Ecological Flows Tool

for the Sacramento River and Delta

EFT

Ecological Flows Tool

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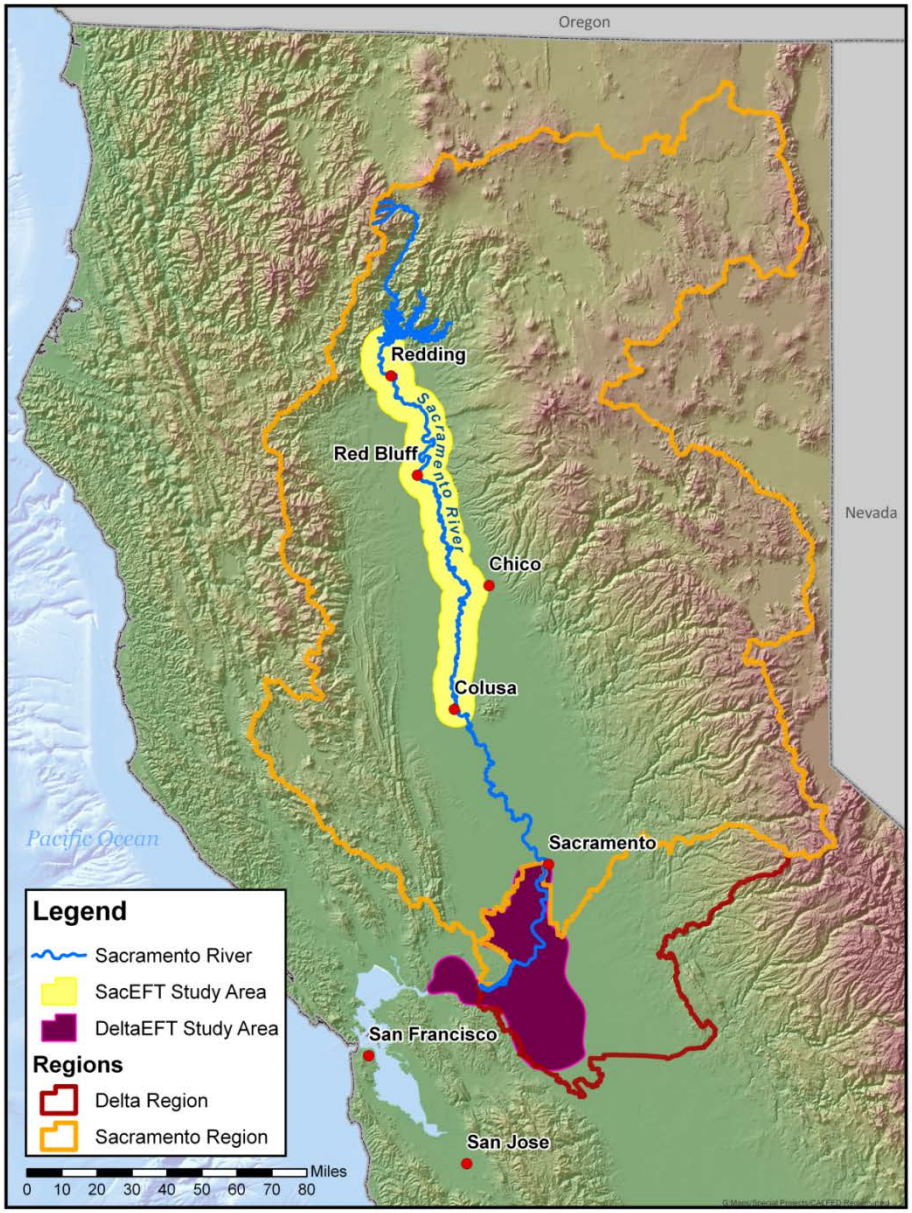
What *is* the EFT?

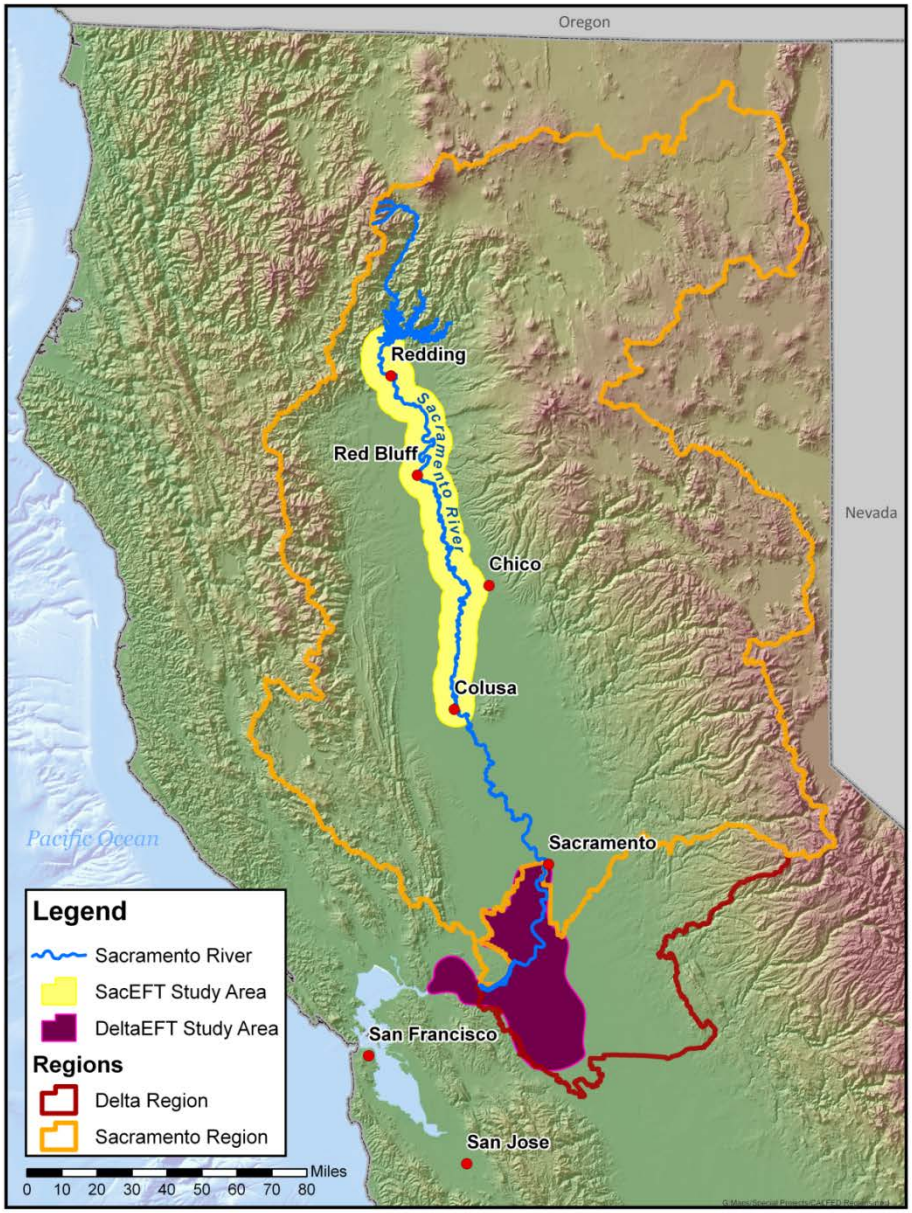
A decision support system that demonstrates how changes in flow management (and other actions) results in changes to the *physical habitats* for species within the Sacramento River and the Delta.



Why develop the EFT?

- Evaluate ecological trade-offs of water projects and their operations.

- Develop a broad set of functional ecological flow guidelines.



Links the Sacramento River and Delta

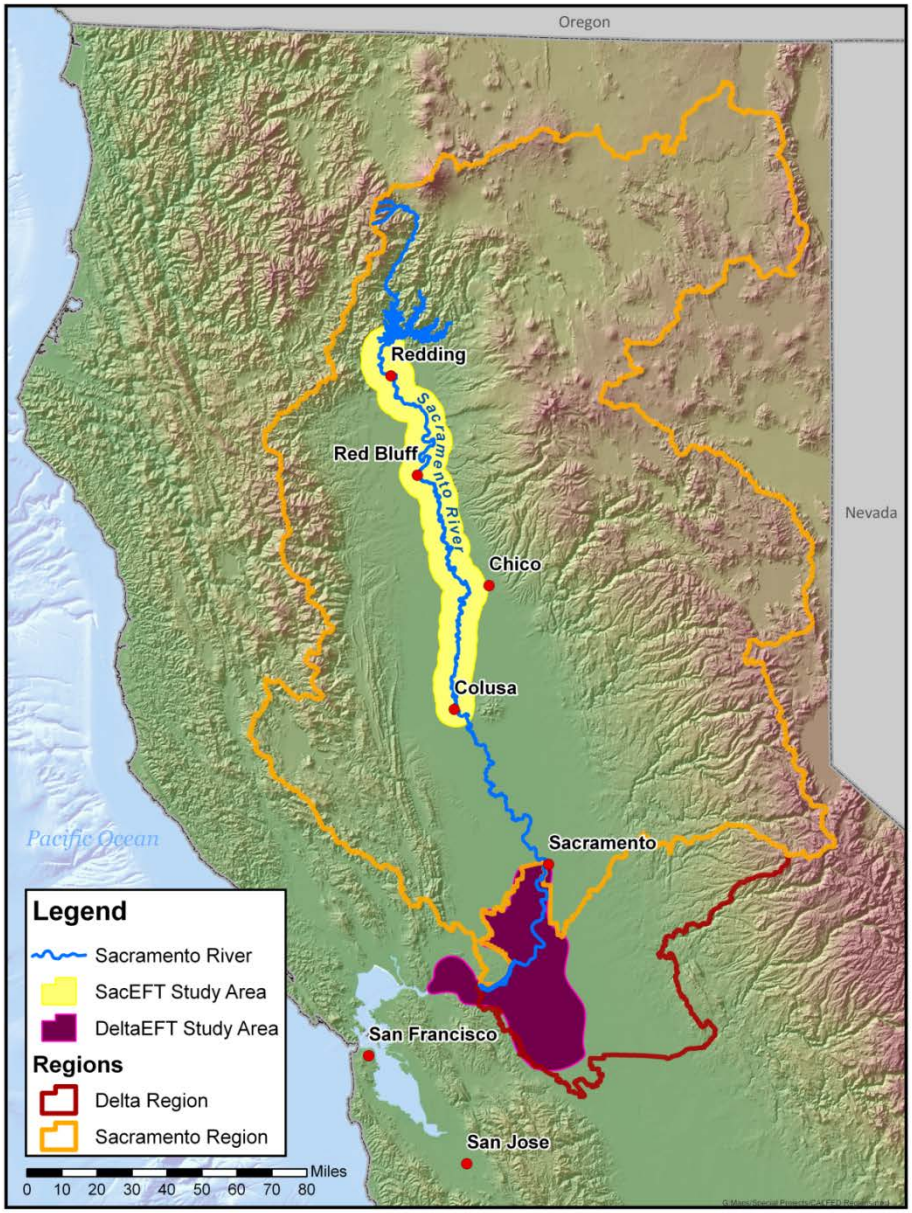
SacEFT
Sacramento River Ecological Flows Tool

