CDFW - Sites 60 day Evaluation Meeting No. 8 (extended): Meeting Agenda and Action Items

Sites Reservoir Project

Date: *July 16, 2019*

Location: *HDR Office: 2379 Gateway Oaks Drive, Suite 200 Fleming Conference Room, or Skype with conference call 1-866-583-7984,,1977661*

Time: 8:00 am – 12:00 pm

Purpose: Continue 60 day evaluation of Operational Scenarios.

Invitees:

Rob Thomson, Sites Authority
Kevin Spesert, Sites Authority
Ali Forsythe, Sites Authority
Duane Linander, CDFW
Kristal Davis Fadtke, CDFW
Ian Boyd, CDFW
Ken Kundargi- CDFW
Johnathan Williams, CDFW
Lenny Grimaldo, ICF
Marin Greenwood, ICF
Jim Lecky, ICF
Mike Dietl, Reclamation
Felipe La Luz – CDFW
Chris Fitzer, ESA Associates
Rob Tull, Jacobs
Reed Thayer, Jacobs
Chad Whittington, Jacobs
John Spranza, HDR
Jelica Arsenijevic, HDR

Action Item		Owner	Deadline	Notes
1	Schedule presentation on CalSim and DSM2 and how Delta is performing.	CH2	TBD	Pending
2	Identify Region 2 concerns	CDFW	7/10/2019	Pending
3	Sutter Bypass Analysis	Authority/CH	7/10/2019	TBD
4	Initiate discussions with CDFW, River Partners and other NGO's to talk about possible effects of projects.	Authority	After July	Ongoing task item
5	Provide carcass/redd reports to ICF	Duane/Lenny	7/10/2019	Complete
6	Potential Sturgeon analysis	Jacobs/ICF	TBD	At RBDD and GCID
7	Send out Presentation	HDR	7/14/19	Complete
8				
9				

Agenda:		
Discussion Topic	**Topic Leader**	**Est Time**
1. Roll Call a. Opeing statements	Ali Forsythe Kristal Davis Fadtke	5 min
2. Review of Action Items from Previous Meeting	Ali Forsythe	15 min
3. Nearfield Effects and Farfield Flow Survival	Marin Greenwood	60 min
4. Functional Flows and Operational Parameters	Chris Fitzer	60 min
5. Discuss CDFW-provided Operational Scenarios	Tull/Leaf	60 min
6. Next steps for 60 day schedule	Group discussion	10 min

Sites Workshop
July 16, 2019
CDFW Operations Scenario - For Discussion Purposes Only

- Two runs:
  - Sites diversions limited to November through March
  - Sites diversion in any month

Sacramento River:

- No monthly pulse protection based on Bend Bridge flow
- Sacramento River flow ramp down rate as per State Water Resources Control Board Order 90-5
  - > 6,000 cfs Sacramento River flow – decrease in flow not to exceed 2.5% per hour and maximum of 15% per day
  - 4,000 cfs to 6,000 cfs Sacramento River flow – decrease in flow not to exceed 100 cfs per hour and maximum of 200 cfs per day
  - < 4,000 cfs Sacramento River flow – decrease in flow not to exceed 100 cfs per day
- Model flow volume, frequency and duration changes in Moulton Weir Bypass inundation
- Model flow volume, frequency and duration changes in Colusa Weir Bypass inundation
- Model flow volume, frequency and duration changes in Tisdale Weir Bypass inundation
- Bypass flow > 10,000 cfs at Wilkins Slough prior to Sites diversions – functional fish flow (Matt Johnson CDFW in conjunction with NMFS SW Science Center pers. comm.)
- Fremont Weir notch diversion prioritization - Preferred alternative 6,000 cfs starting at 15 feet to 29.5 feet elevation at Fremont Weir gauge from November 1 through March 15. After March 15th through April maintain 600 cfs fish passage flow through the Fremont Weir notch (Yolo Bypass Habitat Restoration and Fish Passage Project EIR/EIS 2019)
- Model flow volume, frequency and duration changes in Fremont Weir overtopping inundation

Delta:

- Preferential CVP/SWP WIIN Act Flexibility up to full diversion capacity of 11,200 cfs during excess Delta conditions (USBR ROC LTO BA 2018)
- > 35,000 cfs inflow at Freeport prior to Sites diversions – functional fish flow (NMFS CWF BO 2017 Appendix E, CDFW CWF ITP 2017, Flow-mediated effects on travel time, routing, and survival of juvenile Chinook salmon in a spatially complex, tidally forced river delta, Perry et al 2018)
- NDOI outflow index > 44,500 cfs – functional fish flow longfin smelt (CDFW CWF ITP 2017, Population Dynamics of an Estuarine Forage Fish: Disaggregating Forces Driving Long-Term Decline of Longfin Smelt in California's San Francisco Estuary, Nobriga and Rosenfield 2016)

Sites Project
Functional Flow and Operational Parameter Development and Evaluation

July 16, 2019

California Department of Fish and Wildlife

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Outline of Discussion

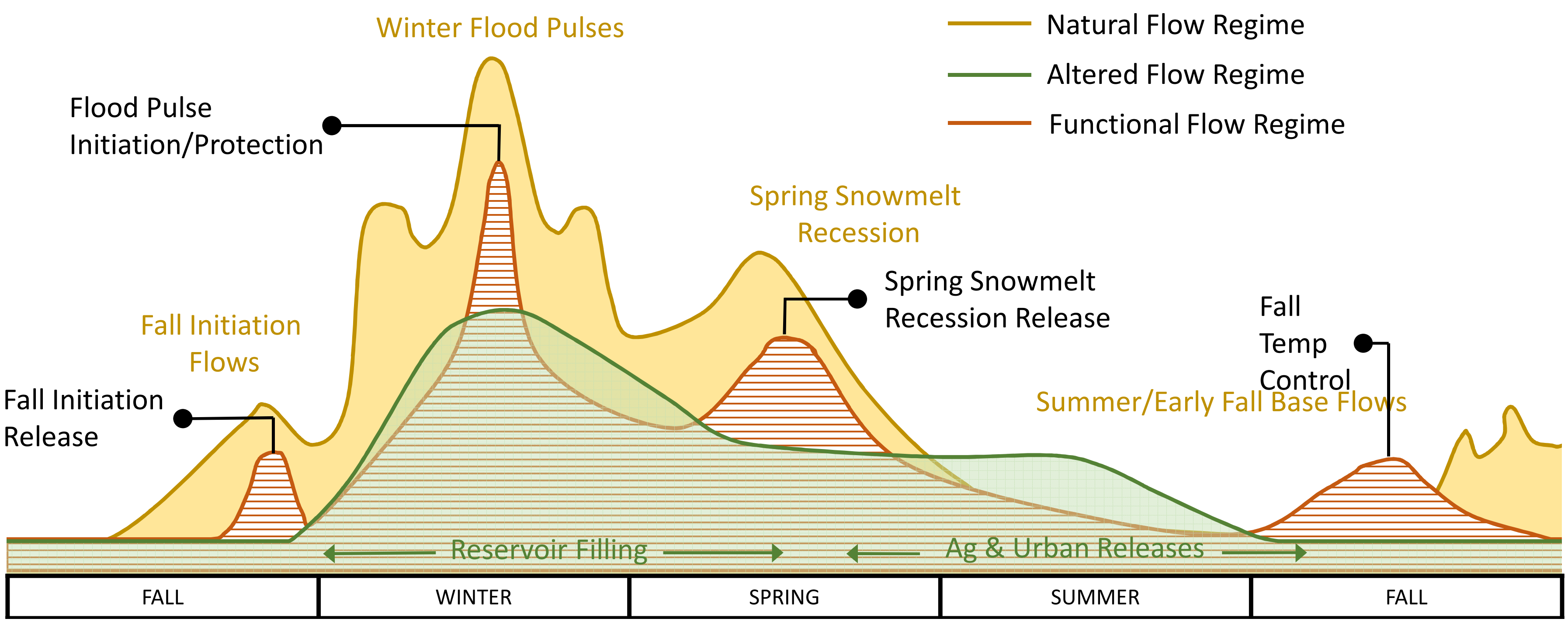
- Functional Flows Approach
  - Conceptual model of functional flows
- Study Reach Characterization of Ecological/Biological Functions
- Operational Parameter Review and Evaluation

Functional Flow Approach

- Process-based approach that preserves the most important aspects of variability of a natural flow regime to which native species have adapted.
- Preservation of key aspects of the flow regime, or *functional flow components*.
- Important functional flow components in California rivers are:
  - **Wet-season initiation flows:** move nutrients downstream, initiate migration
  - **Peak magnitude flows:** transport sediment, restructure/maintain river corridors
  - **Spring-recessional flows:** migratory cues, activate off-channel habitat
  - **Dry-Season low flows:** favors native, anadromous species

Functional Flow Approach

- Provides alternative strategy from minimum instream flows for allocating water budgets.
- Functional flow components are targeted to support specific ecological processes, while minimum instream flow targets may not.
- The functional flow approach also offers flexibility during changing conditions (wet and dry years), which is critical to ensure most efficient allocation of water.



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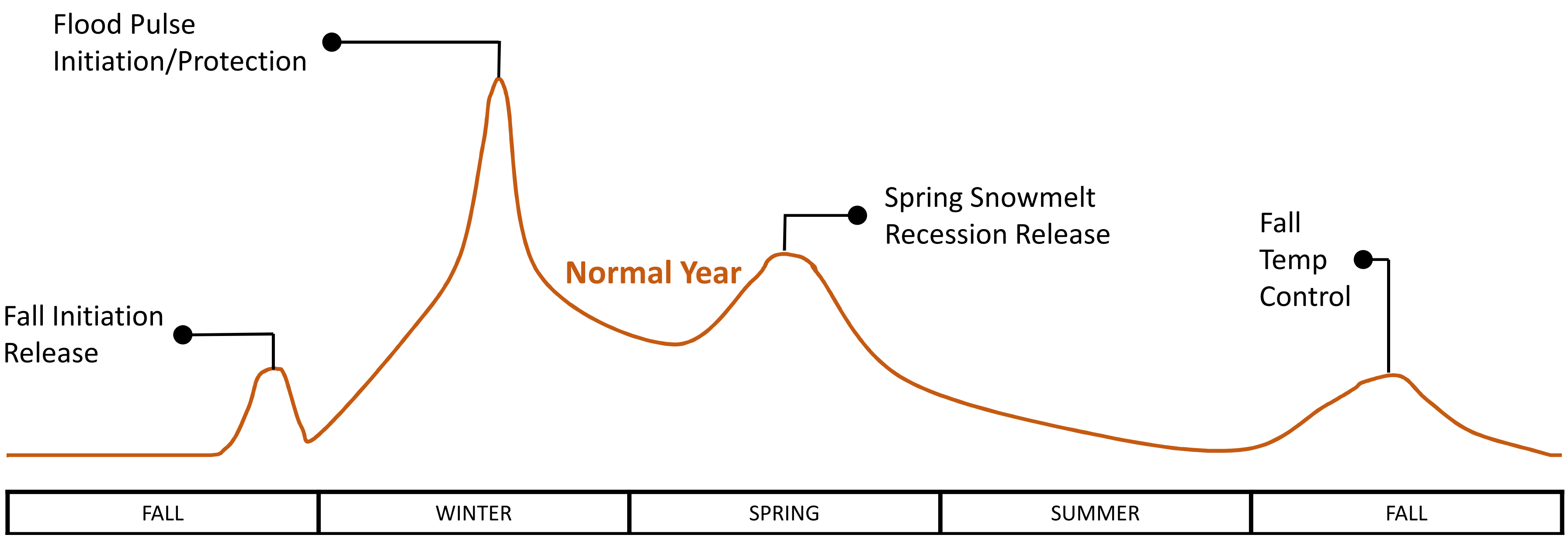

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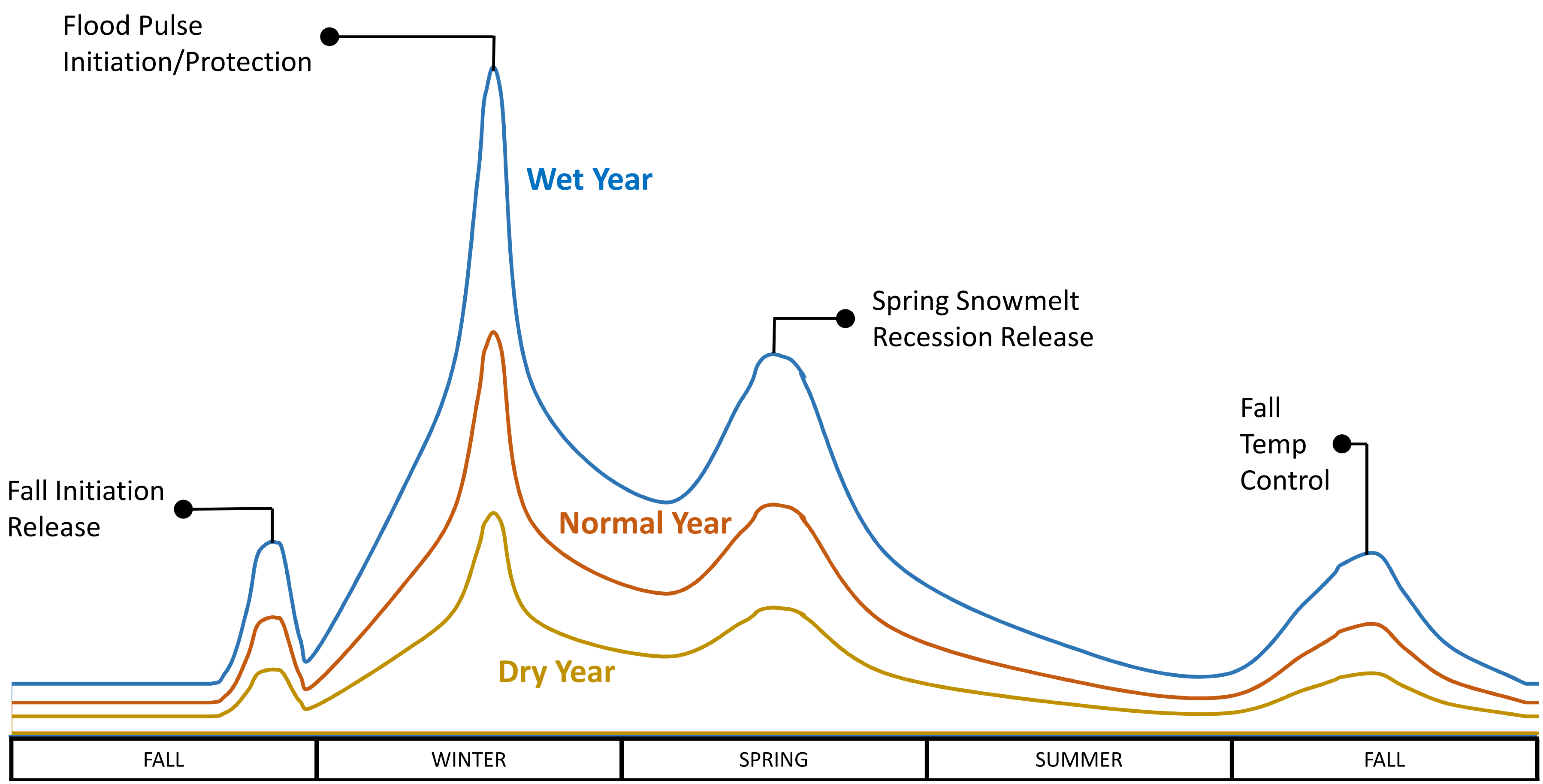

