Power Station Fish Recovery and Return Systems: Why They Are Only Part of a Best Practice Solution

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Outline

- History:Early CEGB smolt return, Sizewell B: Fish return & testing
- Factors that limit FRR success:
  - Biological
    - Swimbladder type
    - Fragility
    - Loss of equilibrium
  - Engineering
    - Pressure changes
    - Forebay issues
    - Debris screening
    - Level changes
    - Recirculation at outfall
- Fish Recovery & Return (FRR) EA guidance
- Integrating FRR into a Best-Practice Solution

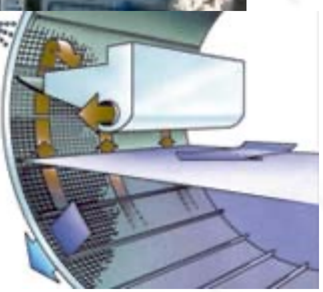
Development of FRR in the UK

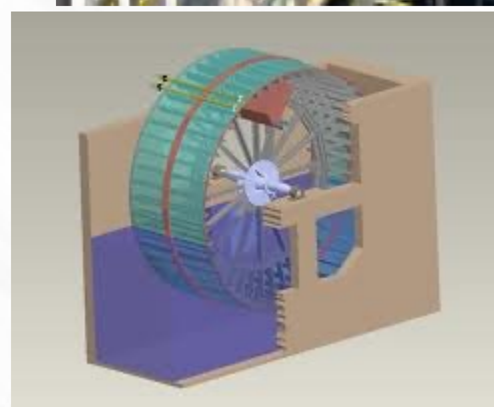
Early CEGB-era Smolt Return

- Oldbury-on-Severn, Uskmouth power station salmonid smolt kills (several thousand per yr)
- Initial smolt rescue by bucket and rope!
- Smooth PVC trash buckets and launders allowed smolts to be diverted to a tank for manual return to estuary
- MAFF trials showed 72% returned alive

1990s: Sizewell B (SZB) Nuclear Station: a Step Forward

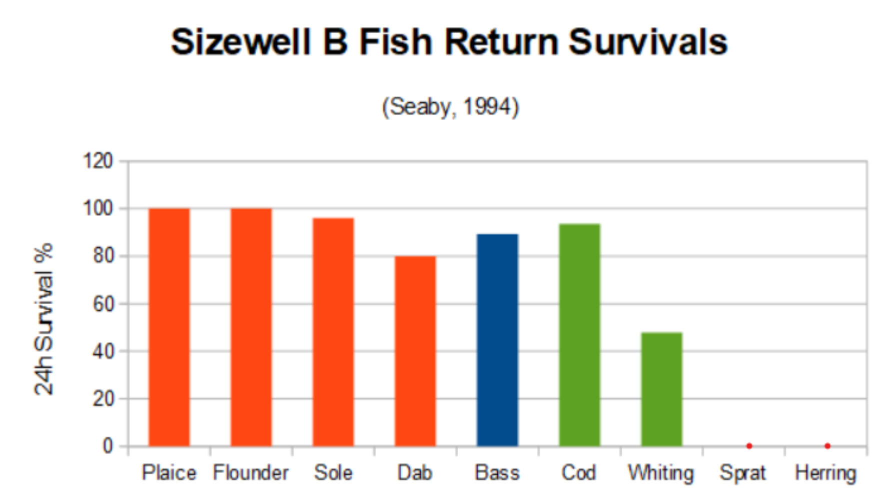
- Fishing industry concerns at SZB Inquiry led to better design intentions
- Whereas at SZA macerated fish and marine debris or sent it to landfill, SZB included option to divert unsorted screen debris into the thermal discharge seal pit and back to sea (with ΔT & Cl)
- There is no dedicated fish return route direct to sea at SZB
- But survival trials showed good results for more robust species despite ΔT & Cl exposure





