Using hydro-ecological models to design resilient policies: principles and examples, including the Sacramento River Ecological Flows Tool (SacEFT)

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CALFED Science Program Workshop:

Linking Physical and Biological Models for Ecosystem Prediction, Planning, and Performance

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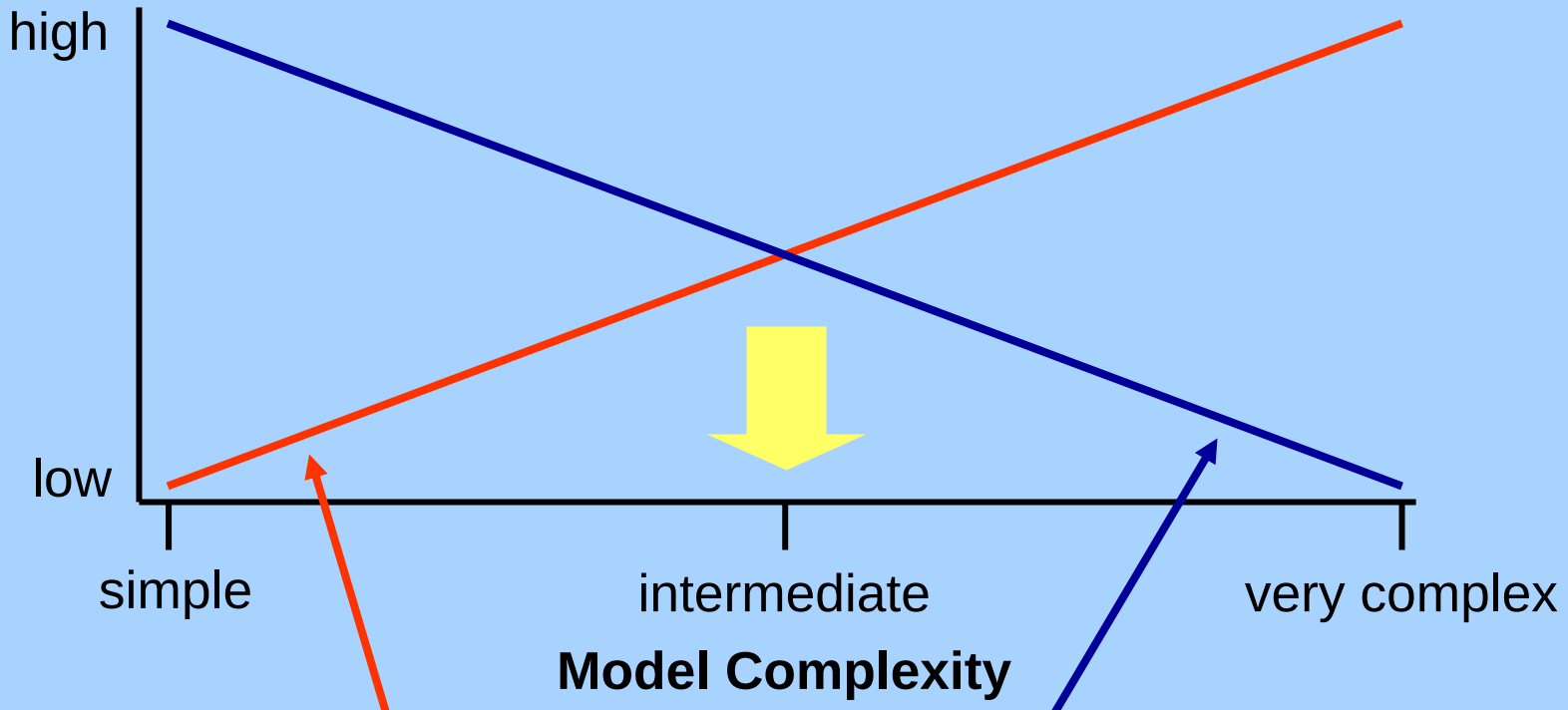
Outline

1. Key lessons from 30+ years of modeling
2. The SacEFT example
3. Potential Extension to the Delta

1. Key Lessons Learned

- Ecological understanding << Hydrodynamic
  - Ecological modeling needs drive hydrodynamic inputs
- Purposes of modeling
  - What decisions, what scales, which users?
  - Explore *range* of possible futures, design AM expts.
  - Resist lure of ever increasing model complexity
- Put models into a decision analysis framework
  - Common inputs, structure for alternative hypotheses
  - Most ecological uncertainties do not affect the *relative* performance of alternative management actions
  - Find most *robust, resilient* actions given uncertainties
- Communicate results at multiple levels

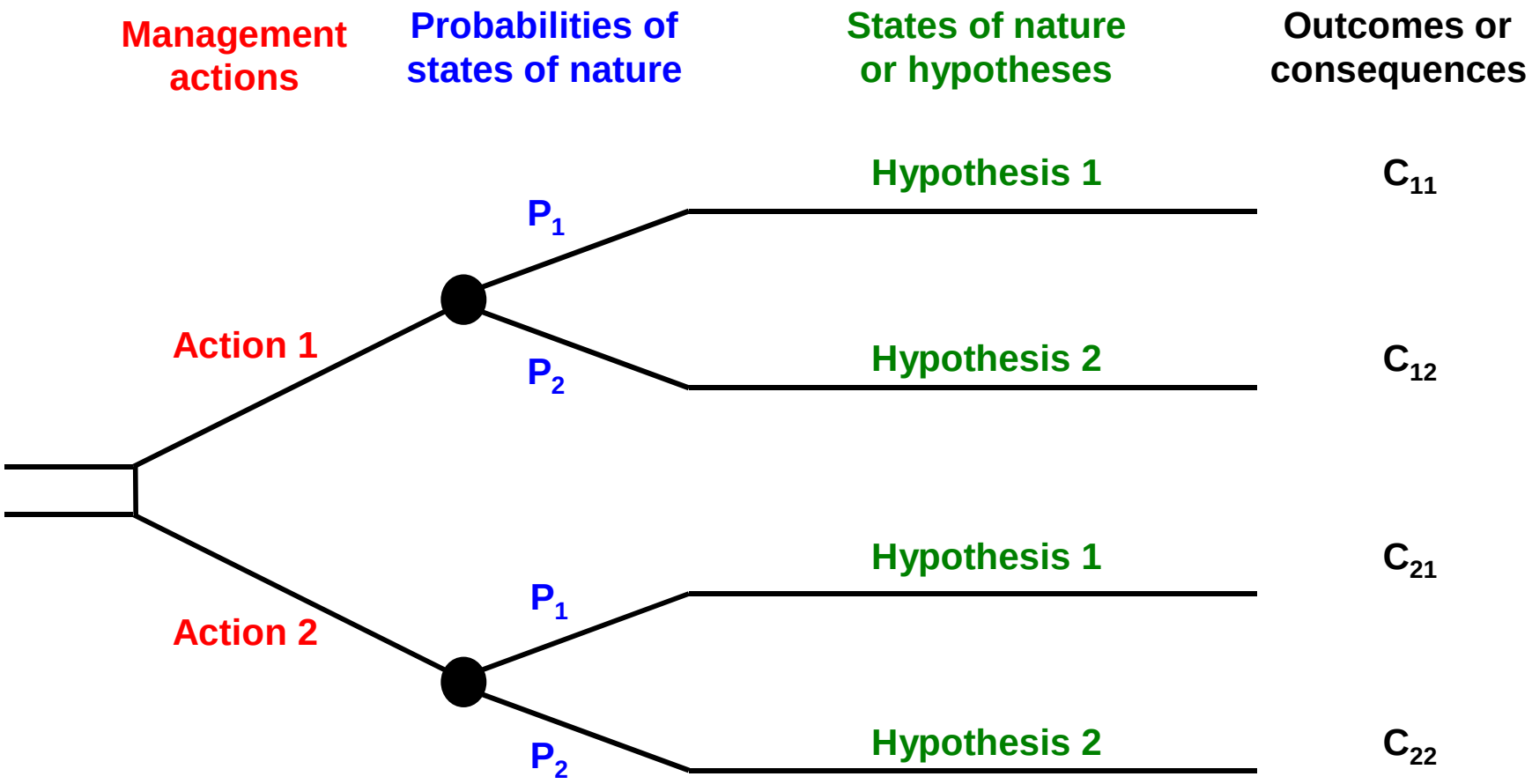
Model Complexity Tradeoffs



- spatial / temporal resolution
- acceptability to specialists
- “realism” of process representation
- cost

- ability to understand model behaviour
- ease of application (data, cost)
- ease of interdisciplinary linkage

Decision Analysis



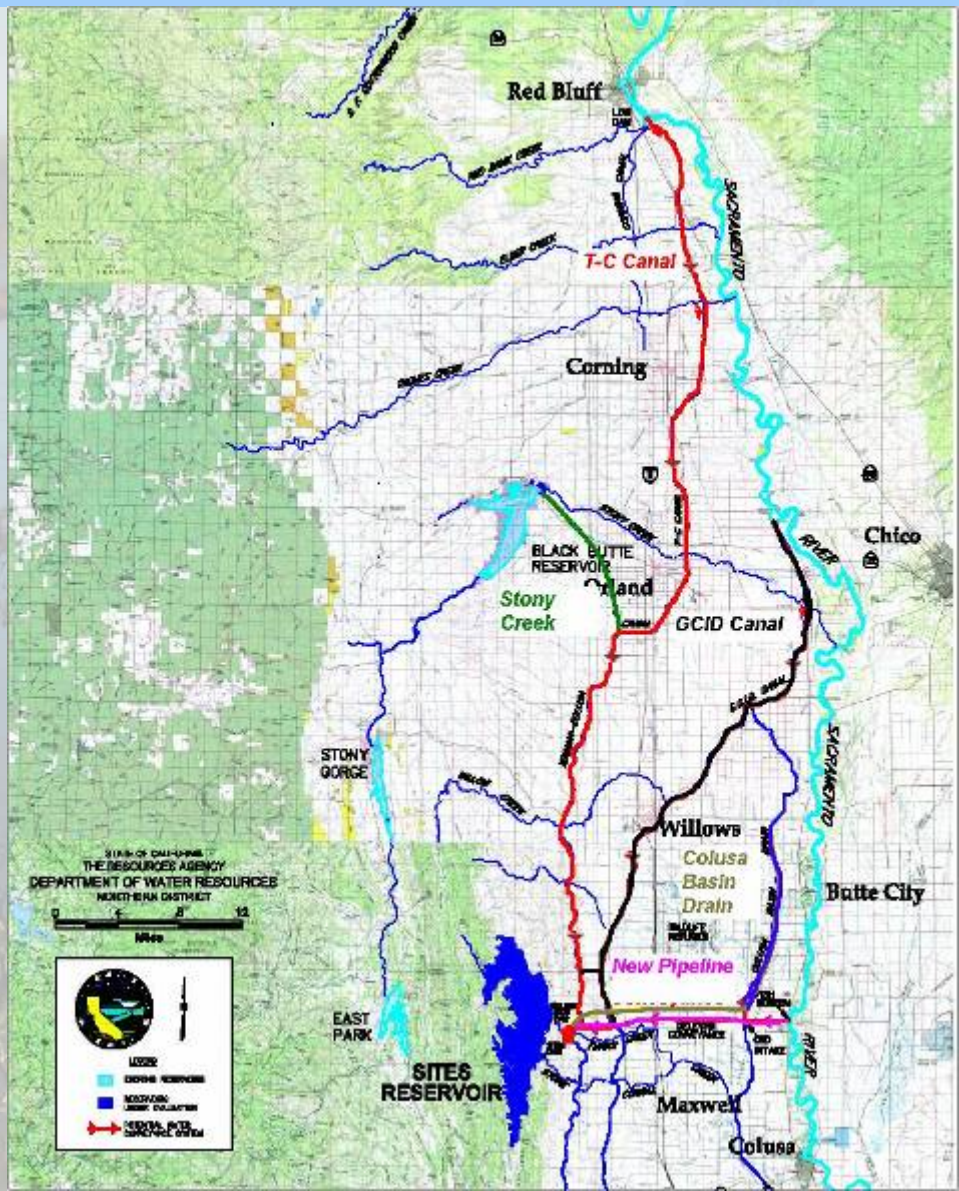
2. Sacramento River Ecological Flows Tool (SacEFT)

