
TIDAL LAGOON
POWER

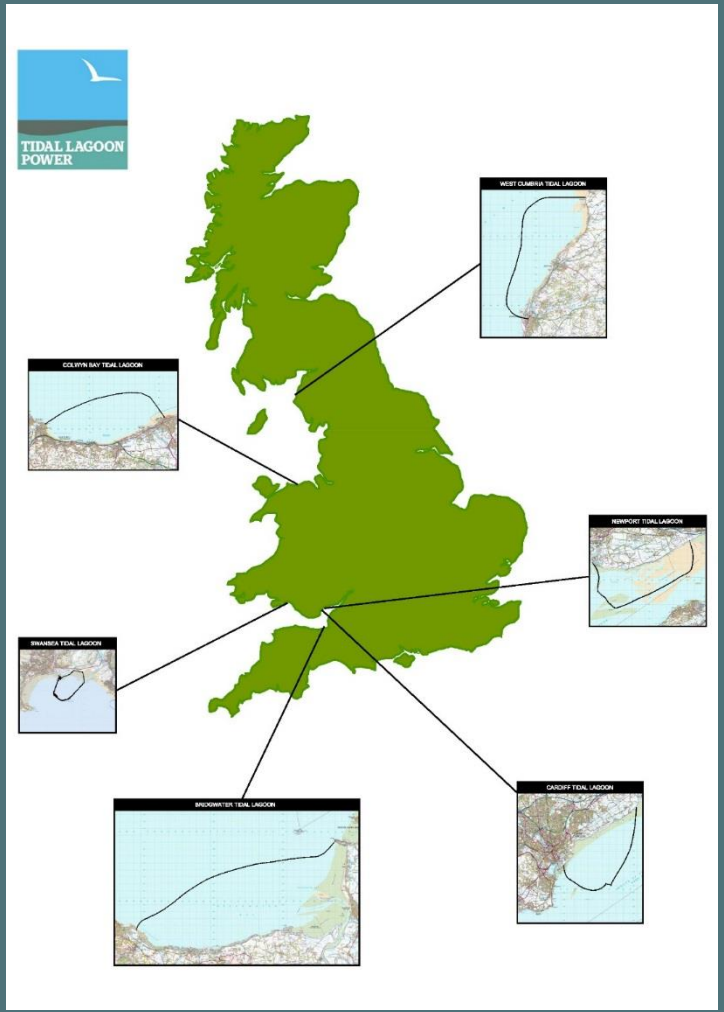
# Tidal Lagoon Swansea Bay

## 5-th Renewable Energy Postgraduate Symposium.

13 July 2015

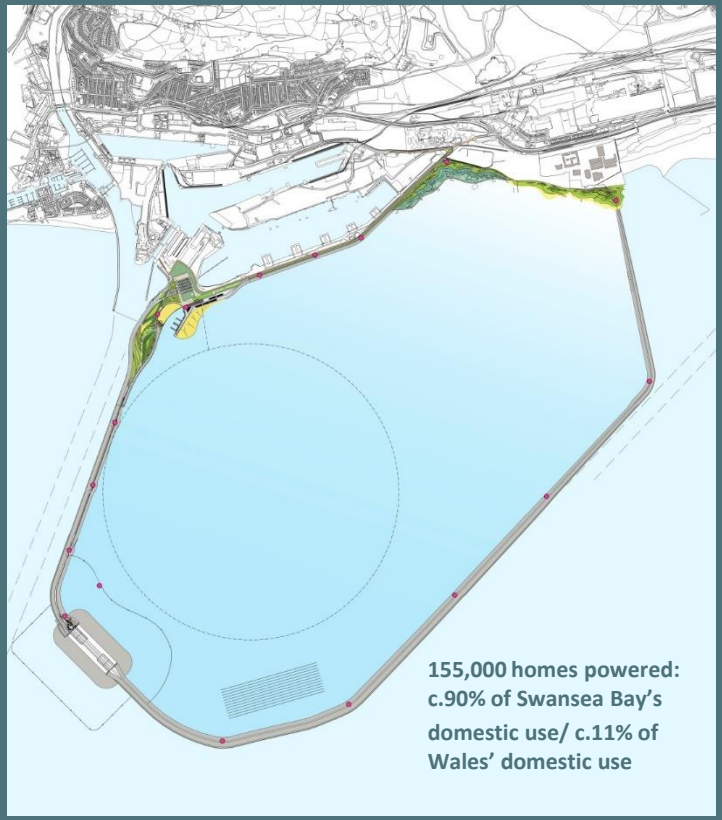
Ton Fijen, Technical Director, Tidal Lagoon Power.

UK fleet of lagoons



# Swansea Bay Tidal Lagoon

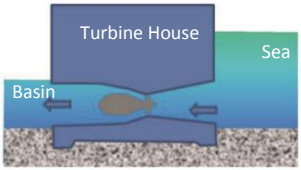
| | |
|---|---|
| Wall length: | 9.5 km |
| Area: | 11.5 $km^2$ |
| Installed capacity: | 320 MW |
| Annual output (net): | 570 GWh |
| Annual $CO_2$ savings: | 270,000 t |
| Design life: | 120 yrs |
| Height of wall: | 5-20 m |
| Wall above low water: | 13 m (max) |
| Wall above high water: | 4.5 m (max) |
| Tidal range Neaps: | 4.1 m |
| Tidal range Springs: | 8.5 m |



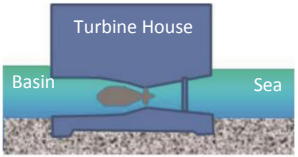
# How a tidal lagoon works

1. Flood tide rises around the low water lagoon
2. Sluice gates are opened, an inward flow of water drives the turbines
3. Gates are shut when lagoon is full
4. Tide ebbs, leaving lagoon full
5. Gates are re-opened, an outward flow of water drives the turbines

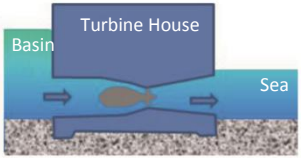
Four tidal movements, four periods of generation per day – 14 hours total daily generation time



Generating on the flood tide



Holding period at low or high water



Generating on the ebb tide

# Energy & Emissions Context

**UK energy sources (2011)** – 88% fossil fuels, 8% nuclear, 4% renewables.

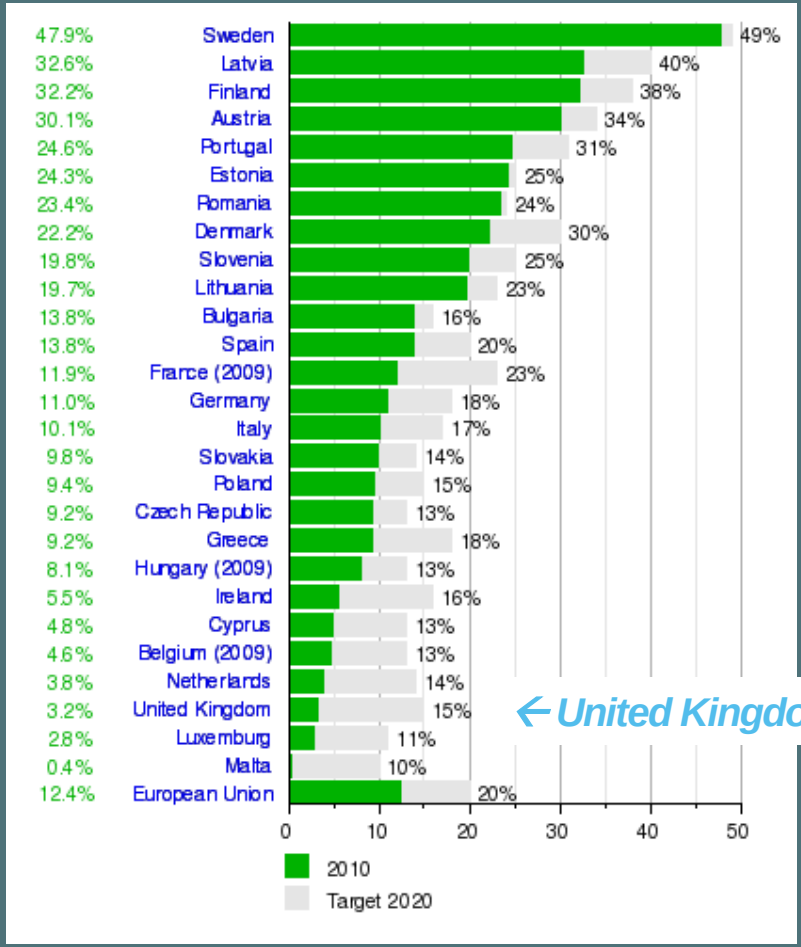
- Ofgem : UK energy crunch by 2017 as power plants expire faster than they are built.

**Climate Change Act 2008** – 80% reduction in carbon dioxide emissions by 2050

**EU Renewables Directive 2009** – 15% of UK energy needs from renewables by 2020

- Equates to 30% of renewable electricity

# Energy & emissions context




**Share of renewable energies in gross final energy consumption in EU-27 countries in 2010 (in %)**

← *United Kingdom*

# Why Swansea ??

- Site of a previous investigation
- Large tides
- Relatively shallow water depths
- Significant Public support
- Environmentally less sensitive
- Acceptable in terms of expected timeline for planning permission, expected total cost
- Good access, road, rail, marine.
- Available electrical infrastructure.

# WHERE ARE WE NOW ??

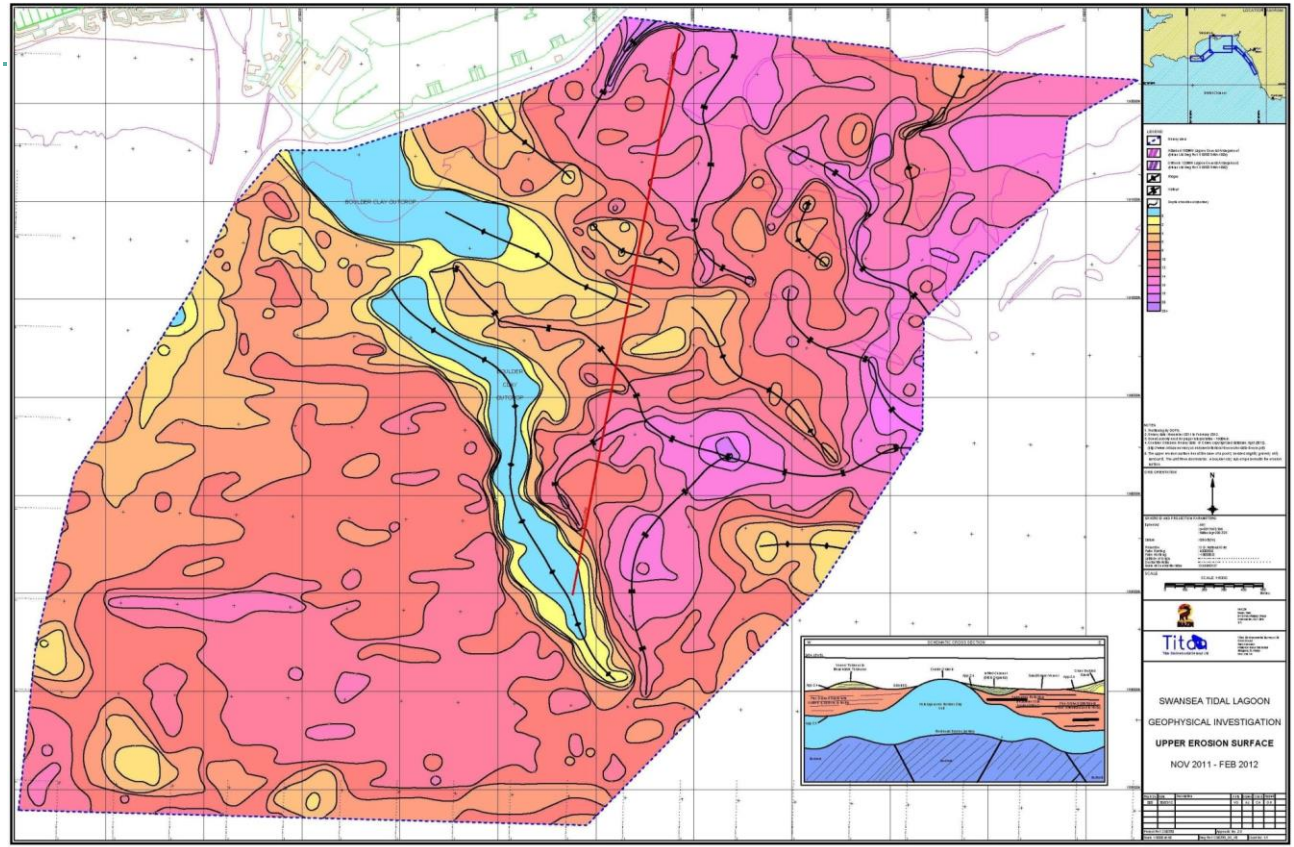
- All EIA/ Planning studies completed.
- Decision Examinators, 9 March 2015
- Decision Secretary of State, 9 June 2015
- Tenders have closed on Turbine, Civil structure Marine and onshore works.
- All preferred bidders have been appointed
- Financial Close for Project , September 2015
- Start of Construction on site:  February 2016

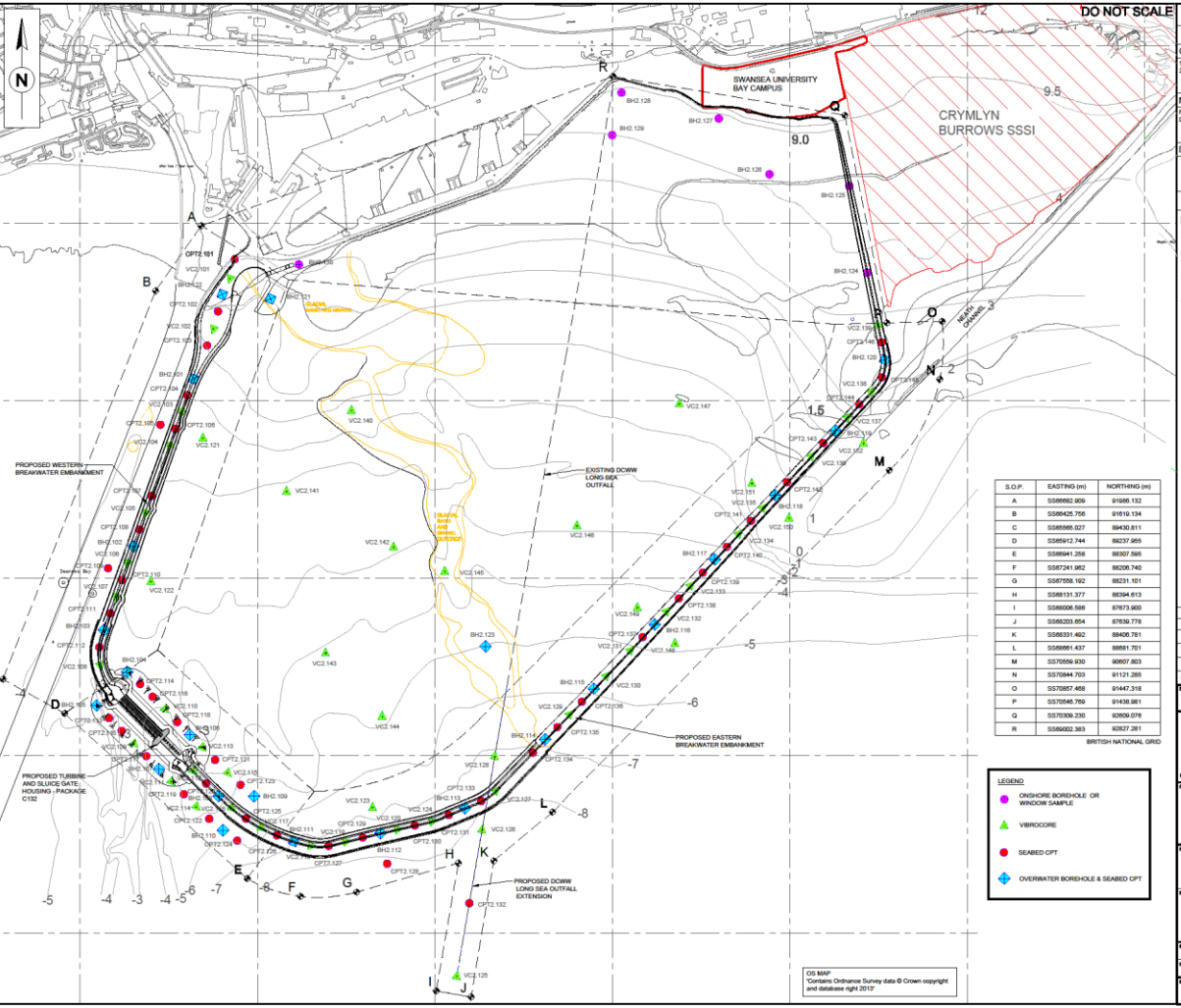
# Work-to-date: EIA, Viability & Design

**2 years of site-specific development work suggests Swansea Bay offers great potential for lagoon construction. Key work streams:**

- **Hydrodynamic modelling**
- **EIA** . 24 specialist studies.
- **Energy optimisation / value engineering** – maximise energy output; reduce cost of sea wall, turbine housing, construction methods
- **Turbine design** – Voith/Alstom/GEAH .
- **Grid connection** – discussions with National Grid & Western Power Distribution
- **Leasing & consents** – engagement with landowners
- **Onshore masterplanning** – maximising onshore opportunities
- Bathymetric survey, soil investigation.

