

Ecosystem Management under Uncertain Hydrologic Conditions

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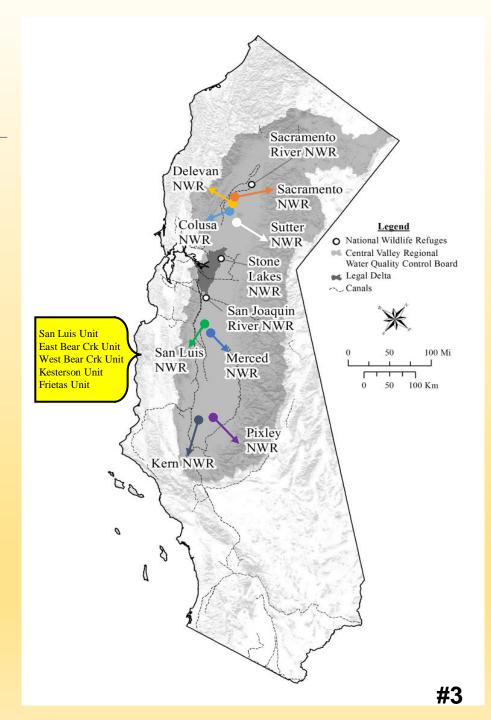
Outline

- 1. Study area and goals
- 2. Importance and relevance
- 3. Methods used

This is still a work in progress. We are not at a stage to start sharing results yet.

Study Area

- 12 wildlife refuges
- In Central Valley
- Managed by USFWS
- CVPIA authorized



Ecological Significance

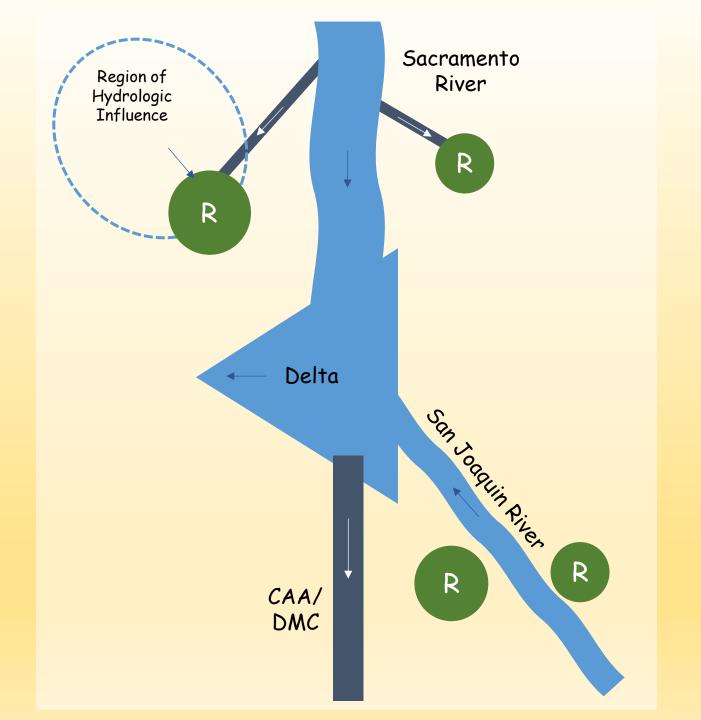
- Part of Pacific Flyway
- Provide essential food resources and resting places for migratory birds
- Home to several aquatic and wildlife species protected under ESA

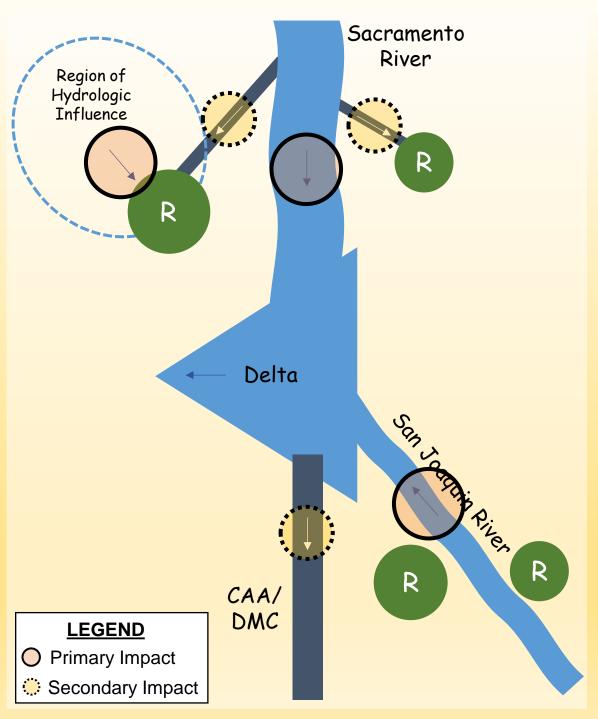




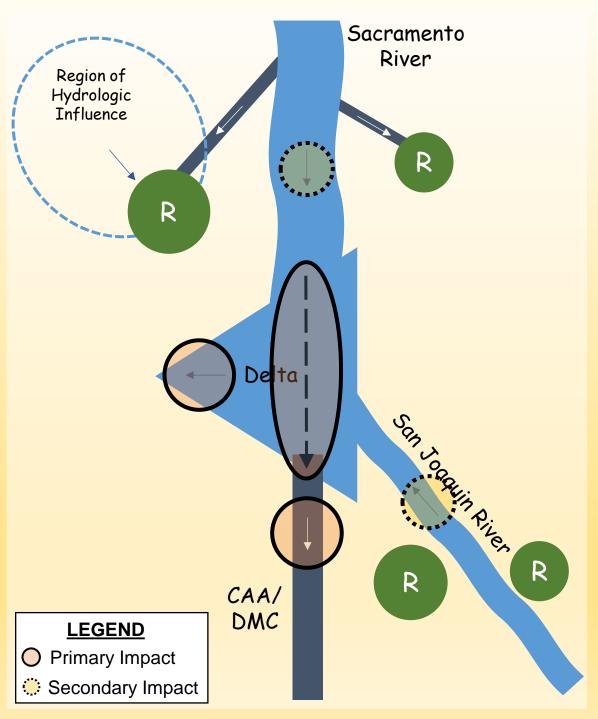
Goals

- Quantify economic and water supply impacts
- Evaluate adaptation strategies
- Develop a decision support tool

