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Pocket Guide to Screening Small Water Diversions

A guide for understanding fish screening and selection of screens for small diversions.

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A guide for planning and selection of fish screens for small diversions.

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Introduction

The purpose of this guide is to acquaint water diverters and resource managers with fish screening methods and devices used for small water diversions. Even where screening is not legally required, it can provide multiple benefits. Screening greatly reduces fish **entrainment**: the mostly passive movement of fish and other aquatic organisms carried along with diverted flow. Screening can also benefit use of diverted water by permitting better exclusion of debris and sediment. Entrainment of fish and aquatic organisms into diversion ditches and pipes often results in these organisms being removed from the natural system. Many studies of unscreened water diversions (2, 4, 5, 6, 9, 10, 11 and 12) reveal significant entrainment of aquatic organisms and, when multiplied by multiple diversions, such losses can deplete the biodiversity of a river basin. This guide presents information covering many effective screening methods with a focus on screening small water diversions of approximately 25 ft^3/s or less. Additional design information for small and large fish screens can be found in references 8, 11,12,13,15 and 16.

Federal protection of listed aquatic species that migrate between the ocean and freshwater is the responsibility of NOAA Fisheries[1] (National Oceanic and Atmospheric Administration). Protection of listed freshwater resident species is overseen by the U.S. Fish and Wildlife Service (FWS). State listed or non-listed native and game species are the responsibility of state resource agencies. When listed species are present, screening may be legally required at water diversions. Applicable screen design criteria can vary by species listing, regulatory agency and geographic location; therefore, prior to starting a screening project, water diverters are encouraged to contact state or federal fishery resource agencies for assistance. Even where screening is not required, installation of fish screens may also qualify for state or federal cost sharing.

Screening objectives, location, screen type and cleaning method must be considered to develop a screen installation that complements the diversion. This guide provides information for planning a successful screen installation as well as additional references for understanding screening.

What Objectives Can Screens Fulfill?

Screening diversions can serve multiple objectives such as fish protection and debris and sediment management. Each objective will impact selection of screen location, screen type and screen cleaning method.

Fish Protection

Fish protection means preventing fish from being entrained or injured by diversion of flow from a stream/lake. Excluding fish is accomplished by screening flow or in some cases using behavioral barriers that attempt to guide fish away from flow diversions. Fish screens are referred to as positive barrier screens because they exclude all aquatic organisms larger than the screen hole size. Fish protection also

[1] NOAA Fisheries is also called National Marine Fisheries Service (NMFS)

requires that screens are designed to prevent water passing through the screen from impinging fish on the screen surface. Impingement can cause impairment of breathing, loss of scales, bruising, and elevated stress levels resulting in fish mortality. Impinged fish may also contact mechanical screen cleaning systems, which can result in direct injury or mortality.

Many types of behavioral barriers including louvers, bar racks, sound, light, electricity, air bubble curtains and combinations of these have been widely tested. As a rule, behavioral barriers provide less secure exclusion than a positive barrier screen. This guide does not discuss behavioral barrier technology. References are given at the end of this guide providing further information on behavioral barriers for excluding fish (1, 12, 13).

Fish screen criteria

Specific fish protection criteria for a screening project (screen design criteria) are selected based on fish life stage or body size, swimming strength and, in some cases, fish behavior. These parameters will differ between species and age class. For listed anadromous salmonids (salmon and sea run trout), NOAA Fisheries and some state agencies publish mandated protection criteria for screening diversions (see references 7 and 16 for examples). These criteria have evolved as a result of years of case studies, research, and industry improvements for screening flow.
NOAA Fisheries criteria for small screens are generally accepted as a standard for most small screening applications regardless of species (12, 17). This guide presents those aspects of west coast NOAA screening criteria that are most widely accepted for small screens *where specific criteria are not available or required*. It is important to note that specific fish screen design criteria have not yet been established for some federally listed species (e.g., delta smelt, longfin smelt, and green sturgeon). In these cases NOAA fisheries criteria are typically used, although more restrictive criteria are sometimes applied based on project specific conditions. Contact your local fish and game or U.S. Fish and Wildlife Office to find out about any specific requirements for your area. Deviating from established screen criteria when not required by law should be done with caution as it can result in using less developed and less tested technology that may result in lower fish protection and increased screen maintenance.

> ***NOAA screen criteria*** *are periodically updated and can vary by geographic region. The criteria are only partially presented herein. The full criteria can be found on the internet using the web addresses given in the references.*

NOAA Fisheries presents two levels of screen criteria, one for protecting juvenile salmonid fingerling size and larger fish, and a second level for protecting smaller salmonid fry.

> Fingerlings are defined as juvenile salmonids larger than 60 mm (2.4 in). The fingerling criteria allow for greater screen approach flow velocity, larger screen openings and minimum screen porosity based on the larger fish size and greater swimming strength of an older juvenile. When NOAA criteria are required, the fingerling criteria can only be used when it can be shown fry are not present during diversion. This is often difficult to prove and therefore NOAA fry criteria are more widely applied for screening.
>
> Salmonid fry are defined as fish less than 60mm long. In general, NOAA fry screen criteria will protect many fish species with body lengths greater than 25 to 50 mm (~1 to 2 inch).

This guide does not discuss specially designed screens required to exclude smaller bodied fish or fish eggs.   Users are encouraged to contact screen manufacturers about applications requiring screen mess openings of less than about 1 mm.

Debris Management and Removal

Fish screens are designed to filter water containing aquatic organisms, debris and sediment   To operate properly, a screen ***must be designed to manage the inflow of debris***.   Debris load can vary by season, screen location and debris type. Woody debris load and domestic refuse are typically greatest during high flow events when material accumulated on stream banks is swept into the water. Aquatic plant load is often highest in late summer and early fall following the plant's active growth period. During this period, the tops of many rooted aquatic plants break off from the roots and are transported downstream. This period may also coincide with leaf drop which can add a large biomass load to a stream in the fall.

Debris plugging of screens can be managed by active or passive cleaning methods. Active cleaning methods rely on mechanical cleaning. Passive methods rely on screen design and flow sweeping along the screen to limit debris impingement.

Early in the screen design process the diverter should weigh the pros and cons of different debris management methods.   General approaches to debris management are:

1. *Exclude debris from the diverted water leaving it in stream/lake or returning it to the stream via a* ***bypass*****.**   Either active or passive debris management methods can be used for this alternative.

2. *Pass debris entrained by the diverted flow downstream with the screened water***.** This generally occurs with rotating screens designed to pass impinged debris over the top of the screen.

3. *Remove debris from the diverted water and collect it onsite for disposal.* This requires rotating screens or screen cleaners designed to remove debris and a debris conveyor system.

Debris management methods 1 and 2 are common for small screen installations. Option 3 increases installation complexity and is only used when removal of debris provides significant benefit for water use or stream management.

Other, less common screen management issues may occur such as operation during icing conditions or screening flow containing biota that can attach to the screen causing biofouling of the surface. Special screen management issues like this need to be identified early in the screening selection as they can impact operating guidelines, selection of screen type, material and cleaning method. Operating a screen during frazzle ice conditions should be avoided or only undertaken following considerable study of the operation. A discussion of biofouling is presented later in this guide in the section on screen cleaning.

Sediment Management

Screens must operate within sediment conditions found in the stream. Sediment is divided into two general types:

- larger bed sediments (bedload) that roll along the channel bottom. Mobile bedload is typically sand and gravel. However, during high flows or in steep streams, cobbles and boulders may also be moved downstream by flow.
- finer suspended sediment that is carried within the water as a mixture. Suspended sediment is generally fine sand, silt and clay material. This material will remain suspended until the water reaches an area of low velocity. Sands settle to the bottom quickly while fine silt and clays can remain suspended for long periods.

It is important to recognize that in most streams sediment load or concentration increases as stream flow increases.

Fish screens that will likely be subjected to periods of significant bedload require special consideration of the following:

- selecting the right screen and cleaning method for the site and sediment conditions,
- having a strong sweeping flow passing the screen to transport sediment away from the screen and
- proper sizing the screen mesh.

Sediment containing a high concentration of sand particles of size close to the screen mesh size can result in particles wedging in the screen openings resulting in difficult cleaning and potential plugging of screens. When possible selecting a screen mesh size that is significantly different than the average sand sediment size can reduce sediment plugging problems.

Suspended sediment is composed of fine material that often passes through a fish screen with the flow. Although fish screens will not exclude most suspended sediment, a screen designed to protect small bodied fish may create local areas of low velocity where suspended sediment deposit. This is frequently the case immediately downstream of screens placed across ditches carrying high suspended sediment loads. Where suspended sediment load is high, providing access or a method to flush sediment away from the front and back of the screen should be considered.

Screen Basics

Fish Screen Hydraulics

Flow velocity measured perpendicular at a distance of three inches upstream of the screen surface is referred to as *screen approach velocity* (V_a) by NOAA, (7). This is the velocity a fish must swim against to avoid impinging on the screen mesh. Flow velocity measured parallel to the screen surface is referred to as *screen sweeping velocity* (V_s). This is the velocity that carries a fish swimming against the approach velocity away from the screen (figure 1). Fish screens should be designed and installed to achieve a nearly uniform flow through the screen, therefore Va at different locations on the screen face should be similar. Fish screen flow capacity is based on the minimum wetted screen area times Va. To increase flow capacity the minimum wetted screen area must be increased as Va is the maximum allowable approach velocity to the screen. NOAA screen criteria also require a minimum Vs/Va ratio of one for screens longer than 4 ft to ensure a sweeping flow along the screen. This requires screens longer than 4ft be set at a maximum angle of 45 degrees to the stream flow

In the absence of a strong sweeping flow, fish are more likely to swim against flow entering the screen until exhaustion impairs their ability to avoid impingement. The time it takes for a particle carried by sweeping flow to pass the length of the screen can be thought of as approximately the duration that a fish will be in danger of impingement. For small screens this duration should be relatively short. Therefore, NOAA small screen criteria (apply to screen lengths < 4 ft) allow screens to be set at any angle to the direction of water flow. Although not required under NOAA small screen criteria, establishing a strong sweeping flow across a small screen is highly recommended and will benefit fish protection and debris and sediment management. Minimizing fish impingement risk requires that the approach velocity (Va) to the screen is less than the fish's swimming ability for a period of minutes referred to as the fish's sustained swimming speed. NOAA salmonid fry criteria for screens with active cleaning systems require sizing the screen to have an approach velocity of **≤ 0.4 ft/s** based on total wetted area of screen fabric. For fingerling size salmonids and larger, an approach velocity **≤ 0.8 ft/s** is allowed. When screening non-salmonids, investigating the fishes swimming ability is recommended. Swimming performance can vary widely between fish species, age class (body size) and can be influenced by water temperature. Data on fish swimming speed may be available from state fish resource management agencies online data bases or references (2,8,18) cited at the end of the guide. The different levels of NOAA screen criteria illustrate the need to determine fish protection objectives early in the screening project. When screen criteria are not mandated, the screen design should be based on balancing screen approach velocity--which impacts fish protection, screen size and screen facility cost—including projected maintenance. The relationship between approach velocity, screen size and fish protection are clear. The relationship between approach velocity and screen O&M is more varied, but often works as follows. Increased approach velocity increases the water force pressing debris against and into the openings in the screen fabric. Debris tightly wedged in the fabric requires more frequent cleaning or more aggressive mechanical cleaning methods. However, both Va and Vs are important. Flow passing through the screen leaves debris behind on the surface. Debris is held in place as long as the force of the water pushing it against the surface caused by Va is greater than the force of water pushing debris along the surface caused by the Vs. Increasing the ratio of Vs/Va provides improved cleaning performance based on flow alone. This is often the case with passive screens that do not rely on a mechanical cleaning. For passive screens to operate without frequent manual cleaning they must have a low approach velocity, a strong sweeping flow, or both.

