Interagency Ecological Program's

CALFED
Fish Facility Technical Team

E-009968

CalFed Fish Facilities Planning Team

This is a bit of a participant "wish list". I do not anticipate involvement by all......but agency participation will be necessary.

National Marine Fisheries Service
Marcin Whitman (Southwest Region) - Fish Passage / Hydraulic Engineer
? Chris Mobly (Southwest Region) - Fisheries Biologist

U. S. Fish and Wildlife Service
Mike Thabault (Sacramento Office) - Fisheries Biologist
? Alex Hoar or Boyd Kanard (Conti Lab - Tuner Falls, Mass.) -Fish Facility Researchers
? Ben Rizzo (East Coast) - East Coat authority on Fish Passage on East Coat

Department of Fish and Game
Kevan Urquarhart (Bay/Delta) - Fish Facility Unit - Biologist
Bob Fugimura (Bay/Delta) - Fish Facility Unit - Biologist
Dan Odenweller (Inland Fisheries) - Fisheries Biologist
George Heise (Ecological Services) - Fish Passage Engineer

U. S. Bureau of Reclamation
Ron Brockman's Assistant (Mid Pacific Region) - Civil Engineer ??
Herb Ng (Tracy Office) - Civil Engineer
Charlie Liston (Denver Technical Center) - Fisheries Biologist (Tracy, RBDD, GCID)
Brent Mefford (Denver Hydraulic Lab) - Hydraulic Engineer (GCID, RBDD)

Army Corp. of Engineers

Advisory Panel (Resource people)
Ken Bates (Washington Dept. of Fisheries and Wildlife)
- Chief Fish Passage Engineer, DWR Fish Facility Advisor

Ron Ott (CalFed Consultant) - Fish Facility Engineer
Ned Taft (Alden Research Labs)
- Fisheries Biologist (Fish Passage, Hydropower), DWR Fish Facility Advisor

Chris Katapodis (Canadian Freshwater Institute) - Hydraulics, Adult Fish Passage
Dennis Dorratcague (Montgomery-Watson Engineers) - Engineer on many big Screens
? Perry Johnson (Consultant)
- Hydraulic Engineer Fish Facilities, formerly with the USBR Hydraulic Lab

? Jerry Cox (MWD Consultant) -Civil Engineer, B/D Hydraulics, Institutional Knowledge
Jim Buell (MWD Consultant) - Fisheries Biologist (B/D Issues and Facilities)
Chuck Hanson (HEI) - Fisheries Biologist (B/D Issues and Fish Facilities)
? Elise Holland (Bay Institute)
- Fisheries Biologist, Former OTA researcher for Fish Passage Tech. report

Department of Water Resources / CalFed Staff (and resource people)
Pete Chadwick
Stein Buer - Civil Engineer, CalFed modeling
CalFed EIR/S person
DWR Modeler - Engineer running model for studies
Darryl Hayes - Civil Engineer, Fish Facilities
? Larry Smith - Engineer (institutional Knowledge)
? Jim Snow - Engineer (Operations questions)
Shawn Mayr - Civil Engineer,ESO, RMA-2 modeler
Ted Frink - Fisheries Biologist, ESO
Jeanne Schalleberger - DOE Civil Engineer, Fish Treadmill
Cost Estimator - DOE Engineer (Preliminary Costs)
Design Engineer - DOE Engineer (Drawings, Design)

E-009970

Structure of the Team

Conducted under the auspices of the Interagency Ecological Program's Fish Facilities Development Team. This project (i.e. Fish Facilities Planning for CalFed alternatives) will be a significant team project effort. The FFDT will be co-Chaired by Dan Odenweller, DFG, and Darryl Hayes, DWR. The IEP is under the CalFed umbrella and is considered the major monitoring and special study resource for Bay-Delta issues.

Objective of the Team

To determine the feasibility of designing and operating a major fish screen diversion associated with the development of CalFed Bay-Delta solutions.

The technical team will conceptualize facilities, develop operational measures, raise significant issues associated with the feasibility and implement programs to finalize planning considerations.

The Team will work with CalFed to incorporate comments and assist in the documentation of the Programmatic EIR/EIS through Phases II and III.

Who does the Work?

DWR, DFG, and CalFed staff will likely do the bulk of the work (i.e. documentation, modeling, etc.). Other agencies will review material (study plans, results, designs, models, documentation, etc.) and comment on products. It is very important that agency positions are represented appropriately on the Team throughout the feasibility planning process.

Since many fish facility criteria are the responsibility of the fishery agencies and not the stakeholders per se, some topics and decisions may be discussed outside the larger group.

Involvement on technical studies related to the CalFed Project Work Team effort will continue outside this effort. These may include, Red Bluff Research Pumping Plant studies, the Fish Treadmill studies, Monitoring studies, etc.

How Do Representatives get included in the Process?

CalFed management will seek agency participation in the development of the fish facilities planning. Each agency will determine the level of involvement necessary in the effort........but fish facilities representation will be required. Letters of commitment / MOU's will be sent to each agency and their representative. This by no means should lock them into a project buyin........