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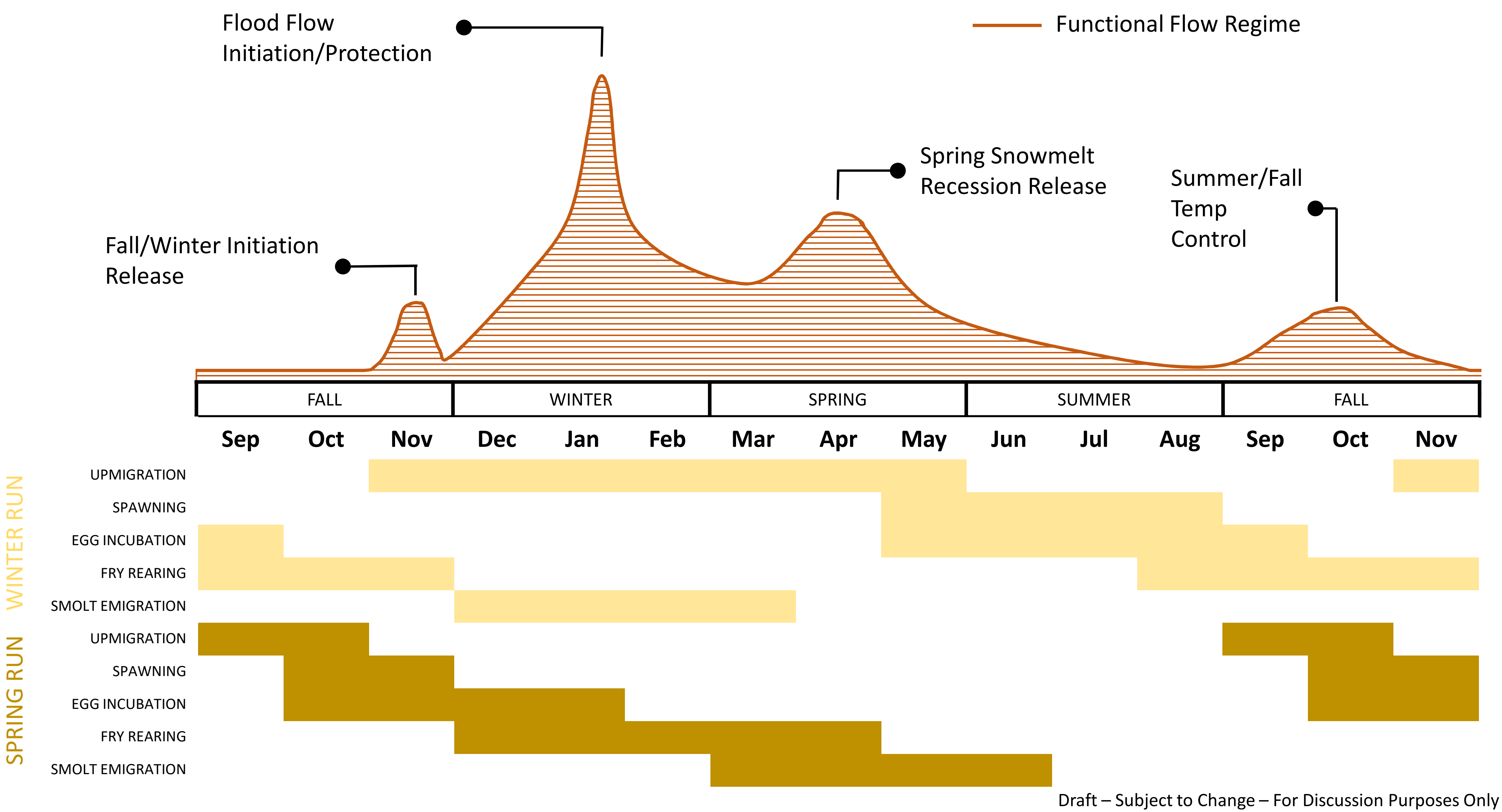

Flood Flow Initiation/Protection
Functional Flow Regime
Spring Snowmelt Recession Release
Summer/Fall Temp Control
Fall/Winter Initiation Release
FALL
WINTER
SPRING
SUMMER
FALL
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
WINTER RUN
UPMIGRATION
SPAWNING
EGG INCUBATION
FRY REARING
SMOLT EMIGRATION
SPRING RUN
UPMIGRATION
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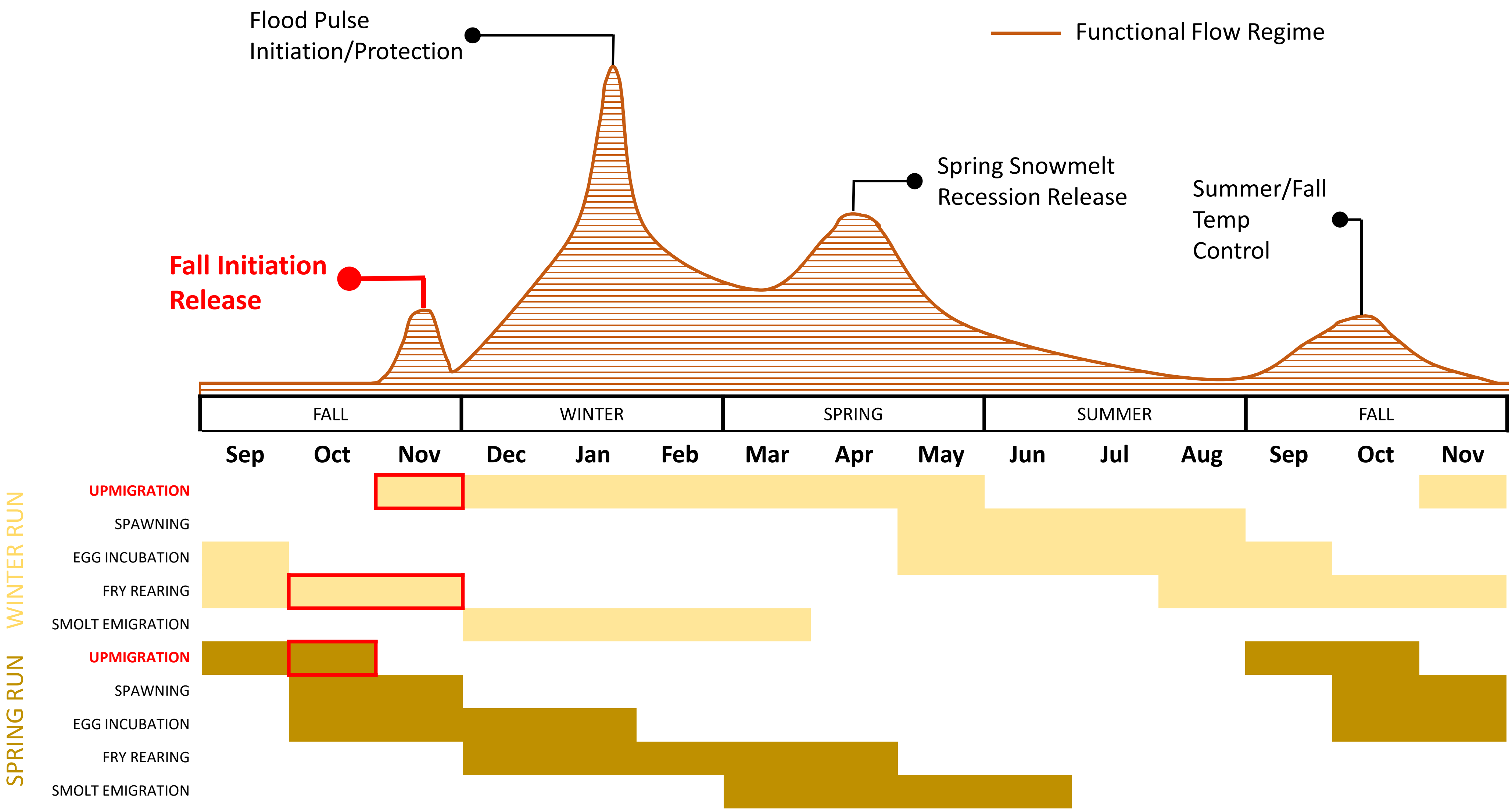

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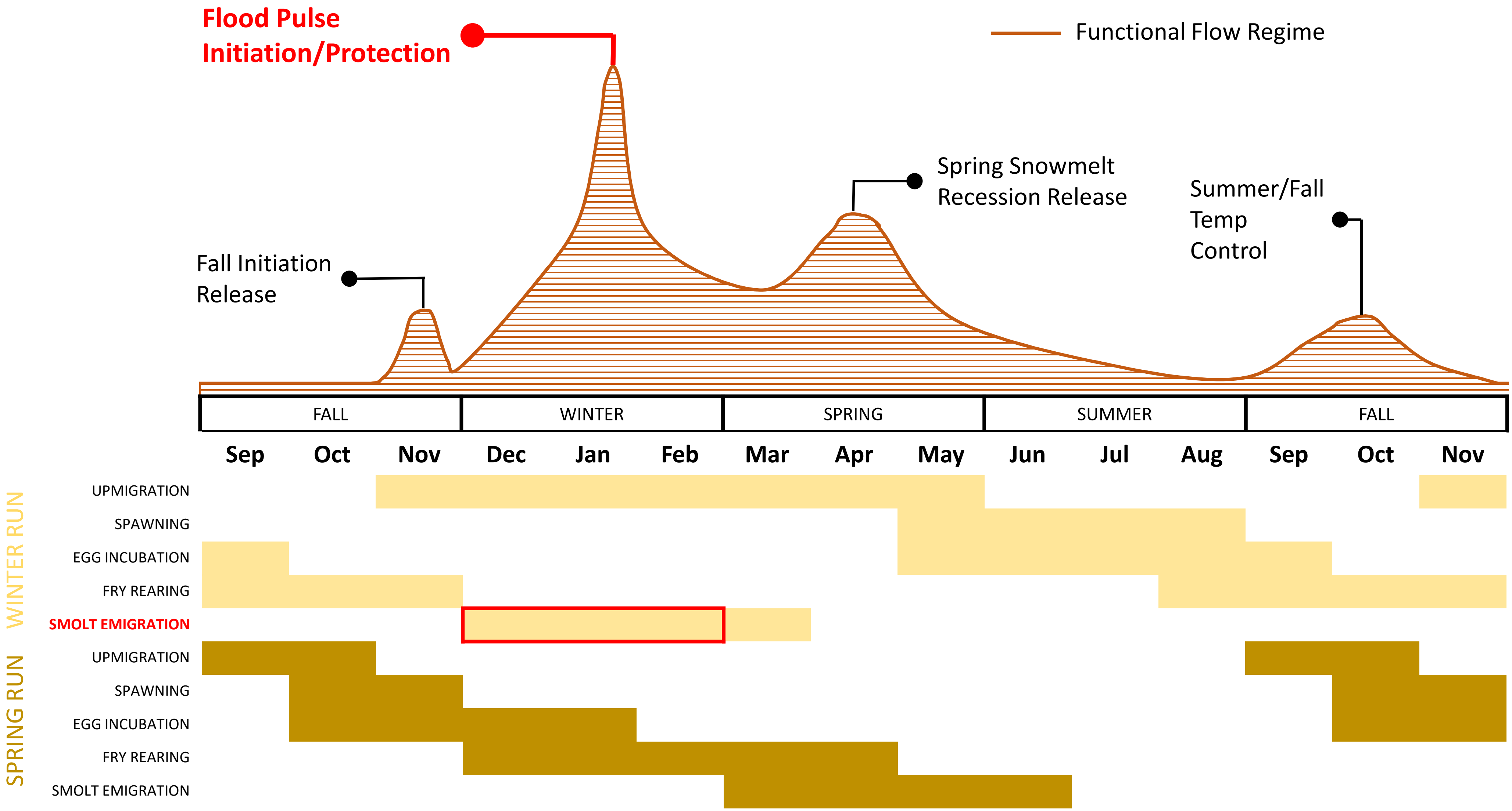

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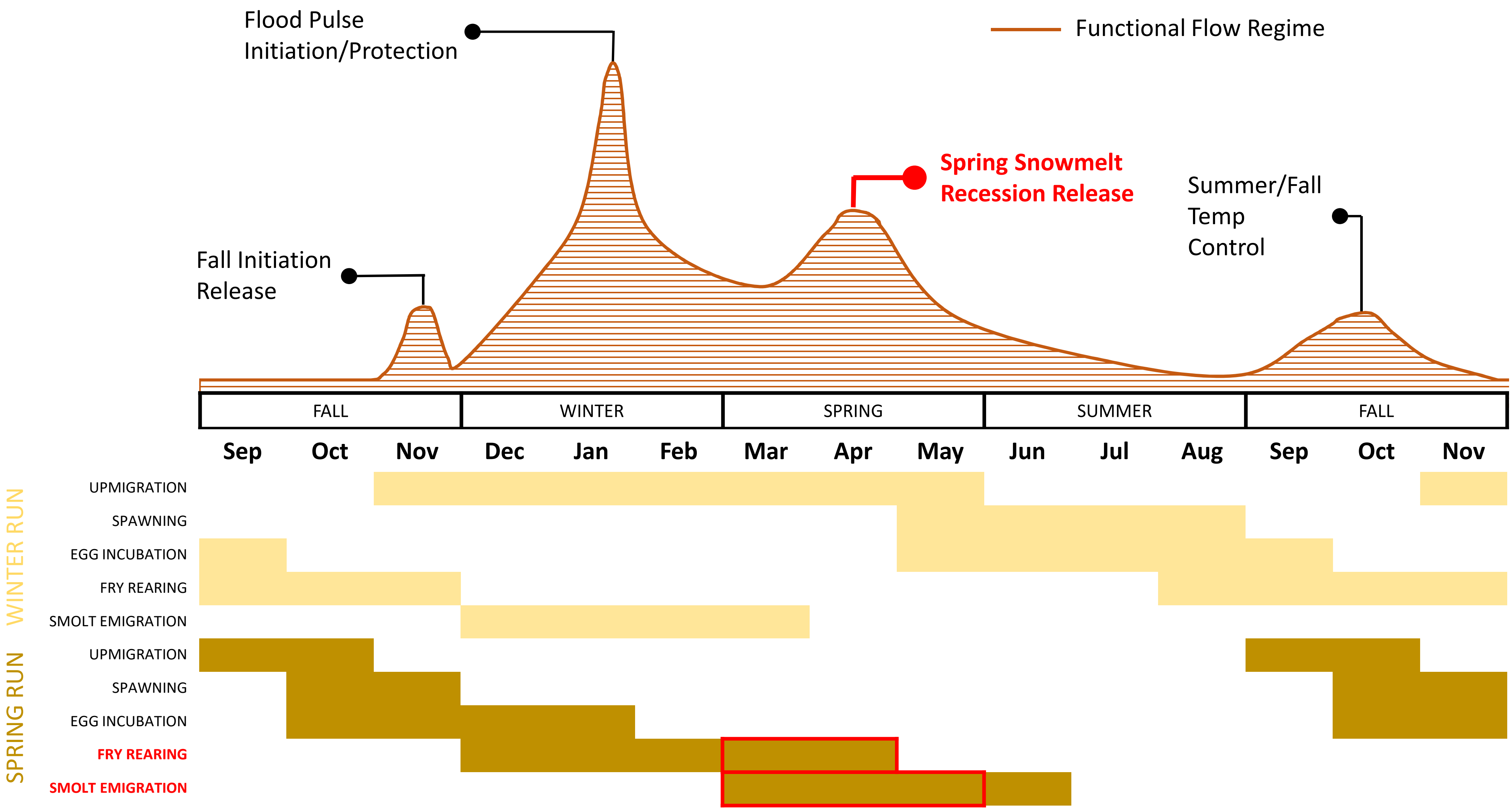

