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Technical Memorandum 2C- Fisheries Evaluation for Phase 1 Conjunctive Use and Enhanced Aquifer Recharge Project:

November 2010

Prepared for

County of Santa Cruz
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701 Ocean Street
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This Technical Memorandum Prepared by DW Alley and Associates in conjunction with Kennedy/Jenks Consultants.

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D.W. ALLEY & Associates aquatic biology

FISHERIES TECHNICAL MEMORANDUM REGARDING GUIDELINES FOR MAINTAINING INSTREAM FLOWS TO PROTECT FISHERIES RESOURCES DOWNSTREAM OF WATER DIVERSIONS IN MID-CALIFORNIA COASTAL STREAMS

November 2010

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INTRODUCTION

D.W. Alley and Associates (D.W. Alley) is pleased to provide the Santa Cruz County Health Services Agency (County) with this technical memorandum (tech memo) in support of the Conjunctive Use and Enhanced Aquifer Recharge Project (Conjunctive Use Project). The Conjunctive Use Project is one of sixteen projects funded by a Proposition 50 Water Bond grant from the State Water Resources Control Board to the Regional Water management Foundation, a subsidiary of the Community Foundation of Santa Cruz County. The Conjunctive Use Project is Project #3 of the grant and is being administered by the County.

The objective of the Conjunctive Use Project is to determine the best approaches for coordinating water projects and increasing groundwater storage to provide reliable drinking water to the lower San Lorenzo River watershed, mitigate declines in groundwater levels, and increase stream baseflow. The Project will investigate the opportunities to use water exchanges, winter streamflow diversion, and/or reclaimed wastewater to replenish groundwater storage in the Santa Margarita Groundwater Basin.

This tech memo summarizes the work performed as part of Task 2 – Surface Water Availability Assessment of the Conjunctive Use Project Scope of Work. This tech memo provides an evaluation of the following items:

- Fisheries Evaluation - Define the surface water flow requirements evaluated with respect to the protection of the local fishery in each of the streams in the project area. This analysis was based on existing studies prepared to assess bypass requirements to sustain instream flows based on requirements by the State Water Resources Control Board, California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service.

This tech memo was prepared concurrent with other memos in other technical areas and was intended to provide a context for developing and evaluating potential project alternatives. Further phases of this project should address, as appropriate and relevant, more detailed fisheries issues as they apply to specific project alternatives.

This tech memo addresses fisheries issues in the following four general categories:

A. Guidelines for Maintaining Instream Flows
B. Instream Flow Studies (Instream Flow Incremental Methodology) Used by Regulatory Agencies to Determine Fishery-Protective Bypass Requirements at Points of Diversion
C. Fish Screening Criteria for Anadromous Salmonids
D. Habitat Suitability Curves

A. GUIDELINES FOR MAINTAINING INSTREAM FLOWS

The draft guidelines developed by the California Department of Fish and Game (CDFG) and the National Marine Fisheries Service (NMFS) in 2002 provide standard, recommended protective terms and conditions to be followed in the absence of site-specific, biological and hydrologic assessments associated with the specific, newly proposed diversion. They also provide direction for site-specific studies when needed. Under the draft guidelines, new diversions are limited to the period December 15 – March 31. Under these draft guidelines, minimum bypass flows past the diversion and cumulative maximum rates of diversion are evaluated in the context of existing water diversions. However, as these are draft and guidelines, site specific studies could be prepared, after consultation with CDFG and NMFS as part of the Coho and steelhead recovery planning process that justifies diversions outside of the December 15 – March 31 period.

Impacts of diverting after March 31 may include reduced adult passage flows, reduced smolt passage flows, reduced spawning flows, reduced egg incubation flows and reduced rearing flows for juvenile steelhead/ coho feeding and growth. The impacts would be reduced if diversion occurs in the larger mainstem rather than in a tributary such as Zayante. Instream Flow Incremental Methodology (IFIM) studies would address minimum bypass flows for these life history phases. The cost of IFIM studies would likely be in the $100k - $200k range, depending on the points of diversions under consideration and consultation with the resource agencies. However, the existing habitat suitability curves may be inappropriate, especially for juvenile rearing. If site specific suitability curves are to be developed, additional funding will be required.

More site specific study may be necessary to develop a more realistic relationship between streamflow and juvenile growth, for example. Our present data on juvenile growth do not separate out the juvenile growth and survival rates that occur before April 1 from growth and survival rates that occur afterwards. We sample juveniles in the fall only. To measure growth during various months and flow conditions, a study must include multiple samplings throughout the spring and summer to measure juvenile growthrate as seasonal flows diminish. Density estimates would also indicate juvenile survival as flows decline. Such a growth/ survival rate study would likely cost in the $75k - $150k range, depending on the points of diversion under consideration and consultation with the resource agencies.

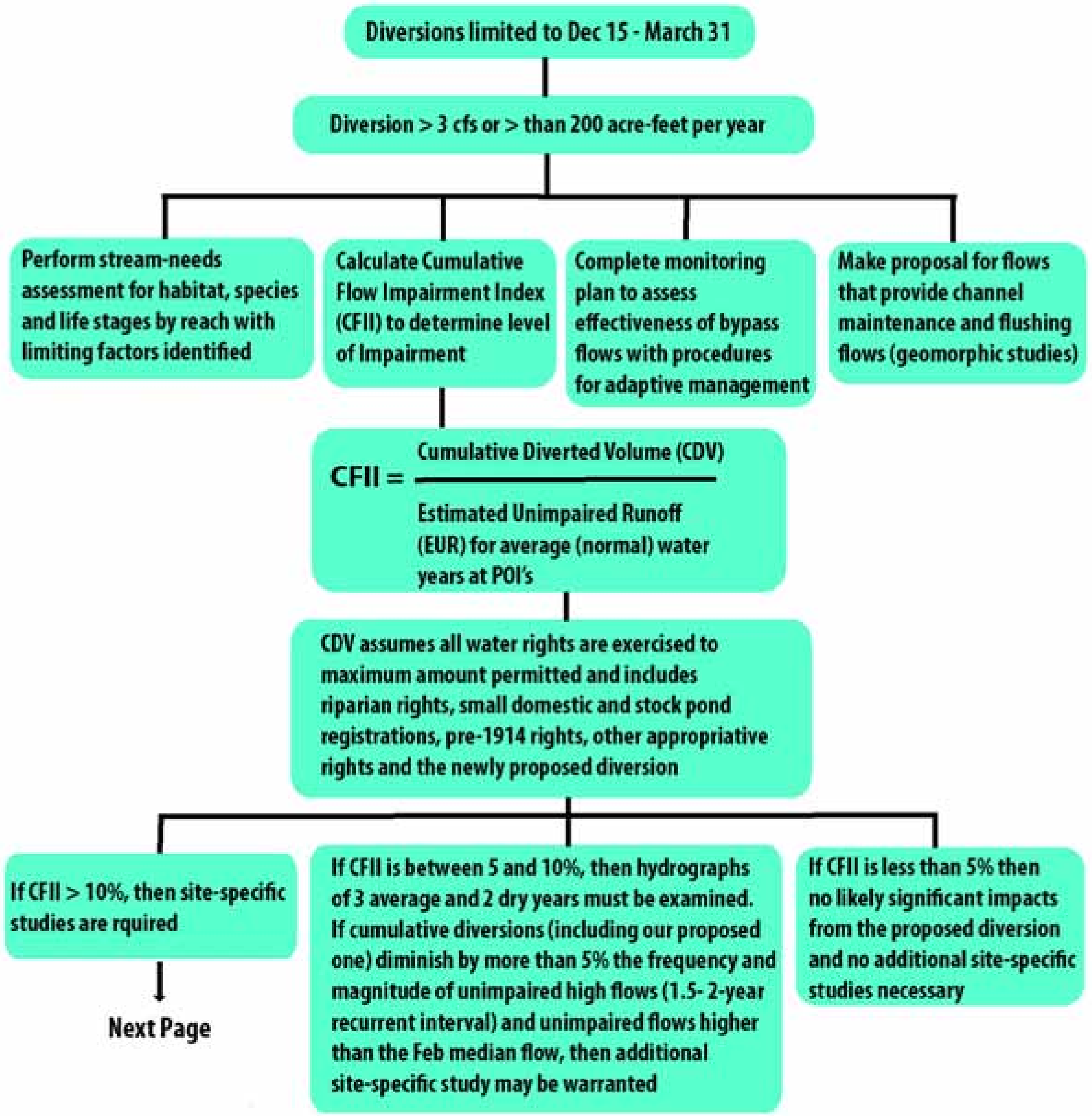
The purpose of the guidelines is to preserve the natural hydrograph, allow flushing flows for recruitment of spawning gravels and to flush fine sediments, as well as prevent riparian encroachment. The guidelines are intended to protect salmonid passage flows and spawning habitat during the period of diversion to ensure that anadromous salmonids will not be adversely impacted by diversions. The guidelines recommend off-stream storage rather than on-stream storage, except in limited circumstances in fishless, ephemeral reaches. Water diversions must be adequately screened, and fish passage facilities must be provided when needed at diversion points.

Overview of Large Diversions ≤3 cfs / ≤200 AFY

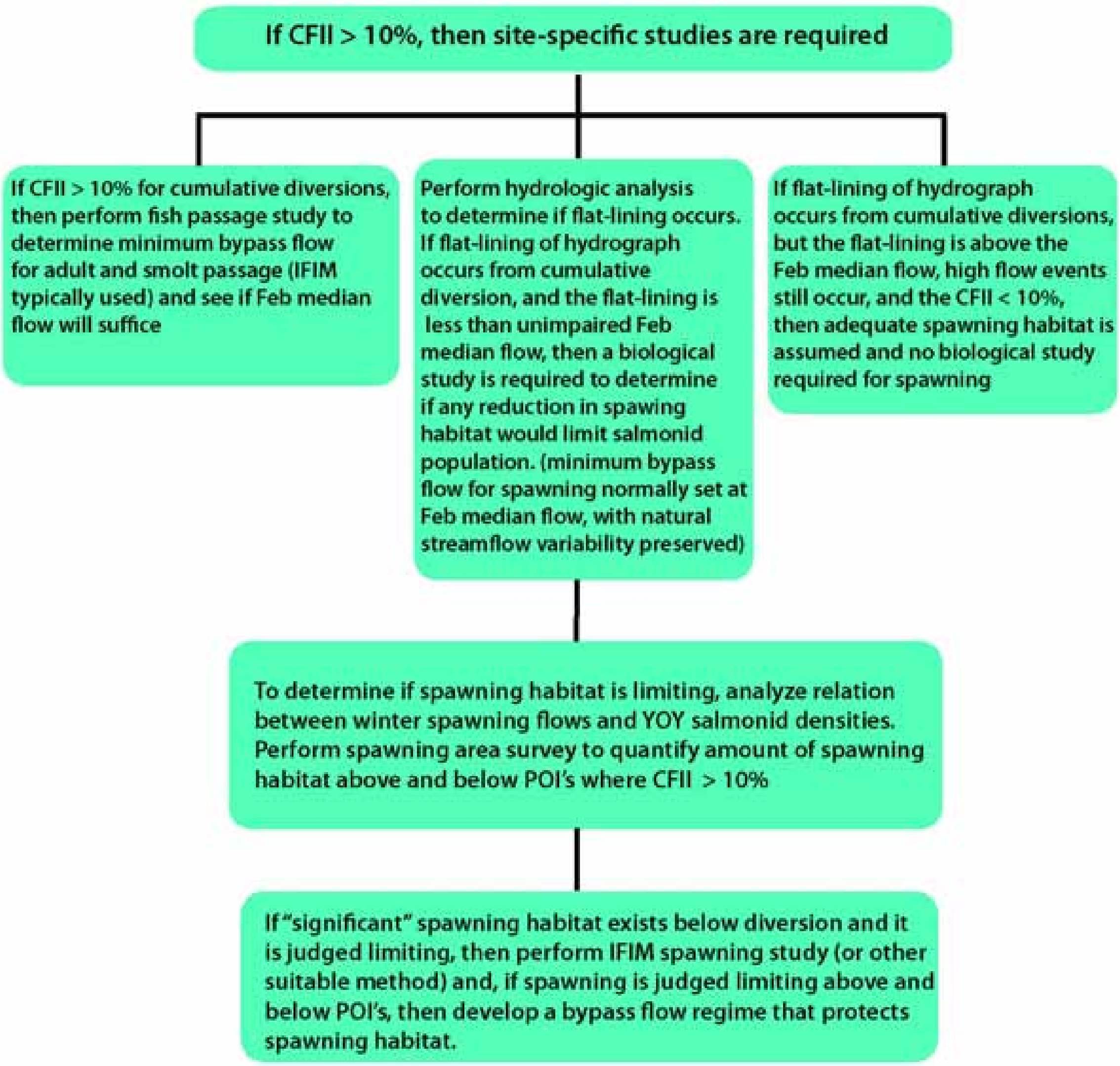
The guidelines provide terms and conditions to be incorporated into water rights permits for small diversions. One category of diversion includes diversions with a greater than 3 cubic-feet-per-second (cfs) diversion rate or a total of more than 200 acre-feet per year of diverted volume. The guidelines require site-specific studies for diversions of this size as summarized on the 2-page flow chart that follows. Site-specific studies should include, at a minimum, the following:

1) A habitat-based stream needs assessment that incorporates habitat, species and life history criteria specific to each diverted stream or stream reach;
2) An evaluation of the existing level of impairment (diversion) and limiting factors for salmonid restoration based upon habitat, species and life history-specific criteria for each diverted stream or stream reach (a Cumulative Flow Impairment Index (CFII) must be calculated);
3) A specific proposal to provide periodic channel maintenance and flushing flows that are representative of the natural hydrograph; and
4) A plan to monitor the effectiveness of stipulated flows and procedures for making subsequent modifications, if necessary.

Flow Chart of 2002 Guidelines for Maintaining Instream Flows for Fish, Downstream of Newly proposed Large Water Diversions (CDFG & NOAA Fisheries)



Flow Chart for Large Water Diversions (continued)



If CFII > 10%, then site-specific studies are required

If CFII > 10% for cumulative diversions, then perform fish passage study to determine minimum bypass flow for adult and smolt passage (IFIM typically used) and see if Feb median flow will suffice

Perform hydrologic analysis to determine if flat-lining occurs. If flat-lining of hydrograph occurs from cumulative diversion, and the flat-lining is less than unimpaired Feb median flow, then a biological study is required to determine if any reduction in spawing habitat would limit salmonid population. (minimum bypass flow for spawning normally set at Feb median flow, with natural streamflow variability preserved)

If flat-lining of hydrograph occurs from cumulative diversions, but the flat-lining is above the Feb median flow, high flow events still occur, and the CFII < 10%, then adequate spawning habitat is assumed and no biological study required for spawning

To determine if spawning habitat is limiting, analyze relation between winter spawning flows and YOY salmonid densities. Perform spawning area survey to quantify amount of spawning habitat above and below POI's where CFII > 10%

If "significant" spawning habitat exists below diversion and it is judged limiting, then perform IFIM spawning study (or other suitable method) and, if spawning is judged limiting above and below POI's, then develop a bypass flow regime that protects spawning habitat.

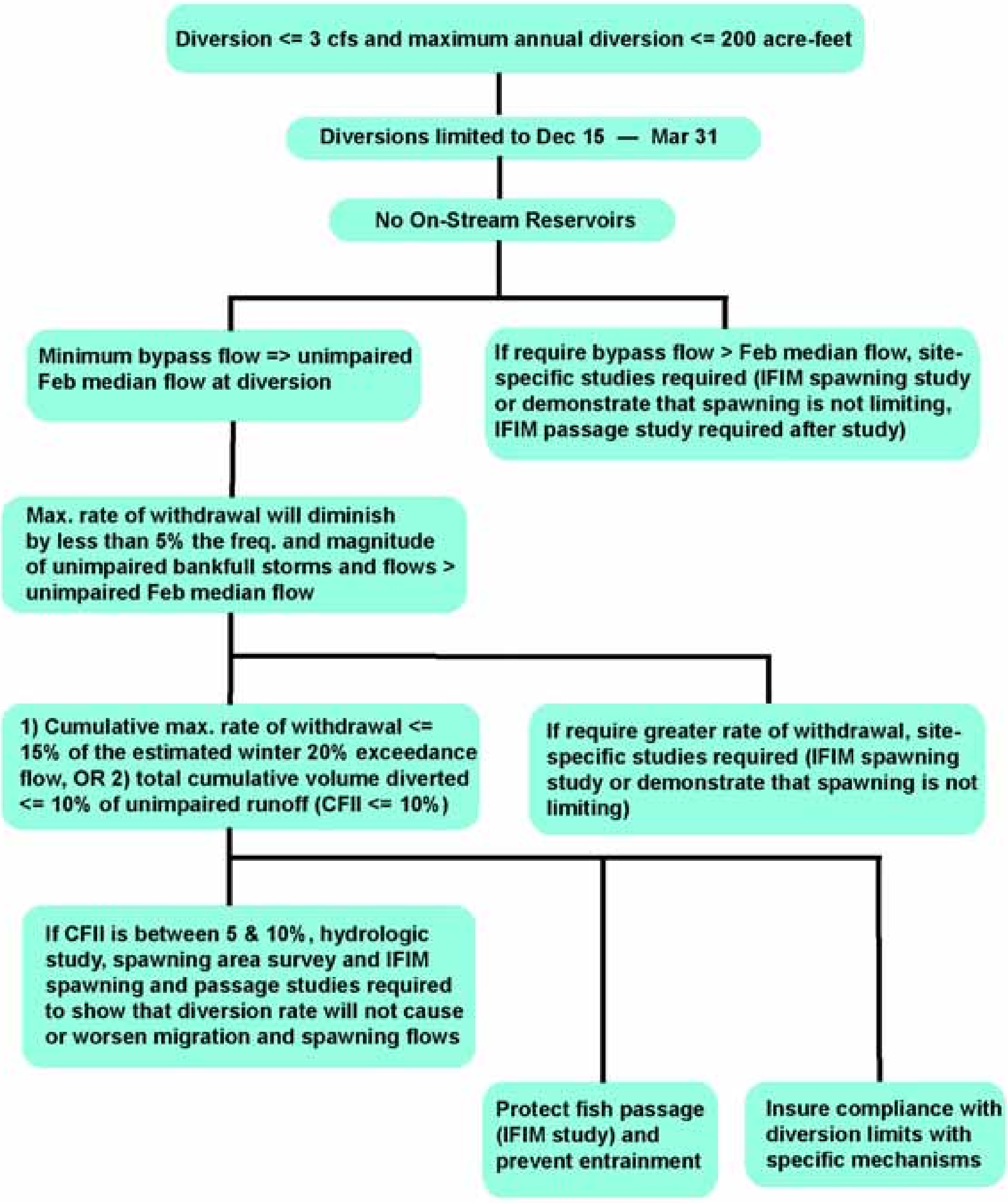
We have data showing that growth rate of YOY juveniles in the mainstem San Lorenzo is positively correlated to the average of the average monthly flows for May – September. We have data showing that YOY densities are often highest after mild winters when spawning habitat is presumably less. We have data which indicates that rearing habitat quality (pool depth and escape cover) limits the density of smolt-sized juveniles in San Lorenzo tributaries. Any new water diversion program would be more palatable to regulatory agencies if increased winter diversion will result in increased summer baseflow, more large instream wood and increased wetted channel in Bean Creek.

