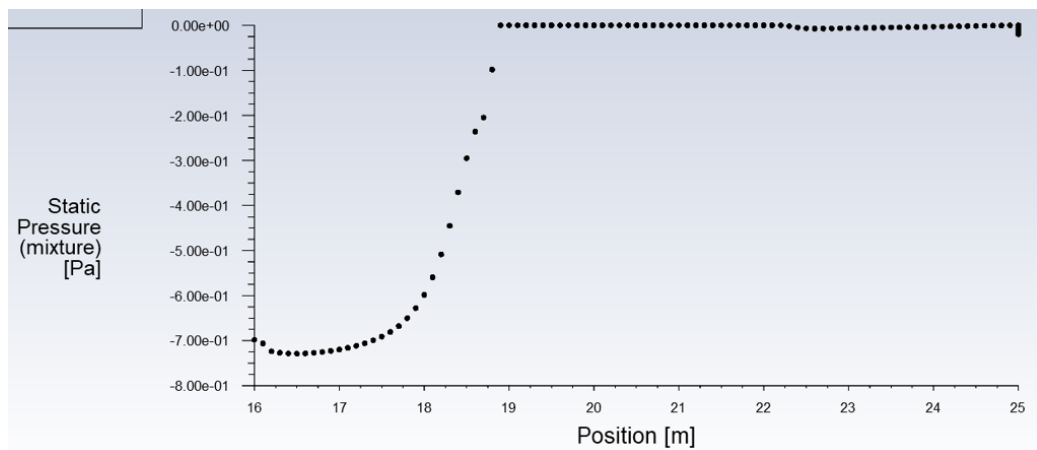
### Mesh - Gmsh .geo file

```
SetFactory("OpenCASCADE");
Point(1) = {0, 0, 0, 1.0};
Point(2) = {15, 0, 0, 1.0};
Point(3) = {15, 2, 0, 1.0};
Point(4) = {16, 2, 0, 1.0};
Point(5) = {16, 0, 0, 1.0};
Point(6) = {25, 0, 0, 1.0};
Point(7) = {25, 6, 0, 1.0};
Point(8) = {0, 6, 0, 1.0};
Point(9) = {0, 3, 0, 1.0};
Line(1) = {1, 2};
Line(2) = {2, 3};
Line(3) = {3, 4};
Line(4) = {4, 5};
Line(5) = {5, 6};
Line(6) = {6, 7};
Line(7) = {7, 8};
Line(8) = {8, 9};
Line(9) = {9, 1};
Curve Loop(1) = {8, 9, 1, 2, 3, 4, 5, 6, 7};
Plane Surface(1) = {1};
Physical Curve("inlet", 10) = {9};
Physical Curve("outlet", 11) = {6, 5};
Physical Curve("ambient", 12) = {7};
Physical Curve("fw", 13) = {8, 1, 2, 3, 4};
Physical Surface("Area3", 14) = {1};
Transfinite Curve {7} = 50 Using Progression 1;
Transfinite Curve {6} = 12 Using Progression 1;
Transfinite Curve {8} = 6 Using Progression 1;
Transfinite Curve {9} = 6 Using Progression 1;
Transfinite Curve {1} = 30 Using Progression 1;
Transfinite Curve {5} = 18 Using Progression 1;
Transfinite Curve {2} = 4 Using Progression 1;
Transfinite Curve {4} = 4 Using Progression 1;
Transfinite Curve {3} = 2 Using Progression 1;
```

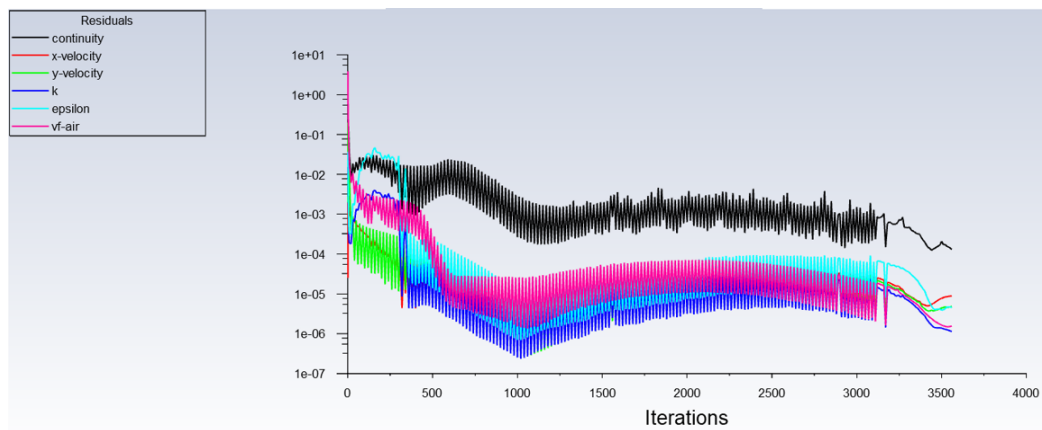
### Results (general)