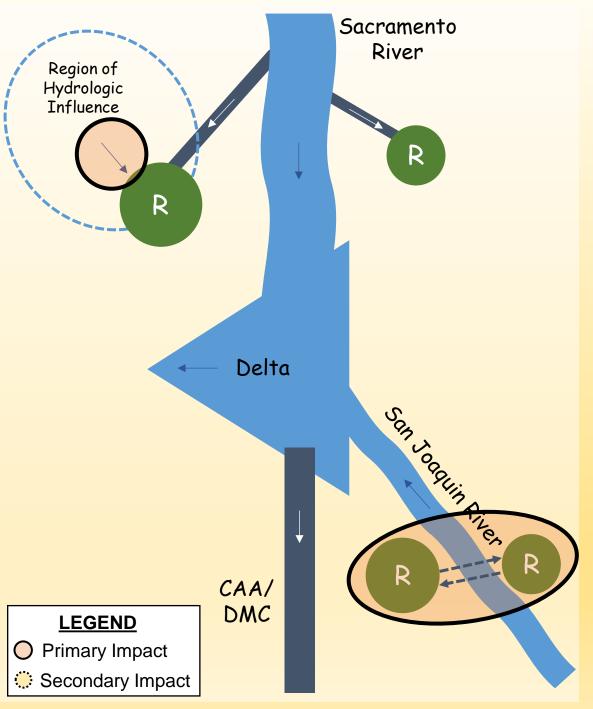




- Two climate scenarios
- Three water management scenarios
- Water trading and other alternatives



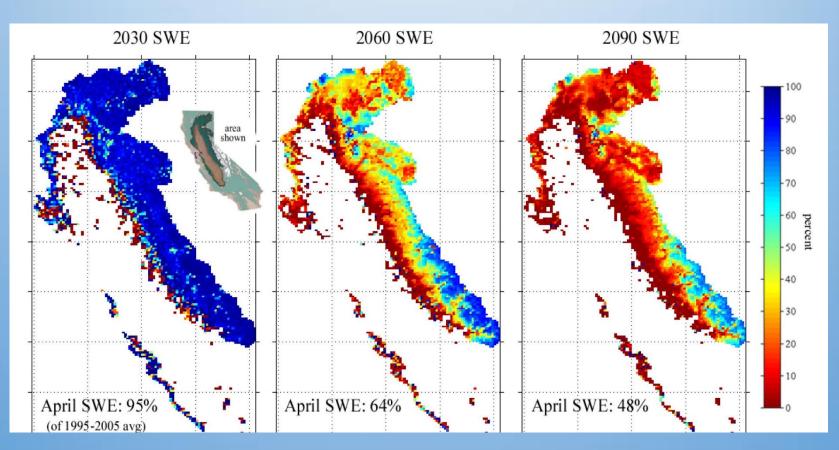
- Two climate scenarios
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- Water trading and other alternatives

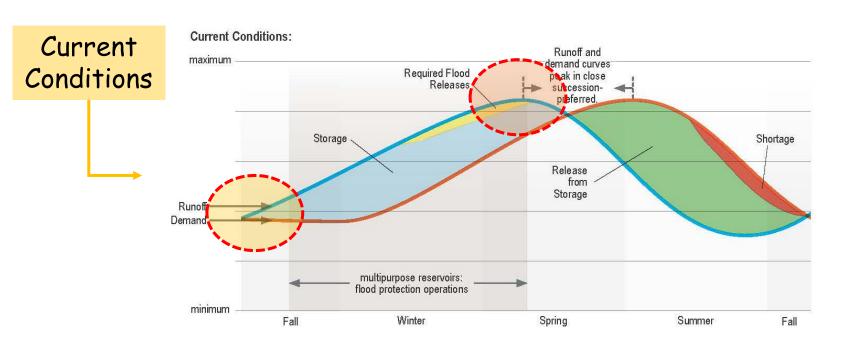


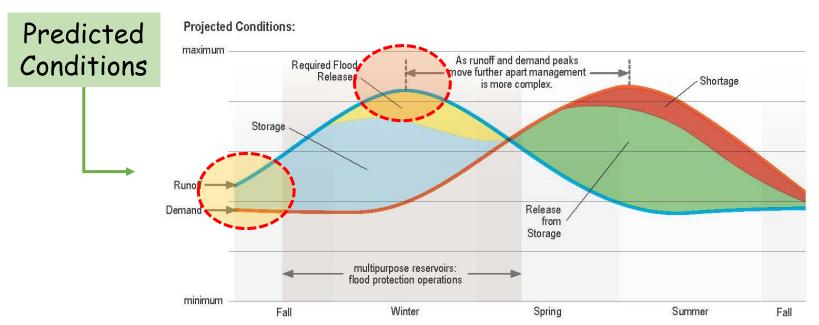
- Two climate scenarios
- Three water management scenarios
- Water trading and other alternatives

