MODELING THE EFFECTS OF SITES RESERVOIR ON FLOODPLAIN REARING HABITAT IN THE SACRAMENTO VALLEY

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OVERVIEW

Sites Reservoir is a proposed off-stream reservoir in California's Sacramento Valley that would be capable of diverting and storing up to 1.5 million acre-feet of excess winter runoff from the Sacramento River and using it to improve water reliability in drier periods. The operations of Sites Reservoir will influence the quantity and quality of off-channel rearing habitat for juvenile salmonids. We performed hydrologic, hydraulic, and ecological modeling to determine the relationships between flows in the Sacramento River and the total area of potentially suitable habitats in the Sacramento River channel, Sutter Bypass, and Yolo Bypass, considering various hydrologic conditions and Sites Reservoir operational scenarios. Existing conditions were evaluated against potential Sites Project diversion scenarios by evaluating changes in the frequency of potential inundation events for different flows that satisfied requisite duration criteria, and changes in average monthly inundated areas that satisfied physical criteria. This process is applicable to other watersheds.

BACKGROUND

Sites Reservoir

Sites Reservoir is a planned, 1.5 MAF capacity offstream reservoir which will be located on the west side of California's Central Valley near Maxwell, California. Existing infrastructure will be used to divert and convey unregulated and unappropriated flow from the Sacramento River (at Red Bluff and Hamilton City) to Sites Reservoir. Releases from Sites Reservoir would ultimately return to the Sacramento River system via existing canals and a new pipeline located near Dunnigan. Diversions to storage typically occur in the winter and releases typically occur in the summer and fall.

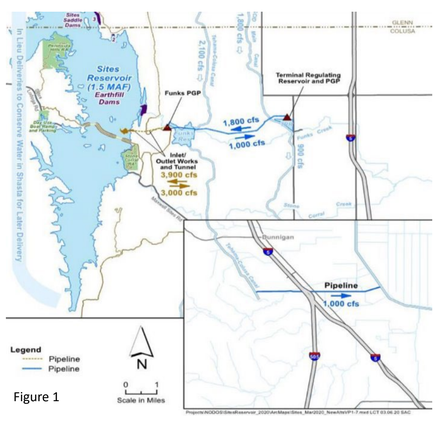

Figure 1

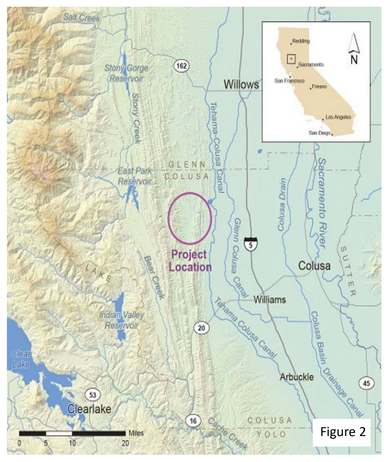

Figure 2

Maps of the project location and proposed facilities

Flood Bypasses in California's Central Valley

Historically, the Central Valley contained large wetlands. Development has reduced the footprint of those wetlands over the past several centuries. While land was reclaimed for development, flood risk still exists. Several flood bypasses were built to protect farms and cities, including the Yolo and Sutter Bypasses. While they were developed for flood protection, research has also shown benefits to wildlife, including salmonids.

Floodplain, secondary channel, and off-channel salmonid rearing habitats along the Sacramento River system are important for outmigrating juvenile salmon, which feed in the productive, shallow, slow-moving waters and rapidly grow before migrating to the ocean. A lateral connection between floodplains and active channels provides fishes with an opportunity to access productive habitats in the aquatic-terrestrial transition zone. For juvenile Chinook salmon in the Central Valley, floodplains provide expanded suitable rearing habitats where growth rates often exceed those in the adjacent main channel (Jeffres et al. 2008, Zeug et al. 2019).Floodplains also provide alternative migration routes for salmon that can buffer populations from poor conditions in the mainstem.

