Irrigated lands water budget

Stephen Hundt

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Context

Where we are

The modeling process

Define problem
- Literature review
- Preliminary analyses
- Data collection

Develop conceptual model
- Processes/ budget
- Boundary conditions
- Hydrogeologic framework
- Data collection

Develop mathematical model
- Choose model code
- Choose how to represent processes and boundary conditions
- Construct the model

Calibration
- History matching
- Sensitivity analysis
- Data collection

Assessment of problem using model

and objective based on simulation results

Project completion

After Reilly (2001) TWRI 3,B8

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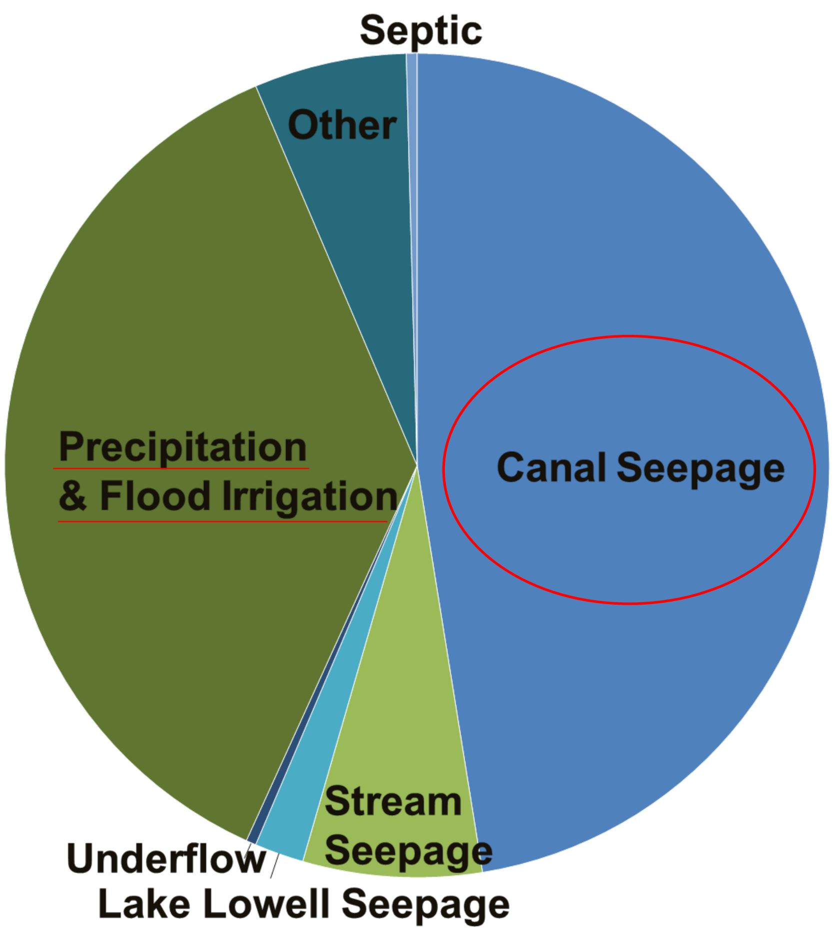
Importance

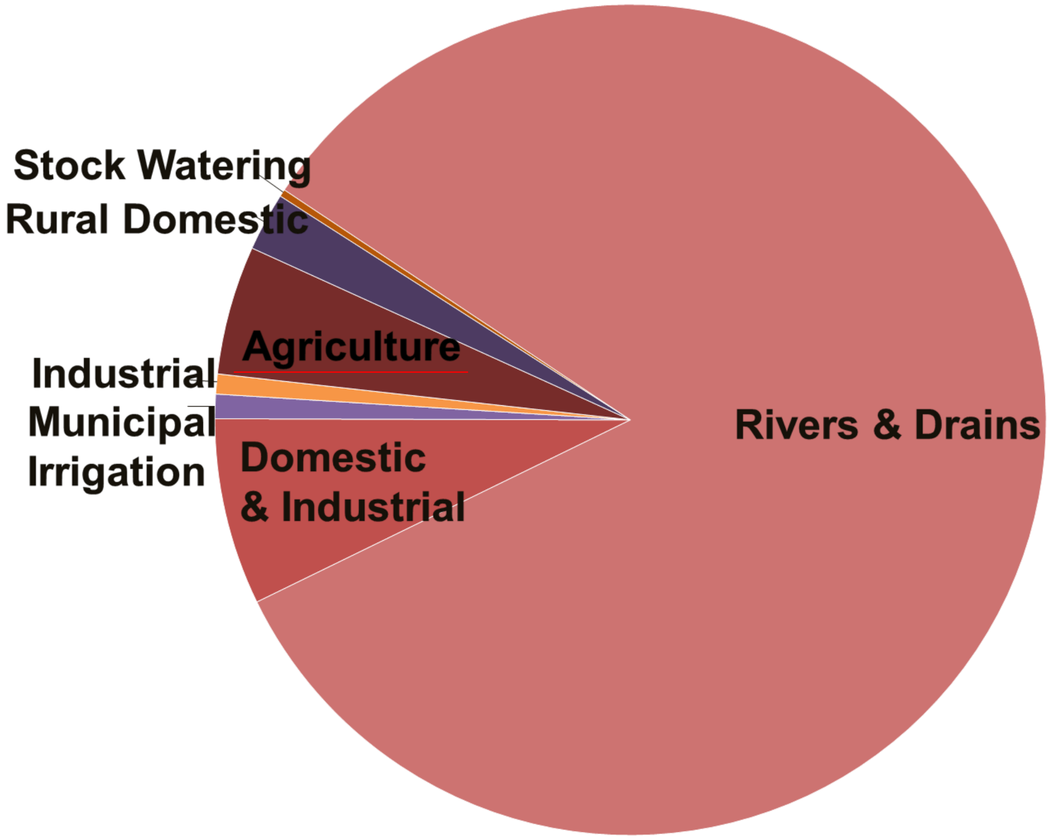
Recharge from precipitation and applied irrigation are significant portion of total inflows

Pumping is a large outflow

Inflows
(Urban, 2004)



Outflows
(Urban, 2004)



Importance

Recharge from precipitation and applied irrigation are significant portion of total inflows

Pumping is a large outflow

Groundwater budget, mean 1967-1997 conditions

Budget Component	Inflows: Volume (acre-ft/yr)	Inflows: Percentage of total inflow	Outflows: Volume (acre-ft/yr)	Outflows: Percentage of total outflow
Canal seepage	702,375	48%	--	--
Total on-farm infiltration (irrigation and precipitation)	674,699	46%	--	--
Tributary underflow (north of Payette River)	59,389	4.1%	--	--
Direct precipitation (non-irrigated lands)	23,470	1.6%	--	--
Direct precipitation (domestic, commercial, municipal, and industrial lands)	1,793	0.12%	--	--
Groundwater discharge to drains	--	--	785,216	51%
Groundwater discharge to rivers	--	--	501,802	33%
Pumping (irrigation)	--	--	136,147	8.9%
Pumping (domestic, commercial, municipal, and industrial)	--	--	85,834	5.6%
Aquifer discharge to wetlands	--	--	21,339	1.4%
Aquifer discharge to Lake Lowell	--	--	3,752	0.24%
Totals	1,461,726		1,534,090	

Schmidt and others (2008) and Sukow (2012)

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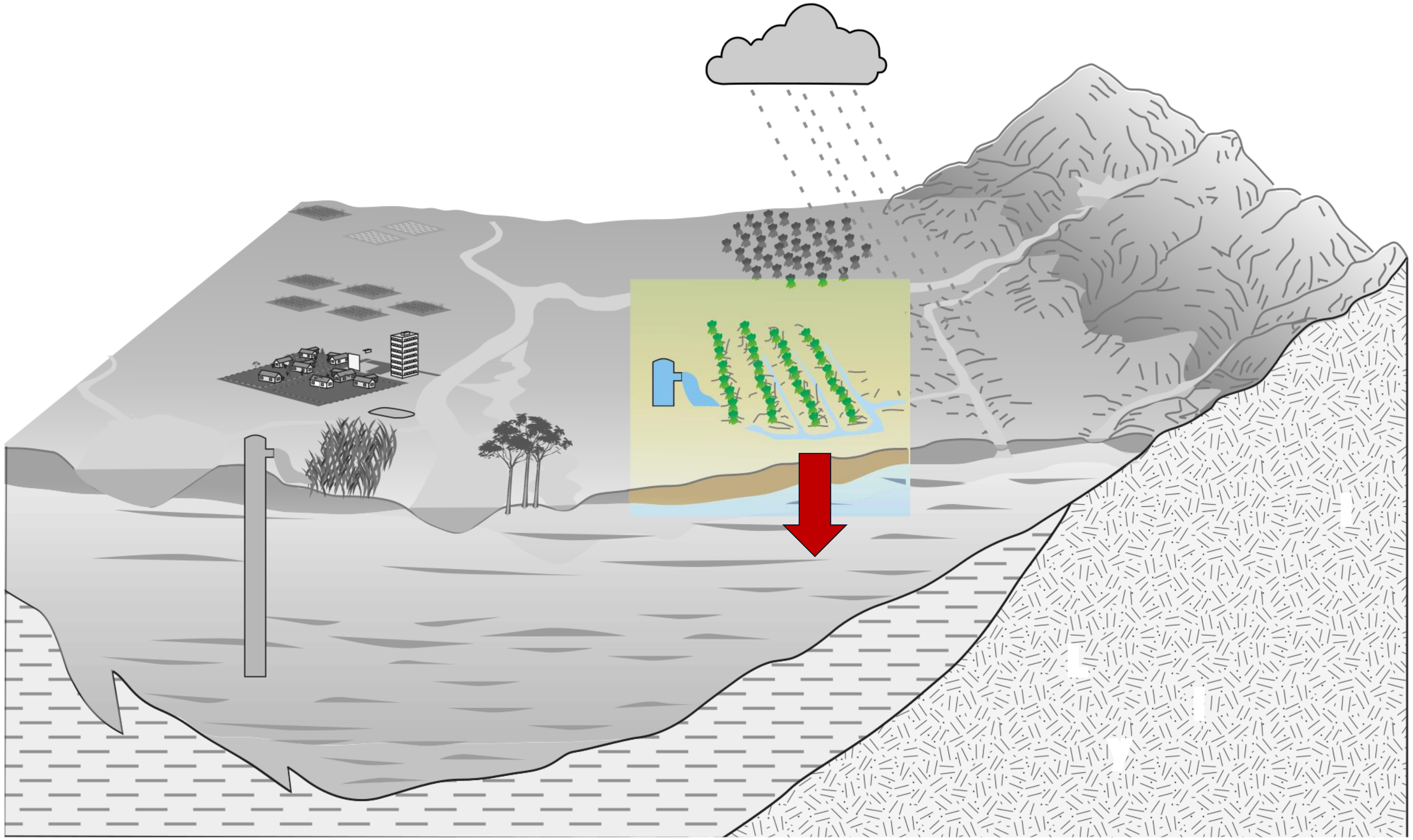
What we need

Groundwater fluxes due to irrigation

Deep percolation of applied irrigation water



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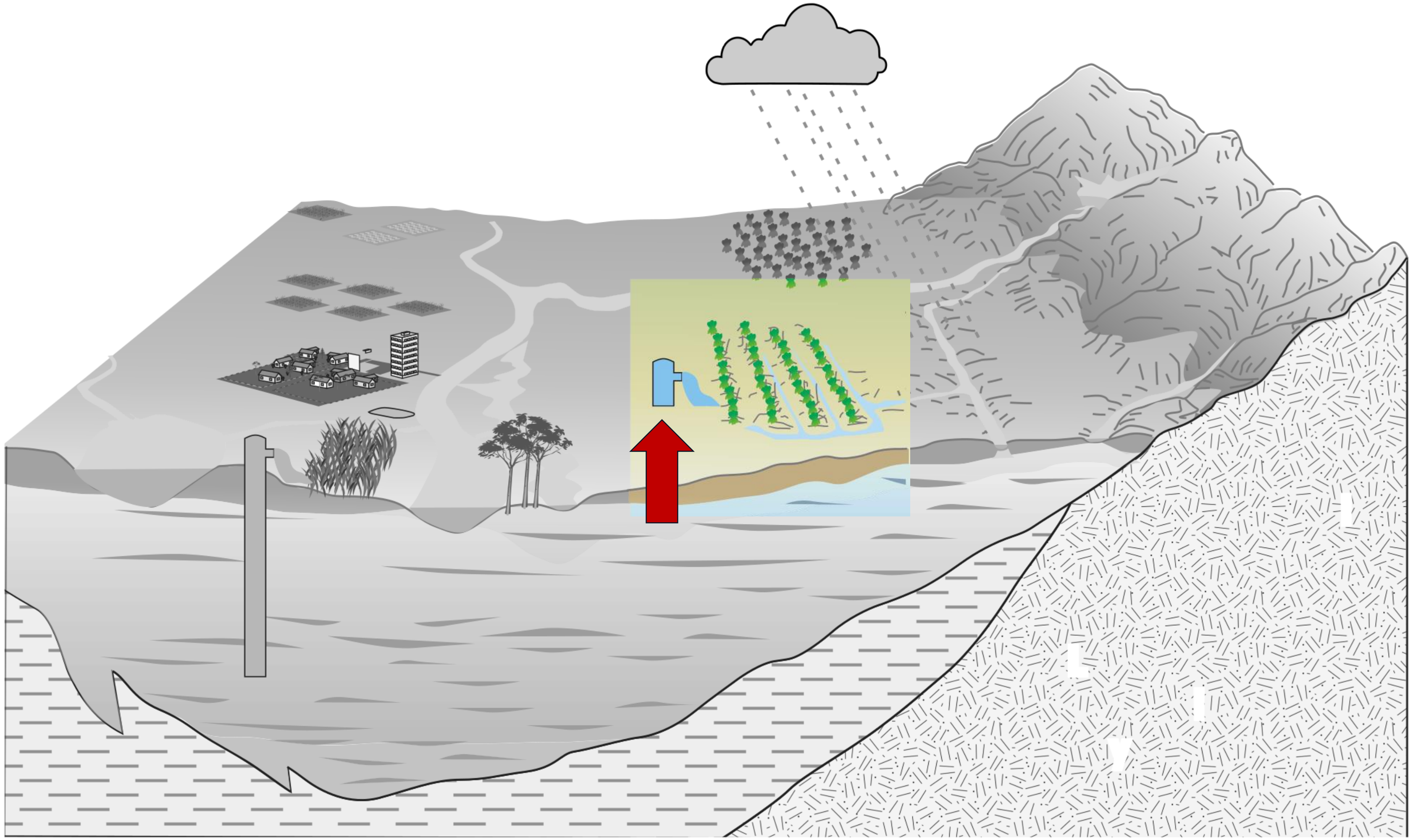
Groundwater fluxes due to irrigation

Groundwater pumping



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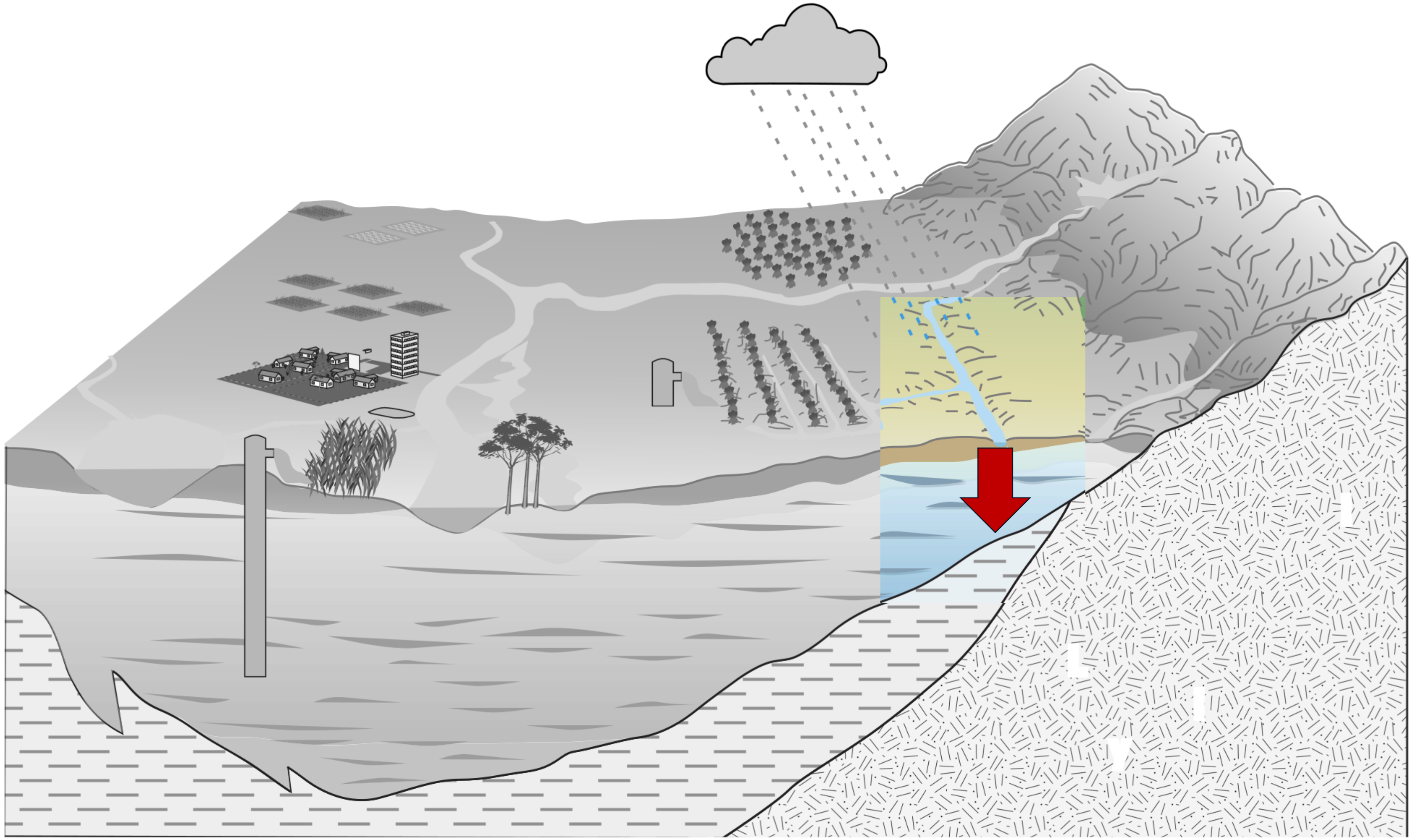
Related groundwater fluxes

Canal leakage



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How we get there

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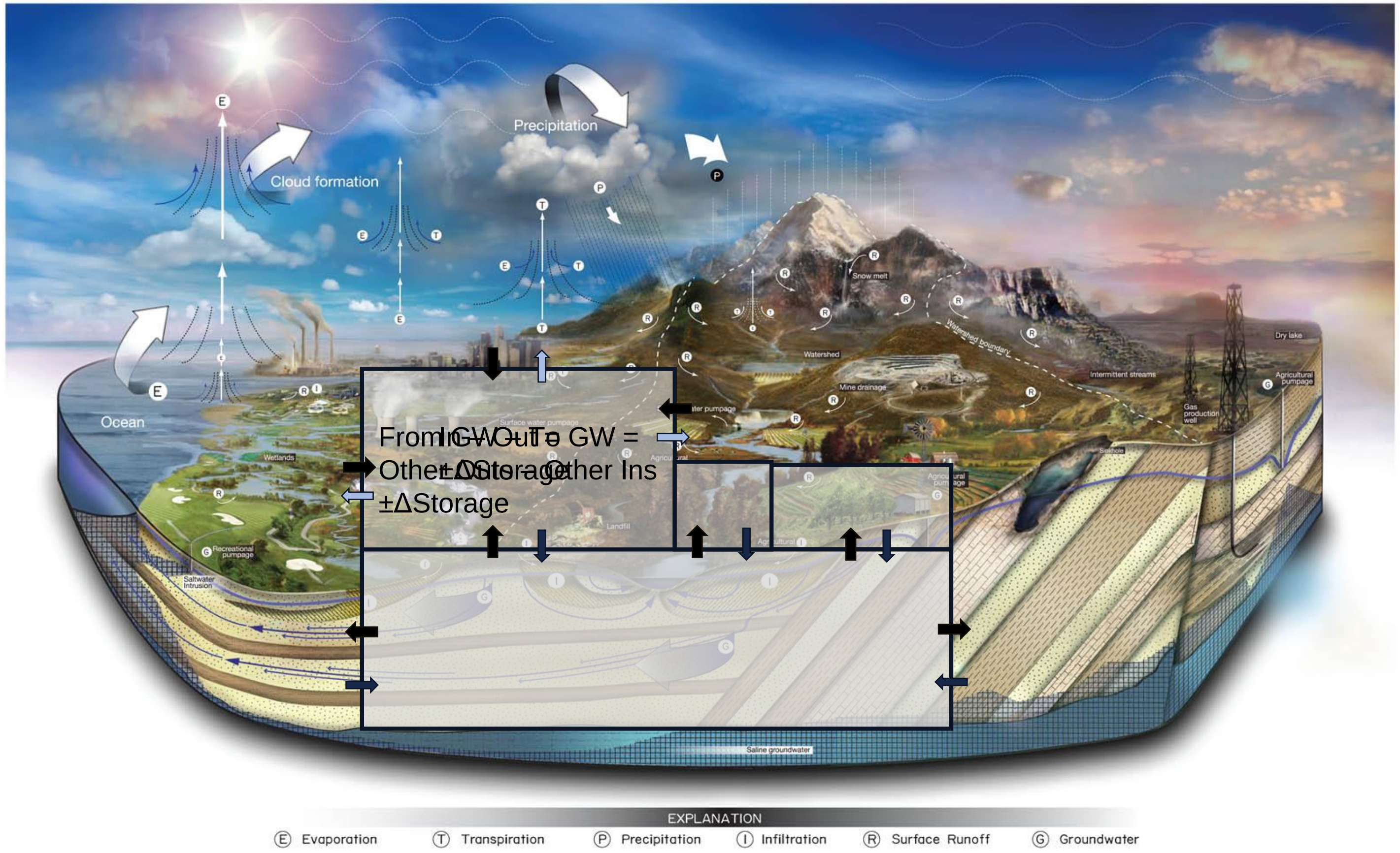
Ideal: direct measurements of fluxes

Water budget approach

Calculate component(s) of interest as remainder of a water balance formula



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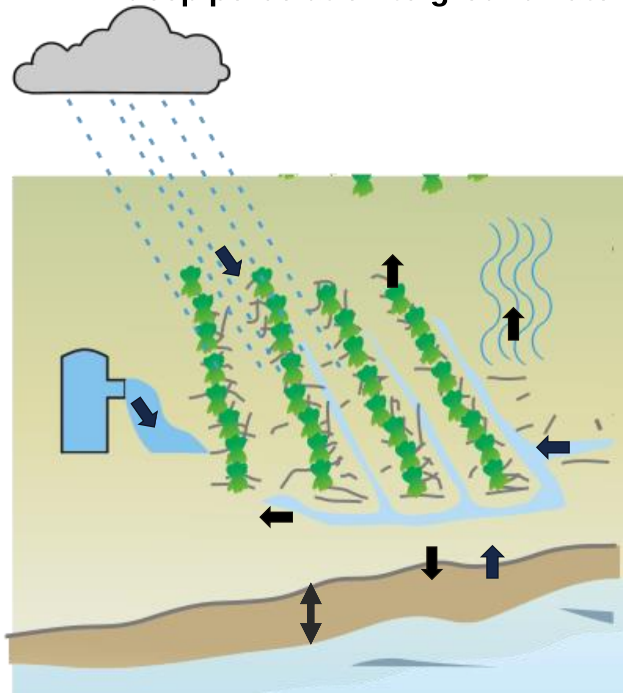
Water budget approach