Overview of Small Diversions ≤3cfs / ≤200 AFY

Another category of diversion includes smaller diversions in which the diversion rate is less than or equal to 3 cfs and the maximum annual diversion volume is less than or equal to 200 acre-feet. In these cases, site-specific studies are not required; if the recommended guideline restrictions summarized in the flow chart that follows:

1) The diversion season for new water rights permits should be limited to the period of seasonal high flows (December 15 – March 31);
2) Additional on-stream reservoirs should not be constructed or permitted unless consistent with the exemptions provisions (Class III streams);
3) Sufficient minimum bypass flows should be maintained to protect fisheries resources (Site-specific studies may be conducted or, in the absence of site-specific studies, the bypass flow should not be less than the estimated unimpaired February median flow at the point of diversion.);
4) The cumulative maximum rate of withdrawal should be limited to maintain a near natural hydrograph and avoid cumulative impacts. (The maximum rate of withdrawal will diminish by less than 5% the frequency and magnitude of high flows of unimpaired 1.5 or 2-year recurrent interval storms and of moderate flows greater than the median unimpaired February flow. Unless there are site-specific data to show that no adverse effects will occur by diverting more water, 1) the cumulative maximum rate of instantaneous withdrawal at the point of diversion should not exceed a flow rate equivalent to 15% of the estimated "winter 20% exceedence flow" OR 2) the total cumulative volume of water to be diverted from the stream at historical points of anadromy should not exceed 10% of the unimpaired runoff between October 1 and March 31 during normal (average) water years (CFII< 10%). For projects contributing to a cumulative diversion of 5 to 10% of the normal unimpaired runoff between October 1 and March 31, hydrologic analysis must demonstrate that the project will not cause or exacerbate significant adverse cumulative effects to migration and spawning flows for salmonids. The "winter 20% exceedence flow" is defined as the 20% exceedence value of the stream's daily average flow duration curve for the December 15 – March 31 period. Cumulative reduction refers to the effects of the newly proposed diversion and other permitted or licensed projects, as well as winter diversions under riparian rights. The applicant must identify all other basis of rights (appropriative, riparian, adobe, pre-1914) in streams potentially affected by the proposed diversion.);
5) Adequate fish passage and protection measures must be provided to facilitate instream movements of fishes and avoid entrainment in diversion intakes (If salmonids are likely to reach the point of diversion, then adequate passage facilities and screening at diversion intakes must be provided.);
6) The applicant should describe the project-specific mechanisms that adequately ensure compliance with diversion limits.

Flow Chart of 2002 Guidelines for Maintaining Instream Flows for Fish, Downstream of Newly Proposed Small Diversions (CDFG & NOAA Fisheries)



The guidelines require compliance and effectiveness monitoring to address and corroborate assumptions used in developing the flow standard. There must be an accounting of existing diversions and enforcement of unpermitted diversions.

Evaluation of Existing Diversions

There must be an accurate evaluation of all existing diversions prior to issuance of the new water rights permit. To do this, DFG and NMFS recommend the following:

1) Develop an evaluation plan to monitor the effectiveness of the flow standards. Specific monitoring activities should be included to determine if the conditions of the water right protect and conserve salmonid habitat. The program should contain a protocol for making refinements (adaptive management) to the flow standard conditions (permit's diversion restrictions) to mitigate adverse effects.
2) Develop a compliance and enforcement program that includes flow gaging and routine, random compliance inspections. It should include maintained streamflow gages and recording devices at key locations to determine compliance with bypass flow requirements and current level of impairment.
3) Over-allocation of diverted water by the new diversion must be prevented. Streams currently over-allocated in the watershed must be identified. Actual and potential **levels of impairment** must be documented. The total maximum volume and maximum rate of withdrawal allowed by existing water permits at any given time must be evaluated and accounted for. This includes rights not fully and/or currently exercised. A month-by-month evaluation of potential diversion must be compared to the unimpaired hydrograph to ensure that sufficient flow remains in the stream to provide sufficient minimum bypass flow to protect salmonids in downstream reaches. Diversions should diminish the natural hydrograph less than 5% in the frequency and magnitude of unimpaired high flows (1.5 to 2-year recurrent interval events) and unimpaired moderate and high flows (flows higher than the February median flow) used by migrating and spawning fishes.

The State Water Resources Control Board (SWRCB) must first determine whether water is available for diversion. A Water Availability Analysis (WAA) must estimate expected unimpaired streamflow at the diversion point. The board must consider the water that has already been allocated to existing water rights holders and the water required for protecting public trust resources, such as fishery resources.

The potential level of impairment to streamflow caused by cumulative diversions can be evaluated by calculating the Cumulative Flow Impairment Index (CFII). This is a way to compare the volume of water that is naturally available to the total volume of water that can be legally diverted from the watershed through existing water rights. It is the following ratio:

$$\text{CFII} = \frac{\text{Cumulative Diverted volume (CDV)}}{\text{Estimated Unimpaired Runoff (EUR)}}$$

The CFII is typically calculated for average (normal) water years. A CFII is typically calculated for several Points of Interest, including the Point of Diversion, immediately downstream at each confluence of a major tributary between the project site and the estuary. The CFII may be calculated downstream of every major water diversion point leading to the estuary. The 2002 guidelines explain the methods of calculating the CDV and EUR. The volume of water diverted for the CDV is for the October 1 to March 31 season. The runoff period for the EUR is from December 15 to March 31.

The CDV is the volume of water diverted under all water rights potentially affecting the streamflow at given Points of Interest (Points of Interest to be decided by DFG and NOAA Fisheries staff). Calculations of potentially diverted water include all existing legal diversions (including riparian rights, small domestic and stockpond registrations, pre-1914 rights and other appropriative rights). If the riparian diversions are not likely to occur during the CDV season, then they may be discounted. A list of diversions must be provided that includes: 1) the season of diversion, 2) the potential maximum instantaneous rate of diversion, 3) the potential maximum volume of diversion, 4) the existing water rights excluded from the computations, and 5) any other assumptions related to the calculations for each diversion in the list.

The Estimated Unimpaired Runoff (EUR) is computed using standard hydrologic techniques that may include prorating known gauge data, application of precipitation runoff models, or other accepted methods. Calculations of the EUR must be accompanied with computational methods, input data, data sources and assumptions sufficient for reviewers to understand and replicate the results.

The level of impairment indicated by the CFII will determine the study effort needed to address significant cumulative impacts of the new water right project.

- If the CFII is greater than 10%, then there are likely significant cumulative impacts. When the CFII is greater than 10%, site-specific studies will be required to assess cumulative impacts, and the Applicant must consult with NMFS and DFG to scope out the site-specific studies needed to assess these impacts.

- When the CFII is between 5 and 10%, the Applicant must provide additional hydrologic analysis to document the estimated effects of cumulative diversions on the stream hydrograph at Points of Interest (POI's): determined by DFG and NMFS staff) during three representative normal (average) years and two representative dry years. If the natural hydrograph is appreciably impaired (diminishes the frequency and magnitude of unimpaired high flows (1.5 or 2-year recurrent interval) and unimpaired moderate and high flows (higher than February median flow) by more than 5%) during the migratory and spawning period of anadromous salmonid species, then additional site-specific study may be warranted.

- If the CFII is less than 5%, it is assumed that significant cumulative impacts due to diversion are unlikely, and no additional studies are required to assess these impacts.

Site Specific Hydrologic Studies of Impacts of Cumulative Diversions

Site-specific studies are required if the hydrograph is appreciably impaired, as indicated if the CFII is greater than 10% or between 5 and 10% in some cases. They are performed to establish terms and conditions in the new water right that ensure that salmonid habitats are not further degraded. The Applicant should consult with NMFS and DFG regarding the scope and methods of studies to be undertaken. Three issues must be addressed:

1) What are the cumulative effects of the new water project and existing projects on stormflows (flushing flows) that maintain and protect geomorphic process downstream from the project site and avoid worsening stream sedimentation? Also, does the project affect the timing of the opening or closure of the sandbar at the rivermouth?
2) What minimum bypass flow and maximum instantaneous rate of withdrawal are needed for the project to protect spawning habitat for anadromous salmonids downstream of the project site?
3) What minimum bypass flow and maximum instantaneous rate of withdrawal are needed for the project to facilitate migratory movements of anadromous salmonids downstream from diversion sites?

The types of site-specific studies that may be required were indicated in the 2004 NOAA Fisheries response to the State Water Resources Control Board regarding the impacts of the Grgich Hills Cellars water rights project (**NOAA Response Fisheries Letter 2004**). For channel maintenance, it was stated that instantaneous, unimpaired flows with recurrent intervals of 1.5 and 2 years must be protected. If the 2-year interval flow is reduced more than 5%, then additional study of the stream's geomorphology and sediment transport characteristics should be carried out to determine the significance of reduced maintenance flows on stream substrates, channel morphology and macrohabitat. Cumulative effects of diversions on the dynamics of sand bar formation at the rivermouth must also be studied. Cumulative diversions during the first seasonal rains in late fall could delay breaching of the sandbar and delay upstream migration of salmonids, especially coho salmon.

In small watersheds where existing diversions already exceed 10% of the total winter runoff, cumulative diversions can reduce spawning habitat by reducing streamflow to the minimum level (February median flow) or lower for significant durations. Diversions may flat-line the streamflow (i.e. remove hydrologic peaks) to the median February flow. Optimal levels of spawning habitat may occur at flows higher than the February median. Three additional studies to establish adequately protective bypass flows for spawning were described in the 2004 response. One recommended study was a hydrologic analysis to determine if cumulative diversions appreciably diminish biologically important high flow events and cause flat-lining of the hydrograph or appreciably diminish biologically important high flow events, even though the CFII is 10% or greater. This analysis is similar to the analysis recommended for projects with CFII values between 5 and 10%. The estimated unimpaired hydrographs at Points of Interest are compared to those resulting from cumulative upstream diversions, including the new project, for three separate representative normal (average) and two representative dry water years during the diversion season. However, the method of determining appreciable diminishment of biologically important high flow events was not stated in the 2004 response.

Site Specific Biological Studies

A biological study is recommended if the results of the previous hydrologic analysis indicate flat-lining (eliminating natural hydrologic peak flows) or appreciable diminishment of important high flow events. This biological study is intended to determine if reduction in spawning habitat at the Points of Interest actually would limit the salmonid population. A qualified fishery biologist must survey spawning and rearing habitat at points upstream and downstream of Points of Interest where the CFII is greater than 10%. The survey must quantify available spawning habitat upstream and downstream of diversions. Most of the spawning habitat in some watersheds is in upper watershed reaches, upstream of water diversions. If site-specific data can demonstrate that minor reductions in available spawning habitat caused by diversions will not adversely affect salmonid populations, then it may be concluded that the February median flow poses no adverse effect to salmonid spawning habitat. It is implied in the 2004 response, though not stated, that the amount of spawning habitat available upstream and downstream of existing and proposed diversions should be compared. The 2004 response stated that biological data must demonstrate that the remaining available spawning habitat located downstream of the diversion project (and presumably other existing diversions) clearly does not limit production of salmonids. We have found that in the San Lorenzo watershed, juvenile steelhead densities are higher in years when high stormflows are absent in the latter portion of the winter, as long as early stormflows are sufficient to provide spawning access to the upper watershed. This would indicate that reduced spawning habitat availability in the latter portion of the winter does not limit the juvenile salmonid population.

Potential Benefits of Conjunctive Use

If optimal spawning conditions cannot be provided by the project, and water diversion is desired under sub-optimal streamflow conditions for spawning, then data must show that the loss of spawning habitat does not limit the juvenile salmonid population size. If spawning is proved not to be limiting and rearing habitat is, then a conjunctive use program that includes enhancement of juvenile rearing habitat with more cover (from increased large instream wood recruitment and retention) and/ or more scour objects or by augmentation of summer rearing flows will have a net biological benefit to salmonids. In the San Lorenzo River drainage, summer baseflows are well below optimal levels, naturally. Data indicate that growth of juvenile salmonids is increased with greater summer streamflow, and juvenile production is increased if the amount of perennial summer flow is increased in Bean Creek. If increased winter diversion under a conjunctive use program will allow reduced summer diversion or reduced effects on the water table by wells, then its net impact may be positive in allowing greater summer baseflow and/or longer perennial reaches in Bean Creek. If winter diversions are injected into the groundwater to increase the water table near Bean Creek, then the length of perennial stream reach may be increased to support more juvenile salmonids.

Instream Flow Incremental Methodology to Estimate Stream Flows for Habitat Protection

Though not stated in the 2004 response, it would seem that an IFIM study described below could be done to simulate the weighted usable area of spawning habitat as a function of streamflow in terms of the stage-discharge relationship. If the February median flow is sufficient to provide optimal spawning habitat, then flat-lining should not be a concern. In the instream flow section of this report, past IFIM results for spawning are provided.

If the aforementioned biological study indicates that a substantial amount of potential spawning habitat is adversely affected by cumulative diversions (and presumably that spawning is shown to limit the salmonid population downstream of diversions), then instream flow studies are recommended, using the IFIM or other suitable methods to evaluate stream flows needed to protect fish spawning habitat during the diversion period. Other suitable methods were not described in the 2004 response. Details of IFIM studies are provided further in Section B.

There remains the issue of adequate bypass flow for anadromous salmonid passage when the CFII is greater than 10% downstream from the diversion site. In these cases, the 2004 response recommended a fish passage assessment to identify flows that are adequate for upstream passage and to determine if the long-term February median flow is adequate to facilitate passage. Details of the fish passage study are described further in the description of instream flow studies.

Summary of Required Hydrologic Information to Satisfy the Guidelines (2002)

1. Season of diversion (Does it continue past March 31?).
2. Proposed maximum diversion rate from the new project (more or less than 3 cfs?).
3. Proposed total annual volume diverted from the new project (more or less than 200 acre-feet?).
4. Estimate long-term unimpaired median daily flow in February.
5. Estimate total unimpaired runoff at the new point of diversion (December 15 – March 31) and at other Points of Interest (likely other points of diversion downstream of the new point of diversion or other points of diversion cumulatively impacting streamflow downstream of the new point of diversion- mouth of Bean Creek, mouth of Zayante Creek, below Felton Diversion, below Tait Street Diversion. Diversions to consider are those surface diversions potentially allowed under water rights during the winter season and given to the Lompico County Water District, the Mount Hermon Association, San Lorenzo Valley Water District in the upper watershed and

the Felton District, Big Basin Water Company, Bracken Brae Association on Boulder Creek, City of Santa Cruz at three diversion points - Newell Creek Dam, Felton and Tait Street.).

6. Estimate cumulative diverted volume (potential volume of water diverted under all bases of right between October 1 and March 31) at all Points of Interest.
7. Determine the Cumulative Flow Impairment Index (CFII) (Item 6 divided by Item 5 above) for three normal (average) years and two dry years.
8. Estimate the channel maintenance and flushing flow required at Points of Interest to determine the cumulative impacts of all diversions on flushing flows needed to protect geomorphological processes downstream of the project site.
9. If the CFII is between 5 and 10%, then simulated unimpaired hydrographs must be contrasted to simulated impaired hydrographs resulting from cumulative diversions, including the project under consideration. The purpose is to evaluate whether cumulative diversions cause flatlining of streamflows to minimum levels during fall and winter. If the 2-year recurring stormflow is reduced more than about 5%, then additional field study of the stream's geomorphology and sediment transport characteristics should be conducted.

Summary of Potentially Required Biological and Hydrological Information for Projects with Maximum Diversion Rates of 3 cfs or Less and Total Diversion Volume of 200 acre-feet or Less to Satisfy the Guidelines (2002)

1. If the project diversion contributes to a cumulative reduction of more than 5% of estimated total volume of unimpaired stream runoff during the December 15 to March 31 period in normal years (CFII of 5% or more), then site specific studies are required even if the bypass flow is at least the median daily flow in February.
2. If the project cannot provide a bypass flow of at least the median daily flow in February, then site-specific studies are also required.
3. Site-specific studies must demonstrate that the long-term median daily flow in February is conducive to salmonid spawning. This would require IFIM studies of the weighted usable area of spawning habitat as a function of streamflow in reaches impacted by diversion downstream of the project.
4. Review of existing winter hydrologic data and juvenile steelhead densities the following fall over multiple years to determine if the amount of available spawning habitat limits juvenile salmonid densities.
5. If it cannot be shown that available spawning habitat does not limit juvenile steelhead densities, then site-specific studies must be performed to determine the percent of spawning habitat located in unimpaired watershed reaches compared to the percent in streamflow-impaired reaches. The example given in the NOAA Fisheries letter (2004) was that if more than 90% of the spawning habitat is in unimpaired reaches, then impacts from the diversion may be assumed to be minimal.
6. If a significant (requires a judgment call by DFG, NOAA Fisheries and the project fishery biologist) portion of spawning habitat is found to exist in impaired reaches, then minimum bypass flows and maximum instantaneous rates of withdrawal allowable to protect spawning habitat downstream from the project

site must be determined. This would require IFIM studies of weighted usable area of spawning habitat as a function of streamflow in reaches impacted by diversions downstream of the proposed project.

7. If the CFII is greater than 10% downstream from the diversion site, a fish passage assessment should be performed to identify flows that are adequate for upstream passage of adult salmonids and to identify if the long-term median February flow is adequate for fish passage. This will require an IFIM study to determine the stage-discharge relationship at critical passage locations, downstream of the proposed diversion site. The fishery biologist must map and photo-document shallow riffles, waterfalls and steep cascades.

Summary of Potentially Required Biological, Geomorphic and Hydrological Information for Projects with Maximum Diversion Rates of More than 3 cfs and Total Diversion Volume of More Than 200 acre-feet to Satisfy the Guidelines (2002)

For water diversions of this size, site-specific biological and hydrological studies must be done. Thus, site-specific biological and hydrological studies described in #3 through #7 for smaller diversions are required otherwise. In addition, geomorphic studies must be done to determine flows required for periodic channel maintenance and flushing of sediment that are representative of the natural hydrograph.

B. INSTREAM FLOW STUDIES (INSTREAM FLOW INCREMENTAL METHODOLOGY) USED BY REGULATORY AGENCIES TO DETERMINE FISHERY-PROTECTIVE BYPASS REQUIREMENTS AT POINTS OF DIVERSION

Introduction

Various environmental concerns are associated with water diversion. Flow reduction from water diversion may potentially impede upstream migration of anadromous salmonids (steelhead and coho salmon) over critically wide and shallow riffles, steep boulder cascades or waterfalls. Such flow reduction may impede downstream migration of spawned adult kelts and juvenile smolts. Reduced streamflow may reduce habitat for salmonid spawning, egg incubation and juvenile rearing habitat downstream of the diversion. The Instream Flow Incremental Methodology (IFIM) is commonly used to determine how depth at critical riffles and the amount of habitat changes with differing amounts of streamflow. The U.S. Fish and Wildlife Service developed this method. It is a process in which hydraulic data are collected in downstream reaches to be affected by water diversion. The hydraulic data are then applied to habitat suitability curves for the species of concern to determine how habitat increases and decreases with streamflow.

Description of the Instream Flow Incremental Methodology

Weighted Usable Area Estimation

After a new diversion point is determined on Zayante or Bean Creek, weighted usable area (WUA) of various types of salmonid habitat may be estimated as a function of streamflow for each life history stage of steelhead and coho salmon during the period of diversion. WUA area may be determined in multiple reaches downstream of the new point of diversion and downstream of existing diversions having cumulative effects on streamflow. The habitat index versus discharge function (widely known as WUA) is a static relationship between discharge and habitat that does not represent how often a specific flow/habitat relationship occurs. For this reason, in many cases WUA should not be considered the final result of a Physical Habitat Simulation (PHABSIM) instream flow study.