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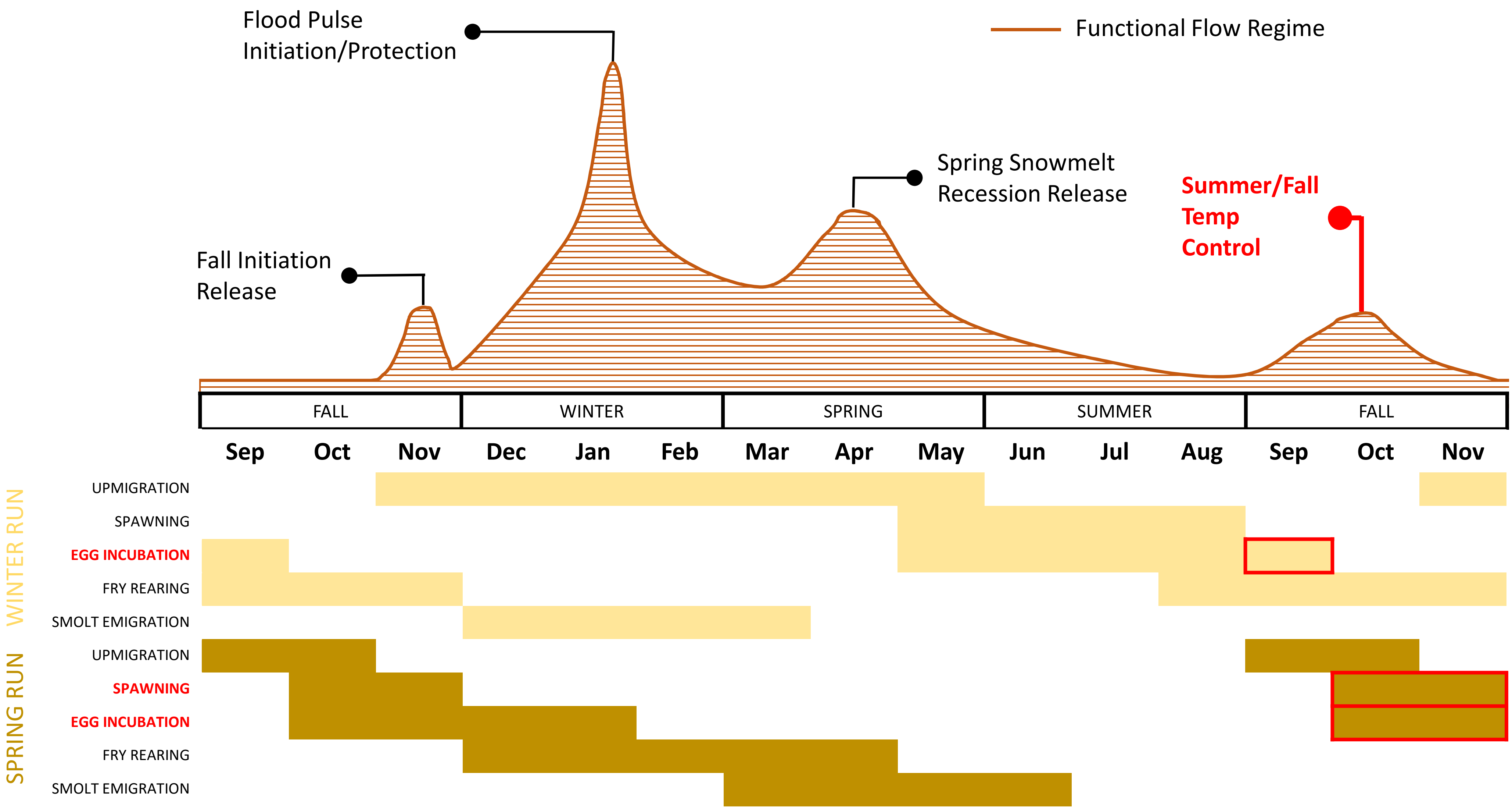

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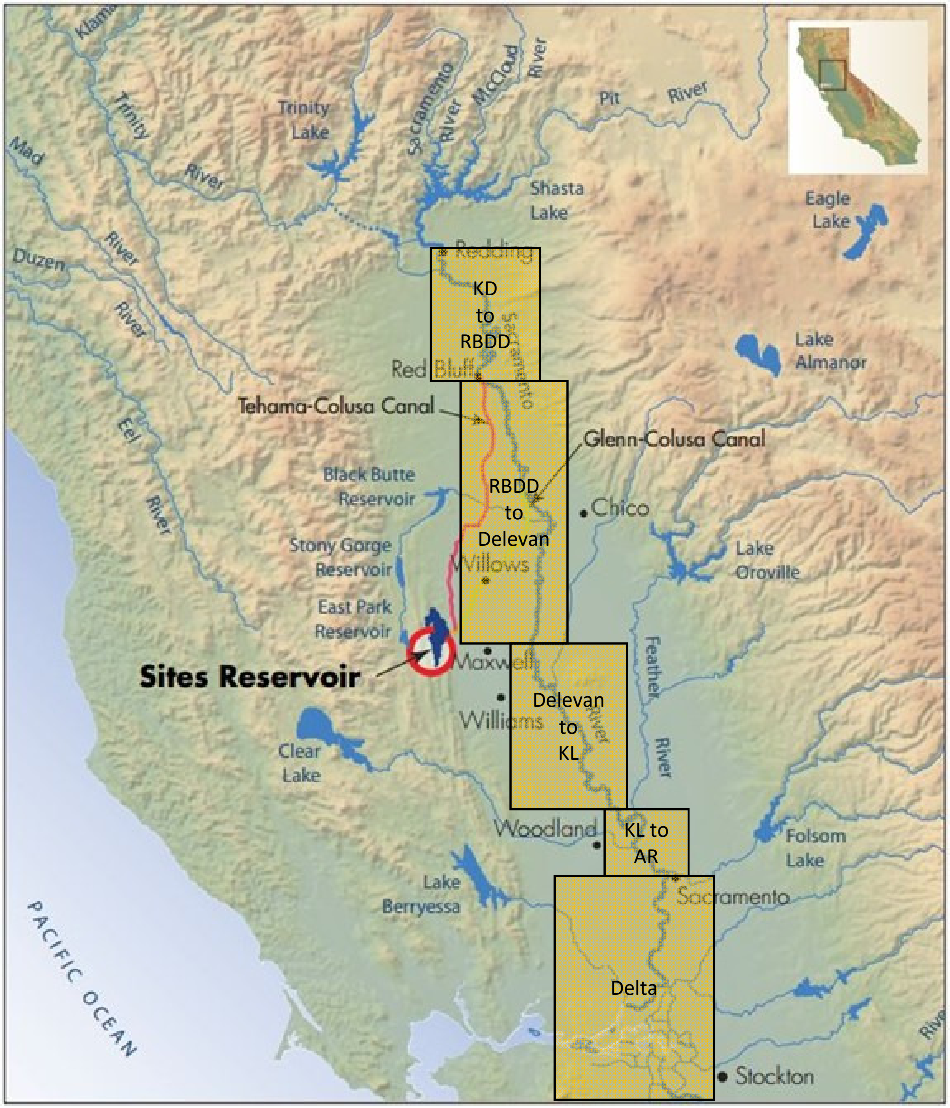
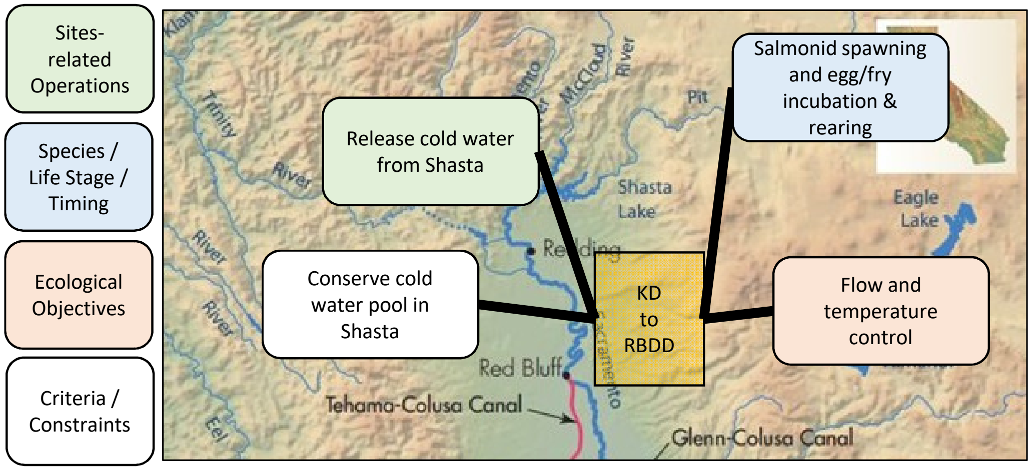
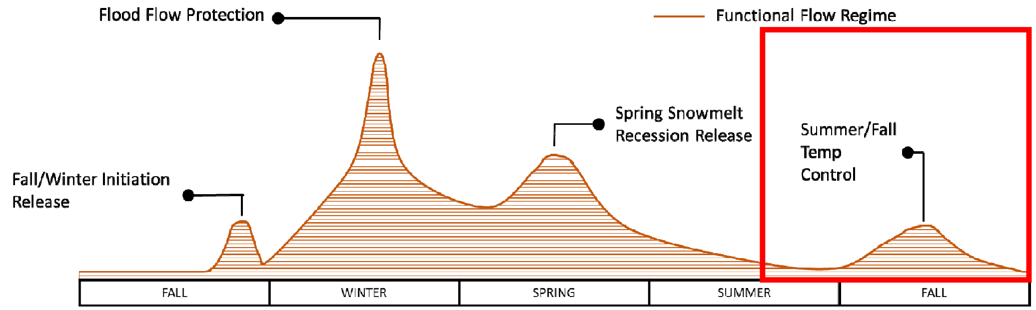
Study reaches



- Reach-scale characterization
  - Species/life-stages/timing
  - Primary ecological functions
    - Drivers
- Operational influence and evaluation
  - Sites operational component/influence
  - Ecological/ biological functions
    - Species/life stages
    - Objectives
    - Parameters/drivers
    - Period of interest
  - Analytical tools and approach
    - Tools
    - Description/parameters
    - Evaluation criteria/metric
- Considerations for refinements
  - Refined operations development and analysis
  - Adaptive management





- Keswick Dam to Red Bluff Diversion Dam
  - Winter-run and Spring-run Chinook Salmon
    - Spawning
    - Egg incubation to fry emergence
    - Migration
  - Major tributaries
    - Clear, Cottonwood, and Battle creeks
  - Primary Functions
    - Coldwater management (migration, holding, spawning, egg to fry emergence)
    - Driver – Shasta Reservoir coldwater pool

Functional Flows

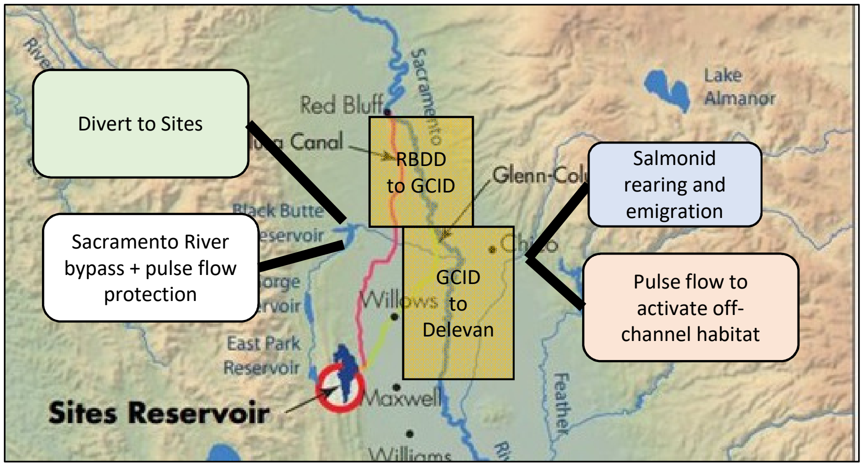
- Summer/Fall Temp Control
  - Winter-run spawning/egg incubation (Summer)
  - Spring-run spawning/egg incubation (Fall)

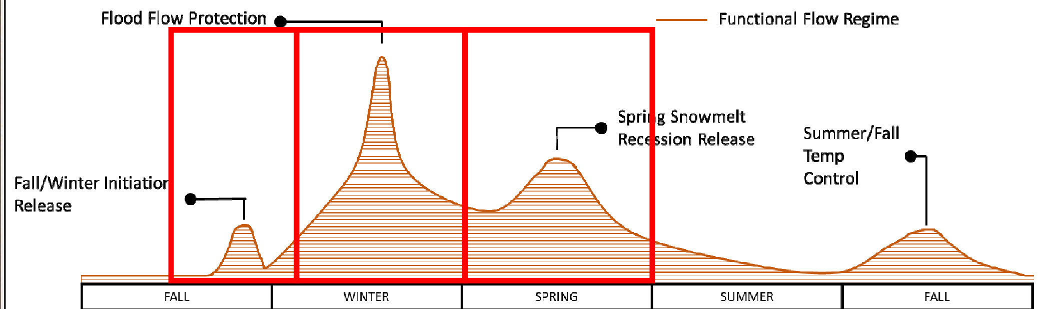
Sites-related Operations

Species / Life Stage / Timing

Ecological Objectives

Criteria / Constraints





- Red Bluff Diversion Dam to Colusa (Delevan)
  - Winter-run and Spring-run Chinook Salmon
    - Migration (adult and juvenile)
    - Rearing
  - Major tributaries
    - Antelope, Mill, Deer, Big Chico, Stoney Cks
  - Bypasses/weirs
    - Sutter/ Moulton, Colusa
  - Primary Functions
    - Active geomorphic reach
    - Habitat complexity, refugia, turbidity, shaded riverine aquatic
    - Driver – flow events

Functional Flows

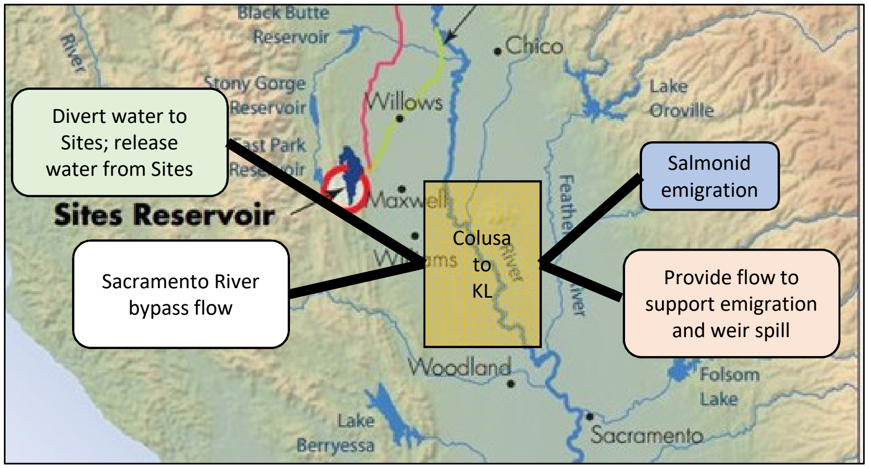
- Fall/Winter Initiation Release
  - Winter-run adult upmigration
  - Spring-run adult upmigration
- Flood Flow Protection
  - Winter-run emigration
  - Off-channel habitat activation/deactivation
- Spring snowmelt recession release
  - Spring-run rearing
  - Spring-run emigration
  - Off-channel habitat activation/deactivation

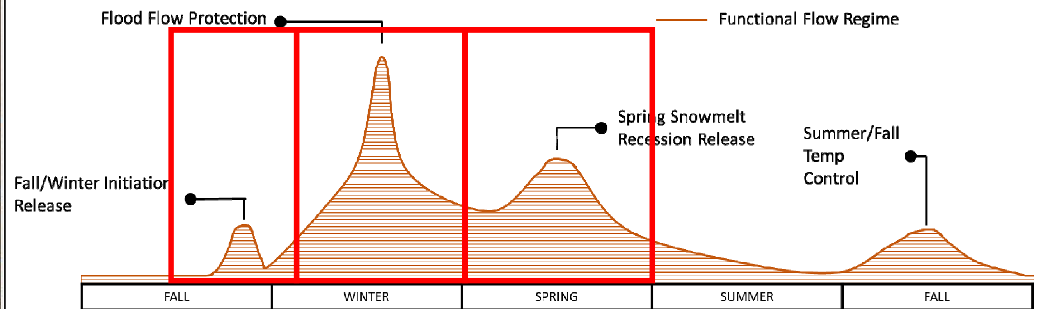
Sites-related Operations

Species / Life Stage / Timing

Ecological Objectives

Criteria / Constraints





- Colusa (Delevan) to Knights Landing
  - Winter-run and Spring-run Chinook Salmon
    - Migration (adult and juvenile)
    - Rearing (limited)
  - Major tributaries
    - None
  - Bypasses/weirs
    - Sutter/ Tisdale
  - Primary Functions
    - Limited ecological functions – confined by levees, limited SRA
    - Driver – Tisdale Weir spills