Agricultural and urban development within historical floodplains of the Sacramento River has impacted their physical and ecological functions, including the ability to attenuate peak flood flows through the lateral movement of water and function as rearing habitat and migration routes for Chinook salmon (Sommer et al. 2001). Currently, only about 5% of the historical floodplain habitats along the Sacramento River currently exist, as a result of levee construction, land use conversion, and flow modification. Reconnecting historical floodplains to river channels can have both ecological and flood control benefits. Floodplain habitat restoration is an essential strategy for restoring healthy salmon populations within the Central Valley and mitigating the impending impacts of climate change on salmonid populations (Whipple et al, 2019; DWR, 2021 [in publication]). However, connection/access alone is not enough. Potential floodplain access benefits for target species depends on the interaction between species life history and timing, duration, and magnitude of floodplain inundation (Whipple et al, 2019).

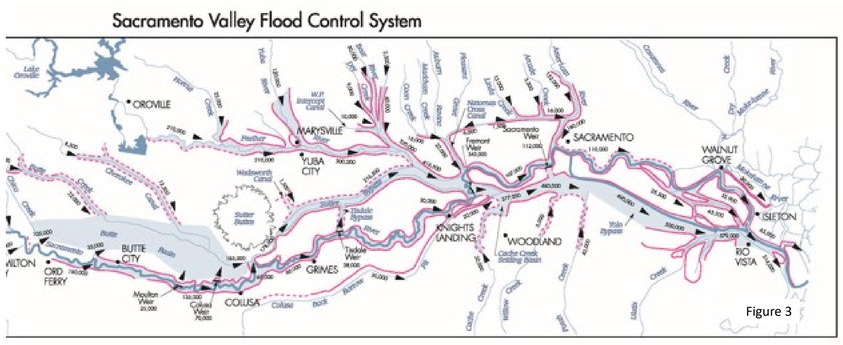

Figure 3

GOALS AND OBJECTIVES

1. Identify range of potentially suitable salmonid rearing habitat on existing floodplains along three primary segments of the Sacramento River:
   a) Mainstem channel from Bend Bridge to Knight's Landing
   b) Sutter Bypass
   c) Yolo Bypass
2. Compare changes in floodplain rearing habitat between existing conditions and potential future conditions associated with Sites Reservoir operations
3. Identify potential impacts or benefits to juvenile salmonids

Ecological Goals and Opportunities

1. Maximize growth of juvenile salmonids from emergence to successful migration to the ocean
2. Understand how we can design and operate Sites Reservoir to optimize the utilization of floodplain habitats by juvenile salmonids

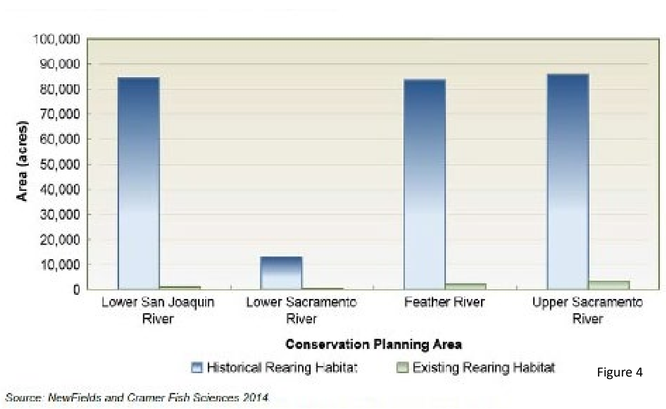

Figure 4

Source: NewFields and Cramer Fish Sciences 2014

APPROACH

1. Identify juvenile salmonid floodplain rearing habitat criteria
2. Use CalSim II and USRDOM to model historical and simulated hydrology for 82 years
3. Develop and configure 1-D and 2-D hydraulic models to determine flow conditions that meet floodplain rearing habitat criteria
4. Produce maps and quantify areas of inundation
5. Compare frequency of floodplain inundation events - historical to with-project operations
6. Perform biological impact or benefit analyses based on changes in floodplain rearing habitat

HABITAT SUITABILITY CRITERIA

The following criteria were developed from existing habitat suitability research and models:

- 2019 Chinook Salmon Habitat Quantification Tool (i.e. Salmon HQT)
- USFWS habitat suitability models
- CVFPP Conservation Strategy and appendices
- Empirical studies on Trinity River restoration sites (1997)

Criteria

- Water Depths ≤ 1 meter
- Water Velocities ≤ 1.5 ft/s
- Suitable Land Cover Types:
  - Agriculture
  - Seasonal Wetlands
  - Non-tidal Marsh
  - Riparian Scrub and Forest
  - Gravel Bar (Active Channel)
  - Open Water
- Hydrology
  - Timing: November 1 – June 30
  - Duration
    - 8 to 17 days - suitable habitat
    - 18 to 24 days - optimal habitat

METHODOLOGY

Operations Modeling

CalSim II, a deterministic water operations model developed for the State Water Project and Central Valley Project, was used to determine monthly flows for the selected alternatives. The Upper Sacramento River Daily Operations Model (USRDOM), a physical flow routing model, was then used to determine daily flows in the mainstem of the Sacramento River and flood bypasses, taking into account storm flows and tributary inflows.

Hydrologic and Hydraulic Modeling

1. 3 HEC-RAS models developed for the Sutter Bypass, Yolo Bypass, and Main Channel of the Sacramento River
2. Boundary conditions for each model were established based on analyses of simulated and historic flows
   a. Correlations between river flows and weir spills
   b. Flow and spill frequency and duration analysis
3. Flow vs habitat area curves were developed from HEC-RAS results to evaluate the effects of Sites Project operations on suitable habitat area

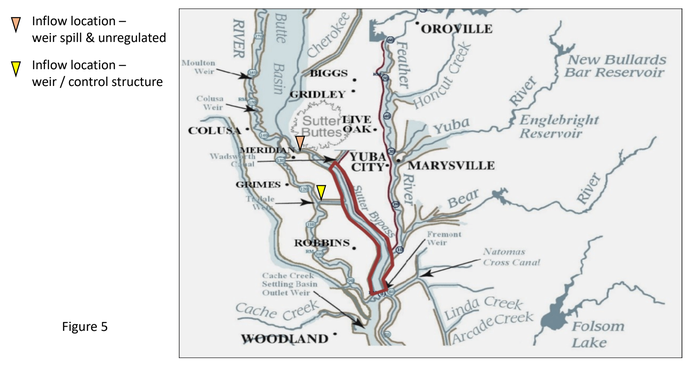

Figure 5

Sutter Bypass

- Sensitivity analyses performed for various Sutter Bypass flows determining which flows through Butte Slough and Tisdale Weir satisfy biological criteria (velocity and depth)
- 16 scenarios developed that bracket the range of events that satisfy both criteria, with the following range of inflows and total flows
- Maps developed showing total acreage of inundation for each land cover type for each scenario

Tisdale Weir (cfs)	Butte Slough (cfs)	Total Sutter Bypass (cfs)
0-1,000	500 – 7,000	500 – 8,000

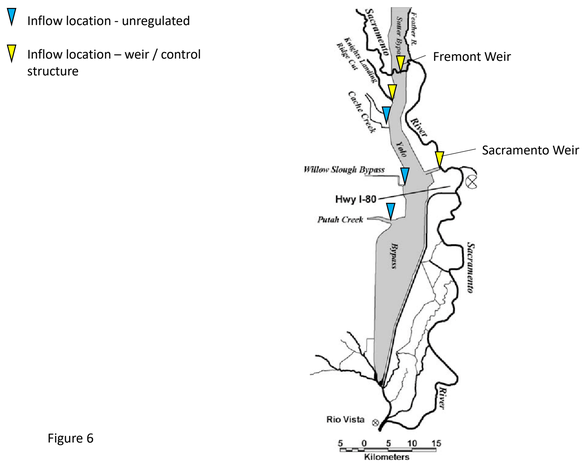

Figure 6

Yolo Bypass

- Sensitivity analyses performed for various Yolo Bypass flows determining which flows from the Westside tributaries (Knight's Landing Ridge Cut, Cache Creek, Willow Slough, Putah Creek) and Fremont Weir satisfy biological criteria (velocity and depth)
- 8 scenarios developed that bracket the range of events that satisfy both criteria, with the following range of inflows and total flows
- Maps developed showing total acreage of inundation for each land cover type for each scenario

