THE UNIVERSITY OF NEWCASTLE

# Marine Pyramids

## Flow modification effects or artificial reef modules situated under a jetty

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**5/12/2013**

# Abstract

The purpose of this report is to determine the effects that the “marine pyramid” artificial reef (AR) modules may have on the flow conditions around a jetty once they are positioned under the jetty.

This study involved the use of computational fluid dynamics (CFD) to ascertain whether there were any benefits or problems caused by their positioning. As it will be impossible to account for all realistic possibilities this was a comparative study where a model jetty was simulated and then the same jetty model with the AR modules in position. With the two sets of simulations a comparison and conclusion was made of their effects on the flow.

The CFD results showed that for this configuration the AR modules reduced the velocity of the water flow around the jetty with the greatest positive affect downstream of the jetty, thereby dissipating the energy of the currents and reducing the impact that tides/currents will have on moored marine craft. Upstream there a slight velocity increase but the magnitude was very low making it negligible.

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## Introduction

Natural reefs act as barriers by dissipating the energy of water currents providing shelter to marine life as well as to coast lines and any other structures in the water. The reef formations act as obstructions that the currents must work to move around and through, hence sapping them of their energy.

The benefits afforded by natural reefs have led to the implementation of artificial reefs. Artificial reefs are created by strategically placing structures underwater to achieve any of the desired benefits that come with naturally occurring reefs.

Prior research was conducted on a specifically engineered artificial reef module called "marine pyramids" to determine various parameters to optimise them to act as a suitable habitat for marine life; primarily looking at the hole sizing to allow for adequate accessibility for the animals versus amount of shelter afforded. This next phase of research aims to determine the net impact that they may have once installed under a jetty situation including, particularly whether or not they will be able to "shelter" moored marine craft from tidal currents.

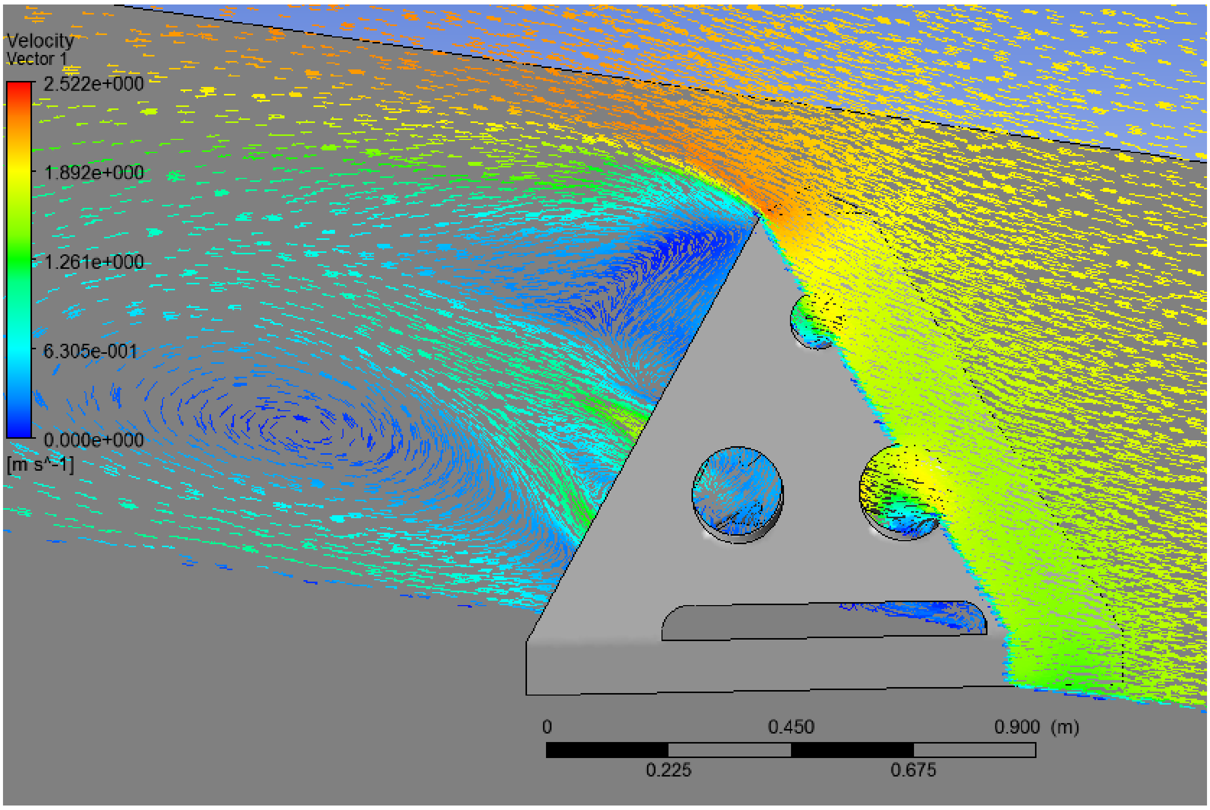


Figure 1: Velocity Vector Plot around Pyramid without any jetty present.

## Methodology

This study aims to use computational fluid dynamics (CFD) to simulate water flow around these artificial reef (AR) modules situated under a jetty model. It is impossible to account for every different type of conditions that may be present in reality as such this study will be a comparative one, in that the simulations will be run for the jetty by itself as well as the same jetty with the AR modules in place and these results will be compared directly.

The various models that will be simulated will include a free surface model to determine if the reef modules drastically increase the water's height, this will be simulated at zero degrees angle of incidence (water flow coming straight at the jetty). As there was found to be very little difference in water height any further simulations will be done without the free surface to reduce the computational demands, solution times and increase the accuracy.

The remaining simulations will be varying the angle of incidence from 5 degrees to 45 degrees to determine the effects at these semi-cross flow configurations. These simulations have been done at two different depths to determine how the ratio of pyramid height to water depth affects the results.

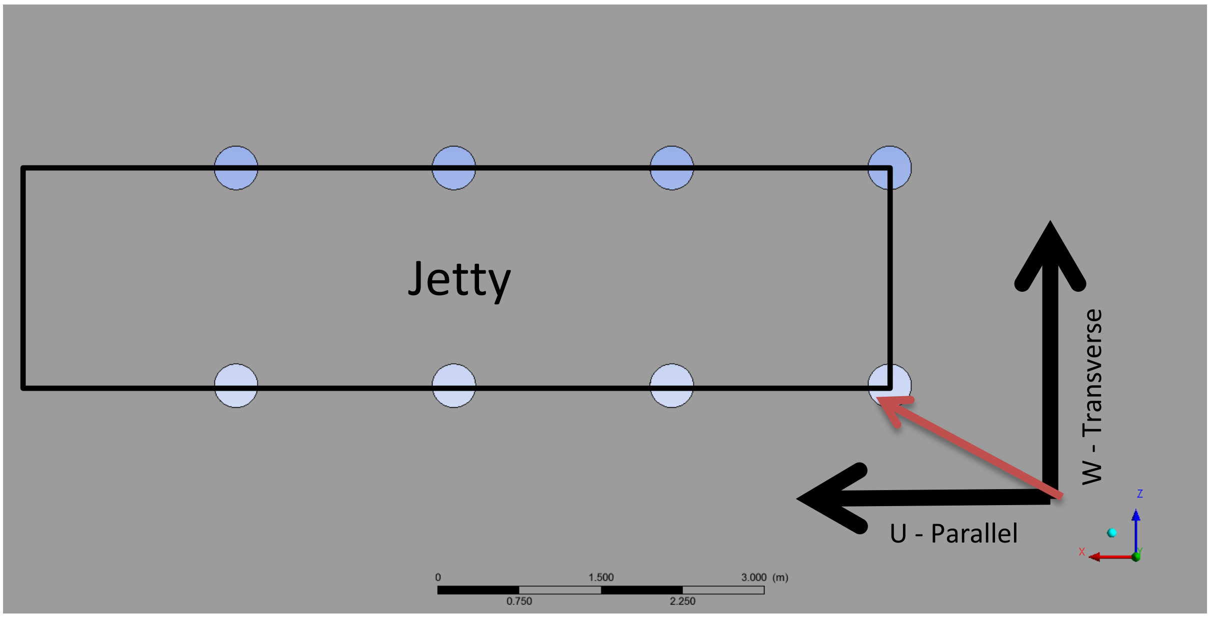


Figure 2: Configuration of the velocity components.

