Groundwater Flow Modeling and Multiple Scenario Analysis: Prescott Active Management Area, Yavapai County, Arizona

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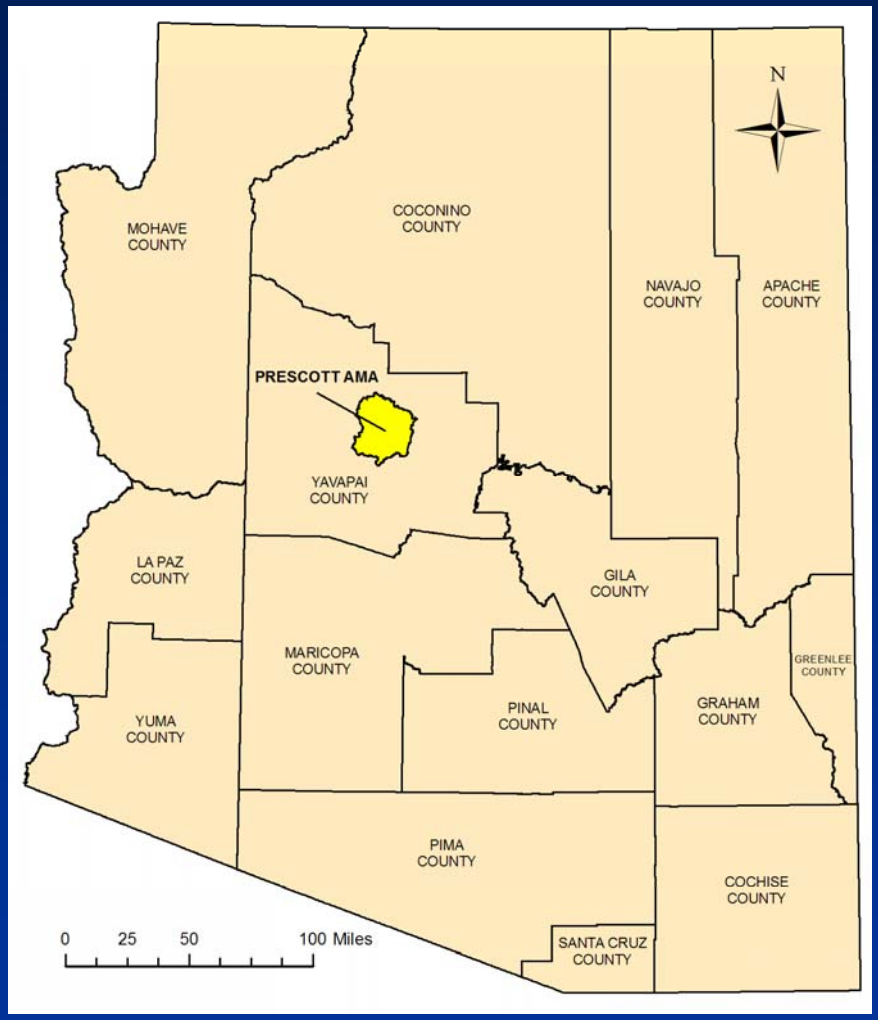
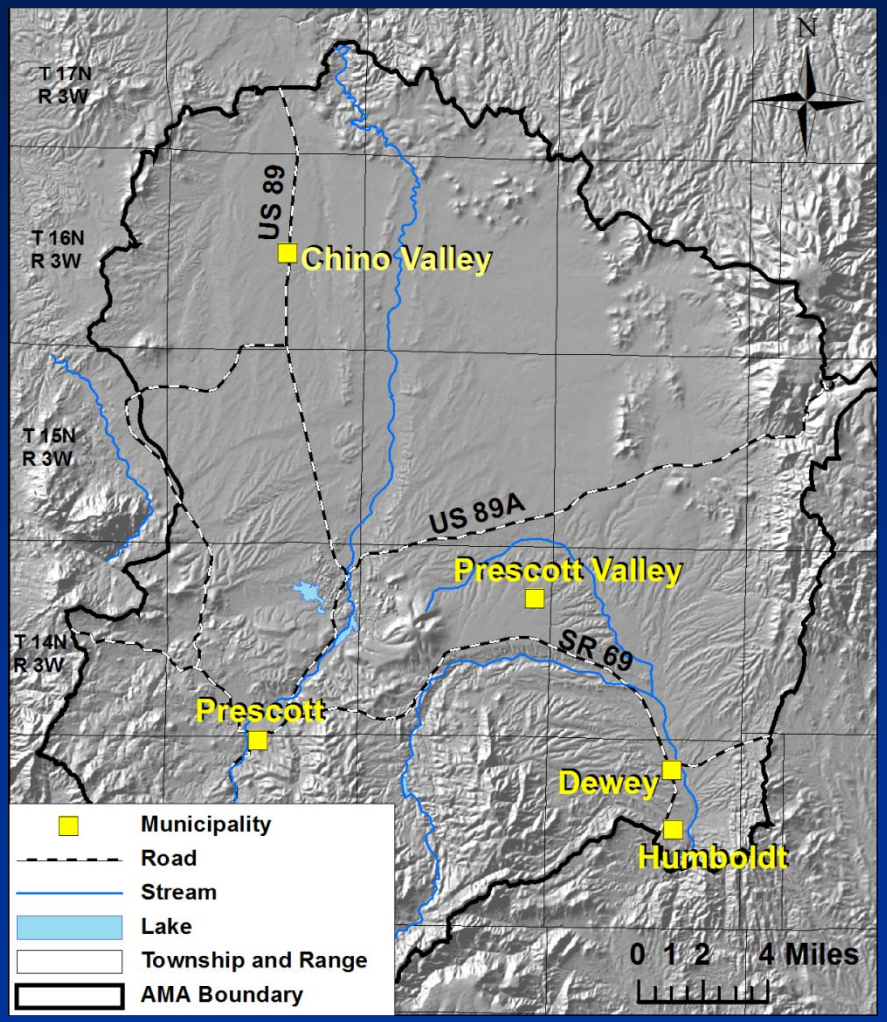
August 13, 2008