Functional Flows

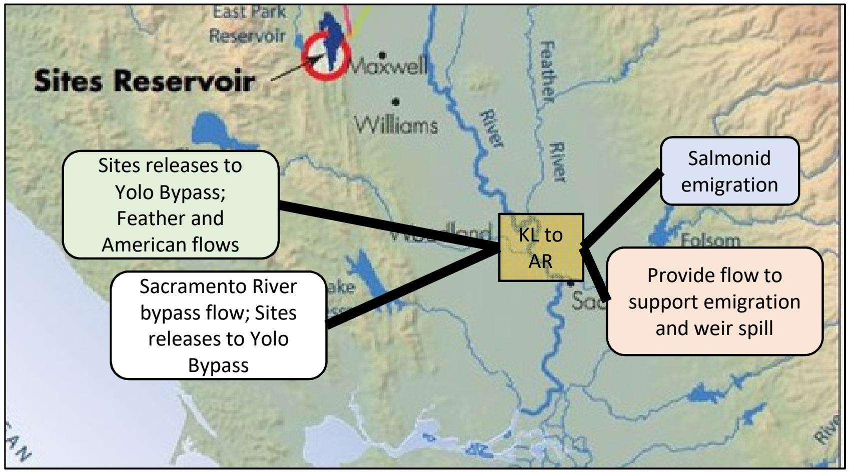
- Fall/Winter Initiation Release
  - Winter-run adult upmigration
  - Spring-run adult upmigration
- Flood Flow Protection
  - Winter-run emigration
  - Bypass activation
- Spring snowmelt recession release
  - Spring-run emigration
  - Bypass activation

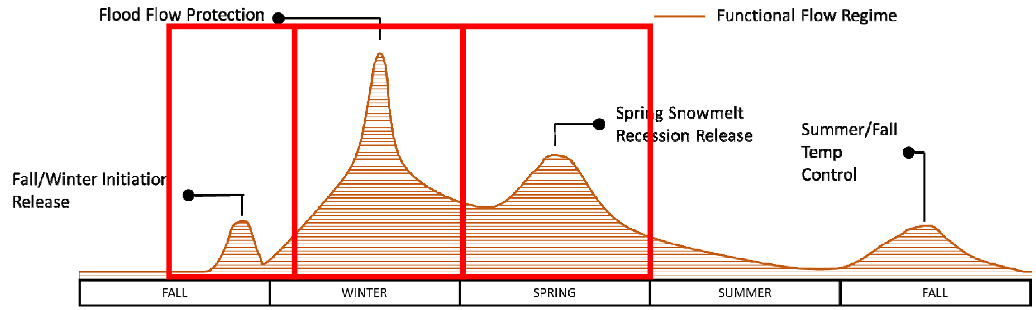
Sites-related Operations

Species / Life Stage / Timing

Ecological Objectives

Criteria / Constraints

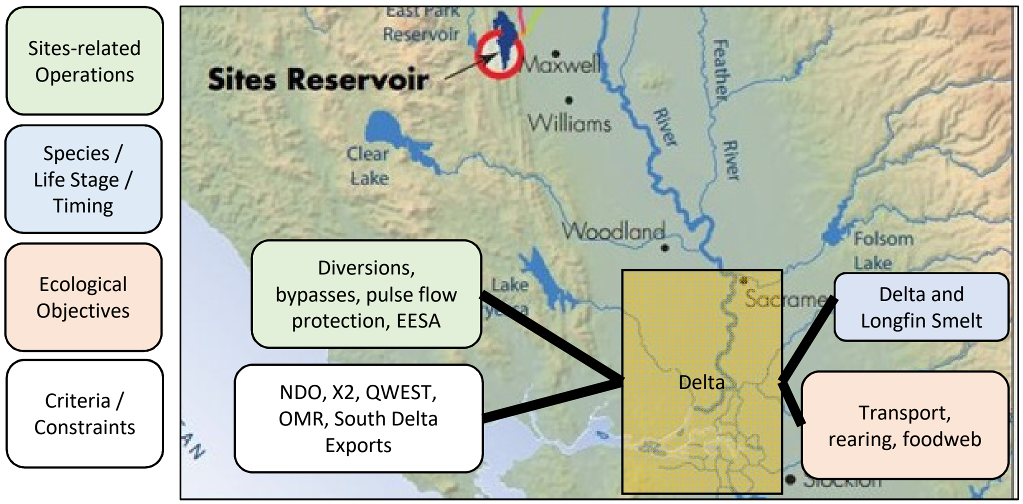


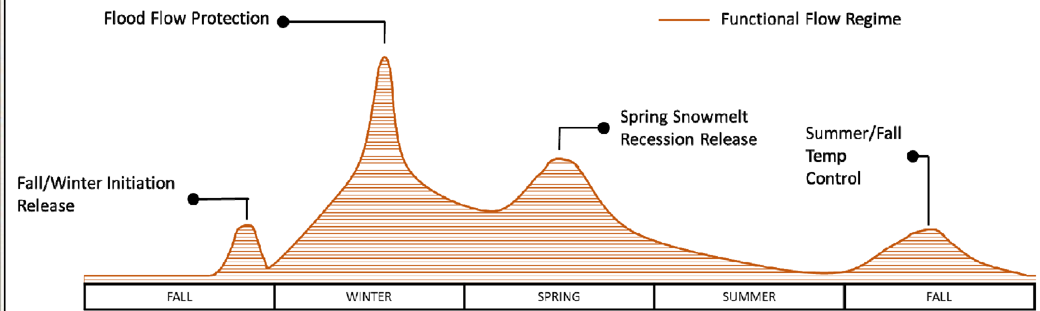


- Knights Landing to American River
  - Winter-run and Spring-run Chinook Salmon
    - Migration (adult and juvenile)
    - Rearing (limited)
  - Major tributaries
    - Feather River, Sutter Bypass, America River
  - Bypasses/weirs
    - Yolo/ Fremont, Sacramento
  - Primary Functions
    - Limited ecological functions – confined by levees, limited SRA
    - Driver – Fremont Weir spills

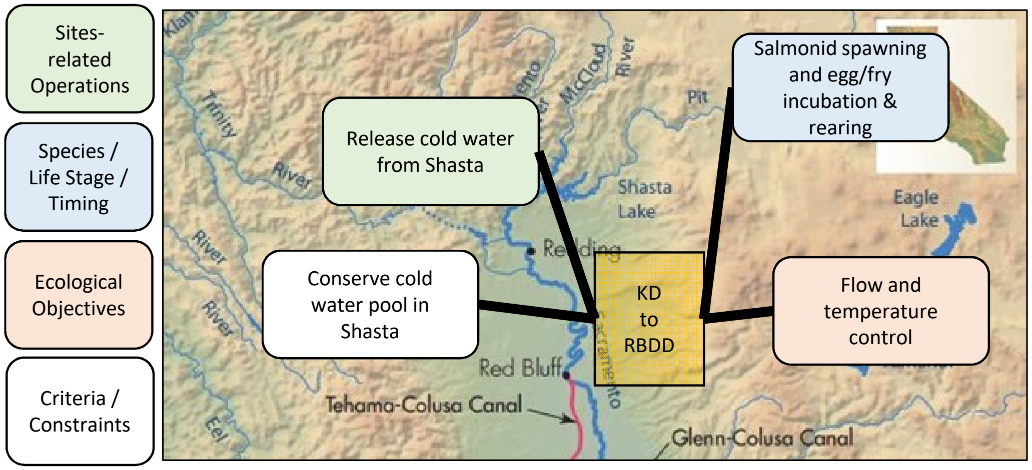
Functional Flows

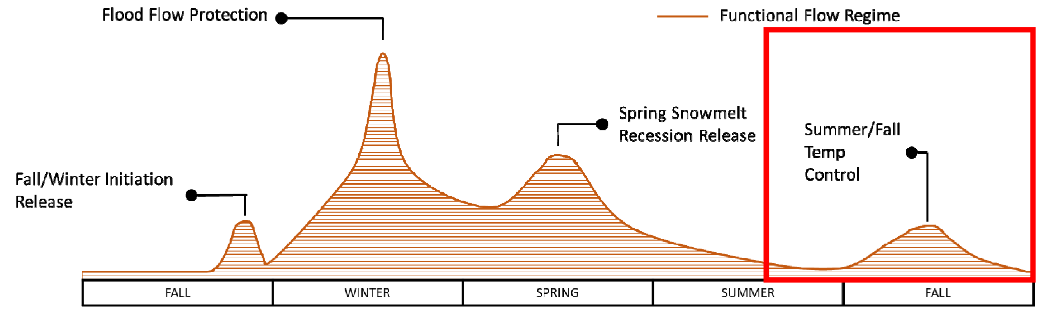
- Fall/Winter Initiation Release
  - Winter-run adult upmigration
  - Spring-run adult upmigration
- Flood Flow Protection
  - Winter-run emigration
  - Bypass activation
- Spring snowmelt recession release
  - Spring-run emigration
  - Bypass activation





- Delta
  - Winter-run and Spring-run Chinook Salmon
    - Migration (adult and juvenile)
    - Rearing (limited)
  - Delta and Longfin Smelt (all life stages)
  - Major tributaries
    - Multiple tributaries and distributaries
  - Primary Functions
    - Tidally-influence estuary, transport processes, low salinity zone
    - Driver – Sac River inflows, CVP/SWP exports, net Delta outflow





Operational Component		**Geography**	**Biological/ Ecological Functions**			**Period of Interest**													**Analytical Tools / Approach**		
Type and location	Quantity (volume)	Region or reach	Primary species/life stage of concern	Ecological and Biological Objective(s)	Parameter/ driver	Life-stage (OBAN); season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Tool	Description (parameters)	Evaluation Criteria/ Metrics
Shasta Reservoir and Sacramento River; FR, AR	Conserved volume, coldwater pool, variable	Keswick to RBDD	WRCS, SRCS; spawning, eggs/alevins to fry	Flow/temp control; survival	Flow, temp	Eggs/alevins													CALSIM; CE-QUAL-W2; USRDOM, OBAN + Henderson; SALMOD	Daily flow and temp, life-cycle, survival	Change in flow-survival (OBAN + Henderson); SALMOD
						Fry															

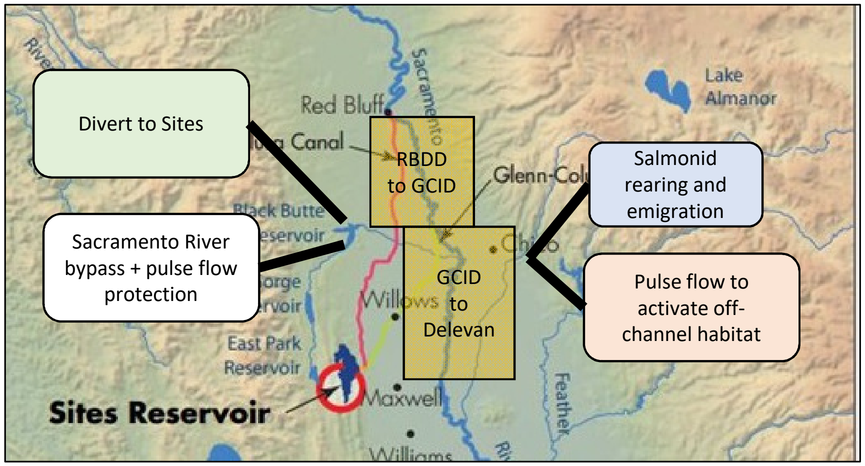
Considerations for Refined Operations Development and Analysis				**Considerations for Adaptive Management**			
Sites Diversion Operational Considerations	Ecological Enhancement Water Account Considerations	Ecological Considerations	Performance Considerations	Objective	Mechanism	Trigger	Contingency Measure/ Action
Trade-offs: EESA developed through Sites diversions and releases	EESA-1 (coldwater pool); EESA-2 (SR temp); EESA-8 (SR augment); EESA-3,4 (Feather/American)	Flow/temp, variability, pulse	Change in flow-survival in OBAN	Survival	Flow, temp, turbidity	Flow, temp, redd/egg incubation, RB screw trap	SR augment

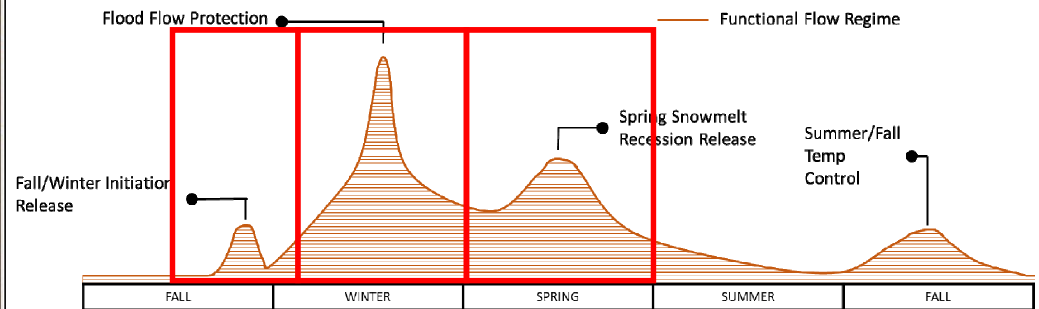
Sites-related Operations

Species / Life Stage / Timing

Ecological Objectives

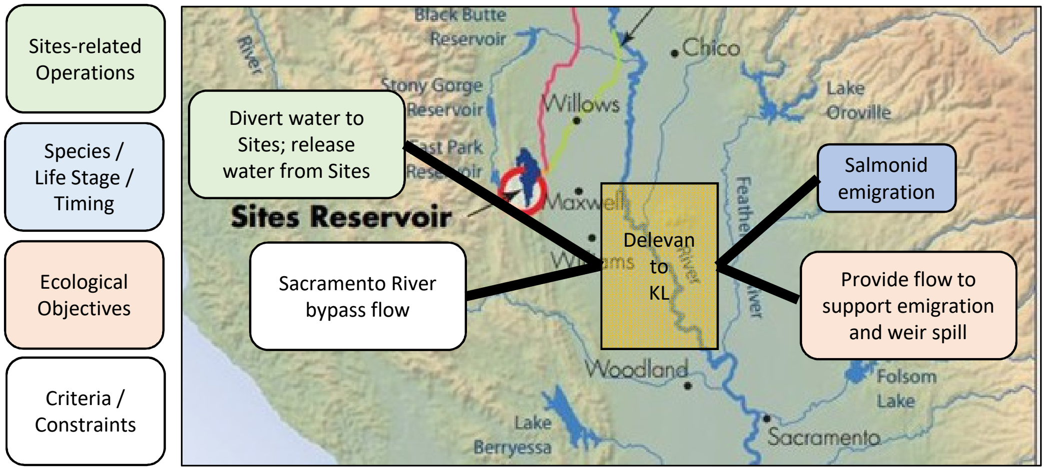
Criteria / Constraints

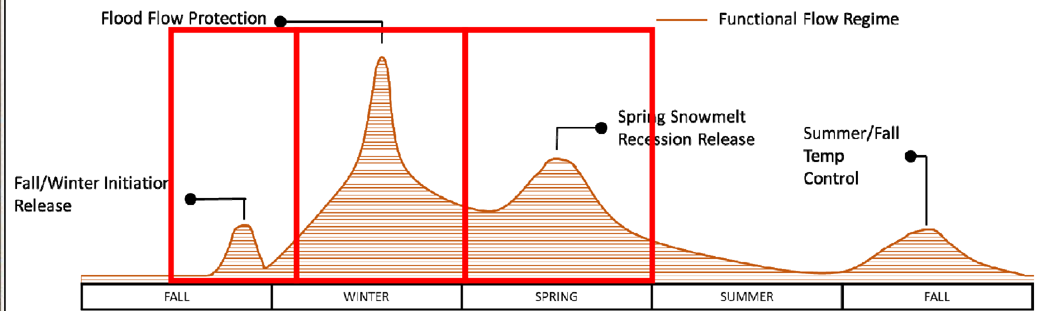




Operational Component			Geography	Biological/ Ecological Functions			Period of Interest													Analytical Tools / Approach		
Type and location	Quantity (volume)	Bypasses/ Pulse Flow Protection	Region or reach	Primary species/life stage of concern	Ecological and Biological Objective(s)	Parameter/ driver	Life-stage (OBAN); season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Tool	Description (parameters)	Evaluation Criteria/ Metrics
Red Bluff PP Ham City PP Delevan PP	2100 1800 2000	3250 4000 5000	Red Bluff to Colusa	WRCS, SRCS, juvenile outmigrants	Geomorphic processes; overbank flows; survival	Flow, temp, turbidity, refugia, predation	Fry Juveniles													USRDOM, HEC, OBAN + Henderson; SALMOD	Daily flow and temp, eco events, life-cycle, survival	Change in events, flow-survival (OBAN + Henderson); SALMOD

