Department of Primary Industries

The practical guide to modern fish-protection screening in Australia

Contents

About this guide

This guide is for anyone interested in learning more about modern fish screens.

A modern fish screen is a physical barrier that prevents fish and debris from being drawn into a pump or channel when water is extracted from a waterway. Modern fish screens protect 90% of native fish and provide a reliable supply of debris-free water. This delivers a range of benefits for both biodiversity and businesses. However, it is important that the right type of screen is used. Screens need to be constructed with the right types of materials, installed to suit the conditions of an individual site, and maintained correctly.

This guide provides an overview of modern screens, their benefits and how they work. It introduces the key principles that need to be considered when planning a screening project. The guide is built on a decade of research and development by NSW DPI Fisheries. It represents a new best practice for Australian water users who want to help look after native fish (Boys *et al*. 2021). The guide is to be used in conjunction with the fisheries design specifications (Boys, 2021), which detail the standards that need to be met for a screen to be considered 'fish-friendly'.

More modern screens being used means more native fish staying in the river and less debris entering infrastructure.

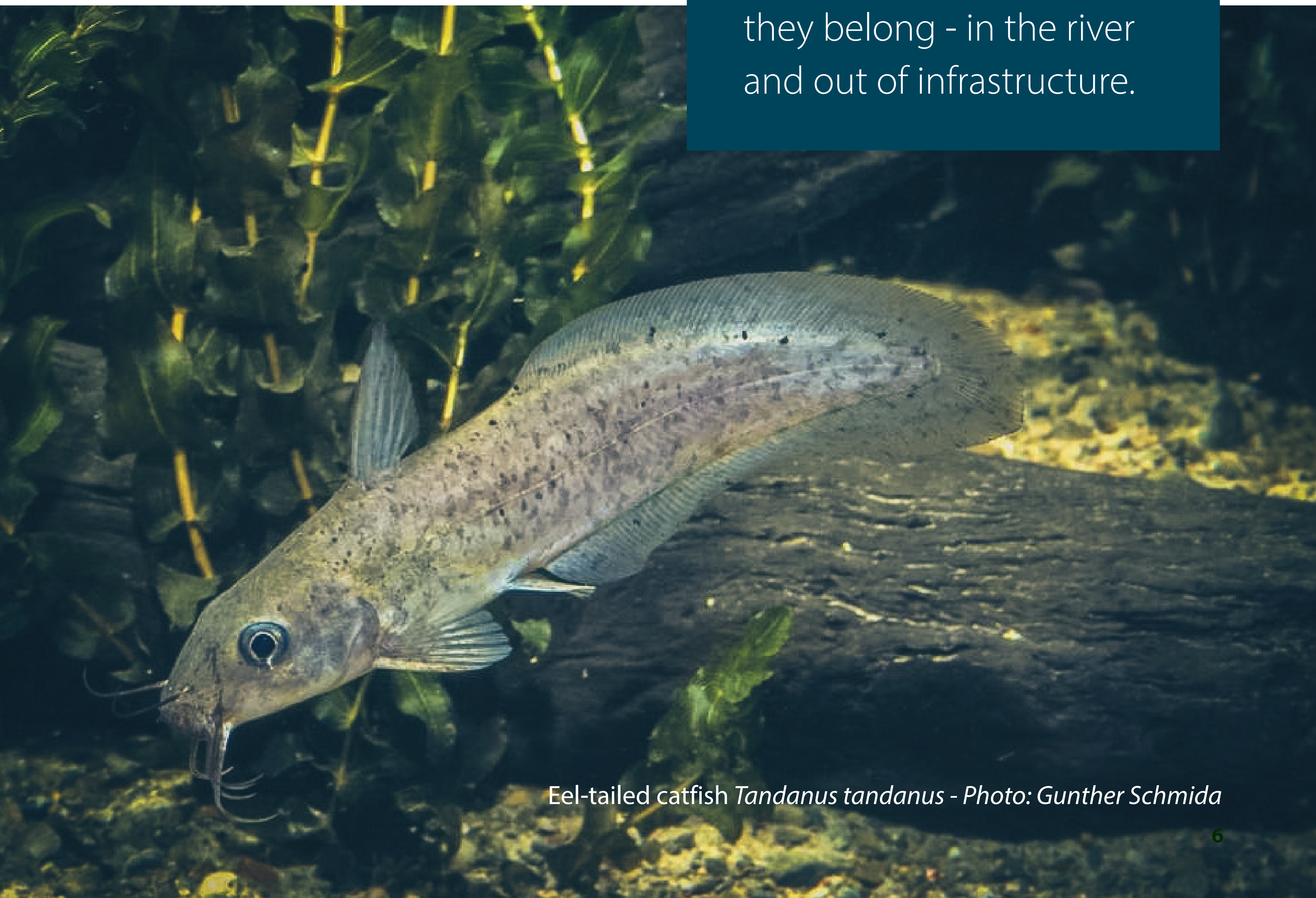
Modern screens are good for fish and good for farms.

Modern fish screens provide real benefits for water users, native fish, recreational anglers and regional economies.

Figure 1.

Screening projects involve collaboration. Pictured are Craig Boys (fisheries scientist), Shane Smith (irrigator), Matt Hansen (recreational fisher) and Samantha Davis (fisheries manager) celebrating the installation of one of four cone screens on the Trangie-Nevertire Irrigation Scheme pump site, Macquarie River, NSW. This screen system protects 33 farms and native fish within the Macquarie River.

Modern fish screens keep fish and debris where they belong - in the river and out of infrastructure.



Eel-tailed catfish *Tandanus tandanus* - *Photo: Gunther Schmida*

Types of water diversions

A water diversion extracts water from a waterway. There are two main types of water diversions in Australia: pumped diversions and gravity-fed diversions. Most water diversions are unscreened or fitted with a simple mesh device known as a 'trash rack'.

A pumped diversion uses a pump to draw water through a pipe from a waterway (usually up and over a riverbank).

A gravity-fed diversion is a canal connected directly to a river, which redirects water using gravity into an open channel.

Figure 2.
Types of water diversions common in Australia.

Modern fish screens versus traditional 'trash racks'

Modern screens are totally different to traditional trash racks. They are designed to protect native fish and exclude virtually all debris.

Figure 3.

Different types of 'trash racks' common on pumped water diversions. These traditional designs offer little or no fish protection and only exclude large debris. Smaller items of debris and fish enter the pumps causing damage to impellers and blocking sprinklers. The improvised screen (bottom right) shows an attempt to exclude fine debris from a citrus farm. This screen is easily blocked because it has a relatively small surface area and no self-cleaning mechanism.

Photos: Craig Boys.

Figure 4.

Fish blocking siphons (left) and in-line pipe filters (right) are a problem for some water users with unscreened or ineffectively-screened diversions.

Photos: Twitter user @irrigationbydave and Steve Datwyler.

Trash racks exclude only large debris, such as tree branches. They don't exclude smaller debris and offer very little protection for native fish (Figure 4). Traditional trash racks can cost water users time and money.

The main problems are:

» **The water velocity is too fast.** Pumps can extract large volumes of water through a narrow opening. This means that the water being drawn into the intake pipe is moving very fast — up to 1 to 3 metres per second. This is faster than the swimming speeds of most Australian fish species, making them highly susceptible to being drawn into the diverted flow or pulled against the trash rack where they are injured and killed.

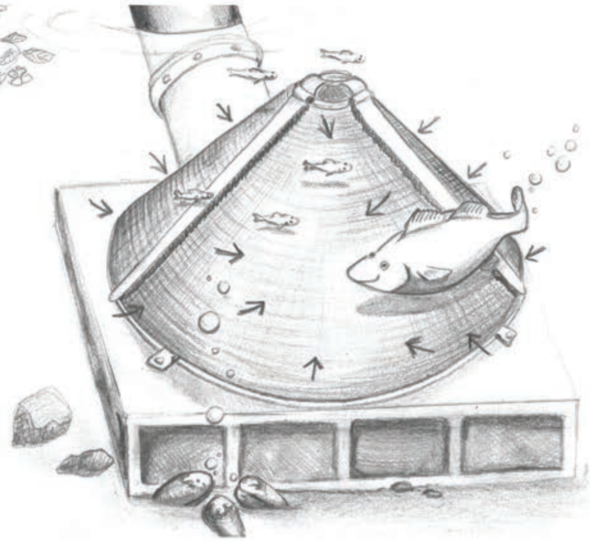
» **The holes are too big**. The holes in traditional trash racks are too big to exclude small items such as sticks, leaves, algae, seeds, fish, shrimp and other aquatic animals. This creates problems for water users, who then must deal with blockages of inline filters, sprinklers, dripper and siphons.

» **The holes are easily blocked.** The high velocities and small overall surface area of traditional screens causes debris to stick on the face of the screen or plug and tangle in the holes. This blocks the water supply, reducing the effective area of the screen, creating high-velocity hot spots and reducing diversion efficiency (e.g. pumping rate and energy use).

Brushes fitted on arms rotate around a cone screen to keep the surface of the mesh clear of mud (visible on the top of the unit).

Unlike traditional trash racks, a modern fish screen allows water to pass through, while excluding debris, and protecting fish and other animals from injury (Figure 5). Modern fish screens lower the speed of the water in front of the intake without changing the volume or rate of water extraction. Less fish and debris are sucked out of rivers or pulled against trash screens. Modern fish screens stop debris entering irrigation systems, lower maintenance costs and protect native fish. The main features are:

- **The water velocity is lower.** Instead of 1 to 3 metres per second, water passes through a modern screen at 0.1 metres per second. This means native fish can swim away from the diversion. Design features such as internal baffles, spread water flow evenly across the screen face.
- **Modern screens use a fine mesh.** Most modern screens use mesh with holes less than 3 mm wide. This stops native fish being sucked into the intake. Debris stays on the surface of the screen, where it can be easily removed.
- **Modern screens are self-cleaning.** Most modern fish screens feature an automatic cleaning mechanism, such as a bristle brush, a water jet or an air-burst system to keep the surface of the screen free from debris.
- **Modern fish screens achieve all this without reducing the amount or rate at which water can be diverted.** In fact, because they are more likely to remain clear of blockages than traditional trash screens, water delivery is improved.



Traditional screen

Costs farmers time and money.

Impacts native fish.

» Water velocity fast

» Holes too big

» Easily blocked

Modern screen

Stops river debris and lowers fish maintenance.

Protects native fish.

