Assessment of fish damage in pumps and turbines – a new standard

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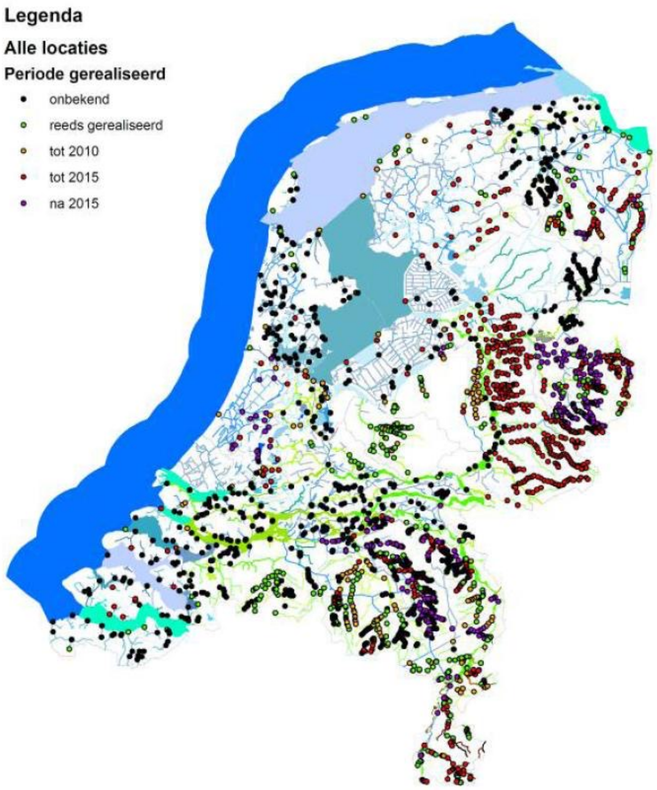
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Need for fish protection

- European Parliament directive (2000/60/EC)
  - preservation of fish habitat
  - unobstructed migration of fish
- pressure exerted on
  - national government, local water authorities :
    remedy potential hazards
  - pump and turbine manufacturers :
    develop fish-friendly alternatives



Developments in the Netherlands

- monitoring of pumping stations since 2005
- review of biological criteria / response models (Pacific Northwest National Laboratory, Oak Ridge National Laboratory, Alden Research Laboratory)
- new fish-friendly pumps and turbines
- NEN 8775 standard on fish damage assessment

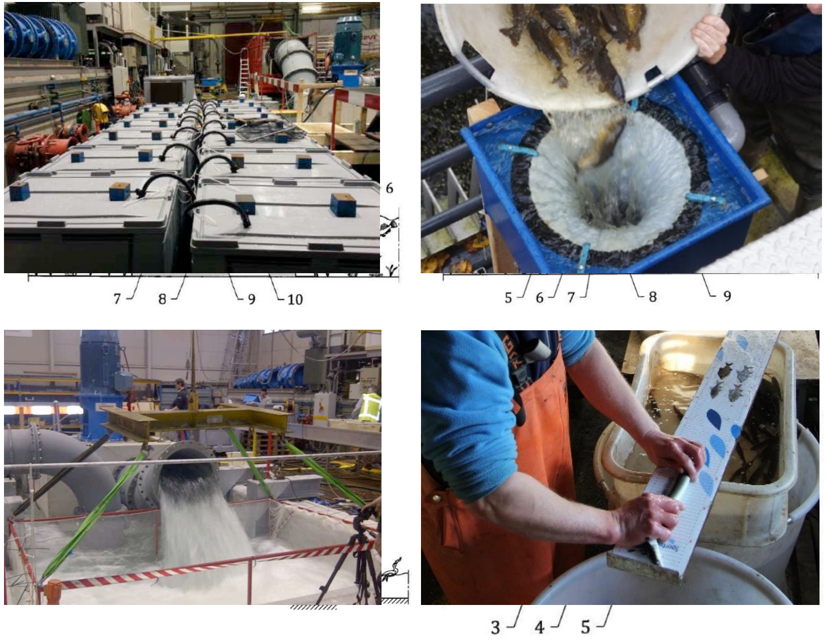
mortality

injury

NEN 8775 standard

Assessment of fish damage in pumps and turbines:

