

# Hypotheses on hydrodynamic modifications due to harvesting of tidal energy

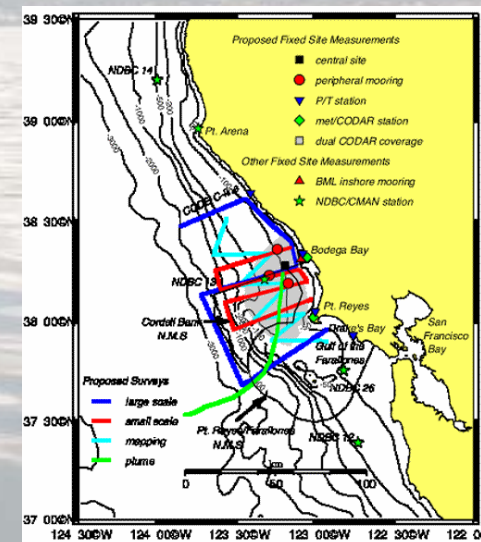
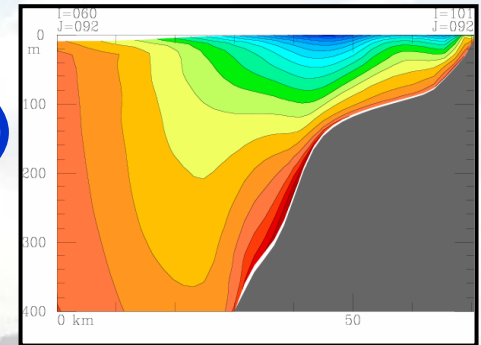
**ICMS Seminar: Marine and Tidal Energy, 5th November 2009**

**Dr Scott J. Couch**  
**Institute for Energy Systems**  
**University of Edinburgh (UoE)**



## Brief Bio:

- MEng & PhD in Civil Engineering (Strathclyde)
- Post-doc positions:
  - Oregon State University
    - Modelling the California Current System.
  - Robert Gordon University
    - Supergen Marine programme.
  - Edinburgh
    - Supergen continuation and consultancy.



## Outline:

1. Introduction.
2. Existing understanding.
3. Some key questions needing to be addressed.
4. What else should we be worrying about?
5. Discussion.



Figure 7.71(a) - 2D heat map of the wave field at the inlet of the channel, showing the wave field at the inlet of the channel.



Figure 7.71(b) - Schematic diagram of the channel showing the wave field at the inlet of the channel.



Figure 7.71(c) - 2D heat map of the wave field at the inlet of the channel, showing the wave field at the inlet of the channel.



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## Tidal energy offers two distinct technology solutions:



MCT's Seagen in Strangford Narrows (1.2MW)

### Tidal Turbines



Annapolis Royal tidal barrage, Canada (20 MW)

### Tidal barrage

In the tidal context, the majority of UoE work is focused on the tidal turbine solution, its exploitation potential and constraints

## Expectation management:

- Majority of content engineering related.
- My work focuses on trying to understand impact of energy harvesting on the tidal system and tidal physics.
- Focus on larger scale impacts.
- Approaches used typically fundamental mathematical analysis and numerical modelling.
  - Typically assume energy extraction device as a 'black box'
  - Not showing any equations today though!

**Let's get started!**

**Tidal current energy technology is a reality!**

**Government support for technology development**

**Development must be balanced against impacts**



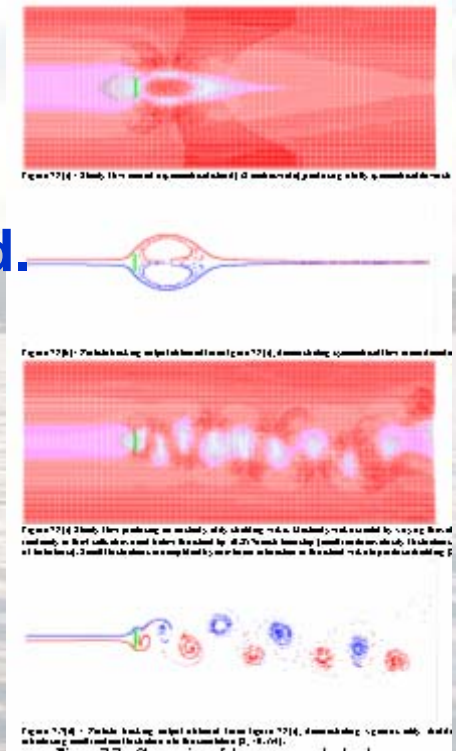
**Some immediate impacts already observable – note wake due to support structure (rhs image – flow from right to left)**