» Same volume, lower velocity

» Fine mesh

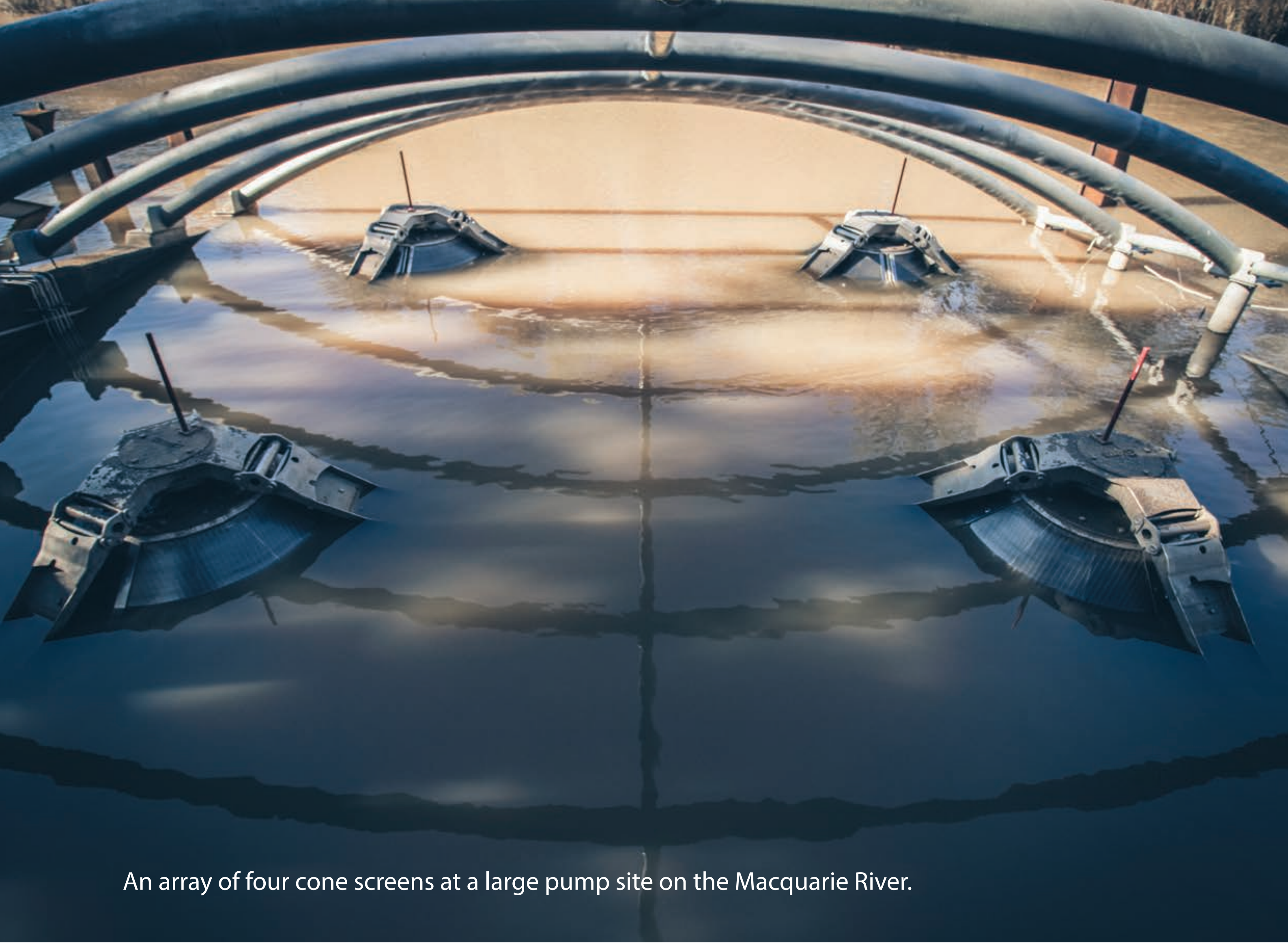
» Self cleaning

Figure 5.

Traditional trash rack screens (left) cost farmers time and money, and harm native fish. The water velocity is too fast, the holes are too big, and the screen is easily blocked. Modern fish screens, such as a cone screen for a pump diversion (right), stop debris and fish entering water diversions or becoming impinged on the screen. They allow the same volume of water to be diverted, but at a lower velocity. They have a fine mesh, with self-cleaning mechanisms to keep the screen clean and effective.

Illustration: Samantha Davis.

Modern screens protect 90% of fish. Big and small.



An array of four cone screens at a large pump site on the Macquarie River.

Types of modern fish screens

Modern fish screens are available in a range of designs to suit different water diversions. Table 1 summarises the main types of modern fish screens available with notes on their suitability for different types of diversions in Australia (photos of most of these screens are provided in Figure 6). Recent examples of these screens installed in Australia can be found at Fish Screens Australia, with the contact details of local suppliers and manufacturers.

Fish screens can be sized, or multiple screens used in groups, to effectively screen a range of discharges. While most diversions can be screened, some screens will better suit some diversions. It is important to choose and install the right technology.

They also provide no debris control. Behavioural barriers are not considered in this guide. Although behavioural fish barriers (such as electro-shock barriers, light or air bubble curtains) have been used overseas, they are considered experimental and far less effective for fish protection than physical screens.

Table 1. Types of modern fish screens

Screen type	Description and suitability
Conical	Cone shaped screens, typically made from wedge wire, self-cleaning with motorised external cleaning brushes to prevent debris build-up and bio-fouling. Internal flow baffle distributes flows evenly across the screen surface. Most suited to shallow water applications. Suitable for both gravity-fed and pump diversions. E.g. ISI/AWMA proprietary design.
Rotary drum	A mesh covered horizontal 'drum' that slowly rotates. Debris is either swept past the screen or transferred over the top (into a diversion channel). Requires a relatively narrow range of water level to operate effectively (if water level is too low, the screen won't clean; if too high, there is a risk of fish being transferred over the screen). Typically installed within the diversion channel downstream of a water control structure and needs a fish bypass. Suitable for gravity-fed diversions.
Travelling belt	Screen material rotates like a conveyer belt. The screen is orientated vertically or at an angle (if the screen is angled too steeply there is greater risk that fish will be carried over the screen). Debris is dragged up and over the screen where it can be deposited in the diversion channel or into a collection trough. Suitable for gravity-fed diversions. E.g. Hydrolox™ traveling water screen.
Vertical panel	A flat-panel screen that is vertically orientated on a supporting frame. Can accommodate greater fluctuations in river flow than a rotating drum, although needs to be high enough to prevent being 'over-topped'. Suitable for gravity-fed diversions when placed downstream of a water control gate. Cleaned with an electric- driven brushing/wiper mechanism. Angling the screen relative to flow will increase sweeping velocity and direct fish towards a bypass.
Coanda	Used at the downstream end of a water control structure (e.g. weir). The water is filtered through the screen as it spills over the structure, with fish 'skimming' over the top of the screen. Typically used as a debris screen and may exert shear and abrasive forces on fish as they pass along the screen face. Suitable for gravity-fed diversions
Horizontal panel	A horizontally orientated flat-panel screen. 10% of flow passes over the top of a screen, directing fish down a bypass. A self-cleaning screen with no moving parts. E.g. Farmers Screen™. Suitable for gravity-fed diversions. Its application is limited to high gradient streams and it may be unsuitable to many lowland rivers in Australia.
Floating, rotating cylinder	The screen operates on the surface of the water, only partially submerged. The cylinder rotates and is either propelled by a water jet or driven by a motor. Internal and/or external water jets clean the screen as it rotates. Low submergence limits the size of diversion that can be screened, however as with many of the pump screens, multiple screens can be used to achieve higher discharges. Because it floats on the surface, extra care must be taken to protect it from damage and disruption from floating debris E.g. Riverscreen™
Fully submerged water-jet cleaned cylinder	The cylinder is fully submerged and cleaned by an internal water-jet. In some designs a spray arm rotates within a fixed cylinder screen, while in others a fixed spray rotates a spinning cylinder. Most use a woven mesh medium and is suited to pump diversions. E.g. Clemons™ and Kleenscreen™
Rotating brushed-cylinder	A rotating wedge wire cylinder with internal and/or external brushes. The rotation of smaller screens can be 'self-propelled', using the flow of water through the pipe to turn an impellor, which rotates the screen. Large screens require electrical power.e.g. ISI/AWMA cylinder screens. Suitable for pump and gravity-fed diversion.
Fixed full or half cylinder	The screen is fixed and doesn't rotate. Cleaned using an internal burst of air delivered from a compressor and storage tank. Half cylinders can be used in shallow water applications e.g. Johnson screens.

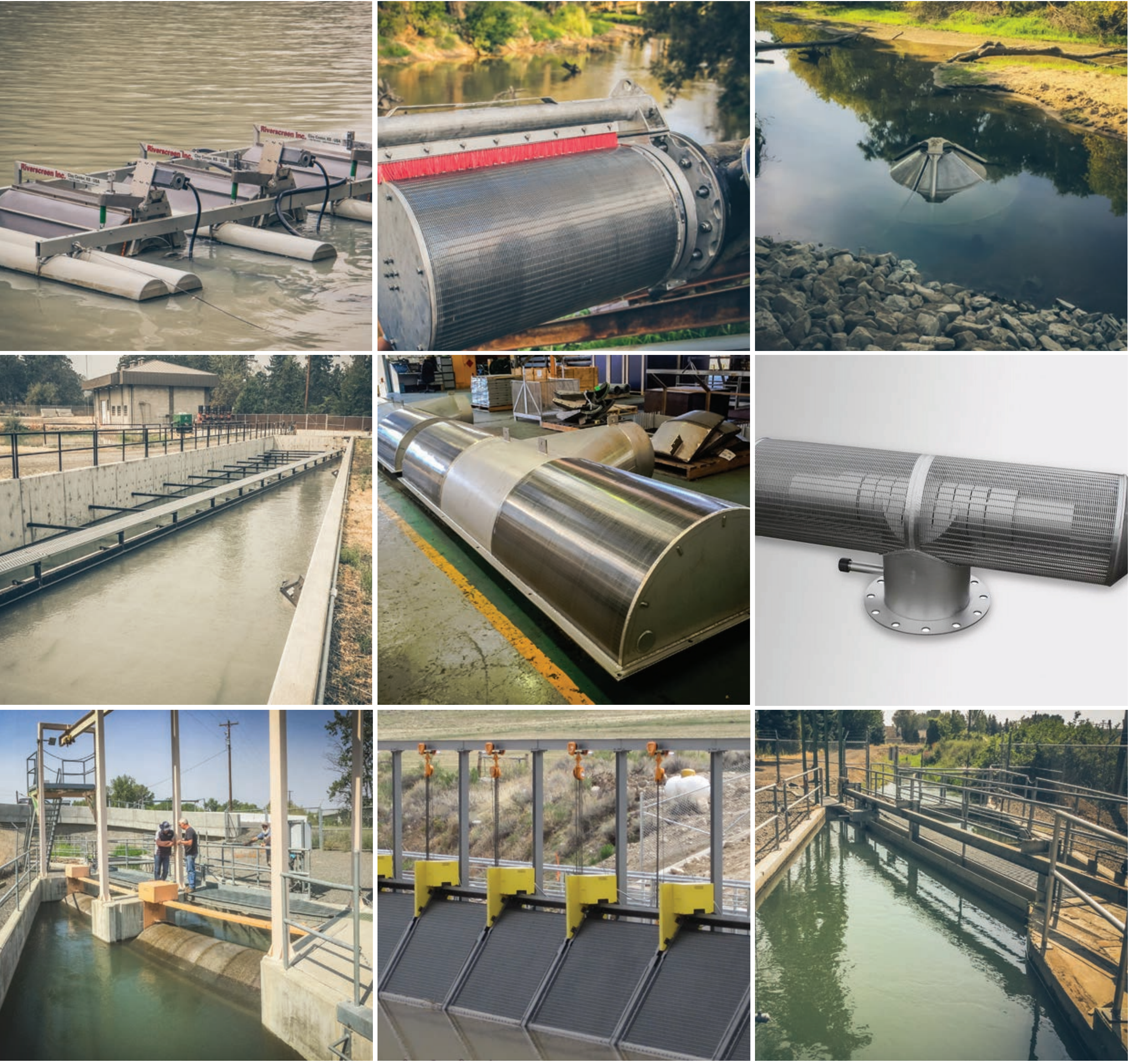


Figure 6.