- Tests with live fish
  - choice and origin of fish
  - transportation and storage
  - requirements set-up
  - preparing and conducting experiments
  - assessment of damage, sedation
  - number of fish, statistics, and accuracy
- Fish mortality model
  - blade strike mortality
  - low to moderate head values



Blade strike mortality model

Model for a pump (simplified)

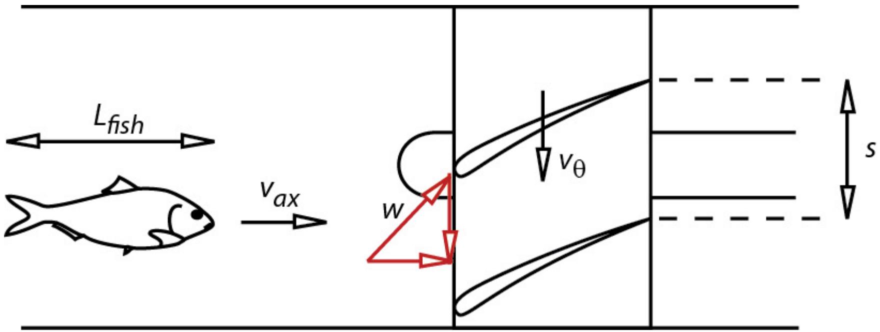
$$t_{fish} = \frac{L_{fish}}{v_{ax}} = \frac{L_{fish}A_1}{Q}$$

$$t_{blade} = \frac{s}{v_\theta} = \frac{2\pi r/n}{N2\pi r/60} = \frac{60}{nN}$$

$$P_{th} = \frac{t_{fish}}{t_{blade}} = \frac{L_{fish}A_1 nN}{60Q}$$

$$f_{MR} = \left[a \cdot \ln\left(\frac{L_{fish}}{t}\right) + b\right](w - 4.8)$$

$$P_m = f_{MR}P_{th}$$



Blade strike mortality model

Model for a turbine (simplified)

$$w_\theta = \Omega r - \frac{v_r}{\tan\alpha}$$

$$t_{fish} = \frac{L_{fish}\sin\alpha}{v_r} = \frac{L_{fish}\sin\alpha\, 2\pi r B}{Q}$$