# Geophysical Interpretation






| S.O.P. | EASTING (m) | NORTHING (m) |
|---|---|---|
| A | SS66682.909 | 91986.132 |
| B | SS66425.756 | 91819.134 |
| C | SS65985.027 | 89430.811 |
| D | SS65912.744 | 89237.955 |
| E | SS66941.258 | 88307.595 |
| F | SS67241.962 | 88206.740 |
| G | SS67558.192 | 88231.101 |
| H | SS68131.377 | 88394.613 |
| I | SS68006.586 | 87673.900 |
| J | SS68203.654 | 87639.778 |
| K | SS68331.492 | 88406.781 |
| L | SS68661.437 | 88681.701 |
| M | SS70559.930 | 90807.803 |
| N | SS70944.703 | 91121.285 |
| O | SS70857.468 | 91447.318 |
| P | SS70546.769 | 91438.981 |
| Q | SS70309.230 | 92609.076 |
| R | SS69002.383 | 92827.281 |

## SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

**CONSTRUCTION**

1. EXPOSED LOCATION, WEATHER RISK, TIDAL WORKING
2. NAVIGATION RISK/VESSEL COLLISION

**MAINTENANCE/CLEANING**

PUBLIC SAFETY RISK ASSESSMENT REQUIRED AT DETAILED DESIGN STAGE.

**DECOMMISSIONING/DEMOLITION**

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES (mm) UNLESS STATED OTHERWISE.
2. ALL LEVELS ARE IN METRES TO CHART DATUM, (CD). CHART DATUM IS 5.0M BELOW ORDNANCE DATUM (OD).
3. ONSHORE BOREHOLE BH2.130 TO BE DONE WHEN RECLAMATION IS COMPLETED.
4. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH TLSB-ATK-00-XX-DR-C-1009

| AREA | NUMBER OF BOREHOLES | NUMBER OF VIBROCORES | NUMBER OF CPT's |
|---|---|---|---|
| WESTERN BREAKWATER | 5 | 10 | 12 |
| TURBINE HOUSE | 7 | 9 | 14 |
| EASTERN BREAKWATER | 10 | 25 | 20 |
| DREDGE AREA | 1 | 8 | 0 |
| LAND | 7 | 0 | 0 |
| TOTAL | 30 | 52 | 46 |

| Rev. | Date | Description | By | Chk'd | App'd |
|---|---|---|---|---|---|
| D | 15/09/14 | FOR TENDER | RJM | JP | IDR |
| C | 15/08/14 | FOR TENDER | RJM | JP | IDR |
| B | 14/08/14 | FOR TENDER | DB | JP | IDR |
| A | 08/08/14 | FOR TENDER | DB | JP | IDR |

Drawing Status: TENDER — Suitability: D2

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Client: TIDAL LAGOON (SWANSEA BAY) PLC

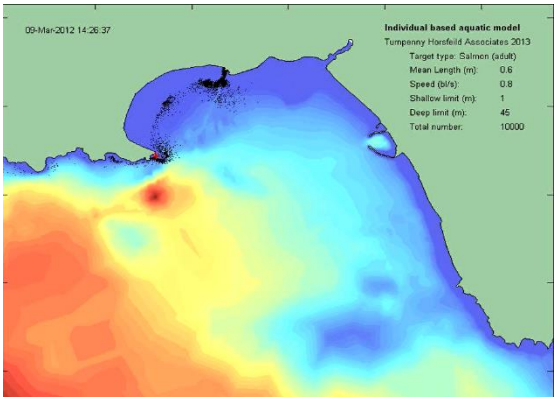
Project Title: SWANSEA BAY TIDAL LAGOON MARINE WORKS: C131

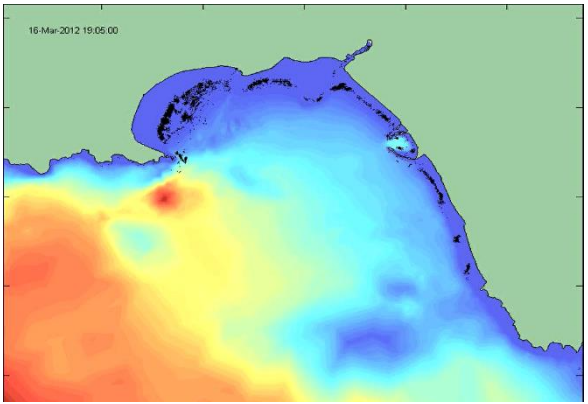
Drawing Title: PHASE 2 SITE INVESTIGATION PLANNED SUMMER 2014

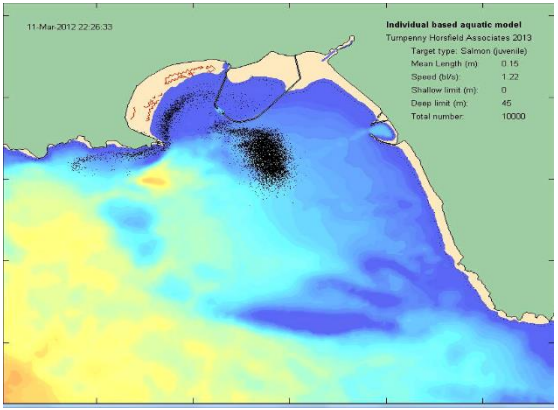
| Scale | Designed | Drawn | Checked | Authorised |
|---|---|---|---|---|
| 1:10 000 | JE | DB | JP | IDR |
| Original Size | Date | Date | Date | Date |
| A1 | 08/07/2014 | 08/07/2014 | 22/07/2014 | 08/08/2014 |

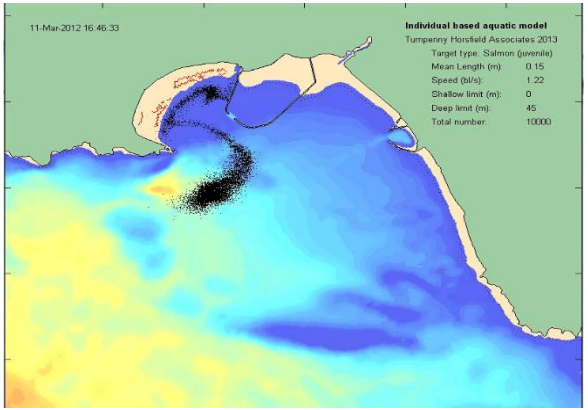
Drawing Number: TLSB-ATK-00-XX-DR-C-1008 — Revision: D