## Aerial view of wake on flood tide:



## Outline:

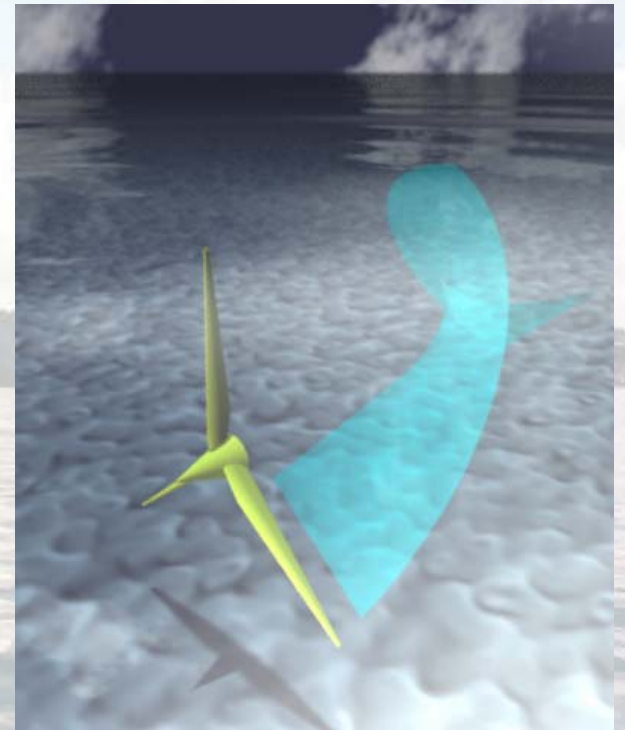
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4. What we don't think is a concern.
5. Discussion.



## Scientific approaches available?

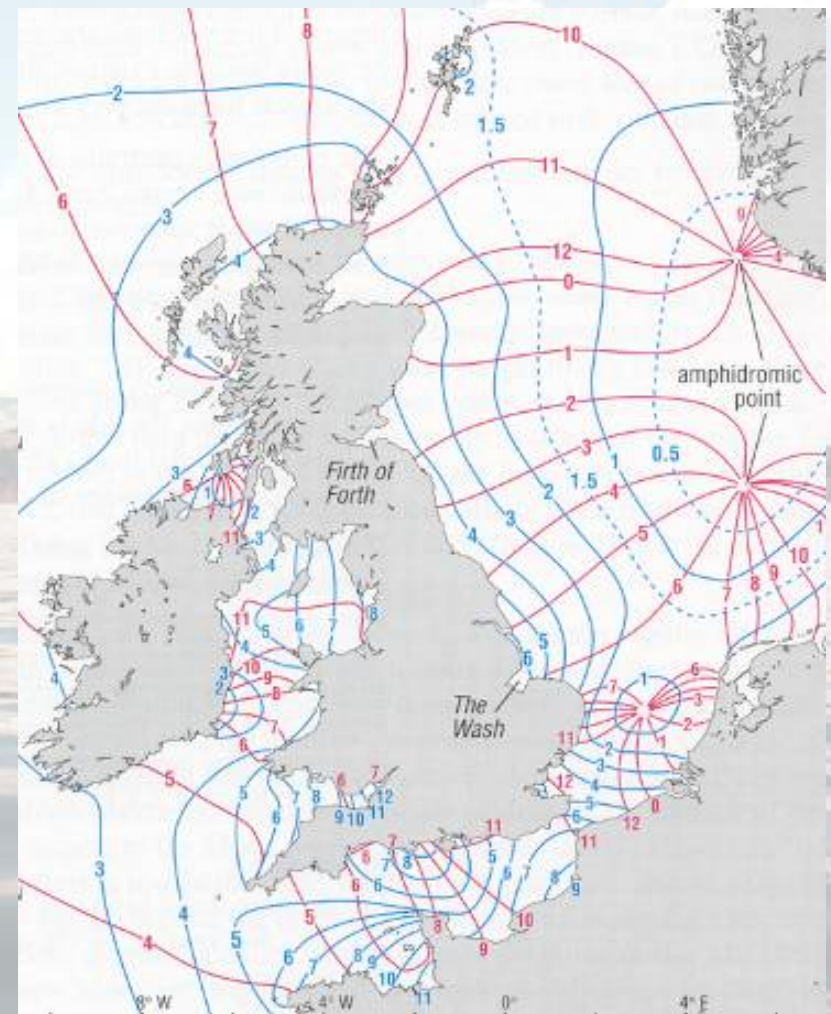
Understanding of the oceanic resource is at the heart of all the key constraints identified. A range of techniques available for enhancing scientific knowledge:

- Appropriate analogy and knowledge transfer (**initial understanding**)
- Physical modelling (**? - limited**)
- Numerical analysis (**strong potential**)
- Numerical modelling (**strong potential**)
- Monitoring of full-scale devices in operation (**Needs project scale – e.g. Energy Technology Institute ReDAPT project**)



## Tidal processes

- Large amount of underlying tidal physics already well understood.
- Coastal oceanography/ engineering obviously a mature sector – lots of cross-over.
- Site specific analysis requires local data collection, observation and understanding.
- Extreme tides of interest for economic project development.

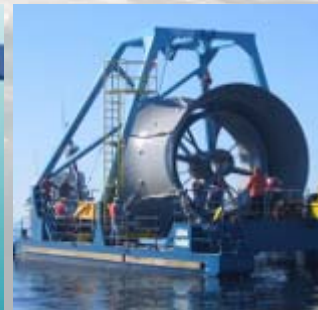
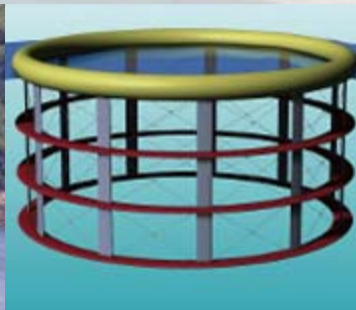


## Characteristics of a site of interest for economic development:

- Physics related:
  - Concentrated kinetic energy resource
    - Spring tide currents  $> 3$  m/s.
  - (Near) bi-directional flow.
  - Preferably limited wave action.
  - Limited turbulence (if that's possible!).
- Other engineering concerns:
  - Grid access.
  - Local supply chain. ... too much to discuss in this forum

## What impacts can we expect on the underlying tidal physics?

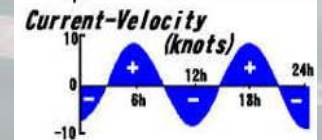
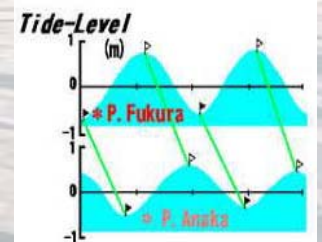
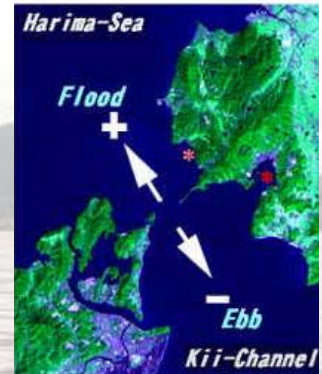
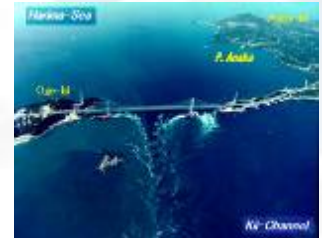
- Energy loss due to:
  - Support structure interaction.
  - Energy capture surface interaction.
- Energy re-distribution
  - In the water column – potential – kinetic interaction.
  - Altered vertical shear profiles, horizontal flow distribution



## Tidal physical processes that support extremes:

Typically some combination of the following -

- Tidal streaming.
- Hydraulic currents.
- Tidal resonance.



