TECHNICAL NOTES

US DEPARTMENT OF AGRICULTURE **NATURAL RESOURCES CONSERVATION SERVICE**

ENGINEERING – 06 **Albuquerque, New Mexico**
September 2013

GUIDE TO FISH SCREENS

- **Introduction:** This technical note explains and provides practical guidance on screens to exclude fish from irrigation pipelines, canals, laterals and field ditches. Pages 2 through 37 of this note are a publication titled, "Pocket Guide to Screening Small Water Diversions." This information is applicable to Diversion Dams (PS-348), Structure for Water Control (PS-587) and others practices where exclusion or separation fish species is needed. Practice Standard 396, Aquatic Organism Passage, may provide additional support and information needed for planning, design, or installations.

- **Procedure:** The "Pocket Guide to Screening Small Water Diversions" was developed for salmon. However, it provides good information and recommendations for all fish species, and the default parameters can be used for planning. The primary parameters needed to design a fish screen are:
  1. Approach velocity (flow velocity toward the screen and based swimming speed of the target fish).
  2. Screen sweeping velocity (flow velocity along the screen and based on the fish's ability to maintain swimming speed before resting).
  3. Ratio of approach to sweeping velocities (approach velocity divided by sweeping velocity)
  4. Percent of open area (typically 27 – 50 percent).
  5. Size of the screen opening (Based on size of the target fish).
  6. Location of the screen (in the stream or river or in the outtake with a bypass back into the river.

  The planner/designer will need to consult with the NRCS State Biologist to obtain specific values for the first five parameters. The sixth parameter must be based on maintenance, debris in the river or stream, and preferences of the producer or client.

Pocket Guide to Screening Small Water Diversions

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

Support for this manual was provided by:

U.S. Forest Service, U.S. Fish and Wildlife Service and the U.S. Bureau of Reclamation

Acknowledgements: Ms. Kim Clarkin, USDA-Forest Service initiated and organized the writing of this manual. Many people and screen manufacturers provided input and photographs for the manual. Special thanks are given to the following people who took time to review and comment during the writing of the manual. Mr. Lewis Stahl, Wyoming Game and Fish, Ms. Kathryn Boyer and Mr. Clarence Prestwich, Natural Resources Conservation Service, Mr. Steve Thomas, NOAA Fisheries, Mr. Dan Meier, U.S. Fish and Wildlife Service and Ms. Connie Svoboda and Mr. Jason Wagner, U.S. Bureau of Reclamation.

Author:
Brent Mefford, P.E
U.S. Bureau of Reclamation
Denver Technical Service Center

Pocket Guide to Screening Small Water Diversions

Introduction

The purpose of this manual is to acquaint water diverters and resource managers with fish screening methods and devices used for small agricultural water diversions. Screening water diversions can provide multiple benefits. Screening greatly reduces the entrainment of fish and other aquatic organisms with diverted flow. Screening can also benefit use of diverted water by permitting better management of debris and sediment exclusion.

Entrainment of fish and aquatic organisms into diversion ditches and pipes often results in these organisms being removed from the natural system. Sampling studies of unscreened water diversions (2, 4, 5, 6, 9, 10, 11 and 12) often reveal significant entrainment of aquatic organisms and, when multiplied by multiple diversions, can deplete the biodiversity of a river basin. Screening flows from < 1 ft^3/s to several thousand ft^3/s is now common and required by law in some states. This manual 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 criteria may apply which can vary by species listing, regulatory agency and geographic location. Prior to starting a screening project, water diverters are encouraged to contact state or federal fishery resource agencies for assistance. 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 compliments the diversion. This guide provides information for planning a successful screen installation and provides additional references for understanding screening.

Screening Objectives

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 entrainment with diverted water resulting in loss of fish from native or stocked waters using a method that does not cause injury to the organism. 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 requires that screens are designed to prevent fish from being impinged on the screen surface by flow passing through the screen. Impingement can cause impairment of breathing, loss of scales, bruising, and elevated stress levels resulting in fish mortality or contact with mechanical screen cleaning systems resulting in direct injury or mortality.

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

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 entrainment protection and far less certainty of performance 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 protection objectives for a screening project 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 requiring a determination of protection goals. 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 screen criteria for small screens is generally accepted as a standard for most small screening applications regardless of species (12, 17). Note, 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. This document 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 federal 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 it is not required by law should be undertaken 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 criteria contains two levels of screen criteria, one for protecting juvenile salmonid fingerling size and larger fish, and a second level for protecting salmonid fry and larger fish. Fingerlings are defined as juvenile salmonids larger than 60 mm (2.4 in) and juvenile fry salmonids as fish less than 60 mm in length. The fingerling criteria allows for greater screen approach flow velocity, screen opening 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 widely used for screening. In general, NOAA fry screen criteria will protect many fish species with body lengths greater than 25 to 50 mm (~1 to 2 inch). Excluding smaller bodied fish including eggs are not discussed herein, but may be feasible with specially designed screens.

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 debris. Debris load can vary by season, screen location and debris type. Woody debris load and domestic refuge are typically greatest during high flow events when material accumulated on stream banks is swept off. 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 fragment from the roots and are transported by flow. 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 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 using bypass flow***.** 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 requires rotating screens designed to pass impinged debris over top the screen.

3. *Remove debris from the diverted water and collect it onsite for disposal.* This requires rotating screens equipped with a debris sluice or conveyor.

Debris management methods 1 and 2 are common for small screen installations. Option 3 increases installation complexity and is only used when special circumstances benefit debris removal.

Sediment Management

Screens can be designed to aid in the management of sediment entrainment associated with diversion of flow. Sediment is divided into larger bed sediments (bed load) that roll along the bottom and finer suspended sediment that is carried within the water as a mixture. Mobile bed sediments are typically sands and gravels. However, during high flows or in steep streams, cobbles and boulders may also be moved downstream by flow. 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 can be designed to exclude a large percent of the bed sediments by selecting the right screen for the site, having a strong sweeping flow passing the screen to transport bed sediment away from the screen and proper sizing of the screen mesh. Suspended sediment is generally composed of fine material that passes through a fish screen with the flow. Although fish screens will not prevent entrainment of suspended sediment, a screen designed to protect small bodied fish may create local areas of low velocity and suspended sediment deposition. This is frequently the case immediately downstream of screens placed across ditches carrying high suspended sediment loads.