Importance

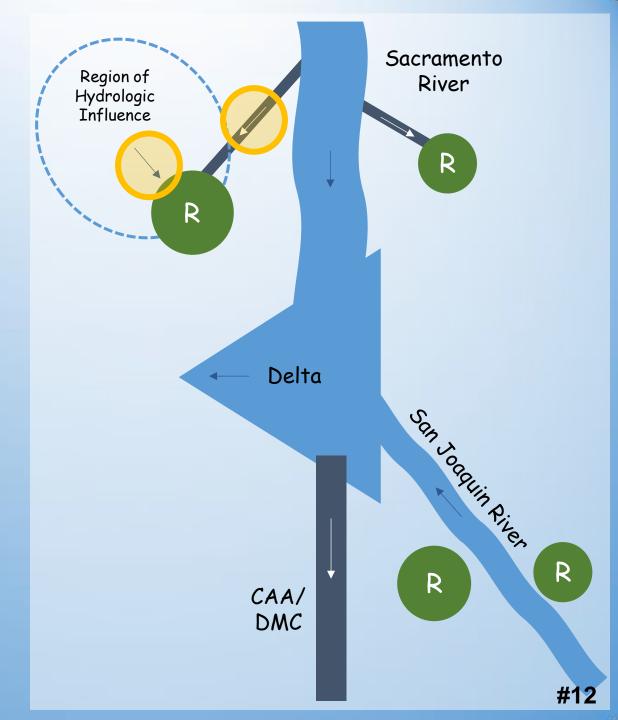
Warm-dry hydroclimatic conditions predicted



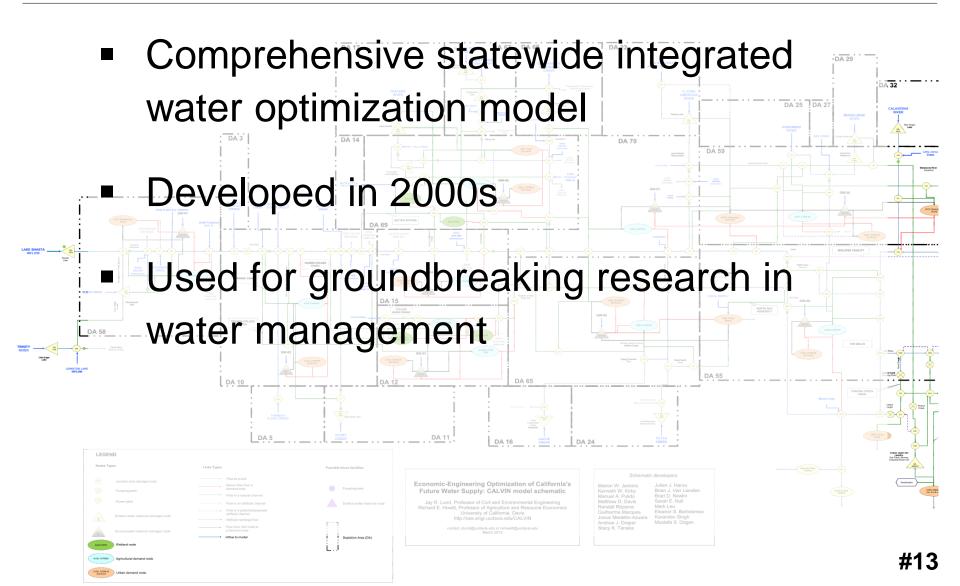




- Critical to quantify impact on refuge deliveries
- Equally important to assess impact in a statewide framework

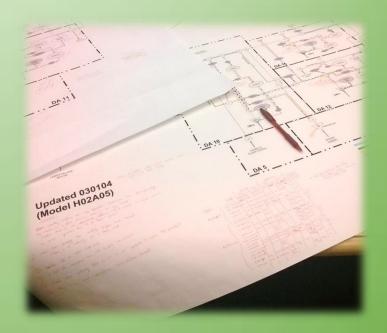


Overview of CALVIN

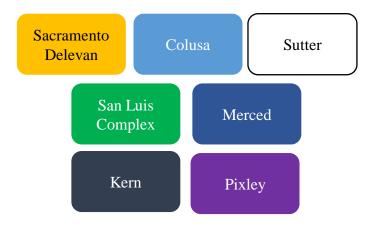


Method

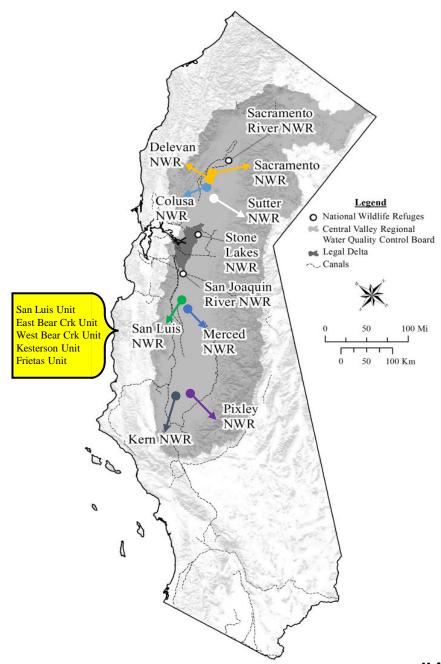
- Refuge representation
- Scenario runs
- Decision Support Tool

