Flood Risk Implications for the Proposed New Severn Barrage

by

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Research Funding

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General Challenges

- Growing world-wide increase in demand for energy - particularly in India and China
- Tidal energy generation has advantage over wind and waves - tides are predictable
- UK target of 15% of energy from renewables by 2020 ➢ about 35% of electrical energy
- Wales' 2025 target for wave and tidal renewable energy is 4 GW - Barrage would meet this target
- Severn Estuary basin is ideal for tidal energy

Potential Power from Tides

- For tidal barrages and impoundments:-

$$\text{Power} \propto A\,H^2$$

A = wetted surface area upstream of a barrage
H = water level difference across a barrage/lagoon

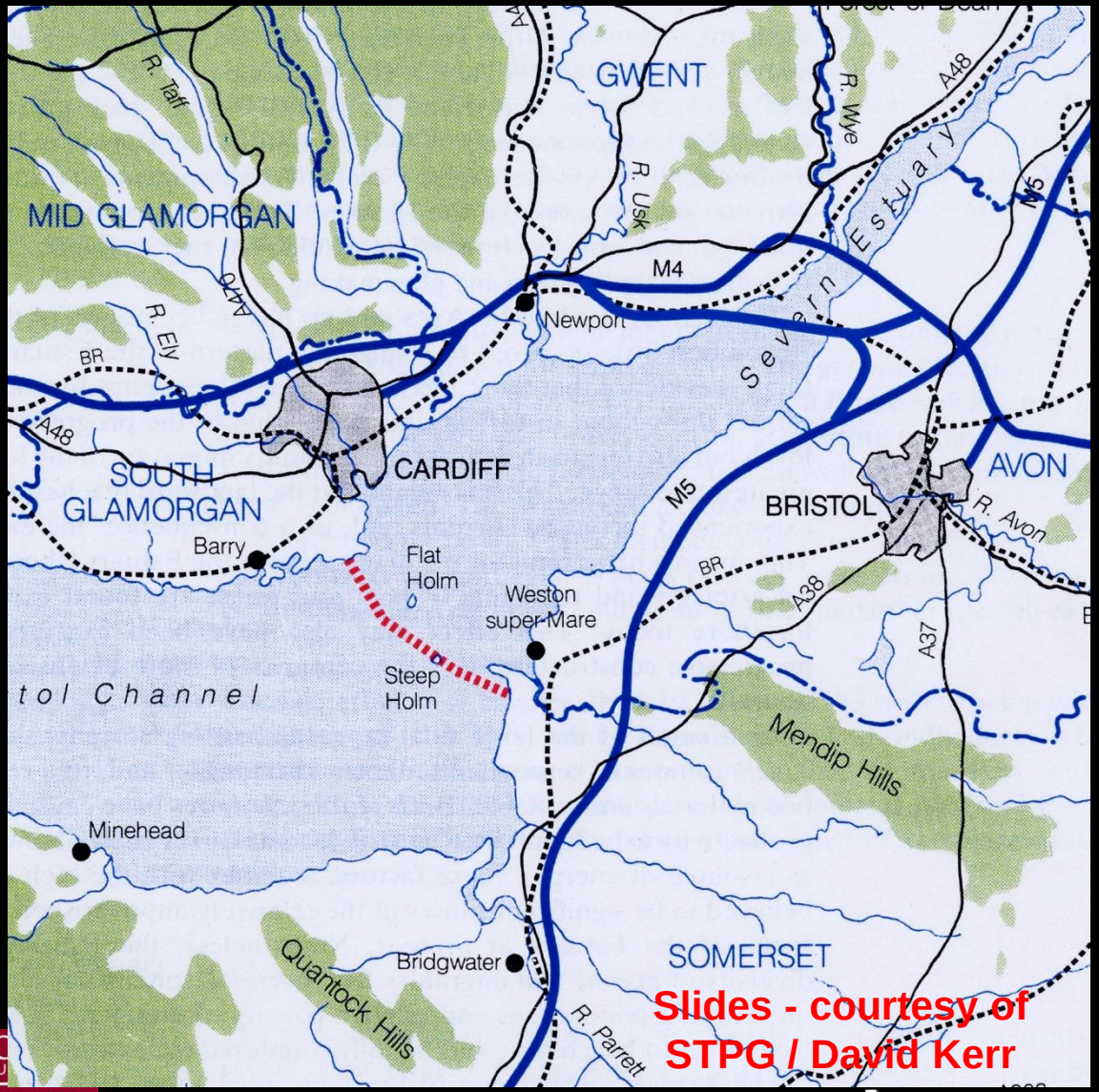
Why the Severn Barrage?

Cardiff-Weston line: **A** = 500 km^2 ≈ 1.5 x Lake Garda

H ≈ 7m for STPG scheme - with ebb generation only

H ≈ 3m for VLH turbines - but generate on ebb & flood

Severn Tidal Power Group Scheme

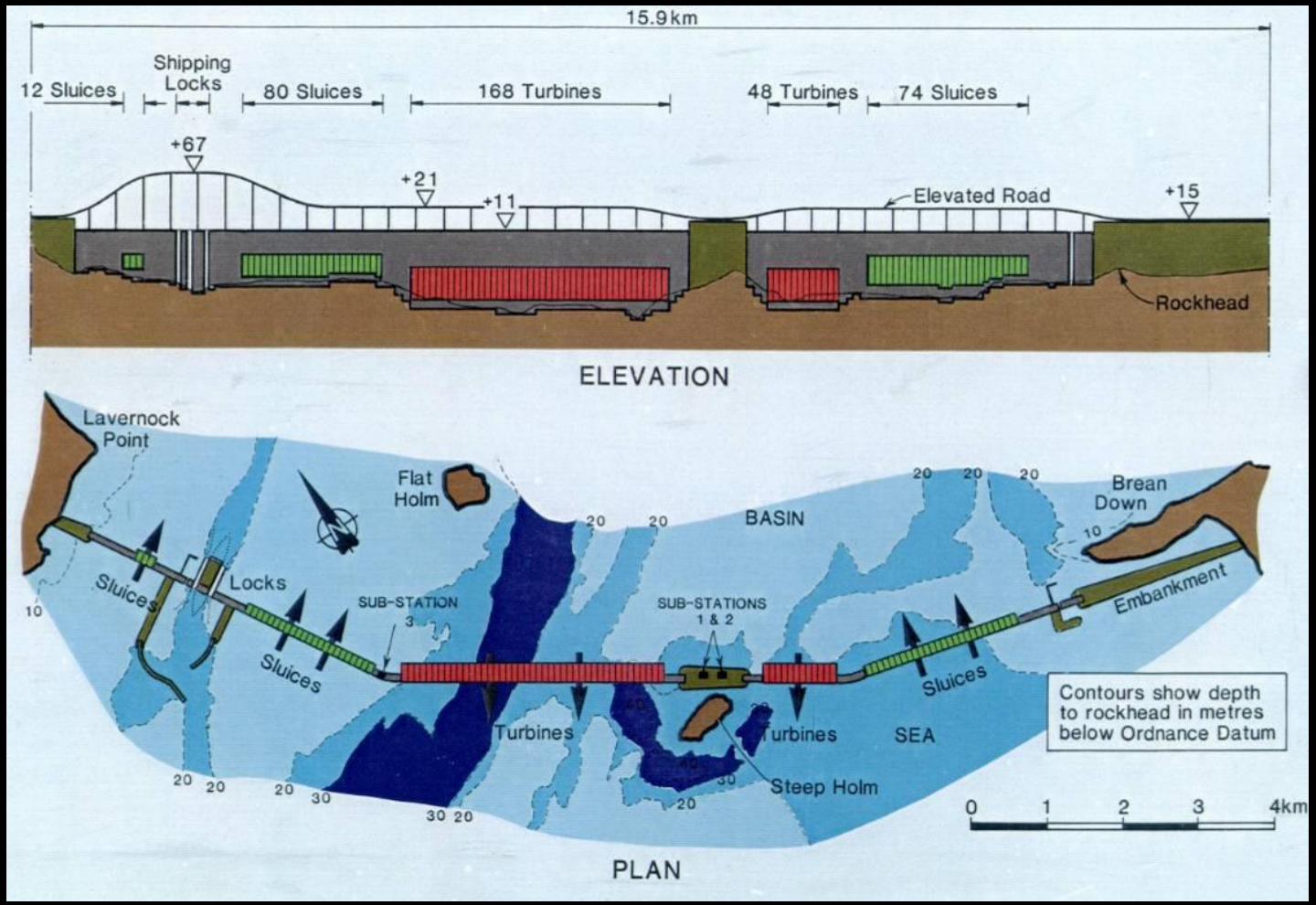


Some key facts:

- 2nd highest spring tidal range ≈ 14 m
- Cardiff to Weston
- Length about 16 km
- Generate ≈ 5% of U.K. electricity
- Total cost ≈ £20 bn
- Save > 6.8 million tonnes carbon pa