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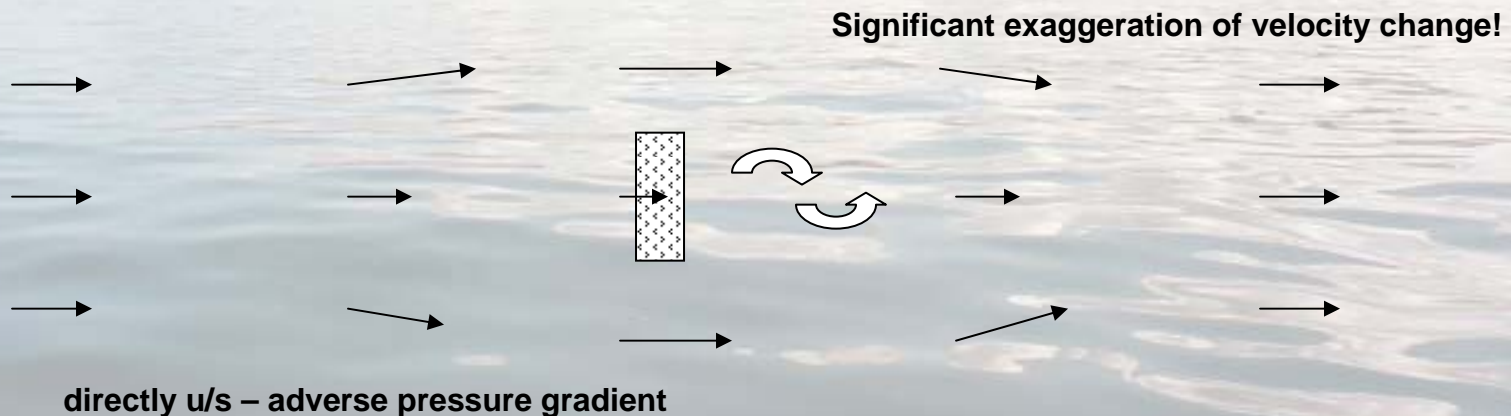
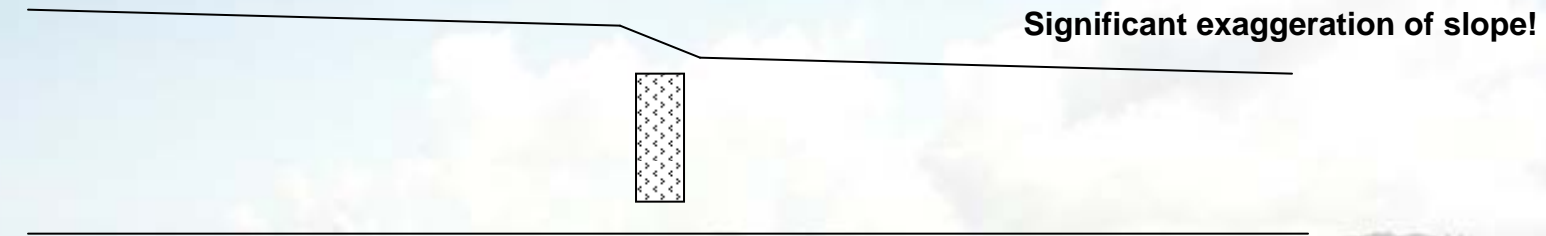


Figure 7.71(c) - 2D heat map of the wave field at the outlet of the channel, showing the wave field at the outlet of the channel.



Figure 7.71(d) - The schematic diagram of the channel, showing the wave field at the inlet of the channel.