***As a general rule**, lower approach velocity equates to increased screen size, better fish protection and in most cases, decreases cleaning issues. Increasing approach velocity generally reduces screen size, reduces fish protection, reduces facility construction cost and increases cleaning issues. This is a general rule and will not be true in all cases.*

Passive screens are generally designed to operate with a Vs/Va ratio in the range of 10 to 20 or greater. A ratio of >10 is recommended for passive screens where Vs is > 2 ft/s. In slow moving flow, very low approach velocity is required to minimize buildup of debris on the screen. Passive screens with Vs/Va ratios < 10 may be acceptable when Vs and debris load are both low, if not and active cleaning system is likely a better choice. Rotating screens are an example of where a low Vs/Va ratio may be desirable to increase debris impingement on the screen.

Screen Location

Screens placed on small pumped diversions are typically mounted directly on the end of the suction pipe (intake) located in the canal, stream or lake. Screens for a gravity diversion can be located

- in-ditch downstream of flow control structures, Figure 3a or
- in-stream/lake at the entrance to the diversion upstream of flow control structures, Figure 3b.

Following are typical pros and cons to consider during selection of either an in-ditch or in-stream location:

Locating a screen in-ditch downstream of the flow control/trashrack structure

Pros

- Ease of dewatering the screen for inspection or maintenance. The screen is often protected from large debris, water craft and the public.
- Flow conditions (depth, velocity and flow direction) are more consistent and predictable than in-stream locations.

Cons

- An in-ditch screen requires a bypass channel or pipe from the screen back to the stream. The bypass provides a route for returning fish to the stream. Bypass flow and the fish conveyance structure must also be large enough to provide sufficient flow depth for the largest fish and to transport debris back to the stream without plugging. The bypass structure can be a significant additional cost.
- Operating a fish bypass requires diverting extra water. Depending on state water regulations, this water may be subtracted from decreed diversion flow. Prior to locating a screen in-ditch, diverters are encouraged to request guidance from their State Engineers Office or State Water Rights Office on how fish screen bypass flows are accounted for in their State.

Fish bypasses generally concentrate fish in the bypass channel or at the point of return to the stream, making them more susceptible to predators like other fish, mammals, birds or people. Bypasses often provide reduced cover and may disorient fish, all of which decrease the fish's natural ability to avoid predators.

Locating screen in-stream/lake at the diversion entrance (upstream of the flow control structure)

Pros

- Locating the screen in-stream/lake prevents entrainment of fish and debris into the diversion. Fish and debris do not pass through the diversion's flow control structure which could harm fish and require debris removal in the control structure.
- A fish-bypass structure is not required.
- Bypass flow for returning fish and debris to the stream is not required.

Cons

- Maintenance access to the screen may be difficult or limited to low flow periods.
- The screen may need to be removed during freezing winter weather to prevent damage to the screen.
- Large woody debris carried by high flows may damage in-stream screens. A debris boom in front of the screen may be required.
- Flow conditions may be highly variable during the year.

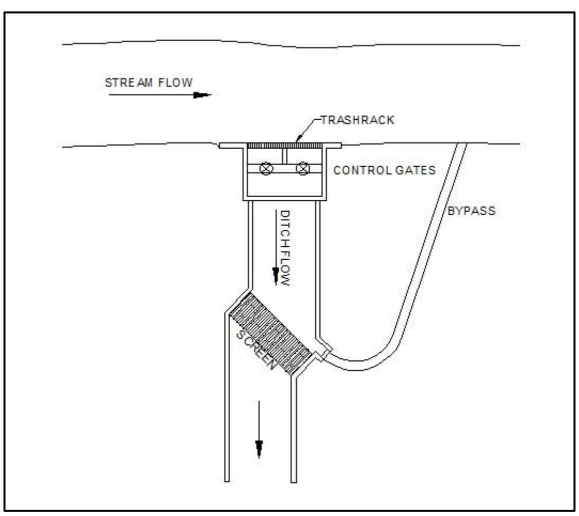


Figure 1a Fish screen located in-ditch

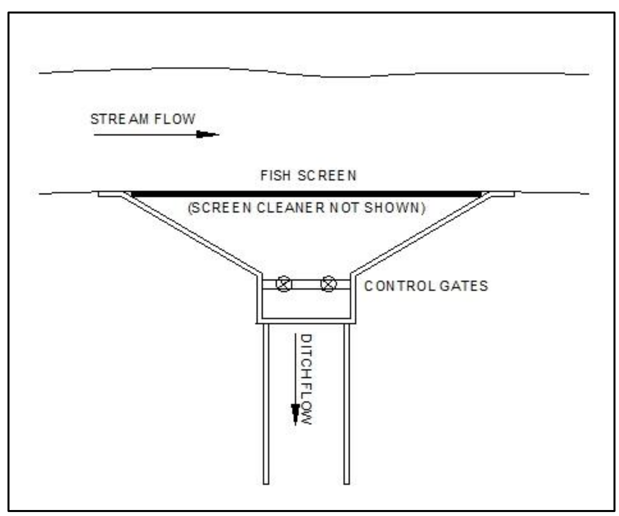


Figure 1b Fish screen located in-stream

Screen Materials

Fish screens are commonly constructed using a metal frame supporting a screen fabric made from metal or a UV-protected synthetic material. The frame and screen fabric should be designed to withstand the maximum difference in water surface or pressure that can occur across the screen were it to totally plug.

Different metals can cause galvanic corrosion when placed in contact with each other. Prior to using dissimilar metals together, consult a galvanic compatibility table to determine their electrochemical similarity. Many metals suppliers can also provide this information. Coatings or insulating materials placed between the metals may be an option when electrochemically dissimilar metals cannot be avoided.

Screen Fabric

Common screen fabrics are woven wire, perforated plate and wedge-wire (also called profile wire). Each fabric type can be made from a variety of different materials including stainless steel, coated steel, aluminum, copper alloys and synthetic materials like acrylic and nylon. Before using fabrics requiring protective coatings, carefully consider the likelihood of wear on the coating due to abrasive flow conditions, screen cleaning and debris impact. Woven wire fish screens (figure 2a) are generally constructed using heavy gauge stainless steel wire. Perforated plate (also called punch plate) screen fabric (figure 2b) is typically made from light gauge stainless steel or aluminum plate. Wedge-wire fish screen fabrics are generally constructed using stainless steel materials (figure2c), although slotted-mesh fabric molded from synthetic materials is also available and can be a good choice.

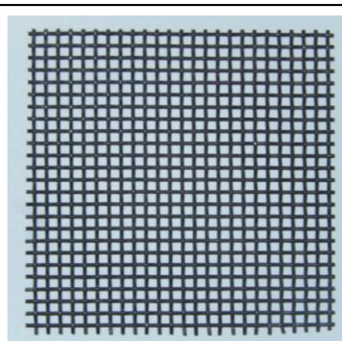


Figure 2a Woven Wire Screen

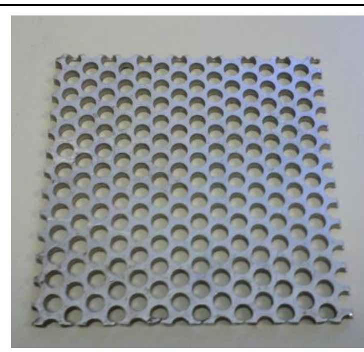


Figure 2b Perforated Plate Screen

Figure 2c Wedge-Wire Screen

Screen Porosity

Terms:

Headloss: drop in the water surface or pressure across the screen

Fish entrapment: fish pinned on the screen surface by flow through the screen

Orifice velocity: water velocity through the screen fabric openings

Screen porosity (percent open area) impacts the headloss required to pass flow through the screen (energy loss as defined by drop in water surface or pressure across the screen), debris plugging potential, fish entrapment and fabric strength. In general, headloss, debris plugging, fish entrapment and fabric strength are all inversely related to screen porosity. To pass the same flow through similar size screens of different porosity, the screen with the lower porosity will require a greater change in water surface or pressure across the screen and will produce a higher orifice velocity. The higher the orifice velocity the tighter fish and debris are held against the screen surface.

NOAA fry and fingerling criteria for screening require screen porosity greater than 40 percent for fingerlings and greater than 27 percent for fry. These criteria are set to limit flow orifice velocity. For this reason, typical porosities of fish screen fabric are between 27 and 50 percent open area.

Screen Fabric Hole Size

Screen hole size is selected based on the screening objective for fish and debris and on the allowable headloss. NOAA fry criteria require openings ≤ 3/32 inch (2.38 mm) for woven wire and perforated plate. The slot width in wedge-wire fabric must be ≤ 0.069 inches (1.75 mm). NOAA fingerling criteria require openings ≤ 0.25 inch (6.35 mm) for all screen fabric types. Where NOAA criteria are not required larger screen openings may be appropriate to meet screening objectives. However, increased hole size reduces protection for smaller bodied fish and increases the amount of debris that passes through the screen.

A concern often over looked in selecting a hole size is debris size and type. For a stream or lake with a dominant debris type (pine needles, plant seeds, peat, aquatic plants, ash from a fire, etc.) it is preferable to size screen openings to be either several times smaller than or several times larger than the size of the dominant debris. This reduces the amount of debris that can become wedged or entangled within the screen holes. Screens with holes smaller than the dominant debris type trap the majority of the debris on the surface allowing it to be cleaned off. Selecting openings larger than the dominant debris size allows the majority of the debris to pass through without wedging in the screen openings.

Some types of debris like filamentous algae and other stringy aquatic plants can cause significant challenges to cleaning a screen with large holes. Stringy debris passing through a screen can wrap around the fabric material forming an entangled mat which is difficult to remove. For this type of debris, consider selecting a hole size small enough to hold the debris on the face of the screen.

Choosing a Screen Fabric

In addition to the considerations above, the choice of screen fabric also depends on the desired durability, cost, fabric structural strength and ease of cleaning. Woven wire is generally a low cost fabric placed on a screen frame with closely spaced structural supports to prevent tearing of the fabric under load. Woven wire fabric can be more difficult to clean than perforated plate and wedge-wire as the woven texture creates a rougher surface with square or rectangular openings that tend to catch debris in the corners. It is a good choice for small screens where debris loads are light to medium and replacement of the screen fabric can be easily accomplished.

Perforated plate is a widely used screen fabric with a smooth surface that is also relatively low cost. Perforated plate is available in several metals, plate thicknesses and synthetic materials. The most common perforated plate material used for fish screens is stainless steel. Perforated plate is generally considered a better fabric for fish screens than woven wire as it provides a smooth surface with round holes that are less likely to trap debris. Like woven wire, use of lightweight perforated plate or lower strength materials will require closely spaced screen frame supports designed to prevent bending of the fabric under load.