Examples of the different types of modern fish screens available (refer to Table 1 for more information). From left to right, top to bottom (Photos by Craig Boys unless stipulated): floating rotating cylinder, brushed rotating cylinder, conical, horizontal panel, fixed half cylinder (Aqseptence), fixed full cylinder (Aqseptence), rotary drum, travelling belt (AWMA), vertical panel.

Anatomy of a modern fish screen

This chapter introduces the main features of a fish-friendly screen. It outlines screen location, hydraulics, orientation, materials and cleaning.

This information should be used with the design specifications for fish screens in Australia (Boys 2021), which prescribe more specific criteria for manufacturers, engineers and suppliers.

Screen location

Where a screen is located will have a major effect on its design and operation. At gravity-fed channels, a screen can be fitted at the entrance of the diversion upstream of any flow control structures, or within the diversion channel downstream of any control structure (Figure 7). The decision to locate the screen at the entrance or further downstream within the diversion channel will depend on site-specific constraints and will affect its design, operation and cost.

Where practical, the screen should be placed as close to the entrance of the diversion as possible. This will keep fish in the main river channel and remove the need for a fish and debris bypass channel, making the project simpler and cheaper. Placing the screen at the entrance to the diversion makes it more likely to be exposed to large debris such as logs during flood conditions, which may require extra flood and debris protection (e.g. debris booms). Dewatering the screen won't be possible for maintenance if the screen is at the channel entrance (therefore the screen will need to be retractable if inspection is required).

The flow conditions (depth and velocity) around the screen are likely to be more variable, dependent on the hydrology of the river.Where a screen cannot be installed at or near the entrance of the diversion channel, the screen should be installed within the channel, usually downstream of a water control structure (Figure 7). Some benefits of this are that the screen can by dewatered for inspection and repair and it is likely to be more protected from large debris. A disadvantage is that an escape route or bypass channel will be required to return fish from the screen back to the river. Not only may the site configuration not allow for this, but it makes the project more complex and costly.

At many lowland river sites in Australia, there would be no head difference from the diversion channel inlet to the bypass channel outlet, making it difficult to design an effective fish bypass.

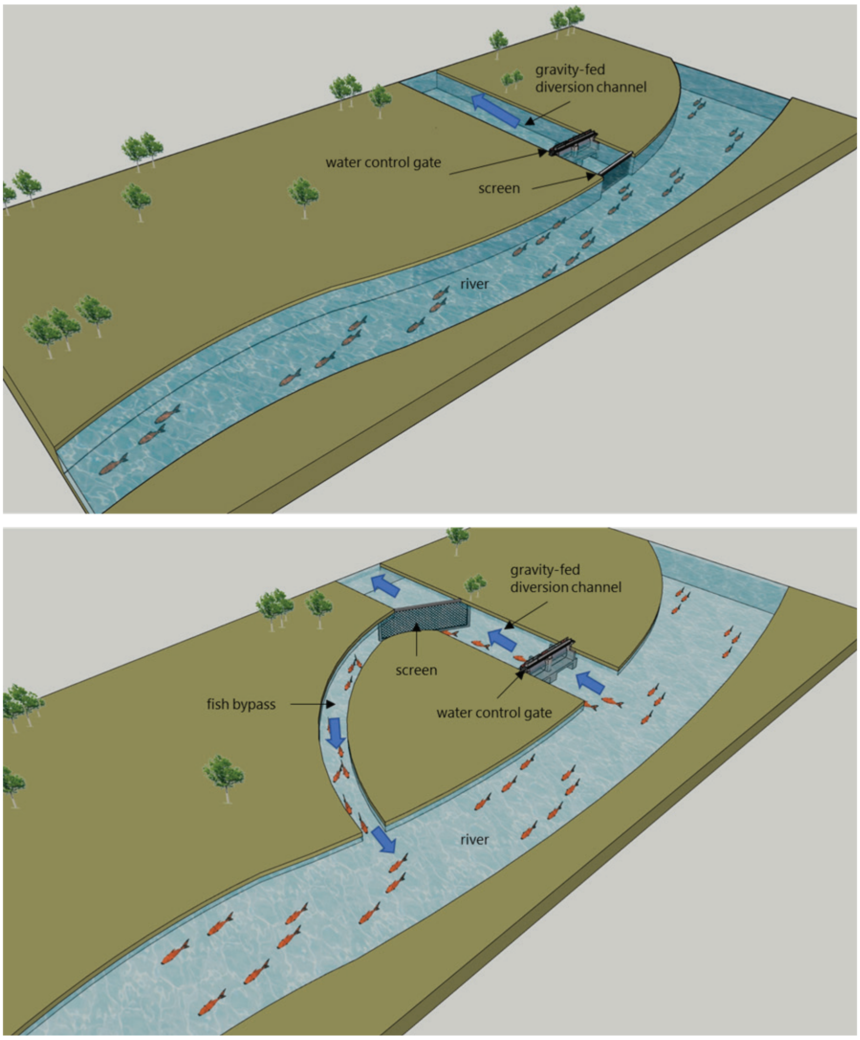


Figure 7.

At a gravity-fed diversion, the screen can be located at the channel entrance (top), or within the diversion channel downstream of any control structure (bottom). The screen prevents fish and debris passing and the bypass returns fish to the river.

Screen hydraulics

A screen keeps fish and debris out of a diversion by creating a physical barrier and significantly lowering the velocity or suction of water in front of the screen. This is achieved without changing the rate or volume of water extraction. Hydraulic features important to the design of a fish screen are (Figure 8):

» **Approach velocity (AV)** – the speed of water perpendicular to the screen face (typically measured 8 cm in front of the screen). It is the primary component of flow that fish must swim against to avoid being drawn onto the screen.

» **Sweeping velocity (SV)** – the speed of water as it flows parallel and adjacent to the screen face. SV encourages fish and debris to move past the screen face, keeping them in the river or directing them towards a fish or debris bypass.

Although the screen medium plays a role in excluding fish from the diversion, research has shown that AV is more important. (Boys *et al*. 2013b). A screen of any hole size will not protect fish if velocities drawing fish onto the screen are too high. Faced with excessive AV that fish cannot escape, a fish will become impinged (trapped) on the screen, suffering injury and almost certain death.

Similarly, if AV is too high, the screen will quickly become covered with debris. This is referred to as 'blinding' of the screen. Even partial-blinding of a screen reduces the effective surface area of the screen, increases head loss and increases AV at the unblocked portion of the screen. If the blinding is not removed by cleaning, fish protection will be reduced, and more and more debris will be sucked onto the screen — until the entire screen is blocked.

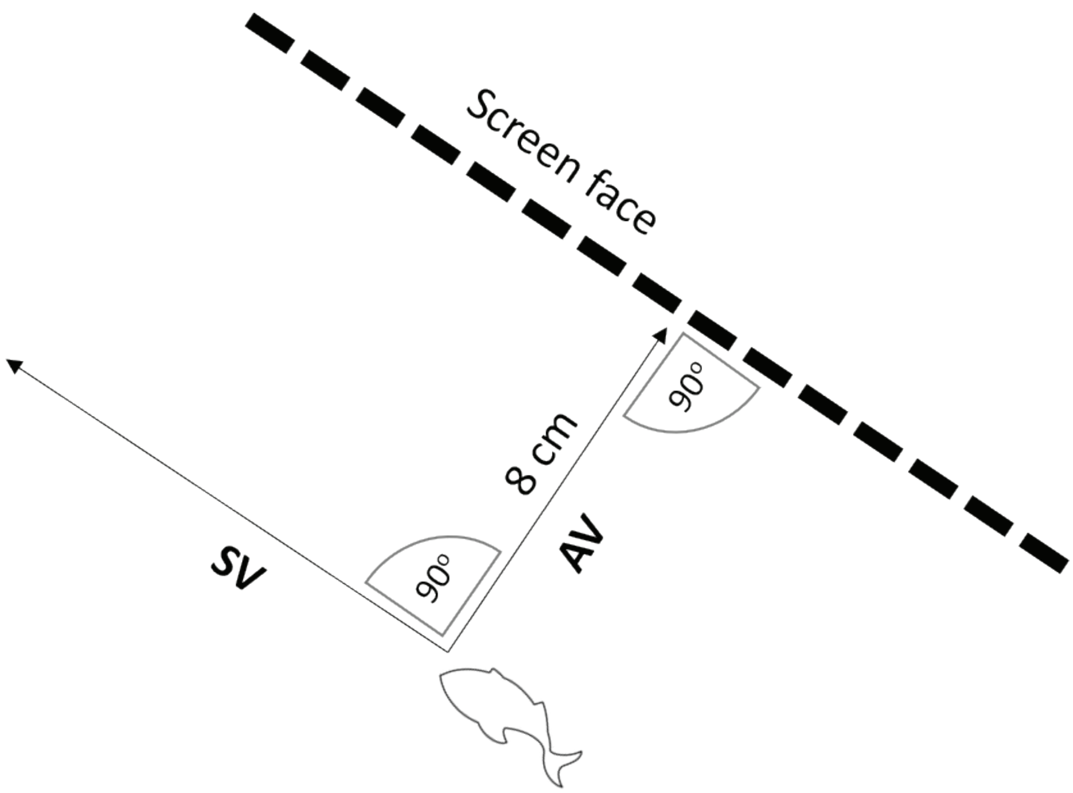


Figure 8.

Three velocity components are usually referred to when describing the hydraulic conditions around a screen. Approach velocity (AV) is perpendicular to the screen face, whereas sweeping velocity (SV) is parallel to the screen face. Internationally, AV is typically reported at 8 cm (3 inches) in front of the screen.

Figure 9.

By lowering the approach velocity in front of the diversion, a properly designed screen will allow fish to move very close to it without becoming impinged. Here, a juvenile Murray cod swims on the surface of a cylinder screen operating with a water velocity of 0.1 m/sec, without being sucked onto the screen (source AWMA).