Sac R Ecological Flow Study Goals

- Sites off-stream storage reservoir (NODOS)
- Raising Shasta Dam
- Water transfers
- Conjunctive use strategies
- BiOps & OCAP
- Delta Vision and the Bay-Delta Conservation Plan (BDCP)

Flow characteristics (magnitude, timing, duration, frequency)

Creation and maintenance of habitats for native species



Sac R Ecological Flow Study Tasks

1) Synthesize existing information
   - Linkages Report

2) Address data gaps
   - Field and modeling studies

3) Develop a decision analysis tool
   - Sacramento Ecological Flows Tool (SacEFT)

4) Conduct review and share findings
   - Stakeholder workshops
   - Final Report

www.delta.dfg.ca.gov/erp/sacriverecoflows.asp

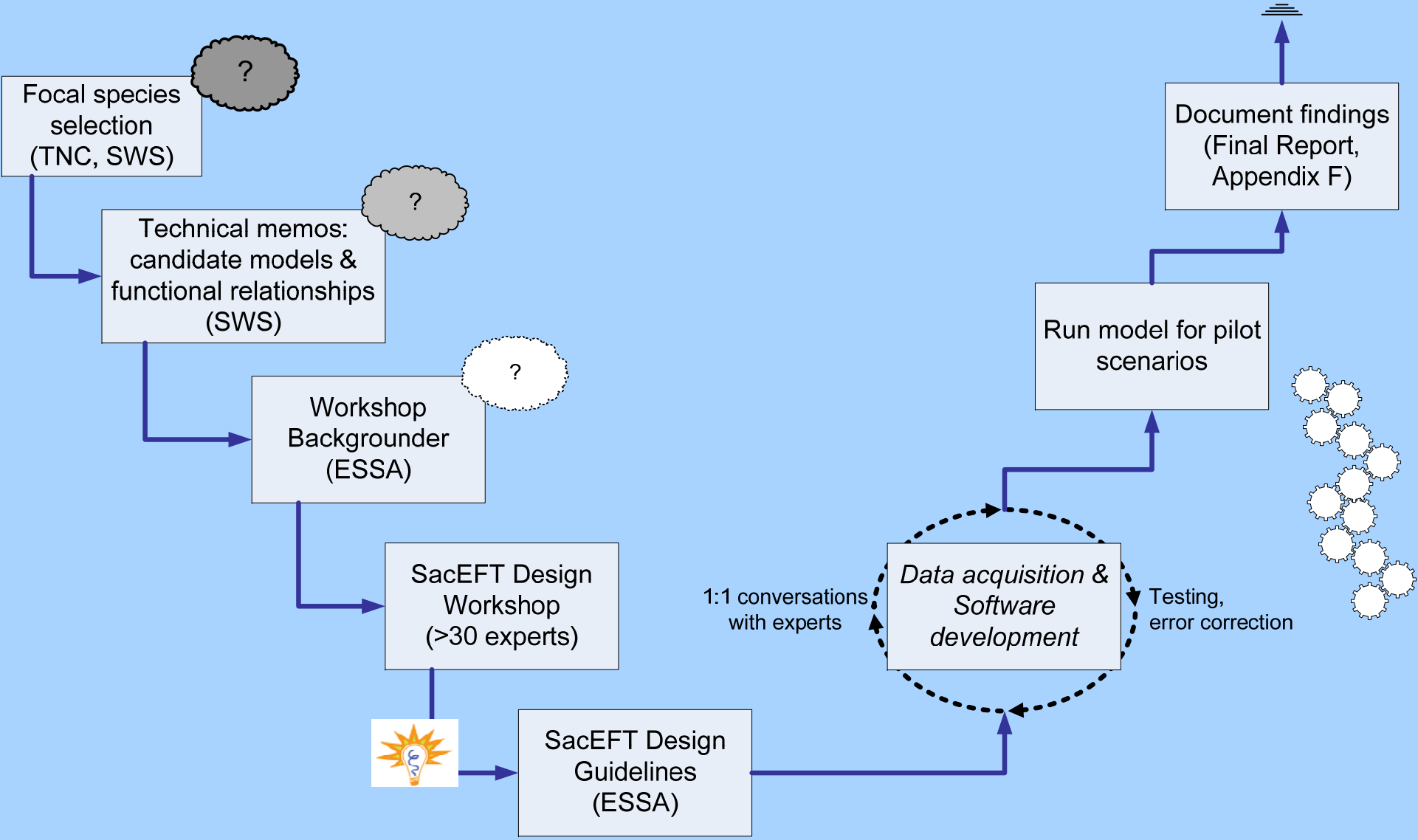
SacEFT: Vision

Make it easy to expand the ecological considerations & science foundation used to evaluate water management alternatives on the Sacramento River

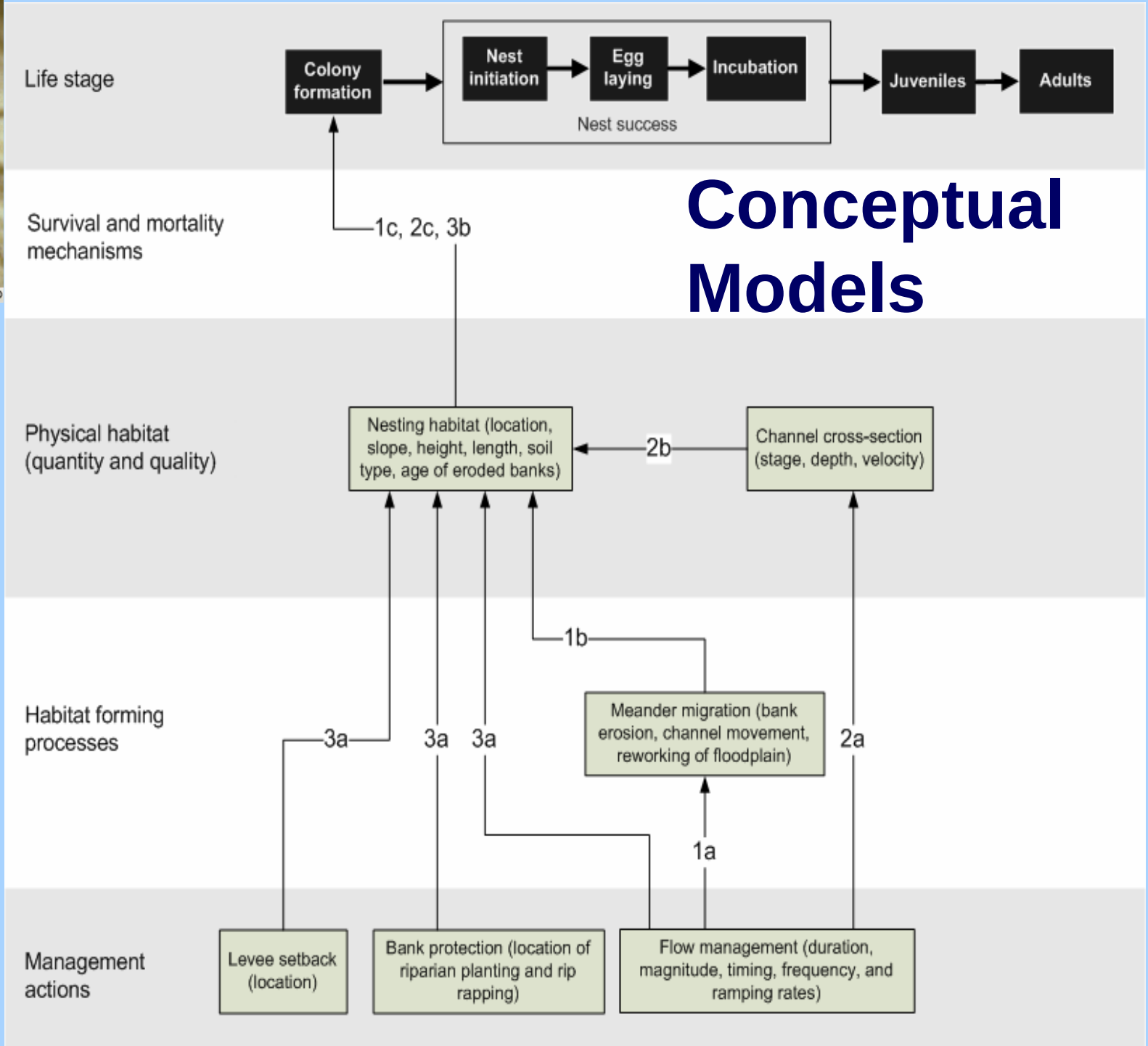
What SacEFT *adds* to water operations planning

1. Allows comparison of effects on multiple ecological targets
2. Enables this comparison amongst alternative water management projects
3. Allows comparison of different management actions
4. Provides a range of outputs from simple to complex for the above comparisons
5. Develop ecological flow regime recommendations