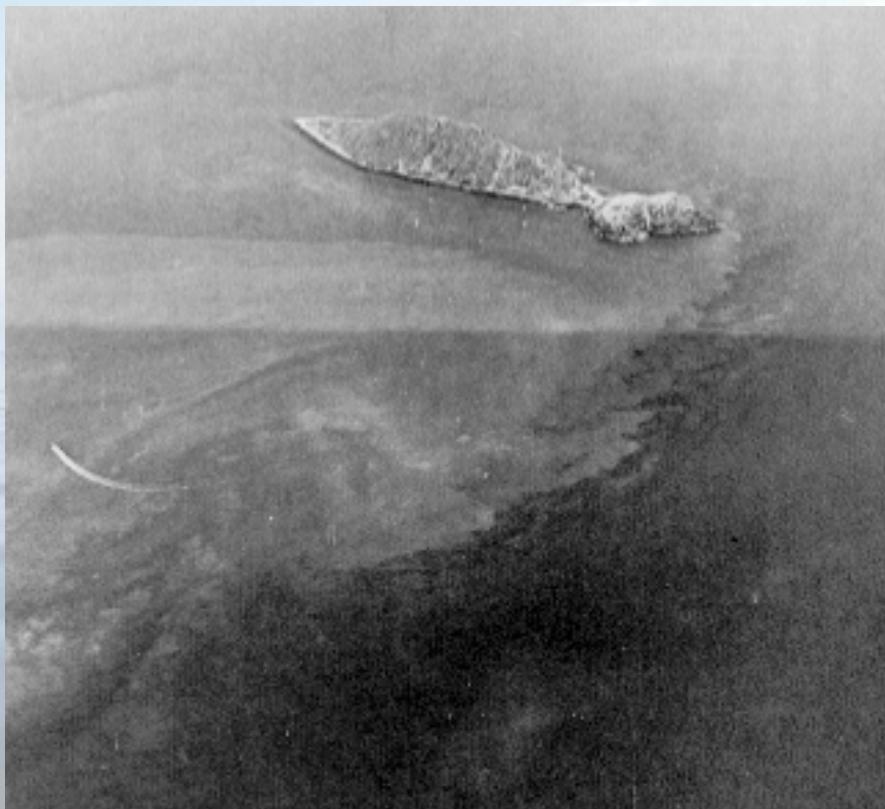
## What fluid response can be expected around an individual device?



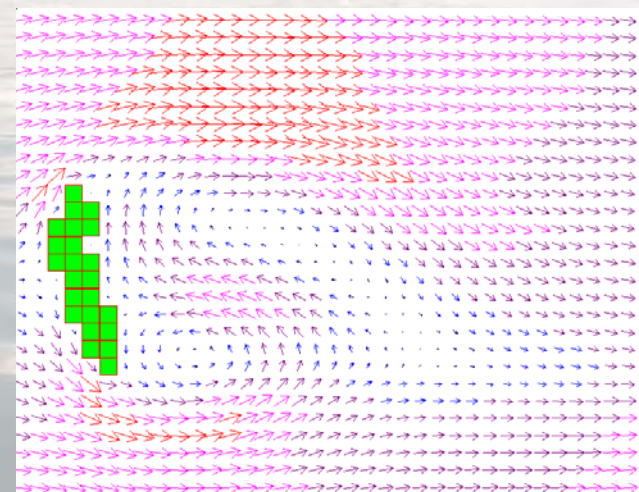
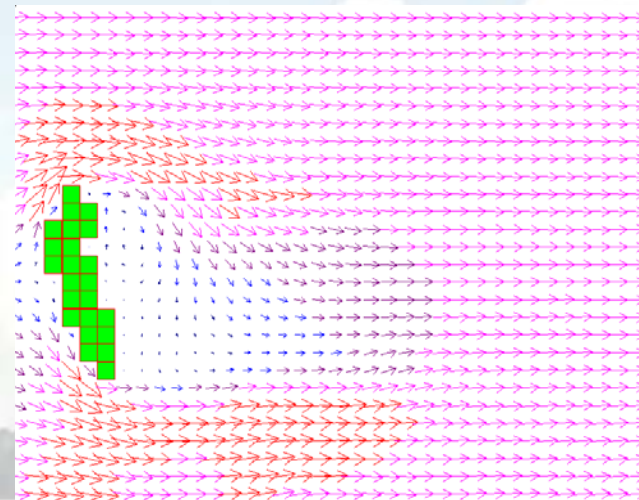
Starting to raise questions – supporting evidence?