Talk Outline

- Hydrogeology of the Prescott AMA
- Previous groundwater modeling in the Prescott AMA
- Updating the Prescott AMA model
- The scenario analysis process
- Scenario results
- Recent Updates
- Conclusions

The Prescott AMA

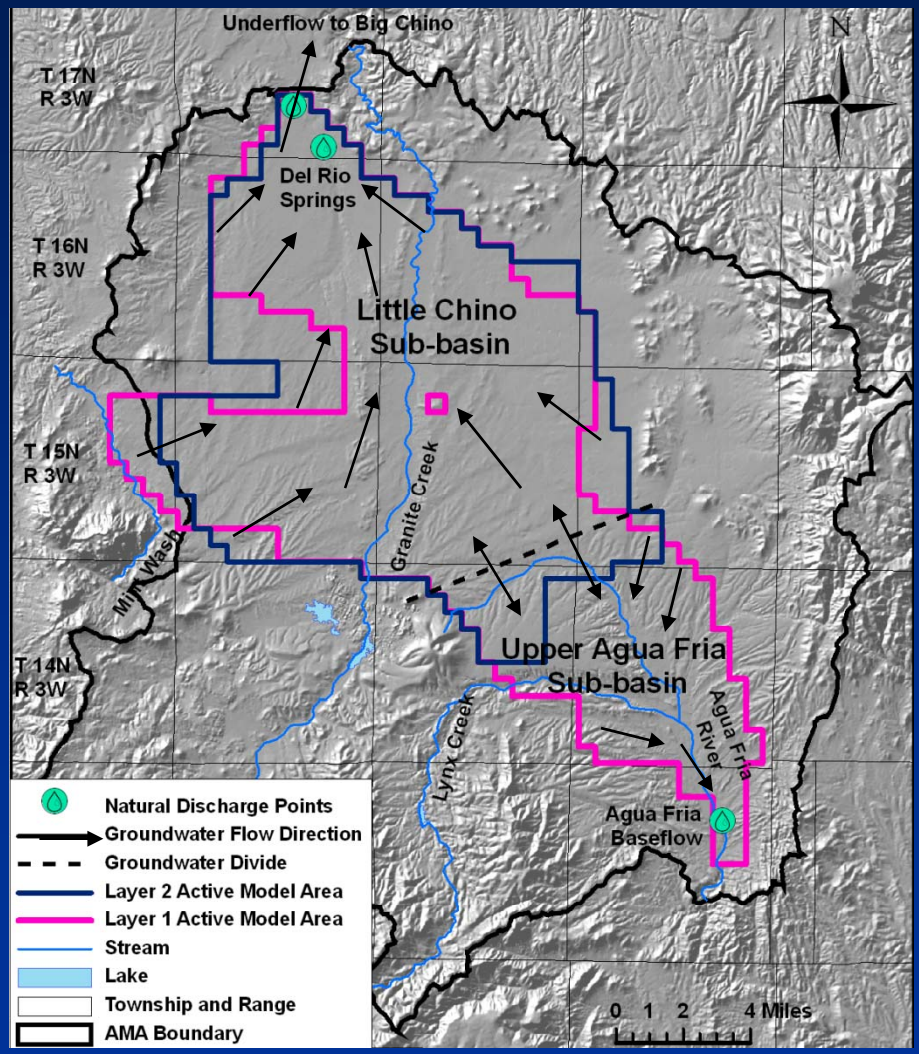




The Hydrogeologic System of the Prescott AMA

- **Two Sub-basins**
- **– Little Chino Sub-basin**
- **– Upper Agua Fria Subbasin**

- **Two Aquifer Units**
- **– Upper Alluvial Unit**
- **– Lower Volcanic Unit**



Groundwater modeling in the Prescott AMA

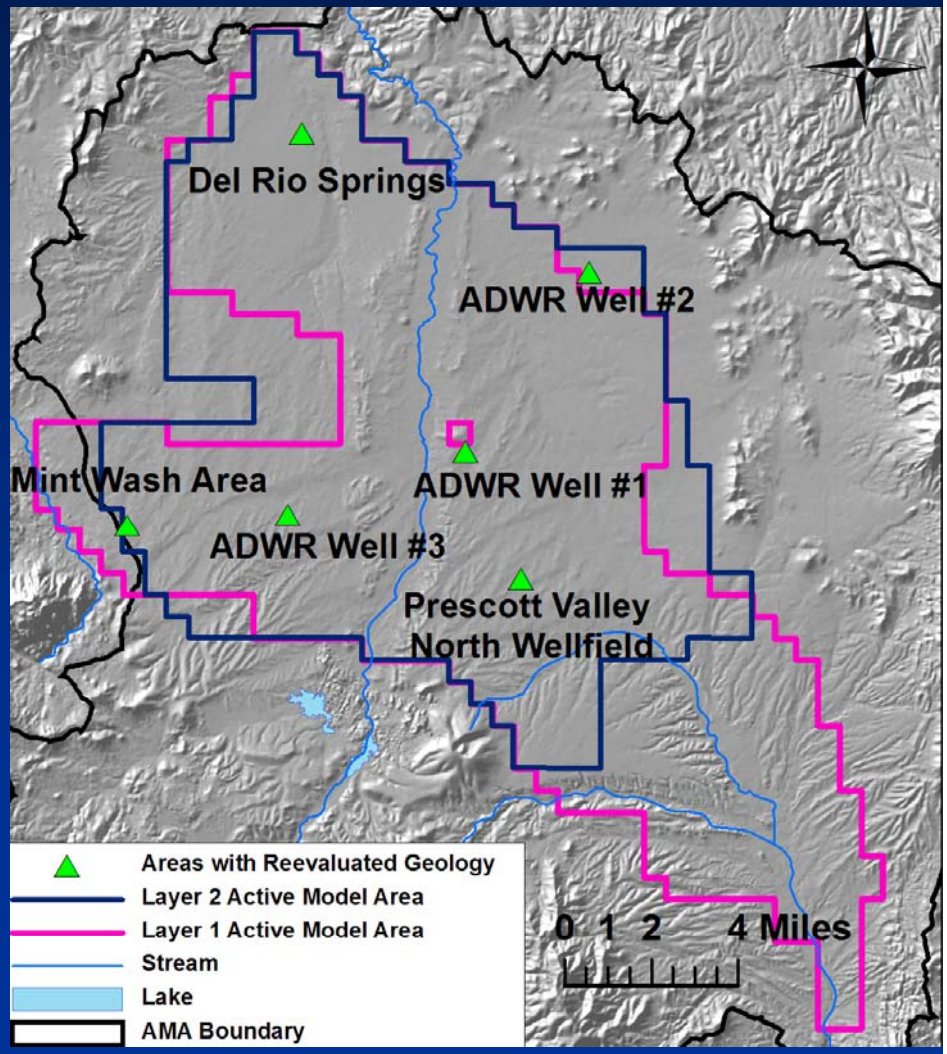
- Corkhill and Mason (1995)
  - Original Prescott AMA groundwater flow model developed to meet guidelines of 1980 Groundwater Management Act
  - Steady-State Simulation (Apr. – Nov. 1939)
  - Transient simulation from 1939 -1994
- Nelson (2002)
  - Steady-State Simulation (Apr. – Nov. 1939)
  - Updated Prescott model from 1939-1999
  - Planning Scenario 1999-2025

