Tidal Current Energy:
Improved methodologies for resource assessment

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Status of industry development:

- Conceptual approach has been proven.
- Multiple technologies undertaking large-scale sea-trials.
- Investment/acquisitions by ‘big business’.
- Development/planning of ‘utility’ scale projects.

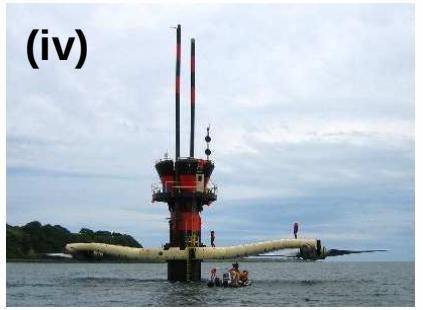


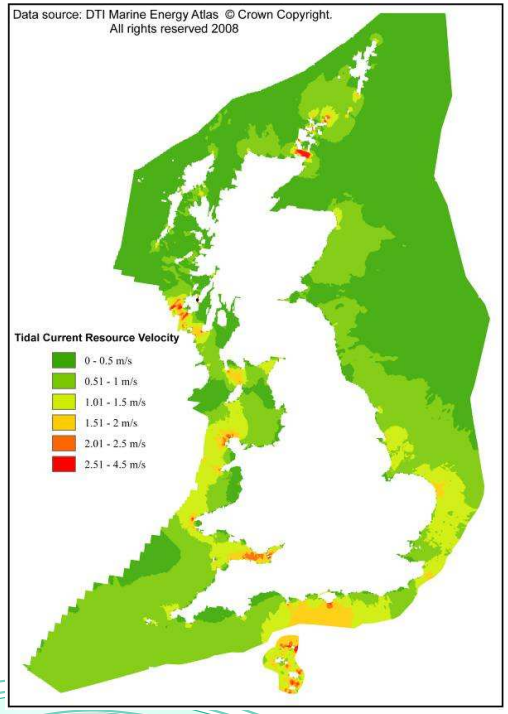
Image sources:
(i) http://www.openhydro.com/images.html
(ii) http://www.utilityweek.co.uk/news/rwe-innogy-to-test-1mw-tidal-t.php
(iii) http://www.atlantisresourcescorporation.com/
(iv) http://www.marineturbines.com

Tidal resource assessment overview:

- **Resource is complex, as are fluid-device interactions.**
- **Every location has its own characteristics.**

Two different approaches are necessary

Parametric for national application



Detailed for project design

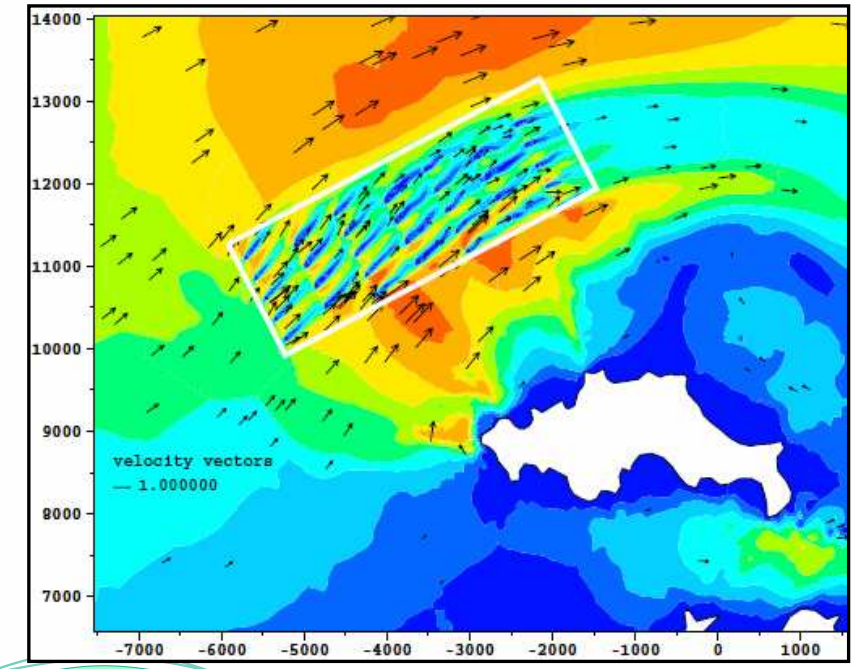
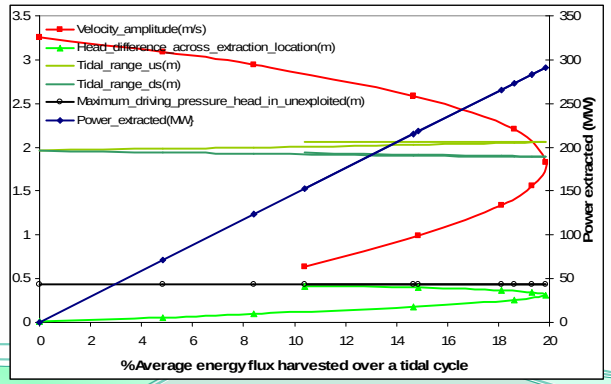
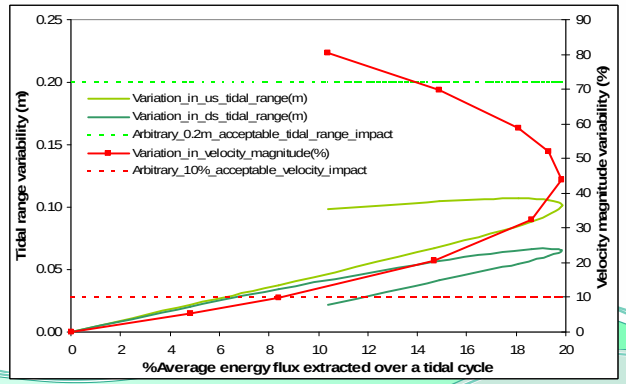


