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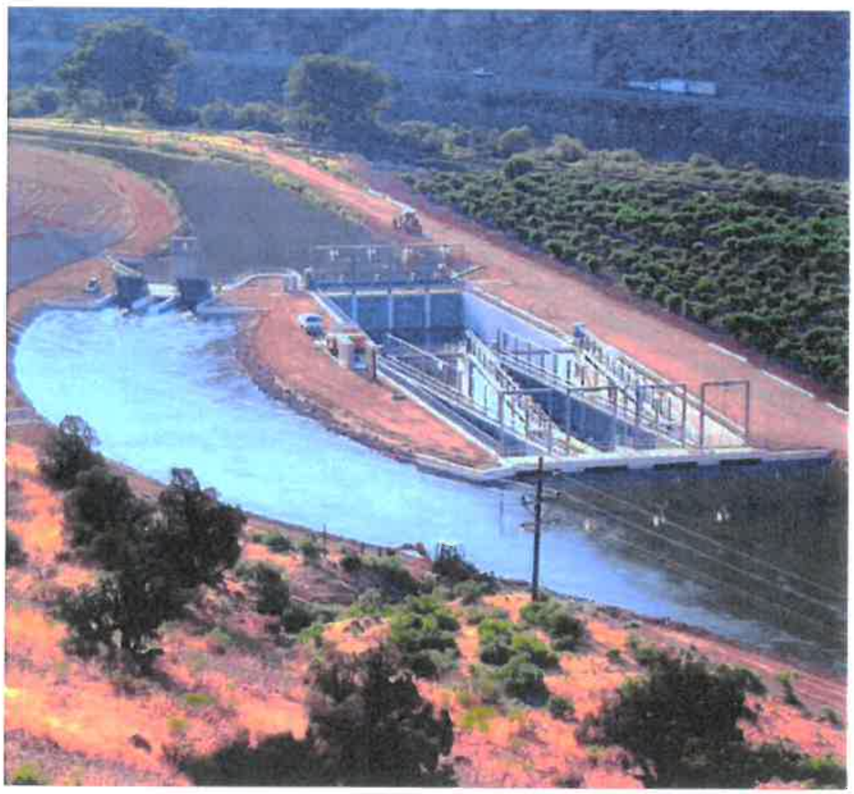
Managing Water in the West

Water Resources Technical Publication

Fish Protection at Water Diversions

A Guide for Planning and Designing Fish Exclusion Facilities



U.S. Department of the Interior
Bureau of Reclamation
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Fish Protection at Water Diversions

A Guide for Planning and Designing Fish Exclusion Facilities

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- Fish bypass: For a fish screen on the river, a bypass in not normally required because the downstream river channel serves as the bypass. If the fish screen structure is too long to satisfy time of exposure criteria (normally limited to 60 seconds), intermediate bypass along the screen structure may be required.

c. In-diversion pool

A fish screen structure located in the diversion pool requires the following hydraulic considerations/elements:

- Screen approach and sweeping velocities: Screen approach and sweeping velocities in the diversion pool will likely be low. Therefore, supplemental structures are used to confine and guide the flow past the screen face

- Fish bypass: Conventional bypass structures may be required for fish screens located in diversion pools.

d. In-closed conduit

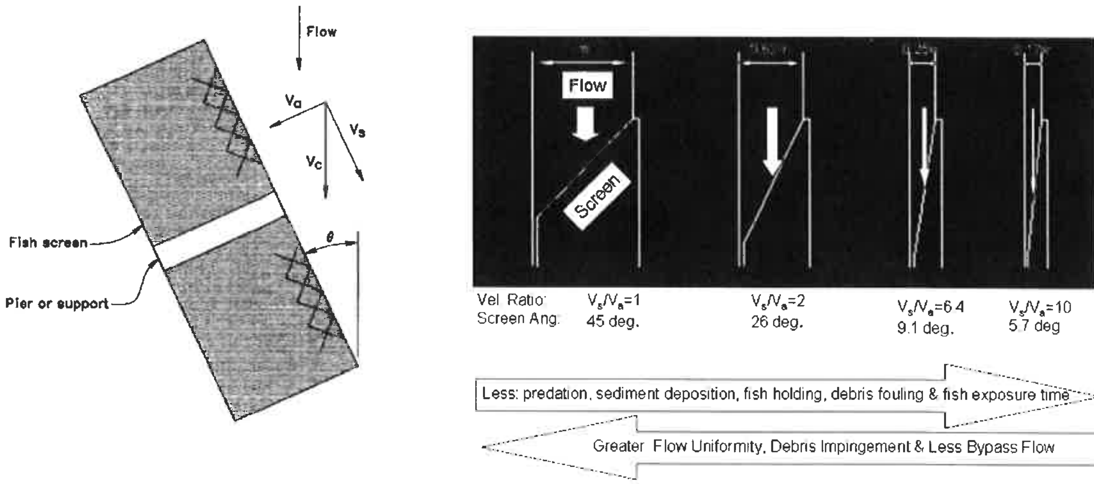
A fish screen structure located in a closed diversion conduit (penstock, pump suction tube) typically requires that the screen converge with the upper conduit surface, thus leading to the bypass entrance.

