Appendix G

# Draft Action Specific Implementation Plan, *Executive Summary*

The following is the executive summary of the Draft Action Specific Implementation Plan (ASIP) for the Battle Creek Salmon and Steelhead Restoration Project. For the full text of the ASIP, please visit the California Bay-Delta Authority's Ecosystem Restoration website at:

http://calwater.ca.gov/Programs/EcosystemRestoration/Ecosystem.shtml

and follow the links for Battle Creek.

# Executive Summary

## Background

In the past century, anadromous salmonid fish species in the Sacramento River system have declined because of a number of factors, including the loss and degradation of spawning habitat as a result of changes in hydrologic regimes caused by water management for flood control, irrigation, and hydropower production. To preserve and enhance current salmonid populations in the Sacramento River system, habitat restoration efforts are needed. Implementation of the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project) will restore approximately 48 miles of anadromous fish habitat in Battle Creek and the Battle Creek watershed. The Restoration Project is a project-specific action of the CALFED Bay-Delta Program (CALFED Program), and project compliance with environmental laws and regulations is consistent with approved CALFED programmatic compliance documents.

Implementation of the Restoration Project will result in incidental take of species listed under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA). In addition, the Restoration Project will result in incidental take of non-listed species that are covered under the California Department of Fish and Game's (DFG's) Natural Community Conservation Planning Act (NCCPA) Approval of the CALFED Bay-Delta Program Multiple Species Conservation Strategy (Programmatic NCCP Determination).

This Restoration Project action-specific implementation plan (ASIP) serves as the biological assessment (BA) for compliance with Section 7 of the ESA and the Natural Community Conservation Plan (NCCP) for compliance with the CESA and the NCCPA. The ASIP tiers from the programmatic CALFED Multi-Species Conservation Strategy (MSCS) and is consistent with the requirements of the programmatic CALFED ESA, CESA, and NCCPA compliance documents and agreements.

# ASIP Purpose

The purpose of this ASIP is to present the information necessary for:

- U.S. Fish and Wildlife Service (USFWS) to issue incidental take authorization under Section 7 of the ESA for one species covered under the CALFED USFWS Programmatic biological opinion (BO) (valley elderberry longhorn beetle);
- USFWS to concur that the Restoration Project will not likely adversely affect one species (bald eagle);
- National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) to issue incidental take authorizations under Section 7 of the ESA for three species covered under the CALFED NOAA Fisheries Programmatic BO (Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead);
- NOAA Fisheries to issue conservation recommendations pursuant to Section 305(b)(2) of the Magnuson Stevens Act necessary to address potential adverse effects of the Restoration Project on Essential Fish Habitat (EFH) for three anadromous fish species (Sacramento River winter-run, Central Valley spring-run, and Central Valley fall/late fall–run Chinook salmon); and
- DFG to issue incidental take authorization under Section 2835 of the NCCPA for 12 species covered under the CALFED Programmatic NCCP Determination (Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley fall/late fall–run Chinook salmon, Central Valley steelhead, American peregrine falcon, bald eagle, California black rail, Cooper's hawk, little willow flycatcher, osprey, yellow-breasted chat, northwestern pond turtle, and ringtail).

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation), as the federal lead agency overseeing the design and construction of the Restoration Project, requests these incidental take authorizations for Restoration Project construction and the adaptive management plan. The Federal Energy Regulatory Commission (FERC), as a cooperating agency responsible for ensuring that proposed changes to the Pacific Gas and Electric (PG&E) Battle Creek Hydroelectric Project (Hydroelectric Project) comply with the ESA and CESA before issuing a license amendment for the Hydroelectric Project, requests these incidental take authorizations for continued operation of the Hydroelectric Project. These incidental take authorizations are requested for the 30-year term of the CALFED Program.

Section 305(b)(2)–(4) of the Magnuson-Stevens Act requires federal action agencies (e.g., Reclamation) to consult with NOAA Fisheries on any action authorized, funded, or undertaken that may adversely affect EFH. Battle Creek is EFH for winter-run Chinook salmon, spring-run Chinook salmon, and fall/late fall–run Chinook salmon. For this project, the EFH assessment is integrated into this ASIP, and the EFH consultation process will be integrated into the NOAA Fisheries BO for the project. NOAA Fisheries will provide EFH Conservation Recommendations for any action that would adversely affect EFH.

# Project Description

The Restoration Project lies within the Battle Creek watershed, which is situated on the volcanic slopes of Mt. Lassen in southeastern Shasta and northeastern Tehama Counties. The purpose of the Restoration Project is to restore approximately 42 miles of salmon and steelhead habitat in Battle Creek and an additional 6 miles of habitat in its tributaries while minimizing the loss of clean and renewable energy produced by the Hydroelectric Project. Specific project objectives are consistent with recovery plans for listed anadromous fish species. Project alternatives are described and analyzed in the EIS/EIR for the Restoration Project. This ASIP analyzes project-related effects of the proposed action (Five Dam Removal Alternative). The project objectives are to:

- restore self-sustaining populations of Chinook salmon and steelhead by restoring their habitat in the Battle Creek watershed and access to it through a voluntary partnership with state and federal agencies, a third-party donor(s), and PG&E;
- establish instream flow releases that restore self-sustaining populations of Chinook salmon and steelhead;
- remove selected dams at key locations in the watershed where the hydroelectric values were marginal because of increased instream flow;
- dedicate water diversion rights for instream purposes at dam removal sites;
- construct tailrace connectors and install failsafe[1] fish screens and fish ladders to increase certainty about restoration components;
- restore stream function by structural improvements in the transbasin diversion to provide a stable habitat and guard against false attraction of anadromous fish away from their migratory destinations;
- avoid Restoration Project impacts on species of wildlife and native plants and their habitats to the extent practicable, minimize impacts that are unavoidable, and restore habitat or compensate for impacts;
- minimize loss of clean and renewable energy produced by the Hydroelectric Project;
- implement restoration activities in a timely manner;

[1] The memorandum of understanding (MOU) signed by Reclamation, USFWS, NOAA Fisheries, DFG, and PG&E defines failsafe as a level of performance and reliability. Those standards are specified in Sections 2.10 and 2.11 of the MOU.

- develop and implement a long-term adaptive management plan with dedicated funding sources to ensure the continued success of restoration efforts; and
- avoid impacts on other established water users/third parties.

Components of the Restoration Project are presented in Table G-1. In addition, the Restoration Project includes the following environmental commitments that will be implemented, as appropriate, to reduce or avoid environmental effects before and/or during Restoration Project construction activities:

- develop and implement a worker environmental education program;
- obtain and implement the conditions of the environmental permits;
- designate work and exclusion zones;
- exclude anadromous fish from spawning habitat in areas where instream work would take place;
- rescue stranded fish;
- remove postconstruction debris from channels;
- implement construction during established environmental timeframes;
- develop and implement a
  - mitigation, compensation, restoration, and reporting plan,
  - stormwater pollution prevention plan,
  - spill prevention and countermeasure plan,
  - wetland and riparian mitigation and monitoring plan, and
  - environmental compliance construction monitoring program;
- compensate for temporary impacts on habitat; and
- implement specified mitigation measures to minimize potential effects on species protected under the Migratory Bird Treaty Act.

# Covered Species and NCCP Communities

CALFED programmatic guidance documents require that effects of implementing CALFED projects on MSCS evaluated species and other special-status species that could be affected by a project must be assessed. This ASIP covers 14 species that are covered under the CALFED USFWS and NOAA Fisheries Programmatic BOs and DFG Programmatic NCCP Determination (Table G-2) and two MSCS evaluated species, the golden eagle and foothill yellow-legged frog, that could be present in or near the project area. Special-status species that are not evaluated in the MSCS that could potentially occur in the Restoration Project area are addressed in the Restoration Project Final

**Table G-1.** Restoration Project Components

| Site Name | Component |
|---|---|
| North Battle Creek Feeder Diversion Dam | 55-cfs fish screen*<br>Fish ladder*<br>Minimum instream flow set for North Battle Creek Feeder reach ranges from 47 to 88 cfs<br>Access road construction and improvements |
| Eagle Canyon Diversion Dam | 70-cfs fish screen*<br>Fish ladder*<br>Removal of a segment of the Eagle Canyon Spring Collection Facility<br>Minimum instream flow set for Eagle Canyon reach ranges from 35 to 46 cfs<br>Improvement of existing access trail |
| Wildcat Diversion Dam, Pipeline, and Canal | Dam and appurtenant facilities removed<br>Improvement of access roads and trail |
| South Diversion Dam and Canal | Dam and appurtenant facilities removed<br>Access road improvements |
| Soap Creek Feeder Diversion Dam | Dam and appurtenant facilities removed<br>Access road improvements |
| Inskip Diversion Dam and South Powerhouse | 220-cfs fish screen*<br>Fish ladder*<br>Construction of South Powerhouse and Inskip Canal connector (tunnel)<br>Minimum instream flow set for Inskip reach ranges from 40 to 86 cfs<br>Access road construction and improvements |
| Lower Ripley Creek Feeder Diversion Dam | Dam and appurtenant facilities removed<br>Access road improvements |
| Coleman Diversion Dam and Inskip Powerhouse | Dam removed<br>Construction of Inskip Powerhouse and Coleman Canal connector<br>Inskip Powerhouse bypass replaced<br>Access road improvements |
| Asbury Pump Station and Diversion Dam | Reoperate<br>Creek flow and stage recorder installed<br>Minimum instream flow set for Baldwin Creek at 5 cfs |

* Reliability and performance standards for fish ladders and fish screens are generally described in the 1999 MOU, Sections 2.10 and 2.11, respectively (see Appendix A of the Final EIS/EIR). More specific information on fish ladders and fish screens is presented in Table 21 and Table 22, respectively, in the Adaptive Management Plan (Terraqua, Inc. 2004).

**Table G-2**. Summary of Effects and Conservation Measures to Avoid, Minimize, and Compensate for Effects of Implementing the Restoration Project on Covered Species



| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| **Fish** | | | |
| Sacramento River winter-run Chinook salmon<br>*Oncorhynchus tshawytscha* (wr) | Potential for direct mortality of an unquantifiable number of eggs and fish associated with construction-related activities<br>Harassment of individuals associated with construction-related activities<br>Temporary loss of migration habitat associated with channel dewatering and removal of fish ladders<br>Potential for loss of an unquantifiable number of fish to entrainment and impingement related to potential for periodic mechanical failure of fish screens | AFISH1—Implement EIS/EIR Mitigation Measure EFISH1: *Avoid or Minimize Accidental Spill of Petroleum Products.*<br><br>AFISH2—Implement EIS/EIR Mitigation Measures EFISH2: *Avoid or Minimize Erosion and Sedimentation* and EFISH3: *Minimize Release of Currently Stored Fine Sediment to the Stream Channel.* | Implementation of the Restoration Project and conservation measures AFISH1 and AFISH2 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the Sacramento River winter-run Chinook salmon and contribute to its recovery.<br>Implementation of the Restoration Project and conservation measures will benefit this species by 1) increasing the extent of spawning and rearing habitat by 5.21 acres and 30.95 acres, respectively, 2) substantially improve survival of eggs and juveniles, and 3) reduction in entrainment losses from current conditions. |
| Central Valley spring-run Chinook salmon<br>*Oncorhynchus tshawytscha* (sr) | Potential for direct mortality of an unquantifiable number of eggs and fish associated with construction-related activities<br>Harassment of individuals associated with construction-related activities<br>Temporary loss of migration habitat associated with channel dewatering and removal of fish ladders<br>Potential for loss of an unquantifiable number of fish to entrainment and impingement related to potential for periodic mechanical failure of fish screens | AFISH1—Implement EIS/EIR Mitigation Measure EFISH1: *Avoid or Minimize Accidental Spill of Petroleum Products.*<br><br>AFISH2—Implement EIS/EIR Mitigation Measures EFISH2: *Avoid or Minimize Erosion and Sedimentation* and EFISH3: *Minimize Release of Currently Stored Fine Sediment to the Stream Channel.* | Implementation of the Restoration Project and conservation measures AFISH1 and AFISH2 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on Central Valley spring-run Chinook salmon and contribute to its recovery.<br>Implementing the Restoration Project and conservation measures will benefit this species by 1) increasing the extent of spawning and rearing habitat by 5.21 acres and 28.93 acres, respectively, 2) substantially improve survival of eggs and juveniles, and 3) reduction in entrainment losses from current conditions. |

| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| Central Valley fall-/late fall–run Chinook salmon *Oncorhynchus tshawytscha* (fr) | Potential for direct mortality of an unquantifiable number of eggs and fish associated with construction-related activities<br>Harassment of individuals associated with construction-related activities<br>Temporary loss of migration habitat associated with channel dewatering and removal of fish ladders<br>Potential for loss of an unquantifiable number of fish to entrainment and impingement related to potential for periodic mechanical failure of fish screens | AFISH1—Implement EIS/EIR Mitigation Measure EFISH1: *Avoid or Minimize Accidental Spill of Petroleum Products.*<br><br>AFISH2—Implement EIS/EIR Mitigation Measures EFISH2: *Avoid or Minimize Erosion and Sedimentation* and EFISH3: *Minimize Release of Currently Stored Fine Sediment to the Stream Channel.* | Implementation of the Restoration Project and conservation measures AFISH1 and AFISH2 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on Central Valley fall-/late fall-run Chinook salmon and contribute to its recovery. Implementing the Restoration Project and conservation measures will benefit this species by 1) increasing spawning and rearing habitat by 4.57 acres and 30.95 acres, respectively, 2) substantially improving survival of eggs and juveniles, and 3) reducing entrainment losses from current conditions. |
| Central Valley steelhead *Oncorhynchus mykiss* (cv) | Potential for direct mortality of an unquantifiable number of eggs and fish associated with construction-related activities<br>Harassment of individuals associated with construction-related activities<br>Temporary loss of migration habitat associated with channel dewatering and removal of fish ladders<br>Potential for loss of an unquantifiable number of fish to entrainment and impingement related to potential for periodic mechanical failure of fish screens | AFISH1—Implement EIS/EIR Mitigation Measure EFISH1: *Avoid or Minimize Accidental Spill of Petroleum Products.*<br><br>AFISH2—Implement EIS/EIR Mitigation Measures EFISH2: *Avoid or Minimize Erosion and Sedimentation* and EFISH3: *Minimize Release of Currently Stored Fine Sediment to the Stream Channel.* | Implementation of the Restoration Project and conservation measures AFISH1 and AFISH2 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the Central Valley steelhead and contribute to its recovery. Implementation of the Restoration Project and conservation measures will benefit this species by 1) increasing the extent of spawning and rearing habitat by 7.00 acres and 18.24 acres, respectively, 2) substantially improve survival of eggs and juveniles, and 3) reduction in entrainment losses from current conditions. |

| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| **Invertebrates** | | | |
| Valley elderberry longhorn beetle *Desmocerus californicus dimorphus* | Potential loss of up to 21 elderberry shrubs that provide habitat could be removed as a result of construction-related activities | AVELB1—Implement EIS/EIR Mitigation Measure EVELB1: *Implement USFWS Standard Valley Elderberry Longhorn Beetle Compensation Guidelines.* | Implementation of the ASIP conservation measure AVELB1 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the valley elderberry longhorn beetle and will help ensure that the existing abundance and distribution of the beetle in the project area are maintained. |
| **Reptiles** | | | |
| Northwestern pond turtle *Clemmys marmorata marmorata* | Potential for temporary loss of habitat as a result of construction-related activities<br>Potential for harassment of individuals as a result of construction-related disturbances | AWPTU1—Implement EIS/EIR Mitigation Measure EWPTU1: *Perform Preconstruction Surveys and Relocate Individuals.* | Implementation of the ASIP conservation measure AWPTU1 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the northwestern pond turtle and will help ensure that the existing abundance and distribution of the turtle in the project area are maintained. In addition, restoration of the affected drainages is expected to improve habitat conditions for the species. |

| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| **Birds** | | | |
| American peregrine falcon<br>*Falco peregrinus anatum* | Potential for harassment of individuals if nesting in or near the project area as a result of construction-related disturbances<br>Potential for mortality of eggs and young if nests are abandoned as a result of construction-related disturbances | APEFA1—Implement EIS/EIR Mitigation Measure EPEFA1: *Perform Preconstruction Surveys, Limit Construction Activities, and Establish Buffers.* | Implementation of the ASIP conservation measure APEFA1 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the American peregrine falcon and will help ensure that the existing abundance and distribution of the American peregrine falcon in the project area are maintained. |
| Bald eagle<br>*Haliaeetus leucocephalus* | Potential for harassment of individual bald eagles that could forage or roost in or near the project area as a result of construction-related disturbances | ABAEA1—Implement EIS/EIR Mitigation Measure EBAEA1: *Perform Preconstruction Surveys, Limit Construction Activities, and Establish Buffers.* | Implementation of the ASIP conservation measure ABAEA1 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the bald eagle and will help ensure that the existing abundance and distribution of the bald eagle in the project area are maintained. In addition, restoration of the affected drainages is expected to improve habitat conditions for the species. |
| California black rail<br>*Laterallus jamaicensis coturniculus* | Construction-related disturbances at the Jeffcoat mitigation site and the Willow Springs disinfection facility could affect reproductive success and the survival of young, and/or result in the abandonment of nests in the emergent wetland habitat. | ABLRA1—Implement EIS/EIR Mitigation Measure EBLRA1: *Conduct Surveys for and Minimize Effects on Nesting California Black Rails.* | Implementation of the ASIP conservation measure ABLRA1 achieves the ASIP goal of avoidance, minimization, and full mitigation of adverse effects of Restoration Project actions on the California black rail. Implementation of this conservation measure will help ensure that the existing abundance and distribution of the black rail in the project area are maintained. |

| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| Cooper's hawk<br>*Accipiter cooperii* | Potential for harassment of individuals if nesting in or near the project area as a result of construction-related disturbances<br>Potential for mortality of eggs and young if nests are abandoned as a result of construction-related disturbances | ACOHA1—Implement EIS/EIR Mitigation Measure ECOHA1: *Perform Preconstruction Surveys, Limit Construction Activities, and Establish Buffers.* | Implementation of the ASIP conservation measure ACOHA1 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the Cooper's hawk and will help ensure that the existing abundance and distribution of the Cooper's hawk in the project area are maintained. |
| Little willow flycatcher<br>*Empidonax traillii brewsteri* | Potential for harassment of individuals if nesting in or near the project area as a result of construction-related disturbances<br>Potential for mortality of eggs and young if nests are abandoned as a result of construction-related disturbances<br>Temporary or permanent loss of habitat (up to 7.2 acres of riparian forest and scrub could be affected, some of which may provide habitat) | AWIFL1—Implement EIS/EIR Mitigation Measure EWIFL1: *Perform Preconstruction Surveys, Install Barriers, and Establish Buffers.*<br><br>AWIFL2—Implement EIS/EIR Mitigation Measures EWIFL2: *Avoid and Minimize Removal and Disturbance of Riparian Habitat at the Lower Ripley Creek Feeder Project Site* and EWIFL3: *Avoid Long-Term Impacts on Woody Riparian Vegetation and Associated Habitat at the Lower Ripley Creek Feeder Project Site.*<br><br>AWIFL3—Implement EIS/EIR Mitigation Measure EWIFL4: *Compensate for the Loss of Woody Riparian Habitat at the Lower Ripley Creek Feeder Project Site.* | Implementation of the ASIP conservation measures AWIFL1, AWIFL2, and AWIFL3 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the little willow flycatcher and will help ensure that the existing abundance and distribution of the little willow flycatcher in the project area are maintained. |

| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| Osprey<br>*Pandion haliaetus* | Potential for harassment of individuals if nesting in or near the project area as a result of construction-related disturbances<br>Potential for mortality of eggs and young if nests are abandoned as a result of construction-related disturbances | AOSPR1—Implement EIS/EIR Mitigation Measure EOSPR1: *Perform Preconstruction Surveys, Limit Construction Activities, and Establish Buffers.* | Implementation of the ASIP conservation measure AOSPR1 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the osprey and will help ensure that the existing abundance and distribution of the osprey in the project area are maintained. |
| Yellow-breasted chat<br>*Icteria virens* | Potential for harassment of individuals if nesting in or near the project area as a result of construction-related disturbances<br>Potential for mortality of eggs and young if nests are abandoned as a result of construction-related disturbances<br>Temporary or permanent loss of habitat (up to 7.2 acres of riparian forest and scrub could be affected, some of which may provide habitat) | AYBCH1—Implement EIS/EIR Mitigation Measure EYBCH1: *Perform Preconstruction Surveys, Install Barriers, and Establish Buffers.*<br><br>AYBCH2—Implement EIS/EIR Mitigation Measures EYBCH2: *Avoid and Minimize Removal and Disturbance of Riparian Habitat* and EYBCH3: *Minimize Long-Term Impacts on Woody Riparian Vegetation and Associated Habitat.*<br><br>AYBCH3—Implement EIS/EIR Mitigation Measure EYBCH4: *Compensate for the Loss of Woody Riparian Habitat.* | Implementation of the ASIP conservation measures AYBCH1, AYBCH2, and AYBCH3 achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effect of Restoration Project actions on the yellow-breasted chat and will help ensure that the existing abundance and distribution of the yellow-breasted chat in the project area are maintained. |

| Covered Species | Effects and Estimated Level of Take | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| **Mammals** | | | |
| Ringtail<br>*Bassariscus astutus* | Potential permanent or temporary loss of up to approximately 90 acres of ringtail habitat.<br>Potential harassment of individuals as a result of noise and visual disturbances. | ARING1—Implement EIS/EIR Mitigation Measures ERING1 through ERING6: *Minimize Removal and Disturbance of Woodland Habitat; Compensate for the Loss of Oak Woodland Habitat; Compensate for Effects on Upland Scrub Habitat; Avoid and Minimize Removal; Disturbance of Riparian Habitat; Avoid Long-Term Impacts on Woody Riparian Vegetation and Associated Habitat; and Compensate for the Loss of Woody Riparian Habitat*, respectively, | Implementation of the ASIP conservation measure ARING1 achieves the ASIP goal of avoidance, minimization, and full mitigation of adverse effects of Restoration Project actions on the ringtail and will help ensure that the existing abundance and distribution of the ringtail in the project area are maintained. |

[1]Complete descriptions of conservation measures are presented in Chapter 4, "Assessment of Project Effects on Covered Species and Conservation Measures" in the Draft ASIP (Jones & Stokes 2004) and the ASIP Addendum (Jones & Stokes 2005b).

Environmental Impact Statement/Environmental Impact Report (EIS/EIR) (Jones & Stokes 2005a). This ASIP also addresses effects of implementing the Restoration Project on seven NCCP communities covered under the Programmatic NCCP Determination that are present in the project area (Table G-3).

# Goals

The MSCS has established programmatic goals for each of the covered species and NCCP communities. It is the collective commitment of the California Bay-Delta Authority (CBDA) to achieve the MSCS goals over the term of the Programmatic BOs and NCCP Determination.

The Restoration Project is a CALFED Ecosystem Restoration Program (ERP) fish passage improvement action and, as such, is designed specifically to help achieve MSCS goals for covered fish species and montane riverine aquatic NCCP habitat. The Restoration Project, however, is not designed to achieve MSCS goals for other covered species and NCCP communities. The ASIP goals established for covered species and NCCP communities are:

- **Covered Fish Species**: Avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on covered fish species and contribute to their recovery.
- **Other Covered Species**: Avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on covered species.
- **Montane Riparian Aquatic Habitat**: Substantially increase the ecological functions of Battle Creek.
- **Other NCCP Communities**: Avoid, minimize, and compensate for adverse effects of Restoration Project actions on the functions and values of NCCP communities.

# Assessment of Effects

## Impact Mechanisms

Impact mechanisms are the specific activities and results of those activities that will be undertaken to implement the Restoration Project that could affect covered species and NCCP communities; they include:

- excavation and vegetation removal;
- dewatering of waters of the United States;
- changing flows;

- alteration of instream flows as they relate to effects on aquatic organisms (other than fish) and riparian vegetation;
- temporary stockpiling and sidecasting of soil, construction materials, and/or other construction wastes;
- removal and redistribution of diversion dam materials;
- construction of temporary and permanent access roads;
- soil compaction, dust, and water runoff from the construction site;
- equipment accessing the sites through stream channels;
- construction-related noise from equipment and helicopters;
- construction of improvements to existing trails for construction access;
- site preparation for temporary water bypass structure;
- development of waste disposal areas to contain material from tunnel excavation and access road construction;
- decommissioning of open water diversion tunnels and conveyance canals;
- implementation of mitigation measures identified in the Restoration Project EIS/EIR (Jones & Stokes 2005c); and
- growth-inducement effects.

# Assessment Methods

## Fish

Existing literature, discussions with fish biologists knowledgeable about the project area, and the findings of the Battle Creek Working Group (BCWG) Biological Technical Team (Kier Associates 1999) provided information used to evaluate the environmental consequences of the Restoration Project on fish and their habitats.

The assessment addresses construction-related effects and long-term effects of implementing the Restoration Project. Construction-related effects are generally of relatively short duration and affect a restricted area, although effects may continue over many years and extend into downstream areas. Long-term effects include changes to key habitat quantity (as estimated by the Instream Flow Incremental Methodology), migration habitat, water temperature, entrainment in diversions, predation, and food. Long-term effects are associated with permanent and ongoing (e.g., hydropower operations) changes in environmental conditions. Monthly models were used to simulate the predicted habitat area and water temperature regime in the project area under the minimum flows for the No Action and Five Dam Removal Alternative.

**Table G-3.** Summary of Effects and Conservation Measures to Avoid, Minimize, and Compensate for Effects of Implementing the Restoration Project on Covered NCCP Communities



| Multi-Species Conservation Strategy NCCP Community | Effects | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| Montane riverine aquatic | Temporary increase in sedimentation and turbidity associated with construction-related activities and demolition of dams | AFISH1—Implement EIS/EIR Mitigation Measure EFISH1: *Avoid or Minimize Accidental Spill of Petroleum Products*[2].<br><br>AFISH2—Implement EIS/EIR Mitigation Measures EFISH2: *Avoid or Minimize Erosion and Sedimentation* and EFISH3: *Minimize Release of Currently Stored Fine Sediment to the Stream Channel*[2] | Implementation of the Restoration Project and conservation measures achieves the ASIP goal to substantially increase the ecological functions of Battle Creek. Implementation of the Restoration Project and conservation measures will benefit species associated with this NCCP community by increasing flows, which will increase the extent of this community, improve continuity of flow, and reestablish more natural water temperature conditions, restoring habitat for anadromous fish along approximately 42 miles of Battle Creek and in 6 miles of its tributaries. |
| Nontidal freshwater permanent emergent wetland | Temporary disturbance of up to 3.01 acres of emergent wetland and emergent scrub wetland at the Coleman Diversion Dam/Inskip Powerhouse and Inskip Diversion Dam/South Powerhouse project sites and the Jeffcoat and Willow Springs mitigation sites.<br><br>Potential for incidental temporary disturbance of emergent wetland and emergent scrub wetland located near construction access roads | ANFPE1—Implement EIS/EIR Mitigation Measure ENFPE1: *Avoid and Minimize Disturbance of Emergent and Emergent Scrub Wetlands*<br><br>ANFPE2—Implement EIS/EIR Mitigation Measure ENFPE2: *Compensate for the Loss of Emergent and Emergent Scrub Wetlands* | Implementation of the ASIP conservation measure achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the functions and values of emergent wetland and emergent scrub wetland communities in the project area. Implementation of these conservation measures will help ensure that the existing functions and values of emergent wetland and emergent scrub wetland in the project area are maintained. |

| Multi-Species Conservation Strategy NCCP Community | Effects | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| Natural seasonal wetland | Temporary or permanent loss of up to 0.86 acre of seasonal wetland<br>Temporary or permanent loss of up to 0.11 acre of groundwater seep wetland | ANSWE1—Implement EIS/EIR Mitigation Measure ENSWE1: *Avoid and Minimize Disturbance of Seasonal Wetlands and Groundwater Seep Wetlands*<br><br>ANSWE2—Implement EIS/EIR Mitigation Measure ENSWE2: *Compensate for the Loss of Seasonal Wetlands and Groundwater Seep Wetlands* | Implementation of the ASIP conservation measure achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the functions and values of seasonal wetland and groundwater seep wetland communities in the project area. Implementation of these conservation measures will help ensure that the existing functions and values of seasonal wetland and groundwater seep wetland in the project area are maintained. |
| Montane riparian | Temporary loss of up to approximately 4.18 acres of riparian forest scrub<br>Minimal permanent loss of riparian forest scrub potentially associated with construction-related activities<br>Potential for loss of individual riparian shrubs and trees that could be associated with dewatering of canals | AMORI1—Implement EIS/EIR Mitigation Measures EMORI1: *Avoid and Minimize Removal and Disturbance of Riparian Habitat* and EMORI2: *Avoid Long-Term Impacts on Woody Riparian Vegetation and Associated Habitat*<br><br>AMORI2—Implement EIS/EIR Mitigation Measure EMORI3: *Compensate for the Loss of Woody Riparian Habitat* | Implementation of the ASIP conservation measure achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the functions and values of riparian forest scrub communities in the project area. Implementation of these conservation measures will help ensure that the existing functions and values of riparian forest scrub in the project area are maintained. |
| Upland scrub | Temporary loss of up to approximately 4.17 acres of mixed chaparral associated with construction-related activities | AUPSC1—Implement EIS/EIR Mitigation Measure EUPSC1: *Compensate for Effects on Upland Scrub Habitat* | Implementation of the ASIP conservation measure achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the functions and values of mixed chaparral communities in the project area. Implementation of these conservation measures will help ensure that the existing functions and values of mixed chaparral in the project area are maintained. |

| Multi-Species Conservation Strategy NCCP Community | Effects | ASIP Conservation Measures to Avoid, Minimize, and Compensate for Effects[1] | Summary of Expected Outcome |
|---|---|---|---|
| Grassland | Temporary loss of up to approximately 35.41 acres of annual grassland<br>Minimal permanent loss of annual grassland potentially associated with construction of project features | AGRAS1—Implement EIS/EIR Mitigation Measure EGRAS1: *Compensate for Effects on Grassland Habitat* | Implementation of the ASIP conservation measure achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the functions and values of annual grassland communities in the project area. Implementation of these conservation measures will help ensure that the existing functions and values of annual grassland in the project area are maintained. |
| Valley/foothill woodland and forest | Temporary or permanent loss of up to approximately 81.01 acres of live oak woodland, blue oak woodland/savanna, gray pine/oak woodland, and westside ponderosa pine | AVFWF1—Implement EIS/EIR Mitigation Measure EVFWF1: *Minimize Removal and Disturbance of Woodland Habitat*<br>AVFWF2—Implement EIS/EIR Mitigation Measure EVFWF2: *Compensate for the Loss of Oak Woodland Habitat* | Implementation of the ASIP conservation measure achieves the ASIP goal to avoid, minimize, and fully mitigate adverse effects of Restoration Project actions on the functions and values of live oak woodland, blue oak woodland/savanna, gray pine/oak woodland, and westside ponderosa pine communities in the project area. Implementation of these conservation measures will help ensure that the existing functions and values of live oak woodland, blue oak woodland/savanna, gray pine/oak woodland, and westside ponderosa pine in the project area are maintained. |

[1] Complete descriptions of ASIP conservation measures for all NCCP communities, except montane riparian, are presented in Chapter 5, “Assessment of Project Effects on Natural Community Conservation Plan Communities and Conservation Measures” in the Draft ASIP (Jones & Stokes 2004) and the ASIP Addendum (Jones & Stokes 2005b).

[2] A complete description of this conservation measure is presented in Chapter 4, “Assessment of Project Effects on Covered Species and Conservation Measures” in the Draft ASIP (Jones & Stokes 2004).

### Wildlife

Biological resource surveys for special-status wildlife species, including covered species, were performed in the Restoration Project area between 2000 and 2005. Existing information was reviewed to determine the location and types of wildlife resources that could exist in the Restoration Project area. The effects on covered species were assessed through quantitative estimates of the extent of footprint effects associated with construction of project features, access roads, etc., on covered species habitat and qualitative assessments of effects of construction-related disturbances on individuals.

## Vegetation and NCCP Communities

Biological resource surveys for special-status plants and NCCP communities were performed in the Restoration Project area in 2000, 2001, 2003, 2004, and 2005. When appropriate, state and federal resource specialists were asked to provide information on special-status plants, noxious weeds, and local ordinances (e.g., oak tree ordinances or policies). The effects on covered NCCP communities were assessed through quantitative estimates of the extent of footprint effects associated with construction of project features, access roads, etc., on each community. Effects of changes in flow and water temperature on the montane riverine aquatic community were determined using the methods used to assess effects on covered fish species.

# ASIP Conservation Measures and Summary of Effects

Project-specific conservation measures to avoid, minimize, and compensate for effects of the Restoration Project were developed in coordination with USFWS, NOAA Fisheries, and DFG. The conservation measures tier from the MSCS programmatic conservation measures identified for each of the covered species and NCCP communities.

The determination of effects of implementing the Restoration Project on covered species is presented in Table G-4. Project implementation may affect or may adversely affect 14 of the 16 covered species and will result in a net benefit to seven of the covered species. Table G-2 presents a summary of effects of implementing the Restoration Project, the estimated levels of take, ASIP conservation measures, and expected outcomes for each covered species. A summary description of the effects of implementing the Restoration Project, ASIP conservation measures, and expected outcomes for each of the NCCP communities is presented in Table G-3.

# References

Jones & Stokes. 2003. *Battle Creek Salmon And Steelhead Restoration Project, environmental impact statement/environmental impact report.* Draft. July. (J&S 03-035.) Sacramento, CA.

———. 2004. *Battle Creek Salmon and Steelhead Restoration Project action specific implementation plan.* Draft. April. (J&S 03-035.) Sacramento, CA.

———. 2005a. *Battle Creek Salmon And Steelhead Restoration Project, environmental impact statement/ environmental impact report*. Final. July. (J&S 03035.03.) Sacramento, CA.

———. 2005b. *Battle Creek Salmon and Steelhead Restoration Project action specific implementation plan.* Addendum. July. (J&S 03-035.) Sacramento, CA.

Kier Associates. 1999. *Battle Creek Salmon and Steelhead Restoration Plan*. Prepared for the Greater Battle Creek Watershed Working Group. January. Sausalito, CA.

Terraqua, Inc. 2004. *Battle Creek Salmon and Steelhead Restoration Project adaptive management plan*. Draft. April. Prepared for the U.S. Department of Interior, Bureau of Reclamation, Pacific Gas and Electric Company, National Marine Fisheries Service, U.S. Fish and Wildlife Service, and California Department of Fish and Game. Wauconda, WA.

**Table G-4.** Summary of Effects on Action-Specific Implementation Plan Covered Species



| Species Name | Status[a] | | | Effect on Species | |
|---|---|---|---|---|---|
| | Federal | State | Other | Net Beneficial Effect[b] | May Affect, May Adversely Affect |
| **Fish** | | | | | |
| Sacramento River winter-run Chinook salmon *Oncorhynchus tshawytscha* (wr) | E | E | – | X | X |
| Central Valley spring-run Chinook salmon *Oncorhynchus tshawytscha* (sr) | T | T | – | X | X |
| Central Valley fall-/late fall–run Chinook salmon *Oncorhynchus tshawytscha* (fr) | SC | SSC | – | X | X |
| Central Valley steelhead *Oncorhynchus mykiss* (cv) | T | – | – | X | X |
| **Invertebrates** | | | | | |
| Valley elderberry longhorn beetle *Desmocerus californicus dimorphus* | T | – | – | | X |
| **Amphibians** | | | | | |
| Foothill yellow-legged frog *Rana boylii* | SC, FS | SSC | SC | | X |
| **Reptiles** | | | | | |
| Northwestern pond turtle *Clemmys marmorata marmorata* | SC, FS | SSC | SC | | X |
| **Birds** | | | | | |
| American peregrine falcon *Falco peregrinus anatum* | D-SC/FS | E, FP | – | | X |
| Bald eagle *Haliaeetus leucocephalus* | T, PR | E, FP | – | X | |
| California black rail *Laterallus jamaicensis coturniculus* | – | CT/FP | SC | | X |
| Cooper's hawk *Accipiter cooperii* | – | SSC | – | | X |
| Golden eagle *Aquila chrysaetos* | PR | E, FP | – | | X |
| Little willow flycatcher *Empidonax traillii brewsteri* | – | – | SC | | X |
| Osprey *Pandion haliaetus* | – | SB | – | X | X |
| Yellow-breasted chat *Icteria virens* | – | SSC | – | | X |

| Species Name | Status[a] Federal | State | Other | Effect on Species: Net Beneficial Effect[b] | May Affect, May Adversely Affect |
|---|---|---|---|---|---|
| **Mammals** | | | | | |
| Ringtail<br>*Bassariscus astutus* | – | FP | – | | X |

[a] Status explanation:

**Federal**

E = Listed as endangered under the federal Endangered Species Act.

T = Listed as threatened under the federal Endangered Species Act.

PR = Federally protected under the Bald and Golden Eagle Protection Act.

C = Species for which USFWS has on file sufficient information on biological vulnerability and threat(s) to support issuance of a proposed rule to list, but issuance of the proposed rule is precluded.

SC = Species of concern; species for which existing information indicates it may warrant listing but for which substantial biological information to support a proposed rule is lacking.

FS = U.S. Forest Service sensitive species (Region).

D- = Species has been delisted from the designated status.

– = No listing.

**State**

E = Listed as endangered under the California Endangered Species Act.

T = Listed as threatened under the California Endangered Species Act.

FP = Fully protected under the California Fish and Game Code.

SSC = Species of special concern in California.

– = No listing.

**Other**

1A = California Native Plant Society (CNPS) List 1A species: presumed extinct in California.

1B = CNPS List 1B species: rare, threatened, or endangered in California and elsewhere.

2 = CNPS List 2 species: rare, threatened, or endangered in California but more common elsewhere.

3 = CNPS List 3 species: plants about which more information is needed to determine their status.

4 = CNPS List 4 species: plants of limited distribution.

– = No listing.

SC = Other species of concern identified by CALFED.

[b] Implementation of the restoration project may result in take of the indicated species; however, the overall effects of the project will be beneficial for those species. Implementation of conservation measures during construction of the project will fully mitigate the adverse effects of the project.

Appendix H

# Habitat Assessment Model for Chinook Salmon and Steelhead

Appendix H

# Habitat Assessment Model for Chinook Salmon and Steelhead

## Introduction

A monthly model was developed for Chinook salmon (i.e., winter, spring, late–fall runs) and steelhead to facilitate assessment of each alternative included in the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project) Draft Environmental Impact Statement and Environmental Impact Report (EIS/EIR). The habitat assessment model considers the habitat capacity index that depends on streamflow and then links streamflow and water temperature conditions to effects on key habitat quantity and survival. A relative estimate of fry and juvenile capacity and production indices is provided for each reach. The simulated indices are not intended as accurate predictions of magnitude for each life stage, but provide sufficient information to compare the relative life stage capacity and production expected to occur under the No Action and action alternatives.

A key premise of this impact assessment is that the tools applied support the comparison of alternatives based on the available physical and biological information. The water temperature survival indices, flow-habitat relationships, and other elements should not be considered as specific management recommendations or targets for the management of flow, water temperature, or other environmental conditions in Battle Creek or elsewhere in Central Valley rivers. These assessment tools are sufficient for evaluating the relative impacts of the restoration alternatives.

## Evaluation of Battle Creek Minimum Flow Requirements

The monthly habitat model was used to simulate the predicted habitat area provided for the minimum flow requirements under each alternative. There are three sets of minimum flow requirements that must be compared among the five alternatives.

1. The No Action minimum flow requirements represent the existing Federal Energy Regulatory Commission (FERC) license flow requirements and are 3 cfs for the North Fork Battle Creek diversion dams and 5 cfs for the South Fork Battle Creek diversion dams.
2. The Anadromous Fish Restoration Program (AFRP) minimum flow requirements are assumed for the No Dam Removal and the Three Dam Removal Alternatives and have higher flow targets for the winter months (December through April) than for the summer months.
3. The 1999 Memorandum of Understanding (MOU) minimum flow requirements are somewhat higher than the AFRP flow requirements and have higher flow targets for the winter months than for the summer months. The MOU flow targets are specified for the Five Dam Removal and Six Dam Removal Alternatives.

# Flow-Habitat Relationships

Streamflow directly influences the availability and function of important habitat elements, including water velocity, depth, wetted area, and cover. Flow-habitat relationships for Battle Creek are based on the Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation (PHABSIM) system (Milhous et al. 1984, Thomas R. Payne and Associates 1998). IFIM and PHABSIM were applied to on-site studies on Battle Creek. In 1988, an instream flow study on Battle Creek was initiated via the Upper Sacramento River Fisheries and Riparian Habitat Management Plan process (USRFRHAC 1989). A comprehensive study that predicted habitat quantity as a function of flow was conducted under the guidance of a technical committee that included biologists from the fisheries agencies and PG&E (Thomas R. Payne and Associates 1998). The flow-habitat relationships that resulted from the study are presented in Tables H-1 through H-8.

In 1992, the modeling results were used by the fisheries agencies in an effort to identify Battle Creek flow needs below dams, along with other actions, that together might increase the abundance of anadromous fish populations. This effort was part of the AFRP and identified flow releases referred to as the *AFRP flows* (USFWS 2001). It was recognized that these AFRP flow releases for the dams on Battle Creek were subject to revision based upon future analysis (USFWS 2001).

In 1998, the BCWG's Biological Technical Team analyzed the IFIM data and modeling results. The analysis identified:

1. priority species and life stages of focus for each reach of Battle Creek,
2. flows to facilitate upstream access over obstacles in the stream channel,
3. rates of flow changes to avoid stranding and isolation of juveniles, and

4. water temperatures influenced both by increased flows and releases of cold spring–fed water to adjacent reaches of Battle Creek.

The instream flow releases at each of the dam sites developed through this process are the *MOU flows*.

Spawning and rearing habitat area was calculated for the FERC (No Action Alternative), AFRP (No Dam Removal Alternative and Three Dam Removal Alternative), and MOU (Five Dam Removal Alternative and Six Dam Removal Alternative) minimum flow requirements. Example calculated habitat areas are shown in Table H-9. The habitat areas are based on the flow-habitat relationships in Tables H-1 through H-8.

