

An Overview of Domestic Well Data in California's Central Valley: Opportunities for Informed Risk Assessment

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goo.gl/DDjT8e



PPIC

PUBLIC POLICY
INSTITUTE OF CALIFORNIA



Agenda

- Background & Motivation
- Previous work on CA domestic wells
- Ongoing Work: Online State Well Completion Report Database (OSWCR)
- Vulnerability Case Study using OSWCR data
- Online Web Application for clean, ready-to-go OSWCR data
- Towards an assessment of Central Valley domestic well vulnerability to water quality contamination
- Conclusions

Background & Motivation

AB 685: Human Right to Water:

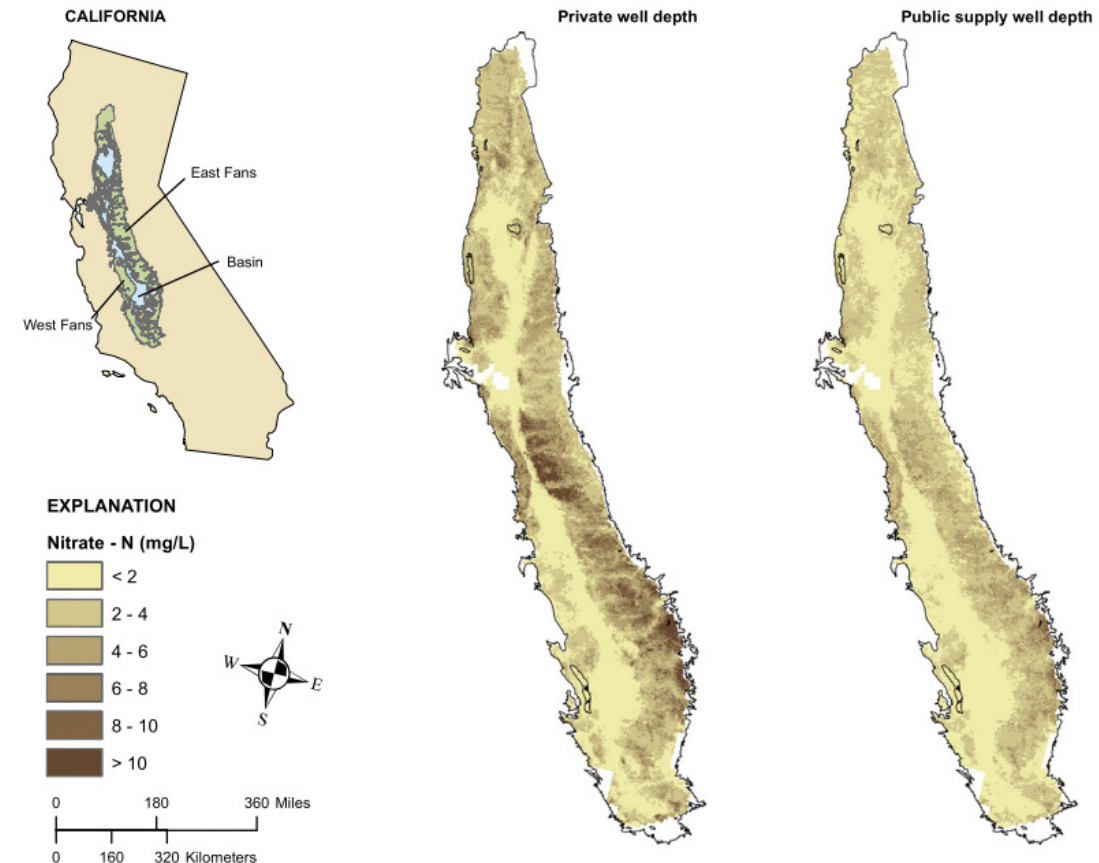
“every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes”



[Left] Donna Johnson, 70, (L) lifts pallets of donated bottled water from the back of her truck during her daily delivery run to residents whose wells have run dry, with resident Gabriel Tapia, 31, in Porterville, California October 14, 2014. Picture taken October 14, 2014. Photograph: Reuters/Lucy Nicholson . [Right] One of the many emergency water tanks in the Tulare Basin, CA during the 2012-2016 drought.

Background & Motivation

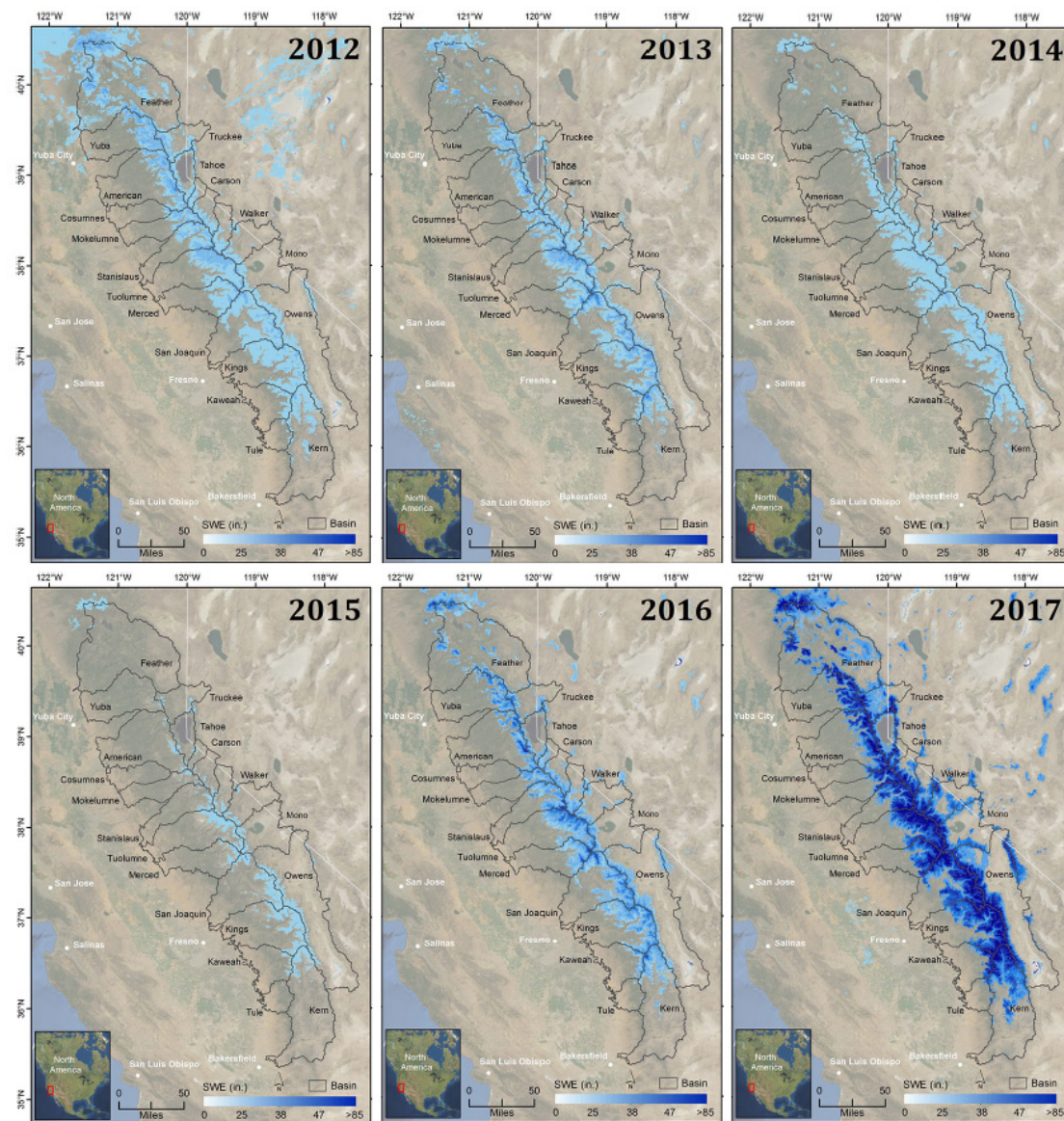
- Shallow domestic wells vulnerable to:
 - non-point source pollutants:
 - **nitrates** (*Ransom et al., 2017; Harter et al., 2012; Faunt et al., 2009; Balazs et al., 2011*)
 - **total dissolved solids** (*Pauloo, 2018 (in prep); CV-SALTS; Cismowski et al., 2006; Schoups et al., 2005; Bertoldi et al., 1991*)
 - drought (*Pauloo, 2018 (in prep); Lund et al., 2018; Gailey et al., 2018; London et al., 2018*)
- Drought → pumping to replace lost surface water (*Hanak et al., 2011*) → groundwater levels fall → well failure.
- Global warming → increased drought risk in California (*Swain et al., 2018; Rhoades et al., 2018; Diffenbaugh et al., 2015; Cook et al., 2015*) → intensification of groundwater demand to replace lost surface water.



(Ransom, 2017)

Background & Motivation

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(CA-DWR, 2018)

Overarching Workshop Goal

- Needs Assessment: estimate cost of implementing *SB 623 (Safe and Affordable Drinking Water Fund)*.
- Today we focus on domestic wells

This Presentation's Goal

- Review existing/ongoing research that informs the cost estimation of SB 623 as it pertains to *domestic well vulnerability to water quality contamination in the Central Valley (CV)*.
- Online State Well Completion Report Database (OSWCR)

Overarching Workshop Goal

- Needs Assessment: estimate the cost of *SB 623 (Safe and Affordable Drinking Water Fund)*.
- Domestic wells

This Presentation's Goal

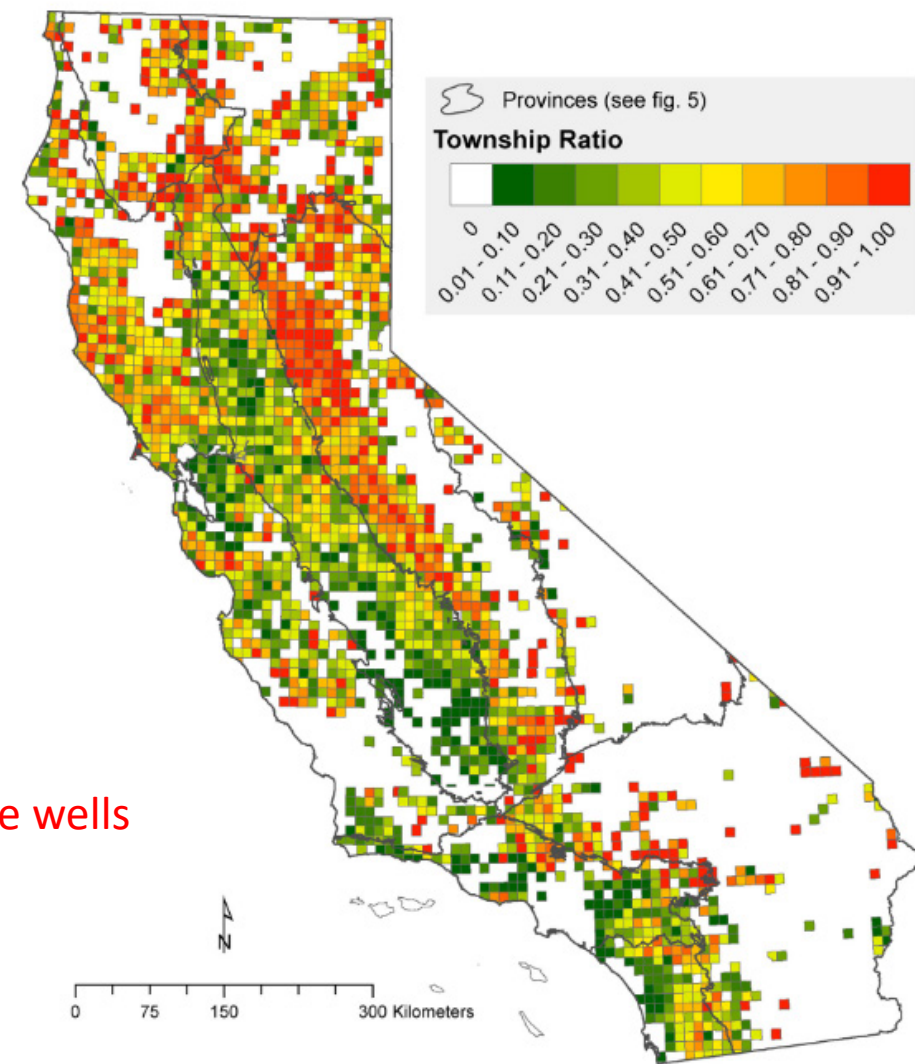
- Review existing/ongoing research that informs the cost estimation of SB 623 as it pertains to *domestic well vulnerability to water **quality** contamination in the Central Valley (CV)*.
- Online State Well Completion Report Database (OSWCR)

Previous Work Characterizing Domestic Wells

- Statewide – Johnson and Belitz, 2015
 - 741,262 scanned OSWCR Well Completion Reports (WCR)
 - 41,671 total WCRs viewed
 - *13,557 domestic WCRs viewed*
 - Statewide, *1.2 million people* rely on domestic wells for drinking water (1990 US Decadal Census)
 - Likely *1.5 million* by 2010.
 - 80% of wells in 3 regions:
 - *Central Valley (31.6%)*
 - *Sierra Nevada (31.5%)*
 - *North Coast Range (16.6%)*

Total wells, NOT active wells

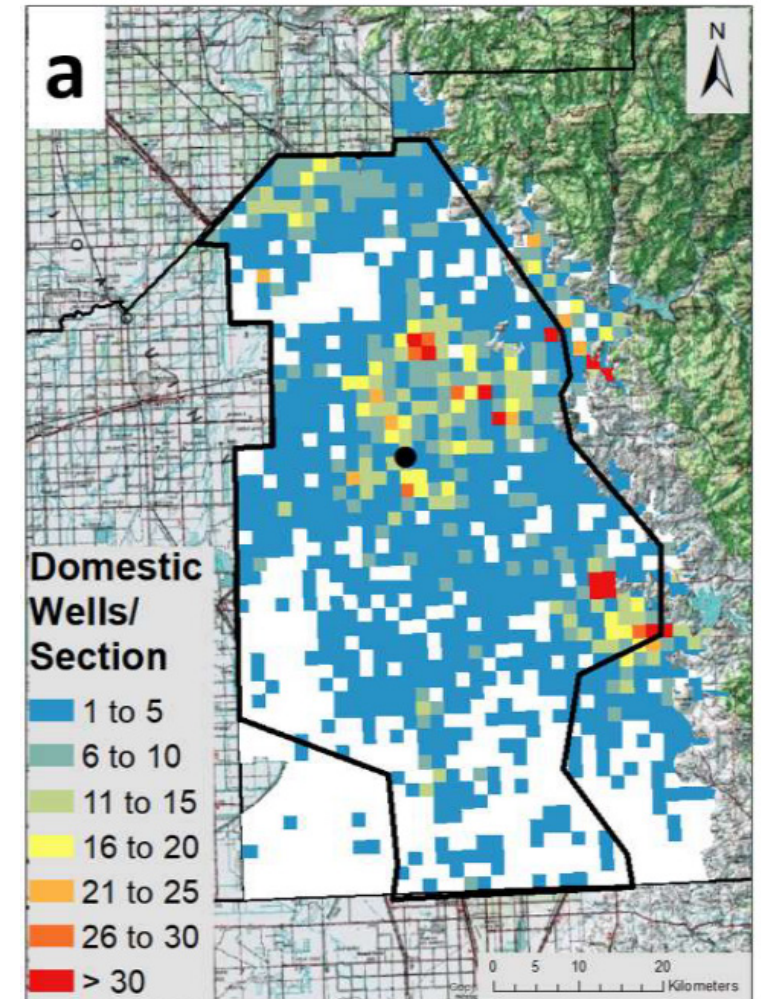
- **Central Valley estimate: 91,598 WCRs**



(Johnson and Belitz, 2015)

Previous Work Characterizing Domestic Wells

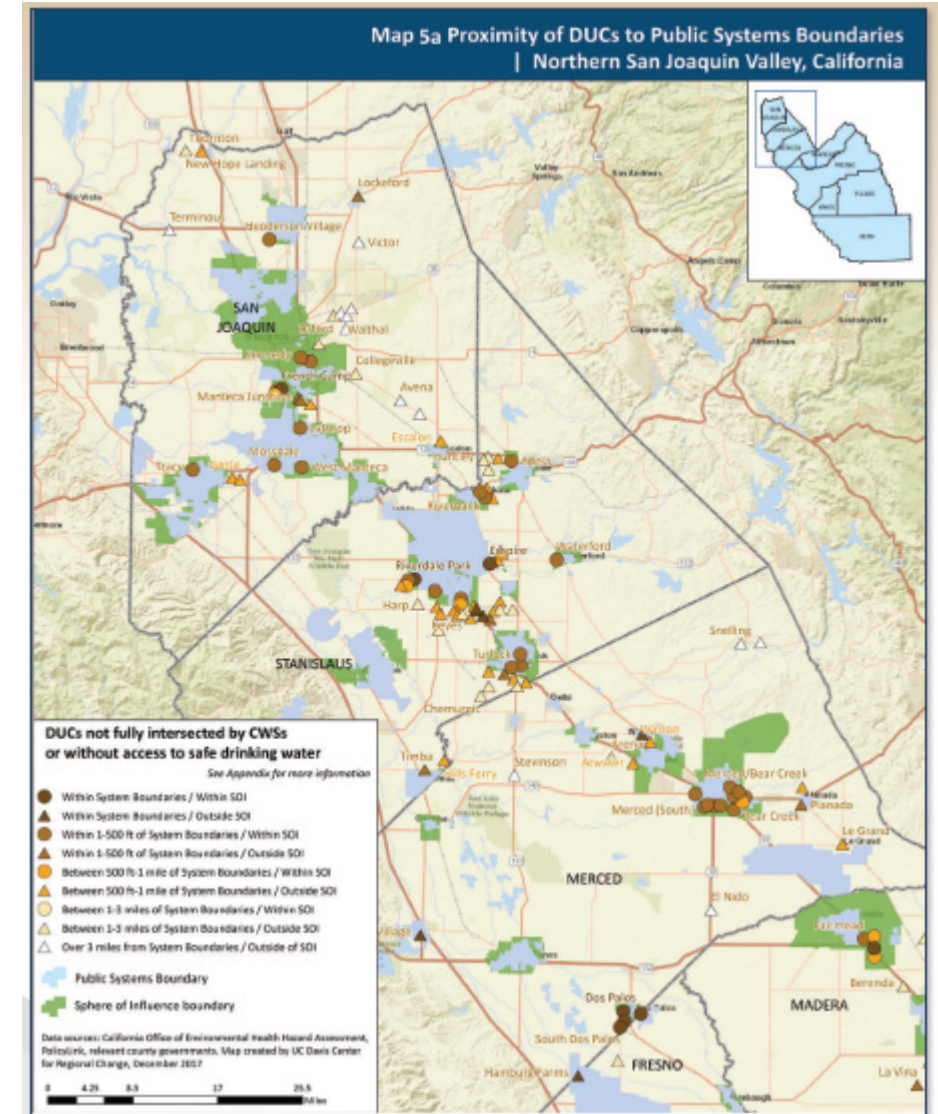
- Basin-Scale – Gailey et al., 2018
 - Tulare county domestic well failure model
 - Economic impact analysis
- Basin-Scale – London et al., 2018
 - Disadvantaged unincorporated communities
 - Proximity to public water systems
- Statewide – Pauloo et al., 2018 (in prep)
 - 943,469 WCRs cleaned/analyzed
 - Best estimates of statewide well count/distribution
 - Cleaned data freely accessible: ucwater.org/oswcr
 - Central Valley wide domestic well failure model
 - Drought simulation / SGMA compliance scenarios



(Gailey, 2018)

Previous Work Characterizing Domestic Wells

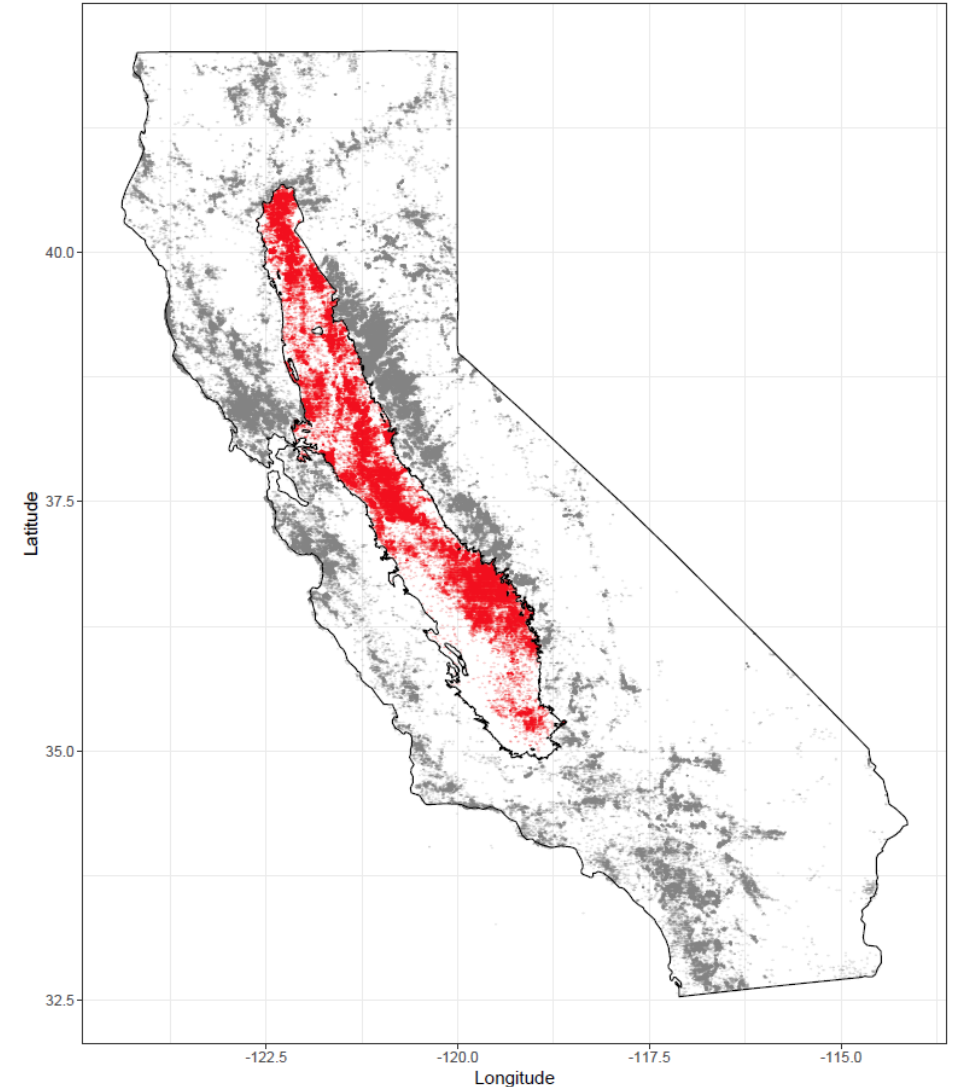
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(London et al., 2018)

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(Pauloo et al., 2018) – in prep

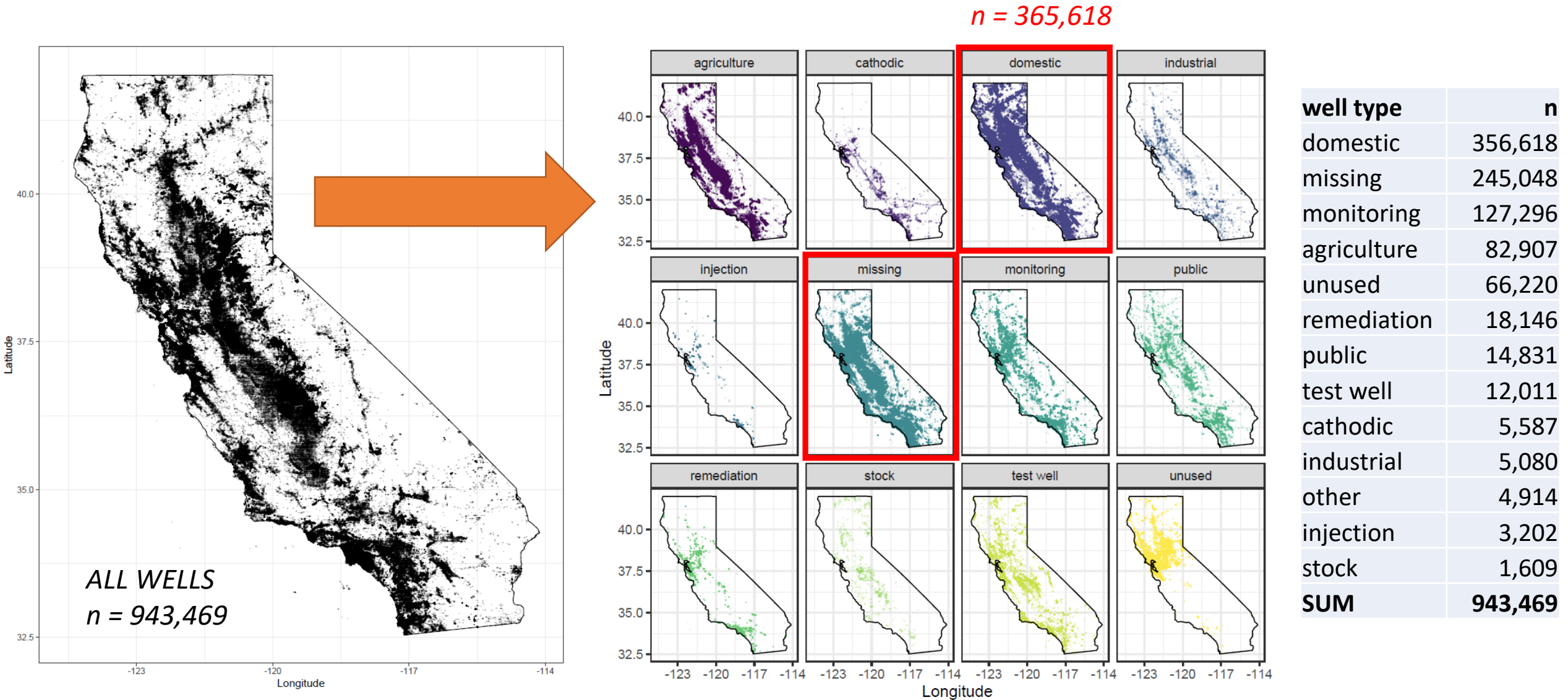
Ongoing Work: OSWCR

Guiding Questions:

1. How many **active** domestic wells are in the Central Valley and where are they located?
2. Where are domestic wells most vulnerable?