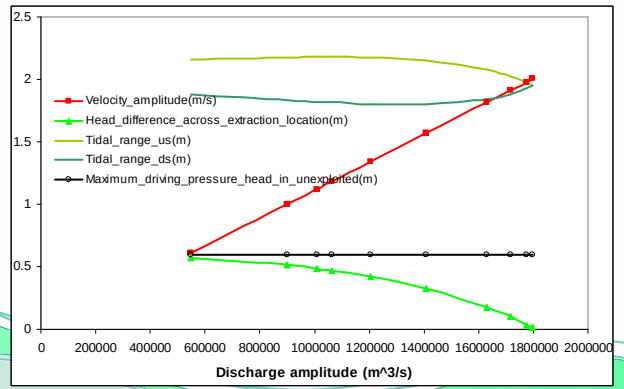
Image source: Hervouet, J-M "Hydrodynamics of Free Surface Flows" – Wiley (2007).

Introduction to parametric approach:

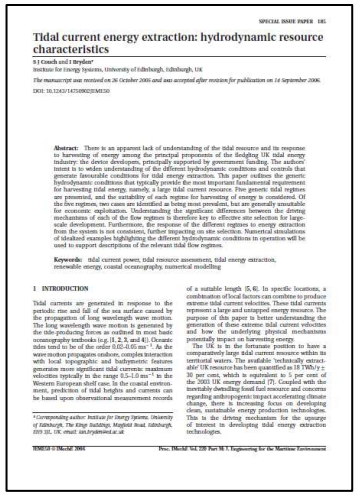
- No full-scale data => utilise detailed hydrodynamic numerical models to investigate generic responses.
  - Existing models could not simulate energy harvesting.
  - Solutions developed within Supergen Marine – presented at previous annual assemblies.
- Create a large database of cases.
- Identify common responses.
- Identify metrics associated with these responses.







Parametric resource assessment background:



SPECIAL ISSUE PAPER 185

Tidal current energy extraction: hydrodynamic resource characteristics

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Abstract: There is an apparent lack of understanding of the tidal resource and its response to harvesting of energy among the principal proponents of the fledgling UK tidal energy industry: the device developers, principally supported by government funding. The authors' intent is to widen understanding of the different hydrodynamic conditions and controls that generate favourable conditions for tidal energy extraction. This paper outlines the generic hydrodynamic conditions that typically provide the most important fundamental requirement for harvesting tidal energy, namely, a large tidal current resource. Five generic tidal regimes are presented, and the suitability of each regime for harvesting of energy is considered. Of the five regimes, two cases are identified as being most prevalent, but are generally unsuitable for economic exploitation. Understanding the significant differences between the driving mechanisms of each of the flow regimes is therefore key to effective site selection for large-scale development. Furthermore, the response of the different regimes to energy extraction from the system is not consistent, further impacting on site selection. Numerical simulations of idealized examples highlighting the different hydrodynamic conditions in operation will be used to support descriptions of the relevant tidal flow regimes.

Keywords: tidal current power, tidal resource assessment, tidal energy extraction, renewable energy, coastal oceanography, numerical modelling

1 INTRODUCTION

Tidal currents are generated in response to the periodic rise and fall of the sea surface caused by the propagation of long wavelength wave motion. The long wavelength wave motion is generated by the tide-producing forces as outlined in most basic oceanography textbooks (e.g. [1, 2, 3, and 4]). Oceanic tides tend to be of the order 0.02–0.05 ms^{-1}. As the wave motion propagates onshore, complex interaction with local topographic and bathymetric features generates more significant tidal currents: maximum velocities typically in the range 0.5–1.0 ms^{-1} in the Western European shelf case. In the coastal environment, prediction of tidal heights and currents can be based upon observational measurement records of a suitable length [5, 6]. In specific locations, a combination of local factors can combine to produce extreme tidal current velocities. These tidal currents represent a large and untapped energy resource. The purpose of this paper is better understanding the generation of these extreme tidal current velocities and how the underlying physical mechanisms potentially impact on harvesting energy.

The UK is in the fortunate position to have a comparatively large tidal current resource within its territorial waters. The available 'technically extractable' UK resource has been quantified as 18 TWh/y ± 30 per cent, which is equivalent to 5 per cent of the 2003 UK energy demand [7]. Coupled with the inevitable dwindling fossil fuel resource and concerns regarding anthropogenic impact accelerating climate change, there is increasing focus on developing clean, sustainable energy production technologies. This is the driving mechanism for the upsurge of interest in developing tidal energy extraction technologies.