Habitat Duration Analysis

A more complete analysis is the habitat duration analysis (HDA), sometimes referred to as a time series analysis. An HDA integrates WUA with hydrology and project operations to provide a dynamic analysis of flow versus habitat. A habitat duration curve is constructed in exactly the same way as a flow duration curve, but uses habitat values instead of discharges as the ordered data. Habitat availability is determined over time. Pre- and post-project diversion scenarios may be compared. However, a clear description of project operation must be available, which may not be the case in the feasibility phase of project design.

Transect Selection for WUA/HAD

A series of transects are established across the stream channel to simulate cross-sectional hydraulic conditions as streamflow changes. These transects are placed at locations relevant to specific life history stages of the salmonids. The type of transects needed will depend on timing and duration of water diversion. If diversion occurs during the rainy season, then adult salmonid passage and spawning transects would be most appropriate.

Passage transects may be established at critically wide and shallow riffles to develop a stage-discharge relationship in which depth conditions across these transects are modeled as a function of streamflow. These same transects may be used to model water depth as a function of streamflow for out-migrating adult kelts (post pawners) and juvenile smolts. According to the NOAA Fisheries (NMFS) response (**2004**), the Thompson (**1972**) approach may be used to identify suitable passage flows as described as follows:

> *To determine the flow to recommend for passage in a given stream, the shallow bars most critical to passage of adult fish are located and a linear transect marked which follows the shallowest course from bank to bank. At each of several flows, the total width and longest continuous portion of the transect meeting minimum depth and maximum velocity criteria are measured. For each transect the flow is selected which meets the criteria on at least 25 percent of the total transect width and a continuous portion equaling at least 10 percent of its total width. The results averaged from all transects is the minimum flow we have recommended for passage. I might caution*

> *that the relationship between flow conditions on the transect and the relative ability of fish to pass has not been evaluated.*

Minimum Depth and Velocity Criteria for Fish Passage

Spawning transects may be established at tails of pools and in runs just above breaks into riffle habitat where adult salmonids are most likely to spawn. It is important to understand that adults prefer spawning glides upstream of steep, narrow riffles and restrict their spawning to the deepest portion of the cross-section (thalweg). The number of transects to be established and the extent of stream channel to be modeled must be negotiated with the regulatory agencies.

If new water diversion continues into the high steelhead-feeding period of spring and early summer after the rains, rearing transects become more important. Rearing transects will be established in pool, riffle and run habitat. If there will be an increase in summer baseflow resulting from the new conjunctive use program, then data from rearing transects may be used to quantify the increase in rearing habitat. We have developed an alternative instream flow method to measure the benefit of augmented streamflow in tributaries (**Alley 1996b; 1997**), based on an empirical model developed by Smith (**1984**). It incorporates escape cover and average habitat depth as important habitat parameters. Details of this instream flow method are described further on.

Thompson (**1972**) provided minimum depth and velocity criteria of 0.6 ft and 8 ft/s for both steelhead and coho salmon. However, although these criteria have been used in past fish passage studies, Thompson did not evaluate their adequacy for passage. Bovee (**1982**), in discussing Thompson's minimum depth criteria, stated the following:

> *The investigator should temper this criterion by the number and length of crossings the fish must make. Fish that encounter very few passage barriers can probably negotiate some fairly shallow water. The same species moving up a stream with many passage bars may arrive at the spawning area in poor condition if the passage depths are minimal.*

The minimum passage depth criteria must be negotiated with the regulatory agencies involved (NOAA Fisheries and CDFG). In previous feasibility studies, we have used 0.6 ft depth as the minimum depth criteria for adult steelhead, using the Thompson (**1972**) approach (**Alley 1990; 1992; 1993a; 1993b**). We recommended 0.7 ft as a minimum depth criteria for spring-run chinook salmon in lower Mill Creek, Tehama County in our passage study (**Alley 1996a**), though we also included necessary streamflows to provide 0.5, 0.6 and 0.8 ft as minimum depth across modeled critical riffles in a Thompson (**1972**) approach.

Recommendations for Zayante, Bean and Boulder and San Lorenzo River

A water diversion in Zayante or Bean Creek will affect streamflow in those tributaries, as well as in the mainstem San Lorenzo. If the timing and degree of water diversion at the

Felton Diversion Dam will change under conjunctive use, then passage, spawning, egg incubation and rearing conditions may require new IFIM modeling in the lower San Lorenzo River. If timing and degree of water diversion in tributaries to Boulder Creek and the middle San Lorenzo River will change under conjunctive use, then habitat conditions may require new IFIM modeling in Boulder Creek and the middle San Lorenzo River. If the CFII is greater than 10% at any Point of Interest in the watershed, then IFIM modeling may be required downstream of that point.

Different reaches may require separate modeling above and below significant tributary confluences, where changes in gradient or geomorphology cause differences in the ratio of pool, run and riffle habitat. Streambed conditions regarding particle size distribution may also change downstream of tributaries that supply much sand or as the gradient flattens in downstream segments. After the stream reaches to be modeled with IFIM are identified, the number of replicate transects per habitat type and the transect locations must be agreed upon.

Field Work to Complete Data Collection

During the IFIM process, fishery biologists walk the stream reaches, map and number each habitat unit, determine the ratio of habitat types and choose transect locations that represent each habitat type (pool, riffle, run, step-run, spawning glide, etc.) at the agreed upon number of replicates. A stratified random method is typically used to choose transect locations. Habitat units of the least common habitat type may be numbered and randomly chosen from. Then transects for other habitat types may be clustered nearby. Professional judgment is also used in choosing transects in the event that randomly chosen transects do not appear representative. Fishery biologists will also locate the most limiting critical passage riffles to be modeled while surveying habitat types. The number of critical riffles to be modeled must be negotiated. Then, regulatory agency personnel are provided the opportunity to visit the transect locations and sign off on their placement before data collection begins.

After transect locations are approved, permanent pins are driven into streambanks, between which water surface elevation and hydraulic characteristics (depth and mean water column velocity) will be measured at typically three streamflows. Temporary benchmarks are established, and the streambed cross-section is surveyed. The assumption is that the streambed cross-section will not change during hydraulic data collection.

Stream Flow Calibration Data for Hydraulic Model

Hydraulic data are collected at a minimum of three calibration streamflows- low, medium and high. Data collected at the three calibration flows are used to model hydraulic conditions over a range of streamflows that extends above, below and between the calibration flows. A stage – discharge relationship is developed. The range of calibration flows should be maximized because a well-calibrated hydraulic model may simulate conditions between 0.4 times the lowest calibration flow and 2.5 times the highest calibration flow. Across the transect, modeled parameters include a minimum of water surface elevation, water depth, water velocity and substrate particle size. The presence of overhead cover and/or escape cover between verticals also may be recorded.

Sufficient data collection points (“verticals”) are established along each transect so that there at least 20 at the lowest calibration. Streambed composition according to particle size is estimated between verticals. The shortcoming of estimating substrate particle size is that it is a surface-only estimate and not an estimate from a core sample that would better estimate particle size and percent fines for buried eggs in spawning gravel. It was found in Soquel Creek that spawning glides are often armored with coarser particles on the streambed surface, with finer sand underneath (**Alley 2003**).

Overhead cover is provided by water turbulence and overhanging vegetation. Escape cover is provided by cracks and crevices under submerged wood, cobbles and boulders, and the presence of submerged, undercut streambanks. Cover ratings are discrete and not continuously changing with flow, but have threshold streamflows when they appear and disappear. Flow relationships developed from escape cover ratings may be described as the percent of wetted cells that possess cover at each calibration flow.

Water depth may be predicted across critical passage riffles to estimate the minimum streamflow to satisfy adequate passage criteria agreed upon by the regulatory agencies (California Department of Fish and Game and National Marine Fisheries Service). These include passage flows for spawning adults, emigrating kelts (post spawners) and emigrating juvenile smolts. The minimum depth for migrating adult spawners may likely be between 0.6 and 0.8 ft minimum depth across 10% of continuous channel width (with a minimum of 5 ft), depending on what is negotiated with the regulatory agencies.

WUA Estimation After Modeling

After the hydraulic data are modeled in different habitat types, WUA may be estimated as a function of streamflow for each salmonid life history phase- spawning, egg incubation, fry rearing, juvenile rearing and adult holding. The Physical Habitat Simulation System (PHABSIM) developed by the USFWS is used to calculate WUA as a function of streamflow. WUA for spawning typically takes precedence over WUA for egg incubation. And since steelhead spawn in the deepest part of the spawning glide (thalweg), streamflow sufficient for maintaining eggs may be considerably less than that needed for spawning, despite what the Bovee (**1982**) curves may indicate. WUA is calculated in PHABSIM by combining the hydraulic model with habitat probability (suitability) curves and the length of each type of habitat (pool, riffle, step-run, run, spawning glide, etc.) in the stream reach to be modeled.

Once WUA for spawning and rearing is modeled as a function of streamflow, the streamflow at which the maximum WUA is available may be predicted. WUA for spawning or rearing will increase as streamflow increases to a maximum WUA and then will decline above a certain streamflow. Transects located only in spawning glides are used to estimate WUA for spawning and egg incubation. All transects may be used to determine WUA for other life stages. Different species will have different habitat suitability curves. The habitat suitability curves that are chosen will determine the shape of the WUA curves.

Habitat Suitability Curves

Bovee (**1982**) developed the habitat suitability curves commonly used for winter steelhead, with the modified Wentworth particle size scale used to describe streambed conditions (**Figures 1–4**). As stated in his IFIM class, Bovee called these BOGSAT curves that were generated by "a bunch of guys sitting around a table," and not from specific data. They were based on general experience. The potential impact of water diversion at any given rate upon spawning WUA may be estimated from WUA area curves generated from the hydraulic simulation curves combined with these Bovee habitat suitability curves. Note that the depth suitability curve from Bovee (**1982**) indicates an optimal depth of 1.15 – 1.25 ft, with reduced suitability at lesser and greater depths. **Figures 5–9** provide IFIM results for WUA simulation for various life stages for three reaches and 36 transects between the San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**). **Figure 10** provides a composite WUA simulation for all three reaches combined.

Appendix C. Habitat Suitability Curves - Winter Steelhead

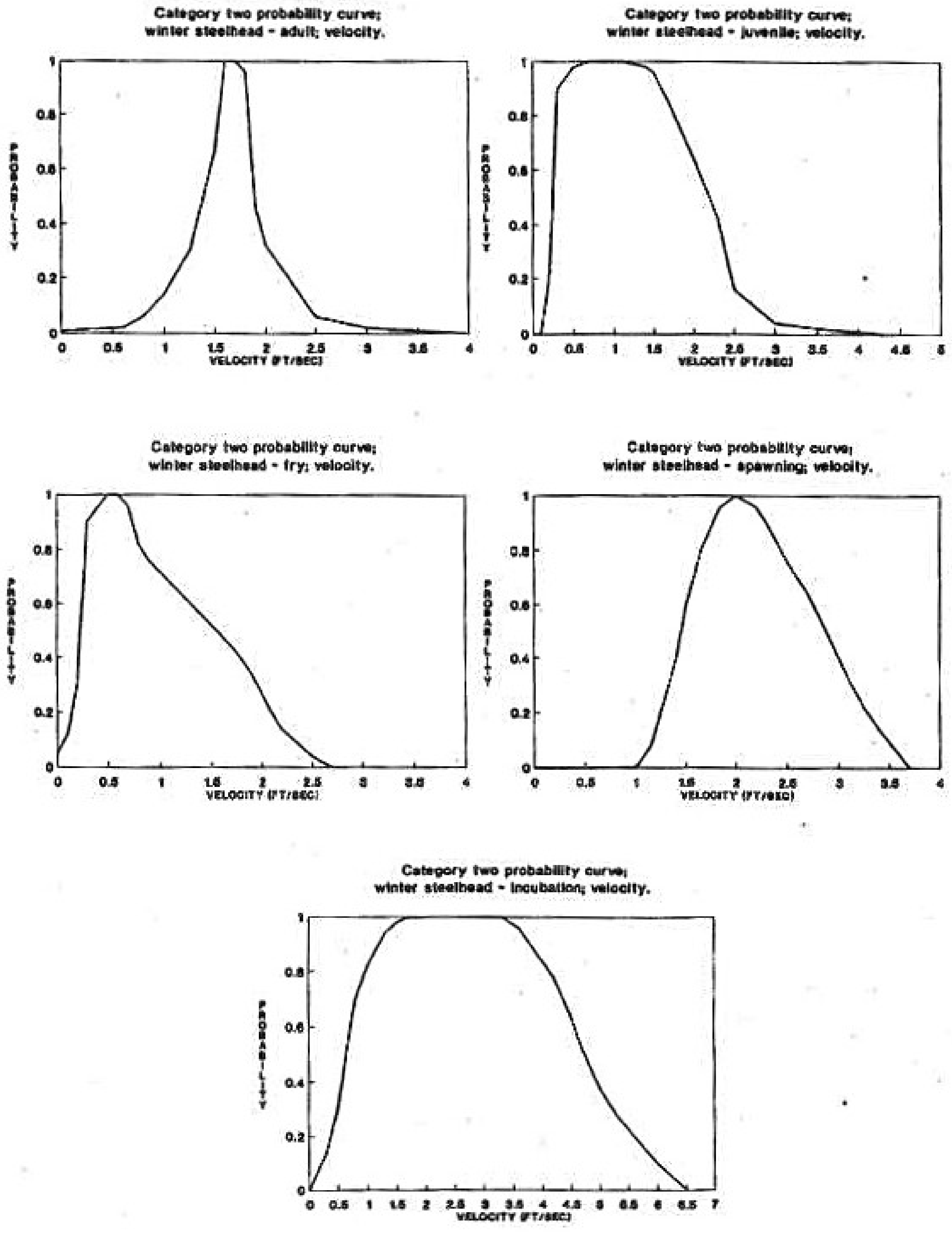


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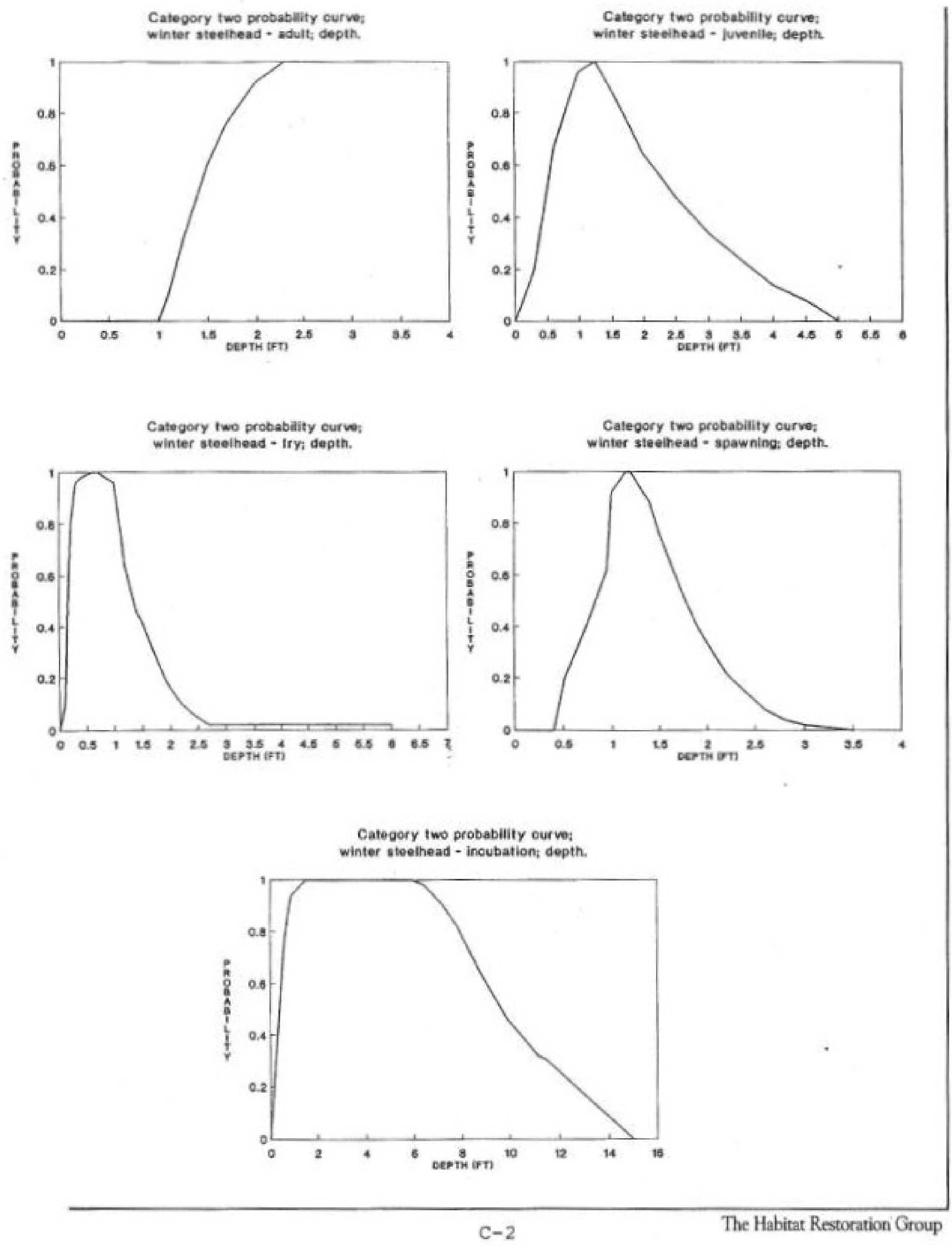
Figure 1. Velocity Probability Curves for Winter Steelhead from Bovee (**1982**).



Category two probability curve; winter steelhead - adult; depth.

Category two probability curve; winter steelhead - juvenile; depth.

Category two probability curve; winter steelhead - fry; depth.

Category two probability curve; winter steelhead - spawning; depth.

Category two probability curve; winter steelhead - incubation; depth.

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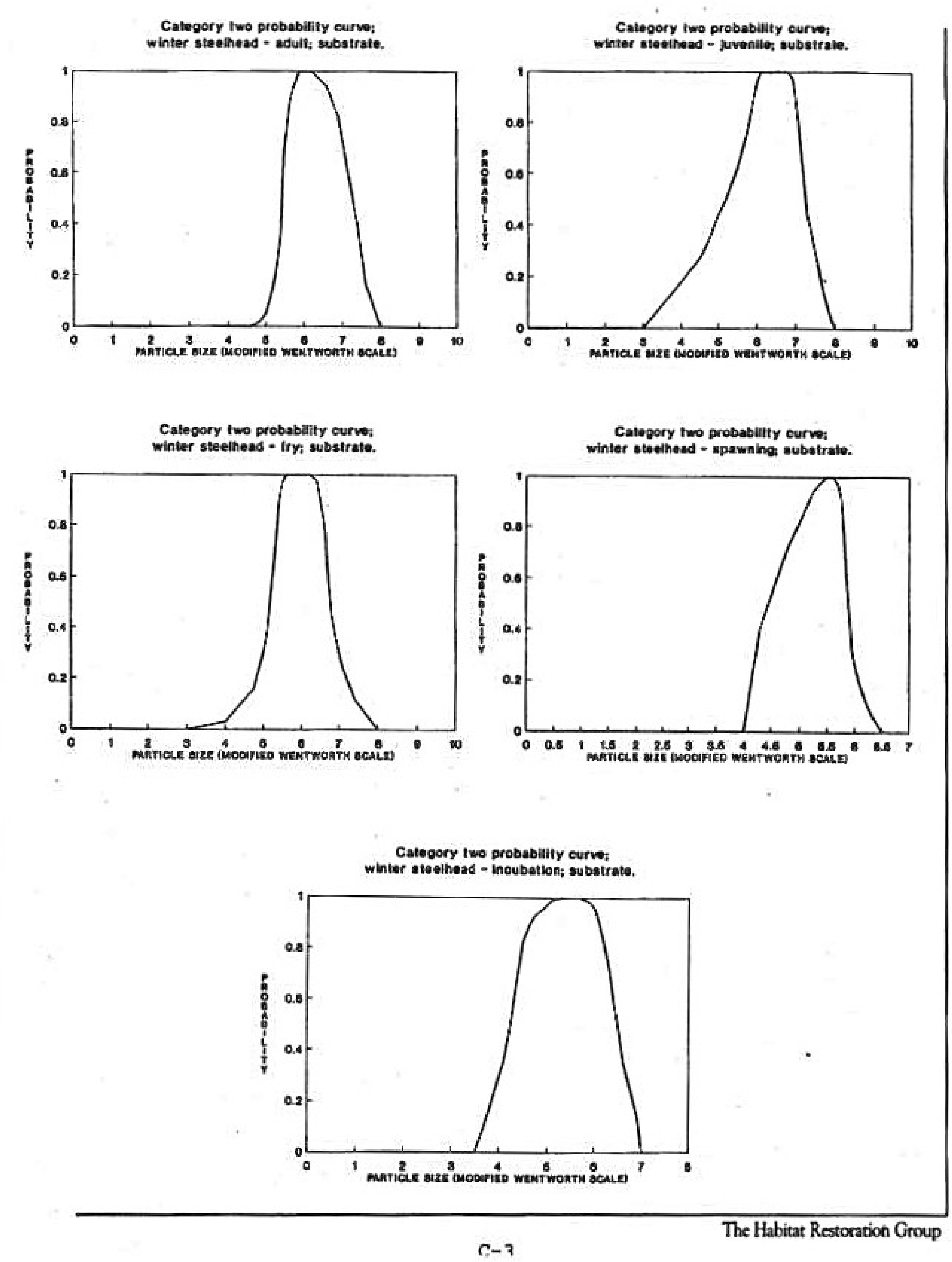
Figure 2. Depth Probability Curves for Winter Steelhead from Bovee (**1982**).


