From: Chris Fitzer [CFitzer@esassoc.com]
Sent: 10/3/2019 4:37:13 PM
To: Alicia Forsythe [aforsythe@sitesproject.org]; Tull, Robert/SAC [Robert.Tull@jacobs.com]; Leaf, Rob/SAC [Rob.Leaf@jacobs.com]; Thad Bettner (tbettner@gcid.net) [tbettner@gcid.net]; Jim Lecky (jim.Lecky@icf.com) [jim.Lecky@icf.com]; John Spranza (john.spranza@hdrinc.com) [john.spranza@hdrinc.com]; Rob Thomson [rthomson@sitesproject.org]
Subject: RE: Sites - CDFW 60-Process -- Next Steps
Attachments: Freeport and NDOI rationale.docx

Hi Ali, all,
Attached is a brief document summarizing rationale for CA WaterFix criteria for Sac River at Freeport and NDOI.
Talk to you tomorrow,
Chris

Chris Fitzer
Fisheries Program Manager

ESA | Environmental Science Associates
Celebrating 50 Years of Work that Matters!

From: Alicia Forsythe <aforsythe@sitesproject.org>
Sent: Wednesday, October 2, 2019 7:35 AM
To: Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Rob Thomson <rthomson@sitesproject.org>
Subject: Sites - CDFW 60-Process -- Next Steps

Hi all – Sorry for the delay in getting this out. Below are the action items that I recorded at our Monday afternoon call. Please let me know if I missed anything.

I'd like to have a follow up call on Friday to check in on progress. Would 9 to 10 AM Friday morning works for folks?

Action Items:
1. Ali to call Kristal on Environmental Criteria
2. Thad to talk with Chuck on WaterFix Freeport and NDOI Criteria
3. Jim and Chris to look at WaterFix Freeport and NDOI Criteria to refresh memories on logic behind it so we can continue to think about if / how might modify
4. Jacobs to complete CALSIM and DSM2 modeling (if possible) on scenarios below from CDFW meeting – with WaterFix scaled Freeport and NDOI

a. 8,000 CFS Wilkins Slough Bypass (including Freeport and NDOI)

b. Percentage Based Diversion, 8K Wilkin Apr/May (incl. FP, NDOI)

5. Ali to schedule a follow up call for Friday
6. Group to think about other options / opportunities for Friday's discussions

Thanks all!

Ali

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 |
aforsythe@sitesproject.org | www.SitesProject.org

Sac River at Freeport

Protection of reverse flows at Georgiana Slough (CWF NMFS BO pp 606)

The probability of a flow reversal in the Sacramento River downstream of Georgiana Slough occurring at some time during a 24-hour period is one hundred percent when Sacramento River flows at Freeport are less than 13,000 cfs (Figure 2-118 top panel). Likewise, when flows are greater than 23,000 cfs, flow reversals are not expected to occur at the Georgiana Slough junction. For the range of flows between 13,000 and 23,000 cfs at Freeport, reverse flows can be expected to occur, but the probability decreases with increasing Freeport flow. Under near term conditions, real-time management would be needed within the Freeport flow range of 13,000 cfs to 23,000 cfs to ensure NDD diversions are not the cause of flow reversals. Below 13,000 cfs, flow reversals at Georgiana Slough are certain to occur so any substantial diversion could increase the magnitude or duration of reverse flows.

Sacramento River at Freeport

- Minimum bypass of 13,000 cfs
- Implement scaled diversions between 13,000 and 23,000 cfs
- Full diversions when flow is greater than 23,000 cfs
- Delta tidal habitat restoration would further mute reverse flows to varying degrees depending on Sacramento River outflow (CWF NMFS BO pp 604)

NDOI – Spring Outflow

Longfin Smelt (CWF CDFW ITP pp 5-28)

Effects of Spring Outflow

DWR has collaborated with CDFW to develop longfin smelt spring (March–May) outflow criteria that are consistent with existing water conveyance/operations including climate conditions. The proposed longfin smelt spring outflow criteria determine March outflow targets based on the Eight River Index and achieve the targets with export curtailments down to a minimum of 1,500-cfs exports; the March outflow target is capped at 44,500 cfs at an Eight River Index of 4,217 TAF and greater (Table 5.3-1). April and May outflow targets are based on the San Joaquin River inflow:export ratio included in the NMFS (2009) BiOp, up to a maximum outflow target of 44,500 cfs; this again involves curtailment of exports as necessary. ***[Note that April and May outflow requirements are already part of the regulatory baseline; no additional modeling necessary.]***

Table CWF CDFW ITP 5.3-1. Proposed Longfin Smelt Spring Outflow Criteria: Monthly Net Delta Outflow Index in Relation to Eight River Index.

Eight River Index (March), TAF	Monthly Net Delta Outflow Index (March), cfs
0	0
545	6,200
1,488	8,800
1,911	12,700
2,140	17,100
2,421	20,000
2,575	25,200
3,104	35,000
3,492	43,700
≥4,217	44,500
Note: Net Delta Outflow Index targets are linearly interpolated for Eight River Index values falling between those shown on the table. This approach is based on the 90% forecast.	

Winter-run Chinook Salmon (CWF CDFW ITP pp 5-33)

Spring Outflow Criteria

As described in Section 4.2.7.2.2 Effect of Take Minimization Measures for longfin smelt, DWR and DFW have collaborated to propose spring Delta outflow criteria to fully mitigate potential adverse effects to longfin smelt (see also Section 5.3.2 Longfin Smelt in Chapter 5 Take Minimization and Mitigation Measures). This has been achieved through curtailment of exports at certain times. As such there would be essentially no difference in upstream operations between PP with longfin smelt spring outflow criteria and PP without such criteria for which the detailed analysis of upstream effects was presented in Section 4.3.4.2 Upstream Hydrologic Changes.

This is reflected in little difference in May and September Shasta reservoir storage between these scenarios (Table 4.D-1 in Appendix 4.D Comparison of Key Hydrological Variables for Proposed Project with Longfin Smelt Spring Outflow Criteria to No Action Alternative and Proposed Project Scenarios). Within the Delta, reduction in south Delta exports to achieve longfin smelt spring outflow criteria would result in more positive Old and Middle River flows in March of below normal and dry water years in particular (Table 4.D-5 in Appendix 4.D), possibly providing a benefit to winter-run Chinook salmon in terms of improved south Delta hydrodynamics (although generally the effects would be expected to be similar to those described in Section 4.3.4.1 Proposed Delta Exports and Related Hydrodynamics). Per the longfin smelt spring outflow criteria (Section 5.3.2 Longfin Smelt in Chapter 5 Take Minimization and Mitigation Measures), the upper limit of the Delta outflow criteria of 44,500 cfs resulted in CalSim modeling giving somewhat greater north Delta exports in wet years for the PP with longfin smelt spring outflow criteria compared to PP, with the result that mean April flows in wet years below the NDD were around 1,600 cfs (5%) less under PP with longfin smelt spring outflow criteria compared to PP and therefore 12% less than NAA (Table 4.D-4 in Appendix 4.D). Given the very high flows at which the longfin smelt outflow criteria would cease, the leveling-off in through-Delta survival observed at high flows (Figure 5.D-45 in Appendix 5.D of ICF International [2016]; Figure 5 of Perry et al. [2016]) and the previously described take minimization measures of operational constraints, real-time operations, and Georgiana Slough nonphysical fish barrier, no additional effects are expected.

9/27/19

NMFS CCVO questions related to Sites Reservoir modeling and analysis:

Questions related to Sites Reservoir modeling and analysis generally fall into two broad categories of "methods" and "other." It is likely that these questions and suggestions cannot be covered in a single meeting with Sites JP, but they provide an overview of expectations regarding the type of analysis needed in an initiation package.

Methods

- Could Sites JP provide a table/listing of analytical tools/models expected to be used (e.g., HEC-5Q, Delta Passage Model), what outputs will be evaluated (e.g., temperature, Delta survival), and what effect/consequence of the project they are intended to be used to evaluate (impacts to incubation/rearing habitat conditions, impacts on juvenile outmigration)? It may be most useful to set up a meeting to go through what Sites JP is using so as to be sure NMFS is on board and that we don't have a better alternative (but don't need to get into super detail of any one; that could be reserved for a follow-up meeting).
    - As an example, for both CWF and ROCON, NMFS produced a "model matrix" that identifies models and analyses that may be relevant or used in the BA/BO analysis (below).

- Could Sites JP provide a review of the "Daily Model" to provide understanding of this new tool?

- Could Sites JP provide primer on the operations that have been agreed to/developed with DFW, including pulse protections, and ramping rates (changes in habitat inundation and stranding)?

- How is Sites JP dealing with the uncertainty related to the Proposed Action? A large number of modeling scenarios might be needed to account for current level of uncertainty regarding reservoir size (~1.0-1.8 MAF) and operations (Pump Storage component, Holthouse Reservoir footprint, Delevan Pipeline). How does JP plan to select the scenarios to be modelled?

Other

- How is climate change considered in the modeling and analysis? Is the modeling based on a projection of conditions at some point in future? If so, what, and where is documentation of the development of that scenario?

- How is eutrophication considered in the proposed reservoir? Downstream of an outfall location?

- How does Sites JP propose to deal with uncertainty? Is there information on an adaptive management approach?

- Could Sites JP provide a better layout of expected consultation (ESA section 7) timeline/time constraints due to WISP, potential administration changes, NEPA, WIIN, etc.?

Model/Analysis table:

Model/Analysis	**Location**	**Type/ Criteria**	**Life-stage**	**Species**	**Description (and NMFS comment)**
CalSim-II	CVP/SWP-wide	Hydrologic	NA	NA	A hydrological planning scenario tool that provides monthly average flows for the entire SWP and CVP system based on an 82-year record.

DSM2-HYDRO	Delta and Suisun Marsh	Hydrologic	NA	NA	One-dimensional hydraulic model used to predict flow rate, stage, and water velocity.
DSM2-PTM	Delta and Suisun Marsh	Hydrologic (Particle tracking)	NA	NA	Simulates fate and transport of neutrally buoyant particles through space and time.
DSM2-ePTM (DWR)	Delta and Suisun Marsh	Hydrologic (Particle tracking)	model calibration based on smolt data; uncertain how applicable to rearing fry	model calibration based on Chinook smolt data; uncertain how applicable to steelhead.	Simulates fate and transport of "behaving" particles through space and time. Seven behavioral parameters; calibration method is based on particle swarm optimization
ePTM (SWFSC)	Delta	Hydrologic (Particle tracking)	model calibration based on smolt data; uncertain how applicable to rearing fry	model calibration based on Chinook smolt data; uncertain how applicable to steelhead.	Simulates fate and transport of "behaving" particles through space and time. Seven behavioral parameters (same seven as in DWR model, though exact interpretation a bit different because of different model structures); undergoing continued refinement by the SWFSC
HEC-5Q	Sacramento and American Rivers	Water Quality	NA	NA	Water quality simulation tool used to provide water temperatures.
DSM2-QUAL	Delta and Suisun Marsh	Water Quality	NA	NA	Used to predict water temperature, dissolved oxygen, and salinity.
DSM2-QUAL Fingerprinting	Delta and Suisun Marsh	Water Quality (Olfactory Cues)	Adults	Chinook, steelhead	Models "source" of water at any location to indicate proportion coming from different upstream locations, and therefore incidates how homing capabilities of fish can be affected by changes in operations.
Reclamation Egg Mort. Model	Trinity, Feather, American, and Stanislaus Rivers	Biological	Egg	?	Uses CalSimII flow and climatic model output to predict monthly water temperature in River basins and upstream reservoirs.
SALMOD	Sacramento River	Biological	Returning Adult, Egg, Alevin	All Chinook	Predicts effects of flows on habitat suitability and quantity for all races of Chinook salmon.

OBAN	Sacramento River	Biological	?	All Chinook	Statistical modeling approach to evaluating scenarios effects.
DPM	Delta to Chipps Island	Biological	Juvenile (migration)	All Chinook	Simulates migration and mortality of Chinook salmon smolts entering the Delta from the Sacramento, Mokelumne, and San Joaquin rivers through a simplified Delta channel network, and provides quantitative estimates of relative Chinook salmon smolt survival.
IOS	Sacramento River	Biological	All	Winter-run Chinook	A stochastic life cycle model for winter-run Chinook salmon.
Salvage-density Analysis	South Delta facilities	Biological (Flow relation)	Juvenile	All Chinook	A model of entrainment into the south Delta facilities as a function of flow based on historical salvage data.
USGS Flow-survival Model	North Delta (Sacramento R.)	Biological (Flow relation)	Juvenile (migration)	Fall-run Chinook (?)	A model that combines equations from statistical models estimating the relationship of Sacramento River inflows on reach-specific travel time, survival, and routing of salmonids to allow assessment of travel time and survival for different operational scenarios.
USGS Entrainment Model	North Delta (Sacramento R.)	Hydrologic (?)	Juvenile (migration)	Fall-run Chinook (?)	A statistical model of probability of entrainment into the central Delta as a function of hydrodynamic variables in the Sacramento River.
SWFSC Temp. Dependent Egg Mort Model	Sacramento River	Biological	Egg	All Chinook	A temperature-dependent mortality model for Chinook salmon embryos that accounts for the effect of flow and dissolved oxygen on the thermal tolerance of developing eggs.
SWFSC WRLCM	Sacramento River	Biological	All	Winter-run Chinook	A state-space and spatially explicit life cycle model of eggs, fry, smolts, juveniles in the ocean, and mature adults that includes density-dependent movement among habitats.

ICF loss analysis	South Delta facilities	Salvage and loss	Juvenile	Chinook, steelhead (mostly certain),sturgeon (?)	
SWFSC RAFT/CVTemp	Sacramento River		Juvenile	Chinook	Models water temperatures at various locations and estimates egg survival based on Reclamation's operations
Habitat Suitability Index (HSI) Modeling	NA	Habitat	All	Chinook	This would likely only be needed if some type of habitat restoration were included in the PA. And would need to be specific. HSI components are worked into other methods, like SALMOD.
Yolo Bypass Fry Rearing Model	Delta	Biological	Juvenile	Chinook	The Yolo Bypass Fry Rearing Model links growth to survival at ocean entry using the few existing relevant studies. May want to look into how updated this model is (don't recall it being used for CWF so may be due for refresh or replaced by something else).
Newman 2008	Delta	Biological	Juvenile	Chinook	Through-Delta survival method. Used in CWF but not relied upon extensively. Also used as a component of the WRLCM during ROC.
Delta Salmonid Travel Time (Perry and Pope 2018)	Delta	Biological	Juvenile	Chinook	
DSM2	Delta	Physical	Juvenile	Chinook, steelhead	Daily flow metrics, 15-minute velocity frequency: percentage positive flow, frequency of velocities above sustained swimming speeds; used in CWF but very data intensive.
6-year study work	Delta	Biological	Juvenile	Chinook, steelhead	Perry under contract with NMFS to work on results from this data, but unsure if that analysis would meet current (?) timeline.
SRKW Analysis	Ocean	Biological	All	SRKW	See CWF. Is largely based on effects to non-listed salmonids, in addition to those

					on listed salmonids (which are not as large a part of the diet).
CCC Steelhead Analysis		Biological	All	CCC Steelhead	
Eulachon Analysis		Biological	All	Eulachon	
Mean end-of-May and end-of-Sep reservoir storage changes from baseline	Sacramento, Feather, American	Physical	Spawner, Egg, Juv	(River dpendant) WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Mean flow changes from baseline (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear Creek (?)	Physical	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Flow threshold exceedance (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Physical	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Water temperature changes from baseline (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Water Quality	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Water temperature threshold exceedance (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Water Quality	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	

Spawning WUA	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Habitat	Spawner,	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Rearing WUA	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Habitat	Juvenile	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Redd dewatering (qualitative or greatest monthly flow reduction)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Habitat	Egg	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	Identified for all dams/tributaries contributing to the Sacramento River. Are impacts to reservoir releases expected/considered at all locations?
Hatchery assessment (lit review and CFM analysis)	Sacramento, Feather, American, Stanislaus, San Joaquin and Trinity Rivers, and Clear creek	Hatchery	Spawner, Juvenile	SR, FR Chinook and CV Steelhead	Are impacts to Hatchery production expected?

From: Whittington, Chad/SAC [Chad.Whittington@jacobs.com]
Sent: 10/4/2019 12:03:24 PM
To: Leaf, Rob/SAC [Rob.Leaf@jacobs.com]
CC: Tull, Robert/SAC [Robert.Tull@jacobs.com]; Thayer, Reed/SAC [Reed.Thayer@jacobs.com]
Subject: RE: Pulse and Post-Pulse Logic Used in CalSim (from Appendix 5.A of the 2016 CWF BA Effects Analysis)

Flag: Follow up

The table below showcases the similarities and differences between the CWF ITP and CalSim in the determination of pulse and post-pulse rules.

Pulse and Post-Pulse Assumptions

CWF ITP	CalSim II
· All pulses of CHNWR and CHNSR shall be protected from October 1 – June 30.	• One or two pulses shall be protected from October 1 – June 30 (depending on whether a pulse ends before December 1) .
· Beginning October 1st, whenever the initial Sacramento River pulse begins, low level pumping takes effect.	• Beginning October 1st, whenever the initial Sacramento River pulse begins, low level pumping takes effect.
• Sacramento River pulse is determined based on real-time monitoring of juvenile fish movement (see Condition of Approval 9.9.5.1). A fish pulse is defined as a Knights Landing Catch Index (KLCI) ≥ 5 where KLCI = (# of CHNWR + # of CHNSR)/(Total Hours Fished/24). • Pulse protection operations shall be implemented within 24 hours of detection of a fish pulse.	• The initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs.
• Pulse protection ends after five consecutive days of daily KLCI < 5.	• The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days.
• Number of allowable pulses is not specified; ASSUME ALL ELIGIBLE PULSES (KLCI ≥ 5) ARE PROTECTED.	• If the initial pulse begins and ends before December 1st, a second pulse period will be afforded the same protective operation.
• Once the pulse protection ends, post-pulse bypass flow operations may remain at Level 1 diversion depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of diversions.	• After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection.
• The criteria for transitioning between and among pulse-protection, Level 1, Level 2, and/or Level 3 operations described in this permit will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the Project's Adaptive Management Program. Based on the outcome of the studies pursued under that program, additional information about appropriate triggers, off-ramps, and other RTO management of NDD intake operations may be integrated into the Test Period Operations Plan and the Full Project Operations Plan.	• After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied.

• The NDDTT shall develop criteria for transitioning between and among pulse protection, Levels 1, 2 and 3 based on best available science. The NDDTT shall recommend transitional criteria to the TOT and IICG for consideration through the Adaptive Management Program, to ensure that the Project will achieve the objectives of Biological Criteria 1 and 2.	
	• Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules.

Chad

From: Whittington, Chad/SAC
Sent: Tuesday, October 01, 2019 3:11 PM
To: Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Thayer, Reed/SAC <Reed.Thayer@jacobs.com>
Subject: Pulse and Post-Pulse Logic Used in CalSim (from Appendix 5.A of the 2016 CWF BA Effects Analysis)

Appendix 5.A of the 2016 CWF BA is at this link.

Here is the relevant excerpt (from the bottom of Page 30).

"

5.A.5.2.4.9 North Delta Diversion Bypass Flows
Bypass flows requirements in the Sacramento River are specified downstream of the north Delta diversion intakes, which govern the flow required to remain in the river before any diversion can occur. The bypass rules include low level pumping at each intake during Sacramento River Pulse flow(s) period. After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection (Level I to Level II and subsequently to Level III) subject to hydrologic and fishery conditions. Minimum bypass flow requirements are specified for July through November, as noted in Table 5.A-13.

Beginning October 1st, whenever the initial Sacramento River pulse begins low level pumping allows diversions of up to 6% of Sacramento River flow flow upstream of the north Delta intakes. The low level pumping is less than or equal to 300 cfs at any one intake, with a combined limit of 900 cfs for the three intakes in the PA. The low level pumping is constrained such that the river flow never falls below 5,000 cfs.

During the initial pulse protection period low level pumping is maintained until the pulse period has ended. For modeling purposes, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs. The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days. If the initial pulse begins and ends before December 1, the May Level 1 post-pulse criteria will go into effect after the pulse until December 1. On December 1, the post-pulse rules defined below for December through April, starting with Level 1 apply. If the initial pulse begins and ends before December 1st, a second pulse period will be afforded the same protective operation.

After the pulse period has ended, the bypass flows noted in the Table 5.A-13 are maintained. After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied. The bypass rules were applied on the mean daily river flows in the CalSim II model. Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules. In actual operations these criteria as well as fishery conditions are expected to guide allowable north Delta intake diversions as described in Section 3.3.3.1 of the BA.

In addition to the bypass flow criteria described above, a linear constraint was applied in the CalSim II PA simulation on the potential diversion at the north Delta intakes, to account for the fish screen sweeping velocity criteria of 0.4 fps based on diversion limitations from DSM2 modeling.
"

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Facility Affordability Analysis Technical Memorandum

To:	Jim Watson
CC:	Rob Thomson JP Robinette
Date:	September 3, 2019
From:	Jeff Herrin
Quality Review by:	Joe Barnes
Authority Agent Review by:	Lee Frederiksen
Subject:	Facility Affordability Analysis

1.0 Purpose and Background

This memorandum documents the evaluation of various facility configurations and sizes in support of the financial affordability analysis. AECOM provided three types of analysis in support of the affordability analysis.

- WISP and federal feasibility reports were reviewed to characterize the commitments for project benefits and potential repayment mechanisms.
- Rough appraisal costs were developed for a variety of facility sizes and configurations
- Operation, maintenance, and replacement (OM&R) costs were estimated for each of the facility configurations

2.0 Benefit Distribution Assumptions

Although the California Water Commission has determined that the Sites Project is eligible for up to $816M in WSIP funding, the financial commitment to specific public benefits was not specified. Benefits identified by the State included recreation and flood damage reduction, neither of which requires the obligation of water supply from the project. It was necessary to estimate what portion of the $816M investment was reasonably intended to purchase water supply.

The Federal government has also indicated an interest in investing in recreation and flood damage reduction benefits through the ongoing feasibility report process. Flood damage reduction is typically cost shared with the State at a 65% (Federal)/35% (State) cost share. Recreation costs have been more typically shared equally between the State and Federal government.

The State's economic analysis determined a maximum benefit of $44M for flood damage reduction and $197M for recreation. Federal economic analysis has determined a benefit of $62M for flood damage reduction and $71M for recreation. Both analyses were based on the Authority's 1.8 MAF reservoir alternative. Table 1 shows the assumed distribution of benefits for the State and Federal government using the average of federal/State determined benefits for flood damage reduction and recreation and applying the cost sharing percentages.

Table 1. Assumed Distribution of Benefits for 1.8 MAF Reservoir

Benefit	**Proposed State Assignment**	**Proposed Federal Assignment**
	$millions	**$millions**
Flood Damage Reduction	$19	$34
Recreation	$67	$67
	Adjusted State for Water	**Adjusted Federal for Water**
	$millions	**$millions**
Anadromous Fish, Refuge, Yolo Bypass Benefits[1]	$730	$1,320

[1] Remaining benefits derived from WSIP responses and Feasibility Report (unpublished draft)

The adjusted water values in Table 1 were provided to Jacobs for use in operations modeling to establish the appropriate storage volumes for State and Federal benefits. The flood damage reduction benefit provided by Sites Dam is essentially the same for all reservoir sizes (improvements in flood damage reduction associated with a higher dam are negligible). The flood damage reduction benefit was held constant across all dam sizes. Recreation benefits are expected to increase with increasing reservoir size. Table 2 shows how the dollar amounts for recreation were proportioned for different reservoir sizes.

Table 2. Assumed Recreation Benefit Assignment for Different Reservoir Sizes

	$millions				
	1.8 MAF	**1.5 MAF**	**1.3 MAF**	**0.8 MAF**	**1.0 MAF**
State	$67	$56	$48	$30	$37
Federal	$67	$56	$48	$30	$37

The assumed distribution of benefits is consistent with both the findings of the WSIP review process as posted on the California Water Commission website and the Federal feasibility report; however, there has not yet been a final assignment of benefits. The most likely future change would be a shift in recreation and flood damage reduction benefits to the State. Should this occur, it would increase the assignment of storage to the Federal government and decrease the assignment of storage to the State.

3.0 Construction Cost Scenarios

This section presents preliminary appraisal-level cost estimates for different sizes and configurations of Sites Reservoir Project facilities.

Construction cost estimates were based on detailed appraisal-level estimates for a 1.3 MAF reservoir (Alternative A in the EIR/S and feasibility report) and for a 1.8 MAF reservoir (Alternative D in the EIR/S and feasibility report). These estimates reflect the current project concepts and conceptual level of project design, with appropriate allowances for contingencies, non-contracts costs, and forward escalation. Other project-related costs are also provided, including environmental mitigation, and temporary and permanent easement acquisition. The Alternative D estimate was used to support the Authority's WSIP application. Estimated prices were developed in October 2015 dollars and have been escalated in this estimate.

The actual project construction cost ultimately would depend on the final design details of the preferred project alternative and the labor and material costs, market conditions, and other variable factors existing at the time of bid. Accordingly, the final project cost would vary from the preliminary estimates presented in this section.

3.1 Scenarios Considered

In addition to Alternative D, six scenarios were considered in detail to evaluate project costs and operations.

- Scenario A1 – 1.5 MAF reservoir with two Delevan pipelines

- Scenario A2 – 1.3 MAF reservoir with two Delevan pipelines
- Scenario A3 – 0.8 MAF reservoir with two Delevan pipelines
- Scenario A4 – 1.0 MAF reservoir with two Delevan pipelines
- Scenario B1 – 1.5 MAF reservoir with one Delevan pipeline
- Scenario B2 – 1.3 MAF reservoir with one Delevan pipeline
- Scenario B3 – 0.8 MAF reservoir with one Delevan pipeline
- Scenario B4 – 1.0 MAF reservoir with one Delevan pipeline

All six scenarios include significant reductions in facilities to reduce costs. These cost reductions include:

- The Delevan intake pumping/generating plant and fish screen is not included in any of the six scenarios. It is replaced with a release structure to allow the delivery of water to the Sacramento River.
- With the elimination of the Delevan intake pumping/generating plant, there is no need for a new substation in Colusa or transmission line along SR 45. It is also assumed that available power sources in the vicinity of the Maxwell Irrigation District pumping plant would be adequate for electrical needs for the release only valve structure.
- None of the six scenarios include pumpback generation. This eliminates the forebay/afterbay (Holthouse or Fletcher Reservoir). Power can still be generated on release only to reduce OM&R.
- None of the six scenarios include the south bridge. A southern road alignment is included in the costs for the 1.5 and 1.3 MAF reservoirs with a shorter road anticipated for a 0.8 MAF reservoir.

3.2 Level and Classification of Cost Estimates

The availability of site data and design information to support preparing cost estimates for the 1.3 MAF and 1.8 MAF reservoirs varies between the facilities that constitute the Sites Reservoir project. Some facilities (like the main dams) are advanced enough to support a lower-bound Class 3 estimate as defined by the Association for Advancement of Cost Engineering, International. Other facilities, like the pumping/generating plants or Holthouse Dam, only support a Class 4 estimate.

The estimate for the 0.8 MAF reservoir dams used dimensions and cost ratios derived from quantities previously developed by DWR (DWR DOE. 2004. *Sites Reservoir Engineering Feasibility Study – Sites Reservoir Alternative Reservoir Size Evaluation*. October.). The estimate for the 1.5 MAF reservoir dams was interpolated between the 1.8 MAF and 1.3 MAF reservoirs without supporting quantities. Similarly, the estimate for the 1.0 MAF reservoir was interpolated from the 0.8 MAF and 1.3 MAF facilities.

3.3 Cost Estimate Considerations

Contract Costs: Contract costs include quantity and unit price estimates, plus allowances for mobilization/demobilization, design contingency, and unlisted items. Note that design contingency incorporates an allowance for procurement strategy covering non-competitive procurements or where limits are placed on the competition and a contract for construction may not go to the lowest responsive, responsible bidder.

Field Cost: The field cost is the sum of the contract cost and construction contingency.

Non-Contract Costs: Non-contract costs include engineering, administration, legal services, and permitting costs.

Construction Cost: The construction cost is the sum of the field cost and non-contract costs. The construction cost can be escalated to the notice to proceed date for the project, and further to the mid-point of construction for each project component if needed.

3.4 Construction Cost Components

3.4.1 Estimate Base and Escalation

The contract, field, and construction cost estimates presented in this section were compiled using individual-estimate worksheets for each NODOS/Sites Reservoir Project feature. All costs are provided in October 2015 dollars. Escalation of construction costs to a notice to proceed date in mid-2022 has been included. Escalation was evaluated using various sources, including the USACE Civil Works Construction Cost Index and the Consumer Price Index. Results varied from 15.3 percent to 15.8 percent over the escalation period. For the project alternatives, 15 percent over 7 years has been applied for each alternative.

3.4.2 Construction Contingency

Construction contingency is a percentage allowance added to develop the field cost. Contingencies are funds for use after construction starts to compensate the contractor for such issues as unforeseen or changed site conditions, owner-directed orders for change, and differences between estimated and actual quantities. Contingency allowances are generally higher for appraisal-level estimates than for feasibility-level estimates.

Table 3 presents the allowances and contingency percentages adopted and applied to the feasibility-level cost estimate for the alternative projects.

Table 3. Allowances and Contingencies for Estimating

Allowances and Contingencies	Percentages
Mobilization/Demobilization	5 percent
Design Contingency	10 percent
Construction Contingency	15 percent
Non-Contract Costs	17 percent

Mobilization/Demobilization at 5 percent and Design Contingency at 10 percent combined are reasonable allowances for feasibility-level estimating on large projects.

The mobilization/demobilization allowance and design and construction contingencies were applied to the contractor costs to develop the contract cost. The construction contingency was applied to the contract cost to arrive at the field cost. Non-contract costs were applied to the field cost to arrive at the construction cost.

3.5 Non-Contract Costs

Non-contract costs include engineering and design, surveying, construction management and inspection, project close-out, administration, legal services, permitting, etc. For the estimates presented in this section, the non-contract costs were estimated to be 17 percent of the total field costs (contract cost plus contingency). Actual non-contract costs would vary from facility to facility; however, 17 percent is assumed to represent the average value. This allowance was used for all six scenarios .

3.6 Other Cost Allowances

3.6.1 Environmental Mitigation

Many environmental laws affect the State's major water supply programs, and environmental concerns play a major role in water policy and planning. Mitigation costs for Alternative C are based on the environmental impact analysis, and implementing the mitigation measures from the *NODOS Preliminary Administrative Draft Environmental Impact Report* (DWR 2013). Additional details are available in *Sites Reservoir Feasibility Study Technical Memorandum: Mitigation Measure Evaluation and Cost Estimate* (AECOM 2016).

The allowances and contingencies by component applied to mitigation cost estimates would be different from the values used for other costs in Table 3 because of the nature of the nature of the work and are presented in Table 4. The mobilization/demobilization allowance and design and construction contingencies were applied to develop the field cost. The non-contract cost allowance was then applied to the field cost to arrive at the construction cost.

Table 4. Cost Estimate Allowances and Contingencies for Mitigation Costs

Component	Value	Basis for Assigned Allowance or Contingency
Mobilization/ Demobilization	2%	Approximately 65% of the mitigation costs are associated with real estate actions, 19% of the costs with environmental and cultural resources monitoring, and the remaining 16% for restoration. Mobilization/demobilization for monitoring largely consists of the mobilization and demobilization of environmental monitoring staff with pickup trucks, and infrequent short-term monitoring by watercraft. In this case, mobilization/demobilization costs are likely to be in the range of 1% to 2%.
Design Contingency	12%	Covers minor unlisted items, minor design and scope changes, and cost estimating refinements. This is the area of greatest uncertainty prior to the negotiation of permits. We recommend increasing the design contingency from 10% to 12%.
Procurement Strategy	1%	The most notable effort would be associated with procuring mitigation credits. The construction contractors selected for facility construction would perform the bulk of the restoration and construction-related tasks. There would be a real estate contractor and one or two environmental monitoring contracts. There may be some small landscaping contracts. Most of the oversight throughout would likely be performed by the environmental contractor, who would work for the Authority.
Escalation to Notice to Proceed	—	This would be consistent with the overall project construction cost estimate.
Construction Contingency	2%	Only 16% of the total mitigation is anticipated to include construction costs related to restoration. The construction contingency for real estate and monitoring should be very low.
Non-Contract Costs	4%	Approximately $52 million in monitoring costs is already included in the mitigation estimates. We do not anticipate another layer of construction management. There would be some design, but the design would be highly constrained by the permits.

Source: Data compiled by AECOM in 2016.

3.6.2 Right-of-Way

ROW costs represent the estimated fair market value of the real estate required for the NODOS/Sites Reservoir Project; they do not include staff costs for appraisals or acquisition, damages to the remaining land caused by the acquisition or construction of the project, or utility relocations that may be necessary.

3.7 Assumptions

Major assumptions made to prepare the preliminary feasibility cost estimates include:

- Competitive market conditions would prevail at the time of bid tender.
- Work would be packaged for bidding so that the magnitude of the contract would not unduly restrict competition.
- The construction schedule assumes a start of field construction activities in the second quarter of 2022 for all scenarios.
- Environmental mitigation and ecosystem enhancement measures would be consistent with those currently used in practice and would be the same for each alternative.
- Builder's Risk Insurance would be available to the contractor.
- Materials such as sand, gravel, and cement would remain available within the haul distances used to prepare the estimates.

3.8 Exclusions

Major exclusions from the cost estimates include:

- Utility costs for system upgrades to provide pumping power or receive generation power are not defied at this time, and no costs are included.
- There would be no new overpasses, interchanges, or sidings required for existing highways, roads, and rail lines associated with constructing the NODOS/Sites Reservoir Project.

3.9 Cost Estimate Summary

Table 5 presents the estimated cost for each of the four NODOS/Sites Reservoir Project scenarios with two Delevan pipelines and Table 6 the cost for scenarios with a single pipeline.

[redacted]

Table 5. Cost Estimate Summary – Two Delevan Pipeline Scenarios

	Scenario A0	Scenario G1	Scenario G2	Scenario G3	Scenario A1	Scenario A2	Scenario A3
	1.8 MAF	1.5 MAF	1.3 MAF	1.0 MAF	1.5 MAF	1.3 MAF	0.8 MAF
Total ($2018) w/o financing cost	$5,234,596,920	$4,662,196,920	$4,446,196,920	$4,346,836,920	$4,240,564,920	$3,972,724,920	$3,642,244,920
% cost reduction	0%	11%	15%	17%	19%	24%	30%
Total ($2015)	$4,846,849,000	$4,316,849,000	$4,116,849,000	$4,024,849,000	$3,926,449,000	$3,678,449,000	$3,372,449,000
	Two Pipelines/with Delevan Intake				Two Pipelines/without Delevan Intake		
RESERVOIRS AND DAMS	Cost	Cost	Cost	Cost	Cost	Cost	Cost
Develop Sites Reservoir Area	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000
Bridge	$215,000,000	$114,000,000	$114,000,000	$114,000,000	$114,000,000	$114,000,000	$114,000,000
Construct Main Dams	$610,000,000	$511,000,000	$400,000,000	$317,000,000	$511,000,000	$400,000,000	$296,000,000
Construct Saddle Dams	$270,000,000	$183,000,000	$94,000,000	$85,000,000	$183,000,000	$94,000,000	$6,000,000
Construct Holthouse Reservoir or Funks Appurtenances	$190,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000
Construct TRR Reservoir	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000
PUMPING AND GENERATING PLANTS							
Construct I/O Structure and 30' Diameter Tunnel	$210,000,000	$210,000,000	$210,000,000	$210,000,000	$210,000,000	$200,000,000	$149,000,000
Sites Pumping-Generating Plant	$800,000,000	$702,000,000	$702,000,000	$702,000,000	$702,000,000	$664,000,000	$601,000,000
TRR Pumping-Generating Plant	$160,000,000	$160,000,000	$160,000,000	$160,000,000	$160,000,000	$160,000,000	$160,000,000
Sacramento River Pumping-Generating Plant	$260,000,000	$260,000,000	$260,000,000	$260,000,000	$16,600,000	$16,600,000	$16,600,000
Sacramento River Fish Screen Structure	$55,000,000	$55,000,000	$55,000,000	$55,000,000	$0	$0	$0
Red Bluff Pump Addition	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000
Canals and Conduits							
Construct Channel to Holthouse	$49,000,000	$49,000,000	$49,000,000	$49,000,000	$49,000,000	$49,000,000	$49,000,000
Construct Delevan Pipeline	$660,000,000	$660,000,000	$660,000,000	$660,000,000	$660,000,000	$660,000,000	$660,000,000
Construct TRR Pipeline	$350,000,000	$373,000,000	$373,000,000	$373,000,000	$373,000,000	$373,000,000	$373,000,000
Transmission Lines, Switchyards and Substations	$190,000,000	$190,000,000	$190,000,000	$190,000,000	$98,000,000	$98,000,000	$98,000,000
General Property	$30,000,000	$30,000,000	$30,000,000	$30,000,000	$30,000,000	$30,000,000	$30,000,000
Mitigation ($350M construction + $150M operation)	$500,000,000	$500,000,000	$500,000,000	$500,000,000	$500,000,000	$500,000,000	$500,000,000
Delevan Pipeline Capacity (Pumping) - cfs	2,000	2,000	2,000	2,000	0	0	0
Delevan Pipeline Capacity (Release) - cfs	1,500	1,500	1,500	1,500	1500	1500	1500
TRR Pipeline Capacity (Pumping) - cfs	1,800	1,800	1,800	1,800	1800	1800	1800
TRR Pipeline Capacity (Release) -cfs	1,200	1,200	1,200	1,200	1,200	1,200	1,200

Table 6. Cost Estimate Summary – One Delevan Pipeline Scenarios

	Scenario B1	**Scenario B2**	**Scenario B3**	**Scenario B4**	**Scenario F2**	**Scenario F3**	**Scenario F4**
	1.5 MAF	1.3 MAF	0.8 MAF	1.0 MAF	1.5 MAF	1.3 MAF	1.0 MAF
Total ($2018) w/o financing cost	$3,847,876,920	$3,580,036,920	$3,249,556,920	$3,439,636,920	$4,122,628,920	$3,906,628,920	$3,807,268,920
% cost reduction	26%	32%	38%	34%	21%	25%	27%
Total ($2015)	$3,562,849,000	$3,314,849,000	$3,008,849,000	$3,184,849,000	$3,817,249,000	$3,617,249,000	$3,525,249,000
	One Pipeline/without Delevan Intake				One Pipeline with Delevan Intake		
RESERVOIRS AND DAMS	Cost	Cost	Cost	Cost	Cost	Cost	Cost
Develop Sites Reservoir Area	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000
Bridge	$114,000,000	$114,000,000	$114,000,000	$114,000,000	$114,000,000	$114,000,000	$114,000,000
Construct Main Dams	$511,000,000	$400,000,000	$296,000,000	$317,000,000	$511,000,000	$400,000,000	$317,000,000
Construct Saddle Dams	$183,000,000	$94,000,000	$6,000,000	$85,000,000	$183,000,000	$94,000,000	$85,000,000
Construct Holthouse Reservoir or Funks Appurtenances	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000
Construct TRR Reservoir	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000
PUMPING AND GENERATING PLANTS							
Construct I/O Structure and 30' Diameter Tunnel	$210,000,000	$200,000,000	$149,000,000	$200,000,000	$210,000,000	$210,000,000	$210,000,000
Sites Pumping-Generating Plant	$702,000,000	$664,000,000	$601,000,000	$626,000,000	$628,000,000	$628,000,000	$628,000,000
TRR Pumping-Generating Plant	$160,000,000	$160,000,000	$160,000,000	$160,000,000	$160,000,000	$160,000,000	$160,000,000
Sacramento River Pumping-Generating Plant	$16,600,000	$16,600,000	$16,600,000	$16,600,000	$217,000,000	$217,000,000	$217,000,000
Sacramento River Fish Screen Structure	$0	$0	$0	$0	$36,000,000	$36,000,000	$36,000,000
Red Bluff Pump Addition	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000
Canals and Conduits							
Construct Channel to Holthouse	$49,000,000	$49,000,000	$49,000,000	$49,000,000	$49,000,000	$49,000,000	$49,000,000
Construct Delevan Pipeline	$389,400,000	$389,400,000	$389,400,000	$389,400,000	$389,400,000	$389,400,000	$389,400,000
Construct TRR Pipeline	$280,000,000	$280,000,000	$280,000,000	$280,000,000	$280,000,000	$280,000,000	$280,000,000
Transmission Lines, Switchyards and Substations	$98,000,000	$98,000,000	$98,000,000	$98,000,000	$190,000,000	$190,000,000	$190,000,000
General Property	$30,000,000	$30,000,000	$30,000,000	$30,000,000	$30,000,000	$30,000,000	$30,000,000
Mitigation ($350M construction + $150M operation)	$500,000,000	$500,000,000	$500,000,000	$500,000,000	$500,000,000	$500,000,000	$500,000,000
Delevan Pipeline Capacity (Pumping) - cfs	0	0	0	0	2,000	2,000	2,000
Delevan Pipeline Capacity (Release) - cfs	750	750	750	750	1,500	1,500	1,500
TRR Pipeline Capacity (Pumping) - cfs	1800	1800	1800	1800	1,800	1,800	1,800
TRR Pipeline Capacity (Release) -cfs	1,200	1,200	1,200	1,200	1,200	1,200	1,200

4.0 OM&R

The financial model requires estimated costs for OM&R. Many long-term OM&R costs are proportional to diversions (e.g., energy for pumping and wheeling costs for GCID and Reclamation facilities). Variable and fixed repair and replacement costs were estimated using INEL Guidelines (Estimation of Economic Parameters of U.S. Hydropower Resources for estimating O&M, 2003) and through comparison to costs for the Central Utah and Animas La Plata Projects. Estimated OM&R costs are summarized in Table 7.

Table 7. Annual OM&R Costs

Two Pipe Size (MAF)	Total Flow (TAF)	Estimated Diversion (TAF)	SOD Flow (TAF)	Pumping Energy	Wheeling	Variable	Var/AF	Fixed/AF	$OM&R/AF	$Generate/AF
1.8	455	503	178	$11,143	$14,126	$25,269	$55.54	$16	$71.54	$19
1.5	389	424	144	$11,174	$11,767	$22,941	$58.97	$19	$77.97	$22
1.3	370	400	129	$10,648	$11,055	$21,703	$58.66	$20	$78.66	$22
1.0	327	348	97	$9.410	$9,770	$19,180	$58.65	$23	$81.65	$22
0.8	299	314	70	$8,604	$8,933	$17,537	$58.65	$25	$83.65	$22

One Pipe Size (MAF)	Total Flow (TAF)	Estimated Diversion (TAF)	SOD Flow (TAF)	Pumping Energy	Wheeling	Variable	Var/AF	Fixed/AF	$OM&R/AF	$Generate/AF
1.5	357	394	98	$10,264	$10,278	$20,542	$57.54	$20	$77.54	$21
1.3	348	377	91	$10,032	$9,922	$20,572	$57.33	$21	$78.33	$21
1.0	319	333	75	$9,196	$9,128	$18,324	$57.44	$24	$81.44	$21
0.8	289	303	60	$8,331	$8,269	$16,600	$57.44	$26	$83.44	$21

Wheeling costs are conservatively estimated at $22/AF. Power costs (Table 8) were derived from modeling by PARO (DWR, 2016).

Table 8. Pumping Energy Costs from Feasibility Report

Pumping-Generation Site								
Planning Alternative	**Alternative A (1.3 MAF)**		**Alternative B (1.8 MAF)**		**Alternative C (1.8 MAF)**		**Alternative D (1.8 MAF)**	
Operations Strategy	**Incidental**	**Optimized**	**Incidental**	**Optimized**	**Incidental**	**Optimized**	**Incidental**	**Optimized**
Pumping	**Annual Revenues**							
T-C Canal Pumping	($302)	($302)	($363)	($363)	($284)	($284)	($323)	($323)
GCID Pumping	($483)	($483)	($549)	($549)	($474)	($474)	($518)	($518)
Delevan Pipeline Intake Facilities	($2,668)	($2,668)	N/A	N/A	($2,910)	($2,910)	($1,737)	($1,737)
TRR Pumping	($507)	($507)	($794)	($794)	($579)	($579)	($643)	($643)
Sites Pumping	($7,629)	($7,018)	($7,168)	($6,661)	($8,621)	($7,982)	($9,256)	($8,509)
Subtotal	**($11,588)**	**($10,977)**	**($8,873)**	**($8,367)**	**($12,868)**	**($12,229)**	**($12,477)**	**($11,731)**
Generation	**Annual Revenues**							
Sites Generation	$5,176	$6,050	$5,120	$5,779	$6,401	$7,054	$6,359	$6,865
TRR Generation	$874	$874	$298	$298	$925	$925	$495	$495
Sacramento River Generation	$1,980	$1,980	N/A	N/A	$2,280	$2,280	$2,152	$2,152
Subtotal	**$8,031**	**$8,905**	**$5,419**	**$6,077**	**$9,606**	**$10,259**	**$9,007**	**$9,512**

Costs derived from modeling performed by the DWR Power and Risk Office (PARO) – Reclamation, 2017 (Appendix H1)

5.0 Limitations

The cost estimates presented in this report are at an appraisal level and useful for the comparison of options. Specifically, no quantities have been developed to support the 1.5 MAF reservoir option. Quantities for other options are derived from available DWR estimates.

6.0 References

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esa ECOSPHERE

Modeling composite effects of marine and freshwater processes on migratory species

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Abstract. Life histories of migratory species such as anadromous fishes make them particularly susceptible to composite effects of processes experienced across distinct habitats and life stages. Therefore, their population dynamics are difficult to quantify and manage without tools such as life-cycle models. As a model species for which life-cycle modeling is particularly useful, we provide an analysis of influential processes affecting dynamics of the Central Valley fall-run Chinook salmon (CVFC) population (*Oncorhynchus tshawytscha*). This analysis demonstrates how, through identification of covariates that affect this population at each life stage and their relationship to one another, it is possible to identify actions that best promote sustainability for this anadromous species. We developed a life-cycle model for CVFC examining primary processes influencing variability in observed patterns of escapement from 1988 to 2016. CVFC are a valuable fishery along the US West Coast; however, their natural population is a fraction of its historic size, and recent low escapements have resulted in substantial restrictions on the fishery. Our model explains 68.3% of variability in historic escapement values. The most influential processes include temperatures experienced during egg incubation, freshwater flow during juvenile outmigration, and environmentally mediated predation during early marine residence. This work demonstrates the need, and methodology, for considering the interactions between freshwater and marine dynamics when evaluating the efficacy of managerial practices in freshwater and the ocean, especially in the context of increased environmental variability, climate change, and dynamic predator populations. The methodology developed in this study can be used toward improved conservation and management of other anadromous fishes and migratory species.

Key words: anadromous fishes; California Current; climate change; composite effects; ecological interactions; ecosystem-based fisheries management; life-cycle model; migratory; salmon.

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INTRODUCTION

Worldwide, a significant number of anadromous fishes have experienced dramatic declines in abundance, including as much as 90–99% in North America (Limburg and Waldman 2009). Their complex life histories involving obligatory migrations and dependence upon freshwater, estuarine, and marine habitats make anadromous fish sensitive to human activities in these varied environments, and especially challenging to manage. To aid in recovery of anadromous species and sustain recovery gains, a life-cycle modeling approach is useful for identifying the most sensitive life stages and for developing effective management strategies. This approach is particularly useful for highly migratory species such as anadromous fishes because it accounts for additive consequences across the full life cycle, allowing for population-level assessments of the efficacy and impact of managerial practices affecting one or more stages or habitats.

We focus on California Central Valley Chinook salmon (*Oncorhynchus tshawytscha*) as a model species subject to composite effects across a wide range of habitats and life stages, and for which a life-cycle modeling approach is particularly informative (Zabel et al. 2006, Crozier et al. 2008, Hendrix et al. 2014). Pacific salmon are a forage item for predators in fresh (Michel et al. 2015) and marine waters (Wells et al. 2017), a dominant prey item in mammalian diets (Chasco et al. 2017), and provide a valuable fishery along the West Coast (Satterthwaite et al. 2015, Riddel et al. 2018). However, coincident with lost and degraded freshwater habitat (Yoshiyama et al. 1998, Williams 2006) and increased variability in the marine environment (Sydeman et al. 2013), the dominant California Chinook population (fall-run, hereafter "CVFC"; Pyper et al. 2013) has declined to a fraction of its historic size (Yoshiyama et al. 1998) and has shown enormous variability in freshwater returns over the last 30 yr (Appendix S1: Fig. S1; Satterthwaite and Carlson 2015, Pacific Fishery Management Council 2017*b*). For example, in 2008 and 2009 extremely low spawner escapement resulted in the near-complete closure of the Chinook salmon fisheries off California and much of Oregon; surprisingly, this event followed the highest recorded escapement in recent decades only six years prior (Lindley et al. 2009; Appendix S1: Fig. S1). All four Central Valley Chinook runs are managed under federal and state conservation initiatives; winter and spring runs are both protected under the Endangered Species Act (ESA), while fall- and late-fall runs have been listed as a Species of Concern by the National Marine Fisheries Service (NMFS). Describing how this population responds to different natural and anthropogenic processes informs strategic management initiatives for stock rebuilding, increased genetic portfolios (Carlson and Satterthwaite 2011), conservation of predators reliant on it (Chasco et al. 2017, Wells et al. 2017), and sustainability of the fishery (Lindley et al. 2009).

Central Valley fall-run Chinook salmon life history and pressures on the population

Central Valley fall-run Chinook salmon spawn from late September to December in the Sacramento River, its tributaries, and tributaries to the San Joaquin River (Fisher 1994, Yoshiyama et al. 1998, Fig. 1). Egg development time and survival are sensitive to water temperature (Zeug et al. 2012, Martin et al. 2017), as well as to increased or variable flows that can destroy eggs, modulate oxygen availability, or expose them to desiccation (Becker et al. 1982, Lapointe et al. 2000, Martin et al. 2017). Most locations where CVFC spawn are below reservoirs, which moderate flows and alter temperatures downstream. Egg and embryo survival can also be reduced by redd superimposition, which occurs at higher rates with increased adult abundance and decreased spawning habitat (McNeil 1964). After emergence, juveniles may rear near their place of birth or disperse downstream or onto floodplains, where growth rates are usually higher (Sommer et al. 2001). In the spring, juveniles undergo transformation to the smolt stage and migrate to the coastal ocean. Tagging studies show that survival during this period has been shown to increase with river discharge (Michel et al. 2015, Perry et al. 2018), and survival can be quite low during dry periods, most likely due to predation by other fish (Sabal et al. 2016). CVFC must migrate through the Sacramento—San Joaquin Delta, which has been heavily modified by channelization, diking, and the operations of a complex water supply infrastructure that alters the hydrodynamics and water quality of the estuary (Nichols et al. 1986). Survival rates for juvenile salmon migrating through the interior Delta are notably low (Buchanan et al. 2013). Hatchery-produced salmon may avoid or experience different mortality sources when released in different locations throughout the system (Huber and Carlson 2015). Very little is known about how

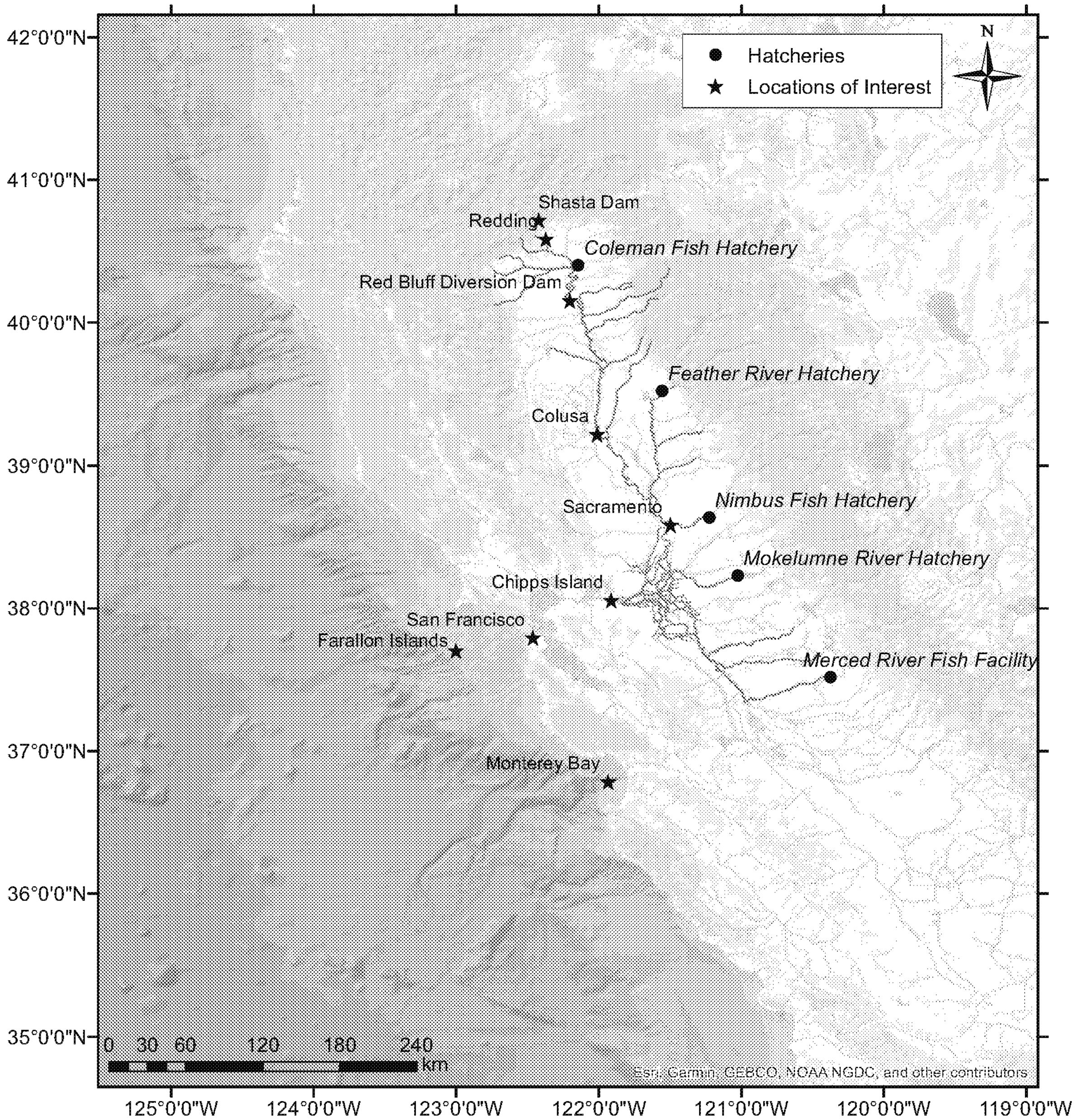

Fig. 1. Map of Central Valley fall-run Chinook habitat, hatchery locations (dots), and key locations (stars).

present conditions in the San Francisco Bay affect growth and survival of juvenile salmon. Survival of CVFC following ocean entry is dependent on predation risk and relatedly to the availability of suitable forage (Wells et al. 2012, Friedman et al. 2018), growth (Woodson et al. 2013, Fiechter et al. 2015), density dependence (Miller et al. 2013), and the occurrence of fronts enhancing trophic interactions (Woodson and Litvin 2015). These processes are affected by environmental variability modulating predator–prey relationships (Emmett and Krutzikowsky 2008, Wells et al. 2017). Factors affecting later ages, other than fishing, are less well understood, although size-at-age is variable and related to ocean conditions, and because mortality rates are often size-dependent, ocean climate variation may influence survival of later ages as well as young-of-the-year salmon (Heath et al. 1994, Wells et al. 2007).

Scope of study

Conservation and recovery efforts for this population require identification of those variables that most affect population dynamics and those that can be affected through management. In this study, we developed a model of CVFC population dynamics (FCα) to identify the processes that best explain the observed variability in CVFC population dynamics over the last three decades, as well as how additive effects among such processes relate to salmon escapement. Building from identification of key processes as well as their relationship to one another over time, we use the parameterized FCα model to illustrate potential effects of two management scenarios: changes to freshwater temperature during incubation and changes to freshwater flow during outmigration. This methodology may be applied toward conservation and management of other types of anadromous fishes and migratory species.

Methods

Model description

FCα is an age- and stage-structured population dynamics model that produces model-based predictions of year t annual adult escapement based on observed returns $t-2$, $t-3$, and $t-4$ yr prior, together with covariates affecting the estimated survival of each brood year cohort. The model predicts the abundance of male (M'_t) and female (F'_t) returns separately; adding the two values provides a model-predicted estimate of total spawner escapement for each year (E'_t). Covariate data were assembled from 1983 to 2016, and model predictions are provided over the period of 1988–2016. A conceptual diagram of the full model is presented in Fig. 2. The model was written and tested in R (version 3.5.1; R Core Team 2018).

Base model.—To quantify the effect of different covariates on annual adult escapement, we first constructed a base model representing known dynamics of the CVFC life cycle. Model testing included the base model and iterative combinations of non-collinear covariates. Eq. 1 shows the base model underlying FCα. This model predicts annual spawner returns (E'_t) based on the number of reported spawners estimated to be female 2, 3, and 4 yr prior (F_{t-2}, F_{t-3}, F_{t-4}; described below); the historic average proportion of males and females that return at ages 2, 3, and 4 ($R_{m.2}$, $R_{m.3}$, $R_{f.3}$, described below); published values of survival at ages 2, 3, and 4 in the ocean (S_2, S_3, S_4) (Magnusson and Hilborn 2003); background survival terms for natural-origin fry (S_{bN}), hatchery origin releases (S_{bH}), and juvenile survival ($S_{b\phi}$) estimated by model fitting; and an annual ocean harvest survival index ($S_{V.t}$; described below). Each female was assumed to have a fecundity (Y) of 5401 (Quinn 2005), and eggs were assumed to be 50% male and female. The model-predicted estimates of male spawners (M'_t) and female spawners (F'_t) were summed to provide a model-predicted estimate of total annual escapement (E'_t). Model-predicted estimates were compared to spawner escapement values reported by the Pacific Fishery Management Council (PFMC; Pacific Fishery Management Council 2017*b*) for the Sacramento River and San Joaquin River combined, for the period of 1983–2016 (E_t). These values result from annual surveys conducted throughout the Sacramento and San Joaquin basins (Kano 2006, Killam et al. 2016); they are treated as observed values in model fitting but are themselves best estimates. Further descriptions of all variables can be found in Table 1. During this period, 93.8% of all CVFC adult escapement was comprised of spawners returning to the Sacramento Basin.

The PFMC escapement data report the total number of adult spawners and jacks returning in each year, but do not differentiate males and females. To estimate these values, we used 11 yr (2000–2010) of spawner return data from Coleman National Fish Hatchery and Feather River Fish Hatchery in the Sacramento River Basin (California Hatchery Scientific Review Group 2012) to construct a relationship between the proportion of jacks to total and proportion of adult males to total returning to the hatcheries (Appendix S1: Fig. S2). Data from these two hatcheries were used as they had the longest overlapping time series and most complete data over the time period. Total females returning each year (F_t) were estimated as $E_t - M_t$, with M_t estimated using the hatchery relationship.

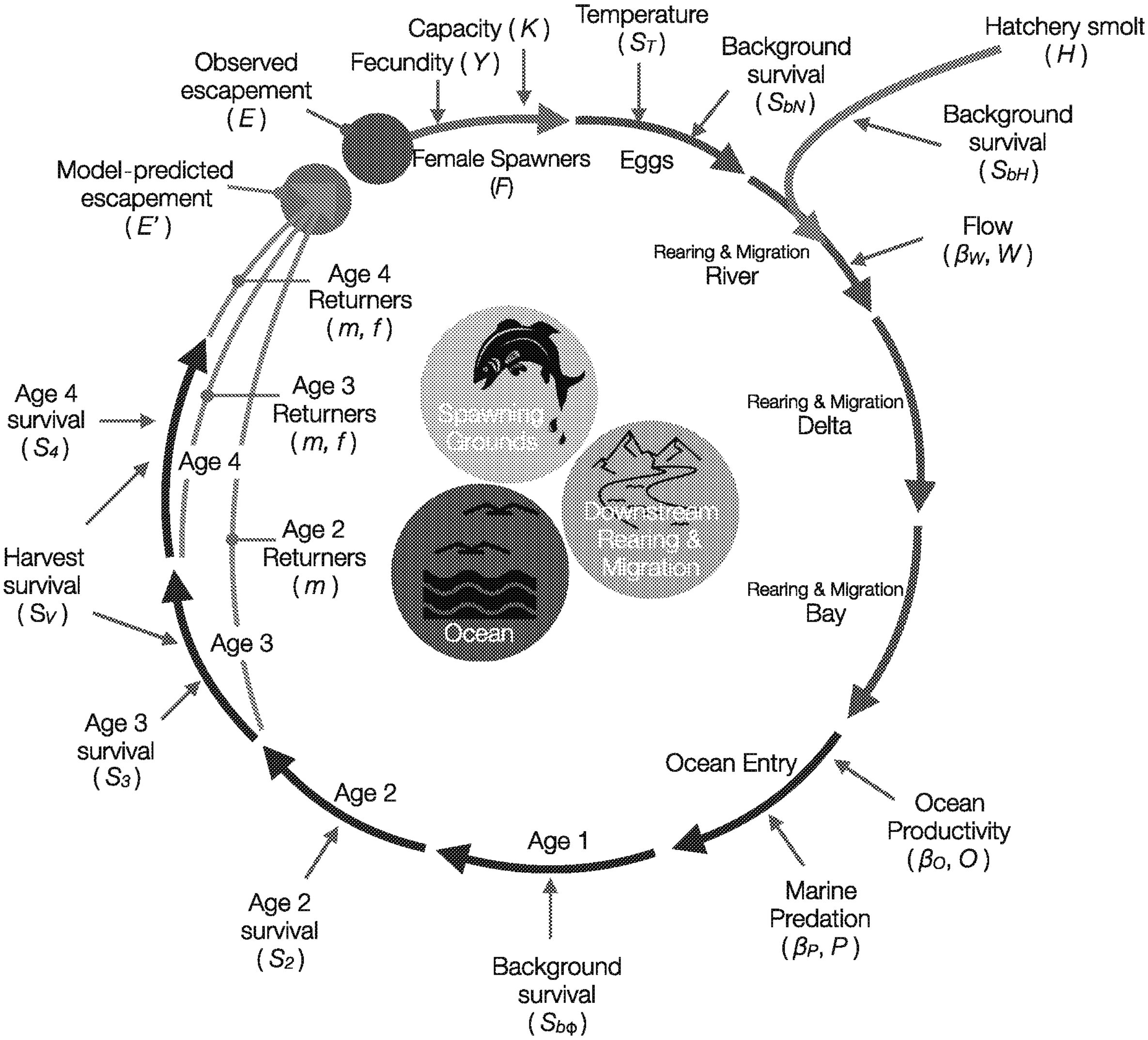

Fig. 2. Simplified diagram of the fall-run life-cycle model (FCα) showing the processes affecting a single brood year cohort. Note annual model-predicted escapement is the sum of these processes across multiple brood year cohorts (for more detail see Appendix S1: Eq. S1).

The average proportion of males and females returning by age category (corresponding to $R_{m.2}$, $R_{m.3}$, $R_{f.3}$; Table 1) were derived from the database of coded-wire-tagged fish maintained by the Regional Mark Processing Center (www.rmpc.org). We queried "Standard Reporting, All Recoveries" for all recoveries of Chinook salmon recorded over the maximum available time period (1990 to 2015) and "Standard Reporting, All Releases" for all releases of Chinook salmon recorded over the same period (1986–2014). We used only Central Valley fall-run Chinook salmon released as fry or smolts in the Sacramento River or its tributaries by Coleman National Fish Hatchery, for which there were data on release, spawner return, and the sex of recovered individuals. We estimated returning age-group percentages for each sex, based on all returns from salmon released over the 29-yr period (Appendix S1: Fig. S3). In FCα, male return estimates are the sum of estimates for age 2, 3, and 4 males (capturing 98% of the returning population; Appendix S1: Fig. S3). Female return estimates are the sum of estimates for age 3 and

Table 1. FCα model terms and descriptions. Observed data are those reported or derived from published annual escapement data.

Variable	Value	Description
t	{1983,1984,...,2016}	Year
E	E_t	Number of total spawners observed in year t
F	F_t	Number of female spawners observed in year t
Y	5401	Average fecundity for an adult female chinook salmon
b_T	$0.024°C^{-1}·d^{-1}$	Slope at which mortality rate increases above T_{crit}
S_T	$S_{T.t}$	Annual temperature-dependent survival
S_2	0.6	Survival for age 2 chinook at sea
S_3	0.7	Survival for age 3 chinook at sea
S_4	0.8	Survival for age 4 chinook at sea
S_V	$S_{V.t}$	Annual ocean harvest survival index
$R_{m.2}$	0.220	Mean proportion of CWT males returning at age-2
$R_{m.3}$	0.583	Mean proportion of CWT males returning at age-3
$R_{f.3}$	0.665	Mean proportion of CWT females returning at age-3
Parameter estimates		
T_{crit}	11.56 (10.80, 12.99)	Temperature threshold at RBDD
S_{bN}	0.043 (0.003, 0.758)	Background survival for naturally spawned fry
S_{bH}	0.403 (0.060, 1.000)	Background survival for hatchery fish released in rivers
$S_{b\phi}$	0.246 (0.083, 0.658)	Background survival for natural and hatchery fish to age-2
β_W	1.448 (0.787, 2.098)	Coefficient for flow-dependent survival
β_P	−1.185 (−1.664, −0.797)	Coefficient for marine predation risk
β_O	–	Coefficient for survival based on ocean productivity
K	–	Spawner capacity
Model-based predictions		
E'	E'_t	Model-predicted number of total spawners in year t
F'	F'_t	Model-predicted number of female spawners in year t
M'	M'_t	Model-predicted number of male spawners in year t

Notes: References and further explanation of variables can be found in methods. 95% confidence intervals are reported in parentheses next to parameter estimates for covariates included in the final model (Model 1). Dashes indicate parameters that were tested but not included in the final model.

4 females (capturing 96% of the returning population; Appendix S1: Fig. S3).

During the last 30 yr, the five primary hatcheries on the Sacramento and San Joaquin rivers and tributaries (Coleman, Feather, Nimbus, Mokelumne, Merced) have released an annual average of 28.3 million hatchery-raised CVFC throughout the system (Huber and Carlson 2015) over the same period as natural fall-run juvenile outmigration. To capture the contribution of hatchery smolts to the return population, we included the total number of sub-yearling salmon released by the five major hatcheries (H). Hatchery release data for 1970–2016 were collected by Huber and Carlson (2015), Appendix B) and A. M. Sturrock et al. (*unpublished manuscript*).

We derived an annual ocean harvest survival index (S_V) from published harvest rates and population estimates defined as $S_V = 1 -$ (ocean harvest/Sacramento Index) (O'Farrell et al. 2013, Pacific Fishery Management Council 2017*a*). Ocean harvest is the annual sum of ocean troll and sport harvest of SRFC south of Cape Falcon, OR, between September 1 and August 31 (Pacific Fishery Management Council 2017*a*). The Sacramento Index approximates the total population of spawners in a given year as the sum of ocean harvest, river harvest, and annual escapement (O'Farrell et al. 2013). S_V was allowed to affect only individuals greater than age 2, corresponding to those individuals typically large enough to be harvested by ocean fisheries (Pacific Fishery Management Council 2017*b*; Satterthwaite et al. 2017).

Error in our model is represented by the difference between predicted and observed data. We estimate the distribution of error as a normal distribution, with a mean equal to zero and a variance equal to the variance of our residuals.

$$\begin{aligned}
M'_t =& \left(F_{t-2} \times \frac{Y}{2} \times S_{bN} + \frac{H_{t-1}}{2} \times S_{bH}\right) \times S_{b\phi} \times S_2 \times R_{m,2} + \\
& \left(F_{t-3} \times \frac{Y}{2} \times S_{bN} + \frac{H_{t-2}}{2} \times S_{bH}\right) \times S_{b\phi} \times S_2 \times S_3 \times S_{V,t} \times R_{m,3} + \\
& \left(F_{t-4} \times \frac{Y}{2} \times S_{bN} + \frac{H_{t-3}}{2} \times S_{bH}\right) \times S_{b\phi} \times S_2 \times S_3 \times S_4 \times S_{V,t-1} \times S_{V,t} \times (1 - (R_{m,2} + R_{m,3})) \\
F'_t =& \left(F_{t-3} \times \frac{Y}{2} \times S_{bN} + \frac{H_{t-2}}{2} \times S_{bH}\right) \times S_{b\phi} \times S_2 \times S_3 \times S_{V,t} \times R_{f,3} + \\
& \left(F_{t-4} \times \frac{Y}{2} \times S_{bN} + \frac{H_{t-3}}{2} \times S_{bH}\right) \times S_{b\phi} \times S_2 \times S_3 \times S_4 \times S_{V,t-1} \times S_{V,t} \times (1 - R_{f,3}) \\
E'_t =& M'_t + F'_t
\end{aligned} \tag{1}$$

Sub-models

Temperature-dependent egg mortality.—We used a temperature-dependent mortality sub-model (Martin et al. 2017) to estimate annual survival (S_T) for eggs incubating in the Sacramento and San Joaquin and their tributaries. The model relates the temperature experienced by an embryo during the ith day of its development (T_i) to its instantaneous mortality rate (h_i; d^{-1}) with two parameters: T_{crit}, the temperature below which there is no mortality due to temperature, and b_T, the slope at which mortality rate increases with temperature above T_{crit} (Eq. 2)

$$h_i = b_T \times \max(T_i - T_{\text{crit}}, 0) \tag{2}$$

Central Valley fall-run Chinook salmon spawn in the Sacramento River and its tributaries, as well as tributaries of the San Joaquin River (Yoshiyama et al. 2000, Palmer-Zwahlen and Kormos 2015). To minimize complexity and data scarcity, we chose a single site, Red Bluff Diversion Dam (RBDD), to approximate patterns in temperature across the system. RBDD is located on the Sacramento River near Red Bluff CA (40°09′16″N, 122°12′07″W). We extracted daily minimum and maximum water temperature data from 1983 to 1989 from California Department of Water Resources reports (Turek 1990) and calculated the mean of these values for each day. We approximated missing data using iterative singular spectrum analysis, a nonparametric method which uses temporal and spatial correlation to fill data gaps (Kondrashov and Ghil 2006). We used daily mean water temperature at Bend Bridge, CA (USGS site 11377100) and from the RMA-11 model (Deas 2002) for this temperature reconstruction. We used temperature data for RBDD from 1990 to 2016 from the River Assessment for Forecasting Temperature (RAFT) model, which uses hydrodynamic and heat transport equations to model water temperature (Pike et al. 2013). RAFT output has a 15-min temporal resolution and 2-km spatial resolution. We averaged the sub-daily data and used linear interpolation to obtain daily mean water temperature at RBDD. To verify RBDD data were representative of the system, we compared mean daily temperatures recorded at RBDD to daily temperatures recorded at 9 other major spawning regions for CVFC and found high correlations between all sites and RBDD (Pearson's r = 0.76–0.91; Table 2). Data for each of the 9 sites were downloaded from the California Department of Water Resources California Data Exchange Center (CDEC).

Table 2. Correlations (Pearson's r) between daily temperature at Red Bluff Diversion Dam (RBDD) and temperatures recorded throughout spawning range of CVFC.

Region	Site ID	Data Coverage	Correlation to RBDD (r)
Clear Creek	IGO	1996–2017	0.80
Butte Creek	BCK	1998–2017	0.82
Feather River	FRA	2002–2017	0.85
Yuba River	YRS	2001–2017	0.83
American River	AFD	1998–2017	0.76
Mokelumne River	MOK	2008–2017	0.91
Stanislaus River	SOK	2001–2017	0.85
Tuolumne River	TTS	2004–2017	0.83
Merced River	CRS	2000–2017	0.85

Note: Site IDs are those used by CDEC.

We used published data on annual CVFC spawning periods (Vogel and Marine 1991, Williams 2006) to estimate temporal patterns in redd constructions over the spawning period (a normal distribution with peak spawning occurring on November 15, and 99.9% of redds spawned from October 1 to December 1). Incubation periods (n, days), starting at each possible fertilization day (October 1 through December 1), were determined using a temperature-dependent maturation function (Zeug et al. 2012, Martin et al. 2017), where the relative developmental state at fertilization equals 0 and increases at a rate, $0.001044(°C^{-1}·d^{-1}) \times T_i + 0.00056(d^{-1})$. Incubation periods ended when the temperature-dependent developmental state exceeded 1.

Temperature-dependent survival throughout the entire embryonic period (S_T) is the product of the daily temperature-dependent survival probabilities for each year (Eq. 3).

$$S_T = 1 - \prod_{i=1}^{n} \exp(-h_i) \tag{3}$$

Given our temperature data do not represent the exact conditions experienced by the widespread CVFC, and to minimize model complexity, we used the published value of b_T from Martin et al. (2017) $0.024°C^{-1}·d^{-1}$. In that study (2017), estimates for b_T were found to be similar across laboratory and field contexts, and laboratory datasets that b_T was fit to include both fall and winter-run embryos, which displayed similar thermal performance curves. T_{crit} was estimated simultaneously with all other model parameters. It is important to note that our T_{crit} estimate does not represent a physiological thermal limit, rather the temperature at one site (RBDD) above which mortality is expected to be high throughout the system.

Density-dependent superimposition of redds.—Capacity effects in spawning grounds have not been well quantified for CVFC, though are presumed to occur (Hallock 1977, Williams 2006) and are considered in the conservation objectives for the population (Pacific Fishery Management Council 2016). In particular, there may be limited optimal habitat for spawning, leading to an increased probability of redds being superimposed by later spawners when female spawner abundance (F) is high (Essington et al. 2000). We evaluated whether female spawner density affects naturally spawned egg-to-smolt survival (S_N) by testing the inclusion of a Beverton-Holt density dependence term (Beverton and Holt 1959) in our models. We note that other factors, such as competition for resources, may also contribute but are untestable at present due to limited data.

$$S_N = S_{bN}/(1 + F/K) \tag{4}$$

In Eq. 4 S_{bN} is the expected egg-to-smolt survival probability in the absence of temperature- or density-dependent survival, and K is a capacity parameter representing the maximum number of spawners.

Environmental covariates

River conditions during outmigration (W).—Flow data used in the model were from a gauge on the Sacramento River at Colusa, CA (39°12′51″N, 121°59′57″W; USGS site 11389500). Data were downloaded from the USGS National Water Information System (https://waterdata.usgs.gov/nwis). We calculated an annual median value for flow in February, aligning with the period at which at 50% of sampled CVFC juveniles were captured by rotary screw traps at Red Bluff Diversion Dam from 2005 to 2017. These data were derived from the Juvenile Salmonid Monitoring biweekly reports provided by USFWS (Poytress et al. 2014).

Delta conditions during outmigration.—Among the possible covariates relating to conditions in the Sacramento–San Joaquin River delta during the peak outmigration period (March to May), the net delta outflow index (NDOI; http://www.water.ca.gov) provides the best approximation of the amount of water and potential habitat available to juvenile salmon. However, mean NDOI during this period was positively correlated with February flow (W, described above) (Pearson's $r = 0.62$) in the Sacramento River. All other potential variables were less descriptive of delta habitat, and those that were marginally descriptive were correlated to February flow at $r > 0.60$. In order to control for collinearity, we only included February flow in our model.

Early marine residence: ocean productivity (O) and marine predation (P).—The North Pacific Gyre

Oscillation (NPGO) is derived from analyses of Northeast Pacific sea-surface temperature and sea-surface height and is an indicator of upwelling strength, nutrient fluxes, and current strength in the California Current Large Marine Ecosystem (CCLME) (Di Lorenzo et al. 2008). Upwelling and nutrient availability influence the production and retention of krill and forage fish on which outmigrating juvenile salmon depend (Dorman et al. 2011, 2015, Wells et al. 2012), and the annual NPGO variability has been shown to influence synchrony of juvenile Chinook salmon survival along the CCLME (Kilduff et al. 2015). We tested the inclusion of NPGO as a covariate of juvenile salmon survival during early marine residence. Monthly NPGO indices were downloaded from a public repository (www.o3d.org/npgo) and summarized as annual means (O) (Kilduff et al. 2015). We also tested seasonal averages describing fall, winter, spring, and summer conditions, but found no significant differences in model performance over the less restrictive annual estimates used by Kilduff et al. (2015).

To test whether inter-annual variation in predation risk was significant in the larger population dynamics of CVFC, we included an annual index of marine predation on juvenile outmigrants equal to the annual estimated abundance of common murre (*Uria aalge*) at Southeast Farallon Island multiplied by the annual proportion of murre diet consisting of salmon (Ainley et al. 1990, Roth et al. 2007, Wells et al. 2017). Common murre were chosen as a proxy for marine predation (P) during early marine residence based on the findings of Wells et al. (2017). Both population estimates and diet composition data were available for all years in the present study. Many other known and potential predators are showing increasing population trends, and may be having similar or greater impacts on juvenile salmon survival, but annual data on population and diet were not available to include in our model.

Transformations, model fitting, and model selection

We converted time series for the survival covariates (W, O, P) to standard scores and estimated coefficients for each covariate (β_W, β_O, β_P), capacity (K), and background survival (S_{bN}, S_{bH}, $S_{b\phi}$) through model optimization. We used the R package *optimx* (Nash and Varadhan 2011) to implement a box-constrained non-linear minimization routine (*nlminb*), iterating over possible beta-parameter values in concert to find a solution that minimized the sum of squared error (SSE) between log-transformed values of observed versus predicted escapement. Within the model, we multiplied standard scores of the survival covariates (W, O, P) by the corresponding coefficient, then transformed these time series using an inverse-logit function (R package *boot*) to scale the variables as survival probabilities from 0 to 1 (function *il* in Eq. 5, Appendix S1: Eq. S1). We constructed profiles of the log-likelihood surfaces for each estimated parameter to obtain 95% confidence intervals.

We used Akaike's Information Criterion (AIC; Sakamoto et al. 1986) to select the most parsimonious model among 32 candidates. All models included the base model and its associated parameters (S_{bN}, S_{bH}, $S_{b\phi}$; Eq. 1). The set of models tested included the base model with no additional parameters (Eq. 1) and all possible combinations of the base model with additional terms and associated parameters (K, S_T, β_W, β_O, β_P; e.g., all possible terms, Appendix S1: Eq. S1). Pairwise correlation coefficients (Pearson's $|r|$) among covariates ranged from 0.001 to 0.467, below established threshold values for collinearity (Dormann et al. 2013).

All models within a AIC difference (Δ) ≤ 4 are reported (Burnham and Anderson 2002, Deriso et al. 2008). Additional descriptive statistics reported include sum of squared error (SSE) between log-transformed values of observed versus predicted escapement, the proportion of variance predicted by the model (R^2), and goodness of fit (logL; log-likelihood ratio statistic). We used bootstrap resampling to estimate error in the model predictions.

Scenario testing

We used the parameterized FCα to evaluate the effect of two simple scenarios reflecting changes in freshwater temperatures during incubation and freshwater flow during outmigration. In the temperature scenario, the daily mean temperature matrix used to estimate egg-fry survival was varied from −3 to +3°C. These values correspond to those derived by Isaak et al. (2018) for projected increases in river temperatures in the northwestern United States. In the flow scenario, observed annual February flow values were varied from −3 to +3 standard deviations from the mean of the original time series (1 SD = 11,762 cfs).

Results

Model performance

The model with the most support included temperature-dependent egg mortality, freshwater flow, and the marine predation index (Model 1; Table 3, Eq. 5). This model explained 68.3% of the variation in spawner returns observed from 1988 to 2016 (Fig. 3). The second best model (Model 2; $R^2 = 0.715$; Table 3) was distinguished by an AIC difference of only 0.176 from the top model and included the spawner capacity submodel. However, confidence intervals for K were extremely wide, and post hoc model testing revealed a relationship between model estimates of K and background survival for natural-origin smolts (S_{bN}), with higher values of K estimated as S_{bN} were minimized. Lacking further data to constrain K, and because these two models are statistically equivalent, we conclude there is a lack of strong evidence for spawner capacity in these models and focus our results on the more parsimonious Model 1 (see *Discussion* for further detail). All additional models had ΔAIC values > 2 from the top model; those with ΔAIC values ≤4 are included in Table 3. The null model (Eq. 1) explained only 1% of the variation in spawner returns. Analysis of variable importance indicated that freshwater flow (W) and predation during the period of early ocean entry (P) were the most influential terms in our model (Fig. 4). Error in model predictions, estimated via bootstrap resampling, was minimal except in the case of a few years (Appendix S1: Fig. S5).

Final model covariates

The median daily temperature recorded from October to December each fall ranged from 10.0°C in 1983 to 14.4°C in 2014, with a positive trend over the 34-yr study period (Fig. 5A.1; see

Table 3. Best performing models found after model selection (ΔAIC ≤ 4).

Model	Terms	R^2	SSE	−logLik	AIC	ΔAIC	EP
1	$T_{\text{crit}}, \beta_W, \beta_P$	0.683	6.110	22.582	−33.164	0.000	6
2	$T_{\text{crit}}, K, \beta_W, \beta_P$	0.715	5.737	23.494	−32.988	0.176	7
3	$T_{\text{crit}}, \beta_W, \beta_O, \beta_P$	0.680	6.114	22.573	−31.147	2.017	7
4	β_W, β_P	0.607	7.511	19.588	−29.175	3.988	5

Notes: All models include the three estimated parameters (EP) from the base model (S_{bN}, S_{bH}, $S_{b\phi}$). Model 1 is discussed in text.

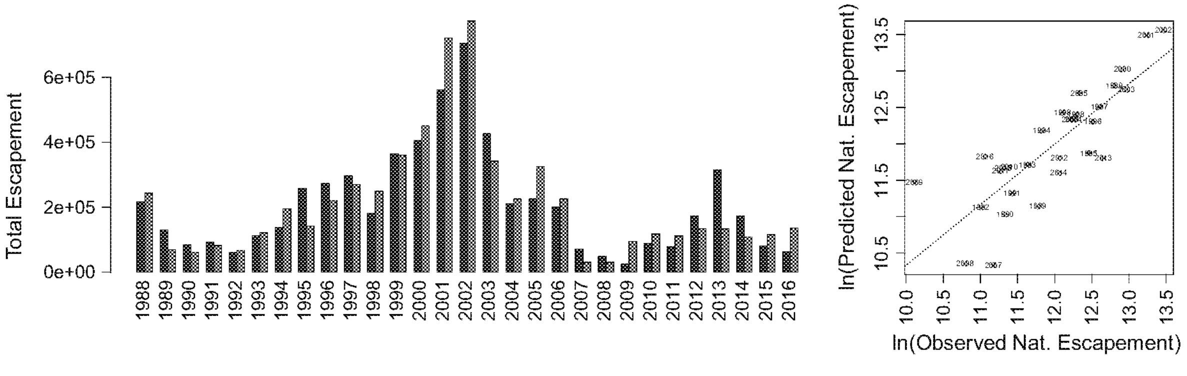

Fig. 3. Final model. Black bars indicate observed escapement; blue bars represent model-predicted escapement by FCα. 1988, 2002 peaks are captured, as are valleys in 1992 and 2008. The 2013 peak is not captured, and returns for 2001 are overestimated.

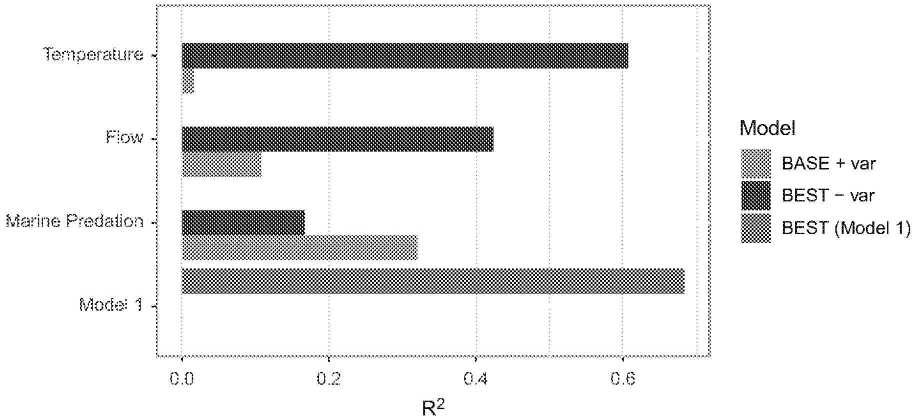

Fig. 4. Variable importance. Shown are all terms that occur in the best model (Model 1), the performance of the base model plus each term individually (gray), and the performance of the best model with that term excluded (dark blue), against the performance of the best model with all terms included (Model 1; blue).

Beer and Anderson 2013, Isaak et al. 2018, for more detailed analyses of temperature trends in this region).

The temperature-dependent mortality model estimated an annual survival based on estimated spawning date, temperature-dependent incubation period, and temperatures experienced during incubation. Therefore, while the median temperature from October to December describes some of the pattern of estimated mortality, it is not a complete depiction of experienced temperatures. Estimated survival based on temperature (Fig. 5A.2, A.3) ranged from <0.01 in 1991, 1996, and 2014 to 0.88 in 2011. The estimate for T_{crit} was 11.56°C (95% CI 10.80, 12.99).

Freshwater flow significantly affected model performance. With flow excluded, the model explained only 42.3% of the variation in CVFC escapement (Fig. 4). The estimate for the flow coefficient (β_W) was 1.448 (95% CI 0.787, 2.098). Significantly, above-average annual flows were uncommon during the period of our analysis, but corresponded to high survival estimates for the years when they occurred (1983, 1986, 1998–2000) (Fig. 5B.1, B.2).

The marine predation index contributed significantly to model performance. Without the inclusion of marine predation, the model explained only 16.7% of the variation in CVFC escapement (Fig. 4). The estimate for the marine predation coefficient (β_P) was −1.185 (95% CI −1.664, −0.797). Marine predation was especially high in the early 2000s and was above average for 11 yr between 2002 and 2016 (Fig. 5C.1, C.2).

Scenarios

We used FCα to evaluate the effect of two simple scenarios reflecting plausible changes in freshwater temperatures during incubation and freshwater flow during outmigration. Results should be interpreted as annual one-year-ahead predictions rather than multi-year patterns.

In years when observed escapement was mid to high (1996–2006), decreases in temperature during the incubation period predicted appreciably higher values of escapement than what was observed. However, in years when observed escapement was low, changes to temperature during the incubation period showed marginal effects. Overall, even a +1°C or −1°C degree shift in incubation temperatures showed substantial effects across years (Fig. 6A).

Increases in flow showed broad effects across years, with higher escapement predicted by increases in flow during the outmigration period in all years except for 2007–2008, when escapement has been shown to have been largely modulated by variability in ocean processes and related predation events (Lindley et al. 2009, Wells et al. 2017). Across all years, the −2 SD and −3 SD flow scenarios were associated with substantially lower escapement. (Fig. 6B).

