GEORGIANA SLOUGH SALMONID MIGRATORY BARRIER

Operations Plan

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CHAPTER 1
Introduction

1.1 Background and Purpose

Under the federal Endangered Species Act (FESA), the National Marine Fisheries Service (NMFS) issued the 2009 *Biological and Conference Opinion for the Long-Term Operations of the Central Valley Project and State Water Project for Chinook Salmon (Oncorhynchus tshawytscha), Steelhead (O. mykiss), and Green Sturgeon (Acipenser medirostris)* (BiOp; NMFS 2009). Reasonable and Prudent Alternative (RPA) Action IV.1.3 of the BiOp required the California Department of Water Resources (DWR) and/or U.S. Bureau of Reclamation (Reclamation) to consider engineering solutions to reduce the diversion of juvenile salmonids from the Sacramento River into the interior and south Sacramento–San Joaquin Delta (Delta).

In response to the RPA, DWR investigated engineering alternatives to reduce the diversion of juvenile salmonids into the interior Delta. In 2009 and 2010, DWR evaluated a non-physical barrier using Bio-Acoustic Fish Fence™ (BAFF) technology at the Head of Old River. In 2011 and 2012, DWR tested the BAFF technology at the divergence of Georgiana Slough and the Sacramento River. During the 2011/2012 BAFF study, DWR determined that the probability for emigrating juvenile salmonids to be entrained into Georgiana Slough was significantly reduced if the BAFF were operational and if the juvenile salmonids were distributed more toward the right bank of the Sacramento River opposite Georgiana Slough. Based on these results, DWR conducted an additional study in 2014 utilizing a Floating Fish Guidance Structure (FFGS), which is a much simpler technology than the BAFF and focuses on guiding fish toward the right bank. The FFGS was installed on the Sacramento River just upstream of the confluence with Georgiana Slough. DWR determined that the FFGS was efficient at guiding emigrating juvenile Chinook salmon toward the right bank within a specific Sacramento River flow range.

In 2019, Reclamation prepared National Environmental Policy Act (NEPA) compliance documentation (Environmental Impact Statement [EIS]) and completed FESA reinitiation of consultation with the U.S. Fish and Wildlife Service (USFWS) and NMFS on the long-term reoperation of the State Water Project (SWP) and Central Valley Project (CVP). BiOps for the project were issued by USFWS and NMFS on October 21, 2019 and the Final EIS was published on December 19, 2019, and the Record of Decision signed on February 19, 2020. The NMFS BiOp described the 2009 RPA Action IV.1.3 (Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities (including Georgiana Slough Non-Physical Barrier)) as part of the environmental baseline, and recommended its continuation as a conservation measure, as follows (pp. 823 of NMFS BiOp 2019):

> *…Reclamation and DWR should support the following physical and non-physical barrier projects…*
>
> *ii. Non-physical exclusion barrier at Georgiana Slough consistent with DWR's prior pilot study results.*

Under the California Endangered Species Act (CESA), the California Department of Fish and Wildlife (CDFW) issued the 2020 *Incidental Take Permit for Long-term Operation of the State Water Project* (SWP ITP; CDFW 2020). SWP Incidental Take Permit (ITP) Condition of Approval (COA) 8.9.1 includes a requirement for construction and operation of a migratory barrier at Georgiana Slough. The construction and operation of the migratory barrier is required to occur within three years (no later than March 31, 2023) of the effective date of the SWP ITP, i.e., March 31, 2020.

Based on results from the previous BAFF and FFGS studies, and in response to the 2019 NMFS BiOp conservation measure and 2020 CDFW SWP ITP COA, DWR proposes the Georgiana Slough Salmonid Migratory Barrier Project (GSSMB; project).

The GSSMB is being implemented over two phases; the first phase includes planning and design, and construction (anticipated to be completed in winter/spring 2023) and the first year of operation, ending on June 30, 2023. The second phase would begin July 1, 2023 and continue through June 30, 2030, with operations generally occurring from mid-November through May (the key months when listed salmonids are present in the Sacramento River) of each year. Specific details regarding proposed operations of the BAFF (Operations Plan) are required to be developed in coordination with CDFW, NMFS, and USFWS to maximize benefits to migrating listed salmonids, including winter- and Central Valley (CV) spring-run Chinook salmon and California CV (CCV) steelhead. Operation of the GSSMB shall not commence until the final Operations Plan and associated criteria are approved in writing by CDFW.

Similar to the 2011/2012 BAFF study and 2014 FFGS study, the anticipated GSSMB benefits include:

1. Reducing impacts of the SWP and CVP operations by deterring emigrating juvenile salmonids from entering Georgiana Slough and thereafter the central and south Delta. Survival is lower in the Delta interior relative to remaining in the mainstem Sacramento River, thus avoidance of this route will improve survival to Chipps Island;

2. Maintaining SWP compliance with FESA and CESA; and

3. Maintaining existing through-Delta water conveyance with reduced impacts on juvenile salmonids by reducing the number of juvenile salmonids that enter the central and south Delta.

CHAPTER 2
Project Description

2.1 Project Location

The GSSMB project site is situated along the Sacramento River at its junction with Georgiana Slough in the north Delta, with staging areas adjacent to the town of Hood, Sutter Slough, Steamboat Slough , and Georgiana Slough (Point Ranch Property) junctions, and the Delta Cross Channel (DCC) (see **Figure 1** and **Figure 2**). **Table 1** summarizes project locations, from upstream to downstream on the Sacramento River.

TABLE 1
SUMMARY OF PROJECT LOCATIONS

Area Name	Starting and Ending Sacramento River Mile#	Nearest Town or Community	GSSMB Activity	Description of Staging Area(s)
Sacramento	59	Sacramento	Study fish release	A possible study fish release site is located at a developed portion of the Sacramento River waterfront (City dock platform under the Tower Bridge).
Hood	–	Hood	Staging only	Possible staging area, approximately 1.8 acres, located on the left bank in Hood west of SR 160. Herein referred to as the “Hood staging area.”
Sutter Slough	34.1 to 34.3	Paintersville	Staging only	Possible staging area, approximately 1.8 acres, on the left bank of Sutter Slough (does not include the Sutter Slough Bridge). Herein referred to as the “Sutter Slough staging area.”
Steamboat Slough	31.8 to 32.9	Paintersville	Staging and study fish release	Possible staging area and study fish release site, approximately 0.46 acre, on the right bank of Steamboat Slough (does not include the Steamboat Slough Bridge). Herein referred to as the “Steamboat Slough staging area.”
DCC	27.0 to 27.2	Locke	Staging only	Possible staging area, approximately 0.9 acre, located on the Sacramento River left bank, south of the DCC. Herein referred to as the “DCC staging area.”
Georgiana Slough	26.4 to 26.7	Walnut Grove	BAFF and study fish release	One potential land-based staging area/area for utilities access (known as the Point Ranch Property), approximately 1.7 acre, is located at a point on the confluence of the Sacramento River and Georgiana Slough. If access to the Point Ranch Property is not available, a barge/flexi-floats with a diesel generator(s) to supply power necessary to operate the BAFF would be located on the water adjacent to the Georgiana Slough project site. On the Sacramento River, DWR would use barges and docks along the left bank. A possible study fish release site is located approximately 2 miles downstream of the BAFF location and junction with the Sacramento River.