Approach velocity

The swimming performance of resident fish will determine the maximum allowable AV of a screen. Ideally, AV should not exceed a level that fish can swim against to avoid impingement. Because swimming capability differs between different species (Watson *et al*. 2019) and different life stages of fish, maximum AV will typically be aimed at protecting the weaker swimmers in the fish community. As AV increases, so does the risk of holding fish and debris on the screen for longer, or pulling it through the holes or slots. Fish that become impinged on screens are prone to injury and death (Stocks *et al*. 2018). One of the biggest causes of a blocked screen is having an AV that is too high.

Traditional unscreened (or improperly-screened) pump or gravity-fed diversions can have AVs as high as 2 to 3 m/sec in front of the intake. These velocities are far too high for fish to swim against and avoid becoming entrained. When the diversion is fitted with a well-designed fish screen, the AV is significantly reduced (for example, down to 0.1 m/sec). As a result, small fish, even eggs or larvae, can pass close to the screen without experiencing much suction force (Figure 9).

International best-practice specifications for fish screens typically recommend maximum AVs of 0.1 m/sec. Research in Australia, where juvenile and adult fish swum in front of screens in both flumes and natural waterways, has led to the adoption of the same maximum allowable AV for Australian screens (Boys 2021). Some of the science directing these specifications is summarised in the Fisheries Specifications section of this guide.

Sweeping velocity

Fish are at greatest risk of being entrained or impinged if they remain close to a screen. Moving them past a screen quickly reduces that risk. This is achieved by using the flow of water adjacent and parallel to the screen face, known as sweeping velocity (SV). SV also helps to keep a screen clear of debris. When SV exceeds AV, a screen will provide better fish protection and debris control. Increasing SV relative to AV will generate more force pushing debris along and past the screen. If AV exceeds SV, debris is more likely to be pulled on to the screen face and will need to be mechanically removed.

For screens located within river habitats, SV is directly related to river flow when the screen face is orientated parallel to the downstream flow. In high-energy upland streams SV can be quite high; it is much lower, variable or even non-existent in lowland floodplain rivers.

In many lowland rivers of the Murray Darling Basin, the hydrology has extended periods of low and zero flow. The regulation of rivers using weirs has converted large stretches of river from lotic (flowing) to lentic (still) weir pools. A screen on a pump diverting directly from a weir pool should not be reliant on SV to operate effectively. The screen should have an active cleaning mechanism to ensure it can operate and stay clean.

SV is more critical in gravity-fed diversions that use a fish bypass, because SV encourages fish and debris towards the entrance of the bypass channel or pipe. In this context, SV can also be important for flushing sediment.

Distributing velocities evenly across the screen face

AV can be determined theoretically, based on diversion discharge and screen surface area (see section on sizing a screen correctly). In practice, however, the theoretical AV will only be achieved if there is a near uniform flow of water across the entire screen face. In many cases, AV and OV can be much higher in some areas of the screen and lower in others.

For example, a screen fitted to the end of a pipe will draw most of the flow through the section of the screen closest to the end of the pipe. When this happens, a localised area of the screen will have an AV that exceeds specifications (for example >0.1 m/sec), whereas other areas will have AVs well below this. Localised velocity 'hotspots' will be far more likely to impinge fish and debris, become blocked, reducing the effective surface area of the screen. When this occurs, AV increases at all other areas on the screen – until the whole screen becomes ineffective for fish protection and is much more likely to be blocked and damaged.

It is critical to distribute AV evenly across the screen face. This is achieved by using a hydraulic diffuser or baffling system (Figure 10). In cylinder and cone screens, this diffuser design is set at time of design and manufacture. For large flat-panel screens in gravity-fed diversions, adjustable louvres behind the screen can be used to improve the evenness of flow through the screen after installation.

For large screen installations, the diffuser design should use computational fluid dynamics (CFD) modelling. CFD is particularly useful when large screens are used in conjunction with strong SV, because excessive SV can affect the evenness of flow across a large screen. If a strong SV is expected at a large screen installation, CFD should be completed to help design internal baffling and flow diffusers. It is beneficial if these diffusers can be adjusted after installation. Diffusers or baffles should not impede the operation of any internal screen cleaning mechanisms, such as air-bursts or water jets.

In summary, the hydraulics around screens can be predicted during the design phase. However, the flow velocities that are achieved with an operating screen can be influenced by surrounding structures, intake position, screen type, river flows, SV, and the type of cleaning mechanism used. Just because a screen has been sized to theoretically meet a certain AV, does not mean that AV will always be achieved if velocities are not distributed evenly across a screen. CFD and the use of internal diffusers or flow baffling can help to distribute flow evenly.

Figure 10.

Adjustable louvres/baffling or internal diffusers should be used to ensure approach velocities are distributed as evenly across the screen face as possible. Without them, localised areas of excessive AV are likely. Top photo shows adjustable louvres behind a vertical screen and the bottom photo shows an internal diffuser within a cylinder screen.

Photos: Craig Boys.

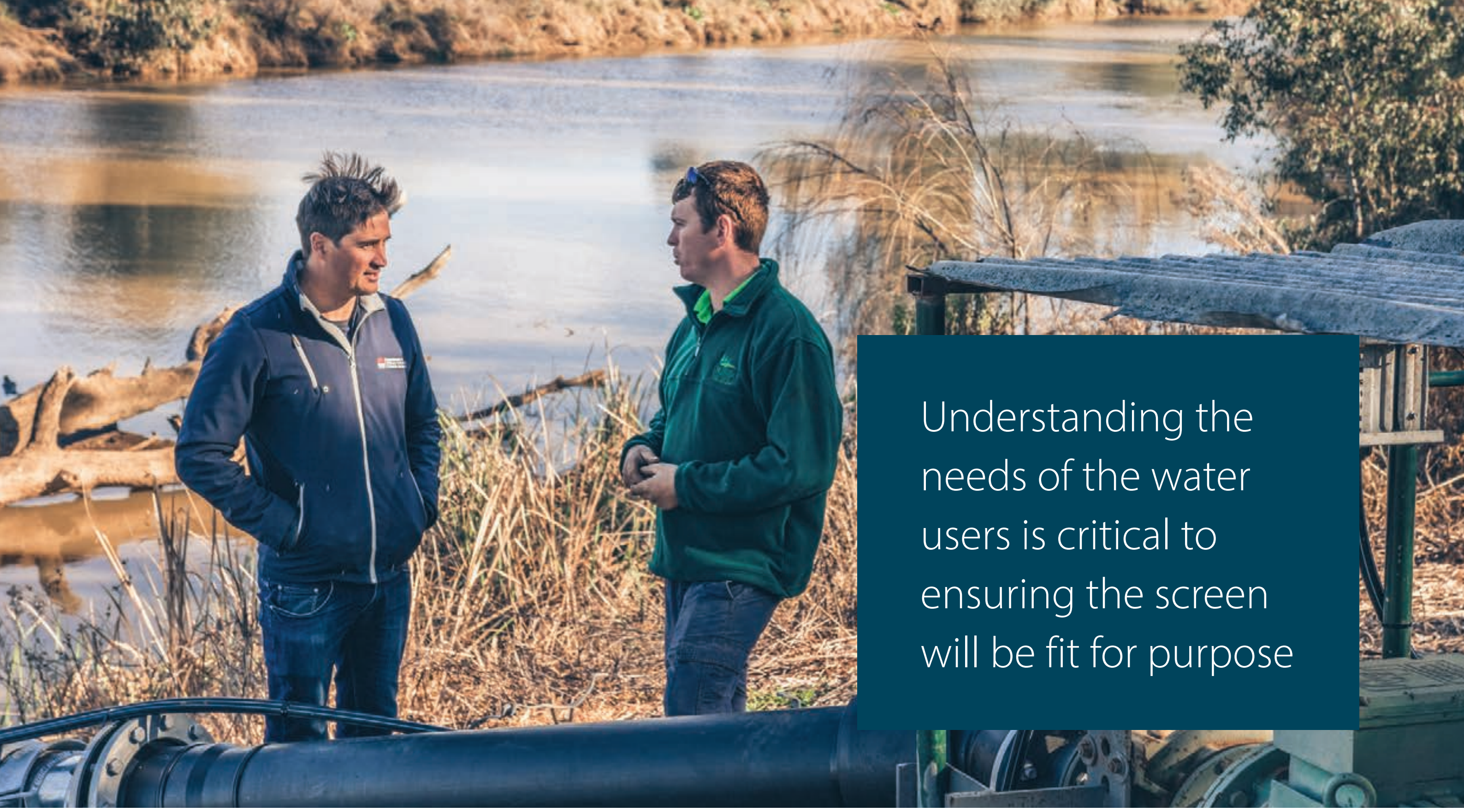
Screen orientation

Screen orientation is one way of creating a larger SV relative to AV. For screens located within a diversion channel, the screen should be angled so that SV exceeds AV and directs fish towards the 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. the screen face is more parallel than perpendicular to the flow). At a 45-degree angle, AV is about equal to the sweeping velocity. It may not always be possible to achieve the desired screen angle at all sites. At some sites, the screen angle may be dictated by site-specific channel geometry, the area the screen occupies and hydraulic conditions.

When the screen is located directly in the waterway (i.e. not down a diversion channel), SV can be very hard to predict. Screens in this context also need to operate under zero flow conditions (without any SV). Orientating a screen to create SV is less of a consideration when the screen is located in the waterway. At some sites, channel morphology and depth at the intake are the main considerations when deciding how to orientate a screen. A screen orientated parallel to the river bank may be less likely to cause an accumulation of debris and less susceptible to damage by large floating debris than one orientated perpendicular to the bank.

Screen hydraulics and orientation

- » A modern fish screen significantly lowers the velocity of water entering the diversion without changing the rate of extraction or volume of water extracted.
- » Most juvenile and small-bodied Australian native species can swim against an approach velocity (AV) of 0.1 m/sec to avoid screen impingement but can't swim against AVs of 1 to 3 m/sec, which are more typical in front of unscreened or poorly screened diversions.
- » When sweeping velocity (SV) exceeds AV, a screen will typically provide better fish protection and debris control.
- » Hydraulic diffusers or baffling behind a screen is often required to distribute flow evenly across the screen face to avoid AV 'hotspots' or areas of screen where the AV exceeds the safe limit for fish.
- » Screen orientation is an important consideration for creating SV, protecting a screen from damage or simply allowing it to fit into a narrow or shallow channel.



Understanding the needs of the water users is critical to ensuring the screen will be fit for purpose

Sizing a screen correctly

AV is a direct function of both the discharge at the water diversion and the effective surface area of the screen. AV increases as the discharge increases and/or the size of the screen decreases. Typically, a larger screen at any discharge will lead to a lower AV.

