National Marine Fisheries Service
Southwest Region

Fish Screening Criteria for Anadromous Salmonids

January 1997

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[1] Adapted from NMFS, Northwest Region

I. General Considerations

This document provides guidelines and criteria for functional designs of downstream migrant fish passage facilities at hydroelectric, irrigation, and other water withdrawal projects. It is promulgated by the National Marine Fisheries Service (NMFS), Southwest Region as a result of its authority and responsibility for prescribing fishways under the Endangered Species Act (ESA), the Federal Power Act, administered by the Federal Energy Regulatory Commission (FERC), and the Fish and Wildlife Coordination Act (FWCA), administered by the U.S. Fish & Wildlife Service.

The guidelines and criteria are general in nature. There may be cases where site constraints or extenuating circumstances dictate a waiver or modification of one or more of these criteria. Conversely, where there is an opportunity to protect fish, site-specific criteria may be added. Variances from established criteria will be considered on a project-by-project basis.

The swimming ability of fish is a primary consideration in designing a fish screen facility. Research shows that swimming ability varies depending on multiple factors relating to fish physiology, biology, and the aquatic environment. These factors include: species, physiological development, duration of swimming time required, behavioral aspects, physical condition, water quality, temperature, lighting conditions, and many others. Since conditions affecting swimming ability are variable and complex, screen criteria must be expressed in general terms and the specifics of any screen design must address on-site conditions.

NMFS may require project sponsors to investigate site-specific variables critical to the fish screen system design. This investigation may include fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage-discharge relationships, seasonal operations, sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other pertinent information. The size of salmonids present at a potential screen site usually is not known, and can change from year-to-year based on flow and temperature conditions. Thus, adequate data to describe the size-time relationship requires substantial sampling over a number of years. NMFS will normally assume that fry-sized salmonids are present at all sites unless adequate biological investigation proves otherwise. The burden of proof is the responsibility of the owner of the screen facility.

New facilities which propose to utilize unproven fish protection technology frequently require:

1) development of a biological basis for the concept;
2) demonstration of favorable behavioral responses in a laboratory setting;
3) an acceptable plan for evaluating the prototype installation;
4) an acceptable alternate plan should the prototype not adequately protect fish.

Additional information can be found in *Experimental Fish Guidance Devices*, position statement of the National Marine Fisheries Service, Southwest Region, January 1994.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other than salmonids, NMFS will generally defer to the more conservative criteria.

General screen criteria and procedural guidelines are provided below. Specific exceptions to these criteria occur in the design of small screen systems (less than 40 cubic feet per second) and certain small pump intakes. These exceptions are listed in Section K, Modified Criteria for Small Screens, and in the separate addendum entitled: Juvenile Fish Screen Criteria For Pump Intakes, National Marine Fisheries Service, Portland, Oregon, May 9, 1996.

II. General Procedural Guidelines

For projects where NMFS has jurisdiction, such as FERC license applications and ESA consultations, a functional design must be developed as part of the application or consultation. These designs must reflect NMFS design criteria and be acceptable to NMFS. Acceptable designs typically define type, location, method of operation, and other important characteristics of the fish screen facility. Design drawings should show structural dimensions in plan, elevation, and cross-sectional views, along with important component details. Hydraulic information should include: hydraulic capacity, expected water surface elevations, and flows through various areas of the structures. Documentation of relevant hydrologic information is required. Types of materials must be identified where they will directly affect fish. A plan for operations and maintenance procedures should be included- i.e., preventive and corrective maintenance procedures, inspections and reporting requirements, maintenance logs, etc.- particularly with respect to debris, screen cleaning, and sedimentation issues. The final detailed design shall be based on the functional design, unless changes are agreed to by NMFS.

All juvenile passage facilities shall be designed to function properly through the full range of hydraulic conditions expected at a particular project site during fish migration periods, and shall account for debris and sedimentation conditions which may occur.

III. Screen Criteria for Juvenile Salmonids

A. Structure Placement

1. General:

The screened intake shall be designed to withdraw water from the most appropriate elevation, considering juvenile fish attraction, appropriate water temperature control downstream or a combination thereof. The design must accommodate the expected range of water surface elevations.