NOTES:

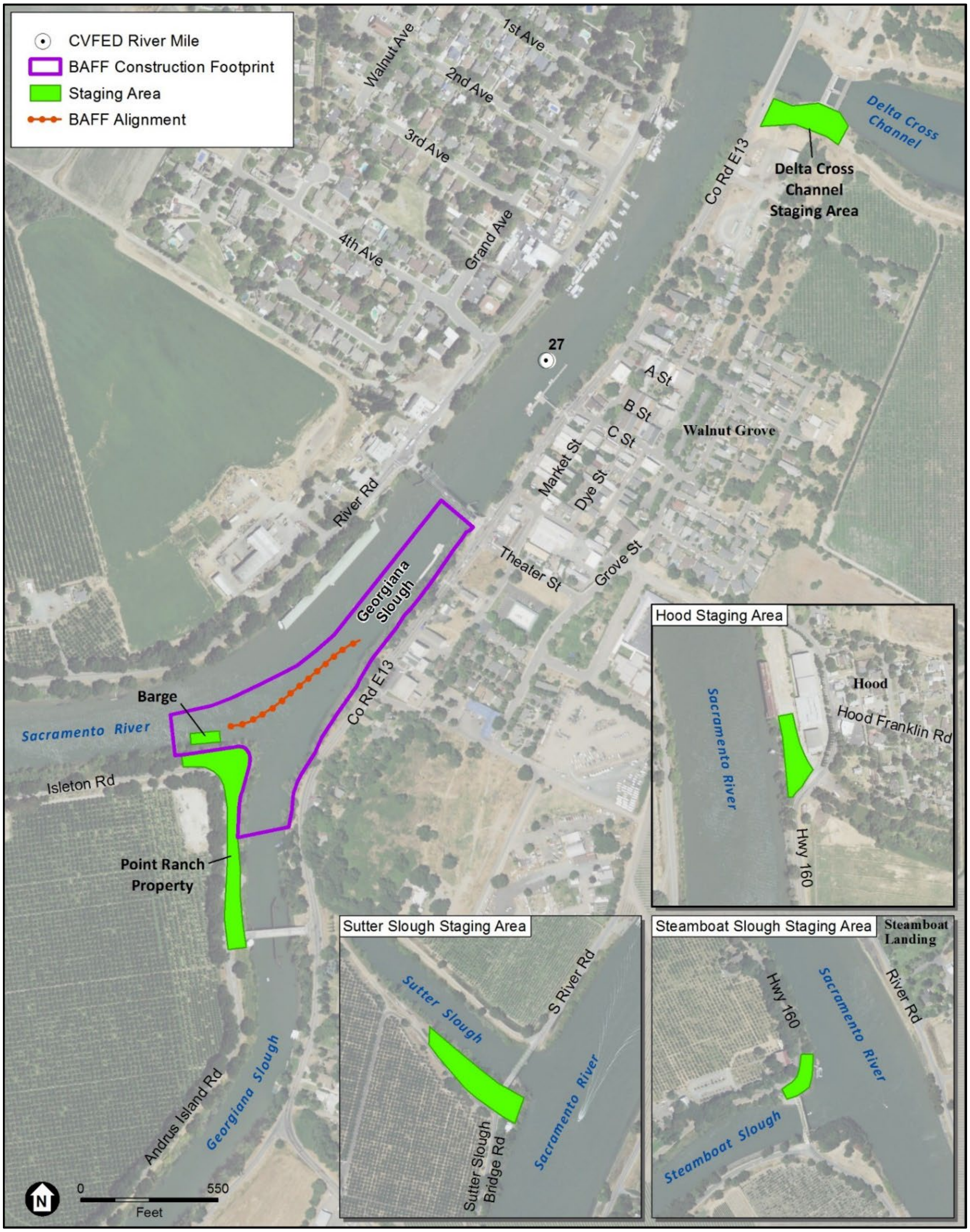
BAFF = Bio-Acoustic Fish Fence™; DCC = Delta Cross Channel; DWR = California Department of Water Resources; GSSMB= Georgiana Slough Salmonid Migratory Barrier; SR = State Route.

The river miles were obtained by using the Clarksburg, Courtland, and Isleton U.S. Geological Survey 7.5-Minute Quadrangles.

SOURCE: Data provided by DWR in 2020

SOURCE: USGS Topo; adapted by ESA, 2020

Figure 1
Georgiana Slough Salmonid Migratory Barrier Overview Map



SOURCE: USDA, 2018; adapted by ESA, 2020

Figure 2
Detailed Map—Georgiana Slough Junction and Staging Areas

2.2 Project Overview

The GSSMB builds on the 2011 and 2012 BAFF and 2014 FFGS studies; however, under the proposed project, the BAFF would seasonally operate from early 2023 through 2030 at the Georgiana Slough junction. Similar to previous studies, the BAFF is being operated as a behavioral deterrent to prevent Sacramento River juvenile salmonids from entering Georgiana Slough during emigration (see additional details below).

DWR proposes the following for the proposed GSSMB:

- Bio-Acoustic Fish Fence (BAFF): The BAFF would be constructed each year in the Sacramento River at Georgiana Slough and would be operated during the winter and spring periods (see below). Up to 31 steel piles (up to 24-inch-diameter) and four concrete pier blocks (up to 24-inch-diameter) would be installed. Piles associated with the BAFF would be retained throughout the project, with removal scheduled at the end of the project period (2030).

- Navigation Aids: Up to 40 concrete anchor blocks would be used for navigation aids, such as buoys and signs at the Sacramento River/Georgiana Slough junction when the BAFF is installed.

- Fish Tracking and other Data Collection Monitoring Equipment: Acoustic telemetry hydrophones/receivers and up to 18 steel piles at the Georgiana Slough junction (up to 24-inch-diameter) would be used to attach equipment for hydroacoustic and hydrodynamic barrier operational monitoring.

- Barrier Construction and Operation Window: To limit the potential for impacts on listed fishes, marine construction, which is defined as pile driving and the installation of anchors and pier blocks, would occur between August 1 and September 30 of each year, when feasible. It is anticipated that the BAFF would be installed in winter/spring (conditions permitting) and be operational during winter and spring periods each year. Specific details regarding proposed operations of the BAFF are described below.