Meeting Structure Proposed

Due to the potential involvement of many people (in some way), it may be wise to consider a facilitator when meetings do occur.......

Some meetings have occurred on the Background stuff (Concepts, issues, direction)

Meeting 1
Note: Schedule when Phase II alternatives are fairly well defined (mid November?)
(Read ahead material given)
Status of Alternatives
Phase II Schedule
Review of Past Efforts on PC Feasibility
Review of Background Issues Report
Discussion of Issues of Concern

Meeting 2
Note: Schedule when progress on concepts is fairly well along - (say February?)
(Read ahead material given)
Conceptual Design of Facility (size, layout, etc.)
Criteria used for Facility
- Fish Treadmill Update
- Red Bluff Pumping Studies

Operations Studies - DWRSIM, DSM
Numerical Modeling of Diversion
- Limits of Facility Operation
- Hydraulic flow patterns
- Tidal Operation
- Sedimentation Modeling

Bypass arrangement (Pumps, lengths, etc.)

Meeting 3
Note: Schedule for early May or one month prior to draft CalFed preferred alternative to go out.
(Read Ahead Material)
Finalization of Alternatives Package
Review and discussion of facility comments
Workplan to resolve outstanding Issues

Prescription for Development

Similar Process for most Major Fish Protective Facility Alternatives

- ✔ Conduct Operations Modeling (to define baseline hydraulic conditions)
- ✔ Conceptualize Design Alternatives and Preliminary Costs
- ✔ Develop Biological / Engineering Study Plan to Address Facility Impacts
- ✔ Identify of Biological / Engineering Needs
- ✔ Collect Site Data (Hydraulic, Fisheries, Water Quality, debris, sediment, etc.)
- ✔ Perform 2-D Numerical Modeling of Facility
- ✔ Conduct Physical Modeling Studies
- ✔ Conduct Final Design and Cost Estimates
- ✔ Construct Phased Facility with Interim Evaluation

Factors Influencing the Choice of Screen Facility Types and Site Configurations

NOTE: Items are *NOT* listed in order of importance

- ✔ Range of flow diverted
- ✔ Percent of river flow diverted
- ✔ Sediment loads (bed load and suspended)
- ✔ Debris
- ✔ Biofouling
- ✔ Flooding
- ✔ Season of operation
- ✔ Operational flexibility
- ✔ Fish swimming abilities / Criteria
- ✔ Variations in river hydraulics
- ✔ Security
- ✔ Site characteristics
- ✔ Maintenance
- ✔ Accessibility
- ✔ Navigation restrictions
- ✔ Short and long term riverain habitat degradation
- ✔ Construction considerations
- ✔ Predation potential
- ✔ Local Fishery Resources
- ✔ Fisheries protection
- ✔ Evaluation Facilities
- ✔ Confidence in Technology
- ✔ Capability of Facility to Maintain, Adjust to Changing conditions
- ✔ Reliability of Facility
- ✔ Cost (Capitol Costs, O&M, Replacement)

Common Features of Major "State-of-the-Art" Off-River Fish Screening Facilities

A large screen facility is many times located off the main river channel to improve hydraulic conditions, reduce debris cleaning problems, control sedimentation, allow access or dewatering of the screen facility for routine maintenance and operation, construction purposes, land or right-of-way issues, or for flood control reasons. Locating the screening facility off-river has it's advantages for the above purposes, but also can add to the complexity of the fish handling issues as well as add to facility components. The following discussion pertains primarily to major screening facilities located off river. For further discussion on the design and configuration of the facility, see the GENERAL FISH SCREEN DESIGN CRITERIA Section later.

Intake Facility

The intake facility must be designed to operate under a wide variety of flow, water level and operational scenarios. The major components or features of the intake are listed below:

Surface Debris Deflector - A floating surface skimming trash/fish deflector should be provided to collect and/or deflect surface debris to prevent it from entering the diversion canal. The deflector may have a secondary benefit of deterring some surface swimming fish from entering the intake if the deflector is carefully aligned in the river.

Intake Channel - The length of the intake channel should be sized to provide good hydraulic flow profiles to the screens. The channel should be smooth and well transitioned. Since sedimentation in this channel is of concern, a minimum velocity should be maintained and the channel should allow access for maintenance activities. Structural features should be minimized to reduce predator accumulation areas.

Trashracks - These should be provided upstream of the screens to further reduce the debris (yet pass fish) that can collect on the screens or in the fish bypass system. Vertically oriented steel bars on nine inch centers (or with variable spacings to allow fish passage) with an automatic vertical raking trash cleaner and conveyor for removing debris from the racks is considered necessary.

Trashrack Covers - For purposes of variable operations, good hydraulics, and isolation of screen bays to prevent unwanted sediment deposition or fish behind the trashracks when a screen bay is not being used, covers should be installed on the face of the trashracks.