Slides - courtesy of STPG / David Kerr

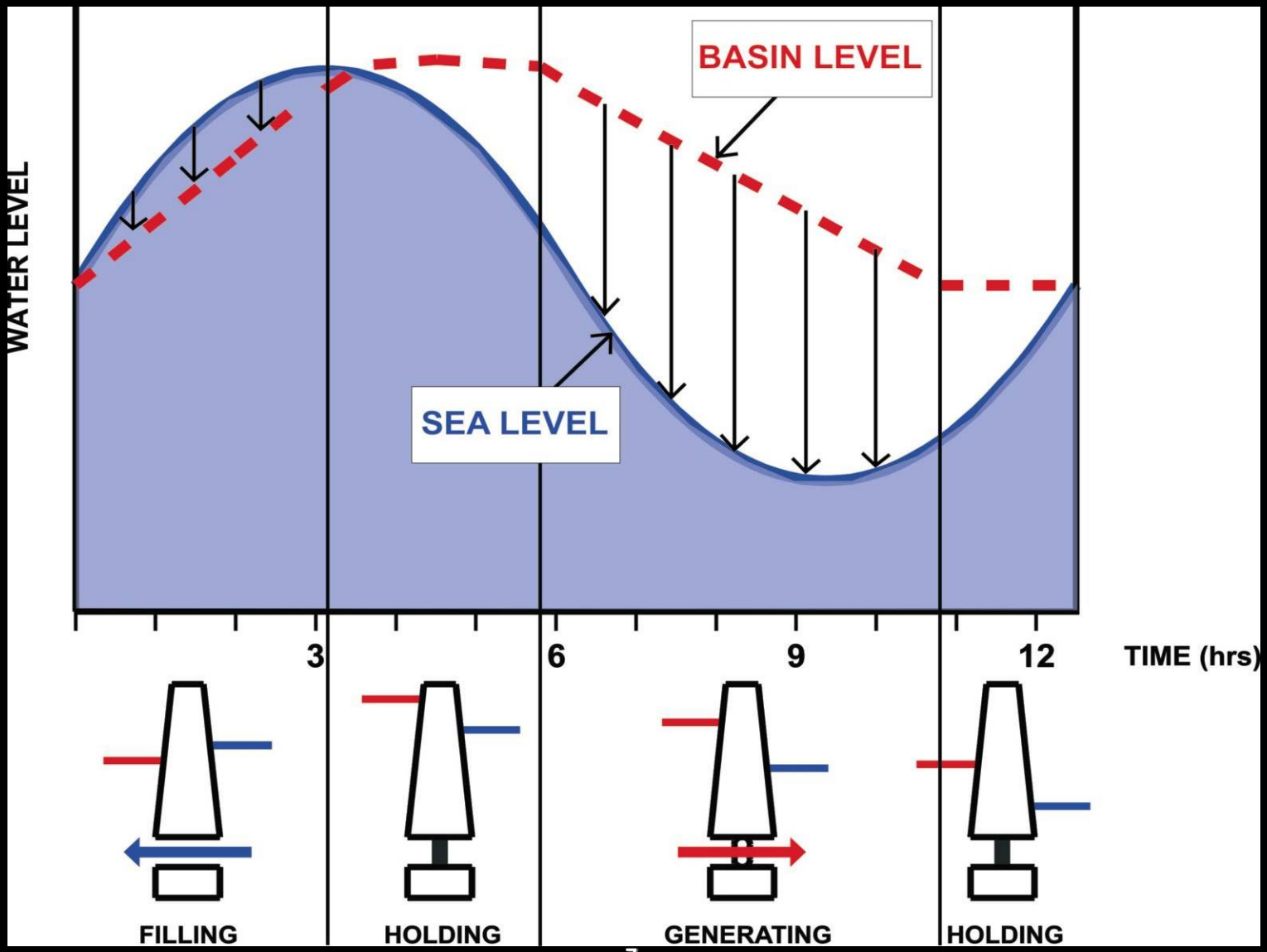
STPG (1989) Severn Barrage Layout



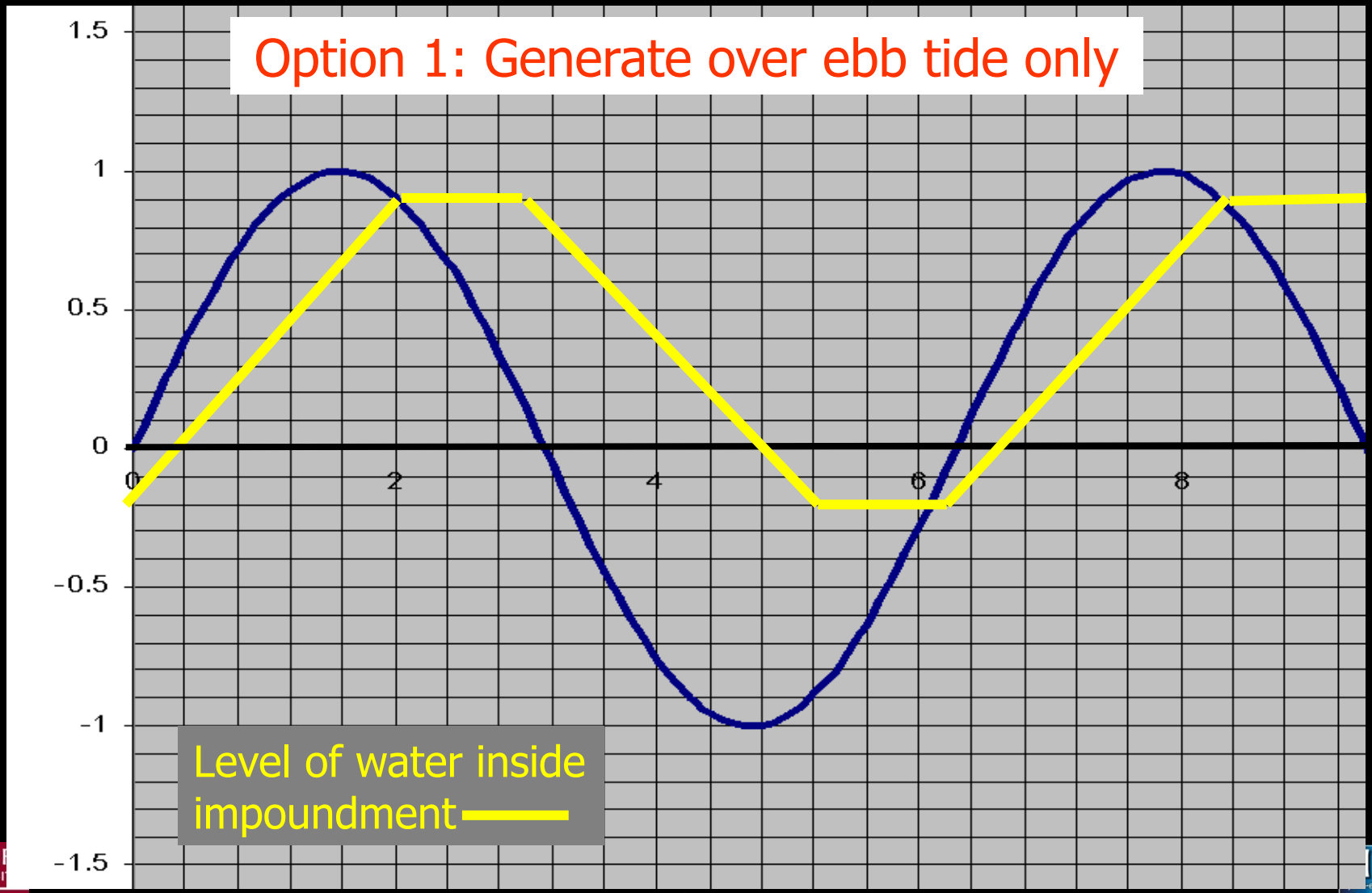
Key facts:

- 216 turbines each 40 MW ≈ 17 TWh/yr
- 166 sluices
- Ship locks
- Fish pass?
- Public road & railway

STPG Operation - Ebb Generation



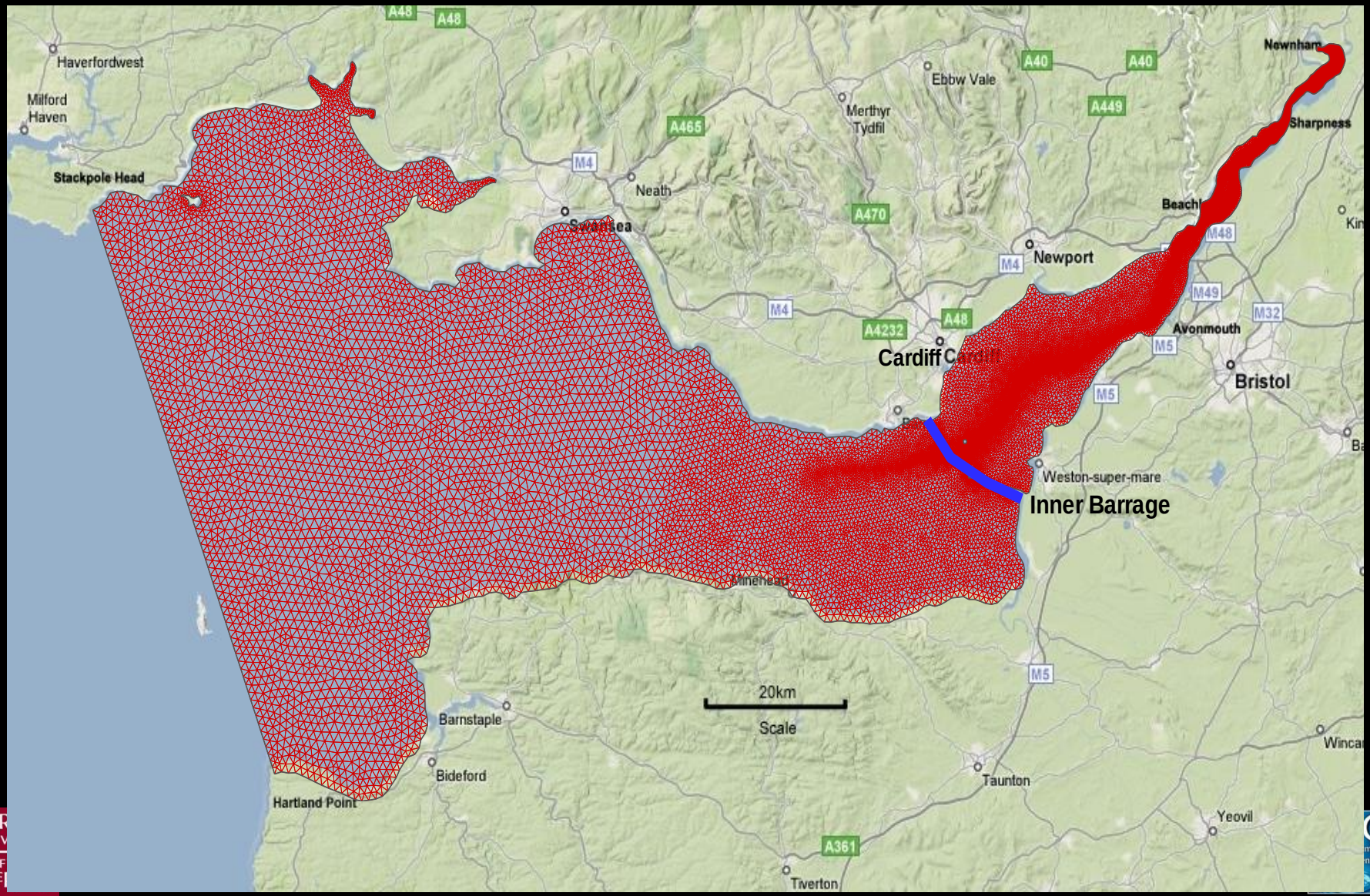
STPG Scheme: One Way Generation



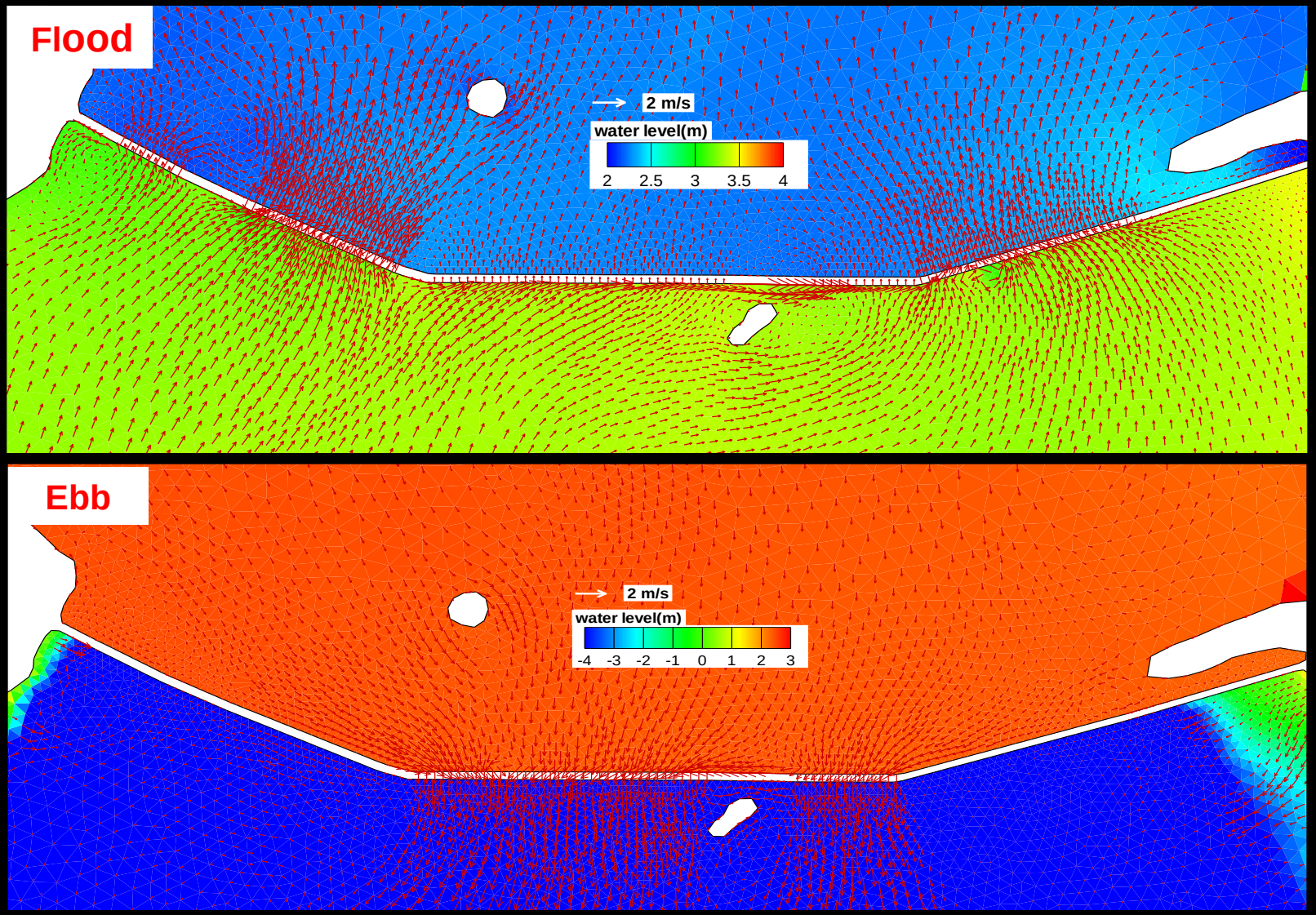
Existing Estuarine Environment

- Tide Range - 14 m on springs, 7 m on neaps
  - High tidal currents and large inter-tidal areas
  - 30 Mt sediment suspended on springs, 4 Mt neaps
  - Little sunlight penetration through water column
  - Reduced saturation dissolved oxygen levels
- Ecology
  - Harsh estuarine regime with high currents
  - Limited aquatic life in water column / bed
  - Bird numbers per km^2 are relatively small

