11. FISH SCREEN AND BYPASS FACILITIES

11.1 Introduction – Fish Screen and Bypass Facilities

This section provides criteria and guidelines to be used in the development of designs of downstream migrant fish screen facilities for hydroelectric, irrigation, and other water withdrawal projects. The design guidance provided in this section applies to *fishway* designs after a decision to provide a passage facility has been made. Unless directly specified herein, this guidance is not intended for use in evaluation of existing facilities, nor does it provide guidance on the application of the design for any particular site. Sections 1, 2, 3, and the Foreword of this document also apply to the guidelines and criteria listed in this section.

In designing an effective fish screen facility, the swimming ability of the fish is a primary consideration. Research has shown that swimming ability of fish varies and may depend upon a number of factors relating to the physiology of the fish, including species, size, duration of swimming time required, behavioral aspects, migrational stage, physical condition and others, in addition to water quality parameters such as dissolved oxygen concentrations, water temperature, lighting conditions, and others. For this reason, screen criteria must be expressed in general terms.

Several categories of screen designs are in use but are still considered as experimental technology by NMFS. These include Eicher screens, modular inclined screens, coanda screens, and horizontal screens. The process to evaluate experimental technology is described in Section 16. Several of these experimental screen types have completed part or all of the experimental technology process, and may be used in specific instances when site conditions allow. Design of these screens, or new conceptual types of experimental screens, may be developed through discussions with NMFS engineers on a case-by-case basis.

Criteria are specific standards for fishway design, maintenance, or operation that cannot be changed without a written waiver from NMFS. For the purposes of this document, a criterion is preceded by the word “must.” In general, a specific criterion can not be changed unless there is site-specific biological rationale for doing so. An example of biological rationale that could lead to criterion waiver is a determination or confirmation by NMFS biologists that the smallest fry-sized fish will likely not be present at a proposed screen site. Therefore, the juvenile fish screen approach velocity criterion of 0.4 ft/s could be increased to match the smallest life stage expected at the screen site. A guideline is a range of values or a specific value for fishway design, maintenance or operation that may change when site-specific conditions are factored into the conceptual fishway design. For the purposes of this document guidelines are preceded by the word “should.” Guidelines should be followed in the fishway design until site-specific information indicates that a different value would provide better fish passage conditions or solve site-specific issues. An example of site-specific rationale that could lead to a modified guideline is when the maximum river depth at a site is 3 feet, as compared to the design guideline for a fishway entrance depth of 6 feet. In this example, safe and timely fish passage could be provided by modifying the guideline to match the depth in the river. It is the responsibility of the applicant to provide compelling evidence in support of any proposed waiver of criteria or modification of a guideline for NMFS approval early in the design process, well in advance of a proposed Federal action. After a decision to provide passage at a particular site has been made, the following design criteria and guidelines are applicable, in addition to those described throughout Section 3.

11.2 Functional Screen Design

A *functional screen design* should be developed that defines type, location, size, hydraulic capacity, method of operation, and other pertinent juvenile fish screen facility characteristics. In the case of applications to be submitted to FERC and for consultations under the ESA, a *functional design* for juvenile (and adult) fish passage facilities must be developed and submitted as part of the FERC License Application or as part of the Biological Assessment for the facility. It must reflect NMFS input and design criteria and be acceptable to NMFS. *Functional design* drawings must show all pertinent hydraulic information, including water surface elevations and flows through various areas of the structures. *Functional design* drawings must show general structural sizes, cross-sectional shapes, and elevations. Types of materials must be identified where they may directly affect fish. The final detailed design must be based on the *functional design*, unless changes are agreed to by NMFS.

11.3 Site Conditions

To minimize risks to anadromous fish at some locations, NMFS may require investigation (by the project sponsors) of important and poorly defined site-specific variables that are deemed critical to development of the screen and bypass design. This investigation may include factors such as fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage/flow relationships, seasonal operational variability, potential for sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other information. The life stage and size of juvenile salmonids present at a potential screen site usually is not known, and may change from year to year based on flow and temperature conditions. Thus, adequate data to describe the size-time relationship requires substantial sampling efforts over a number of years. For the purpose of designing juvenile fish screens, NMFS will assume that *fry*-sized salmonids and low water temperatures are present at all sites and apply the appropriate criteria listed below, unless adequate biological investigation proves otherwise. The burden-of-proof is the responsibility of the owner of the diversion facility.

11.4 Existing Screens

11.4.1 Acceptance Criteria and Guidelines for Existing Screens

If a fish screen was constructed prior the establishment of these criteria, but constructed to NMFS criteria established August 21, 1989, or later, approval of these screens may be considered providing that all six of the following conditions are met:

11.4.1.1 The entire screen facility must function as designed.

11.4.1.2 The entire screen facility has been maintained and is in good working condition.

11.4.1.3 When the *screen material* wears out, it must be replaced with *screen material* meeting the current criterion stated in this document. To comply with this condition, structural modifications may be required to retrofit an existing facility with new *screen material.*

11.4.1.4 No mortality, injury, entrainment, impingement, migrational delay, or other harm to anadromous fish has been noted that is being caused by the facility;

11.4.1.5 No emergent *fry* are likely to be located in the vicinity of the screen, as agreed to by NMFS biologists familiar with the site.