Calculate component(s) of interest as remainder of a water balance formula

$$\text{In} \quad - \quad \text{Out} \quad = \quad \pm\Delta\text{Storage}$$

In	Out	±ΔStorage
precipitation	evaporation (irrigation and bare soil)	Δ soil moisture
surface water deliveries	transpiration	
groundwater deliveries	runoff	
groundwater uptake	**deep percolation to groundwater**	



Agricultural Soil

(modified from Faunt, 2009)

Known and unknown quantities

Unknown	~Known
Unmeasured well rates (most)	Municipal well rates (some)
Canal leakage volumes	Evapotranspiration
Deep percolation of irrigation water (incidental recharge)	Precipitation
	Surface water diversions & destinations
	Land use
	Well locations, classification, and screen depths (many)
Throughflow of canal water (tail water)	
Soil moisture storage characteristics	

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Spatial scale

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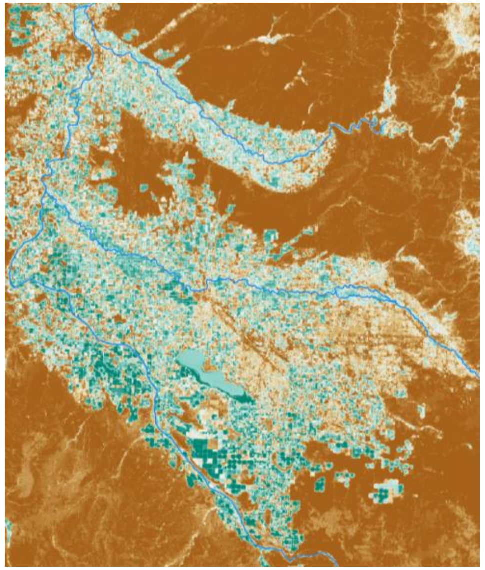
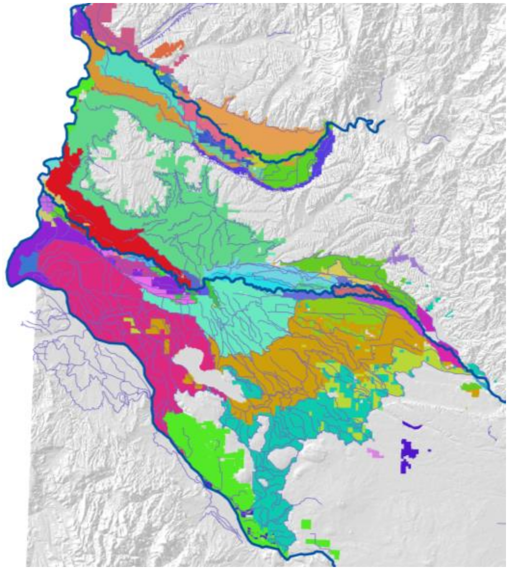
Distributed, district, or point

Distributed



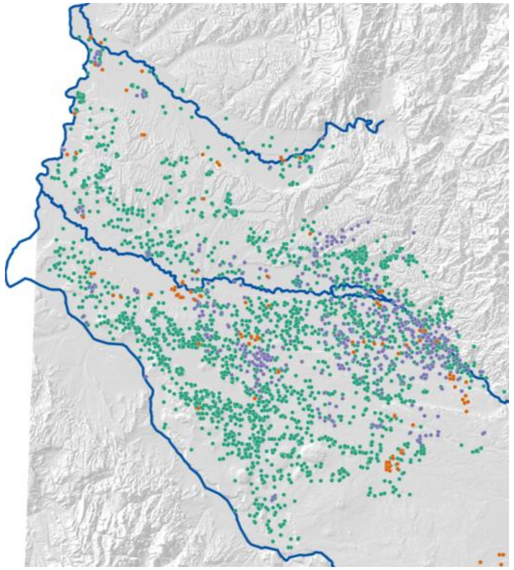
evapotranspiration
precipitation

District



surface water deliveries

Point



well locations
well rates

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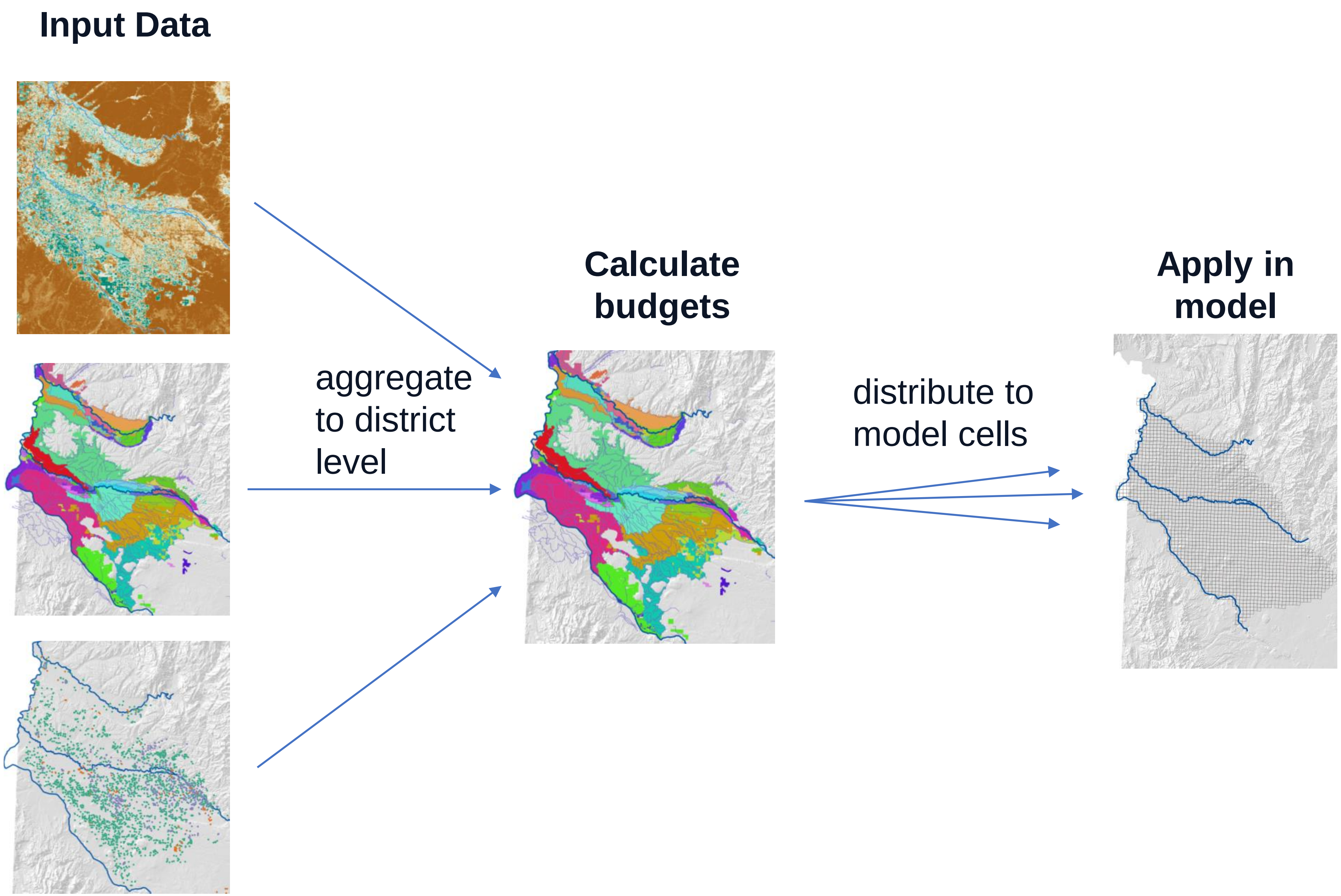
Calculations



Estimating component volumes

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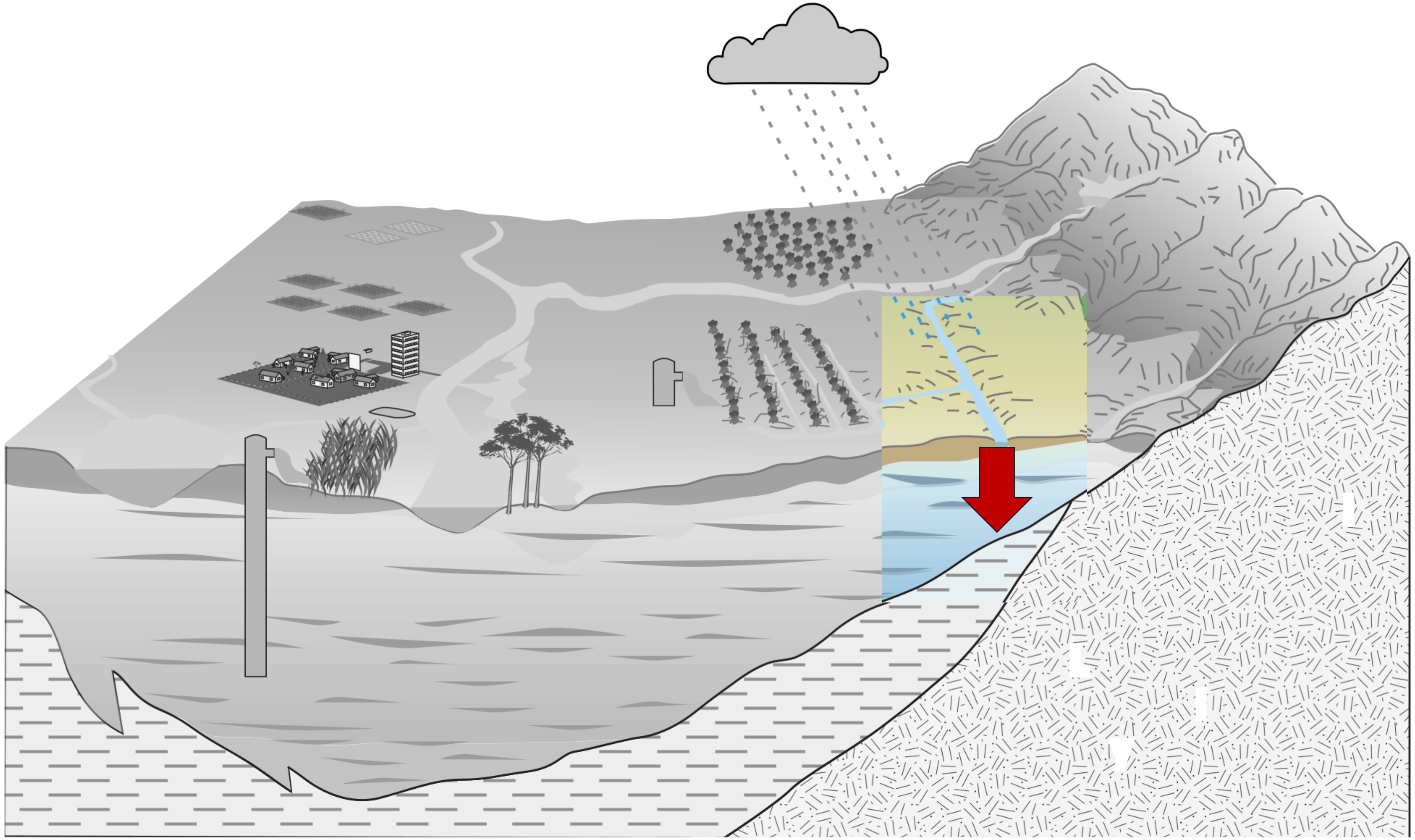
Surface water system budget



(modified from Faunt, 2009)

Surface water system budget

$$\text{In} - \text{Out} = \cancel{\pm\Delta\text{Storage}}$$

$$\text{In} = \text{Out}$$

- Diversions (div)
- Precipitation (ppt)

- Evapotranspiration (et)
- Leakage (leak)
- Through flow (tail) + Ag runoff
- Net Deliveries (deliv)

$$\text{div} + \text{ppt} = \text{et} + \text{leak} + \text{tail} + \text{deliv}$$

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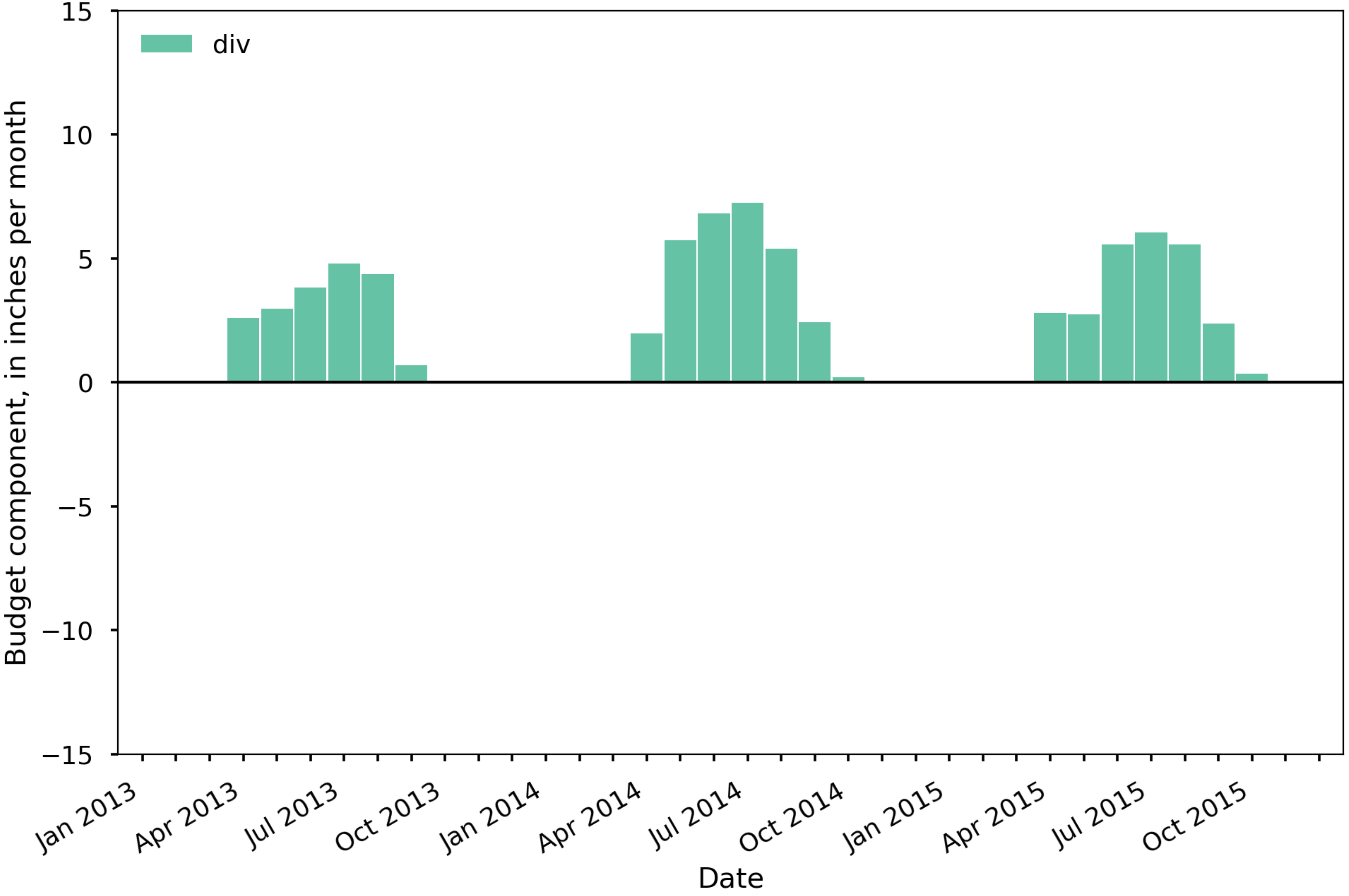
Surface water system budget: Inflows

Diversions

div + ppt = et + leak + tail + deliv



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Surface water system budget: Inflows

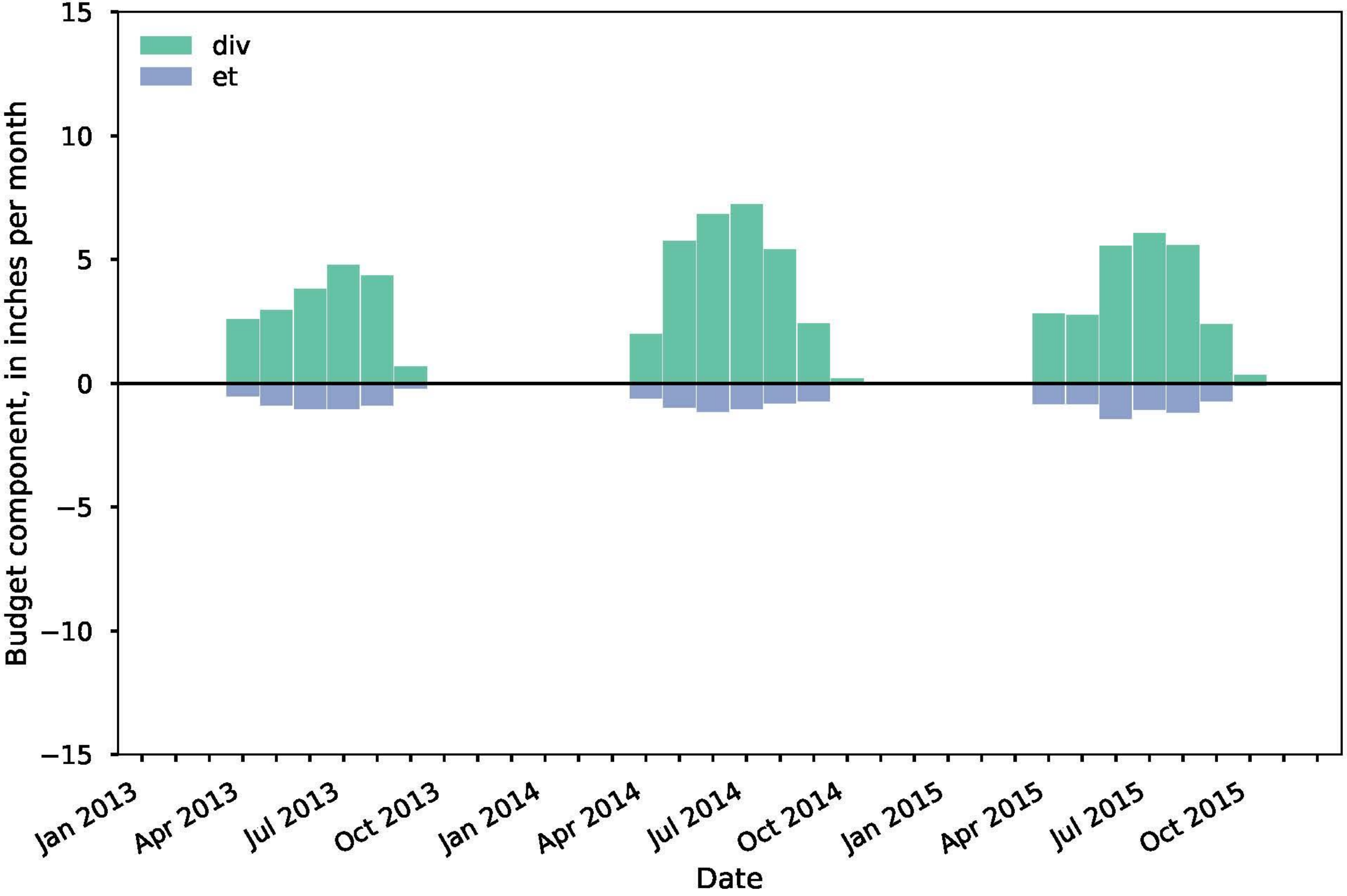
Precipitation

$$\text{div} + \cancel{\text{ppt}} = \text{et} + \text{leak} + \text{tail} + \text{deliv}$$

Surface water system budget: Outflows

Evapotranspiration

div + ~~ppt~~ = **et** + leak + tail + deliv



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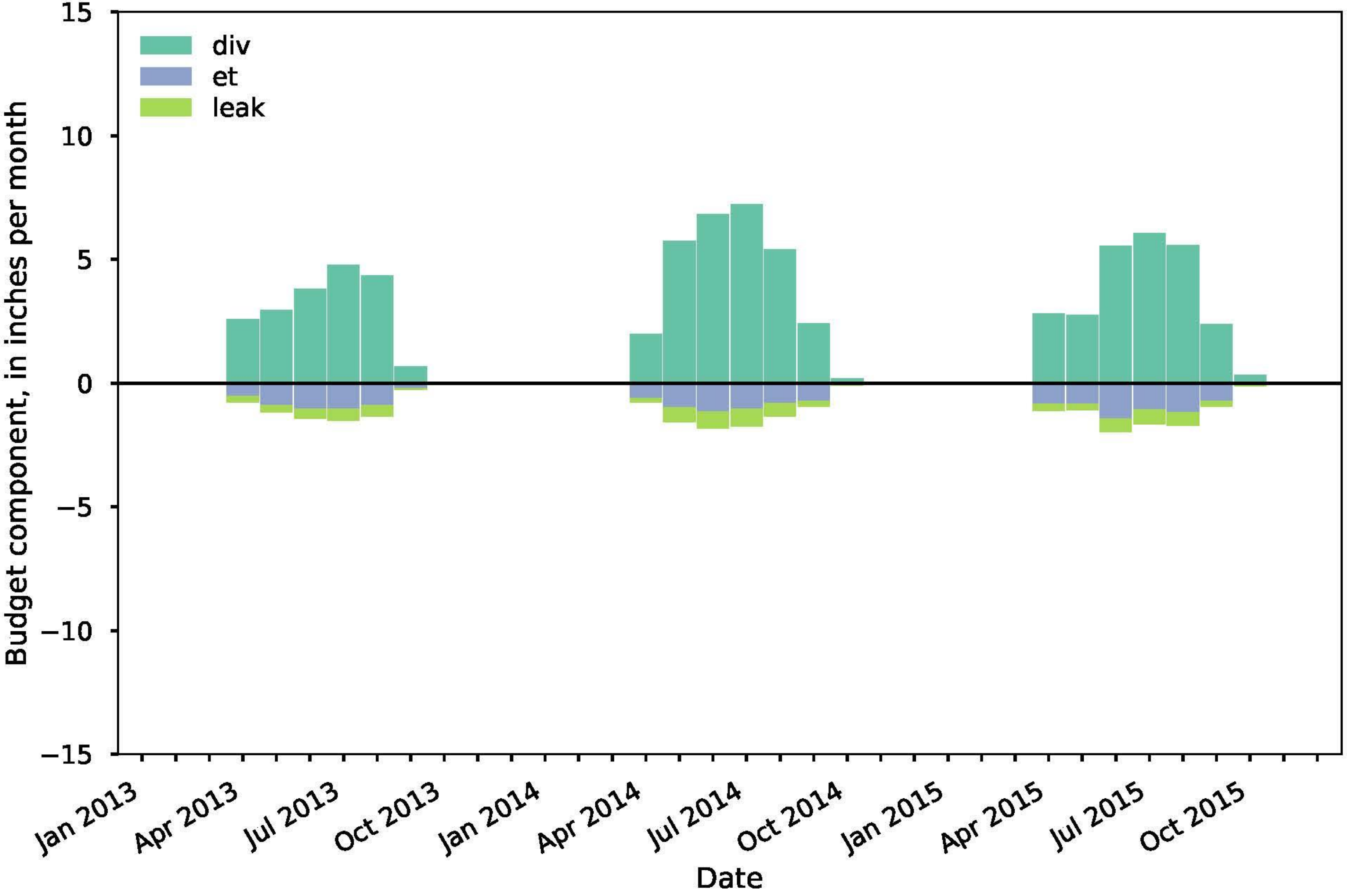
Surface water system budget: Outflows