For on-river screens, it is preferable to keep the fish in the main channel rather than put them through intermediate screen bypasses. NMFS decides whether to require intermediate bypasses for on-river, straight profile screens by considering the biological and hydraulic conditions existing at each individual project site.

2. Streams and Rivers:

Where physically practical, the screen shall be constructed at the diversion entrance. The screen face should be generally parallel to river flow and aligned with the adjacent bankline. A smooth transition between the bankline and the screen structure is important to minimize eddies and undesirable flow patterns in the vicinity of the screen. If trash racks are used, sufficient hydraulic gradient is required to route juvenile fish from between the trashrack and screens to safety. Physical factors that may preclude screen construction at the diversion entrance include excess river gradient, potential for damage by large debris, and potential for heavy sedimentation. Large stream-side installations may require intermediate bypasses along the screen face to prevent excessive exposure time. The need for intermediate bypasses shall be decided on a case-by-case basis.

2. Canals:

Where installation of fish screens at the diversion entrance is undesirable or impractical, the screens may be installed at a suitable location downstream of the canal entrance. All screens downstream of the diversion entrance shall provide an effective juvenile bypass system- designed to collect juvenile fish and safely transport them back to the river with minimum delay. The angle of the screen to flow should be adequate to effectively guide fish to the bypass. Juvenile bypass systems are part of the overall screen system and must be accepted by NMFS.

3. Lakes, Reservoirs, and Tidal Areas:

a. Where possible, intakes should be located off shore to minimize fish contact with the facility. Water velocity from any direction toward the screen shall not exceed the allowable approach velocity. Where possible, locate intakes where sufficient sweeping velocity exists. This minimizes sediment accumulation in and around the screen, facilitates debris removal, and encourages fish movement away from the screen face.

b. If a screened intake is used to route fish past a dam, the intake shall be designed to withdraw water from the most appropriate elevation in order to provide the best juvenile fish attraction to the bypass channel as well as to achieve appropriate water temperature control downstream. The entire range of forebay fluctuations shall be accommodated by the design, unless otherwise approved by NMFS.

B. Approach Velocity

Definition: *Approach Velocity* is the water velocity vector component perpendicular to the screen face.

Approach velocity shall be measured approximately three inches in front of the screen surface.

1. Fry Criteria - less than 2.36 inches {60 millimeters (mm)} in length.

If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply:

Design approach velocity shall not exceed-

Streams and Rivers:	0.33 feet per second
Canals:	0.40 feet per second
Lakes, Reservoirs, Tidal:	0.33 feet per second (salmonids) [2]

2. Fingerling Criteria - 2.36 inches {60 mm} and longer

If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply:

Design approach velocity shall not exceed -
All locations: 0.8 feet per second

[2] Other species may require different approach velocity standards, e.g.- in California, the U.S. Fish & Wildlife Service requires 0.2 fps approach velocity where delta smelt are present in the tidal areas of the San Francisco Bay estuary.

3. The *total submerged screen area required* (excluding area of structural components) is calculated by dividing the maximum diverted flow by the allowable approach velocity. (Also see Section K, Modified Criteria for Small Screens, part 1).

4. The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of the 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 Velocity

Definition: *Sweeping Velocity* is the water velocity vector component parallel and adjacent to the screen face.

1. Sweeping Velocity shall be greater than approach velocity. For canal installations, this is accomplished by angling screen face less than 45° relative to flow (see Section K, Modified Criteria for Small Screens). This angle may be dictated by specific canal geometry, or hydraulic and sediment conditions.

D. Screen Face Material

1. Fry criteria

If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply for screen material:

a. Perforated plate: screen openings shall not exceed 3/32 inches (2.38 mm), measured in diameter.

b. Profile bar: screen openings shall not exceed 0.0689 inches (1.75 mm) in width.

c. Woven wire: screen openings shall not exceed 3/32 inches (2.38 mm), measured diagonally. (e.g.: 6-14 mesh)

d. Screen material shall provide a minimum of 27% open area.