Wedge-wire screen is a specialized, highly durable screen fabric constructed using triangular shaped wire welded or mechanically attached at the point to backing supports running normal to the wire. The construction technique results in a screen fabric with parallel rows of wire with open slots between rows. The wire size and spacing are varied to provide fabrics with different porosity, slot width and fabric strength. Wedge-wire is ideal for fish screens due to its smooth upstream face and expanding orifice opening in profile. The inverted triangular shaped wire design (see figure 3) results in the smallest opening of the slots at the upstream surface which reduces debris wedging below the screen surface. Wedge-wire screen fabric is typically constructed of stainless steel, although other metals and synthetics are available. Wedge-wire is a widely used fish screen fabric on larger screens, but can also be applied to small screens. The fabric is generally more expensive, more durable and stronger, requiring less frame support than most other types of screen fabric.

Many molded or woven screen fabrics are available in synthetic materials, many of which are manufactured specifically for fish screening applications. These materials should be UV protected, have a low expansion/contraction ratio from exposure to changes in temperature and water, remain malleable in freezing temperatures (if applicable) and provide good abrasion resistance.

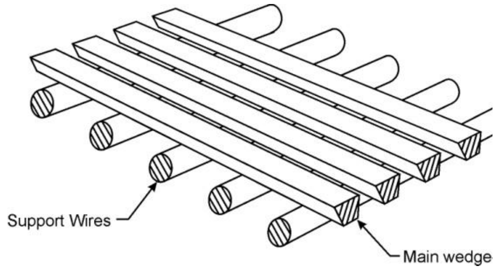


Figure 3 – An example of wedge-wire construction

Figure 4- An example of a slotted acrylic screen material manufactured for traveling screens. Source – Hydrolox Screens

Site Conditions that Affect Screen Type

Terms:

Screen Baffling: Additional porous structure placed downstream of and close to the screen to adjust flow uniformity through the fish screen. Often perforated plate or louver bars are used as baffling.

Prior to selecting a screen type and cleaning method, site conditions should be assessed. The following questions should be answered:

1. Is there electric power at the site?

   If power is not available at the site, passive screens should be considered along with moving screens and active cleaning methods that are used for remote sites. Many small screens can operate using alternate power sources, such as solar or wind- generated power with battery storage, and flow- driven paddle wheels or propellers mounted downstream of the screen.

2. What is the **headloss** (water surface or pressure drop) across the screen?

   The headloss, h_l *(ft)*, through a clean fish screen structure is a cumulative function of approach velocity, screen fabric, screen baffling and screen geometry. For small screens, headloss of the screen fabric can be estimated based on Va as ten times the approach velocity head or:

$h_l \approx 10V_a^{\,2}/64$ where, V_a (ft/s), is calculated by dividing the diverted flow (ft^3/s) by the submerged screen area (ft^2). For example, for Va=0.4 ft/s, the screen fabric headloss is about 0.3 inches. Actual screen headloss, accounting for screen geometry and partial loss of screen area due to debris plugging, can be 10 times or more the headloss calculated above, or for the example about 3 inches. This assumes little or no baffling is used for a small screen. Additional head may be required for screens requiring a high sweeping velocity or a flow-driven power source.

3. What is the typical depth of flow at the site?

    The minimum water depth at the site should submerge enough screen fabric to meet the approach velocity objective (see Screen Hydraulics section). Screening shallow flows requires a large screen surface area located close to the channel bottom. Screen types designed to operate in shallow flows include: horizontal bottom screens, ramp style bottom screens, inclined bank screens, cone screens and tubular screens (see screen catalogue). When flow depth allows a greater choice of screen types, screening cost is generally inversely related to flow depth.

4. What is the typical channel velocity at the site?

    Screen sites located in low gradient channels with slow moving flow (<~1 ft/s sweeping velocity) require screens with active cleaning or oversized screen areas. Sites with higher velocity flow allow for wider use of passive screens with V_S/V_a ratios exceeding 10.

5. Do site constraints strongly limit the allowable footprint for the screen installation?

    Site constraints (other structures, right-of-way, or topography) may limit the screen installation footprint either across or along the channel. Minimizing structure footprint is achieved by maximizing use of flow depth on the screen and using the maximum allowable approach velocity. A common example of this is the use of two screens, one on either side of the channel centerline with a common center bypass (see “vee” style flat plate screen in selection guide).

6. What are typical debris types and loads at the screening site?

    Effective debris management is crucial to a successful fish screening project. Knowing the types of debris and approximate load (amount) carried by the flow when choosing the site, screen type and cleaning method will help avoid debris related problems during operation.

7. What is the average ratio of screened flow to channel flow?

    A low-maintenance screening facility providing good fish protection is much easier to achieve when screened flow is significantly less than the channel flow. For screens located in-stream where flow conditions can be highly variable, maintenance and fish protection benefit when a minimum of 20 percent of the stream flow stays in-stream passing by the screen. For in-ditch screens, bypasses should be designed to carry a minimum of 10 percent of diverted flow. Where bypass flows must be reduced, lower screen approach velocity should be used as fish will take more time to find and enter the bypass.

Cleaning Methods

Terms:

Design Flow: The normal maximum flow used for sizing the screen.

Back flushing: Reversing the direction of flow through the screen or passing flow from the backside to the frontside of the screen

All fish screens require periodic maintenance to maintain a screen's ability to pass the design flow within headloss constraints. However, screening to exclude fish, debris and coarse bed sediments often reduces maintenance required in the downstream water delivery system. For many irrigators, screening means focusing normal delivery system maintenance (removing debris and coarse sediment) on the screen location.

Many cleaning methods are available. Most methods fall into one of the following three categories with combinations of cleaning methods also possible.

1. Back-flushing the screen to lift impinged debris off the surface using compressed air or pressurized water or rotating/pivoting the screen to back-wash the screen using screened flow.

2. Mechanical or hand brushing or raking the upstream face of the screen.

3. Creating a large sweeping velocity (V_s) to approach velocity (V_a) ratio such that debris is swept along the screen by the sweeping flow.

Back-flushing to remove debris is commonly used on small and large screens. Air-burst back flushing is based on the sudden expansion of compressed air behind the screen resulting in displaced water moving backwards through the screen. Air- bursts for small screens are generally sustained for a few seconds and timed to occur on a periodic schedule. If sweeping velocity surrounding the screen is low, longer bursts are necessary to allow material to move past the screen. Submerged spray jets or other methods of back flushing using pressurized water behind the screen exist, but are less commonly used on small screens due to pumping requirements and difficulties of achieving back flow over the entire screen surface. These methods keep debris in the channel, rather than allowing it into the diversion.

A different type of back-flushing allows debris to move with the diverted water. Screened water flowing through the screen a second time is the primary means of cleaning screens that rotate, such as drum screens and traveling belt screens. Flow initially passes in through the front screen face impinging debris on the screen (figure 5). As the debris-laden screen rotates, screened flow passes through the back side, pushing debris off the drum or belt on the backside. Although less commonly used, a flat plate screen angled across the flow either horizontally or vertically can be pivoted about its axis to alter the side of the screen flow enters, thus back-flushing the screen (figure 6). This method is not commonly used because it allows fish to escape past the screen during the pivoting action.

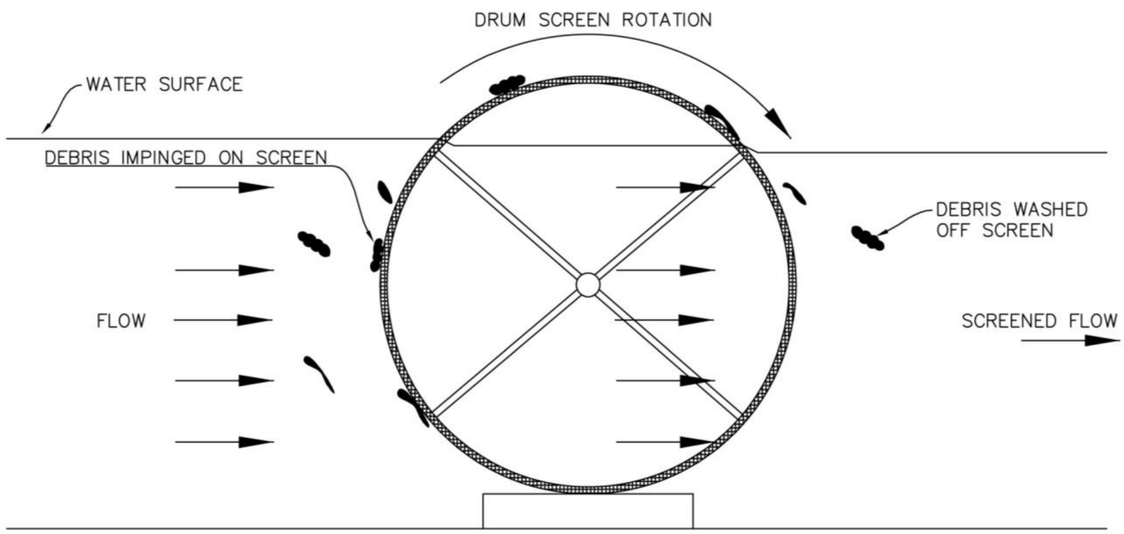


Figure 5 – Flow through a drum screen back-flushing debris carried over the screen off the downstream side.

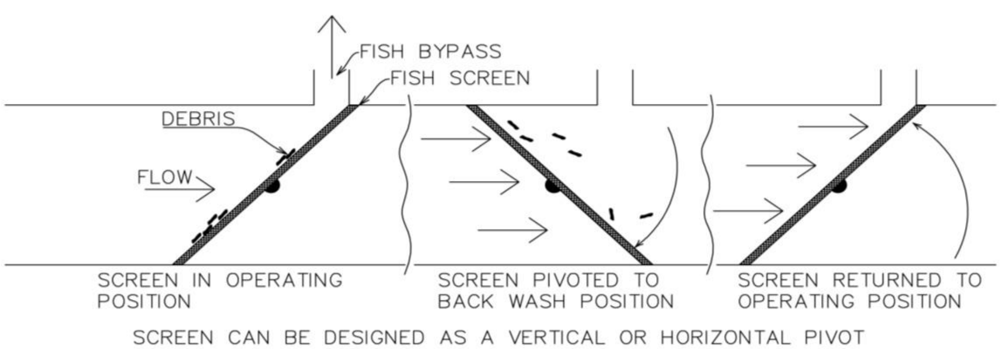


Figure 6 – Pivoting a vertical flat plate screen to back-flush debris off the screen.

Mechanically operated brushes are used on many larger vertical flat plate screens to remove impinged debris. Typically, a vertically mounted counter-weighted brush is moved horizontally along the upstream screen face to dislodge debris (figure7). Debris is then carried downstream by sweeping flow. Brushes can also be used on small vertical flat plate screens. Light duty cable drives can be used or, where screen length is less than about 3 ft, linear actuators are an option. Brushes or scraper bars can also used on the upstream side of rotating screens when it is desirable to dislodge debris from the upstream screen face, keeping the debris out of the screened flow channel (figure 8). Hand raking a screen is also an option for maintaining small flat plate screens at sites that are frequently inspected. This is only recommended if debris impingement is light or flow conditions permit a passive screen design with periodic hand raking as a backup. If frequent hand raking is likely, flat plate screens should be inclined at an angle from 20 to 45 degrees off vertical. This allows for better contact between a handheld rake/brush and the screen surface.