Canal leakage

div + ~~ppt~~ = et + **leak** + tail + deliv



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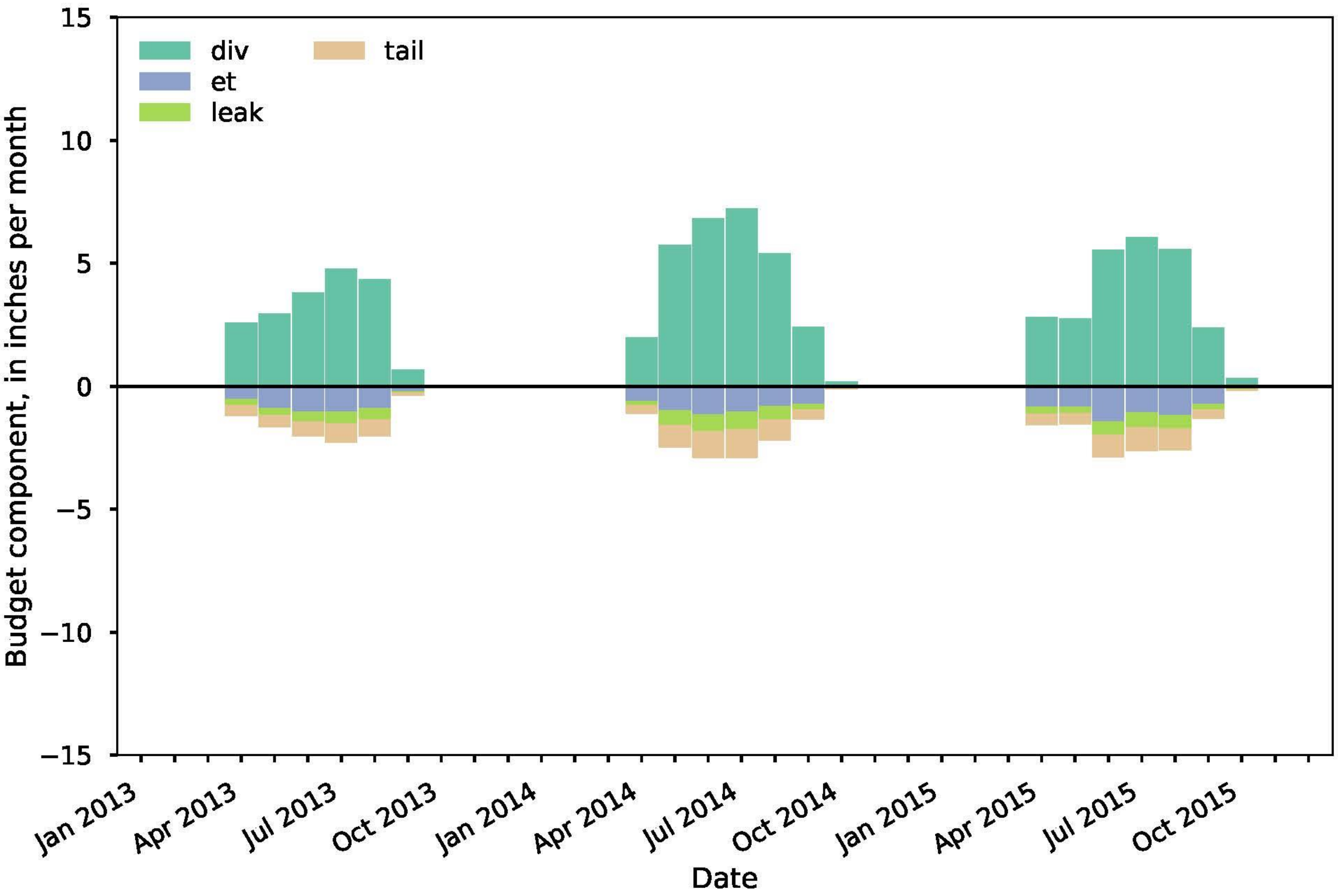
Surface water system budget: Outflows

Through flow / tail water

$\text{div} + \cancel{\text{ppt}} = \text{et} + \text{leak} + \textbf{tail} + \text{deliv}$



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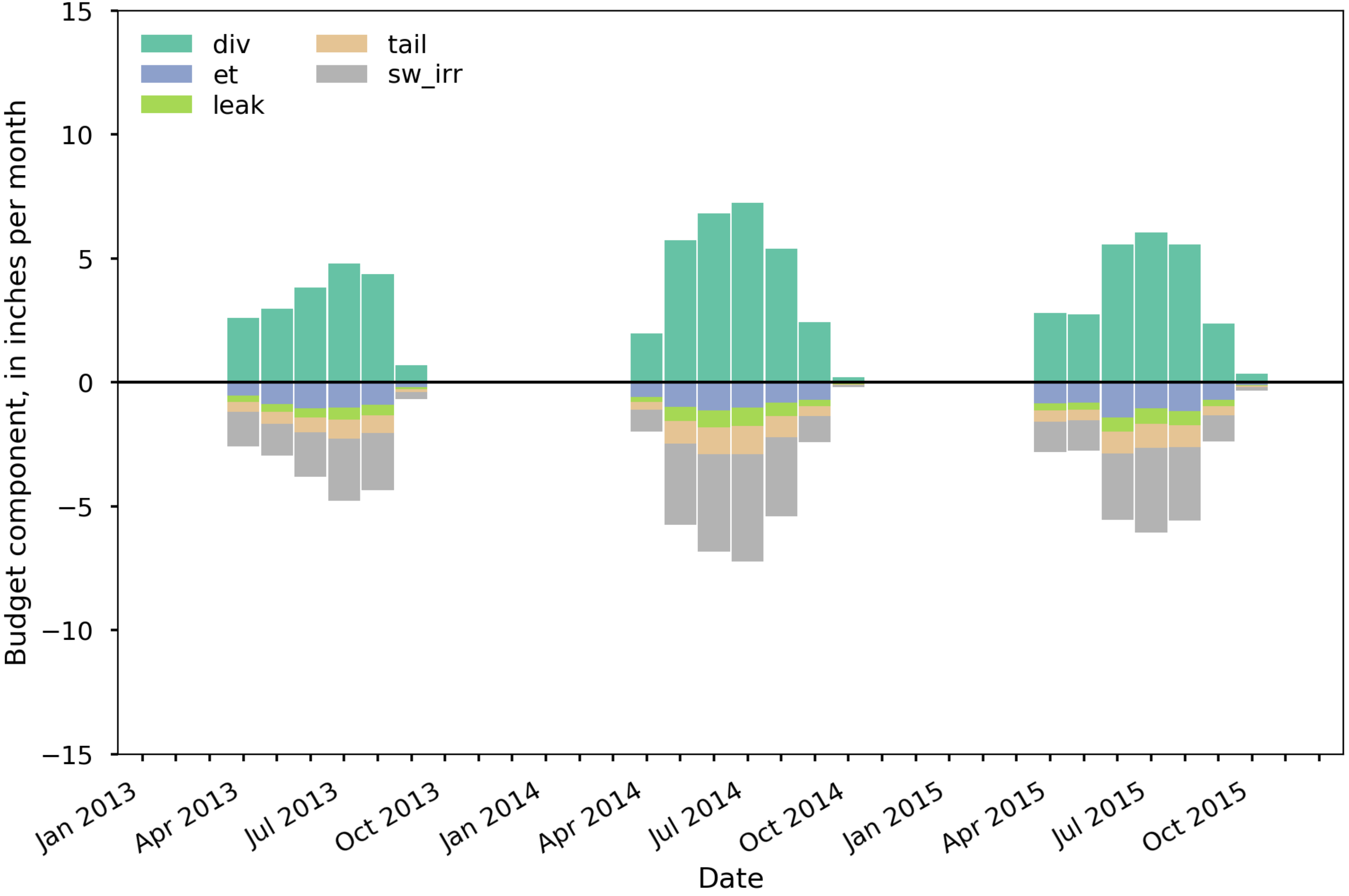
Surface water system budget: Outflows

Deliveries

$div + \cancel{ppt} = et + leak + tail + \mathbf{deliv}$



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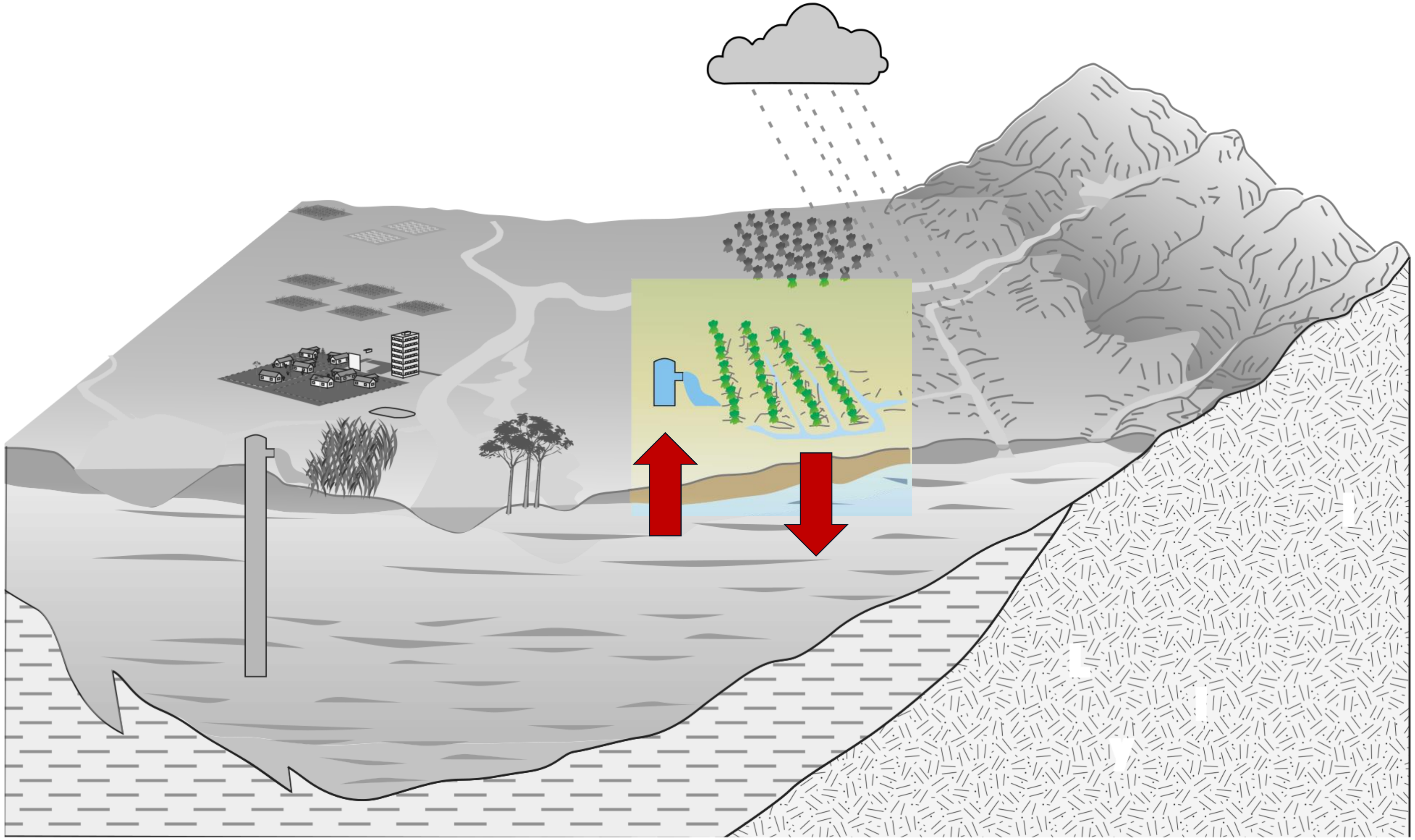
Soil water budget



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Soil water budget

$$\text{In} - \text{Out} = \pm\Delta\text{Storage}$$

$$\text{In} = \text{Out}$$

- Surface water irrigation (deliv)
- Precipitation (ppt)
- From soil moisture (soil)
- Groundwater irrigation (gw)

- Evapotranspiration (et)
- To soil moisture (soil)
- Infiltration (infil)

$$\text{deliv} + \text{ppt} + \text{gw} + \text{soil} = \text{et} + \text{soil} + \text{infil}$$

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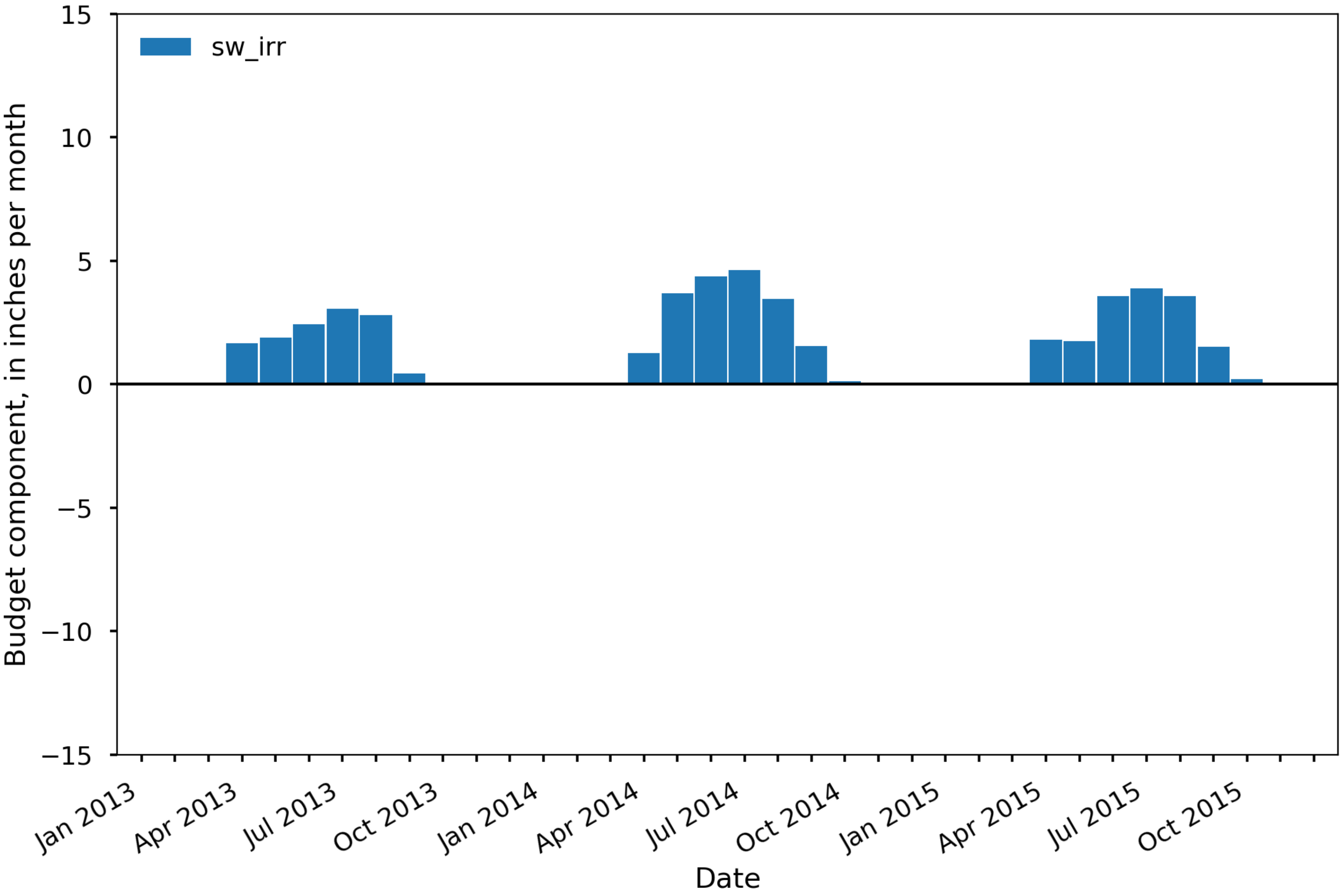
Soil water budget: Inflows

Surface water irrigation (deliveries)

deliv + ppt + gw + soil = et + infil + soil



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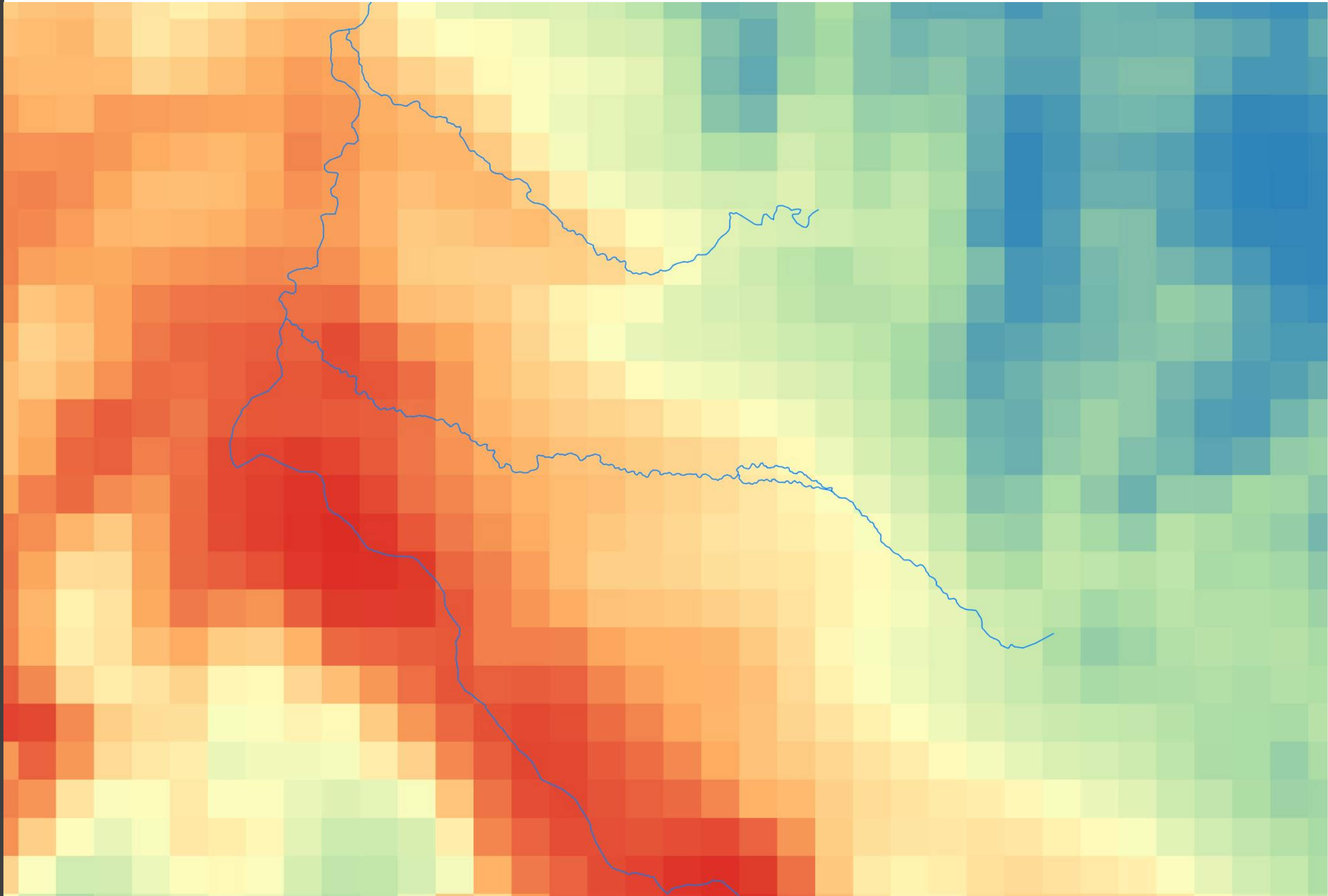
Soil water budget: Inflows