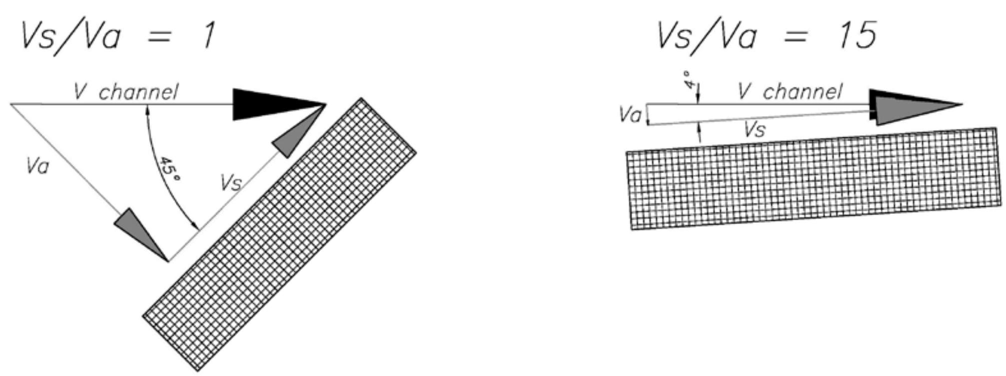
Understanding Fish Screen Hydraulics

Flow velocity measured normal to the screen surface is referred to as *screen approach velocity* (V_a). 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). NOAA screen criteria require a minimum Vs/Va ratio of one for screens longer than 4 ft. This requires a screen > 4ft in length be set at an angle of 45 degrees or less to the stream flow. Creating a strong sweeping flow is highly desirable feature for transporting fish and debris away from the screen. 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 (applies to screen lengths < 4 ft) allow screens to be set at any angle to the stream and bypass flow. Although not required under NOAA small screen criteria, establishing a strong sweeping flow across a small screen is recommended and will benefit fish protection and debris and sediment management.

Minimizing fish impingement risk also requires that the approach velocity (V_a) to the screen is less than the fish's swimming ability for short periods referred to as the fish's sustained swimming speed. Sustained swimming speed can vary widely between fish species and age class (body size). NOAA fry criteria for screens with active cleaning systems require a screen approach velocity of ≤ 0.4 ft/s for canals and ≤ 0.33 ft/s for rivers, streams, and lakes based on total area of screen fabric. For fingerling size salmonids and larger, an approach velocity ≤ 0.8 ft/s is allowed.

The different levels of NOAA screen criteria illustrate the need to determine fish protection objectives early in the screening project. When screen criteria is not mandated, the screen design should be based on balancing screen approach velocity which impacts fish protection, screen size and initial cost with projected maintenance requirements. As a general rule, lower approach velocity equates to increased screen size, better fish protection and lower operation and maintenance (O&M) costs. Increasing approach velocity reduces screen size, reduces fish protection and often increases O&M costs. This is a general rule and will not be true in all cases. The relationship between approach velocity, screen size and fish protection are clear. The relationship between approach velocity and screen O&M cost is more varied, but can often be explained as follows. Increased approach velocity increases the water force pressing debris against and into the openings in the screen fabric. Debris forced into the screen fabric often becomes tightly interlocked with the fabric requiring increased cleaning frequency or more aggressive mechanical cleaning methods.

For passive screens to operate without frequent manual cleaning they must have a low approach velocity, a strong sweeping flow, or both. 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 V_a is greater than the force of water pushing debris along the surface caused by V_s. Increasing the ratio of V_s/V_a provides improved cleaning performance based on flow alone. Passive screens are generally designed to operate with a V_s/V_a ratio in the range of 10 to 20 or greater. A ratio of ~15 is recommended where V_s is > 1 ft/s. In contrast, active rotating screens designed to capture and pass debris over the screen as they rotate are best suited to operation under conditions with low ratios of V_s/V_a often between 1 and 5.



Example of a screen set at 45 degrees to the flow to create a strong debris impinging flow.

Example of a screen set at a shallow angle to the flow to create a strong debris flushing flow.

Figure 1- Effect of fish screen orientation on debris impingement.

Selecting Screen Location

Screens placed on small pumped diversions are typically mounted directly on the end of the suction pipe located in the canal, stream or lake. Screens for a gravity diversion can be located in-stream/lake at the entrance to the diversion upstream of flow control structures or in-ditch downstream of flow control structures. There are many pros and cons to consider during selection of either an in-stream/lake or in-ditch location. The major reasons for selecting an in-stream or in-ditch screen location are:

Locating screen in-stream/lake

Pros

- Locating the screen in-stream/lake prevents entrainment of fish and debris into the diversion. Fish and debris are not passed through the diversion's flow control structure which could harm fish and require debris removal in the control structure.
- Diverting extra flow (called bypass flow) for returning fish and debris to the stream is not required.
- A fish-bypass structure is not required.

Cons

- Access to the screen may be difficult or limited to low flow periods.
- In freezing climates removal of the screen during winter periods may be required to prevent damage to the screen.
- In-stream screens may be subjected to damage from large woody debris carried by high flows.
- Flow conditions may be highly variable during the year.

Locating screen in-ditch

Pros

- Locating the screen in-ditch downstream of the flow control gates allow the screen installation to be dewatered for inspection or maintenance.
- Screens are protected from large debris, water craft and other activates occurring on the stream/lake.
- Flow conditions (depth, velocity and flow direction) approaching the screen are more consistent and predictable than in-stream locations.