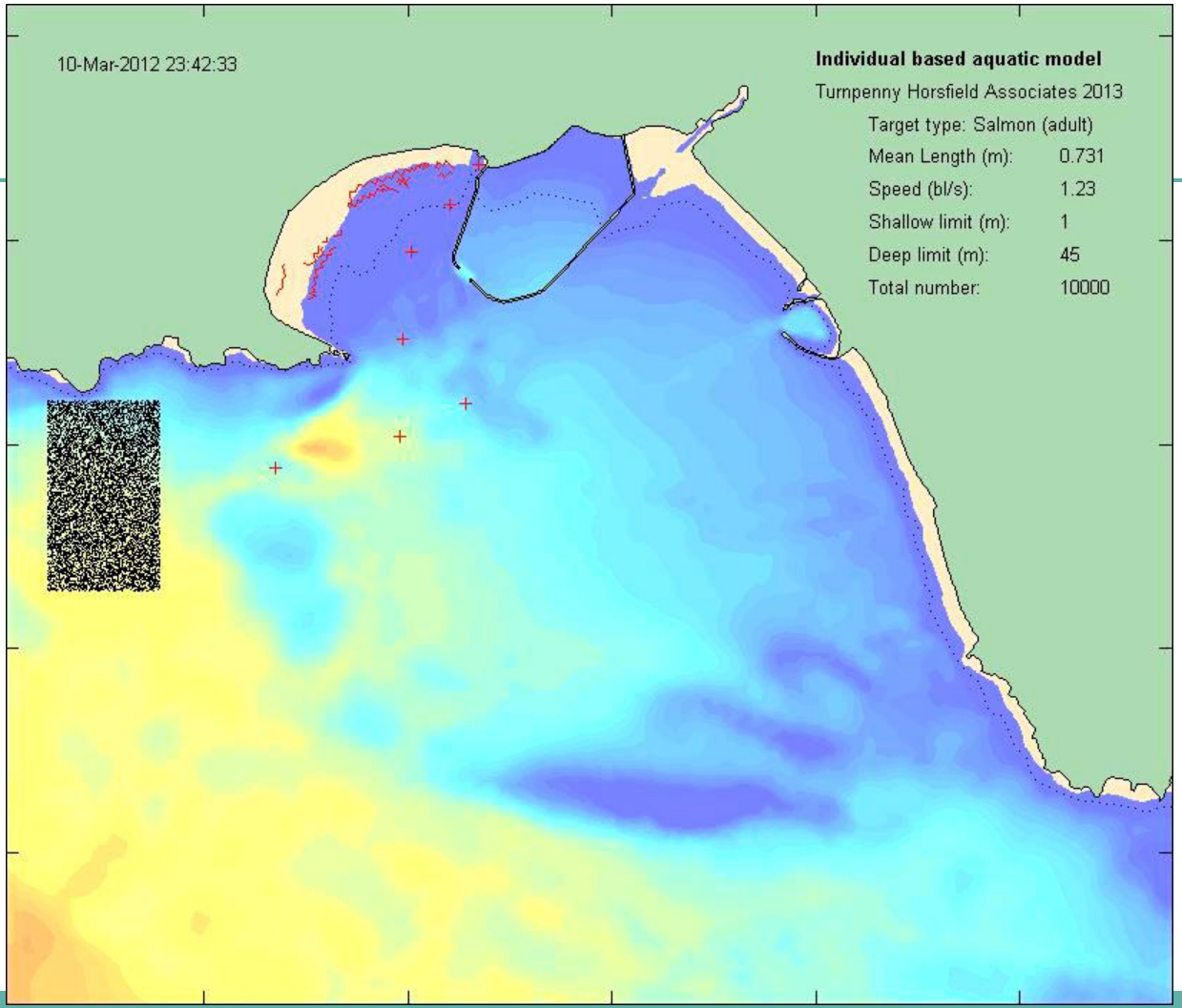
# Fish Encounter Modelling

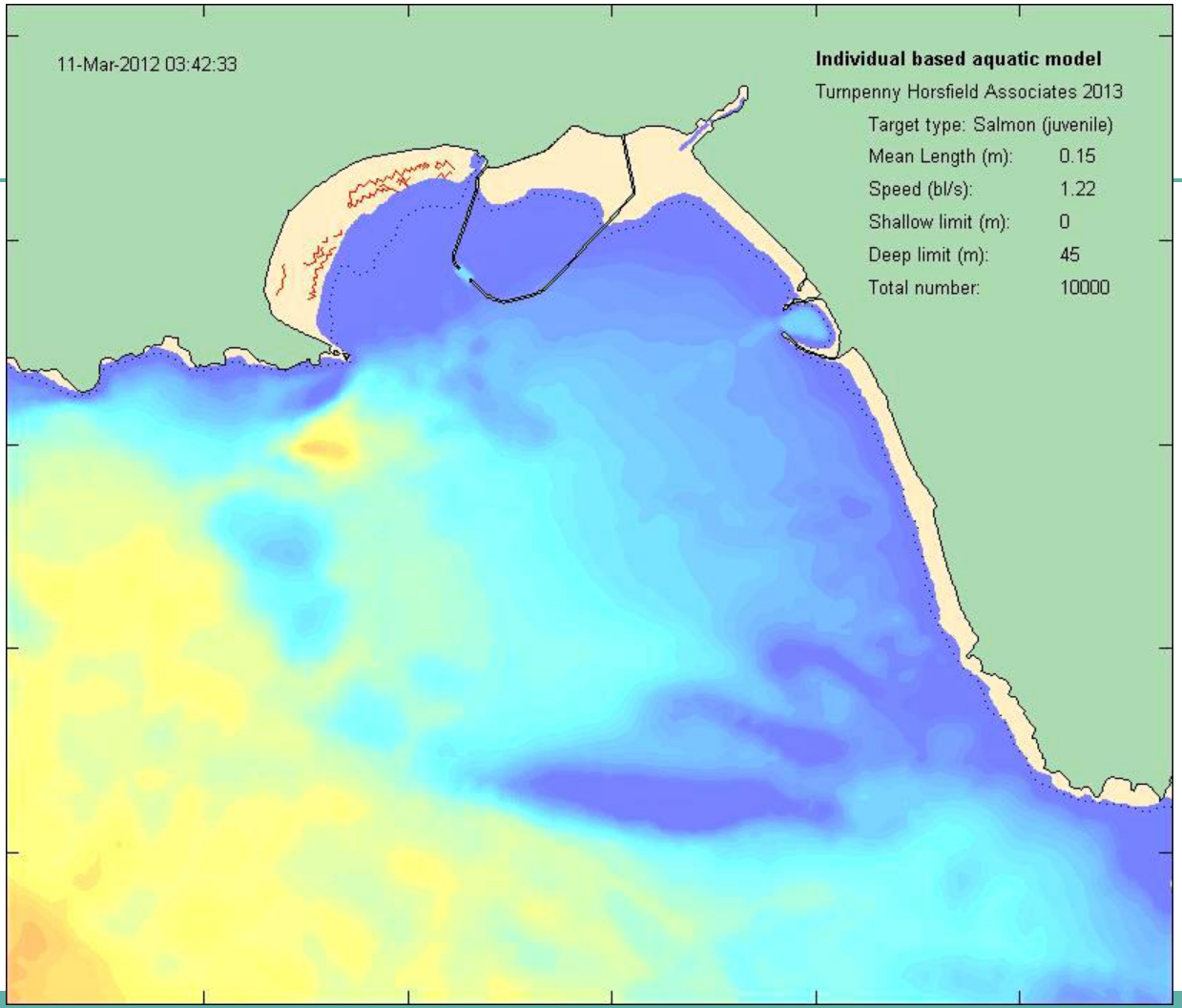


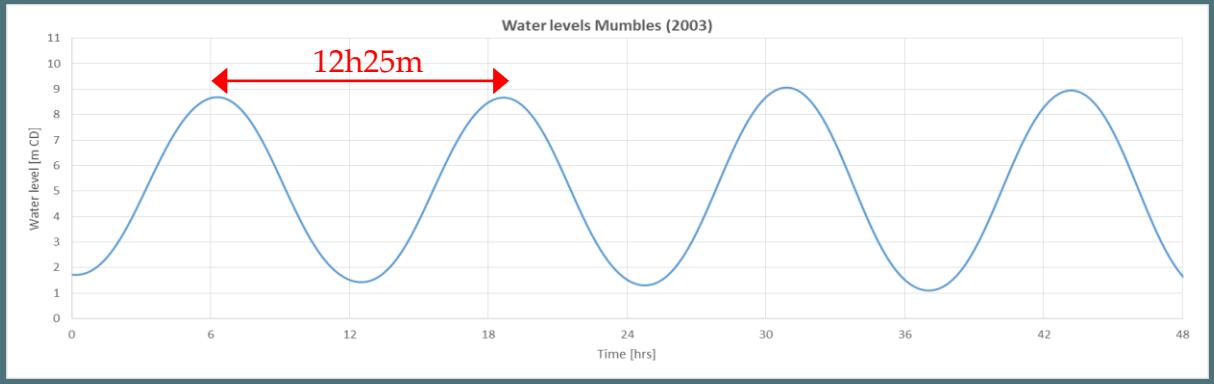



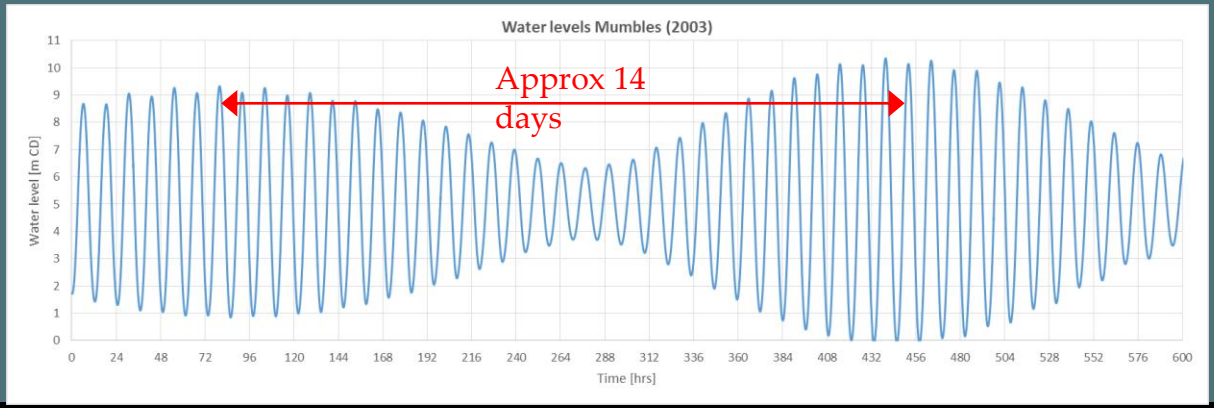




10-Mar-2012 23:42:33
Individual based aquatic model
Turnpenny Horsfield Associates 2013
Target type: Salmon (adult)
Mean Length (m): 0.731
Speed (bl/s): 1.23
Shallow limit (m): 1
Deep limit (m): 45
Total number: 10000


11-Mar-2012 03:42:33
Individual based aquatic model
Turnpenny Horsfield Associates 2013
Target type: Salmon (juvenile)
Mean Length (m): 0.15
Speed (bl/s): 1.22
Shallow limit (m): 0
Deep limit (m): 45
Total number: 10000

# Understanding the tides





Full Moon


Three Quarter Half Moon


New Moon


First Quarter Half Moon

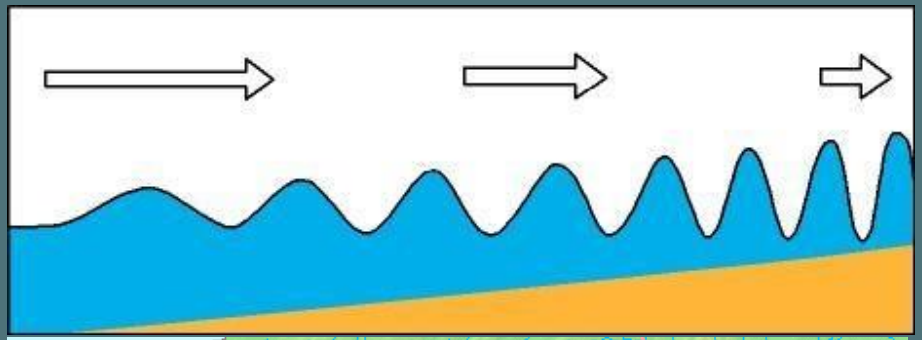
# Understanding the tides

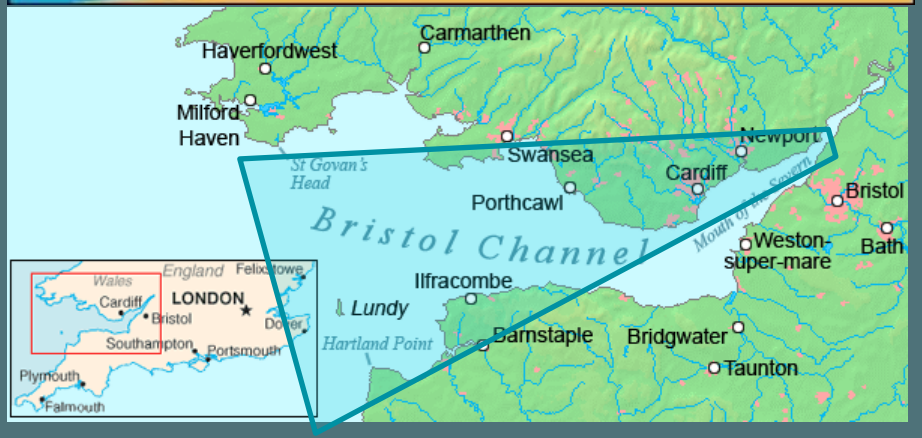
- Why do we have such a large tidal range?

Shoaling

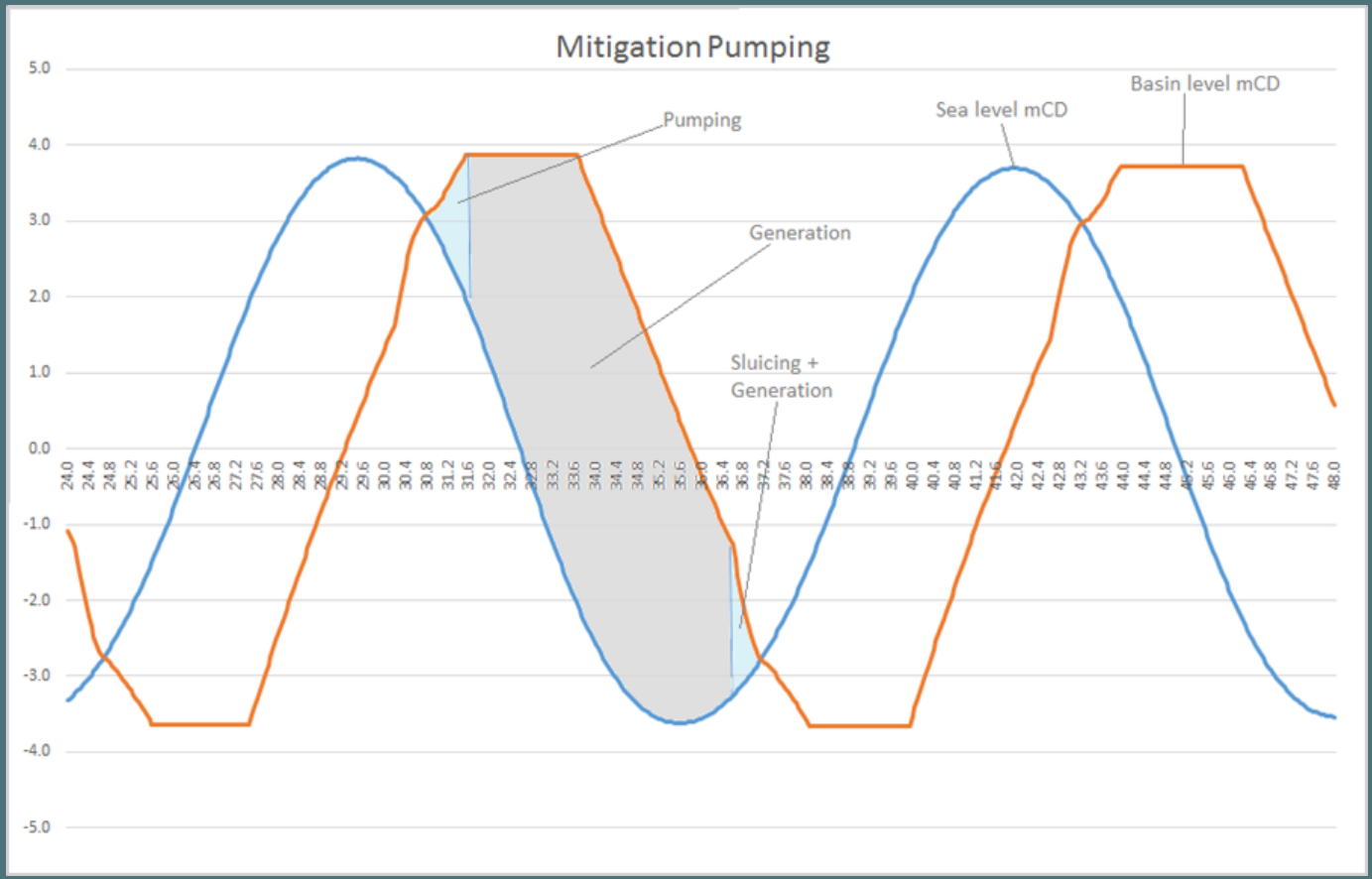
+

Funneling





# Generation, sluicing and Mitigation Pumping



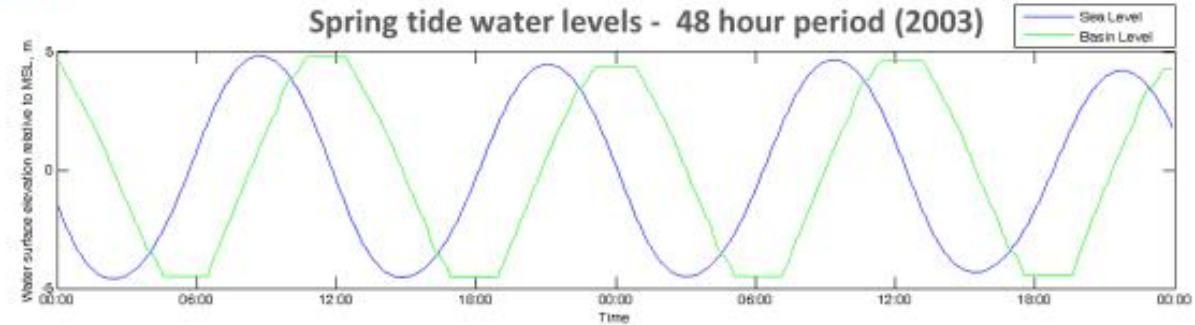




**Figure 1 B (Mitigation pumping)**

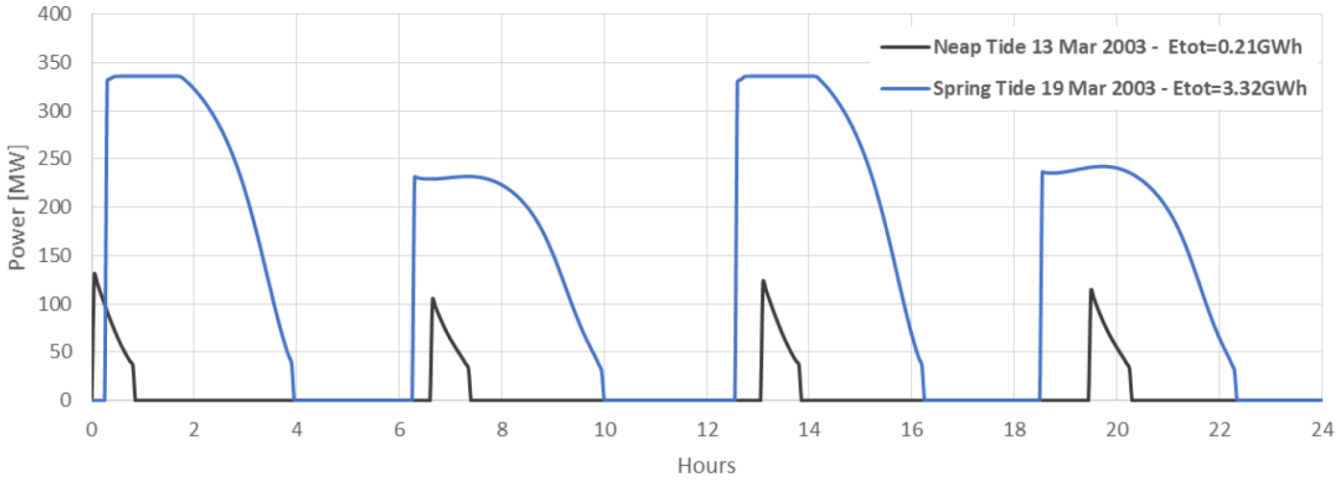
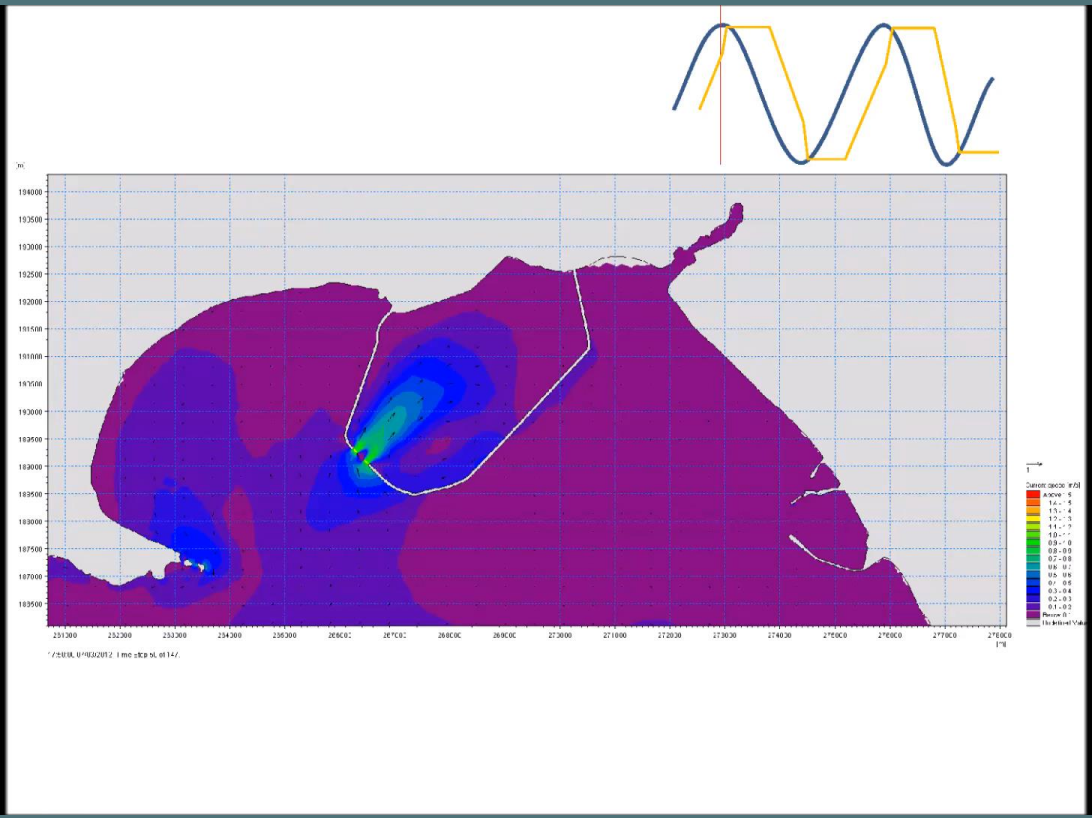