E-009975

Fish Screen Structure

"V" Configuration Fixed Vertical Screens

Sawtooth or "V" configured vertical fixed plate screens have been most commonly used when the required screen surface area is sufficiently large. The surface area required to maintain approach velocities is achieved by orienting the screens in a sawtooth configuration, with the wide mouth upstream, tapering to a bypass in the relatively narrow downstream portion of the screens. This configuration of the vertical fixed screen is superior to the linear configuration in many respects. The "V" design incorporates a fish guidance concept, which leads fish directly to the bypass, minimizes the time that fish are exposed to the screens before entering the bypass, and decreases the potential for fatigued fish to become impinged on the screens. With the screens angled to the flow, there is less potential for screen clogging because debris is shunted down the screen to the bypass. Because the individual screen reaches are shorter, there is less potential for the materials being resuspended during cleaning operations to be re-entrained on the screens. However, there are two disadvantages to this configuration. First, the potential is greater for sediment and debris to be concentrated in the entrance to the bypass. Second, the narrow configuration at the end of the "V" makes it difficult to design a good cleaning system for that portion of the screen immediately upstream of the bypass entrance.

Another inherent problem with this type of configuration is the differential head loss produced down the sides of the "V", which can result in nonuniform approach velocities. With screens containing several "V"s, channel hydraulics can create a potential for unequal distribution of flow through each "V". Baffles can be used to equalize head loss down the taper of each "V", and equalize approach velocities within the "V". Flow vanes placed upstream of each channel or stoplogs placed downstream of a screen bay can be used to redirect or equalize flow in the approach and exit channels for uniform flow distribution in each "V".

Operating Decks - Decks should be provided to support hoists, vehicles and/or crane systems necessary for installing, removing, and maintenance of the trashracks, covers, stoplogs, bulkheads, fish screens, cleaners and other appurtenances. This deck should be positioned above the flood elevations to secure the facility during any event.

Fish Screens - Based on the excellent field performance and experience of flat plate screen systems and previous research, screens should consist of stainless steel wedgewire panels.

Flow Control Baffles - This feature should be placed immediately behind the screens to regulate velocities over the entire screen surface. They are integral to the proper hydraulic (and biological) performance of the screen due to the variability in the hydraulics at the site.

Screen Cleaning System - The cleaning system could consist of a combination of horizontally moving brushes or water (or air) backwash systems. It should be automatically activated by water head differential or timing.

Hydraulic Sediment Resuspension System - In addition to good hydraulics and maintenance control measures, a system of underwater spray nozzles placed near the facility invert, should be designed to resuspend the sediments that may become trapped or that accumulate on the bottom whereby reducing the efficiency of the facility.

Stoplogs - For dewatering of one or more screen bays for maintenance or modifications, these should be provided.

Fish Pumpback / Bypass Structure

Fish bypass facilities are required by the existing criteria. Besides off-river designs, they may also apply to long flat plate on-river screens if fish exposures are too long.

Fish Bypass - Each of the screen bays should have an independent bypass pipe to return fish and a portion of the diverted water back to the river. Each bypass entrance should be designed to prevent fish from swimming back through the facility. This can be accomplished with either an adjustable weir at the bypass entrance or with high enough velocities at the entrance.

Fish Lift or Pump Facility - To overcome the hydraulic head that must be overcome to return the fish back to the river or into a holding (or "salvage") facility, this feature will be placed within the bypass system. This feature must not damage or delay the passage of fish through the bypass. A discussion of this feature is provided later in the report.

Evaluation / Fish Holding Facility

An evaluation facility consisting of fish holding tanks, recovery tanks, work tables, and etc., will be integral to any fish screen facility. To determine if the screen facility features are performing adequately, the fish sampling facility should be capable of recovering, holding, counting, sorting, etc.) fish from various components of the facility. The facility should be plumbed with both river water and a clear water supply and be capable of connecting to the fish bypass.

Fish Transport / Collection Facilities - Each screen bypass/evaluation facility should provide for the capability of collecting and transporting fish. This would be a mandatory feature when the screen is located in a "dead end" location (such as in the South Delta). It may also be desirable to have this capability at other sites to collect and possibly transport them elsewhere, such as across the Delta or to a grow out facility off site. This could include the need for larger holding facilities, truck loading stations, and additional life support features. Consideration should be given to a fish holding "recovery" area. Fish could then be released at an appropriate time of day or appropriate tidal cycle.