Severn Barrage - Grid Configuration



Velocity Field Around STPG Barrage

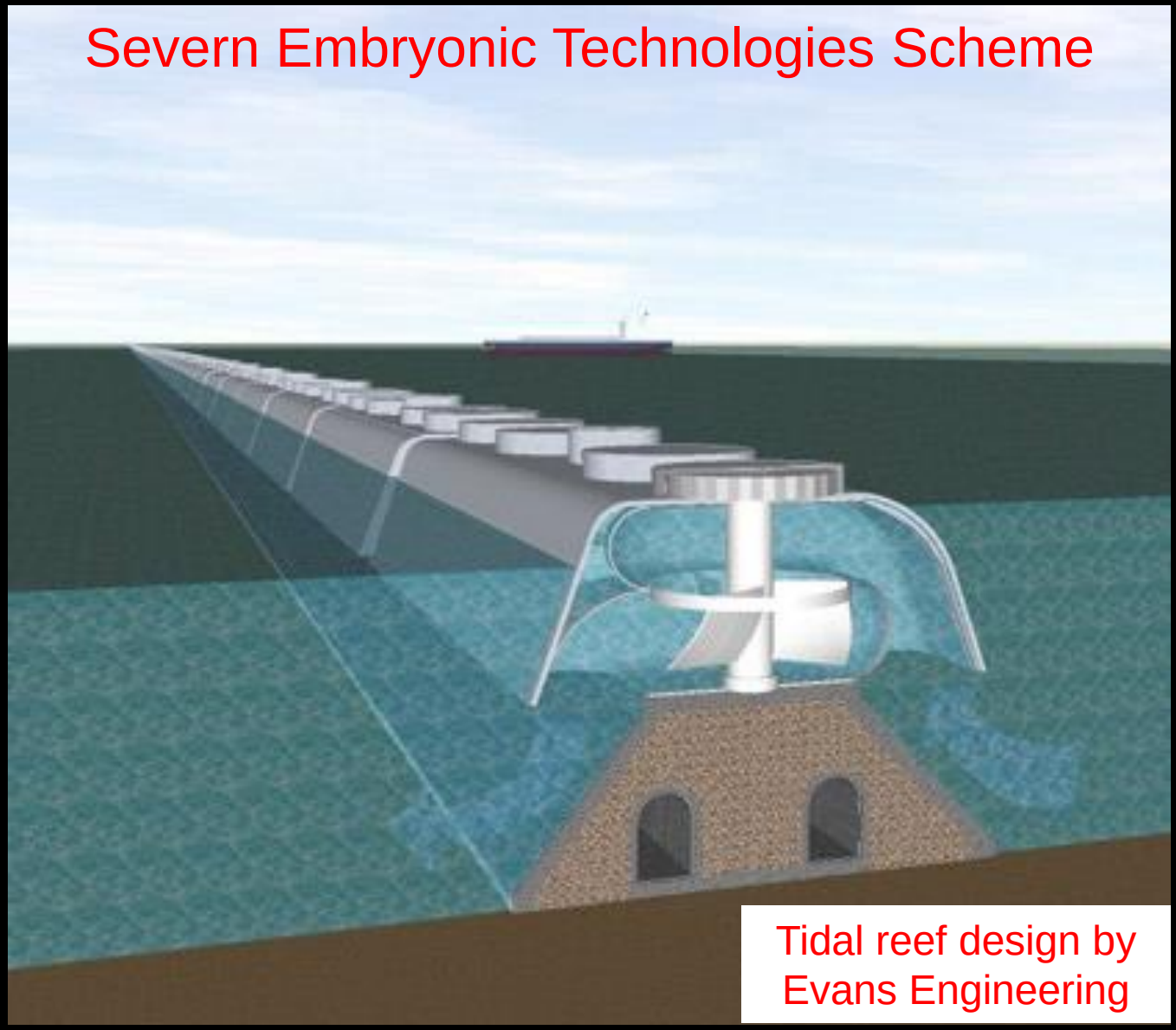


Main Effects of STPG Barrage

- Spring tide range reduced from 14 m to 7 m
  - Significant loss of upstream inter-tidal habitats
  - Reduced currents up & downstream of barrage
  - Reduced turbidity / suspended sediment levels
  - Increased light penetration through water column - with increased water clarity
  - Increased primary productivity and changed bio-diversity of benthic fauna and flora
- Upstream tidal range of 7m still relatively large compared to most deltas world-wide

Tidal Reef - Low Head Scheme

Severn Embryonic Technologies Scheme



Tidal reef design by
Evans Engineering

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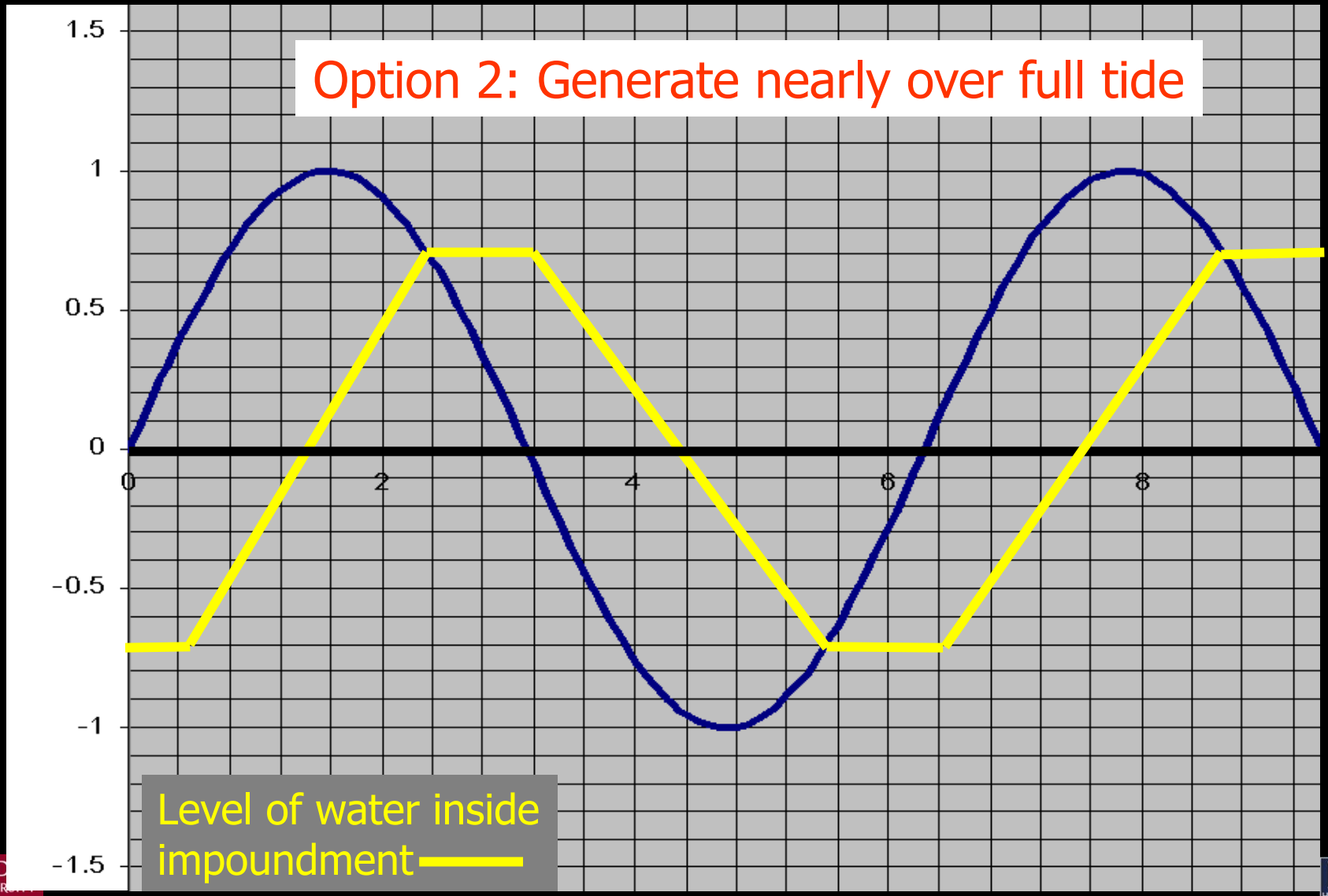
Hydro-environmental
Research Centre

Alternative: Two Way Generation

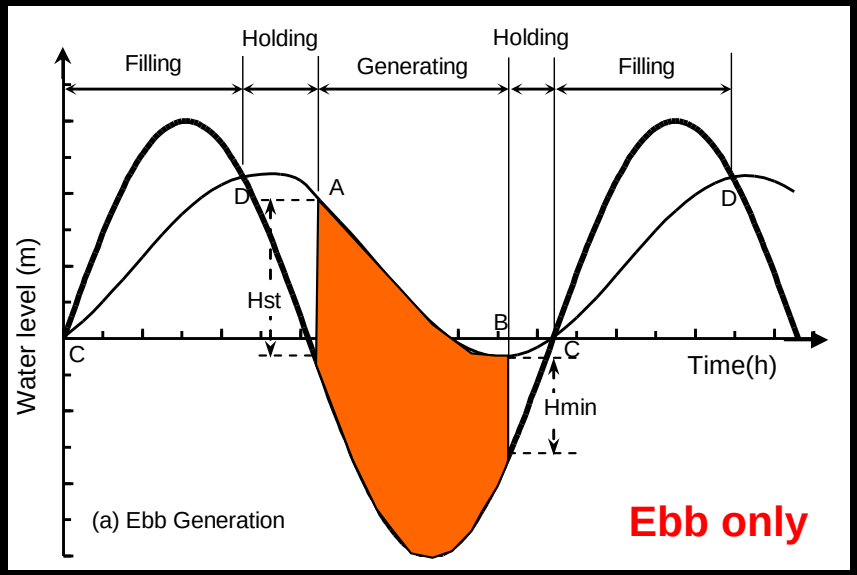


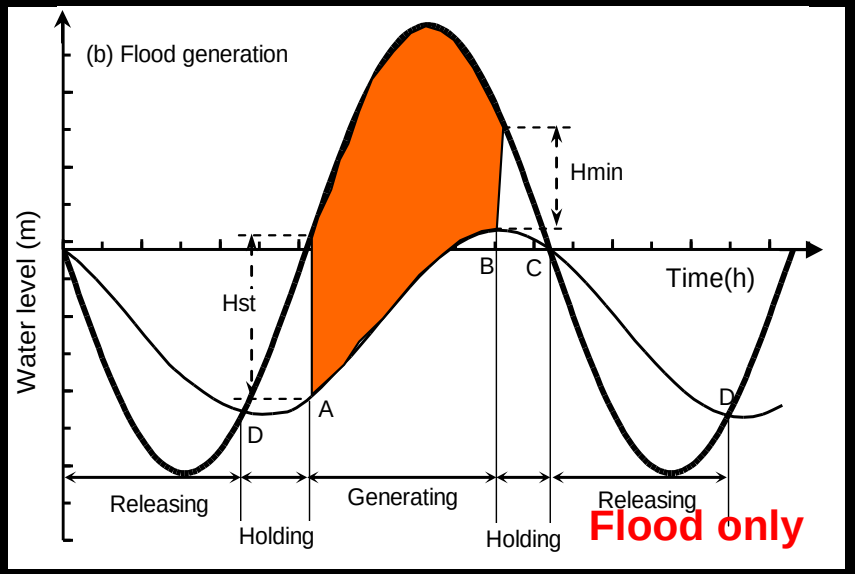
Hafren Power Severn Barrage Scheme

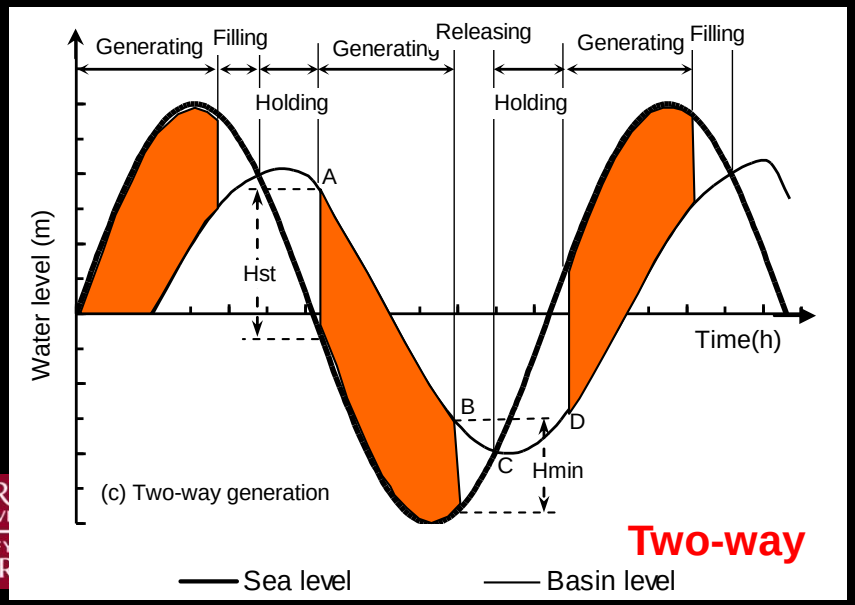
Some key facts:

- 1026 VLH turbines each 9m, 6.3MW ≈ 16.4TWh/yr
- No sluice gates
- Length about 18km
- Total cost ≈ £25bn
- Ship locks
- Save > 7.2 million tonnes carbon pa
- Road/rail, fish pass?