Cons

- In-ditch screens require a bypass channel or pipe from the screen back to the stream. The bypass provides an escape route for returning fish to the stream. Bypass flow and conveyance structure must also be large enough to provide sufficient flow depth for the largest fish and transport debris back to the stream without plugging. The bypass structure can be a significant additional cost.
- The fish bypass requires diversion of flow to operate the bypass. This flow may be in addition to or subtracted from decreed diversion flow. Water law varies between states on accounting of fish screen bypass flow. A diverter is encouraged to request an opinion from

their State Engineers Office or State Water Rights Office on how fish screen bypass flows are accounted for in their state prior to selecting to locate a screen in-ditch.

- Fish bypasses can provide increased opportunity in the bypass channel or at the point of return to the stream for predators (other fish, mammals, birds or people). Fish bypasses generally concentrate fish, provide reduced cover and may disorient fish all which decrease the fish's natural ability to avoid predators.

Selecting a Screen

Screen Material

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 strong enough to prevent collapse of the screen should the screen fabric become totally plugged. The screen should be designed to withstand this condition as it produces the maximum water differential across the screen. Use of dissimilar metals that can cause a galvanic corrosion when placed in contact with each other should be avoided. When using dissimilar metals a galvanic compatibility table should be consulted to determine their electrochemical similarity. Many metals suppliers can also provide this information. When using electrochemically dissimilar metals cannot be avoided, coating or placing an insulating material between the metals may be an option.

Screen Fabric

Common screen fabrics used are woven wire, perforated plate and wedge-wire (also called profile wire). Each fabric type can be found constructed of different materials including stainless steel, coated steel, aluminum, copper alloys and synthetic materials like acrylic and nylon. Fish screen fabric materials requiring protective coatings should be considered carefully due to the likelihood of abrasive flow conditions, screen cleaning and debris impact wear on the coating. 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.

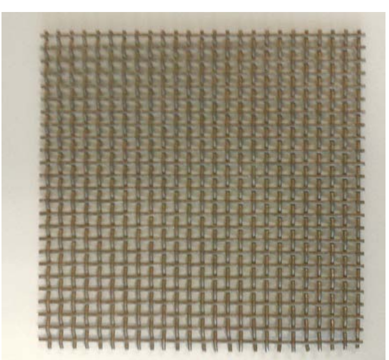


Figure 2a - Woven Wire Screen

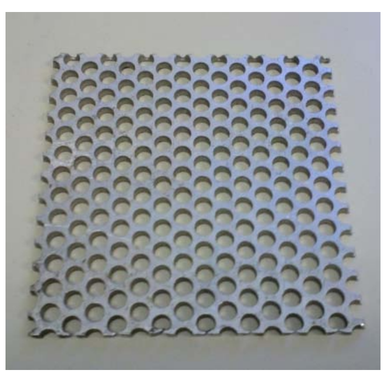


Figure 2b – Perforated Plate Screen

Figure 2c - Wedge-wire Screen

Wedge-wire refers to 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.

Screen Porosity

Screen porosity (percent open area) impacts the energy required to pass flow through the screen (headloss 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. NOAA fry and fingerling criteria for screening require a screen porosity (open area) > 27 percent and > 40 percent, respectively. These criteria are set to limit flow velocity as it passes through the openings (referred to as orifice velocity) in the screen surface. 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 to produce a higher orifice velocity. Fish entrapment is a measure of a fish's ability to free itself once impinged on the screen surface. In general, the higher the orifice velocity the tighter fish and debris are held against the screen surface. 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, debris and 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/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 is done to reduce the amount of debris particles 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 screening when large holes are used. Screens with holes large enough to allow stringy material to pass through the holes can be particularly difficult to clean. Stringy debris passing through a screen can wrap around the fabric material forming an entangled mat with the screen which is difficult to remove. For this type of debris, consideration should be given to selecting a hole size small enough to hold the debris on the face of the screen.

Choosing a Screen Fabric

Choosing a screen fabric should include consideration of durability, cost, fabric structural support required 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 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 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 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 constructed from synthetic materials. Many of these fabrics are manufactured specifically for fish screening applications. When choosing a synthetic screen fabric, the material 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.

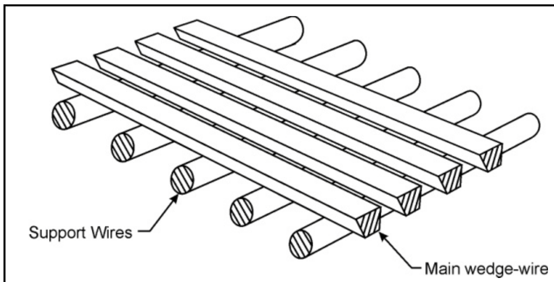


Figure 3 – An example of wedge-wire construction

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

Source – Hydrolox Screens

Performing a Site Assessment

Fish 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 shifting normal delivery system maintenance associated with downstream debris and coarse sediment management upstream to the screen.

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. The most common forms of alternate energy are solar or wind generated power with battery storage and flow driven drives using paddle wheels or propellers mounted downstream of the screen.

2. What is the allowable headloss (water surface drop) across the screen?

   The head drop through a clean fish screen structure is a cumulative function of approach velocity, screen fabric, screen baffling and screen type. For small screens with little or no internal baffling, the headloss, h_l *(ft)*, due to approach velocity for typical screen fabrics can be estimated as ten times the approach velocity head or approximately:

   $h_l \approx {10V_a^2}/{64}$ 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 headloss due to the screen is about 0.3 inches. Actual headloss, accounting for screen geometry and partial loss of screen area due to debris plugging, can be 5 to 10 times the headloss calculated above or for the example about 3 inches. In addition, 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 flow depth at the site should submerge enough screen fabric to meet the approach velocity objective. 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, inclined bottom screens, inclined bank screens, cone screens and tubular screens. 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 supporting slow moving flow (<~1 ft/s) require screens with active cleaning or very large screen areas. Sites supporting higher velocity flow allow for wider use of passive screens with V_s/V_a ratios exceeding 10.