11.4.1.6 When biological uncertainty exists, access to the diversion site by NMFS is permitted by the diverter for verification of the above criteria.

11.5 Structure Placement

11.5.1 Specific Criteria and Guidelines – Structure Placement: Streams and Rivers

11.5.1.1 Instream Installation: Where physically practical and biologically desirable, the screen should be constructed at the point of diversion with the screen face generally parallel to river flow. However, physical factors may preclude screen construction at the diversion entrance. Among these factors are excess river gradient, potential for damage by large debris, access for maintenance, operation and repair, and potential for heavy sedimentation. For screens constructed at the bankline, the screen face must be aligned with the adjacent bankline and the bankline must be shaped to smoothly match the face of the screen structure to minimize turbulence and eddying in front, upstream, and downstream of the screen. Adverse alterations to riverine habitat must be minimized.

11.5.1.2 Canal Installation: Where installation of fish screens at the diversion entrance is not desirable or impractical, the screens may be installed in the canal downstream of the entrance at a suitable location. All screens installed downstream from the diversion entrance must be provided with an effective *bypass system*, as described in Sections 11.9 through 11.12, designed to collect and transport fish safely back to the river with minimum delay. The screen location must be chosen to minimize the effects of the diversion on instream flows by placing the bypass outfall as close as biologically feasible (i.e., considering minimizing length and optimizing the hydraulics of the bypass pipe) and practically feasible to the point of diversion.

11.5.1.3 Functionality: All screen facilities must be designed to function properly through the full range of stream hydraulic conditions as defined in Section 3 and in the diversion conveyance, and must account for debris and sedimentation conditions which may occur.

11.5.2 Specific Criteria and Guidelines – Structure Placement: Lakes, Reservoirs, and Tidal Areas

11.5.2.1 Intake Locations: Intakes must be located offshore where feasible to minimize fish contact with the facility. When possible, intakes must be located in areas with sufficient ambient velocity to minimize sediment accumulation in or around the screen and to facilitate debris removal and fish movement away from the screen face. Intakes in reservoirs should be as deep as practical, to reduce the numbers of juvenile salmonids that encounter the intake.

11.5.2.2 Surface Outlets: If a reservoir outlet is used to pass fish from a reservoir, the intake must be designed to withdraw water from the most appropriate elevation based on providing the best juvenile fish attraction and appropriate water temperature control downstream of the project. The entire range of *forebay* fluctuation must be accommodated in design. Since surface outlet designs must consider a wide spectrum of site-specific hydraulic and fish behavioral conditions, NMFS engineers and biologists must be involved in developing an acceptable conceptual design for any surface outlet fish passage system before the design proceeds.

11.6 Screen Hydraulics – Rotating Drum Screens, Vertical Screens, and Inclined Screens

11.6.1 Specific Criteria and Guidelines – Screen Hydraulics

11.6.1.1 Approach Velocity: The *approach velocity* must not exceed 0.40 ft/s for *active screens*, or 0.20 ft/s for *passive screens*. Using these approach velocities will minimize screen contact and/or impingement of juvenile fish. For screen design, *approach velocity* is calculated by dividing the maximum screened flow amount by the vertical projection of the *effective screen area*. An exception may be made to this definition of *approach velocity* for screen where a clear egress route minimizes the potential for impingement. If this exception is approved be NMFS, the *approach velocity* is calculated using the entire *effective screen area*, and not a vertical projection. For measurement of approach velocity, see Section 15.2.

11.6.1.2 Effective Screen Area: The minimum *effective screen area* must be calculated by dividing the maximum screened flow by the allowable *approach velocity*.

11.6.1.3 Submergence: For rotating drum screens, the design submergence must not exceed 85%, nor be less than 65% of drum diameter. Submergence over 85% of the screen diameter increases the possibility of entrainment over the top of the screen (if entirely submerged), and increases the chance for impingement with subsequent entrainment if fish are caught in the narrow wedge of water above the 85% submergence mark. Submerging rotating drum screens less than 65% may reduce the self-cleaning capability of the screen. In many cases, stop logs may be installed downstream of the screens to achieve proper submergence. If stop logs are used, they should be located at least two drum diameters downstream of the back of the drum.

11.6.1.4 Flow Distribution: The screen design must provide for nearly uniform flow distribution (see Section 15.2) over the screen surface, thereby minimizing *approach velocity* over the entire screen face. The screen designer must show how uniform flow distribution is to be achieved. Providing adjustable *porosity* control on the downstream side of screens, and/or flow *training wall*s may be required. Large facilities may require hydraulic modeling to identify and correct areas of concern. Uniform flow distribution avoids localized areas of high velocity, which have the potential to impinge fish.