  The barrier components would be removed by the end of June. Mobilization and demobilization, both land- and water-based, would occur within 15 days prior to and after each activity. Supporting infrastructure, including piles, would remain in place throughout the year during the duration of the project (early 2023 through 2030).

- Staging Area Improvements: To prepare, install, and operate the BAFF, DWR may conduct improvements, such as adding gravel and grading at the staging areas. To provide electricity to the potential Point Ranch Property staging area (adjacent to Georgiana Slough), DWR may install a new power pole. The new power pole would replace an existing pole located on the Point Property in an existing disturbed area that is clear of vegetation and other sensitive resources.

- Operations Staging Area: This area will consist of multiple conex boxes used to house the BAFF operations and control equipment and air compressor system, and an office trailer. Other BAFF operating equipment such as the air manifold system with rain shelter, portable power distribution panel and temporary security fencing will also utilize this area.

- <u>Barrier Removal and Site Restoration:</u> As described above, to limit the potential for impacts on listed fishes, marine construction (i.e., removal of piles) would occur between August and September of each year, when feasible. The BAFF components would be removed by the end of June. Supporting infrastructure, including piles, would be removed at the completion of the project. Piles would be removed utilizing a vibratory hammer to unseat the pile and/or by cutting the pile below the substrate line (i.e., bed of river). All equipment would be removed from staging areas and the sites would be restored to prior existing conditions.

- <u>Performance Monitoring:</u> Each year DWR will conduct monitoring to assess performance of the BAFF. This may include the installation of fish tracking and other data collection monitoring equipment, including steel piles at the Georgiana Slough junction to attach equipment for hydroacoustic and hydrodynamic barrier operational monitoring. DWR would also tag and release hatchery-reared juvenile Chinook salmon and steelhead for acoustic telemetry-based fish tracking. DWR may also capture, tag, and release predatory fish by hook-and-line sampling. DWR would release acoustic-tagged juvenile Chinook salmon and/or steelhead at one or more sites. Lastly, the monitoring plan will consider monitoring and performance measures associated with operations timing and associated fish presence, including specific targets and objectives intended to minimize the down-time of the BAFF during periods of winter-run and spring-run Chinook salmon emigration, which may include information regarding annual comparisons of operating periods with emigration timing (e.g., fish presence at rotary screw trap monitoring locations, seine data, eDNA). Details of performance monitoring are being developed as part of a separate monitoring plan.

As described above, the GSSMB builds on the 2011 and 2012 BAFF studies; however, under the proposed GSSMB project, several improvements have been made to improve BAFF system operations and reliability. These improvements include the following:

- Re-designed the air system for automation and remote operation, improved diagnostics, and reliability.
- Modular packaged, and fully integrated compressed air system.
- New power cables that make handling, deployment, and storage much easier.
- Remote monitoring and operating capabilities.
- Redundancy in power and communication units to minimize operating down time.
- Installation of a Pacific Gas and Electric Company (PG&E) power source to increase operational reliability, reduce environmental impacts (carbon emissions from using generators), and eliminate the hazards (environmental, personnel) of working with fossil fuels to power electrical generators. (Note, see additional discussion below regarding seasonal PG&E power limitations.)

2.3 Project Schedule

The annual construction/operation period is anticipated to begin July 1 and end June 30. Marine (i.e., in-water) construction is anticipated to take up to 30 days and would generally occur between August 1 and September 30 to avoid or minimize the potential for impacting Delta Smelt and Chinook salmon and/or steelhead migrating through the Delta. However, during year one, in-water construction may occur during January/February (2023) due to permit approval delays. Barrier and study/ data collection equipment (e.g., fish tagging station, hydrophones) installation (i.e., installation activities other than marine construction) is also anticipated to take up to 30 days and would occur prior to operations.

Removal consists of two separate activities: (1) removal of the barrier components and study/data collection equipment (by end of June on annual basis), and (2) removal of the piles and remaining supporting infrastructure (August and September; annual basis and at end of ITP period [2030]). DWR would remove the BAFF and study/data collection equipment between June and September after each operational period. DWR may remove the piles associated with the BAFF to reposition the alignment as necessary in future years. Because removal of the piles may require use of a vibratory hammer, DWR would complete this activity within or as close to August/September to the maximum extent practicable.

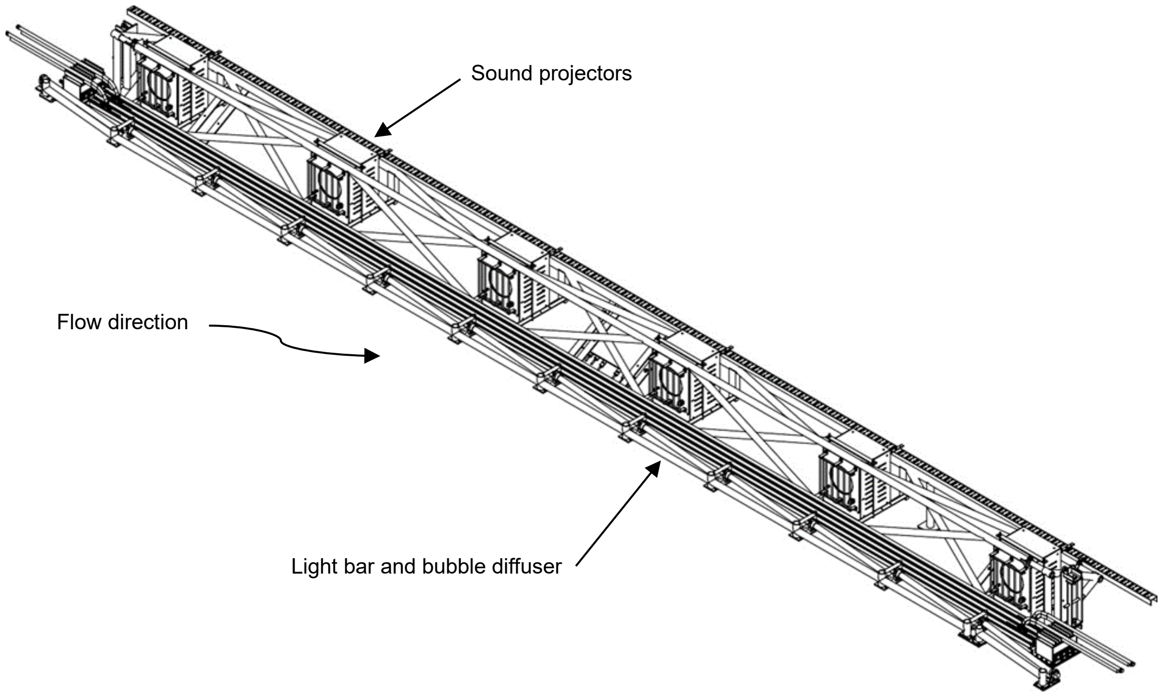
2.4 Non-Physical Barrier Technology

The GSSMB consists of a BAFF that would be installed, operated, and monitored from 2023 through 2030 at Georgiana Slough. Similar to the previous studies, the BAFF is being implemented and monitored for its effectiveness as a behavioral deterrent to prevent emigrating juvenile salmonids in the Sacramento River from entering Georgiana Slough (DWR 2015; Romine et al. 2016).