# Fry Capacity Index for Steelhead and Chinook Salmon

The fry capacity index is based on the estimated spawning habitat area provided by minimum flow requirements for each alternative during the spawning and incubation period. The relationship between streamflow and spawning habitat area was developed from existing instream flow studies (Thomas R. Payne and Associates 1998). Habitat area generally increases as flow increases, reaching a maximum area and declining at higher flows (Tables H-1 through H-8). Substrate, depth, and velocity are the primary determinants of spawning habitat quantity. The flow-habitat relationships are slightly different for steelhead and Chinook salmon because of differences in substrate, depth, and velocity preferences.

The number of potential redds supported is calculated by dividing spawning habitat area by redd area. Redd size varies by species. A redd area of 56 square feet is assumed for steelhead and 100 square feet is assumed for Chinook salmon. Observed redd size for Central Valley Chinook salmon ranges from 75 square feet to 650 square feet (Reynolds et al. 1990). A smaller redd size has been documented in the lower American River, where Snider and Vyverberg (1996) calculated an average size of 62 square feet when measured on the ground and 196 square feet when measured from aerial photographs. The average size of a steelhead redd is smaller than a Chinook salmon redd (Reynolds et al. 1990). Reiser and White (1981 in Reiser and Bjornn 1979) and Hunter (1973) estimated steelhead redd sizes from 47 to 58 square feet (4.4 square meters to 5.4 square meters). The Central Valley Salmon and Steelhead Restoration and Enhancement Plan indicated steelhead redd sizes ranging from 22.5 to 121 square feet and averaging 56 square feet (Reynolds et al. 1990).

The number of fry in each redd is based on the number of eggs potentially spawned by each species and the expected baseline survival of eggs. The number of eggs in each redd is assumed to be 4,000 for steelhead and 3,800 for Chinook salmon (Kier Associates 1999). As a baseline survival, about 25% of the eggs in each redd are assumed to survive through emergence. Therefore, each redd could produce 1,000 steelhead fry or 950 Chinook salmon fry. The baseline survival does not include effects of water temperature.

The potential number of redds that could be supported by the available habitat is calculated by dividing spawning habitat area, as predicted from the flow habitat relationships in Tables H-1 through H-8, by approximate redd area for each species. The total potential population of eggs is calculated as number of redds multiplied by the number of eggs for each species that are expected to survive through emergence. Spawning habitat is assumed to be saturated (i.e., all available spawning habitat is used by each species). The proportion of the total potential population of eggs spawned each month is calculated by multiplying the total potential population of eggs by the monthly proportion of the population that would be expected to spawn. Spawning habitat area is the minimum area that is provided by minimum flow requirements during the month of spawning and during subsequent months of incubation. Steelhead fry are assumed to emerge from the redd after 2 months of incubation and Chinook after 3 months. Therefore, flow requirements during 2 consecutive months are considered in the calculation of fry capacity index for steelhead and flows during three consecutive months are considered in the calculation for Chinook salmon.

The assumed proportion of the population spawning each month is based on existing information on life stage timing. The use of the proportion spawning each month avoids habitat saturation during the first month of spawning and weights spawning habitat use according to the assumed distribution of the life stage through the entire spawning period.

# Effects of Water Temperature on the Fry Production Index

The estimated water temperature effect on survival of eggs and larvae varies with temperature and by species (Figure H-1). Survival during incubation is assumed to decline with warming temperature between 54ºF and 62ºF for Chinook salmon and 53°F and 59°F for steelhead. Chinook salmon eggs and larvae require temperatures between 39.2ºF and 53.6ºF for the highest survival rates (Myrick and Cech 2001). Chinook salmon eggs that incubated in water above 62ºF experienced 100% mortality before the eyed stage (Hinze 1959 in Myrick and Cech 2001). Studies of fall-run Chinook salmon in the Sacramento River showed that eggs survive temperatures between 35ºF and 62ºF (Myrick and Cech 2001). Alderice and Velsen (1978 in Healey 1991) and Seymour (1956 in Alderice and Velsen 1978) found less than 50% egg survival when temperature was greater than 60.8ºF. The optimal water temperature for steelhead spawning and incubation has been reported to fall in the range between 39ºF and 52ºF (Myrick and Cech 2001).

Monthly average water temperature is used to calculate a monthly survival rate (Figure H-1). Monthly average water temperature is simulated for each reach based on average meteorology and the minimum flow requirements for each alternative. The effect of water temperature on emergent fry production index is calculated by multiplying the number of emerging fry in a month by the product of water temperature survival rates during the period of incubation. The monthly survival rates include the rate for the month of spawning through the month of emergence (two consecutive months for steelhead and three consecutive months for Chinook salmon). Additional temperature information is discussed in Appendix R of this report, "Water Temperature in the Battle Creek Restoration Area."

# Juvenile Capacity Index for Steelhead and Chinook Salmon

The juvenile capacity index in each reach for each month is dependent on the minimum flow requirement under each alternative and associated habitat area (Table H-9), the fry capacity index in the reach, and the number of surplus fry from upstream reaches. The juvenile capacity index is juvenile rearing habitat area, as predicted from the flow-habitat relationships in Tables H-1 through H-8, divided by the habitat need for each juvenile. For steelhead, the assumed habitat need is 6 square feet for each juvenile. The habitat need is based on the observed density of juveniles in Keswick, North Battle Creek Feeder, and the southern reaches of Battle Creek (Kier Associates 1999) divided by an estimated habitat area calculated from flow estimates and application of the flow-habitat relationship (Tables H-1 through H-8). For Chinook salmon, the assumed habitat need is 2 square feet (Kier Associates 1999).

For the purpose of this analysis, the flow-habitat relationships for juveniles are used to calculate the juvenile capacity indices. Flow-habitat relationships for fry are not used. Flow-habitat relationships for fry generally predict the greatest habitat area at low flow, indicating the observed preference of low velocity. Fry distribute themselves near low-velocity shoreline with very shallow depths and cover, such as rootwads, rocks, and debris. The instream flow model may underestimate the actual low-velocity area provided by microhabitat features. Fry habitat capacity, therefore, was not considered in this analysis. At higher flows, low-velocity areas will likely still occur near shore and near microhabitat features. In addition, the habitat area needed to support a fry is substantially less than the habitat need of a juvenile.

The calculated juvenile capacity index is assumed to be the upper limit for the number of juveniles rearing in the reach. If the sum of the number of fry emerging in the reach, the number of juveniles remaining in the reach from the previous month, and the number of surplus fry from the upstream reach is less than the calculated juvenile capacity index, all juveniles are assumed to rear in the reach. If the juvenile capacity index is exceeded, the remaining fry are considered surplus. The number of fry emerging was described above under the fry capacity index.

The surplus fry in a month are assumed to move downstream to the next reach with available habitat area, surviving at an assumed rate of 80%. For steelhead, juveniles are assumed to rear year-round, so the total annual capacity index is the number of juveniles remaining at the end of December, the last month of the simulation. For Chinook salmon, fry migration occurs over several months, potentially vacating habitat that could be occupied by newly emergent fry. The monthly capacity index for juvenile Chinook salmon is the number of rearing juvenile salmon times the proportion of the population migrating each month. The annual capacity index is the sum of the migrants for each month from all reaches.

Surplus fry may be considered as lost production or may contribute to production in the Sacramento River downstream of Battle Creek. Total surplus is the sum of surplus juveniles for all months that would exit the mainstem reach.

# Effects of Water Temperature on the Juvenile Production Index

The estimated water temperature effect on survival of juveniles varies with temperature and by species (Figure H-2). Survival during rearing is assumed to decline with warming temperature between 64ºF and 73ºF for Chinook salmon and 65°F and 75°F for steelhead. Marine (1997) and Myrick and Cech (2001) observed maximum growth rates for juvenile Chinook salmon at water temperatures of 62.6ºF–68ºF and 66.2ºF, respectively. Rich (1997) found that fish from the Nimbus State Fish Hatchery reared at 75.2ºF died before the end of the experiment. Juvenile rearing success is assumed to deteriorate at water temperatures ranging from 62.6ºF to 77ºF. Nimbus Hatchery steelhead preferred temperatures between 62.6ºF and 68ºF (Cech and Myrick 1999). Steelhead can be expected to show significant mortality at temperatures exceeding 77ºF (Raleigh et al. 1984, Myrick and Cech 2001).

Monthly average water temperatures simulated for the minimum instream flow requirements are used to calculate a monthly survival rate (Figure H-2). Monthly average water temperature is simulated for each reach based on average meteorology and the minimum flow requirements for each alternative. The effect of water temperature on juvenile production index is calculated by multiplying the number of rearing juveniles in a month by the water temperature survival rate for the month. Water temperature is cooler at the upstream end of a reach and warmer at the downstream end. Survival rate is the average of the survival rates estimated for the monthly water temperatures at the upstream and downstream ends of the reach. Water temperature effects are not incorporated into the estimate of surplus fry.

The calculation of the juvenile production index assumes that adult steelhead can access all reaches of Battle Creek and that Chinook salmon can access all reaches except Keswick. Late fall–run Chinook salmon may be limited primarily to reaches downstream of Wildcat and Coleman Diversion Dams; therefore, the production index may be overestimated. Including the production represented by the mainstem of Battle Creek, Coleman and Wildcat reaches might be a better estimate of the expected production index. Production indices for fall-run Chinook salmon are not simulated because current management objectives include blocking fall-run Chinook salmon from continuing upstream at the Coleman National Fish Hatchery. Although the timing of spawning, rearing, and outmigration are different between the two runs, the production index for fall-run Chinook salmon may be similar in magnitude and pattern to the production index represented by late fall–run Chinook salmon.

Additional temperature information is discussed in Appendix R of this report, "Water Temperatures in the Battle Creek Restoration Area."

# Printed References

Alderice, D.F., and Velsen, F.P.J., 1978. Relation between temperature and incubation time for eggs of chinook salmon (*Oncorhynchus tshawytscha*): Journal of the Fisheries Research Board of Canada, v. 35, p. 69-75.

Cech, J.J., Jr. & C.A. Myrick. 1999. Steelhead and chinook salmon bioenergetics: temperature, ration, and genetic effects. pp.72, Univ. Calif. Water Resources Center, Davis, CA.

Healey, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). pp.311-393. In: C. Groot & L. Margolis (ed.) Pacific salmon life histories, Univ. BC Press, Vancouver, BC.

Hunter, J. G. 1973. A discussion of game fish in the State of Washington as related to water requirements. Report by the Washington Department of Game, Fishery Management Division, to the Washington State Department of Ecology, Olympia.

Kier Associates. 1999. Battle Creek Salmon and Steelhead Restoration Plan. Prepared for the Greater Battle Creek Watershed Working Group. January 1999.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's Guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Report FWS/OBS-81/43 v.p.

Myrick, C.A. and J.J. Cech. 2001. Temperature Effects on Chinook Salmon and Steelhead: a Review Focusing on California's Central Valley Populations. Available at http://www.cwemf.org/Pubs/Tempreview.pdf.

Thomas R. Payne and Associates. 1998. A 1989 Instream Flow Study: 1 of 8 Components. Prepared for California Department of Fish and Game.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. U.S. Fish. Wildl. Serv. FWS/OBS-82/10.60 64 pp.

Reiser, D.W., and T.C. Bjornn. 1979. Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America: Habitat Requirements of Anadromous Salmonids. General Technical Report PNW-96. U.S. Department of Agriculture Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Reynolds F.L., R.L. Reavis, and J. Schuler. 1990. Central Valley salmon and steelhead restoration plan. California Department of Fish and Game, Inland Fisheries Division.

Rich, A.A. 1997. Testimony regarding water right applications for the Delta Wetlands Project proposed by Delta Wetland Properties for water storage on Webb Tract, Bacon Island, Bouldin Island, and Holland Tract in Contra Costa and San Joaquin Counties. Submitted to the State Water Resources Control Board by California Department of Fish and Game. July 1997.

Snider, WM. & K. Vyverberg. 1996. Chinook salmon redd survey, lower American River, Fall 1995. Sacramento (CA): California Department of Fish and Game.

U.S. Fish and Wildlife Service. 2001. Final Restoration Plan for the Anadromous Fish Restoration Program: A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California. Prepared by USFWS and the Anadromous Fish Restoration Program Core Group. Sacramento, California. January 9, 2001. Available at http://www.delta.dfg.ca.gov/afrp/documents/Restplan_final.html.

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council. 1989. Upper Sacramento River Fisheries and Riparian Habitat Management Plan. State of California Resources Agency.

**Table H-1.** Flow-Habitat Relationships for the Mainstem Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 5 | 13.2 | 0.3 | 4.4 | 0.5 |
| 10 | 15.1 | 0.4 | 6.4 | 0.8 |
| 15 | 16 | 0.7 | 8.6 | 1.2 |
| 20 | 16.5 | 1 | 10.4 | 1.6 |
| 25 | 16.6 | 1.1 | 11.9 | 1.9 |
| 30 | 16.3 | 1.2 | 13.6 | 2.2 |
| 35 | 15.9 | 1.3 | 14.6 | 2.3 |
| 40 | 15.6 | 1.4 | 15.4 | 2.3 |
| 45 | 15.2 | 1.5 | 16 | 2.4 |
| 50 | 14.7 | 1.5 | 16.5 | 2.3 |
| 60 | 13.8 | 1.5 | 17 | 2.3 |
| 70 | 13.1 | 1.5 | 17.1 | 2.1 |
| 80 | 12.3 | 1.5 | 17.1 | 2 |
| 90 | 11.5 | 1.5 | 17 | 1.8 |
| 100 | 11.2 | 1.4 | 16.8 | 1.8 |
| 120 | 9.9 | 1.4 | 16.1 | 1.7 |
| 140 | 8.9 | 1.3 | 15.2 | 1.5 |
| 160 | 8.1 | 1.2 | 14.2 | 1.4 |
| 180 | 7.4 | 1.1 | 13.1 | 1.3 |
| 200 | 7 | 1 | 12.1 | 1.2 |
| 250 | 6 | 0.8 | 10.1 | 1 |
| 300 | 5.4 | 0.6 | 8.7 | 0.8 |
| 350 | 4.8 | 0.5 | 7.5 | 0.6 |

Note: cfs = cubic feet per second.

**Table H-2.** Flow-Habitat Relationships for the Wildcat Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 3 | 0.9 | 0 | 0.4 | 0 |
| 10 | 1.9 | 0 | 1.1 | 0.2 |
| 15 | 2.3 | 0.1 | 1.6 | 0.3 |
| 20 | 2.4 | 0.1 | 1.8 | 0.3 |
| 25 | 2.6 | 0.2 | 2 | 0.3 |
| 30 | 2.6 | 0.2 | 2.2 | 0.3 |
| 35 | 2.6 | 0.3 | 2.2 | 0.3 |
| 40 | 2.6 | 0.3 | 2.3 | 0.3 |
| 45 | 2.5 | 0.3 | 2.2 | 0.2 |
| 50 | 2.5 | 0.4 | 2.2 | 0.2 |
| 60 | 2.4 | 0.4 | 2.1 | 0.2 |
| 70 | 2.3 | 0.4 | 2 | 0.2 |
| 80 | 2.3 | 0.4 | 1.9 | 0.1 |
| 90 | 2.3 | 0.3 | 1.8 | 0.1 |
| 100 | 2.2 | 0.3 | 1.8 | 0.1 |
| 120 | 2.1 | 0.3 | 1.7 | 0.1 |
| 140 | 2 | 0.2 | 1.7 | 0.1 |
| 160 | 1.8 | 0.2 | 1.6 | 0.1 |
| 180 | 2 | 0.1 | 1.5 | 0.1 |
| 200 | 1.6 | 0.1 | 1.4 | 0.1 |
| 220 | 1.5 | 0.1 | 1.4 | 0.1 |
| 240 | 1.4 | 0.1 | 1.3 | 0 |

Note: cfs = cubic feet per second.

**Table H-3.** Flow-Habitat Relationships for the Eagle Canyon Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 3 | 1 | 0 | 0.4 | 0.1 |
| 10 | 2.1 | 0.1 | 1.2 | 0.3 |
| 15 | 2.6 | 0.1 | 1.7 | 0.4 |
| 20 | 2.7 | 0.2 | 2 | 0.5 |
| 25 | 2.9 | 0.3 | 2.2 | 0.5 |
| 30 | 3 | 0.4 | 2.4 | 0.5 |
| 35 | 2.9 | 0.5 | 2.4 | 0.4 |
| 40 | 2.9 | 0.5 | 2.5 | 0.4 |
| 45 | 2.9 | 0.6 | 2.4 | 0.4 |
| 50 | 2.8 | 0.6 | 2.4 | 0.4 |
| 60 | 2.7 | 0.6 | 2.3 | 0.3 |
| 70 | 2.6 | 0.6 | 2.2 | 0.3 |
| 80 | 2.6 | 0.6 | 2.1 | 0.2 |
| 90 | 2.6 | 0.5 | 2.1 | 0.2 |
| 100 | 2.5 | 0.5 | 2 | 0.2 |
| 120 | 2.4 | 0.4 | 2 | 0.1 |
| 140 | 2.2 | 0.3 | 1.9 | 0.1 |
| 160 | 2.1 | 0.3 | 1.9 | 0.1 |
| 180 | 1.9 | 0.2 | 1.8 | 0.1 |
| 200 | 1.8 | 0.2 | 1.7 | 0.1 |
| 220 | 1.7 | 0.2 | 1.6 | 0.1 |
| 240 | 1.6 | 0.1 | 1.5 | 0.1 |

Note: cfs = cubic feet per second.

**Table H-4.** Flow-Habitat Relationships for the North Battle Feeder Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 3 | 1.6 | 0 | 0.6 | 0 |
| 10 | 3.8 | 0 | 2.1 | 0.2 |
| 15 | 4.7 | 0.1 | 3.1 | 0.3 |
| 20 | 5.1 | 0.1 | 3.5 | 0.4 |
| 25 | 5.6 | 0.2 | 4 | 0.5 |
| 30 | 5.8 | 0.3 | 4.3 | 0.6 |
| 35 | 6 | 0.4 | 4.5 | 0.6 |
| 40 | 6 | 0.4 | 4.6 | 0.7 |
| 45 | 6.1 | 0.5 | 4.7 | 0.7 |
| 50 | 6.1 | 0.5 | 4.7 | 0.7 |
| 60 | 5.9 | 0.7 | 4.6 | 0.7 |
| 70 | 5.6 | 0.8 | 4.4 | 0.7 |
| 80 | 5.3 | 0.9 | 4.1 | 0.6 |
| 90 | 5.1 | 1 | 4 | 0.6 |
| 100 | 4.8 | 1 | 3.8 | 0.5 |
| 120 | 4.3 | 1 | 3.4 | 0.4 |
| 140 | 3.9 | 0.9 | 3.2 | 0.3 |
| 160 | 3.6 | 0.8 | 2.9 | 0.2 |
| 180 | 3.4 | 0.6 | 2.9 | 0.2 |
| 200 | 3.2 | 0.5 | 2.6 | 0.1 |

Note: cfs = cubic feet per second.

**Table H-5.** Flow-Habitat Relationships for the Keswick Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 3 | 1.9 | 0.1 | | |
| 10 | 4 | 0.1 | | |
| 15 | 4.5 | 0.2 | | |
| 20 | 4.6 | 0.2 | | |
| 25 | 4.7 | 0.3 | | |
| 30 | 4.7 | 0.3 | | |
| 35 | 4.7 | 0.3 | | |
| 40 | 4.5 | 0.4 | | |
| 45 | 4.4 | 0.4 | | |
| 50 | 4.4 | 0.4 | | |
| 60 | 4.4 | 0.4 | | |
| 70 | 4.3 | 0.4 | | |
| 80 | 4.3 | 0.4 | | |
| 90 | 4.2 | 0.3 | | |
| 100 | 4.1 | 0.3 | | |

Note: cfs = cubic feet per second.

**Table H-6.** Flow-Habitat Relationships for the Coleman Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 5 | 0.1 | 0 | 0.4 | 0.2 |
| 10 | 2 | 0 | 0.8 | 0.4 |
| 15 | 2.7 | 0.1 | 1.4 | 0.7 |
| 20 | 2.9 | 0.2 | 1.8 | 0.8 |
| 25 | 3.2 | 0.3 | 2.1 | 0.9 |
| 30 | 3.4 | 0.4 | 2.4 | 0.9 |
| 35 | 3.5 | 0.6 | 2.6 | 1 |
| 40 | 3.5 | 0.7 | 2.7 | 1 |
| 45 | 3.5 | 0.8 | 2.8 | 1 |
| 50 | 3.5 | 0.9 | 2.9 | 1 |
| 60 | 3.4 | 1 | 2.9 | 1 |
| 70 | 3.3 | 1.1 | 2.8 | 0.9 |
| 80 | 3.2 | 1.2 | 2.7 | 1 |
| 90 | 3.1 | 1.3 | 2.6 | 0.9 |
| 100 | 3 | 1.4 | 2.5 | 0.9 |
| 120 | 2.8 | 1.5 | 2.3 | 0.7 |
| 140 | 2.6 | 1.4 | 2.1 | 0.6 |
| 160 | 2.3 | 1.3 | 2 | 0.5 |
| 180 | 2.1 | 1.2 | 1.8 | 0.5 |
| 200 | 1.9 | 1.1 | 1.7 | 0.4 |
| 220 | 1.8 | 1 | 1.6 | 3.2 |
| 240 | 1.8 | 0.9 | 1.5 | 0.3 |
| 260 | 1.8 | 0.8 | 1.4 | 0.2 |

Note: cfs = cubic feet per second.

**Table H-7.** Flow-Habitat Relationships for the Inskip Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 5 | 2.3 | 0 | 0.5 | 0.2 |
| 10 | 4.1 | 0.1 | 1.6 | 0.6 |
| 15 | 5.6 | 0.2 | 3 | 1.2 |
| 20 | 6.2 | 0.3 | 3.7 | 1.4 |
| 25 | 6.8 | 0.5 | 4.4 | 1.5 |
| 30 | 7.1 | 0.8 | 5 | 1.6 |
| 35 | 7.3 | 1.1 | 5.5 | 1.6 |
| 40 | 7.4 | 1.3 | 5.8 | 1.6 |
| 45 | 7.4 | 1.4 | 6 | 1.6 |
| 50 | 7.3 | 1.6 | 6.1 | 1.6 |
| 60 | 7 | 1.8 | 6.1 | 1.6 |
| 70 | 6.8 | 1.9 | 5.9 | 1.4 |
| 80 | 6.5 | 2.1 | 5.7 | 1.5 |
| 90 | 6.3 | 2.2 | 5.5 | 1.4 |
| 100 | 6.1 | 2.3 | 5.2 | 1.4 |
| 120 | 5.6 | 2.4 | 4.8 | 1.2 |
| 140 | 5.2 | 2.3 | 4.5 | 1.1 |
| 160 | 4.8 | 2.1 | 4.2 | 1 |
| 180 | 4.3 | 1.9 | 3.9 | 0.8 |
| 200 | 4 | 1.8 | 3.6 | 0.7 |
| 220 | 3.7 | 1.6 | 3.3 | 0.6 |
| 240 | 3.7 | 1.5 | 3.1 | 0.5 |
| 260 | 3.6 | 1.3 | 2.9 | 0.4 |

Note: cfs = cubic feet per second.

**Table H-8.** Flow-Habitat Relationships for the South Reach of Battle Creek

| Flow (cfs) | Steelhead Rearing (acres) | Steelhead Spawning (acres) | Chinook Rearing (acres) | Spring Spawning (acres) |
|---|---|---|---|---|
| 5 | 4.3 | 0.1 | 2.2 | 0.4 |
| 10 | 5.3 | 0.2 | 3 | 0.6 |
| 15 | 6.4 | 0.4 | 3.6 | 0.6 |
| 20 | 6.7 | 0.5 | 4 | 0.6 |
| 25 | 6.9 | 0.6 | 4.3 | 0.7 |
| 30 | 7 | 0.6 | 4.6 | 0.7 |
| 35 | 6.9 | 0.7 | 4.7 | 0.7 |
| 40 | 6.8 | 0.7 | 4.7 | 0.7 |
| 45 | 6.7 | 0.7 | 4.8 | 0.7 |
| 50 | 6.7 | 0.8 | 4.8 | 0.7 |
| 60 | 6.4 | 0.8 | 4.6 | 0.8 |
| 70 | 6.2 | 0.9 | 4.5 | 0.8 |
| 80 | 5.9 | 0.9 | 4.4 | 0.7 |
| 100 | 5.5 | 1 | 4.1 | 0.5 |
| 120 | 5.2 | 1 | 3.9 | 0.4 |
| 140 | 5 | 0.9 | 3.7 | 0.4 |
| 160 | 4.8 | 0.8 | 3.7 | 0.3 |
| 180 | 4.7 | 0.7 | 3.7 | 0.3 |
| 200 | 4.6 | 0.6 | 3.6 | 0.3 |

Note: cfs = cubic feet per second.

**Table H-9.** Calculated Rearing and Spawning Area (acres) for Peak Months of Steelhead and Chinook Salmon Lifestage Occurrence Under Minimum Flows



| | Steelhead Rearing Area [i] | Steelhead Spawning Area [ii] | Spring-run Chinook Rearing Area [iii] | Spring-run Chinook Spawning Area [iv] | Winter-run Chinook Rearing Area [v] | Winter-run Chinook Spawning Area [vi] | Late Fall–run Chinook Rearing Area [vii] | Late Fall–run Chinook Spawning Area [viii] |
|---|---|---|---|---|---|---|---|---|
| **No Action** | | | | | | | | |
| Keswick | 1.92 | 0.06 | – | – | – | – | – | – |
| NBC Feeder | 1.62 | 0.01 | 0.62 | 0.04 | 0.62 | 0.04 | 0.62 | 0.04 |
| Eagle Canyon | 1.02 | 0.01 | 0.41 | 0.07 | 0.41 | 0.07 | 0.41 | 0.07 |
| Wildcat | 0.9 | – | 0.36 | 0.05 | 0.36 | 0.05 | 0.36 | 0.05 |
| South | 4.26 | 0.12 | 2.17 | 0.39 | 2.17 | 0.39 | 2.17 | 0.39 |
| Inskip | 2.3 | – | 0.53 | 0.2 | 0.53 | 0.2 | 0.53 | 0.2 |
| Coleman | 0.11 | – | 0.37 | 0.17 | 0.37 | 0.17 | 0.37 | 0.17 |
| Main | 13.18 | 0.27 | 4.39 | 0.55 | 4.39 | 0.55 | 4.39 | 0.55 |
| **Total** | **25.31** | **0.47** | **8.85** | **1.47** | **8.85** | **1.47** | **8.85** | **1.47** |
| **Five Dam Removal** | | | | | | | | |
| Keswick | 1.92 | 0.06 | – | – | – | – | – | – |
| NBC Feeder | 6.06 | 0.89 | 4.14 | 0.69 | 4.68 | 0.69 | 4.68 | 0.63 |
| Eagle Canyon | 2.93 | 0.57 | 2.42 | 0.44 | 2.42 | 0.44 | 2.42 | 0.39 |
| Wildcat | 2.62 | 0.34 | 2.23 | 0.28 | 2.23 | 0.28 | 2.23 | 0.25 |
| South | 6.82 | 0.95 | 4.38 | 0.71 | 4.75 | 0.71 | 4.75 | 0.67 |
| Inskip | 7.37 | 2.08 | 5.72 | 1.62 | 5.85 | 1.62 | 5.85 | 1.47 |
| Coleman | 3.53 | 1.22 | 2.74 | 0.98 | 2.73 | 0.98 | 2.73 | 0.96 |
| Main | 12.3 | 1.36 | 16.15 | 1.96 | 17.14 | 1.96 | 17.14 | 1.67 |
| **Total** | **43.55** | **7.47** | **37.78** | **6.68** | **39.8** | **6.68** | **39.8** | **6.04** |

| | Steelhead Rearing Area [i] | Steelhead Spawning Area [ii] | Spring-run Chinook Rearing Area [iii] | Spring-run Chinook Spawning Area [iv] | Winter-run Chinook Rearing Area [v] | Winter-run Chinook Spawning Area [vi] | Late Fall–run Chinook Rearing Area [vii] | Late Fall–run Chinook Spawning Area [viii] |
|---|---|---|---|---|---|---|---|---|
| **No Dam Removal** | | | | | | | | |
| Keswick | 1.92 | 0.06 | – | – | – | – | – | – |
| NBC Feeder | 5.81 | 0.42 | 4.63 | 0.66 | 4.63 | 0.59 | 4.28 | 0.66 |
| Eagle Canyon | 2.96 | 0.6 | 2.39 | 0.46 | 2.35 | 0.46 | 2.35 | 0.35 |
| Wildcat | 2.65 | 0.36 | 2.2 | 0.29 | 2.17 | 0.29 | 2.17 | 0.23 |
| South | 6.74 | 0.63 | 4.56 | 0.62 | 3.99 | 0.62 | 3.99 | 0.68 |
| Inskip | 7.12 | 1.27 | 5.85 | 1.58 | 5.05 | 1.58 | 5.05 | 1.62 |
| Coleman | 3.37 | 0.88 | 2.88 | 1.02 | 2.88 | 0.92 | 2.36 | 1.02 |
| Main | 13.84 | 1.44 | 16.81 | 1.96 | 17.14 | 2.25 | 17.03 | 1.8 |
| **Total** | **44.41** | **5.66** | **39.32** | **6.59** | **38.21** | **6.71** | **37.23** | **6.36** |
| **Six Dam Removal** | | | | | | | | |
| Keswick | 1.92 | 0.06 | – | – | – | – | – | – |
| NBC Feeder | 6.06 | 0.89 | 4.14 | 0.69 | 4.68 | 0.69 | 4.68 | 0.63 |
| Eagle Canyon | 2.93 | 0.57 | 2.42 | 0.44 | 2.42 | 0.44 | 2.42 | 0.39 |
| Wildcat | 2.62 | 0.34 | 2.23 | 0.28 | 2.23 | 0.28 | 2.23 | 0.25 |
| South | 6.82 | 0.95 | 4.38 | 0.71 | 4.75 | 0.71 | 4.75 | 0.67 |
| Inskip | 7.37 | 2.08 | 5.72 | 1.62 | 5.85 | 1.62 | 5.85 | 1.47 |
| Coleman | 3.53 | 1.22 | 2.74 | 0.98 | 2.73 | 0.98 | 2.73 | 0.96 |
| Main | 12.3 | 1.36 | 16.15 | 1.96 | 17.14 | 1.96 | 17.14 | 1.67 |
| **Total** | **43.55** | **7.47** | **37.78** | **6.68** | **39.8** | **6.68** | **39.8** | **6.04** |

| | Steelhead Rearing Area [i] | Steelhead Spawning Area [ii] | Spring-run Chinook Rearing Area [iii] | Spring-run Chinook Spawning Area [iv] | Winter-run Chinook Rearing Area [v] | Winter-run Chinook Spawning Area [vi] | Late Fall–run Chinook Rearing Area [vii] | Late Fall–run Chinook Spawning Area [viii] |
|---|---|---|---|---|---|---|---|---|
| **Three Dam Removal** | | | | | | | | |
| Keswick | 1.92 | 0.06 | – | – | – | – | – | – |
| NBC Feeder | 5.81 | 0.42 | 4.63 | 0.66 | 4.63 | 0.59 | 4.28 | 0.66 |
| Eagle Canyon | 2.96 | 0.6 | 2.39 | 0.46 | 2.35 | 0.46 | 2.35 | 0.35 |
| Wildcat | 2.65 | 0.36 | 2.2 | 0.29 | 2.17 | 0.29 | 2.17 | 0.23 |
| South | 6.74 | 0.63 | 4.56 | 0.62 | 3.99 | 0.62 | 3.99 | 0.68 |
| Inskip | 7.12 | 1.27 | 5.85 | 1.58 | 5.05 | 1.58 | 5.05 | 1.62 |
| Coleman | 3.37 | 0.88 | 2.88 | 1.02 | 2.88 | 0.92 | 2.36 | 1.02 |
| Main | 13.84 | 1.44 | 16.81 | 1.96 | 17.14 | 2.25 | 17.03 | 1.8 |
| **Total** | **44.41** | **5.66** | **39.32** | **6.59** | **38.21** | **6.71** | **37.23** | **6.36** |

Note: If the removal of a dam under an alternative precludes the need for a minimum flow requirement, the minimum flow requirement for the adjacent upstream or downstream dam is applied.

[i] Values are for the month of July.

[ii] Values are for the month of February.

[iii] Values are for the month of February.

[iv] Values are for the month of September.

[v] Values are for the month of October.

[vi] Values are for the month of June.

[vii] Values are for the month of July.

[viii] Values are for the month of March.

**Figure H-1.** Estimated Water Temperature Effect on Monthly Survival of Eggs and Larvae of Chinook Salmon and Steelhead

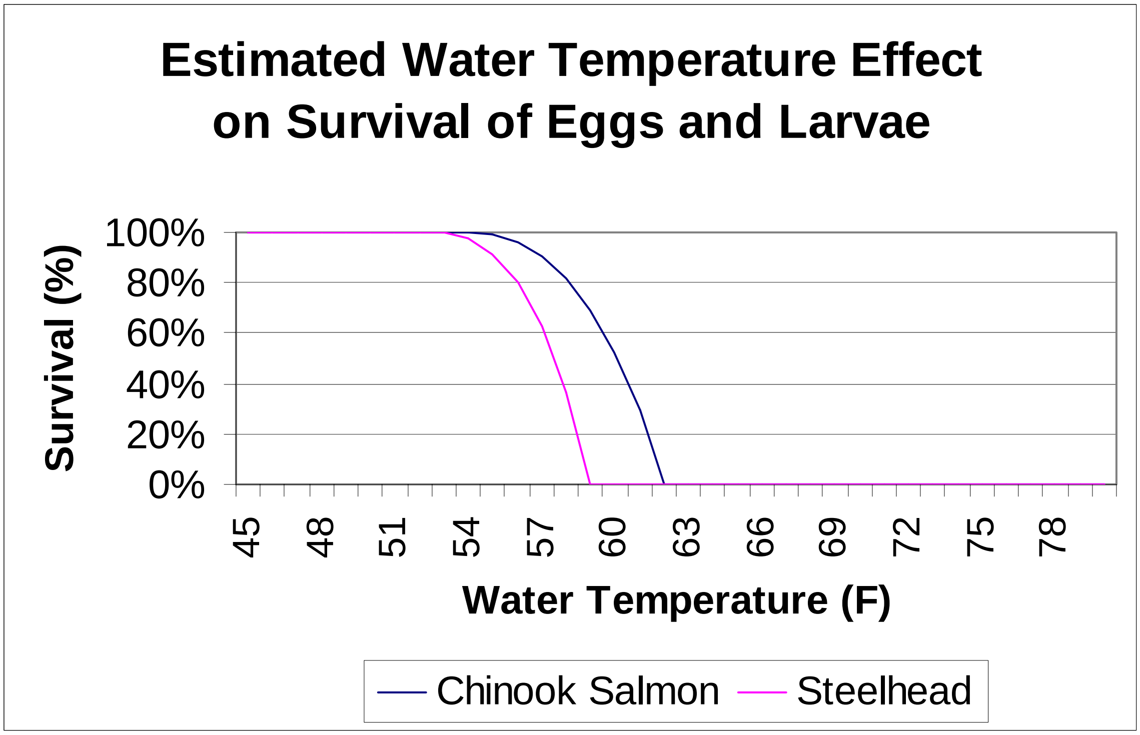
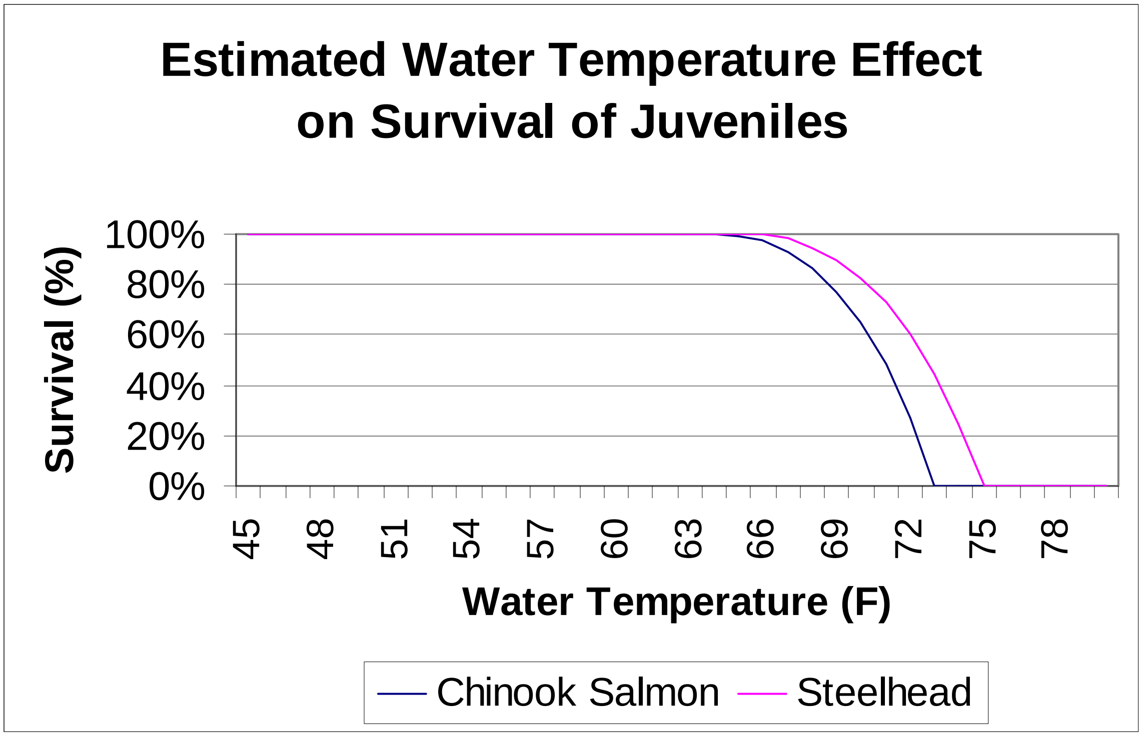


**Figure H-2.** Estimated Water Temperature Effect on Monthly Survival of Juvenile Chinook Salmon and Steelhead



Appendix I

# Development and Assumptions of the Monthly Battle Creek Hydrology and Hydroelectric Power Model

Appendix I
# Development and Assumptions of the Monthly Battle Creek Hydrology and Hydroelectric Power Model

## Purpose of the Monthly Hydrology and Hydroelectric Power Model

The two main purposes of this monthly hydrology and hydroelectric power model are to determine:

- the relative value of the Battle Creek Hydroelectric Project to the Pacific Gas & Electric Company (PG&E) under different restoration alternatives that have different streamflow targets and diversion capacities at the eight existing diversion dams and
- the range of monthly streamflows in each reach of Battle Creek that are likely to occur for each restoration alternative under the range of monthly flows observed for the last 41 year (1963–2003).

To identify relative hydroelectric power values and the restoration habitat values of streamflows, the monthly diversions and streamflows must be calculated for a range of Battle Creek monthly flows that are representative of the likely future flows. This appendix documents the assumptions about the hydrology and hydroelectric power diversion flows that allow the monthly flows in each reach of Battle Creek to be estimated.

## Organization of the Appendix

This appendix describes the existing hydrology in the Battle Creek watershed and the hydrology and hydroelectric power model used. This description includes the model assumptions, data used in the model, and verification of the model's applicability to the Battle Creek watershed. A general description of the model results, presented in Appendix J, "Results from Monthly Flow and Power Generation Model," is also provided to facilitate the reader's interpretation of the results. The appendix is organized as follows.

- Daily Hydrology of Battle Creek describes the existing water sources in the Battle Creek watershed, the names and locations of powerhouses and diversions in the project area, typical monthly minimum and maximum flows in the creek and in the diversion structures, and the data used in the model.
- Monthly Hydrology Calculations describes steps performed to run the model.
- Upstream Flow Comparisons is a comparison of estimated flows using the model and using the watershed fraction that shows the model's applicability to the Battle Creek watershed.
- Calculated North Fork Battle Creek Monthly Flows and Diversions and Calculated South Fork Battle Creek Monthly Flows and Diversions include descriptions of the results tables (in Appendix J) and information that clarifies how the results were determined.
- Estimating Monthly Hydroelectric Power Production describes the typical powerhouse operations, model methodology, and assumptions used to calculate the hydroelectric costs.

# Daily Hydrology of Battle Creek

The monthly flows and diversions that are used in the model to estimate monthly hydropower production, along with corresponding estimates of fish habitat conditions and water temperatures that govern fish production and survival, are only a partial representation of the variations in the hydrology and aquatic habitat conditions that will actually occur under existing conditions or the restoration alternatives. This section describes the observed daily variations in Battle Creek hydrology and demonstrates that the calculations in the monthly model are a reasonable approximation of future potential habitat conditions in each reach of Battle Creek.

Several water stage gages are operated by PG&E in the Battle Creek watershed below the diversion dams and in the canal system. Some of the gaged flow data are reported by PG&E to the U.S. Geological Survey (USGS). However, only relatively low flows are reported by PG&E to demonstrate compliance with the requirements of the Federal Energy Regulatory Commission (FERC). Higher flows passing the diversion dams are not "rated" (i.e., stage-discharge curves have not been developed for higher flows) and are therefore not reported to the USGS. The PG&E records reported to the USGS include flows at each of the five hydroelectric powerhouses: Volta 1 and Volta 2, South, Inskip, and Coleman. PG&E maintains additional gages in their canal system to indicate how much water is being diverted at each of the eight diversion dams. The data from these diversion gages is proprietary information that PG&E is not required to make public. However, PG&E has provided some of these diversion records from recent years (1998–2002) to assist in verifying the monthly hydrology model assumptions.

# Battle Creek Runoff Patterns

The daily hydrology of Battle Creek has been accurately measured for many years by the USGS flow gage located just downstream of the Coleman National Fish Hatchery (CNFH) and with a series of canal and flow gages operated by PG&E. Daily Battle Creek flows at the CNFH and the flows at four of the PG&E powerhouses will be used to characterize the range of hydrologic conditions that have been observed during 1989–2000. This period included a wide range of wet, normal, and dry years.

Battle Creek flows generally have a very large baseflow component (i.e., water originating from springs and shallow groundwater seepage), with only short periods of direct surface runoff following major storm events. The series of diversions that were constructed early in the 1900s have been able to capture most of the streamflow as far upstream as possible to maximize the hydroelectric power production from both the North Fork Battle Creek and South Fork Battle Creek.