+

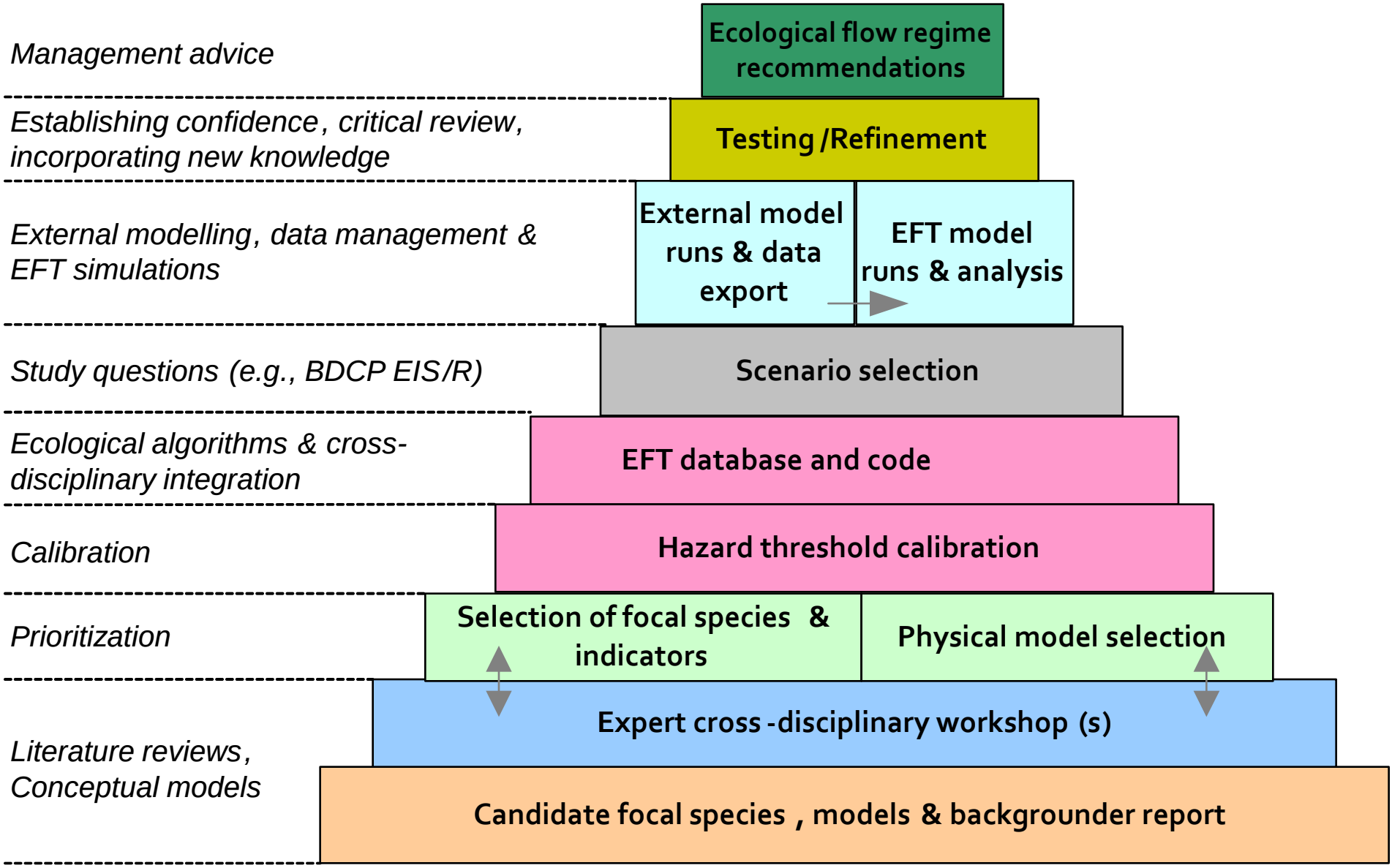
DeltaEFT
Delta Ecological Flows Tool

=

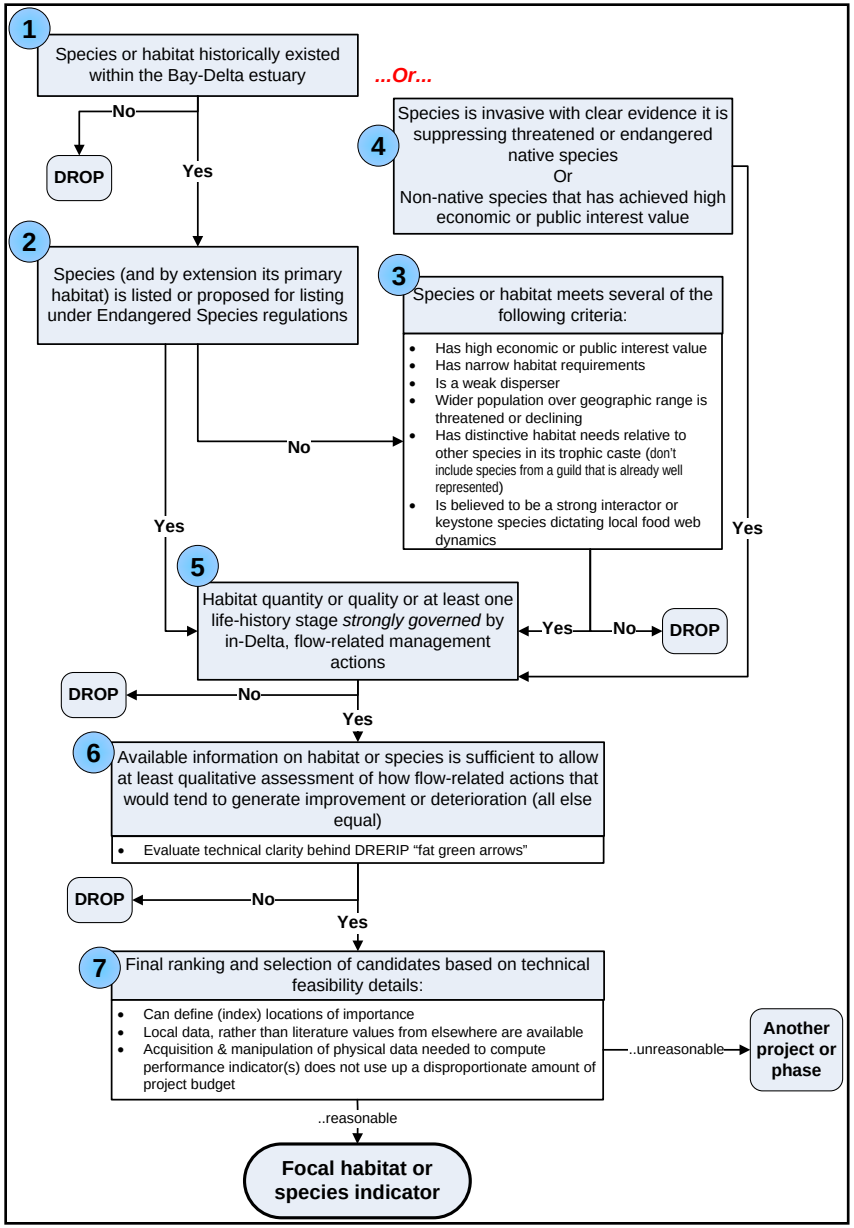
EFT
Ecological Flows Tool



Development process



EFT focal species selection



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SacEFT focal species

Steelhead trout

Chinook salmon

Green sturgeon

Bank swallow

Western pond turtle

Fremont cottonwood

SacEFT performance measures

Sacramento River		
Focal Species & Habitats	**Performance Measures**	
Fremont cottonwood	FC1	Successful cottonwood initiation
	FC2	Cottonwood seedling scour
Bank swallow (BASW)	BASW1	Habitat potential/suitability
	BASW2	Risk of nest inundation and bank sloughing during nesting
Western pond turtle	LWD1	Index of old vegetation recruited to the Sacramento River mainstem
Green sturgeon (GS)	GS1	Egg-to-larvae survival
Chinook salmon, Steelhead trout (CS)	CS1	Area of suitable spawning habitat (ft2)
	CS3	Egg-to-fry survival (proportion)
	CS5	Redd scour
	CS6	Redd dewatering (proportion)
	CS2	Area of suitable rearing habitat (ft2)
	CS4	Juvenile stranding (index)

SacEFT physical inputs

Focal Species Performance Measures	Physical datasets and submodels				
	Flow	Stage - Discharge	Temperature	Sediment Transport	Meander Migration
Fremont cottonwood (FC)	●	●			
Bank swallow (BASW)	●				●
Green sturgeon (GS)			●		
Chinook, steelhead (CS)	●		●	●[1]	
Large Woody Debris (LWD) recruitment	●				●

[1] Certain indicators only. The linkage between channel bed conditions and Chinook and steelhead is restricted to weighted useable area for spawning. According to source data from Mark Gard (USFWS), rearing habitat is unaffected by substrate conditions. We relate substrate suitability curves taken from *River-2D* with substrate conditions predicted by the TUGS sediment transport model.