The effective surface area of a screen is the area of screen face which is submerged, minus any area of the submerged screen face where water flow is blocked by structural components (e.g. frames or brushes). These non-submerged or blocked portions of the screen should not be included in calculations of effective screen area. Calculating minimum effective surface area requires three pieces of information:

1. The maximum allowable AV (m/sec), as prescribed in the Australian fisheries specifications (Boys 2021).
2. The maximum possible discharge at the diversion (if in ML/day it should be converted to m3/sec by dividing by 86.4). It is critical not to underestimate this value otherwise the screen will be too small for larger flows, meaning the desired AV will be exceeded and screen performance will be affected.
3. The proportion of the screen that will be submerged and not blocked by other components of the screen system. This should be determined using the shallowest water depth at which the diversion will operate (i.e. the minimum possible screen submergence).

The minimum effective screen area is calculated by dividing the maximum diversion discharge by the maximum allowable approach velocity:

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

Local hydraulic conditions can be hard to predict and may make part of the screen surface ineffective (passing more than the allowable AV). To help avoid this, it is wise to be conservative and oversize the screen (by as much as 20%) to account for variations that may occur in AV across the screen. Design screens to accommodate the greatest possible discharge or flow at the diversion. Under-sized screens don't meet fish protection requirements, are difficult to keep clean and have reduced performance.

A modern screen fitted to a floating pontoon allows water to be extracted from the surface of the Macquarie River. Water jets keep the rotating screen clear of debris.

Screening material

A fish screen should be designed and constructed to operate underwater for its lifespan. Material selection, preparation and coating will affect how long a screen will last and how much it will cost to maintain.

A cheaper screen may perform to the fisheries specifications at the time of installation, but is likely to degrade quickly, resulting in reduced asset life and higher maintenance costs. A screen made of higher-quality components may cost more upfront, but will perform to specification for much longer, need less maintenance and have a reduced whole of life cost.

In the United States and New Zealand, the focus has been on reducing the cost of screens. This led to more screens being manufactured using cheaper but inferior materials. Water users and governments in both these countries are now repairing and replacing hundreds of screens well before their intended lifespan (Les Perkins and Adrian Meredith, Australian Fish Screening Advisory Panel, pers. comm.). Quality of material and build is now a primary consideration when new screens are installed in those countries and the same must be the case in Australia.

A screen is a significant investment. However, if designed using quality materials and manufacturing methods, the screen should have a minimum 25-year lifespan. As with purchasing any on-farm asset, it pays to 'do your homework', seek recommendations from others and shop around. You can find Australian screen manufacturers and suppliers at the Fish Screens Australia website.

Type of materials

Screens can be made from a variety of materials. Current designs use:.

- Grade 304 stainless steel is the most suitable metal for use in freshwater applications.
- Grade 316 or 2205 or 2507 stainless steel is suitable for more corrosive environments, like more saline waterways such as estuaries or marine environments.
- Copper Nickel (Cu-Ni) is an alloy that can be used where biofouling by shellfish or other marine organisms is likely. Greater than 90% copper is typically used. The ongoing use of Copper Nickel is being investigated because of potential environmental contamination concerns.
- Ferrous materials are sometimes used for screen components such as motors, gear boxes and retrieval systems. Its use should be avoided, however, if used, a strong protective coating should be applied professionally to prevent corrosion. Any damage to this coating will result in corrosion. It is also wise to use anodes.
- Acrylic or nylon polymers are used in components such as brushes. These are sometimes used as screen mesh for very small screens, although the Hydrolox™ travelling belt screen is an exception. Some low-cost screens have a screen frame wrapped in a thin sheet of moulded or woven nylon. These materials are likely to distort and deteriorate rapidly and need to be replaced to ensure they continue to meet fisheries specifications.

A screen made of higher-quality components may cost more upfront, but will perform to specification for much longer, need less maintenance and have a reduced whole-of-life cost.

Screen mesh types

The mesh or screen mesh type will affect its cost, durability, strength and ease of cleaning. The three main types are: wedge wire, perforated plate and woven wire (Figure 11).

Wedge wire

Wedge wire is a very durable screen medium made by welding a continuous coil of triangle or wedge-shaped wire to backing wires that run in a perpendicular direction. This results in a screen with parallel slots and a very smooth, even surface. The screen can be used as a flat panel or bent to form cylinders or cones. The wire spacing can be varied to create different slot widths, porosities and screen strengths.

Wedge wire is a popular medium for fish screens internationally because of its structural integrity, durability and ability to resist damage and distortion. Wedge wire can achieve a very uniform slot width and its shape helps keep the screen clean. The inverted triangular wire means that the narrowest portion of the slot is at the front of the screen and the widest portion at the back (Figure 11).

This keeps more debris on the face of the screen where it can be washed or brushed off. Any debris that can fit through the slot is more likely to pass straight through.

Wedge wire screens are typically made from stainless steel and, while the most expensive of the screen mediums described here, they are the strongest and most durable, requiring less frame support than other materials. Wedge wire can be used for large and small screens. The large open area of screen face (porosity) achieves a relatively low head loss compared with perforated plate, but maintains strength

Perforated plate

Perforated plate is made by punching holes in a plate of any thickness. It is relatively low cost and its smooth surface, durability and strength make it superior to woven wire. Stainless steel is most commonly used, although aluminium and polymer products are available.

The round holes of perforated plate catch less debris than woven wire and, unlike woven wire, do not distort over time. The porosity (or open area) of perforated plate is typically lower than wedge wire and woven wire, which means head loss across the screen can be greater and the screen surface area will need to be larger. Like woven wire, perforated plate requires a closely-spaced frame for structural integrity.

Woven wire

Woven wire is a metal medium made by interweaving wires into a lattice network. Woven wire is very cheap, so damaged screens can be regularly replaced. It can be very finely woven to create very small aperture sizes. For example, 50-micron woven wire mesh can be used for some types of low-discharge pump screens. Woven wire is an inferior product to perforated plate and wedge wire. Woven wire is typically only used for small rotating pump screens if debris and fish loads are light to medium, and when the screen owner is prepared to regularly replace damaged or distorted screen medium.

Some of the disadvantages of woven wire are:

- Low durability. The wire medium is easily damaged and can distort and break over time. It requires ongoing maintenance and to ensure debris control and fish protection.
- Very low structural strength. Woven wire needs a closely spaced internal support frame to maintain its shape, stop water flow through the screen and reduce the effective surface area of the screen, which in turn affects AV. This can be overcome with a larger screen.
- Hard to clean. The rough texture of the weave makes the screen hard to clean and the square corners of the rectangular openings readily catch debris. However, this is not necessarily the case for very fine weaves.

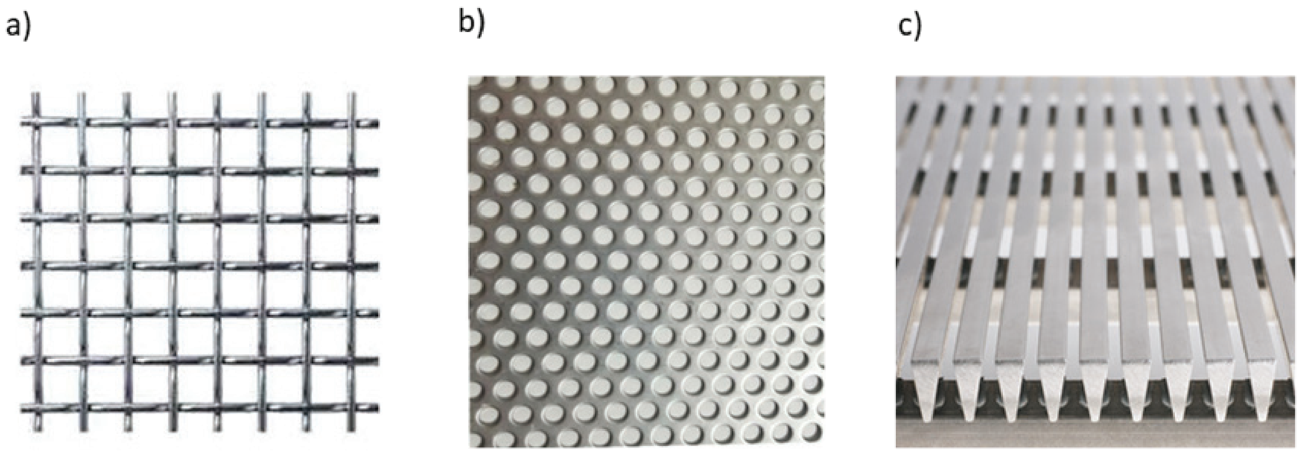


Figure 11.

Common mediums used to create screens are a) woven wire, b) perforated plate, and c) wedge wire. Strength, durability and performance increase from left to right, as does cost.

Screen material and hydraulics

The type of material used for a modern fish screen will affect how the screen performs. There is a relationship between head loss, screen porosity, mesh hole size, screen strength and screen cleaning. These factors interact to determine whether or not a screen will work as intended, protecting fish and excluding debris.

Head loss is the difference in the height of the water surface from the front to the back of the screen. The higher the head loss, the more restricted the flow. Increasing head loss will reduce the amount of water that can be drawn by a pump or gravity-fed channel.

Many gravity-fed diversions in Australia operate over a very flat topography and low gradient. These diversions often need to deliver water for hundreds of kilometres across a very small change in elevation. At these diversions, even a small increase in head loss at the intake can compromise water delivery.

A properly designed screening system (including the screen and any baffling) should not increase head loss to an extent where it affects the ability to deliver water. Head loss should always be calculated and clearly communicated between the engineers and water user through the screen design process.

If designed to comply with the fisheries design specifications (Boys 2021) and with a good cleaning system, the screening medium should add minimal head loss. This is because an effective fish-protection screen has extremely low velocities. Any extra head loss introduced by the screen will be minor relative to head loss created at other components of the pumping system (e.g. pipes, bends, valves or the height the water needs to be lifted)

The screen medium used will influence porosity, head loss and strength. In general, the round holes of perforated plate have a lower porosity than other materials, and therefore higher head loss. Woven mesh has high porosity, but reduced strength. Wedge wire has good strength and porosity. However, hole size or porosity of the screening medium need not affect head loss at the recommended fisheries specifications (Boys 2021).

Meeting these fisheries specifications will also ensure the screen face will remain clear of debris. If a screen cannot be kept clean, the hydraulics change, fish protection is compromised, and head loss will increase.

Screens can be fitted with external and internal brushes to assist with cleaning.

Keeping a screen clean

A screen will only protect fish and reliably deliver water if it stays clean. If any debris becomes impinged and remains on the screen, its effective surface area will be reduced. This raises the water velocity across the clean area of the screen and can result in fish impingement or entrainment and more debris accumulation. It will also increase head loss at the screen reducing diversion performance and pump efficiency and increasing energy consumption.

Modern fish screens have a larger surface area, and therefore lower AV, which reduces the debris that is sucked onto the screen and the force at which it is held. Finer mesh keeps debris on the screen face, rather than it becoming plugged, entwined or lodged in a coarser mesh. Debris held lightly on the screen face is much easier to remove For screens in gravity fed canals, maintaining a SV that exceeds AV can also help with self-cleaning.