West Side Tributaries (cfs)	Fremont Weir (cfs)	Total Yolo Bypass (cfs)
930-6,200	0 – 15,000	930 – 21,200

Main Channel of the Sacramento River

- Sensitivity analyses performed for flows in the main channel of the Sacramento River determining flows necessary to satisfy biological criteria (velocity and depth)
- Based on the approach used in WSIP
- HEC-RAS 1D model of the Sacramento River from Bend Bridge to Knights Landing
- Steady-state simulations of flows from 5,000 to 55,900 cfs (40 increments)
- 3 reaches evaluated:
  - Reach 1: Bend Bridge to Hamilton City (including both diversions to Sites Reservoir)
  - Reach 2: Hamilton City to Colusa
  - Reach 3: Colusa to Knight's Landing
- Maps developed showing total acreage of inundation for each land cover type for each scenario

OBSERVATIONS, TRENDS, AND OPPORTUNITIES

- Sutter Bypass flows tend to be very flashy, and do not necessarily occur with the frequency (floodplain inundation every 2-3 years) and duration (minimum 7 days) to satisfy salmonid rearing criteria.
- Flows that meet the critical depth and velocity criteria tend to occur on the rising or falling limb of these larger events
- Sites operations may be able to increase the quality and quantity of floodplain habitat areas in the Sutter Bypass by:
  - Targeting diversions / releases that optimize floodplain activation flows in the Bypass
  - Trying to increase the frequency and duration of those optimal flows in the Bypass
- In general, Sacramento River flows of 20,000 – 25,000 cfs at Hamilton City appear to be critical for initiating and optimizing floodplain rearing habitat in the Sutter Bypass

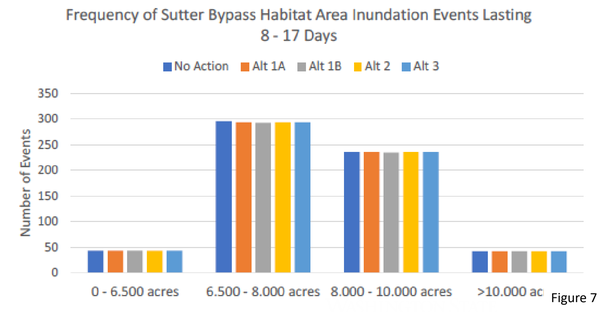

Figure 7

Figure 7 shows the occurrence of inundation events lasting 8-17 days in the Sutter Bypass over an 82-year period

FINDINGS

- Project alternatives show little to no change in habitat area and the frequencies of inundation events of suitable duration.
- Across study areas, inundation events lasting longer than 24 days appear unaffected by the Project.
- There is more variability for events lasting 8 to 17 or 18 to 24 days. In some instances, Project alternatives demonstrate an increase in habitat area, and more frequent inundation events of suitable duration.
  - Project alternatives' summer and fall ecosystem releases to the Yolo Bypass produce significantly more habitat area than the NAA in those months.
  - On average, in-channel Sacramento flows are higher in the late summer and fall with Project alternatives. Accordingly, habitat area tends to increase in Reaches 1 and 2 during those months.
  - At times, Project alternatives show a reduction in the frequency of habitat inundation events. For example, winter months show a decrease in in-channel average habitat area under Project alternatives due to project diversions.
- Habitat inundation does not increase linearly with flows, especially for the Sutter and Yolo Bypasses.
- Sites provides an opportunity to optimize suitable habitat during high-flow events while storing water for habitat flows during dryer periods.