$$t_{blade} = \frac{s}{w_\theta} = \frac{2\pi r / n}{w_\theta}$$

$$P_{th} = \frac{t_{fish}}{t_{blade}}$$

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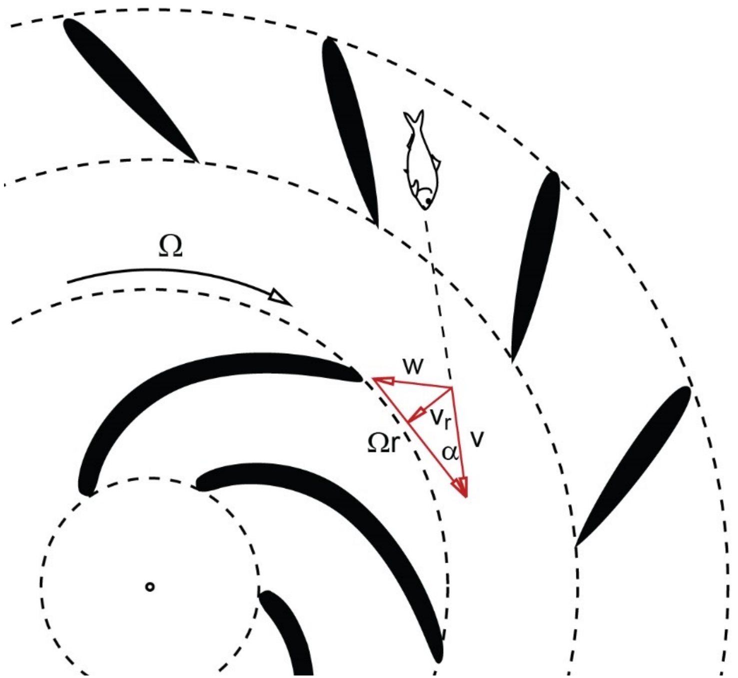
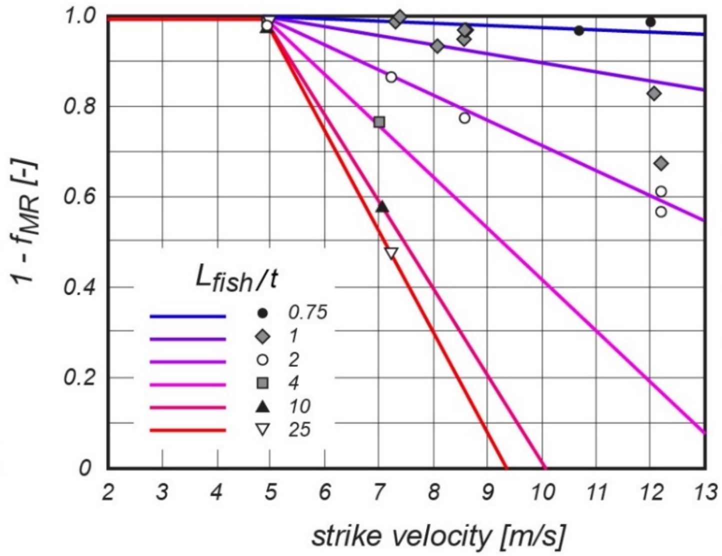
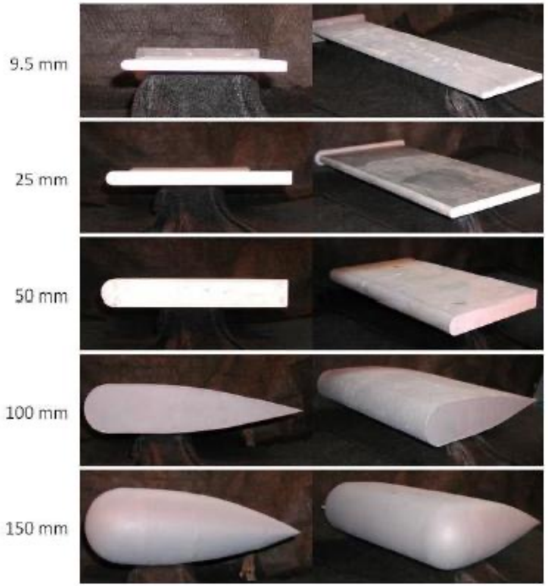


Blade strike mortality model

Biological response model (example)





Blade strike mortality model

Assumptions

- blade strike is prime cause of mortality
- fish are aligned with the flow
- fish move with the flow as passive and neutrally buoyant objects
- fish enter the rotor distributed uniformly over the entrance area

Advantages

- no need for CFD analyses
- low on resources (time, computer, software)
- fish damage analysis in wide operating range