## Existing interaction understanding (i):

- Islands

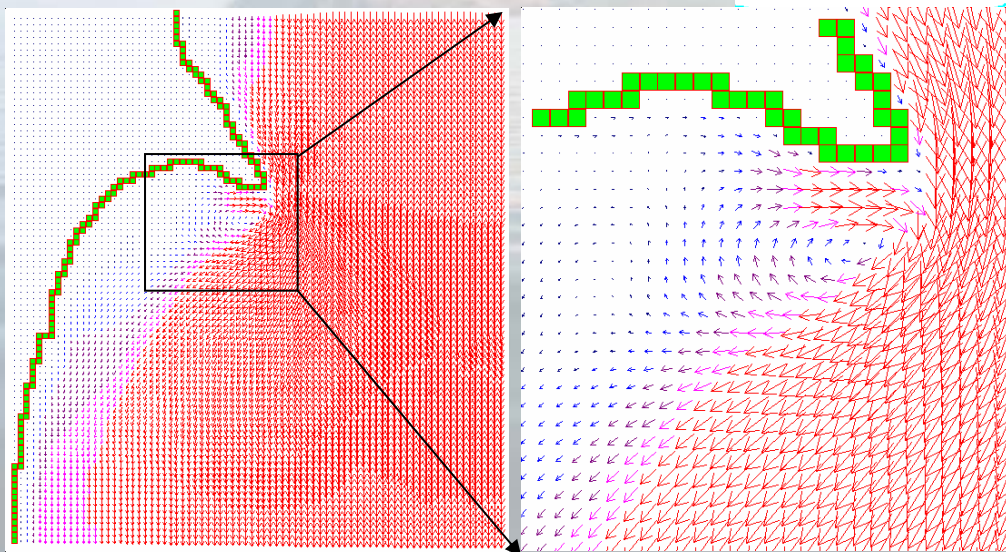
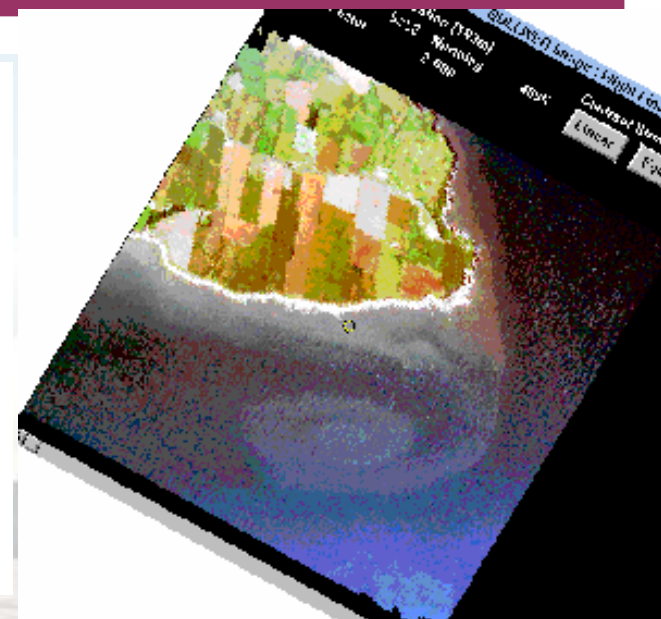
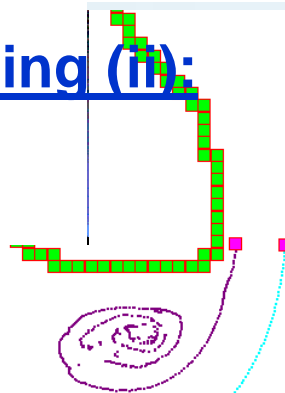


Source: Wolanski et al. 1984.

