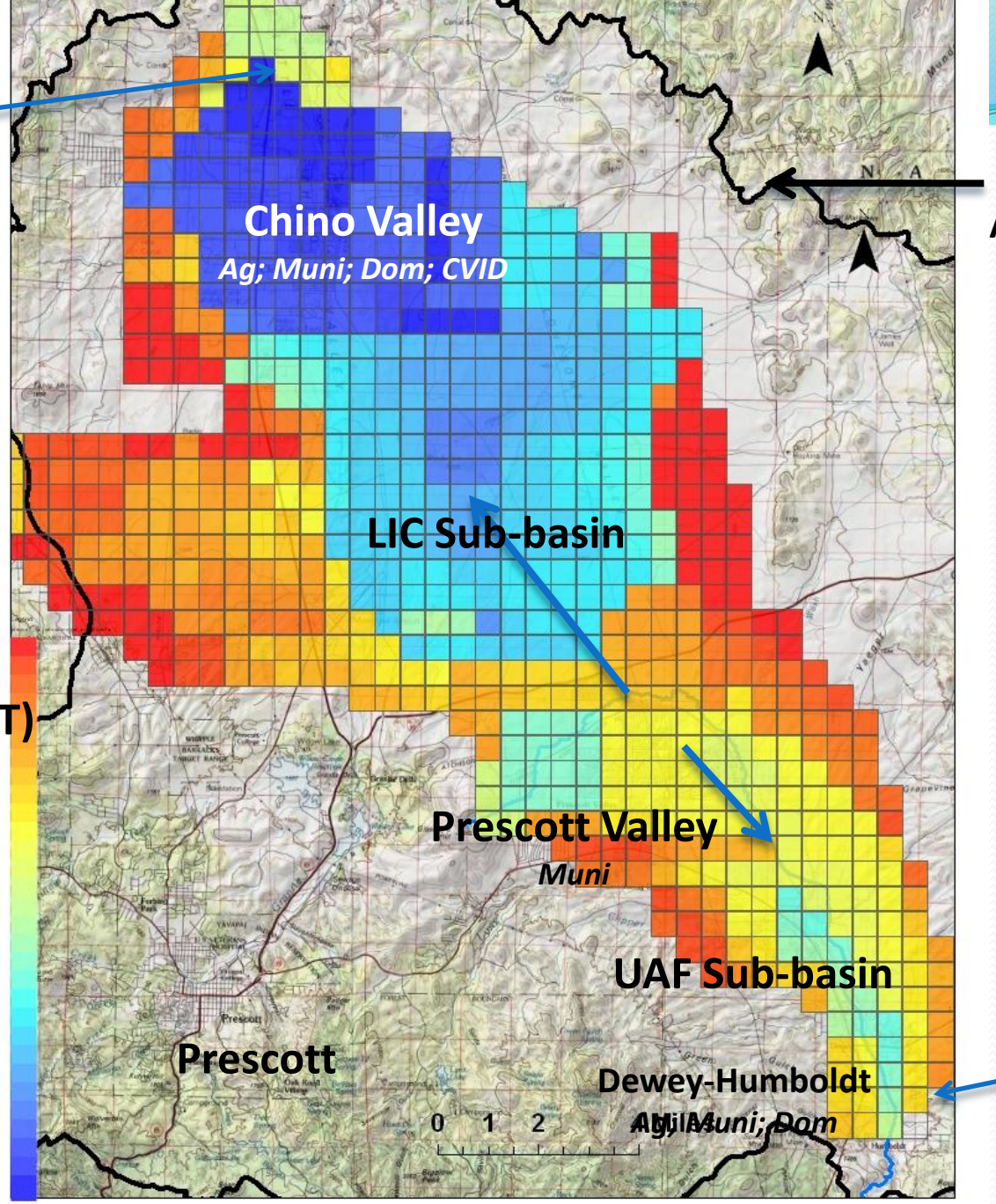
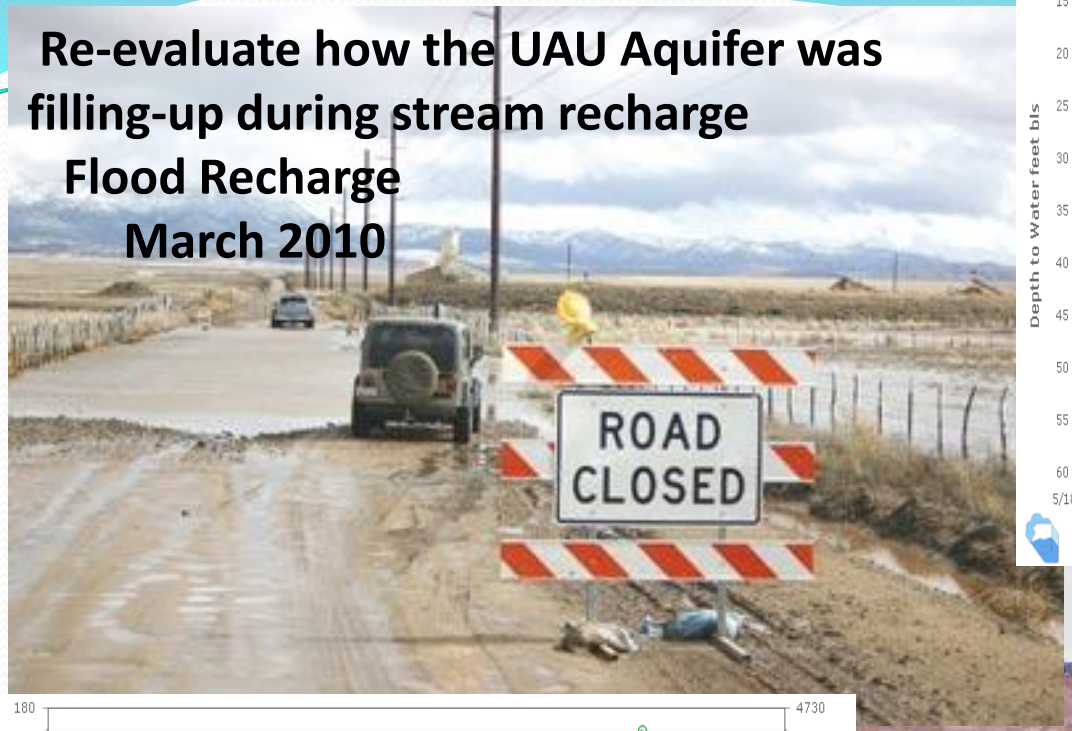
Provisional ADWR Prescott AMA Groundwater Flow Model

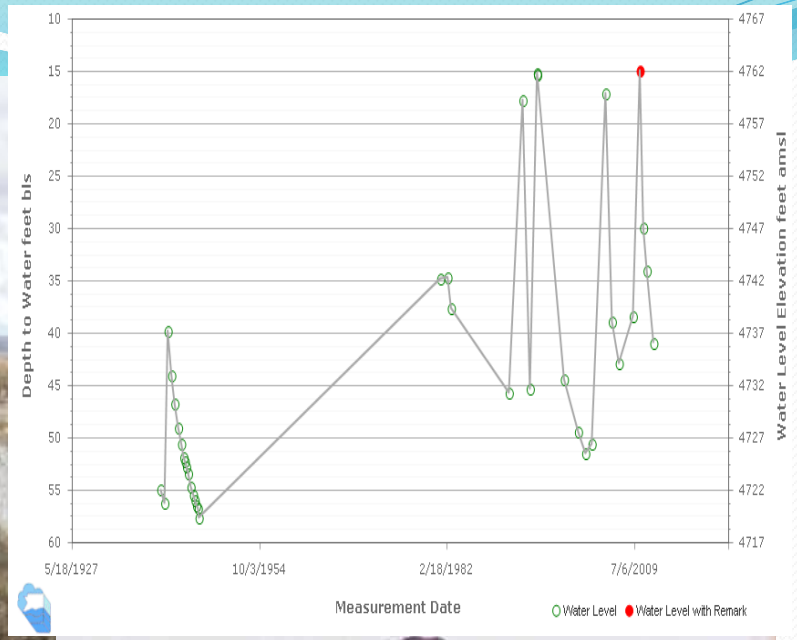
Natural Recharge Discussion (Continued…)

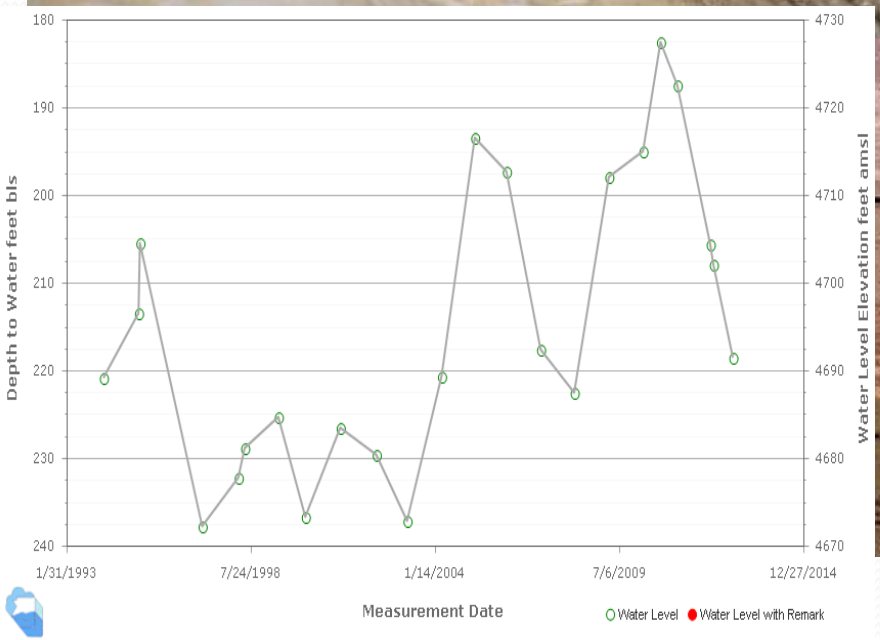

Del Rio Springs
Chino Valley
Ag; Muni; Dom; CVID
Prescott
AMA Boundary
LIC Sub-basin
Map Shows
Simulated Total
Transmissivity (T)
Low T in red
High T in Blue
Prescott Valley
Muni
UAF Sub-basin
Agua Fria
River
Baseflow
Prescott
Dewey-Humboldt
Ag; Muni; Dom
0 1 2

Re-evaluate how the UAU Aquifer was filling-up during stream recharge

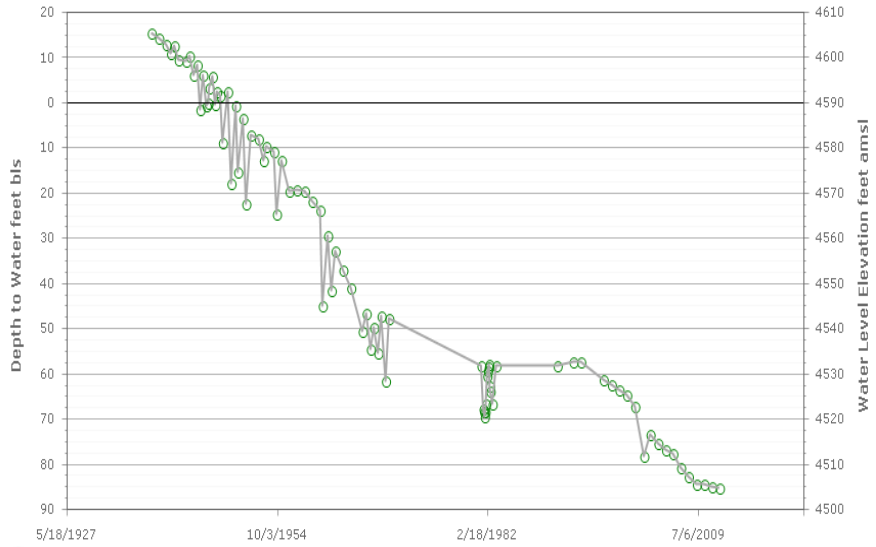
Flood Recharge March 2010

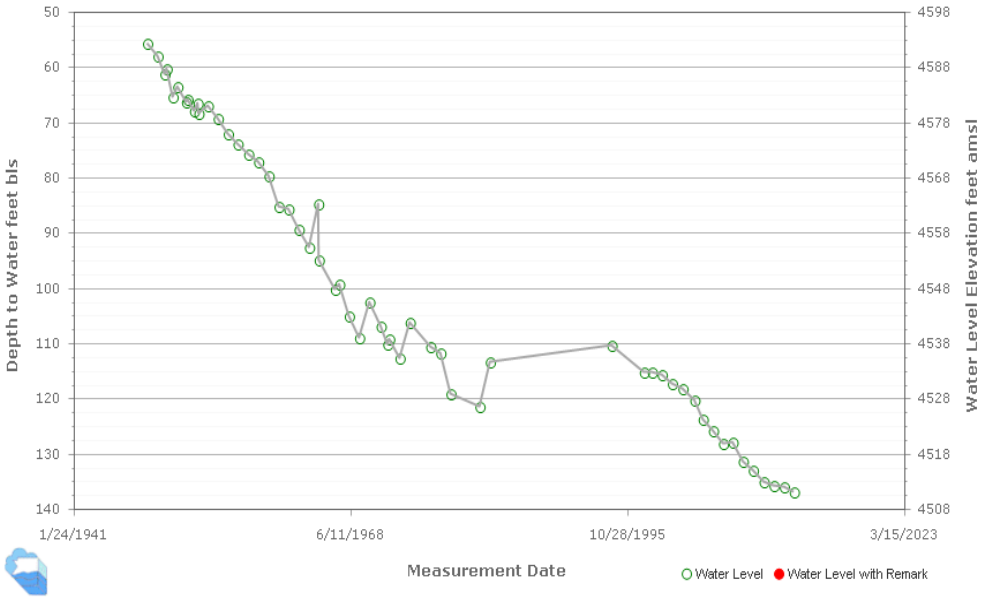


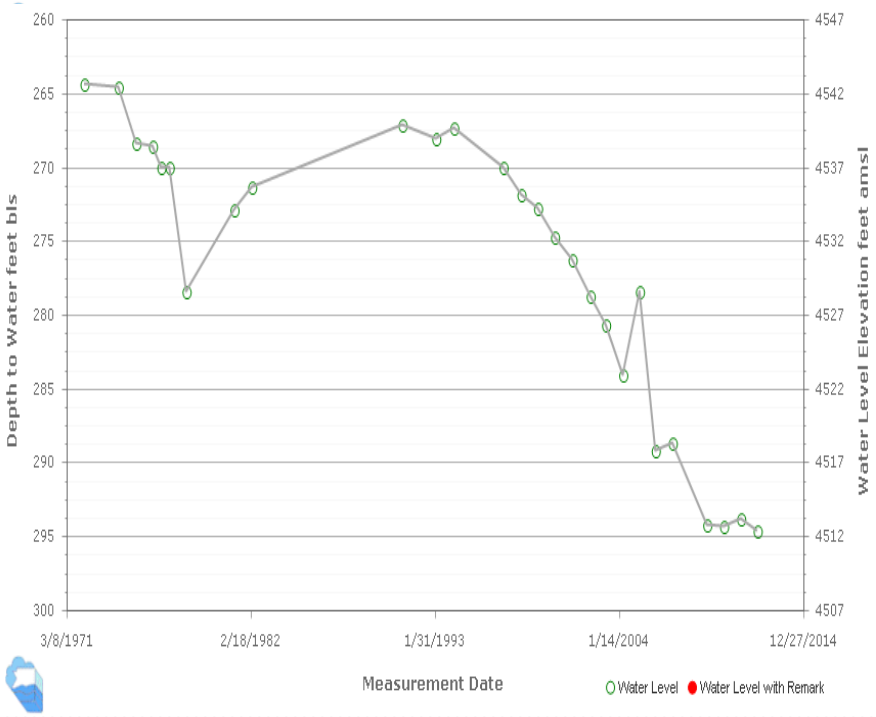




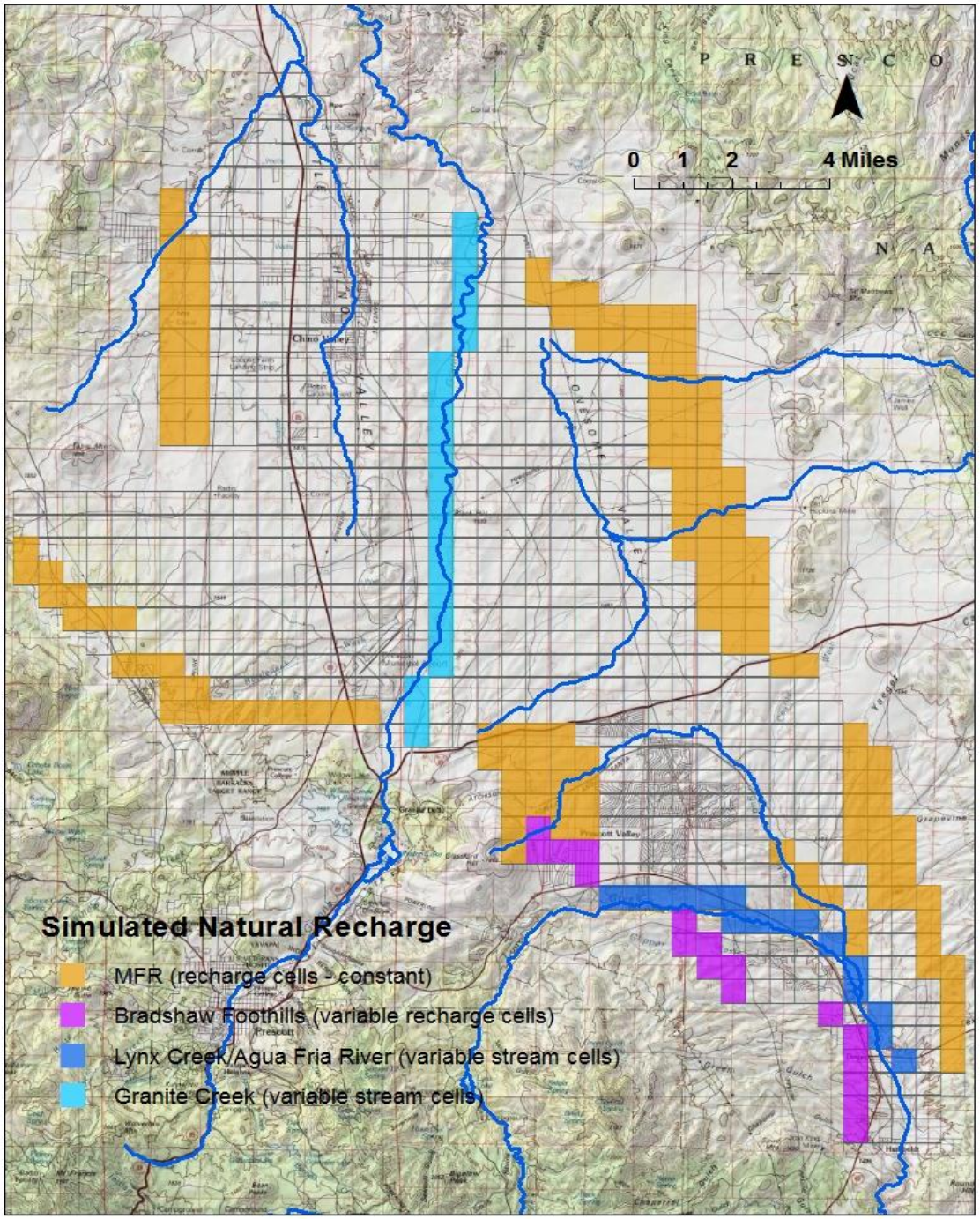
Flood Recharge Early 1995 →


Depth to Water feet bls
Water Level Elevation feet amsl
20
10
0
10
20
30
40
50
60
70
80
90
4610
4600
4590
4580
4570
4560
4550
4540
4530
4520
4510
4500
5/18/1927
10/3/1954
2/18/1982
7/6/2009


Depth to Water feet bls
Water Level Elevation feet amsl
50
60
70
80
90
100
110
120
130
140
4598
4588
4578
4568
4558
4548
4538
4528
4518
4508
1/24/1941
6/11/1968
10/28/1995
3/15/2023
Measurement Date
Water Level
Water Level with Remark


Depth to Water feet bls
Water Level Elevation feet amsl
260
265
270
275
280
285
290
295
300
4547
4542
4537
4532
4527
4522
4517
4512
4507
3/8/1971
2/18/1982
1/31/1993
1/14/2004
12/27/2014
Measurement Date
Water Level
Water Level with Remark


Depth to Water feet bls
Water Level Elevation feet amsl
340
345
350
355
360
365
370
375
380
385
390
4573
4568
4563
4558
4553
4548
4543
4538
4533
4528
4523
3/25/1960
3/8/1971
2/18/1982
1/31/1993
1/14/2004
Measurement Date
Water Level
Water Level with Remark



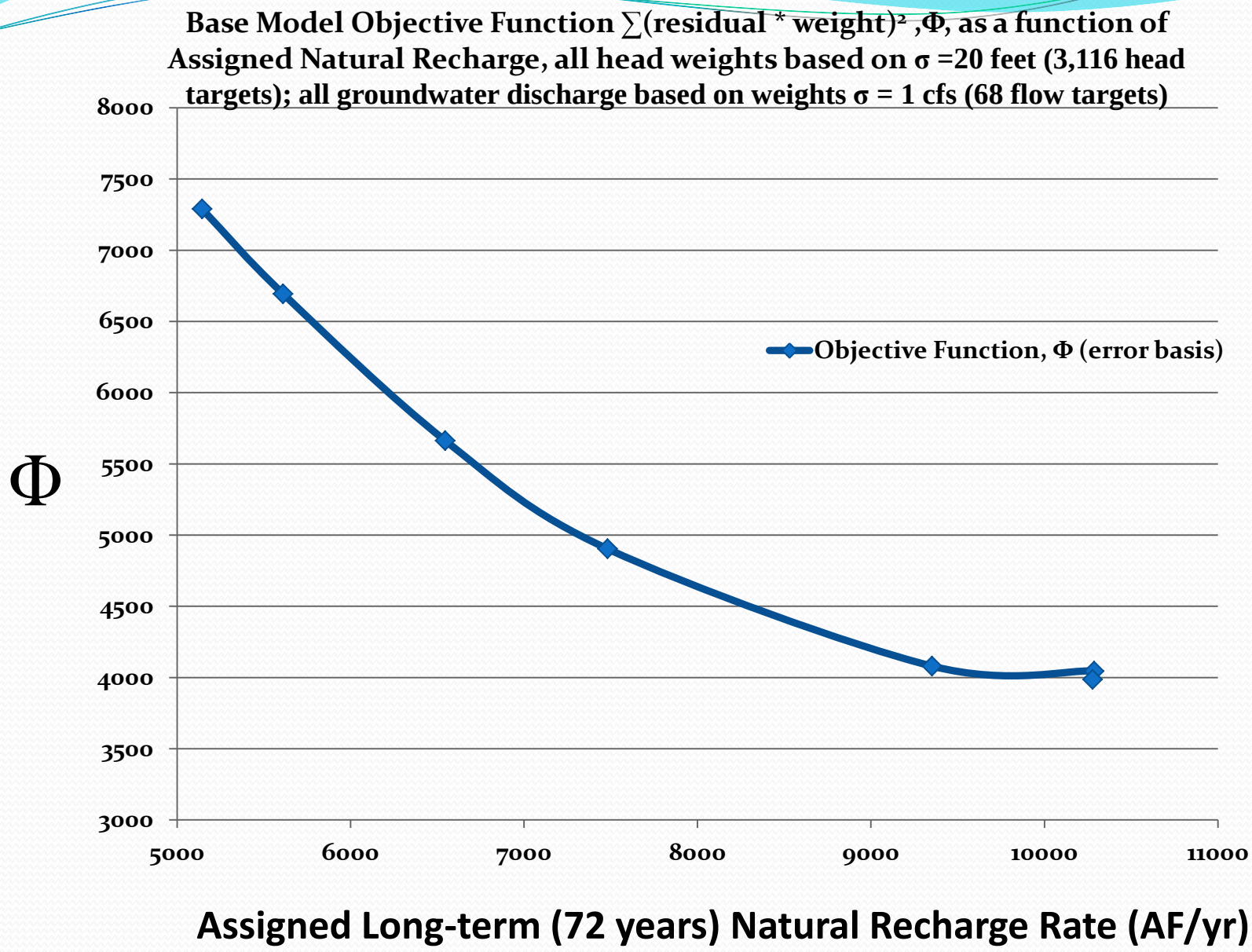
Prescott AMA Groundwater Flow Model & Recharge Discussion (…Continued)

Plausible Range of Natural Recharge Based on available data: 7,500 – 12,000 AF/yr

"Base Model"
Long-Term Natural Recharge Rate ~70% Variable Streams ~30% Uniform MFR

Transient 1939-2011		AF/yr
MFR	=	2,558
Upper Agua Fria River	=	379
Granite Creek	=	3,524
Lynx/Agua Fria	=	2,593
Bradshaw FootHills	=	870
Total Natural Recharge	=	9,924

5) Simulated Water budgets 1939-2011; 1941-65; 1965-95; 1995-2011
6) Observed and Simulated Heads & Flows
7) Alternative Conceptual Models (K & RCH)
8) Parameter reliability


Base Model Objective Function ∑(residual * weight)² ,Φ, as a function of Assigned Natural Recharge, all head weights based on σ =20 feet (3,116 head targets); all groundwater discharge based on weights σ = 1 cfs (68 flow targets)
Φ
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
5000
6000
7000
8000
9000
10000
11000
Objective Function, Φ (error basis)
Assigned Long-term (72 years) Natural Recharge Rate (AF/yr)

Simulated Water Budget, Long-term rates (1939-2011)

1939-1941----------1965----------1995-------2011

Simulated Water Budget - *Long-term* (1939-2011):Annualized Rates in AF/yr for 1939-2011 period (72 years) Long-term (1939-2011) Natural Recharge Rate = 10,000 AF/yr		
Simulated Inflow Component	**IN AF/yr**	**IN AF/yr**
Storage		19070
Agricultural-related Recharge	7760	12700
Artificial Recharge	1210	
Natural Recharge (recharge cells)	***3700***	
Natural Recharge* (stream cells[1])		***6300***
Total Inflow		**38070**
Simulated Outflow Component		**Out AF/yr**
Storage		13010
Pumping		17700
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1730
Underflow UAF** Sub-basin		1140
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River		3630
Total Outflow		**38010**
Net Change-in-Storage: Long-term (1939-2011) Annualized Rate of Water Lost from Storage		**6,060**

*Head-dependent boundaries.**Specified flux - uniform long-term underflow rates. [1]This predominately losing reach has a small rate of groundwater discharge out contained in the streamflow out term. [2]This predominately gaining reach has a small rate of stream inflow contained within the Natural Recharge (stream cells).

