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Hydraulic design of an optimised vertical-slot fishway targeted at multi-range fish-biology based design criteria for low, medium and high river flows

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Hydraulic design of an optimised vertical-slot fishway

targeted at fish biology based design criteria for:
• low,
• medium, and
• high flows
Presentation content

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Project context and challenges

• Water supply drought security project in upper-mid section of Darling River (unregulated),
  – triggered need for a significant fishway.
• Existing weir a major barrier to both fish passage and connectivity
  – to be further raised 1m.

• Large head difference, ~4.5m.
• Sheet pile rock fill weir type
  – highly variable u/s fish movement limit.
• Need to pass a broad range of fish sizes <90mm to 700mm.
• Maintenance of entrance slot attraction flow.
• Self regulating fishway operation at an unpowered site.
• Lower cost fishway.
Fishway hydraulic design performance issues

Single fixed design criteria.

Initial performance issues:
• Orifice entrance – reduced entrance accessibility
  o supplied concept – T.O. entrance slot 90 ML/day
  o initial detailed design
    – T.O. entrance slot 650 ML/day
    – 1.3m tailwater range
    – 49 percentile
• Issues achieving turbulence objectives (30 to 80 W/m$^3$)
• Attraction to second fishway entrance.
Site hydrology and multi-level design criteria

Design fish size reduced to adult Murray cod <700mm
Basic fishway hydraulic equation

Vertical slot hydraulics:

\[ Q = C_a \cdot A \cdot \sqrt{2g \cdot \Delta h} \]

Flow Discharge, \( Q \)

Key variables:

- waterway area of flow entering slot, \( A = b \times d \)
- slot headloss, \( \Delta h \) (also \( Dh \))
Basic principles

At sites where tailwater rises faster than headwater:

• downstream fishway depth > upstream fishway depth

• entrance headloss < exit headloss

RESULT: Reduced fishway entrance attraction and potentially poor performance.
Solution components 1

Fish Attraction:

- Two entrances:  
  A - low, medium and portion of high flows
  B - high flows

- Entrance A - approach channel, low flow weir crest and castellated wall
- Entrance B – high sill level and an attraction overflow weir
Solution components 2

Fishway Channel:
• Entrance A - variable slot opening geometry
• Internal baffles:
  o variable slot widths
  o variable heights.

Narrower slot widths nearer the bottom reduces fishway flow rates
  o reduces turbulence and promotes passage of smaller fish (at low river Q)

Wider slot widths nearer the top increases fishway flow rates
  o helps to maintain entrance slot attraction flow velocities (at higher river Q)
  o acceptable increase in turbulence – able to be negotiated by larger fish

Baffles allowed to progressively overtop, become submerged and drown out
  o redistributes available headloss to other baffles including the entrance.
Baffle unit and plate details

- **Five internal baffle types** (1.6m to 3.85m high):
  - Purple: 1 off
  - Light purple: 3 off
  - Orange: 4 off
  - Gold: 9 off
  - Yellow: 12 off
  - Total 29

- **Keyhole**
  - Entrance A slot plate

- **Constant width**
  - Entrance B slot plate
    - (not shown)
Variable baffle heights and slot geometry
Entrance A operation - 25 to 3200 ML/day

Exit

Low flow crest

Entrance A
Hydraulic results – 25 ML/day

- Fishway Entrance A commences operation - small fish 20 to 100mm.
- Normal maximum structure differential head case, $\Delta H = 4.325\text{m}$.
- (Design max. $\Delta H = 4.485\text{m}$ w/ 0.16m lower tailwater).
Hydraulic results – 200 ML/day

- Criteria change - medium fish 100 to 300mm.
- $\Delta H = 3.97m$. Attraction at A $\sim 110$mm.
Hydraulic results – 450 ML/day

- Criteria change - medium fish 100 to 700mm.
- $\Delta H = 3.52m$. Attraction at A ~90mm.
Hydraulic results – 1000 ML/day

- Criteria change - medium fish 300 to 700mm.
- ΔH= 2.97m. Attraction at A ~51mm.
Hydraulic results – 1500 ML/day

- Criteria continues - medium fish 300 to 700mm.
- $\Delta H = 2.61m$. Attraction at A ~145mm.
Hydraulic results – 3200 ML/day

- Medium fish 300 to 700mm.
- Entrance A ceases operation.
- $\Delta H = 1.58\text{m}$. Attraction at A ~95mm.
Entrance B operation - 4070 to 7070 ML/day
Hydraulic results – 4070 ML/day

- **Medium fish** 300 to 700mm.
- Entrance B commences operation with min. 300mm depth over d/s fishway.
- $\Delta H = 1.19$ m. Attraction at B ~200mm.
Hydraulic results – 5500 ML/day

- Medium fish 300 to 700mm.
- \( \Delta H = 0.62 \text{m} \). Attraction at B \( \sim 95 \text{mm} \).
Hydraulic results – 7070 ML/day

- Fish passage continues over weir - medium fish 300 to 700mm +.
- Entrance B ceases operation at near weir drown-out.
- ΔH = 0.15m. Attraction at B > 50mm.
Conclusions

A multi-range design criteria approach has the potential to deliver significant fish passage performance benefits at high head sites requiring fishways that are self regulating and operationally simple.

The long-term benefits for asset owners of reduced on-going costs comes at the expense of a more complex and challenging design process that needs to be supported by appropriate design fees.

Success requires a cohesive collaboration between:

- fish biologists
- experienced design engineers
- asset owners; and
- stakeholders.

Detailed hydraulic fishway design during the Concept Stage is key to an efficient design process that reduces project risks for the next stages.
Existing weir pre-raising
Proposed raised weir and fishway

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