Three Modes of Operation Studied



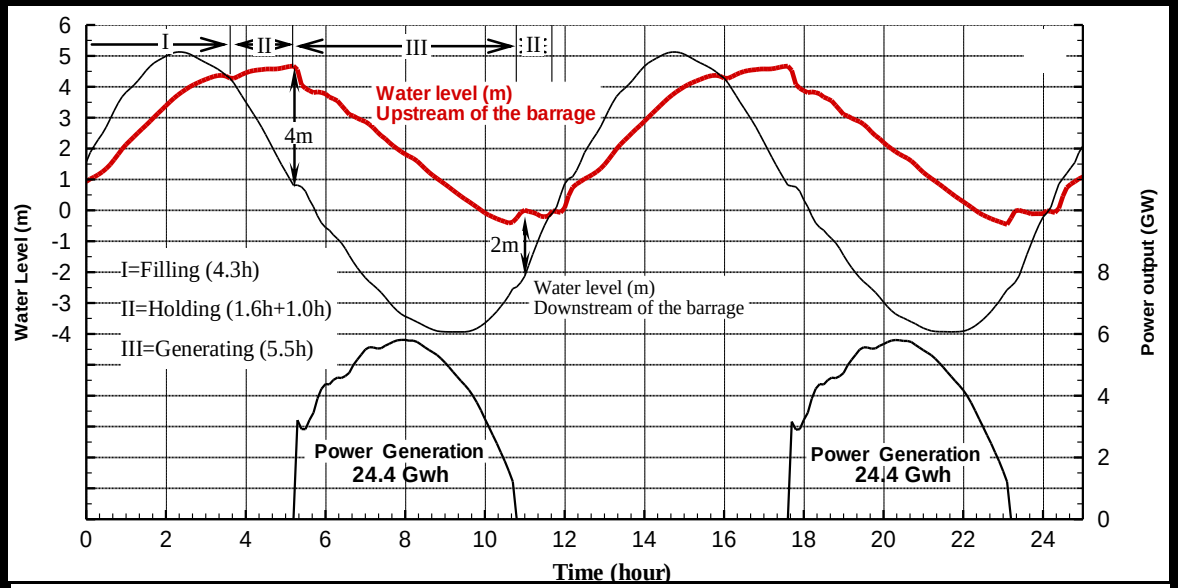




Model predictions resulted in peak power output for:-

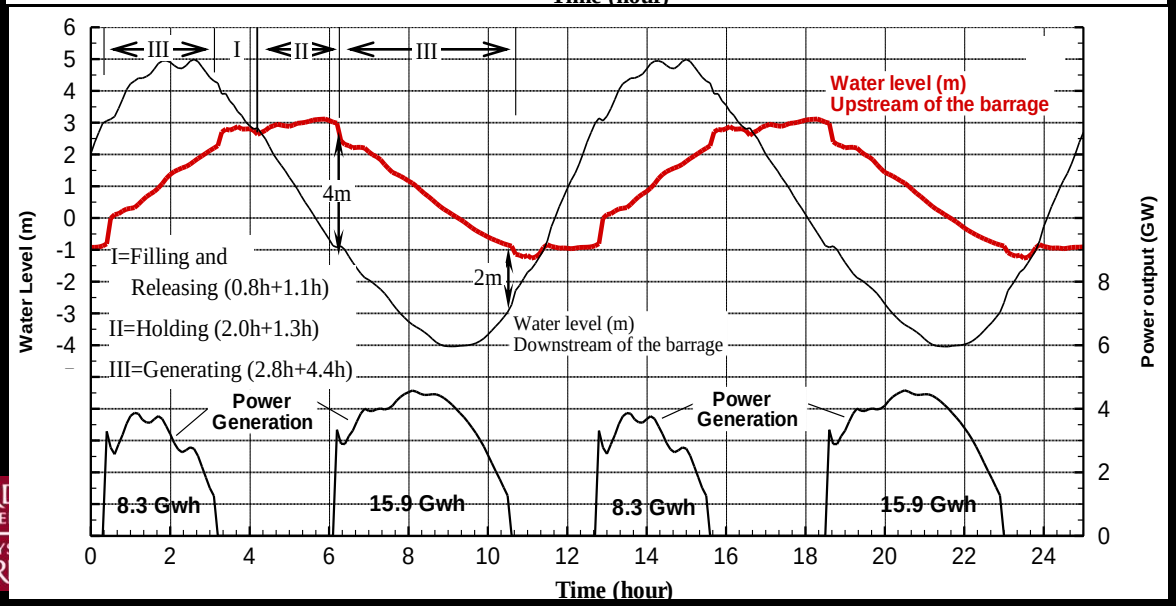
- **Starting Head = 4.0 m**
- **Minimum Head = 2.0 m**

Water levels and Power Output



Ebb Only

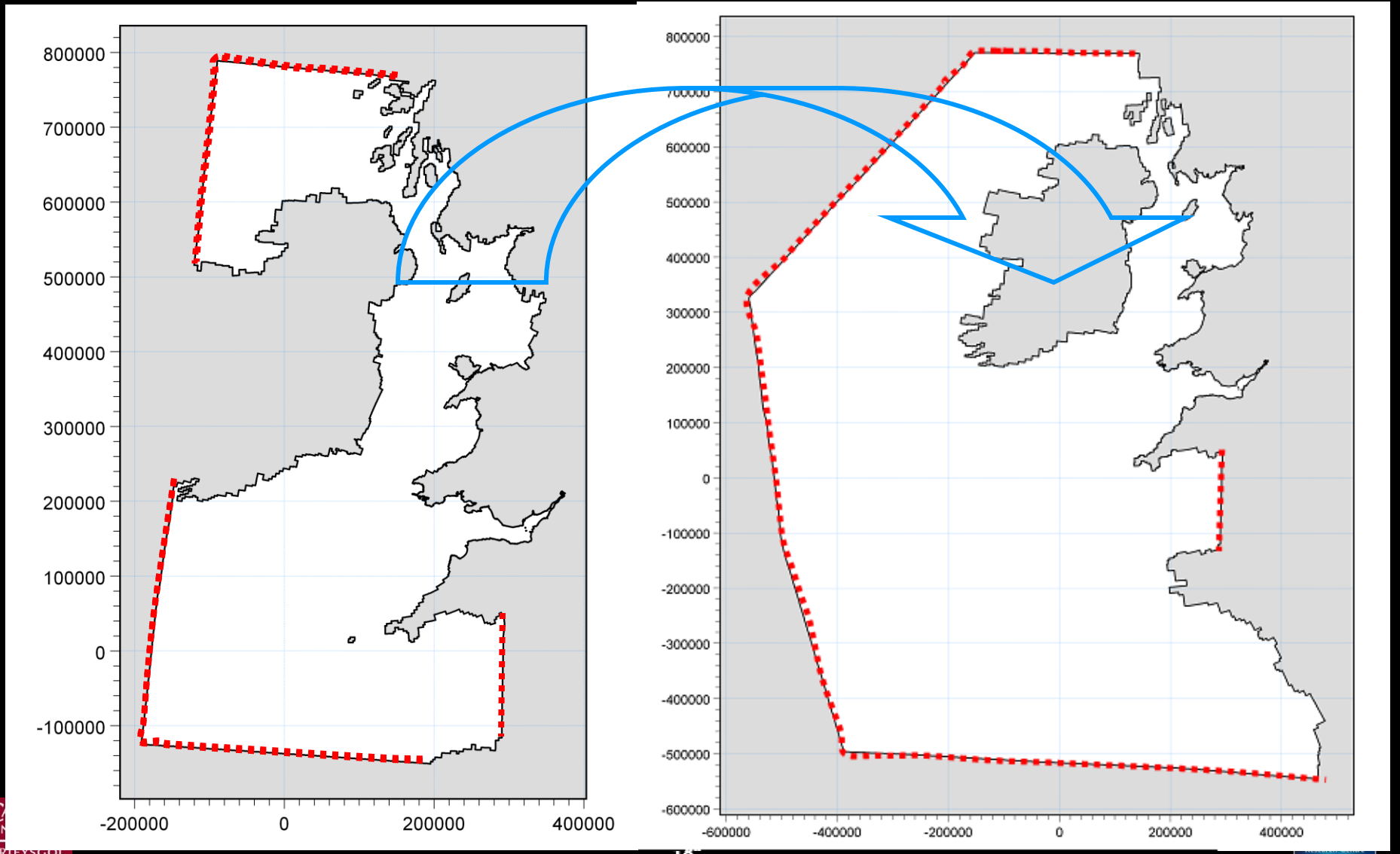
- 48.8 GWh/24.8h
- 5.2 m mean tide
- High tide 4.6 m