Category two probability curve; winter steelhead - adult; substrate.

Category two probability curve; winter steelhead - juvenile; substrate.

Category two probability curve; winter steelhead - fry; substrate.

Category two probability curve; winter steelhead - spawning; substrate.

Category two probability curve; winter steelhead - incubation; substrate.

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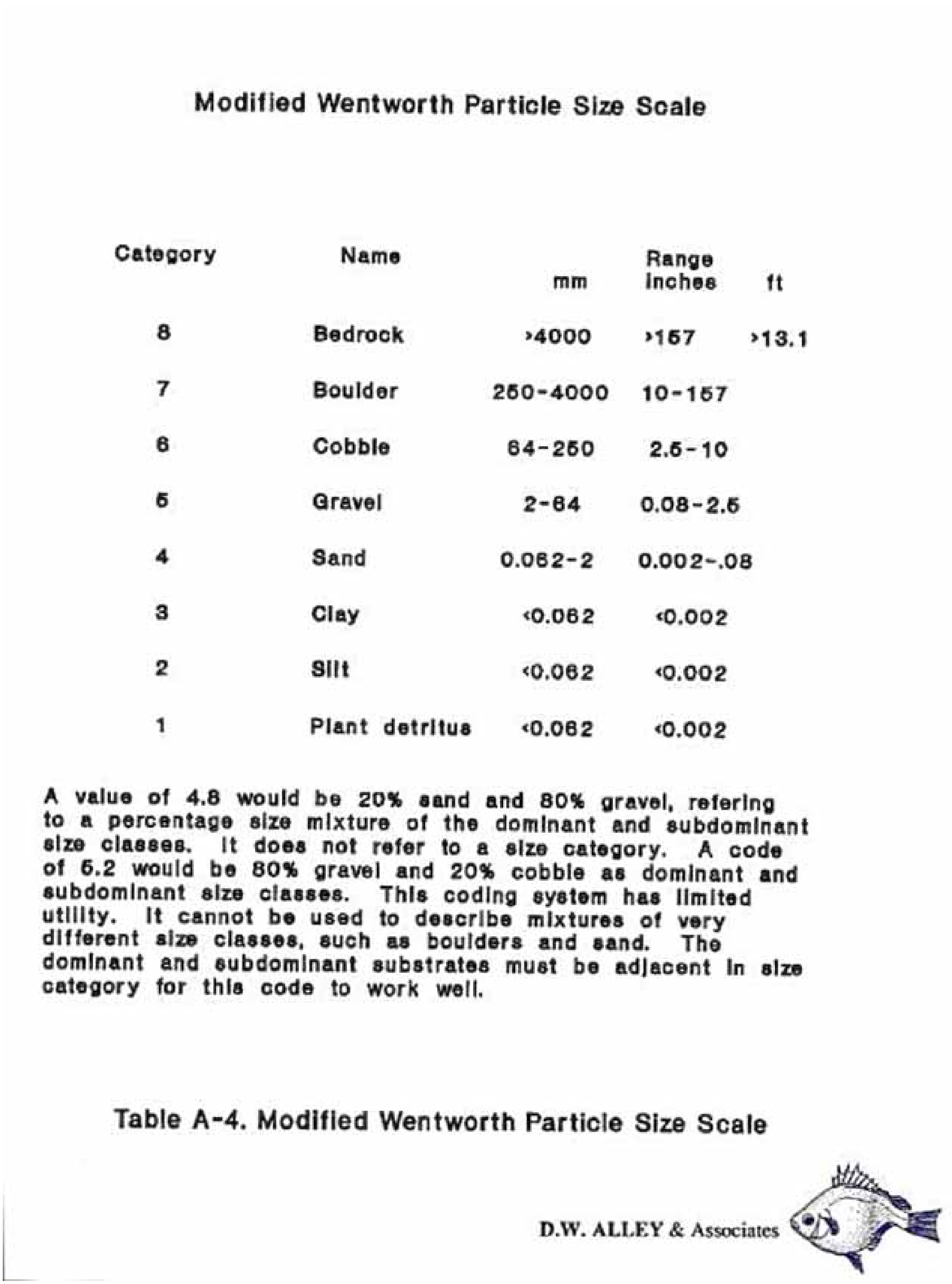
Figure 3. Substrate Probability Curves for Winter Steelhead from Bovee (**1982**).



Modified Wentworth Particle Size Scale

Category	Name	Range mm	Range inches	Range ft
8	Bedrock	>4000	>157	>13.1
7	Boulder	250-4000	10-157	
6	Cobble	64-250	2.5-10	
5	Gravel	2-64	0.08-2.5	
4	Sand	0.062-2	0.002-.08	
3	Clay	<0.062	<0.002	
2	Silt	<0.062	<0.002	
1	Plant detritus	<0.062	<0.002	

A value of 4.8 would be 20% sand and 80% gravel, refering to a percentage size mixture of the dominant and subdominant size classes. It does not refer to a size category. A code of 5.2 would be 80% gravel and 20% cobble as dominant and subdominant size classes. This coding system has limited utility. It cannot be used to describe mixtures of very different size classes, such as boulders and sand. The dominant and subdominant substrates must be adjacent in size category for this code to work well.

Table A-4. Modified Wentworth Particle Size Scale

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Figure 4. Modified Wentworth Particle Size Scale

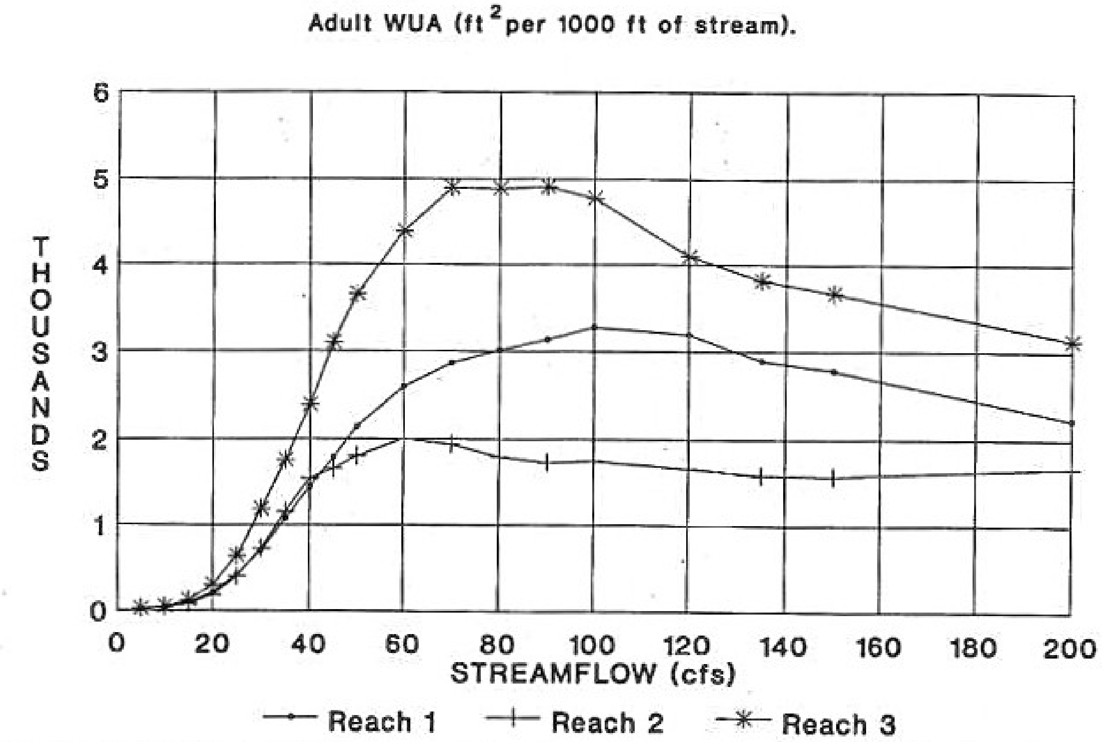

Figure 5. Steelhead Habitat, Carmel River. Composite Weighted Usable Area (WUA) from hydraulic simulations with appropriate weighting factors.

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Figure 5. Simulation of Weighted Usable Area for Adult Steelhead in Reaches Between San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**).

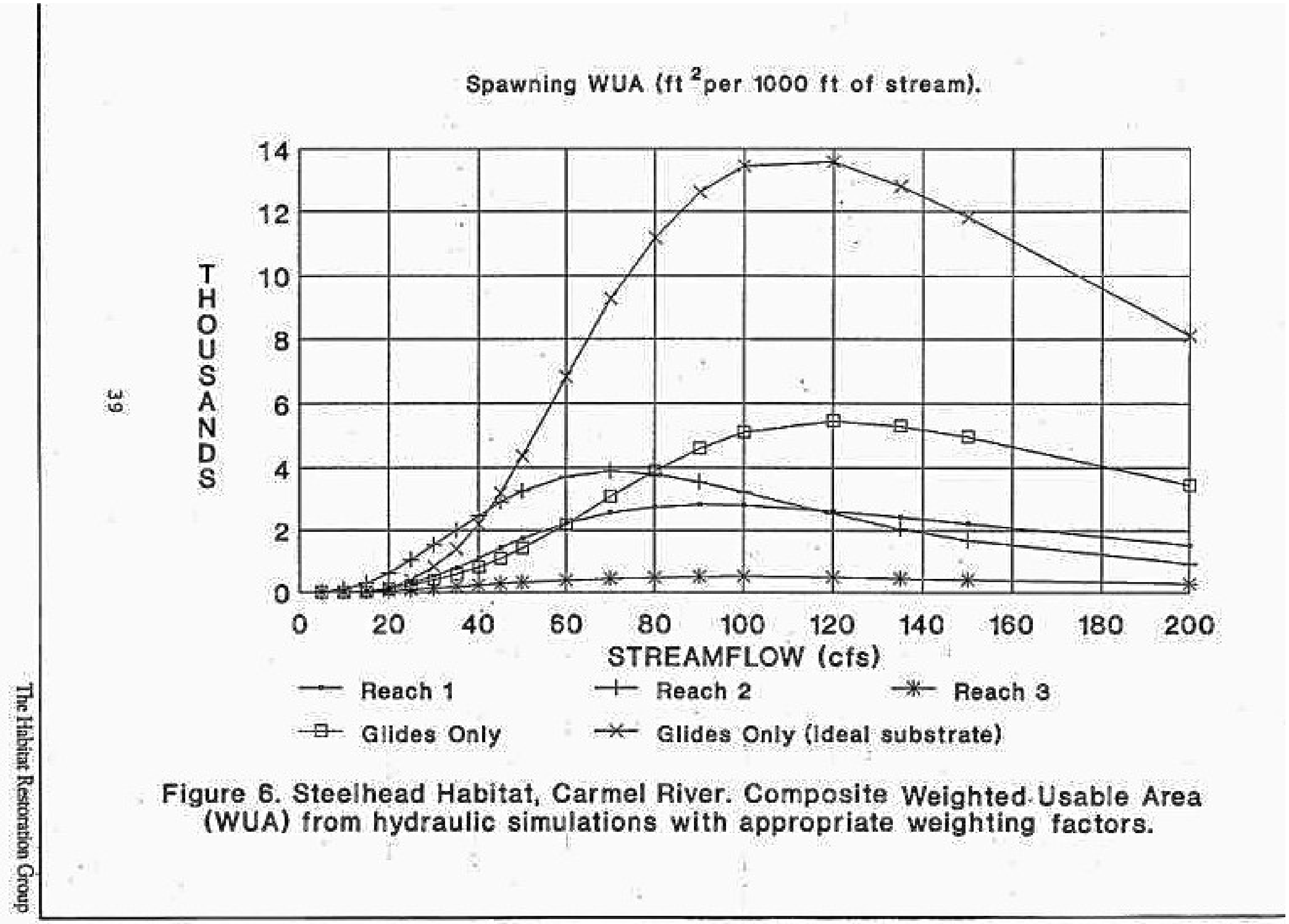

Figure 6. Steelhead Habitat, Carmel River. Composite Weighted Usable Area (WUA) from hydraulic simulations with appropriate weighting factors.

Figure 6. Simulated Weighted Usable Area for Spawning of Steelhead Between the San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**).

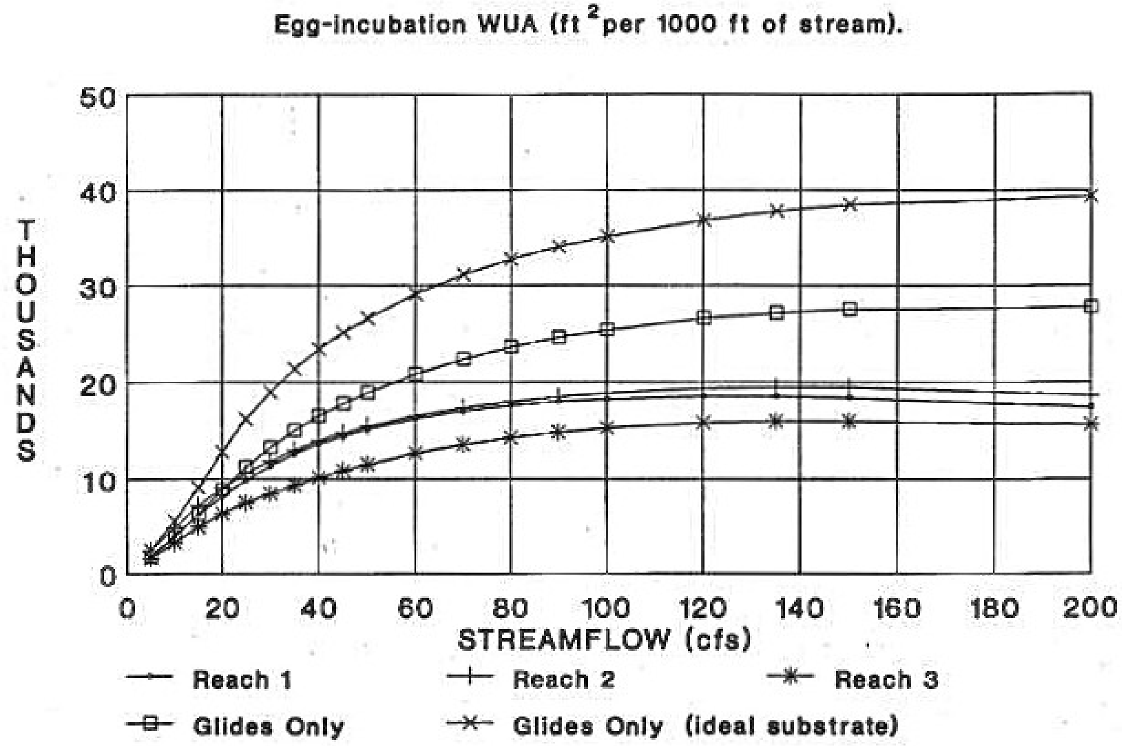

Figure 2. Steelhead Habitat, Carmel River. Composite Weighted Usable Area (WUA) from hydraulic simulations with appropriate weighting factors.

Figure 7. Simulated Weighted Usable Area for Egg Incubation of Steelhead Between the San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**).

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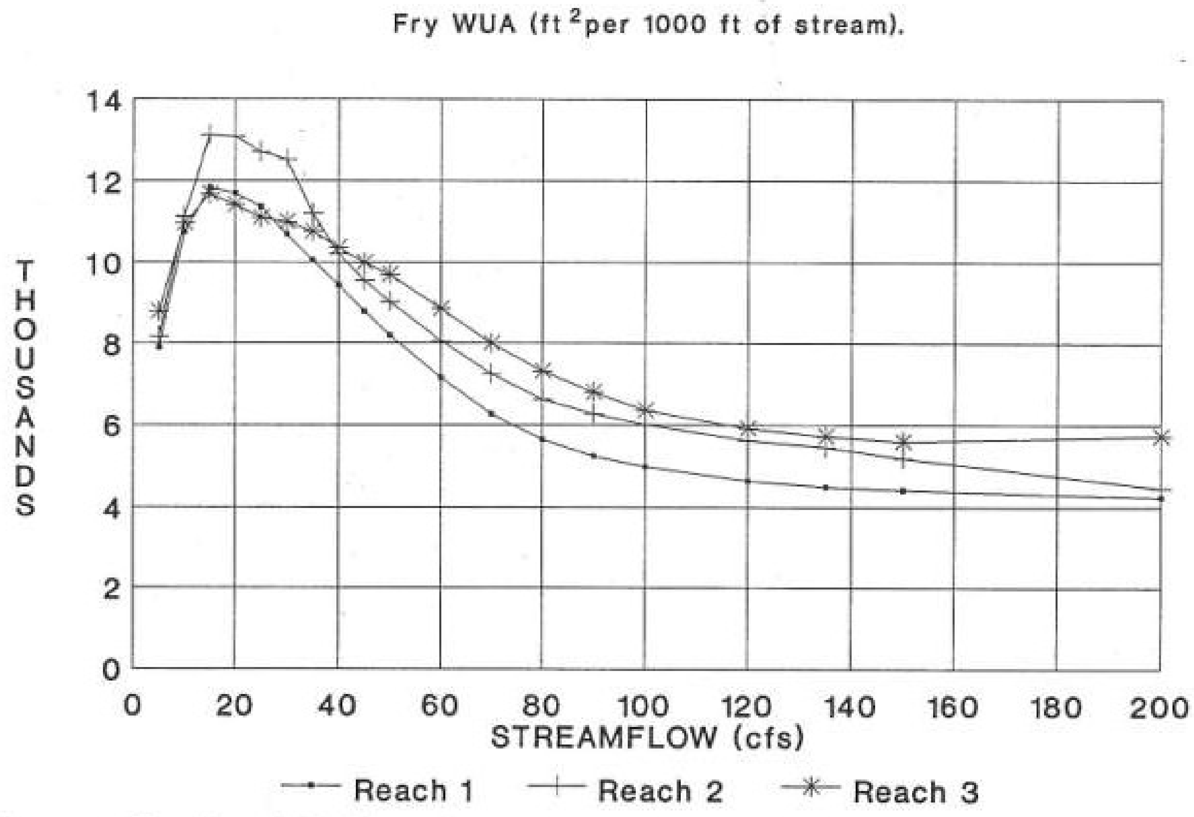

Figure 3. Steelhead Habitat, Carmel River. Composite Weighted Usable Area (WUA) from hydraulic simulations with appropriate weighting factors.