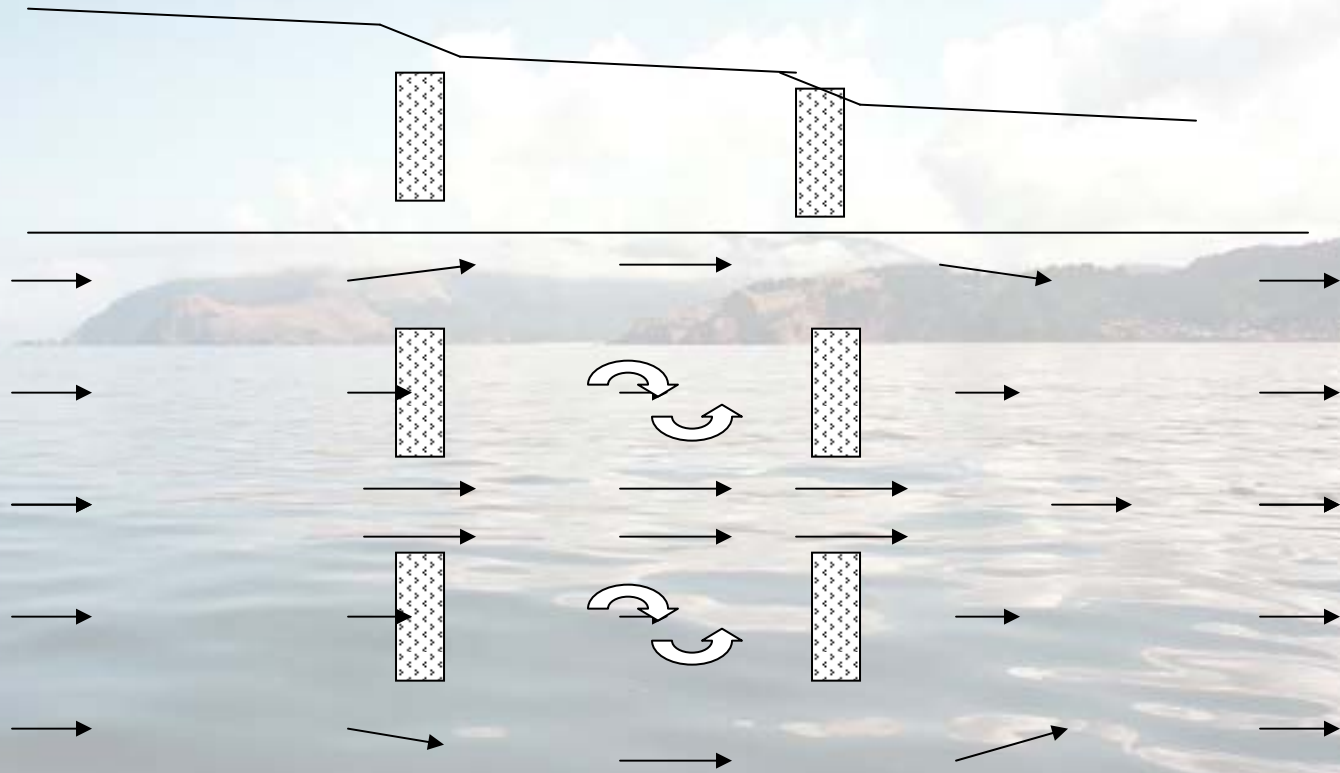


## Existing interaction understanding (ii):

- Headlands



## What fluid response can be expected around multiple devices?



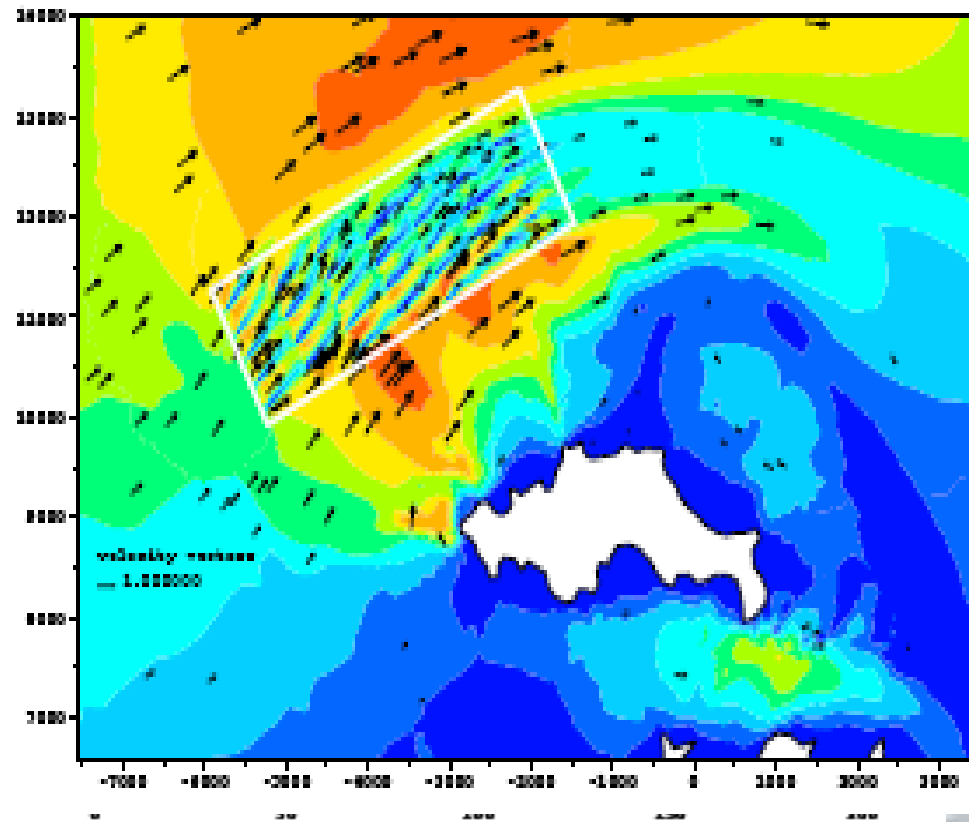
**Generating more questions**

## What fluid response can be expected around a farm of devices?

free surface with pier

### Man-made 'structures'

- Here we see the influence of a marine structure on the flow:
- raised head u/s
- lowered head d/s
- This is for a bridge pier – same physics for tidal energy devices:



## Some general thoughts:

- Impact of one device on tidal physics is local, small scale.
- However, wake effects not understood/difficult to observe.
- Additive impact of multiple devices difficult to quantify.
- (Limited) experience of developers in device interactions +ve.
  - MCT observational programme restrictions just lifted.
    - Intensive seal monitoring – observers + GPS tracking
  - Verdant Power
    - Fish passage monitoring – avoidance behaviour

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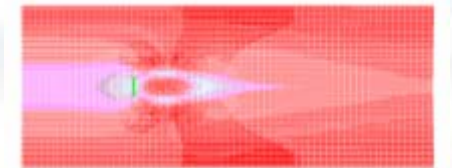


Figure 7.71(a) - 2D plot showing the cross-section of the wave field in the plane of the wave propagation.



Figure 7.71(b) - 2D plot showing the cross-section of the wave field in the plane of the wave propagation, similar to Figure 7.71(a) but with a different internal structure.

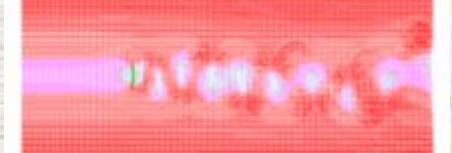


