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

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UC DAVIS UNIVERSITY OF CALIFORNIA PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA UC WATER Security and Sustainability Research Initiative NSF

Agenda

- Background & Motivation
- Goals: Overall and Today
- Previous work on CA domestic wells
- Ongoing Work: Online State Well Completion Report Database (OSWCR)
    1. How many active domestic wells are in the Central Valley and where are they located?
    2. Where are the most vulnerable wells?
- 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

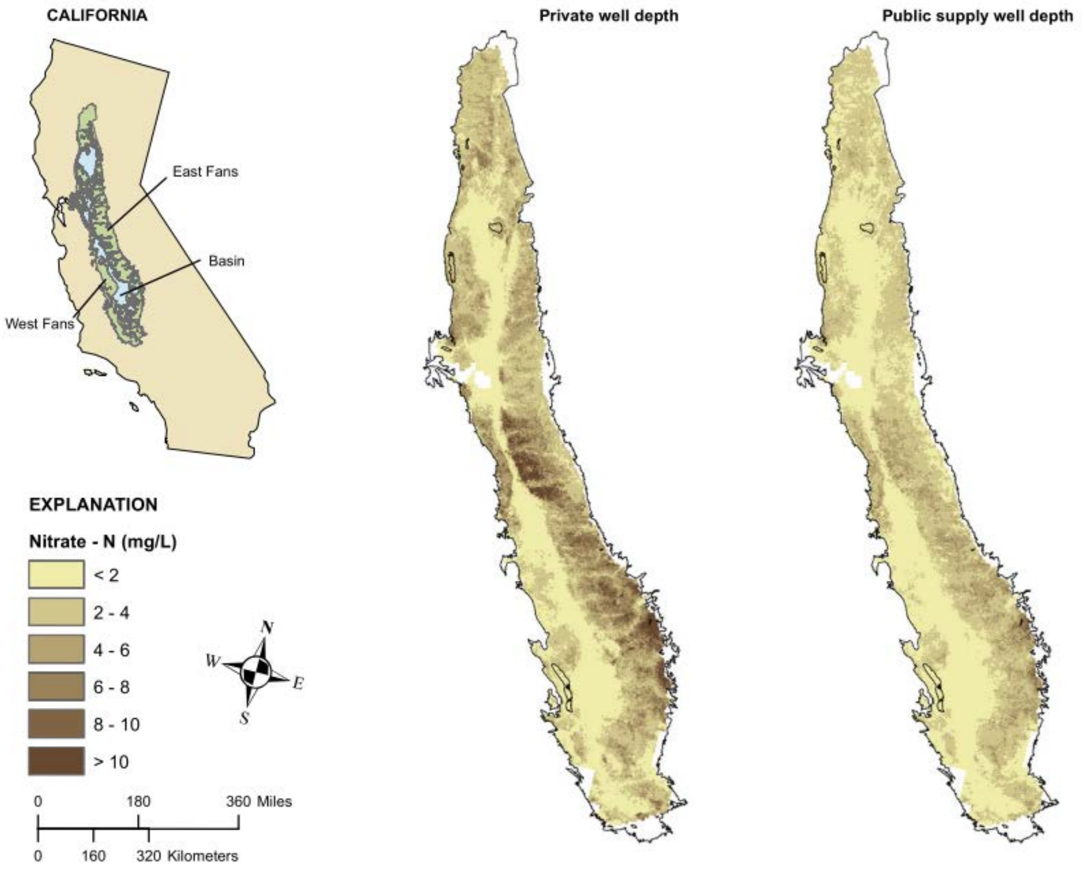
AB 685: Human Right to Water:

> *"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: Reut.ers/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)

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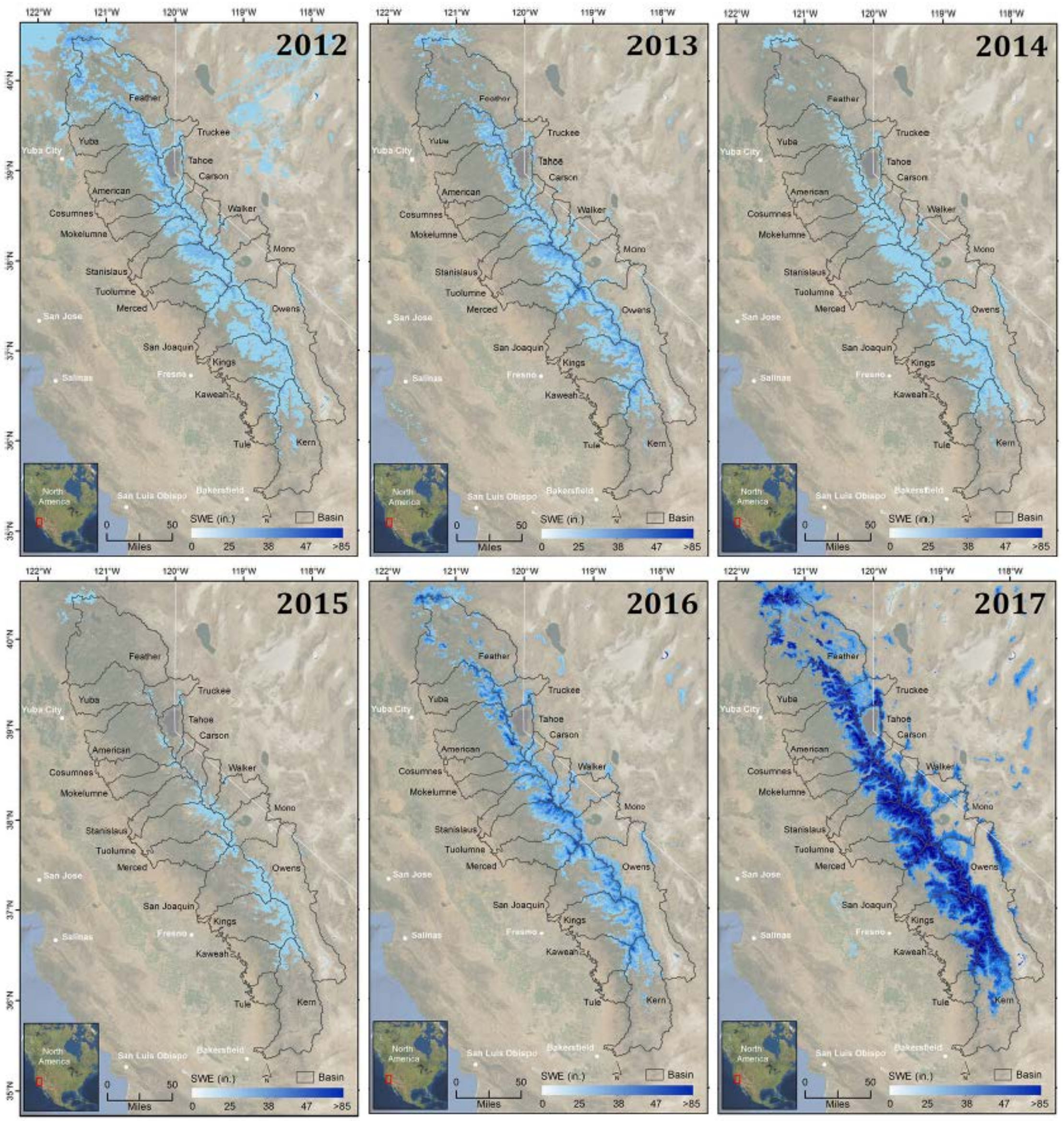

(CA-DWR, 2018)

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)

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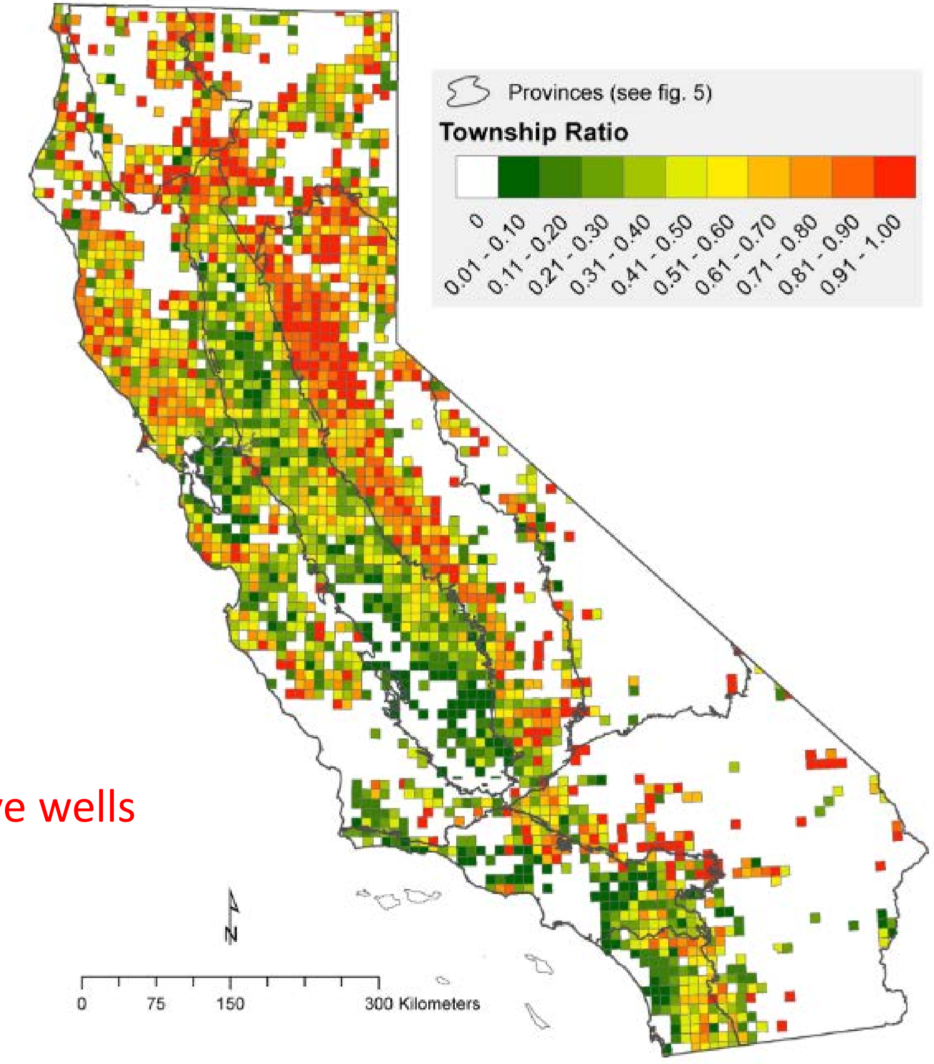
Previous Work Characterizing Domestic Wells

- 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

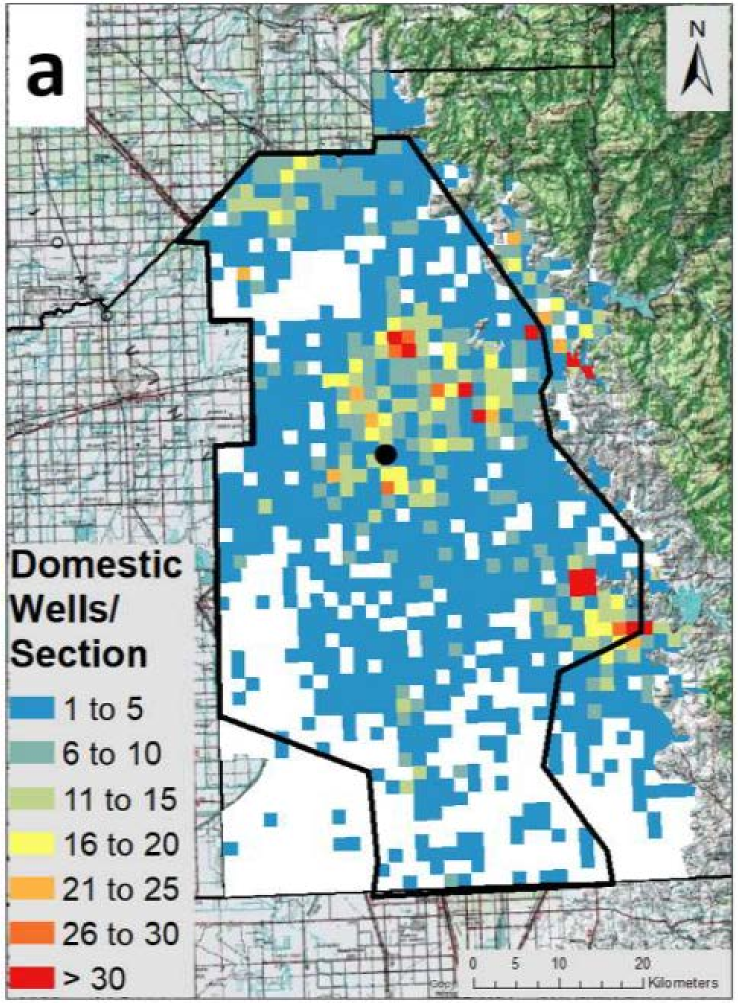
- Central Valley *estimate*: **91,598 WCRs**



(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)

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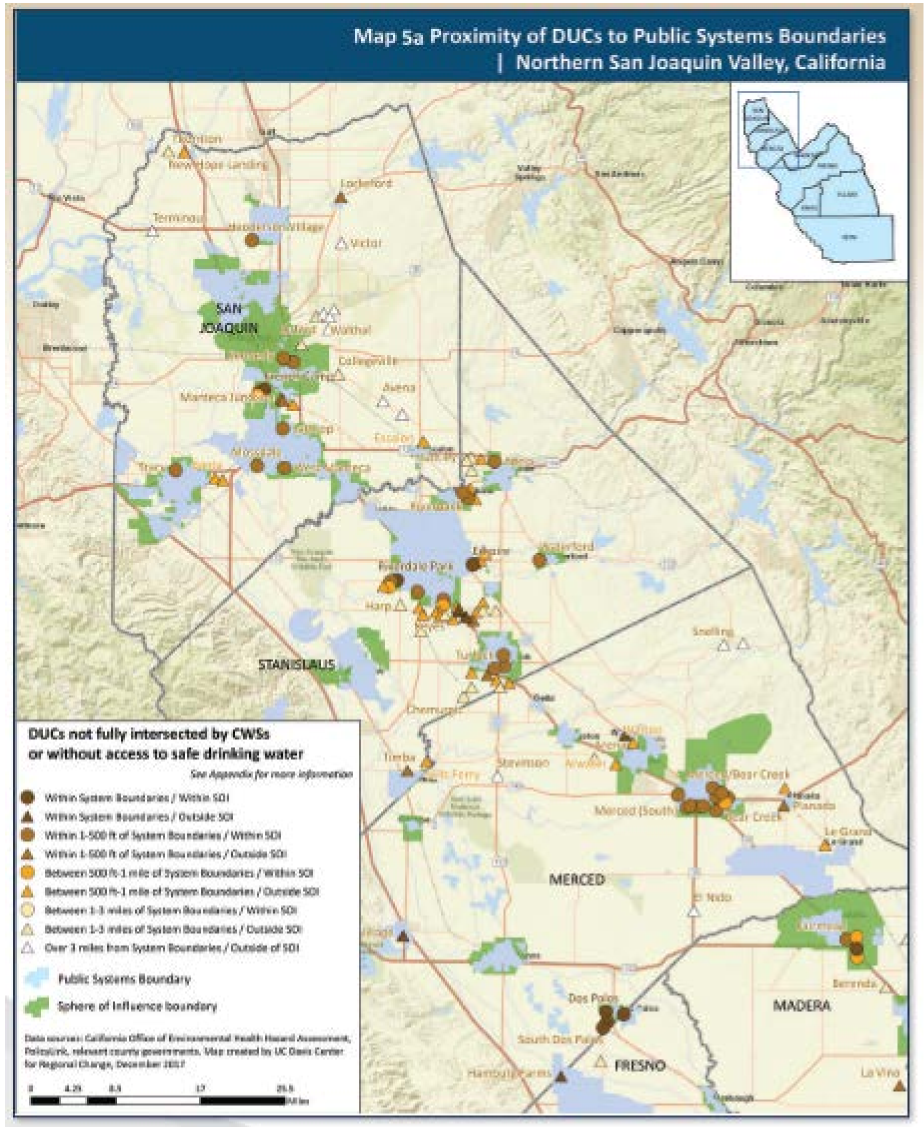

(London et al.., 2018)

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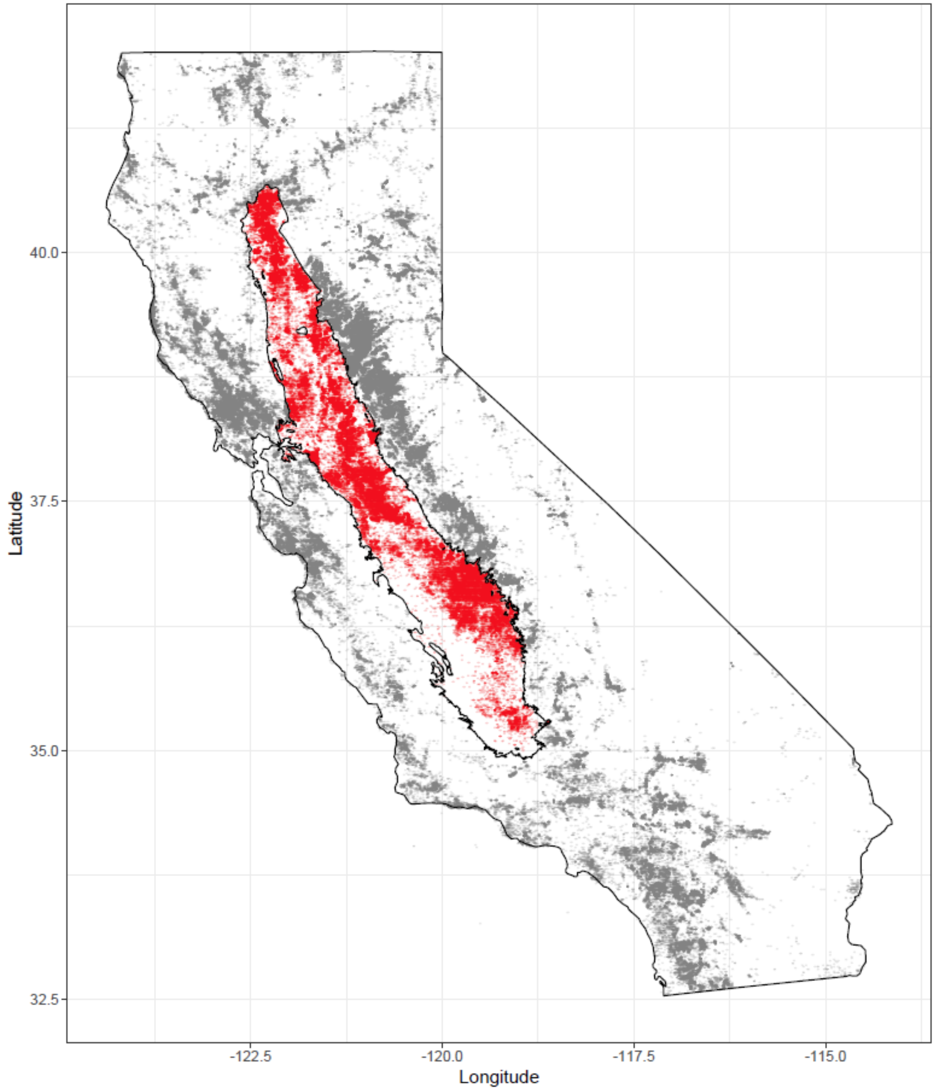


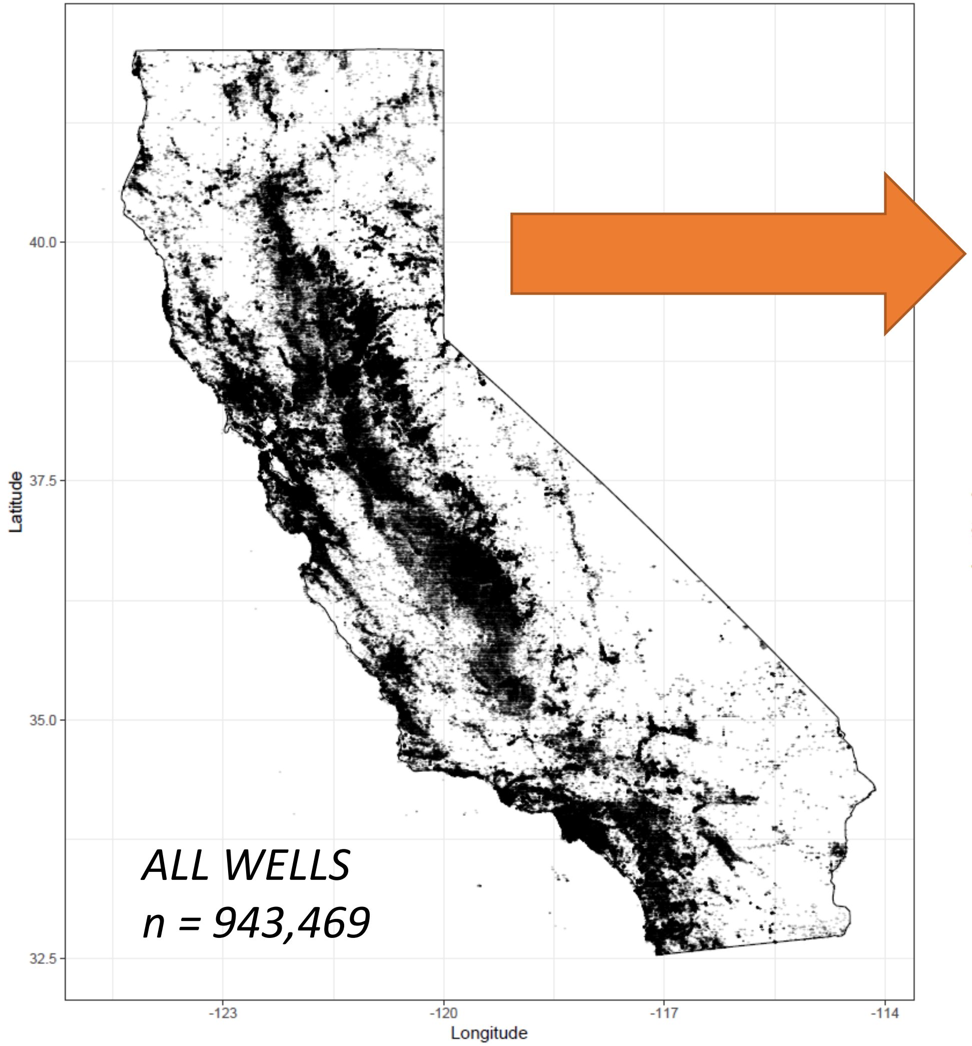
(Pauloo et al., 2018) – in prep

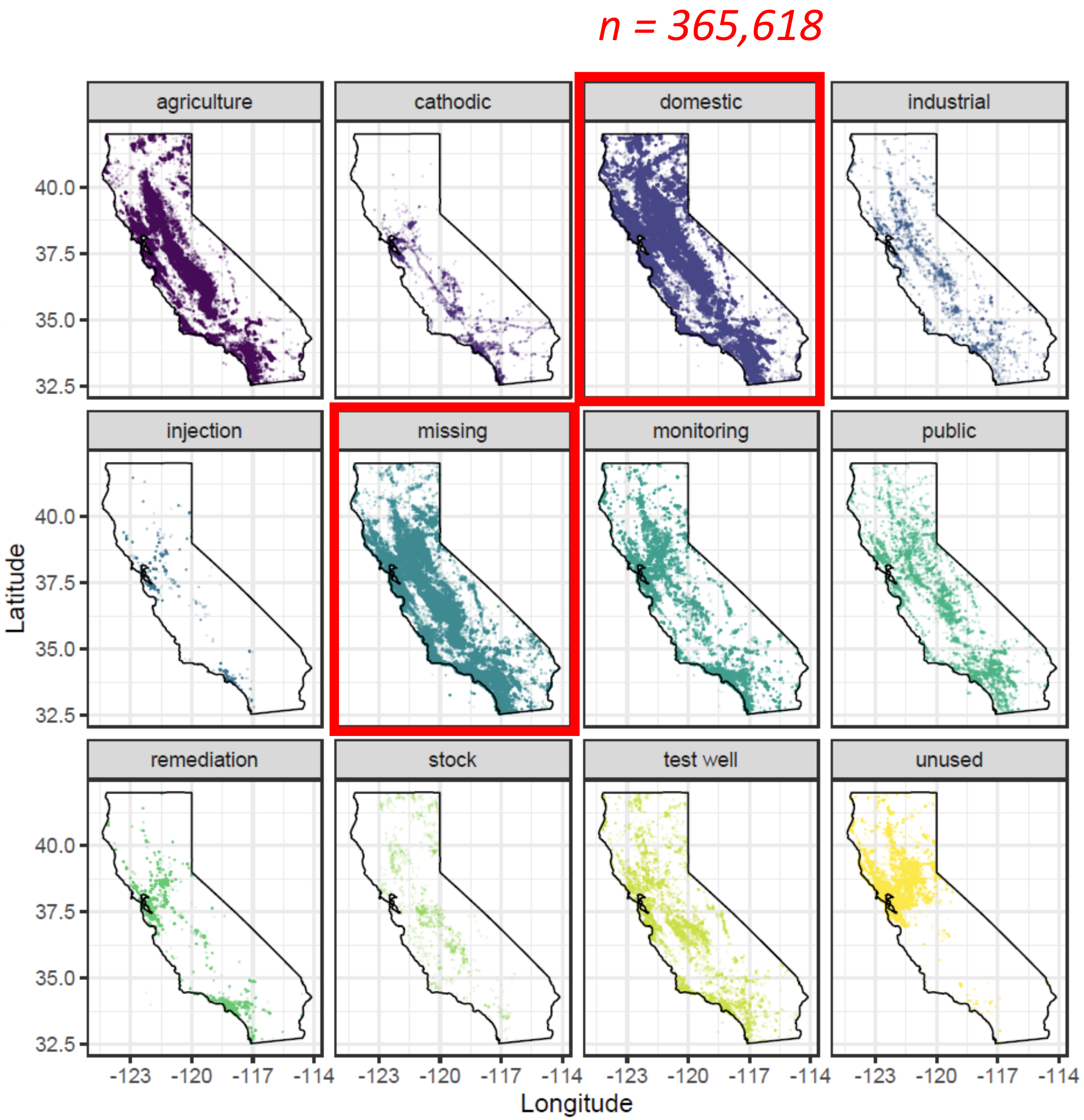
Ongoing Work: OSWCR

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

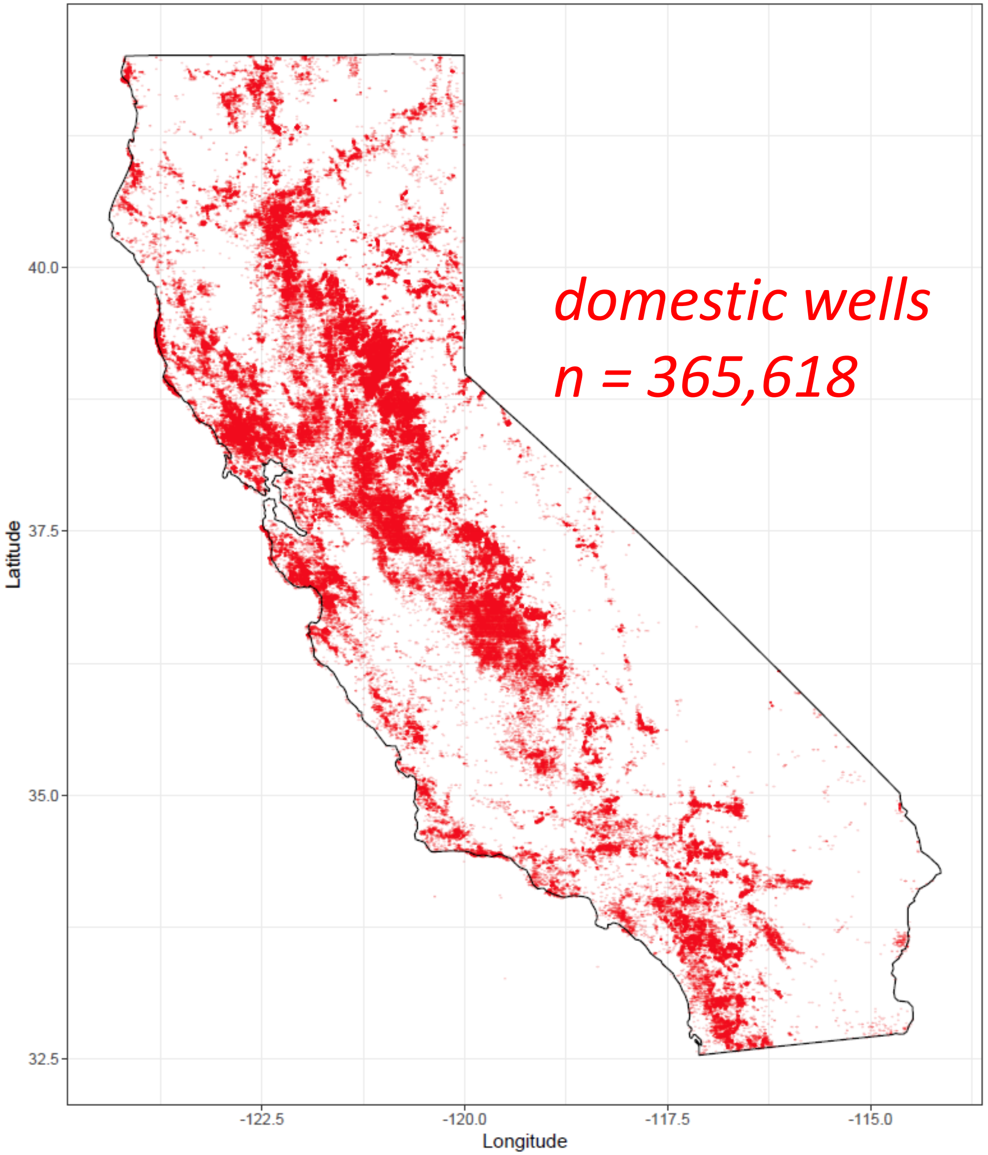


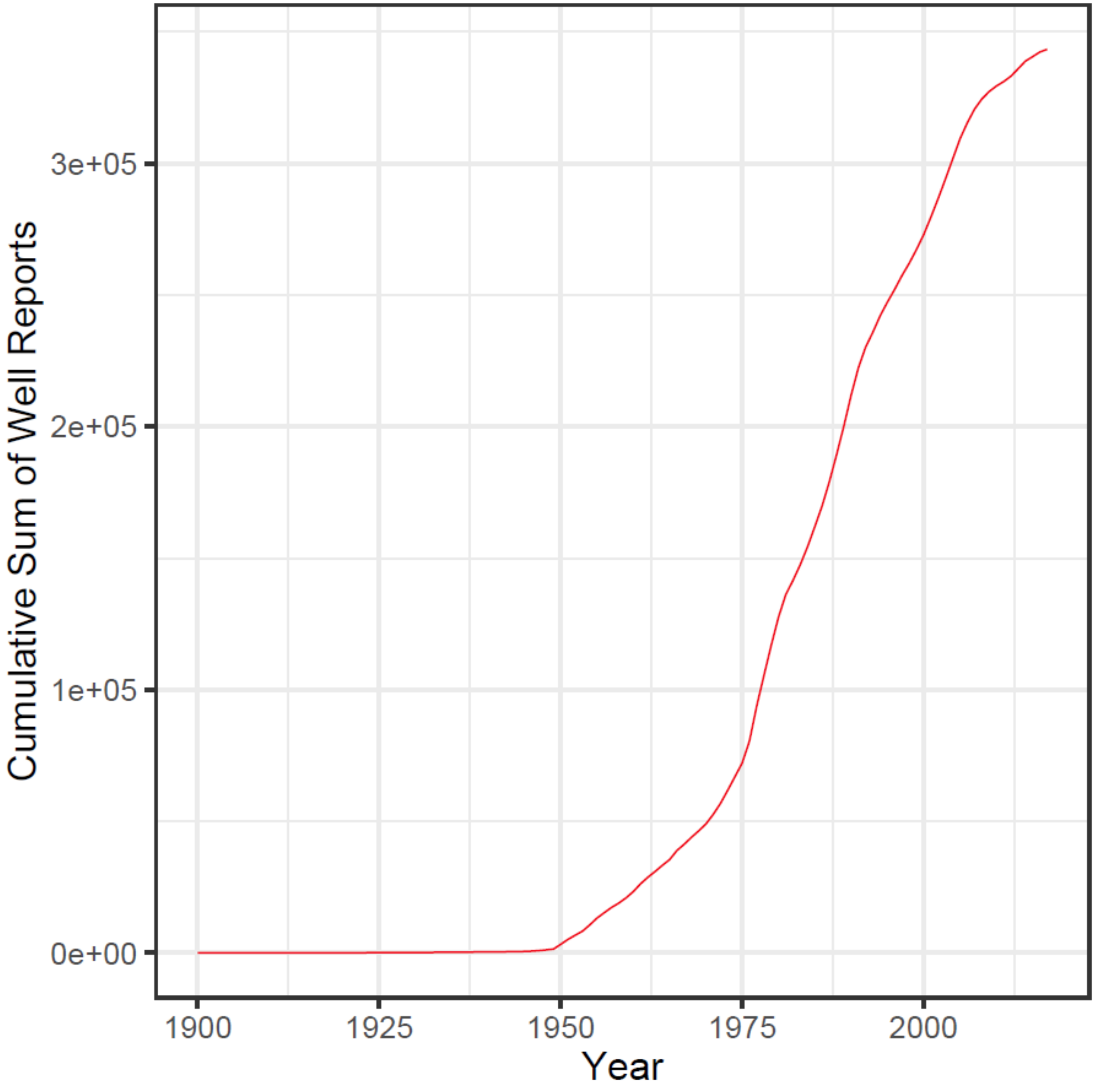


well type	n
domestic	356,618
missing	245,048
monitoring	127,296
agriculture	82,907
unused	66,220
remediation	18,146
public	14,831
test well	12,011
cathodic	5,587
industrial	5,080
other	4,914
injection	3,202
stock	1,609
SUM	**943,469**

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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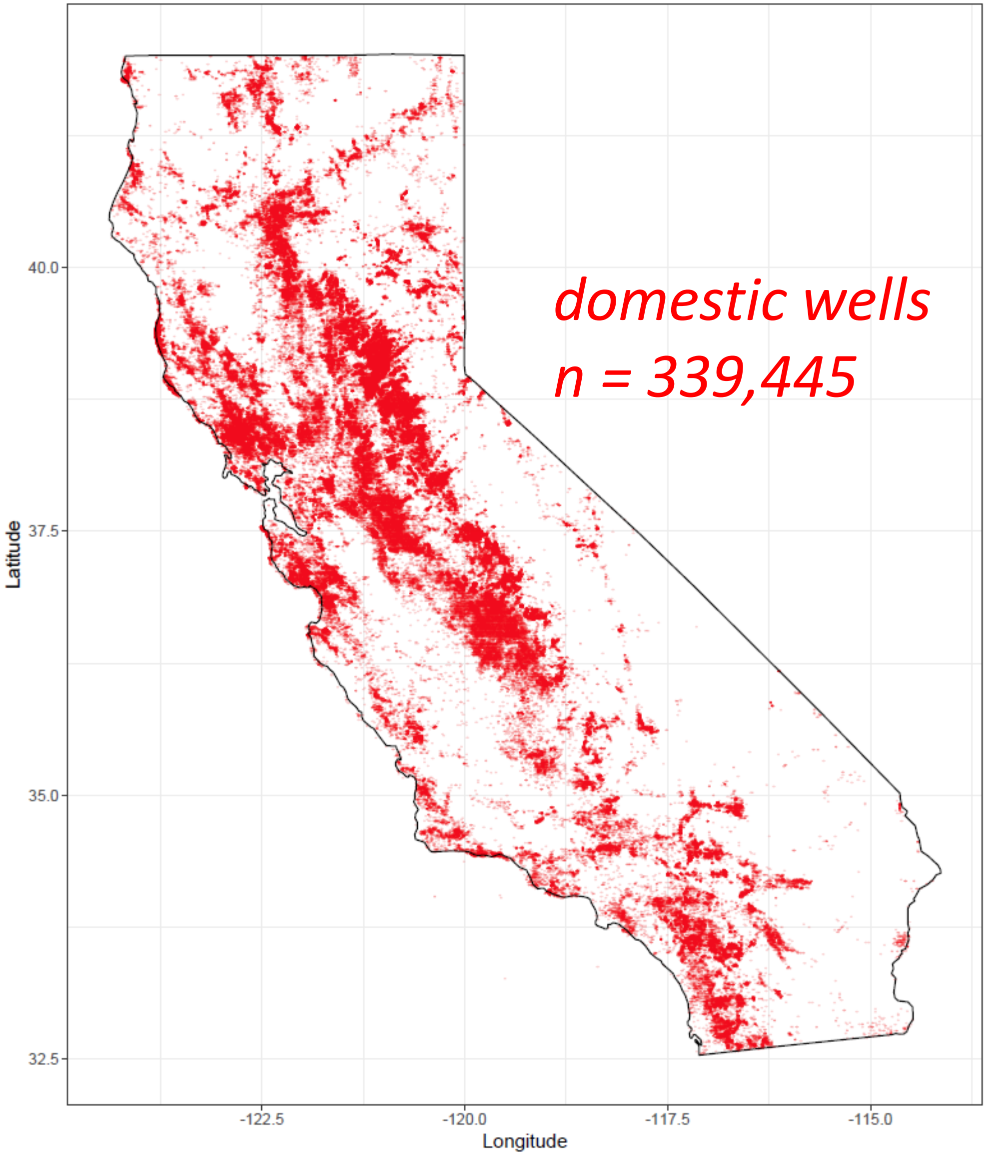

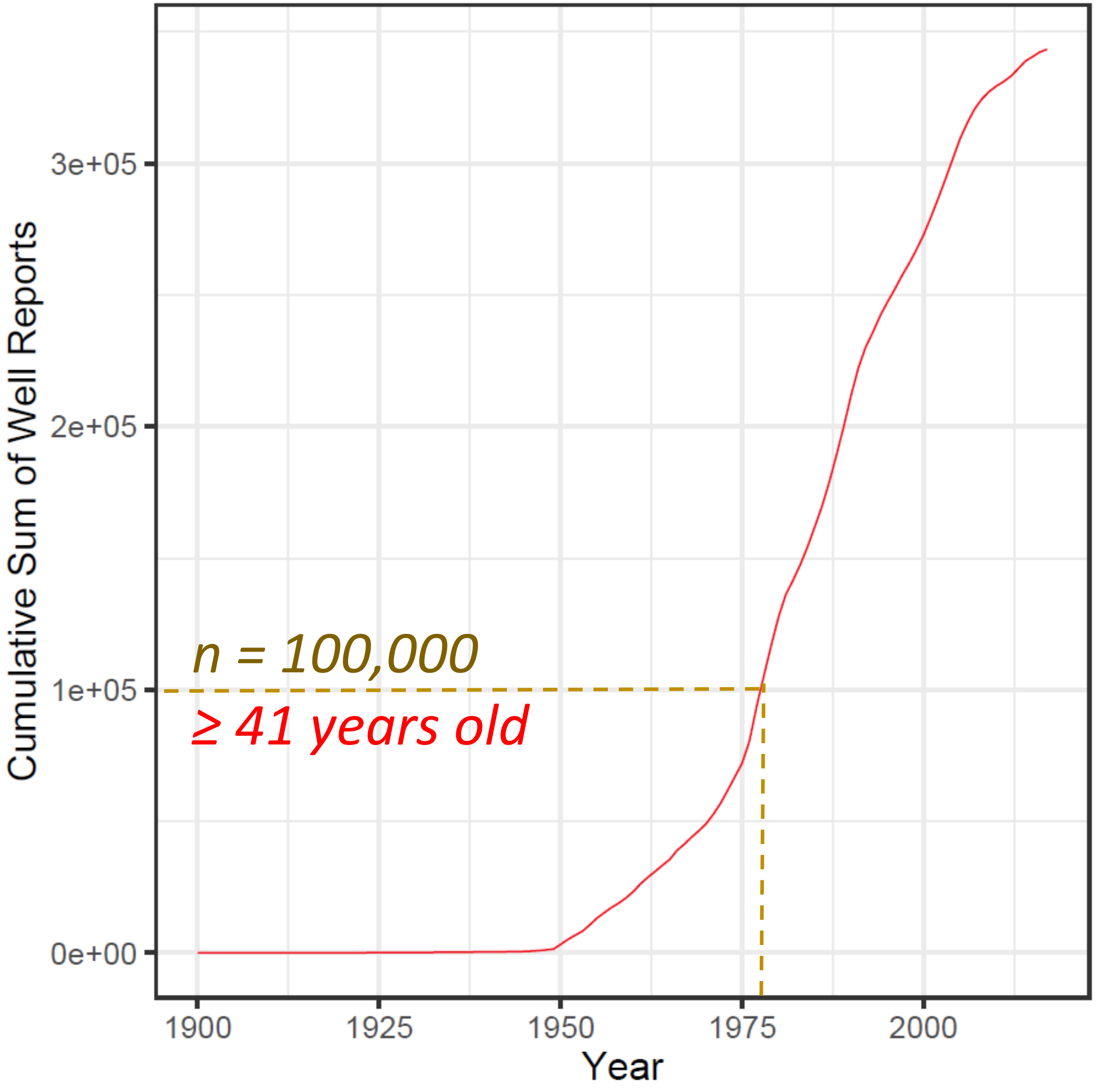

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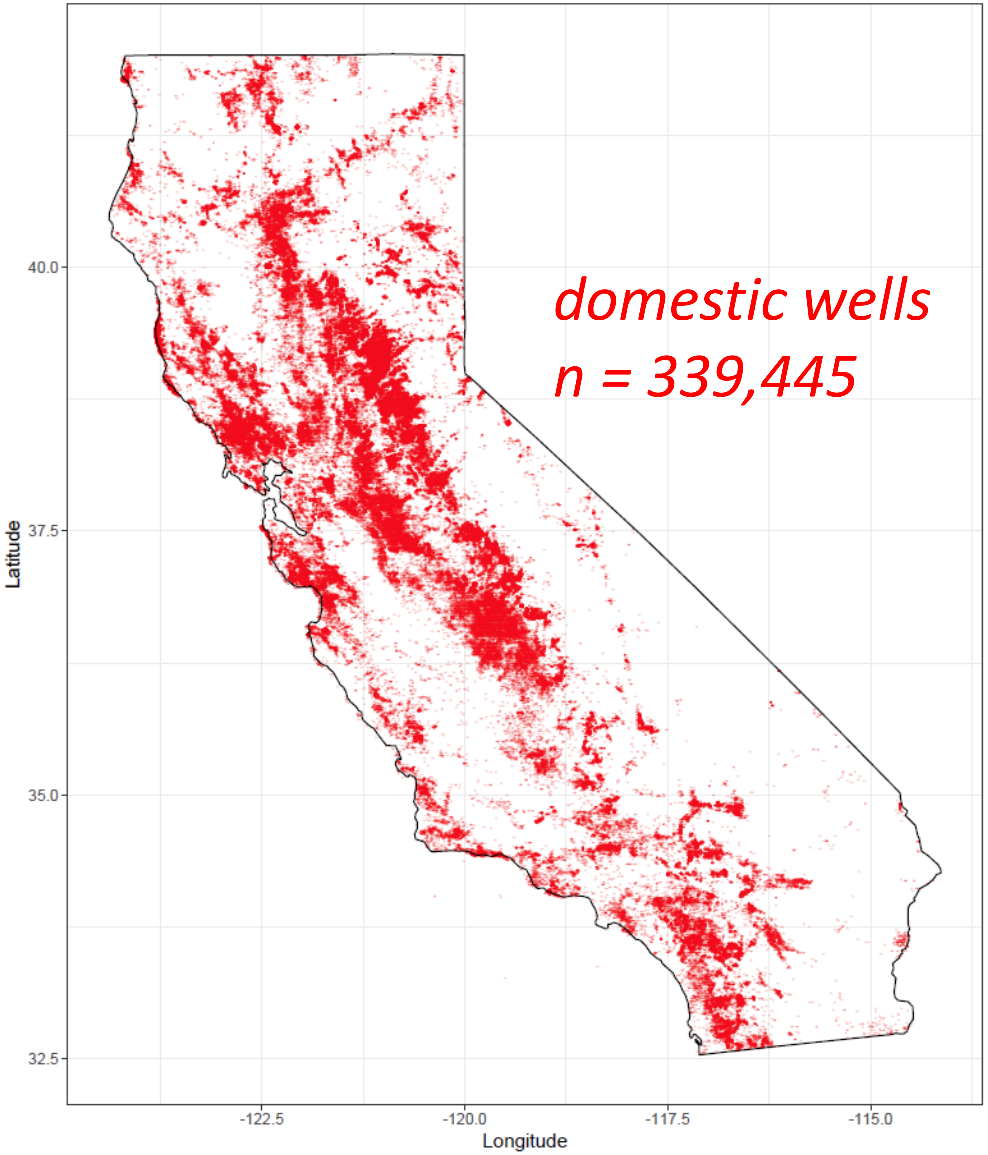

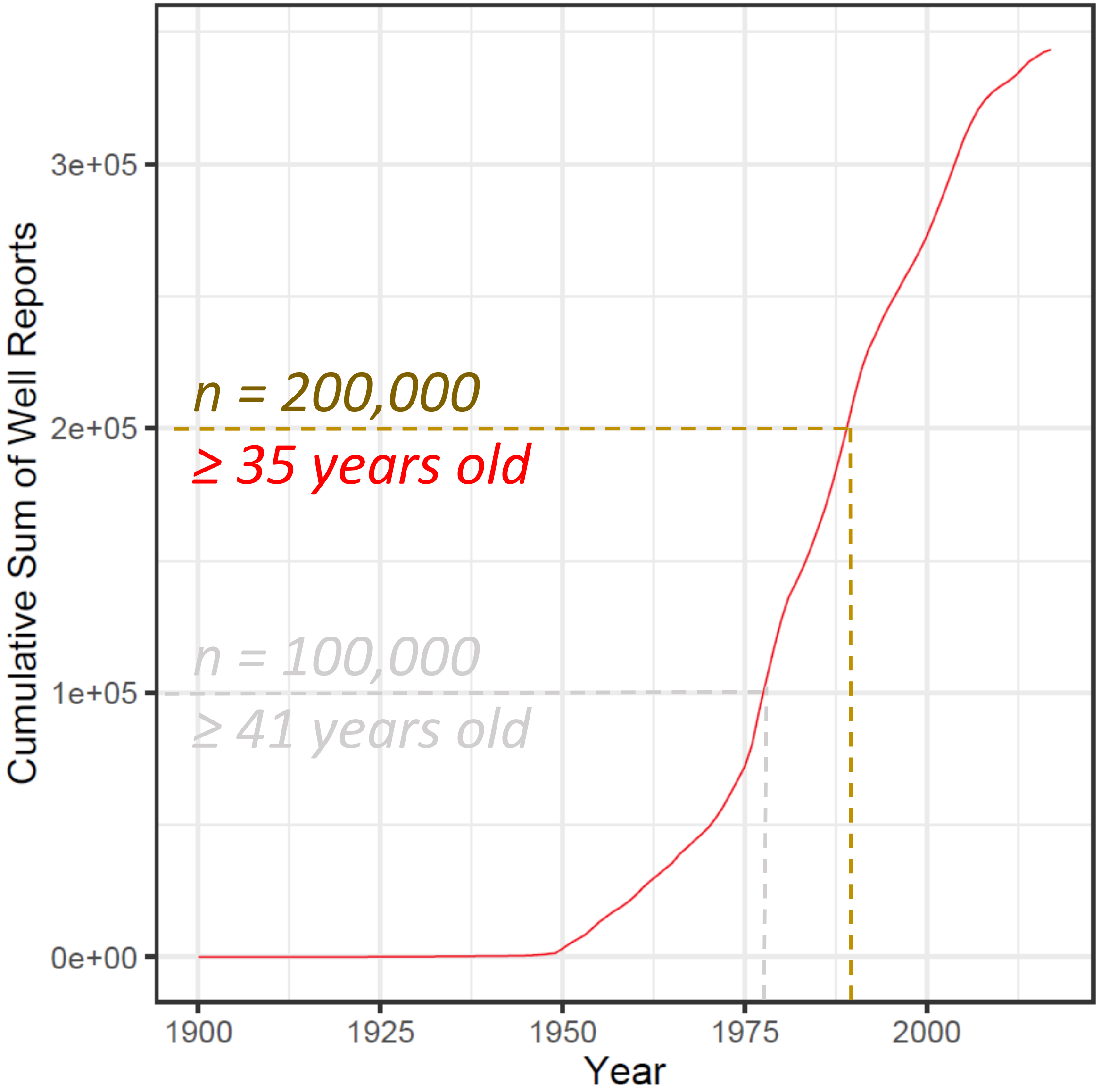

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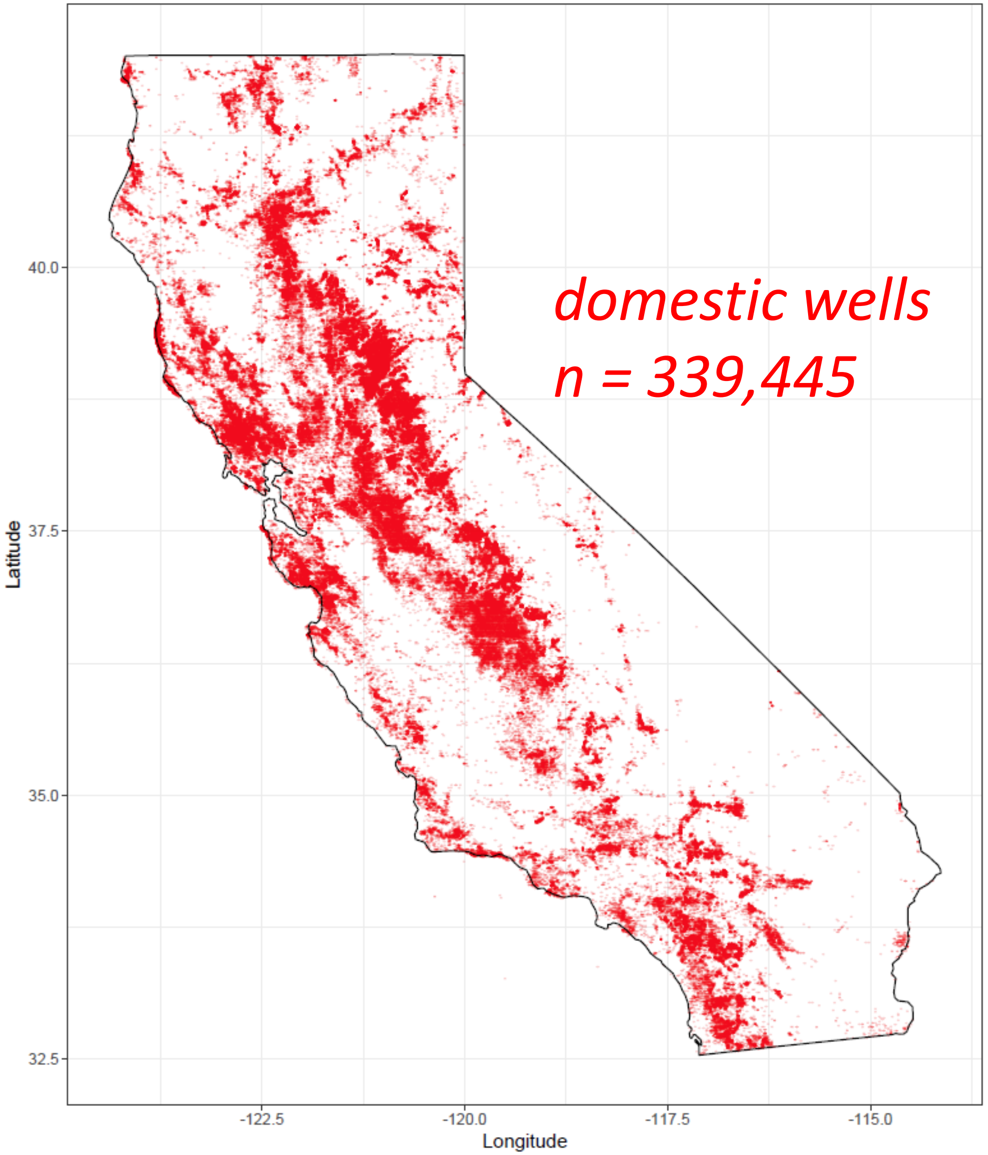

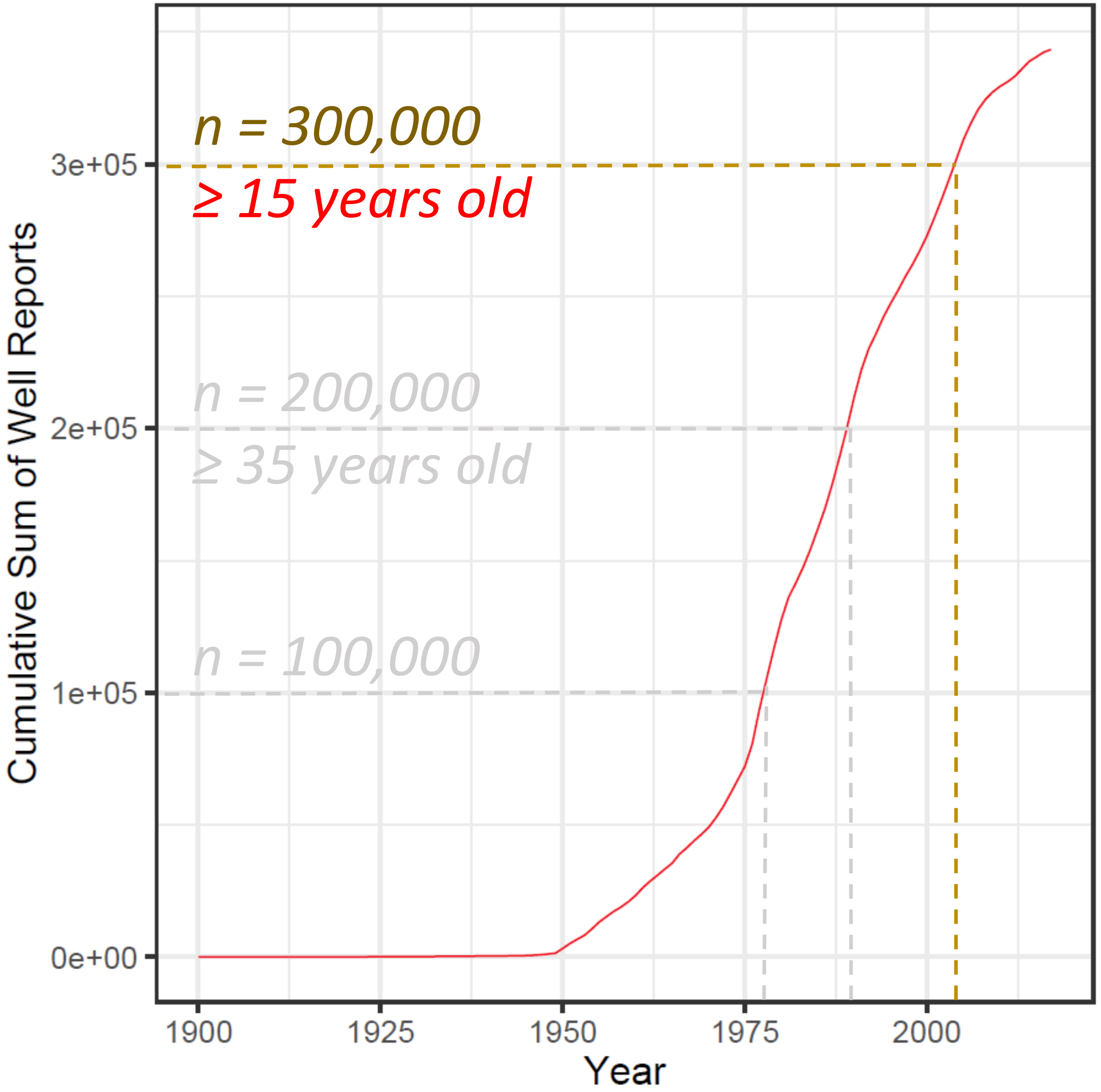

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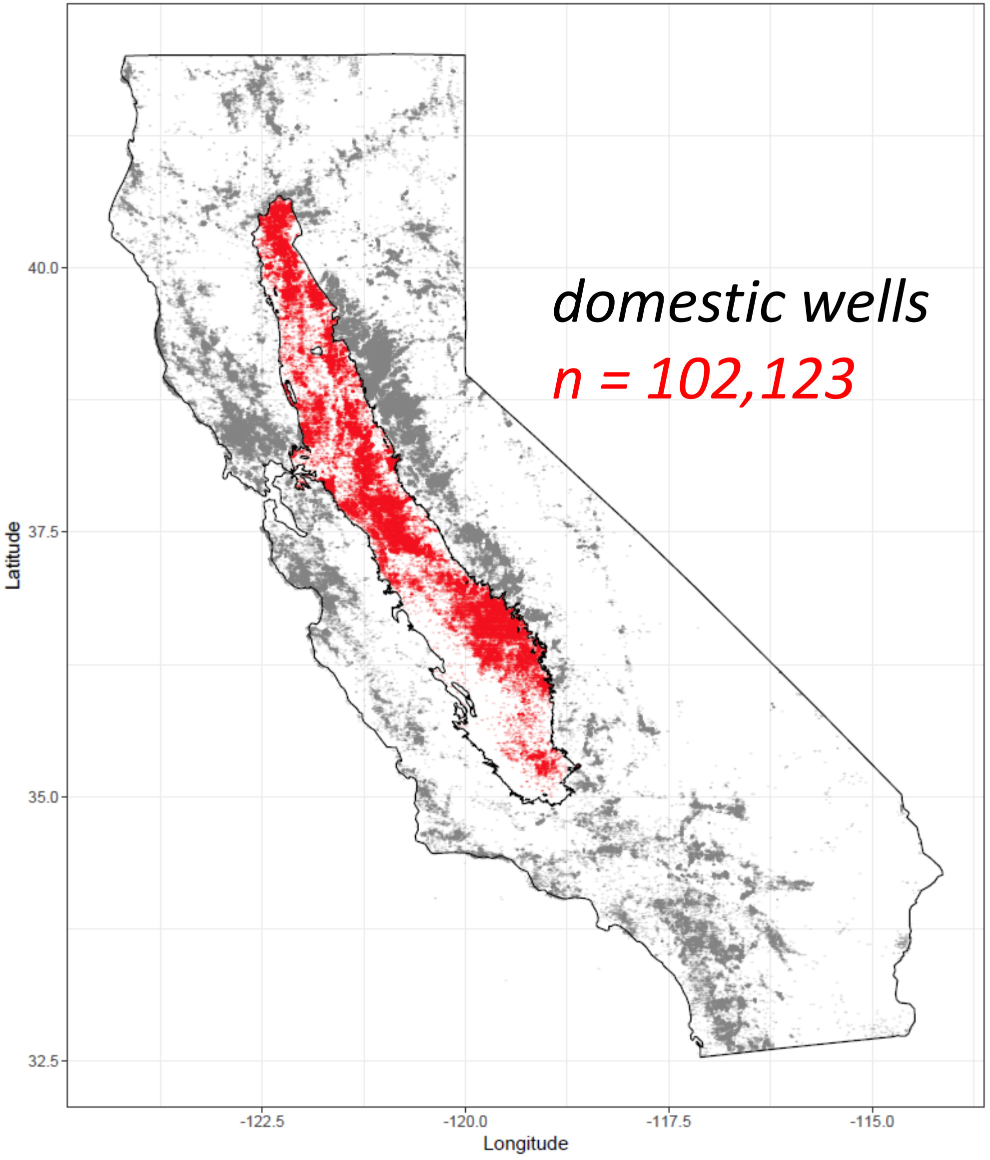
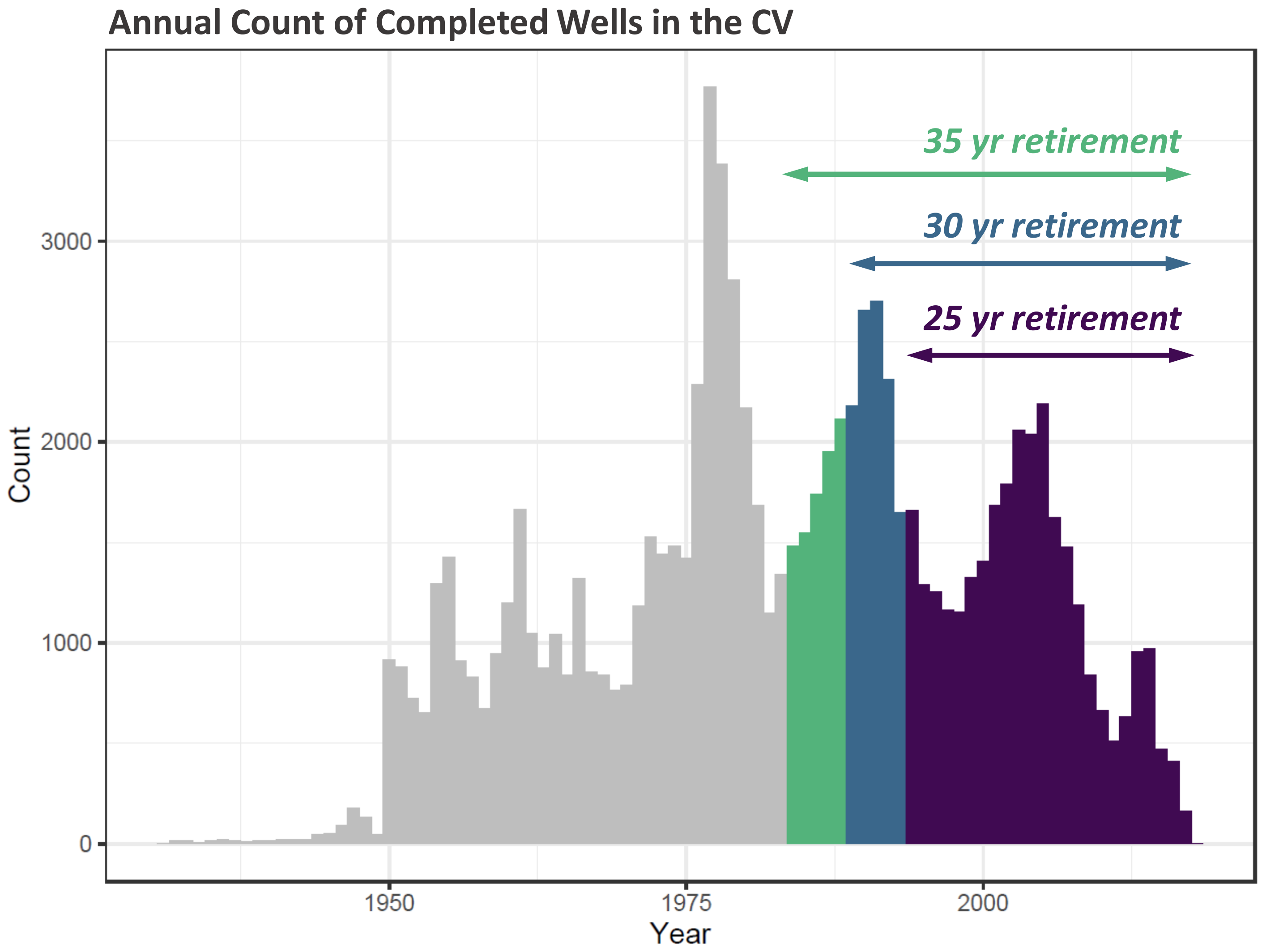
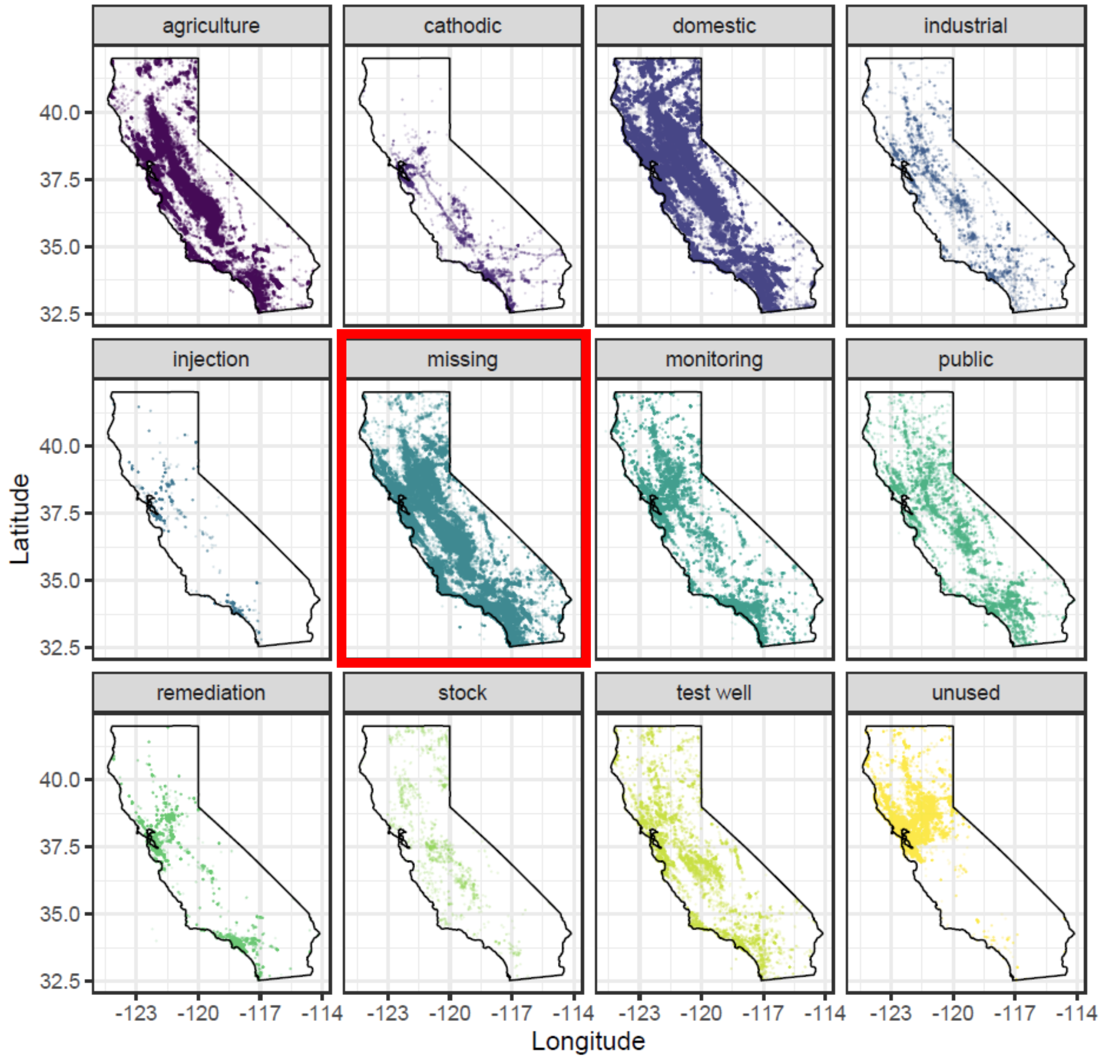




Q1: How many active domestic wells are in the Central Valley and where are they located?

A1: Examine spatial distribution, consider retirement age, **consider "missing" (undesignated) wells**



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

Scale	***missing well type***	***domestic well count***	***adjusted dom well count***
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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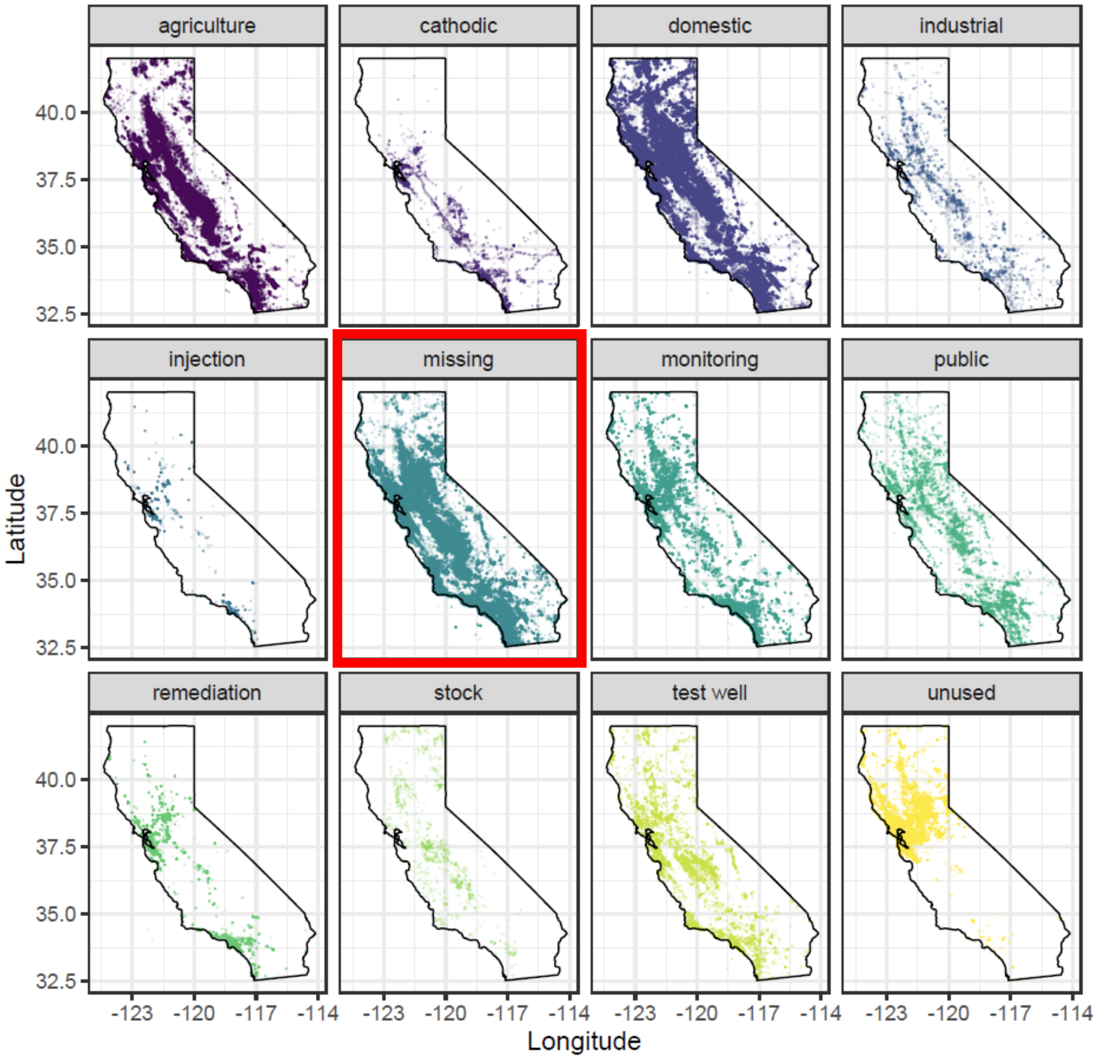

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20% added
80% original

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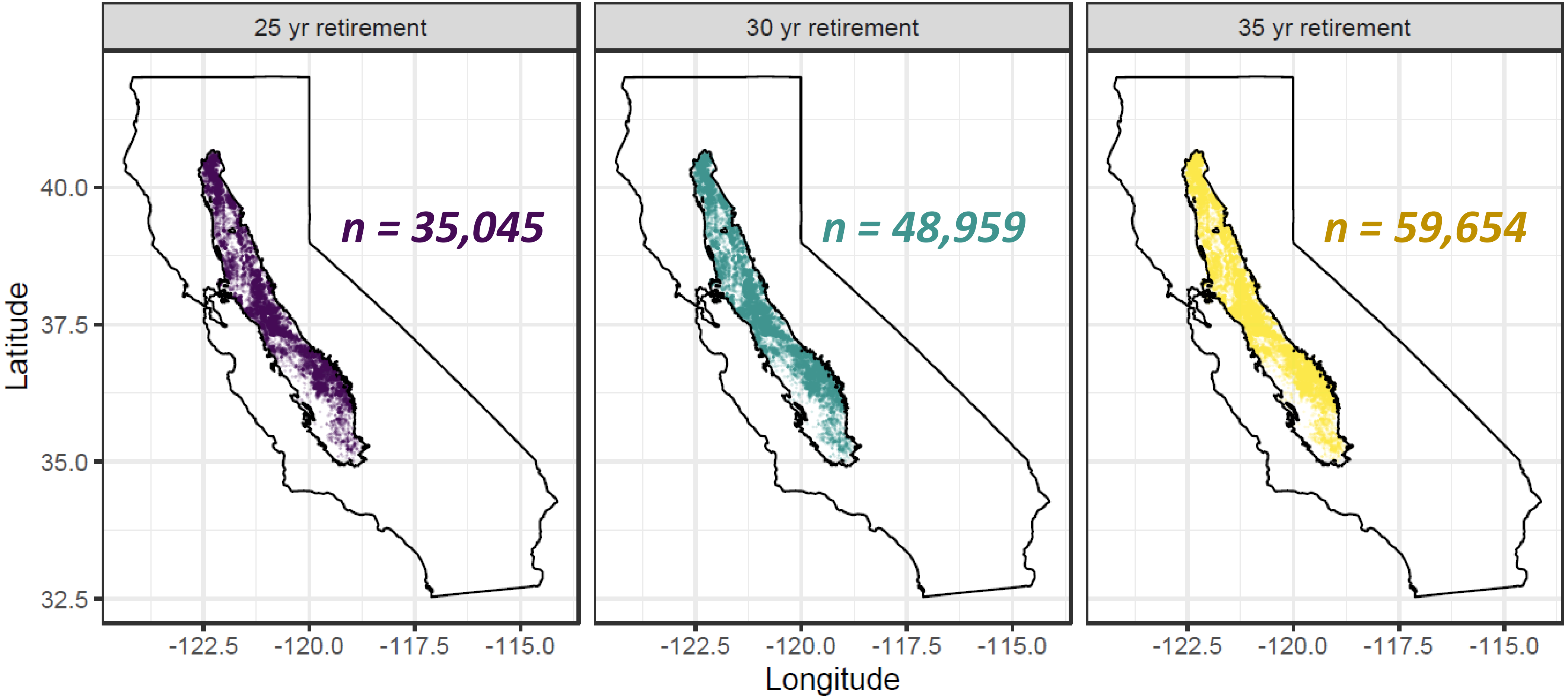
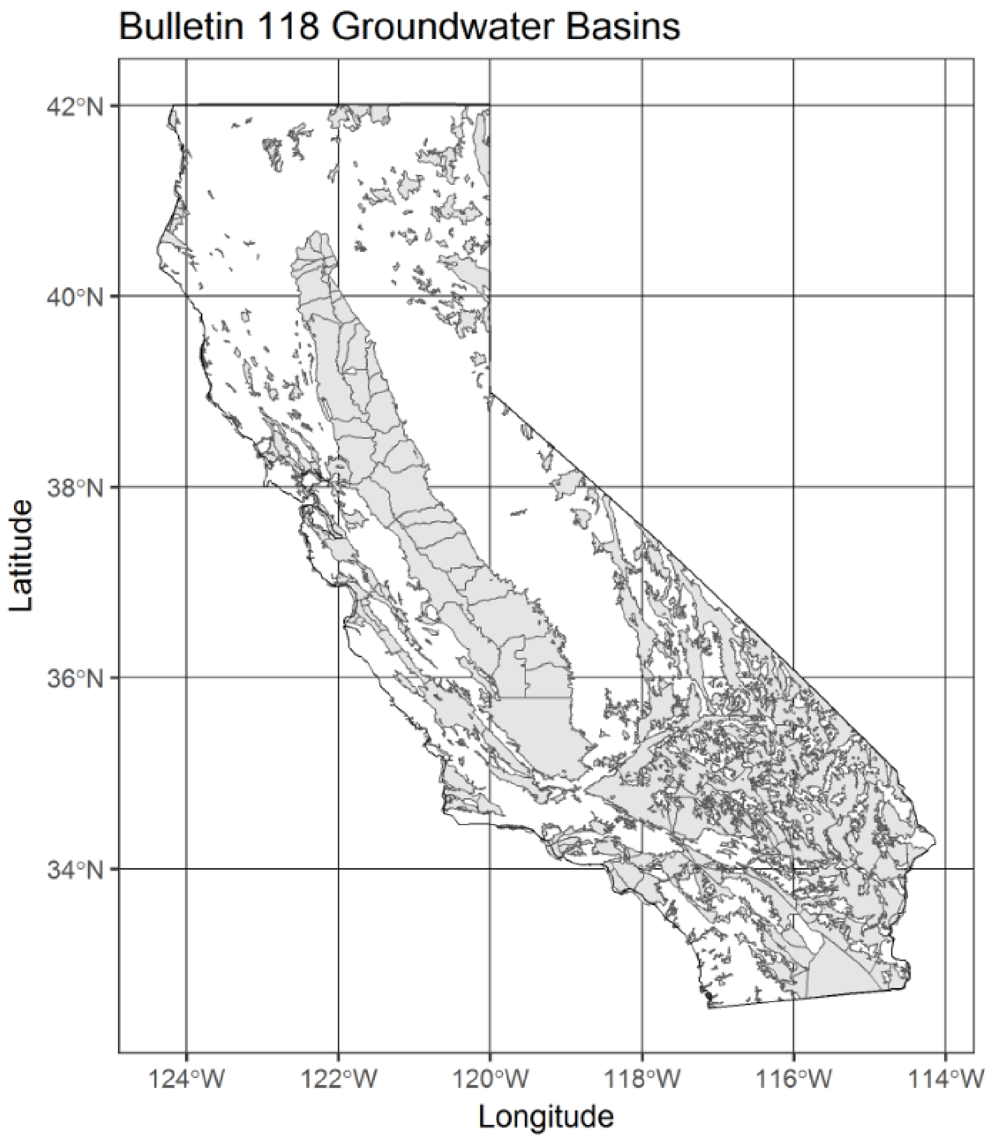
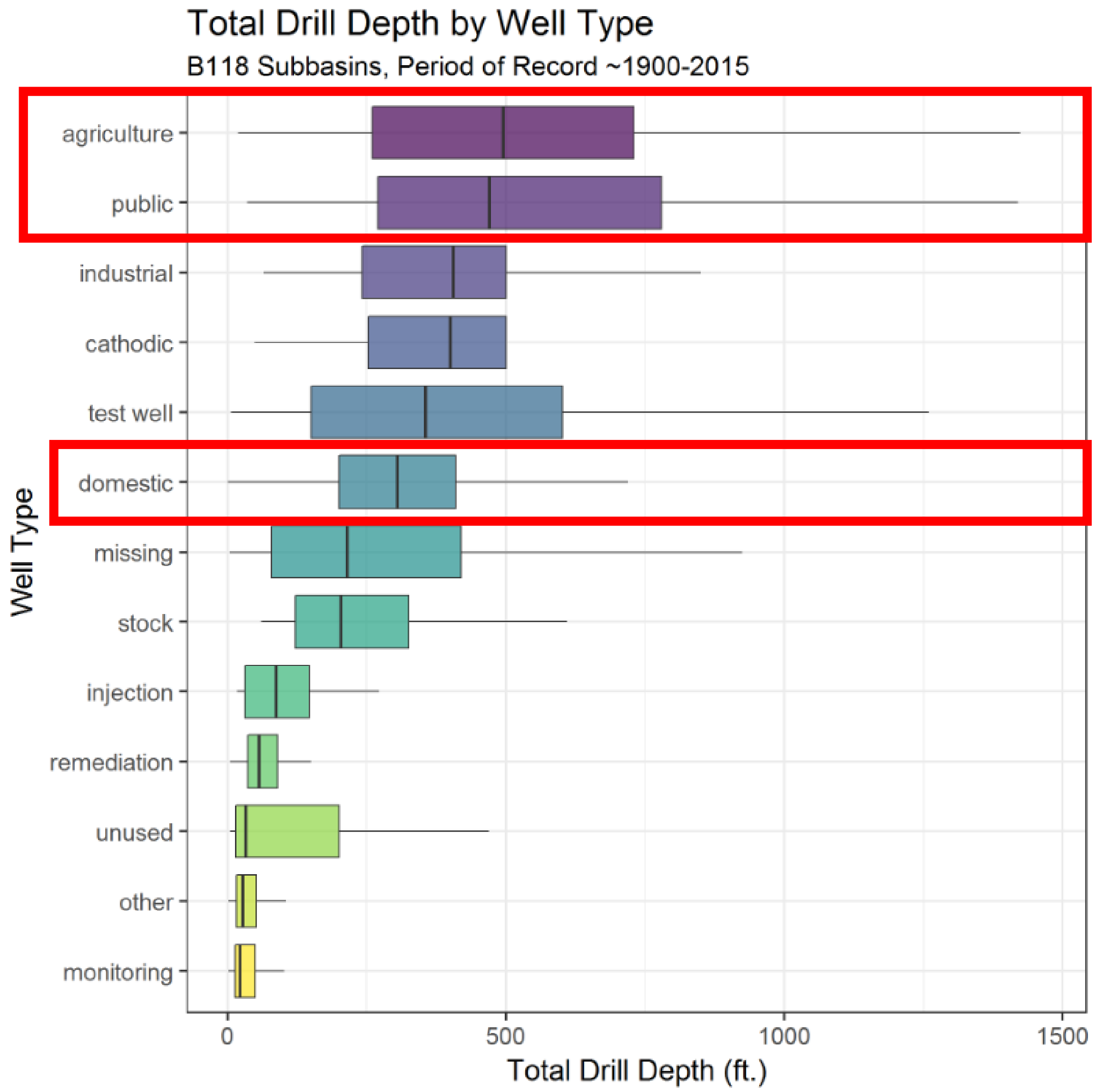


Final estimates are adjusted for missing wells.

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).



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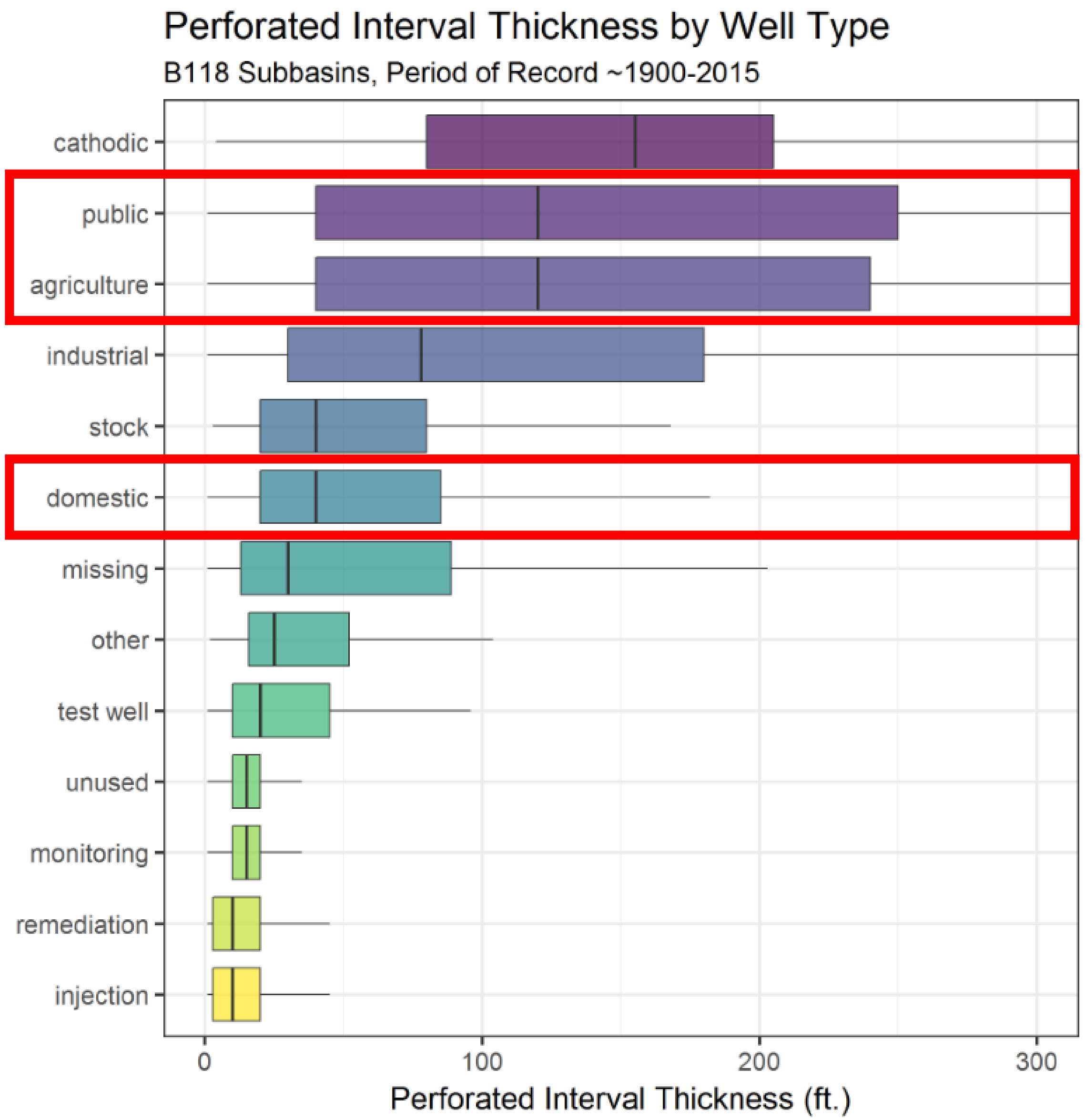

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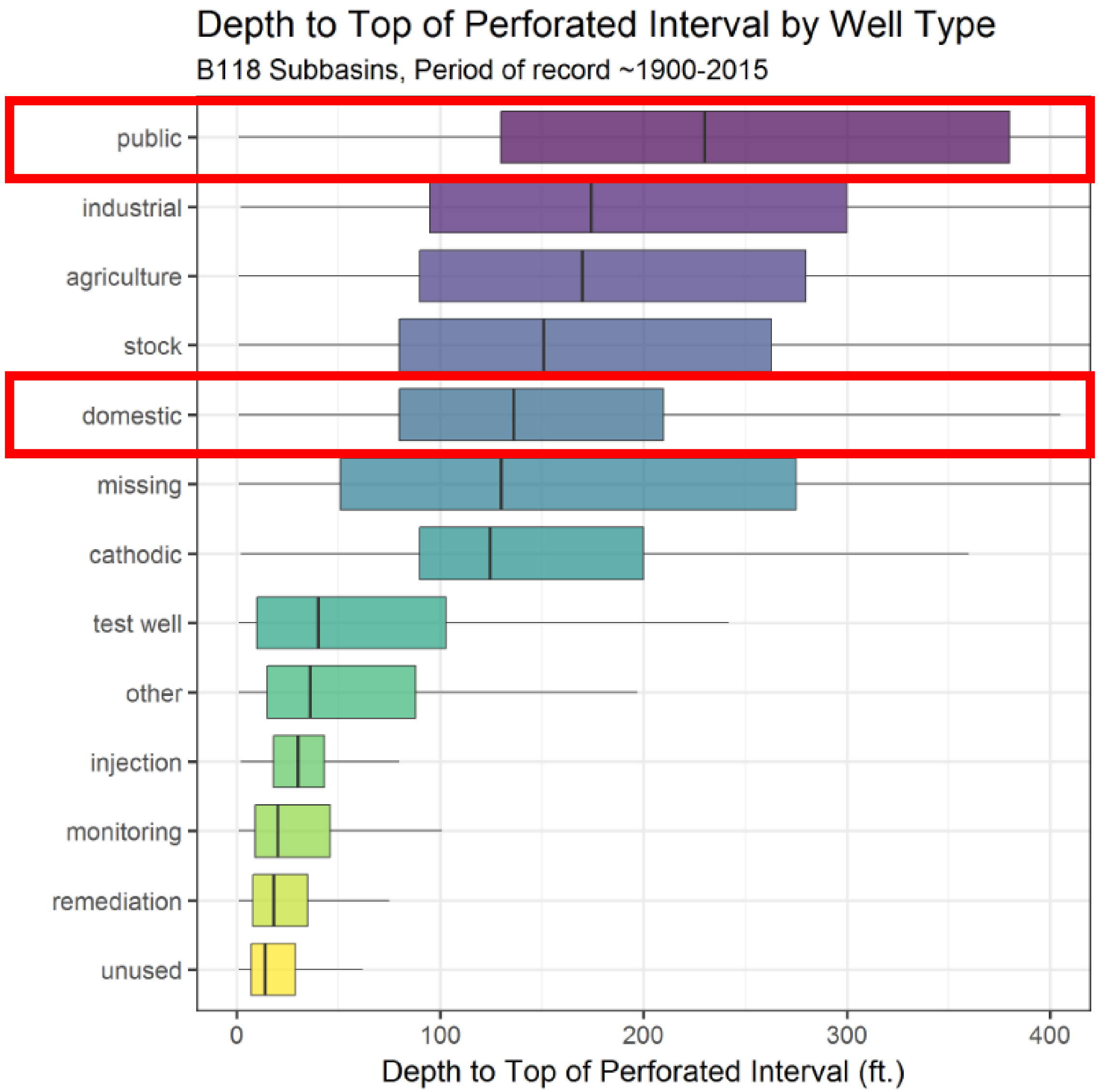
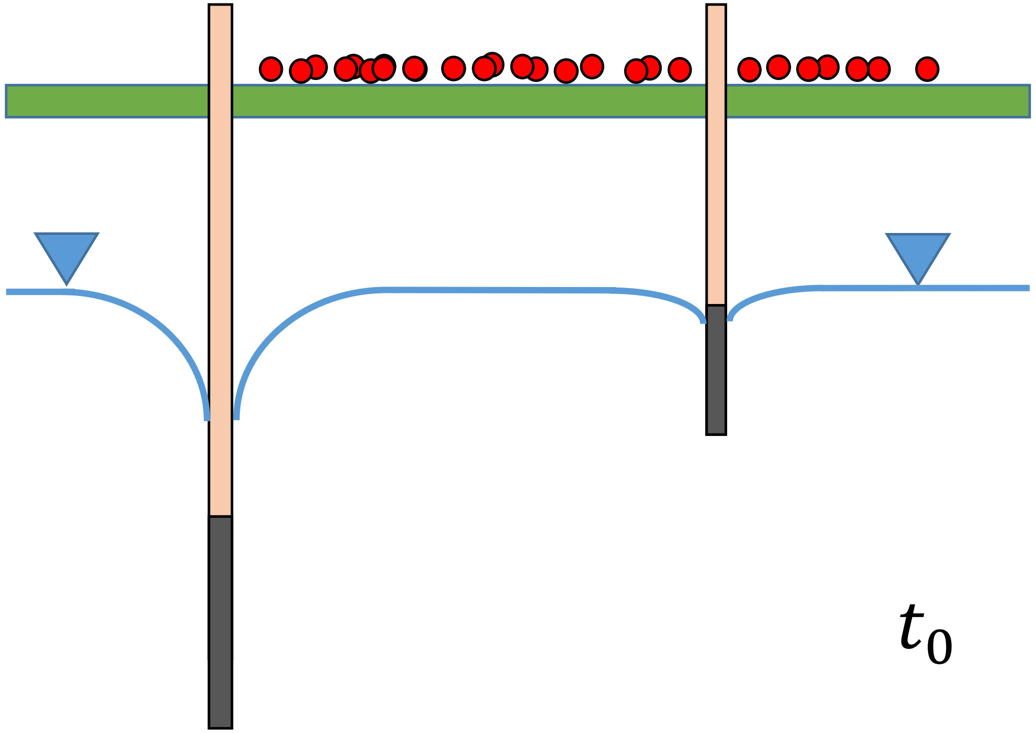


"Entryway" for contaminants migrating from the top-down: nitrates, salts



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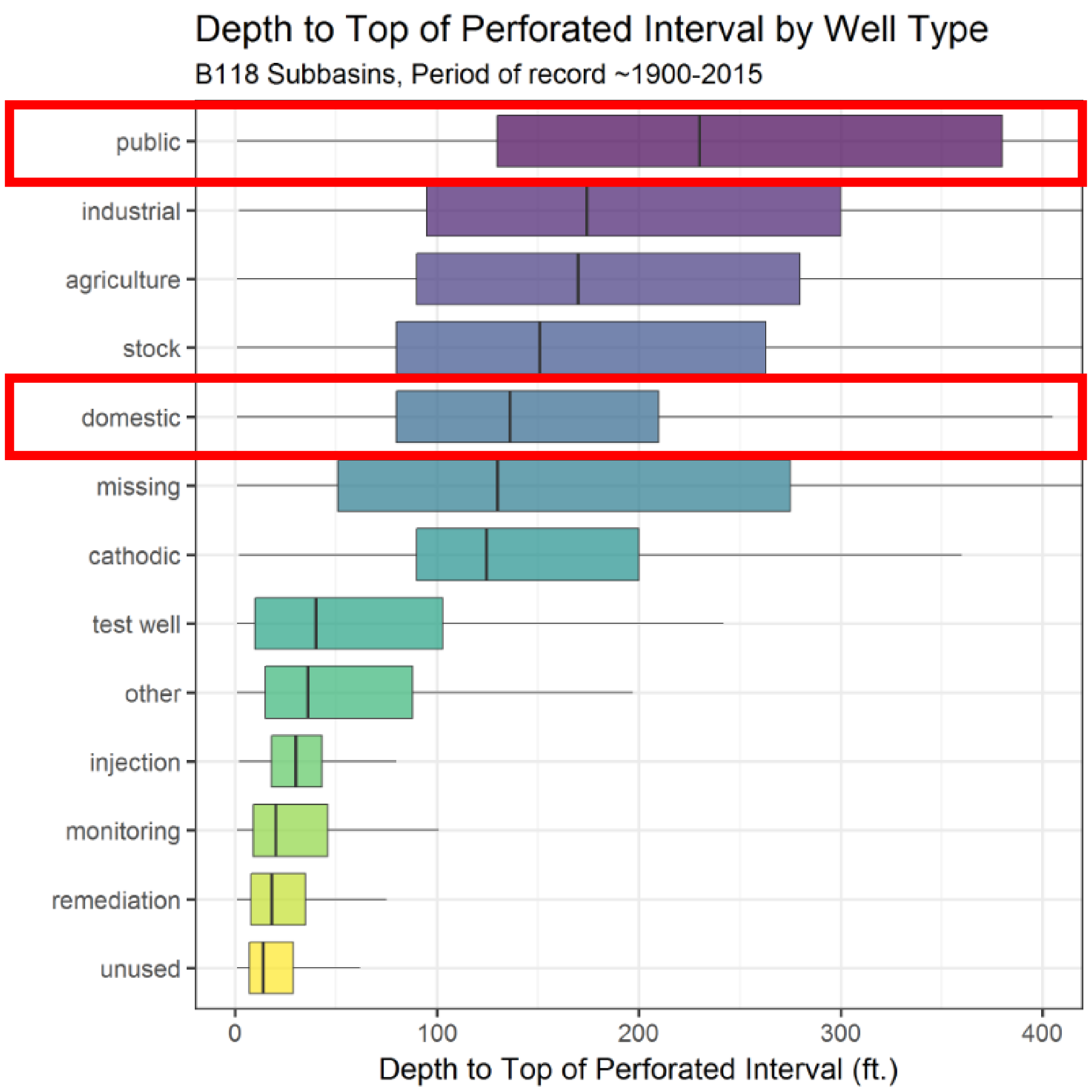

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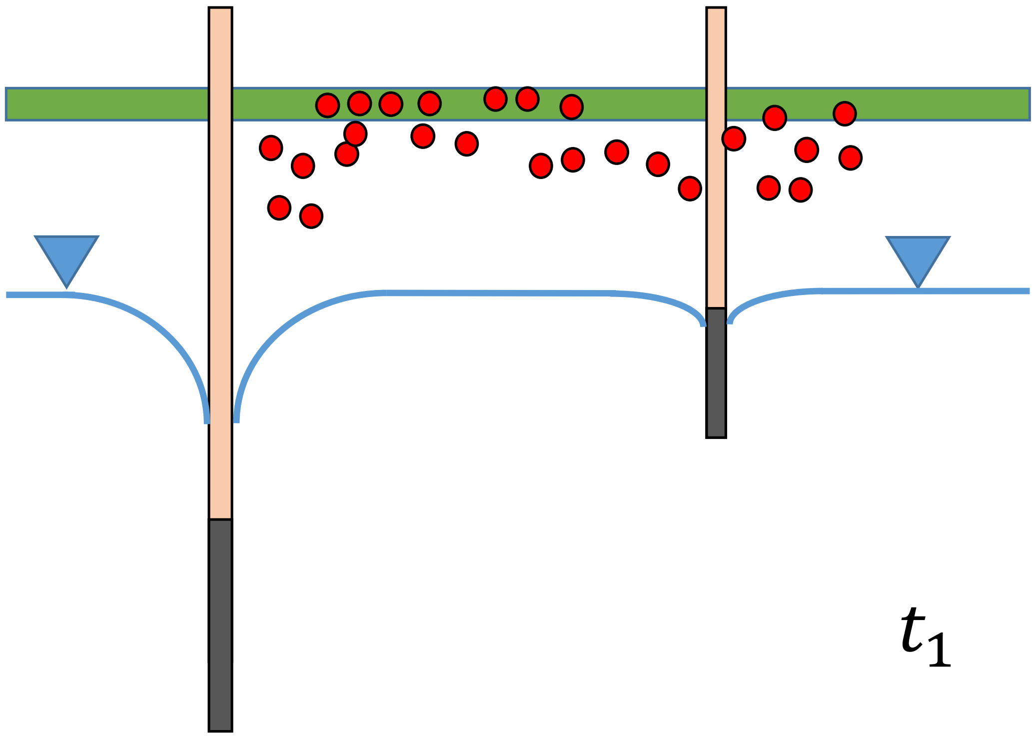

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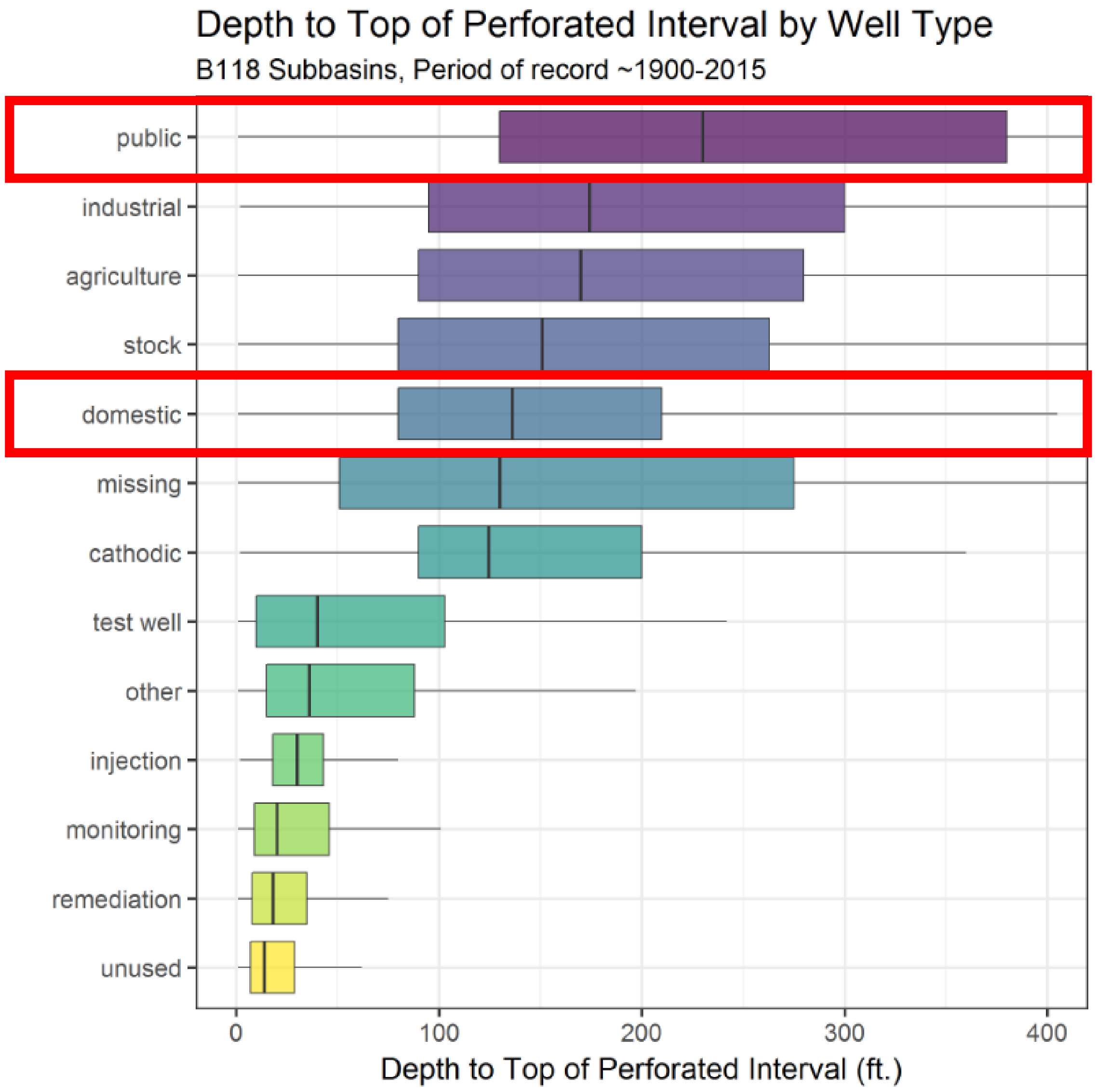

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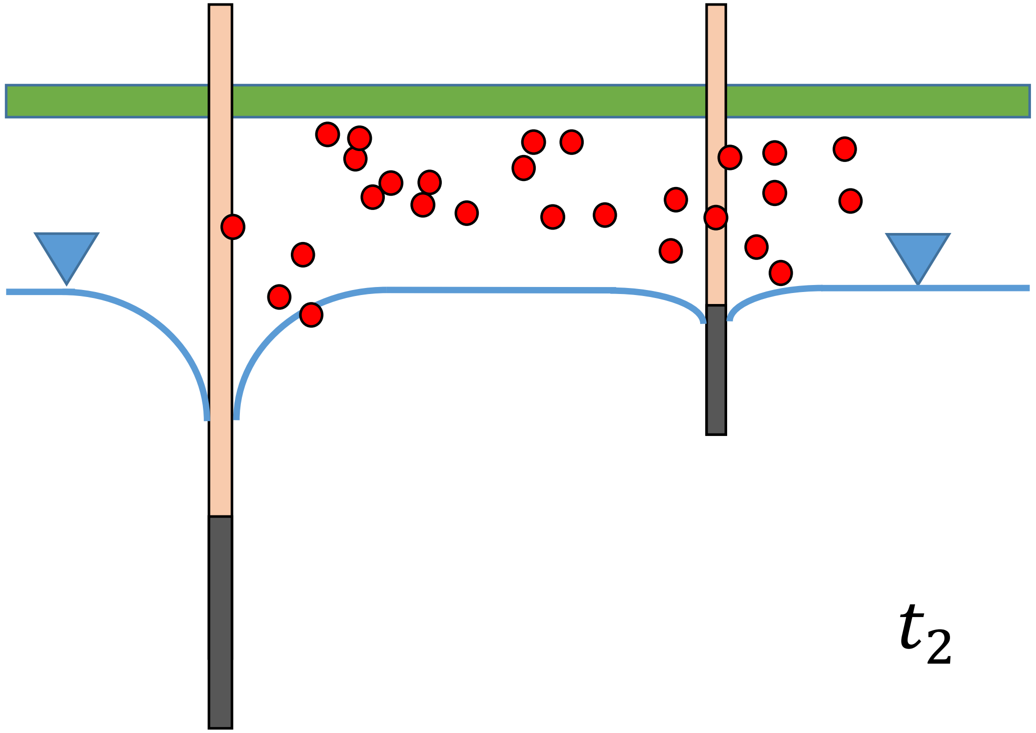

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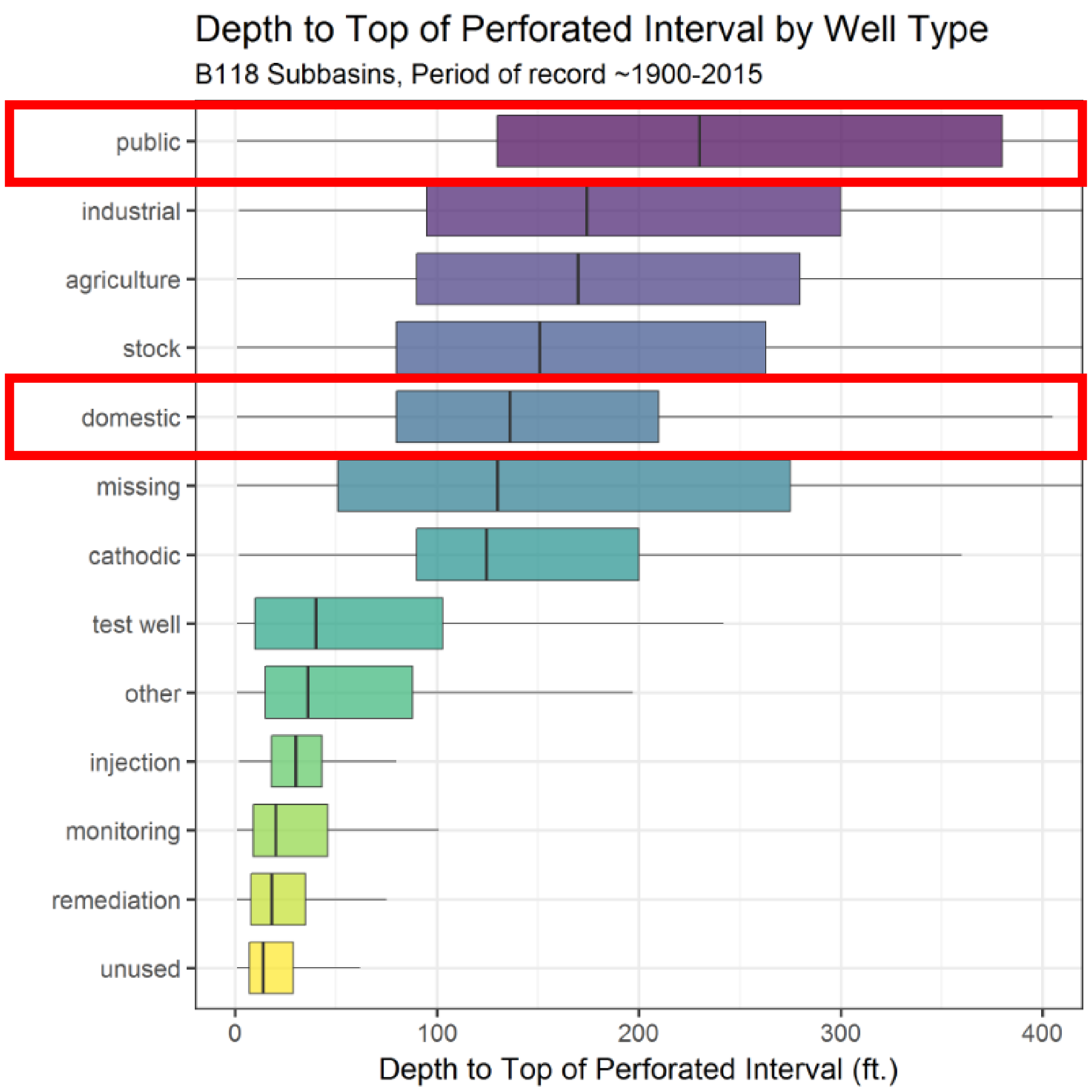

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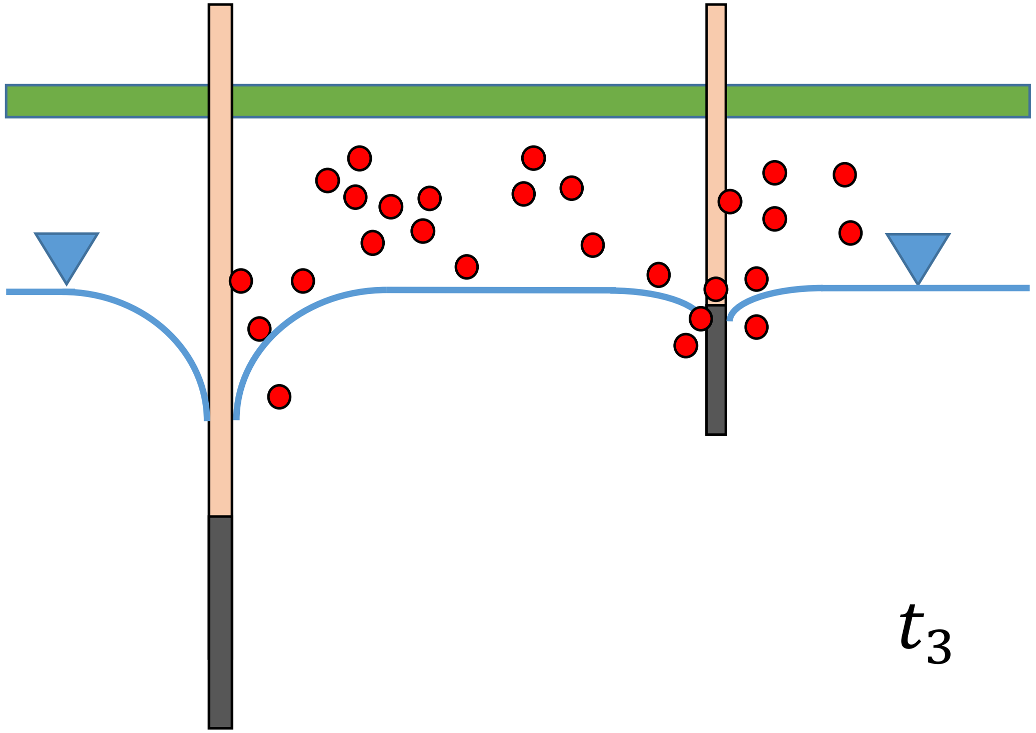

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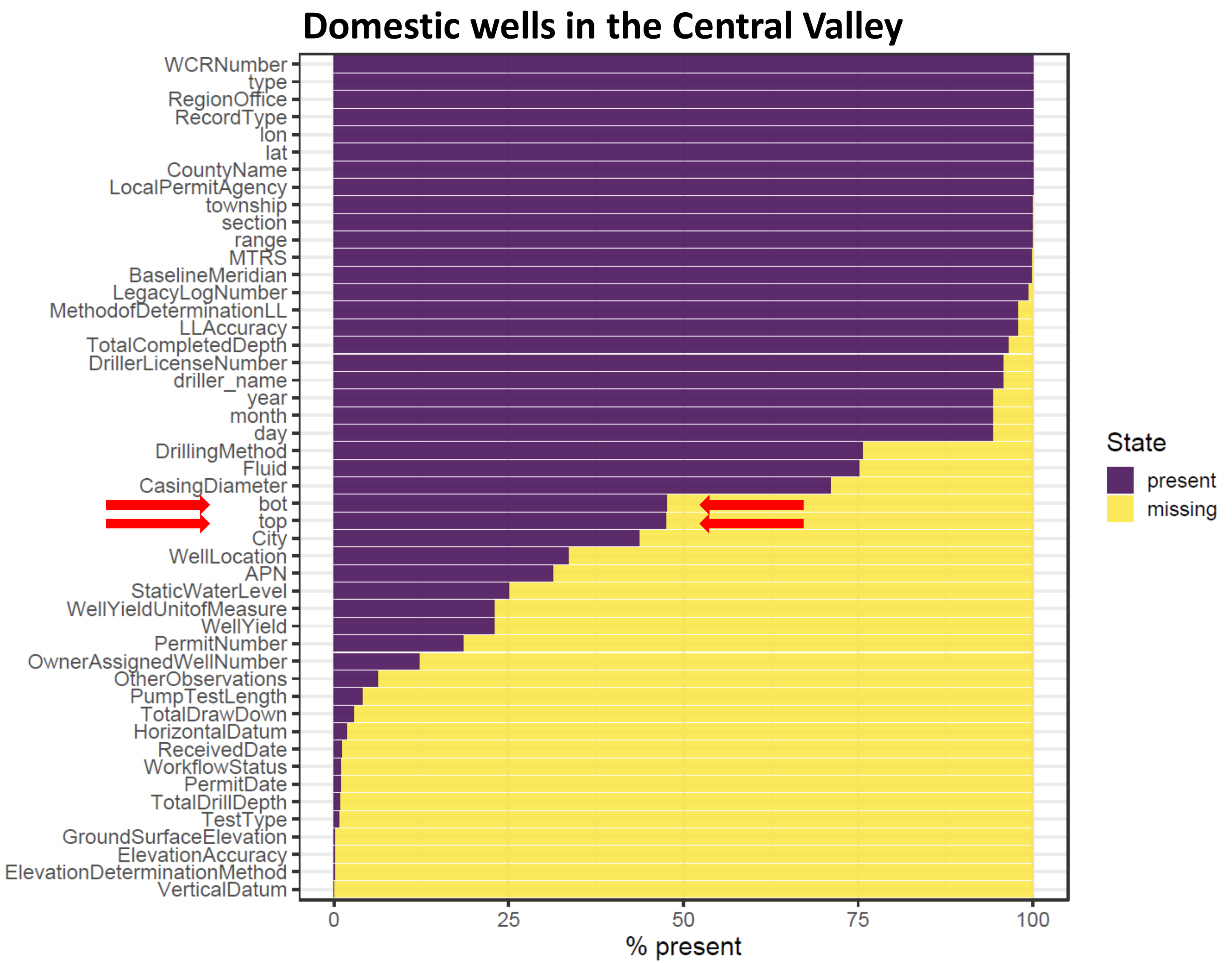

Top/Bottom of Perforated Interval missing for ~50% of CV data.

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

Use simple linear model to impute bottom.

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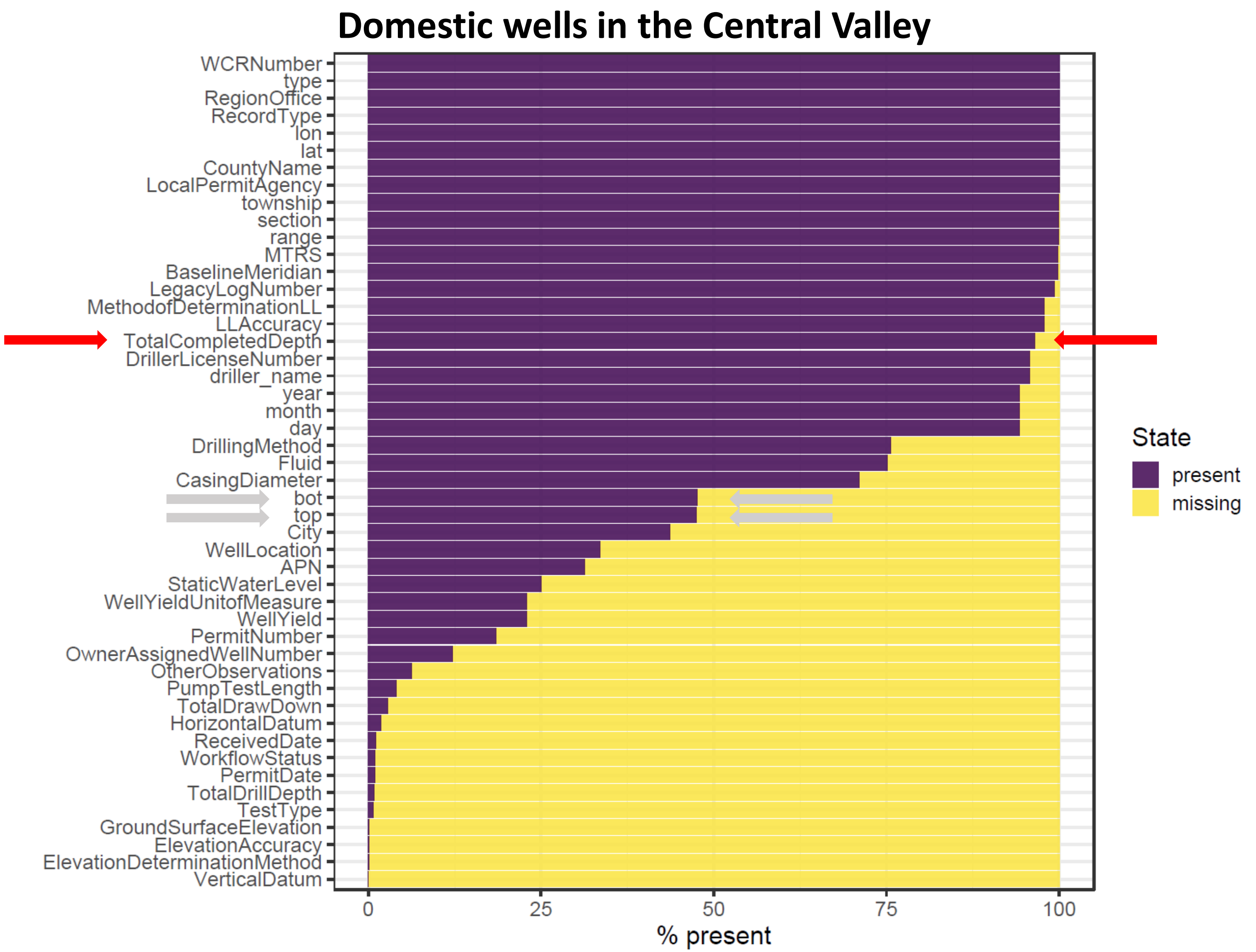

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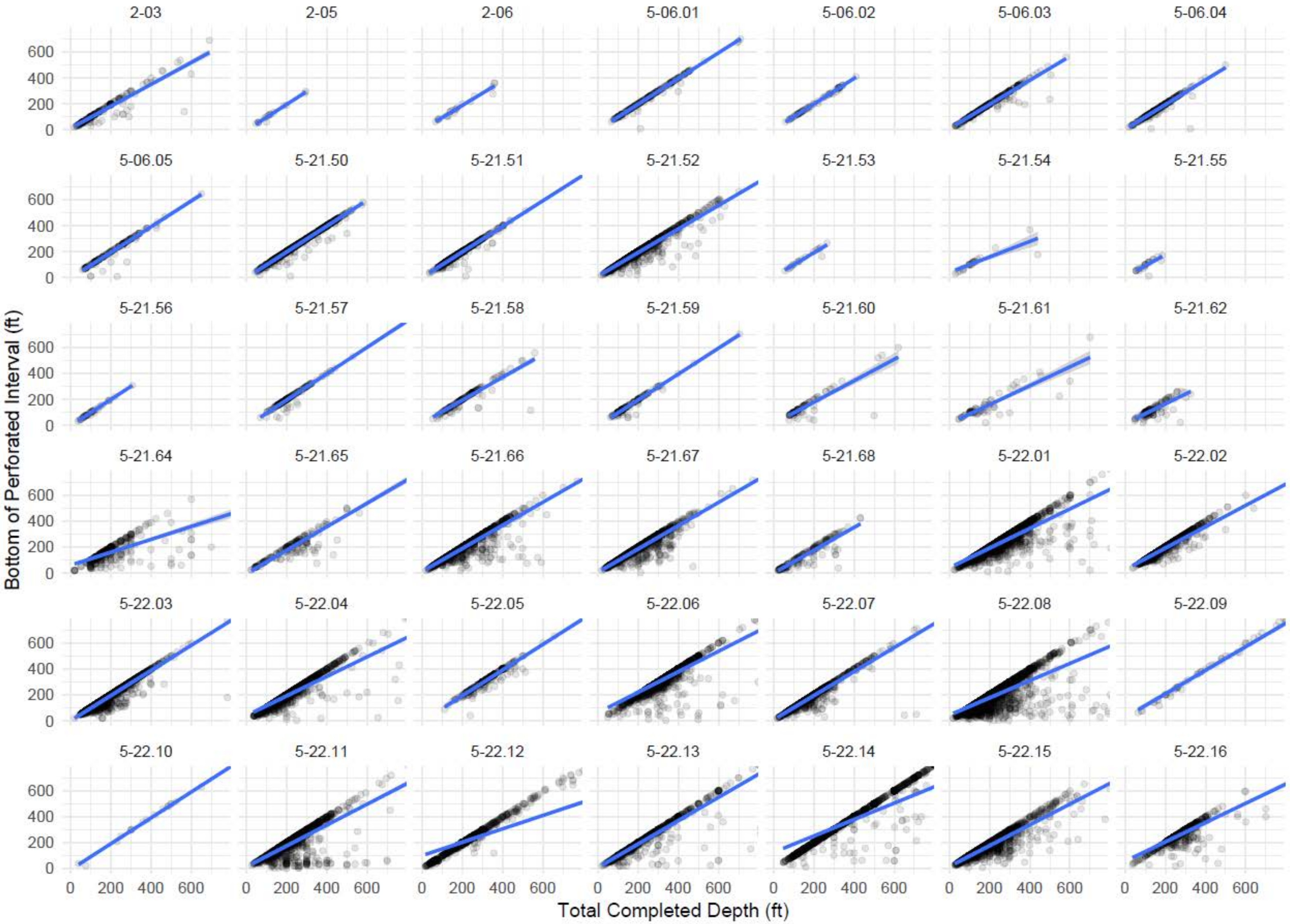

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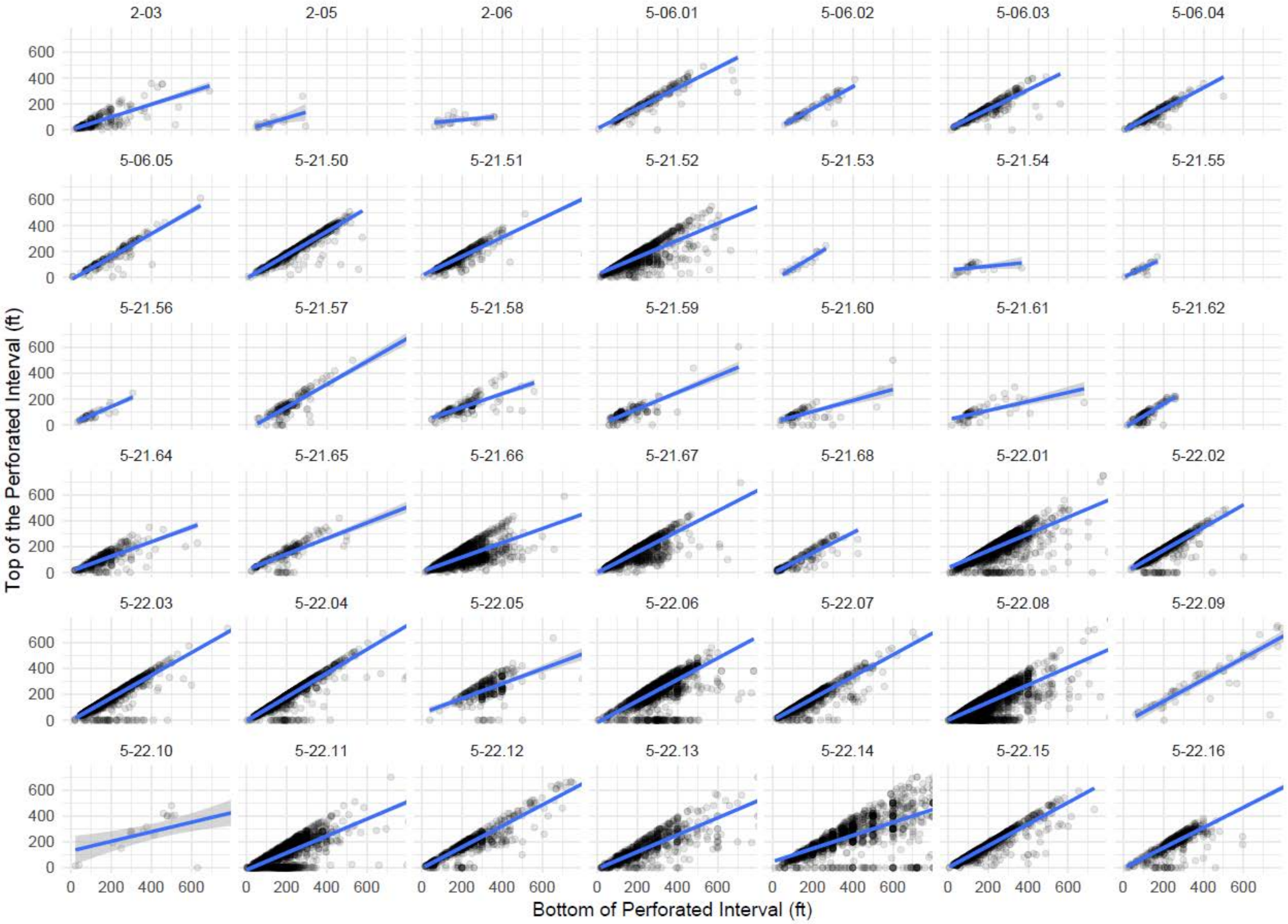

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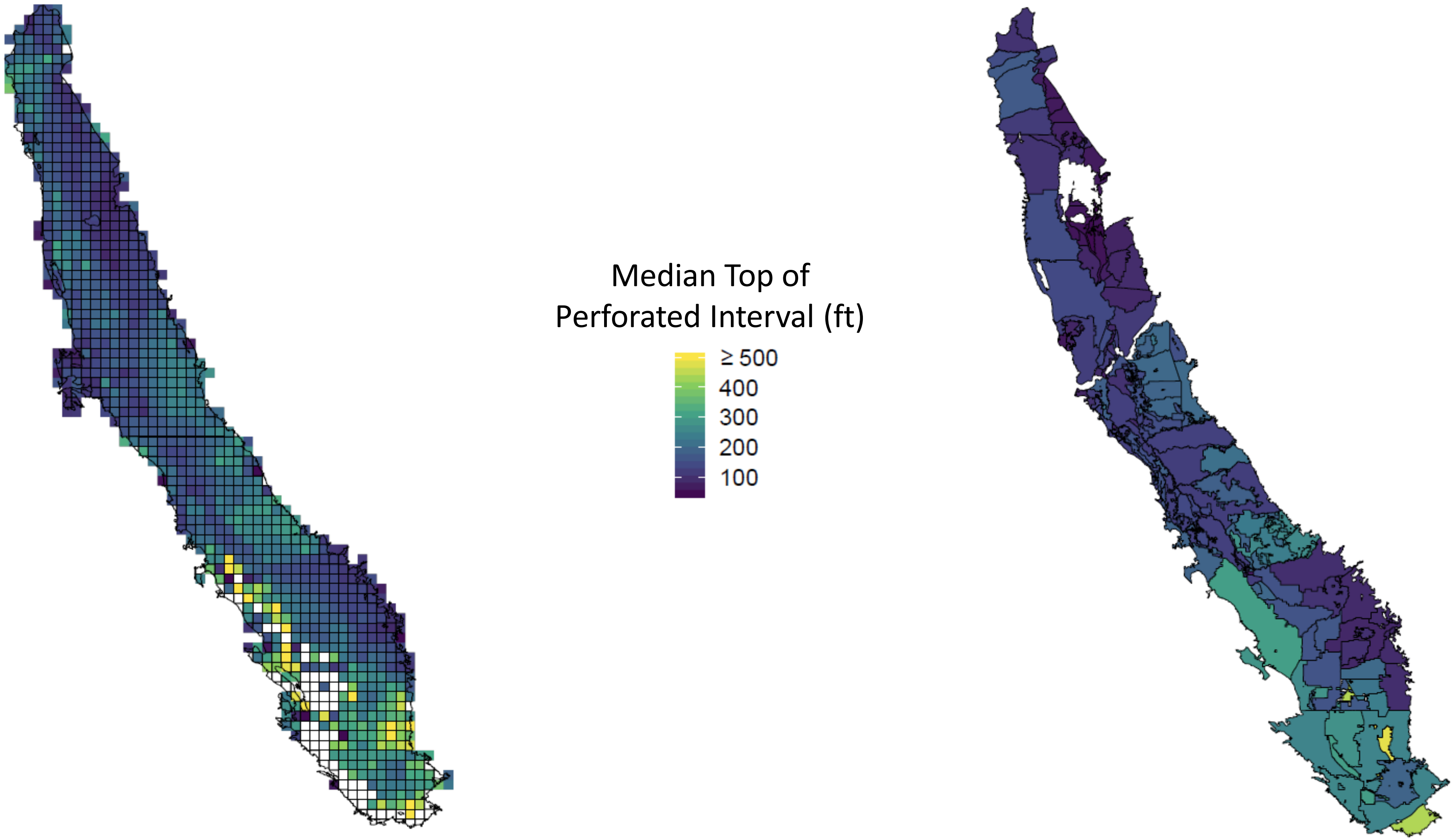
Public Land Survey Township ($36\ miles^2$)	Groundwater Sustainability Agency

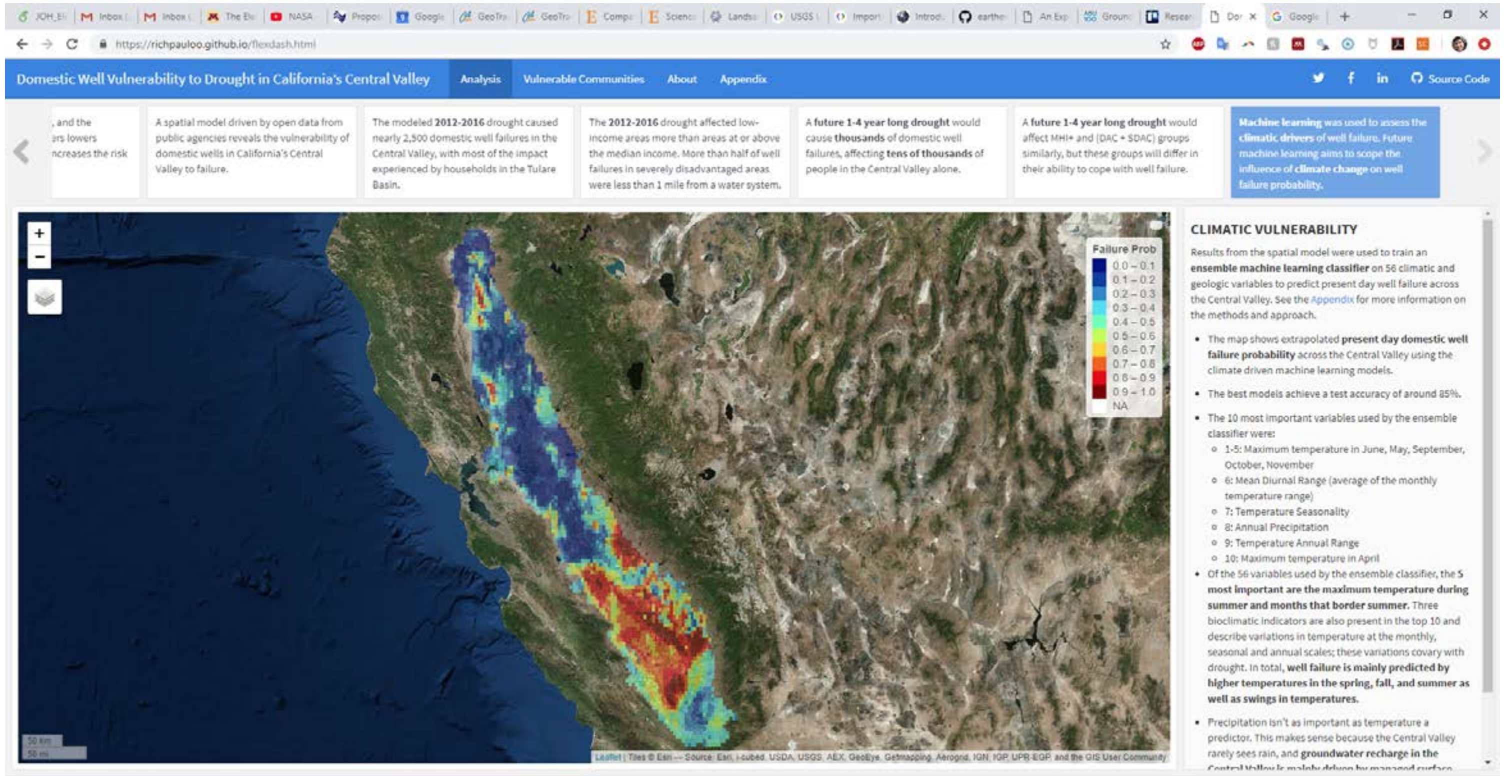


Case Study using OWCR data (3 minutes)

- 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?***

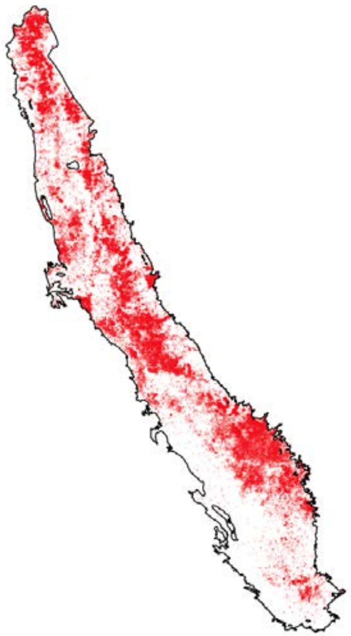
  2. ***Are well failures more associated with particular social drivers of vulnerability, like income?***



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



Domestic well data

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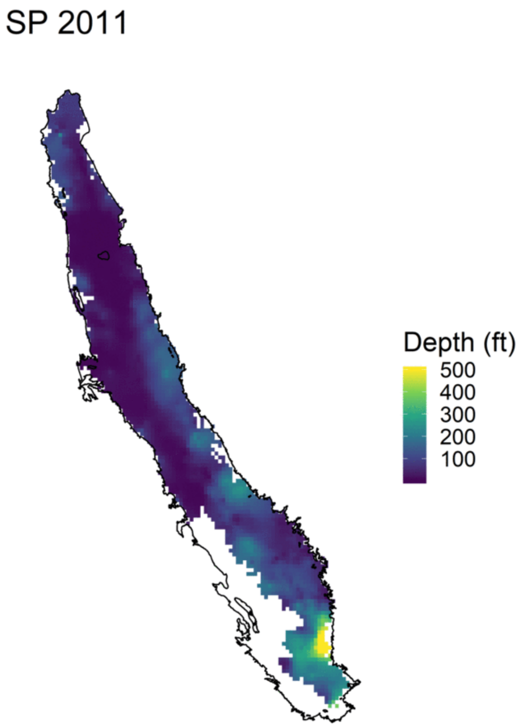

Groundwater level data

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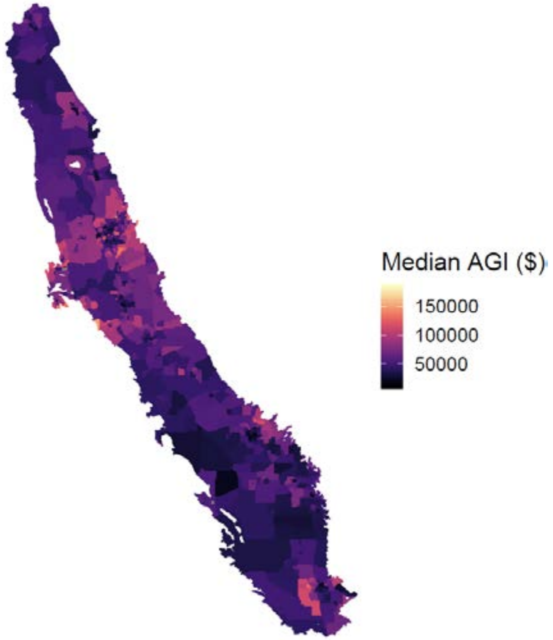

Census tract data

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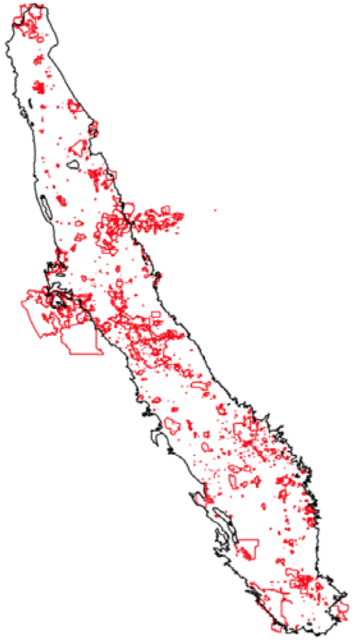
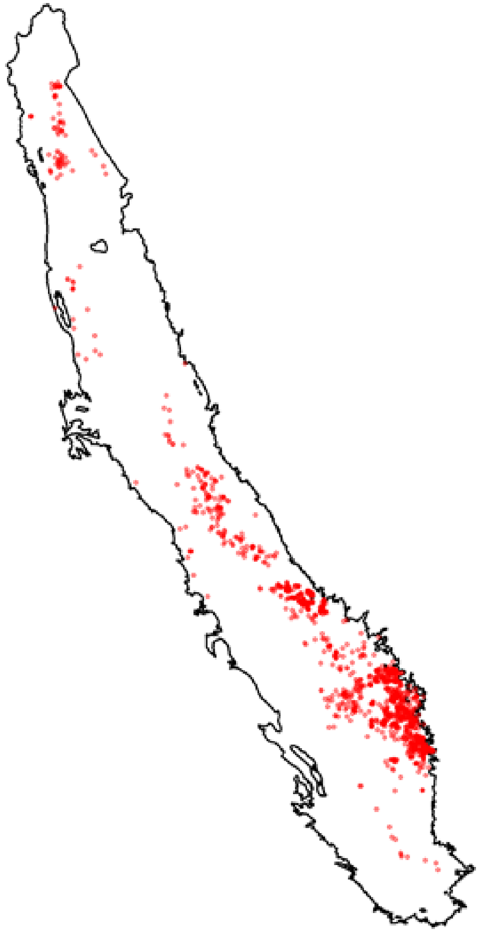


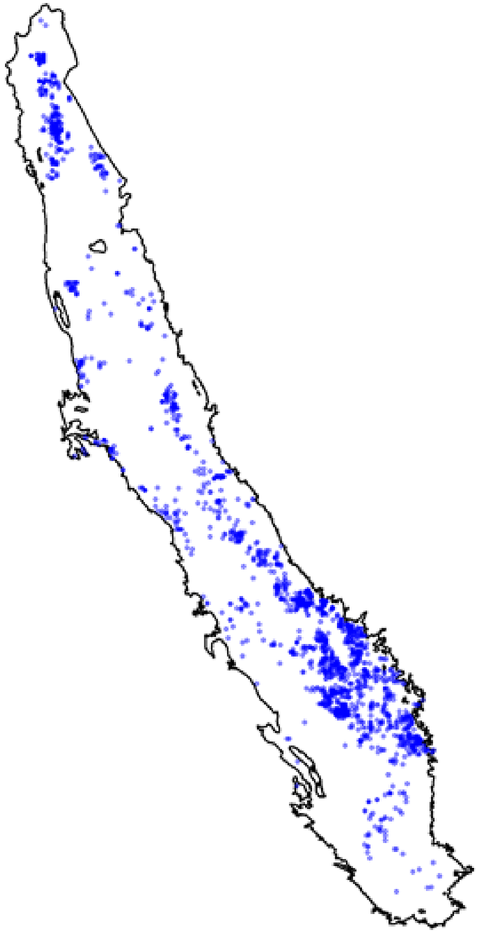
Water System Boundaries

Results: 2012-2016 drought

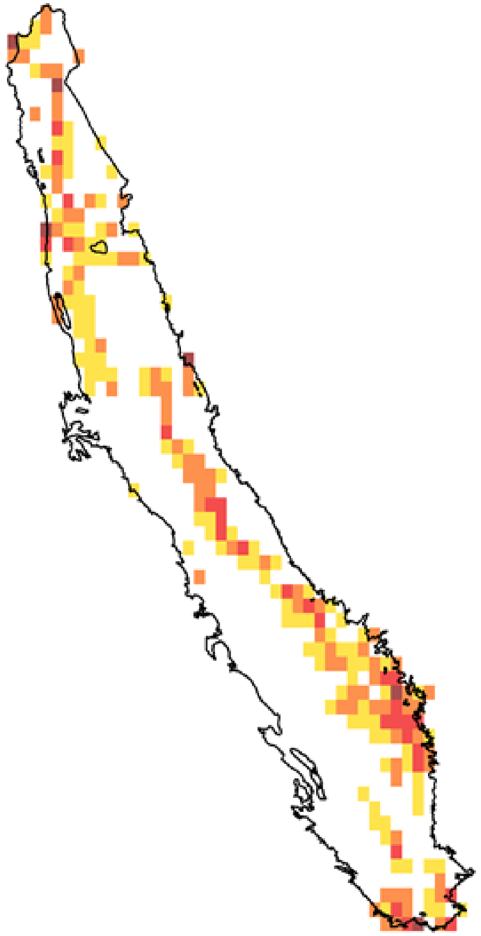
Point Pattern		Kernel Density Estimate	



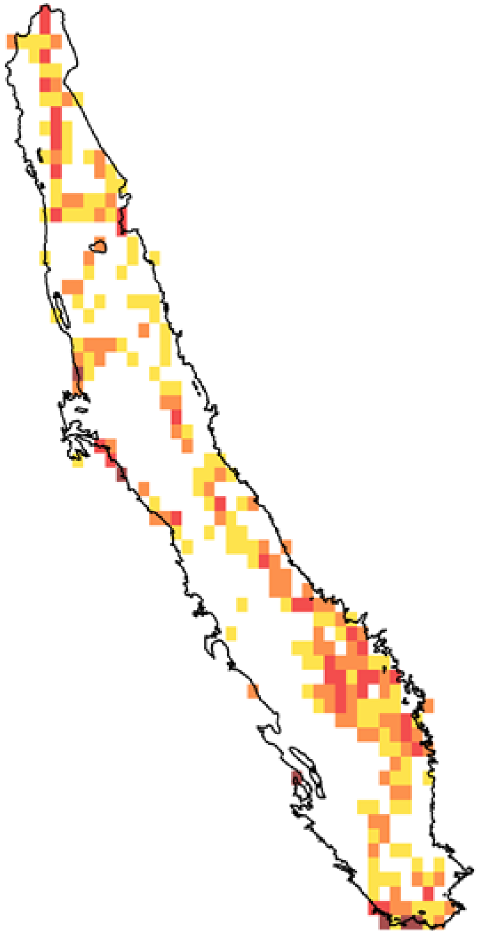
Observed



Predicted



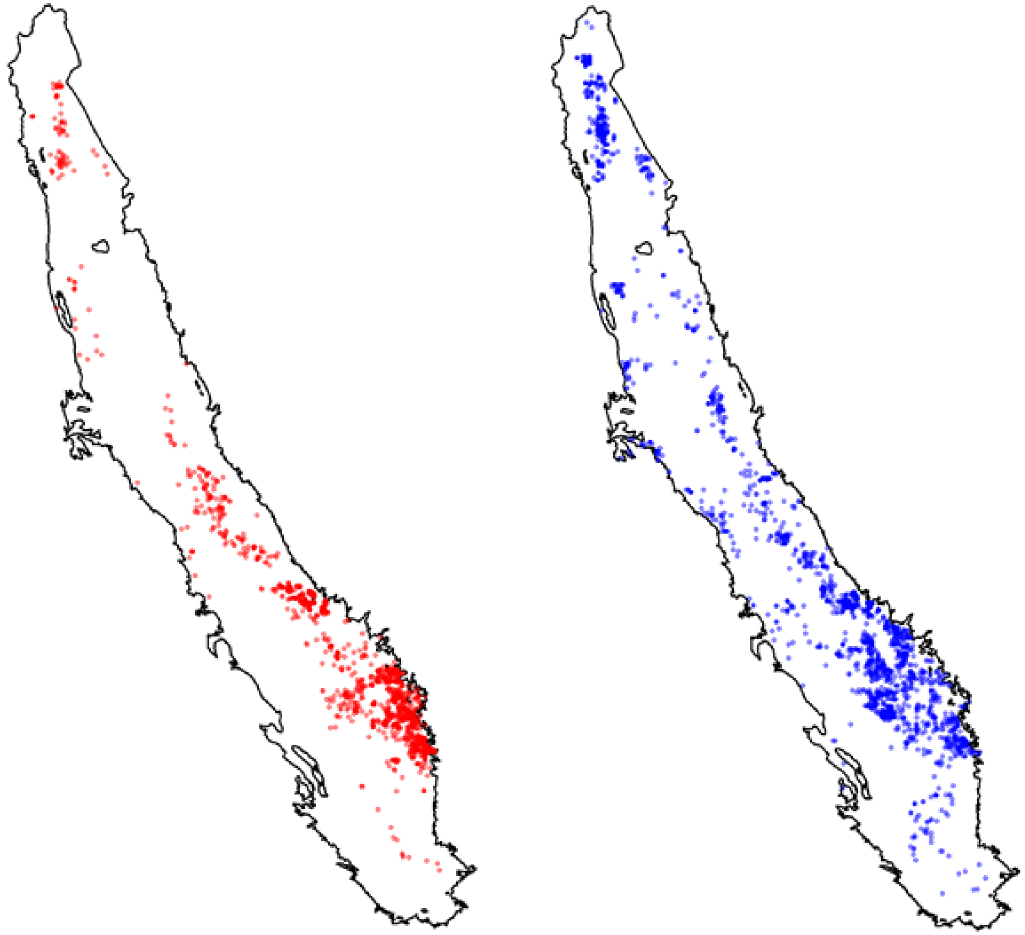
Observed

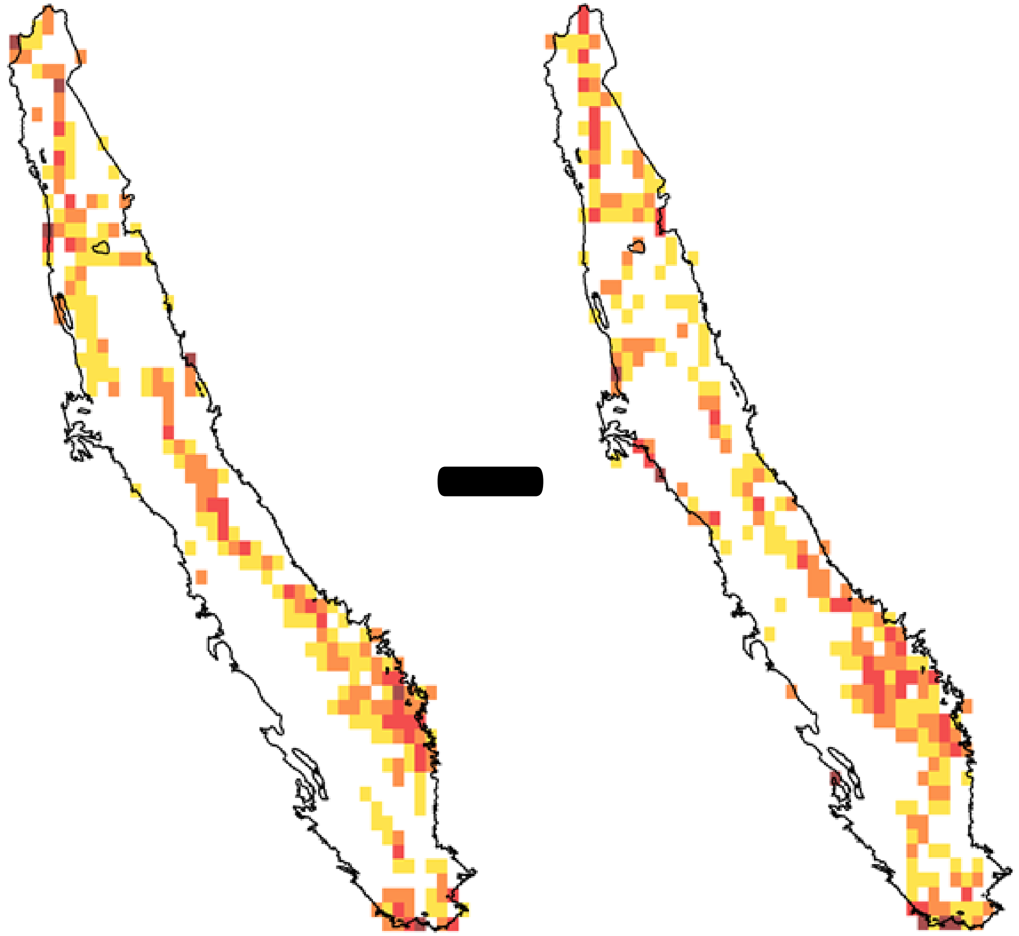


Predicted

Results: 2012-2016 drought

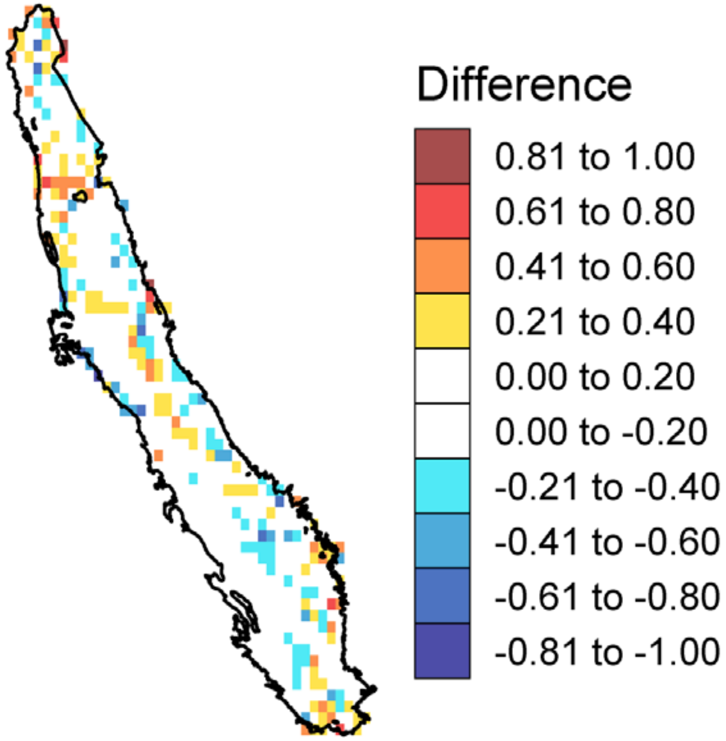
Point Pattern	Kernel Density Estimate



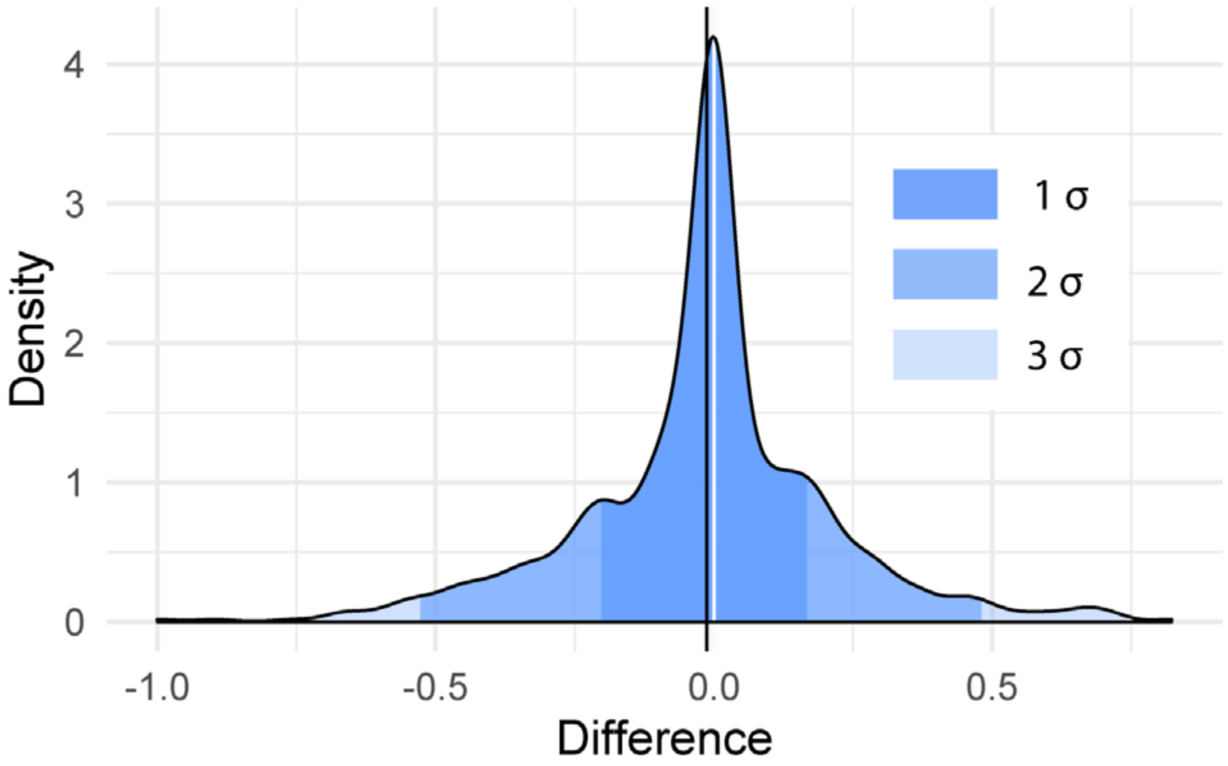


Results: 2012-2016 drought

Kernel Density Residual

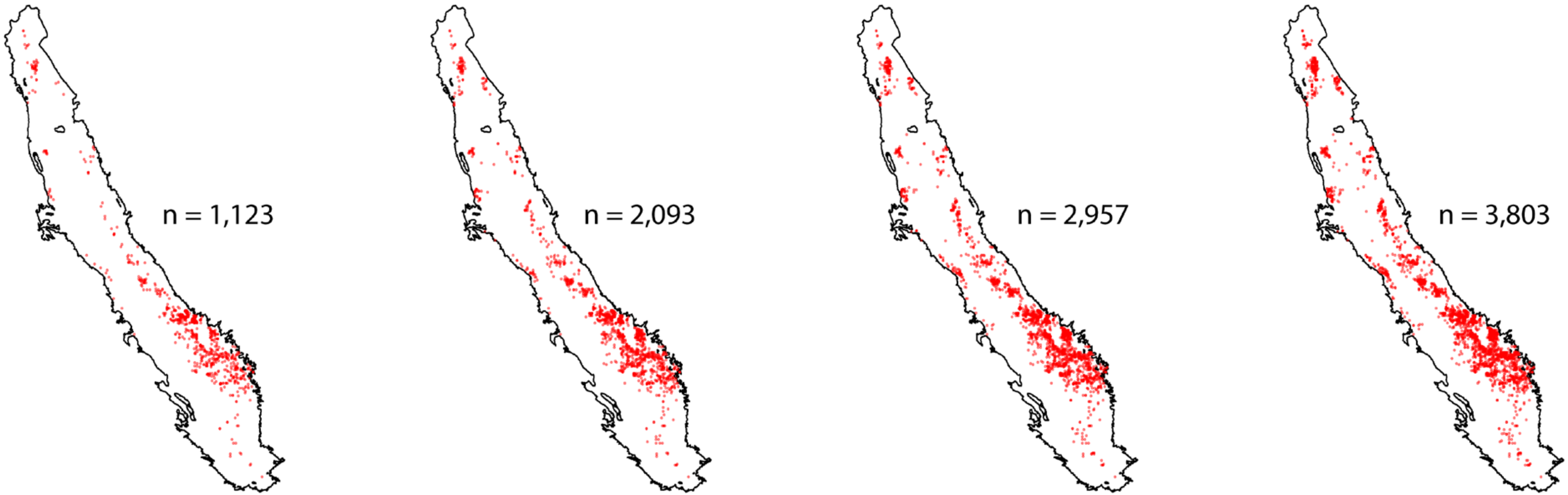


Density Plot of Residuals

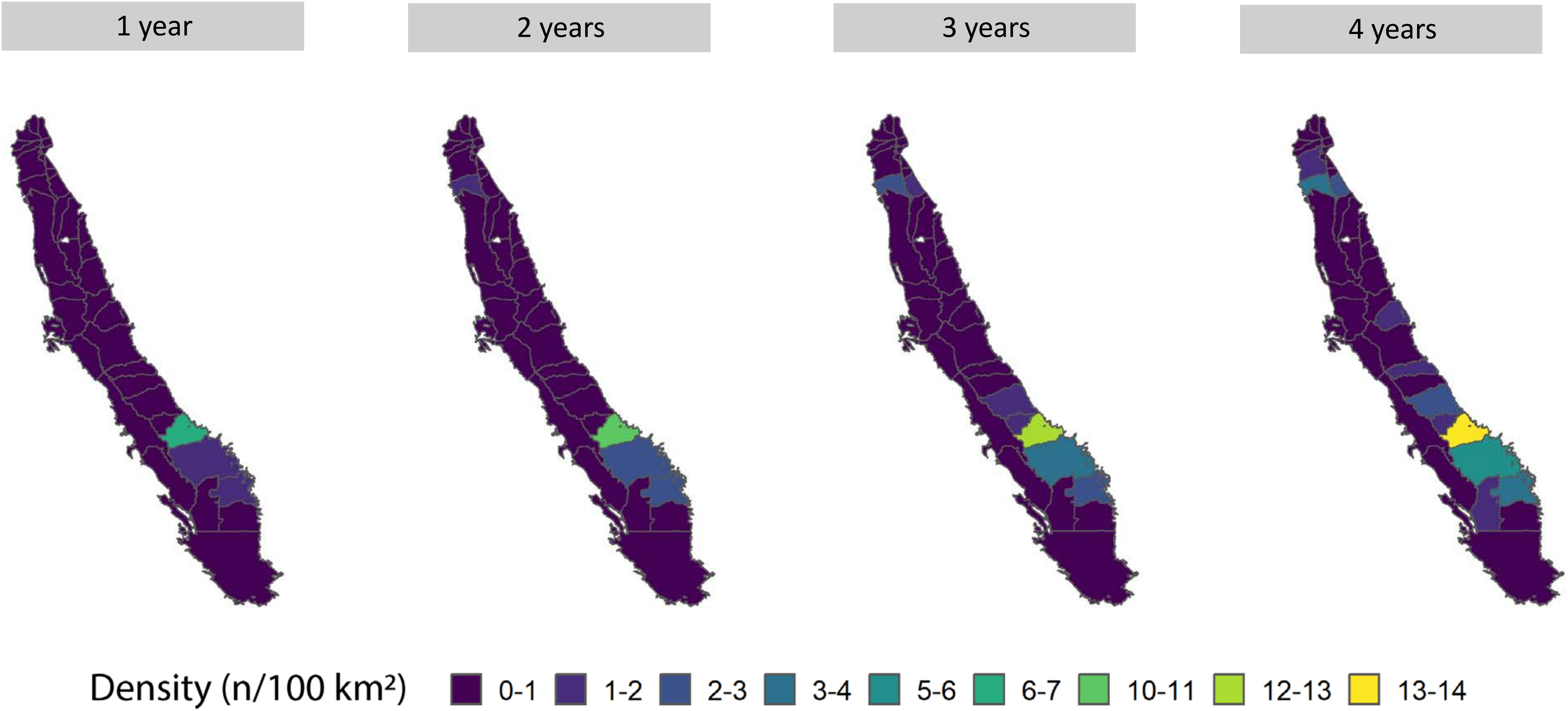


Results: Extended drought (t_0 = January 2017)

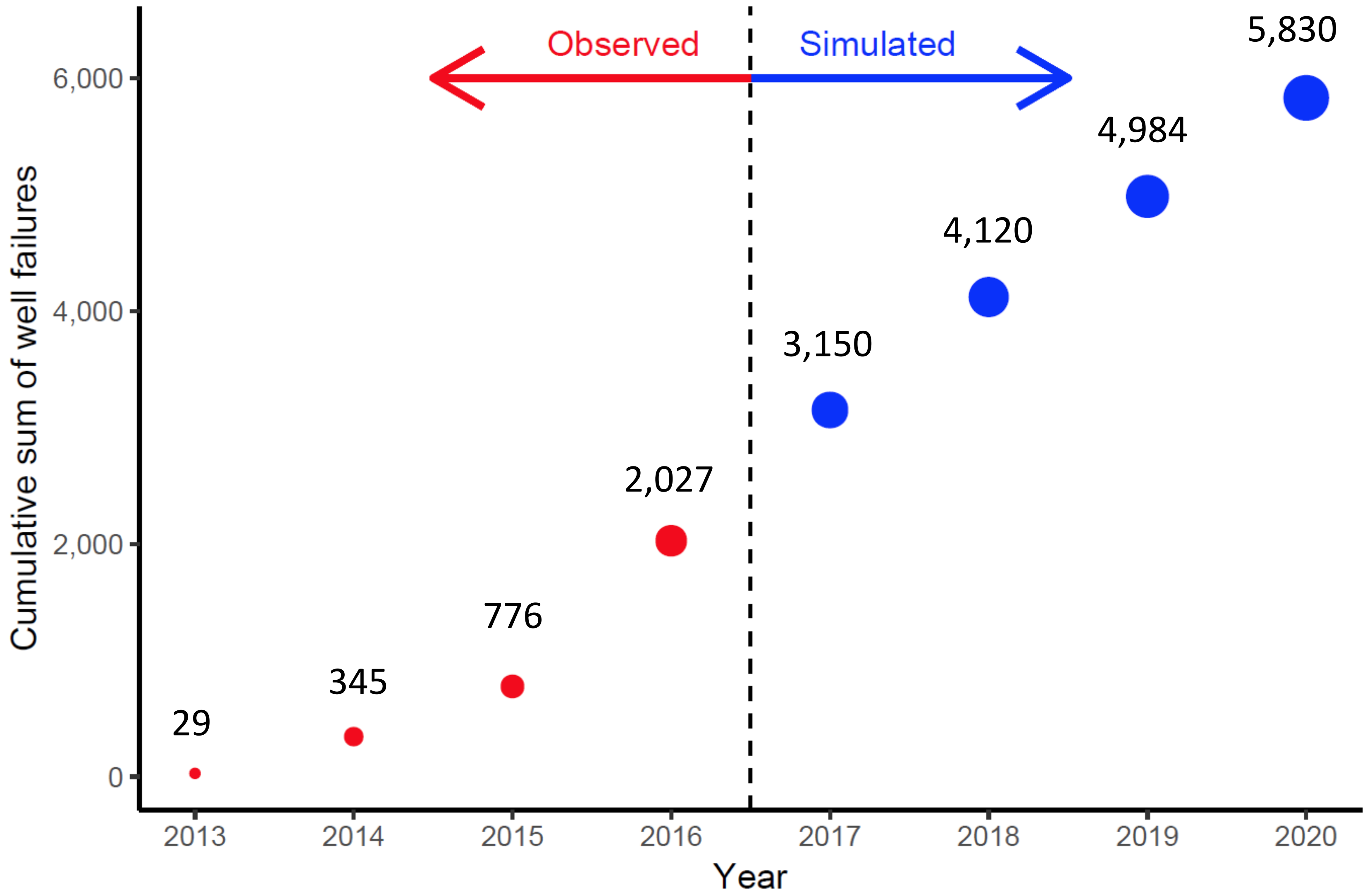
1 year | 2 years | 3 years | 4 years



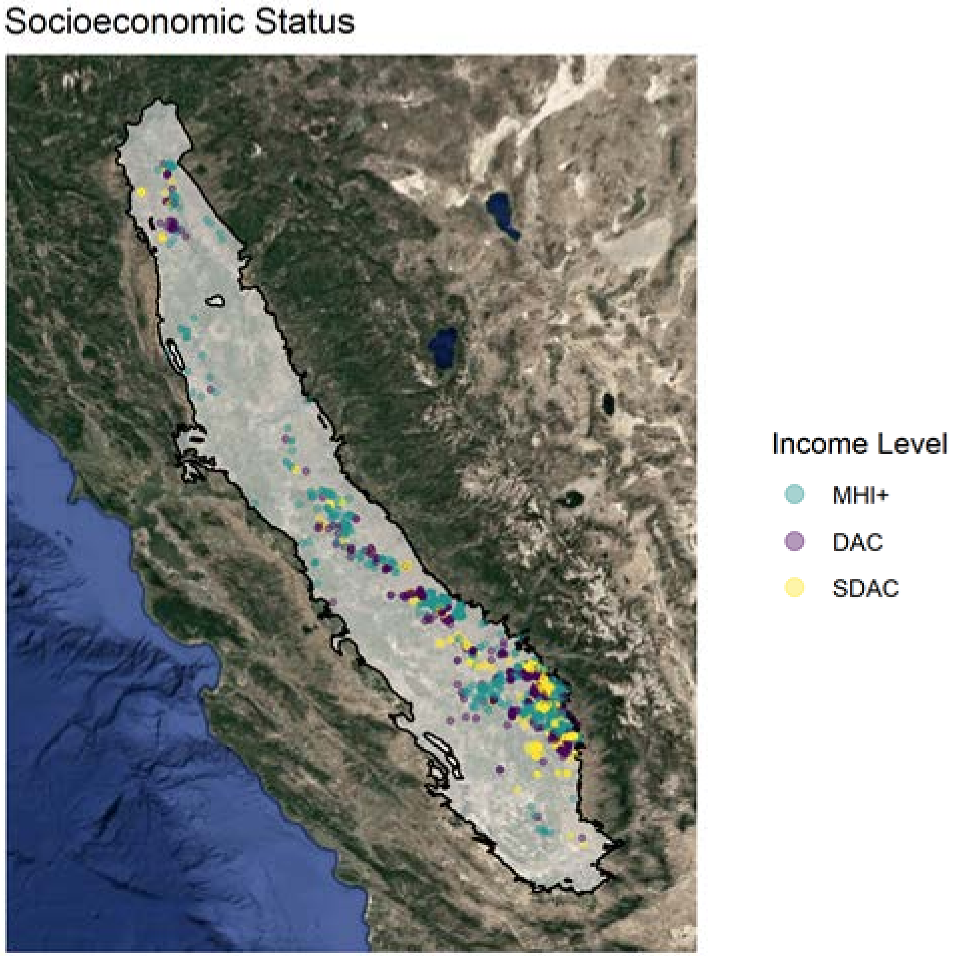
Results: Extended drought (t_0 = January 2017)



Results: Extended drought (t_0 = January 2017)



Results: 2012-2016 drought SE Impact

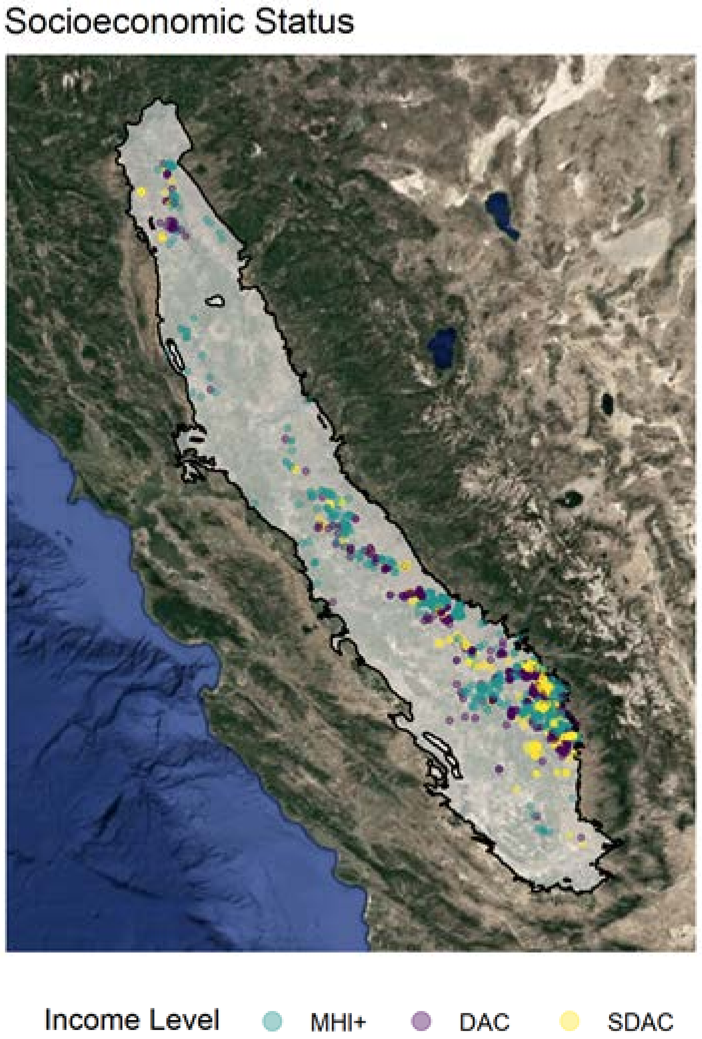


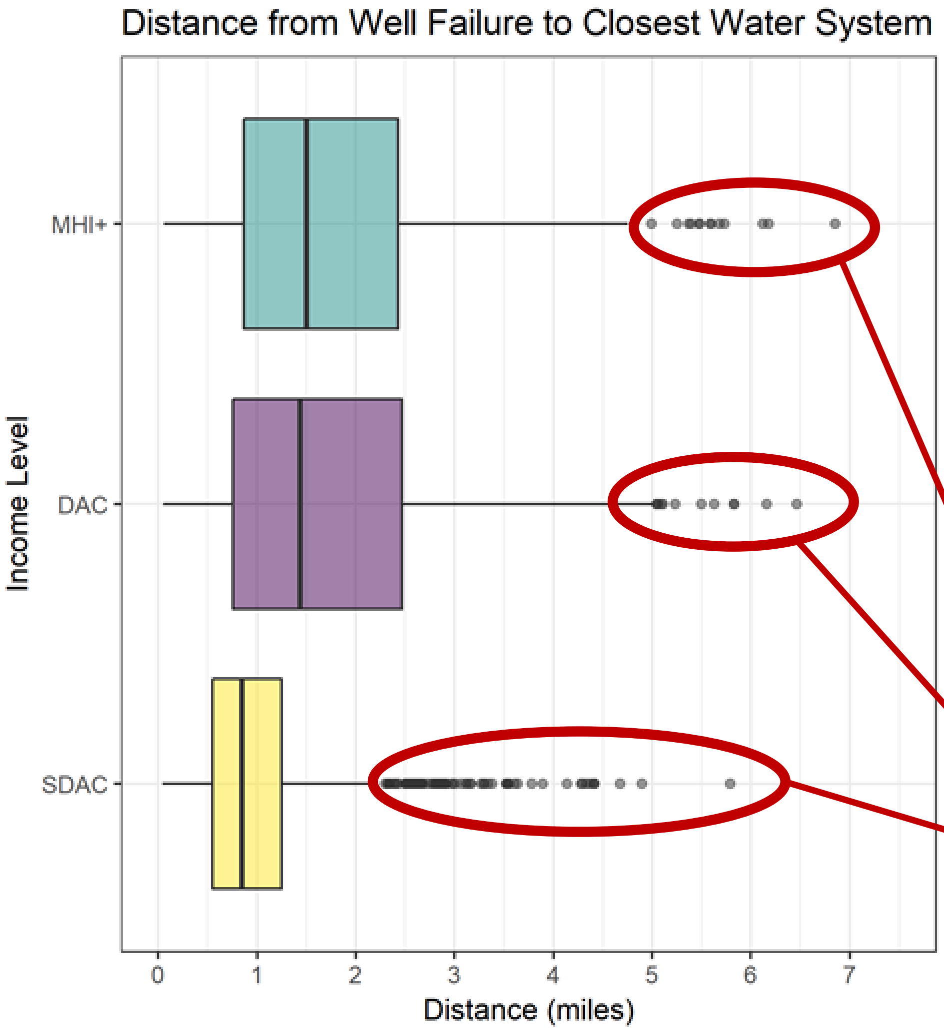
income_level	n_well_failures
MHI+	941
DAC	602
SDAC	826

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

~ **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





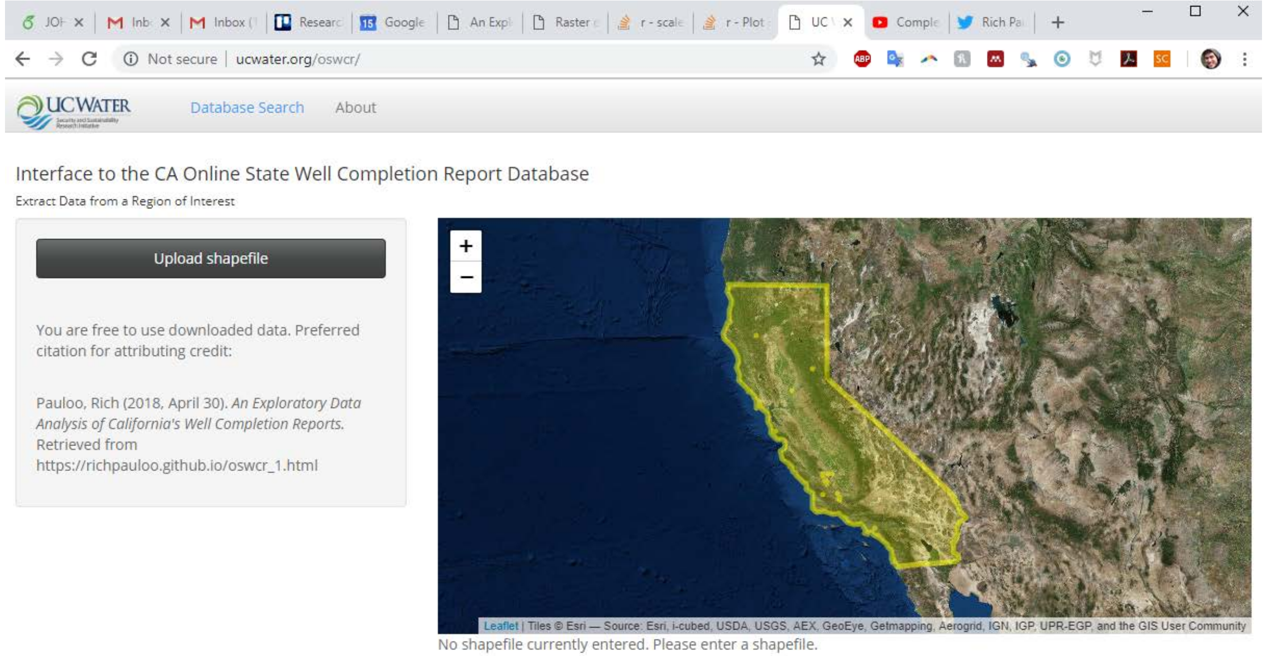
income_level	median_d (miles)
MHI+	1.50
DAC	1.44
SDAC	0.85

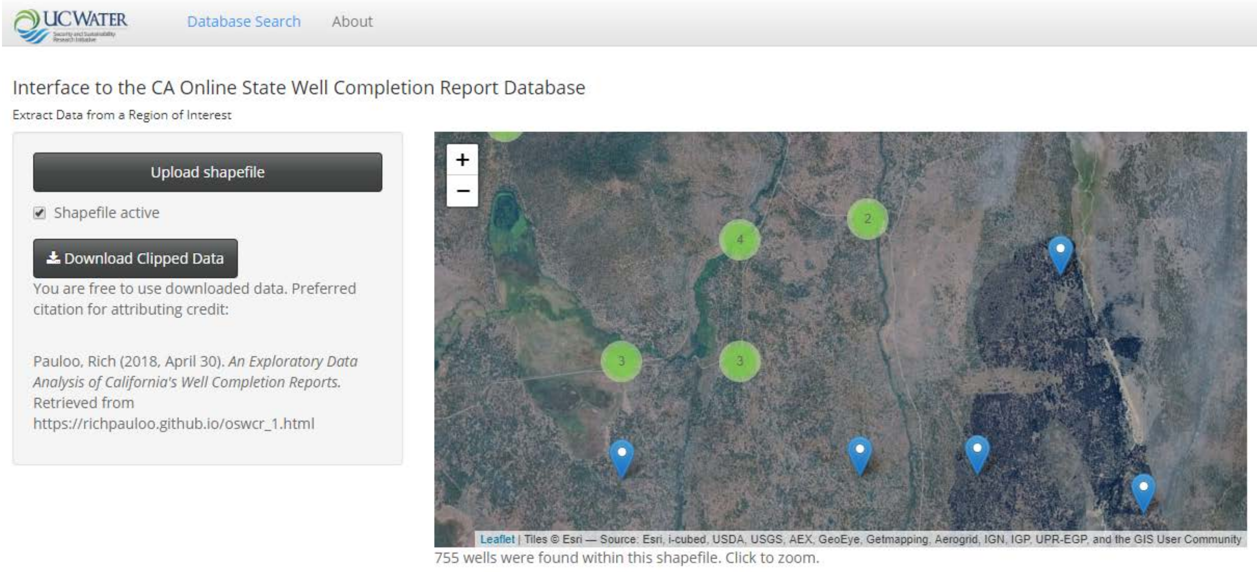
More than half of well failures in SDACs were **less than 1 mile** from a water system.

Some well failures are relatively remote.

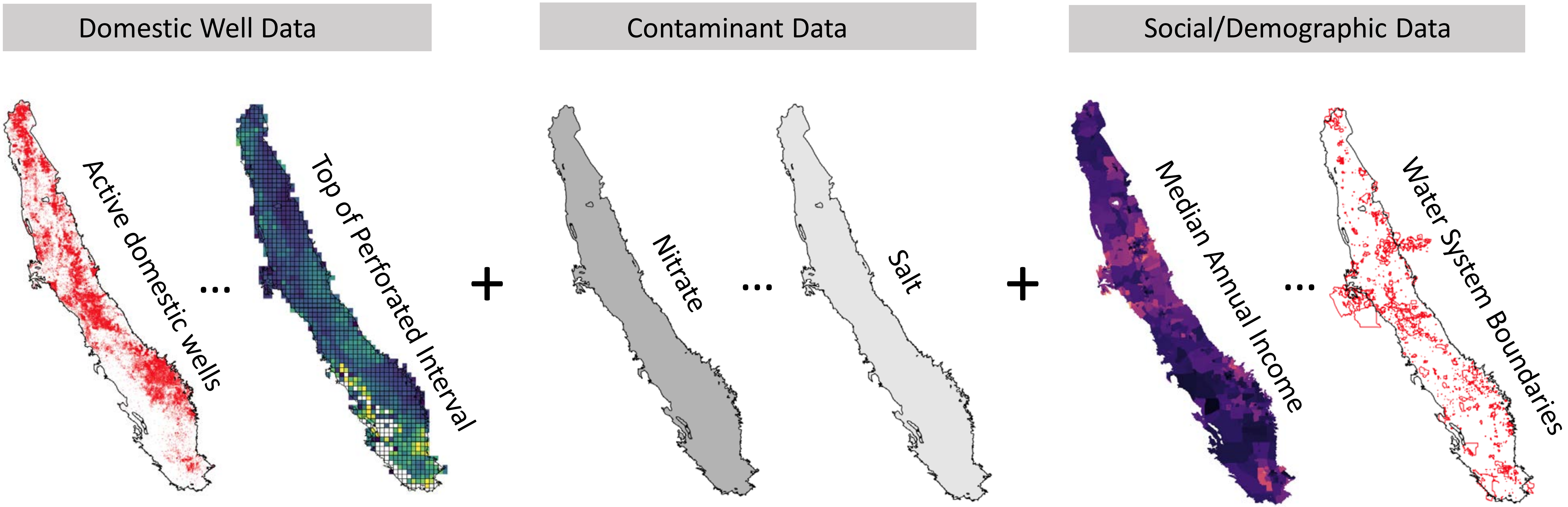
Web Application

- 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



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 Fencl, 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 goo.gl/DDjT8e

Appendix

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

Table 1: Count of well types across CA.

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

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

Appendix

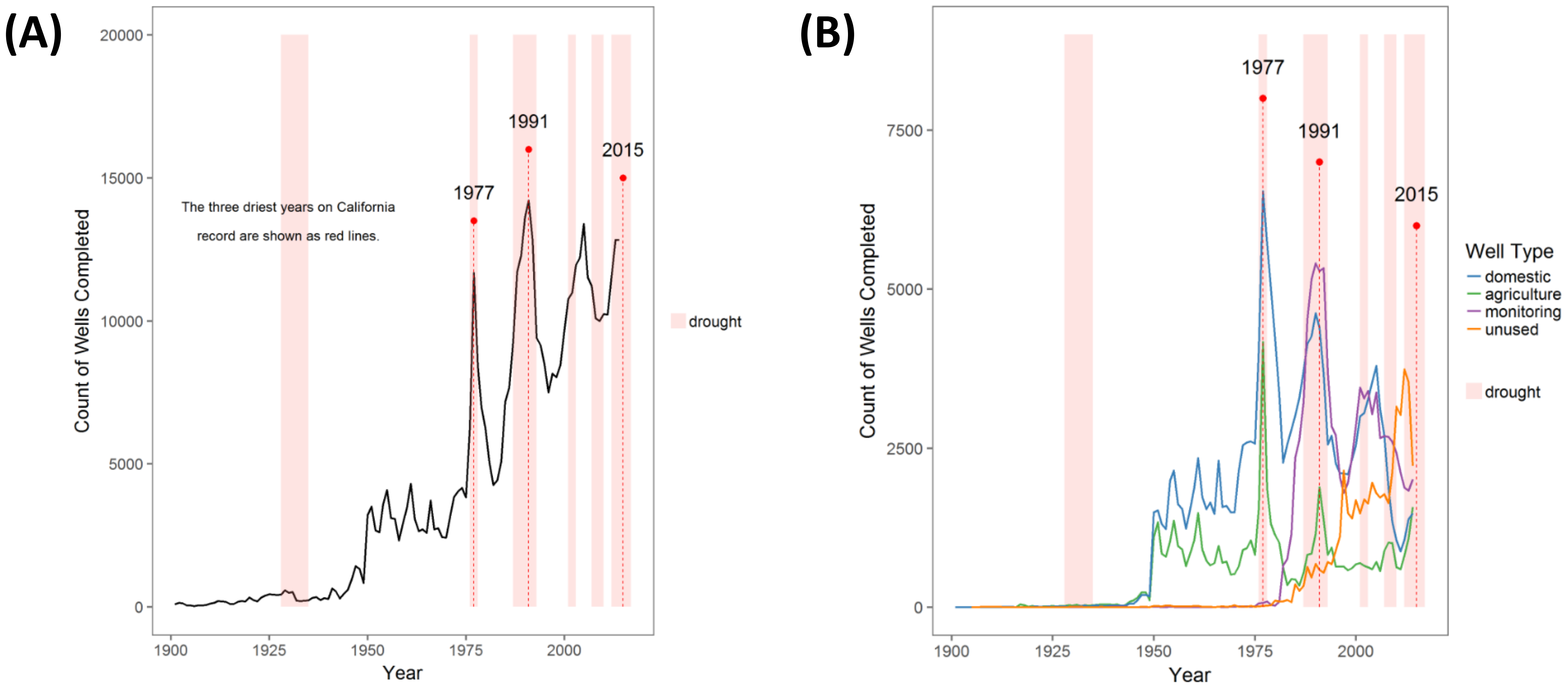


Figure 1: **(A)** *Annual count of all wells drilled in Bulletin 118 basins.* **(B)** *Same as (A), but broken down by the 4 most common well types.*

Appendix

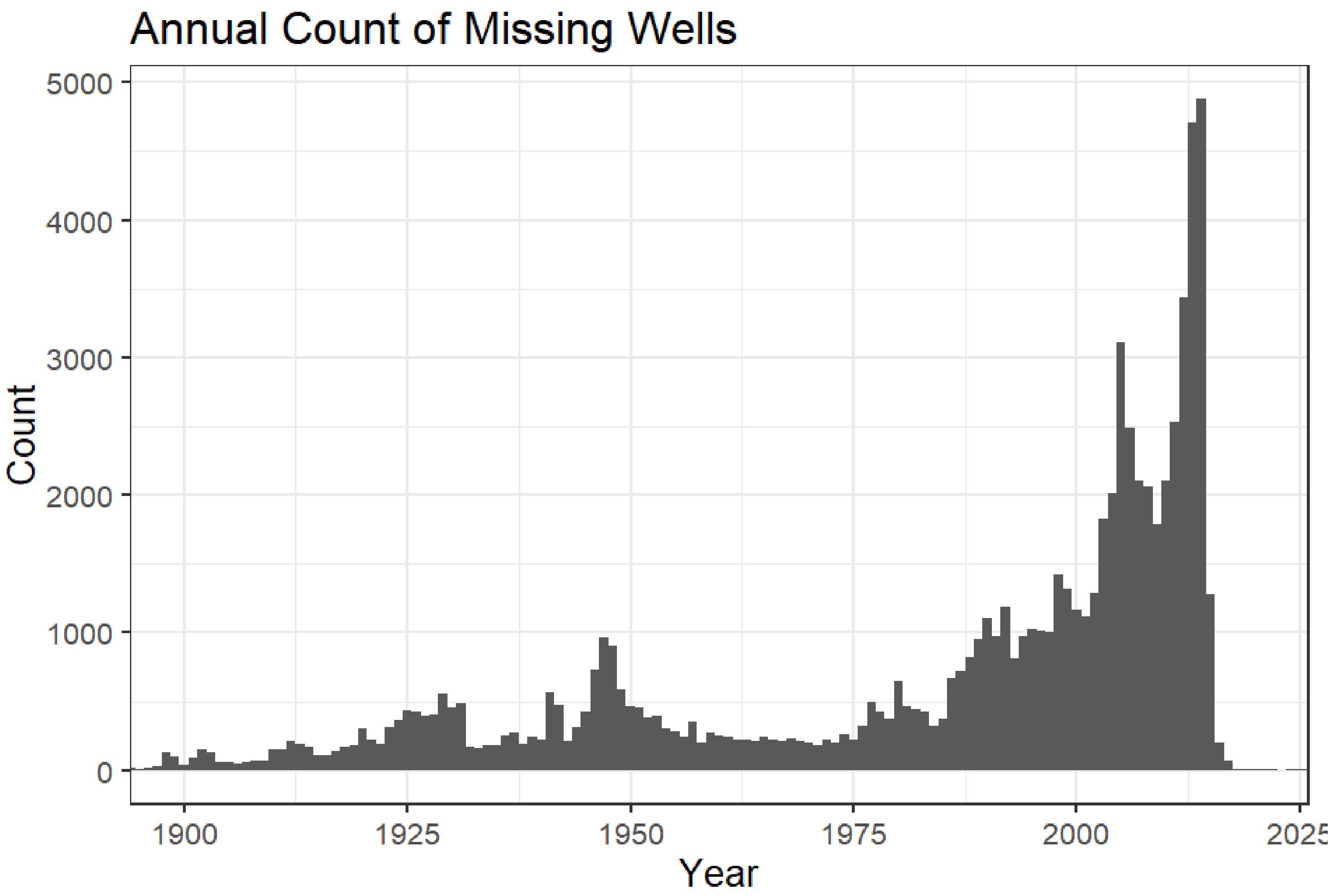


Figure 3: Annual count of well type “missing”.

Appendix

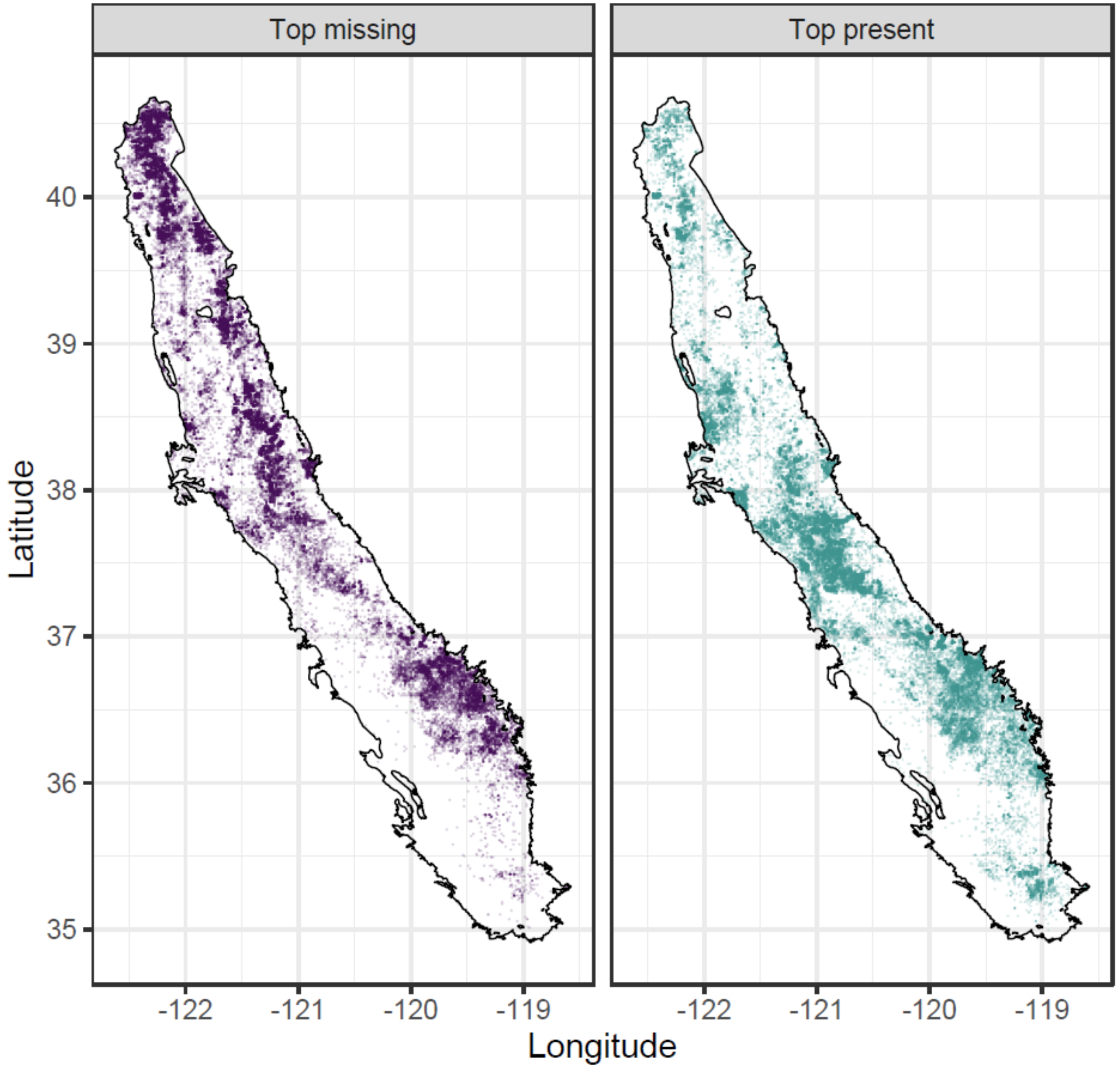


Figure 4: Missing and present Top of Perforated Interval data.

Appendix

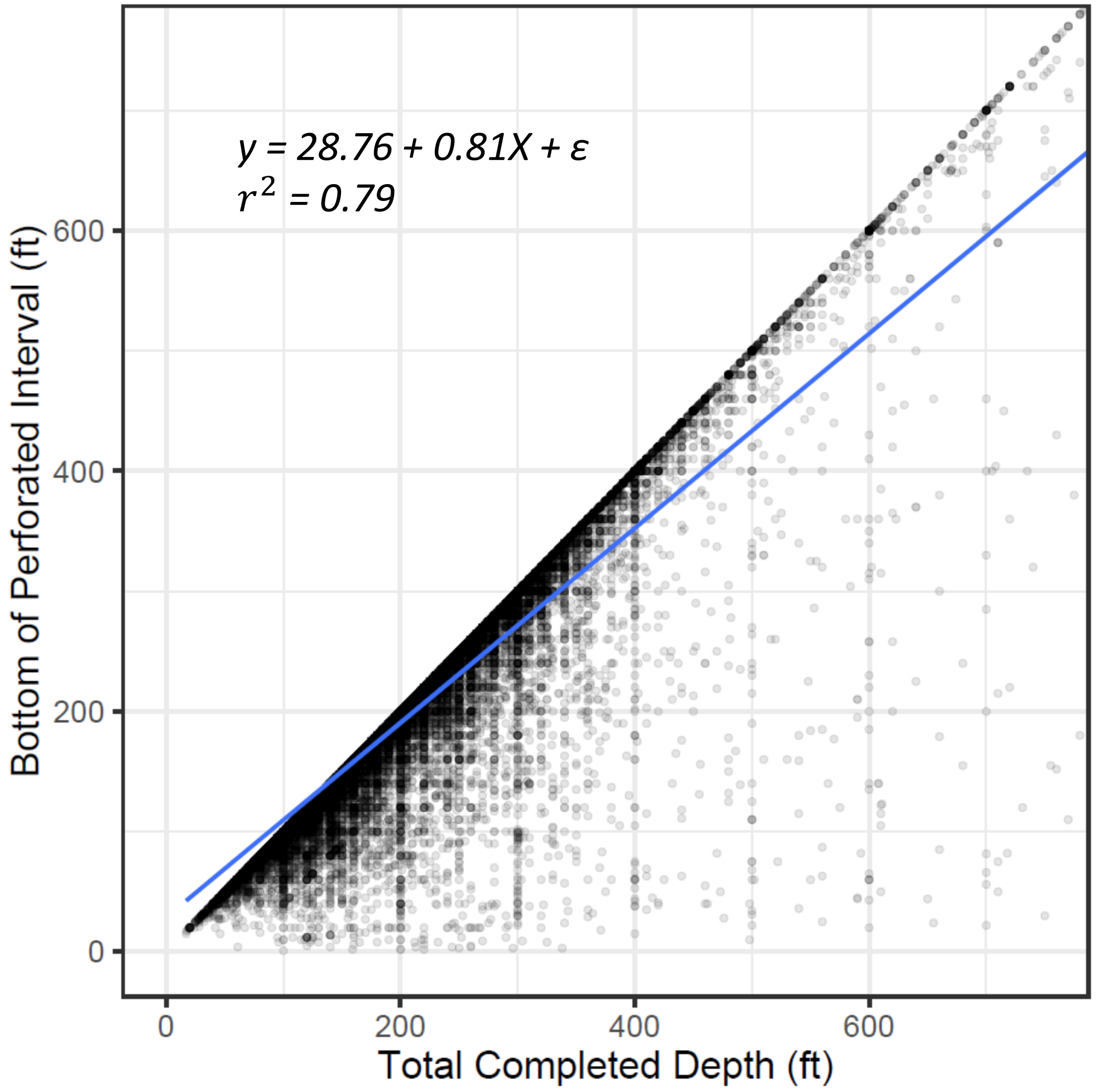


Figure 5: Completed Depth v Bottom of Perforated Interval. (CV-wide)

Appendix

	bot v tot_completed_depth			top v bot		
Basin_Subb	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)