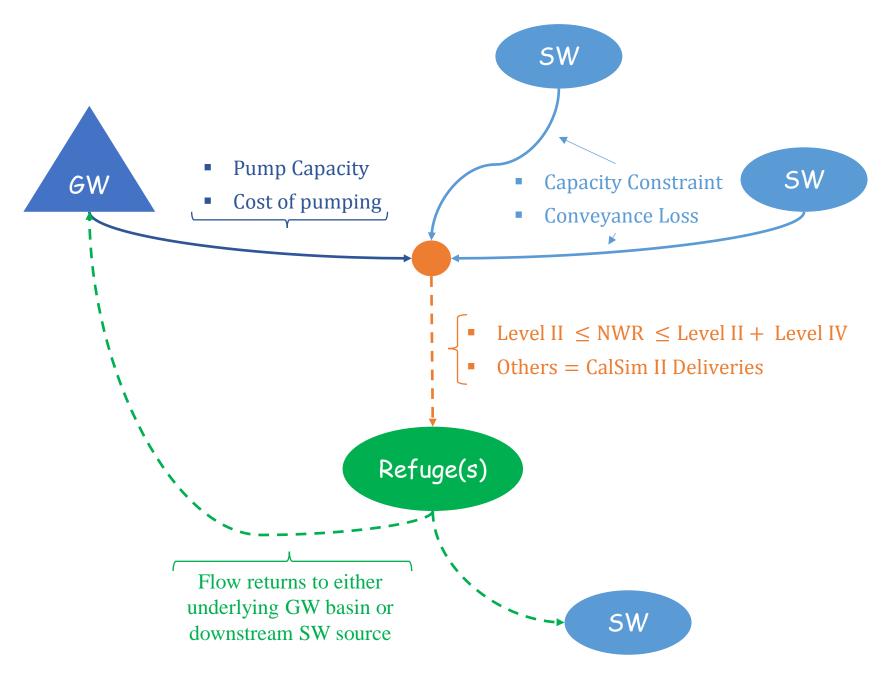


NWRs aggregated into seven nodes

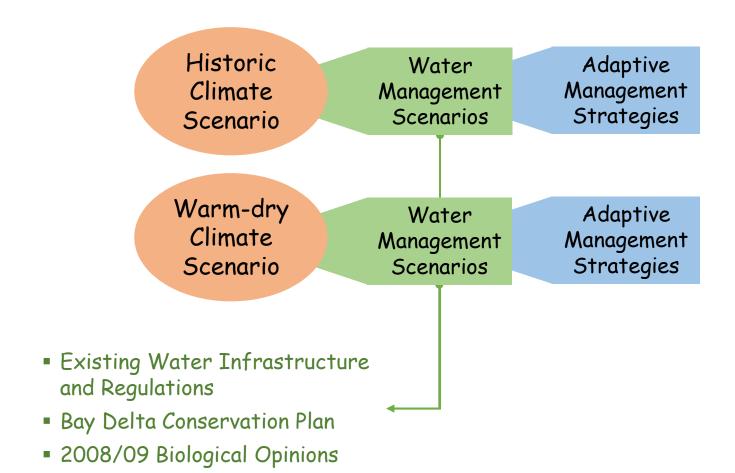


Followed CalSim II representation for other refuges





Scenario Runs



So far we have only examined the impact on the refuge deliveries, however, we have said nothing about improving refuge management.

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Decision Support Tool

1. Select CVPIA Refuge(s) to manage collectively

South of Delta

☐ San Luis Unit

☐ Kesterson Unit

☐ Freitas Unit

San Luis NWR Complex

☐ East Bear Creek Unit

■ West Bear Creek Unit

North of Delta

☐ Delevan NWR

☐ Colusa NWR

☐ Sutter NWR

South of Delta

☐ Merced NWR

☐ Kern NWR

☐ Sacramento NWR

Spreadsheet based simulation-optimization tool

Designed for refuge managers and USFWS staff responsible for annual and multi-year planning

□ I	Pixley NWR			•	outflow requiremen	its	deliveries.	
	ater allocatio			et Habitat Ac	reage O User	Defined O Defau	lt	
Use arr		rcent allocation scena	rio		Target Max	(acres)	Target Min (acres)
•	5	0%	Seasonal	Wetland				
Percent	allocation scenario is	used to determine:	Irrigated	Wetland				
	el II deliveries if using t d in the Drought Conti	he water delivery timeser incency Plan for the	Permane	ent Wetland				
simulat	tion or optimization ru		Semi-Per	rmanent Wetland				
	mum and minimum o used to define manage			naged Wetland				
5. Refu	uge Water St	pply Portfolio	2					
	Level II D	elivery (af)	Level IV D	elivery (af)	Other Sou	irces (af) ⁴	Precipita	ation (in)
	☐ Conveyano	ce Loss 1 50%	☐ Conveyance Loss 1 50%		Local SW	GW	1	
	User-defined ²	Final TS ³	User-defined ²	Final TS 3	User-defined ²	User-defined ²	User-defined ²	Final TS 3
Mar								
Apr								
May								
Jun								
Jul								

Conveyance loss: It is an on/off option. Check the box and type in an estimated percent conveyance loss value to consider conveyance loss in the analysis

values with values entered in the "User-defined" column.