Simulated Water Budget, 1941-1965

1939-1941----------1965----------1995--------2011

Simulated Water Budget: Dry Period: 1941-1965; Annualized Rates for 1941-1965 (24-year period) **Annualized Natural Recharge Rate (1941-1965) = 4,030 AF/yr – "Dry" period**		
Simulated Inflow Component	**IN AF/yr**	**IN AF/yr**
Storage		18350
Agricultural-related Recharge	9640	12650
Artificial Recharge	0	
Natural Recharge (recharge cells)	***3010***	
Natural Recharge* (stream cells[1])		***1020***
Total Inflow		**32020**
Simulated Outflow Component		**Out AF/yr**
Storage		8600
Pumping		15300
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1940
Underflow UAF** Sub-basin		1140
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River		4170
Total Outflow		**31950**
Net Change-in-Storage: Annualized (1941-1965) Rate of Water Lost from Storage		**9,750**

*Head-dependent boundaries. **Specified flux – uniform long-term underflow rates. [1]This predominately losing reach has a small rate of groundwater discharge out contained in the streamflow out term. [2]This predominately gaining reach has a small rate of stream inflow contained within the Natural Recharge (stream cells).

Simulated Water Budget, 1965-1995

1939-1941----------1965----------1995--------2011

Simulated Water Budget: Wet Period: 1965-1995; Annualized Rates for 1965-1995 (30 year period) **Annualized Natural recharge Rate (1965-1995) = 14,940 AF/yr – "Wet" period**		
Inflow Component	**IN AF/yr**	**IN AF/yr**
Storage		19400
Agricultural-related Recharge	9320	14410
Artificial Recharge	550	
Natural Recharge (recharge cells)	***4540***	
Natural Recharge* (stream cells[1])		***10400***
Total Inflow		**44210**
Outflow Component		**Out AF/yr**
Storage		18850
Pumping		18400
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1650
Underflow UAF** Sub-basin		1130
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River		3700
Total Outflow		**44530**
Net Change-in-Storage: Annualized (1965-1995) Rate of Water Lost from Storage		**550**

*Head-dependent boundaries. **Specified flux – uniform long-term underflow rates. [1]This predominately losing reach has a small rate of groundwater discharge out contained in the streamflow out term. [2]This predominately gaining reach has a small rate of stream inflow contained within the Natural Recharge (stream cells)[2].

Simulated Water Budget, 1995-2011

1939-1941----------1965----------1995-------2011

Simulated Water Budget: 1995-2011 (Annualized Rates for 1995-2011) Annualized Natural recharge Rate (1995-2011) = 9,380 AF/yr		
Inflow Component	**AF/yr**	**In Af/yr**
Storage		20550
Agricultural-related Recharge	2860	10260
Artificial Recharge	3900	
Natural Recharge (recharge cells)	***3500***	
Natural Recharge* (stream cells[1])		***5880***
Total Inflow		**36,690**
Outflow Component		**Out Af/yr**
Storage		8970
Pumping		21650
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1530
Underflow UAF** Sub-basin		1130
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River		2520
Total Outflow		**36,600**
Net Change-in-Storage: Annualized (1995-2011) Rate of Water Lost from Storage		**11,580**

*Head-dependent boundaries. **Specified flux – uniform long-term underflow rates. [1]This predominately losing reach has a small rate of groundwater discharge out contained in the streamflow out term. [2]This predominately gaining reach has a small rate of stream inflow contained within the Natural Recharge (stream cells)[2].

Simulated Water Budget, 1995-2011

1939-1941----------1965----------1995-------2011

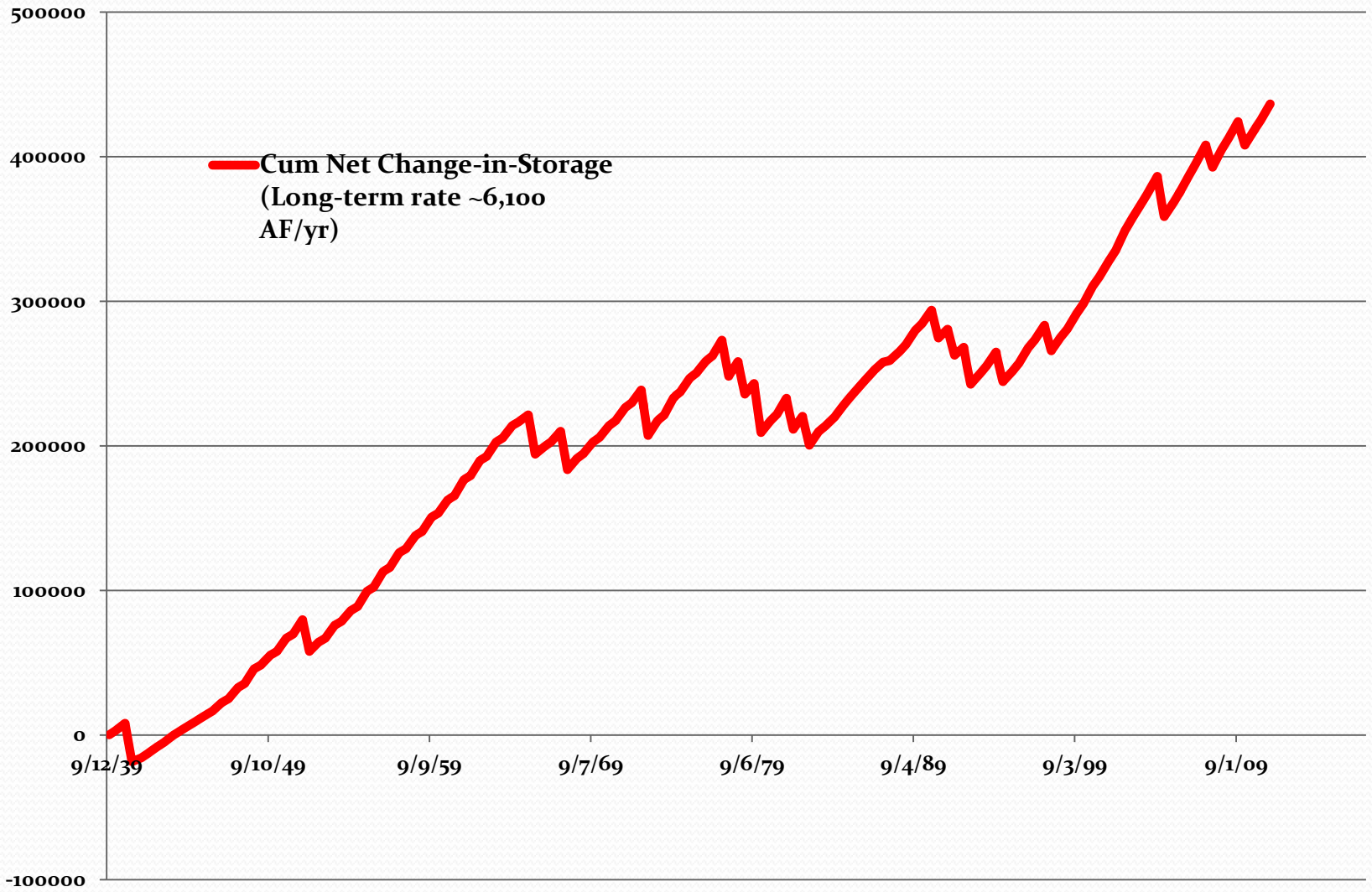
Simulated Water Budget: 1995-2011 (Annualized Rates for 1995-2011) Annualized Natural recharge Rate (1995-2011) = 9,380 AF/yr		
Inflow Component	**AF/yr**	**In Af/yr**
Storage		20550
Agricultural-related Recharge	2860	10260
Artificial Recharge	3900	
Natural Recharge (recharge cells)	***3500***	
Natural Recharge* (stream cells[1])		***5880***
Total Inflow		**36,690**
Outflow Component		**Out Af/yr**
Storage		8970
Pumping		21650
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1530
Underflow UAF** Sub-basin		1130
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River (Original Net Natural Groundwater Discharge Rate, circa 1939 ≈ 6,500 AF/yr)		2520
Total Outflow		**36,600**
Net Change-in-Storage: Annualized (1995-2011) Rate of Water Lost from Storage …….Plus "Hidden-Cost" of Long-term Net Capture	**11,580 + 4,000 AF/yr ??**	

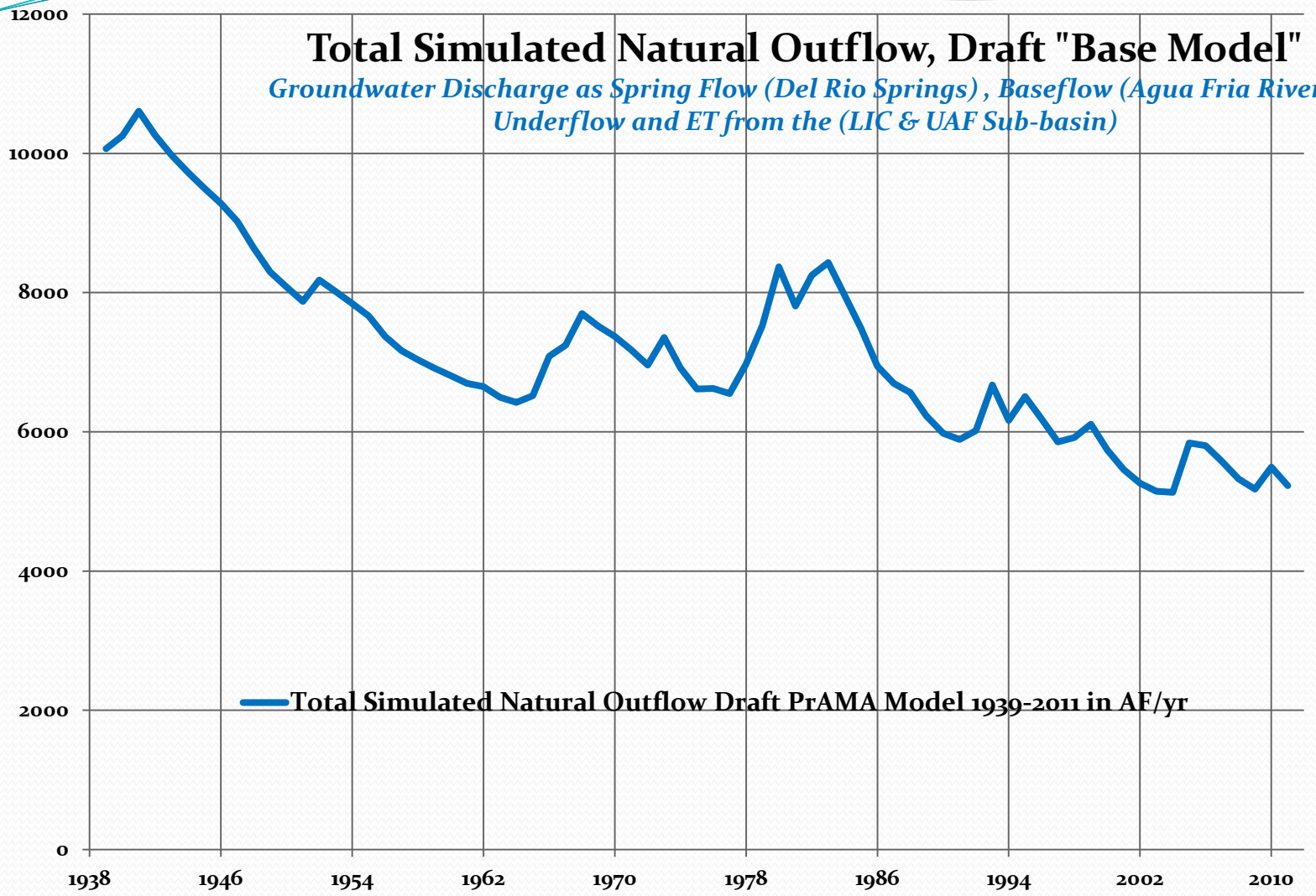
*Head-dependent boundaries. **Specified flux – uniform long-term underflow rates. [1]This predominately losing reach has a small rate of groundwater discharge out contained in the streamflow out term. [2]This predominately gaining reach has a small rate of stream inflow contained within the Natural Recharge (stream cells)[2].

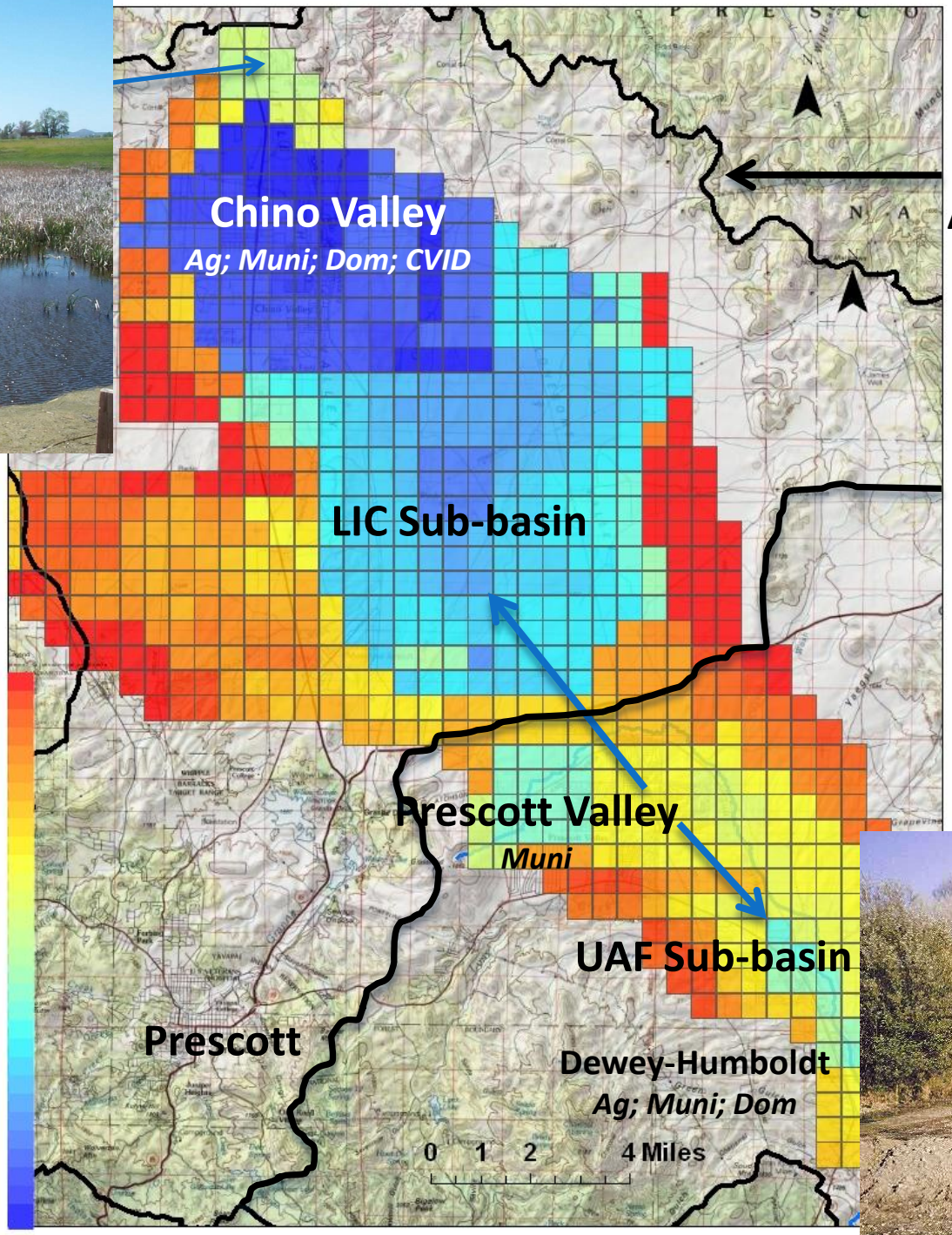
Hypothetical Water Budget Based on 1995-2011 Demand Average and a Very Wet Year (i.e., 2004/05)		
Inflow Component	**AF/yr**	**In Af/yr**
Agricultural-related Recharge		2860
Artificial Recharge		3900
Natural Recharge (stream + MFR/MFR)		**34,527**
Total Inflow		**41,287**
Outflow Component		**Out Af/yr**
Pumping		21650
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1530
Underflow UAF** Sub-basin		1130
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River		2520
Total Outflow		27,630
Net Change-in-Storage: Annualized (1995-2011) Rate of Water *Added to* Storage	**13,657 AF/yr**	
Natural recharge based on "Base" Model, simulation year 2004/05. A "wet" year such as 2005 was relatively rare period with the exception of the mid-19709's to mid-1990's period.		

Hypothetical Water Budget Based on 1995-2011 Demand Average & and Very Dry {for example year (2012)} Results in a NET Negative Imbalance ≈ 18,000 AF/yr		
Inflow Component		**IN AF/yr**
Agricultural-related Recharge		2860
Artificial Recharge		3900
Natural Recharge (recharge – Long-term constant MFR and/or MBR; no variable stream recharge)		**2,930**
Total Inflow		9,690
Outflow Component		**Out AF/yr**
Pumping		21650
Evapotranspiration* (saturated zone)		800
Underflow LIC* Sub-basin		1530
Underflow UAF** Sub-basin		1130
Groundwater Discharge*[2] at Del Rio Springs and Baseflow, Agua Fria River		2520
Total Outflow		27,630
Net Change-in-Storage: Annualized (1965-1995) Rate of Water *Lost from* Storage	**17,940 AF/yr**	
Natural recharge based on "Base" Model, for a nominally-dry year: 53 out of 72 of the simulated years between 1939 and 2011 imposed nominal natural recharge – in this case, 2,930 AF/yr.		

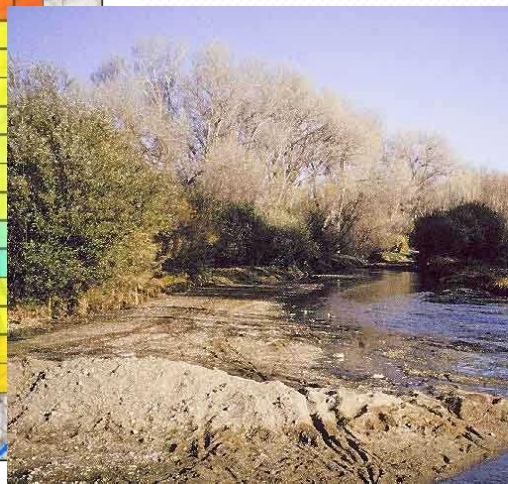
Cumulative Net Change-in-Storage




Total Simulated Natural Outflow, Draft "Base Model"
Groundwater Discharge as Spring Flow (Del Rio Springs) , Baseflow (Agua Fria River), Underflow and ET from the (LIC & UAF Sub-basin)
12000
10000
8000
6000
4000
2000
0
1938
1946
1954
1962
1970
1978
1986
1994
2002
2010
Total Simulated Natural Outflow Draft PrAMA Model 1939-2011 in AF/yr

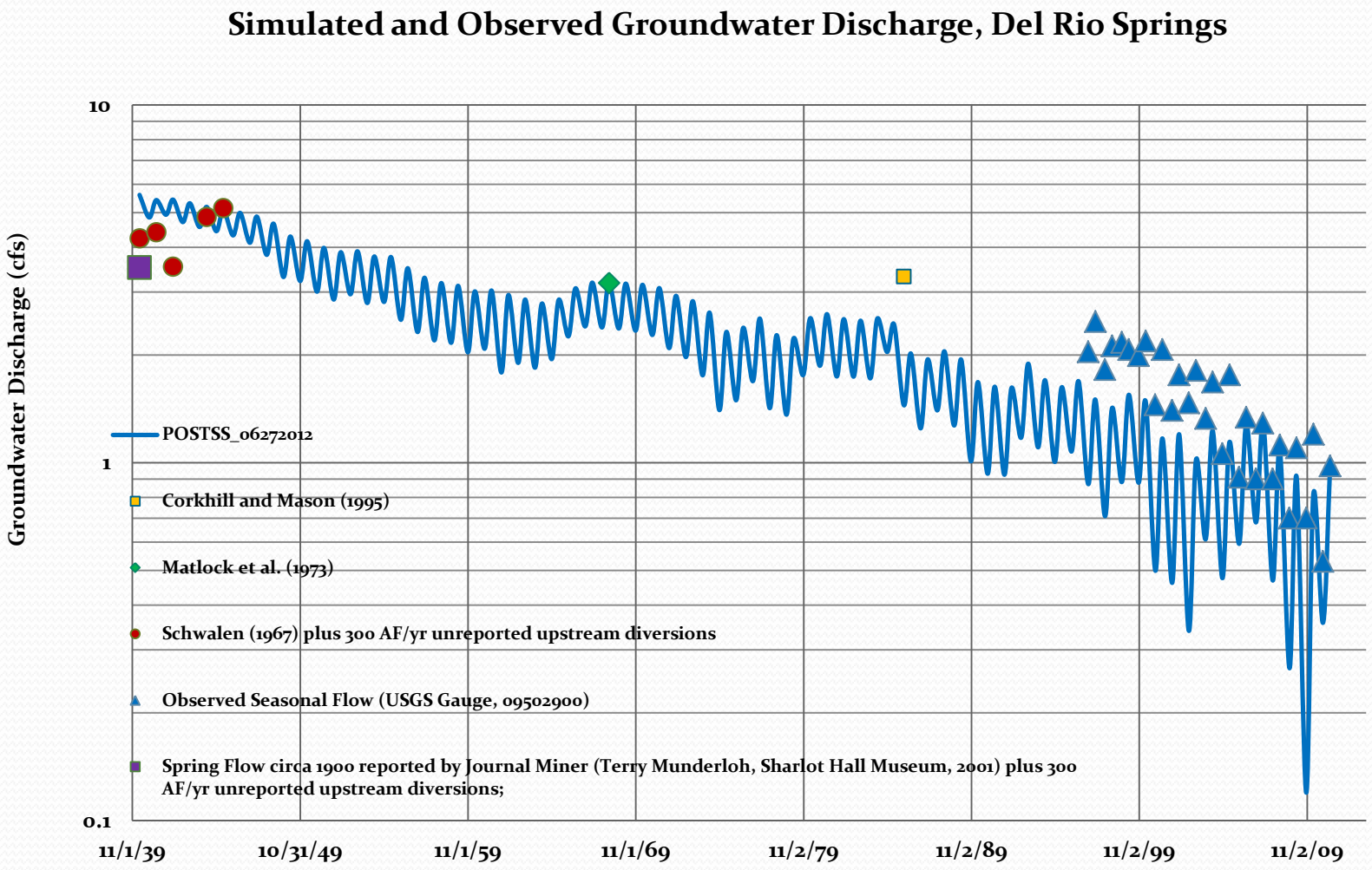


Prescott AMA Boundary



Simulated & Observed Groundwater Discharge Del Rio Springs

Base Solution – calibrated Natural Recharge ≈ 9,920 AF/yr

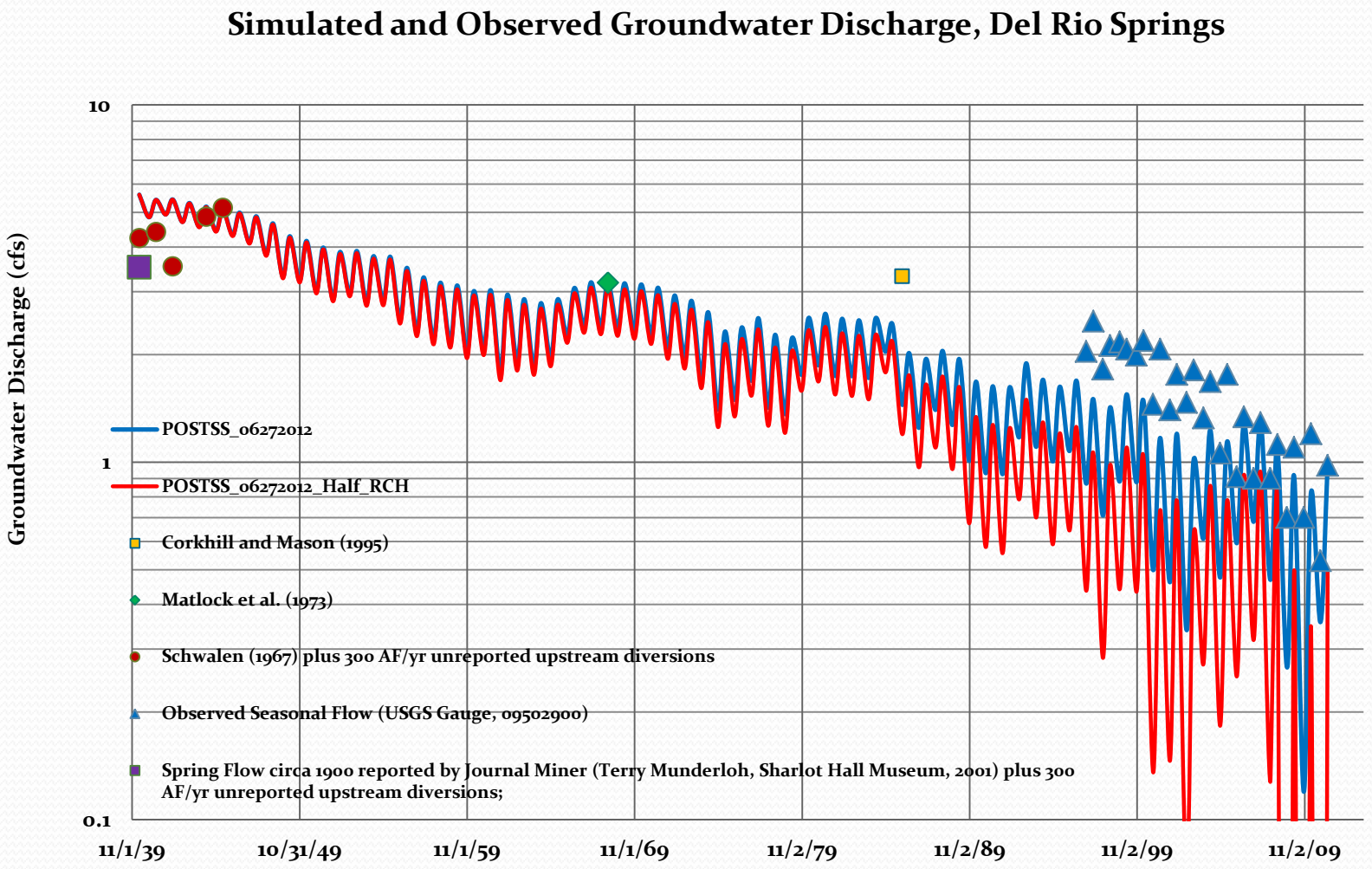


Del Rio Springs

Simulated & Observed Groundwater Discharge Del Rio Springs

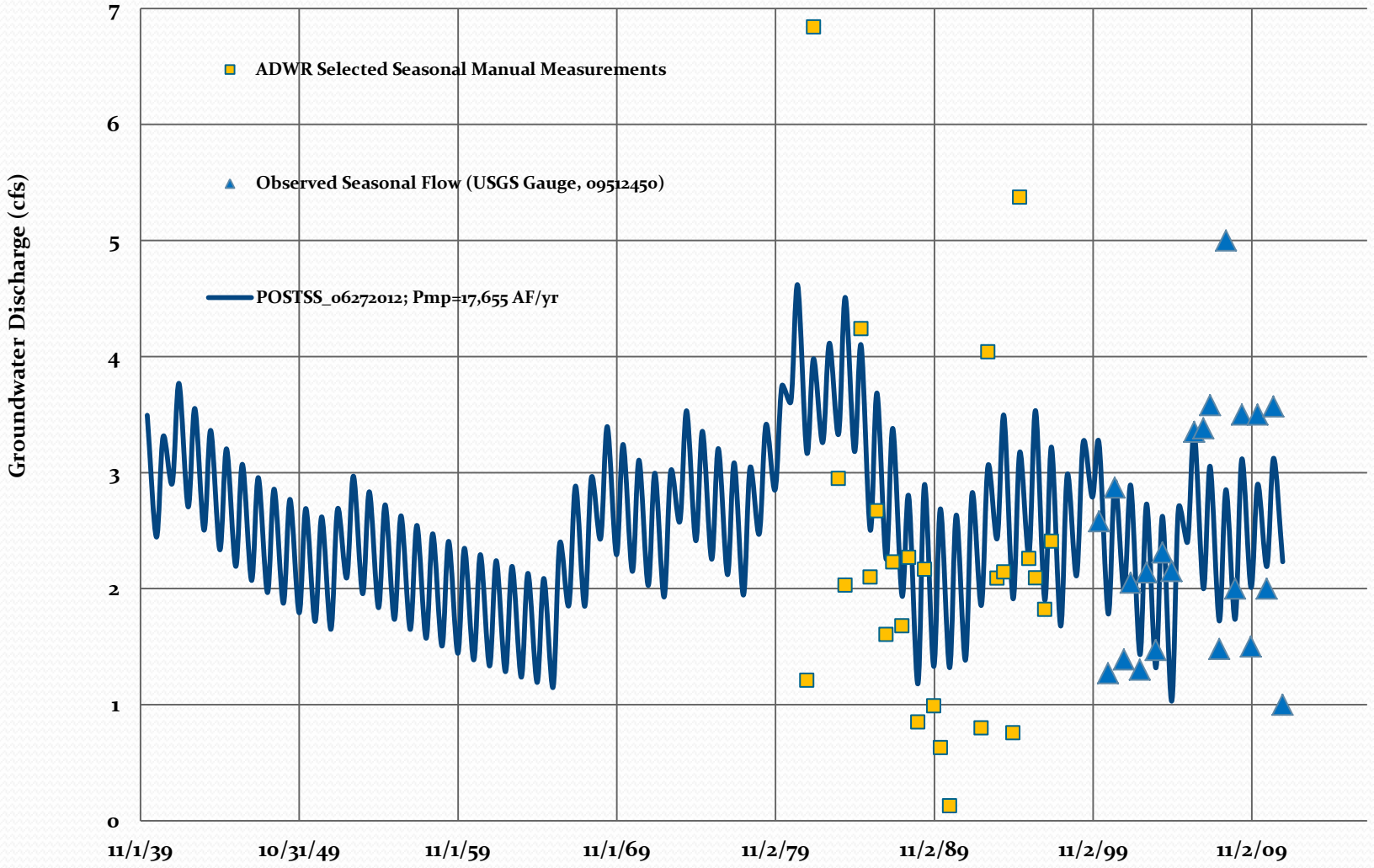
Base Model Solution – calibrated Natural Recharge ≈ 9,920 AF/yr

Base Model -- with reduced Natural Recharge ≈ 5,100 AF/yr

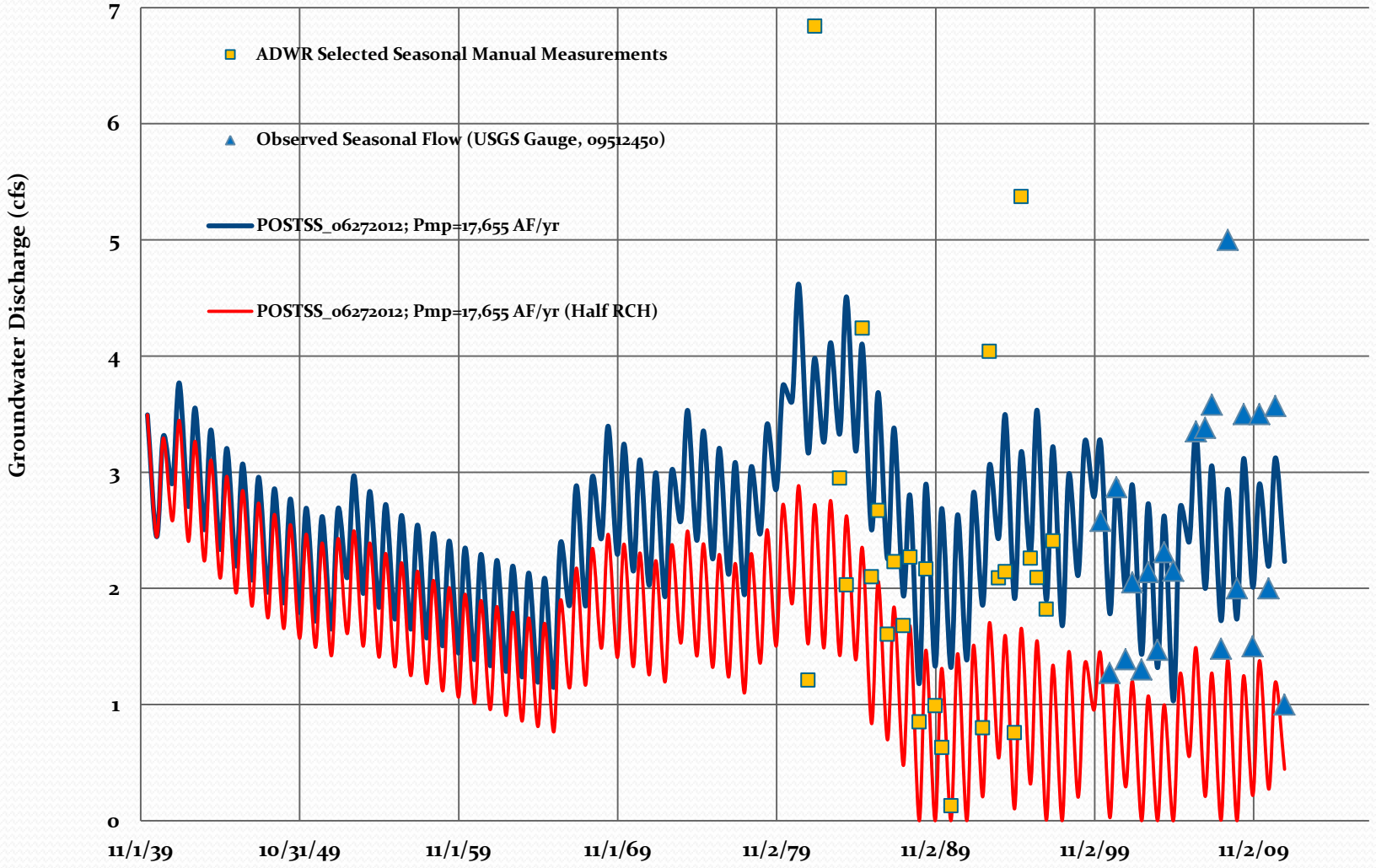


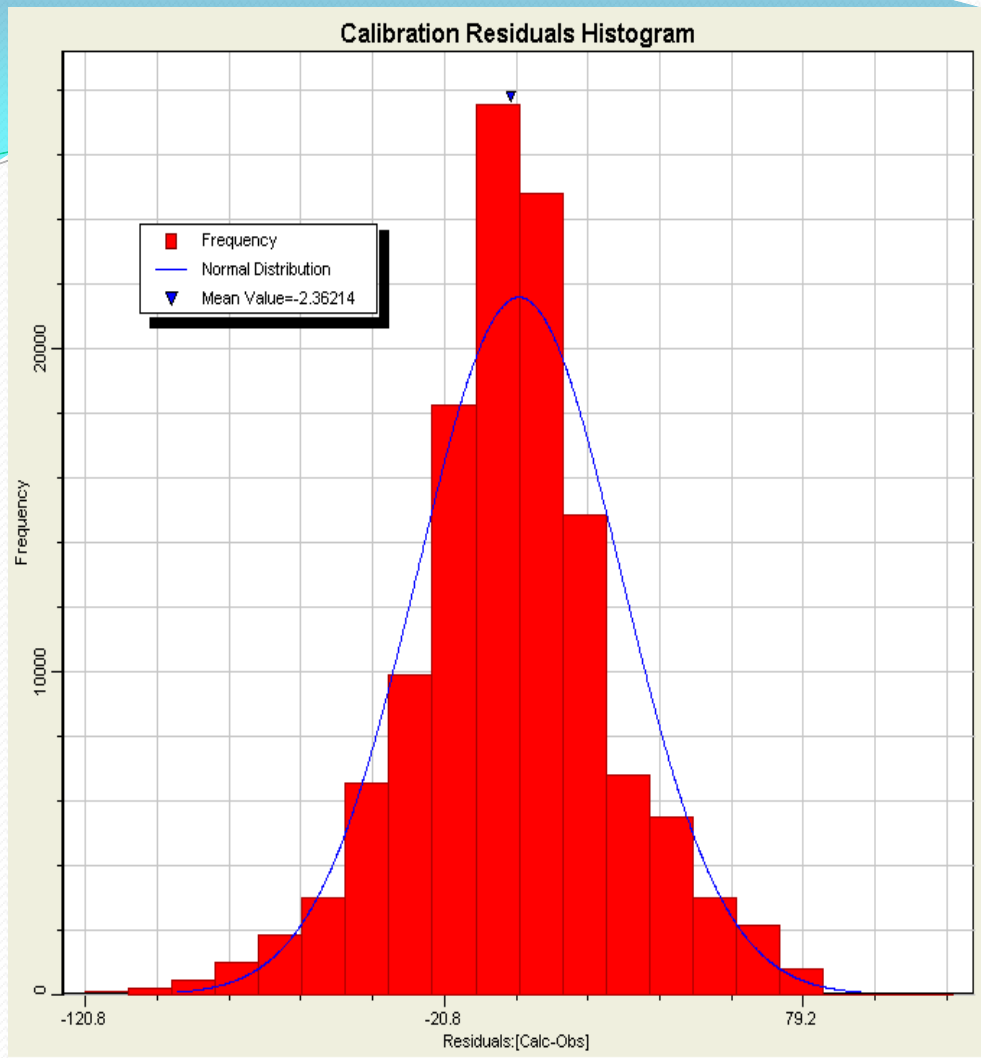
Del Rio Springs

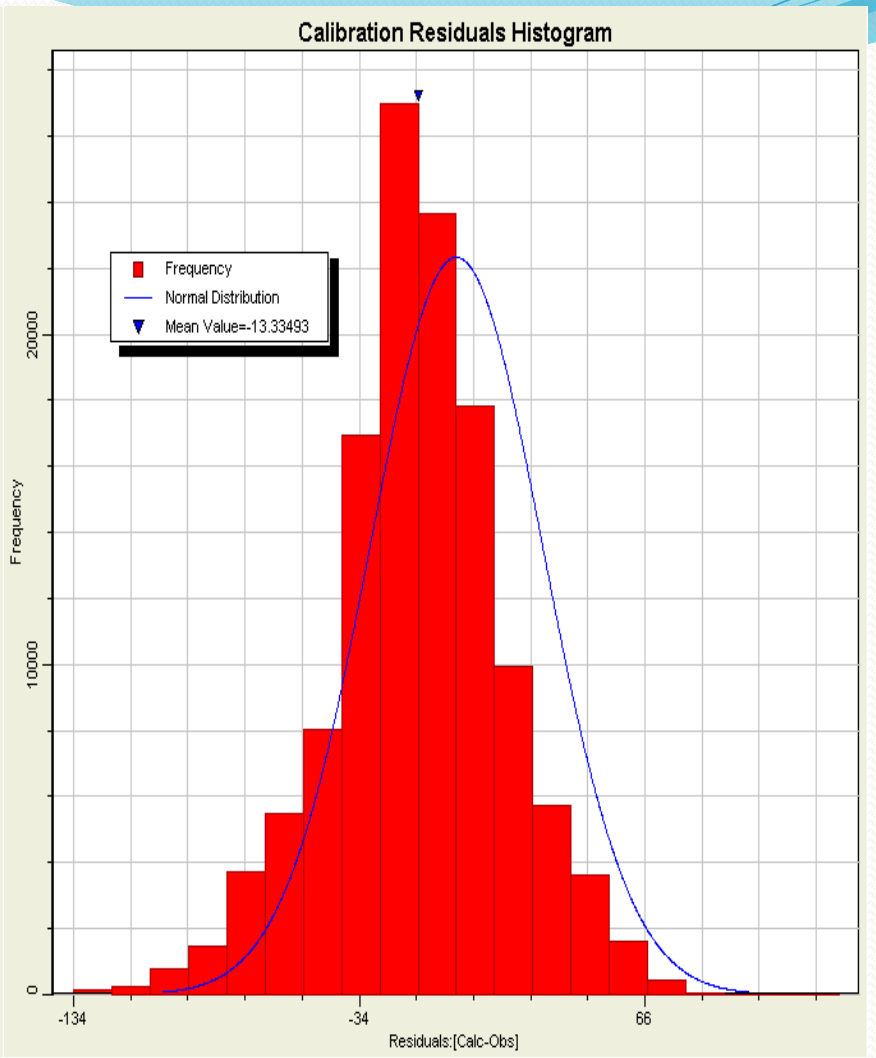
Simulated and Observed Groundwater Discharge, Agua Fria River



Simulated and Observed Groundwater Discharge, Agua Fria River

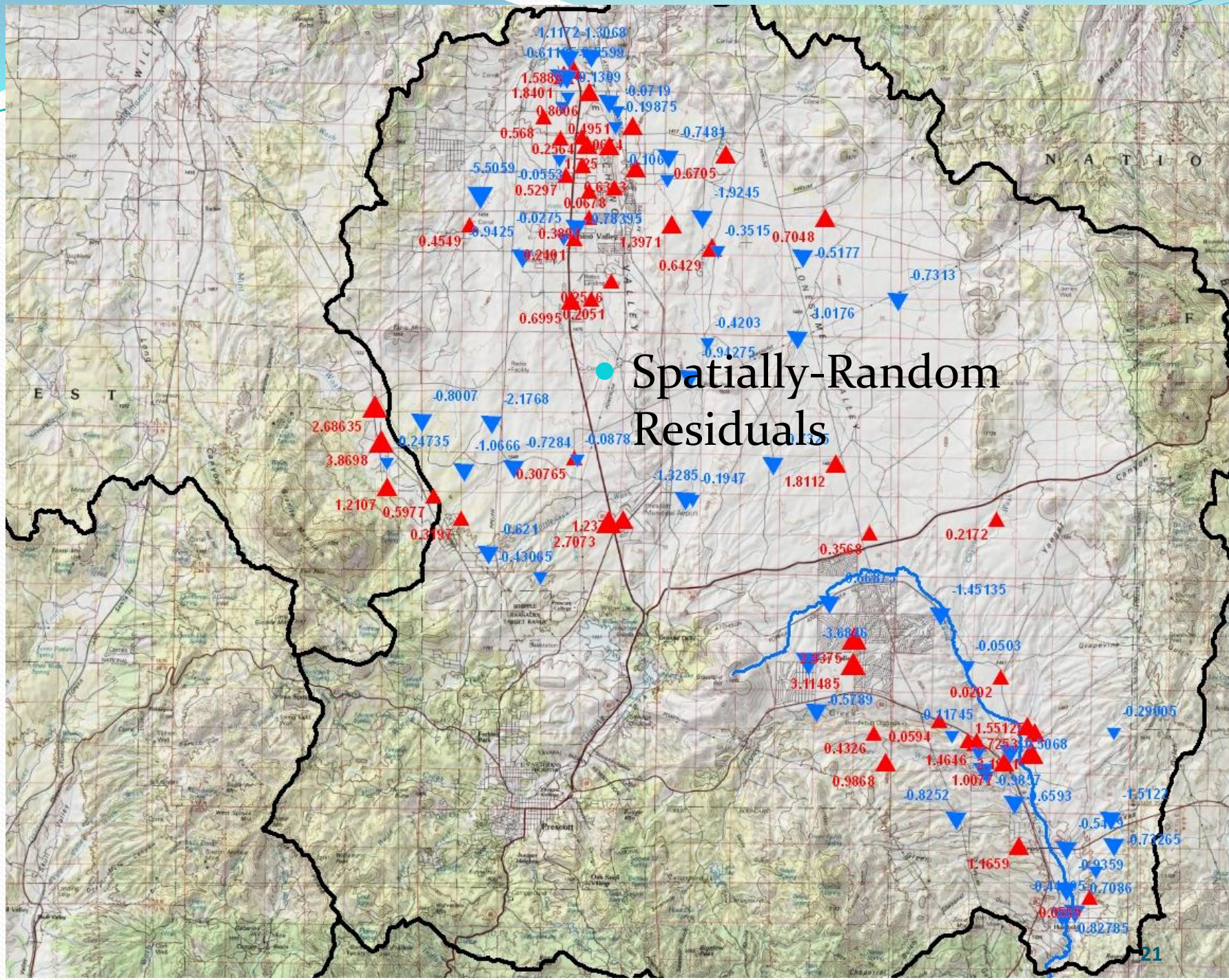


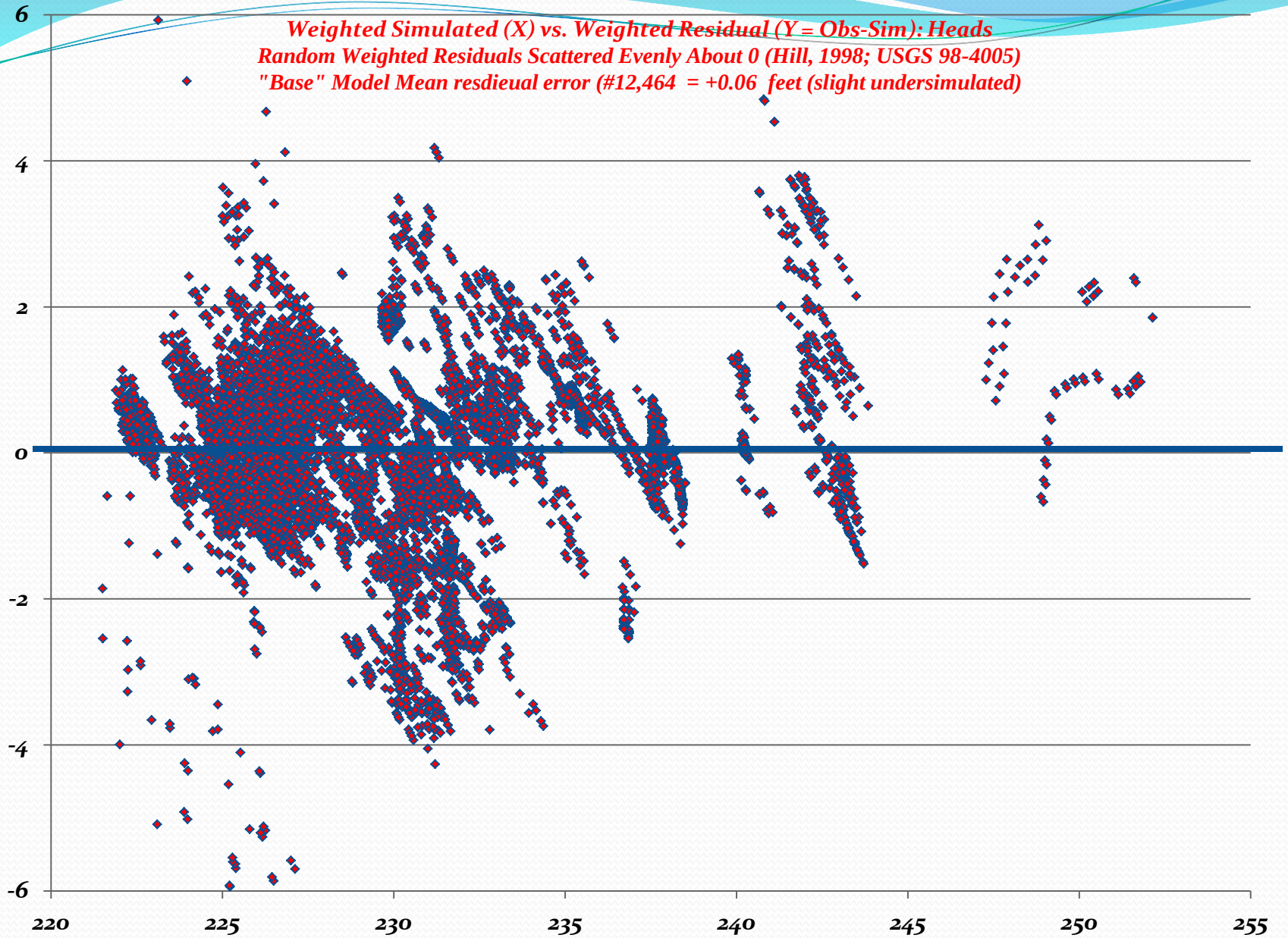




Calibrated Model long-term transient natural recharge rate = 9,920 AF/yr = sim-obs = - 2.4 feet slightly under-simulated Base Model

ACM Model long-term transient nat recharge rate = 5,100 AF/yr = sim – obs = -13.3 feet fairly significant under-simulated bias

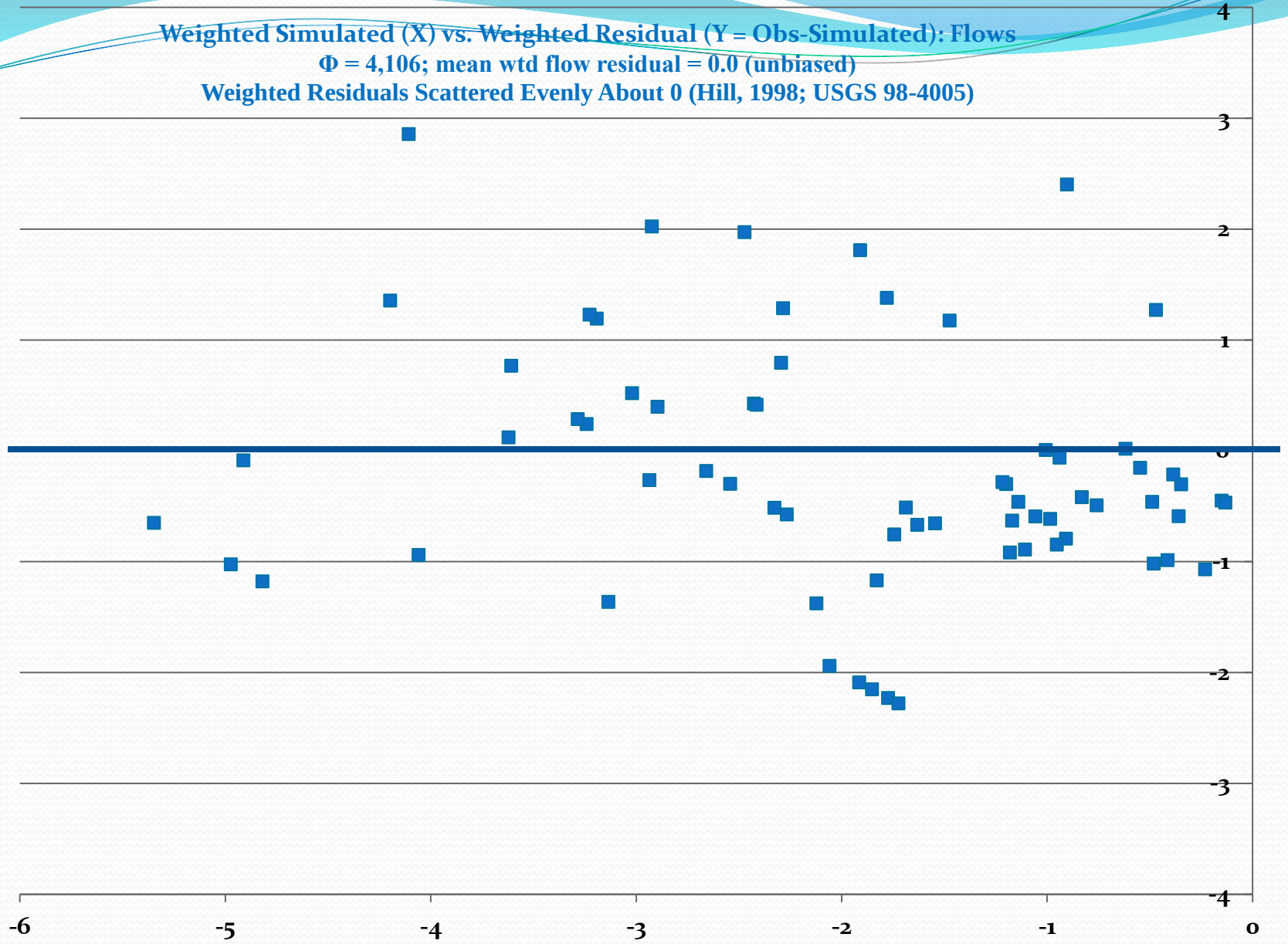

Spatially-Random Residuals

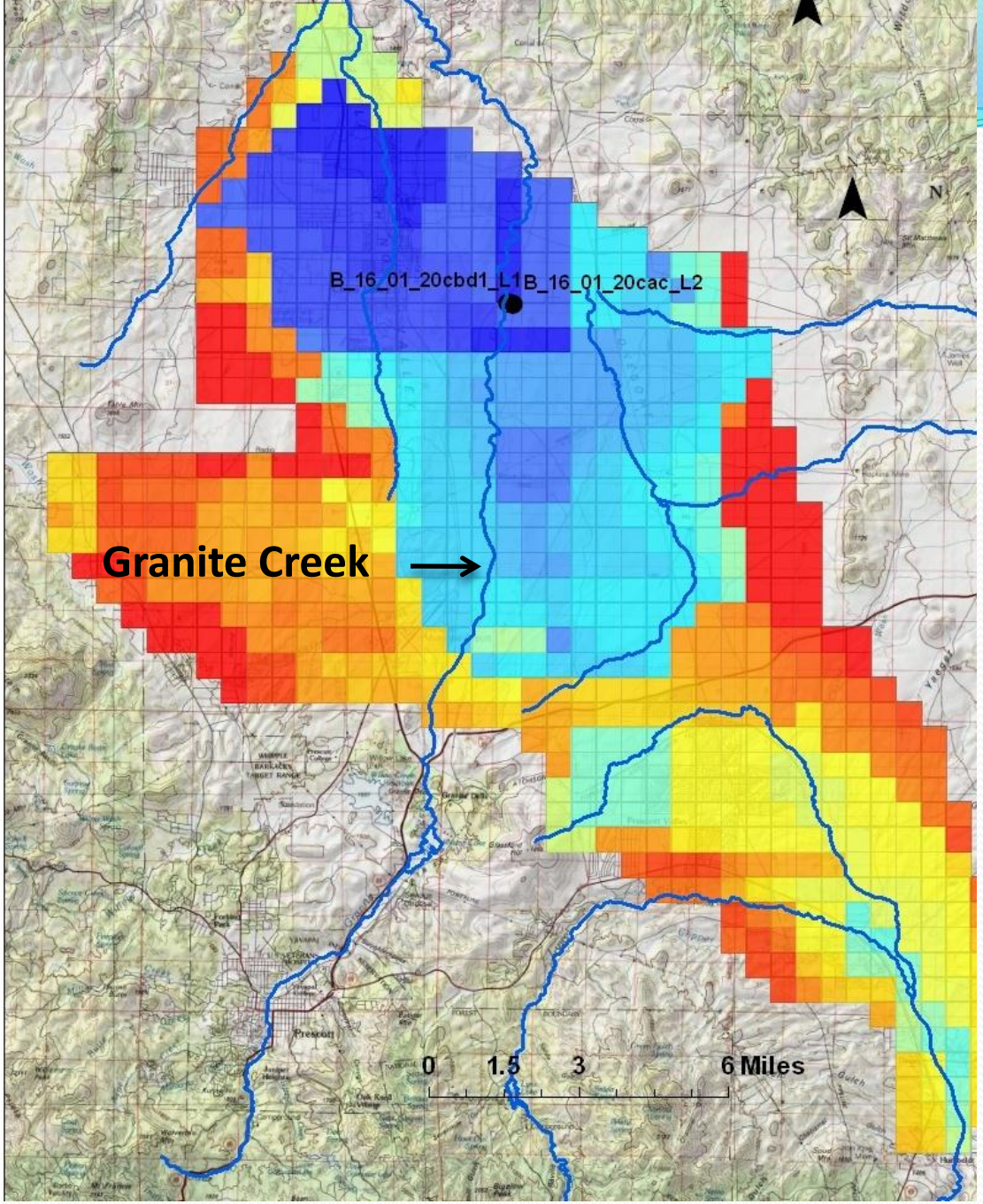

Weighted Simulated (X) vs. Weighted Residual (Y = Obs-Sim): Heads
Random Weighted Residuals Scattered Evenly About 0 (Hill, 1998; USGS 98-4005)
"Base" Model Mean resdieual error (#12,464 = +0.06 feet (slight undersimulated)
6
4
2
0
-2
-4
-6
220
225
230
235
240
245
250
255

Weighted Simulated (X) vs. ~~Weighted~~ Residual (Y = Obs-Simulated): Flows

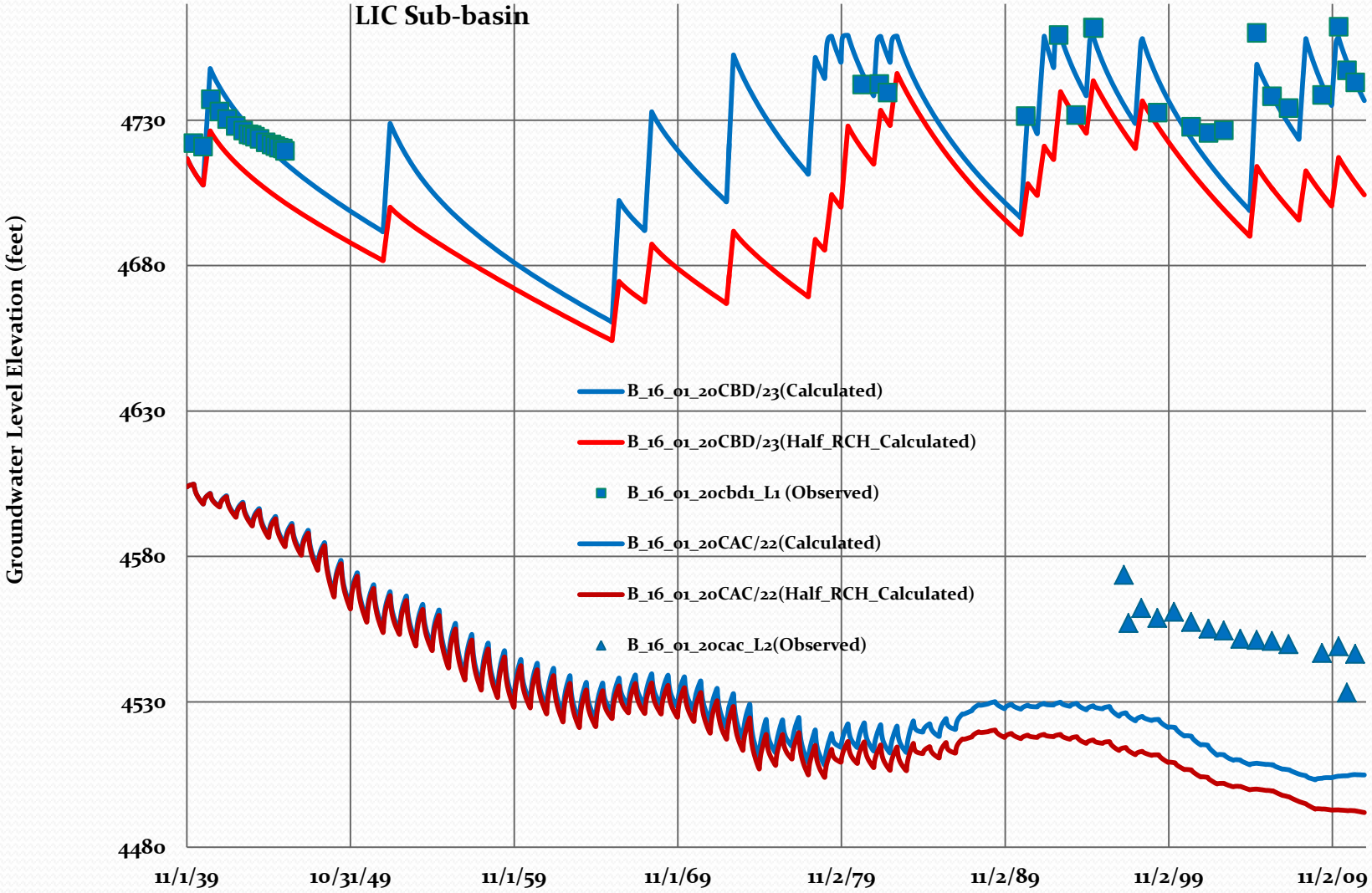
Φ = 4,106; mean wtd flow residual = 0.0 (unbiased)

Weighted Residuals Scattered Evenly About 0 (Hill, 1998; USGS 98-4005)

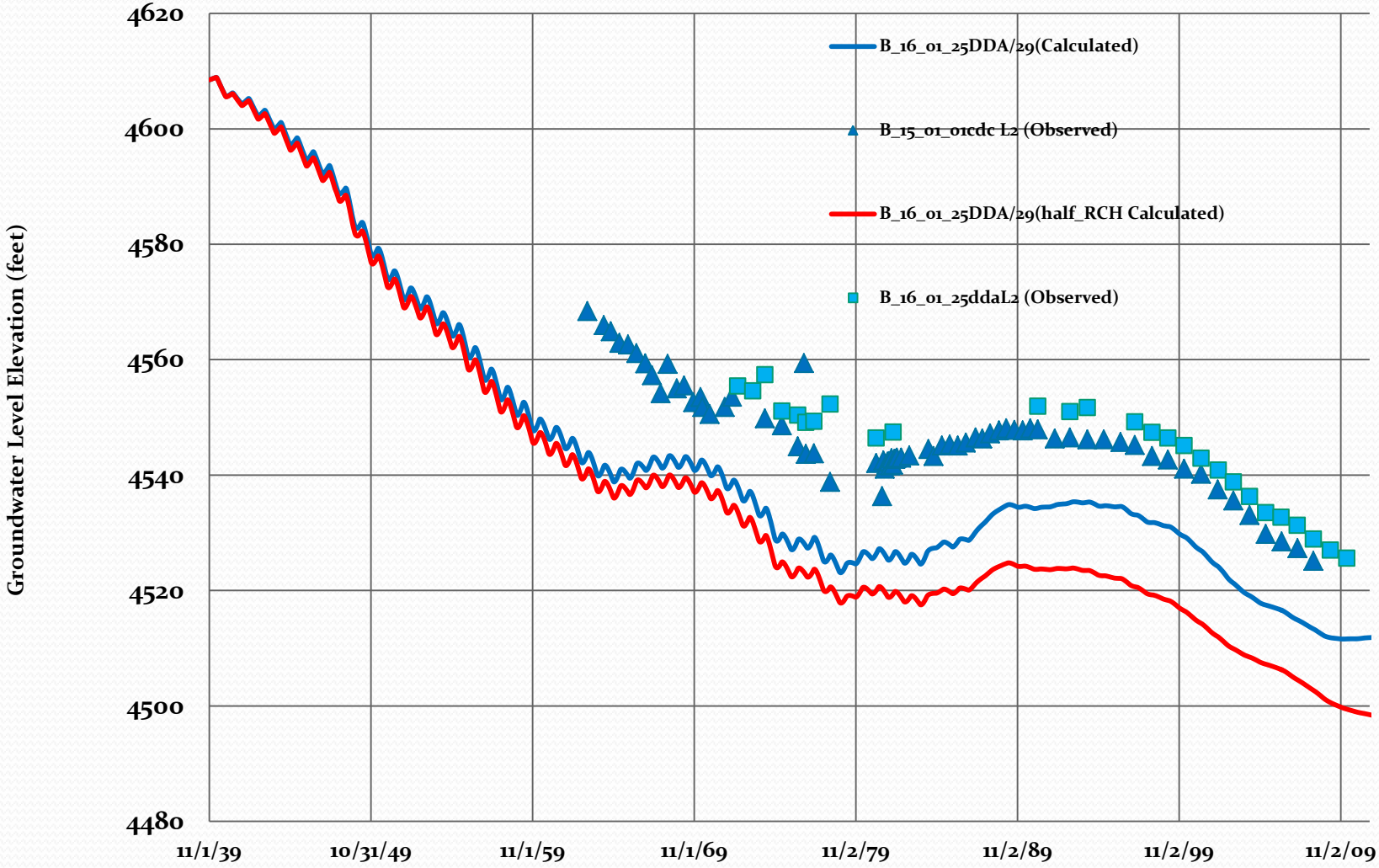


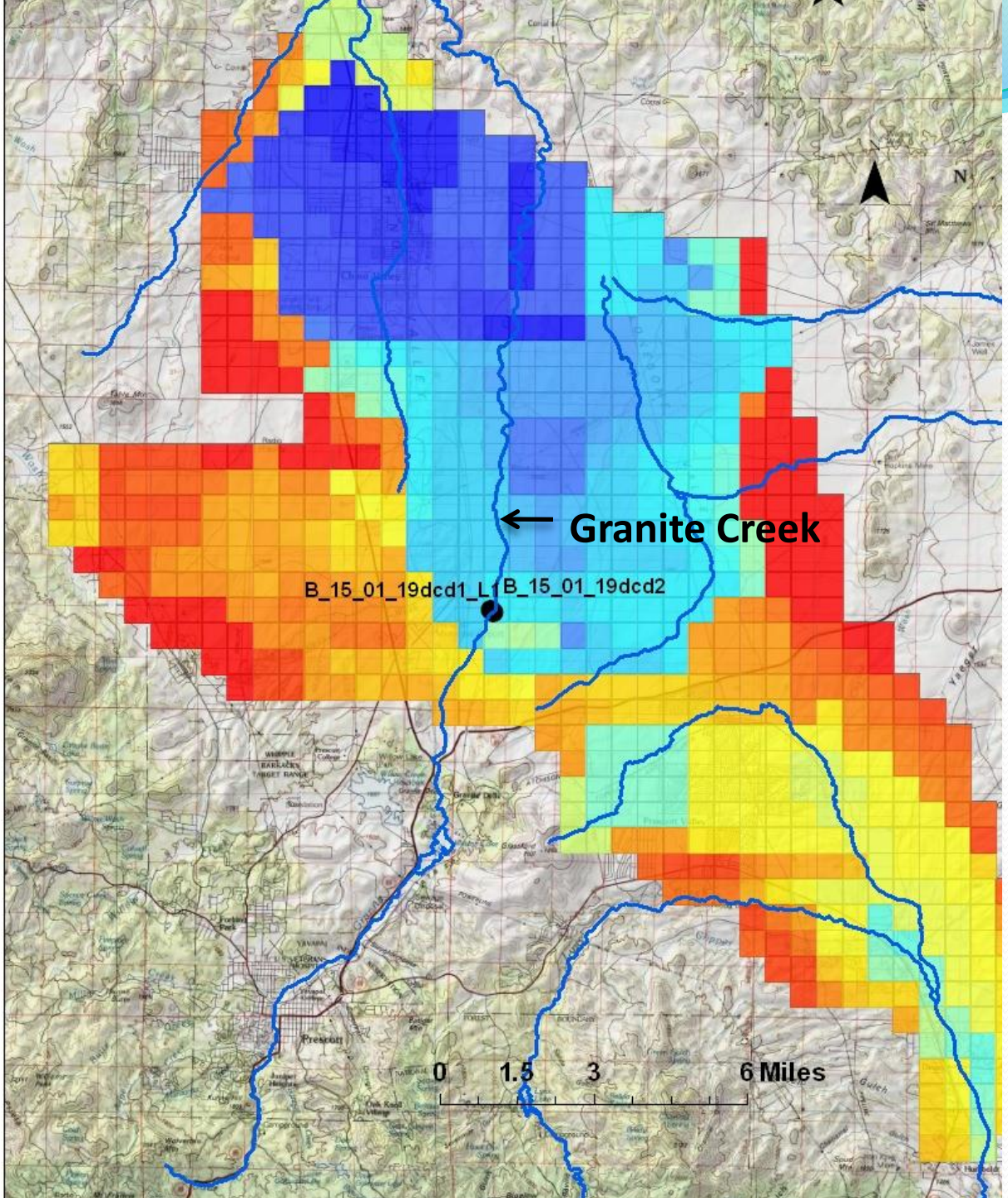

B_16_01_20cbd1_L1
B_16_01_20cac_L2
Granite Creek
N
Prescott
0
1.5
3
6 Miles

Simulated and Observed Heads near Granite Creek - North LIC Sub-basin

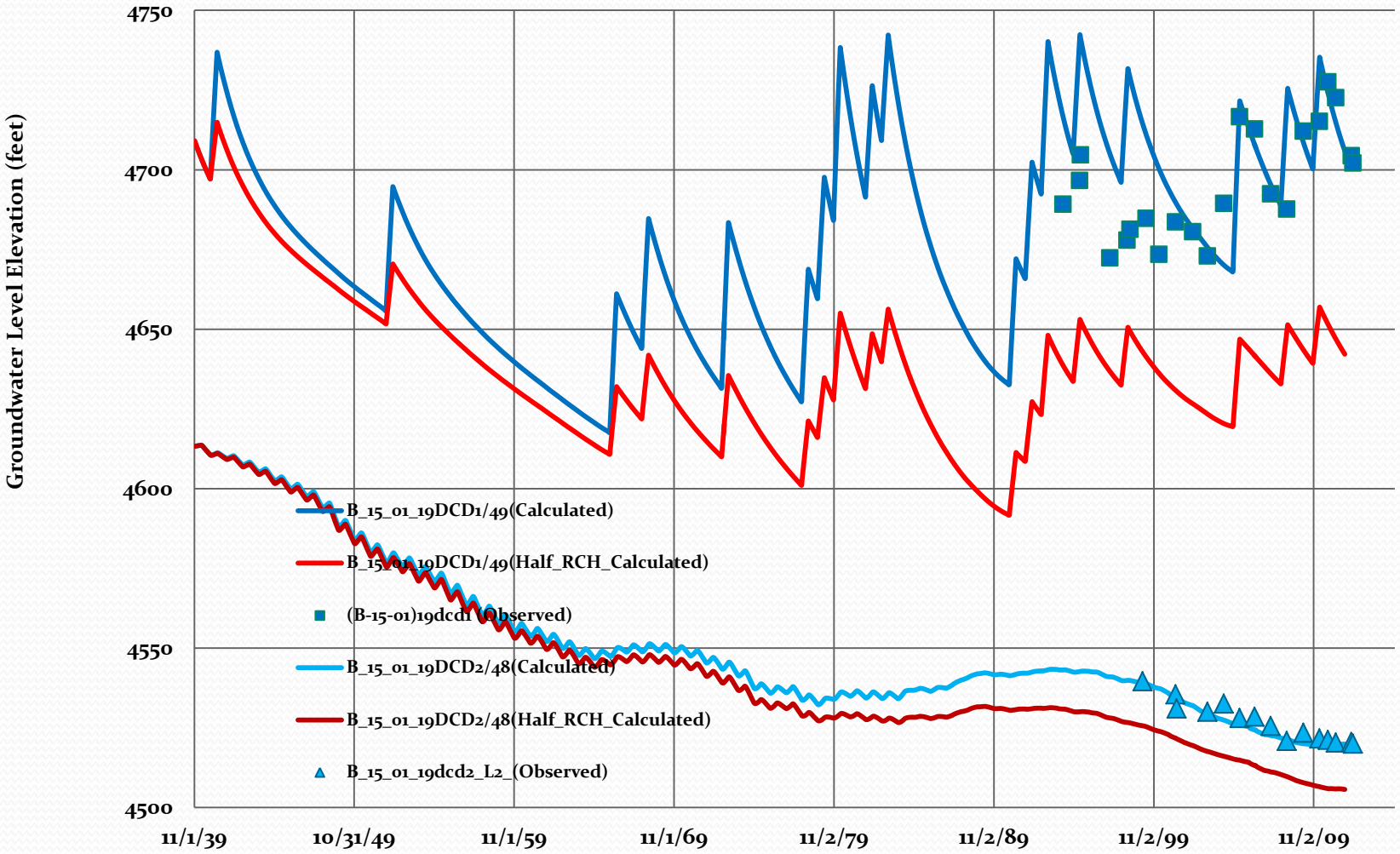


Simulated and Observed Heads Far Eastern LIC Sub-basin

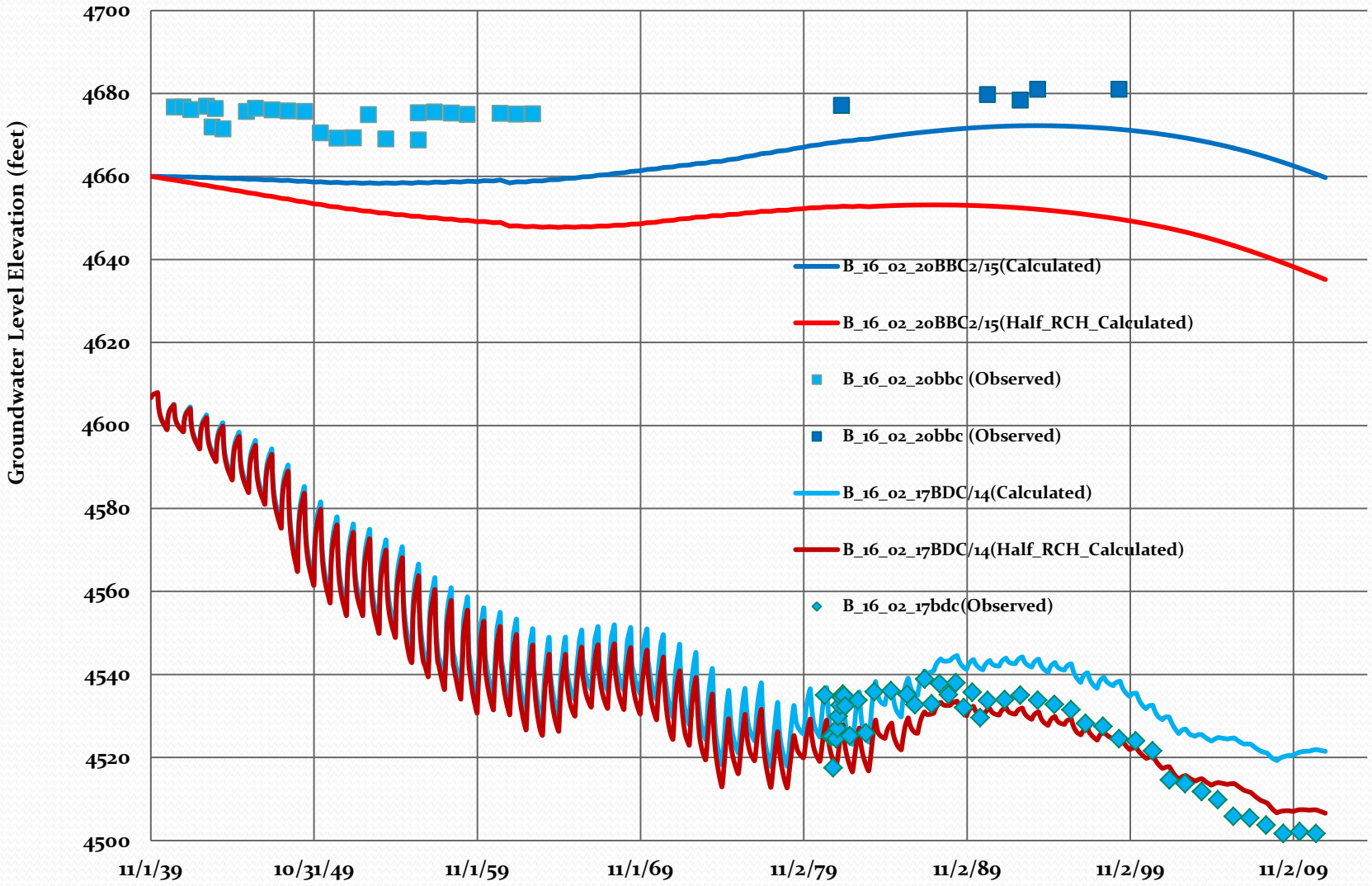


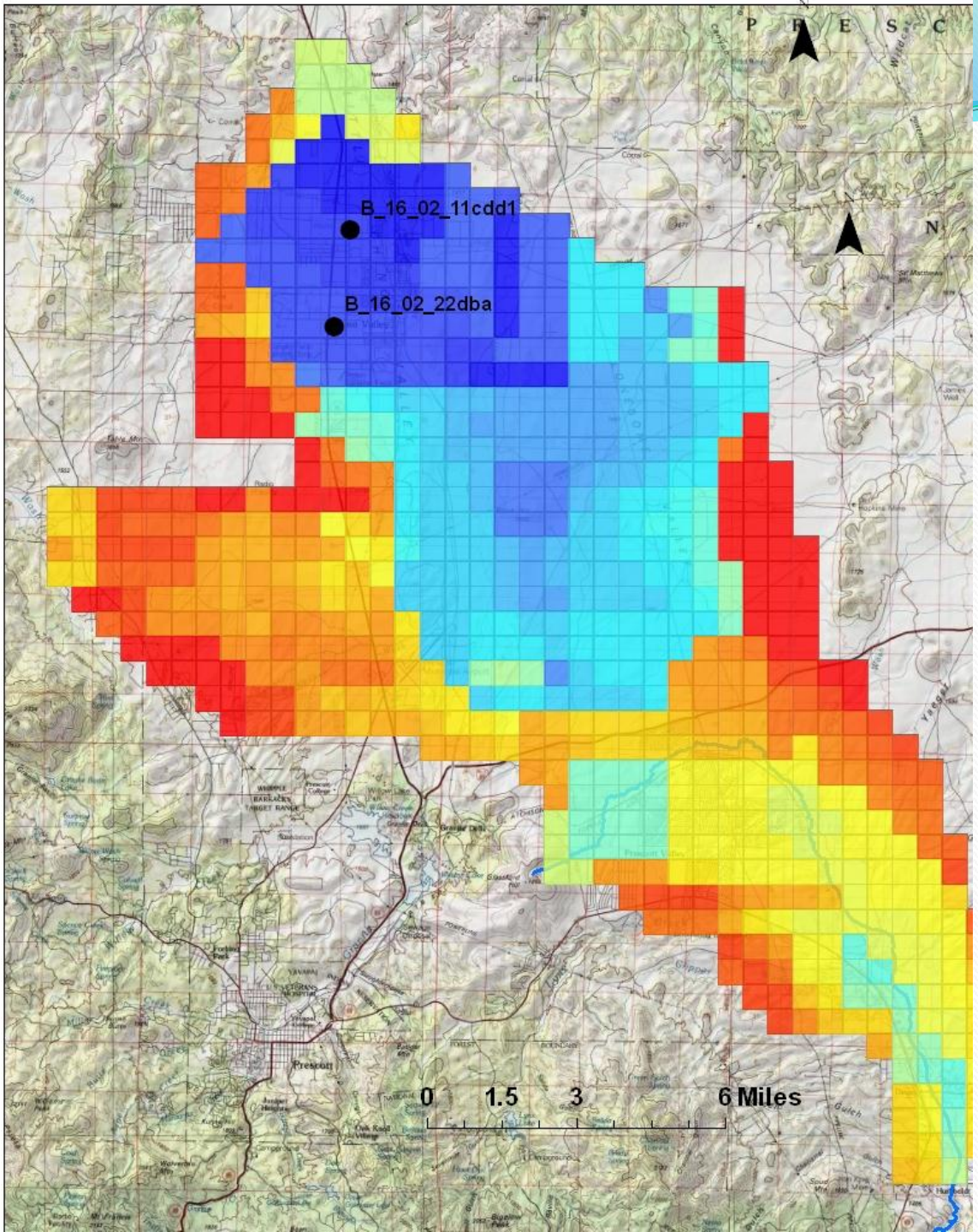

Granite Creek
B_15_01_19dcd1_L1
B_15_01_19dcd2
N
Prescott
0 1.5 3 6 Miles

Simulated and Observed Heads near Granite Creek - South LIC Sub-basin

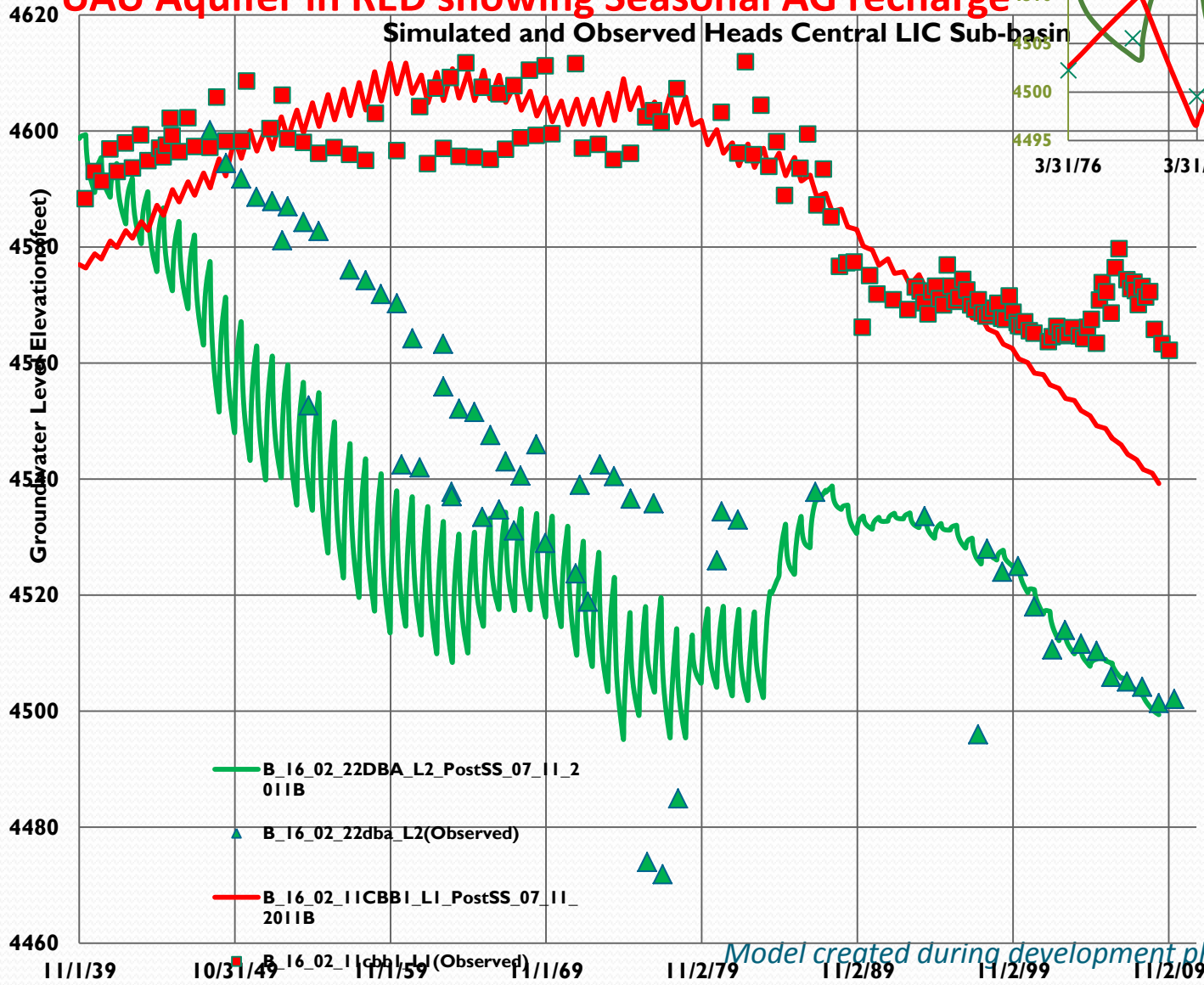


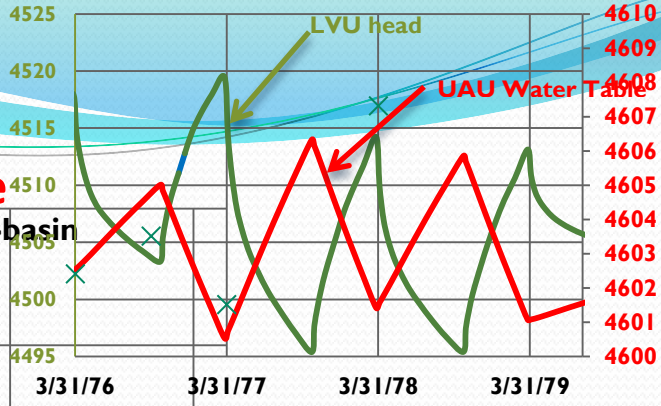
Simulated and Observed Heads Northwest LIC



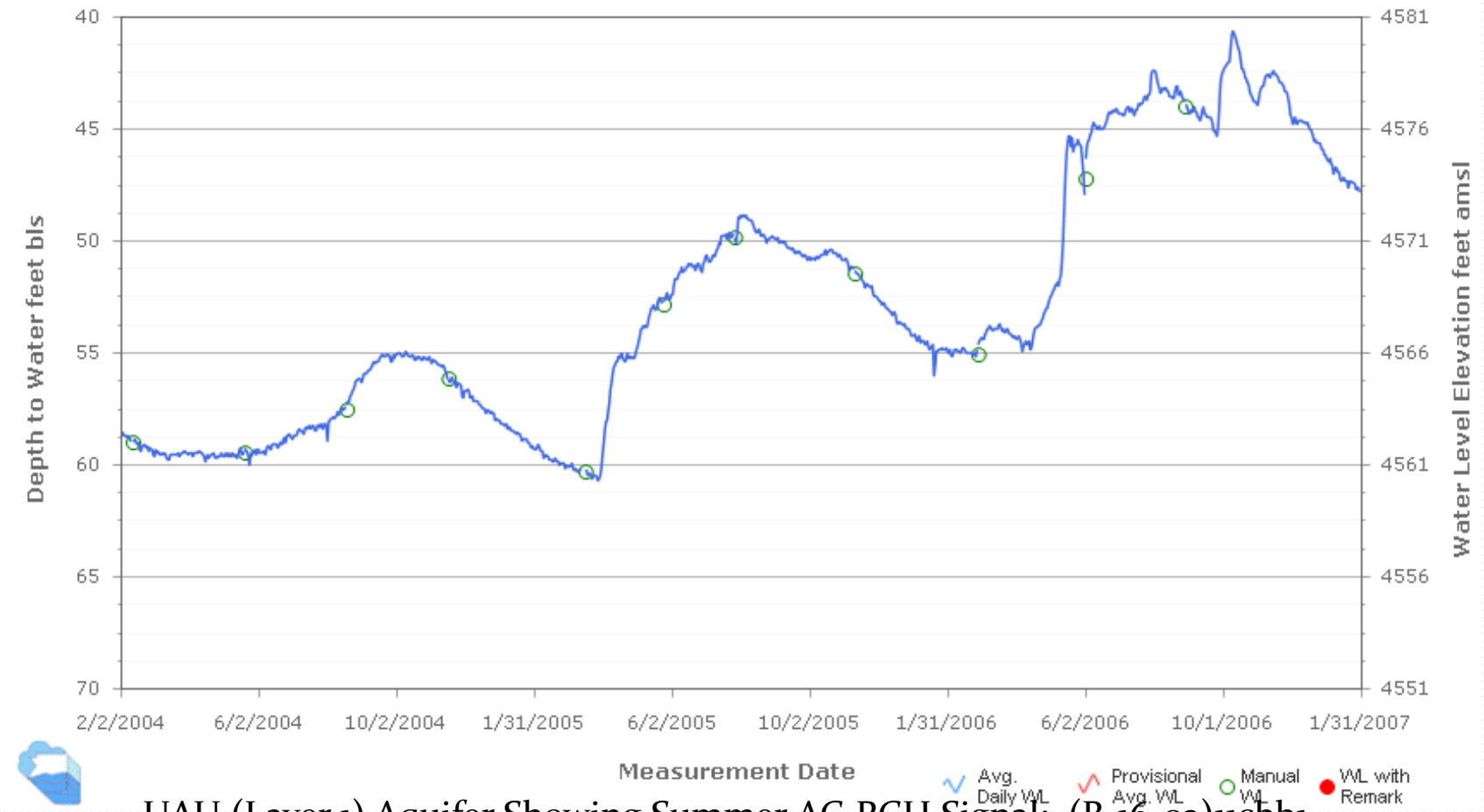

B_16_02_11cdd1
B_16_02_22dba
N
0
1.5
3
6 Miles
Prescott

UAU Aquifer in RED showing Seasonal AG recharge

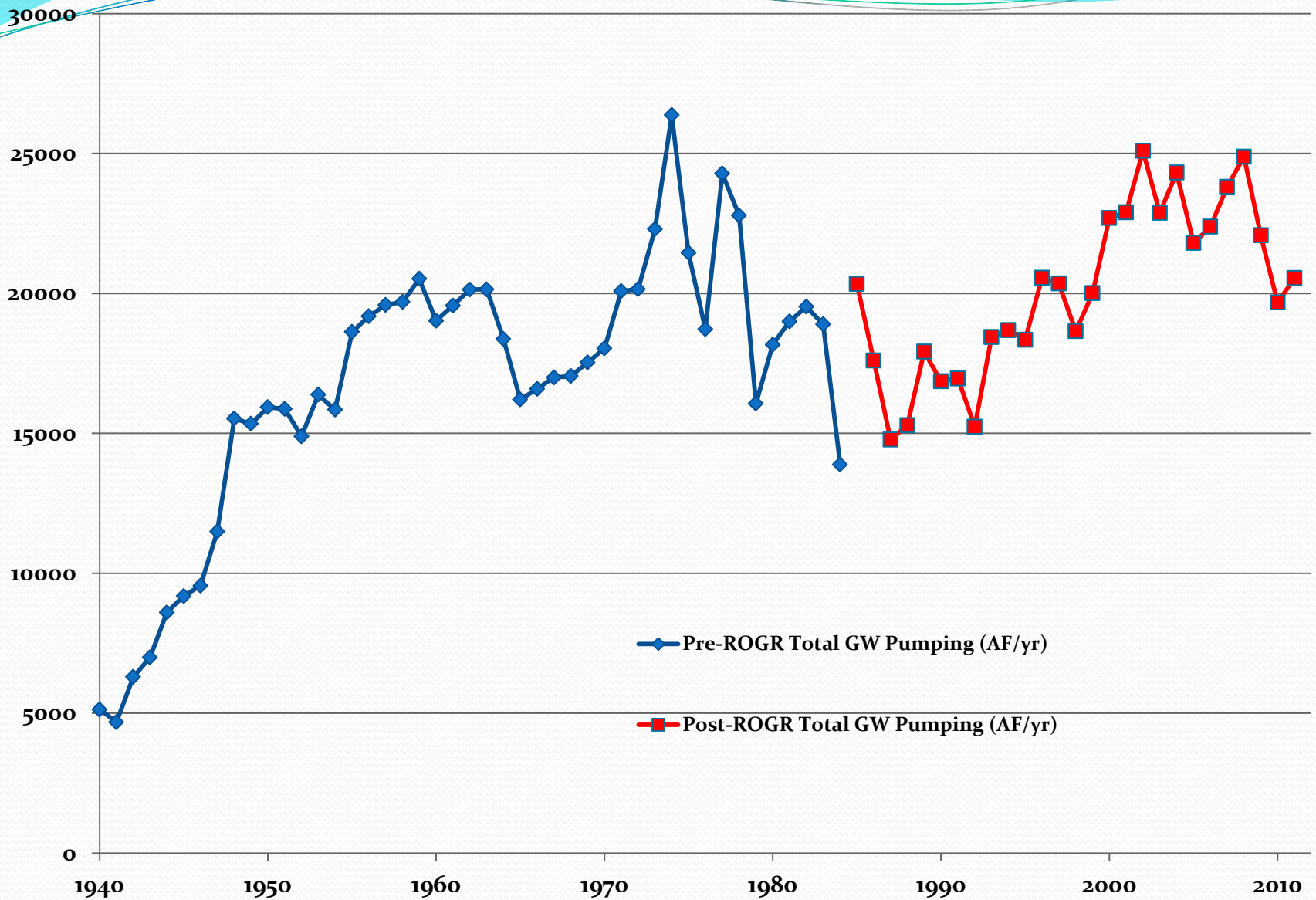


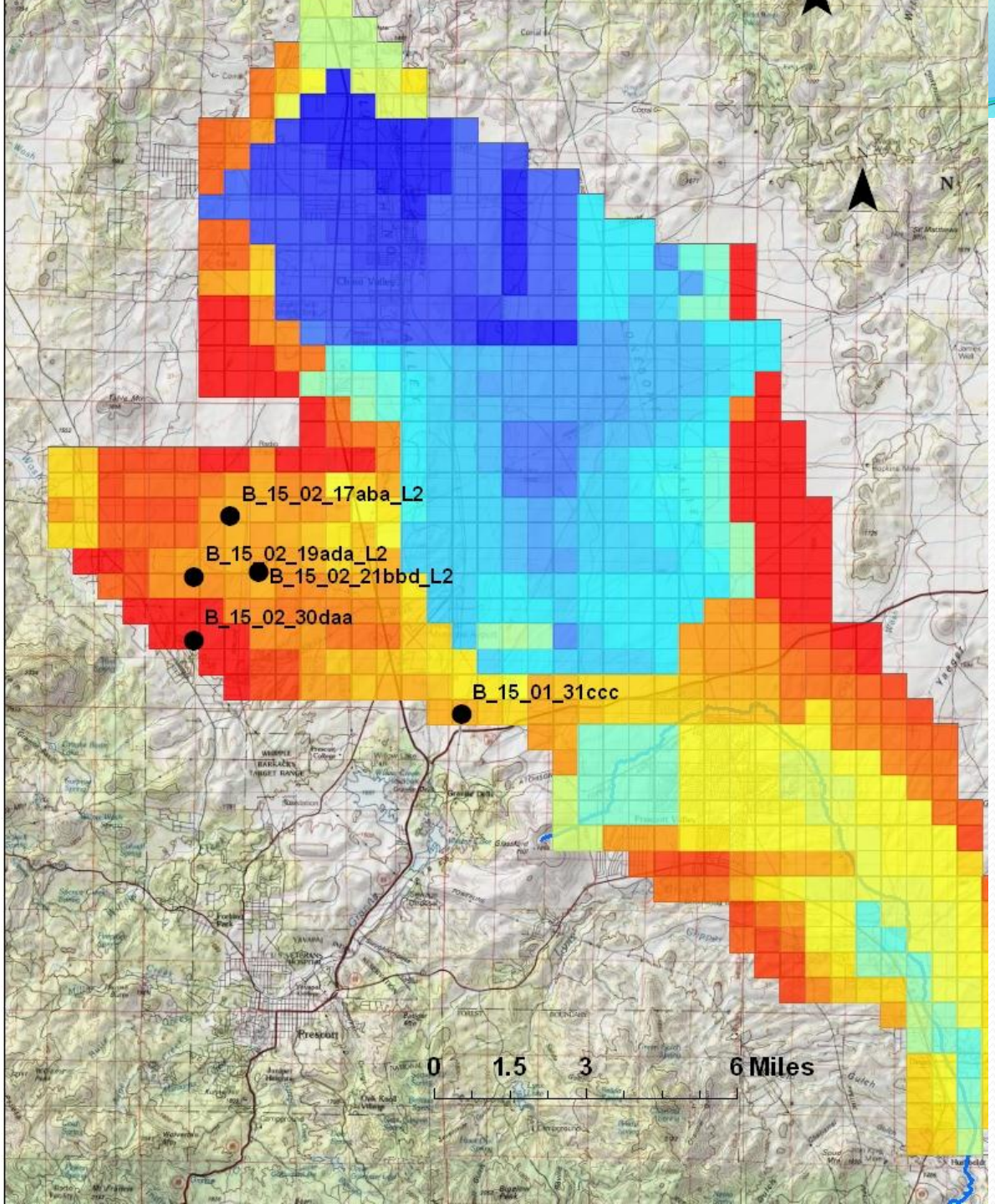


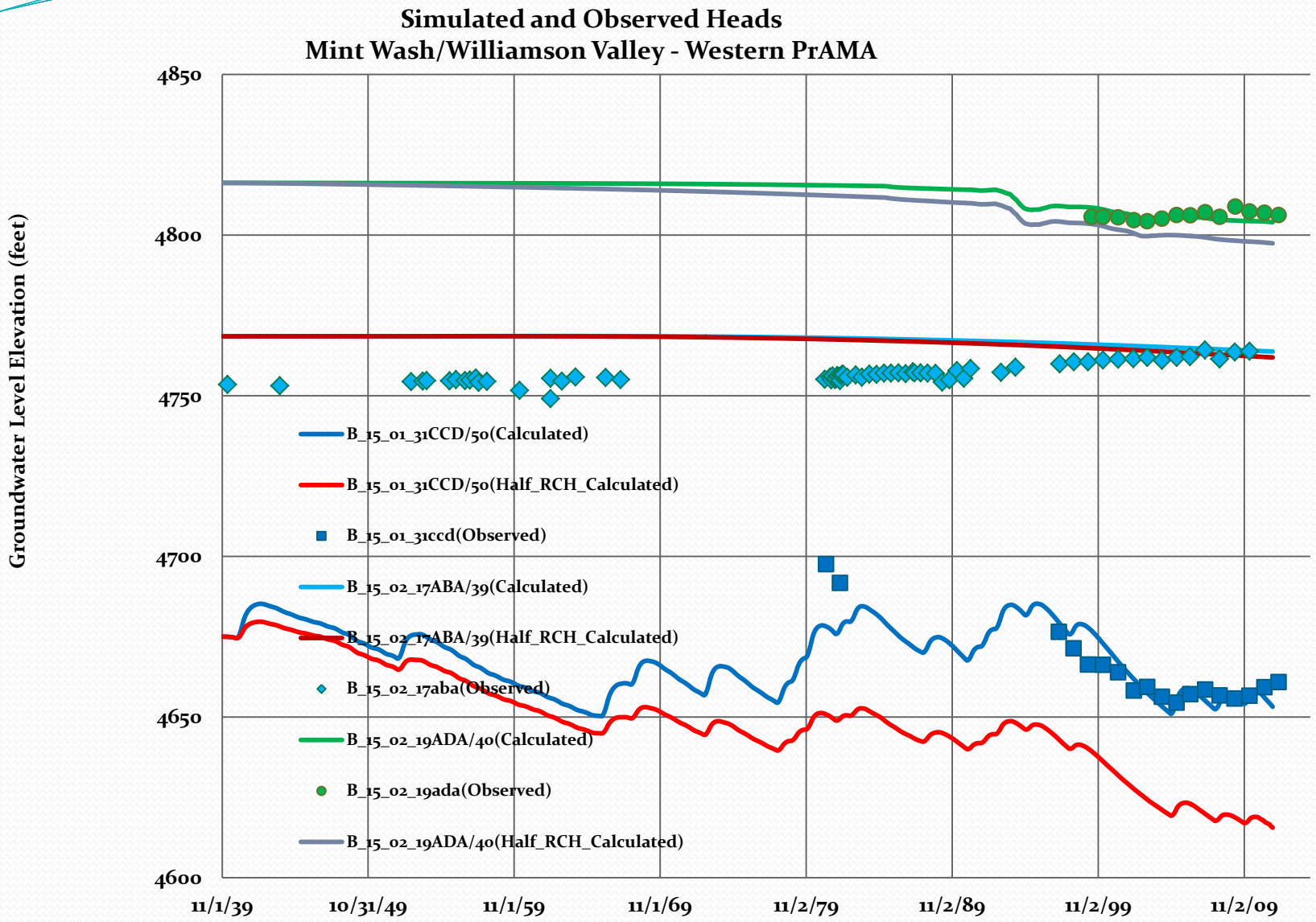
Model created during development phase

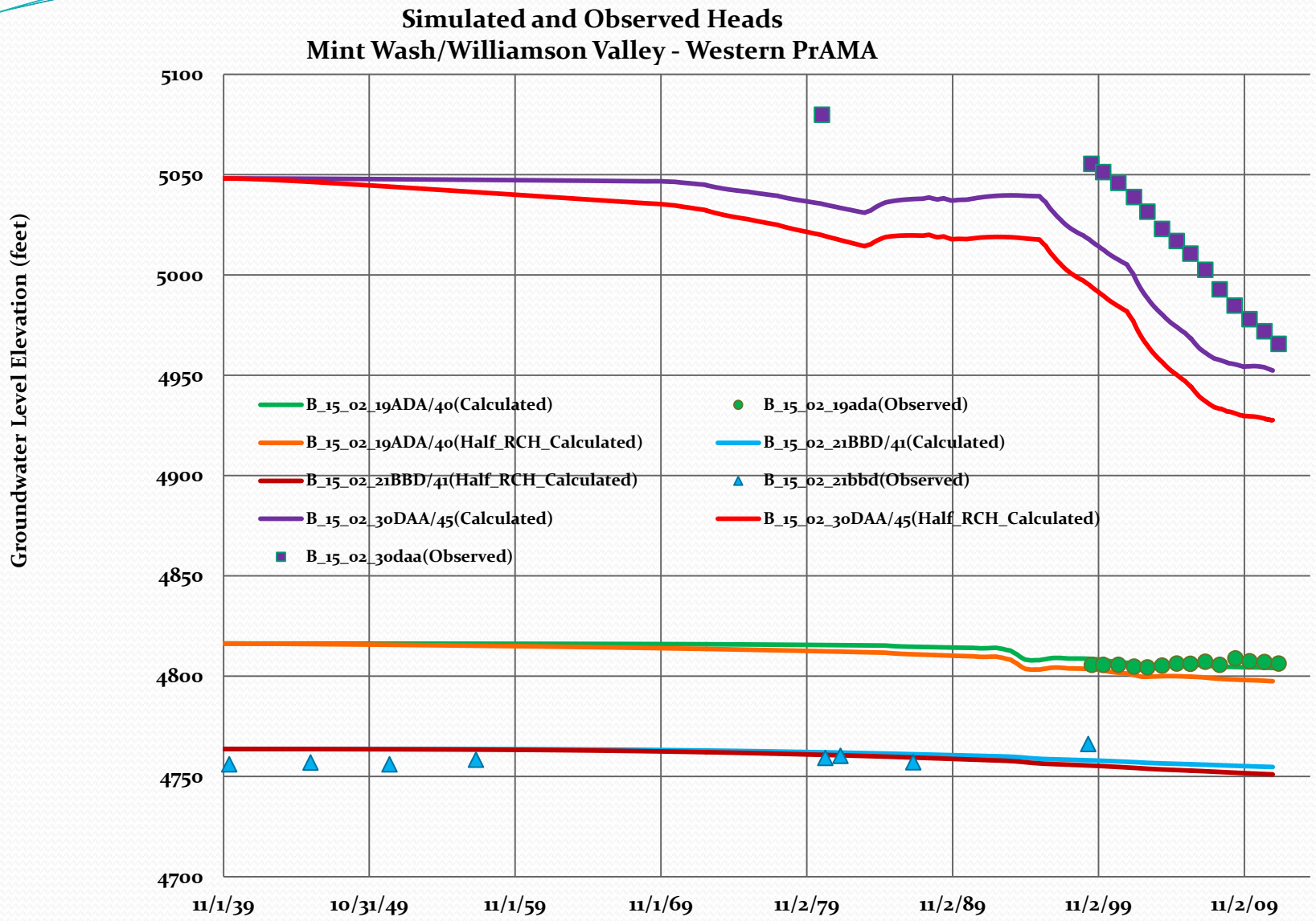


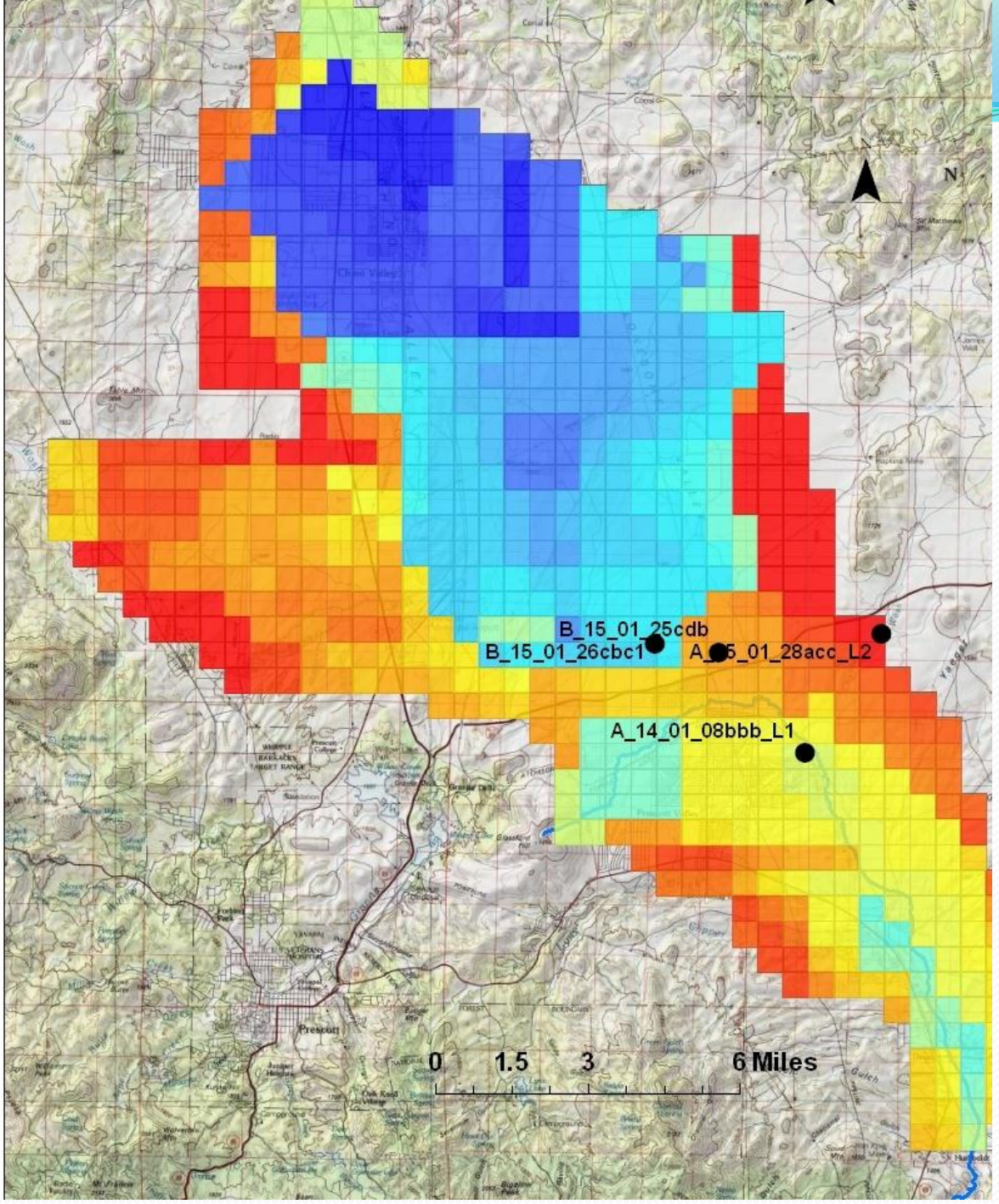
UAU (Layer 1) Aquifer Showing Summer AG RCH Signal: (B-16-02)11cbb1


30000
25000
20000
15000
10000
5000
0
1940
1950
1960
1970
1980
1990
2000
2010
Pre-ROGR Total GW Pumping (AF/yr)
Post-ROGR Total GW Pumping (AF/yr)

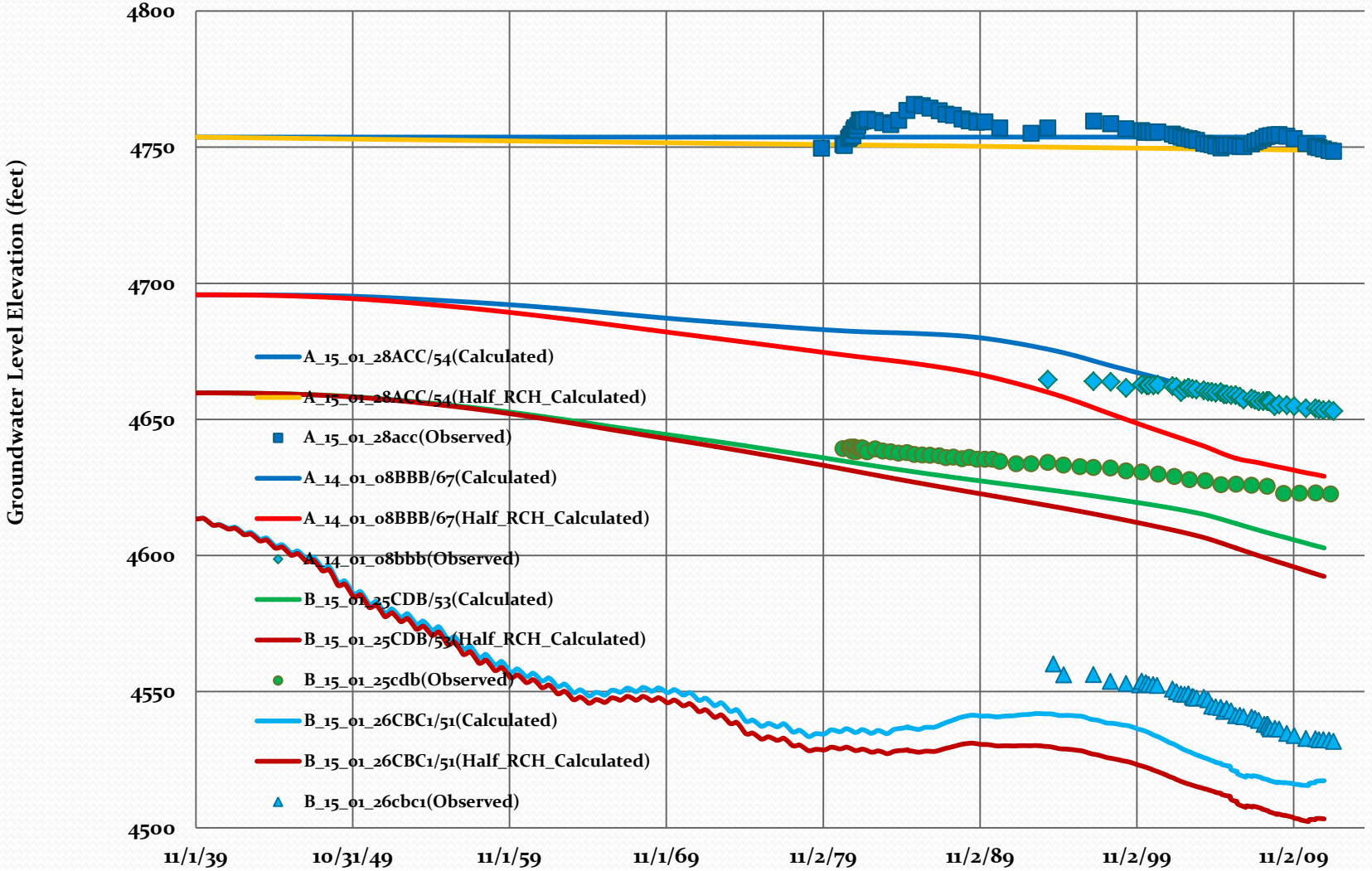

B_15_02_17aba_L2
B_15_02_19ada_L2
B_15_02_21bbd_L2
B_15_02_30daa
B_15_01_31ccc
N
0 1.5 3 6 Miles

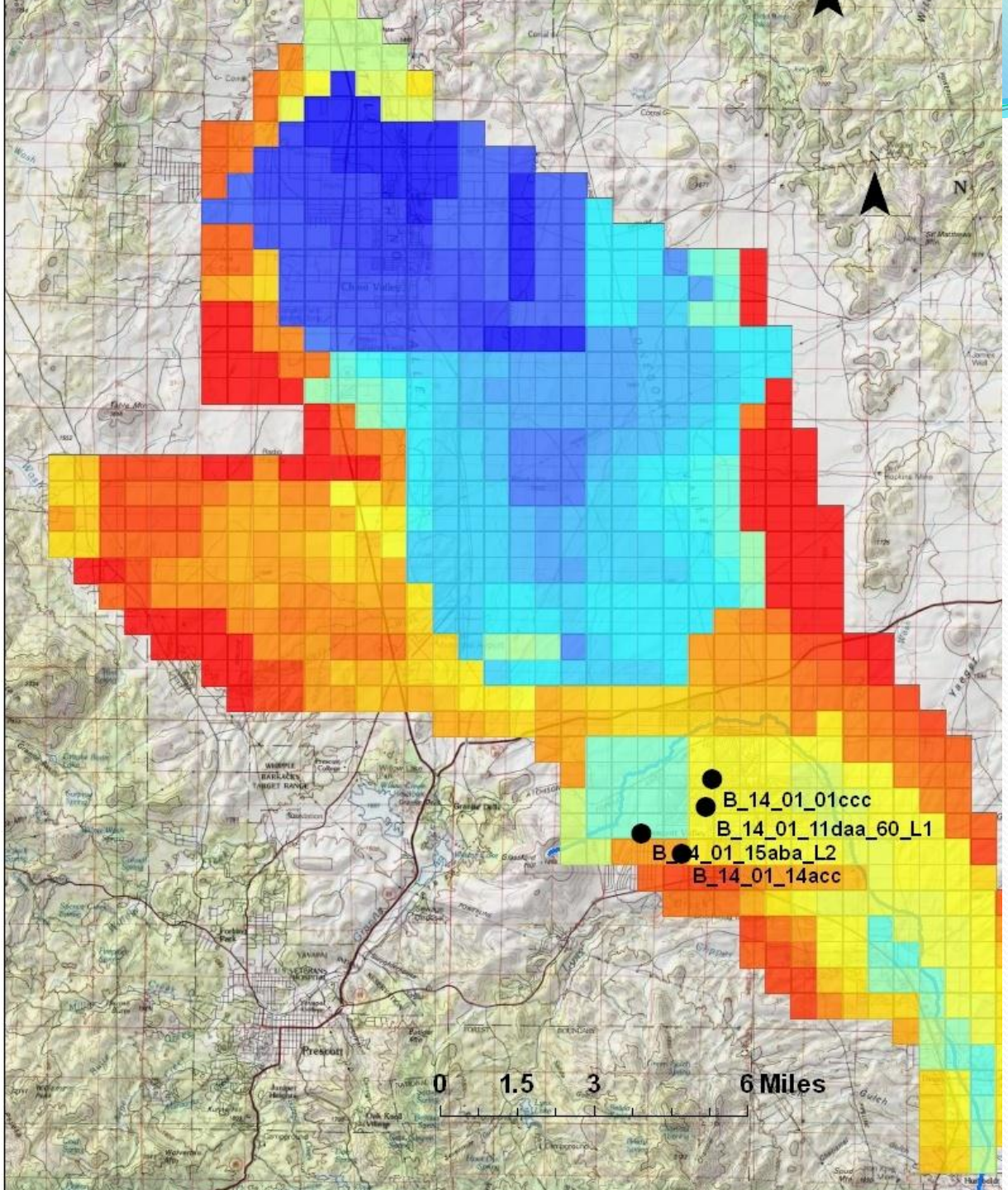

Simulated and Observed Heads
Mint Wash/Williamson Valley - Western PrAMA
Groundwater Level Elevation (feet)
4850
4800
4750
4700
4650
4600
11/1/39
10/31/49
11/1/59
11/1/69
11/2/79
11/2/89
11/2/99
11/2/09
B_15_01_31CCD/50(Calculated)
B_15_01_31CCD/50(Half_RCH_Calculated)
B_15_01_31ccd(Observed)
B_15_02_17ABA/39(Calculated)
B_15_02_17ABA/39(Half_RCH_Calculated)
B_15_02_17aba(Observed)
B_15_02_19ADA/40(Calculated)
B_15_02_19ada(Observed)
B_15_02_19ADA/40(Half_RCH_Calculated)


Simulated and Observed Heads
Mint Wash/Williamson Valley - Western PrAMA
Groundwater Level Elevation (feet)
5100
5050
5000
4950
4900
4850
4800
4750
4700
11/1/39
10/31/49
11/1/59
11/1/69
11/2/79
11/2/89
11/2/99
11/2/09
B_15_02_19ADA/40(Calculated)
B_15_02_19ADA/40(Half_RCH_Calculated)
B_15_02_21BBD/41(Half_RCH_Calculated)
B_15_02_30DAA/45(Calculated)
B_15_02_30daa(Observed)
B_15_02_19ada(Observed)
B_15_02_21BBD/41(Calculated)
B_15_02_21bbd(Observed)
B_15_02_30DAA/45(Half_RCH_Calculated)

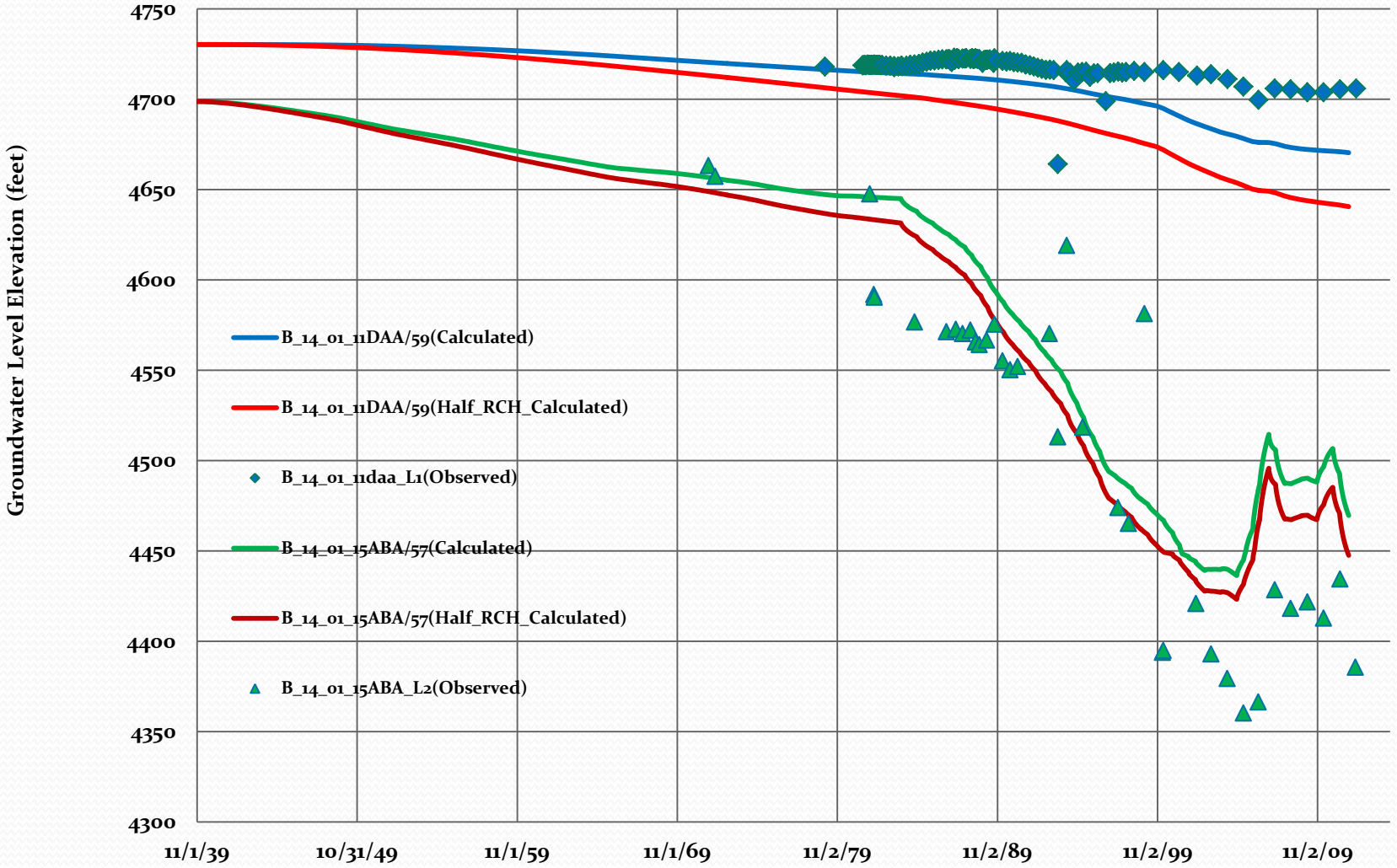

B_15_01_25cdb
B_15_01_26cbc1
A_14_01_08bbb_L1
0
1.5
3
6 Miles
N

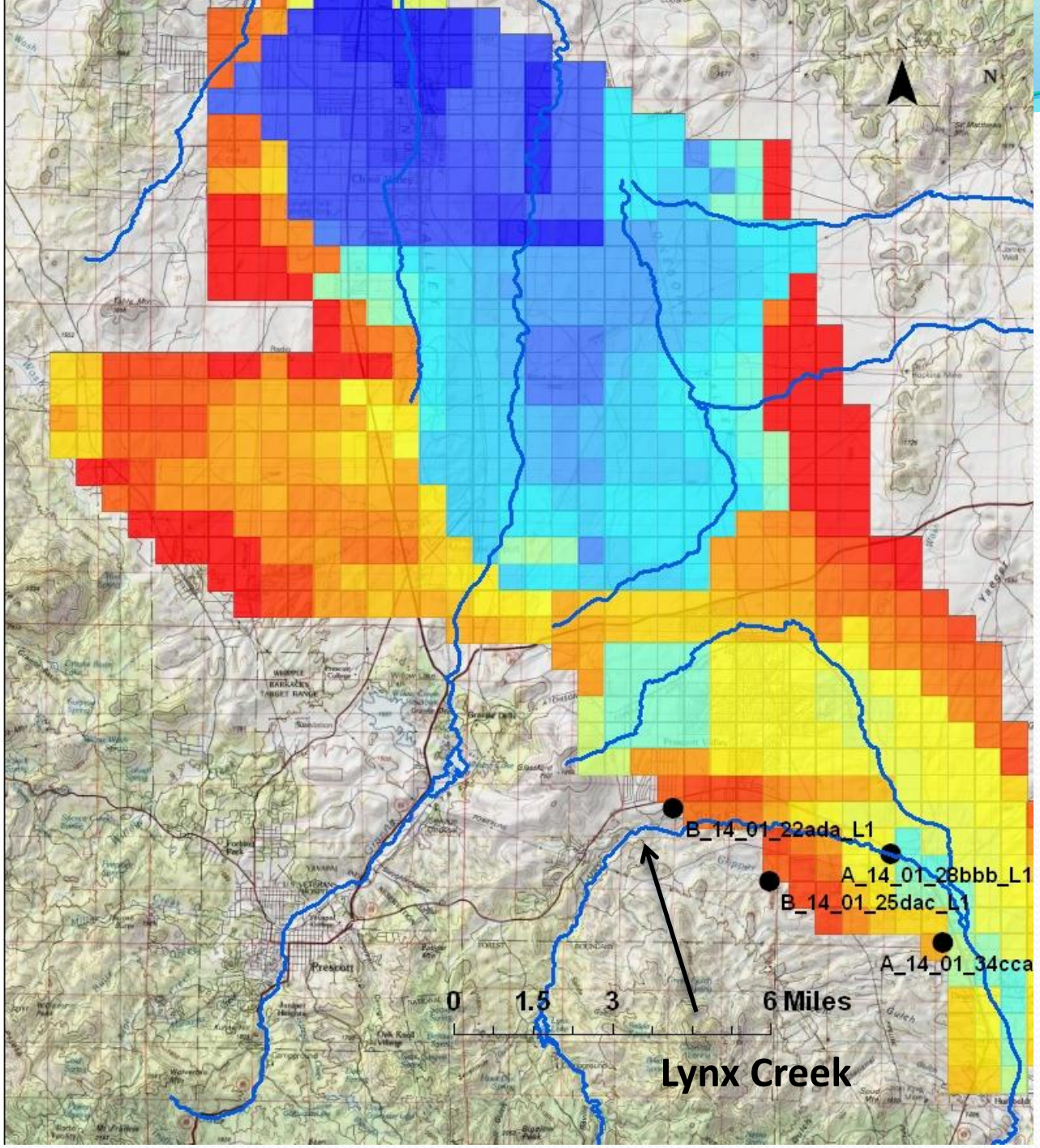
Simulated and Observed Heads Near UAF / LIC Sub-basin Divide



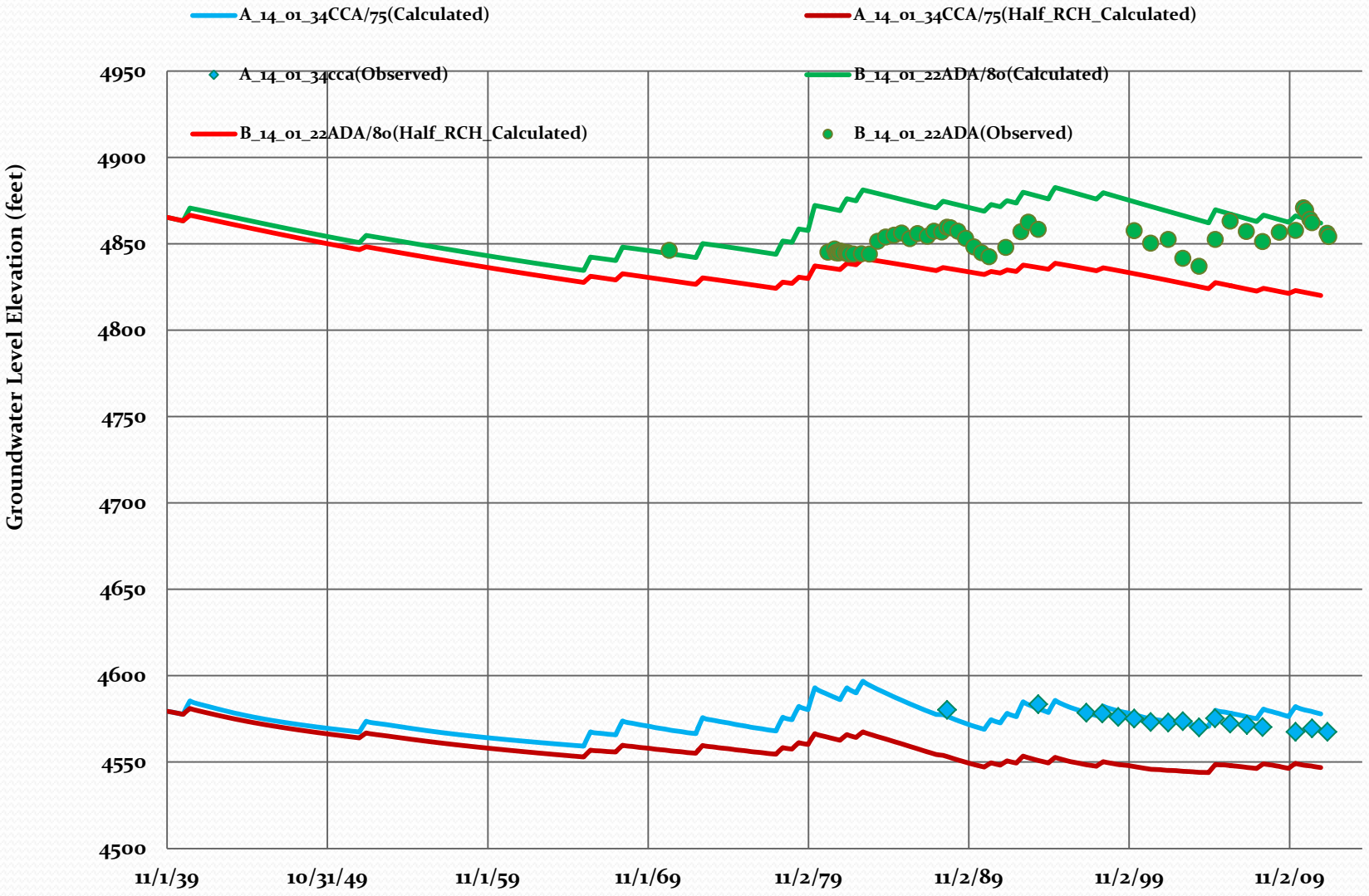

N
B_14_01_01ccc
B_14_01_11daa_60_L1
B_14_01_15aba_L2
B_14_01_14acc
Prescott
0
1.5
3
6 Miles

Simulated and Observed Heads PV's Upper Well Field, UAF Sub-basin

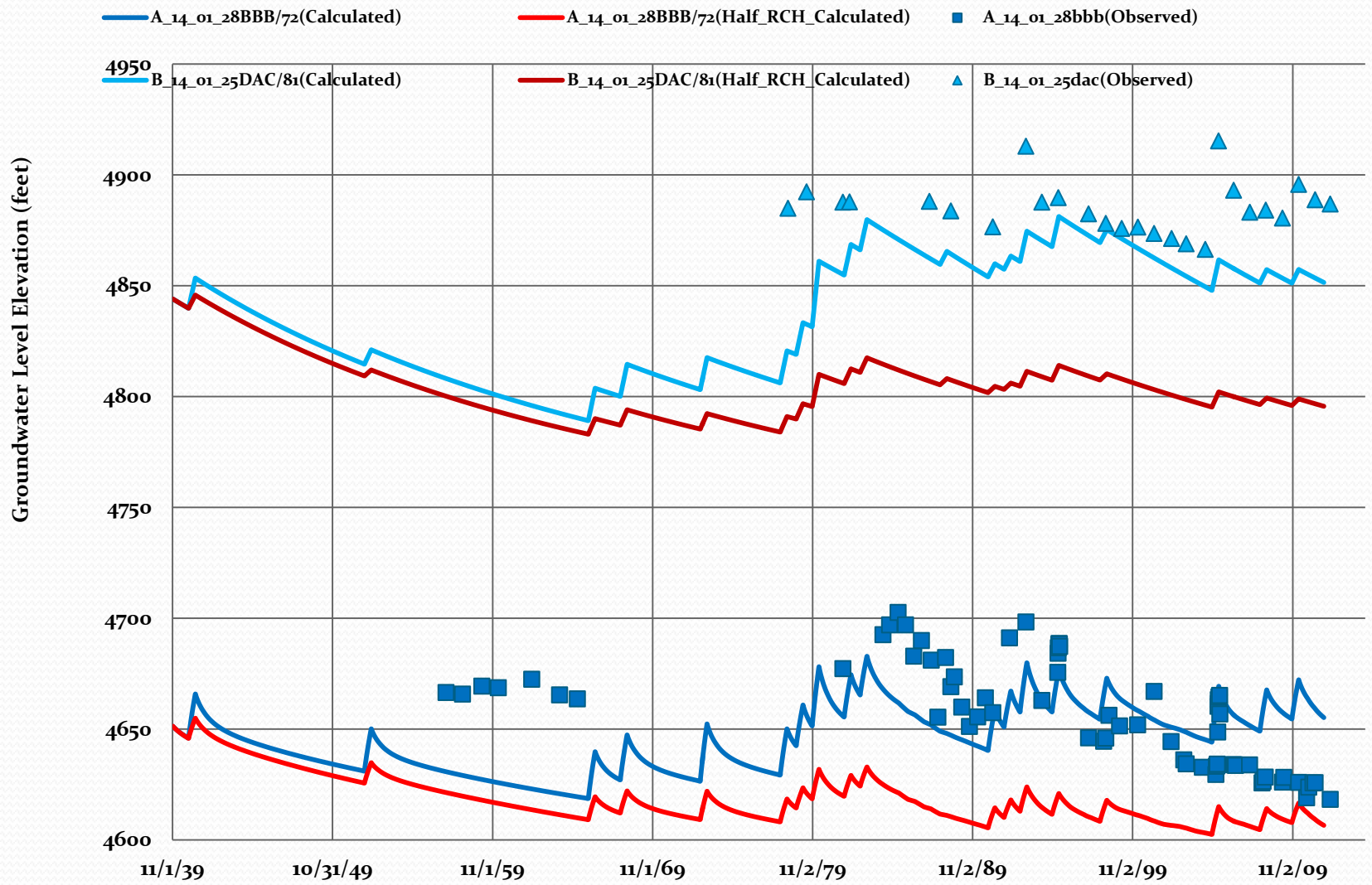



N
B_14_01_22ada_L1
A_14_01_28bbb_L1
B_14_01_25dac_L1
A_14_01_34cca
Prescott
0
1.5
3
6 Miles
Lynx Creek

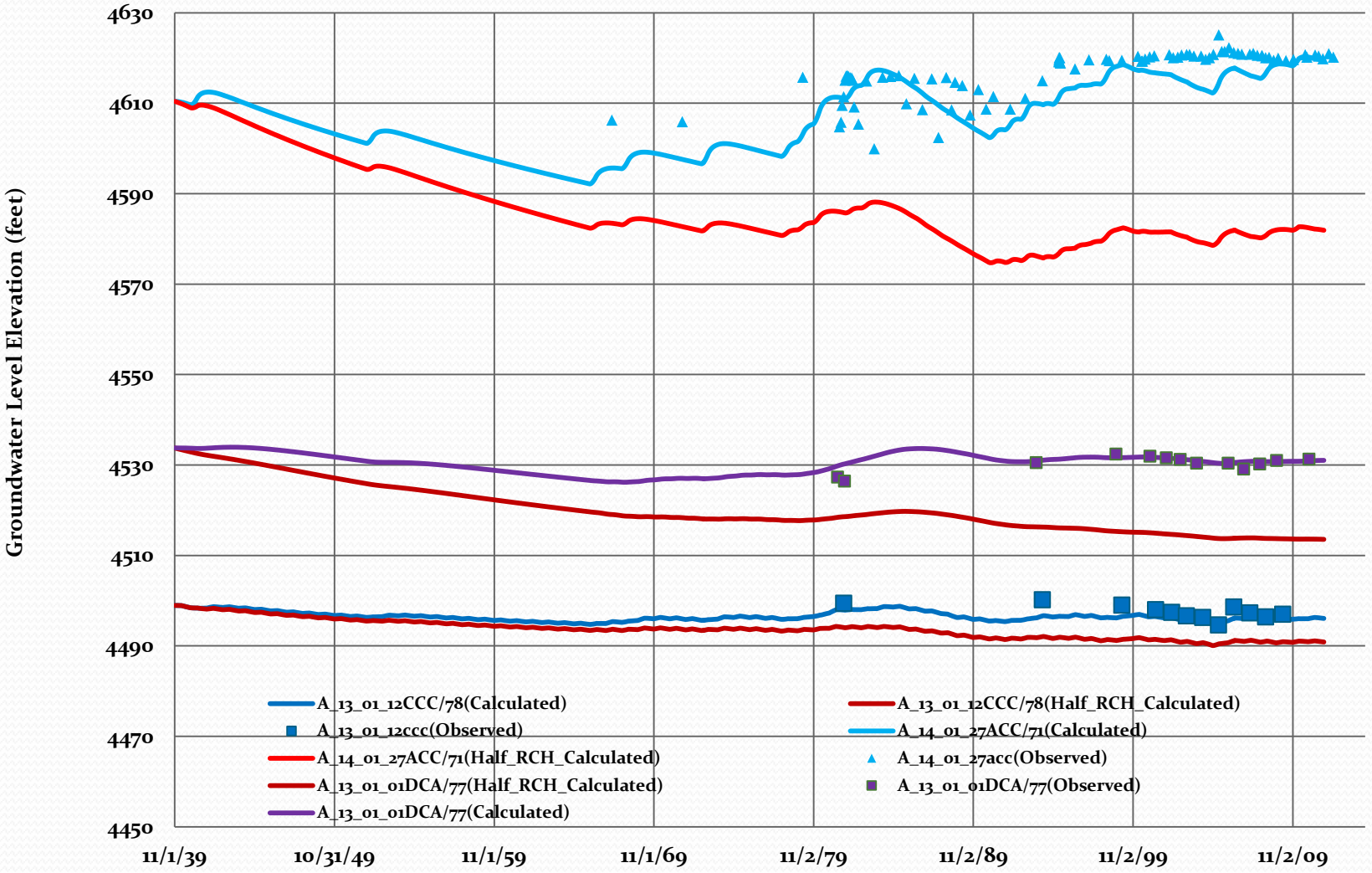
Simulated and Observed Heads Near Lynx Creek, UAF Sub-basin



Simulated and Observed Heads Near Lynx Creek, UAF Sub-basin



Simulated and Observed Heads Lower UAF Sub-basin



Model Calibration: Objective, Φ, Minimize Error

Steady State: K, Recharge and Underflow Distribution

Transient: Time-dependent Stresses and S

Initial parameter estimates:
$\Phi = 100$

Optimal parameters:
$\Phi = 25$

p_2

p_1

Calibration Targets

$$\Phi = \Sigma\ (residual * weight)^2$$

Head Targets

UAU SS & Tran σ=20 feet; σ^{-1}=0.05 ft^{-1}

LVU SS σ =10 feet; Tran= 20 feet; σ^{-1}= 0.1 ft^{-1}

Baseflow Targets (Groundwater Discharge)

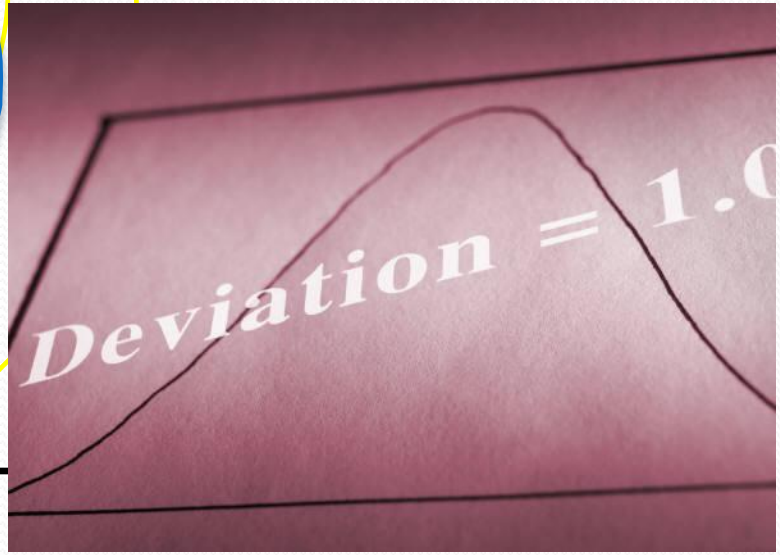
SS Del Rio Springs μ = 6cfs; σ = 0.5 cfs

Transient σ = 1.0 cfs

Agua Fria River μ = 4cfs; σ = 1.0 cfs

Transient σ = 1.0 cfs

SS Prior Information: 3 LVU Zones



Evaluate Alternative Conceptual Models

Ensemble Forecast: Multiple predictions from an ensemble of slightly different initial conditions and/or various versions of models. The objectives are to improve the accuracy of the forecast through averaging the various forecasts, which eliminates non-predictable components, and to provide reliable information on forecast uncertainties from the diversity amongst ensemble members. Forecasters use this tool to measure the likelihood of a forecast.

http://www.wrh.noaa.gov/fgz/gprod.php?pil=afd&sid=fgz&wfo=fgz

- Alternative Initialization Assumptions
  - True Pre-development: Higher natural recharge rate (PEST)
  - USGS AG RCH Assumptions: Natural recharge rate similar to base
  - Different Layer 2:Layer 1 pumping ratios – largely insensitive
- Alternative Natural Recharge Assumptions
  - Constrained Natural recharge 5K AF/yr - Higher model error & bias
  - Lowest possible rate without losing target wells $\approx 4{,}300$ AF/yr
  - Forced MFR:Stream RCH =1:1
    - Resulted in Nat RCGH ~ 5K AF/yr – higher model errror and bias
    - Similar to USGS NARGFM Concept (BCM) – i.e., MFR locations
  - Alternate Natural Recharge Locations (valley locations – low RCH rates
  - Started PEST with natural recharge 5K ended at 9K AF/yr (600 iterations)
- No UAF Sub-basin Underflow – higher model error & bias; less plausible
  - Data shows low seasonal flow; tried higher exempt pumpage in UAF – didn't fix
- Alternative Weighting schemes
  - Heads and flows – insensitive about assigned weights;
  - Weighting consistent with standard error
- No prior information – higher LVU K's, recharge, lower model error
- *PEST AG RCH (steady and transient state)*
- *Grid Refinement (1320'X1,320') near Del Rio: 52X 47 (new)*
  - *Similar to "Base" but improved improve reliability of parameter estimates*

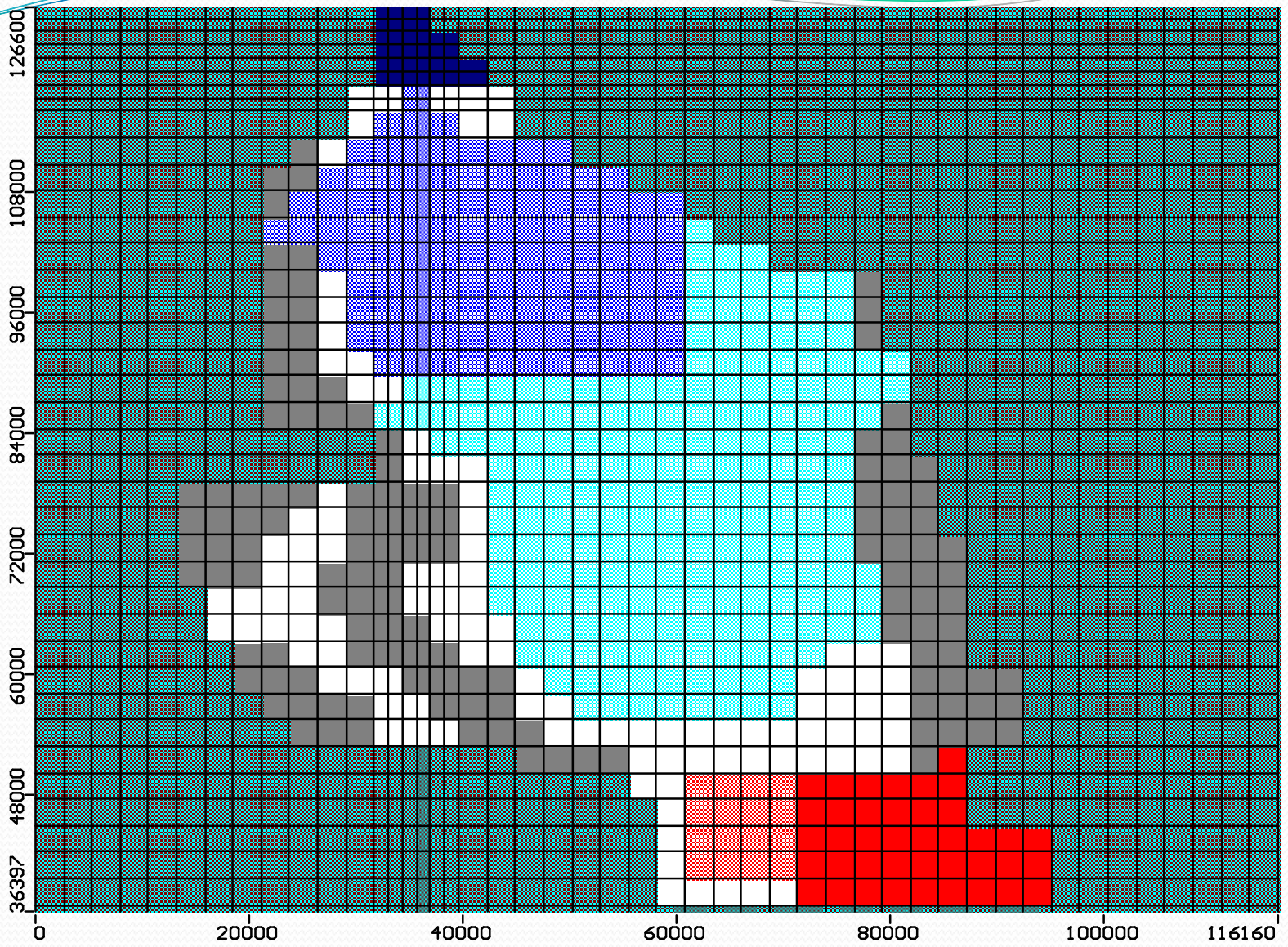
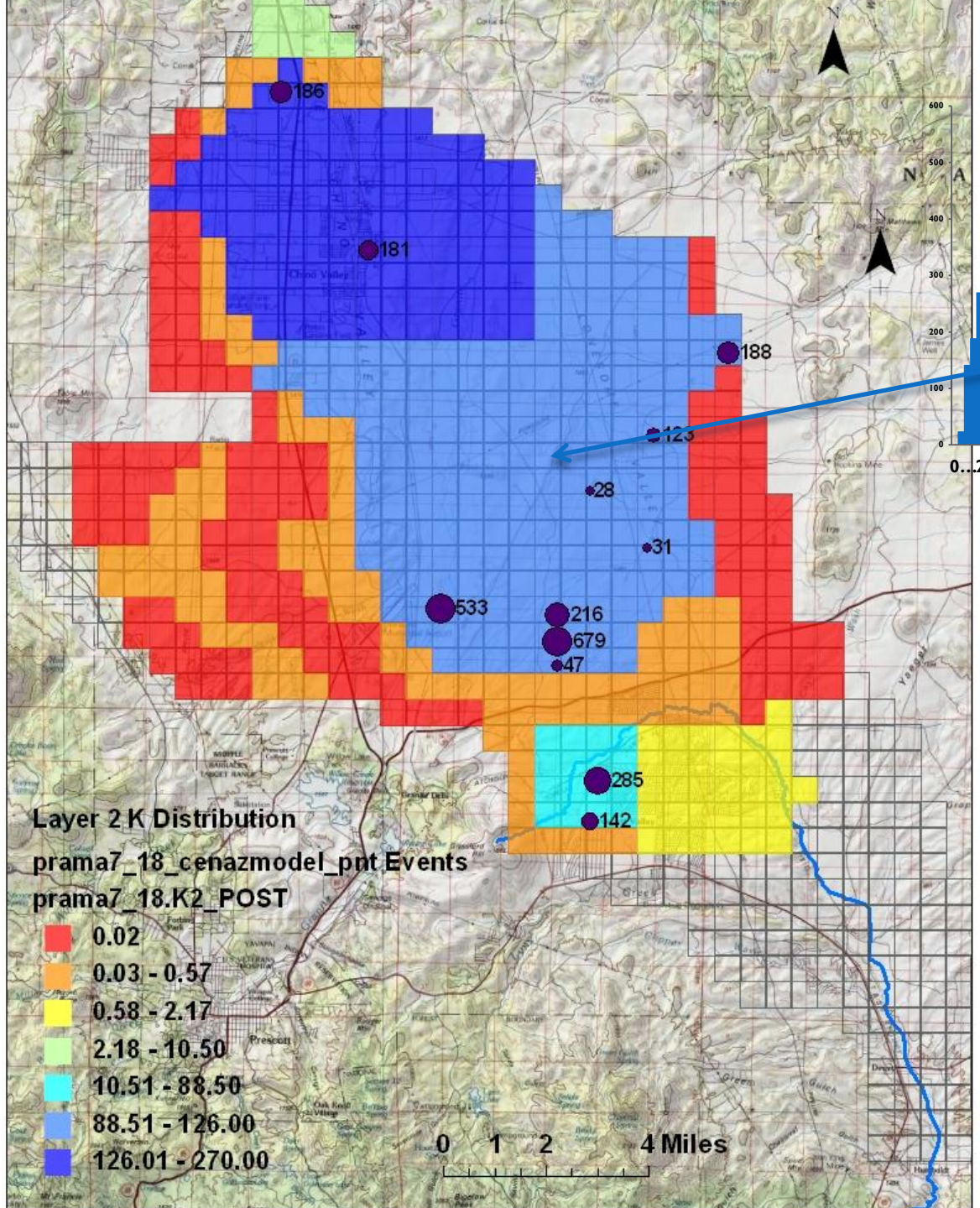

126600
108000
96000
84000
72000
60000
48000
36397
0
20000
40000
60000
80000
100000
116160

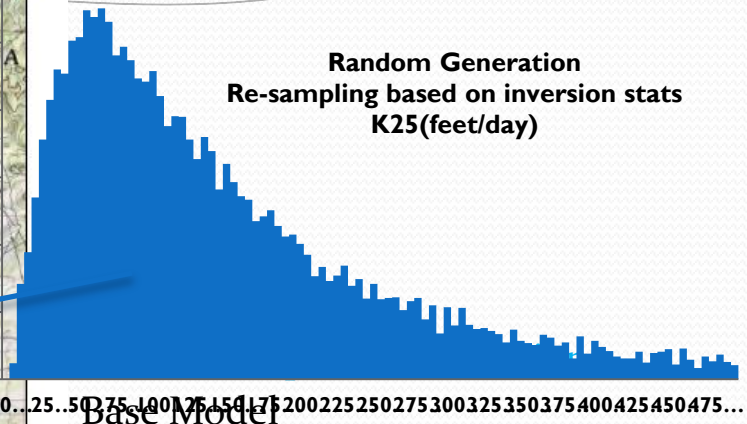
Table D.1.

ACM / Nat RCH Model All models applied recharge (RCH cells) along portions of Granite & Lynx Creek and Agua Fria River Blue = Solution plausible; Green = Plausible solution, but less likely; Red = Solution much less unlikely	Steady State Annualized Natural recharge using both stream cells and recharge cell	
	Total rate of simulated natural recharge AF/yr Steady State	PEST Φ Steady State All models applied same weighting and target number
Base Model	9,167	175.7
ACM 5: Lower prior info weighting on 3 LVU K zones[b]	9,910	173
ACM: No prior information	10,770	171.2
ACM 6: Underflow into model assigned near Watson Lake	9,474	`174.3
ACM 4: Initialization assumes true pre-development[a]	10,613	185
ACM 9: Same initial stresses applied in USGS NARGFM	8,340	175.5
ACM: Same as Base except Layer 2 thickness=250 feet	8,600	182.4
ACM: "Base except Layer 2 thickness=250 feet; lower prior[b]	10,000	175.8
ACM: Same as Base except Layer 2 thickness=400 feet	9,050	177.3
ACM: "Base except Layer 2 thickness=400; lower prior[b]	11,160	172.6
ACM: Same as Base except Layer 1 1owered by 15 feet	8,840	182.1
ACM: " Base except Layer 1 1owered by 15 feet; lower prior[b]	10,460	178.3
ACM: "Same as Base except Layer 1 increased by 15 feet	9,890	170.7
ACM: "Base except Layer 1 increased by 15 feet; lower prior[b]	10,090	169.3
ACM: Grid Refinement (1,320'X1,320') near Del Rio BC-new	*11,000*	*162*
ACM: PEST AG RCH (4,500 AF/yr; but Tran NatRCH=>10.2K–new	*7,836*	*168*
ACM 3b: Assumed steady state baseflow mean = 3cfs	9,336	170.5
ACM 3: No underflow in UAF Sub-basin* 12 parameter	7,780	178
ACM 3a: No underflow in UAF Sub-basin 13 parameter	8,080	177
ACM 2: Natural recharge PEST constrained to ~5,000 AF/yr	5,000	201
ACM 8: MFR-to-stream recharge constrained to 1:1	5,200	241
ACM 10: Constrained PEST to Lowest Possible Nat RCH	4,310	224
ACM 11: Limit LIC Sub-Basin Underflow to 100 AF/yr	5710	189

ACM / Nat RCH Model All models applied variable recharge (RCH cells) along portions of Granite & Lynx Creek and Agua Fria River unless otherwise noted Blue = Solution plausible; Green=Plausible solution, but less likely Red = Solution not likely	Transient State Annualized Natural recharge RCH cells only	
	Annualized Rate of Simulated long-term natural recharge AF/yr	PEST Φ Transient All models applied same weighting and target number
Base Model variation–variable natural recharge using only recharge cells	9,352	4,080
Base Model variation–variable natural recharge rate fixed at higher rate	10,287	4,045
ACM 6: Underflow into model assigned near Watson Lake	9,659	3,876
ACM Grid Refinement (1320X1320), near Del Rio BC – new	*12,000*	*3,810*
ACM: Optimized / TranPEST AG RCH (down 7.5%)	*10,240*	*3,750*
ACM 1 Base with all constant natural recharge	9,352	4,518
ACM 3: No underflow UAF Sub-basin–variable natural recharge rate	7,950	5,235
ACM 7 Base Model variation with lower natural recharge set to 7,482	7,482	4,903
ACM 2: PEST Constrained natural recharge ~5,000 AF/yr	5,100	7,300
ACM 8: MFR-to-stream recharge constrained to 1:1	5,200	7,948
ACM 10: Constrained PEST to Lowest Possible Nat RCH	4,310	16,969
ACM 11: Limit LIC Sub-Basin Underflow to 100 AF/yr	5710	7,370