1990s: Sizewell B (SZB) Trials

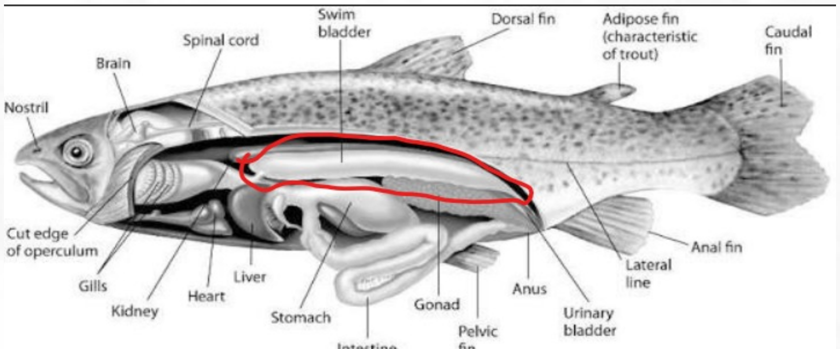
- 24h survivals of screened fish held in simulated thermal discharge conditions
- High survivals of flatfish and bass, cod
- <50% survival of whiting, also pout
- But zero survival of sprat, herring



- Very similar outcomes reported in other UK and French power station trials

Biological and Engineering Limitations of FRR

Biological Vulnerabilities: 1. Barotrauma- Swimbladder Rupture



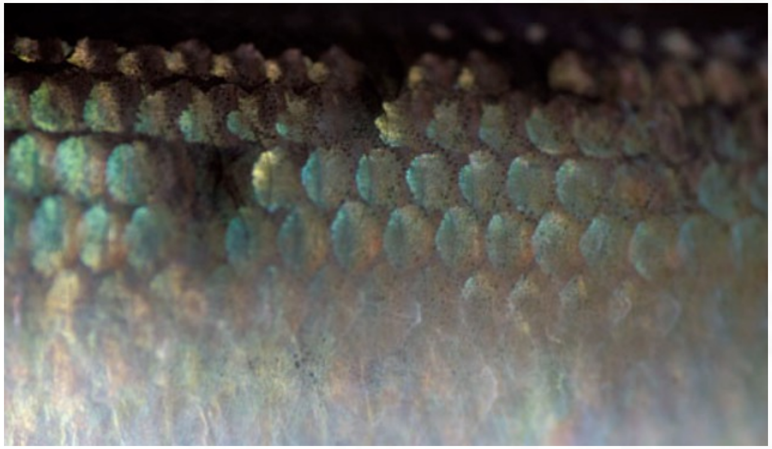
- Fish may have vented swimbladders (physostomes), closed (physoclists) or none
- Physostomes (eg gadoids) adapt only slowly (hours) to pressure change and sudden pressure reduction may cause s/b to expand and rupture (Boyle's Law)
- In SZB trial 35% of impinged ***whiting*** & 66% of ***pout*** had ruptured swimbladders
- Burst swimbladders commonly reported in screen catches from stations with deep tunnels

Biological Vulnerabilities: 2. Barotrauma- Gas Embolisms

'Red-Eye' in Herring

- 'Red-eye', often found post-impingement in herring and sprat is caused is caused by gas embolisms caused by sudden pressure shock
- Probably another factor in the high mortality of these species.