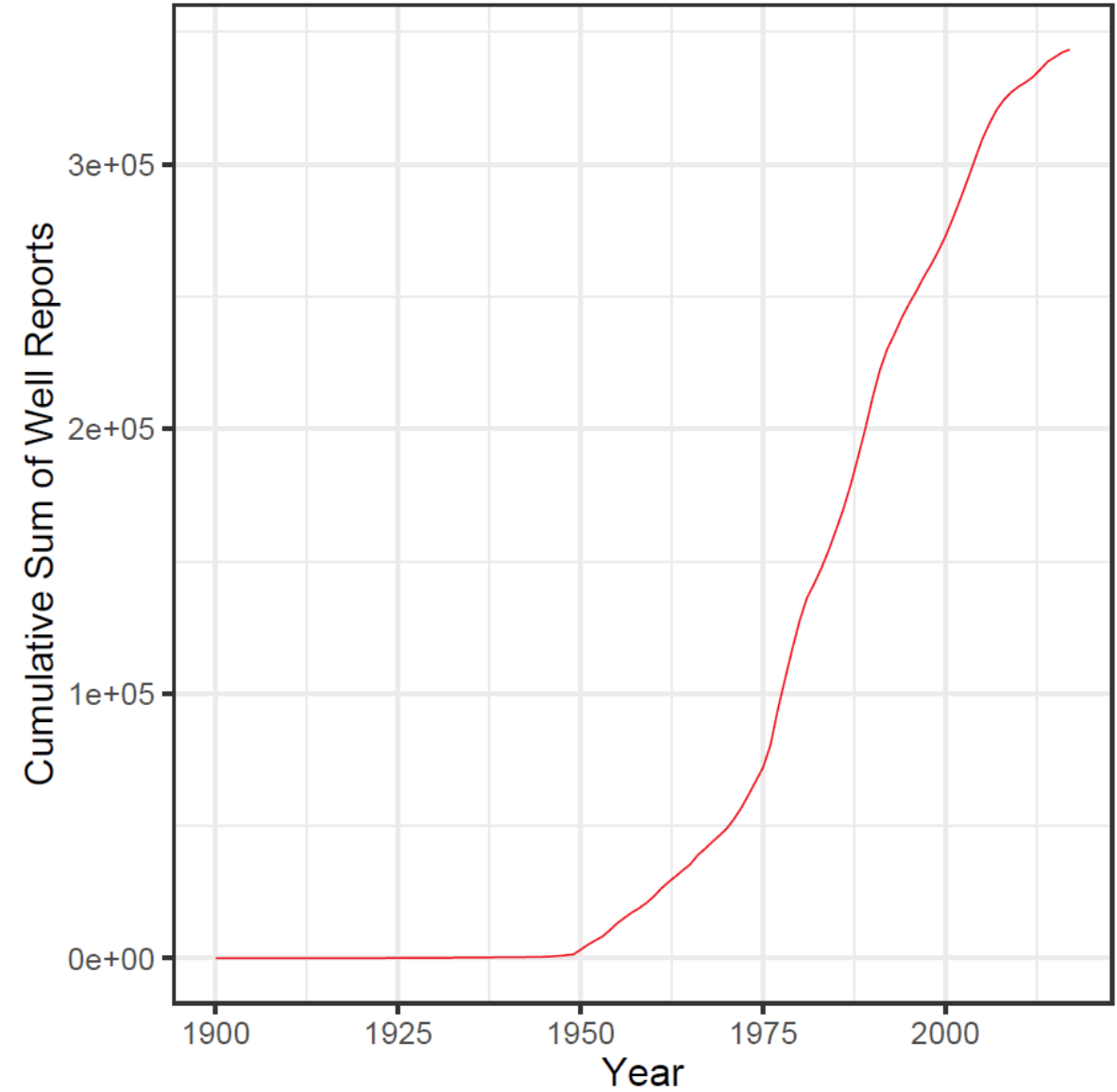
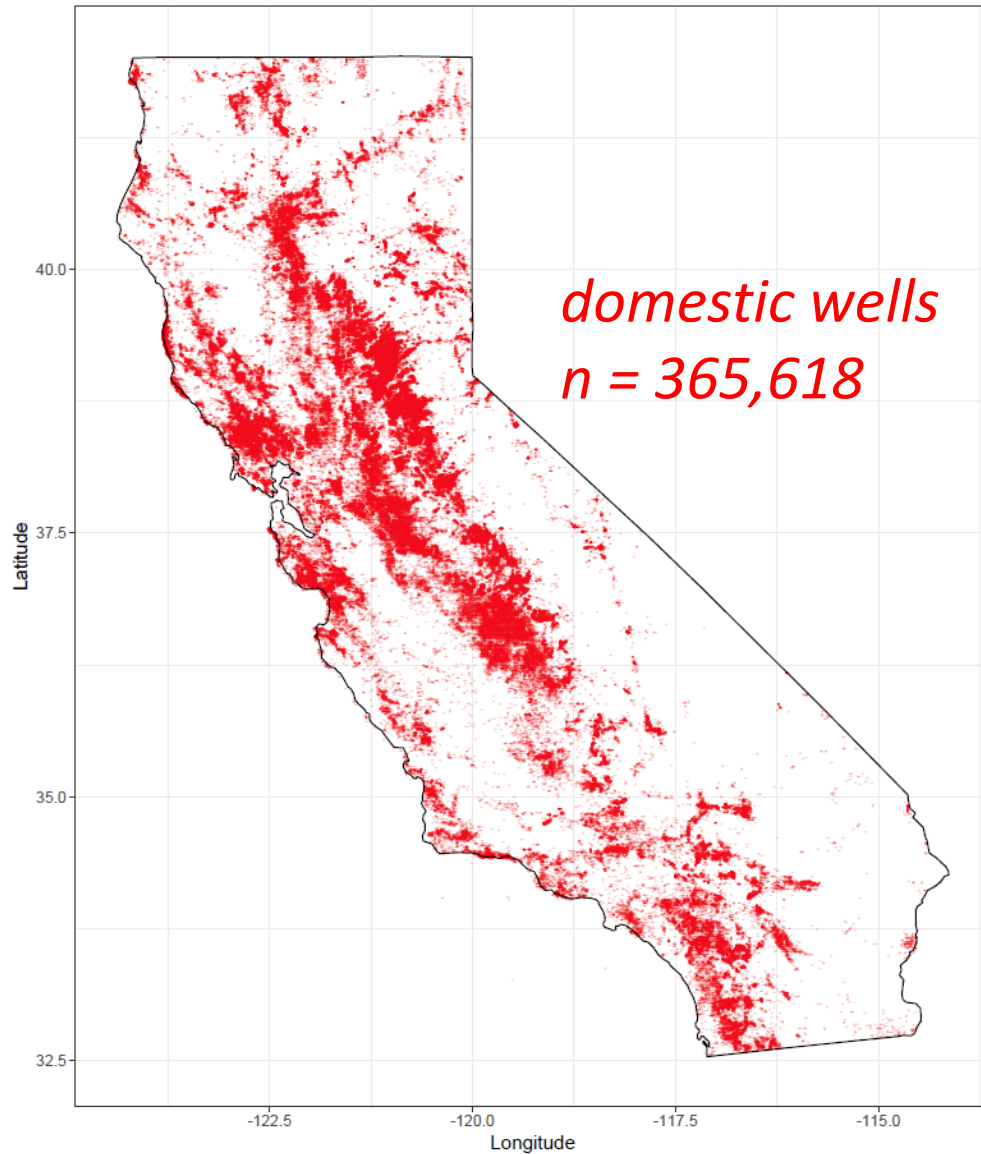
Q1: How many active domestic wells are in the Central Valley and where are they located?

A1: Examine spatial distribution



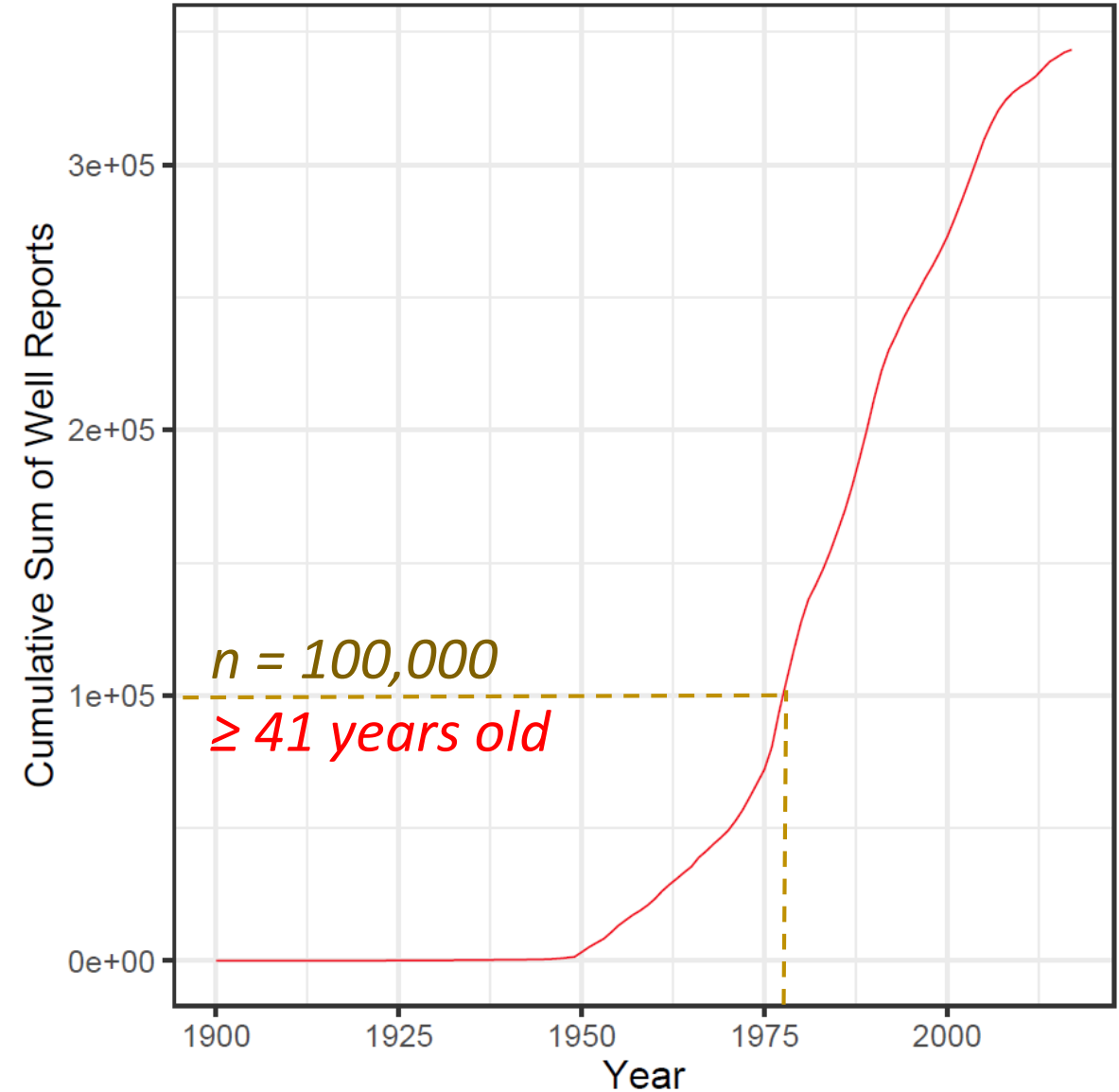
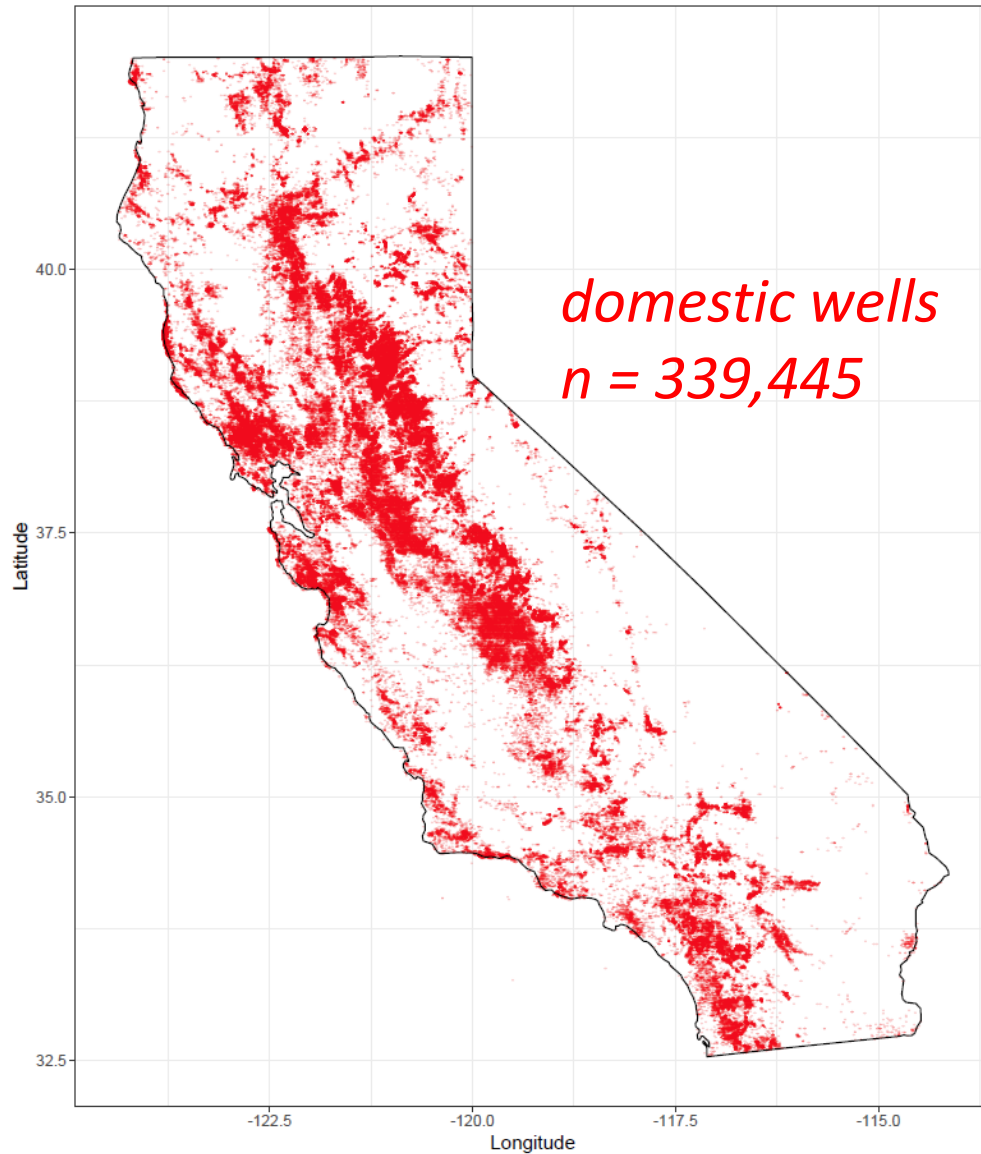
Q1: How many active domestic wells are in the Central Valley and where are they located?