The U velocity component runs parallel to the jetty, and the W velocity component runs perpendicular (transverse) to the jetty. The angle of incidence is measured off the parallel component (the red arrow).

# Results

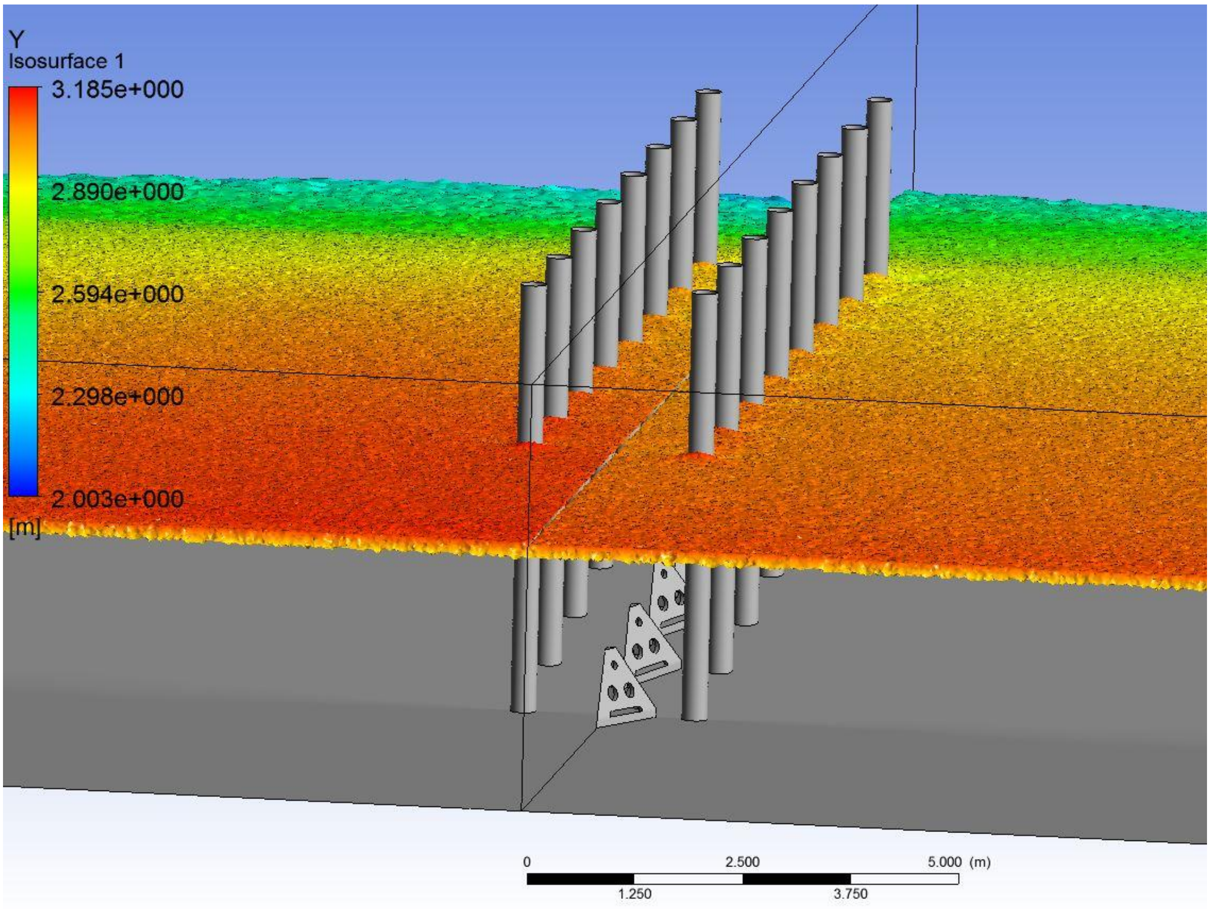


Figure 3: Isosurface of water volume fraction coloured by height. (Left half is jetty without reef, Right half is with reef)

The isosurface shows the level that water is at for both cases (left half is no reef, right half has reef). It shows that there is no real difference between the two different simulations. This suggests that the reef modules should not cause any significant upwelling of the surface that could have adverse effects on a moored.

As a result of the minimal change in water surface height the remaining simulations at varying angles of incidence were done neglecting the surface to reduce the computational demand, solution time and allow for a more refined mesh.

To determine whether there would be any positive or negative outcomes caused by the reef modules for these simulations the average velocity was measured on a plane 1m downstream and parallel to the jetty a location where a moored vehicle may be found.

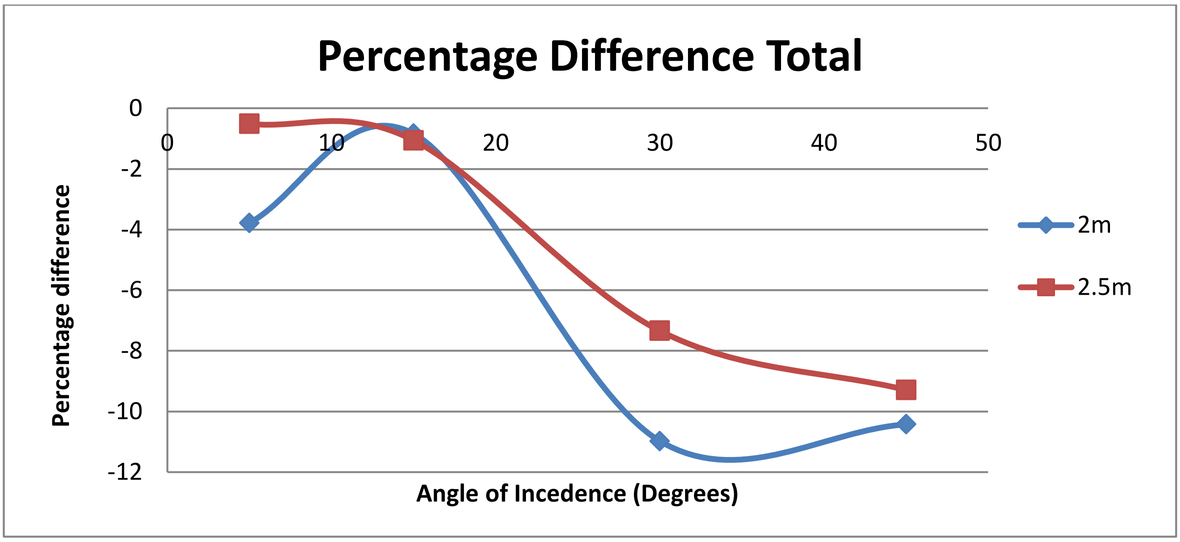


Figure 4: Total velocity reduction in plane 1m downstream of jetty (normalised against no reef simulation).