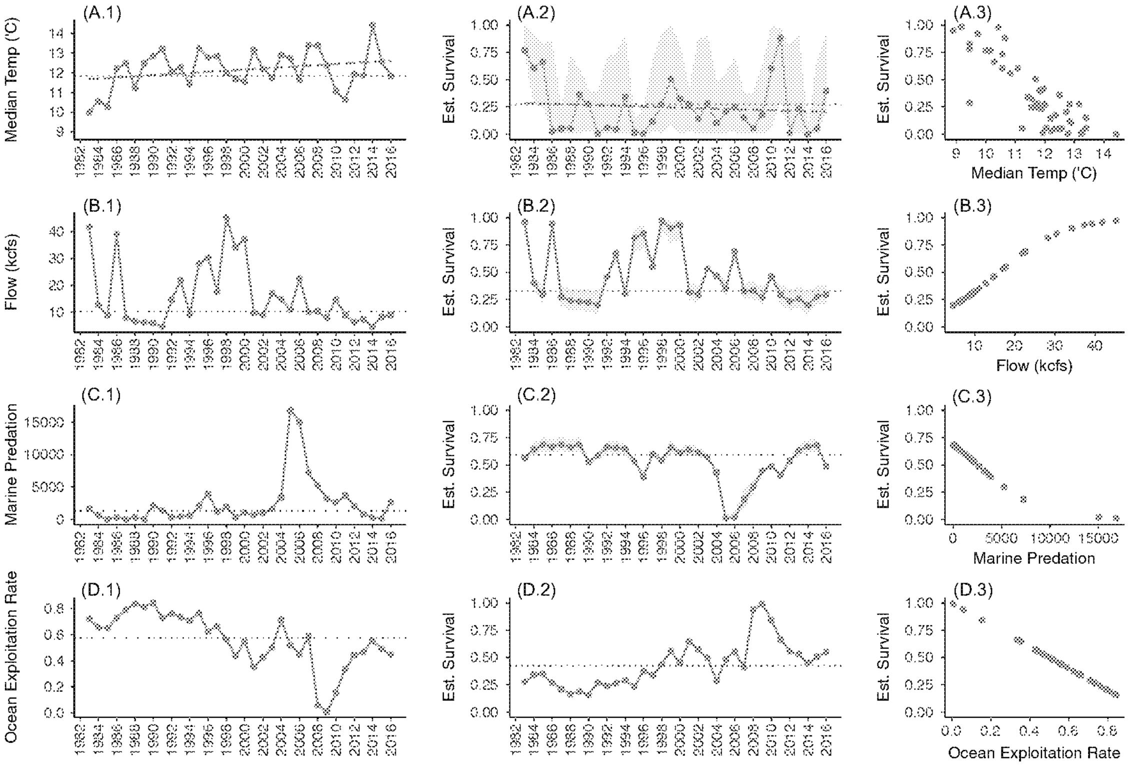

Fig. 5. Annual observed values for final environmental covariates (Temp, Flow, Marine Predation) and annual ocean harvest rate (A.1–D.1). Covariate relationships to model-predicted survival each year based on final parameter values (Table 1) are shown in A.2–D.2. Gray ribbons around model-predicted survival reflect 95% confidence intervals around parameter estimates for T_{crit}, β_W, and β_P (A.2., B.2, C.2, respectively). The median values for each covariate across the study period are shown as gray dotted lines. A trend line for median incubation temperatures (A.1) and temperature-dependent survival (A.2) is shown in red (dashed). A.3–D.3 shows covariate relationships to survival. Note, presented here are median temperature values during the spawning period from October to December to summarize the range of conditions included in the temperature-mortality model.

$$\begin{aligned}
M'_t =& \left(F_{t-2} \times \frac{Y}{2} \times S_{T.t-2} \times S_{bN} + \frac{H_{t-1}}{2} \times S_{bH}\right) \times il(\beta_W W_{t-1}) \times il(\beta_P P_{t-1}) \times S_{b\phi} \times S_2 \times R_{m.2} + \\
& \left(F_{t-3} \times \frac{Y}{2} \times S_{T.t-3} \times S_{bN} + \frac{H_{t-2}}{2} \times S_{bH}\right) \times il(\beta_W W_{t-2}) \times il(\beta_P P_{t-2}) \times S_{b\phi} \times S_2 \times S_3 \times S_{V.t} \times R_{m.3} + \\
& \left(F_{t-4} \times \frac{Y}{2} \times S_{T.t-4} \times S_{bN} + \frac{H_{t-3}}{2} \times S_{bH}\right) \times il(\beta_W W_{t-3}) \times il(\beta_P P_{t-3}) \times S_{b\phi} \times S_2 \times S_3 \times S_4 \times S_{V.t-1} \\
& \times S_{V.t} \times (1 - (R_{m.2} + R_{m.3})) \\
F'_t =& \left(F_{t-3} \times \frac{Y}{2} \times S_{T.t-3} \times S_{bN} + \frac{H_{t-2}}{2} \times S_{bH}\right) \times il(\beta_W W_{t-2}) \times il(\beta_P P_{t-2}) \times S_{b\phi} \times S_2 \times S_3 \times S_{V.t} \times R_{f.3} + \\
& \left(F_{t-4} \times \frac{Y}{2} \times S_{T.t-4} \times S_{bN} + \frac{H_{t-3}}{2} \times S_{bH}\right) \times il(\beta_W W_{t-3}) \times il(\beta_P P_{t-3}) \times S_{b\phi} \times S_2 \times S_3 \times S_4 \times S_{V.t-1} \\
& \times S_{V.t} \times (1 - R_{f.3}) \\
E'_t =& M'_t + F'_t
\end{aligned} \tag{5}$$

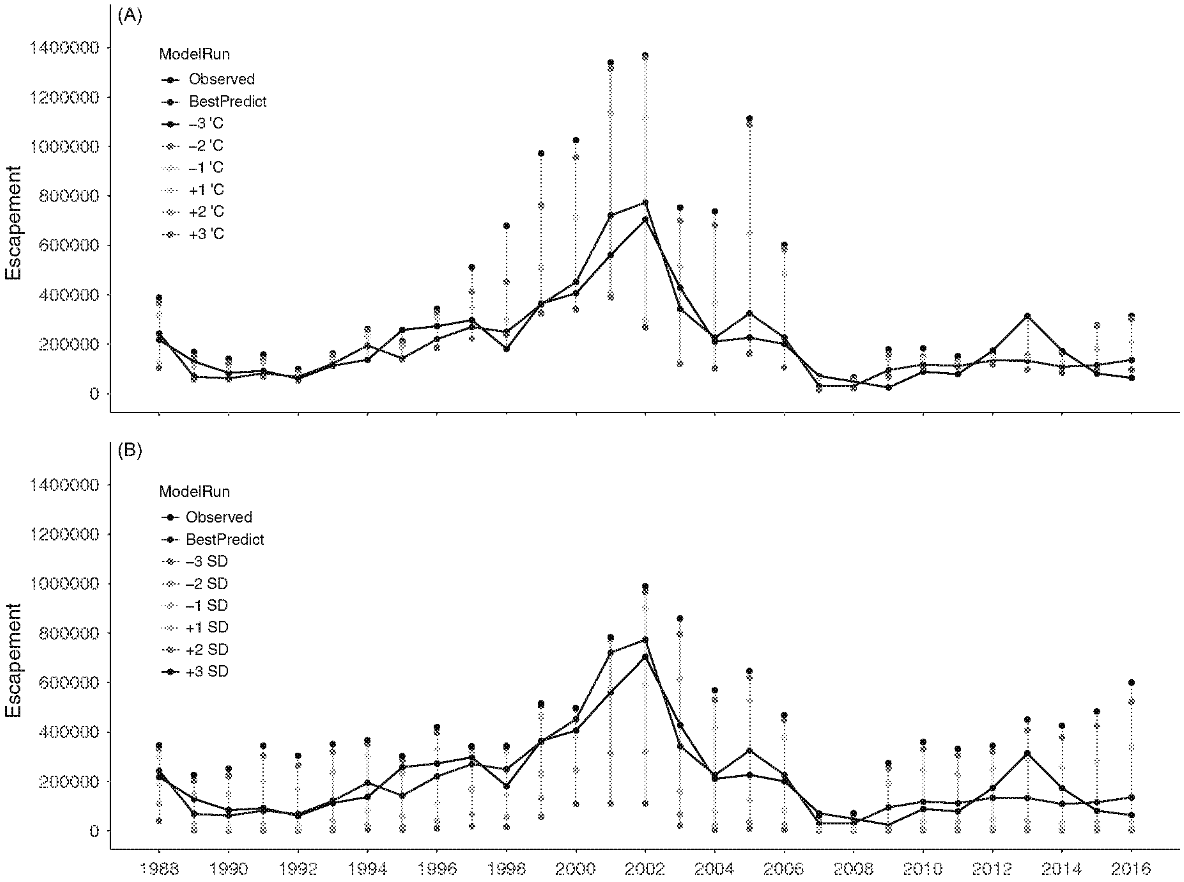

Fig. 6. Annual point estimates of escapement in response to scenarios of increased or decreased freshwater temperatures during incubation (A), and flow during outmigration (B). 1 SD pertains to a fixed variation of 11762 cfs applied to the observed flow each year. Results should be interpreted as annual point estimates rather than multi-year or cumulative patterns.

DISCUSSION

Our results show that population dynamics of CVFC result from composite effects of processes in the freshwater and marine environment. For example, during the limited years of high flow observed in this time series our model predicted high survival when other processes were more typical (1998–2000; Fig. 5). In 2006, above-average flows corresponded to a higher survival estimate for juvenile outmigrants, but marine predation during the early marine residence period was particularly high. Notably, 2006 was the year of outmigration for much of the adult cohort that contributed to the low returns observed in 2008. In a different phase of the system, the fall of 1995 was estimated to have extremely low egg-fry survival corresponding to high incubation temperatures. However, flow in the spring of 1996 was particularly high, which may have compensated for the temperature effect and contributed to relatively high returns in 1999 (Figs 3, 5).

We observed a positive trend in fall incubation temperatures throughout the study period (Fig. 5A.1), and the temperature-dependent mortality model was included in three of the four top models. Temperature-dependent mortality has also been shown to affect Central Valley winter-run Chinook salmon (Martin et al. 2017). Given the increasing trend toward warmer temperatures and known egg-fry mortality, it is likely this covariate will become increasingly important as we focus on the current period and near future.

This may be especially so for CVFC as they spawn in lower-foothill reaches of the Sacramento and San Joaquin rivers (Fisher 1994, Yoshiyama et al. 1998), likely making them more susceptible to intra-annual temperature fluctuations as well as increasing temperature trends. This situation may be exacerbated by the effects of reservoirs, which typically elevate water temperatures in the fall and winter in downstream river reaches (Caissie 2006, Olden and Naiman 2010).

Flow has direct and indirect effects on juvenile salmon outmigration dynamics. Freshwater flow, moderated by snowmelt, rain, and water operations, affects outmigration timing, size, and survival of juvenile Chinook salmon. Timing of juvenile salmon outmigration coincides with peak flows (Kjelson et al. 1982, Healey 1991, Williams 2006). Michel et al. (2015) and Wells et al. (2017) demonstrated higher survival for juvenile Central Valley Chinook salmon outmigrating during higher flows. Sturrock et al. (2015) found significant differences in the phenology of outmigrating CVFC between a wet and dry year, with fry contributing to a higher proportion of returning spawners from the same broodyear, and evidence suggesting higher in-river mortality in the drier year. High flows in the Sacramento and San Joaquin rivers are positively correlated with turbidity, which has been associated with higher survival, likely due to increased ability to avoid predation (Gregory and Levings 1998). Higher flows likely create improved rearing and migration habitat (e.g., increased woody debris, primary productivity, and access to flooded sloughs and wetlands; Quinn 2005). From the standpoint of management, high flows are related to pumping operations and routing probabilities in the Sacramento–San Joaquin Delta, and higher survival among outmigrants in this region has been observed during higher flows (Brandes and McLain 2001). Water management and habitat modifications (e.g., dams, diversions) have altered freshwater flow and temperatures experienced by outmigrating CVFC (Yoshiyama et al. 2001). These changes coupled with reduced genetic and phenotypic diversity in the population (see Satterthwaite and Carlson 2015, Herbold et al. 2018) mean the population is likely more susceptible to inter-annual variations in temperature and flow resulting from natural processes, climate change, and management practices (Lindley et al. 2009, Herbold et al. 2018). Thus, the effects of freshwater flow and temperature described here may be increased over what we expect with a more diverse population.

The inclusion of the marine predation index had the most significant effect on model performance. Common murre, among several predator populations, have been recovering in the Gulf of the Farallones region and have shown a sharply increasing abundance since 2001 (Wells et al. 2017). Predation was exceptionally high during 2005–2006 when there were very low abundances of krill and juvenile rockfish (Schroeder et al. 2014). Predation pressure remained higher than the median for the majority of years following Common murre increases in the early 2000s (Fig. 5). In the absence of preferred prey (juvenile rockfish), common murre shift to a diet dominated by northern anchovy, which overlap spatially and temporally with outmigrating juvenile salmon, resulting in significant incidental impacts on salmon (Wells et al. 2017, Warzybok et al. 2018). It is likely that under similar circumstances additional predators switch to forage inshore on anchovy, further increasing predation risk on juvenile salmon (e.g., rhinoceros auklet (*Cerorhinca monocerata*), Warzybok et al. 2018). For example, Fleming et al. (2016) reported a similar phenomenon for humpback whales in the central California Current ecosystem whose isotopic ratios indicated a switch to diets consistent with sardine and anchovy during years of low krill abundance. With increasing environmental variability in the CCLME (Sydeman et al. 2013), and increasing predator populations (e.g., California sea lions (*Zalophus californianus*), Laake et al. 2018; harbor seals (*Phoca vitulina*), Carretta et al. 2016; common murre, Wells et al. 2017; Brandt's cormorants (*Phalacrocorax penicillatus*), Capitolo et al. 2014), it is likely there will be increasingly higher and more variable predation risk for outmigrating juvenile salmon, especially in years in which primary forage are less abundant. This is likely to cause greater variability in adult population dynamics and increased likelihood of reductions in the fishery and escapement.

Recruitment to the fishery and ultimately escapement variability may be more dependent on ocean conditions for CVFC than other Central Valley Chinook runs. For example, the ocean condition during winter, when late-fall and winter-run salmon outmigrate (Fisher 1994), is less variable temporally and spatially than the spring when CVFC outmigrate (Checkley and Barth 2009). In winter, upwelling intensity is lower (Checkley and Barth 2009), the associated mesoscale features (e.g., fronts, upwelling shadows, eddies) are less common (Graham and Largier 1997, Wing et al. 1998), and the salmon preyscape is less rich (Ainley et al. 1996). However, when upwelling begins in late winter, it promotes a more abundant forage base in the spring (Schroeder et al. 2013, Fiechter et al. 2015, Friedman et al. 2018). Optimal upwelling in spring and summer creates heterogeneous retentive areas in which forage is available to outmigrating salmon (Graham and Largier 1997, Wing et al. 1998); however, if upwelling is too intense forage can be advected offshore (Cury and Roy 1989). Such physical and biological dynamics are largely responsible for variability in forage and, ultimately, survival of CVFC salmon during their first spring and summer at sea (Fiechter et al. 2015, Wells et al. 2016, Henderson et al. 2019). Reduced prey availability leads to reduced growth (Fiechter et al. 2015, Henderson et al. 2019) and increased predation on smaller fish (Woodson et al. 2013), including from predators seeking alternative prey (Wells et al. 2017). This process, emergent from a series of regional conditions, is likely the reason basin-scale covariates such as annual NPGO were uninformative when predation was included in the model (note, post hoc analyses using seasonal averages of NPGO also did not improve model performance); that is, while NPGO describes some of the underlying processes mediating forage availability and predation pressure, predation pressure is the more proximate covariate of outmigration survival. Importantly, our results indicate that a life cycle model parameterized with demonstrated processes will improve fit above the inclusion of coarse ecosystem indicators alone.

Our analysis was inconclusive on whether female spawner densities (*K*) affect egg-to-fry survival in CVFC. A comparison of Model 1 and Model 2 (which included *K*) showed the main effect of including *K* was to substantially decrease the starting number of natural-origin fry the model, while increasing the estimate of background survival (S_{bN}) for those natural fry remaining. The low capacity (*K*) estimated in Model 2 effectively decoupled the relationship between the number of spawners and the number of emergent fry, leading to similar estimates of natural-origin fry abundance regardless of spawner densities. Unfortunately, we cannot differentiate between these two models without additional data on the number of natural-origin fry in the system, or their proportion relative to hatchery-origin fry. Importantly, all other final parameters (T_{crit}, S_{bH}, $S_{b\phi}$, β_W, β_P) were similar between the two models, with marine predation, flow, and temperature showing the strongest relationship to variability in annual escapement. Improved estimates of spawning habitat availability over time would be particularly useful for future models.

Our model examines the effects of environmental factors on the productivity of CVFC. However, as discussed by Lindley et al. (2009), there has likely been a reduction in the underlying productivity of this stock related to physiological changes in individuals (e.g., reduced egg size, age at maturation, reduced genetic diversity; Heath et al. 2003, Satterthwaite and Carlson 2015), brought on by large-scale habitat modification (Yoshiyama et al. 2001) and hatchery introgression (Willmes et al. 2018). Due to a lack of physiological time series and knowledge of confounding effects with environmental covariates (Heath et al. 1994), we were unable to include these physiological effects in the model presented here. However, we separately tested the inclusion of a survival term that decreased over time (corresponding to the hypothesis of decreased productivity) and found that it increased model performance in terms of AIC, log-likelihood, and variance explained. The top model including this term was otherwise identical to our final model. As these physiological time series become available, it will be prudent to include such terms in future models.

Finally, we used the parameterized FCα model to estimate the effect of changes in temperature during incubation, as well as flow during outmigration, on model-predicted escapement. As flow was the stronger covariate in the model, it is no surprise that variations in flow showed a greater effect, with increases in flow during outmigration relating positively to increased adult escapement. Interestingly, for the recent years characterized by low freshwater flow and high incubation temperatures, the models representing increased temperature and decreased flow beyond what was observed provided a more accurate prediction than our final parameterized model (Fig. 6). This indicates compounding effects beyond what is presently captured in our model. Freshwater conditions have carryover effects on the survival of salmon at sea as they relate to the size, condition, timing, and abundance of outmigrants. Each of these dynamics can affect survival at sea through size-selective mortality (Woodson et al. 2013), match–mismatch of salmon with their preferred prey (Satterthwaite et al. 2014), and competition (Miller et al. 2013). This points to a need to consider the interactions between freshwater and marine dynamics when considering the tradeoffs associated with different managerial scenarios. As well, this makes clear the need to consider a full life-cycle model to accommodate the implications of environmental variability and managerial action at any given life stage on the fisheries and spawning populations.

Life-cycle models such as the one presented here provide a tool that enables integration of data series and mechanistic models across life stages and habitats to describe the composite effects of processes contributing to population dynamics and can be used for strategic ecosystem-based management of migratory species such as anadromous fish. Our results support the hypothesis that escapement variability in CVFC is largely described by composite effects of freshwater and marine processes during the smolt to juvenile period. These results align with and reconcile previous research demonstrating the importance of these phases for recruitment to the population (Beamish and Mahnken 2001, Kilduff et al. 2014, Woodson and Litvin 2015, Wells et al. 2016, Michel 2018). Our results also point to key management levers related to the most influential processes found to affect the CVFC population (freshwater temperature, flow, and marine predation). In particular for CVFC, freshwater temperatures may be managed, as is presently done for Central Valley winter-run Chinook, through modification of dam operations to optimize the temperature of spawning areas. Similarly, pulse flow releases during juvenile outmigration will likely increase survival rates through the freshwater system. However, this operation will be most effective if considered relative to the potential for survival at sea, which relates both to predation risk (Wells et al. 2017) and the development of suitable forage (Friedman et al. 2018) upon which outmigrating juvenile Chinook rely. With increasingly variable marine conditions (Sydeman et al. 2013), in addition to increasing and dynamic predator populations (Chasco et al. 2017, Wells et al. 2017), the impact of prey-switching in years of low productivity will likely increase. Continued study of marine ecosystem dynamics can be pursued simultaneously with, and complement efforts to increase survival in the freshwater phase. Overall, management actions that promote diversity in the natural population will increase resilience in the population through strengthened portfolio effects (Mantua and Francis 2004, Carlson and Satterthwaite 2011, Satterthwaite and Carlson 2015, Herbold et al. 2018). The results of our work can be used to develop long-term strategies to sustain populations such as CVFC and thereby reduce variability in harvest and escapement. Finally, the methodology developed in this study can be used to improve conservation and management of other anadromous fishes and migratory species.

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SUPPORTING INFORMATION

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Estimating spatial-temporal differences in Chinook salmon outmigration survival with habitat and predation related covariates

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<A>Abstract

Low survival rates of Chinook salmon smolts in California's Central Valley have been attributed to multiple biological and physical factors, but it is not clear which factors have the largest impact. We used five-years of acoustic telemetry data for 1709 late-fall Chinook salmon smolts to evaluate the effect of habitat and predation related covariates on outmigration survival through the Sacramento River. Using a Cormack-Jolly-Seber mark-recapture model, we estimated survival rates both as a function of covariates (covariate model) and as a function of river location and release year (spatial-temporal model). Our covariate model was overwhelmingly supported as the preferred model based on model selection criteria, suggesting the covariates adequately replicated spatial and temporal patterns in smolt survival. The covariates in the selected model included individual fish covariates, habitat specific covariates, and temporally variable physical conditions. The most important covariate affecting salmon survival was flow. We describe the importance of these parameters in the context of juvenile salmon predation risk and suggest that additional research on predator distribution and density could improve model estimates.

Introduction

Salmon smoltification and outmigration from freshwater rearing habitats is a time of increased mortality as fish undergo physiological changes and encounter new stressors (Connor et al. 2003; Welch et al. 2008; Nislow and Armstrong 2012). Much of the research on outmigration mortality has examined the effect of dam passage on survival (Skalski et al. 2001; Williams et al. 2001; Welch et al. 2008; Elder et al. 2016), with relatively few studies focusing on how other environmental conditions affect survival. Environmental conditions that have been linked to outmigration mortality include flow (Connor et al. 2003; Smith et al. 2003; Michel et al. 2015; Courter et al. 2016), temperature (Connor et al. 2003; Smith et al. 2003), turbidity (Gregory and Levings, 1998; Smith et al. 2003), and predation (Beamesderfer et al. 1996; Friesen and Ward 1999; Schreck et al. 2006). Some of these factors, such as water temperature and flow, are expected to increasingly affect juvenile salmon survival and population production as the climate changes (Jonsson and Jonsson 2009; Mantua et al. 2010; Katz et al. 2013; Russell et al. 2012). Many of the published correlations between outmigration survival and environmental characteristics have examined survival over relatively large temporal and spatial scales, whereas individual fish experience mortality at a particular time and place. To better understand how habitat and predation related covariates influence salmon smolt mortality it is necessary to look at the conditions experienced by fish as they are migrating through a habitat.

Most Chinook salmon spawned in the Sacramento River have long outmigrations (~500 kilometers) through multiple habitats, and it is believed that the precipitous decline of multiple salmon populations in this system is partially due to anthropogenic habitat modifications and poor out-migration survival (Yoshiyama et al. 1998; Katz et al. 2013; Michel *in press*). Currently, survival of Chinook salmon smolts from the Sacramento River to the ocean is markedly lower than smolt out-migration survival from the Columbia and Fraser rivers in the Pacific Northwest region of the United States and Canada (Welch et al. 2008; Michel et al. 2015; Buchanan et al. 2018), but it is unclear what factors cause this increased mortality. Previous research has found that interannual variability in smolt survival is much greater in the Sacramento River than in the Sacramento-San Joaquin delta or the San Francisco Bay, suggesting that the river has a large influence on outmigration success (Michel et al. 2015). Within the river, outmigration survival rates vary both spatially and interannually (Singer et al. 2013; Michel et al. 2013). This spatial and temporal variability is likely driven by changes in the underlying environmental and habitat features comprising the river landscape.

Identifying the main factors that affect smolt mortality is important to establish restoration priorities and give managers quantitative data on how to optimize survival of threatened salmonids. This is especially important given recent findings that suggest outmigration survival has a larger effect on smolt-to-adult ratios than marine survival (Michel *in press*). To identify which factors had the largest influence on outmigration survival, we developed a series of mark-recapture models using five years of acoustic telemetry data for late-fall Chinook Salmon. We then used model selection to identify which covariates had the largest influence on survival. Our analysis builds upon the research conducted by Singer et al. (2013) and Michel et al. (2015), whose primary objective was to identify temporal and spatial differences in the mortality of outmigrating juveniles. In contrast, our objective was to model survival solely as a function of covariates that were hypothesized to affect salmon survival through habitat modification and increased predation risk.

Methods

Study Area.—The northernmost extent of our study was the release location for late-fall run smolts at the Coleman National Fish Hatchery (Figure 1). We included all detections of acoustically tagged fish from the release location to the ocean, but we only included covariates for reaches between the release location and the I-80 Bridge in Sacramento. This was for two reasons: 1) hydrodynamic model estimates for temperature and flow below the city of Sacramento were not as reliable as the upstream estimates, and 2) survival variability was much larger in the reaches upstream of Sacramento than in the Sacramento-San Joaquin delta or San Francisco Bay (Michel et al. 2015). Riverine habitat varied spatially across the ~300 kilometers of Sacramento River that defined our study area. There was a general upriver to downriver gradient in habitat features associated with human influence. For example, diversion density, amount of armored bank, and agriculture/developed land use increased from the upper to lower reaches.

Acoustic tagging.— Late-fall run Chinook salmon were obtained from the United States Fish and Wildlife Service (USFWS) Coleman National Fish Hatchery, implanted with acoustic tags, and released annually during the winter months (December and January) from 2007 through 2011. Details regarding the surgical procedures and initial acoustic tag study design are documented in Michel et al. 2013 and Ammann et al. 2013. Briefly, small acoustic tags (Vemco 69 kHz, 7 mm dia. X 20.5 mm long, weighing 1.8 g in air and 1.0 g in water) were surgically implanted into the peritoneal cavity of anesthetized fish through a 12 mm incision. The incision was then closed with two simple interrupted stitches with nonabsorbable nylon cable-type suture. All fish were allowed to recover for a minimum of 24 hours before release. During the first year of this study (2007), smolts were tagged and released directly into Battle Creek, a tributary of the Sacramento

River where the Coleman Hatchery is located (Figure 1). From 2008-2010 tagged smolts were released concurrently from three locations along the mainstem Sacramento River: Jelly's Ferry, Irvine Finch and Butte City to increase sample size of fish detected throughout the river and to estimate differences in survival between newly released fish and those released upstream (Figure 1). In 2011, all fish were released at Jelly's Ferry due to a slightly reduced sample size. In addition to the acoustic tag data (n=1350) utilized in Michel et al. (2013) and Michel et al. (2015), we used acoustic tag data provided by the USFWS (n=359). These fish were tagged in accordance with the procedures described above, but released directly into Battle Creek in 2010 and 2011, simultaneous to the release of the remaining hatchery stock (batch released). The mean hatchery release during these dates was approximately 600,000 fish (range: 155k – 889k).

Acoustic receivers were located from the fish release sites in the upper Sacramento River to the Golden Gate Bridge at the entrance to the Pacific Ocean. We divided the Sacramento mainstem study region into 19 reaches demarcated by 20 acoustic receiver locations along the mainstem Sacramento River (Figure 1). These reach locations were selected based on inter-annual consistency in receiver location throughout the 5-year study period; however, detections from inconsistently deployed receivers were retained to improve precision of survival and detection probabilities (see 'mark-recapture analysis' section).

Acoustic telemetry data processing. —We used a series of algorithms to ensure our acoustic telemetry data did not include any false detections. The acoustic receivers automatically processed detection data by dropping incomplete codes from the detection file. To ensure that we removed any false detections due to acoustic pulse train collisions, we performed several additional quality control procedures. First, we removed all detections that occurred prior to the release date and time. We then removed all detections from fish that had only a single detection throughout the study. We required three or more detections within 10 days at a single receiver location to verify those detections were not the result of pulse train collisions. We also examined the encounter history of each individual fish and removed any detections that indicated upstream movements. Furthermore, we calculated the transit time between receivers (number of river kilometers between receivers divided by the difference in seconds between the last upstream detection and first downstream detection) and removed any detections resulting from a fish traveling at speeds greater than 10 km hour^{-1} (2.78 m s^{-1}). We also assumed that any tag consistently detected at a single receiver location for more than 4 weeks, and not subsequently detected downstream, was a mortality. We selected the 4 weeks cutoff after a preliminary examination of the data indicated fish detected at a single location for more than 4 weeks were never detected at another receiver. These fish (n=58) were considered known mortalities (i.e., treated the same way as a harvested fish in a standard mark-recapture model) and did not have any impact on the estimated survival or detection probabilities downstream from where the presumed mortality occurred.

Mark-recapture analysis.—To estimate survival of out-migrating late-fall run Chinook salmon, we fit a Cormack-Jolly-Seber (CJS) survival model (Cormack 1964; Jolly 1965; Seber 1965) using the marked (Laake et al. 2013) and RMark package (Laake and Rexstad 2008, Collier and Laake 2013) within the R programming language (version 3.3.1, R Core Team 2017). We used the marked package for the initial model selection due to its computational efficiency and RMark for parameter estimation due to better analytical functionality (see appendix). The CJS model was originally conceived to calculate survival of tagged animals over time by recapturing individuals and estimating survival and recapture probabilities using maximum likelihood. A spatial form of the CJS model can be used for species that migrate unidirectionally, and are recaptured, throughout a migratory corridor (Burnham 1987). Using this space for time substitution, we used individual fish encounter histories to estimate the likelihood that a fish would survive and be detected at each receiver (Lebreton et al. 1992). In the standard formulation of the CJS model, detection probabilities are estimated for a single resampling occasion (i) in time or space. However, our encounter histories included detections both from receivers at the reach boundaries as well as receivers within the reach. Thus, our estimated detection parameter represents the probability of detection from receiver (i) to receiver (i+1).

Spatial-temporal model.— Prior to fitting a covariate model, we fit a model that estimated a different survival for every reach in every year. This spatial-temporal model provided a means to evaluate how well our covariate model replicated outmigration survival. We assumed that differences between the spatial-temporal model and the covariate model were the result of unaccounted variance due to missing covariates. Due to the inherent complexity of the Sacramento River ecosystem, it was not feasible to measure or estimate all potential covariates that influence salmon survival. For example, there is no hydrodynamic model currently capable of estimating turbidity levels throughout the river.

The spatial-temporal smolt survival estimates were converted to survival per 10km values to allow for comparisons between reaches via:

$$\Phi_{10} = \sqrt[l]{\Phi_R}$$

where Φ_{10} is the survival estimate per 10km, Φ_R is survival per reach, and l is reach length divided by ten.

Covariate model.—We included multiple individual, release group, reach specific, and time-varying covariates in our analysis to identify the factors contributing to the mortality of out-migrating smolts. Each of the covariates included in the analysis had an *a priori* hypothesized relationship with smolt survival (Table 1).

The individual covariates we included were length, condition, and transit speed. Fish size has been known to influence juvenile salmon survival (Zabel and Achord 2004), thus we included both length and condition factor (Fulton's $k = \frac{W}{L^3} * 100$) as individual covariates. Length was hypothesized to affect survival through predator gape limitation whereas condition factor is an indicator of fish health and stamina. We also included individual fish transit speed within each reach, which we estimated with a mixed effects model (see details below), because faster moving fish would have less exposure to predators.

Release group effects included release group size, a release reach effect, and the mean annual flow at Bend Bridge (see Figure 1 for location) in the release year. We included a binary group covariate for release group size to distinguish fish released in synchrony with thousands of other hatchery fish from those released in small (e.g. 50-100 fish) batches based on the hypothesis that large releases would result in increased survival due to predator swamping (Fritts and Pearsons 2008; Furey et al. 2016). To test the hypothesis that the potential survival advantage of large releases would diminish as fish diffused downstream, we also included an interaction between release group size and distance from release site. We included a release reach effect to test if survival in the first reach after release differed from fish released upstream of the release site. We hypothesized survival rate in the release reach would be lower because newly released hatchery fish are naïve and more susceptible to predation (Alvarez and Nicieza

2003; Huntingford 2004; Jackson and Brown 2011). The final release group specific covariate was the mean annual flow measured at the Bend Bridge gauge during the months of smolt outmigration (December-March). This covariate was included to test if survival decreased in low flow (e.g., drought) conditions. Bend Bridge was selected to represent mean annual flow because it was upstream of the major tributaries and diversions and was collinear with the flow measurements throughout the river.

The reach specific covariates included in the model were sinuosity, diversion density, adjacent cover density, and off-channel habitat density. We selected these features because we hypothesized they would influence survival by affecting predation risk. More natural habitats with increased sinuosity, adjacent cover density, and off-channel habitat density are hypothesized to provide more predator refuge (reviewed by Roni et al. 2014). Furthermore, agricultural and municipal water diversions along the Sacramento River pose a risk to out-migrating salmon through direct entrainment (Hanson 2001; Kimmerer 2008; Mussen et al. 2014), as well as indirectly by providing structure for salmonid predators (Sabal et al. 2016). We hypothesize that the latter has more of an effect on Chinook smolt survival since the diversions are typically not in operation during the months of outmigration. These reach specific data were derived from GIS layers available from multiple sources (Table 1) and plotted in a Geographic Information System (using ESRI ArcGIS 10.3). Because we were using static GIS layers, we were unable to determine if the available off-channel habitats were connected to the mainstem under different flow regimes. We were also unable to measure inter-annual differences in adjacent cover density.

The time-varying covariates we included in the model were flow and temperature, which we obtained from the River Assessment for Forecasting Temperature (RAFT) model. The RAFT model is a 1-dimensional physical model that estimates temperature and flow every 15-minutes at a 2 km spatial resolution (Pike et al. 2013). We included temperature as a covariate because predator metabolisms, and predation rates, increase at higher temperatures (Petersen and Kitchell 2001). We included multiple aspects of flow (see below) derived from the RAFT model because flow is important to smolt survival (Kjelson and Brandes 1989; Cavallo et al. 2013; Zeug et al. 2014; Michel et al. 2015; Courter et al. 2016). We associated values for each of these variables with each tagged fish in space and time at the 2-km spatial resolution, and then calculated the reach-level means for each fish for each variable. We assumed that RAFT model predictions were accurate (i.e. we did not propagate RAFT model uncertainty into the mark-recapture model) based on results from model validations (Pike et al. 2013; Daniels et al. 2018).

Due to the importance of flow to outmigrating salmon survival, we fit a variety of models with different flow standardizations to test which aspects of flow had the largest influence on survival. We scaled (subtracted the mean and divided by the standard deviation) the time-varying estimates of flow in two ways: 1) by reach, and 2) by year and reach. We scaled by reach to detect within reach patterns of survival relative to *inter*-annual flow conditions. In other words, is reach-specific survival dependent on whether flows are above or below average compared to other years? Since this parameter could distinguish between annual differences in flow (i.e., low flow versus high flow year), we did not include the annual flow at Bend Bridge in any models that included flow scaled only by reach. Thus, we could test if the spatially explicit estimates of flow added any additional information beyond a single measure of mean annual flow. The year and reach scaling tested whether *intra*-annual changes in flow within a reach were important to salmon survival. In other words, we wanted to determine if periods of higher flows within a reach, such as those after large precipitation events, would increase survival relative to periods of lower flows within the same year. This hypothesis was based on previous studies that have observed large increases in survival due to controlled changes in flow rate (Cavallo et al. 2013; Courter et al. 2016). Scaling by both year and reach removes the effect of annual differences in flow such that it is impossible to distinguish high flow years from low flow years with this parameter. Thus, models in which flow was scaled by year and reach could also include the mean annual flow at Bend Bridge. We also fit models that included an interaction between the mean annual flow and the time-varying flow standardized by year and reach to test the hypothesis that precipitation events would have a larger impact on survival in years with lower flows. We tested this hypothesis based on work by Courter et al. (2016) that suggested flow has a large impact on survival in reaches with relatively low flow but has a negligible impact in reaches with high flow.

To estimate the effect of a covariate (e.g. flow) on fish survival throughout a reach, it is necessary to have a covariate value for every fish in every reach. When we did not detect an individual fish at a receiver there was uncertainty as to when that fish might be within that reach and, thus, what covariate value should be used. To impute covariate data in locations where fish were not detected, we fit a mixed-effects model where the response was transit speed of individual fish detected at both upstream and downstream acoustic receivers of a single reach. Our independent covariates were release year, release week, reach, and fish condition. We also included a random intercept for each individual fish to account for individual behavioral variability. We fit the model using the 'lme4' package (Bates et al. 2015) and selected the model with the lowest Akaike's Information criterion (AIC; Burnham and Anderson 2002). To verify that the mixed-effects model did not unduly violate any assumptions, we examined model diagnostics (QQplot and residuals) using the DHARMa package (Hartig 2018). We then used the results from the mixed-effects model based on detected fish to estimate the dates and times undetected fish were present within each reach.

Prior to fitting the CJS models, all continuous covariates were standardized by subtracting the mean and dividing by the standard deviation. Standardized coefficients could then be interpreted as the estimated change in survival predicted from one standard deviation increase in the covariate value. We also conducted pairwise comparisons of all continuous individual, habitat, and physical covariates to determine if any covariates were collinear (Supplemental figure S1). From pairs that had correlation coefficients greater than 0.7 (Dormann et al. 2012), we selected a single covariate that we hypothesized would have the largest influence on survival based on results from previous studies.

Model selection.—We fit a series of CJS models to determine which covariates (individual, release group, reach specific, or time varying) had the greatest impact on out-migrating smolt survival. With the exceptions of collinear variables and the restrictions noted above, we fit models with all possible combinations of covariates and selected the most appropriate models with adequate support using Quasi-Akaike's information criterion (QAICc) (Burnham and Anderson 2002). QAIC adjusts the AIC value based on an overdispersion parameter ($\hat{c}$), which we estimated using the median $\hat{c}$ method for the spatial temporal model within program MARK (White and Burnham 1999). If the observed data has no overdispersion, $\hat{c}$ will be approximately equal to 1. Values of $\hat{c}$ greater than 4 indicates the model structure is inadequate and does not account for a sufficient amount of variation in the data (Burnham and Anderson 2002). Our median $\hat{c}$ was 1.45, indicating the model was satisfactory but slightly overdispersed. We selected the most appropriate model by examining the difference in QAIC values between each model and the model with the lowest QAIC (ΔQAIC). We assumed models with ΔQAIC < 2 had equal support (Burnham and Anderson 2002); thus, if multiple models had a ΔQAIC < 2, we selected the one with the fewest parameters.

Covariate plots.—To determine which covariates had the largest influence on survival, we plotted the ΔQAIC between the selected covariate model and the same model without a single covariate. In the case of covariates that were included as main effects and in an interaction, we also removed the interaction. We will refer to these models as our covariate importance analysis.

We used marginal model plots to evaluate the effect of individual covariates on outmigrating smolt survival. To produce these plots, the β parameter coefficients from the selected covariate model were used to simulate what survival would be for the 95% observed range of a single covariate. With the exception of reach length, covariates not included in the individual response plots were set to zero for binomial covariates or to their mean for continuous covariates. Reach length was set to 10 km for all plots except the one that explicitly focused on the effect of reach length.

<A> **Results**

<B> *Spatial-temporal model*

Based on the model that included a reach by year interaction, we observed that survival was not consistent spatially or temporally. We saw a general trend of lower per-reach survival in the upper and middle reaches, compared to the more downstream reaches, but the location and severity of mortality varied inter-annually (Figure 2). The high flows in 2011 negatively impacted our detection efficiencies, rendering 12 receivers without reliable detection data; however, the detection efficiencies in the lower river and the estuary remained high and provided sufficient data to estimate out-migration survival through the river. The receiver locations with low detection efficiencies often resulted in survival estimates of 1 due to numerical boundary issues.

<B> *Covariate model*

The selected covariate model had 15 survival parameters and fit the data nearly as well as the spatial-temporal model that had 110 survival parameters. As a result, the covariate model had a much lower QAICc value (ΔQAICc = 55.90), implying it was more parsimonious. Although the covariate model showed some deviation from the spatial-temporal model, especially in the most upstream reaches, these tended to be relatively small and not significantly different from zero (Figure 3).

The top covariate model included a combination of an individual covariate (transit speed), group covariates (batch release, interaction between batch release and distance from release site, release reach, and the mean annual flow recorded at Bend Bridge), reach specific covariates (reach length, sinuosity, and diversion density), and time-varying covariates that were estimated for when a fish passed through a specific reach (reach flow, interaction between reach flow and annual flow, and water temperature). Based on the standardized beta coefficients for the covariates (Table 2) and the results from the covariate importance analysis (Figure 4), annual flow and reach length had the largest influence on survival. Flow was the most important covariate in predicting outmigration success, with increased levels of annual flow correlating to increased smolt survival (Figure 5a). Above average reach flows within a year (e.g., large precipitation events) helped improve survival much more in low flow years than in high flow years. As would be expected, longer reaches had lower survival rates (Figure 5b). Based on the covariate importance analysis, the next most important variables affecting survival were diversion density, release reach, and the interaction between release group size and distance from release location. Survival increased relative to diversion density (Figure 5c), was lower in the first reach after release (Figure 5d), and increased for approximately the first 200 km from the release site when fish were released concurrently with thousands of hatchery fish (Figure 5e). Finally, the covariates that had the least effect on survival were sinuosity (increase), transit speed (increase), and water temperature (decrease) (Figure 5 f-h).

<A>**DISCUSSION**

Conservation of salmonid populations depends on understanding what physical and biological factors have the largest impact on mortality during different life history stages. Recent research has shown that the outmigration period may have the largest influence on smolt to adult survival rates and cohort strength (Michel *in press*). Therefore, identifying the primary factors that affect survival of outmigrating smolts can help prioritize management actions that will be most beneficial to the conservation of imperiled populations. While we could not include all possible sources of mortality in our analysis, we conclude that flow remains the single most influential factor for determining survival of late-fall Chinook salmon smolts outmigrating from California's Central Valley.

<B>*Spatial and temporal survival heterogeneity*

The spatial-temporal model indicated that survival through different reaches varied interannually, which is likely a result of the dynamic nature of the Sacramento River system. Overall, we can conclude from our reach-specific survival estimates that increased mortality rates occurred most frequently in the upper and middle regions of the Sacramento River, and decreased rates occurred through the lower reaches. We compared the observed values for the covariates included in the selected model to determine if fish had different behaviors in the upper reaches and if any aspects of the physical habitat differed. The most striking difference between the upper reaches and the lower reaches was the diversion density. This implies that increased diversion desity, and the coincident anthropogenic habitat modifications of the lower river, reduced mortality of outmigrating smolts. Much of the previous work that has examined the effects of habitat modification and restoration on salmonid populations has focused on egg incubation, freshwater/estuarine rearing, and available spawning habitat (reviewed in Roni et al. 2014) or the effects of fish passage on outmigration mortality (Skalski et al. 2001; Williams et al. 2001; Welch et al. 2008; Elder et al. 2016). We do not know of any studies that have explicitly looked at the effect of channel alteration on salmon outmigration survival. A valuable future study would be to examine if channelized habitats have lower predator densities or if the deeper waters make it easier for salmon to avoid predators.

In addition to the higher mortality rates in the upper reaches, the biggest discrepancies between the spatial-temporal model and the covariate model also occurred in the upper reaches. This suggests our covariate model would benefit from including additional covariates that contributed to smolt mortality in the upper reaches. Based on previous research, we believe that including covariates such as turbidity and predator density would likely improve our explanatory power. Turbidity likely improves salmon survival by decreasing predation risk (Gregory and

Levings 1998). Likewise, high predator densities in the upper and middle reaches may partially explain the increased mortality rates in these locations. Naïve, hatchery raised fish, are more susceptible to predation after release (Alvarez and Nicieza 2003; Huntingford 2004; Jackson and Brown 2011). This was reflected in our covariate model where newly released fish had a lower survival rate than fish released upstream. Including turbidity and predator density in a mark recapture model could improve model fit and provide important information necessary to develop a purely mechanistic model to estimate outmigration mortality.

<B>*Time-varying covariates*

Model selection for the covariate model provided insight into which time-varying physical covariates had the largest influence on survival of out-migrating late-fall Chinook Salmon. Flow exerted the greatest overall effect on outmigration success, with increased annual flow positively related to increased smolt survival. Studies have repeatedly demonstrated that flow is the most important factor affecting survival of Chinook salmon (Conner et al. 2003, Smith et al. 2003; Zeug et al. 2014; Michel et al. 2015). In addition to the effect of annual flow, we also found that variability in flow within a reach affected survival rates, particularly in low flow years. If flow within a reach was well above the annual average, as it would be after a precipitation event, there was relatively little (1.6% per 10 km) difference between survival in a low and high flow years. In contrast, below average flows within a reach resulted in large (5% per 10 km) differences in survival between low and high flow years. This provides a potential explanation for results observed by Courter et al. (2016), where survival was highly dependent on flow within a low flow (< 125 cms) reach, but had no effect in a reach with higher flows (100-300 cms).

Our study also builds on previous work by including measurements of both spatially explicit flow and transit speed as covariates in our model. This allowed us to separate the effect of flow from transit speed, suggesting that there are features inherent to flow itself, not just its effect on travel time, which affects survival. Flow has been significantly reduced and homogenized in the Sacramento River system from historic levels (Buer et al. 1989), in particular during the winter months when runoff from storm events is captured behind dams. Flow magnitude affects the amount of off-channel and floodplain habitat available for juvenile salmon rearing (Nislow and Armstrong, 2012; Merenlender and Matella 2013). Fish residing in these habitats have accelerated growth rates that may aid individuals in predator avoidance and survival (Sommer et al. 2001; Limm and Marchetti 2009). Furthermore, the highest sediment loads for the Sacramento River were observed with the highest peak flows (Stern et al. 2016), which can increase turbidity rates and decrease predation rates (Gregory and Levings 1998). Whatever the specific mechanism, flow was clearly the most important factor influencing the outmigration success of late-fall run Chinook smolts in 2007-2011. Perhaps more importantly, the effect of flow propagates throughout a cohort's life history and can be used to estimate smolt-to-adult ratios (Michel *in press*). Threshold flow values could be determined through combined controlled-release and tagged-release studies in the Central Valley.

We also found survival was higher at lower water temperatures. We hypothesize that this effect was the result of increased predator metabolism, and thus consumption, at increased temperatures (Petersen and Kitchell 2001). This effect was relatively minor (1.3% per 10 km) over the small range of temperatures we observed during the fall-run winter outmigration months. However, we expect this effect will be more pronounced for fall and winter run fish that are outmigrating during warmer months and may exhibit adverse responses to warmer temperatures (Baker et al. 1995; Lehman et al 2017).

<B> *Release group covariates*

Acoustically tagged fish had higher survival rates when they were released concurrently with thousands of hatchery fish. Based on the interaction between release size and distance from release location, this effect persisted for approximately 200 km from the release location. One explanation for this improved overall survival is the theory of "predator swamping;" whereby predators, inundated by prey, pose less of a threat to individual smolts. This effect has been demonstrated for Chinook salmon in the Yakima River (Fritts and Pearsons 2008) and juvenile sockeye salmon in British Columbia (Furey et al. 2016). We examined the difference in arrival times at the acoustic receiver locations for each of the release groups, and found that fish from the same release group arrived at the same location within approximately 24 hours for the first 100 km (Supplemental fig S2). After the first 100 km the river has more channel alterations and fish arrival times were more dispersed. However, fish survival rates in these lower sections of the river were generally higher than in the upstream reaches, most likely due to decreased predation rates in the channelized portions of the river.

<B> *Individual covariates*

Predicted transit speeds were also an important factor, with increasing transit speeds corresponding to increased survival. For out-migrating yearling smolts, it is likely that transit speed in the context of our study is a proxy for duration of exposure to mortality factors. Previous studies have found that survival rates decline over longer migration distances (Bickford and Skalski 2000; Muir et al 2001; Smith et al. 2002). However, these studies have primarily found that survival was related to distance traveled but not to travel time. Anderson et al. (2005) explained this apparent discrepancy by suggesting that survival was a function of both migration distance and predation risk. This provides further motivation to study the factors that influence the spatial distribution, and density, of salmon predators throughout the Sacramento River.

<B>*Reach specific characteristics*

Model selection results provided evidence that reach length, diversion density, and sinuosity were associated with outmigrating smolt survival. After accounting for all other covariates, survival was higher with increasing sinuosity, suggesting that more natural river conditions were better for smolt survival than the deeper and more armored portions of the river. This result is in contrast to our other finding that the highest survival rates were in the lower, more channelized sections of the river. We suspect that the larger covariate effect of diversion density accounts for the variation associated with increased survival in the lower reaches. Because the diversions are typically not operational during the period when late-fall Chinook are outmigrating, we suspect this effect is more a function of the habitat conditions in locations where diversions are more abundant. Diversions were highly correlated to other habitat variables typical of agricultural zones; namely depth, armored banks and agricultural and developed land use (Supplemental figure S1). Because we did not wish to obfuscate the results of our analysis, we withdrew these collinear factors from our modeling efforts, but the role of “diversions” on survival could be equally viewed as the role of depth, agriculture and developed land, and armored banks. These modified habitats may result in reduced predator densities and predation mortality.

<B> Conclusions

Flow, diversion density, and release strategy had the strongest influence on survival of out-migrating, hatchery origin, late-fall run Chinook salmon during the 2007-2011 water years. For years with high flow, gains in in-river survival can lead to a three-fold increase in total outmigration survival, while survival in the delta and estuary remain the same (Michel et al. 2015). There is limited natural habitat remaining for Chinook salmon in the Central Valley as a result of human activities, and increasingly managers are turning to habitat restoration efforts to restore salmon populations. When we compare physical covariates, metrics for habitat features and individual covariates, flow remains the most important factor affecting out-migration survival of late-fall run hatchery raised smolts. Although our study used hatchery fish, which have limitations as wild fish surrogates, these results suggest that maintaining flow during periods of salmon outmigration is an important step towards conserving Chinook salmon in the Central Valley.

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Figure Captions

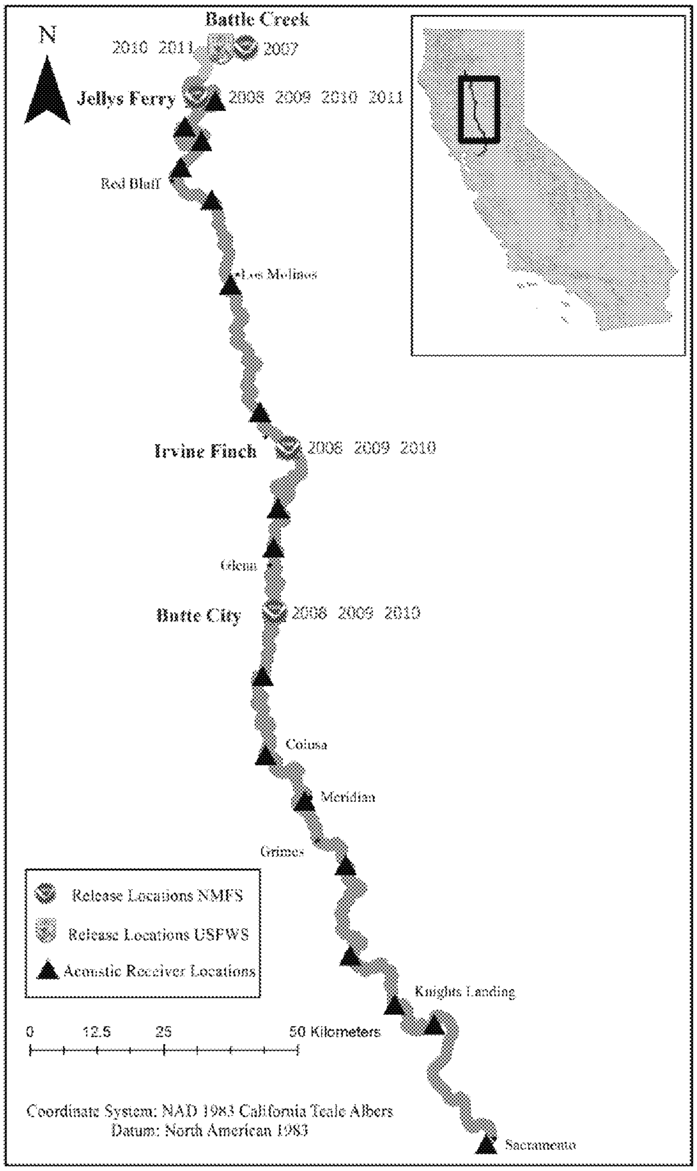
Figure 1: Map of the mainstem Sacramento River. Our study area extended from above Red Bluff in the north to the city of Sacramento in the south. Late-fall run Chinook salmon yearling smolts were released at Battle Creek, Jelly's Ferry, Irvine Finch or Butte City during the winter (Dec-Jan) of each of our study years. The locations of the 20 acoustic receivers that delineated our 19 river reaches are shown as red stars.

Figure 2: Map depicting reach-specific survival estimates (per 10km) for 2008-2010. Colors represent per reach survival risk and standard error is represented as the grey buffer surrounding each reach. The values adjacent to each reach represent the survival estimate for a given reach (per 10 km) from our full survival model.

Figure 3. Difference between survival estimates in the spatial-temporal model and the covariate model for each reach (labeled as the distance (River km) between the upstream boundary and the Golden Gate Bridge). Negative values represent occasions when the covariate model had a larger estimate of survival and was presumably missing covariates that increased smolt mortality. Error bars represent the 95% confidence interval estimated with the delta method.

Figure 4: A barplot depicting the results of covariate removal analysis to determine the importance of each variable to the final model. Delta QAIC values represent the change in QAIC when specific variables are removed from the full model.

Figure 5: Covariate response plots showing the effect of the individual covariates on the apparent survival rate through a 10 km reach. The grey shaded region represent the 95% confidence interval.



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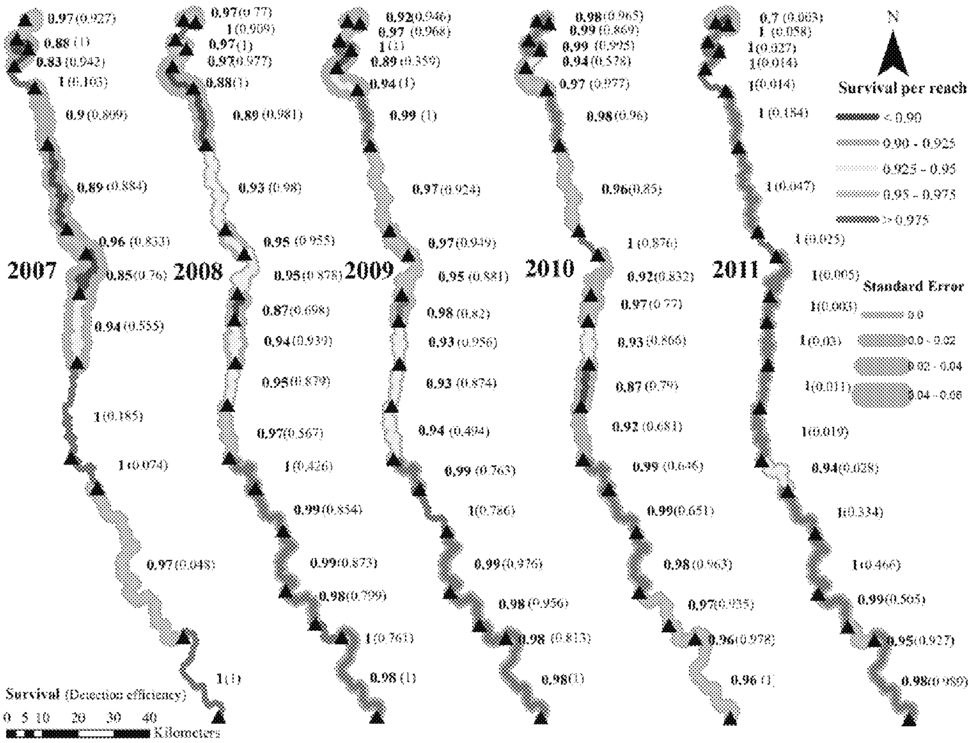

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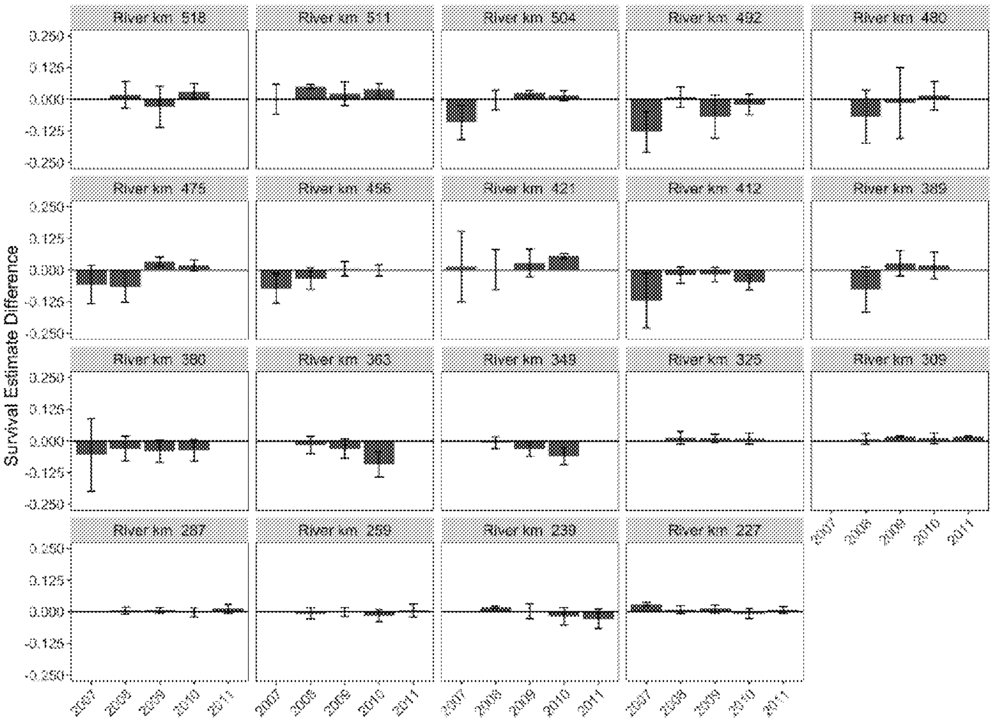

Figure 3. Difference between survival estimates in the spatial-temporal model and the covariate model for each reach (labeled as the distance (River km) between the upstream boundary and the Golden Gate Bridge). Negative values represent occasions when the covariate model had a larger estimate of survival and was presumably missing covariates that increased smolt mortality. Error bars represent the 95% confidence interval estimated with the delta method.

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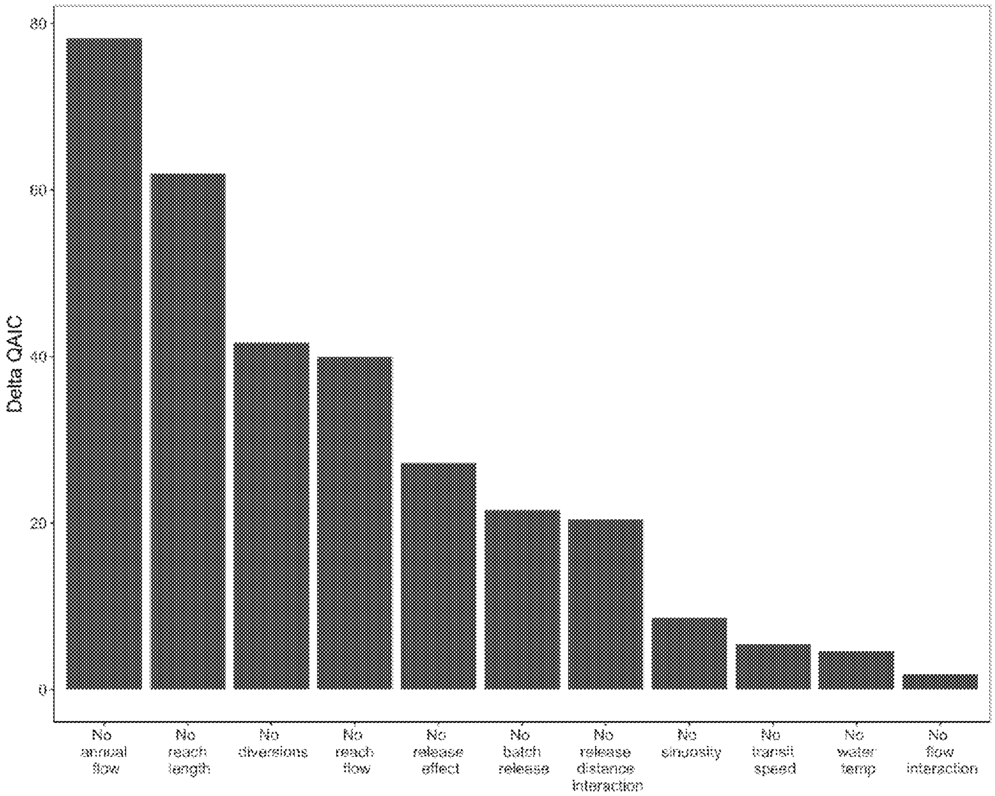

Figure 4: A barplot depicting the results of covariate importance analysis to determine how removing a single covariate influenced the fit of the selected model. Delta QAIC values represent the change in QAIC when specific variables are removed from the full model.

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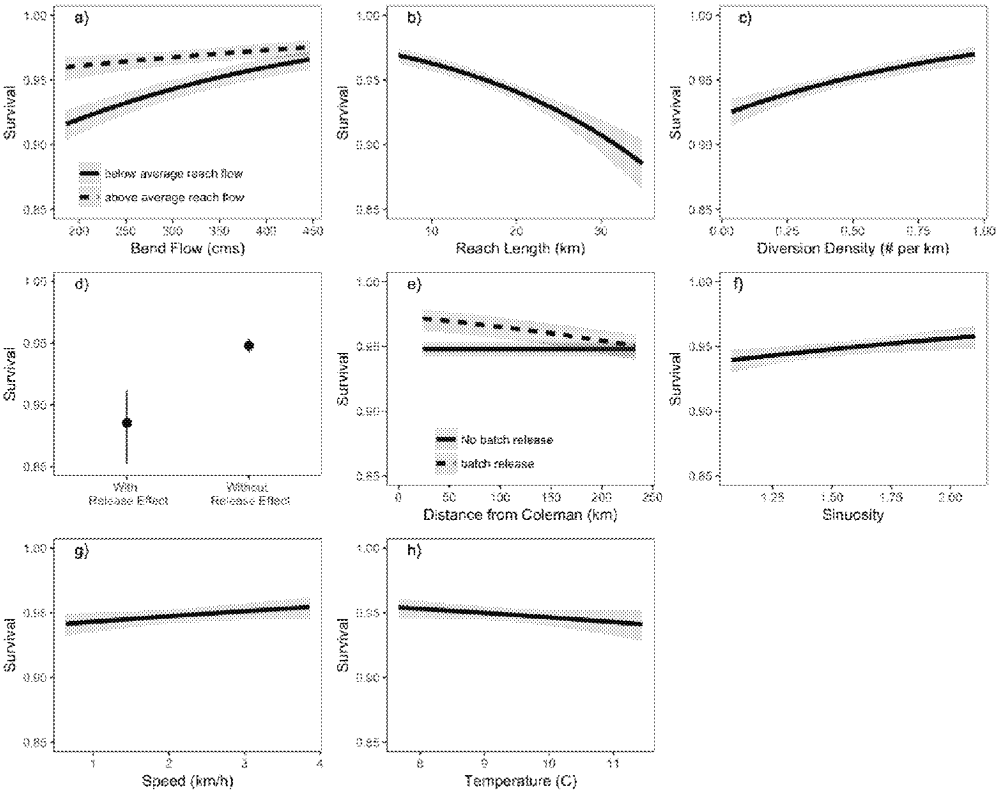

Figure 5: Covariate response plots showing the effect of the individual covariates on the apparent survival rate through a 10 km reach. The grey shaded region represent the 95% confidence interval.

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Table 1: A description of the covariates included in the mark recapture model.

Category	Covariate	Range	Definition	Hypothesized relationship with survival
Individual	Fish Length[1]	135 - 204 mm	Fork length	Larger fish may exceed gape width of predators
	Fish Condition[1]	0.59 - 1.32	Fulton's K	Increased condition improves predator escape capability
	Transit speed[2]	0.02 - 8.25 km h^{-1}	Reach specific transit speed	Faster moving fish have less exposure to predators
Release group	Batch release[2]	Binary	Tagged fish released concurrently with large hatchery releases.	Predator swamping
	Release reach[1]	Binary	Difference in survival between newly released fish and those released upstream.	Newly released hatchery fish are naïve and susceptible to predation
	Annual flow[3]	179 - 499 cms	Mean flow measured at Bend Bridge throughout outmigration (December-March).	Increased flows produce more habitat and predator refugia throughout the river
Reach specific	Sinuosity[4]	1.04 - 2.74	River distance divided by Euclidean distance.	More natural habitats have more predator refugia
	Diversion density[5]	0 - 1.05 num km^{-1}	Number of diversions per reach length.	Increased predator densities near diversions
	Adjacent cover density[6]	0.2 - 0.76 %	Percent of non-armored river bank with adjacent natural woody vegetation.	Increased cover produces more predator refugia
	Off-channel habitat density[6]	0 - 1.62 %	Off-channel habitat within 50 m of river expressed as percentage of river area	Increased off-channel habitat produces more predator refugia
Time varying	Temperature[7]	6.2 - 12.9 °C	Mean water temperature per reach	Increased temperatures results in increased predation due to higher metabolic demands of predators
	Inter-annual Reach flow[7]	215 – 447 cms	Mean water flow per reach	Higher flows within a reach will produce more habitat and predator refugia within that reach
	Intra-annual Reach flow[7]	129 – 902 cms	Mean water flow per reach and year	Higher intra-annual flows (e.g., precipitation or dam releases) decreases predation due to increased turbidity and increased predator refugia.

[1]Measured during tagging and release; [2]Observed travel times and mixed effects model estimates; [3]California Water Data Library; [4]National Hydrography Dataset; [5]Passage Assessment Database - verified by field survey; [6]Department of Water Resources; [7]River Assessment for Forecasting Temperature (RAFT) model

Table 2. Beta estimates (standard errors) of covariates included in mark recapture models with a delta QAICc < 2. The Battle Creek, Sacramento-San Joaquin Delta (Sac-SJ Delta), and San Francisco Bay (SF Bay) covariate are beta estimates for the three reaches where habitat and predation related covariates were not included in the model. See Table 1 for definitions of the other covariates. The selected model is in bold.

Covariate	Model 1	**Model 2**	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	2.918 (0.050)	**2.900** **(0.049)**	2.899 (0.049)	2.917 (0.050)	2.943 (0.049)	2.942 (0.049)	2.936 (0.049)
Battle Creek	-2.000 (0.141)	**-1.986** **(0.140)**	-1.957 (0.141)	-1.969 (0.142)	-2.023 (0.141)	-1.992 (0.142)	-2.013 (0.141)
Sac-SJ Delta	-2.673 (0.096)	**-2.656** **(0.095)**	-2.659 (0.095)	-2.678 (0.096)	-2.695 (0.096)	-2.698 (0.096)	-2.691 (0.096)
SF Bay	-2.888 (0.260)	**-2.868** **(0.259)**	-2.899 (0.261)	-3.042 (0.240)	-2.926 (0.259)	-2.959 (0.261)	-2.913 (0.259)
Reach length	-0.463 (0.047)	**-0.446** **(0.046)**	-0.444 (0.045)	-0.461 (0.047)	-0.445 (0.049)	-0.442 (0.049)	-0.457 (0.049)
Sinuosity	0.168 (0.050)	**0.147** **(0.049)**	0.145 (0.049)	0.167 (0.050)	0.181 (0.051)	0.181 (0.051)	0.188 (0.051)
Adjacent cover					0.073 (0.053)	0.076 (0.053)	0.089 (0.052)
Diversion density	0.421 (0.057)	**0.382** **(0.052)**	0.379 (0.052)	0.418 (0.057)	0.423 (0.056)	0.421 (0.056)	0.419 (0.056)
Off-channel habitat	0.118 (0.062)			0.120 (0.062)	0.143 (0.065)	0.147 (0.065)	0.147 (0.065)
Fish condition			0.050 (0.030)	0.054 (0.030)		0.054 (0.030)	
Annual flow	0.404 (0.039)	**0.406** **(0.039)**	0.405 (0.039)	0.402 (0.039)	0.387 (0.038)	0.387 (0.038)	0.396 (0.038)
Reach flow (year)	0.320 (0.047)	**0.320** **(0.047)**	0.315 (0.047)	0.314 (0.047)	0.309 (0.047)	0.304 (0.047)	0.327 (0.046)
Annual flow: Reach flow	-0.112 (0.046)	**-0.113** **(0.046)**	-0.107 (0.046)	-0.106 (0.046)	-0.115 (0.046)	-0.109 (0.046)	-0.106 (0.046)
Temperature	-0.079 (0.041)	**-0.080** **(0.041)**	-0.078 (0.041)	-0.077 (0.041)			
Transit speed	0.079 (0.034)	**0.078** **(0.034)**	0.081 (0.034)	0.083 (0.035)	0.069 (0.035)	0.073 (0.035)	
Release reach	-0.821 (0.131)	**-0.857** **(0.130)**	-0.865 (0.130)	-0.829 (0.131)	-0.781 (0.135)	-0.787 (0.135)	-0.781 (0.135)
Batch release	0.694 (0.147)	**0.701** **(0.146)**	0.689 (0.147)	0.679 (0.147)	0.637 (0.143)	0.625 (0.143)	0.651 (0.143)
Batch release: Distance	-0.003 (0.000)	**-0.003** **(0.000)**	-0.003 (0.000)	-0.003 (0.000)	-0.003 (0.000)	-0.003 (0.000)	-0.003 (0.000)
Survival covariates	16	**15**	16	17	16	17	15
Delta QAICc	0	**0.29**	0.71	1.20	1.27	1.38	1.63

Decoupling outmigration from marine survival indicates outsized influence of streamflow on cohort success for California's Chinook salmon populations

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Abstract

Historically, marine survival estimates for salmon have been confounded with freshwater seaward migration ("outmigration") survival. Telemetry studies have revealed low and variable survival during outmigration, suggesting marine mortality may not be the primary source of variability in cohort size as previously believed. Using a novel combination of tagging technologies, survival during these two life stages was decoupled over five years for Sacramento River Chinook salmon. Outmigration survival ranged from 2.6% to 17%, marine survival ranged from 4.2% to 22.8%. Influential environmental drivers in both life stages were also compared to smolt-to-adult ratios (SAR) for three Chinook salmon populations over 20 years. Streamflow during outmigration had higher correlation with SAR (r-squared >0.34) than two marine productivity indices (r-squared <0.08). The few SAR estimates that were poorly predicted by flow occurred during years with the lowest marine productivity, suggesting most inter-annual SAR fluctuations are explained by outmigration survival, but abnormally poor marine conditions also reduce SAR. The outsized influence of flow on SAR provides managers with a powerful mitigation tool in a watershed where flow is tightly regulated.

Keywords

-Chinook salmon
-Survival
-California
-River regulation
-Marine productivity
-Smolt-to-adult
-Acoustic telemetry

Introduction

Convention is that variability in salmon cohort success is set during the early marine residence period. To date, direct evidence of how outmigration (freshwater plus estuarine) survival might be affecting overall cohort success has been scarce throughout the range of salmon populations. Historically, it has been difficult to parse out outmigration survival from marine survival, further obfuscating the causes and magnitude of outmigration mortality. Recent telemetry studies have estimated very low survival during the outmigration life stage of certain salmon stocks (Buchanan et al. 2013; Michel et al. 2015; Clark et al. 2016), suggesting that marine survival is likely higher than what the literature indicates. Many models attempting to explain marine survival using marine environmental indicators suffer from large amounts of unexplained variation in some years (Koslow et al. 2002; Logerwell et al. 2003; Sharma et al. 2013); and there is potential that variation due to outmigration survival has been incorrectly attributed to marine survival in these models. Through the accurate partitioning of outmigration and marine survival, it may be possible to identify new survival bottlenecks which will require new and different management solutions.

Marine conditions are often blamed for poor cohort success of California's Central Valley Chinook salmon (*Oncorhynchus tshawytscha*) populations, but there is a building body of evidence to suggest that outmigration survival may be playing a large role (Buchanan et al. 2013; Michel et al. 2015). Gross et al. (1988) posited that anadromous life history strategies evolve in fishes when migration to the ocean provides gains to individual fitness that outweigh the costs of the migration itself. It is believed that salmon have evolved this life history strategy because the ocean provides a more favorable tradeoff between abundant food and predation risk. However, the Central Valley may be an example of a system where the costs of outmigration are high enough that the anadromous life history strategy is no longer sustainable, and is only persisting through the assistance of humans (such as through hatcheries, or transporting outmigrants past regions of poor survival). Three of the four distinct salmonid Evolutionarily Significant Units (ESUs) that are found there are listed under the U.S. Endangered Species Act (ESA), and the fourth is a "species of concern". Many inland stressors have been identified that have led to the decline of these populations, including the loss of 47% of spawning and rearing habitat due to dams without fish passage (Yoshiyama et al. 2001) and 97% of the productive floodplain rearing habitat to diking (Whipple et al. 2012). These dams and levees are one-time historical perturbations, but have ongoing impacts and will likely never be completely reversed. While it is almost certain that populations will not return to pre-dam and pre-diking levels without reversing these habitat changes, studies must also concentrate on the contemporary stressors that are governing annual outmigration survival dynamics, such as warm stream and estuary temperatures during outmigration, slow water velocities, low turbidity, and abundant predators (Baker et al. 1995; Newman and Rice 2002; Grossman 2016). However, these are just the symptoms of a larger problem: the fundamental alteration of the Central Valley hydrological regime. The dams and diversions of the Central Valley have resulted in the reduction and homogenization of river flows (Buer et al. 1989), which in turn can alter water temperatures, slow water velocities associated with large flow events, lower turbidity and provide more suitable habitat for warm-water predator species. These same dams and diversions give resource managers tight control over streamflow and associated covariates. In contrast, managers have no control over the environmental variables that are thought to govern marine survival. Therefore, if outmigration survival is found to have a large influence on the magnitude and variability in cohort success, this suggests that managers can likely do more to help these populations.

A novel method of pairing outmigration survival estimates derived from an acoustic tagging study with smolt-to-adult ratio (SAR) estimates derived from coded-wire tag (CWT) recoveries from the same cohorts was used to investigate the relative importance of (1) freshwater and estuarine outmigration (hereafter simply termed "outmigration") survival versus (2) marine survival rates for Central Valley Chinook salmon over the 5-year time series of the acoustic tagging study. Expanding beyond this time series, many additional years of SAR estimates were regressed against environmental drivers that are believed to be influential on survival in each region to investigate the importance of these environmental drivers on smolt-to-adult dynamics and ultimately gain insights on where the majority of mortality might be occurring every year.

Methods

Study system

California's Central Valley includes the two largest rivers in the state. In the northern portion of the valley, the Sacramento River flows north to south and in the southern portion of the valley, the San Joaquin River flows south to north (Fig. 1). These two rivers meet to create the freshwater portion of their shared estuary: the Sacramento-San Joaquin River Delta (hereafter "Delta"), an expansive and complex network of tidal freshwater river channels and sloughs. It is connected to the west by a series of increasingly saline bays, most notably the San Francisco Bay, which comprise the brackish portion of the estuary ("Bays" in Fig. 1). The estuary connects to the Pacific Ocean at the narrow passage at the Golden Gate, beyond which salmon have access to the productive waters of the Gulf of the Farallones.

Outmigration survival estimates

In an attempt to decouple outmigration and marine survival of Central Valley Chinook salmon, cohorts that were tagged using both acoustic tags (for estimation of outmigration survival) and coded-wire tags ("CWT"; for estimation of overall cohort success) were identified. Outmigration survival estimates were used from two acoustic tagging studies conducted on hatchery-origin late-fall-run Chinook salmon from 2007 to 2011 (Michel et al. 2015; Iglesias et al. 2017). These studies released their acoustic tagged fish as part of larger hatchery releases that were also coded-wire tagged. CWTs are tiny, injectable, magnetized wire segments that are embossed with a release group serial code, with release groups of thousands of fish often sharing the same serial code. Recovery of tagged adults allows the estimation of smolt-to-adult ratio (SAR) of these larger release groups. SAR represents the proportion of fish of a harvestable size recovered from the total number of juveniles released into the wild and was therefore used as an index of cohort success.

To assess the contribution of outmigration survival to overall SAR, and to factor out estimates of marine survival, outmigration survival from acoustic tagged release groups were associated to the SAR estimates from the most appropriate CWT release groups. However, some of the acoustic tagged release groups were not released in exact synchrony with a respective CWT release group. For these, if one or more CWT release groups were released within 7 days of the acoustic tag group's release date, that acoustic tag group's outmigration survival was associated to the respective CWT release group(s). For the purposes of these studies, outmigration survival was estimated as total survival from release to the Golden Gate Bridge, thereby including river and estuarine survival. For more information on the acoustic tagging, tracking, and estimation of survival for the acoustic tagging studies, refer to Michel et al. (2015).

Smolt-to-Adult estimates

SAR is a survival metric often used for hatchery fish because of the fairly accurate estimates of how many smolts are released. Hatchery Chinook salmon are often raised up to the smolting stage before release, which is the beginning of the SAR period. The end of the SAR period is when a fish either returns to the spawning grounds or hatchery, or is captured by commercial or recreational fisheries. These various recapture scenarios ("strata"), and their associated CWT recoveries, occur after Chinook salmon have spent at least one year in the ocean (2+ year old), and can commonly occur for salmon that have spent as many as 3 years in the ocean (4+ year old; Fig. 2). SAR therefore represents the survival of a cohort from smolting to the point at which they reach harvestable and minimum reproductive (i.e. "adult") size. Thus, survival during the SAR period for a CWT group will be the product of 1) "outmigration survival" (S_O) and 2) "marine survival" (S_M), survival during the first year at sea plus an amalgamation of year 2, 3, and 4 survival depending on recapture time of individuals within the CWT group. Due to this complexity, SAR should be treated as an index of survival that primarily represents survival from hatchery release to age 2, with some additional mortality from latter periods (but that are thought to be relatively small contributions compared to critical survival bottlenecks of outmigration and the first year at sea [Magnusson and Hilborn 2003; Quinn 2005 and references therein]).

The SAR in the Central Valley is most often calculated using CWT recoveries (CWT_R). Approximately 25% of all hatchery-origin fall-run Chinook salmon (since 2007) and 100% of all hatchery-origin late-fall-run and winter-run Chinook salmon (since 1992) in the Central Valley have CWTs inserted into their snouts as juveniles. Once the salmon attain harvestable size (hereafter "adults"), the CWTs are recovered from the fisheries through creel surveys, from the spawning grounds through carcass surveys, and through the hatcheries (for additional details on recovery sources, refer to Table 1). All CWT data were downloaded from the Pacific States Marine Fisheries Commission's Regional Mark Processing Center's Regional Mark Information System database (http://www.rmpc.org/).

The first brood year (i.e., the year the eggs were spawned; "BY" hereafter) for which SAR could be accurately estimated was 1999 for both winter and fall-run Chinook salmon, and 1993 for late-fall-run Chinook salmon (despite the absence of spawning ground and recreational river fishery recoveries until the late 1990s). Since an estimated 61 to 97% (mean 80%) of late-fall-run Chinook salmon escapement are counted at hatcheries (using CWT data from recovery years 2000-2016 when spawning ground and recreational river fishery recoveries occured), using only hatchery returns in years prior to the late 1990s could bias SAR estimates low for those years, but would likely still capture the major population trends.

For creel and carcass surveys, full coverage of all fishing areas and spawning grounds is not possible; sampling fractions (r) are therefore estimated per stratum (i.e., unique recovery type, area and year combinations). Sampling fractions are the fraction of estimated total number of salmon caught (if a fishery) or that returned (if a hatchery or spawning area) that were examined for presence of a CWT per stratum, with some additional nuances outlined in Palmer-Zwahlen and Kormos (2015). Details on how total number of salmon per stratum were estimated can be found in O'Farrell et al. (2012). Expansion factors, the reciprocal of sampling fractions, are applied to the total CWTs observed per CWT release group that are recovered from that respective stratum to produce expanded CWT recoveries ($eCWT_R$). Finally, since Chinook salmon spawning age is variable (minimum age 2 years), SAR for the full cohort cannot be estimated until the CWTs from the fifth year after release are processed. Thus, SAR estimates beyond BY 2012 are not reported. Total expanded recoveries for each release group (N_e) is therefore estimated as:

$$N_e = \sum_{y=1}^{Y}[\mathrm{eCWT}_R Ocean\ Fishery + \mathrm{eCWT}_R River\ Fishery + \mathrm{eCWT}_R Spawning\ Grounds + \mathrm{CWT}_R Hatchery] \quad \ldots (1)$$

where Y is total number of return years for which CWTs are observed for that CWT release group. Note that hatchery CWT recoveries are not expanded because all CWTs are presumed to be recovered from hatchery returns.

SAR is expressed as the proportion of expanded recoveries (N_e) out of all smolts released from the hatchery for that CWT release group (N_r):

$$SAR = \frac{N_e}{N_r} \qquad (2)$$

The standard error (SE) of the SAR for a CWT release group is a function of N_e, N_r, and the total number of observed CWTs (before expansion, N_d) (Skalski and Townsend 2005):

$$SE(SAR) = \sqrt{\frac{\frac{N_e}{N_r}\left(1 - \frac{N_e}{N_r}\right)}{N_r} + \frac{\left(\frac{1-r}{r^2}\right)N_d}{{N_r}^2}} \qquad (3)$$

For proper variance calculation, sampling fractions are needed per stratum. However, protocols for estimating sampling fractions differed substantially by year and recapture type. Overall, the sampling fraction for all CWTs recovered (across the strata) per brood year and per population in this analysis was never below 0.21, and the mean was 0.35 for winter-run, 0.49 for fall-run, and 0.63 for late-fall-run. Therefore, a global sampling fraction (r) was applied to equation 3 using a conservative estimate of 0.2:

$$SE(SAR) = \sqrt{\frac{\frac{N_e}{N_r}\left(1 - \frac{N_e}{N_r}\right)}{N_r} + \frac{\left(\frac{1-0.2}{0.2^2}\right)N_d}{{N_r}^2}} \qquad (4)$$

When calculating SAR and standard error for more CWT release groups that were released on the same day, N_e, N_r, and N_d were totaled among those CWT release groups. However, because there can be large heterogeneity in SAR estimates for different CWT release groups released in the same year, annual SAR and standard errors are calculated differently (Skalski and Townsend 2005). Annual SAR is a weighted average across CWT release groups:

$$\widehat{SAR} = \frac{\sum_{k=1}^{K} N_{ek}}{\sum_{k=1}^{K} N_{rk}} \qquad (5)$$

Where K is the number of CWT release groups in a year. Standard error of the annual SAR is estimated as:

$$SE(\widehat{SAR}) = \sqrt{\frac{\sum_{k=1}^{K} N_{rk}(SAR_k - SAR)^2}{(K-1)\sum_{k=1}^{K} N_{rk}}} \qquad (6)$$

For the late-fall-run and winter-run populations, the only hatcheries that release smolts in the Central Valley are the United States Fish and Wildlife Service's (USWFS) Coleman National Fish Hatchery (CNFH) and Livingston Stone National Fish Hatchery (LSH), respectively. Both of these hatcheries release the majority of their fish into the uppermost portions of the Sacramento River that is available to anadromy, more than 500 river km from the Pacific Ocean. Because multiple hatcheries in the Central Valley release fall-run smolts, to compare fall-run release groups over the same outmigration corridor as the late-fall-run and winter-run, only fall-run CWT recoveries from CNFH release groups were used. All CWT release groups that were trucked and released downstream, a management strategy intended to artificially increase SARs (by reducing outmigration mortality) of hatchery smolts, were also excluded. This is because one of the main objectives of this study was to explicitly measure the magnitude and variability in natural outmigration survival.

SAR estimates are the combination of survival over a finite outmigration period and non-discrete marine period (due to various CWT recapture times). To ascertain the magnitude of the bias introduced by the latter periods of the non-discrete marine period on overall SAR, SAR estimates were compared to survival rates from hatchery release to the end of age 2 for winter-run Chinook salmon for the same brood years, as estimated from a Sacramento River winter-run Chinook salmon cohort reconstruction model ([O'Farrell et al. 2012]; data provided by M. O'Farrell, NOAA-NMFS). This was done using a linear regression model fitted between the two variables, after logit-transformation (due to the range of both variables being bound by 0 and 1). Currently, a salmon cohort reconstruction model does not exist for Central Valley fall or late-fall-run Chinook salmon.

Outmigration vs. Marine Survival comparison

The outmigration survival component of SAR, as estimated from acoustic telemetry, was factored out to get an estimate of marine survival for those brood years:

$$S_M = \frac{SAR}{S_O} \qquad (7)$$

To incorporate error in estimates of both SAR and S_O, parametric bootstrapping was employed. SAR was assumed to have a normal distribution on the real scale and S_O was assumed to have a normal distribution on the logit scale. Given these distributions, SAR and S_O were generated 1000 times each and transformed back to the real scale, such that (SAR_1^*, SAR_2^*, ..., SAR_{1000}^*) and (S_{O1}^*, S_{O2}^*, ..., S_{O1000}^*) yielded S_{M1}^*, S_{M2}^*, ..., S_{M1000}^*. Mean S_M and standard error of the mean were estimated from these values on the logit scale and back transformed to the real scale. The 95% confidence intervals were also generated given:

$$logit^{-1}\left[\, logit\left(\widehat{S_M}\right) \pm\ 1.96 \times SE[logit(\widehat{S_M})]\right] \qquad (8)$$

This was done for late-fall-run Chinook salmon only, and not for fall-run or winter-run Chinook salmon due to the lack of acoustic tag data old enough to estimate respective SAR values.

Freshwater outmigration survival vs. SAR

Michel et al. (2015) demonstrated that much of the annual variability in outmigration survival may be occurring during the freshwater portions of the outmigration. To evaluate the effect of annual freshwater outmigration survival (S_{FW}) dynamics on SAR, a linear model was fitted to survival rates estimated from acoustic tags and the CWT-based SAR. The acoustic tag-estimated survival rates encompassed the river and Delta regions combined (i.e., from release to Chipps Island; data from Michel et al. [2015]).

In order to incorporate error, parametric bootstrapping was employed for both SAR and S_{FW}. SAR data was generated 1000 times on the real scale, then transformed to the logit scale due to SAR being bounded by 0 and 1, such that $[logit(SAR_1^*), logit(SAR_2^*), \ldots, logit(SAR_{1000}^*)]$ datasets were created. S_{FW} was generated 1000 times on the logit scale, again because S_{FW} is bounded by 0 and 1, such that $[logit({S_{FW}}_1^*), logit({S_{FW}}_2^*), \ldots, logit({S_{FW}}_{1000}^*)]$ datasets were created. The SAR datasets were fitted to their respective S_{FW} datasets per iteration of 1000 different linear models, such that 1000 estimates of r-squared values were generated. The median, 5% and 95% percentile values (i.e., 95% confidence intervals) of the r-squared estimates were then calculated.

Environmental covariates vs. SAR

The relationship between SAR and variables that characterize the river and ocean environments were evaluated for each of the three Chinook salmon populations. Linear regression models were fitted between logit-transformed SAR estimates and environmental indices. Because extreme outliers can mask strong and persistent trends, Cook's distances were estimated for all points in all models (Cook 1977) to determine if any annual SAR values exert excessive leverage on the linear regressions. The linear regression model was fitted with and without any annual SAR value with a Cook's distance > 1.

Environmental covariates thought to influence survival during the outmigration and marine survival life stages were selected in an attempt to determine the relative contribution of these factors on cohort success. For the river environment, the literature suggests that flow may have the greatest influence on outmigration survival (Newman and Rice 2002; Smith et al. 2003; Michel et al. 2015). Flow values (cubic feet per second) were used from the United States Geological Survey's Bend Bridge gauging station on the Sacramento River (USGS station number 11377100). This gauge is located approximately 20 and 60 river kilometers downstream from the release locations used by the CNFH and LSFH, respectively. Distribution of flow values were right-skewed, and thus log-transformed for normality.

A single variable (upwelling) and a multivariate index of productivity were chosen for the marine environment. Upwelling is a key variable in determining the quality of marine conditions for salmon (Kope and Botsford 1990; Scheuerell and Williams 2005; Wells et al. 2016). Mean monthly coastal upwelling index as computed by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service for the 39° N 125° W station, the closest station to the Gulf of the Farallones (https://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/upwelling.html) was used as the single covariate. The upwelling index represents wind-driven cross-shore transports computed from surface pressure analyses (in cubic meters per second along each 100 meters of coastline). The Multivariate Ocean Climate Indicator (MOCI) as described in Garcia-Reyes and

Sydeman (2017) was used as the multivariate index of productivity. This unitless environmental indicator, specific to California's continental shelf, synthesizes numerous ocean and atmospheric variables to give an index of the state of the ecosystem productivity (http://www.faralloninstitute.org/moci). The MOCI is estimated for both the Northern California region (38 to 42°N latitude) and the Central California region (34.5 to 38°N latitude). Since juvenile salmon from the Central Valley are known to occupy both these regions (MacFarlane 2010), the mean seasonal MOCI between these regions was used. Low MOCI values represent high marine productivity, and high MOCI values represent low marine productivity.

Daily mean flow at Bend Bridge was averaged over a 14-day window, starting the day of release, for each CWT release group, to represent the mean river travel time from release to Delta entry (as estimated for acoustic tagged hatchery-origin late-fall-run Chinook salmon smolts [Michel et al. 2012]). These release group-specific 14-day mean flows were then averaged per year and weighted to the size of each CWT release group. For the marine environment, the first few months at sea is the most critical survival period of the marine phase of a salmon's life history (Kilduff et al, 2014), specifically during the first spring at sea for Central Valley salmon stocks and mediated through environmental drivers such as upwelling (Wells et al. 2012; Woodson et al. 2013). Therefore, the mean monthly upwelling index across the months of March, April, and May for the year of outmigration were used, as well as the mean of the Northern and Central California spring MOCI.