Fish Return Pipeline Outlet Structure

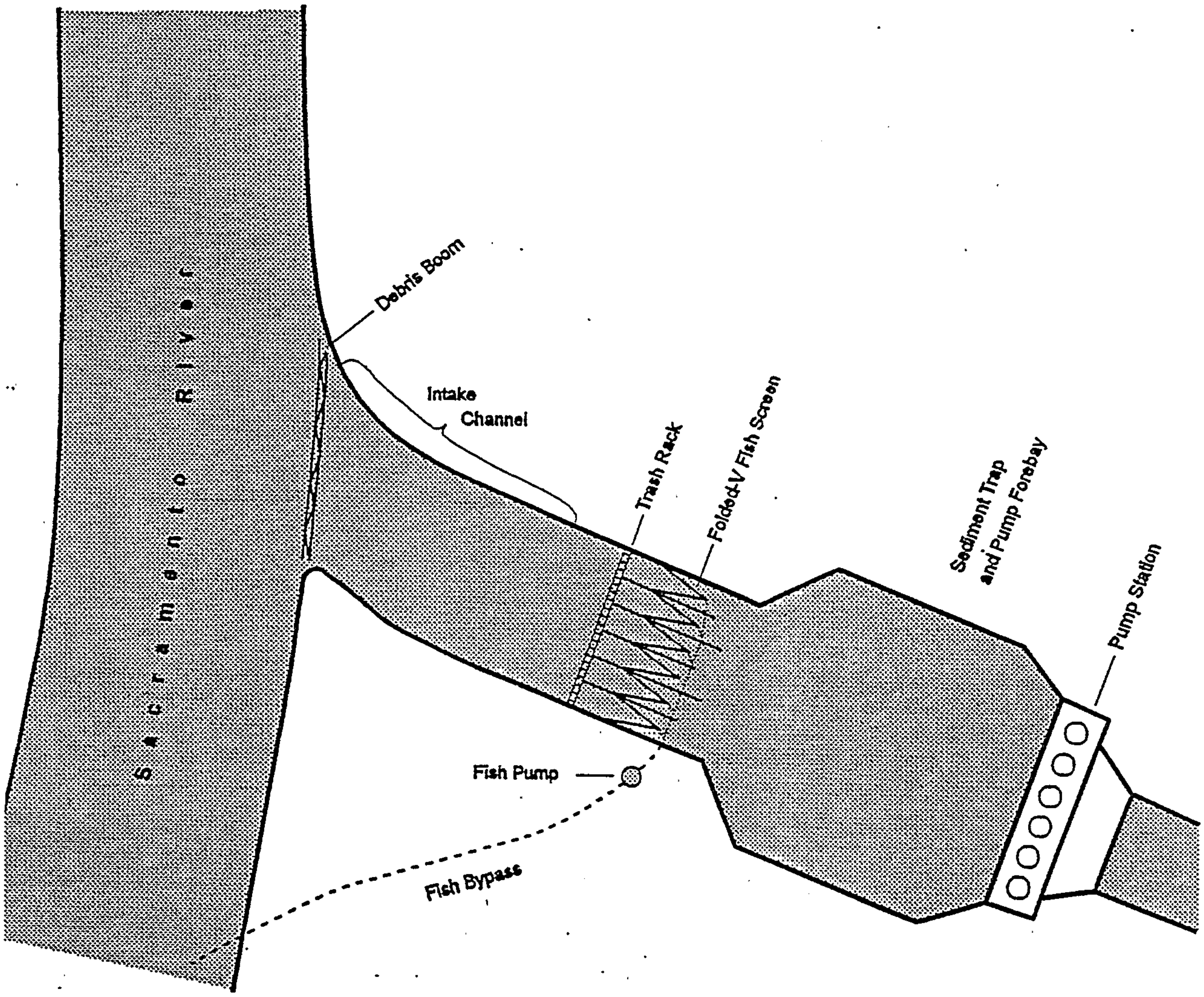
For river releases from a fish bypass, the fish return structure should be located near mid-channel in a deeper, swift moving section of the river downstream of the influence of the intake channel. The outlet structure will transition in shape from a buried round pipe to a submerged outlet structure on the river bottom. The outlet should point downstream, and be parallel to the direction of flow in the river. The outlet velocity from the bypass pipe should be approximately that of the river velocity. The bottom structure should be streamlined to reduce accumulations of predatory fish at the outfall and should be constructed to allow continued navigation in the river.

