Design specifications for fish-protection screens in Australia

Edition 1

What is a fish screen?

A fish screen is a physical barrier that prevents fish from swimming or being drawn into a diversion when water is extracted for human use. When used correctly, fish screens can supply debris-free water without harming fish and other aquatic life.

However, if designed incorrectly a screen can kill or injure fish and disrupt water delivery. This document summarises the key design and operational specifications that should be met if a screen is to be considered fish friendly. Meeting these specifications will also improve the debris control performance of a screen and its ongoing maintenance. It is intended for use by those supplying or engineering fish screens in Australia and should be used in companion with the *The practical guide to modern fish-protection screening in Australia* (Boys *et al*. 2021). The specifications will continue to be updated as science and technology evolves.

Contents

Why are fisheries specifications required for screen design?

Designing a fish-protection screen is a complex task and different sites have their own challenges. In some instances, civil engineering constraints, river hydrology, requirements of the water user and the available budget will call for design trade-offs.

While this may result in some reduced functionality in order to make a screening project viable, functionality should not be reduced to such an extent that the screen does not protect fish or is difficult to clean and maintain.

These design specifications will help those involved in screening projects make informed decisions about a minimum standard of functionality. Deviating from these standards will result in poorer fish protection and debris control, increased maintenance costs and increased risk of screen failure.

The key message is just because a screen is designed to exclude debris, does not necessarily make it safe for fish. It is important to adhere to fisheries specifications in the design and operation of a screen.

A clear set of fisheries design specifications is important for several reasons:

» If the primary purpose for installing a screen is fish protection, it needs to protect fish.

» If public funds intended for natural resource management are being invested, the screen needs to protect fish.

» Specifications allow fisheries and natural resource managers to evaluate the suitability of different screen types.

» Specifications help screen manufacturers and suppliers to provide fit-for purpose products and supports product research and development.

» Specifications ensure a minimum set of standards are upheld regardless of the jurisdiction of the water infrastructure program implementing a project.

» A screen that performs well from a fish protection perspective should also perform well from a debris exclusion and maintenance perspective — reducing the risk to water users, infrastructure and protecting the long-term viability of the investment.

Not all screens are created equal

A screen designed to exclude debris is not necessarily safe for fish. A fish-protection screen must meet a minimum set of design specifications. These specifications are outlined in this document.

By meeting these specifications, the screen will protect fish and also be a reliable asset for water users. It will be easier to clean and maintain, providing a reliable source of water.

These specifications are intended for screens where the purpose is fish protection. They may not be appropriate if the aim is 100% exclusion, e.g. where translocation of invasive species needs to be prevented. In such instances, more stringent species-specific specifications may need to be developed.

What is in the specifications and how were they developed?

The fisheries specifications provide the current requirements for screen design and operation. They cover: water velocities in front of the screen face; screening material, including maximum aperture size of the slot, hole or mesh; and (if required) how a fish bypass or escape route should be designed. Where other criteria are critical to the long-term performance of a screen, these are also prescribed (e.g. having an active cleaning mechanism). The specifications deal with design and operation concepts that are explained in a companion document: *The practical guide to modern fish screening in Australia* (Boys *et al*. 2021).

Compared with other parts of the world such as North America or New Zealand, screen design for an Australian context is a new and rapidly evolving science. As such, these specifications draw heavily on current international best practice (e.g. Anonymous 1995, Bejakovich 2006). This is particularly the case where data are deficient on the requirements of Australian fish species, for example about bypass design. Where local studies have been performed on Australian fish (e.g. Boys *et al.* 2012, Boys *et al.* 2013a, Boys *et al*. 2013b, Stocks *et al.* 2018), these have been used to adapt criteria to Australian conditions.

Currently, these fisheries design specifications assume that all life stages of fish are present and need protecting at a screening project. Many Australian native species undertake extensive migrations (both upstream and downstream), a behaviour which makes them susceptible to being drawn into water diversions or being exposed to fish-protection screens. These migrations can occur across all life stages — egg, larval, juvenile or adult.