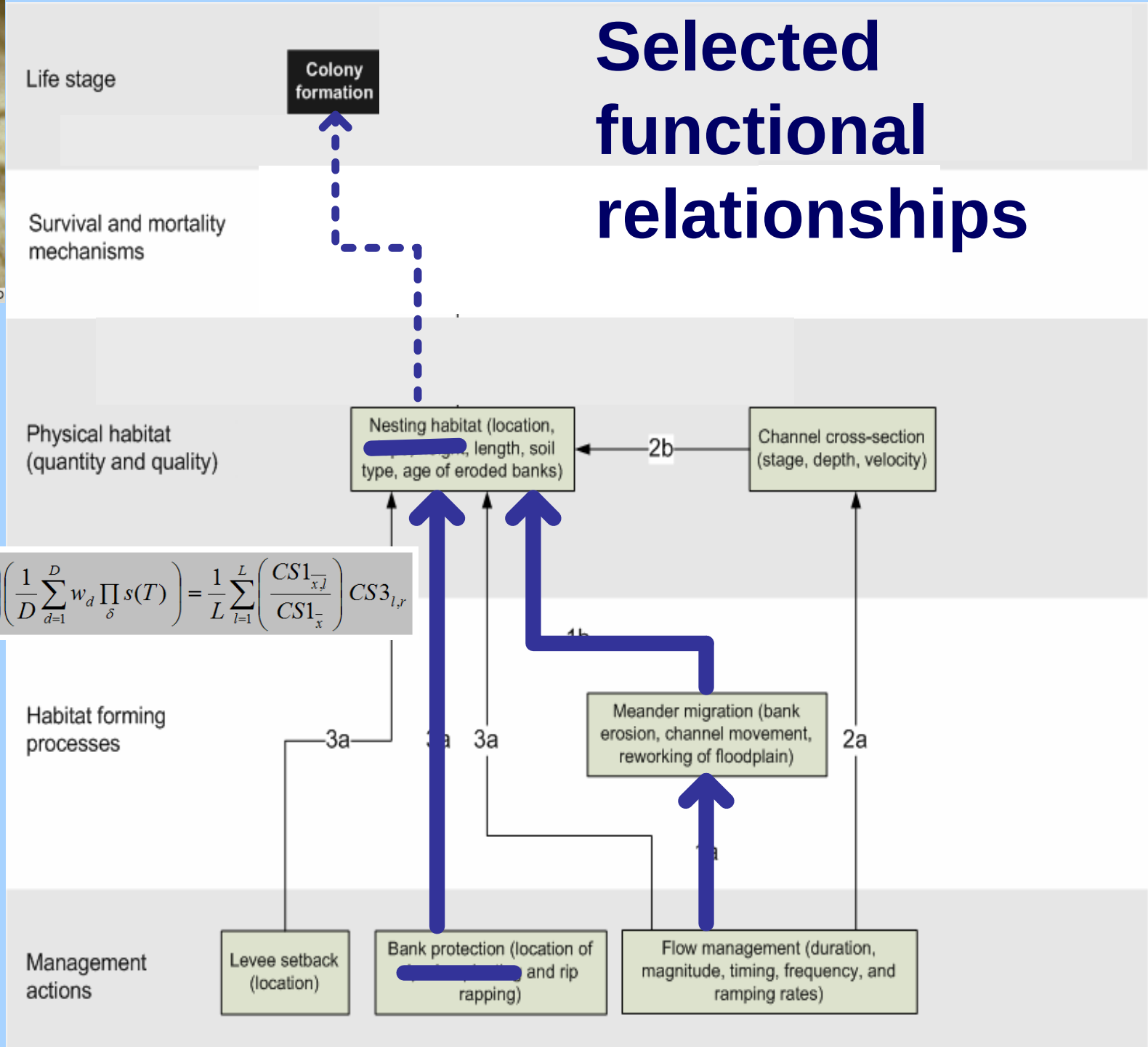
SacEFT development process



Conceptual Models

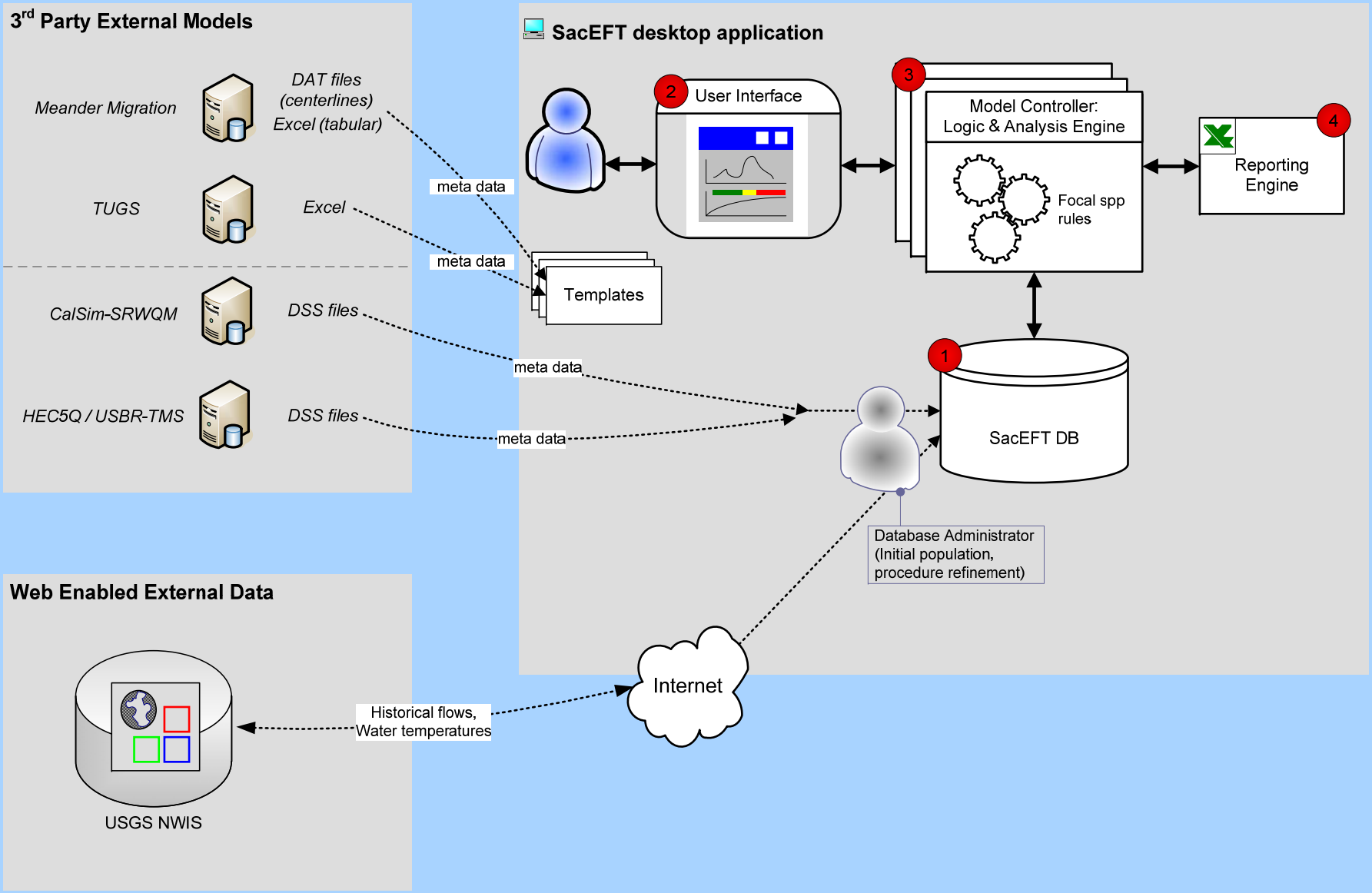


Selected functional relationships

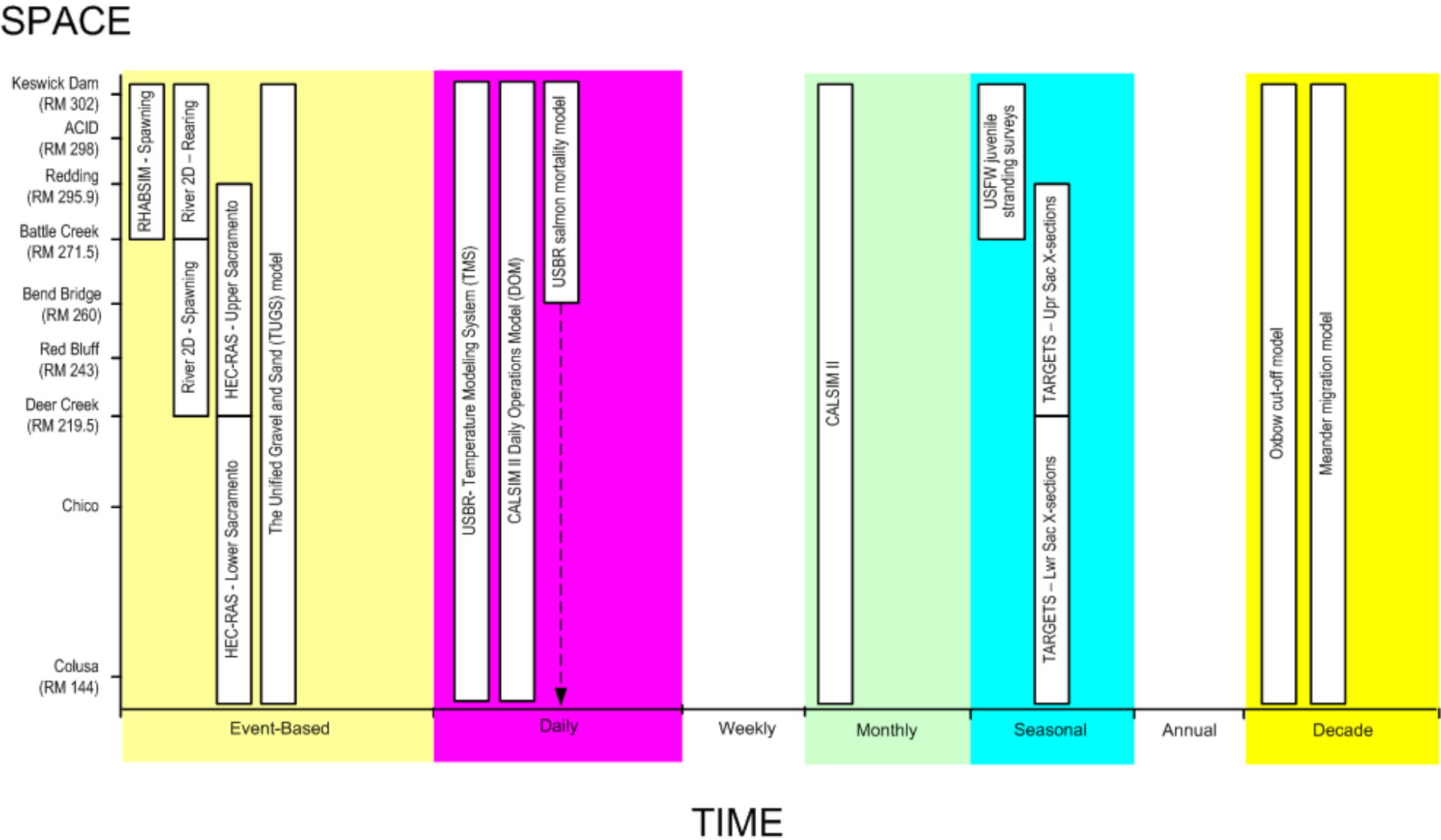


$$CS2_r = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{CS1_{\overline{x},l}}{CS1_{\overline{x}}}\right)\left(\frac{1}{D}\sum_{d=1}^{D} w_d \prod_{\delta} s(T)\right) = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{CS1_{\overline{x},l}}{CS1_{\overline{x}}}\right) CS3_{l,r}$$

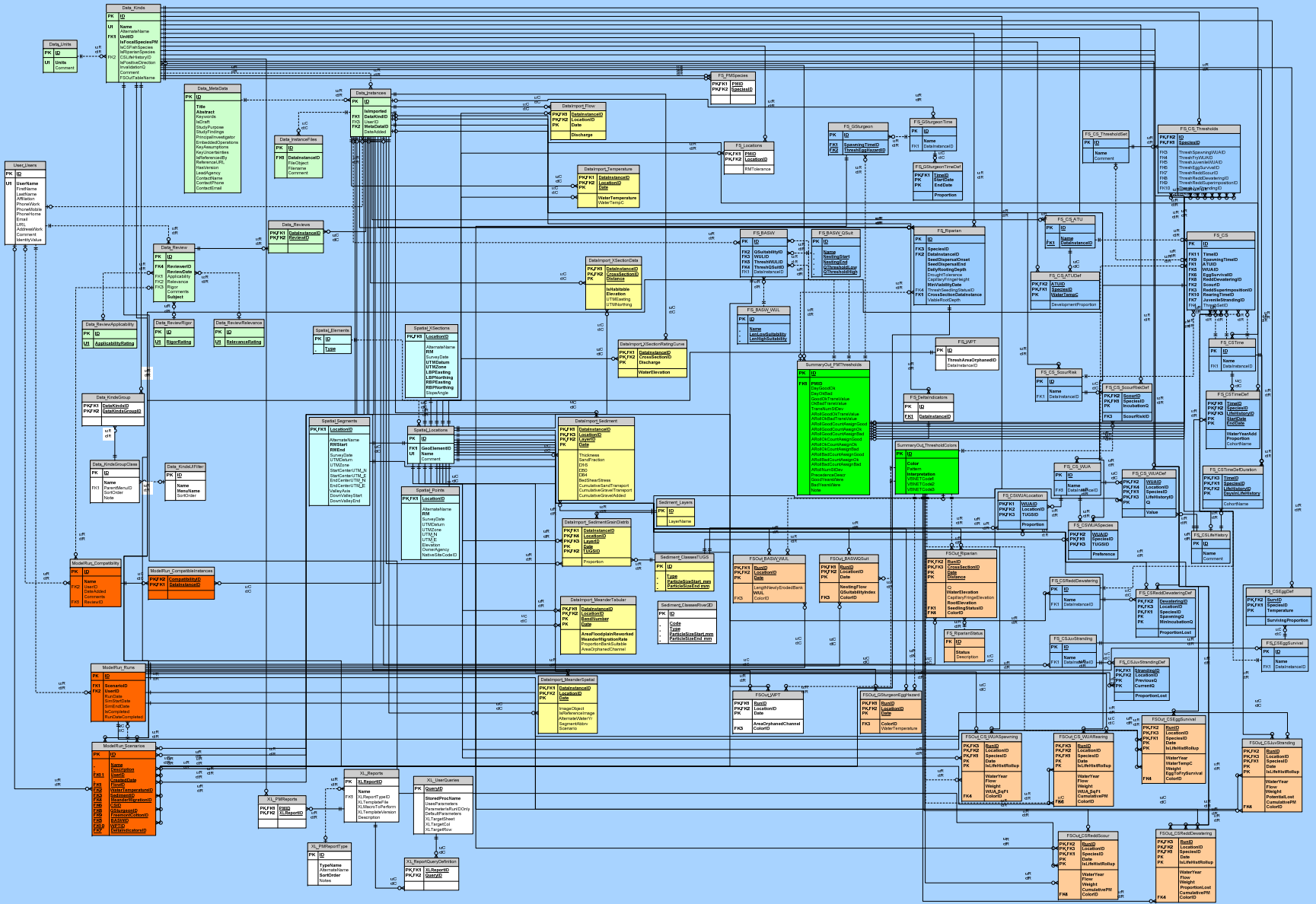
SacEFT structure designed for routine water operations gaming…