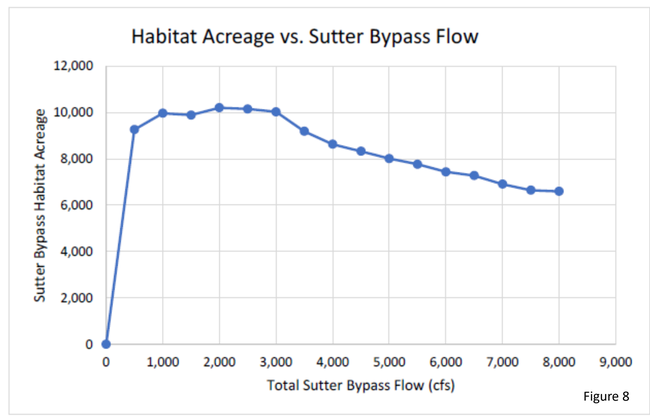

Figure 8

Figure 8 shows the relationship between suitable habitat acreage and flow in the Sutter Bypass

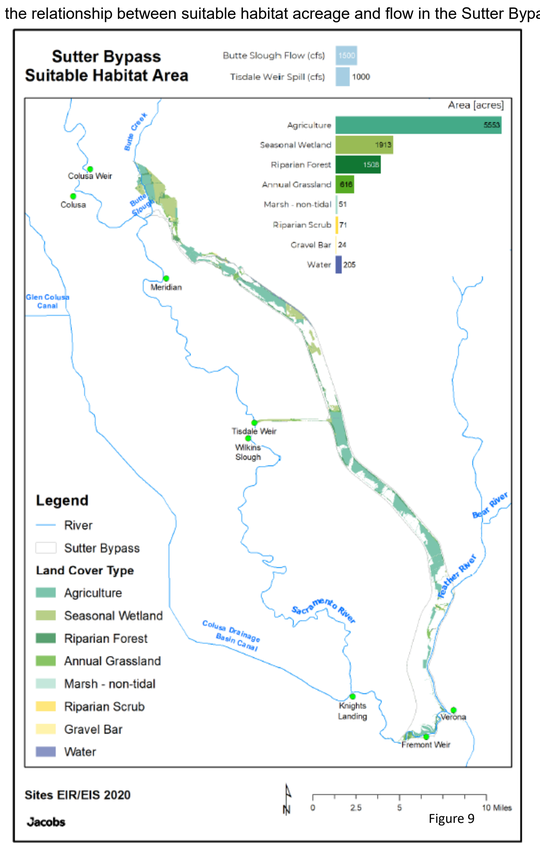

Figure 9

Figure 9 shows suitable habitat, by land cover type, in the Sutter Bypass when Bute Slough is flowing at 1,500 cfs and the Tisdale Weir is spilling at 1,000 cfs.

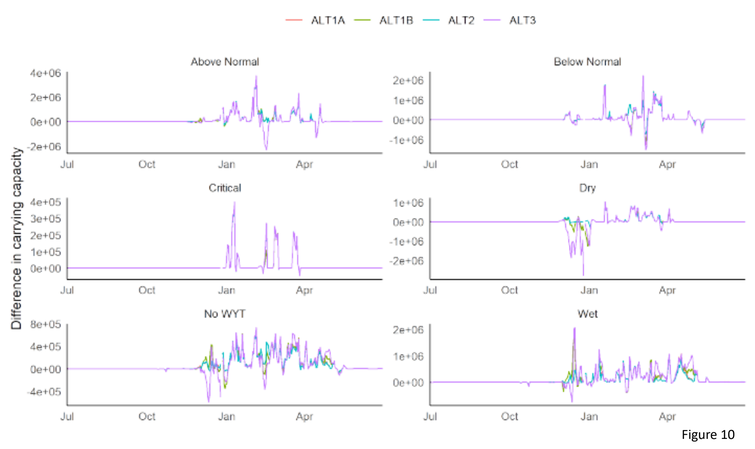

Figure 10

Figure 10 shows a plot of the difference in carrying capacity for chinook salmon in the Sutter Bypass between each operational alternative and the Existing Condition (NAA) in each water year type and combined across all year types (No WYT). Note that the scale of the y axis changes among the plots.