**Figure 2 A (Turbining only)**

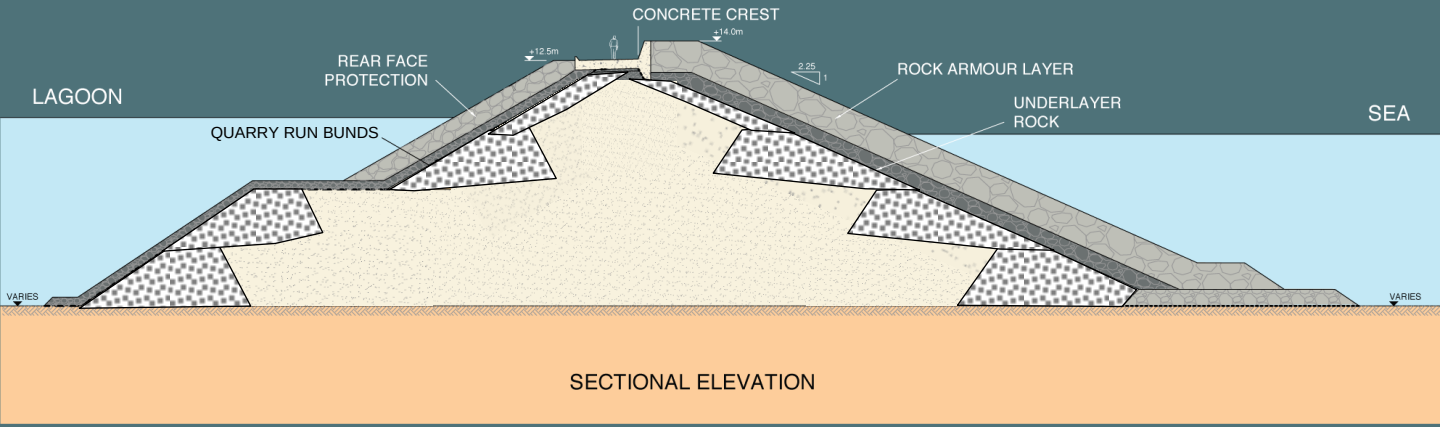
# Energy modelling

## 2D modelling animation (dt = 15min)



# Breakwater design

1. Breakwater comprises bunds of quarry run with sand fill in between
2. Armour rock is placed on top
3. Rock and quarry run is transported from our own quarry to the lagoon by sea



# Design validation

Physical scale model testing (HR Wallingford laboratories )

- 2D model on 1:35 scale
- Testing of frequent & extreme conditions up to 1 in 500 year storm
- Aim: validate & optimize design on armour & cap stability & overtopping

# Physical model test bund wall

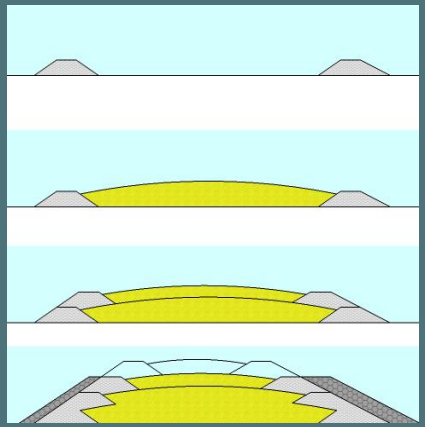
## Validation on hydraulic design

1 in 500 yr conditions-

1-3t rear slope

# Bund construction

- Dumping of Quarry Run bunds with Side Stone Dumping Vessels or Split Barge Dumping
- Hydraulically placed sand fill in between bunds with Cutter Suction Dredger or Trailing Suction Hopper Dredger
- Placement of various rock grades on top



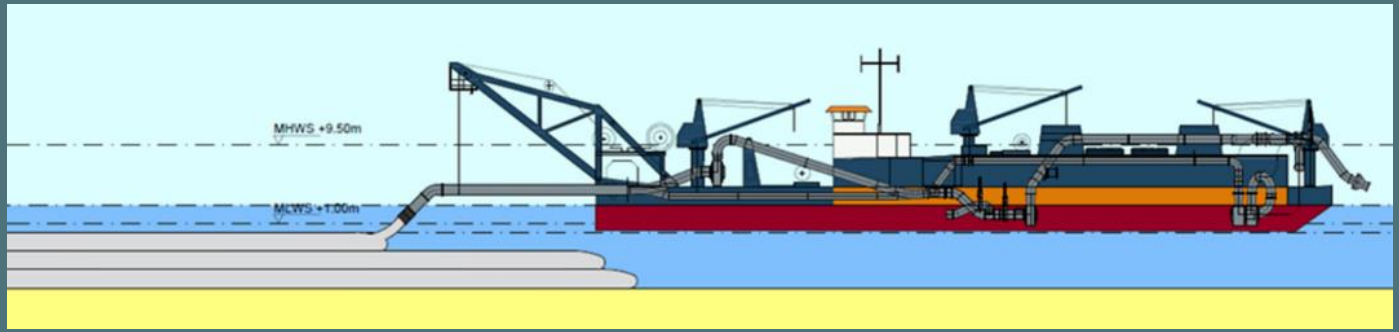
Side Stone Dumping Vessel

Split barge

# Bund wall construction – hydraulic sand infill

**Cutter Suction Dredger** (left & below):

The sand infill will be placed by hydraulically filling in between the quarry run bunds



# Sediment removal area

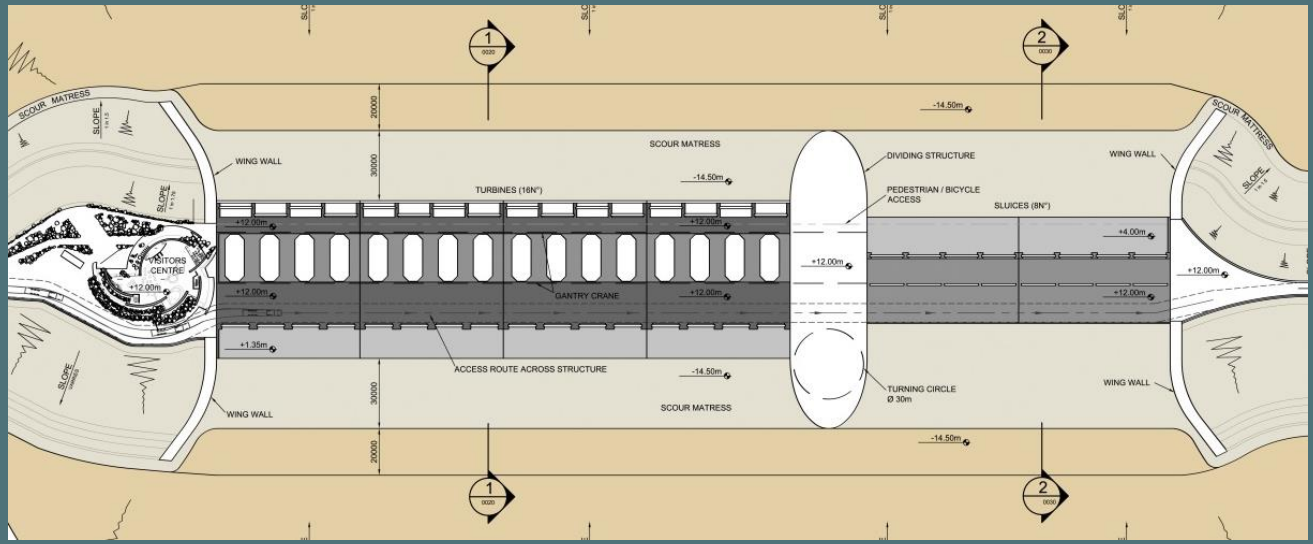
**Key information**

- Sediment removal area approx 2.5 km$^2$
- Average depth of sediment removal 3 m.
- Alternative: Smaller area, increased depth.
- Average depth of removal for turbine housing 12 m below sea bed.

# Dean Quarry – St. Keverne, Cornwall

- High density gabbro rock
- Construction of wave protected facility with two berths suitable for 10,000t barges
- Annual capacity of  about 1 million tonnes
- Alternative sourcing: Rock from quarry in Norway, Scotland, Ireland

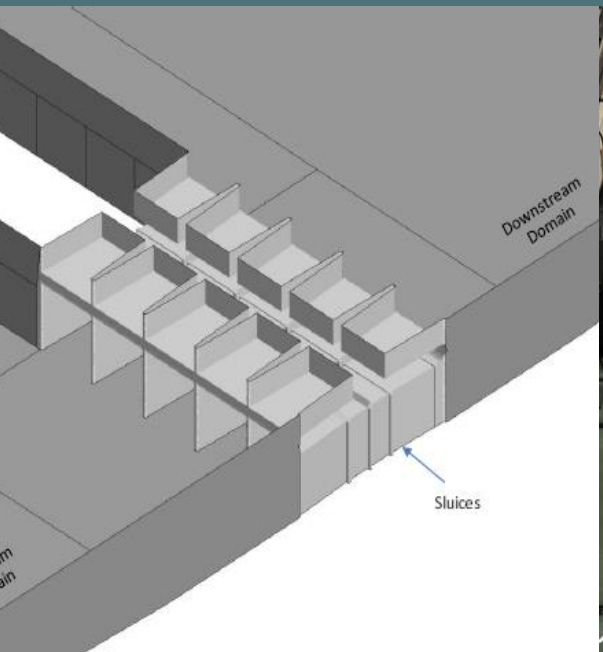
# Turbine and Sluice-gate housing structure.

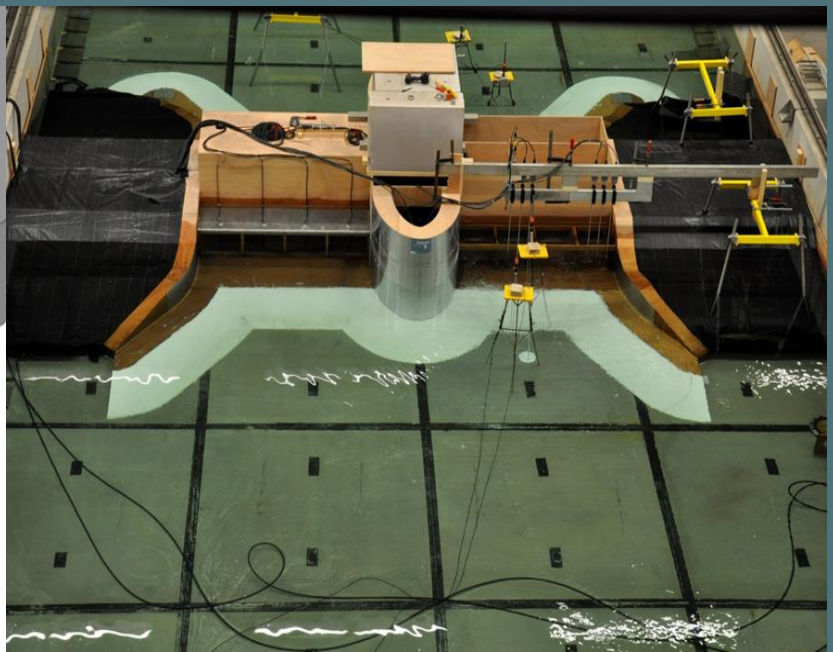


# Turbine and Sluice Physical modelling

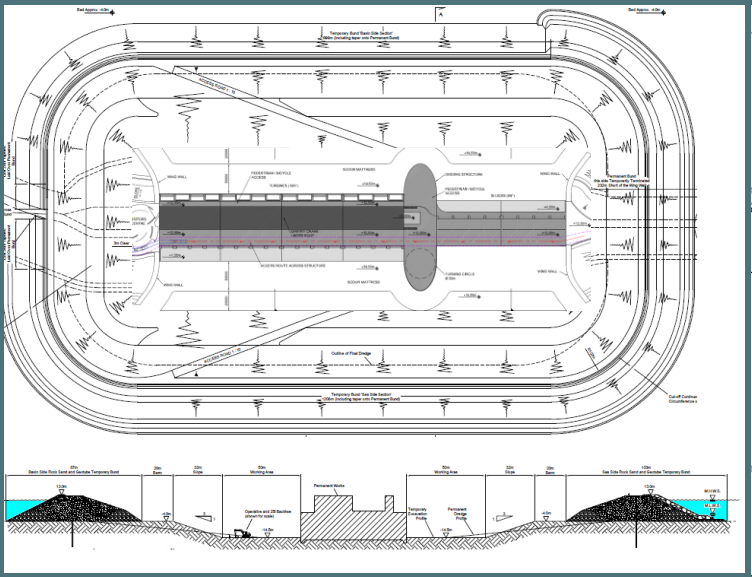
**3D model & CFD and physical modelling**

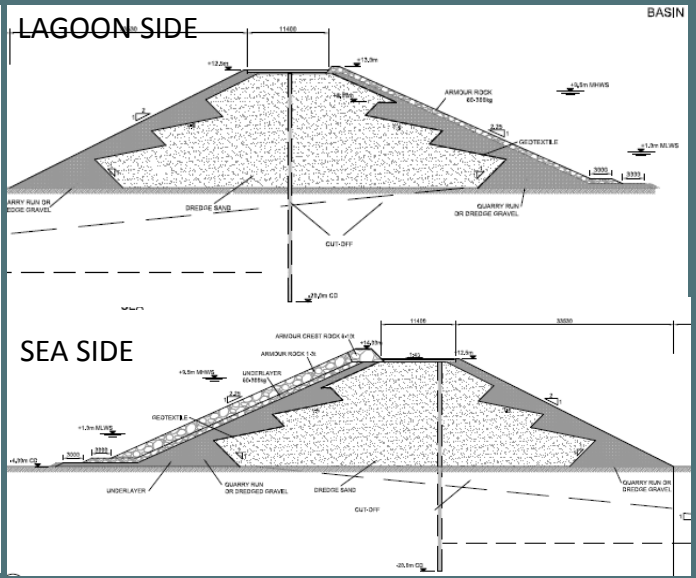
- TLP commissioned Deltares (Holland) to do this modelling
- Validation with physical model + wave action
- Alignment with  turbine model tests
- Finished  March 2015