DeltaEFT

Delta Ecological Flows Tool

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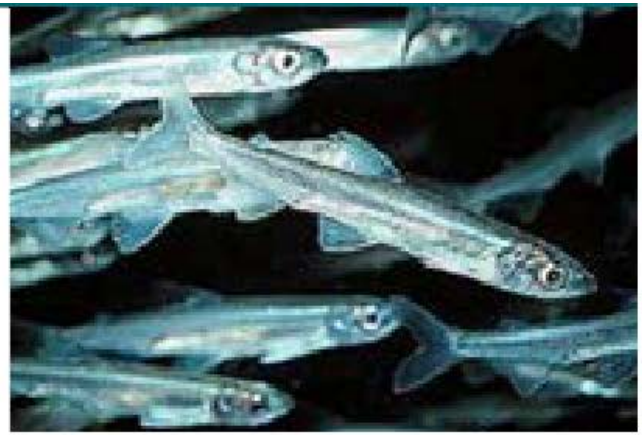
DeltaEFT focal species and habitats

Steelhead trout

Chinook salmon



Delta smelt

Splittail

Tidal wetlands

Invasive species deterrence

DeltaEFT performance measures

Delta Ecoregion		
Focal Species & Habitats	**Performance Measures**	
Chinook & Steelhead (CS)	CS7	Smolt weight gain in alt. migration corridors
	CS9	Smolt mortality index as a funtion of passage time (negatively correlated with CS7)
	CS10	Smolt temperature preference index (departures from optimum v. weight gain)
Delta smelt (DS)	DS1	Spawning success index
	DS2	Index of habitat suitability
	DS4	Entrainment risk (index)
Splittail (SS)	SS1	Proportion of maximum potential spawning habitat (index)
Fresh/brackish tidal wetlands (TW)	TW1	Brackish wetland area
	TW2	Freshwater wetland area
Invasive species deterrence (ID)	ID1	Brazilian waterweed suppression
	ID2	(Corbula) Invasive clam larvae and recruit suppression
	ID3	(Corbicula) Invasive clam larvae and recruit suppression

DeltaEFT physical inputs

Focal Species and Performance Measures		Physical Datasets											
		Flow			Stage			Temperature			Salinity		
		T	D	H	T	D	H	T	D	H	T	D	H
Invasive species deterrence													
ID1	Brazilian waterweed suppression											●	
ID2	Overbite clam suppression											●	
ID3	Asiatic clam suppression											●	
Chinook & Steelhead													
CS7	Smolt Development & Growth		●						●				
CS9	Smolt predation risk	●[1]	●[1]										
CS10	Smolt Thermal Stress	●[1]	●[1]						●				
Delta smelt													
DS1	Index of spawning success								●			●	
DS2	Index of habitat suitability											●	
DS4	Index of risk of entrainment		●										
Splittail													
SS1	Spawning habitat extent		●										
Tidal wetlands													
TW1	Tidal wetland area brackish						●[2]						
TW2	Tidal Wetland Area Freshwater						●[2]						

[1] Hourly data (instantaneous top of hour values) are tidally filtered at stations where tidal effects exist (< ~3m elevation of mean sea level); otherwise non-filtered.

[2] Top of hour values are used.