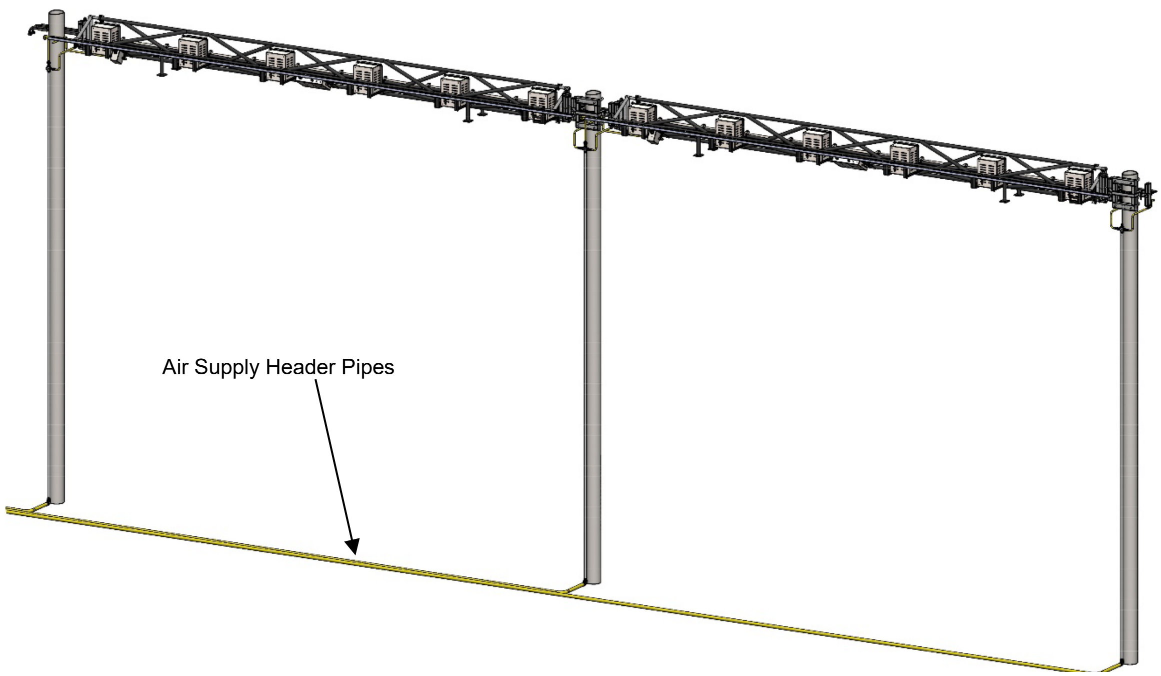
2.4.1 Bio-Acoustic Fish Fence (BAFF)

The BAFF is a multi-stimulus fish barrier that combines high-intensity light-emitting diode (LED) modulated intense lights (MILs), an air bubble "curtain," and sound emitted at frequencies and levels that are repellent to Chinook salmon (Bowen et al. 2012; Bowen and Bark 2012). The sound system and MIL flash rate can be tuned to known sensitivities of various fish species. Investigations have indicated that the most effective acoustic deterrents for multiple fish species fall within the sound frequency range of 5 to 600 hertz (Hz) (Bowen and Bark 2012). Studies with Chinook salmon and Delta Smelt have shown that when the sound and strobe light flash rate were tuned according to these species' sensitivities, the barrier was particularly effective as a deterrent for juvenile Chinook salmon (Bowen et al. 2008). Based on these studies, it has been hypothesized that sound is the deterrent. The sound is trapped by refraction within the bubble curtain, producing a sharply defined sound field that fish do not detect until within close proximity to the barrier. The flashing MILs are aligned such that the light beam projects onto the bubble curtain. This helps identify the bubbles so that the source of the sound can be determined by the fish. The narrow, vertical MIL beam minimizes light saturation within the experimental area.

The BAFF, installed at the divergence of the Sacramento River and Georgiana Slough, would be up to approximately 800 feet long, comprising up to 20 separate 40-foot frame sections. Each frame section would have approximately six sound projectors, 12 MILs, and a perforated "bubble" pipe (**Figure 3 A**). The bubble pipe would be positioned along each frame below and upstream of the sound projectors. A bubble curtain would be created by passing compressed air into the perforated pipe. Air flow rate would typically be 1.38 cubic feet per minute (cfm) per linear foot length of barrier. The MILs would be powered from an "accumulator" positioned on each frame section. A mounting plate would be attached to the support tray to house the accumulators. The junction of each frame section can pivot with the adjacent section, and where needed each frame section can be supported at either end with a piling or support column to a pier block. The frame sections could be adjusted vertically at the pile attachments to adjust for the uneven riverbed contour. The sections would be positioned along the barrier line such that its effectiveness would be optimized. In the main portion of the channel, this is approximately 12 feet from the channel bottom (**Figure 3 B**). The top of the frame sections would be at least 6 feet below the water surface elevation at low tide. The barrier frame would be supported by up to 31 piles (up to 24-inch-diameter) in the riverbed. Up to four concrete pier blocks (up to 24-inch-diameter) would be situated in shallow water to ensure the system remains in alignment.



A) Three-dimensional rendering of BAFF frame with light, sound, and bubble diffuser components.



B) Three-dimensional rendering of BAFF frame suspended off riverbed on piles.

Source: Renderings provided by Fish Guidance Systems in 2021

Figure 3
Conceptual Design of the Bio-Acoustic Fish Fence

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CHAPTER 3
Operational Considerations

This chapter provides a summary overview of primary operational considerations.

3.1 Salmonid Migration Windows

Salmonid migration windows are presented below as a basis for informing the operational periods of the GSSMB.

3.1.1 Sacramento River Winter-Run Chinook Salmon

Sacramento River winter-run Chinook salmon (WRCS) was listed as endangered in 1994 (59 FR 440). Juvenile WRCS outmigration through the Delta occurs from October through April (**Table 2**). While Delta presence is greater in December through April, early migrating natural WRCS are present in October and November (ITP) (CDFW 2020).