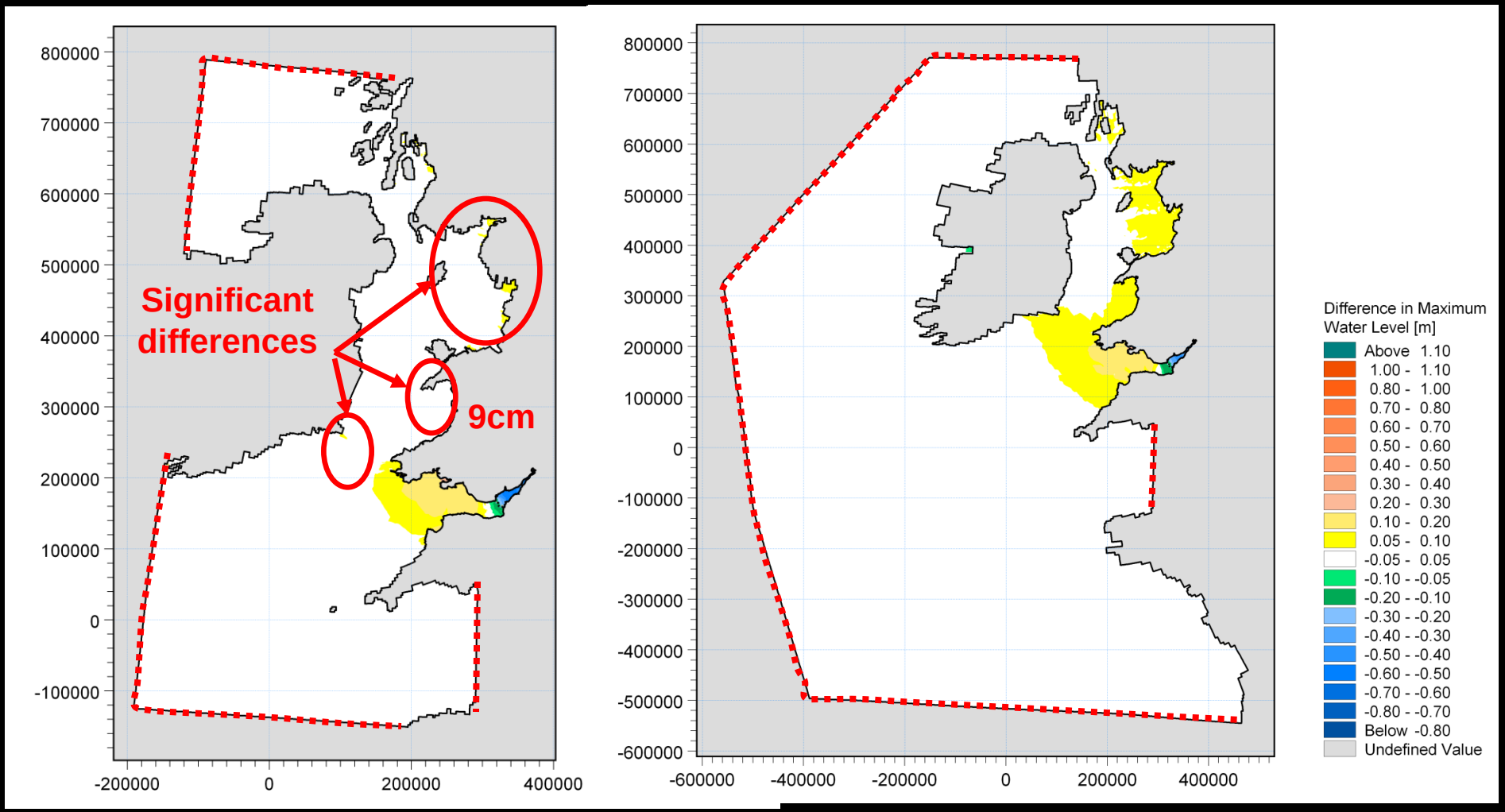
Two-Way

- 48.4 GWh/24.8h
- 4.4 m mean tide
- High tide 3.2 m

Irish Sea & Continental Shelf Model



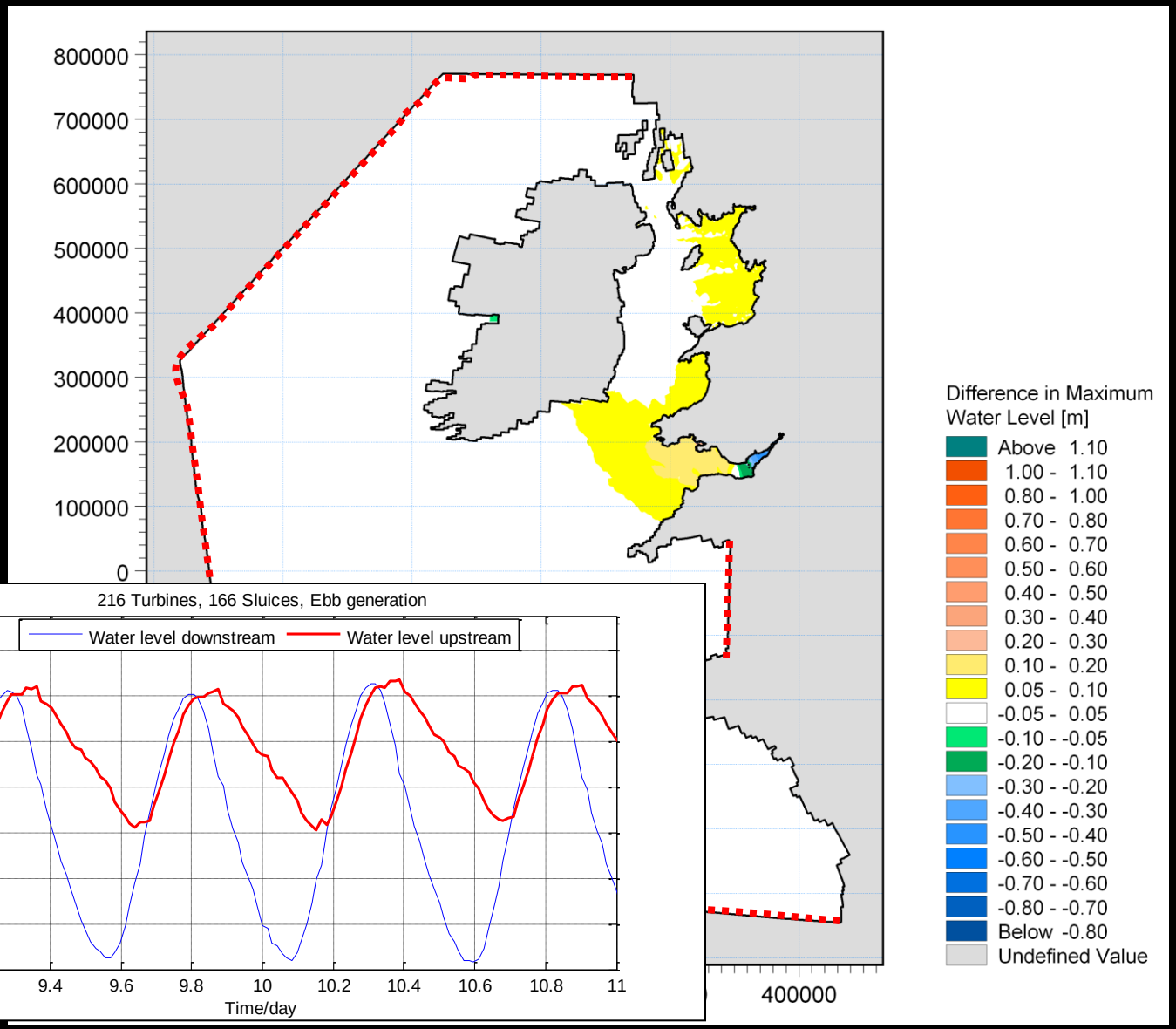
Impacts of Different BC on Far Field



Peak water level differences – Without and With Barrage

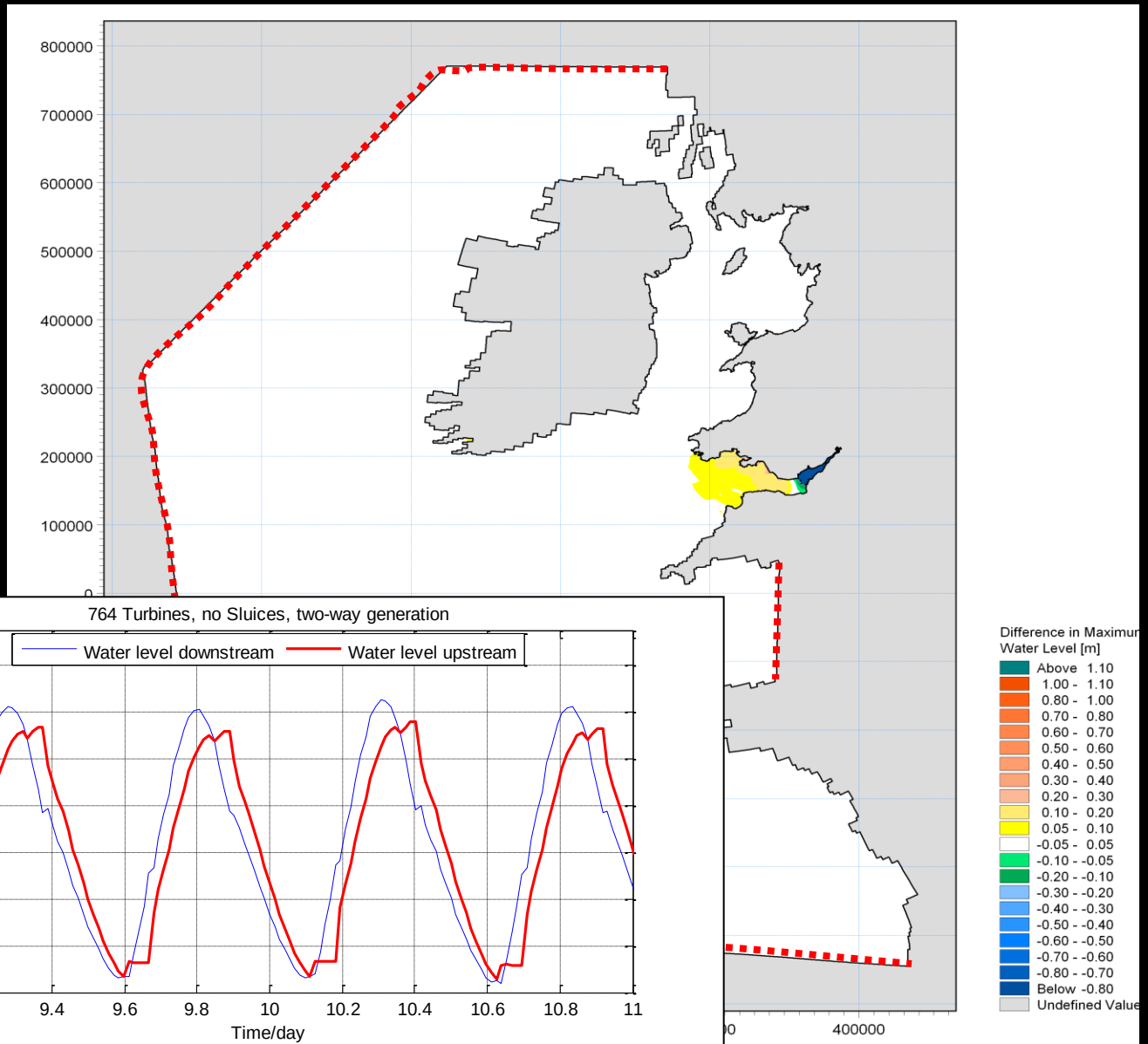
STPG Scheme - Ebb Generation

216 Turbines - 166 Sluices



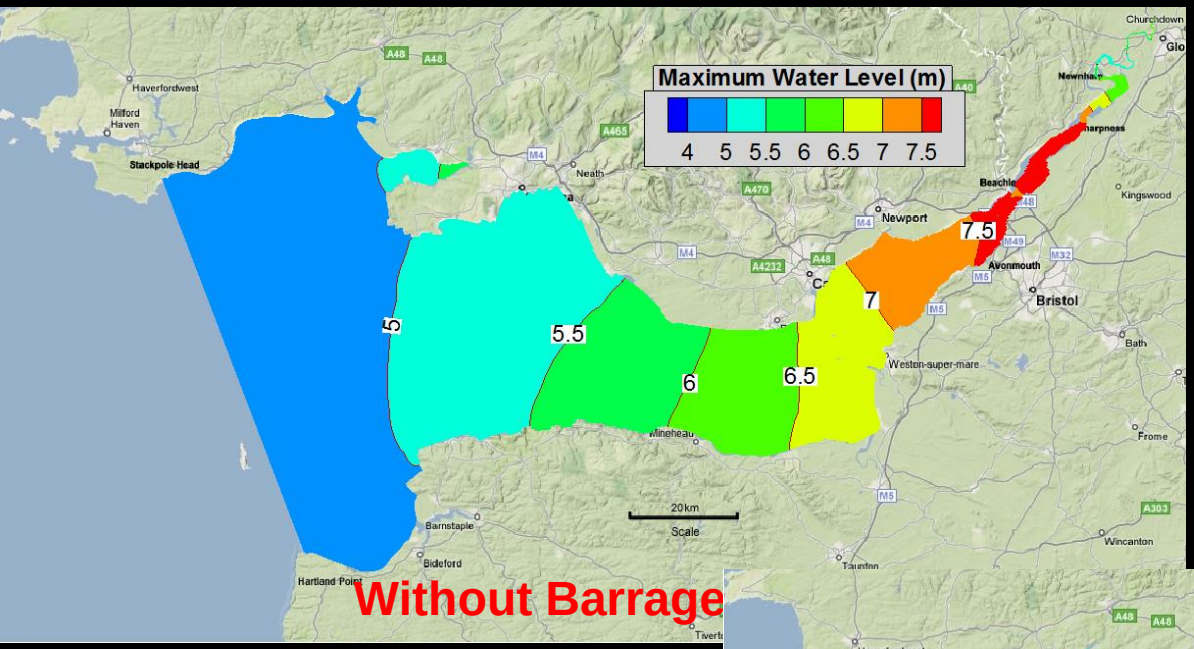
Two-Way Generation

764 Turbines - No Sluices

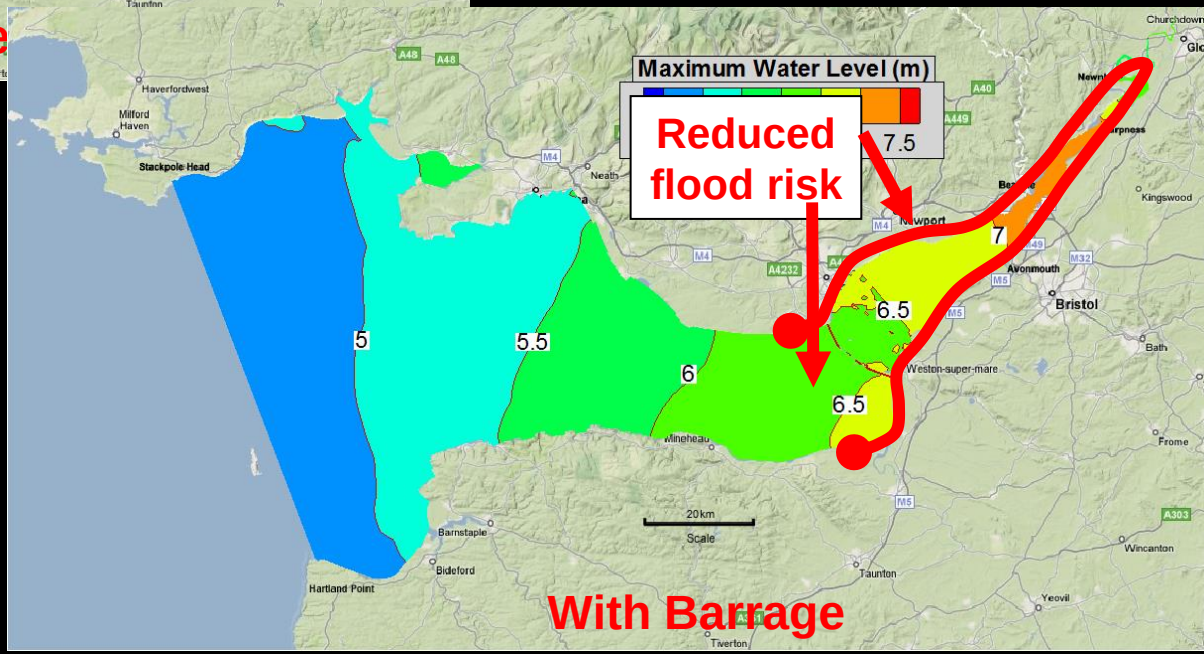


Peak Water Levels - Ebb Only

216 Turbines - 166 Sluices



Without Barrage



With Barrage

Continental Shelf Model Boundary Elevations

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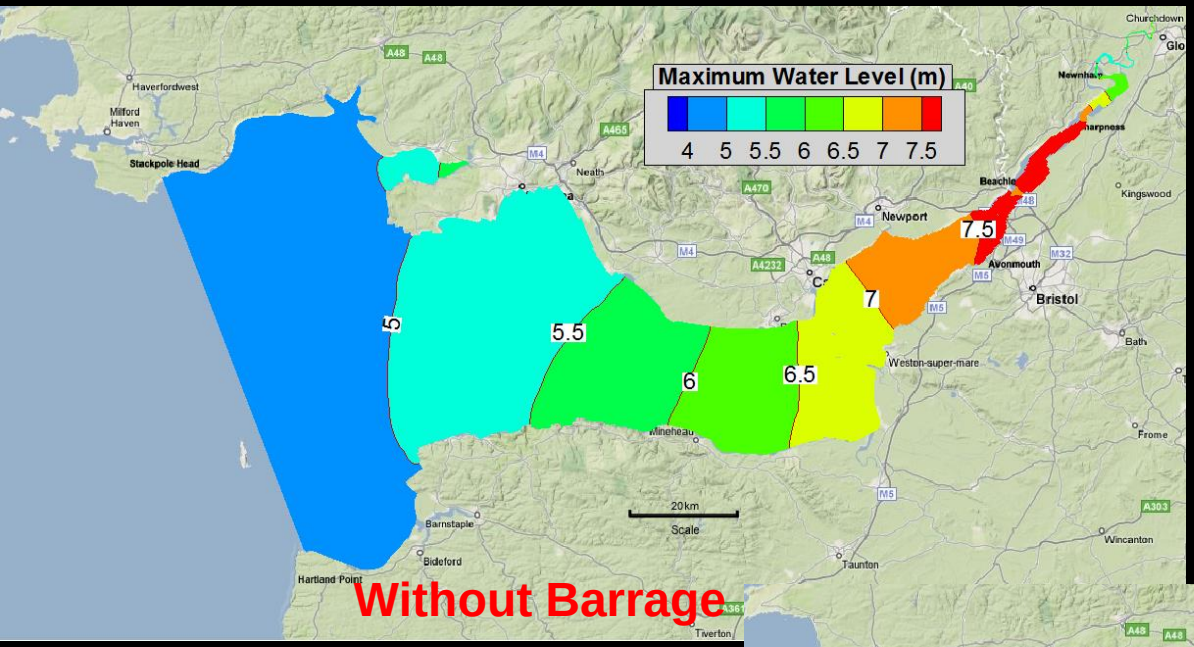
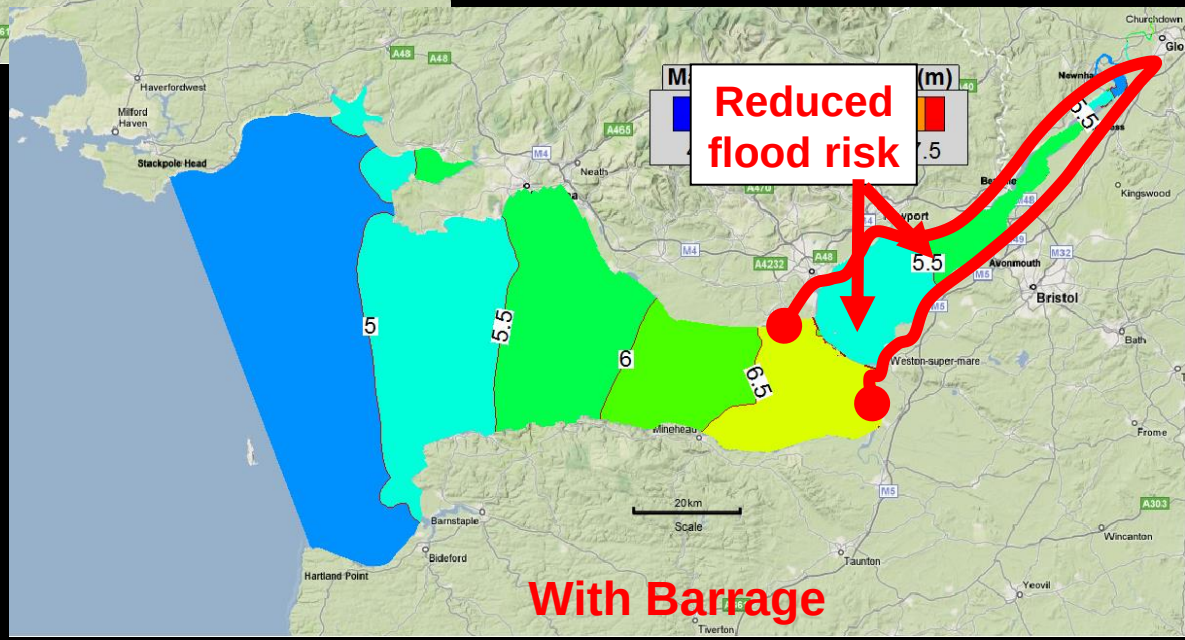
Peak Water Levels - Two Way