Table I-1 provides a summary of the diversion dam locations (river mile), including the upstream watershed area and the approximate elevation and capacity of the diversions. The maximum capacity of each powerhouse is also given. Whenever Battle Creek flows are greater than 350 cubic feet per second (cfs), the diversion capacities throughout the Battle Creek system are exceeded, and spills below the diversion dams will increase flows in all reaches of both the North Fork Battle Creek and South Fork Battle Creek.

# Battle Creek Diversion Dams

The North Fork Battle Creek has five diversion dams. The two upstream diversions at Al Smith Dam and Keswick Dam are upstream of the potential restoration area and are considered in the monthly model to be a single diversion located at Keswick Dam. The diversions from the Al Smith and Keswick Dams each have a capacity of 45 cfs, and the water is conveyed to the Volta I and Volta II powerhouses (operated in series), which each have a capacity of 128 cfs. Some additional water is diverted from Millseat Creek to fill the Volta I and II Powerhouse penstocks during periods of moderate runoff.

The North Battle Creek Feeder Diversion Dam is located just upstream of the Volta II Powerhouse and downstream of Bailey and Rock Creeks. The dam diverts a maximum of 50 cfs into the Cross Country Canal which has a capacity of 150 cfs and which also conveys the Volta II tailrace flow to the South Powerhouse.

The Eagle Canyon Diversion Dam, located on the North Fork Battle Creek downstream of Digger Creek, diverts a maximum of 64 cfs to the Inskip Canal, which connects to the Inskip Powerhouse penstock.

The Wildcat Diversion Dam is located about 2.5 miles upstream of the confluence of the North Fork Battle Creek with the South Fork Battle Creek. Historically, the dam diverted a maximum of 18 cfs to the Wildcat Canal, which has not been used since August 1995. The Wildcat Canal joins the Coleman Canal, which connects to the Coleman Powerhouse penstock, located just upstream of the CNFH.

The South Diversion Dam is the upstream diversion dam on the South Fork Battle Creek and has a capacity of about 85 cfs. The South Canal diverts a maximum of about 15 cfs from Soap Creek and joins the Cross Country Canal to connect with the South Powerhouse penstock, which has a capacity of 190 cfs. Water from the South Powerhouse is rediverted at the Inskip Diversion Dam, which has a capacity of about 220 cfs, and flows into the Inskip Canal, which is joined by the Eagle Canyon Canal at the Inskip Powerhouse penstock, which has a capacity of about 290 cfs. Water from the Inskip tailrace is rediverted at the Coleman Diversion Dam, which has a capacity of about 340 cfs; flows in the Coleman Canal; and is joined by the Wildcat Canal and diversions from Baldwin Creek (i.e., Pacific Power Canal and Ashbury Pump, which have a total capacity of 60 cfs) to the Coleman Powerhouse penstock, which has a capacity of about 380 cfs.

The FERC minimum flow requirement below each of the North Fork Battle Creek diversion dams is 3 cfs. The FERC minimum flow requirement for each of the South Fork Battle Creek diversion dams is 5 cfs. PG&E usually operates these diversions to maintain slightly more flow than the FERC requirements. Diversions are made as far upstream as possible to maximize the hydroelectric power production.

# Historical Daily Battle Creek Flow Patterns

Figures I-1 through I-6 show the daily Battle Creek flows and daily powerhouse flows for calendar years 1989–2000. The average monthly Battle Creek flows and the minimum monthly Battle Creek flows are also shown in the figures. The flow scale on these graphs has a maximum of 1,000 cfs, which is a moderate flow of 2.8 cfs per square mile for the 357-square-mile watershed upstream of the USGS gage. For reference, 0.5 inch of runoff from the entire watershed would produce a flow of 4,800 cfs if the runoff occurred in just 1 day. A flow of 1,000 cfs is therefore equivalent to about 0.1 inch of runoff from the entire watershed.

Twelve years of daily flow and powerhouse flows are presented below to provide a clear description and understanding of the basic hydrology of Battle Creek.

Figure I-1b shows that the baseflow at the beginning of 1989 was about 350 cfs. Storm events that occurred in January and February 1989 were isolated, and the runoff was elevated for only a few days following the rainfall. The baseflow measured between storms was about 300 cfs. Some major rainfall in March raised the baseflow to about 900 cfs at the beginning of April. The baseflow then declined through April–July without any major additional storms. The baseflow had declined to only about 200 cfs by the end of August. A few storms in September–December maintained the baseflow between 200 cfs and 300 cfs.

Figure I-1a shows that the Volta Powerhouse flows were a maximum of about 125 cfs, the South Powerhouse flows were a maximum of about 200 cfs, and the Inskip Powerhouse flows were a maximum of about 275 cfs. The Coleman Powerhouse flows were a maximum of about 350 cfs and included almost all of Battle Creek flows during the summer and fall when Battle Creek flows are less than 350 cfs.

Because the North Fork Battle Creek and South Fork Battle Creek diversion dams and powerhouses form a “cascade” that diverts more and more of the Battle Creek flows, the powerhouse flows remain proportional to each other during the summer and fall. Even during periods of powerhouse outage, which can be observed in the powerhouse flow records, the diversion canals may continue to divert water, and the water is spilled into the river upstream of the powerhouses. For example, the Coleman Powerhouse experienced an outage during August 1989, and the Inskip Powerhouse experienced an outage during October 1989.

Figure I-1b shows that the runoff in winter 1990 was much less than in winter 1989. Baseflow was maintained at about 300 cfs during the winter by a few isolated storms. Battle Creek flows were only about 200 cfs from July through the end of the year. The minimum monthly flows were very similar to the average monthly flows in a drought low-flow year like 1990.

Figure I-2a shows that Battle Creek flows in 1991 remained only slightly higher than 200 cfs until some rainfall events in March (i.e., “Miracle March”). Baseflow returned to 200 cfs by the end of July and remained at about 200 cfs through the end of the year.

Figure I-2b shows that 1992 was another extremely dry year. A small storm in early January raised the baseflow to 225 cfs, and February storms raised the baseflow to 300 cfs through April. The baseflow then declined to less than 200 cfs from July through October. The baseflow was raised slightly to 200 cfs at the end of October and was maintained at about 200 cfs until the end of the year. This 3-year sequence of dry years, which provided a baseflow of only 200 cfs, would represent an extremely great challenge to any of the restoration alternatives because all three of the Chinook salmon cohorts (i.e., with a minimum life cycle of 3 years) would have been affected.

Figure I-3a indicates that a wet winter returned in 1993, raising the baseflow to 400 cfs in January, to 500 cfs in February, and to 700 cfs in March–May. The baseflow declined substantially in June and July, reaching about 300 cfs at the end of July and 225 cfs by the end of September. The baseflow was increased by a few storms to about 300 cfs by the end of the year. The maximum Coleman Powerhouse flows were apparently slightly reduced to about 325 cfs (as a result of slightly limited turbine capacity caused by mechanical troubles). The maximum powerhouse flows were maintained through July because of the high flows.

Figure I-3b shows that 1994 was another relatively dry year. Baseflow was maintained just above 300 cfs in January and increased to 400 cfs in February from several storms. Baseflow was about 300 cfs in April and May and declined to less than 200 cfs in July, August, and September. Battle Creek flows increased slightly in October and November, and the baseflow increased to 300 cfs by several storms in December. The maximum Coleman Powerhouse flows of about 325 cfs were achieved only in February–May.

Figure I-4a shows that 1995 was a very wet year, with flows of more than 1,000 cfs from January through May. Although baseflow was just 300 cfs at the beginning of January, baseflow was elevated to 600 cfs by the end of February and was more than 700 cfs through June. Streamflow declined in July and August, and the baseflow was about 300 cfs in September, October, and November. Another storm in December raised the baseflow to 400 cfs by the end of the year. The Coleman Powerhouse flow was about 325 cfs during the winter and was out for maintenance in May. The Inskip and Coleman Powerhouse flows were reduced to about 250 cfs beginning in September because interim minimum flows of 35 cfs were released from Eagle Canyon and Coleman Diversion Dams, and there was not quite enough flow to allow full powerhouse flows.

Figure I-4b shows that 1996 was another fairly wet year. The baseflow of 400 cfs at the beginning of the year was increased by storms in January to 700 cfs and was maintained above 600 cfs through May. Many storm flows peaked above 1,000 cfs during the winter. The flows declined in June and July to a baseflow of less than 300 cfs in August and September and slightly more than 300 cfs through November. The CNFH flow gage had some missing records in December, but it appears that the flows were elevated because the powerhouse flows were at capacity (i.e., 325 cfs at Coleman) by the end of the year. The powerhouse flows were near capacity through June, and the Inskip and Coleman Powerhouse flows were reduced in July to mid-November to allow the interim minimum flows below Coleman and Eagle Canyon Diversion Dams.

Figure I-5a shows that 1997 was a moderately wet year, with winter baseflow of more than 400 cfs through May. The CNFH gage had many missing records, but the Coleman Powerhouse flow was near capacity of above 300 cfs through May. Baseflow declined to a minimum of about 250 cfs in August. Inskip and Coleman Powerhouse flows were reduced to about 200 cfs in August –October because of the interim minimum flows released below Coleman and Eagle Canyon Diversion Dams. Rainfall was sufficient to raise the baseflow to 300 cfs by early November and to more than 400 cfs at the end of the year.

Figure I-5b shows that 1998 was a very wet year. January storms raised flows to more than 1,000 cfs. Battle Creek flows remained above 1,000 cfs through June. Baseflow declined in July and August to about 425 cfs in September and October. Major storms in November produced flows of greater than 1,000 cfs, and baseflow was about 500 cfs at the end of the year. Powerhouse flows were near capacity for the entire year, with maintenance periods of about 1 month for each powerhouse.

Figure I-6a shows that 1999 was another moderately wet year. Baseflow was more than 425 cfs in January, and a series of winter storms raised the baseflow and maintained flow above 600 cfs through May. The baseflow declined in June and July and was a minimum of about 300 cfs in August. A few small storms raised the baseflow to about 325 cfs by the end of the year. The Powerhouse flows were near capacity through June. Inskip and Coleman Powerhouse flows were restricted from July through the end of the year to allow the interim minimum flows to be released below Coleman and Eagle Canyon Diversion Dams.

Figure I-6b shows that runoff in 2000 was again very high in the months, with several peak flows exceeding 1,000 cfs. Baseflow was 600 cfs at the beginning of April but declined in April and May to about 400 cfs. The baseflow declined in June and July to a minimum of about 275 cfs in August and September. Baseflow increased slightly to 300 cfs in October and remained at 300 cfs for the remainder of the year. The powerhouse flows were near capacity (slightly limited Coleman capacity of 300 cfs) through May. Coleman Powerhouse was down for maintenance in June and was restricted to only about 200 cfs from June through the end of the year to allow the interim minimum flows to be released below Coleman and Eagle Canyon Diversion Dams.

The sustained baseflow of Battle Creek is the most remarkable feature about the hydrology. This baseflow is the result of the basin geology that allows most of the rainfall to percolate into the shallow groundwater and emerge as baseflow from the many springs that feed the streams throughout the basin. The next section describes how the monthly hydrology and hydropower diversion model was formulated.

# Battle Creek Monthly Minimum and Maximum Flows

The daily Battle Creek flows are generally very well sustained because of the high contribution of baseflow from snowmelt in the higher elevations and from springs throughout the basalt basin. Storm events produce increased runoff for several days following the rainfall. Because the effect of these higher flows on temperatures and aquatic habitat conditions are uncertain, the monthly flow, hydropower, water temperature, and fish habitat model uses monthly minimum flows. The minimum monthly flows may be a better estimate of the limiting flow and temperature conditions in each reach than the average monthly flow.

Figure I-6b shows the Battle Creek flows measured at the CNFH during 2000. The monthly flows for 2000 are shown to indicate the magnitude of daily variation in flows above and below the monthly average flows. The monthly flows for 2000 are close to the 50% (median) monthly flows for 1963–2003.

During the winter, the daily variations in Battle Creek flow are substantial. In contrast, during the summer and fall months, the daily variations in the Battle Creek flows are small because most of the flow originates from springs.

Figure I-7 shows the monthly maximum and minimum flows compared to the monthly average Battle Creek flows for 1983–2002. As the monthly average flow increases to about 500 cfs, the minimum flow is still more than 80% of the average flow. As the monthly average flow increases to 1,000 cfs, the minimum monthly flow can be as little as 50% of the monthly average flow. The maximum flow can be several times the average flow, if the average monthly flow is greater than 500 cfs because the high runoff may last only for a few days, if the rainfall is not sustained throughout the month.

In general, the use of monthly minimum flows to characterize monthly habitat flows for the fish habitat and water temperature model appears to be a reasonable assumption for Battle Creek because the flows are dominated by sustained baseflow sources (i.e., springs) during most of the year. The minimum flow (i.e., baseflow) is almost always greater than 80% of the monthly average flows when the monthly average flow is less than about 500 cfs. The minimum monthly flow is at least 50% of the monthly average flow when the monthly flow is between 500 and 1,000 cfs. Habitat conditions are assumed to be relatively good for these higher flow months, and the differences between the No-Action Alternative and any of the restoration alternatives are relatively small in these high flow months because a maximum of 350 cfs can be diverted into the hydropower system.

Table I-2 shows the cumulative distribution (i.e., percentiles) of the monthly minimum (i.e., minimum daily flow in each month) flows for the USGS gage at the CNFH for 1940–2000. The cumulative distribution of the monthly average flows for the same time period are also shown in Table I-2. The hydrology model will distribute the monthly flows at the CNFH to each of the diversion dams and calculate the diversions and release flows for each alternative. Because the future flows in any one year cannot be predicted, the model calculates the range of conditions corresponding to the range of monthly minimum flows that are expected to occur in the future.

# Monthly Hydrology Calculations

The fist step in the monthly hydrology model is to estimate the natural or unimpaired flows (i.e., no upstream diversions) at each diversion dam location.

Using the watershed area-flow method, the total flow measured at the base of the watershed is apportioned to points throughout the watershed on the basis of the percentage of total drainage area at the point being estimated. For example, the total drainage area at the base of the gaged watershed (CNFH) is 357 square miles, and the total drainage area at the Eagle Canyon Diversion Dam on the North Fork Battle Creek is estimated to be 177 square miles. Thus, under the area-flow method, 50% of the measured daily flow at the CNFH is the assumed flow at the Eagle Canyon Diversion Dam under natural, unimpaired conditions (with no upstream diversions for hydroelectric power).

The resource agencies thought that the area-flow method would be appropriate for the assessments of the restoration alternatives. The PG&E records from recent years (i.e., water years [WY] 1998–2002) have been used to confirm the area-flow estimates used in the monthly model. Discussion with PG&E staff about the specific hydrology of the watershed helped refine the area-method modeling. In particular, the existence of volcanic soils and fractured geology throughout the watershed provides a nearly constant baseflow at several major springs. The area-flow method assumes uniform runoff across the entire watershed. To increase the accuracy of the model, the flows from the major springs were estimated, and the area-flow method fractions were adjusted to estimate the combined monthly flows from springs and surface runoff sources within each watershed area. The assumed spring flow and the area-flow fractions for each diversion dam are identified in the next section.

The monthly model uses the full range of measured monthly minimum flows at the USGS gage below the CNFH from 1963–2003. For each calendar month, the monthly minimum flows are ranked from smallest to largest, and the percentile values (i.e., minimum, 10%, 20%, 30%, … maximum) of monthly minimum flow values are determined. Table I-2 gives the monthly minimum flow values for Battle Creek obtained from the 1940–2000 flow record. The model uses the 10%, 30%, 50%, 70%, and 90% monthly minimum flow values to approximate the full range of future likely flows. Each of these five flow values is assumed to be representative of monthly minimum flows expected in about 20% of the future years. The 10% flow values are representative of the lowest flows that would be exceeded in 90% of the future years.

For example, Table I-2 indicates that the 10% monthly minimum flow value for January would be 232 cfs. This value is used in the monthly hydrology model to represent the lowest 20% of the future January monthly minimum flows. In January, the 30% monthly minimum flow is 272 cfs, the 50% monthly minimum flow is 333 cfs, the 70% monthly minimum flow is 387 cfs, and the 90% monthly minimum flow is 524 cfs. The highest flows generally occur in March–May. During these months the minimum monthly flows range from about 300 cfs (i.e., 10% minimum flow) to about 700 cfs (i.e., 90% minimum flow). The lowest flows generally occur in August and September. The minimum monthly flows in these summer months range form about 150 cfs to about 300 cfs.

The use of monthly minimum flows in the hydrology model gives conservatively low estimates of the flows below the diversion dams and also gives conservatively low estimates of the hydropower diversions and powerhouse flows. The diversions and streamflows will likely be higher on many days in each month than the values calculated with the monthly model.

# Upstream Flow Comparisons

One of the basic assumptions of the monthly hydrology model is that the upstream natural flows can be calculated from the watershed fraction of the entire Battle Creek flow measured at the CNFH. For example, the North Fork Battle Creek watershed upstream of Keswick Diversion Dam is about 89 square miles. This area is about 25% of the entire Battle Creek watershed area of 357 square miles. It includes the portion of Millseat Creek that can be diverted into the canals that connect with the Volta powerhouses. If the watershed area method is accurate, the Volta powerhouse flows should be about 25% of the entire Battle Creek flow.

Figure I-8a indicates that the Volta II Powerhouse flows for 2000 were approximately equal to 25% of the entire Battle Creek flow. It may be surprising that this upstream portion of the North Fork Battle Creek watershed does not yield a greater fraction of the total Battle Creek flow because the rainfall in this portion of the watershed is likely to be higher than the average across the entire watershed. Nevertheless, the 25% fraction provides a good estimate of the Volta powerhouse flow.

Figure I-8b shows the measured South Canal diversions and estimated release and spill below South Diversion Dam during 2000. The South Fork Battle Creek watershed upstream of the South Diversion Dam is about 67 square miles, representing 19% of the entire Battle Creek watershed. The South Diversion Dam diversions appear to follow the 19% estimate of the Battle Creek flow measured at the CNFH. The South Diversion Dam spill was estimated from a stage-discharge curve for the South Diversion Dam gage. The maximum spill was about 50 cfs during January–May. The combined flow estimate for South Diversion Dam appears to follow the 19% estimate based on the fraction of the watershed above South Diversion Dam. Some of the direct runoff during storm events may originate in the rocky portion of the watershed downstream of the confluence. The South Diversion Dam flow during the summer and fall baseflow periods appears to be proportional to the CNFH flow. The area-flow method appears to work well for the North Fork Battle Creek above Keswick Dam and for the South Fork Battle Creek above South Diversion Dam. It is assumed that all Battle Creek flows are proportional to their upstream watershed areas.

# Calculated North Fork Battle Creek Monthly Flows and Diversions

The monthly hydrology model calculates all flows and diversions for each month for the five representative percentiles of Battle Creek monthly minimum flows. This calculation provides a description of the range of flows likely in each reach or diversion canal under each of the restoration alternatives. Table I-3 shows an example of the calculations for the North Fork Battle Creek and South Fork

Battle Creek assuming the 50% (median) monthly minimum flow values under the Five Dam Removal Alternative.

Table I-3 is printed from the monthly spreadsheet. The top section shows the input parameters that describe the hydrology and the restoration alternative features. The hydrology at each diversion dam is specified with a constant spring flow (in cubic feet per second) and with a watershed area (in square miles). The fraction of the nonspring flow measured at the CNFH gage corresponding to the watershed size is shown for each diversion location. The restoration alternatives are specified with connector capacities between the South Powerhouse and the Inskip Canal and between the Inskip Powerhouse and the Coleman Canal. The diversion capacities are specified at each diversion dam. A value of 0 indicates that the diversion dam is removed in the alternative. The target minimum flow values are shown for each month at each diversion dam. A value of 0 indicates that the diversion dam is removed.

The monthly flows at the CNFH are given on the top line. The portion of this flow that is assumed to come from constant springs (55 cfs) is given on the next line. The upstream flows at Keswick (representing all Volta diversions) are estimated with an effective watershed area of 89 square miles, representing 25% of the nonspring CNFH flow. The January flow at Keswick Dam is calculated to be 69 cfs. The minimum FERC flow at Keswick Dam is 3 cfs, so the calculated diversion to the Volta I and II powerhouses for January is 66 cfs. A portion of this diversion would actually have been diverted at the Al Smith diversion, and some would have been diverted from Millseat Creek into the canals connecting to the Volta I and II Powerhouse penstocks.

The next diversion dam is the North Battle Creek Feeder Diversion Dam. There are relatively large streams (Bailey Creek and Rock Creek) that join the North Fork Battle Creek just upstream of the dam. The North Battle Creek Feeder diversion capacity is about 50 cfs. The estimated flow at the feeder in January is 37 cfs, but the target flow is 88 cfs, so the calculated diversion to the Cross Country Canal and the South Powerhouse is 0 cfs. Because the target flows are relatively high, feeder dam diversions are calculated only in May for these 50% monthly minimum flows.

The next diversion dam is the Eagle Canyon Diversion Dam. Digger Creek enters the North Fork Battle Creek just upstream. The diversion capacity is 64 cfs. There are 5 cfs of springs assumed between the North Battle Creek Feeder and Eagle Canyon Diversion Dams. The watershed area upstream of Eagle Canyon Diversion Dam is 177 square miles (50% of the Battle Creek watershed). The calculated January flow is 77 cfs. The target minimum flow below Eagle Canyon Diversion Dam is 46 cfs in January, so the January diversion is calculated to be 31 cfs.

The last diversion dam on the North Fork Battle Creek is the Wildcat Diversion Dam. The watershed area is 189 square miles (representing 53% of the total Battle Creek nonspring flow). There are an assumed 10 cfs of springs between Eagle Canyon and Wildcat Diversion Dams. The Wildcat Diversion Dam would be removed in the Five Dam Removal alternative, and the Wildcat diversions would be eliminated. The January flow is calculated to be 65 cfs.

Because of the relatively high minimum flow targets below North Battle Creek Feeder Diversion Dam and Eagle Canyon Diversion Dam, most of the North Fork Battle Creek flow below the Keswick Diversion Dam will remain in the stream. The Volta powerhouse flows will remain the same as they are under the No-Action Alternative in all of the restoration alternatives.

# Calculated South Fork Battle Creek Monthly Flows and Diversions

Table I-3 also gives the monthly model calculations for the South Fork Battle Creek flows and diversions for the Five Dam Removal Alternative with median (50%) minimum monthly flows. The first diversion is at the South Diversion Dam. There are no upstream springs, and the watershed area is 67 square miles, with a flow fraction of 19%. South Diversion Dam is removed under the Five Dam Removal Alternative. The January flow at South Diversion Dam is 52 cfs. The Soap Creek flows are calculated to be 10 cfs from the springs plus 6 square miles (2%) of the nonspring CNFH flow. For January, the Soap Creek flow is calculated to be 15 cfs. The Soap Creek diversions are not allowed in the Five Dam Removal Alternative. Soap Creek diversions in the No-Action Alternative enter South Canal, which joins the Cross Country Canal from Volta and Feeder, connecting to Union Canal and the South Powerhouse. For January, the South Powerhouse flow is 66 cfs. The Five Dam Removal Alternative includes a connector from the South Powerhouse tailrace to the Inskip Canal.

The next diversion dam is Inskip Diversion Dam. The upstream watershed is 88 square miles, representing a flow of about 25% of Battle Creek nonspring flow. The calculated flow at Inskip Diversion Dam in January is 79 cfs. The target minimum flow is 86 cfs in January, so no additional diversions at Inskip Dam are allowed in January. Some diversions at Inskip Dam are calculated in the other months when the target minimum flows are less than the flows at Inskip Dam.

The Ripley Creek flow is calculated to be 5 cfs from springs plus 12 square miles (3% ) of the nonspring CNFH flow. For January, the Ripley Creek flow is 14 cfs. No diversions are allowed in the Five Dam Removal Alternative. The calculated Eagle Canyon Canal flow for January is 31 cfs, and the connector supplies 66 cfs, so the Inskip Powerhouse flow is 97 cfs. The Five Dam Removal Alternative includes a connector from the Inskip Powerhouse tailrace to the Coleman Canal.

The last diversion dam on the South Fork Battle Creek is Coleman Diversion Dam. The upstream watershed is 115 square miles, representing about 32% of the nonspring Battle Creek flow. The spring flow upstream of Coleman is 15 cfs.

The calculated flow at the Coleman Diversion Dam is 105 cfs in January. The Coleman Diversion Dam is removed in the Five Dam Removal Alternative.

There are two diversions on Baldwin Creek that increase the Coleman Canal flow. The Pacific Power diversion has a capacity of 24 cfs, and the Asbury Dam and pump have a capacity of 35 cfs. Baldwin Creek flow is estimated from the watershed of 14 square miles (4%) of the nonspring Battle Creek Flow and includes Darrah Springs, which supply the Darrah Springs Hatchery with a constant assumed flow of 25 cfs. The calculated flow for Baldwin Creek in January is 36 cfs. The minimum flow target is 5 cfs, so the calculated diversion to the Coleman Canal in January is 31 cfs. The calculated January flow below the confluence of the North Fork Battle Creek and South Fork Battle Creek, including the flow from Baldwin Creek, is estimated from a total spring flow of 55 cfs plus flow from a watershed of 340 square miles (95%) of nonspring CNFH flow minus all the diversions to the powerhouse canals. The calculated January flow in the mainstem of Battle Creek is 192 cfs. The flows from Coleman Diversion Dam of 105 cfs, plus the flow from Wildcat Dam of 65 cfs has increased by 17 cfs at the confluence. The Baldwin flow of 5 cfs gives the total mainstem flow of 192 cfs. The Coleman Powerhouse flow is calculated to be 128 cfs in January. Another 4% of the CNFH flow is estimated to enter Battle Creek downstream of Baldwin Creek.

The monthly flow model, using the distribution of monthly minimum flows, with the combination of constant spring flows plus watershed area estimates of the fraction of the CNFH flow at each diversion dam, provides a reasonable method for estimating the likely range of future flows at each upstream dam for each restoration alternative. The monthly results of flows and diversions for each restoration alternative are given in Appendix J of this report, “Results from Monthly Flow and Power Generation Model.”

# Estimating Monthly Hydroelectric Power Production

Monthly diversions at each diversion dam are calculated from the total available flow at that diversion, the required minimum streamflow below the diversion, and the capacity of the conveyance and generation facilities that the diversion must pass through. The upstream diversions on the North Fork Battle Creek (Al Smith and Keswick) are assumed to be operated to capacity if there is sufficient water available. The sequential diversions on the North Fork Battle Creek are also maximized subject to available water and canal capacities. The South Fork Battle Creek diversions are then limited by available water or remaining powerhouse capacities.

The Battle Creek power plants are operated as run-of-the-river facilities, generating electricity 24 hours per day because there are no storage facilities available for peaking power generation. Each hydroelectric powerhouse has an assumed capacity. The energy production is calculated with the simple equation that estimates the daily energy:

$$\text{Energy (KWh)} = 2.0 \times \text{Flow (cfs)} \times \text{Head (feet)} \times \text{Efficiency}$$

The *head* and *efficiency* at each powerhouse can be multiplied together to give the *effective head*. The efficiencies are generally about 80%. The Volta 1 and Volta 2 Powerhouses are operated in series, and the total effective head is used. The Volta I and II Powerhouses have a combined effective head of 1,100 feet. The megawatt hours (MWh) production at each plant for each month is calculated from the number of days in the month.

For example, for the Five Dam Removal Alternative at 50% monthly minimum flows, the calculated January production at the:

- Volta I and II Powerhouses was 4,522 MWh with 66 cfs flow,
- South Powerhouse was 1,500 MWh with 66 cfs flow,
- Inskip Powerhouse was 1,777 MWh with 97 cfs flow, and
- Coleman Powerhouse was 3,168 MWh with 128 cfs flow.

The combined annual energy production was 135,351 MWh. Power production results for each powerhouse for each of the five percentile flow values are given in Appendix J, “Results from Monthly Flow and Power Generation Model.”

# Conclusions

The monthly flow and hydropower diversion model is an important tool for evaluating the flows and energy production for the No-Action Alternative and the restoration alternatives. The results for each restoration alternative, using the range of monthly minimum flows to characterize the future conditions, can be reviewed in Appendix J, “Results from the Monthly Flow and Power Generation Model.”

**Table I-1.** Battle Creek Stream and Diversion Data

| Battle Creek Location | Battle Creek Reach | River Mile | Elevation (feet) | Watershed Area ($mile^2$) | Diversion Capacity (cfs) |
|---|---|---|---|---|---|
| Confluence with Sacramento River | BC | 0.0 | – | – | – |
| Coleman National Fish Hatchery Weir | BC | 7.5 | – | 357 | – |
| Coleman Powerhouse Tailrace | BC | 8.0 | 490 | – | – |
| Baldwin Creek | BC | 15.9 | – | 14 | |
| North Fork and South Fork Confluence | BC | 17.1 | 830 | 337 | – |
| Wildcat Diversion Dam | NFBC | 2.8 | 1,070 | – | 18 |
| Eagle Canyon Diversion Dam | NFBC | 5.4 | – | 186 | 64 |
| Digger Creek | NFBC | 5.5 | 1,470 | – | – |
| North Battle Creek Feeder Diversion Dam | NFBC | 9.6 | – | 133 | 50 |
| Bailey Creek | NFBC | 9.8 | 2,110 | – | – |
| Fish Blockage | NFBC | 14.5 | – | – | – |
| Keswick Diversion Dam | NFBC | 15.1 | 3,650 | 80 | 45 |
| Al Smith Diversion Dam | NFBC | 16.5 | 3,800 | 65 | 45 |
| Coleman Diversion Dam | SFBC | 2.5 | 1,000 | 102 | 340 |
| Ripley Creek | SFBC | – | – | – | – |
| Inskip Diversion Dam | SFBC | 8.0 | 1,415 | 88 | 220 |
| Soap Creek | SFBC | – | – | – | – |
| South Diversion Dam | SFBC | 14.4 | 2,030 | 67 | 100 |
| Fish Blockage | SFBC | 18.9 | – | – | – |

Notes:
cfs = cubic feet per second.
BC = Mainstem Battle Creek.
NFBC = North Fork Battle Creek.
SFBC = South Fork Battle Creek.

**Table I-2**. Historical Monthly Flows in Battle Creek below the Coleman National Fish Hatchery (cubic feet per second) for the 1940–2000 Period of Record

Average Flow = 501 cfs | Drainage Area = 357 square miles | Data Source: U.S. Geological Survey

**Minimum Monthly Flows**

| Percentile | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 196 | 197 | 227 | 203 | 227 | 179 | 152 | 135 | 140 | 102 | 166 | 181 |
| 10 | 232 | 246 | 279 | 305 | 292 | 213 | 171 | 157 | 153 | 177 | 199 | 219 |
| 20 | 260 | 274 | 312 | 355 | 336 | 249 | 197 | 178 | 174 | 190 | 216 | 242 |
| 30 | 272 | 301 | 354 | 384 | 363 | 270 | 206 | 187 | 184 | 209 | 230 | 254 |
| 40 | 292 | 365 | 375 | 430 | 405 | 285 | 219 | 204 | 200 | 215 | 242 | 266 |
| 50 | 333 | 383 | 424 | 474 | 446 | 326 | 242 | 223 | 217 | 230 | 252 | 286 |
| 60 | 368 | 451 | 491 | 529 | 560 | 408 | 268 | 233 | 229 | 246 | 273 | 316 |
| 70 | 387 | 506 | 525 | 566 | 634 | 454 | 301 | 254 | 246 | 259 | 294 | 330 |
| 80 | 434 | 555 | 601 | 643 | 654 | 480 | 330 | 272 | 265 | 276 | 310 | 354 |
| 90 | 524 | 614 | 681 | 725 | 722 | 539 | 358 | 301 | 290 | 311 | 346 | 412 |
| 100 | 694 | 920 | 1,110 | 845 | 1,020 | 1,010 | 650 | 471 | 433 | 415 | 452 | 620 |

**Average Monthly Flows**

| Percentile | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 220 | 260 | 266 | 231 | 266 | 207 | 163 | 150 | 153 | 139 | 199 | 209 |
| 10 | 272 | 339 | 372 | 355 | 346 | 271 | 197 | 171 | 176 | 199 | 250 | 254 |
| 20 | 350 | 393 | 426 | 438 | 387 | 298 | 221 | 188 | 189 | 220 | 262 | 296 |
| 30 | 409 | 509 | 490 | 463 | 432 | 318 | 234 | 205 | 208 | 232 | 278 | 337 |
| 40 | 464 | 551 | 528 | 504 | 491 | 367 | 252 | 226 | 218 | 250 | 299 | 402 |
| 50 | 550 | 697 | 613 | 567 | 590 | 416 | 276 | 240 | 237 | 270 | 335 | 440 |
| 60 | 737 | 756 | 734 | 666 | 669 | 508 | 347 | 251 | 253 | 291 | 348 | 492 |
| 70 | 838 | 898 | 767 | 802 | 757 | 557 | 371 | 280 | 271 | 311 | 392 | 573 |
| 80 | 989 | 958 | 884 | 920 | 850 | 653 | 398 | 294 | 285 | 329 | 432 | 778 |
| 90 | 1,290 | 1,201 | 1,167 | 1,023 | 922 | 750 | 441 | 327 | 315 | 372 | 553 | 987 |
| 100 | 2,434 | 1,919 | 1,802 | 1,160 | 1,578 | 1,453 | 817 | 540 | 449 | 589 | 1,058 | 1,602 |

**Maximum Monthly Flows**

| Percentile | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 254 | 316 | 311 | 307 | 320 | 236 | 177 | 155 | 162 | 199 | 221 | 254 |
| 10 | 484 | 505 | 457 | 456 | 429 | 338 | 223 | 187 | 194 | 223 | 297 | 293 |
| 20 | 716 | 671 | 585 | 525 | 497 | 381 | 253 | 199 | 213 | 252 | 350 | 436 |
| 30 | 1,030 | 1,128 | 837 | 584 | 532 | 440 | 271 | 216 | 231 | 273 | 415 | 597 |
| 40 | 1,308 | 1,474 | 1,184 | 663 | 604 | 481 | 291 | 244 | 250 | 324 | 520 | 970 |
| 50 | 1,870 | 1,950 | 1,415 | 788 | 758 | 597 | 336 | 269 | 272 | 357 | 621 | 1,160 |
| 60 | 2,164 | 2,292 | 1,584 | 932 | 890 | 668 | 418 | 292 | 289 | 432 | 807 | 1,554 |
| 70 | 3,088 | 2,730 | 1,998 | 1,247 | 1,057 | 771 | 459 | 320 | 301 | 496 | 1,189 | 2,178 |
| 80 | 3,498 | 3,180 | 2,492 | 1,670 | 1,336 | 876 | 489 | 341 | 332 | 558 | 1,292 | 2,948 |
| 90 | 5,340 | 3,988 | 4,074 | 2,384 | 1,436 | 1,183 | 600 | 416 | 415 | 742 | 2,015 | 3,610 |
| 100 | 10,900 | 7,140 | 6,390 | 6,430 | 4,090 | 3,140 | 980 | 636 | 1,020 | 4,140 | 6,380 | 7,080 |

Note: Minimum monthly flows used to approximate monthly baseflow values.

**Table I-3.** Example Printout of Monthly Calculations of Battle Creek Flows and Diversions for Five-Dam Removal Alternative for Median (50%) Monthly Minimum Flows



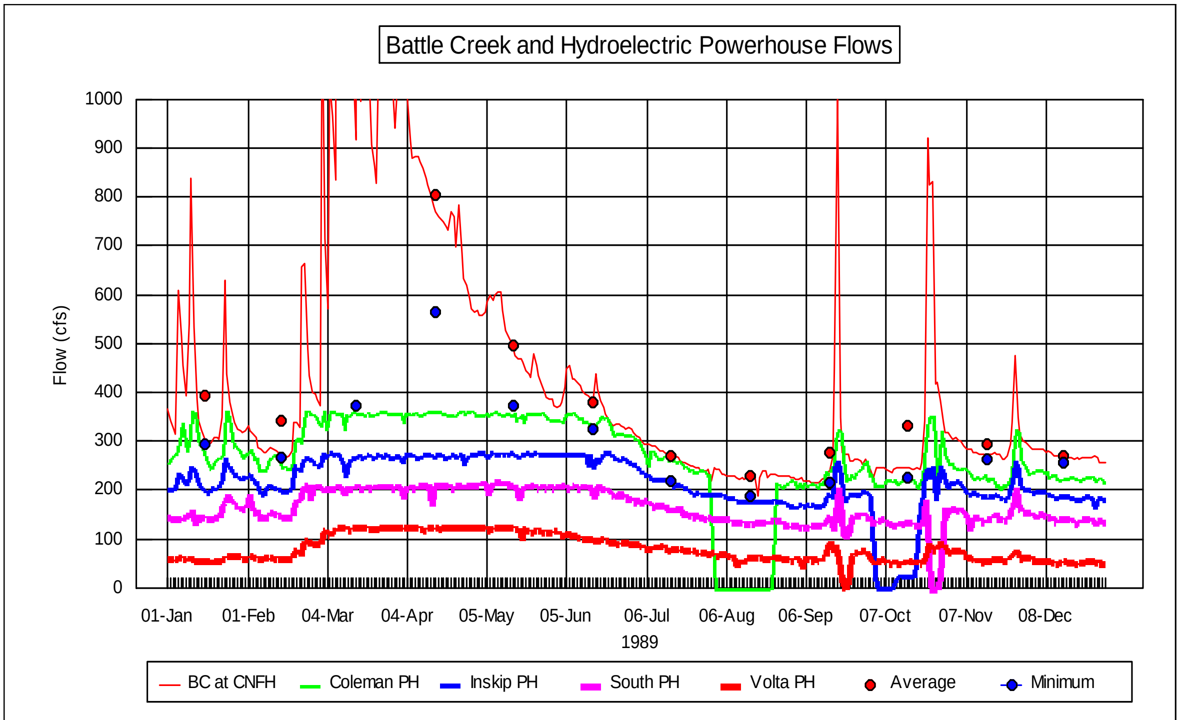
| Upstream Springs | Area ($mile^2$) | Fraction | Location | Connector Capacity (cfs) | Diversion Capacity (cfs) | Instream Flow Targets (cfs) Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 89 | 0.25 | Keswick | | 128 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 0 | 133 | 0.37 | NBC Feeder | | 50 | 88 | 88 | 88 | 67 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 88 |
| 5 | 177 | 0.5 | Eagle Canyon | | 64 | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| 10 | 189 | 0.53 | Wildcat | | 0 | 0 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| 0 | 67 | 0.19 | South | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 88 | 0.25 | Inskip | 220 | 220 | 86 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 86 |
| 0 | 115 | 0.32 | Coleman | 340 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 6 | 0.02 | Soap | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 12 | 0.03 | Ripley | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 14 | 0.04 | Baldwin | | 35 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 55 | 340 | 0.95 | Confluence | | | | | | | | | | | | | | |

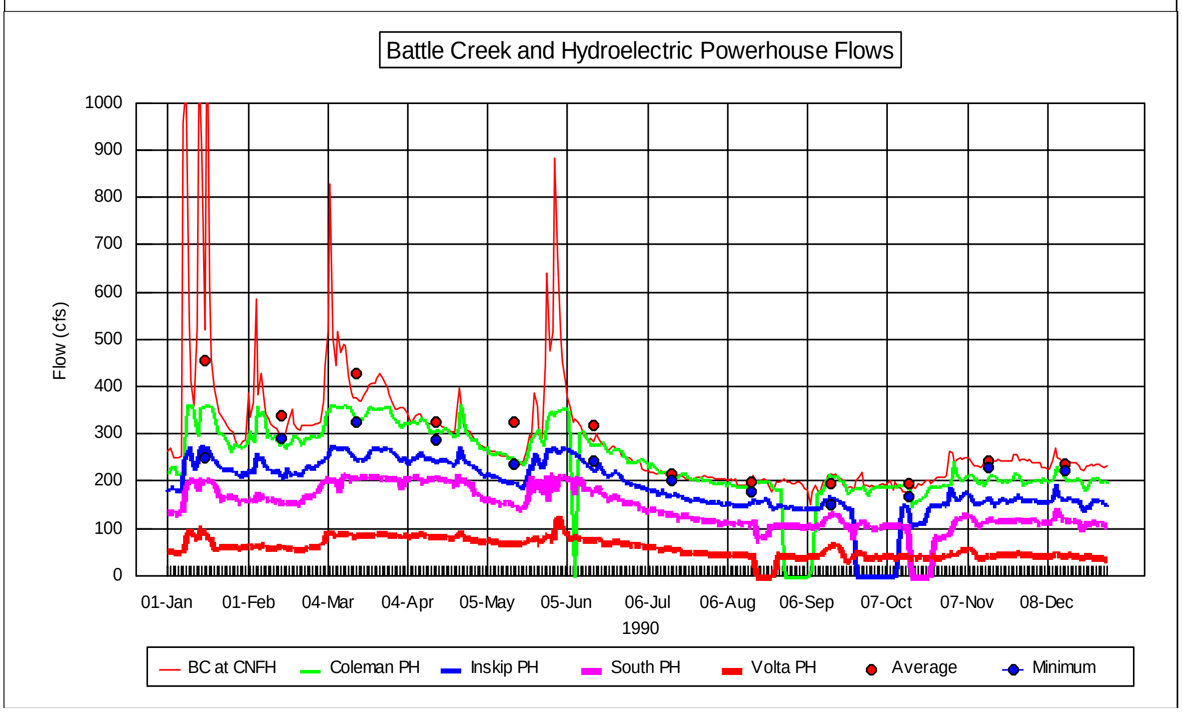
| | | | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | 357 | Battle Creek at CNFH Flow | 333 | 383 | 424 | 474 | 446 | 326 | 242 | 223 | 217 | 230 | 252 | 286 |
| | | Total Springs | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| Watershed | 89 | Keswick Springs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fraction | 0.25 | Estimate of Keswick Flow | 69 | 82 | 92 | 104 | 97 | 68 | 46 | 42 | 40 | 44 | 49 | 58 |
| Capacity | 128 | Estimate of Volta Diversions | 66 | 79 | 89 | 101 | 94 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| | | Instream Flow Target | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | | Flow Below Keswick Dam | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Watershed | 133 | Upstream Springs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fraction | 0.37 | Estimate of Feeder Flow | 37 | 43 | 48 | 55 | 51 | 36 | 26 | 24 | 23 | 25 | 27 | 31 |
| Capacity | 50 | Estimate of NFBC Diversion | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Instream Flow Target | 88 | 88 | 88 | 67 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 88 |
| | | Flow Below NFBC Feeder Dam | 37 | 43 | 48 | 55 | 47 | 36 | 26 | 24 | 23 | 25 | 27 | 31 |
| Watershed | 177 | Upstream Springs | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Fraction | 0.50 | Estimate of Eagle Flow | 77 | 89 | 99 | 111 | 100 | 75 | 54 | 49 | 48 | 51 | 57 | 65 |
| Capacity | 64 | Estimate of Eagle Diversion | 31 | 43 | 53 | 64 | 64 | 40 | 19 | 14 | 13 | 16 | 22 | 19 |

| Upstream Springs | Area ($mile^2$) | Fraction Location | Connector Capacity (cfs) | Diversion Capacity (cfs) | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Instream Flow Targets (cfs) | | | | | | | | | | | |
| | | Instream Flow Target | | | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| | | Flow Below Eagle Canyon Dam | | | 46 | 46 | 46 | 47 | 36 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| Watershed | 189 | Upstream Springs | | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Fraction | 0.53 | Estimate of Wildcat Dam Flow | | | 65 | 67 | 68 | 71 | 59 | 54 | 51 | 51 | 50 | 51 | 52 | 64 |
| Capacity | 0 | Estimate of Wildcat Diversion | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Instream Flow Target | | | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| | | Flow Below Wildcat Dam | | | 65 | 67 | 68 | 71 | 59 | 54 | 51 | 51 | 50 | 51 | 52 | 64 |
| | | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Watershed | 67 | Upstream Springs | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fraction | 0.19 | Estimate of South Dam Flow | | | 52 | 62 | 69 | 79 | 73 | 51 | 35 | 32 | 30 | 33 | 37 | 43 |
| Capacity | 0 | Estimate of South Dam Diversion | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Instream Flow Target | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Flow Below South Dam | | | 52 | 62 | 69 | 79 | 73 | 51 | 35 | 32 | 30 | 33 | 37 | 43 |
| Watershed | 6 | | | | | | | | | | | | | | | |
| Fraction | 0.02 | Estimate of Soap Creek Flow | | | 15 | 16 | 16 | 17 | 17 | 15 | 13 | 13 | 13 | 13 | 13 | 14 |
| Capacity | 0 | Estimate of Soap Creek Diversion | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Instream Flow Target | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Soap Creek Flow | | | 15 | 16 | 16 | 17 | 17 | 15 | 13 | 13 | 13 | 13 | 13 | 14 |
| Capacity | 150 | Estimate of Cross-Country Canal Flow | | | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| Capacity | 120 | Estimate of South Canal Flow | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Capacity | 222 | Estimate of South PH Flow | | | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| Capacity | 220 | South PH Connector | | | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| Watershed | 88 | Upstream Springs | | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Fraction | 0.25 | Estimate of Inskip Dam Flow | | | 79 | 91 | 101 | 113 | 106 | 77 | 56 | 51 | 50 | 53 | 59 | 67 |
| Capacity | 220 | Estimate of Inskip Diversion | | | 0 | 5 | 15 | 52 | 66 | 37 | 16 | 11 | 10 | 13 | 19 | 0 |
| | | Instream Flow | | | 86 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 86 |