Fitting a screen with an active cleaning mechanism can help to remove debris or biofouling from the screen face before it affects performance. Brushes, wipers, water jets and air-bursts can dislodge debris from the screen face. Some screens have cleaning systems such as rotating cylinders or travelling belts that operate continuously, while others use a periodic cycle of cleaning.

The regularity of a cleaning cycle depends on the debris load, which changes based on season and river flow conditions. The cleaning cycle can be pre-programmed or operated automatically using a SCADA system, which can measure head loss at the screen or other metrics of pump performance. Regular cleaning cycles are imperative because it is far harder to clean a screen that has been left to foul for extended periods.

If the diversion is not being operated for extended periods, removing the screen from the water, or still operating the cleaning mechanism, can reduce the risk of biofouling. In waters where biofouling may be a significant problem, anti-biofouling coatings may be considered. Copper-nickel alloy screens with >90% copper, while more expensive than traditional stainless-steel screens, are often favoured in estuaries due to their superior anti-fouling properties.

Brushes, air-burst and water jet are common ways to keep a fish screen clean, and each are described below.

The aggressive nature of brush cleaning dislodges organisms before they can attach. Brushes can also penetrate holes or slots in the screen to unplug blockages. In some screen designs, brushes can sweep the external and internal surfaces of a screen, preventing biofouling on both sides of the screen (Figure 12). Brushes have low on-going maintenance costs, with good quality polymer brushes lasting more than 5 years (depending on debris loads and the frequency of cleaning required).

Water-jet cleaning uses high-pressure water jetted from the inside or outside of the screen. It is typically used with woven mesh cylinder screens but can be used with travelling-belt screens. The water jet is directed at the exposed part of the screen (as it rotates above the water surface), or the submerged part of a screen.

Water-jet cleaning uses a high-pressure water supply by recycling some of the flow moving through a pump or, in the case of a gravity-fed diversion, by using a separate dedicated pump. Some designs rotate the screen past a fixed water jet.

Air-burst systems use a timed release of pressurised air. The force and velocity of the expanding air lifts trapped particles from the screen. This system needs an air compressor and storage tank. Automated solenoid valves control the timing and duration of the air-burst.

Travelling-belt screens drag accumulated debris from the water and deposit it on the other side of the screen (i.e. in the diversion channel) or on a bin where it can be removed. Often the rotating screen will work in conjunction with a brush, wiper or water jet. However, because this cleaning system works by impinging and dragging debris, care needs to be taken that fish are not being impinged and dragged as well.

The performance of brushes, air-burst and water jets has not been assessed in Australia. In the United States, the U.S. Bureau of Reclamation evaluated these systems on mechanical complexity, hydraulic impacts, cleaning performance and fish impacts (Walker *et al*. 2017).

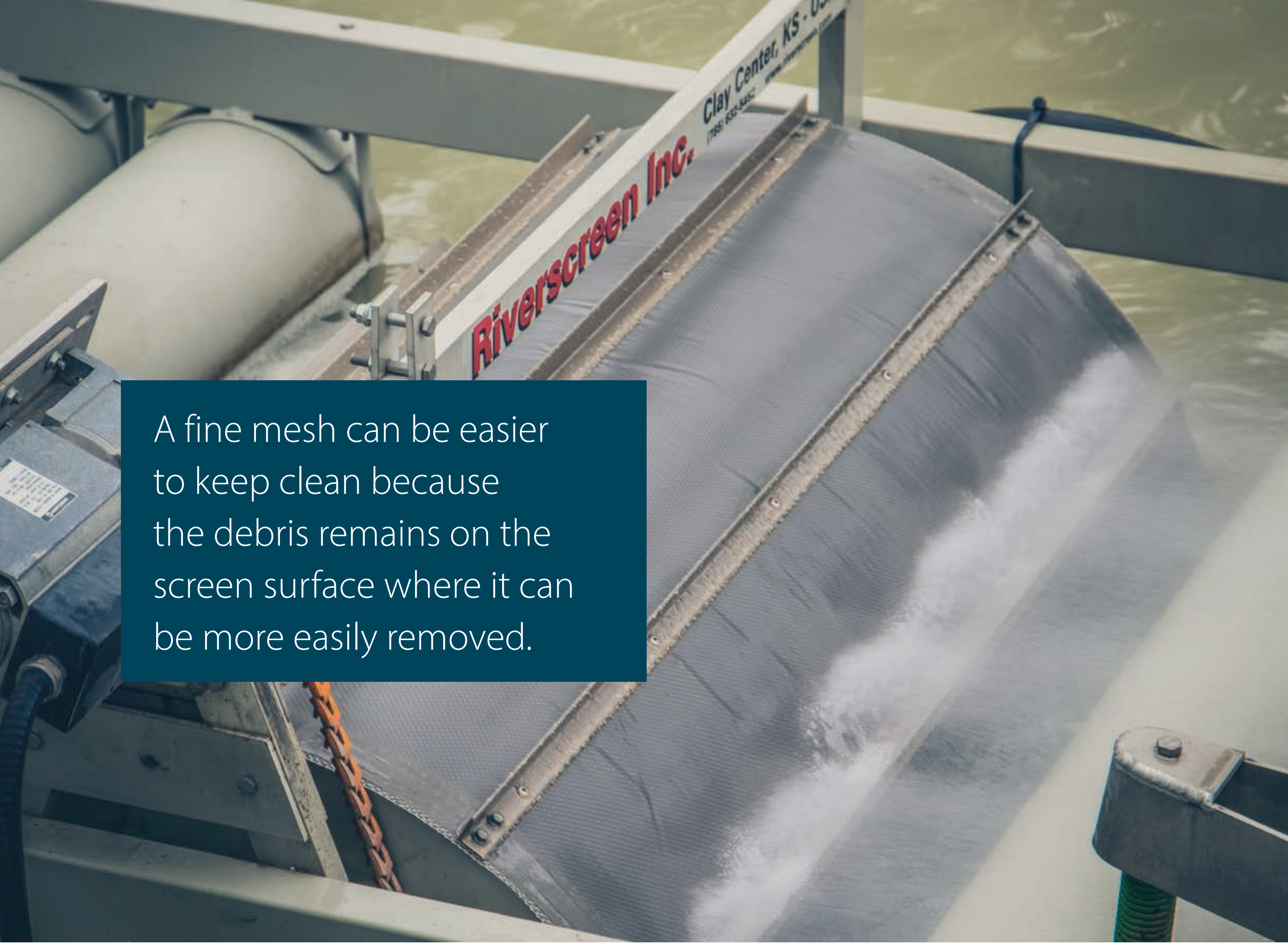
The review concluded:

- “Mechanical complexity was lowest with the automated brush system because it had the least complex design with fewer components, and no plumbing required.
- Hydraulic impacts were lowest with the water jet system that creates a limited zone of turbulence, and no impacts to the diverted water.
- Cleaning performance was highest with the automated brush system as it was the only in-water method that could remove biofouling as well as debris.
- Fish impacts were estimated to be comparable between the automated brush system and a continuous water jet since both create a smaller zone of turbulence and the constant nature allows fish to avoid the turbulence.
- There was no direct research that studied fish behaviour for any of the presented cleaning methods. Sudden turbulence and acoustics caused by an air-burst may cause stress or damage to fish in the area, but more information is needed to make this determination. It would be beneficial to further study the fish impact from the air-burst system.

Figure 12. (over page)

Screen cleaning can be achieved in a number of ways. The effectiveness of brushes in preventing biofouling is demonstrated in the bottom left photos, where organisms have attached to all the non-brushed surfaces, and the mesh is clean and clear.

Photos: Craig Boys.



A fine mesh can be easier to keep clean because the debris remains on the screen surface where it can be more easily removed.

Fish bypasses and escape routes

A fish bypass is a pipe or channel that gives fish a route of passage away from a screen and back to the main river channel (Figure 7 page 17). It is needed when a screen is placed within a diversion channel, downstream of a water control structure. In such instances, fish can't return to the river and accumulate in front of the screen where they will likely become injured and die.

Bypasses have been used extensively in other countries. There are several important design features to minimise the time it takes fish to find the entrance to a bypass and enter. These recommendations have been used in developing the fisheries design specifications for screens in Australia (Boys 2021).

They will be refined to include specific bypass design and performance for Australian fish species. The specifications include advice on bypass entrance design and location, as well as sweeping and entrance velocities.

Key considerations for screening projects

Is it a new diversion or is the screen being retrofitted to an existing diversion?

Civil works are often the largest cost of a screening project. Retrofitting a screen to an existing site can be challenging – requiring dewatering, disassembly of existing infrastructure, craning and the manufacture and installation of bespoke manifolds, couplings and retrieval systems. This can add substantial cost to the project.

If a screen is incorporated when a new diversion is installed, much (if not all) of the cost can be absorbed in the civil works budget. In some cases, a fish protection screen can reduce the cost of a new diversion. For example, a fish screen can act as the main filtration system, replacing the need for secondary inline filters.

What is the minimum and maximum river depth at the diversion?

Different screens have different operating constraints relating to water depth. The design drawings for the site configuration should always nominate high and low water/river levels. River gauge data can establish flow duration curves for different river stage heights and the water user can advise how diversion volume typically changes with river height.

Minimum water level

Minimum water level is a major constraint. Only the submerged part of the screen contributes to the effective screen area. The less screen that is submerged, the lower the effective screen area and the higher the velocity through the screen. Therefore, a screen that is designed to meet fisheries specifications when 100% submerged may not meet these specifications when partially submerged. It is important to know the minimum channel depth at which the screen will need to operate.

Shallow intakes can be particularly challenging. Not only is the potential footprint of the screen more constrained, but the screen may need to be designed to account for partial submergence. Some screens are designed for use in shallow water conditions, including some cone screens, half cylinder screens or a floating screen such as the RiverscreenTM (Figure 6, top row, far left). In some instances, pumping at minimum river levels either doesn't occur or occurs so infrequently that incorporating these aspects into the design is not required. At gravity fed diversions, which need a fish bypass channel, a minimum depth is needed for the bypass to operate effectively.

Maximum water level

Most pump screens are designed to operate when fully submerged so maximum water level is not as important as minimum water level. However, if a floating screen (e.g. Riverscreen™) is used, the suction pipe will need flexible couplings to ensure the intake can rise and fall with the changing river height. Vertical or drum screens fitted to gravity-fed diversions have a maximum operating height that, once exceeded, will be overtopped, rendering the screen ineffective. They tend to perform best located downstream of a water control structure, or if the river height does not change dramatically (e.g. in a stable weir pool). It is also important to know the maximum river height to ensure that any infrastructure that cannot be submerged (e.g. electronics) is located above the flood height.

Figure 13.