The residuals of the flow linear models were graphically compared to upwelling and MOCI to evaluate if any variability in SAR that was unexplained by flow could be explained by the marine environmental covariates. Two contour plots were generated by interpolating the known SAR values (all three salmon populations combined, to increase resolution) across a grid of flow and either upwelling or MOCI values (using Akima interpolation [Akima 1970]), bounded by the limits of the current dataset. Because SAR values could be influenced by population-specific life history strategies, annual logit-scale SAR values were standardized within populations (i.e., z-score: subtracted the mean and divided by the standard deviation for each SAR value), and then combined. All analyses were performed using program R (version 3.5.1, R Core Team 2016) along with the "akima" package (Akima and Gebhardt 2016).

Results

Smolt-to-Adult estimates

Annual SAR values were estimated for 20 consecutive years for late-fall-run, and 14 consecutive years for winter-run and fall-run Chinook. The number of CWTs released per run and per year ranged from 30,451 to 3,128,686. Annual SAR ranged from 0.02% to 3.29% overall, and mean annual SAR for these years were 1.00% (0.1 SE) for late-fall-run Chinook salmon, 0.64% (0.18 SE) for winter-run Chinook salmon, and 0.81% (0.26 SE) for fall-run Chinook salmon (Table 2).

There was a strong positive relationship between the winter-run Chinook salmon SAR values and hatchery release to end of age-2 survival, as estimated by cohort reconstruction (r-squared 0.95; Fig. 3). Because the two variables are approximately equal under the same conditions (95% confidence intervals of the linear model between these two variables overlap the 1:1 line), SAR was used to represent the combined outmigration and marine survival during the first year at sea.

Outmigration vs. Marine Survival comparison

Overall, outmigration survival ranged from 2.6% to 17%, and marine survival ranged from 4.2% to 19% for eight late-fall-run Chinook salmon CWT release groups (or cluster of release groups) from brood years 2007 through 2010 (Fig. 4). For the eight CWT release groups, five were estimated to have higher marine survival than the respective outmigration survival estimate, two groups had the opposite pattern, and one group had approximately equal survival in both periods. SAR estimates were distributed above and below the BY 1993-2012 long-term median SAR (0.81%; represented by the black dashed line in Fig. 4), suggesting that these release groups experienced overall survival that was roughly representative of the larger pool of CWT release group SAR estimates.

Freshwater outmigration survival vs. SAR

Freshwater survival had a strong positive relationship with overall SAR for these same eight CWT release group clusters (r-squared 0.62; Fig. 5), indicating freshwater outmigration survival was an important factor in overall SAR for those cohorts.

Environmental covariates vs. SAR

Flow during outmigration was a strong predictor of SAR in all three of the Chinook salmon runs (r-squared 0.45 for late-fall-run, 0.57 for winter-run, and 0.35 for fall-run Chinook salmon, after removing the extreme outliers identified by Cook's distance), while both upwelling and MOCI during the first spring at sea had little influence over SAR (Fig. 6). All points in all linear models had Cook's distances <1 with the exception of 20.0 and 1.9 for outmigration year (i.e., brood year +1; "OY" hereafter) 2006 in both the fall-run and winter-run Chinook salmon linear models between SAR and flow (red labeled points in Fig. 6. d and g). The r-squared of the linear regressions with the outlier included was 0.08 for fall-run and 0.16 for winter-run (linear regressions shown in Fig. 6. d and g do not include the OY 2006 year). In both cases, these outliers had lower SAR than what would be predicted by flow during outmigration given the remainder of the datasets.

The residuals from the three flow regressions were plotted against spring upwelling index, and spring MOCI. For fall-run and winter-run Chinook salmon OY 2006, the residual was predicted based on the linear regression that was fitted to the dataset that did not include OY 2006 (due to having a Cook's distance > 1). Model performance was poorest in predicting annual SAR in years with some of the lowest upwelling and MOCI indices (Fig. 7). Specifically, for late-fall-run Chinook salmon, model performance was poor in OYs 1998 and 2005; years with the lowest spring upwelling indices and the highest MOCI indices (i.e., low productivity) from the 20-year time series. For winter-run Chinook salmon, the flow model performed poorly in explaining the low SAR that occurred for salmon outmigrating during OY 2005 and 2006; these same years also had the first and third lowest spring upwelling index values and the highest MOCI index values for the 14-year time series. For fall-run Chinook salmon, the model poorly explained the low SAR for outmigrating salmon in OY 2006; the year with the third lowest spring upwelling index and the second highest MOCI index for the 14-year time series.

For all three runs, flow was the primary driver of year-to-year variation in SAR for the variables tested (Fig. 6), with marine productivity only playing a major role in annual dynamics when productivity was at low levels (Fig. 7). High SAR values tended to only occur when flow was higher than average and productivity was not near abnormally low levels (Fig. 8). The OY 2014-2017 cohorts (for which SAR values are not yet available) are predicted to have poor SAR based on the trends seen in the existing data with the exception of the OY 2015 late-fall Chinook salmon and all three runs in OY 2017 as predicted by the upwelling contour plot (Fig. 8). The MOCI contour plot has all three runs in OY 2017 falling outside the bounds of the contour plot.

Discussion

This study indicates that outmigration survival, and the conditions that affect it, are the primary drivers of SAR dynamics, and marine survival likely only plays a critical role in years with abnormally unfavorable marine conditions for salmon. Lindley et al. (2009) also suggested that ocean conditions can have infrequent and yet drastic effects on salmon cohorts, while the long-term, steady degradation of the freshwater environment likely plays a larger role in population health of Central Valley Chinook salmon populations. In a sense, these populations are extremely stressed due to the degraded freshwater environment, and cumulative to this, poor marine conditions can then result in extremely low survival rates.

This study used a novel combination of short-term acoustic tagging data paired with long-term coded-wire tag recovery data to estimate marine survival rates for California Chinook salmon populations. The results indicated that marine survival for California Chinook salmon populations is similar in scale to outmigration survival. Given that these marine survival estimates are confounded with return river survival, net marine survival is likely higher than outmigration survival in most years. Two studies have found exceptionally low outmigration survival rates for California Central Valley Chinook salmon stocks compared to other large West Coast rivers (Buchanan et al. 2013; Michel et al. 2015). Given these low outmigration survival rates, it would be mathematically impossible for these fished populations to be sustainable if marine survival was much lower than outmigration survival and hatchery propagation did not exist (Michel et al. 2015). Indeed, the average annual SAR estimates in this study were below 1% for all three populations; for Upper Columbia and Snake River Chinook salmon populations, the Columbia River Basin Fish and Wildlife Program suggests that a minimum of 2% SAR is required for population survival and 4% for population recovery (NPCC 2009). This study is an additional line of evidence suggesting that for California Central Valley Chinook salmon populations, the risks of outmigration may now be too high and these populations are likely no longer sustainable.

That the contribution of marine survival to cohort success has been overestimated over the past decades of salmon research is an emerging concept, and one that is not unique to California or Chinook salmon. It has been suggested for Atlantic salmon (*Salmo salar*) in the Bay of Fundy, Canada (Lacroix 2008), for steelhead (*Oncorhynchus mykiss*) in the Cheakamus River, British Columbia (Melnychuk et al. 2014), and for sockeye salmon (*Oncorhynchus nerka*) in the Fraser River, British Columbia (Clark et al. 2016). The emergence of this concept is fundamentally linked to the advent of acoustic tags small enough for tagging juvenile salmon; because accurate estimates of outmigration survival before acoustic tags was difficult if not impossible. Without an estimate of outmigration survival, outmigration survival and marine survival cannot be parsed, which may lead researchers to believe that marine survival was driving population declines. Potential factors leading to this misconception include the fact that less is known about marine survival dynamics, marine residency is substantially longer in duration than the outmigration period, and recruitment is set during early marine residence for many strictly marine fishes and this concept was transferred to salmon. Managers and biologists should ensure that salmon life-cycle and forecast models incorporate some index of outmigration survival.

Streamflow during outmigration was found to have a large influence on SAR dynamics. Over 35% of all variability in annual SAR dynamics can be explained by flow during outmigration for three different Chinook salmon populations (after removal of an extreme outlier). Flow has been found by numerous studies to have strong influences on outmigration survival of salmon populations worldwide, including Central Valley Chinook salmon populations (Kjelson and Brandes 1989; Zeug et al. 2014). Increases in flow usually cause or are coincident with changes in many other river conditions that are beneficial to the survival of outmigrating salmon, such as increased water velocities (Hogasen 1998), decreased water temperatures (Smith et al. 2003), increased turbidity (Gregory and Levings 1998), and increases in habitat area that reduce exposure to predators and increase growth opportunities (Sommer et al. 2001). Among existing studies, this is one of only a few studies have demonstrated that flow can ultimately have a strong influence on overall cohort success in the Central Valley (Sturrock et al. 2015; Wells et al. 2017).

These results demonstrate that marine survival is also a major contributor to overall cohort strength. While the indices used for marine productivity in this analysis did not show strong relationships with SAR, this is not evidence of a lack of influence of marine survival on SAR variability, as they cannot capture all the relevant factors (e.g., abundance of predators, alternative prey, etc.). Moreover, the magnitude of marine survival was found to be as large a contributor to SAR as outmigration survival. Furthermore, three of the study years showed evidence of poor marine productivity leading to low SAR, all of which were corroborated with existing literature. The first of these three years, 1998, was a record El Nino-Southern Oscillation (ENSO) event with drastic effects on the California marine ecosystem (Lynn et al. 1998), which likely had a strong negative impact on marine survival of salmon (Pearcy and Schoener 1987; Johnson 1988). In 2005, during the well-documented delayed spring upwelling and resulting poor productivity of the northern California Current (Schwing et al. 2006; Barth et al. 2007), there was evidence of strong size and growth-rate selective early-marine mortality of Central Valley Chinook salmon (Woodson et al. 2013). In 2006, spring upwelling was similarly delayed as in 2005, especially off the coast of Central California where juvenile Central Valley Chinook salmon first recruit to after leaving the San Francisco Bay, leading to a similar situation of poor productivity (Lindley et al. [2009] and references therein). It is widely accepted that the poor early-marine survival of Central Valley fall-run Chinook salmon in the springs of 2005 and 2006 were the proximate causes of the collapse of that stock and the temporary closure of the fishery (Lindley et al. 2009), and in this analysis, the otherwise strong positive relationship between flow and SAR for fall-run and winter-run Chinook salmon was likely overshadowed by abnormally poor early-marine survival in OY 2006, as demonstrated by the high Cook's distances of those points.

These results also provide insights into how river and marine conditions might have varied influences on different salmon populations. High flows during outmigration benefited all three populations, despite the juveniles leaving at different sizes and at different times of the year. However, marine productivity seems to have affected the different runs differently in some years. For example, the late-fall-run Chinook salmon did not experience the OY 2006 crash, while the winter-run and fall-run did, despite all three benefitting from relatively high flows during outmigration. This could be due to the late-fall-run's predisposition to a larger size at ocean entry, especially if size-selective mortality is at play (which is often seen during poor ocean conditions [Holtby et al. 1990; Saloniemi et al. 2004; Woodson et al. 2013]). Lindley et al. (2009) reported on this discrepancy between the fall-run and late-fall-run Chinook salmon in those years: "Curiously, Sacramento River late-fall-run Chinook salmon escapement has declined only modestly since 2002, while the [Sacramento River fall-run] in the same river basin fell to record low levels." This is strong support for the concept of allowing Central Valley salmon to exhibit many life-history strategies and thereby diversifying the Central Valley salmon's portfolio and increasing population stability (Schindler et al. 2010; Carlson and Satterthwaite 2011).

As with many large-scale correlative survival studies, there are noteworthy caveats. Firstly, the survival estimates used in this analysis are for hatchery-origin fish only. While the trends discovered in this analysis likely effect wild populations similarly, empirical estimates of SAR for wild Central Valley Chinook salmon do not currently exist. Secondly, the effects of acoustic tagging on juvenile salmon can bias survival estimates low, through mortality related to the tag or surgery, mortality due to behavioral changes, or tag shedding. A subset of the fish used to generate the acoustic tag survival estimates used here from Michel et al. (2015) were also submitted to a laboratory tag effects study. In that study, no fish shed their tags over 160 days (exceeding the maximum outmigration time) and tagged fish growth and survival was not significantly different than untagged fish (Ammann et al. 2013). However, no tests were conducted to address mortality related to behavioral changes, and therefore it is conceivable that outmigration survival estimates used in this study were biased low. Thirdly, the strong relationship between flow during outmigration and SAR may be mediated in some part through marine survival. Climatic dynamics that led to increases or decreases in precipitation over the inland portions of the salmon's range may have also influenced marine conditions in a manner not captured by the marine productivity indices, but had an influence on SAR nonetheless. A similar scenario was demonstrated by Lawson et al. (2004) with coho salmon populations in the Pacific Northwest. One potential avenue for a post-hoc investigation of this concept would be to look for correlation between flow during outmigration and the marine productivity indices. Using the combined datasets, the r-squared for a linear model between flow during outmigration and spring upwelling was 0.07, and 0.19 between flow and spring MOCI, showing some evidence of relationships between these freshwater and marine indices. These relationships are likely driven by the trend that years with extremely high flows typically have low spring productivity (see conspicuous lack of points in upper-right quadrant of figure 8a and lower-right quadrant of figure 8b). This phenomenon may be in part explained by the effects of ENSO, which often manifests itself in California with heavy precipitation and low productivity of coastal waters (Schonher and Nicholson 1989; Jacox et al. 2015). In the one year that contradicted this trend in this dataset, OY 2005, when flow during outmigration and ocean productivity were both extremely low, SAR values were at their lowest levels (1st lowest for late-fall-run, 2nd lowest for winter-run, and 3rd lowest for fall-run). For salmon, it is perhaps a fortunate climatic concurrence that low marine productivity seems to be frequently associated with high outmigration flows in California.

The management implications of this study are important: while we do not have the luxury of mitigation actions when it comes to marine conditions, we have some control over conditions in the freshwater environment, and therefore potentially control over 35% of the annual variability in salmon population abundances, and thus can somewhat buffer these populations from the negative effects of poor marine conditions. Managers should explore approaches to increase river flow and other associated beneficial river conditions during the outmigration season of Central Valley Chinook salmon populations.

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Table 1. The different sources of CWT recoveries and the agency, method, and first collection year for each. In the last column, years highlighted in black represent the first brood year for which SAR was estimated.

Chinook salmon run	**Recovery type**	**Recovery Agency**[c]	**Collection methods**	**Brood Year when first available**
Winter	Ocean recreational fishery[a]	CDFW	Creel surveys	1991[b]
Winter	Ocean commercial fishery[a]	CDFW	Creel surveys	1991[b]
Winter	River recreational fishery	CDFW	Creel surveys	*No fishery*
Winter	Spawning ground	USFWS	Carcass surveys	**1999**
Winter	Hatchery	USFWS	Hatchery returns	1991[b]
Late-fall	Ocean recreational fishery[a]	CDFW	Creel surveys	1993[b]
Late-fall	Ocean commercial fishery[a]	CDFW	Creel surveys	1993[b]
Late-fall	River recreational fishery	CDFW	Creel surveys	1998
Late-fall	Spawning ground	CDFW	Carcass surveys	1999
Late-fall	Hatchery	USFWS	Hatchery returns	**1993**[b]
Fall	Ocean recreational fishery[a]	CDFW	Creel surveys	1979[b]
Fall	Ocean commercial fishery[a]	CDFW	Creel surveys	1979[b]
Fall	River recreational fishery	CDFW	Creel surveys	1998
Fall	Spawning ground	CDFW	Carcass surveys	**1999**
Fall	Hatchery	USFWS	Hatchery returns	1979[b]

[a] Some ocean fishery recoveries are received from out-of-state sources

[b] First year of consistent Coded-wire tagging

[c] CDFW refers to the California Department of Fish and Wildlife, and USFWS refers to the United States Fish and Wildlife Service.

Table 2. The estimated annual SAR (%), standard errors (SE), and total number of release days for each run and each brood year. Standard errors were calculated using equation 6.

	Late-fall run			Winter run			Fall run		
Brood Year	**SAR (%)**	**SE**	**Total Release Days**	**SAR (%)**	**SE**	**Total Release Days**	**SAR (%)**	**SE**	**Total Release Days**
1993	0.50	0.07	3						
1994	1.80	0.42	5						
1995	1.02	0.13	5						
1996	1.64	0.23	5						
1997	0.69	0.10	6						
1998	0.85	0.08	3						
1999	1.03	0.14	5	2.23	0.21	1	3.29	0.14	3
2000	0.77	0.11	4	0.34	0.03	1	0.78	0.05	4
2001	1.10	0.19	4	0.24	0.02	1	0.70	0.06	5
2002	1.44	0.25	4	1.88	0.09	1	0.94	0.12	2
2003	1.44	0.16	4	1.38	0.07	1	0.30	0.04	1
2004	0.26	0.07	4	0.08	0.01	1	0.10	0.03	2
2005	1.72	0.24	3	0.11	0.01	1	0.02	0.01	2
2006	0.87	0.16	3	0.29	0.04	1	0.04	0.01	4
2007	0.79	0.16	3	0.28	0.05	1	0.13	0.01	4
2008	0.56	0.05	4	0.05	0.01	1	0.59	0.04	3
2009	0.58	0.10	3	0.59	0.04	2	2.39	0.09	3
2010	1.21	0.14	3	0.43	0.06	1	1.46	0.08	4
2011	0.91	0.09	5	0.42	0.03	1	0.45	0.04	3
2012	0.88	0.10	4	0.62	0.07	1	0.15	0.02	3

Figure Captions

Figure 1. Map of the Central Valley, including portions of major rivers accessible to Chinook salmon populations delineated by major regions, major cities and points of interest, and salmon hatcheries relevant to this study.

Figure 2. A schematic representing the various recapture points for CWTs along the salmon life cycle that contribute to the estimation of a SAR for a given CWT group. The colored arrows represent life stage transitions, each with inherent levels of natural mortality. The circle shape represents hatchery release and rectangles represent CWT recoveries. Green-filled shapes represent events that occur in freshwater, and blue-filled shapes represent events that occur in the ocean. While recoveries of 5+ year old salmon are possible, they are extremely rare and therefore not represented in this schematic.

Figure 3. The relationship between winter-run Chinook salmon SAR values (%) and survival from hatchery release to the end of age-2 (%). The solid black line represents the 1:1 line. The black dotted line represents the linear model between these two variables, and the grey shaded area the 95% confidence interval around the linear model. The intercept, slope, r-squared and significance of the linear model is provided in the top left corner of the plot frame.

Figure 4. The range of possible relationships between outmigration survival and marine survival given known CWT release group SAR values for late-fall-run Chinook salmon. Each grey line represents the SAR value for a specific CWT release group, and the point along each line that represents the actual outmigration and marine survival for each release group is unknown, with the exception of the years for which acoustic tagging data outmigration survival estimates existed (black points, respective marine survival estimates with bootstrapped 95% confidence

intervals represented alongside). The black dashed line represents the median SAR for all CWT release groups. The black dotted line represents the location where outmigration and marine survival are equal (i.e., 1:1 line): if a point falls above this line, marine survival was higher than outmigration survival.

Figure 5. The relationship between freshwater outmigration survival (i.e., release to Chipps Island) for acoustic-tagged late-fall-run Chinook salmon release groups and their associated % SAR. The red lines represents 1000 linear models between 1000 parametric bootstrapped samples of these two variables, with the mean r-squared (and bootstrapped 95% confidence intervals) of these models represented in the top left corner of the plot frame.

Figure 6. The relationship between annual SAR and (1) flow during outmigration (a, d, g), (2) upwelling during the first spring at sea (b, e, h), and (3) MOCI during the first spring at sea (c, f, i), for late-fall-run Chinook salmon (a, b, c) winter-run Chinook salmon (d, e, f) and fall-run Chinook salmon (g, h, i). The solid lines in all panels represent the linear model for that relationship, as well as the r-squared value. Note that the r-squared values in plots d and g did not include the OY 2006 because it was determined to be an outlier (datapoint represented in red).

Figure 7. The relationship between the residuals from the flow versus SAR linear model and spring upwelling during the first spring at sea (a, c, e), and between the residuals from the flow versus SAR linear model and spring MOCI during the first spring at sea (b, d, f). The dotted lines in all panels represent the zero line for residuals. The points with the largest negative residual values have been labeled with their year of ocean entry. The closer points fall to the zero line, the better they were predicted by the flow model. The three different runs of Chinook salmon are represented: late-fall-run (a, b); winter-run (c, d) and fall-run (e, f).

Figure 8. The influence of (1) flow during outmigration and spring upwelling during the first year at sea on SAR (a), and (2) flow during outmigration and spring MOCI during the first year at sea on SAR (b). Logit-scale SAR values have been standardized; yellow colors represent low SAR values, and blue colors represent high SAR values. Empty symbols represent the location of actual data that were interpolated across; size of these symbols increase proportionally with standardized SAR values. Solid black symbols represent conditions experienced by cohorts for which SAR values are not yet available, spanning OY 2014-2017. Square symbols represent late-fall-run Chinook salmon, circle symbols are for fall-run Chinook salmon, and triangle symbols are for winter-run Chinook salmon (no point exists for OY 2015 fall-run because no CNFH salmon were released in the river that year).

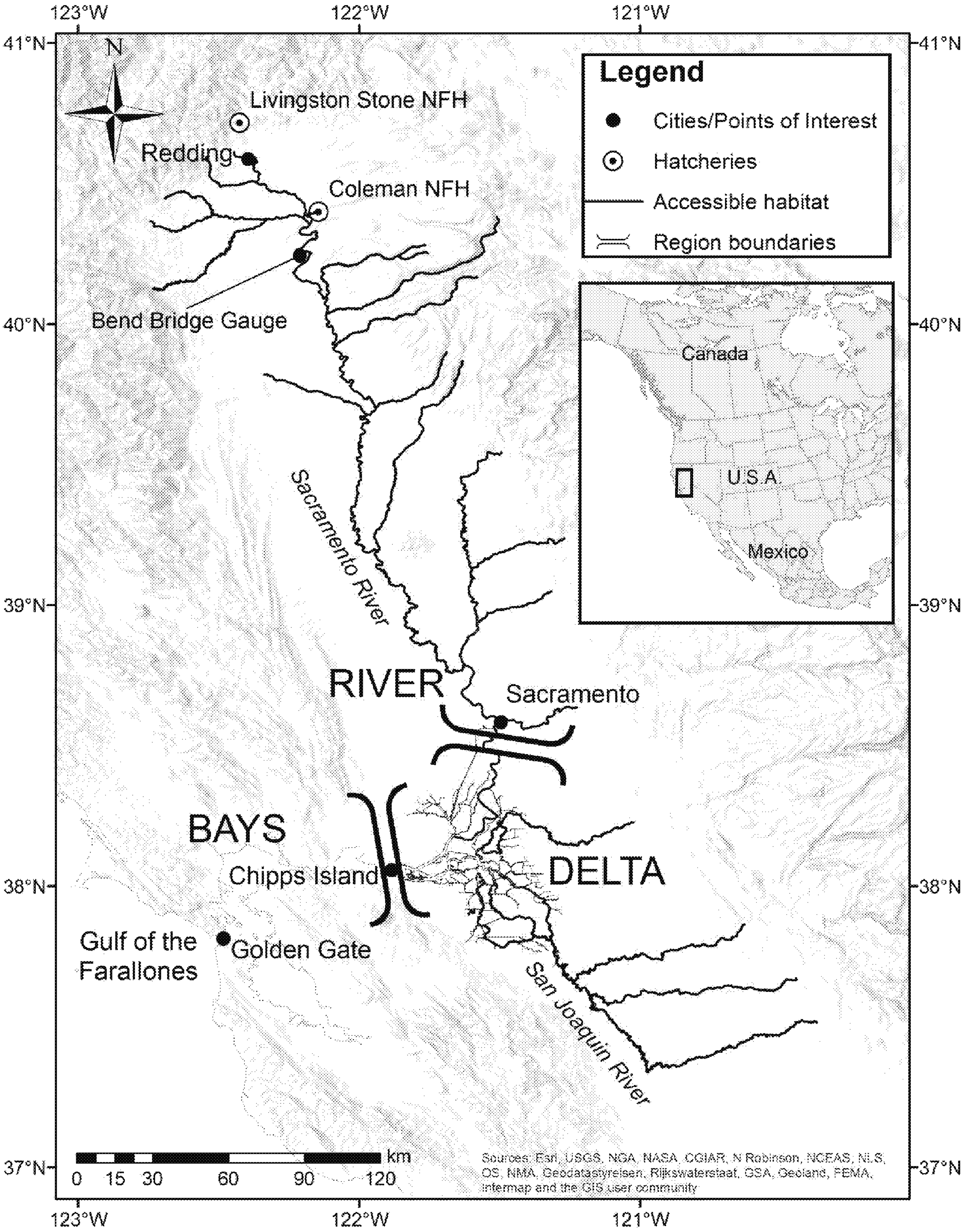
123°W
122°W
121°W
41°N
40°N
39°N
38°N
37°N
N
Livingston Stone NFH
Redding
Coleman NFH
Bend Bridge Gauge
Sacramento River
RIVER
Sacramento
BAYS
Chipps Island
DELTA
Gulf of the Farallones
Golden Gate
San Joaquin River
Legend
● Cities/Points of Interest
⊙ Hatcheries
Accessible habitat
Region boundaries
Canada
U.S.A.
Mexico
0 15 30 60 90 120 km
Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

Figure 1.

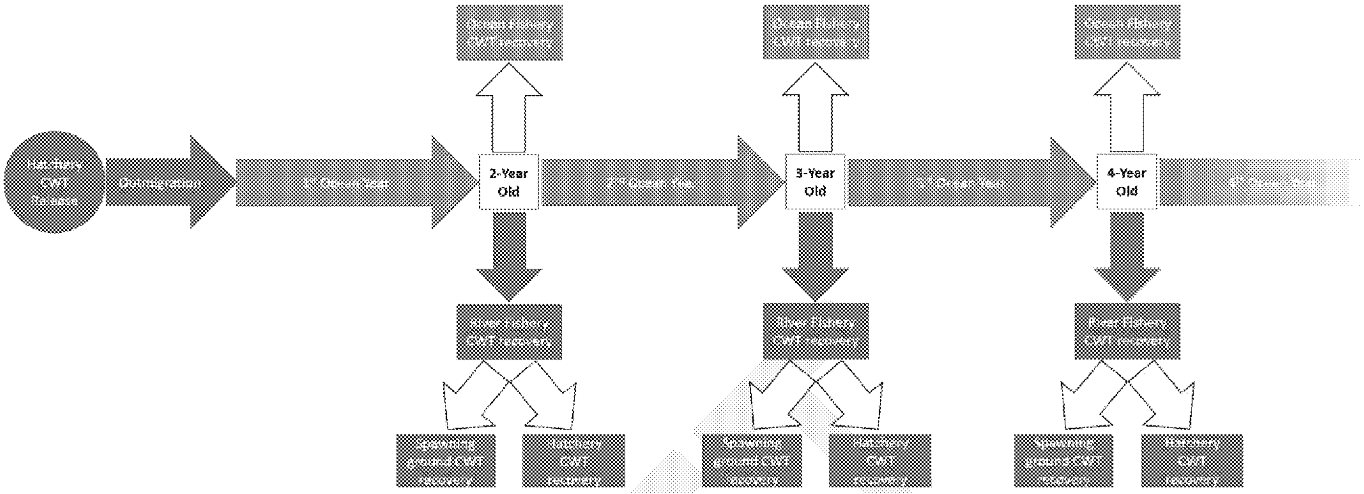
Hatchery CWT Release
Outmigration
1st Ocean Year
2-Year Old
Ocean Fishery CWT recovery
River Fishery CWT recovery
Spawning ground CWT recovery
Hatchery CWT recovery
2nd Ocean Yea
3-Year Old
Ocean Fishery CWT recovery
River Fishery CWT recovery
Spawning ground CWT recovery
Hatchery CWT recovery
3rd Ocean Year
4-Year Old
Ocean Fishery CWT recovery
River Fishery CWT recovery
Spawning ground CWT recovery
Hatchery CWT recovery
4th Ocean Year

Figure 2.

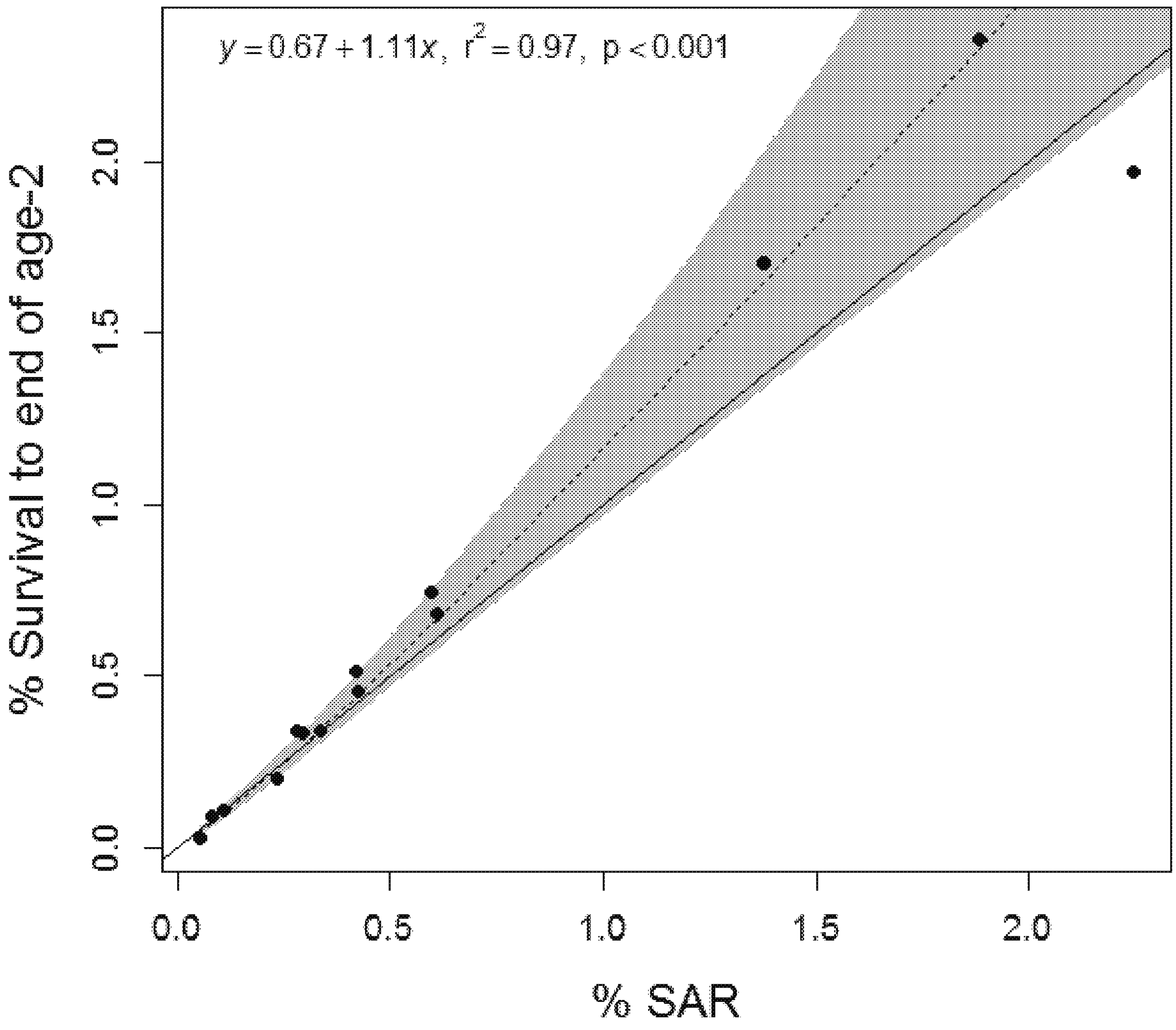
$y = 0.67 + 1.11x,\ r^2 = 0.97,\ p < 0.001$
% Survival to end of age-2
0.0
0.5
1.0
1.5
2.0
% SAR
0.0
0.5
1.0
1.5
2.0

Figure 3.

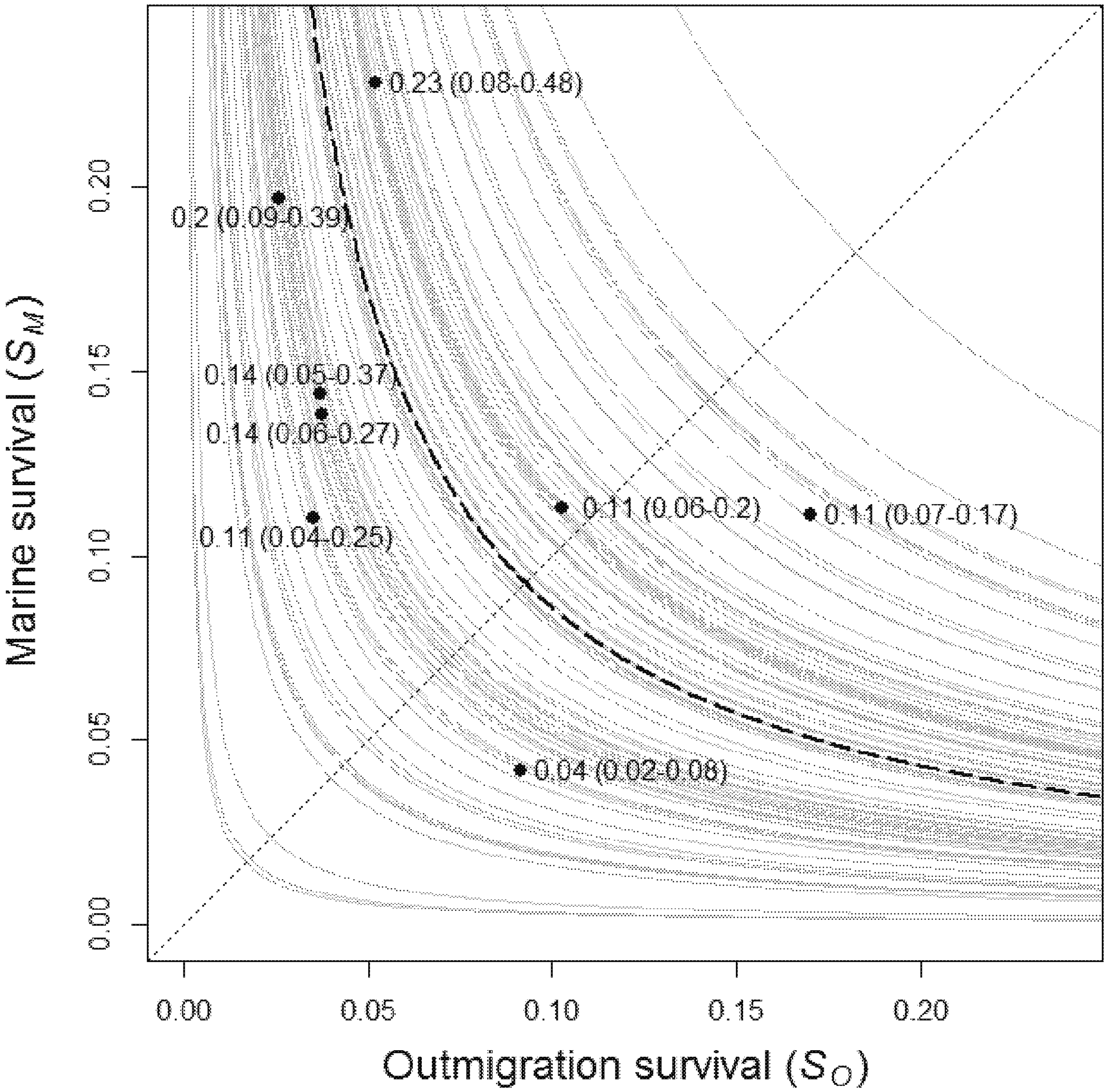
0.23 (0.08-0.48)
0.2 (0.09-0.39)
0.14 (0.05-0.37)
0.14 (0.06-0.27)
0.11 (0.04-0.25)
0.11 (0.06-0.2)
0.11 (0.07-0.17)
0.04 (0.02-0.08)
Marine survival (S_M)
0.00
0.05
0.10
0.15
0.20
Outmigration survival (S_O)
0.00
0.05
0.10
0.15
0.20

Figure 4.

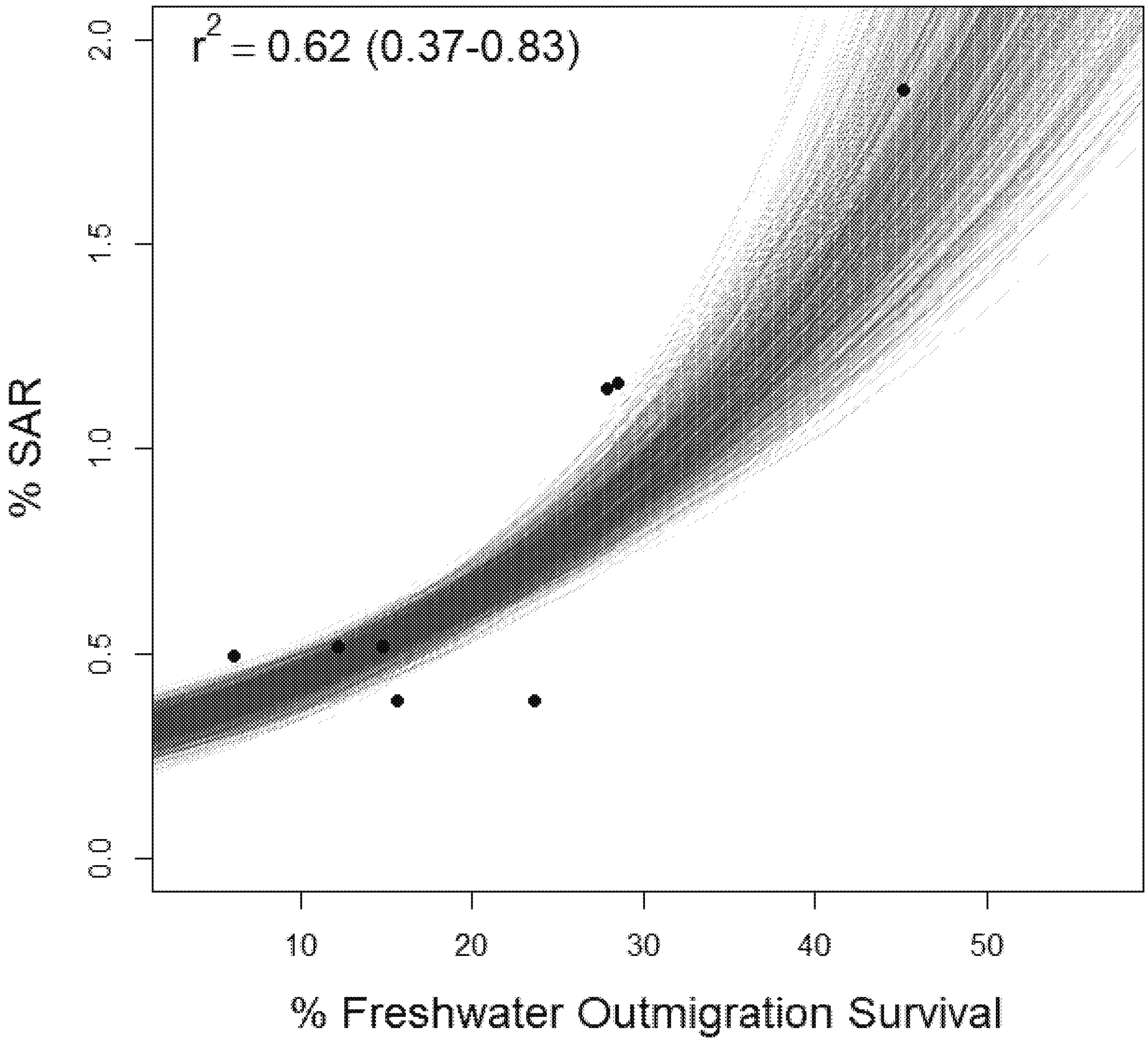
$r^2 = 0.62$ (0.37-0.83)
% SAR
0.0
0.5
1.0
1.5
2.0
10
20
30
40
50
% Freshwater Outmigration Survival

Figure 5.

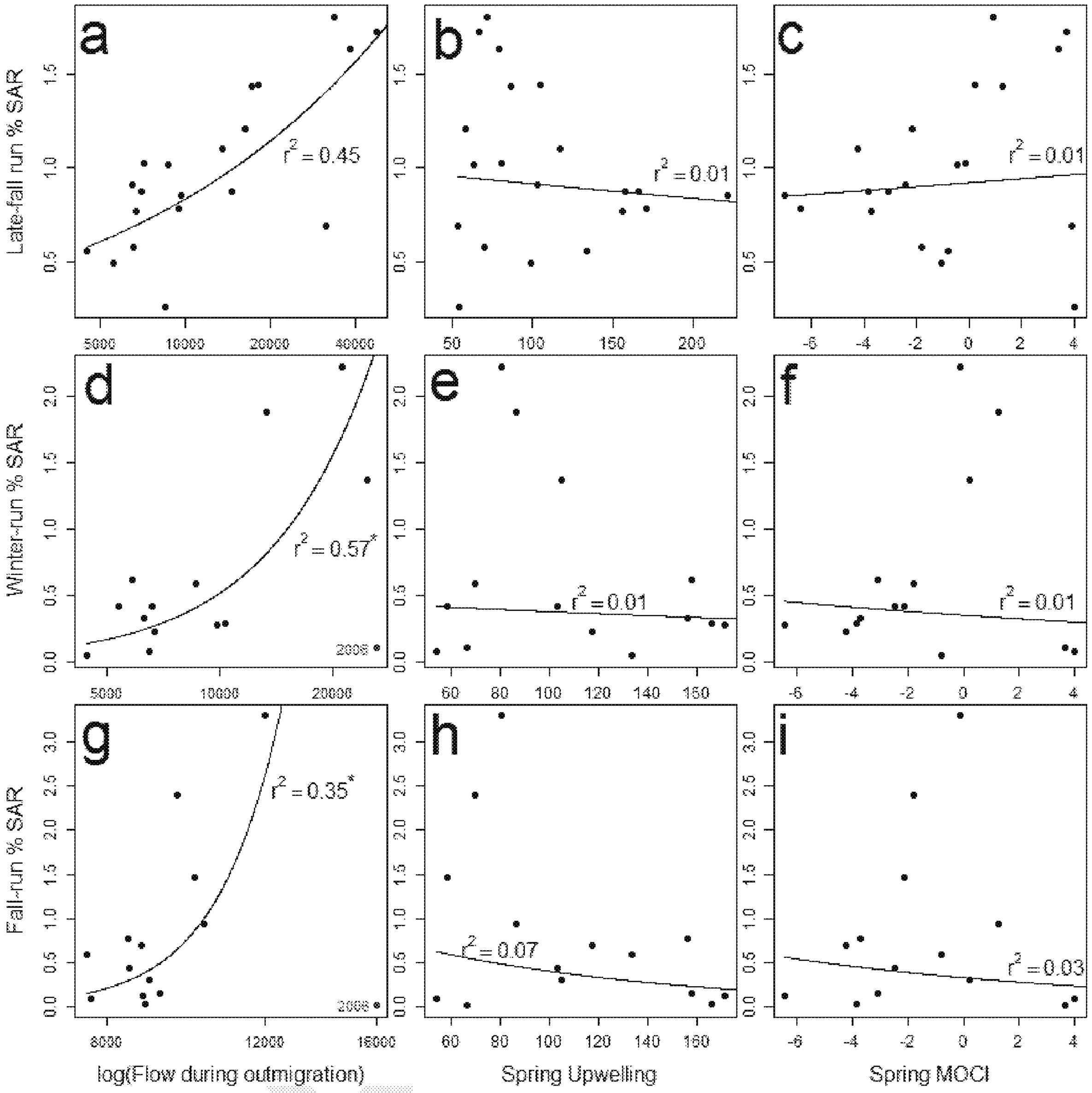
a
b
c
d
e
f
g
h
i
Late-fall run % SAR
Winter-run % SAR
Fall-run % SAR
r² = 0.45
r² = 0.01
r² = 0.01
r² = 0.57*
r² = 0.01
r² = 0.01
r² = 0.35*
r² = 0.07
r² = 0.03
2006
2006
5000
10000
20000
40000
50
100
150
200
-6
-4
-2
0
2
4
8000
12000
16000
60
80
100
120
140
160
0.5
1.0
1.5
2.0
2.5
3.0
log(Flow during outmigration)
Spring Upwelling
Spring MOCI

Figure 6.

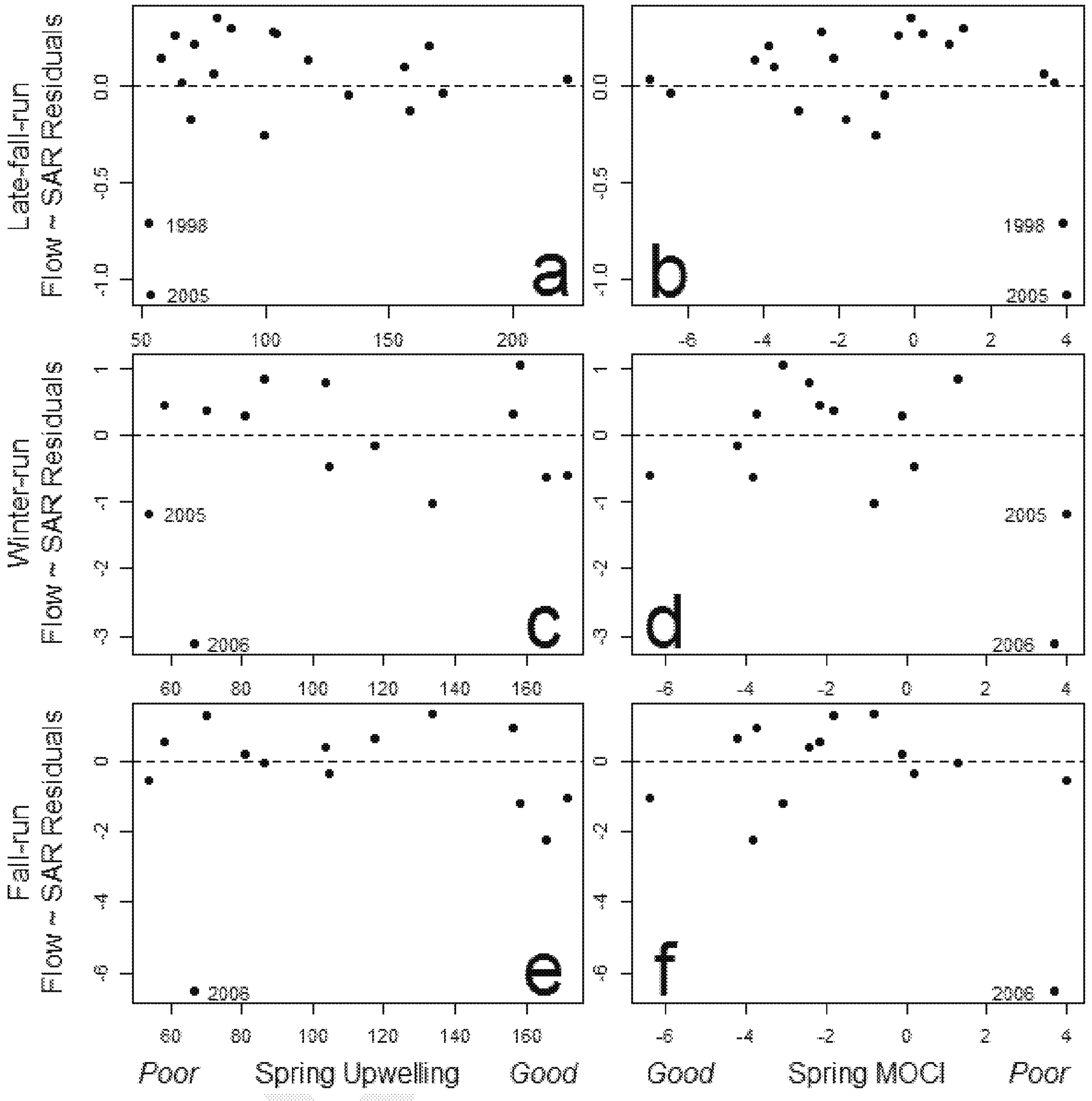
Late-fall-run
Flow ~ SAR Residuals
Winter-run
Flow ~ SAR Residuals
Fall-run
Flow ~ SAR Residuals
1998
2005
2006
a
b
c
d
e
f
0.0
-0.5
-1.0
1
0
-1
-2
-3
-2
-4
-6
50
100
150
200
60
80
100
120
140
160
-6
-4
-2
0
2
4
Poor
Spring Upwelling
Good
Good
Spring MOCI
Poor

Figure 7.

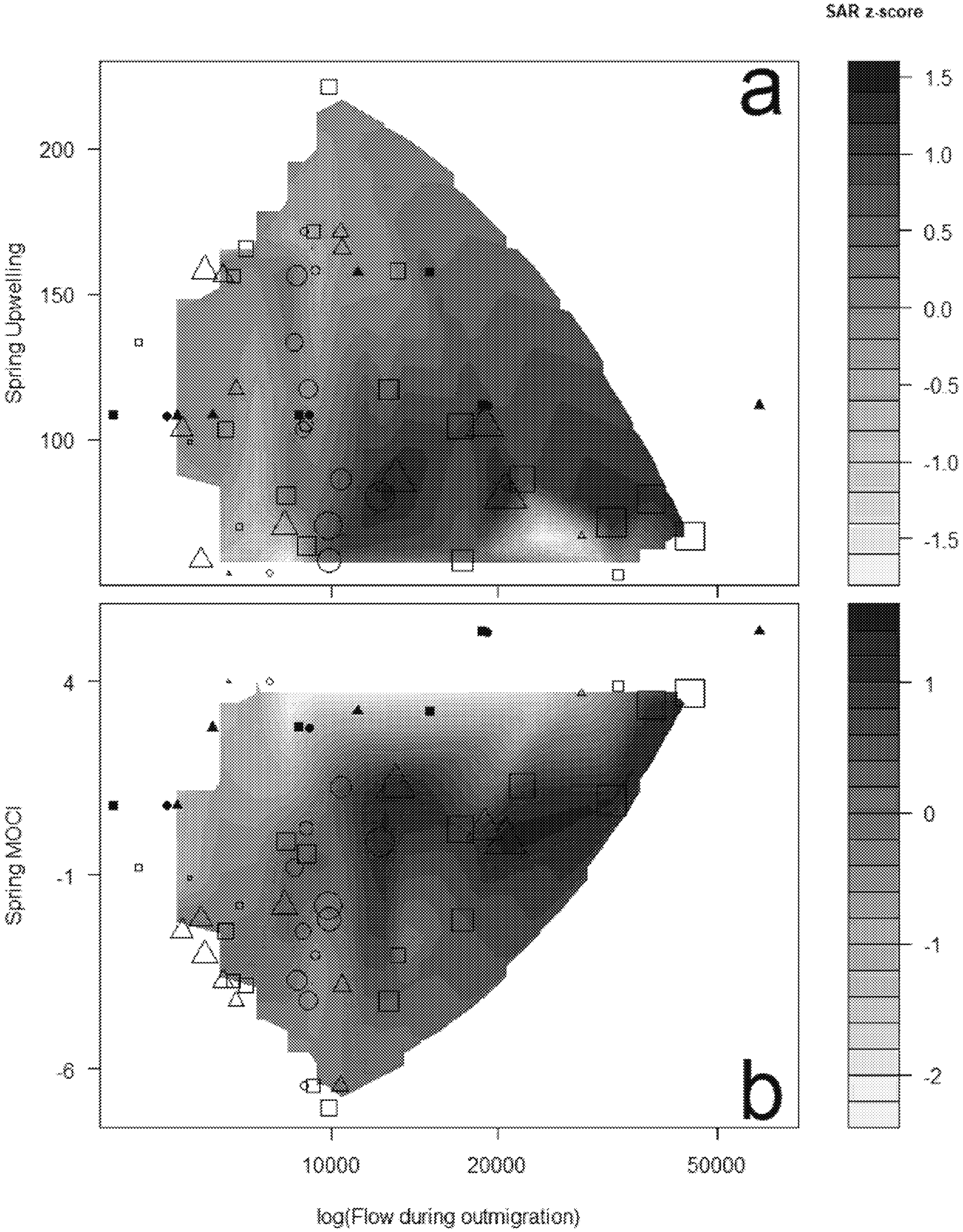
SAR z-score
a
Spring Upwelling
200
150
100
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
b
Spring MOCI
4
-1
-6
1
0
-1
-2
10000
20000
50000
log(Flow during outmigration)

Figure 8.

From: Chris Fitzer [CFitzer@esassoc.com]
Sent: 10/10/2019 7:41:51 AM
To: Rob Thomson [rthomson@sitesproject.org]
CC: Alicia Forsythe [aforsythe@sitesproject.org]; Tull, Robert/SAC [Robert.Tull@jacobs.com]; Leaf, Rob/SAC [Rob.Leaf@jacobs.com]; Thad Bettner (tbettner@gcid.net) [tbettner@gcid.net]; Jim Lecky (jim.Lecky@icf.com) [jim.Lecky@icf.com]; John Spranza (john.spranza@hdrinc.com) [john.spranza@hdrinc.com]
Subject: RE: Sites - CDFW 60-Process -- Next Steps

Thanks, Rob.
The intent of my earlier email was to try to identify the basis/rationale for the WaterFix criteria (from a review of the CDFW ITP and NMFS BO), to better understand CDFW's stance and also inform potential refinements to criteria that could be negotiated as part of Sites.
I generally agree with all your other points. I would add that I do think we should understand how Sites would work with a future WaterFix/Delta Conveyance project, as it could be the basis for a future regulatory condition in the Delta (i.e., senior to Sites diversions).
Thanks,

Chris Fitzer
Fisheries Program Manager

ESA | Environmental Science Associates
Celebrating 50 Years of Work that Matters!

From: Rob Thomson <rthomson@sitesproject.org>
Sent: Thursday, October 10, 2019 4:49 AM
To: Chris Fitzer <CFitzer@esassoc.com>
Cc: Alicia Forsythe <aforsythe@sitesproject.org>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>
Subject: Re: Sites - CDFW 60-Process -- Next Steps

Thanks Chris. Just a few points

The WaterFix criteria are a basis for the negotiation with CDFW. In my opinion, which may be corrected by counsel, they are NOT an appropriate regulatory baseline for this project

The WaterFix criteria are permit conditions for that project and not overall regulations to be applied to all other operations (such as EBMUD diversions at Freeport), water rights, and all other issues associated with the Sacramento River and the Delta

The WaterFix criteria are also not 'reasonably foreseeable' by normally applied NEPA/CEQA criteria. Those criteria may be the basis for a future, unfunded, un-approved project call Delta Conveyance but that project does not have a published NOP/NOI, Draft EIR/EIS, or any other environmental analysis. Delta Conveyance is still developing the project description

Failing to acknowledge and negotiation from the published science behind the WaterFix criteria would also be an error. Likewise, failing to negotiate from the anticipated upstream benefits would also be an error on our part

Blindly accepting the statistically based, broad-scale model results (like OBAN) has not been immediately accepted by CDFW, but seemed to be more readily accepted by NMFS. Likewise, completely accepting the regression (correlation, ANOVA) based model results (as any of the tagged fish studies) should not be fully accepted as 'the truth' by the Sites Project (or the VA parties). It's all part of the negotiation of a project permit - not the regulatory baseline

Now that we are not driven to an expedited schedule, I suggest we use the time available to
1) consider the results and uncertainty behind the available science with the regulatory agencies
2) in concert with Reclamation and DWR, develop the affordable and operable project description
3) discuss 1 and 2 with the NGOs
4) prepare permit applications consistent with the first 3 items

BTW - items 1-4 are consistent with the process we attempted to implement (on the expedited schedule, but not very successfully for various reasons) in late 2016

Hope to work with you later in October

Rob Thomson
805-689-5854

On Oct 4, 2019, at 1:37 AM, Chris Fitzer <CFitzer@esassoc.com> wrote:

Hi Ali, all,
Attached is a brief document summarizing rationale for CA WaterFix criteria for Sac River at Freeport and NDOI.
Talk to you tomorrow,
Chris

Chris Fitzer
Fisheries Program Manager

ESA | Environmental Science Associates
Celebrating 50 Years of Work that Matters!

From: Alicia Forsythe <aforsythe@sitesproject.org>
Sent: Wednesday, October 2, 2019 7:35 AM
To: Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Rob Thomson <rthomson@sitesproject.org>
Subject: Sites - CDFW 60-Process -- Next Steps

Hi all – Sorry for the delay in getting this out. Below are the action items that I recorded at our Monday afternoon call. Please let me know if I missed anything.

I'd like to have a follow up call on Friday to check in on progress. Would 9 to 10 AM Friday morning works for folks?

Action Items:
1. Ali to call Kristal on Environmental Criteria
2. Thad to talk with Chuck on WaterFix Freeport and NDOI Criteria
3. Jim and Chris to look at WaterFix Freeport and NDOI Criteria to refresh memories on logic behind it so we can continue to think about if / how might modify
4. Jacobs to complete CALSIM and DSM2 modeling (if possible) on scenarios below from CDFW meeting – with WaterFix scaled Freeport and NDOI
   a. 8,000 CFS Wilkins Slough Bypass (including Freeport and NDOI)
   b. Percentage Based Diversion, 8K Wilkin Apr/May (incl. FP, NDOI)
5. Ali to schedule a follow up call for Friday

6. Group to think about other options / opportunities for Friday's discussions

Thanks all!

Ali

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 |
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<Freeport and NDOI rationale.docx>

Sent: 10/14/2019 7:44:44 AM
To: Obegi, Doug [dobegi@nrdc.org]; jon@baykeeper.org; Barry Nelson (barry@westernwaterstrategies.com) [barry@westernwaterstrategies.com]; greg@bayecotarium.org; Chris Shutes [blancapaloma@msn.com]; Kim Delfino [KDelfino@defenders.org]; Zwillinger, Rachel (Mail Contact) [rzwillinger@defenders.org]
CC: Monique Briard (Monique.Briard@icf.com) [Monique.Briard@icf.com]; Jim Watson [jwatson@sitesproject.org]; Jim Lecky (jim.Lecky@icf.com) [jim.Lecky@icf.com]; Tull, Robert/SAC [Robert.Tull@jacobs.com]; Kevin Spesert [kspesert@sitesproject.org]; John Spranza (john.spranza@hdrinc.com) [john.spranza@hdrinc.com]; Grimaldo, Lenny [Lenny.Grimaldo@icf.com]
Subject: RE: Sites Meeting with NRDC, et al. - Follow-up
Attachments: 20190813 Sites NRDC Mtg_Final.pdf

Thank you Doug and Chris for the refinements to the Action Items. Below is an updated list. I've also attached a PDF of the presentation. (Note that the PDF file changes templates and page numbers part way thru. We actually used 2 presentations that day and I combined them both into one PDF file. The actual PPT files are too large to send via email.)

And thanks Doug for the four papers!

Action Items:

1. Schedule a terrestrial focused meeting to focus on (among other topics): (1) terrestrial species and habitat impacts; (2) impacts to refuge and refuge easements; (3) impacts to giant garter snake; and (4) mitigation strategy for terrestrial species.
2. Look at possibility of releasing the Daily Model. (Note, I talked with the team on this late last week. We are scheduling an internal Sites discussion on the possibility of releasing the model along with the timing and what documentation should accompany a release. I should have more info on this in about 2 weeks.)
3. Can Sites add the Yolo Bypass to the floodplain modeling effort? (Note, we are already planning on adding the Sutter Bypass to the floodplain modeling effort, but had not planned on including Yolo. So this action item is focused on Yolo as we had not originally planned on including the Yolo Bypass in the floodplain modeling effort. Sutter will be included.)
4. Continue discussion on effects to salmonid survival throughout the Sacramento River and Delta. Check Freedman (spelling?) 2019 paper and a recent paper from the Stanislaus River – Doug sent over papers on 10/9.
5. Email copy of PPT presentation from meeting. – Completed with this email.
6.

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From: Obegi, Doug <dobegi@nrdc.org>
Sent: Wednesday, October 9, 2019 5:25 PM
To: Alicia Forsythe <aforsythe@sitesproject.org>; jon@baykeeper.org; Barry Nelson (barry@westernwaterstrategies.com) <barry@westernwaterstrategies.com>; greg@bayecotarium.org; Chris Shutes <blancapaloma@msn.com>; Kim Delfino <KDelfino@defenders.org>; Zwillinger, Rachel (Mail Contact) <rzwillinger@defenders.org>
Cc: Monique Briard (Monique.Briard@icf.com) <Monique.Briard@icf.com>; Jim Watson <jwatson@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Kevin Spesert <kspesert@sitesproject.org>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Grimaldo, Lenny

<Lenny.Grimaldo@icf.com>
Subject: RE: Sites Meeting with NRDC, et al. - Follow-up

Hi Ali,

Thank you for following up on our prior meeting, and I agree that it makes sense to hold off on scheduling another meeting at this point.

Attached are 3 papers from 2018 and 2019 regarding Sacramento River flows and salmon survival, including the Friedman et al 2019 paper I mentioned in the meeting, as well as the Zeug et al 2014 paper showing a very strong correlation between Stanislaus River flows and juvenile salmon survival.

In terms of the action items from the meeting, I thought that item #4 was not limited to impacts downstream of Freeport (see Perry et al 2018), but instead was regarding impacts in the Sacramento River below the intakes as well as further downstream. I believe item #3 was broader floodplain inundation modeling, not limited to Yolo Bypass (?). In addition, would you please email us a copy of the PPT presentation that was shared at the meeting with us? That was on my list of action items from the meeting.

Thanks,
-d

From: Alicia Forsythe <aforsythe@sitesproject.org>
Sent: Wednesday, October 9, 2019 4:16 PM
To: jon@baykeeper.org; Barry Nelson (barry@westernwaterstrategies.com) <barry@westernwaterstrategies.com>; greg@bayecotarium.org; Obegi, Doug <dobegi@nrdc.org>; Chris Shutes <blancapaloma@msn.com>; Kim Delfino <KDelfino@defenders.org>; Zwillinger, Rachel (Mail Contact) <rzwillinger@defenders.org>
Cc: Monique Briard (Monique.Briard@icf.com) <Monique.Briard@icf.com>; Jim Watson <jwatson@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Kevin Spesert <kspesert@sitesproject.org>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Grimaldo, Lenny <Lenny.Grimaldo@icf.com>
Subject: Sites Meeting with NRDC, et al. - Follow-up

All –

I sincerely apologize for the long delay in circling back to you all after our meeting. I know how important it is to follow up on our commitments and time just got away from me on this. My apologies.

I wanted to say thank you very much for taking the time to chat with us. Below are the action items that I recorded. Please let me know if I missed any or have mischaracterized any.

I also wanted to share that we continue with our discussions with CDFW on operating criteria (diversion criteria). We have also had an initial re-engagement meeting with NMFS and plan to meet with them and CDFW together in the coming weeks. NMFS is agreeable to us entering into a contract with them to run their winter-run life-cycle model for the Project. We are starting to work on the contracting effort and are hopeful that this wraps up about the time we have revised operational criteria for NMFS to run – likely late this calendar year.

We have also continued to work on refinements to the Project to right-size it for the current participants. We continue to consider a number of right-sizing actions, such as reducing the size of the reservoir along with no Delevan intake. Once the Authority identifies a preferred project, we will assess the changes and how best to move forward with the CEQA / NEPA compliance effort.

There is a lot in flux right now, so I'd like to hold off on meeting again. As we narrow down on a preferred project and new operations criteria, I would like to circle back and get your input on these. I am always happy to chat if you have questions or suggestions in the meantime.

Action Items:

1. Schedule a terrestrial focused meeting to focus on (among other topics): (1) terrestrial species and habitat impacts; (2) impacts to refuge and refuge easements; (3) impacts to giant garter snake; and (4) mitigation strategy for terrestrial species.
2. Look at possibility of releasing the Daily Model. (Note, I talked with the team on this late last week. We are scheduling an internal Sites discussion on the possibility of releasing the model along with the timing and what documentation should accompany a release. I should have more info on this in about 2 weeks.)
3. Can Sites add the Yolo Bypass to the floodplain modeling effort?
4. Continue discussion on effects to salmonid survival downstream of Freeport. Check Freedman (spelling?) 2019 paper and a recent paper from the Stanislaus River (Doug, I didn't catch the title of this one. Can you send it over or send the title?)

We will follow up on these action items in the coming weeks.

Please don't hesitate to contact me if you have any questions, thoughts or concerns on the Sites Project.

Ali

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NRDC & Team
Sites Project
Status and Updates
Meeting

August 13, 2019

Proposed Agenda

Purpose: Update on Sites Project Activities, Modeling Tools and Analysis

1. Introductions
2. Initial Remarks
3. General Sites Overview and Project Progression Post Draft EIR/S, WSIP, and Reclamation Feasibility Report
4. New Modeling Analysis and Tools
   a. Sacramento River
   b. Delta
5. Modeling Analysis and Tools Currently Under Development
   a. Water Quality/Temperature
   b. Others
6. Mitigation Brainstorming
7. Action Items and Next Steps

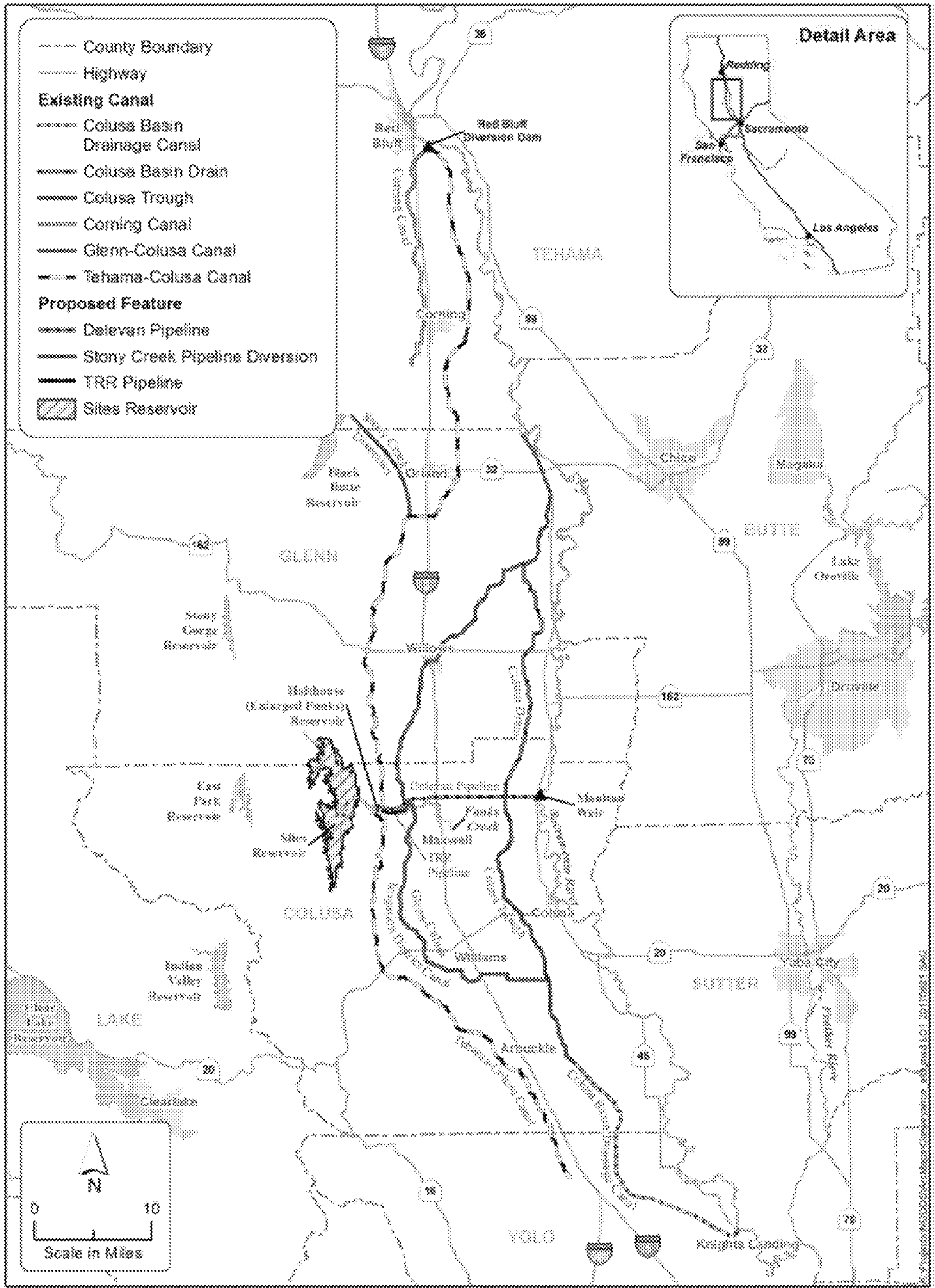
General Sites Overview

- New reservoir, regulating forebays, pipeline and Sacramento River diversion
  - 1.82 MAF storage
  - Two 300'+ earthen dams, 9 saddle dams
  - Two forebay regulating reservoirs connecting to existing irrigation canals
  - 14 miles of twin, 10' diameter pipelines and two pump/generation
  - New 2,000 cfs diversion/pumping facility

- Sustainable Surface Water Infrastructure Improvement
  - Benefits endangered species and refuges
  - Increases water supply in drier years
  - Reduces regional flooding
  - Increases recreation
  - Provides resiliency with future climate change

- Proposed by a local joint-powers authority. Participants throughout CA, Reclamation, State.

Regional Map



Sites

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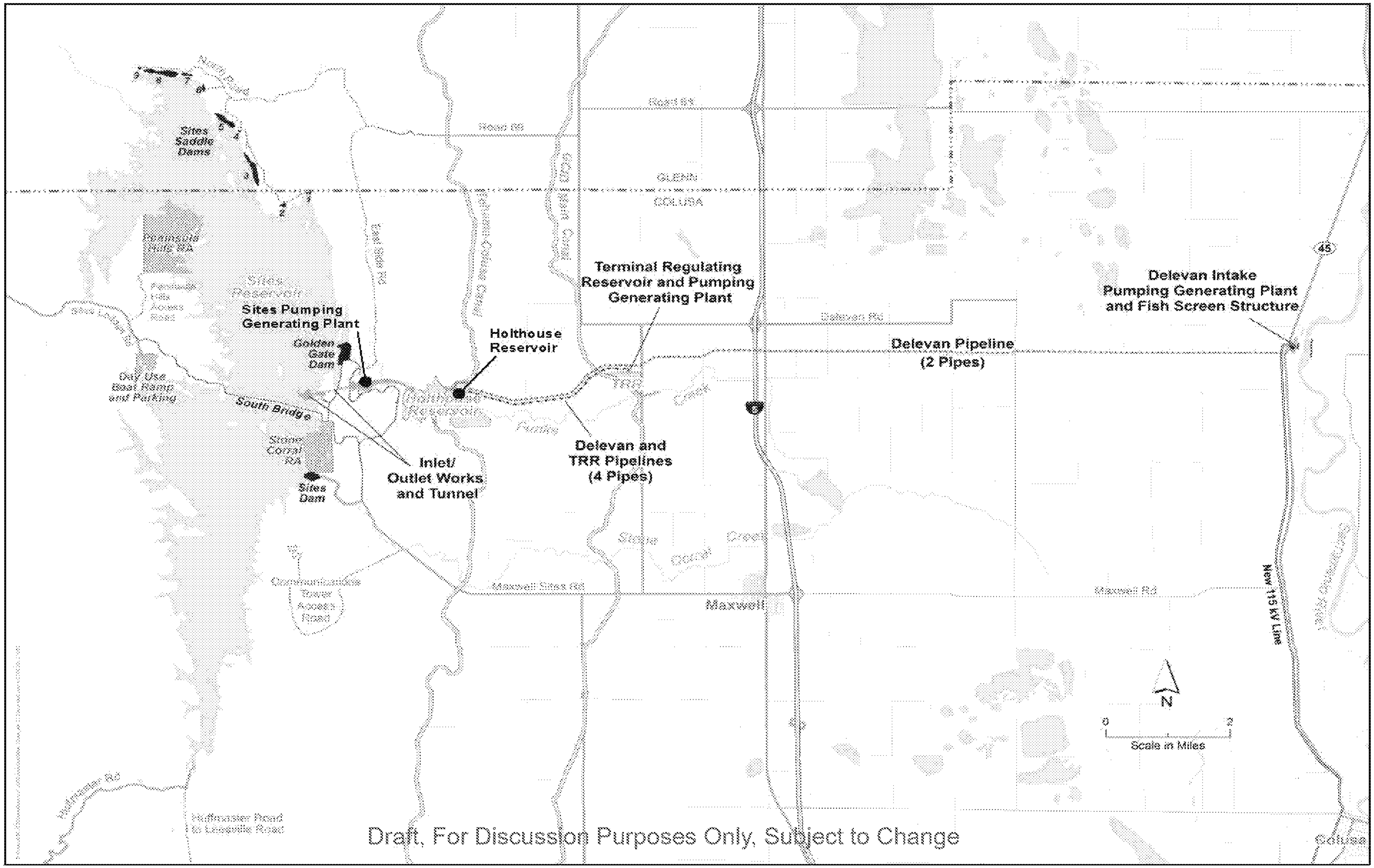
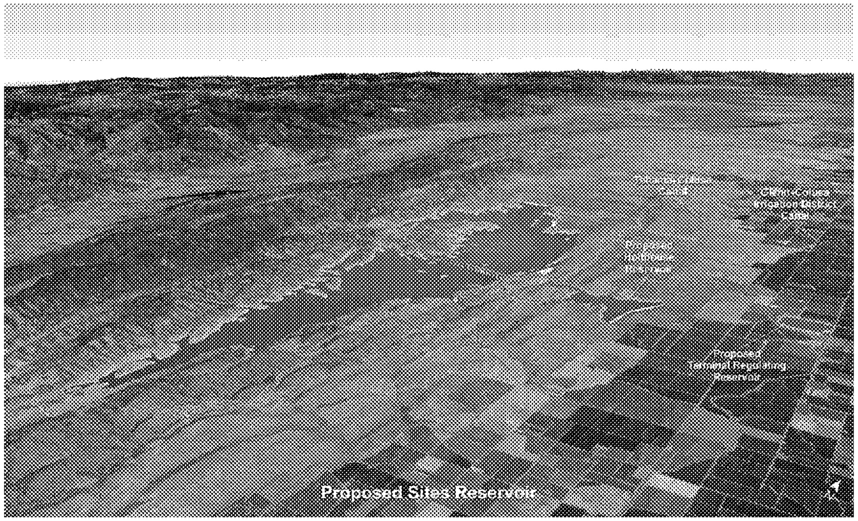
Project Facilities



Project Objectives

- <u>Primary</u>:
  - Water Supply and Water Supply Reliability
  - Anadromous Fish Benefits
  - Operational Flexibility
  - Pelagic Estuarine Fish Food
  - Level 4 Refuge Supply
- <u>Secondary:</u>
  - Hydropower
  - Recreation
  - Flood Damage Reduction



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Preliminary Results - Supply

- Water Supply and Water Supply Reliability
  - Captures and stores storm-related, unregulated Sacramento River discharge
  - Provides additional supply in drier years
- CVP Operational Flexibility

Preliminary Results - Environment

- Anadromous Fish Benefits
  - Increases summer/fall cold water for juvenile winter-run chinook salmon
  - Provides additional flow stability in fall/early winter
- Pelagic Estuarine fish food
  - Provides later summer/fall flows carrying food for Delta smelt
- Level 4 Refuge Supply
  - Provides additional incremental Level 4 supplies

Project Progression: Post Draft EIR/S, WSIP, Reclamation Feasibility Report

- Cost and Financing
  a. Regulating reservoir: Replace Holthouse with Fletcher
  b. Advance pumped-storage hydropower & grid interconnection
  c. Improve estimates of potential mitigation
  d. Construction sequencing to allow initial operations sooner
  e. Secured USDA Rural Development conditional construction loan
- Engagement
  a. Landowners & community
  b. State and federal agencies
  c. Water industry
  d. Elected officials

Project Progression: Post Draft EIR/S, WSIP, Reclamation Feasibility Report

- Ongoing work with Reclamation
  a. Feasibility report is still a work in progress
  b. Role as investor (a federal asset) or just a participant (cooperative operations)
- Adding capacity
  a. 9 "service area providers" & senior-level advisors
  b. New environmental manager: Ali Forsythe
- Developing tools to aid in response to comments
  a. Daily model for upper Sacramento River
  b. Analyze effects to off-channel habitat areas
  c. 2-D reservoir temperature model

Sites Appeal to Public Benefit Ratio Review: Salmonid Benefits

February 23, 2018

Table A.1-2: Annual Production Results from SALMOD for the Four Sacramento River Chinook Salmon Species

Species	2015		2030		2070	
	Without Sites	Sites Increment	Without Sites	Sites Increment	Without Sites	Sites Increment
Winter	1912017	63594 (3.3%)	1996967	68269 (3.4%)	1818783	109752 (6.0%)
Spring	429539	8767 (2.0%)	437648	4147 (0.9%)	357458	17520 (4.9%)
Fall	17977800	172775 (1.0%)	17896789	226190 (1.3%)	15507733	623264 (4.0%)
Late-Fall	2877697	32864 (1.1%)	2892264	20442 (0.7%)	2744016	95108 (3.5%)
All Runs	23197052	277999 (1.2%)	23223668	319047 (1.4%)	20427989	845644 (4.1%)

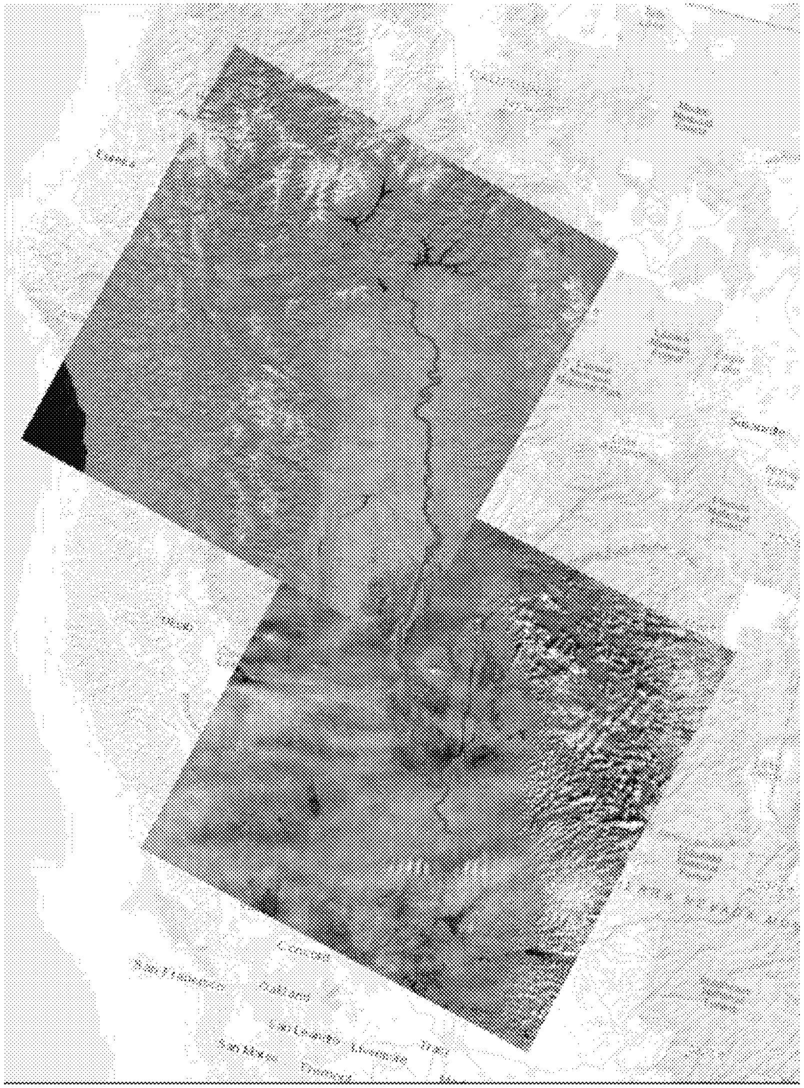
Table A.1-3: Incremental Changes in Dry and Critical Years' Average Annual Production Results from SALMOD with the Sites Reservoir (Water year types are based on D-1641 40-30-30 Sacramento River Index)

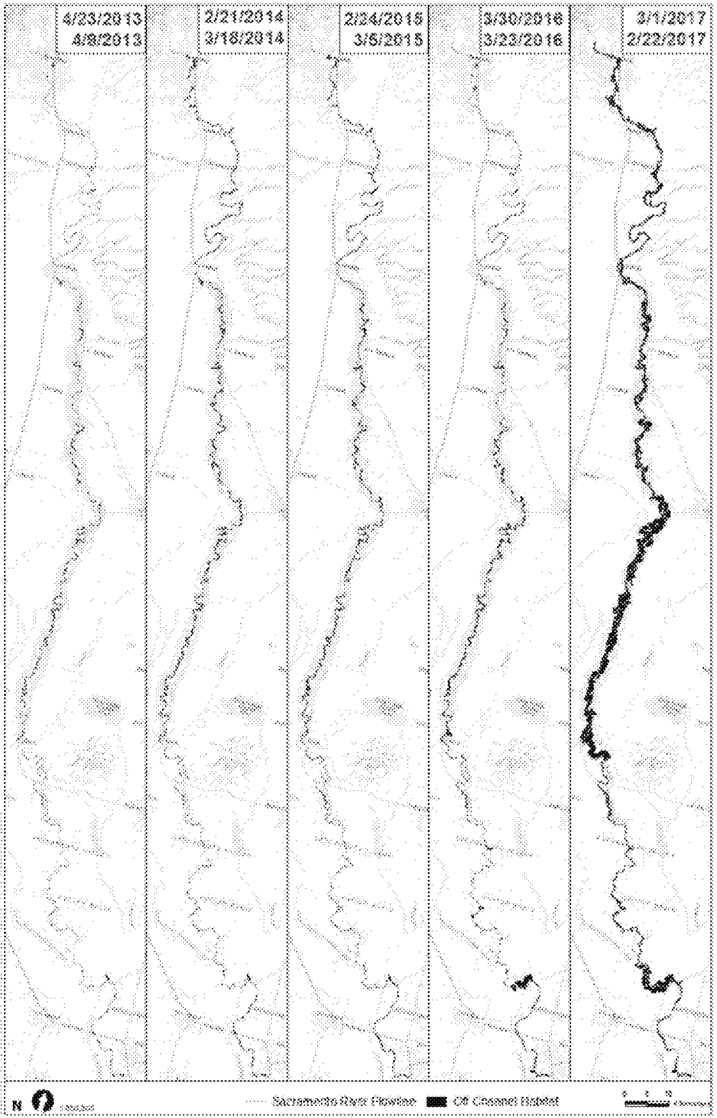
Species	Sites Increment in Dry Years			Sites Increment in Critical Years		
	2015	2030	2070	2015	2030	2070
Winter	2.3%	2.6%	6.1%	23.3%	14.8%	66.7%
Spring	1.3%	0.3%	6.3%	20.2%	6.0%	64.8%
Fall	1.6%	0.6%	7.0%	3.9%	3.1%	11.3%
Late-Fall	2.3%	1.2%	1.6%	4.4%	1.6%	21.2%

Additional Considerations for Salmonids

- Temperature/flow Stabilization Benefit
- In River Survival
  - Wilkins Slough Criterion
  - Refine OBAN analysis
  - Pulse flow protections for all pulses
  - Proportional river flow criteria
- Floodplain Benefits
  - Inclusion of Freemont notch and bypass protections
  - Maintain spill frequency and duration
- Integration of Voluntary Agreement measures
- Development of real time operations measures
- Development of minimization and mitigation measures

New Modeling Analysis and Tools – Off-channel Habitat





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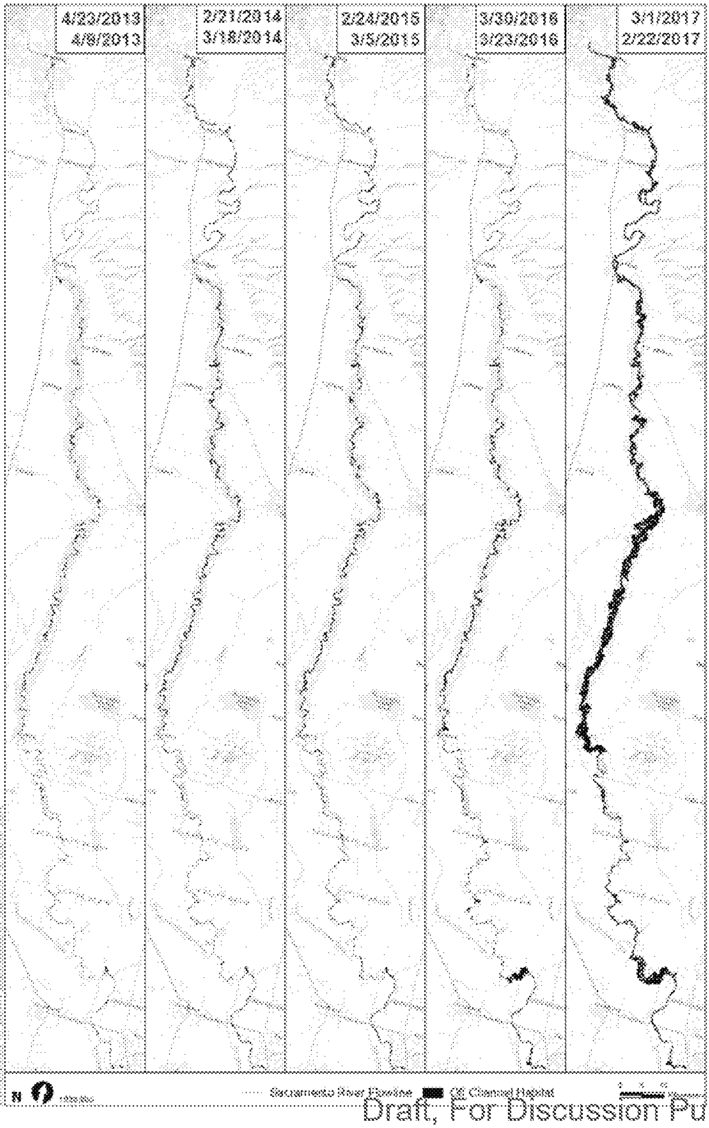
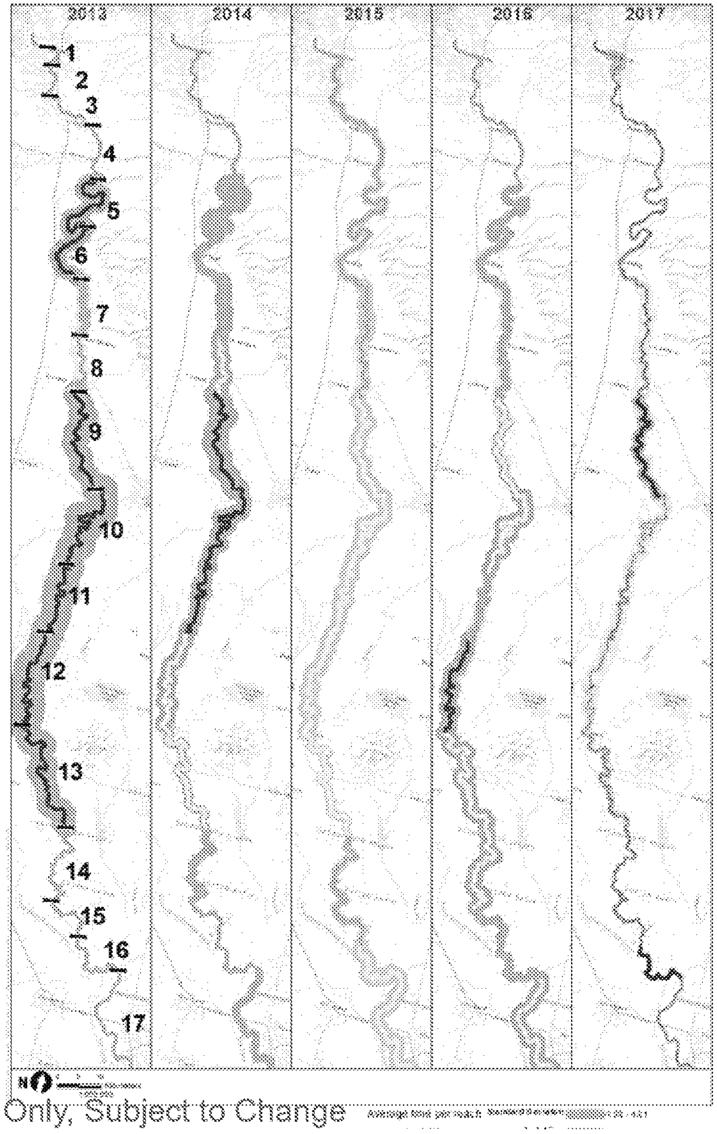
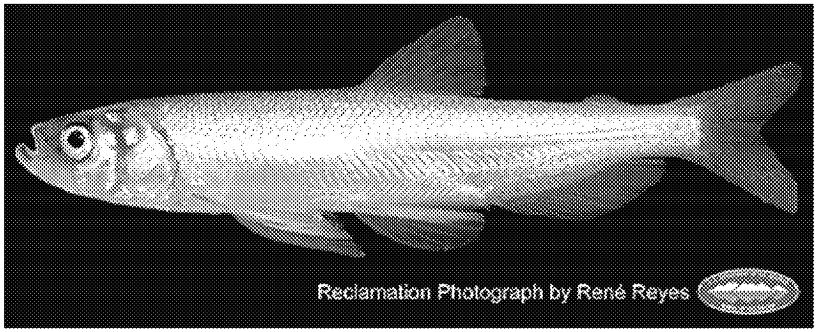
New Modeling Analysis and Tools – Off-channel Habitat





