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Calibration of the California Central Valley Groundwater-Surface Water Simulation Model – Coarse Grid (C2VSim-CG)

CWEMF 2025 Annual Meeting

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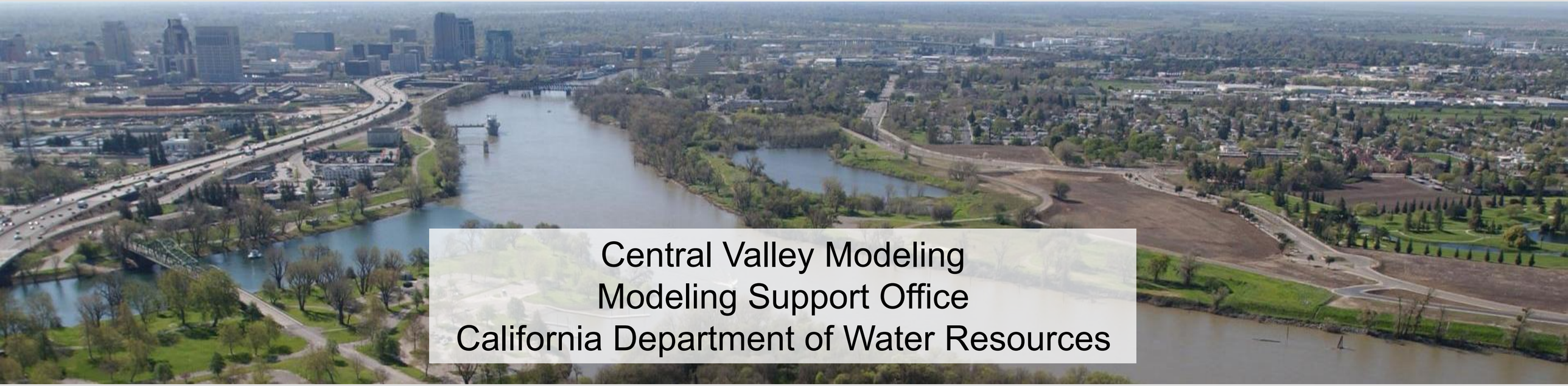

Central Valley Modeling
Modeling Support Office
California Department of Water Resources

Acknowledgments

- Co-authors
- Modeling Support Office (CA-DWR)
- Sustainable Groundwater Management Office (CA-DWR)
- PEST/PEST++ developers
- S.S. Papadopulos & Associates
- Woodard & Curran
- Stantec

C2VSim-CG

- Integrated hydrologic model of the ~20,000 mi^2 Central Valley, California
- Finite element method (Galerkin approach) with 1392 elements averaging 14 mi^2 in area
- Simulates water demands, water deliveries, and movement of water through vadose zone and GW aquifer

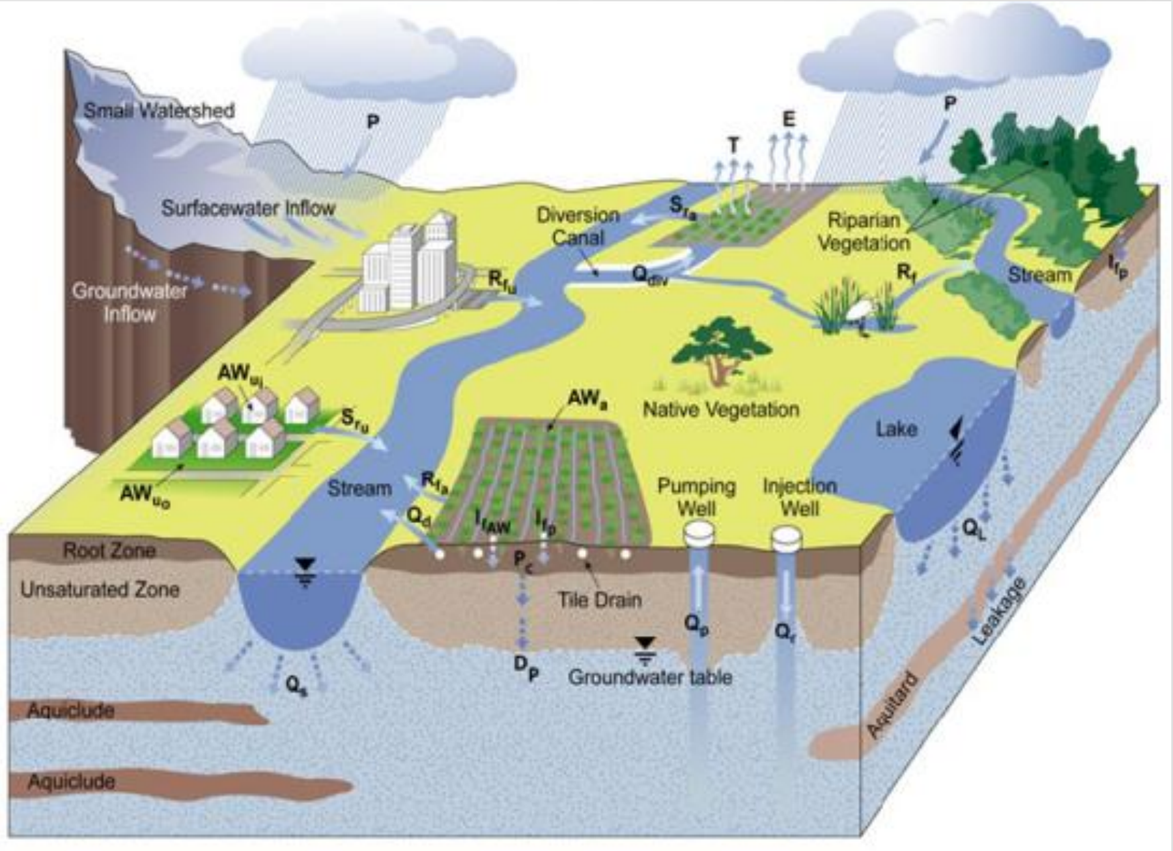

Fig 1.1 of Dogrul & Kadir (2024)