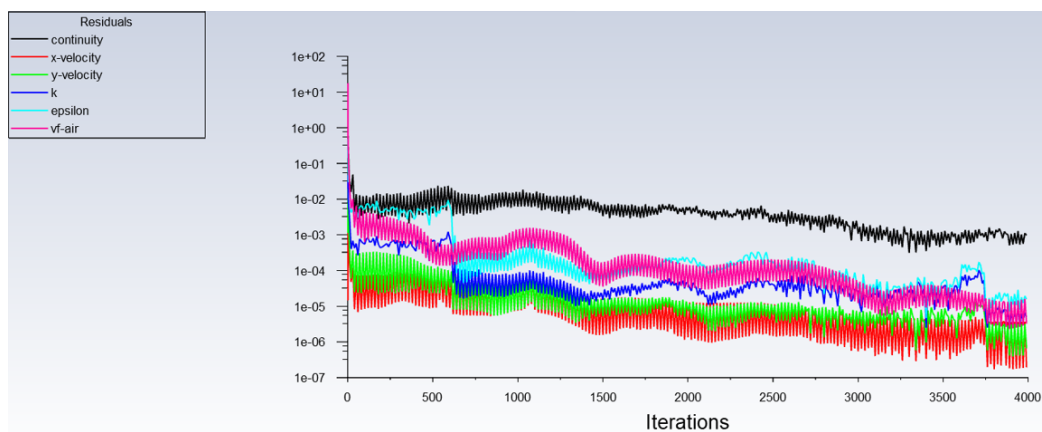
**Figure 3.1:** Position vs outlet velocity



**Figure 3.2:** Position vs outlet static pressure



**Figure 3.3:** Residuals vs iterations for laminar flow



**Figure 3.4:** Residuals vs iterations for turbulent flow

## Results (case specific)

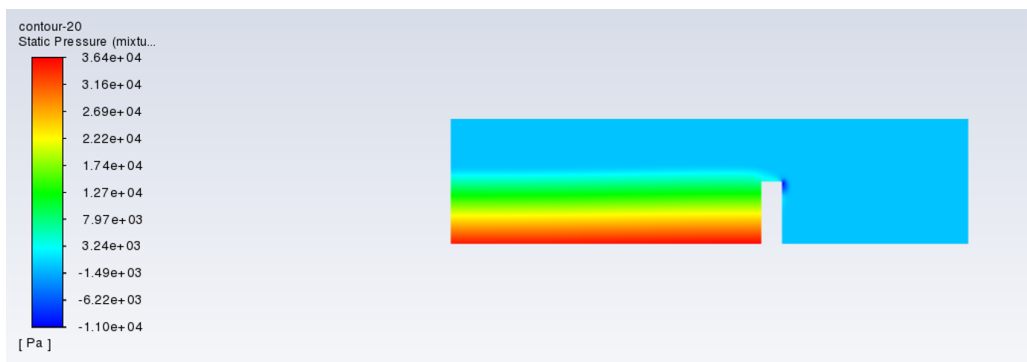
- Case specific versions of the general plots are not shown explicitly, but they follow similar trends.

### Case 1: $H = 0\text{ m}$

Laminar flow ( $Re = 0.005\text{ m/s}$ )



**Figure 4.1 A:** Velocity profile diagram under laminar conditions with height of stream over weir = 0m

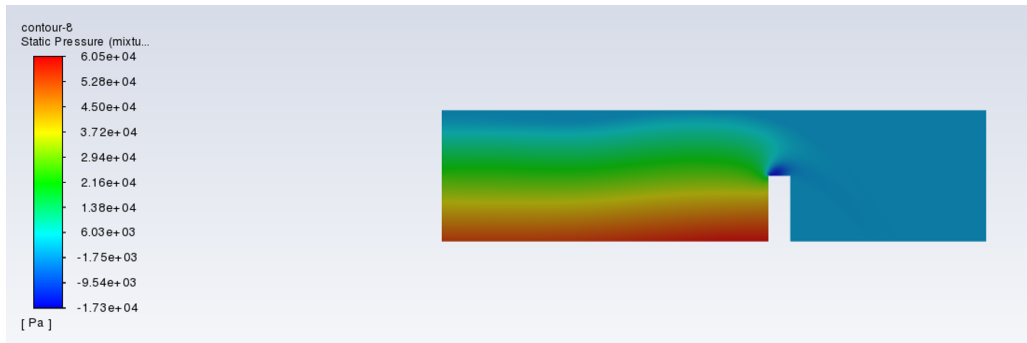


**Figure 4.1 B:** Pressure field diagram under laminar conditions with height of stream over weir = 0m

Turbulent flow ( $v = 5\text{ m/s}$ )