T = Tidally Filtered Daily Average **D = Daily Average** **H = Hourly**

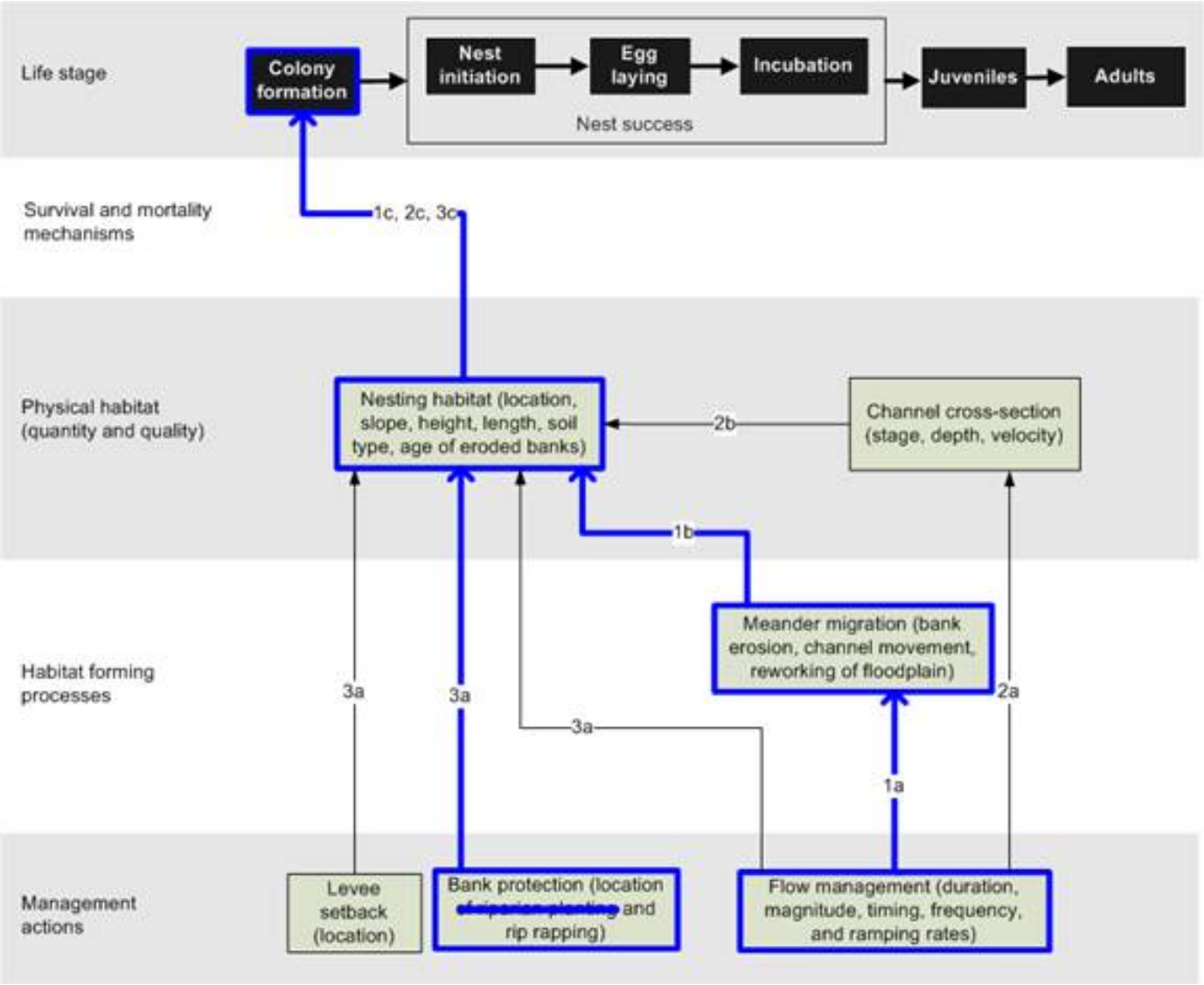
DeltaEFT physical inputs by location

DeltaEFT
Delta Ecological Flows Tool

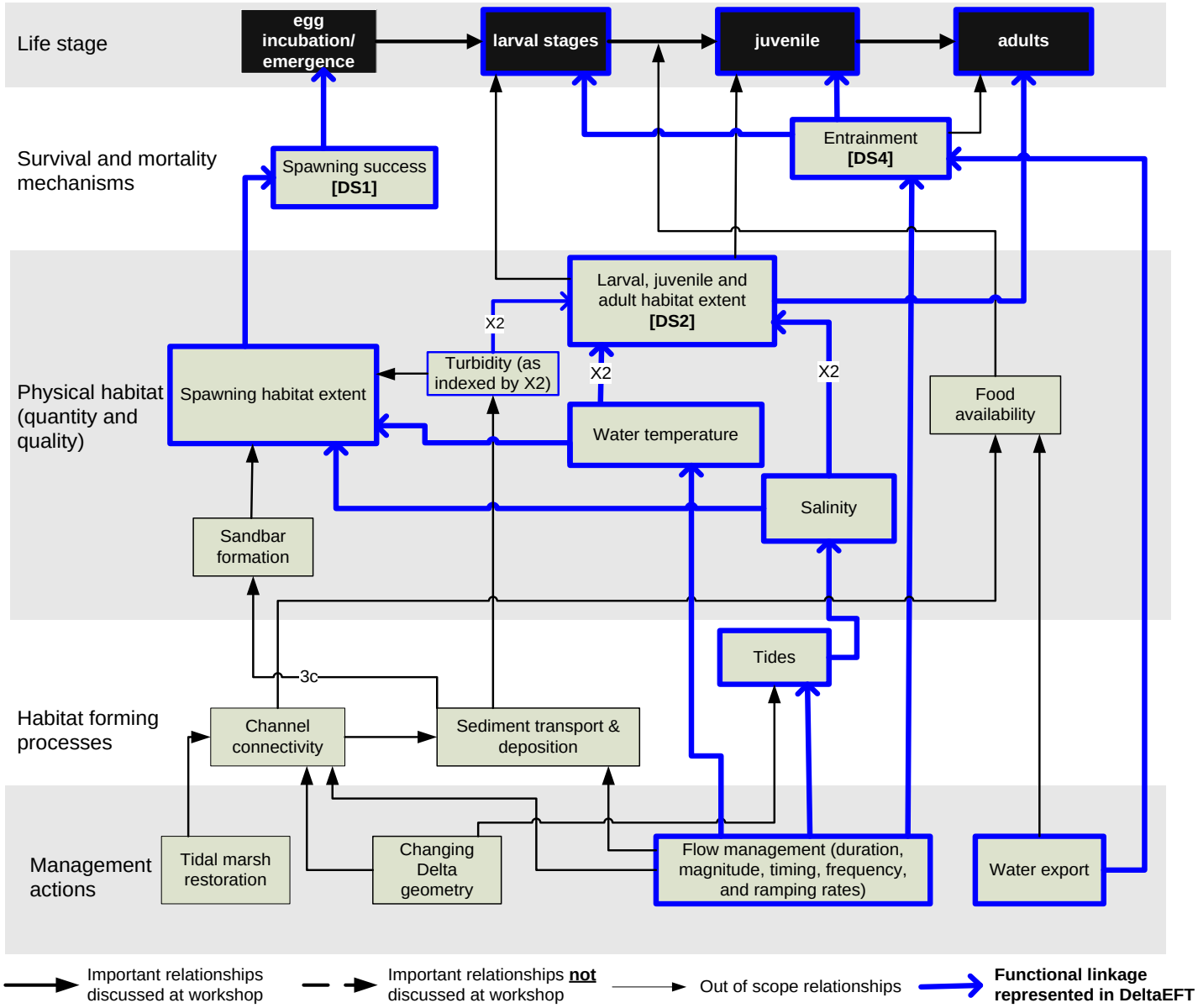
LocationID	Name	RM	RKI	DSM2	CDEC	CS7		CS9	CS10		DS1		DS2	DS4	SS1	TW1	TW2		TW3	ID1	ID2	ID3
				SCENARIO:		HISTORICAL																
						F	T	F	F	T	T	E	E	F	F	S	E	S	S	E	E	E
39	KNIGHTS LANDING (using SACRAMENTO R A BUTTE CITY CA)	168			KNL	•	•															
414	SACRAMENTO R A VERONA CA				VON	•																
84	SACRAMENTO R A SACRAMENTO CA	59.5	178	RSAC178	IST	•																
86	SACRAMENTO R A FREEPORT CA		155	RSAC155	FPT	•																
389	SACRAMENTO RIVER AT HOOD		142	RSAC142	SRH					•												
308	SACRAMENTO R AB DELTA CROSS CHANNEL CA		128	RSAC128	SDC	•		•	•													
307	SACRAMENTO R BL GEORGIANA SLOUGH CA		123	RSAC123	GSS	•		•	•													
300	SACRAMENTO R A RIO VISTA CA		101	RSAC101	RVB,RIV	•	•	•	•	•	•	•								•	•	•
461	CACHE SLOUGH A RYER ISLAND			CACHE_RYE																		
357	EMMATON (USBR)		92	RSAC092	EMM							•	•							•	•	•
325	COLLINSVILLE ON SACRAMENTO RIVER		81	RSAC081	CSE		•													•	•	•
335	SUTTER BYPASS AT RD 1500 PUMP			SUT_US_MI	SBP																	
473	Steamboat Slough			STMBT_S																		
426	SAN FRANCISCO BAY A PITTSBURG CA		77	RSAC077	PTS						•	•	•							•	•	•
324	SUISUN BAY A MALLARD IS CA		75	RSAC075	MAL		•			•	•	•	•								•	
463	Delta Cross Channel			DCC																		
311	GEORGIANA SLOUGH NR SACRAMENTO R	50		GEORG_SL	GGS																	
85	FREMONT WEIR SPILL TO YOLO BYPASS NR VERONA CA		244	RSAC244	FRE	•									•							
316	SACRAMENTO WEIR SPILL TO YOLO		182	RSAC182		•									•							
424	N MOKELUMNE NR WALNUT GROVE CA		19	RMKL019																		
390	LITTLE POTATO SLOUGH NR TERMINOUS CA		8	RSMKL008	STI					•	•	•										
381	PORT CHICAGO		64	RSAC064	PCT						•	•	•								•	
302	SAN JOAQUIN R A JERSEY POINT CA		18	RSAN018	JER						•	•										
338	SAN JOAQUIN R A ANTIOCH CA		7	RSAN007	ANH						•	•								•	•	•
374	MIDDLE RIVER AT TRACY BLVD		63	RSAN063	MTB																	
385	ROUGH AND READY ISLAND		58	RSAN058	RRI																	
371	CARQUINEZ STRAIT A MARTINEZ CA		54	RSAC054	MRZ						•	•	•								•	
326	SAN JOAQUIN R A VENICE ISLAND - TIDE GAGE CA		43	RSAN043	VNI																	
386	SAN ANDREAS LANDING		32	RSAN032	SAL				•	•	•	•								•	•	•
305	OLD R A BACON ISLAND CA		24	ROLD024	OBI									•								
459	MIDDLE R AT BORDEN HWY NR TRACY CA		23	RMID023	VIC						•	•										
301	SAN JOAQUIN R BL GARWOOD BRIDGE A STOCKTON CA		27	RMID027	SJG																	
309	MIDDLE R AT MIDDLE RIVER CA		15	RMID015	MDM									•								
365	HOLLAND CUT NR BETHEL ISLAND CA		14	ROLD014	HLL						•	•										
330	BELDON LANDING		11	SLMZU011	BDL							•				•		•	•		•	
437	DWR-CD 1479, 11km up Steamboat Slough, below Sutter Slough		11	SLSBT011																		
358	FARRAR PARK		9	SLDUT009	FRP						•	•								•	•	•
345	BARKER SLOUGH PUMPING PLANT (KG000000)		2	SLBAR002	BKS												•					
344	BETHEL ISLAND		3	SLPPR003	BET															•	•	•
319	GOODYEAR SLOUGH		3	SLGYR003	GYS																•	
327	SUNRISE CLUB		2	SLCBN002	SNC																•	
331	NATIONAL STEEL		25	SLMZU025	NSL																•	
333	VOLANTI		12	SLSUS012	VOL																•	

Flow (F), Temperature (T), Electroconductivity (E), Stage (S)

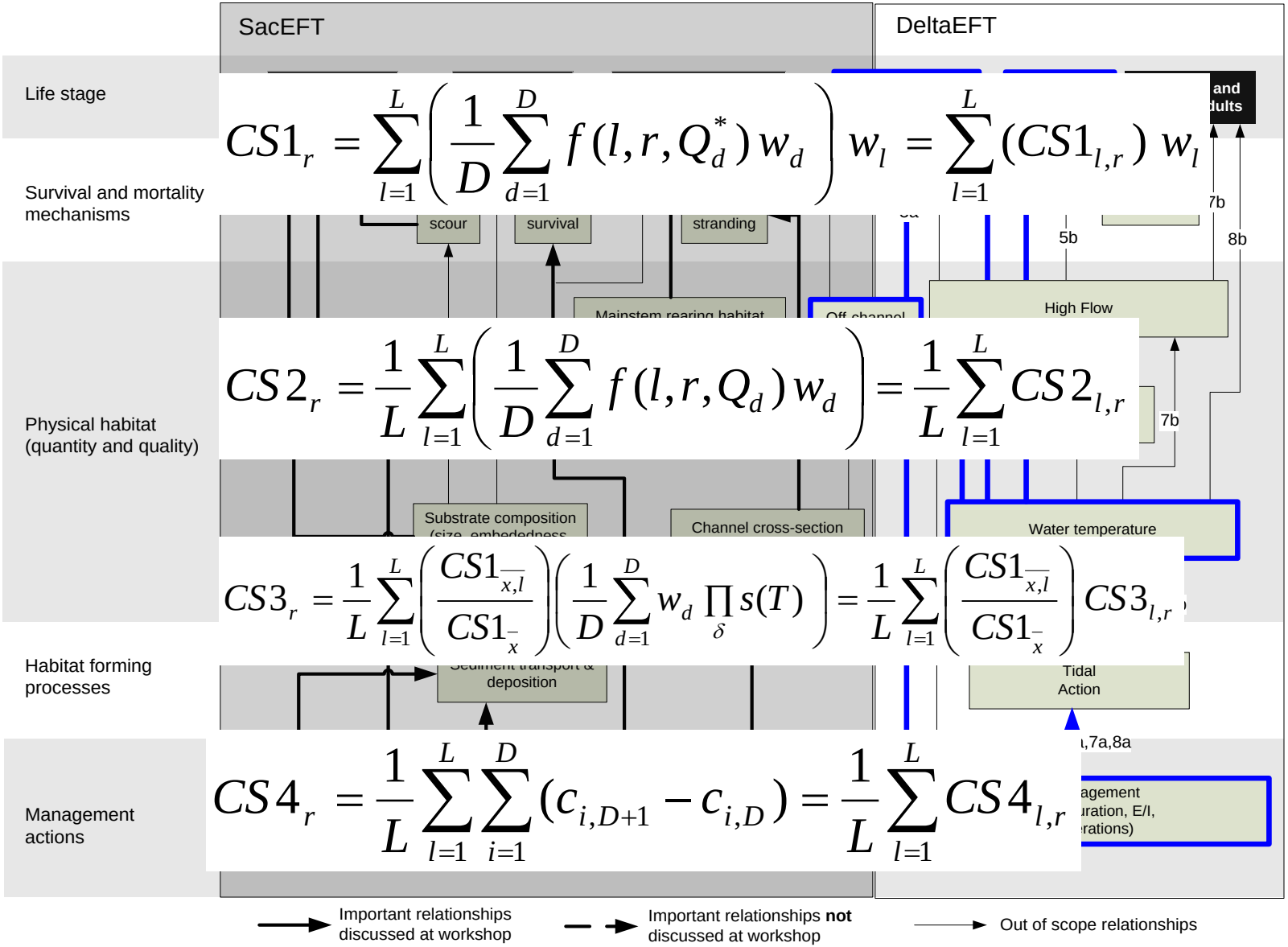
Modeling performance measures: *bank swallows*