Biological Vulnerabilities: 3. Scale Loss/Skin Damage

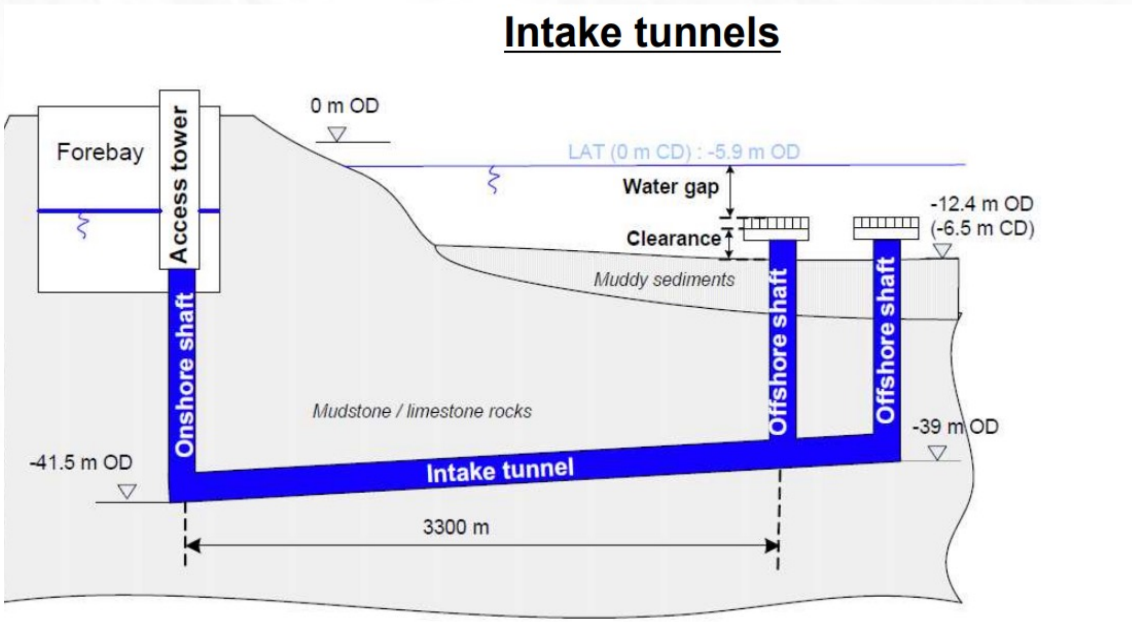


- Fragile pelagic fish such sprat, herring, shad have deciduous scales and normally avoid contact with hard beds and structure (thigmophobic)
- Once scales are lost, epithelial damage occurs and osmotic balance cannot be maintained ***(blood 16ppt vs seawater 34ppt)***.
- The fish show a rapid loss of equilibrium and quickly die
- **Probably the main factor in low survivability in fish return systems**

Biological Vulnerabilities: 4. Predation Risk at FRR Outfall

- Even in the best-designed FRR systems fish are subjected to rapid changes of direction and velocity with potential to disturb vestibular balance
- **Such disturbance leaves returned fish vulnerable to predation at the FRR outfall**