A1: Examine spatial distribution, **consider retirement age**



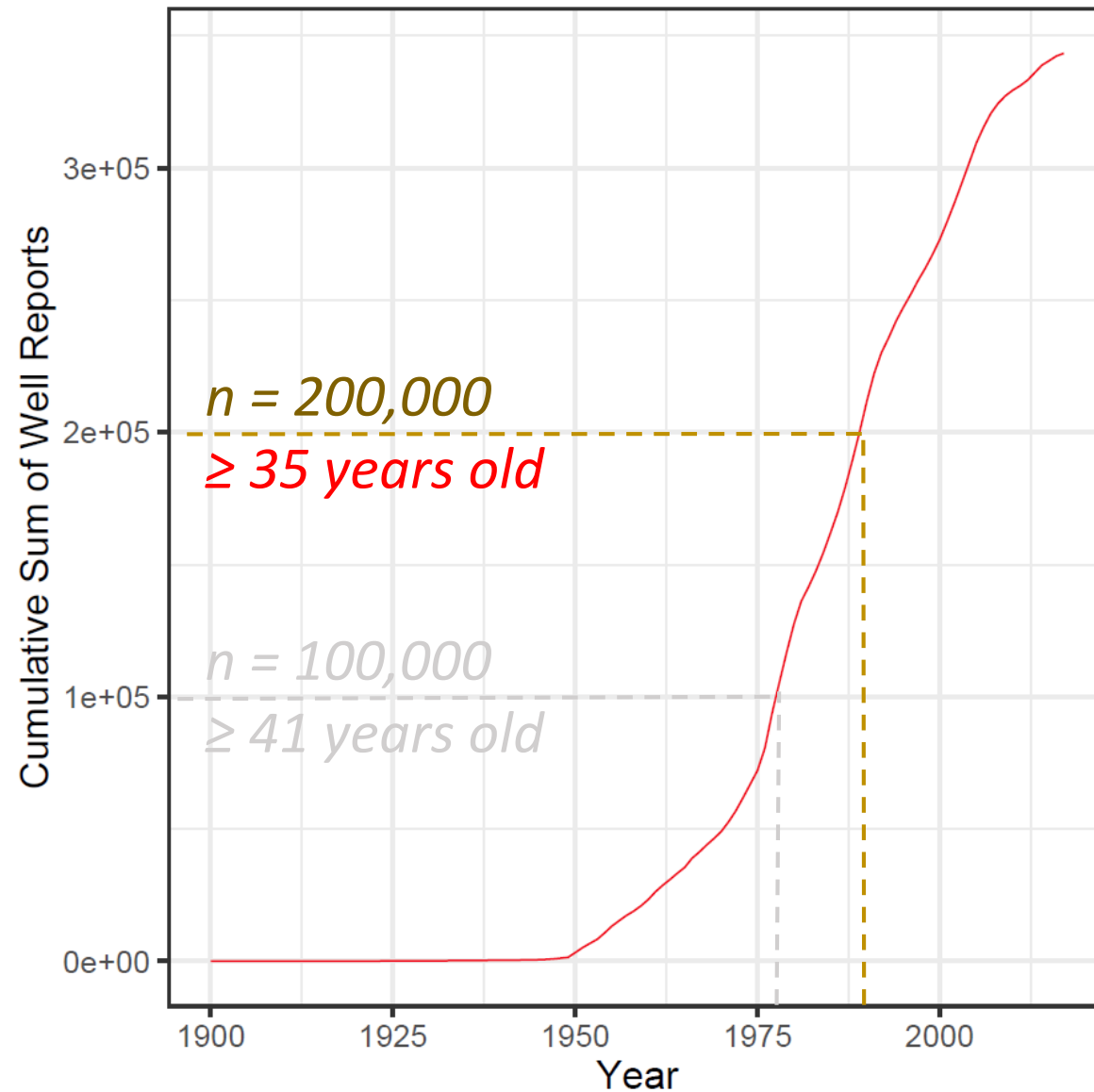
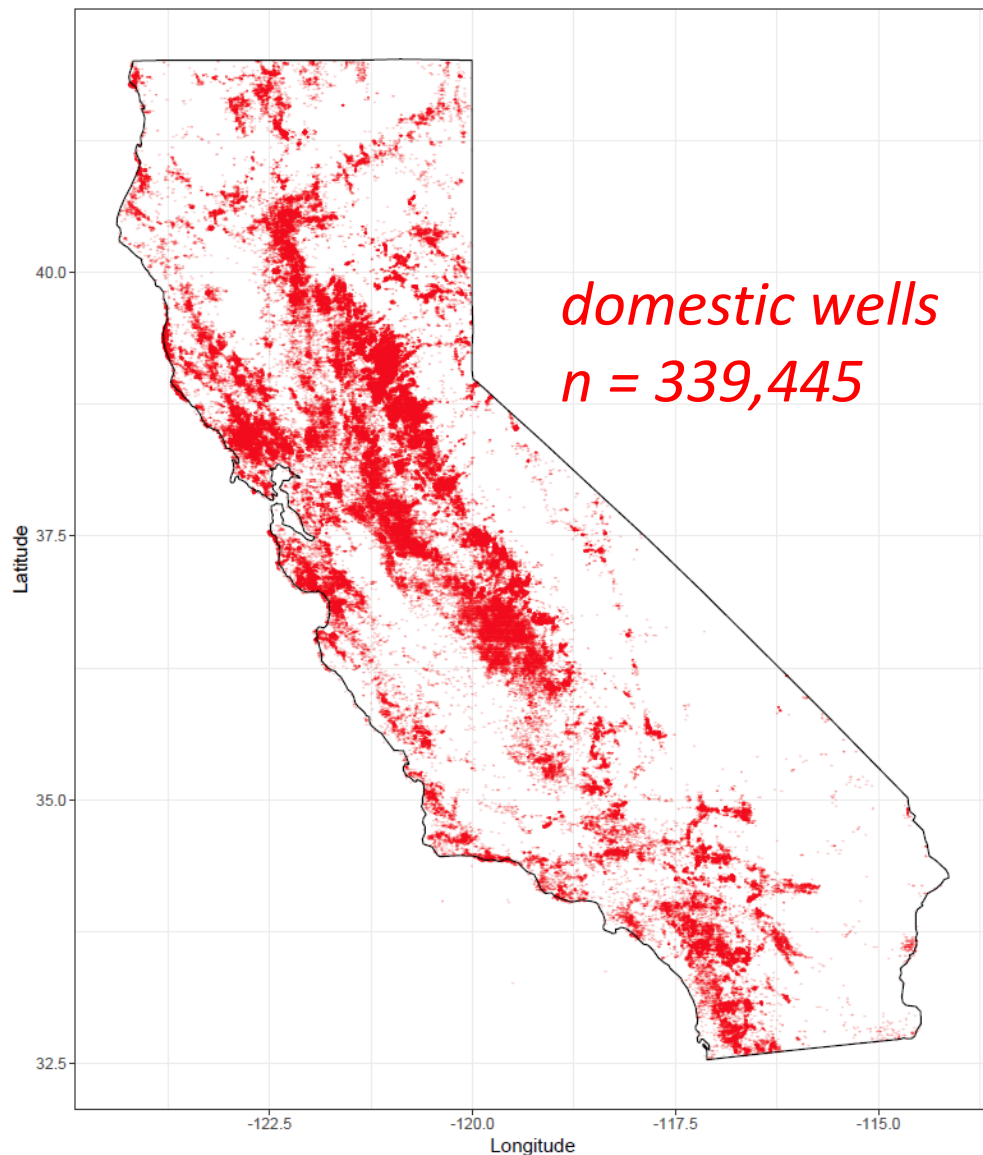
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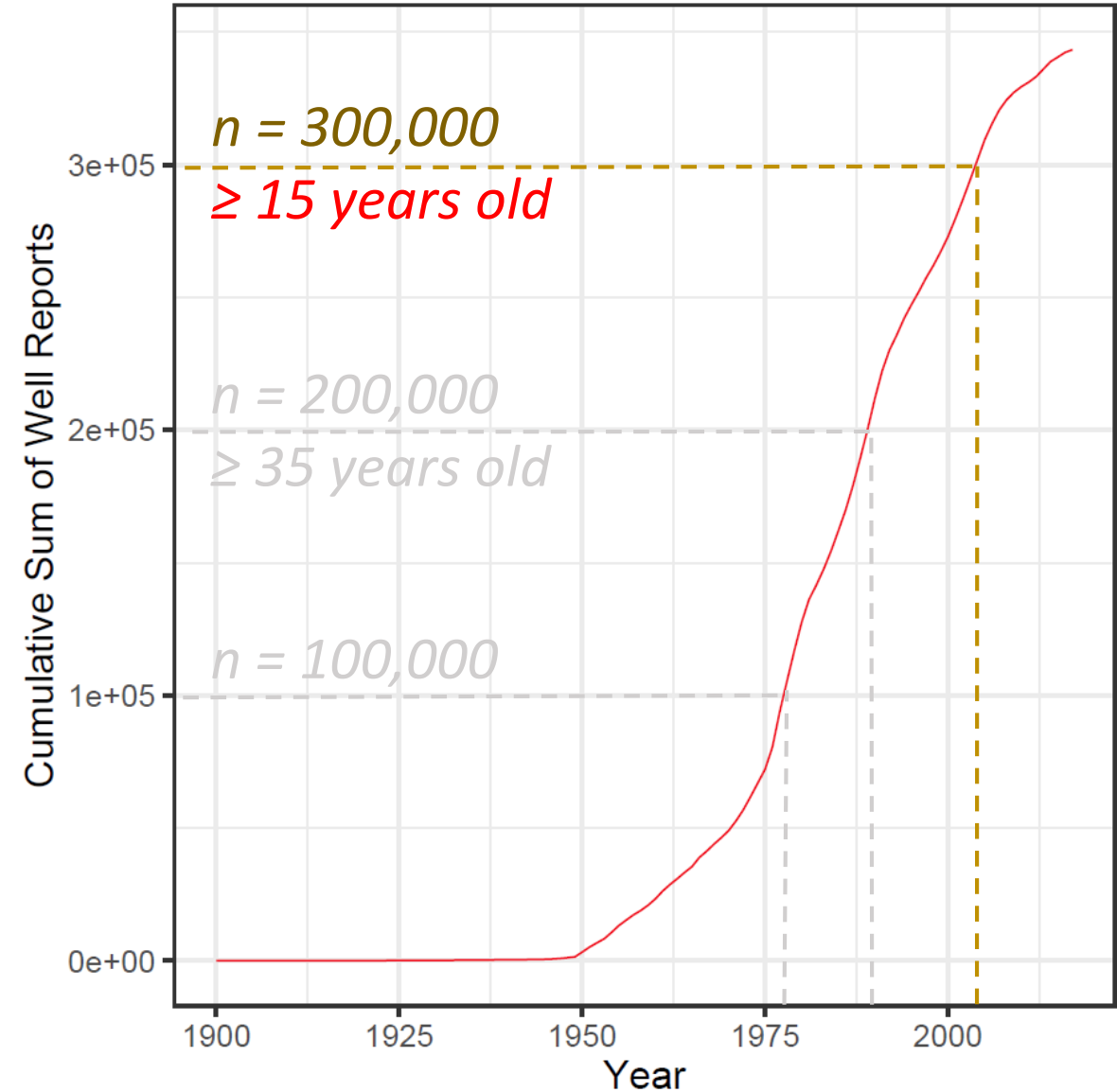
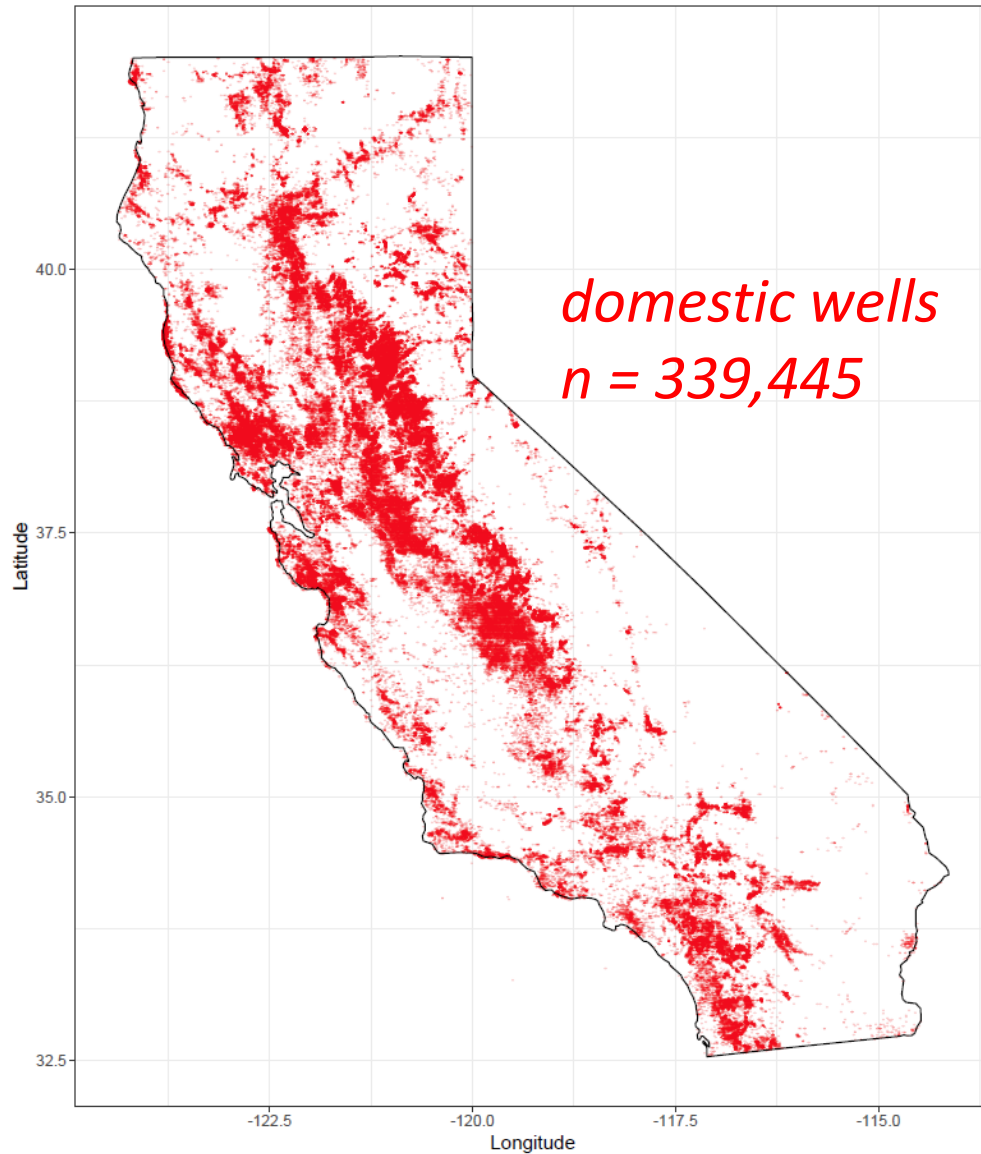
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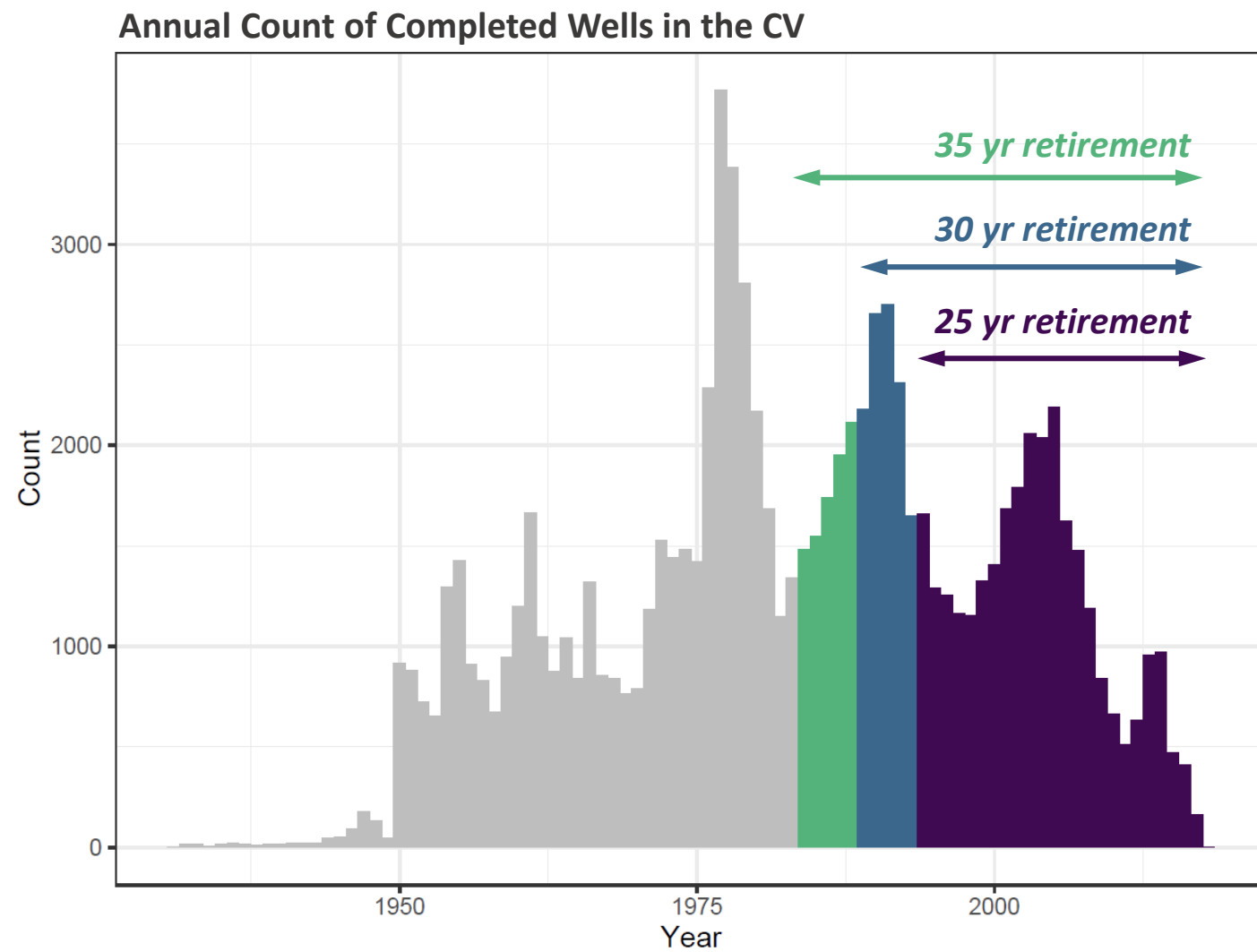
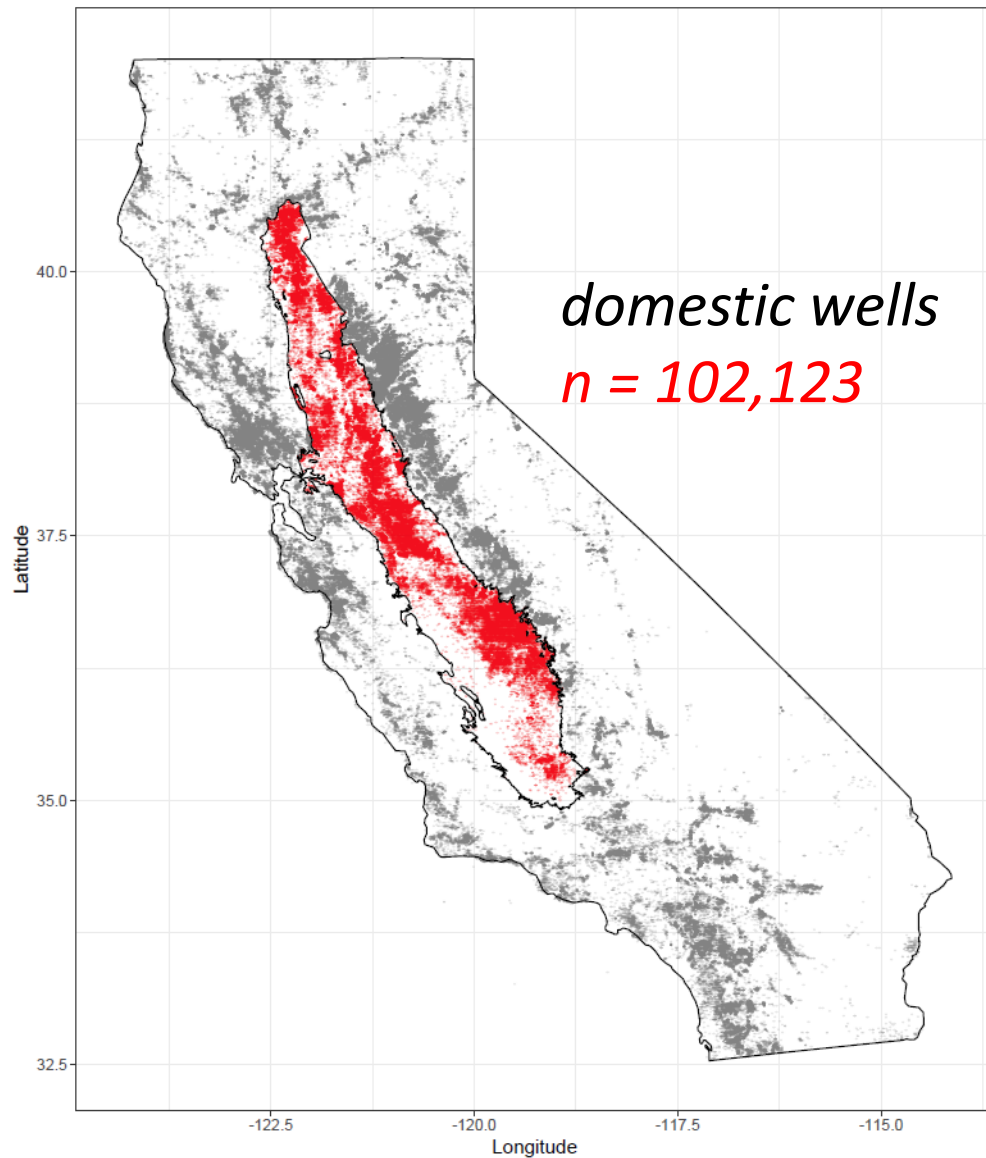
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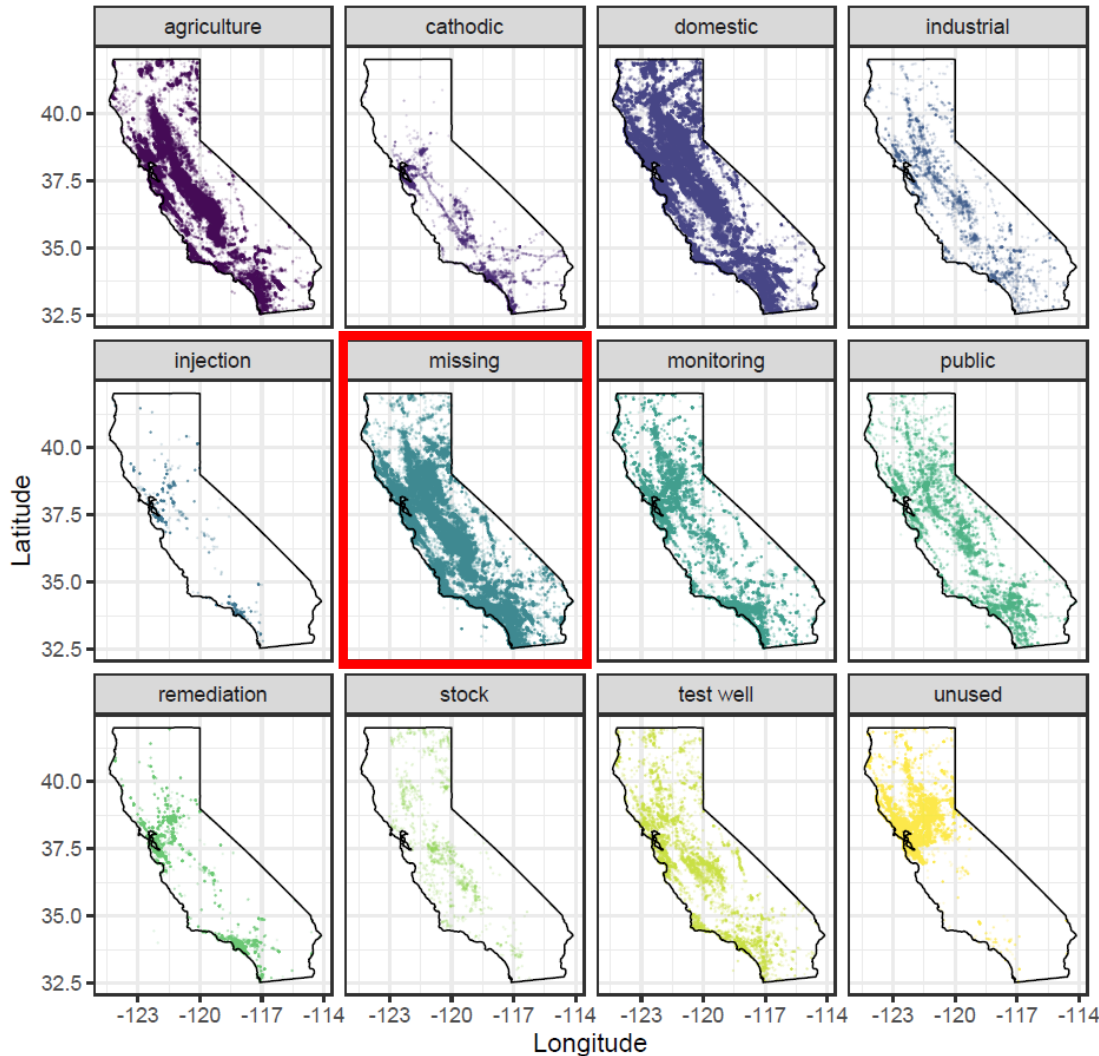
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A1: Examine spatial distribution, consider retirement age, consider “missing” (undesigned) wells



Assume all wells are missing completely at random → proportionally distribute missing well types.

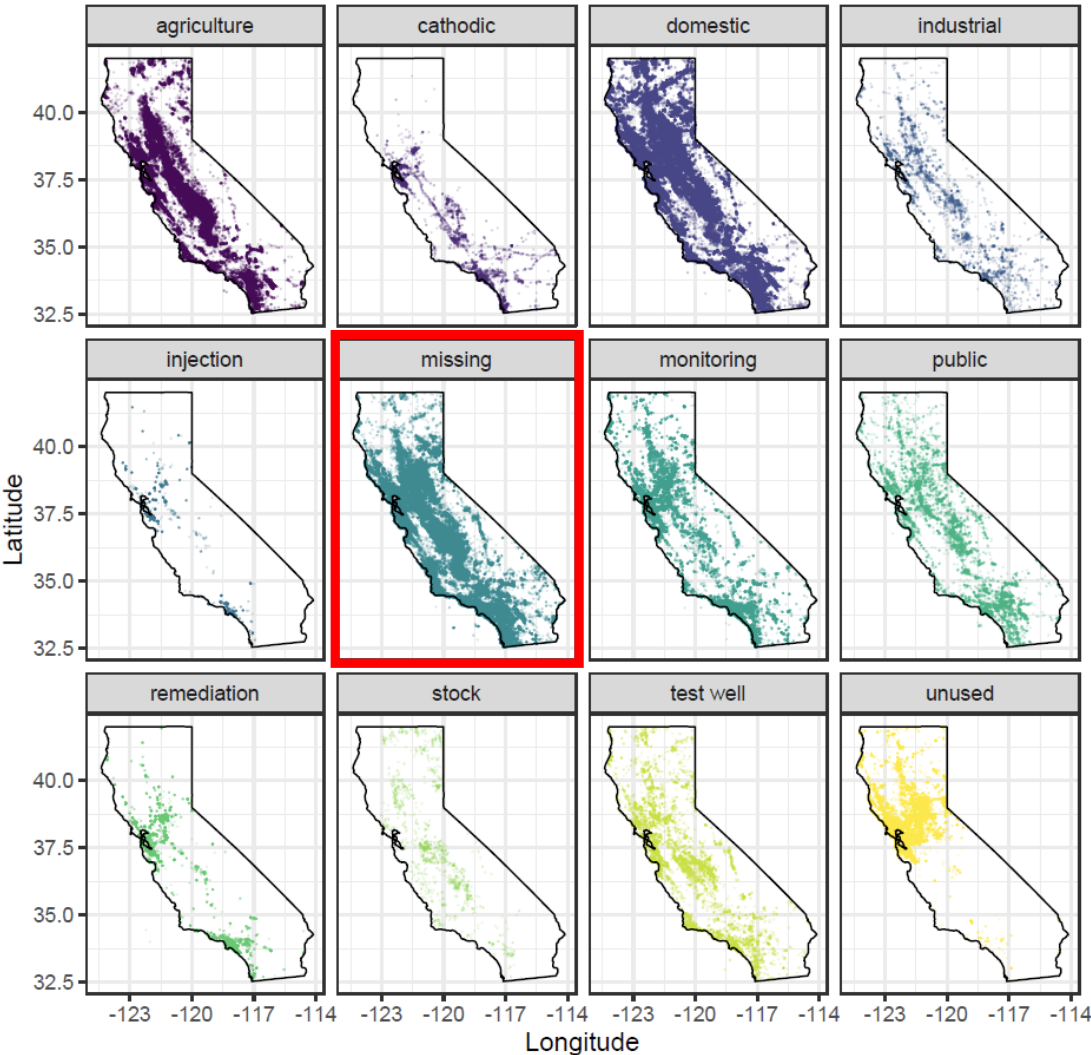
<i>Scale</i>	<i>missing well type</i>	<i>domestic well count</i>	<i>adjusted dom well count</i>
Statewide	245,048	356,618	481,741
Central Valley	54,316	102,123	129,201



Actual active well count lower due to retirement.

Q1: How many active domestic wells are in the Central Valley and where are they located?

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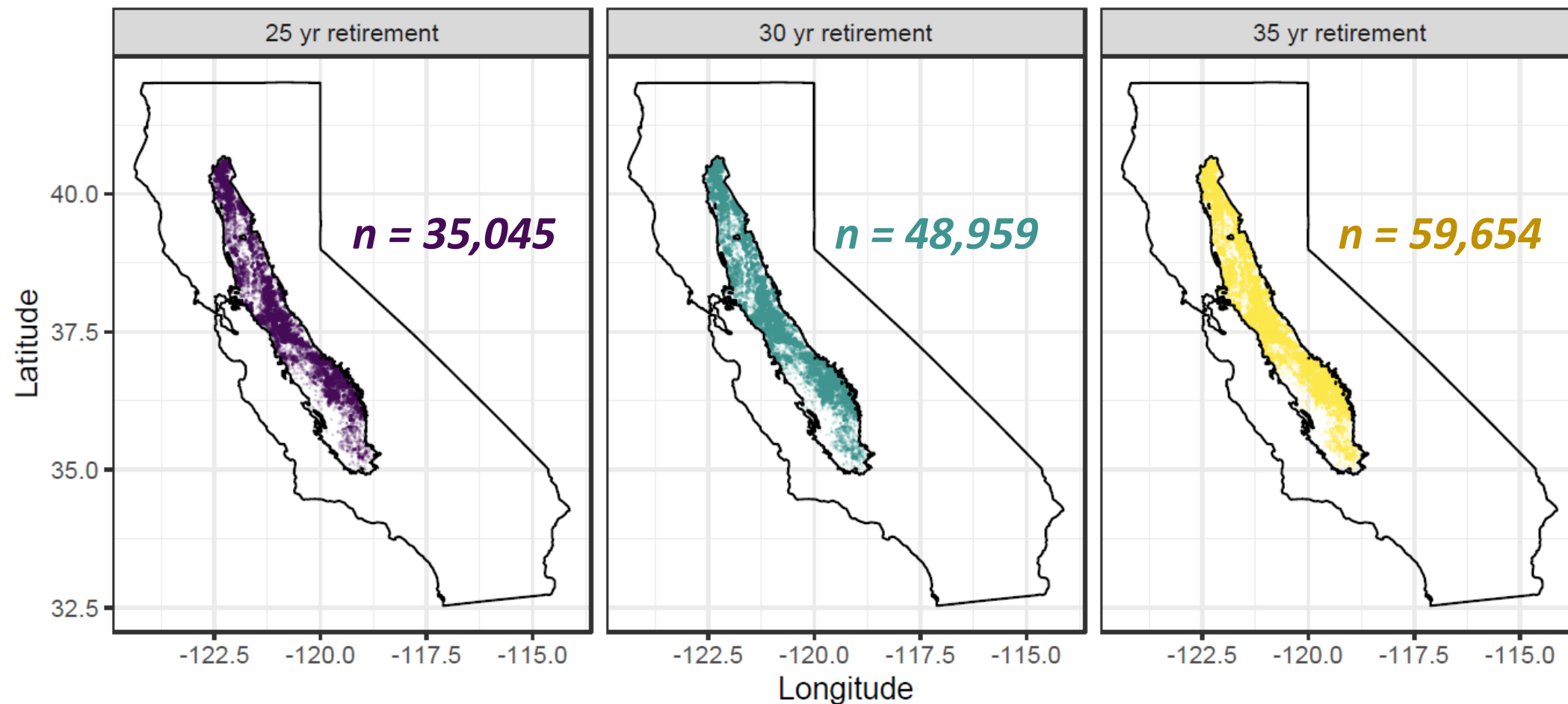
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Scale	missing well type	domestic well count	adjusted dom well count	20% added 80% original
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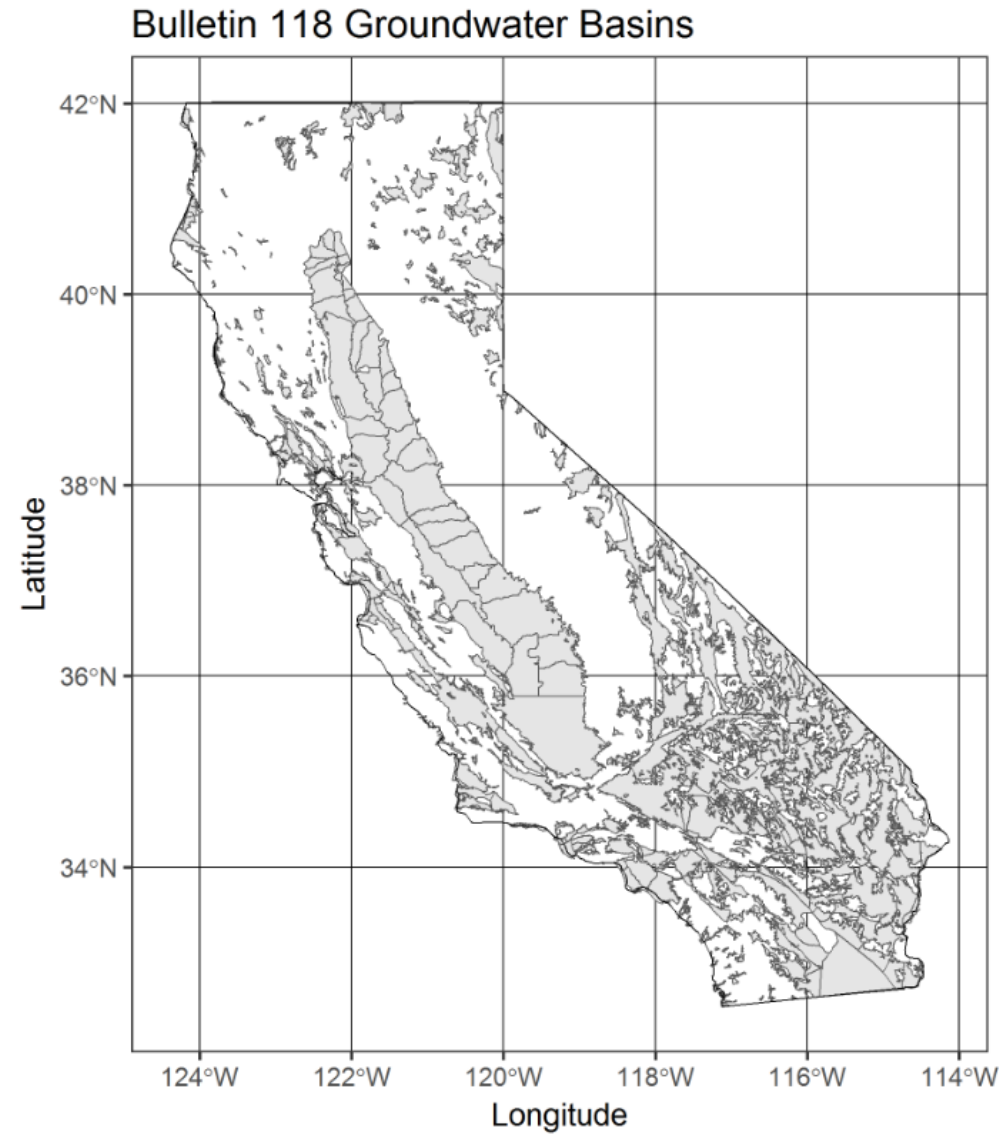
A1: Examine spatial distribution, consider retirement age, consider “missing” (undesignated) wells



Final estimates are adjusted for missing wells.

Q2: Where are domestic wells most vulnerable?