3.1.2 Central Valley Spring-Run Chinook Salmon

Central Valley spring-run Chinook salmon (SRCS) was listed as threatened by NMFS in 1999 (64 FR 50394). Juvenile SRCS outmigration through the Delta occurs from December through May. While presence is greatest in April and May, outmigrating juveniles are present December through March.

TABLE 2
TEMPORAL OCCURRENCE OF JUVENILE SACRAMENTO RIVER WINTER-RUN AND SPRING-RUN CHINOOK SALMON IN THE DELTA

Relative Abundance	High (^)			Medium (x)			Low (#)			None (-)		
Species	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WRCS	#	x	^	x	-	-	-	-	-	#	#	x
SRCS	#	#	#	^	x	-	-	-	-	-	-	#

Source: NMFS (2019). Data from Delta Juvenile Fish Monitoring Program.

3.2 Fish Hatchery Releases

Under drought conditions, water temperatures in the lower Sacramento River can exceed 20° C which are stressful for salmon and can lead to increased mortality. According to the EPA, migrating juvenile salmon exposure to water temperatures of 20° C for extended periods of time may cause increased disease, impaired smoltification, reduced growth, and increased predation

(U.S. Environmental Protection Agency 2003). In laboratory studies, increased mortality of juvenile Chinook salmon generally occurred when water temperatures exceeded 20° (Yates et al., 2008).

The Coleman National Fish Hatchery produces millions of juvenile salmon each year for release into the Sacramento River. The fish are released downstream of the hatchery into Battle Creek, a tributary to the Sacramento River, to begin their journey downstream into the Pacific Ocean. In some years, however, drought conditions have forced the hatchery to truck salmon to the San Francisco Bay to increase survival. Transporting juvenile salmon to the San Francisco Bay occurred in 2014, 2015, and 2021, all of which were drought years.

The Livingston Stone National Fish Hatchery, a substation of the Coleman National Fish Hatchery complex, is located at the foot of the Shasta Dam. It is the only fish hatchery to produce winter-run Chinook salmon. It typically produces approximately 250,000 juvenile winter-run Chinook salmon for releases each February.

The Feather River Fish Hatchery produces millions of juvenile fall- and spring-run Chinook salmon each year for release into the Feather River. Similar to Coleman, in some years, however, drought conditions have forced the hatchery to truck salmon to the San Francisco Bay to increase survival.

The Nimbus Fish Hatchery produces millions of juvenile Chinook salmon and steelhead each year for release into the American River. Similar to Coleman, in some years, however, drought conditions have forced the hatchery to truck salmon to the San Francisco Bay to increase survival.

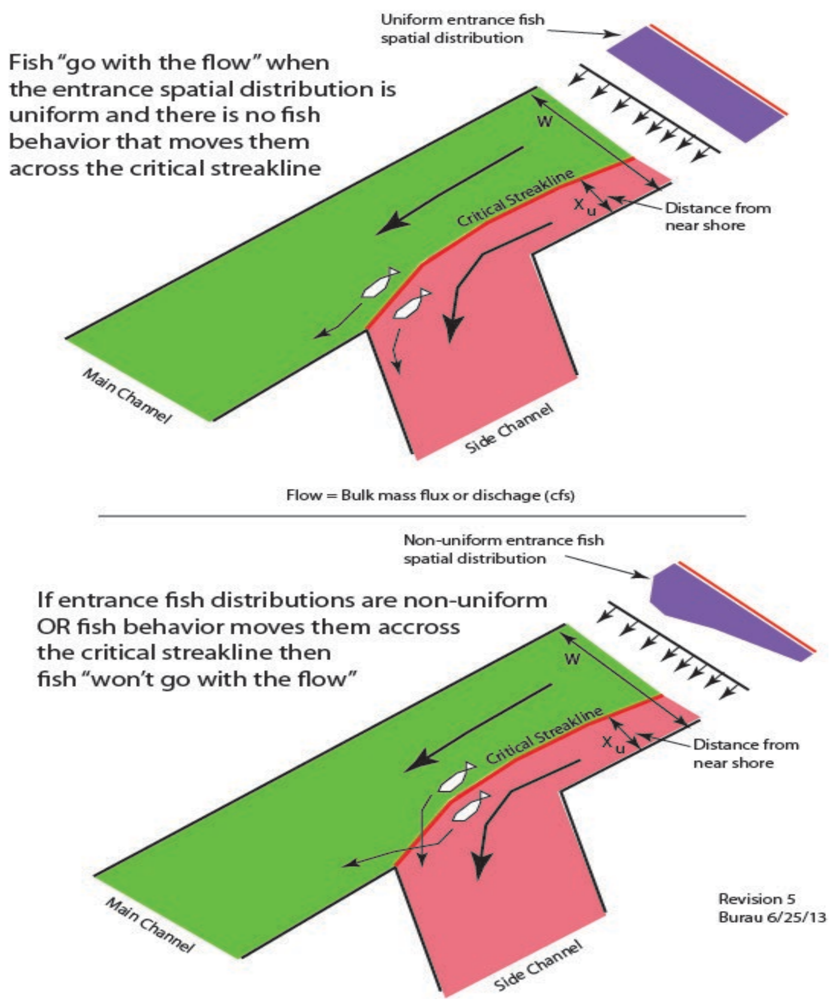
3.3 Junction Hydrodynamics and Critical Streakline

Evidence from past studies on juvenile Chinook salmon entrainment into Georgiana Slough suggests that instantaneous water velocity patterns in the immediate vicinity of the Georgiana Slough divergence affect entrainment into Georgiana Slough (Horn and Blake 2004; DWR 2012; DWR 2015; DWR 2016). The location of the split between the entrainment zones,[1] defined as the critical streakline, is the point in the river cross-section where the two entrainment zones meet. The critical streakline concept is a way of collapsing a complex flow field into its essence with regard to fish routing/entrainment fates, providing a simple metric for comparing the potential for entrainment under a variety of conditions within a junction and between junctions. For example, the critical streakline represents the line separating parcels of water that either remain in a main river channel (Sacramento River); green region in **Figure 4** or enter a side channel (Georgiana Slough); red region in Figure 4. The distribution of fish in relation to the critical streakline has been documented as an important predictor of the risk of entrainment into Georgiana Slough.

In addition to varying critical streakline positions associated with fluctuating downstream discharges, many tidally forced junctions in the Delta, including the Georgina Slough junction,

[1] The position in the Sacramento River where fish on one side of the streakline will have a high likelihood of being entrained into Georgiana Slough while fish on the other side will likely remain in the mainstem channel as they move downstream.