Modeling performance measures: *Delta smelt*



Modeling performance measures: *Chinook salmon*



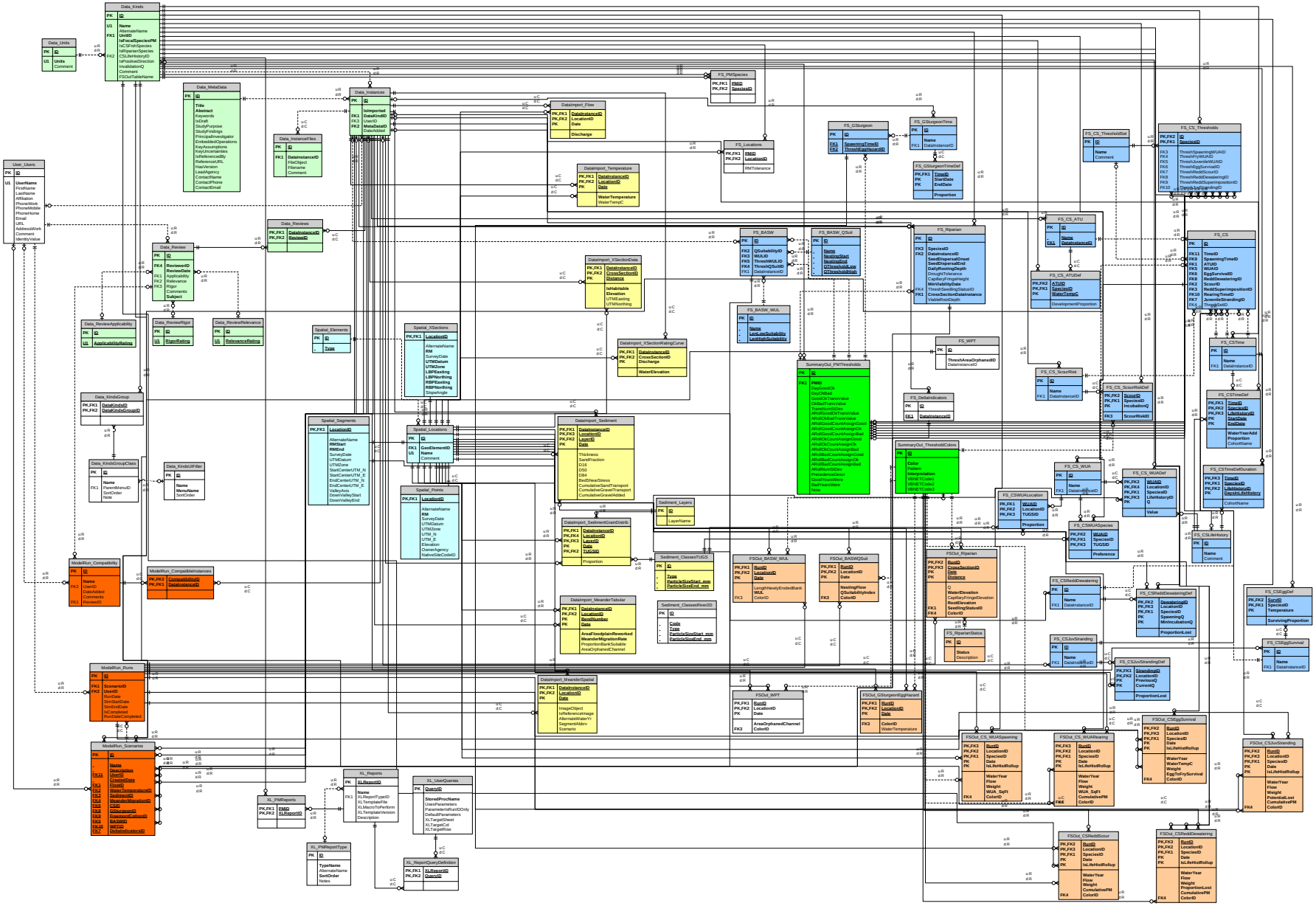
$$CS1_r = \sum_{l=1}^{L}\left(\frac{1}{D}\sum_{d=1}^{D} f(l,r,Q_d^*)\,w_d\right) w_l = \sum_{l=1}^{L}(CS1_{l,r})\,w_l$$

$$CS2_r = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{1}{D}\sum_{d=1}^{D} f(l,r,Q_d)\,w_d\right) = \frac{1}{L}\sum_{l=1}^{L} CS2_{l,r}$$

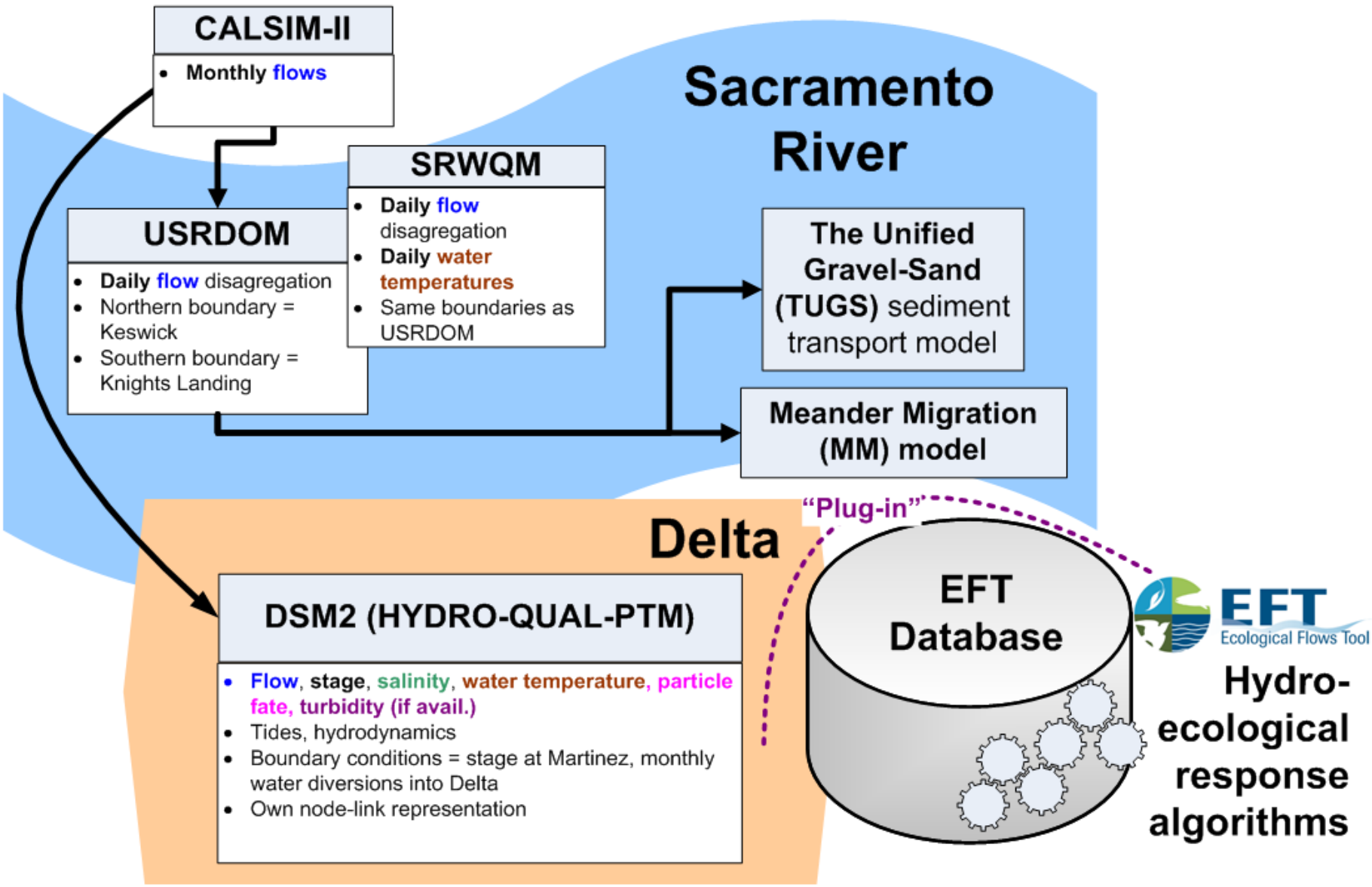
$$CS3_r = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{CS1_{\overline{x},l}}{CS1_{\overline{x}}}\right)\left(\frac{1}{D}\sum_{d=1}^{D} w_d \prod_{\delta} s(T)\right) = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{CS1_{\overline{x},l}}{CS1_{\overline{x}}}\right) CS3_{l,r}$$

$$CS4_r = \frac{1}{L}\sum_{l=1}^{L}\sum_{i=1}^{D}(c_{i,D+1} - c_{i,D}) = \frac{1}{L}\sum_{l=1}^{L} CS4_{l,r}$$