764 Bulb Turbines - No Sluices



Without Barrage



With Barrage

Continental Shelf Model Boundary Elevations

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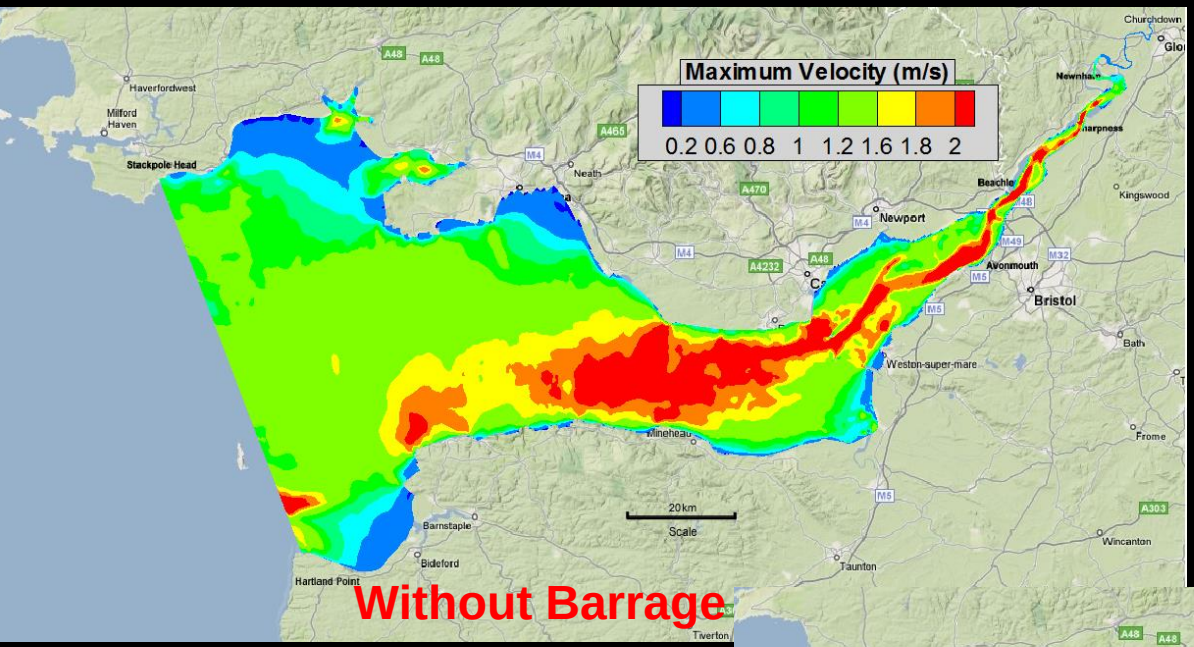
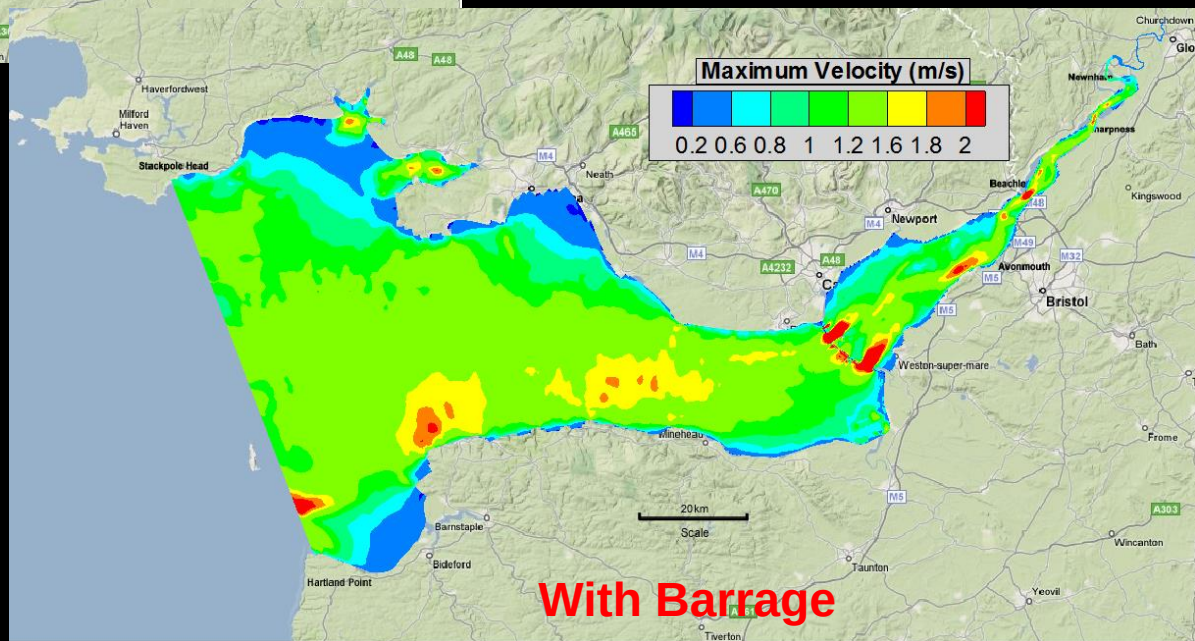
Peak Tidal Currents - Ebb Only

216 Turbines - 166 Sluices



Without Barrage



With Barrage

Continental Shelf Model Boundary Elevations

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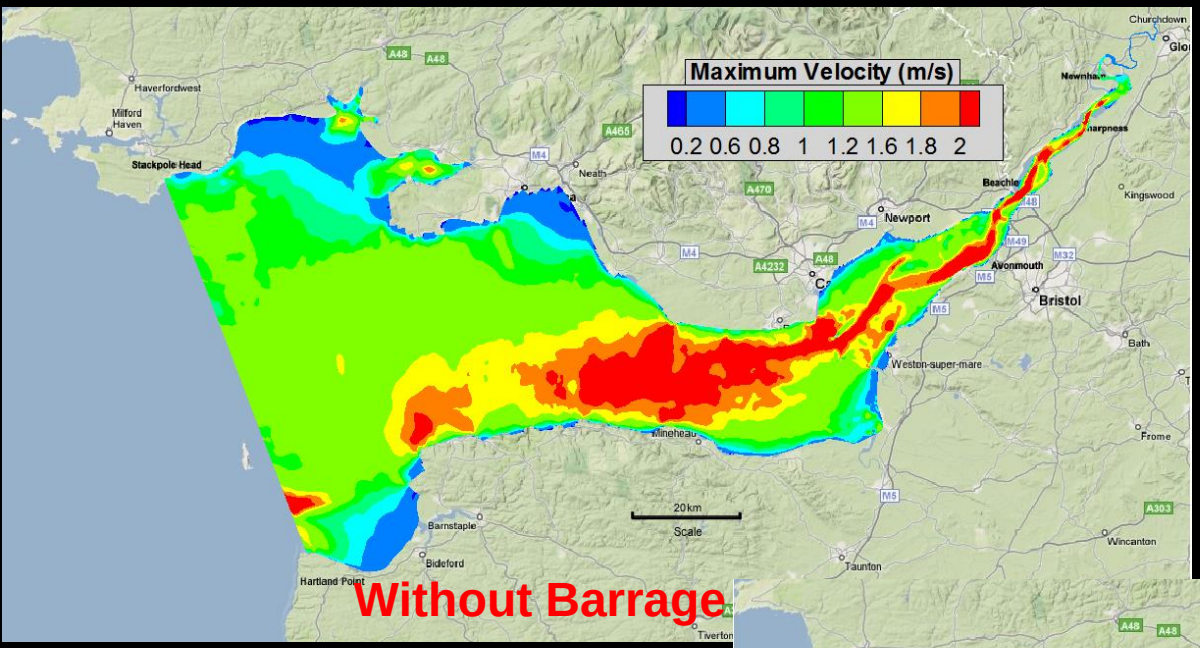
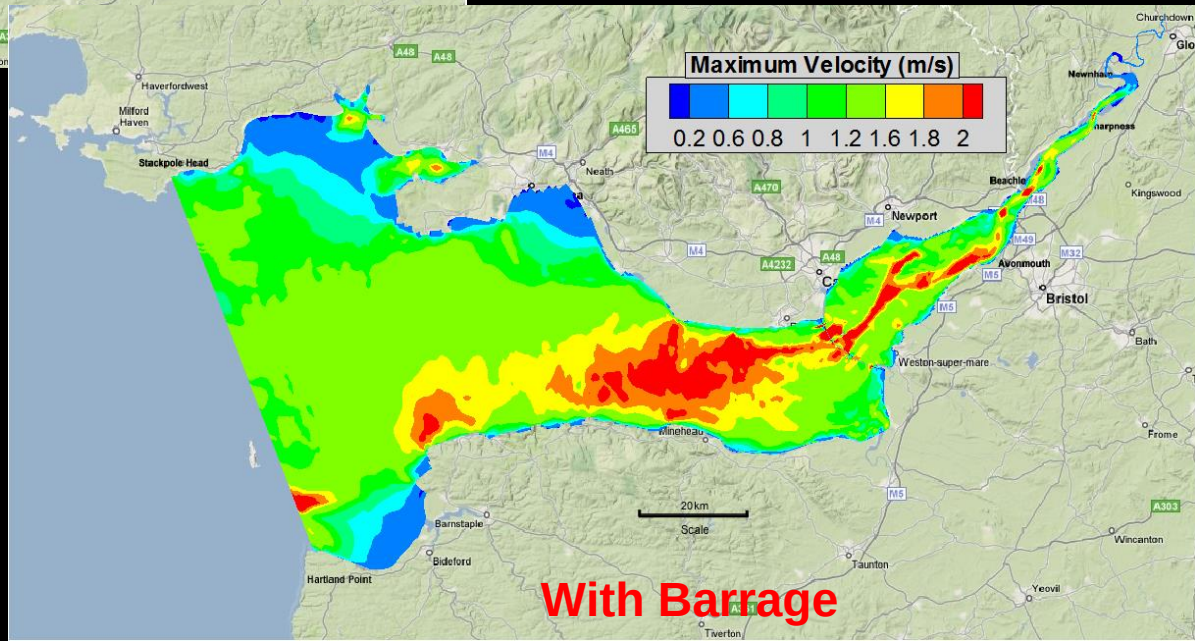
Peak Tidal Currents - Two Way