Passive fish screens are designed to operate without a mechanical cleaning mechanism. These screens use a combination of high sweeping velocity, low approach velocity and a fine meshed screen to minimize debris plugging. There are no definitive design guidelines for designing passive screens. General rules for passive screens are presented below, but they do not guarantee a self cleaning screen for all debris types. It is not uncommon for a well designed passive screen to operate for days or weeks without additional cleaning being required. However, most passive screens require periodic cleaning to remove debris that accumulates over time. Passive screens generally operate best when ample flow passes by the screen. As a general rule, flow passing by the screen should be greater than about 20 percent of the screened flow. Three basic approaches for designing passive screens are: drop through inclined ramps, high V_s/V_a ratio screens and ultra low V_a screens.

- Drop-through inclined ramps are bottom screens that accelerate flow over the screen using a sudden drop in channel elevation (figure 9). These screens rely on a high sweeping velocity down the face of the screen combined with small screen openings that minimize material catching on the screen fabric as it washes over the surface. These types of screens often require 1 ft or more drop in the water surface across the screen. Coanda screens are a special type of drop-through screen that use tilted wedge-wire fabric to increase the through-flow screen efficiency (15). Guidance and software for the design of Coanda and inclined ramp screens is presented in reference 15. As with all types of bottom screens, the screen should incorporate structural features that ensure sufficient flow depth always exists above the screen to pass fish downstream.

- High V_s/V_a ratio screens are designed to provide a sweeping velocity (Vs) greater than about 15 times the approach velocity (Va, see screen hydraulics section). A high Vs/Va screen requires aligning the screen at a shallow angle to the channel to produce a high Vs and sizing the screen area to achieve a Va < 1/15th that of Vs (see figure 1b). This method can be used to size passive screens for any orientation of a flat plate screen where a smooth transition from the channel boundary to the screen is provided. Bottom and bank-aligned screens are the most common as flow can be easily transitioned with minimal turbulence onto the screen. All bottom oriented screens should incorporate structural features that ensure bypass flow by preventing 100 percent of the flow from passing through the screen.

- Ultra low V_a screens are generally designed to operate with approach velocity less than 0.1 ft/s. In still water or under conditions of low sweeping velocity, a target approach velocity of 0.05 ft/s may be appropriate to minimize rapid debris plugging of the screen.

Many types of screens can be designed to operate as passive or quasi-passive screens. Quasi-passive means a screen is designed following passive screen guidelines and is also equipped with a mechanical cleaning device as a backup. An example is a passive design for a bottom screen that is equipped with an air-burst system to augment cleaning during periods of high sediment or debris loading.

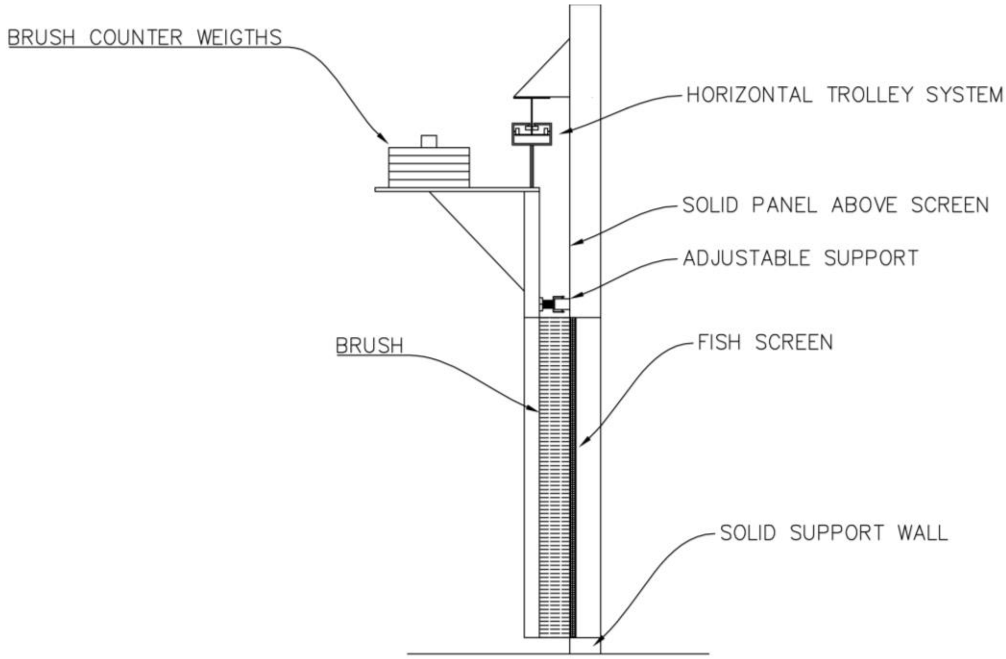


Figure 7 – Elevation view of typical flat plate screen brush cleaner. Brush moves horizontally along the screen.

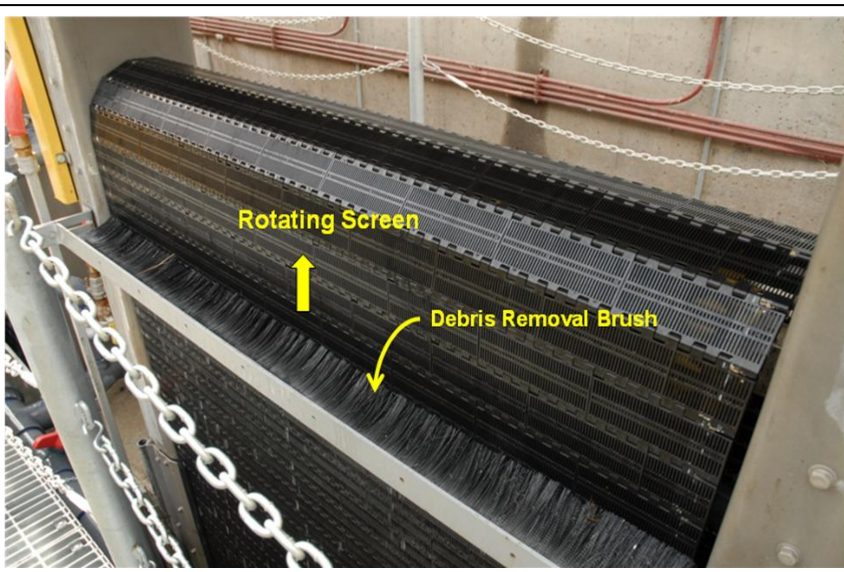


Figure 8 - Rotating traveling belt screen with brush cleaner. Source - Hydrolox Screens

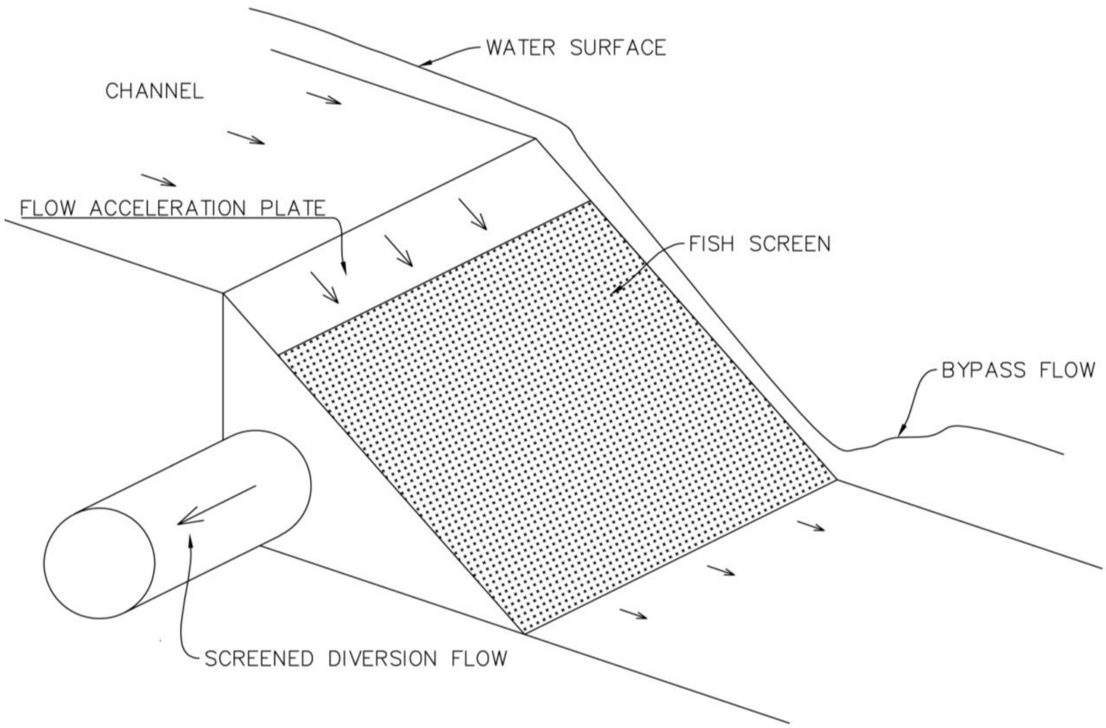


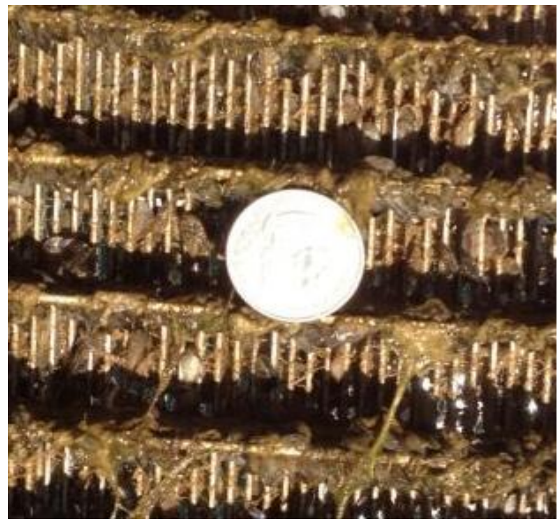
Figure 9 – Passive inclined-ramp drop-through style diversion screen. Bypass flow carries debris away from screen.

Screen Biofouling

Biofouling refers to aquatic organisms attaching to and growing on the screen fabric. Both plants and animals can impair screen flow by attaching to the upstream and downstream faces of the screen. The most common organisms that grow on screens in fresh water are algae, fresh water sponges and fresh water mussels. Of notable concern for screens are Zebra and Quagga mussels. These mollusks are exotic species that were first found in the great lakes in the 1980's and have spread through much of the eastern U.S and to several western states. They are filter feeders that, in the right water quality, can grow and multiply rapidly. Screens designed to protect fish can provide an ideal substrate for mussels to attach on. Figure 10 shows a three month growth of Quagga mussels and algae on a sample of wedge-wire screen suspended in Lake Mead on the Colorado River. The screen was not cleaned during the three month period. Once attached to the screen, mussels can be difficult to remove and often require high velocity jetting or scraping to remove them.

Waters where biofouling may be a significant problem require special attention to the cleaning method and screen material, and may require using an anti-biofouling coating that has been shown to limit growth of the target organisms. A screen equipped with an aggressive cleaning system that cleans both internal and external faces of the screen fabric is recommended. Examples are cylinder screens or traveling belt screens equipped with internal and external cleaning systems. For small screens it may also be practical to remove and replace screen panels every couple of weeks, allowing a removed panel to totally dry prior to cleaning and being reinstalled. Screens constructed from a copper -nickel alloy with >90 percent copper will generally prevent biofouling; however in some instances, mussels have been found to attach to copper- nickel. This material is expensive and a sample should be tested on site for several months prior to using it. Many companies are also marketing anti-biofouling and mussel resistant coatings. Coatings applied to fish screens must be durable and should not significantly change the screen porosity and hole size. These materials should also be tested on site if possible.