EFT relational database



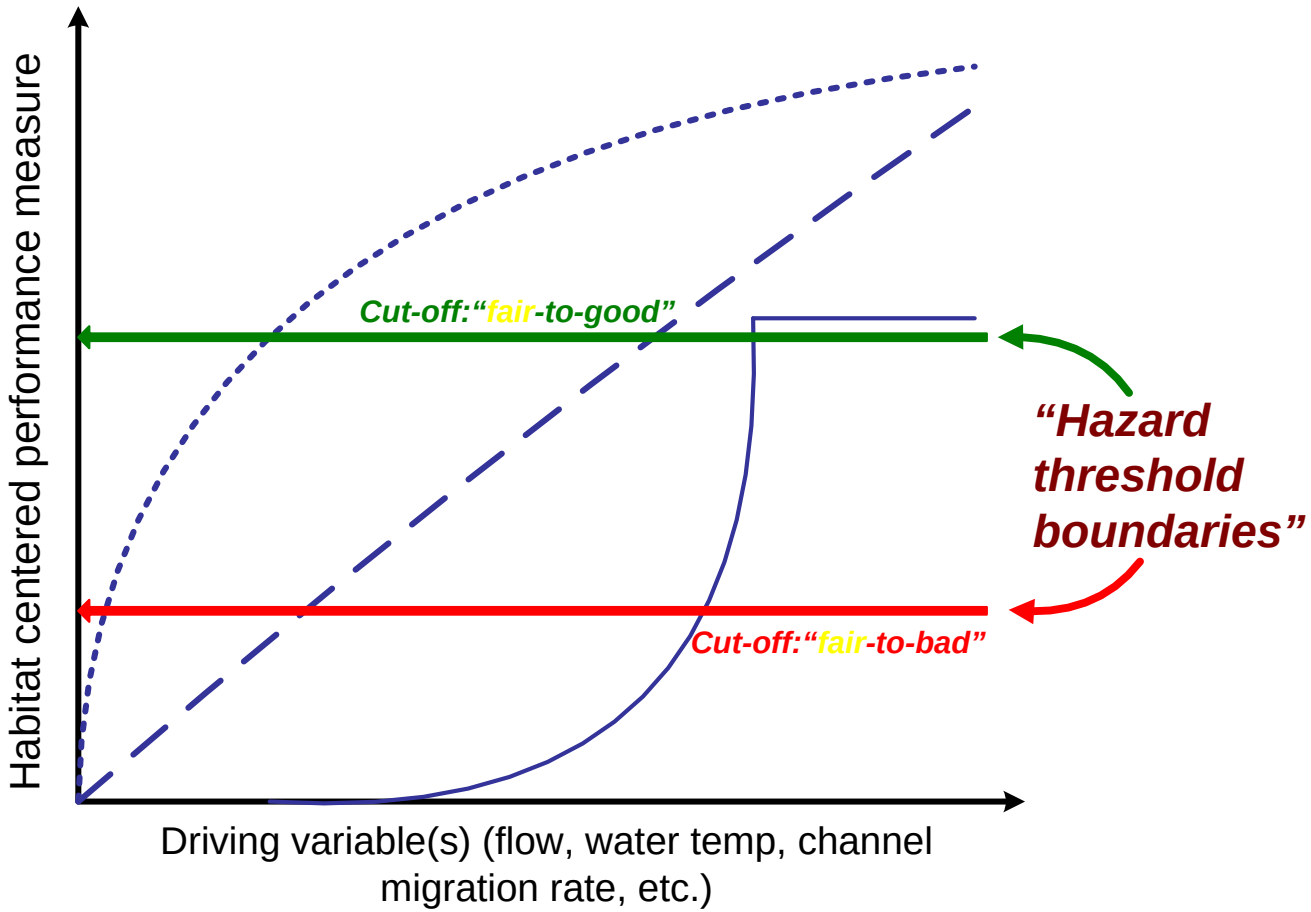
EFT hydrologic foundation



EFT: multiple analysis products

Question	Analysis
1. What water operation alternative has preferable environmental performance?	1. Multi-year roll-up of indicator performance (% change in number of simulation years having a favorable rating).
2. What explains why a particular ecosystem function is/isn't being achieved?	2. Graphs and daily output data by index location
3. What is the spatial pattern of performance for a particular ecosystem function?	3. Spatial visualizations with data features.
4. What water operation criteria/guidelines would improve conditions for a given species?	4. Use "good year" flow & water temperature traces to inform target ranges and specific flow rules.

Indicator ratings



SacEFT
Sacramento River Ecological Flows Tool

Analysis of the North-of-the-Delta Offstream Storage Investigation

Prepared for

Statewide Infrastructure Investigations Branch

Prepared by

The Nature Conservancy
Protecting nature. Preserving life.

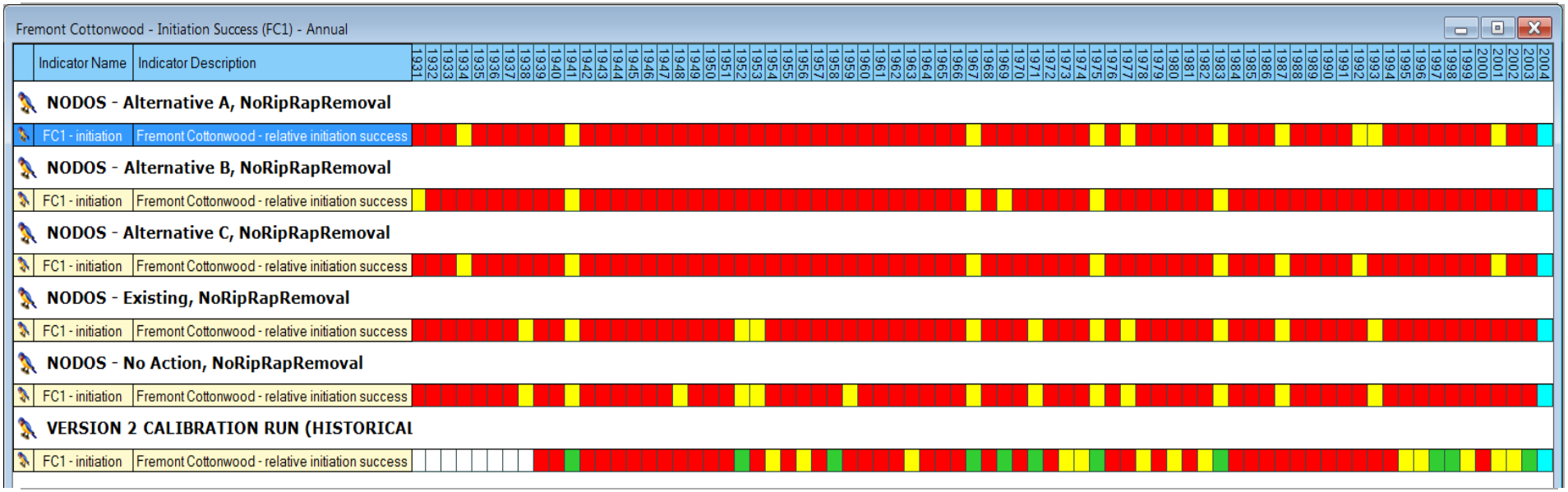
Sacramento River Project
500 Main St.
Chico, CA 95928

and

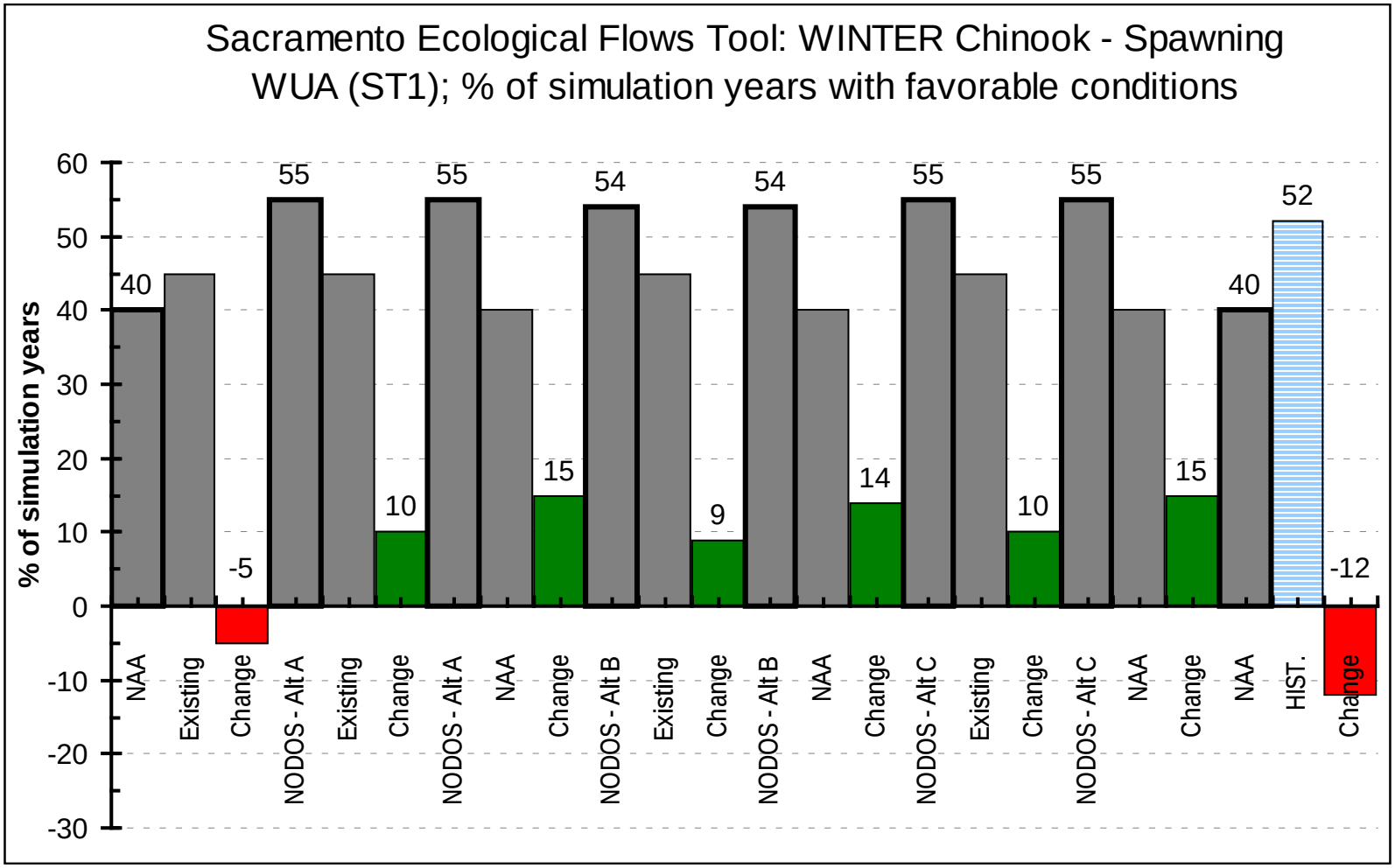
600 - 2695 Granville St.
Vancouver, BC
Canada V6H 3H4