Objectives for the Prescott AMA Model Update

1) Extend the active model area to include the western part of the AMA (referred to as ‘the Mint Wash area’),
2) Update the geologic structure at specified locations based on newly available data,
3) Reevaluate model parameter values based on new techniques and newly available data, and
4) Extend the transient simulation to include the years 1999-2004.

Structural Changes

- Prescott Valley North Wellfield
- Mint Wash Extension
- ADWR Monitor Well #1
  - Black Hill
- ADWR Monitor Well #2
  - Lonesome Valley
- ADWR Monitor Well #3
  - SW Little Chino Valley



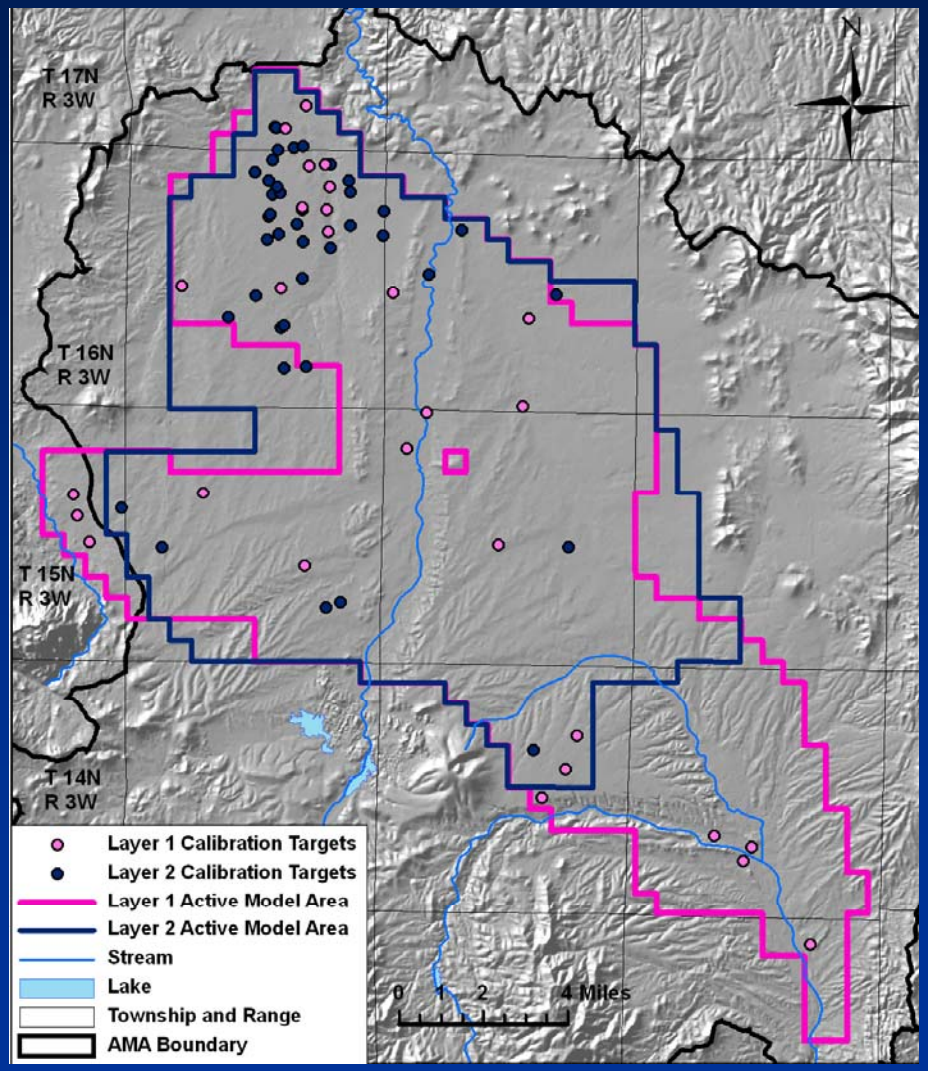
Calibration Criteria

The best calibrated models should have three attributes:

- Good fit to head and flux targets,
- Weighted residuals that are randomly distributed, and
- Realistic optimal parameter values

(Hill, 1998)