Figure 10 - View of Quagga mussels and algae on the front face of wedge-wire screen after 3 months without cleaning.



View of the back face of the screen

Starting a Screening Project

Contact agencies and organizations that may have oversight authority and be able to offer assistance with screen planning, design, installation and maintenance:

1. State fisheries agencies can verify if there are listed or threatened fish or other aquatic species in the water body you divert from that dictate specific screening criteria that must be followed.

2. Your local Natural Resources Conservation Service (NRCS) office can tell you if screening your diversion qualifies for federal government cost sharing, and/or engineering design assistance.

3. The State Engineers' Office or State Water Rights Office provides information about regulations covering bypass flows for in-ditch screens(see section *Screen Location*).

Enlist help for screen design from local agencies or organizations interested in protecting our fisheries resource. Successful installations generally are the result of cooperative effort. Try to put together a group including a design engineer, fish biologist and, if the diversion is on public land, a knowledgeable representative of the management agency.

Basic Steps for Selecting a Small Screen

Working with the other interested parties:

1. Determine your fish protection objectives (fish species, size and swimming strength).
2. Determine major debris types, when they occur and approximate debris loads (amounts).
3. Determine the maximum amount of flow to be screened.
4. Investigate potential screening sites. Evaluate both in-stream/lake and in-ditch options, taking into consideration the pros and cons listed in the Screen Location section. For all potential sites determine flow characteristics in channel and ditch under maximum diversion for low and high stream flow conditions during the diversion period. For each potential site, fill out Table 1.
5. Determine if the diversion has sufficient head during low stream flow periods to make water deliveries with the addition of a fish screen. As a general rule for small screens in open channels, a minimum of 0.3 to 0.5 ft of drop in water surface across the screen structure should be assumed unless specific test data are available. If there is any question on available head at the site the operator of the diversion should be consulted about known water delivery issues with insufficient head and a visual inspection of the ditch looking for banklines indicating freeboard upstream and downstream of the screen site should be conducted. When possible, the diversion should be observed during operation prior to selecting or designing a screen.

Carefully consider the type and size of the screen facility to reduce installation and maintenance costs for meeting your fish protection goals. The screen descriptions presented in the next section of this guide will help you evaluate the best type of screen for your application. However, there is no substitute for an experienced screen design engineer who can help select the type of screen and can optimize the design to fit the site conditions as well as the desired ease of maintenance.

Table 1. Site flow characteristics during diversion period

	High channel flow (___ft^3/s)	**Low channel flow** (___ ft^3/s)
Max diversion flow, ft^3/s		
Velocity in channel, ft/s		
Depth in channel, ft		
Velocity in ditch, ft/s		
Depth in ditch, ft		
Debris and sediment (major type, ~load)		

Fish Screen Catalogue

The following pages provide information specific to screen types that are commonly used for small fish screening applications and that are commercially available or can be built by a local metal fabricator. Not all manufacturers of small fish screens are listed: most types of fish screens are available from a variety of manufacturers, many of which are not listed. Most screen fabrics can be purchased from screen fabric manufacturers directly for custom screen fabrication. Commercial screens discussed or shown are not endorsed by the government.

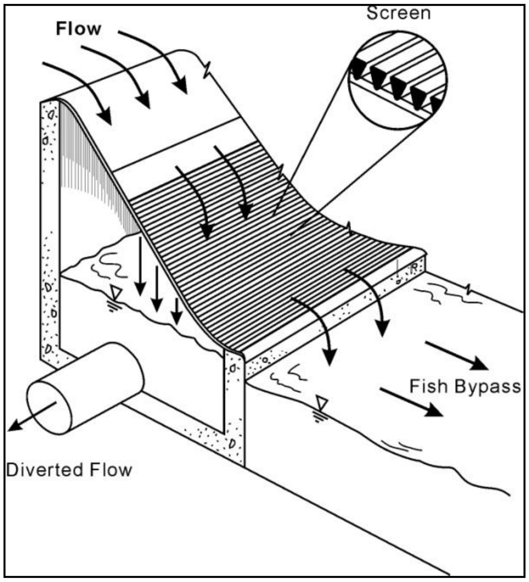
The catalogue demonstrates the wide variety of fish screening techniques and methods available. It's goal is to educate water diverters and others interested in protecting aquatic organisms in America's rivers, streams and lakes. We encourage you to evaluate all types of fish screening options during the selection process. Screens are presented in the catalogue by cleaning category. General screen cleaning categories presented are:

Passive screens
Rotating screens
Mechanically-cleaned screens

Some screen types may be suited to more than one cleaning type. The screens are presented in the most common forms.

Passive Screens

Coanda Screen

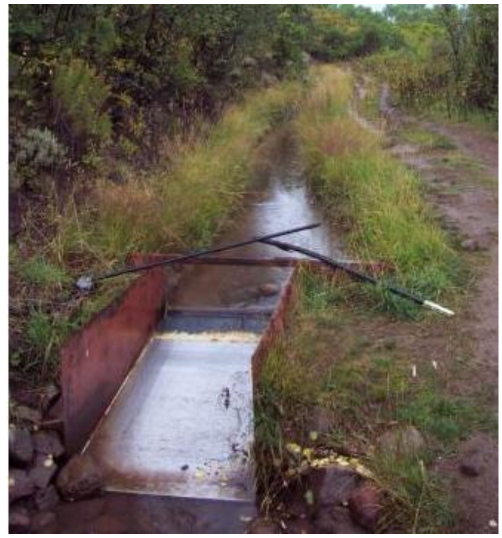


Coanda Screen

Source: USBR

Standard Application	Flow diversion at an elevation drop.
Strong Points	High flow capacity screen. Can be designed using USBR Coanda screen design program.
Issues	Difficult to adjust bypass flow. Possible dewatering of the screen toe and loss of bypass flow during low flows. Generally not NOAA approach velocity compliant.
Standard Mounting	Inline with the channel
Cleaning	Passive
Screen Material	Tilted wedge-wire
Flow Capacity	~ $1 ft^3/s/ft^2$
Power Requirements	None
Water Surface Drop across the Screen (Head Requirements)	>~1 ft
Fish Bypass	Fish and debris are transported by non-diverted flow passing over screen surface.
Commercially Available	Yes
Search Key Words	Coanda screen, Hendrick Screens, Johnson Screens, Norris Screens

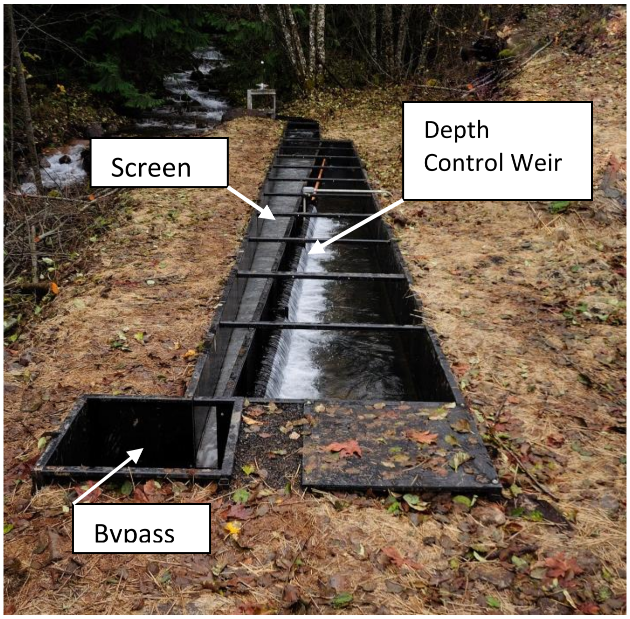
Flat Plate Down Ramp

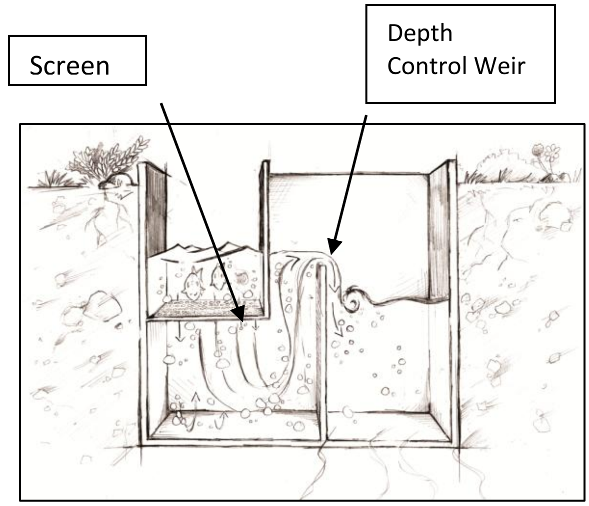


Source: USBR

Standard Application	Flow diversion at an elevation drop.
Strong Points	Passive screen with high diversion capacity. Can be designed using USBR Coanda screen design program. Simpler to construct than a curved Coanda screen.
Issues	Difficult to control bypass flow. Possible dewatering of the screen toe and loss of bypass flow during low flows. Generally not approach velocity NOAA compliant.
Standard Mounting	In line with stream or ditch
Cleaning	Passive
Screen Material	Tilted wire wedge-wire, flat wedge wire or perforated plate
Flow Capacity	Generally < $1 ft^3/s/ft^2$. Best when constructed using tilted wedge wire screen and an upstream acceleration ramp (see figure 9) as specified by the USBR Coanda design guidance program, reference 15.
Power Requirements	None
Water Surface Drop across the Screen (Head Requirements)	Generally >1 ft
Fish Bypass	Fish and debris are transported by additional flow passing over screen.
Commercially Available	Yes
Search Key Words	Corrugated Water Screens, Watson Irrigation

Horizontal Flat Plate – Bottom Screen





Source: Farmers Conservation Alliance (FCA)

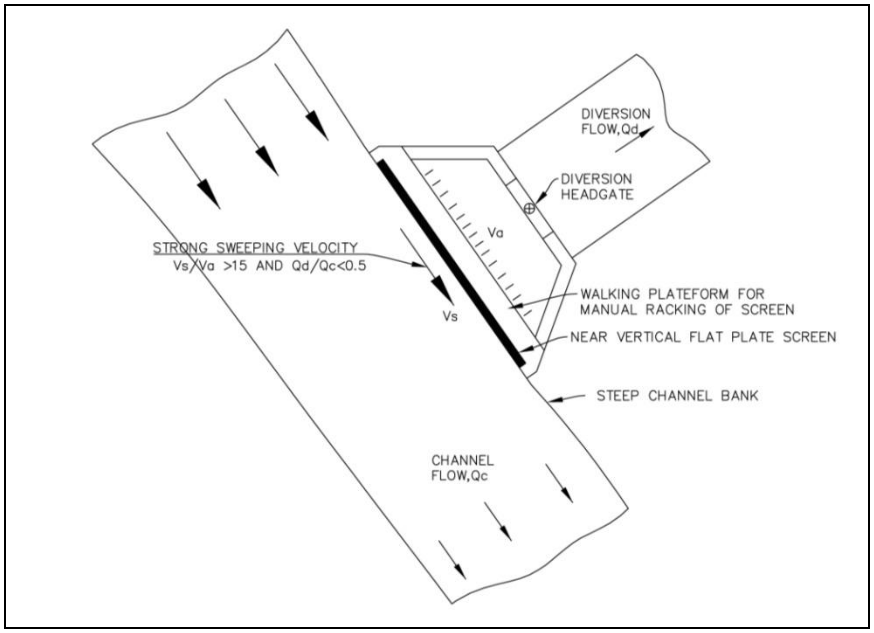
Standard Application	Passive screen designed for shallow water diversion. Flow passes through a horizontal bottom screen.
Strong Points	Generally low maintenance. Good for shallow flow. Smaller screens can be installed with limited construction.
Issues	Exposes bottom oriented fish to full screen length. In locations where the channel moves significant amounts of sand along the bed the screen can plug with bed sediments that move along the screen.
Standard Mounting	Horizontal in channel
Cleaning	Passive
Screen Material	Wedge-wire or perforated plate
Flow Capacity	1 to >25 ft^3/s
Power Requirements	None
Water Surface Drop across the Screen (Head Requirements) (Typical)	~ 0.5 ft
Fish Bypass	Fish and debris are transported by bypass flow passing over screen. A method to prevent unwatering of the screen is needed to ensure sufficient depth of bypass flow for fish.
Commercially Available	Yes
Search Key Words	Horizontal screens, FCA screens