deliv + **ppt** + gw + soil = et + infil + soil

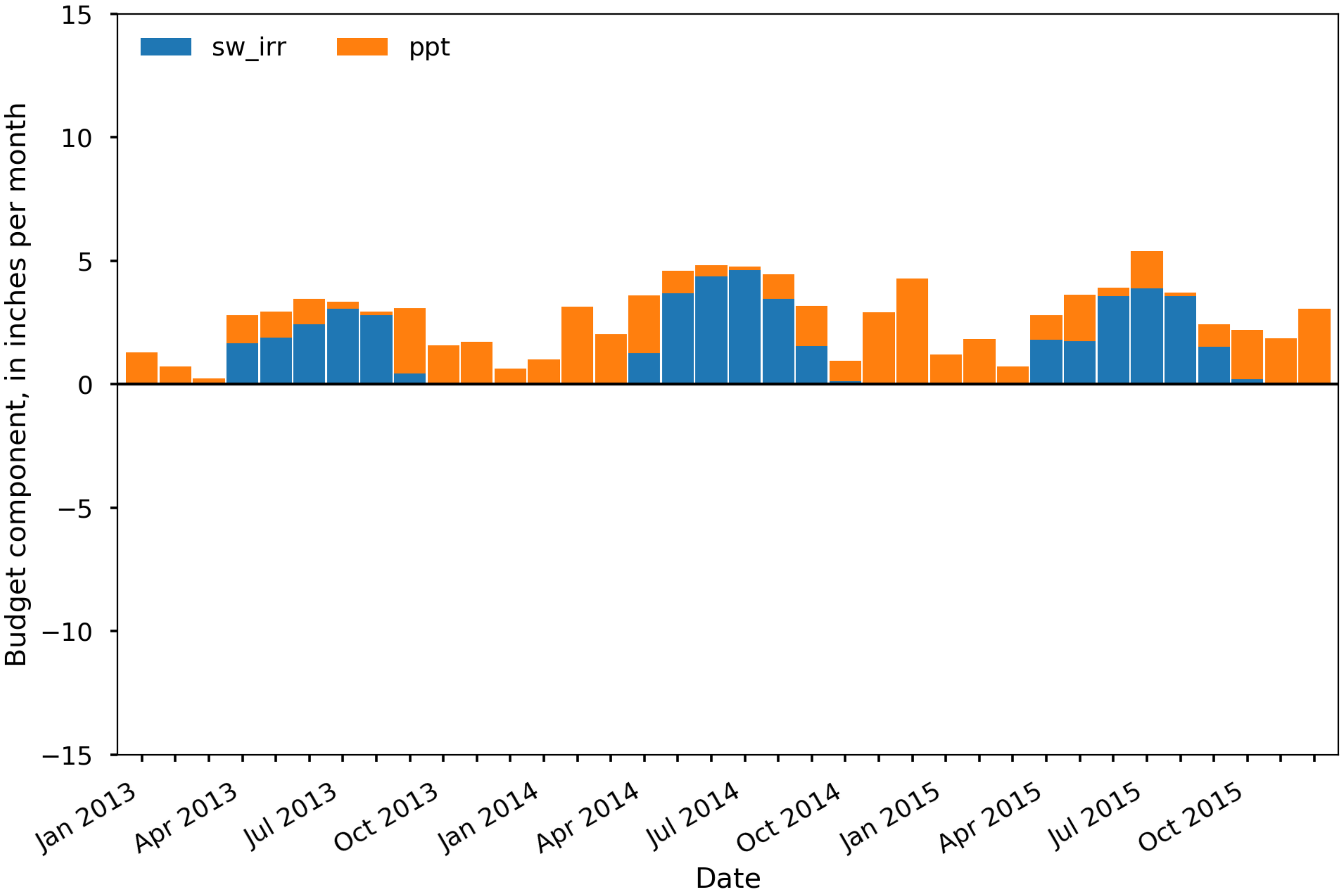
Precipitation



Soil water budget: Inflows

Precipitation

deliv + **ppt** + gw + soil = et + infil + soil



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Soil water budget: Inflows

Soil moisture storage decrease

deliv + ppt + **gw** + soil = et + infil + soil

Wait…

Soil water budget: Inflows

Groundwater irrigation

deliv + ppt + gw + **soil** = et + infil + soil

Wait…

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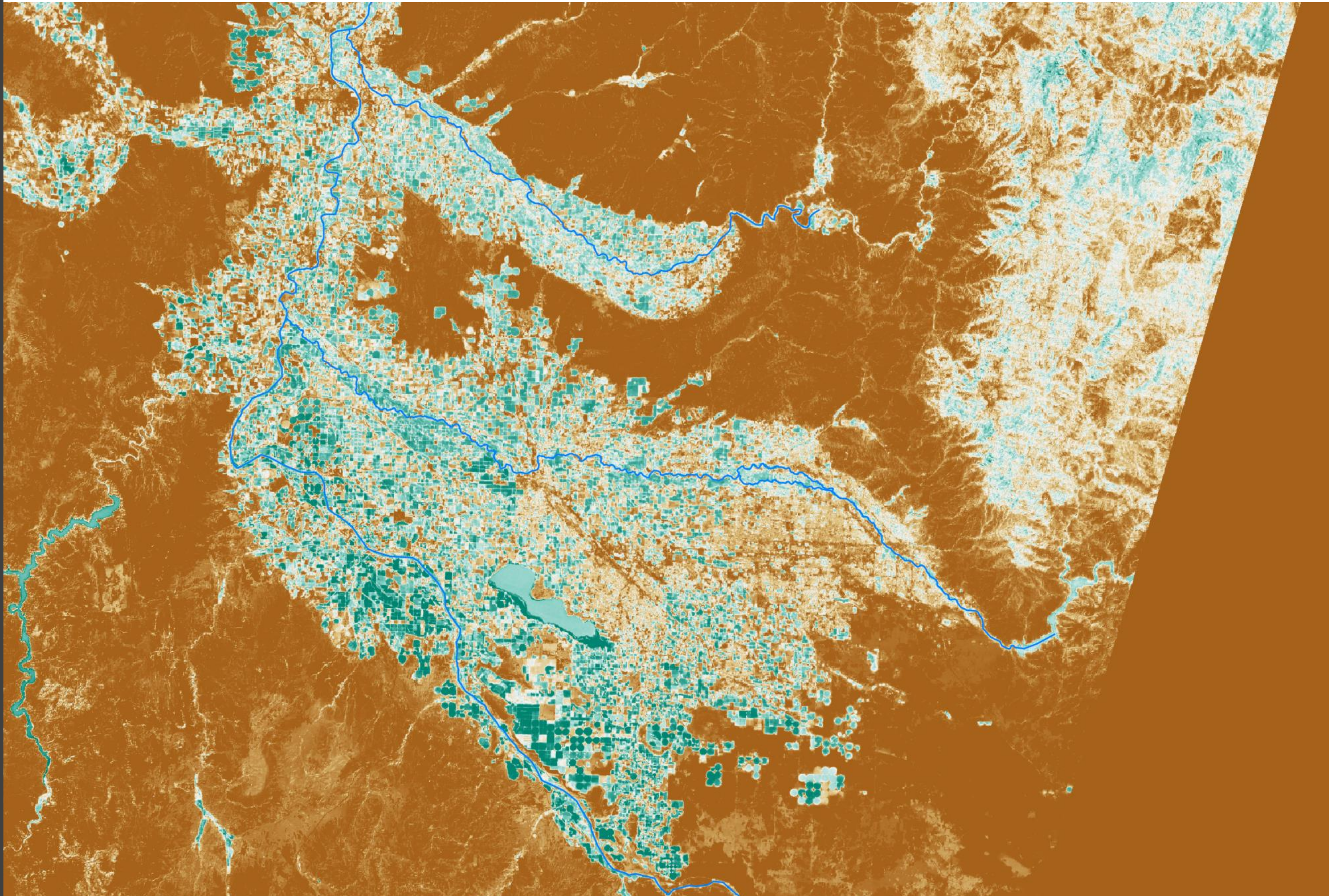
Soil water budget: Outflows

deliv + ppt + gw + soil = **et** + infil + soil



Evapotranspiration

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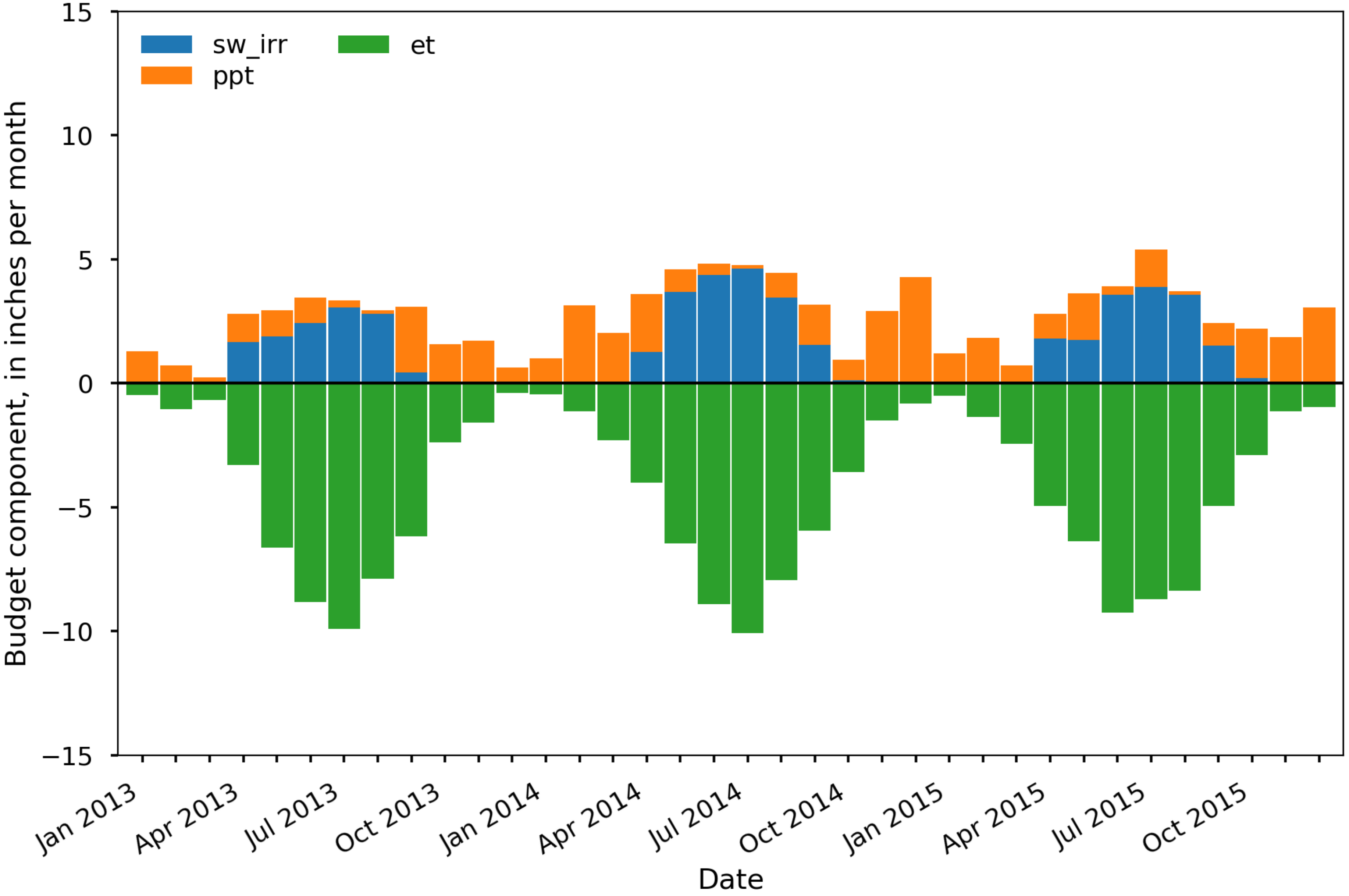
Soil water budget: Outflows

Evapotranspiration

deliv + ppt + gw + soil = **et** + infil + soil



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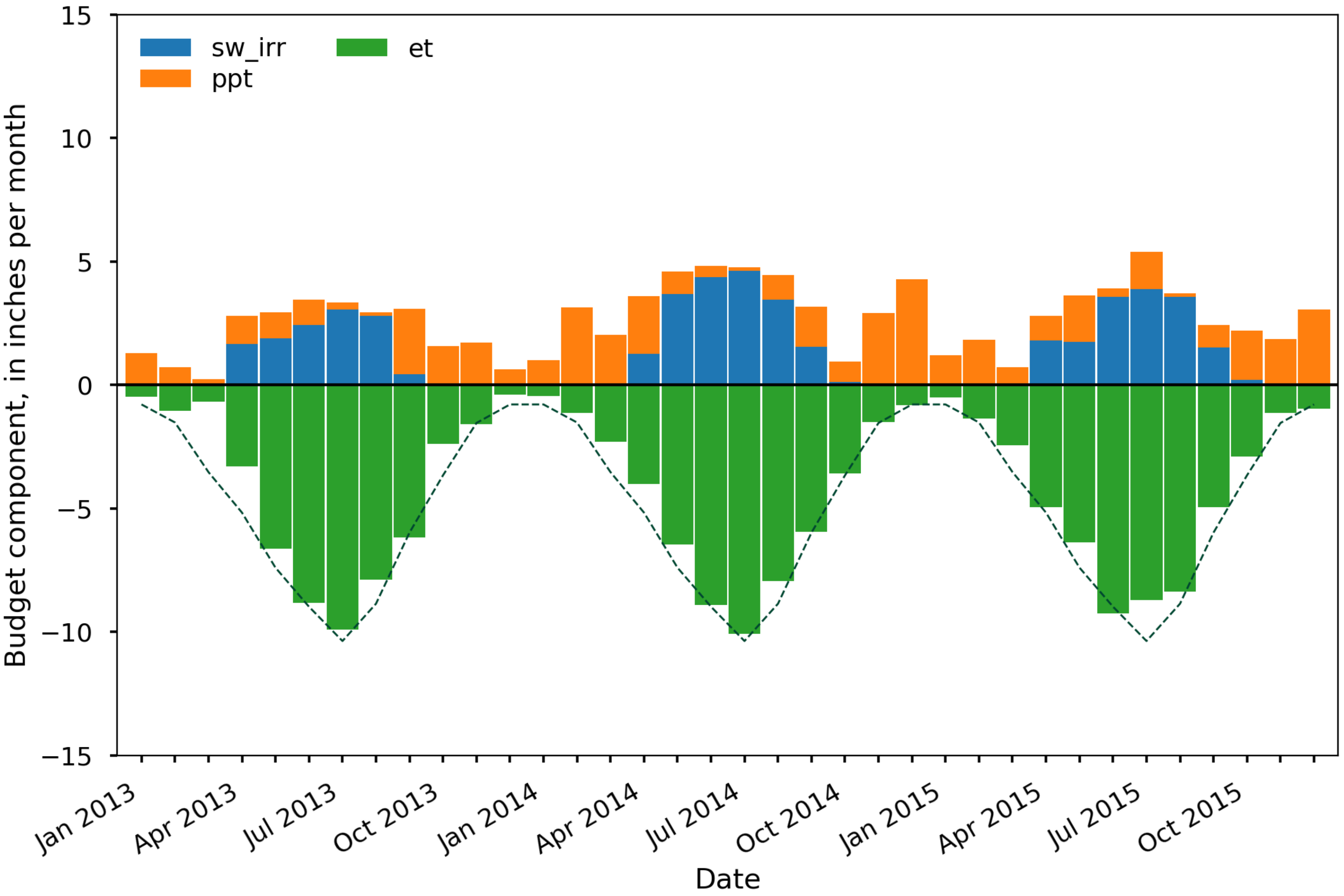
Soil water budget: Outflows

Evapotranspiration

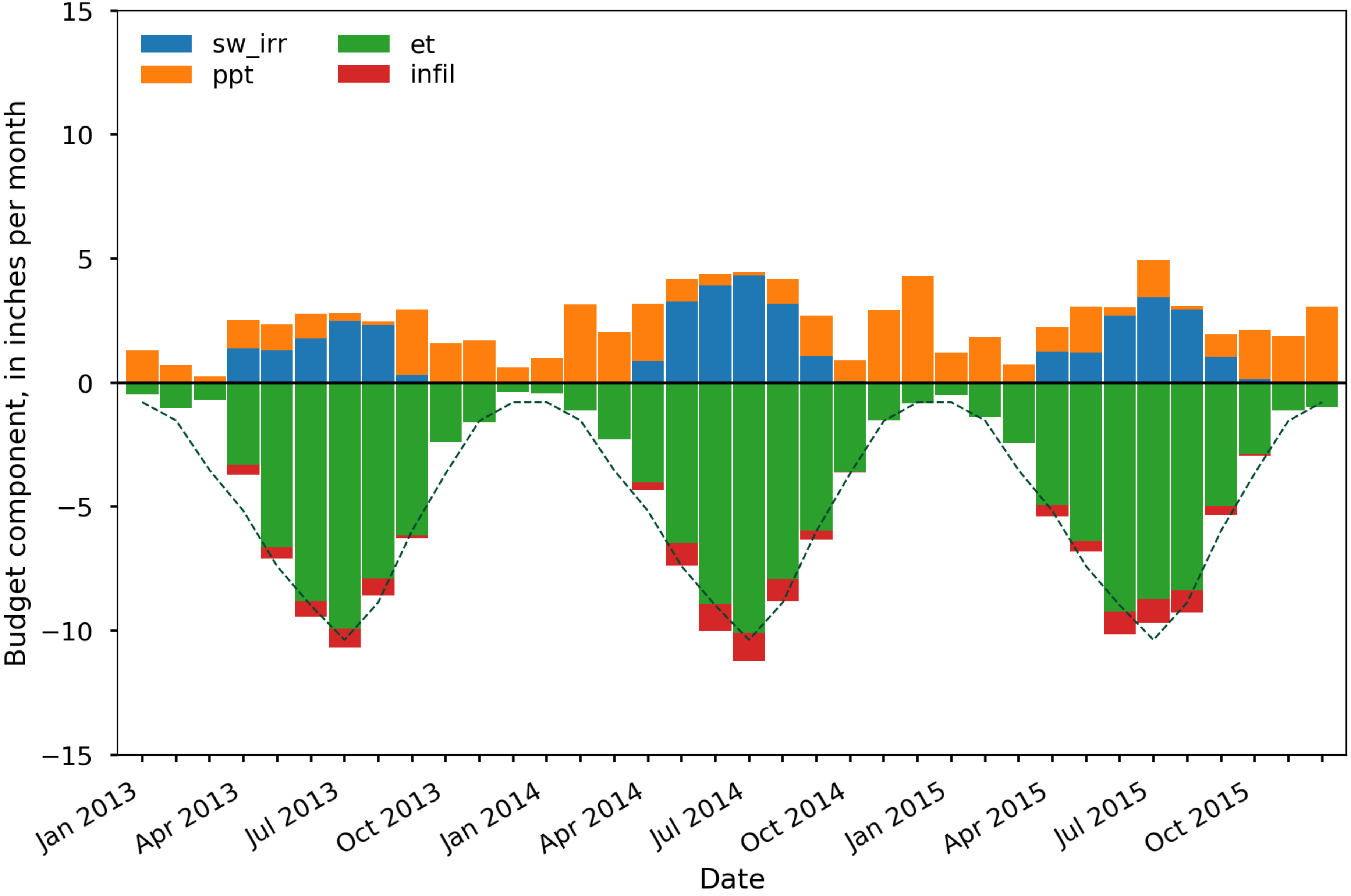
deliv + ppt + gw + soil = et + **infil** + soil



Soil water budget: Outflows

Deep percolation of irrigation water

deliv + ppt + gw + soil = et + **infil** + soil



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Soil water budget: Outflows

Soil moisture storage increase

deliv + ppt + gw + soil = et + infil + **soil**

Wait…

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Soil water budget: Remainder

Assuming no soil moisture storage

$$deliv + ppt + gw + \cancel{soil} = et + infil + \cancel{soil}$$

$$deliv + ppt + gw = et + infil$$

$$gw = et + infil - deliv - ppt$$

???

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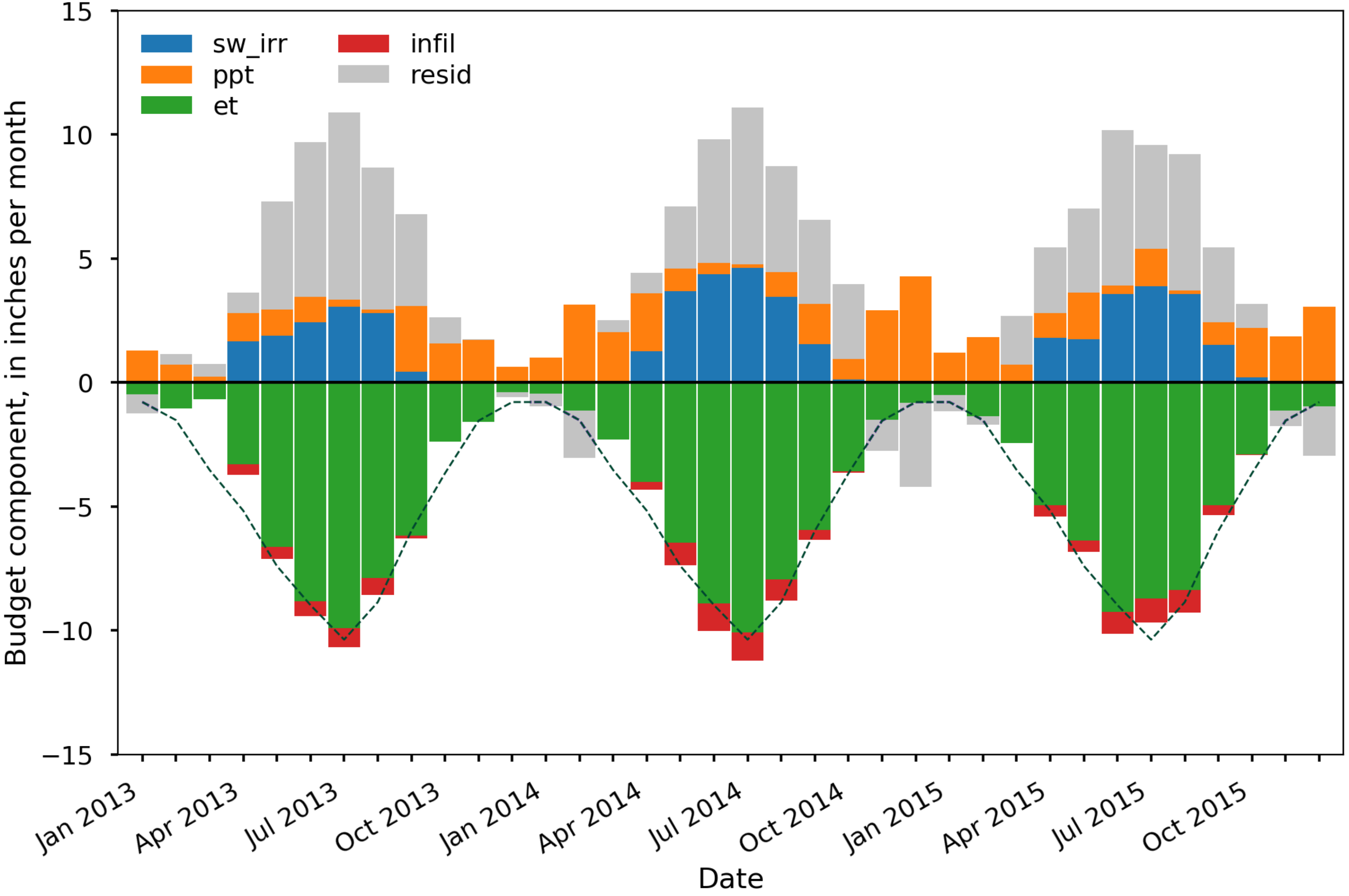
Soil water budget: Remainder