The specifications outlined here are broadly assumed to be appropriate for the protection of most species and life stages of fish. However, this assumption is continually being tested. It is likely that the susceptibility to entrainment, injury or death at screens is dependent on factors such as a fish's size, development stage and species-specific differences in physiology and behaviour. Therefore, while generalisations have been made across different species and life stages, it may be necessary to refine or expand the specifications in the future. This will be particularly relevant to elements of design where there is insufficient data for Australian species, such as fish bypasses and escape routes.

The Australian Fish Screen Advisory Panel (AFSAP) will continue to review and develop the specifications. The AFSAP is a multi-jurisdictional and multi-stakeholder group of fisheries scientists, fisheries managers, water users, manufacturers and recreational anglers, with representation by international experts. The AFSAP meets regularly to exchange information and ensure that as modern screening is rolled out across Australia that best practice design is being followed. The AFSAP supports the national standardisation of specifications. While states and territories can develop their own specifications, there is significant benefit in ensuring a standardised approach.

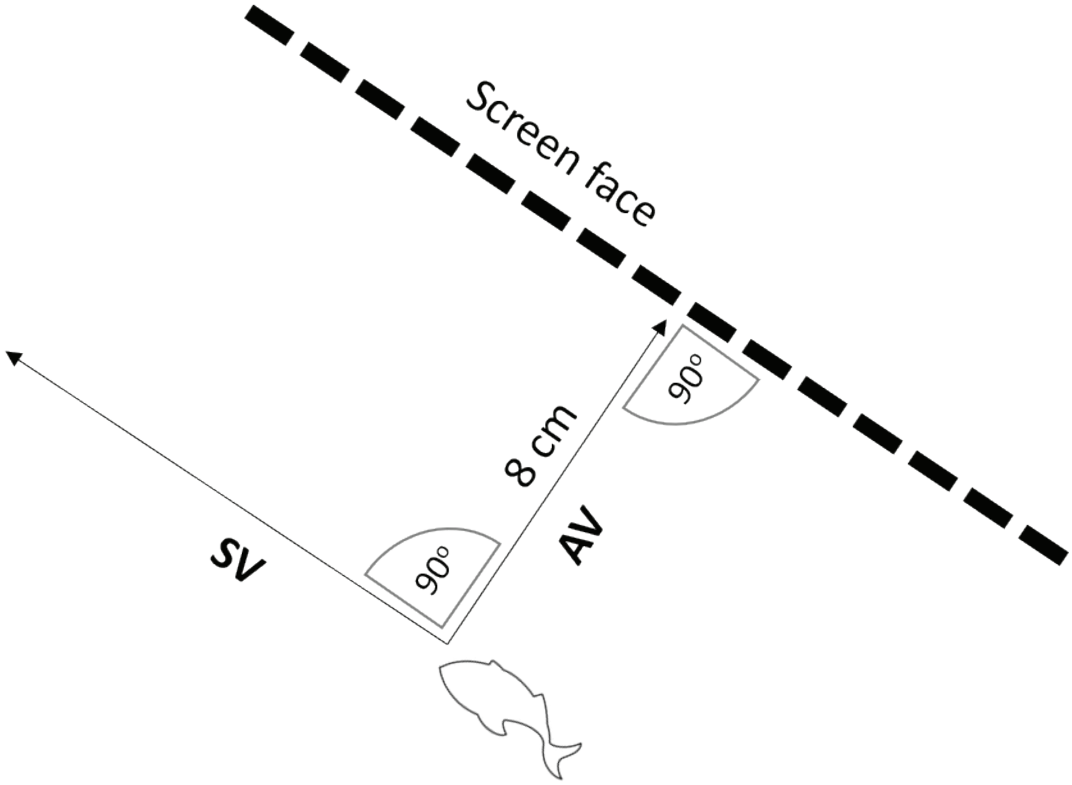

Figure 1. Approach velocity (AV) and sweeping velocity are to be measured 8 cm in front of the screen face.