Model validation

Flowserve

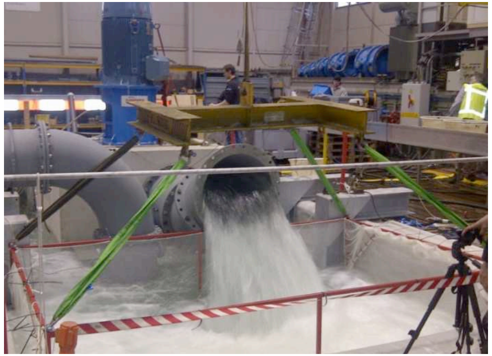
axial-flow, two-bladed pump

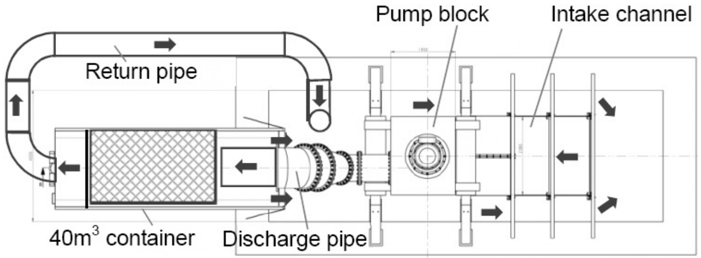
slanted leading edge

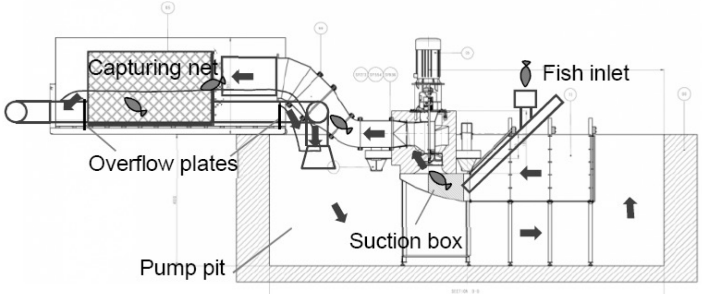
D_i = 56 cm

Speed: 200-380 rpm

Head: 1.4 – 4.0 m







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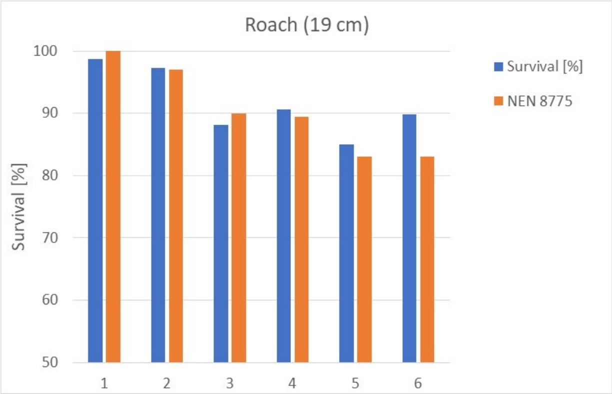
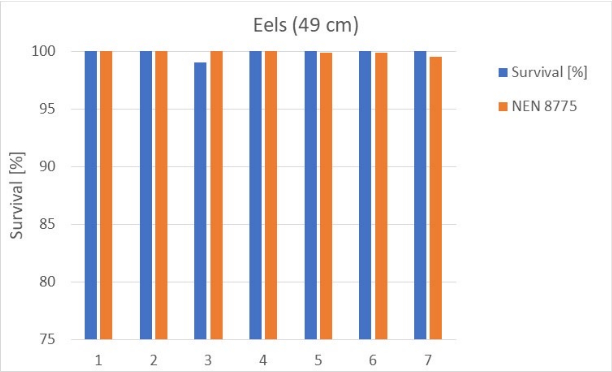
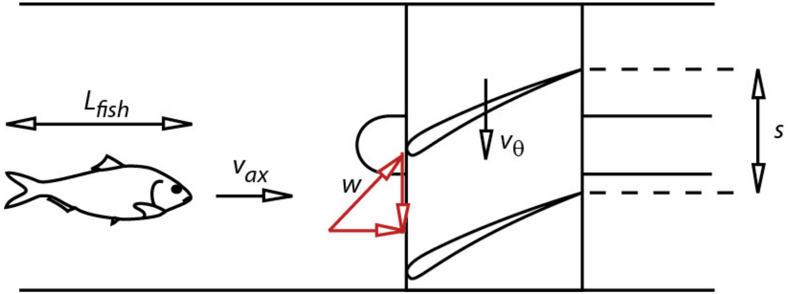
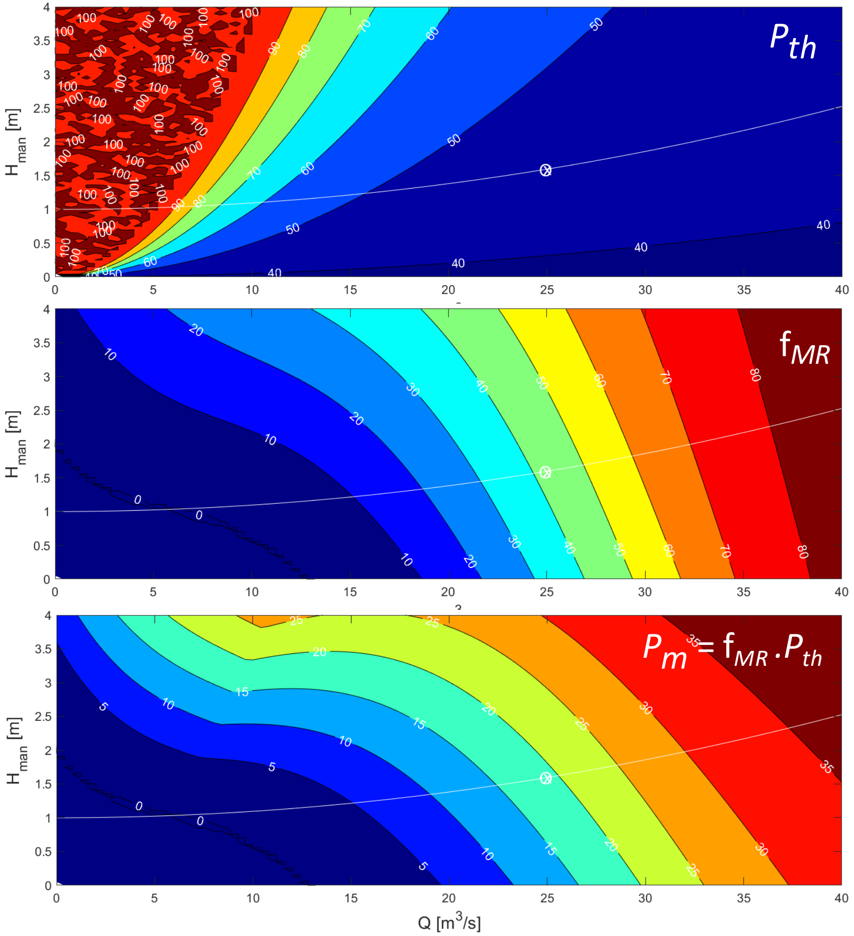