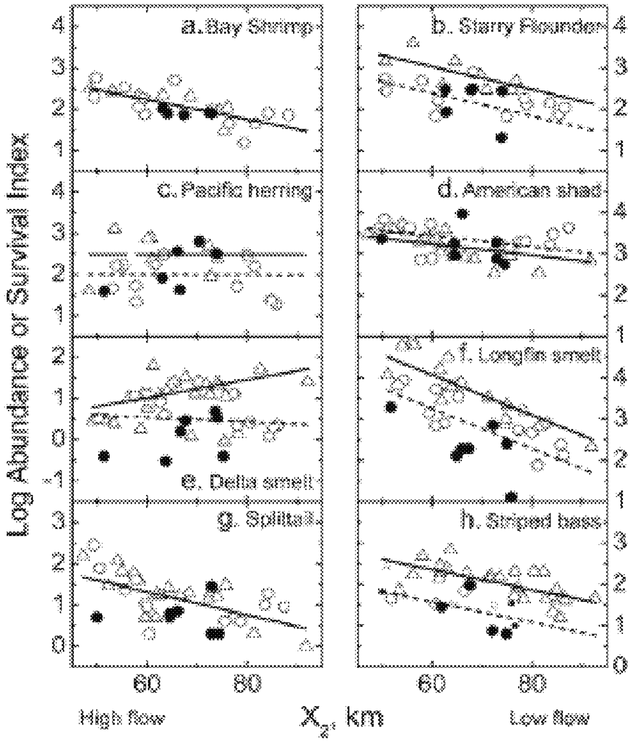
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered


Reclamation Photograph by René Reyes

1. Spring Outflow-Fall Abundance Relationship (Kimmerer et al. 2009)
2. Direct and Indirect Entrainment Effects (Grimaldo et al. 2009)

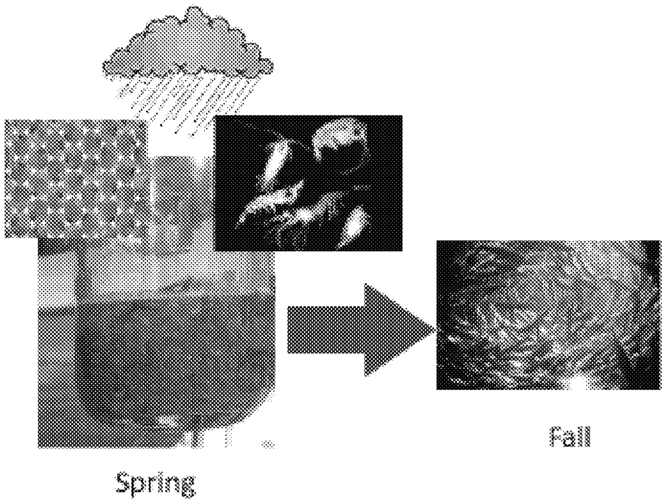
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

1. Winter-spring outflow-Fall Abundance Relationship



Kimmerer et al. 2009

Underlying conceptual model



Potential mechanisms underlying survival

-Improved survival and growth

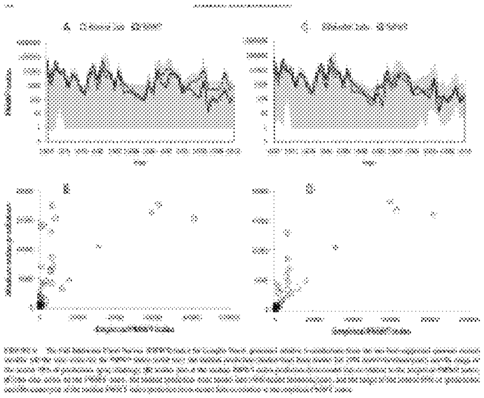
-Reduced entrainment

-Improved habitat and rearing conditions (e.g., reduced predation, improved retention, etc)

New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

1. Winter-spring outflow-Fall Abundance Relationship Effects to be Considered

- Examine changes in X_2 during winter-spring period (Jan-Jun) per Kimmerer et al. 2009
- Examined differences in stock-recruit relationships using Nobriga-Rosenfield approach



Nobriga and Rosenfield (2016)

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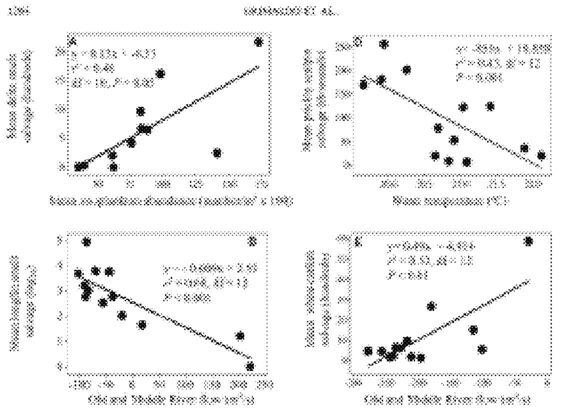
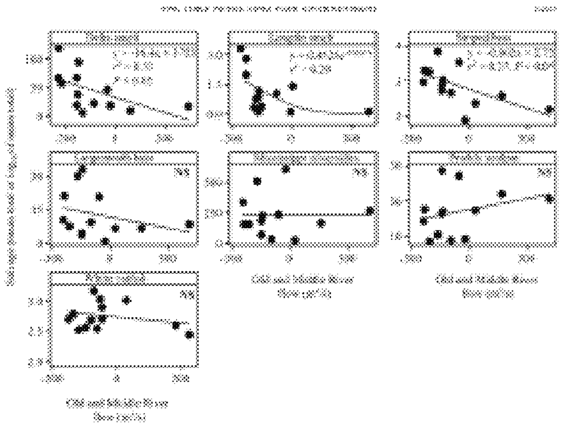
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

2. Direct and indirect entrainment effects





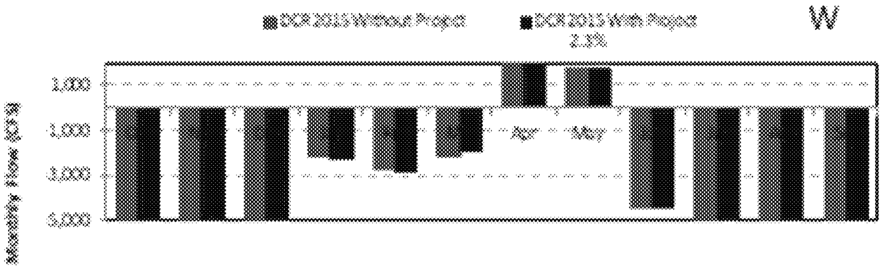
Potential approaches to examine Longfin Smelt entrainment Effects

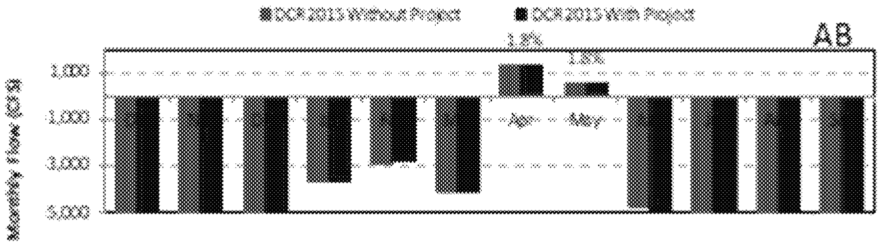
Direct entrainment (% difference in OMR and Qwest)
-Larvae (PTM, Jan-Mar)
-Juveniles (Existing salvage relationships, Mar-May)
-Adults ((Existing salvage relationships, Dec-Feb)

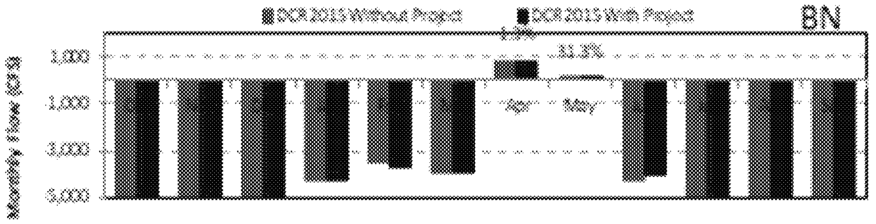
Indirect entrainment (% difference in X_2)
-Larvae (Jan-Feb)
-Juveniles (Mar-May)
-Adults (Dec-Feb)

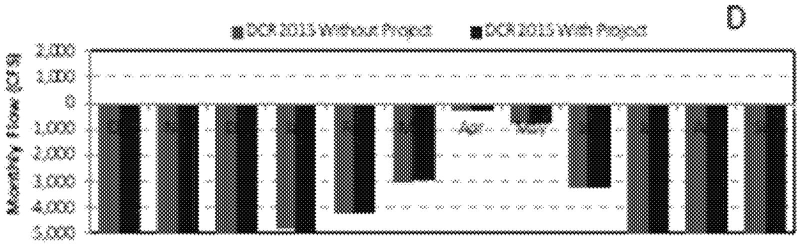
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

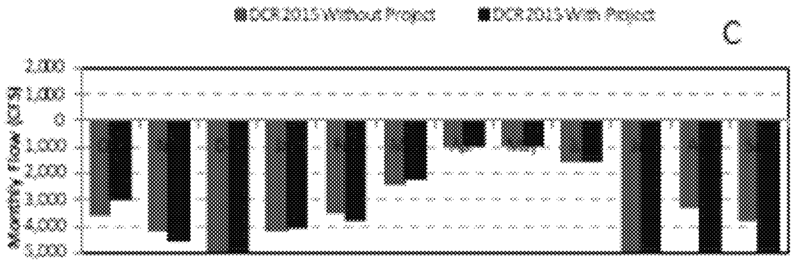
OMR Modeling Output





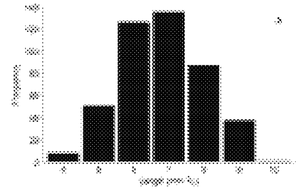


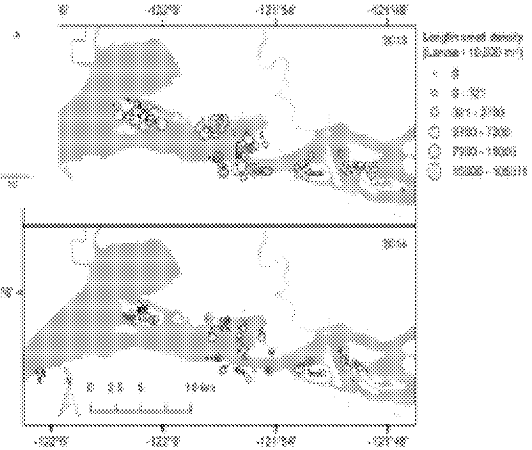




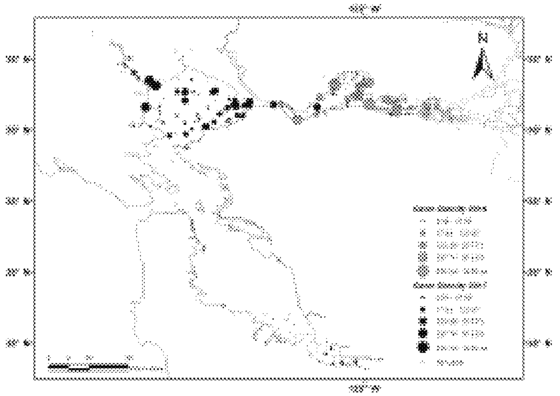
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

Results to be put in context of the new science and existing FWS/NMFS BiOps





Grimaldo et al. 2017



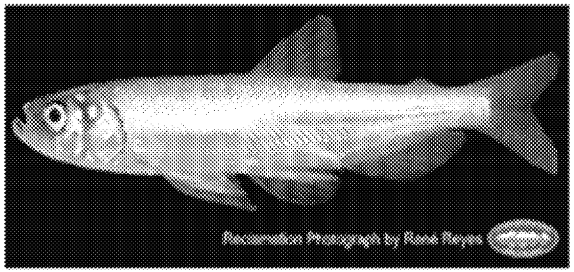
Grimaldo et al. in prep

- Fish are hatching and rearing in tidal marshes and shallow habitats
- Fish are hatching and rearing in SF Bay habitats and tributaries
- Real-time work groups and OMR protections

Water Year and Sacramento Valley WY Index Classification	Combined SWP and CVP Expanded Salvage (number of individuals)
2009 Dry	0
2010 Below Normal	0
2011 Wet	4 (1 individual)
2012 Below Normal	0
2013 Dry	8 (2 individuals)
2014 Critical	0
2015 Critical	0
2016 Below Normal	0
2017 Wet	0

New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

Delta Smelt

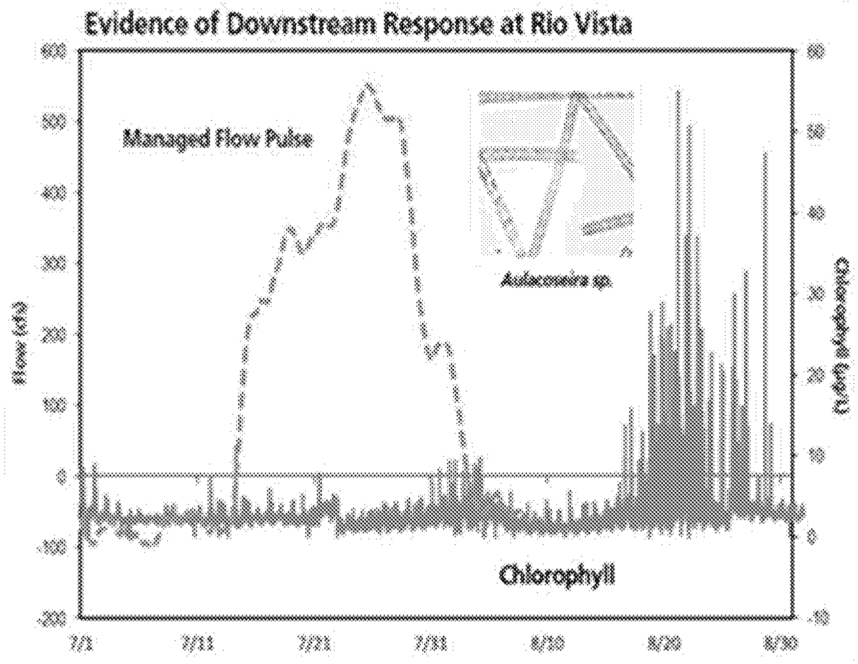


Effects Considered

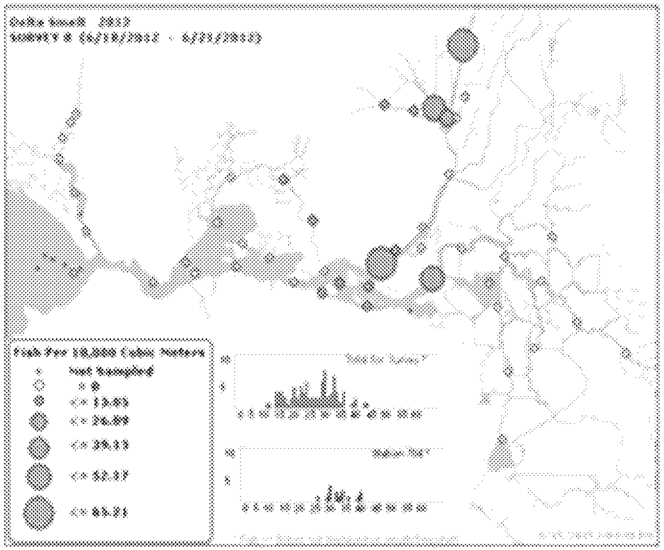
1. North Delta lower trophic food enhancements
2. Fall X_2
3. Direct and indirect entrainment effects (Grimaldo et al. 2009)

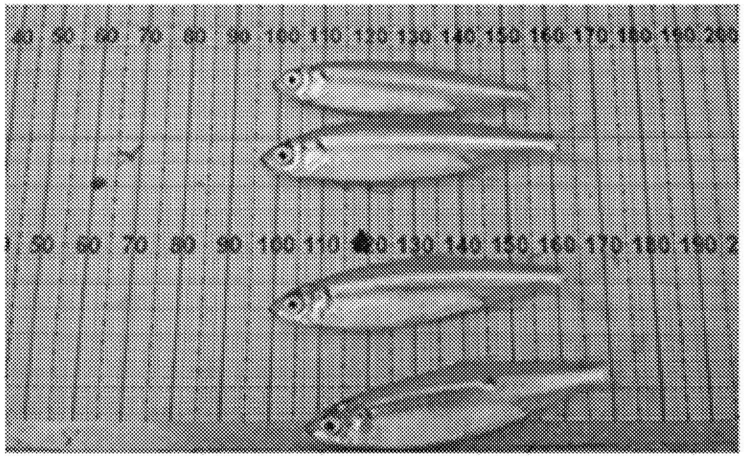
New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

North Delta lower trophic food enhancements



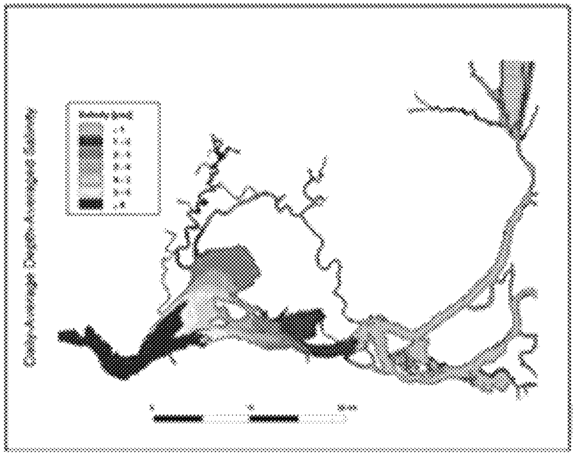
Source: California Natural Resources Agency (2017).





New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

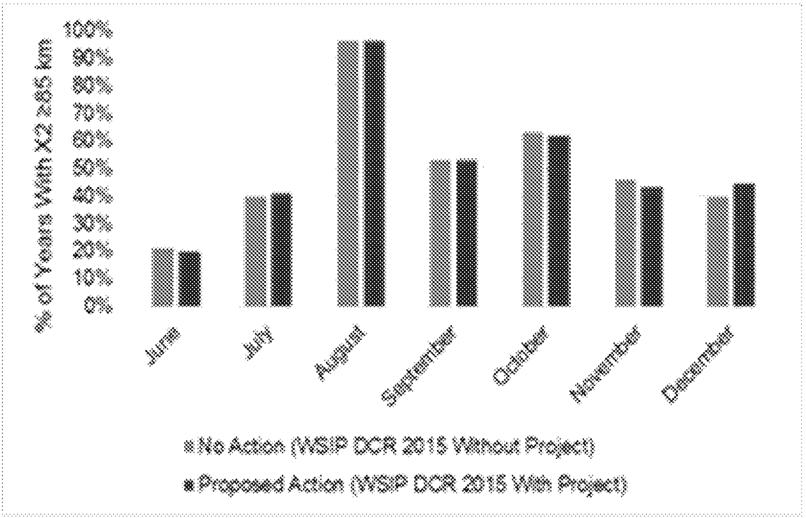
Fall X_2



Source: MacWilliams et al. 2011

Potential approaches to examine Delta Smelt entrainment fall habitat effects

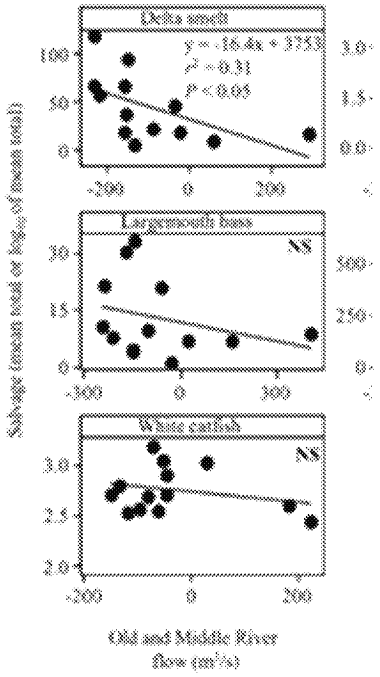
Changes in X_2(% difference)
-Examine differences in X_2 during W and AB falls (Sept-Nov)



Source: Table SQ-01-b [p.92, p.94] in Appendix C, *Modeling Results Compendium From Sites Project's Water Storage Investment Program (WSIP) Application.*

New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

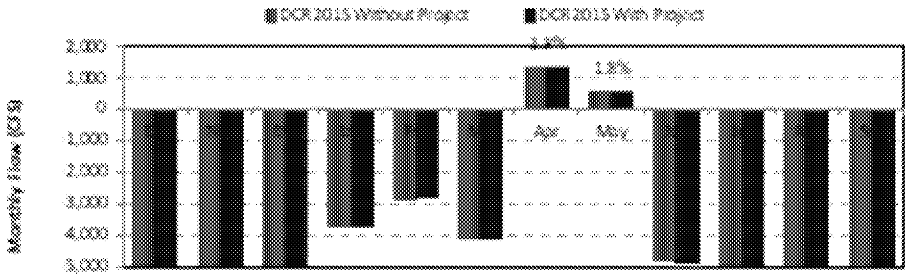
Direct and indirect entrainment effects (Grimaldo et al. 2009)



Grimaldo et al. 2009

Potential approaches to examine Delta Smelt entrainment effects

Direct entrainment (% difference in OMR)
-Juveniles (Existing salvage relationships, Apr-May)
-Adults ((Existing salvage relationships, Jan-Mar)

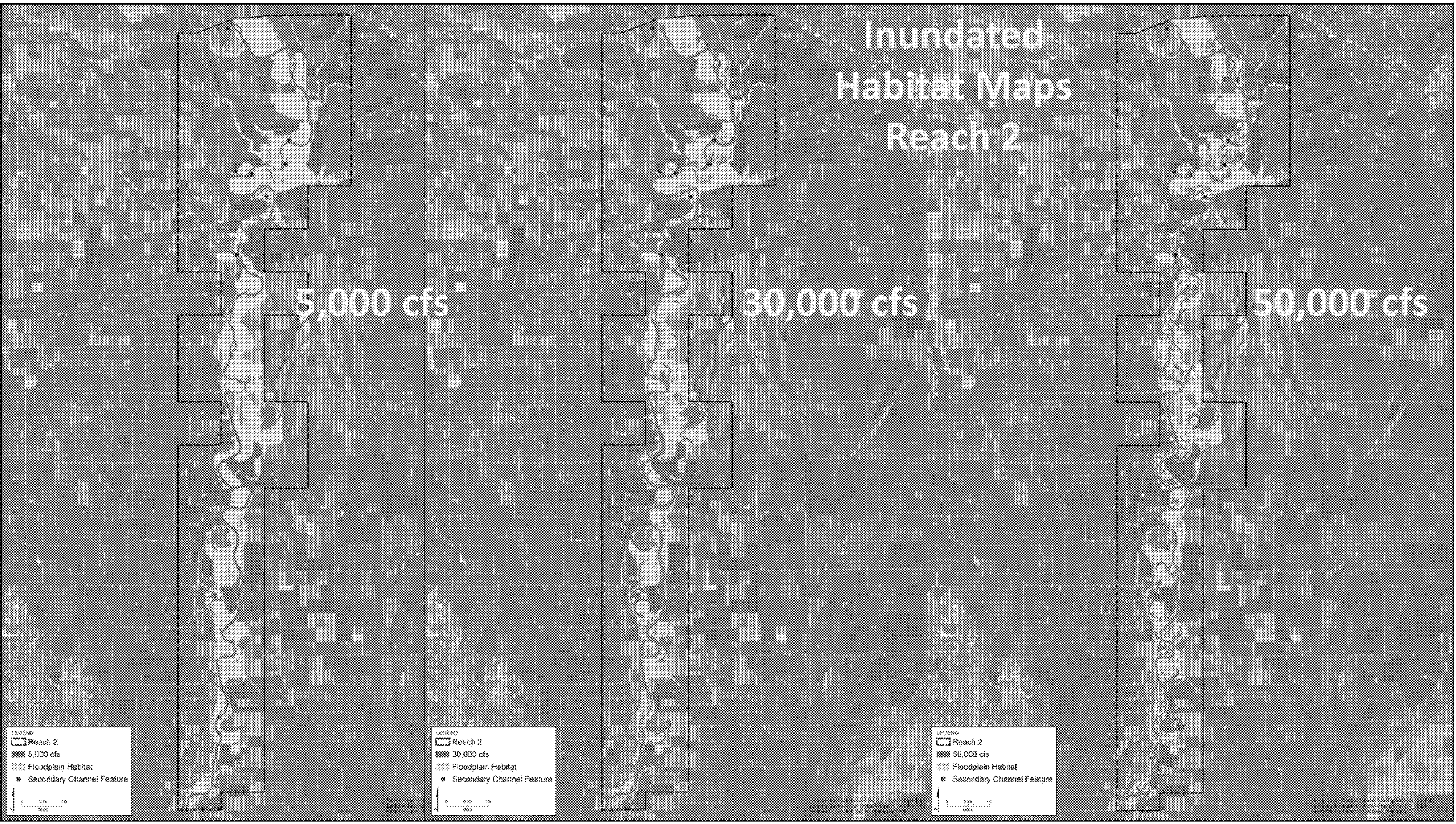


Modeling Analysis and Tools Currently Under Development

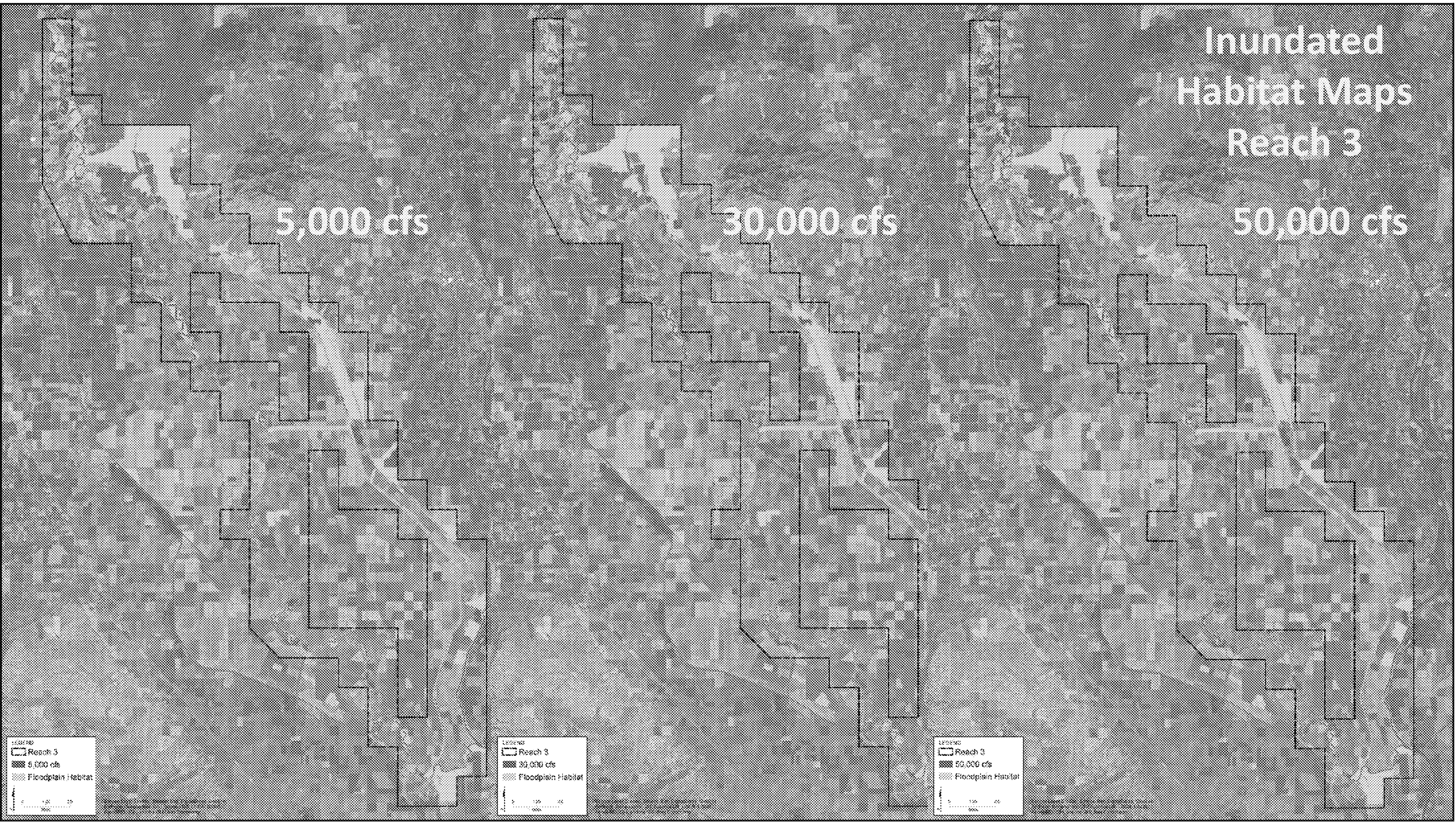
- Sacramento River Flood Plain and Off-channel Habitat Analyses
  - Identify current floodplain habitat availability along 3 reaches of the Sacramento River
  - Determine floodplain habitat characteristics that may be preferential for salmonid rearing and holding
  - Provide qualitative assessments of potential for habitat improvement opportunities associated with Sites

Transition to Rob Tull's Slides

Inundated Habitat Maps Reach 2

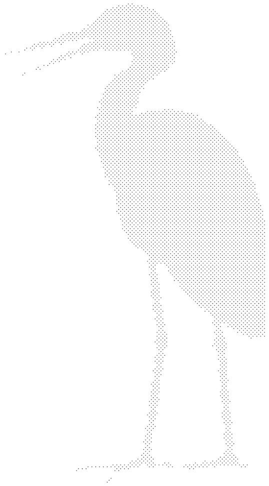


Inundated Habitat Maps Reach 3




River Flow
5,000 cfs
15,000 cfs
25,000 cfs
35,000 cfs
50,000 cfs
Habitat
Annual Grassland
Bare Gravel and Sand
Marsh - non-tidal
Riparian Forest
Riparian Scrub
Seasonal Wetland
TNC 191.7R
TNC 191L
TNC 189R
TNC 189.5L
TNC_187.0R

Daily Modeling Evaluation of Sites Reservoir Operations

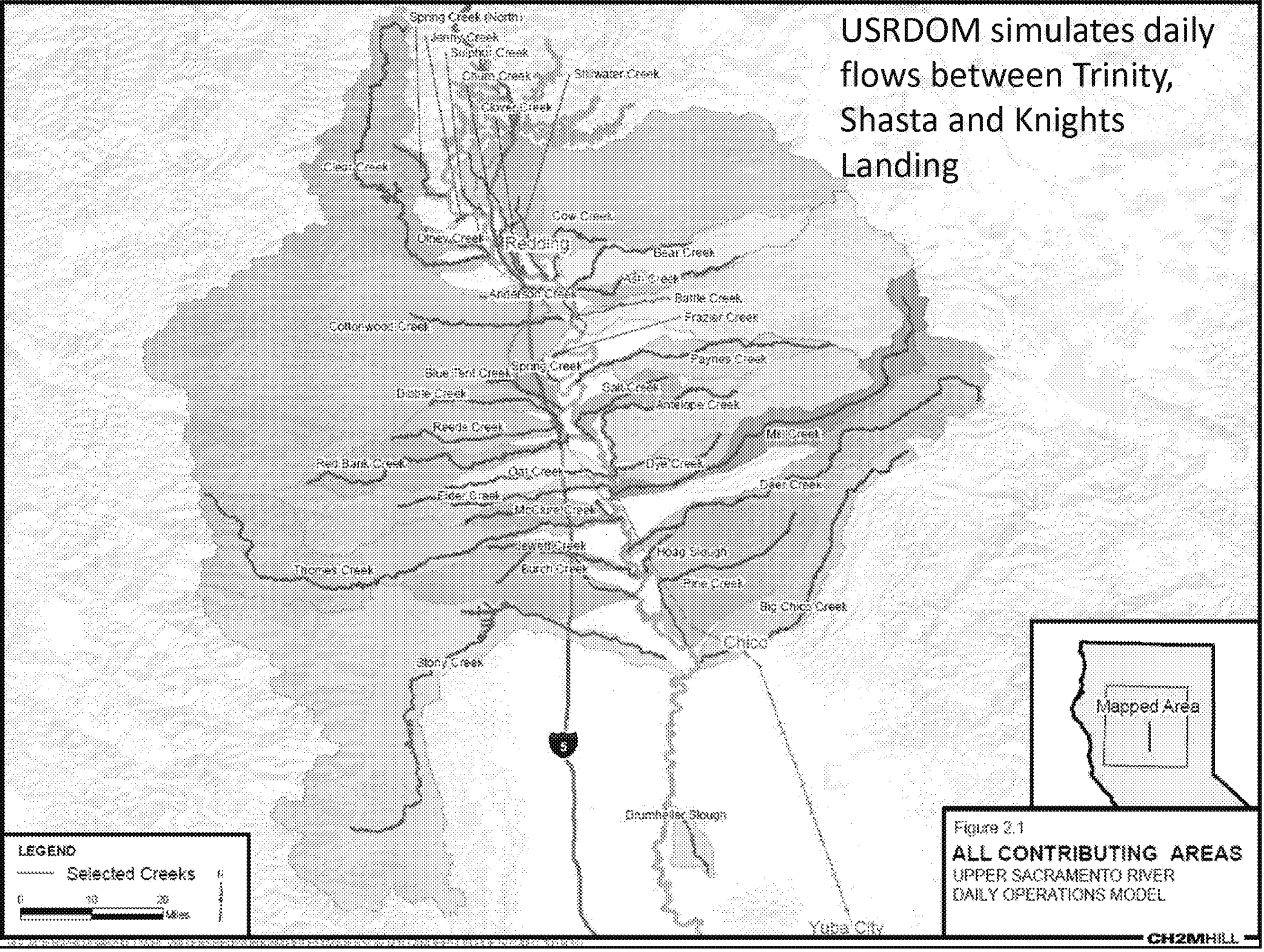


Daily Modeling for Sites Project

- A set of daily modeling tools has been developed to evaluate flow available for potential diversion to the proposed Sites Reservoir under a range of hydrologic conditions and operations criteria
- These tools can be used to:
  - Support further understanding of the interactions of Sites Project with flow conditions in the Sacramento River and Delta
  - Evaluate the affect of various flow regulations, facility constraints, and operation criteria on flow availability for the Sites Project

Daily Model - USRDOM

- Upper Sacramento River Daily Operations Model
- Simulates daily flow conditions in the Upper Sacramento River based on operations specified by CalSim II
- Can be used to evaluate Sites Reservoir benefits
- Original hydrology dataset included 82-year period from WY 1922 to WY 2003 using available historical gage records and operations data

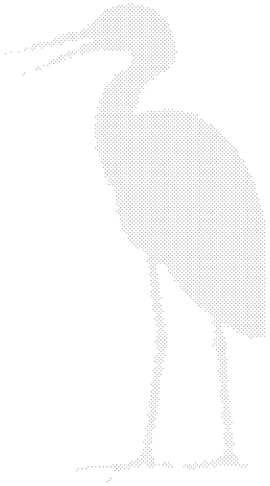


USRDOM simulates daily flows between Trinity, Shasta and Knights Landing

Figure 3.1
ALL CONTRIBUTING AREAS
UPPER SACRAMENTO RIVER
DAILY OPERATIONS MODEL

Daily Flow Characterization

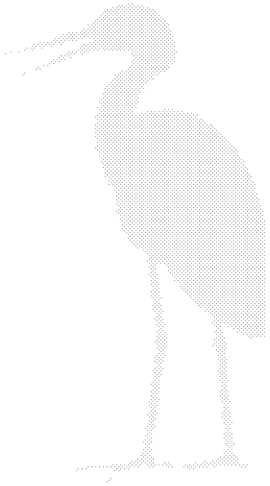
1. Characterize daily flows subject to hydrology and regulatory requirements for October 1st, 2008 – May 31st, 2018
   - Period consistent with implementation of NMFS's RPA from the 2009 BiOp
2. Characterization uses historical records and accounting for current flow requirements
   - Delta balance conditions from COA reports
   - Term 91 conditions
   - Delta outflow requirements
   - Export/Inflow ratio constraint
   - San Joaquin River exports
   - Health and safety requirements
   - Fall X2
   - Spring X2
   - Jersey Point, Emmaton, Rio Vista water quality standards



Historical Data Compilation

1. USGS Daily Flow
    - American River at Fair Oaks
    - Sacramento tributary flows
2. CDEC Daily Data
    - San Luis storage from WY 2007 through May 2018
    - Feather River flow
3. Reclamation Data

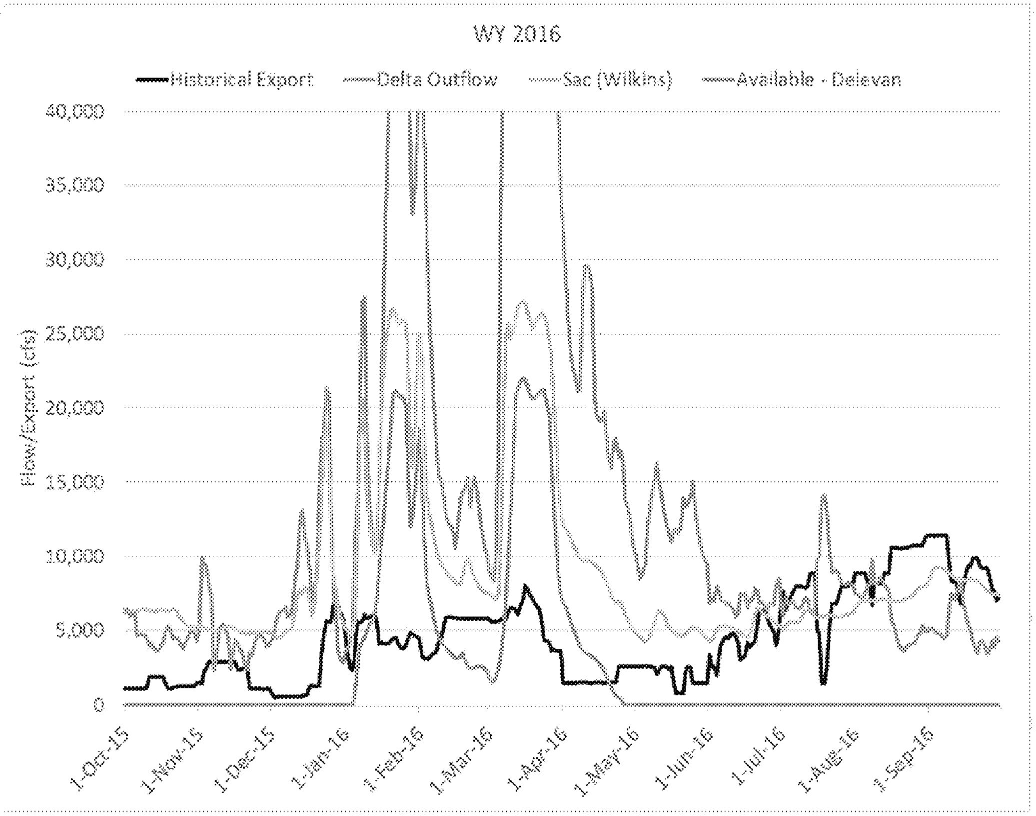
- CVO COA Reports from WY 2008 through November 2017
- Dayflow from WY 2008 through WY 2017

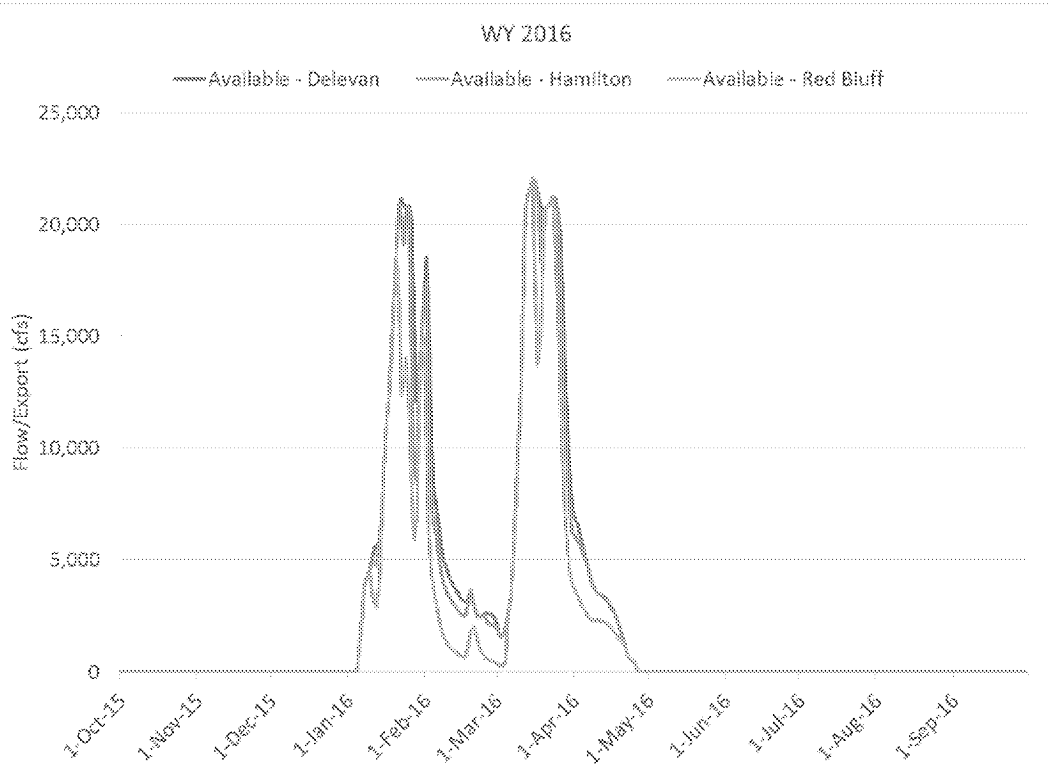


Historical Data Compilation

1. Delta Operations for Salmonids and Sturgeon (DOSS) meeting summaries from January 2009 through June 15th 2018
2. Smelt Working Group (SWG) meeting summaries from January 2009 through June 15th 2018
3. Delta Assessment Team (DAT) Summaries from January 2009 through June 15th 2018
4. Water Operations Management Team (WOMT) from January 2009 through June 15th 2018
5. SWRCB Term 91 indicator data from January 2007 through May 2018

Daily Flows – Example





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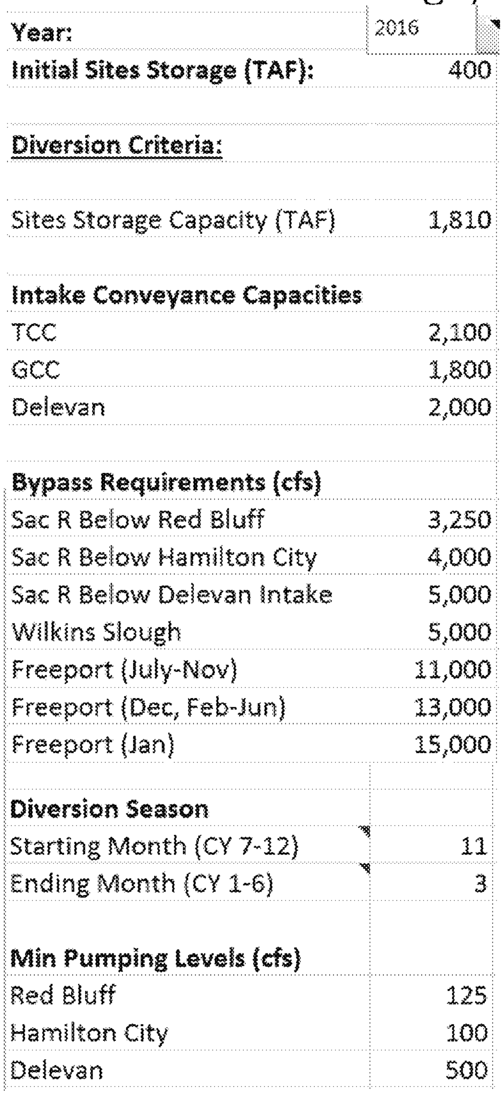
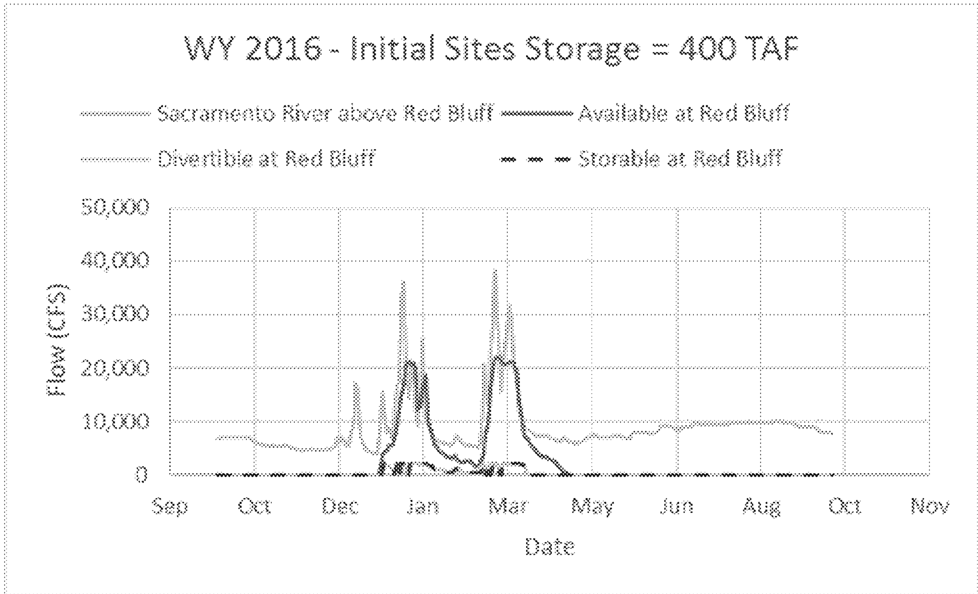
Example 1 (2016 hydrology with low initial Sites storage)

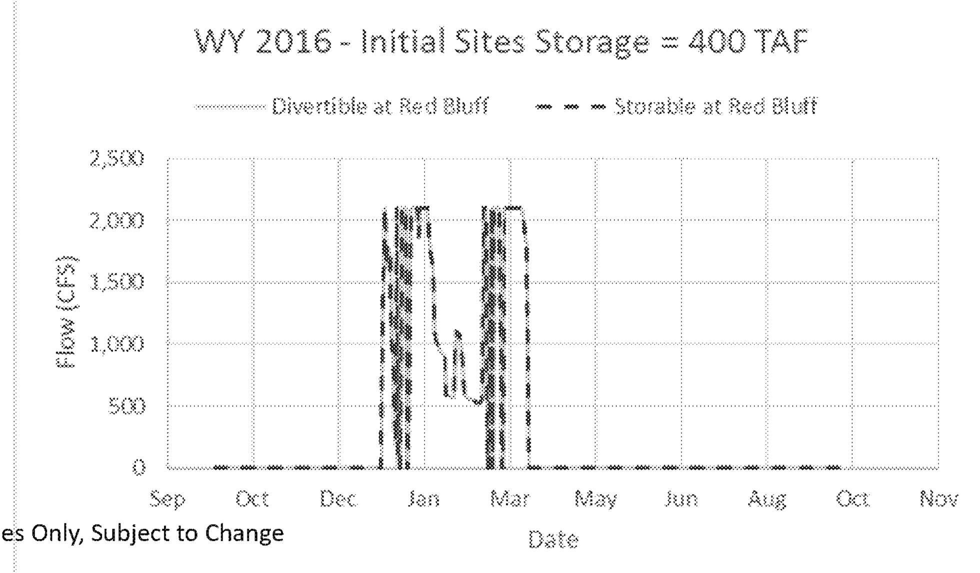


Year:	2016
Initial Sites Storage (TAF):	400
Diversion Criteria:	
Sites Storage Capacity (TAF)	1,810
Intake Conveyance Capacities	
TCC	2,100
GCC	1,800
Delevan	2,000
Bypass Requirements (cfs)	
Sac R Below Red Bluff	3,250
Sac R Below Hamilton City	4,000
Sac R Below Delevan Intake	5,000
Wilkins Slough	5,000
Freeport (July-Nov)	11,000
Freeport (Dec, Feb-Jun)	13,000
Freeport (Jan)	15,000
Diversion Season	
Starting Month (CY 7-12)	11
Ending Month (CY 1-6)	3
Min Pumping Levels (cfs)	
Red Bluff	125
Hamilton City	100
Delevan	500

Hydrology, availability, divertibility, and storability at Red Bluff intake:

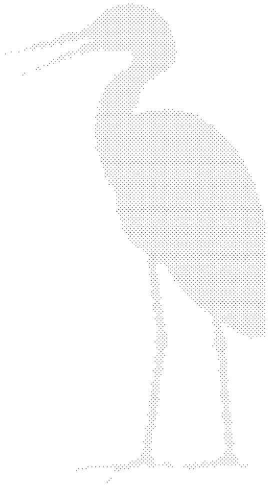


Zoomed in on Divertible and Storable Flow:

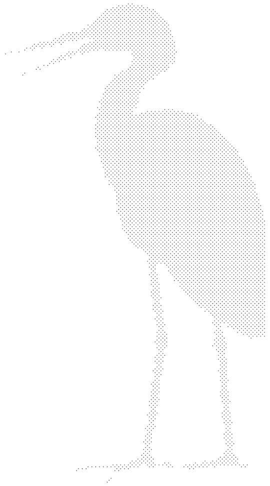


Ability to Evaluate Multiple Scenarios

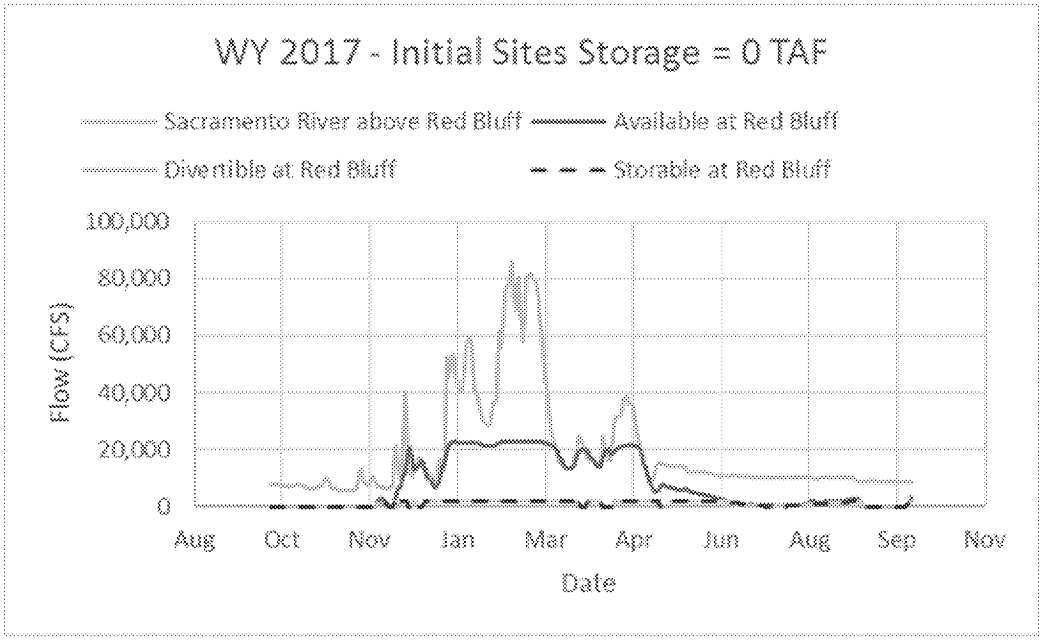
- A macro is built into the spreadsheet tool to iterate through multiple combinations of varying inputs and constraints
- The inputs and outputs from each scenario can be fed into Power BI to sift through the data and analyze relationships between the inputs (i.e., minimum pumping levels or bypass flow requirements) and outputs (i.e., Divertible and Storable flows)
  - Power BI is a business analytics service developed by Microsoft. It provides a platform for interactive visualizations of data

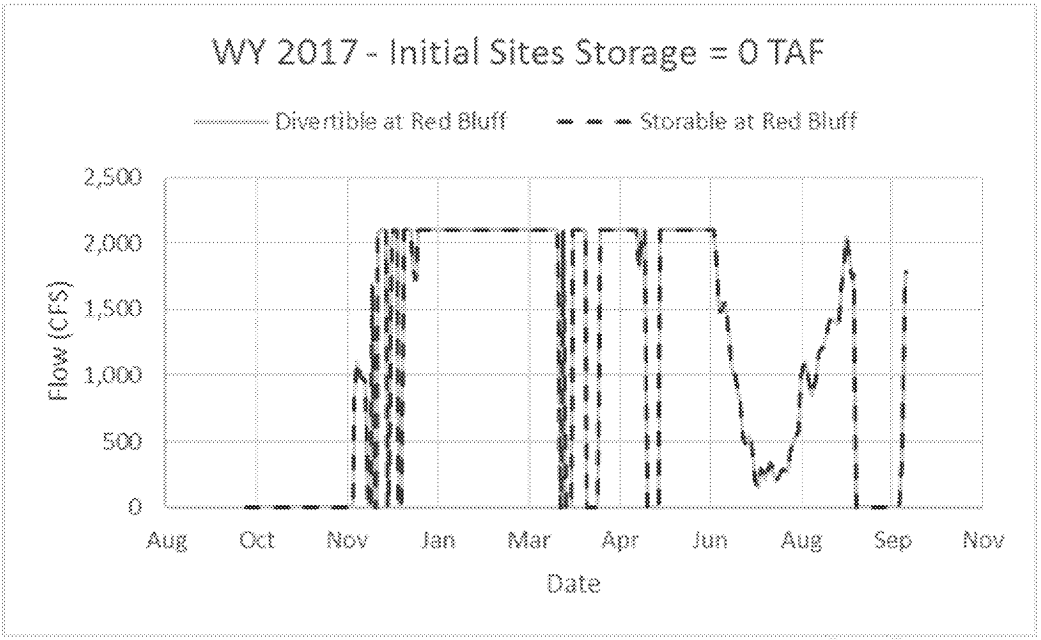


Example WY 2017 (Wet)



Red Bluff Intake (TCC) – WY 2017 (W)





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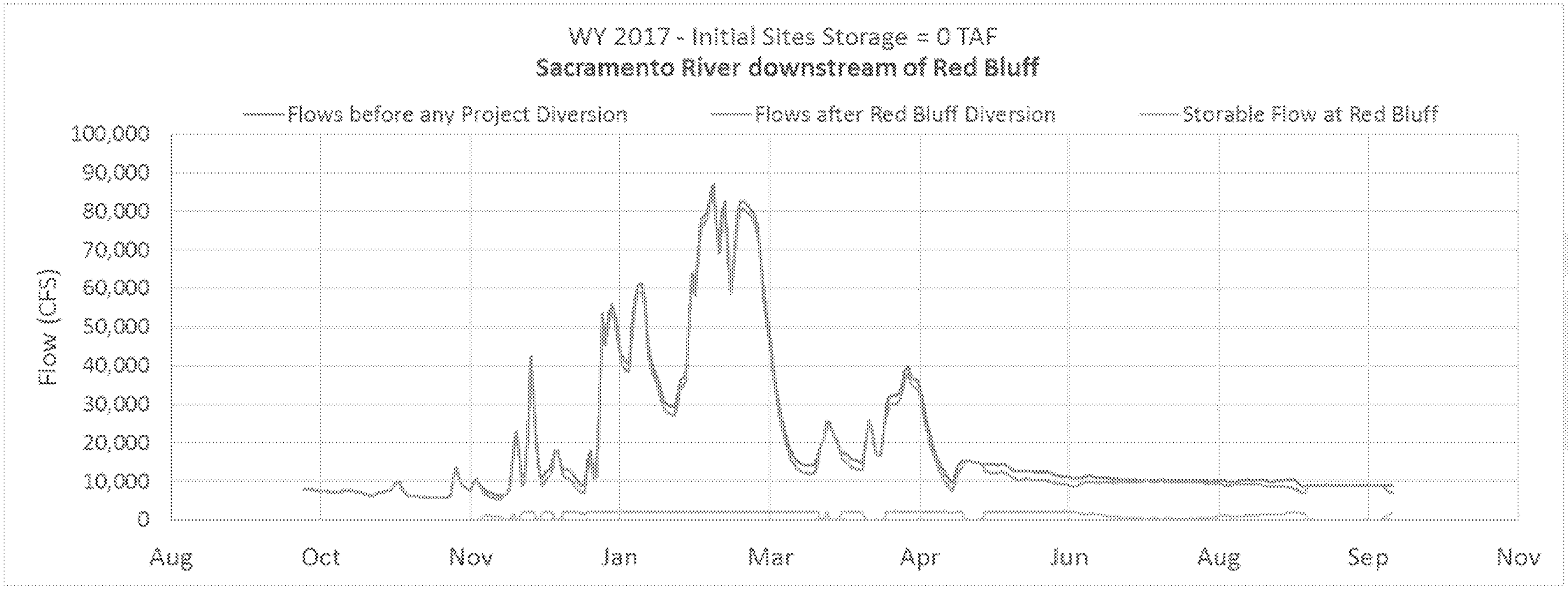
Red Bluff – WY 2017 (W)



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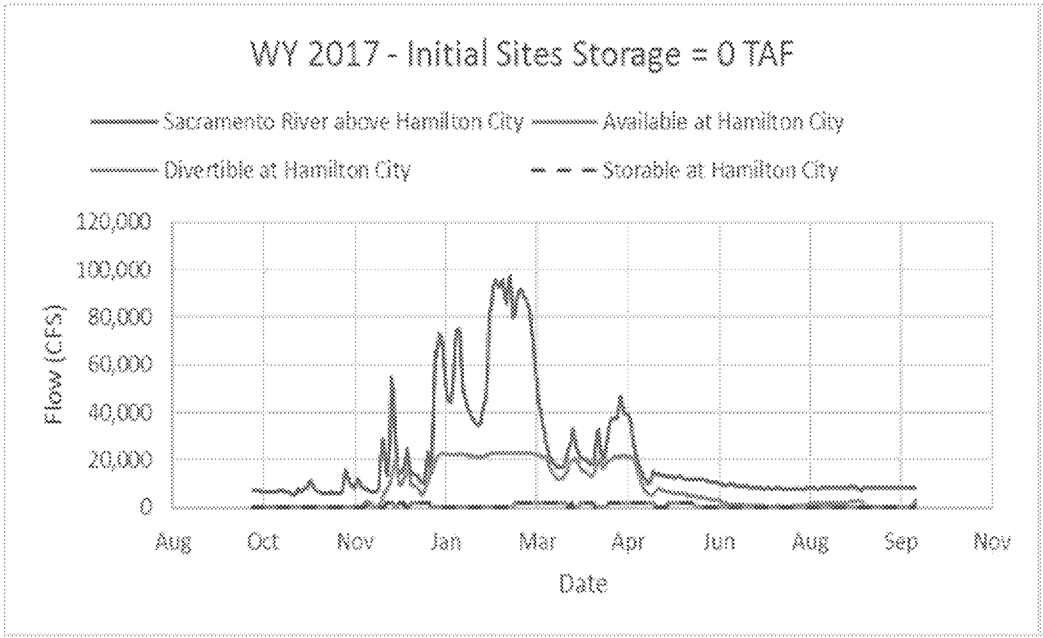
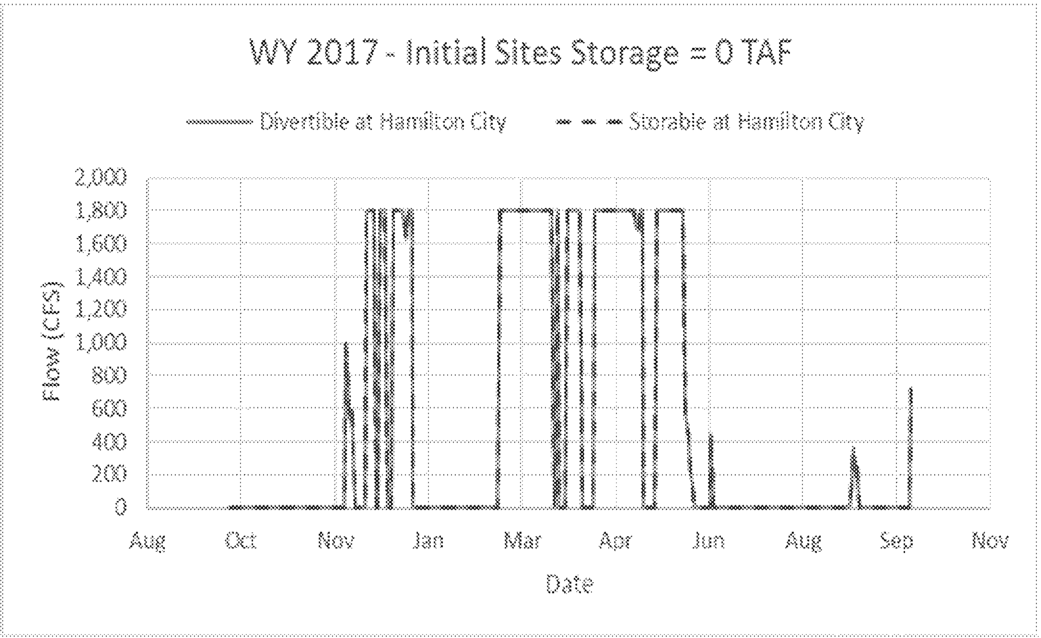
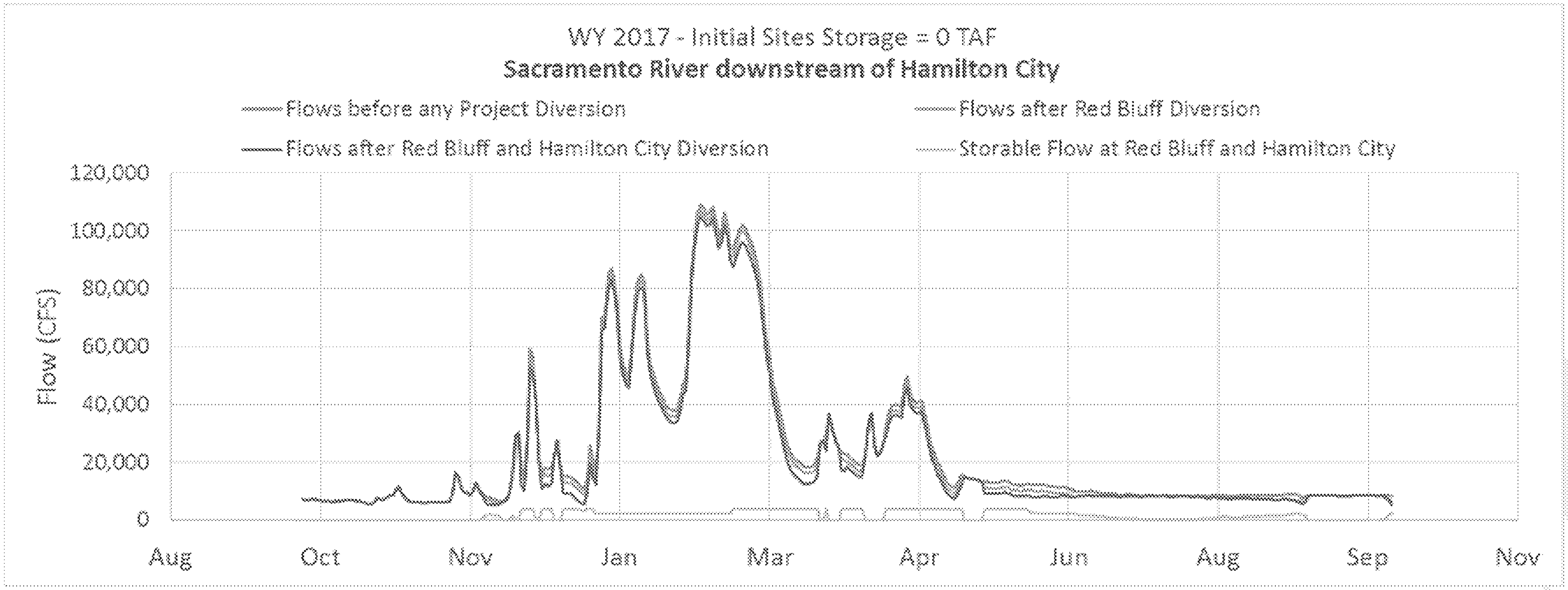
Hamilton City Intake (GCC) – WY 2017 (W)





Sites

Hamilton City – WY 2017 (W)



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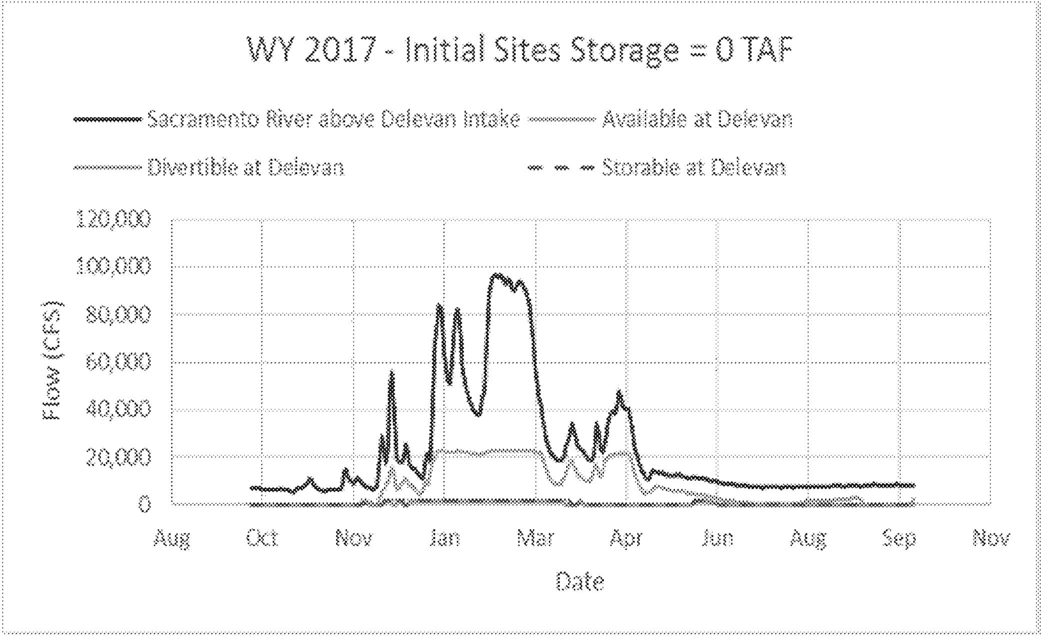
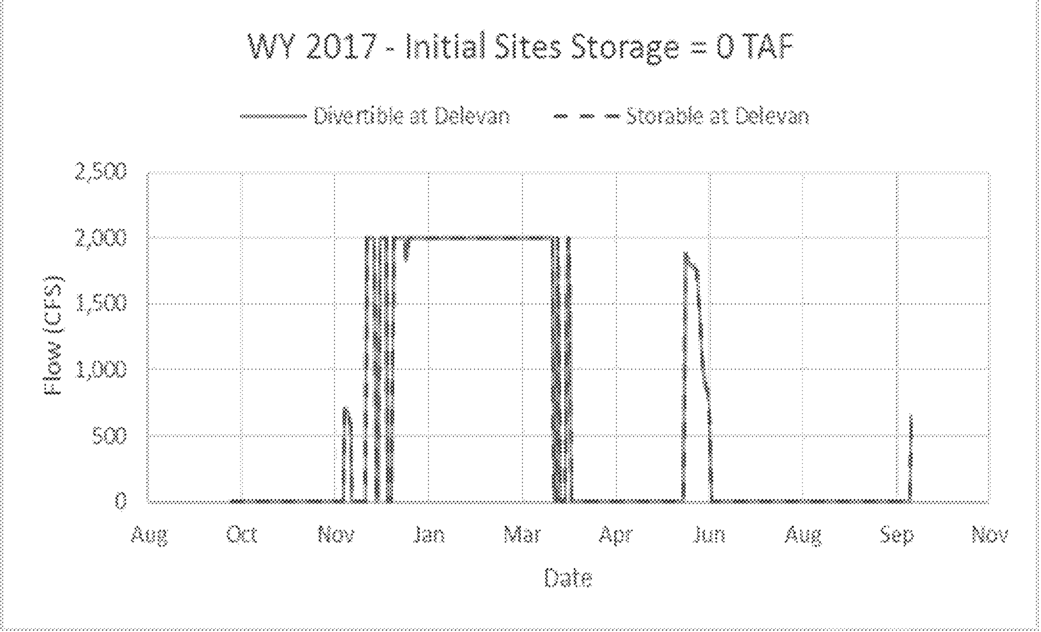
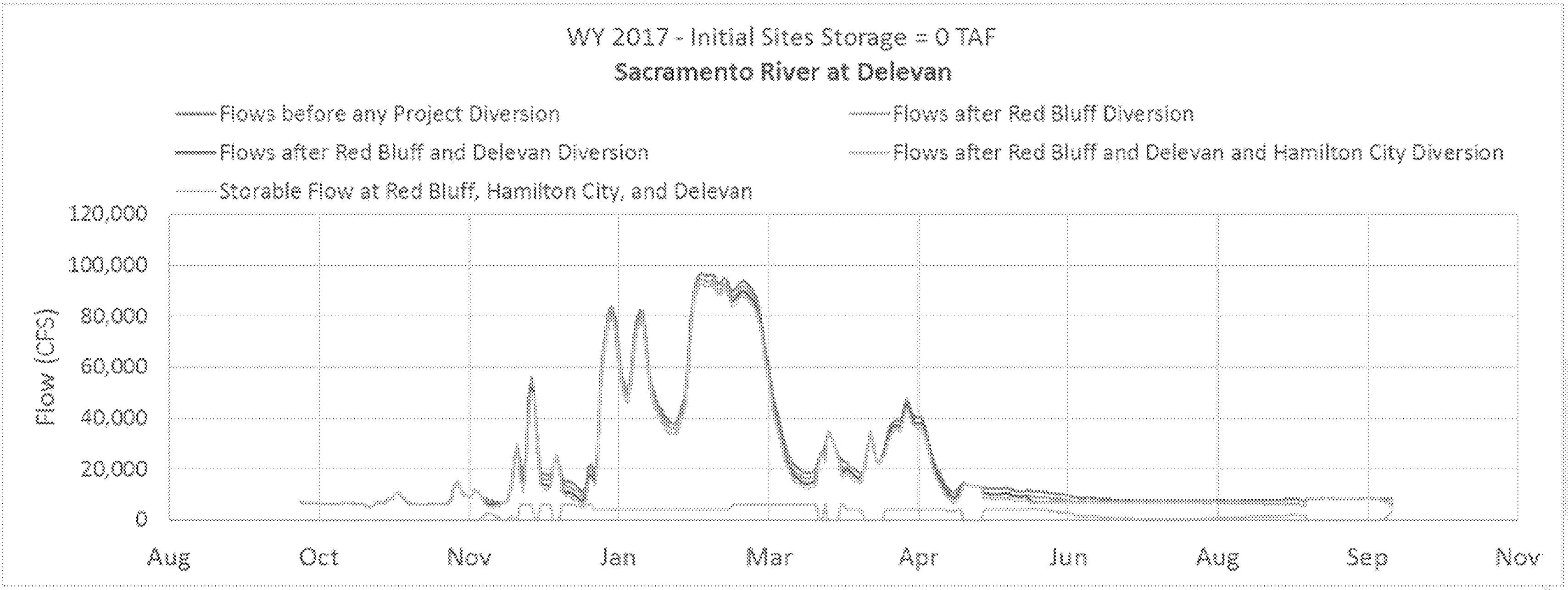
Delevan Intake – WY 2017 (W)


WY 2017 - Initial Sites Storage = 0 TAF


WY 2017 - Initial Sites Storage = 0 TAF

Delevan – WY 2017 (W)



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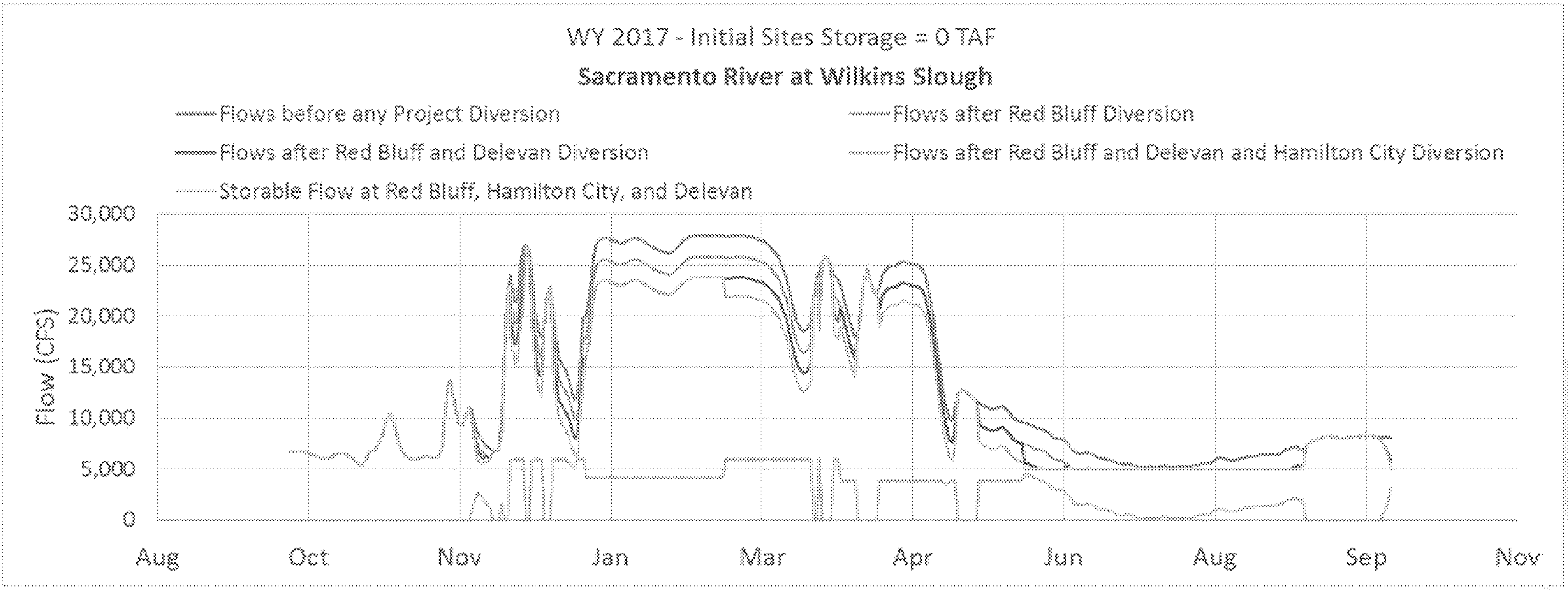
Wilkins Slough – WY 2017 (W)



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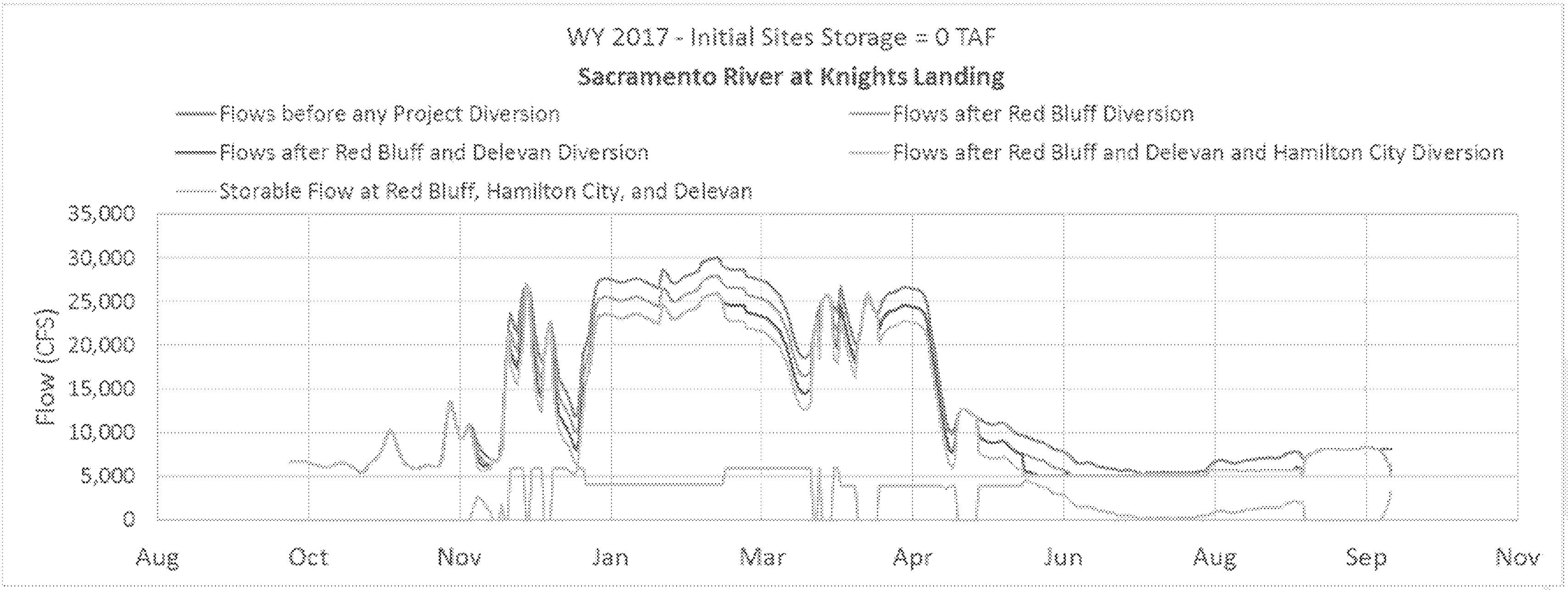
Knights Landing – WY 2017 (W)



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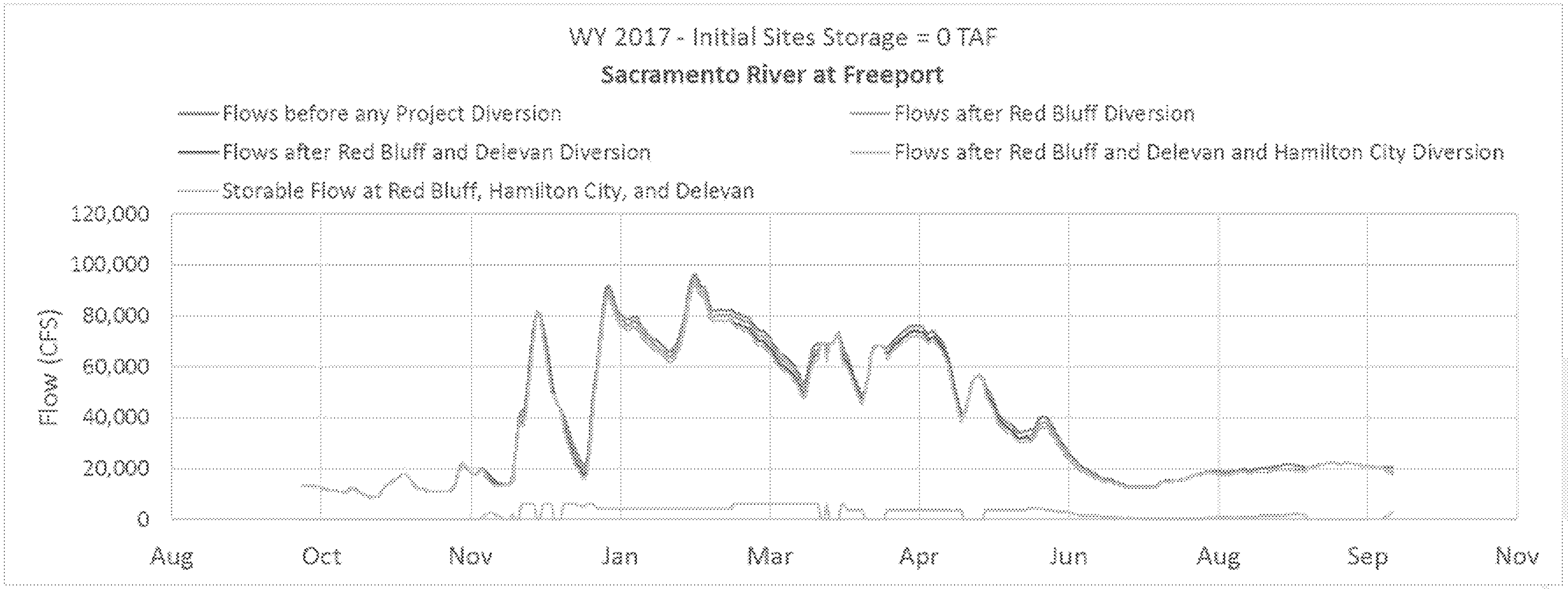
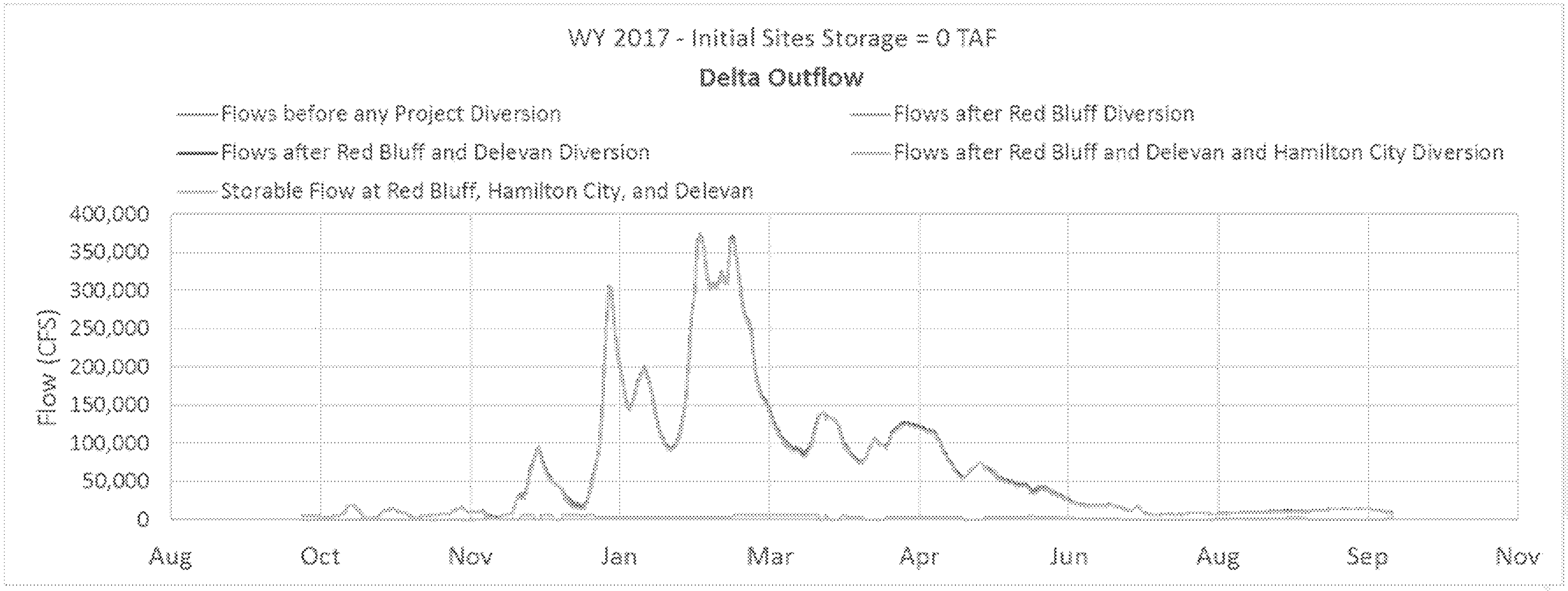
Freeport – WY 2017 (W)

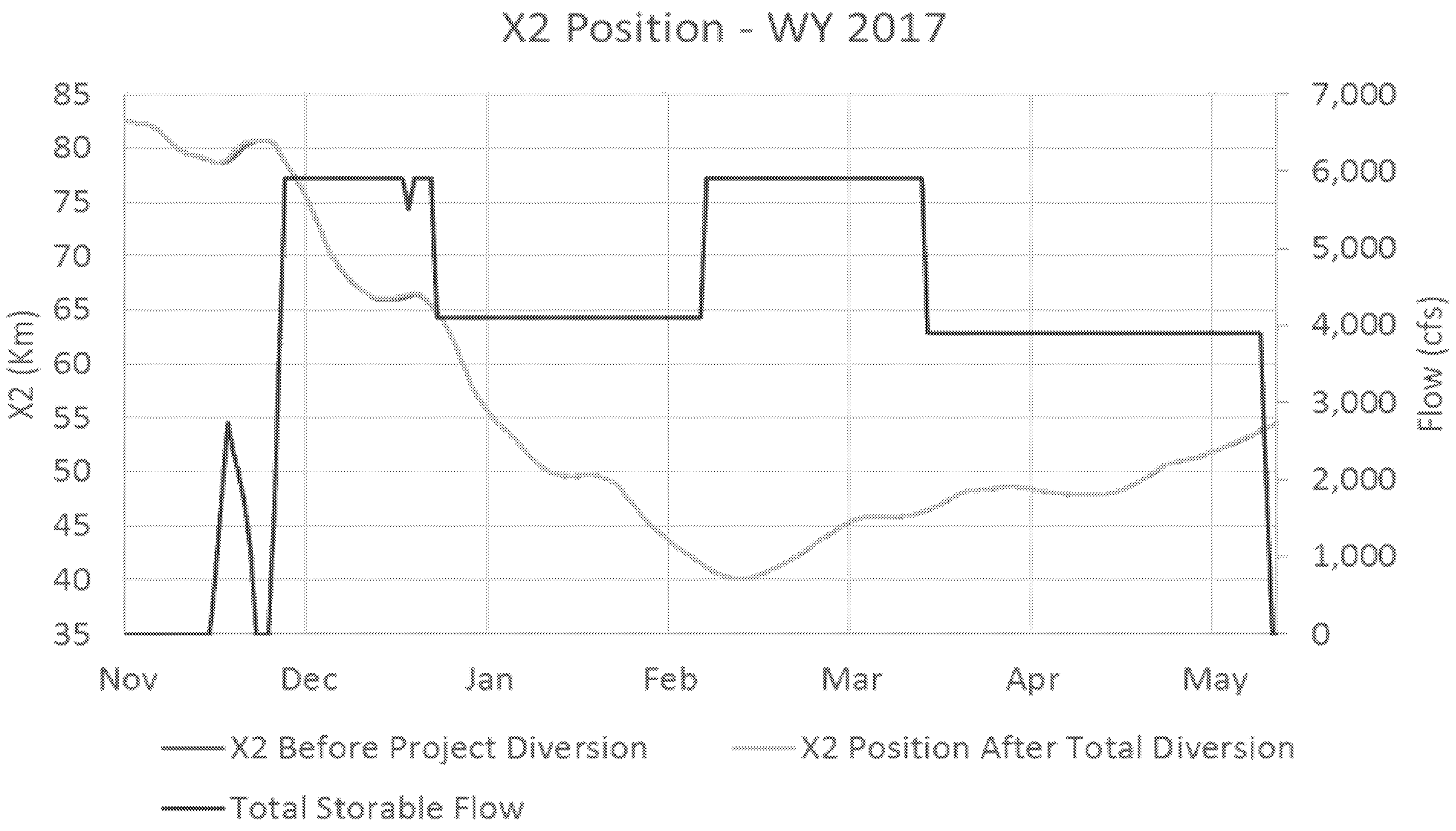


Draft, For Discussion Purposes Only, Subject to Change

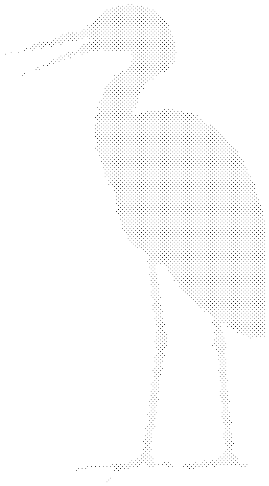
Delta Outflow – WY 2017 (W)



Draft, For Discussion Purposes Only, Subject to Change


X2 Position - WY 2017
X2 (Km)
85
80
75
70
65
60
55
50
45
40
35
Flow (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Nov
Dec
Jan
Feb
Mar
Apr
May
X2 Before Project Diversion
X2 Position After Total Diversion
Total Storable Flow

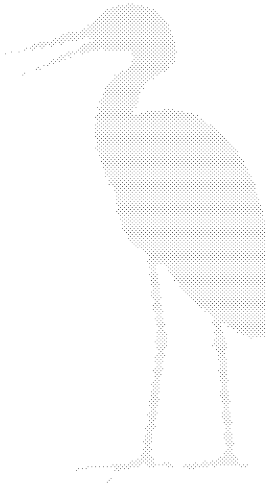
Reservoir Water Quality and Temperature Modeling



Sites

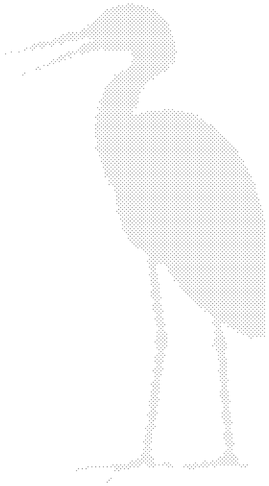
Sites Reservoir 2D Water Quality Model

1. The US Army Corps of Engineers CE-QUAL-W2 computer model is being applied to Sites Reservoir to evaluate water quality in reservoir releases for a range of operational scenarios.
2. The CE-QUAL-W2 model simulates lake water quality in two dimensions, assuming the lake is well mixed laterally.
3. Model inputs include bathymetric data, inflows and outflows, meteorological data, water quality in inflows, and initial water quality conditions in the lake.