A1: Examine depth properties

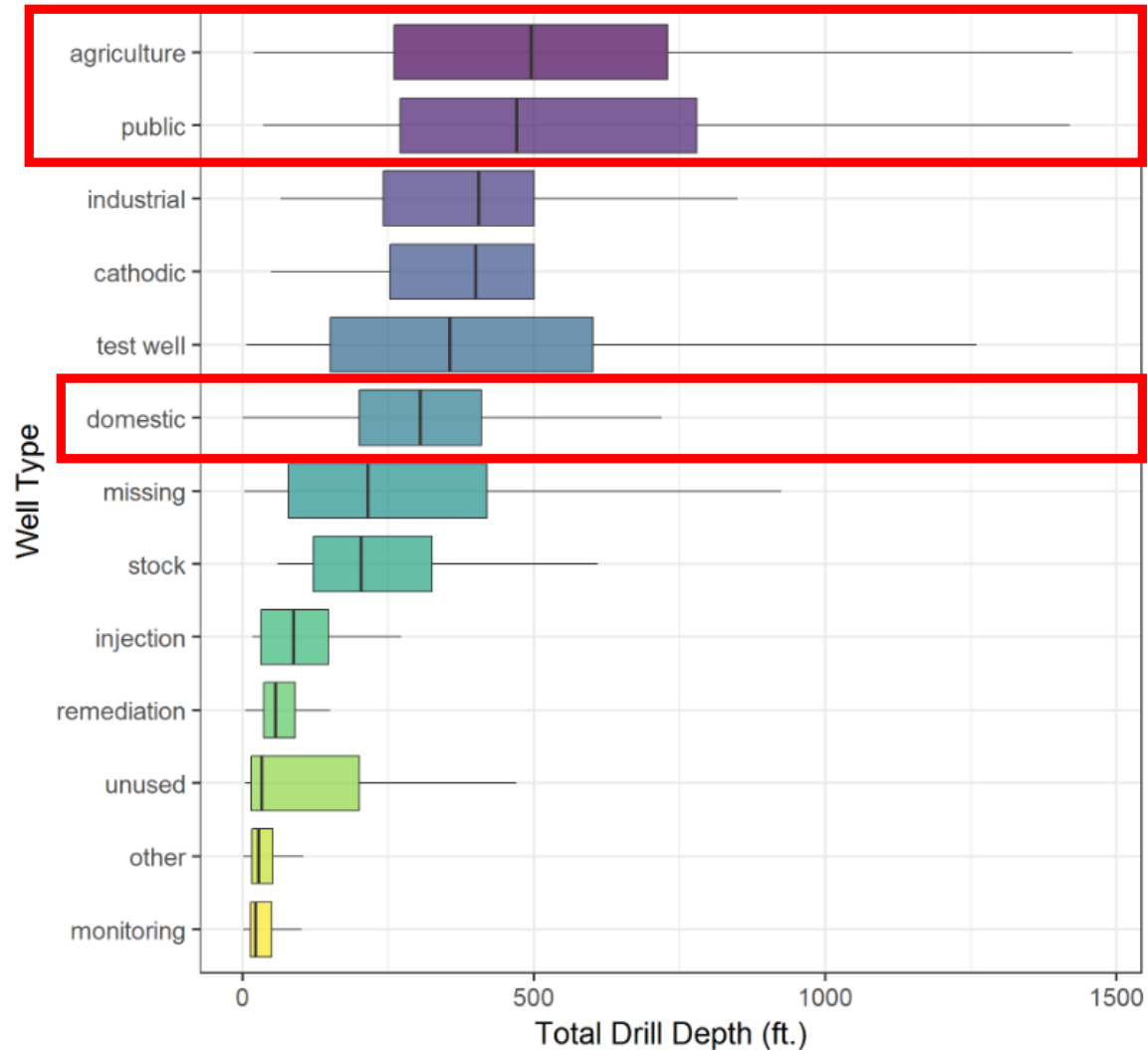


Q2: Where are domestic wells most vulnerable?

A1: Examine depth properties (**drill depth**, perforated interval thickness, top of perforated interval).

Total Drill Depth by Well Type

B118 Subbasins, Period of Record ~1900-2015

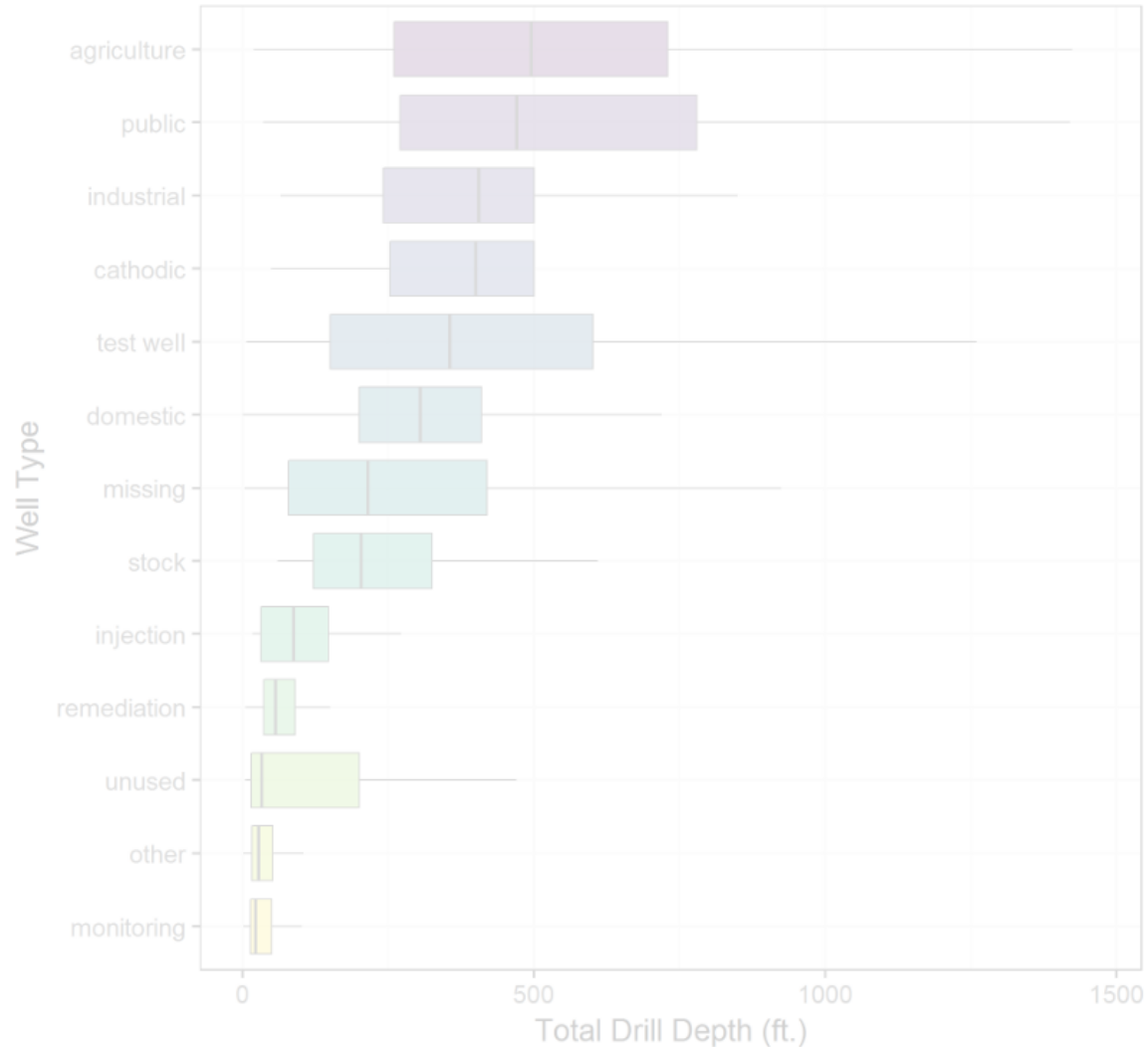


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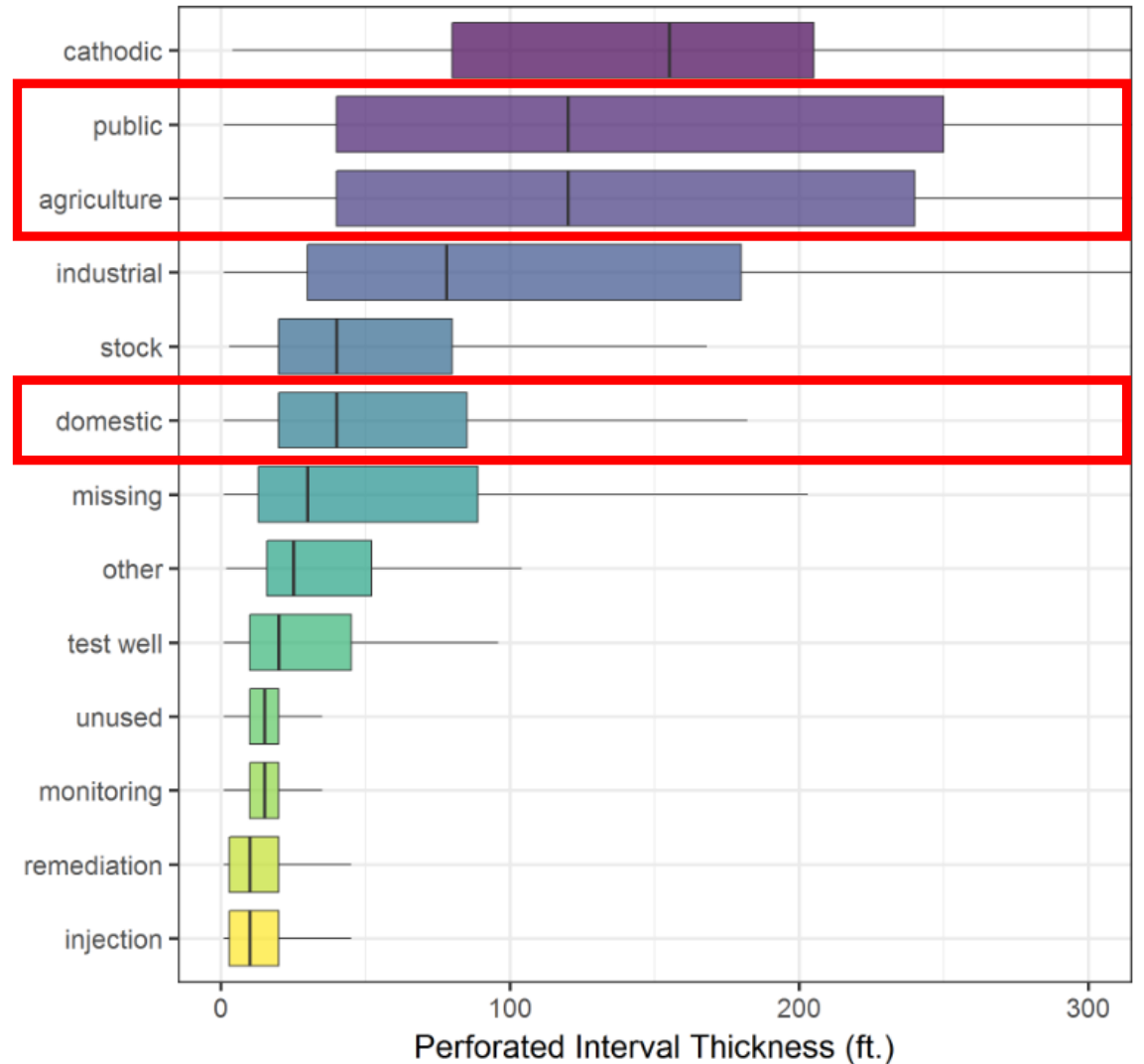
Total Drill Depth by Well Type

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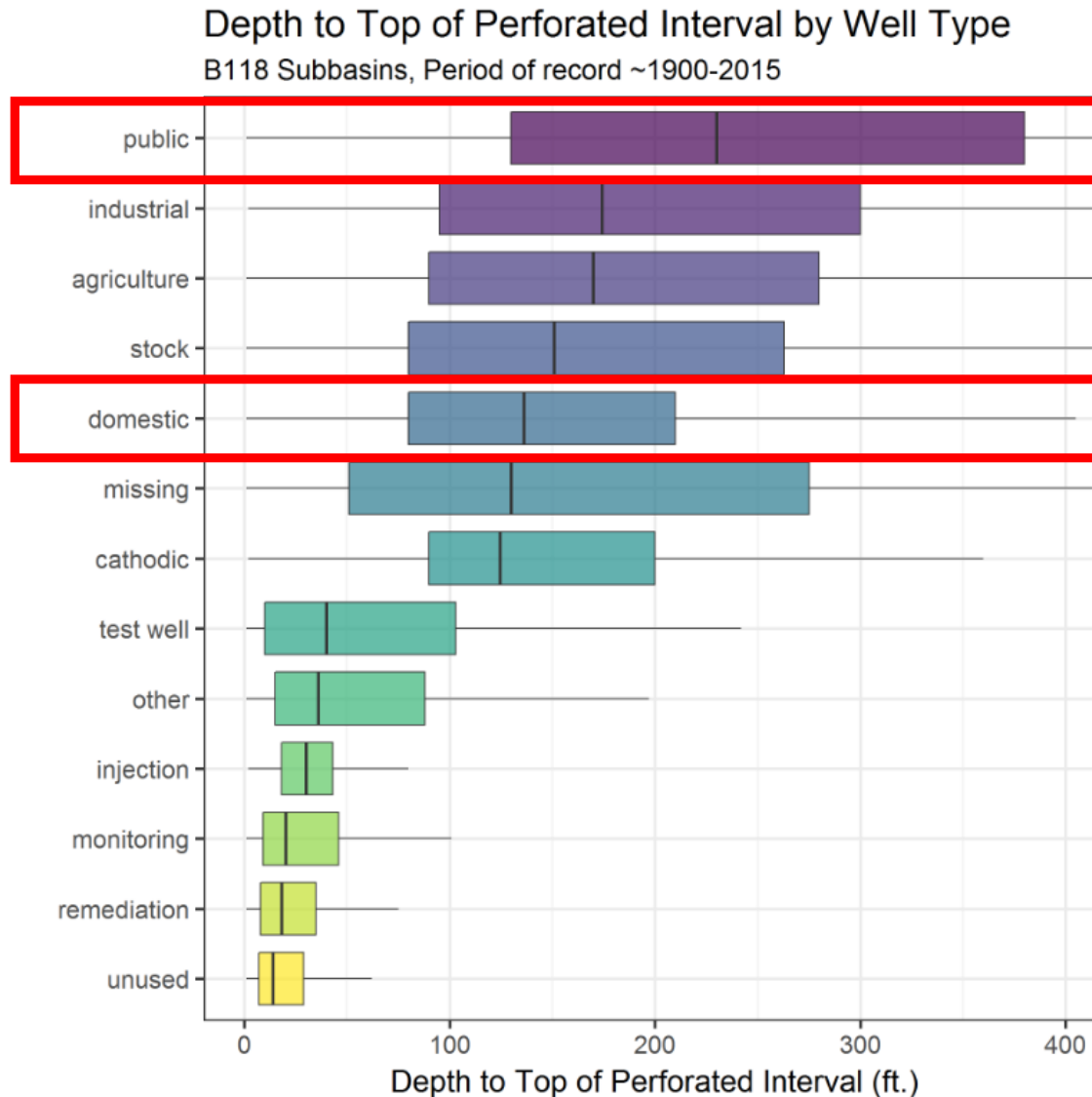
Perforated Interval Thickness by Well Type

B118 Subbasins, Period of Record ~1900-2015

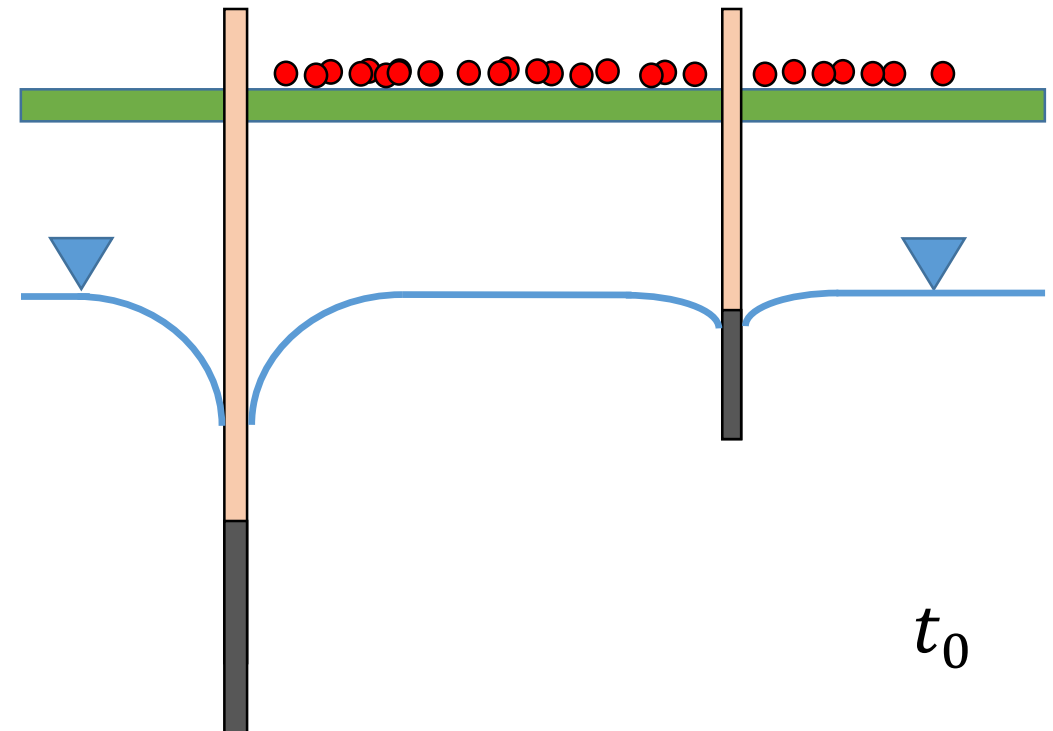


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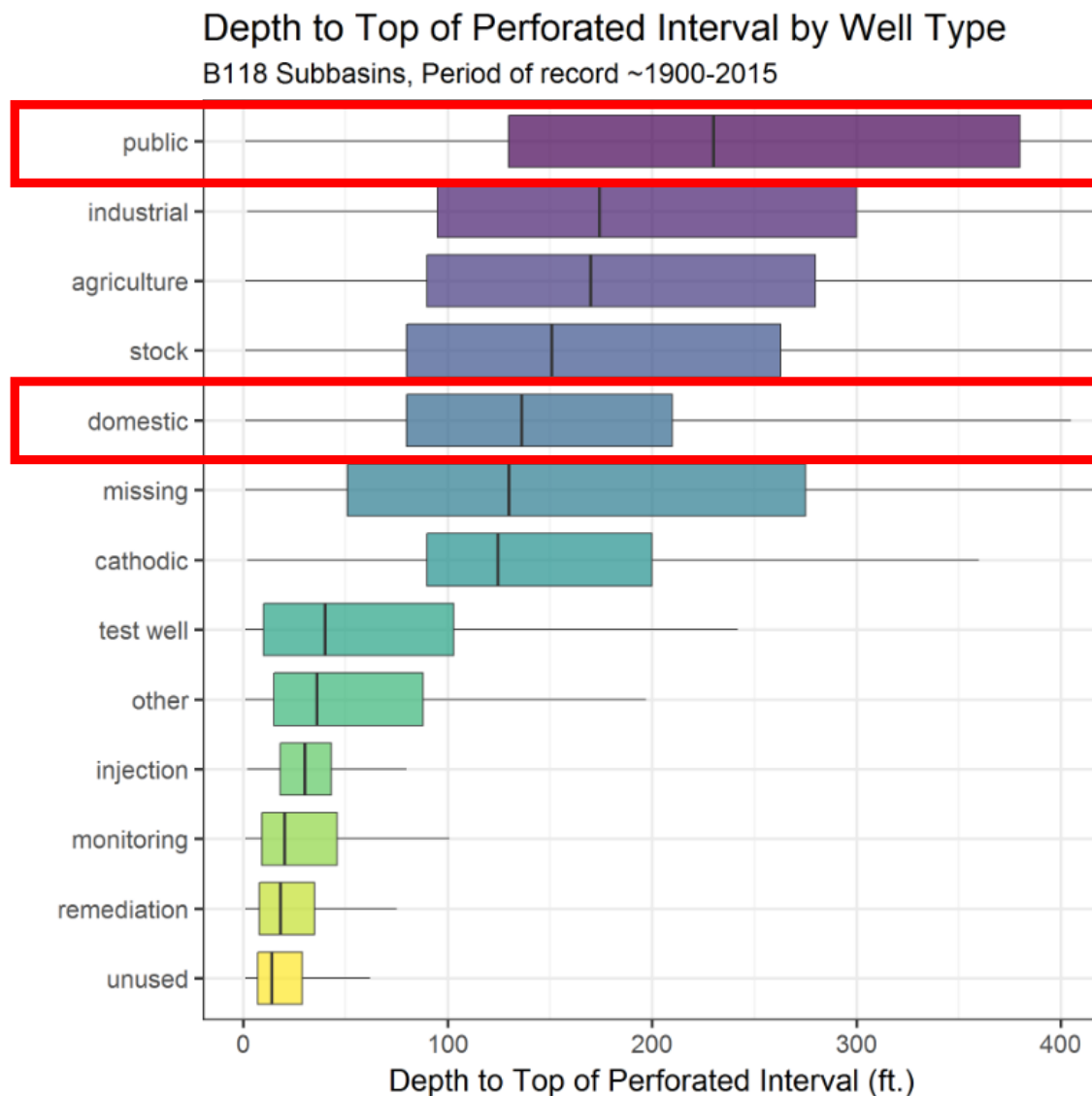


“Entryway” for contaminants migrating from the top-down: nitrates, salts

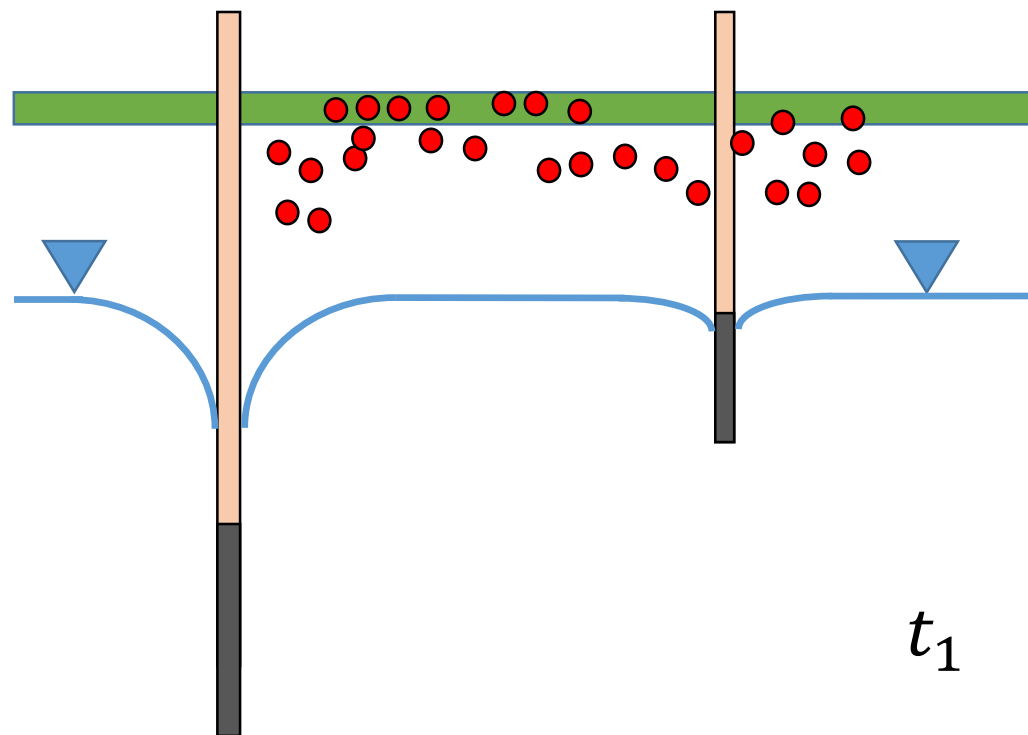


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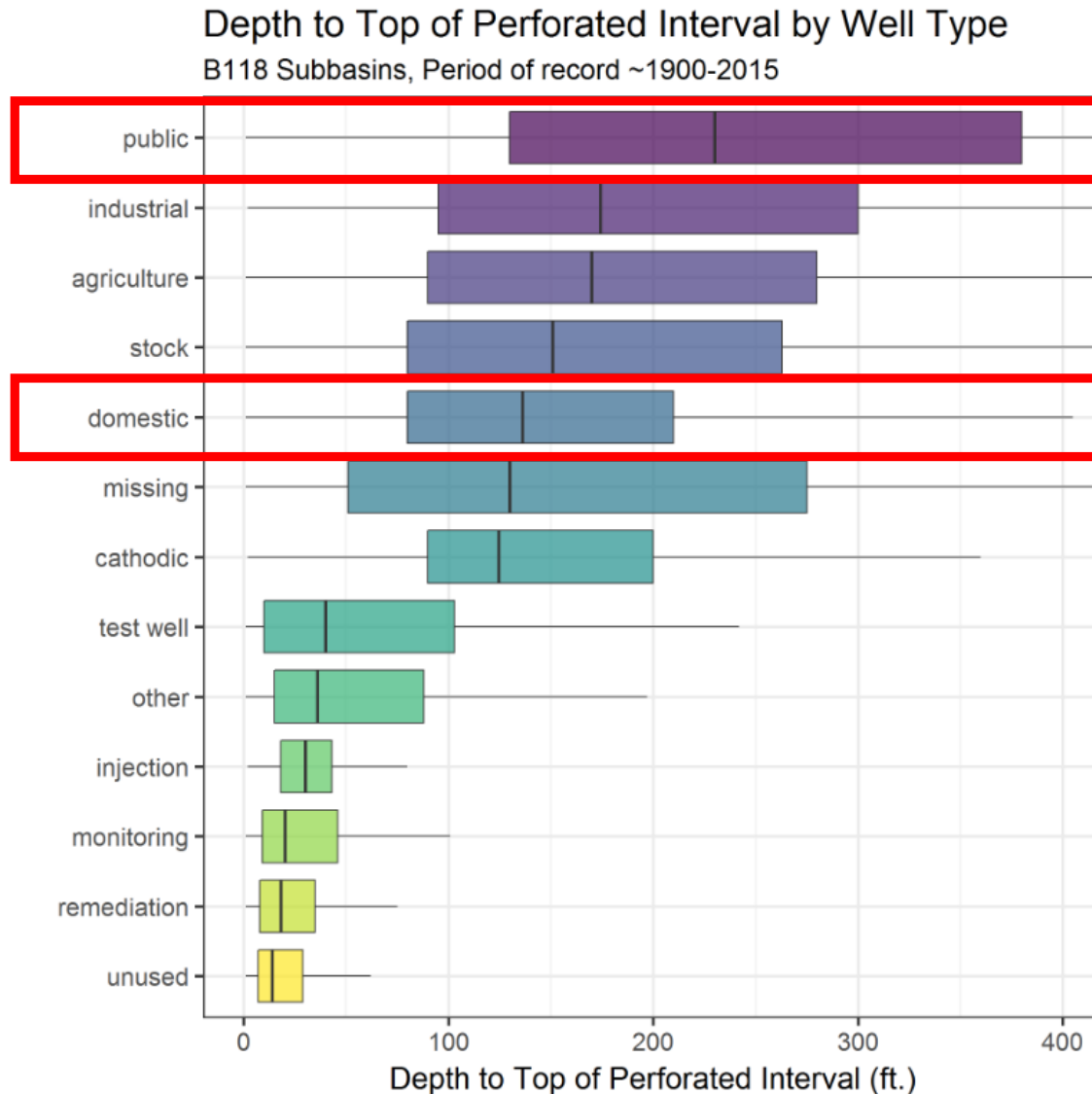