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

Site constraints may limit the screen installation footprint either normal to 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 variant 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 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, it is beneficial for maintenance and fish protection to maintain a minimum of 20 percent of the channel flow bypassing a 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 Method

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, 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 V_s/V_a velocity 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 burst times are necessary to allow material to move past the screen. Using submerged spray jets or other methods of back flushing using pressurized water behind the screen is possible, but is not commonly used on small screens due to pumping requirements and difficulties of achieving back flow over the entire screen surface. Back flushing using screened water flowing through the screen a second time is the primary means of cleaning screens that rotate like drum screens and traveling belt screens. Flow initially passes in through the front screen face impinging debris on the screen (figure 5). By rotating the screen passes the debris over the screen and again into the flow on the back side where screened flow passes out through the screen pushing debris off the drum or belt. 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.

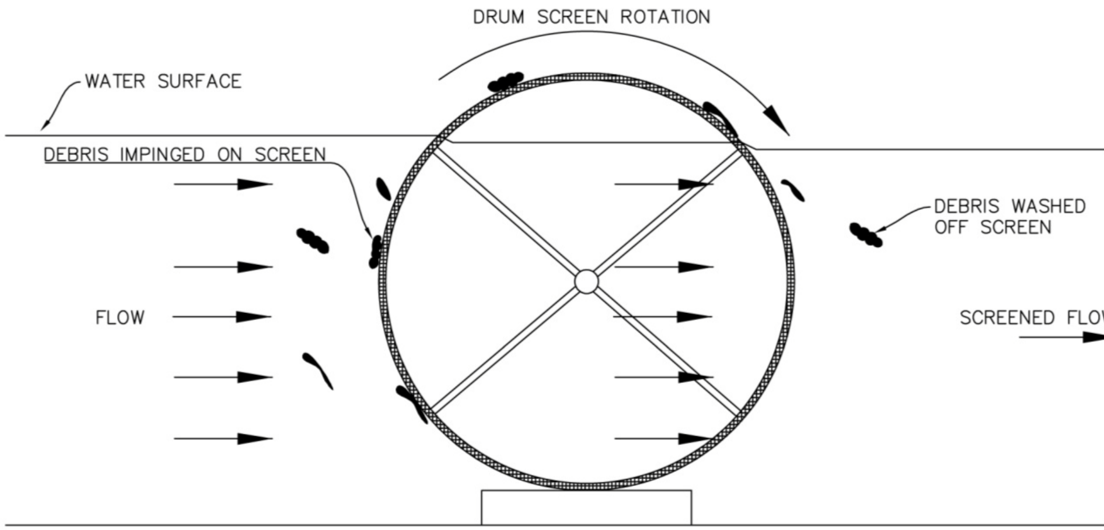


Figure 5 – Flow through a drum screen back flushing debris carried over the screen off the downstream side.

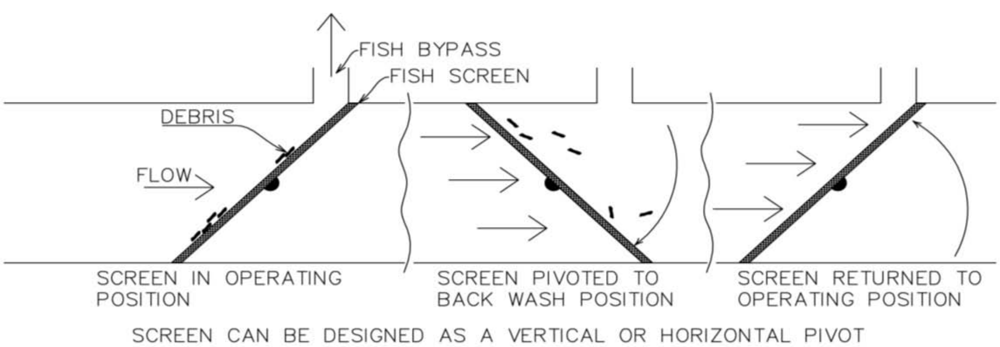


Figure 6 – Pivoting a flat plate screen to back flush debris off the screen.

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, low cost 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 that can be chosen for maintaining small flat plate screens for sites that are frequently inspected. This is only recommended if debris impingement load 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 mounted 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.

Guidelines are presented herein but following these guidelines does 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 bypasses the screen. As a general rule for passive screens, flow bypassing the screen should be greater than about 20 percent of the screened flow. Three basic approaches can be used for the design of passive screens. These are: drop through inclined-ramps, V_s/V_a ratio adjusted 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 grade (figure 9). These screens rely on a high sweeping velocity down the face of the screen combined with small screen openings. Small openings are used to minimize material entanglement with 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 screen to increase the through flow screen efficiency (15). Guidance and software for the design of Coanda and inclined ramp screens is presented by Wahl at http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/. As with all types of bottom screens, the screen should incorporate structural features that ensure adequate bypass flow passes the screen under all conditions.

V_s/V_a ratio adjusted screens are based on designing the screen to provide a sweeping velocity greater than about 15 times the approach velocity (see screen hydraulics section). This is done by determining the sweeping velocity using the near screen channel velocity and calculating the maximum approach velocity that will meet the V_s/V_a ratio target. The submerged screen area required is then calculated as Q_s/V_a, where Q_s is the desired flow through the screen. This method can be used to design 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. As with all bottom screens, the screen should incorporate structural features that prevent 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.