Engineering Limitations 1:
Deep Tunnels Create Sharp Pressure Changes

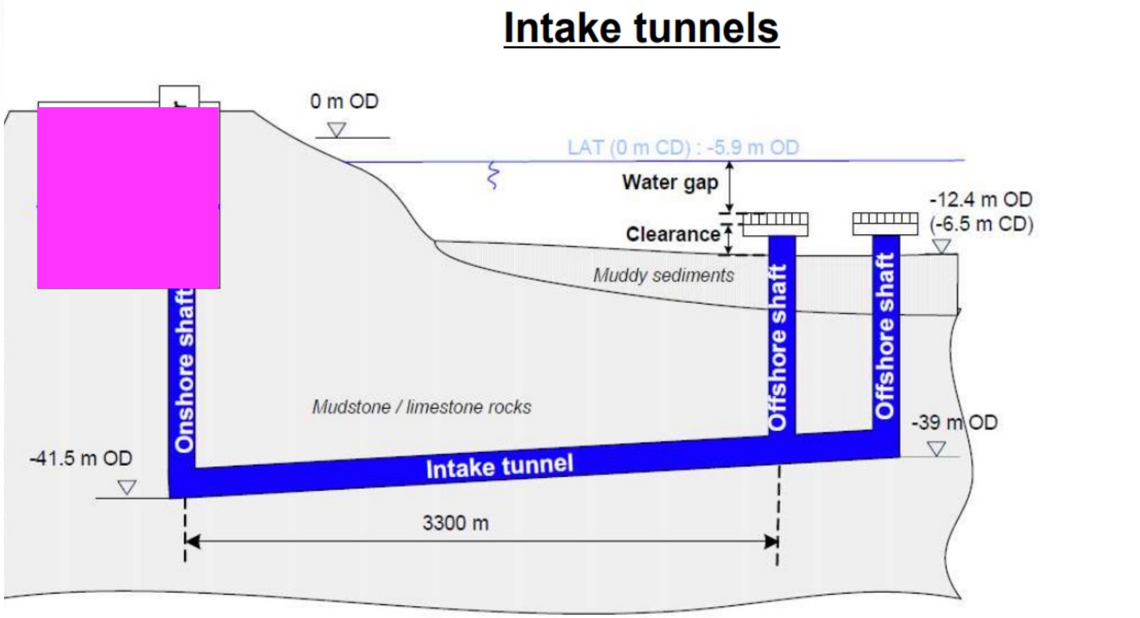


- In this example (HPC) a fish may experience pressure change from water body to forebay ranging from 1 to 5.2 atm

  - a potential 5-fold swim-bladder volume change

- **Engineering cannot avoid this**

Engineering Limitations 2:
Turbulence and Delay in Forebay/Screenwell

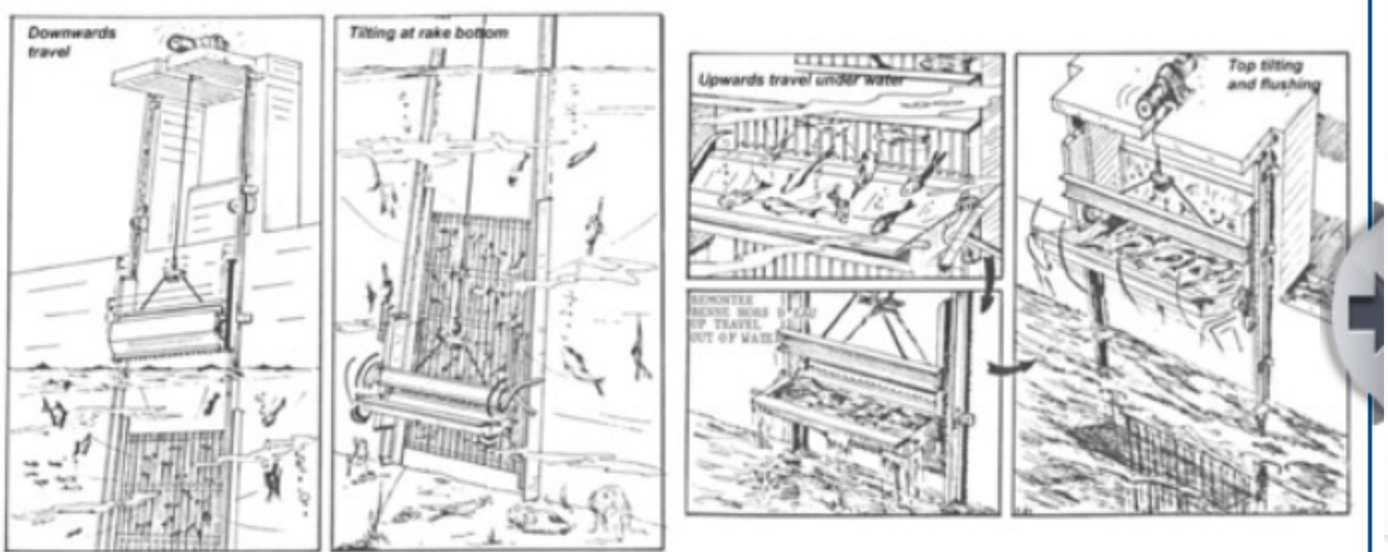


- Fish exiting intake riser discharged into a large turbulent water body in the screenwell
- **Potential for disorientation, exhaustion and abrasion**