Upstream Migrant Fish Collection Facility

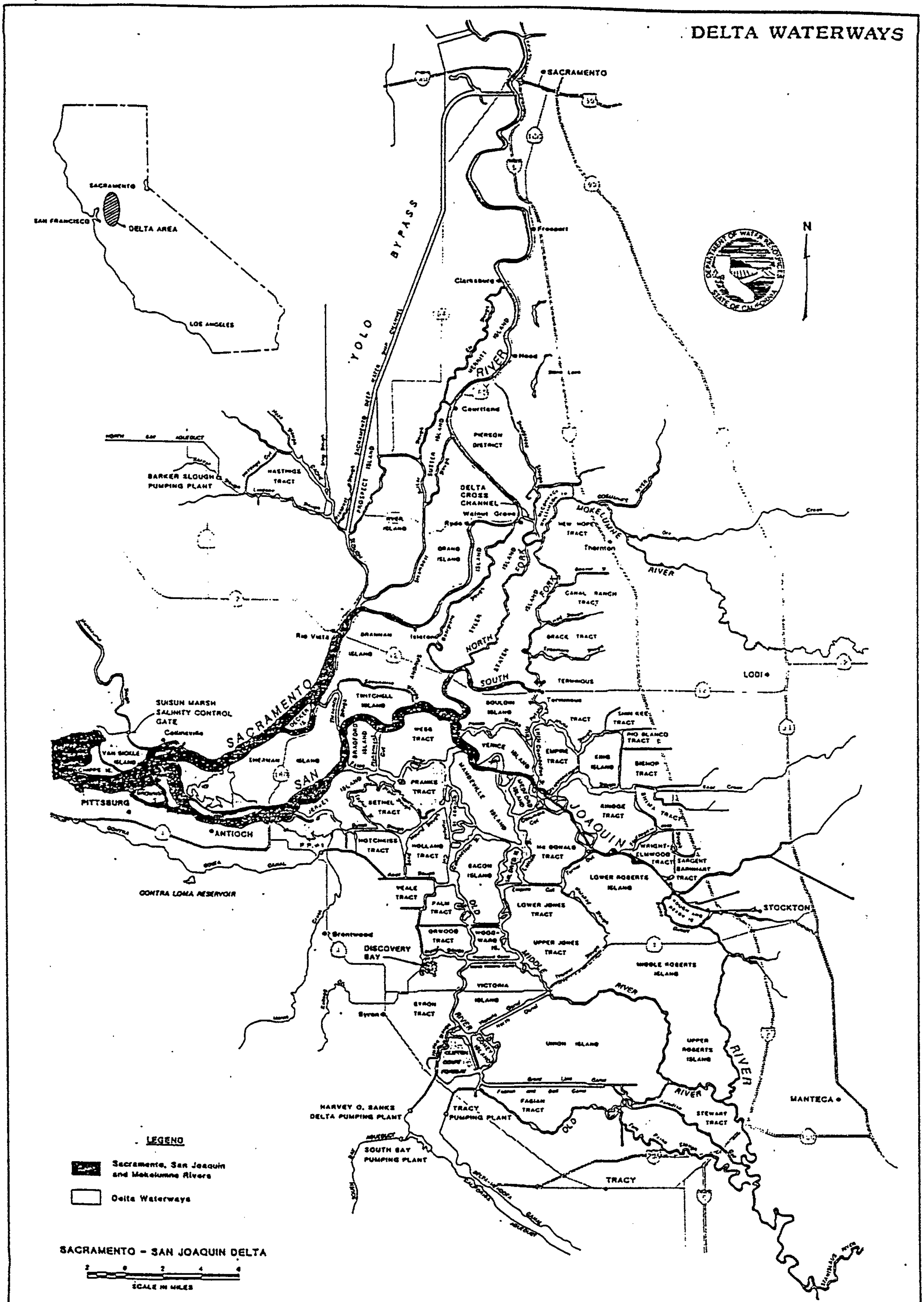
For non-isolated diversion facilities, an upstream migrant fish collection, trapping and transportation facility must be constructed on the downstream side of the screen structure. A fish collection, trapping and transportation facility is integral to the proper operation of an open "Through Delta" water transfer facility. Attraction flows from the Sacramento River could possibly attract several upmigrating fish to the outlet of the pumping plant at the upper end of Snodgrass Slough.

The facility must be designed to attract and collect several species. These would include fish of vastly different sizes and swimming abilities. Fish needing to be collected include chinook salmon, steelhead, striped bass, American shad, green and white sturgeon, longfin smelt and splittail. A "false weir" type fish ladder may not be passable for all species, so a combination of facilities including a fish elevator or lock facility may be the only viable option.

Fish elevators have been used at several dams in the United States for passing striped bass, American shad, salmon and even sturgeon. High velocity flows attract fish into a rectangular channel adjacent to a bar rack which passes the majority of the diverted flow. Periodically, the channel is closed off and a fish crowding device concentrates the fish into a holding pen filled with water. This pen is then sealed off and lifted to a higher level where it mates into an upper water channel. Fish passing into this channel are then sluiced into a another fish collection device, a fish slide passing them over the barrier or into a transport vehicle. If necessary, fish could be sorted and held in large temperature controlled tanks for temporary periods and then transported a short distance and released in the river, upstream of the intake facility, to continue their migration to their respective spawning areas.



Large Off-River (4,000 - 15,000 cfs) Diversion Facility with Folded-V Fish Screens.


DELTA WATERWAYS
SACRAMENTO
SAN FRANCISCO
DELTA AREA
LOS ANGELES
YOLO BYPASS
SACRAMENTO RIVER
MOKELUMNE RIVER
NORTH FORK
SOUTH FORK
SAN JOAQUIN
OLD RIVER
MIDDLE RIVER
BARKER SLOUGH PUMPING PLANT
SUISUN MARSH SALINITY CONTROL GATE
DELTA CROSS CHANNEL
PITTSBURG
ANTIOCH
CONTRA LOMA RESERVOIR
DISCOVERY BAY
STOCKTON
LODI
MANTECA
TRACY
HARVEY O. BANKS DELTA PUMPING PLANT
TRACY PUMPING PLANT
SOUTH BAY PUMPING PLANT
LEGEND
Sacramento, San Joaquin and Mokelumne Rivers
Delta Waterways
SACRAMENTO - SAN JOAQUIN DELTA
SCALE IN MILES

GENERAL FISH SCREEN CRITERIA

The California Department of Fish and Game and the National Marine Fisheries Service (Southwest Division), have established general parameters for the siting, operations and design of fish screening facilities. Established criteria however, are applicable to protecting anadromous species and may not reflect the needs of other species that may be present at the potential Delta diversion facility sites. The U. S. Fish and Wildlife Service, however, has required additional screen criteria for the protection of juvenile delta smelt (through the issuance of various project Biological Opinions).