The total velocity magnitude shows that the simulations with the reef have slightly lower average velocities. As expected it is also a function of the water depth in relation to the pyramid's height as the solution at 2.5m has lower reductions than the 2m case. The reduction does vary with angle of incidence however not in a linear fashion. It does seem to converge to a value of 10% around 45 degrees for both cases.

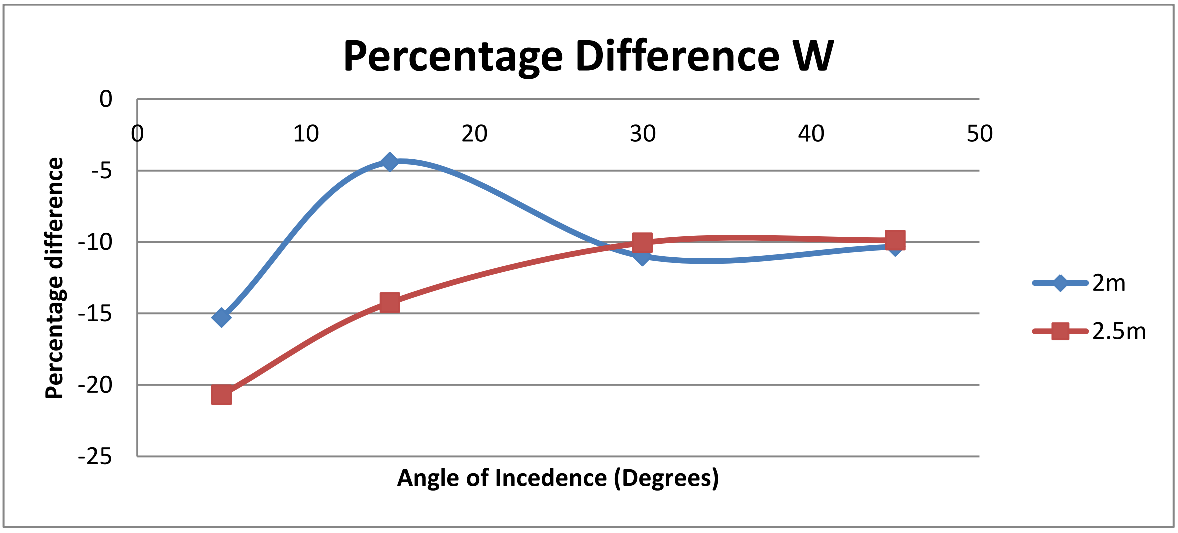


Figure 5: Transverse velocity reduction in plane 1m downstream of jetty (normalised against no reef simulation).

The velocity component that gets modified the most (as a percentage of itself) is the v component (vertical). However the actual magnitude is negligible. The transverse velocity component (w) which would most probably be the component most likely to affect a moored boat is reduced considerably for all cases with the minimum reduction been 4.5% and the maximum of 20%. At the lower angles of incidence this does not equate to much as the magnitude is very small, however between 30 and 45 degrees this reduction is 10% which is quite large and at these angles the magnitude of this component makes up a considerable amount of the total velocity.

## Conclusion

Based on the findings of these simulations the marine pyramid AR modules in this arrangement do have a positive effect on the on the area downstream of the jetty by reducing the average velocity, which can be taken as the dissipation of current flows. At the larger angles of incidence the modules reduce mainly the transverse velocity which could lead to reduce the impact that tides and currents may have on moored marine craft. Upstream of the jetty the AR modules also modify the flow. In some cases by increasing the average velocity, however this can be classified as negligible as the magnitude of the velocity components that get increased are very low.

## Appendix A1 – Velocity charts (magnitude)

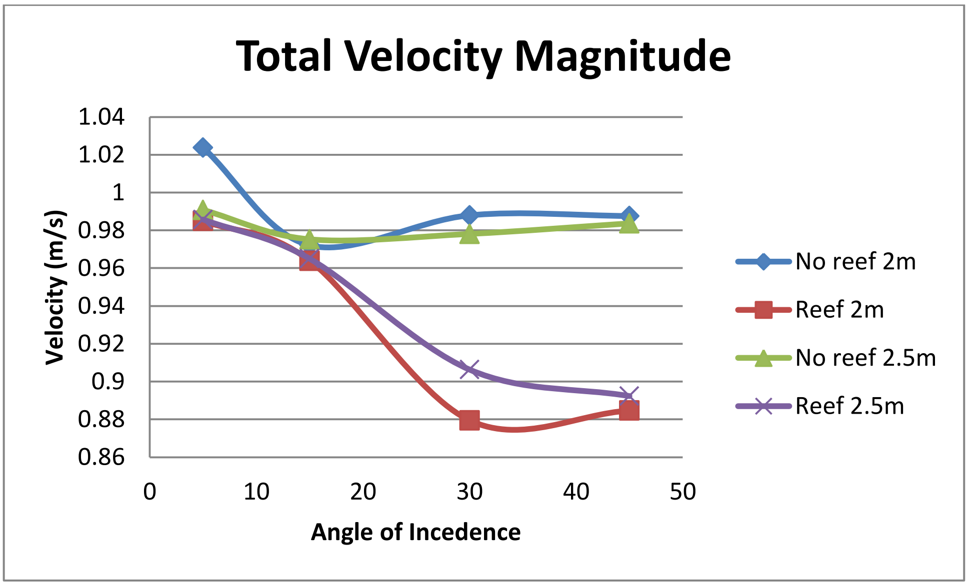


Figure 6: Average total velocity at 1m plane

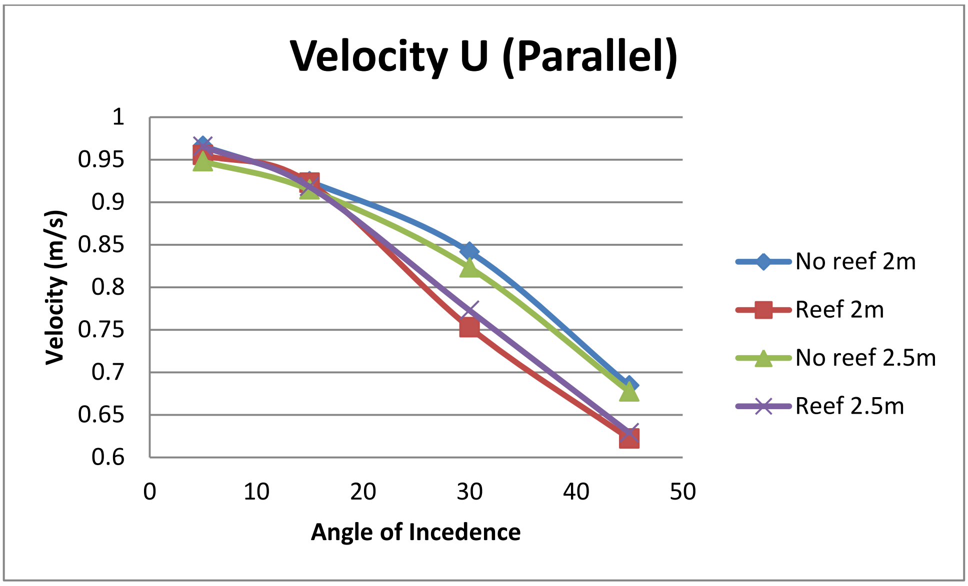


Figure 7: Average U component of velocity at 1m plane.