2. Fingerling Criteria

If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply for screen material:

a. Perforated plate: Screen openings shall not exceed 1/4 inch (6.35 mm) in diameter.

b. Profile bar: screen openings shall not exceed 1/4 inch (6.35 mm) in width

c. Woven wire: Screen openings shall not exceed 1/4 inch (6.35 mm) in the narrow direction

d. Screen material shall provide a minimum of 40% open area.

3. The screen material shall be corrosion resistant and sufficiently durable to maintain a smooth and uniform surface with long term use.

E. Civil Works and Structural Features

1. The face of all screen surfaces shall be placed flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face and ready access to bypass routes.

2. Structural features shall be provided to protect the integrity of the fish screens from large debris. Trash racks, log booms, sediment sluices, or other measures may be needed. A reliable on-going preventive maintenance and repair program is necessary to ensure facilities are kept free of debris and the screen mesh, seals, drive units, and other components are functioning correctly.

3. Screens located in canals - surfaces shall be constructed at an angle to the approaching flow, with the downstream end terminating at the bypass system entrance.

4. The civil works design shall attempt to eliminate undesirable hydraulic effects (e.g.- eddies, stagnant flow zones) that may delay or injure fish, or provide predator opportunities. Upstream training wall(s), or some acceptable variation thereof, shall be utilized to control hydraulic conditions and define the angle of flow to the screen face. Large facilities may require hydraulic monitoring to identify and correct areas of concern.

F. Juvenile Bypass System Layout

Juvenile bypass systems are water channels which transport juvenile fish from the face of a screen to a relatively safe location in the main migratory route of the river or stream. Juvenile bypass systems are necessary for screens located in canals because anadromous fish must be routed back to their main migratory route. For other screen locations and configurations, NMFS accepts the

option which, in its judgement, provides the highest degree of fish protection given existing site and project constraints.

1. The screen and bypass shall work in tandem to move out-migrating salmonids (including adults) to the bypass outfall with minimum injury or delay. Bypass entrance(s) shall be designed such that out-migrants can easily locate and enter them. Screens installed in canal diversions shall be constructed with the downstream end of the screen terminating at a bypass entrance. Multiple bypass entrances (intermediate bypasses) shall be employed if the sweeping velocity will not move fish to the bypass within 60 seconds [3] assuming the fish are transported at this velocity. Exceptions will be made for sites without satisfactory hydraulic conditions, or for screens built on river banks with satisfactory river conditions.

2. All components of the bypass system, from entrance to outfall, shall be of sufficient hydraulic capacity to minimize the potential for debris blockage.

3. To improve bypass collection efficiency for a single bank of vertically oriented screens, a bypass training wall may be located at an angle to the screens.

4. In cases where insufficient flow is available to satisfy hydraulic requirements at the main bypass entrance(s), a *secondary screen* may be required. Located in the main screen's bypass channel, a secondary screen allows the prescribed bypass flow to be used to effectively attract fish into the bypass entrance(s) while allowing all but a reduced residual bypass flow to be routed back (by pump or gravity) for the primary diversion use. The residual bypass flow (not passing through the secondary screen) then conveys fish to the bypass outfall location or other destination.

5. Access is required at locations in the bypass system where debris accumulation may occur.

6. The screen civil works floor shall allow fish to be routed to the river safely in the event the canal is dewatered. This may entail a sumped drain with a small gate and drain pipe, or similar provisions.

G. Bypass Entrance

1. Each bypass entrance shall be provided with independent flow control, acceptable to NMFS.

2. Bypass entrance velocity must equal or exceed the maximum velocity vector resultant along the screen, upstream of the entrance. A gradual and efficient acceleration into the bypass is required to minimize delay of out-migrants.

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[3] In California, 60 second exposure time applies to screens in canals, using a 0.4 fps approach velocity. Where more conservative approach velocities are used, longer exposure times may be approved on a case-by-case basis, and exceptions to established criteria shall be treated as variances.