Steady-State Simulation Calibration Targets



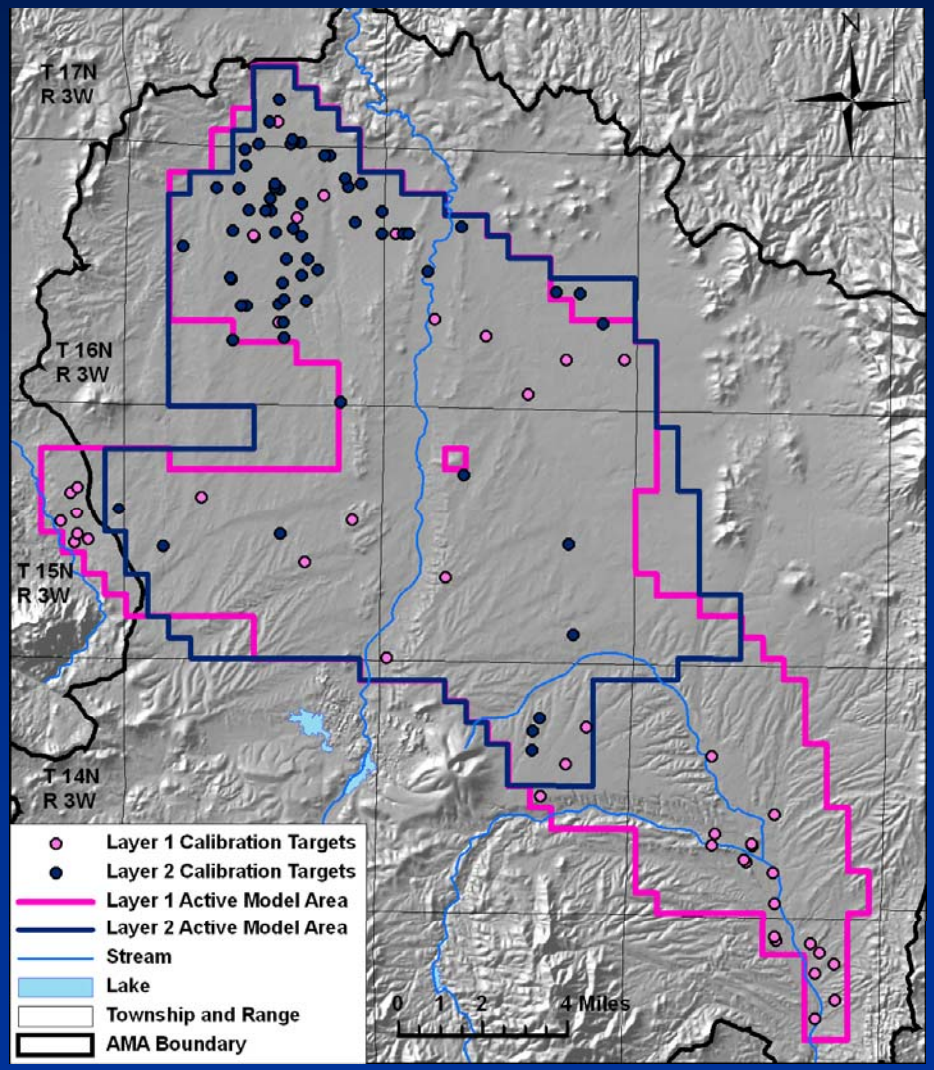
- **72 steady state head targets (29 original)**

- **Layer 1 – 26 head targets**
- **Layer 2 – 46 head targets**

- **Flux at Del Rio Springs**
- **Flux at Agua Fria River**

- **Residual error = 9.14 ft**
- **Error as % total water-level change = 2.0 %**

Transient Simulation Calibration Targets



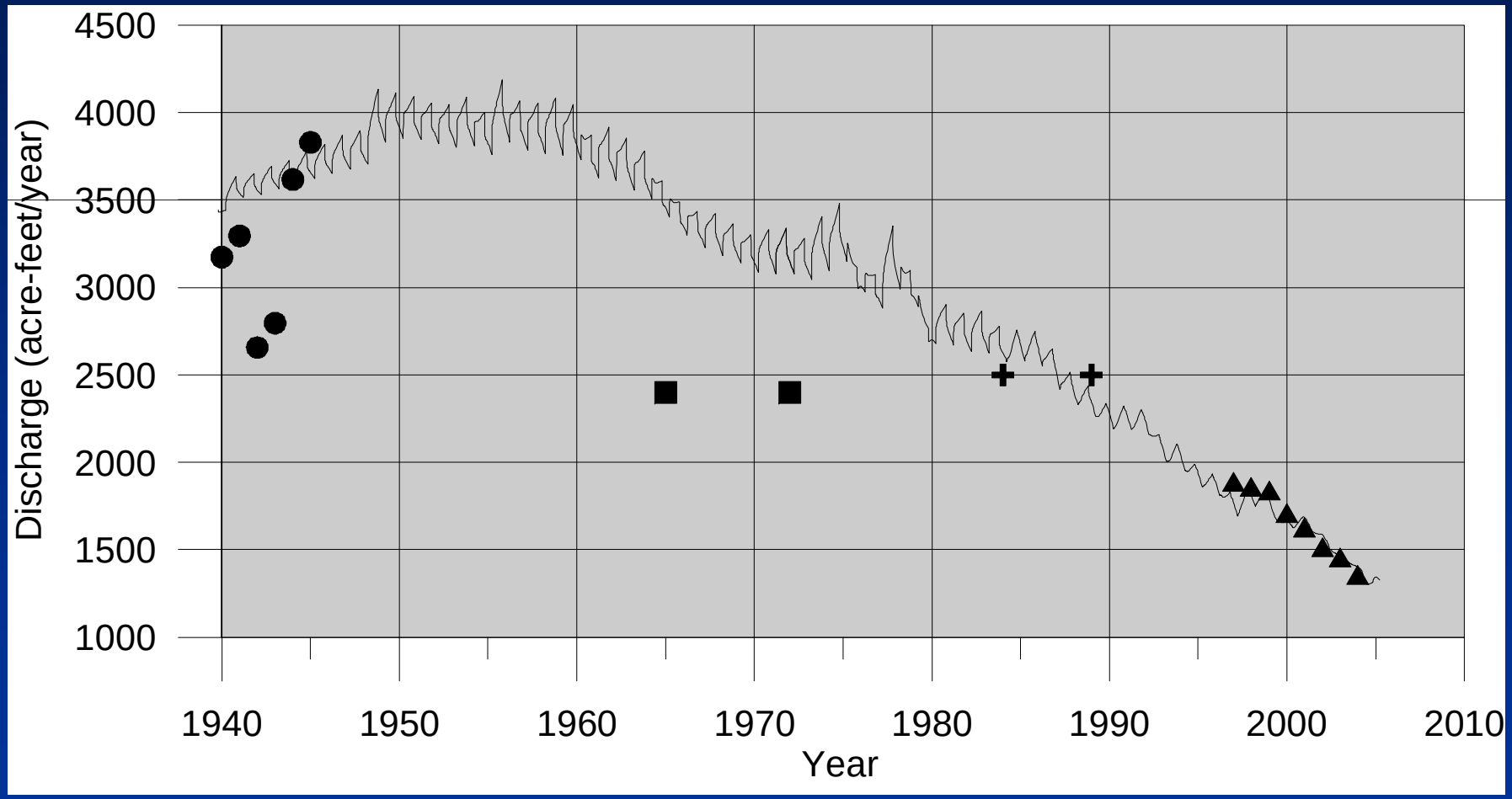
- **2324 transient head targets (391 original)**