Passive Tube Screen

Source: Pump-Rite Screens

Standard Application	Small pump diversions. Well suited for shallow water where tube is fully submerged.
Strong Points	Drop-in passive screen designed for very low approach velocity.
Issues	Screen can plug in water containing high amounts of algae or suspended detritus. Performance can be affected by sediment or biofouling. May require periodic manual cleaning if plugging is a problem.
Standard Mounting	Generally lay directly on channel bed. Can be suspended in water column.
Cleaning	Manual
Screen Material	Stainless steel smooth punch plate, 0.075" hole size
Flow Capacity	Small, generally 0.033 to 3.0 ft^3/s
Power Requirements	None
Water Surface Drop across the Screen (Head Requirements)	Low
Fish Bypass	Not required
Commercially Available	Yes
Search Key Words	Passive pump screen, Pump-Rite screens

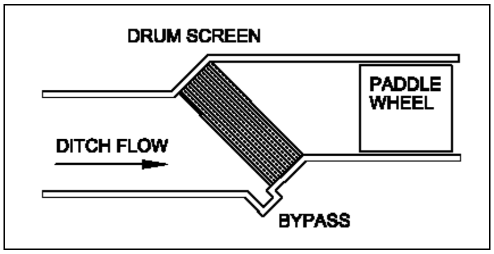
Fixed Flat Plate Bank or Wall Screens



Standard Application	In-stream screen used for gravity diversion or pump sump
Strong Points	Good cleaning characteristics when located on a straight bankline mounted flush with the bank.
Issues	Generally designed as a high Vs/Va screen. Site requires strong sweeping flow adjacent to bankline. Cleaning effectiveness can be impacted by changes in stream conditions that effect sweeping flow alignment .. A mechanical cleaner is recommended if diversion flow is > 0.5 times the upstream channel flow.
Standard Mounting	Best on straight stream reaches. Screen mounted parallel to stream flow, generally flush with stream bank.
Cleaning	Passive, requires Vs/Va ratios > ~15 with occasional manual cleaning (see similar screens in air- and water-burst cleaning section
Screen Material	Wedge-wire, perforated plate
Flow Capacity	0 to >25 ft^3/s
Power Requirements	None
Water Surface Drop across the Screen (Head Requirements	~>0.3ft across screen structure
Fish Bypass	None
Commercially Available	Screen fabric only
Search Key Words	Wedge-wire screen, Hendrick Screens, Johnson Screens, Norris Screens, Corrugated Water Screens

Rotating Screens

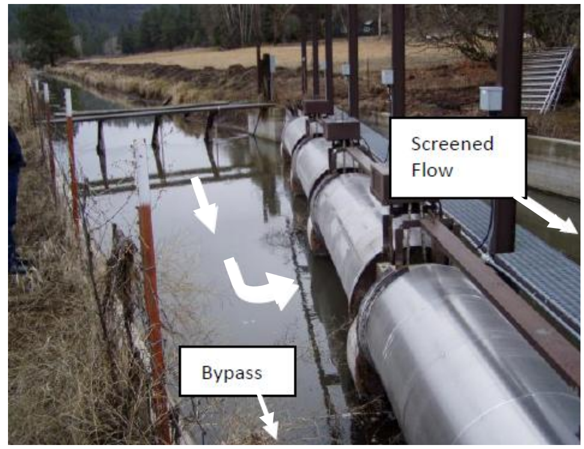
Paddle Wheel Driven Drum Screen



Screen drum shown in raised position Source: USBR

Standard Application	Gravity flow within a diversion ditch or canal.
Strong Points	Continuously rotating drum provides active cleaning of aquatic plants and small woody debris.
Issues	Water level on drum must be between 0.65 and 0.85 of the drum diameter to provide effective cleaning. Requires paddle wheel connected to a geared drive unit located in diversion channel downstream of screen.
Standard Mounting	Screens are normally mounted in canal at an angle to the canal flow to guide fish to the bypass. Angles between 15 deg and 45 degrees to the flow are recommended.
Cleaning	The drum continuously rotates. When the flow depth is within design limits, most debris is carried over the screen and washed off the downstream side by diversion flow passing through the screen. Information on paddlewheel can be found in reference 3.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	Can be designed for small to large flow. Paddlewheel units are generally less than about 15 ft^3 /s. NOAA compliant screens require screen surface area be calculated as the vertical projected screen area equal to the flow depth times the screen length.
Power Requirements	Rotating the drum requires mechanical paddle wheel drive unit. Information on paddlewheels can be found in reference 3.
Water Surface Drop across the Screen (Head Requirements	0.3 ft to >0.5 ft depending on structure design and drive unit
Fish Bypass	Pipe or open channel
Commercially Available	Screen drum is available, no known commercial manufacturers of complete unit. Most are built by state screen shops in Idaho and Washington.

Motor Driven Drum Screen



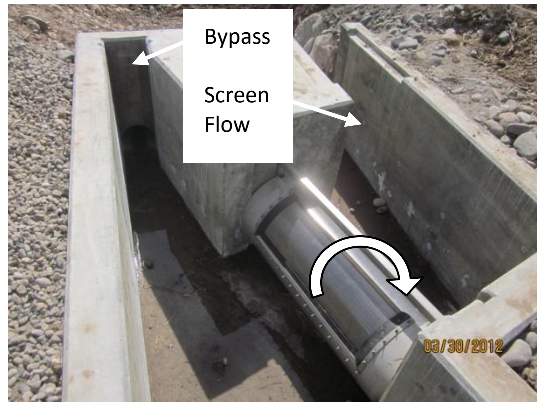
Drums shown in raised position Source: USBR

Standard Application	Gravity flow within a diversion ditch or canal with debris passed downstream with diverted flow.
Strong Points	Continuously rotating drum provides active cleaning of aquatic and small woody debris. (see figure 5)
Issues	Water level on drum must be between 0.65 and 0.85 of the drum diameter to provide effective cleaning.
Standard Mounting	Screens are normally mounted in canal at an angle to the canal flow to guide fish to the bypass. Angles between 15 deg and 45 degee to the flow are recommended.
Cleaning	The drum continuously rotates. When the flow depth is within design limits, most debris is carried over the screen and washed off the downstream side by diversion flow passing through the screen.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	Can be designed for small to large flow (>25 ft^3/s) with multiple drums. Screen surface area normally calculated as the vertical projected screen area equal to the flow depth times the screen length. Flow capacity is the submerged screen area times the flow approach velocity.
Power Requirements	Rotating the drum requires electric drive. Solar power may be an option on small units.
Water Surface Drop across the Screen (Head Requirements	0.3 ft to 0.75 ft depending on structure design and drive unit
Fish Bypass	Pipe or open channel required for in-canal applications.
Commercially Available	Screen drum is available. No known manufacturers of complete unit.
Search Key Words	Drum screens, Hendrick screens, Johnson screens, Norris screens

Turbine Drum Screen with Internal Water Wheel

Screen set normal to channel with pipe bypass (not visible).

Source: Wyoming Game and Fish

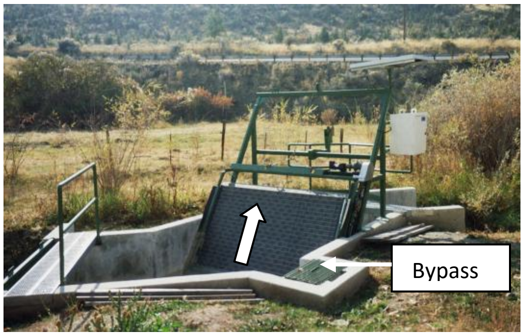


Screen set at an angle to flow.

Source: Wyoming Game and Fish

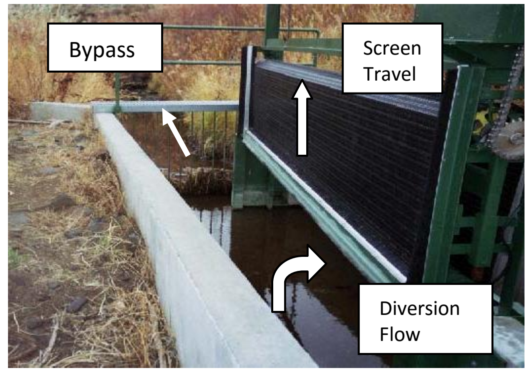
Standard Application	Small diversions, often used where entrainment of adult fish is the primary objective due to high Va.
Strong Points	Drop in rotating drum requiring no external mechanical drive.
Issues	Partial blockage of the screen drum is required to pass flow through the internal paddle wheel. This can yield areas of high approach velocity to the screen. Can be difficult to meet NOAA criteria. Screens are commonly set normal to the flow for operation of the internal paddle wheel which can cause poor attraction to the fish bypass.
Standard Mounting	Drop in unit set in vertical guides (slots)
Cleaning	Backwashed by flow through the screen as screen rotates.
Screen Material	Perforated plate
Flow Capacity	0.5 to ~15 ft^3/s
Power Requirements	None
Water Surface Drop across the Screen (Head Requirements	Varies with design, can be>0.5 times the height of the drum
Fish Bypass	Pipe or open channel required for in-canal applications.
Commercially Available	Yes
Search Key Words	Water driven drum screen, AquaScreen Enterprises, BWM Inc.

Vertical or Inclined Traveling Belt Screen



Inclined traveling screen.

Source: Hydrolox screens



Vertical traveling screen in raised position.