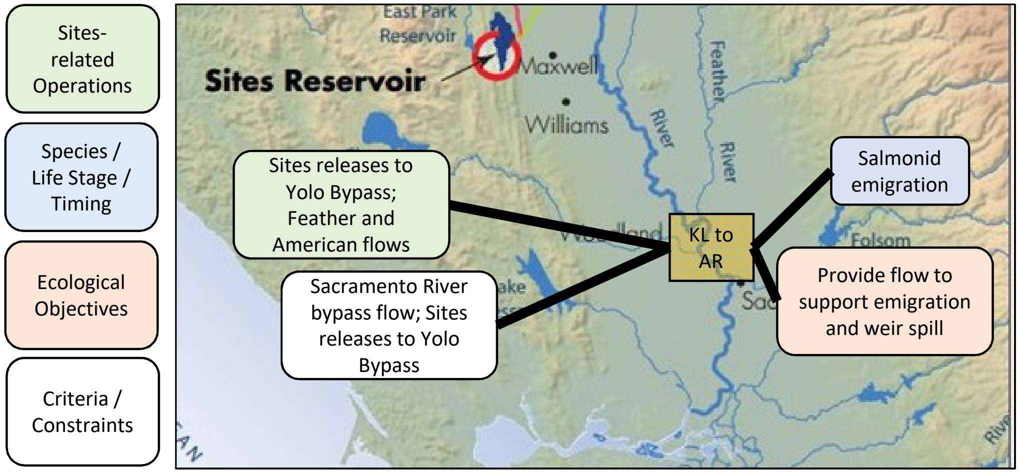
Considerations for Refined Operations Development and Analysis				Considerations for Adaptive Management			
Sites Diversion Operational Considerations	Ecological Enhancement Water Account Considerations	Ecological Considerations	Performance Considerations	Objective	Mechanism	Trigger	Contingency Measure/ Action
Bypasses, pulse protection, diversion prioritization	EESA-8 (SR augment)	Flow variability, pulse, turbidity	Change in events; flow-survival in OBAN	Ecological processes for improved survival	Flow events	Off-channel habitat activation.	Floodplain restoration/ enhancement (functional flow)

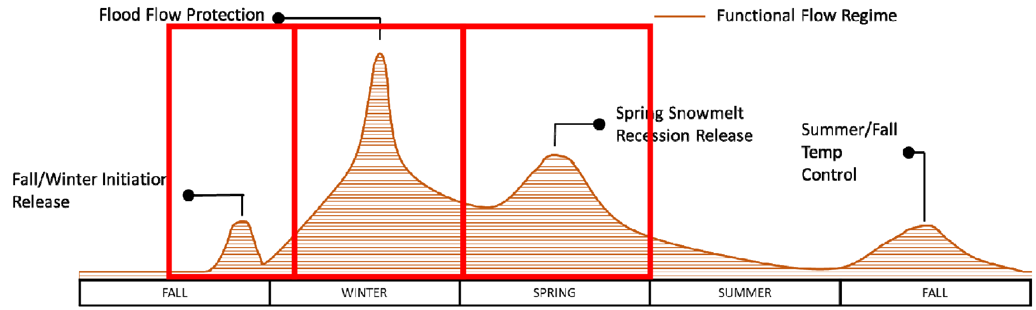




Operational Component Geography			Biological/ Ecological Functions			Period of Interest													Analytical Tools / Approach		
Type and location		Region or reach	Primary species/life stage of concern	Ecological and Biological Objective(s)	Parameter/ driver	Life-stage (OBAN); season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Tool	Description (parameters)	Evaluation Criteria/ Metrics
Weirs/ Bypasses	Colusa, Moulton, Tisdale weirs	Colusa to Knights Landing	WRCS, SRCS, juvenile outmigrants	Floodplain, rearing, growth	Spill/inundation frequency and duration	Winter-spring flows													USRDOM	Daily flow, weir spills (frequency, duration, magnitude)	Change in spill/ inundation events (timing, frequency [spills per model period], duration [no. days], magnitude [area inundated])

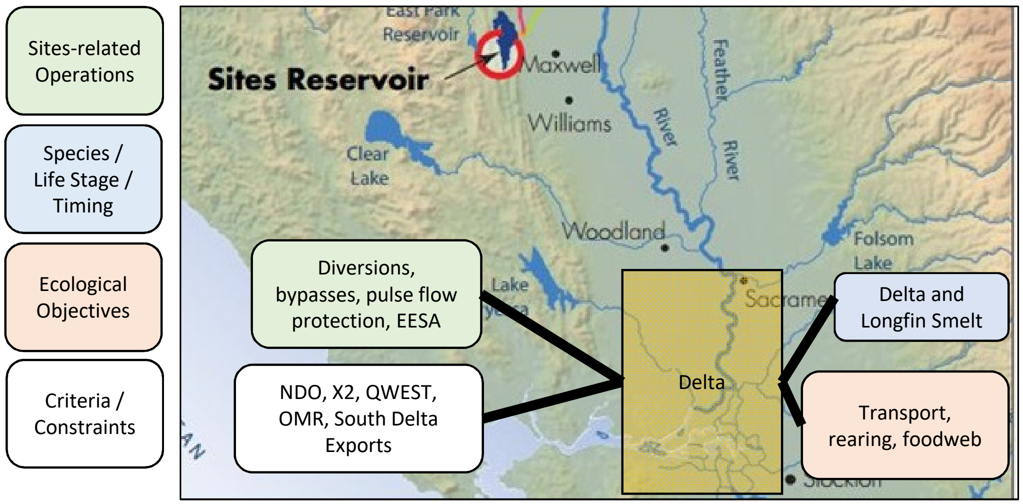
Considerations for Refined Operations Development and Analysis				Considerations for Adaptive Management			
Sites Diversion Operational Considerations	Ecological Enhancement Water Account Considerations	Ecological Considerations	Performance Considerations	Objective	Mechanism	Trigger	Contingency Measure/ Action
Sites diversions and bypass flows		Surrogate floodplain innundation	Spill event (frequency, duration, magnitude)	Bypass inundation		Wier spills	Sites diversion bypass flows





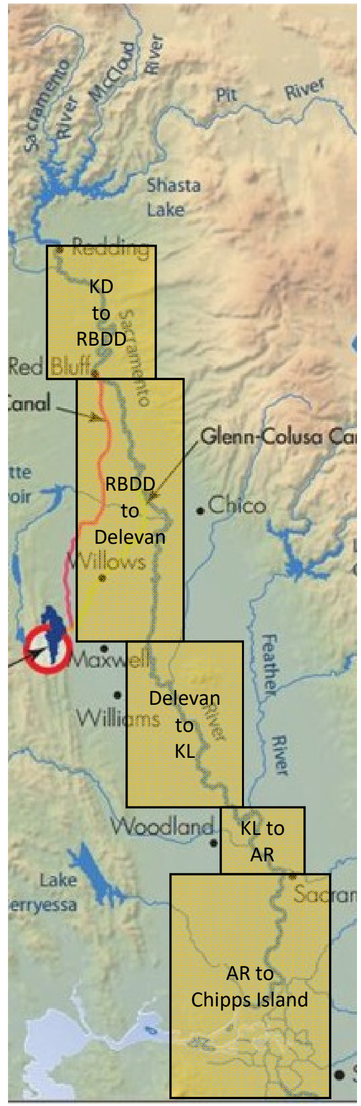
Operational Component Geography			Biological/ Ecological Functions			Period of Interest													Analytical Tools / Approach		
Type and location		Region or reach	Primary species/life stage of concern	Ecological and Biological Objective(s)	Parameter/ driver	Life-stage (OBAN); season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Tool	Description (parameters)	Evaluation Criteria/ Metrics
Weirs/ Bypasses	Fremont, Sacramentoweirs	Knights Landing to AR (Delta)	WRCS, SRCS, juvenile outmigrants	Floodplain, rearing, growth	Spill/inundation frequency and duration	Winter-spring flows													USRDOM	Daily flow, weir spills (frequency, duration, magnitude)	Change in spill/ inundation events (timing, frequency [spills per model period], duration [no. days], magnitude [area inundated])

Considerations for Refined Operations Development and Analysis				Considerations for Adaptive Management			
Sites Diversion Operational Considerations	Ecological Enhancement Water Account Considerations	Ecological Considerations	Performance Considerations	Objective	Mechanism	Trigger	Contingency Measure/ Action
Sites diversions and bypass flows	EESA-5 Yolo Bypass Flow Enhancement	Surrogate floodplain inundation	Sill event (frequency, duration, magnitude)	Bypass inundation		Wier spills	Sites diversion bypass flows



Operational Component	Geography	Biological/ Ecological Functions			Period of Interest													Analytical Tools / Approach		
Type and location	Region or reach	Primary species/life stage of concern	Ecological and Biological Objective(s)	Parameter/ driver	Life-stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Tool	Description (parameters)	Evaluation Criteria/ Metrics
Delta outflow; south Delta exports	Delta	WRCS, SRCS, DS, LFS	Survival, food production, larval transport	Transport, position of LSZ														CALSIM, DSM, PTM	Outflow, LSZ	Sac River inflow, NDO, posiiton of X2/LSZ, QWEST, OMR, CVP/SWP exports

Considerations for Refined Operations Development and Analysis				Considerations for Adaptive Management			
Sites Diversion Operational Considerations	Ecological Enhancement Water Account Considerations	Ecological Considerations	Performance Considerations	Objective	Mechanism	Trigger	Contingency Measure/ Action
Sites diversions and bypass flows	EESA-5 Yolo Bypass Flow Enhancement						



Criteria / Constraints	Sites-related Operations	Species, Life Stage, Timing	Ecological Objectives
Conserve cold water pool in Shasta	Release cold water from Shasta	Salmon spawning and egg/fry incubation & rearing	Flow and temperature control
Sacramento River bypass + pulse flow protection	Divert water to Sites	Salmon rearing and emigration	Pulse flow to activate off-channel habitat
Sacramento River bypass flow	Divert water to Sites; release water from Sites	Salmon emigration	Provide flow to support emigration and weir spill
Sacramento River bypass flow; Sites releases to Yolo Bypass	Sites releases to Yolo Bypass; Feather R. and American R. outflows	Salmon emigration	Provide flow to support emigration and weir spill
NDO, X2, QWEST, OMR, South Delta Exports	Diversions, bypasses, pulse flow protection, EESA	Delta and Longfin Smelt	Transport, rearing, foodweb

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Sites Project: Near-Field Analyses and Far-Field Flow-Survival Analyses

California Department of Fish and Wildlife

July 16, 2019

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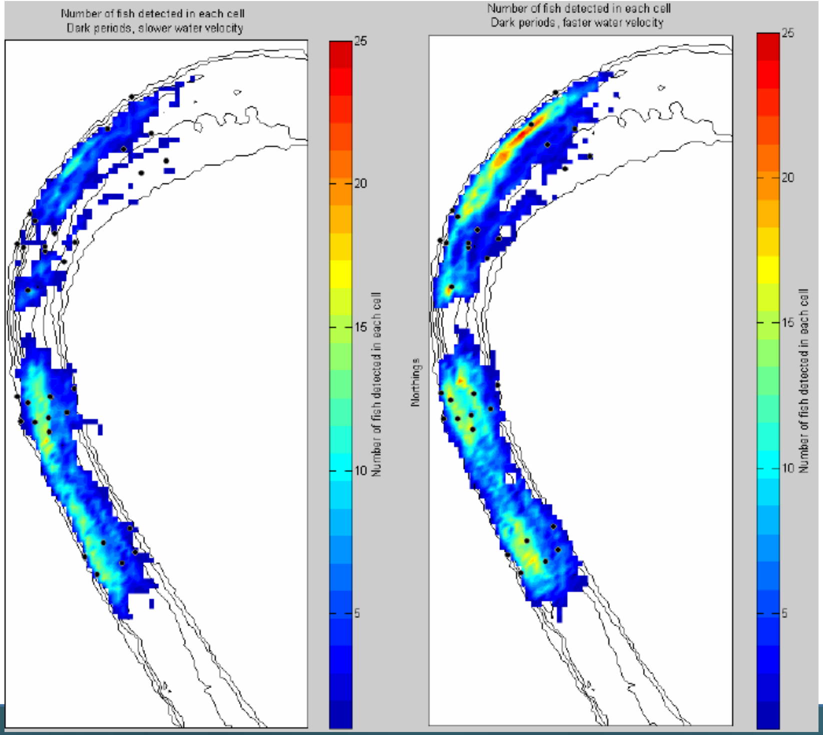
Outline of Discussion

- Near-field effects
  - Spatial distribution (screen exposure)
  - Entrainment; impingement, screen contact, screen passage
  - Predation
  - Stranding behind screens during high flow
  - Attraction to screens during reservoir discharge
- Far-field effects
  - Henderson et al. migration flow-survival
  - OBAN

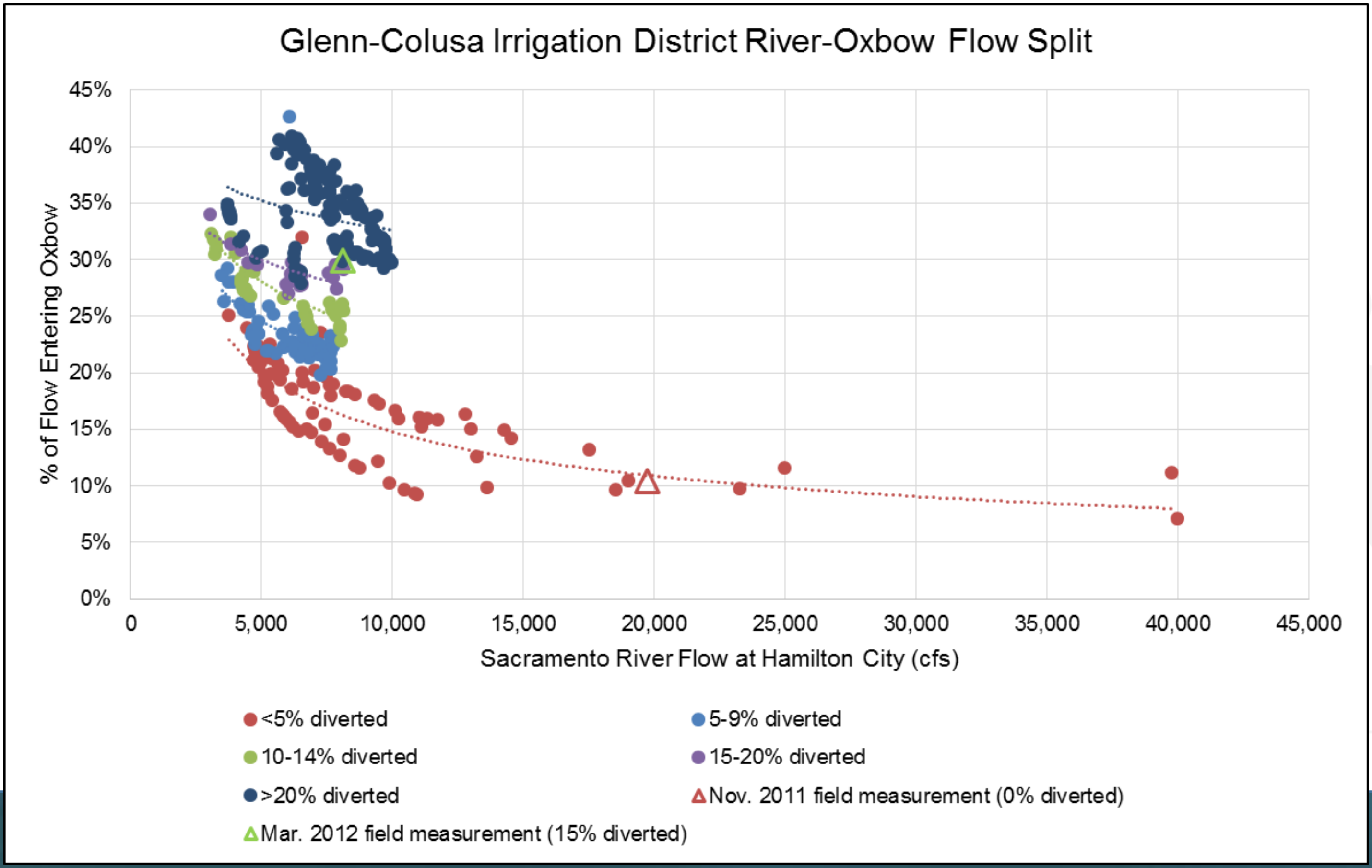
Near-field effects

- Spatial distribution (screen exposure)
  - Generally qualitative discussion based on observations at other locations (e.g., Clarksburg Bend)