Assuming no soil moisture storage

et + infil - ppt - deliv



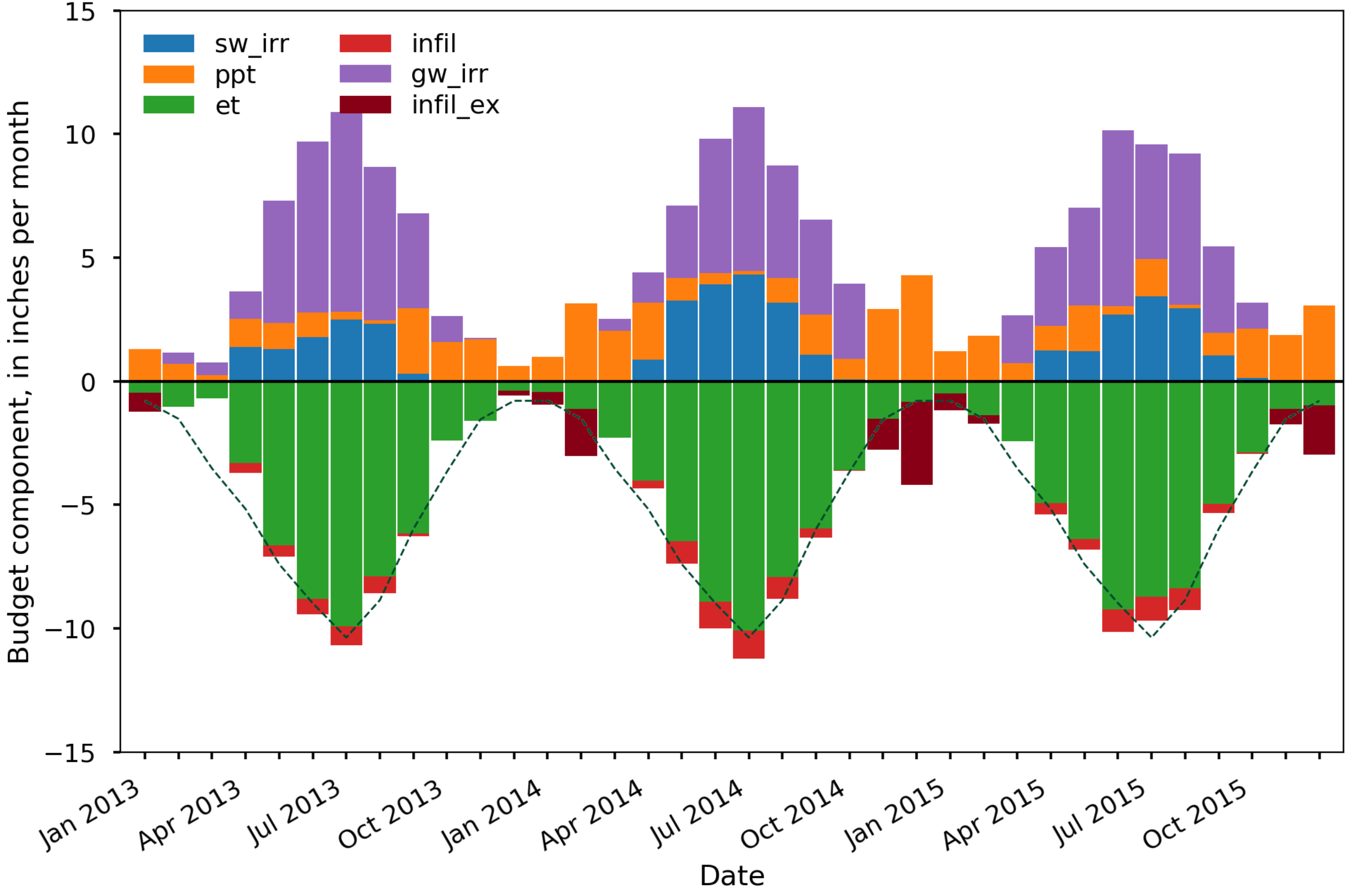
Soil water budget: Remainder

Assuming no soil moisture storage

if et + infil > ppt + deliv:
Remainder = groundwater

if et + infil < ppt + deliv:
Remainder = infiltration

et + infil - ppt - deliv



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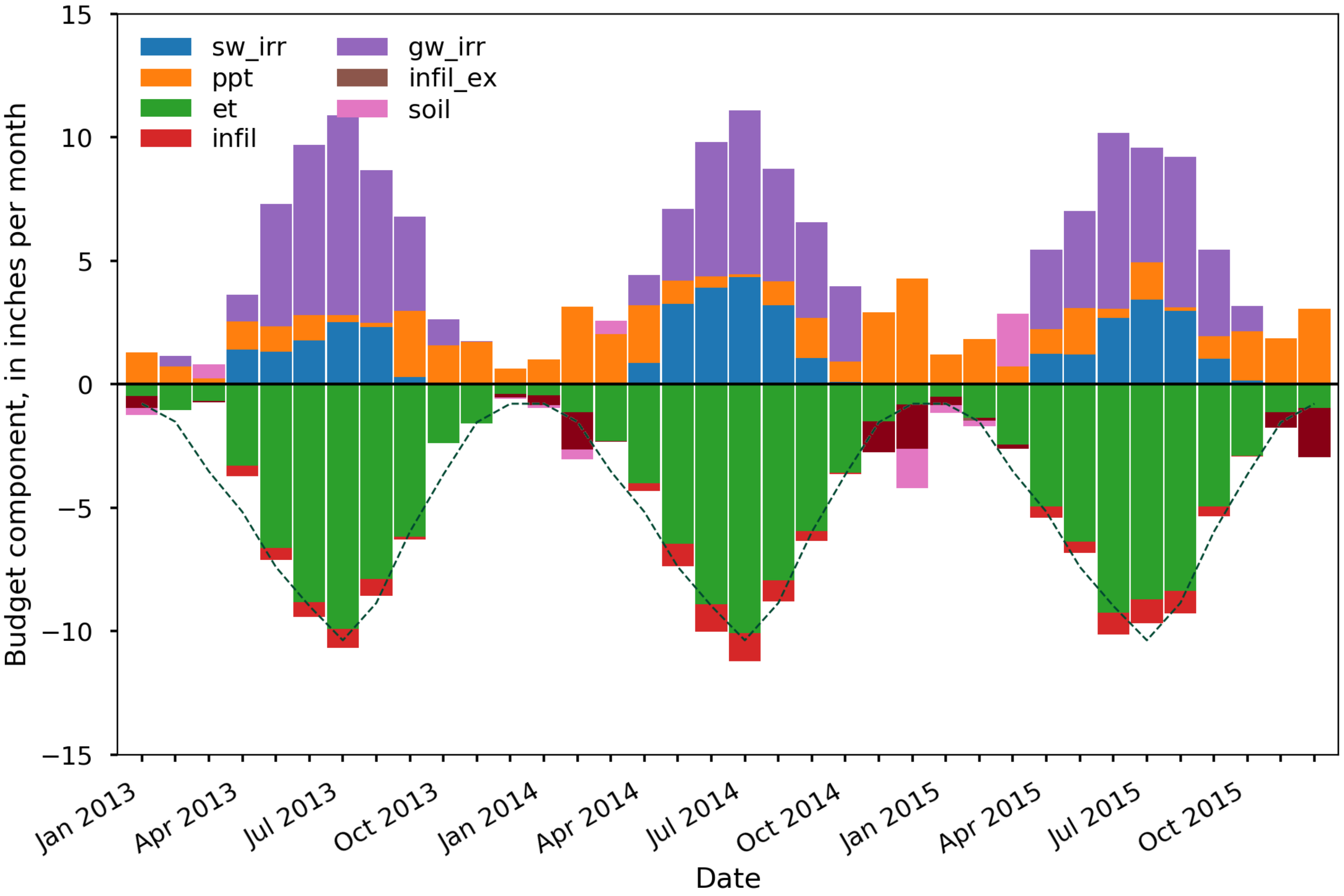
Soil water budget: Remainder

Carrying over available soil moisture from winter to March

if et + infil > ppt + deliv:
Remainder = groundwater

if et + infil < ppt + deliv:
Remainder = infiltration

et + infil + soil - ppt – deliv – soil



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Estimating volumes: summary

Quantity	Source	Estimation Method	Adjustable Parameter
SW Diversion	Data	Watermaster	No
Canal precipitation	Assumption	= 0	No
Canal evapotranspiration	Data	METRIC	No
Canal leakage	Assumption	% diversion	Yes
Tail water	Data / estimate	???	No
Delivered water	Budget residual	Budget residual	No
Field precipitation	Data	PRISM dataset	No
Deep percolation of irrigation water	Assumption	% ET + excess supply	Yes
To and from soil	Assumption	Carry excess ppt to meet March ET	No
Field evapotranspiration	Data	METRIC	No
Groundwater deliveries	Budget residual	Budget residual	No

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Spatial distribution

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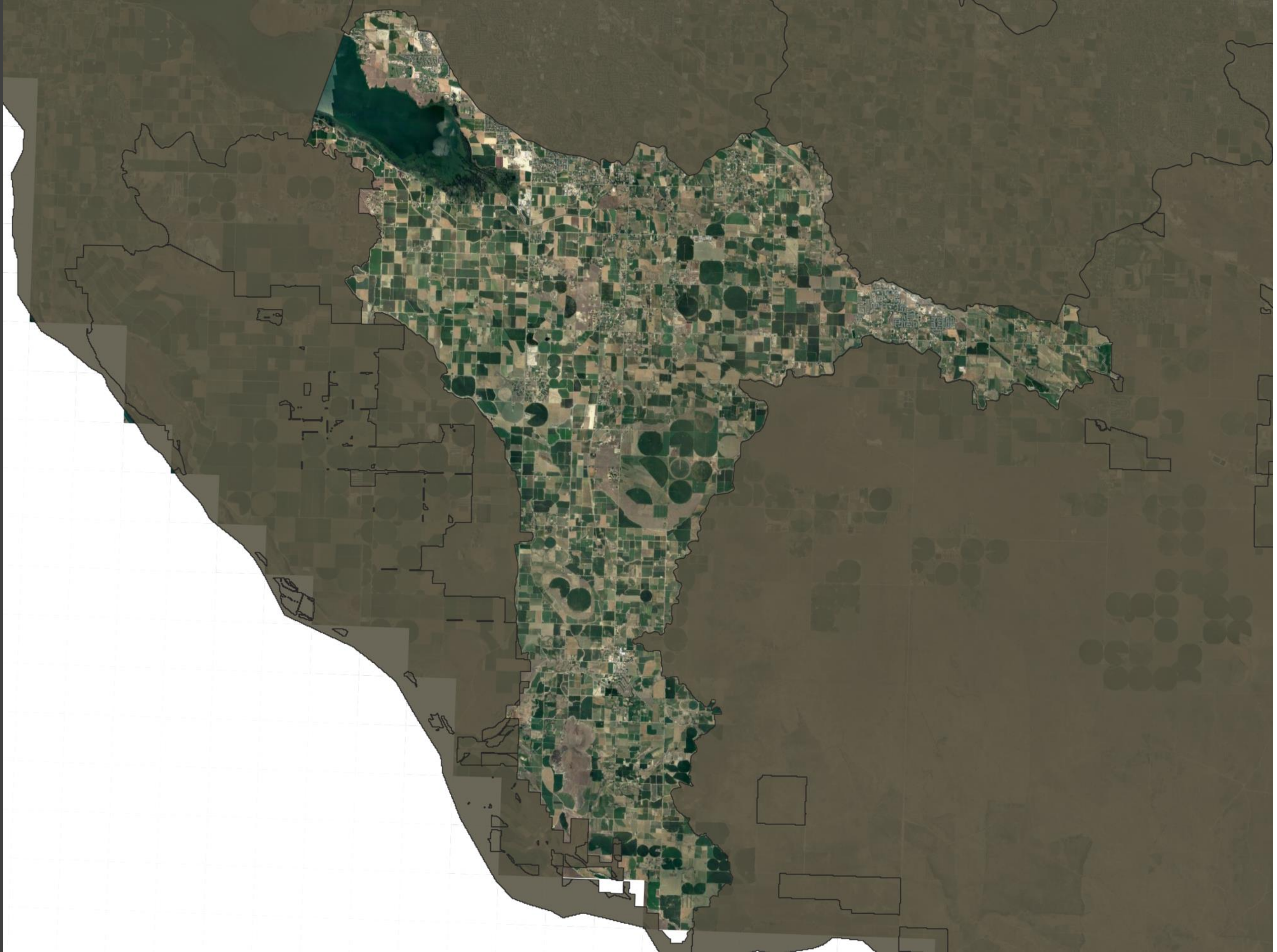
Deep percolation of irrigation (incidental recharge)

Distribute proportional to district ET
- Varies monthly



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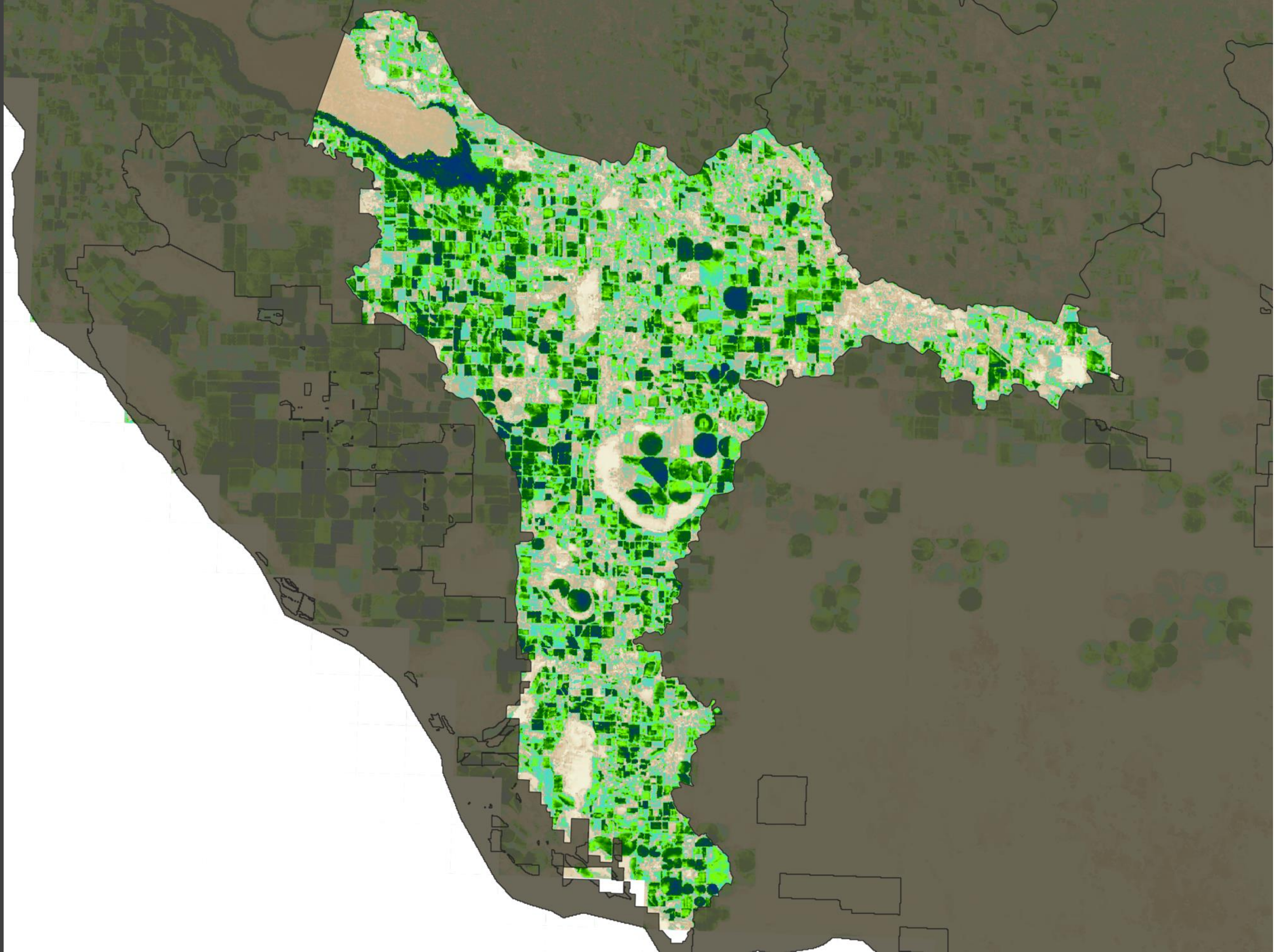

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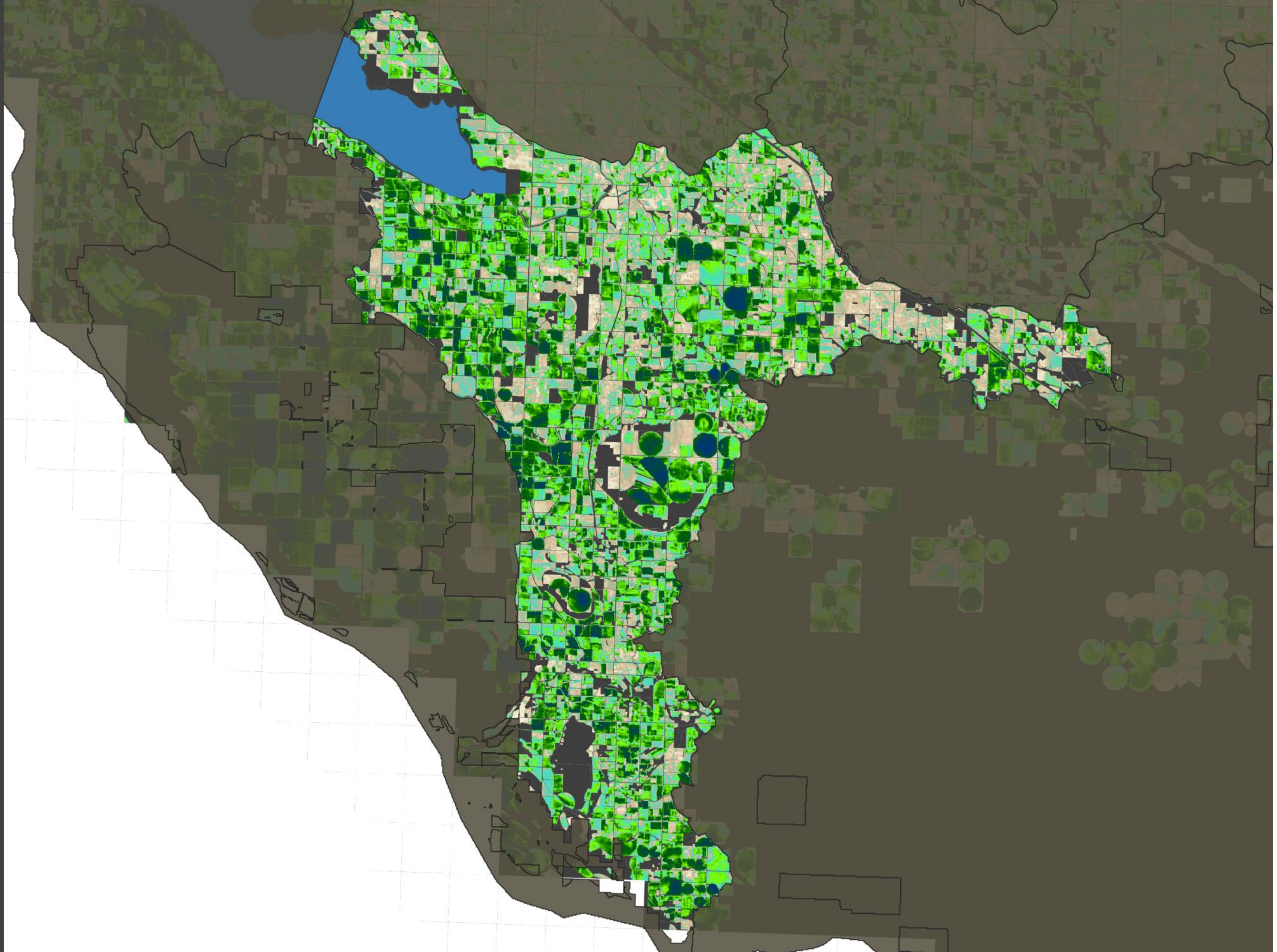

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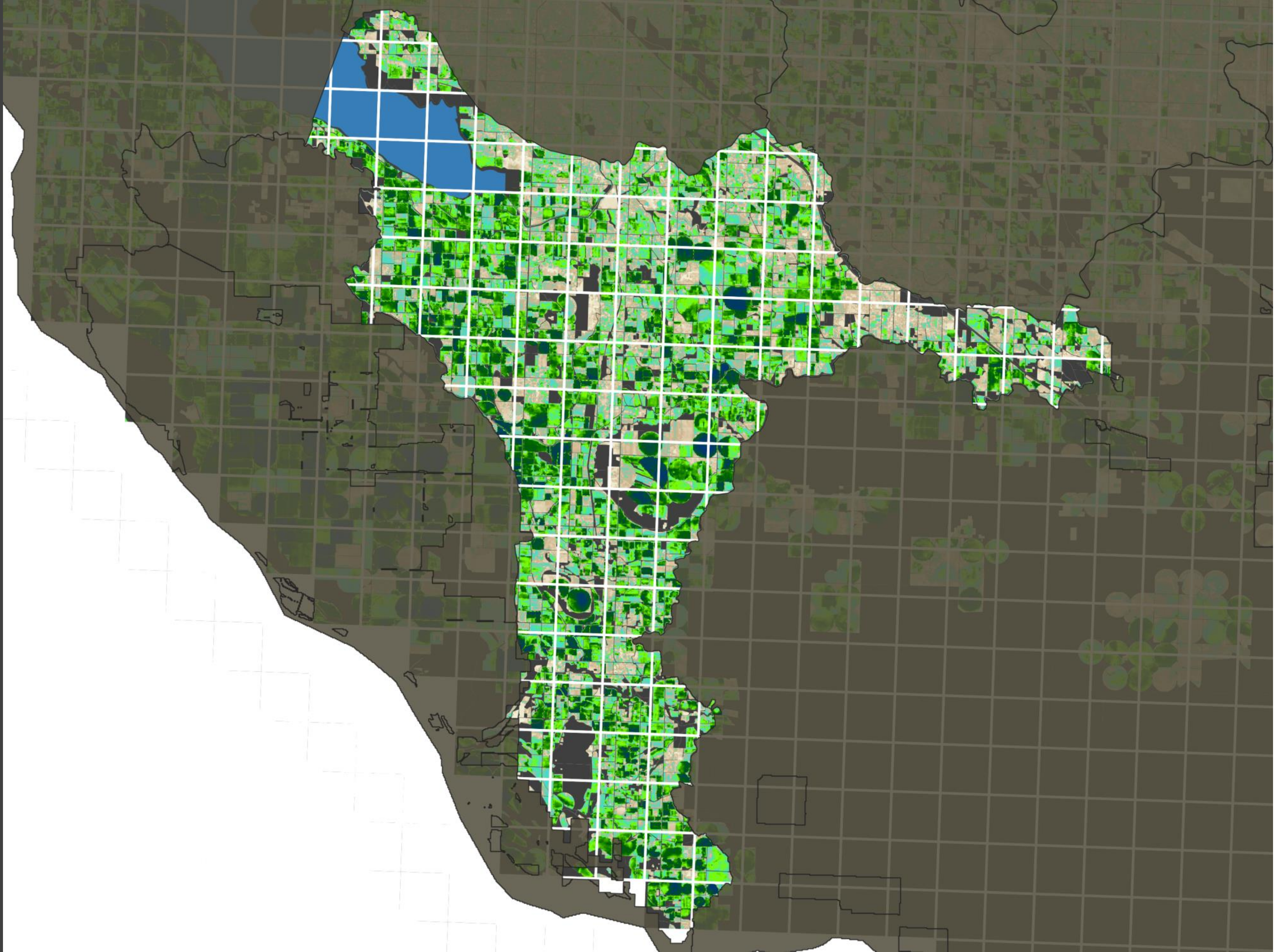