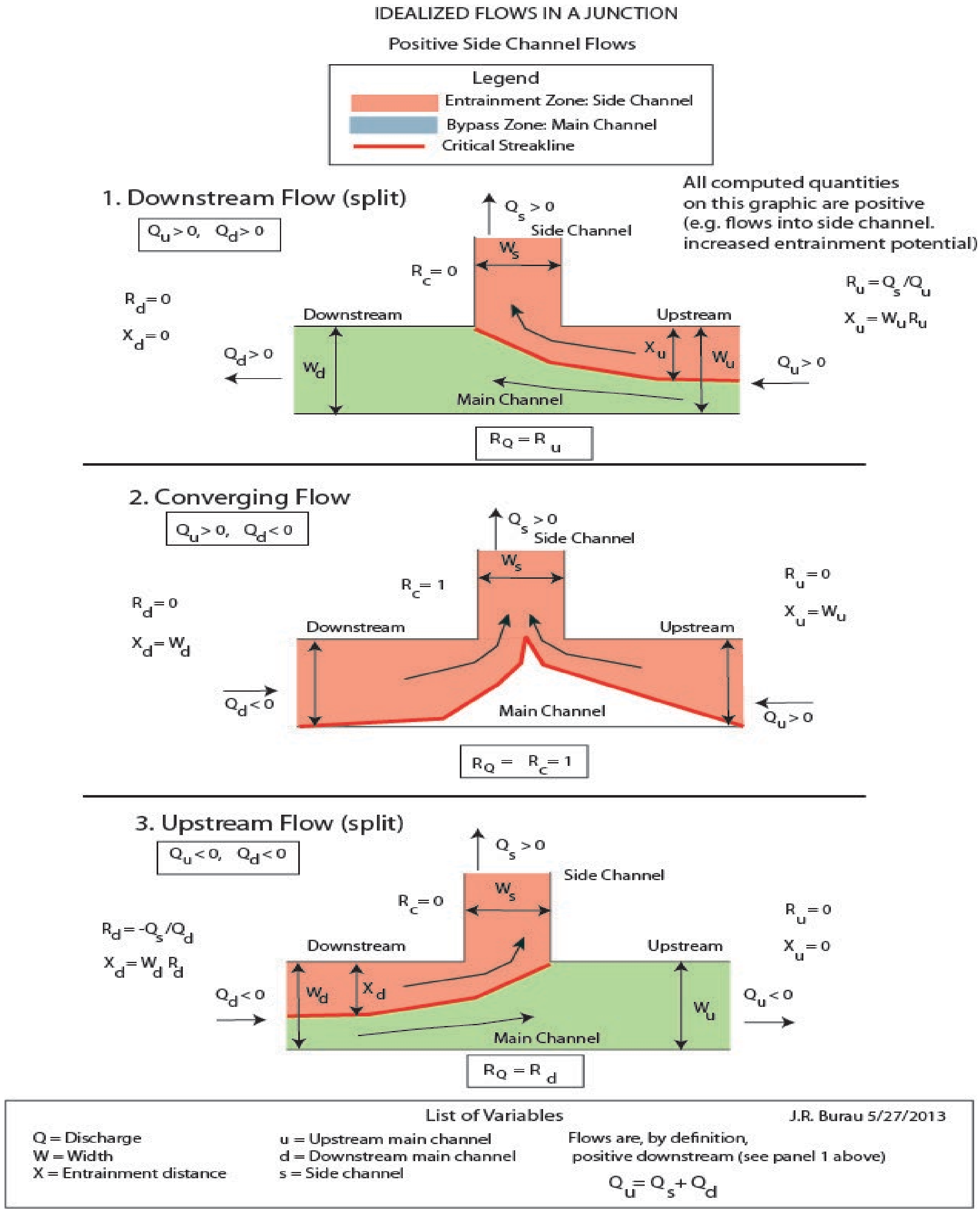
experience velocity conditions where the flow converges into the side channel from both upstream and downstream (e.g. during flood tides). Under relatively low discharge conditions in the Sacramento River, flows can reverse on the flood tide, creating a critical streakline that is variable relative to the cross-section of the river (similar to downstream flow splits, albeit in reverse). Under these conditions, it is possible that fish that have moved downstream of the junction in the Sacramento River can be advected back upstream and entrained into Georgiana Slough under reversing flows on flood tides. These three hydraulic conditions (downstream flow [split], converging flow, and upstream flow [split]) are conceptually depicted in **Figure 5** with example time series plots from 2012 BAFF study conditions in **Figure 6**.



Source: USGS, DWR 2015

Note: Red regions denote the entrainment zone for the side channel whereas the green regions show the region where fish continue along the main channel. The red line between these regions is the critical streakline. Top panel shows the required conditions for fish to "go with the flow" – in this case the bulk discharge in each channel. These conditions include a uniform entrance fish spatial distribution and behaviors that don't result in fish crossing the critical streakline. In the bottom panel are indicated those conditions that create conditions where fish aren't distributed in proportion to the flows in each channel. These conditions include a non-uniform entrance fish distribution as is shown and behaviors that cause fish to transit the critical streakline.