Engineering Limitations 3:

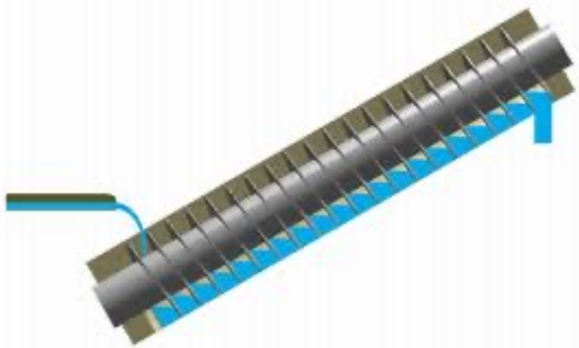
Debris Separation & Removal in Fish Return Route

- Intake head bar screens typically 150+mm spacings, allowing sticks and other debris to enter.
- This cannot be allowed to enter launders due to blockage risk, so drum screens are sometimes protected from larger debris entering by ~50mm raked screens in forebay. Survivability of large fish unknown.
- **Potential for disorientation, exhaustion and abrasion**



Engineering Limitations 4:
Dealing with Site Levels and Sea Walls

- Changes in deck levels along fish return route present engineering issues and may present additional trauma risk for fish
- Archimedean screw pumps may be required to cross nuclear-critical sea defence walls



Environment Agency Best Practice/Scientific Evidence

- The 2005 Screening Guidance and 2010 Cooling Water Guide form the basis for fish protection on all new UK CCGT and NNB stations
- Guidance is predicated on the principle that it is better to prevent fish entry than to entrap, handle and return fish: but not all fish can be excluded at the intake point

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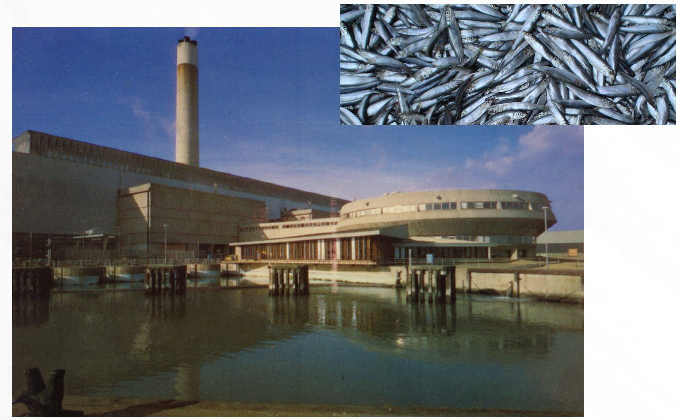
  – Intake water velocities < target fish sustainable swimspeed
  – Some form of warning stimulus at the abstraction point (eg acoustic &/or strobe lighting)
  – Well designed FRR to return fish to water body

Intake Approach Velocity:
Keep it low enough and fish will be able to escape?

Why it is Not Enough to Limit Intake Velocity

The case of juvenile clupeids and the stone-throw test

- Small clupeids are often the largest part of the impingement catch at coastal stations
- At Fawley PS clupeids of 60-70mm frequently seen to swim for hours in CW inlets @ 0.5m/s