Standard Application	Excellent for deeper water sites requiring a screen that can operate under a wide range of flow and debris conditions.
Strong Points	A proven technology with good cleaning characteristics providing high reliability for diversion of flow. Can work well in sediment laden flows.
Issues	Numerous moving parts with seasonal adjustment of traveling belt and drives required.
Standard Mounting	Vertical or inclined up to about 30 degrees depending on screen.
Cleaning	Traveling belt is cleaned by flow back washing, stationary brush, scraper or spray wash system.
Screen Material	Wire fabric or articulated slotted panels
Power Required	Yes, solar can be used for small screens
Water Surface Drop across the Screen (Head Requirements	~0.2 ft to 0.5 ft depending on screen porosity and internal support bracing
Fish Bypass	Can be used in-river or in-ditch with bypass
Commercially Available	Yes
Search Key Words	Belt screen, Hydrolox Screens, Siemens, FPI Screens, International Water Screens

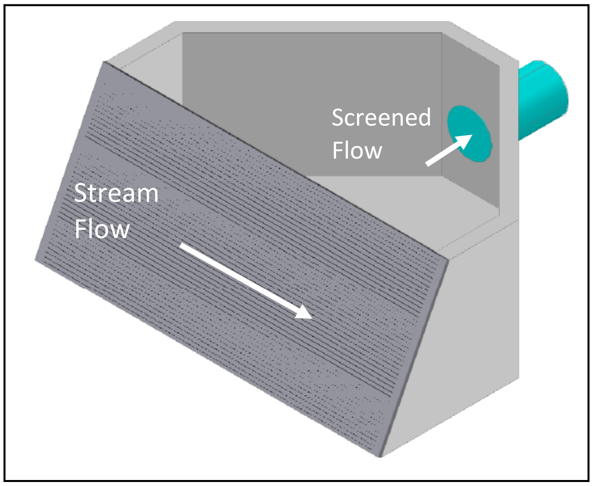
Horizontal Traveling Belt Screen

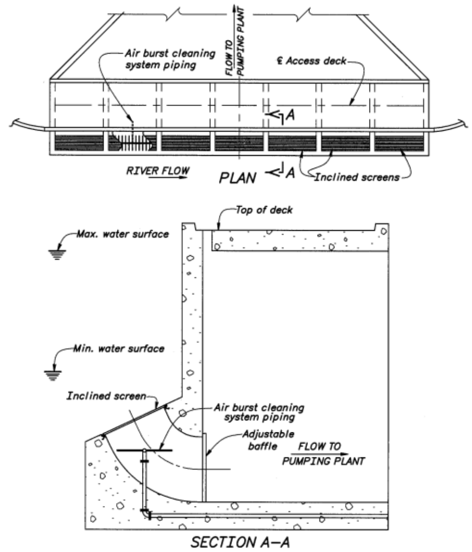
Source: Wyoming Game and Fish

Standard Application	In-stream or in-ditch bank mounted applications.
Strong Points	Belt movement assists in moving debris downstream with bypass flow. Operates well over a wide range of sweeping velocity.
Issues	Relatively new design with short history of operation.
Standard Mounting	Stand alone screen set in vertical guides.
Cleaning	Horizontally rotating screen with scraper bar.
Screen Material	Articulated slotted panels
Power Requirements	Yes, may be run off solar power
Water Surface Drop across the Screen (Head Requirements	~0.2 ft to 0.5 ft
Fish Bypass Structure	Not required for in-stream installations
Commercially Available	Yes
Search Key Words	Horizontal belt screen, Hydrolox Screens

Mechanically Cleaned Screens – Air Burst Cleaning

Submerged Inclined Screen

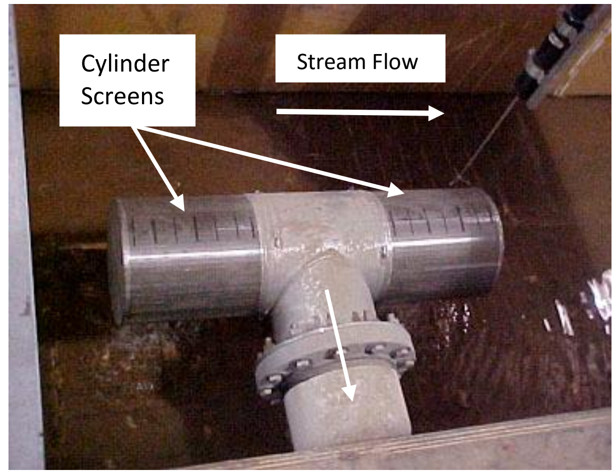




Source: USBR

Standard Application	In- river screen mounted in stream bank with screen parallel to the flow.
Strong Points	Can draw from the middle of the water column avoiding bed sediments and floating debris. Sloped screen increases submerged screen area in shallow flow.
Issues	May be difficult to inspect or access screen.
Standard Mounting	Bank aligned vault.
Cleaning	Air burst or manual cleaning when combined with strong sweeping flow.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	<1 to >25 ft^3/s
Power Requirements	Power required for compressed air cleaning system.
Water Surface Drop across the Screen (Head Requirement)	~0.3 ft to 0.5 ft depending on channel alignment
Fish Bypass	Not required for in-stream installations
Commercially Available	Screen panels only
Search Key Words	Wedge-wire screen, perforated plate, woven wire fish screen, Corrugated Water Screens

Stationary Cylindrical Tee Screen with Internal Air Burst System or Water Spray Jets

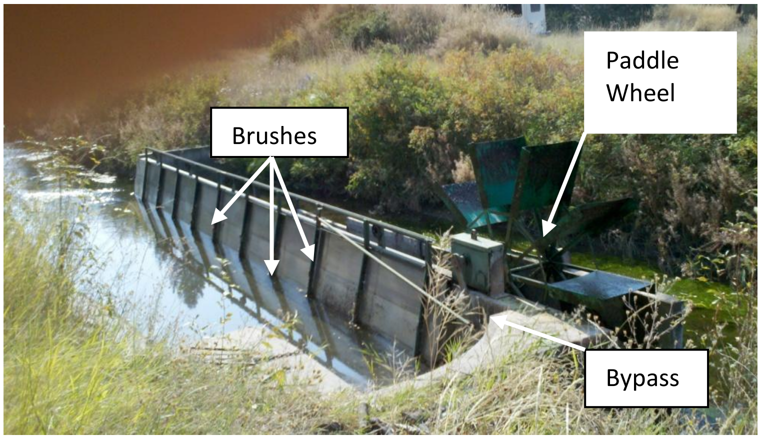


Source: USBR

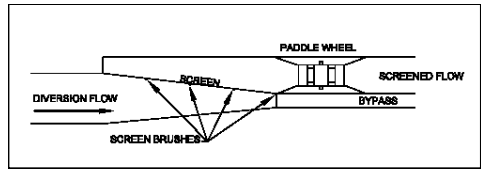
Standard Application	Pump or gravity flow through headwall. Can be used in still water or water flowing at less than 5 ft/s. Water should submerge the screen by a minimum of ½ the screen diameter.
Strong Points	Cylinder shape provides large surface area per unit length with small footprint. No moving parts in water.
Issues	Should be placed parallel to channel flow to achieve best through screen uniformity. Screens set in-river are subject to impact and snagging of large debris. Requires large volume of compressed air to achieve good cleaning of the entire screen. Generally an internal ported sleeve extending the length of the cylinder is required to distribute flow along the length of the cylinder. The diameter of the ports in the sleeve varies to achieve a nearly uniform flow through the outer screen.
Standard Mounting	Screens are normally mounted parallel to a river bank or in front of a headwall. Screens can be mounted as a single unit or end-to-end as a tee unit with an exit pipe located between units (screen shown above).
Cleaning	Internal air burst systems or rotating water spray jets. Air burst systems intended for use on pump inlet screens should be designed to avoid entrainment of large amounts of air into the pump during screen cleaning.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	0.5 to >25 ft^3/s, Flow capacity based on cylindrical screen area times the design flow approach velocity.
Power Requirements	Cleaning systems generally require electricity.
Water Surface Drop across the Screen (Head Requirement)	~0.3 ft to 0.6 ft depending on internal baffle design and channel velocity
Fish Bypass	Not required for in-stream installations
Commercially Available	Yes
Search Key Words	Cylindrical screens, Hendrick Screens, Johnson Screens, Intake Screens Inc.

Mechanically Cleaned Screens – Brush Cleaning

Vertical Flat Plate Screen with Paddlewheel Driven Brushes

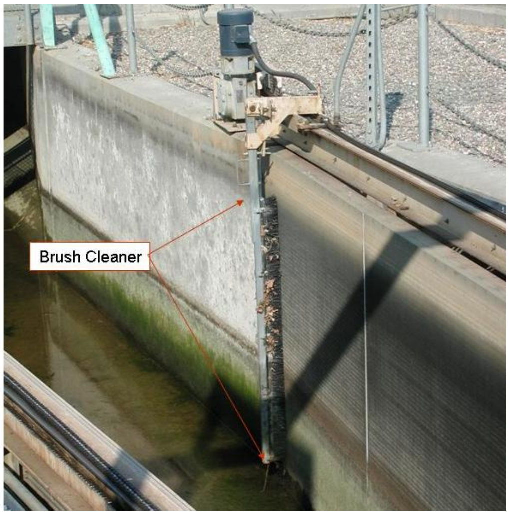


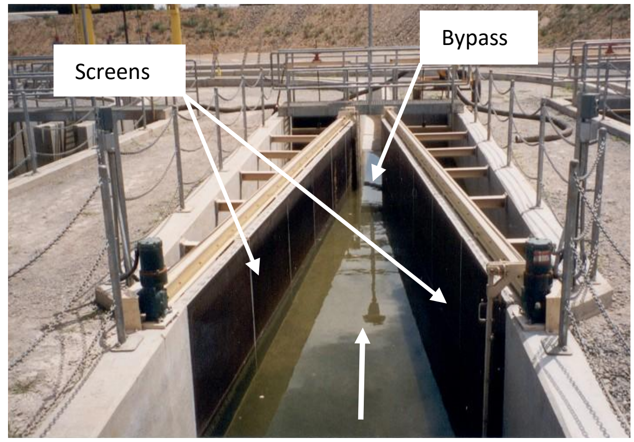
Flathead Indian Irrigation Project



Standard Application	In-ditch or in-stream screen used for gravity diversion
Strong Points	Simple design with flow driven brush cleaner.
Issues	Continuously moving brushes and drive linkage can increase maintenance. Paddlewheel requires a minimum diversion flow to operate cleaner.
Standard Mounting	Screens are normally mounted at an angle of between 15 and 45 degrees to the channel flow..
Screen Baffling	Baffles are typically not used on short screens. For long screens (~>10 ft) slots should be provided as a part of the screen support structure a few inches behind the screens to receive baffle panels if approach flow uniformity is found to be poor during operation.
Cleaning	A mechanical connection that converts the paddlewheel rotation into a linear motion for the brush(es) is required. Multiple brushes connected to a single rotating gear drive are shown. Multiple brushes connected to a single drive allow the entire screen to be cleaned using a linear stroke less than the full screen length.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	~10 to >25 ft^3/s (Not generally used on small capacity screens due to complexity of cleaning mechanism)
Power Requirements	None (paddle wheel)
Water Surface Drop across the Screen (Head Requirement)	~0.2 ft to 0.6 ft depending on baffling and channel velocity
Fish Bypass	Bypass placed at downstream end of screen.
Commercially Available	Screen panels only
Search Key Words	Wedgewire screen, perforated plate, woven wire screen