- **Layer 1 – 716 targets at 45 wells (130 original)**
- **Layer 2 – 1608 targets at 68 wells (261 original)**

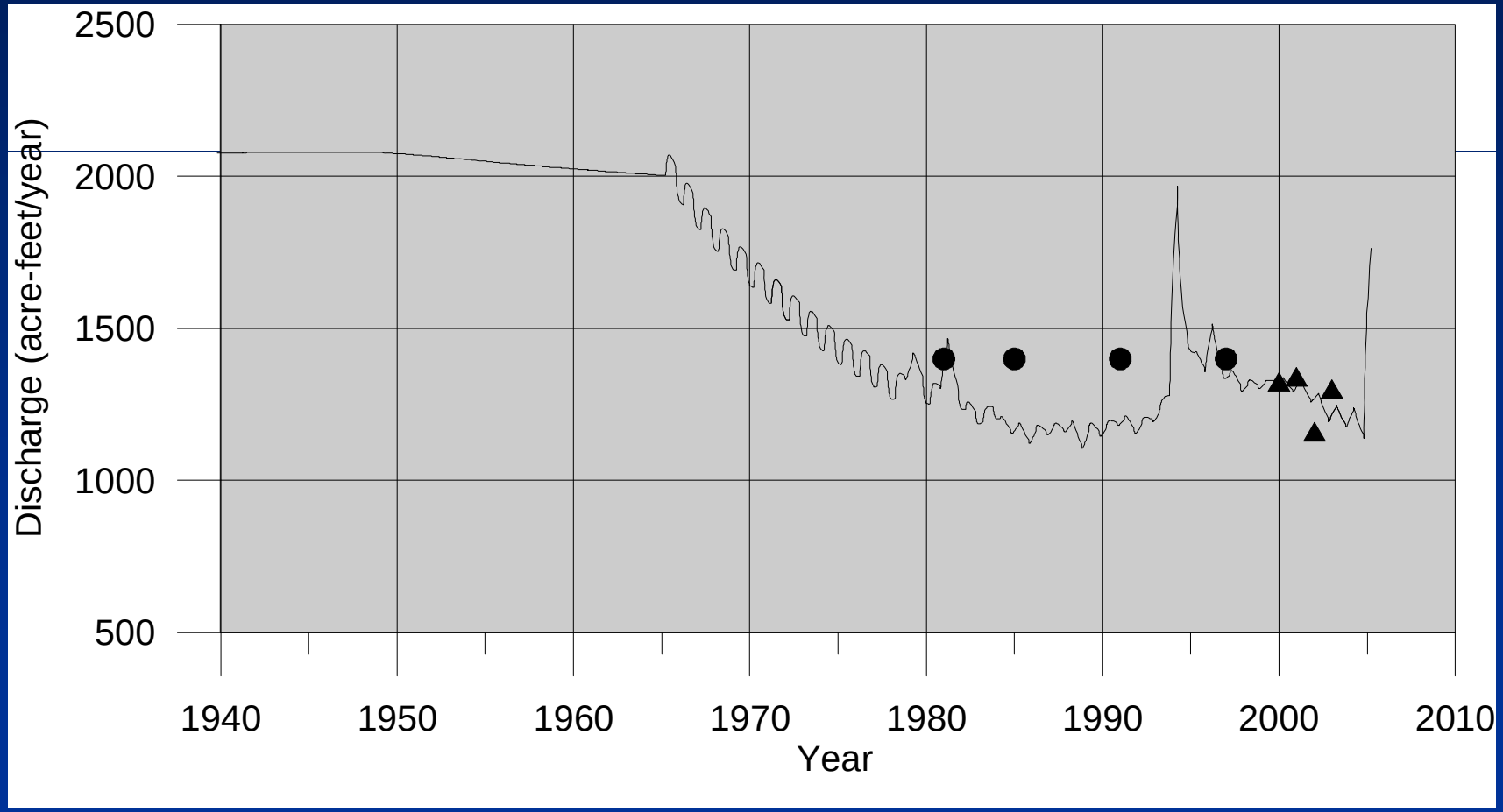
- **Flux at Del Rio Springs**
- **Flux at Agua Fria River**

- **Residual Error = 17.96 ft.**
- **Error as % total water-level change = 2.9%**

Simulated and measured discharge at Del Rio Springs (1940 – 2004)



Simulated and measured discharge as baseflow at the Agua Fria River (1940 – 2004)



Transient Simulation Results (1940 – 2004)

- INFLOW
  - Recharge = 1,015,000 ac-ft
- OUTFLOW
  - Pumpage = 1,048,000 ac-ft
  - Del Rio Springs = 204,000 ac-ft
  - Agua Fria Baseflow = 108,000 ac-ft
  - Underflow = 149,000 ac-ft
- CHANGE IN STORAGE

  Inflow – Outflow = **- 494,000 ac-ft**

So we understand past changes, but…

what about the future?