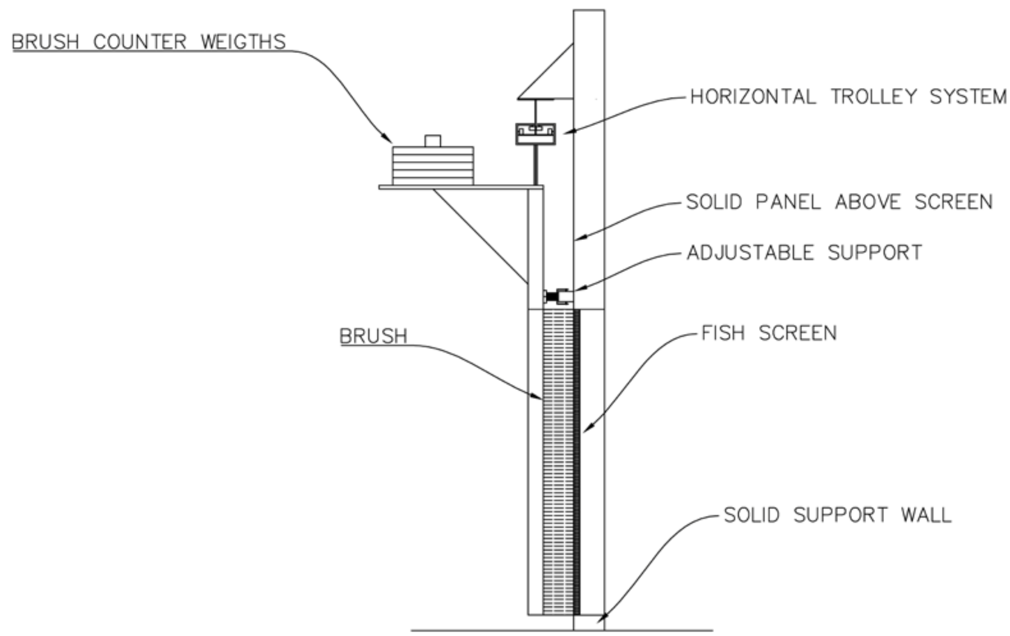


Figure 7 – Elevation view of typical flat plate screen brush cleaner. Brush moves horizontally along the screen.

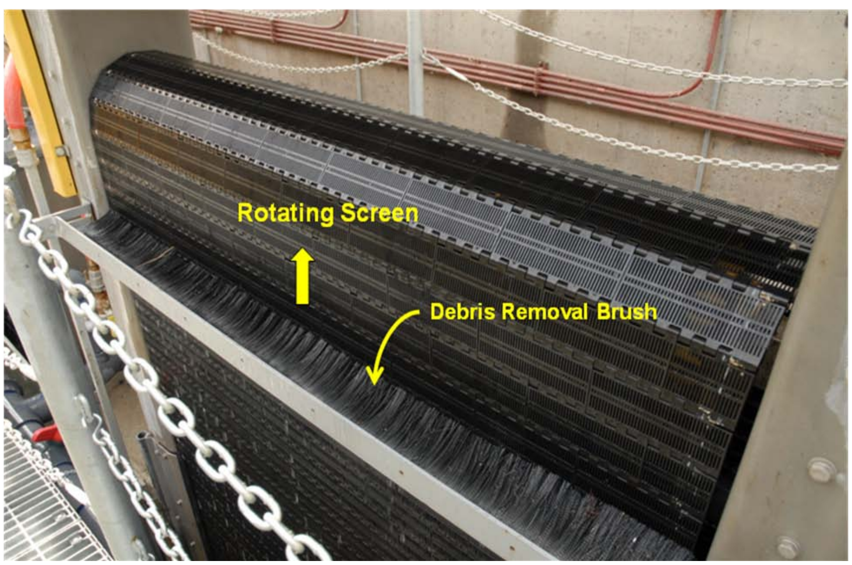


Figure 8 - Rotating traveling screen with brush cleaner.