Figure 4
Conceptual Diagram of Critical Streakline and Entrainment in a Junction

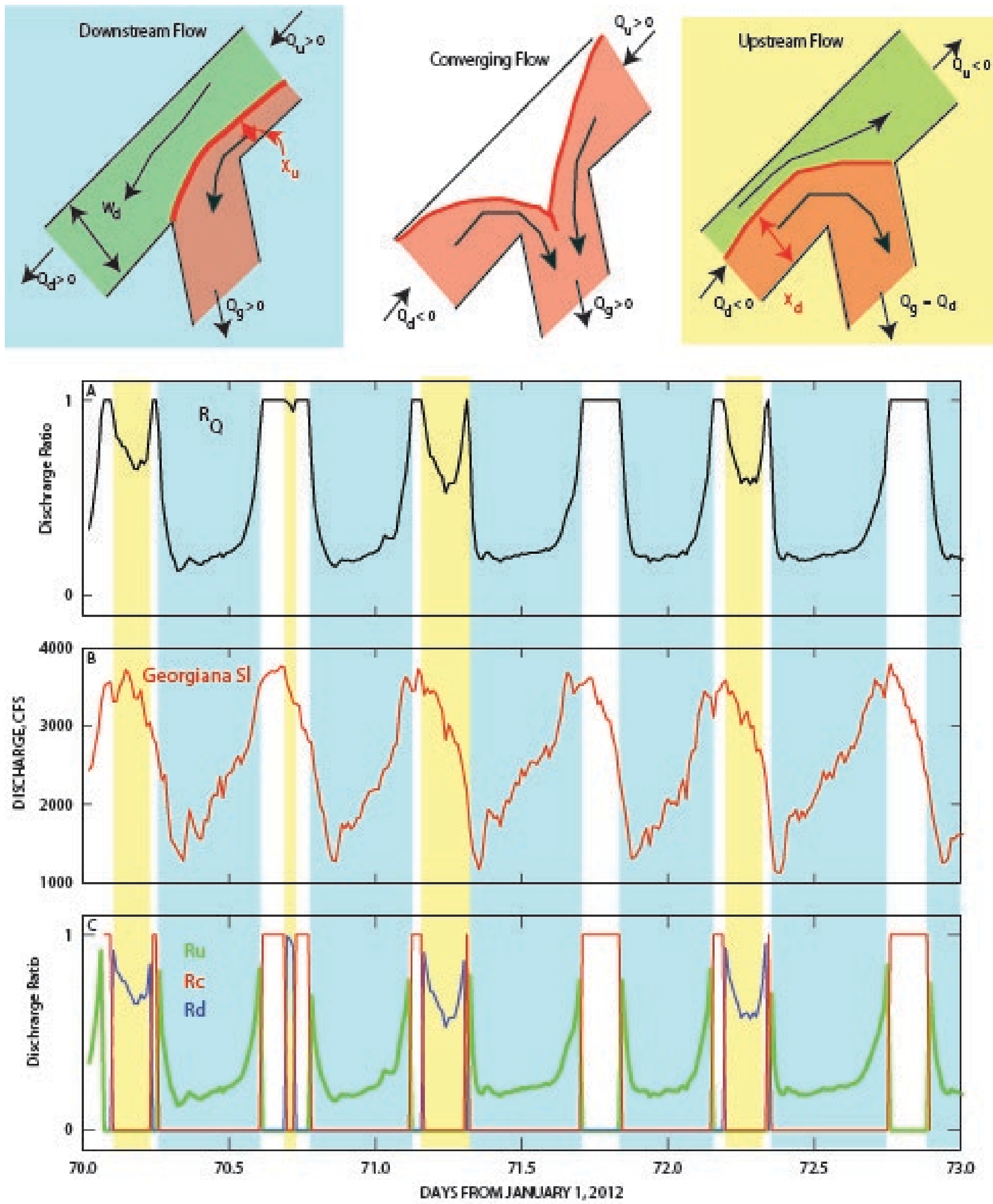


Source: USGS, DWR 2015

Notes: 1) downstream flow in the main channel; 2) converging flow; and 3) upstream flow.

Figure 5

Three Flow Conditions in a Tidally Forced Junction Where the Water is Entering a Side Channel



Source: USGS; DWR 2015

Notes: Time series plots of (A) the total discharge ratio, R, (B) the discharge in Georgiana Slough, and (C) the component discharge ratios RU (flow entering Georgiana Slough from upstream, green), RD (flow entering Georgiana Slough from downstream, blue) and RC (converging flow into Georgiana Slough) during low Sacramento River flow period.

Figure 6
Time-Series Plots of Converging and Upstream Flow Conditions

3.4 2011 and 2012 BAFF Study Results

The migration of juvenile salmonids from the Sacramento River into the interior Delta through pathways such as Georgiana Slough and the DCC has been shown to contribute to greater mortality relative to remaining in the Sacramento River (Brandes and McLain 2001; Perry 2010; Perry et al. 2010; Perry et al. 2012; Singer et al. 2013; Perry et al. 2018). To identify potential engineering approaches to reduce the percentage of the juvenile salmonids entrained into Georgiana Slough, DWR operated a BAFF in 2011 and 2012 and FFGS in 2014 to assess the effectiveness of non-physical and physical barriers as a method for guiding downstream migrating juvenile salmonids. The experimental design of the tests included the use of acoustic-tagged juvenile Chinook salmon (2011, 2012, and 2014) and yearling steelhead (2012), released upstream of the barriers when they were on and when they were off, to determine effectiveness.

During the 2011 study, the BAFF reduced the percentage of juvenile late fall-run Chinook salmon passing into Georgiana Slough from 22.1 percent (BAFF Off) to 7.4 percent (BAFF On), a reduction of approximately two-thirds of the fish that would have been entrained (DWR 2012). Analysis of the 2012 study data showed that the percentage of juvenile Chinook salmon migrating into Georgiana Slough was reduced from 24.1 percent (BAFF Off) to 11.4 percent (BAFF On), approximately one-half less (DWR 2015).

In 2012, this technology was tested on steelhead in addition to late fall-run Chinook Salmon, a total of 23.4 percent of the steelhead were entrained into Georgiana Slough when the BAFF was off compared to 10.5 percent when the BAFF was on, representing a 12.9 percentage point (or approximately one-half) overall reduction in steelhead entrainment into Georgiana Slough (DWR 2015). These findings demonstrated that an integrated multi-sensory (light, sound, and air bubbles) non-physical barrier was able to significantly reduce juvenile salmonid entrainment into Georgiana Slough similarly for both steelhead and Chinook salmon.

During the 2014 study, the FFGS reduced the percentage of juvenile Chinook salmon passing into Georgiana Slough during a subset of environmental conditions, with the FFGS effectiveness being highly dependent upon discharge, fish cross-stream position, and time of day (Romine et al. 2016). Under intermediate Sacramento River discharge conditions (8,794 – 12,394 cubic feet per second [cfs] upstream of the junction with Georgiana Slough and the DCC), the percentage of juvenile Chinook salmon passing into Georgiana Slough was 21.2 percent (FFGS Off) compared to 13.5 percent (FFGS On), a reduction of approximately one-third of the fish that would have been entrained. Under higher Sacramento River discharge conditions (12,395 – 21,083 cfs), the percentage of juvenile Chinook salmon passing into Georgiana Slough increased by around one-half, from 11.7 percent for FFGS Off compared to 17.3 percent for FFGS On. Under lower Sacramento River discharge conditions (4,344 – 8,793 cfs), entrainment differences were negligible. These findings show that a FFGS reduced juvenile salmonid entrainment but only during intermediate discharge; overall, there was little difference in entrainment between FFGS Off and FFGS On. It was suggested that the complex hydrodynamics of the Georgiana Slough junction might require dynamic operation of the FFGS for success (e.g., moving the FFGS toward the bank to avoid turbulence and increased entrainment during high discharge) (DWR 2015).

3.5 BAFF Power Source Availability

During the Operations Plan development, DWR was made aware that power requirements (being provided to the primary staging area by Pacific Gas and Electric [PG&E]) for the full BAFF system would only be available for a November through April time period due to seasonal demands in the area. If operations are to be required outside of this time period, additional resources, including equipment (e.g., diesel generators), fuel, staffing, etc. would be required.

3.6 Operational Costs

As stated above, the BAFF and its operational components will operate off the new PG&E service during the November through April operations period and if operations are to be required outside of this time period, additional resources, including equipment (e.g., diesel generators), fuel, staffing, etc. would be required.