764 Bulb Turbines - No Sluices



Without Barrage



With Barrage

Continental Shelf Model Boundary Elevations

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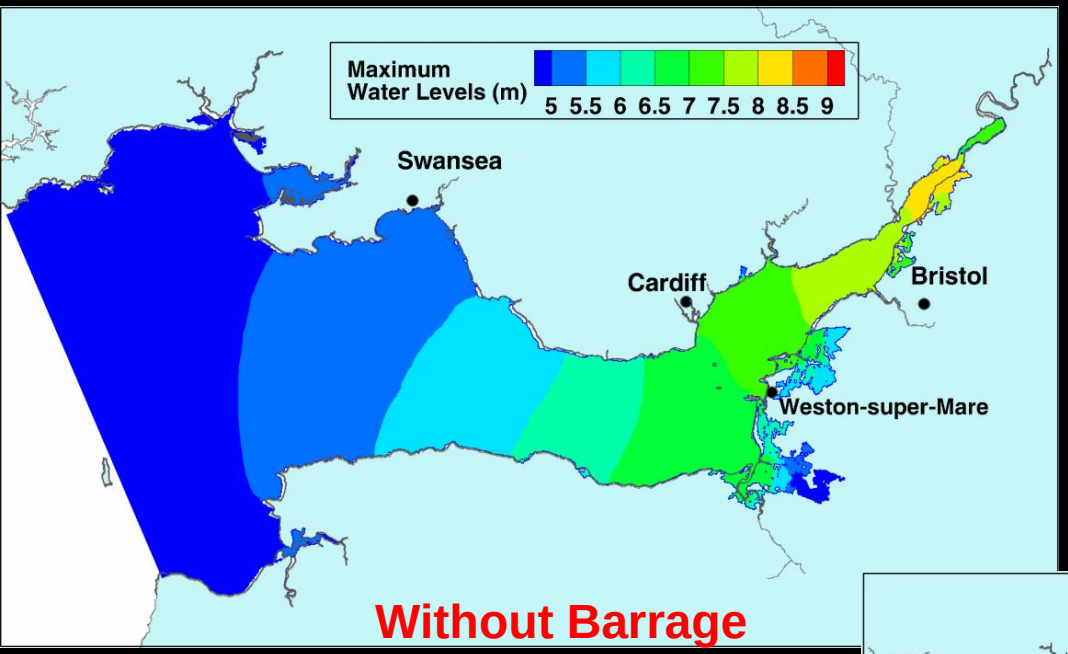
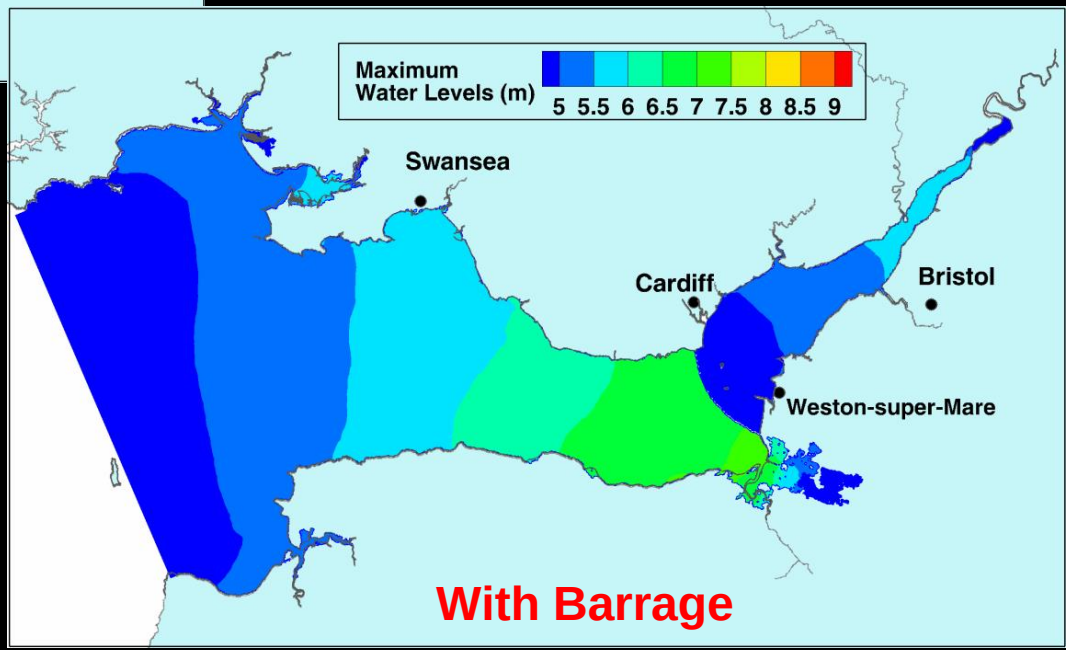
Peak Water Levels - (2005)

1026 VLH Turbines - No Sluices



Without Barrage



With Barrage

Continental Shelf Model Boundary Elevations

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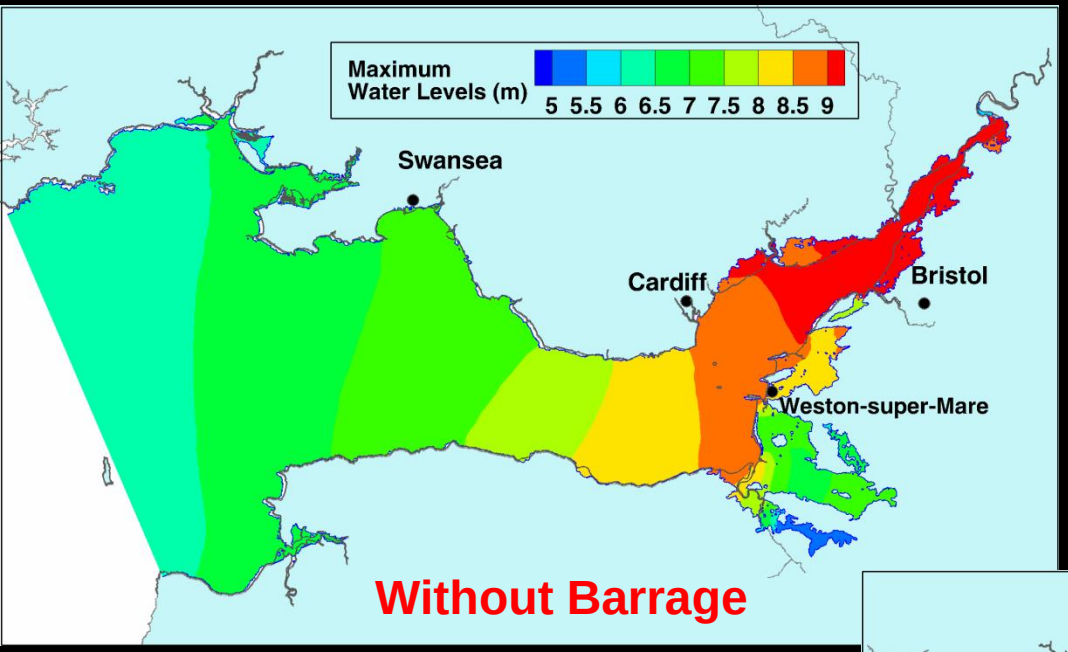
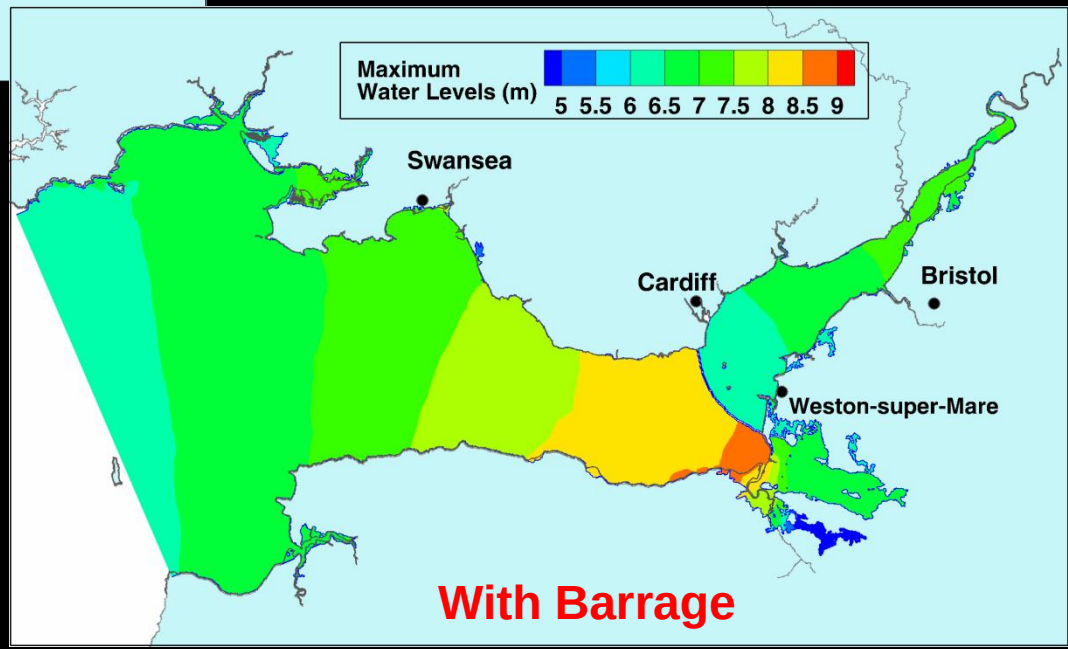
Peak Water Levels - (2145)

1026 VLH Turbines - No Sluices



Without Barrage



With Barrage

Continental Shelf Model Boundary Elevations

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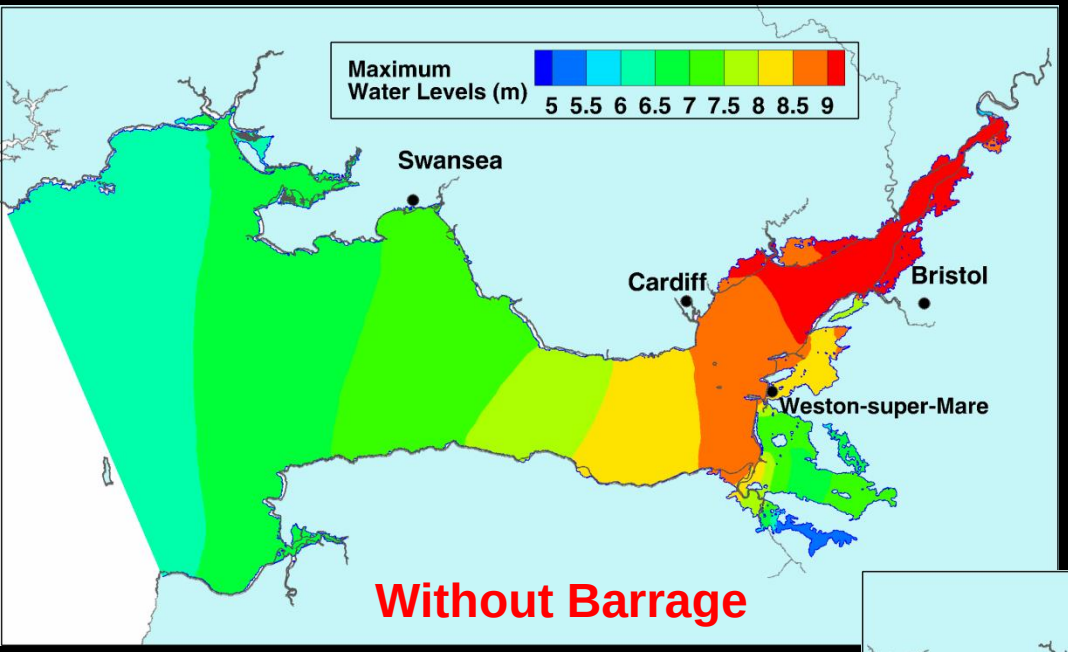
Peak Water Levels - (2145)

1026 VLH Turbines - No Sluices



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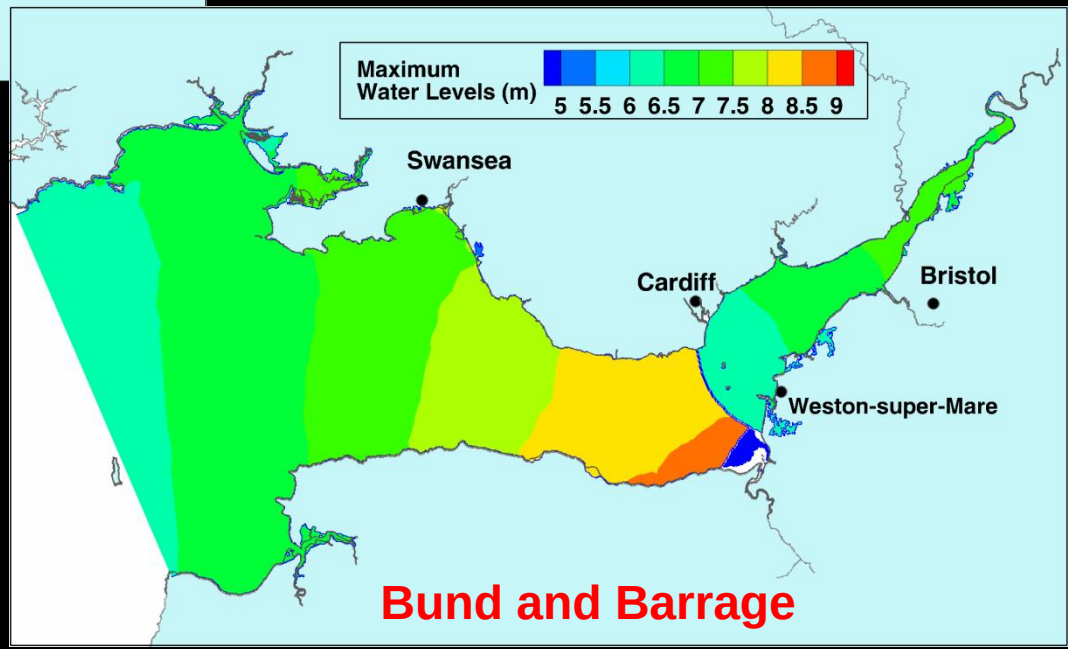

Bund and Barrage

Continental Shelf Model Boundary Elevations

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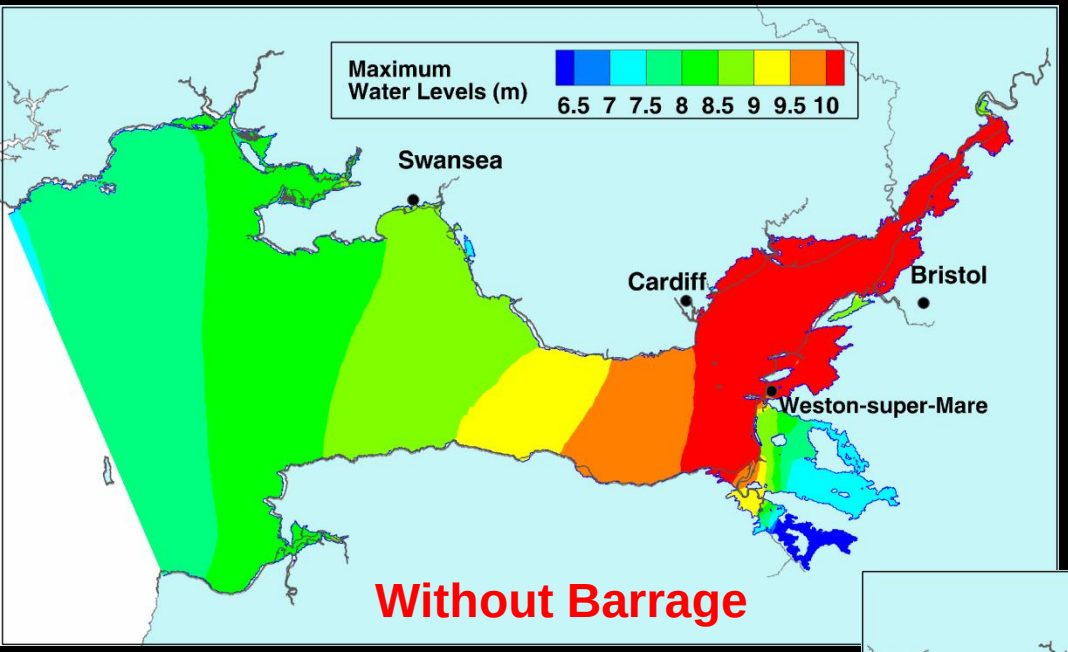
Peak Water Levels - (2145 + Surge)