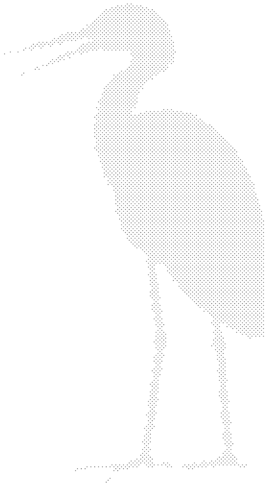
Sites Reservoir 2D Water Quality Model

- High resolution topographic data (2 ft contours) collected by DWR
- Developed model grid for CE-QUAL-W2 model with 128 2' layers and 36 lateral segments.
- Obtained hourly meteorological data from California Irrigation Management Information System (CIMIS) for Durham, California (temperature, wind, solar radiation) and from Yuba City Airport (cloud cover).
- Developed hourly meteorological input for representative 12 year period 2007-2018.
- Obtained water quality data for Sacramento River stations near water intakes.
- Utilize data from other nearby reservoirs.



Water Quality Model Implementation

- Analysis will focus on temperature and dissolved oxygen, but will also include evaluation of other parameters (to the extent possible) including pH, sedimentation, nitrogen and phosphorus concentration, and algal biomass.
- Will be used in conjunction with the daily river operations model to evaluate water quality operations over a range of hydrologic and operating conditions.
- Evaluate withdrawal capability of reservoir outlet structure to make releases to meet river temperatures.



Mitigation Brainstorming

- Maximizing Ecological Benefits
  - Add resiliency to the species
  - Contribute to recovery
- Restoration Project Opportunities
  - River Partners
  - Voluntary Agreements
- Onsite / Offsite Compensatory Mitigation
  - Land Acquisition and Restoration
  - Land Acquisition and Protection of Existing Habitat (Conservation Easements)
  - Restoration/Enhancement of Protected Lands

Action Items and Next Steps

- Continued Dialogue
  - Topics?
- Action Items

Sent: 10/14/2019 7:47:21 AM
To: Obegi, Doug [dobegi@nrdc.org]; jon@baykeeper.org; Barry Nelson (barry@westernwaterstrategies.com) [barry@westernwaterstrategies.com]; greg@bayecotarium.org; Chris Shutes [blancapaloma@msn.com]; Kim Delfino [KDelfino@defenders.org]; Zwillinger, Rachel (Mail Contact) [rzwillinger@defenders.org]
CC: Monique Briard (Monique.Briard@icf.com) [Monique.Briard@icf.com]; Jim Watson [jwatson@sitesproject.org]; Jim Lecky (jim.Lecky@icf.com) [jim.Lecky@icf.com]; Tull, Robert/SAC [Robert.Tull@jacobs.com]; Kevin Spesert [kspesert@sitesproject.org]; John Spranza (john.spranza@hdrinc.com) [john.spranza@hdrinc.com]; Grimaldo, Lenny [Lenny.Grimaldo@icf.com]
Subject: RE: Sites Meeting with NRDC, et al. - Follow-up
Attachments: 20190813 Sites NRDC Mtg_Final.pdf

Thank you Doug and Chris for the refinements to the Action Items. Below is an updated list. I've also attached a PDF of the presentation. (Note that the PDF file changes templates and page numbers part way thru. We actually used 2 presentations that day and I combined them both into one PDF file. The actual PPT files are too large to send via email.)

And thanks Doug for the four papers!

Revised Action Items:
1. Schedule a terrestrial focused meeting to focus on (among other topics): (1) terrestrial species and habitat impacts; (2) impacts to refuge and refuge easements; (3) impacts to giant garter snake; and (4) mitigation strategy for terrestrial species.
2. Look at possibility of releasing the Daily Model. (Note, I talked with the team on this late last week. We are scheduling an internal Sites discussion on the possibility of releasing the model along with the timing and what documentation should accompany a release. I should have more info on this in about 2 weeks.)
3. Can Sites add the Yolo Bypass to the floodplain modeling effort? (Note, we are already planning on adding the Sutter Bypass to the floodplain modeling effort, but had not planned on including Yolo. So this action item is focused on Yolo as we had not originally planned on including the Yolo Bypass in the floodplain modeling effort. Sutter will be included.)
4. Continue discussion on effects to salmonid survival throughout the Sacramento River and Delta. – Doug sent over papers on 10/9.
5. Email copy of PPT presentation from meeting. – Completed with this email.
6.

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 | aforsythe@sitesproject.org | www.SitesProject.org

From: Obegi, Doug <dobegi@nrdc.org>
Sent: Wednesday, October 9, 2019 5:25 PM
To: Alicia Forsythe <aforsythe@sitesproject.org>; jon@baykeeper.org; Barry Nelson (barry@westernwaterstrategies.com) <barry@westernwaterstrategies.com>; greg@bayecotarium.org; Chris Shutes <blancapaloma@msn.com>; Kim Delfino <KDelfino@defenders.org>; Zwillinger, Rachel (Mail Contact) <rzwillinger@defenders.org>
Cc: Monique Briard (Monique.Briard@icf.com) <Monique.Briard@icf.com>; Jim Watson <jwatson@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Kevin Spesert <kspesert@sitesproject.org>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Grimaldo, Lenny

<Lenny.Grimaldo@icf.com>
Subject: RE: Sites Meeting with NRDC, et al. - Follow-up

Hi Ali,

Thank you for following up on our prior meeting, and I agree that it makes sense to hold off on scheduling another meeting at this point.

Attached are 3 papers from 2018 and 2019 regarding Sacramento River flows and salmon survival, including the Friedman et al 2019 paper I mentioned in the meeting, as well as the Zeug et al 2014 paper showing a very strong correlation between Stanislaus River flows and juvenile salmon survival.

In terms of the action items from the meeting, I thought that item #4 was not limited to impacts downstream of Freeport (see Perry et al 2018), but instead was regarding impacts in the Sacramento River below the intakes as well as further downstream. I believe item #3 was broader floodplain inundation modeling, not limited to Yolo Bypass (?). In addition, would you please email us a copy of the PPT presentation that was shared at the meeting with us? That was on my list of action items from the meeting.

Thanks,
-d

From: Alicia Forsythe <aforsythe@sitesproject.org>
Sent: Wednesday, October 9, 2019 4:16 PM
To: jon@baykeeper.org; Barry Nelson (barry@westernwaterstrategies.com) <barry@westernwaterstrategies.com>; greg@bayecotarium.org; Obegi, Doug <dobegi@nrdc.org>; Chris Shutes <blancapaloma@msn.com>; Kim Delfino <KDelfino@defenders.org>; Zwillinger, Rachel (Mail Contact) <rzwillinger@defenders.org>
Cc: Monique Briard (Monique.Briard@icf.com) <Monique.Briard@icf.com>; Jim Watson <jwatson@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Kevin Spesert <kspesert@sitesproject.org>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Grimaldo, Lenny <Lenny.Grimaldo@icf.com>
Subject: Sites Meeting with NRDC, et al. - Follow-up

All –

I sincerely apologize for the long delay in circling back to you all after our meeting. I know how important it is to follow up on our commitments and time just got away from me on this. My apologies.

I wanted to say thank you very much for taking the time to chat with us. Below are the action items that I recorded. Please let me know if I missed any or have mischaracterized any.

I also wanted to share that we continue with our discussions with CDFW on operating criteria (diversion criteria). We have also had an initial re-engagement meeting with NMFS and plan to meet with them and CDFW together in the coming weeks. NMFS is agreeable to us entering into a contract with them to run their winter-run life-cycle model for the Project. We are starting to work on the contracting effort and are hopeful that this wraps up about the time we have revised operational criteria for NMFS to run – likely late this calendar year.

We have also continued to work on refinements to the Project to right-size it for the current participants. We continue to consider a number of right-sizing actions, such as reducing the size of the reservoir along with no Delevan intake. Once the Authority identifies a preferred project, we will assess the changes and how best to move forward with the CEQA / NEPA compliance effort.

There is a lot in flux right now, so I'd like to hold off on meeting again. As we narrow down on a preferred project and new operations criteria, I would like to circle back and get your input on these. I am always happy to chat if you have questions or suggestions in the meantime.

Action Items:
1. Schedule a terrestrial focused meeting to focus on (among other topics): (1) terrestrial species and habitat impacts; (2) impacts to refuge and refuge easements; (3) impacts to giant garter snake; and (4) mitigation strategy for terrestrial species.
2. Look at possibility of releasing the Daily Model. (Note, I talked with the team on this late last week. We are scheduling an internal Sites discussion on the possibility of releasing the model along with the timing and what documentation should accompany a release. I should have more info on this in about 2 weeks.)
3. Can Sites add the Yolo Bypass to the floodplain modeling effort?
4. Continue discussion on effects to salmonid survival downstream of Freeport. Check Freedman (spelling?) 2019 paper and a recent paper from the Stanislaus River (Doug, I didn't catch the title of this one. Can you send it over or send the title?)

We will follow up on these action items in the coming weeks.

Please don't hesitate to contact me if you have any questions, thoughts or concerns on the Sites Project.

Ali

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 | aforsythe@sitesproject.org | www.SitesProject.org

NRDC & Team

Sites Project

Status and Updates

Meeting

August 13, 2019

Proposed Agenda

Purpose: Update on Sites Project Activities, Modeling Tools and Analysis

1. Introductions
2. Initial Remarks
3. General Sites Overview and Project Progression Post Draft EIR/S, WSIP, and Reclamation Feasibility Report
4. New Modeling Analysis and Tools
    a. Sacramento River
    b. Delta
5. Modeling Analysis and Tools Currently Under Development
    a. Water Quality/Temperature
    b. Others
6. Mitigation Brainstorming
7. Action Items and Next Steps

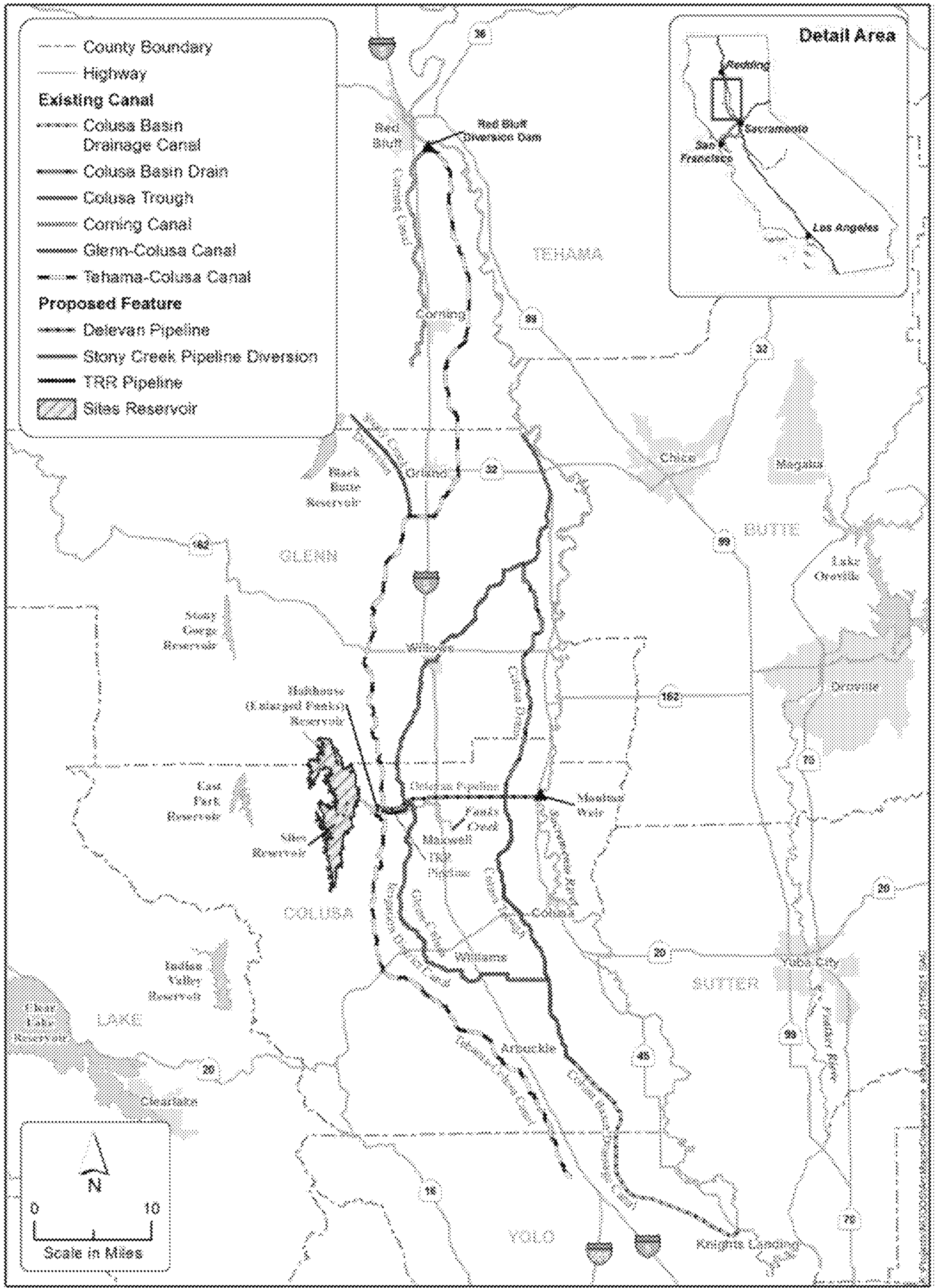
General Sites Overview

- New reservoir, regulating forebays, pipeline and Sacramento River diversion
  - 1.82 MAF storage
  - Two 300'+ earthen dams, 9 saddle dams
  - Two forebay regulating reservoirs connecting to existing irrigation canals
  - 14 miles of twin, 10' diameter pipelines and two pump/generation
  - New 2,000 cfs diversion/pumping facility

- Sustainable Surface Water Infrastructure Improvement
  - Benefits endangered species and refuges
  - Increases water supply in drier years
  - Reduces regional flooding
  - Increases recreation
  - Provides resiliency with future climate change

- Proposed by a local joint-powers authority. Participants throughout CA, Reclamation, State.

Regional Map



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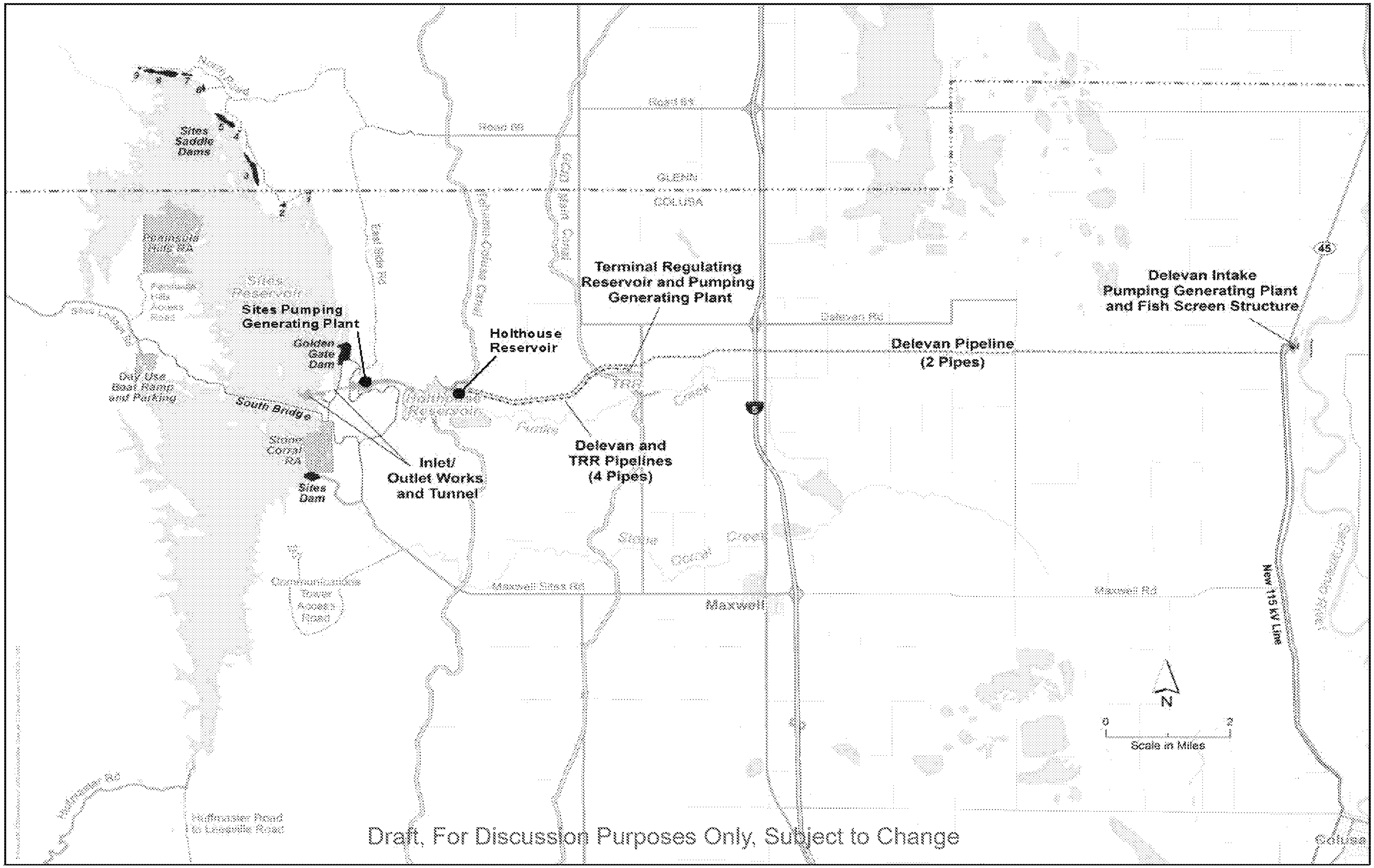
Project Facilities



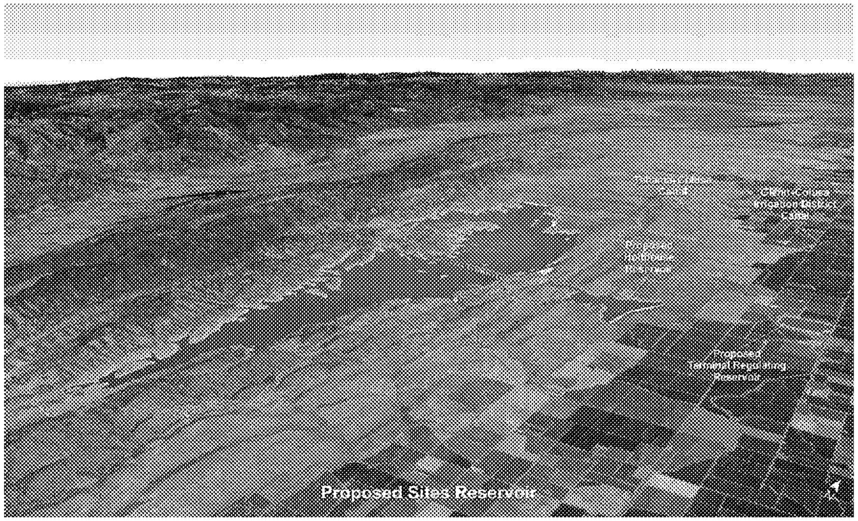
Project Objectives

▪Primary:

- Water Supply and Water Supply Reliability
- Anadromous Fish Benefits
- Operational Flexibility
- Pelagic Estuarine Fish Food
- Level 4 Refuge Supply

▪Secondary:

- Hydropower
- Recreation
- Flood Damage Reduction



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Preliminary Results - Supply

- Water Supply and Water Supply Reliability
  - Captures and stores storm-related, unregulated Sacramento River discharge
  - Provides additional supply in drier years
- CVP Operational Flexibility

Preliminary Results - Environment

- Anadromous Fish Benefits
  - Increases summer/fall cold water for juvenile winter-run chinook salmon
  - Provides additional flow stability in fall/early winter
- Pelagic Estuarine fish food
  - Provides later summer/fall flows carrying food for Delta smelt
- Level 4 Refuge Supply
  - Provides additional incremental Level 4 supplies

Project Progression: Post Draft EIR/S, WSIP, Reclamation Feasibility Report

- Cost and Financing
  1. Regulating reservoir: Replace Holthouse with Fletcher
  2. Advance pumped-storage hydropower & grid interconnection
  3. Improve estimates of potential mitigation
  4. Construction sequencing to allow initial operations sooner
  5. Secured USDA Rural Development conditional construction loan
- Engagement
  1. Landowners & community
  2. State and federal agencies
  3. Water industry
  4. Elected officials

Project Progression: Post Draft EIR/S, WSIP, Reclamation Feasibility Report

- Ongoing work with Reclamation
  - a. Feasibility report is still a work in progress
  - b. Role as investor (a federal asset) or just a participant (cooperative operations)
- Adding capacity
  - a. 9 "service area providers" & senior-level advisors
  - b. New environmental manager: Ali Forsythe
- Developing tools to aid in response to comments
  - a. Daily model for upper Sacramento River
  - b. Analyze effects to off-channel habitat areas
  - c. 2-D reservoir temperature model

Sites Appeal to Public Benefit Ratio Review: Salmonid Benefits

February 23, 2018

Table A.1-2: Annual Production Results from SALMOD for the Four Sacramento River Chinook Salmon Species

Species	2015		2030		2070	
	Without Sites	Sites Increment	Without Sites	Sites Increment	Without Sites	Sites Increment
Winter	1912017	63594 (3.3%)	1996967	68269 (3.4%)	1818783	109752 (6.0%)
Spring	429539	8767 (2.0%)	437648	4147 (0.9%)	357458	17520 (4.9%)
Fall	17977800	172775 (1.0%)	17896789	226190 (1.3%)	15507733	623264 (4.0%)
Late-Fall	2877697	32864 (1.1%)	2892264	20442 (0.7%)	2744016	95108 (3.5%)
All Runs	23197052	277999 (1.2%)	23223668	319047 (1.4%)	20427989	845644 (4.1%)

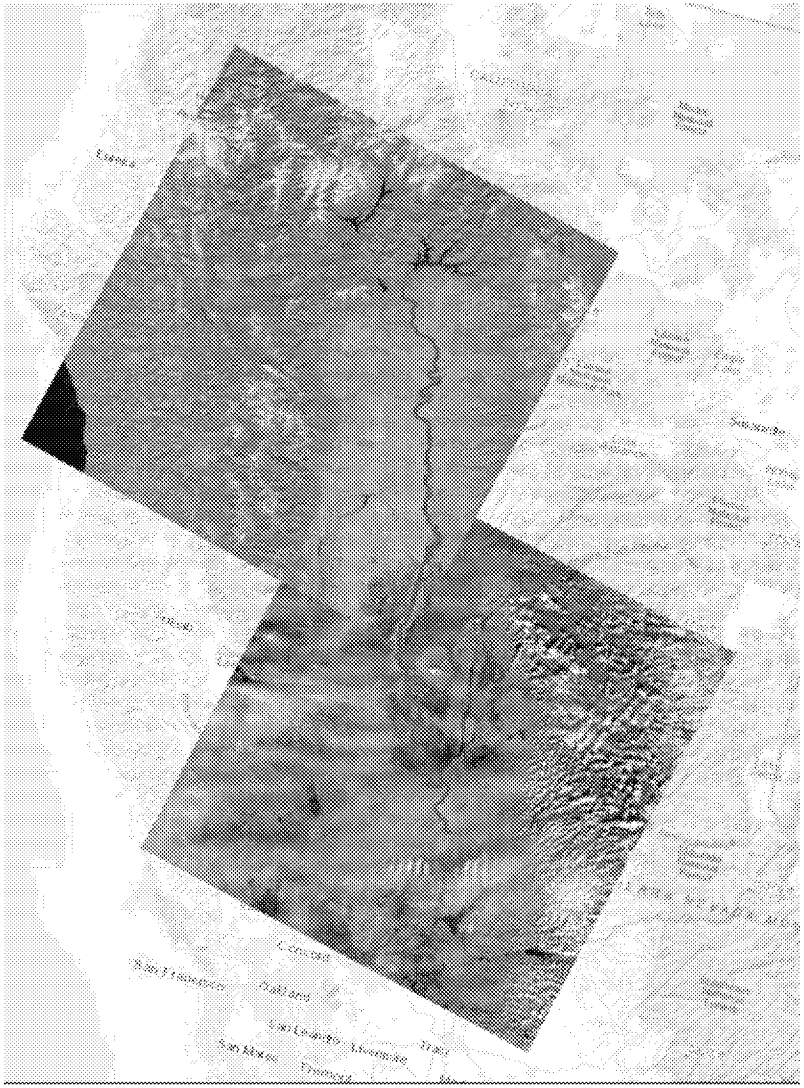
Table A.1-3: Incremental Changes in Dry and Critical Years' Average Annual Production Results from SALMOD with the Sites Reservoir (Water year types are based on D-1641 40-30-30 Sacramento River Index)

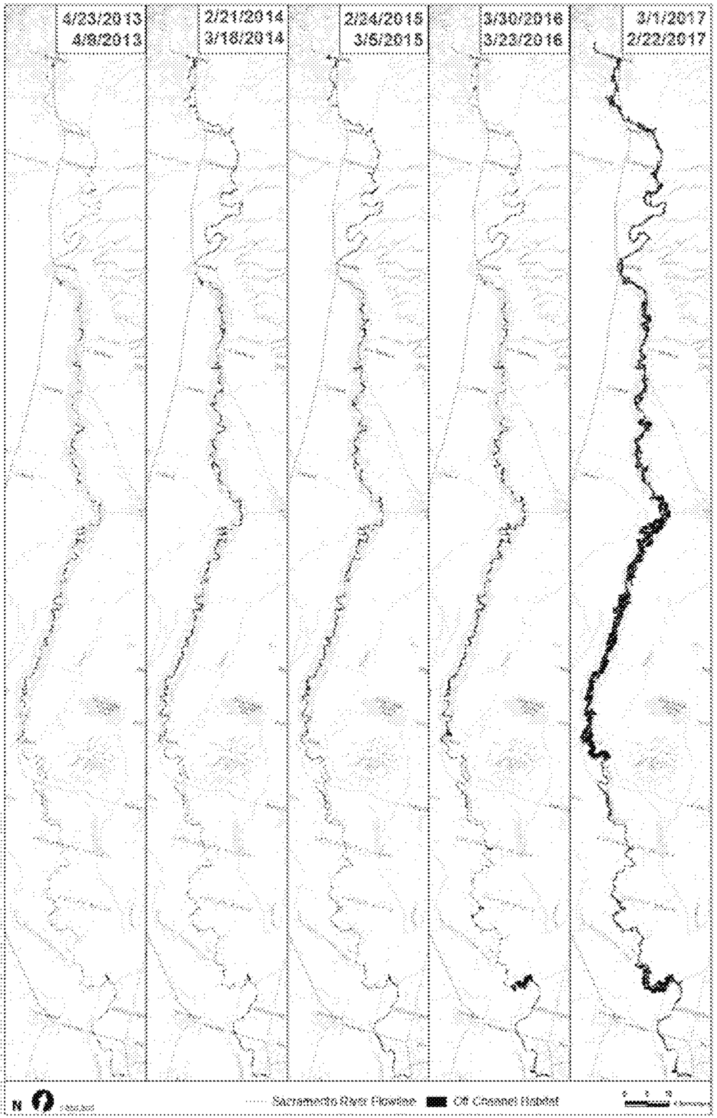
Species	Sites Increment in Dry Years			Sites Increment in Critical Years		
	2015	2030	2070	2015	2030	2070
Winter	2.3%	2.6%	6.1%	23.3%	14.8%	66.7%
Spring	1.3%	0.3%	6.3%	20.2%	6.0%	64.8%
Fall	1.6%	0.6%	7.0%	3.9%	3.1%	11.3%
Late-Fall	2.3%	1.2%	1.6%	4.4%	1.6%	21.2%

Additional Considerations for Salmonids

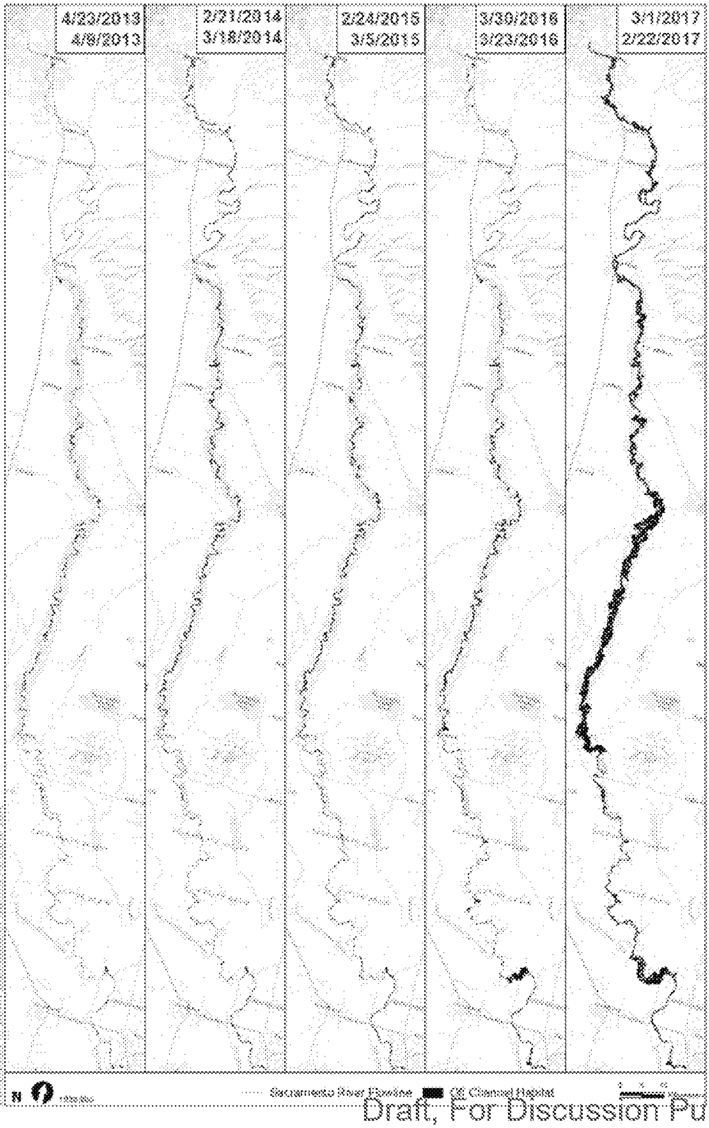
- Temperature/flow Stabilization Benefit
- In River Survival
  - Wilkins Slough Criterion
  - Refine OBAN analysis
  - Pulse flow protections for all pulses
  - Proportional river flow criteria
- Floodplain Benefits
  - Inclusion of Freemont notch and bypass protections
  - Maintain spill frequency and duration
- Integration of Voluntary Agreement measures
- Development of real time operations measures
- Development of minimization and mitigation measures

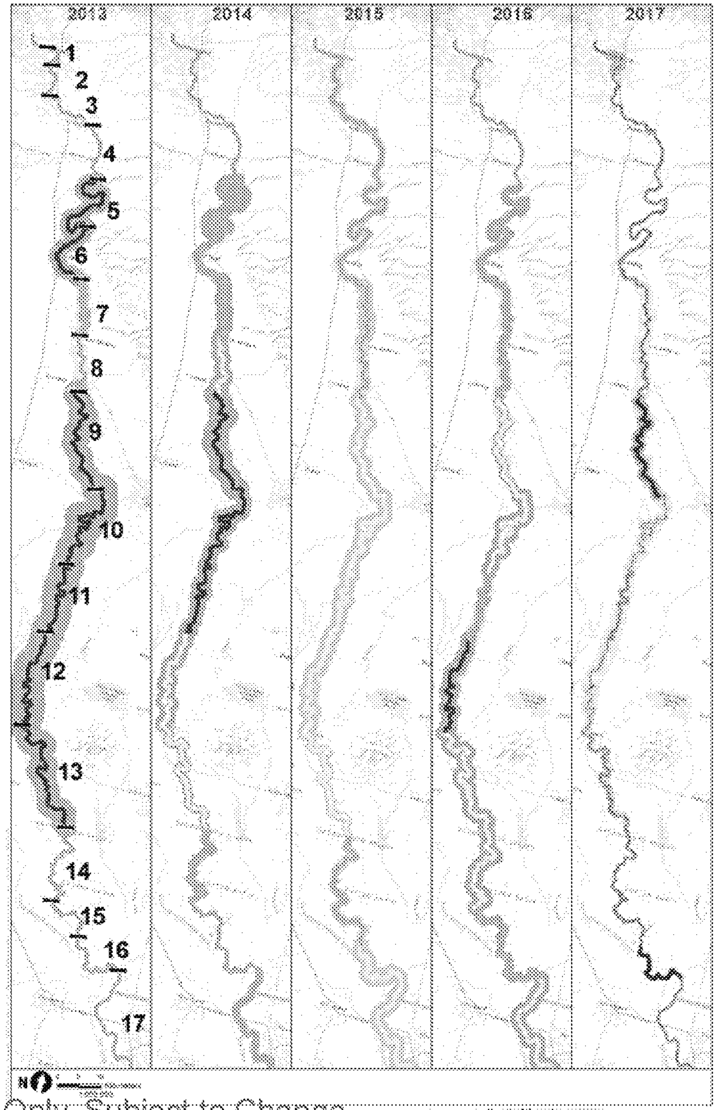
New Modeling Analysis and Tools – Off-channel Habitat



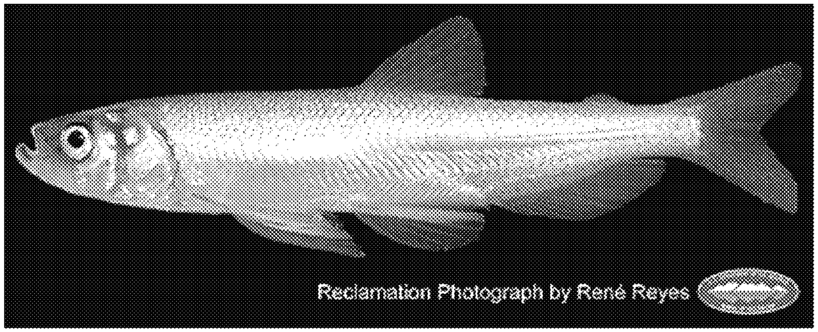


New Modeling Analysis and Tools – Off-channel Habitat





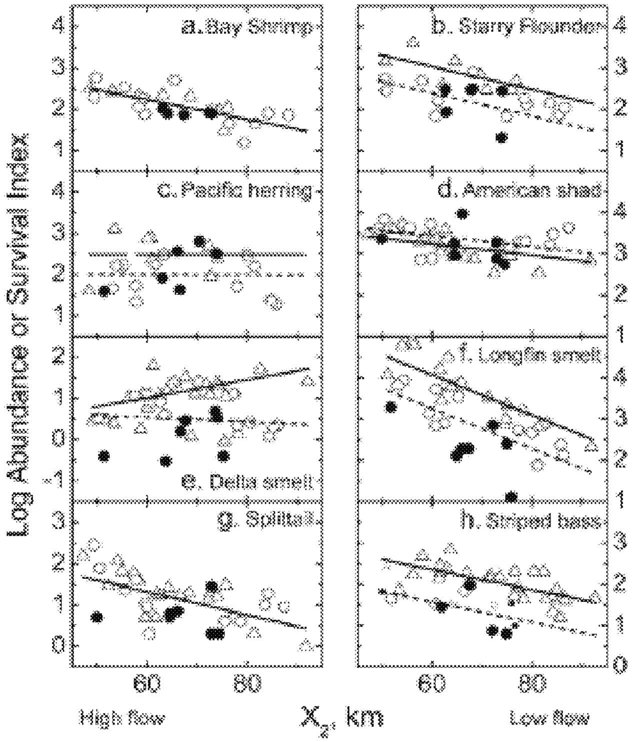
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered


Reclamation Photograph by René Reyes

1. Spring Outflow-Fall Abundance Relationship (Kimmerer et al. 2009)
2. Direct and Indirect Entrainment Effects (Grimaldo et al. 2009)

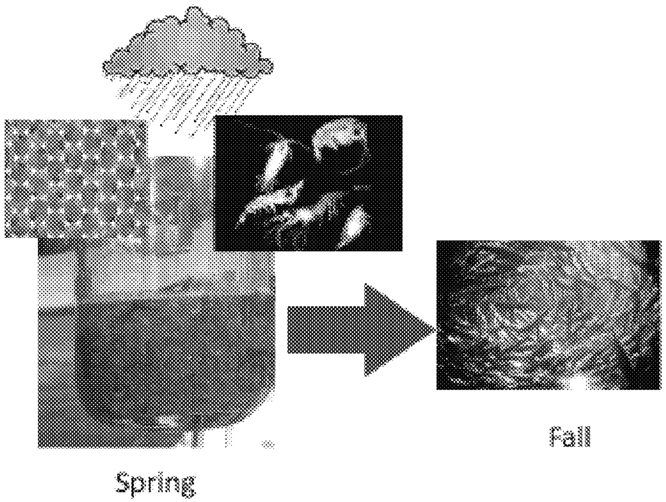
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

1. Winter-spring outflow-Fall Abundance Relationship



Kimmerer et al. 2009

Underlying conceptual model



Potential mechanisms underlying survival

-Improved survival and growth

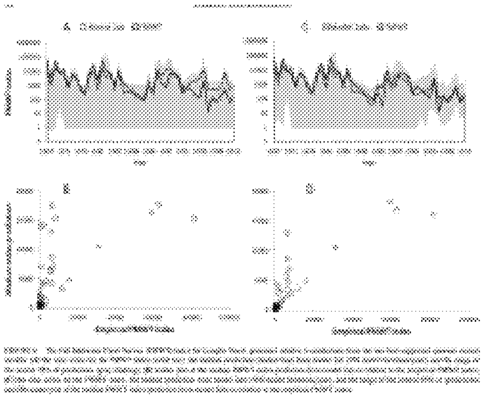
-Reduced entrainment

-Improved habitat and rearing conditions (e.g., reduced predation, improved retention, etc)

New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

1. Winter-spring outflow-Fall Abundance Relationship Effects to be Considered

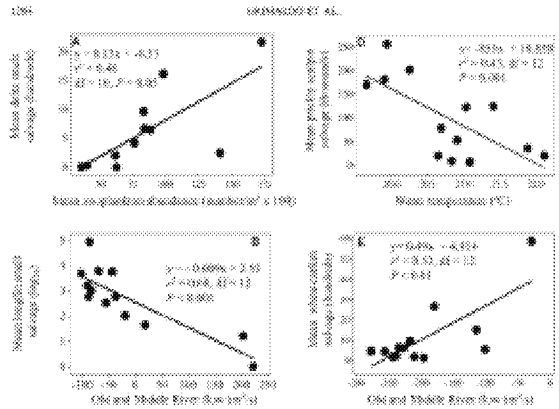
- Examine changes in X_2 during winter-spring period (Jan-Jun) per Kimmerer et al. 2009
- Examined differences in stock-recruit relationships using Nobriga-Rosenfield approach

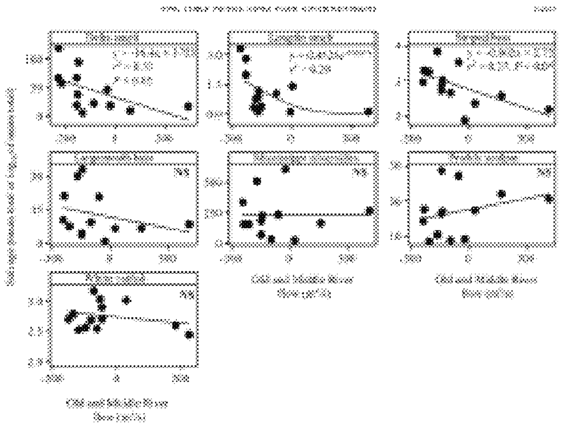


Nobriga and Rosenfield (2016)

New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

2. Direct and indirect entrainment effects





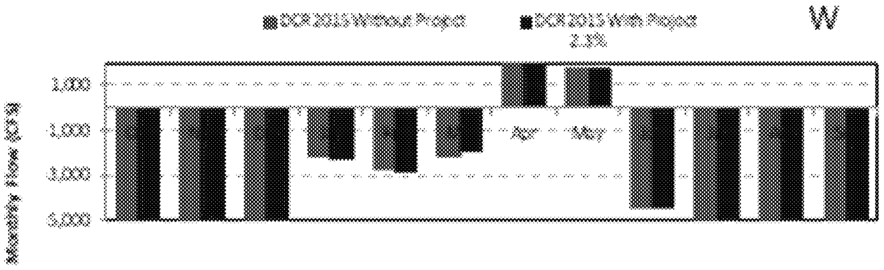
Potential approaches to examine Longfin Smelt entrainment Effects

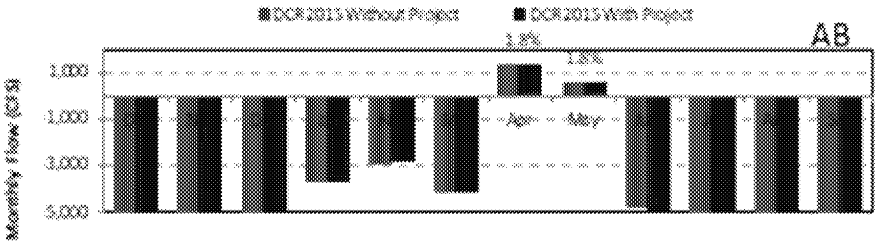
Direct entrainment (% difference in OMR and Qwest)
-Larvae (PTM, Jan-Mar)
-Juveniles (Existing salvage relationships, Mar-May)
-Adults ((Existing salvage relationships, Dec-Feb)

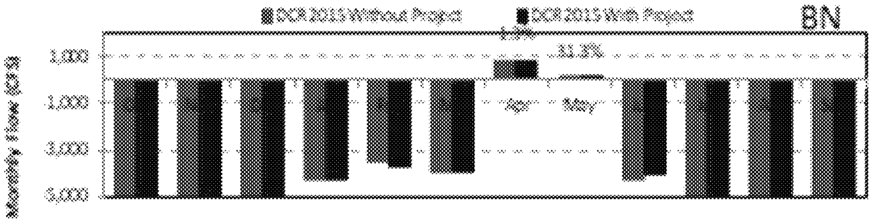
Indirect entrainment (% difference in X_2)
-Larvae (Jan-Feb)
-Juveniles (Mar-May)
-Adults (Dec-Feb)

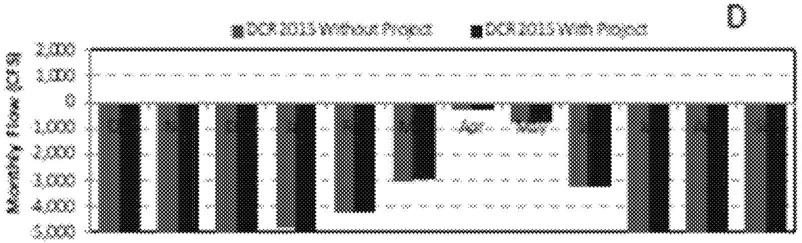
New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

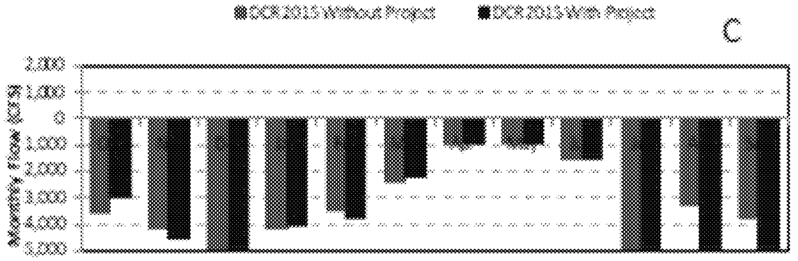
OMR Modeling Output





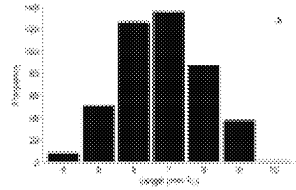


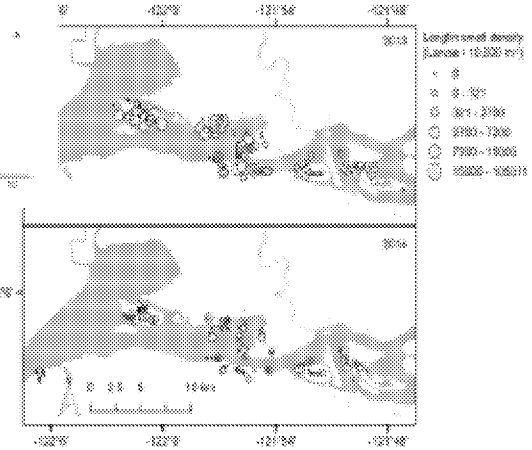




New Modeling Analysis and Tools – Longfin Smelt Effects to be analyzed / considered

Results to be put in context of the new science and existing FWS/NMFS BiOps

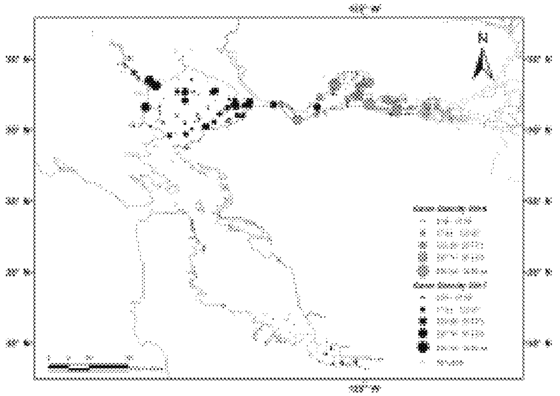




Grimaldo et al. 2017

- Fish are hatching and rearing in tidal marshes and shallow habitats
- Fish are hatching and rearing in SF Bay habitats and tributaries
- Real-time work groups and OMR protections

Water Year and Sacramento Valley WY Index Classification	Combined SWP and CVP Expanded Salvage (number of individuals)
2009 Dry	0
2010 Below Normal	0
2011 Wet	4 (1 individual)
2012 Below Normal	0
2013 Dry	8 (2 individuals)
2014 Critical	0
2015 Critical	0
2016 Below Normal	0
2017 Wet	0



Grimaldo et al. in prep

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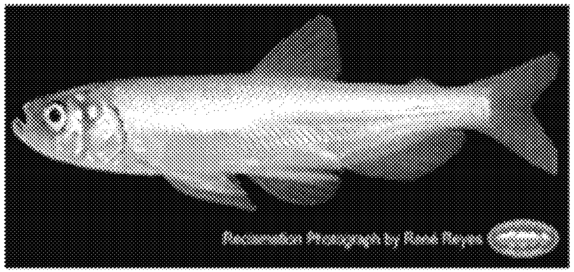
New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

Delta Smelt

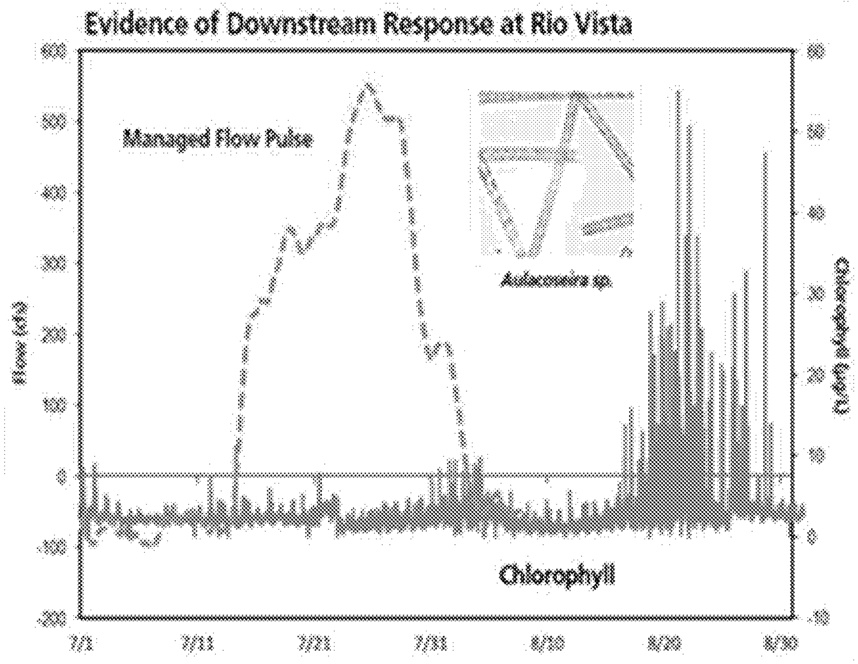

Reclamation Photograph by René Reyes

Effects Considered

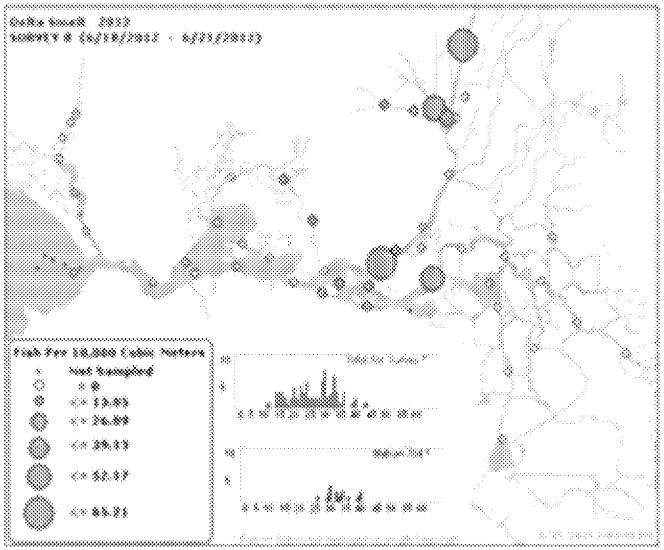
1. North Delta lower trophic food enhancements
2. Fall X_2
3. Direct and indirect entrainment effects (Grimaldo et al. 2009)

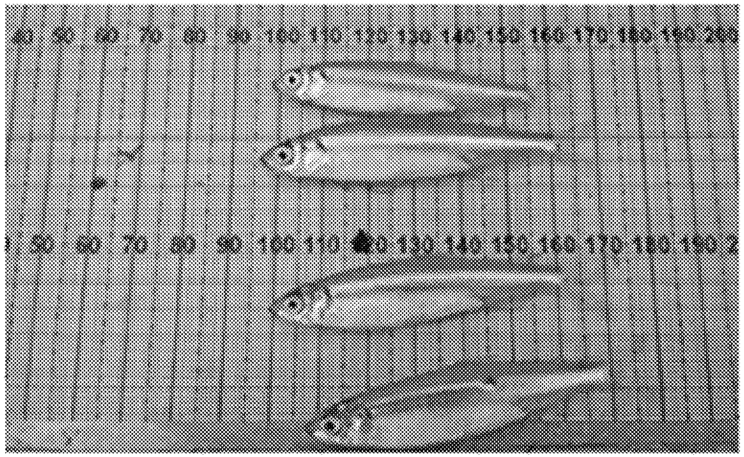
New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

North Delta lower trophic food enhancements



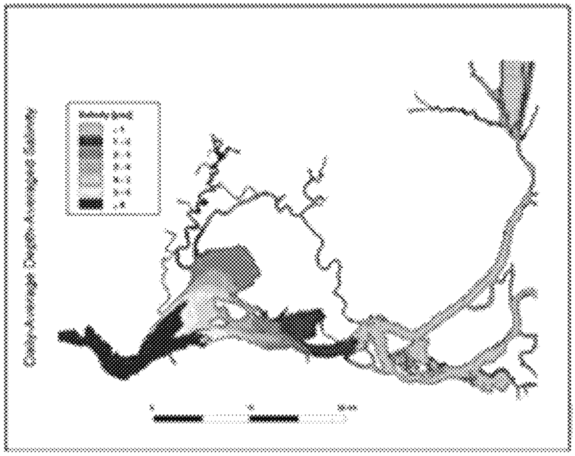
Source: California Natural Resources Agency (2017).





New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

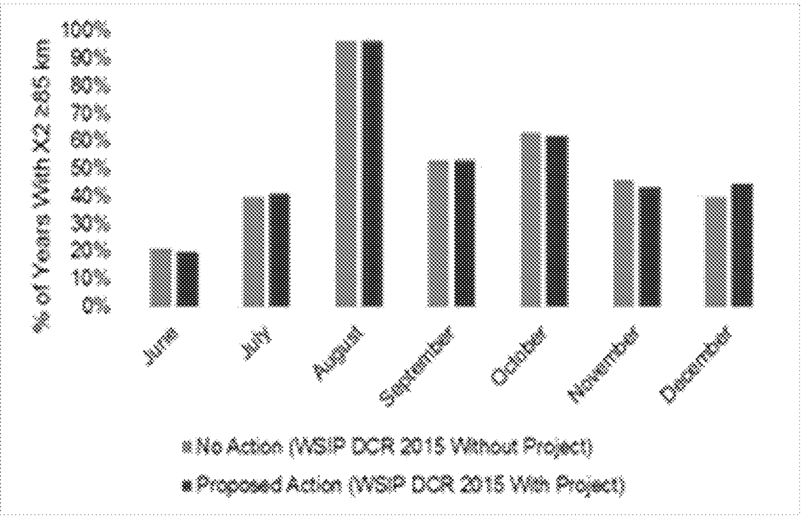
Fall X_2



Source: MacWilliams et al. 2011

Potential approaches to examine Delta Smelt entrainment fall habitat effects

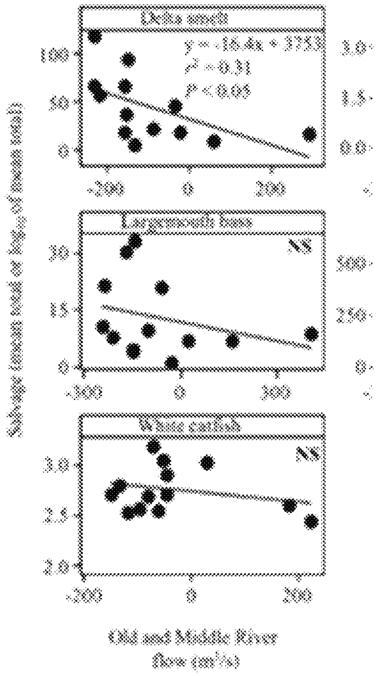
Changes in X_2(% difference)
-Examine differences in X_2 during W and AB falls (Sept-Nov)



Source: Table SQ-01-b [p.92, p.94] in Appendix C, *Modeling Results Compendium From Sites Project's Water Storage Investment Program (WSIP) Application.*

New Modeling Analysis and Tools – Delta Smelt Effects to be analyzed / considered

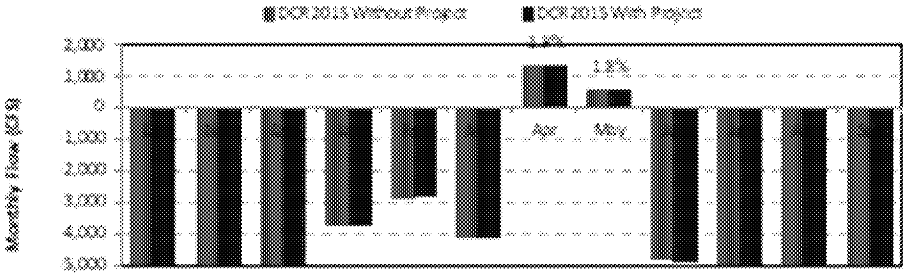
Direct and indirect entrainment effects (Grimaldo et al. 2009)



Grimaldo et al. 2009

Potential approaches to examine Delta Smelt entrainment effects

Direct entrainment (% difference in OMR)
-Juveniles (Existing salvage relationships, Apr-May)
-Adults ((Existing salvage relationships, Jan-Mar)

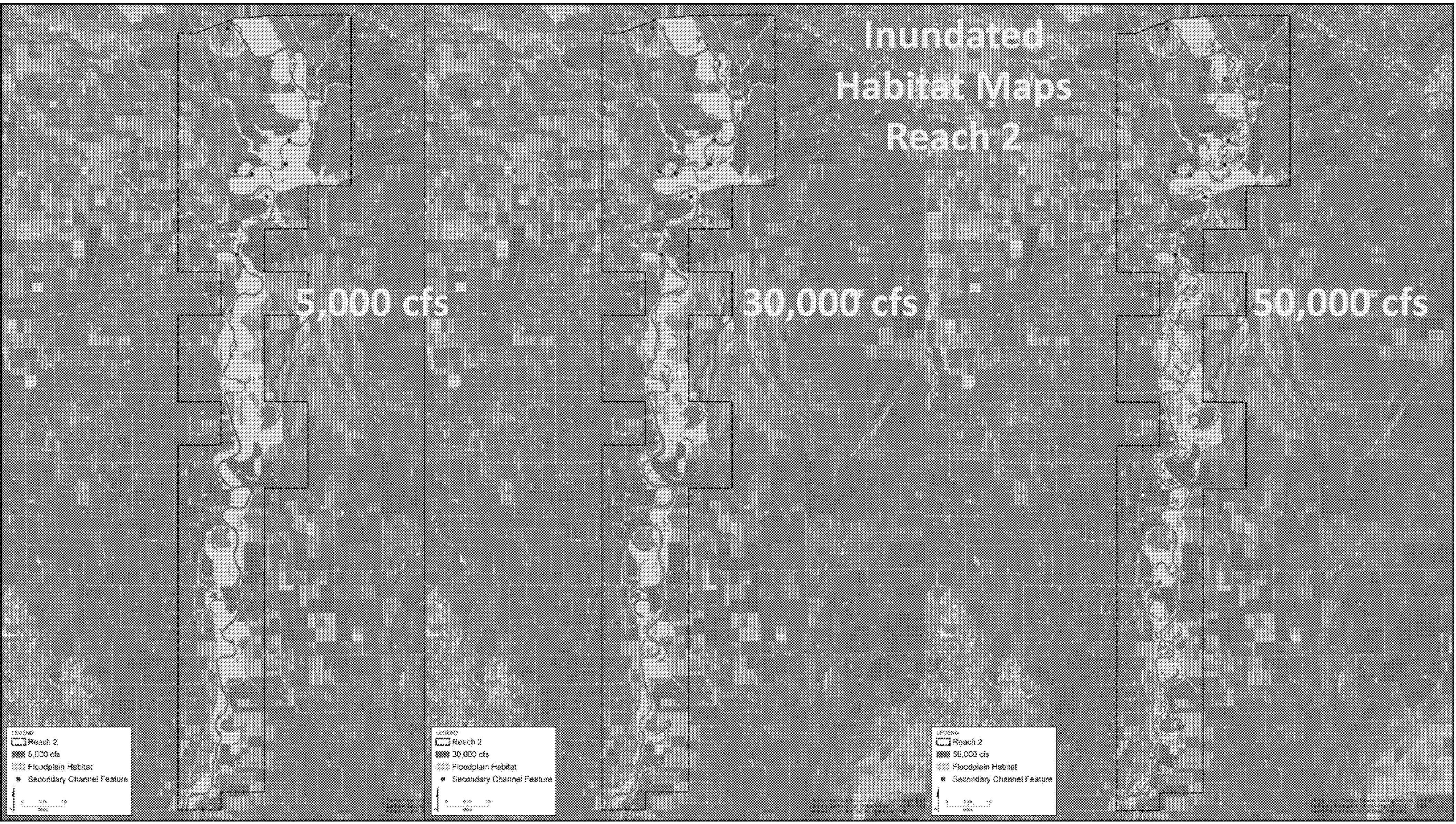


Modeling Analysis and Tools Currently Under Development

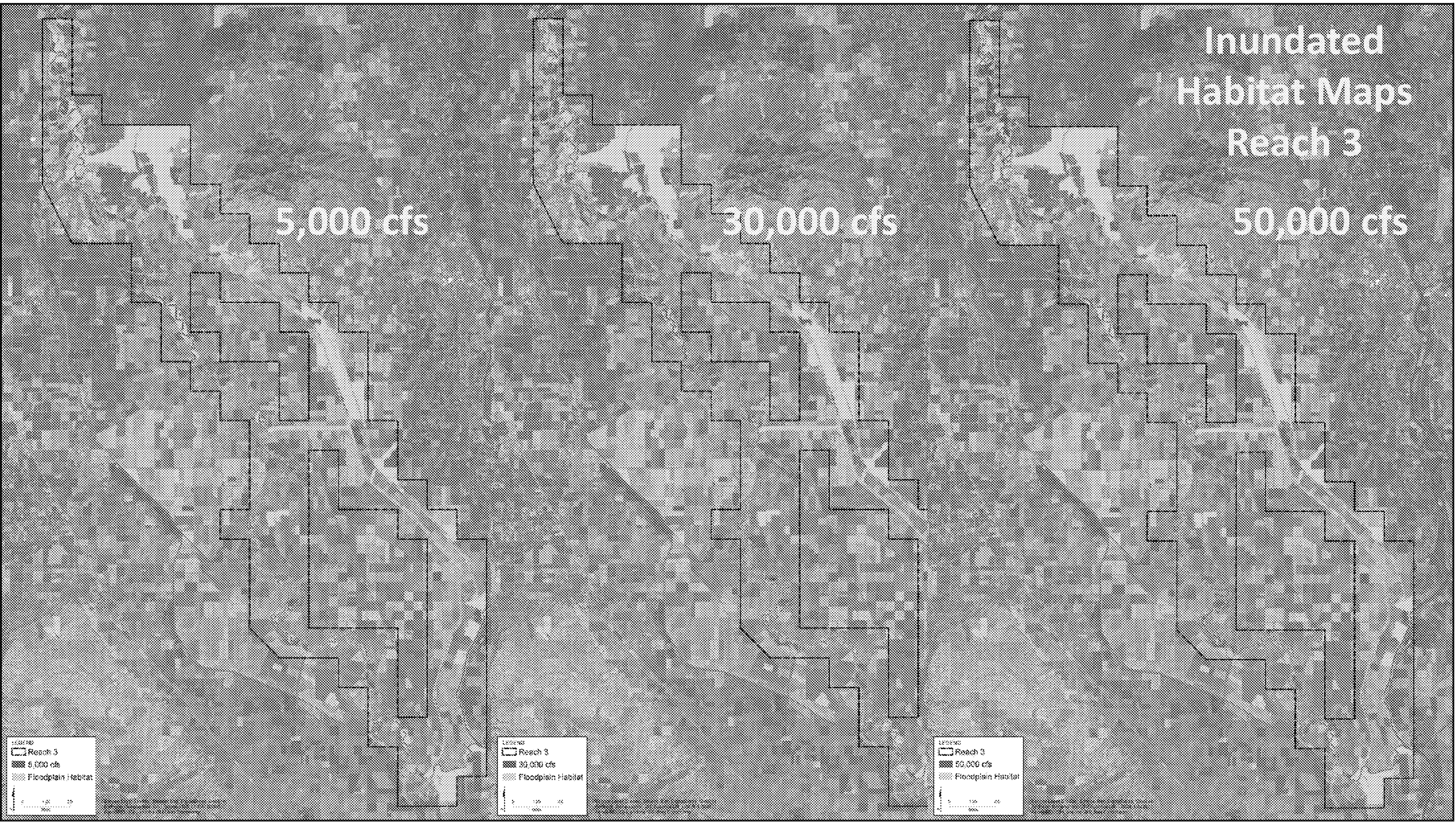
- Sacramento River Flood Plain and Off-channel Habitat Analyses
    - Identify current floodplain habitat availability along 3 reaches of the Sacramento River
    - Determine floodplain habitat characteristics that may be preferential for salmonid rearing and holding
    - Provide qualitative assessments of potential for habitat improvement opportunities associated with Sites

Transition to Rob Tull's Slides

Inundated Habitat Maps Reach 2

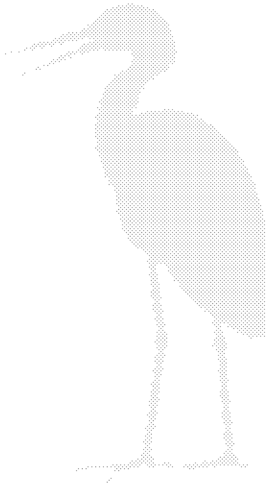


Inundated Habitat Maps Reach 3




River Flow
5,000 cfs
15,000 cfs
25,000 cfs
35,000 cfs
50,000 cfs
Habitat
Annual Grassland
Bare Gravel and Sand
Marsh - non-tidal
Riparian Forest
Riparian Scrub
Seasonal Wetland
TNC 191.7R
TNC 191L
TNC 189R
TNC 189.5L
TNC_187.0R

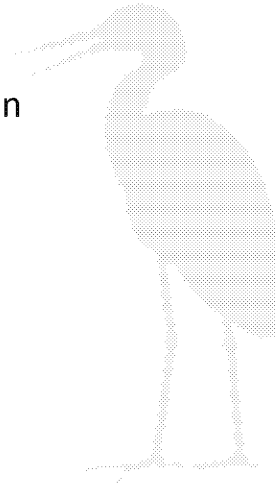
Daily Modeling Evaluation of Sites Reservoir Operations



Sites

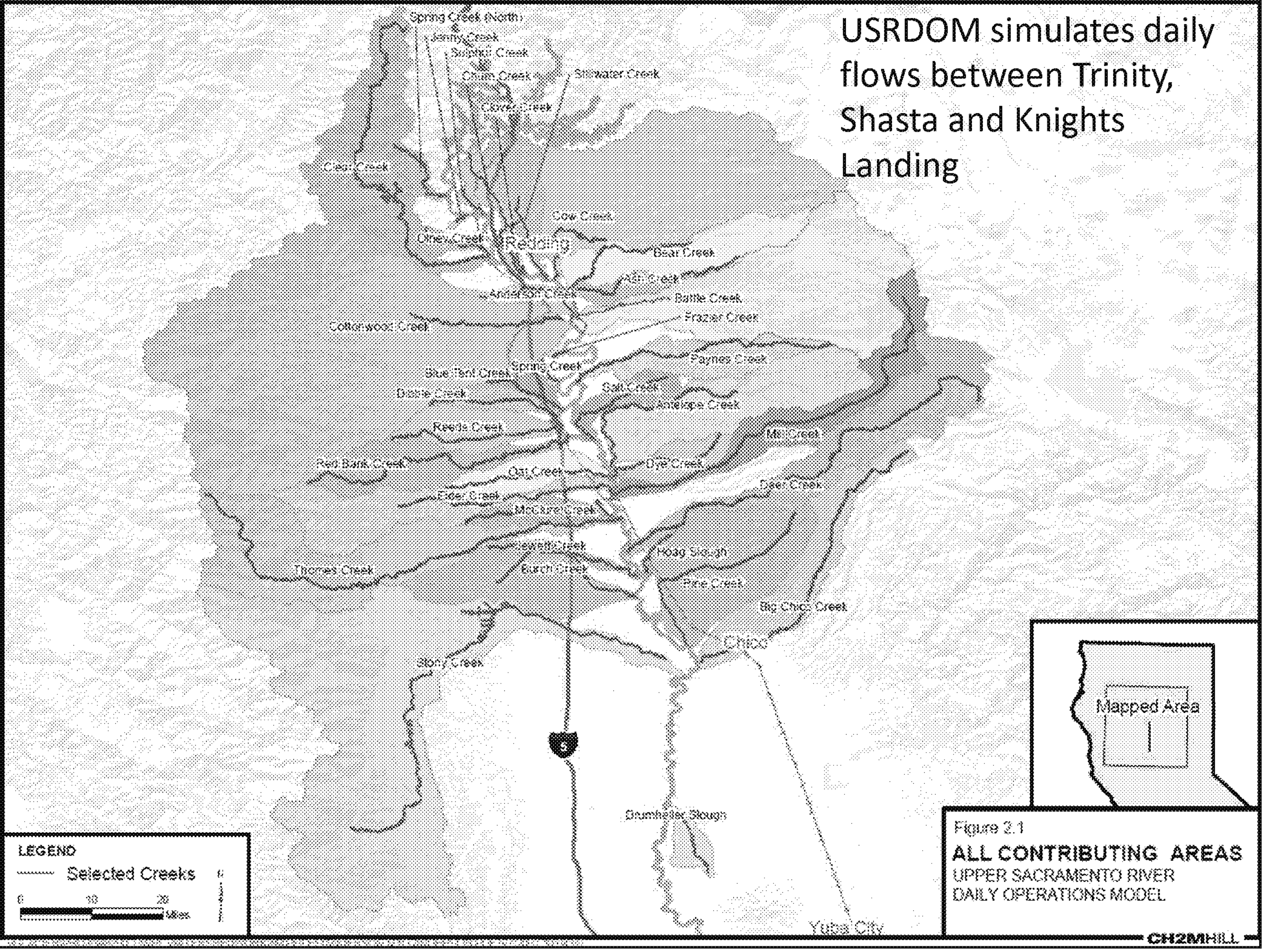
Daily Modeling for Sites Project

- A set of daily modeling tools has been developed to evaluate flow available for potential diversion to the proposed Sites Reservoir under a range of hydrologic conditions and operations criteria
- These tools can be used to:
  - Support further understanding of the interactions of Sites Project with flow conditions in the Sacramento River and Delta
  - Evaluate the affect of various flow regulations, facility constraints, and operation criteria on flow availability for the Sites Project



Daily Model - USRDOM

- Upper Sacramento River Daily Operations Model
- Simulates daily flow conditions in the Upper Sacramento River based on operations specified by CalSim II
- Can be used to evaluate Sites Reservoir benefits
- Original hydrology dataset included 82-year period from WY 1922 to WY 2003 using available historical gage records and operations data



USRDOM simulates daily flows between Trinity, Shasta and Knights Landing

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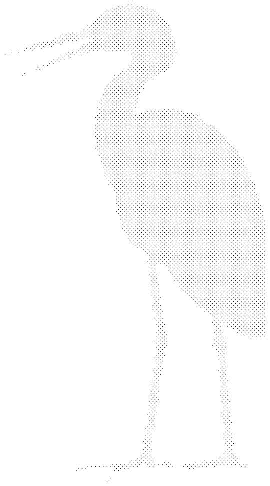
Daily Flow Characterization

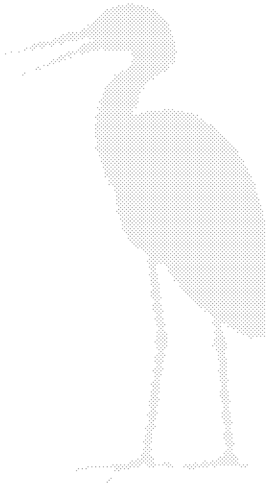
1. Characterize daily flows subject to hydrology and regulatory requirements for October 1st, 2008 – May 31st, 2018
    - Period consistent with implementation of NMFS's RPA from the 2009 BiOp
2. Characterization uses historical records and accounting for current flow requirements
    - Delta balance conditions from COA reports
    - Term 91 conditions
    - Delta outflow requirements
    - Export/Inflow ratio constraint
    - San Joaquin River exports
    - Health and safety requirements
    - Fall X2
    - Spring X2
    - Jersey Point, Emmaton, Rio Vista water quality standards



Historical Data Compilation

1. USGS Daily Flow
    - American River at Fair Oaks
    - Sacramento tributary flows
2. CDEC Daily Data
    - San Luis storage from WY 2007 through May 2018
    - Feather River flow
3. Reclamation Data

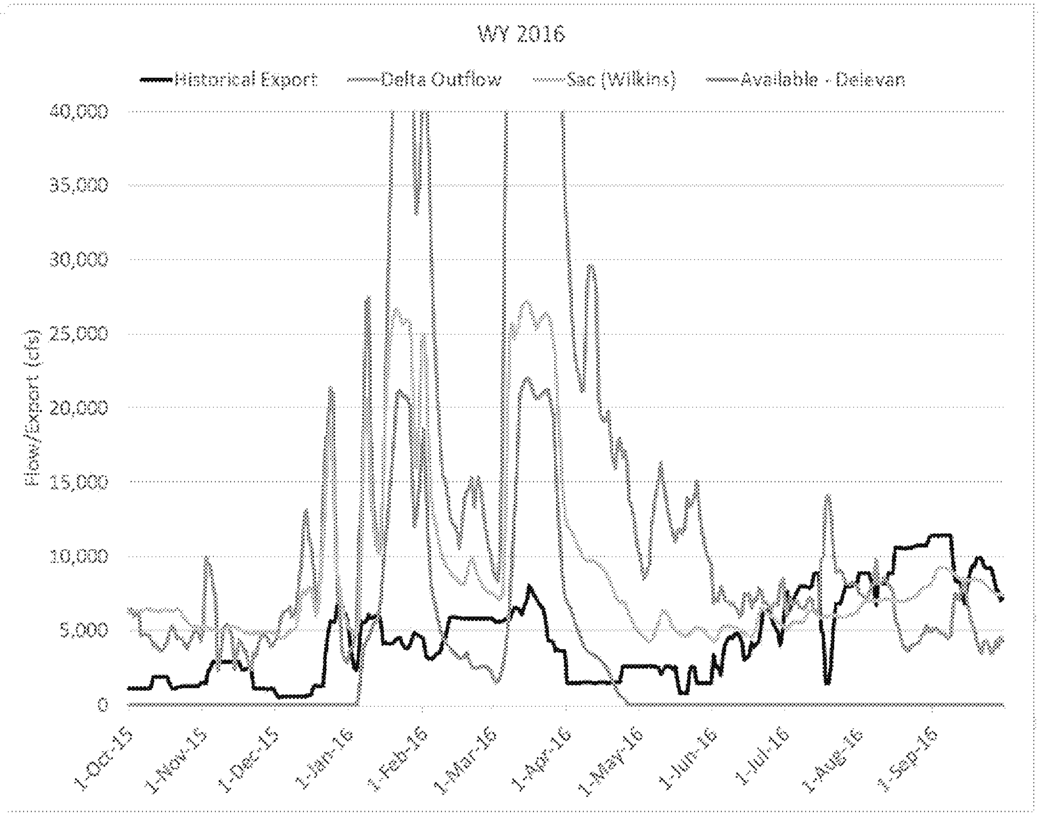
- CVO COA Reports from WY 2008 through November 2017
- Dayflow from WY 2008 through WY 2017

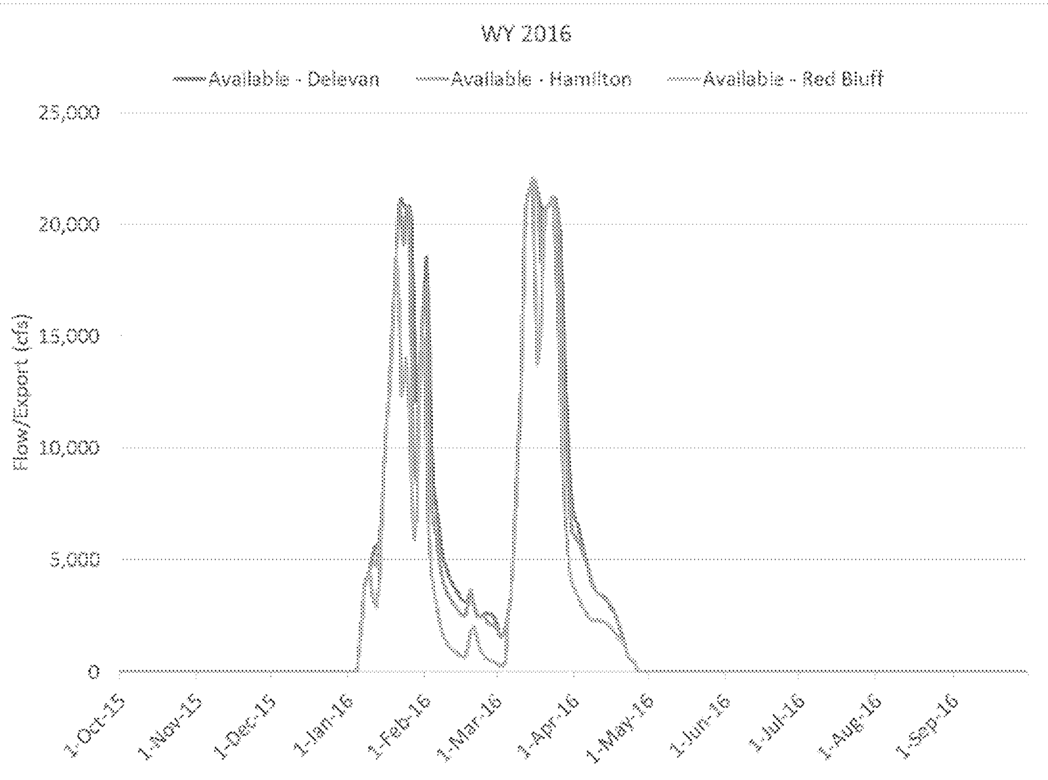


Historical Data Compilation

1. Delta Operations for Salmonids and Sturgeon (DOSS) meeting summaries from January 2009 through June 15th 2018
2. Smelt Working Group (SWG) meeting summaries from January 2009 through June 15th 2018
3. Delta Assessment Team (DAT) Summaries from January 2009 through June 15th 2018
4. Water Operations Management Team (WOMT) from January 2009 through June 15th 2018
5. SWRCB Term 91 indicator data from January 2007 through May 2018

Daily Flows – Example





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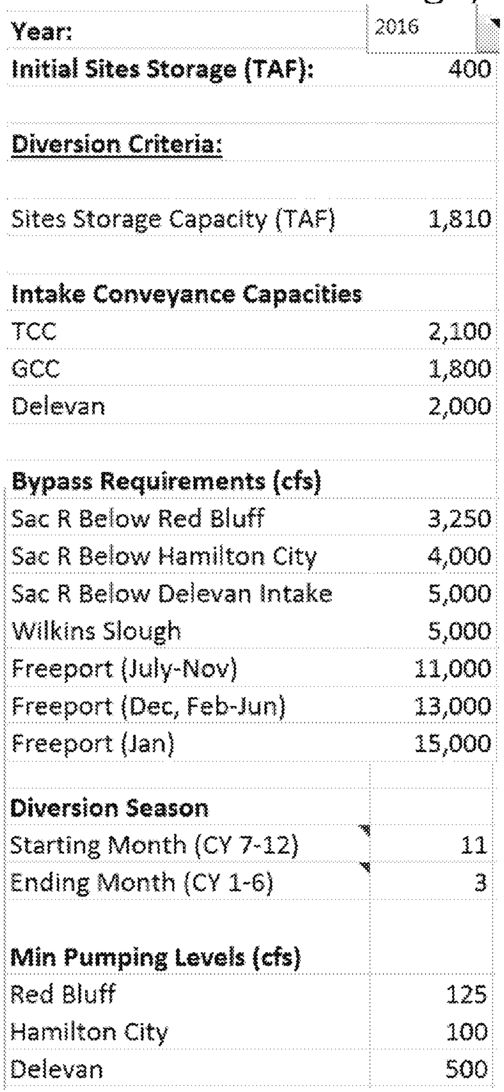
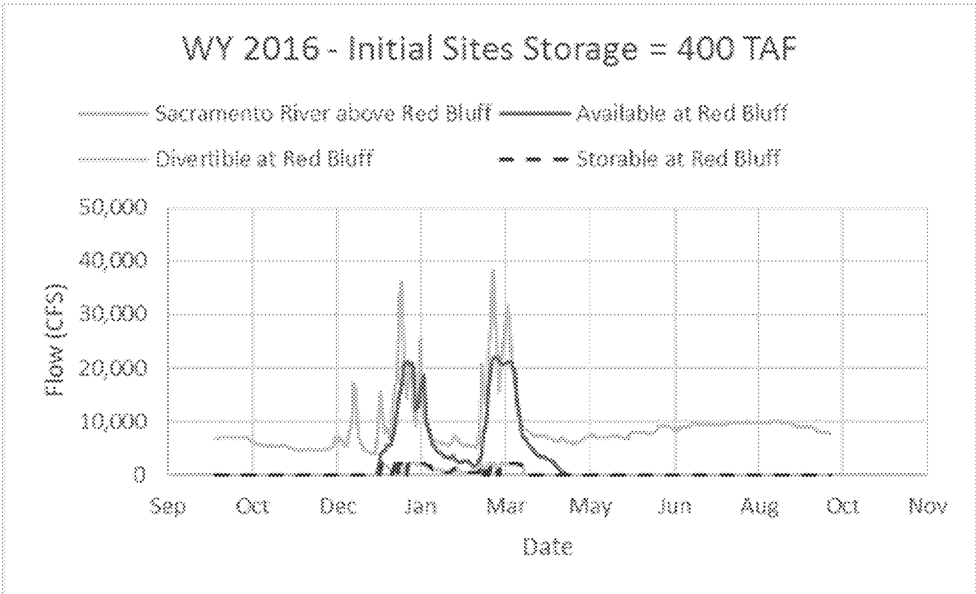
Sites

Example 1 (2016 hydrology with low initial Sites storage)

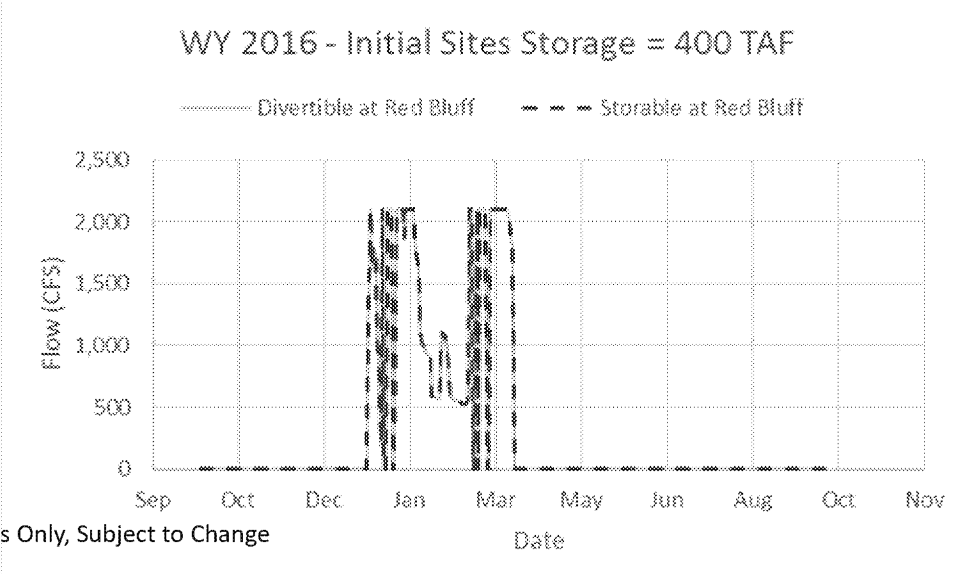


Year:	2016
Initial Sites Storage (TAF):	400
Diversion Criteria:	
Sites Storage Capacity (TAF)	1,810
Intake Conveyance Capacities	
TCC	2,100
GCC	1,800
Delevan	2,000
Bypass Requirements (cfs)	
Sac R Below Red Bluff	3,250
Sac R Below Hamilton City	4,000
Sac R Below Delevan Intake	5,000
Wilkins Slough	5,000
Freeport (July-Nov)	11,000
Freeport (Dec, Feb-Jun)	13,000
Freeport (Jan)	15,000
Diversion Season	
Starting Month (CY 7-12)	11
Ending Month (CY 1-6)	3
Min Pumping Levels (cfs)	
Red Bluff	125
Hamilton City	100
Delevan	500

Hydrology, availability, divertibility, and storability at Red Bluff intake:



Zoomed in on Divertible and Storable Flow:



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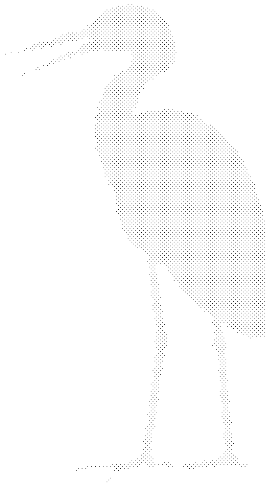
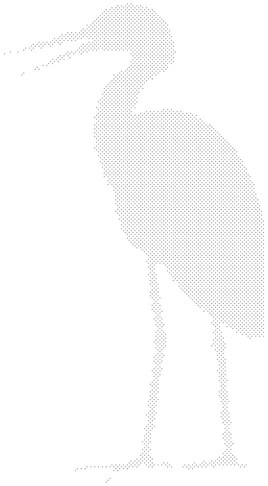
Ability to Evaluate Multiple Scenarios

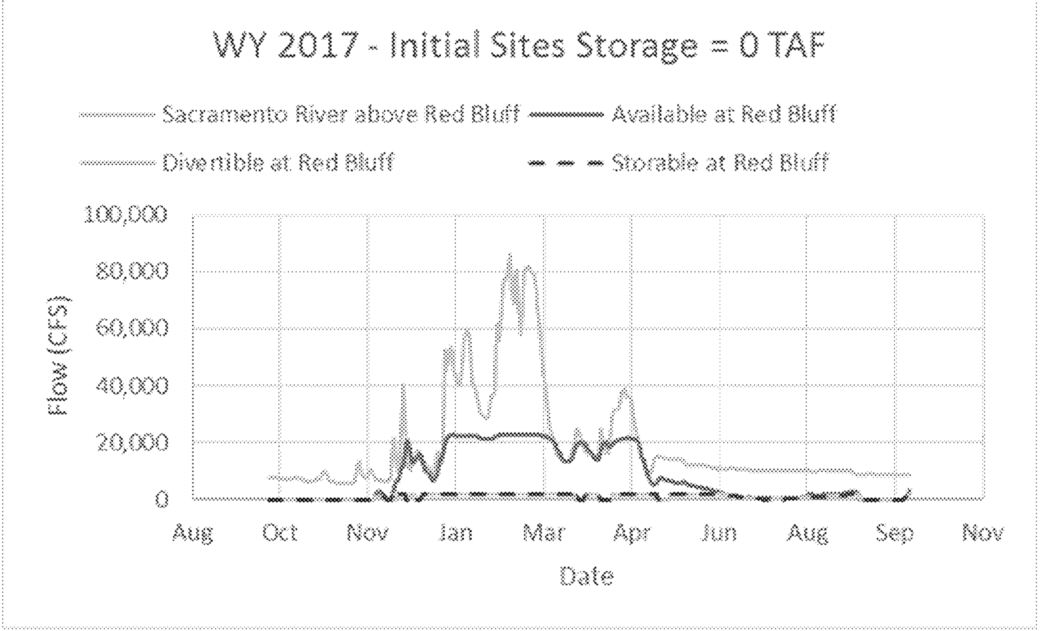
- A macro is built into the spreadsheet tool to iterate through multiple combinations of varying inputs and constraints
- The inputs and outputs from each scenario can be fed into Power BI to sift through the data and analyze relationships between the inputs (i.e., minimum pumping levels or bypass flow requirements) and outputs (i.e., Divertible and Storable flows)
  - Power BI is a business analytics service developed by Microsoft. It provides a platform for interactive visualizations of data