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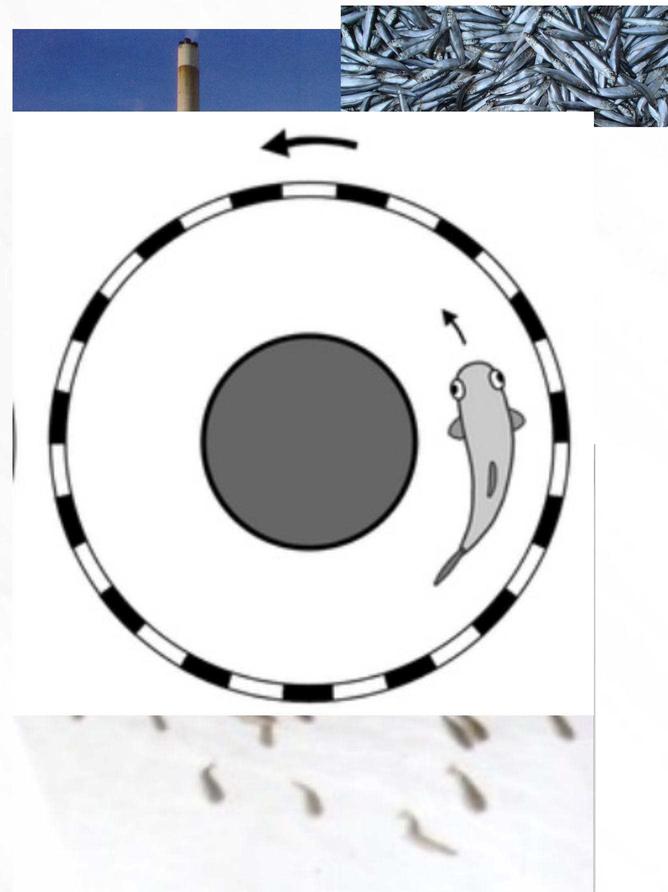

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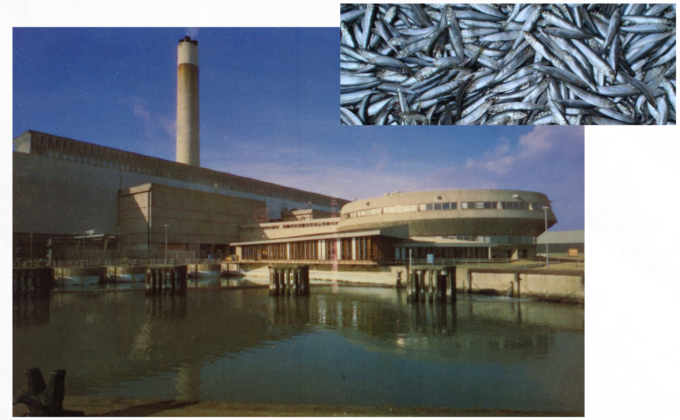

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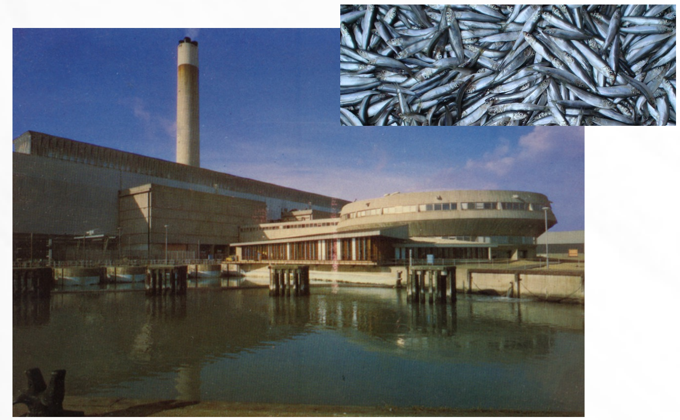

- Conclusion: maintaining velocity below sustainable swim-speed will not by itself prevent entrapment

Are Acoustic Fish Deterrents the Answer?

AFD Strengths & Weaknesses

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- Bottom fish (flatfish, eels etc) react poorly (0-30% deflection)

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- AFDs work best with 'hearing specialists' such as sprat, herring, shads and cyprinids (60-95% deflection)

- Other spp. with a swimbladder such as gadoids, bass react moderately (54-76% deflection)

- Bottom fish (flatfish, eels etc) react poorly (16-46% deflection)

Hence AFD is not the fix-all solution!