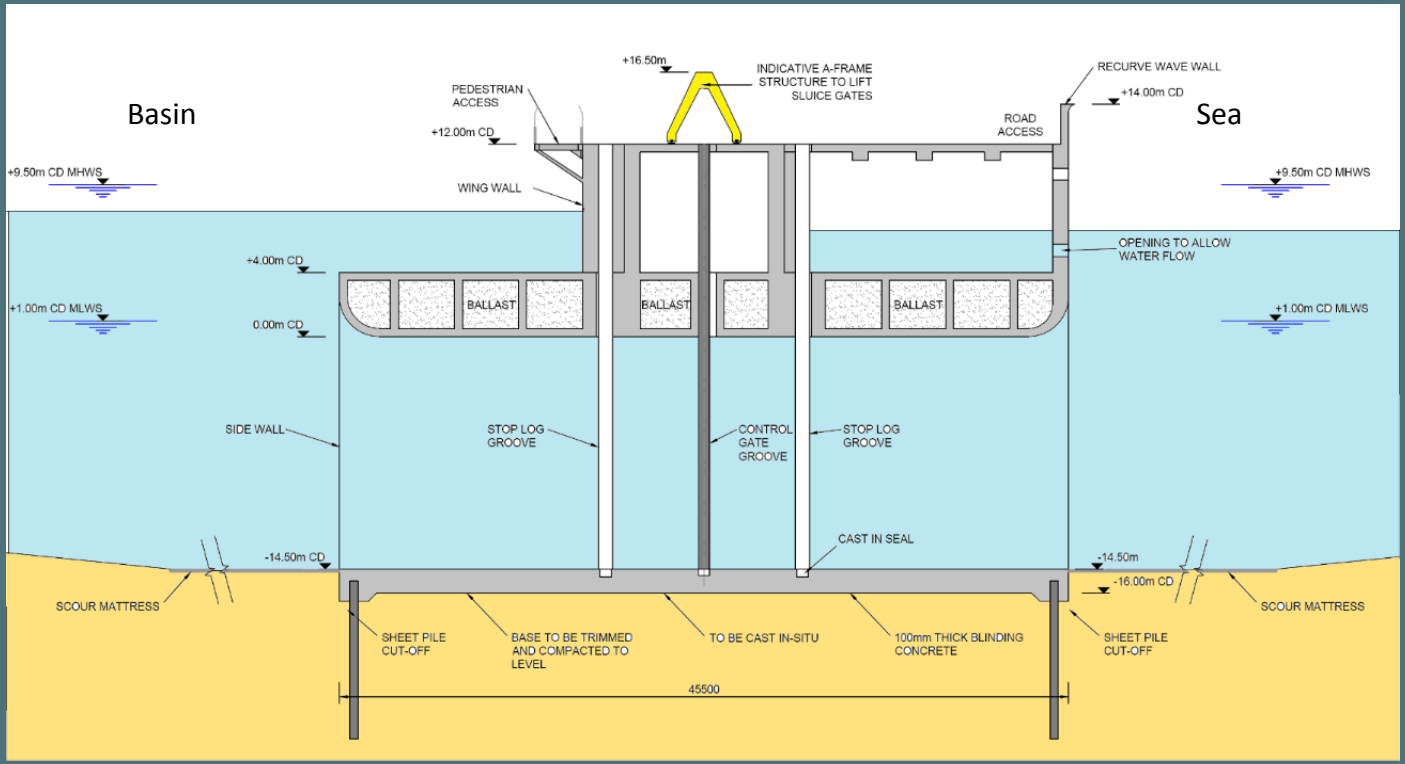



# Temporary bund wall (cofferdam)

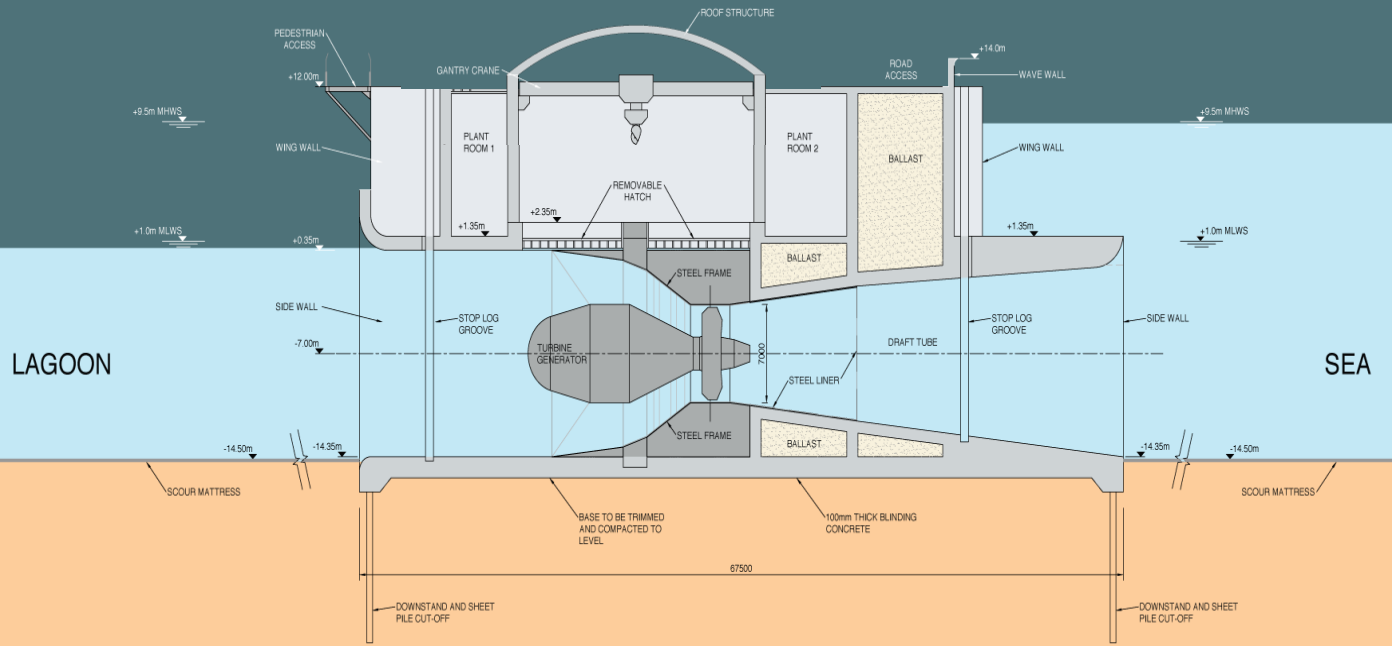




# Sluice- gate structure.



# Turbine housing structure.



# Turbines design and iteration

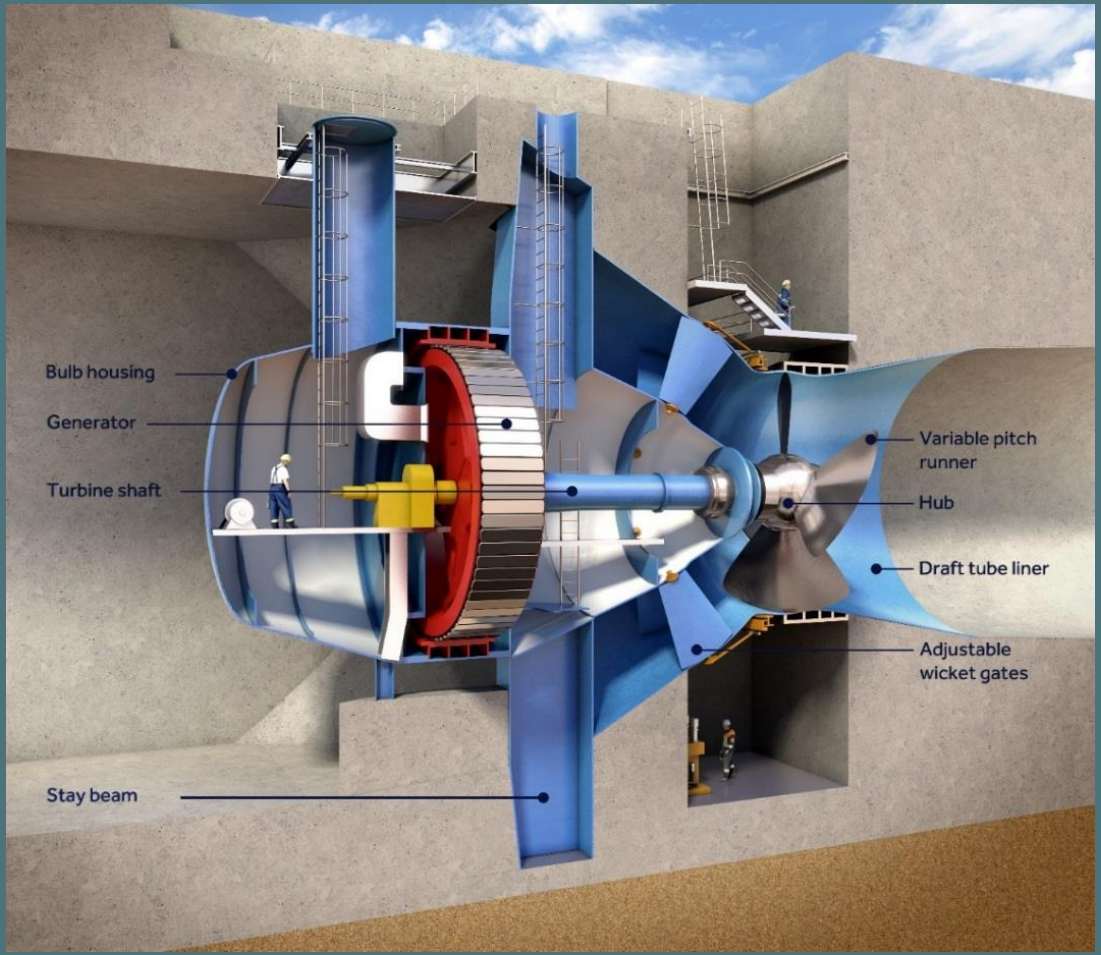
Three major hydro turbine suppliers in a competitive design tender to supply low head, bi-directional bulb turbines.

Variable speed double regulated bulb turbines, from Andritz

- Movable guide vanes
- Variable pitch propeller (Kaplan runner)
- squirrel cage induction generators (cheaper to manufacture & more robust design)
- Converters
- Delivers higher efficiency over 4 quadrants
- Compact design allows for installation of complete units from dockside assembly plant

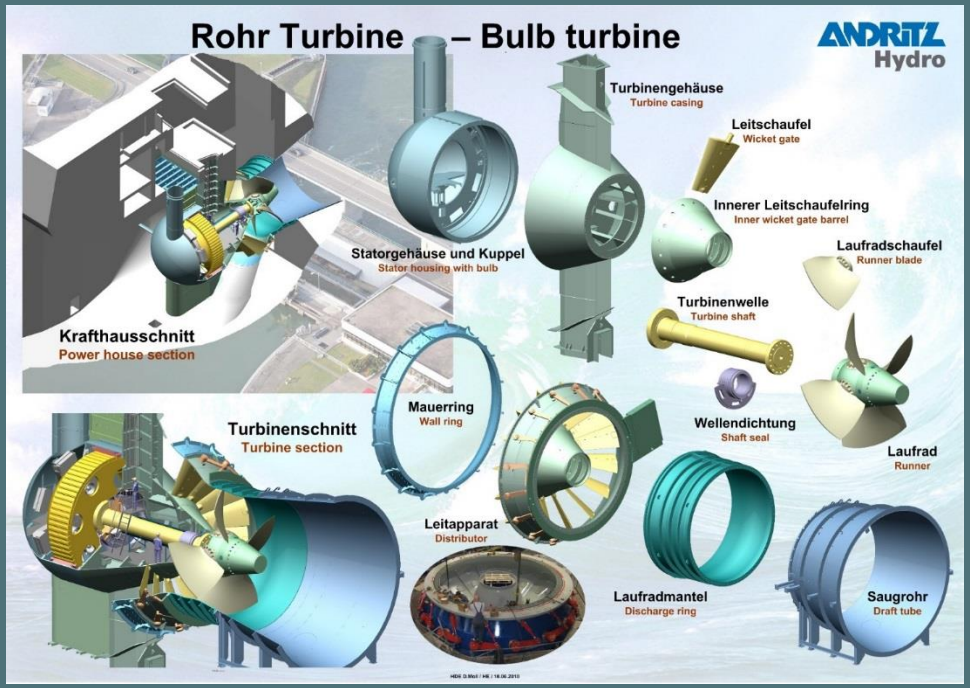
Significant iterative improvements in power output, pumping performance and efficiencies

# Double Regulated Bulb Turbine

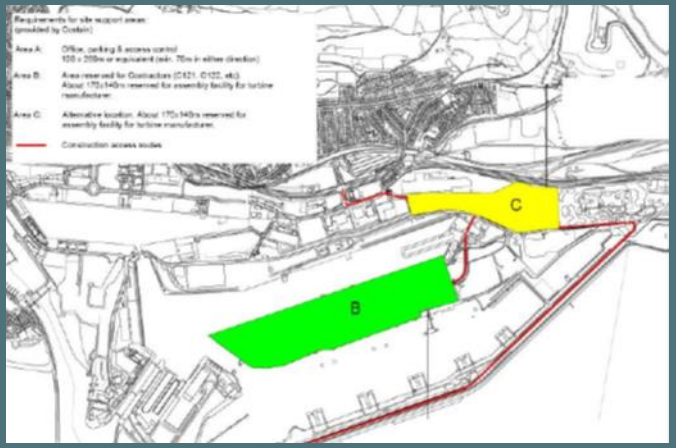


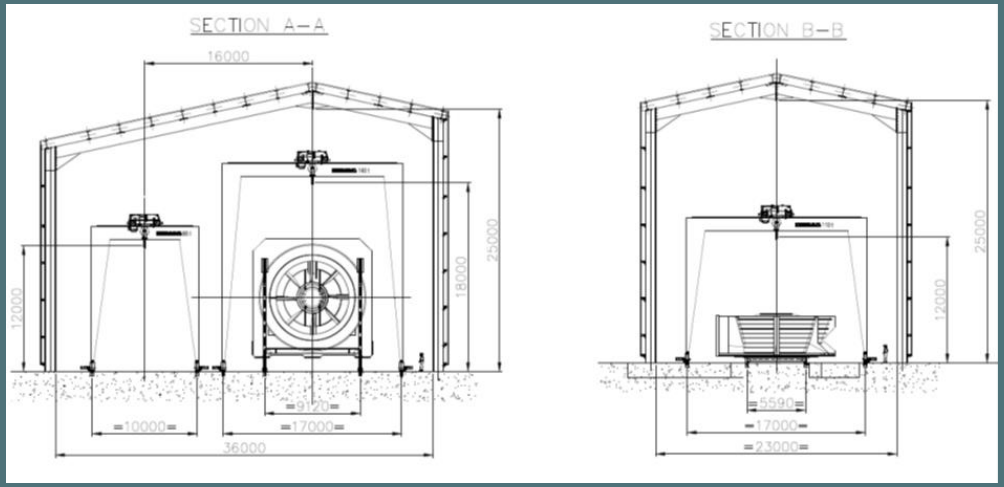
# Andritz turbine for Shiwa.