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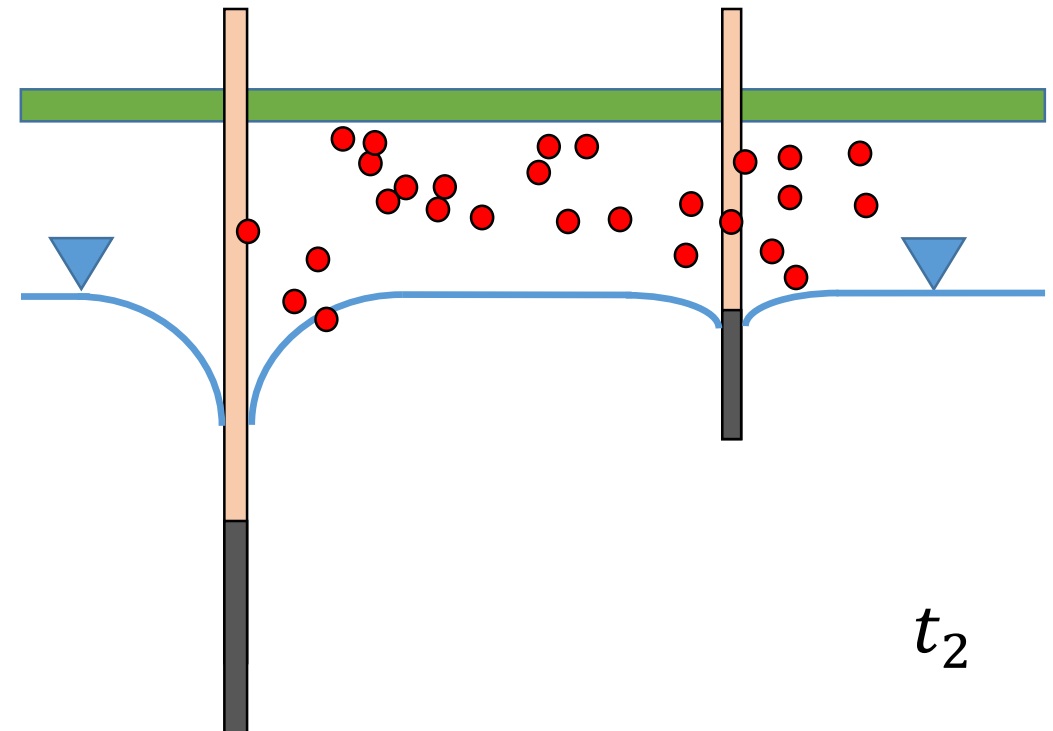


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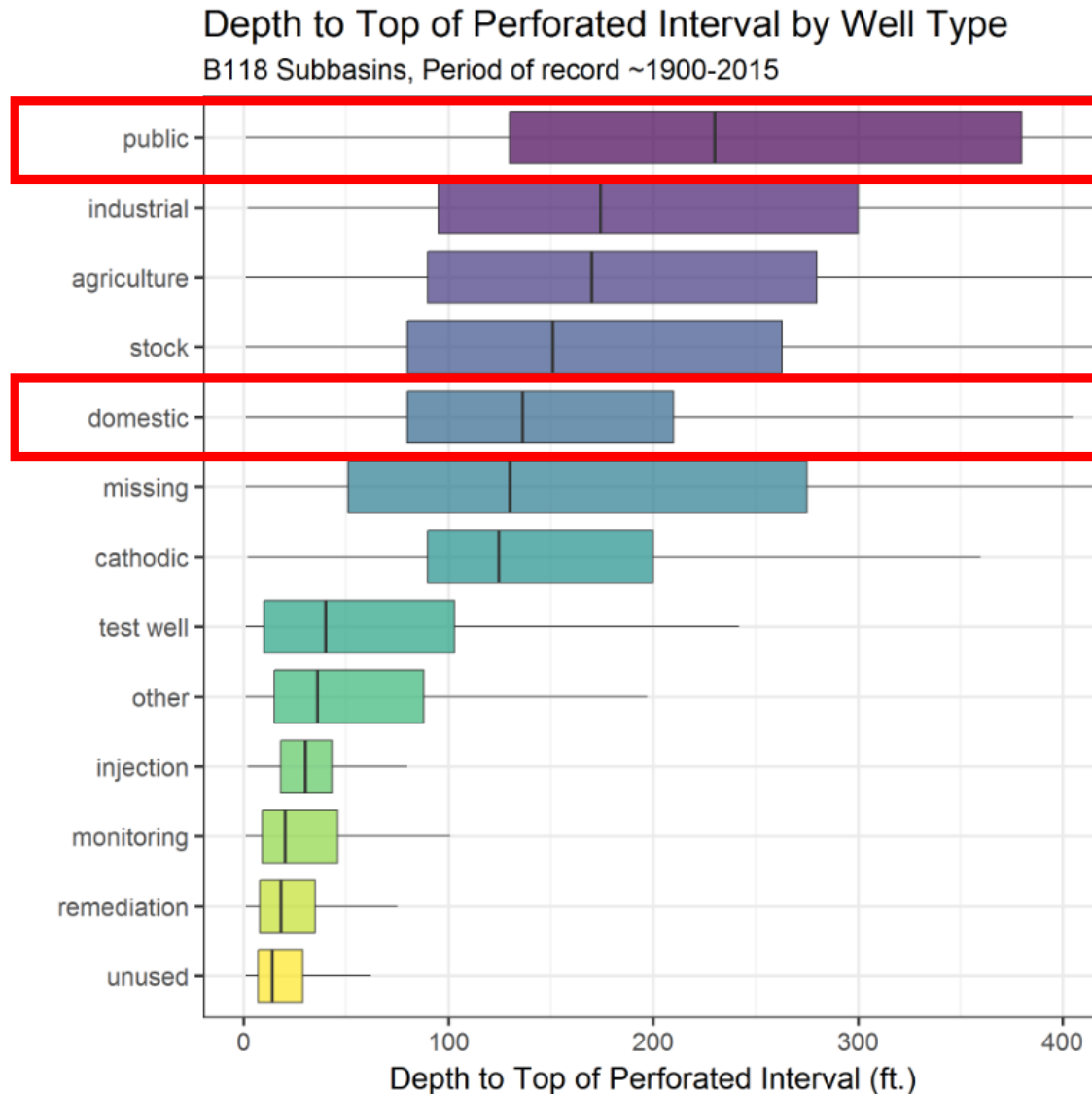


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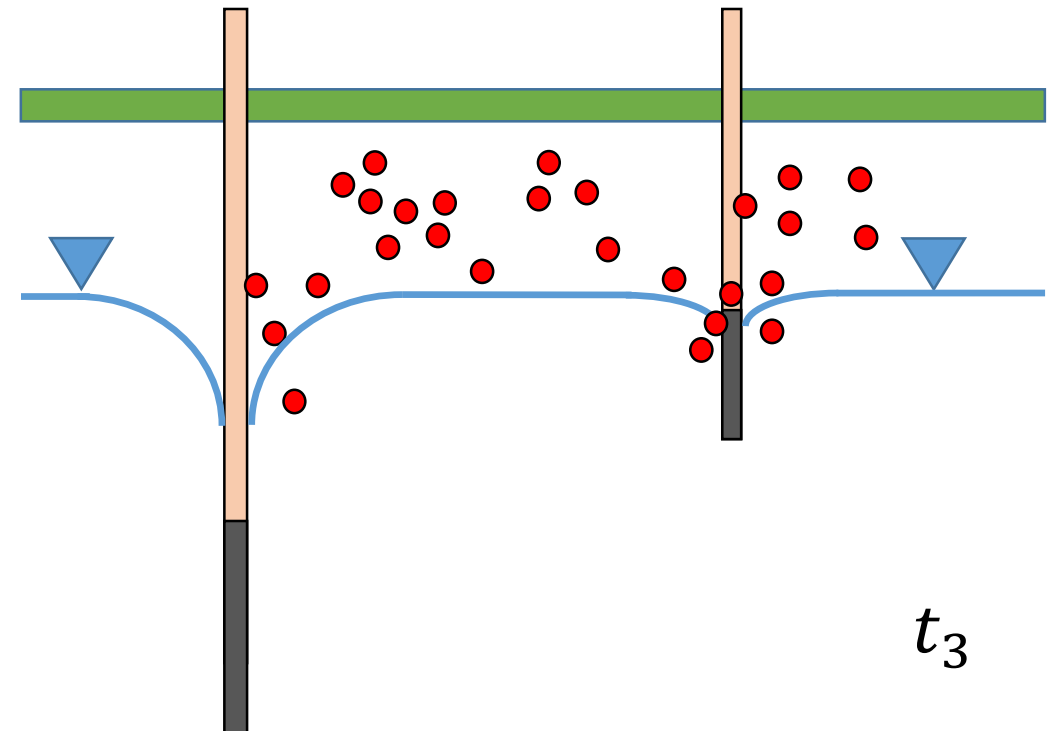


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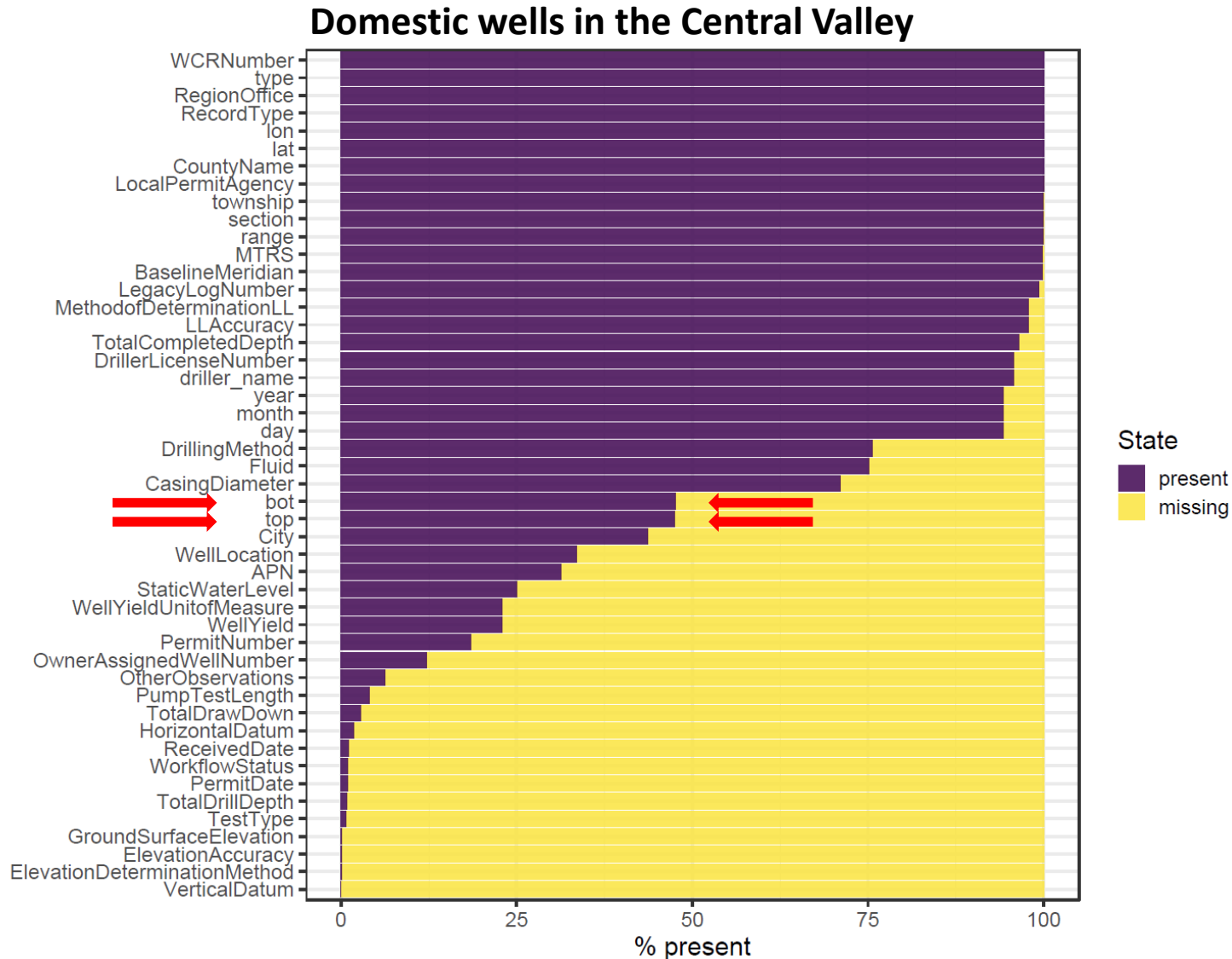


“Entryway” for contaminants migrating from the top-down: nitrates, salts



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Top/Bottom of Perforated Interval missing for ~50% of CV data.

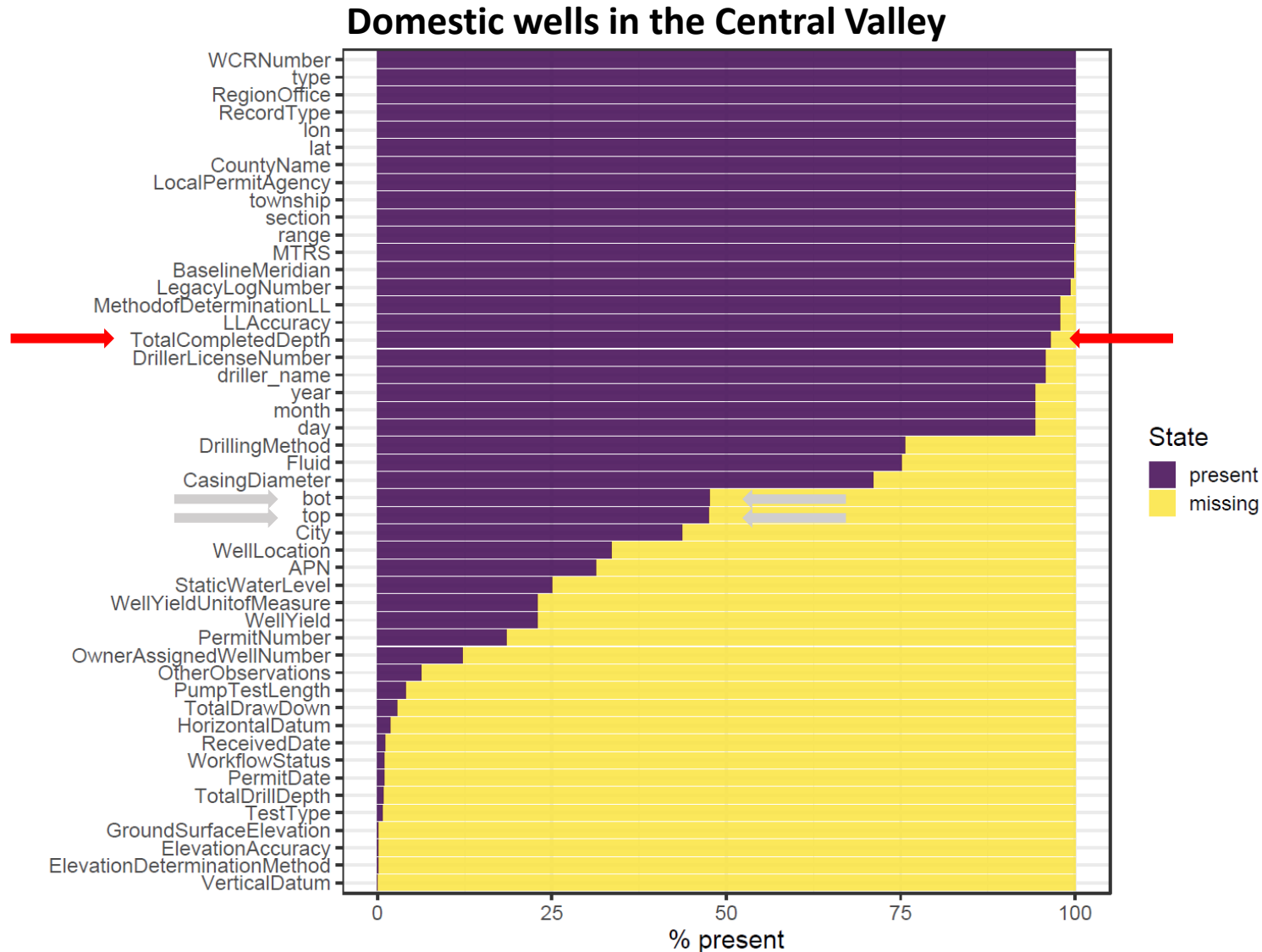
But Total Completed Depth is present for nearly 100% of samples!

Use simple linear model to impute bottom.

Use simple linear model to impute top.

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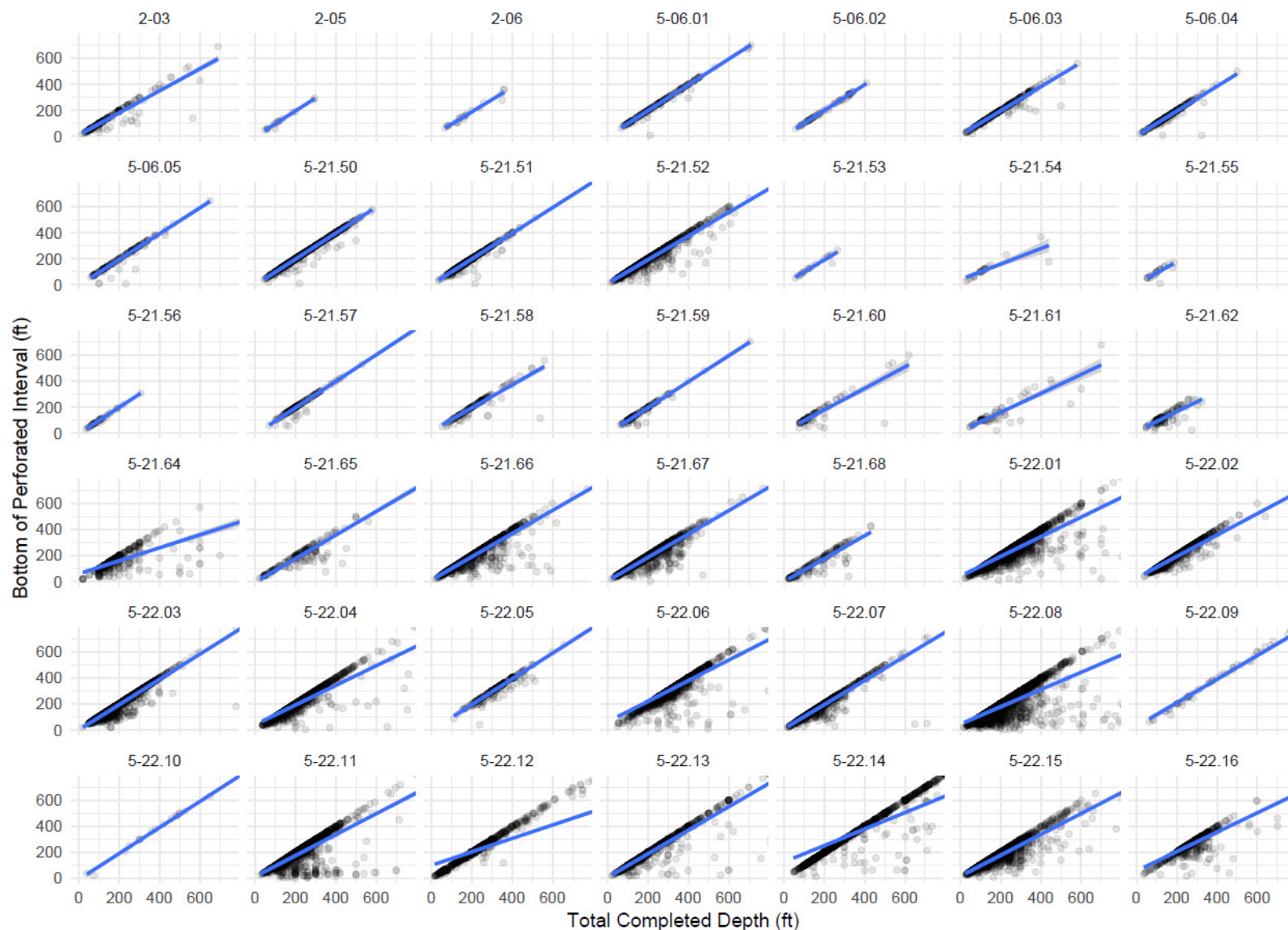
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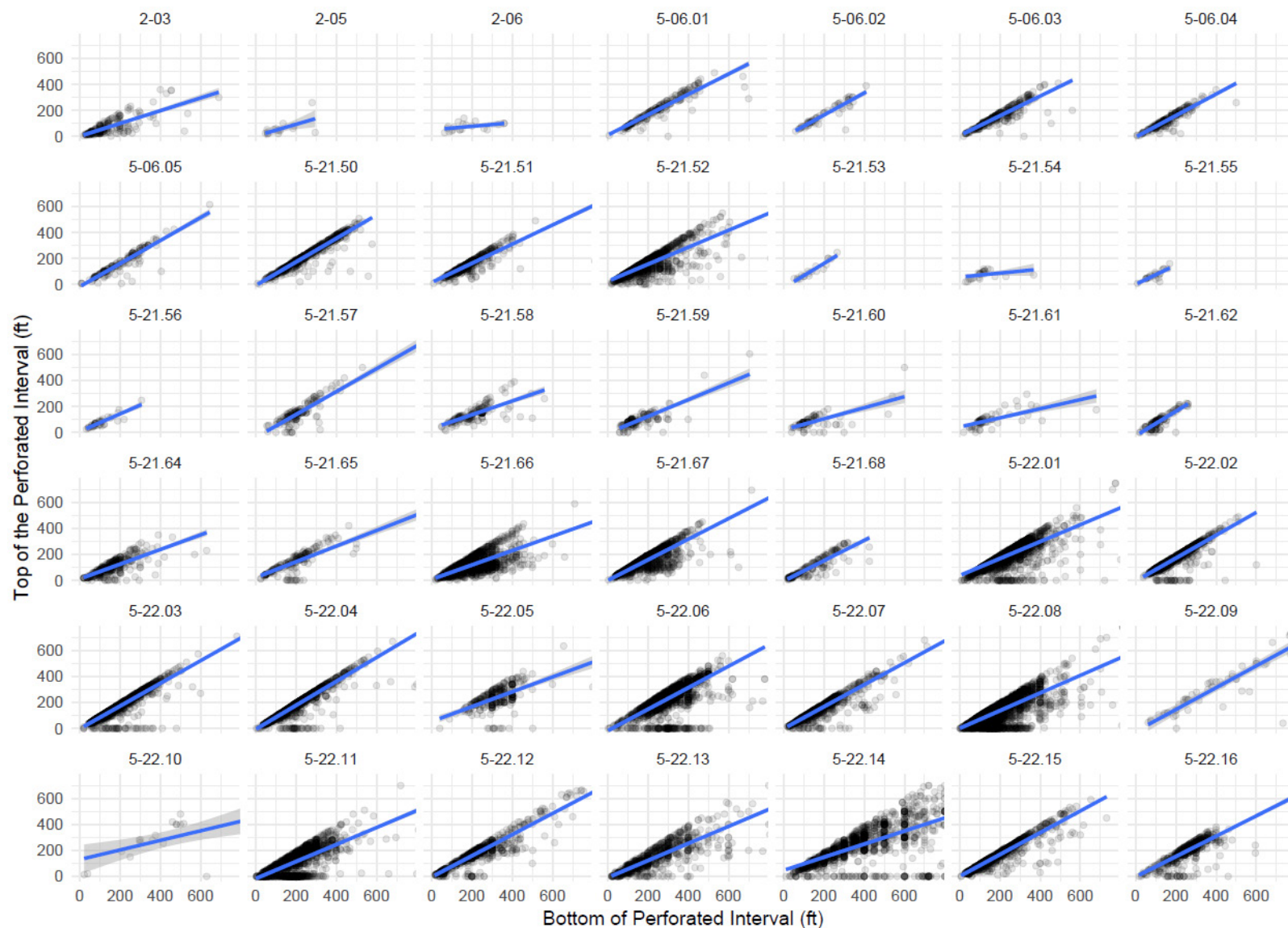
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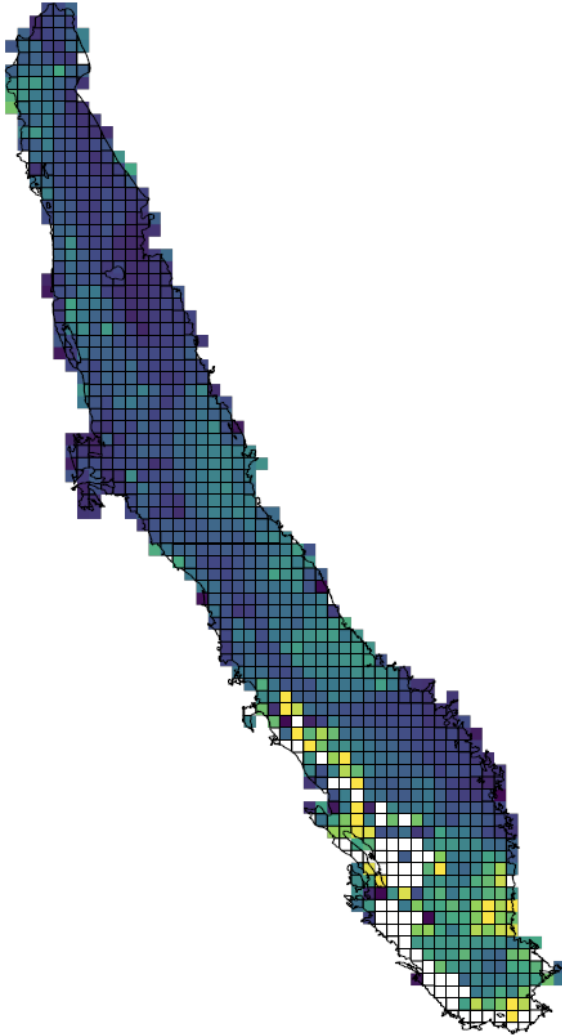
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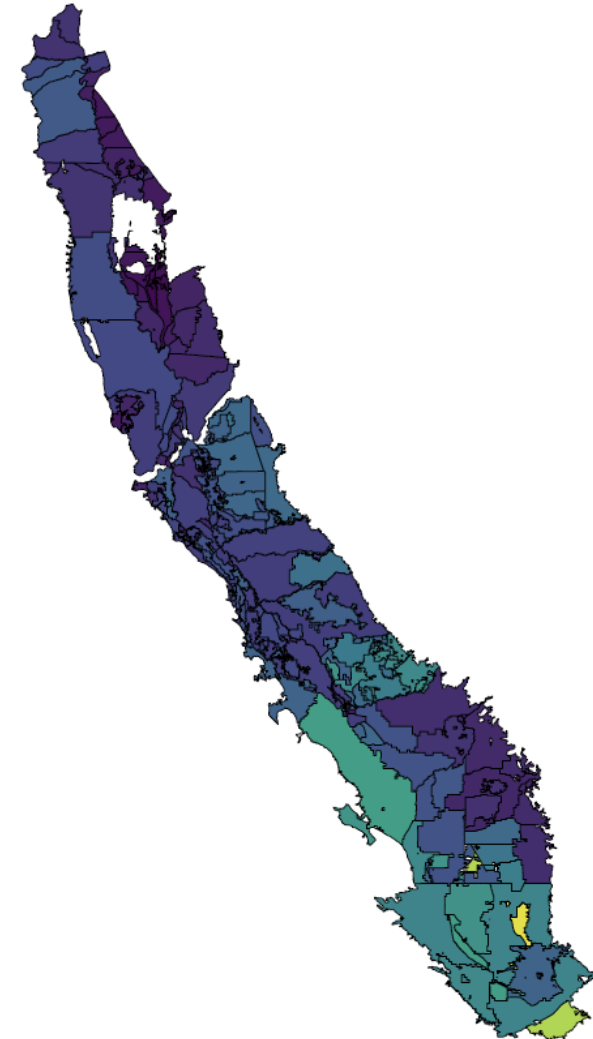
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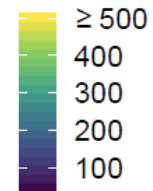
Public Land Survey Township (36 *miles*²)