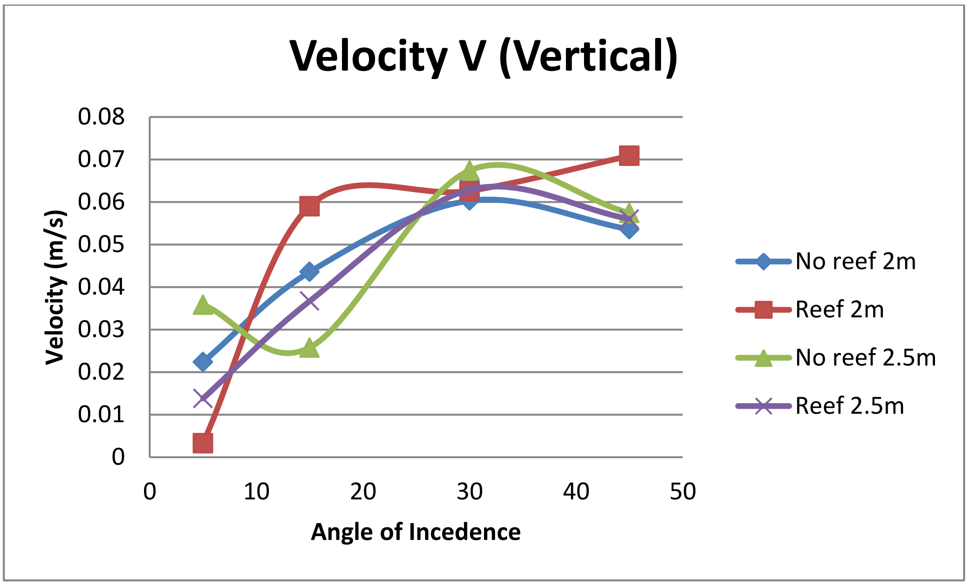


Figure 8: Average V component of velocity at 1m plane.

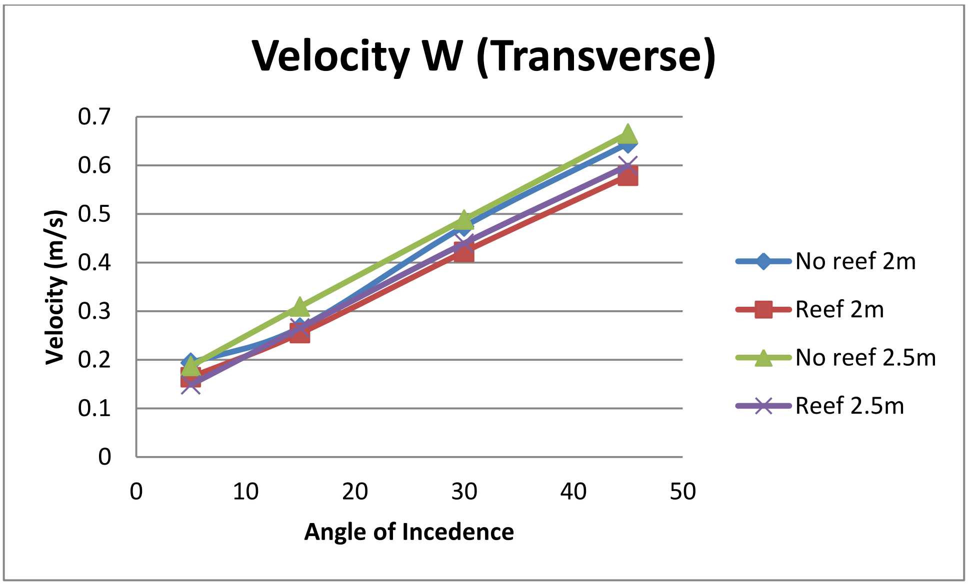


Figure 9: Average W component of velocity at 1m plane.

## Appendix A2 – Velocity Difference Charts (normalised against no reef)

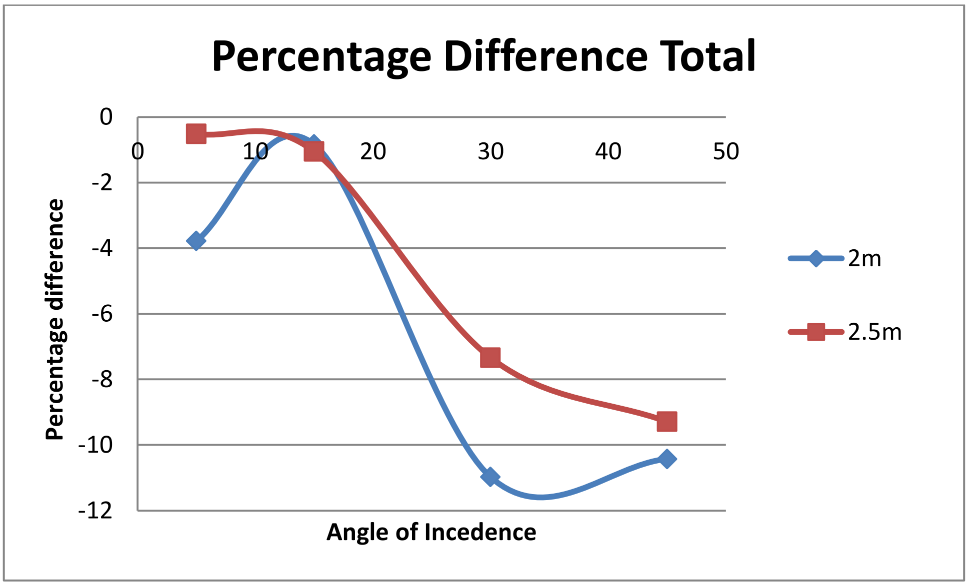


Figure 10: Percentage difference of the total velocity of the reef to the no reef simulations.

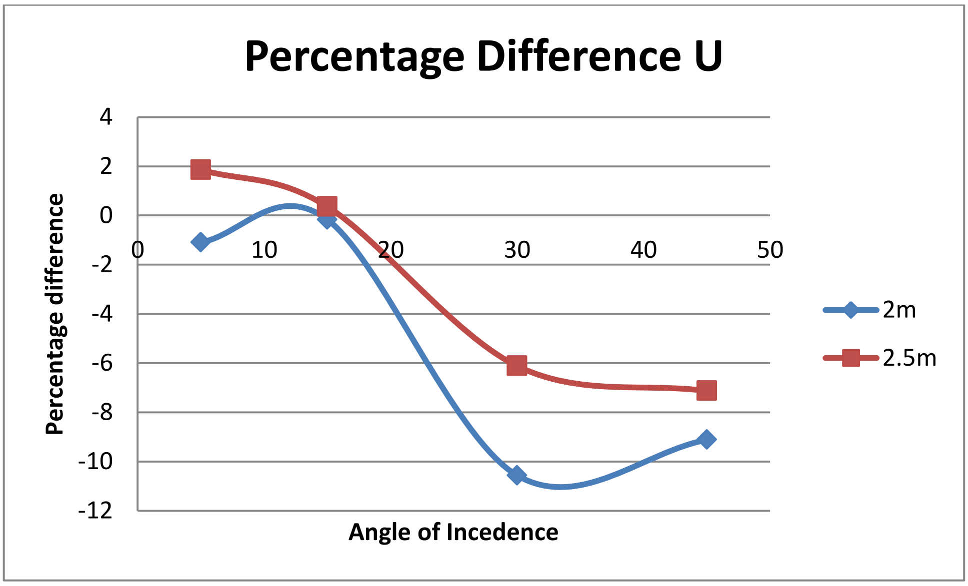


Figure 11: Percentage difference of the U velocity of the reef to the no reef simulations.