Source - Hydrolox Screens

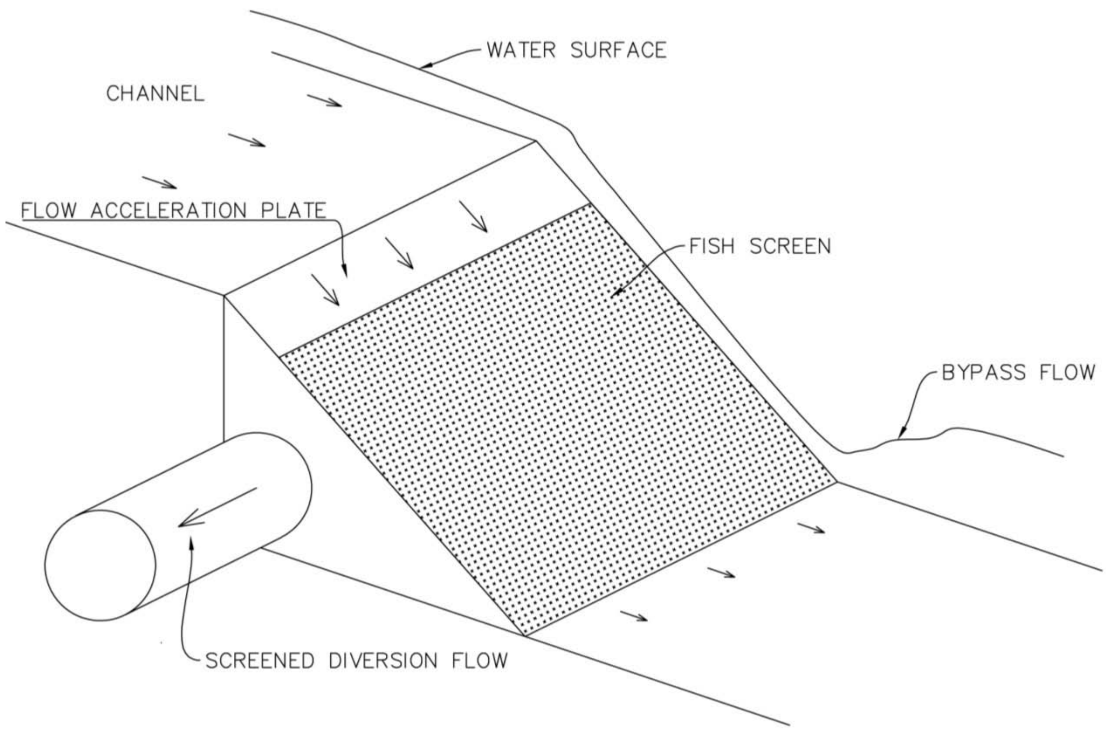


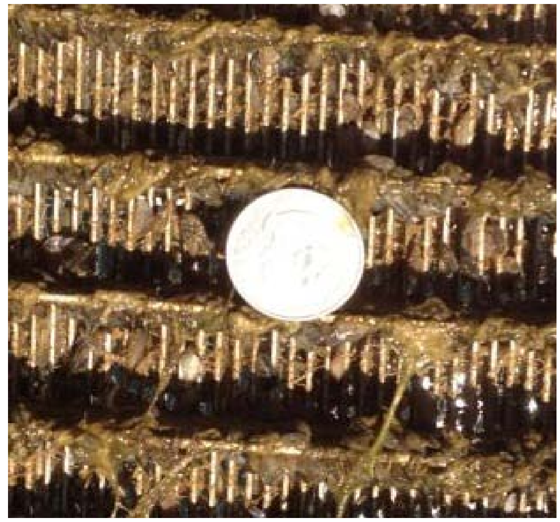
Figure 9 – Passive inclined ramp drop-through style diversion screen. Bypass flow carries debris away from screen.

Screen Biofouling

Biofouling refers to aquatic organisms attaching too and growing on the screen fabric. Organisms can impair screen flow by attaching to the upstream and downstream faces of the screen. Biofouling can be caused by both aquatic plants and animals. The most common organisms that grow on screens in freshwater 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.

In waters where biofouling of a screen may be a significant problem consideration should be given to the cleaning method, screen material and possibly using an anti-biofouling coating that has been tested for the 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

How to Start Your Screening Project

1. Contact your local state fisheries agency to inquire if there are listed or threatened fish or other aquatic species in the water body you divert from that dictate screening criteria that must be followed.

2. Contact your local Natural Resources Conservation Service (NRCS) office to inquire if screening your diversion qualifies for federal government cost sharing.

3. Contact State Engineers' Office or State Water Rights Office to inquire as to regulations covering bypass flows for screening in-ditch.

Basic Steps for Designing or Selecting a Small Screen

1. Determine your fish protection objectives (fish species, size and swimming strength).

2. Determine major debris types, when they occur and approximate debris loads.

3. Determine the maximum amount of flow to be screened.

4. Investigate screening sites. Consider both in-stream/lake and in-ditch options. For all potential sites determine approximate channel/ditch flow, velocity and depth under maximum diversion for both average minimum and maximum stream flow conditions during the diversion period.

5. Determine if sufficient head is available during maximum diversion at minimum stream flows to support screening. As a general rule for small screens in open channels, a minimum of 0.3 ft of drop in water surface across the screen structure should be assumed unless specific test data is available.

6. The type and size of the screen facility should be carefully considered to reduce capital cost and maintenance for meeting your fish protection goals.

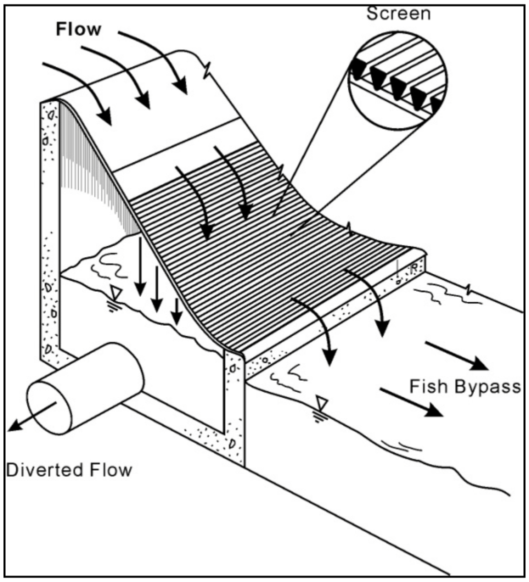
7. Use the screening examples presented in the fish screen selection guide in the next section of this guide to evaluate the best type of screen for your application.

Fish Screen Selection Guide

The following pages provide information specific to screen types commonly used for small fish screening applications. The guide focuses on common screen types that are commercially available or can be built by a local metal fabricator. Most screen fabrics can be purchased from screen fabric manufacturers directly when custom screen fabrication is desired. Not all manufacturers of small fish screens are listed herein. Most types of fish screens are available from different manufacturers, many of which are not listed in this guide. Commercial screens discussed or shown are not endorsed by the government. Screens are presented to demonstrate the wide variety of fish screening techniques and methods available. The selection guide is intended to educate water diverters and others interested in protecting aquatic organisms in America's rivers, streams and lakes. We encourage the use of the information presented in this guide to evaluate all types of fish screening options during your selection process.

Passive Screens

Coanda Screen



Coanda Screen

Source – USBR

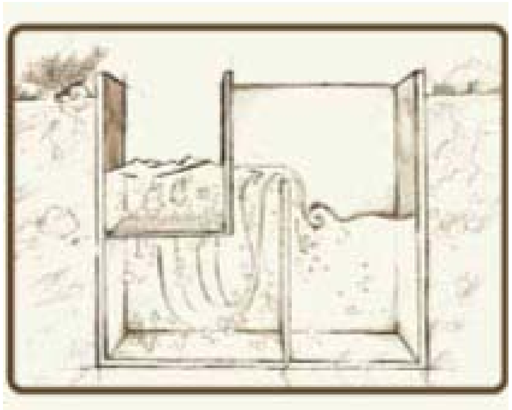
Standard Application	Flow diversion at an elevation drop.
Strong Points	High flow capacity screen. Can be designed using USBR Coanda screen design program.
Issues	Difficult to control bypass flow. Possible dewatering of the screen toe and loss of bypass flow during low flows.
Standard Mounting	Normal to channel
Cleaning	Passive
Screen Material	Tilted wedge-wire
Flow Capacity	~ $1ft^3/s/ft^2$
Power Requirements	None
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.
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 and an upstream acceleration ramp
Power Requirements	None
Head Requirements	Generally >1 ft
Fish Bypass	Fish and debris are transported by additional flow passing over screen.
Commercially Available	Yes
Search Key Words	Tilted wire screen, Hendrick Screens, Johnson Screens, Norris screens