# Turbine components

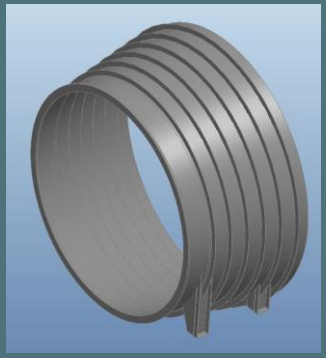


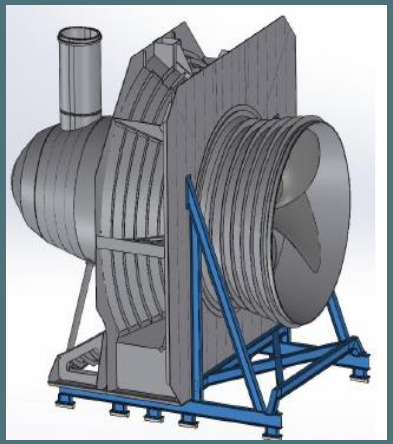
# Dockside turbine assembly hall

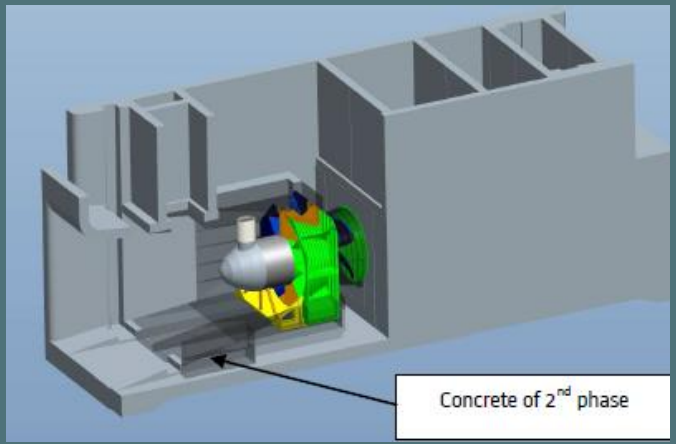


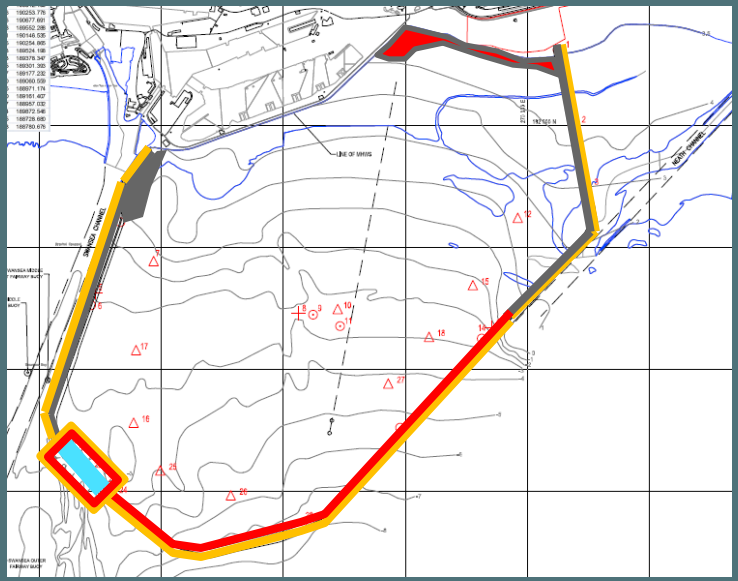
# Turbine and gate housing







# Construction quantities



**Sand fill – approx. 7-8 M m3**

- Perm. Bund wall: 4-5Mm3
- Temp. bund wall: 1Mm3
- Landscaping: 2Mm3

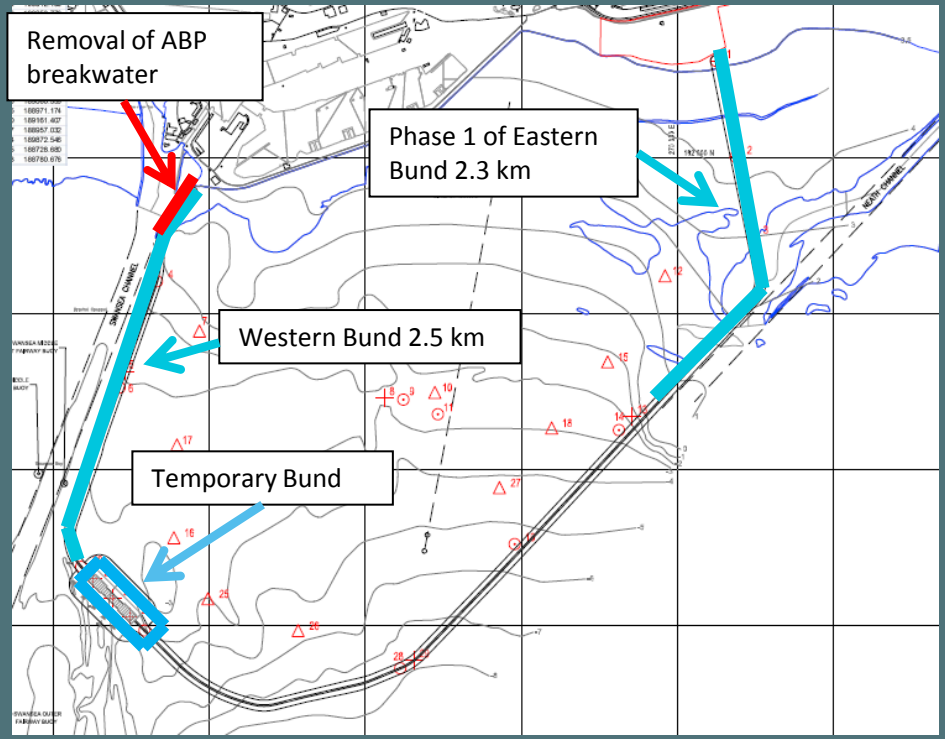
**Rock – approx. 4 to 6 M tonne of quarry run and armour**

- Perm. Bund wall: 6M tonne
- Temp. bund wall: 1M tonne (re-used)

**Concrete – approx. 200,000 m3 of reinforced concrete in turbine and sluice gate structures**

- Turbine housing: 120,000 m3
- Sluicegate housing: 40,000 m3
- Flow guiding structures: 40,000 m3

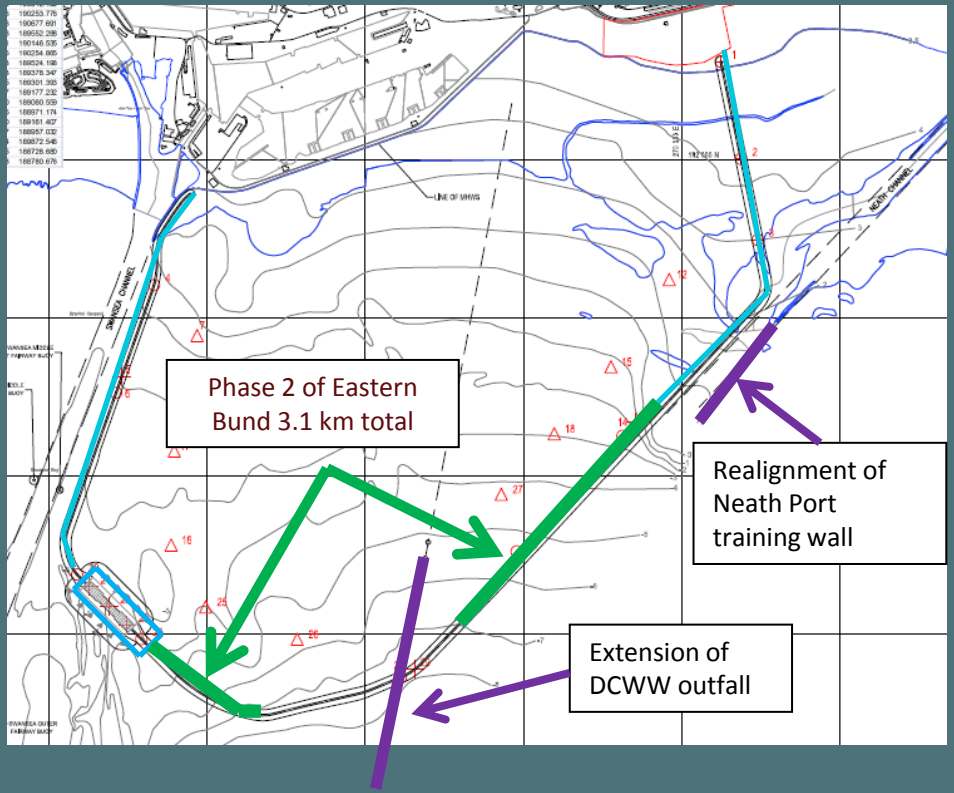
# Construction sequence – 1st season




**Construction sequence:**

- Construct temporary bund – **team 1**
- Construct western bund starting from shore and working out – **team 2**
- Remove ABP breakwater
- Construct Phase 1 eastern bund starting from shore – **team 2**

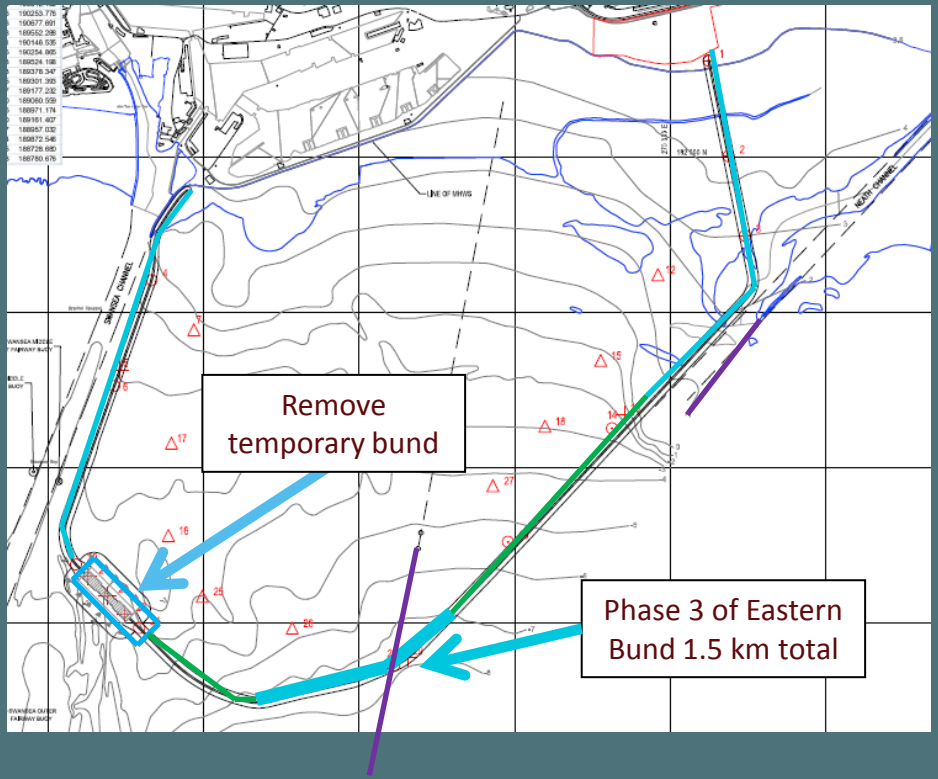
# Construction sequence – 2nd season




**Construction sequence:**

- Extend DCWW outfall by 1500m
- Realignment of Neath Port training wall
- Construct phase 2 of the Eastern Bund

# Construction sequence – 3rd season

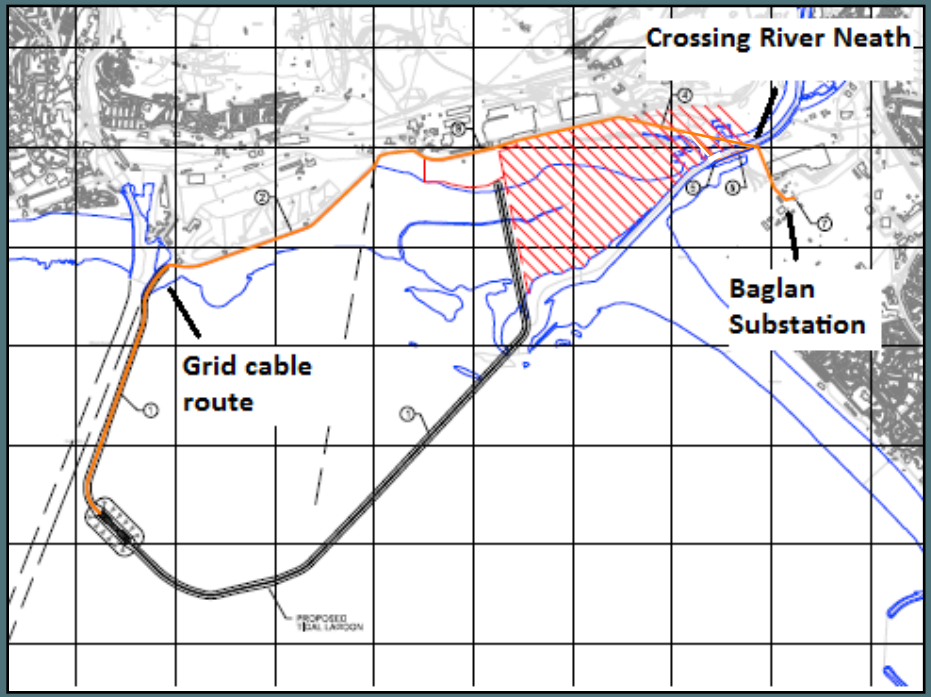


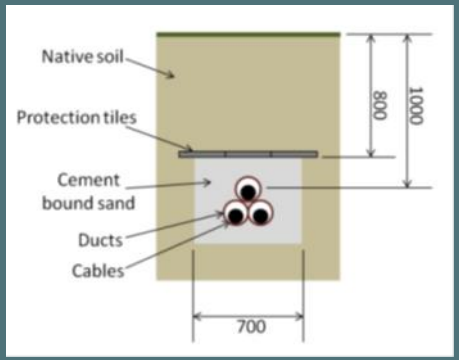

**Construction sequence:**

- Remove temporary bund – team 1
- Construct final section of Eastern Bund – team 2
- Note materials from temporary bund will be re-used where possible in closing the eastern bund.

# Grid connection

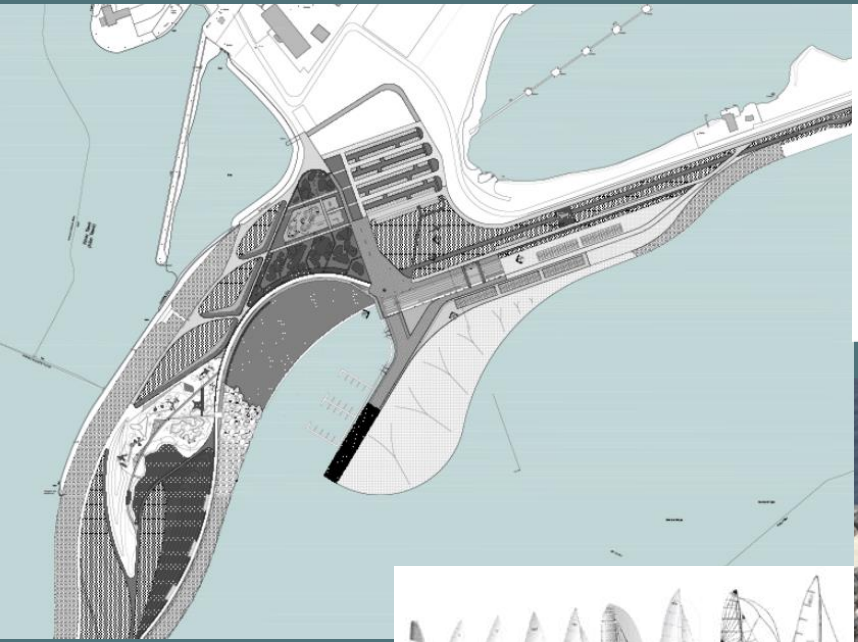
- Along Western bund wall
- South of ABP Queens Dock, and  across to Fabian Way
- Along Fabian Way in westbound verge
- Across Crymlyn Burrows SSSI, under existing metalled track
- River Neath crossing – Directional Drilling