11.6.1.5 Screens Longer Than Six Feet:

- Screens longer than 6 feet must be angled and must have *sweeping velocity* greater than the *approach velocity*. This angle may be dictated by site-specific geometry, hydraulic, and sediment conditions. Optimally, *sweeping velocity* should be at least 0.8 ft/s and less than 3 ft/s.
- For screens longer than 6 feet, *sweeping velocity* must not decrease along the length of the screen.

11.6.1.6 Inclined Screen Face: An inclined screen face must be oriented less than 45° vertically with the screen length (upstream to downstream) oriented parallel to flow, unless the inclined screen is placed in line with riverbank and reasonably matching the slope of the riverbank.

11.6.1.7 Horizontal Screens: Horizontal screens have been evaluated as an experimental technology, and may only be considered if the majority of flow passes over the end of the screen at a minimum depth of 1 foot, and positive downstream *sweeping velocity* in excess of the approach velocity exists for the entire length of screen. Post construction monitoring of the facility must occur. Since site-specific design conditions are required, NMFS engineers must be consulted throughout the development and evaluation of the design.

11.7 Screen Material

11.7.1 Specific Criteria and Guidelines – Screen Material

11.7.1.1 Circular Screens: Circular screen face openings must not exceed $^{3}/_{32}$ inch in diameter. Perforated plate must be smooth to the touch with openings punched through in the direction of approaching flow.

11.7.1.2 Slotted Screens: Slotted screen face openings must not exceed 1.75 mm (approximately $^{1}/_{16}$ inch) in the narrow direction.

11.7.1.3 Square Screens: Square screen face openings must not exceed $^{3}/_{32}$ inch on a diagonal.

11.7.1.4 Material: The *screen material* must be corrosion resistant and sufficiently durable to maintain a smooth uniform surface with long term use.

11.7.1.5 Other Components: Other components of the screen facility (such as seals) must not include gaps greater than the maximum screen opening defined above.

11.7.1.6 Open Area: The percent open area for any *screen material* must be at least 27%.

11.8 Civil Works and Structural Features

11.8.1 Specific Criteria and Guidelines – Civil Works and Structural Features

11.8.1.1 Placement of Screen Surfaces: The face of all screen surfaces must be placed flush (to the extent possible) with any adjacent screen bay, pier noses, and walls to allow fish unimpeded movement parallel to the screen face and ready access to bypass routes.

11.8.1.2 Structural Features: Structural features must be provided to protect the integrity of the fish screens from large debris, and to protect the facility from damage if overtopped by flood flows. A *trash rack*, log boom, sediment sluice, and other measures may be required.

11.8.1.3 Civil Works: The civil works must be designed in a manner that prevents undesirable hydraulic effects (such as eddies and stagnant flow zones) that may delay or injure fish or provide predator habitat or predator access.

11.9 Bypass Facilities

11.9.1 Specific Criteria and Guidelines – Bypass Layout

11.9.1.1 Bypass Location:

- The screen and bypass must work in tandem to move out-migrating salmonids (including downstream migrant adult salmonids such as steelhead *kelts*, if present) to the bypass outfall with a minimum of injury or delay.
- The bypass entrance must be located so that it may easily be located by out-migrants.
- The bypass entrance and all components of the *bypass system* must be of sufficient size and hydraulic capacity to minimize the potential for debris blockage.
- Screens greater than or equal to 6 feet in length must be constructed with the downstream end of the screen terminating at a bypass entrance. Screens less than or equal to 6 feet in length may be constructed perpendicular to flow with a bypass entrance at either or both ends of the screen, or may be constructed at an angle to flow, with the downstream end terminating at the bypass entrance.
- Some screen systems do not require a bypass system. For example, an end of pipe screen located in a river, lake, or reservoir does not require a bypass system because fish are not removed from their habitat. A second example is a river bank screen with sufficient hydraulic conditions to move fish past the screen face.

11.9.1.2 Multiple Entrances: Multiple bypass entrances should be used if the *sweeping velocity* may not move fish to the bypass within 60 seconds, assuming fish are transported along the length of the screen face at a rate equaling *sweeping velocity*.

11.9.1.3 Training Wall: A *training wall* must be located at an angle to the screen face, with the bypass entrance at the apex and downstream-most point. For many facilities, the wall of the civil works opposite to the screen face may serve as a *training wall*. For single or multiple *vee screen* configurations, *training wall*s are not required, unless an intermediate bypass must be used.

11.9.1.4 Secondary Screen: In cases where there is insufficient flow available to satisfy hydraulic requirements at the bypass entrance for the primary screens, a secondary screen may be required within the primary bypass. The secondary *bypass flow* conveys fish to the bypass outfall location or other destination, and returns secondary screened flow for water use.