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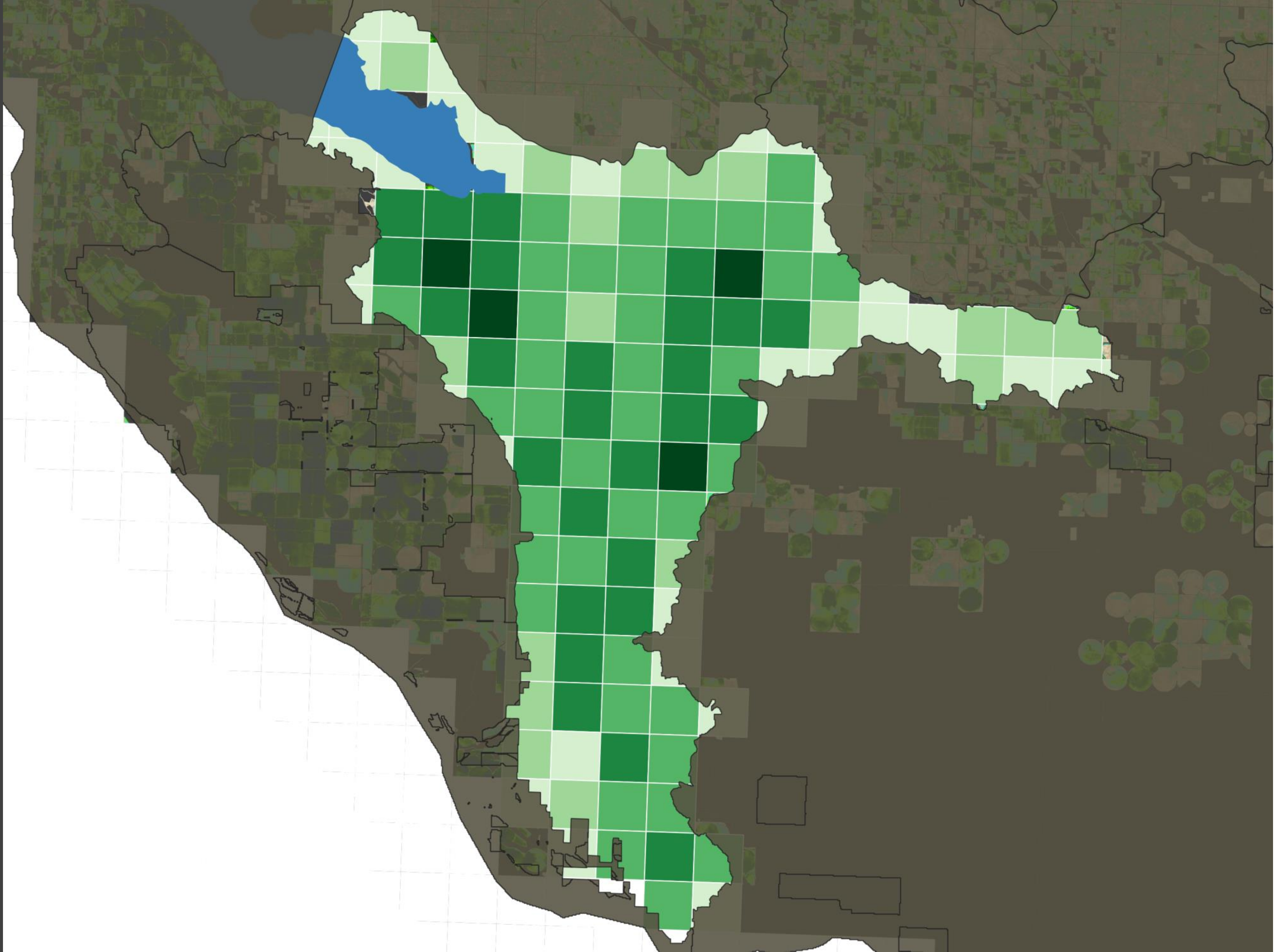
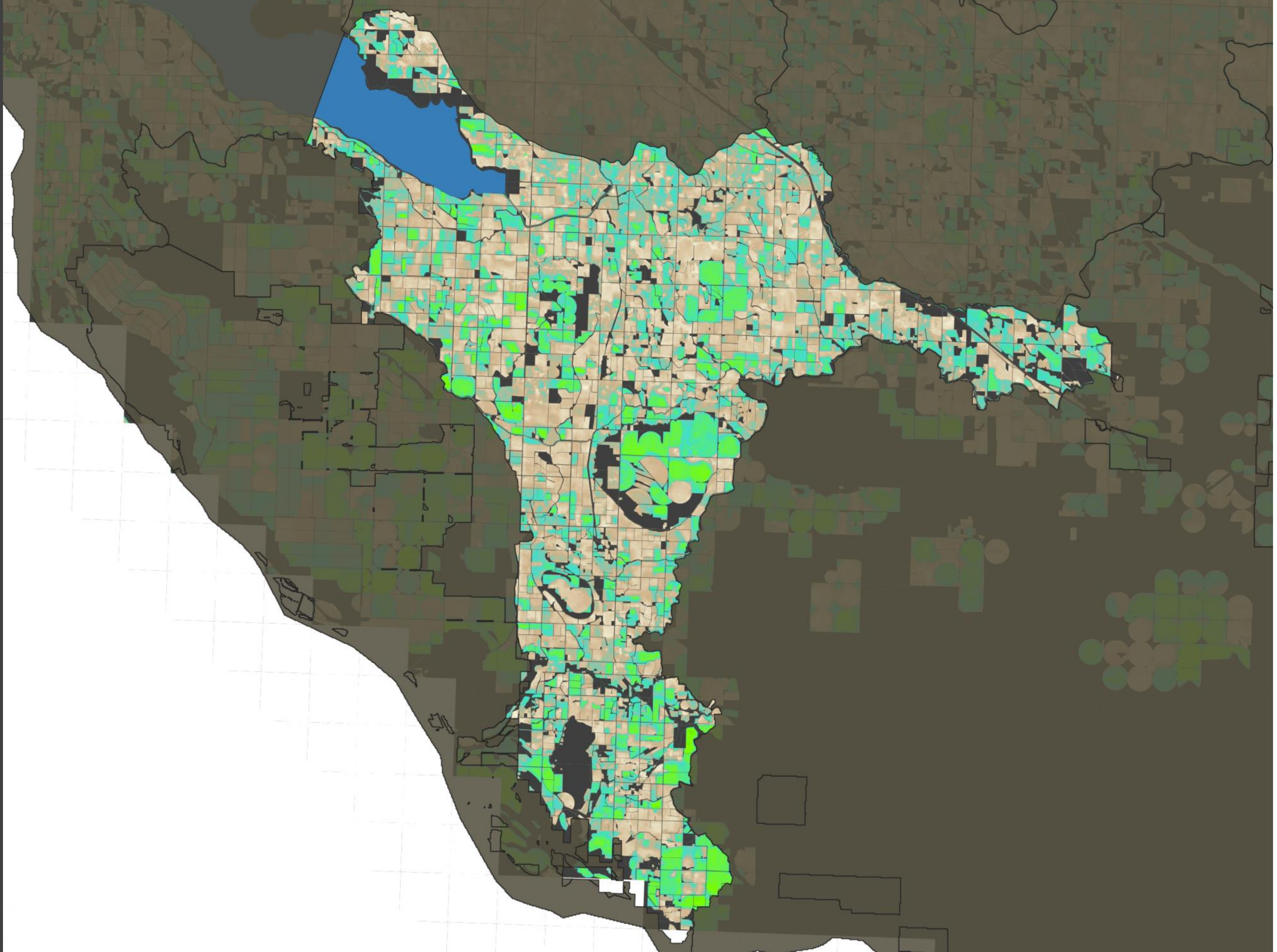


Deep percolation of irrigation (incidental recharge)

April ET



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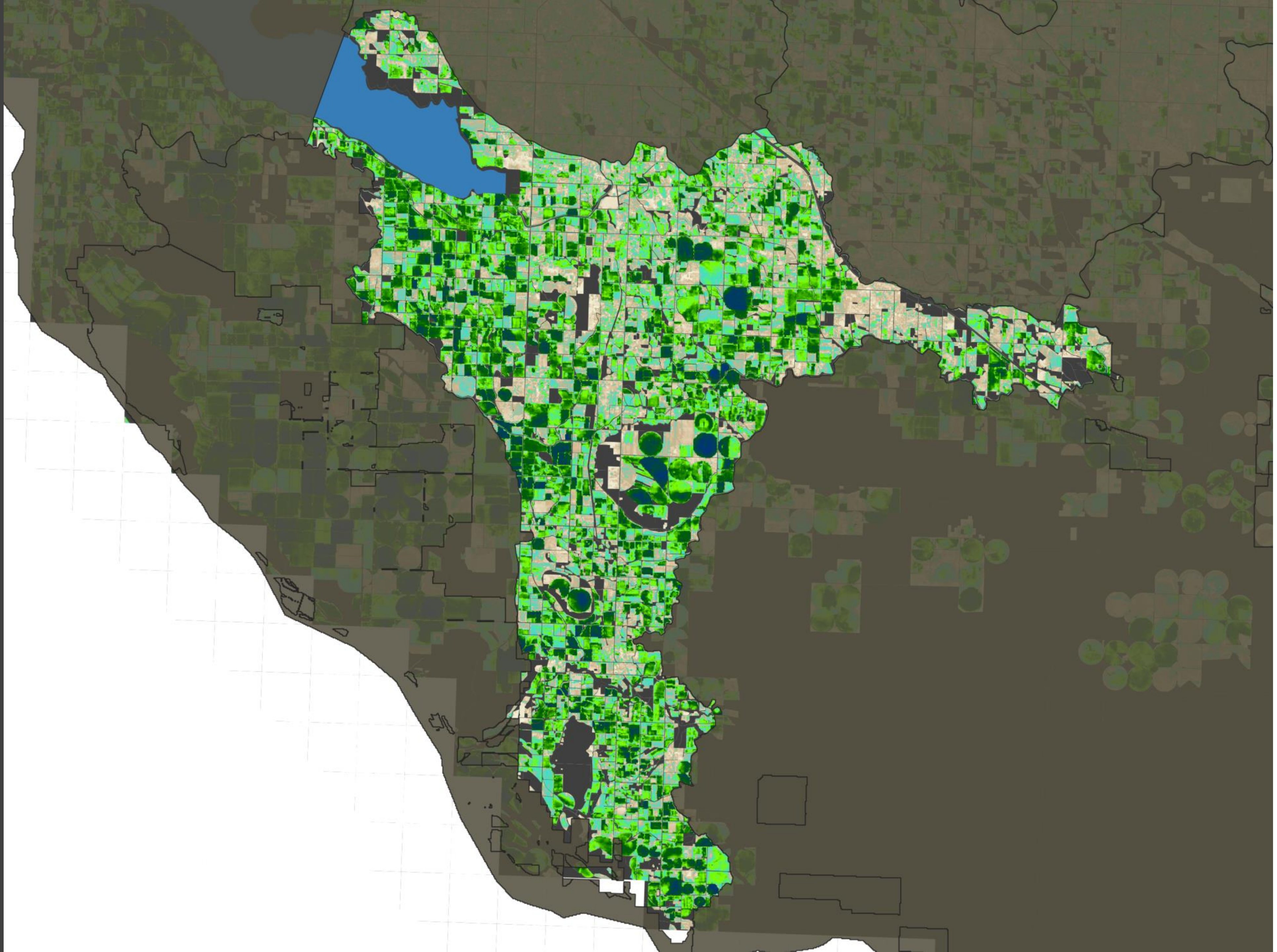
Deep percolation of irrigation (incidental recharge)

June ET



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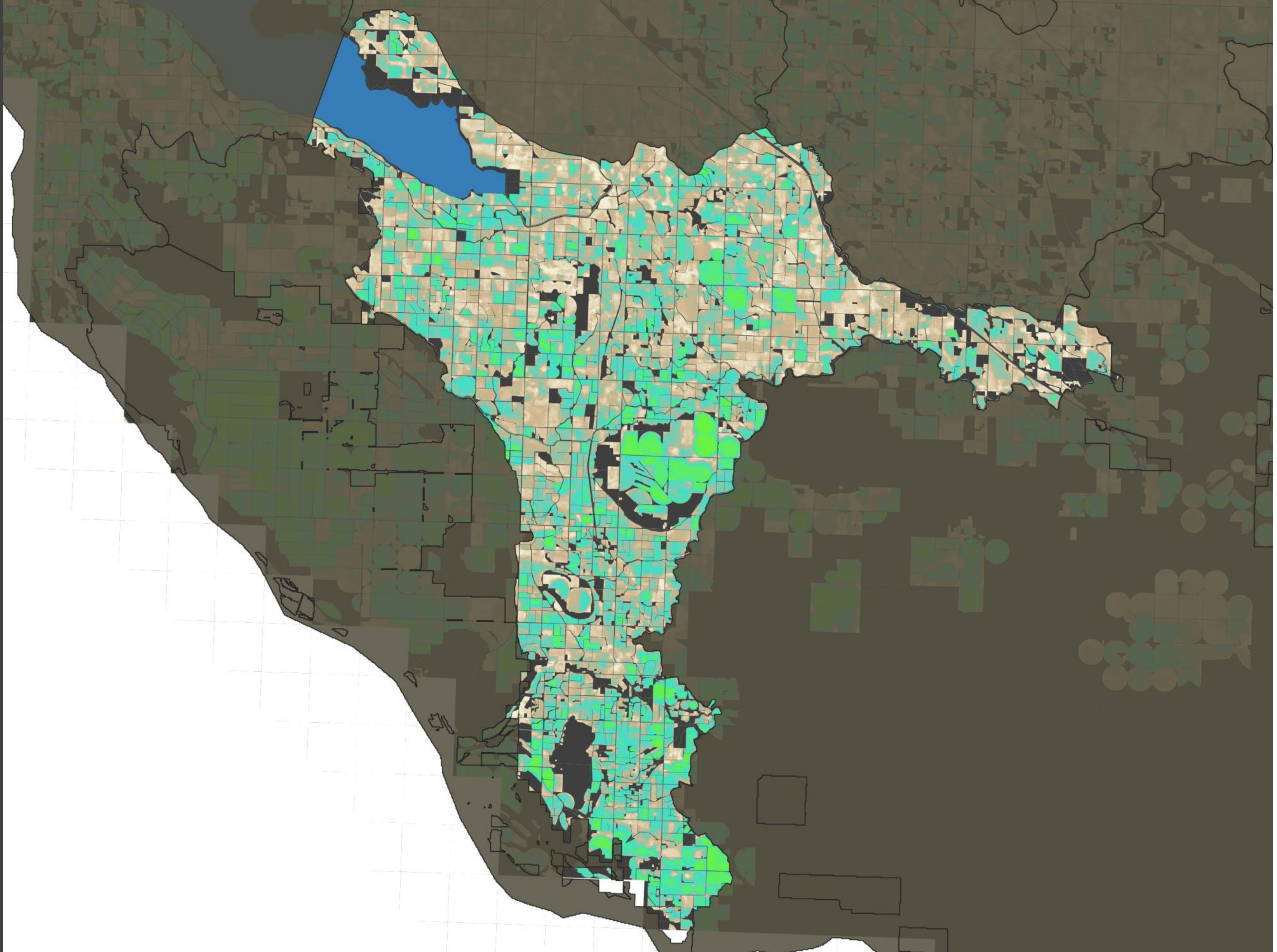
Deep percolation of irrigation (incidental recharge)

September ET



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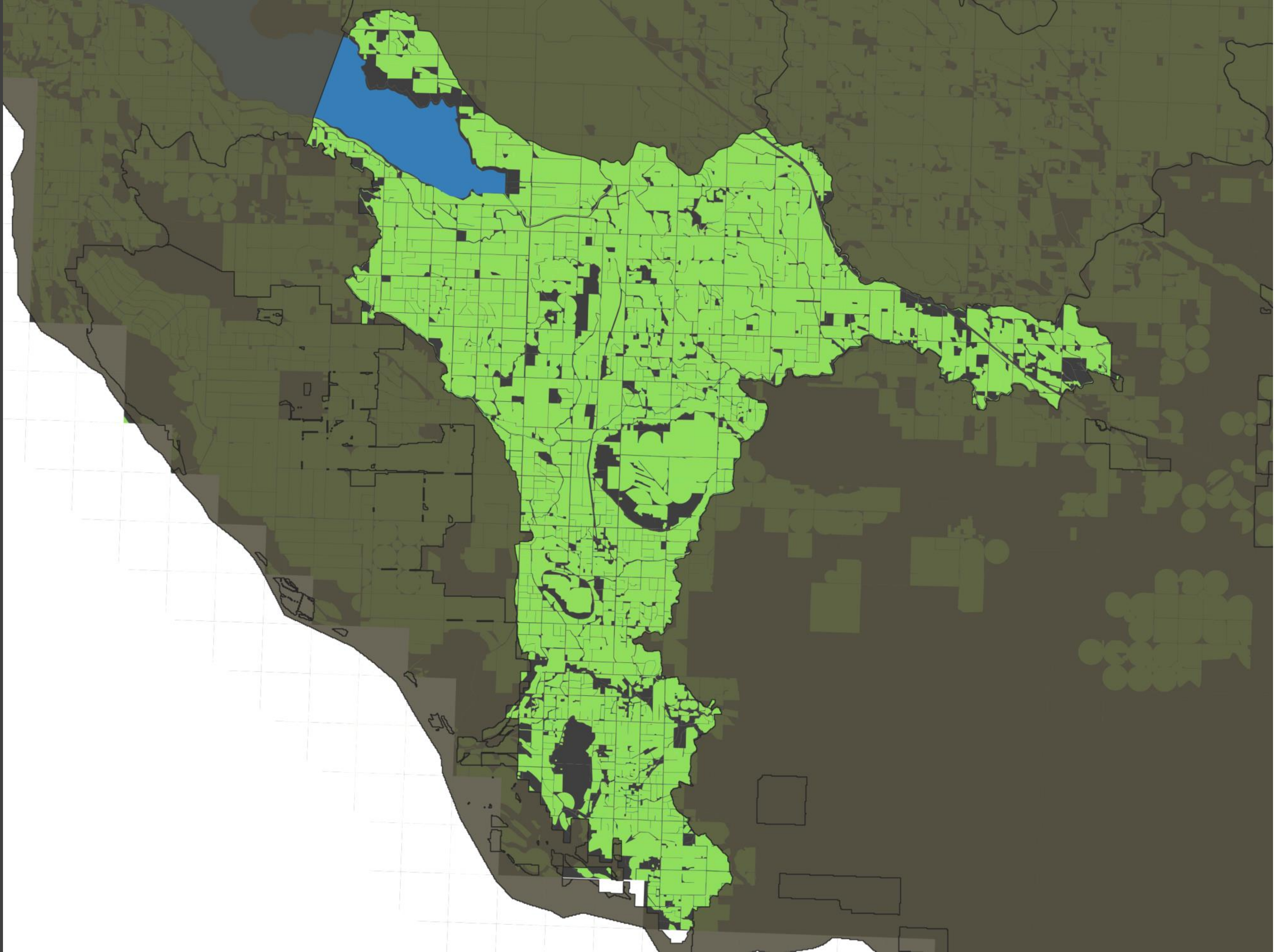
Deep percolation of irrigation (incidental recharge)

Irrigated Area



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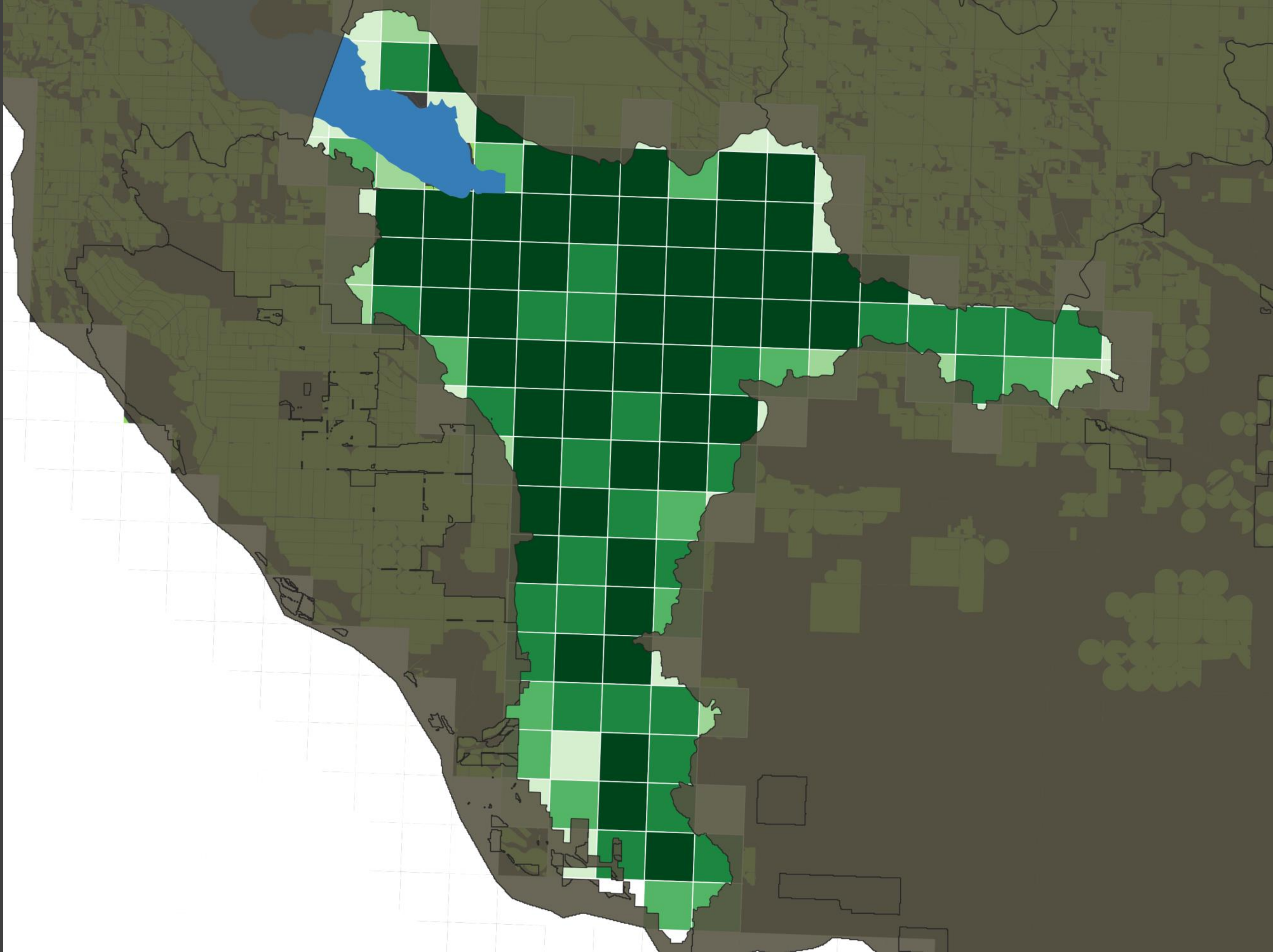
Deep percolation of irrigation (incidental recharge)

Area Proportion

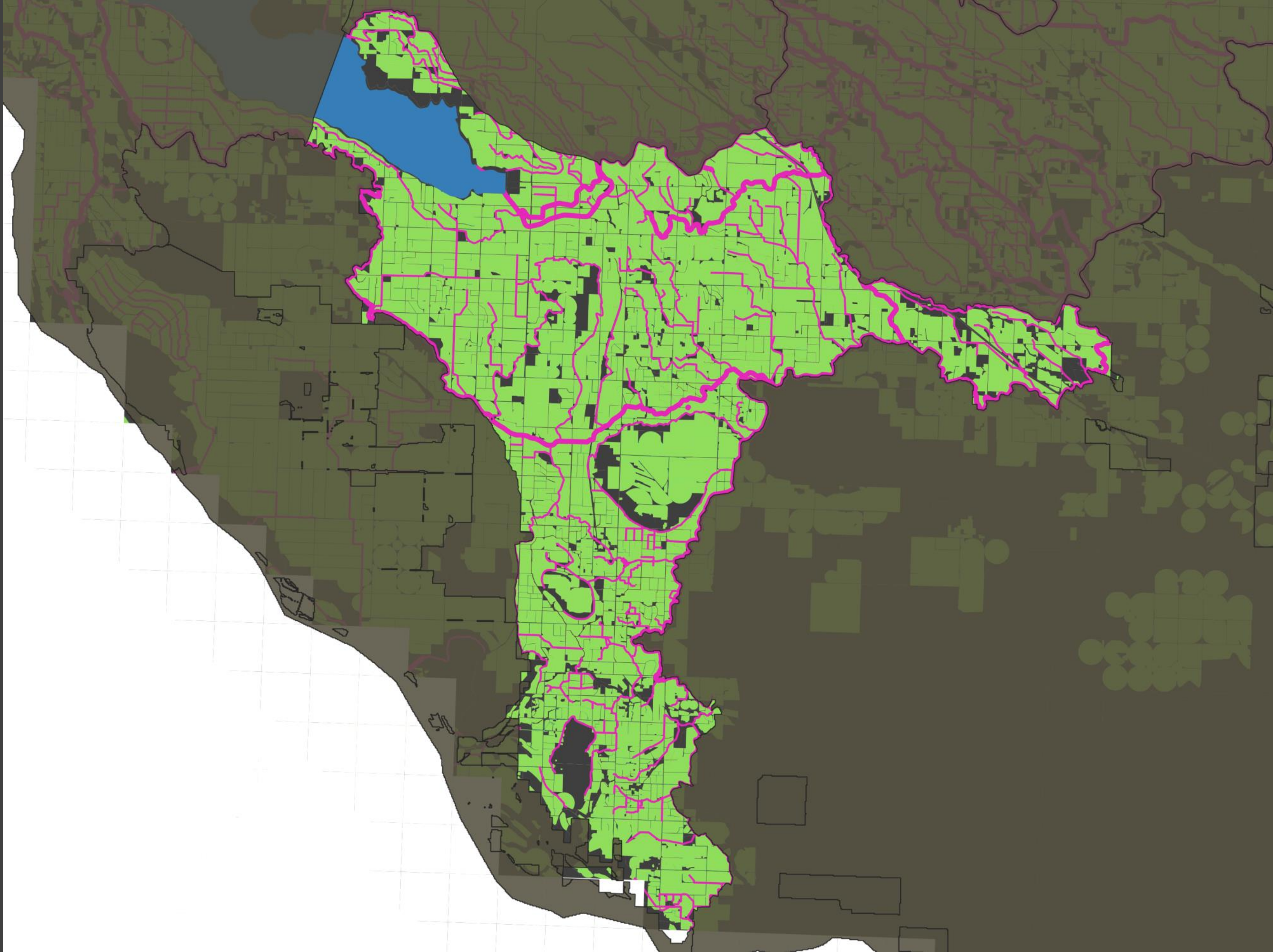


Canal leakage

Proportional to district irrigated area
- Will change with each land use dataset

OR

Proportional to district major canal length
- Invariant



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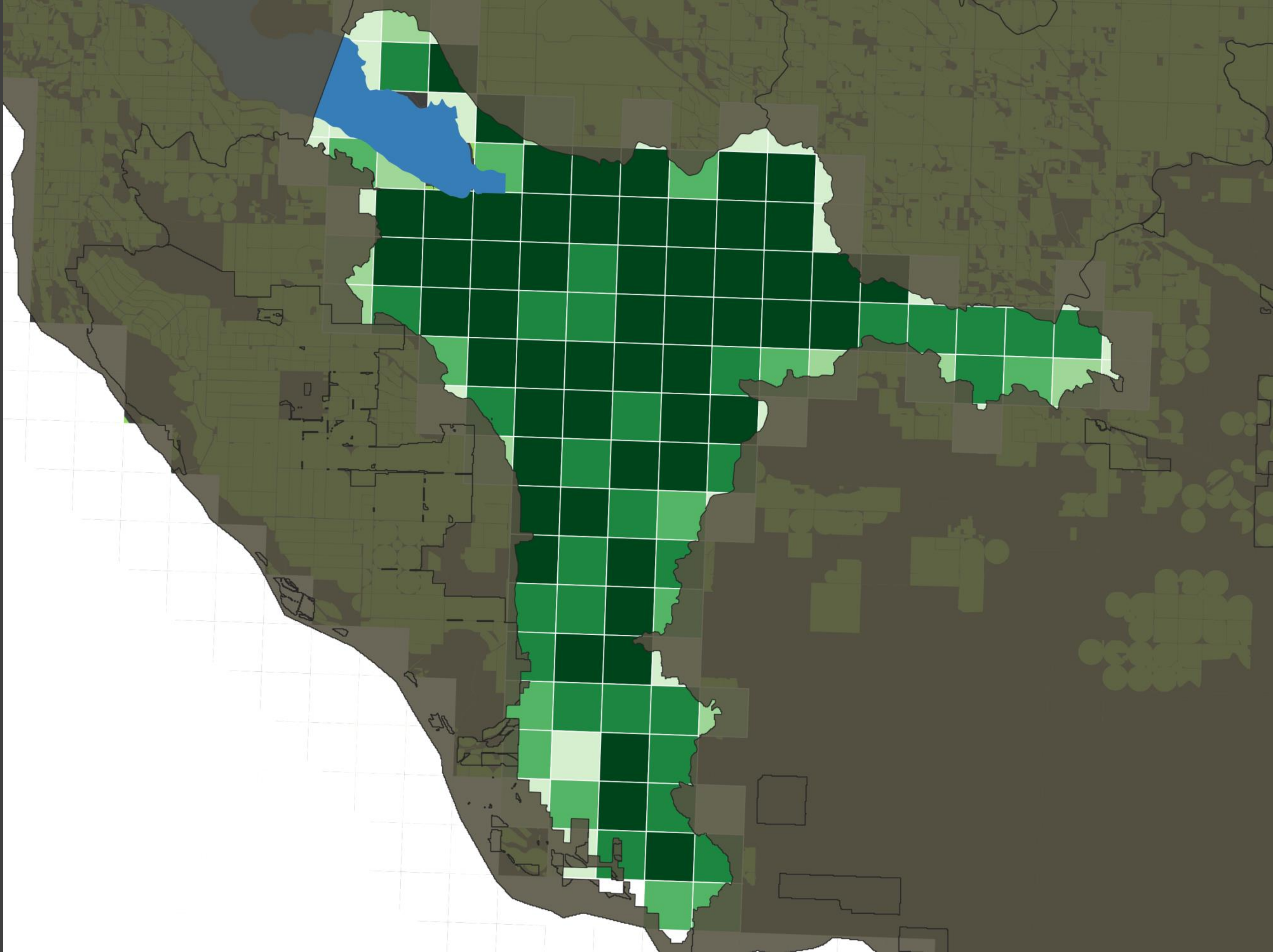