The Best Practice Solution

The Best Practice Solution

- Approach velocities below the target fish species' maximum sustainable swim-speed are a prerequisite for fish to escape
- This table shows how AFD and FRR are mirror-images in terms of fish protection: one complements the other
- The Best Practice solution therefore requires all three measures working together- missing out any one of them compromises fish protection

Fish Group	AFD	FRR
Pelagic	60-95%	0-10%
Demersal	54-76%	50-80%
Epibenthic	16-46%	>80%

Reported AFD Deflection Efficiencies and FRR survival rates for estuarine power station sites (Environment Agency Screening Best Practice Guide 2005)

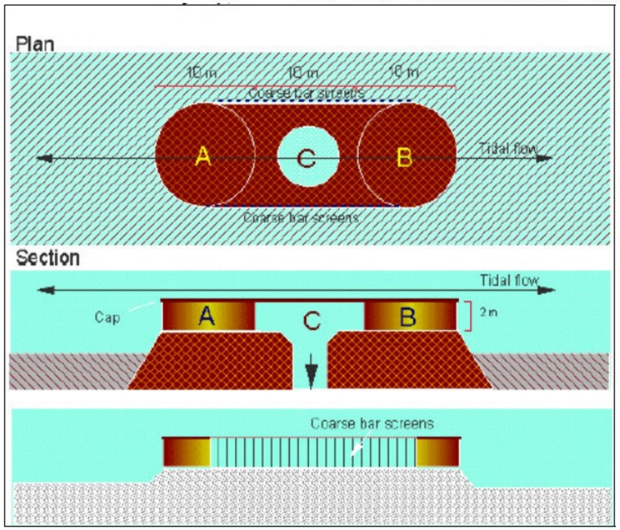
The End -Thank You!

Why Do Fish Enter Water Intakes?

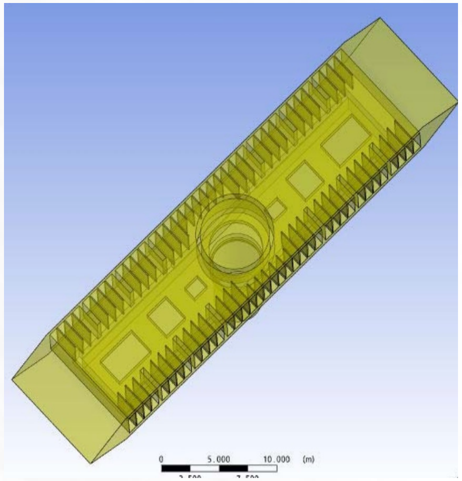
Fish become entrained when:

- Present in the abstraction zone of influence
- Water velocities too high to resist
- When positively rheotactic (smolts, elvers, salt marsh fish)
- When they lack orientation cues (due to low visibility or large size of intake)

Fawley Power Station and Saltmarsh



Plan
10 m
10 m
10 m
Coarse bar screens
A
C
B
Tidal flow
Coarse bar screens
Section
Tidal flow
Cap
A
C
B
2 m
Coarse bar screens



0
5.000
10.000
(m)

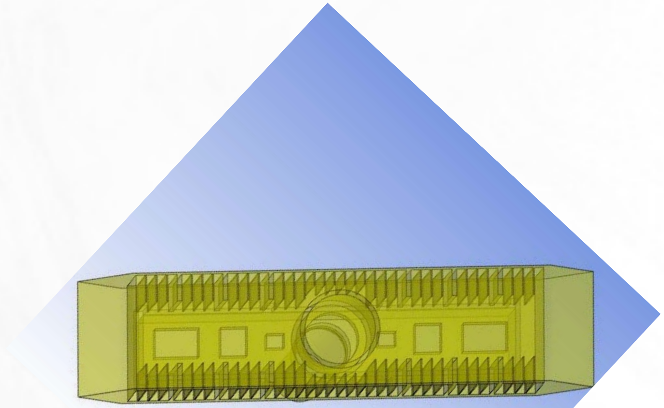


Figure 3.14a Final Arrangement, Plan mid-way up the screens
Current velocity = 1.5m/s, Water level = 0.1mOD (MSL)