Projecting the Future Based on the Past

- In theory, groundwater flow models can be used to project future conditions for 2x period of calibration*
- Prescott AMA model calibrated to 65 year period of record
- Model could potentially be used to predict conditions out to the year 2135
- Dry model cells and uncertainties regarding future conditions limit future scenarios to 2025

*Faust, et al, 1981

Objectives of Multiple Scenario Analysis for the Prescott AMA

5) Identify critical driving forces impacting groundwater resources in the AMA

6) Develop several future scenarios based on these driving forces,

7) Simulate the future scenarios with the groundwater model, and

8) Provide policy recommendations based on simulation results.

Multiple Scenario Analysis: Scenario Development Process

- Characterization of Current Situation
- Identification of Central Issue
- Identification of Driving Forces
- Identification of Critical Uncertainties
- Uncertainties mandate *Multiple* Scenario Analysis

(Gallopin, 2002)

The Scenario Development Process

- Town management plans for the City of Prescott, Town of Prescott Valley, and Town of Chino Valley
- Meetings with local water resources professionals from the Prescott AMA, Yavapai County, and local municipalities

Driving Forces

- Population Growth
  - 2nd fastest growing county in the fastest growing state in the U.S.
- Conservation Strategies
  - Education, Incentives, Pricing, Restrictions
- Importation Policies
  - Big Chino Water Ranch
  - Town of Chino Valley Importation Project

Seven Scenarios

- **Baseline**
- Projected Growth
- **Projected Growth with Conservation**
- **Projected Growth with Conservation and Augmentation**
- Low Growth
- Low Growth with Conservation
- **Low Growth with Conservation and Augmentation**

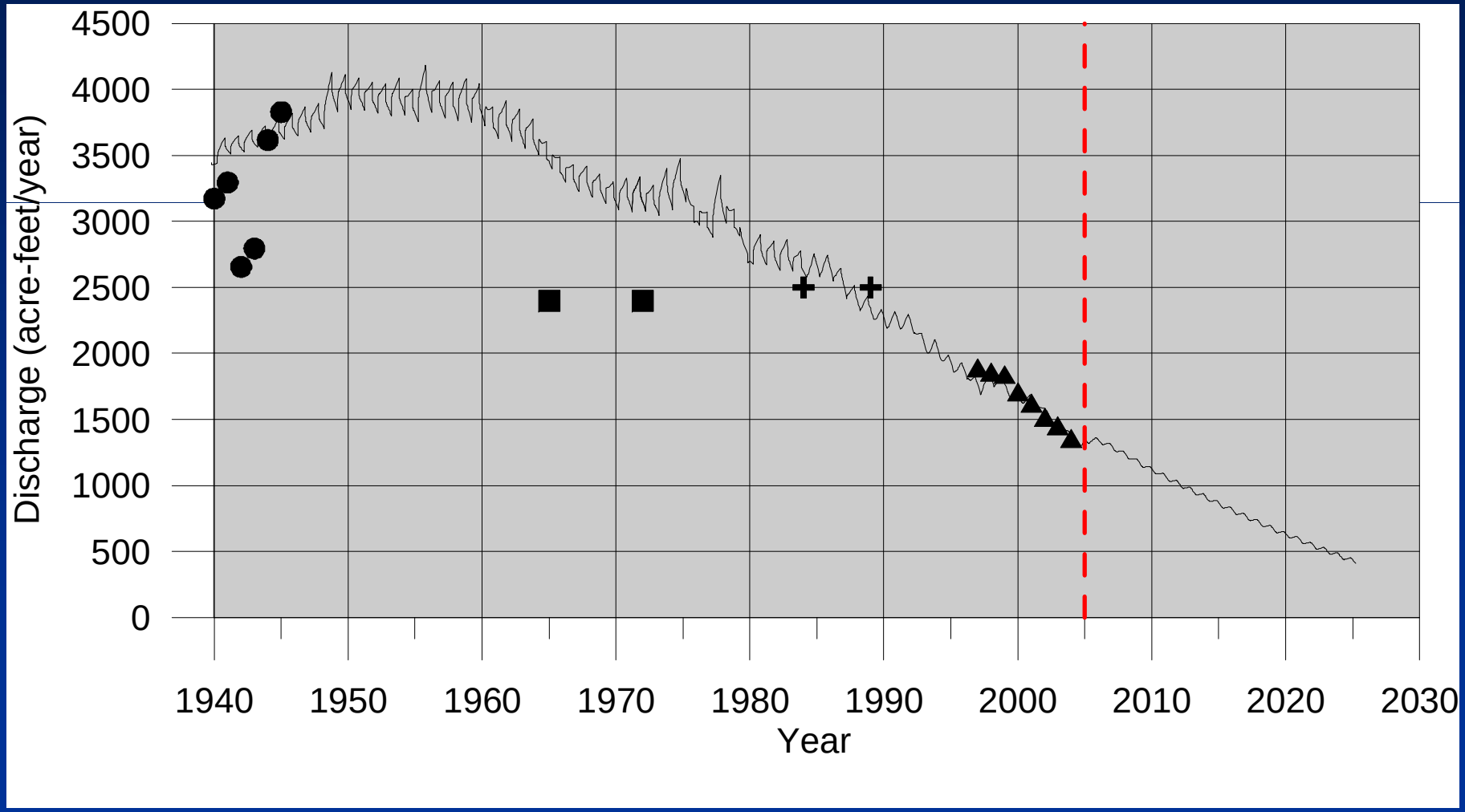
Summary of Scenario Results

Scenario	Average Water Level Change (ft)	Change in Natural Discharge	Change in Storage (ac-ft)
Baseline	-22.3	-34%	-154,000
PG Con	-38.3	-52%	-174,000
PG ConAug	-6.3	-20%	-37,000
LG ConAug	-0.5	-12%	-17,000