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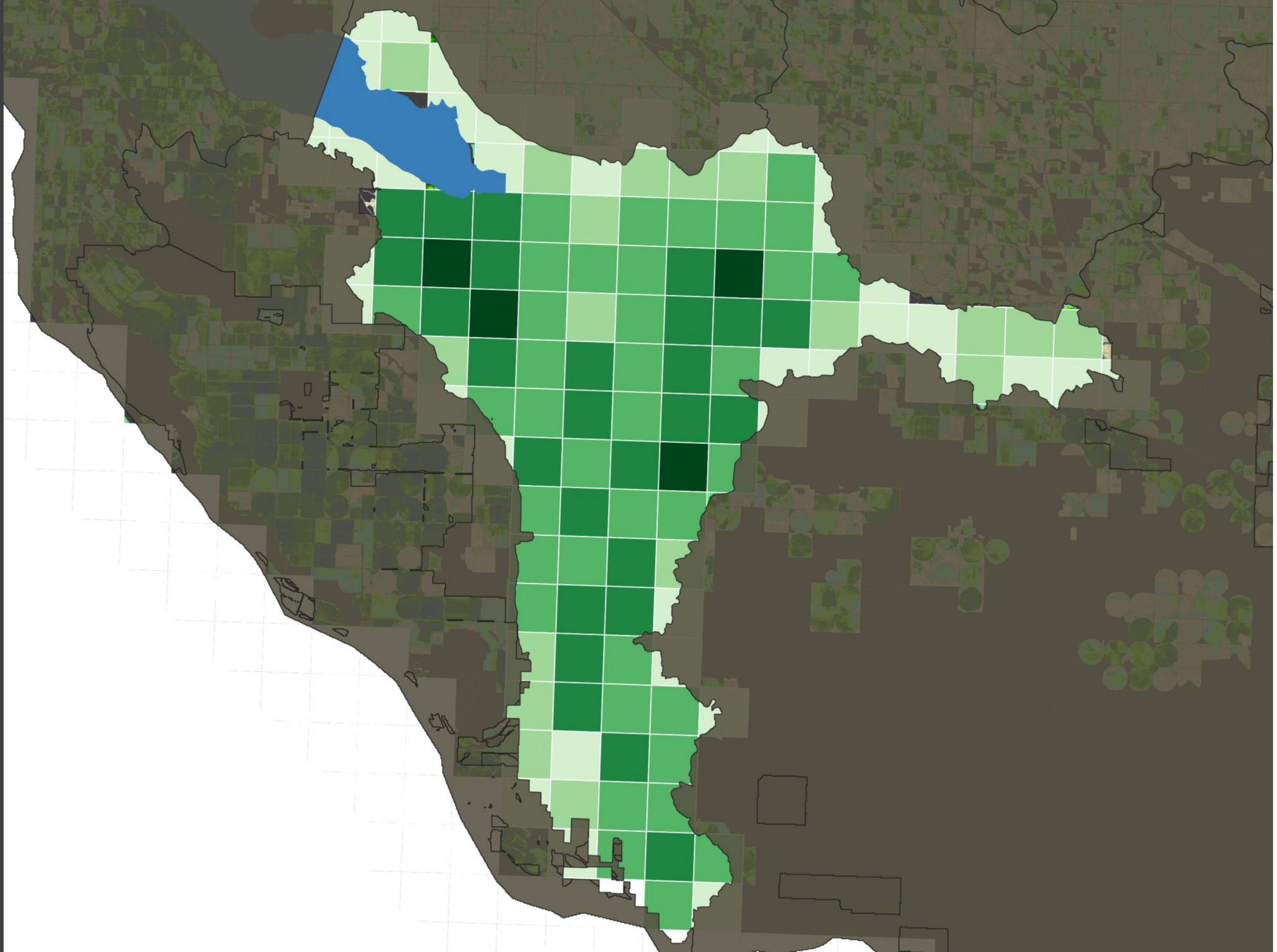
Deep percolation of irrigation (incidental recharge)

Distribute proportional to district ET
- Varies monthly



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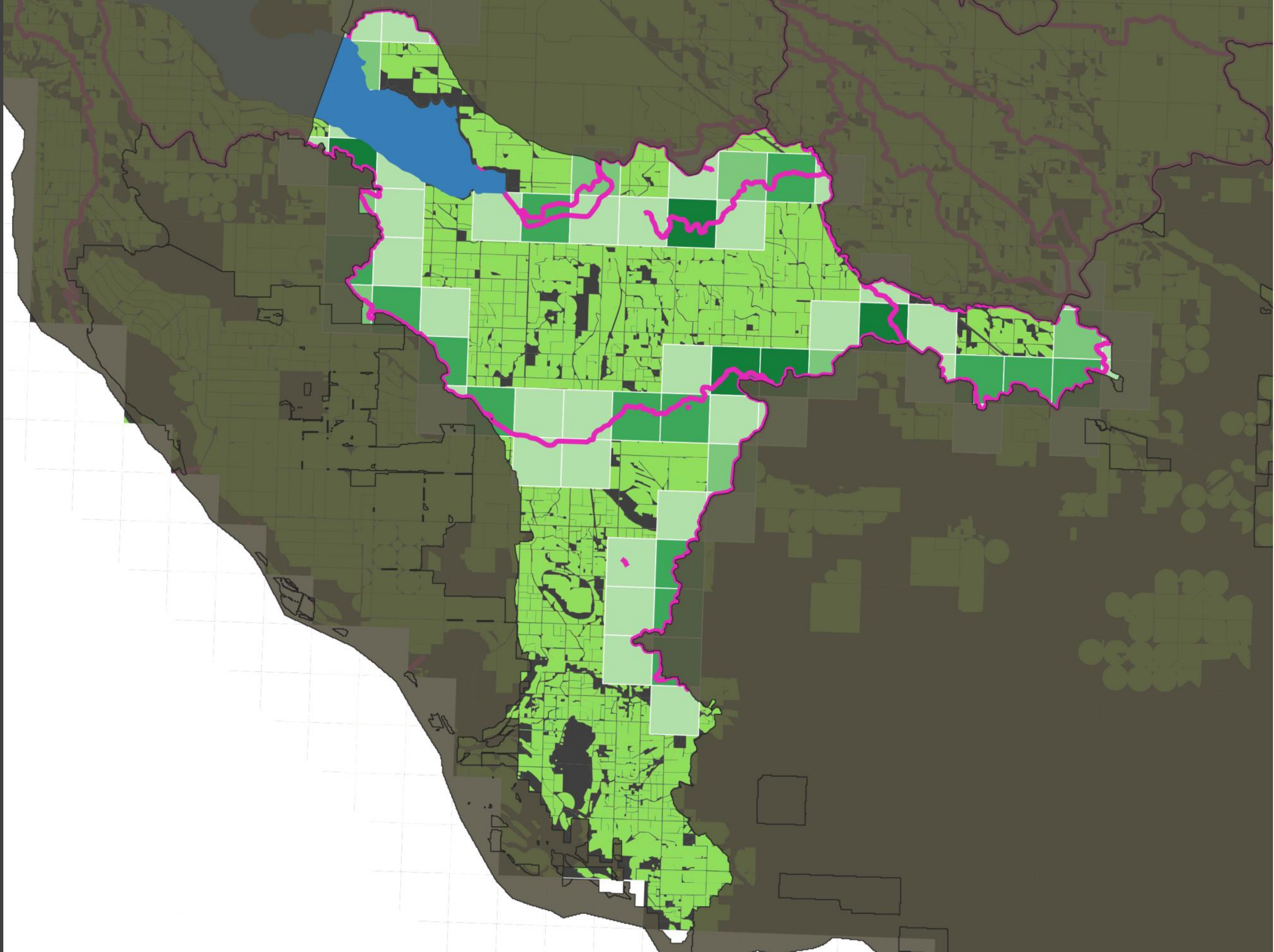

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Canal leakage

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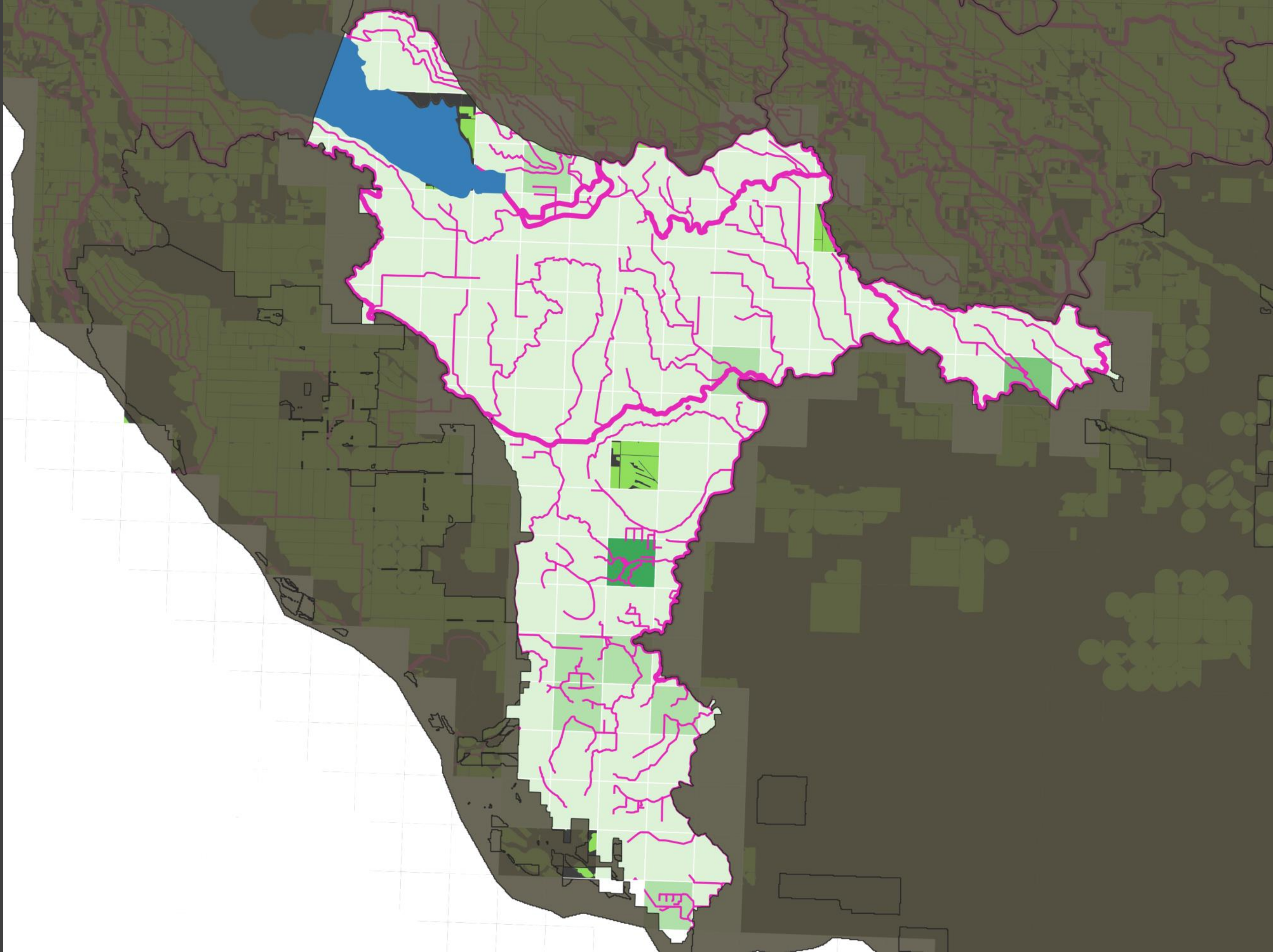

Pumping distribution: measured

Pumping distribution: unmeasured

Areal distribution of wells

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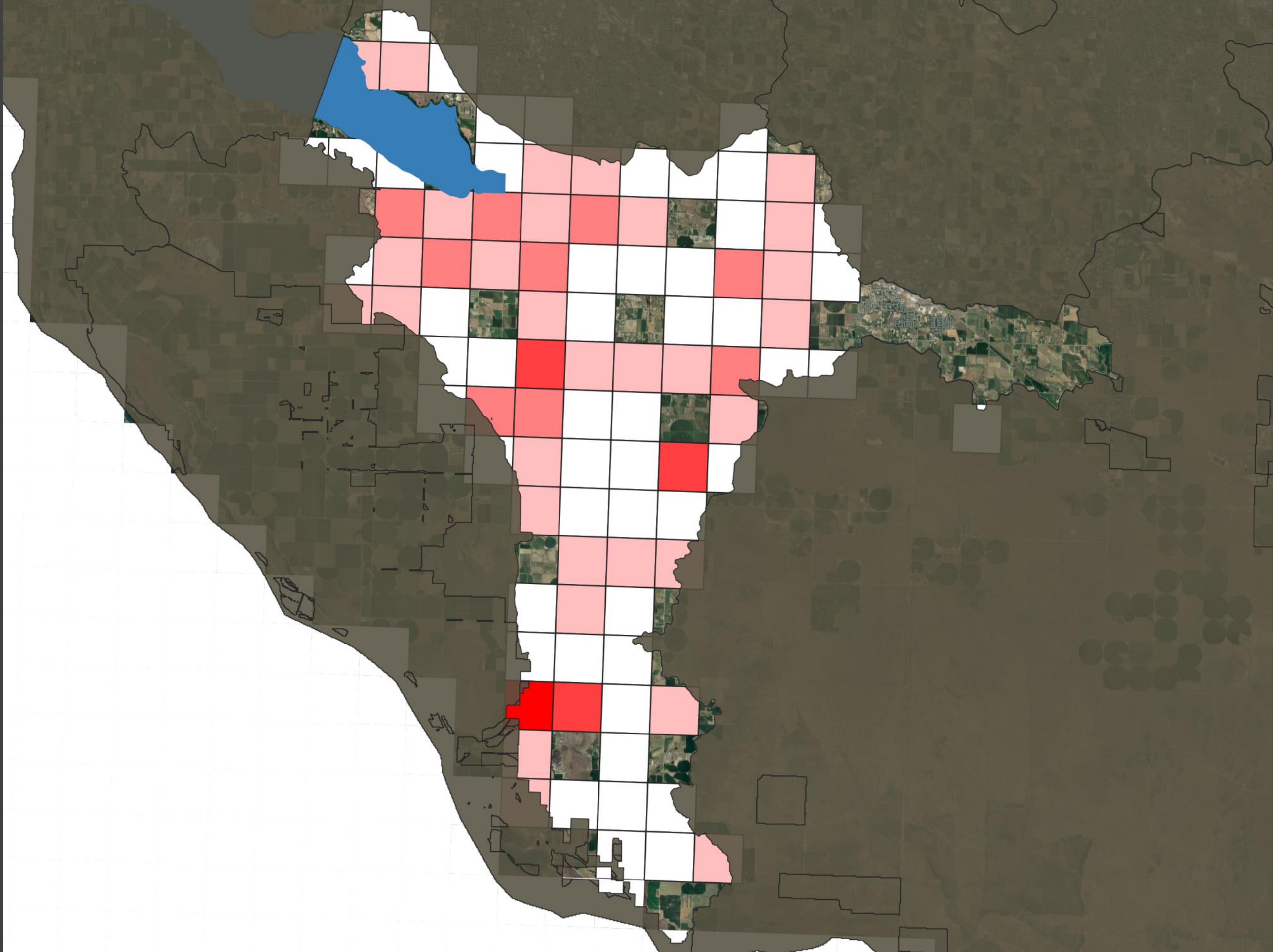
Pumping distribution: unmeasured

Distribution of pumping in row, column



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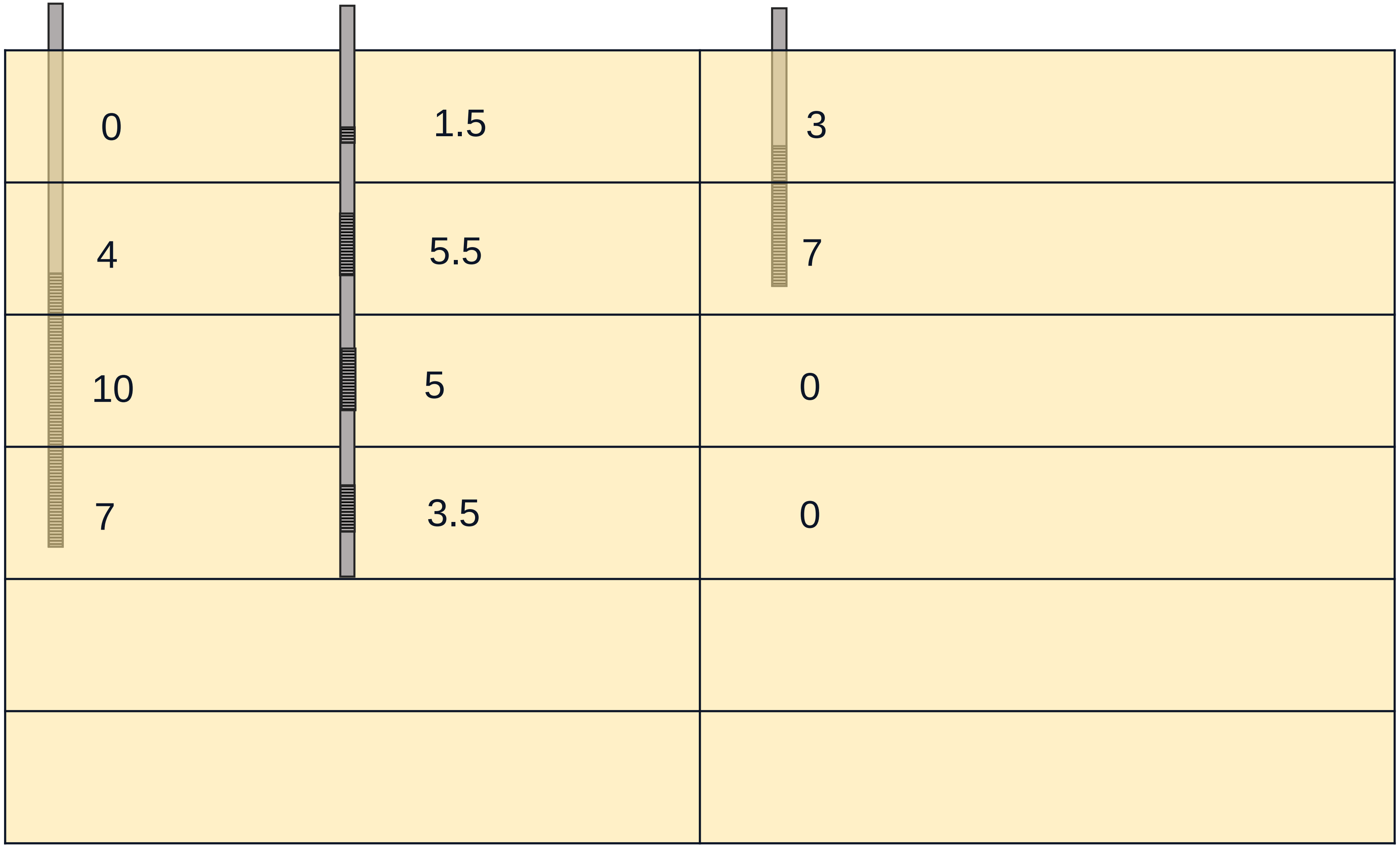
Pumping distribution: unmeasured

Vertical distribution (row, column, *layer*)

- One representative pumping well in each cell based upon nearby well logs
  - Not all well logs checked