Userdefined: Allow users to override any default values determined for Level II and Level IV deliveries, and precipitation. Users can enter a value for a particular month or leave the field blank. Final TS: The final timeseries used in the simulation-optimization analysis. This field will auto-populate values based on the choices users make in the previous modules as well as overrides default

"Other Source (af)": These options are user-defined options only. Unless users specify a value, a default value of zero will be assigned. This field includes local surface water supplies or GW pumping supplies in excess of Level II and Level IV deliveries. This could include pumped groundwater for procuring maintenance flows, riparian water rights, flood flows or drainwater supplie

2. Select simulation scenario

Historic Climate Conditions

O existing water management

O with more rigorous Delta

outflow requirements

O existing water management

Warm-Dry Climate Conditions

infrastructure

infrastructure

O with Peripheral Canal

O with more rigorous Delta

O with Peripheral Canal

Choose one

Simulation scenarios are based on the

Hydrologic Influence (RHI) is determined

for each refuge. Then, the impact of each

CALVIN model runs. Region of

simulation scenario on the RHI is

assessed as percent change in flows

percent change is applied to the

"Default" Level II and Level IV

Base case is defined as the historic

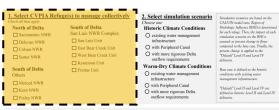
"Default" Level II and Level IV are

defined as historic Level II and Level IV

conditions with existing water

management infrastructure.

compared to the base case. Finally, the



Water allocation scenario	4. Target Habitat Acre	eage O User Def
e arrows to aejine the percent attocation scenario		Target Max (act
30%	Seasonal Wetland	
ercent allocation scenario is used to determine:	Irrigated Wetland	
) Level II deliveries if using the water delivery timeseries utlined in the Drought Contingency Plan for the	Permanent Wetland	
	Semi-Permanent Wetland	

Level IV Delivery (af)

	reage O User Defined O D	
	Target Max (acres)	Target Min (acres)
Seasonal Wetland		
Irrigated Wetland		
Permanent Wetland		
emi-Permanent Wetland		
Total Managed Wetland		

Other Sources (af) 4

Local SW

1. Select CVPIA Refuge(s) to manage collectively

Check all that apply South of Delta North of Delta San Luis NWR Complex ☐ Sacramento NWR San Luis Unit ☐ Delevan NWR East Bear Creek Unit ☐ Colusa NWR West Bear Creek Unit ☐ Sutter NWR Kesterson Unit **South of Delta** Freitas Unit Others ☐ Merced NWR ☐ Kern NWR ☐ Pixley NWR

ticular month or leave th out modules as well as or al surface water supplies	verrides default
	us modules as well as o

. Select CVPIA Refu back all that apply North of Delta	South of Delta	2. Select simulation scenario	Simulation scenarios are based on the CALVIN model nots. Region of Hydrologic Influence (RHI) is determined
Sacramento NWR Delevan NWR Colusa NWR Sutter NWR	San Luis NWR Complex San Luis Unit East Bear Creek Unit West Bear Creek Unit	Historic Climate Conditions O existing water management infrastructure O with Peripheral Canal O with more rigorous Delta outflow requirements	ryamong: requires (1871) is alternated for each spring. Then, the impact of each simulation scenario on the RHI is assented as percent change in plous compared to the base case. Finally, the percent change is applied to the "Default" Level II and Level IV deliveries.
South of Delta Others Merced NWR Kern NWR Pixley NWR	Freitas Unit	Warm-Dry Climate Conditions O existing water management infrastructure O with Peripheral Canal O with more rigorous Delta outflow requirements	Base case is defined as the historic conditions with existing water management infrastructure. "Default" Level II and Level IV are defined as historic Level II and Level IV deliveries.

Water allocation scenario	4. Target Habitat Ac	reage	O User Defined	С
e arrows to define the percent allocation scenario		т	arget Max (acres)	_
50%	Seasonal Wetland			_
	Irrivated Wetland			Τ
				_

2. Select simulation scenario

Choose one

Historic Climate Conditions

- O existing water management infrastructure
- O with Peripheral Canal
- O with more rigorous Delta outflow requirements

Warm-Dry Climate Conditions

- O existing water management infrastructure
- O with Peripheral Canal
- O with more rigorous Delta outflow requirements

Simulation scenarios are based on the CALVIN model runs. Region of Hydrologic Influence (RHI) is determined for each refuge. Then, the impact of each simulation scenario on the RHI is assessed as percent change in flows compared to the base case. Finally, the percent change is applied to the "Default" Level II and Level IV deliveries.

Base case is defined as the historic conditions with existing water management infrastructure.

"Default" Level II and Level IV are defined as historic Level II and Level IV deliveries.

	Other Sou	ırces (af) ⁴	Precipitation (in)		
,	Local SW	GW			
	User-defined ²	User-defined ²	User-defined ²	Final TS	
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theories, and precipitation. User care enter a value for a particular month or laune the field hypopalate values based on the choices users ranke in the previous modules as well as overside slap populate values of zero will be antigreal. This field includes local medicar water napplies or GW absence for procuring maintenance flows, openium unter-rights, flood flows or distinuous rights.

3. Water allocation scenario

Use arrows to define the percent allocation scenario



50%

Percent allocation scenario is used to determine:

- 1) Level II deliveries if using the water delivery timeseries outlined in the Drought Contingency Plan for the simulation or optimization runs, and
- 2) maximum and minimum constraints on the habitat acreage used to define management objectives.

orth of Delta	South of Delta	Historic Climate Conditions	Hydrologic Influence
Sacramento NWR	San Luis NWR Complex	O existing water management	for each refuge. Then simulation scenario o
Delevan NWR	☐ San Luis Unit	infrastructure	assessed as percent ch
Colusa NWR	■ East Bear Creek Unit	O with Peripheral Canal	compared to the base tercent change is are
Sutter NWR	■ West Bear Creek Unit	O with more rigorous Delta	"Default" Level II ar
J Daniel H W K	☐ Kesterson Unit	outflow requirements	deliveries.
outh of Delta	☐ Freitas Unit	Warm-Dry Climate Conditions	Base case is defined a
thers	L i i cius cini	O existing water management	conditions with existi
Merced NWR		infrastructure	management infrastr
		O with Peripheral Canal	"Default" Level II or
Kern NWR		O with more rigorous Delta	