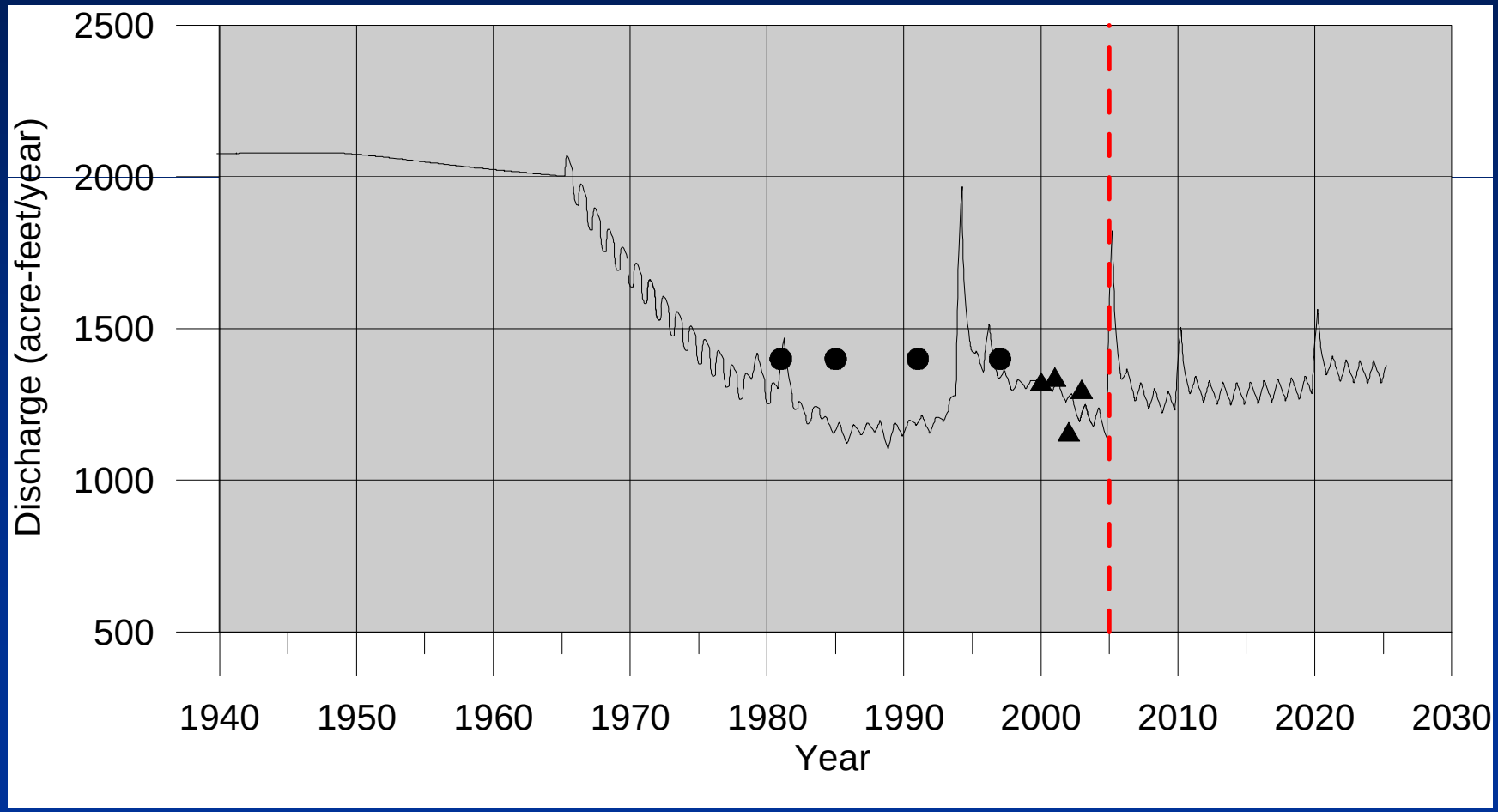
The Baseline Scenario

- 2005 pumpage and artificial recharge rates maintained through 2024.
- Flood recharge imposed in 2009 and 2019
- Designed to assess the impact of continuing current activities