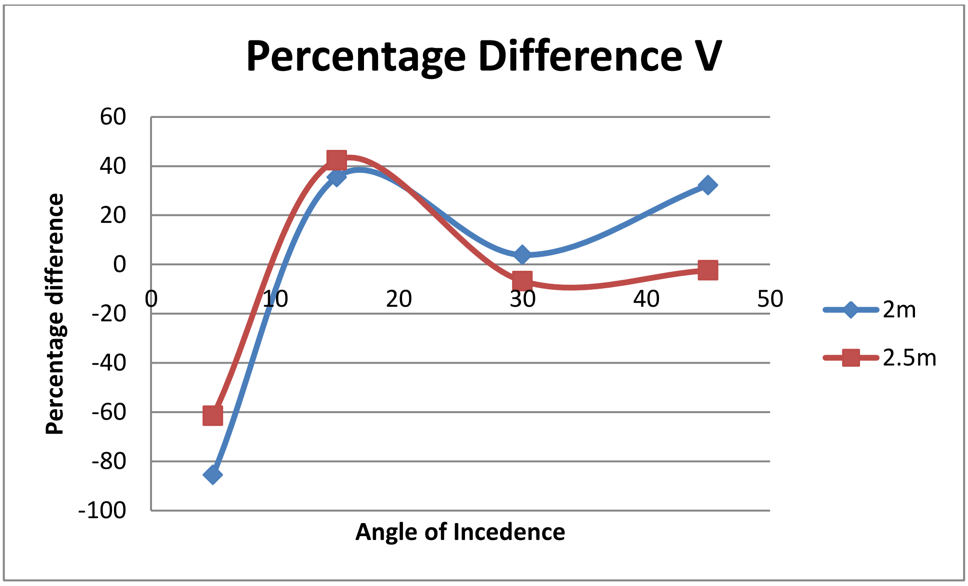


Figure 12: Percentage difference of the V velocity of the reef to the no reef simulations.

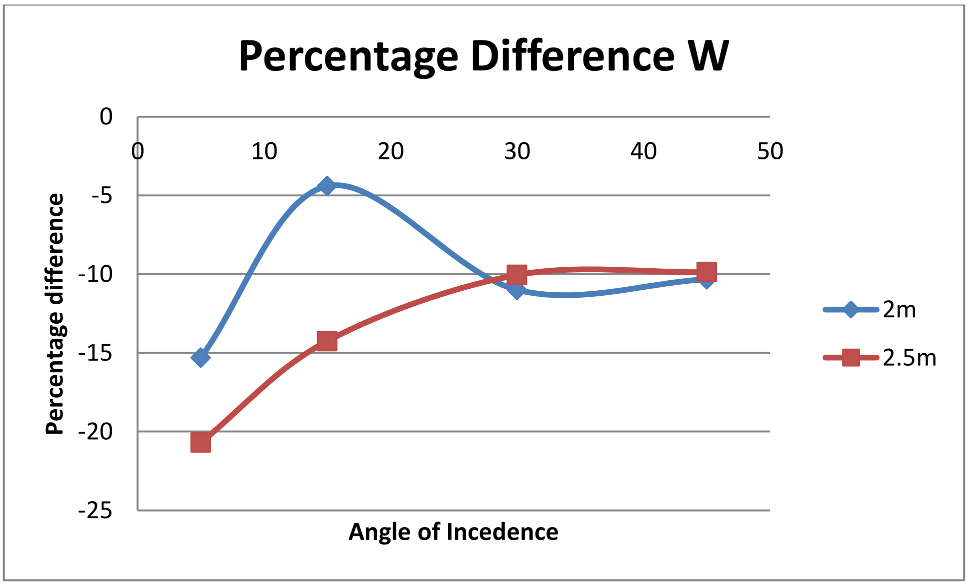


Figure 13: Percentage difference of the W velocity of the reef to the no reef simulations.

## Appendix A3 – Select pictures

The following pictures show each of the 2m deep simulations for all of the angles of incidence that were simulated for the with and without the pyramids in between the piers. The blue represents the floor, piers and pyramids. The green coloured surfaces encapsulate and show the areas where the velocity is equal to or higher than 10% of the inlet velocity (1m/s). It clearly shows in all of the cases that the pyramids reduce the amount of higher velocity flow in the whole domain supporting the idea that they will shelter anything in the vicinity. Red arrows indicate direction of water flow.