Electricity use at the project site during the November through April period will depend on the BAFF operations schedule. If the BAFF were to operate 24 hours a day for 7 days per week, the electrical operating costs are estimated to be $50,000 per month. As a result, operating costs alone could easily exceed $300,000 for one season (i.e., November through April period). If the BAFF is operated outside of this period (e.g., May), additional costs would be incurred associated with diesel generator acquisition and fuel consumption, totaling approximately $126,000/month.

As described above, under certain conditions, it is possible that fish that have moved downstream of the junction in the Sacramento River can be advected back upstream and entrained into Georgiana Slough under reversing flows on flood tides. This critical streakline concept, which correlates varying river discharge to changing complex tidally forced junction hydraulics, provides an important consideration for fish routing/entrainment and associated BAFF performance at the Georgiana Slough junction.

Operational changes to the GSSMB that reflect drought conditions and water temperatures should be considered in seasonal operation of the GSSMB. Modifying operations when salmon are being trucked past the GSSMB reduces operations and maintenance costs and extends the life of components which equates to less downtime and continued operation of the barrier when juvenile salmon are migrating downstream.

Optimization of BAFF operations is an important consideration to minimize operational costs. The above topics are included in this proposal to initiate further discussion.

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CHAPTER 4
Proposed BAFF Operations

4.1 Construction and Removal

As described above, to limit the potential for impacts on listed fishes, marine construction, which is defined as pile driving and the installation of anchors and pier blocks, would occur between August and September of each year. Supporting infrastructure, including piles, would remain in place throughout the year during the duration of the project (late 2022/early 2023 through 2030). Piles may be removed and reset as needed during the August/September window if it is determined that the BAFF alignment needs to be adjusted. Piles would be removed at the completion of the project utilizing a vibratory hammer to unseat the piles and/or by cutting the pile below the substrate line (i.e., bed of river). All equipment would be removed from staging areas and the sites would be restored to prior existing conditions.

4.2 Operations Window

Based on information presented above (see Table 2), December through April has been determined to be the key period for operation of the BAFF for WRCS juvenile outmigrants at the Sacramento River junction with Georgiana Slough. The operations window is based on the high and medium temporal occurrence in the Delta that occurs from December through April (NMFS 2019).

December through May is determined to be the key period for operation of the BAFF for SRCS juvenile outmigrants at the Sacramento River junction with Georgiana Slough. The operations window is based on the high and medium temporal occurrence in the Delta that occurs in April and May as well as the low temporal occurrence of juveniles from December through March (NMFS 2019).

The proposed operations window includes an adaptive approach that covers all periods of medium and high temporal occurrence of WRCS and SRCS (mid-November through April/May) and informed by real-time fish monitoring at the Knights Landing Screw Trap and Delta juvenile fish monitoring program (Sacramento trawl, beach seines), and associated operations of the DCC (see Table 3). It also covers five of seven months of low occurrence. The only period it does not cover is September and October when early migrating WRCS may occur in low numbers in the lower Sacramento River/north Delta. Additionally, while not presented in this plan, the mid-November through April/May operations window covers all periods of high occurrence (and the vast majority of medium occurrence) for juvenile fall- and late fall-run Chinook salmon and juvenile steelhead.

Importantly, as discussed above, the month of May is outside of the period where full PG&E power is available to accommodate the BAFF system. As a result, May operations (BAFF

ON/OFF) will be considered on an annual basis within an adaptive framework considering juvenile salmonid outmigration timing patterns and increased operational costs associated with supplemental power source (diesel generator).

TABLE 3
GSSMB BAFF OPERATIONS SCHEDULE

Season	BAFF Operational Status
October 15 - November 15	BAFF is installed; if BAFF is installed and operational prior to November 15 then BAFF operations would correspond to DCC gate operations (when DCC gates closed for fishery protection purposes, BAFF would be ON). BAFF may be turned OFF for maintenance, monitoring studies, or power issues
November 16 - December 31	BAFF operations would correspond to DCC gate operations (when DCC gates closed for fishery protection purposes, BAFF would be ON). BAFF may be turned OFF for maintenance, monitoring studies, or power issues
January 1 – April 30	BAFF is ON. BAFF may be turned OFF for maintenance, monitoring studies, or power issues
May 1 - May 31	May operations (ON/OFF) will be considered on an annual basis within an adaptive framework considering juvenile salmonid outmigration timing patterns and increased operational costs associated with supplemental power source (diesel generator)
June 30 – October 15	BAFF is removed (out)

4.3 Operations Window Adjustments

4.3.1 Damage/repairs

Floating debris such as trees or logs pose a serious risk to operations of the BAFF during high river discharge events, especially first flush events that mobilize debris that has accumulated during the prior low flow season. Damage to the BAFF system would likely require the use of divers, and barge mounted heavy equipment to repair. Work of this nature is time consuming and could require up to several days to weeks, depending on the extent of the damage and river conditions (flow and turbidity to conduct dive-based work safely). During the repairs, partial or all the BAFF system may not be operational. BAFF operating downtime will be recorded and documented in the Annual Operations Report.

4.3.2 Maintenance

The BAFF system will require periodic maintenance to ensure its operation and effectiveness. Debris removal, air-line issues, light bar cleaning/replacement, and audio speaker cleaning/replacement are normal for this system. Maintenance of the BAFF may require diver assistance and potentially barge mounted equipment and could require hours to days to complete, depending on river conditions. During this work, partial or all the BAFF system by not be operational. BAFF operating downtime will be documented in the Annual Operations Report.

Monitoring to capture baseline conditions may be conducted during these maintenance periods as well as other times when the BAFF is turned off for targeted ‘BAFF OFF’ monitoring. This will allow for periodic comparison of baseline during off periods, to performance monitoring data when the BAFF is operational. These experiments will be described in the monitoring plan.

4.4 Performance Monitoring

As summarized above, each year DWR will conduct monitoring to assess the performance of the BAFF. This may include the installation of fish tracking and other data collection monitoring equipment, including steel piles at the Georgiana Slough junction to attach equipment for hydroacoustic and hydrodynamic barrier operational monitoring. DWR would also acoustic-tag and release hatchery-reared juvenile Chinook salmon and steelhead for acoustic telemetry-based fish tracking. DWR may also capture, tag, and release predatory fish by hook-and-line sampling. DWR would release acoustic-tagged juvenile Chinook salmon and/or steelhead at one or more sites. Analysis of data collected as part of existing monitoring programs (e.g., juvenile salmonid outmigration monitoring) will also be conducted to inform the operational period, especially the month of May, when full PG&E power is insufficient in meeting BAFF power requirements. Details of performance monitoring are being developed as part of a separate monitoring plan. Performance monitoring may result in changes to the proposed operations schedule, if warranted.

CHAPTER 5
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