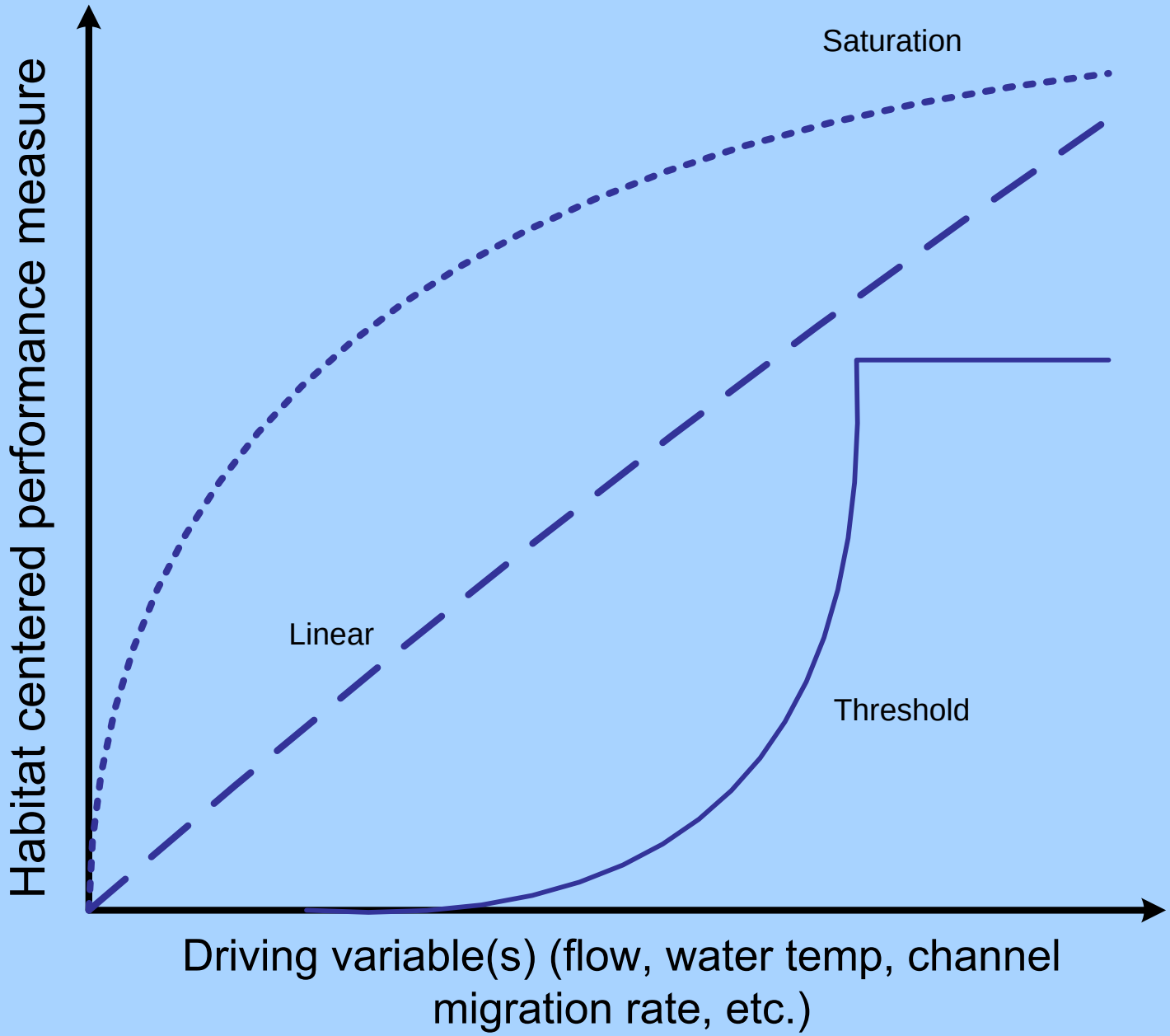
Space and Time Scales in SacEFT Submodels



Backbone: relational database



Traffic light indicator ratings



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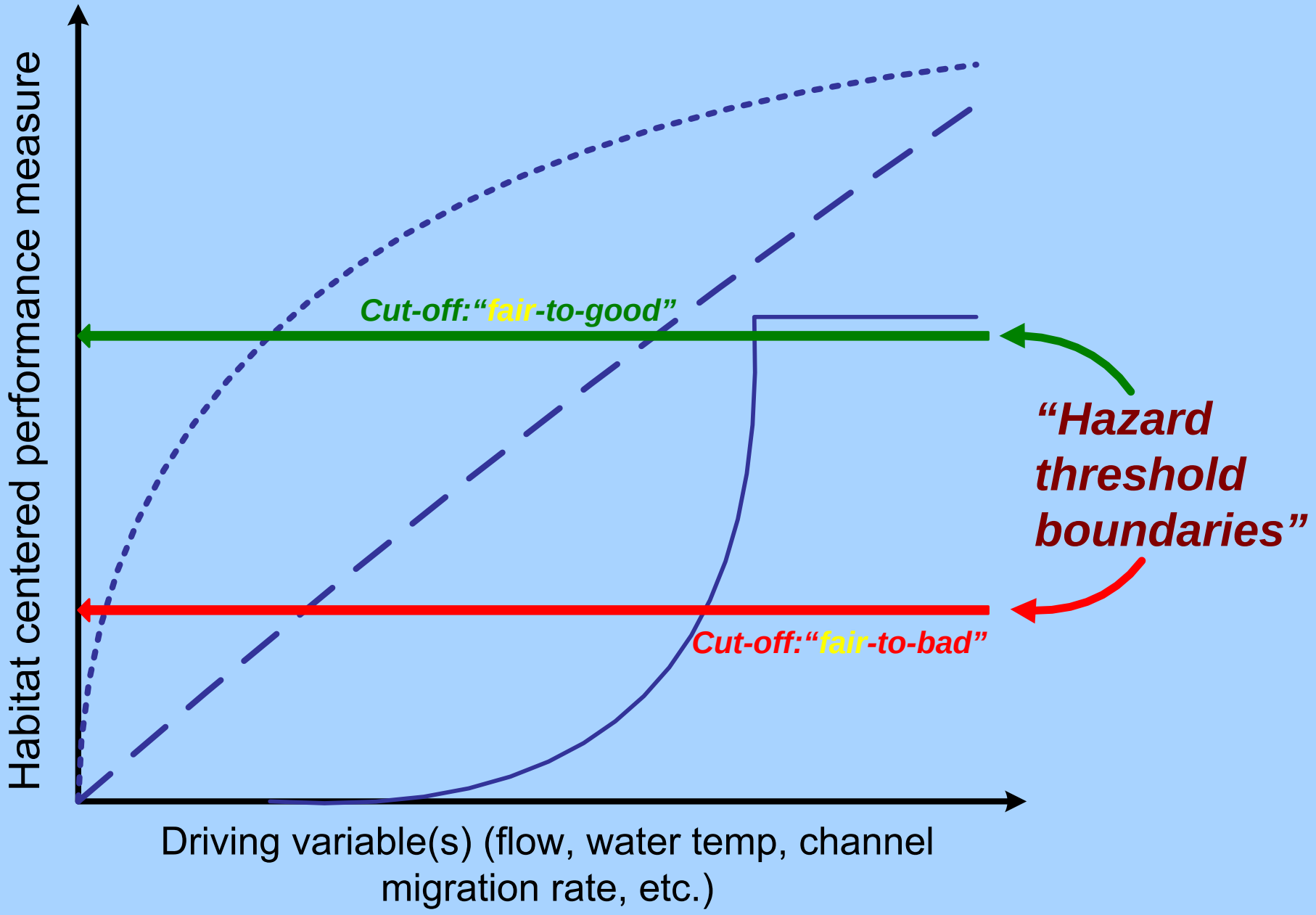