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Figure 8. Simulated Weighted Usable Area for Steelhead Fry Between the San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**).

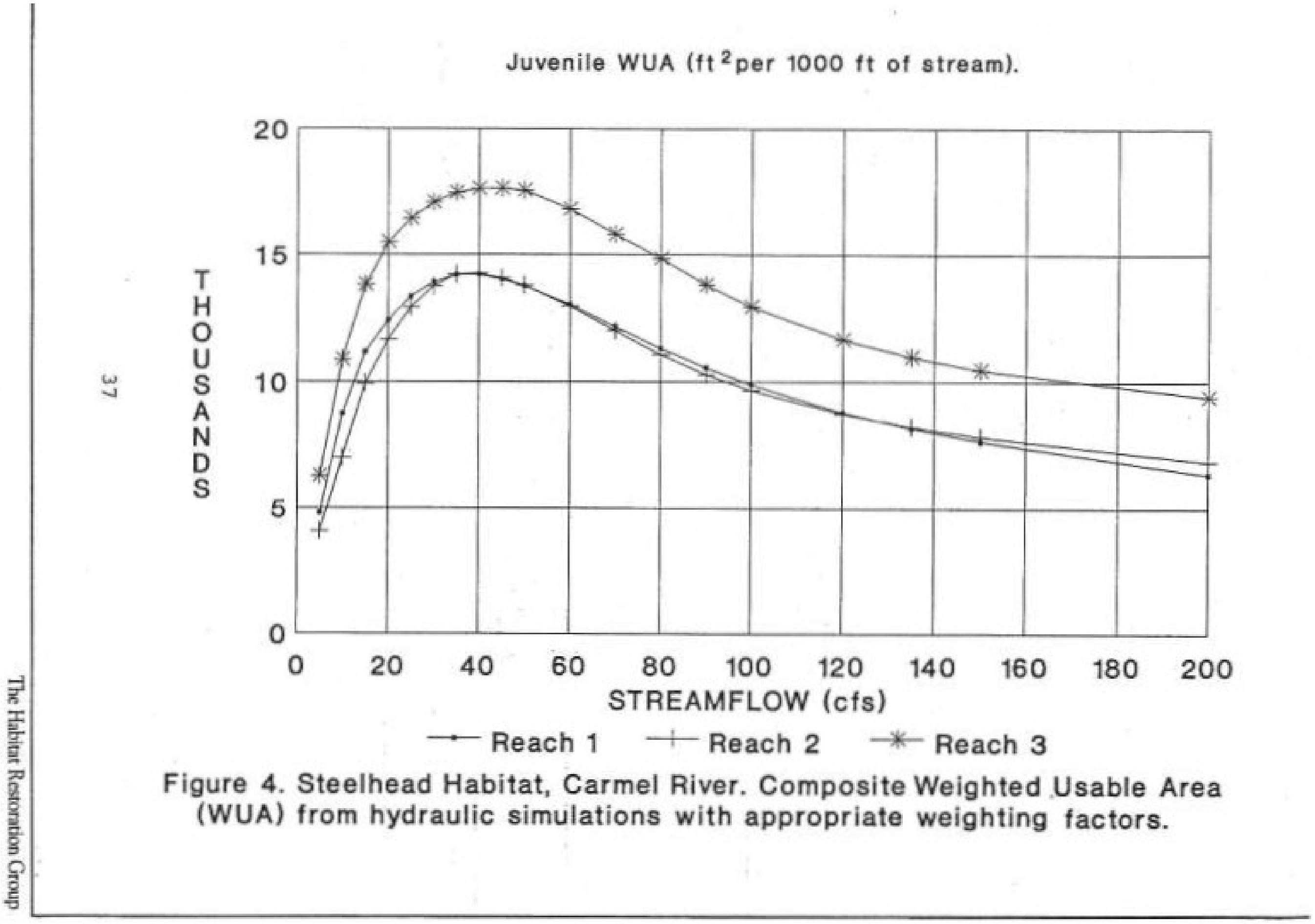

Figure 4. Steelhead Habitat, Carmel River. Composite Weighted Usable Area (WUA) from hydraulic simulations with appropriate weighting factors.

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Figure 9. Simulated Weighted Usable Area for Steelhead Juveniles Between the San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**).

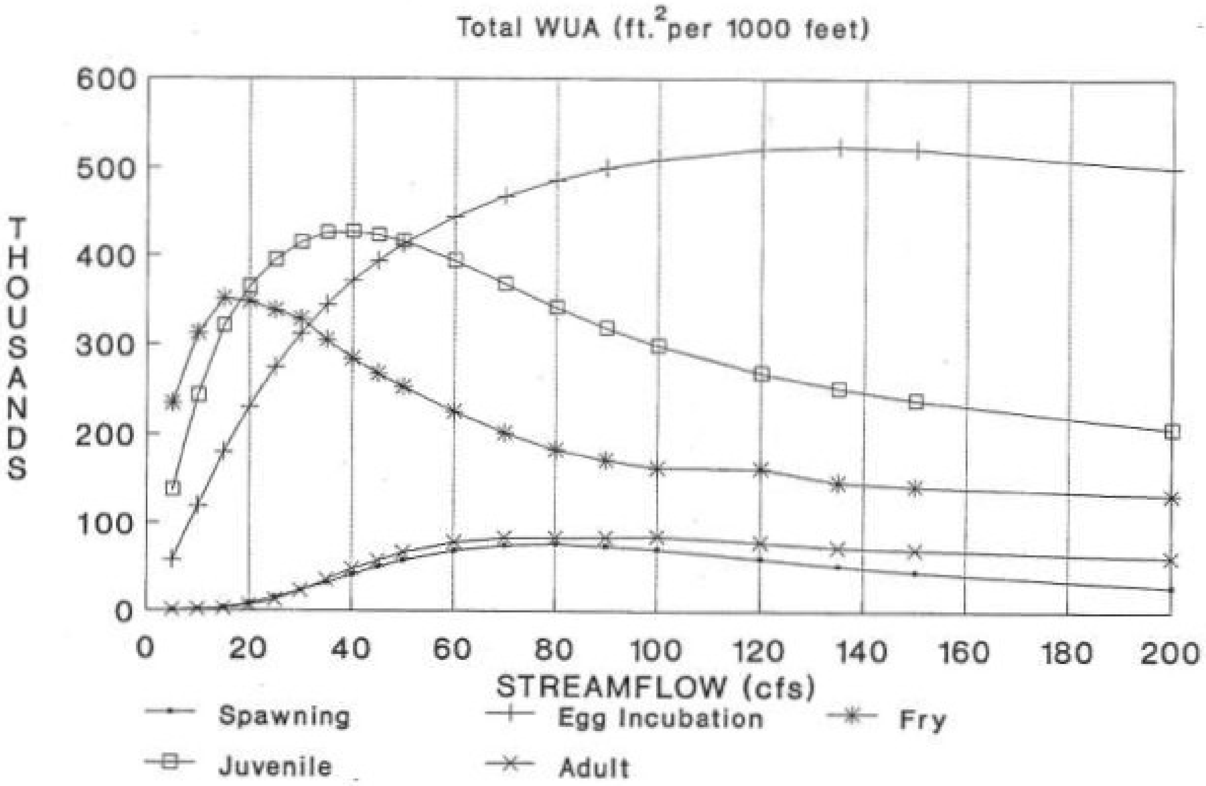

Figure 7. Total WUA for all reaches combined/ stream discharge relationship, Carmel River.

Figure 10. Simulated Weighted Usable Area for All Life Stages in Three Combined Reaches Between the San Clemente and Los Padres Dams on the Carmel River (**Alley 1990**).

C. FISH SCREENING CRITERIA FOR ANADROMOUS SALMONIDS

A functional design must be developed for any newly proposed water diversion as part of the application or consultation during the ESA review. The design must reflect the National Marine Fisheries Service (NMFS; also known as NOAA Fisheries) design criteria that are detailed below. Information in this section that is relevant to the proposed project would pertain to streams/ rivers and the modified criteria for small screens (less than 40 cfs diversion rate) found at the end of the excerpt in Section K. NMFS has separate approach velocity criteria for fry compared to fingerlings, with 0.33 ft/s maximum for fry and 0.8 ft/s for fingerlings for both small and large diversions with no time of exposure specified. Based on discussion with NOAA Fisheries staff, criteria for approach velocity, sweeping velocity and screen face material should be based on those that assume small steelhead and coho salmon fry are present. We recommend that juvenile bypass channels be avoided due to their additional design complexity, maintenance and regulatory criteria.

DFG fish screening criteria provided from the Sacramento Valley Fish Screen Program (2000) were also reviewed and compared to the NMFS criteria. The DFG criteria state that where feasible, the on-stream fish screen structure is preferred over bypass channel systems. Differences between the DFG and NMFS criteria include differing approach velocities. For self-cleaning screens in streams and rivers, DFG requires 0.33 ft/s maximum approach velocity where exposure to the fish screen does not exceed fifteen minutes, or 0.4 ft/s maximum approach velocity for small (less than 40 cfs) pumped diversions using manufactured, self-contained screens. DFG has additional criteria for screens that are not self-cleaning. NMFS requires all diversions to be self-cleaning. DFG states that sweeping velocity should be at least two times the allowable approach velocity for streams and rivers. NMFS states only that sweeping velocity shall be greater than approach velocity.

The fish screen should be designed with the most demanding criteria satisfied when criteria differ between CDG and NMFS. DFG has additional regulations regarding screen construction, repair, relocation, modification and reconstruction of the intake facilities related to change of creek alignment or increase in the intake size to satisfy diversion requirements or increase intake rate.

National Marine Fisheries Service Fish Screening Criteria

The following sections regarding fish screening criteria was excerpted from the NMFS publication (**1997**).

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.

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 trash rack 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.
3. 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.
4. 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
   NMFS Fish Screen Criteria 5

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. NMFS Fish Screen Criteria 6

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 ¼-inch (6.35 mm) in diameter.
    b. Profile bar: screen openings shall not exceed ¼-inch (6.35 mm) in width
    c. Woven wire: Screen openings shall not exceed ¼-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 NMFS Fish Screen Criteria 7 option which, in its judgment, 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 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. NMFS Fish Screen Criteria 8
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 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. NMFS Fish Screen Criteria 9
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. NMFS Fish Screen Criteria 10
   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.

Department of Fish and Game Fish Screening Criteria

The following information was excerpted from the DFG publication (**2000**) providing California Department of Fish and Game fish screening criteria.

A. Structure Placement

1. Streams and Rivers (flowing water): The screen face shall be parallel to the flow and adjacent bankline (water's edge), with the screen face at or streamward of a line defined by the annual low-flow water's edge.

The upstream and downstream transitions to the screen structure shall be designed and constructed to match the bankline, minimizing eddies upstream of, in front of, and downstream of, the screen.

Where feasible, this “on-stream” fish screen structure placement is preferred by the California Department of Fish and Game.

2. In Canals (flowing water): The screen structure shall be located as close to the river source as practical, in an effort to minimize the approach channel length and the fish return bypass length. This “in canal” fish screen location shall only be used where an "on-stream" screen design is not feasible. This situation is most common at existing diversion dams with headgate structures.
   The current National Marine Fisheries Service - Southwest Region criteria for these types of installations shall be used.
3. Small Pumped Diversions: Small pumped diversions (less than 40 cubic-feet per second) which are screened using “manufactured, self-contained” screens shall conform to the National Marine Fisheries Service - Southwest Region criteria.
4. Non-Flowing Waters (tidal areas, lakes and reservoirs): The preferred location for the diversion intake structure shall be offshore, in deep water, to minimize fish contact with the diversion. Other configurations will be considered as exceptions to the screening criteria as described in Section 5.F. below.

B. Approach Velocity (Local velocity component perpendicular to the screen face)

1. Flow Uniformity: The design of the screen shall distribute the approach velocity uniformly across the face of the screen. Provisions shall be made in the design of the screen to allow for adjustment of flow patterns. The intent is to ensure uniform flow distribution through the entire face of the screen as it is constructed and operated.
2. Self-Cleaning Screens: The design approach velocity shall not exceed:
   a. Streams and Rivers (flowing waters) - Either:
      1) 0.33 feet per second, where exposure to the fish screen shall not exceed fifteen minutes, or
      2) 0.40 feet per second, for small (less than 40 cubic-feet per second) pumped diversions using “manufactured, self-contained” screens.
   b. In Canals (flowing waters) - 0.40 feet per second, with a bypass entrance located every one-minute of travel time along the screen face.
   c. Non-Flowing Waters (tidal areas, lakes and reservoirs) - The specific screen approach velocity shall be determined for each installation, based on the species and life stage of fish being protected. Velocities which exceed those described above will require a variance to these criteria (see Section 5.F. below).

      (Note: At this time, the U.S. Fish and Wildlife Service has selected a 0.2 feet per second approach velocity for use in waters where the Delta smelt is found. Thus, fish screens in the Sacramento-San Joaquin Estuary should use this criterion for design purposes.)

3. Screens Which Are Not Self-Cleaning: The screens shall be designed with an approach velocity one-fourth that outlined in Section B above. The screen shall be cleaned before the approach velocity exceeds the criteria described in Section B.
    a. Frequency of Cleaning: Fish screens shall be cleaned as frequently as necessary to prevent flow impedance and violation of the approach velocity criteria. A cleaning cycle once every 5 minutes is deemed to meet this standard.
    b. Screen Area Calculation: The required wetted screen area (square feet), excluding the area affected by structural components, is calculated by dividing the maximum diverted flow (cubic-feet per second) by the allowable approach velocity (feet per second). Example: 1.0 cubic-feet per second / 0.33 feet per second = 3.0 square feet. Unless otherwise specifically agreed to, this calculation shall be done at the minimum stream stage.

C. **Sweeping Velocity (Velocity component parallel to screen face)**

1. In Streams and Rivers: The sweeping velocity should be at least two times the allowable approach velocity.
2. In Canals: The sweeping velocity shall exceed the allowable approach velocity. Experience has shown that sweeping velocities of 2.0 feet per second (or greater) are preferable.
3. Design Considerations: Screen faces shall be designed flush with any adjacent screen bay piers or walls, to allow an unimpeded flow of water parallel to the screen face.

D. Screen Openings

1. Porosity: The screen surface shall have a minimum open area of 27%. We recommend the maximum possible open area consistent with the availability of appropriate material, and structural design considerations.

   The use of open areas less than 40/% shall include consideration of increasing the screen surface area, to reduce slot velocities, assisting in both fish protection and screen cleaning.

2. Round Openings: Round openings in the screening shall not exceed 3.96mm (5/32in). In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in).
3. Square Openings: Square openings in screening shall not exceed 3.96mm (5/32in) measured diagonally. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in) measured diagonally.
4. Slotted Openings: Slotted openings shall not exceed 2.38mm (3/32in) in width. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 1.75mm (0.0689in).

E. Screen Construction

1. Material Selection: Screens may be constructed of any rigid material, perforated, woven, or slotted that provides water passage while physically excluding fish. The

largest possible screen open area which is consistent with other project requirements should be used. Reducing the screen slot velocity is desirable both to protect fish and to ease cleaning requirements. Care should be taken to avoid the use of materials with sharp edges or projections which could harm fish.

2. Corrosion and Fouling Protection: Stainless steel or other corrosion-resistant material is the screen material recommended to reduce clogging due to corrosion. The use of both active and passive corrosion protection systems should be considered.

   Consideration should be given to anti-fouling material choices, to reduce biological fouling problems. Care should be taken not to use materials deemed deleterious to fish and other wildlife.

3. Project Review and Approval: Plans and design calculations, which show that all the applicable screening criteria have been met, shall be provided to the Department before written approval can be granted by the appropriate Regional Manager.

   The approval shall be documented in writing to the project sponsor, with copies to both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. Such approval may include a requirement for post-construction evaluation, monitoring and reporting.

4. Assurances: All fish screens constructed after the effective date of these criteria shall be designed and constructed to satisfy the current criteria. Owners of existing screens, approved by the Department prior to the effective date of these criteria, shall not be required to upgrade their facilities to satisfy the current criteria unless:
   a. The controlling screen components deteriorate and require replacement (i.e., change the opening size or opening orientation when the screen panels or rotary drum screen coverings need replacing),
   b. Relocation, modification or reconstruction (i.e., a change of screen alignment or an increase in the intake size to satisfy diversion requirements) of the intake facilities, or
   c. The owner proposes to increase the rate of diversion which would result in violation of the criteria without additional modifications.
5. Supplemental Criteria: Supplemental criteria may be issued by the Department for a project, to accommodate new fish screening technology or to address species-specific or site-specific circumstances.
6. Variances: Written variances to these criteria may be granted with the approval of the appropriate Regional Manager and concurrence from both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. At a minimum, the rationale for the variance must be described and justified in the request.

   Evaluation and monitoring may be required as a condition of any variance, to ensure that the requested variance does not result in a reduced level of protection for the aquatic resources.

It is the responsibility of the project sponsor to obtain the most current version of the appropriate fish screen criteria. Project sponsors should contact the Department of Fish and Game, the National Marine Fisheries Service (for projects in marine and anadromous waters) and the U.S. Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance.

D. HABITAT SUITABILITY CURVES FOR SAN LORENZO RIVER WATERSHED

The most accurate habitat suitability curves would be those generated by actual observation and measurement of hydraulic conditions used by salmonids in the San Lorenzo River mainstem and tributaries. These data have been collected in the past by PG&E biologists in Sierran streams where hydropower is generated. **Actual data were collected at steelhead spawning locations on the Carmel River (Figure 11) that were utilized to derive alternative WUA curves (Alley 1996c).** The curves generated from data collection specific to the San Lorenzo River and its tributaries may be very different from those commonly used from Bovee (**1982**). Fish may be spawning at a wider range of water velocities and at shallower depths in the San Lorenzo system. Substrate conditions where spawning occurs will likely be far from optimal because of the high sediment content of Santa Cruz County streams.

Habitat suitability curves generated in specific tributaries may be quite different from those generated in the mainstem. Late spawners in any given season in the San Lorenzo system may utilize shallower and slower water than earlier spawners but may contribute a larger contribution to the young-of-the-year (YOY) population because their redds are less likely to be washed away by later storms. YOY production was especially high in Soquel Creek and the San Lorenzo River after winters in which most storms (and those of highest magnitude) came early in the winter with a few smaller storms afterwards, as was the case in 2002. Habitat use data may be different when collected during wet years versus dry years. Data collected over a range of rainfall years would provide the most robust suitability curves.