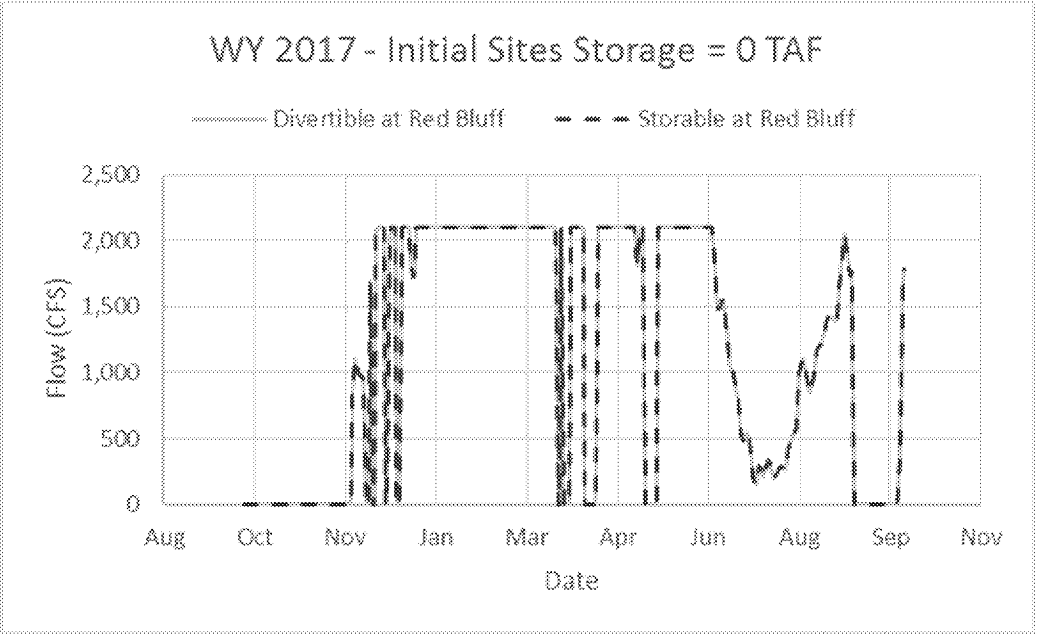
Example WY 2017 (Wet)



Red Bluff Intake (TCC) – WY 2017 (W)



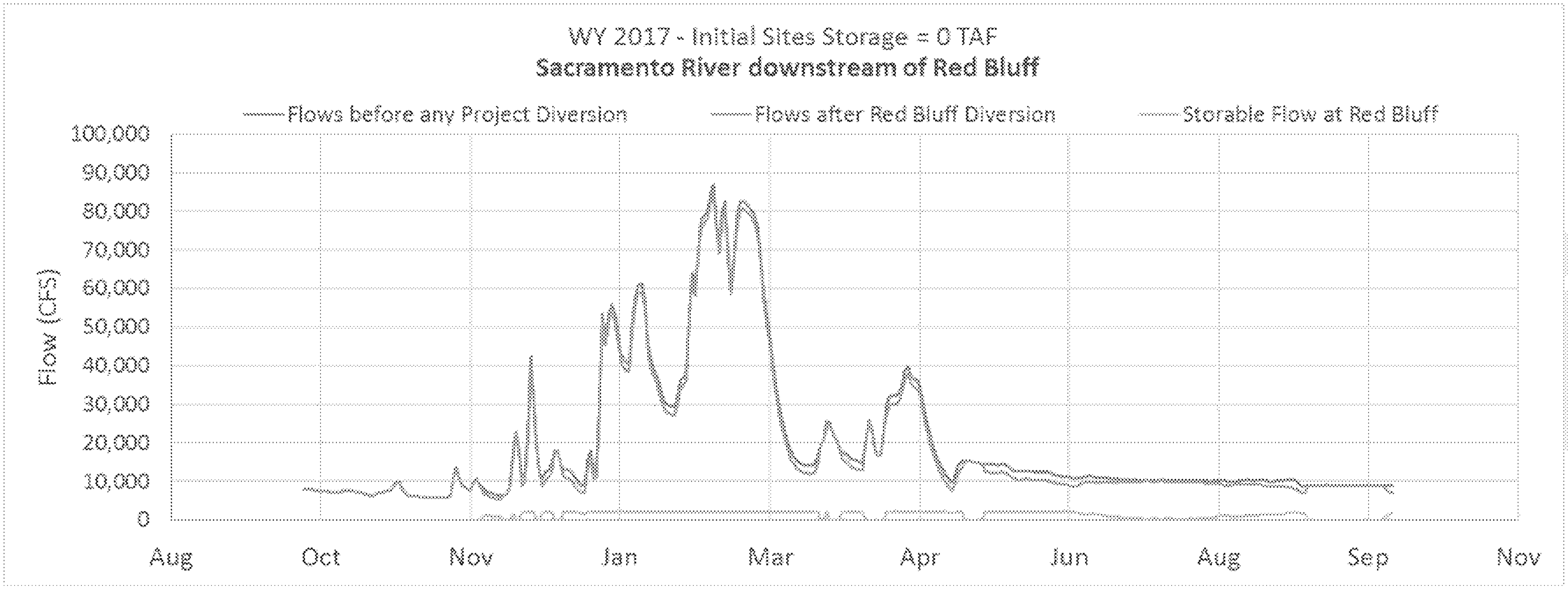
WY 2017 - Initial Sites Storage = 0 TAF



WY 2017 - Initial Sites Storage = 0 TAF

Sites

Red Bluff – WY 2017 (W)



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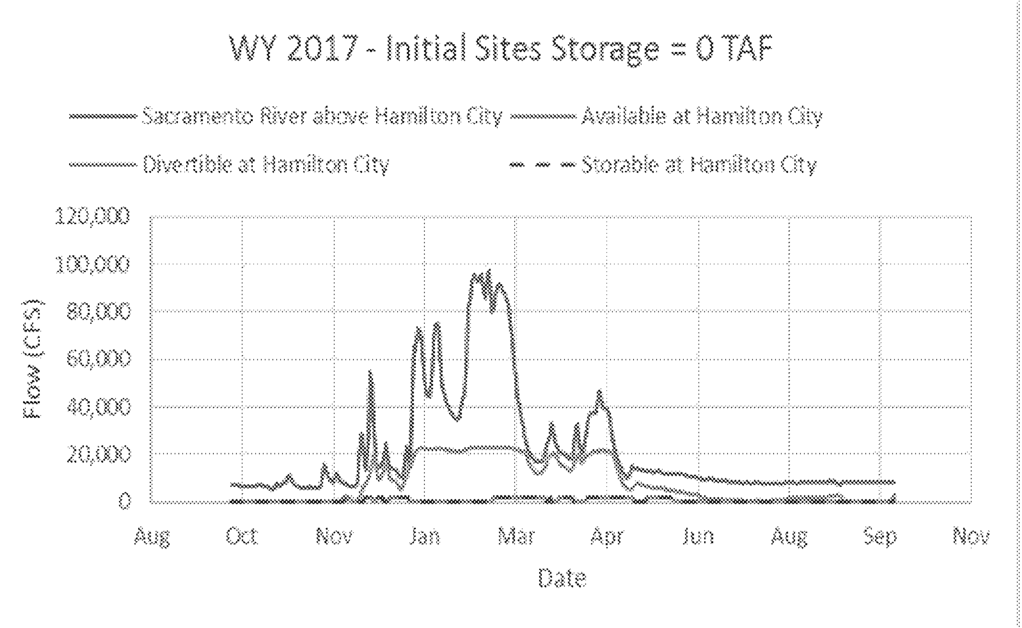
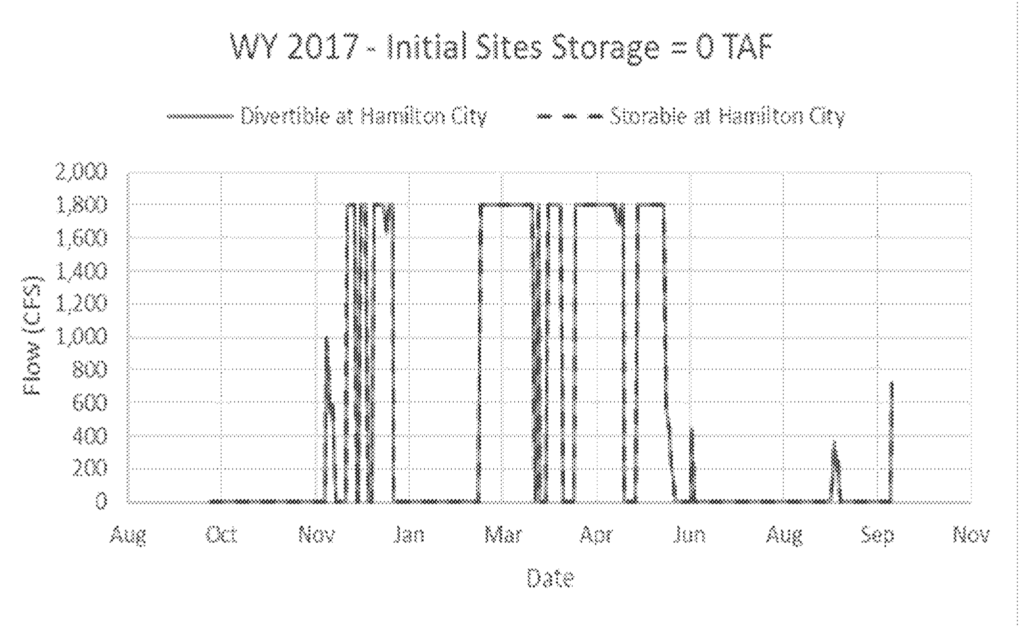
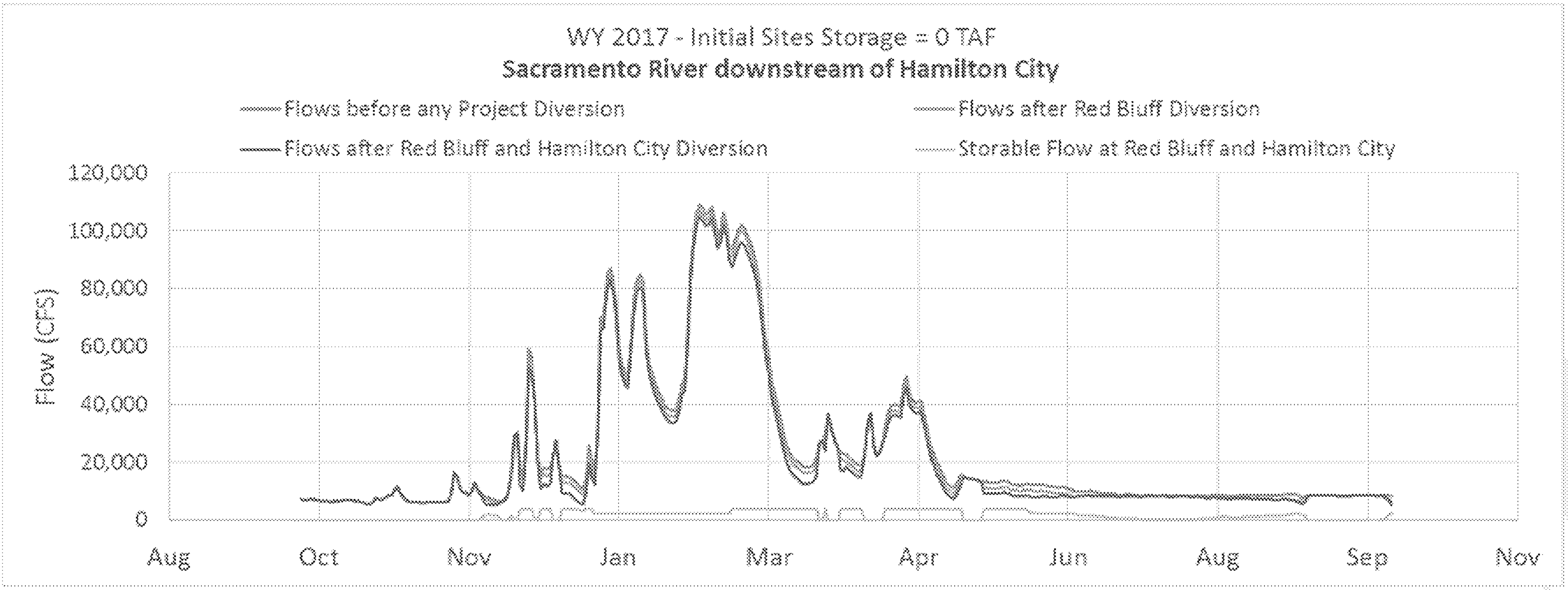
Hamilton City Intake (GCC) – WY 2017 (W)





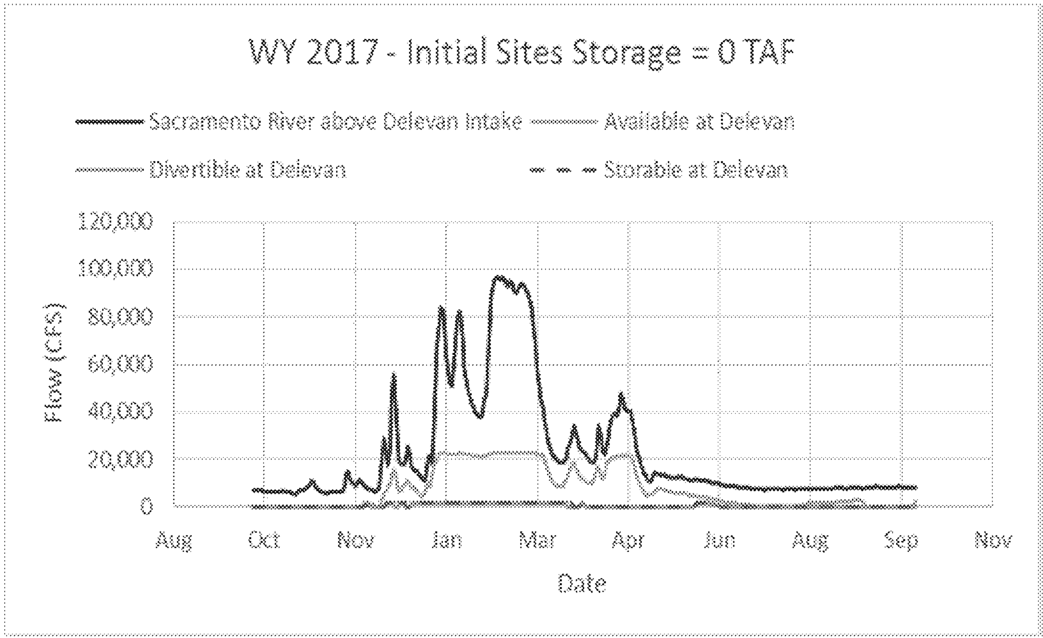
Draft, For Discussion Purposes Only, Subject to Change

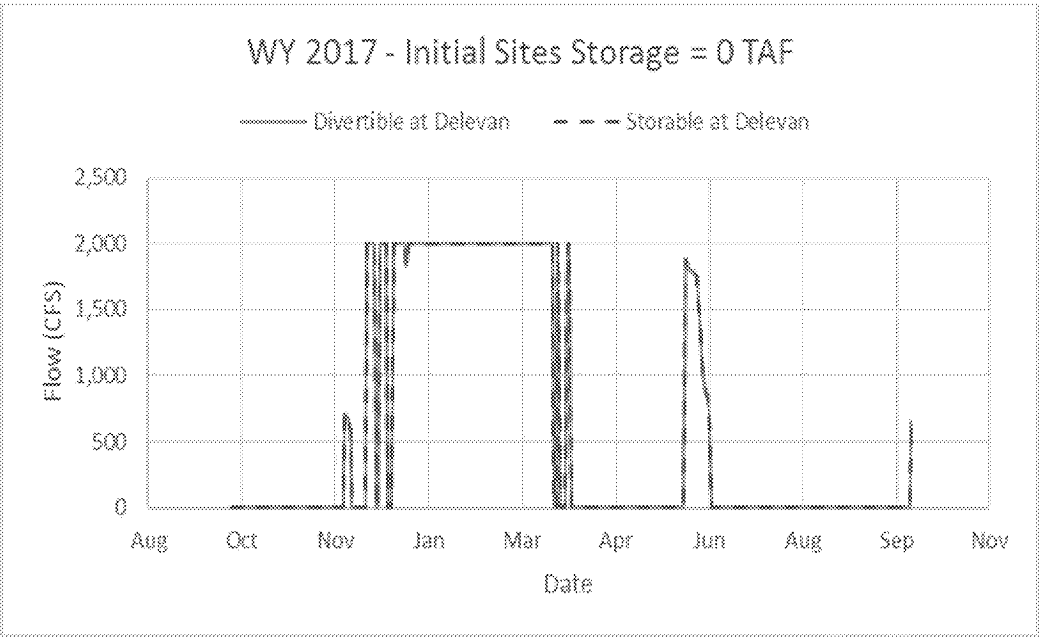
Hamilton City – WY 2017 (W)



Draft, For Discussion Purposes Only, Subject to Change

Delevan Intake – WY 2017 (W)

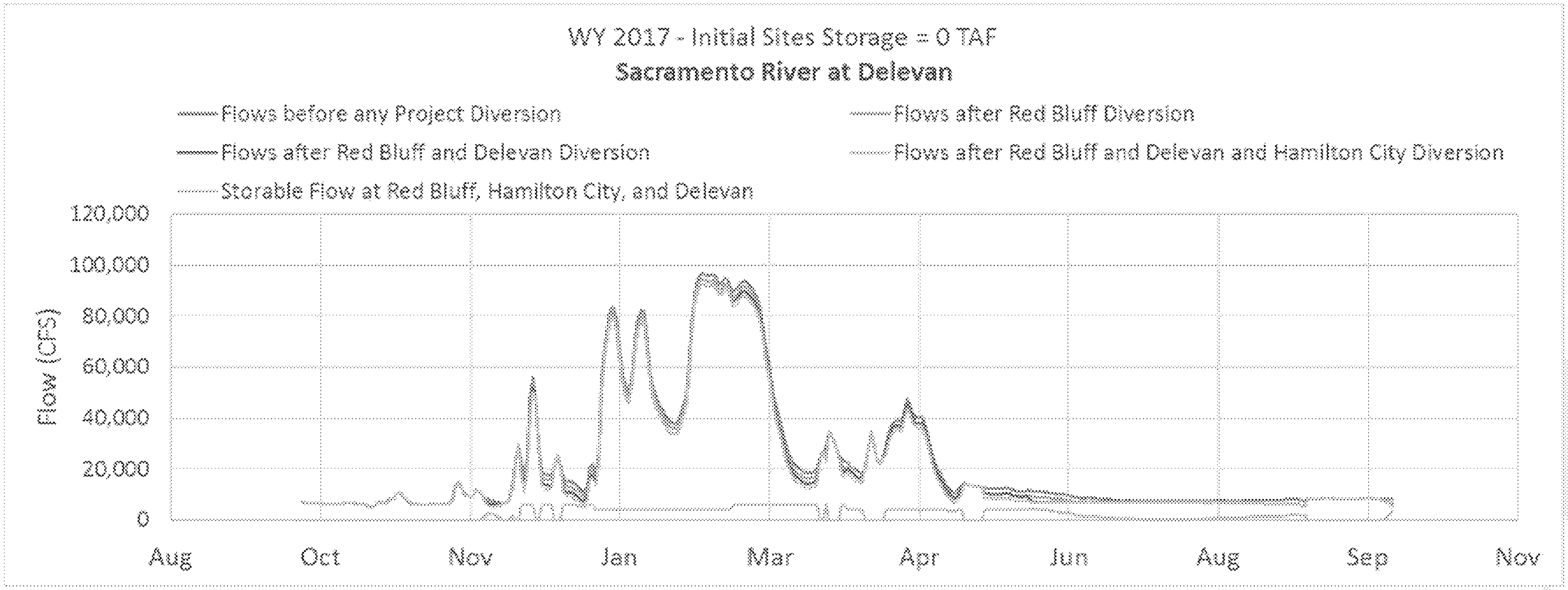

WY 2017 - Initial Sites Storage = 0 TAF


WY 2017 - Initial Sites Storage = 0 TAF

Draft, For Discussion Purposes Only, Subject to Change

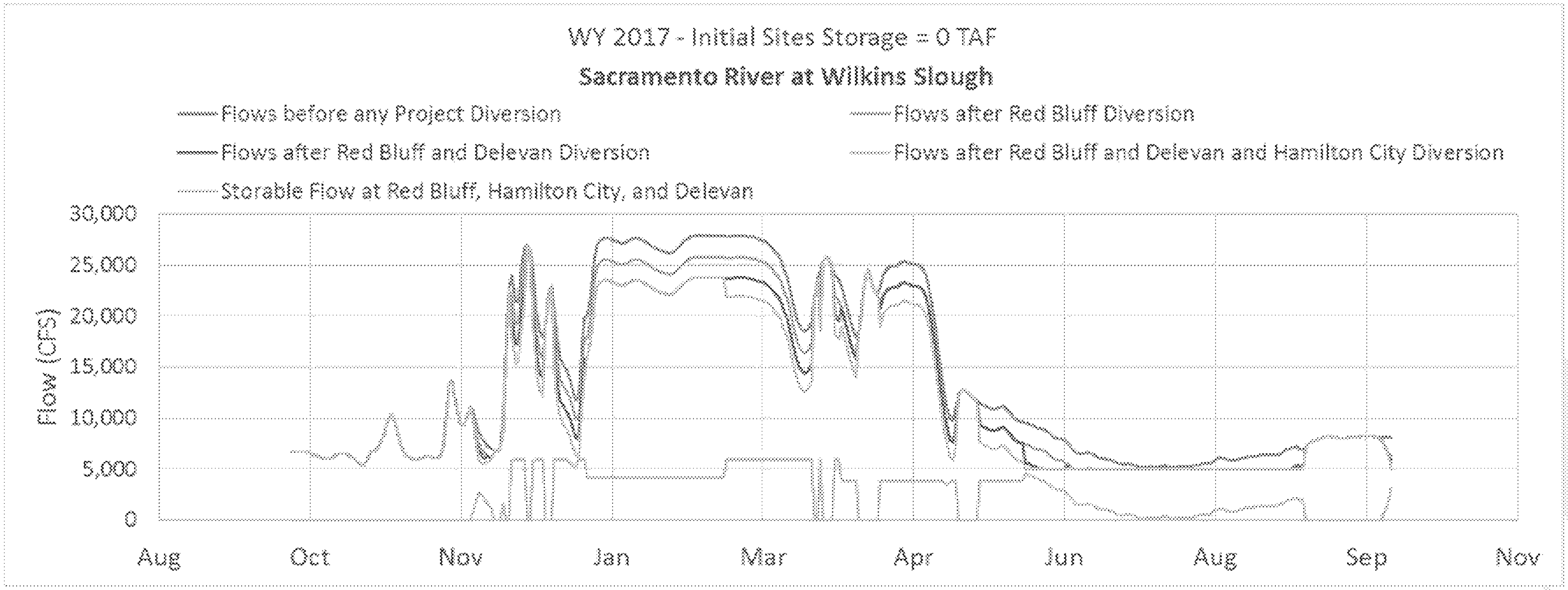
Sites

Delevan – WY 2017 (W)



Draft, For Discussion Purposes Only, Subject to Change

Wilkins Slough – WY 2017 (W)



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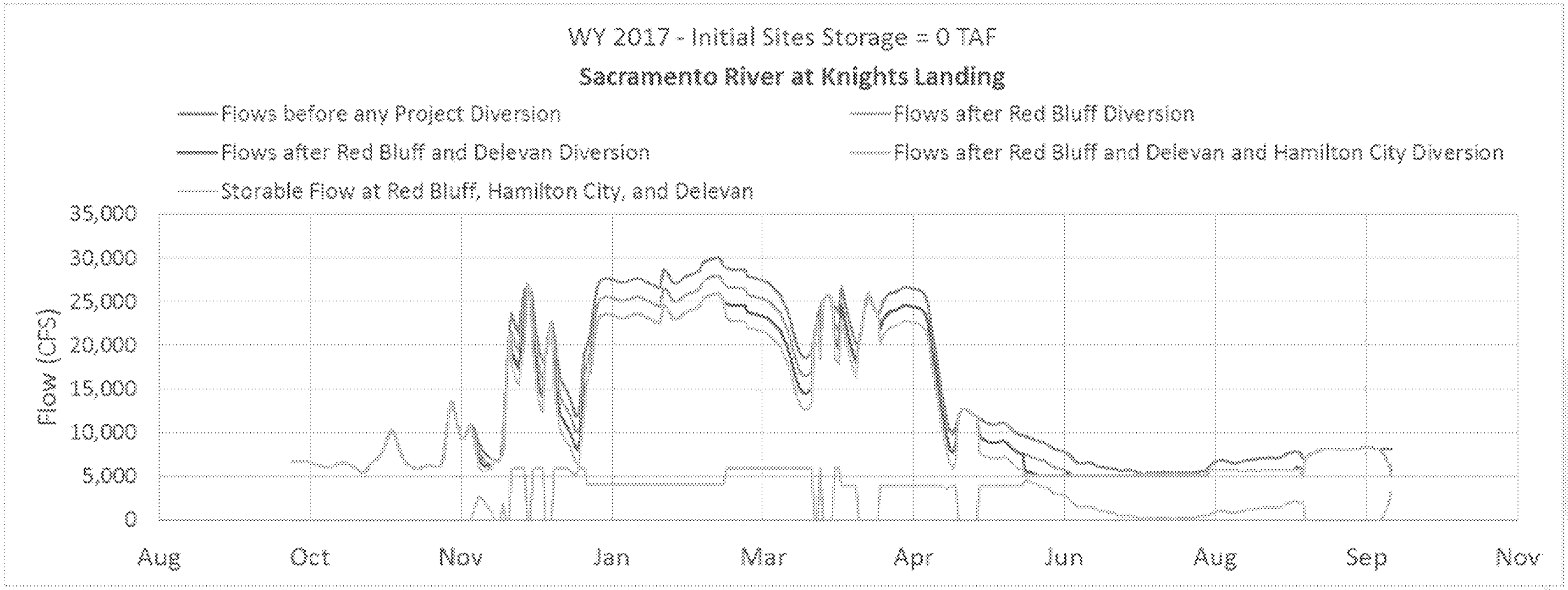
Knights Landing – WY 2017 (W)



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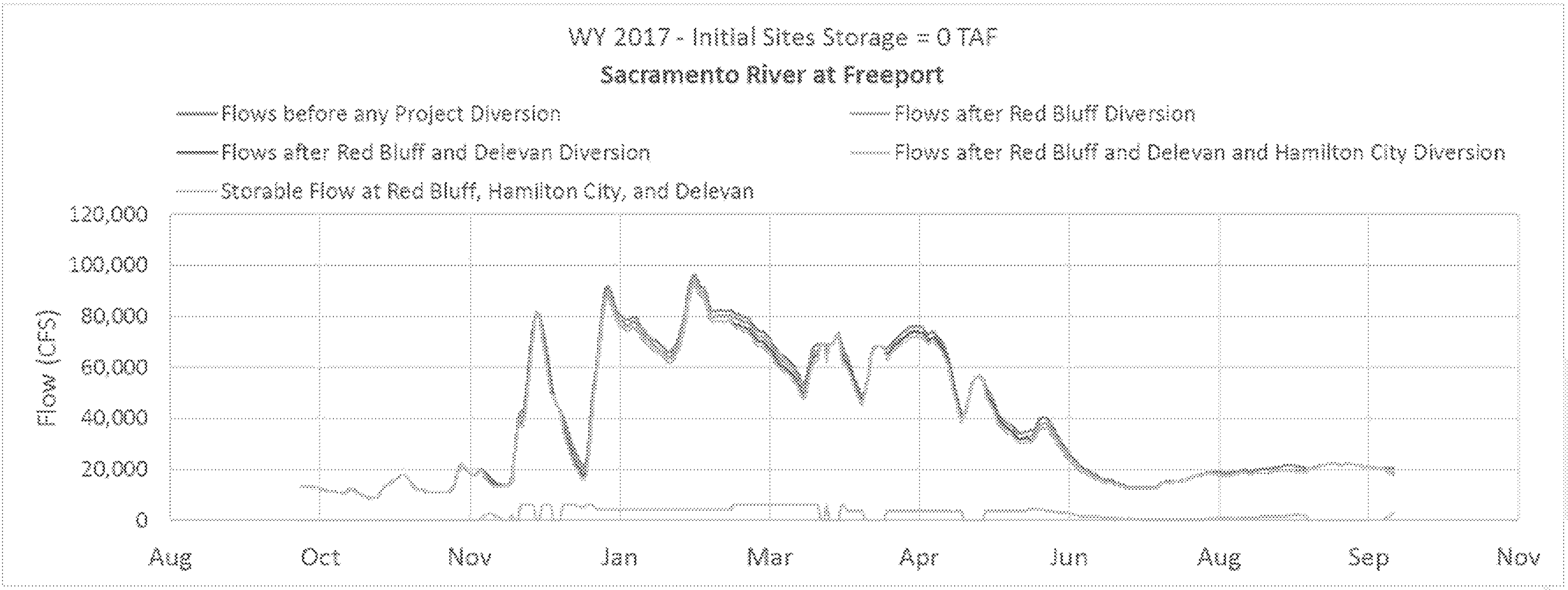
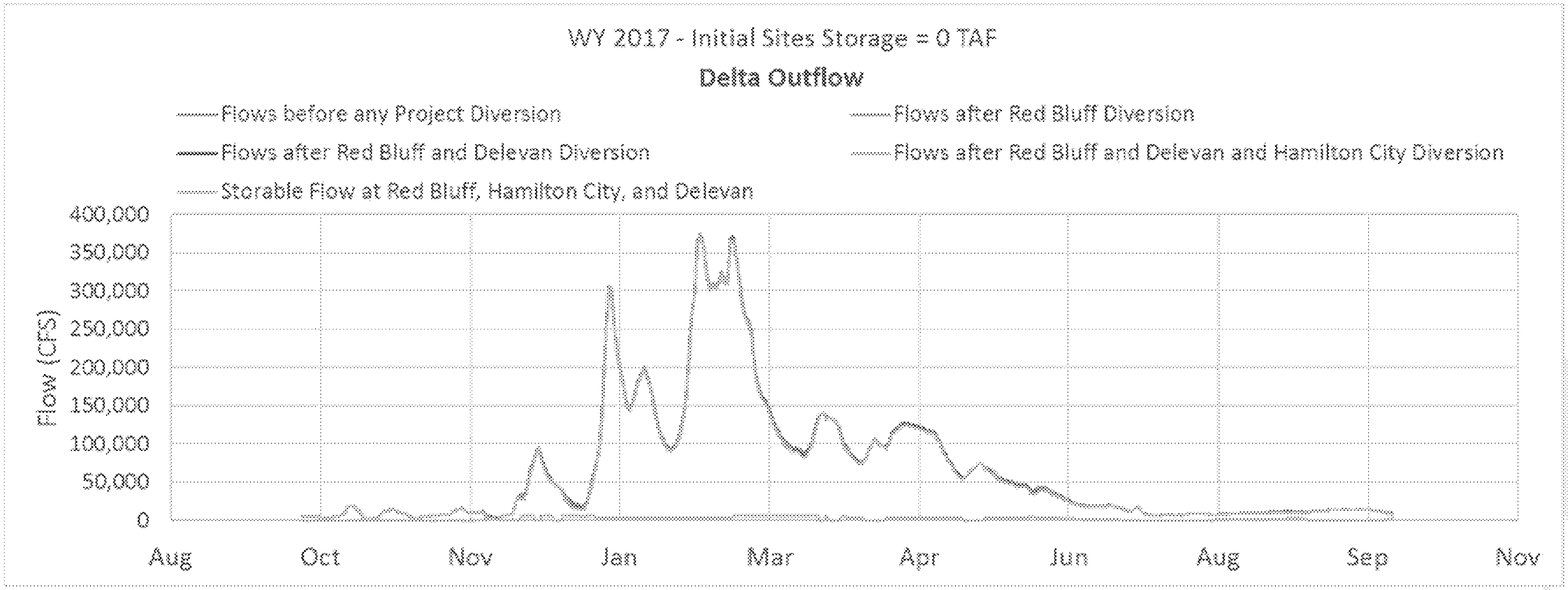
Freeport – WY 2017 (W)



Draft, For Discussion Purposes Only, Subject to Change

Delta Outflow – WY 2017 (W)



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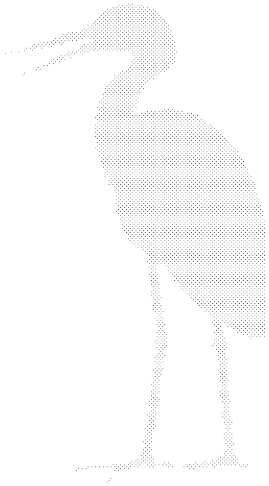
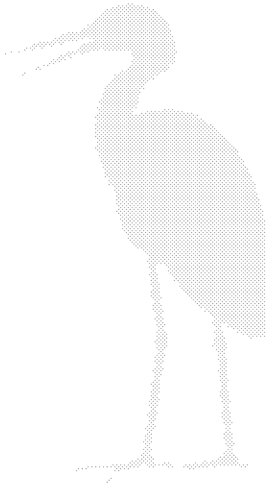
X2 Position - WY 2017

Reservoir Water Quality and Temperature Modeling



Sites Reservoir 2D Water Quality Model

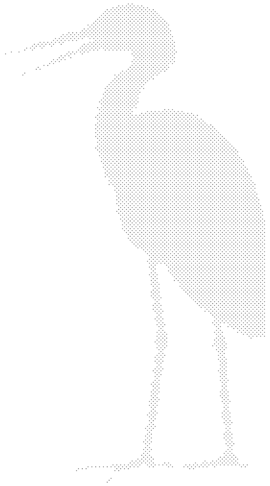
1. The US Army Corps of Engineers CE-QUAL-W2 computer model is being applied to Sites Reservoir to evaluate water quality in reservoir releases for a range of operational scenarios.
2. The CE-QUAL-W2 model simulates lake water quality in two dimensions, assuming the lake is well mixed laterally.
3. Model inputs include bathymetric data, inflows and outflows, meteorological data, water quality in inflows, and initial water quality conditions in the lake.



Sites

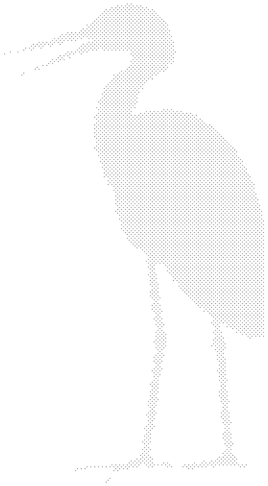
Sites Reservoir 2D Water Quality Model

- High resolution topographic data (2 ft contours) collected by DWR
- Developed model grid for CE-QUAL-W2 model with 128 2' layers and 36 lateral segments.
- Obtained hourly meteorological data from California Irrigation Management Information System (CIMIS) for Durham, California (temperature, wind, solar radiation) and from Yuba City Airport (cloud cover).
- Developed hourly meteorological input for representative 12 year period 2007-2018.
- Obtained water quality data for Sacramento River stations near water intakes.
- Utilize data from other nearby reservoirs.



Water Quality Model Implementation

- Analysis will focus on temperature and dissolved oxygen, but will also include evaluation of other parameters (to the extent possible) including pH, sedimentation, nitrogen and phosphorus concentration, and algal biomass.
- Will be used in conjunction with the daily river operations model to evaluate water quality operations over a range of hydrologic and operating conditions.
- Evaluate withdrawal capability of reservoir outlet structure to make releases to meet river temperatures.



Mitigation Brainstorming

- Maximizing Ecological Benefits
  - Add resiliency to the species
  - Contribute to recovery
- Restoration Project Opportunities
  - River Partners
  - Voluntary Agreements
- Onsite / Offsite Compensatory Mitigation
  - Land Acquisition and Restoration
  - Land Acquisition and Protection of Existing Habitat (Conservation Easements)
  - Restoration/Enhancement of Protected Lands

Draft, For Discussion Purposes Only, Subject to Change

Action Items and Next Steps

- Continued Dialogue
  - Topics?
- Action Items

Draft, For Discussion Purposes Only, Subject to Change

From: Whittington, Chad/SAC [Chad.Whittington@jacobs.com]
Sent: 10/4/2019 12:03:24 PM
To: Leaf, Rob/SAC [Rob.Leaf@jacobs.com]
CC: Tull, Robert/SAC [Robert.Tull@jacobs.com]; Thayer, Reed/SAC [Reed.Thayer@jacobs.com]
Subject: RE: Pulse and Post-Pulse Logic Used in CalSim (from Appendix 5.A of the 2016 CWF BA Effects Analysis)

Flag: Follow up

The table below showcases the similarities and differences between the CWF ITP and CalSim in the determination of pulse and post-pulse rules.

Pulse and Post-Pulse Assumptions	
CWF ITP	**CalSim II**
· All pulses of CHNWR and CHNSR shall be protected from October 1 – June 30.	• One or two pulses shall be protected from October 1 – June 30 (depending on whether a pulse ends before December 1) .
· Beginning October 1st, whenever the initial Sacramento River pulse begins, low level pumping takes effect.	• Beginning October 1st, whenever the initial Sacramento River pulse begins, low level pumping takes effect.
• Sacramento River pulse is determined based on real-time monitoring of juvenile fish movement (see Condition of Approval 9.9.5.1). A fish pulse is defined as a Knights Landing Catch Index (KLCI) ≥ 5 where KLCI = (# of CHNWR + # of CHNSR)/(Total Hours Fished/24). • Pulse protection operations shall be implemented within 24 hours of detection of a fish pulse.	• The initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs.
• Pulse protection ends after five consecutive days of daily KLCI < 5.	• The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days.
• Number of allowable pulses is not specified; ASSUME ALL ELIGIBLE PULSES (KLCI ≥ 5) ARE PROTECTED.	• If the initial pulse begins and ends before December 1st, a second pulse period will be afforded the same protective operation.
• Once the pulse protection ends, post-pulse bypass flow operations may remain at Level 1 diversion depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of diversions.	• After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection.
• The criteria for transitioning between and among pulse-protection, Level 1, Level 2, and/or Level 3 operations described in this permit will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the Project's Adaptive Management Program. Based on the outcome of the studies pursued under that program, additional information about appropriate triggers, off-ramps, and other RTO management of NDD intake operations may be integrated into the Test Period Operations Plan and the Full Project Operations Plan.	• After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied.

• The NDDTT shall develop criteria for transitioning between and among pulse protection, Levels 1, 2 and 3 based on best available science. The NDDTT shall recommend transitional criteria to the TOT and IICG for consideration through the Adaptive Management Program, to ensure that the Project will achieve the objectives of Biological Criteria 1 and 2.	
	• Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules.

Chad

From: Whittington, Chad/SAC
Sent: Tuesday, October 01, 2019 3:11 PM
To: Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Thayer, Reed/SAC <Reed.Thayer@jacobs.com>
Subject: Pulse and Post-Pulse Logic Used in CalSim (from Appendix 5.A of the 2016 CWF BA Effects Analysis)

Appendix 5.A of the 2016 CWF BA is at this link.

Here is the relevant excerpt (from the bottom of Page 30).

"

5.A.5.2.4.9 North Delta Diversion Bypass Flows
Bypass flows requirements in the Sacramento River are specified downstream of the north Delta diversion intakes, which govern the flow required to remain in the river before any diversion can occur. The bypass rules include low level pumping at each intake during Sacramento River Pulse flow(s) period. After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection (Level I to Level II and subsequently to Level III) subject to hydrologic and fishery conditions. Minimum bypass flow requirements are specified for July through November, as noted in Table 5.A-13.

Beginning October 1st, whenever the initial Sacramento River pulse begins low level pumping allows diversions of up to 6% of Sacramento River flow flow upstream of the north Delta intakes. The low level pumping is less than or equal to 300 cfs at any one intake, with a combined limit of 900 cfs for the three intakes in the PA. The low level pumping is constrained such that the river flow never falls below 5,000 cfs.

During the initial pulse protection period low level pumping is maintained until the pulse period has ended. For modeling purposes, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs. The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days. If the initial pulse begins and ends before December 1, the May Level 1 post-pulse criteria will go into effect after the pulse until December 1. On December 1, the post-pulse rules defined below for December through April, starting with Level 1 apply. If the initial pulse begins and ends before December 1st, a second pulse period will be afforded the same protective operation.

After the pulse period has ended, the bypass flows noted in the Table 5.A-13 are maintained. After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied. The bypass rules were applied on the mean daily river flows in the CalSim II model. Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules. In actual operations these criteria as well as fishery conditions are expected to guide allowable north Delta intake diversions as described in Section 3.3.3.1 of the BA.

In addition to the bypass flow criteria described above, a linear constraint was applied in the CalSim II PA simulation on the potential diversion at the north Delta intakes, to account for the fish screen sweeping velocity criteria of 0.4 fps based on diversion limitations from DSM2 modeling.
"

Chad Whittington
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Water Resources Engineer | BIAF
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2485 Natomas Park Dr., Suite 600
Sacramento, CA 95833
USA
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From: Leaf, Rob/SAC [Rob.Leaf@jacobs.com]
Sent: 10/21/2019 10:55:45 AM
To: Spranza, John [John.Spranza@hdrinc.com]; Rob Thomson [rthomson@sitesproject.org]; Alicia Forsythe [aforsythe@sitesproject.org]; Lecky, Jim [Jim.Lecky@icf.com]; Chris Fitzer [CFitzer@esassoc.com]; Tull, Robert/SAC [Robert.Tull@jacobs.com]; Thad Bettner (tbettner@gcid.net) [tbettner@gcid.net]; Jim Watson [jwatson@sitesproject.org]
CC: Thayer, Reed/SAC [Reed.Thayer@jacobs.com]
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion
Attachments: Sac_Valley WY_D-1641.pdf

A simple approach is to regulate operations assuming that the previous forecasted (50% exceedance) water year type is used until sometime in February or March of the new year at which time forecasts for the new year become reliable (spread across the range of 50% - 90% exceedance forecasts begins to narrow). That's the current approach used for Fall X2 determination.

The most critical component of a good forecast model is measuring the development of the snowpack. Snowpack coming into the new year is a strong indicator of what water year class we will be in for the new year. The more snowpack factors into the forecast the narrower the spread across the range of 50% - 90% exceedance forecasts. October through January runoff conditions are highly variable are typically not related to snowpack/snowmelt conditions. The runoff conditions in the October through January period do not reliably indicate what runoff we will see in the Spring.

Rob

From: Spranza, John <John.Spranza@hdrinc.com>
Sent: Monday, October 21, 2019 7:09 AM
To: Rob Thomson <rthomson@sitesproject.org>; Alicia Forsythe <aforsythe@sitesproject.org>; Lecky, Jim <Jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Watson <jwatson@sitesproject.org>
Subject: [EXTERNAL] RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

I think we should discuss. I have attached how the Sac Valley water year type is calculated in D-1641. I'm not sure if this was updated for the Water Fix ITP.

John Spranza

D 916.679.8858 M 818.640.2487
Contents and attachments are part of the deliberative process, which is deemed to be exempt from Public Records Act requests and is subject to the confidentiality agreement between recipient and the Sites Project Authority. Further distribution to other organizations is not permissible

From: Rob Thomson [mailto:rthomson@sitesproject.org]
Sent: Sunday, October 20, 2019 11:52 AM
To: Alicia Forsythe <aforsythe@sitesproject.org>; Lecky, Jim <Jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; Spranza, John <John.Spranza@hdrinc.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Watson <jwatson@sitesproject.org>
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

Should we discuss this internally and suggest some method to CDFW?

From: Alicia Forsythe <aforsythe@sitesproject.org>
Sent: Sunday, October 20, 2019 9:48 AM
To: Lecky, Jim <Jim.Lecky@icf.com>; Rob Thomson <rthomson@sitesproject.org>; Chris Fitzer <CFitzer@esassoc.com>; Spranza, John <John.Spranza@hdrinc.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Watson <jwatson@sitesproject.org>
Subject: Re: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

Let's be sure to talk with CDFW on this on Tuesday.

————————

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 | aforsythe@sitesproject.org | www.SitesProject.org

From: Lecky, Jim <Jim.Lecky@icf.com>
Sent: Friday, October 18, 2019 12:28:23 PM
To: Rob Thomson <rthomson@sitesproject.org>; Chris Fitzer <CFitzer@esassoc.com>; Spranza, John <John.Spranza@hdrinc.com>; Alicia Forsythe <aforsythe@sitesproject.org>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Watson <jwatson@sitesproject.org>
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

I can only think of two options. 1. Assume continuation of prior water-year type until proven otherwise or 2. Assume a dry year until proven otherwise. NOAA is improving its multi-year forecasting so there may be an option for that in the future.

From: Rob Thomson <rthomson@sitesproject.org>
Sent: Friday, October 18, 2019 9:19 AM
To: Chris Fitzer <CFitzer@esassoc.com>; Spranza, John <John.Spranza@hdrinc.com>; Alicia Forsythe <aforsythe@sitesproject.org>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Lecky, Jim <Jim.Lecky@icf.com>; Jim Watson <jwatson@sitesproject.org>
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

Doubling back on this discussion – how does CDFW (or we) intend to determine the water year type in October-January? How would we determine which column to select to determine the applicable diversion criteria? January and February are clear. By March, we should have a reasonable idea of the year type.

From: Chris Fitzer <CFitzer@esassoc.com>
Sent: Tuesday, October 15, 2019 8:34 AM
To: Spranza, John <John.Spranza@hdrinc.com>; Alicia Forsythe <aforsythe@sitesproject.org>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Rob Thomson <rthomson@sitesproject.org>; Jim Watson <jwatson@sitesproject.org>
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

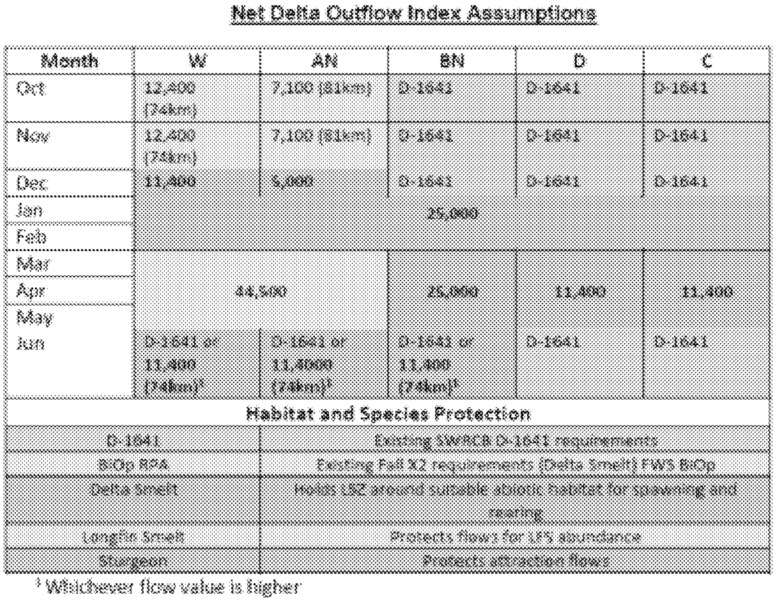
Attached are suggested edits to the talking point document and a couple small ones on the summary comparison table.
In regards to the table pasted below, perhaps we hold on to these water-year-based NDOI criteria for future negotiations, similar to the Sept 2019 scenario.
Thanks,

Chris Fitzer
Fisheries Program Manager

ESA | Environmental Science Associates
Celebrating 50 Years of Work that Matters!

From: Spranza, John <John.Spranza@hdrinc.com>
Sent: Tuesday, October 15, 2019 6:55 AM
To: Alicia Forsythe <aforsythe@sitesproject.org>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; Rob Thomson <rthomson@sitesproject.org>; Jim Watson <jwatson@sitesproject.org>
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

Just a few revisions in each. With respect to stacking Freeport and NDOI, I think the way it is now is fine, but see my note about monthly or daily average.
Also, with NDOI, we do not put any water year criteria on the 44.5k. Based on the below graphic that CDFW provided us in their DEIR comments, do we want to rethink that?



Net Delta Outflow Index Assumptions

Month	W	AN	BN	D	C
Oct	12,400 (74km)	7,100 (81km)	D-1641	D-1641	D-1641
Nov	12,400 (74km)	7,100 (81km)	D-1641	D-1641	D-1641
Dec	11,400	5,000	D-1641	D-1641	D-1641
Jan	25,000				
Feb					
Mar	44,500		25,000	11,400	11,400
Apr					
May					
Jun	D-1641 or 11,400 (74km)[1]	D-1641 or 11,4000 (74km)[1]	D-1641 or 11,400 (74km)[1]	D-1641	D-1641

Habitat and Species Protection

D-1641	Existing SWRCB D-1641 requirements
BiOp RPA	Existing Fall X2 requirements (Delta Smelt) FWS BiOp
Delta Smelt	Holds LSZ around suitable abiotic habitat for spawning and rearing
Longfin Smelt	Protects flows for LFS abundance
Sturgeon	Protects attraction flows

[1] Whichever flow value is higher

John Spranza

D 916.679.8858 M 818.640.2487

From: Alicia Forsythe [mailto:aforsythe@sitesproject.org]
Sent: Monday, October 14, 2019 4:30 PM
To: Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; Spranza, John <John.Spranza@hdrinc.com>; Rob Thomson <rthomson@sitesproject.org>; Jim Watson <jwatson@sitesproject.org>
Subject: RE: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

Hi all – Attached is a revised table along with revised talking points.

1. In the table, I highlighted all changes in green (sorry I realized part way thru that I forgot to turn on tracking). I have a few questions for the team using the notes function that I could use help on. Once we have completed all changes to the table, I'll try to get it to fit on one page.
2. Revised talking points are provided in track changes and clean version. Please make new changes on the clean version. I tried to focus these more on the technical topics.

Your quick review is appreciated! Please have all comments to me by noon tomorrow.

Thanks all!

Ali

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 |
aforsythe@sitesproject.org | www.SitesProject.org

From: Alicia Forsythe
Sent: Monday, October 14, 2019 1:37 PM
To: Tull, Robert/SAC <Robert.Tull@jacobs.com>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thad Bettner (tbettner@gcid.net) <tbettner@gcid.net>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>; Chris Fitzer <CFitzer@esassoc.com>; John Spranza (john.spranza@hdrinc.com) <john.spranza@hdrinc.com>; Rob Thomson <rthomson@sitesproject.org>; Jim Watson <jwatson@sitesproject.org>
Subject: Sites - CDFW 60-Process -- Next Steps -- Small Group Discussion

Hi all - Sorry about not getting these out earlier. Attached are 2 very draft items for our discussion at 2 PM today.

Ali

Alicia Forsythe | Environmental Planning and Permitting Manager | Sites Reservoir Project | 916.880.0676 |
aforsythe@sitesproject.org | www.SitesProject.org

From: Whittington, Chad/SAC
To: Leaf, Rob/SAC
Cc: Tull, Robert/SAC; Thayer, Reed/SAC
Subject: RE: Pulse and Post-Pulse Logic Used in CalSim (from Appendix 5.A of the 2016 CWF BA Effects Analysis)
Date: Friday, October 4, 2019 12:03:24 PM

The table below showcases the similarities and differences between the CWF ITP and CalSim in the determination of pulse and post-pulse rules.

Pulse and Post-Pulse Assumptions	
CWF ITP	**CalSim II**
· All pulses of CHNWR and CHNSR shall be protected from October 1 – June 30.	• One or two pulses shall be protected from October 1 – June 30 (depending on whether a pulse ends before December 1) .
· Beginning October 1st, whenever the initial Sacramento River pulse begins, low level pumping takes effect.	• Beginning October 1st, whenever the initial Sacramento River pulse begins, low level pumping takes effect.
• Sacramento River pulse is determined based on real-time monitoring of juvenile fish movement (see Condition of Approval 9.9.5.1). A fish pulse is defined as a Knights Landing Catch Index (KLCI) = 5 where KLCI = (# of CHNWR + # of CHNSR)/(Total Hours Fished/24). • Pulse protection operations shall be implemented within 24 hours of detection of a fish pulse.	• The initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs.
• Pulse protection ends after five consecutive days of daily KLCI < 5.	• The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days.
• Number of allowable pulses is not specified; ASSUME ALL ELIGIBLE PULSES (KLCI = 5) ARE PROTECTED.	• If the initial pulse begins and ends before December 1st, a second pulse period will be afforded the same protective operation.
• Once the pulse protection ends, post-pulse bypass flow operations may remain at Level 1 diversion depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of diversions.	• After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection.
• The criteria for transitioning between and among pulse-protection, Level 1, Level 2, and/or Level 3 operations described in this permit will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the Project's Adaptive Management Program. Based on the outcome of the studies pursued under that program, additional information about appropriate triggers, off-ramps, and other RTO management of NDD intake operations may be integrated into the Test Period Operations Plan and the Full Project Operations Plan.	• After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied.

- The NDDTT shall develop criteria for transitioning between and among pulse protection, Levels 1, 2 and 3 based on best available science. The NDDTT shall recommend transitional criteria to the TOT and IICG for consideration through the Adaptive Management Program, to ensure that the Project will achieve the objectives of Biological Criteria 1 and 2.	
	- Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules.

Chad

From: Whittington, Chad/SAC
Sent: Tuesday, October 01, 2019 3:11 PM
To: Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Tull, Robert/SAC <Robert.Tull@jacobs.com>; Thayer, Reed/SAC <Reed.Thayer@jacobs.com>
Subject: Pulse and Post-Pulse Logic Used in CalSim (from Appendix 5.A of the 2016 CWF BA Effects Analysis)

Appendix 5.A of the 2016 CWF BA is at this link.

Here is the relevant excerpt (from the bottom of Page 30).

"

5.A.5.2.4.9 North Delta Diversion Bypass Flows
Bypass flows requirements in the Sacramento River are specified downstream of the north Delta diversion intakes, which govern the flow required to remain in the river before any diversion can occur. The bypass rules include low level pumping at each intake during Sacramento River Pulse flow(s) period. After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection (Level I to Level II and subsequently to Level III) subject to hydrologic and fishery conditions. Minimum bypass flow requirements are specified for July through November, as noted in Table 5.A-13.

Beginning October 1st, whenever the initial Sacramento River pulse begins low level pumping allows diversions of up to 6% of Sacramento River flow flow upstream of the north Delta intakes. The low level pumping is less than or equal to 300 cfs at any one intake, with a combined limit of 900 cfs for the three intakes in the PA. The low level pumping is constrained such that the river flow never falls below 5,000 cfs.

During the initial pulse protection period low level pumping is maintained until the pulse period has ended. For modeling purposes, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs. The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins

Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days. If the initial pulse begins and ends before December 1, the May Level 1 post-pulse criteria will go into effect after the pulse until December 1. On December 1, the post-pulse rules defined below for December through April, starting with Level 1 apply. If the initial pulse begins and ends before December 1st, a second pulse period will be afforded the same protective operation.

After the pulse period has ended, the bypass flows noted in the Table 5.A-13 are maintained. After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied. The bypass rules were applied on the mean daily river flows in the CalSim II model. Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules. In actual operations these criteria as well as fishery conditions are expected to guide allowable north Delta intake diversions as described in Section 3.3.3.1 of the BA.

In addition to the bypass flow criteria described above, a linear constraint was applied in the CalSim II PA simulation on the potential diversion at the north Delta intakes, to account for the fish screen sweeping velocity criteria of 0.4 fps based on diversion limitations from DSM2 modeling.
"

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9/27/19

NMFS CCVO questions related to Sites Reservoir modeling and analysis:

Questions related to Sites Reservoir modeling and analysis generally fall into two broad categories of "methods" and "other." It is likely that these questions and suggestions cannot be covered in a single meeting with Sites JP, but they provide an overview of expectations regarding the type of analysis needed in an initiation package.

Methods

- Could Sites JP provide a table/listing of analytical tools/models expected to be used (e.g., HEC-5Q, Delta Passage Model), what outputs will be evaluated (e.g., temperature, Delta survival), and what effect/consequence of the project they are intended to be used to evaluate (impacts to incubation/rearing habitat conditions, impacts on juvenile outmigration)? It may be most useful to set up a meeting to go through what Sites JP is using so as to be sure NMFS is on board and that we don't have a better alternative (but don't need to get into super detail of any one; that could be reserved for a follow-up meeting).
    - As an example, for both CWF and ROCON, NMFS produced a "model matrix" that identifies models and analyses that may be relevant or used in the BA/BO analysis (below).

- Could Sites JP provide a review of the "Daily Model" to provide understanding of this new tool?

- Could Sites JP provide primer on the operations that have been agreed to/developed with DFW, including pulse protections, and ramping rates (changes in habitat inundation and stranding)?

- How is Sites JP dealing with the uncertainty related to the Proposed Action? A large number of modeling scenarios might be needed to account for current level of uncertainty regarding reservoir size (~1.0-1.8 MAF) and operations (Pump Storage component, Holthouse Reservoir footprint, Delevan Pipeline). How does JP plan to select the scenarios to be modelled?

Other

- How is climate change considered in the modeling and analysis? Is the modeling based on a projection of conditions at some point in future? If so, what, and where is documentation of the development of that scenario?

- How is eutrophication considered in the proposed reservoir? Downstream of an outfall location?

- How does Sites JP propose to deal with uncertainty? Is there information on an adaptive management approach?

- Could Sites JP provide a better layout of expected consultation (ESA section 7) timeline/time constraints due to WISP, potential administration changes, NEPA, WIIN, etc.?

Model/Analysis table:

Model/Analysis	Location	Type/ Criteria	Life-stage	Species	Description (and NMFS comment)
CalSim-II	CVP/SWP-wide	Hydrologic	NA	NA	A hydrological planning scenario tool that provides monthly average flows for the entire SWP and CVP system based on an 82-year record.

DSM2-HYDRO	Delta and Suisun Marsh	Hydrologic	NA	NA	One-dimensional hydraulic model used to predict flow rate, stage, and water velocity.
DSM2-PTM	Delta and Suisun Marsh	Hydrologic (Particle tracking)	NA	NA	Simulates fate and transport of neutrally buoyant particles through space and time.
DSM2-ePTM (DWR)	Delta and Suisun Marsh	Hydrologic (Particle tracking)	model calibration based on smolt data; uncertain how applicable to rearing fry	model calibration based on Chinook smolt data; uncertain how applicable to steelhead.	Simulates fate and transport of "behaving" particles through space and time. Seven behavioral parameters; calibration method is based on particle swarm optimization
ePTM (SWFSC)	Delta	Hydrologic (Particle tracking)	model calibration based on smolt data; uncertain how applicable to rearing fry	model calibration based on Chinook smolt data; uncertain how applicable to steelhead.	Simulates fate and transport of "behaving" particles through space and time. Seven behavioral parameters (same seven as in DWR model, though exact interpretation a bit different because of different model structures); undergoing continued refinement by the SWFSC
HEC-5Q	Sacramento and American Rivers	Water Quality	NA	NA	Water quality simulation tool used to provide water temperatures.
DSM2-QUAL	Delta and Suisun Marsh	Water Quality	NA	NA	Used to predict water temperature, dissolved oxygen, and salinity.
DSM2-QUAL Fingerprinting	Delta and Suisun Marsh	Water Quality (Olfactory Cues)	Adults	Chinook, steelhead	Models "source" of water at any location to indicate proportion coming from different upstream locations, and therefore incidates how homing capabilities of fish can be affected by changes in operations.
Reclamation Egg Mort. Model	Trinity, Feather, American, and Stanislaus Rivers	Biological	Egg	?	Uses CalSimII flow and climatic model output to predict monthly water temperature in River basins and upstream reservoirs.
SALMOD	Sacramento River	Biological	Returning Adult, Egg, Alevin	All Chinook	Predicts effects of flows on habitat suitability and quantity for all races of Chinook salmon.

OBAN	Sacramento River	Biological	?	All Chinook	Statistical modeling approach to evaluating scenarios effects.
DPM	Delta to Chipps Island	Biological	Juvenile (migration)	All Chinook	Simulates migration and mortality of Chinook salmon smolts entering the Delta from the Sacramento, Mokelumne, and San Joaquin rivers through a simplified Delta channel network, and provides quantitative estimates of relative Chinook salmon smolt survival.
IOS	Sacramento River	Biological	All	Winter-run Chinook	A stochastic life cycle model for winter-run Chinook salmon.
Salvage-density Analysis	South Delta facilities	Biological (Flow relation)	Juvenile	All Chinook	A model of entrainment into the south Delta facilities as a function of flow based on historical salvage data.
USGS Flow-survival Model	North Delta (Sacramento R.)	Biological (Flow relation)	Juvenile (migration)	Fall-run Chinook (?)	A model that combines equations from statistical models estimating the relationship of Sacramento River inflows on reach-specific travel time, survival, and routing of salmonids to allow assessment of travel time and survival for different operational scenarios.
USGS Entrainment Model	North Delta (Sacramento R.)	Hydrologic (?)	Juvenile (migration)	Fall-run Chinook (?)	A statistical model of probability of entrainment into the central Delta as a function of hydrodynamic variables in the Sacramento River.
SWFSC Temp. Dependent Egg Mort Model	Sacramento River	Biological	Egg	All Chinook	A temperature-dependent mortality model for Chinook salmon embryos that accounts for the effect of flow and dissolved oxygen on the thermal tolerance of developing eggs.
SWFSC WRLCM	Sacramento River	Biological	All	Winter-run Chinook	A state-space and spatially explicit life cycle model of eggs, fry, smolts, juveniles in the ocean, and mature adults that includes density-dependent movement among habitats.

ICF loss analysis	South Delta facilities	Salvage and loss	Juvenile	Chinook, steelhead (mostly certain),sturgeon (?)	
SWFSC RAFT/CVTemp	Sacramento River		Juvenile	Chinook	Models water temperatures at various locations and estimates egg survival based on Reclamation's operations
Habitat Suitability Index (HSI) Modeling	NA	Habitat	All	Chinook	This would likely only be needed if some type of habitat restoration were included in the PA. And would need to be specific. HSI components are worked into other methods, like SALMOD.
Yolo Bypass Fry Rearing Model	Delta	Biological	Juvenile	Chinook	The Yolo Bypass Fry Rearing Model links growth to survival at ocean entry using the few existing relevant studies. May want to look into how updated this model is (don't recall it being used for CWF so may be due for refresh or replaced by something else).
Newman 2008	Delta	Biological	Juvenile	Chinook	Through-Delta survival method. Used in CWF but not relied upon extensively. Also used as a component of the WRLCM during ROC.
Delta Salmonid Travel Time (Perry and Pope 2018)	Delta	Biological	Juvenile	Chinook	
DSM2	Delta	Physical	Juvenile	Chinook, steelhead	Daily flow metrics, 15-minute velocity frequency: percentage positive flow, frequency of velocities above sustained swimming speeds; used in CWF but very data intensive.
6-year study work	Delta	Biological	Juvenile	Chinook, steelhead	Perry under contract with NMFS to work on results from this data, but unsure if that analysis would meet current (?) timeline.
SRKW Analysis	Ocean	Biological	All	SRKW	See CWF. Is largely based on effects to non-listed salmonids, in addition to those

					on listed salmonids (which are not as large a part of the diet).
CCC Steelhead Analysis		Biological	All	CCC Steelhead	
Eulachon Analysis		Biological	All	Eulachon	
Mean end-of-May and end-of-Sep reservoir storage changes from baseline	Sacramento, Feather, American	Physical	Spawner, Egg, Juv	(River dpendant) WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Mean flow changes from baseline (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear Creek (?)	Physical	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Flow threshold exceedance (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Physical	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Water temperature changes from baseline (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Water Quality	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Water temperature threshold exceedance (daily data)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Water Quality	Spawner, Egg, Juv	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	

Spawning WUA	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Habitat	Spawner,	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Rearing WUA	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Habitat	Juvenile	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	
Redd dewatering (qualitative or greatest monthly flow reduction)	Sacramento, Feather, American and Trinity Rivers (?), and Clear creek (?)	Habitat	Egg	(River dpendant) SONCC, WR, SR, and FR/LFR Chinook, CV steelhead and GS	Identified for all dams/tributaries contributing to the Sacramento River. Are impacts to reservoir releases expected/considered at all locations?
Hatchery assessment (lit review and CFM analysis)	Sacramento, Feather, American, Stanislaus, San Joaquin and Trinity Rivers, and Clear creek	Hatchery	Spawner, Juvenile	SR, FR Chinook and CV Steelhead	Are impacts to Hatchery production expected?

Sites Project
Technical Assistance Meeting

Sites Reservoir Project

Date: *October 30, 2019*

Location: *ICF Office: 980 9th St., Suite 1200*
12th floor Appalachian Conference Room

Time: 1:00 pm – 4:00 pm

Purpose: Continue discussions regarding Interagency Consultation of the Sites Reservoir Project

Invitees:

Jelica Arsenijevic, HDR ☐
Monique Briard, ICF ☐
Dan Cordova, Reclamation ☐
Kristal Davis-Fadtke, CDFW ☐
Mike Dietl, Reclamation ☐
Chris Fitzer, ESA Associates ☐
Ali Forsythe, Sites Authority ☐
Marin Greenwood, ICF ☐
Lenny Grimaldo ☐
Jason Hasrick, ICF ☐
Ken Kundargi, CDFW ☐
Rob Leaf, Jacobs ☐
Jim Lecky, ICF ☐
Cathy Marcinkevage, NMFS ☐
Evan Sawyer, NMFS ☐
John Spranza, HDR ☐
Lauren Sullivan, FWS ☐
Rob Thomson, Sites Authority ☐
Rob Tull, Jacobs ☐

Agenda:

	Discussion Topic	Topic Leader	Est Time
1	Introductions	Ali Forsythe	5 min
2	Overview of effects analysis o Construction effects o Operations effects ▪ Sacramento River - near field ▪ Sacramento River - far field ▪ Feather River ▪ American River ▪ Delta ▪ Life cycle models o Cross-walk NMFS-provided model matrix and methods used to date	Marin Greenwood / Jason Hassrick	60 min
3	Overview of daily model and examples of its use o What it is? o How it has been used? o What's its role in environmental review?	Rob Tull	60 min
4	CDFW 60-day process outcomes	Ali Forsythe and Kristal Davis-Fadtke	20 min

5	Additional Modeling o Calsim II o NMFS life cycle model o Others?	Group	30 min
5	Next Steps	Group	10 min

Meeting Minutes:

Value Planning Analysis Technical Memorandum

Sites
Program Management Team

To:	Mike Azevedo, Lewis Bair, Thad Bettner, Gary Evans, Rob Kunde, Shelly Murphy, Randall Neudeck, Dan Ruiz, Jeff Sutton, Jamie Traynham, Bill Vanderwaal
CC:	Rob Tull
Date:	October 14, 2019
From:	Joe Barnes, Jeff Herrin, Pete Rude (Jacobs), Jeff Smith (Jacobs)

1.0 Value Planning Effort

Representatives from the Reservoir Committee and Authority Board met on October 2, 2019 to discuss approaches that could potentially lower the cost of the project. Several facility modifications were identified, and appraisal level costs are provided in this analysis to allow a comparison of alternatives.

At this level of evaluation, the analysis is useful for identifying alternatives that merit further evaluation. The analysis is not sufficiently refined to distinguish between two alternatives of similar cost (e.g., + 10 to 15%).

Construction cost estimates for many of the facilities were derived from appraisal-level estimates for a 1.3 million acre feet (MAF) reservoir (Alternative A in the Environmental Impact Report/Environmental Impact Statement [EIR/S] and feasibility report) and for a 1.8 MAF reservoir (Alternative D in the EIR/S and feasibility report). Several new facilities were estimated, where possible using the unit rates from similar facilities in the existing estimates. Estimated prices were developed in October 2015 dollars and have been escalated in this estimate.

The actual project construction cost ultimately would depend on the final design details of the preferred project alternative and the labor and material costs, market conditions, and other variable factors existing at the time of bid. Accordingly, the final project cost is expected to vary from the preliminary estimates presented in this section.

2.0 General Limitations

AECOM represents that our services were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession within the limits prescribed by our client. No other warranties, either expressed or implied, are included or intended in this brief appraisal-level cost estimate.

We have used background information, conceptual designs, and data by others to prepare this appraisal-level cost estimate. We have relied on this information, as furnished, and is neither responsible for nor has confirmed the accuracy of this information.

The appraisal-level cost estimate presented herein is for the current study only and should not be extended or used for any other purposes.

3.0 Value Planning Facility Options and Alternatives

The meeting on October 2, 2019 identified both modifications to previously evaluated facilities and alternative facilities to reduce cost. A comprehensive table showing approximately 59 facility options that were considered in this analysis, along with their respective costs, is provided in Attachment 2.

There are numerous ways of combining the individual facility options into alternatives. To speed the analysis, we have looked at nine complete alternatives. There are many other ways of combining the facilities that can be further evaluated at the direction of the Value Planning working group.

The initial alternatives are shown in Table 1.

Table 1. Initial Alternatives for consideration.

Features	Initial Alternatives								
	1	2	3	4a	4b	5a	5b	6a	6b
1.5 MAF Reservoir	•	•	•	•	•	•	•	•	
1.3 MAF Reservoir									•
Funks/Sites PGP	•	•		•	•	•	•		
TCRR and Upgraded TRR PGP			•					•	•
Delevan Canal/Pipeline Release	•	•	•	•	•				
Dunnigan Canal to CBD Release						•		•	
Dunnigan to River Release							•		•
Multi-Span Bridge	•		•	•	•	•	•	•	•
South Road to Lodoga		•							
South Road to Residents	•		•	•	•	•	•	•	•
Rockfill Embankment Dam	•	•	•			•	•		
Earthfill Dam				•				•	•
Hardfill Dam					•				

MAF = million acre feet
PGP = Pumping/Generating Plant
TCRR = Tehama-Colusa Regulating Reservoir
TRR = Terminal Regulating Reservoir

For purposes of comparison, we have included Alternative D, the alternative presented in the WSIP application in the comparison of alternatives. The new alternatives include the following:

- Alternative 1 – Refer to Figure 1. This alternative reduces the size of the reservoir to 1.5 MAF and uses a multi-span bridge to reduce costs. The other features are generally consistent with Alternative D.

- Alternative 2 – Refer to Figure 2. This alternative is very similar to Alternative 1 but uses the southern road with the more direct route to Lodoga in place of the bridge.

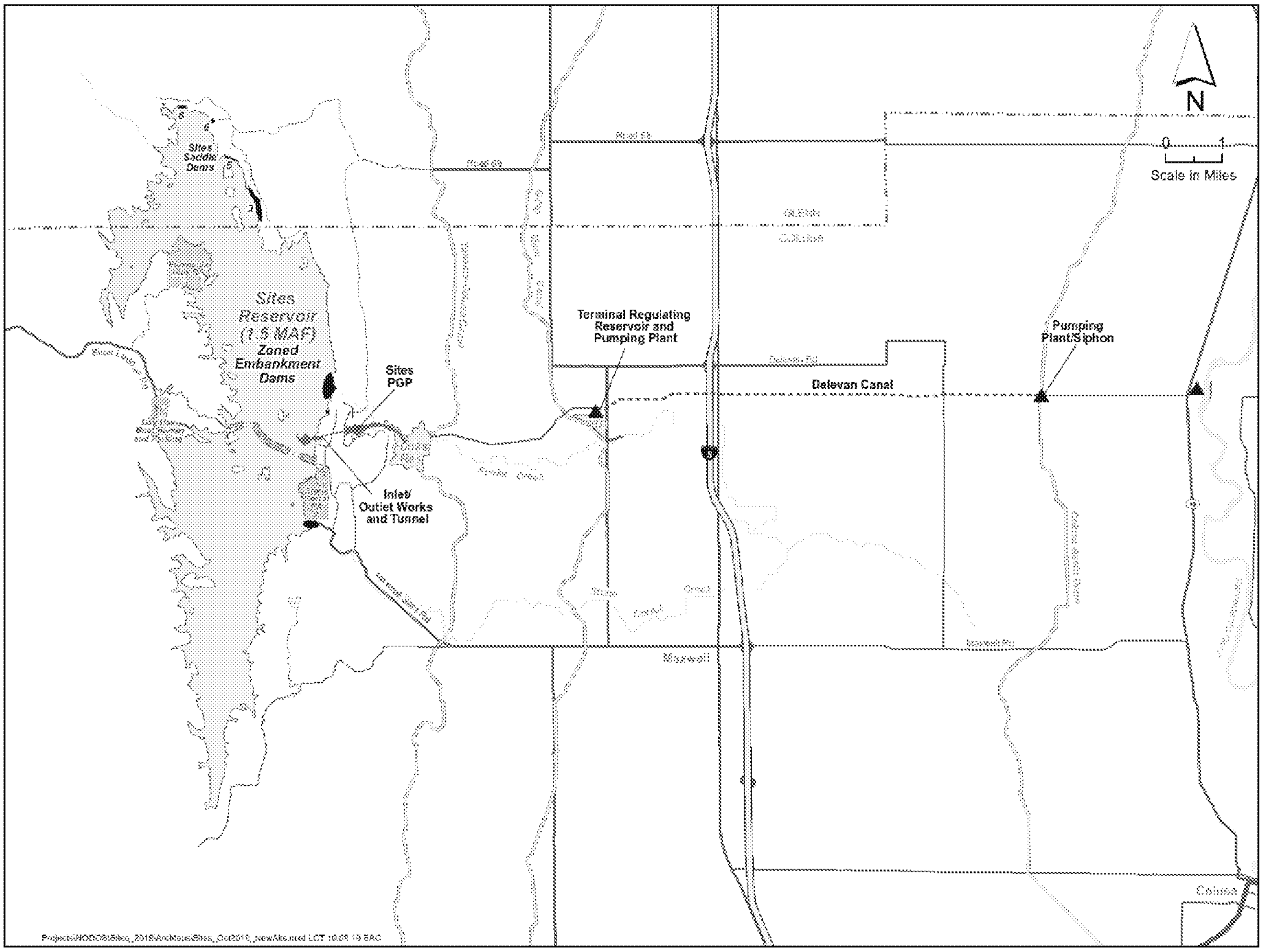
- Alternative 3 – Refer to Figure 3. This alternative eliminates the Sites Pumping/Generating Plant and replaces it with the Tehama-Colusa Regulating Reservoir (TCRR) and Pumping Plant near Road 69 in combination with an upgraded Terminal Regulating Reservoir (TRR) to fill Sites Reservoir. Water would be released to the Sacramento River through a canal/pipeline to the Delevan release structure. The canal portion would begin at the TRR and continue east to the Colusa Basin Drain (CBD). It would be necessary to siphon under the CBD and pump the water to the river. The two-span bridge is used in this alternative.

- Alternatives 4a and 4b – Refer to Figures 4a and 4b. These alternatives include the single Sites Pumping/Generating Plant (PGP) with releases through the Delevan Canal/Pipeline. Alternative 4a uses an earthfill dam and Alternative 4b uses a hardfill dam in place of the zoned rockfill dam.
- Alternatives 5a and 5b – Refer to Figures 5a and 5b. These alternatives replace the Delevan Canal/Pipeline with a southern release near the southern terminous of the Tehama-Colusa (T-C) Canal. Alternative 5a releases water to the CBD. Water released to the CBD would be conveyed through the lower portion of the CBD to the Sacramento River. Alternative 5b conveys water by canal to the CBD, then uses a siphon and pumping plant to convey water on to the river.
- Alternatives 6a and 6b – Refer to Figures 6a and 6b. These alternatives combine the TCRR and upgraded TRR with the southern release structure and an earthfill dam. Alternative 6a appears to have the lowest construction cost.

A summary of alternative costs, including a cost comparison with Alternative D, is included in Table 2.

Table 2. Summary of Estimated Costs

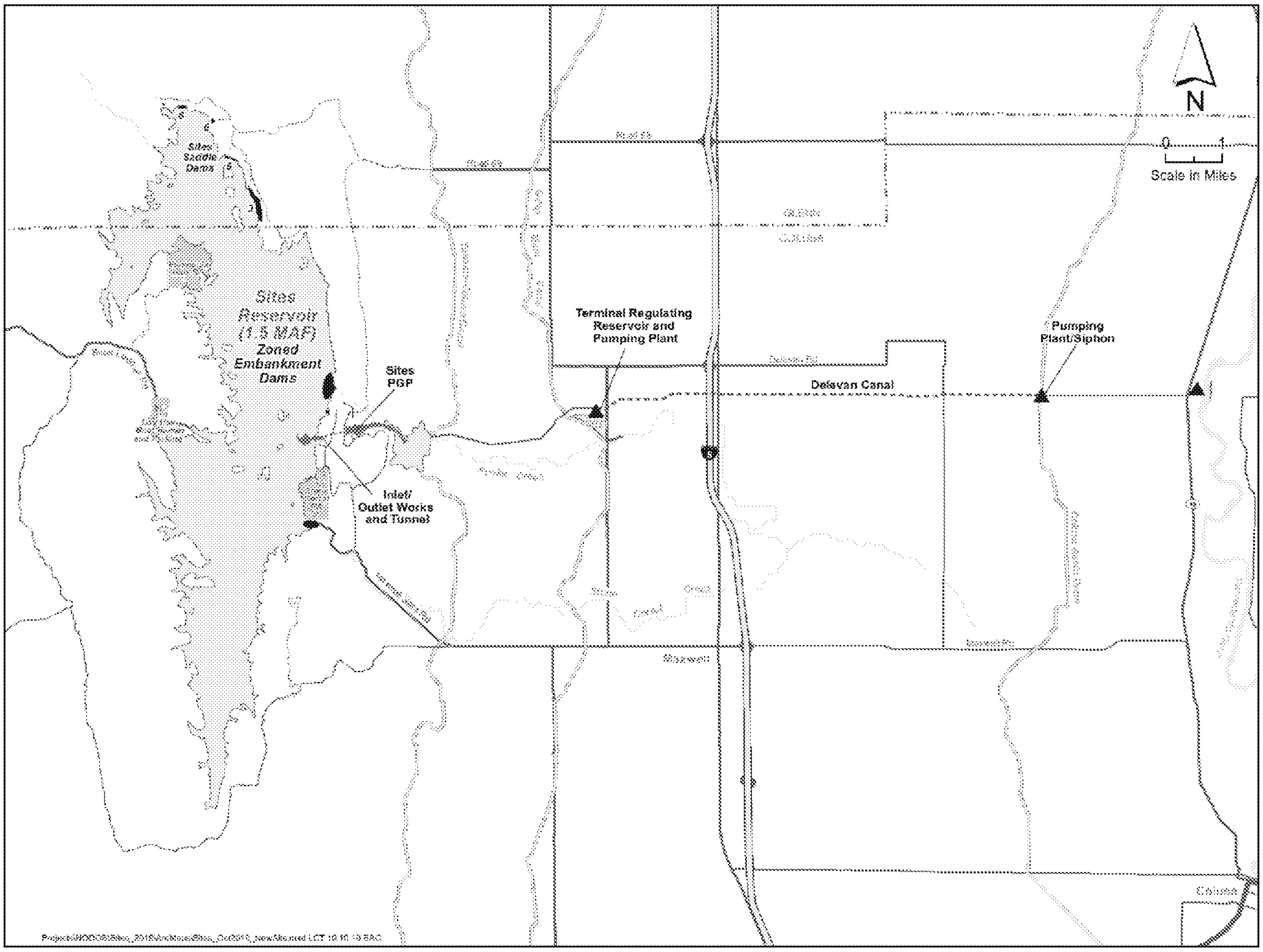
Alternative	**Estimated Costs ($2018) (financing cost not included)**	**Cost Reduction from Alternative D**
Alternative D	$5,235 million	0%
Alternative 1	$3,970 million	24%
Alternative 2	$3,988 million	24%
Alternative 3	$3,868 million	26%
Alternative 4a	$3,828 million	27%
Alternative 4b	$3,861 million	26%
Alternative 5a	$3,548 million	32%
Alternative 5b	$3,876 million	26%
Alternative 6a	$3,417 million	35%
Alternative 6b	$3,584 million	32%



Alternative 1

Figure 1. Alternative 1

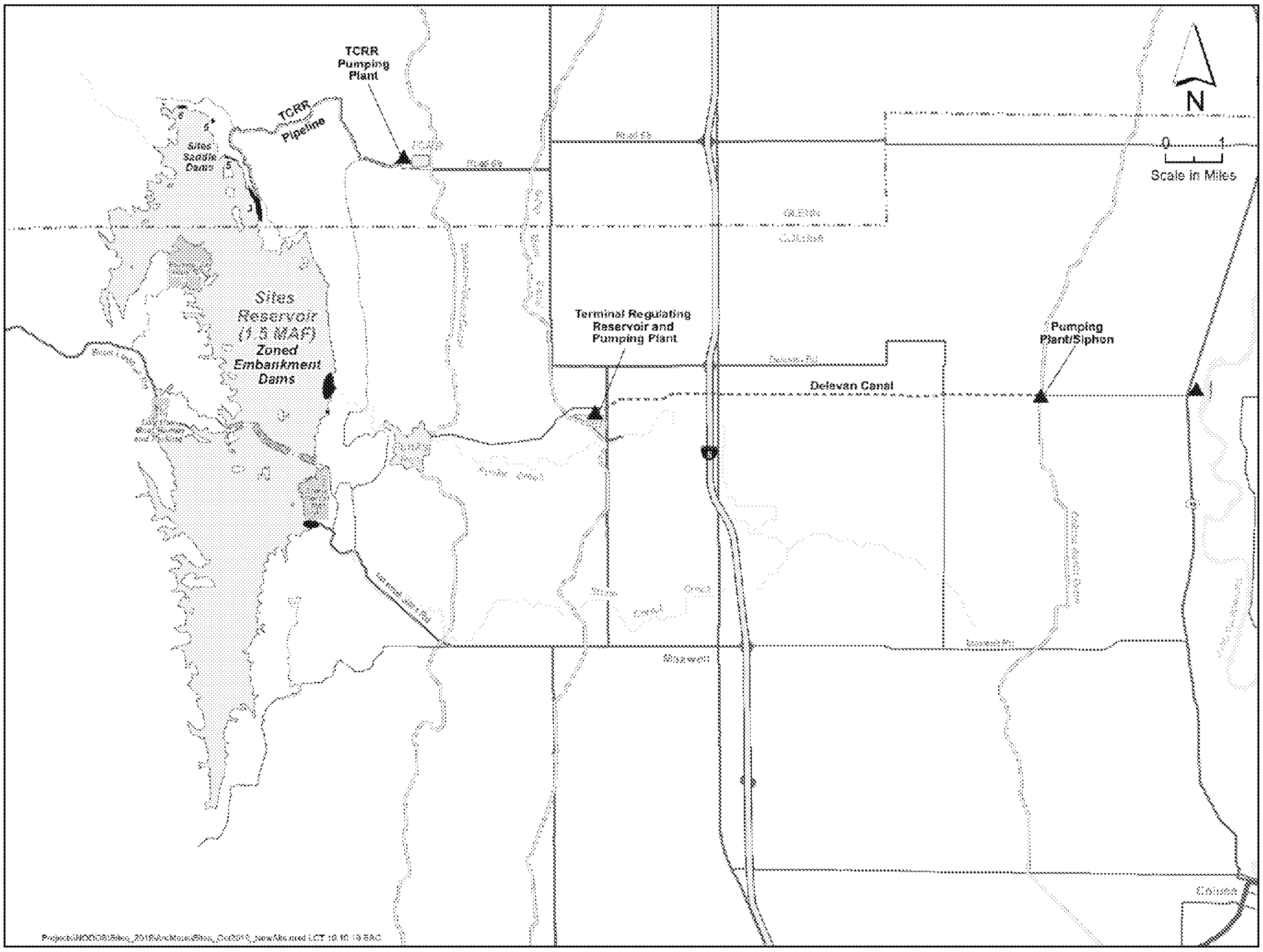
- Estimated cost - $3,970 million
- Cost reduction from Alternative D – 24%



Alternative 2

Figure 2. Alternative 2

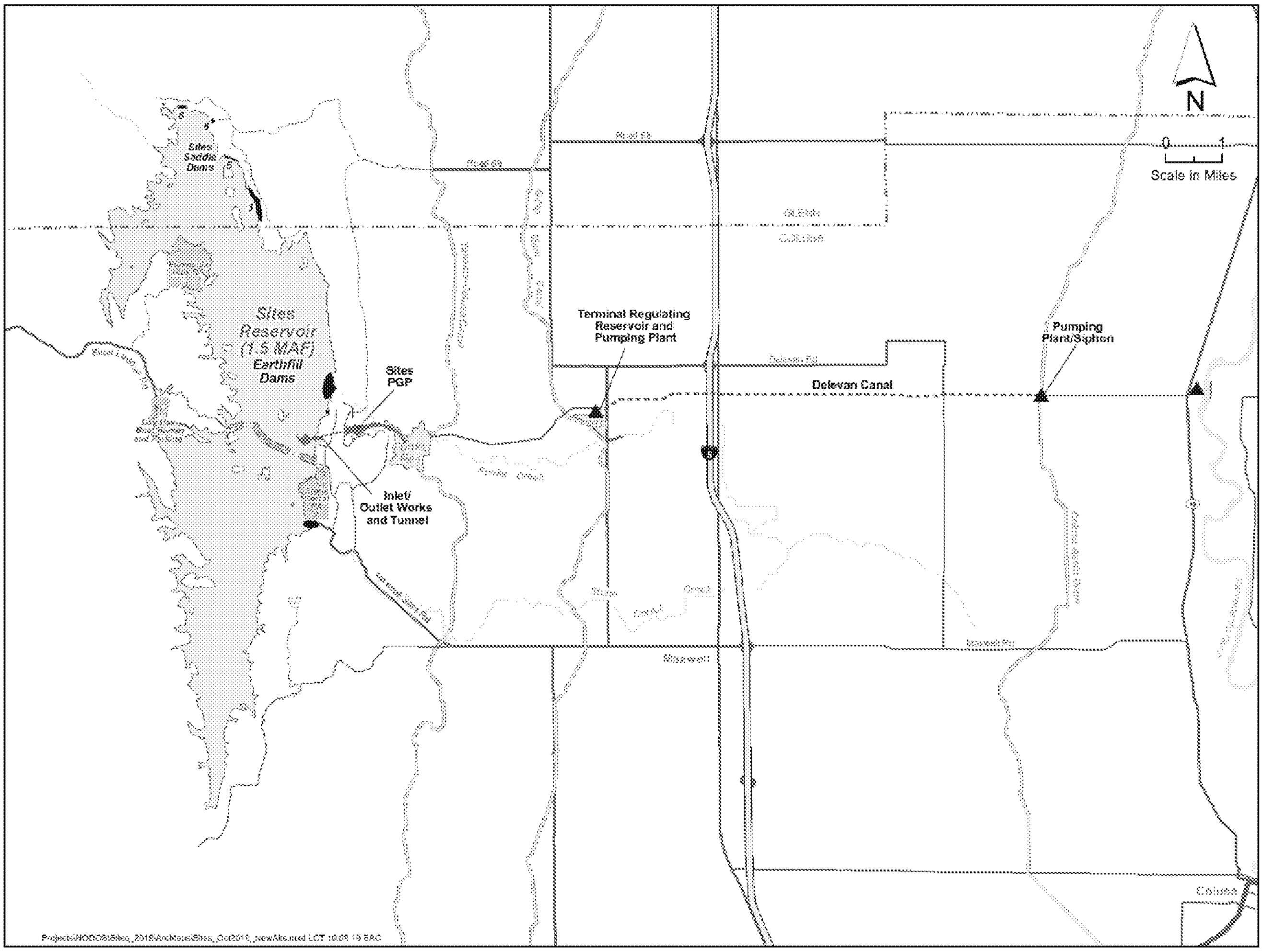
- Estimated cost - $3,988 million
- Cost reduction from Alternative D – 24%