August 5, 2011

Output example (Q1): multi-year summary

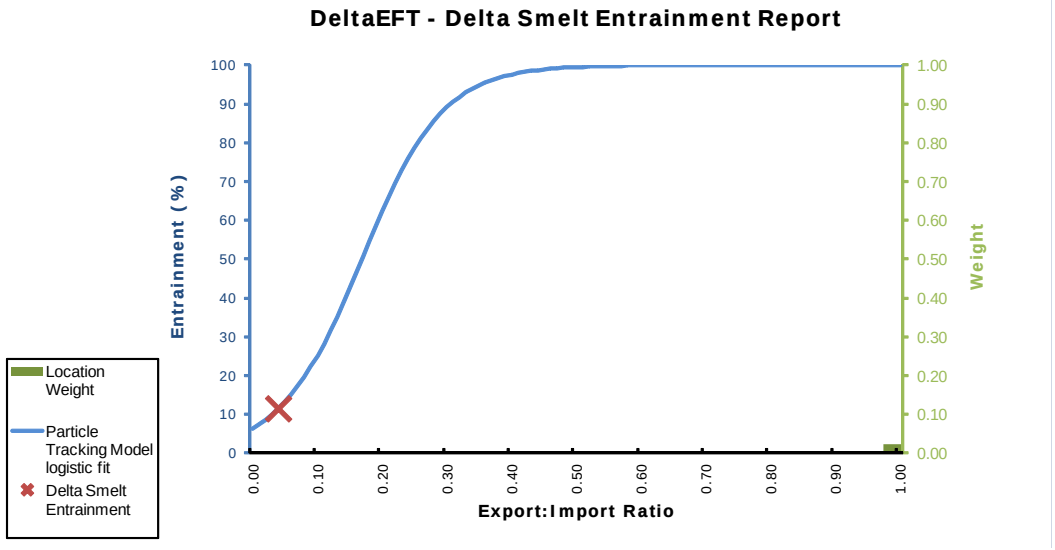


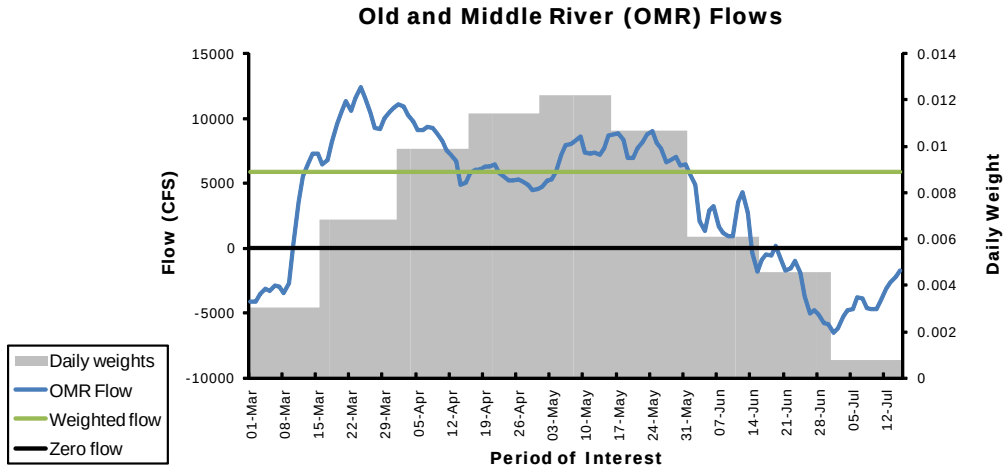
Output example: multi-year summary



Output example (Q2): detailed daily results for a selected year/location

Scenario:	VERSION 2 (HISTORICAL)
Water year:	1995
Location of interest:	TURNER CUT NR HOLT CA
Units	Percentage



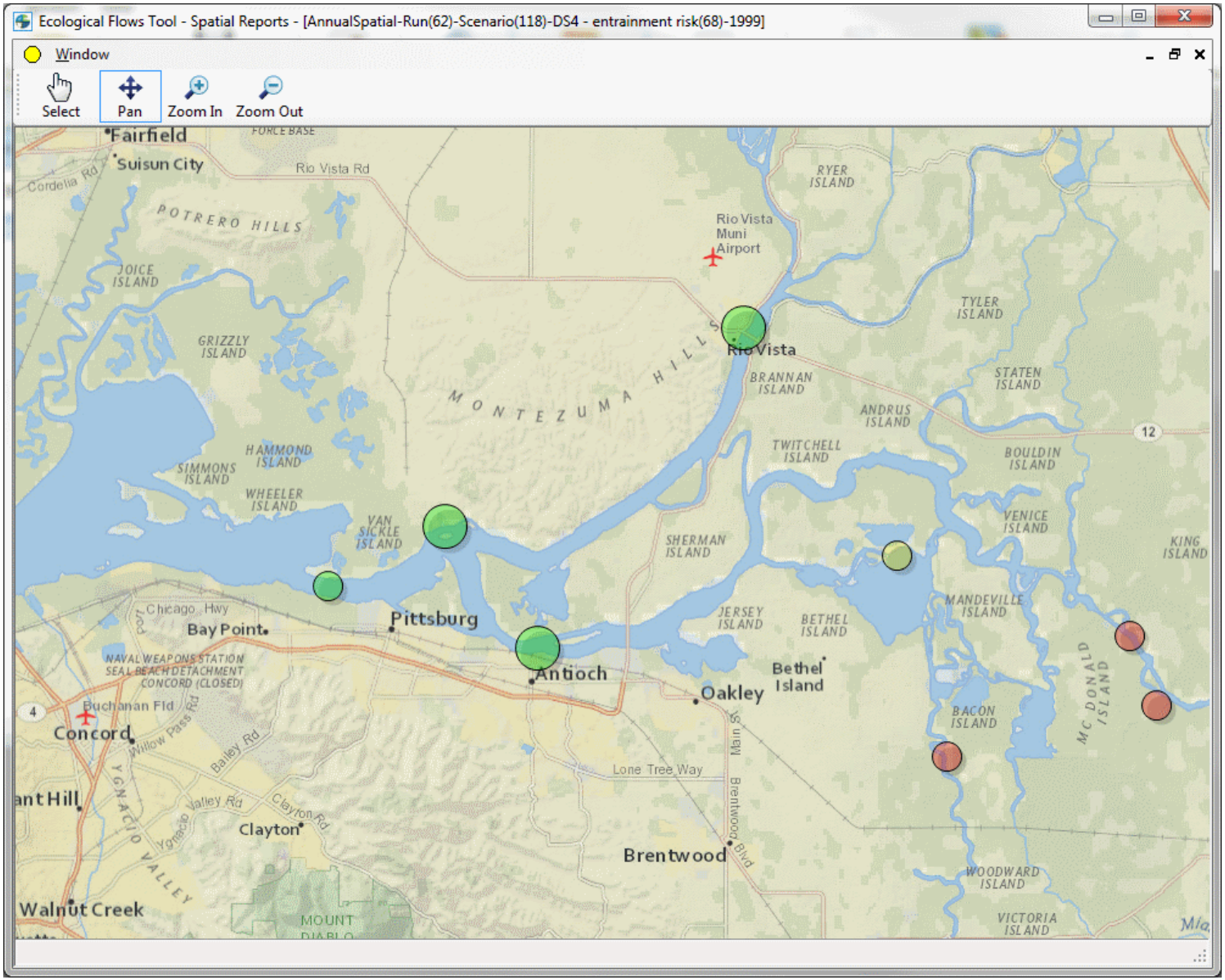


Output example: alternatives summary

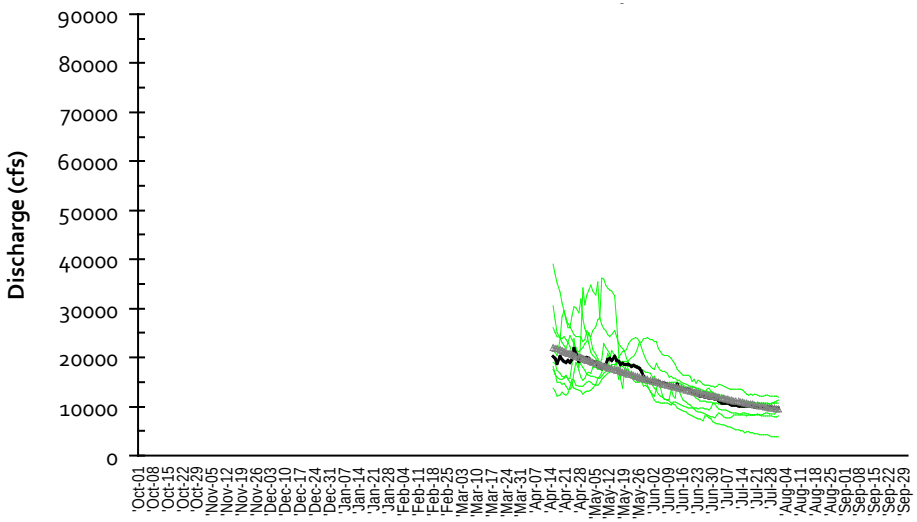
increased / decreased percentage of simulation years having a favorable rating vs. existing conditions.