3. Ambient lighting conditions are required from the bypass entrance to the bypass flow control.

4. The bypass entrance must extend from floor to water surface.

H. Bypass Conduit Design

1. Smooth interior pipe surfaces and conduit joints shall be required to minimize turbulence, debris accumulation, and the risk of injury to juvenile fish. Surface smoothness must be acceptable to the NMFS.

2. Fish shall not free-fall within a confined shaft in a bypass system.

3. Fish shall not be pumped within the bypass system.

4. Pressure in the bypass pipe pipe shall be equal to or above atmospheric pressure.

5. Extreme bends shall be avoided in the pipe layout to avoid excessive physical contact between small fish and hard surfaces and to minimize debris clogging . Bypass pipe centerline radius of curvature (R/D) shall be 5 or greater. Greater R/D may be required for supercritical velocities.

6. Bypass pipes or open channels shall be designed to minimize debris clogging and sediment deposition and to facilitate cleaning. Pipe diameter shall be 24 inches (0.610 m) or greater and pipe velocity shall be 2.0 fps (0.610 mps) or greater, unless otherwise approved by NMFS. (See *Modified Criteria for Small Screens*) for the entire operational range.

7. No closure valves are allowed within bypass pipes.

8. Depth of flow in a bypass conduit shall be 0.75 ft. (0.23 m) or greater, unless otherwise authorized by NMFS (See Modified Criteria for Small Screens).

9. Bypass system sampling stations shall not impair normal operation of the screen facility.

10. No hydraulic jumps should exist within the bypass system.

I. Bypass Outfall

1. Ambient river velocities at bypass outfalls should be greater than 4.0 fps (1.2 mps), or as close as obtainable.

2. Bypass outfalls shall be located and designed to minimize avian and aquatic predation in areas free of eddies, reverse flow, or known predator habitat.

3. Bypass outfalls shall be located where there is sufficient depth (depending on the impact velocity and quantity of bypass flow) to avoid fish injuries at all river and bypass flows.

4. Impact velocity (including vertical and horizontal components) shall not exceed 25.0 fps (7.6 mps).

5. Bypass outfall discharges shall be designed to avoid adult attraction or jumping injuries.

J. Operations and Maintenance

1. Fish Screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NMFS. Proven cleaning technologies are preferred.

2. Open channel intakes shall include a trash rack in the screen facility design which shall be kept free of debris. In certain cases, a satisfactory profile bar screen design can substitute for a trash rack.

3. The head differential to trigger screen cleaning for intermittent type systems shall be a maximum of 0.1 feet (.03 m), unless otherwise agreed to by NMFS.

4. The completed screen and bypass facility shall be made available for inspection by NMFS, to verify compliance with design and operational criteria.

5. Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved.

K. Modified Criteria for Small Screens (Diversion Flow less than 40 cfs)

The following criteria vary from the standard screen criteria listed above. These criteria specifically apply to lower flow, surface-oriented screens (e.g.- small rotating drum screens). Forty cfs is the approximate cut off; however, some smaller diversions may be required to apply the general criteria listed above, while some larger diversions may be allowed to use the "small screen" criteria below. NMFS will decide on a case-by-case basis depending on site constraints.

1. The required screen area is a function of the approach velocity listed in Section B, Approach Velocity, Parts 1, 2, and 3 above. Note that "maximum" refers to the greatest flow diverted, not necessarily the water right.

2. Screen Orientation:

   a. For screen lengths six feet or less, screen orientation may be angled perpendicular to the flow.

b. For screen lengths greater than six feet, screen-to-flow angle must be less than 45 degrees. (See Section C Sweeping Velocity, part 1).

c. For drum screens, design submergence shall be 75% of drum diameter. Submergence shall not exceed 85%, nor be less than 65% of drum diameter.

d. Minimum bypass pipe diameter shall be 10 in (25.4 cm), unless otherwise approved by NMFS.

e. Minimum pipe depth is 1.8 in (4.6 cm) and is controlled by designing the pipe gradient for minimum bypass flow.

Questions concerning this document can be directed to NMFS Hydraulic Engineering Staff at:

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Adopted,

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Authorizing Signature: