Pinal AMA Historical Groundwater Model Review Part 2

ELOY AND MARICOPA STANFIELD BASIN STUDY

GROUNDWATER SUB-GROUP MEETING

SEPTEMBER 29, 2020

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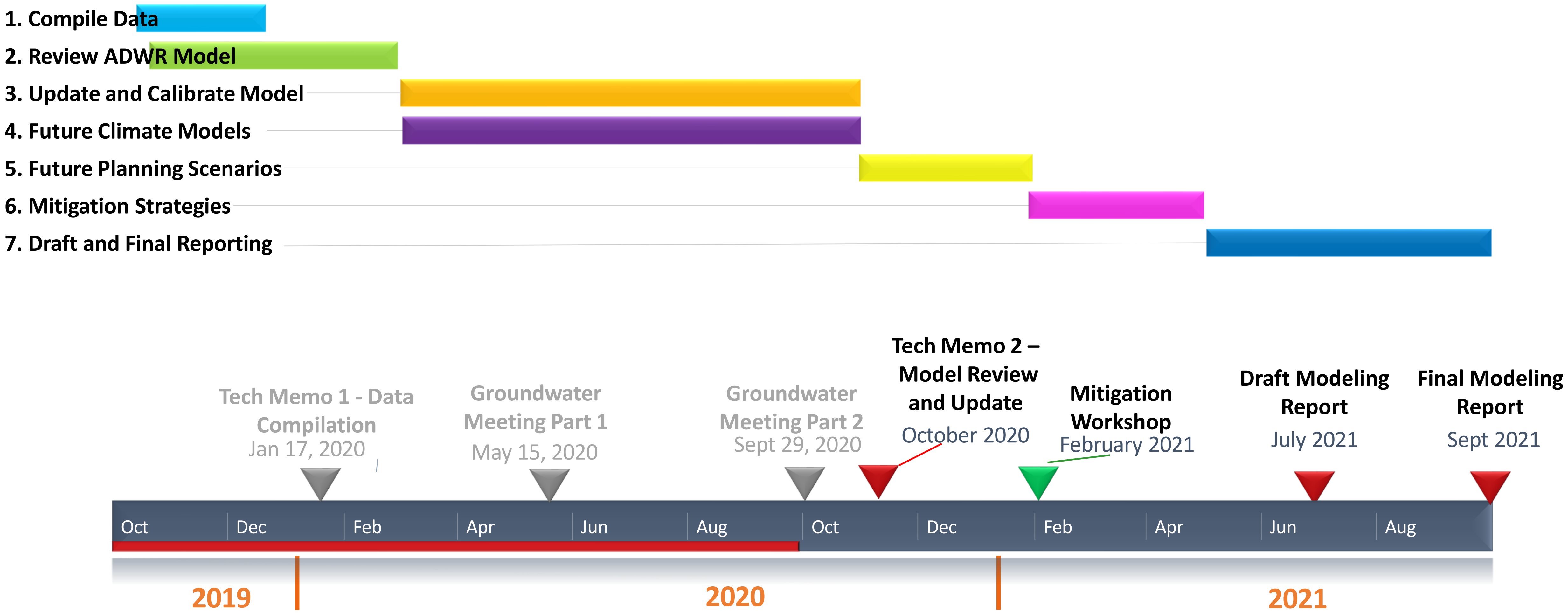
Tentative Revised Schedule



Introduction

History

- ADWR 2014 – original model
- ADWR 2019 – extended model through 2015
- M&A 2020 – this study, updated through 2018 with minor adjustments

Study Objective

- Facilitate evaluation of future Pinal basin groundwater mgmt. alternatives proposed by Stakeholders
- Alternatives include groundwater pumping increases from 5% to 50% more than current, and consider climate change effects
- Focus on model's regional-scale accuracy and regional feasibility for Stakeholder alternatives

Results

- Update showed no issues that warranted substantial model modification; made a few adjustments
- Model review has not identified concerns about model's ability to meet study objectives
- Ready to proceed with predictive modeling

What was covered in the last meeting?

Date : May 15th

We reviewed component inflows and outflows for the ADWR 2019 model.

Outline

1. Review of Hydraulic Properties

2. Review of Simulated Subsidence

- Break for Questions -

3. Model 3-Year Update (2016 – 2018)

4. Review of Historical Model Performance with the updates

- Conclusions and Questions -

1. Review of Hydraulic Properties

2. Review of Simulated Subsidence

3. Model 3-Year Update (2016 – 2018)

4. Review of Historical Model Performance with Updates

a. Introduce of terms
b. Review hydraulic conductivity changes made in ADWR 2019 model from the 2014 model
c. Aquifer tests for hydraulic conductivity
d. Aquifer tests for specific yield

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Aquifer Properties - Definitions

Hydraulic conductivity (K)

- Ability of water to move through aquifer material
- Higher in coarser material (e.g. gravels and sands) and lower in finer material (e.g. clays and slits)
- Model has both horizontal (Kxy) and vertical (Kz) hydraulic conductivities

Aquifer Transmissivity

- Rate at which groundwater flows horizontally through an aquifer
- Aquifer Transmissivity = Aquifer Thickness * Hydraulic conductivity

Aquifer Storage

- Describes the release of water (stored volume) in aquifer as the hydraulic head declines
- Specific Yield (unconfined conditions) – water release due to gravity drainage
- Specific storage (confined conditions) – water release due to pressure changes in aquifer

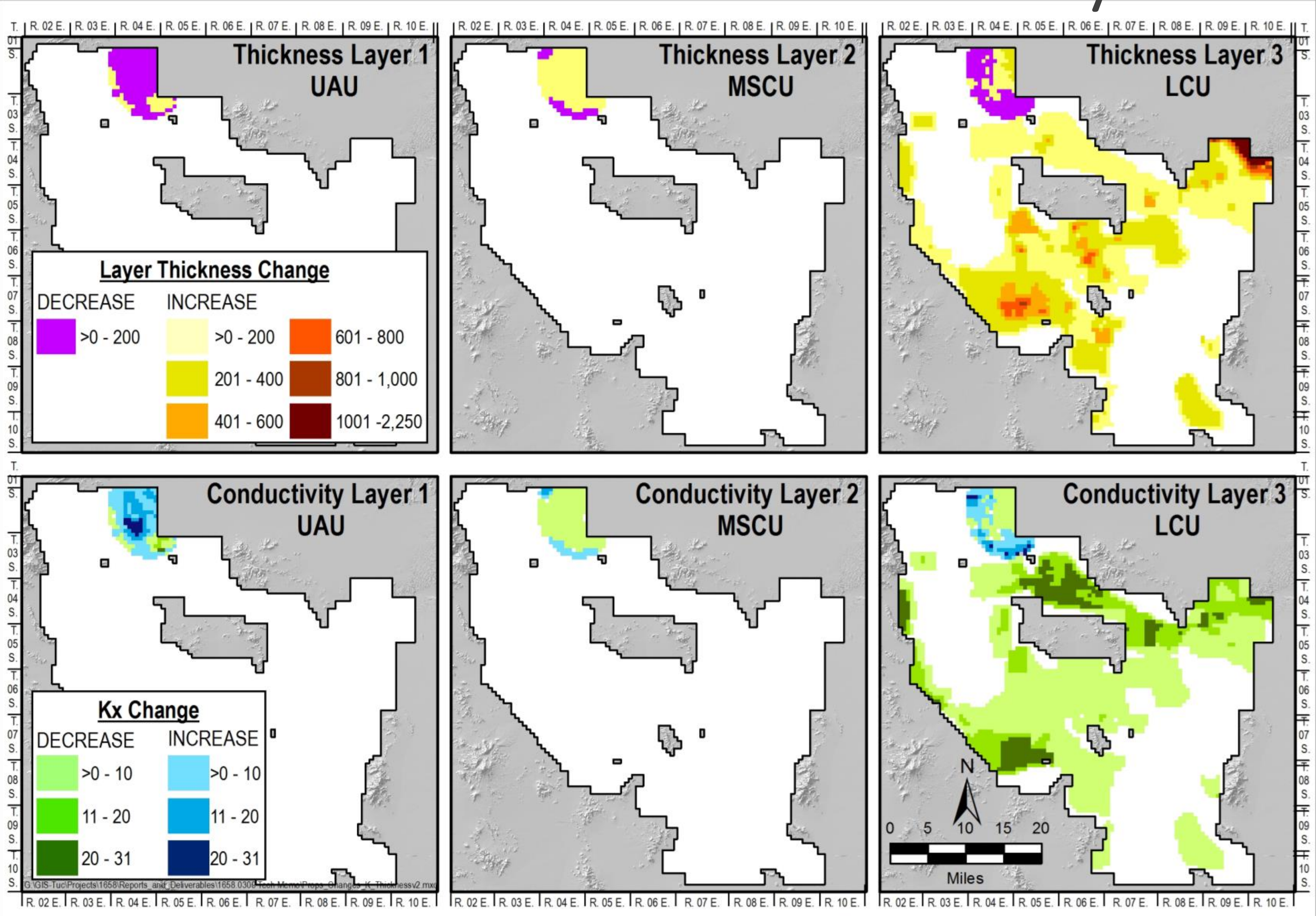
Review: Horizontal Hydraulic Conductivity (K_{xy})

- Model layer thickness was changed in ADWR 2019 model (top row of maps)

Aquifer Transmissivity =
↑(Aquifer Thickness) * ↓(K_{xy})

- Horizontal hydraulic conductivity (K_{xy}) was adjusted by ADWR to maintain same model calibration (bottom row of maps)

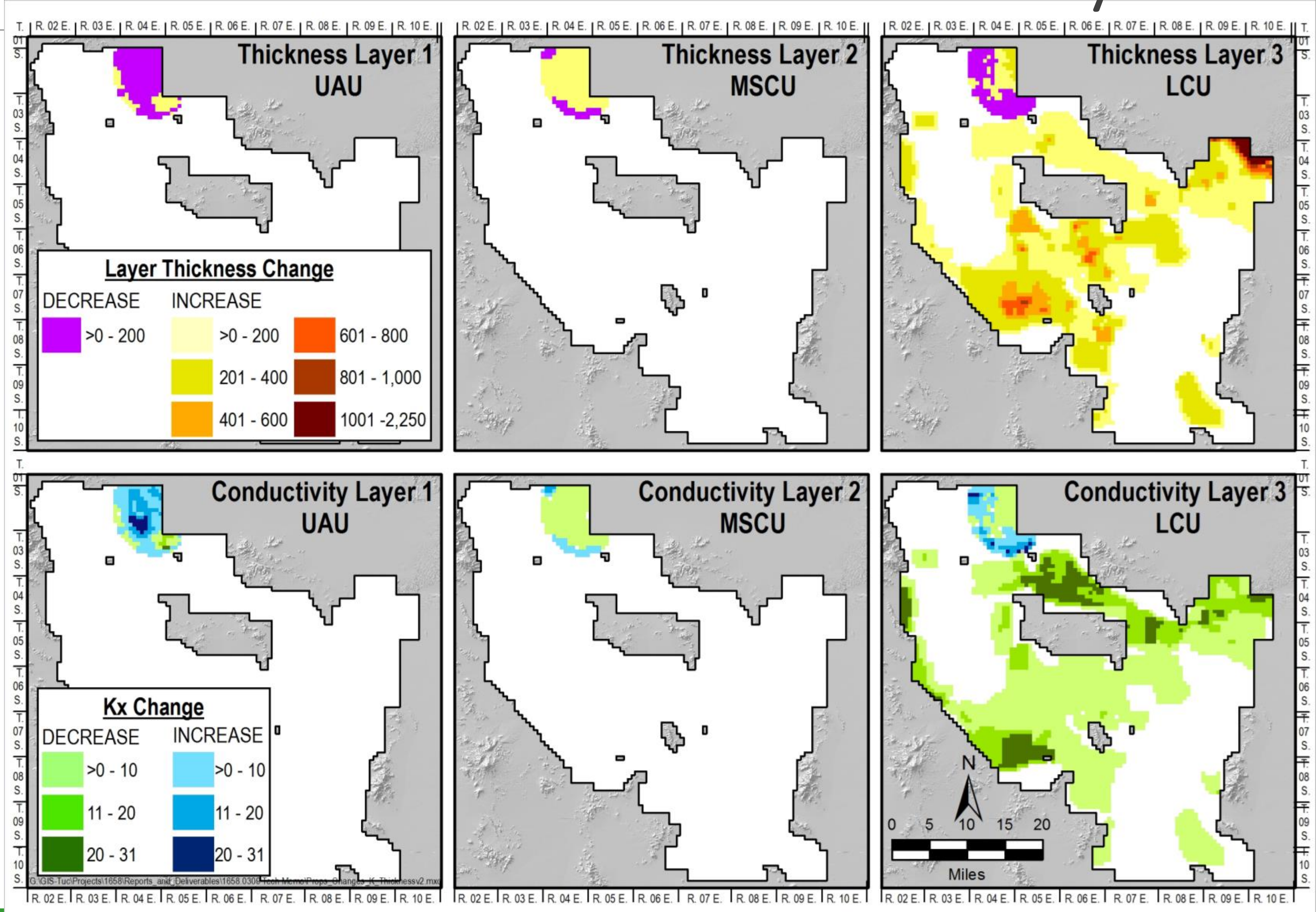
- **The behavior of the model effectively did not change with the ADWR 2019 model update**



Review: Horizontal Hydraulic Conductivity (K_{xy})

Kxy Changes (bottom map row)

- Layer 1 and 2 Kxy had minor changes from +30 to -10 ft/day in the northwestern corner of GRIC
- Layer 3 Kxy mostly decreased -5 to -30 ft/day along Gila river and Casa Grande ridge
- The modified K values are still within a reasonable range for this type aquifer



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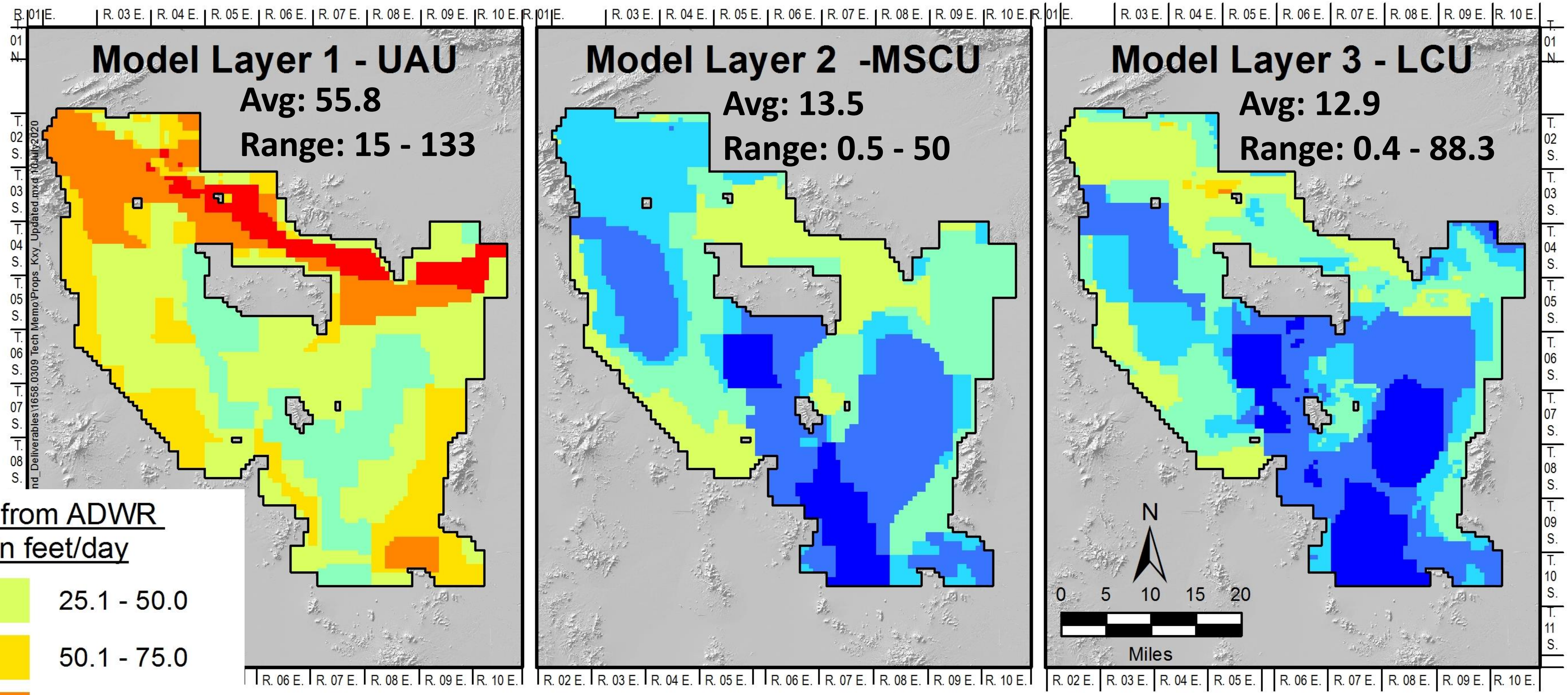
Review: Resulting Kxy in ADWR 2019 Model

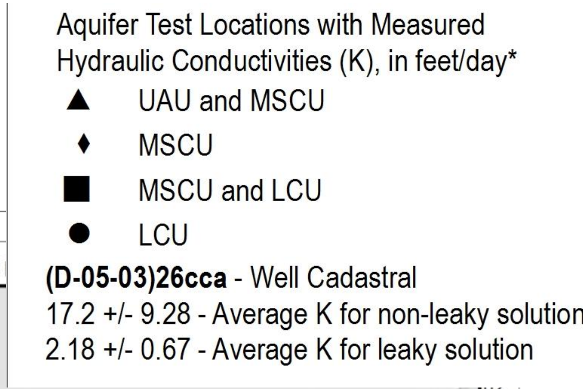


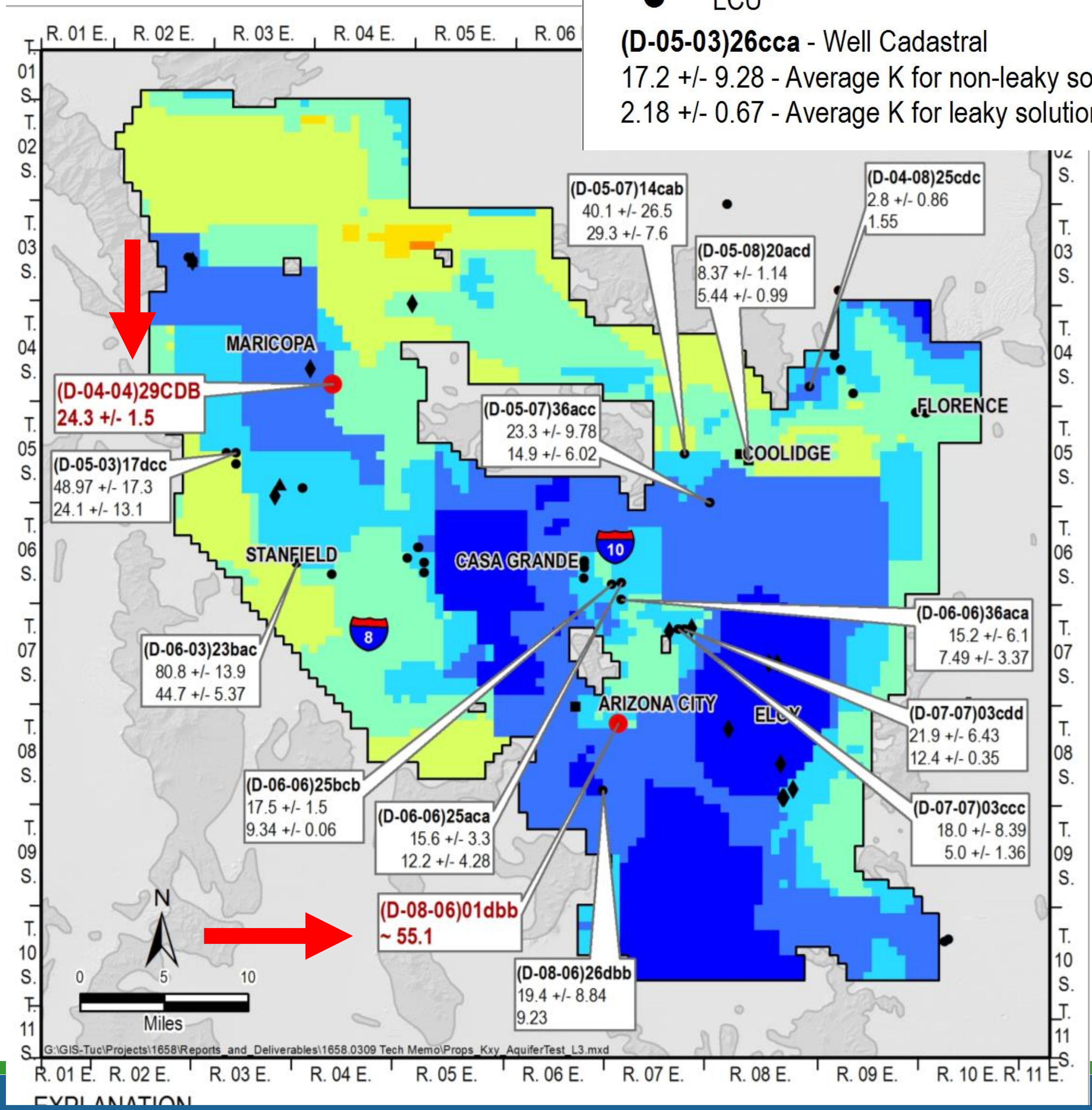
Hydraulic Conductivities from ADWR 2019 Pinal Flow Model, in feet/day

0.4 - 1.0	25.1 - 50.0
1.1 - 5.0	50.1 - 75.0
5.1 - 10.0	75.1 - 100.0
10.1 - 25.0	100.1 - 133.0

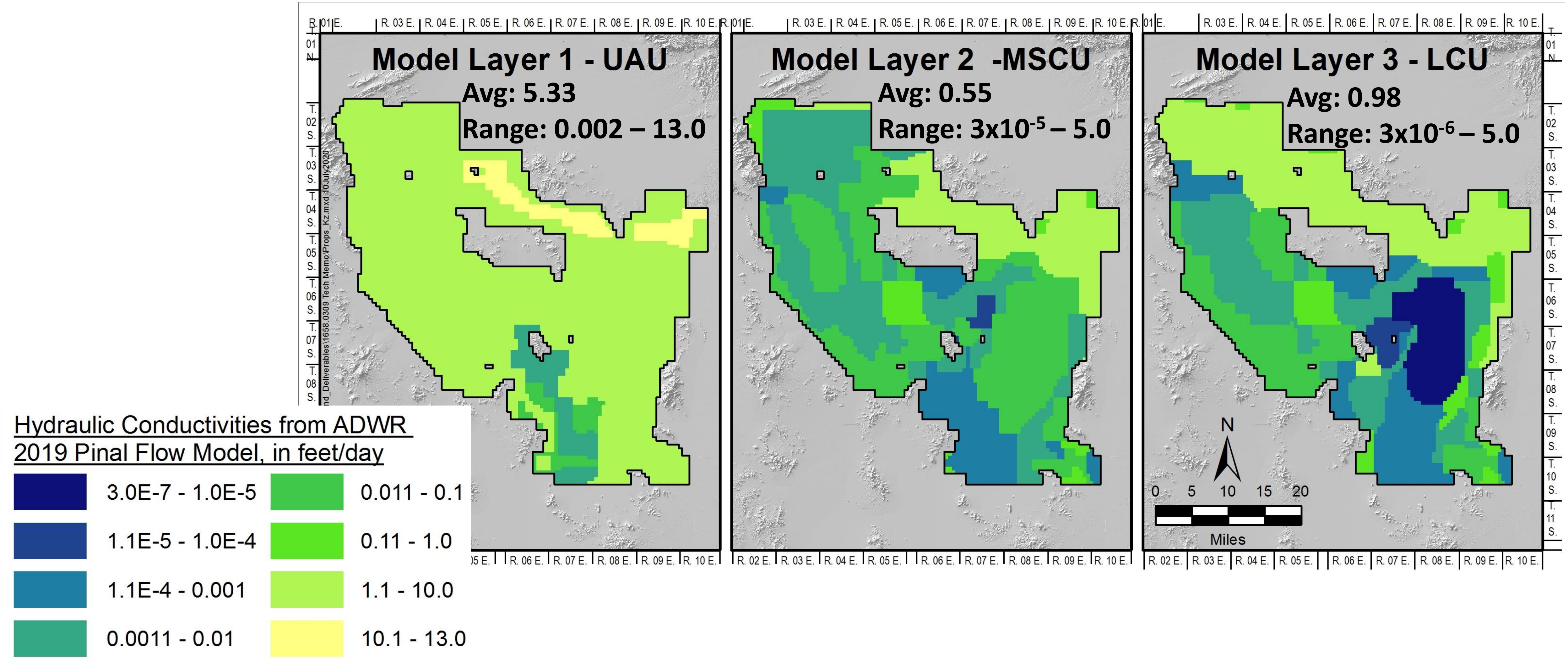
Review: Aquifer Test Data for K_{xy}

- Added 2 additional aquifer tests from stakeholders (shown in red)
- Evaluated published aquifer test data from ADWR 2014 model
- ADWR re-analyzed a substantial number of aquifer tests using “leaky” analytical methods, meaning that the confined aquifer unit response to pumping test was influenced by leakage from overlying units (results shown in black)
- The consideration of leaky aquifer conditions tended to lower the estimated K values in Layers 2 and 3
- Review showed the calibrated model K values were reasonably consistent with estimated ranges from aquifer test analyses, and sufficient for regional model accuracy

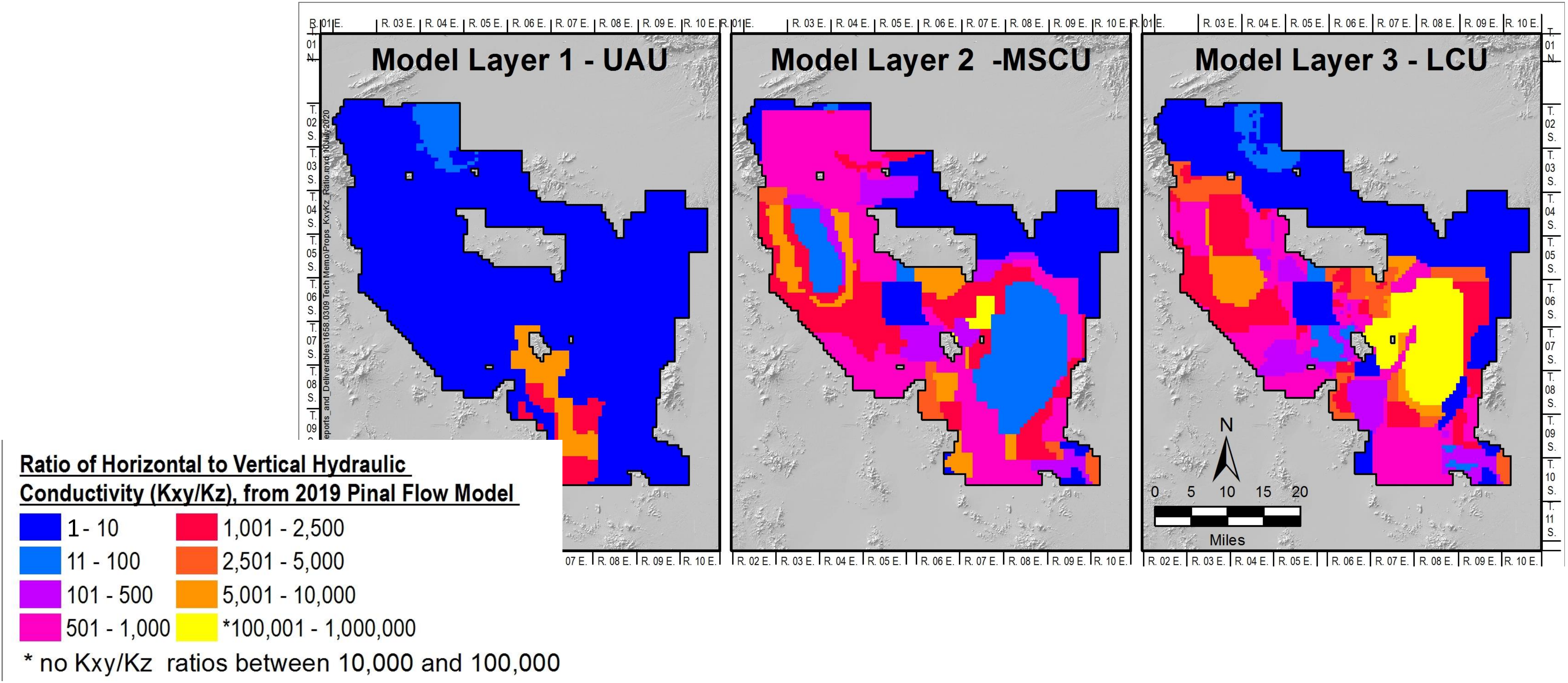




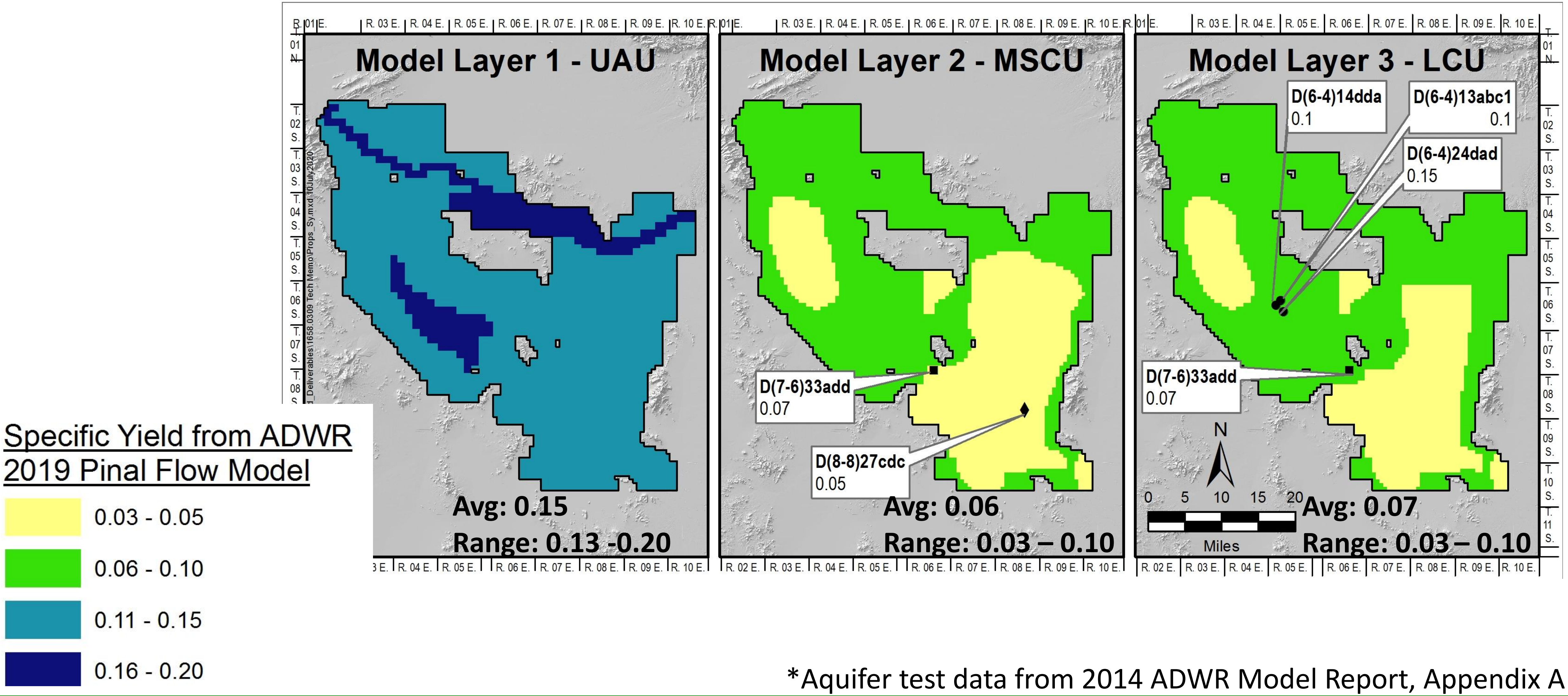
Review: Vertical Hydraulic Conductivity (K_z)



Review: Ratio of Horizontal to Vertical (K_{xy}/K_z)



Review: Specific Yield (Sy)



*Aquifer test data from 2014 ADWR Model Report, Appendix A

1. Review of Hydraulic Properties

2. Review of Simulated Subsidence

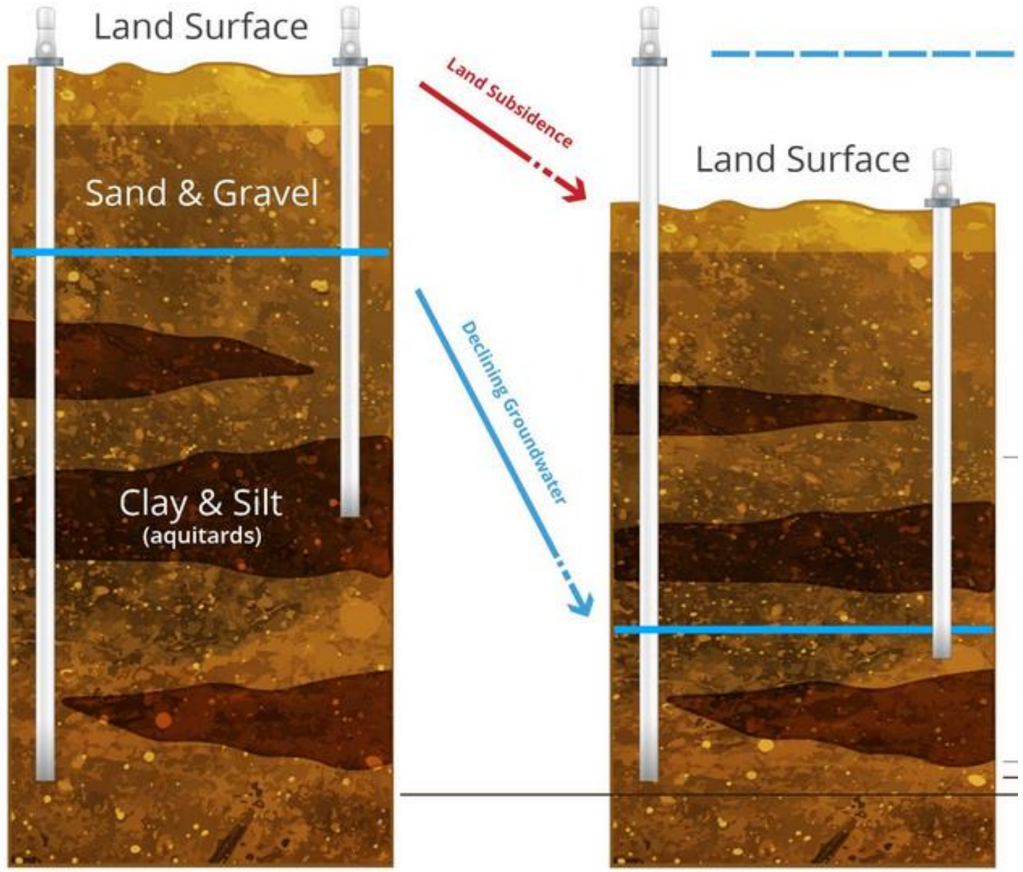
3. Model 3-Year Update (2016 – 2018)

4. Review of Historical Model Performance with Updates

a. Introduction to subsidence
b. When and where subsidence occurs in Pinal
c. Model Specific Storage
d. Compressible sediment representation in the Model

Introduction to Subsidence

- Subsidence is compaction of the sediments caused by lowering of the hydraulic head.
- When pressure is decreased, pore space matrix is no longer supported and matrix compresses (shown on right)
- Cumulative effect causes the land surface to lower; this is subsidence
- Causes problems with canals and structures, for example
- Generally not recoverable



Source: Willcox Subsidence storyboard by ADWR
https://www.arcgis.com/apps/MapJournal/index.html?appid=c5758018997c402b863c11e36727ed31

Measured Land Subsidence in Model Area

Sources of Measured Subsidence Data

- Point measurements from 1952 – 1977 (Laney et al, 1978)
- Point measurements from 1922* – 1992 (B. Conway, ADWR)
- INSAR Data from early 2000's – 2020 (not shown)

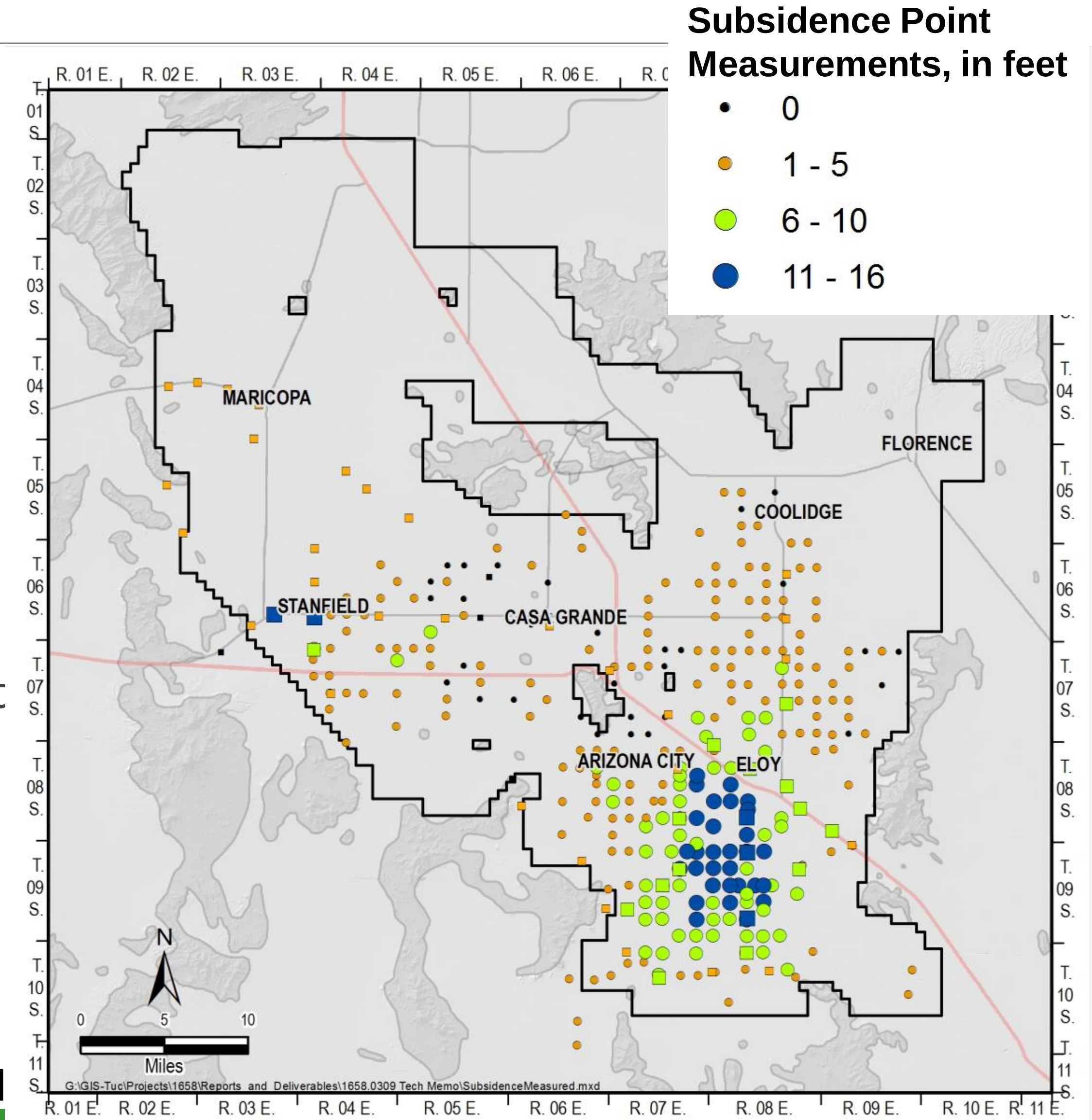
When did it occur?

- Majority subsidence occurred pre-1990's
- Since early 2000's measured subsidence is appx. one foot or less based on INSAR data

Where did it occur?

- Subsidence occurs generally south of Sacaton Mountains
- Largest measured subsidence (11 to 16 feet) occurs south of Eloy and I-10

* Starting year varied



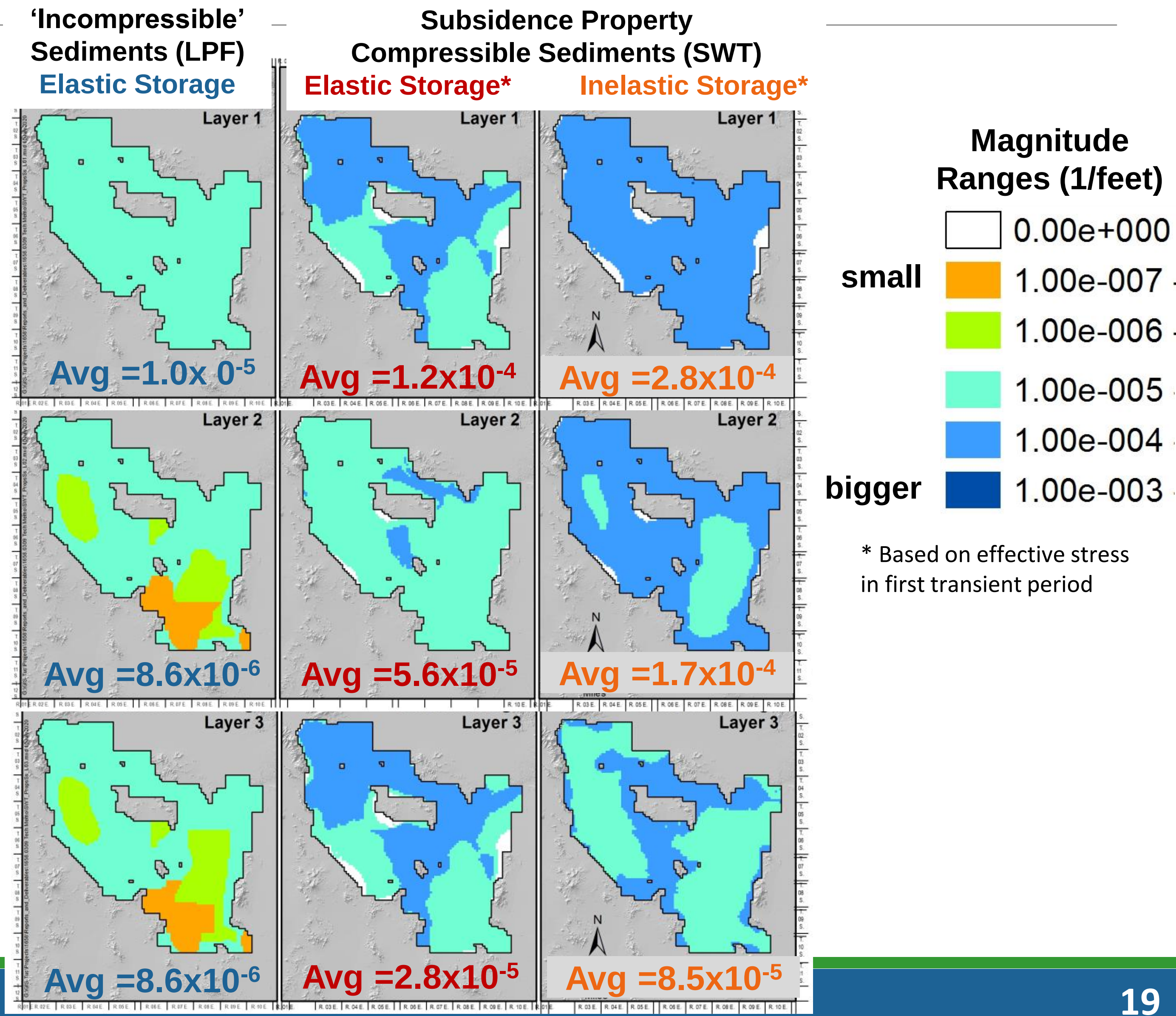
Review: Subsidence in Model

- Model uses Subsidence Package: “MODFLOW SWT”
  - Complex phenomenon with many parameters to “estimate” in the SWT package
  - ADWR representation of subsidence followed a principal of “parsimony” for the representation (simple approach)

- Reviewed two key components in Subsidence Package
  1. Inelastic/elastic specific storage
     - Base Modflow file (LPF) contains contains only elastic storage (incompressible sediments)
     - SWT contains elastic and inelastic storage for compressible sediments
  2. Compressible sediment thickness

Review: Specific Storage

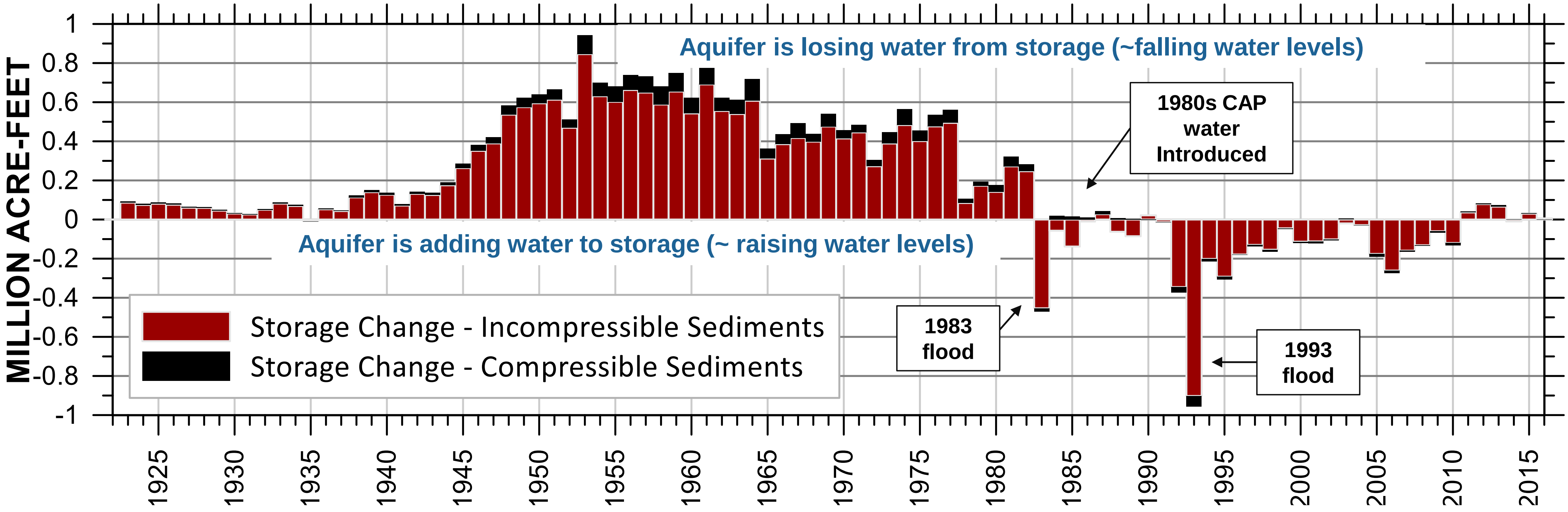
- Specific storage ranges in ADWR 2019 model appear to be reasonable for sedimentary basins
- Trends include:
  - Specific Storage decreases from layer 1 to layer 3
  - Incompressible sediments are approximately an order magnitude lower than compressible sediments
  - Inelastic storage is set to be 3 times greater than elastic storage for compressible sediments



* Based on effective stress in first transient period

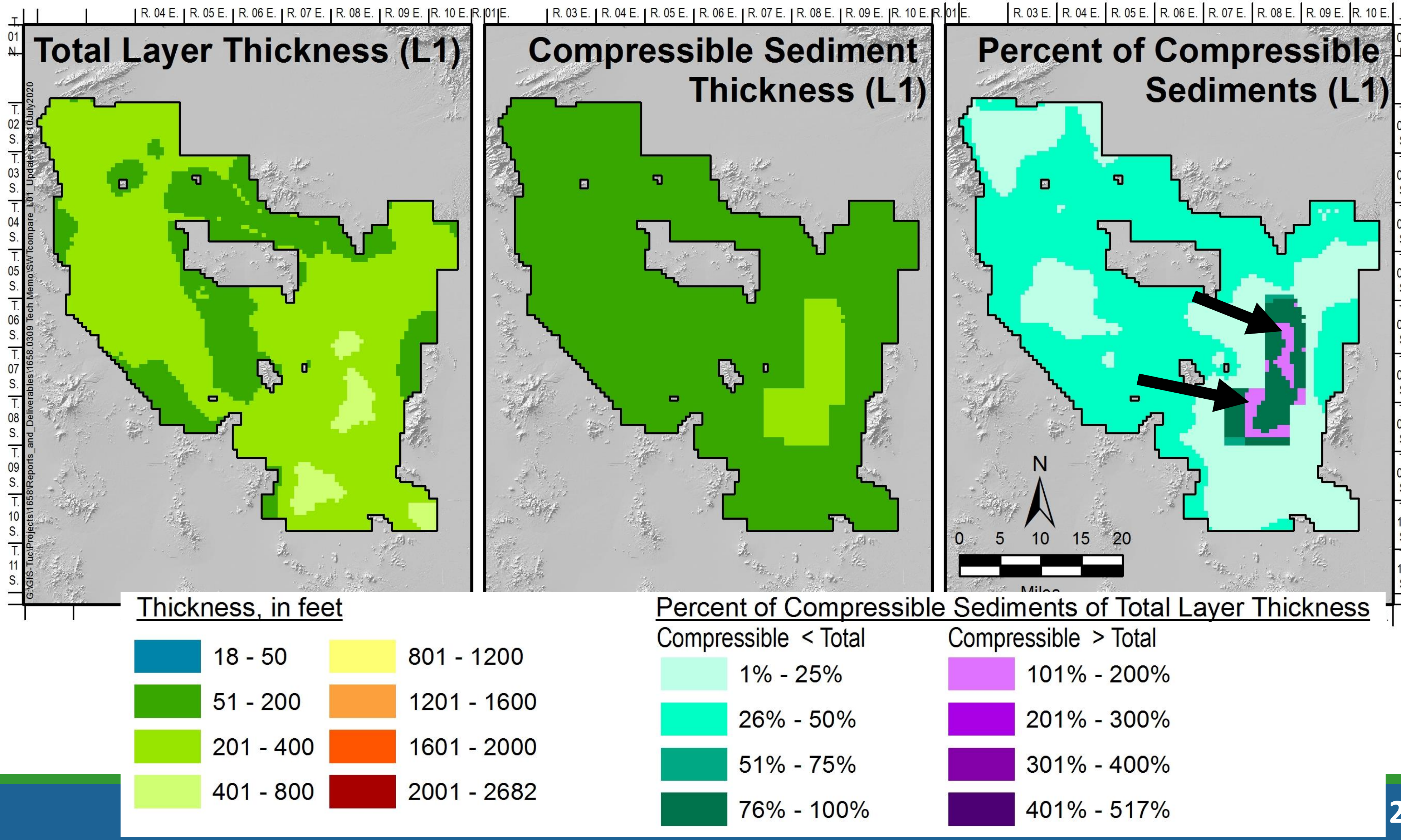
Changes in Total Aquifer Storage

- Between the years 1923 – 2015 about 13% of total storage release is from compressible beds



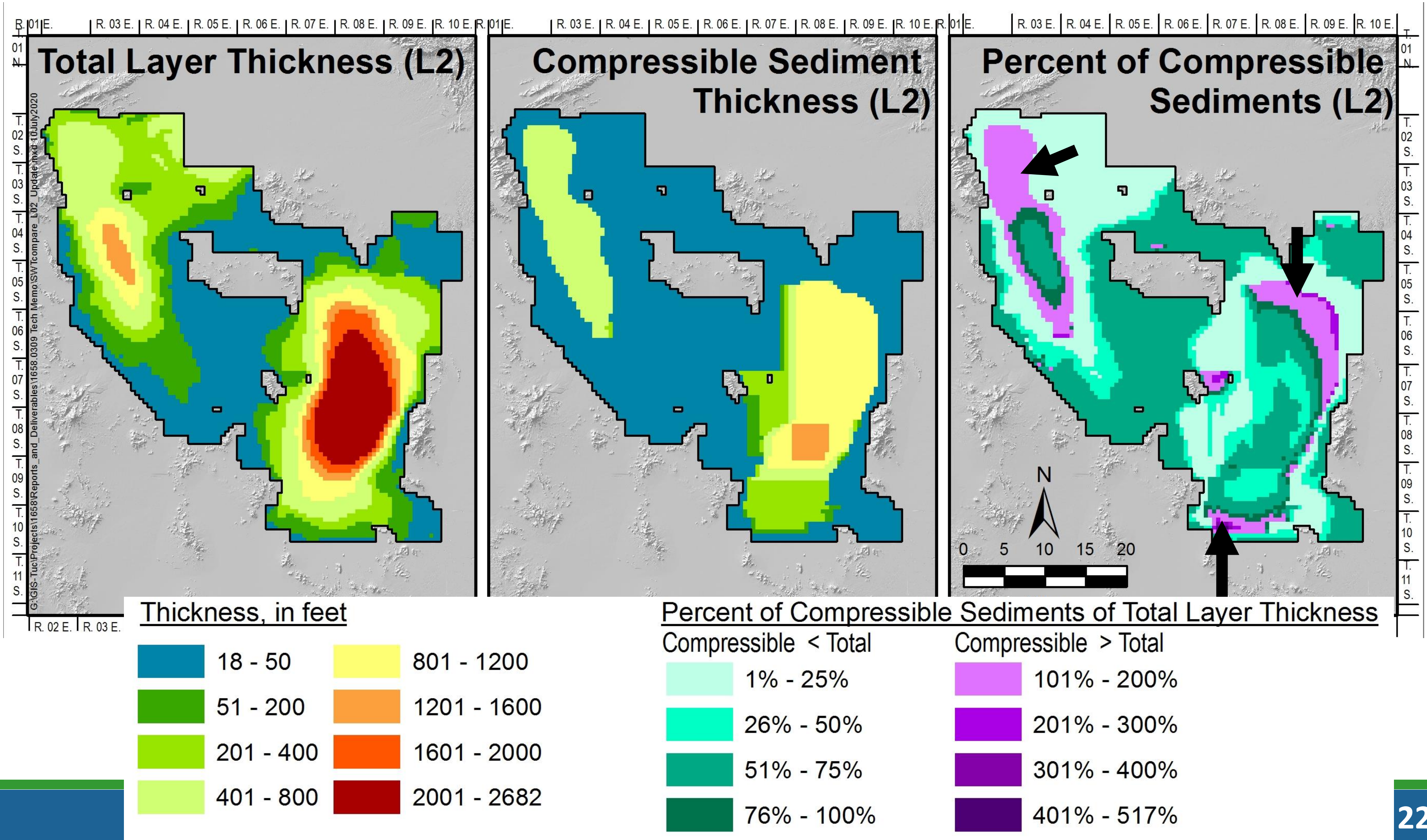
Review: Layer 1 Compressible Sediment Thickness

- Default value = 65 feet
- In some areas (purple), interbed thickness exceeds model layer thickness
- M&A 2020: adjusted the model by reducing thickness in these areas to equal 100%



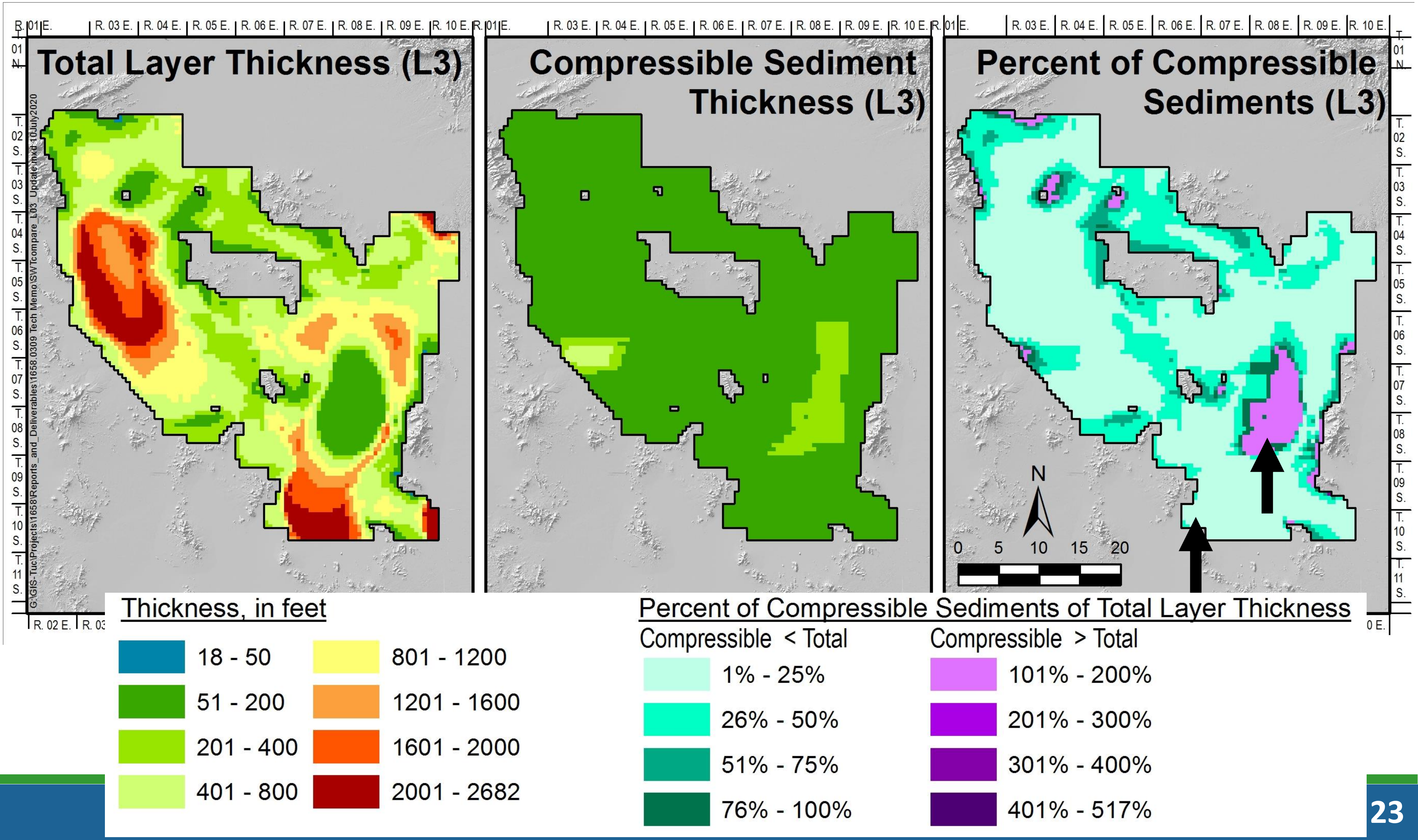
Review: Layer 2 Compressible Sediment Thickness

- Default value = 30 feet
- In some areas (purple), interbed thickness exceeds model layer thickness
- M&A 2020: adjusted the model by reducing thickness in these areas to equal 100%



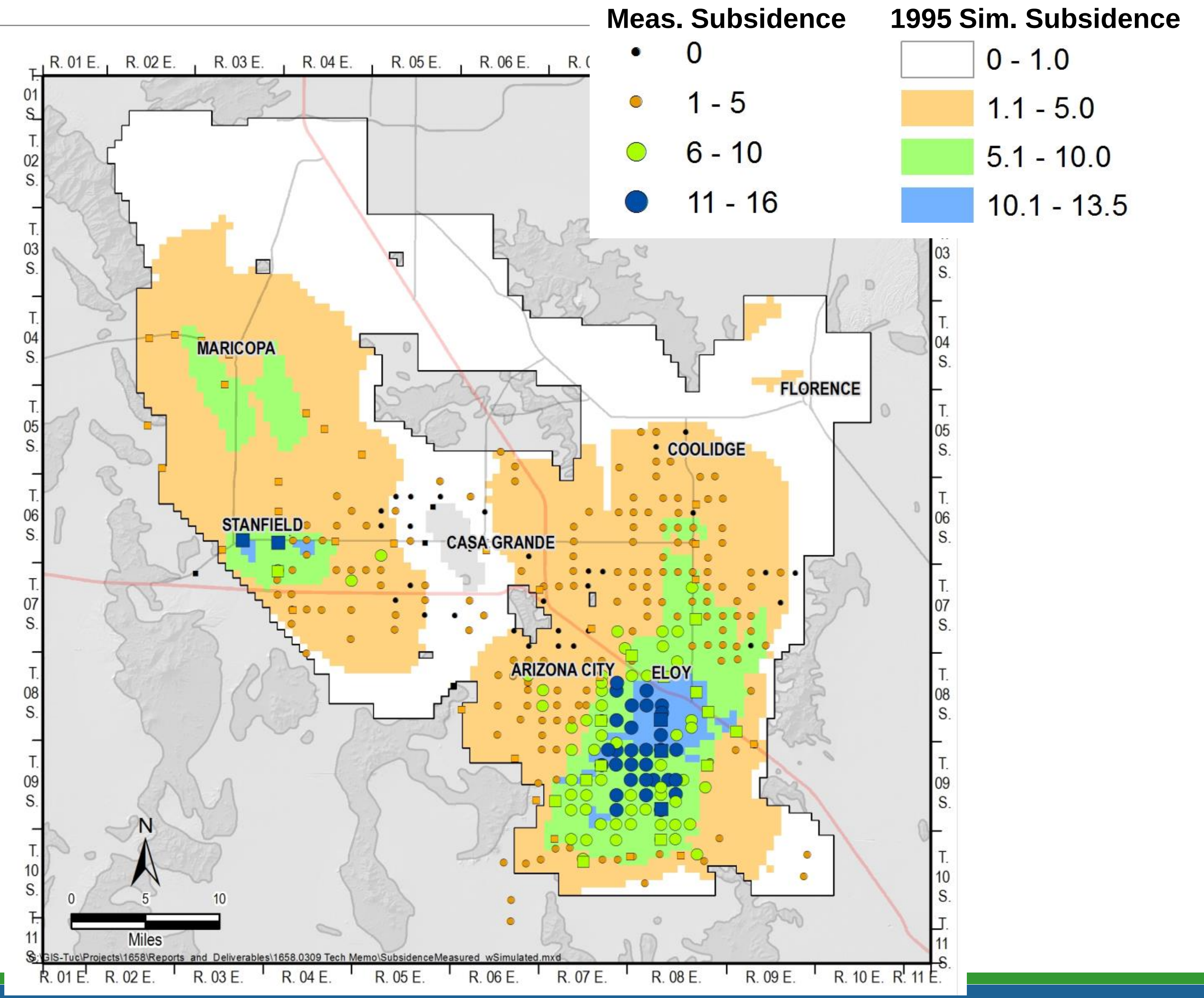
Review: Layer 3 Compressible Sediment Thickness

- Default value = 99 feet
- In some areas (purple), interbed thickness exceeds model layer thickness
- M&A 2020: adjusted the model by reducing thickness in these areas to equal 100%



Model Review: Measured vs Simulated Subsidence

- Conclusion: Simulated subsidence in model is consistent with measured subsidence data



- Break for Questions -

1. Review of Hydraulic Properties in Model

2. Review of Subsidence

3. Model 3-Year Update (2016 – 2018)

4. Review of Historical Model Performance with Updates

a. Summary of 3-year Update
b. Inflows
c. Outflows

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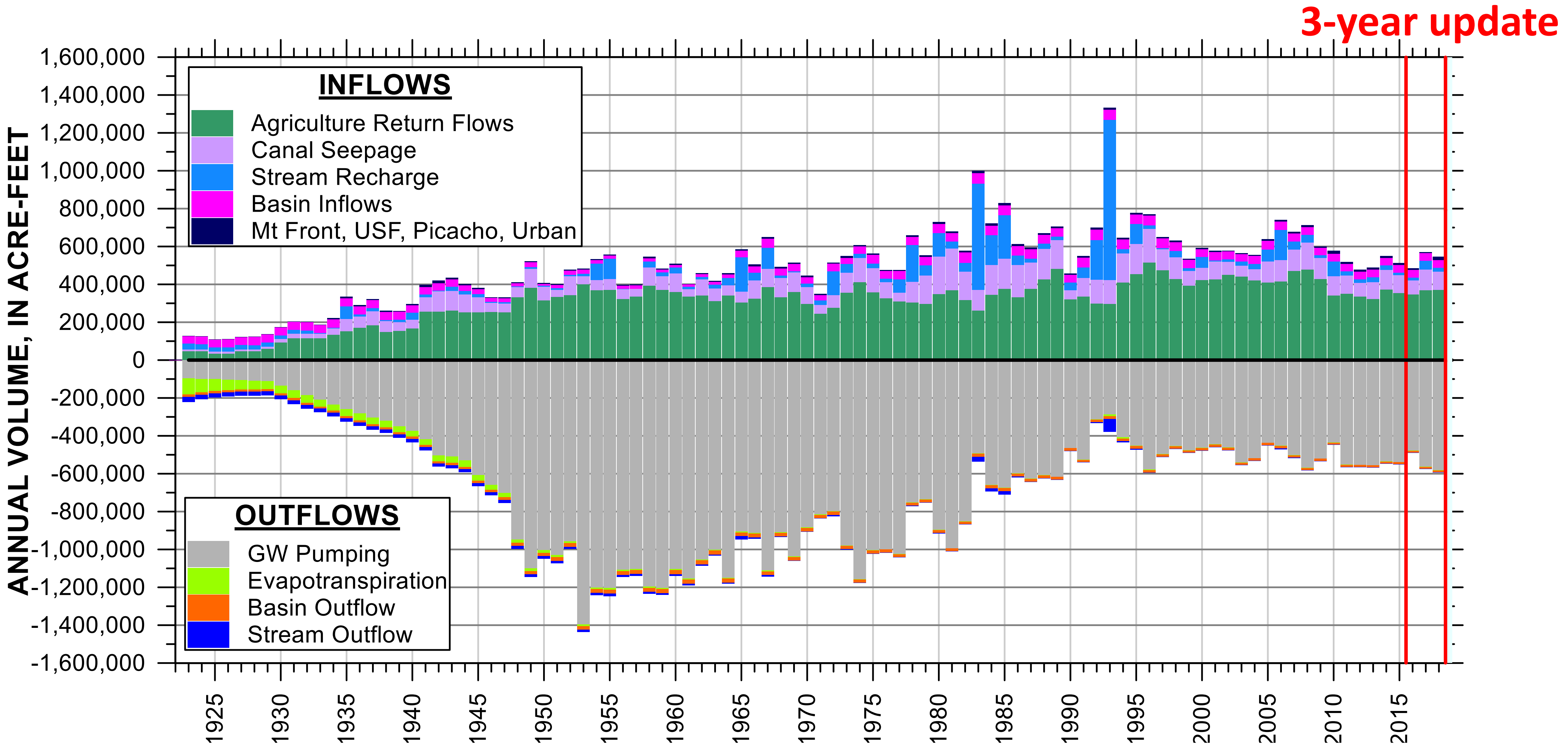
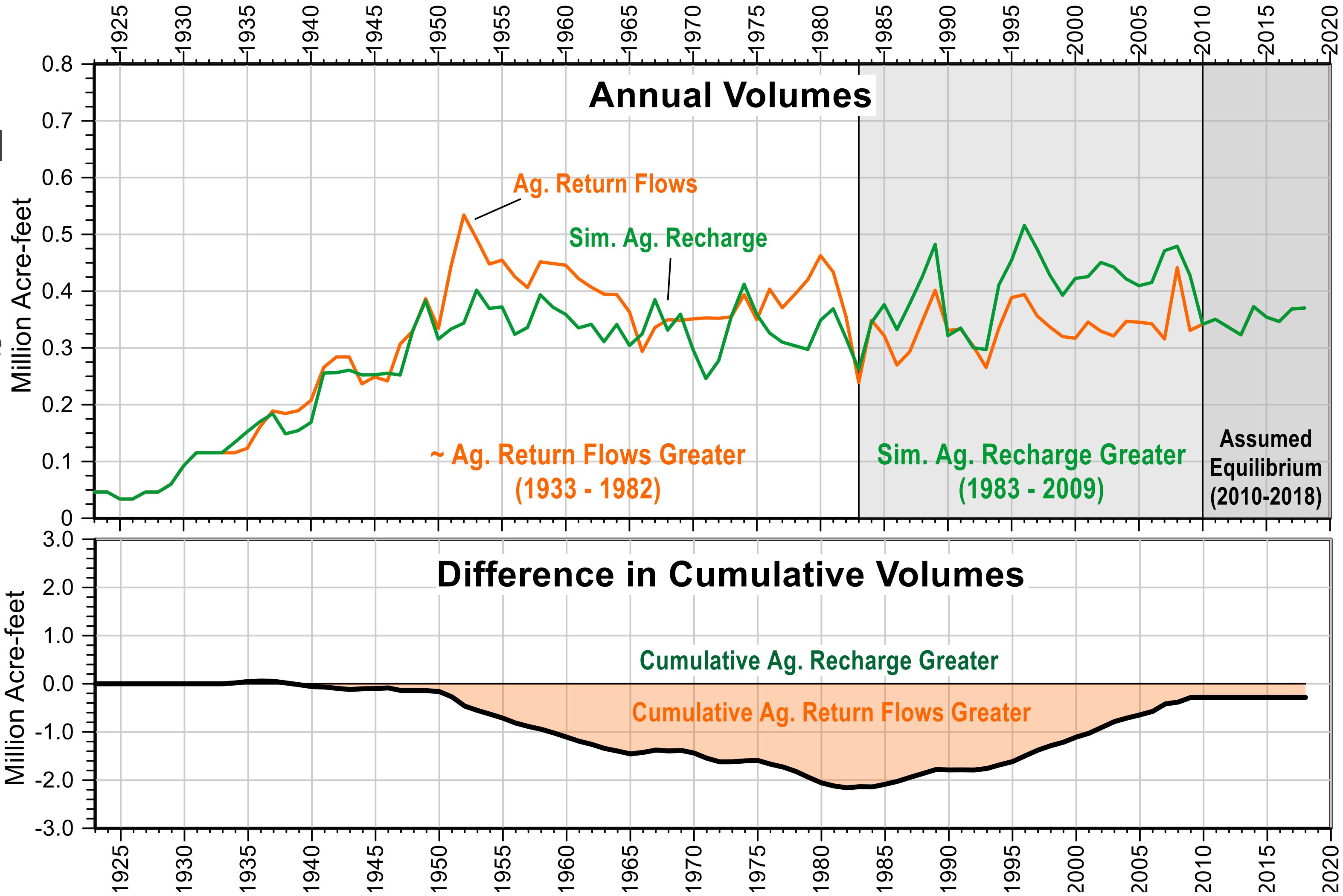
Summary of 3-Year Model Update (2016 – 2018)



Update Inflows: Agricultural Recharge

- Estimated Ag Return flows by ADWR for years 1923 – 2009 are updated from our previous presentation, based on further M&A review (shown right)
- 3-year update used similar method reported in ADWR 2019 model update
  - USDA cropland data rasters
  - Irrigation requirements by crop
  - Irrigation efficiency values
- 2010 – 2018: simulated aquifer recharge rates reachs an assumed equilibrium with estimated Ag Return flows



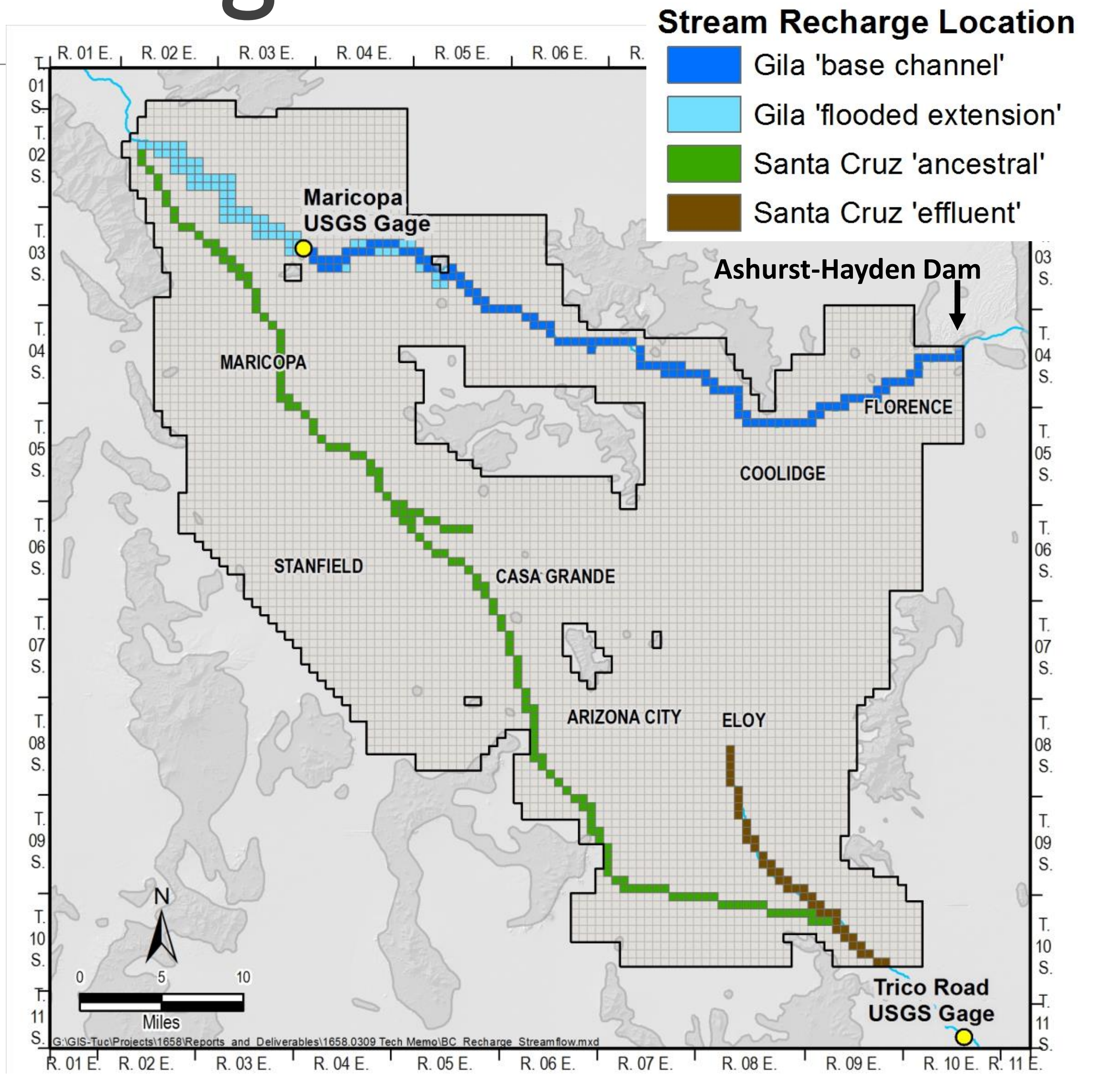
Update Inflows : Stream Recharge

Gila River

- Sourced from measured flow at Maricopa USGS gage and SCIP annual reports for flow at Ashurst-Hayden Dam
- Used same distribution from year 2015 in ADWR 2019 model (base channel conditions)

Santa Cruz River

- Sourced from Trico Road USGS gage
- Calculated infiltration loss along 7.1-mile stretch from Trico Road to edge of Pinal model (different method than described in ADWR 2019 model report)
- Used same distribution from year 2015 in ADWR 2019 model



Update Inflows : Canal Seepage and Picacho Reservoir

CAP Aqueduct

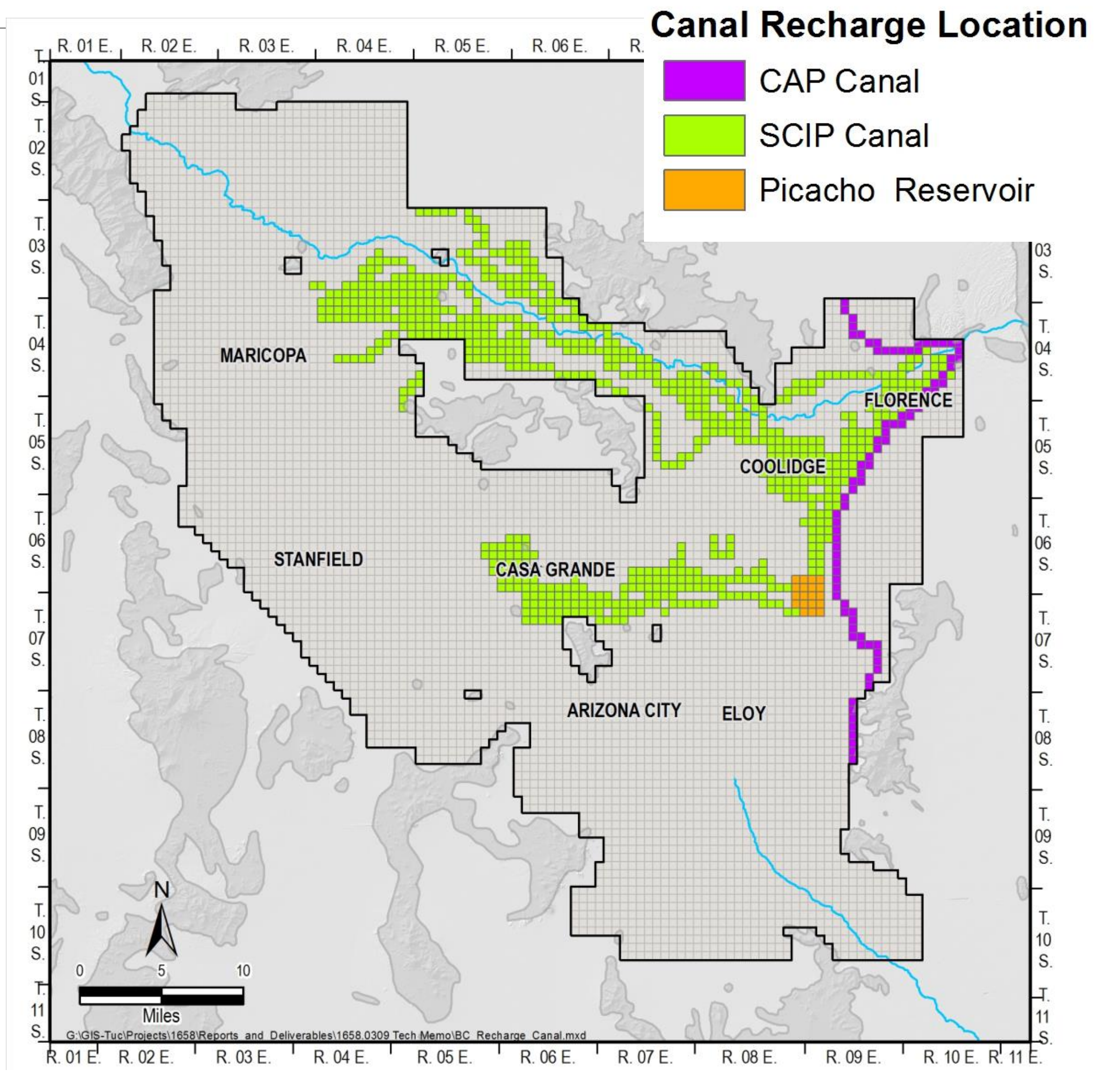
- Set at same constant rate used in ADWR 2019 model

San Carlos Irrigation Project (SCIP) Canals

- Total canal deliveries sourced from SCIP annual reports
- Assumed 37% seepage loss of total SCIP deliveries based on 10-year average seepage loss (2006-2015) in ADWR 2019 model
- Distribution similar to ADWR 2019 model

Picacho Reservoir

- Applied same seepage calculation method used in ADWR 2019 model
- Storage volumes sourced from SCIP annual reports



Update Inflows : Other Recharge

Underground Storage Facilities (USFs)

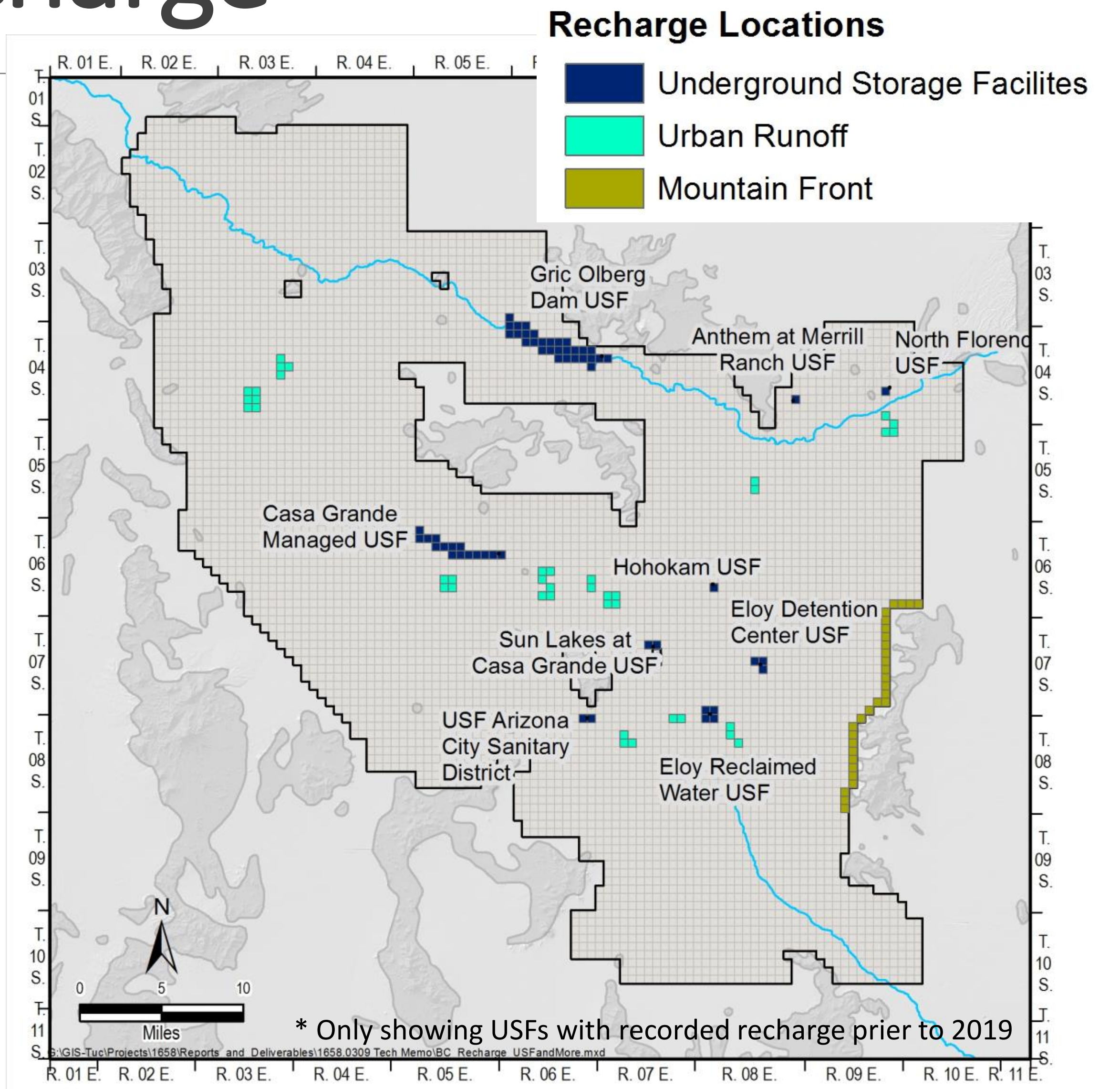
- Sourced from ADWR USF/GSF database
- Added GRIC USF (began recharging in 2015)
- Minor adjustments to historical distribution and volumes

Urban Runoff

- Same rate and location as year 2015 (3,182 AF/yr)

Mountain-Front Recharge

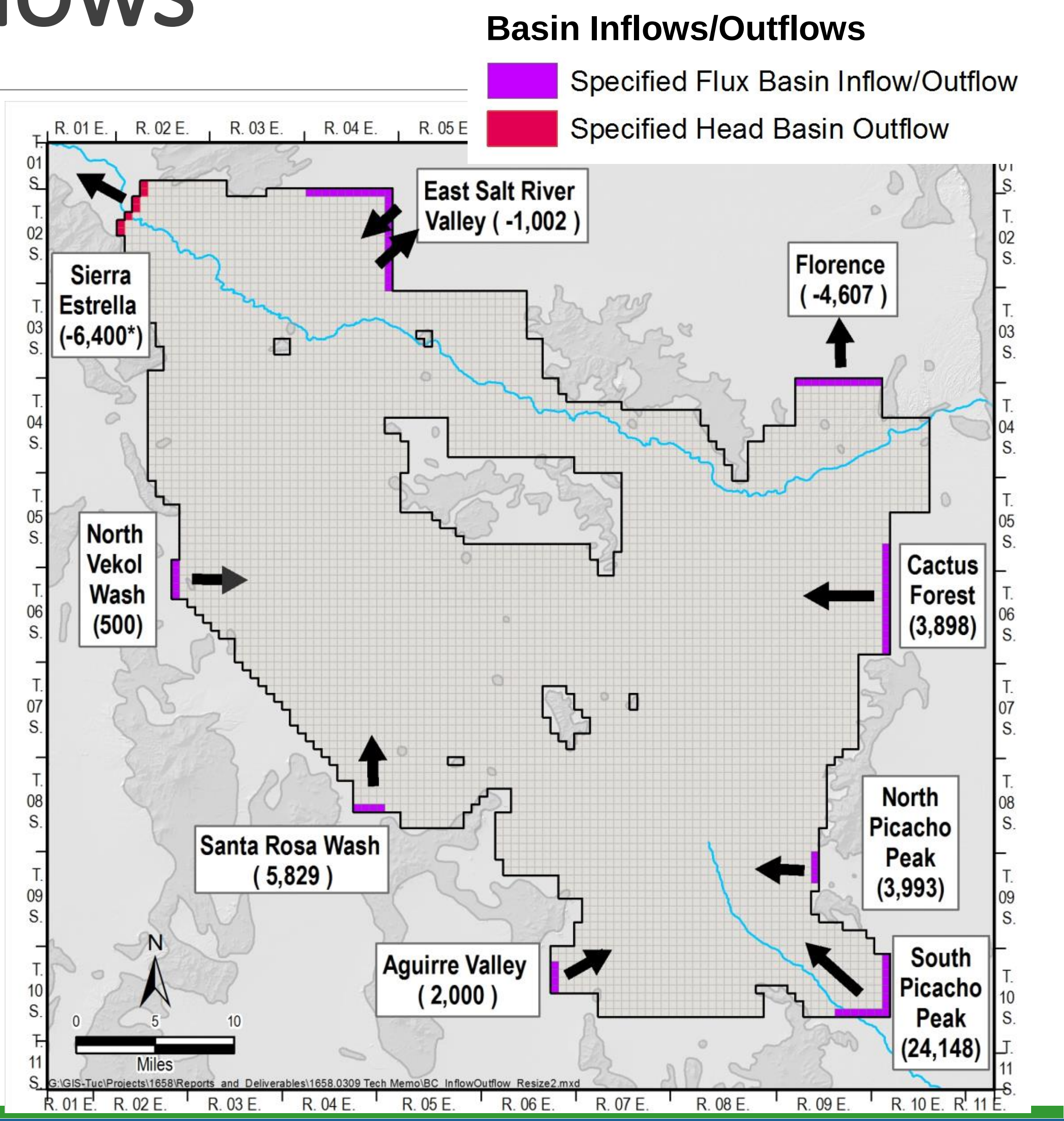
- Same rate and location as year 2015 (500 AF/yr)



* Only showing USFs with recorded recharge prier to 2019

Update: Basin Inflows/Outflows

- Maintained same constant rates and locations from year 2015
- Adjusted historical model
  - Restored inflows at dry cell locations (Santa Rosa Wash, Cactus Forest, Aguirre Valley)
  - Restored 93,000 AF of cumulative inflows over the 96- year model simulation period (1923 – 2018)



Update Outflows: Groundwater Pumping

Pumping from ADWR (78% of pumping in 3-year period)

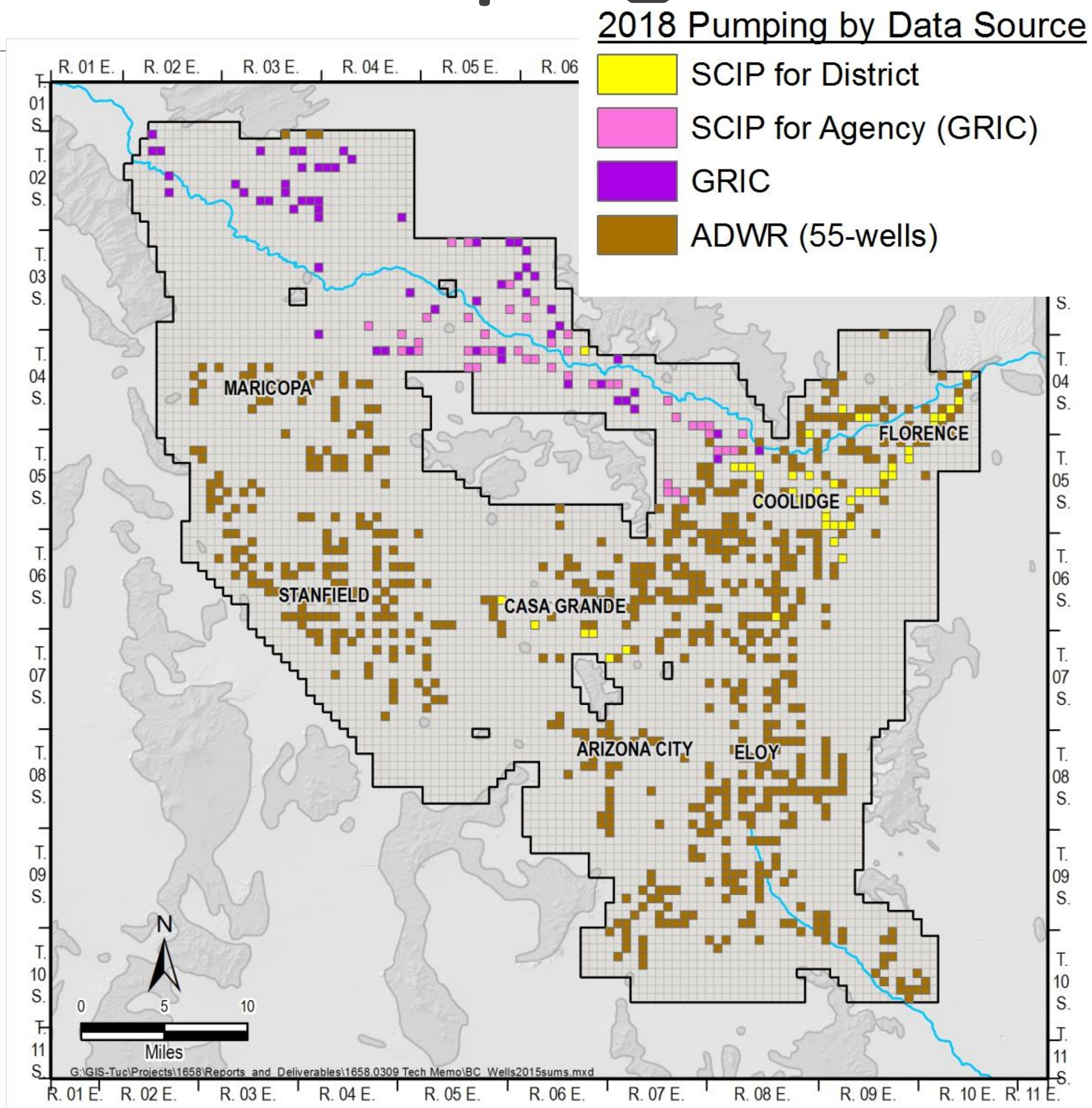
- Downloaded from ADWR web portal
- Used similar layer distribution from ADWR 2019 model

GRIC (12% of pumping in 3-year period)

- Sourced from GRIC (P. Mock)
- Improved location and volumes as compared to ADWR 2019 model

SCIP (10% of pumping in 3-year period)

- Sourced from SCIP, Bureau of Indian Affairs (A. Fisher)
- Improved location information as compared to ADWR 2019 model



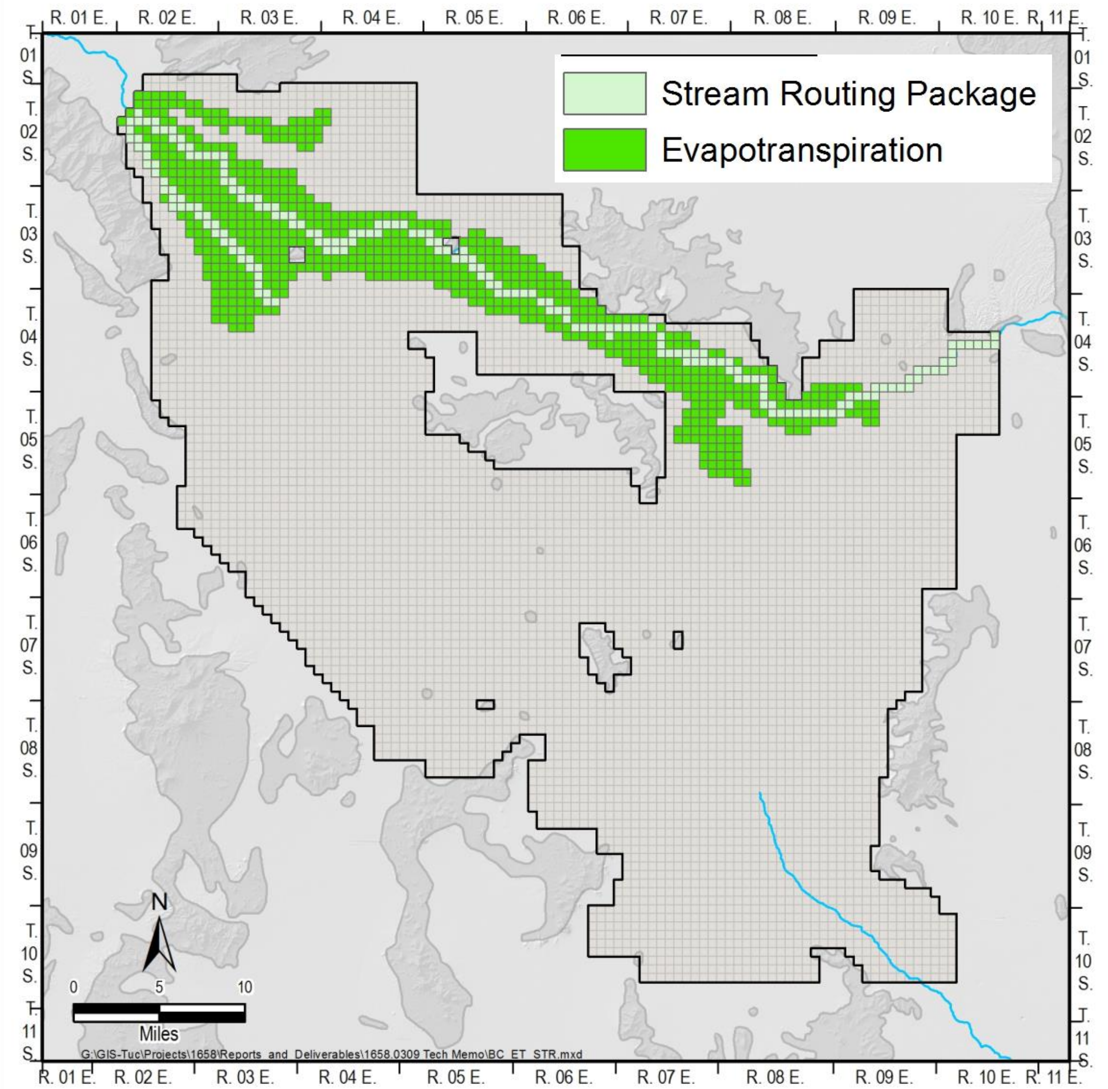
Update Outflows : Evapotranspiration and Stream Outflow

Evapotranspiration (ET)

- Calculated by model using EVT package
- Maintained same EVT model properties from ADWR 2019 model

Stream Outflow (STR)

- Calculated by model using STR package
- Maintained same STR model properties from ADWR 2019 model



1. Review of Hydraulic Properties in Model

2. Review of Simulated Subsidence

3. Model 3-Year Update (2016 – 2018)

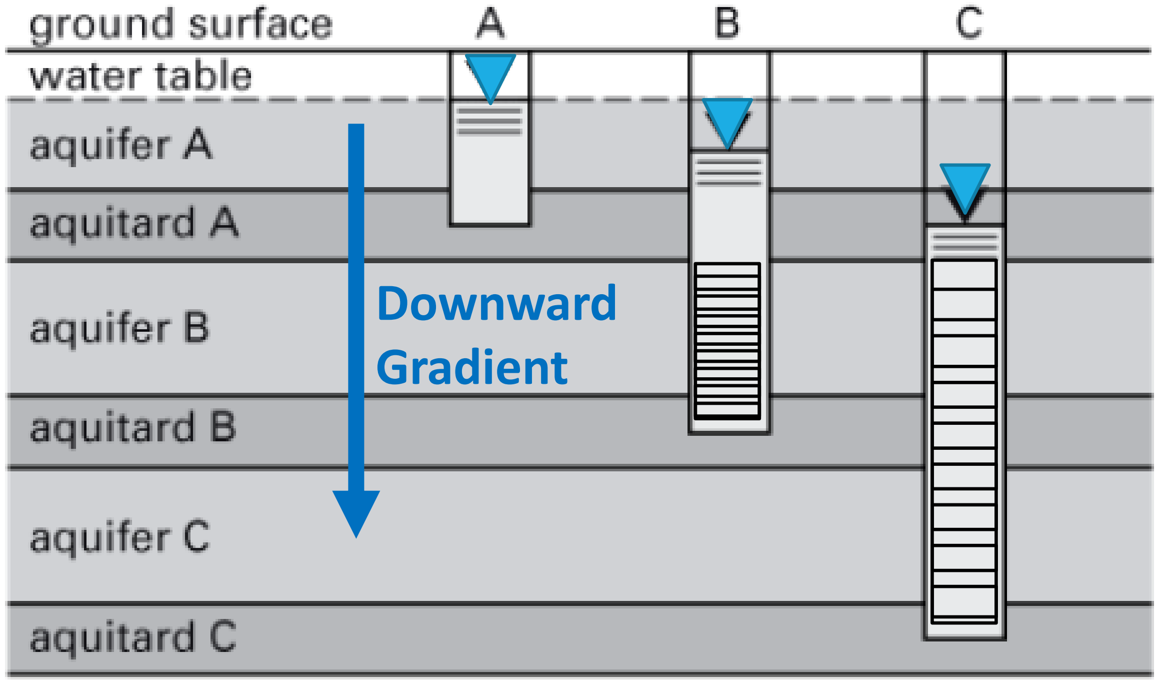
4. Review of Historical Model Performance with Updates

a. Methods to evaluate model calibration
b. Calibration statistics
c. Option to switch to MODFLOW NWT during predictive modeling

Calibration: Comparing Measured vs Simulated heads

- The substantial vertical gradients in 2019 ADWR model make calculating simulated heads across multiple layers challenging
- High vertical gradients occur due to deep Ag. pumping, shallow Ag. recharge and low vertical conductivies
- Wells screened across multiple layers requires consideration of how each layer is represented in that measured or simulated head
- Important to consider when comparing measured and simulated heads for calibration

Example of how water levels are affected by well screens crossing multiple aquifer layers

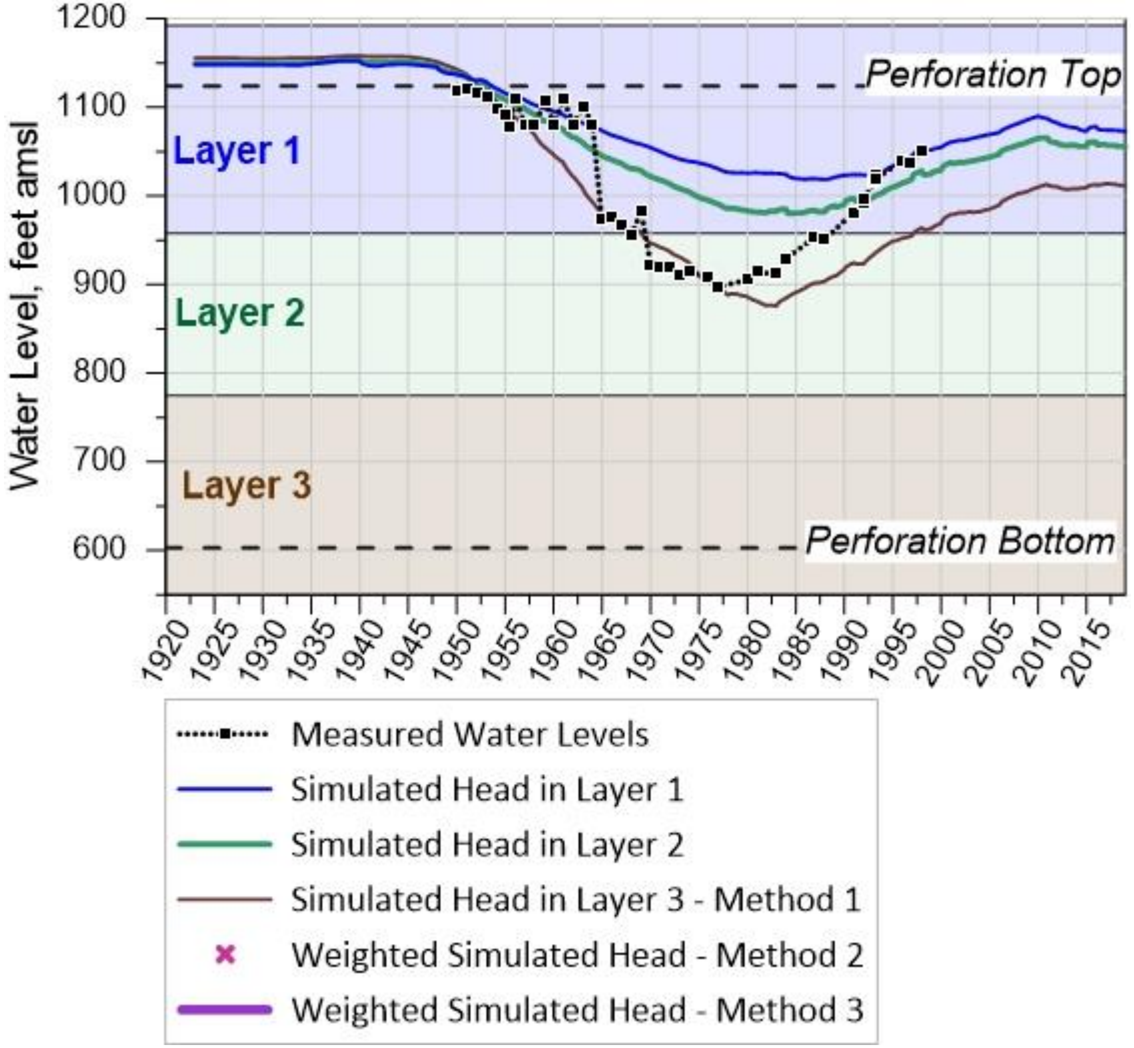


https://www.chegg.com/homework-help/questions-and-answers/following-figure-well-c-pumped-following-conclusions-plausible-regarding-vertical-gradient-q25053883

3 Methods for Sim. Heads Vs. Meas. Comparison in Model

Method 1 (brown line)

- ADWR (2014): selected single layer simulated head for calibration with no layer weighting



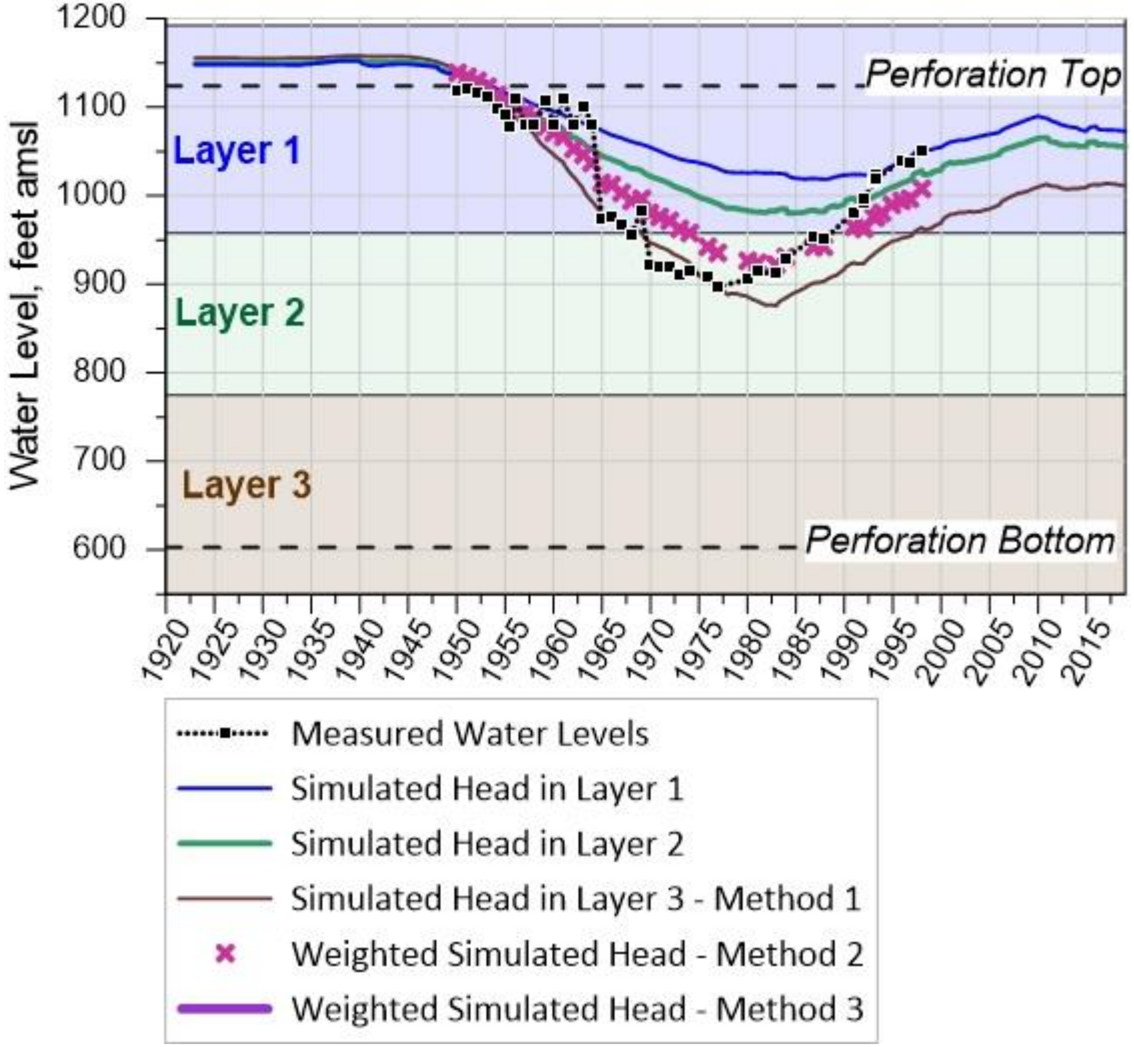
3 Methods for Sim. Heads Vs. Meas. Comparison in Model

Method 1 (brown line)

- ADWR (2014): selected single layer simulated head for calibration with no layer weighting

Method 2 (pink X's)

- ADWR (2019): weighted simulated heads for multiple layers limited by screened interval & measured saturated interval for calibration



3 Methods for Sim. Heads Vs. Meas. Comparison in Model

Method 1 (brown line)

- ADWR (2014): selected single layer simulated head for calibration with no layer weighting

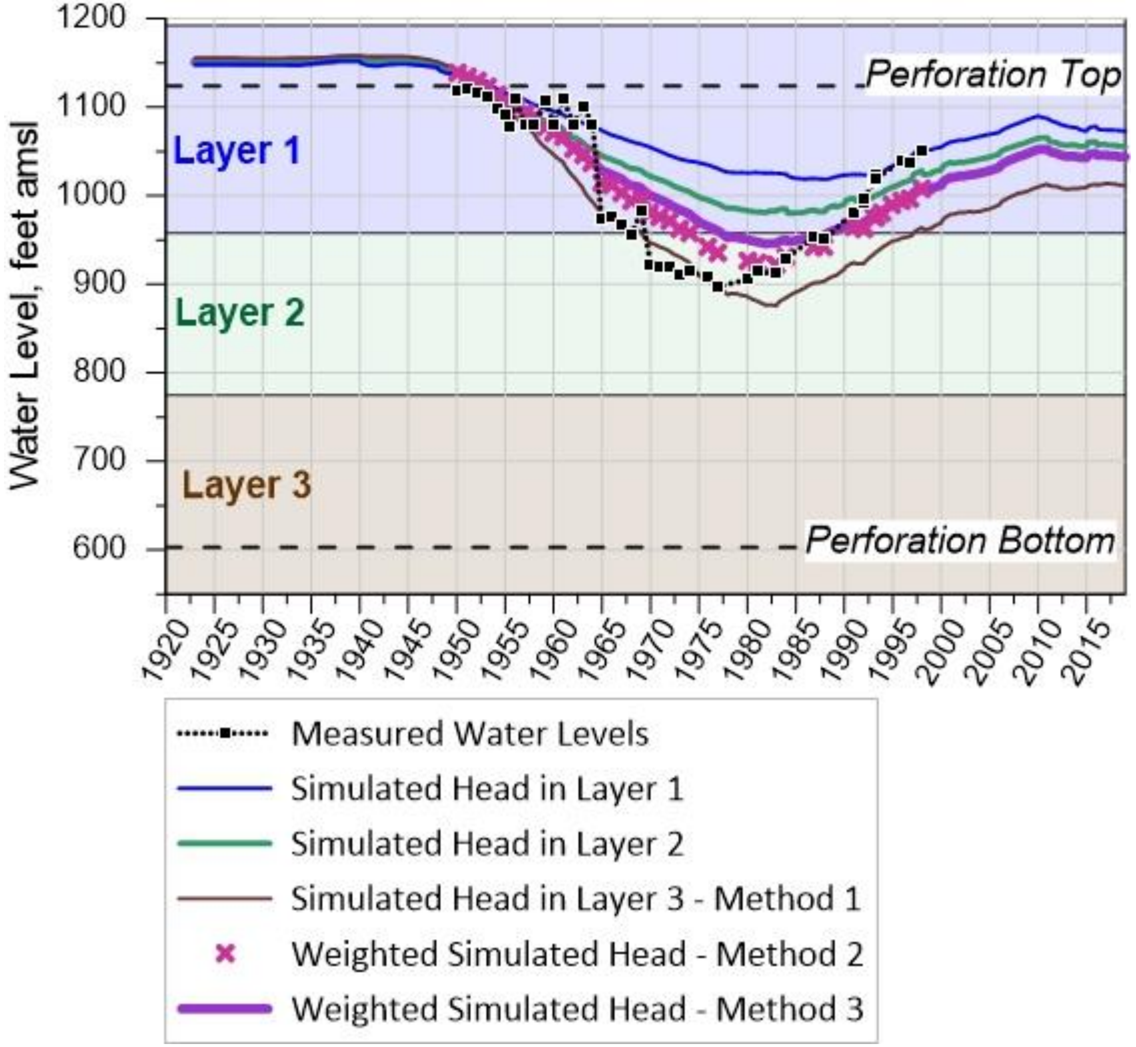
Method 2 (pink X's)

- ADWR (2019): weighted simulated heads for multiple layers limited by screened interval & measured saturated interval for calibration

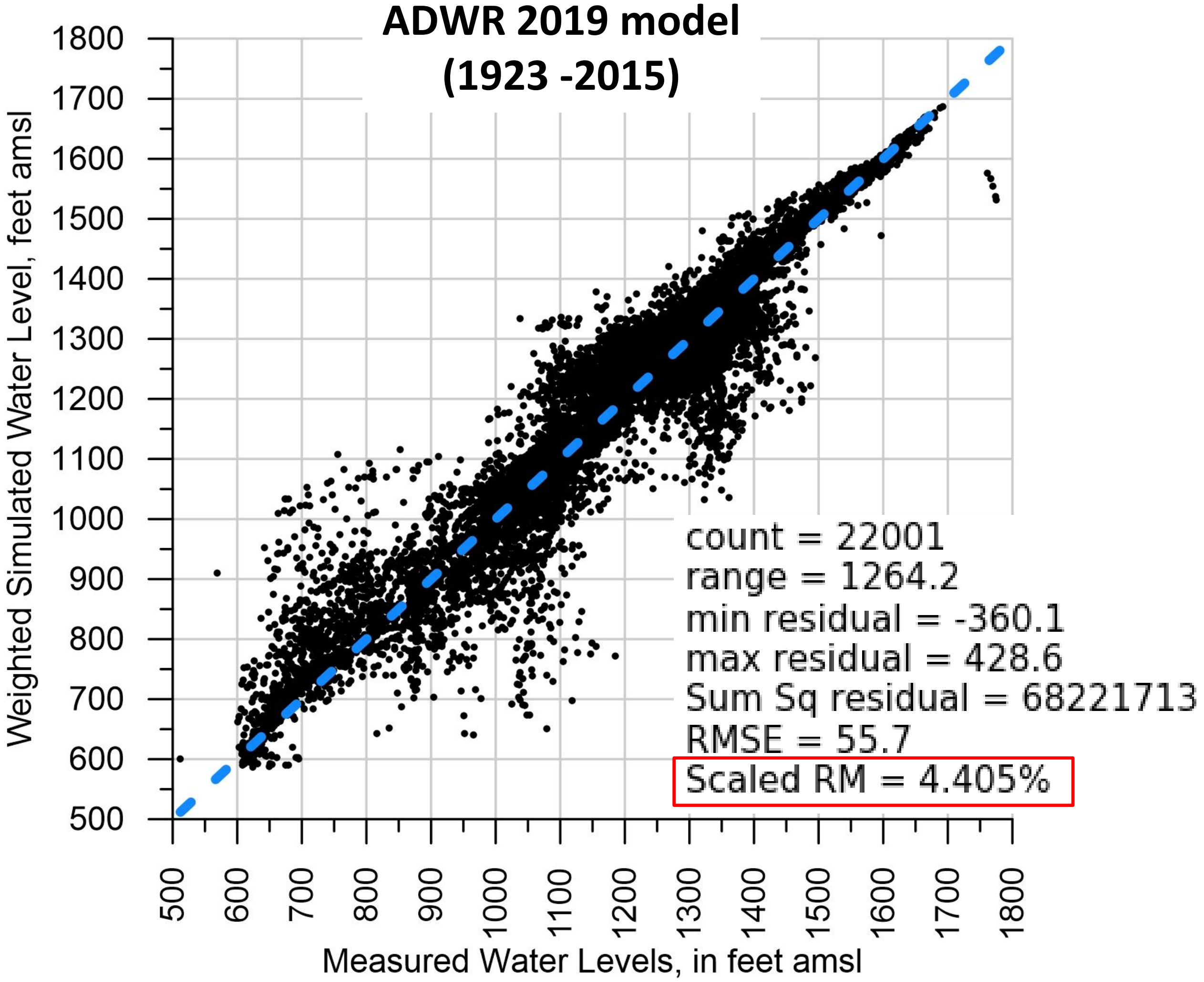
Method 3* (purple line)

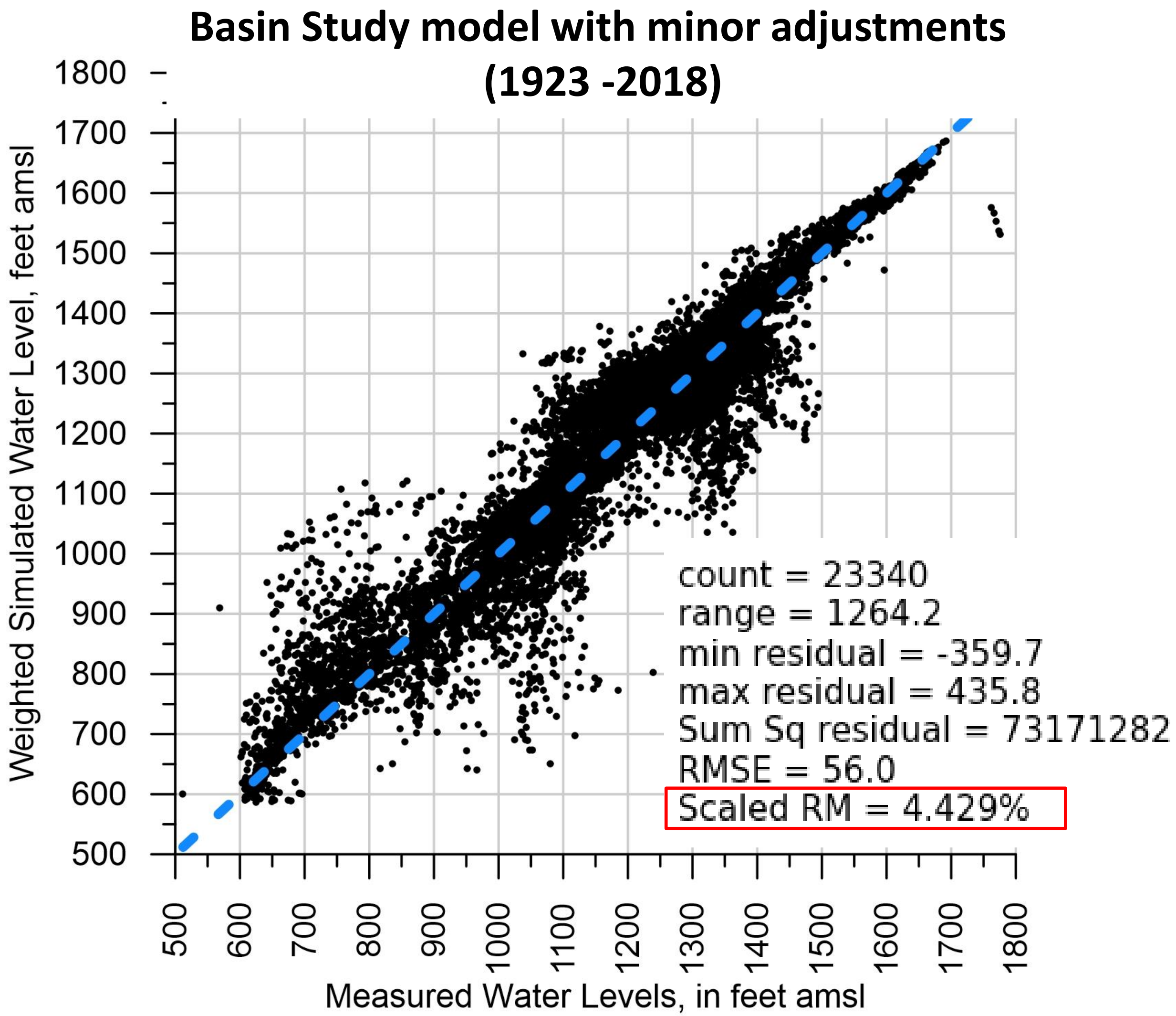
- M&A (2020): weighted simulated heads for multiple layers limited by screened interval & simulated saturated interval for calibration

* Used method 3 in following calibration stats.



Calibration: Changes resulted in negligible difference from ADWR 2019





Option of Switching to MODFLOW NWT

- **ADWR Predictive Model Demonstrated Dome Instability**
  - The numerical solution in MODFLOW 2005 version used by ADWR can be subject to stability problems with model cell drying/wetting
  - The ADWR historical model used a numerical convergence criteria of 0.1 feet, but the predictive model required a looser criteria of 13 feet for the solution to converge
  - We have not evaluated the ADWR predictive simulations, and make no implications about the effect of the larger convergence criteria; however, we recognize we may encounter some stability problems for predictive scenarios
- **Potential Option**
  - Switch to MODFLOW NWT version which could provide a more stable solution for predictive scenarios
  - We have not run predictive scenarios with any MODFLOW version
  - A preliminary MODFLOW NWT historical model simulation altered the calibration, but an initial assessment indicates parameters can be defensibly and easily adjusted to restore calibration, if NWT is needed

Conclusions and Next Steps

Conclusions

- Update showed no issues which warranted substantial model modification; made a few adjustments
- Model review has not identified concerns about model’s ability to meet study objectives
- Ready to proceed with predictive modeling

Next Steps

- Technical Memo documenting changes – October 2020
- Predictive model simulations (5)
  - Reclamation climate projections
  - CAP:SAM supply/demand

Questions and Discussion

Thank you!

Brittney Bates

Hale Barter

Juliet McKenna