5. Screen Hydraulics (Sizing Screen Area, Approach and Sweeping Velocities)

Fish screens are set at an angle to the flow to reduce flow velocity normal to the screens to safe levels for fish and to establish flow parallel to the screen to guide fish past the screen. If screens are oriented normal (90 degrees) to the channel flow, the fish tend to hold in front of the screens or are impinged on the screen. In either case, the fish are not directed to the bypass entrance. Published criteria for the design of screens that are applied for juvenile salmon, National Marine Fisheries Service (NMFS) now called the National Ocean and Atmospheric Administration Department of Fisheries (NOAA Fisheries) (attachment A), require screens to be oriented at angles less than 45 degrees to the flow to create a sweeping flow in front of the screens. The screens are aligned at angles ranging from parallel to the flow (0 degrees) up to 15 degrees. This reduces the width of the structure while increasing the ratio of sweeping velocity to approach velocity.

a. Sizing screen area

The flow approaching the fish screens can be characterized in a vector format (figure 37a). The resultant, or channel velocity, V_c , can be broken into an approach velocity component, V_a, that is normal to the screen face and a sweeping



a. Screen approach velocity and sweeping velocity (Pearce and Lee, 1991).

b. Velocity ratio as a function of screen angle placement.

Figure 37.—Screen hydraulics.

velocity component, V_s, that is parallel to the screen face. The component normal to the screen face V_a, is that part of the channel velocity that draws fish and debris to the screen surface. The component parallel to the screen face, V_s, is that part of the channel velocity that directs fish and debris along the screen

Approach velocity, $V_a = V_c (\sin \theta)$
Sweeping Velocity, $V_s = V_c (\cos \theta)$
Where: V_c = channel resultant velocity and,
θ = Angle between screen face and channel flow line

Computed approach velocity vectors are based on the total flow passing through the screen divided by the effective wetted screen cross-sectional area. This is measured from the top of the screen or water surface (whichever is less) down to the bottom of the screen material and excludes the screen face area blocked-out by structural support members. The total submerged screen area required, A (effective wetted screen cross-sectional area), will be based on the maximum allowable screen approach velocity, V_a, from the resource agencies, and the maximum design flow, Q, diverted through the screens. This required effective area can be calculated by dividing the maximum diverted flow by the allowable approach velocity:

$$A = Q/V_a$$

To account for area lost to the submerged structural components (e.g., guides and support frame), the calculated effective screen area, A, should be increased by a factor of 5 to 10 percent.

Knowing the minimum operating water depth, D_{min}, at the design flow, and the calculated total effective (submerged) screen area, A, based on allowed approach velocity and diversion flow; the required overall screen length, L, can be determined by dividing the effective area by the depth [$L = A/D_{min.}$]. In the event the diverted flow changes with water depth, a complete range of calculations may need to be evaluated to determine the maximum required screen length. The quantity and the length of the individual screens can then be determined. The length of individual fish screens should be based, in part, on the requirements of the screen guides which need to carry the loadings into the structure and/or supports and, in part, on the handling and transporting requirements of the screens.

The ability of fish to avoid impingement on a screen depends on species, size, physical condition, and stamina. Physical condition and stamina can vary widely with water quality and exposure to stressors. Therefore, fish screens must be designed to protect fish from entrainment or impingement under less than perfect conditions. Specific velocity design criteria are available for juvenile salmon; however, few criteria are available for other fish species and sizes. Salmon criteria are discussed in more detail in attachment A; however, it should be recognized that it is appropriate to establish criteria based on the specific fish species and fish sizes for which the screen is being designed.

b. Screen approach velocity

The fishery resource agencies define the screen approach velocity, V_a, as the local channel velocity component vector perpendicular to the face of the screen, measured approximately 3 inches in front of the screen face.

At this time, the maximum permissible approach velocities in California range from 0.33 to 0.4 ft/s for salmonid fry, depending on the screen structure placement, and 0.8 ft/s for salmonid fingerlings (attachment A and table 4). Screen approach velocities as low as 0.2 ft/s are required for screens in California that exclude Delta Smelt. Likewise, the NOAA Fisheries Northwest Region requires that approach velocities not exceed 0.4 ft/s if salmonid fry are present and 0.8 ft/s if fish no smaller than salmonid fingerlings are present (attachment A).