Horizontal Flat Plate – Bottom Screen



Source - Farmers Conservation Alliance (FCA)

FCA Screen

Source – Wyoming Game and Fish

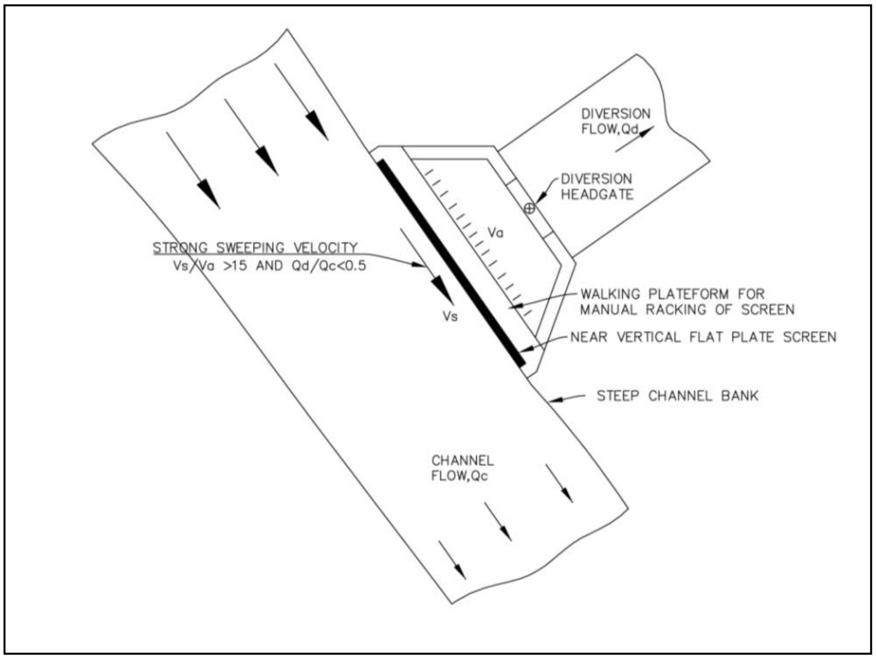
Standard Application	Passive screen designed for shallow water diversion. Flow passes through a horizontal bottom screen.
Strong Points	Generally low maintenance. Good for shallow flow. Smaller screens can be installed with limited construction.
Issues	Exposes bottom oriented fish to full screen length. Screen can plug with bed sediments. Some internal baffling below the screen may be required for large screens.
Standard Mounting	Horizontal in channel
Cleaning	Passive
Screen Material	Wedge-wire or perforated plate
Flow Capacity	Small to large
Power Requirements	None
Head Requirements (Typical)	0.1 to 0.3 ft
Fish Bypass	Fish and debris are transported by bypass flow passing over screen. A weir wall between screen channel and screened diversion flow prevent dewatering of bypass.
Commercially Available	Yes
Search Key Words	Horizontal screens, FCA screens

Passive Tube Screen

Source – Pump-Rite Screens

Standard Application	Small pump diversions especially suited for shallow water where tube is fully submerged.
Strong Points	Drop-in passive screen designed for very low approach velocity.
Issues	Performance can be affected by sediment or biofouling.
Standard Mounting	Generally laid directly on channel bed.
Cleaning	Passive
Screen Material	Punch plate, Woven wire
Flow Capacity	Small, generally < 5 ft^3/s
Power Requirements	None
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 with proper site.
Issues	Very site dependent. Cleaning effectiveness can be impacted by changes in stream conditions. 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
Screen Material	Wedge-wire, perforated plate
Flow Capacity	Small to large
Power Requirements	None
Head Requirements	<~0.3ft across screen
Fish Bypass	None
Commercially Available	Screen fabric only
Search Key Words	Wedge-wire screen, Hendrick Screens, Johnson Screens, Norris 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. High silt loads can result in sediment deposits either side of the screen. 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. Flow capacity is the submerged screen area times the flow approach velocity.
Power Requirements	Rotating the drum requires mechanical paddle wheel drive unit. Information on paddlewheels can be found in reference 3.
Head Requirements	0.3 ft to 0.6 ft depending on structure design and drive unit
Fish Bypass	Pipe or open channel
Commercially Available	Screen drum is available, no known manufacturers of complete unit
Search Key Words	Drum screen, Hendrick screens, Johnson screens, Norris screens

Motor Driven Drum Screen

Drums 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 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.
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 30 deg 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 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.
Head Requirements	0.3 ft to 0.6 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

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 not tightly limited by head.
Strong Points	Rotating drum requiring no external mechanical drive.
Issues	The large head drop through the drum results in high approach velocity to the screen. May not meet NOAA criteria. Poor attraction to the bypass if set normal to channel.
Standard Mounting	Drop in unit set in vertical guides (slots)
Cleaning	Backwashed as screen rotates.
Screen Material	Perforated plate
Power Requirements	None
Head Requirements	>0.5 times the height of the drum
Fish Bypass	Generally required
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.