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- Hydraulic current.
- Resonant system.
- Tidal streaming.

Also recommend 3 levels of assessment appropriate for tidal current energy application:

- ***Theoretical*** **resource.**
- ***Technical*** **resource.**
- ***Practical*** **resource.**

Sustainable Development Commission

Tidal Power in the UK

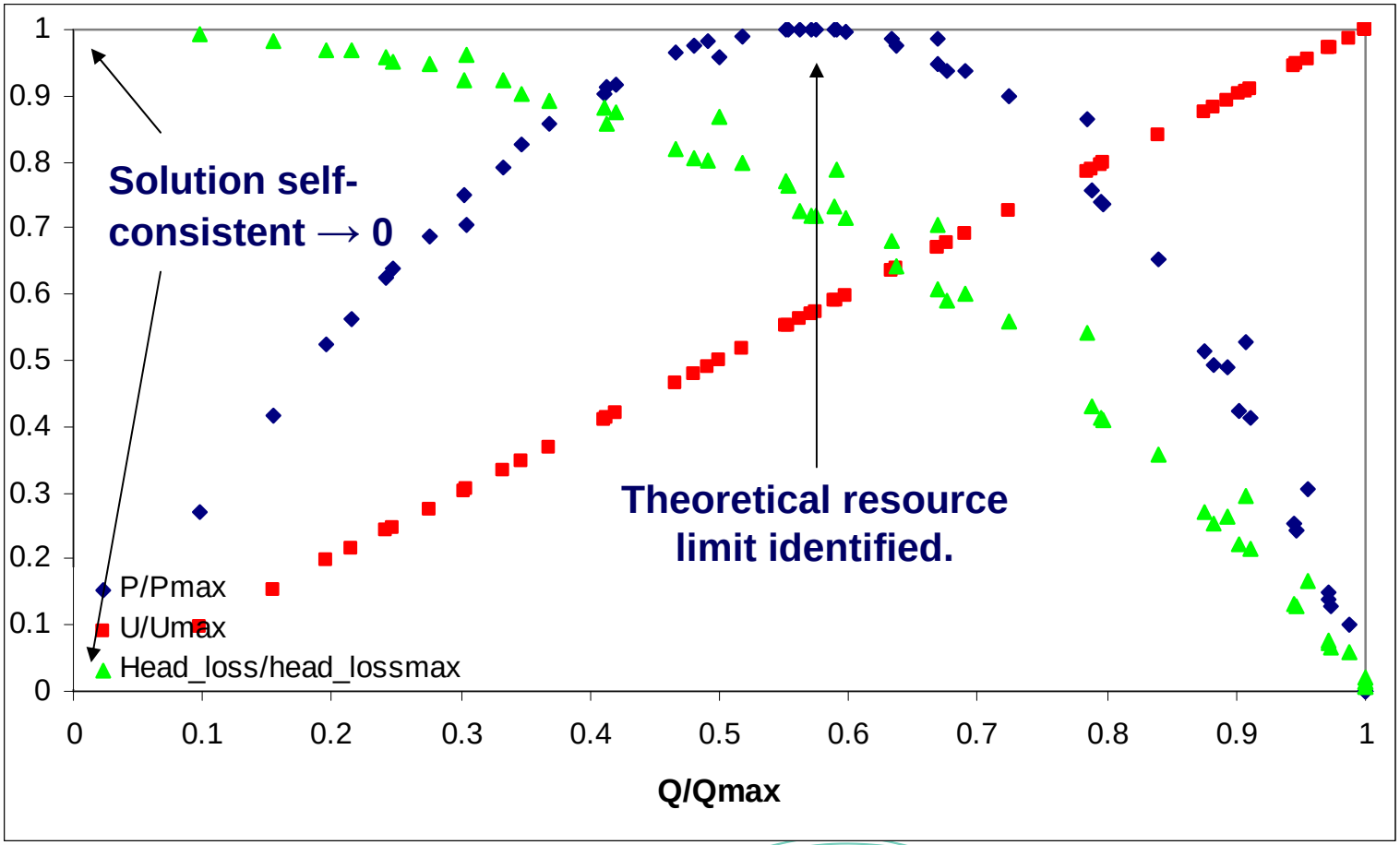
Research Report 5 - UK case studies

An evidence-based report by AEA Energy & Environment for the Sustainable Development Commission