**Figure 4.2 A:** Velocity profile diagram under turbulent conditions with height of stream over weir = 0m



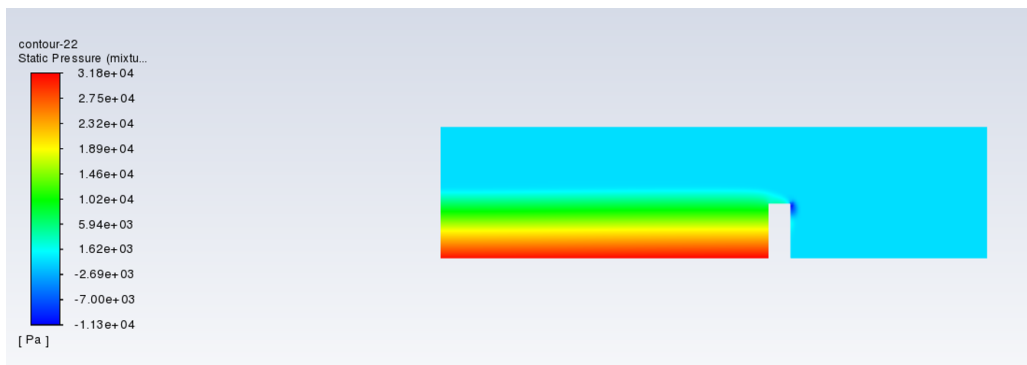
**Figure 4.2 B:** Pressure field diagram under turbulent conditions with height of stream over weir = 0m

Case 2:  $H = 0.5 \text{ m}$

Laminar flow ( $v = 0.005 \text{ m/s}$ )

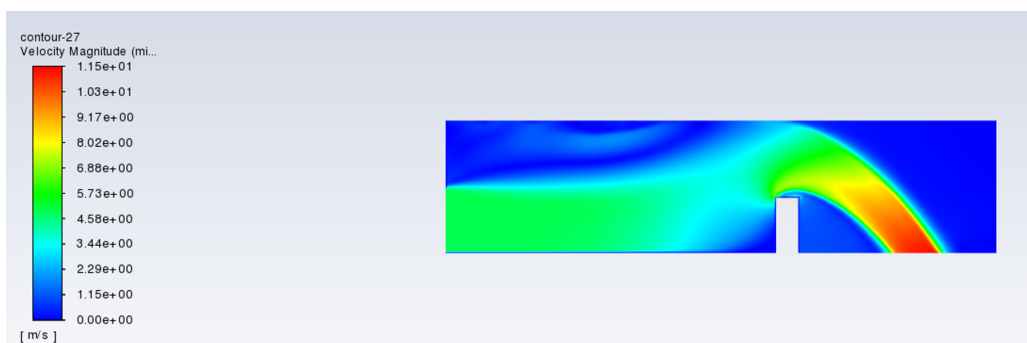


**Figure 5.1 A:** Velocity profile diagram under laminar conditions with height of stream over weir = 0.5m



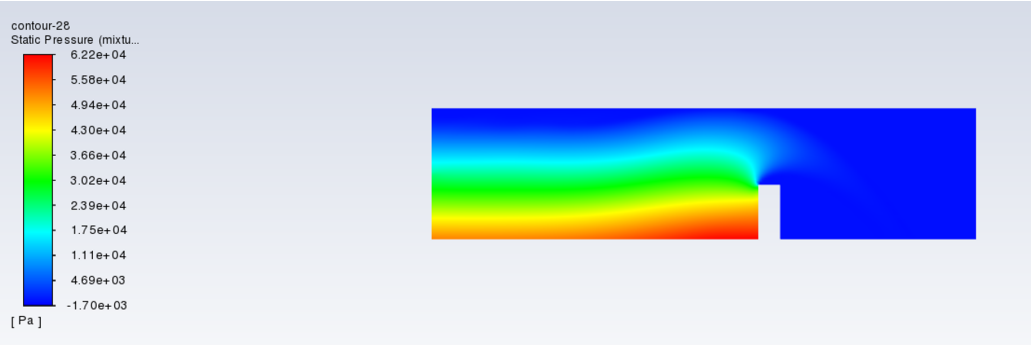
**Figure 5.1 B:** Pressure field diagram under laminar conditions with height of stream over weir = 0.5m

Turbulent flow ( $v = 5 \text{ m/s}$ )