Alternative 3

Figure 3. Alternative 3

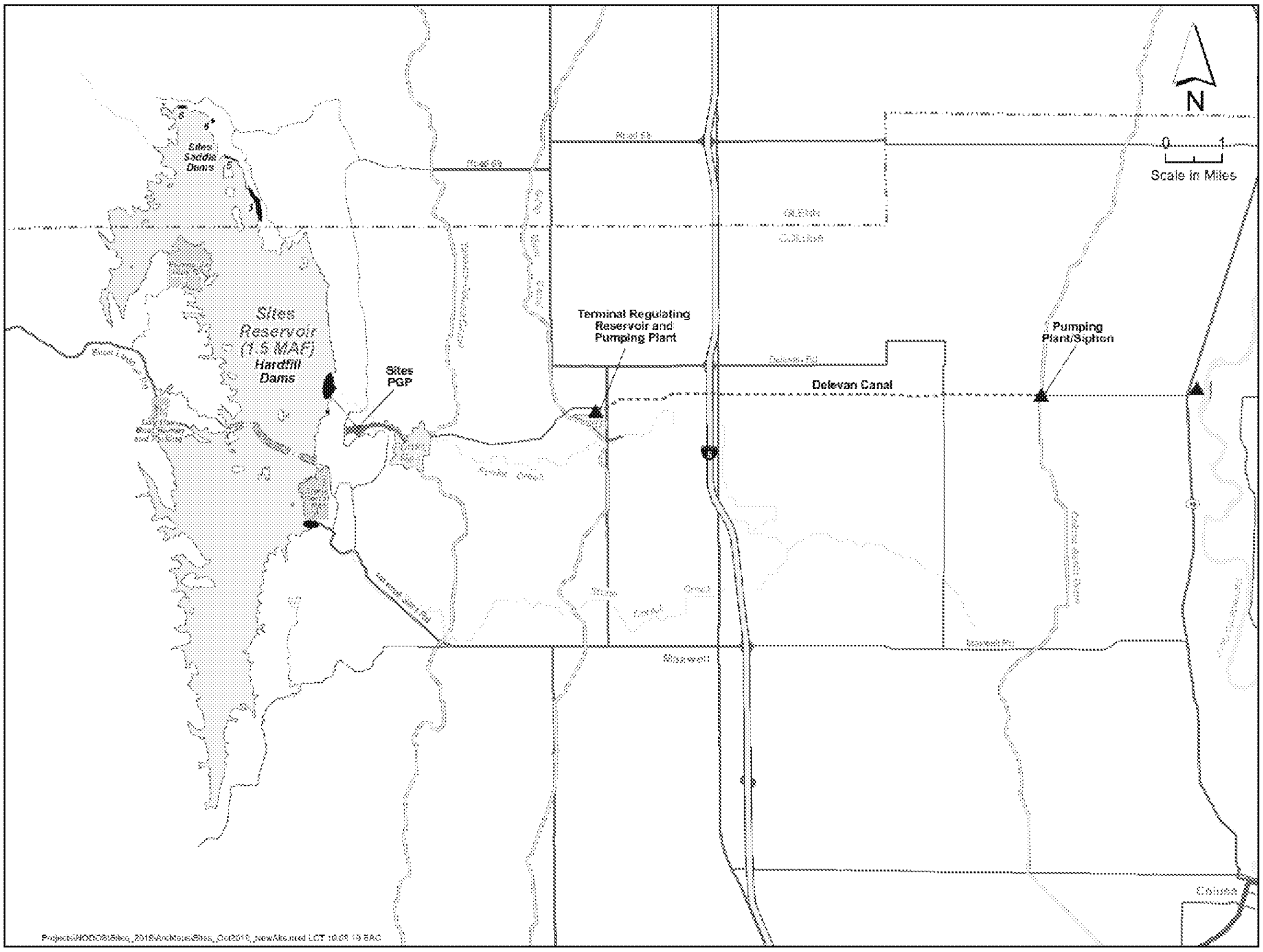
- Estimated cost - $3,868 million
- Cost reduction from Alternative D – 26%



Alternative 4a

Figure 4a. Alternative 4a

- Estimated cost - $3,828 million
- Cost reduction from Alternative D – 27%



Alternative 4b

Figure 4b. Alternative 4b

- Estimated cost - $3,861 million
- Cost reduction from Alternative D – 26%

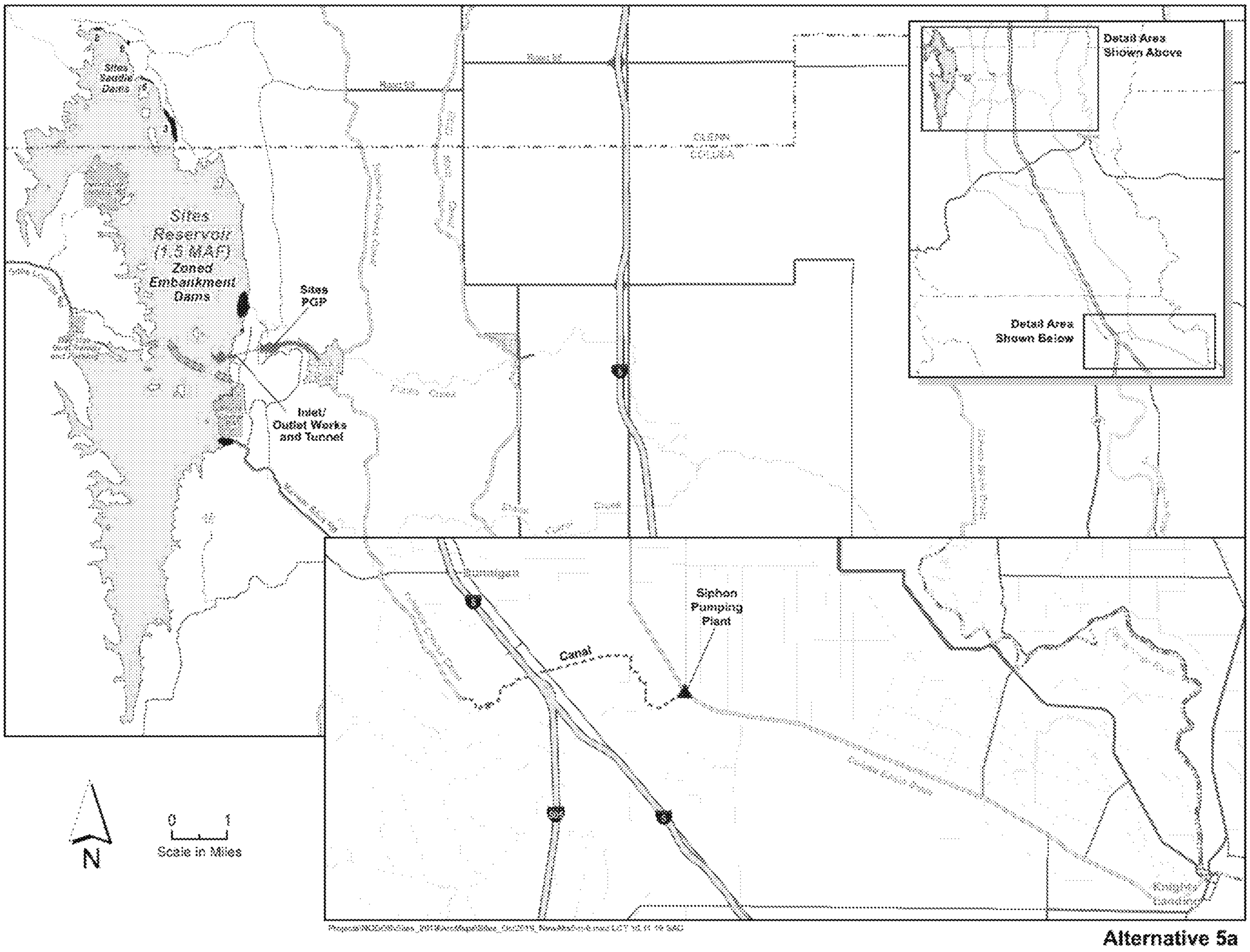


Figure 5a. Alternative 5a

- Estimated cost - $3,548 million
- Cost reduction from Alternative D – 32%

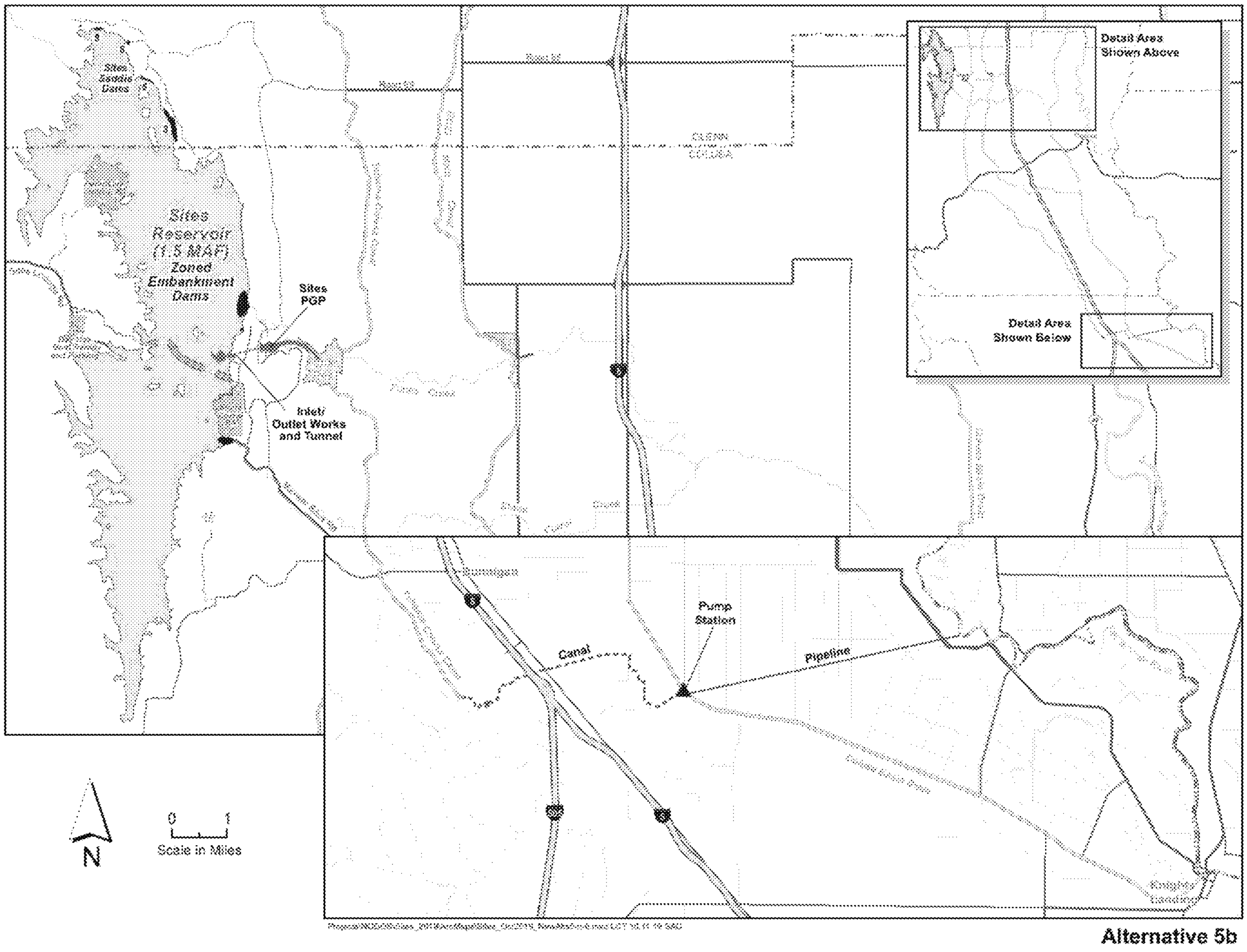


Figure 5b. Alternative 5b

- Estimated cost - $3,876 million
- Cost reduction from Alternative D – 26%

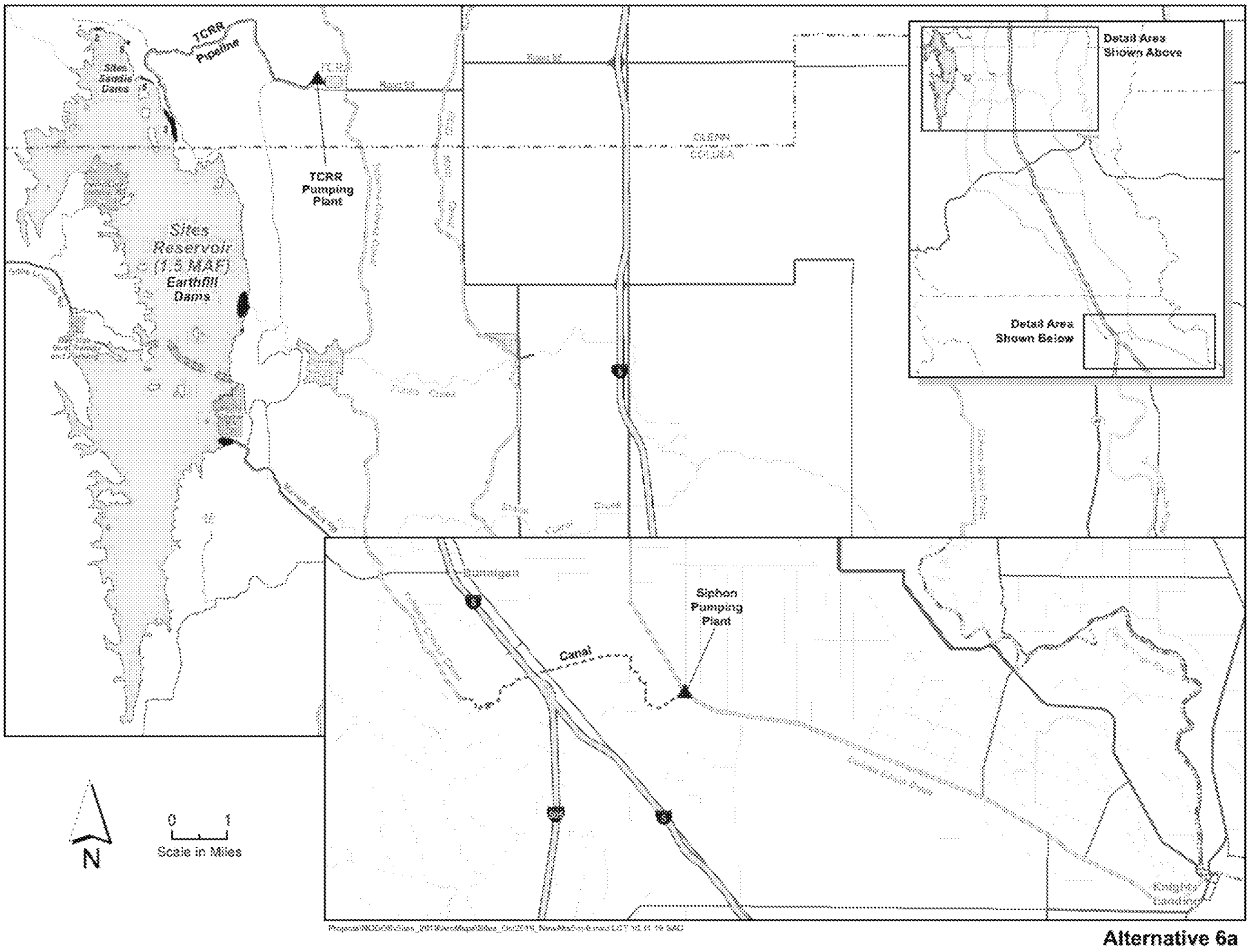


Figure 6a. Alternative 6a

- Estimated cost - $3,417 million
- Cost reduction from Alternative D – 35%

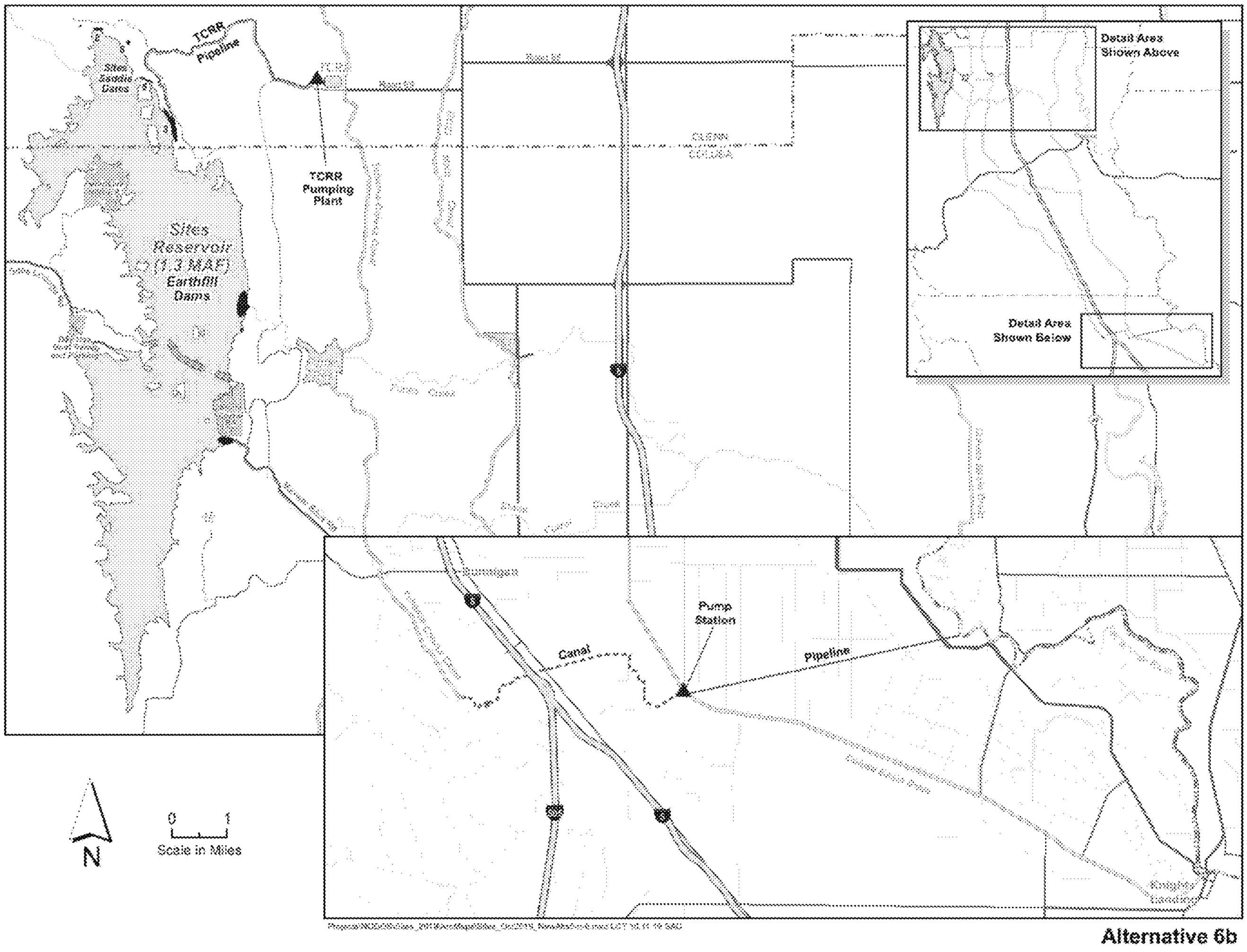


Figure 6b. Alternative 6b

- Estimated cost - $3,584 million
- Cost reduction from Alternative D – 32%

4.0 Environmental Mitigation

HDR reviewed the existing mitigation cost estimates currently being used and found that when applied to the Value Planning Alternatives, the estimated mitigation costs do not result in any significant changes in estimated mitigation costs (>$50M). Their October 11, 2019 memorandum concluded that until additional analysis can be performed on a specific project description, the existing $500M estimate should be retained.

5.0 Emergency Reservoir Drawdown

It is proposed to distribute the emergency reservoir release flow required by the State of California Department of Water Resources, Division of Safety of Dams (DSOD) to different locations around Sites Reservoir. For the alternative project evaluation, it is assumed that these release points would include Hunters Creek, Stone Corral Creek, Funks Creek, the Glenn-Colusa Irrigation District (GCID) and T-C Canals, and an open channel that would connect the TRR with the CBD. For the channel, it is assumed that emergency release water would be conveyed to TRR through the TRR Pipeline.

The emergency release flow required is a function of the size of Sites Reservoir. DSOD requires that 10-percent of the height of the reservoir must be reduced over a period of seven days. Table 3 provides an estimate of the average 7-day emergency release flow required for various reservoir sizes to meet the criteria. Also shown in the table is AECOM's assumed distribution of the required release to the creeks and canals listed above. Additional evaluation of the downstream watersheds and the downstream impacts will be needed to refine the distribution of releases between the candidate release points.

Regarding the canal to the CBD, AECOM assumes that the capacity would be between 750 and 1,000 cubic feet per second (cfs), which would be the equivalent release for one of the two 12-foot-diameter Delevan Pipes. A flow of 1,000 cfs is used in the table. In distributing the remaining flows as shown in the table, the following assumption were made:

1. The flows allocated to Stone Corral Creek and Funks Creek are approximately equivalent to 50-year flows estimated from published regression curves for Coastal Range areas. These flows are estimated at the Sites and Golden Gate Dams.

2. The flows allocated to the GCID and TC Canals represent minimum spare capacity that could be available to convey emergency releases. Capacity could be higher during certain time of the year.

3. After accounting for the releases described above, the balance of the required release was assigned to Hunters Creek at the north end of the valley. This release could be distributed to two or three of the larger saddle dams at the north end of Sites Reservoir, which are adjacent to Hunters Creek, or are on tributaries. At each release point, an outlet works pipeline would be provided at the base of the dam with energy dissipation valve(s) at the downstream end.

4. The release to Hunters Creek is sizeable. One feasible approach to reduce impacts would be to provide a dry dam on the creek with sized outlet works that would use storage routing to reduce the flow released to the creek downstream. There is at least one suitable site for such a dam on the creek where it passes out of the eastern ridge into the valley. This is not included with this cost estimate.

Also shown on the Table 3 is the estimated size of the twin outlet works tunnels required to pass the water being released to Funks Creek, the GCID and T-C canals, and the canal to the CBD. Tunnel size is based on the assumed distribution of the required emergency release to the various discharge points.

Table 3. Emergency Release – Assumed Distribution of Flows

Reservoir Size	**1.8 MAF**	**1.5 MAF**	**1.3 MAF**	**1.0 MAF**	**0.8 MAF**
Emergency Release Required (cfs)	21,700	17,950	15,450	12,000	9,650
Stream Releases (cfs)					
Hunters Creek Release Structure	11,250	7,500	5,000	4,500	3,000
Stone Corral Creek	3,500	3,500	3,500	3,500	3,500
Total =	14,750	11,000	8,500	8,000	6,500
Remaining Release Required =	**6,950**	**6,950**	**6,950**	**4,000**	**3,150**
I/O Tower and Tunnel Releases					
Funks Creek	4,500	4,500	4,500	2,550	3,150
GCID Main Canal	700	700	700	700	0
T-C Canal	750	750	750	750	0
Canal Conveyance to Colusa Basin Drain	1,000	1,000	1,000	0	0
Total =	6,950	6,950	6,950	4,000	3,150
I/O Tunnel Required Release (cfs) =	**6,950**	**6,950**	**6,950**	**4,000**	**3,150**
Estimated Twin I/O Tunnel Sizes (feet) for 20 feet per second (fps) maximum velocity (ft) =	**15**	**15**	**15**	**11**	**10**

6.0 Stony Creek Diversion

Stony Creek was evaluated as a potential diversion location for supplemental water supply.

One option is to explore periodically use of the seasonal dam approach that has been used in the past to provide supplemental flows in years when there is good storage in Black Butte Reservoir. Constructing a seasonal diversion would be an O&M activity. Water would be diverted into a gated structure that we temporarily install that directs the water into the T-C Canal Constant Head Orifice (CHO). This approach would add minimal capital cost.

Constructing an inflatable dam in a moving streambed is problematic. CALFED studied constructing a pipeline from Black Butte Reservoir to the T-C Canal (CALFED, 2002, *OUWUA and TCCA Regional Water Use* Efficiency *Project*) at a cost of $92.6 million. The escalated cost including non-contract costs is approximately $190 million. As an alternative, the Authority could consider an approach to drop pumps into Stony Creek to divert water into the T-C Canal when water is available. The cost estimate for providing pumps and a fish screen with electrical hook-up is approximately $38 million to allow a diversion of up to 300 cfs. It is unknown at this time if water rights can be obtained for a 300 cfs diversion.

An email from Jeff Sutton describing the limitations of the existing system is included as Attachment 4. The email also touches on the water rights and permitting issues that would need to be addressed for a diversion from Stony Creek.

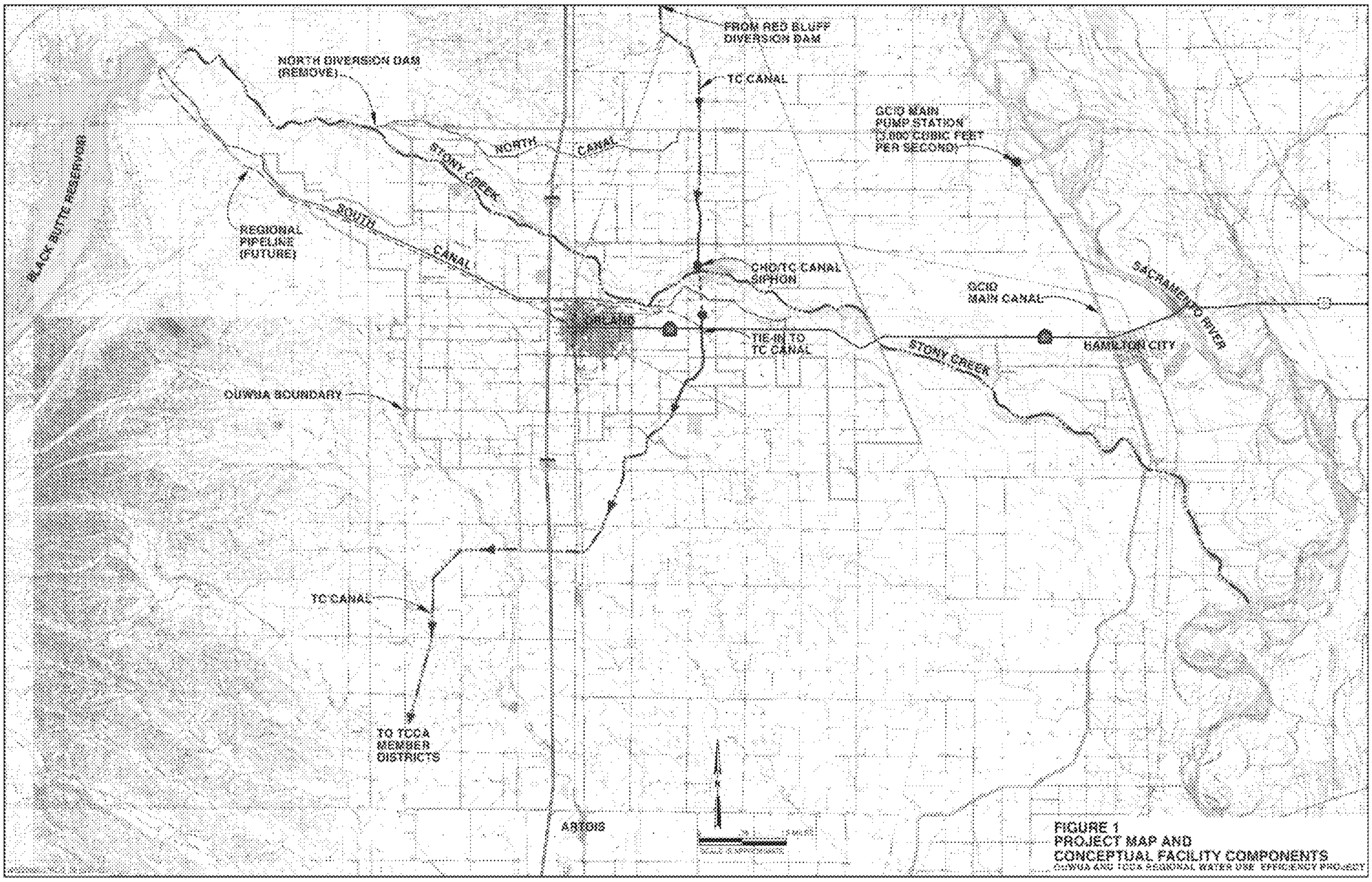


Figure 7. Stony Creek Diversion options

7.0 Attachments

[redacted]

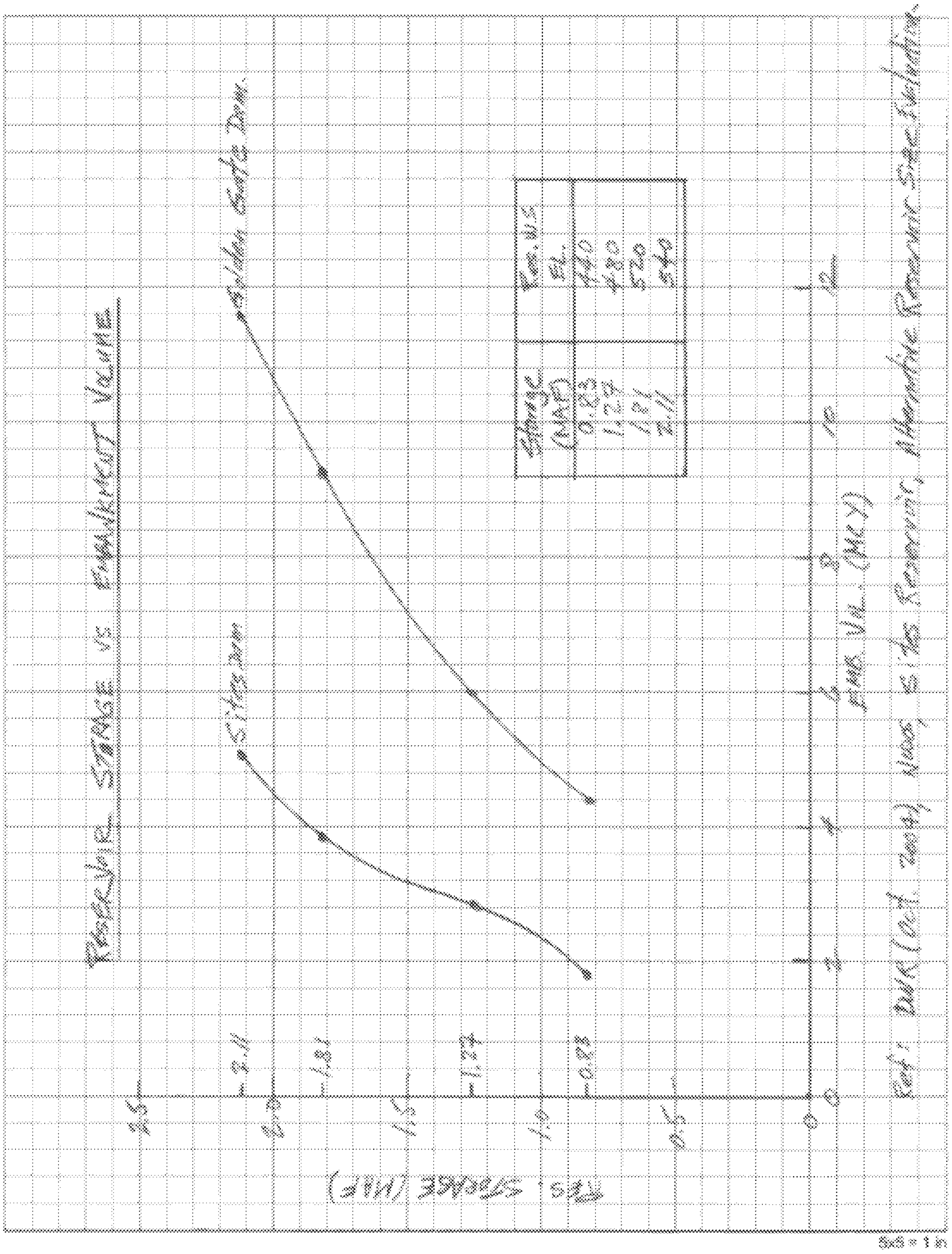
	Component Cost	Alternative D	Alternative 1	Alternative 2	Alternative 3	Alternative 4a	Alternative 4b	Alternative 5a	Alternative 5b	Alternative 6a	Alternative 6b
Total ($2018) w/o financing cost		$5,234,596,920	$3,969,916,920	$3,988,276,920	$3,868,396,920	$3,828,436,920	$3,860,836,920	$3,547,636,920	$3,875,956,920	$3,416,956,920	$3,584,356,920
% cost reduction		0%	24%	24%	26%	27%	26%	32%	26%	35%	32%
Total ($2015)		$4,846,849,000	$3,675,849,000	$3,692,849,000	$3,581,849,000	$3,544,849,000	$3,574,849,000	$3,284,849,000	$3,588,849,000	$3,163,849,000	$3,318,849,000
RESERVOIRS AND DAMS											
Develop Sites Reservoir Area	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000
Single Span Bridge	$215,000,000	$215,000,000									
Short Span Bridges	$125,000,000		$125,000,000		$125,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000
Lodoga Road (Long Route)	$114,000,000										
Lodoga Road (Direct Route)	$180,000,000			$180,000,000							
South Road Property Access	$38,000,000		$38,000,000		$38,000,000	$38,000,000	$38,000,000	$38,000,000	$38,000,000	$38,000,000	$38,000,000
Construct Main Dams (1.8 MAF) - Zoned Embankment	$610,000,000	$610,000,000									
Construct Main Dams (1.5 MAF) - Zoned Embankment	$511,000,000		$511,000,000	$511,000,000	$511,000,000			$511,000,000	$511,000,000		
Construct Main Dams (1.5 MAF) - Earthfill	$380,000,000					$380,000,000				$380,000,000	
Construct Main Dams (1.5 MAF) - Hardfill	$690,000,000						$690,000,000				
Construct Main Dams (1.3 MAF) - Zoned Embankment	$400,000,000										
Construct Main Dams (1.3 MAF) - Earthfill	$320,000,000										$320,000,000
Construct Saddle Dams (1.8 MAF)	$270,000,000	$270,000,000									
Construct Saddle Dams (1.5 MAF)	$183,000,000		$183,000,000	$183,000,000	$183,000,000	$183,000,000	$183,000,000	$183,000,000	$183,000,000	$183,000,000	
Construct Saddle Dams (1.3 MAF)	$94,000,000										$94,000,000
Construct Forebay/Afterbay (Fletcher/Holthouse)	$190,000,000	$190,000,000									
Funks Reservoir Structures/Dredging	$22,000,000		$22,000,000	$22,000,000		$22,000,000	$22,000,000	$22,000,000	$22,000,000		
Construct TRR Reservoir	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000
North T-C Regualting Reservoir	$39,000,000				$39,000,000					$39,000,000	$39,000,000
Hunters Creek Release Structures (at 3 Saddle Dams)	$84,000,000		$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000
PUMPING AND GENERATING PLANTS											
Construct I/O Structure and Single 30' Diameter Tunnel	$210,000,000	$210,000,000					$0				
Construct I/O Struture and Twin 15" Diameter Tunnels	$280,000,000		$280,000,000	$280,000,000	$280,000,000	$280,000,000	$0	$280,000,000	$280,000,000	$280,000,000	$280,000,000
Sites Pumping-Generating Plant (5,900 cfs) - with Delevan	$800,000,000	$800,000,000									
Sites Pumping-Generating Plant (4,000 cfs) - w/o Delevan	$634,000,000		$634,000,000	$634,000,000		$634,000,000	$634,000,000	$634,000,000	$634,000,000		
T-C North Pumping Plant - 2100 cfs	$185,000,000				$185,000,000					$185,000,000	$185,000,000
TRR Pumping-Generating Plant - 1800 cfs	$160,000,000	$160,000,000	$160,000,000	$160,000,000		$160,000,000	$160,000,000	$160,000,000	$160,000,000		
Increased Head TRR PumpGen Plant - 1800 cfs	$185,000,000				$185,000,000					$185,000,000	$185,000,000
CBD Pumping Plant for Delevan Release (750 cfs)	$34,000,000		$34,000,000	$34,000,000		$34,000,000	$34,000,000				
Sacramento River Pumping-Generating Plant (2000 cfs)	$260,000,000	$260,000,000									
Sacramento River Release Structure - 1500 cfs	$16,000,000										
Sacramento River Release Structure - 750 cfs	$8,000,000		$8,000,000	$8,000,000	$8,000,000	$8,000,000	$8,000,000				
Sacramento River Fish Screen Structure	$55,000,000	$55,000,000									
Red Bluff Pump Addition	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000
CBD Pumping Plant for T-C Extension (750 cfs)	$34,000,000								$34,000,000		$34,000,000
Canals and Conduits											
Construct Channel to Holthouse	$49,000,000	$49,000,000									
Reduced Channel with Hunters Creek Discharge	$31,000,000		$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000
Construct Delevan Pipeline - Two Pipeline	$660,000,000	$660,000,000									
Construct Delevan Pipeline - One Pipeline	$389,400,000										
Delevan Canal to CBD (750 cfs)	$150,000,000		$150,000,000	$150,000,000	$150,000,000	$150,000,000	$150,000,000				
CBD Siphon and Pipeline to River (750 cfs)	$210,000,000		$210,000,000	$210,000,000	$210,000,000	$210,000,000	$210,000,000				
TCRR Pipeline to Sites Reservoir (2100 cfs)	$410,000,000				$410,000,000					$410,000,000	$410,000,000
Construct TRR Pipeline - Four Pipelines (with Afterbay)	$350,000,000	$350,000,000									
Construct TRR Pipeline - Three Pipelines	$260,000,000		$260,000,000	$260,000,000		$260,000,000	$260,000,000				
Construct TRR Pipeline - Two Pipelines	$210,000,000				$210,000,000			$210,000,000	$210,000,000	$210,000,000	$210,000,000
T-C Canal Extension to CBD	$73,000,000							$73,000,000	$73,000,000	$73,000,000	$73,000,000
Siphon, Turnout, and Pipeline from CBD to River	$270,000,000								$270,000,000		$270,000,000

Release Structure - 750 cfs for South Outfall	$8,000,000							$8,000,000	$8,000,000	$8,000,000	$8,000,000
Stony Creek Diversion to TC	$37,000,000										
Transmission Lines, Switchyards and Substations											
Sites PGP and Colusa Substations,Switchyards, Transmission	190,000,000	190,000,000									
Sites PGP Substation, Switchyard, Transmission	98,000,000		98,000,000	96,000,000		96,000,000	96,000,000	98,000,000	98,000,000		
TRR and T-C from Cogen Substation	105,000,000				$105,000,000					$105,000,000	$105,000,000
General Property											
Recreation and O&M Facility	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000
Mitigation ($350M construction + $150M operation)											
Construction Impacts	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000
Operation Impacts	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000

Attachment 2. Res Storage vs Embank Vol Plot.pdf and Alt Dam ROM Costs

AECOM Imagine it. Delivered.

JOB TITLE SITES RESERVOIR - AUTHORITY
PROJECT/JOB NO. 60476765.27000 CALCULATION NO.
COMPUTED BY M. Forrest DATE 10/7/19.
VERIFIED BY DATE
SCALE SHEET NO. 1 OF



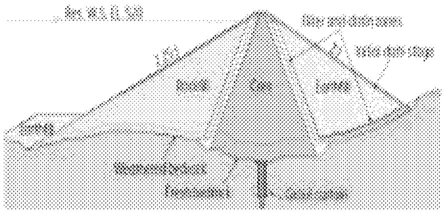
Storage (MAF)	Res. W.S. EL.
0.83	440
1.27	480
1.81	520
2.11	540

Ref: DWR (Oct. 2004), Nods, Sites Reservoir, Alternative Reservoir Size Evaluation.

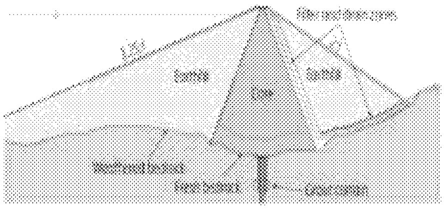
Attachment 3. Alternative-section_dams

Dam Types Drive Affordability

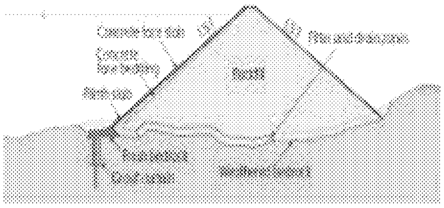
Option #1 Zoned Earth- and Rockfill Dams



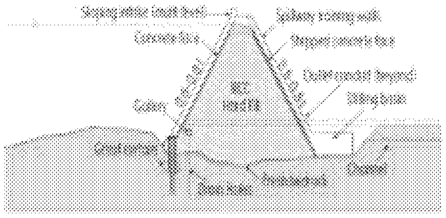
Option #2 Zoned Earthfill Dams



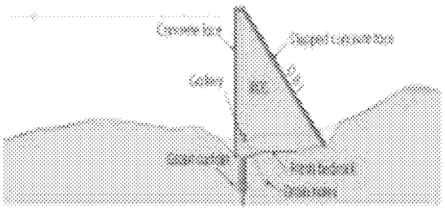
Option #3 Concrete Faced Rockfill Dams



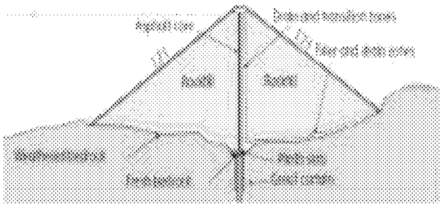
Option #4 RCC Hardfill Dams



Option #5 RCC Dams



Option #6 Asphalt Core Rockfill Dams



Attachment 4. 10/4 email from Jeff Sutton re: Stony Creek Diversion Operation

[redacted]

From: Jeff Sutton <jsutton@tccanal.com>
Sent: Friday, October 04, 2019 5:19 PM
To: 'William Vanderwaal' <wvanderwaal@rd108.org>
Cc: Herrin, Jeff <jeff.herrin@aecom.com>; 'Rob Kunde' <rkunde@wrmwsd.com>
Subject: RE: Action Items from Value Planning Session - Kunde Comments

Basically, we create a berm in the creek, and direct a portion of the creek into a gated structure that we temporarily install that directs the water into the CHO (Constant Head Orifice) into the canal. It was installed originally for putting water from the canal into Stony Creek as a restoration measure by USBR.

When utilized, we run it backwards, both literally in regard to the CHO system, and figuratively, we take water from the creek instead of putting in. Historically this was developed to provide additional water when we weren't allowed to lower the RBDD gates. Thus it is only permitted to be utilized from April 1 to May 15th, and September 15 to October 31st. These were times we were likely to still have irrigation demand, but when our diversion from the Sac River was unavailable because the diversion dam gates had to be up. Currently, those permit conditions still exist, and I have to get streambed alteration permit whenever we utilize this, which I am unsure if they would still allow under the old procedures. BTW, it also includes several other environmental details like flushing flows before it occurs, a bypass flow down the creek, a biologist to check it all out before it all operates, etc. We typically ran about 300 cfs into the canal. It has been run as high as about 500 cfs, but then you start to have concrete vibrating from what I have heard (it was before my time), which I would not be OK with.

I am guessing if we were to do something permanent in nature here, a fish screen would be required for those diversion (not a real sophisticated one, I don't believe juveniles would be an issue, but there would certainly be some new requirements if this was going to be used regularly as part of this project. This procedure has not been used since 2010. Now, since we have the RBPP and fish screen, we can divert from the river whenever we have an allocation. The only utility the diversion on Stony Creek currently has for the TC is to augment supply if we get a reduced allocation. Problem is, when that happens, there is usually no water in Black Butte for us (we are the last water right behind Black Butte, and in most dry years we typically don't have any water with our name on it up there.

For Sites, it could provide some significant winter and spring water supplies in wet years, but there could potentially be some water right issues, permits terms would be interesting, and would require some screened diversion infrastructure from the creek in my opinion.

Hope that is helpful. Glad to discuss further if needed.

Jeffrey P. Sutton
General Manager
Tehama-Colusa Canal Authority
P.O. Box 1025
Willows, CA 95988
Phone: (530) 934-2125
Cell: (530) 301-1030

From: William Vanderwaal [mailto:wvanderwaal@rd108.org]
Sent: Friday, October 04, 2019 4:58 PM
To: Rob Kunde; Herrin, Jeff
Cc: Jeff Sutton
Subject: RE: Action Items from Value Planning Session - Kunde Comments

Rob and Jeff Herrin,
So, the Black Butte water can be diverted from Stony Creek into the TC Canal and gravity flow similar to water from the TC Pumping Plant. Water wouldn't be released into Stony Creek.
However, yes, the water could be released into the TC Canal and down to Bird Creek vs a pipeline at Delevan.

Jeff Sutton, can you describe in more detail how you'd divert into the TC from Stony Creek?

Thanks
Bill V

William R Vanderwaal
RD-108/DWD
530.812.6276

From: Rob Kunde [mailto:rkunde@wrmwsd.com]
Sent: Friday, October 04, 2019 3:51 PM
To: Herrin, Jeff <jeff.herrin@aecom.com>; William Vanderwaal <wvanderwaal@rd108.org>
Subject: Re: Action Items from Value Planning Session - Kunde Comments

Thanks Jeff. My understanding from the meeting was some combination of Black Butte, Shasta Reservoir Storage Exchange, and TC Canal terminus release facilities might eliminate the need for the Delevan pipeline.

Robert J. Kunde, P.E.

Retired Annuitant

Wheeler Ridge-Maricopa Water Storage District

12109 Highway 166, Bakersfield, CA 93313

direct: 661-527-6070

cell: 661-345-3719

rkunde@wrmwsd.com

From: Dietl, Michael [mdietl@usbr.gov]
Sent: 10/29/2019 3:04:28 PM
To: Michael Mosley [mmosley@usbr.gov]; David Van rijn [dvanrijn@usbr.gov]; Francia Morales [fmorales@usbr.gov]; Donald Bader [dbader@usbr.gov]; Kristin White [knwhite@usbr.gov]; Kabir, Jobaid [jkabir@usbr.gov]; John [john.spranza@hdrinc.com]; WELSH, RICHARD [rwelsh@usbr.gov]; NATALIE WOLDER [nwolder@usbr.gov]; Anastasia Leigh [aleigh@usbr.gov]; Rob Thomson [rthomson@sitesproject.org]; Laurie Warner Herson [laurie.warner.herson@phenixenv.com]; Alicia Forsythe [aforsythe@sitesproject.org]; Jim Watson [jwatson@sitesproject.org]; Donna Garcia [dcgarcia@usbr.gov]
Subject: NODOS Summary of Management Review Comments
Attachments: Summary of Management Review Comments on North of Delta Offstream Storage 10-29-19.docx

Attached is a brief summary of the comments received for discussion tomorrow. The comment themes are my interpretation after reviewing the individual comments, we have your comments collated and will address them all with you as we move forward.

--
Mike Dietl
Project Manager
Bureau of Reclamation
Interior Region 10 · California-Great Basin
2800 Cottage Way, Room W-2830
Sacramento, CA 95825
Office Phone: 916.978.5070
E-mail: mdietl@usbr.gov

Summary of Management Review Comments on North of Delta Offstream Storage/Sites Reservoir Investigation, Administrative Draft Final Feasibility Report

Date: October 29, 2019

Background: Reclamation and Sites Authority decided on October 15, 2019, to undertake a management review of the current version of the NODOS/Sites Reservoir Investigation Administrative Draft Final Feasibility Report.

Comments received from: Kevin Tanaka, Natalie Wolder, Mark Moreburg, Nate Martin, Bob Colella, Linda Colella, Sonya Nechanicky Mike Dietl, and Sites Authority.

Major Comments/Issues

1. The no action baseline is becoming out of date with the issuance of new biological opinions for the Long -Term Operation of the Central Valley Project and State Water Project, a revised Coordinated Operations Agreement for the Operation of the Central Valley Project and State Water Project, potential voluntary settlement agreements, expansion of Los Vaqueros, and expansion of Lake Shasta.

    a. Should the no action baseline be changed, remodeling, contracting efforts, and subsequent reviews would take 2 years to be in a condition to release to the Commissioner. Sufficient funds may or may not be available and additional coordination with modeling resources needs to be completed.

2. Right sizing/reformulation of project for a new locally preferred plan and how to include an unidentified and unanalyzed project description.

3. Potential insufficient funding to reimburse/credit the State of California for Incremental Level 4 Refuge conveyance costs.

4. Numerous editorial changes to language on environmental status of the EIS, IL4 Refuge, Water Rights, etc. Most suggested changes improve the document, however some discussion with commenters is necessary for resolution.

Next Steps:

Value Planning Analysis Technical Memorandum

Sites
Program Management Team

To: Mike Azevedo, Lewis Bair, Thad Bettner, Gary Evans, Rob Kunde, Shelly Murphy, Randall Neudeck, Dan Ruiz, Jeff Sutton, Jamie Traynham, Bill Vanderwaal

CC: Rob Tull

Date: October 14, 2019

From: Joe Barnes, Jeff Herrin, Pete Rude (Jacobs), Jeff Smith (Jacobs)

1.0 Value Planning Effort

Representatives from the Reservoir Committee and Authority Board met on October 2, 2019 to discuss approaches that could potentially lower the cost of the project. Several facility modifications were identified, and appraisal level costs are provided in this analysis to allow a comparison of alternatives.

At this level of evaluation, the analysis is useful for identifying alternatives that merit further evaluation. The analysis is not sufficiently refined to distinguish between two alternatives of similar cost (e.g., + 10 to 15%).

Construction cost estimates for many of the facilities were derived from appraisal-level estimates for a 1.3 million acre feet (MAF) reservoir (Alternative A in the Environmental Impact Report/Environmental Impact Statement [EIR/S] and feasibility report) and for a 1.8 MAF reservoir (Alternative D in the EIR/S and feasibility report). Several new facilities were estimated, where possible using the unit rates from similar facilities in the existing estimates. Estimated prices were developed in October 2015 dollars and have been escalated in this estimate.

The actual project construction cost ultimately would depend on the final design details of the preferred project alternative and the labor and material costs, market conditions, and other variable factors existing at the time of bid. Accordingly, the final project cost is expected to vary from the preliminary estimates presented in this section.

2.0 General Limitations

AECOM represents that our services were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession within the limits prescribed by our client. No other warranties, either expressed or implied, are included or intended in this brief appraisal-level cost estimate.

We have used background information, conceptual designs, and data by others to prepare this appraisal-level cost estimate. We have relied on this information, as furnished, and is neither responsible for nor has confirmed the accuracy of this information.

The appraisal-level cost estimate presented herein is for the current study only and should not be extended or used for any other purposes.

3.0 Value Planning Facility Options and Alternatives

The meeting on October 2, 2019 identified both modifications to previously evaluated facilities and alternative facilities to reduce cost. A comprehensive table showing approximately 59 facility options that were considered in this analysis, along with their respective costs, is provided in Attachment 2.

There are numerous ways of combining the individual facility options into alternatives. To speed the analysis, we have looked at nine complete alternatives. There are many other ways of combining the facilities that can be further evaluated at the direction of the Value Planning working group.

The initial alternatives are shown in Table 1.

Table 1. Initial Alternatives for consideration.

Features	**Initial Alternatives**								
	1	**2**	**3**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**
1.5 MAF Reservoir	•	•	•	•	•	•	•	•	
1.3 MAF Reservoir									•
Funks/Sites PGP	•	•		•	•	•	•		
TCRR and Upgraded TRR PGP			•					•	•
Delevan Canal/Pipeline Release	•	•	•	•	•				
Dunnigan Canal to CBD Release						•		•	
Dunnigan to River Release							•		•
Multi-Span Bridge	•		•	•	•	•	•	•	•
South Road to Lodoga		•							
South Road to Residents	•		•	•	•	•	•	•	•
Rockfill Embankment Dam	•	•	•			•	•		
Earthfill Dam				•				•	•
Hardfill Dam					•				

MAF = million acre feet
PGP = Pumping/Generating Plant
TCRR = Tehama-Colusa Regulating Reservoir
TRR = Terminal Regulating Reservoir

For purposes of comparison, we have included Alternative D, the alternative presented in the WSIP application in the comparison of alternatives. The new alternatives include the following:

- Alternative 1 – Refer to Figure 1. This alternative reduces the size of the reservoir to 1.5 MAF and uses a multi-span bridge to reduce costs. The other features are generally consistent with Alternative D.
- Alternative 2 – Refer to Figure 2. This alternative is very similar to Alternative 1 but uses the southern road with the more direct route to Lodoga in place of the bridge.
- Alternative 3 – Refer to Figure 3. This alternative eliminates the Sites Pumping/Generating Plant and replaces it with the Tehama-Colusa Regulating Reservoir (TCRR) and Pumping Plant near Road 69 in combination with an upgraded Terminal Regulating Reservoir (TRR) to fill Sites Reservoir. Water would be released to the Sacramento River through a canal/pipeline to the Delevan release structure. The canal portion would begin at the TRR and continue east to the Colusa Basin Drain (CBD). It would be necessary to siphon under the CBD and pump the water to the river. The two-span bridge is used in this alternative.

- Alternatives 4a and 4b – Refer to Figures 4a and 4b. These alternatives include the single Sites Pumping/Generating Plant (PGP) with releases through the Delevan Canal/Pipeline. Alternative 4a uses an earthfill dam and Alternative 4b uses a hardfill dam in place of the zoned rockfill dam.

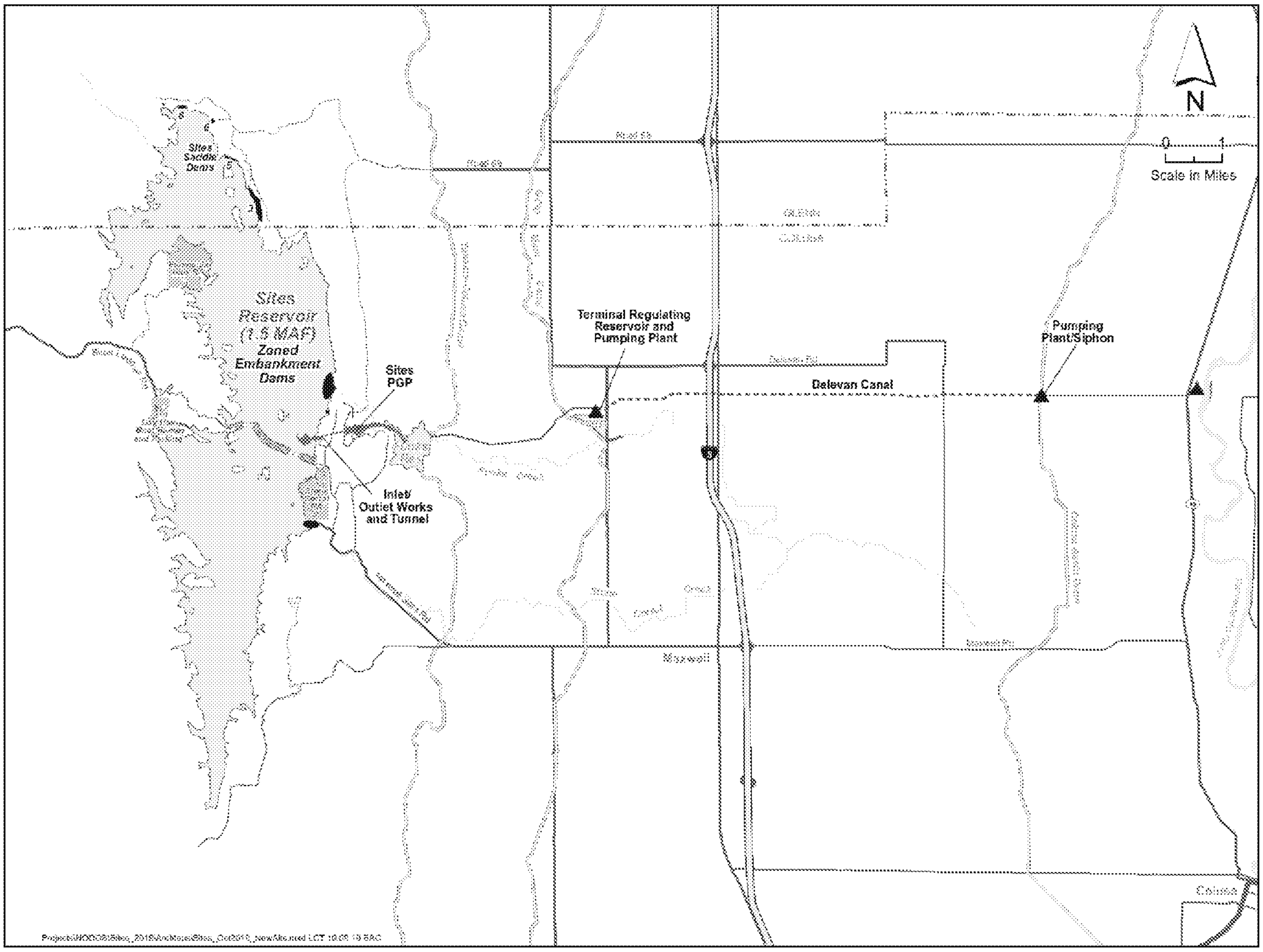
- Alternatives 5a and 5b – Refer to Figures 5a and 5b. These alternatives replace the Delevan Canal/Pipeline with a southern release near the southern terminous of the Tehama-Colusa (T-C) Canal. Alternative 5a releases water to the CBD. Water released to the CBD would be conveyed through the lower portion of the CBD to the Sacramento River. Alternative 5b conveys water by canal to the CBD, then uses a siphon and pumping plant to convey water on to the river.

- Alternatives 6a and 6b – Refer to Figures 6a and 6b. These alternatives combine the TCRR and upgraded TRR with the southern release structure and an earthfill dam. Alternative 6a appears to have the lowest construction cost.

A summary of alternative costs, including a cost comparison with Alternative D, is included in Table 2.

Table 2. Summary of Estimated Costs

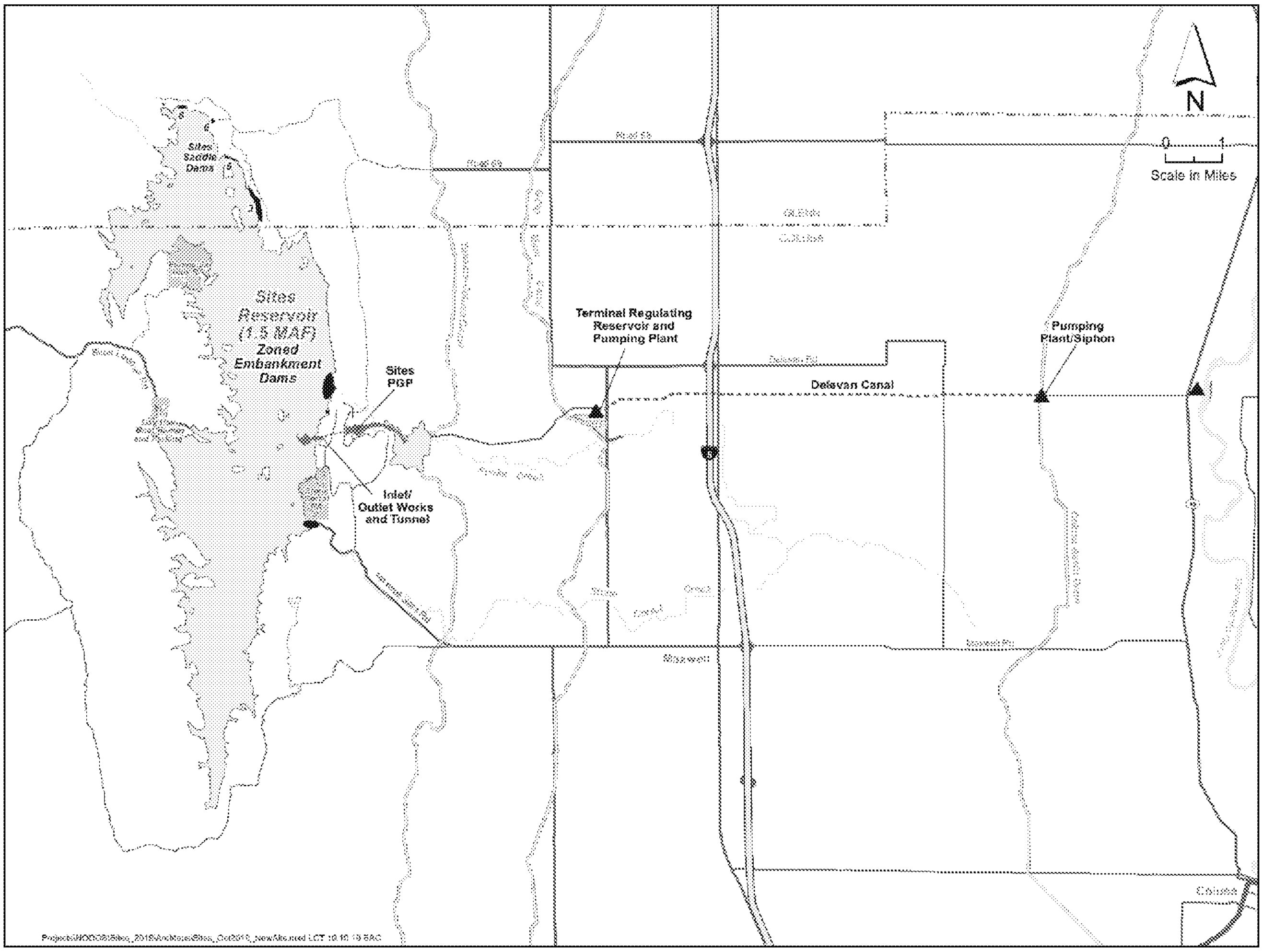
Alternative	**Estimated Costs ($2018) (financing cost not included)**	**Cost Reduction from Alternative D**
Alternative D	$5,235 million	0%
Alternative 1	$3,970 million	24%
Alternative 2	$3,988 million	24%
Alternative 3	$3,868 million	26%
Alternative 4a	$3,828 million	27%
Alternative 4b	$3,861 million	26%
Alternative 5a	$3,548 million	32%
Alternative 5b	$3,876 million	26%
Alternative 6a	$3,417 million	35%
Alternative 6b	$3,584 million	32%



Alternative 1

Figure 1. Alternative 1

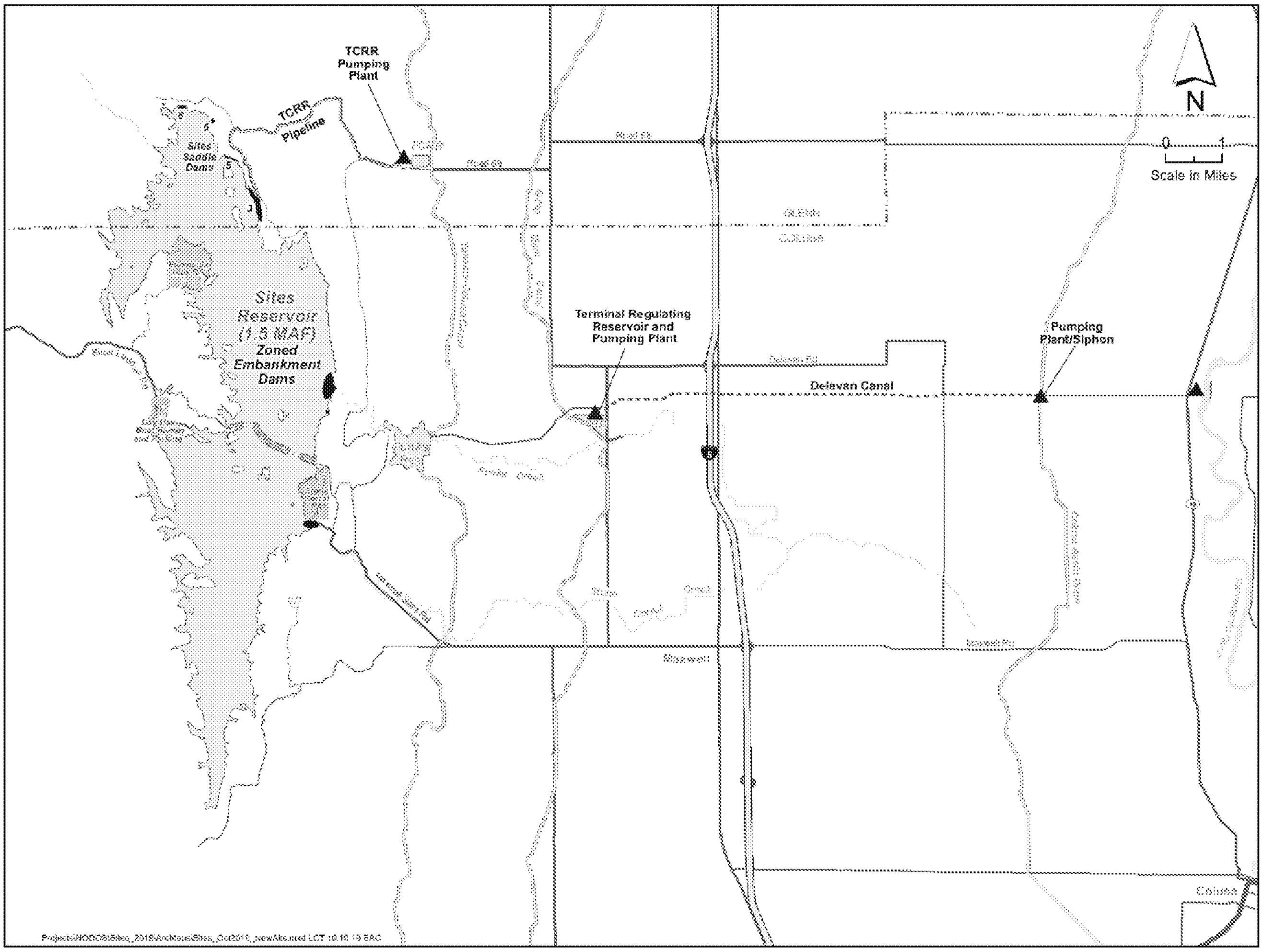
- Estimated cost - $3,970 million
- Cost reduction from Alternative D – 24%



Alternative 2

Figure 2. Alternative 2

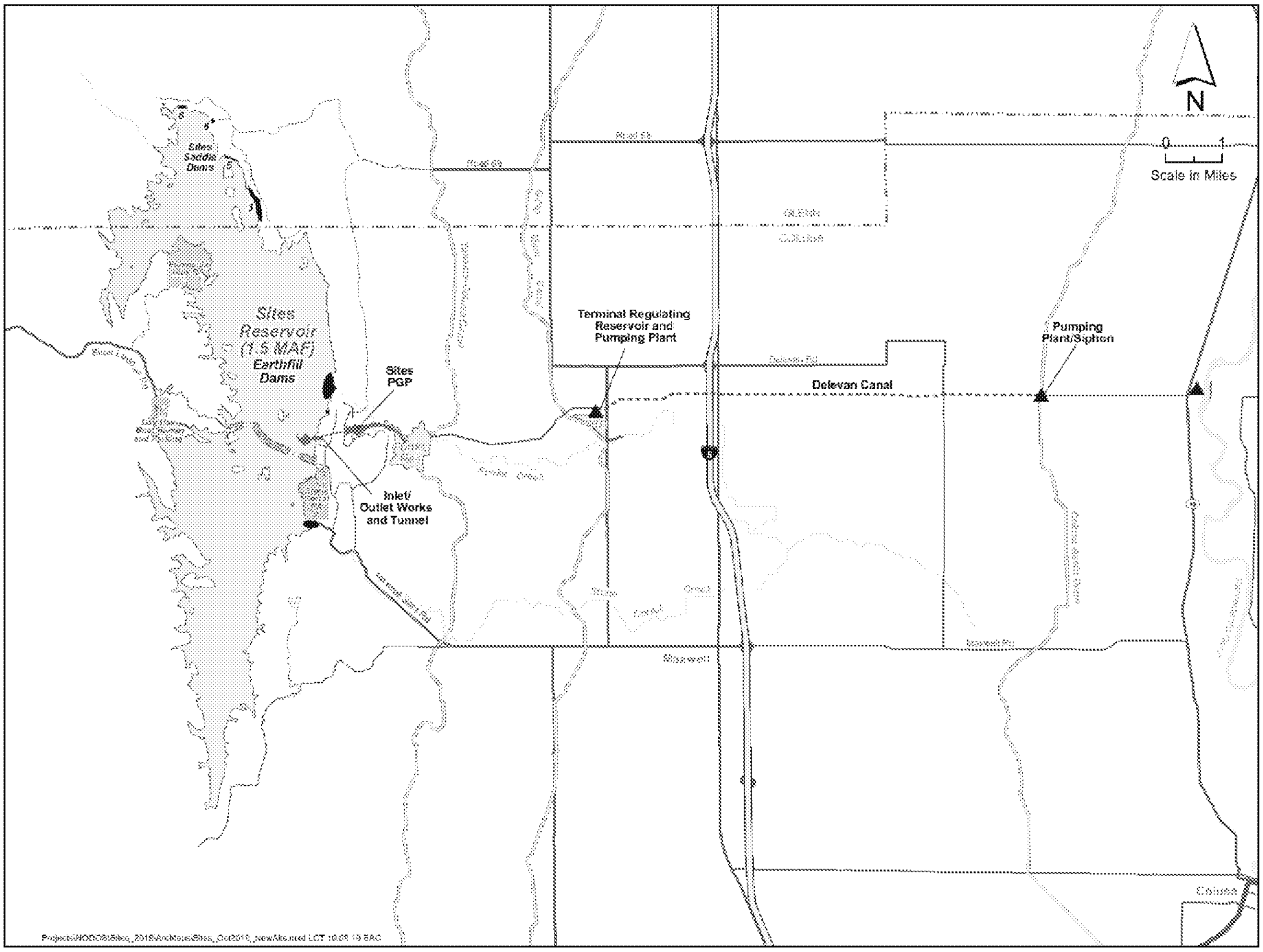
- Estimated cost - $3,988 million
- Cost reduction from Alternative D – 24%



Alternative 3

Figure 3. Alternative 3

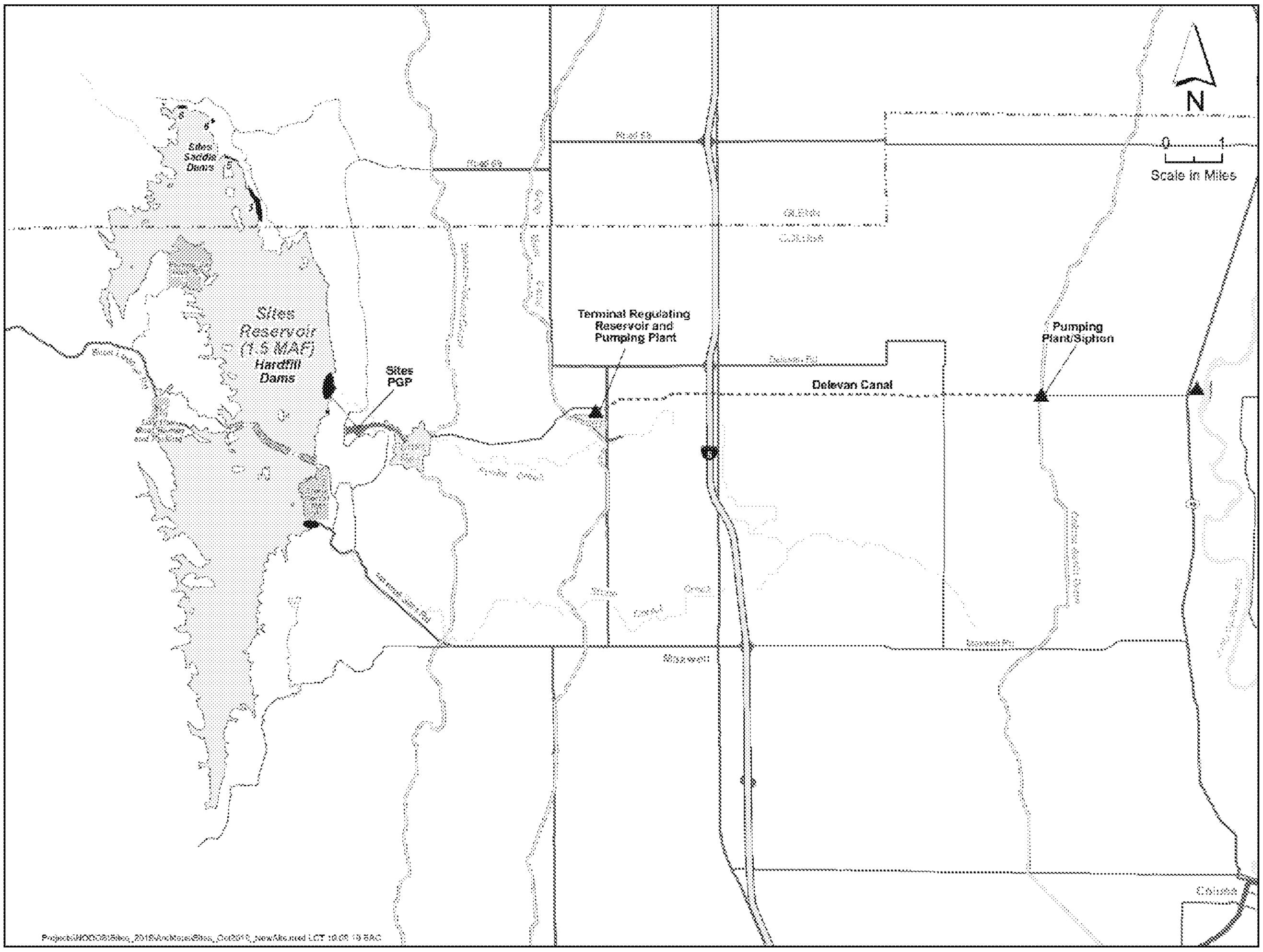
- Estimated cost - $3,868 million
- Cost reduction from Alternative D – 26%



Alternative 4a

Figure 4a. Alternative 4a

- Estimated cost - $3,828 million
- Cost reduction from Alternative D – 27%



Alternative 4b

Figure 4b. Alternative 4b

- Estimated cost - $3,861 million
- Cost reduction from Alternative D – 26%

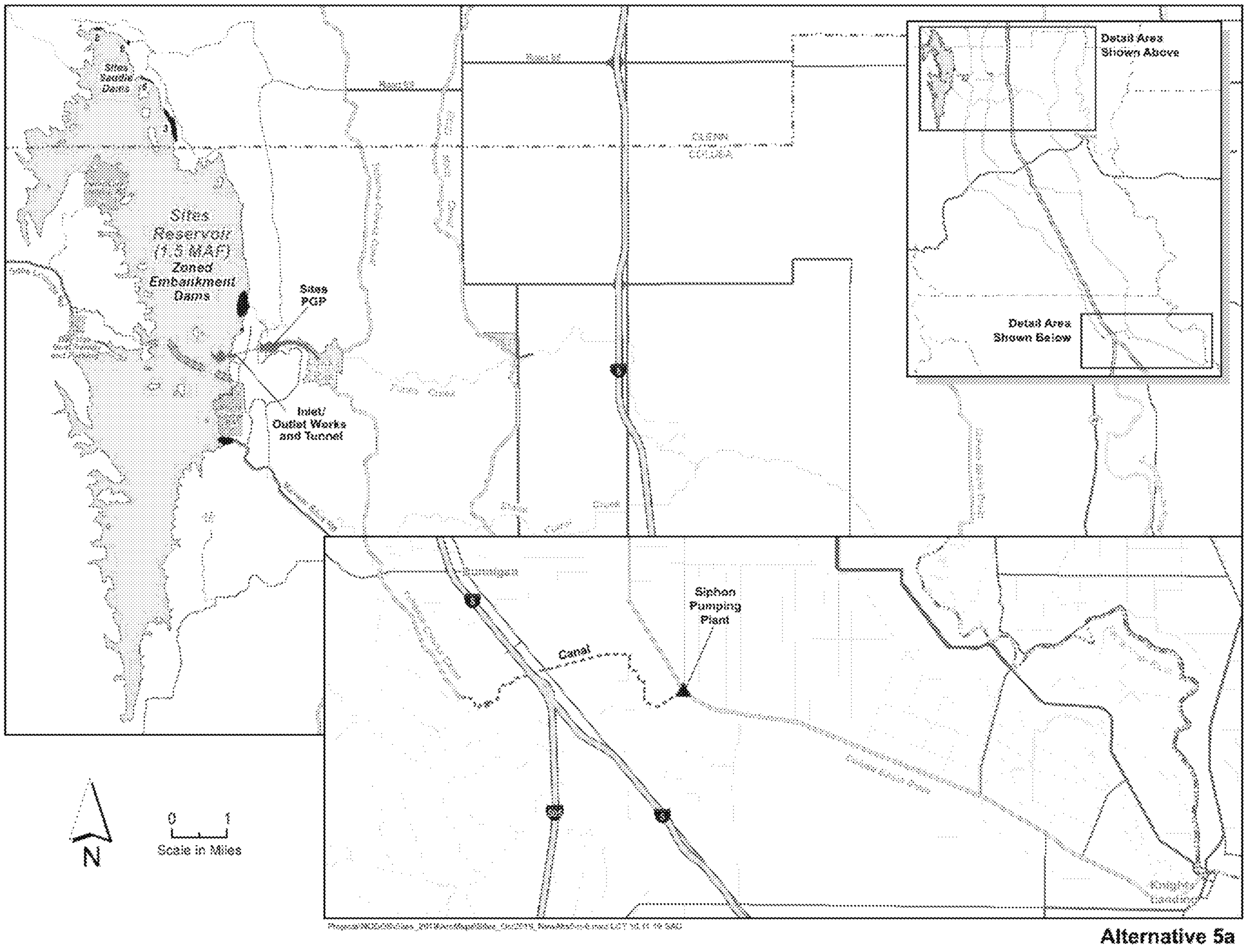


Figure 5a. Alternative 5a

- Estimated cost - $3,548 million
- Cost reduction from Alternative D – 32%

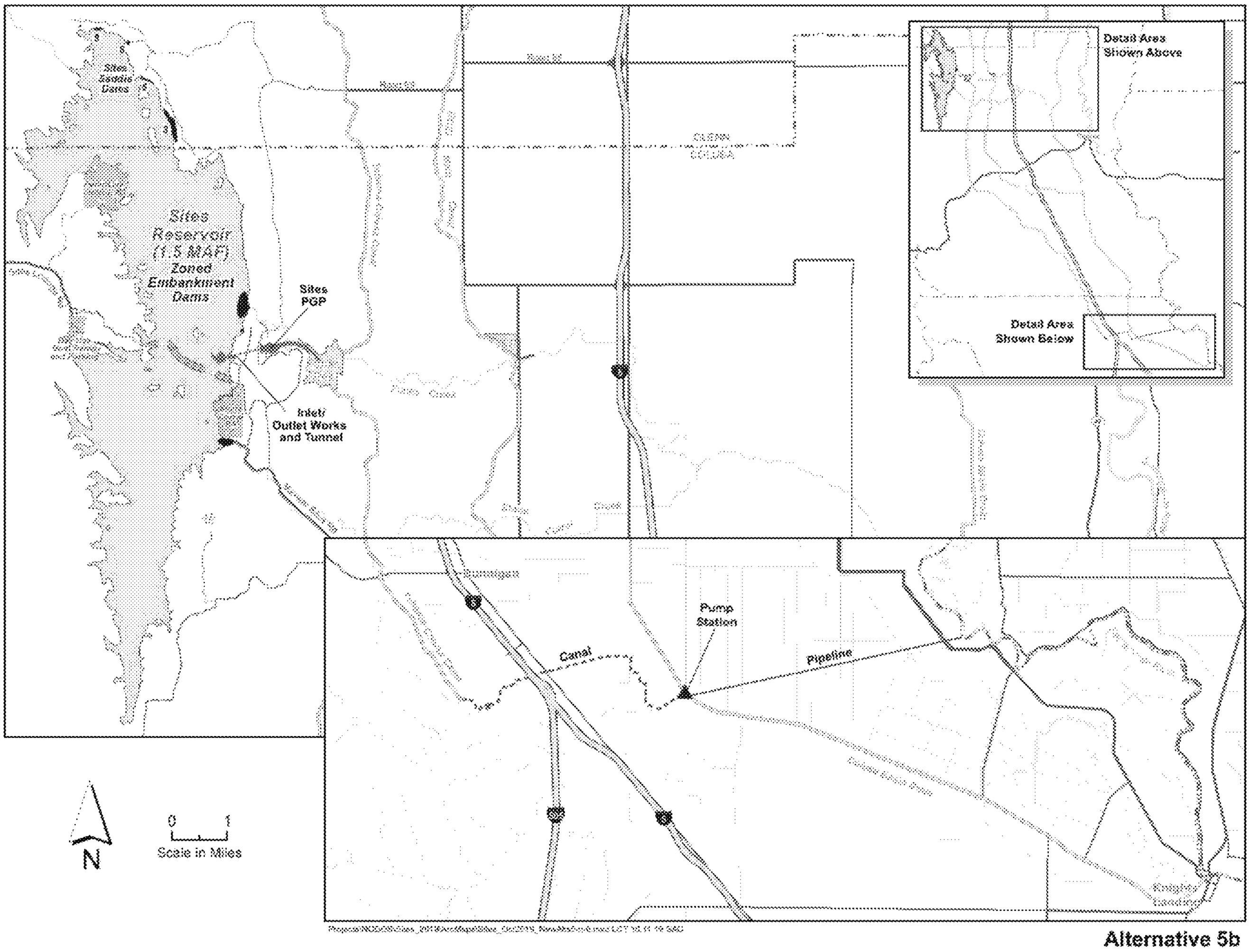


Figure 5b. Alternative 5b

- Estimated cost - $3,876 million
- Cost reduction from Alternative D – 26%

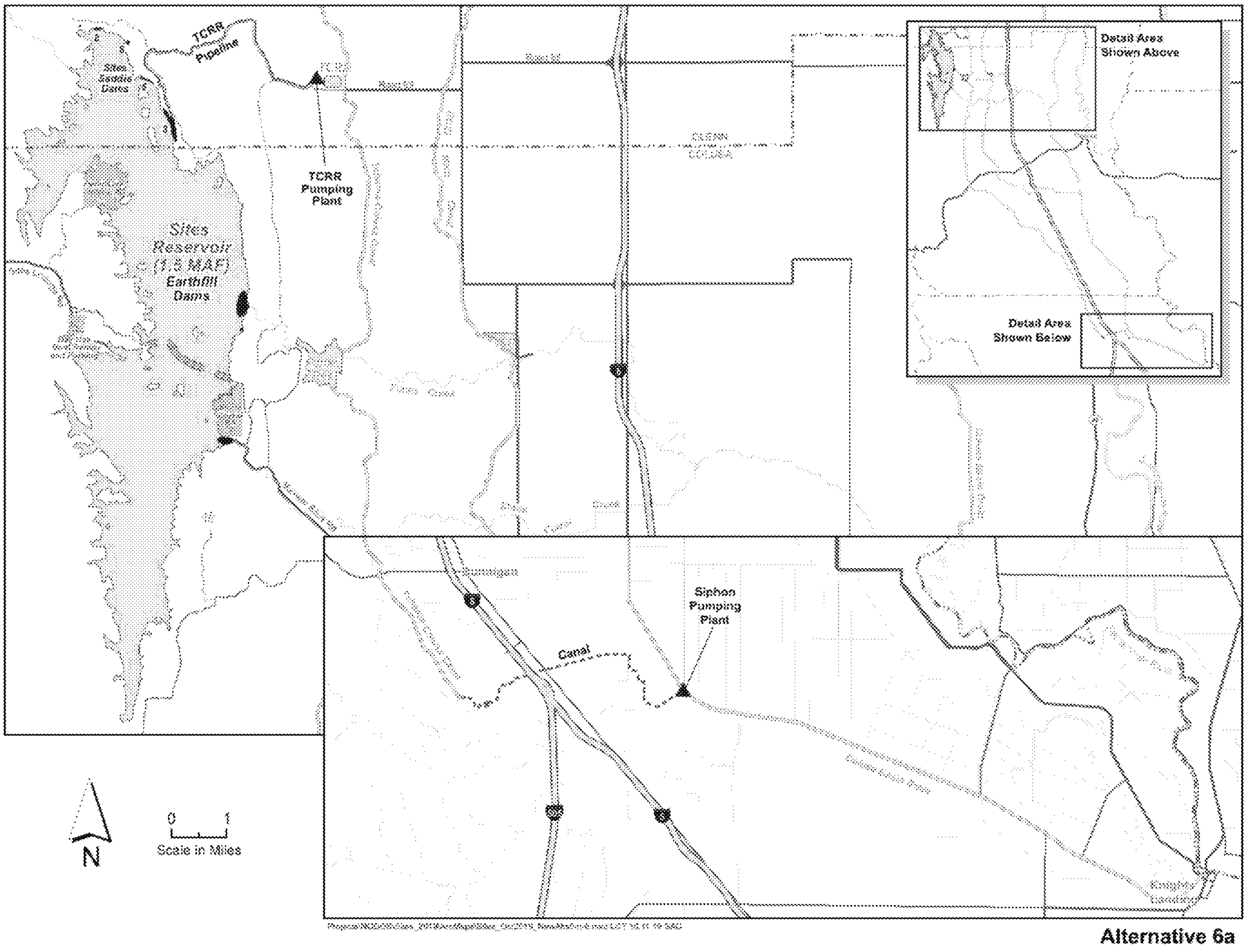


Figure 6a. Alternative 6a

- Estimated cost - $3,417 million
- Cost reduction from Alternative D – 35%

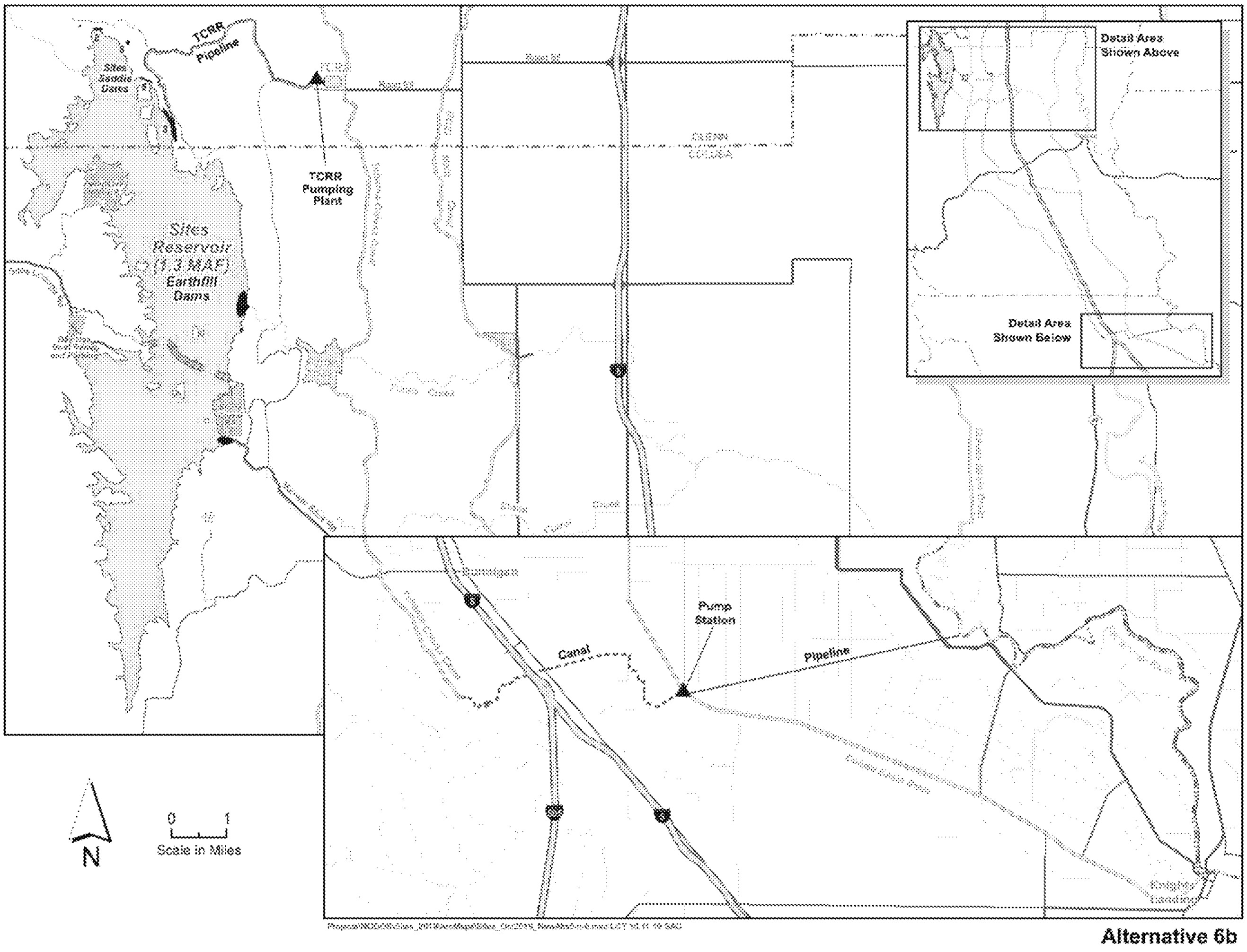


Figure 6b. Alternative 6b

- Estimated cost - $3,584 million
- Cost reduction from Alternative D – 32%

4.0 Environmental Mitigation

HDR reviewed the existing mitigation cost estimates currently being used and found that when applied to the Value Planning Alternatives, the estimated mitigation costs do not result in any significant changes in estimated mitigation costs (>$50M). Their October 11, 2019 memorandum concluded that until additional analysis can be performed on a specific project description, the existing $500M estimate should be retained.

5.0 Emergency Reservoir Drawdown

It is proposed to distribute the emergency reservoir release flow required by the State of California Department of Water Resources, Division of Safety of Dams (DSOD) to different locations around Sites Reservoir. For the alternative project evaluation, it is assumed that these release points would include Hunters Creek, Stone Corral Creek, Funks Creek, the Glenn-Colusa Irrigation District (GCID) and T-C Canals, and an open channel that would connect the TRR with the CBD. For the channel, it is assumed that emergency release water would be conveyed to TRR through the TRR Pipeline.