Groundwater Sustainability Agency



Median Top of
Perforated Interval (ft)

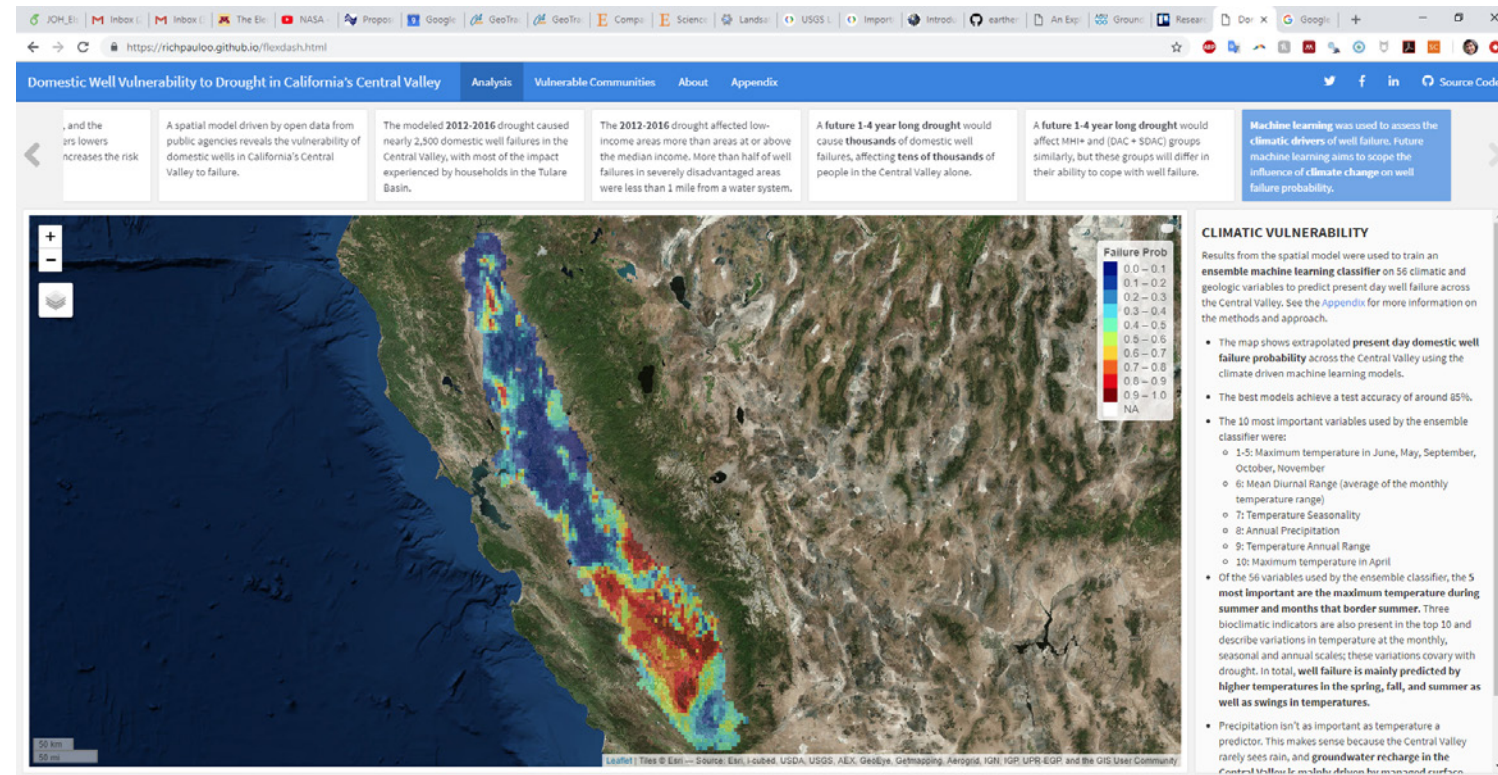


Case Study using OWCR data (3 minutes)

- Motivation: ~2,500 reported CV domestic well failures during 2012-2016 drought

- Questions:

1. *How would a future extended drought affect domestic well failure in California's Central Valley?*
2. *Are well failures more associated with particular social drivers of vulnerability, like income?*

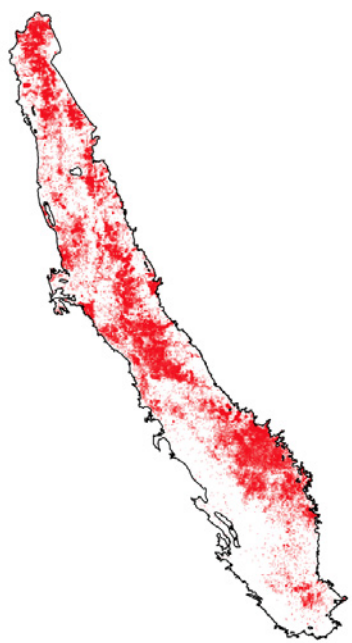


Winning submission to the 2018 California Water Data Challenge: goo.gl/D5fLwY

Approach:

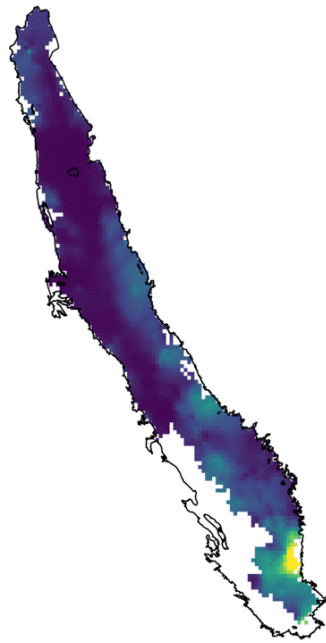
- Develop a Central Valley wide spatially-explicit well failure model
 - Calibrate to 2012-2016 observed failure
 - Simulate 1, 2, 3, 4 year droughts by scaling 2012-2016 drought by 0.25, 0.50, 0.75, 1.00
 - Identify economic status of populations and compare impact

SP 2011



Domestic well data

+



Groundwater level data

Depth (ft)
500
400
300
200
100

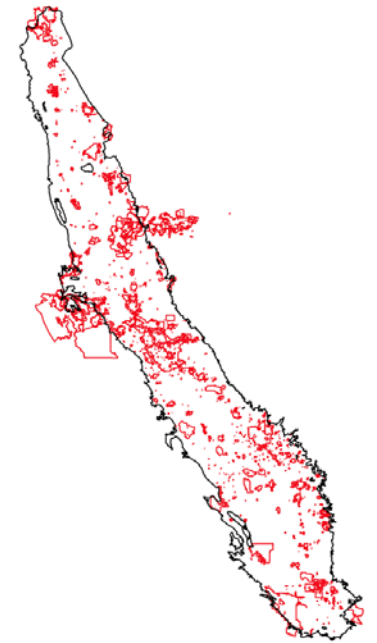
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Census tract data

Median AGI (\$)
150000
100000
50000

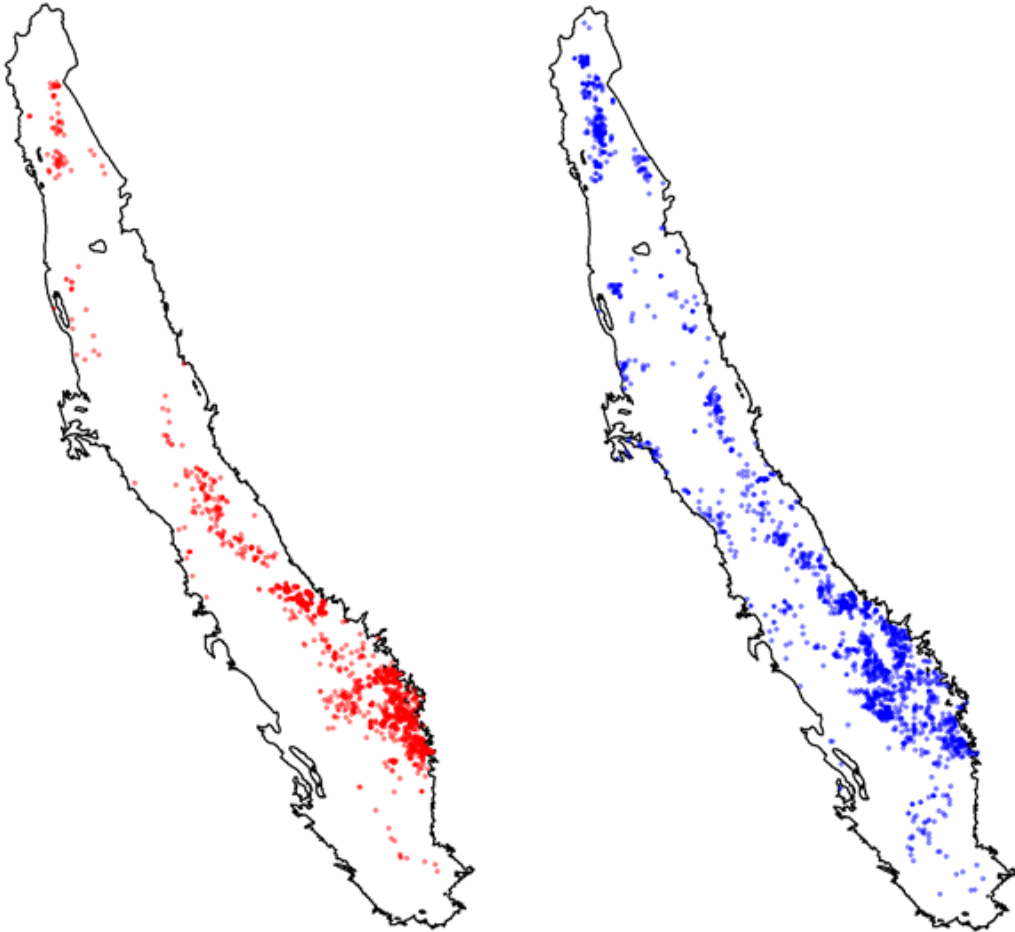
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Water System Boundaries

Results: 2012-2016 drought

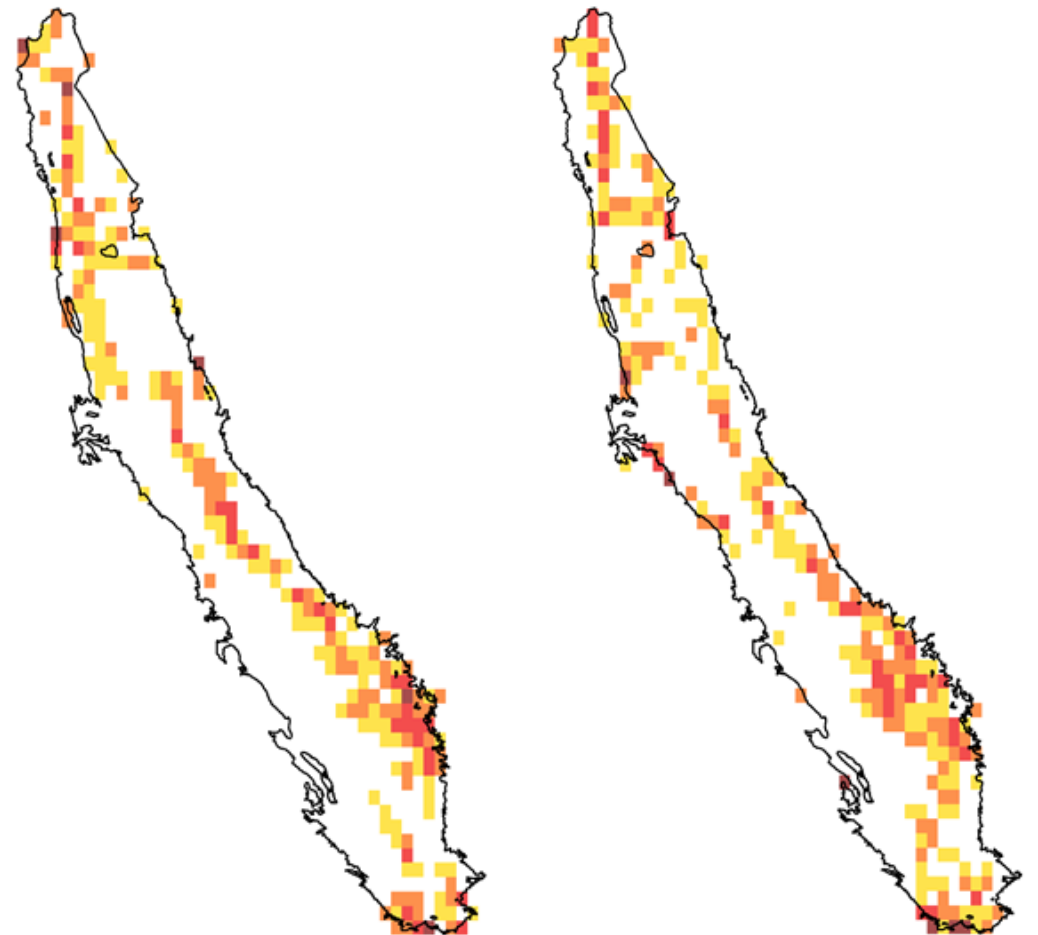
Point Pattern



Observed

Predicted

Kernel Density Estimate

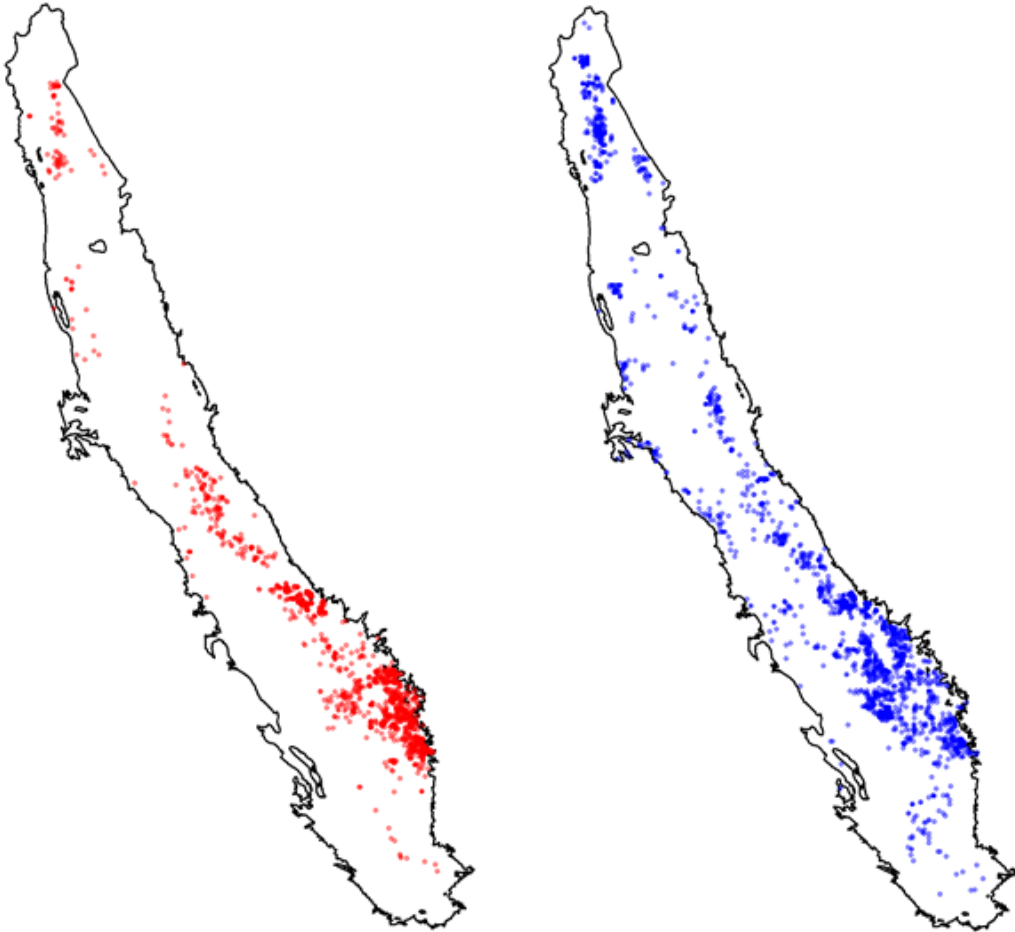


Observed

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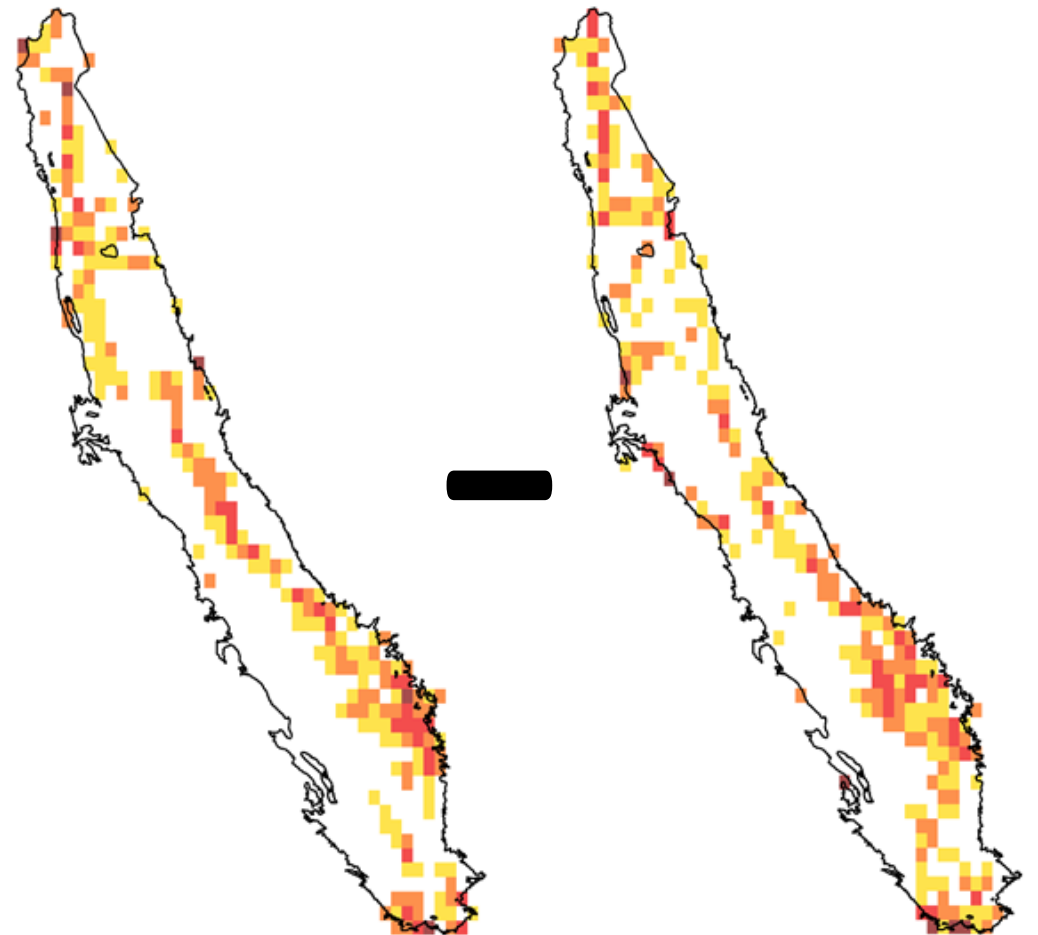
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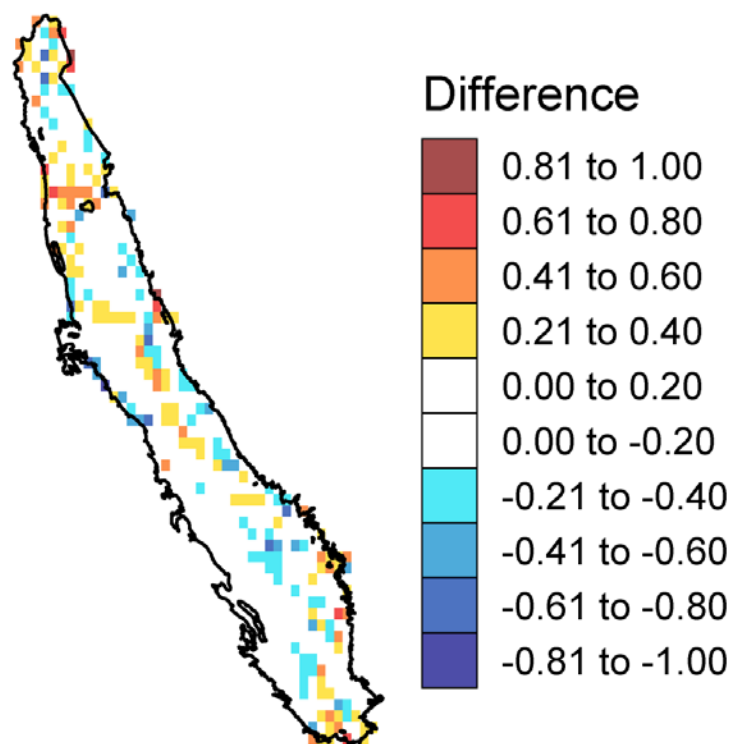