# Architectural designs

## Western Landfall Building – O&M, boating centre

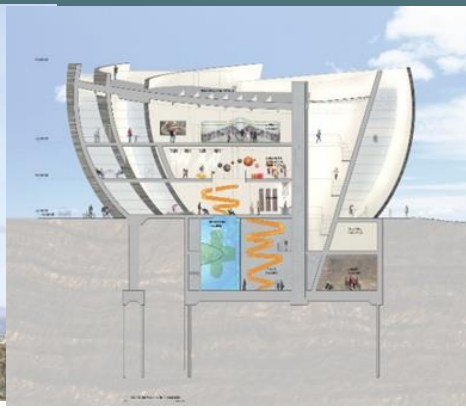


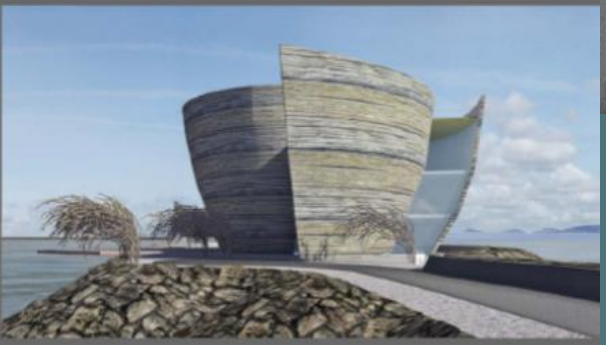
# Architectural designs

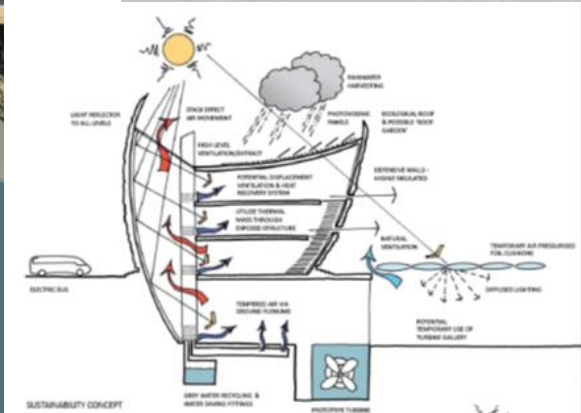
## Western Landfall Building – O&M, boating centre

# Architectural designs

## Offshore Building – O&M and visitor centre

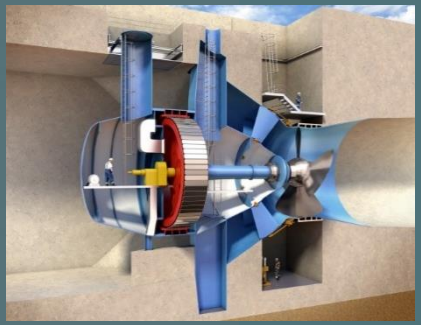






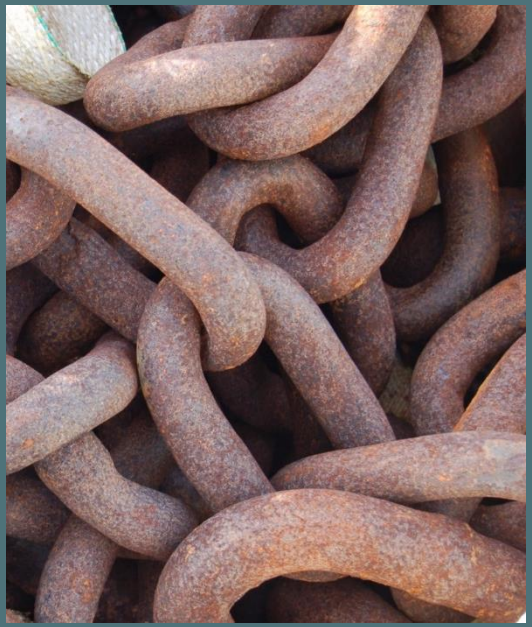
# A UK supply chain

Realising a 50% Welsh, 65% UK content aim

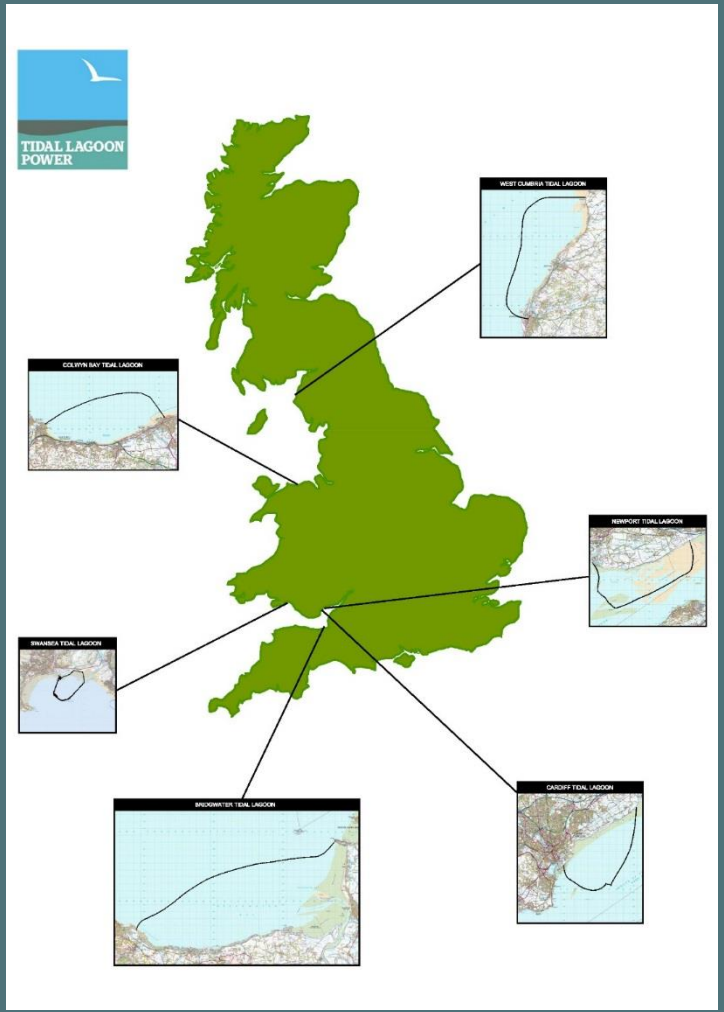
# Employment and economic stimulus in Wales

- **Construction:** 1850 full time equivalent jobs (5,540 new job years) directly created during three-year construction
- **Operations & maintenance:** est. 60 long-term, permanent jobs running the lagoon
- **Leisure:** est. up to 90 additional leisure industry jobs
- **Gross Value Added:** £173m during construction, £264m lifetime operations, £252m lifetime leisure impacts



Independent data from Cardiff Business School. *Turning the Tide: the economic significance of the Tidal Lagoon Swansea Bay*, Prof M Munday, Prof C Jones, Welsh Economy Research Unit, Cardiff University

UK fleet of lagoons




DO NOT SCALE
COMMERCIAL IN CONFIDENCE
NEWPORT
CARDIFF / CAERDYDD
CARDIFF / CAERDYDD
PENARTH
MOUTH OF THE SEVERN / ABER HAFREN
Middle
Tidal Lagoon Power
TLP-CARDIFF
LOCATION PLAN


DO NOT SCALE
SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION
CONSTRUCTION
MAINTENANCE/CLEANING
DECOMMISSIONING/DEMOLITION
LAGOON WALL
TURBINE HOUSING
NEWPORT / CASNEWYDD
WELSH GROUNDS
AREA TO DREDGE
PORTISHEAD
THE SEVERN
DRAFT
ATKINS
TIDAL LAGOON
(SWANSEA BAY) PLC
TIDAL LAGOON NEWPORT
LAGOON LOCATION
TLN-ATK-SO-XX-DR-C-0001
A


COMMERCIAL IN CONFIDENCE
NOT TO SCALE
IRISH SEA
MARYPORT
WORKINGTON
COCKERMOUTH
Tidal Lagoon Power
TLP-WEST CUMBRIA
LOCATION PLAN
TLP-WEST CUMBRIA-000014


COMMERCIAL IN CONFIDENCE

| No | Description | By | Date | Chkd | Appd |
|---|---|---|---|---|---|

Tidal Lagoon Power
The Lydiate
61 Lansdown Road
Cheltenham
England
GL50 2JB

TIDAL LAGOON POWER

Project
TLP-COLWYN BAY

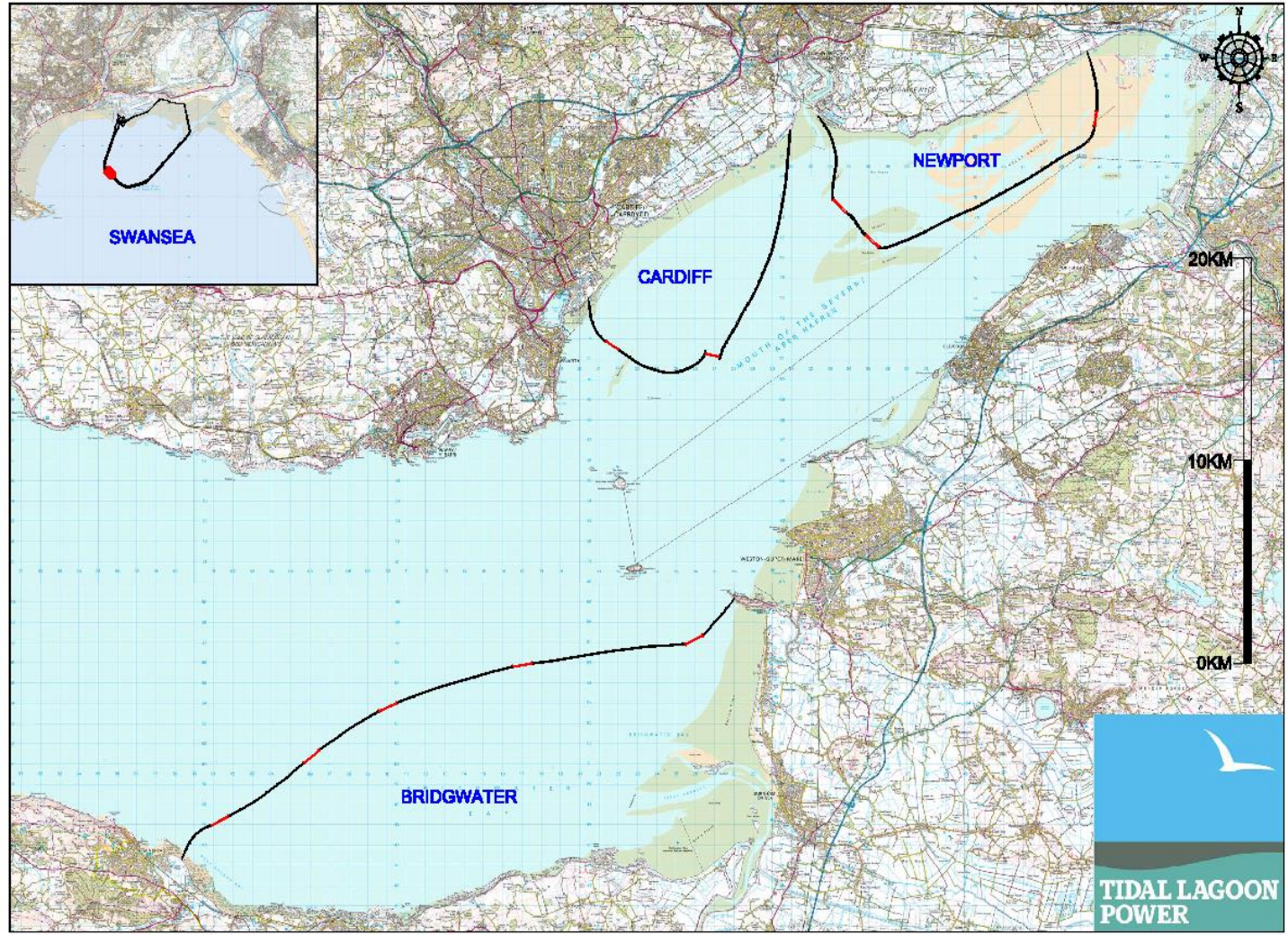
Title
LOCATION PLAN

| Engineer | Drawn | Checked | Authorised | Status |
|---|---|---|---|---|
| | BC | TVDP | TVDP | |
| | Date: 03.08.15 | Date: 06.08.15 | Date: 06.08.15 | |

Drawing Number
TLP-COLWYN-000014

Rev
D


DO NOT SCALE
COMMERCIAL IN CONFIDENCE
WESTON-SUPER-MARE
BRIDGWATER BAY
BRIDGWATER
BAY
Tidal Lagoon Power
TLP BRIDGWATER
LOCATION PLAN


SWANSEA
CARDIFF
NEWPORT
BRIDGWATER
20KM
10KM
0KM
N
W
E
S
TIDAL LAGOON
POWER

# Future Lagoons: key statistics

| Item | SBTL | Cardiff | Newport | Bridgwater | Colwyn Bay | West-Cumbria | Total |
|---|---|---|---|---|---|---|---|
| Surface area [km$^2$] | 11.5 | 69.8 | 64.5 | 281.6 | 123.6 | 156.4 | 725.4 |
| Total wall length [km] | 9.9 | 21.3 | 27.6 | 32.5 | 25.6 | 31.3 | 148.2 |
| Bund wall length [km] | 9.5 | 19.7 | 25.9 | 27.0 | 23.5 | 28.4 | 134.0 |
| Cofferdam length [km] | 1.9 | 5.0 | 5.3 | 15.1 | 7.2 | 8.1 | 42.5 |
| No. of turbines | 16 | 90 | 65 | 220 | 75 | 100 | 566 |
| No. of sluices | 8 | 25 | 30 | 95 | 50 | 70 | 278 |
| No. of blocks | 1 | 2/3 | 2/3 | 5 | 3 | 3 | 16 |
| Emax [GWh/year] | 975 | 10,356 | 10,425 | 38,311 | 7,774 | 10,362 | 78,203 |
| Average tide [m] | 6.67 | 9.21 | 9.46 | 8.58 | 5.75 | 5.92 | |
| Net AEP [GWh] - without pumping | 512 | 4,828 | 4,352 | 14,190 | 2,958 | 3,955 | 30,795 |
| Power installed [MW] | 320 | 2,700 | 1,950 | 6,600 | 2,250 | 3,000 | 16,820 |

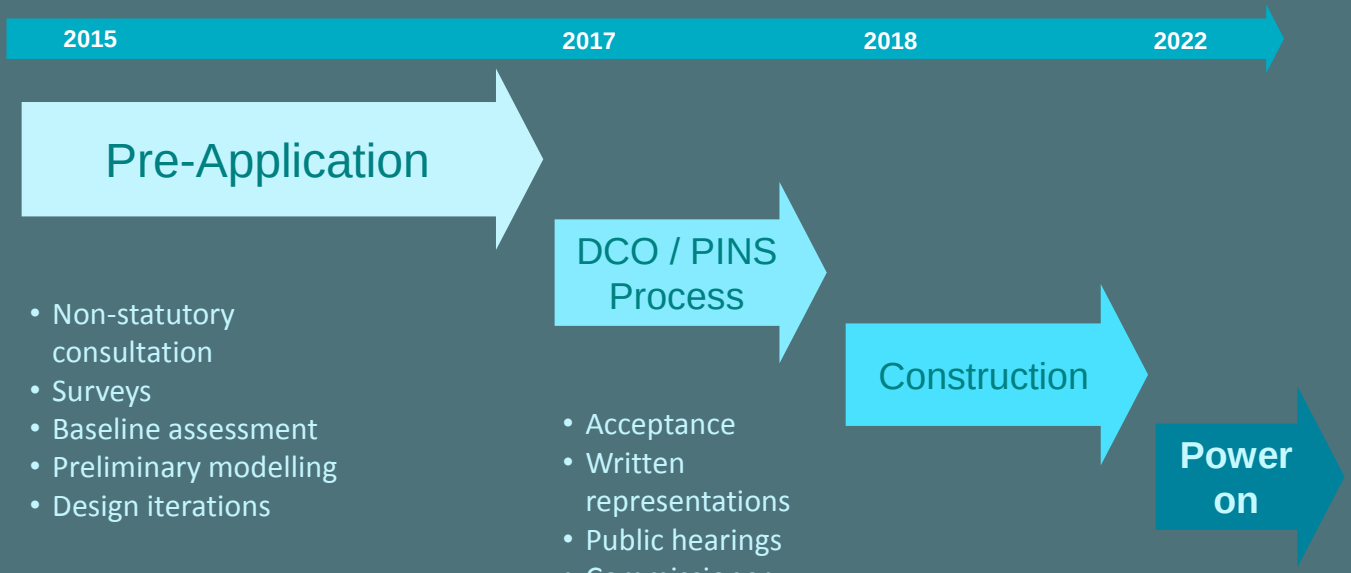
# Some UK statistics:

- UK electricity consumption 290 TWh in 2013
- Renewable installed capacity: 19.5 GW in 2013. ( Mainly wind ).
- Renewables 15 % of electricity generation ( 2013).
- Cardiff Tidal Lagoon, 5.5 TWh or about 2 % of UK demand.
- 6 potential Tidal Lagoons can provide about 8 % of electricity demand.