1026 VLH Turbines - No Sluices



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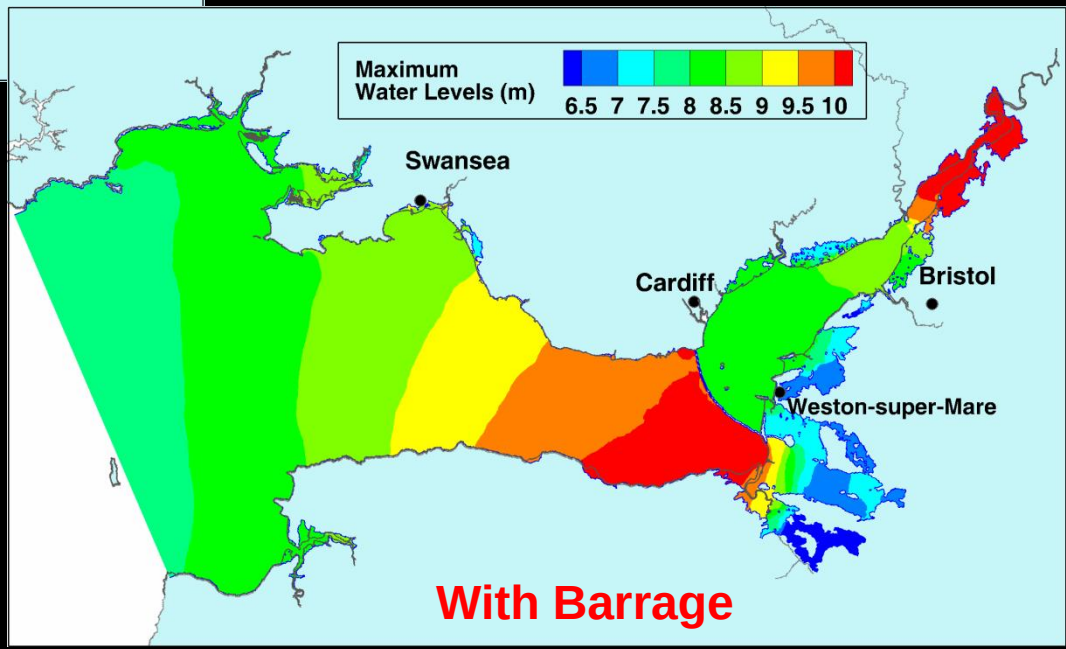

With Barrage

Continental Shelf Model Boundary Elevations

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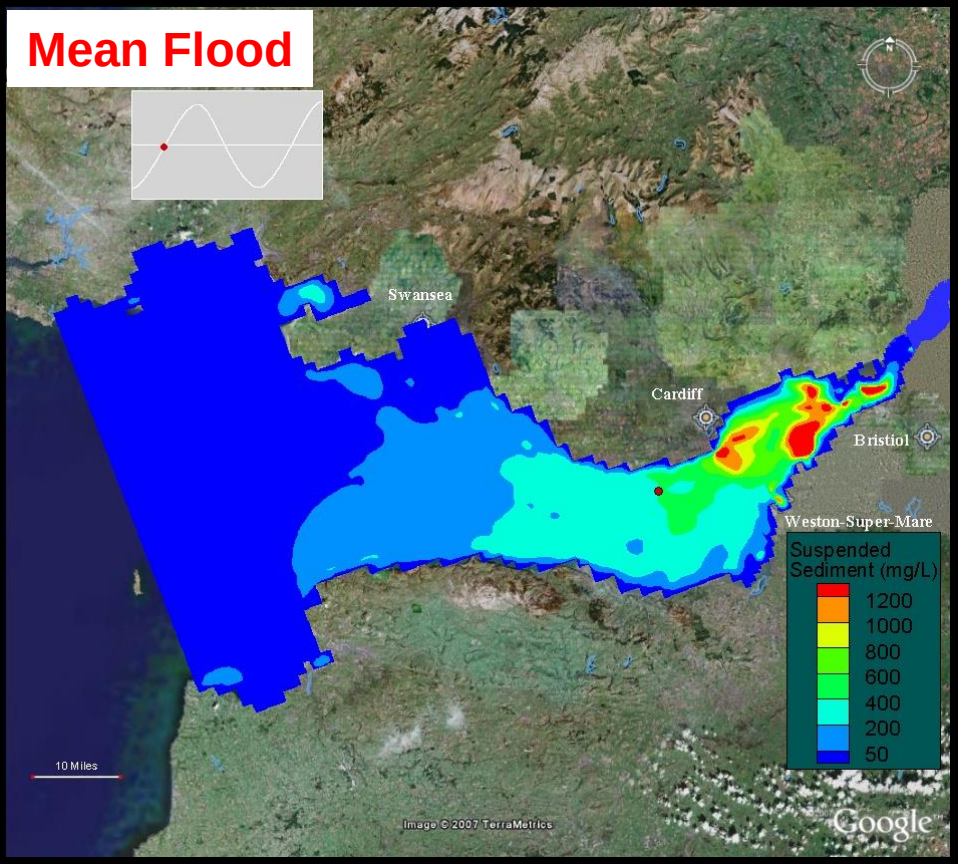
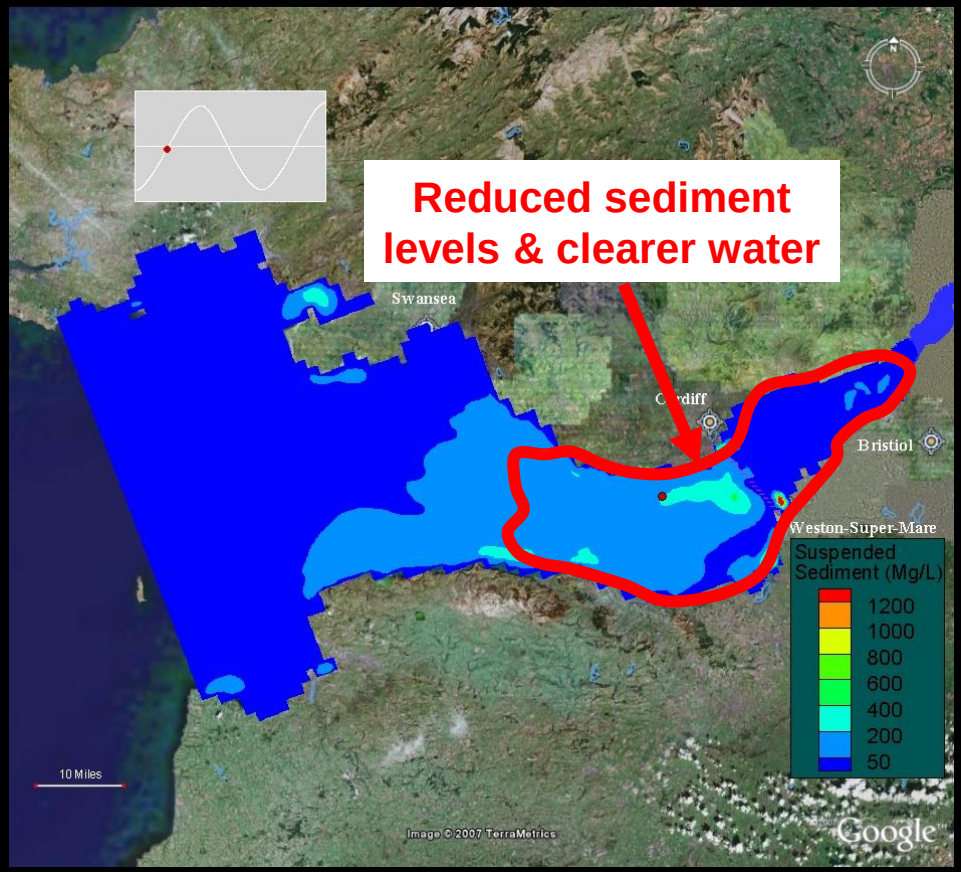
High Suspended Sediment Levels

Dynamic region of high turbidity

Suspended Sediment Levels - STPG

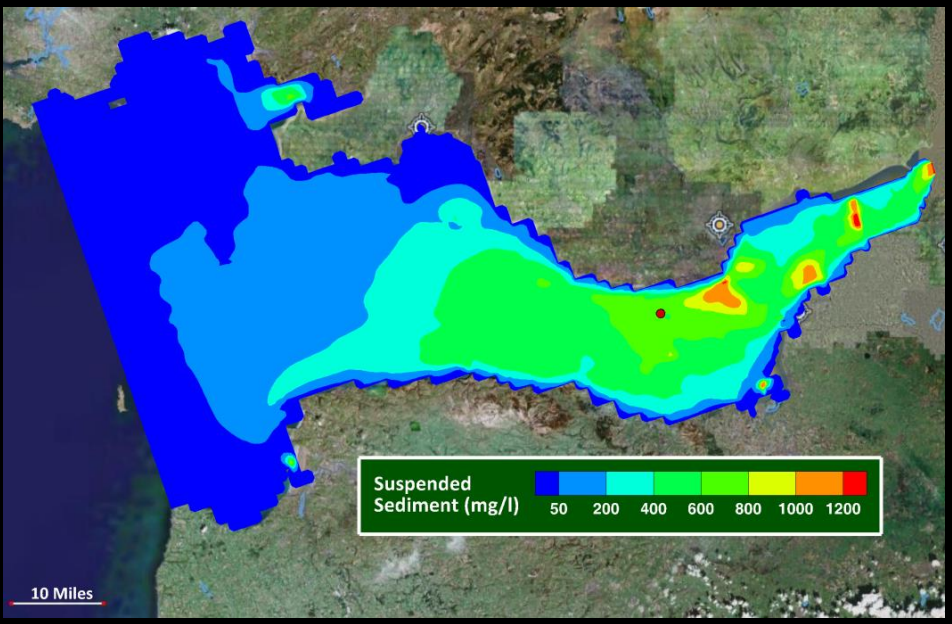




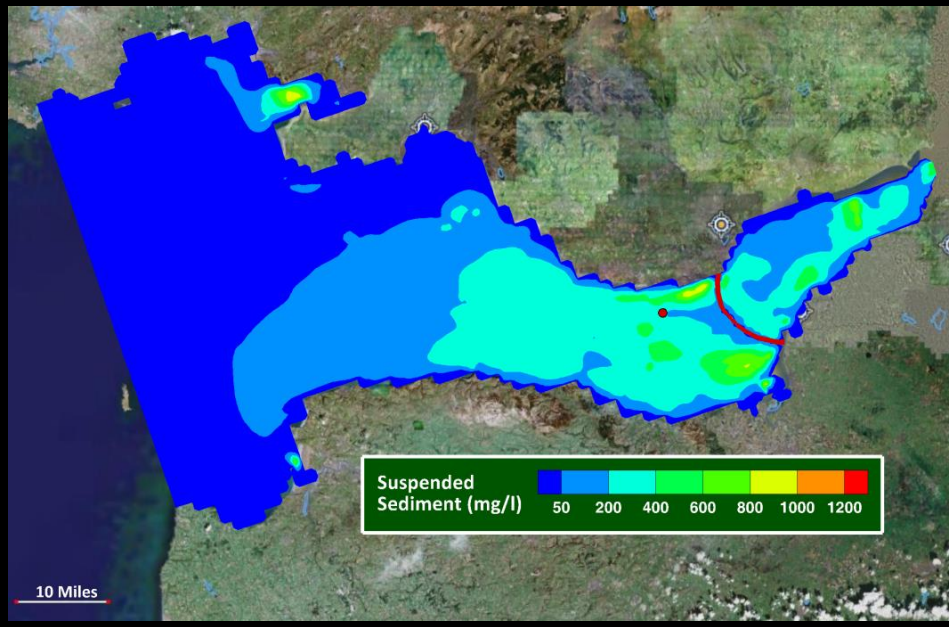
Without Barrage **With Barrage**

Mean Flood - Spring Tide

Suspended Sediment Levels – HP



Without Barrage



With Barrage

Mean Ebb - Spring Tide

Summarising for Two-Way Scheme

- Severn Barrage with Low Head Turbines would:
  - Provide 5% of UK's electricity from renewables
  - Reduce intertidal habitats by ≈ 50km^2 (140km^2 STPG)
  - Reduce flood risk upstream and combat sea level rise
  - Reduce (to varying degree) tidal currents & suspended sediments, but increase light penetration & water clarity
  - Change ecology and benthic flora and fauna
  - Enhance opportunities for tourism and recreation
  - Two-way generation offers potential for optimal energy provision and minimal hydrodynamic change
  - Fish challenges partially reduced due to lower velocities

Thank You

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