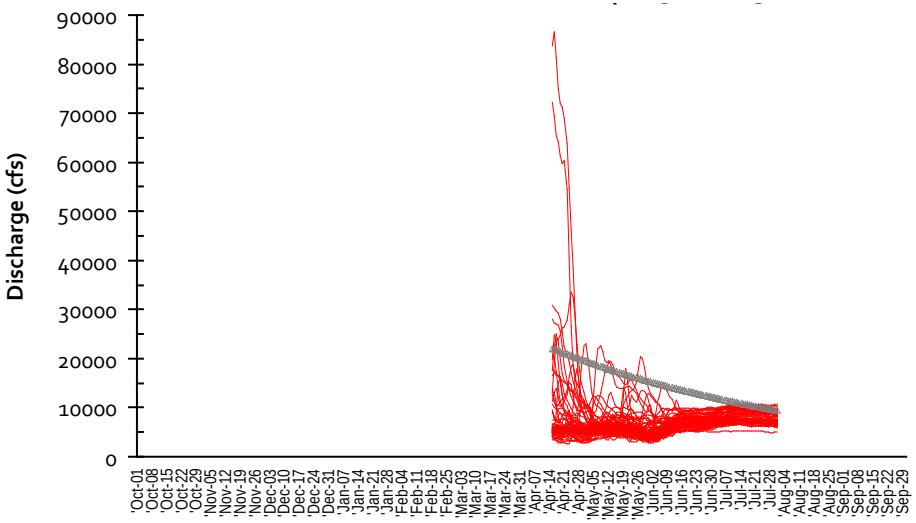
Focal species	Performance measure	Alternatives (below) vs. Existing Conditions				NAA vs.
		NAA {#1}	NODOS – Alt A {#2}	NODOS – Alt B {#4}	NODOS – Alt C {#6}	Historic Conditions {#8}
Fremont Cottonwood	Initiation success (FC1)	ni (+/-0)	ni (+/-0)	ni (+/-0)	ni (+/-0)	- - (-17)
	Post-initiation scour risk (FC2)	+ (+9)	++ (+20)	ni (+2)	++ (+25)	++ (+10)
Bank Swallows	Habitat potential/suitability (BASW1)**	ni (+/-0)	- (-4)	- (-5)	ni (- 3)	ni (+1)
	Peak flow during nesting period (BASW2)	ni (+/-0)	ni (+/-0)	ni (+/-0)	ni (+/-0)	+ (+4)
Western Pond Turtles	Large Woody Debris Recruitment (LWD)**	ni (-3)	ni (-3)	ni (-3)	ni (-3)	- - (-29)
Green Sturgeon	Egg temperature preferences (GS1)	ni (+1)	+ (+6)	+ (+8)	+ (+8)	n/a
Steelhead	Spawning WUA (ST1)	ni (+/- 0)	ni (+2)	ni (+2)	ni (+2)	++ (+14)
	Thermal egg mortality (ST3)	ni (+/-0)	ni (+/-0)	ni (+/-0)	ni (+/-0)	ni (+/-0)
	Redd Dewatering (ST6)	ni (+/-0)	+ (+5)	+ (+6)	+ (+5)	+ (+9)
	Redd Scour (ST5)	ni (+/-0)	ni (+/-0)	ni (+/-0)	ni (+/-0)	- - (-16)

Output example (Q3): spatial data visualizations

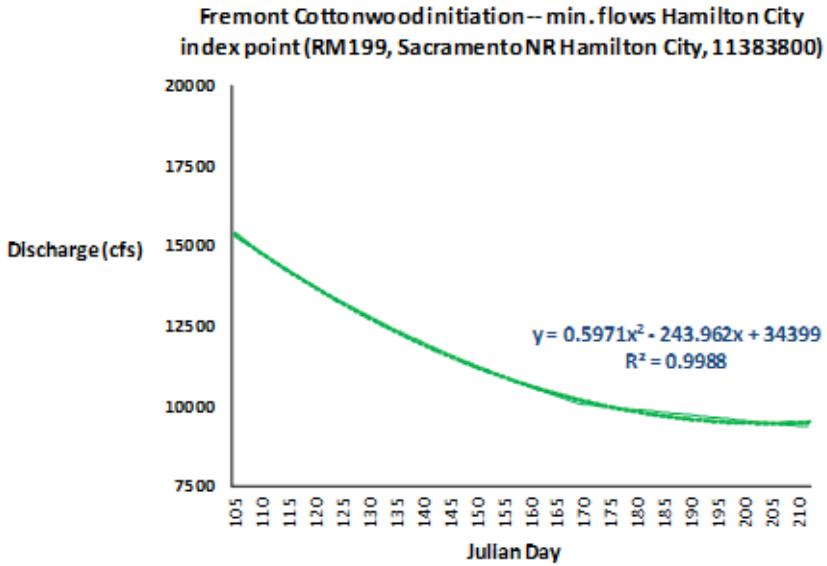


Q4: Ecological flow recommendations





Q4: Ecological flow recommendations

Sacramento River		
Fremont Cottonwood		
Indicator	FC1	Relative initiation success
Objective & Rationale	Periodically provide recession flows that support areas for riparian initiation (as indexed by Fremont cottonwoods) *in the target zone for initiation* (i.e., riparian channel bank areas above **8,500 cfs elevation + 3ft**). (SacEFT Design Document Section 4.3.4, pp. 96-100).	
Timing	O N D J F M A M J J A S	
Location	Hamilton City (RM199, SACRAMENTO R NR HAMILTON CITY CA, 11383800)	
Variable & Condition	76 out of 108 days of flows (70%) at Hamilton City (RM199) between Apr-15 (105) and July-31 (212) equal or exceed flows predicted by the following equation: **Min. target Q (cfs) = $0.5971x^2 - 243.962x + 34399$ (where x = Julian day)** 	
Recurrence	At least once every 8 years.	
References	Mahoney and Rood 1998; Roberts et al. 2002; Roberts 2003; HEC-RAS supplemented stage-discharge relations; Alexander 2004	

Q4: Ecological flow recommendations

Splittail		
Indicator	**SS1**	**Spawning habitat extent (Yolo)**
Objective & Rationale	Maintaining flow regimes that result in periodic inundation of riparian and floodplain habitat during winter and spring is important for splittail viability. When flooded, the majority of splittail spawning habitat is located in Yolo bypass, consequently inundation of the floodplain plays a large role in determining the extent of available spawning habitat. (DeltaEFT Design Document Section 2.2.3, pp. 100-105).	
Timing	O N D J F M A M J J A S (Feb 21)	
Location	Fremont Weir (FREMONT WEIR SPILL TO YOLO BYPASS NR VERONA CA, RSAC155, 11391021)	
Variable & Condition	100 < Q_{avg}< 2000 cfs for at least 75% of the period shown (approx. four weeks within this period)	
Recurrence	4 out of 10 years	
Potential conflicts & trade-offs	Notching Fremont Weir should provide habitat	
References	Moyle et al. (2004); Sommer *et al.* (2002), Feyrer *et al.* (2006)	

Delta Smelt		
Indicator	**DS4**	**Entrainment index**
Objective & Rationale	The indicator simulates entrainment risk from the CVP and SWP export operations. The indicator applies only to the larval and juvenile life stages. Low flow years historically have higher incidences of entrainment than high flow years because fish are distributed closer to the points of diversion. The indicator is based on the results of a Particle Tracking Model (PTM) experiment (Kimmerer and Nobriga 2008). (Design Document Section 2.2.2, pp. 89-100).	
Timing	O N D J F M A M J J A S	
Locations	Combined Old + Middle River (OLD R A BACON ISLAND CA, ROLD024, 11313405) + (MIDDLE R AT MIDDLE RIVER CA, RMID015, 11312676)	
Variable & Condition	≤ Normal WYT: Q_{avg} > −2,000cfs > Normal WYT: Q_{avg} > 0cfs	
Other Triggers	Juvenile smelt detected through trawls	
Recurrence	Annually	
Potential conflicts & trade-offs	May conflict with export objectives	
References	Kimmerer and Nobriga (2008); Moyle (1992); Sommer *et al.* (1997); Nobriga *et al.* (2001).	

EFT
Ecological Flows Tool
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What it does

- Links Sacramento & Delta ecoregions
- Multiple focal species & habitats
- Rapid alternatives comparison
- Evaluates multiple actions (gravel, channel migration, floodplain activation, conveyance, operations)
- Links with existing models
- Develops new ecological flow guidelines

What it doesn't do

- Not a population model
- Does not consider effects on other beneficial uses (e.g., power) but designed to be paired with models that assess these objectives

Information

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