October 2007

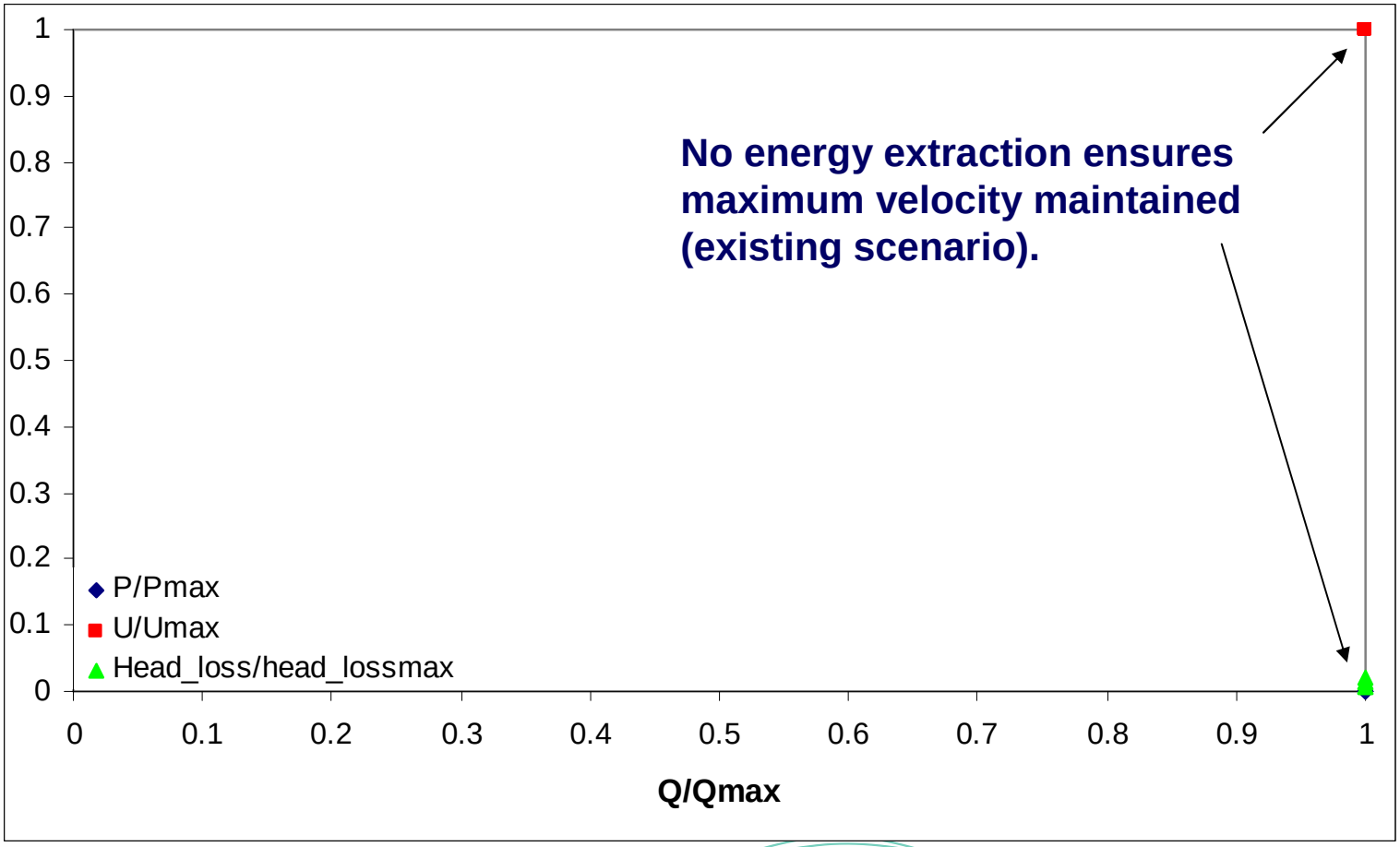
Embodying the solution:

- **Consistent non-dimensional response across all cases.**

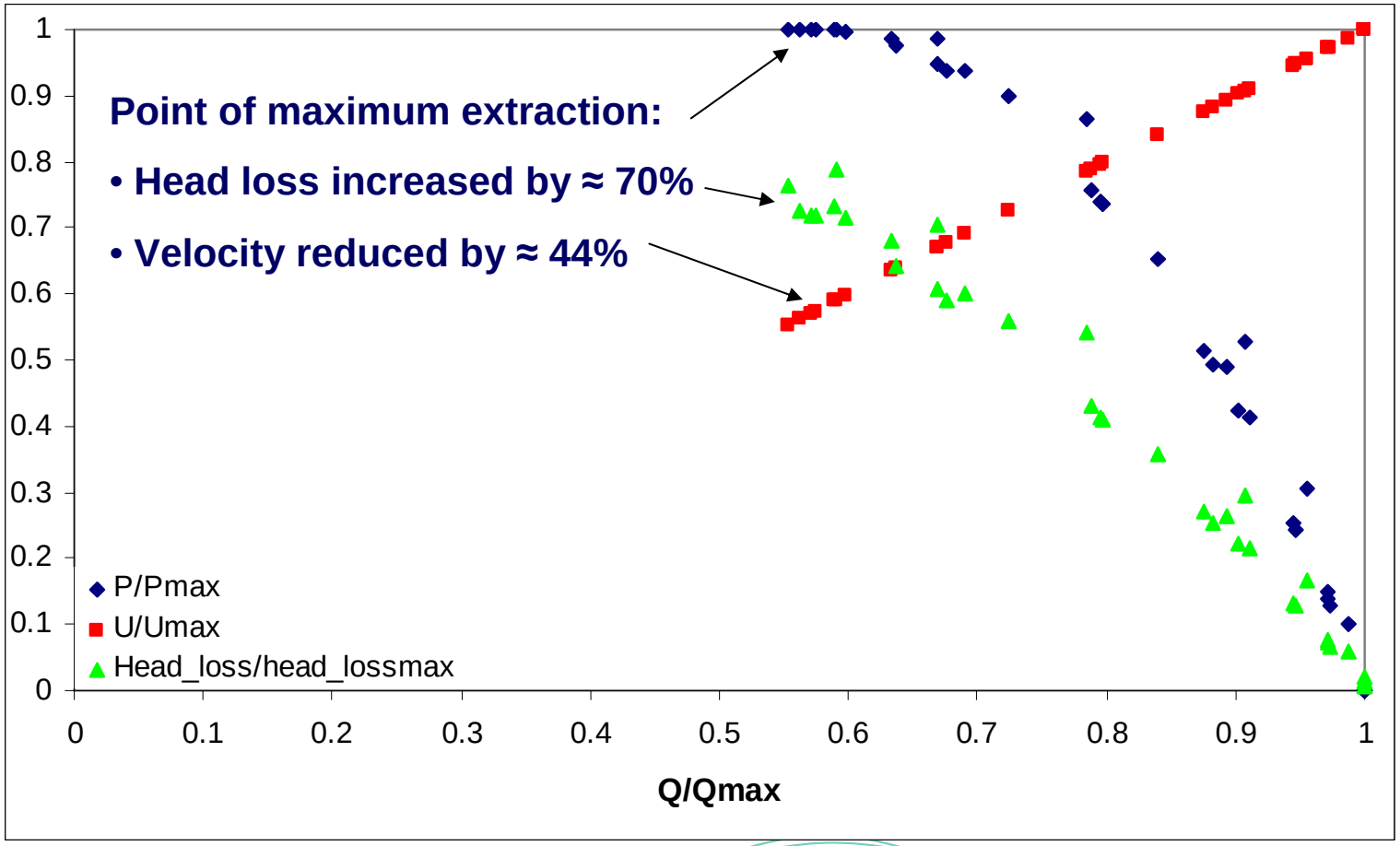


Compendium of all hydraulic current case numerical model results.

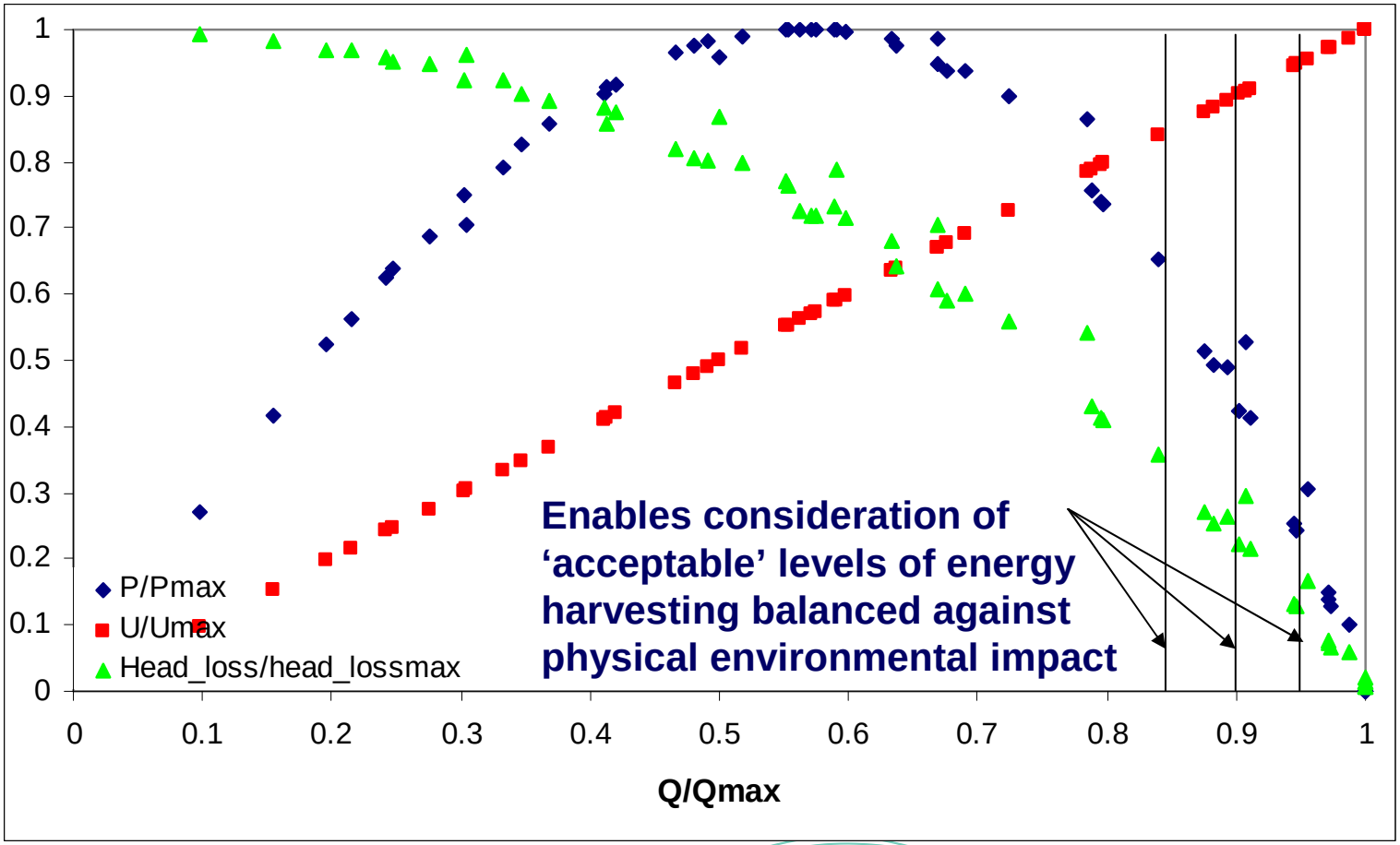
Consistent non-dimensional response (i):