A goal of the water diversion scenario may be to maximize spawning WUA. Any water diversion that reduces streamflow below the flow at maximum spawning WUA will reduce spawning area and, presumably, spawning success. The amount of spawning WUA predicted at each simulated streamflow and the shape of the WUA versus streamflow curve will depend on the shape of the habitat probability curves and the estimated length of each spawning glide in the modeled reach. Differing WUA curves were generated in the proposed inundation zone of the New Los Padres Dam on the Carmel River due my modification of the Bovee (**1982**) depth probability curve and the assumed minimum water velocity at which spawning may occur (**Figure 12**). **Figures 13–15** provide the Bovee (**1982**) probability curves. **Figure 16** shows the Alley modification of the depth probability curve. The Snider assumption in **Figure 12** for spawning habitat was that habitat with mean column water velocity as low as 0.5 ft/sec would be utilized, where as the Bovee and Alley assumption was that habitat with mean water column velocity as low as 1.0 ft/ sec would be utilized. **Figures 17 and 18** also show the difference in WUA simulation caused by changing the Bovee (**1982**) depth probability curve (**Figure 14**) to the Alley (**1996c**) curve (**Figure 16**). The amount of WUA will increase with this modification once the simulated depth increases above 1.25 ft.

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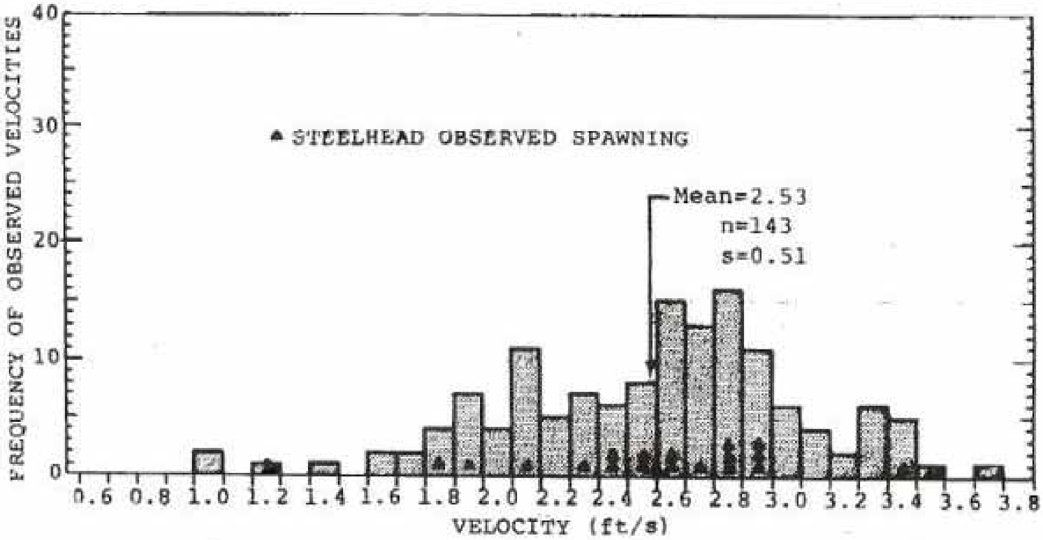

Figure III-4. Velocity of water over top of steelhead nests in Carmel River below San Clemente Dam, Feb. 22-March 10, 1982. Streamflow at time of measurement ranged from 150-230 cfs at Robles del Rio USGS gage. Velocity measured at 0.6' depth from water surface.

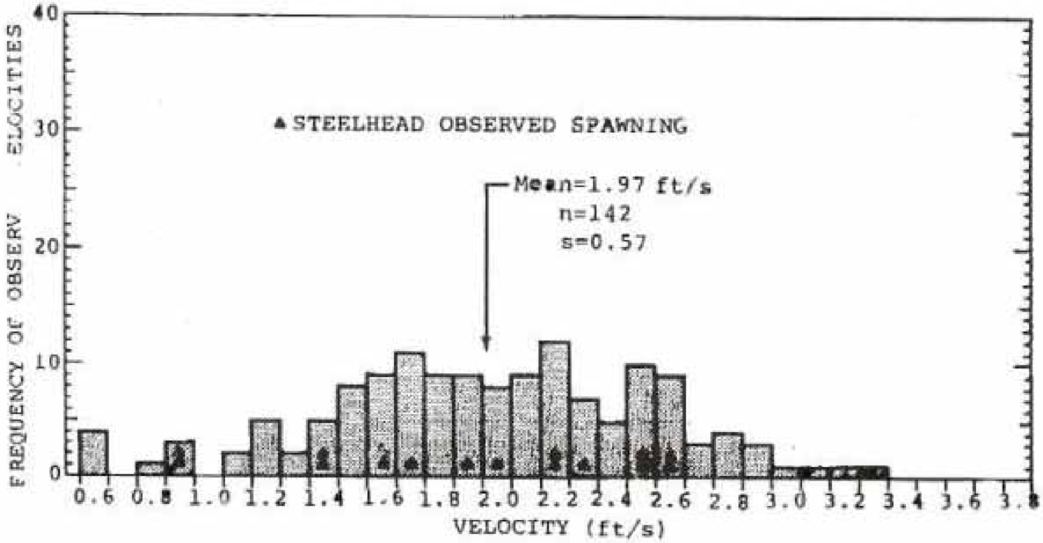

Figure III-5. Velocity of water over depression in steelhead nests in Carmel River below San Clemente Dam, Feb. 22-Mar. 10, 1982. Streamflow at time of measurements ranged from 150-230 cfs at Robles del Rio USGS gage. Velocity measured at 0.6; depth from surface of water.

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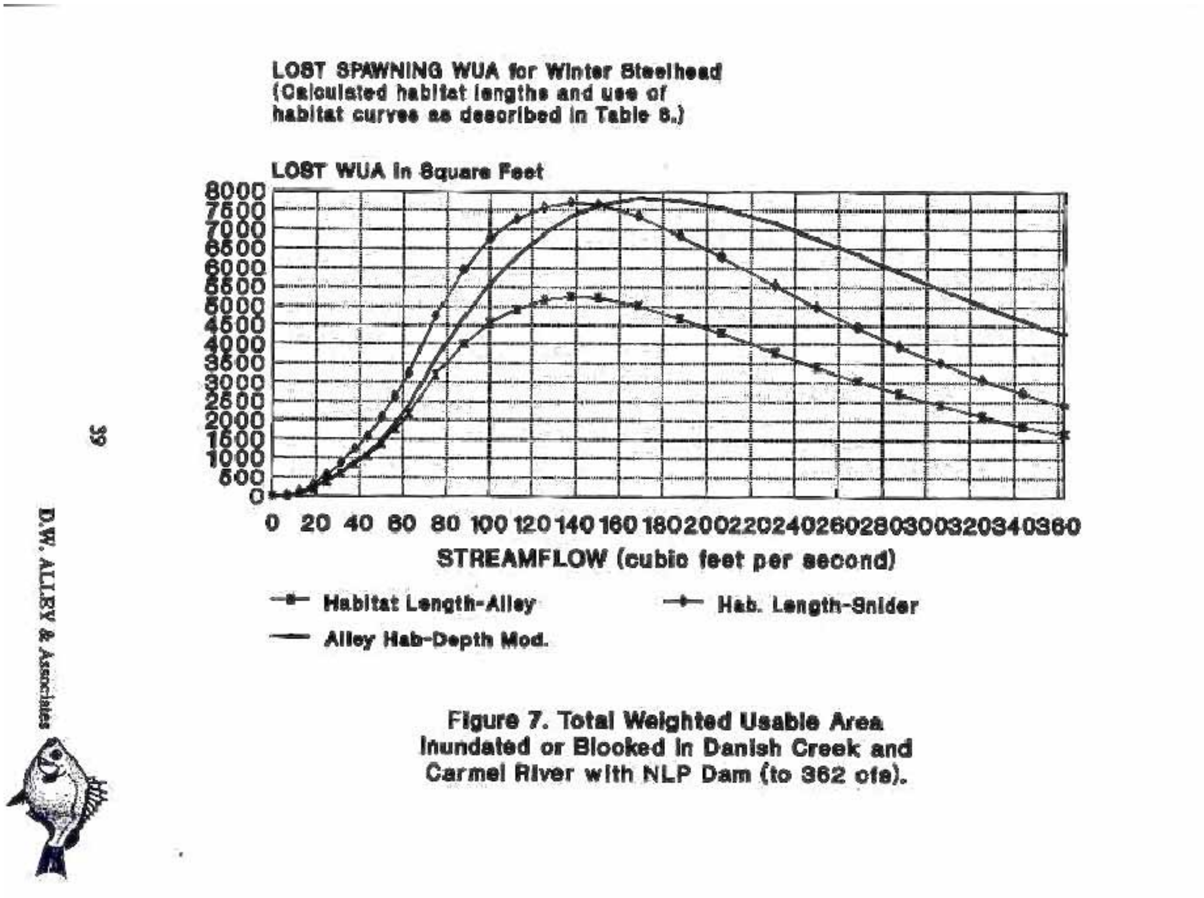
Figure 11. Dettman Frequency Distributions for Water Velocity at Steelhead Spawning Locations and Over Depressions in Steelhead Spawning Nests in the Carmel River below San Clemente Dam.



LOST SPAWNING WUA for Winter Steelhead
(Calculated habitat lengths and use of
habitat curves as described in Table 8.)

Figure 7. Total Weighted Usable Area
Inundated or Blocked in Danish Creek and
Carmel River with NLP Dam (to 362 cfs).

Figure 12. Predicted Loss of Weighted Usable Spawning Habitat from Inundation of Stream Habitat by the Proposed New Los Padres Dam (**Alley 1996c**).

Steelhead Habitat Use Curve
Upper Carmel River, California, 1995
Winter Steelhead - Adult; Velocity

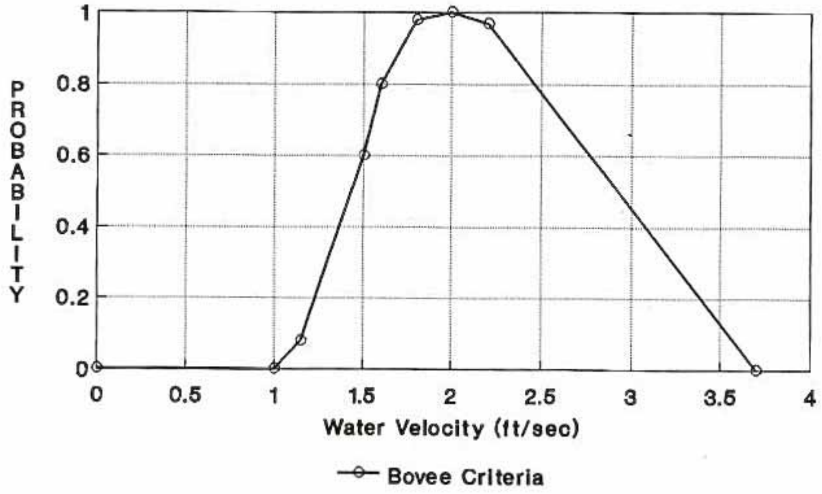


Fig A-1. Steelhead Spawning Use Curve - Velocity (Bovee 1982 Criteria)

Figure 13. Velocity Probability Curve for Winter Steelhead Spawning (Bovee (**1982**)).

Spawning Habitat Use Curve
Upper Carmel River, California, 1995
Winter Steelhead - Adult; Depth

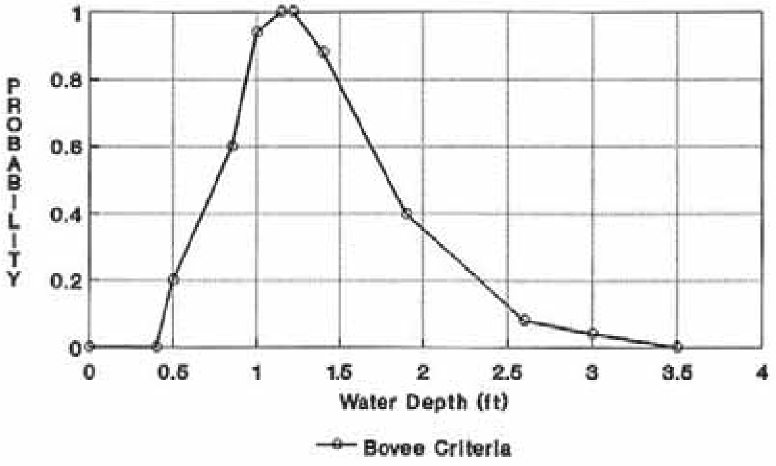
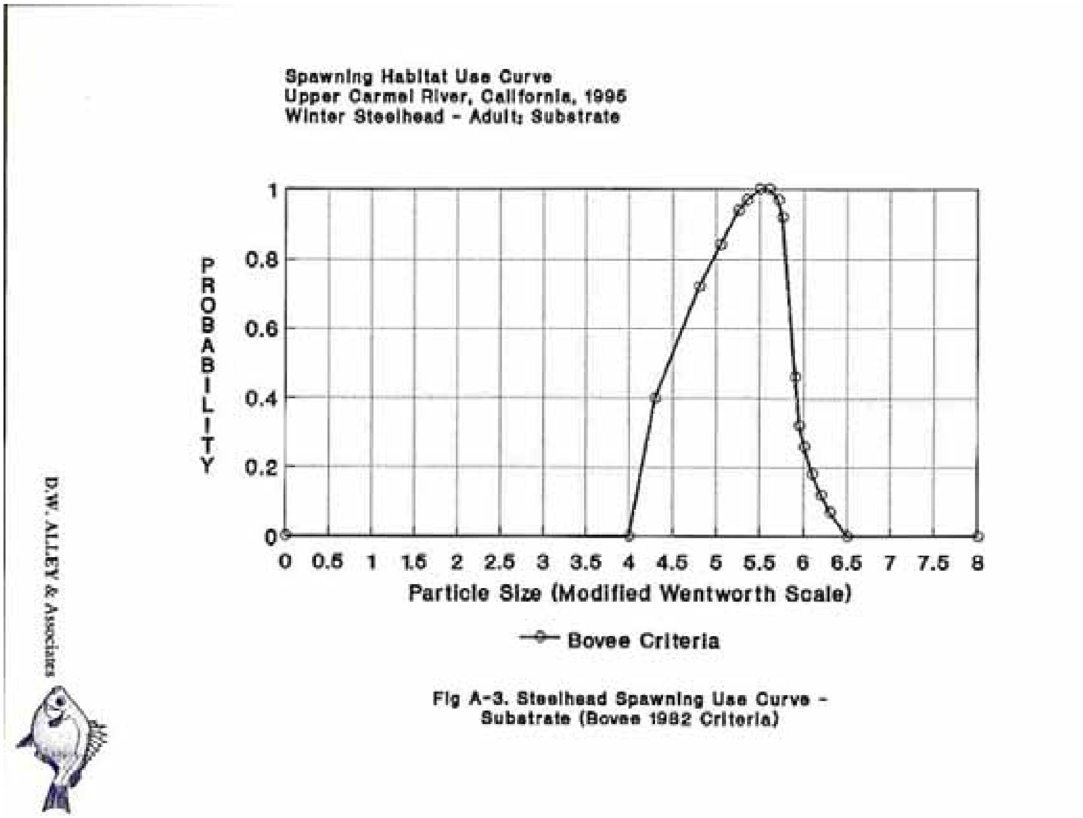


Fig A-2. Steelhead Spawning Use Curve - Depth (Bovee 1982 Criteria).

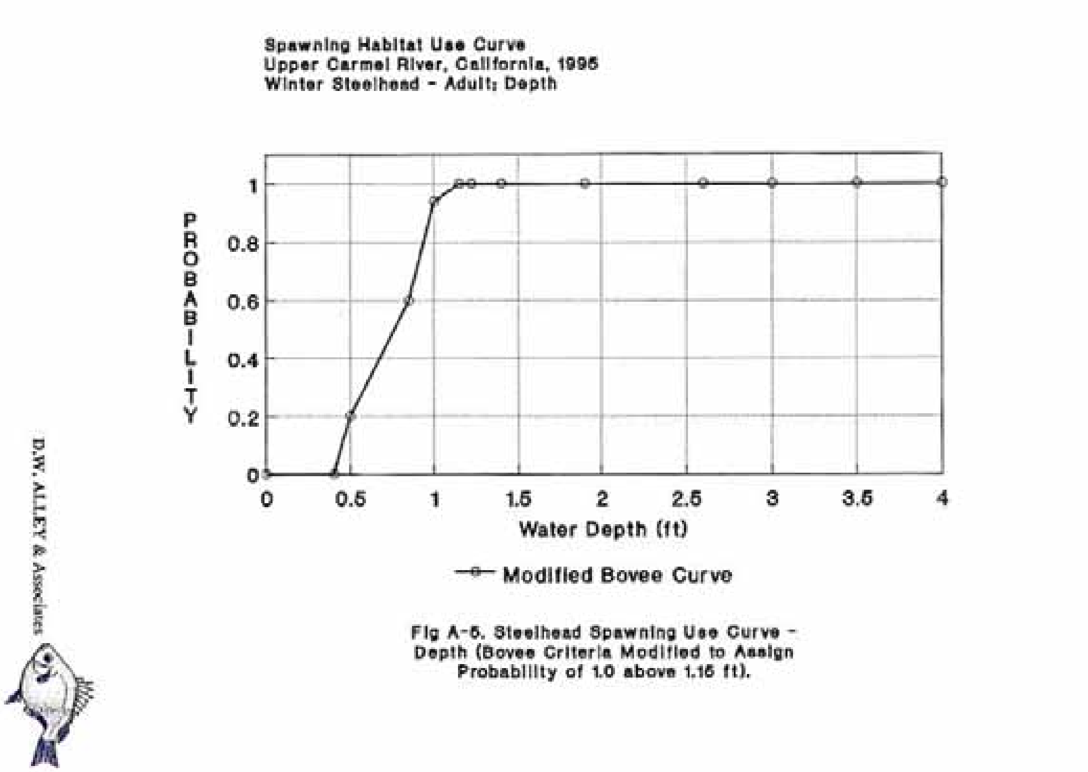
Figure 14. Depth Probability Curve for Winter Steelhead Spawning (Bovee (**1982**)).



Spawning Habitat Use Curve
Upper Carmel River, California, 1995
Winter Steelhead - Adult; Substrate

Fig A-3. Steelhead Spawning Use Curve -
Substrate (Bovee 1982 Criteria)

Figure 15. Substrate Probability Curve for Winter Steelhead Spawning (Bovee (**1982**)).



Spawning Habitat Use Curve
Upper Carmel River, California, 1995
Winter Steelhead - Adult; Depth

Fig A-5. Steelhead Spawning Use Curve -
Depth (Bovee Criteria Modified to Assign
Probability of 1.0 above 1.15 ft).

Figure 16. Depth Probability Curve for Winter Steelhead Spawning (Alley (**1996c**)).

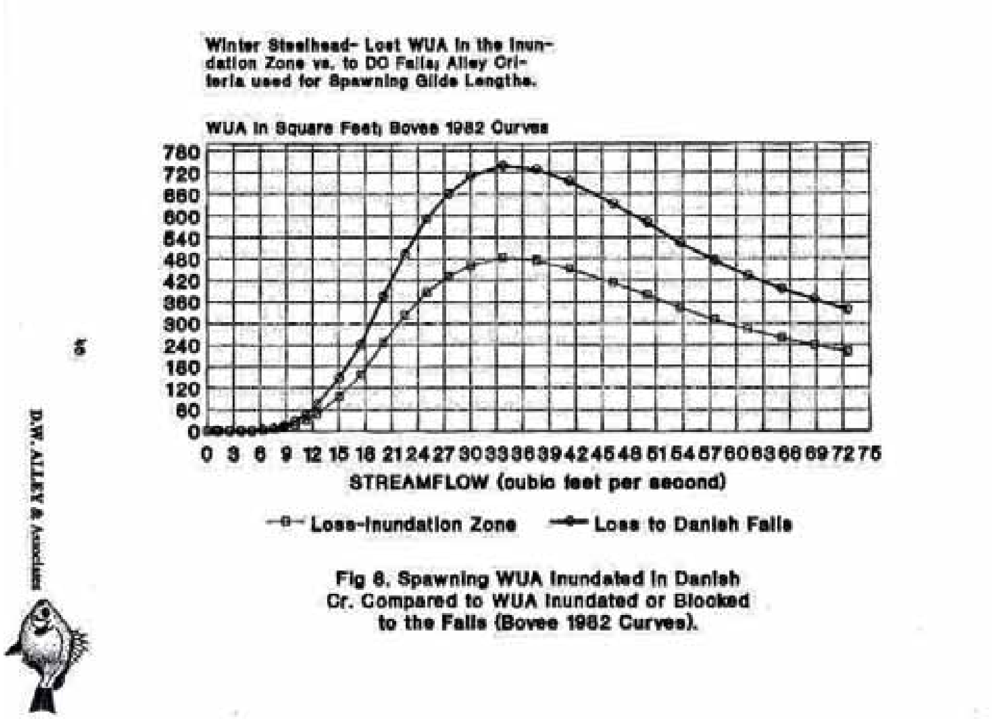


Fig 8. Spawning WUA Inundated in Danish Cr. Compared to WUA Inundated or Blocked to the Falls (Bovee 1982 Curves).