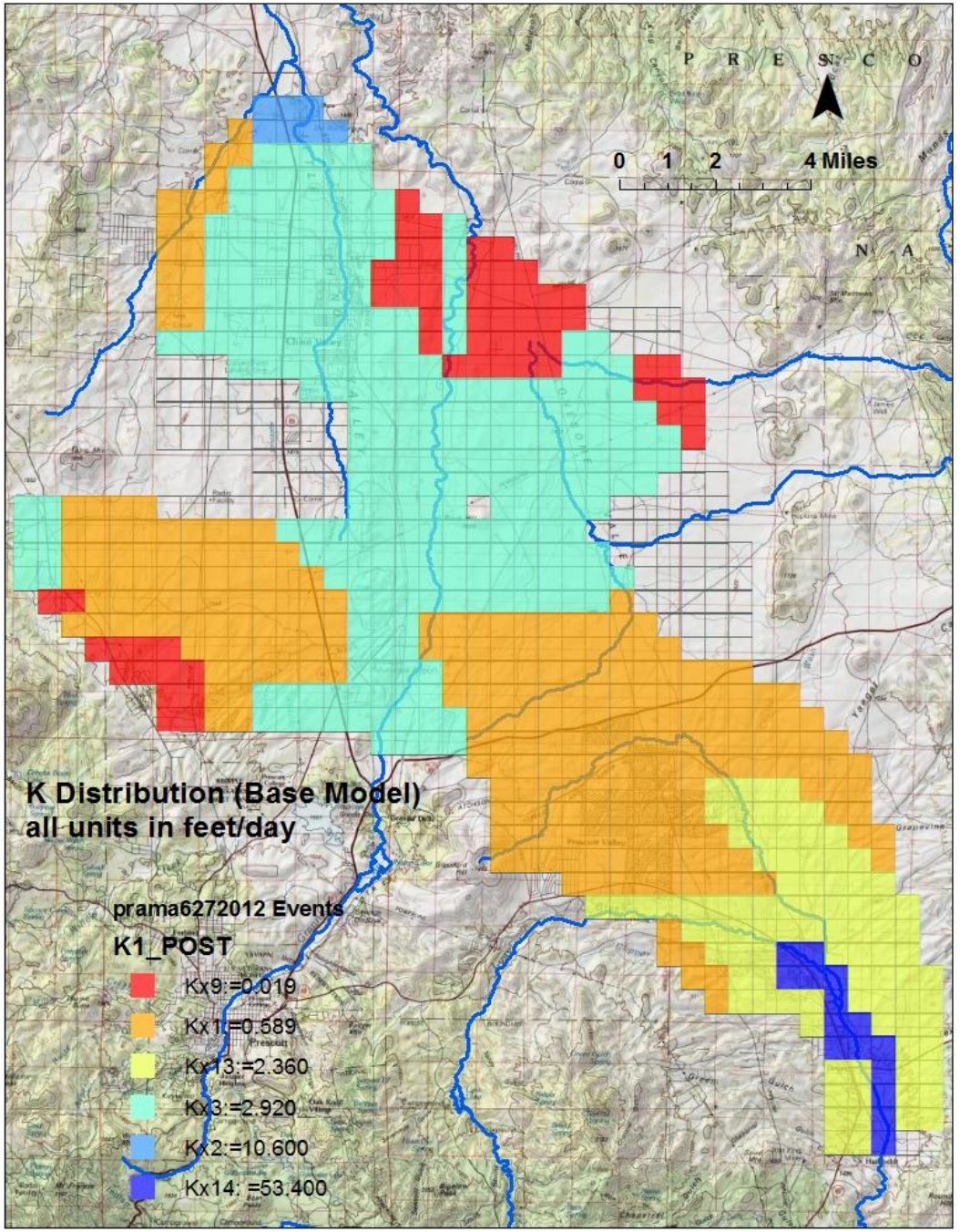
Log-normal K Distribution of Central LIC Sub-Basin LVU K 25 Diagnostic Stats

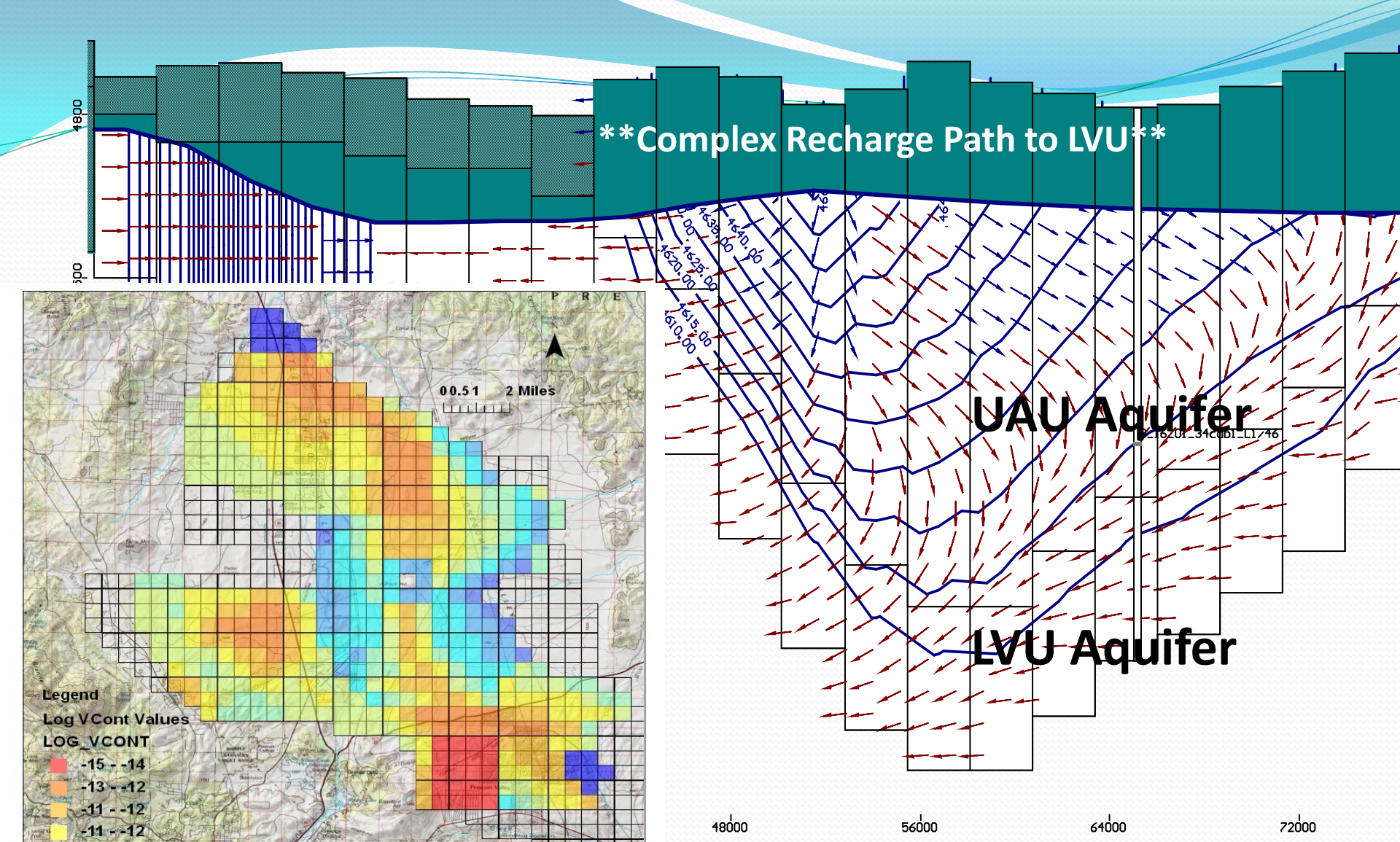


Base Model

Est. Parameter	95% CI
K13= 2.4	0.89 --- 6.3
K14= 53	24 -------121
K1 = 0.6	0.2 ---- 1.2
K23= 272	116 ---- 639
K25 = 138	37 ---- 513
K26 = 102	36 ----- 290
K2 = 10.6	6 ----- 19
K3 = 2.9	1.3 --- 6.6
Kz3 = 0.00151	0.0008 – 0.003
K9 = 0.019	0.009 – 0.037
RCH=9200	4,100 - 14,300
UF_LIC=2320	0 - 4,640
UF_UAF=1140	-1,480---3,760

Layer 1 K-Distribution





Aquitard – very sensitive!

Kz (ft/d)=0.0015 95% CI=0.0007–0.003

Longer residence time for water in stream = >more recharge (losing reach)

Composite Scale Sensitivites (CSS)
Steady State: Transient State Ratios

- *PrAMA Model Tran (72 yrs)*
  - ***> 5 : 1***
- *SCAMA North Tran (20 yrs $_{quasi\text{-}SS}$)*
  - ***11 : 1*** ***(inner valley system changes rapidly)***
- *USGS N-Aquifer (35 yrs)*
  - ***86 : 1***

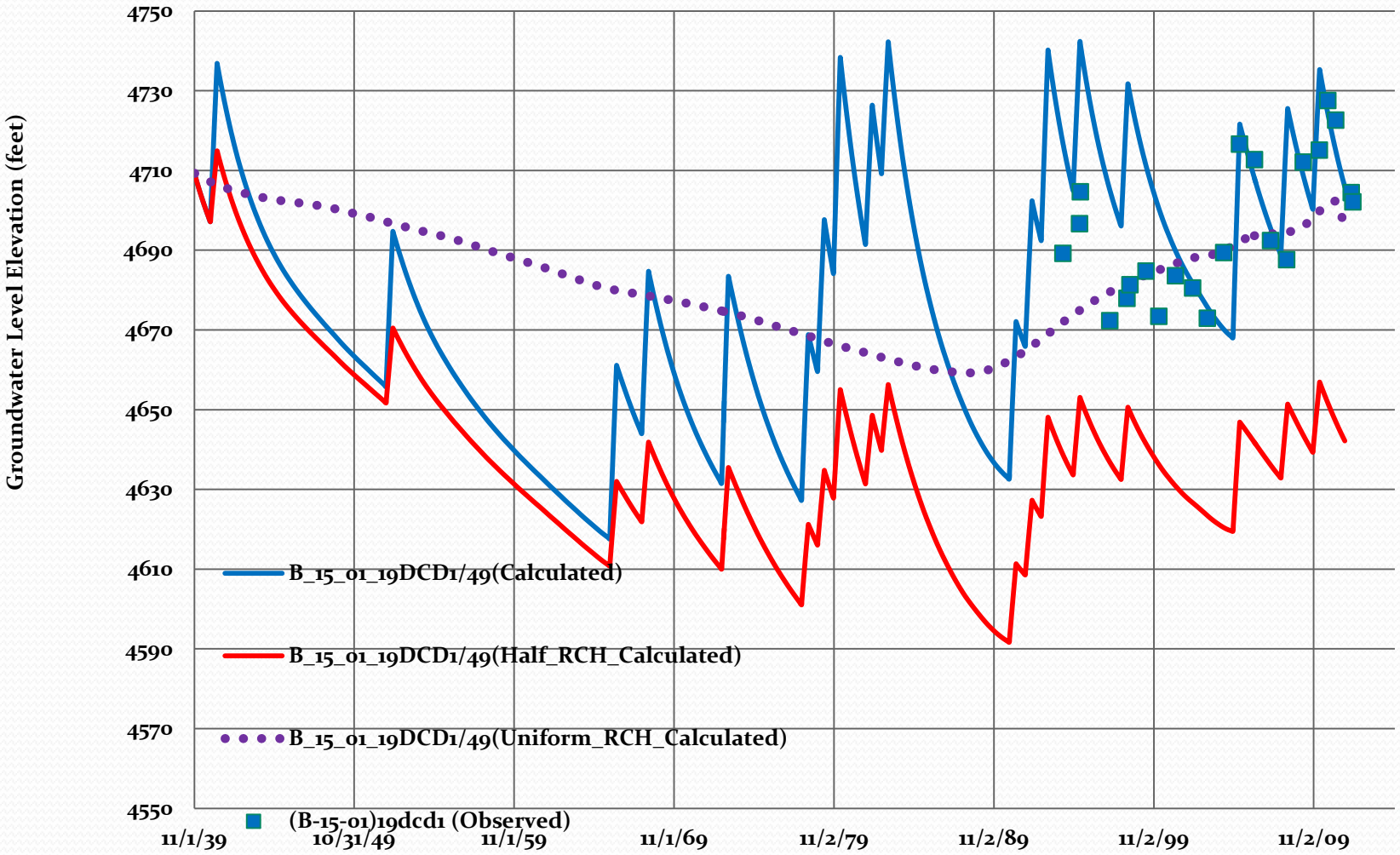
Synopsis: Model Initialization is Important
Must Understand Parameter Relations!

Model Parameter Composite Sensitivity Steady State > 3 72-Year Transient State (common parameters) {modified slide}		
Parameter (15-P)	Steady scaled	72-Year Transient State scaled
Kx13	0.32	0.023
Kx14	0.29	0.032
Kx1	0.53	0.12
Kx23	0.19*	0.12
Kx25	0.059*	0.12
Kx26	0.055*	0.00071
Kx2	0.68	0.042
Kx3	0.24	0.064
Kz3*	0.25	0.14
Kx9	0.33	0.12
Underflow UAF	0.014	0.0027
Underflow LIC	0.17	0.079
MFR	0.49	0.069
Gran Crk RCH	0.28	0.025
Lynx AF RCH	0.54	0.055
S (all Sy and Ss)	N/A	3.86

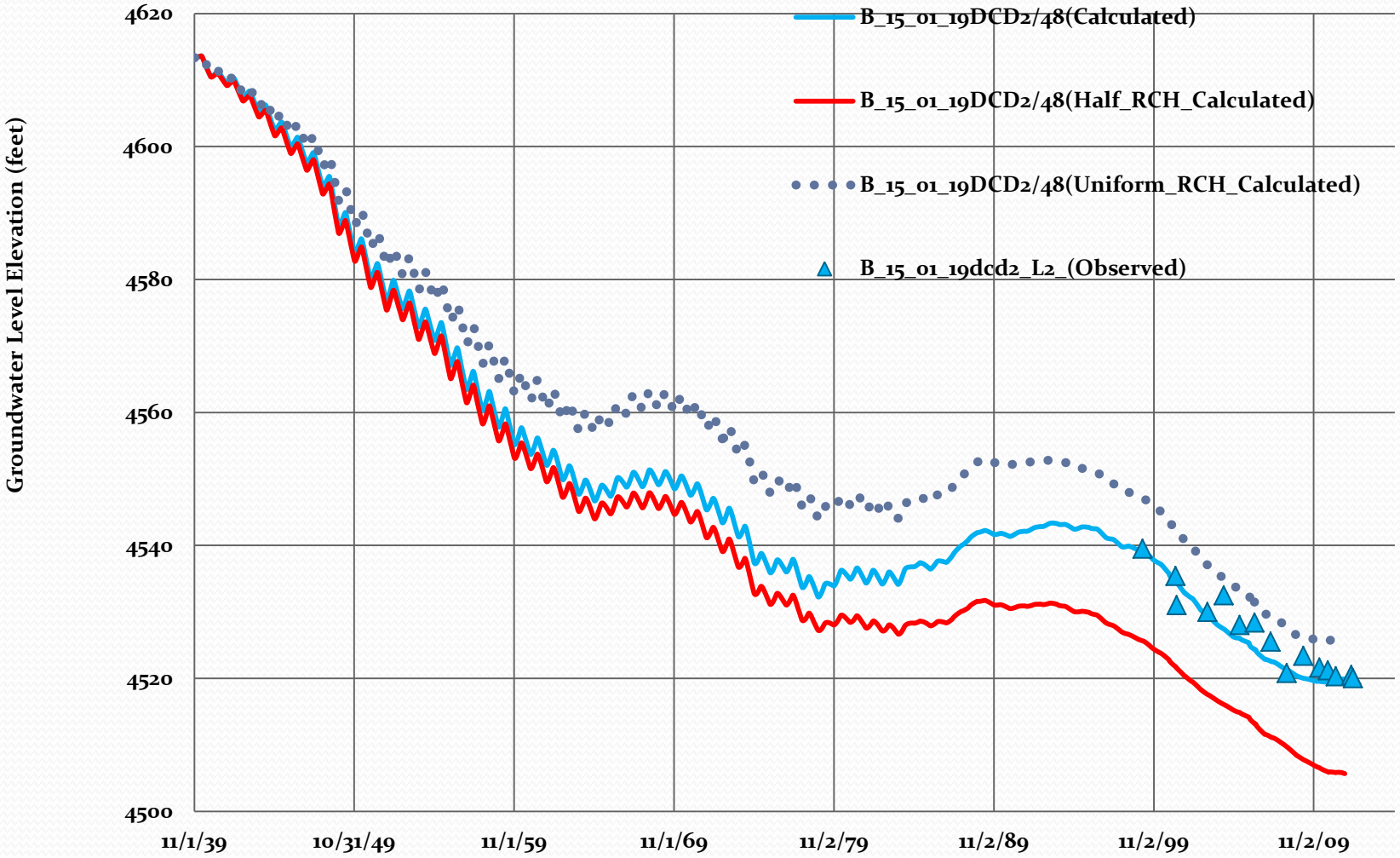
Calibration Target Composite Sensitivity

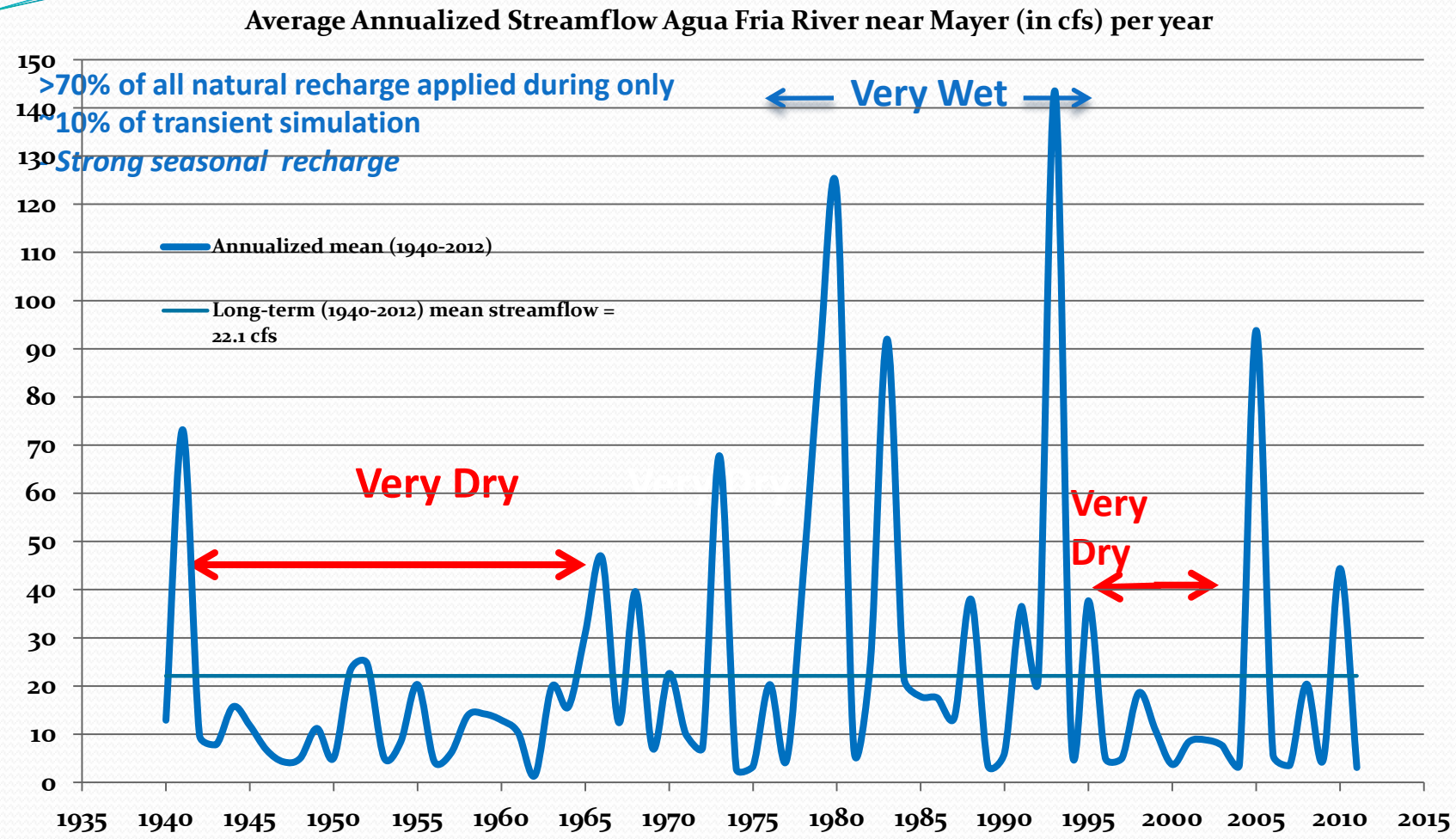
	Steady State (Targets)	72-Year Transient State (targets)
Del Rio Springs	**2.44 (1)**	**0.54 (38)**
Agua Fria Baseflow	**0.694 (1)**	**0.19 (30)**
Layer 1 heads	**0.31 (61)**	**0.21 (1,413)**
Layer 2 heads	**0.54 (43)**	**0.026 (1,775)**
Prior info	**0.39 (3)**	N/A

Simulated and Observed Heads near Granite Creek - South LIC Sub-basin

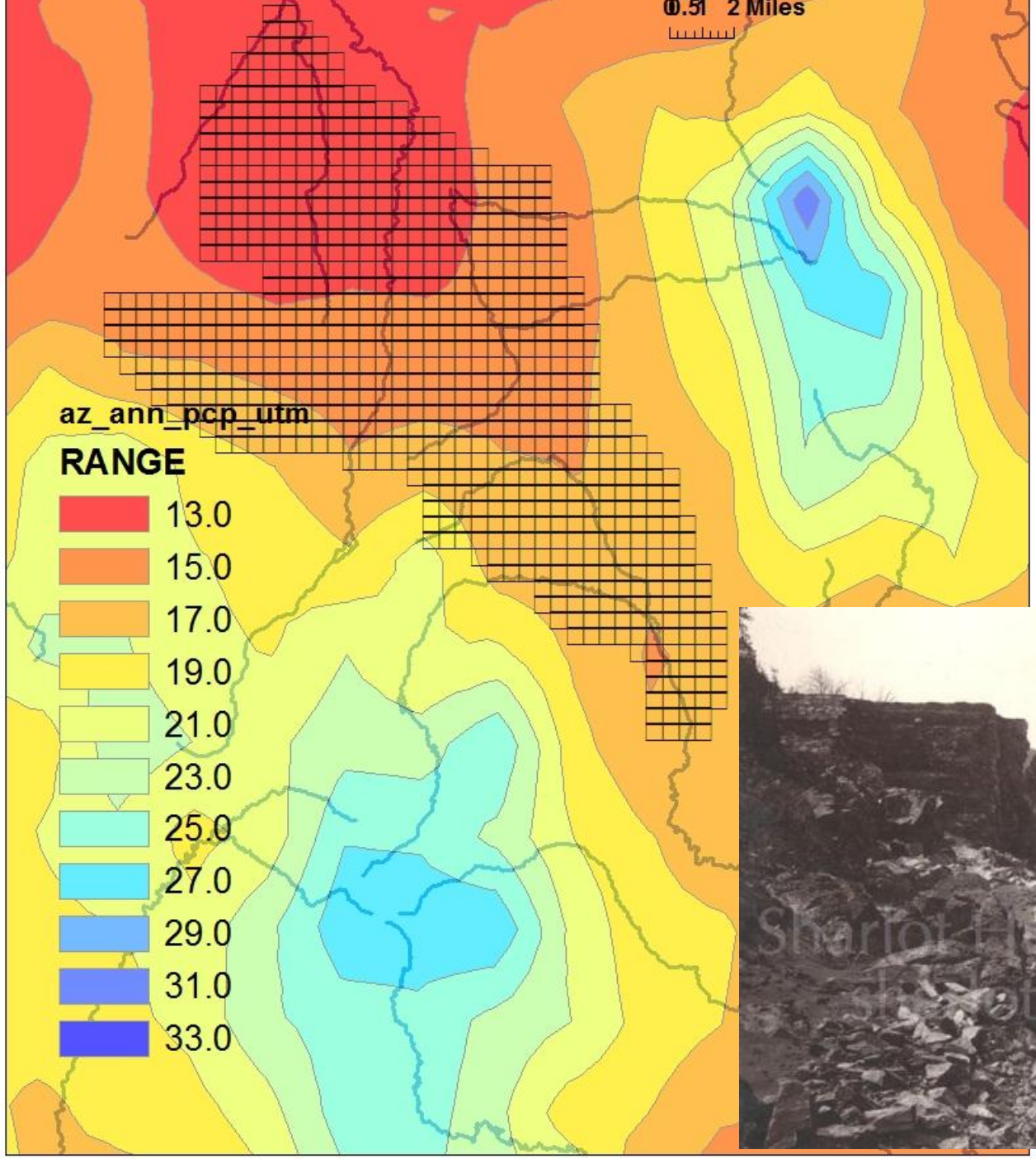


Simulated and Observed Heads near Granite Creek - South LIC Sub-basin





- **Annual Stream Recharge Variability for other areas**
- Tucson AMA: Max 469,900; Min 15,750; Mean: 63,000 AF/yr
- **Santa Cruz AMA: Max≈ 100,000 AF/yr; Min ≈10,000 AF/yr**
- **Gila River ~ Pinal AMA 1993 alone ≈ 800,000 AF/yr**


0 0.5 1 2 Miles
az_ann_pcp_utm
RANGE
13.0
15.0
17.0
19.0
21.0
23.0
25.0
27.0
29.0
31.0
33.0

Questions?

Thanks to…

- ADWR Basic Data
- ADWR Modeling
- USGS (SW gauges)

Some of the photos
Provided courtesy of:
-Prescott Courier;
-Chino Valley Review;
-CWAG;
-Sharlot Hall Museum