Fish mortality at a glance

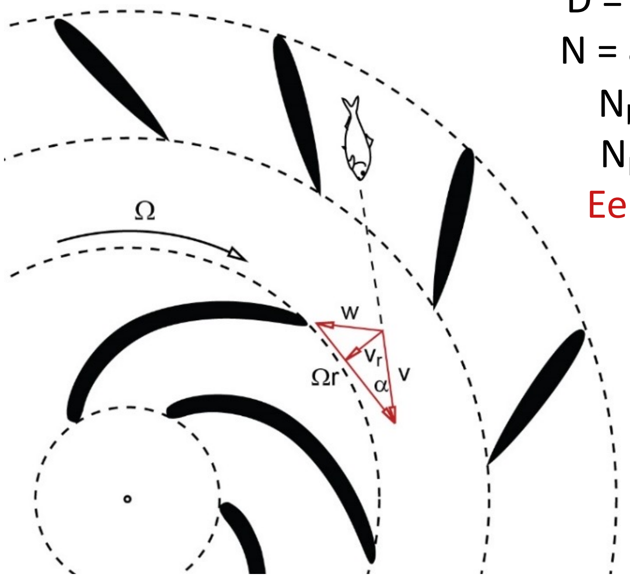
axial-flow pump (N_s = 4.5)
conventional design
D = 2.80 m
N_{blade} = 4
variable speed drive
Trout 25 cm