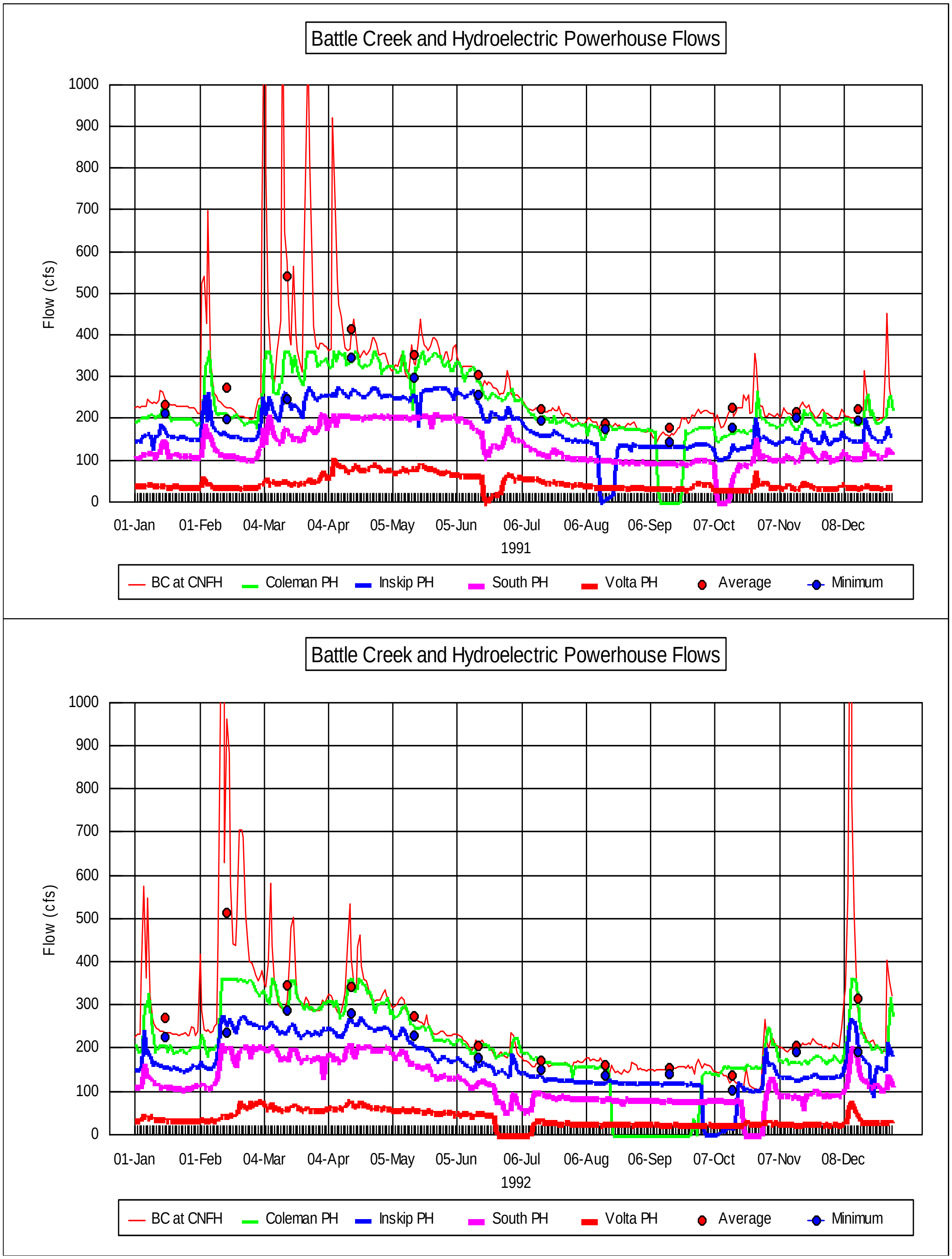
**Table I-3.** Continued

| Upstream Springs | Area (mile$^2$) | Fraction | Location | Connector Capacity (cfs) | Diversion Capacity (cfs) | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Target | | | | | | | | | | | | | | | |
| | | Flow Below Inskip Dam | | | | 79 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 67 |
| Watershed | 12 | | | | | | | | | | | | | | | | |
| Fraction | 0.03 | Estimate of Ripley Creek Flow | | | | 14 | 16 | 17 | 19 | 18 | 14 | 11 | 11 | 10 | 11 | 12 | 13 |
| Capacity | 0 | Estimate of Ripley Creek Diversion | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Instream Flow Target | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Ripley Creek Flow | | | | 14 | 16 | 17 | 19 | 18 | 14 | 11 | 11 | 10 | 11 | 12 | 13 |
| Capacity | 283 | Estimate of Inskip PH Flow | | | | 97 | 126 | 157 | 218 | 229 | 141 | 78 | 65 | 60 | 70 | 86 | 74 |
| Capacity | 340 | Inskip PH Connector | | | | 97 | 126 | 157 | 218 | 229 | 141 | 78 | 65 | 60 | 70 | 86 | 74 |
| Watershed | 115 | Upstream Springs | | | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Fraction | 0.32 | Estimate of Coleman Dam Flow | | | | 105 | 132 | 137 | 119 | 94 | 79 | 69 | 66 | 65 | 67 | 70 | 101 |
| Capacity | 0 | Estimate of Coleman Diversion | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Instream Flow Target | | | | 86 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 86 |
| | | Flow Below Coleman Dam | | | | 105 | 132 | 137 | 119 | 94 | 79 | 69 | 66 | 65 | 67 | 70 | 101 |
| Watershed | 14 | Upstream Springs | | | | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Fraction | 0.04 | Estimate of Baldwin Creek Flow | | | | 36 | 38 | 39 | 41 | 40 | 36 | 32 | 32 | 31 | 32 | 33 | 34 |
| Capacity | 24 | Estimate of Pacific Power Diversion | | | | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| Capacity | 35 | Ashbury Pipe Pumping | | | | 7 | 9 | 10 | 12 | 11 | 7 | 3 | 3 | 2 | 3 | 4 | 5 |
| | | Instream Flow Target | | | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | Baldwin Creek Flow | | | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Watershed | 340 | Upstream Springs | | | | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| Fraction | 0.95 | Flow Below Confluence | | | | 192 | 208 | 215 | 200 | 163 | 141 | 127 | 124 | 123 | 125 | 129 | 172 |
| Capacity | 380 | Estimate of Coleman PH Flow | | | | 128 | 159 | 191 | 254 | 264 | 172 | 106 | 91 | 86 | 97 | 114 | 103 |

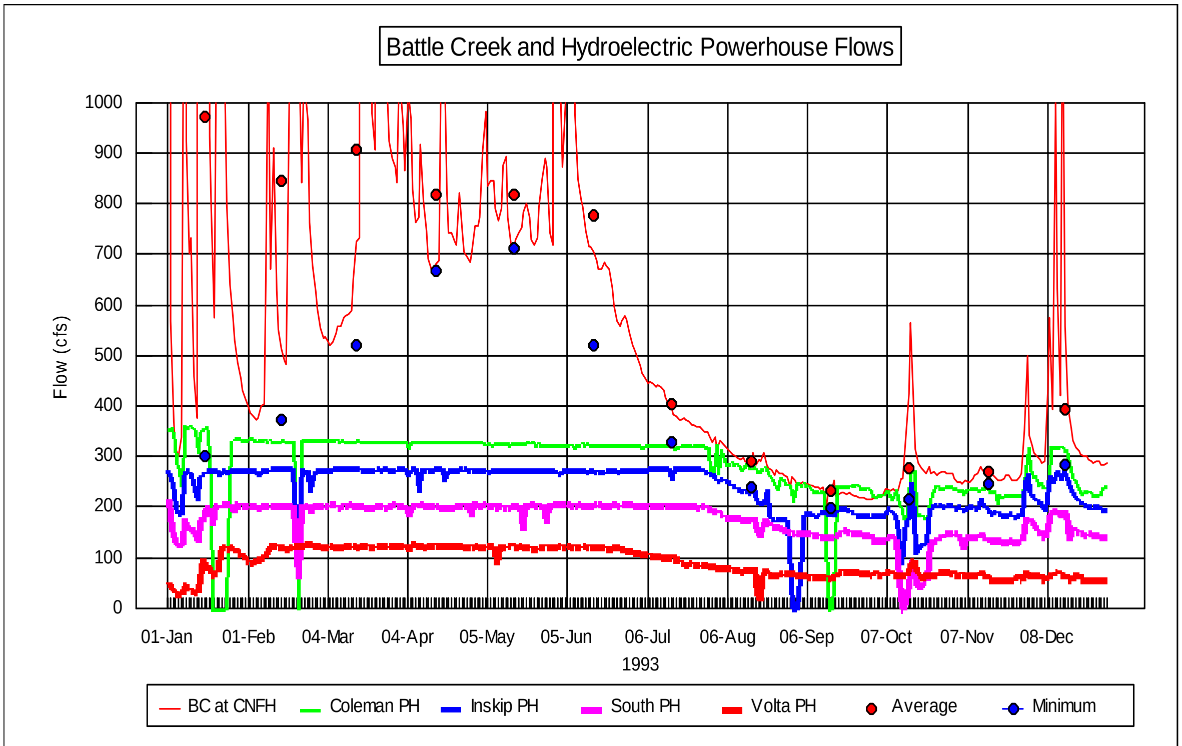


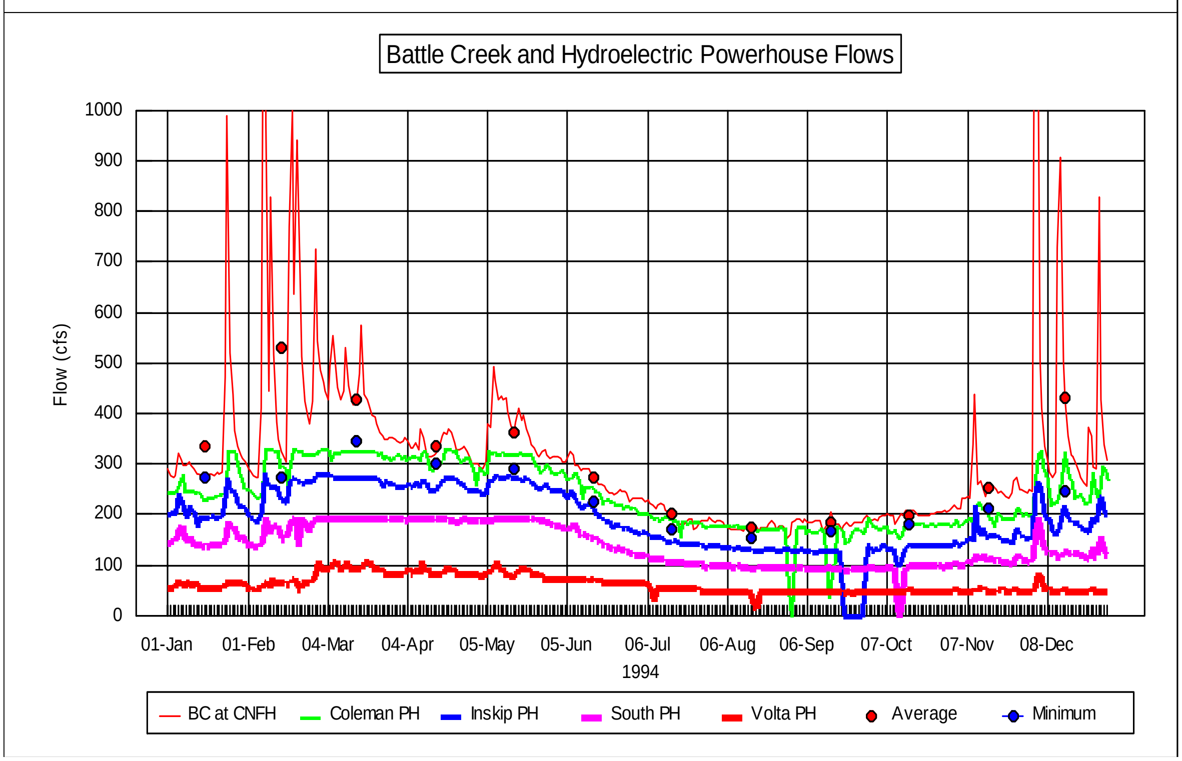




**Figures I-1a and I-1b.** Battle Creek and Hydroelectric Powerhouse Flows for 1989 and 1990

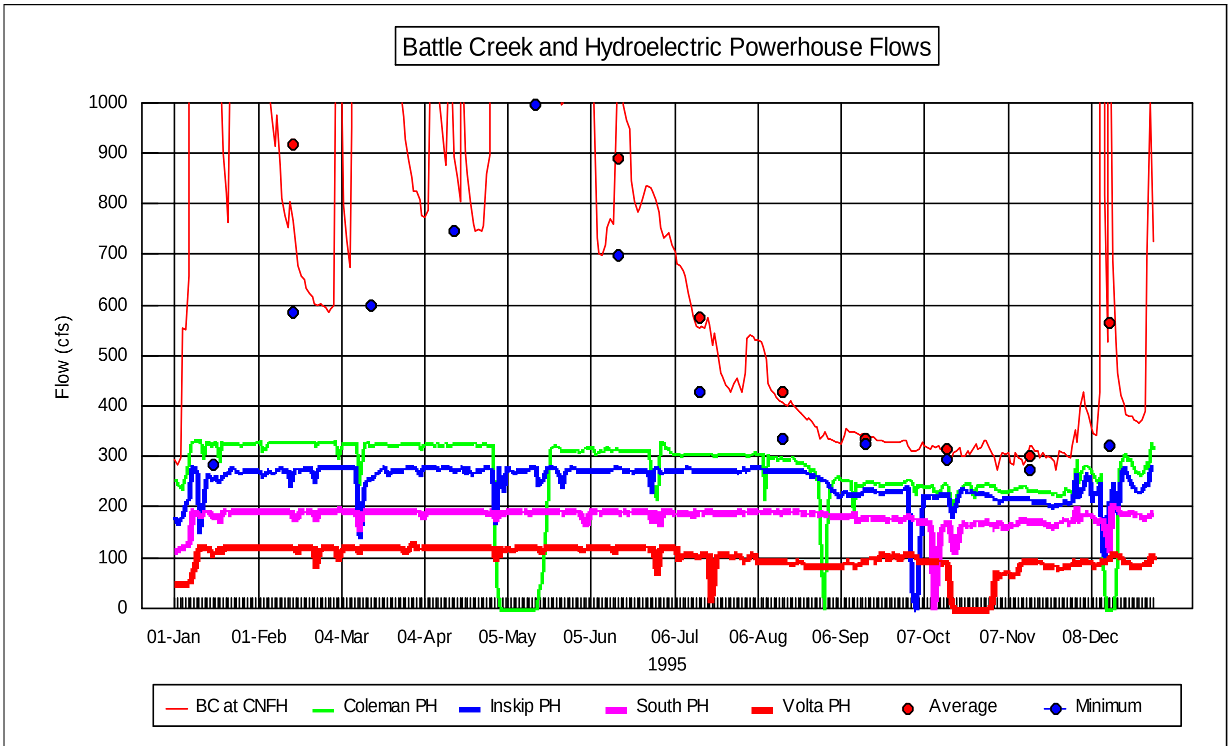


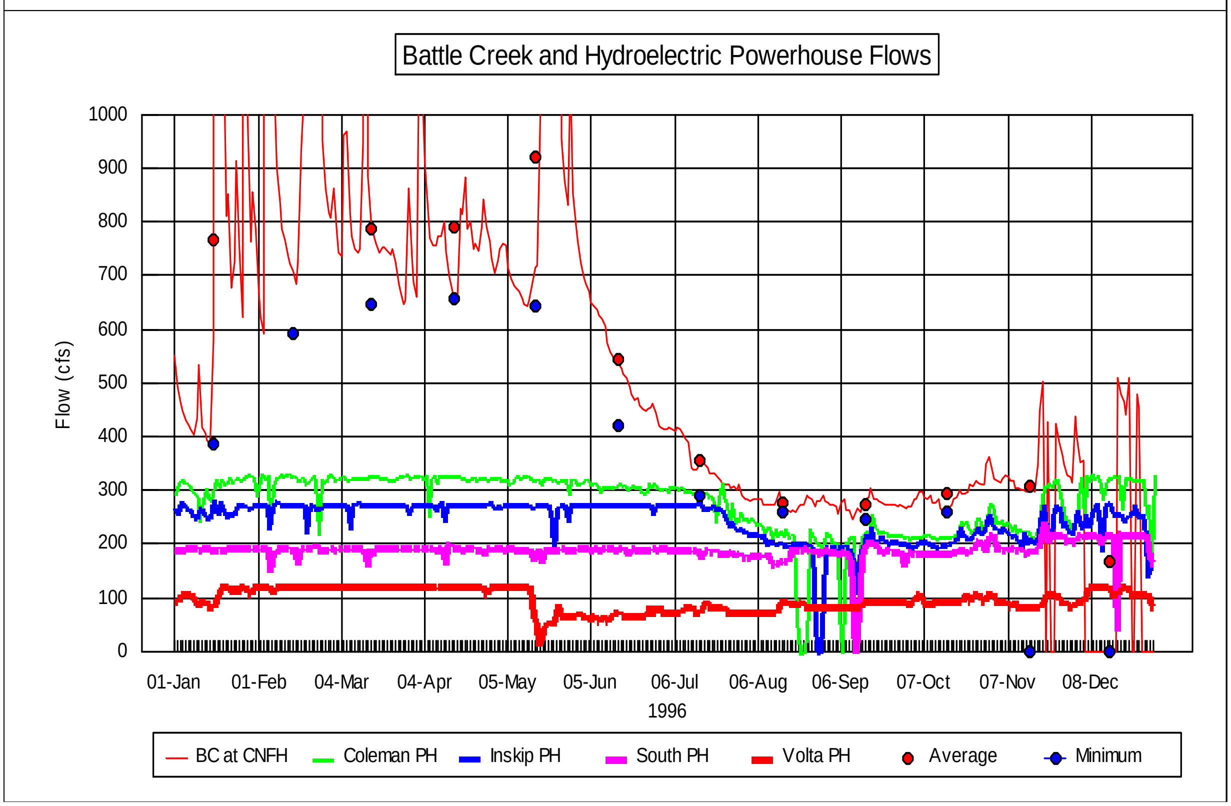

**Figures I-2a and I-2b.** Battle Creek and Hydroelectric Powerhouse Flows for 1991 and 1992



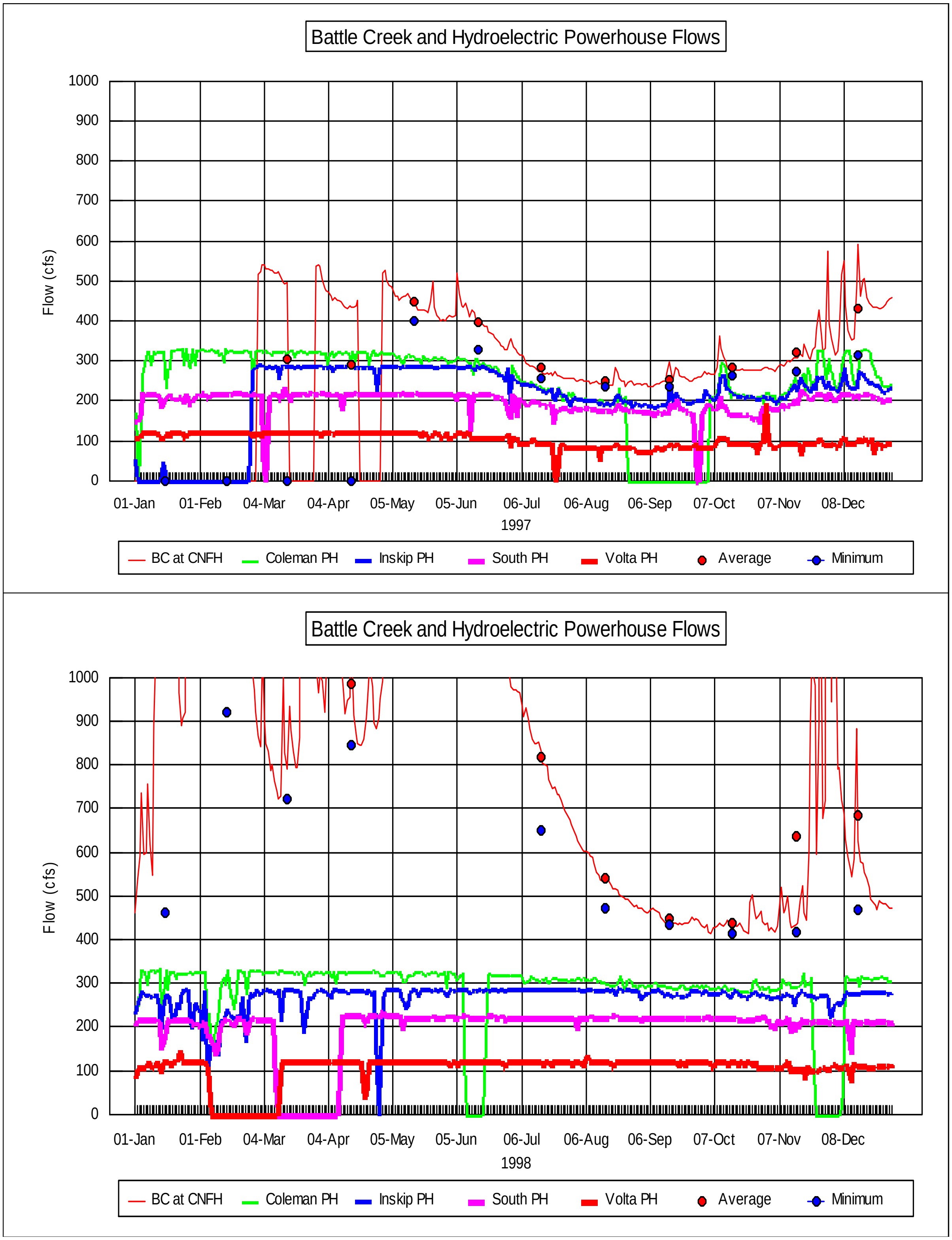




**Figures I-3a and I-3b.** Battle Creek and Hydroelectric Powerhouse Flows for 1993 and 1994

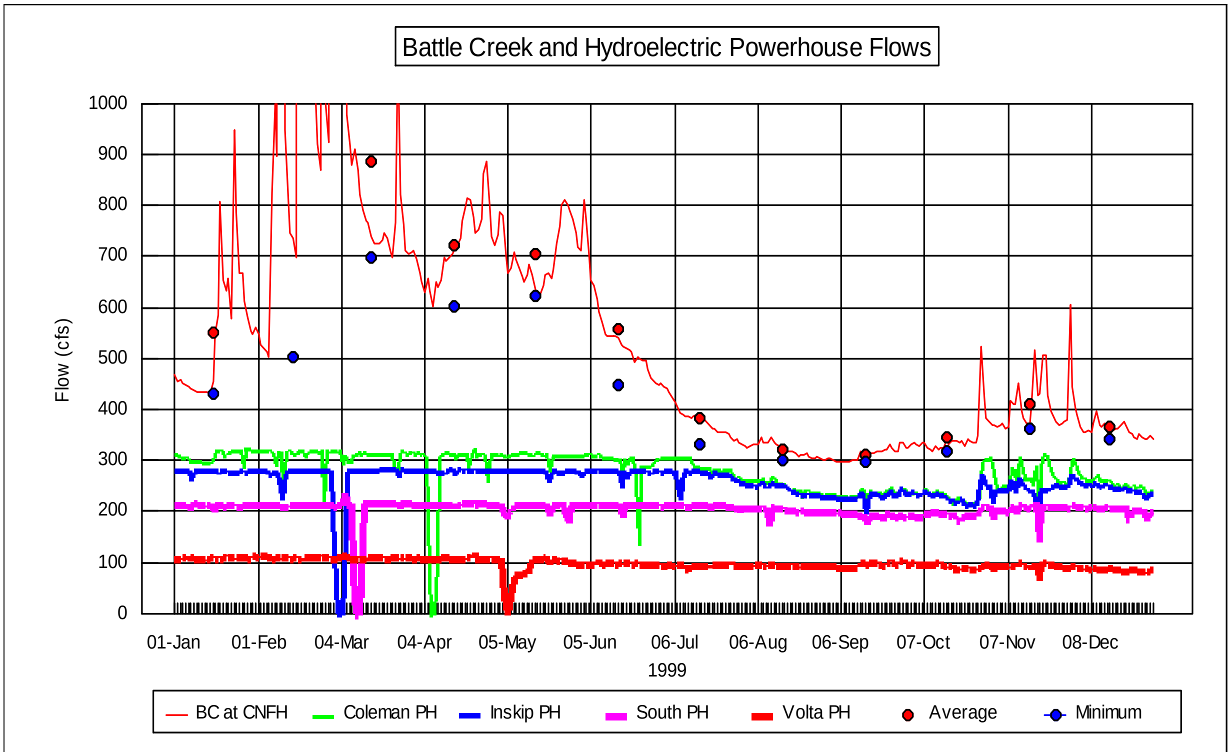


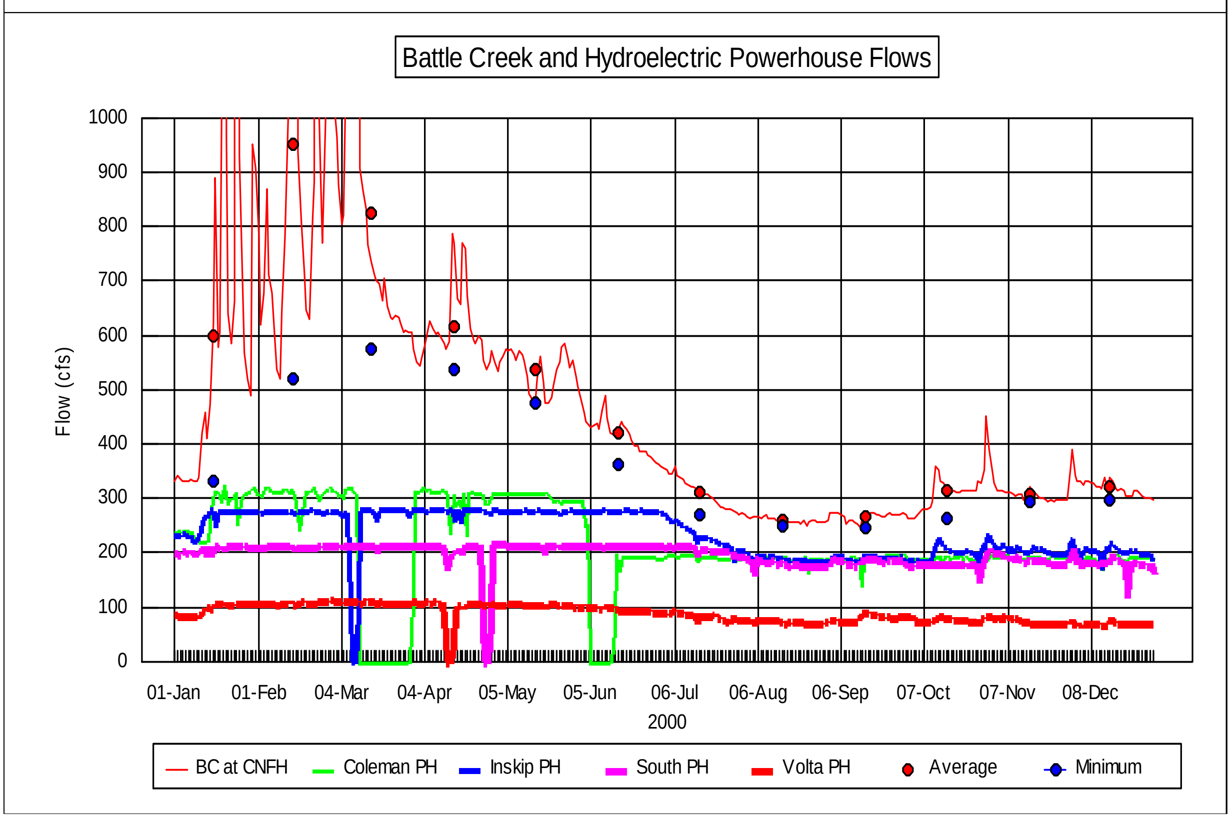




**Figures I-4a and I-4b.** Battle Creek and Hydroelectric Powerhouse Flows for 1995 and 1996




**Figures I-5a and I-5b.** Battle Creek and Hydroelectric Powerhouse Flows for 1997 and 1998




**Figures I-6a and I-6b.** Battle Creek and Hydroelectric Powerhouse Flows for 1999 and 2000

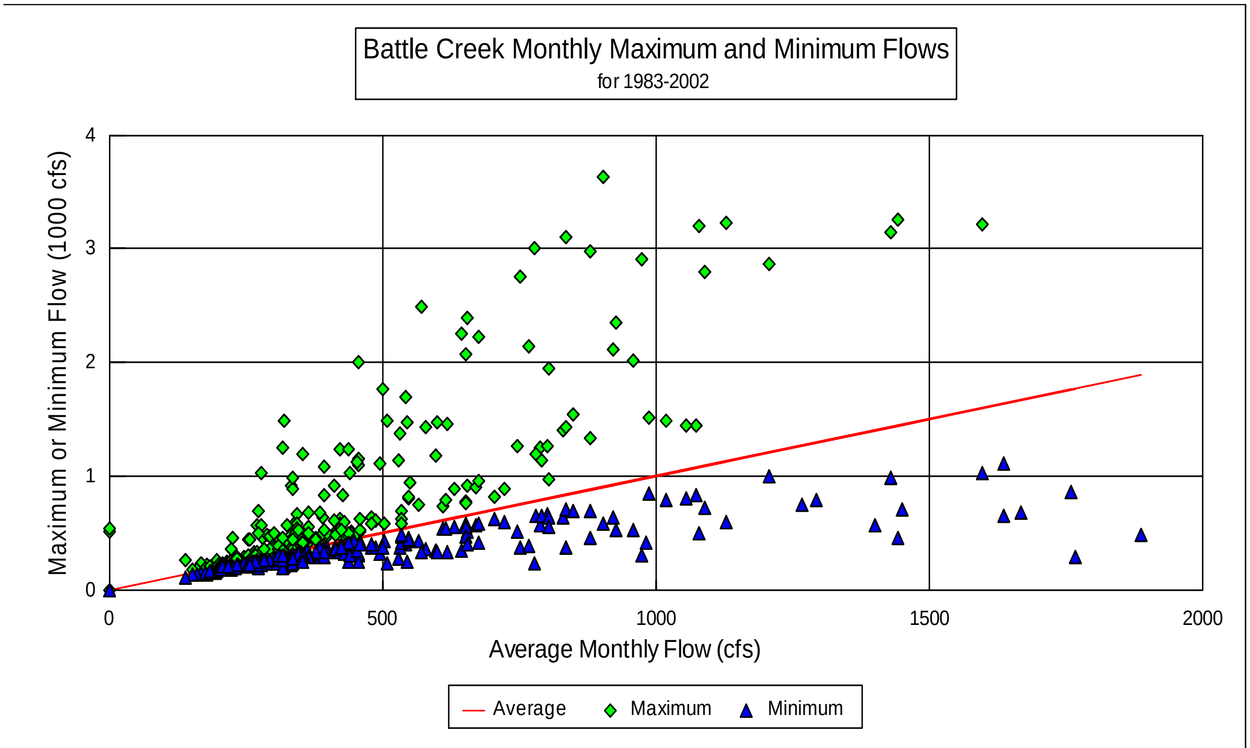
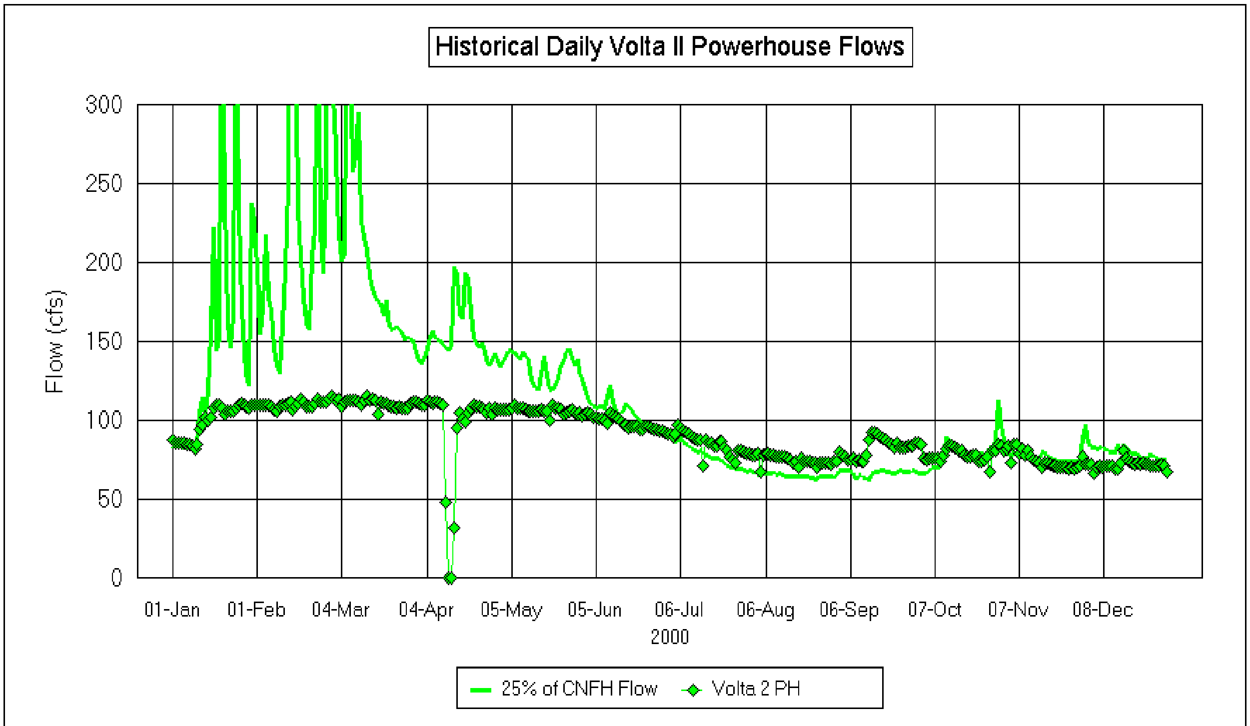



**Figure I-7.** Battle Creek Monthly Minimum and Maximum Flows Compared with the Monthly Average Flows for 1983–2002



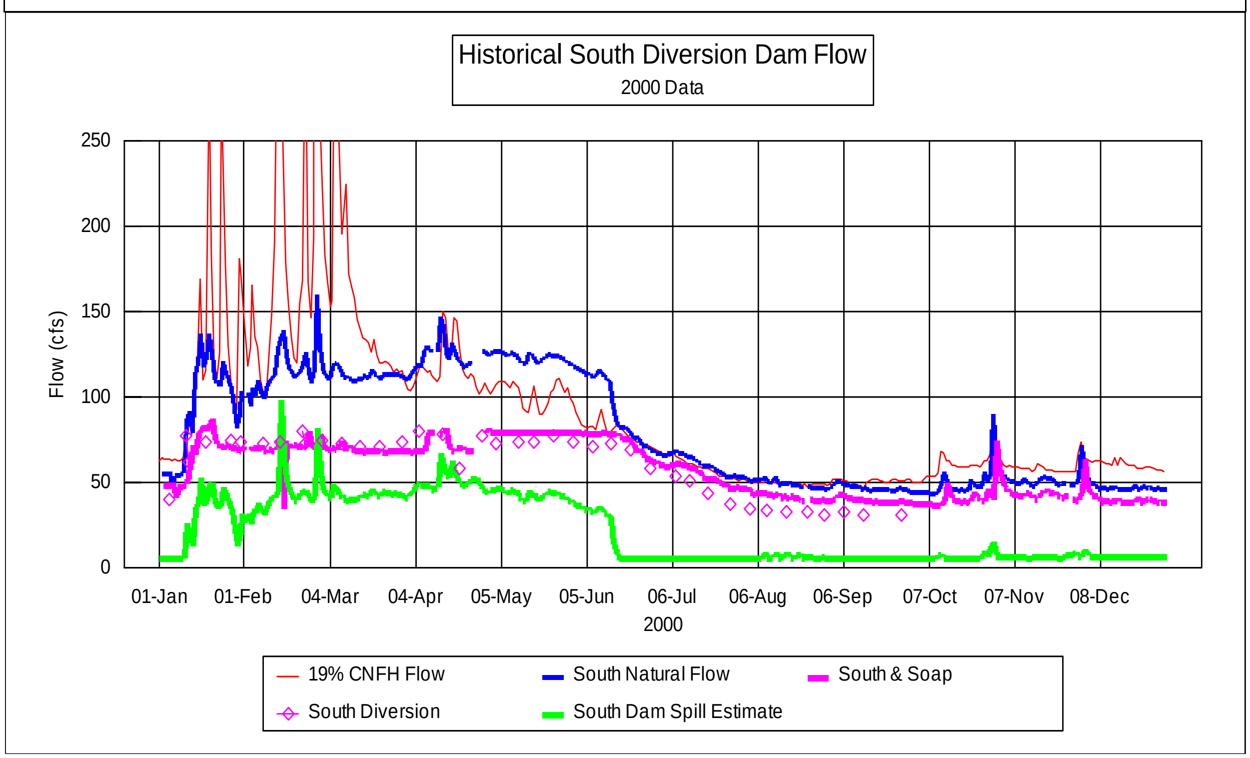




**Figure I-8.** Daily North Fork Battle Creek Diversions above Volta II Powerhouse and South Fork Battle Creek Diversions at South Dam Compared with Watershed Fractions of the U.S. Geological Survey Streamflow Gage at the Coleman National Fish Hatchery

Appendix J

# Results from Monthly Flow and Power Generation Model

Appendix J
# Results from Monthly Flow and Power Generation Model

This appendix presents the results of monthly flow and diversion calculations for each alternative. The assumptions, methodology and an example calculation are presented in Appendix I of this report, “Development and Assumptions of the Monthly Battle Creek Hydrology and Hydroelectric Power Model.”

## Explanation of Model Results

Each of the following tables provides the results from the monthly model for each of the restoration alternatives. The tables are given in downstream sequence for the North Fork Battle Creek and then the South Fork Battle Creek diversion dam locations. The calculated monthly diversion flows and downstream fish habitat flows are given for each diversion dam location. The diversion capacity is given for each diversion dam. When the diversion dam is removed in a restoration alternative, the diversion flows are shown as 0 cfs.

For each alternative, the calendar months each have five calculated flows, showing the range of likely future flows and diversions, corresponding to the 10%, 30%, 50%, 70%, and 90% Battle Creek flows (i.e., relatively dry to relatively wet hydrology for each month).

The target fish habitat flow for each month is given in the downstream flow tables. If the diversion dam is removed in an alternative, the target flows are given as 0 cfs.

The five powerhouse flows are given as the last five tables. Each powerhouse capacity is given.