Consistent non-dimensional response (ii):

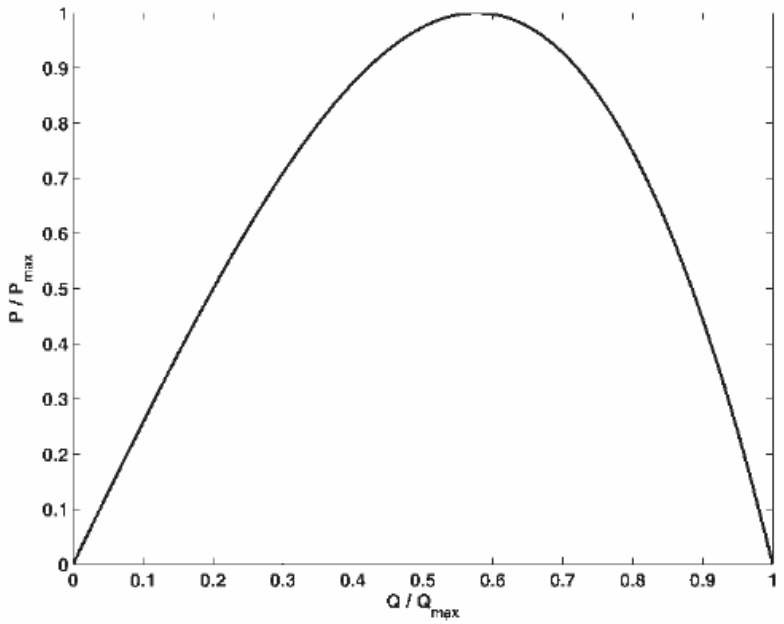


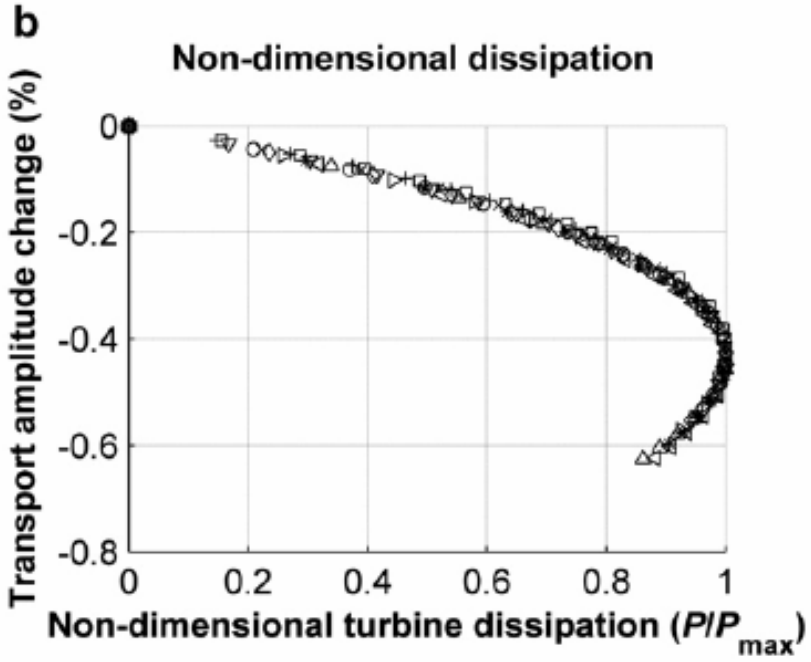
Consistent non-dimensional response (iii):



Compendium of all hydraulic current case numerical model results.

Analytical solutions proposed in the literature:





- **Both relate extractable power to flow discharge rate.**

Left: Sutherland, Foreman & Garrett (2007) Proc. IMechE, Vol 221, Part A.