Purpose of calibration

- Version R374 of C2VSim-CG (released 2018) provides GW module for CalSim 3, a water planning model for State Water Project & Central Valley Project

- "Stress-response" properties of model are important
  - Stresses: rain, water deliveries, GW pumping
  - Responses: movement of water, change in storage

- Undertake calibration to make stress-response properties of model compatible with historical observations to the greatest extent possible

Version timeline of C2VSim-CG

Version R374
Used in CalSim 3

Version 1.0
“Model 1.0”

Started revised version
“Model Provisional”

Material in this talk limited to Model 1.0 and Model Provisional

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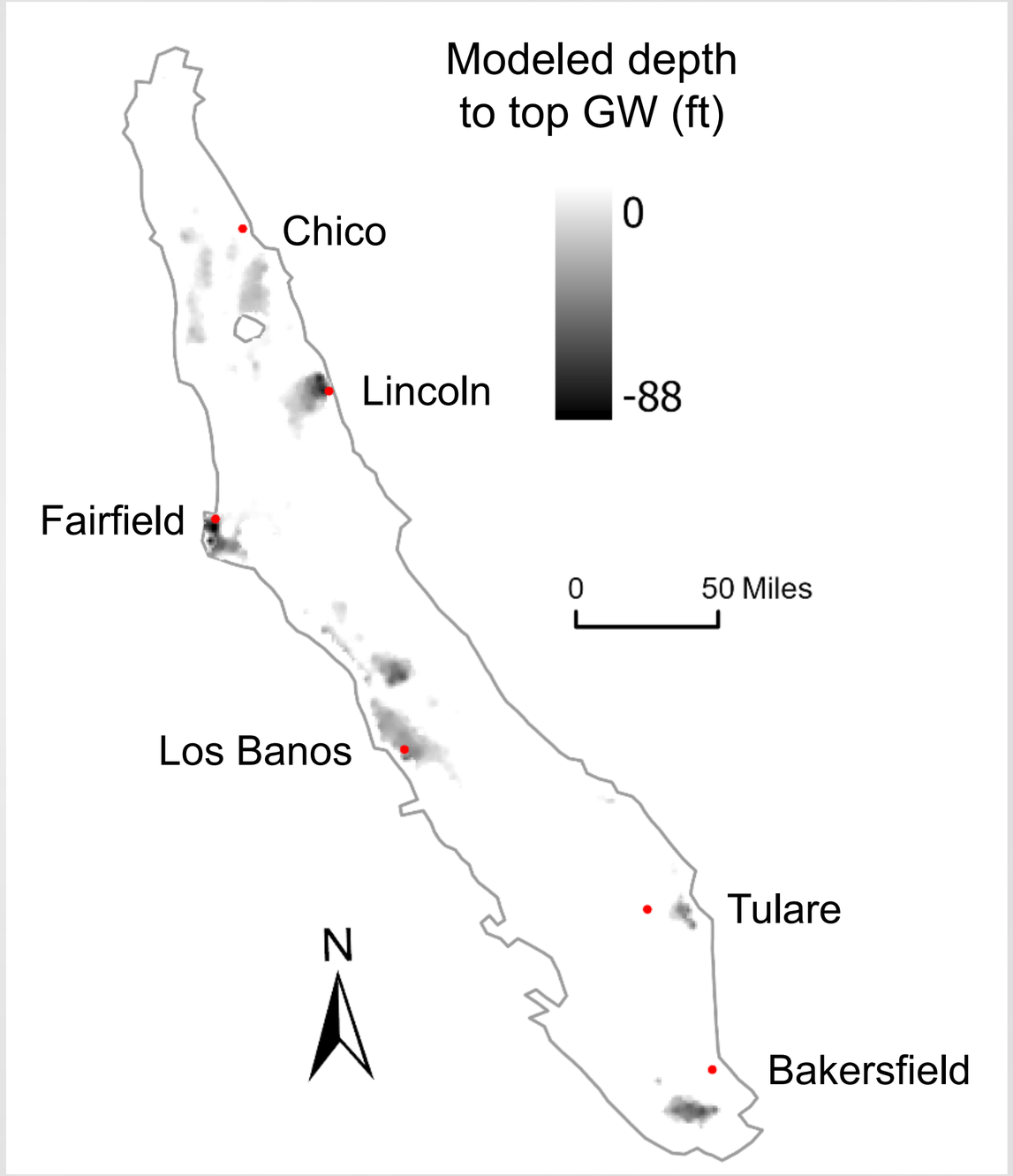
Model 1.0: attention on top-of-GW above ground surface

- Map shows depth to top-of-GW averaged over WYs 1984-2015 from Model 1.0
- Above ground surface at 12% nodes (~ area), up to 88 ft
- Not physical realistic – water not usually pooled in these areas
- Model errors in shallow GW levels would impact simulated GW-SW interactions



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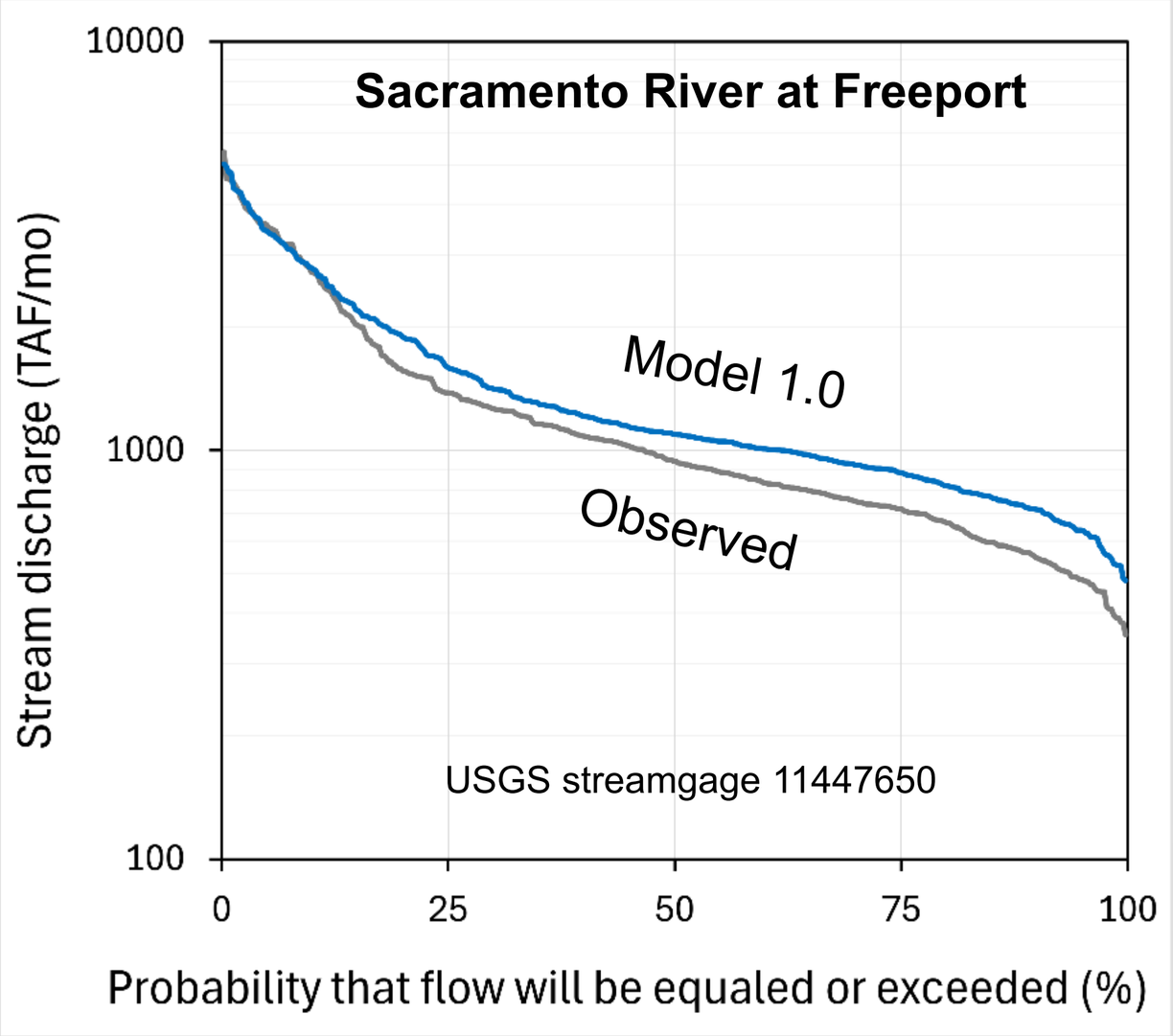
Model 1.0 tends to overestimate major streamflows

- Example for the Sacramento R. at Freeport streamgage. Largest gaged flow averaging ~ 15 MAF/yr.
- Model tends to overestimate flows, especially lower flows at high probabilities of exceedance
- In models, overestimated streamflows can cause reservoirs to not release enough water during dryer periods



Objective

- Improve C2VSim-CG fits to historical GW levels and streamflows
- Attempt to achieve this by undertaking a calibration using PEST software (PEST = Parameter Estimation) (Doherty, 2015)
- Calibration period: WYs 1984-2015, with 10-yr warm-up (1974-1983)

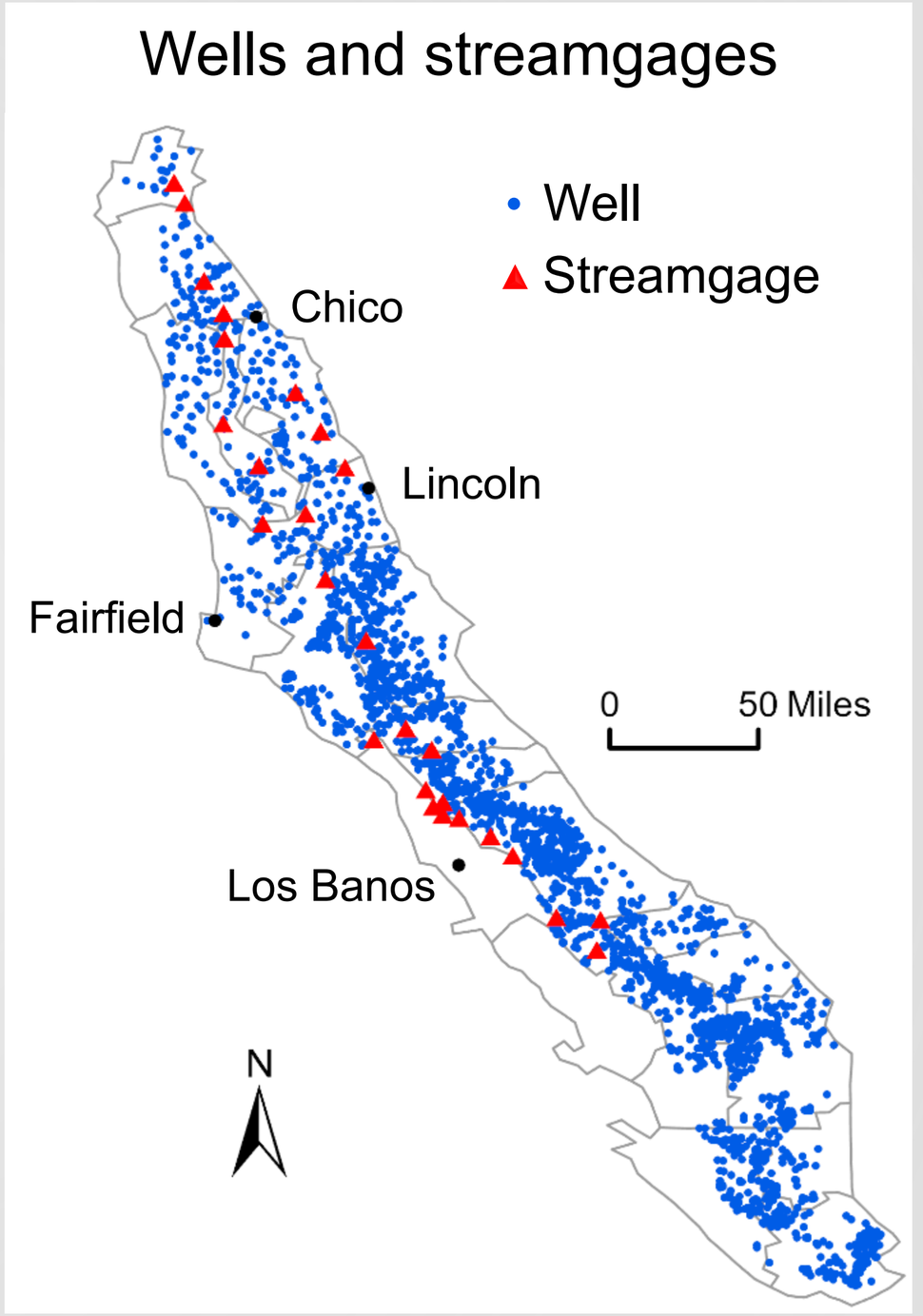
Calibration approach

- Objective: minimize weighted model errors summed across all observation gages (“objective function”)
- Parameters estimated together in single calibration run so that parameter interaction effects are accounted for
- Provides “automated” approach readily reproduced and documented
- Finished adding parameters for 4/5 subsystems shown below

Finished	Finished	Finished	Finished	In progress
Aquifer	**Streambed**	**Potential ET**	**Unsaturated zone**	**Root zone**

Calibration observations

- Observation gages shown on map include streamgages and wells (GW levels)
- Selected 2,652 wells as follows:
  - List of 3,474 wells provided by SGMO from work on fine-grid C2VSim model
  - Time-series GW levels provided by W&C
  - Selected wells screened in single aquifer layer of C2VSim-CG, then performed QA/QC
- Selected 27 streamgages providing relatively continuous periods of data (~10 yrs or more)



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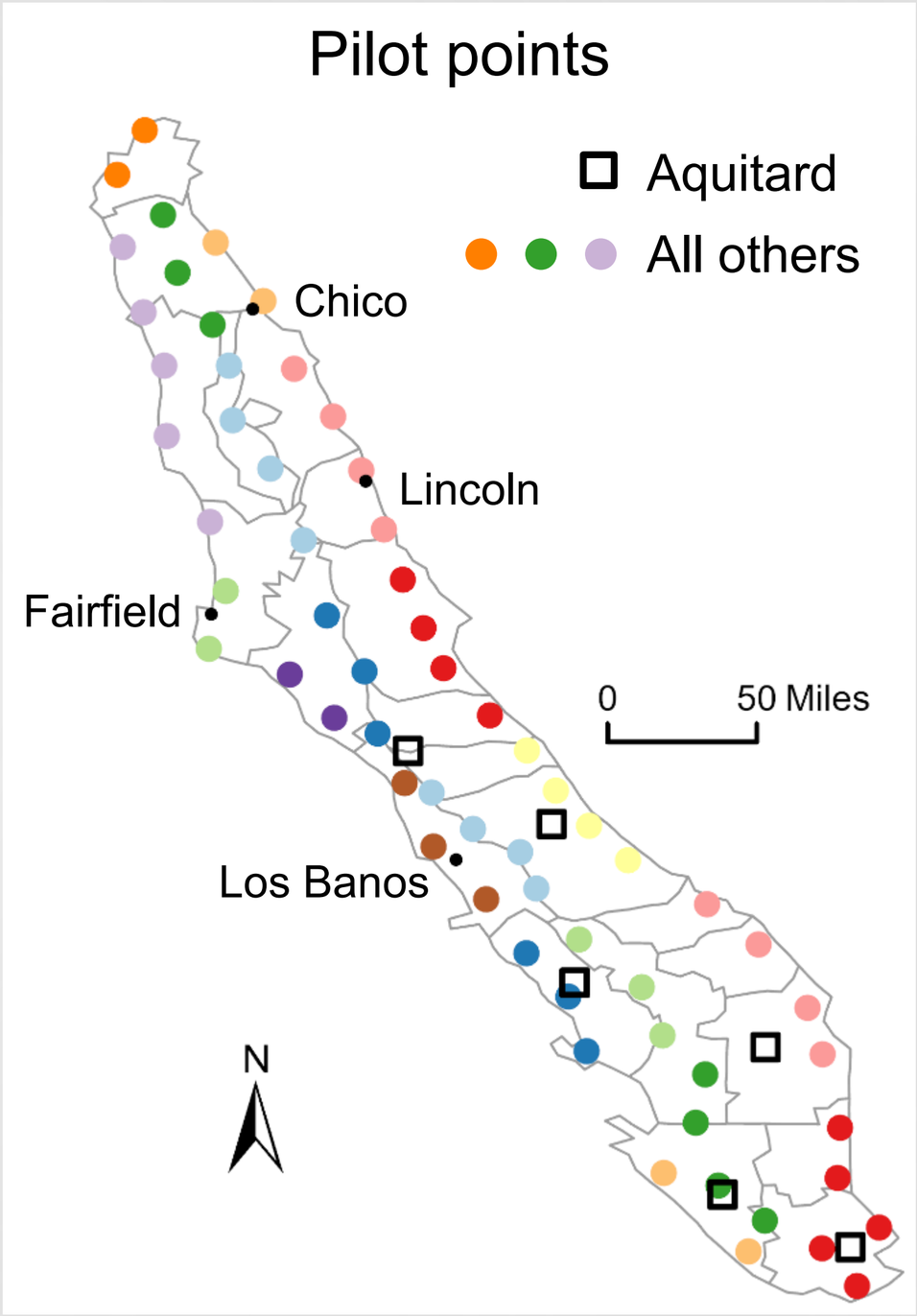
Updates to model inputs other than calibration parameters

- ❑ Update to historical potential ET (help from Stantec)
  - Out of concerns over low values in Model 1.0: 38% lower than in C2VSim-CG R374 (Sacramento Valley). Connection to elevated GW level issue?
- ❑ Update to historical land use acreages to improve accuracy
  - Data provided by Sustainable Groundwater Management Office
- ❑ Change to “small watersheds” (simulate inflows from ungaged watersheds)
  - Number reduced from 210 to 151

Calibration tools

- Pilot points (shown on map) are locations where parameters are being estimated
  - Adopted from Model 1.0
  - Colors represent “tied” relationship (groups)
- Optimization engines compared: PEST_HP and PEST++ IES in early testing (tied pars)
  - Decided to go with PEST_HP based on objective function lowering
- Runs done over internet using Azure cloud
  - Software = “PEST.cloud”; developed by SSP&A in collaboration with John Doherty
  - Provides us with up to 800 simultaneous runs



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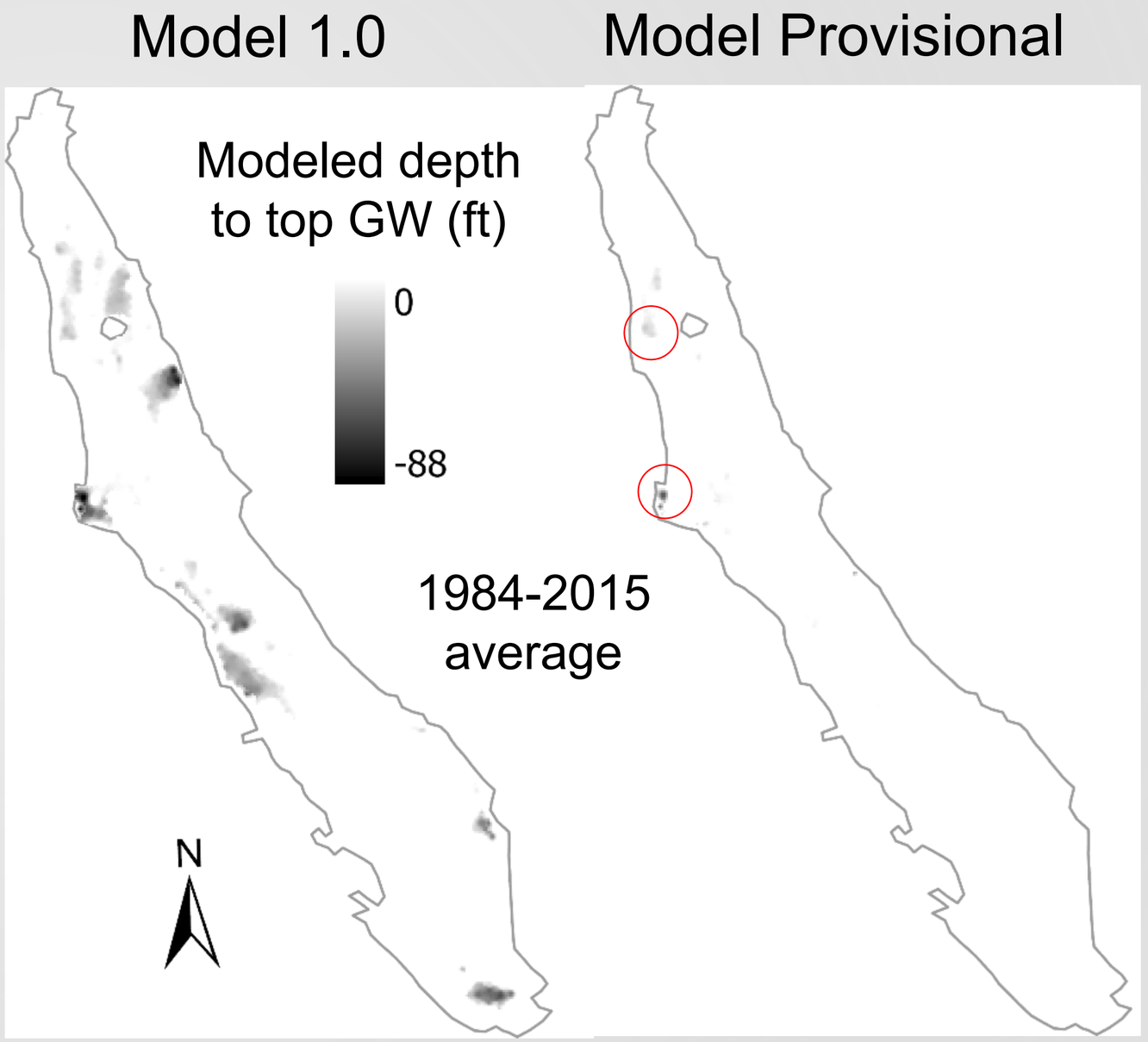
Result slide 1/3: modeled depth to top of groundwater

- Before calibration: Top of GW above ground surf. over 12% area
- After calibration: Top of GW above ground surf. over 2.6% area
- Reduction in area by ~78%
- Where still occurs (circled on right), GW table is fairly shallow (few tens of feet)



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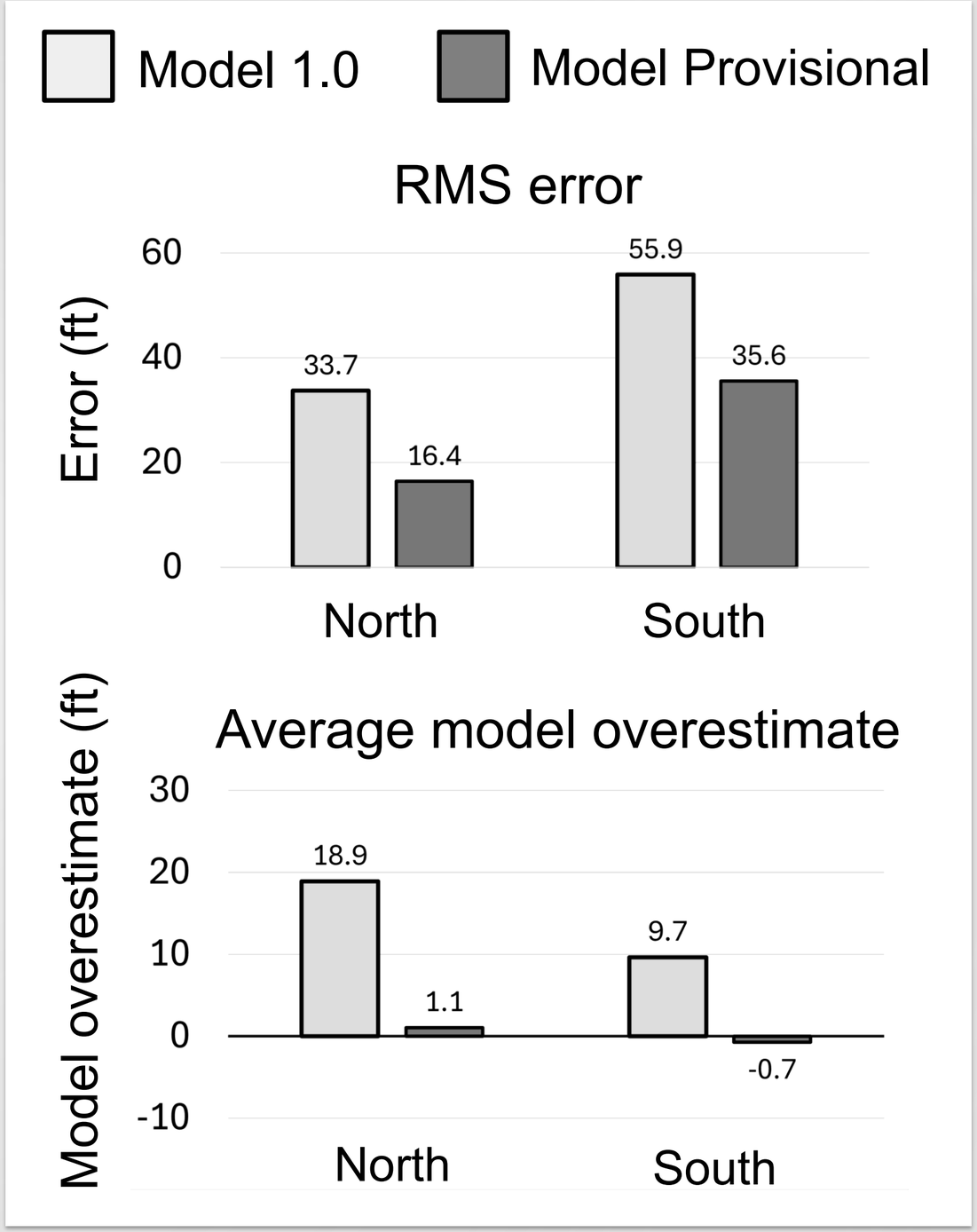
Result slide 2/3: Model errors in GW heads relative to well observations

- Charts showing RMS error and bias averaged across wells in 2 bins (North & South)
- RMS error reduction: 17 ft in North, 20 ft in South
- Current RMS error magnitudes: “Pretty good” in North (16.4 ft), not so good in South (35.6 ft)
- Current bias (model overestimate) ~ 1 ft, so largely removed by calibration



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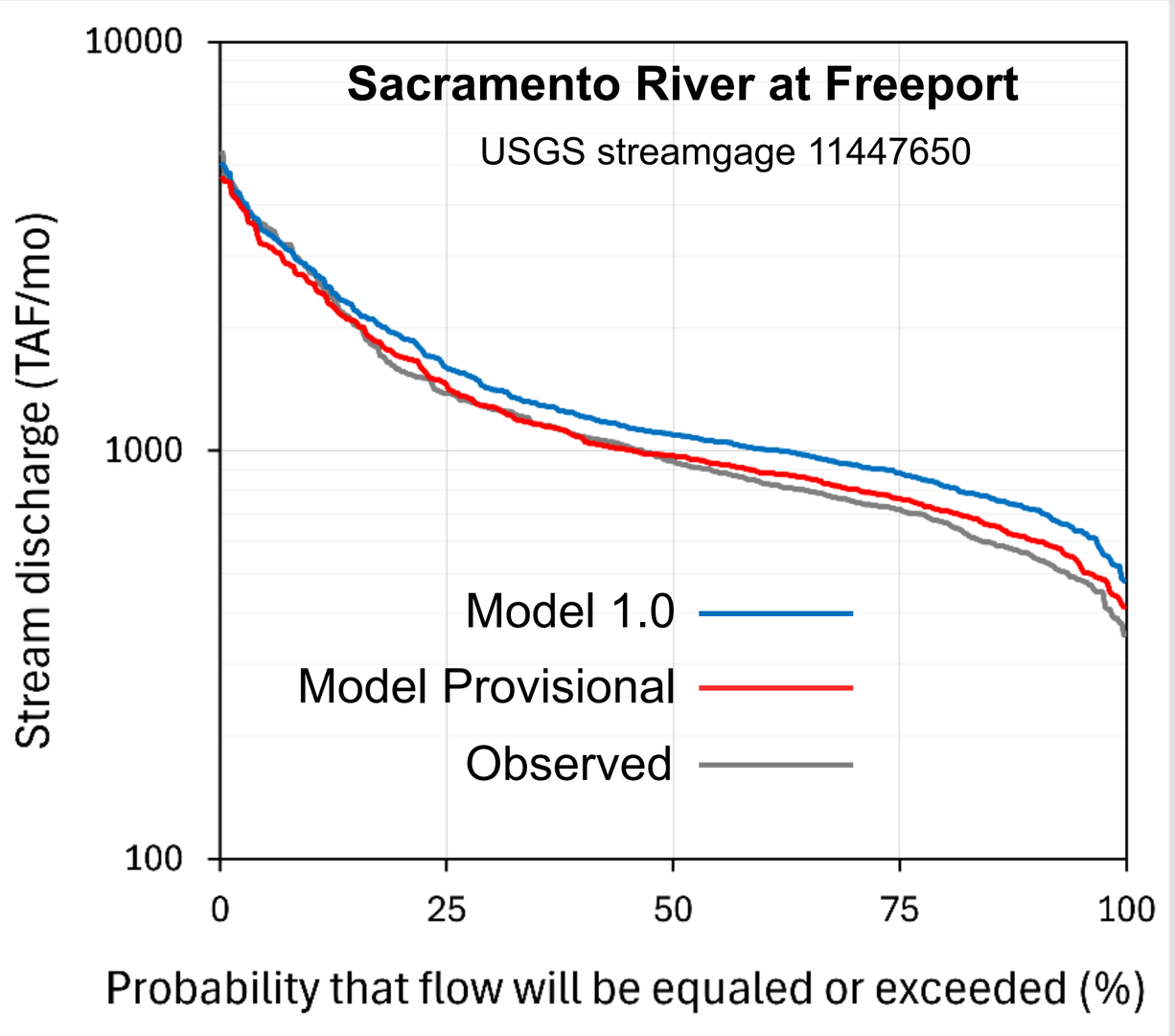
Result slide 3/3: model overestimates of streamflow

- Revisit Sacramento River at Freeport
- Ave monthly flow (area under curve): overestimates reduced from 12% (150 TAF) to 0.5% (5.7 TAF)
- Model Provisional follows observed curve much closer than Model 1.0
- As log-scale shows, greater fractional reductions in model error at the lower flows



Summary

- Developing a PEST calibration package for C2VSim-CG. In process of adding root zone parameters.
- Average overestimates in GW levels (heads) lowered by ~18 ft in Sacramento Valley (North), ~10 ft in San Joaquin Valley (South)
- RMS errors in GW level remain relatively high in San Joaquin Valley at 36 ft (but improved from 56 ft)
- Model bias in streamflow volume substantially lowered (+12% to +0.5% for Sacramento River at Freeport)

Thank You

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References

Dogrul, E. C., & Kadir, T. N. (2024). Integrated Water Flow Model, IWFM, Revision 1594: Theoretical Documentation. DWR Technical Memorandum, California Department of Water Resources, 161 p. Accessed on 28 May 2024 from https://data.cnra.ca.gov/dataset/iwfm-integrated-water-flow-model.

Doherty, J. (2015). Calibration and Uncertainty Analysis for Complex Environmental Models. Watermark Numerical Computing, Brisbane, Australia. ISBN: 978-0-9943786-0-6.