1. Select CVPIA Refuge(s) to manage collectively 2. Select simulation scenario

■ 50%		Target Max (acres)	Target Min (acres)
30%	Seasonal Wetland		
Percent allocation scenario is used to determine:	Irrigated Wetland		
Level II deliveries if using the water delivery timeseries outlined in the Drought Contingency Plan for the	Permanent Wetland		
simulation or optimization runs, and 2) maximum and minimum constraints on the habitat	Semi-Permanent Wetland		
acreage used to define management objectives.	Total Managed Wetland		

	Level II D	Level II Delivery (af)		Level IV Delivery (af)		Other Sources (af) 4		Precipitation (in)	
	☐ Conveyance Loss ¹ 50%		☐ Conveyance Loss 1 50%		Local SW GW				
	User-defined ²	Final TS ³	User-defined ²	Final TS 3	User-defined ²	User-defined ²	User-defined ²	Final TS	
Mar									
Apr									
May									
Jun									
Jul									
Aug									
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Nov									
Dec									
Jan									
Feb									

- Consequence loss: It is an on/off option. Check the box and type in an estimated percent consequence loss value to consider conveyance loss in the analysis.

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- Final TS. Pind if the princip used in the simulation parameters analysis. This field will auto-populate values based on the choices neer waske in the previous mediales as well as oversides defined with values with values entered in the "User-defined" column.
- "Other Source (af)": These options are sear-defined options only. Unless users specify a value, a default value of zero will be assigned. This field includes local surface water supplies or GW pumping supplies in excess of Level II and Level IV deliveries. This could include bumped groundwater for procuring maintenance flows, riburian water rights, flood flows or dusinwater supplies.

4. Target Habitat Acreage O User Defined O Default

	Target Max (acres)	Target Min (acres)
Seasonal Wetland		
Irrigated Wetland		
Permanent Wetland		
Semi-Permanent Wetland		
Total Managed Wetland		

5. Refuge Water Supply Portfolio

	Level II Delivery (af)		Level IV Delivery (af)		Other Sou	irces (af) ⁴	Precipitation (in)	
	☐ Conveyanc	ee Loss ¹ 50%	☐ Conveyance	e Loss ¹ 50%	Local SW	GW		
	User-defined ²	Final TS ³	User-defined ²	Final TS ³	User-defined ²	User-defined ²	User-defined ²	Final TS ³
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
Jan								
Feb								

I. Select CVPIA Re
Check all that apply
North of Delta
Sacramento NWR
Delevan NWR
Colusa NWR
Sutter NWR
South of Delta

Others

Merced NWR

Kem NWR

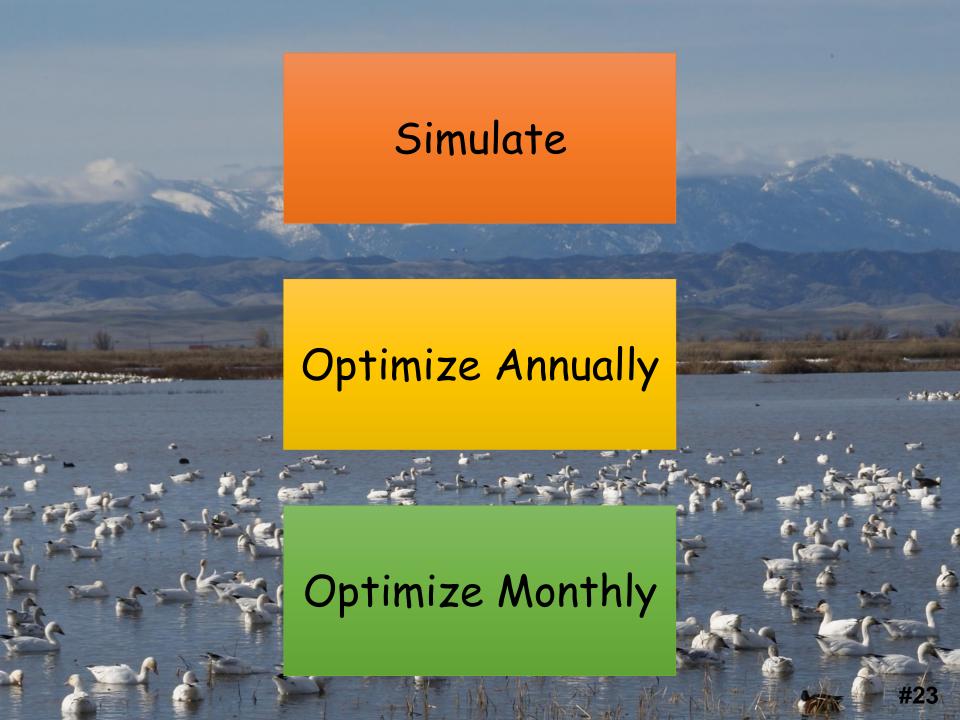
Pixley NWR

3. Water allocation
Use arrows to define the perce
503
Percent allocation scenario is not

- . Conveyance loss: On/off option. Check the box and type in an estimated percent conveyance loss value to consider conveyance loss in the analysis.
- 2. User-defined: Allows users to overwrite default values. Users can enter a value for a particular month or leave the field blank.
- 3. Final TS: The final timeseries used in the simulation-optimization analysis.
- 4. "Other Source (af)": These options are user-defined options only. Unless users specify a value, a default value of zero will be assigned. This field includes local surface water supplies or GW pumping supplies in excess of Level II and Level IV deliveries. This could include pumped groundwater for procuring maintenance flows, riparian water rights, flood flows or drainwater supplies.