Right: Polagye & Malte (2011) Renewable Energy, Vol 36(1),

Finalised parametric solutions:

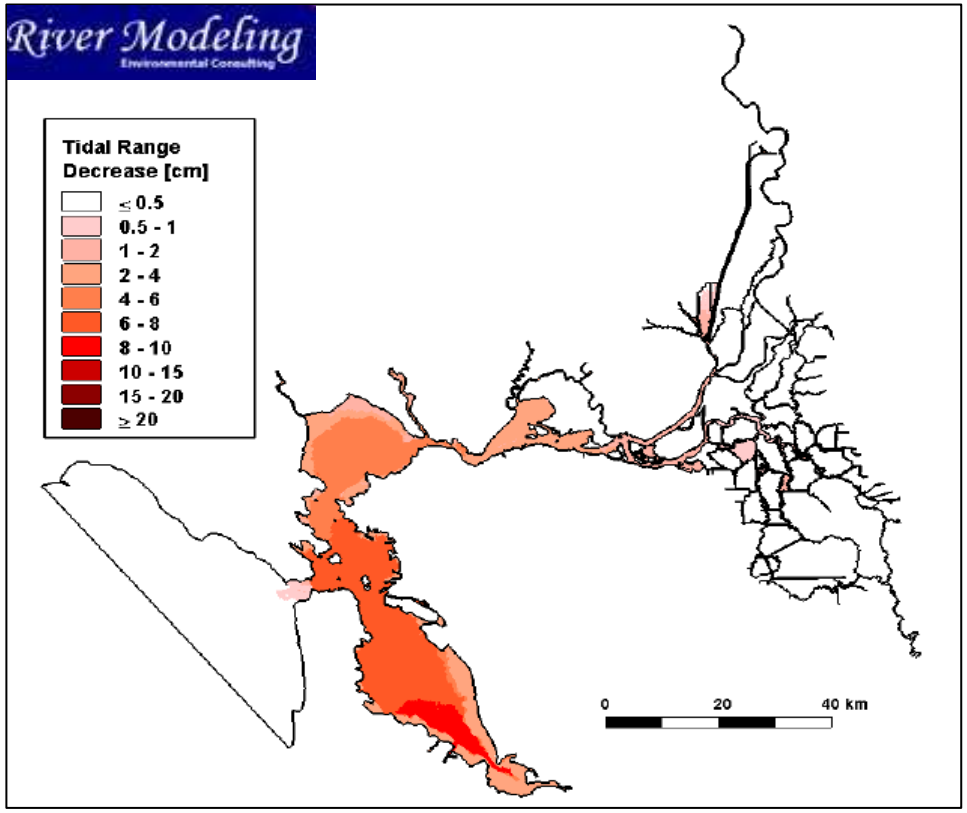
- **Combined analysis of 30Gb worth of numerical model output data – embodied in previous graphs.**

Identified local 'driving' mechanism	Expression of theoretical limit of tidal current energy harvesting.	Expression of 'environmentally acceptable' limit of tidal current energy harvesting.	Hydrodynamic response limiting energy harvesting.
Hydraulic current	$P_{Theoretical} = 0.2\rho g Q_{\max} a_o$	$P_{acceptable} = 0.086\rho g Q_{\max} a_o$	Velocity reduction
Resonant basin	$P_{Theoretical} = 0.2\rho g Q_{\max} a_o$	$P_{acceptable} = 0.033\rho g Q_{\max} a_o$	Downstream tidal range
Tidal streaming	$P_{Theoretical} = 0.16\rho g Q_{\max} a_o$	$P_{acceptable} = 0.020\rho g Q_{\max} a_o$	Downstream tidal range

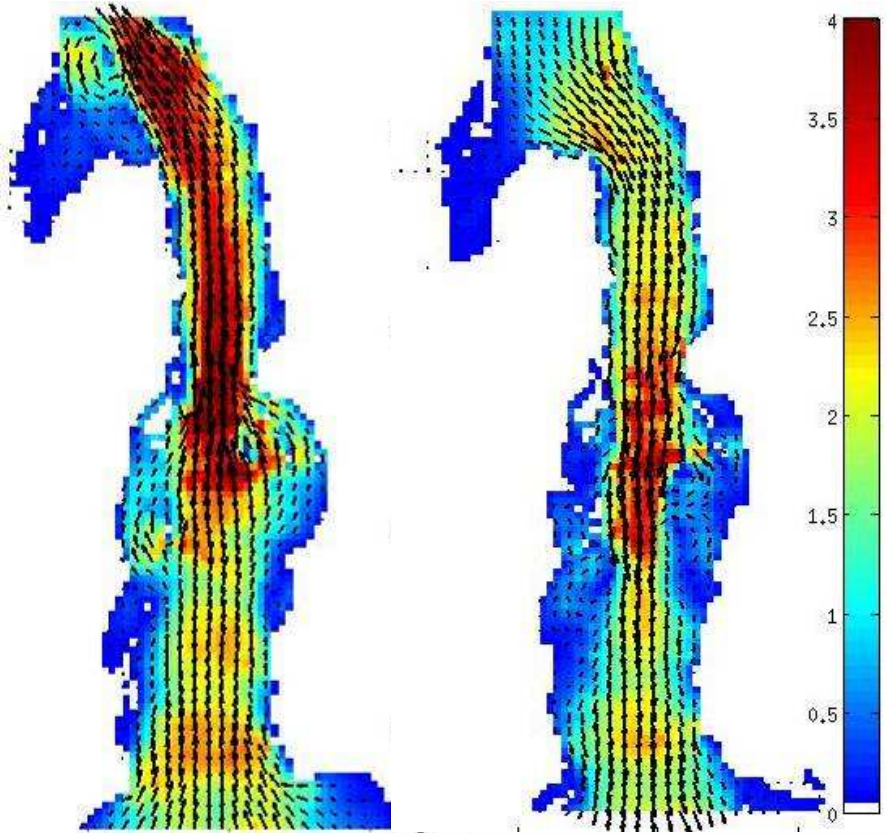
- **Caveats:**
  - **No explicit modelling of turbulent wake**
  - **No differentiation between energy 'harvested'.**