Observed

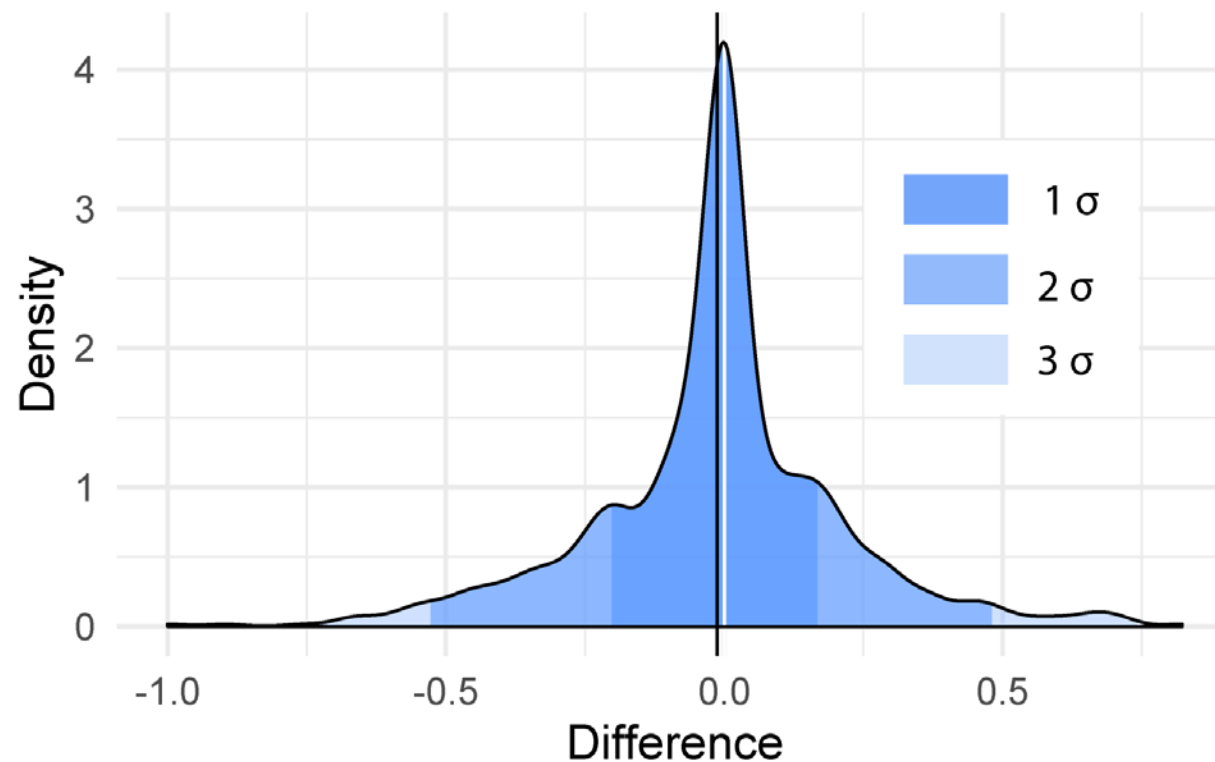
Predicted

Results: 2012-2016 drought

Kernel Density Residual

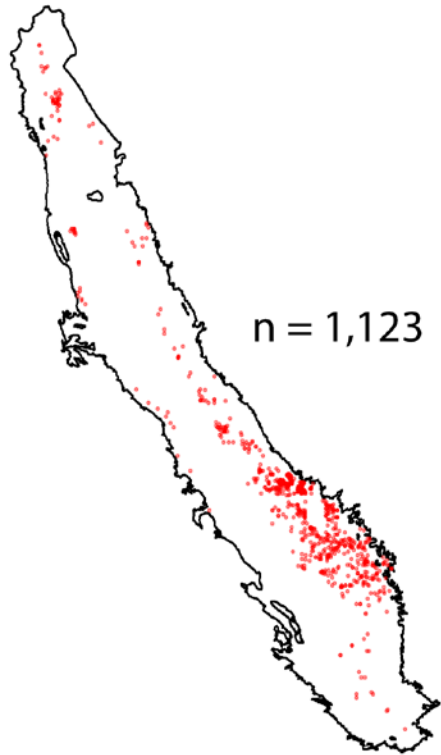


Density Plot of Residuals

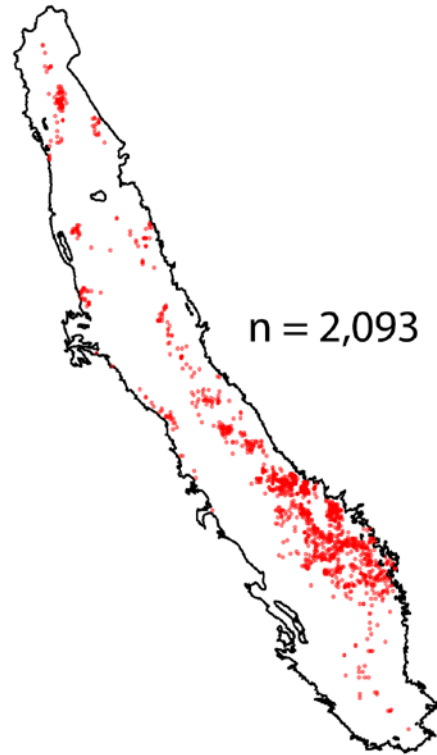


Results: Extended drought (t_0 = January 2017)

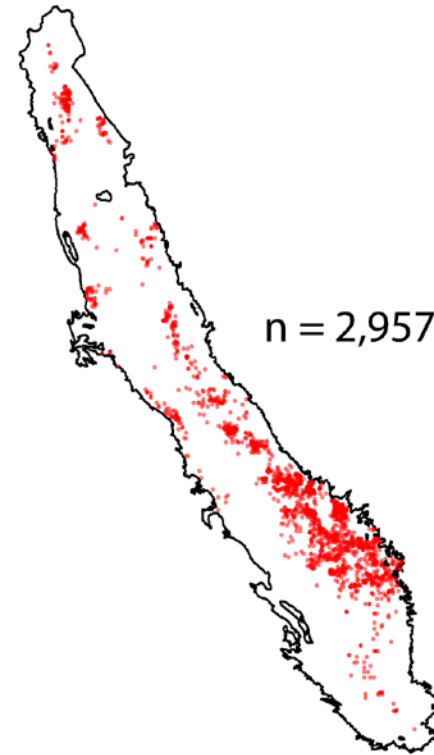
1 year



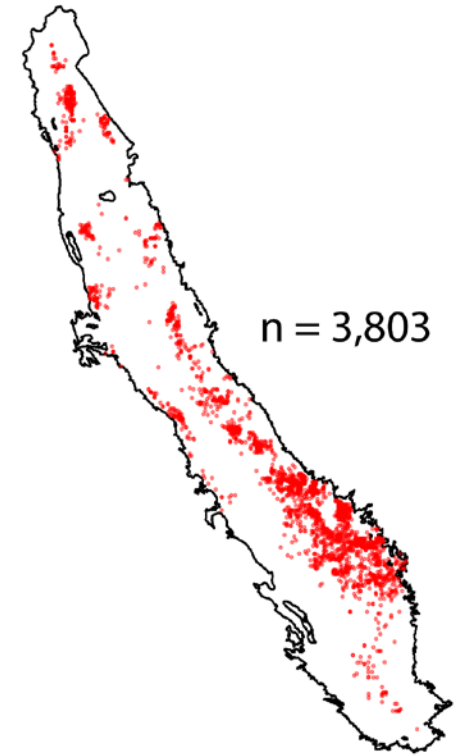
2 years



3 years



4 years



Failures during 2012 – 2016 drought $\approx$ 2,500

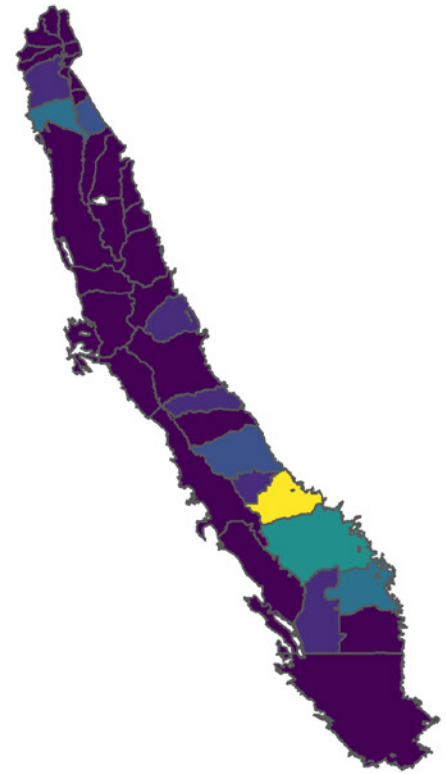
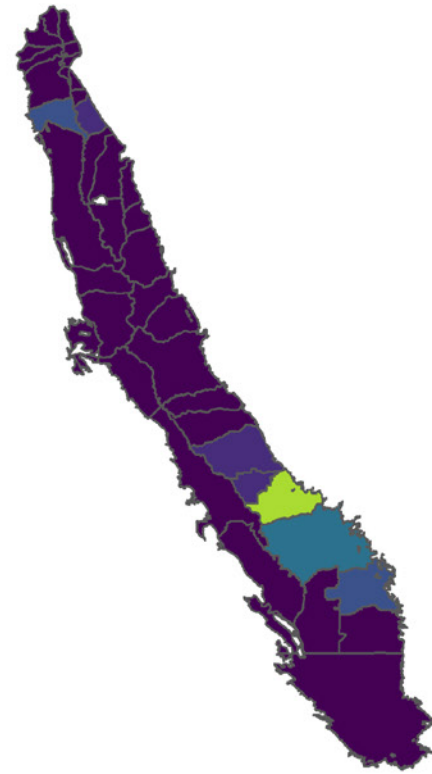
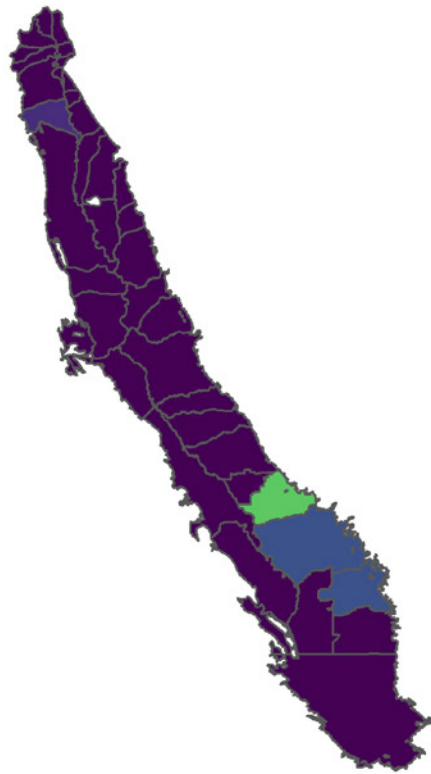
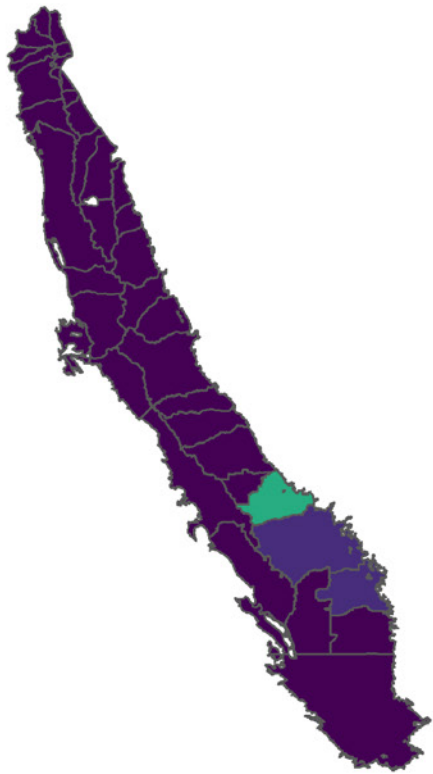
Results: Extended drought (t_0 = January 2017)

1 year

2 years

3 years

4 years



Density (n/100 km²)

0-1

1-2

2-3

3-4

5-6

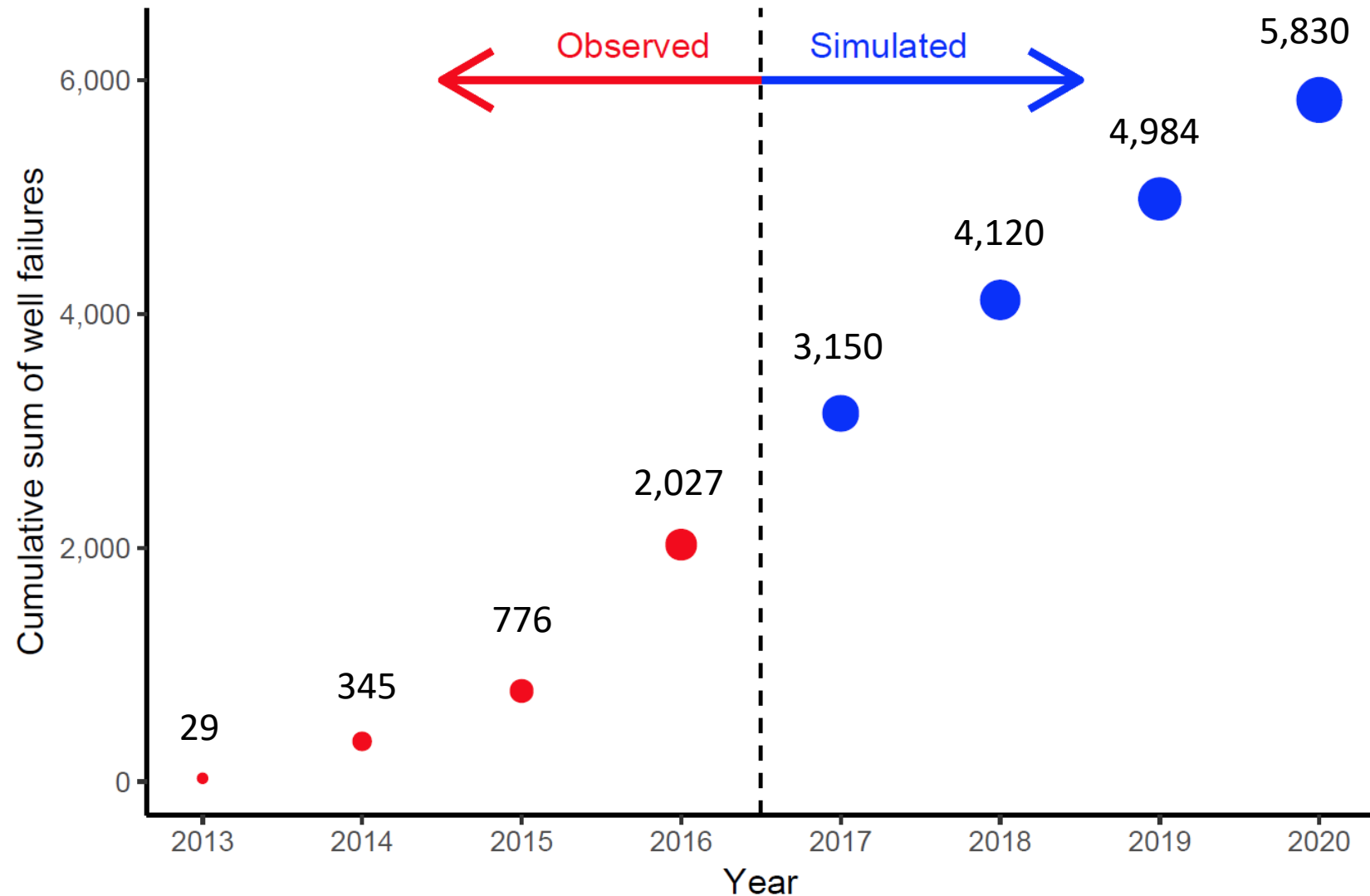
6-7

10-11

12-13

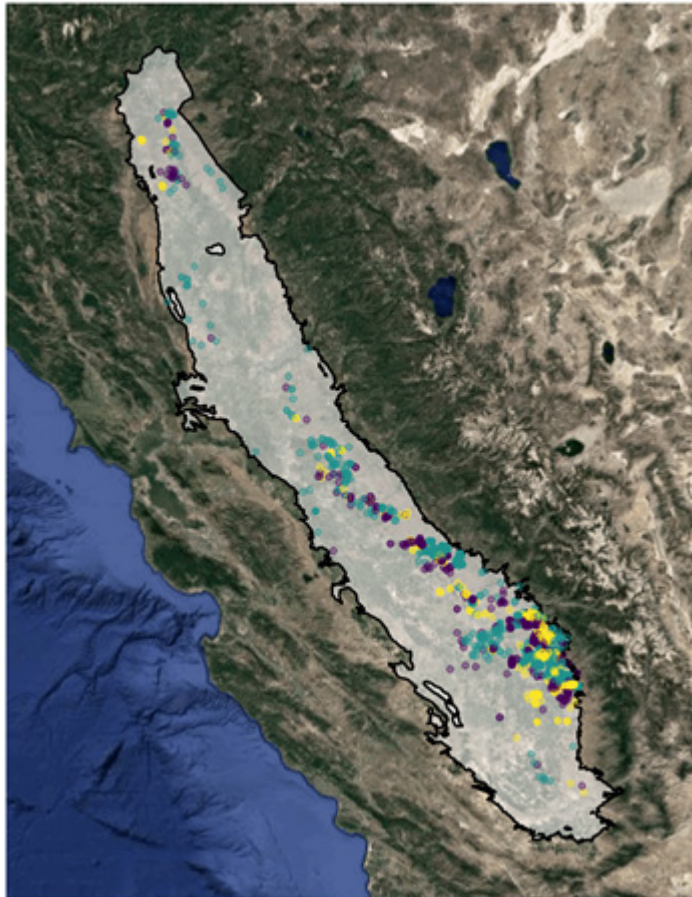
13-14

Results: Extended drought (t_0 = January 2017)



Results: 2012-2016 drought SE Impact

Socioeconomic Status



Income Level

- MHI+
- DAC
- SDAC

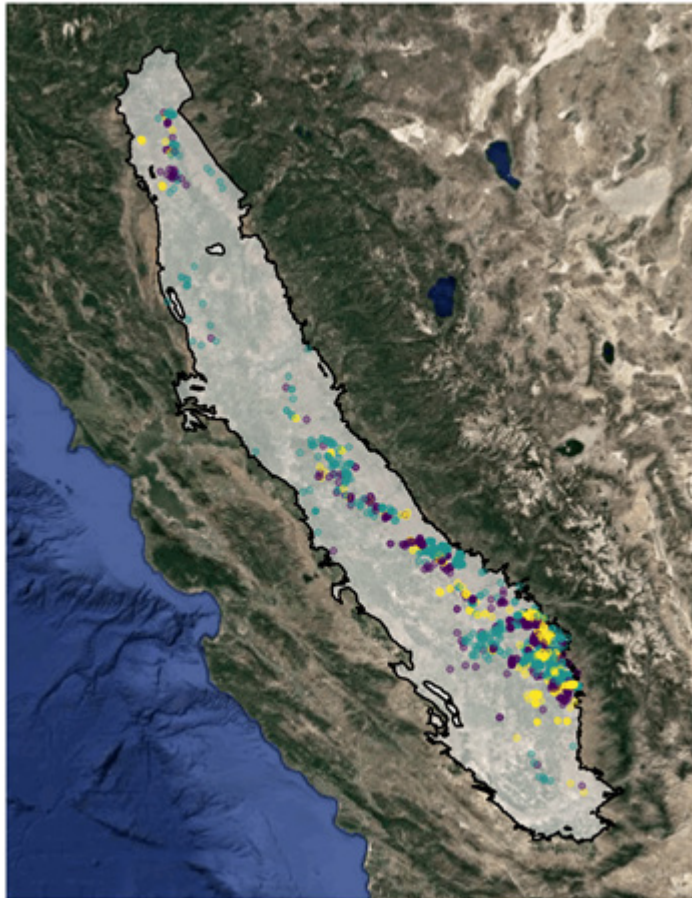
income_level	n_well_failures
MHI+	941
DAC	602
SDAC	826

$$\frac{1428}{941} = 1.52$$

~ 1.5 times more well failures were reported by households in disadvantaged (DAC) and severely disadvantaged (SDAC) census tracts, compared to communities at or above the Median Household Income (MHI+).

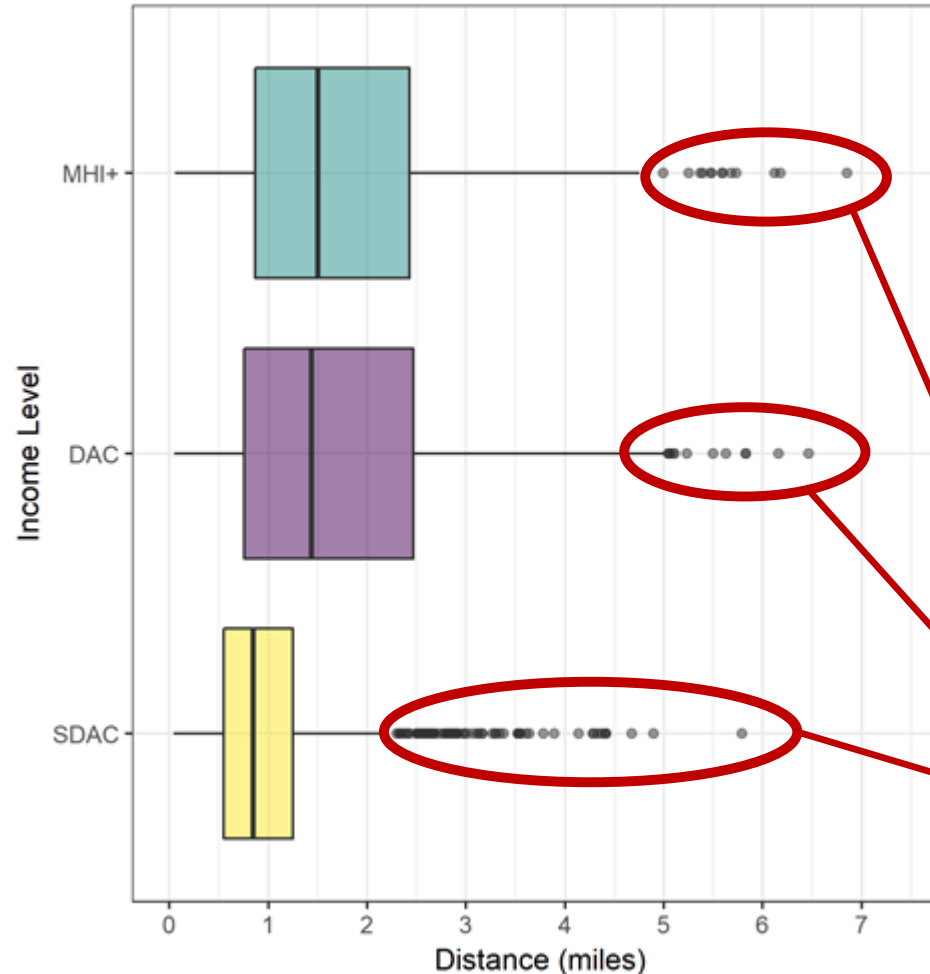
Results: 2012-2016 drought SE Impact

Socioeconomic Status



Income Level ● MHI+ ● DAC ● SDAC

Distance from Well Failure to Closest Water System



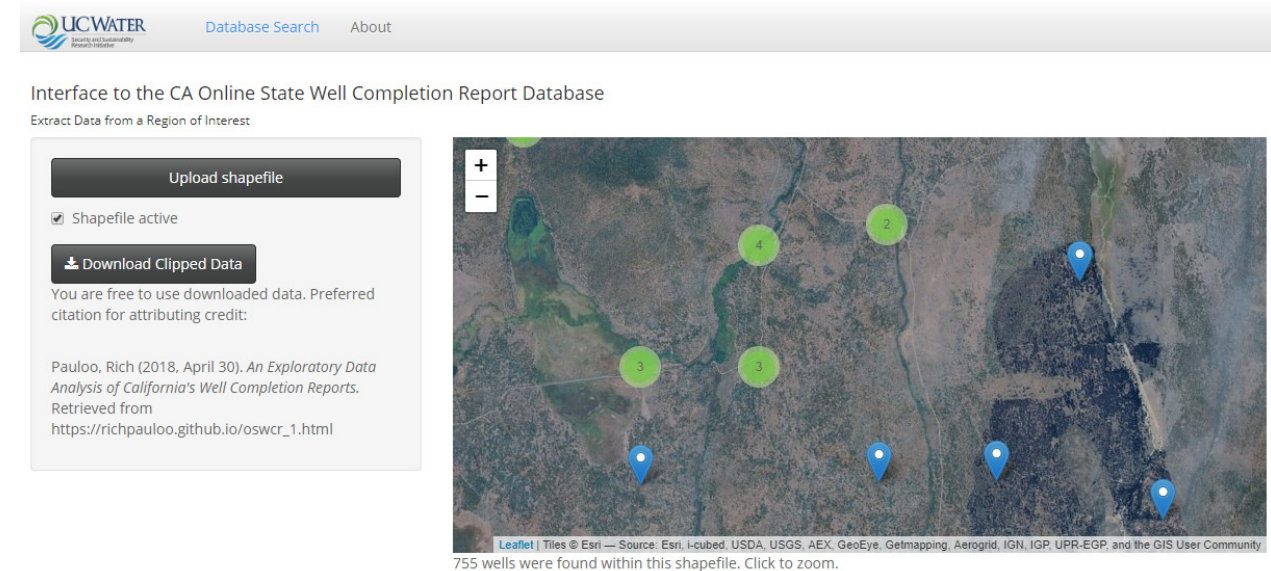
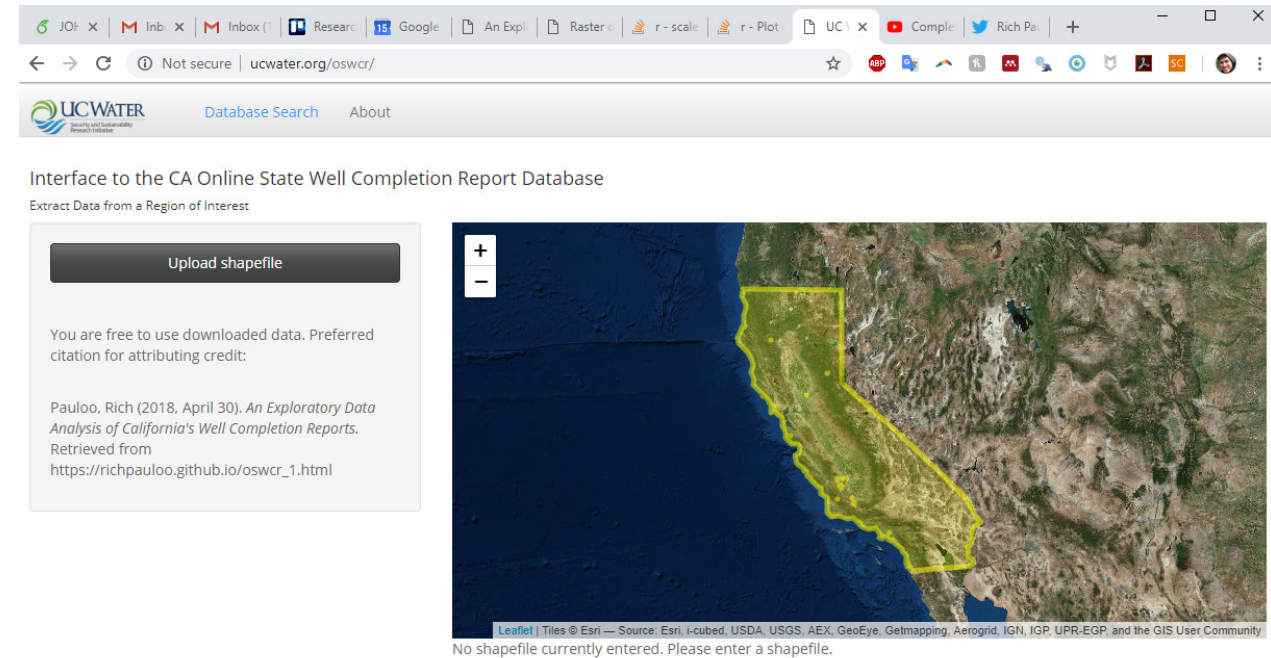
income_level	median_d (miles)
MHI+	1.50
DAC	1.44
SDAC	0.85

More than half of well failures in SDACs were **less than 1 mile** from a water system.

Some well failures are relatively remote.