Near-field effects

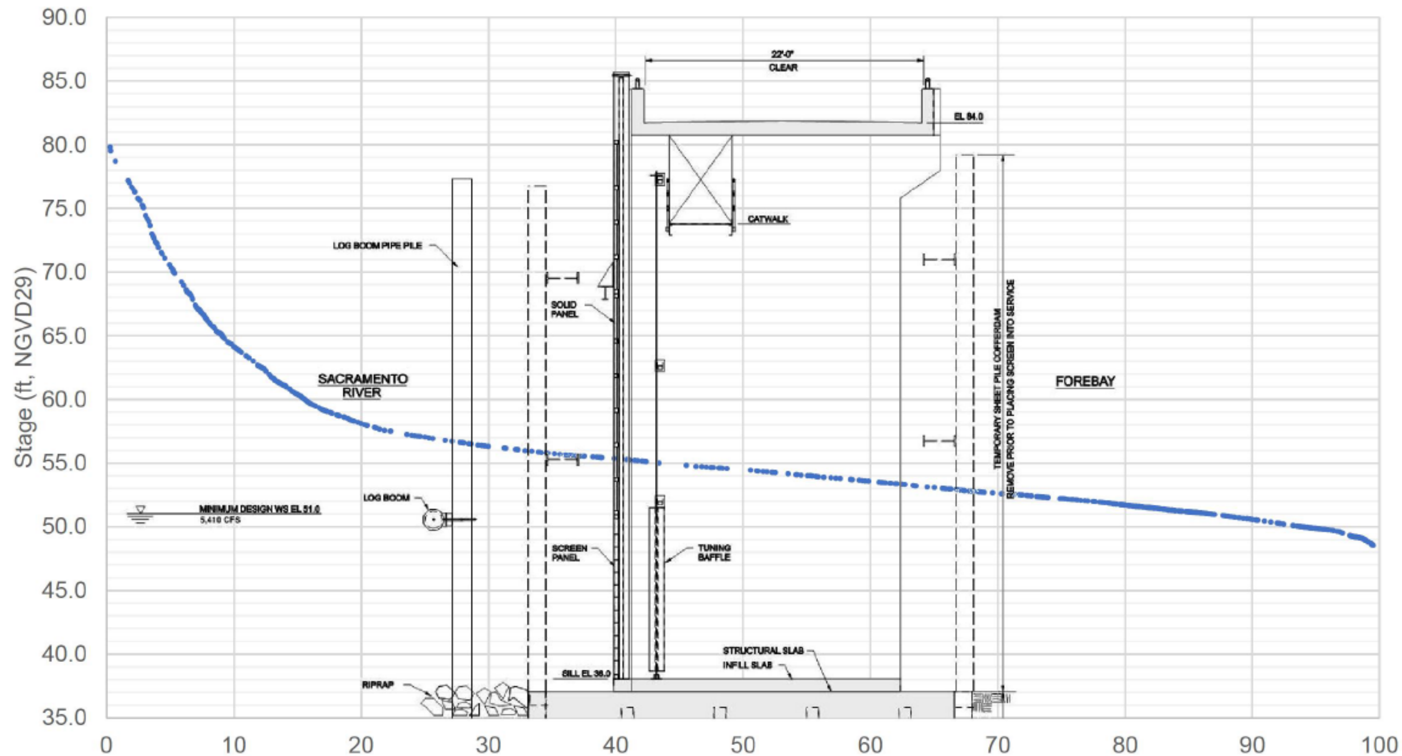
- Spatial distribution (screen exposure)
  - Consideration of % flow entering GCID oxbow



Near-field effects

- Spatial distribution (screen exposure)
  - Vertical distribution in relation to screens

Stage Frequency Curve - Annual
Sacramento River at Butte City, CA



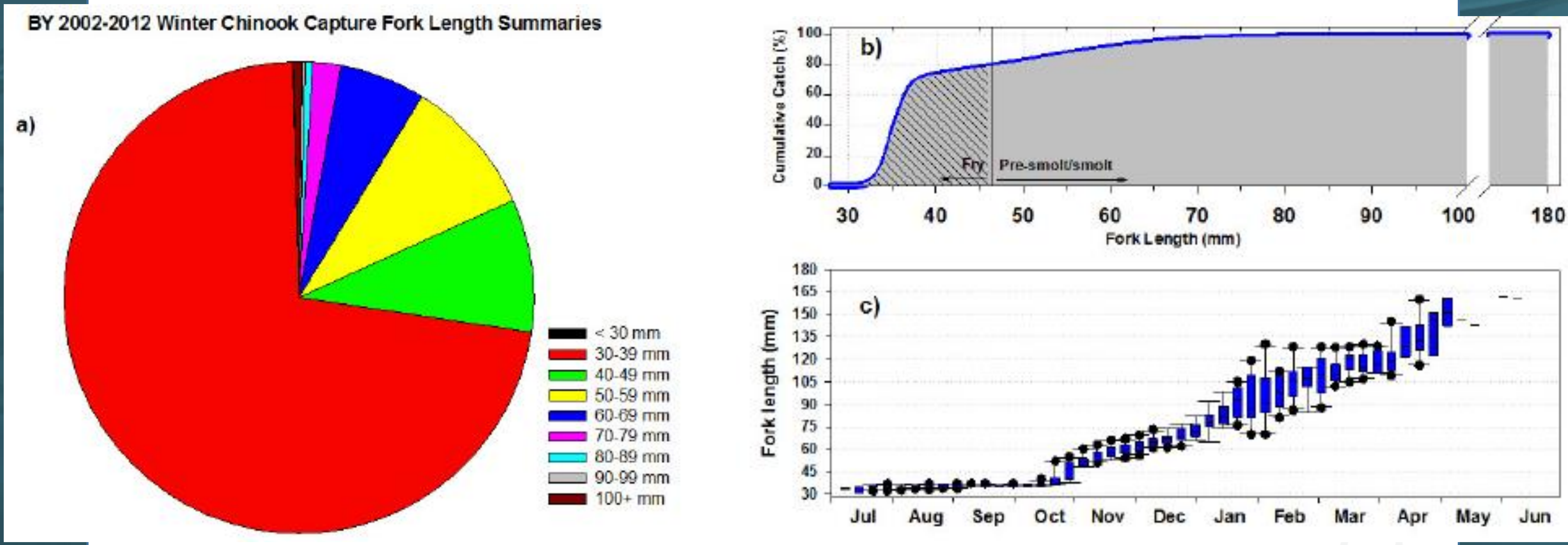
Percent Exceedance
(CA Dept of Water Resources Station ID BTC: SACRAMENTO RIVER AT BUTTE CITY;
Average Daily Data from January 1998 - April 2019)

Near-field effects

- Entrainment through screens
  - 1.75-mm screen opening
  - Theoretical ≥25-mm fork length (FL) exclusion (salmonids)
  - Freeport observations: one fish ~ 30-mm FL (may have been entrained at smaller size and reared within forebay)
  - Considered size distribution of fish from RBDD

Near-field effects

- Entrainment through screens
  - Very small % susceptible to entrainment based on size (e.g., Winter-Run Chinook Salmon)

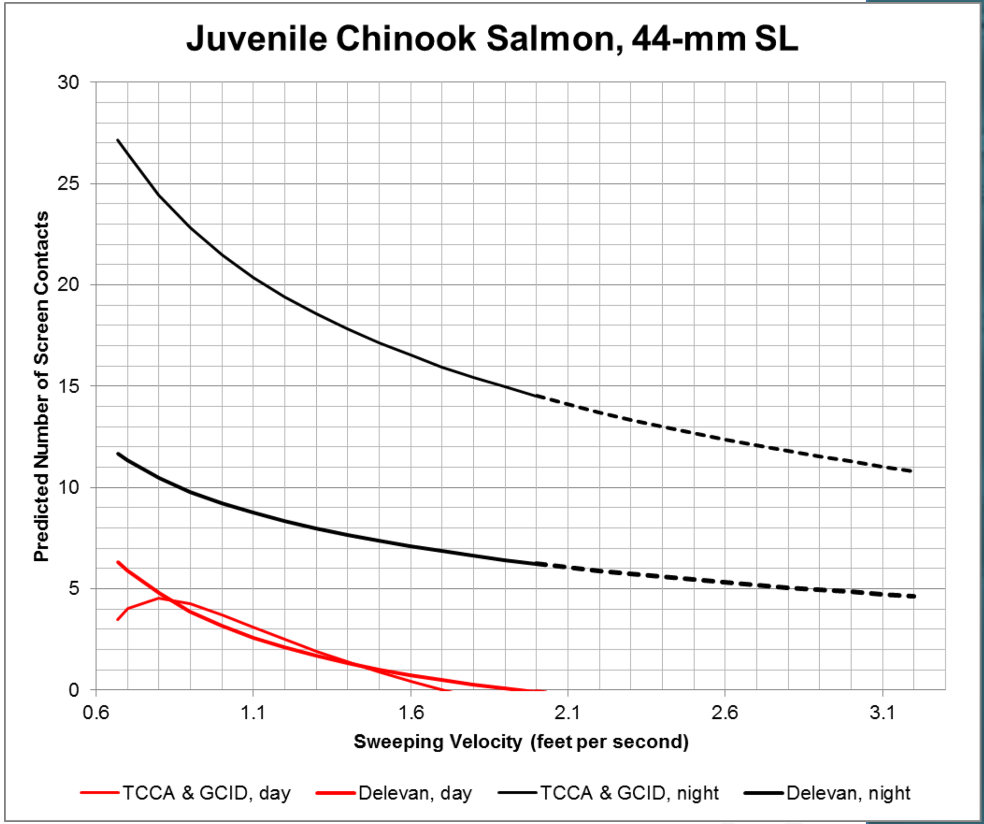


Near-field effects

- Impingement
  - Qualitative discussion based on UCD fish treadmill studies of juvenile Chinook Salmon (Swanson et al. 2004)
  - Impingement and injury rates were not related to any velocity variables; injury rate was not different between test fish and control fish

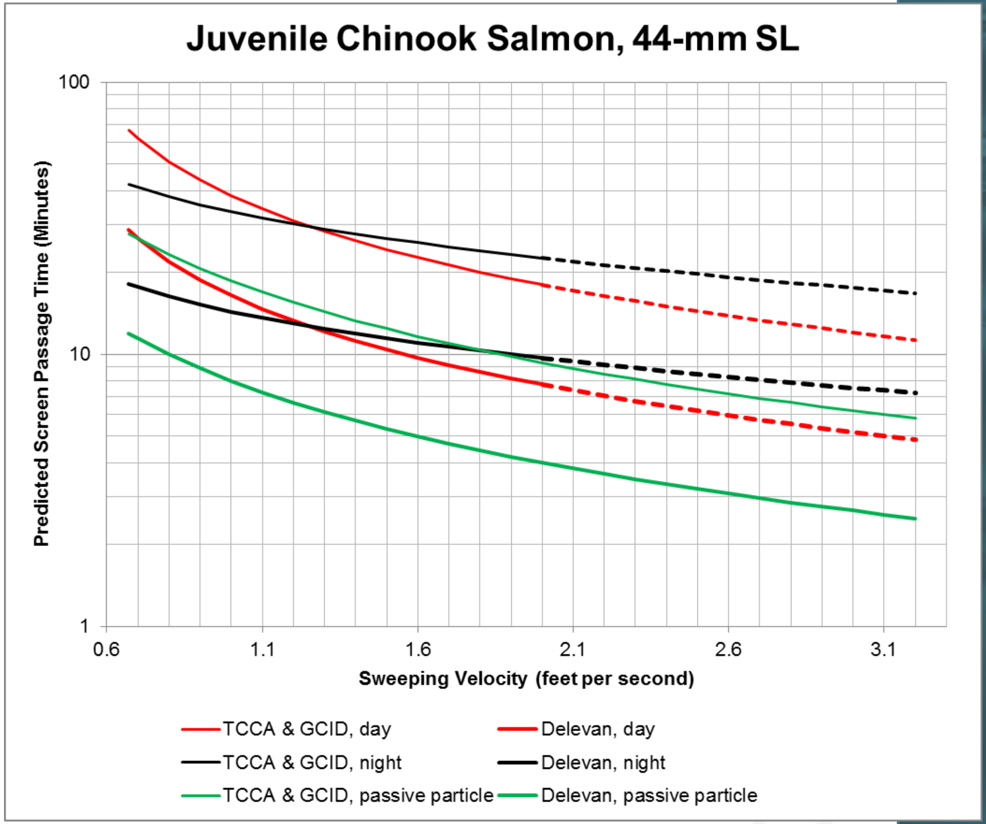
Near-field effects

- Screen contact rate
  - Estimates based on UCD fish treadmill studies (Swanson et al. 2004)
  - Approach velocity = 0.33 ft/s
  - TCCA & GCID screens ~1,100 feet long; Delevan ~480 feet long
  - Relevant only to fish passing close to the screen (test flume was 4 feet wide)



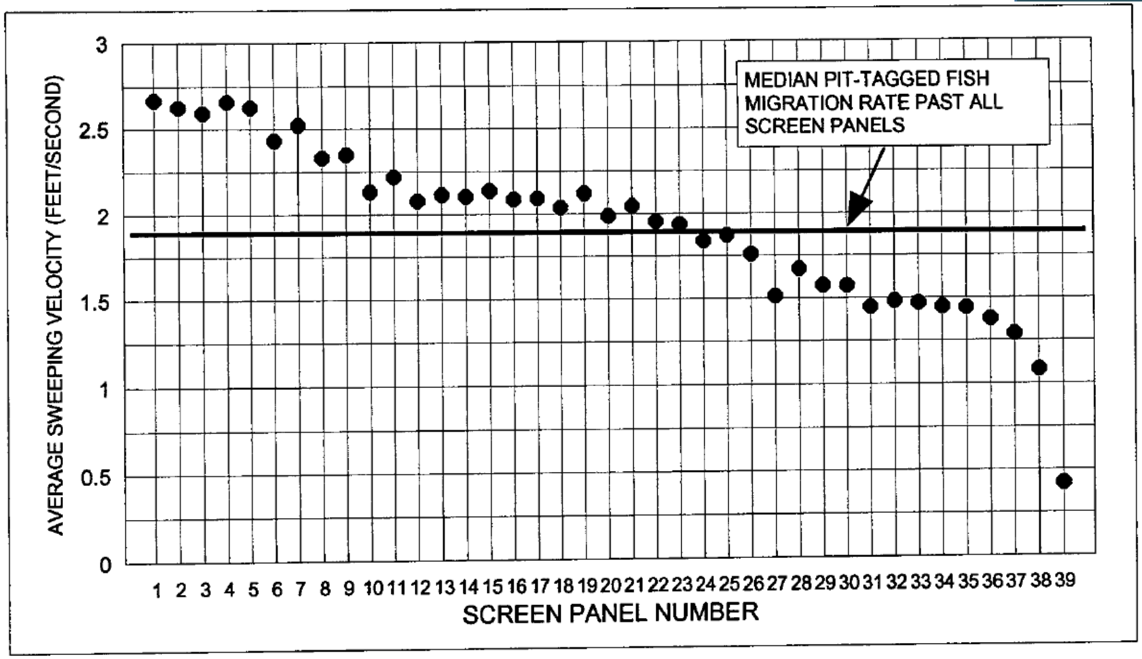
Near-field effects

- Screen passage time
  - Estimates based on UCD fish treadmill studies (Swanson et al. 2004)
  - Approach velocity = 0.33 ft/s
  - Note: estimates longer than passive particle theoretical passage time (swimming against current)