Specifications

Refer to Boys *et al*. (2021) *The practical guide to modern fish-protection screening in Australia*, for a more detailed explanation of the concepts described in these specifications.

A. Screen location and orientation

1. Where practical, the screen should be installed as close to the entrance of the diversion intake as possible (i.e. within or adjacent to the main river channel), which negates the need for a fish bypass.
2. A screen located at the intake entrance is typically orientated so that the predominant length of screen face is as parallel to the river flow as possible. However, site-specific factors such as site depth, gradient, sediment and protection from large debris load will also dictate screen orientation.
3. The screen should be installed with adequate clearance between the screen and the bottom of the river bed to prevent entrainment of sediment and benthic aquatic organisms.
4. Where installation of the screen at the intake entrance is not feasible or desirable, the screen may be located within the diversion channel downstream of the entrance and any water control structure. When this occurs, an effective bypass system may be required to safely and quickly transport fish back to the river.
5. If located within a diversion channel, the screen should be adequately angled so that sweeping velocity exceeds approach velocity, which will direct fish towards a fish bypass. Typically, this is achieved by ensuring the screen has a maximum angle of 45 degrees relative to the direction of the intake flow (i.e. is closer to parallel than perpendicular to the predominant channel flow. At a 45-degree angle, the approach velocity is about equal to the sweeping velocity. At some sites, screen angle options may be constrained by site-specific channel geometry and hydraulic conditions.

B. Hydraulics

Approach velocity

1. Approach velocity is defined as the water velocity vector perpendicular to the screen face and measured 8 cm in front of the screen face. It is the primary component of flow that fish must swim against to avoid being pulled against the screen (Figure 1).
2. Approach velocity shall not exceed 0.1 m/sec.

Sweeping velocity

3. Sweeping velocity is defined as the water velocity vector parallel and adjacent to the screen face. It is the primary component of flow that moves fish past a screen and intake.
4. *Screens located in the main river channel or at the entrance to the diversion intake* need to operate effectively in the absence of any river flow and sweeping velocity. Therefore, no sweeping velocity is prescribed in this context.
5. *Screens that are located down a diversion channel, downstream of a water control structure and requiring a fish bypass (see section F),* shall maintain a sweeping velocity that is greater than the approach velocity to ensure fish can be effectively guided towards the bypass entrance without delay. Typically, this is achieved by ensuring the screen angle relative to the intake flow does not exceed 45 degrees.
6. Sweeping velocities at screens located within diversion channels should be sufficient to avoid the deposition of sediment and the accumulation of debris.

C. Screen construction

Screening material

1. Screening material should be corrosion resistant and sufficiently durable to maintain its smoothness, shape and the maximum slot, hole or aperture size with long-term use.
2. The surface of the screen should be smooth and uniform.
3. Wedge wire (profile bar), perforated plate and woven mesh are all acceptable fabrics for the screen face, however because the screening material used will influence strength, durability and asset life, this should be acknowledged at the design stage and accounted for in maintenance and replacement schedules provided to the screen owner.
4. All other structural components of the screen should be corrosion resistant and durable.

Effective screen surface area

5. The effective surface area of the screen is defined as the area of screen face that is *submerged*, minus any area of the submerged screen face where water flow is occluded by structural components (e.g. frames or brushes). None of the screen face that is out of the water should be included in the calculation of effective screen area.
6. The submergence of the screen should be assessed at the lowest channel depth at which the diversion will operate (i.e. its minimum possible submergence).
7. A screen should be sized so that its minimum effective surface area is large enough to ensure the maximum allowable approach velocity is not exceeded at the highest possible diverted flow.
8. The minimum effective submerged screen area required should be calculated by dividing the maximum possible discharge at the diversion by the maximum allowable approach velocity:

$$\text{Minimum effective screen area (m}^2\text{)} = \frac{\text{Maximum diversion discharge (m}^3\text{/sec)}}{\text{Maximum allowable approach velocity (i.e. 0.1 m/sec)}}$$