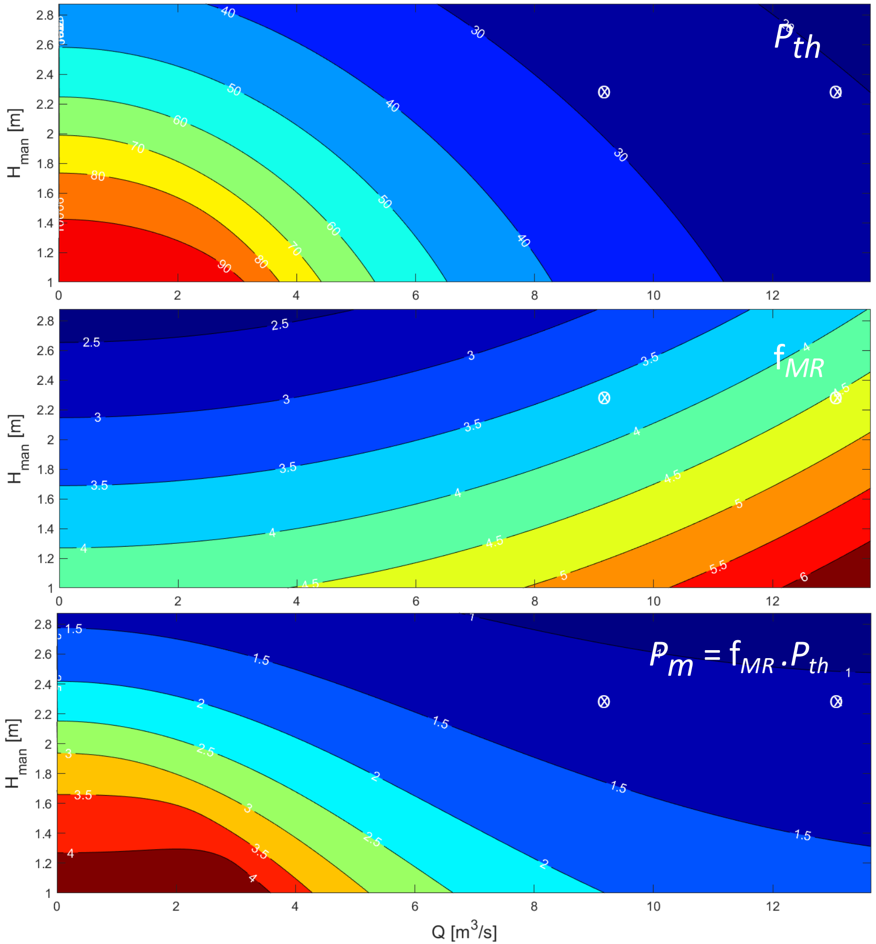




Fish mortality at a glance

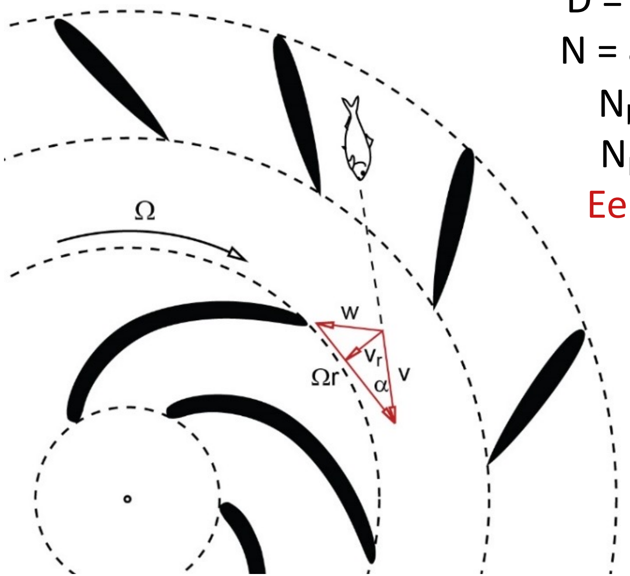
Kaplan turbine (N_s = 4)
D = 0.65 m
N = 88 rpm
N_{blade} = 4
N_{IGV} = 14
Eel 20 cm

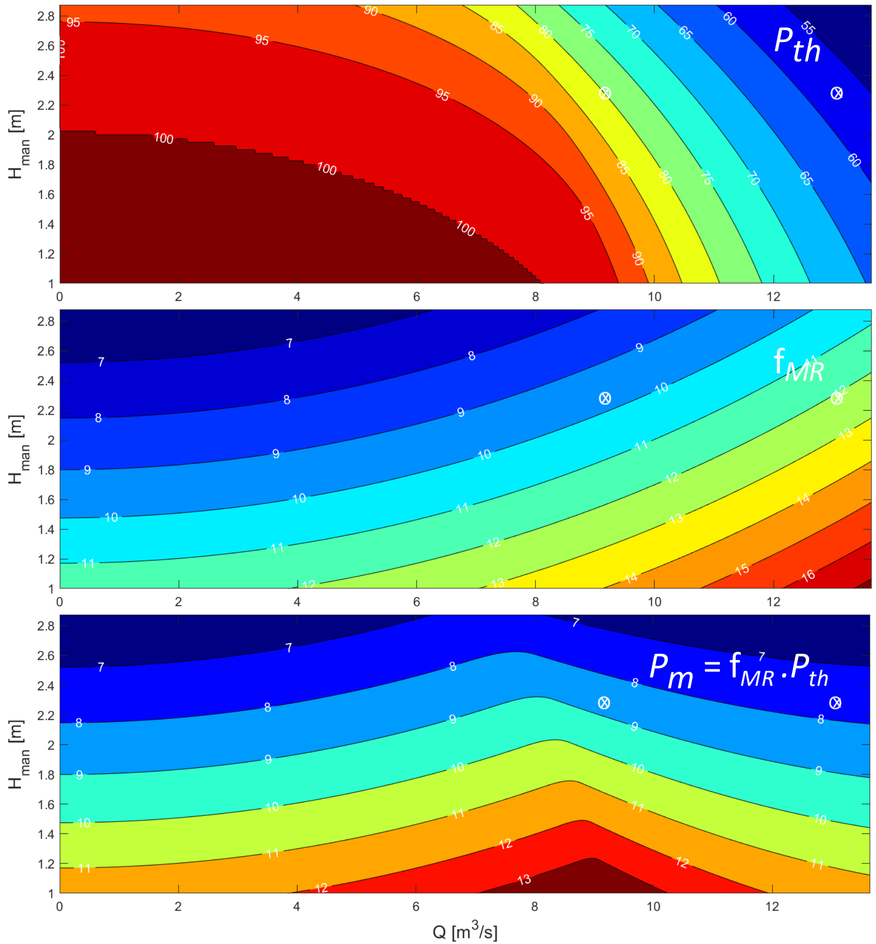




Fish mortality at a glance

Kaplan turbine (N_s = 4)
D = 0.65 m
N = 88 rpm
N_{blade} = 4
N_{IGV} = 14
Eel 50 cm

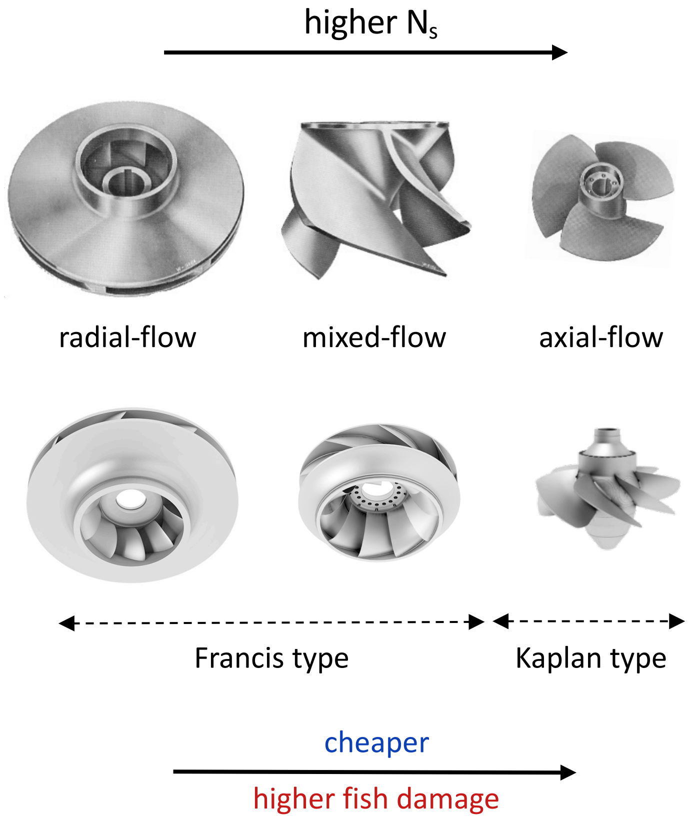




Blade strike damage vs. specific speed

Pump and turbine selection:

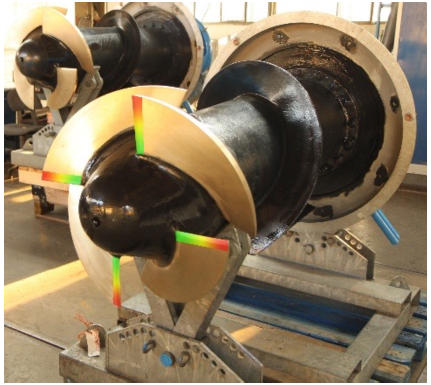
- range of specific speed values N_s
  - low N_s : radial-flow type
  - medium N_s : mixed-flow/Francis type
  - high N_s : axial-flow/Kaplan type
- for same duty head and flow rate:
  larger N_s --> smaller size and higher speed
- for same duty and fish length:
  larger N_s --> higher strike probability
  & higher mutilation ratio



Recent developments

Pump and turbine selection/design

- lower specific speed pump:
  - more fish friendly
  - larger size & lower speed, more expensive
- fewer blades
- thicker leading edges
- leading edges with high slant angle



conventional pump

fish-friendly pump

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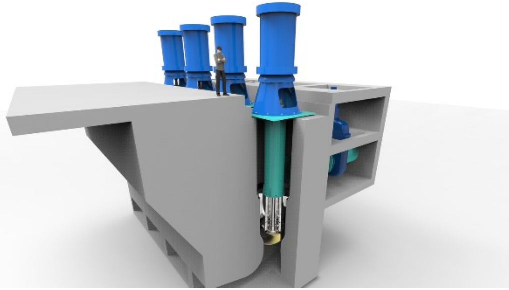
New pump designs

Pentair-Nijhuis

Bedford pumps



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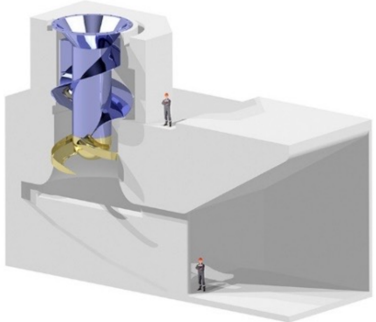
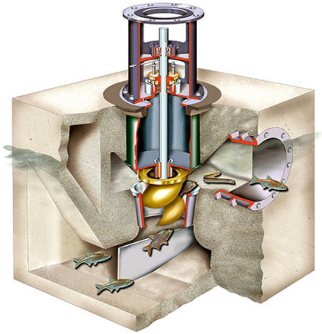


Bosman Watermanagement



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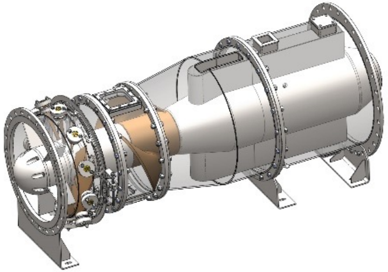
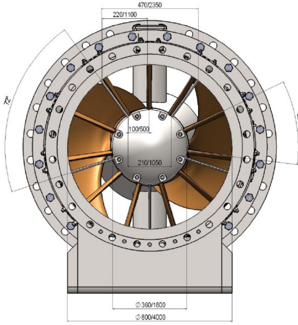
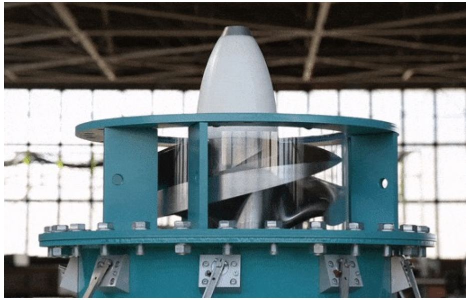
New turbine designs

Pentair-Nijhuis





Natel Energy



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