Resource assessment methodologies

Real world validation test-cases:



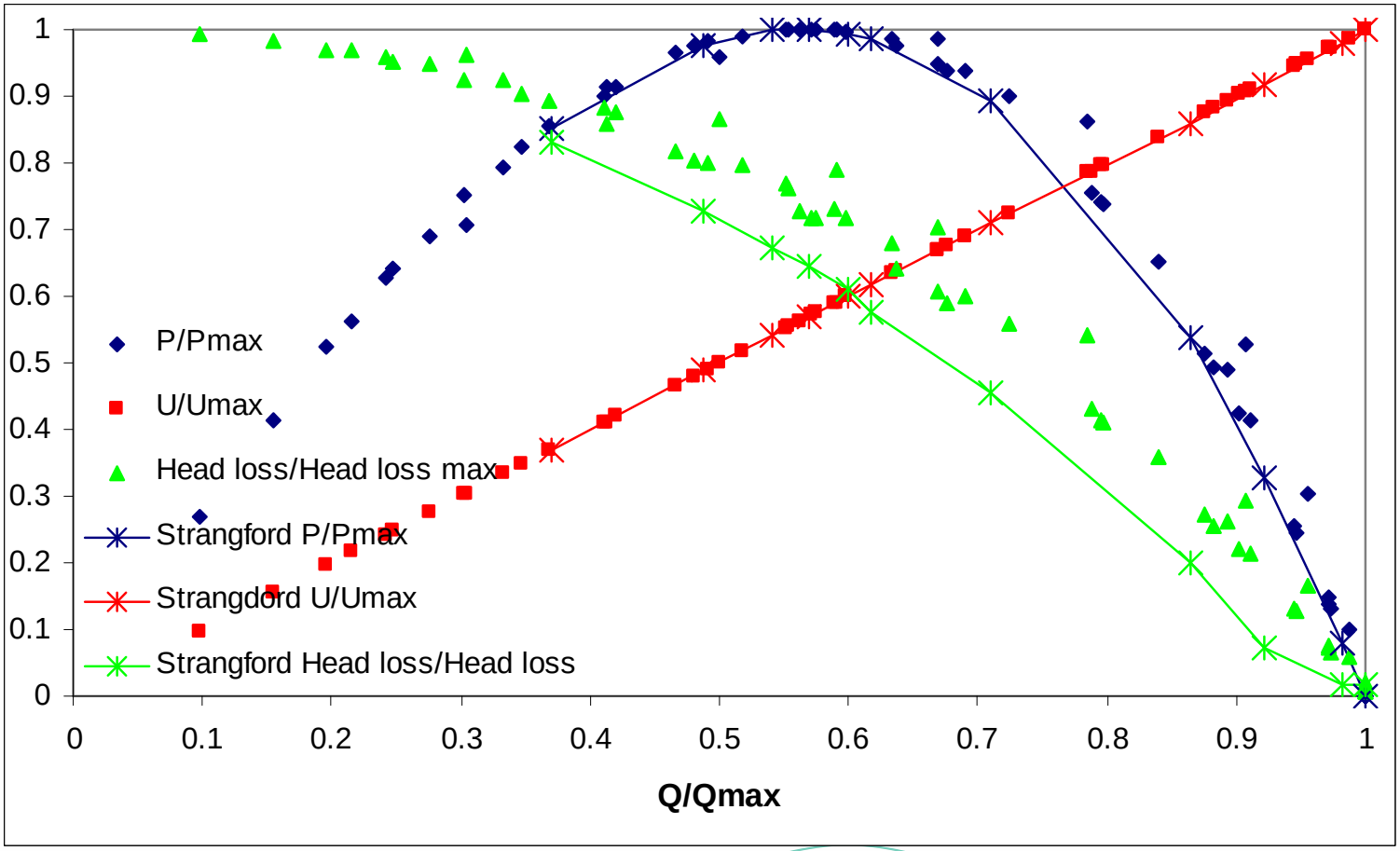
San Francisco Bay (River Modelling).



Strangford Narrows (subset of domain).

Resource assessment methodologies

Comparing Strangford Narrows simulation with theory:

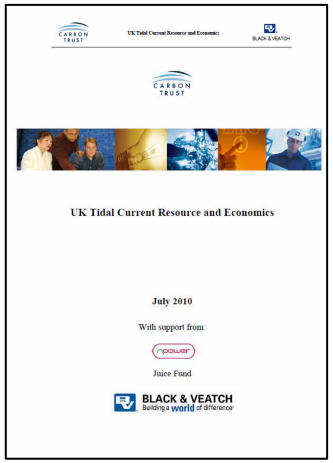


Conclusions

- **Robust repeatable methodology developed.**
- **Analysis outcomes for tidal current energy*:**

2004-5 Marine Energy Challenge

18.6 TWh/year (5% UK demand)



2008-10 Marine Energy Accelerator

Significant increase

*** Analysis conducted by collaborators at Black & Veatch Consulting Ltd.**