Design criteria is based on the protection of the species and lifestages of the fish present at the site, their life history, seasonal variations and diurnal occurrence and abundance of such species, and their swimming abilities and stamina. Until more specific criteria are developed, it is assumed that modifications (operational or structural) can be made at a facility at a future time.

The Primary function of a screening facility is to physically exclude critical fish species from the diversion channel and return them to the river downstream from the facility. The facility should be designed to minimize delays and disorientation of downstream juvenile migrants, protect resident species from diversion, and discourage predation at the facility over what may be experienced in the existing condition.

It should be noted that not all the given criteria for fish screening facility operations and design can be strictly met. Specifically, several of the hydraulic requirements listed in the criteria are difficult or impossible to meet due to unique Delta conditions. Variances to the criteria are allowable under the Fish and Game code and Federal guidelines if the facility is deemed the best available option (state-of-the-art), can meet the stated objectives for fish protection and is properly mitigated for lower efficiencies.

The following criteria are summarized from:

- National Marine Fisheries service (National Marine Fisheries Service, Southwest Division 1992)
- California Department of Fish and Game (1987), *Technical Report 6* of the *Delta Fish Facilities Report* (1982-87)
- California Department of Fish and Game General Fish Screening Criteria (February 1993)
- Design of Fishways and Other Fish Facilities by Charles Clay (1994)

- Army Corps of Engineers, fisheries criteria summary included in the *Riverbed Gradient Restoration Project Report*, prepared by Resources Consultants & Engineers, Inc. (1992).

The screening criteria include both specific criteria and general guidelines on screen configuration, approach velocity and distribution, sweeping velocities, screen mesh sizing and type, porosity control, exposure time, cleaning frequency, bypass and outfall location and design. General criteria are specified for each of these components.

Screen types considered that could comply with these criteria, and may be feasible in some locations, include vertical flat plate screens, floating rotary drum screens, vertical or horizontal traveling screens and fixed fully submerged cylindrical screens. The feasible design concepts being carried forward at this stage of the planning process that can meet the objectives of the CalFed solutions process (Major facilities of Alternatives A-J) are primarily vertical flat plate screens. For multiple intake facility options, submerged screens may be acceptable. Unproven, but promising facilities using positive barrier technologies for diversions include short exposure, high velocity screens such as the Modular Inclined Screen design. These facilities should be capable of meeting a majority of the criteria listed below.

Fish bypass issues and fish pumping remain as the most controversial elements of the facility design. However, the cumulative impacts of all the facility components are also largely unknown for major diversions. Some of these areas of concerns are currently being addressed in related studies, but some elements may need to be investigated once the facility would go on-line. The added flexibility of an extra screen bay, an evaluation facility which can isolate and test screen facility features, and room for expanded features are integral and necessary components of the design. Phased construction, implementation and evaluation of the intake facility may also be warranted to assure the facility will perform as expected. Phased construction could consist of constructing one bay of a multi-bayed facility and operating it for an evaluation period.

The following sections are an expanded interpretation of the existing screen criteria applied to several basic areas. They represent the intent of the criteria which is to protect fish from the diversion facility. While the existing criteria is written primarily for salmonids and trout, they should have general application to the protection of most fish species that can be screened (i.e. eggs and larvae not considered for protection)

Flow

Since juvenile migrants are very sensitive to changes in flow and velocity, the general flow requirements for the facility are:

- Flow characteristics should provide even velocity increases and decreases; therefore, structures should be designed with smooth velocity transitions.

- To the extent possible, uniform flow should be achieved throughout the general screen area.

- Reverse flows and excessive turbulence should be minimized or avoided.

- Flow patterns must move the fish downstream through the facility quickly.

- Water depths should be sufficient to maintain avian predation rates at or below existing levels.

The screen facility should be designed to provide uniform dispersion of hydraulic energy through all areas of the screen. Changes in velocity or nonuniform approach velocities should be avoided because it may cause a behavioral avoidance in these areas, resulting in delayed passage to the bypass or past the screen. Particular attention should be given in the design to the hydraulics in the upstream and downstream channels to the facility, changes in water surface elevation, the configuration of the facility, screen orientation to flow, ice or debris accumulation on the screen, or sedimentation of bedload materials at the base of the screens. All of these factors can cause nonuniform velocities on the screens.