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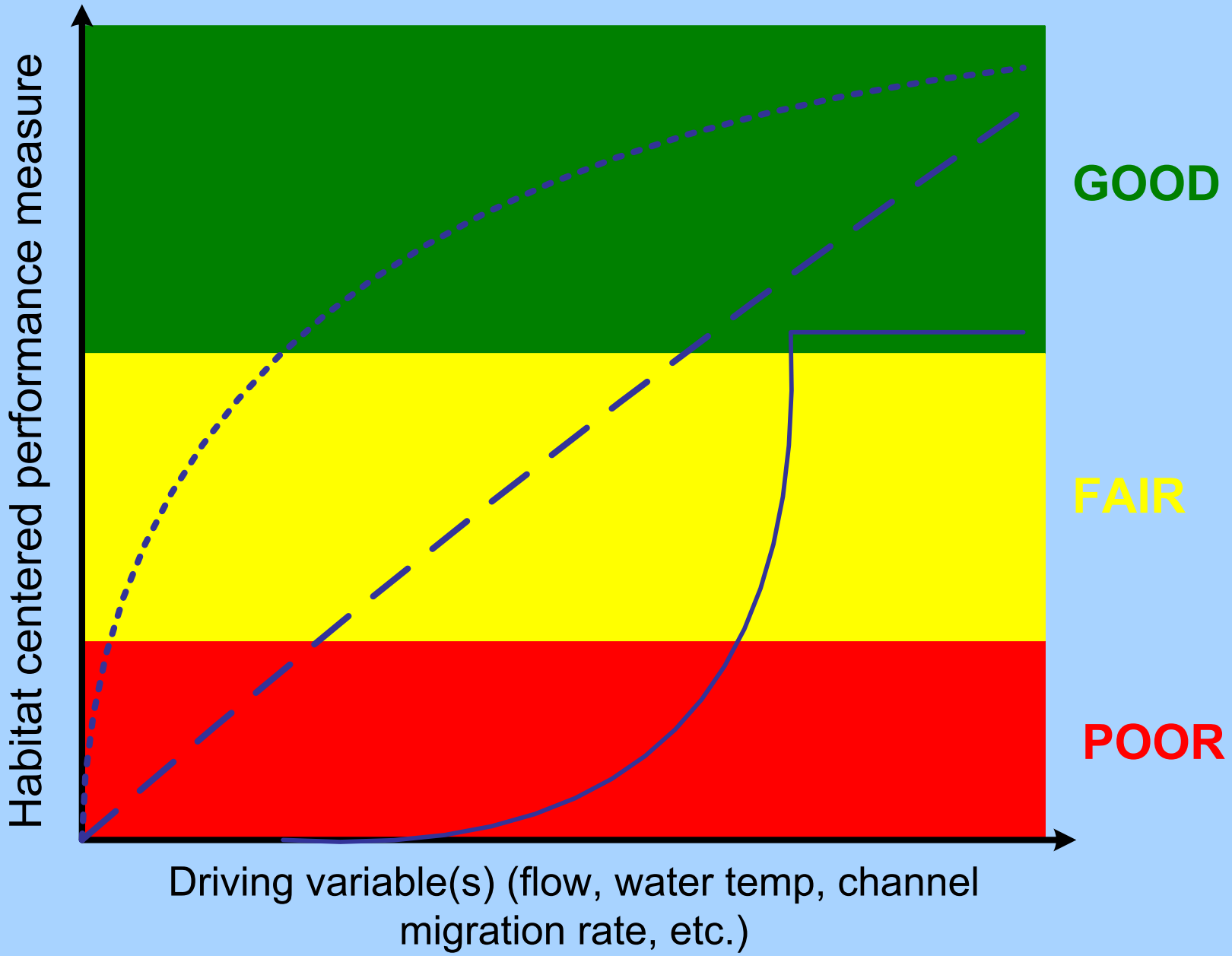
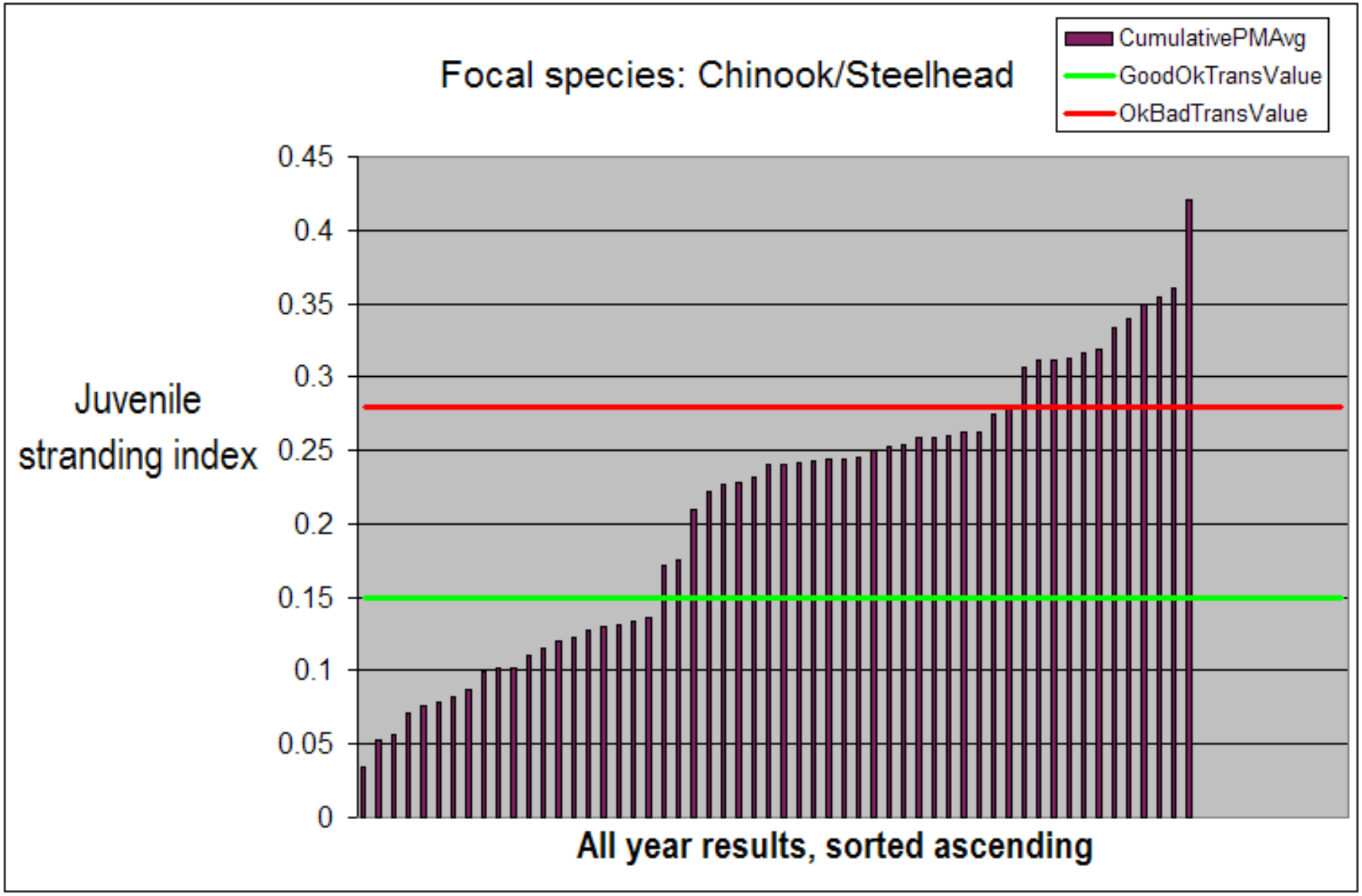


“Traffic lights”: *hazard threshold boundaries*



Initial application: 12 scenarios

Flow Scenario		Channel Actions			
		Gravel Augmentation: TUGS		Channel Revetment: MM	
		ng – No Gravel	g+ – Preferred Gravel[δ]	cc – Current Channel (No Revetment removal)	r^2 – Select Revetment Removal
H – Historical flows & operations (1939 - 2004)		H-ng	H-g+	H-cc	H-r^2
Future Hydro System	N – NODOS (Sites Reservoir)	N-ng	N-g+	N-cc	N-r^2
	S – Shasta +18.5	S-ng	S-g+	S-cc	S-r^2

- 4 historical simulations, including status quo & preferred gravel augmentation & revetment removal
- 8 future hydrosystem simulations, including status quo & gravel / revetment removal variations