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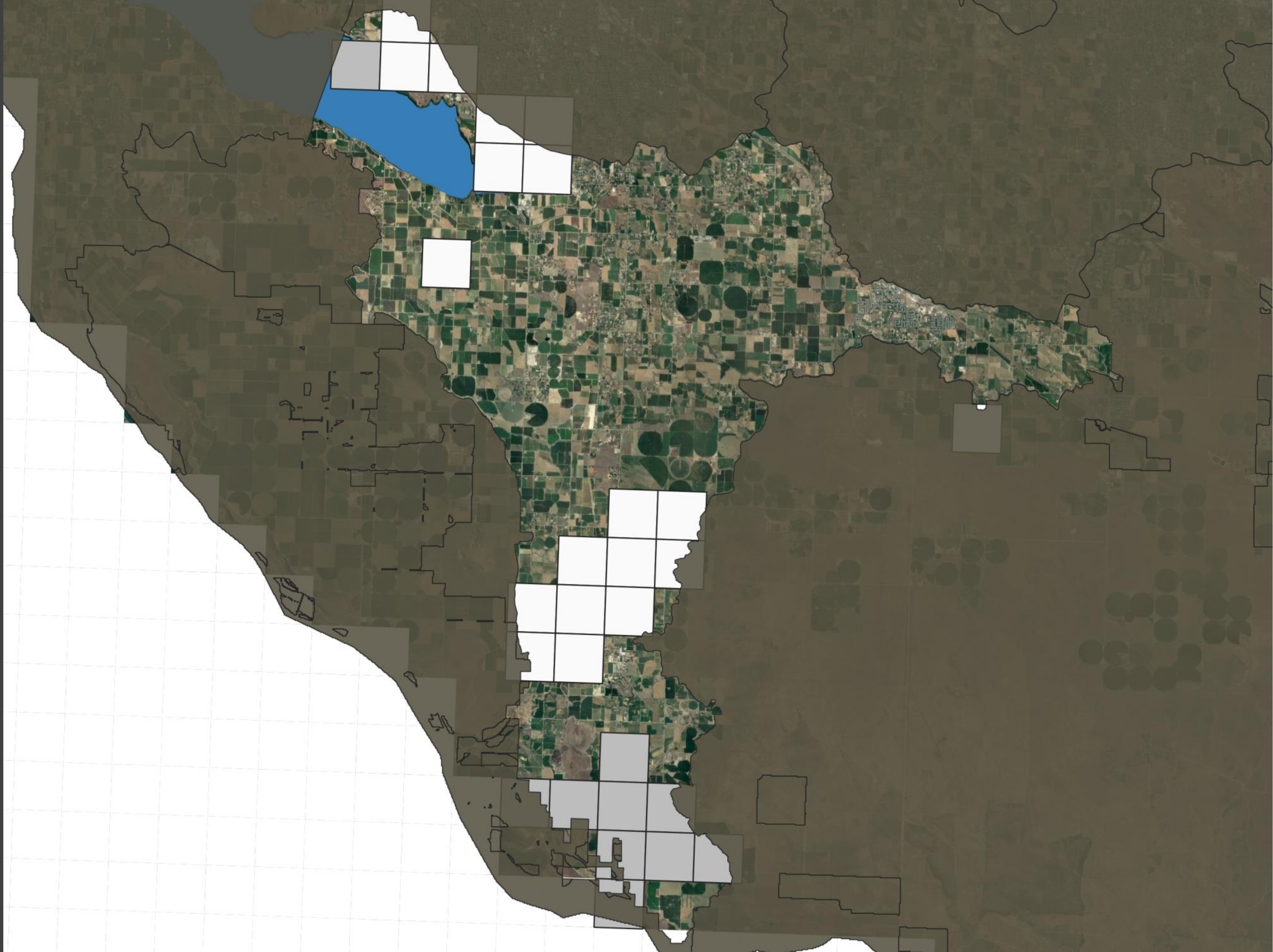
Pumping distribution: unmeasured

Vertical distribution:
Layer 1



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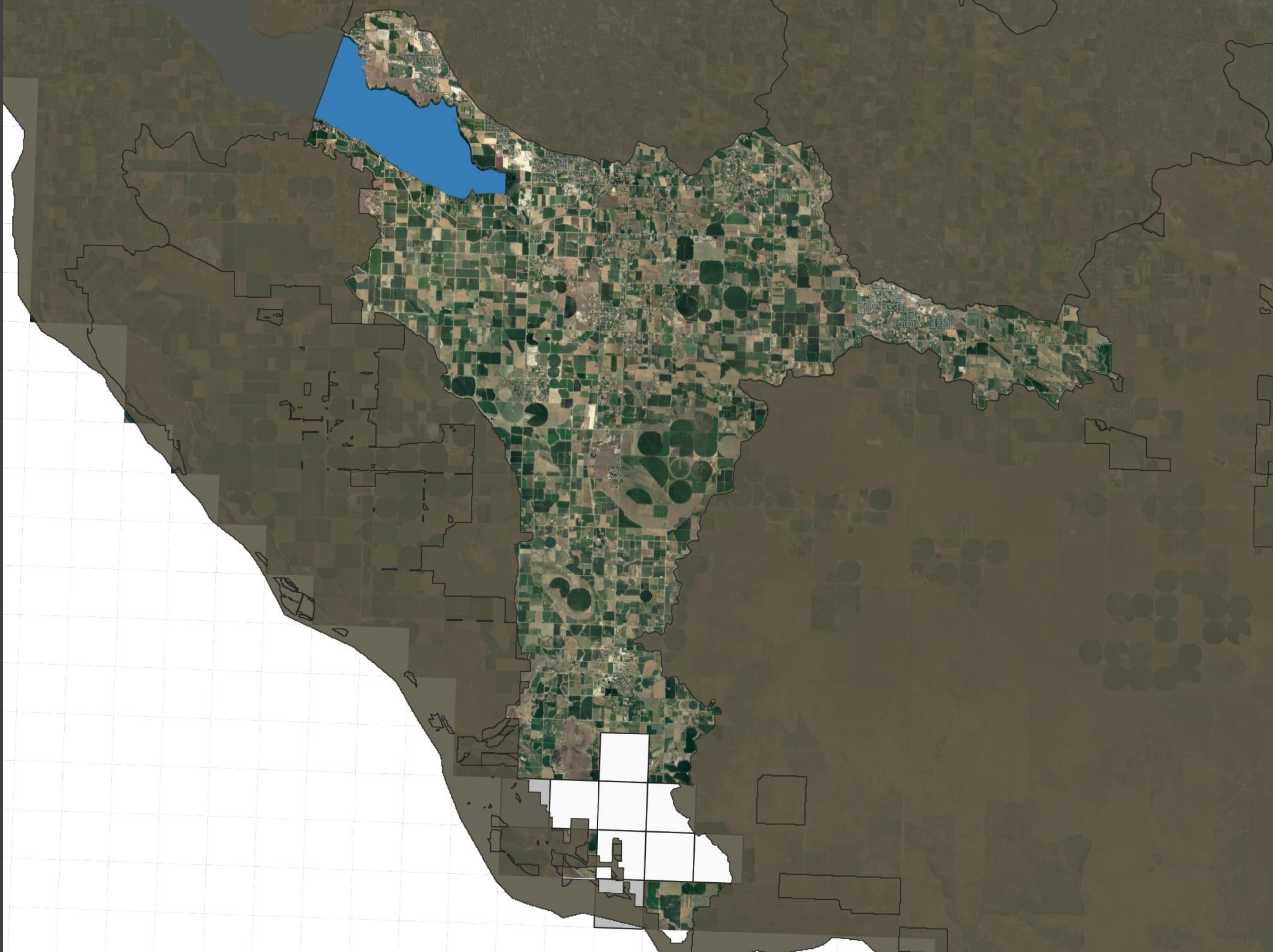
Pumping distribution: unmeasured

Vertical distribution: Layer 2



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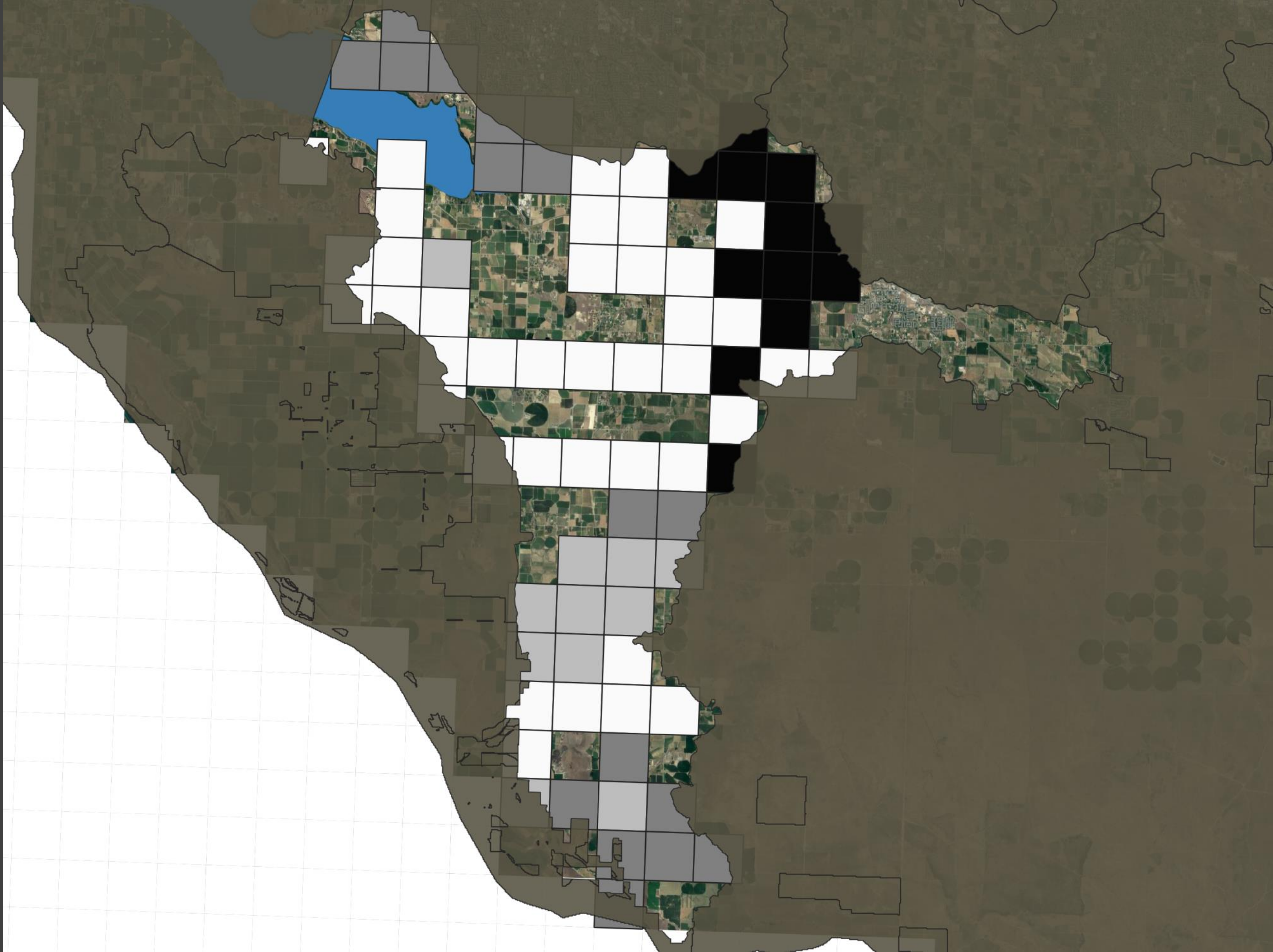
Pumping distribution: unmeasured

Vertical distribution:
Layer 3



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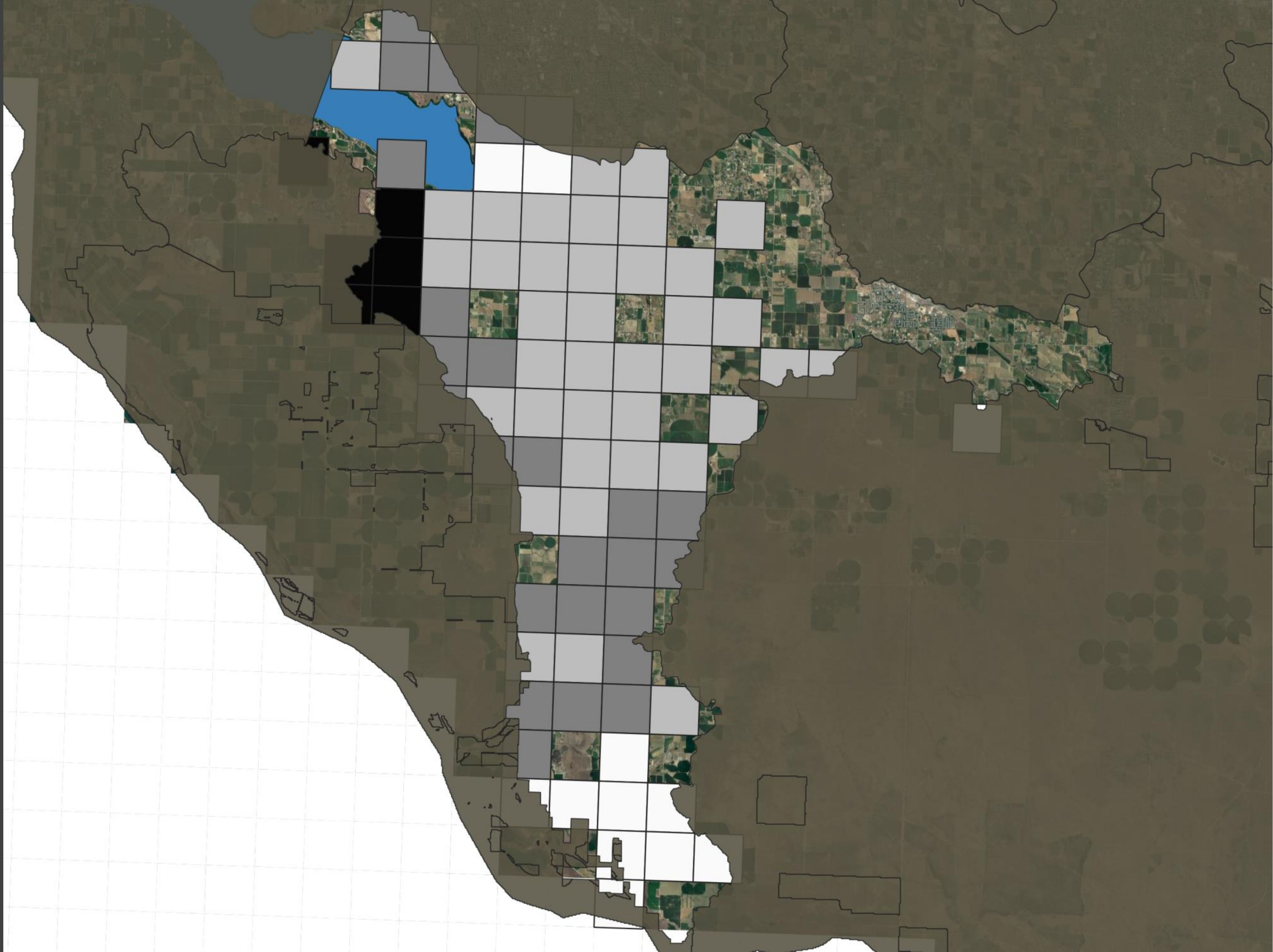
Pumping distribution: unmeasured

Vertical distribution:
Layer 4



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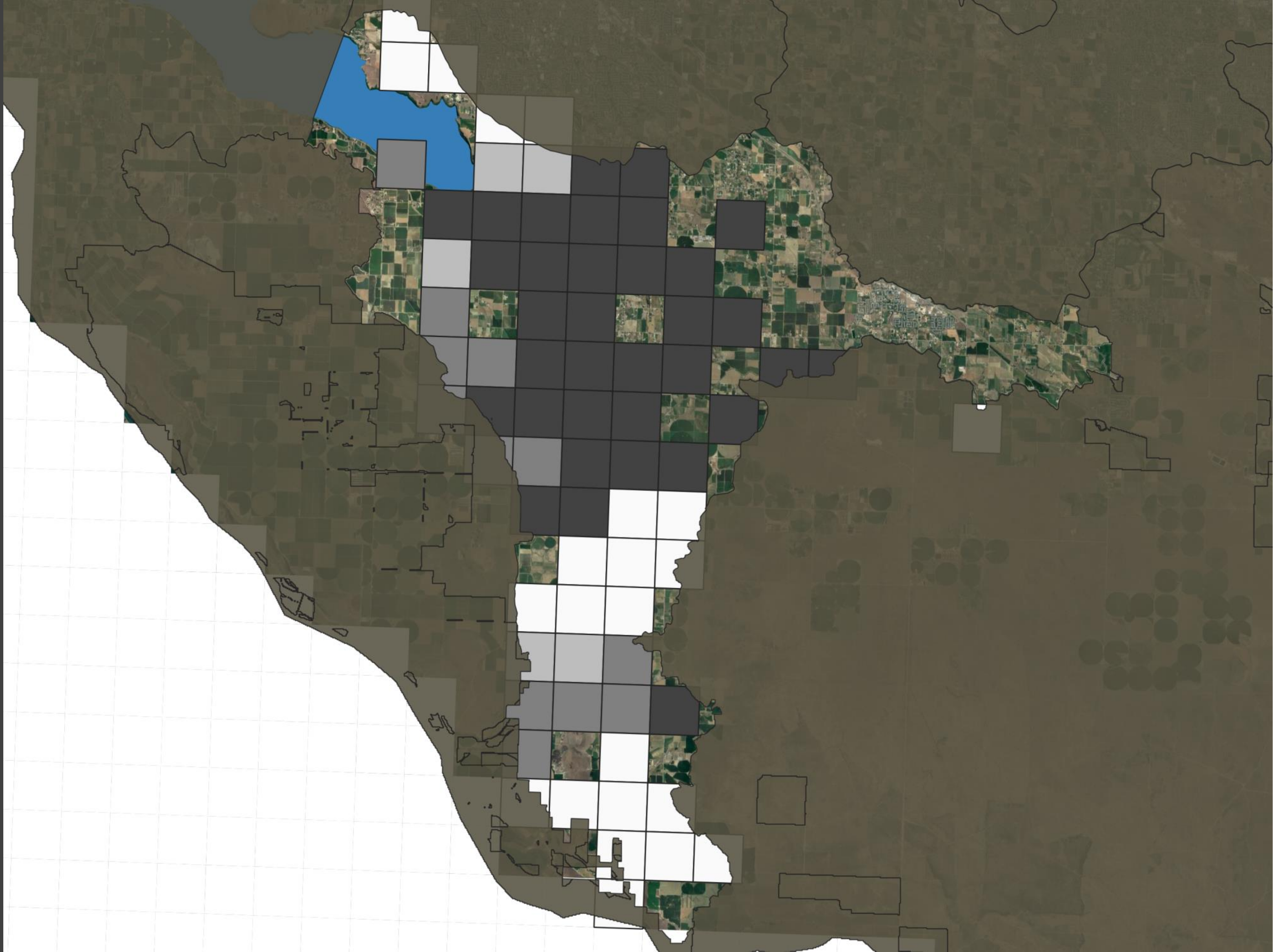
Pumping distribution: unmeasured

Vertical distribution:
Layer 5



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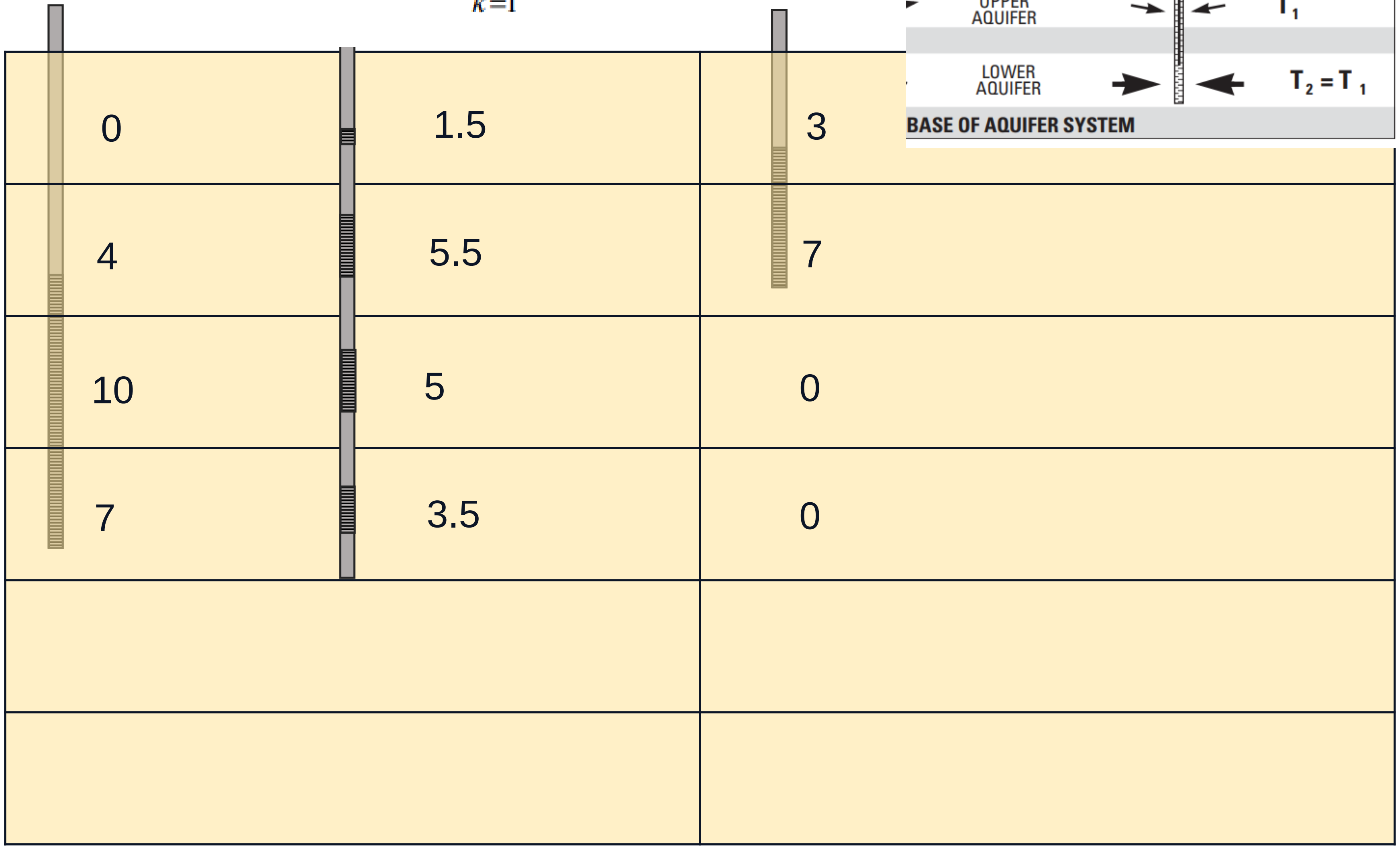
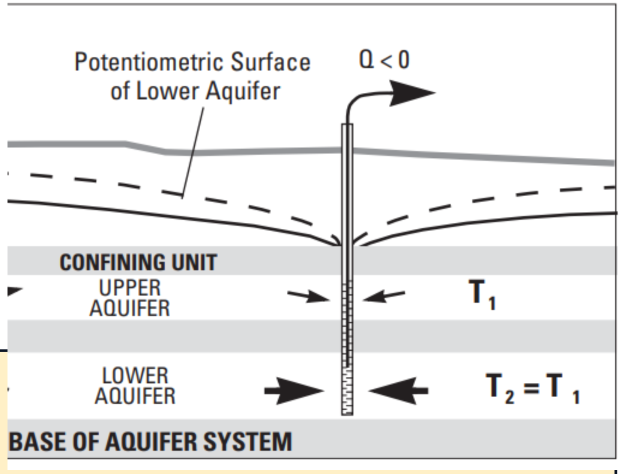
Pumping by Layer

Proportional to transmissivity

$$Q_{j,i,k} = \frac{T_{j,i,k}}{\sum_{k=1}^{NL} T_{j,i,k}} Q_{TOT}$$





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Summary

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Summary

Flux	Adjustable Parameters Affecting Volume	Spatial Distribution	Adjustable Parameters Affecting Distribution
Canal Leakage	Leakage factor (proportion of SW delivery to district)	Proportional to area or canal length	-
Deep percolation of irrigation	Percolation factor (proportion of district ET)	Proportional to ET	-
Groundwater pumping (row, col)	Leakage factor, percolation factor	Proportional to GW right	-
Groundwater pumping (layer)	“”	Proportional to layer screen length * cell hydraulic conductivity	Hydraulic conductivity (horizontal)

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Thanks for listening!

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