By using two screens, one on either side of the diversion channel, the screen surface area is doubled. The screens guide fish and debris to a centre bypass.

Photo: Craig Boys.

What is the available footprint for the screen?

The location and depth of the diversion and the surrounding civil structures can all constrain the area available to install a screen. Area is an important consideration because the maximum effective screen area will affect the approach velocity to which fish are exposed. The smaller the screen surface area, the higher the approach velocity. Screens can be designed to maximise surface area while minimising footprint. For example, using a cylinder instead of a flat plate, or using two screens on either side of a diversion channel to double the surface area within the same footprint (Figure 13).

What proportion of river flow is typically diverted?

The greater the river flow diverted, the more likely the screen will encounter more debris and fish loads. In large rivers, gravity-fed diversions are more likely to divert a larger proportion of river flow than pump diversions. In some instances, this can be the majority of river flow, as was reported during a study at Berembed Weir on the Murrumbidgee - where at times up 75% of the river flow was being diverted (Baumgartner *et al*. 2007). In smaller tributary streams, even smaller pumps can divert a large proportion of river flow. In summary, the larger the proportion of river flow diverted, the more focus needs to be given to screen cleaning and whether there is sufficient sweeping velocity to help clearing debris and fish from in front of the screen.

What type and amount of sediment and debris is expected?

Debris can come in many sizes. Large debris such as logs and branches can damage screens. Small debris such as leaves, grass, sticks, macrophytes, algae, and coarse sand can block the screen mesh. The risk of damage and blocking can be eliminated or reduced through proper design. It is crucial to understand the type of debris, its size and approximate load (amount) expected at the diversion under different river flows.

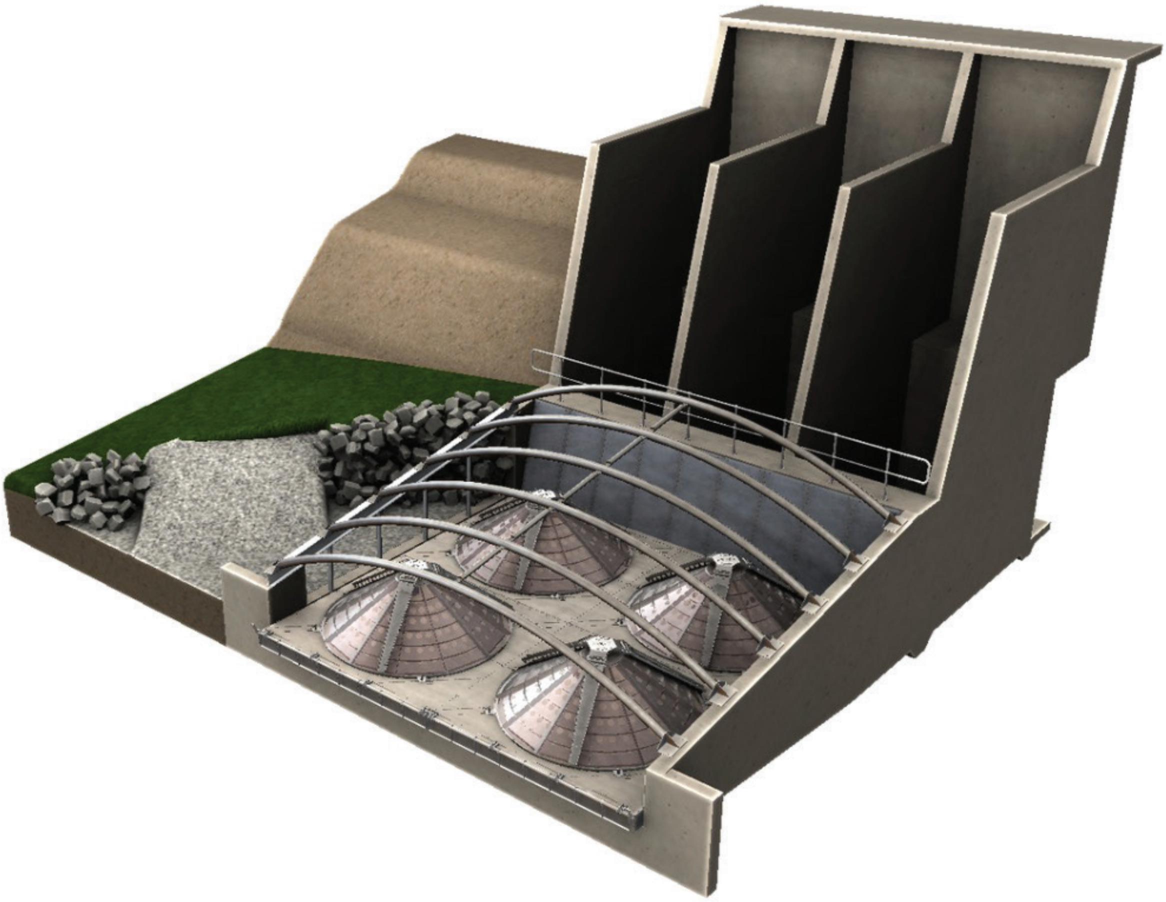
As detailed in the screen material section, a fish screen will perform better when the mesh size is several times smaller than the size of debris typically expected at the diversion. This is because the debris will remain on the surface of the screen, where it can be easily washed or swept off. Because large debris mobilised during floods (e.g. logs and branches) tend to be suspended in the flow, submerged screens in the deepest part of the channel are likely to be less exposed to damage than screens that float on the surface. The velocity of flow will be lower near the bottom of the channel.

The risk of flood damage can be reduced by making the screen retractable or by installing a flood guard (Figure 14). Extra structures built around a screen increase the likelihood that debris will become entangled on the guards and may need to be inspected and debris manually removed following larger flow events.

Screens placed further down a gravity fed diversion may be less exposed to large debris floating down a river during flood but can be more prone to smaller debris accumulating in front of the screen and this will need to be managed, either manually or via a bypass channel.

Sediment management can be important at sites exposed to high silt loads. Screens and their cleaning mechanisms can be buried if sediment builds up around the screen. It is, therefore, important to evaluate the possibility of sediment deposit. Installing a screen can also create localised changes in the hydraulic conditions at the site.

In some instances, sediment management may be as simple as locating the screen away from a known depositional zone. One solution is to use a skid or floating pontoon (Figure 19b). Raising a screen off the river bed is good practice, regardless of sedimentation. Sand particles are perfectly sized to lodge in wedge wire screens. Lifting the screen will avoid it being damaged by travelling 'sand slugs' (Figure 15). If sedimentation is expected at a screen located down a gravity-fed diversion, it is essential to ensure that a sweeping velocity is created at the screen using a fish and debris bypass. Sediment sumps upstream of screens and bypasses can also help manage sediment.



Figure

Large debris mobilised during floods can damage screens. Installing a flood guards such as at the 'roll cage' at the Trangie-Nevertire Irrigation Scheme pump site can help reduce this risk.

Photo: AWMA.

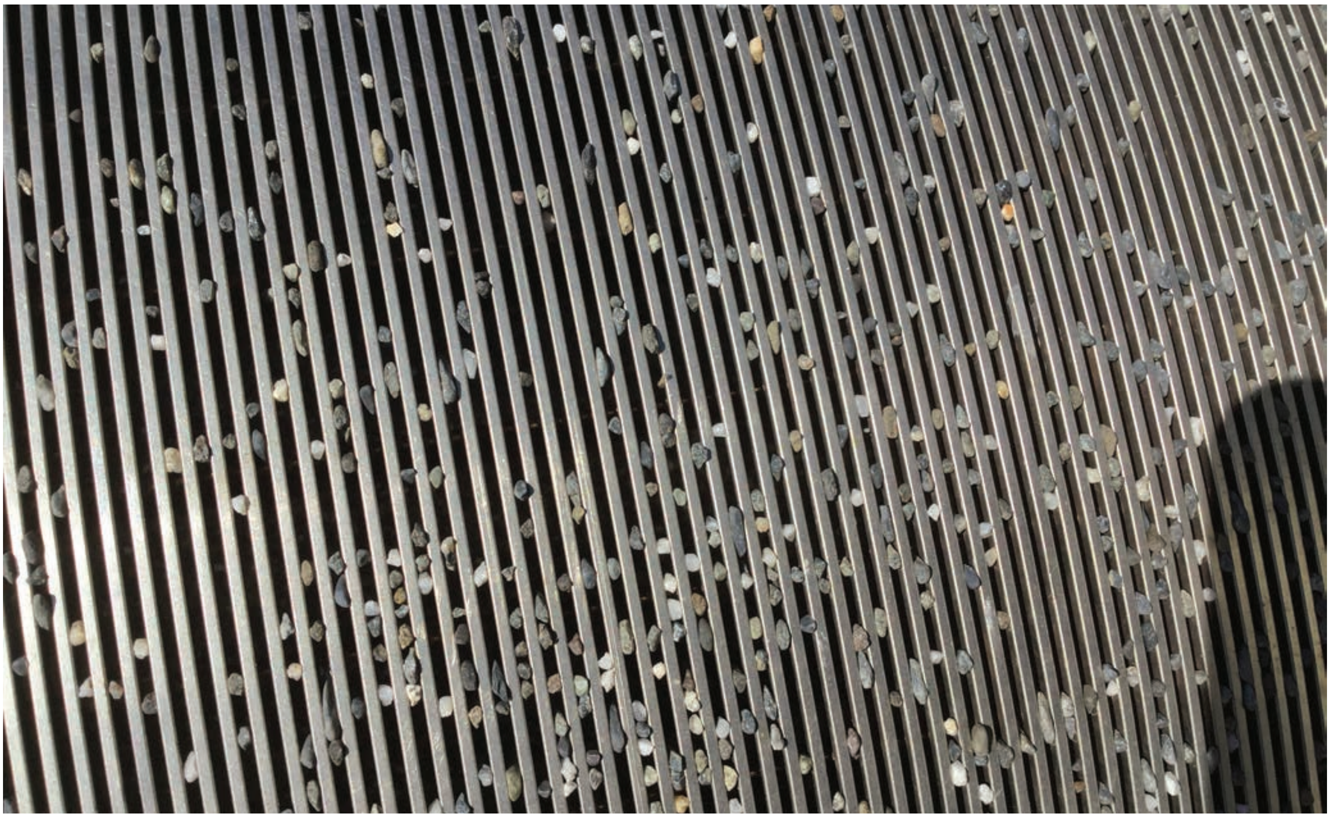


Figure 15.

Screen placement and the cleaning system used are very important considerations that will prevent a screen becoming blocked. Pictured here is an air-burst cleaned wedge wire screen that became plugged with sand in a sandy stream in California. The solution was to relocate the screen further off the sandy bed and replace the air-burst system with a physical brush.

Photo: Craig Boys.

Is the site subject to extreme events such as flooding or temperature?

If the site is subject to flooding, the flood level should be established and all above water infrastructure housed above this line. Consider whether the screen needs to be accessed or retrieved during flood events and whether heavy debris present during floods might cause damage to the screening system.