Figure 17. Spawning Weighted Usable Area Simulation Generated for Danish Creek, Using Bovee (**1982**) Habitat Probability Curves (**Alley 1996c**).

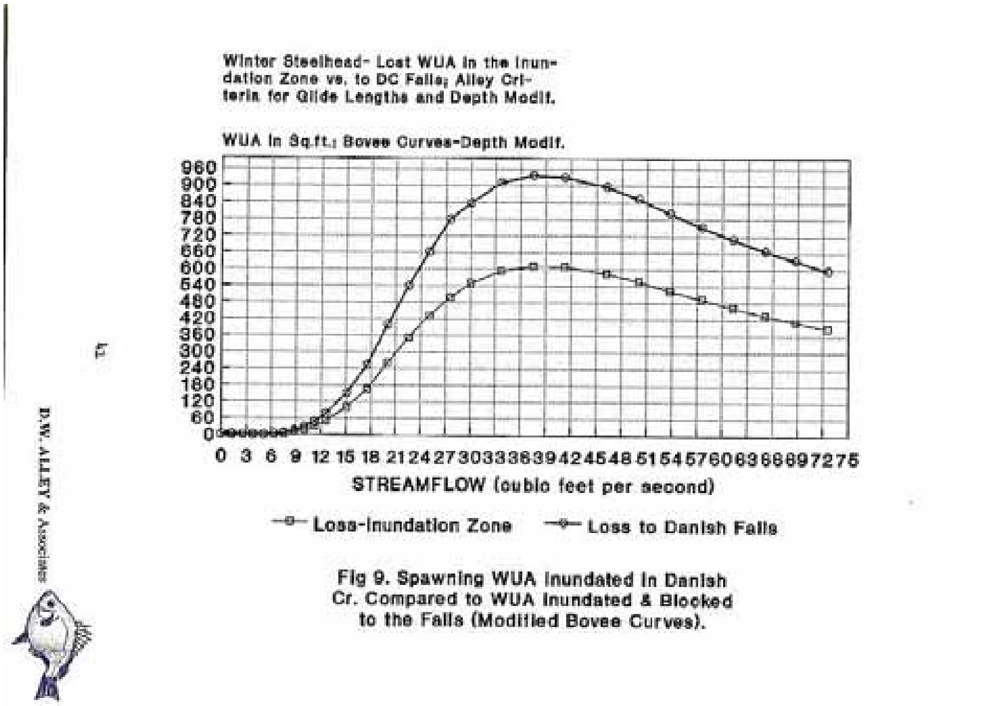


Fig 9. Spawning WUA Inundated in Danish Cr. Compared to WUA Inundated & Blocked to the Falls (Modified Bovee Curves).

Figure 18. Spawning Weighted Usable Area Simulation Generated for Danish Creek, Using Bovee (**1982**) Habitat Probability Curves With Alley Depth Modification (**Alley 1996c**).

However, it may be argued that spawning success may not limit densities of smolt-sized juvenile steelhead (which is likely the case in Zayante and Bean creeks), and it is these juveniles that are most important to adult returns because they will soon smolt to the ocean. Based on our experience it is juvenile rearing habitat that most limits the size of this size class of juvenile steelhead and not spawning habitat. If juvenile rearing habitat is most limiting, sub-optimal spawning conditions will still provide adequate spawning opportunity and egg survival to produce enough fry to fully saturate the rearing habitat with smolt-sized juveniles in most years. There is evidence from our local sampling of steelhead juveniles that YOY densities are higher in years when most storms occur early in the spawning season to allow spawning access, and few spring stormflows occur and they are small. These weather patterns likely allow better egg survival after redds are made and better fry survival after they emerge from the gravels. However, this does not necessarily translate into higher densities of smolt-sized juveniles, except in lower mainstem reaches and lagoons where YOY's may reach smolt-size in one growing season. Spring streamflow greatly influences juvenile steelhead growth rate, with accelerated growth at higher spring baseflows in wetter years. In these wetter years, there may be fewer YOY's, but a higher percentage of them may reach smolt size during the first growing season in middle and lower mainstem reaches and in the lower reaches of larger tributaries, such as Zayante Creek. A change in water management that can increase late spring and summer baseflows that would benefit rearing habitat for larger juvenile steelhead may mitigate the reduction in winter spawning habitat resulting from winter water diversion.

We may look at WUA simulations from past IFIM work to roughly assess the feasibility of new water diversions. More contemporary IFIM work and negotiations with regulatory agencies will be required to assess feasibility of newly proposed water diversions. However, past work can give ballpark estimates of how much water may be available for diversion to take a first cut at feasibility. We may look at past concerns and requirements stated by CDFG from previous feasibility studies. In addition, if newly proposed winter water diversions will result in increased spring and summer baseflow from reduced water diversion and/or pumping in the summer, then our methods used on Carbonera Creek regarding treated wastewater augmentation of streamflow may be used to estimate increased juvenile rearing habitat as a mitigation for increased winter diversions.

IFIM studies were performed on Zayante Creek at two locations in the late 1970's by Santa Cruz County staff, including John Ricker (**Santa Cruz County Planning Department 1979**). WUA curves were generated for steelhead and coho salmon. Coho salmon are detected sporadically in small numbers lately, and discussions with regulatory agencies will determine if they are a consideration in current feasibility studies. **Figures 19 and 20** provide the results of simulations in Zayante Creek below Mountain Charlie Creek. **Figures 21 and 22** provide IFIM results on Zayante Creek near Woodwardia. **Figures 23 and 24** provide IFIM results in the mainstem San Lorenzo River in Henry Cowell Park, upstream of Eagle Creek and downstream of Zayante Creek and the Felton Diversion point. The methods used at that time add uncertainty to the WUA versus streamflow relationships because hydraulic data were used from both pool and riffle transects to calculate WUA for spawning and egg incubation (**John Ricker personal communication**). Nowadays, only hydraulic data collected in spawning glides where salmonids actually spawn are used to simulate WUA for spawning and egg incubation. Data from pool transects may have over-estimated water depth, under-estimated water velocity and under-estimated gravel content. Data from riffle transects may have under-estimated water depth, over-estimated water velocity and under-estimated gravel content. Fish passage was not considered in the earlier County work. Additional transects would be needed at critical passage riffles to determine if flows required for fish passage would be higher than flows required for spawning and egg incubation.

Figure 19. Weighted Usable Area for Salmonid SPAWNING in Zayante Creek Below Mountain Charlie Creek. (Source: Santa Cruz County (1979)).

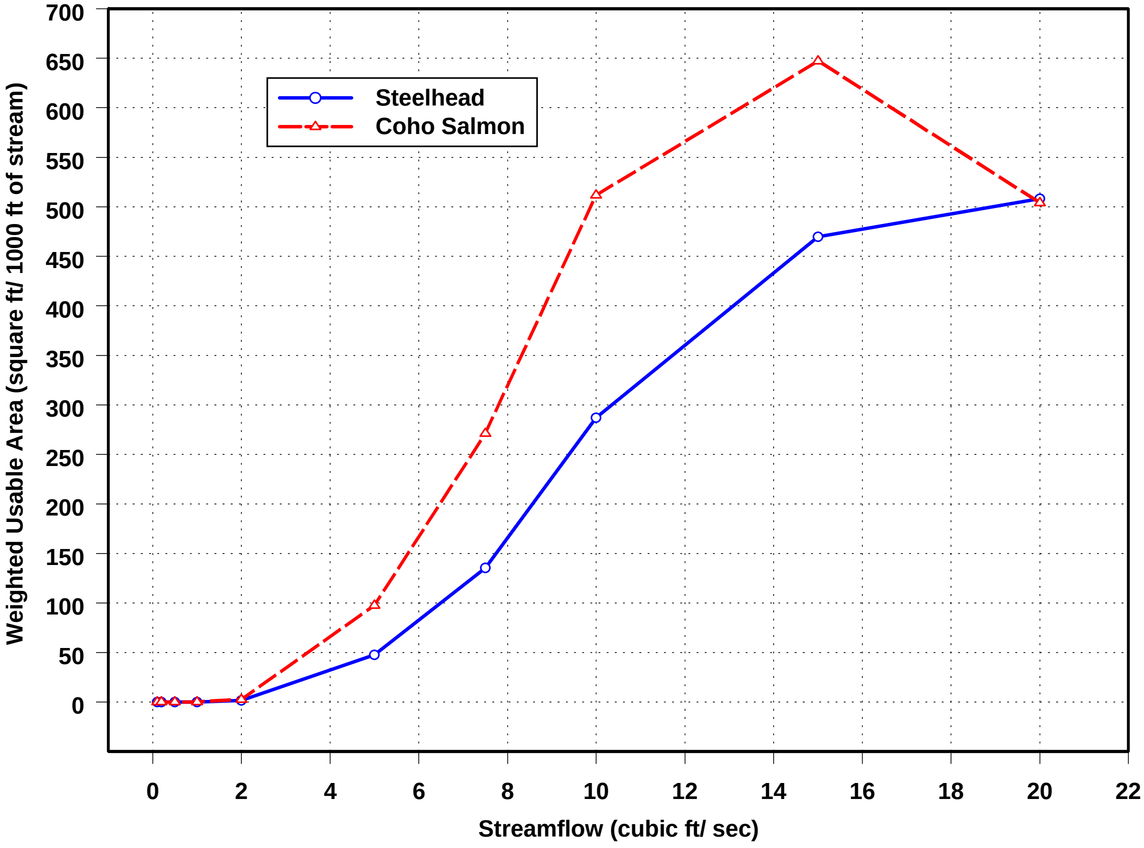


Figure 20. Weighted Usable Ara for Salmonid EGG INCUBATION in Zayante Creek Below Mountain Charlie Creek. (Source: Santa Cruz County (1979)).

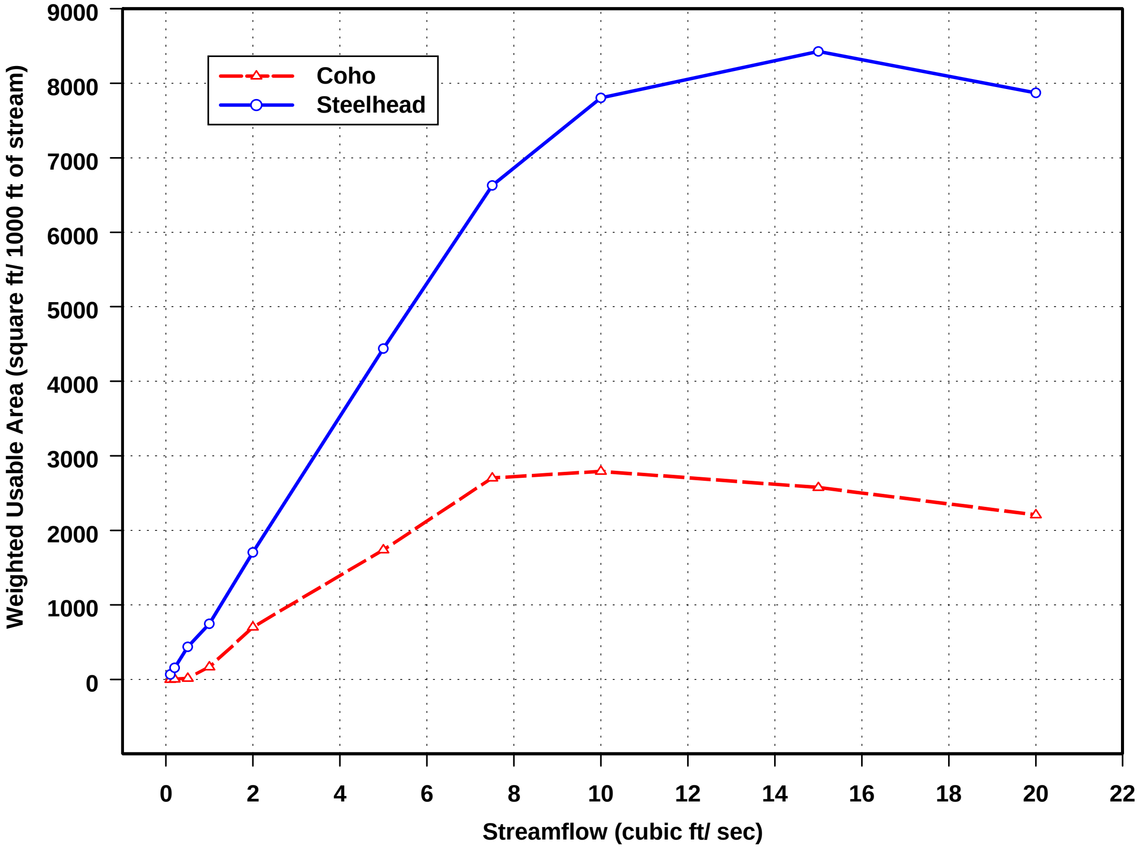


Figure 21. Weighted Usable Area for Salmonid SPAWNING in Zayante Creek at Woodwardia.
(Source: Santa Cruz County (1979)).

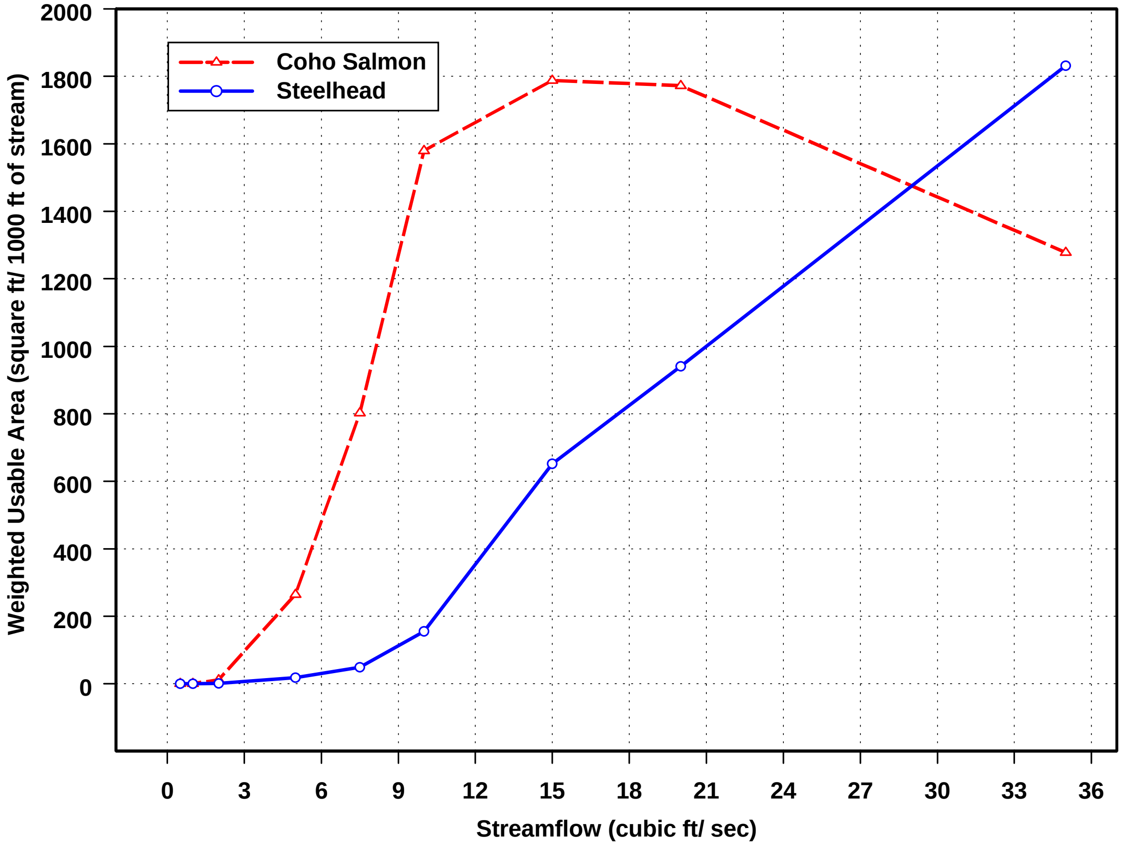


Figure 22. Weighted Usable Area for Salmonid EGG INCUBATION in Zayante Creek at Woodwardia. (Source: Santa Cruz County (1979)).

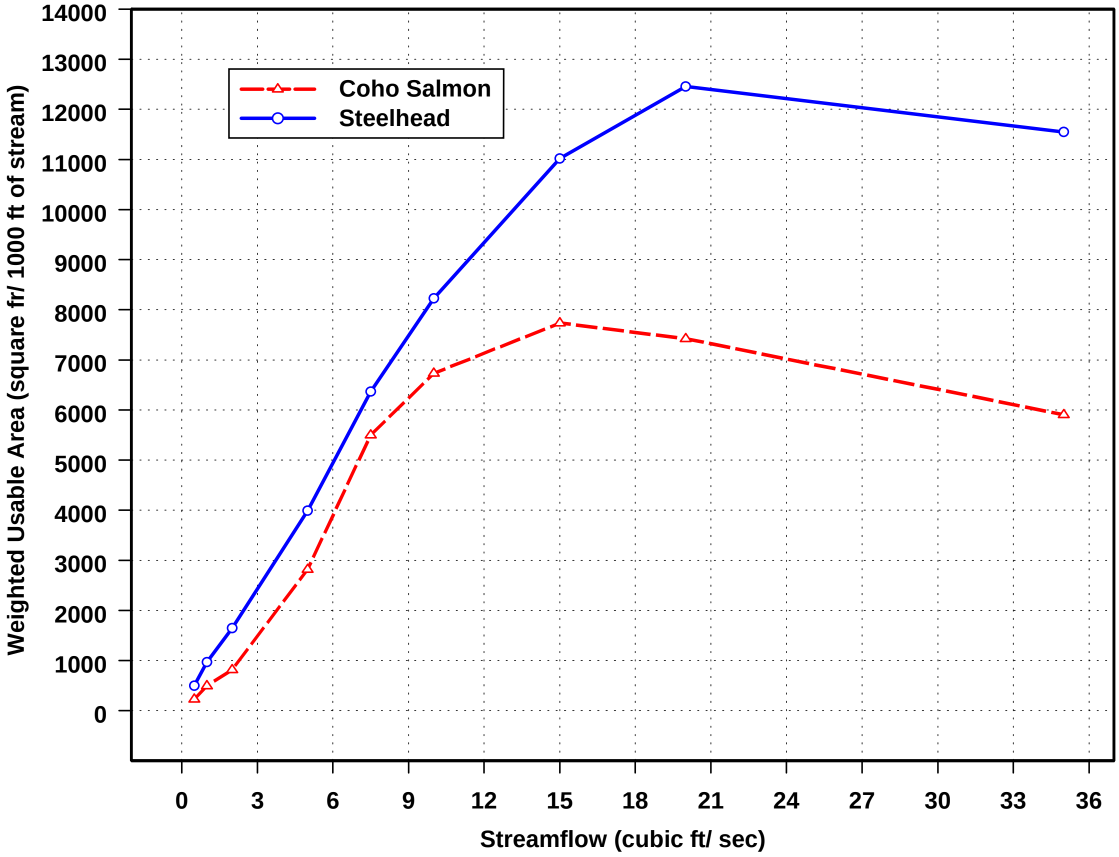


Figure 23. Weighted Usable Area for Salmonid SPAWNING in the San Lorenzo River, Upstream of Eagle Creek. (Source: Santa Cruz County (1979)).