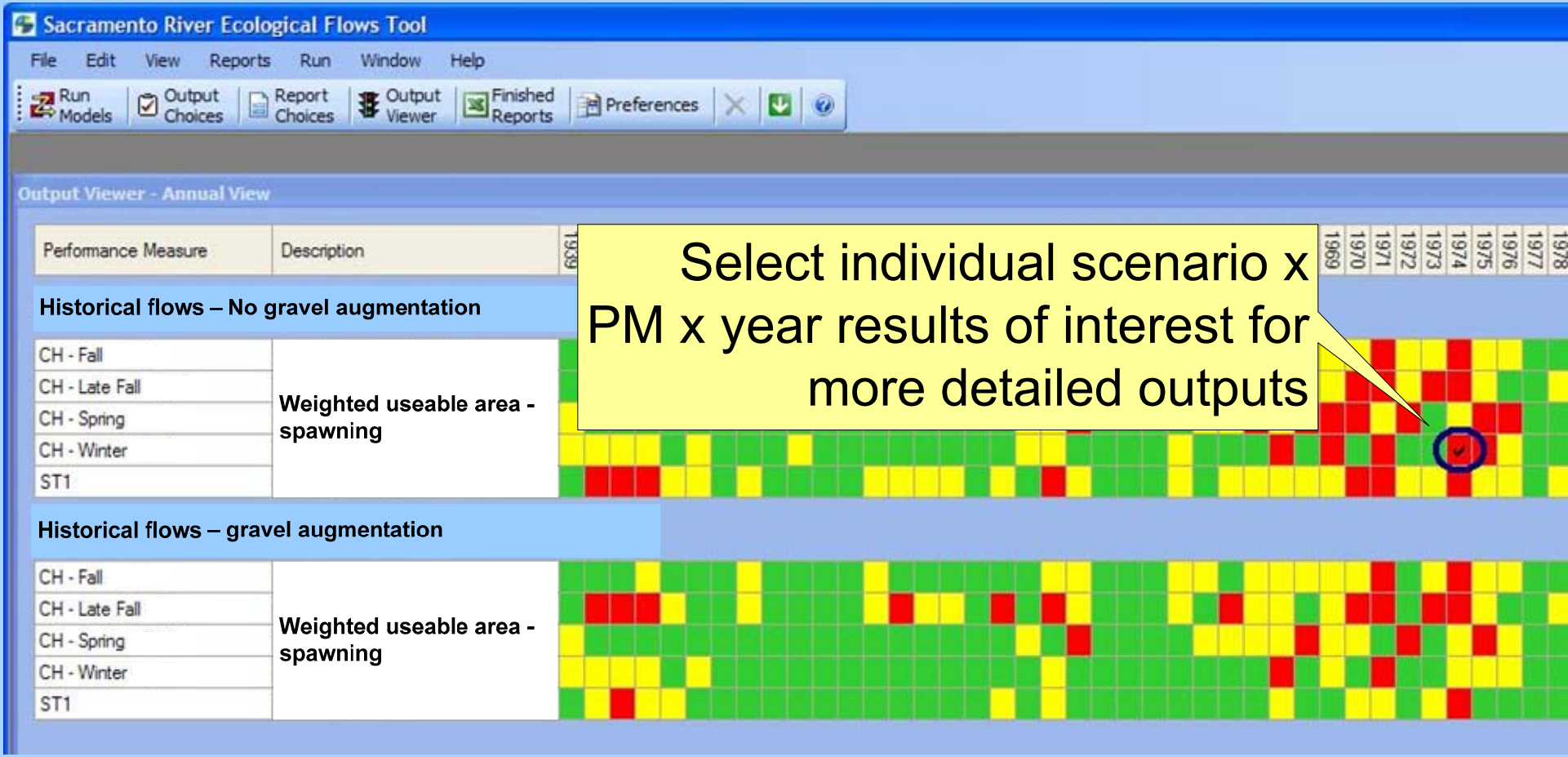
“Traffic light” indicator ratings

User interface: multi-year roll-up output concept

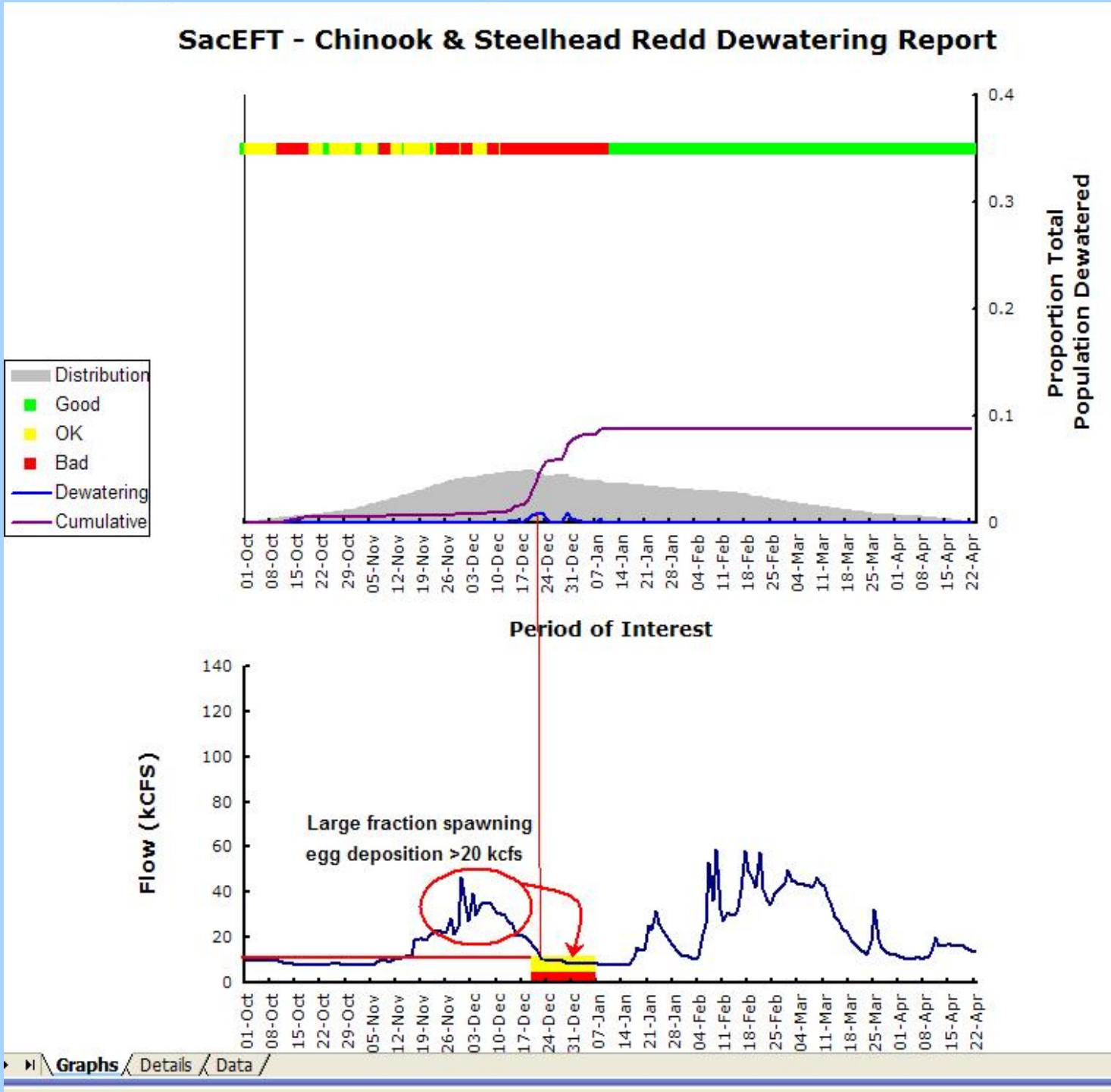
Output Viewer - Rollup View

Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
Historical flows – No gravel augmentation						
CH - Fall	**Weighted useable area - spawning**			5	39	56
CH - Late Fall				23	32	45
CH - Spring				16	24	60
CH - Winter				12	28	60
ST1				19	40	41
Historical flows – gravel augmentation						
CH - Fall	**Weighted useable area - spawning**			5	32	63
CH - Late Fall				23	26	51
CH - Spring				9	21	70
CH - Winter				7	25	68
ST1				7	19	74

“Traffic light” indicator ratings
User interface: Annual output concept



Details in Excel



Historical run provides *context*; "Future No-Action" is *baseline*

Output Viewer - Rollup View

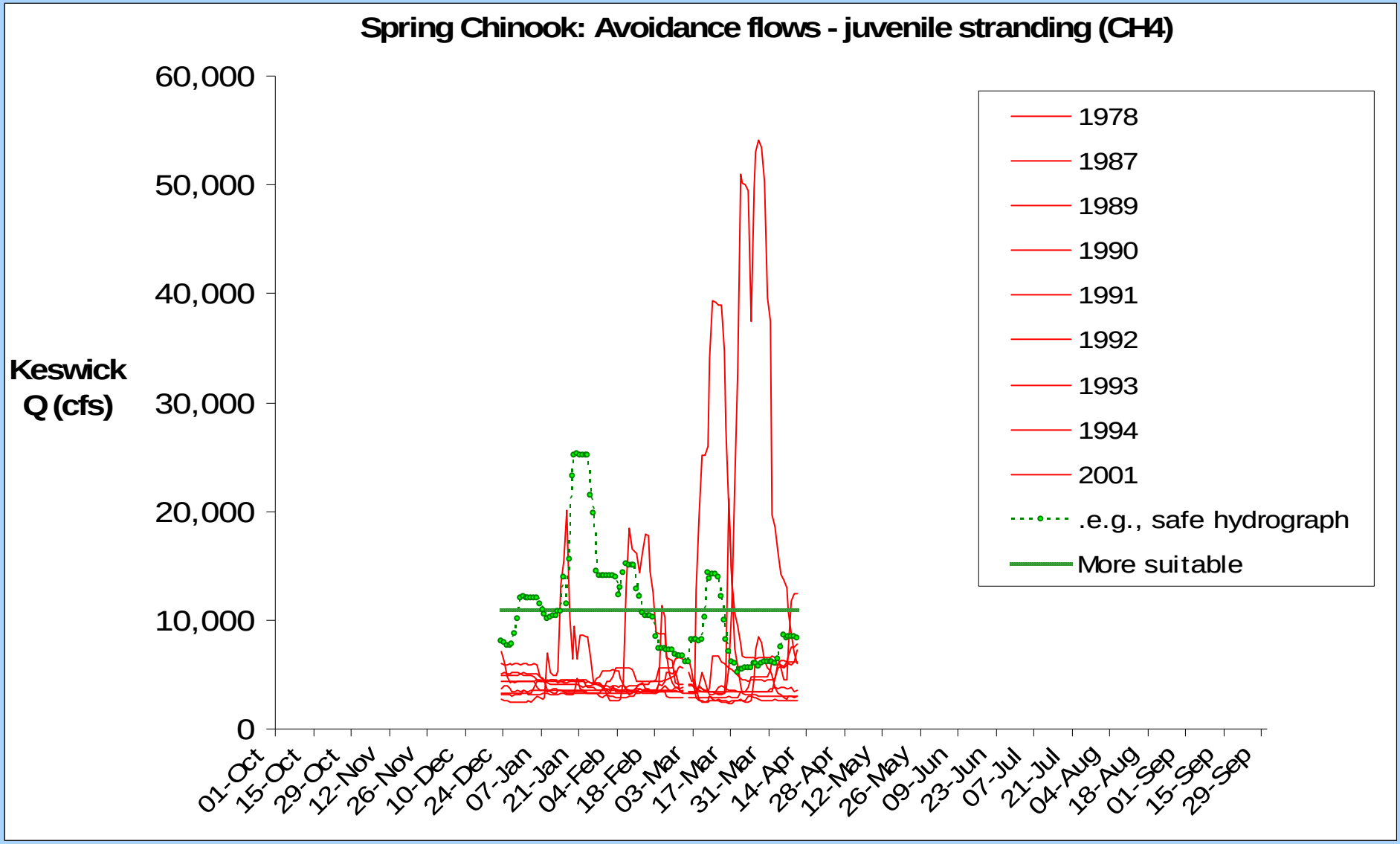
Performance Measure	Description		Multi-Year Rollup	% Poor	% Fair	% Good
4b-Historical-T2, GravelAugmentation, Revetment			**Historical**			
FC - initiation	Freemont Cottonwood - relative init...			64	21	15
6d-Shasta, GravelAugmentation, Revetment			**Shasta**			
FC - initiation	Freemont Cottonwood - relative init...			85	4	11
7b-NODOS-AF2B, GravelAugmentation, DummyRevetment			**NODOS**			
FC - initiation	Freemont Cottonwood - relative init...			77	8	15
8b-FNA2, GravelAugmentation, DummyRevetment			**Future No-Action**			
FC - initiation	Freemont Cottonwood - relative init...			83	8	9

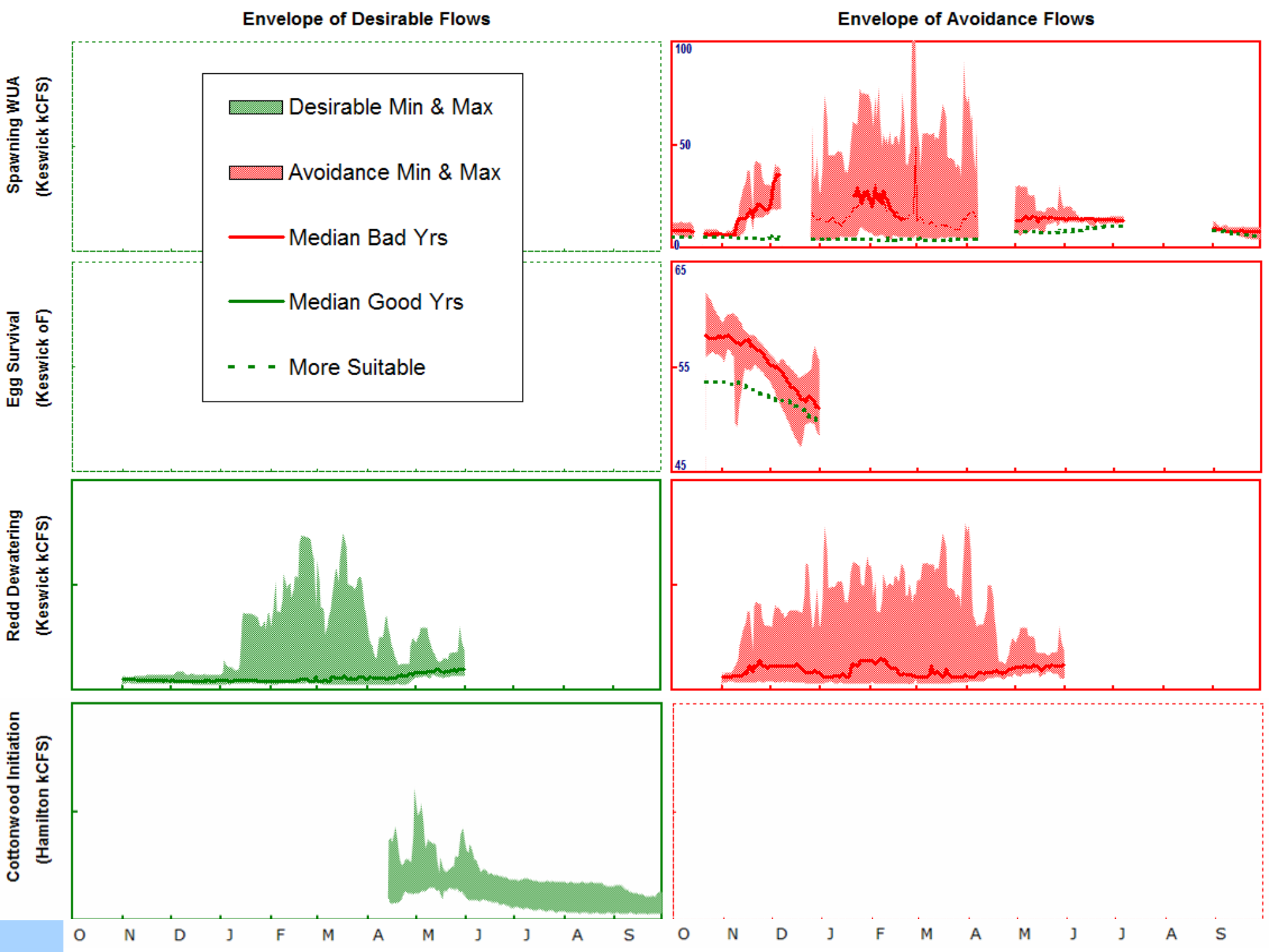
Annual View | Rollup View | Create Reports | 0 Report(s) will be created based on your selections

Practical management implications

Selection of hydrographs for "green" (good) & "red" (poor) performing years yields *target & avoidance flow ranges*

… Juvenile stranding




Envelope of Desirable Flows
Envelope of Avoidance Flows
Spawning WUA (Keswick kCFS)
Egg Survival (Keswick oF)
Redd Dewatering (Keswick kCFS)
Cottonwood Initiation (Hamilton kCFS)
Desirable Min & Max
Avoidance Min & Max
Median Bad Yrs
Median Good Yrs
More Suitable
100
50
0
65
55
45
O N D J F M A M J J A S
O N D J F M A M J J A S

SacEFT target & avoidance flows

1. <u>Not</u> required every single year,
2. Conditions will sometimes benefit one target to detriment of another,
3. Cottonwood recruitment flows needed once every 5 to 10 years,
4. Trade-offs exist - there will be winners and losers in any year,
5. Take advantage of different water years,
6. Target & avoidance flows bracket range of discharges to evaluate experimentally.