**Table J-1.** Calculated Diversion Flows (cfs) for All of the Alternatives at North Fork Battle Creek Feeder Diversion Dam (Capacity of 50 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 22 | 23 | 28 | 31 | 29 | 19 | 14 | 13 | 12 | 15 | 18 | 20 |
| 30% | 27 | 30 | 37 | 41 | 38 | 27 | 19 | 16 | 16 | 19 | 22 | 25 |
| 50% | 34 | 40 | 45 | 49 | 48 | 33 | 23 | 21 | 20 | 22 | 24 | 28 |
| 70% | 41 | 41 | 36 | 26 | 22 | 49 | 30 | 24 | 24 | 25 | 29 | 34 |
| 90% | 36 | 22 | 22 | 22 | 22 | 32 | 37 | 30 | 29 | 32 | 36 | 44 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 22 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 17 | 22 | 22 | 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 4 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 3 | 8 | 15 | 21 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 4 | 19 | 21 | 26 | 22 | 22 | 3 | 0 | 0 | 0 | 0 | 0 |
| 90% | 21 | 22 | 22 | 22 | 22 | 32 | 10 | 3 | 0 | 0 | 0 | 7 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 4 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 3 | 8 | 15 | 21 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 4 | 19 | 21 | 26 | 22 | 22 | 3 | 0 | 0 | 0 | 0 | 0 |
| 90% | 21 | 22 | 22 | 22 | 22 | 32 | 10 | 3 | 0 | 0 | 0 | 7 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 22 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 17 | 22 | 22 | 16 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table J-2.** Calculated Fish Habitat Flows (cfs) for All of the Alternatives below North Fork Battle Creek Feeder Diversion Dam

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 10% | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 30% | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 50% | 3 | 3 | 3 | 6 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 70% | 3 | 18 | 25 | 40 | 66 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 90% | 25 | 58 | 83 | 100 | 98 | 30 | 3 | 3 | 3 | 3 | 3 | 3 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | 88 | 88 | 88 | 67 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 88 |
| 10% | 25 | 26 | 31 | 34 | 32 | 22 | 17 | 16 | 15 | 18 | 21 | 23 |
| 30% | 30 | 33 | 40 | 44 | 41 | 30 | 22 | 19 | 19 | 22 | 25 | 28 |
| 50% | 37 | 43 | 48 | 55 | 47 | 36 | 26 | 24 | 23 | 25 | 27 | 31 |
| 70% | 44 | 59 | 61 | 66 | 66 | 47 | 33 | 27 | 27 | 28 | 32 | 37 |
| 90% | 61 | 80 | 88 | 100 | 98 | 47 | 40 | 33 | 32 | 35 | 39 | 47 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 |
| 10% | 25 | 26 | 31 | 34 | 30 | 22 | 17 | 16 | 15 | 18 | 21 | 23 |
| 30% | 30 | 33 | 40 | 40 | 30 | 30 | 22 | 19 | 19 | 22 | 25 | 28 |
| 50% | 37 | 40 | 40 | 40 | 30 | 30 | 26 | 24 | 23 | 25 | 27 | 31 |
| 70% | 40 | 40 | 40 | 40 | 66 | 30 | 30 | 27 | 27 | 28 | 32 | 37 |
| 90% | 40 | 58 | 83 | 100 | 98 | 30 | 30 | 30 | 32 | 35 | 39 | 40 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 |
| 10% | 25 | 26 | 31 | 34 | 30 | 22 | 17 | 16 | 15 | 18 | 21 | 23 |
| 30% | 30 | 33 | 40 | 40 | 30 | 30 | 22 | 19 | 19 | 22 | 25 | 28 |
| 50% | 37 | 40 | 40 | 40 | 30 | 30 | 26 | 24 | 23 | 25 | 27 | 31 |
| 70% | 40 | 40 | 40 | 40 | 66 | 30 | 30 | 27 | 27 | 28 | 32 | 37 |
| 90% | 40 | 58 | 83 | 100 | 98 | 30 | 30 | 30 | 32 | 35 | 39 | 40 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | 88 | 88 | 88 | 67 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 88 |
| 10% | 25 | 26 | 31 | 34 | 32 | 22 | 17 | 16 | 15 | 18 | 21 | 23 |
| 30% | 30 | 33 | 40 | 44 | 41 | 30 | 22 | 19 | 19 | 22 | 25 | 28 |
| 50% | 37 | 43 | 48 | 55 | 47 | 36 | 26 | 24 | 23 | 25 | 27 | 31 |
| 70% | 44 | 59 | 61 | 66 | 66 | 47 | 33 | 27 | 27 | 28 | 32 | 37 |
| 90% | 61 | 80 | 88 | 100 | 98 | 47 | 40 | 33 | 32 | 35 | 39 | 47 |

**Table J-3.** Calculated Diversion Flows (cfs) for All of the Alternatives at Eagle Canyon Diversion Dam (Capacity of 64 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 27 | 28 | 33 | 36 | 34 | 24 | 19 | 18 | 17 | 20 | 23 | 25 |
| 30% | 32 | 35 | 42 | 46 | 43 | 32 | 24 | 21 | 21 | 24 | 27 | 30 |
| 50% | 39 | 45 | 50 | 60 | 53 | 38 | 28 | 26 | 25 | 27 | 29 | 33 |
| 70% | 46 | 64 | 64 | 64 | 64 | 54 | 35 | 29 | 29 | 30 | 34 | 39 |
| 90% | 64 | 64 | 64 | 64 | 64 | 64 | 42 | 35 | 34 | 37 | 41 | 49 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 6 | 9 | 17 | 24 | 31 | 12 | 2 | 0 | 0 | 3 | 9 | 2 |
| 30% | 16 | 23 | 36 | 43 | 49 | 26 | 10 | 6 | 5 | 11 | 16 | 11 |
| 50% | 31 | 43 | 53 | 64 | 64 | 40 | 19 | 14 | 13 | 16 | 22 | 19 |
| 70% | 44 | 64 | 64 | 64 | 64 | 64 | 34 | 22 | 20 | 23 | 32 | 30 |
| 90% | 64 | 64 | 64 | 64 | 64 | 64 | 48 | 34 | 31 | 36 | 45 | 50 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 2 | 5 | 13 | 20 | 34 | 17 | 7 | 3 | 2 | 8 | 14 | 0 |
| 30% | 12 | 19 | 32 | 36 | 43 | 31 | 15 | 11 | 10 | 16 | 21 | 7 |
| 50% | 27 | 35 | 40 | 47 | 53 | 38 | 24 | 19 | 18 | 21 | 27 | 15 |
| 70% | 36 | 51 | 53 | 58 | 64 | 54 | 35 | 27 | 25 | 28 | 37 | 26 |
| 90% | 53 | 64 | 64 | 64 | 64 | 64 | 42 | 35 | 36 | 41 | 50 | 39 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table J-4.** Calculated Fish Habitat Flows (cfs) for All of the Alternatives below Eagle Canyon Diversion Dam

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 10% | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 30% | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 50% | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 70% | 3 | 15 | 24 | 44 | 78 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 90% | 23 | 68 | 101 | 123 | 121 | 31 | 3 | 3 | 3 | 3 | 3 | 3 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| 10% | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 33 | 32 | 35 | 35 | 46 |
| 30% | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| 50% | 46 | 46 | 46 | 47 | 36 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |
| 70% | 46 | 55 | 60 | 70 | 78 | 37 | 35 | 35 | 35 | 35 | 35 | 46 |
| 90% | 60 | 90 | 106 | 123 | 121 | 48 | 35 | 35 | 35 | 35 | 35 | 46 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 10% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 48 |
| 30% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 50% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 70% | 50 | 50 | 50 | 50 | 78 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 90% | 50 | 68 | 101 | 123 | 121 | 31 | 30 | 30 | 30 | 30 | 30 | 50 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 52 | 55 | 63 | 70 | 64 | 47 | 37 | 33 | 32 | 38 | 44 | 48 |
| 30% | 62 | 69 | 82 | 86 | 73 | 61 | 45 | 41 | 40 | 46 | 51 | 57 |
| 50% | 77 | 85 | 90 | 97 | 83 | 68 | 54 | 49 | 48 | 51 | 57 | 65 |
| 70% | 86 | 101 | 103 | 108 | 142 | 84 | 65 | 57 | 55 | 58 | 67 | 76 |
| 90% | 103 | 132 | 165 | 187 | 185 | 95 | 72 | 65 | 66 | 71 | 80 | 89 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 52 | 55 | 63 | 70 | 66 | 47 | 37 | 33 | 32 | 38 | 44 | 48 |
| 30% | 62 | 69 | 82 | 89 | 84 | 61 | 45 | 41 | 40 | 46 | 51 | 57 |
| 50% | 77 | 89 | 99 | 111 | 100 | 75 | 54 | 49 | 48 | 51 | 57 | 65 |
| 70% | 90 | 119 | 124 | 134 | 142 | 101 | 69 | 57 | 55 | 58 | 67 | 76 |
| 90% | 124 | 154 | 170 | 187 | 185 | 112 | 83 | 69 | 66 | 71 | 80 | 96 |

**Table J-5.** Calculated Diversion Flows (cfs) for All of the Alternatives at Wildcat Diversion Dam (Capacity of 18 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 16 | 16 | 18 | 18 | 18 | 15 | 14 | 13 | 13 | 14 | 15 | 16 |
| 30% | 17 | 18 | 18 | 18 | 18 | 17 | 15 | 14 | 14 | 15 | 16 | 17 |
| 50% | 18 | 18 | 18 | 18 | 18 | 18 | 16 | 16 | 15 | 16 | 17 | 18 |
| 70% | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 17 | 16 | 17 | 18 | 18 |
| 90% | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 16 | 16 | 18 | 18 | 18 | 15 | 14 | 13 | 13 | 14 | 15 | 14 |
| 30% | 17 | 18 | 18 | 18 | 18 | 17 | 15 | 14 | 14 | 15 | 16 | 17 |
| 50% | 18 | 18 | 18 | 18 | 18 | 18 | 16 | 16 | 15 | 16 | 17 | 18 |
| 70% | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 17 | 16 | 17 | 18 | 18 |
| 90% | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table J-6.** Calculated Fish Habitat Flows (cfs) for All of the Alternatives below Wildcat Diversion Dam

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 10% | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 30% | 3 | 3 | 5 | 6 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 50% | 4 | 6 | 7 | 9 | 8 | 4 | 3 | 3 | 3 | 3 | 3 | 3 |
| 70% | 6 | 22 | 32 | 53 | 89 | 8 | 3 | 3 | 3 | 3 | 3 | 4 |
| 90% | 31 | 79 | 114 | 138 | 136 | 39 | 5 | 3 | 3 | 4 | 5 | 7 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 62 | 62 | 64 | 64 | 53 | 50 | 49 | 47 | 45 | 49 | 50 | 62 |
| 30% | 63 | 64 | 66 | 67 | 55 | 52 | 50 | 49 | 49 | 50 | 51 | 63 |
| 50% | 65 | 67 | 68 | 71 | 59 | 54 | 51 | 51 | 50 | 51 | 52 | 64 |
| 70% | 67 | 80 | 86 | 97 | 107 | 61 | 53 | 52 | 51 | 52 | 53 | 65 |
| 90% | 85 | 119 | 137 | 156 | 154 | 74 | 55 | 53 | 53 | 54 | 55 | 68 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 10% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 30% | 50 | 50 | 52 | 53 | 32 | 30 | 30 | 30 | 30 | 30 | 30 | 50 |
| 50% | 51 | 53 | 54 | 56 | 35 | 31 | 30 | 30 | 30 | 30 | 30 | 50 |
| 70% | 53 | 57 | 58 | 59 | 89 | 35 | 30 | 30 | 30 | 30 | 30 | 51 |
| 90% | 58 | 79 | 114 | 138 | 136 | 39 | 32 | 30 | 30 | 31 | 32 | 54 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 68 | 71 | 81 | 88 | 82 | 62 | 50 | 47 | 45 | 52 | 58 | 64 |
| 30% | 79 | 87 | 102 | 107 | 93 | 78 | 60 | 55 | 54 | 61 | 67 | 74 |
| 50% | 96 | 106 | 113 | 121 | 106 | 88 | 70 | 65 | 63 | 67 | 73 | 83 |
| 70% | 107 | 126 | 129 | 135 | 171 | 108 | 84 | 74 | 71 | 75 | 85 | 95 |
| 90% | 129 | 161 | 196 | 220 | 218 | 121 | 93 | 84 | 84 | 90 | 100 | 111 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 68 | 71 | 81 | 88 | 84 | 62 | 50 | 47 | 45 | 52 | 58 | 64 |
| 30% | 79 | 87 | 102 | 110 | 104 | 78 | 60 | 55 | 54 | 61 | 67 | 74 |
| 50% | 96 | 110 | 121 | 135 | 123 | 94 | 70 | 65 | 63 | 67 | 73 | 83 |
| 70% | 111 | 144 | 150 | 161 | 171 | 125 | 87 | 74 | 71 | 75 | 85 | 95 |
| 90% | 149 | 183 | 201 | 220 | 218 | 138 | 103 | 87 | 84 | 90 | 100 | 118 |

**Table J-7.** Calculated Diversion Flows (cfs) for All of the Alternatives at South Diversion Dam (Capacity of 100 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 28 | 31 | 37 | 42 | 39 | 25 | 17 | 14 | 13 | 18 | 22 | 26 |
| 30% | 36 | 41 | 51 | 57 | 53 | 35 | 23 | 20 | 19 | 24 | 28 | 32 |
| 50% | 47 | 57 | 64 | 62 | 68 | 46 | 30 | 27 | 25 | 28 | 32 | 38 |
| 70% | 57 | 62 | 62 | 62 | 62 | 66 | 41 | 32 | 31 | 33 | 40 | 47 |
| 90% | 62 | 62 | 62 | 62 | 62 | 62 | 52 | 41 | 39 | 43 | 50 | 62 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 3 | 6 | 12 | 17 | 24 | 10 | 2 | 0 | 0 | 3 | 7 | 1 |
| 30% | 11 | 16 | 26 | 32 | 38 | 20 | 8 | 5 | 4 | 9 | 13 | 7 |
| 50% | 22 | 32 | 39 | 49 | 53 | 31 | 15 | 12 | 10 | 13 | 17 | 13 |
| 70% | 32 | 55 | 58 | 66 | 67 | 55 | 26 | 17 | 16 | 18 | 25 | 22 |
| 90% | 58 | 67 | 67 | 67 | 67 | 67 | 37 | 26 | 24 | 28 | 35 | 37 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 3 | 6 | 12 | 17 | 24 | 10 | 2 | 0 | 0 | 3 | 7 | 1 |
| 30% | 11 | 16 | 26 | 32 | 38 | 20 | 8 | 5 | 4 | 9 | 13 | 7 |
| 50% | 22 | 32 | 39 | 49 | 53 | 31 | 15 | 12 | 10 | 13 | 17 | 13 |
| 70% | 32 | 55 | 58 | 66 | 67 | 55 | 26 | 17 | 16 | 18 | 25 | 22 |
| 90% | 58 | 67 | 67 | 67 | 67 | 67 | 37 | 26 | 24 | 28 | 35 | 37 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table J-8.** Calculated Fish Habitat Flows (cfs) for All of the Alternatives below South Diversion Dam

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 10% | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 30% | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 50% | 5 | 5 | 5 | 17 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 70% | 5 | 23 | 26 | 34 | 47 | 9 | 5 | 5 | 5 | 5 | 5 | 5 |
| 90% | 26 | 43 | 55 | 64 | 63 | 29 | 5 | 5 | 5 | 5 | 5 | 5 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 33 | 36 | 42 | 47 | 44 | 30 | 22 | 19 | 18 | 23 | 27 | 31 |
| 30% | 41 | 46 | 56 | 62 | 58 | 40 | 28 | 25 | 24 | 29 | 33 | 37 |
| 50% | 52 | 62 | 69 | 79 | 73 | 51 | 35 | 32 | 30 | 33 | 37 | 43 |
| 70% | 62 | 85 | 88 | 96 | 109 | 75 | 46 | 37 | 36 | 38 | 45 | 52 |
| 90% | 88 | 105 | 117 | 126 | 125 | 91 | 57 | 46 | 44 | 48 | 55 | 67 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 10% | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 19 | 18 | 20 | 20 | 30 |
| 30% | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 50% | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 70% | 30 | 30 | 30 | 30 | 42 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 90% | 30 | 38 | 50 | 59 | 58 | 24 | 20 | 20 | 20 | 20 | 20 | 30 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 10% | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 19 | 18 | 20 | 20 | 30 |
| 30% | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 50% | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 70% | 30 | 30 | 30 | 30 | 42 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 90% | 30 | 38 | 50 | 59 | 58 | 24 | 20 | 20 | 20 | 20 | 20 | 30 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 33 | 36 | 42 | 47 | 44 | 30 | 22 | 19 | 18 | 23 | 27 | 31 |
| 30% | 41 | 46 | 56 | 62 | 58 | 40 | 28 | 25 | 24 | 29 | 33 | 37 |
| 50% | 52 | 62 | 69 | 79 | 73 | 51 | 35 | 32 | 30 | 33 | 37 | 43 |
| 70% | 62 | 85 | 88 | 96 | 109 | 75 | 46 | 37 | 36 | 38 | 45 | 52 |
| 90% | 88 | 105 | 117 | 126 | 125 | 91 | 57 | 46 | 44 | 48 | 55 | 67 |

**Table J-9.** Calculated Diversion Flows (cfs) for All of the Alternatives at South Tailrace to Inskip Canal Connector (Capacity of 220 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 150 | 102 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 145 | 150 | 150 | 133 | 73 | 58 | 56 | 61 | 70 | 86 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 50 | 55 | 70 | 81 | 88 | 51 | 33 | 27 | 26 | 35 | 45 | 44 |
| 30% | 67 | 80 | 103 | 119 | 128 | 76 | 48 | 40 | 38 | 49 | 58 | 59 |
| 50% | 93 | 119 | 141 | 170 | 174 | 107 | 63 | 55 | 53 | 58 | 68 | 73 |
| 70% | 121 | 188 | 199 | 220 | 220 | 179 | 93 | 69 | 65 | 71 | 86 | 92 |
| 90% | 198 | 220 | 220 | 220 | 220 | 220 | 125 | 93 | 85 | 94 | 109 | 135 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 150 | 102 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 145 | 150 | 150 | 133 | 73 | 58 | 56 | 61 | 70 | 86 |

**Table J-10.** Calculated Diversion Flows (cfs) for All of the Alternatives at Inskip Diversion Dam (Capacity of 220 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 112 | 120 | 141 | 157 | 149 | 100 | 74 | 65 | 62 | 77 | 91 | 104 |
| 30% | 137 | 155 | 187 | 206 | 193 | 135 | 96 | 84 | 82 | 97 | 110 | 125 |
| 50% | 174 | 205 | 220 | 218 | 220 | 170 | 117 | 106 | 102 | 110 | 124 | 145 |
| 70% | 207 | 214 | 214 | 214 | 214 | 220 | 154 | 125 | 120 | 128 | 150 | 172 |
| 90% | 214 | 214 | 214 | 214 | 214 | 214 | 190 | 154 | 148 | 161 | 182 | 220 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 11 | 28 | 9 | 0 | 0 | 0 | 0 | 6 | 0 |
| 30% | 0 | 0 | 0 | 30 | 46 | 23 | 7 | 3 | 2 | 8 | 13 | 0 |
| 50% | 0 | 5 | 15 | 52 | 66 | 37 | 16 | 11 | 10 | 13 | 19 | 0 |
| 70% | 6 | 35 | 40 | 75 | 69 | 68 | 31 | 19 | 17 | 20 | 29 | 0 |
| 90% | 40 | 62 | 74 | 69 | 69 | 86 | 45 | 31 | 28 | 33 | 42 | 12 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 55 | 61 | 78 | 91 | 97 | 55 | 34 | 28 | 25 | 37 | 48 | 48 |
| 30% | 75 | 89 | 115 | 134 | 141 | 84 | 52 | 43 | 41 | 53 | 64 | 66 |
| 50% | 105 | 133 | 158 | 189 | 192 | 118 | 69 | 60 | 57 | 64 | 75 | 82 |
| 70% | 135 | 209 | 220 | 215 | 209 | 197 | 102 | 75 | 72 | 78 | 95 | 103 |
| 90% | 220 | 209 | 209 | 209 | 209 | 209 | 138 | 102 | 94 | 104 | 121 | 151 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 5 | 6 | 8 | 10 | 9 | 4 | 2 | 0 | 0 | 2 | 3 | 5 |
| 30% | 8 | 9 | 13 | 14 | 13 | 8 | 4 | 3 | 3 | 4 | 5 | 7 |
| 50% | 11 | 14 | 17 | 20 | 18 | 11 | 6 | 5 | 5 | 5 | 7 | 9 |
| 70% | 15 | 22 | 21 | 0 | 0 | 18 | 9 | 7 | 6 | 7 | 9 | 11 |
| 90% | 22 | 0 | 0 | 0 | 0 | 0 | 13 | 9 | 9 | 10 | 12 | 16 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 11 | 28 | 9 | 0 | 0 | 0 | 0 | 6 | 0 |
| 30% | 0 | 0 | 0 | 30 | 46 | 23 | 7 | 3 | 2 | 8 | 13 | 0 |
| 50% | 0 | 5 | 15 | 52 | 66 | 37 | 16 | 11 | 10 | 13 | 19 | 0 |
| 70% | 6 | 35 | 40 | 75 | 70 | 68 | 31 | 19 | 17 | 20 | 29 | 0 |
| 90% | 40 | 62 | 75 | 70 | 70 | 87 | 45 | 31 | 28 | 33 | 42 | 12 |

**Table J-11.** Calculated Fish Habitat Flows (cfs) for All of the Alternatives below Inskip Diversion Dam

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 10% | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 30% | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 50% | 5 | 5 | 15 | 45 | 29 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 70% | 5 | 57 | 62 | 72 | 89 | 34 | 5 | 5 | 5 | 5 | 5 | 5 |
| 90% | 62 | 84 | 100 | 111 | 110 | 65 | 5 | 5 | 5 | 5 | 5 | 8 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | 86 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 86 |
| 10% | 54 | 57 | 65 | 61 | 40 | 40 | 39 | 35 | 34 | 40 | 40 | 50 |
| 30% | 64 | 71 | 84 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 59 |
| 50% | 79 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 67 |
| 70% | 86 | 86 | 86 | 61 | 84 | 40 | 40 | 40 | 40 | 40 | 40 | 78 |
| 90% | 86 | 86 | 90 | 106 | 105 | 43 | 40 | 40 | 40 | 40 | 40 | 86 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 10% | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 30% | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 50% | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 70% | 40 | 40 | 41 | 71 | 94 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 90% | 40 | 89 | 105 | 116 | 115 | 70 | 30 | 30 | 30 | 30 | 30 | 40 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 10% | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 29 | 30 | 30 | 40 |
| 30% | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 50% | 40 | 40 | 40 | 40 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 70% | 40 | 40 | 41 | 66 | 83 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| 90% | 40 | 78 | 94 | 105 | 104 | 59 | 30 | 30 | 30 | 30 | 30 | 40 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | 86 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 86 |
| 10% | 54 | 57 | 65 | 61 | 40 | 40 | 39 | 35 | 34 | 40 | 40 | 50 |
| 30% | 64 | 71 | 84 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 59 |
| 50% | 79 | 86 | 86 | 61 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 67 |
| 70% | 86 | 86 | 86 | 61 | 83 | 40 | 40 | 40 | 40 | 40 | 40 | 78 |
| 90% | 86 | 86 | 89 | 105 | 104 | 42 | 40 | 40 | 40 | 40 | 40 | 86 |

**Table J-12.** Calculated Flows (cfs) for All of the Alternatives in the Inskip Tailrace to Coleman Canal Connector (Capacity of 340 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 47 | 53 | 70 | 94 | 116 | 57 | 27 | 22 | 21 | 30 | 47 | 40 |
| 30% | 67 | 81 | 107 | 152 | 169 | 100 | 52 | 38 | 35 | 54 | 70 | 58 |
| 50% | 97 | 126 | 157 | 218 | 229 | 141 | 78 | 65 | 60 | 70 | 86 | 74 |
| 70% | 129 | 209 | 218 | 263 | 283 | 234 | 123 | 87 | 82 | 91 | 117 | 95 |
| 90% | 217 | 254 | 283 | 283 | 283 | 283 | 165 | 123 | 115 | 130 | 156 | 148 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 65 | 71 | 88 | 101 | 107 | 65 | 43 | 36 | 35 | 47 | 58 | 58 |
| 30% | 85 | 99 | 125 | 144 | 151 | 94 | 62 | 52 | 50 | 63 | 74 | 76 |
| 50% | 115 | 143 | 168 | 199 | 202 | 128 | 79 | 70 | 67 | 74 | 85 | 92 |
| 70% | 145 | 219 | 230 | 230 | 230 | 207 | 112 | 85 | 82 | 88 | 105 | 113 |
| 90% | 230 | 230 | 230 | 230 | 230 | 230 | 148 | 112 | 104 | 114 | 131 | 161 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 70 | 85 | 45 | 26 | 22 | 21 | 27 | 38 | 38 |
| 30% | 51 | 58 | 71 | 109 | 120 | 74 | 42 | 33 | 31 | 43 | 54 | 47 |
| 50% | 66 | 84 | 104 | 154 | 165 | 101 | 59 | 50 | 47 | 54 | 65 | 55 |
| 70% | 86 | 145 | 154 | 199 | 220 | 170 | 89 | 65 | 62 | 68 | 85 | 65 |
| 90% | 153 | 190 | 220 | 220 | 220 | 220 | 117 | 89 | 84 | 94 | 111 | 98 |

**Table J-13.** Calculated Diversion Flows (cfs) for All of the Alternatives at Coleman Diversion Dam (Capacity of 340 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 157 | 173 | 201 | 224 | 213 | 144 | 107 | 96 | 92 | 113 | 132 | 149 |
| 30% | 190 | 221 | 266 | 293 | 275 | 194 | 138 | 122 | 119 | 141 | 159 | 180 |
| 50% | 239 | 292 | 323 | 321 | 322 | 242 | 169 | 153 | 147 | 159 | 178 | 208 |
| 70% | 283 | 319 | 319 | 317 | 314 | 321 | 221 | 179 | 173 | 184 | 214 | 246 |
| 90% | 319 | 315 | 312 | 311 | 311 | 318 | 270 | 221 | 211 | 230 | 260 | 317 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 65 | 76 | 104 | 127 | 156 | 87 | 52 | 40 | 17 | 37 | 55 | 54 |
| 30% | 98 | 124 | 169 | 196 | 218 | 137 | 81 | 65 | 42 | 64 | 82 | 83 |
| 50% | 147 | 195 | 230 | 274 | 290 | 185 | 112 | 96 | 70 | 82 | 101 | 111 |
| 70% | 191 | 302 | 318 | 317 | 314 | 297 | 164 | 122 | 96 | 107 | 137 | 149 |
| 90% | 303 | 315 | 312 | 311 | 311 | 318 | 213 | 164 | 134 | 153 | 183 | 220 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table J-14.** Calculated Fish Habitat Flows (cfs) for All of the Alternatives below Coleman Diversion Dam

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 10% | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 30% | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 50% | 5 | 5 | 9 | 55 | 30 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 70% | 5 | 73 | 81 | 97 | 125 | 37 | 5 | 5 | 5 | 5 | 5 | 5 |
| 90% | 61 | 117 | 145 | 163 | 161 | 86 | 5 | 5 | 5 | 5 | 5 | 5 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 72 | 86 | 98 | 98 | 75 | 65 | 58 | 53 | 51 | 60 | 63 | 76 |
| 30% | 85 | 107 | 126 | 107 | 84 | 72 | 64 | 62 | 61 | 64 | 67 | 89 |
| 50% | 105 | 132 | 137 | 119 | 94 | 79 | 69 | 66 | 65 | 67 | 70 | 101 |
| 70% | 116 | 148 | 150 | 130 | 162 | 95 | 76 | 70 | 69 | 71 | 75 | 117 |
| 90% | 126 | 162 | 174 | 196 | 194 | 109 | 83 | 76 | 75 | 77 | 82 | 136 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 50 | 50 | 50 | 50 |
| 10% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 50 | 50 | 50 | 50 |
| 30% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 50 | 50 | 50 | 50 |
| 50% | 50 | 50 | 50 | 50 | 30 | 30 | 30 | 30 | 50 | 50 | 50 | 50 |
| 70% | 50 | 50 | 50 | 87 | 120 | 30 | 30 | 30 | 50 | 50 | 50 | 50 |
| 90% | 50 | 112 | 140 | 158 | 156 | 81 | 30 | 30 | 50 | 50 | 50 | 50 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 48 | 49 | 53 | 57 | 45 | 35 | 32 | 31 | 30 | 32 | 33 | 46 |
| 30% | 51 | 56 | 63 | 66 | 54 | 42 | 34 | 33 | 33 | 34 | 37 | 50 |
| 50% | 56 | 66 | 71 | 78 | 64 | 49 | 39 | 36 | 35 | 37 | 40 | 54 |
| 70% | 60 | 82 | 85 | 115 | 141 | 65 | 46 | 40 | 39 | 41 | 45 | 60 |
| 90% | 71 | 133 | 158 | 175 | 173 | 105 | 53 | 46 | 45 | 47 | 52 | 70 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10% | 72 | 86 | 98 | 98 | 75 | 65 | 58 | 53 | 51 | 60 | 63 | 76 |
| 30% | 85 | 107 | 126 | 107 | 84 | 72 | 64 | 62 | 61 | 64 | 67 | 89 |
| 50% | 105 | 132 | 137 | 119 | 94 | 79 | 69 | 66 | 65 | 67 | 70 | 101 |
| 70% | 116 | 148 | 150 | 130 | 161 | 95 | 76 | 70 | 69 | 71 | 75 | 117 |
| 90% | 126 | 162 | 173 | 195 | 193 | 108 | 83 | 76 | 75 | 77 | 82 | 136 |

**Table J-15**. Calculated Fish Habitat Flows (cfs) for All of the Alternatives at Mainstem Battle Creek

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| Target | | | | | | | | | | | | |
| 10% | 19 | 15 | 16 | 16 | 16 | 15 | 14 | 14 | 14 | 14 | 15 | 15 |
| 30% | 21 | 16 | 18 | 20 | 19 | 15 | 15 | 14 | 14 | 15 | 15 | 15 |
| 50% | 26 | 20 | 26 | 74 | 47 | 17 | 15 | 15 | 15 | 15 | 15 | 16 |
| 70% | 32 | 105 | 123 | 161 | 226 | 55 | 16 | 15 | 15 | 15 | 16 | 17 |
| 90% | 121 | 208 | 271 | 313 | 310 | 135 | 19 | 16 | 16 | 16 | 18 | 21 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| Target | | | | | | | | | | | | |
| 10% | 150 | 156 | 169 | 170 | 135 | 122 | 113 | 106 | 103 | 116 | 120 | 144 |
| 30% | 167 | 179 | 201 | 183 | 148 | 132 | 121 | 118 | 117 | 121 | 125 | 159 |
| 50% | 192 | 208 | 215 | 200 | 163 | 141 | 127 | 124 | 123 | 125 | 129 | 172 |
| 70% | 209 | 238 | 246 | 238 | 280 | 165 | 137 | 129 | 128 | 130 | 136 | 191 |
| 90% | 246 | 292 | 324 | 364 | 361 | 194 | 147 | 137 | 135 | 139 | 145 | 213 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| Target | | | | | | | | | | | | |
| 10% | 111 | 112 | 113 | 113 | 73 | 72 | 70 | 70 | 89 | 90 | 91 | 112 |
| 30% | 113 | 113 | 115 | 117 | 76 | 72 | 72 | 71 | 91 | 92 | 92 | 112 |
| 50% | 118 | 117 | 119 | 121 | 80 | 74 | 72 | 72 | 92 | 92 | 92 | 113 |
| 70% | 124 | 122 | 123 | 161 | 226 | 80 | 73 | 72 | 92 | 92 | 93 | 114 |
| 90% | 137 | 208 | 271 | 313 | 310 | 135 | 76 | 73 | 93 | 93 | 95 | 118 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| Target | | | | | | | | | | | | |
| 10% | 137 | 143 | 156 | 167 | 150 | 119 | 102 | 97 | 95 | 105 | 113 | 131 |
| 30% | 154 | 166 | 188 | 197 | 171 | 143 | 116 | 109 | 107 | 117 | 126 | 146 |
| 50% | 179 | 196 | 208 | 223 | 195 | 160 | 131 | 123 | 120 | 126 | 135 | 159 |
| 70% | 198 | 233 | 240 | 276 | 338 | 197 | 152 | 136 | 133 | 138 | 153 | 178 |
| 90% | 238 | 321 | 382 | 422 | 419 | 252 | 169 | 152 | 151 | 160 | 175 | 205 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| Target | | | | | | | | | | | | |
| 10% | 156 | 165 | 187 | 193 | 167 | 134 | 115 | 106 | 103 | 119 | 128 | 147 |
| 30% | 182 | 202 | 236 | 226 | 197 | 158 | 131 | 123 | 122 | 132 | 141 | 170 |
| 50% | 223 | 251 | 268 | 264 | 227 | 181 | 146 | 138 | 135 | 141 | 150 | 191 |
| 70% | 252 | 302 | 310 | 302 | 343 | 229 | 171 | 151 | 148 | 153 | 168 | 220 |
| 90% | 310 | 356 | 387 | 427 | 424 | 257 | 195 | 171 | 166 | 175 | 190 | 263 |

**Table J-16.** Calculated Flows (cfs) for All of the Alternatives at Volta Powerhouse (Capacity of 128 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 94 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 128 | 97 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 128 | 128 | 128 | 118 | 73 | 58 | 56 | 61 | 70 | 86 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 94 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 128 | 97 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 128 | 128 | 128 | 118 | 73 | 58 | 56 | 61 | 70 | 86 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 94 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 128 | 97 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 128 | 128 | 128 | 118 | 73 | 58 | 56 | 61 | 70 | 86 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 94 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 128 | 97 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 128 | 128 | 128 | 118 | 73 | 58 | 56 | 61 | 70 | 86 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 94 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 128 | 97 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 128 | 128 | 128 | 118 | 73 | 58 | 56 | 61 | 70 | 86 |

**Table J-17.** Calculated Flows (cfs) for All of the Alternatives at South Powerhouse (Capacity of 222 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 101 | 109 | 127 | 142 | 135 | 90 | 67 | 59 | 57 | 70 | 83 | 94 |
| 30% | 124 | 140 | 169 | 186 | 175 | 123 | 87 | 76 | 74 | 88 | 100 | 114 |
| 50% | 158 | 186 | 208 | 222 | 221 | 154 | 106 | 96 | 92 | 100 | 112 | 131 |
| 70% | 188 | 222 | 222 | 222 | 222 | 222 | 140 | 113 | 109 | 116 | 136 | 156 |
| 90% | 222 | 222 | 222 | 222 | 222 | 222 | 172 | 140 | 134 | 146 | 165 | 202 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 150 | 102 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 145 | 150 | 150 | 133 | 73 | 58 | 56 | 61 | 70 | 86 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 50 | 55 | 70 | 81 | 88 | 51 | 33 | 27 | 26 | 35 | 45 | 44 |
| 30% | 67 | 80 | 103 | 119 | 128 | 76 | 48 | 40 | 38 | 49 | 58 | 59 |
| 50% | 93 | 119 | 141 | 170 | 174 | 107 | 63 | 55 | 53 | 58 | 68 | 73 |
| 70% | 121 | 188 | 199 | 221 | 222 | 179 | 93 | 69 | 65 | 71 | 86 | 92 |
| 90% | 198 | 222 | 222 | 222 | 222 | 222 | 125 | 93 | 85 | 94 | 109 | 135 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 50 | 55 | 70 | 81 | 88 | 51 | 33 | 27 | 26 | 35 | 45 | 44 |
| 30% | 67 | 80 | 103 | 119 | 128 | 76 | 48 | 40 | 38 | 49 | 58 | 59 |
| 50% | 93 | 119 | 141 | 170 | 174 | 107 | 63 | 55 | 53 | 58 | 68 | 73 |
| 70% | 121 | 188 | 199 | 221 | 222 | 179 | 93 | 69 | 65 | 71 | 86 | 92 |
| 90% | 198 | 222 | 222 | 222 | 222 | 222 | 125 | 93 | 85 | 94 | 109 | 135 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 59 | 56 | 36 | 26 | 22 | 21 | 27 | 33 | 38 |
| 30% | 51 | 58 | 71 | 79 | 74 | 51 | 35 | 30 | 29 | 35 | 41 | 47 |
| 50% | 66 | 79 | 89 | 101 | 99 | 65 | 43 | 39 | 37 | 41 | 46 | 55 |
| 70% | 80 | 109 | 114 | 124 | 150 | 102 | 58 | 47 | 45 | 48 | 57 | 65 |
| 90% | 114 | 128 | 145 | 150 | 150 | 133 | 73 | 58 | 56 | 61 | 70 | 86 |

**Table J-18.** Calculated Flows (cfs) for All of the Alternatives at Inskip Powerhouse (Capacity of 283 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 144 | 153 | 178 | 198 | 188 | 129 | 98 | 88 | 85 | 102 | 119 | 134 |
| 30% | 173 | 195 | 234 | 256 | 241 | 172 | 124 | 110 | 107 | 126 | 142 | 160 |
| 50% | 218 | 255 | 275 | 283 | 278 | 213 | 150 | 137 | 132 | 142 | 158 | 183 |
| 70% | 258 | 283 | 283 | 283 | 283 | 279 | 195 | 159 | 154 | 163 | 189 | 216 |
| 90% | 283 | 283 | 283 | 283 | 283 | 283 | 237 | 195 | 187 | 202 | 228 | 274 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 47 | 53 | 70 | 94 | 116 | 57 | 27 | 22 | 21 | 30 | 47 | 40 |
| 30% | 67 | 81 | 107 | 152 | 169 | 100 | 52 | 38 | 35 | 54 | 70 | 58 |
| 50% | 97 | 126 | 157 | 218 | 229 | 141 | 78 | 65 | 60 | 70 | 86 | 74 |
| 70% | 129 | 209 | 218 | 263 | 283 | 234 | 123 | 87 | 82 | 91 | 117 | 95 |
| 90% | 217 | 254 | 283 | 283 | 283 | 283 | 165 | 123 | 115 | 130 | 156 | 148 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 67 | 76 | 101 | 121 | 141 | 82 | 50 | 39 | 36 | 55 | 72 | 58 |
| 30% | 96 | 118 | 157 | 179 | 194 | 125 | 77 | 63 | 60 | 79 | 95 | 83 |
| 50% | 141 | 178 | 209 | 246 | 255 | 166 | 103 | 90 | 85 | 95 | 111 | 106 |
| 70% | 181 | 270 | 283 | 283 | 283 | 261 | 148 | 112 | 107 | 116 | 142 | 139 |
| 90% | 283 | 283 | 283 | 283 | 283 | 283 | 190 | 148 | 140 | 155 | 181 | 200 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 65 | 71 | 88 | 101 | 107 | 65 | 43 | 36 | 35 | 47 | 58 | 58 |
| 30% | 85 | 99 | 125 | 144 | 151 | 94 | 62 | 52 | 50 | 63 | 74 | 76 |
| 50% | 115 | 143 | 168 | 199 | 202 | 128 | 79 | 70 | 67 | 74 | 85 | 92 |
| 70% | 145 | 219 | 230 | 230 | 230 | 207 | 112 | 85 | 82 | 88 | 105 | 113 |
| 90% | 230 | 230 | 230 | 230 | 230 | 230 | 148 | 112 | 104 | 114 | 131 | 161 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 41 | 45 | 53 | 70 | 85 | 45 | 26 | 22 | 21 | 27 | 38 | 38 |
| 30% | 51 | 58 | 71 | 109 | 120 | 74 | 42 | 33 | 31 | 43 | 54 | 47 |
| 50% | 66 | 84 | 104 | 154 | 165 | 101 | 59 | 50 | 47 | 54 | 65 | 55 |
| 70% | 86 | 145 | 154 | 199 | 220 | 170 | 89 | 65 | 62 | 68 | 85 | 65 |
| 90% | 153 | 190 | 220 | 220 | 220 | 220 | 117 | 89 | 84 | 94 | 111 | 98 |

**Table J-19.** Calculated Flows (cfs) for All of the Alternatives at Coleman Powerhouse (Capacity of 380 cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action Alternative | | | | | | | | | | | | |
| 10% | 205 | 221 | 253 | 277 | 265 | 191 | 151 | 138 | 134 | 157 | 178 | 196 |
| 30% | 241 | 274 | 321 | 349 | 330 | 244 | 184 | 167 | 163 | 187 | 207 | 229 |
| 50% | 293 | 348 | 380 | 380 | 380 | 296 | 218 | 200 | 194 | 207 | 227 | 259 |
| 70% | 339 | 380 | 380 | 380 | 380 | 380 | 274 | 229 | 221 | 234 | 267 | 299 |
| 90% | 380 | 380 | 380 | 380 | 380 | 380 | 325 | 274 | 263 | 283 | 314 | 374 |
| Five Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 74 | 81 | 99 | 123 | 145 | 83 | 52 | 46 | 45 | 55 | 73 | 67 |
| 30% | 95 | 111 | 139 | 185 | 201 | 128 | 78 | 63 | 61 | 80 | 97 | 86 |
| 50% | 128 | 159 | 191 | 254 | 264 | 172 | 106 | 91 | 86 | 97 | 114 | 103 |
| 70% | 162 | 246 | 257 | 303 | 326 | 270 | 152 | 115 | 109 | 119 | 147 | 126 |
| 90% | 256 | 296 | 328 | 329 | 329 | 322 | 197 | 152 | 144 | 160 | 188 | 182 |
| No Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 113 | 124 | 156 | 180 | 208 | 134 | 95 | 83 | 59 | 81 | 101 | 99 |
| 30% | 149 | 177 | 224 | 252 | 273 | 187 | 127 | 110 | 87 | 110 | 130 | 132 |
| 50% | 201 | 251 | 287 | 333 | 348 | 239 | 161 | 143 | 117 | 130 | 150 | 162 |
| 70% | 247 | 362 | 380 | 380 | 380 | 355 | 217 | 172 | 144 | 157 | 190 | 202 |
| 90% | 365 | 380 | 380 | 380 | 380 | 380 | 268 | 217 | 186 | 206 | 237 | 277 |
| Three Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 87 | 94 | 112 | 126 | 131 | 86 | 63 | 55 | 53 | 66 | 79 | 80 |
| 30% | 108 | 124 | 152 | 172 | 178 | 117 | 83 | 72 | 70 | 84 | 96 | 99 |
| 50% | 141 | 171 | 198 | 231 | 232 | 153 | 102 | 92 | 88 | 96 | 107 | 116 |
| 70% | 173 | 252 | 263 | 265 | 268 | 238 | 137 | 108 | 104 | 111 | 130 | 139 |
| 90% | 263 | 267 | 270 | 271 | 271 | 264 | 175 | 137 | 128 | 139 | 158 | 190 |
| Six Dam Removal Alternative | | | | | | | | | | | | |
| 10% | 68 | 72 | 82 | 100 | 114 | 71 | 50 | 46 | 45 | 52 | 64 | 64 |
| 30% | 80 | 88 | 103 | 142 | 152 | 102 | 68 | 58 | 56 | 69 | 81 | 74 |
| 50% | 97 | 116 | 138 | 190 | 200 | 132 | 87 | 77 | 73 | 81 | 92 | 84 |
| 70% | 119 | 182 | 193 | 239 | 263 | 206 | 119 | 93 | 89 | 96 | 115 | 96 |
| 90% | 192 | 232 | 265 | 266 | 266 | 259 | 149 | 119 | 113 | 124 | 143 | 132 |

Appendix K

# Water Temperature and Aquatic Habitat in Battle Creek

Appendix K
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**Appendix K Water Temperature and Aquatic Habitat in Battle Creek**

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# Appendix K
# Water Temperature and Aquatic Habitat in Battle Creek

## Introduction

Water temperature affects the quality of habitat used by river life stages of anadromous fish. In Battle Creek, water temperature is influenced primarily by hydrological and meteorological conditions, water diversions, flow releases below diversion dams, and the diversion of cold spring water from the stream channel. Fish populations are influenced by the distribution of water temperatures in the stream habitat.