While the screen will likely be insulated from major temperature events, any infrastructure and control gear above the water line should be checked for suitability for high and low temperature extremes. Ultraviolet resistant materials should be used when needed.

Do I need to maintain and inspect my fish screen?

A fish screen is like any other piece of infrastructure: it will only continue to give years of reliable operation if properly maintained. Depending on the issue, a damaged screen will perform poorly for water delivery, fish protection or debris control. If the damage is not repaired early, it may reduce the life of the screen.

A screen manufacturer or supplier can provide a maintenance manual and schedule to ensure ongoing performance and extended life of the screen. The schedule should outline the frequency of inspection and any monthly or annual servicing requirements, including the frequency and approximate cost of replacing parts (e.g. brushes).

A well-designed screen should operate without regular monitoring and, in many instances, only need a detailed annual inspection outside of the main water diversion period. Certain sites or times of year (e.g. areas of high debris deposition or during flood) may need more attention — such as monitoring and removing accumulated debris or removing, or retracting, the screen.

Depending on the auxiliary equipment supporting a fish screen there will be other maintenance considerations. These could include:.

- Debris removal after floods or other events
- Anode replacement (if fitted)
- Visual check of the mechanical components and seals
- Inspection of wiring harnesses or hydraulic hoses
- Inspection and testing of any rotating components
- Checking for oil leaks, hydraulic drive or gearbox
- Any air or water hose pipe fittings
- Inspection for corrosion of any ferrous metal parts and coating integrity
- Physical damage.

Do I need a retrieval system?

Screen retrieval systems are used to safely and easily raise a screen above the waterline to allow access for regular inspection and maintenance (Figure 16). They should be considered for installations where screens are underwater, not visible and located directly in the waterway. A retrieval system will allow the screen to be removed when the diversion is not in use, can help protect the screen in floods, and allow the screen to be easily removed in the rare event of blockage or malfunction. A retrieval system allows screens to be inspected without the need for divers, which is more convenient, affordable and improved safety.

Not all installations need a retrieval system. Screens on floating pontoons can be easily viewed and accessed without retrieval. Similarly, screens that are installed within a diversion channel, downstream of a water control structure, can be dewatered for inspection. In some instances, it may be desirable to install a retrieval system. The site will need to support the installation of the retrieval system and there should be enough capital budget to cover the extra cost. Sometimes the cost of a retrieval system is more than the screen. If a retrieval system is not in use, consider how the screen will be periodically inspected.

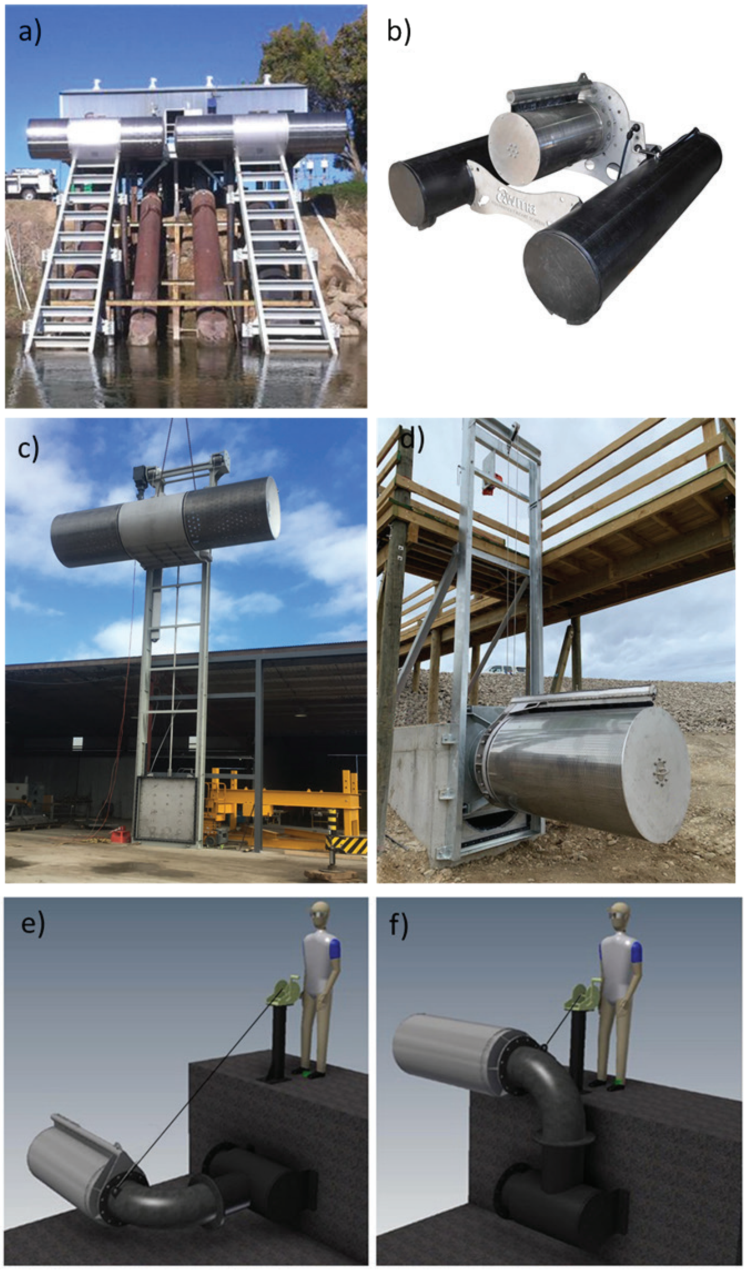


Figure 16.

Different retrieval systems can be used to help with screen inspection and maintenance. Pictured here are inclined (a) and vertical (c & d) rail and winch, submersible and floatable pontoons (b) and a pivoting intake pipe in the down (e) and raised (f) position.

Images: AWMA.

Will the screen be the main form of filtration?

When the diversion supplies sprinkler or drip irrigation, there is often some form of fine filtration at the diversion. Typically, on the pressure side of pumps, these filters require back washing to maintain performance and prevent damage. Some irrigators report having to regularly backwash filters (up to 30 times a day) or filters being destroyed when a school of fish has been sucked up by the pump.

If a screen is installed to reduce the load on filters, or remove them, this should be considered at the time of design. A key benefit is potential savings in filtration costs. This is particularly the case for greenfield installations, where a fine mesh modern screen at the intake may replace the need for secondary filtration that can cost many times more to install and operate. In some instances, secondary filtration will still be needed but an intake screen will reduce the debris load and therefore cleaning, back flushing and maintenance of the filter. This will significantly extend the life of the filter.

Is there electrical power at the site?

Some fish screens need power to operate, which can add extra costs at remote sites. Power (either single phase 240/220VAC, or more likely three phase 415/400VAC) is usually needed to operate the cleaning mechanism (such as brushes, wipers or an air compressor), water control gates, retrieval system or a control system (e.g. SCADA: Supervisory Control and Data Acquisition).

The need for, and availability of, power should be identified early in the design phase. When mains power is not available, it may be possible to use alternate power sources such as solar DC or inverted 240VAC/415VAC. Some screens, particularly of small to moderate size, can have a 'self-propelled' or powerless cleaning mechanism, or a manual winch retrieval system. Some screens rotate for cleaning using gears driven by the force of water pushing an internal impeller or external water paddle. Others redivert some of the diverted flow under pressure to spin and spray the screen.

Do I require permits, concurrences or approvals before installing a screen?

In some cases, work may be needed either on or around a pump site or gravity-fed diversion to install a screen. This work could include:

- » Adjusting the pump or gravity-fed intake
- » Excavating material from the riverbed or the riverbank
- » Removing instream woody habitat or riparian vegetation
- » Recontouring or stabilising the bank using concrete, rock or other material
- » Installing piles, debris guards or rail systems
- » Installing temporary cofferdams and dewatering the site.

These activities may need approval or permission from state agencies. Depending on the project, you may qualify for an exemption. Always check the requirements in your area at the start of the design and planning process. In NSW, relevant agencies include: New South Wales Natural Resources Access Regulator (NRAR), WaterNSW, NSW Crown Lands and NSW DPI Fisheries.

A note on metering compliance. A modern fish screen will not affect the metering of water, because it only changes the speed of the water fish are exposed to at the intake of a diversion, not the volume of water taken, or the rate at which it is taken. However, depending on the state or territory, certain conditions may need to be met when installing a screen to ensure the diversion remains lawful.

Within New South Wales, all water licence and approval holders subject to water metering must do so with equipment that complies with the Australian Standard AS4747: 'Meters for non-urban supply'. For a meter to be accurate (within 5% error) and therefore AS4747 compliant, there must be a certain length of pipe approaching the meter where there is to be no water disturbance. A disturbance could be created by components such as flanges, pipe bends, an offtake, or a filter or screen. The meter manufacturer will stipulate the minimum number of pipe diameters away from the meter that must be disturbance free. Because a modern fish screen is located at the end of the pipe, it is generally well beyond the allowable disturbance distance and will therefore will not impact meter accuracy or compliance under AS4747.

Additional consideration needs to be given to water cleaned screens. Any offtake of water off the main supply line for screen cleaning must comply with AS4747. If in doubt, check with a person duly qualified in assessing the compliance of metering equipment. Those outside of NSW need to check if any similar requirements exist in their state or territory.

Fisheries specifications for the design of fish-protection screens in Australia

The NSW Department of Primary Industries has released fisheries specifications as a stand-alone companion to this guide. The specifications provide manufacturers and those installing screens with a clear set of minimum design standards that must be met to ensure a screen can be considered fish friendly (Boys 2021).

Choosing the right modern fish screen may require a certain degree of flexibility and pragmatism to accommodate site specific-challenges, while remaining within budget. However, it's important not to deviate too much from acceptable standards, as this will result in poorer fish protection and debris control, increased maintenance costs and increased risk of screen failure. Fisheries specifications are intended to guard against this risk, providing the most up-to-date requirements for screen design and operation.


Leica

A fisheries researcher pours a jar of larval fish into a screen-testing flume to determine which velocities and mesh sizes provide the greatest protection for Australian native fish.

The specifications (Boys 2021) 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).

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

» If the main purpose of a screen is fish protection, it needs to protect fish.

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

» Specifications provide fisheries and natural resource managers with an objective way of evaluating the suitability of different screen types.

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

» Specifications ensure a minimum set of standards are upheld regardless of the jurisdiction of 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 and protecting the long-term viability of the investment.

Compared with other parts of the world such as North America or New Zealand, the application of modern fish screens in Australia is relatively new. As such, the Australian specifications outlined 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, bypass design). Where local laboratory or field-based 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 tailor criteria to Australian conditions.

The Australian Fish Screen Advisory Panel (AFSAP) will continue to review and develop the specifications as required (ASFAP). 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 several times a year to exchange information and ensure that as modern screening is rolled out across Australia, best practice design is being adopted. 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.

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