Source – Hydrolox screens

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 periodic 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
Head Requirements	~0.2 ft to 0.6 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

Horizontal Traveling Belt Screen

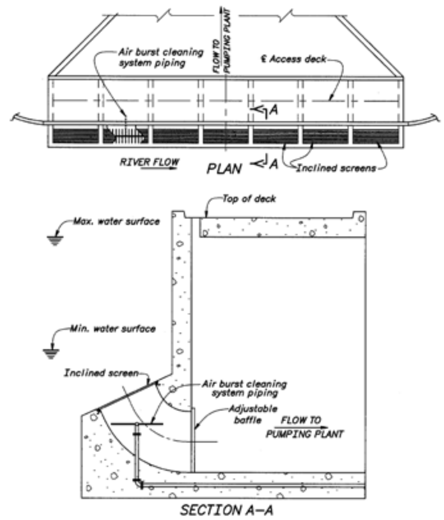
Source – Wyoming Game and Fish

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
Head Requirements	~0.1 ft to 0.3 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 – Idaho Fish and Game



Source – USBR

Standard Application	Shallow water flows where it is desirable to elevate the screen off the bottom.
Strong Points	Can draw from the middle of the water column avoiding bed sediments and floating debris.
Issues	May be difficult to access screen when placed in-stream.
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
Power Requirements	Power required for compressed air cleaning system.
Head Requirements	~0.2 ft to 0.6 ft depending on baffling and channel velocity
Fish Bypass	Not required for in-stream installations
Commercially Available	Screen panels only
Search Key Words	Wedge-wire screen, perforated plate

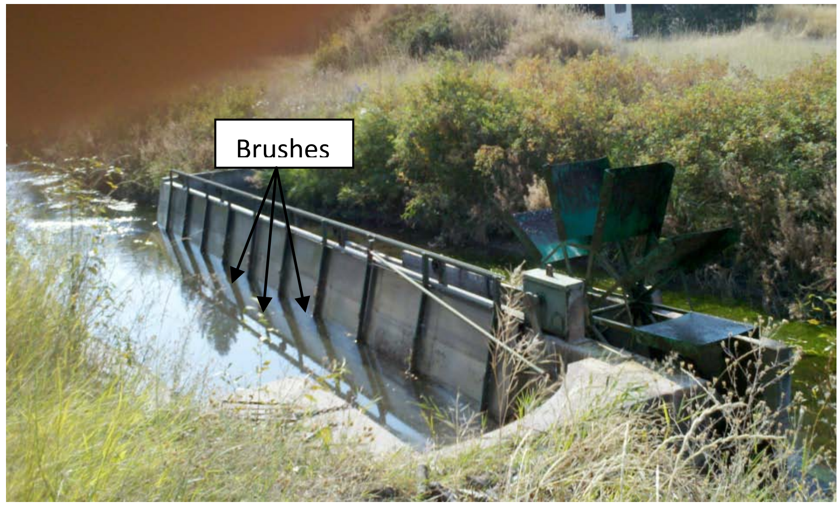
Stationary Cylindrical Tee Screen with Internal Air Burst System or Water Spray Jets

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.
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).
Screen Baffling	Generally an internal ported sleeve extends the length of the cylinder. The diameter of the ports in the sleeve varies to achieve a nearly uniform flow through the outer screen.
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	Flow capacity based on submerged screen area times the design flow approach velocity.
Power Requirements	Cleaning systems generally require electricity.
Head Requirements	~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.

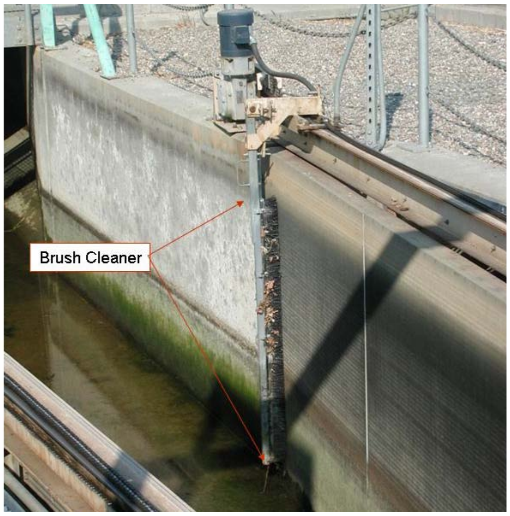
Mechanically Cleaned Screens – Brush Cleaning

Vertical Flat Plate Screen with Paddlewheel Driven Brushes



Standard Application	In-ditch or on-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 will have a minimum diversion flow requirement to operate cleaner.
Standard Mounting	Screens are normally mounted at an angle of between 15 and 45 degrees to the channel wall.
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 allows 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	Determined by submerged screen area times the flow approach velocity.
Power Requirements	None
Head Requirements	~0.2 ft to 0.6 ft depending on baffling and channel velocity
Fish Bypass	Debris and fish pass through a bypass at the downstream end of the screen.
Commercially Available	Screen panels only
Search Key Words	Wedgewire screen, perforated plate, woven wire screen

“Vee” Style Vertical Flat Plate Screen



Red Bluff Pumping Plant
Source – USBR

Standard Application	Generally used for screening larger flows.
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 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	Determined by submerged screen area times the flow approach velocity.
Power Requirements	Cleaning systems generally require electricity.
Head Requirements	~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	Generally limited, an internal ported riser surrounding the screen outflow pipe can be used to improve uniformity of screen approach flow.
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 for in-stream installations
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	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. 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 sleeve extends the length of the cylinder. 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	Flow based on submerged screen area times the flow approach velocity.
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 for in-stream installations
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 attempt to create a behavioral response on the part of the fish to avoid entrainment.

Bypass for Fish Screen – A channel or pipe used to return fish from a 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 the screen to promote improved uniformity of flow through the screen. Often perforated plate or louver bars are used as baffling.

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

Cruising Speed – A swimming speed that fish can maintain for long periods of time (hours).

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 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 minutes.

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. 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.
3. 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.
4. 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.
5. 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.
6. 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
7. National Marine Fisheries Southwest Region, Fish Screening Criteria for Anadromous Salmonids, 1997, Web site:http://www.swr.nmfs.noaa.gov/hcd/fishscrn.pdf
8. 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
9. 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.
10. 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.
11. 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
12. 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
13. 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
14. U.S. Department of Energy Bonneville Power Administration, Fish and Wildlife Program Upper Salmon River Anadromous Fish Passage Project
15. 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/
16. 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
17. 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.