Baffles can be used to fine tune flow uniformity across the screen by adjusting the differential head over the entire screens. Baffles to create uniform flow conditions through the screens should be used behind the screens rather than as flow direction structures in front of the screen. If direction structures are used in front of the screens, they must not create flow separation zones or eddies in front of the screen that may act to delay fish. Baffles alone may not be sufficient to correct nonuniform approach velocities.

Trash Rack

The trash rack protects the screens from debris and sediment while not interfering with fish passage. The design should be consistent with the expected maximum flow heights and velocities in the channel and the types of debris anticipated.

The recommended criteria for the rack are:

- The rack should be located well upstream of the fish screens to avoid interference with the hydraulics of the fish screen.

- The orientation of the trash rack to the screen should be such to reduce floating, suspended, and bedload debris loading to the screen.
- Bars in the rack should be oriented to minimize turbulence across and through the rack (parallel to the flow).
- The flow transition should be as smooth as possible to avoid delay of juvenile fish passing through the rack or provide habitat for predators.
- A through rack velocity of at least 2 fps is recommended to reduce predator accumulations.
- Bar spacing should not interfere with fish passage, with a spacing of at least 9 inches. (Alternately spaced bars may be considered if larger openings are provided, such as narrow at top, wider at bottom or alternately wide and narrow spacings.)
- The rack should be cleaned frequently (debris removed) so debris loading on the rack does not cause flow distortions across the fish screen or cause excessive headloss.

<u>Screen Material and Hole Size</u>

Screen material should be smooth and durable with no protrusions that could injure fish, and should be protected from corrosion and ultraviolet damage.

The openings in the screen mesh must be small enough to prevent critical fish species from passing through the screen into the diversion. Screens are not designed to prevent the entrainment of seasonal occurrences of eggs and larvae for several species, including striped bass, delta smelt or splittail which may be known to occur in the area. The minimum size of fish expected to be found at the facility depends on the species present, and the proximity of the diversion to spawning and juvenile rearing areas. For juvenile salmonids 30 mm or less in length, it is recommended:

- Perforated plate screens must not exceed 5/32 inch (0.156 inch) in the horizontal dimension.
- Continuous slot profile screens must not exceed 3/32 inch (0.093 inch) in the horizontal dimension.

Note: Revised screen opening requirements are proposed by NMFS and CDFG to be smaller for steelhead fry protection. If adopted, profile screens would not exceed 1.75 mm in width. For perforated plate screens or woven mesh, it should be reduced to 1/8 inch. The minimum open area would be reduced to 27 %

Screen mesh requirements for other species may be smaller if the level of protection for smaller fish is desirable or likely to occur.

Requirements for the prevention of 30 mm and larger delta smelt entrainment are similar to that of salmonids.

Present criteria requires a minimum open area of 50 percent.

Structural

The structural supports for the screen should be designed so that they do not impact the uniform flow conditions across and through the screens for the full range of river and diversion flows expected. The supporting structure should be designed to accommodate the hydraulic, debris, and sediment loads expected for the range of operation.

All screen junctions and seals must be fish-tight and smooth. The alignments between screens and screen bays should not be easily compromised by debris or water velocity.

Approach and Sweeping Velocities

The approach and sweeping velocity components are well described by Resource Consultants and Engineers (1992): "... A fish experiences two velocity components on approaching the screen: the approach velocity, which is the water velocity perpendicular to the face of the screens, and the sweeping velocity, which is the velocity parallel to the face of the screens. To avoid impingement on the screen, a fish must sustain a swimming speed greater than or equal to the approach velocity for the time it takes the fish to locate and enter the fish bypass system. Therefore, it is critical to design screening facilities that have approach velocities less than the sustained swimming speed of the weakest-swimming fish expected at the facility and to provide a sweeping velocity that guides fish to the bypass before they become exhausted. The sweeping velocity past the face of the screen should provide a net downstream component of flow, and should be sufficient to passively guide fish to the bypass before they become fatigued."

Impingement results when approach velocities to the screen and/or time necessary for a fish to enter the bypass exceed the sustained swimming capability of the fish.

The maximum approach velocity to the screen should be less than or equal to 0.33 fps for salmonid fry protection. Requirements for delta smelt and American shad may be more restrictive. Approach velocities along the screen surface should be uniform and are intended to be maximum values, not averaged velocities. Baffling arrangements behind the fish screens are generally required to achieve this uniformity goal, although additional screen area may be necessary if uniformity can not be assured. The CDFG is proposing modified approach velocity requirements depending on site configuration, size and fish exposure potential.

Sweeping velocities are generated parallel to the face of the screens and serve to passively guide fish to the bypass. These sweeping velocities should be positive downstream and be at least twice the approach velocity to the screens.

Screen Area Requirements

The minimum area of the screen needed to meet the current 0.33 fps approach velocity standard is approximately the design flow of the diversion divided by 0.33 fps. If velocity criteria is mandated to be lower or screen velocity uniformity is poor, the screen area would correspondingly increase. Calculated screen area shall not include areas with any backing plates, supports, seals, etc., that exclude uniform flow from passing through the screen.