In this appendix, the temperature regime under the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project) is predicted using SNTEMP (Pacific Gas and Electric Company, Land and Water Quality Unit 2001), which is the analysis method the Battle Creek Working Group (BCWG) Biological Technical Team (Kier Associates 1999) used to develop the Battle Creek project alternatives and select the Proposed Action, as presented in the environmental impact statement/environmental impact report (EIS/EIR) (Jones & Stokes 2003) and the action specific implementation plan (ASIP) (Jones & Stokes 2004). The temperature analysis is presented for habitat under the Proposed Action and the No Action Alternative and assessed in relation to temperature tolerances of anadromous salmonids. For most of the year, water temperatures are sufficiently cool to provide high-quality habitat for steelhead and Chinook salmon.

Warmer water temperatures may limit habitat quality during the summer months of June–September (Kier Associates 1999). Several factors cause warming in Battle Creek. Dry and warm meteorological conditions tend to increase water temperature, whereas wet and cold conditions lead to lower water temperatures. Water diversions from North Fork to South Fork Battle Creek tend to warm the North Fork Battle Creek by removing its cool water and to cool the South Fork Battle Creek by introducing relatively cold water at South and Inskip Powerhouses. The flow released below diversion dams also affects water temperature. In general, larger streamflows warm more slowly than smaller streamflows. Finally, diversions of relatively cold spring water out of the stream channel increase instream water temperatures.

# Approach to Assessment of Temperature Effects

As water temperature increases toward the extremes of the tolerance range of a fish, biological effects, such as impaired growth and increased susceptibility to disease and predation, are more likely to occur (Myrick and Cech 2001; Sullivan et al. 2000). Once temperatures exceed the tolerance range for a species at a certain life stage, survival rate decreases, depending on the magnitude and duration of elevated temperatures. Different life stages and species have different temperature responses, and the tolerance ranges that are identified in available literature are relatively broad (Jones & Stokes 2003, Section 4.1, "Fish"). Conclusive studies of the thermal requirements for Chinook salmon and steelhead in Central Valley streams are limited (Myrick and Cech 2001). For the purposes of this assessment of effects, survival estimates focus on the most temperature-sensitive life stages and the month in which the temperature extreme exists. Temperature response survival estimates are based on studies reported in the literature and impact analysis techniques used for the same assemblage of fish in the Sacramento River. The presence and absence of temperature-sensitive life stages are based on results of life history studies in the nearby Sacramento River and results of trapping and survey estimates on Battle Creek that have produced juvenile and adult abundance indices (U.S. Fish and Wildlife Service [USFWS] 2001).

Water temperatures in Battle Creek were modeled using SNTEMP, a cross-sectional, averaged, one-dimensional model, which was applied to the Battle Creek system, including the natural stream channels and Hydroelectric Project canals (Pacific Gas and Electric Company, Land and Water Quality Unit 2001).

Development of the SNTEMP model for Battle Creek is described in Appendix R, "Water Temperatures in the Battle Creek Restoration Area," of the Final EIS/EIR (*during public review of the Draft SEIS/REIR, see Appendix M, "Instream Flow Effects on Water Temperature in the Battle Creek Restoration Project Area," in the Draft EIS/EIR [Jones & Stokes 2003]*). The SNTEMP model simulated the Battle Creek temperature distribution using specified hydrology (dry, normal, and wet water years) and meteorology (hot, normal, and cold climate conditions). The SNTEMP model output subsequently used for this analysis consisted of monthly mean temperature predictions for three modeling simulation conditions (dry-warm, normal-normal, and wet-cold) along the 9.6 miles of North Fork Battle Creek downstream of North Battle Creek Feeder Diversion Dam and along the 14.4 miles of South Fork Battle Creek downstream of South Diversion Dam. The 9.2 miles of mainstem Battle Creek between the confluence and the Coleman Powerhouse were also simulated.

The results of the SNTEMP model are summarized in Figures K-1 through K-8. It should be noted that the daily temperatures will vary throughout the month, causing the actual mortality relationships to vary throughout the month as the fish respond to daily average temperatures; however, presenting the performance of the two alternatives on average over a month provides a suitable comparative analysis.

The temperature thresholds presented in the ASIP for survival and suitability for the different life stages of the priority species for the Restoration Project are described below.

- **Winter-Run Chinook Salmon Embryos—**Chinook salmon embryos are particularly sensitive to warmer temperatures. For winter-run Chinook, the embryonic life stage occurs in April through August. The warmest water temperature conditions occur during July (Figures K-9 through K-11) Temperature-survival relationships indicated on the figures are those developed for the same assemblage of Chinook salmon in the nearby upper Sacramento River for use in a similar impact analysis for a temperature control project (USFWS 1990; U.S. Department of the Interior, Bureau of Reclamation 1991). These temperature-survival relationships were applied to Battle Creek in the Restoration Plan (Kier Associates 1999) and confirmed for winter-run Chinook salmon in later studies by the USFWS.
- **Winter-Run Chinook Salmon Juveniles—**Winter-run Chinook salmon juveniles are more temperature-sensitive during September (Figure K-12) when warm climate conditions occur. The temperature response indicated in the figure includes lethality (Brett 1952; Raleigh et al. 1984; Myrick and Cech 2001) and preferred temperature range (Groot and Margolis 1991). Literature covering the response for exposure to temperatures between lethal and preferred shows considerable variation; factors that increase the difficulty of replicating a response include food availability (Bisson and Davis 1976) and acclimation temperature (Brett 1952).
- **Spring-Run Chinook Salmon Embryos—**Chinook salmon embryos are particularly sensitive to warmer temperatures. For spring-run Chinook, the peak months for the embryonic life stage are September through November. Spring-run Chinook salmon embryos are likely most at risk during the month of September because this month typically has the highest water temperature (Figure K-13). Temperature-survival relationships indicated on these figures are those developed for the same assemblage of Chinook salmon in the nearby upper Sacramento River for use in a similar impact analysis for a temperature control project (USFWS 1990; U.S. Department of the Interior, Bureau of Reclamation 1991). These temperature-survival relationships were applied to Battle Creek in the Restoration Plan (Kier Associates 1999) and confirmed for winter-run Chinook salmon in later studies by the USFWS.
- **Spring-Run Chinook Salmon Smolts**—Spring-run Chinook salmon smolts are more temperature-sensitive during June when the last of these smolt populations are present (Brown pers. comm.) and warm water conditions occur (Figure K-14). The temperature response indicated in the figure refers to the advanced juvenile life stages of anadromous salmonids when the parr stage transforms to smolt (smoltification) during the spring. Changes in behavior and physiology prepare the smolts for survival in saltwater. Based primarily on controlled experiments, water temperatures high enough to interrupt the smoltification process vary by species (Wedemeyer et al. 1980). From literature reviews, Zedonis and Newcomb (1997) identified three categories of thermal tolerance for salmonid smolts for the Trinity River.

The three categories—optimal, marginal, and unsuitable—were defined by the relative likelihood that smolts would revert to parr or lose their ability to osmoregulate in seawater.

- **Spring-Run Chinook Salmon Adults**—Over-summering spring-run Chinook salmon are more temperature-sensitive during July and August, when energy reserves are low, as the adults are reaching the end of their prespawning holding period (Figures K-15 and K-16). The temperature response indicated on the figures includes the preferred temperature range (California Department of Water Resources 1988) and a range where the exposure represents stressful conditions. The relationships were presented in the Battle Creek Restoration Plan (Kier Associates 1999).
- **Steelhead Smolts—**Steelhead smolts are more temperature-sensitive during June (Figure K-17), when the last of these smolt populations is present (Brown pers. comm.) and warm water conditions occur. The temperature response indicated in the figure refers to the advanced juvenile life stages of anadromous salmonids when the parr stage transforms to smolt (smoltification) during the spring. Changes in behavior and physiology prepare the smolts for survival in saltwater. Based primarily on controlled experiments, water temperatures high enough to interrupt the smoltification process vary by species (Wedemeyer et al. 1980). From literature reviews, Zedonis and Newcomb (1997) identified three categories of thermal tolerance for salmonid smolts for the Trinity River. The three categories—optimal, marginal, and unsuitable—were defined by the relative likelihood that smolts would revert to parr or lose their ability to osmoregulate in seawater. Studies examining relationships between water temperature and smoltification for steelhead have observed a reduction in migratory tendencies in response to elevated temperatures (greater than 55.4ºF) (Zaug 1981) and reduced physiological changes at higher temperatures (59ºF) that were inferred to be associated with a sharp decline in the number of outmigrating wild steelhead smolts captured in traps (Kerstetter and Keeler 1976).

# Assessment of Temperature Effects on Anadromous Salmonids

As indicated previously, the minimum instream flow requirements and release of presently diverted spring water are increased over present Federal Energy Regulatory Commission requirements (i.e., minimum flow requirements described in the 1999 Memorandum of Understanding, included as Appendix A in the Final EIS/EIR [*during public review of the Draft SEIS/REIR, see Appendix A in the Draft EIS/EIR*]) in the reaches downstream of the North Battle Creek Feeder Diversion Dam on North Fork Battle Creek and downstream of the South Diversion Dam on South Fork Battle Creek. The higher flows and cold spring waters will substantially cool water temperature at most locations, especially during the warmer months (Figures K-9 through K-17), and are likely to have a substantial beneficial effect on steelhead, Chinook salmon, and essential fish habitat for Chinook salmon.

Potential beneficial effects provided by cooler water temperatures in each reach from June through September are estimated using the SNTEMP model (Figures K-9 through K-17). A general indication of the magnitude of beneficial water temperature effects over all months is presented using the Warming Model for unspecified runoff and climate conditions described in Appendix R, "Water Temperatures in the Battle Creek Restoration Area," of the Final EIS/EIR (*during public review of the Draft SEIS/REIR, see Appendix M, "Instream Flow Effects on Water Temperature in the Battle Creek Restoration Area" in the Draft EIS/EIR*). Both approaches illustrate that, during summer months, higher flows associated with the Restoration Project substantially increase the extent of usable spawning and rearing habitat.

There are two short segments in South Fork Battle Creek where baseline conditions provide cooler summer temperatures than the Restoration Project. These cooler summer temperatures occur when the Inskip and South Powerhouses inject cooler North Fork Battle Creek water into South Fork Battle Creek. However, the powerhouses do not reliably inject cooler water under baseline conditions—canal and turbine outages occur at unpredictable times, producing substantial temperature fluctuations that reduce habitat value compared to the stabilized conditions under the Restoration Project.

The Restoration Project will result in cooler temperatures throughout most of the reaches during the month of July. An exception to this is immediately below the Inskip and Coleman Diversion Dams (Figures K-18 through K-20). Point estimates of temperature changes over the length of the project area for June (Figure K-9), August (Figure K-11), and September (Figure K-13) also reveal warmer temperatures will occur immediately below the Inskip and Coleman Diversion Dams under the Restoration Project.

Under the baseline conditions during the summer, Inskip Powerhouse discharges North Fork Battle Creek water. This discharge can result in an 8°F cooling of the water temperature immediately upstream of the Coleman Diversion Dam and downstream into the Coleman reach. Inversely, when an outage is needed to repair the turbine or canal, the cool water shuts off at the intake, causing the temperature below the powerhouse to suddenly warm 8°F. The warming affects several miles of stream downstream of the discharge points.

Under the Restoration Project during the summer, the cooler Inskip Powerhouse flow will bypass South Fork Battle Creek via connectors, which can result in temperatures as much as 8°F warmer in the 1-mile stream segment below Coleman Dam (cooled under baseline conditions). Although the Restoration Project will not provide the cooler discharges noted as part of the baseline conditions, it will not result in a significant reduction of habitat because it will stabilize the overall temperature regime by eliminating fluctuations associated with outages. The downstream segment of the Coleman reach is cooler under the

Restoration Project because of the higher minimum flows compared to baseline conditions (Figures K-9 through K-17).

Under baseline conditions, South Powerhouse discharges cool water from Upper South Fork and North Fork Battle Creek during the summer months, resulting in a 6°F cooling of the water temperature immediately downstream of the powerhouse to Inskip Diversion Dam and into the upstream segment of the Inskip reach. Inversely, when an outage is needed to repair the turbine or canal, the cool water shuts off at the intake, causing the temperature below the powerhouse to suddenly warm 6°F.

Under the Restoration Project, the cooler powerhouse flow will bypass South Fork Battle Creek via connectors, resulting in temperatures as much as 4°F warmer in the 1-mile stream segment below Inskip Diversion Dam. The Restoration Project will not result in a significant reduction of habitat because it will stabilize the overall temperature regime by eliminating fluctuations associated with outages. Water temperatures are cooler in the downstream segment of the Inskip reach under the Restoration Project because of the higher minimum flows. Overall, the Restoration Project creates a temperature regime in which temperature warms as the stream drops in elevation (Figures K-21 and K-22), providing the salmon with the environmental cue to continue their upstream migration to the reaches that have the most reliable cold water environment in the South Fork Battle Creek (Figures K-9 through K-17).

The extension of cooler water temperatures into downstream reaches under the higher instream flow requirements of the Restoration Project occurs during warmer months (Figures K-9 through K-17). Cooler temperatures are especially apparent in North Fork and South Fork Battle Creek above Inskip Dam (Figure K-18). The cooler water temperature under higher instream flow and the addition of cold water to the North Fork and South Fork Battle Creek from the Eagle Canyon Spring and Bluff Spring Complexes substantially increase suitable habitat for all Chinook salmon and steelhead temperature-sensitive life stages during June–September (Figures K-9 through K-17). Water temperatures during October–May are cool and generally have minimal effect on survival.

The comparative analyses of the biological consequences shown in Figures K-9 through K-13 compare the estimated survival rates as predicted by SNTEMP model for June–September. These analyses focus on stream reaches that are functional for various life stages of the priority species during vulnerable times. This approach, described in Chapter 3, is similar to that developed by the BCWG Technical Team (Kier Associates 1999). In addition to survival estimates during the warm season, point survival estimates and their corresponding water temperatures are provided at the start and terminus of the reach for the entire year (Tables K-1 through K-8).

It should be noted that there are significant differences in the results of the two comparative analysis methods that predict water temperature and characterize survival rates (e.g., there is a 50% difference in survival rates in one case). The adaptive management plan for the Restoration Project (refer to Appendix C of the

Final EIS/EIR [*during public review of the Draft SEIS/REIR, see Appendix D, "Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan" in the Draft EIS/EIR*]), recognizes the uncertainty associated with prediction of water temperature regimes and survival rates for different life stages under various environmental conditions. The adaptive management plan includes measures to:

- improve modeling efforts during the postproject period,
- apply those improvements to real-time temperature management in the project area, and
- provide necessary improvements though the Water Acquisition Fund.

The SNTEMP model was determined to adequately meet the current modeling needs. The model examined the expected survival for critical salmonid life stages, including spring-run and winter-run Chinook salmon embryos, steelhead and spring-run Chinook salmon smolts, juvenile Chinook salmon, and prespawning adult spring-run Chinook salmon (Figures K-9 through K-17). The model results are described below.

Winter-run Chinook salmon embryo survival rates (Figure K-9) at locations where the estimated survival rates exceed 50% predict that the Restoration Project substantially improves temperature conditions over baseline conditions in the South Diversion reach; however, embryo survival rates are essentially unchanged between baseline and restoration conditions in the Eagle Canyon and North Battle Creek Feeder reaches. Winter-run Chinook salmon embryo survival rates throughout the year (Table K-1) generally indicate that the Restoration Project improves conditions in the Eagle Canyon reach and to a lesser extent the Wildcat reach, but not elsewhere, compared to baseline conditions.

The portions of the project area shown in the longitudinal profile for September where survival of spring-run Chinook salmon embryos exceeds 50% (Figure K-13) show that the Restoration Project substantially improves temperature conditions. The Restoration Project provides cooler, more stable habitat in the reaches below South Diversion, Eagle Canyon, and Wildcat Diversion Dams compared to baseline conditions. In addition, the Restoration Project provides substantial improvements over baseline conditions in the reaches with estimated survival rates above 90%, including the Eagle Canyon and South Diversion reaches.

Prior to spring-run Chinook salmon spawning activity in the late summer and fall, the adults and unfertilized ova can be vulnerable to adverse effects of elevated temperatures (Kier Associates 1999). The August longitudinal temperature regime in Figure K-16 shows that the Restoration Project provides substantially more habitat in the temperature range preferred for adult salmon holding in both the Eagle Canyon and South Diversion reaches. The Restoration Project also improves adult holding areas in the Wildcat and Inskip reaches. For the Restoration Project, the temperature range is categorized as stressful compared to an unsuitable classification under baseline conditions.

For steelhead, spawning begins in December and ends in April, with incubation extending through May (Table K-3). Spawning is supported under both baseline conditions and the Restoration Project. Under the Restoration Project, however, cool temperatures extend farther downstream and through May. The cooler water temperatures in April and May generally indicate higher embryo survival in the forks and in the mainstem of Battle Creek.

Juvenile spring-run Chinook salmon benefit from cooler water temperatures that would support rearing through May (Table K-5). Spring-run smolts outmigrate through June (Brown pers. comm.), and the Restoration Project results in substantial cooling to optimum temperatures in the reaches below South Diversion and Wildcat Diversion Dams. The Restoration Project also cools the temperatures considered unsuitable for the Inskip, Coleman, and mainstem reaches under baseline conditions (Figure K-14).

Juvenile winter-run Chinook salmon benefit from the cooler temperatures that extend to the lower elevation reaches during juvenile emigration periods under the Restoration Project. The emigration of winter-run Chinook salmon juveniles from the spawning areas is highly dependent on streamflow conditions and water year type. Emigration past Red Bluff Diversion Dam generally peaks in September (National Oceanic and Atmospheric Administration, National Marine Fisheries Service 1997). During September of normal years, the Restoration Project temperature is 65°F or less, which is more than 10°F less than the temperature resulting in lethal response during a short exposure (Figure K-12). Substantial improvements in the temperature regime in September are provided under the Restoration Project in the Inskip, Coleman, Wildcat, and mainstem reaches (Figure K-8 and Table K-5).

For steelhead, juvenile rearing occurs year-round (Table K-7). The last smolts of the emigration period are present in June (Brown pers. comm.), when the lower elevation reaches of the project area become unsuitable for smolts (Figure K-17). The Restoration Project temperatures in June are marginally suitable for maintaining smolts in good condition in the North Battle Creek Feeder and South Diversion reaches, representing a substantial improvement over baseline conditions in the South Diversion reach (Figure K-17). There is a general indication that steelhead juveniles residing in the summer benefit from the Restoration Project's cooler temperatures in the lowest elevation reaches, except for the terminus of the South Fork- and terminus of the mainstem (Table K-7).

Additional water temperature benefits related to coldwater refugia are not fully captured by the one-dimensional SNTEMP water temperature analysis. The importance of coldwater refugia for the overall performance of the project is recognized in the adaptive management plan located in Appendix C, "Revised Draft Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan, Executive Summary," of the Final EIS/EIR (*during public review of the Draft SEIS/REIR, see Appendix D, "Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan" in the Draft EIS/EIR*). Under baseline conditions, cool springs are diverted into canals that convey flow from Eagle Canyon Diversion Dam and Soap Creek Feeder

Diversion Dam. At Eagle Canyon Diversion Dam, the spring flow is approximately 12 cubic feet per second (cfs), and the temperature of the spring flow is near 52°F year-round. Under the Restoration Project, the spring flow would discharge to North Fork Battle Creek and would cool streamflow during the warmer months (Figure K-23). The cooling would provide temperatures more conducive to supporting spawning and rearing and would especially benefit winter- and spring-run Chinook salmon and steelhead.

Soap Creek inflow to South Fork Battle Creek would also increase under the Restoration Project. Flow in Soap Creek originates from Bluff Springs and would contribute cool water to South Fork Battle Creek. Under baseline conditions, flow in Soap Creek is diverted and does not contribute to cooling of South Fork Battle Creek. The approximate effect of Soap Creek flow, based on 15 cfs at a minimum water temperature of 52–54°F, is shown in Figure K-24. Coldwater refugia can develop in the bottom of pools, provided that stratification is allowed to occur through flow management. Development of coldwater refugia will be substantially beneficial, providing temperatures more conducive to support of adult holding, spawning, smolting, and rearing and especially benefiting early spawning winter- and spring-run Chinook salmon and steelhead.

Stream reaches receiving cool spring flow are expected to provide cool water refugia that will better support spawning and rearing of Chinook salmon and steelhead, benefits not fully reflected by the simulated water temperature. The longitudinal temperature profiles for the driest months show regions with potential to develop coldwater refugia (outside the powerhouse cooling zones). Specifically, inputs are visible in the profiles at the locations upstream of Coleman Powerhouse:

1. mainstem at 8.5 miles,
2. Inskip at 13 miles,
3. South Diversion at 21 miles, and
4. Eagle Canyon at 14.5 miles.

The minimum flow requirements under the Restoration Project support future adaptive management of water temperature to realize benefits from spring-flow refugia to meet the adult holding, rearing, and spawning life stage needs of Chinook salmon and steelhead (Figures K-5 through K-8).

Fall/late fall–run Chinook salmon survival is less affected by water temperature than the other Chinook salmon runs because spawning occurs in late fall and winter. Winter- and spring-run Chinook salmon and steelhead juveniles and smolts would receive the most temperature benefits from increased flows and cool water accretions because embryos and smolts generally occur during warmer months. Fall/late fall–run juveniles would benefit from cooler water temperatures through the summer (Table K-5).

# References Cited

## Printed References


Bisson, P. A. and G. E. Davis. 1976. Production of juvenile Chinook salmon *Oncorhynchus tshawytscha*, in a heated model stream. *Fish. Bull*. v. 74, p. 763–774.

Brett, J. R. 1952. Temperature tolerance in young Pacific Salmon, genus *Oncorhynchus*. *Journal of the Fisheries Research Board of Canada*, v. 9, p. 265–325.

California Department of Water Resources. 1988. *Water temperature effects on Chinook salmon (*Oncorhynchus tshawytscha*) with an emphasis on the Sacramento River —a literature review*.

Groot, M. C. and L. Margolis (editors). 1991. *Pacific salmon life histories*. Vancouver, British Columbia: UBC Press.

Jones & Stokes. 2003. *Draft environmental impact statement/environmental impact report, Battle Creek Salmon and Steelhead Restoration Project*. (J&S 03-035.) July. Sacramento, CA.

Jones & Stokes. 2004. *Draft action specific implementation plan, Battle Creek Salmon and Steelhead Restoration Project.* (J&S 03-035). April. Sacramento, CA.

Kerstetter, T. H. and M. Keeler. 1976. *Smolting in steelhead trout* (Salmo gairdneri*): A comparative study of populations in two hatcheries and the Trinity River, northern California, using gill Na, K, ATPase assays*. Humboldt State University, Sea Grant Program. Humboldt, CA.

Kier Associates. 1999. Battle Creek Salmon and Steelhead Restoration Plan. Prepared for the Battle Creek Working Group. January. Sausalito, CA.

Myrick, C. A. and J. J. Cech. 2001. Temperature effects on Chinook salmon and steelhead: a review focusing on California's Central Valley populations. Available: <http://www.cwemf.org/Pubs/Tempreview.pdf>.

National Oceanic Atmospheric Administration, National Marine Fisheries Service. 1997. Proposed Recovery Plan for the Sacramento River winter-run Chinook salmon. August. National Marine Fisheries Service—Southwest Region, Long Beach, CA.

Pacific Gas and Electric Company, Land and Water Quality Unit. 2001. *Stream temperature model for the Battle Creek Salmon and Steelhead Restoration Project.* January 12.

Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. U.S. Fish and Wildlife Service. FWS/OBS-82/10.

Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting criteria. Portland, OR: Sustainable Ecosystems Institute.

U.S. Department of the Interior, Bureau of Reclamation. 1991. *Planning report/final environmental statement: Shasta outflow temperature control Shasta County, California*. Final Statement No: FES91.

U.S. Fish and Wildlife Service. 1990. *Fish and Wildlife Coordination Act report: An analysis of fish and wildlife impacts of Shasta Dam water temperature control alternatives*. December.

U.S. Fish and Wildlife Service. 2001. *Final restoration plan for the Anadromous Fish Restoration Program: A plan to increase natural production of anadromous fish in the Central Valley of California*. Prepared by U.S. Fish and Wildlife Service and the Anadromous Fish Restoration Program Core Group. Sacramento, California. January 9. Available: <http://www.delta.dfg.ca.gov/afrp/documents/Restplan_final.html>.

USFWS, see U.S. Fish and Wildlife Service.

Wedemeyer, G. A., R. L. Saunders, and W. C. Clarke. 1980. Environmental factors affecting smoltification and early marine survival of anadromous salmonids. *Mar. Fish Rev*. 42 (6): 1–14.

Zaugg, W. S. 1981. Advanced photoperiod and water temperature effects on Na+ - K + adenosine triphosphatase activity and migration of juvenile steelhead (*Salmo gairdneri*). *Canadian Journal of Fisheries and Aquatic Sciences*, v. 38, pp. 758–764.

Zedonis, P. A. and T. J. Newcomb. 1997. *Flow and temperatures for protection of spring salmon and steelhead smolts in the Trinity River, California*. U.S. Fish and Wildlife Service, Arcata, CA.

# Personal Communication

Brown, Matt. U.S. Fish and Wildlife Service. March 31, 2004—conversation with Harry Rectenwald, California Department of Fish and Game.

**Table K-1.** Estimated Survival of Chinook Salmon Eggs in Response to Water Temperature during Incubation at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project 

| | Potential Occurrence of Spawning and Incubation for Spring-, Winter-, Fall-, and Late Fall–Run Chinook Salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Estimated Incubation Survival by Month (%)* | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 99% | 96% | 87% | 96% | 99% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 99% | 96% | 87% | 96% | 99% | 100% | 100% | 100% |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 81% | 49% | 0% | 24% | 67% | 98% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 97% | 90% | 72% | 88% | 96% | 100% | 100% | 100% |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 79% | 0% | 0% | 0% | 0% | 0% | 25% | 97% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 87% | 66% | 15% | 52% | 79% | 99% | 100% | 100% |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 54% | 100% |
| Restoration Project | 100% | 100% | 100% | 99% | 63% | 5% | 0% | 0% | 33% | 91% | 100% | 100% |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 99% | 52% | 0% | 0% | 52% | 99% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 99% | 52% | 0% | 0% | 52% | 99% | 100% | 100% |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 79% | 0% | 0% | 0% | 0% | 79% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 96% | 21% | 0% | 0% | 21% | 96% | 100% | 100% |

| | Potential Occurrence of Spawning and Incubation for Spring-, Winter-, Fall-, and Late Fall–Run Chinook Salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 96% | 78% | 27% | 53% | 81% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 96% | 21% | 0% | 0% | 21% | 96% | 100% | 100% |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 59% | 0% | 0% | 0% | 0% | 0% | 0% | 81% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 57% | 0% | 0% | 0% | 0% | 57% | 100% | 100% |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 75% | 0% | 0% | 0% | 60% | 97% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 57% | 0% | 0% | 0% | 0% | 57% | 100% | 100% |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 77% | 0% | 0% | 0% | 0% | 0% | 0% | 96% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 18% | 0% | 0% | 0% | 0% | 0% | 100% | 100% |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 53% | 0% | 0% | 0% | 0% | 0% | 0% | 87% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 33% | 0% | 0% | 0% | 0% | 56% | 100% | 100% |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| Restoration Project | 100% | 100% | 100% | 98% | 0% | 0% | 0% | 0% | 0% | 0% | 96% | 100% |

Note:
* Values in this table are based on water temperatures in Table K-2.

**Table K-2.** Monthly Water Temperatures Corresponding to Chinook Salmon Egg Survival at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project. 

| | Potential Occurrence of Spawning and Incubation for Spring-, Winter-, Fall-, and Late Fall–Run Chinook Salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Water Temperatures by Month (°F)* | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | <54.9 | 55 | 56 | 57.4 | 56 | 55 | <54.9 | <54.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 55 | 56 | 57.4 | 56 | 55 | <54.9 | <54.9 | <54.9 |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | <54.9 | 58.1 | 60.2 | >61.9 | 61.2 | 59.1 | 55.3 | <54.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 55.7 | 57 | 58.8 | 57.3 | 56 | <54.9 | <54.9 | <54.9 |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | 58.3 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | 61.2 | 55.7 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 57.4 | 59.2 | 61.5 | 60 | 58.3 | 55 | <54.9 | <54.9 |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | 59.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | 55 | 59.4 | 61.9 | >61.9 | >61.9 | 60.9 | 56.9 | <54.9 | <54.9 |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | <54.9 | 55 | 60 | >61.9 | >61.9 | 60 | 55 | <54.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 55 | 60 | >61.9 | >61.9 | 60 | 55 | <54.9 | <54.9 |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | <54.9 | 58.3 | >61.9 | >61.9 | >61.9 | >61.9 | 58.3 | <54.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 56 | 61.3 | >61.9 | >61.9 | 61.3 | 56 | <54.9 | <54.9 |

| | Potential Occurrence of Spawning and Incubation for Spring-, Winter-, Fall-, and Late Fall–Run Chinook Salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Water Temperatures by Month (°F)* | | | | | | | | | | | |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | <54.9 | 56 | 58.3 | 61.1 | 59.9 | 58.1 | <54.9 | <54.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 56 | 61.3 | >61.9 | >61.9 | 61.3 | 56 | <54.9 | <54.9 |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | 59.6 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | 58.1 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 59.7 | >61.9 | >61.9 | >61.9 | >61.9 | 59.7 | <54.9 | <54.9 |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | <54.9 | 58.6 | >61.9 | >61.9 | >61.9 | 59.6 | 55.7 | <54.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 59.7 | >61.9 | >61.9 | >61.9 | >61.9 | 59.7 | <54.9 | <54.9 |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | 58.4 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | 56 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 61.4 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | <54.9 | <54.9 |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | 59.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | 57.4 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | <54.9 | 60.9 | >61.9 | >61.9 | >61.9 | >61.9 | 59.8 | <54.9 | <54.9 |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | <54.9 | <54.9 | <54.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | <54.9 |
| Restoration Project | <54.9 | <54.9 | <54.9 | 55.3 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | >61.9 | 56 | <54.9 |

Note:

* Values are based on the relationship between Chinook Salmon egg survival and water temperature depicted on Figure H-1 in Appendix H of the Final EIS/EIR.

**Table K-3.** Estimated Survival of Steelhead Eggs in Response to Water Temperature during Incubation at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project



| | Potential Occurrence of Spawning and Incubation for Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun* | Jul* | Aug* | Sep* | Oct | Nov | Dec |
| Steelhead Occurrence | | | | | | | | | | | | |
| Location | Estimated Incubation Survival by Month (%)[†] | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 91% | 80% | 51% | 80% | 91% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 91% | 80% | 51% | 80% | 91% | 100% | 100% | 100% |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 95% | 33% | 0% | 0% | 0% | 0% | 85% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 83% | 62% | 8% | 55% | 80% | 100% | 100% | 100% |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 28% | 0% | 0% | 0% | 0% | 0% | 0% | 83% | 100% |
| Restoration Project | 100% | 100% | 100% | 98% | 53% | 0% | 0% | 0% | 30% | 92% | 100% | 100% |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| Restoration Project | 100% | 100% | 100% | 91% | 0% | 0% | 0% | 0% | 0% | 65% | 100% | 100% |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 91% | 0% | 0% | 0% | 0% | 91% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 91% | 0% | 0% | 0% | 0% | 91% | 100% | 100% |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 30% | 0% | 0% | 0% | 0% | 30% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 81% | 0% | 0% | 0% | 0% | 81% | 100% | 100% |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 81% | 25% | 0% | 0% | 33% | 94% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 81% | 0% | 0% | 0% | 0% | 81% | 100% | 100% |

**Table K-3.** Continued



| | Potential Occurrence of Spawning and Incubation for Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun* | Jul* | Aug* | Sep* | Oct | Nov | Dec |
| Steelhead Occurrence | | | | | | | | | | | | |
| Location | Estimated Incubation Survival by Month (%)† | | | | | | | | | | | |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 34% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 97% | 15% | 0% | 0% | 0% | 0% | 84% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 21% | 0% | 0% | 0% | 0% | 0% | 0% | 81% | 100% |
| Restoration Project | 100% | 100% | 100% | 99% | 0% | 0% | 0% | 0% | 0% | 0% | 93% | 100% |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 52% | 100% |
| Restoration Project | 100% | 100% | 100% | 97% | 0% | 0% | 0% | 0% | 0% | 0% | 98% | 100% |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| Restoration Project | 100% | 100% | 100% | 86% | 0% | 0% | 0% | 0% | 0% | 0% | 81% | 100% |

Note:

*Spawning does not occur during this month.
†Values in this table are based on water temperatures in Table K-4.

**Table K-4.** Monthly Water Temperatures Corresponding to Steelhead Egg Survival at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project



| | Potential Occurrence of Spawning and Incubation for Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun* | Jul* | Aug* | Sep* | Oct | Nov | Dec |
| Steelhead Occurrence | | | | | | | | | | | | |
| Location | Water Temperatures by Month (°F)† | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | <53.5 | 55 | 56 | 57.5 | 56 | 55 | <53.5 | <53.5 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | 55 | 56 | 57.5 | 56 | 55 | <53.5 | <53.5 | <53.5 |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | 54.5 | 58.1 | >58.9 | >58.9 | >58.9 | >58.9 | 55.6 | <53.5 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | 55.8 | 57 | 58.8 | 57.3 | 56 | <53.5 | <53.5 | <53.5 |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | 58.3 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 55.8 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | 54 | 57.4 | >58.9 | >58.9 | >58.9 | 58.2 | 54.9 | <53.5 | <53.5 |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | 55 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 56.9 | <53.5 | <53.5 |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | <53.5 | 55 | >58.9 | >58.9 | >58.9 | >58.9 | 55 | <53.5 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | 55 | >58.9 | >58.9 | >58.9 | >58.9 | 55 | <53.5 | <53.5 |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | <53.5 | 58.2 | >58.9 | >58.9 | >58.9 | >58.9 | 58.2 | <53.5 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | 60 | >58.9 | >58.9 | >58.9 | >58.9 | 60 | <53.5 | <53.5 |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | <53.5 | 60 | 58.3 | >58.9 | >58.9 | 58.1 | 54.6 | <53.5 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | 60 | >58.9 | >58.9 | >58.9 | >58.9 | 60 | <53.5 | <53.5 |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 58.1 | <53.5 |

**Table K-4.** Continued 

| | Potential Occurrence of Spawning and Incubation for Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun* | Jul* | Aug* | Sep* | Oct | Nov | Dec |
| Steelhead Occurrence | | | | | | | | | | | | |
| Location | Water Temperatures by Month (°F)† | | | | | | | | | | | |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | <53.5 | <53.5 |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | 54.2 | 58.6 | >58.9 | >58.9 | >58.9 | >58.9 | 55.7 | <53.5 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | <53.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | <53.5 | <53.5 |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | 58.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 60 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | 53.6 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 54.8 | <53.5 |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 57.4 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | 54.2 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 54 | <53.5 |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | <53.5 | <53.5 | <53.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | <53.5 |
| Restoration Project | <53.5 | <53.5 | <53.5 | 55.5 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | >58.9 | 60 | <53.5 |

Note:

*Spawning does not occur during this month.
†Values are based on the relationship between Steelhead egg survival and water temperature depicted on Figure H-1 in Appendix H of the Final EIS/EIR.

**Table K-5.** Estimated Survival of Juvenile Chinook Salmon in Response to Water Temperature during Rearing at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project 

| | Potential Occurrence of Juvenile Spring-, Winter-, Fall-, and Late Fall–Run Chinook salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Estimated Juvenile Survival by Month (%)* | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 90% | 28% | 58% | 95% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 66% | 0% | 0% | 0% | 0% | 91% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 88% | 88% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

**Table K-5.** Continued 

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Potential Occurrence of Juvenile Spring-, Winter-, Fall-, and Late Fall–Run Chinook salmon | | | | | | | | | | | |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Estimated Juvenile Survival by Month (%)* | | | | | | | | | | | |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 95% | 9% | 0% | 0% | 16% | 99% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 96% | 58% | 58% | 96% | 100% | 100% | 100% |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 96% | 58% | 58% | 96% | 100% | 100% | 100% |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 99% | 55% | 0% | 5% | 85% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 74% | 0% | 0% | 72% | 100% | 100% | 100% |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 94% | 12% | 0% | 0% | 54% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 97% | 68% | 77% | 98% | 100% | 100% | 100% |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 98% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 62% | 0% | 0% | 68% | 100% | 100% | 100% |

Note:
* Values in this table are based on water temperatures in Table K-6.

**Table K-6.** Monthly Water Temperatures Corresponding to Juvenile Chinook Salmon Survival at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project



| | Potential Occurrence of Juvenile Spring-, Winter-, Fall-, and Late Fall–Run Chinook salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Water Temperatures by Month ($^{o}$F)* | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 67.5 | 72 | 70.4 | 66.5 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | 69.9 | >72.9 | >72.9 | >72.9 | >72.9 | 67.3 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 67.8 | 67.8 | <65.1 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |

| | Potential Occurrence of Juvenile Spring-, Winter-, Fall-, and Late Fall–Run Chinook salmon | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Spring-Run | | | | | | | | | | | | |
| Winter-Run | | | | | | | | | | | | |
| Fall-Run | | | | | | | | | | | | |
| Late Fall–Run | | | | | | | | | | | | |
| Location | Water Temperatures by Month ($^{o}$F)* | | | | | | | | | | | |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | 66.5 | 72.7 | >72.9 | >72.9 | 72.4 | 65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 66.3 | 70.4 | 70.4 | 66.3 | <65.1 | <65.1 | <65.1 |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 66.3 | 70.4 | 70.4 | 66.3 | <65.1 | <65.1 | <65.1 |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | 65.1 | 70.6 | >72.9 | 72.8 | 68.2 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 69.3 | >72.9 | >72.9 | 69.5 | <65.1 | <65.1 | <65.1 |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | <65.1 | 66.8 | 72.6 | >72.9 | >72.9 | 70.7 | <65.1 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 66 | 69.8 | 69 | 65.8 | <65.1 | <65.1 | <65.1 |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | <65.1 | <65.1 | <65.1 | 65.8 | >72.9 | >72.9 | >72.9 | >72.9 | >72.9 | >72.9 | <65.1 | <65.1 |
| Restoration Project | <65.1 | <65.1 | <65.1 | <65.1 | <65.1 | 70.2 | >72.9 | >72.9 | 69.8 | <65.1 | <65.1 | <65.1 |

Note:
*Values are based on the relationship between Juvenile Chinook Salmon survival and water temperature depicted on Figure H-2 in Appendix H of the Final EIS/EIR.

**Table K-7.** Estimated Survival of Juvenile Steelhead in Response to Water Temperature during Rearing at Various Locations in Battle Creek under the Baseline Conditions and the Restoration Project



| | Potential Occurrence of Juvenile Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Steelhead | | | | | | | | | | | | |
| Location | Estimated Juvenile Survival by Month (%)* | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 96% | 62% | 79% | 99% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 84% | 0% | 0% | 0% | 4% | 97% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 95% | 95% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

| | Potential Occurrence of Juvenile Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Steelhead | | | | | | | | | | | | |
| Location | Estimated Juvenile Survival by Month (%)* | | | | | | | | | | | |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 99% | 50% | 0% | 0% | 54% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 99% | 79% | 79% | 99% | 100% | 100% | 100% |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 99% | 79% | 79% | 99% | 100% | 100% | 100% |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 100% | 77% | 16% | 48% | 94% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 88% | 2% | 2% | 87% | 100% | 100% | 100% |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 98% | 52% | 0% | 0% | 77% | 100% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 100% | 85% | 90% | 100% | 100% | 100% | 100% |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | 100% | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 44% | 100% | 100% |
| Restoration Project | 100% | 100% | 100% | 100% | 100% | 81% | 0% | 14% | 85% | 100% | 100% | 100% |

Note:

* Values in this table are based on water temperatures in Table K-8.