Figure 7.71(c) - 2D plot showing the cross-section of the wave field in the plane of the wave propagation, similar to Figure 7.71(a) but with a different internal structure.



Figure 7.71(d) - 2D plot showing the cross-section of the wave field in the plane of the wave propagation, similar to Figure 7.71(a) but with a different internal structure.

## General thoughts:

- Individual devices, or very small arrays not a major impact.
- Concerns arise when industry more mature – larger arrays.
- Cumulative impact potentially more significant (?)
  - In reality still a big unknown.
- Very large scale – what extra physical interactions generated?
  - Blockage ?
  - Degenerative effects (hydraulic current example) ?
  - Farms impacting on each other ?
  - Intertidal zone perhaps now a concern ?

## Discussion topics – (or what my thoughts are in areas that I know even less about!):

- Wave-current interaction
- Turbulence –
  - existing levels in highly energetic flows.
  - enhanced generation by devices,
- Sediment transport
- Scale of extractable resource.



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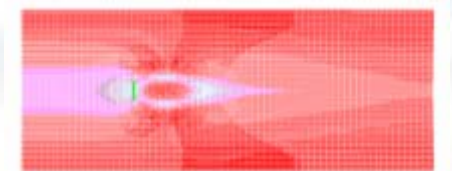


Figure 7.71(a) - 2D plot of the wave function  $\psi(x, y, z, t)$  at  $t = 0$  for a wave packet moving in the  $x$  direction.



Figure 7.71(b) - 2D plot of the wave function  $\psi(x, y, z, t)$  at  $t = 0$  for a wave packet moving in the  $x$  direction.



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