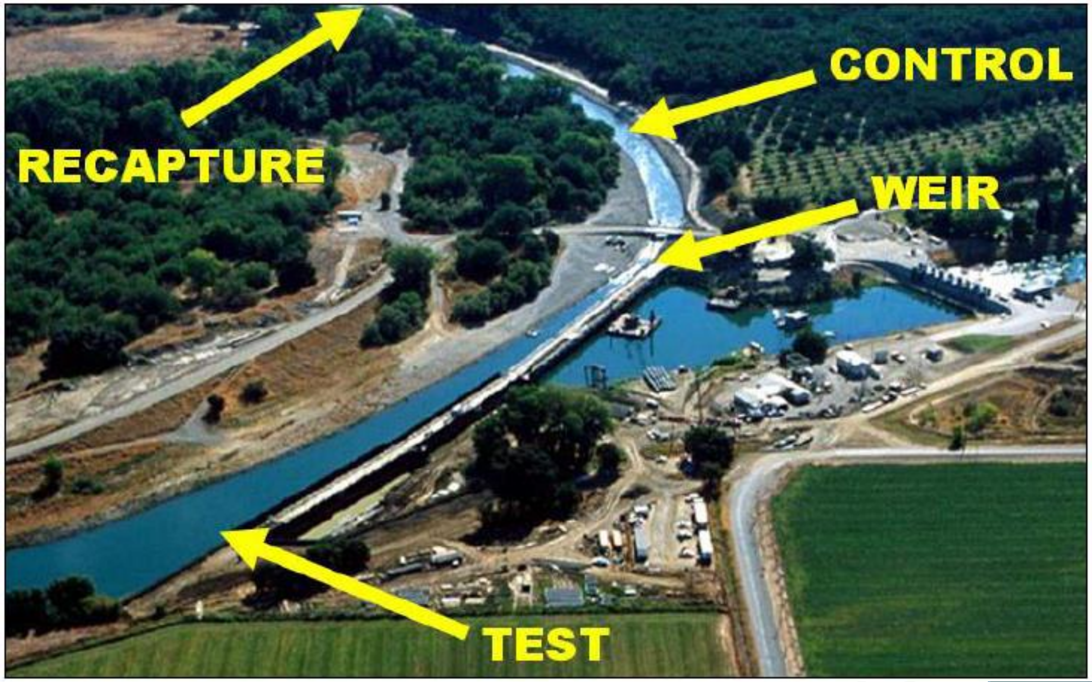
Near-field effects

- Screen passage time
  - GCID observations (Vogel & Marine 1995)
  - PIT-tagged juvenile Chinook Salmon
  - Screen passage time similar to sweeping velocity



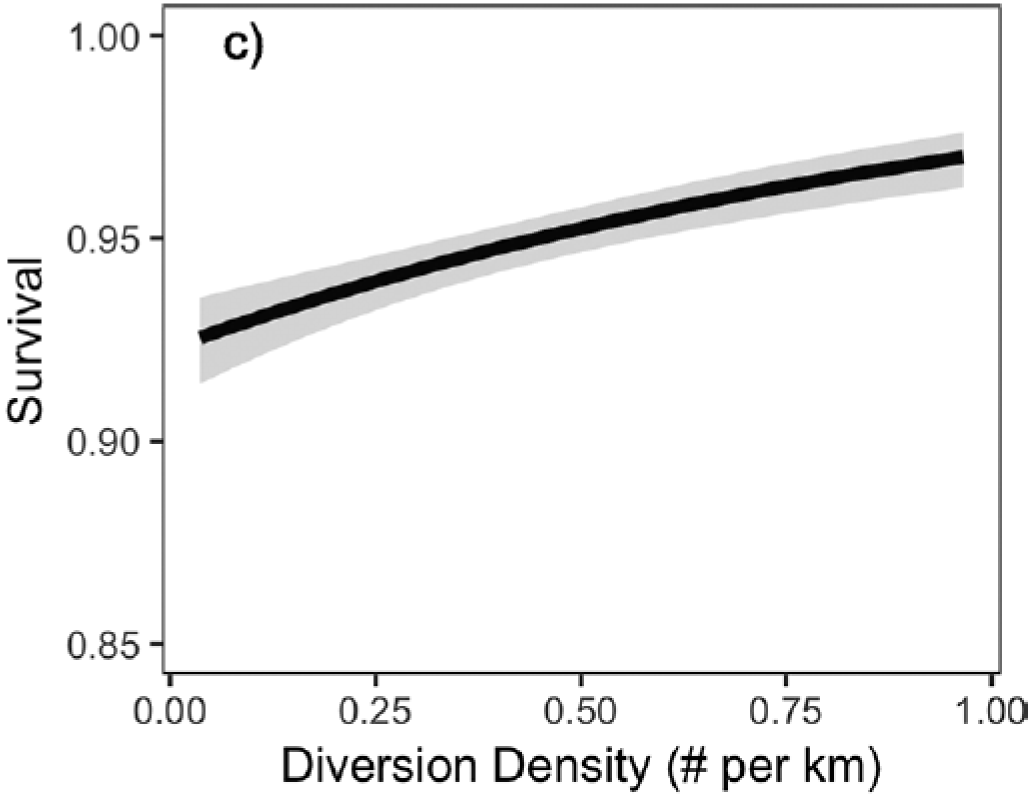
Near-field effects

- Predation
  - GCID observations (Vogel 2008)
  - Juvenile Chinook Salmon
  - Survival past screens: mean = 95%
  - However, recapture rates similar: ‘test’ to ‘recapture’ = 98% per 100 m); ‘weir’ to ‘recapture’ = 96%
  - Uncertainty because of batch release and sequential release (downstream to upstream)



Near-field effects

- Predation
  - Henderson et al. (2018) – juvenile Chinook Salmon
  - Examined significance of diversion density (number per km)
  - Found *positive* relationship with survival
  - Cautioned that this may reflect habitat conditions (e.g., riprapped banks) in diversion reaches



Near-field effects

- Stranding behind screens
  - Overtopping of screens
  - Very rare events (100-year flood at TCCA; >100,000 cfs at GCID)

Near-field effects

- Attraction to screens during reservoir discharge
  - Lift 1.75-mm screens during Delevan releases
  - Lower 19-mm picket panel (adult salmonid & Pacific Lamprey size criterion)
  - Discharge velocity ≤ 1 ft/s (salmonid criterion)
  - Initial calculations ~0.25 ft/s
  - Uncertainty in juvenile salmonids entering structure during releases

Near-field effects

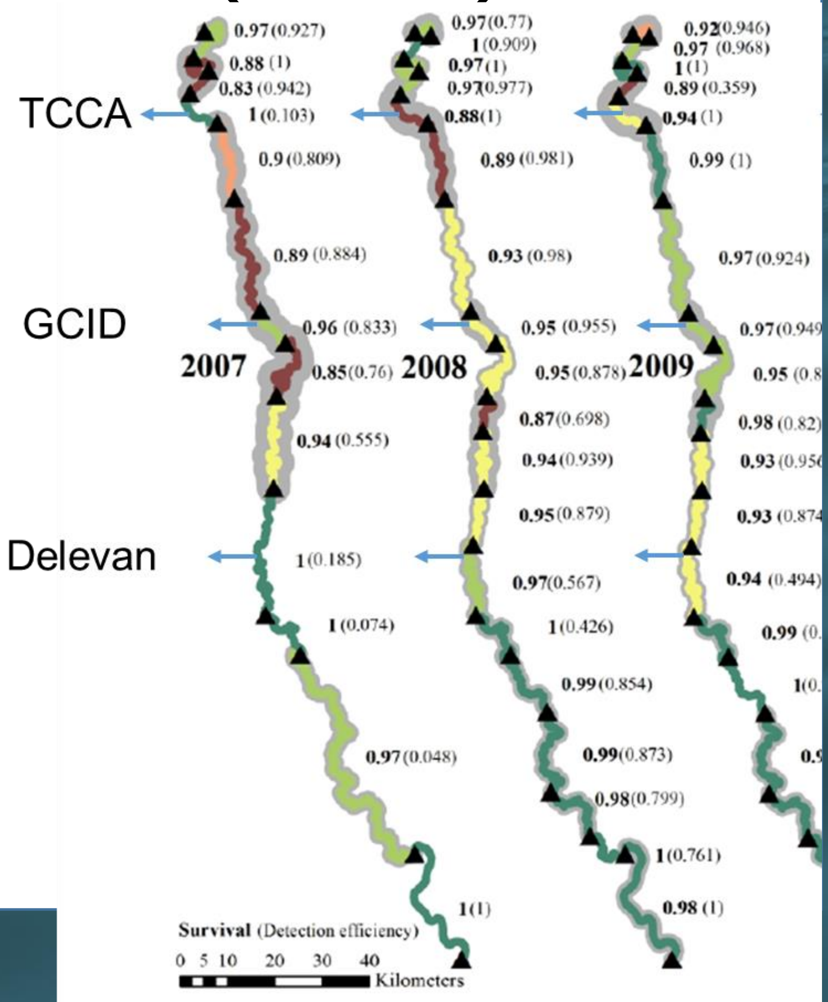
- Technical Studies and Monitoring
  - Baseline and post-construction technical studies: fish distribution (e.g., spatial); juvenile salmonid survival; predator habitat, density, and distribution; refugia field and lab studies; hydraulic screen evaluations
  - Monitoring: entrainment; impingement; stranding behind screens; attraction to screens during reservoir discharge
  - Inform assessment of biological objectives and adaptive management

Far-field effects

- Henderson et al. (2018) migration flow-survival
- OBAN model incorporating Henderson et al. adjustment

Far-field effects

- Henderson et al. (2018)
  - Peer-reviewed (CJFAS)
  - 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



Far-field effects: Henderson et al.

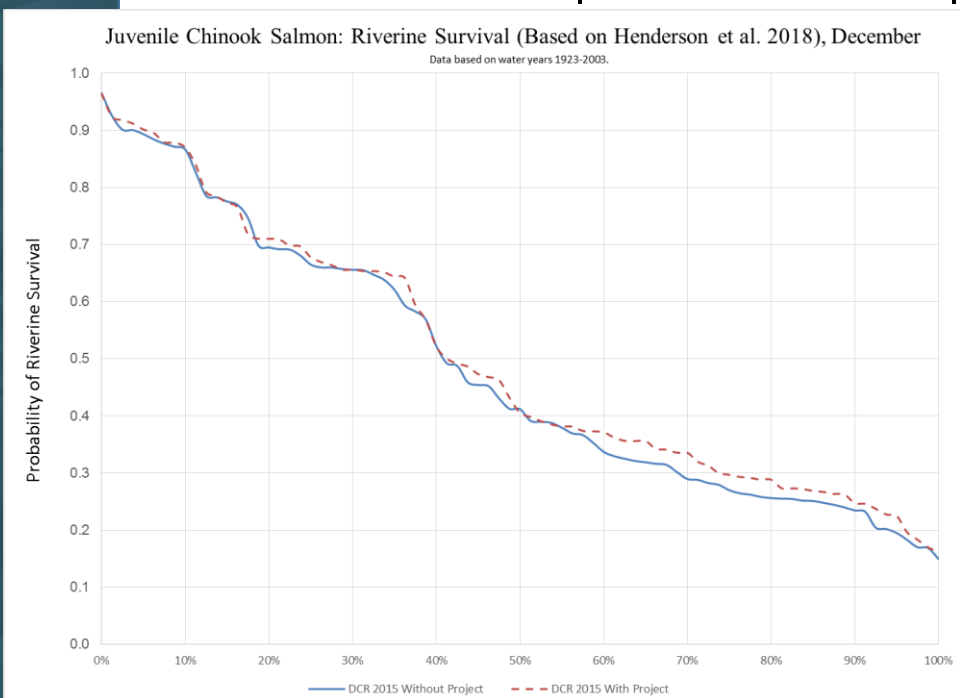
Category	Covariate	Range	Definition	Hypothesized relationship with survival	Notes/source	Source/assumption for analysis of proposed action
Individual	Transit speed	0.02–8.25 km/h	Reach-specific transit speed	Faster fish have less exposure to predators	Observed travel times and mixed effects model estimates	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

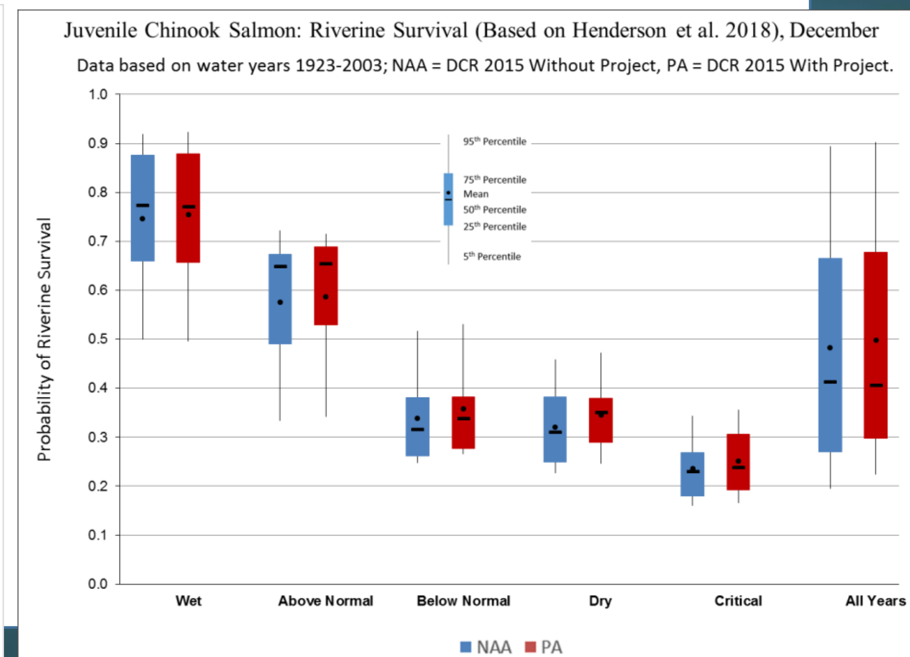
Far-field effects: Henderson et al.

- Focused on Dec-Mar
  - Limited by Bend Bridge mean flow
  - DCR 2015 With and Without Project operations
- 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 1 results
  - Generally similar or greater survival With Project
  - Influence of Bend Bridge flows (flow stabilization)
  - Reach-specific flows less important





Far-field effects: Henderson et al.