Percent allocation scenario is use		
Level II deliveries if using the water delivery timeseries outlined in the Drought Contingency Plan for the	Permanent Wetland	
simulation or optimization rurs, and 2) maximum and minimum constraints on the habitat	Semi-Permanent Wetland	
acreage used to define management objectives.	Total Managed Wetland	

	Level II Delivery (af)		Level IV Delivery (af)		Other Sources (af) 4		Precipitation (in)	
	☐ Conveyance	e Loss 1 50%	☐ Conveyano	e Loss 1 50%	Local SW	GW		
	User-defined ²	Final TS ³	User-defined ²	Final TS ³	User-defined ²	User-defined ²	User-defined ²	Final TS ³
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
Jan								
Feb								



Optimization Objective

"The needs of wildlife and their habitats come first on refuges, in contrast to other public lands managed for multiple uses."

Construction of the second second

"Seasonal wetlands and other habitats at the Complex provide essential food resources and resting areas for winter residents, birds continuing south, and returning spring migrants..."

> -Comprehensive Conservation Plan (USFWS, 2009)

Objective: Maximize total habitat acreage

LP Formulation

$$Max\left\{\sum_{i} HabitatAcreage_{i}\right\}$$

Subject to

WaterDemand ≤ WaterSupply

 $MinHabitatAcreage_i \le HabitatAcreage_i \le MaxHabitatAcreage_{i,k}$

Where

i = Habitat land-use types

j = Month

k = Allocation scenarios: 100%, 75%, 50%, and 25%

WaterDemand_i

$$= \sum_{i} HabitatAcreage_{i,t-1} * HabitatWaterDemand_{i,j} \\ + \sum_{\cdot} HabitatAcreage_{i,t} * HabitatWaterDemand_{i,j}$$

	Seasonal Wetland	Irrigated Wetland	Permanent Wetland	Semi- permanent Wetland
March	0.50	0.50	0.50	0.50
April	0.00	1.00	1.00	1.00
May	0.00	0.00	1.50	1.00
June	0.00	1.50	2.00	2.00
July	0.00	0.00	2.00	1.00
August	0.50	0.00	2.00	0.00
September	2.00	2.00	1.75	0.00
October	1.00	1.00	1.00	2.00
November	0.75	0.75	0.75	0.75
December	0.25	0.25	0.25	0.25
January	0.25	0.25	0.25	0.25
February	0.25	0.25	0.25	0.25

WaterSupply_{j,k}

 $= (1 - LossL2) * L2_{j,k} + (1 - LossL4) * L4_{j,k} + Precip_{j}$ $* TotalMaxAcreage_{k} + LocalSWInflow_{i}$

+ GWExcessL2L4;

3. Water allocation scenario

Use arrows to define the percent allocation scenario



50%

5. Refuge Water Supply Portfolio									
	Level II Delivery (af)		Level IV Delivery (af)		Other Sources (af) 4		Precipitation (in)		
	☐ Conveyanc	ee Loss ¹ 50%	☐ Conveyance Loss ¹ 50%		Local SW	Local SW GW			
	User-defined ²	Final TS ³	User-defined ²	Final TS ³	User-defined ²	User-defined ²	User-defined ²	Final TS ³	
Mar									
Apr									
May									
Jun									
Jul									
Aug									
Sep									
Oct									
Nov									
Dec									
Jan									
Feb									

#27

$MinHabAcreage_i = OR(0, User Defined_i)$

MaxHabAcreage_{i,k}

- $= OR(MaxPercentAllocation_k)$
- * HistMaxAcreage_i, User Defined_i)

4. Target Habitat Acreage O User Defined O Default Target Max (acres) Target Min (acres) Seasonal Wetland Irrigated Wetland Permanent Wetland Semi-Permanent Wetland Total Managed Wetland

Major Habitat type	100%	75%	50%	25%
Seasonal Wetland	1	0.9	0.5	0
Irrigated Wetland	1	0.9	0.5	0
Permanent Wetland	1	0.5	0.25	0.2
Semi-permanent Wetland	1	0.5	0.25	0.2
Total habitat acreage (<u>acres</u>)	1	0.9	0.7	0.4

Results

- Work in progress
- Competing water demands
- Water trading will increase refuge habitat and reduce scarcity