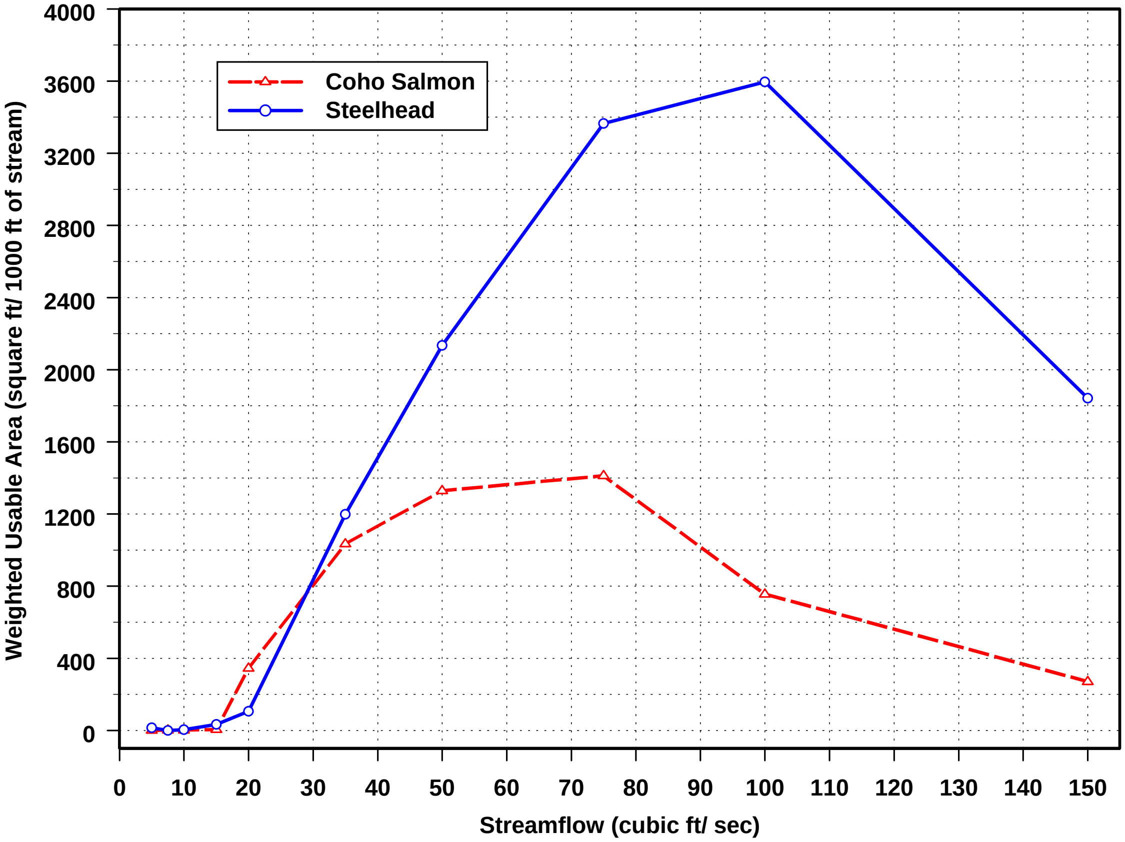
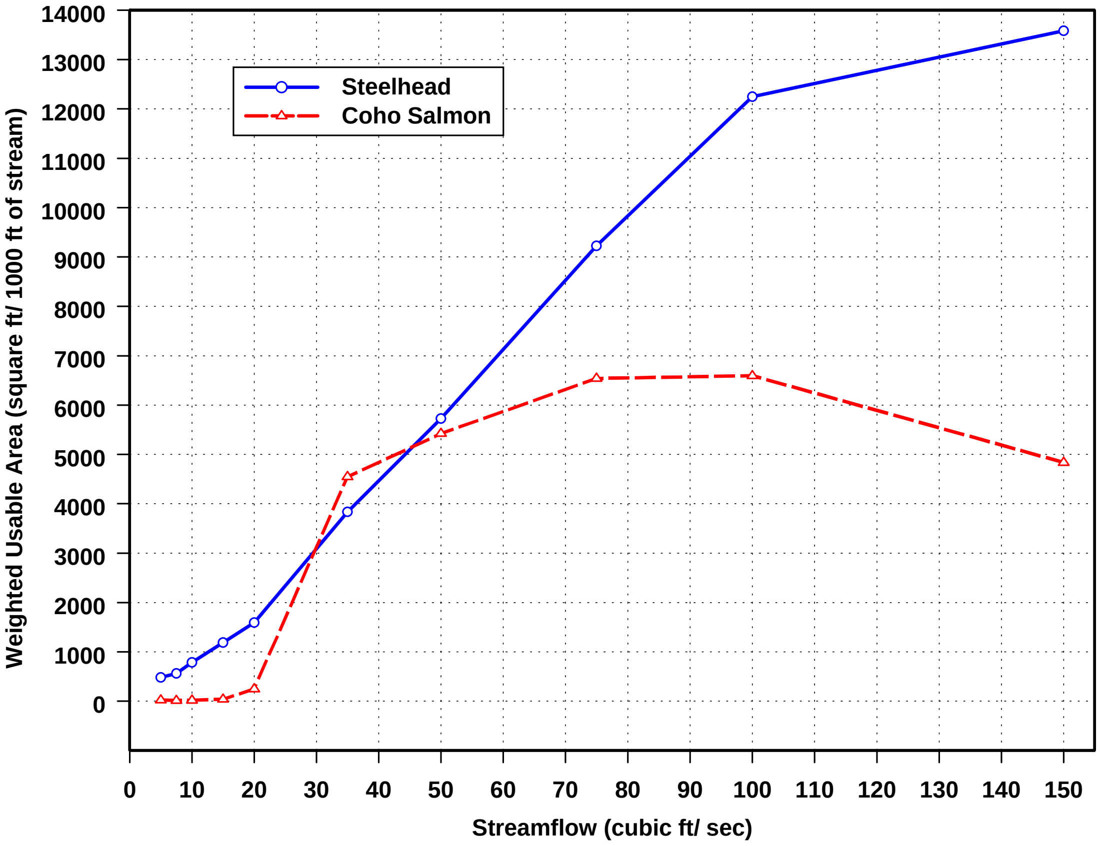


Figure 24. Weighted Usable Area for Salmonid EGG INCUBATION in the San Lorenzo River, Upstream of Eagle Creek. (Source: Santa Cruz County (1979)).



Rather than providing optimal passage and spawning conditions throughout the rainy season, it may be sufficient to provide sufficient passage flows only after stormflow events for days sufficient to allow adults to reach their spawning grounds above the proposed diversion point and optimal spawning conditions for awhile longer after that. Then egg incubation flows that would keep the thalweg inundated would be required between storms and until fry have emerged. Trapping data at the Felton Diversion Dam indicate that most adult steelhead migrate soon after stormflow maxima and during elevated flows between storms occurring in short succession. Sufficient attraction flows must be provided of sufficient duration to allow adult steelhead/ coho salmon to reach spawning habitat in the affected reach. A bypass flow schedule proposed for a previously considered water impoundment on Kings Creek is provided in **Table 1** from Alley (**1993b**). The bypass schedule was based on IFIM results for passage and spawning summarized in **Table 2**. **Table 2** provides a summary of maximum WUA for spawning and rearing and passage requirements if critical riffles are modified, based on our limited 1992 data and the County's 1978 report. IFIM transects and simulated flows were limited in both studies, and more numerous transects, collected over a wider range of streamflows, would be required in any future feasibility study. CDFG personnel who reviewed the release schedule in 1993 had stated that insufficient data were collected for them to comment on preliminary bypass flow recommendations. Additionally, since 1992 we have become increasingly aware of the importance of late spawning that may continue into May and the important juvenile growth that occurs in late spring. Therefore, bypass flows for spawning should probably continue until May 1. Bypass flows for egg incubation should probably continue until June 1, and juvenile rearing flows should be protected after April 1 as described earlier because it is an important time for juvenile steelhead/ coho feeding and growth. However, as mentioned earlier, juvenile sampling generally occurs in the fall and there are no data about juvenile growth and survival before and after April 1. Therefore, as described earlier. a site-specific study to compare streamflow and juvenile growth would be necessary to establish these data.

Alternative Method for Quantifying Enhancement of Summer Rearing Habitat in Tributary Reaches from Baseflow Augmentation

The baseflow augmentation to be expected from the new conjunctive use program that incorporates new diversion projects must be quantified in order to quantify the potential enhancement of summer rearing habitat. Instream flow methods used on Carbonera Creek (**Alley 1996b; 1997**) may be used to model increased rearing habitat to be expected from baseflow augmentation. An empirical model was developed by Smith (**1984**) to predict the density of larger juveniles (Size Class II =>75 mm SL and usually yearlings in tributary reaches) based on model inputs of average habitat depth and the habitat escape cover index. The model is most predictive when rearing habitat is saturated with Size Class II juveniles. Changes in habitat depth and escape cover are measured as streamflow declines at representative monitoring sites in tributary and/or mainstem reaches where summer baseflow is expected to increase from the water project.

The expected baseline density of Size Class II steelhead at the minimum baseflow in the fall can be determined for each monitored habitat within each monitoring site, using the Smith empirical model that provides fish density isoclines along the gradient of increasing cover and depth. The density isoclines represent increases of 6 Size Class II juveniles per 100 ft of habitat (**Figure 25**). For each habitat type in each monitoring site, the relationship between streamflow and average habitat depth is plotted for the calibration streamflows. The same may also be done for escape cover if it changes as streamflow declines.

These plots are used to predict increased average habitat depth and cover resulting from incremental augmentation in streamflow. The specific water depth and habitat cover increases resulting from flow increases in the 0.25 cfs to 0.5 cfs range as estimated in Technical Memorandum (TM) 1C will vary by location and will need to be matched with site-specific information. . The increase by habitat type in baseline fish density may be predicted using these plots and the fish density isoclines. The total number of Size Class II juveniles may be predicted at the lowest baseflow and at incremental flow increases by extrapolating from model-generated yearling densities by habitat type at the monitoring sites to the number of feet of each habitat type found in each reach. Habitat proportions in reaches are determined by habitat typing. The percent increase in Size Class II numbers in each reach may be calculated for incremental increases in the minimum, pre-project, dry-season baseflow. In addition, actual juvenile steelhead densities may be sampled at the monitoring sites to compare to the densities predicted by the empirical model.

Our previous modeling of the density of YOY reaching smolt size in the mainstem San Lorenzo River was well correlated with the average mean monthly streamflow for May - September at the Big Trees gage between the Zayante and Boulder creek confluences. Our previous work did not address survival rate of smolt-sized juveniles and was unable to show correlation of flow and growth rate downstream of Zayante.

We did detect a good correlation between increased survival of YOY (not smolt-size juveniles) in Boulder Creek and increased fall baseflow in different years and less so in Zayante Creek. However, other factors such as earlier spring/summer flows and spawning success also contributed to the correlation. Where a gage was available in Bean Creek, survival of YOY (not smolt sized individuals) was correlated with average mean monthly strteamflow for May-September with an r-squared of only 0.59. A juvenile growth/survival rate study as described earlier will be needed to fine-tune the relationship between streamflow, growth and survival; especially when flow augmentation is in the 0.25 to 0.5 cfs range.

It is important to realize that few YOY reach smolt size in tributaries under any baseflow conditions that we have monitored in the last 15 years of fall, juvenile sampling. Juvenile growth may occur throughout the summer in parts of the mainstem River, especially downstream of Zayante Creek, but may not occur in tributaries except in the wettest years in the largest, sunniest tributaries.

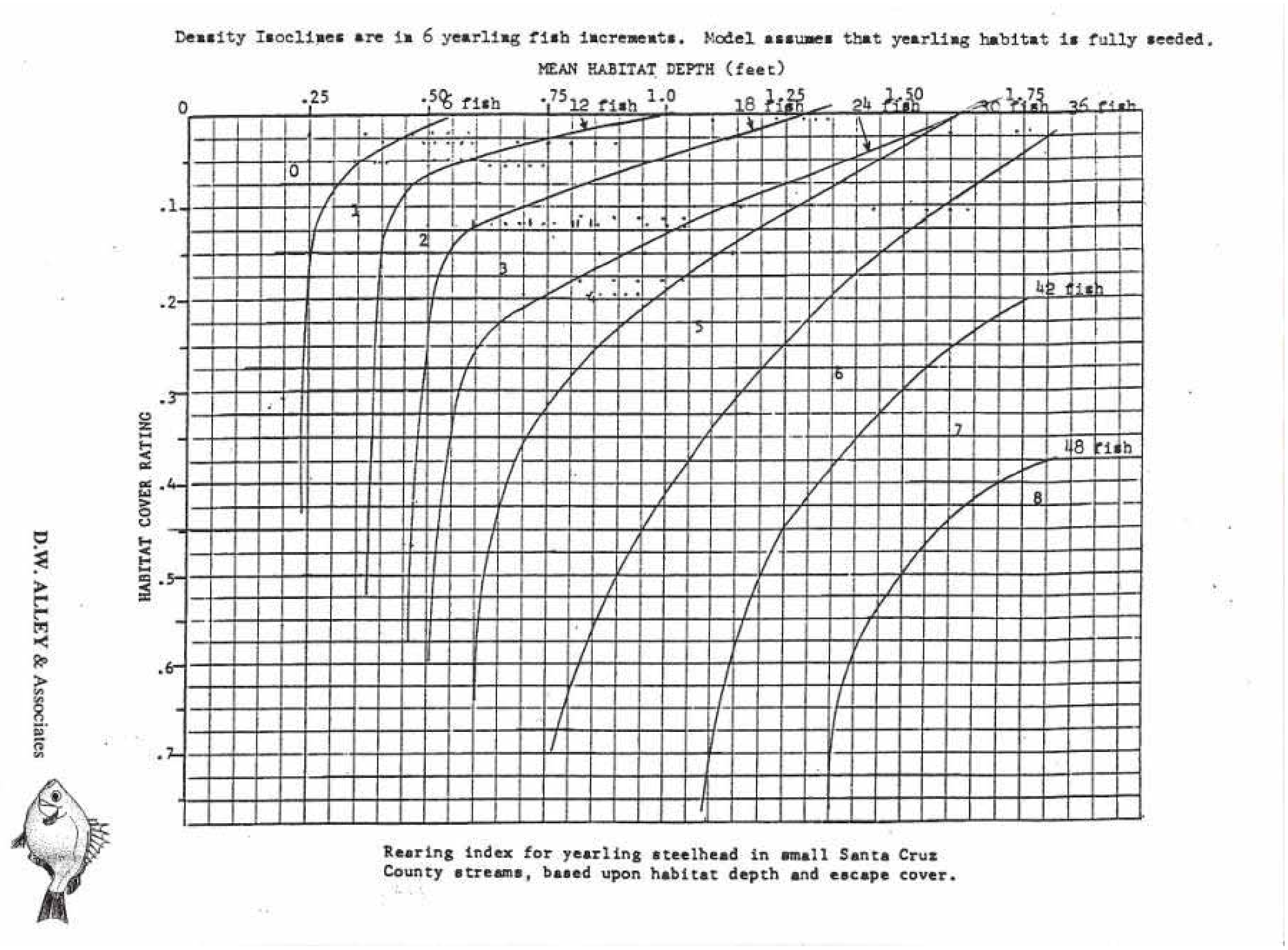


Figure 25. Steelhead Density Isoclines Developed from an Empirical Rearing Index Model. (Smith 1984.)

Table 1. Preliminary minimum bypass flows from the proposed Kings Creek Dam for steelhead and coho salmon migration, spawning, egg incubation and rearing, based on hydraulic modeling at three IFIM transects in Kings Creek and 14 IFIM transects in the mainstem San Lorenzo River, downstream of the Boulder Creek confluence.

Life Stage/ Dates	Minimum Bypass Streamflow (Cubic feet/ sec (cfs))
Adult Passage & Spawning, Egg Incubation/ After first SLR Gorge Passability (30 cfs at Big Trees and at least twice the previous day's streamflow) and Between Nov 15 and April 1	8 cfs* for 12-day periods beginning 2 days after each storm that provides at least 30 cfs at Big Trees for at least 2 storms before Jan 1 and 4 storms during Jan 1 – Apr 1. During drought– minimum of 1 time before Feb 1 and 1 time during Feb 1 – Apr 1 with at least 20 cfs at Big Trees, And the entire natural flow for a 12-day period after each storm in which the SLR flow below Boulder Creek is < 40 cfs,** below Newell Creek is < 60 cfs,** below Fall Creek is < 60 cfs,** below Eagle Creek is < 30 cfs** **Minimum of 4 cfs between 12-day releases for egg incubation**
Continued Egg Incubation/ April 1 – April 15	Minimum of 4 cfs
Continued Post-Spawner and Smolt Passage/ Apr 15 – May 1	Minimum of 3 cfs
Continued Smolt Passage & Juvenile Rearing/ May 1 – 1st SLR Gorge Passability after Nov 1	Minimum of 2 cfs

* Releases from the dam assume that other tributaries contribute sufficient streamflow to create 1.33 times the dam release below the first Kings Creek Road Crossing. A geomorphologist would need to determine flushing flows.

** Assumes that modifications were made to partial migrational barriers downstream of the project site.

Table 2. Results of IFIM spawning transects, indicating maximum Weighted Usable Area (WUA) for spawning and rearing as a function of streamflow in the San Lorenzo River Drainage and Minimum Passage Flow if Known Critical Passage Impediments Were Modified. (Included are streamflows required to produce these pre-project WUA's with ideal substrate conditions. Sources were D.W. ALLEY & Associates (**1993b**) and Santa Cruz County (**1979**).)

Location	**Streamflow (cfs) for Max. WUA-Fry Rearing**	**Streamflow (cfs) for Max. WUA-Juvenile Rearing**	**Streamflow (cfs) for Max. WUA-Spawning (Pre-Project)**	**Streamflow (cfs) for Max. WUA-Spawning (Ideal) Substrate)**	**Minimum Passage Flow (cfs) Using Thompson's Rule for 0.6 ft depth**
Kings Ck, 500 ft below 1st Road Xing (1992)	6	10+	10+	10+	12
Zayante Ck. Below Mt. Charlie (1978)	5	7.5	20+	–	–
Zayante Ck Near Woodwardia (1978)	7.5	10	35+	–	–
SLR, 2,300 ft above Teilh Drive (1992)	4.5	6	7	6.5	10
SLR at Waterman Gap (1978)	5	7.5	15+	–	–
SLR below Boulder Ck (1992)	25	30	70	50	15
SLR below Boulder Ck (1978)	–	20	75+	–	–
SLR below Newell Ck (1992)	20	30	110	70	25
SLR below Fall Ck (1992)	15	30	80	55	20
SLR above Eagle Ck, Above Gorge (1978)	50	75	100 (Similar WUA at 75)	–	–
SLR below Eagle Ck, Within Gorge (1992)	15	20	70	45	35

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