9. In the rare instances where the screen surface area cannot be made large enough to ensure the maximum approach velocity is not exceeded at the highest discharge (e.g. where site-specific conditions may limit the total surface area of screen), any approach velocity exceedance should be small, infrequent and for only a small proportion of the diversion's total operating time. These parameters should be defined, articulated and justified during the design process. Consideration should also be given to how the screen will effectively operate at the highest flows without becoming blocked or hazardous to fish.

Aperture size

The maximum allowable aperture size refers to the maximum size of mesh, slot or hole in the screening material.

10. The maximum aperture size shall be:
    a. 2 mm for wedge wire (slot width);
    b. 3 mm for woven mesh (measured from corner to corner of the opening); and
    c. 3 mm diameter for perforated plate.
11. The maximum allowable aperture size should not be exceeded at any gaps between different components of the screen (e.g. joins, gears and mounts). Brushes and seals can be used between parts to prevent fish movement through gaps that exceed the maximum allowable aperture size.

D. Hydraulic baffling

1. The screen design should provide for uniform flow distribution over the screen surface, minimising any localised areas of high approach velocity.
2. This may be accomplished by mounting hydraulic baffling on the downstream side of the screen face (as in the top left photo), which more evenly distributes flow across the screen face without occluding flow.
3. Hydraulic baffling can be fixed at the design phase (for proven and inaccessible screen types) or adjusted after screen installation if screen hydraulics are hard to predict or vary under different operating conditions.
4. For high volume screens or those in complex hydraulic environments, computational fluid dynamics of physical hydraulic model studies may be required to prove that localised areas of high velocity can be avoided at all flows.

E. Screen cleaning and maintenance

A fish screen will only continue to operate as prescribed if the screen face remains clean.
As soon as the screen begins to foul with debris, all other hydraulic parameters change. As such:

1. Passive screens (those without an active cleaning mechanism) should be avoided whenever possible.
2. Active cleaning can be achieved with physical brushing, wipers, water jet or air burst.
3. Cleaning should be automated and regular enough to keep the screen free from debris and to maintain its continual operation.
4. Screens should be regularly maintained. The screen manufacturer or supplier should provide the screen owner with an inspection and maintenance schedule.

F. Fish bypass design

A fish bypass is a channel or pipe that safely and quickly transports fish from the screen face back to the main waterway.

1. A fish bypass is required where it is reasonable to assume that, without one, a fish's exposure to the screen would be prolonged, or if they would be unlikely to find their way back to the main waterway. A bypass is more likely to be required when a screen is located in a diversion channel or downstream from a water control structure.
2. The bypass entrance should be positioned at the downstream end of the screen so that it can be easily found by the fish. A long screen may require more than one bypass along its length.
3. The bypass entrance should extend to the bottom of the channel.
4. Water velocity at the bypass entrance should be faster than the velocity sweeping in front of the screen. This will encourage fish to keep moving down the bypass rather than return upstream.
5. A minimum velocity of 0.9 m/sec at the bypass entrance should reduce the likelihood of escape of fish entering the bypass.
6. Because fish have a tendency to avoid rapid changes in water velocity, there should be a gradual acceleration of flow towards the bypass entrance. This can be achieved using a hydraulically-efficient "bell-mouth" entrance shape.
7. To guide fish to a bypass, the sweeping velocity should be greater than the screen approach velocity. This reduces exposure time along the face of the screen.
8. To reduce avoidance of the bypass, its entrance should blend with surroundings and have ambient lighting.
9. The bypass channel should be smooth, with no sharp edges or sharp bends and take the shortest possible path back to the river.
10. The bypass should be designed to effectively pass smaller debris or exclude larger items. Regular inspection of the bypass will ensure blockages are removed.

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