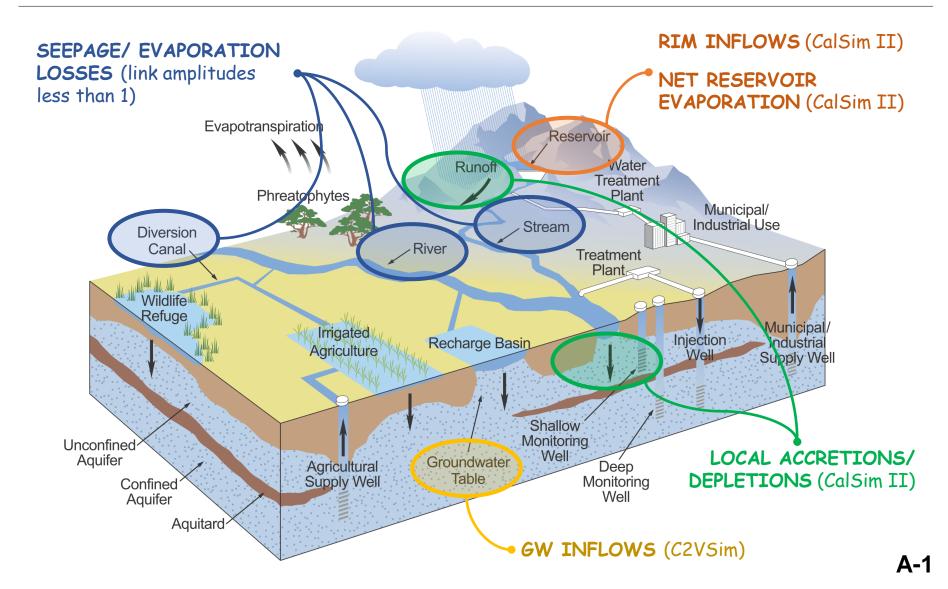
Karandev Singh kvsingh@ucdavis.edu



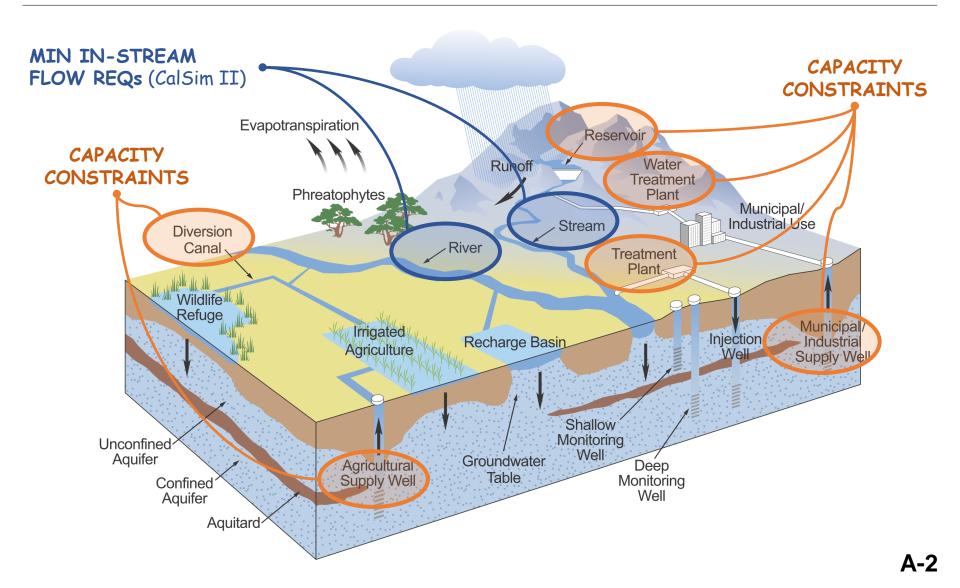
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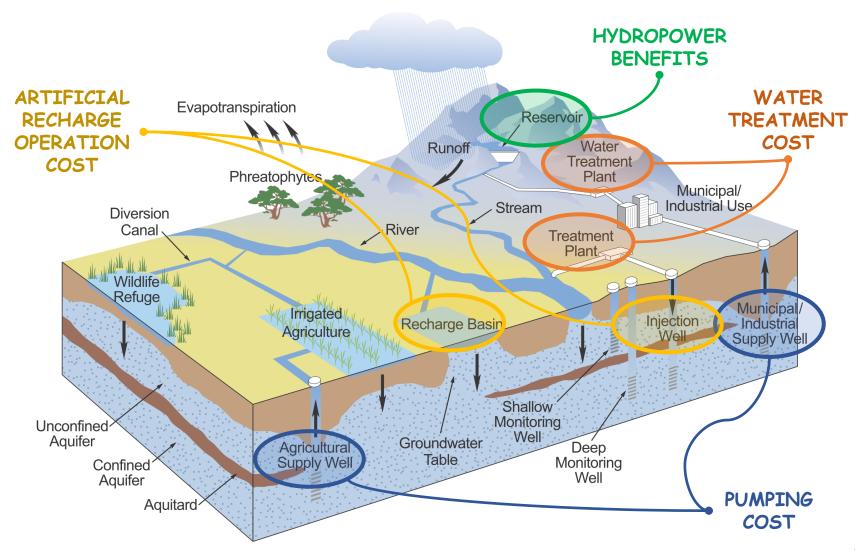
CALVIN Hydrology



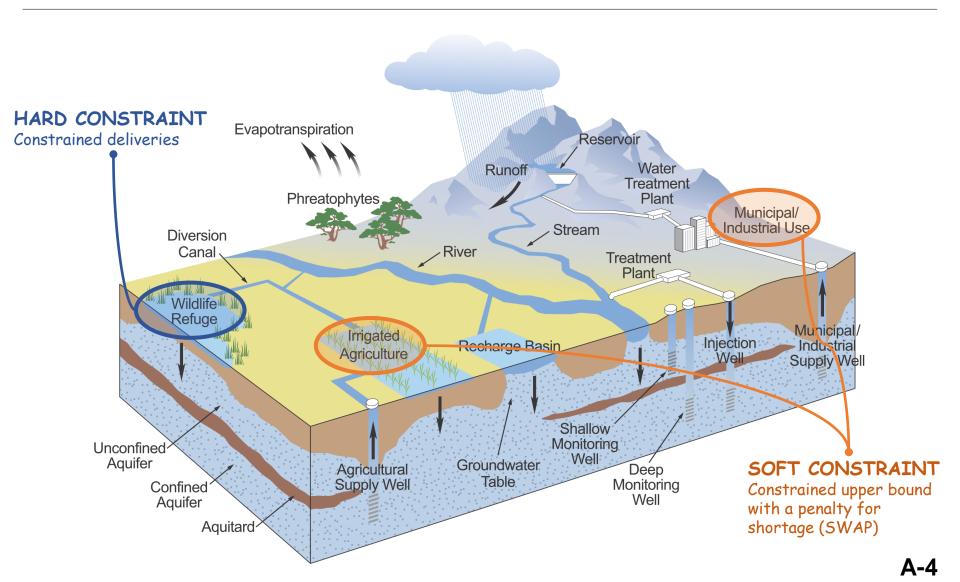
CALVIN Constraints



CALVIN Operating Costs



CALVIN Demands



CALVIN Outputs