Summary: How SacEFT adds value

1. Expands ecological considerations
2. Provides multiple levels of communication
3. Acts as an “eco plug-in” without re-inventing tools
4. Catalyzes exploration of new alternatives

3. SacEFT ⇒ DeltaEFT?

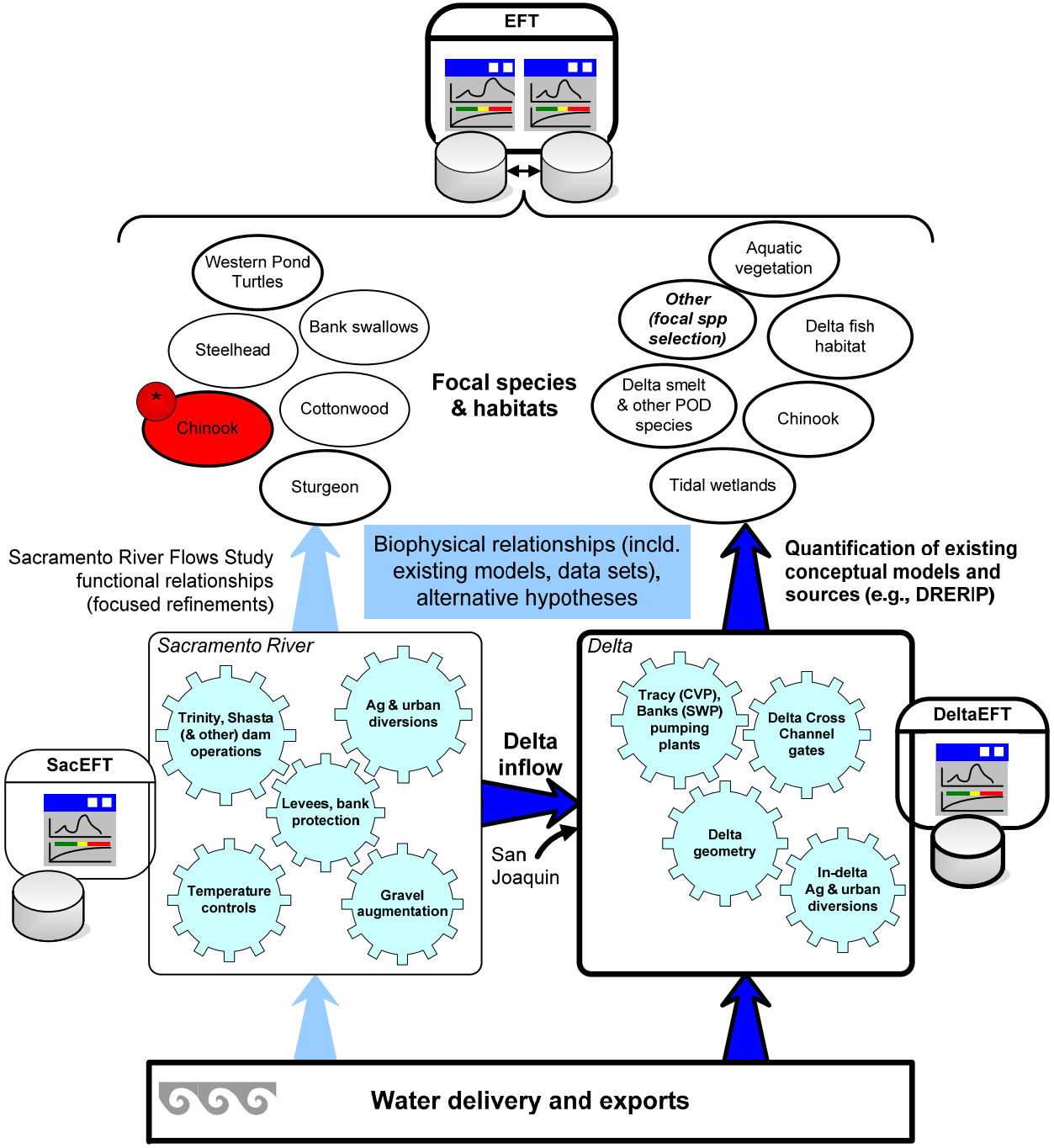
SacEFT:

Peer review of functional relationships & targets

DeltaEFT:

1. **Leverage existing investment**
2. **Unite ecological water operations planning**
3. **Intra & Inter-regional analysis of multiple focal species tradeoffs**
4. **Quantify biophysical linkages, building on DRERIP conceptual models, existing tools**
5. **Emphasize communication**

The Vision

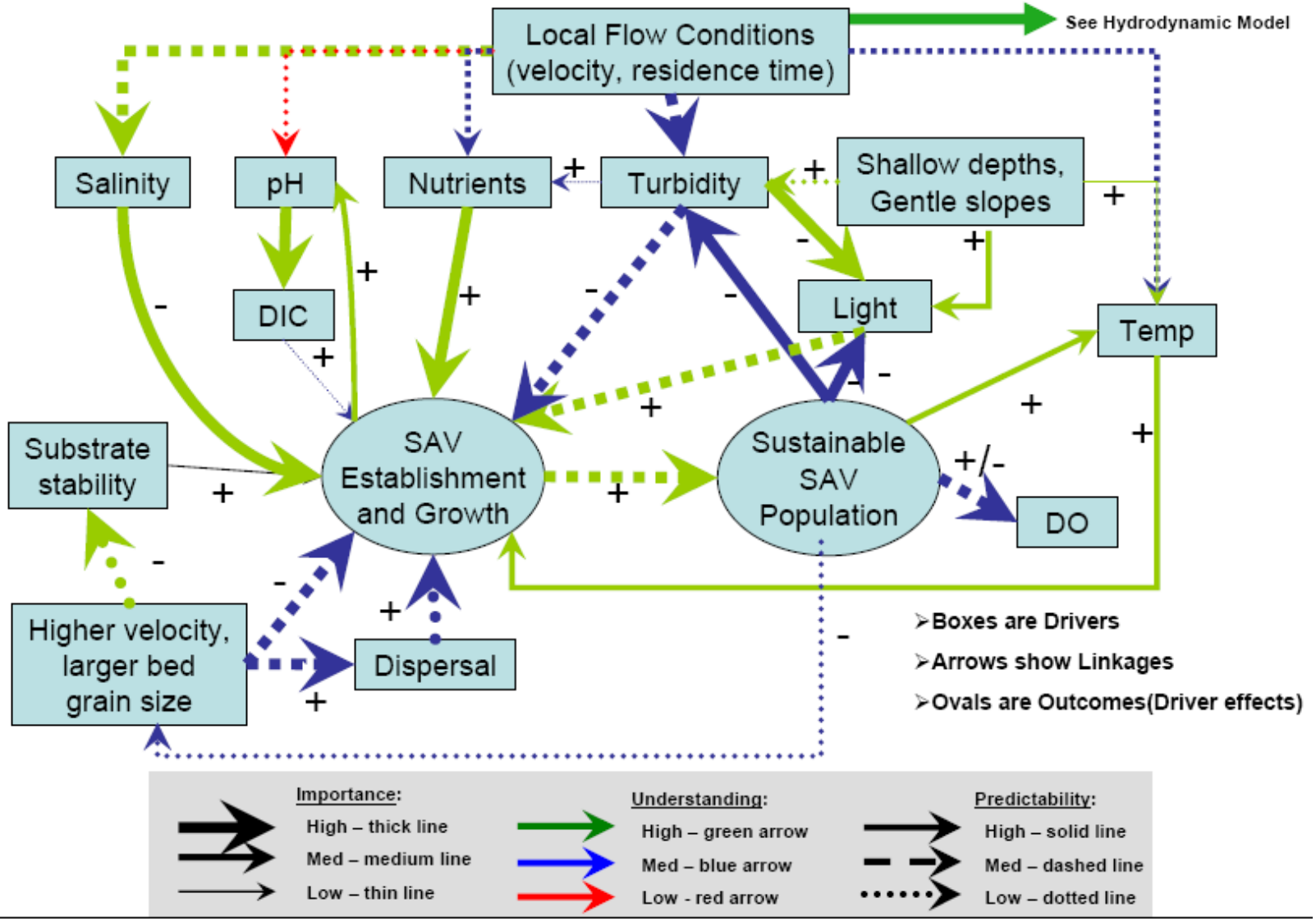

EFT
Western Pond Turtles
Steelhead
Bank swallows
Chinook
*
Cottonwood
Sturgeon
Focal species & habitats
Aquatic vegetation
Other (focal spp selection)
Delta fish habitat
Delta smelt & other POD species
Chinook
Tidal wetlands
Sacramento River Flows Study functional relationships (focused refinements)
Biophysical relationships (incld. existing models, data sets), alternative hypotheses
Quantification of existing conceptual models and sources (e.g., DRERIP)
Sacramento River
Trinity, Shasta (& other) dam operations
Ag & urban diversions
Levees, bank protection
Temperature controls
Gravel augmentation
SacEFT
Delta inflow
San Joaquin
Delta
Tracy (CVP), Banks (SWP) pumping plants
Delta Cross Channel gates
Delta geometry
In-delta Ag & urban diversions
DeltaEFT
Water delivery and exports