The actual area of the wetted screen required is affected by the porosity and geometry of the screening material and the orientation of the screen relative to the flow. The minimum screen area must be submerged during the lowest stream flows and may not include any areas that are blocked by screen guides or structural members.

Screen Configuration

To the greatest extent possible, screens should be located parallel to the flow to minimize fish contact with the screens. Where site conditions make construction, facility operation, or flow control difficult, a screen may be installed in a canal downstream of the diversion. This option must provide a fish bypass system to return diverted fish back to the river. Otherwise the screen should be installed parallel with the adjacent river bank of the river where the river would act as a bypass.

Angled screens are the least difficult way to provide uniform approach velocities and positive guidance to the bypass (if necessary). With angled screens, fish are guided by the sweeping flow component while they resist the approach flows.

Screen Cleaning

Clogging of screens causes increased through screen velocities on other areas of the screens, often resulting in nonuniform approach velocities. Screens should be continually cleaned to maintain design approach velocities. Debris on the screen surface is a hazard to the fish being swept past the screen face and can cause damage to the screen surface due to a build up of hydraulic pressure.

Any cleaning method used should be designed to provide continuous, efficient cleaning, particularly during high flow events, which usually convey the highest debris loads and may coincide with peak fish concentrations. The facility should also be designed to safely allow manual cleaning of the screens should the need arise.

Approach Channel Configuration

The approach channel should be designed to provide minimum velocity gradients (i.e., uniform flow), yet provide a net guiding flow to the bypass. Therefore, the channel should have straight and uniform approach and escape channels, with no protrusions that might cause flow distortions, fish disorientation, or delay, whether in the channel or at the screen face. The configuration of the channel and the screen should provide a net downstream flow to passively guide fish to the bypass.

When approach and escape channel designs are constrained by the conditions of the site, training walls and flow vanes can be used to eliminate eddies, achieve even flow distribution across the screen face, and/or enhance sweeping currents across the face of the screens.

Because of the fluctuations in flow, directionally adjustable flow vanes and/or baffles should be provided.

Bypass Configuration

The bypass system must be designed to attract fish, transport them to the river without delay or injury, and deliver fish to the mainstream in a manner that minimizes the potential for predation. The bypass entrance must be located so that fish are guided to the opening, rather than the fish having to actively seek the opening. NMFS requires fish bypass facilities be provided when fish exposures exceed one minute (based on a theoretical fish transport time through the facility equal to the sweeping velocity). This requirement is based on approach velocities of 0.4 fps and protection of salmon fry. This maximum exposure time allowable is dependent on the swimming ability of the all fish species to be protected. For alternative screen lengths and/or sweeping velocities, the number and spacing of additional bypasses may be different. The CDFG has no such provision for bypass spacing.

The entrance to the bypass must provide a large enough opening to prevent debris clogging and provide sufficient flow to attract fish. Velocity gradients should be gradually increasing at the bypass to minimize avoidance of the bypass entrance.

Bypass entrance lighting should be engineered to attract fish. If the bypass is open-topped at the entrance and immediately downstream of the entrance, it provides a more attractive lighted entrance for fish, and allows the screen operators to determine if debris jams are present at the entrance. Lights can be added to provide an attractant at night.

Effective bypasses have widths somewhere between 18 and 24 inches. A width of 24 inches is recommended. Narrower entrances can be a behavioral deterrent.

The flow transition into the bypass must be gradual to minimize strong velocity gradients or turbulence that may cause delays in downstream migration. The entrance velocity to the bypass should be equal to or slightly greater than the sweeping velocity past the screens. This condition should be held in both high and low flow conditions. Therefore, the entrances should be designed with flow adjustment capabilities. An adjustable ramped bypass entrance weir may facilitate optimal conditions.

For multiple bypasses, entrance velocities should be controllable at each bypass. Each bypass should lead to an independent bypass conduit, or to a well designed manifold system that will allow each bypass to operate independently.

Bypass conduits can be pipe or open channel. Generally, open channels are used when the gross head is small and the distance to the discharge point is short.

If conduits are made of pipe, they should be constructed with smooth joints and gradual bends to minimize both injury to fish and potential debris clogging. Pumps that could increase fish stress or injury should not be used to transport fish, but hydraulic situations may warrant their use. The vertical drop between the bypass opening and the outfall should be sufficient to prevent back pressure in the pipe when receiving waters are high. Water velocity in the pipe should be maintained below 10 fps, with no negative pressure anywhere in the pipeline.

Exits

The bypass discharge must be designed to minimize the potential for predation of fish as they reenter the river. Fish can become momentarily disoriented as they exit the discharge and are more susceptible to predation.

Discharges should be designed to minimize the flow disturbances as fish become adjusted to the conditions in the river. This can be accomplished by using a submerged outfall or a series of outfalls in the mainstream of the river. Discharge velocities should approximate the velocity of the river at the discharge point, but not be negative. The discharge should not create any dead or backwater areas.