Efforts should be made to generate uniform screen approach velocities on the screen face to eliminate local high velocity hot-spots that might exaggerate fish impingement, fish injury, and debris accumulation. There are several design approaches that can be used to generate uniform screen approach velocities.

These alternative approaches are discussed in more detail in chapter IV.A.4 of this document. NMFS (NOAA Fisheries) juvenile fish screen criteria for screen approach velocity uniformity (see attachment A.1, NMFS 1995, item B.4) states:

> The screen design must provide for uniform flow distribution over the screen surface, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of screens, unless it can be shown unequivocally (such as with a physical hydraulic model study) that localized areas of high velocity can be avoided at all flows.

c. Sweeping velocities

Sweeping velocity is important for achieving good fish guidance and movement of debris past screens. NOAA Fisheries requires a sweeping velocity, V_s, that is equal to or greater than the screen approach velocity, V_a. Following NOAA Fisheries criteria, a screen can be oriented at angles up to 45 degrees to the flow. Other fishery resource agencies criteria may differ. Some State fishery resource agencies require a sweeping velocity of at least twice the approach velocity, which corresponds to a maximum screen angle of 26 degrees to the flow.

When screens are oriented normal to the channel, no sweeping flow is produced to guide fish to a bypass. Instead, fish hold in front of the screen. Therefore, screens are set at an angle to the flow with the objectives of reducing hydraulic forces that would impinge fish against the screen face and establishing a sweeping flow that effectively guides fish along the length of the screen and to the bypass. To allow for unimpeded flow of water parallel to the screen face, the screen support structure should be designed flush with any adjacent screen bay, piers, or walls.

The fish screen structure should be located in the channel where the flow distribution approaching the facility is uniform and well directed. For in-canal sites, the upstream canal section should be straight for at least 40 times the canal flow depths. With in-river, in-diversion pool, and closed conduit siting; the influence of the structure and boundary configurations on the approach flow field must be evaluated. For more complex sites, laboratory physical scale modeling may be required to site the screen and develop acceptable velocity flow fields.

d. Sweeping/approach velocity ratio

The ratio of V_s/V_a affects how debris passes a screen. Generally, higher ratios of V_s/V_a shed debris better than low ratios. The following guidelines were developed from flume tests at Reclamation's Water Resources Research Laboratory using pond weeds passed in front of flat- plate screens. Screens made of profile bar (wedge wire) and punch plate (perforated plate) materials were tested and performed similarly.

$V_s/V_a < 5$, High debris impingement on the screen.
$5 < V_s/V_a < 10$, Moderate to low debris impingement on the screen.
$V_s/V_a > 15$, Very low debris impingement on the screen.

A high degree of debris impingement on the screen is desirable when removal of debris from the flow is an objective. For example, minimizing the debris passing into a bypass is important when designs require long fish bypasses or contain secondary dewatering screens. Screens used at low V_s/V_a ratios to capture debris are typically traveling screens and drum screens

The middle range of V_s/V_a is the most commonly used for screen designs. Sweeping to approach velocity ratios between 5 and 10 generally result in a high percentage of the debris being carried or "rolled" along the screen. Most types of debris that becomes impinged is easily dislodged by common screen cleaning techniques.

Sweeping to approach velocity ratios greater than 15 yields a strong hydraulic cleaning component. These screens can operate for longer periods with minimal cleaning required. However, screen cleaning devices are recommended for high V_s/V_a screens and are generally required by fishery resource agencies.

Designing a screen with the V_s/V_a ratio as a design objective may require expanding or contracting the channel width (or depth) to change V_s and/or increasing the screen area to reduce V_a. Many small diversion screens are designed with an approach velocity less than that required by fish criteria to increase the V_s/V_a ratio and, therefore, reduce cleaning problems. Reclamation field and laboratory experience leads to a guideline of keeping V_a less than 0.5 ft/s when considering debris content. Screens designed to operate in a high sweeping flow are generally aligned at shallow angles or parallel to the channel flow to limit the component of channel velocity directed at the screen, V_a. For example, based on geometry, a screen designed for a maximum approach velocity of 0.4 ft/s in a channel flowing at 2.0 ft/s should, ideally, be angled into the flow 11.5 degrees ($\sin 11.5° = .4/2.0$). In practice, screen angles greater than or less than the geometrically ideal angle can be used.

In general, the flatter the screen angle (lower V_s/V_a ratio) the greater flow uniformity at the fish screen, higher debris impingement, and lower fish bypass flow required. Conversely the steeper the screen angle to the flow the less predation, fish holding, fish exposure time and debris fouling, figure 37b.

6. Uniform Flow Distribution on Screen Surface

Flow passes through the screen because of head (water level differentials) across the screen. These differentials are typically not uniform over an entire screen

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