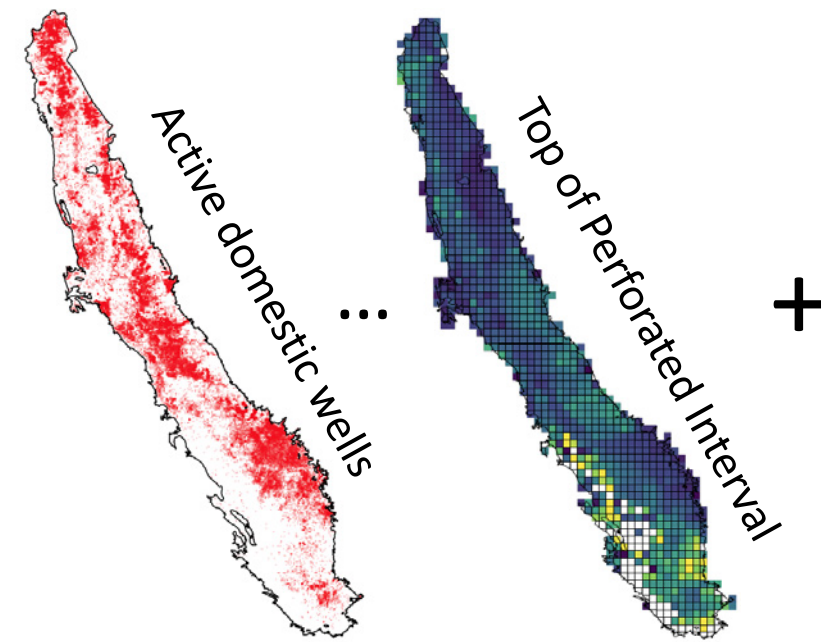
Web Application

- Download clean OSWCR data: ucwater.org/oswcr/
- Cleaning script: goo.gl/MthQQd
- Used by researchers, consultants at:
 - UC Davis
 - Stanford
 - Pacific Institute
 - Community Water Center
 - Tully & Young
- [Youtube video](#)

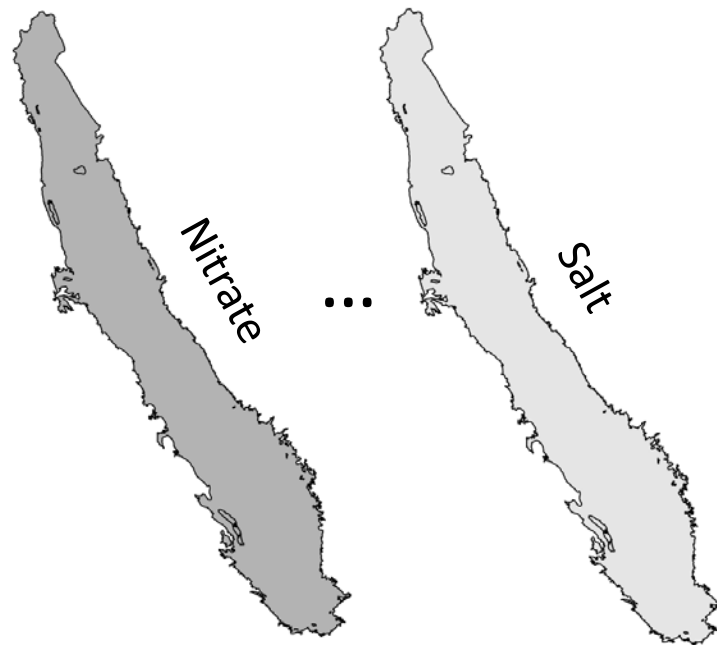


Conclusion: Towards an assessment of Central Valley domestic well vulnerability to water quality contamination

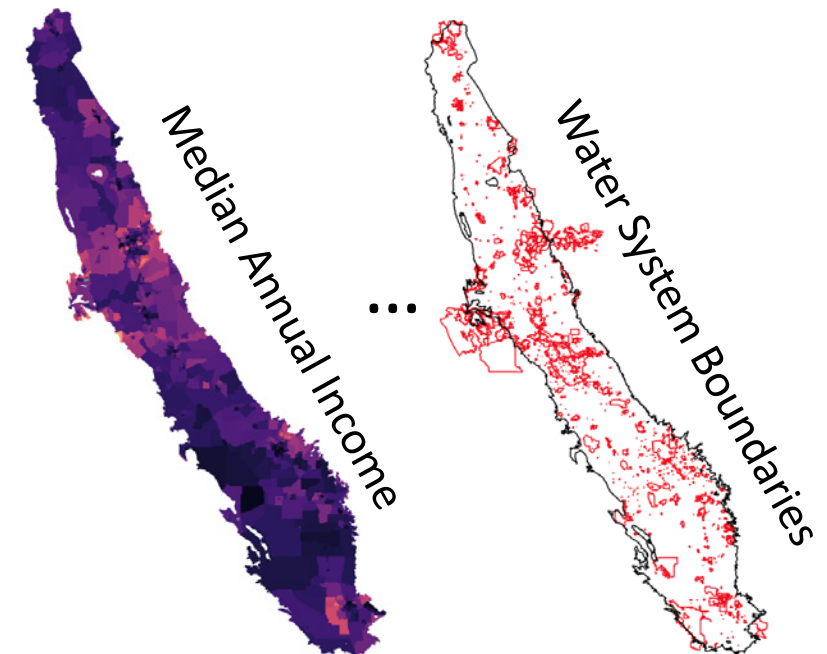
Domestic Well Data



Contaminant Data



Social/Demographic Data



Conclusions

- There are ~120,000 domestic WCRs in the Central Valley. Assuming a moderate retirement age of 25-35 years and accounting for missing well types, active well estimate is ~**35,000 – 60,000**.
- Key WCR information that informs water quality vulnerability includes: *well location (x, y)*, and *top of the screened interval (z)*.
- A simple data-driven spatial/geographic approach leveraging existing datasets (e.g. – OSWCR, salt, nitrate) can provide a rapid first-order estimate of the count and distribution of vulnerable domestic wells.

Thank You for your Attention!

Acknowledgements: state-led open data initiatives, Rob Gailey, Debbie Franco, Ben Breezing, Alvar Escriva Bou, Herve Guillon, Amanda Fencel, Thomas Harter, Graham Fogg, Darcy Bostic, Nisha Marwaha

Resources:

- OSWCR Exploratory Data Analysis: goo.gl/MthQQd
- 2018 California Water Data Challenge: goo.gl/D5fLwY
- OSCWR data download tool: ucwater.org/oswcr/



richpauloo.github.io



[@RichPaulooo](https://twitter.com/@RichPaulooo)



goo.gl/DDjT8e

Appendix

Statewide	
<i>well type</i>	<i>n</i>
<i>domestic</i>	356,618
<i>missing</i>	245,048
<i>monitoring</i>	127,296
<i>agriculture</i>	82,907
<i>unused</i>	66,220
<i>remediation</i>	18,146
<i>public</i>	14,831
<i>test well</i>	12,011
<i>cathodic</i>	5,587
<i>industrial</i>	5,080
<i>other</i>	4,914
<i>injection</i>	3,202
<i>stock</i>	1,609
SUM	943,469

Table 1: Count of well types across CA.

	Statewide		Central Valley	
<i>well type</i>	<i>n</i>	<i>n+missing</i>	<i>n</i>	<i>n+missing</i>
<i>domestic</i>	356,618	481,741	102,123	129,201
<i>monitoring</i>	127,296	171,959	46,779	59,182
<i>agriculture</i>	82,907	111,996	22,168	28,046
<i>unused</i>	66,220	89,454	16,906	21,389
<i>remediation</i>	18,146	24,513	3,935	4,978
<i>public</i>	14,831	20,035	3,848	4,868
<i>test well</i>	12,011	16,225	3,336	4,221
<i>cathodic</i>	5,587	7,547	2,056	2,601
<i>industrial</i>	5,080	6,862	1,501	1,899
<i>other</i>	4,914	6,638	1,026	1,298
<i>injection</i>	3,202	4,325	632	800
<i>stock</i>	1,609	2,174	540	683

Table 2: Count of well types across CA and CV adjusted for missing wells.

Appendix

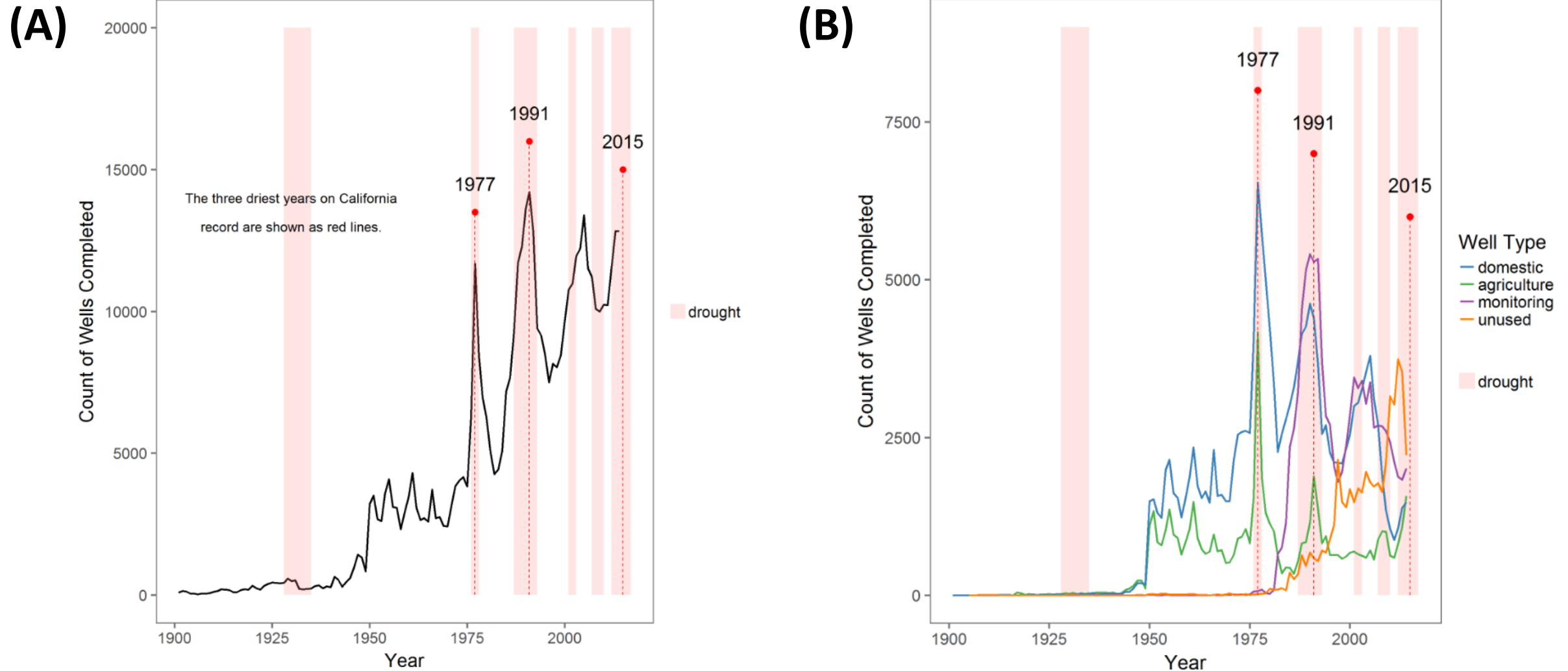


Figure 1: **(A)** Annual count of all wells drilled in Bulletin 118 basins. **(B)** Same as (A), but broken down by the 4 most common well types.

Appendix

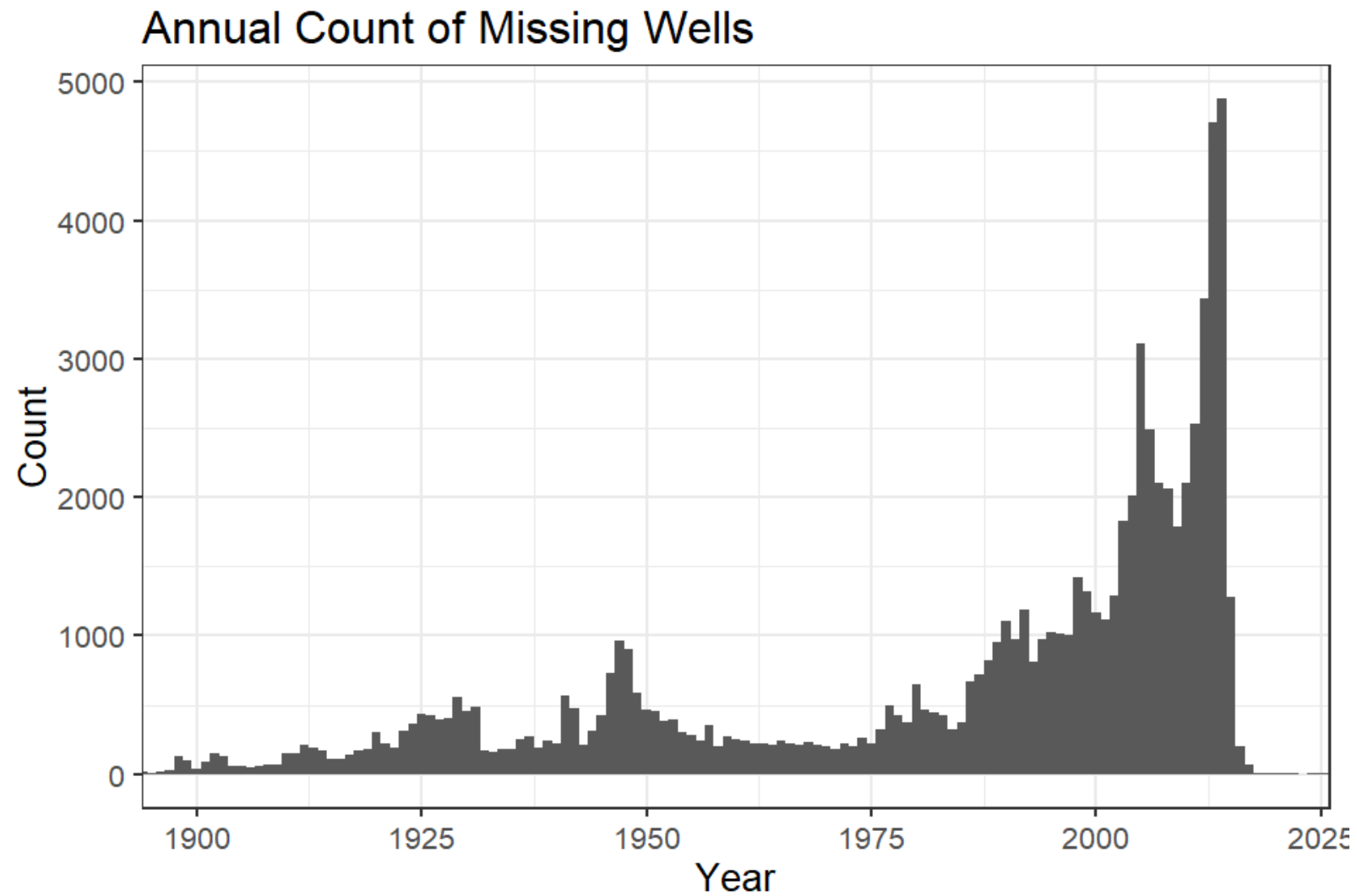


Figure 3: Annual count of well type “missing”.

Appendix

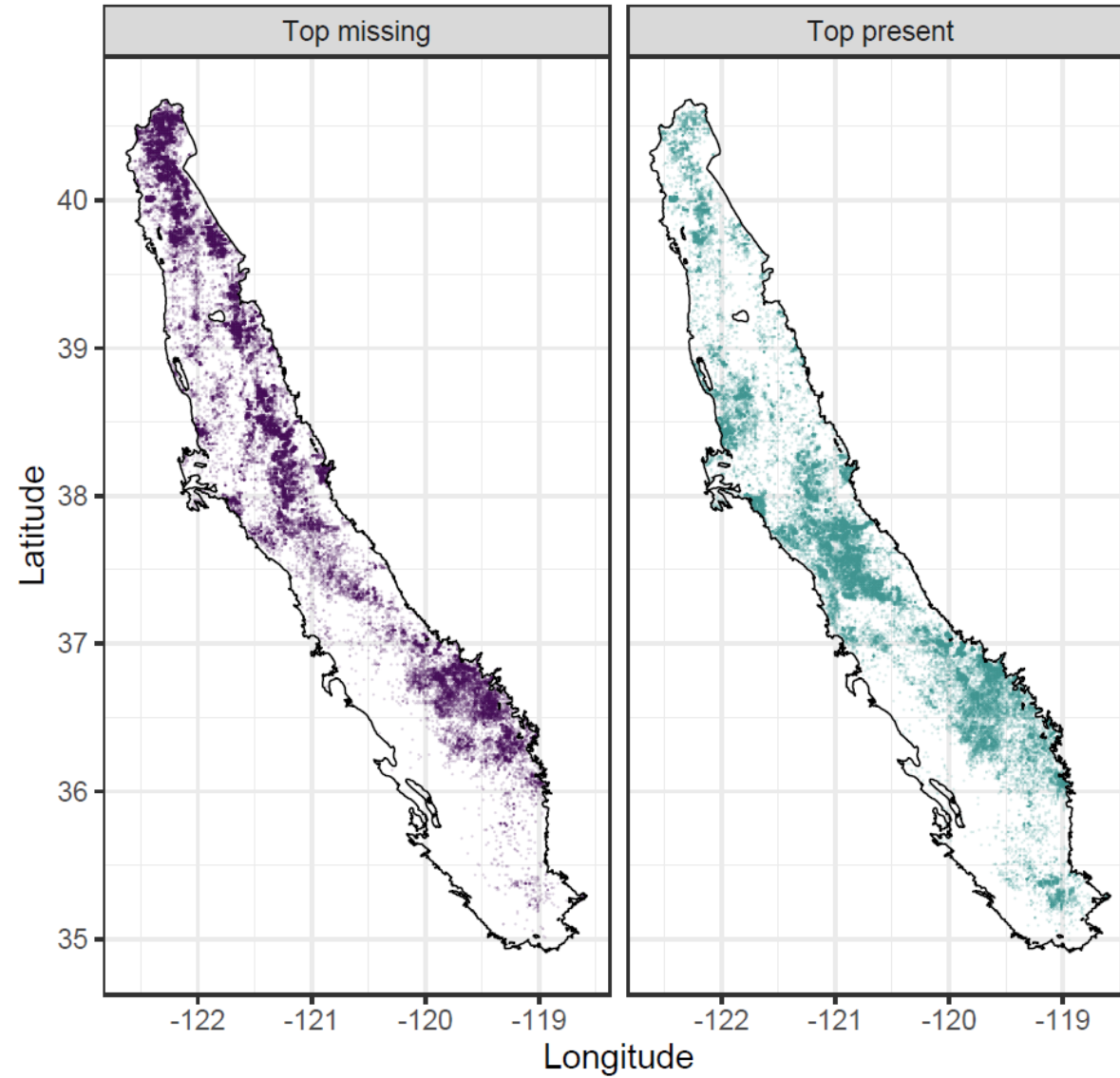


Figure 4: Missing and present Top of Perforated Interval data.

Appendix

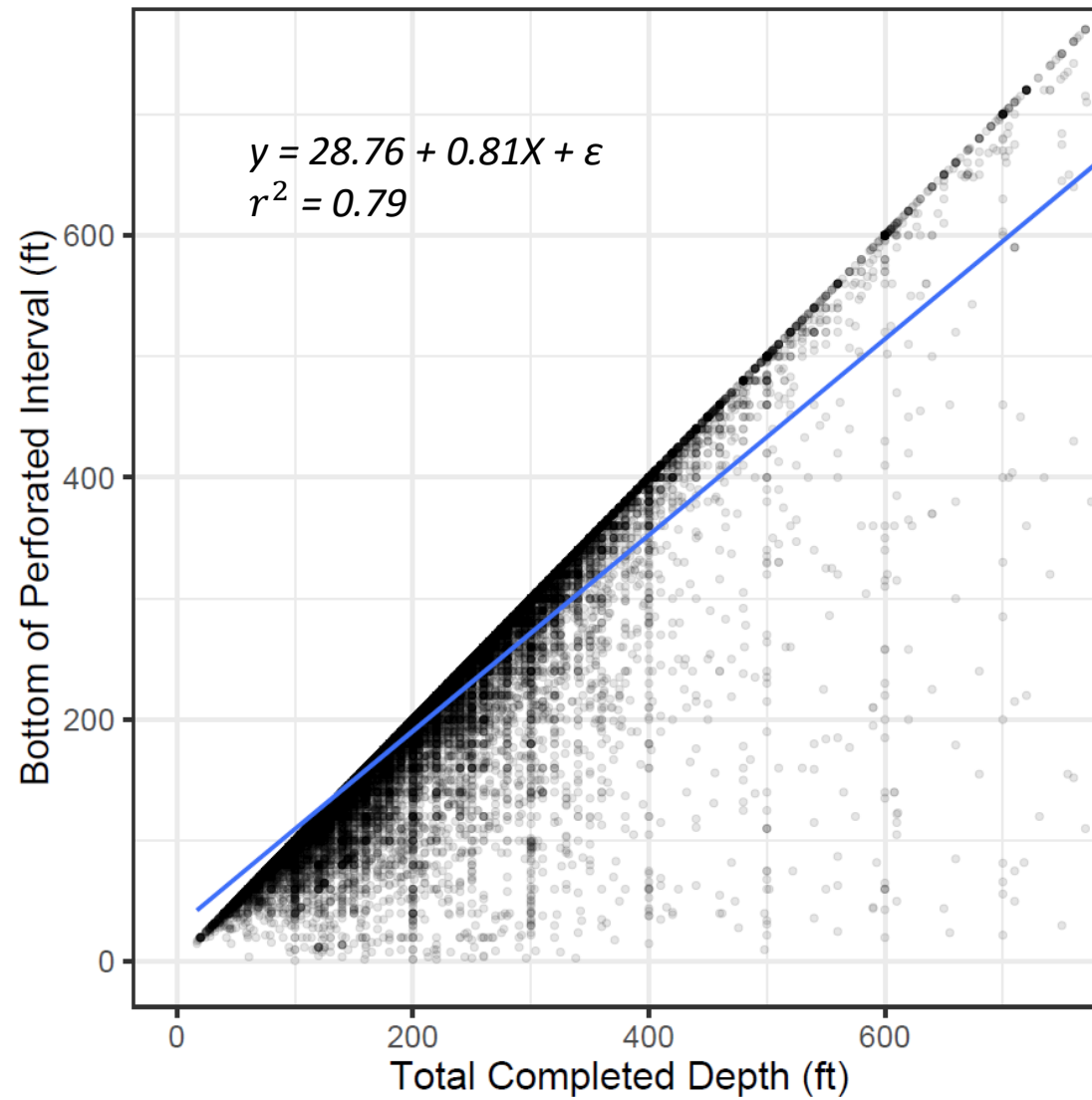


Figure 5: Completed Depth v Bottom of Perforated Interval. (CV-wide)

Appendix

Basin_Subb	bot v tot_completed_depth			top v bot		
	β_0	β_1	r^2	β_0	β_1	r^2
5-22.14	124.9	0.63	0.65	46.97	0.5	0.49
5-22.10	-8.51	1	1	129.83	0.37	0.43
5-22.13	8.28	0.9	0.86	-9.3	0.66	0.71
5-22.12	100.1	0.52	0.56	-4.33	0.82	0.88
5-22.11	13.86	0.8	0.61	-16.83	0.66	0.51
5-22.09	25.79	0.91	0.97	-23.88	0.84	0.85
5-22.08	44.35	0.66	0.61	0.25	0.68	0.6
5-22.05	-4.15	0.99	0.93	53.25	0.57	0.31
5-22.06	62.08	0.79	0.65	-18.62	0.83	0.56
5-22.04	41.11	0.75	0.74	-6.83	0.92	0.85
5-22.03	0.11	0.97	0.94	-2.89	0.87	0.85
5-22.07	8.33	0.93	0.92	-2.17	0.85	0.87
5-22.02	27.04	0.82	0.83	-5.78	0.88	0.83
02-06	-0.27	0.94	0.97	49.83	0.14	0.18
2-05	-3.42	0.99	0.98	2.05	0.45	0.35
5-22.15	15.74	0.8	0.86	-0.08	0.84	0.89
5-22.01	40.93	0.76	0.75	37.37	0.65	0.6
2-03	11.27	0.85	0.87	1.25	0.49	0.57
5-22.16	56.56	0.74	0.66	-3.89	0.78	0.61
5-21.66	11.21	0.89	0.88	8.08	0.55	0.56
5-21.65	-5.88	0.91	0.91	22.19	0.6	0.62
5-21.67	5.43	0.9	0.91	-0.83	0.79	0.8
5-21.68	-1.53	0.88	0.85	-5.09	0.78	0.8
5-21.64	60.34	0.5	0.46	11.57	0.57	0.55
5-21.61	13.13	0.73	0.78	41.46	0.35	0.46
5-21.62	12.58	0.76	0.66	-27.29	0.95	0.75
5-21.59	-4.97	1	0.96	-6.06	0.64	0.65
5-21.58	17.02	0.88	0.81	29.77	0.53	0.54
5-21.52	10.25	0.91	0.93	24.06	0.65	0.67
5-21.51	0.02	0.99	0.96	14.97	0.74	0.76
5-21.57	-9.17	1.02	0.96	-39.64	0.88	0.77
5-21.56	-4.12	1.01	0.99	6.74	0.68	0.8
5-21.55	5.17	0.85	0.65	-0.48	0.74	0.66
5-21.54	38.19	0.6	0.72	56.12	0.15	0.12
5-21.50	-2.92	1	0.98	-8.42	0.9	0.92
5-21.53	5.64	0.93	0.93	-27.15	0.94	0.91
5-06.01	-1.76	0.99	0.98	9.38	0.78	0.85
5-06.02	0.72	0.99	1	-6.59	0.85	0.84
5-06.03	8.43	0.93	0.94	5.83	0.76	0.78
5-06.05	-5.71	0.99	0.93	-17.93	0.89	0.86
5-06.04	2.57	0.95	0.9	-6.62	0.83	0.85
5-21.60	12.18	0.83	0.75	19.17	0.43	0.43

Table 3: Linear model coefficients and goodness of fit for top v bottom.

Don't forget!

- We've only been talking about Central Valley domestic wells!
- ~350,000 domestic wells outside of CV (including missing wells)
- Population = upwards of 1 million
- Loss of alpine snowpack **ALSO** threatens alpine granitic/volcanic aquifers
 - different water retention properties = different “breaking points” (Markovich et al., 2016)