**Table K-8.** Monthly Water Temperatures Corresponding to Juvenile Steelhead Survival at Various Locations in Battle Creek under Baseline Conditions and the Restoration Project



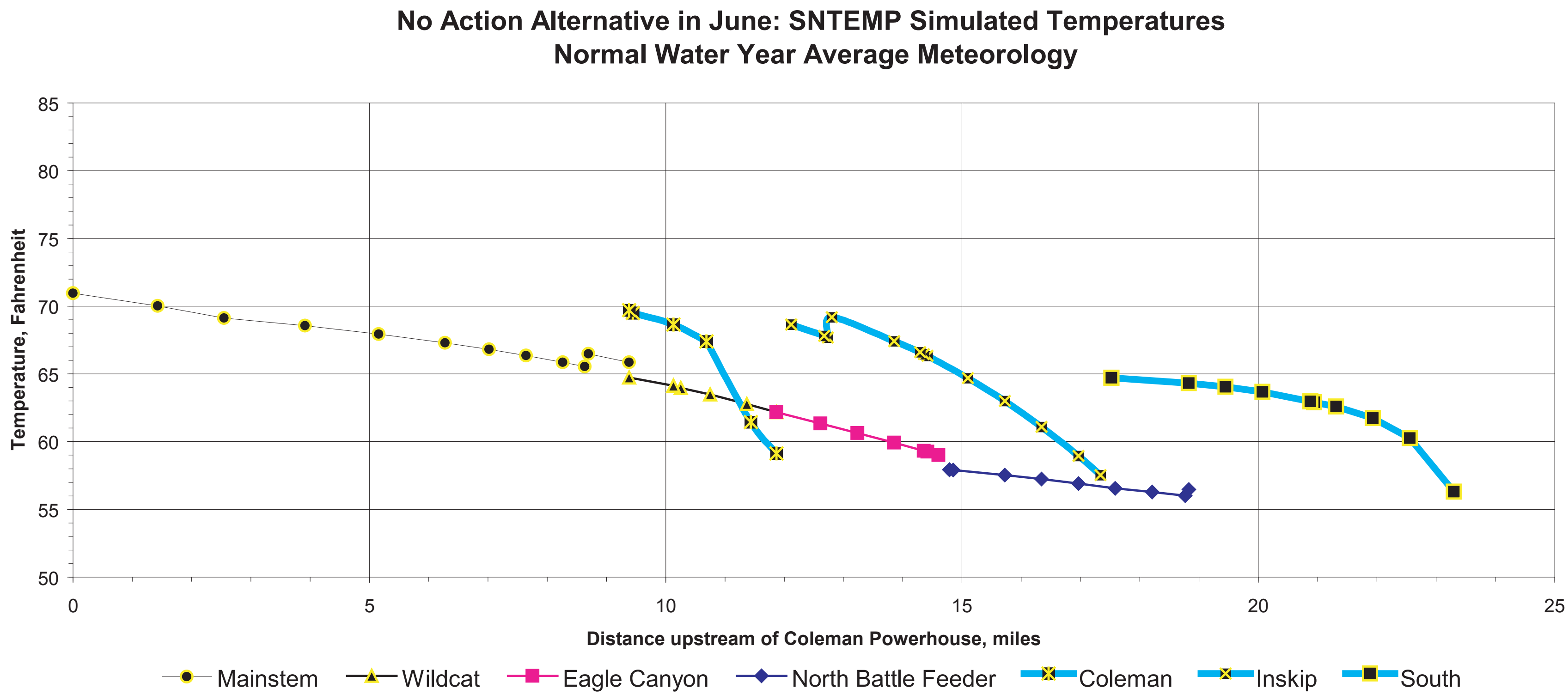
| | Potential Occurrence of Juvenile Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Steelhead | | | | | | | | | | | | |
| Location | Water Temperatures by Month ($^oF$)* | | | | | | | | | | | |
| **North Battle Creek Feeder Diversion Dam** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| **Eagle Canyon Diversion Dam** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| **Wildcat Diversion Dam** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 67.7 | 71.9 | 70.4 | 66.5 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| **Mouth of North Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | 69.8 | >74.9 | >74.9 | >74.9 | 74.8 | 67.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| **South Diversion Dam** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| **South Powerhouse** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 68 | 68 | <66.3 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| **Inskip Diversion Dam** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |

**Table K-8.** Continued 

| | Potential Occurrence of Juvenile Steelhead | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Steelhead | | | | | | | | | | | | |
| Location | Water Temperatures by Month ($^oF$)* | | | | | | | | | | | |
| **Above Inskip Powerhouse** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | 66.5 | 72.7 | >74.9 | >74.9 | 72.5 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 66.5 | 70.4 | 70.4 | 66.5 | <66.3 | <66.3 | <66.3 |
| **Coleman Diversion Dam** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 66.5 | 70.4 | 70.4 | 66.5 | <66.3 | <66.3 | <66.3 |
| **Mouth of South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 70.6 | 74.4 | 72.8 | 68.2 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 69.3 | 74.9 | 74.9 | 69.4 | <66.3 | <66.3 | <66.3 |
| **Below the Confluence of North and South Fork Battle Creek** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | 67 | 72.6 | >74.9 | >74.9 | 70.6 | <66.3 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 69.7 | 69 | <66.3 | <66.3 | <66.3 | <66.3 |
| **Battle Creek at Coleman Powerhouse** | | | | | | | | | | | | |
| Baseline | <66.3 | <66.3 | <66.3 | <66.3 | >74.9 | >74.9 | >74.9 | >74.9 | >74.9 | 73 | <66.3 | <66.3 |
| Restoration Project | <66.3 | <66.3 | <66.3 | <66.3 | <66.3 | 70.2 | >74.9 | 74.4 | 69.7 | <66.3 | <66.3 | <66.3 |

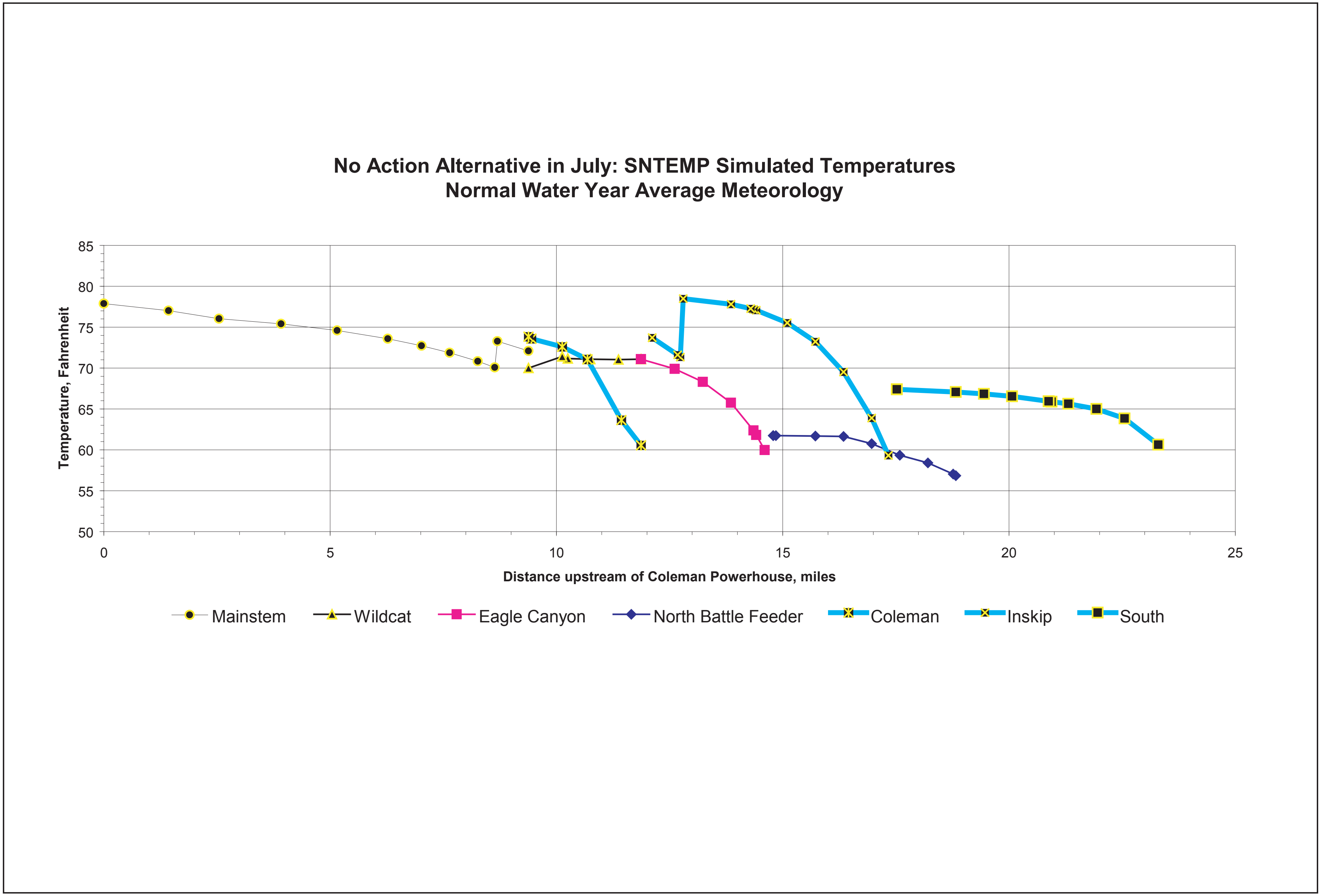
Note:

*Values are based on the relationship between Juvenile Steelhead survival and water temperature depicted in Figure H-2 in Appendix H in the Final EIS/EIR.



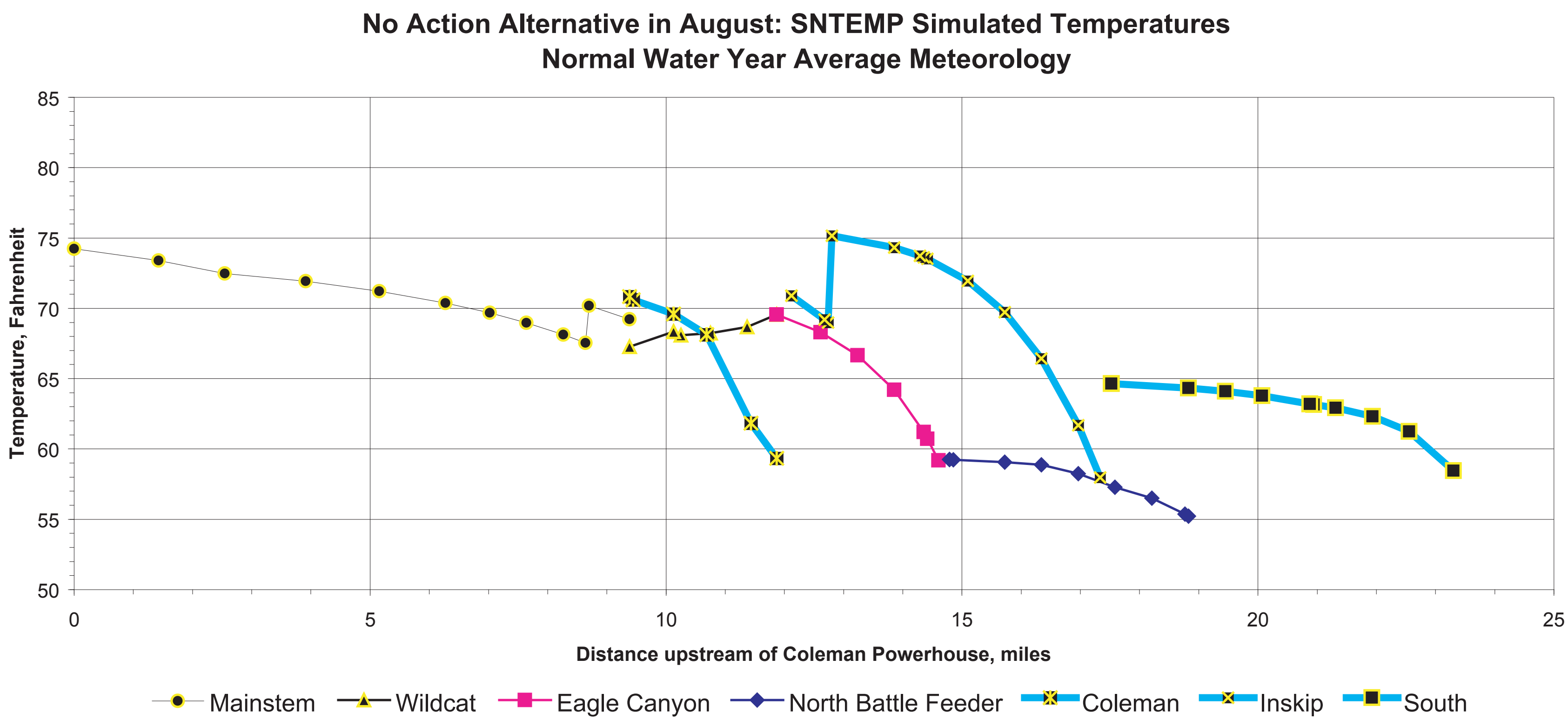

03035.03 FEIS/EIR

**Figure K-1**
**SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in June**



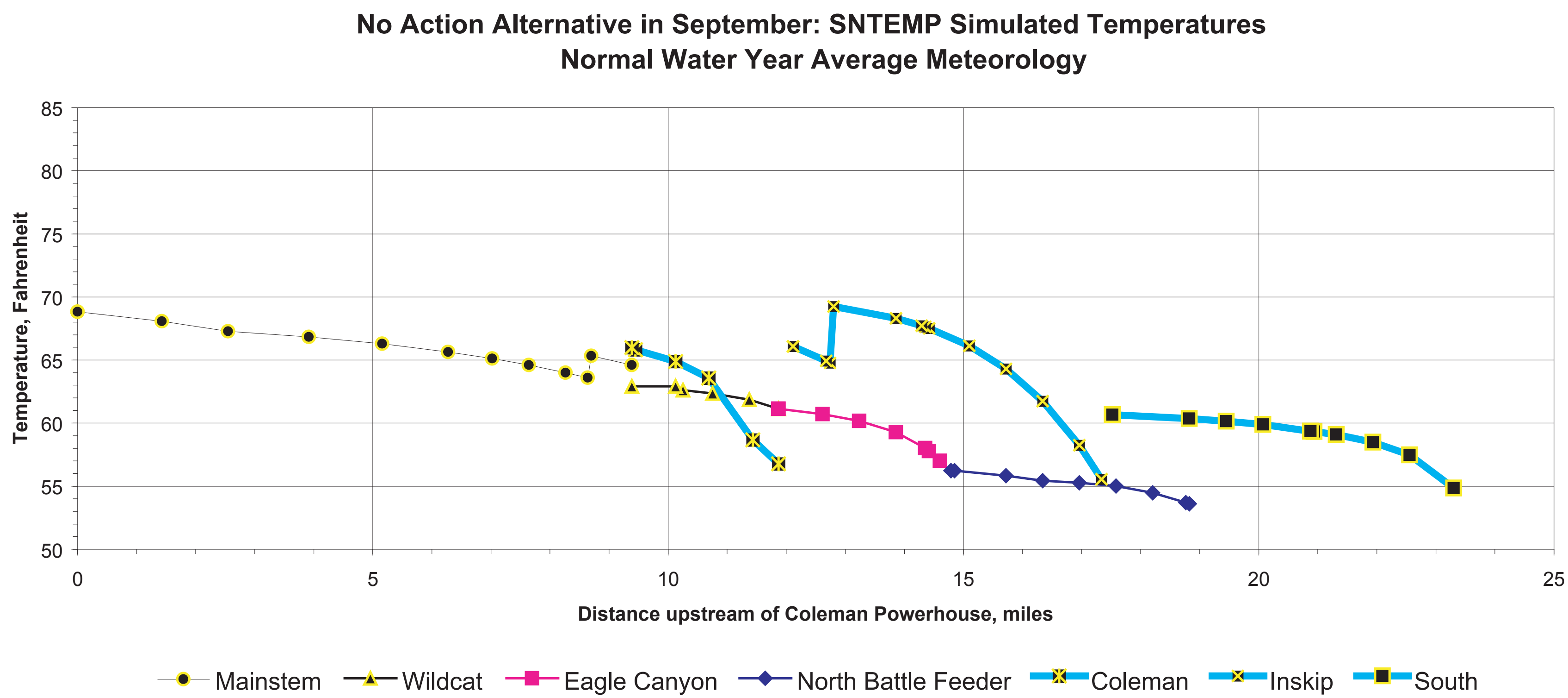

03035.03 FEIS/EIR

**Figure K-2**
**SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in July**




03035.03 FEIS/EIR

**Figure K-3**
**SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in August**




03035.03 FEIS/EIR

**Figure K-4**
**SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in September**

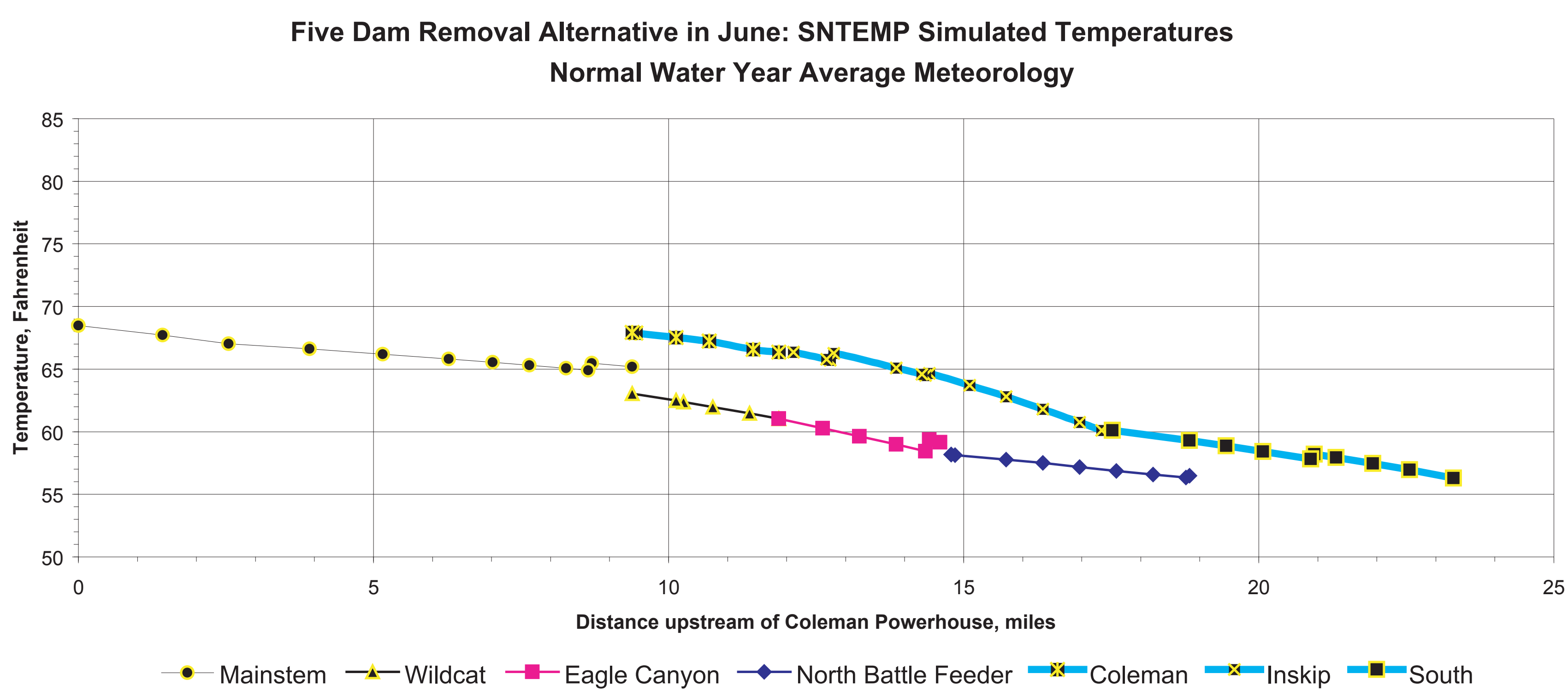



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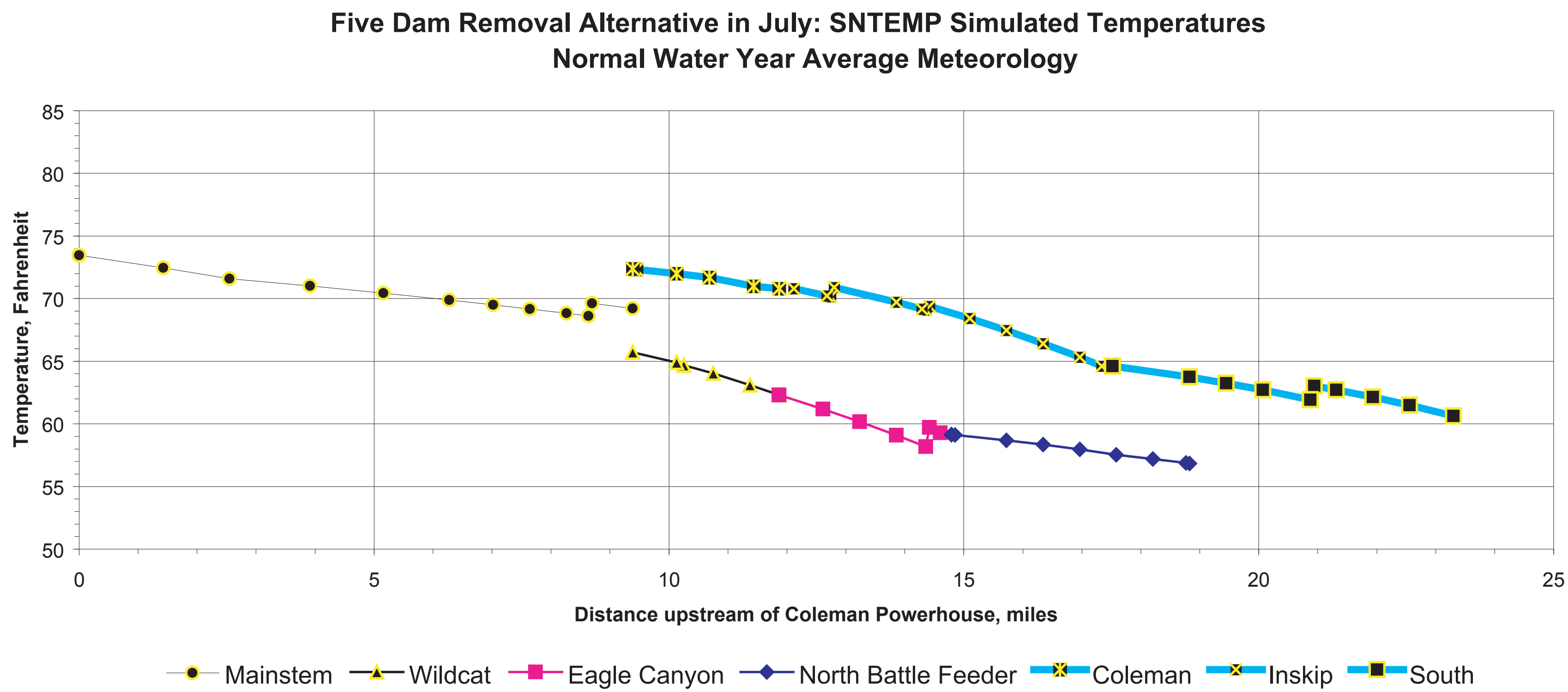
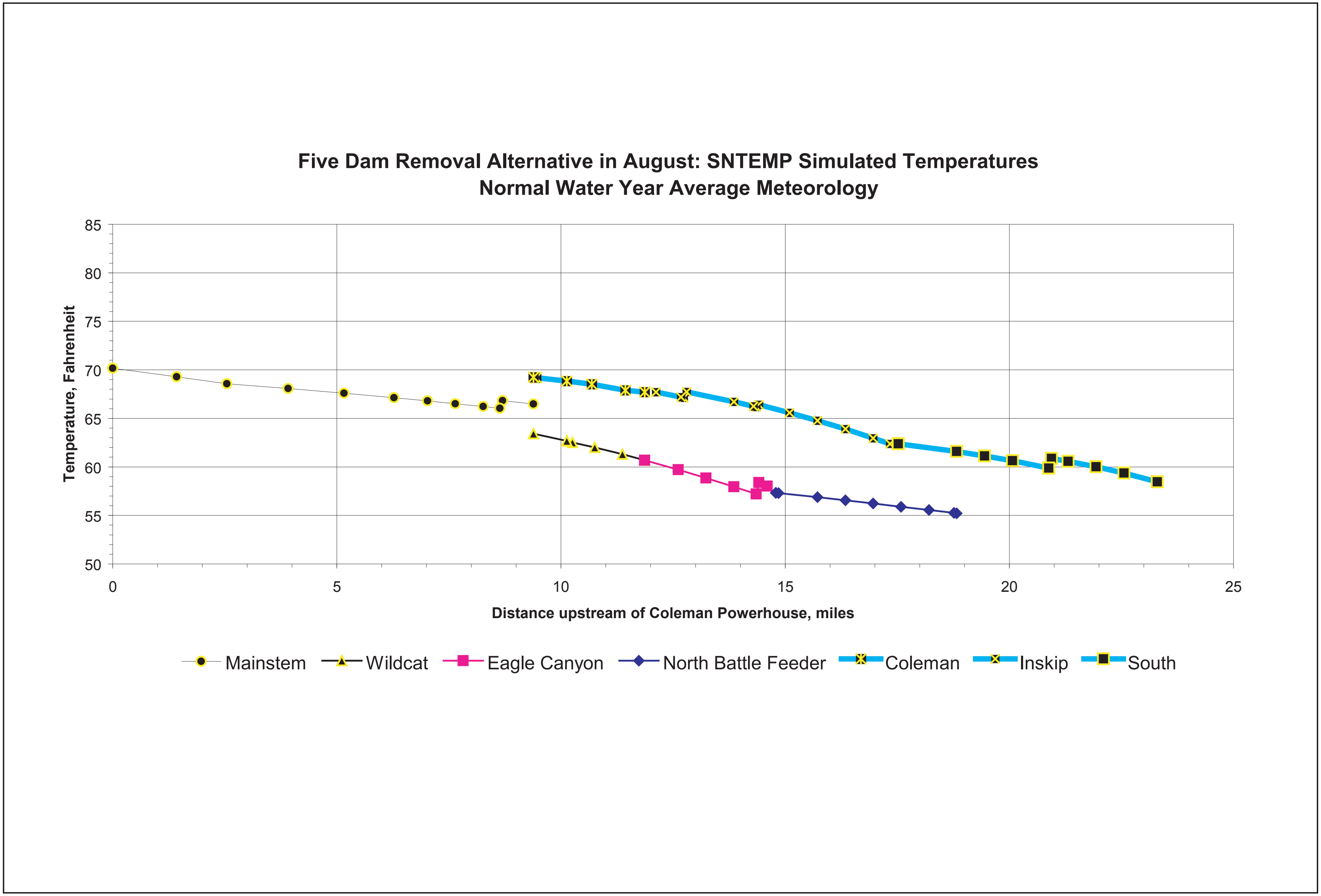
**Figure K-5**
**SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in June**




03035.03 FEIS/EIR

**Figure K-6**
**SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in July**




03035.03 FEIS/EIR

**Figure K-7**
**SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in August**

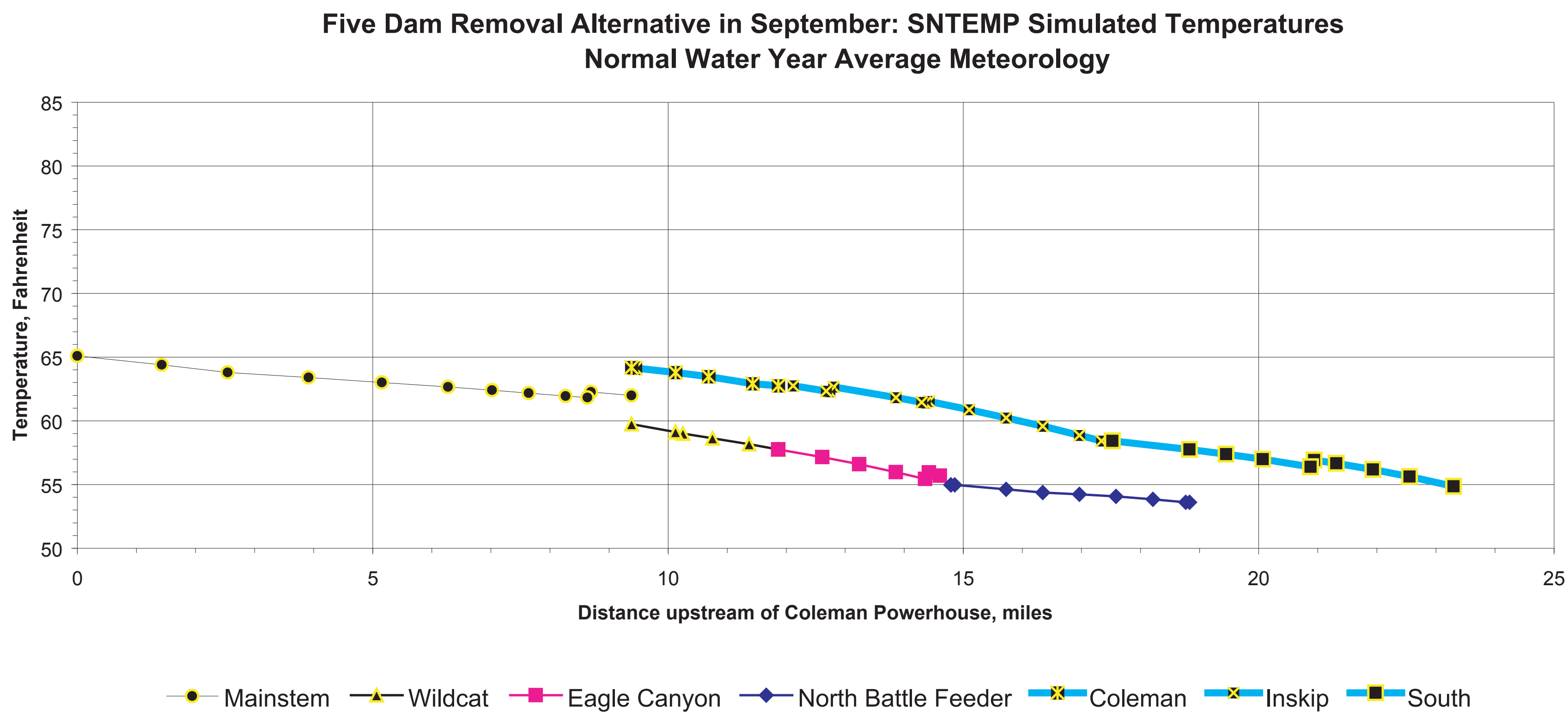



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**Figure K-8**
**SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in September**

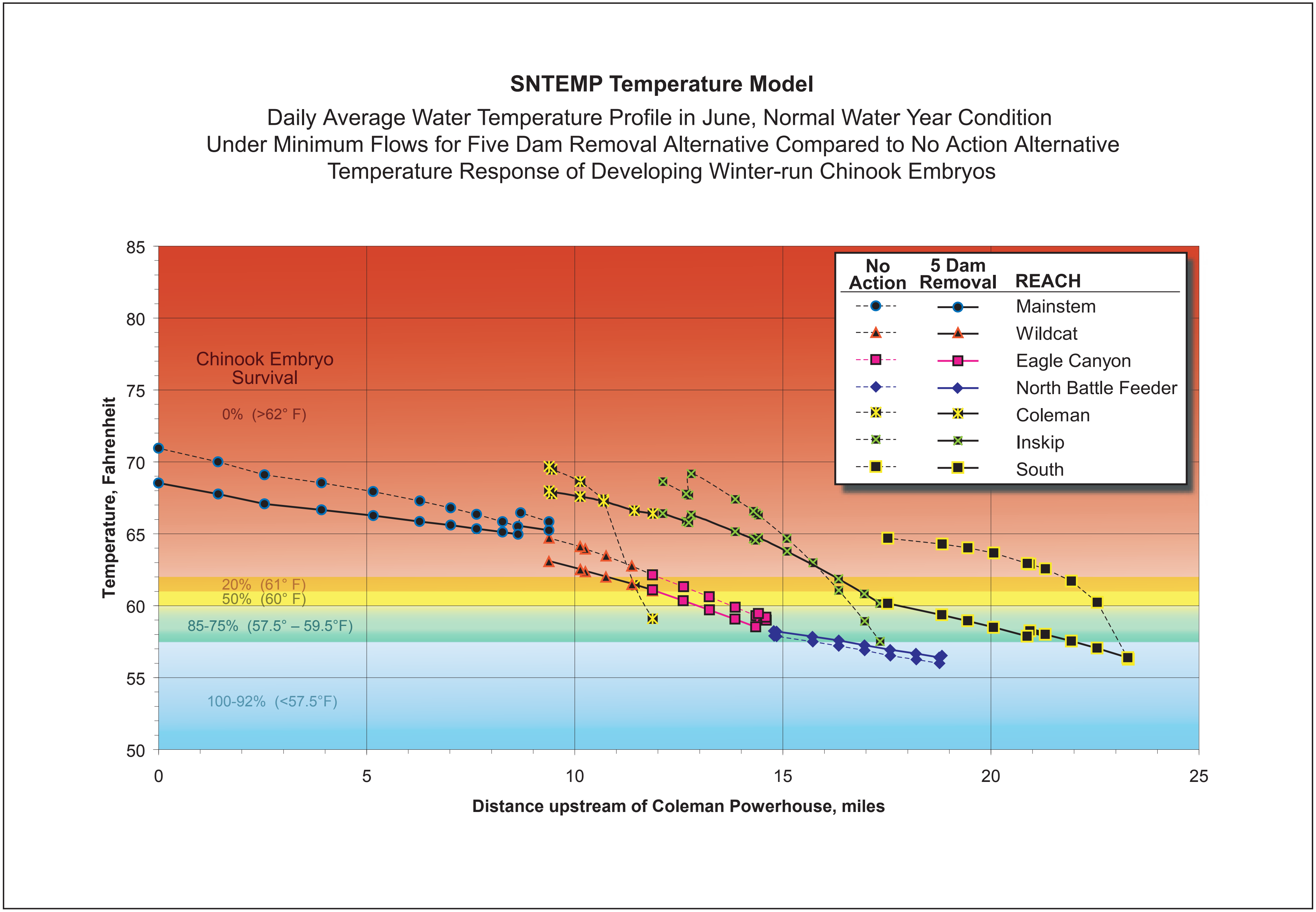


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**Figure K-9**
**Temperature Response of Developing Winter-run Chinook Embryos**
**Daily Average Water Temperature Profile in June**

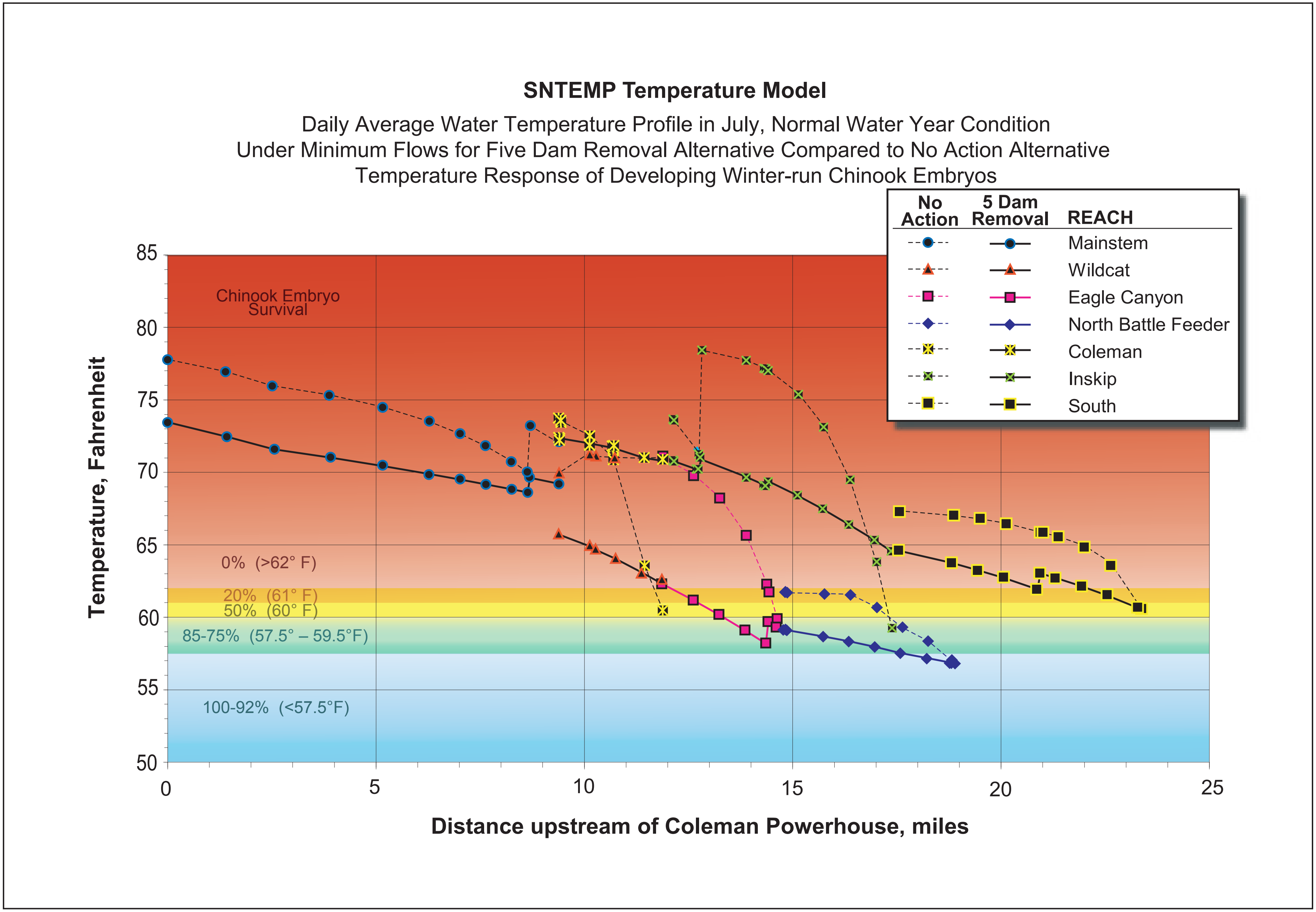


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**Figure K-10**
**Temperature Response of Developing Winter-Run Chinook Embryos**
**Daily Average Water Temperature Profile in July**

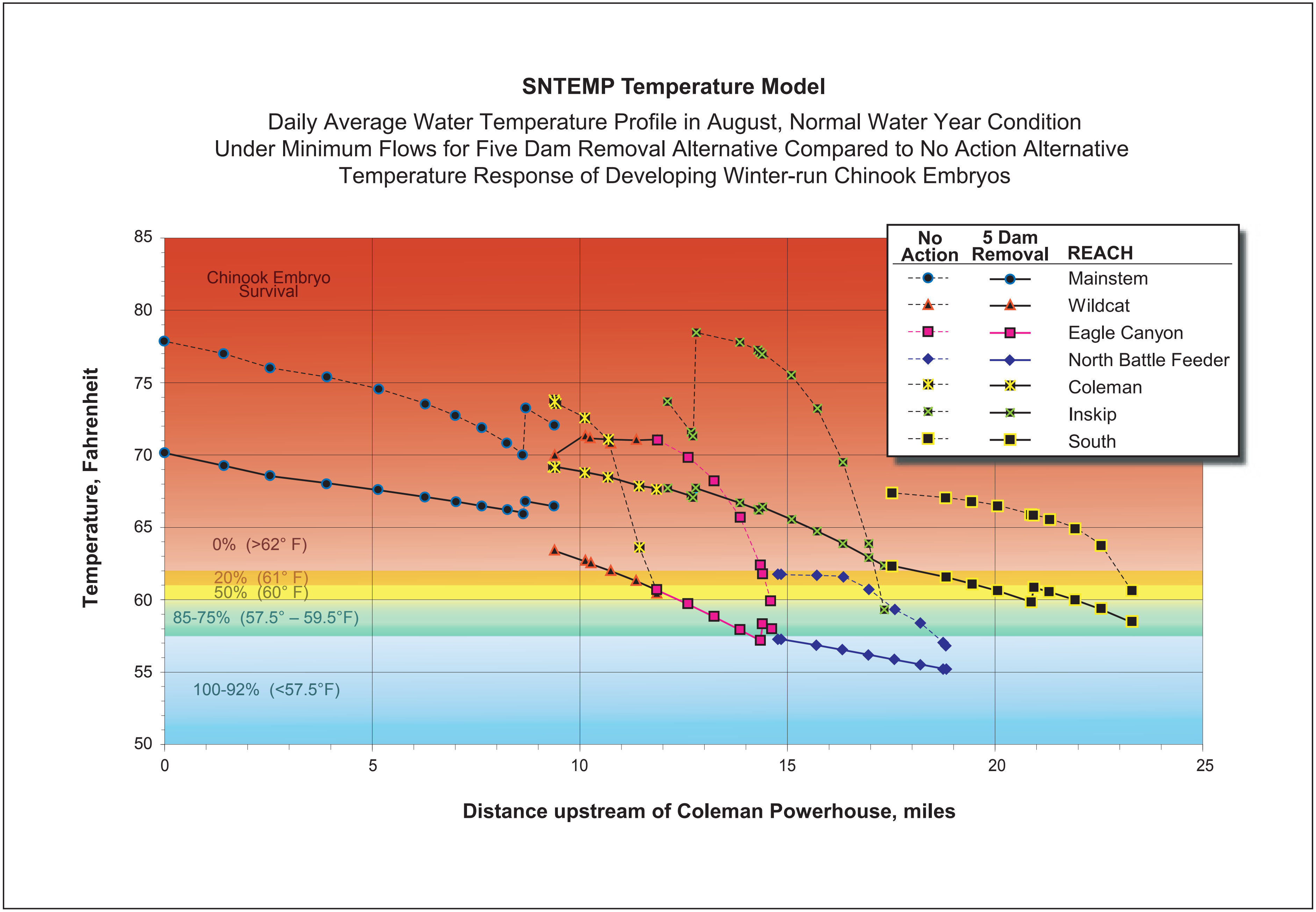


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**Figure K-11**
**Temperature Response of Developing Winter-Run Chinook Embryos**
**Daily Average Water Temperature Profile in August**