**Figure 5.2 A:** Velocity profile diagram under turbulent conditions with height of stream over weir = 0.5m



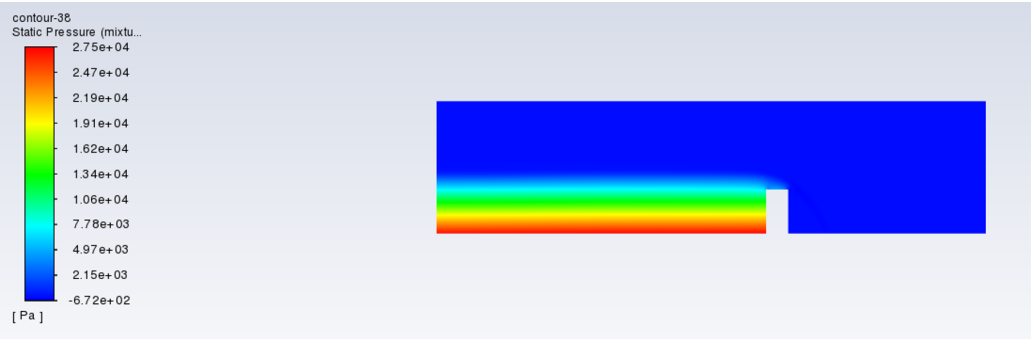
**Figure 5.2 B:** Pressure field diagram under turbulent conditions with height of stream over weir = 0.5m

**Case 3:**  $H = 1\text{ m}$

Laminar flow ( $v = 0.005\text{ m/s}$ )

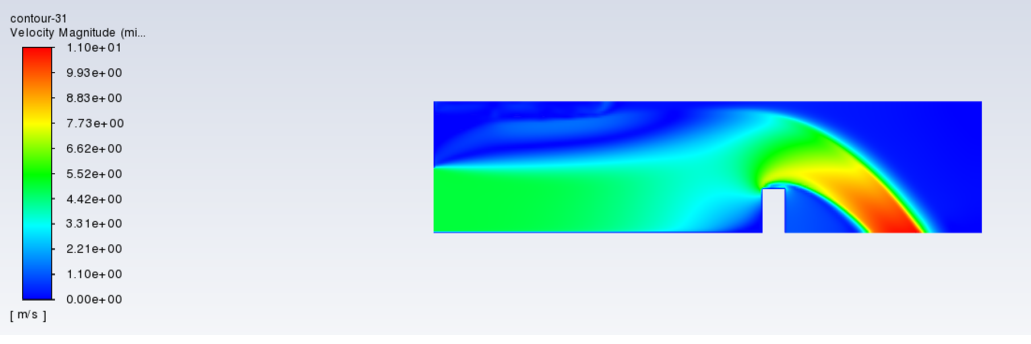


**Figure 6.1 A:** Velocity profile diagram under laminar conditions with height of stream over weir = 1m

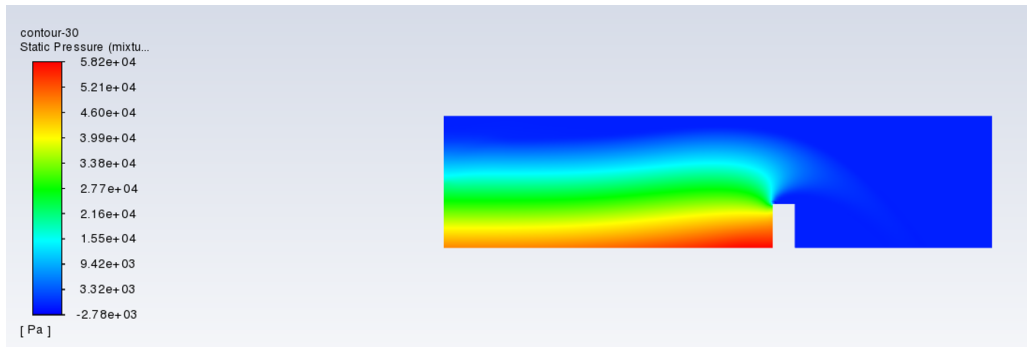


**Figure 6.1 B:** Pressure field diagram under laminar conditions with height of stream over weir = 0.5m

Turbulent flow ( $v = 5\text{ m/s}$ )



**Figure 6.2 A:** Velocity profile diagram under turbulent conditions with height of stream over weir = 1m



**Figure 6.2 B:** Pressure field diagram under turbulent conditions with height of stream over weir = 1m

## Conclusion

Weirs are mainly used to control the flow rates of rivers during periods of high discharge. Sluice gates (or in some cases the height of the weir crest) can be altered to increase or decrease the volume of water flowing downstream. For constant fluid flow rate, as the height of the weir decreases, distance covered by the fluid over the flat surface also decreases. On an average we observe that the fluid reaches 5 to 6m ahead of weir in case of turbulent flow (minimum in case where  $H=0$ ) where as less than 1m in case of laminar flows. Thus, for the optimum outflow conditions for turbulent flow is that the height of weir should be as close to the height of stream for minimum ahead reach of fluid and controlled outflow of fluid.