Build on DRERIP Conceptual Models

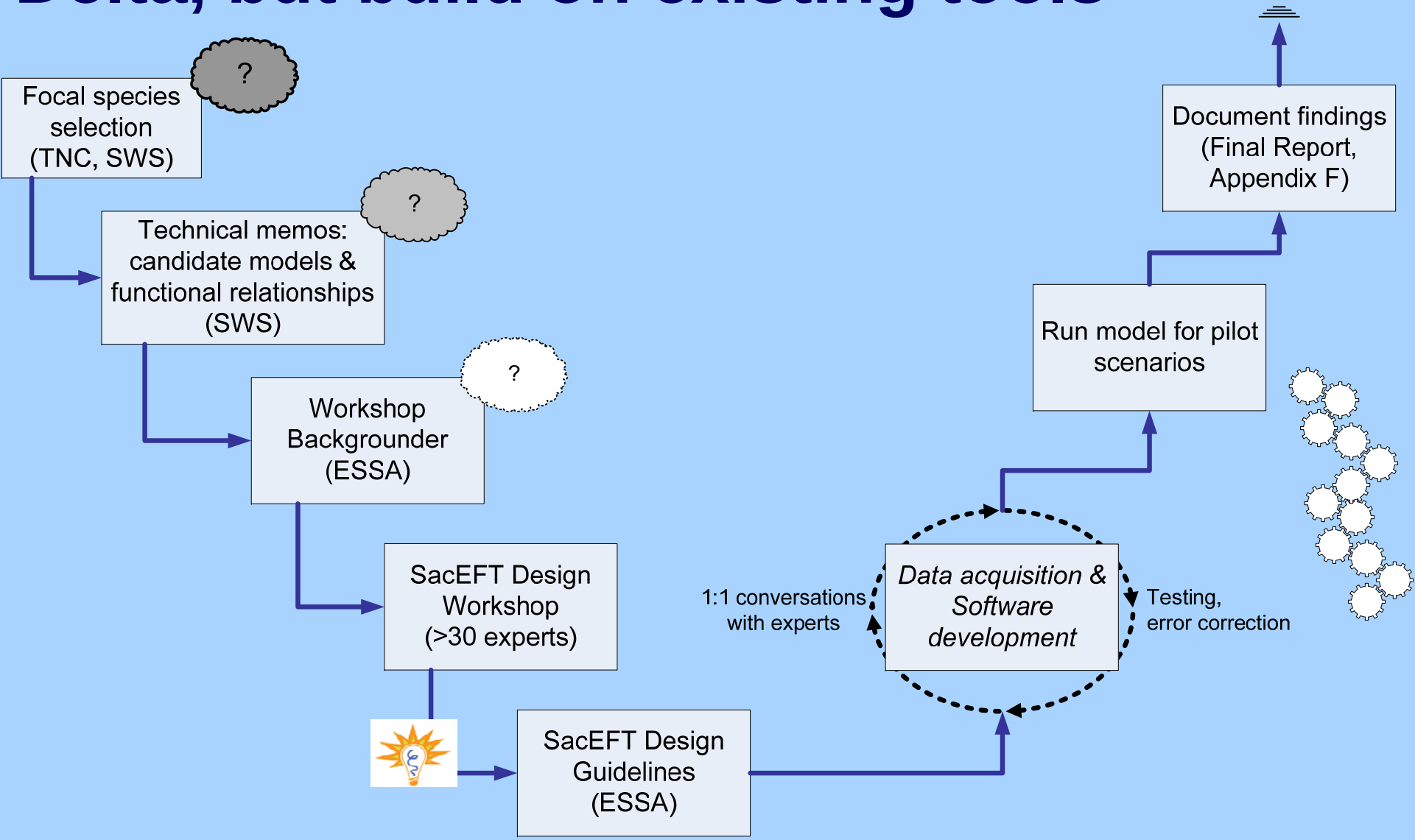
Ecosystem Models	Species Models
Aquatic food web	Sacramento splittail
Operations	Longfin smelt
Toxicity	Chinook salmon
Pyrethoroids	Steelhead
Mercury	Green sturgeon
Selenium	White sturgeon
Dissolved organic compounds	Delta smelt
Floodplains	Invasive clams
Tidal wetlands	Centrarchids
Sediment	
Transport	
Aquatic vegetation	
Riparian	
Dissolved oxygen	
Delta fish habitat	

DRERIP Conceptual Model Structure

Fig.2 Submersed Aquatic Vegetation Establishment, Growth and Dispersal Sub Model



Use similar development process in Delta, but build on existing tools



SacEFT ⇒ DeltaEFT

Finding acceptable, resilient, robust options:

- Intra-regional tradeoffs
- Inter-regional tradeoffs

Key Challenges for Delta Modeling

- Managing expectations
  - Exploration and relative comparison, not prediction
- What are “critical” hydro-ecological linkages?
  - Different decisions ⇒ space / time scales ⇒ tools
  - What’s well enough understood to be quantified?
  - How do we incorporate qualitative measures?
  - How can we bracket uncertainty?
- Can we:
  - use existing tools to explore *range* of possible futures?
  - put models into a decision analysis framework?
  - find most *robust, resilient* actions given uncertainties?
  - communicate results at multiple levels?
  - learn from natural variability, AM expts?

Further information

www.delta.dfg.ca.gov/erp/sacriverecoflows.asp

- Backgrounder Document
- Design Document
- Final Report + Appendix F

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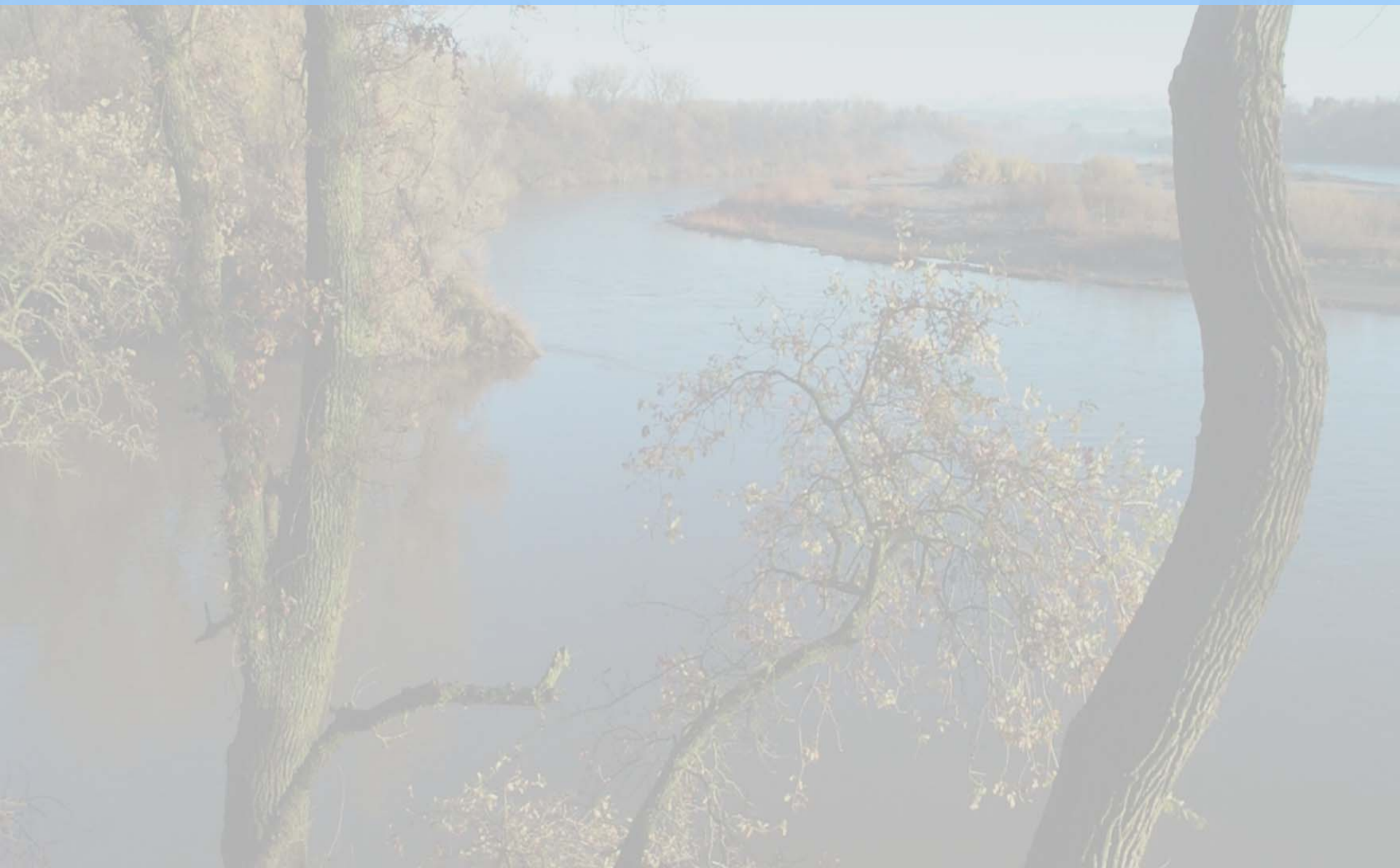
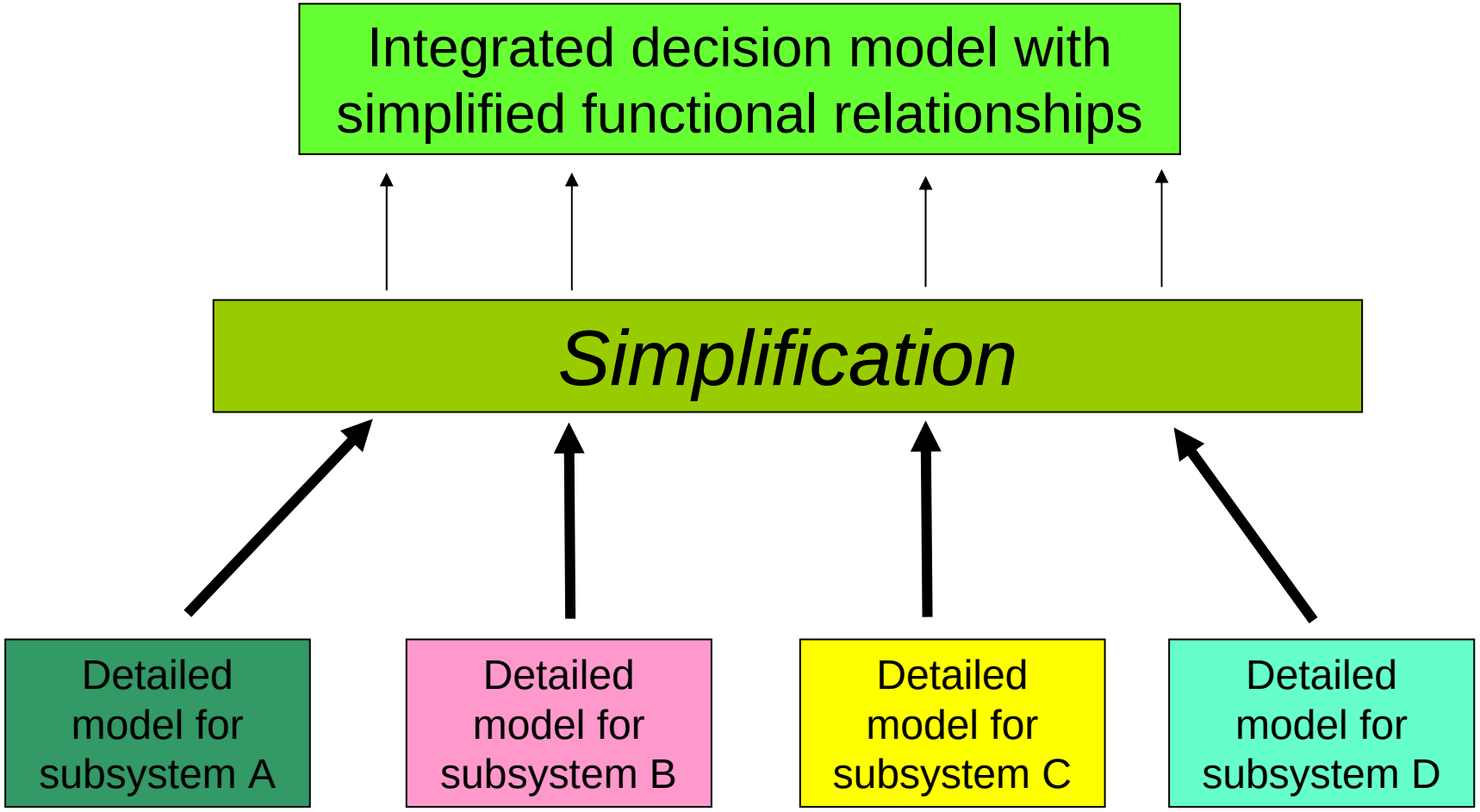
Questions?

Extra Slides



A hierarchy of models for the Delta?



Most Sensitive SacEFT Performance Measures

Action	Most Sensitive Performance Measures
Water temperature	Chinook and steelhead incubation and early rearing performance measures (lower water temperatures increase period of vulnerability)
Flow	Fremont cottonwood - initiation success (FC)
	Chinook and steelhead rearing weighted useable area (WUA) (CH2)
	Chinook and steelhead redd scour risk (CH5)
Rip rap removal (channel migration)	n/a
Gravel augmentation	Chinook and steelhead spawning WUA (CH1)