## 5 degrees

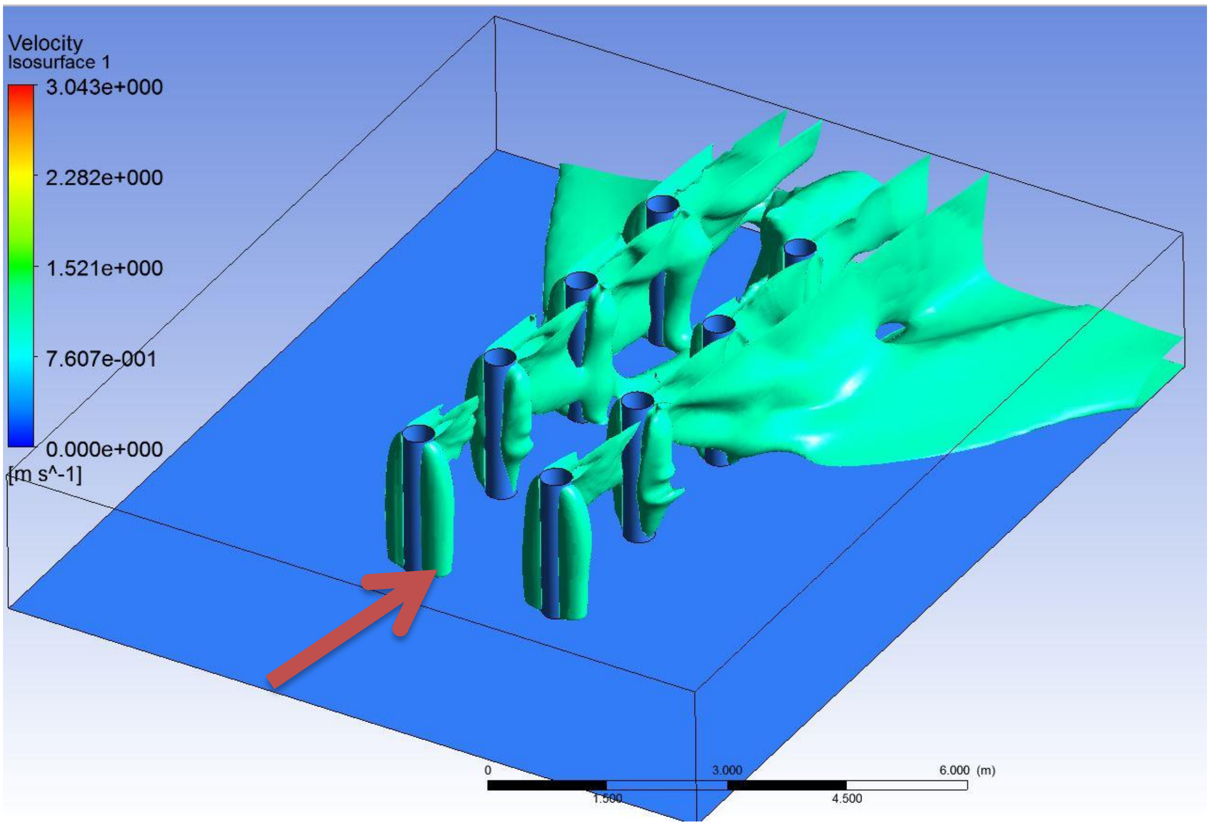


Figure 14: 5 degrees no reef

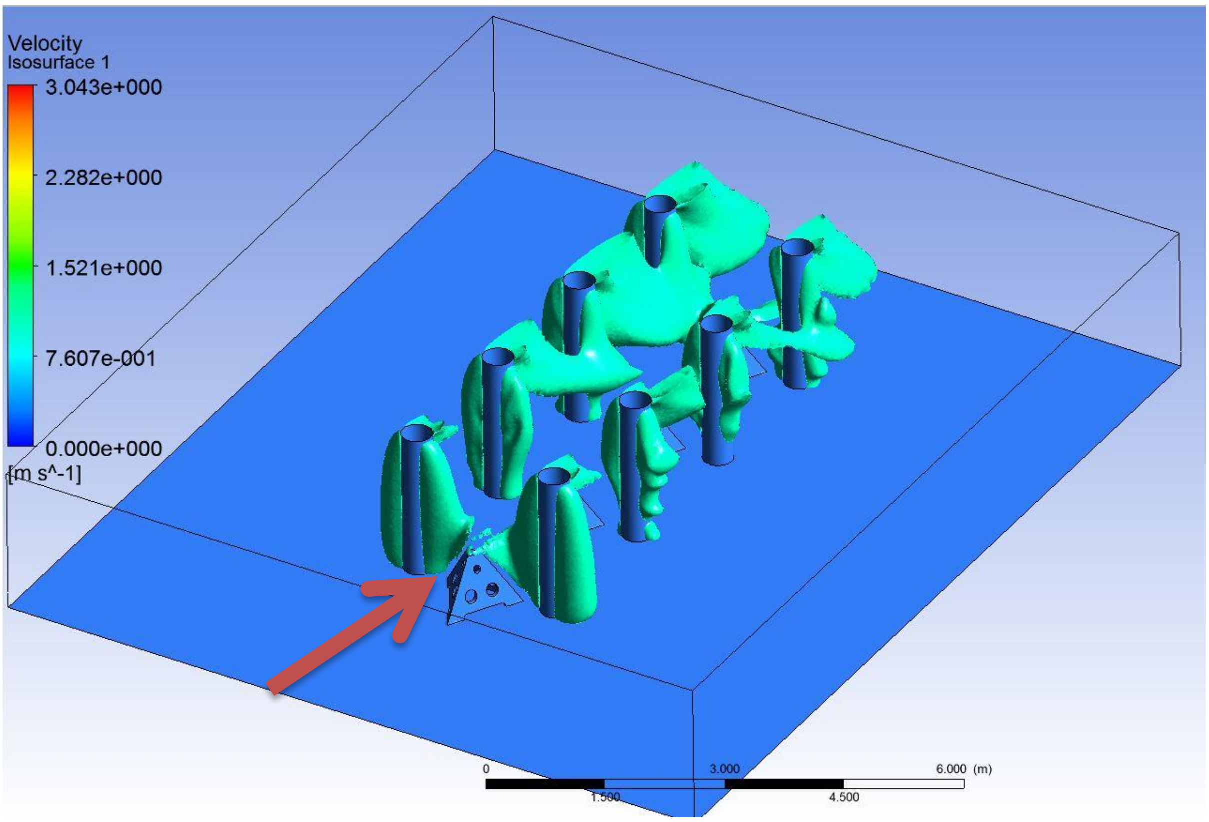


Figure 15: 5 degrees with reef

## 15 Degrees

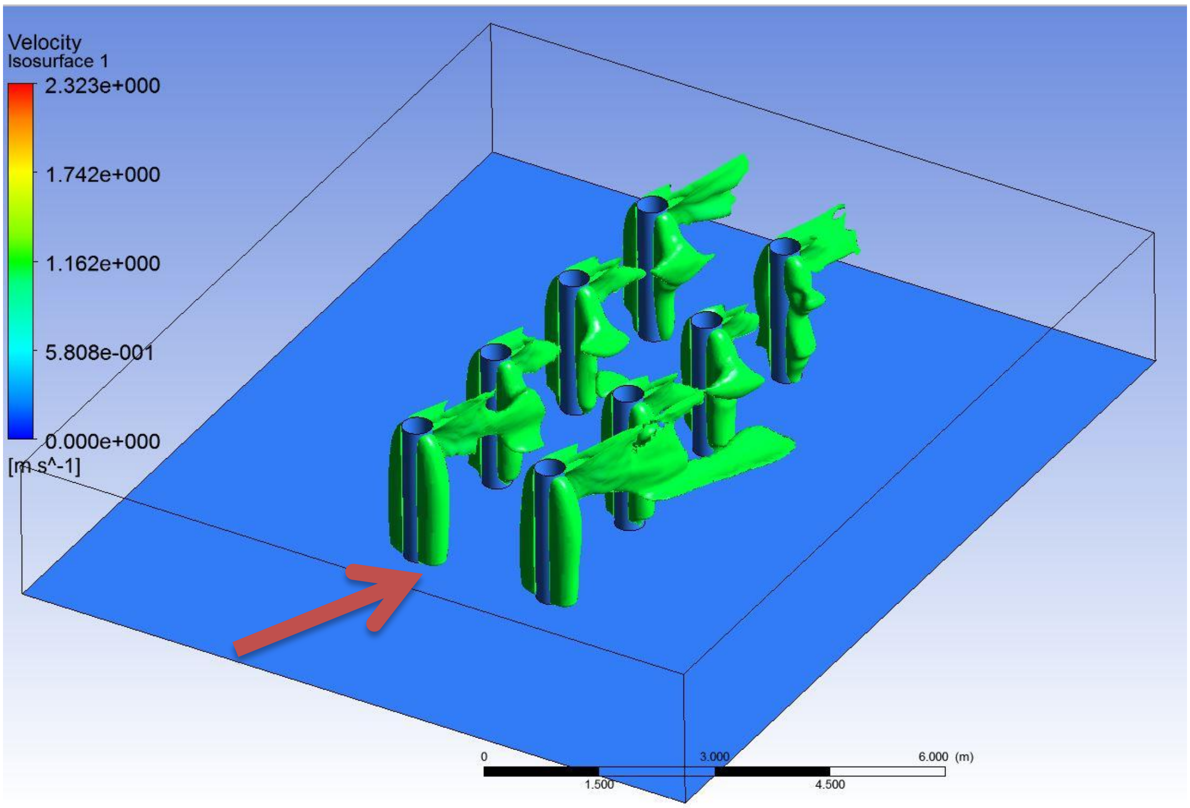