"Vee" Style Vertical Flat Plate Screen with Brushes





Source: USBR

Standard Application	Generally used for screening larger flows due to more complex geometry or used where it is desirable to shorten the overall length of the screen structure.
Strong Points	Flow through both sides of vee provides a large flow area per length of structure. Vee shape guides fish and debris to center bypass.
Issues	Bypass flow with fish and debris must be passed under or through screened flow in a pipe. Requires a minimum of two screen cleaners, one per side. Larger screens generally require screen baffles behind the screen on the downstream 1/3 to achieve good distribution of flow through the screen.
Standard Mounting	Screens are normally mounted at an angle of between 15 and 45 degrees to the channel wall.
Baffling	Vertical slots are recommended a few inches behind the screen face to receive perforated plate baffle panels.
Cleaning	Larger screens typically use wiper brushes mounted on trolleys that sweep along the screen. Small screens can use bottom mounted air burst systems or spray jet systems.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	No limit, typically >10 ft^3/s
Power Requirements	Cleaning systems generally require electricity.
Water Surface Drop across the Screen (Head Requirement)	~0.2 ft to 0.6 ft depending on baffling and channel velocity
Fish Bypass	Debris and fish pass through the downstream center opening between screens.
Commercially Available	Screen panels only
Search Key Words	Screen panels, Hendrick Screens, Johnson Screens, Norris screens

Cone Screen with External Brushes

Source: ISI screens

Source: ISI screens

Standard Application	Pump or gravity flow through headwall. Placed in slow moving flow with channel velocity < 0.5 ft/s.
Strong Points	Good for shallow flows because the conical shape provides a large screen area for small water depths. Designed for low channel velocity areas such as backwater or impoundments.
Issues	Uniform distribution of flow through the screen decreases with increasing channel velocity.
Standard Mounting	Screens are normally mounted on or near the channel bottom. The exit pipe passes out the base of the cone screen and is elbowed to a pump or passed through a headwall.
Baffling	An internal ported riser on the discharge line can be used to improve uniformity of screen approach flow in larger screens.
Cleaning	Screens with external wiper brushes, internal air burst systems or spray jet systems are recommended.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	Typically >5 ft^3/s for commercially available screens
Power Requirements	Cleaning systems generally require electricity. Some manufacturers offer propeller drives located in the discharge pipe to operate wiper brush cleaning systems without electricity.
Head Requirements	~0.1 ft to 0.3 ft for baffled screens
Fish Bypass	Not required
Commercially Available	Yes
Search Key Words	Cone screens, Intake Screens Inc., Hendrick Screens

Cylindrical Screen with Brush Cleaning System

Screen with propeller drive for rotating the screen cylinder past brush during cleaning.

Source: ISI Screens

Standard Application	Generally used in-stream/lake on a pump or gravity flow system. Can be used in still water or water flowing at less than ~5 ft/s. Water should submerge the screen by a minimum of ½ the screen diameter.
Strong Points	Cylinder shape provides large surface area per unit length with small footprint. Internal and external brushes provide good cleaning of the screen fabric.
Issues	Should be placed parallel to channel flow to achieve best through-screen uniformity. Screens protruding into flow are subject to impact and snagging of large debris.
Standard Mounting	Screens are normally mounted parallel to a river bank or in front of a headwall. Screens can be mounted as a single unit or end-to-end as a tee unit with an exit pipe located between units.
Baffling	Generally an internal ported discharge sleeve extends the length of the cylinder to improve uniformity of flow withdrawal along the cylinder screen. The diameter of the ports in the sleeve varies to achieve a nearly uniform flow through the outer screen.
Cleaning	Moving screens with stationary internal and external wiper brushes or stationary screens with moving brushes.
Screen Material	Wedge-wire, perforated plate or woven wire
Flow Capacity	5 to >25 ft^3/s
Power Requirements	Cleaning systems generally require electricity. Some manufacturers offer propeller drives located in the discharge pipe to operate wiper brush cleaning systems without electricity (see photos above).

Head Requirements	~0.2 ft to 0.6 ft depending on baffle design and channel velocity
Fish Bypass	Not required
Commercially Available	Yes
Search Key Words	Cylinder screens, Intake Screens Inc.

Glossary and Units

Definitions commonly used when referring to the legal requirements, design and operation of screening installations is given below.

Active Screens –Fish screens equipped with a cleaning system

Approach Velocity, Va – The flow velocity measured perpendicular to the screen face typically at a distance of 3 inches in front of the screen face, V_a.

Anadromous Fish – Fish that live in saltwater and migrate into freshwater streams and lakes to spawn.

Behavioral Devices – Non-physical barriers that rely on a behavioral avoidance response to discourage fish from approaching and passing into a diversion

Bypass for Fish Screen – A channel or pipe used to return fish from an in-ditch screen to a natural channel or lake.

Bypass Flow , Q_b – The diverted flow required to effectively attract fish into the bypass entrance(s) and convey fish to the bypass outfall location or other destination.

Baffling – Additional structure placed downstream of (and immediately next to) the screen to improve flow uniformity through the screen. Often perforated plate or louver bars are used as baffling for flat plate screens and pipe containing multiple orifices for cylindercal screens.

Channel Flow – Water flow in stream or ditch upstream of a screen

Channel Velocity, V_c – Flow velocity measured within the channel upstream of a fish screen structure.

Darting/Burst Speed – A rapid swimming speed that fish can achieve in a single effort for a short duration.

Endangered Fish Species – Species determined by U.S. Fish and Wildlife Service or NOAA Fisheries, under the Endangered Species Act, to be in imminent danger of extinction throughout all or a significant portion of their range are listed as "endangered."

Entrainment – The unwanted passage of fish through a water diversion.

Fingerling – Fish greater than 60 mm in length (approximately size of a human finger).

Fry – Fish generally between 25 and 60 mm in length.

Head Differential – The water pressure or water level difference across the surface of a screen.

Impingement – The occurrence of physical contact with a screen surface due to flow which the organism is not able to avoid.

Larval Stage – Fish less than 25 mm in length.

Listed Fish Species – The authority to list species as threatened or endangered is shared by NOAA Fisheries, which is responsible for listing most marine species, and FWS which administers the listing of all other plants and animals. There are two classifications under which a species may be listed: "threatened" or "endangered."

Native Fish Species – Any species that naturally occurred within a given body of water, as opposed to an introduced species.

Passive Screens – Fish screens with no automated cleaning system.

Predation – Occurs when fish are preyed upon by aquatic, terrestrial or avian animals.

Screen Headloss – The energy loss incurred by flow through a screen structure expressed as a drop in water surface for free surface flow or drop in pressure in closed conduits.

Screen Porosity – The ratio of open area to total area of the screen.

Sustained Swimming Speed – A fish swimming speed that fish can maintain for long periods.

Sweeping Velocity, Vs – The average flow velocity parallel to and adjacent to the screen face, V_s.

Slot Velocity, V_t – (**Also called orifice velocity**) The flow velocity passing through the screen slot openings (slot velocity is greater than screen approach velocity).

Threatened Fish Species – Species determined likely to become endangered in the foreseeable future are listed as "threatened."

Units

Units are presented in English with common alternatives listed below.

Flow – cubic feet per second (ft^3/s or cfs)	
gallons per minute (gpm)	449 gpm = 1 ft^3/s
liters per second (l/s)	28.3 l/s = 1 ft^3/s
Velocity - feet per second (ft/s)	
meters per second (m/s)	0.3048 m/s=1 ft/s

References

1. Amaral, S. and Taft, N., The use of Angled Bar Racks and Louvers for Protecting Fish at Water Intakes – A Symposium on Cooling Water Intake Technologies to Protect Aquatic Organisms, Electric Power Research Institute. Web site: http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/upload/2008_06_10_316b_meetings_symposium_amaral.pdf
2. Bell, M.,1991. Fisheries Handbook of Engineering Requirements and Biological Criteria, U.S. Army Corps of Engineers North Pacific Division.
3.
4. Best, E.L., J.D. Sechrist, and S.D. Hiebert. 2004. Fish entrainment investigations at the Huntley Diversion Dam, Yellowstone River, Montana. US Bureau of Reclamation, Denver, CO.

5. Bonneville Power Administration Fish and Wildlife Program, Fish Screen Paddlewheel Design Report, Upper Salmon River Anadromous Fish Passage Project, U.S. Department of Energy, Project Number: 1994-015-00, May 2006.
6. Hanson, C.H. 2001. Are juvenile Chinook salmon entrained at unscreened diversions in direct proportion to the volume of water diverted? Pp. 331-341 *in* R.L. Brown ed., Contributions to biology of Central Valley salmonids, Volume 2. California Department of Fish and Game Bulletin 179.
7. Hiebert, S., R. Wydowski, and T. Parks. 2000. Fish entrainment at the Lower Yellowstone Diversion Dam, Intake Canal, Montana 1996-1998. USDI Bureau of Reclamation, Denver, CO.
8. Katopodis, C. and Gervais, R. 2011. Ecohydraulic Analysis of Fish Fatigue Data, wileyonlinelibrary.com DOI: 10.1002/rra.1566
9. Mogen, J., Best E., Sechrist, J., Hueth, C., Fish entrainment investigations at St. Mary Diversion Dam , Montana, Draft Technical Memorandum, USDI Bureau of Reclamation Technical Service Center Fisheries and Wildlife Resources Group, Denver, CO, 2011
10. National Marine Fisheries Southwest Region, Fish Screening Criteria for Anadromous Salmonids, 1997, Web site:http://www.swr.nmfs.noaa.gov/hcd/fishscrn.pdf
11. NOAA Nation Marine Fisheries Service, (Thomas, S.), Fish Screen Design Criteria for Small Diversions, Fish Friendly Farming Workshop, March 2011, Web site: http://www.fishfriendlyfarming.org/downloads/FFF_Screen_Presentation3_stevethomas.pdf
12. Sechrist, J.D. and K.P. Zehfuss. 2010. Fish entrainment investigations at the Fort Shaw Diversion 2003 2004, Sun River, Montana. Intermountain Journal of Science 16:4-26.
13. Sechrist, J.D., E.L. Best, and S.D. Hiebert. 2005. Fisheries entrainment investigations at Frenchtown Diversion Canal, Frenchtown, MT: Report of findings 2003-2004. USDI Bureau of Reclamation, Denver, CO.
14. The Trout Conservancy of Montana, Trout Entrainment in Montana, A Guidebook and Primer, March 2010. Web site: http://www.montanatrout.org/images/entrainment/TrtEntrMT.pdf
15. Turnpenny, A.W.H., and O'Keeffe N. O., Environment Agency, Screening for Intake and Outfalls: a best Practice Guide, Science Report SC030231, England, 2005. Web site: http://publications.environment-agency.gov.uk/PDF/SCHO0205BIOC-E-E
16. U.S. Bureau of Reclamation, Fish Protection at Water Diversions, April 2006 Web site: http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/fishprotection/index.html
17. U.S. Department of Energy Bonneville Power Administration, Fish and Wildlife Program Upper Salmon River Anadromous Fish Passage Project
18. U.S. Forest Service, 2013. FishXing, Web site: http://www.stream.fs.fed.us/fishxing/
19. Wahl , T., Hydraulic Performance of Coanda-Effect Screens, U.S. Bureau of Reclamation Hydraulic Investigations and Laboratory Services Group, PAP 877, 2001. Web site: http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/
20. Washington Department of Fish and Wildlife, Fish Protection Screen Guidelines for Washington State, April 2000. Web site: http://www.wdfw.wa.gov/publications/00050/wdfw00050.pdf
21. Zydlewski, G. B., Johnson, J.R., Stow, J., Burger, C., Validation of Existing Fish Screen Criteria for Juvenile Bull Trout (Salvelinus confluentus), Technical Information Leaflet No. AB-00-01, U.S. Fish and Wildlife Service, October 2000.