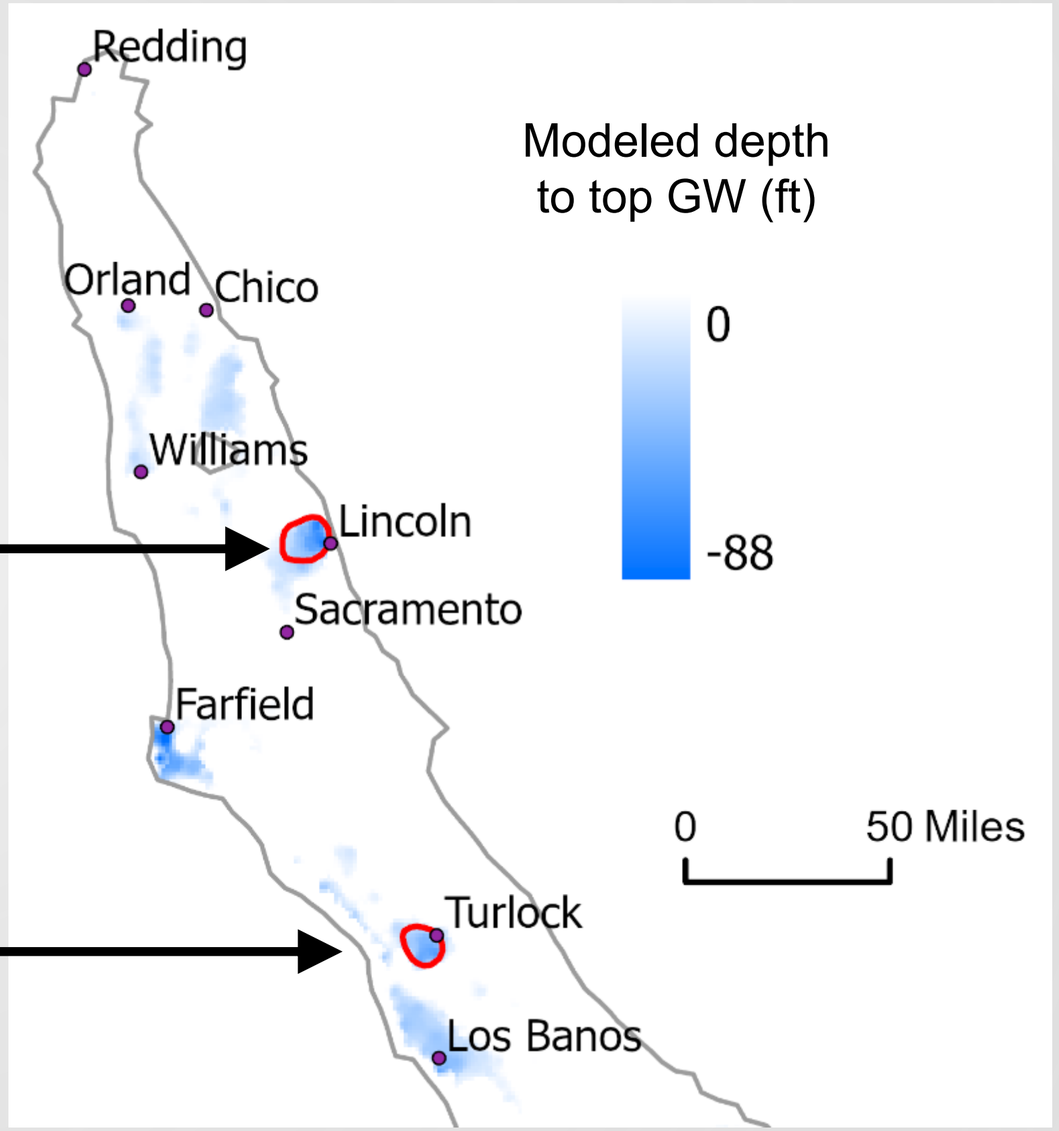
Supplementary slides

Version 1.0: Closer look at GW levels above ground surface

- Compared modeled values to well observations near towns of Lincoln and Turlock

- Lincoln, CA:
  - Model: 29 ft above ground
  - Obs: 40 ft below ground

- Turlock, CA:
  - Model: 36 ft above ground
  - Well: 14 ft below ground



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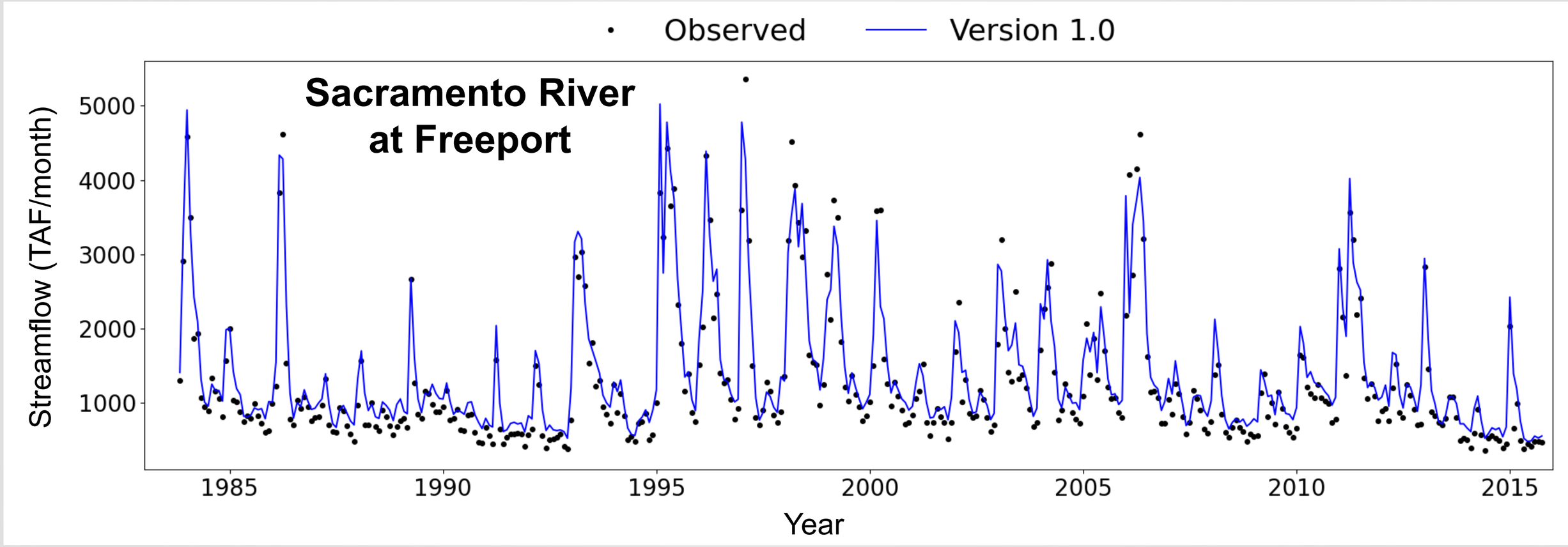
Version 1.0: Model overestimates in major streamflows



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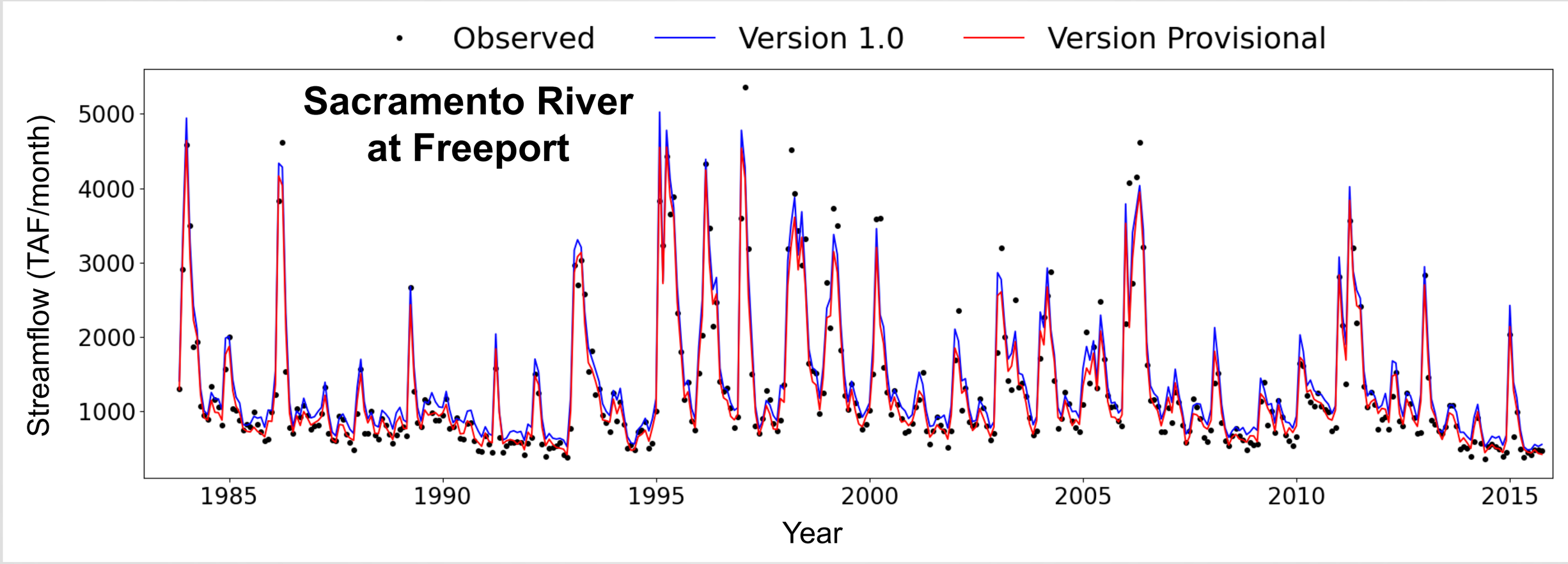
Streamflows of Sac. R. @ Freeport, v1.0 vs. Provisional

- ❑ Flow volume overestimates greatly reduced: 12% to 1%
- ❑ Nash-Sutcliffe efficiency slightly improved: 0.88 to 0.92



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