The emergency release flow required is a function of the size of Sites Reservoir. DSOD requires that 10-percent of the height of the reservoir must be reduced over a period of seven days. Table 3 provides an estimate of the average 7-day emergency release flow required for various reservoir sizes to meet the criteria. Also shown in the table is AECOM's assumed distribution of the required release to the creeks and canals listed above. Additional evaluation of the downstream watersheds and the downstream impacts will be needed to refine the distribution of releases between the candidate release points.

Regarding the canal to the CBD, AECOM assumes that the capacity would be between 750 and 1,000 cubic feet per second (cfs), which would be the equivalent release for one of the two 12-foot-diameter Delevan Pipes. A flow of 1,000 cfs is used in the table. In distributing the remaining flows as shown in the table, the following assumption were made:

1. The flows allocated to Stone Corral Creek and Funks Creek are approximately equivalent to 50-year flows estimated from published regression curves for Coastal Range areas. These flows are estimated at the Sites and Golden Gate Dams.

2. The flows allocated to the GCID and TC Canals represent minimum spare capacity that could be available to convey emergency releases. Capacity could be higher during certain time of the year.

3. After accounting for the releases described above, the balance of the required release was assigned to Hunters Creek at the north end of the valley. This release could be distributed to two or three of the larger saddle dams at the north end of Sites Reservoir, which are adjacent to Hunters Creek, or are on tributaries. At each release point, an outlet works pipeline would be provided at the base of the dam with energy dissipation valve(s) at the downstream end.

4. The release to Hunters Creek is sizeable. One feasible approach to reduce impacts would be to provide a dry dam on the creek with sized outlet works that would use storage routing to reduce the flow released to the creek downstream. There is at least one suitable site for such a dam on the creek where it passes out of the eastern ridge into the valley. This is not included with this cost estimate.

Also shown on the Table 3 is the estimated size of the twin outlet works tunnels required to pass the water being released to Funks Creek, the GCID and T-C canals, and the canal to the CBD. Tunnel size is based on the assumed distribution of the required emergency release to the various discharge points.

Table 3. Emergency Release – Assumed Distribution of Flows

Reservoir Size	**1.8 MAF**	**1.5 MAF**	**1.3 MAF**	**1.0 MAF**	**0.8 MAF**
Emergency Release Required (cfs)	21,700	17,950	15,450	12,000	9,650
Stream Releases (cfs)					
Hunters Creek Release Structure	11,250	7,500	5,000	4,500	3,000
Stone Corral Creek	3,500	3,500	3,500	3,500	3,500
Total =	14,750	11,000	8,500	8,000	6,500
Remaining Release Required =	**6,950**	**6,950**	**6,950**	**4,000**	**3,150**
I/O Tower and Tunnel Releases					
Funks Creek	4,500	4,500	4,500	2,550	3,150
GCID Main Canal	700	700	700	700	0
T-C Canal	750	750	750	750	0
Canal Conveyance to Colusa Basin Drain	1,000	1,000	1,000	0	0
Total =	6,950	6,950	6,950	4,000	3,150
I/O Tunnel Required Release (cfs) =	**6,950**	**6,950**	**6,950**	**4,000**	**3,150**
Estimated Twin I/O Tunnel Sizes (feet) for 20 feet per second (fps) maximum velocity (ft) =	**15**	**15**	**15**	**11**	**10**

6.0 Stony Creek Diversion

Stony Creek was evaluated as a potential diversion location for supplemental water supply.

One option is to explore periodically use of the seasonal dam approach that has been used in the past to provide supplemental flows in years when there is good storage in Black Butte Reservoir. Constructing a seasonal diversion would be an O&M activity. Water would be diverted into a gated structure that we temporarily install that directs the water into the T-C Canal Constant Head Orifice (CHO). This approach would add minimal capital cost.

Constructing an inflatable dam in a moving streambed is problematic. CALFED studied constructing a pipeline from Black Butte Reservoir to the T-C Canal (CALFED, 2002, *OUWUA and TCCA Regional Water Use* Efficiency *Project*) at a cost of $92.6 million. The escalated cost including non-contract costs is approximately $190 million. As an alternative, the Authority could consider an approach to drop pumps into Stony Creek to divert water into the T-C Canal when water is available. The cost estimate for providing pumps and a fish screen with electrical hook-up is approximately $38 million to allow a diversion of up to 300 cfs. It is unknown at this time if water rights can be obtained for a 300 cfs diversion.

An email from Jeff Sutton describing the limitations of the existing system is included as Attachment 4. The email also touches on the water rights and permitting issues that would need to be addressed for a diversion from Stony Creek.

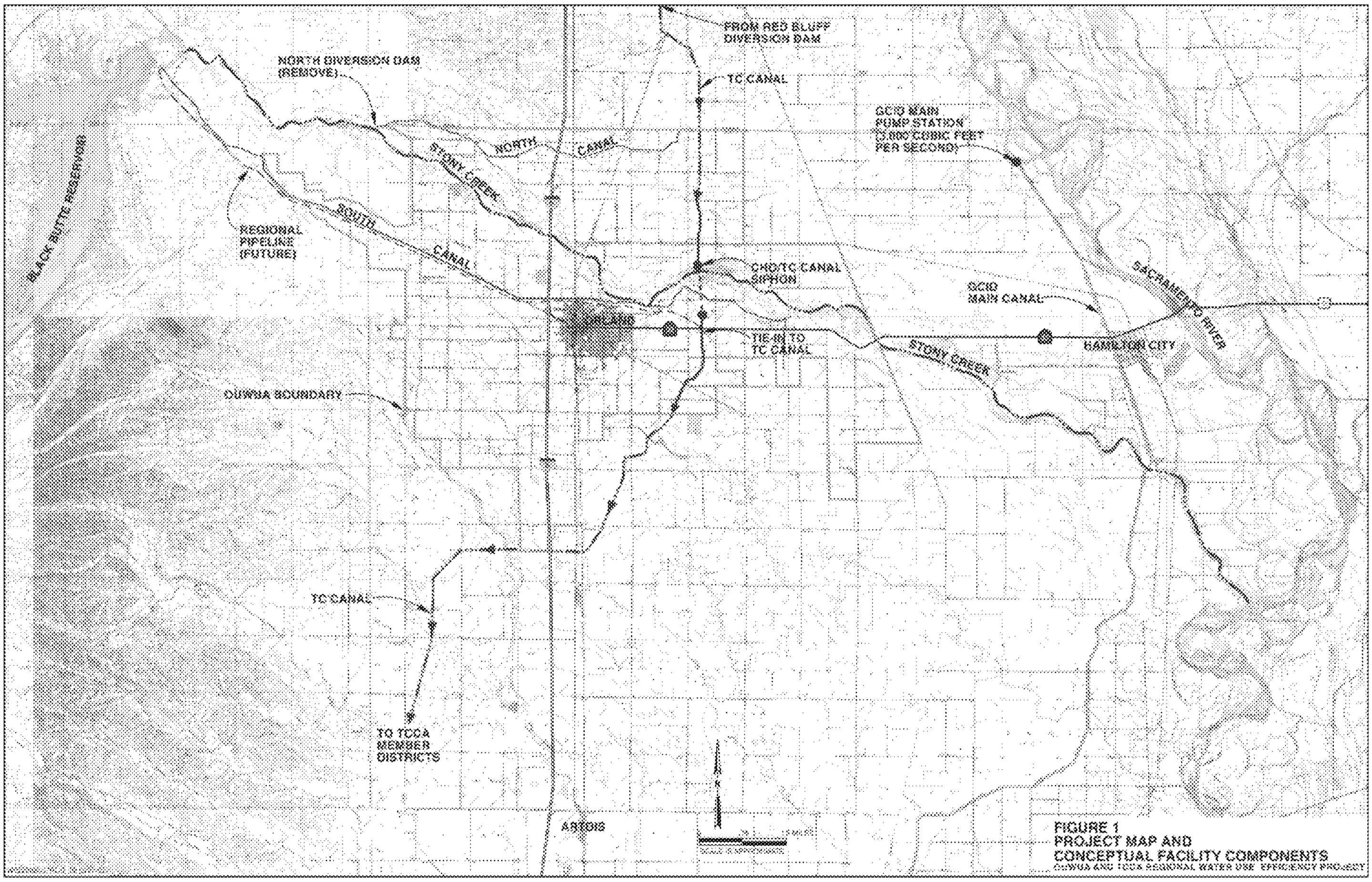


Figure 7. Stony Creek Diversion options

7.0 Attachments

[redacted]

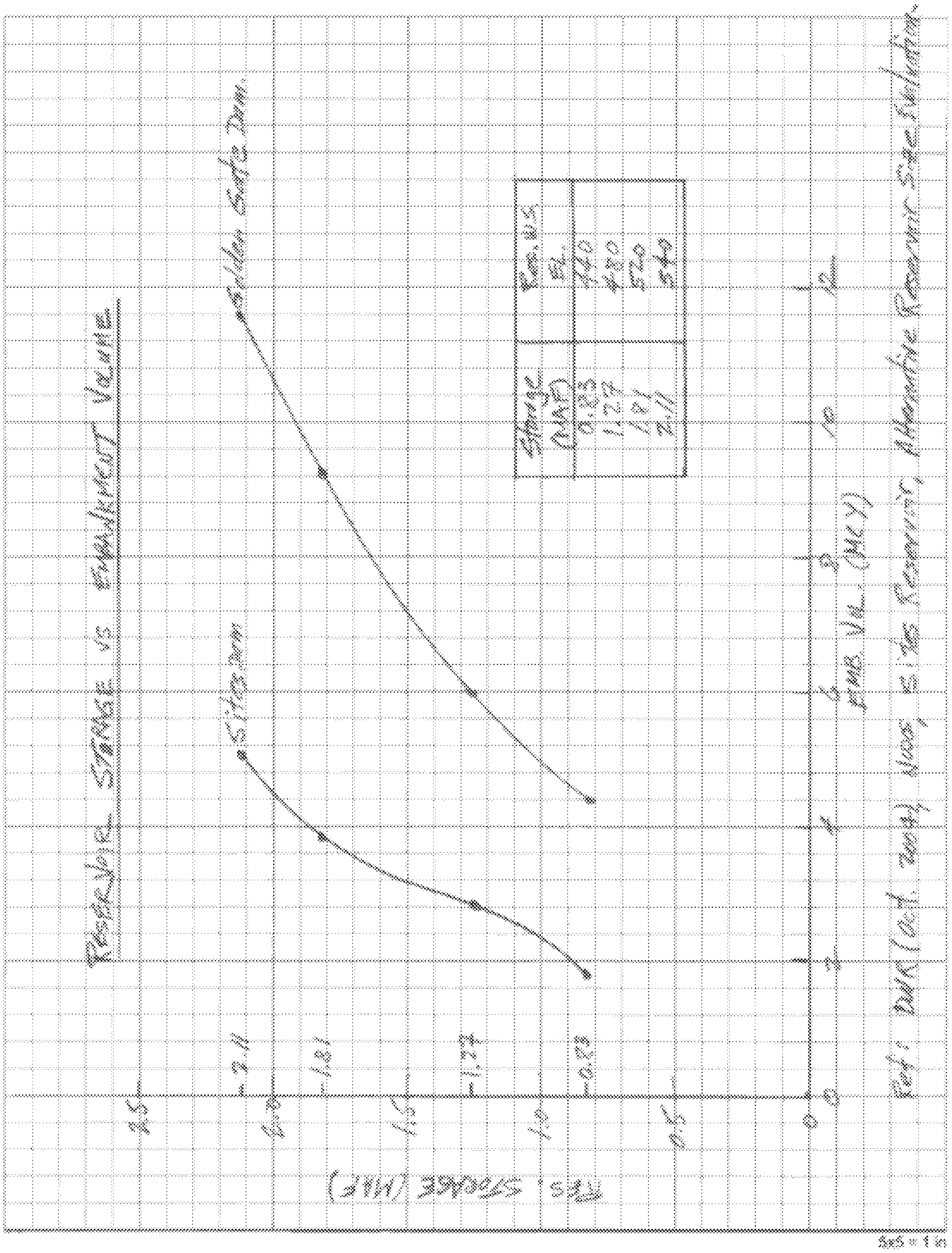
	Component Cost	Alternative D	Alternative 1	Alternative 2	Alternative 3	Alternative 4a	Alternative 4b	Alternative 5a	Alternative 5b	Alternative 6a	Alternative 6b
Total ($2018) w/o financing cost		$5,234,596,920	$3,969,916,920	$3,988,276,920	$3,868,396,920	$3,828,436,920	$3,860,836,920	$3,547,636,920	$3,875,956,920	$3,416,956,920	$3,584,356,920
% cost reduction		0%	24%	24%	26%	27%	26%	32%	26%	35%	32%
Total ($2015)		$4,846,849,000	$3,675,849,000	$3,692,849,000	$3,581,849,000	$3,544,849,000	$3,574,849,000	$3,284,849,000	$3,588,849,000	$3,163,849,000	$3,318,849,000
RESERVOIRS AND DAMS											
Develop Sites Reservoir Area	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000	$255,000,000
Single Span Bridge	$215,000,000	$215,000,000									
Short Span Bridges	$125,000,000		$125,000,000		$125,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000
Lodoga Road (Long Route)	$114,000,000										
Lodoga Road (Direct Route)	$180,000,000			$180,000,000							
South Road Property Access	$38,000,000		$38,000,000		$38,000,000	$38,000,000	$38,000,000	$38,000,000	$38,000,000	$38,000,000	$38,000,000
Construct Main Dams (1.8 MAF) - Zoned Embankment	$610,000,000	$610,000,000									
Construct Main Dams (1.5 MAF) - Zoned Embankment	$511,000,000		$511,000,000	$511,000,000	$511,000,000			$511,000,000	$511,000,000		
Construct Main Dams (1.5 MAF) - Earthfill	$380,000,000					$380,000,000				$380,000,000	
Construct Main Dams (1.5 MAF) - Hardfill	$690,000,000						$690,000,000				
Construct Main Dams (1.3 MAF) - Zoned Embankment	$400,000,000										
Construct Main Dams (1.3 MAF) - Earthfill	$320,000,000										$320,000,000
Construct Saddle Dams (1.8 MAF)	$270,000,000	$270,000,000									
Construct Saddle Dams (1.5 MAF)	$163,000,000		$163,000,000	$163,000,000	$163,000,000	$163,000,000	$163,000,000	$163,000,000	$163,000,000	$163,000,000	
Construct Saddle Dams (1.3 MAF)	$94,000,000										$94,000,000
Construct Forebay/Afterbay (Fletcher/Holthouse)	$190,000,000	$190,000,000									
Funks Reservoir Structures/Dredging	$22,000,000		$22,000,000	$22,000,000		$22,000,000	$22,000,000	$22,000,000	$22,000,000		
Construct TRR Reservoir	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000
North T-C Regualting Reservoir	$39,000,000				$39,000,000					$39,000,000	$39,000,000
Hunters Creek Release Structures (at 3 Saddle Dams)	$84,000,000		$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000	$84,000,000
PUMPING AND GENERATING PLANTS											
Construct I/O Structure and Single 30' Diameter Tunnel	$210,000,000	$210,000,000					$0				
Construct I/O Struture and Twin 15" Diameter Tunnels	$280,000,000		$280,000,000	$280,000,000	$280,000,000	$280,000,000	$0	$280,000,000	$280,000,000	$280,000,000	$280,000,000
Sites Pumping-Generating Plant (5,900 cfs) - with Delevan	$800,000,000	$800,000,000									
Sites Pumping-Generating Plant (4,000 cfs) - w/o Delevan	$634,000,000		$634,000,000	$634,000,000		$634,000,000	$634,000,000	$634,000,000	$634,000,000		
T-C North Pumping Plant - 2100 cfs	$185,000,000				$185,000,000					$185,000,000	$185,000,000
TRR Pumping-Generating Plant - 1800 cfs	$160,000,000	$160,000,000	$160,000,000	$160,000,000		$160,000,000	$160,000,000	$160,000,000	$160,000,000		
Increased Head TRR PumpGen Plant - 1800 cfs	$185,000,000				$185,000,000					$185,000,000	$185,000,000
CBD Pumping Plant for Delevan Release (750 cfs)	$34,000,000		$34,000,000	$34,000,000		$34,000,000	$34,000,000				
Sacramento River Pumping-Generating Plant (2000 cfs)	$260,000,000	$260,000,000									
Sacramento River Release Structure - 1500 cfs	$16,000,000										
Sacramento River Release Structure - 750 cfs	$8,000,000		$8,000,000	$8,000,000	$8,000,000	$8,000,000	$8,000,000				
Sacramento River Fish Screen Structure	$55,000,000	$55,000,000									
Red Bluff Pump Addition	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000	$3,849,000
CBD Pumping Plant for T-C Extension (750 cfs)	$34,000,000								$34,000,000		$34,000,000
Canals and Conduits											
Construct Channel to Holthouse	$49,000,000	$49,000,000									
Reduced Channel with Hunters Creek Discharge	$31,000,000		$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000	$31,000,000
Construct Delevan Pipeline - Two Pipeline	$660,000,000	$660,000,000									
Construct Delevan Pipeline - One Pipeline	$369,400,000										
Delevan Canal to CBD (750 cfs)	$150,000,000		$150,000,000	$150,000,000	$150,000,000	$150,000,000	$150,000,000				
CBD Siphon and Pipeline to River (750 cfs)	$210,000,000		$210,000,000	$210,000,000	$210,000,000	$210,000,000	$210,000,000				
TCRR Pipeline to Sites Reservoir (2100 cfs)	$410,000,000				$410,000,000					$410,000,000	$410,000,000
Construct TRR Pipeline - Four Pipelines (with Afterbay)	$350,000,000	$350,000,000									
Construct TRR Pipeline - Three Pipelines	$260,000,000		$260,000,000	$260,000,000		$260,000,000	$260,000,000				
Construct TRR Pipeline - Two Pipelines	$210,000,000				$210,000,000			$210,000,000	$210,000,000	$210,000,000	$210,000,000
T-C Canal Extension to CBD	$73,000,000							$73,000,000	$73,000,000	$73,000,000	$73,000,000
Siphon, Turnout, and Pipeline from CBD to River	$270,000,000								$270,000,000		$270,000,000

Release Structure - 750 cfs for South Outfall	$8,000,000							$8,000,000	$8,000,000	$8,000,000	$8,000,000
Stony Creek Diversion to TC	$37,000,000										
Transmission Lines, Switchyards and Substations											
Sites PGP and Colusa Substations,Switchyards, Transmission	190,000,000	190,000,000									
Sites PGP Substation, Switchyard, Transmission	98,000,000		98,000,000	98,000,000		98,000,000	98,000,000	98,000,000	98,000,000		
TRR and T-C from Cogen Substation	105,000,000				$105,000,000					$105,000,000	$105,000,000
General Property											
Recreation and O&M Facility	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000
Mitigation ($350M construction + $150M operation)											
Construction Impacts	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000	350,000,000
Operation Impacts	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000	150,000,000

Attachment 2. Res Storage vs Embank Vol Plot.pdf and Alt Dam ROM Costs

AECOM Imagine it. Delivered.

JOB TITLE SITES RESERVOIR - AUTHORITY
PROJECT/JOB NO. 60476765.27000 CALCULATION NO.
COMPUTED BY M. Forrest DATE 10/7/19.
VERIFIED BY DATE
SCALE SHEET NO. 1 OF

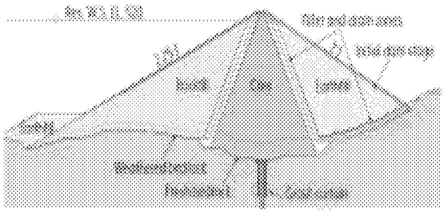


Storage (MAF)	Res. W.S. El.
0.83	440
1.27	480
1.81	520
2.11	540

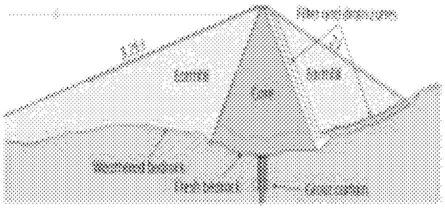
Attachment 3. Alternative-section_dams

Dam Types Drive Affordability

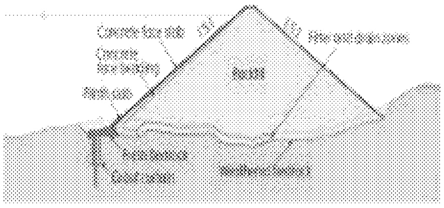
Option #1 Zoned Earth- and Rockfill Dams



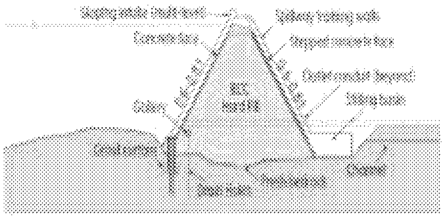
Option #2 Zoned Earthfill Dams



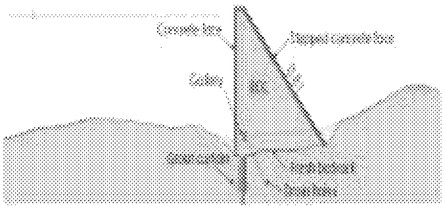
Option #3 Concrete Faced Rockfill Dams



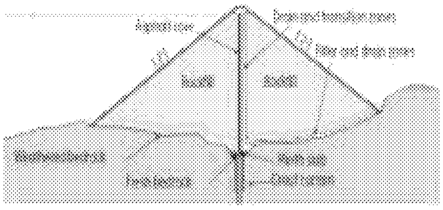
Option #4 RCC Hardfill Dams



Option #5 RCC Dams



Option #6 Asphalt Core Rockfill Dams



Attachment 4. 10/4 email from Jeff Sutton re: Stony Creek Diversion Operation

From: Jeff Sutton <jsutton@tccanal.com>
Sent: Friday, October 04, 2019 5:19 PM
To: 'William Vanderwaal' <wvanderwaal@rd108.org>
Cc: Herrin, Jeff <jeff.herrin@aecom.com>; 'Rob Kunde' <rkunde@wrmwsd.com>
Subject: RE: Action Items from Value Planning Session - Kunde Comments

Basically, we create a berm in the creek, and direct a portion of the creek into a gated structure that we temporarily install that directs the water into the CHO (Constant Head Orifice) into the canal. It was installed originally for putting water from the canal into Stony Creek as a restoration measure by USBR.

When utilized, we run it backwards, both literally in regard to the CHO system, and figuratively, we take water from the creek instead of putting in. Historically this was developed to provide additional water when we weren't allowed to lower the RBDD gates. Thus it is only permitted to be utilized from April 1 to May 15th, and September 15 to October 31st. These were times we were likely to still have irrigation demand, but when our diversion from the Sac River was unavailable because the diversion dam gates had to be up. Currently, those permit conditions still exist, and I have to get streambed alteration permit whenever we utilize this, which I am unsure if they would still allow under the old procedures. BTW, it also includes several other environmental details like flushing flows before it occurs, a bypass flow down the creek, a biologist to check it all out before it all operates, etc. We typically ran about 300 cfs into the canal. It has been run as high as about 500 cfs, but then you start to have concrete vibrating from what I have heard (it was before my time), which I would not be OK with.

I am guessing if we were to do something permanent in nature here, a fish screen would be required for those diversion (not a real sophisticated one, I don't believe juveniles would be an issue, but there would certainly be some new requirements if this was going to be used regularly as part of this project. This procedure has not been used since 2010. Now, since we have the RBPP and fish screen, we can divert from the river whenever we have an allocation. The only utility the diversion on Stony Creek currently has for the TC is to augment supply if we get a reduced allocation. Problem is, when that happens, there is usually no water in Black Butte for us (we are the last water right behind Black Butte, and in most dry years we typically don't have any water with our name on it up there.

For Sites, it could provide some significant winter and spring water supplies in wet years, but there could potentially be some water right issues, permits terms would be interesting, and would require some screened diversion infrastructure from the creek in my opinion.

Hope that is helpful. Glad to discuss further if needed.

Jeffrey P. Sutton
General Manager
Tehama-Colusa Canal Authority
P.O. Box 1025
Willows, CA 95988
Phone: (530) 934-2125
Cell: (530) 301-1030

From: William Vanderwaal [mailto:wvanderwaal@rd108.org]
Sent: Friday, October 04, 2019 4:58 PM
To: Rob Kunde; Herrin, Jeff
Cc: Jeff Sutton
Subject: RE: Action Items from Value Planning Session - Kunde Comments

Rob and Jeff Herrin,
So, the Black Butte water can be diverted from Stony Creek into the TC Canal and gravity flow similar to water from the TC Pumping Plant. Water wouldn't be released into Stony Creek.
However, yes, the water could be released into the TC Canal and down to Bird Creek vs a pipeline at Delevan.

Jeff Sutton, can you describe in more detail how you'd divert into the TC from Stony Creek?

Thanks
Bill V

William R Vanderwaal
RD-108/DWD
530.812.6276

From: Rob Kunde [mailto:rkunde@wrmwsd.com]
Sent: Friday, October 04, 2019 3:51 PM
To: Herrin, Jeff <jeff.herrin@aecom.com>; William Vanderwaal <wvanderwaal@rd108.org>
Subject: Re: Action Items from Value Planning Session - Kunde Comments

Thanks Jeff. My understanding from the meeting was some combination of Black Butte, Shasta Reservoir Storage Exchange, and TC Canal terminus release facilities might eliminate the need for the Delevan pipeline.

Robert J. Kunde, P.E.

Retired Annuitant

Wheeler Ridge-Maricopa Water Storage District

12109 Highway 166, Bakersfield, CA 93313

direct: 661-527-6070

cell: 661-345-3719

rkunde@wrmwsd.com

Summary of Operational Scenarios, Yield and Affordability
Sites Reservoir Project

Criteria	CDFW-Revised Operational Scenario Provided for Discussion	8,000 Wilkins with WaterFix Criteria	Scaled Diversion with WaterFix Criteria	Draft EIR/S & WSIP Application	Potential Revised Project – Sept 2019
Facility Components					
Reservoir Size	1.5 MAF	1.5 MAF	1.5 MAF	1.8 MAF	1.5 MAF
Delevan Intake	Not included; Outlet only facility	Not included; Outlet only facility	Not included; Outlet only facility	Included	Not included; Outlet only facility
Operational Scenario					
Wilkins Slough Bypass Flow	> 10,000 cfs; no diversions at Red Bluff or Hamilton City Sept thru December	8,000 cfs	8,000 cfs April/May; all other times, 5,000 cfs; Scaled diversion	5,000 cfs (3-day average)	8,000 cfs April/May; all other times, 5,000 cfs; Scaled diversion
Fremont Weir Notch	Prioritize the Fremont Weir Notch preferred alternative	Prioritize the Fremont Weir Notch preferred alternative	Prioritize the Fremont Weir Notch preferred alternative	Not included	Prioritize the Fremont Weir Notch preferred alternative
Flows into the Sutter Bypass System[1]	Consider frequency and duration of spills at Moulton, Colusa, and Tisdale	Consider frequency and duration of spills at Moulton, Colusa, and Tisdale	Consider frequency and duration of spills at Moulton, Colusa, and Tisdale	Assumed no change	Consider frequency and duration of spills at Moulton, Colusa, and Tisdale
Freeport Bypass Flow	>35,000 cfs between January and May (applied as a monthly average)	Modeled WaterFix Criteria[2] (applied on a daily basis)	Modeled WaterFix Criteria[2] (applied on a daily basis)	Maintain Delta Water Quality[3]	Maintain Delta Water Quality[3] + 15,000 cfs February and March (applied on a monthly average)
Net Delta Outflow Index (NDOI) Prior to Project Diversions	>44,500 cfs between March and May	Modeled WaterFix Criteria[2] (using >44,500 cfs between March and May as a surrogate)	Modeled WaterFix Criteria[2] (using >44,500 cfs between March and May as a surrogate)	None	None; Minor changes in X2; Mitigation proposed
Yield (Holthouse Deliveries) and Costs[4]					
Public Water Agency Yield (Average / Dry Year)	113 TAF (A) 193 TAF (D)	136 TAF (A) 234 TAF (D)	138 TAF (A) 239 TAF (D)	237 TAF (A) 459 TAF (D)	182 TAF (A) 321 TAF (D)
State Yield (Average / Dry Year)	32 TAF (A) 15 TAF (D)	38 TAF (A) 18 TAF (D)	43 TAF (A) 18 TAF (D)	86 TAF (A) 56 TAF (D)	62 TAF (A) 36 TAF (D)
Federal Yield (Average / Dry Year)	44 TAF (A) 52 TAF (D)	47 TAF (A) 50 TAF (D)	53 TAF (A) 54 TAF (D)	132 TAF (A) 187 TAF (D)	88 TAF (A) 120 TAF (D)
Yield (Average / Dry Year)	190 TAF (A) 259 TAF (D)	220 TAF (A) 302 TAF (D)	234 TAF (A) 312 TAF (D)	455 TAF (A) 702 TAF (D)	332 TAF (A) 477 TAF (D)
Meets Total Yield Need?[6]	No	No	No	Yes	No
$ Per AF Financed[5] (traditional / with WIFIA loan)	$1,152/AF traditional With WIFIA Loan not calculated, but likely $40 to $60/AF cost reduction	To be determined	To be determined	$772/AF traditional $681/AF with WIFIA	$767/AF traditional ** $713/AF with WIFIA **

Notes on next page.

Notes:
All scenarios assume the following:

- Pulse flow protection modeled as protecting the first pulse October thru May. Cease diversions for 7 days during pulses of 15,000 cfs to 25,000 cfs as measured at Bend Bridge.
- Reclamation included at 25% cost share for operational flexibility.

1. Not currently represented in the modeling framework.
2. Modeled WaterFix Freeport criteria applied on a daily basis October through June. Modeled WaterFix NDOI criteria applied using 44,500 cfs between March and May as a surrogate. Actual WaterFix operations criteria (as described in CDFW ITP and NMFS BO) for both Freeport and NDOI cannot be modeled in CALSIM II because the criteria are biologically-based (i.e., based on fish presence at Knights Landing rotary screw trap).
3. Maintain Delta Water Quality = 15,000 cfs in January; 13,000 cfs in December and February thru June; 11,000 cfs all other times.
4. Yield values determined using CALSIM II modeling; Costs determined using a financial model or interpolated from similar model runs (interpolated values denoted with a **).
5. Cost per acre-foot financed. Costs are long-term average for deliveries at Holthouse. Additional costs would be incurred for further conveyance by individual members.
6. Total Yield Need:

Total Average Annual Yield Needed
Sites Reservoir Project

Member	**Yield (Holthouse Deliveries)**
Public Water Agencies [a]	
North of Delta	52,142 AF
South of Delta	140,750 AF
Sub-total Public Water Agencies	192,892 AF
Environmental Benefits [b]	
State	
Incremental Level 4	26,000 AF
Yolo Bypass	60,000 AF
Sub-total State	86,000 AF
Federal – Anadromous Fish	132,000 AF
Sub-total Environmental Benefits	218,000 AF
Total	**410,892 AF**

Notes:
a. Based on Phase 2 participation.
b. Based on Alternative D in Reclamation's draft Feasibility Study. Assumes Reclamation participation of about 25%. State costs are assumed fixed at $816M, thus, increasing per acre-foot costs will reduce the State environmental benefits. Reduced Reclamation participation will reduce the temperature and flow stability benefits, but would allow for additional deliveries to public water agencies.

From: Kundargi, Kenneth@Wildlife [Kenneth.Kundargi@wildlife.ca.gov]
Sent: 10/29/2019 4:18:19 PM
To: Tull, Robert/SAC [Robert.Tull@jacobs.com]; Davis-Fadtke, Kristal@Wildlife [Kristal.Davis-Fadtke@wildlife.ca.gov]; Spranza, John [John.Spranza@hdrinc.com]; Leaf, Rob/SAC [Rob.Leaf@jacobs.com]; Thayer, Reed/SAC [Reed.Thayer@jacobs.com]; Whittington, Chad/SAC [Chad.Whittington@jacobs.com]; Alicia Forsythe [aforsythe@sitesproject.org]; Jim Lecky (jim.Lecky@icf.com) [jim.Lecky@icf.com]
Subject: RE: Sites/CDFW Small group modeling discussion - follow up review
Attachments: SItes Revised Scenarios 10-29-2019 KNK.docx

See attached.

From: Tull, Robert/SAC <Robert.Tull@jacobs.com>
Sent: Tuesday, October 29, 2019 10:04 AM
To: Davis-Fadtke, Kristal@Wildlife <Kristal.Davis-Fadtke@wildlife.ca.gov>; Spranza, John <John.Spranza@hdrinc.com>; Kundargi, Kenneth@Wildlife <Kenneth.Kundargi@wildlife.ca.gov>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thayer, Reed/SAC <Reed.Thayer@jacobs.com>; Whittington, Chad/SAC <Chad.Whittington@jacobs.com>; aforsythe (aforsythe@sitesproject.org) <aforsythe@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>
Subject: RE: Sites/CDFW Small group modeling discussion - follow up review

Hi Kristal,

Thanks for the clarification. We will include 8,000 cfs at Wilkins for the entire emigration period in Scenario A.

Thanks,
Rob

From: Davis-Fadtke, Kristal@Wildlife <Kristal.Davis-Fadtke@wildlife.ca.gov>
Sent: Tuesday, October 29, 2019 8:53 AM
To: Tull, Robert/SAC <Robert.Tull@jacobs.com>; Spranza, John <John.Spranza@hdrinc.com>; Kundargi, Kenneth@Wildlife <Kenneth.Kundargi@wildlife.ca.gov>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thayer, Reed/SAC <Reed.Thayer@jacobs.com>; Whittington, Chad/SAC <Chad.Whittington@jacobs.com>; aforsythe (aforsythe@sitesproject.org) <aforsythe@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>
Subject: [EXTERNAL] RE: Sites/CDFW Small group modeling discussion - follow up review

Good morning Rob,

Thank you for providing these details to confirm our understanding of what will be modeled. At the last Executive Team meeting the expectation was that we would refine some of the criteria, which I see below. However, one scenario included 8,000 cfs at Wilkins Slough through the entire emigration period, not just in April and May, and we would like to see that in Scenario A. Limiting Wilkins to 8,000 in only April and May for both scenarios is not consistent with the expectations from the Executive Team.

Thank you,

Kristal

From: Tull, Robert/SAC <Robert.Tull@jacobs.com>
Sent: Monday, October 28, 2019 4:56 PM
To: Spranza, John <John.Spranza@hdrinc.com>; Kundargi, Kenneth@Wildlife <Kenneth.Kundargi@wildlife.ca.gov>; Davis-Fadtke, Kristal@Wildlife <Kristal.Davis-Fadtke@wildlife.ca.gov>; Leaf, Rob/SAC <Rob.Leaf@jacobs.com>; Thayer, Reed/SAC <Reed.Thayer@jacobs.com>; Whittington, Chad/SAC <Chad.Whittington@jacobs.com>; aforsythe

(aforsythe@sitesproject.org) <aforsythe@sitesproject.org>; Jim Lecky (jim.Lecky@icf.com) <jim.Lecky@icf.com>
Subject: Sites/CDFW Small group modeling discussion - follow up review

Ken,

Today we discussed modeling a range based on two scenarios with differing pulse and post-pulse protection criteria at Freeport.
Please review Scenario A and B below and make sure these criteria are consistent with your understanding of our discussions today.

The two scenarios are assumed to include Alt D criteria except:

- No Bend Bridge based pulse period protections
- Freeport WQ criteria (monthly average 15kcfs Jan, 13kcfs Dec, Feb-May and 11kcfs otherwise) will be adjusted for reduced anticipated WQ effects (from more constrained smaller project)

- **Scenario A**
  - Period October 1st – June 30th
  - Level 1 starts October 1st
  - Pulse periods are based on WaterFix (2016 ITP) from October 1st – March 31st
  - 3-tiered post-pulse periods are based on WaterFix (Level 1 conditions begin once the pulse period has ended; post-pulse levels (1-3) are then determined by the number of days since the pulse period has ended that flow is greater than 20k cfs at Freeport; 15 days = drop from Level 1 to Level 2; 30 days = drop from Level 2 to Level 3)
  - No low-level pumping is allowed during pulse periods
  - Bypass flows will be based on a 7-day moving average at Freeport
  - NDOI of 44,500 March 1st – May 31st
  - 8k cfs at Wilkins Slough April and May

- **Scenario B**
  - Period January 1st – March 31st (assumes mitigation and Georgiana Slough is protected via the BiOp)
  - Level 1 (or 2) starts January 1st
  - Pulse periods are based on WaterFix (2016 ITP) from January 1st – March 31st
  - 3-tiered post-pulse periods:
    - A pulse is initiated in the same manner as Scenario A, but the pulse period is skipped and Level 1 conditions are initiated (or maintained) instead. Additionally, the countdown of days when flow at Freeport is greater than 20k cfs begins immediately.
  - NDOI of 44,500 March 1st – May 31st (same as Scenario A)
  - 8k cfs at Wilkins Slough April and May (same as Scenario A)

Thanks for all your time today,
Rob

-----Original Appointment-----
From: Spranza, John <John.Spranza@hdrinc.com>
Sent: Friday, October 25, 2019 1:52 PM
To: Spranza, John; Tull, Robert/SAC; Kundargi, Kenneth (Kenneth.Kundargi@wildlife.ca.gov); Davis-Fadtke, Kristal@Wildlife; Leaf, Rob/SAC; Thayer, Reed/SAC; Whittington, Chad/SAC; aforsythe (aforsythe@sitesproject.org); Jim Lecky (jim.Lecky@icf.com)
Subject: FW: Sites/CDFW Small group modeling discussion

When: Monday, October 28, 2019 9:00 AM-11:00 AM (UTC-08:00) Pacific Time (US & Canada).
Where: Jacobs Office - 2485 Natomas Park Drive, Suite 600, Sacramento, CA : call in 866-583-7984;; 1977661

-----Original Appointment-----
From: Spranza, John <John.Spranza@hdrinc.com>
Sent: Friday, October 25, 2019 8:11 AM
To: Spranza, John; Kundargi, Kenneth (Kenneth.Kundargi@wildlife.ca.gov); Davis-Fadtke, Kristal@Wildlife; Leaf, Rob/SAC; Thayer, Reed/SAC; Whittington, Chad/SAC; aforsythe (aforsythe@sitesproject.org); Jim Lecky (jim.Lecky@icf.com)
Subject: [EXTERNAL] Sites/CDFW Small group modeling discussion
When: Monday, October 28, 2019 9:00 AM-11:00 AM (UTC-08:00) Pacific Time (US & Canada).
Where: Jacobs Office - 2485 Natomas Park Drive, Suite 600, Sacramento, CA : call in 866-583-7984;; 1977661

Monday morning was the winner for this meeting. Call in added

---

Ken,

Today we discussed modeling a range based on two scenarios with differing pulse and post-pulse protection criteria at Freeport.
Please review Scenario A and B below and make sure these criteria are consistent with your understanding of our discussions today.

The two scenarios are assumed to include Alt D criteria except:

- No Bend Bridge based pulse period protections
- Freeport WQ criteria (monthly average 15kcfs Jan, 13kcfs Dec, Feb-May and 11kcfs otherwise) will be adjusted for reduced anticipated WQ effects (from more constrained smaller project)

- **Scenario A**
    - Period October 1st – June 30th
    - Level 1 starts October 1st
    - Pulse periods are based on WaterFix (2016 ~~ITP~~Application) from October 1st – March 31st For modeling, the initiation of the pulse is defined by the following criteria: (1) Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs.
    - 3-tiered post-pulse periods are based on WaterFix (Level 1 conditions begin once the pulse period has ended; post-pulse levels (1-3) are then determined by the number of days since the pulse period has ended that flow is greater than 20k cfs at Freeport; 15 days = ~~drop~~ increase from Level 1 to Level 2; 30 days = ~~drop~~ increase from Level 2 to Level 3)
    - No low-level pumping is allowed during pulse periods
    - Bypass flows will be based on a 7-day moving average at Freeport
    - NDOI of 44,500 March 1st – May 31st
    - 8k cfs at Wilkins Slough April and May No scaled diversions

- **Scenario B**
    - Period January 1st – March 31st (assumes mitigation and Georgiana Slough is protected via the BiOp)
    - Level 1 (or 2) starts January 1st
    - Pulse periods are based on WaterFix (2016 Application~~ITP~~) from January 1st – March 31st. For modeling, the initiation of the pulse is defined by the following criteria: (1) Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs.
    - 3-tiered post-pulse periods:
        - A pulse is initiated in the same manner as Scenario A, but the no diversion pulse period is skipped and Level 1 conditions are initiated (or maintained) instead. Additionally, the countdown of days when flow at Freeport is greater than 20k cfs begins immediately.
    - NDOI of 44,500 March 1st – May 31st (same as Scenario A)
    - 8k cfs at Wilkins Slough April and May (same as Scenario A) No scaled diversions

Commented [KK1]: No Delevan Intake and 1.3 or 1.5 MAF storage?

Commented [KK2]: Suggest including pulse protection

Commented [KK3]: For clarity please explain the purpose for adjusting for WQ effects.

Commented [KK4]: Clarify if you are modeling 1 or 2 pulse protections from the CWF Application or unlimited pulse protection from the CWF ITP

Assume that you will be using the flow based CWF ITP modeling assumption (CWF Application Table 3-22):

"For modeling, the initiation of the pulse is defined by the following criteria: (1) Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs."

If so, please state explicitly.

Commented [KK5]: Assumes that wild spring-run cannot be identified using length at date due to overlap with hatchery fall-run releases. There will be impact to spring-run that will need to be mitigated.

Commented [KK6]: Be aware that CWF ITP only allows for Level I pumping and the only trigger is KLCI >5. Offramp is KLCI <5 for with transitions to Level 2 and 3 TBD and not permitted. It is the ITP **Application** that includes these modeling assumptions.

"Post-pulse bypass flow operations from December 1 through June 30 may
remain at Level 1 diversion depending on fish presence, abundance, and movement in
the north Delta; however, the exact levels will be determined through initial operating
studies evaluating the level of protection provided at various levels of diversions."

Commented [KK7]: Wilkins Slough is 8000 cfs throughout the emigration period as per email 10/29/2019

Commented [KK8]: Not necessary here and inconsistent with baseline.

Commented [KK9]: Experimental minimization measure not avoidance measure. Sites diversions may reduce the effectiveness of this minimization measure.

Commented [KK10]: Which one is it

Commented [KK11]: Detail then that bypass flows at Red Bluff are 3250 cfs, GCID are 4000 cfs, and Wilkins Slough is 5000 cfs outside of April and May

Thanks for all your time today,
Rob

Our assumption is that you will model the following at Freeport:

Level I Post-Pulse Operations			Level II Post-Pulse Operations			Level III Post Pulse Operations		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**
Dec–Apr								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000 cfs	no limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,000 cfs plus 0% of the amount over 20,000 cfs
May								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping

Commented [KK12]: October 1 as previously stated.

Level I Post-Pulse Operations			**Level II Post-Pulse Operations**			**Level III Post Pulse Operations**		
If Sacramento River flow is over…	**But not over…**	**The bypass is…**	**If Sacramento River flow is over…**	**But not over…**	**The bypass is…**	**If Sacramento River flow is over…**	**But not over…**	**The bypass is…**
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	12,400 cfs plus 0% of the amount over 20,000 cfs
Jun								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,400 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,600 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	11,800 cfs plus 0% of the amount over 20,000 cfs

<table>
<tr><th colspan="3">Level I Post-Pulse Operations</th><th colspan="3">Level II Post-Pulse Operations</th><th colspan="3">Level III Post Pulse Operations</th></tr>
<tr><td>If Sacramento River flow is over...</td><td>But not over...</td><td>The bypass is...</td><td>If Sacramento River flow is over...</td><td>But not over...</td><td>The bypass is...</td><td>If Sacramento River flow is over...</td><td>But not over...</td><td>The bypass is...</td></tr>
<tr><td colspan="3">Bypass flow requirements in other months:</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">If Sacramento River flow is over...</td><td colspan="3">But not over...</td><td colspan="3">The bypass is...</td></tr>
<tr><td colspan="3">Jul–Sep</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">0 cfs</td><td colspan="3">5,000 cfs</td><td colspan="3">100% of the amount over 0 cfs</td></tr>
<tr><td colspan="3">5,000 cfs</td><td colspan="3">No limit</td><td colspan="3">A minimum of 5,000 cfs</td></tr>
<tr><td colspan="3">Oct–Nov</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">0 cfs</td><td colspan="3">7,000 cfs</td><td colspan="3">100% of the amount over 0 cfs</td></tr>
<tr><td colspan="3">7,000 cfs</td><td colspan="3">No limit</td><td colspan="3">A minimum of 7,000 cfs</td></tr>
</table>

Commented [KK13]: Assume as stated previously that Level 1 will be modeled during October and November In Scenario A

Sites

Topic: **Sites Reservoir Project** **2019 October 22**

Talking Points: **Near-term Targets for 180-day Time Extension**

Purpose: Summarize near-term objectives that need to be incorporated into the revised work plan to enable the Phase 2(2019) project agreement to be extended through June 30, 2019 in a manner that maintains a positive cash flow.

At Friday's (Oct 18, 2019) Reservoir Committee meeting, a short presentation was followed by a lot of discussion, which resulted in:

a. Consensus that an additional 3-month time extension is needed (i.e. through the end of June 30, 2019).

b. Identified 3 tentative targets:

   1. By December 19 Res. Comm Mtg, have a well-developed project description

   2. By March 19, Res. Comm Mtg, make progress on

      a. Draft consolidated Operations Plan

      b. Draft Operations Agreement

      Both based on Reclamation's role consisting of annual exchanges of water stored in Sites (i.e. no investment in storage or other purposes such as flood or recreation).

   3. By March 19, Res. Comm Mtg, have narrowed the permitting uncertainty through pre-permit application consultations with the state and federal fishery agencies.

   Recognizing the modeling process, which takes time, is needed to convert the flow results into temperature and biological effects that can be used to validate early working assumptions.

c. During the 180-day extension, consider a cash call, either

   1. Approve a cash call at the December 19 meetings with funds due by the end of March

   2. Approve a cash call at the March 19 meetings with funds due by the end of June

   Target cash call amount of $10/acre-ft of participation

~~Ken,~~

~~Today we discussed modeling a range based on two scenarios with differing pulse and post-pulse protection criteria at Freeport.~~
~~Please review Scenario A and B below and make sure these criteria are consistent with your understanding of our discussions today.~~

The two scenarios are assumed to include Alt D criteria except:

- No Bend Bridge based pulse period protections
- Freeport WQ criteria (monthly average 15kcfs Jan, 13kcfs Dec, Feb-May and 11kcfs otherwise) will be adjusted for reduced anticipated WQ effects (from more constrained smaller project)

- Revised CDFW proposed
  - Same as previously defined by CDFW letter
  - Bypass flows will be based on a 7-day moving average at Freeport
  - 2 week GCID maintenance period (If needed)

- **Scenario A**
  - Period October 1st – June 30th
  - Level 1 starts October 1st
  - Pulse periods are based on WaterFix (2016 ~~ITP~~Application) from October 1st – March 31st For modeling, the initiation of the pulse is defined by the following criteria: (1) Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs.
  - 3-tiered post-pulse periods are based on WaterFix (Level 1 conditions begin once the pulse period has ended; post-pulse levels (1-3) are then determined by the number of days since the pulse period has ended that flow is greater than 20k cfs at Freeport; 15 days = ~~drop~~ increase from Level 1 to Level 2; 30 days = ~~drop~~ increase from Level 2 to Level 3)
  - No low-level pumping is allowed during pulse periods
  - Bypass flows will be based on a 7-day moving average at Freeport
  - NDOI of 44,500 March 1st – May 31st
  - 8k cfs at Wilkins Slough April and May No scaled diversions
  - 2 week GCID maintenance period (If needed)

- **Scenario B**
  - Period January 1st – March 31st (assumes mitigation and Georgiana Slough is protected via the BiOp)
  - Level 1 (or 2) starts January 1st
  - Pulse periods are based on WaterFix (2016 Application~~ITP~~) from January 1st – March 31st. -For modeling, the initiation of the pulse is defined by the following criteria: (1)

Commented [KK1]: No Delevan Intake and 1.3 or 1.5 MAF storage?

Commented [KK2]: Suggest including pulse protection

Commented [KK3]: For clarity please explain the purpose for adjusting for WQ effects.

Formatted

Commented [LR4]: Per Thad's feedback to Rob Tull

Commented [KK5]: Clarify if you are modeling 1 or 2 pulse protections from the CWF Application or unlimited pulse protection from the CWF ITP

Assume that you will be using the flow based CWF ITP modeling assumption (CWF Application Table 3-22):

"For modeling, the initiation of the pulse is defined by the following criteria: (1) Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs."

If so, please state explicitly.

Commented [KK6]: Assumes that wild spring-run cannot be identified using length at date due to overlap with hatchery fall-run releases. There will be impact to spring-run that will need to be mitigated.

Commented [KK7]: Be aware that CWF ITP only allows for Level I pumping and the only trigger is KLCI >5. Offramp is KLCI <5 for with transitions to Level 2 and 3 TBD and not permitted. It is the ITP **Application** that includes these modeling assumptions.

"Post-pulse bypass flow operations from December 1 through June 30 may
remain at Level 1 diversion depending on fish presence, abundance, and movement in
the north Delta; however, the exact levels will be determined through initial operating
studies evaluating the level of protection provided at various levels of diversions."

Commented [KK8]: Wilkins Slough is 8000 cfs throughout the emigration period as per email 10/29/2019

Commented [LR9]: Per Thad's feedback to Rob Tull

Commented [KK10]: Not necessary here and inconsistent with baseline.

Commented [KK11]: Experimental minimization measure not avoidance measure. Sites diversions may reduce the effectiveness of this minimization measure.

Commented [KK12]: Which one is it

Commented [LR13R12]: Probably Level 2 so that we have a wide enough range to find an affordable project

Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs.

- 3-tiered post-pulse periods:
  - A pulse is initiated in the same manner as Scenario A, but the no diversion pulse period is skipped and Level 1 conditions are initiated (or maintained) instead. Additionally, the countdown of days when flow at Freeport is greater than 20k cfs begins immediately.
- NDOI of 44,500 March 1st – May 31st (same as Scenario A)
- 8k cfs at Wilkins Slough April and May (same as Scenario A) No scaled diversions
- 2 week GCID maintenance period (if needed)

Commented [KK14]: Detail then that bypass flows at Red Bluff are 3250 cfs, GCID are 4000 cfs, and Wilkins Slough is 5000 cfs outside of April and May

Commented [LR15]: Per Thad's feedback to Rob Tull

~~Thanks for all your time today,~~
~~Rob~~

Our assumption is that you will model the following at Freeport:

Level I Post-Pulse Operations			**Level II Post-Pulse Operations**			**Level III Post Pulse Operations**		
If Sacramento River flow is over…	**But not over…**	**The bypass is…**	**If Sacramento River flow is over…**	**But not over…**	**The bypass is…**	**If Sacramento River flow is over…**	**But not over…**	**The bypass is…**
Dec–Apr								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000 cfs	no limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,000 cfs plus 0% of the amount over 20,000 cfs

Commented [KK16]: October 1 as previously stated.

Level I Post-Pulse Operations			**Level II Post-Pulse Operations**			**Level III Post Pulse Operations**		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**
May								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	12,400 cfs plus 0% of the amount over 20,000 cfs
Jun								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs

<table>
<tr><th colspan="3">Level I Post-Pulse Operations</th><th colspan="3">Level II Post-Pulse Operations</th><th colspan="3">Level III Post Pulse Operations</th></tr>
<tr><th>If Sacramento River flow is over…</th><th>But not over…</th><th>The bypass is…</th><th>If Sacramento River flow is over…</th><th>But not over…</th><th>The bypass is…</th><th>If Sacramento River flow is over…</th><th>But not over…</th><th>The bypass is…</th></tr>
<tr><td>20,000 cfs</td><td>no limit</td><td>17,400 cfs plus 20% of the amount over 20,000 cfs</td><td>20,000 cfs</td><td>no limit</td><td>13,600 cfs plus 20% of the amount over 20,000 cfs</td><td>20,000 cfs</td><td>no limit</td><td>11,800 cfs plus 0% of the amount over 20,000 cfs</td></tr>
<tr><td colspan="3">Bypass flow requirements in other months:</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">If Sacramento River flow is over…</td><td colspan="3">But not over…</td><td colspan="3">The bypass is…</td></tr>
<tr><td colspan="3">Jul–Sep</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">0 cfs</td><td colspan="3">5,000 cfs</td><td colspan="3">100% of the amount over 0 cfs</td></tr>
<tr><td colspan="3">5,000 cfs</td><td colspan="3">No limit</td><td colspan="3">A minimum of 5,000 cfs</td></tr>
<tr><td colspan="3">Oct–Nov</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">0 cfs</td><td colspan="3">7,000 cfs</td><td colspan="3">100% of the amount over 0 cfs</td></tr>
<tr><td colspan="3">7,000 cfs</td><td colspan="3">No limit</td><td colspan="3">A minimum of 7,000 cfs</td></tr>
</table>

Commented [KK17]: Assume as stated previously that Level 1 will be modeled during October and November In Scenario A

California
WATER COMMISSION

Water Storage Investment Program Quarterly Report

The Quarterly Report is intended to document applicants' progress toward complying with regulation section 6013 and receiving final WSIP funding, including any changes in the magnitude of public benefits that could affect cost allocation. Applicants must provide a summary level update of the project status for the requirements and milestones listed below. The template may be modified as necessary to effectively communicate information. If minimal activities occurred during a reporting period, the report can be condensed.

- Note any issues or concerns that have, will, or could affect milestones or requirements.
- Identify key issues, including legal issues such as lawsuits or injunctions related to the project, that need to be resolved.
- Discuss how the actual schedule is progressing in comparison to the schedule provided in the Initial Report or the last reported schedule.
- Update the project schedule as needed.
- Note any milestones or accomplishments that occurred since submittal of the prior Quarterly Report.

Project Information

Project Name:
Sites Reservoir Project

Applicant Name:
Sites Project Authority (Authority)

Date:
October 30, 2019

Reporting Period:
July 1, 2019 through September 30, 2019

General Update and Key Issues

Please provide a general update and describe any key issues that occurred during this reporting period. You may attach additional documents or pages if more space is needed:

No significant issues occurred and there were no variances from the schedule. Work continues to progress in the key areas related to the project's operations and benefits to the local, state, and federal participants, environmental analyses and documentation, certifications and agreements, engineering, economics, financing, risk management, and landowner and community outreach. Refer to Attachment A for additional information.

Items Required Prior to Scheduling a Final Award Hearing

The following items must be provided prior to scheduling a hearing. As applicable, please describe the status, estimated completion date, and percent complete of:

1. **Contracts for non-public cost share:**

   Status: Multiple agreements are planned. Refer to Attachment A
   Estimated Completion Date: December 2021
   Percent Complete: 20%

2. **Contracts for administration of public benefits:**

   Status: Starting. Refer to Attachment A
   Estimated Completion Date: December 2021
   Percent Complete: 0%

3. **Completed feasibility studies:**

   Status: In Progress. Refer to Attachment A
   Estimated Completion Date: June 2021
   Percent Complete: 50%

4. **Final environmental documentation:**

   Status: In Progress. Refer to Attachment A
   Estimated Completion Date: December 2020
   Percent Complete: 20%

5. **All required federal, state, and local approvals, certifications, and agreements:**

   Status: In Progress. Refer to Attachment A
   Estimated Completion Date: December 2021
   Percent Complete: 5%

Items Required to Execute a Funding Agreement

Please provide an update, as applicable, on the following documents, which are needed to execute a funding agreement for the project:

- Applicant's audited financial statements
- Final project costs, schedule, and scope of work
- Evidence of bilateral communications
- Limited waiver of sovereign immunity (see regulations section 6013(f)(8))

Updates to information provided in the Initial Report or prior Quarterly Reports are only needed when a significant change has occurred. The Commission may request submittal of updated information prior to executing a funding agreement.

- Applicant's Audited Financial Statements: An audit for Fiscal Year 2018 was completed in July 2019.
- Final Project Costs, Schedule, and Scope of Work: No change since last reporting period.
- Evidence of Bilateral Communications: The Authority, Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR) continue to maintain effective communication and collaboration. DWR and Reclamation are active in the Authority's Reservoir Operations Work Group. Additionally, the Authority and Reclamation participate in regular Project Integration meetings, Federal Feasibility Study meetings engineering/geotechnical coordination meetings, and environmental coordination meetings.
- Limited Waiver of Sovereign Immunity: Not applicable.

Status Update

Provide a status update for the following, as applicable:

- Labor Compliance
- Urban Water Management Plans
- Agricultural Water Management Plans
- Groundwater Management or Groundwater Sustainability Plans
- Potential effect of other conditionally eligible projects on the applicant's public benefits

Updates to information provided in the Initial Report or prior Quarterly Reports are only needed when a significant change has occurred. The Commission may request submittal of updated information prior to executing a funding agreement.

▪ Labor Compliance	No change since last reporting period
▪ Urban Water Management Plans	Not applicable
▪ Agricultural Water Management Plans	Not applicable

- Groundwater Management or Groundwater Sustainability Plans

  No change since last reporting period
- Potential effect of other conditionally eligible projects on the applicant's public benefits

  No change since last reporting period

Attachment A: Supplement for Reporting Period Ending September 30, 2019

Sites
Program Management Team

1.0 Items Required Prior to Scheduling a Final Award Hearing

1) **Contracts for non-public cost share (ongoing)**

Based on the following, the estimated completion date is December 2021 and the estimated percent complete is approximately 20%.

Local Project Participants (Participants): The original participation agreements were signed in 2016 and were replaced with a new agreement effective April 1, 2019. The Authority is working with the Participants to extend the current agreement through at least June 2020. For post-planning activities, a successor agreement is contemplated.

Signed Amendment:

- Estimated Completion Date: June 30, 2020
- Percent Complete: 70%

Successor Participation Agreement Signed:

- Estimated Completion Date: December 2021
- Percent Complete: 0%

Reclamation: The Authority and Reclamation are updating the existing cost share agreement (2015) for continued planning and pre-construction activities. This first amendment will extend the term for 5 additional years from the date it is signed. In addition, the Authority is working with Reclamation on a financial assistance agreement to support the completion of the planning phase. A new agreement may be needed for post-planning activities.

Signed Cost Share Amendment:

- Estimated Completion Date: November 2019
- Percent Complete: 90%

Financial Assistance Agreement:

- Estimated Award Date: August 2020
- Percent Complete: 5%

Funding Agreement:

- Estimated Completion Date: December 2021
- Percent Complete: 0%

2) Contracts for administration of public benefits (ongoing)

Based on the following, the estimated completion date is December 2021 and the estimated percent complete is approximately 0%.

State of California (WSIP): The Authority and the California Department of Fish and Wildlife (CDFW) are conducting focused discussions on the state permit application processes (refer to item #5).

- Estimated Completion Date: December 2021
- Percent Complete: 0%

Federal (Reclamation), Non-WSIP: The Authority continues to work with Reclamation through the development of a Reclamation compliant feasibility report, to identify additional public benefits (refer to item #3)

3) Completed Feasibility Studies (ongoing)

Based on the following, the estimated completion date is December 2021 and the estimated percent complete is approximately 50%.

The Authority and Reclamation continue to update and refine the draft Feasibility Report from the version that was included as an attachment to the Authority's WSIP application. Updated analysis includes the project's feasibility as a locally sponsored storage project in compliance with WSIP requirements and the level of federal participation, which requires compliance with Reclamation's requirements. Efforts continue to improve the project's cost-effectiveness and risk management. Also, analysis is underway to evaluate the potential for phased implementation. The Authority plans to further advance the engineering, environmental, economic and financial analysis before requesting the Water Commission consider the project's feasibility.

Reclamation Compliant Feasibility Studies:

- Estimated Completion Date: December 2020
- Percent Complete: 70%

WSIP Compliant Feasibility Studies:

- Estimated Completion Date: June 2021
- Percent Complete: 35%

The Authority and Reclamation plan to start focused geotechnical investigations to support additional design, initial permit applications and refinement of the cost estimate. Reclamation and the Authority have been preparing a work plan, are completing environmental documentation, preparing permit applications (refer to item #5), and developing both monitoring and health and safety protocols to support these focused geotechnical investigations.

Focused Geotechnical Investigations - Field Work:

- Estimated Start Date: October 2019
- Estimated Completion Date: December 2019
- Percent Complete: 0%

Environmental, Permitting, and Monitoring Support: Refer to item #5

4) **Final Environmental Documentation (ongoing)**

Based on the following, the estimated completion date is December 2020 and the estimated percent complete is approximately 20%.

The Authority, as the state lead agency, and Reclamation, as the federal lead agency, continue to perform additional environmental analysis to support the development of a Final Environmental Impact Report / Environmental Impact Statement (EIR/EIS). Current work focuses on developing responses to comments received on the Draft EIR/EIS. Comments have been reviewed, categorized and initial responses to individual comments have been completed. Also, a number of master responses to comments have been developed. Preparation of the remaining sections of the Final EIR/EIS, including minor edits and updates to the Draft EIR/EIS, has also begun.

Draft EIR/EIS:

- Estimated Completion Date: August 2017
- Percent Complete: 100%

Final EIR/EIS:

- Estimated Completion Date: December 2020
- Final EIR/EIS, Percent Complete: 20%

5) **All required federal, state, and local approvals, certifications, and agreements (ongoing)**

Based on the following, the estimated completion date is December 2021 and the estimated percent complete is approximately 5%.

Federal: The Authority and Reclamation continue to prepare the draft Biological Assessment in compliance with the Federal Endangered Species Act and the draft Programmatic Agreement in compliance with the National Historic Preservation Act. Throughout this time period, the Authority and Reclamation met several times with the U.S. Fish and Wildlife Service (USFWS) to discuss approach to the Biological Assessment. The schedule for the Biological Assessment has been extended to allow for additional analysis and discussion with USFWS and the National Marine Fisheries Service (NMFS).

- Estimated Completion Date: December 2021
- Percent Complete: 14%

State of California: The Authority continues to have productive meetings with CDFW to discuss the project, the permit application process, and supporting information to include the permit applications. These meetings are expected to continue over the next few months.

○ Estimated Completion Date:	December 2021
○ Percent Complete:	7%

Local: To allow Reclamation to perform focused geotechnical investigations, the Authority has been assisted Reclamation to obtain encroachment permits from Colusa County, Maxwell ID, and GCID and, where applicable, access agreement with landowners.

Focused Geotechnical Investigations (refer to item #3): The Authority and Reclamation continue to advance the environmental documentation for the focused geotechnical investigations. A Biological Opinion for the geotechnical investigations was received from the USFWS on September 30, 2019 and the National Historic Preservation Act, Section 106 consultation with the State Historic Preservation Office was completed on September 26, 2019. In addition, Reclamation signed a Categorical Exclusion on September 30, 2019. The focused geotechnical investigations are being undertaken and funded by Reclamation.

Environmental, Permitting, and Monitoring Support to Focused Geotechnical Investigations:

○ Estimated Completion Date:	December 2019
○ Percent Complete:	50%

FISH EFFECTS ANALYSIS

Methods Overview, 10/30/2019

Sites

Agenda items

- Overview of effects analysis
  - Construction effects
  - Operations effects
    - Sacramento River - near field
    - Sacramento River - far field
    - Feather River
    - American River
    - Delta
    - Life cycle models
  - Cross-walk NMFS-provided model matrix and methods used to date

Construction Effects

- (Geotechnical Explorations)
- Turbidity and suspended sediment
- Release and exposure of contaminants
- Underwater noise
    - NMFS spreadsheet model
- Fish stranding
- Direct physical injury
- Loss and alteration of habitat

Near-Field Effects (Sacramento River) - Salmonids

- Spatial distribution (screen exposure)
  - Horizontal/vertical: literature review, with specific info. for water surface elevations of screens, etc., % flow split at GCID
- Entrainment through screens
  - Consideration of size distribution (RBDD) vs. mesh size
- Impingement, screen contact, and screen passage
  - Literature review & Swanson et al. equations
- Predation
  - Literature review, including Vogel GCID studies
- Stranding behind screens during high flow
  - High flow, based on water surface elevation
- Attraction to screens during reservoir discharge

Near-Field Effects (Sacramento River) – Green Sturgeon

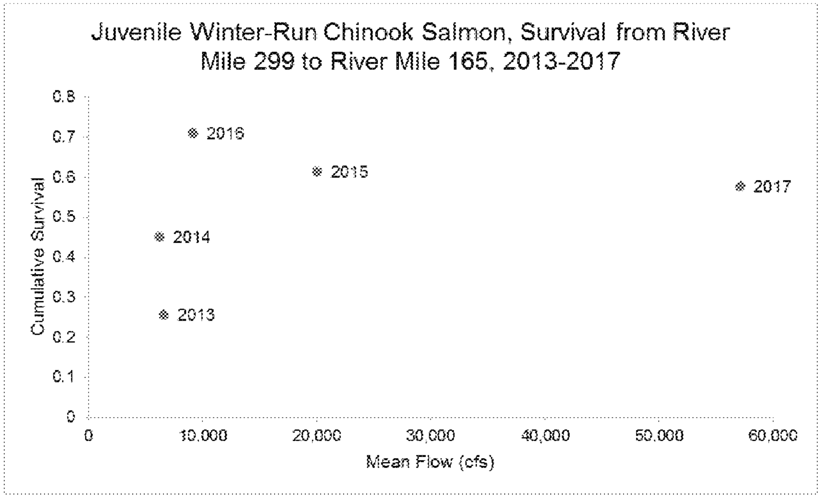
- Review of protective velocity criteria
  - Verhille et al. (2014)
- Entrainment through screens
  - Size distribution

Far-Field Effects (Sacramento River) - Salmonids

- Temperature effects
  - HEC-5Q/USRWQM, incl. 7DADM, etc.; Anderson/Martin models (Winter-Run)
- Redd scour/entombment
  - USRDOM, >40,000 cfs
- Redd dewatering
  - USRDOM, USFWS relationships
- Habitat capacity
  - Spawning WUA w/ CalSim
  - Rearing WUA w/ CalSim
- Juvenile stranding
  - USRDOM, USFWS relationships
- SALMOD
- Floodplain inundation and access
  - Yolo Bypass: daily downscaled CalSim; habitat inundation area (DWR 2016); mean number of days flooded (considering Takata et al. 2017)

Far-Field Effects (Sacramento River) - Salmonids

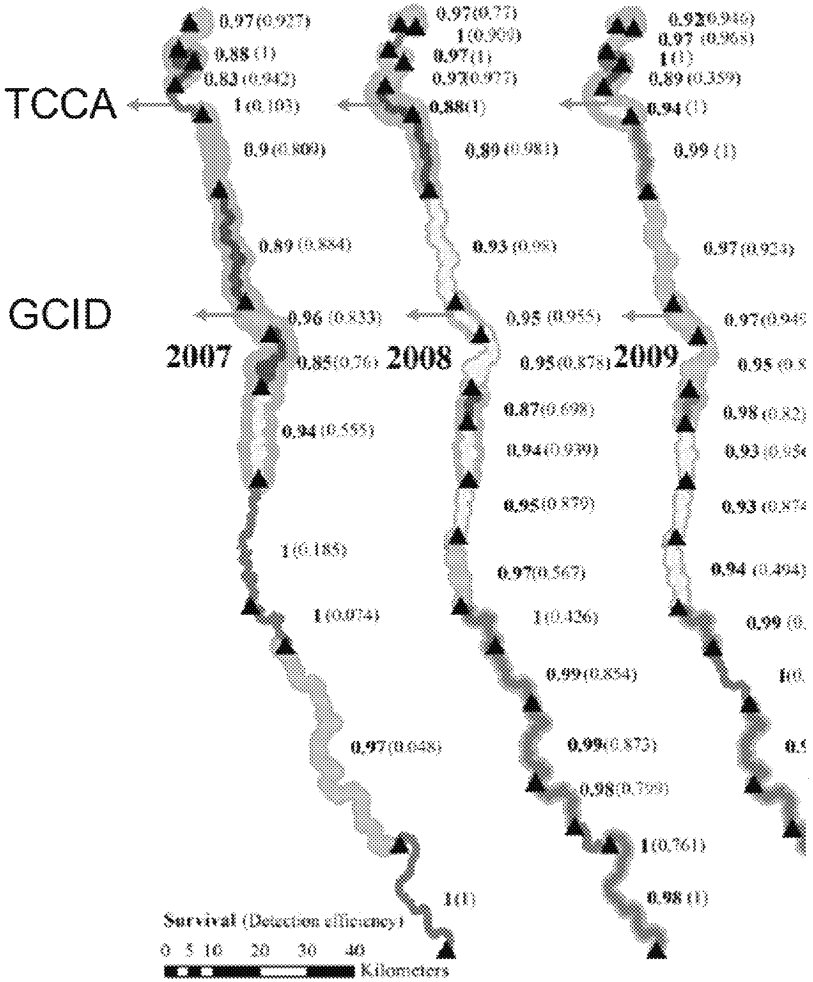
- Migration flow-survival
  - Quantitative analysis based on Henderson et al. (2018) – see next slides
  - Qualitative discussion considering Michel (2018) and Hassrick et al. in prep.

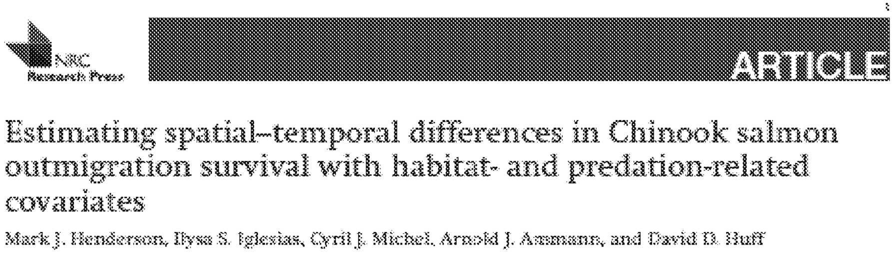


- Sites reservoir releases effects
  - Temperature
  - Water quality (mercury, salinity, false attraction)

Far-Field Flow-Survival Analysis

- Henderson et al. (2018) paper for quantitative analysis
  - Multiple reaches from above Red Bluff down to Knights Landing
  - Focus on Sites withdrawal period (winter/spring), daily timescale
  - Incorporates flow and temperature effects
  - Also includes other (non-operations) covariates
  - Results will allow adjustment of other models, e.g., OBAN




NRC Research Press

ARTICLE

Estimating spatial–temporal differences in Chinook salmon outmigration survival with habitat- and predation-related covariates

Mark J. Henderson, Ilysa S. Iglesias, Cyril J. Michel, Arnold J. Ammann, and David D. Huff

Draft – Subject to Change – For Discussion Purposes Only

Sites

Far-Field Flow-Survival Analysis

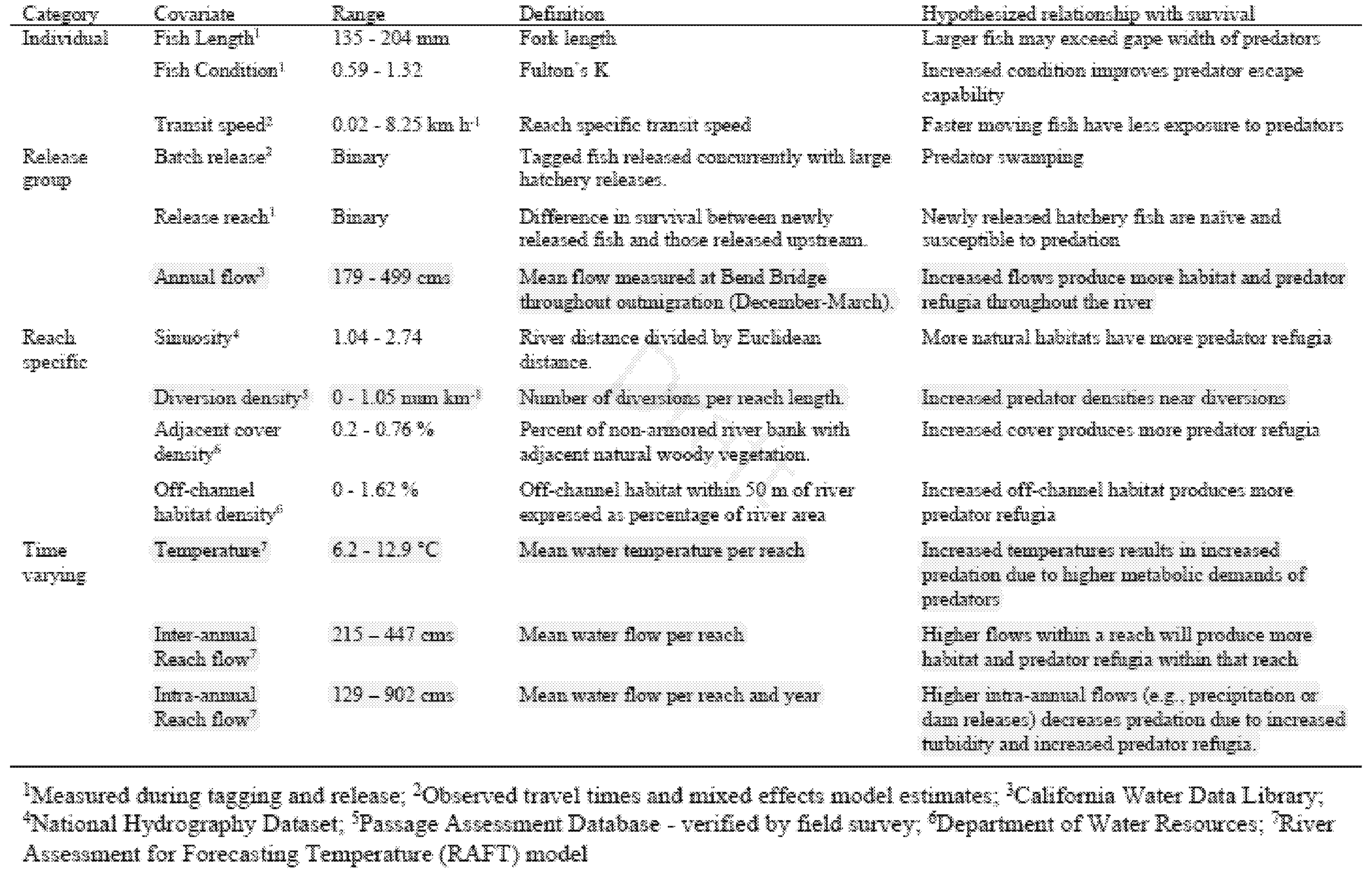


Table 1: A description of the covariates included in the mark recapture model.

Category	Covariate	Range	Definition	Hypothesized relationship with survival
Individual	Fish Length[1]	135 - 204 mm	Fork length	Larger fish may exceed gape width of predators
	Fish Condition[1]	0.59 - 1.32	Fulton's K	Increased condition improves predator escape capability
	Transit speed[2]	0.02 - 8.25 km h-1	Reach specific transit speed	Faster moving fish have less exposure to predators
Release group	Batch release[2]	Binary	Tagged fish released concurrently with large hatchery releases.	Predator swamping
	Release reach[1]	Binary	Difference in survival between newly released fish and those released upstream.	Newly released hatchery fish are naïve and susceptible to predation
	Annual flow[3]	179 - 499 cms	Mean flow measured at Bend Bridge throughout outmigration (December-March).	Increased flows produce more habitat and predator refugia throughout the river
Reach specific	Sinuosity[4]	1.04 - 2.74	River distance divided by Euclidean distance.	More natural habitats have more predator refugia
	Diversion density[5]	0 - 1.05 num km-1	Number of diversions per reach length.	Increased predator densities near diversions
	Adjacent cover density[6]	0.2 - 0.76 %	Percent of non-armored river bank with adjacent natural woody vegetation.	Increased cover produces more predator refugia
	Off-channel habitat density[6]	0 - 1.62 %	Off-channel habitat within 50 m of river expressed as percentage of river area	Increased off-channel habitat produces more predator refugia
Time varying	Temperature[7]	6.2 - 12.9 °C	Mean water temperature per reach	Increased temperatures results in increased predation due to higher metabolic demands of predators
	Inter-annual Reach flow[7]	215 – 447 cms	Mean water flow per reach	Higher flows within a reach will produce more habitat and predator refugia within that reach
	Intra-annual Reach flow[7]	129 – 902 cms	Mean water flow per reach and year	Higher intra-annual flows (e.g., precipitation or dam releases) decreases predation due to increased turbidity and increased predator refugia.

[1] Measured during tagging and release; [2] Observed travel times and mixed effects model estimates; [3] California Water Data Library; [4] National Hydrography Dataset; [5] Passage Assessment Database - verified by field survey; [6] Department of Water Resources; [7] River Assessment for Forecasting Temperature (RAFT) model

Far-field effects: Henderson et al.

Category	Covariate	Range	Definition	Hypothesized relationship with survival	Notes/source	Source/assumption for analysis of proposed action
Individual	Transit speed	0.02–8.25 km/h	Reach-specific transit speed	Faster fish have less exposure to predators	Observed travel times and mixed effects model estimates	Assumed mean value from Henderson et al.
Release group	Batch release	Binary	Tagged fish released concurrently with large hatchery releases	Predator swamping	Observed travel times and mixed effects model estimates	Assumed fish not released with large hatchery releases
	Annual flow	179–499 cumecs (6,321–17,622 cfs)	Mean flow measured at Bend Bridge throughout outmigration (December–March)	Increased flows produce more habitat and predator refugia throughout the river	California Water Data Library	USRDOM
Reach-specific	Sinuosity	1.04–2.74	River distance divided by Euclidean distance	More natural habitats have more predator refugia	National Hydrography Dataset	Assumed same values as Henderson et al.
	Diversion density	0–1.05 diversions/km	No. of diversions per reach length	Increased predator densities near diversions	Passage Assessment Database—verified by field survey	Added one to reach 13 to account for Delevan intake; otherwise assumed same values as Henderson et al.
Time-varying	Temperature	6.2–12.9°C (42–55°F)	Mean water temperature per reach	Increased temperatures results in increased predation due to higher metabolic demands of predators	River Assessment for Forecasting Temperature (RAFT) model	USRWQM
	Intra-annual reach flow	129–902 cumecs (4,556–31,853 cfs)	Mean water flow per reach and year	Higher intra-annual flows (e.g., precipitation or dam releases) decrease predation due to increased turbidity and increased predator refugia	RAFT model	USRDOM

Far-field effects: Henderson et al.

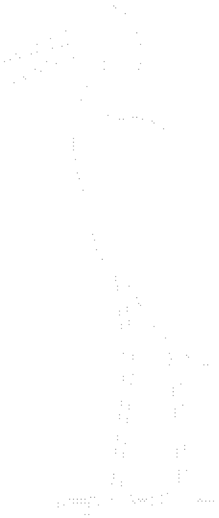
- Focused on Dec-Mar
  - Bend Bridge mean flow covariate period
- Scenario 1
  - Equal numbers of fish beginning migrating on each day, Dec-Mar
  - All fish begin migration at Jellys Ferry (upstream of Red Bluff and all project intakes)

Far-field effects: Henderson et al.

- Scenario 2
  - Equal numbers of fish beginning migrating on each day, Dec-Mar
  - Equal numbers of fish beginning migration at the upstream end of each Henderson et al. reach
- Scenario 3
  - Equal numbers of fish beginning migration at the upstream end of each Henderson et al. reach
  - Fish moving in proportion to daily proportion of flow

Far-Field Effects (Feather River) - Salmonids

- Temperature effects
    - Reclamation temperature model
- Redd scour/entombment
- Redd dewatering
- Habitat capacity
    - Spawning WUA
    - Rearing WUA



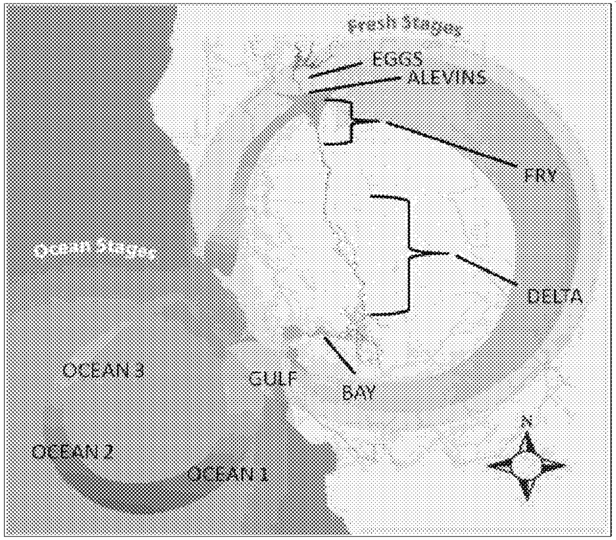
Far-Field Effects (American River) - Salmonids

- Temperature effects
  - HEC-5Q, e.g., for 7DADM
- Redd scour
  - CalSim
- Redd dewatering
  - CalSim/Bratovich et al. (2017)
- Habitat capacity
  - Spawning WUA (USFWS)
  - Rearing WUA (USFWS)

Delta - Salmonids

- South Delta Entrainment
  - Qualitative consideration of CalSim OMR, etc.
- Juvenile through-Delta survival
  - DSM2-HYDRO Velocity Summary
  - Analysis based on Perry et al. (2018) - STARS
  - Delta Passage Model

Life Cycle Modeling: OBAN



General Details:

- Winter-Run Chinook Salmon
- Egg/alevin temperature effects
- Fry rearing flow effects
- Juvenile Yolo flow effects
- Juvenile south Delta export effects
- Juvenile DCC effects
- Ocean conditions not affected by project but included in model (productivity and harvest)
- Incorporate flow-survival adjustment based on Henderson et al. (2018) model

Life cycle modeling: IOS

Application of a Life Cycle Simulation Model to Evaluate Impacts of Water Management and Conservation Actions on an Endangered Population of Chinook Salmon

(1) spawning, models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds

(2) Early development, models the impact of temperature on maturation timing and mortality of eggs at the spawning grounds

(3) fry rearing, models the relationship between temperature and mortality of salmon fry during the river rearing period

(4) river migration, estimates mortality of migrating salmon smolts in the Sacramento River between the spawning and rearing grounds and the Delta

(5) Delta passage, models the impact of flow, route selection, and water exports on the survival of salmon smolts migrating through the Delta to San Francisco Bay

(6) ocean survival, that estimates the impact of natural mortality and ocean harvest to predict survival and spawning returns (escapement) by age

Zeug et al. Environ Model Assess (2012) 17:455–467

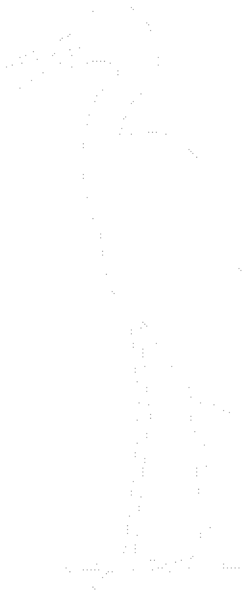
Critical Habitat

Salmonids:

- Adult migration corridors
- Spawning habitat
- Adequate river flows
- Water temperatures
- Habitat and adequate prey free of contaminants
- Riparian and floodplain habitat
- Juvenile emigration corridors
- Estuarine areas

Green Sturgeon

- Sacramento and Feather River far-field effects
  - Temperature effects (Sac-USRWQM, Feather-Reclamation temp. model)
    - Spawning and egg incubation
    - Non-spawning adult presence
    - Pre- and post-spawn adult holding, immigration, and post-spawn emigration
    - Larval and juvenile rearing and emigration
  - Flow effects (CalSim)
- Flow effects Delta
  - South Delta entrainment – salvage-density method (CalSim)
  - Delta outflow – White Sturgeon year-class strength regression (CalSim)
- Critical Habitat
  - Food resources
  - Substrate type / size
  - Water flow and quality
  - Migration corridor
  - Water depth
  - Sediment quality



Delta Smelt

- North Delta food subsidy from Colusa Basin Drain
  - Qualitative discussion based on pilot study years
- South Delta entrainment
  - Adults & Larvae/early juveniles – consideration of OMR flows
- Flow effects
  - Spring – *Eurytemora affinis* – X2 regression
  - Summer – *Pseudodiaptomus forbesi* subsidy to LSZ (QWEST)
  - Fall – consideration of Delta outflow/X2 in relation to habitat attributes
- Upstream sediment entrainment
  - Modeling of sediment concentration in river flow in relation to diversions
- Critical habitat
  - Physical habitat, water, river flow, salinity

Longfin Smelt Outflow-Abundance

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ARTICLE

Population Dynamics of an Estuarine Forage Fish: Disaggregating Forces Driving Long-Term Decline of Longfin Smelt in California's San Francisco Estuary

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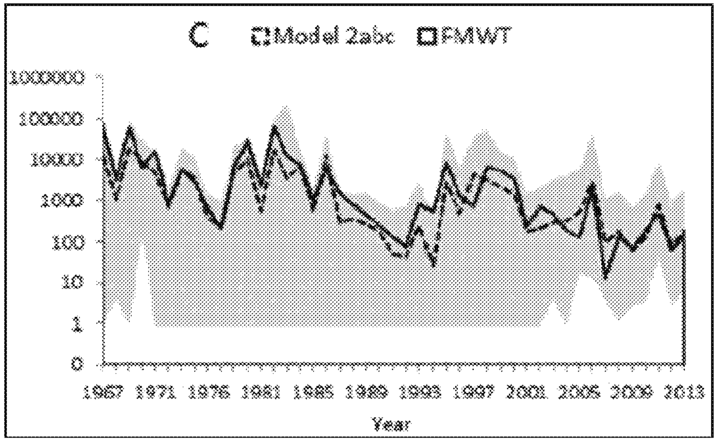

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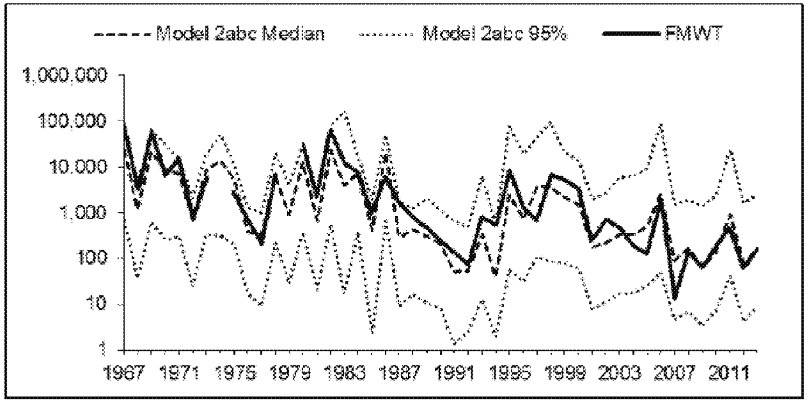

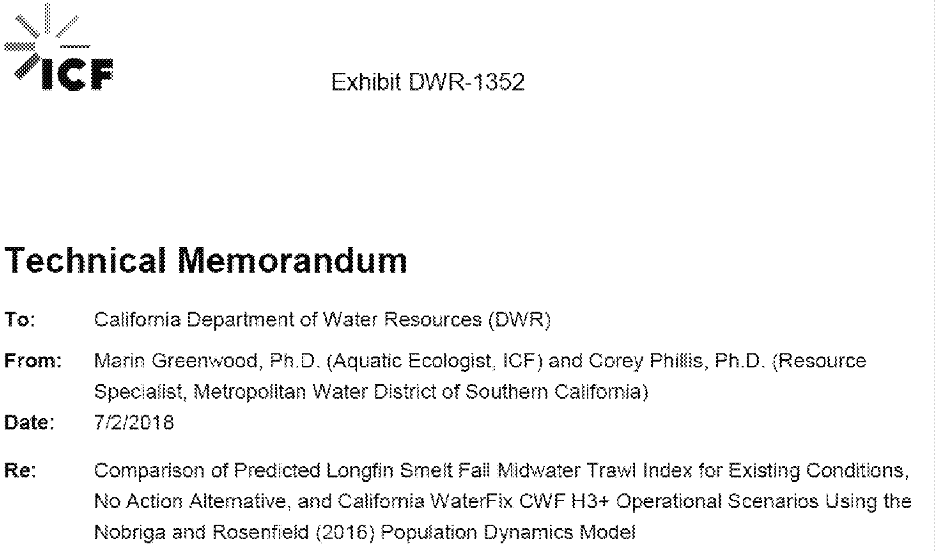

ICF

Exhibit DWR-1352

Technical Memorandum

To: California Department of Water Resources (DWR)

From: Marin Greenwood, Ph.D. (Aquatic Ecologist, ICF) and Corey Phillis, Ph.D. (Resource Specialist, Metropolitan Water District of Southern California)

Date: 7/2/2018

Re: Comparison of Predicted Longfin Smelt Fall Midwater Trawl Index for Existing Conditions, No Action Alternative, and California WaterFix CWF H3+ Operational Scenarios Using the Nobriga and Rosenfield (2016) Population Dynamics Model