Figure 16: 15 degrees no reef

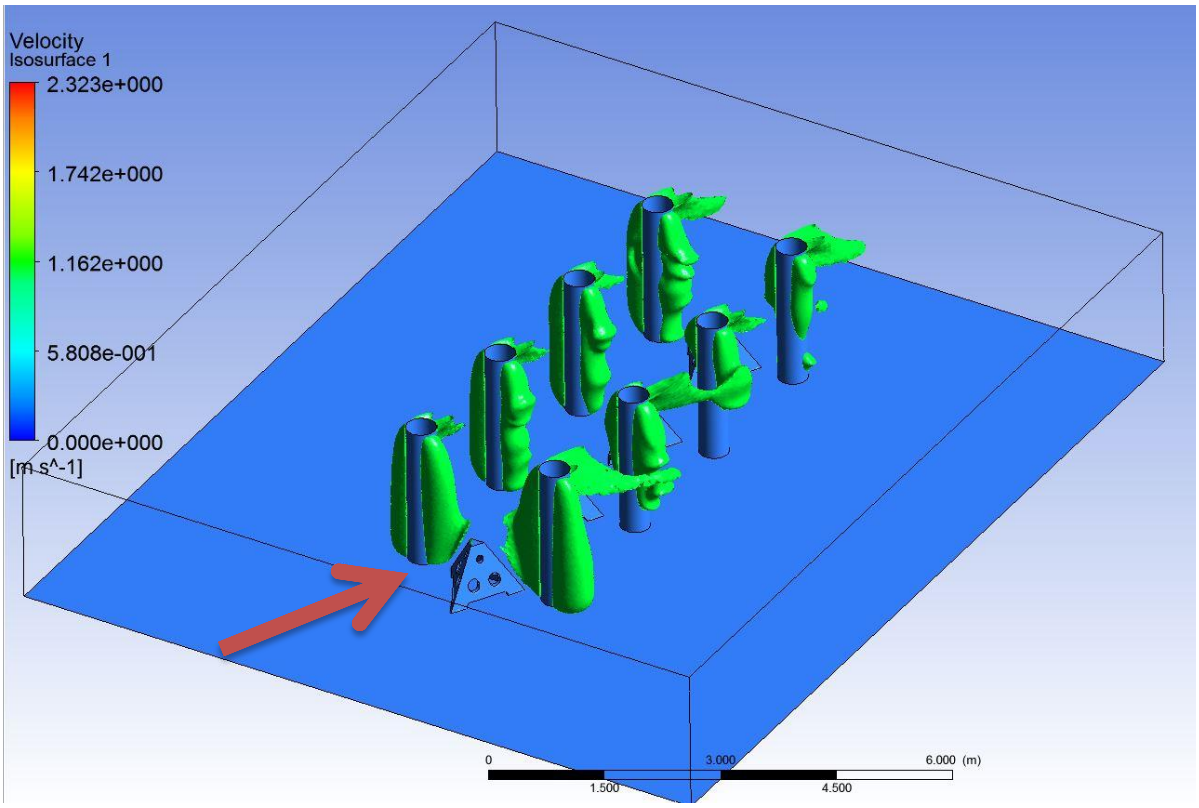


Figure 17: 15 degrees with reef

## 30 Degrees

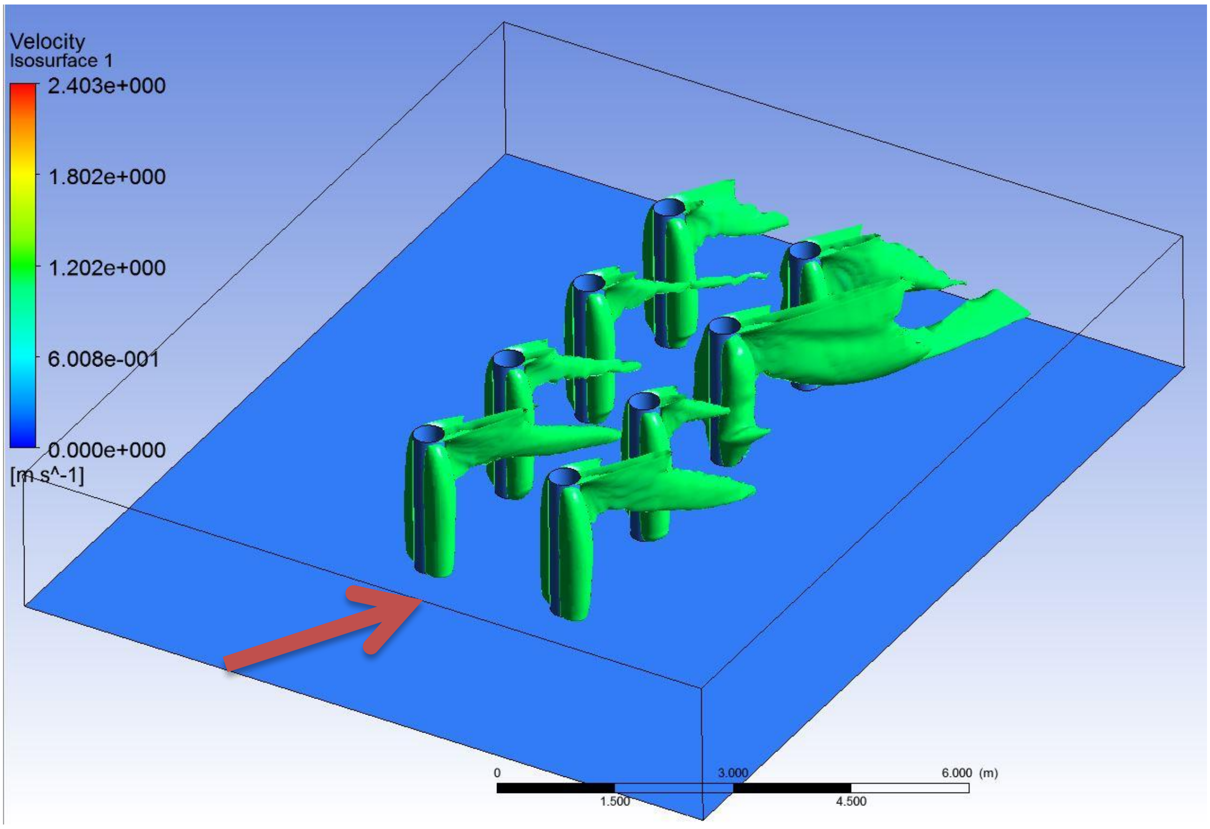


Figure 18: 30 degrees no reef