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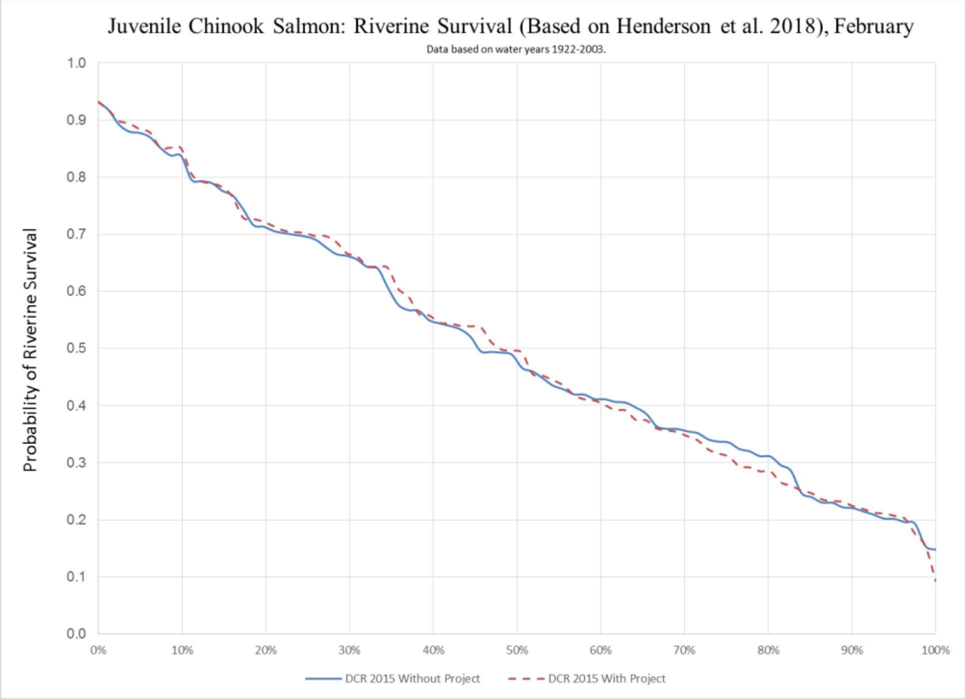
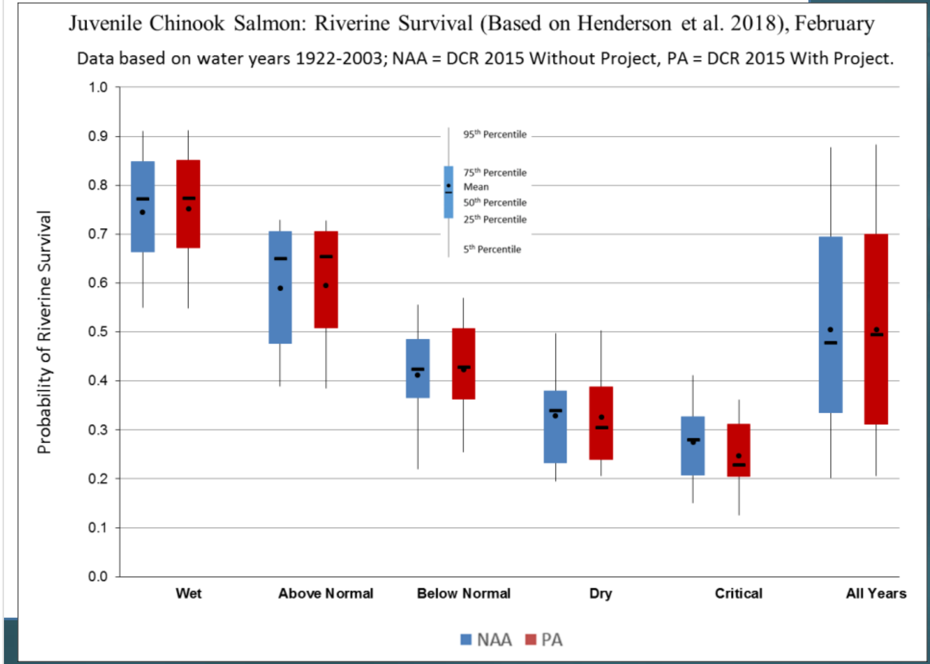
  - Reach-specific flows less important





Far-field effects: Henderson et al.

- Scenario 1 results
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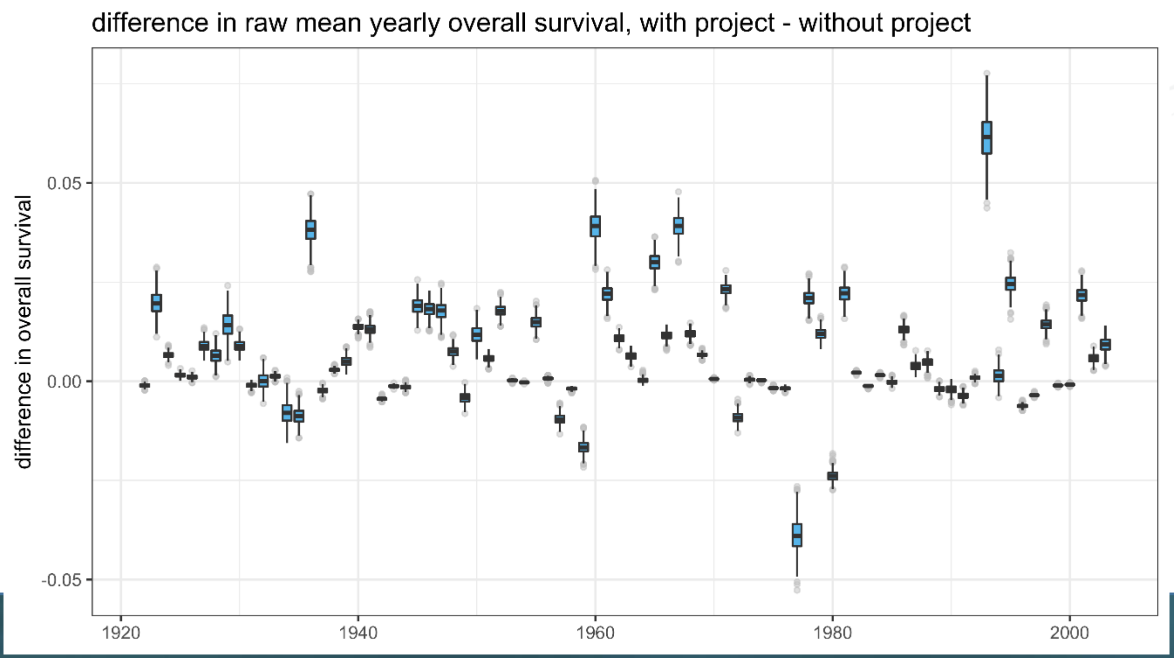
  - Reach-specific flows less important



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: Henderson et al.

Scenario 1: Lowest absolute survival (longest migration); largest differences (Bend Bridge flows act for longer)

	December			January			February			March		
	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without
Wet	0.75	0.75	0.01 (1%)	0.75	0.76	0.01 (1%)	0.74	0.75	0.01 (1%)	0.72	0.73	0.01 (1%)
Above Normal	0.58	0.59	0.01 (2%)	0.58	0.59	0.01 (1%)	0.59	0.60	0.01 (1%)	0.54	0.55	0.00 (1%)
Below Normal	0.34	0.36	0.02 (6%)	0.40	0.41	0.01 (2%)	0.41	0.42	0.01 (3%)	0.34	0.33	0.00 (-1%)
Dry	0.32	0.35	0.02 (8%)	0.33	0.34	0.01 (4%)	0.33	0.33	0.00 (-1%)	0.28	0.28	0.00 (0%)
Critical	0.24	0.25	0.02 (7%)	0.31	0.30	-0.01 (-4%)	0.28	0.25	-0.03 (-10%)	0.21	0.23	0.01 (6%)

Note: Results are based on all fish starting migration upstream of Red Bluff at Jellys Ferry, with equal numbers of fish starting migration each day in December–March. This scenario is referred to Scenario 1 in the text.

Scenario 2: Similar relative differences to scenario 3 in wetter years (leveling off of flow-survival relationship)

	December			January			February			March		
	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without
Wet	0.87	0.87	0.00 (1%)	0.87	0.87	0.00 (0%)	0.87	0.87	0.00 (0%)	0.85	0.86	0.00 (0%)
Above Normal	0.77	0.78	0.01 (1%)	0.77	0.78	0.01 (1%)	0.78	0.78	0.00 (0%)	0.75	0.75	0.00 (0%)
Below Normal	0.62	0.63	0.02 (3%)	0.66	0.67	0.01 (1%)	0.67	0.68	0.01 (1%)	0.61	0.60	0.00 (-1%)
Dry	0.60	0.62	0.02 (3%)	0.61	0.62	0.01 (2%)	0.61	0.61	0.00 (-1%)	0.56	0.56	0.00 (0%)
Critical	0.54	0.55	0.02 (3%)	0.60	0.59	-0.01 (-2%)	0.57	0.54	-0.03 (-5%)	0.51	0.53	0.02 (3%)

Note: Results are based on fish equal numbers of fish starting at the upstream end of each Henderson et al. (2018) reach with equal numbers of fish starting migration each day in December–March. This scenario is referred to Scenario 2 in the text.

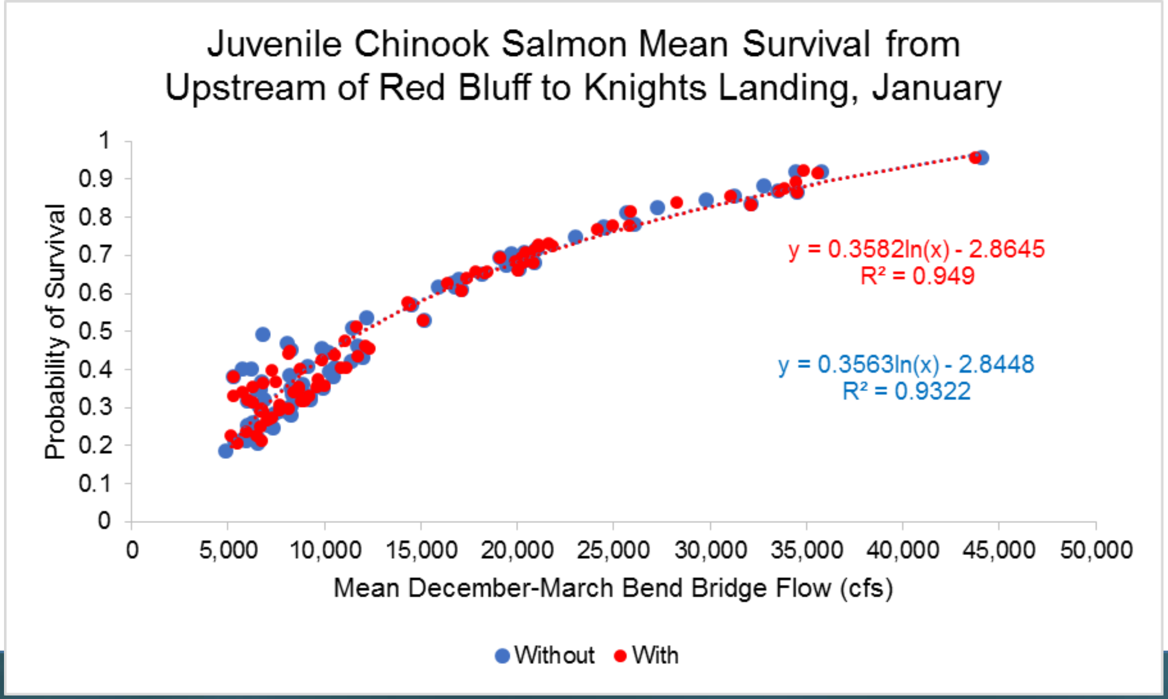
Scenario 3: Flow-weighted migration generally increases survival With Project compared to Scenario 2

	December			January			February			March		
	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without
Wet	0.87	0.87	0.00 (0%)	0.87	0.87	0.00 (0%)	0.87	0.87	0.00 (0%)	0.86	0.86	0.00 (0%)
Above Normal	0.71	0.71	0.01 (1%)	0.78	0.79	0.01 (1%)	0.79	0.79	0.00 (0%)	0.76	0.76	0.00 (0%)
Below Normal	0.61	0.63	0.02 (4%)	0.69	0.69	0.01 (1%)	0.70	0.71	0.01 (2%)	0.63	0.63	0.00 (-1%)
Dry	0.61	0.64	0.03 (4%)	0.62	0.63	0.01 (2%)	0.63	0.63	0.00 (0%)	0.58	0.59	0.00 (0%)
Critical	0.53	0.55	0.02 (4%)	0.61	0.61	0.00 (-1%)	0.59	0.56	-0.03 (-4%)	0.53	0.55	0.02 (5%)

Note: Results are based on fish equal numbers of fish starting at the upstream end of each Henderson et al. (2018) reach with fish starting migration each day in each month in proportion to flow occurring on each day. This scenario is referred to Scenario 3 in the text.

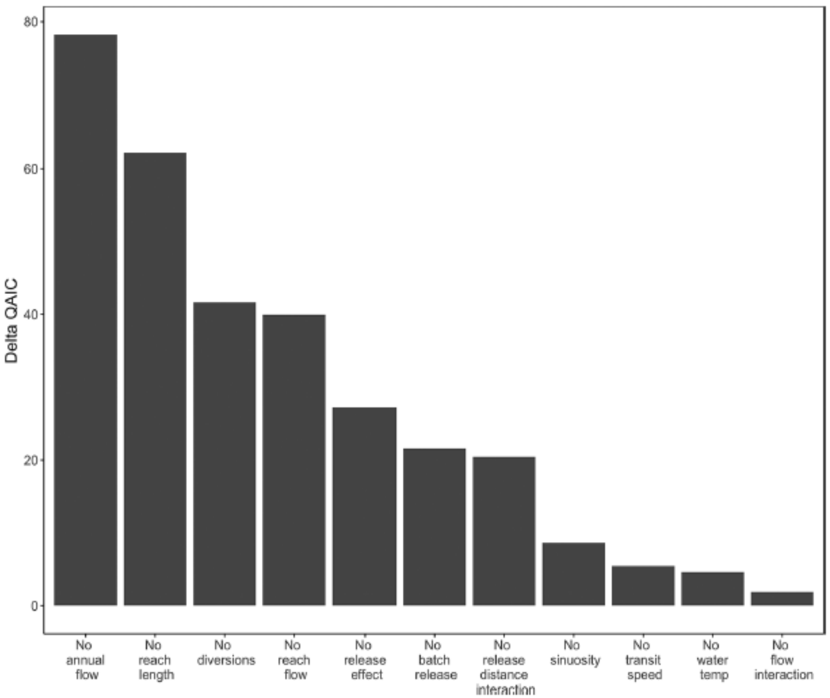
Far-field effects: Henderson et al.

- Dominance of Bend Bridge flow effect
  - Reflecting wetter vs. drier years
  - Consider exploration of same Bend Bridge flow With and Without Project

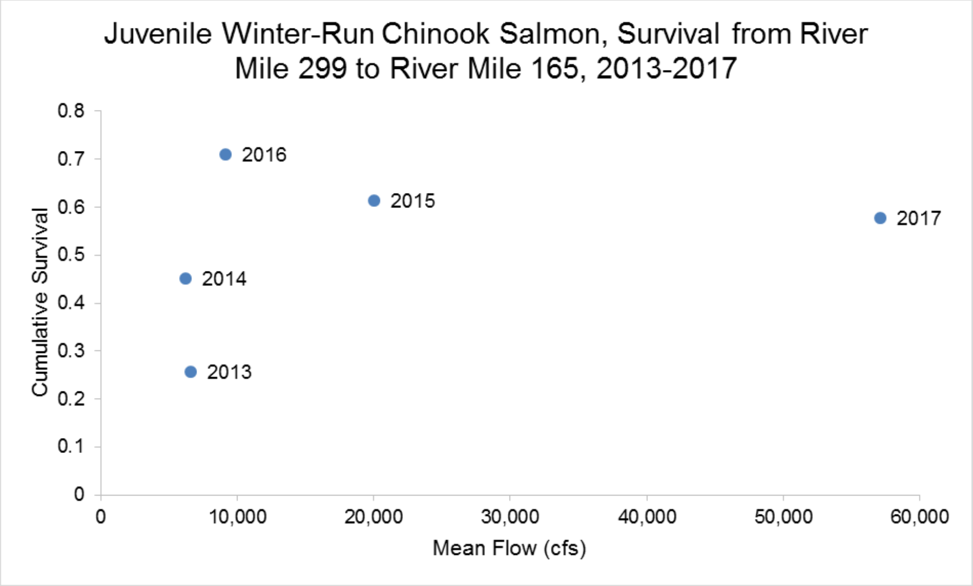


Far-field effects: Henderson et al.

- Dominance of Bend Bridge flow effect
  - Reflecting wetter vs. drier years
  - No clear flow-survival relationship for Winter-Run (Hassrick et al.)



Henderson et al. importance of covariates



Developed from data in Hassrick et al. (in prep.)

Far-field effects: OBAN

- Incorporated Scenario 1 Henderson et al. results
  - Monthly weighting (Dec = 0; Jan = 0.28; Feb = 0.36; Mar = 0.36)
  - Generally probability of greater escapement under With Project