# Future lagoons: volume & programme

| Lagoon | Turbines | Sluices | Construction start | Power On |
|---|---|---|---|---|
| **Swansea** | 16 | 8 | 2015 | 2019 |
| **Cardiff** | 60-90 | 30 | 2018 | 2023 |
| **Newport** | 60-70 | 20 | 2019 | 2024 |
| **Bridgwater** | 180-220 | 95 | 2021 | 2027 |
| **Colwyn Bay** | 65-75 | 50 | 2022 | 2027 |
| **West Cumbria** | 80-100 | 70 | 2020 | 2025 |

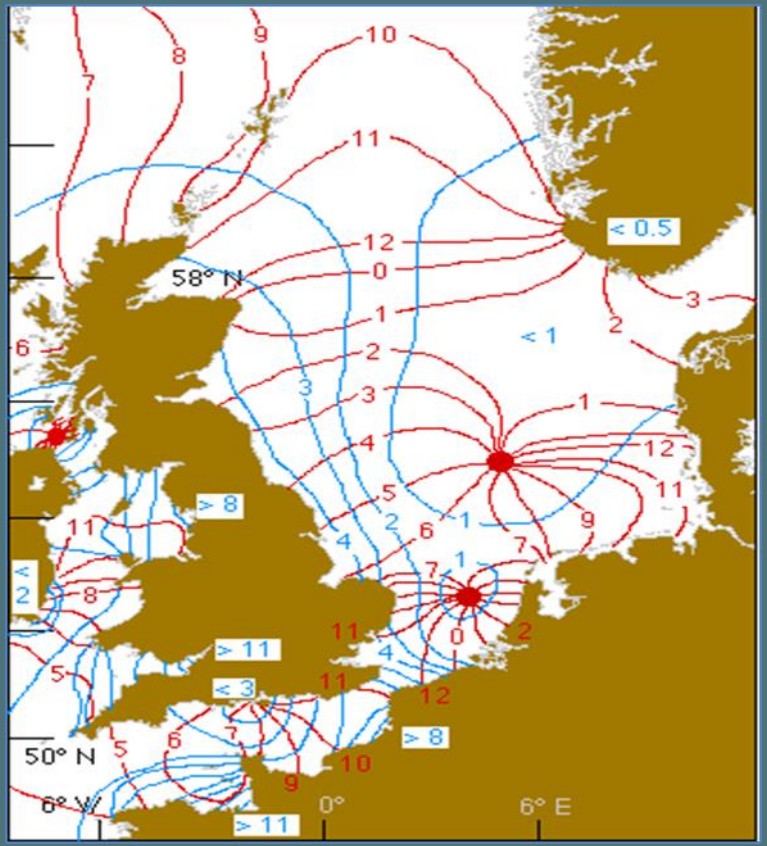
# Cardiff Timeline



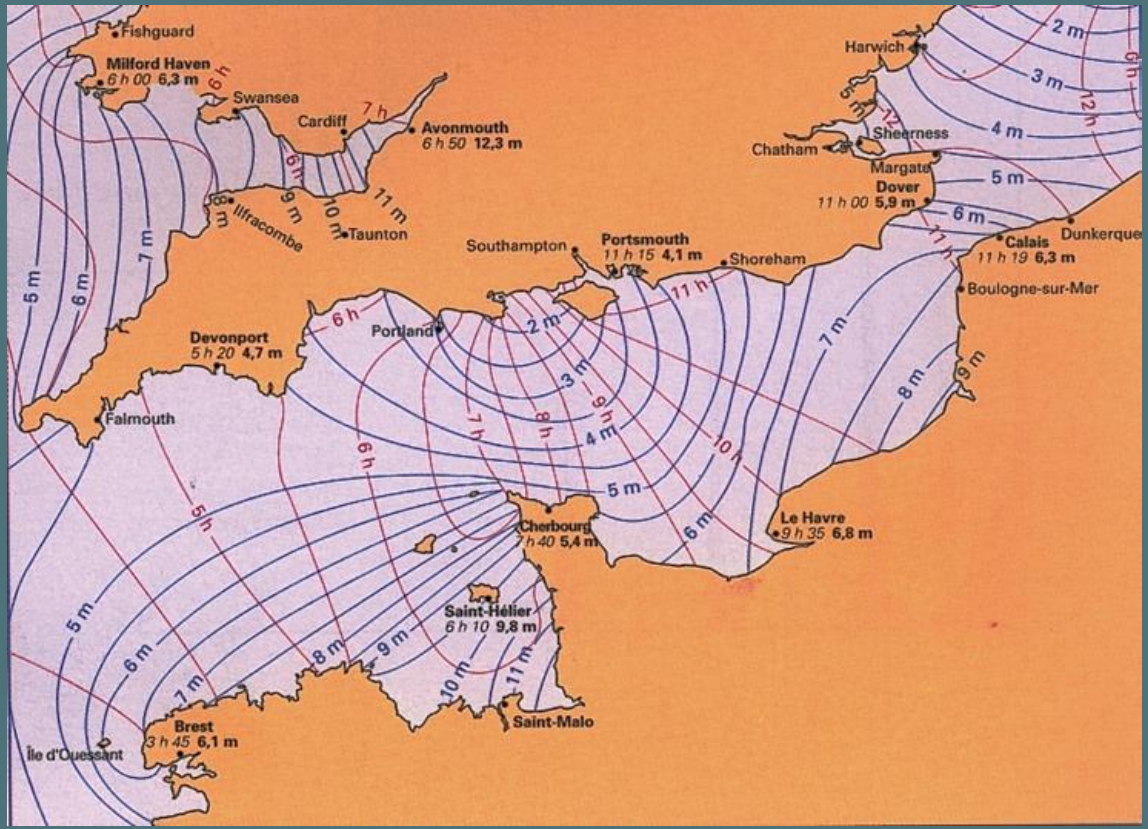
# R & D Focus:

- 2 D power output modelling
- Multi-basin lagoons.
- More balanced power output, base load ?
- Housing structure, in-situ versus caisson construction.
- Reduce Loss of intertidal area.
- Compensation of intertidal habitat.
- Combining tidal lagoons and wind turbines
- Improve fish friendliness.
- Sedimentation, maintenance dredging

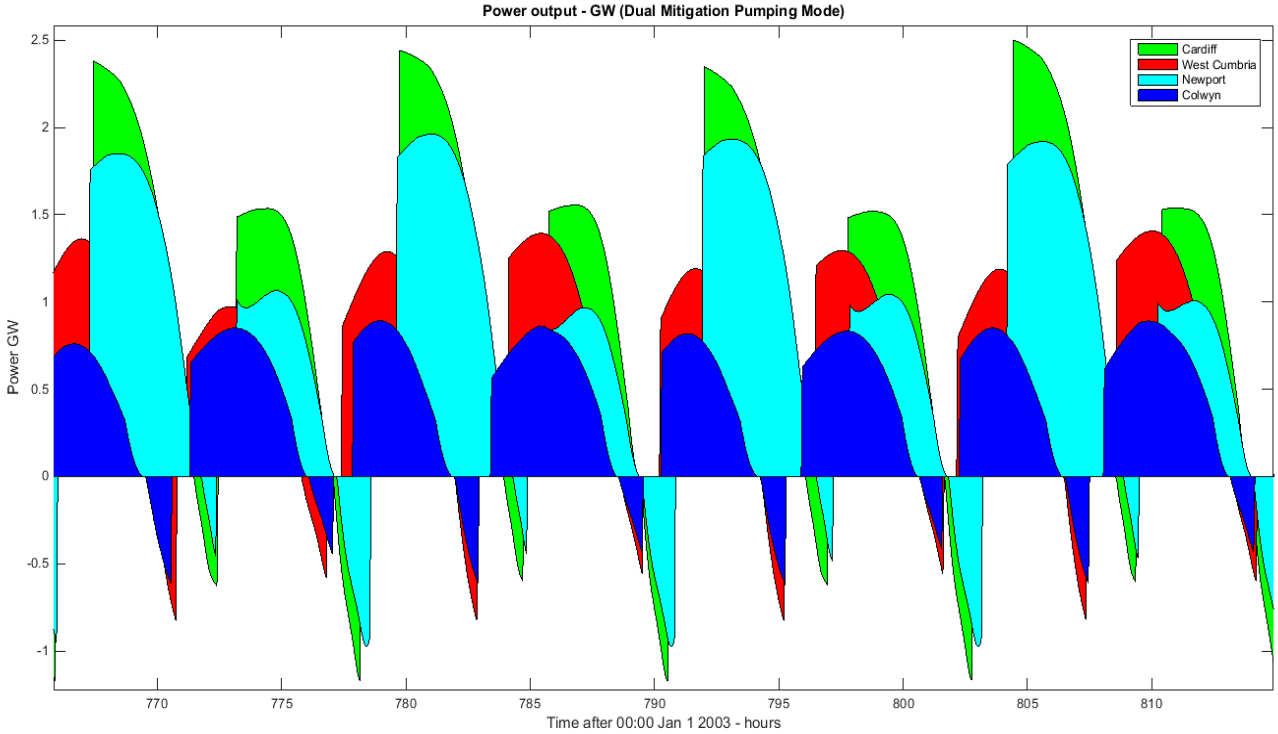
# High tides and Phasing



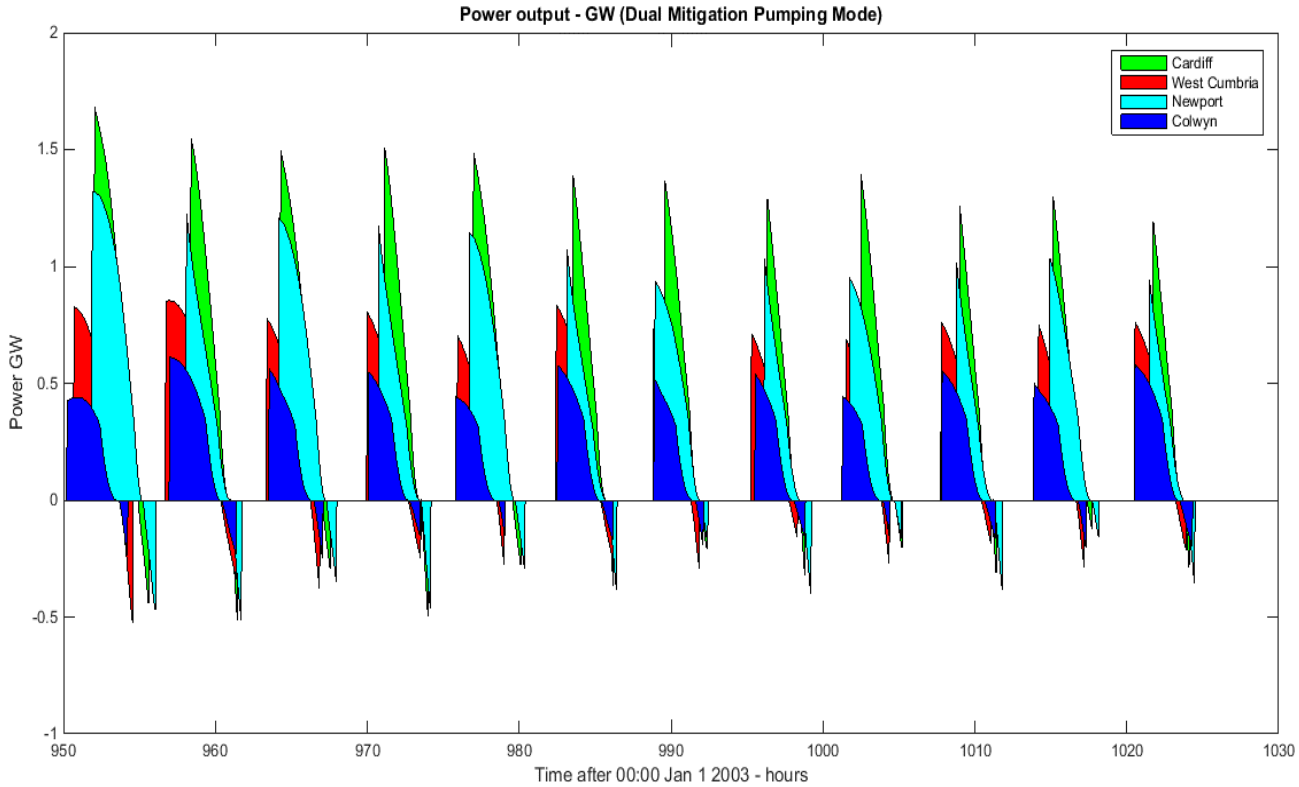
# More Detail in Severn



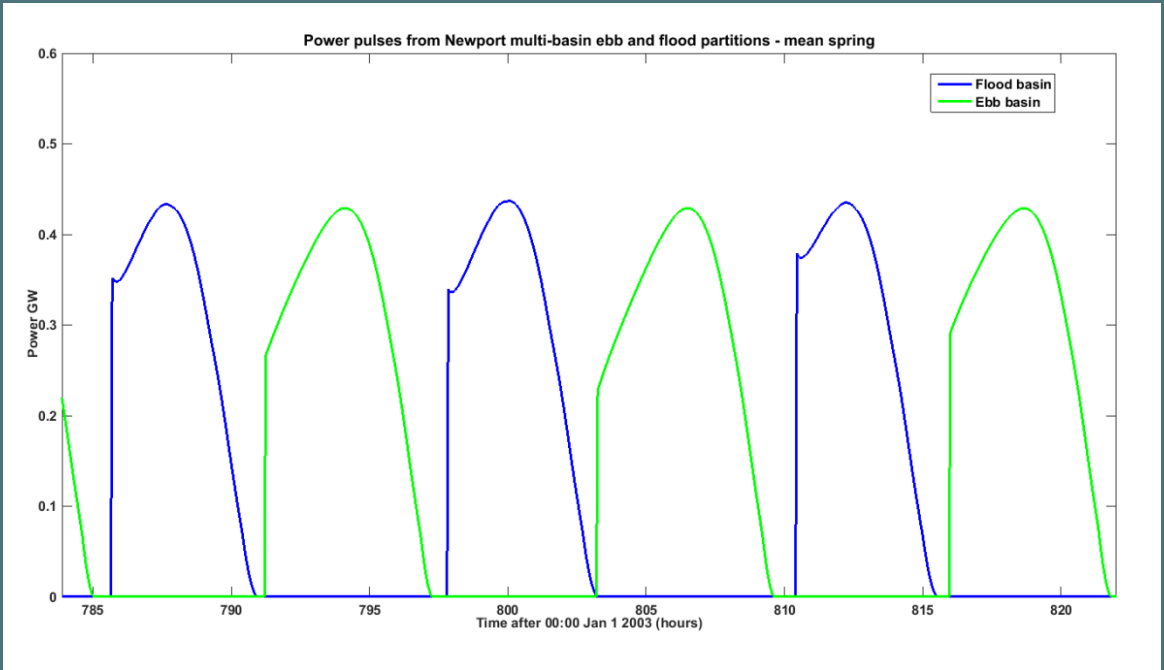
# Power Output 4 lagoons, spring tide.



# Power output, 4 lagoons Neap tide



# Newport, 2 – lagoon system.



# THANK YOU!

TIDAL LAGOON POWER