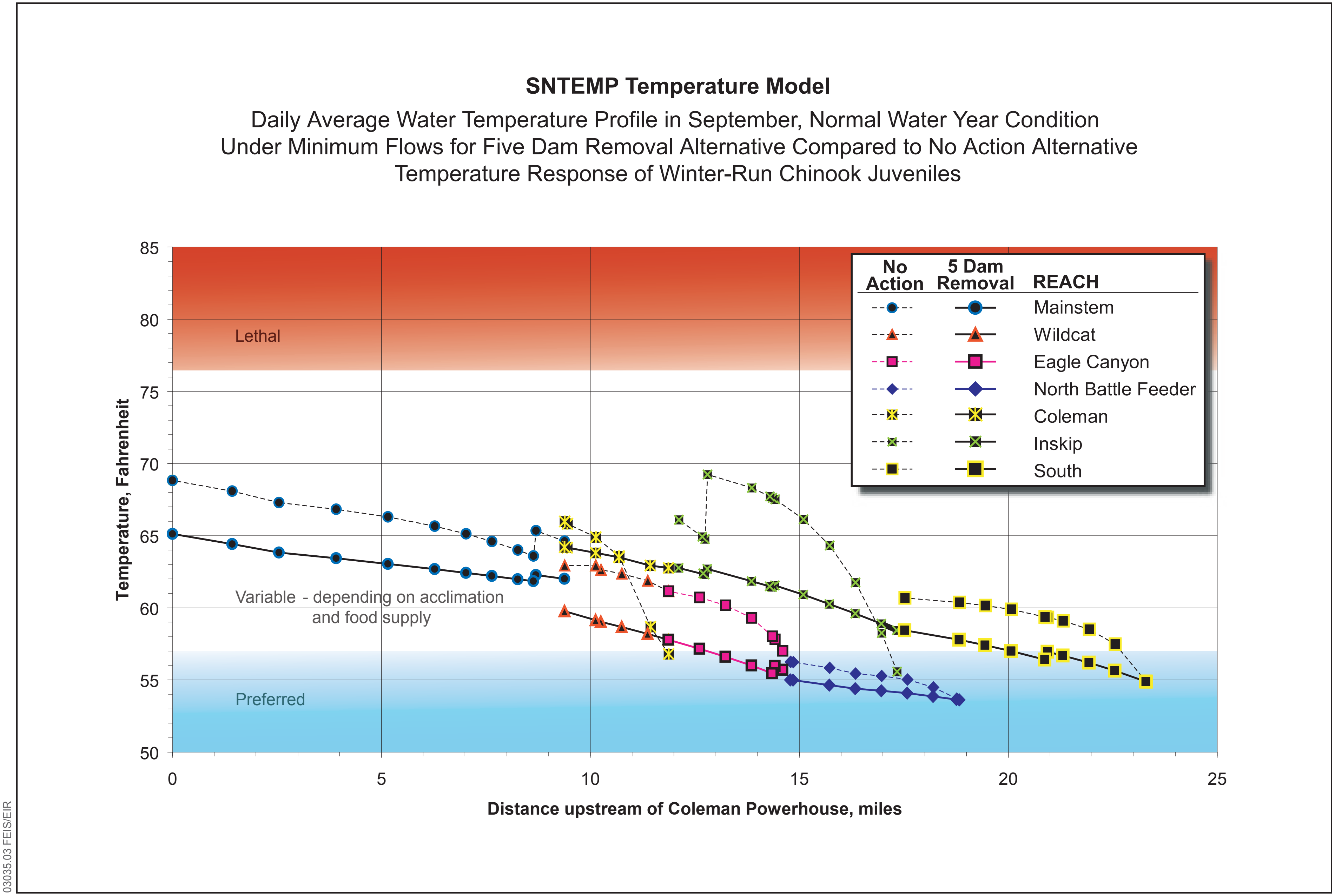
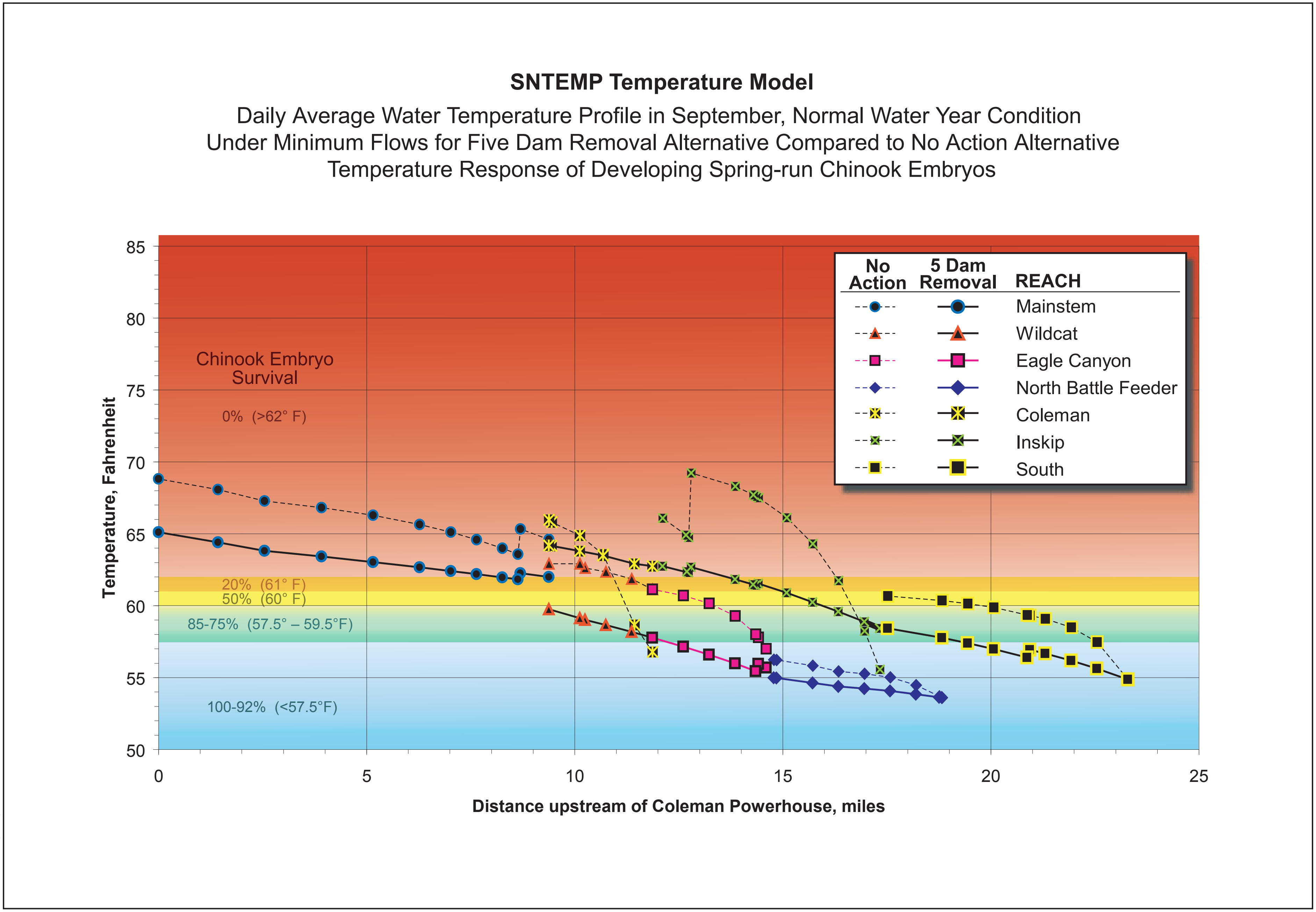



**Figure K-12**
**Temperature Response to Developing Winter-Run Chinook Juveniles Daily Average Water Temperature Profile in September**




03035.03 EIR (7-04)

**Figure K-13**
**Temperature Response of Developing Spring-run Chinook Embryos**
**Daily Average Water Temperature Profile in September**

## SNTEMP Temperature Model

Daily Average Water Temperature Profile in June, Normal Water Year Condition
Under Minimum Flows for Five Dam Removal Alternative Compared to No Action Alternative
Temperature Tolerance of Chinook Smolts

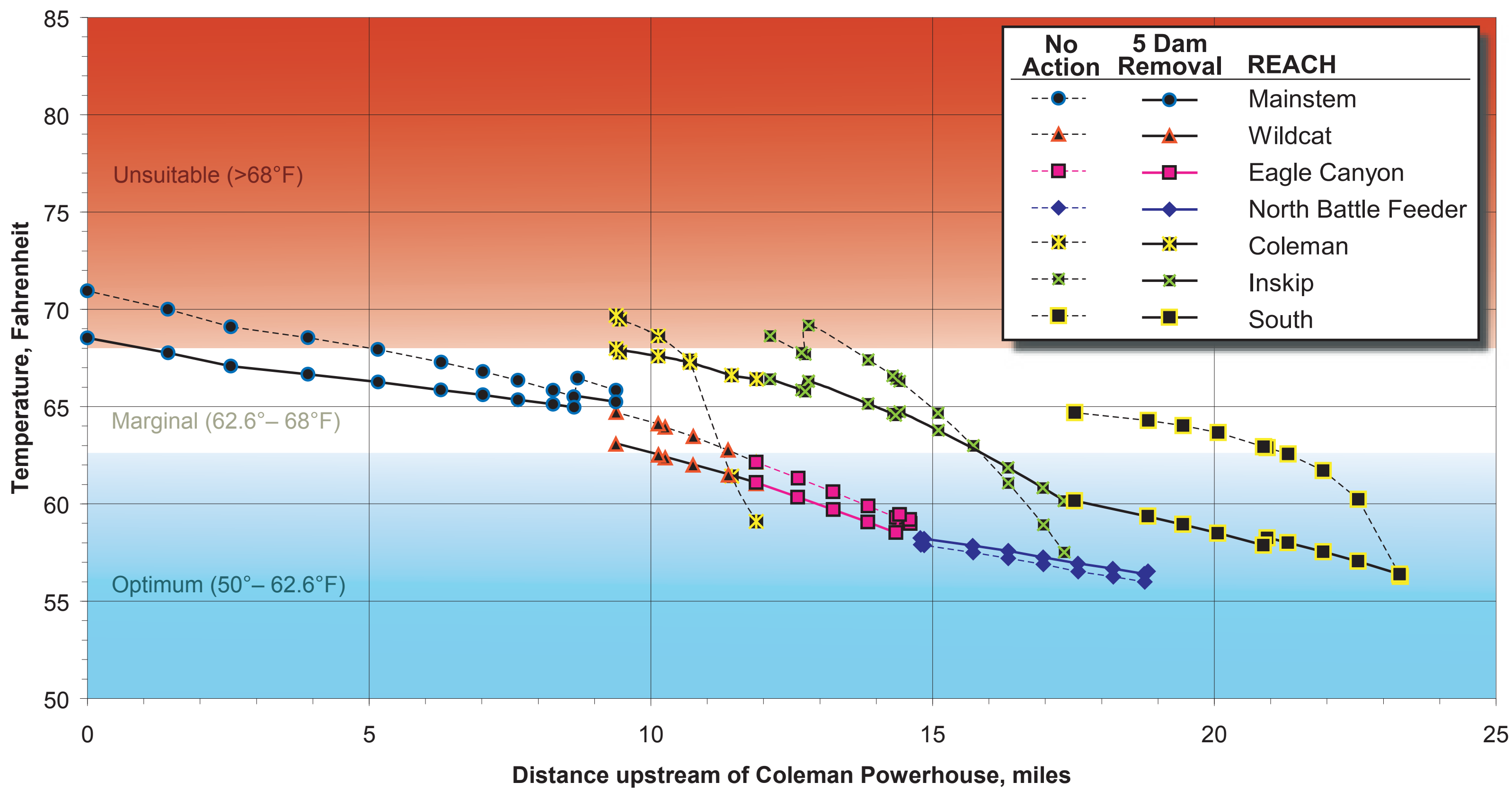
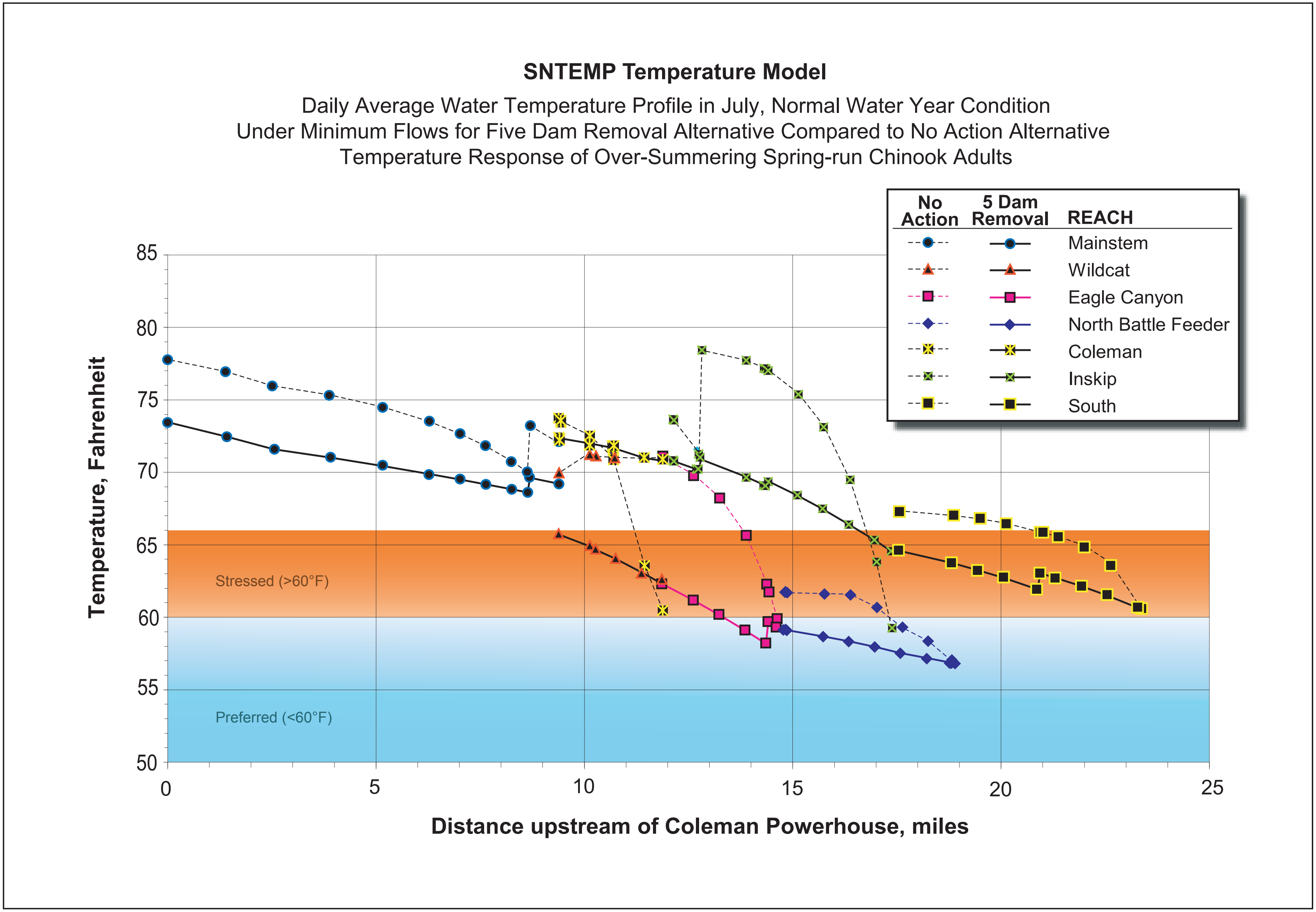


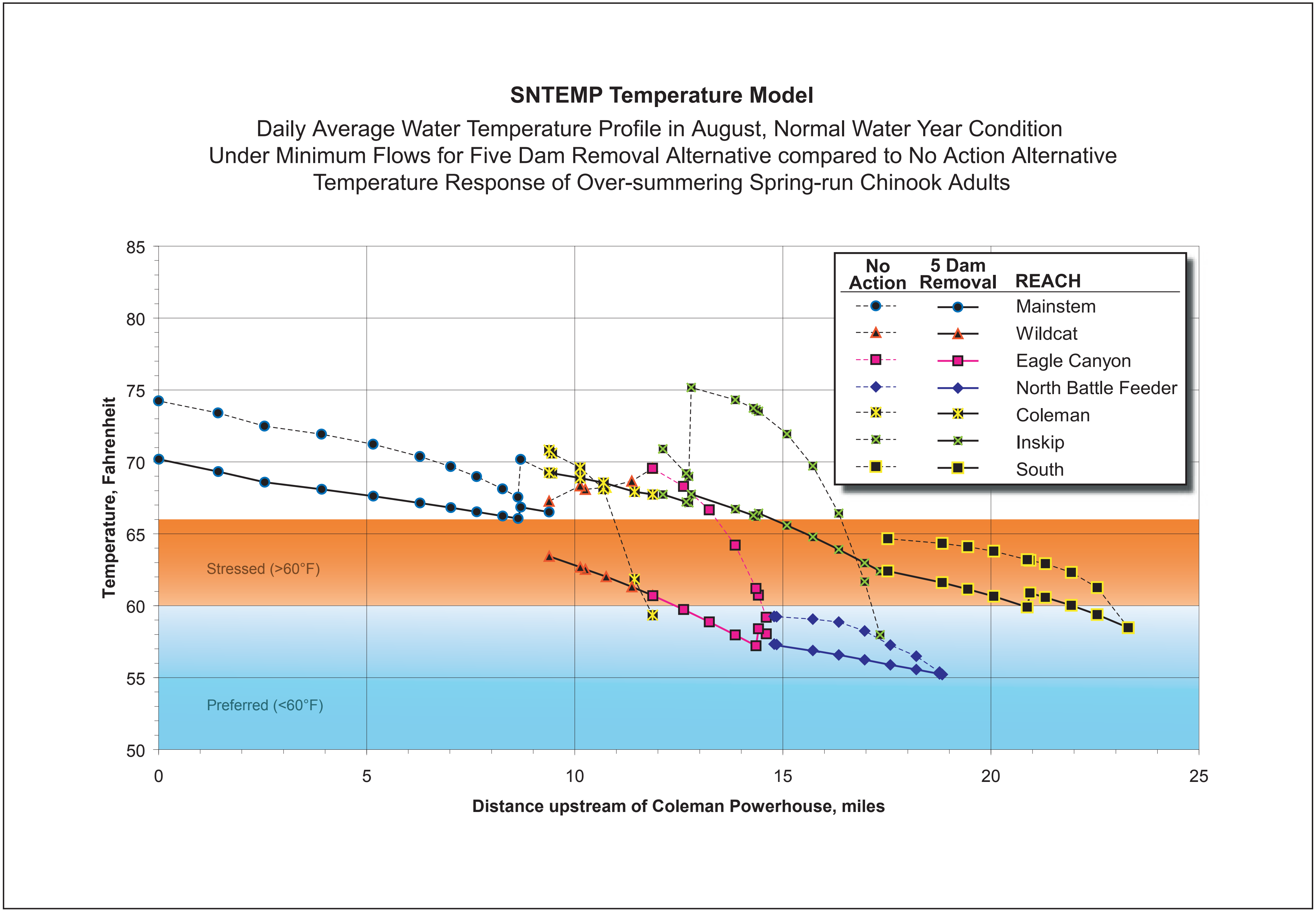



**Figure K-14**
**Temperature Tolerance of Chinook Smolts**



03035.03 FEIS/EIR

**Figure K-15**
**Temperature Response of Over-Summering Spring-run Chinook Adults**
**Daily Average Water Temperature Profile in July**




03035.03 FEIS/EIR

**Figure K-16**
**Temperature Response of Over-summering Spring-run Chinook Adults**
**Daily Average Water Temperature Profile in August**

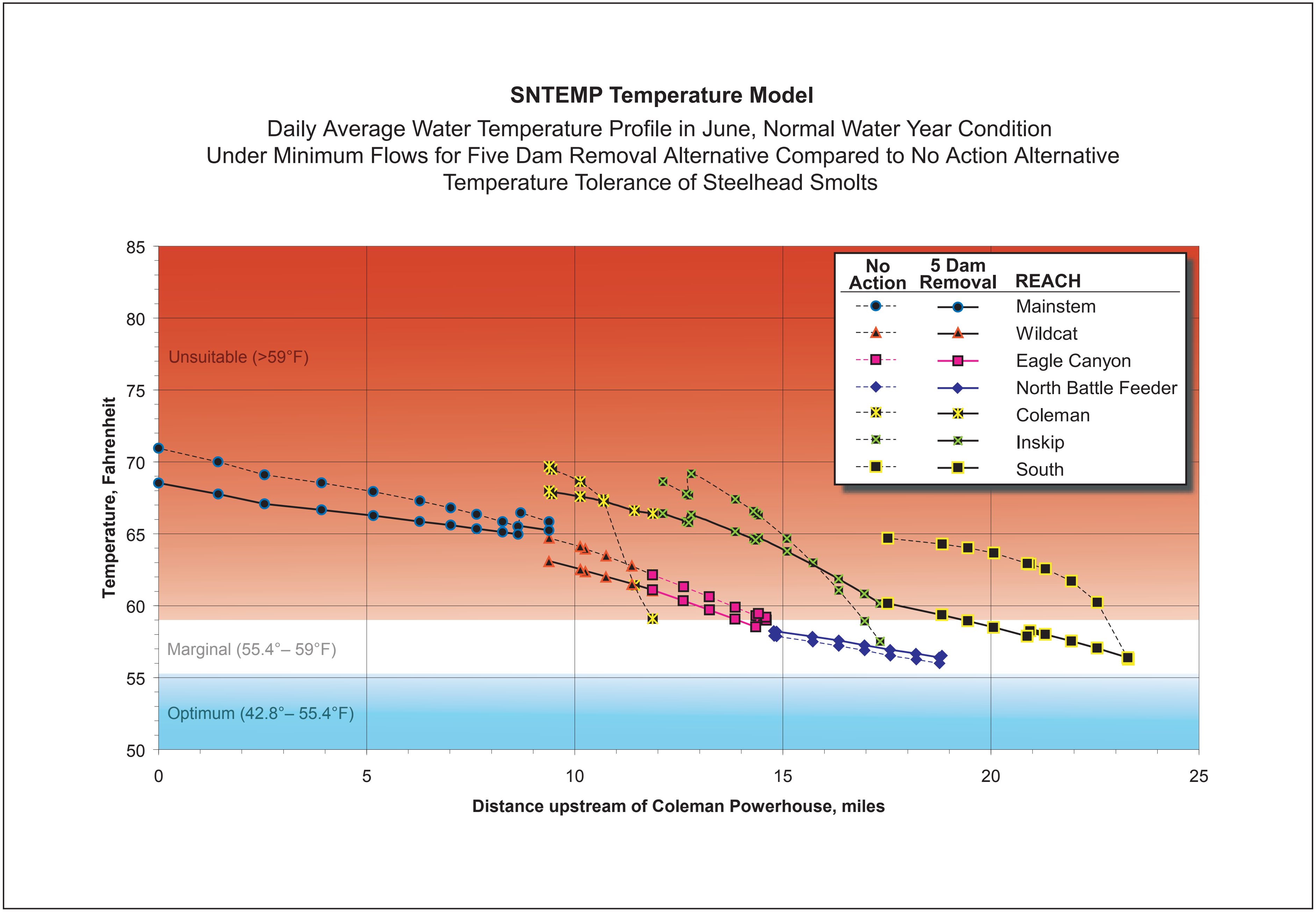



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**Figure K-17**
**Temperature Tolerance of Steelhead Smolts**

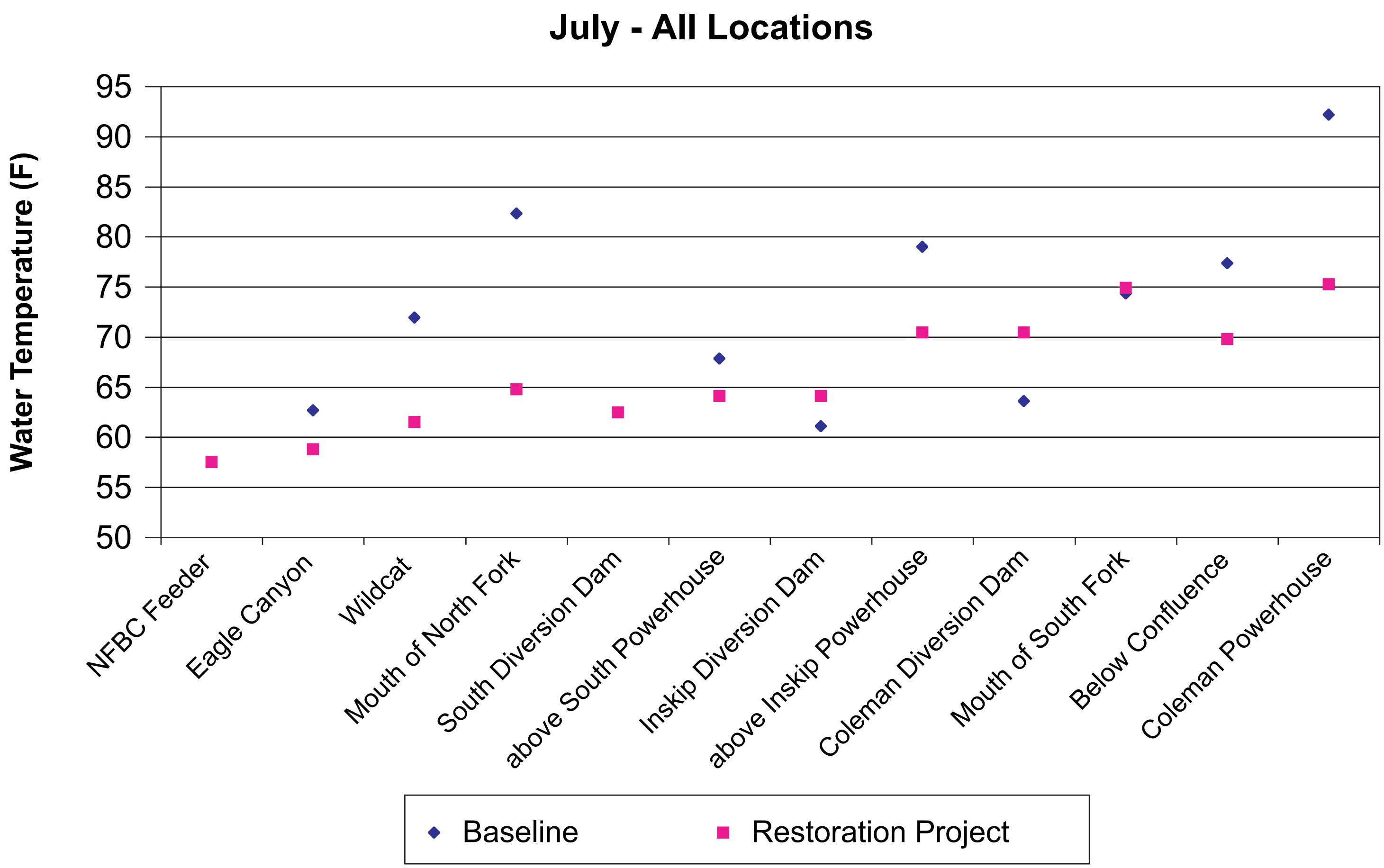


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**Figure K-18**
**Estimated Average July Water Temperature for Selected Locations on Battle Creek, Minimum Instream Flow Requirements under Baseline Conditions and for the Restoration Project**

Figure K-19

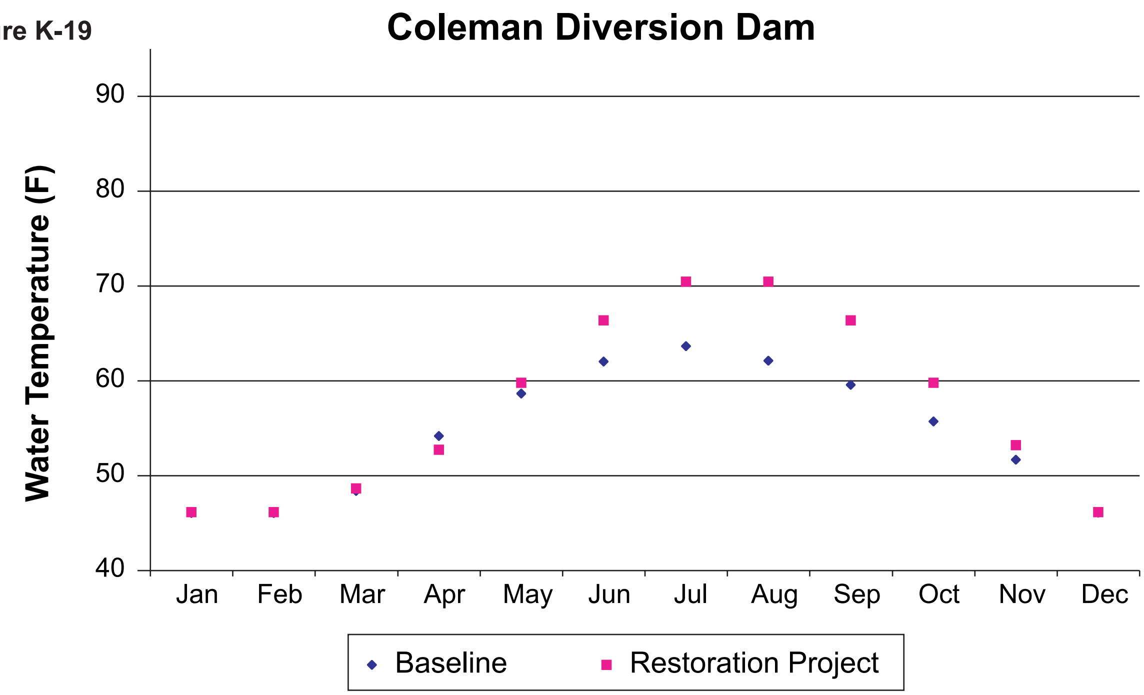
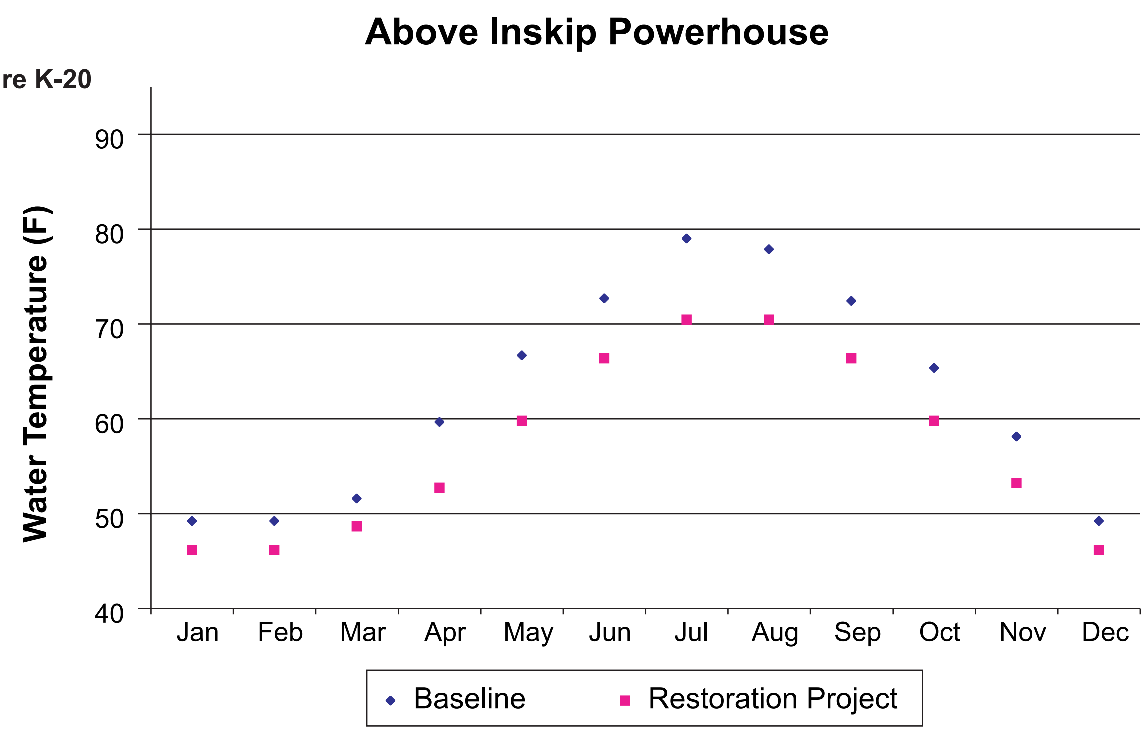



Figure K-20

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**Figures K-19 and K-20**
**Estimated Average Monthly Water Temperature at Coleman Diversion Dam and above Inskip Powerhouse, Minimum Instream Flow Requirements under Baseline Conditions and for the Restoration Project**

Figure K-21

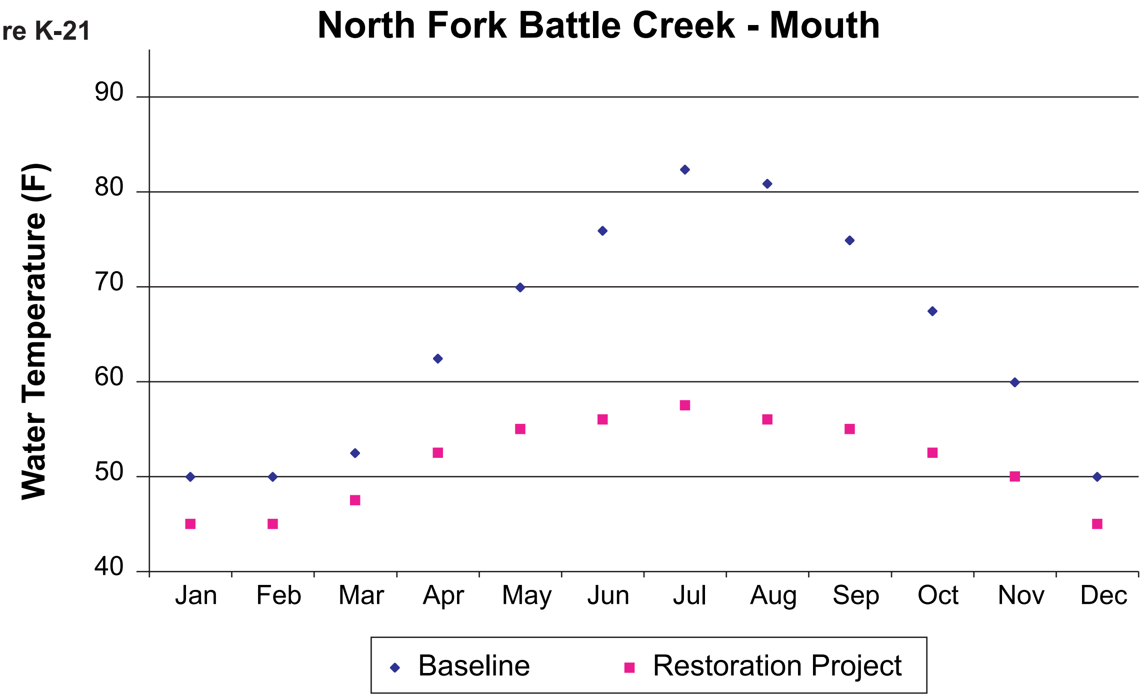
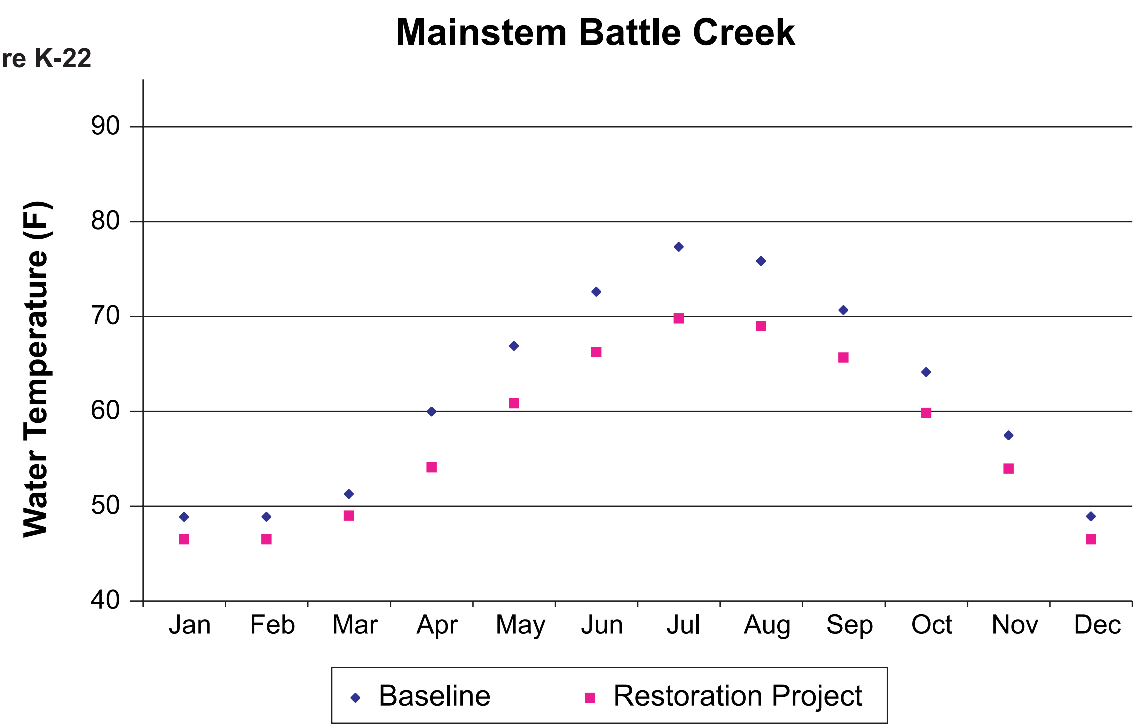



Figure K-22

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**Figures K-21 and K-22**
**Estimated Average Monthly Water Temperature at the Mouth of North Fork Battle Creek and on the Mainstem of Battle Creek, Minimum Instream Flow Requirements under Baseline Conditions and for the Restoration Project**

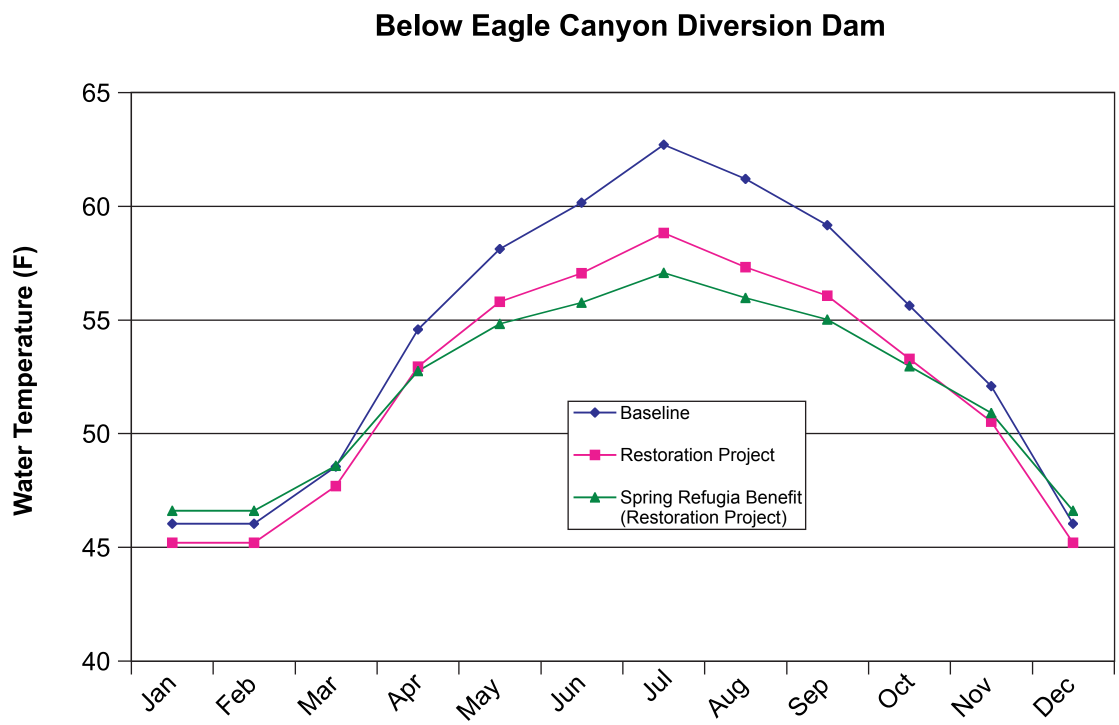


Figure K-23. Water Temperature Effects to North Fork Battle Creek below Eagle Canyon Diversion Dam.

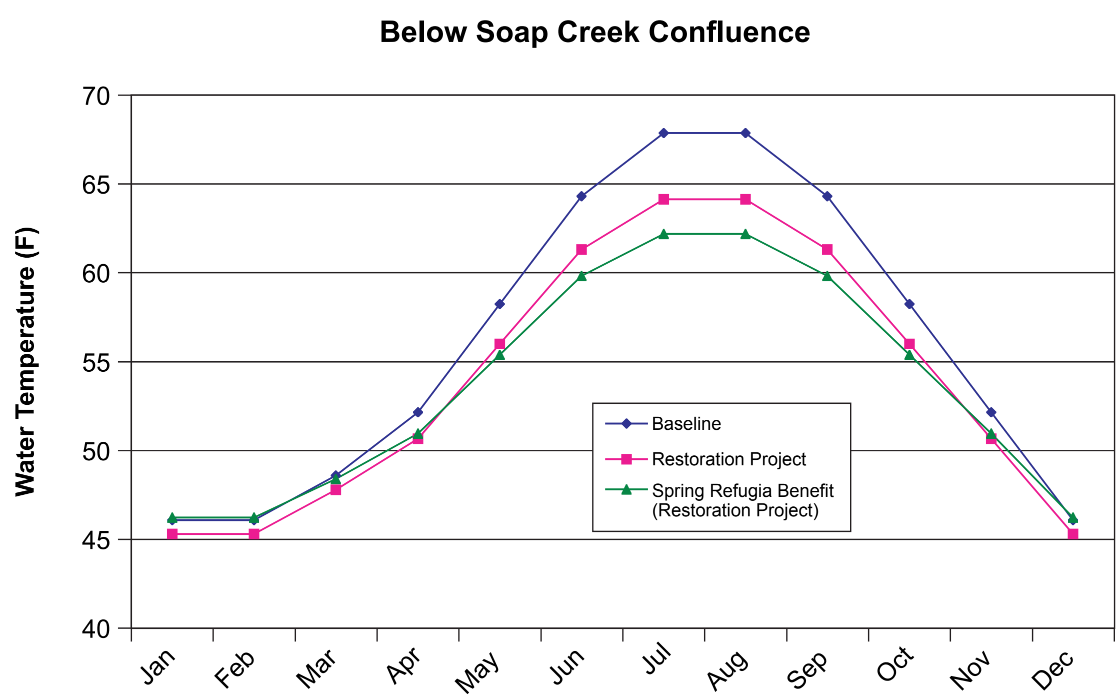


Figure K-24. Water Temperature Effects to South Fork Battle Creek below the Soap Creek Confluence.

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**Figures K-23 and K-24**
**Water Temperature Effects to North Fork and South Fork Battle Creek**