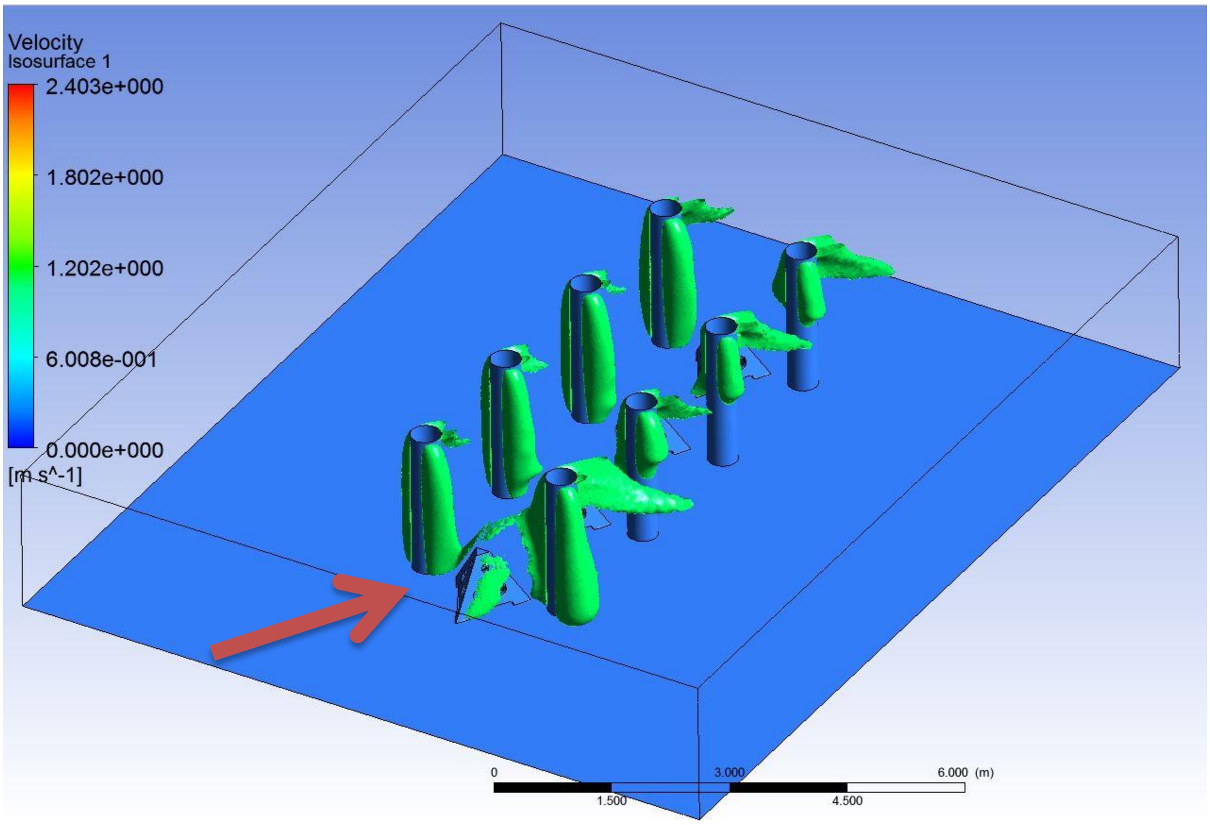


Figure 19: 30 degrees with reef

## 45 Degrees

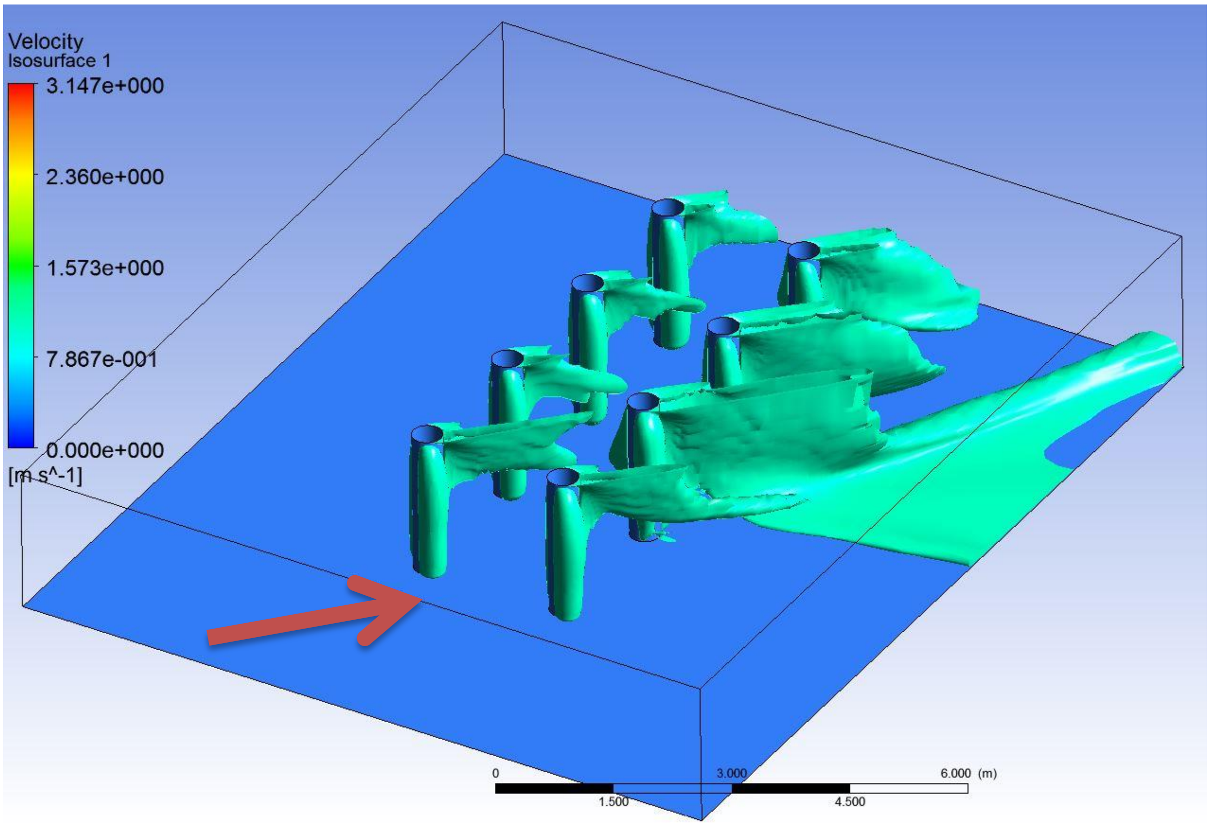


Figure 20: 45 degrees no reef

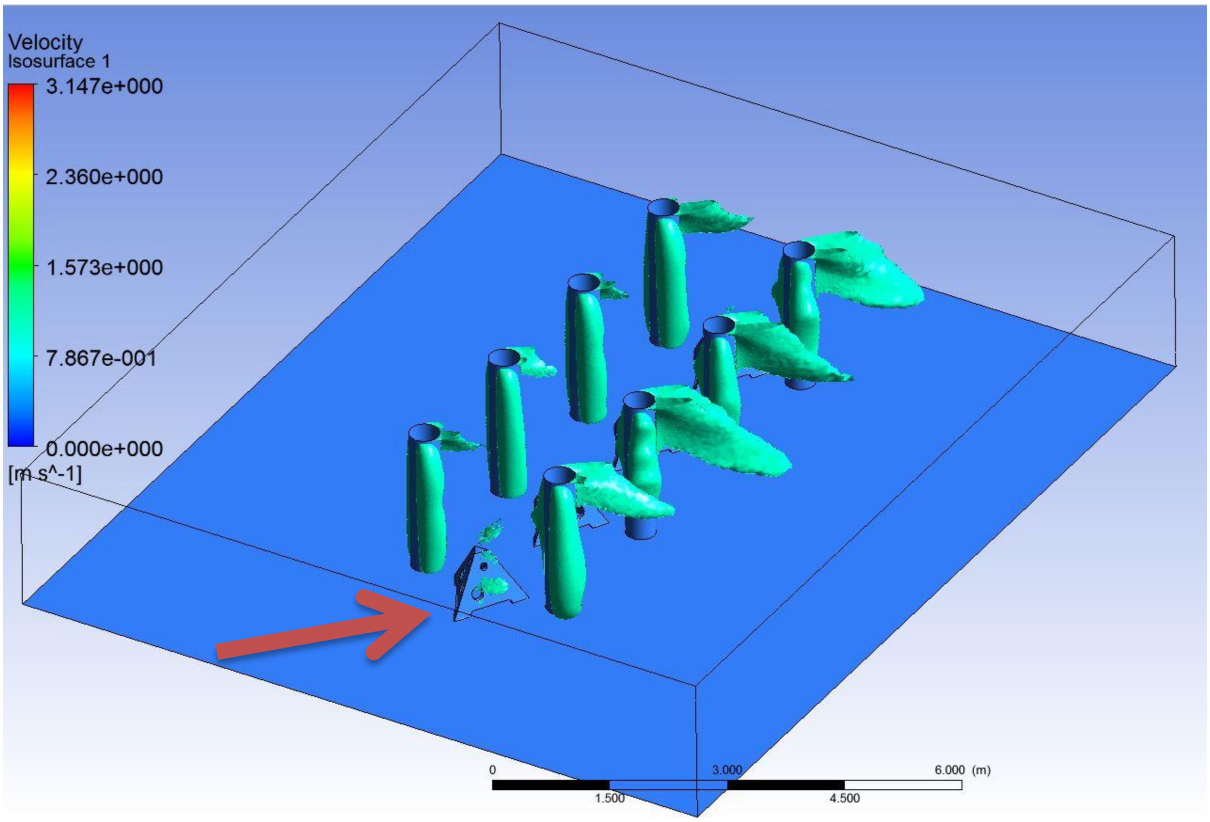


Figure 21: 45 degrees with reef