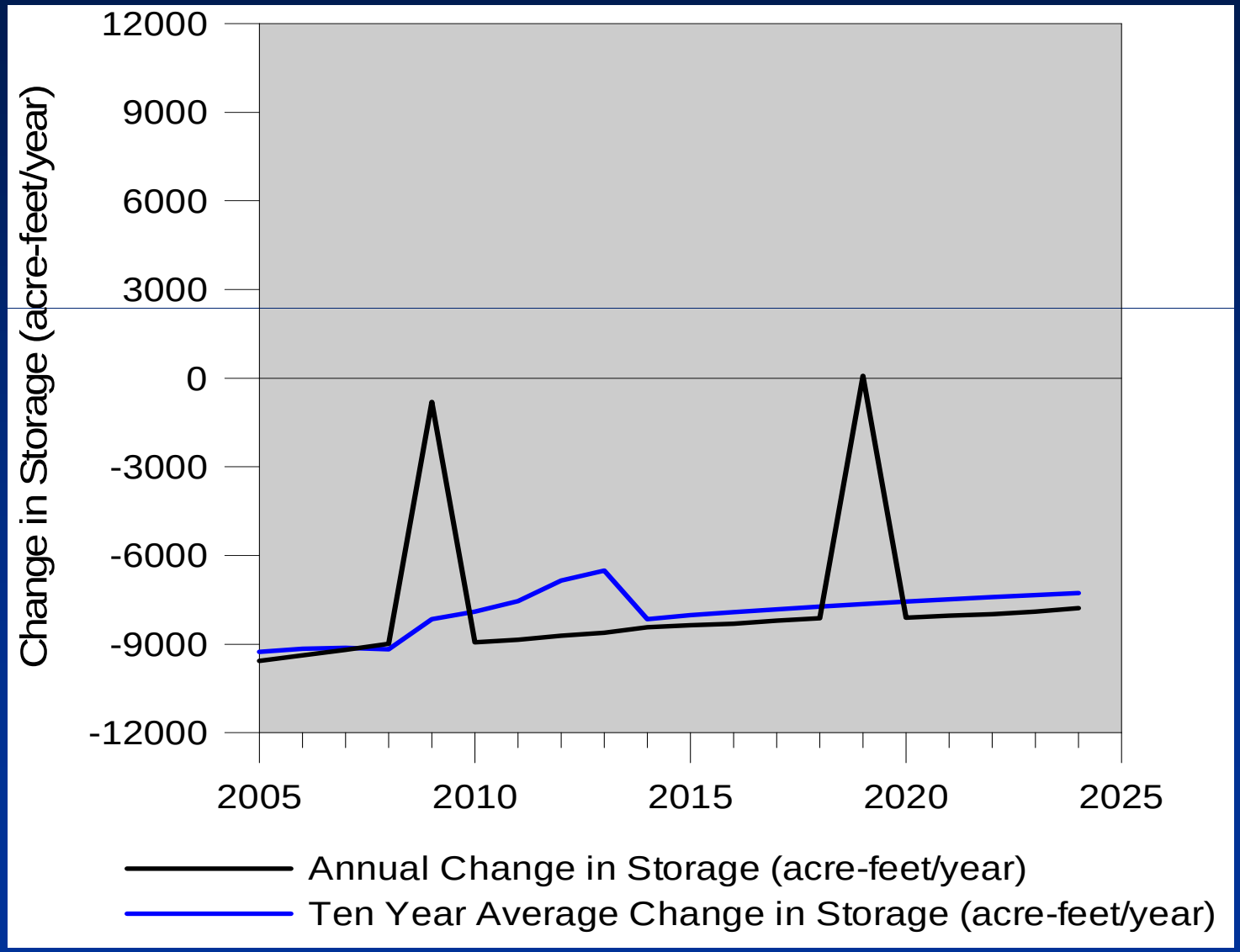
Simulated Discharge at Del Rio Springs: Baseline Scenario



Simulated Discharge as Baseflow in the Agua Fria River: Baseline Scenario



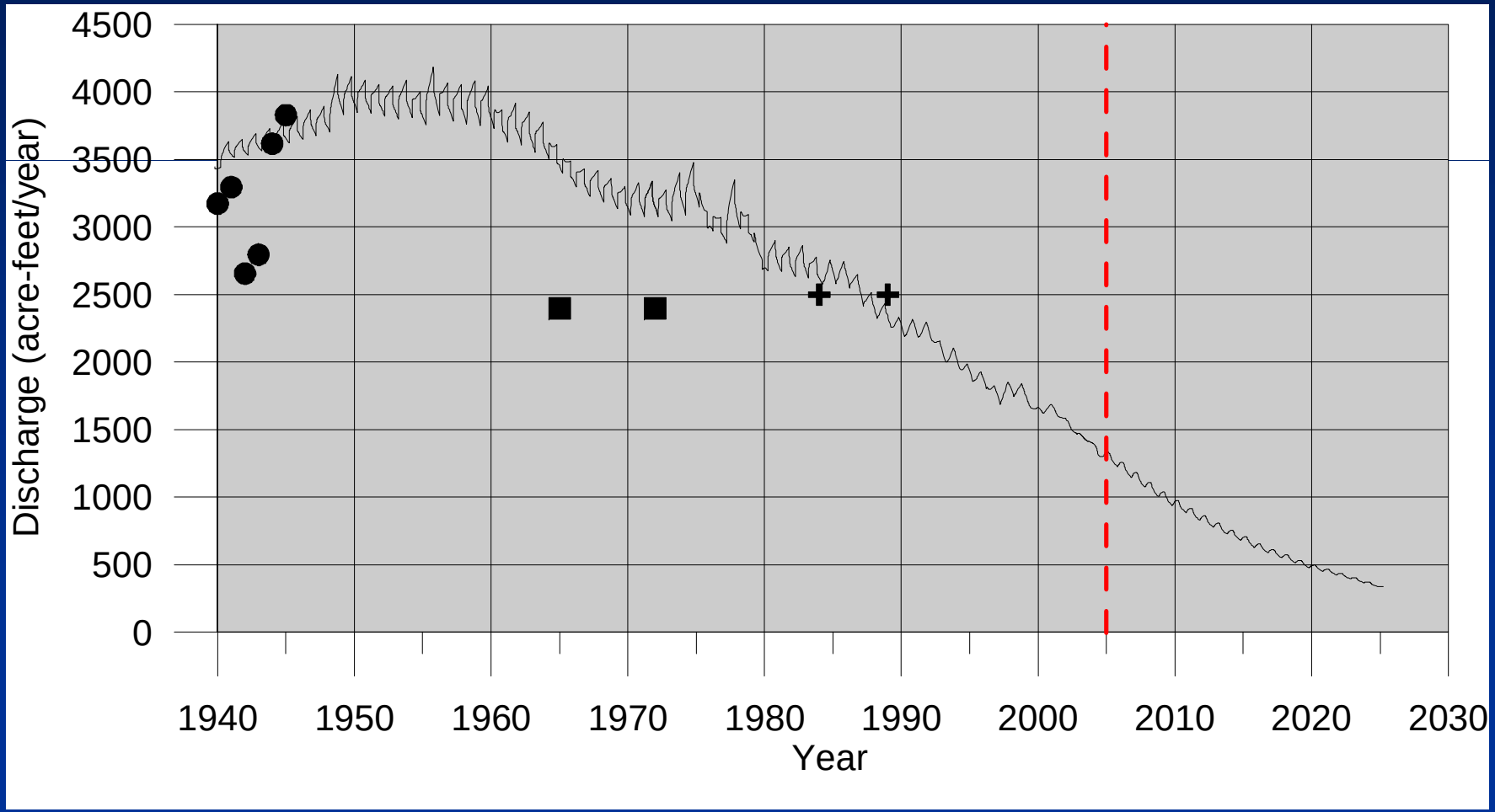
Change in Storage: Baseline Scenario



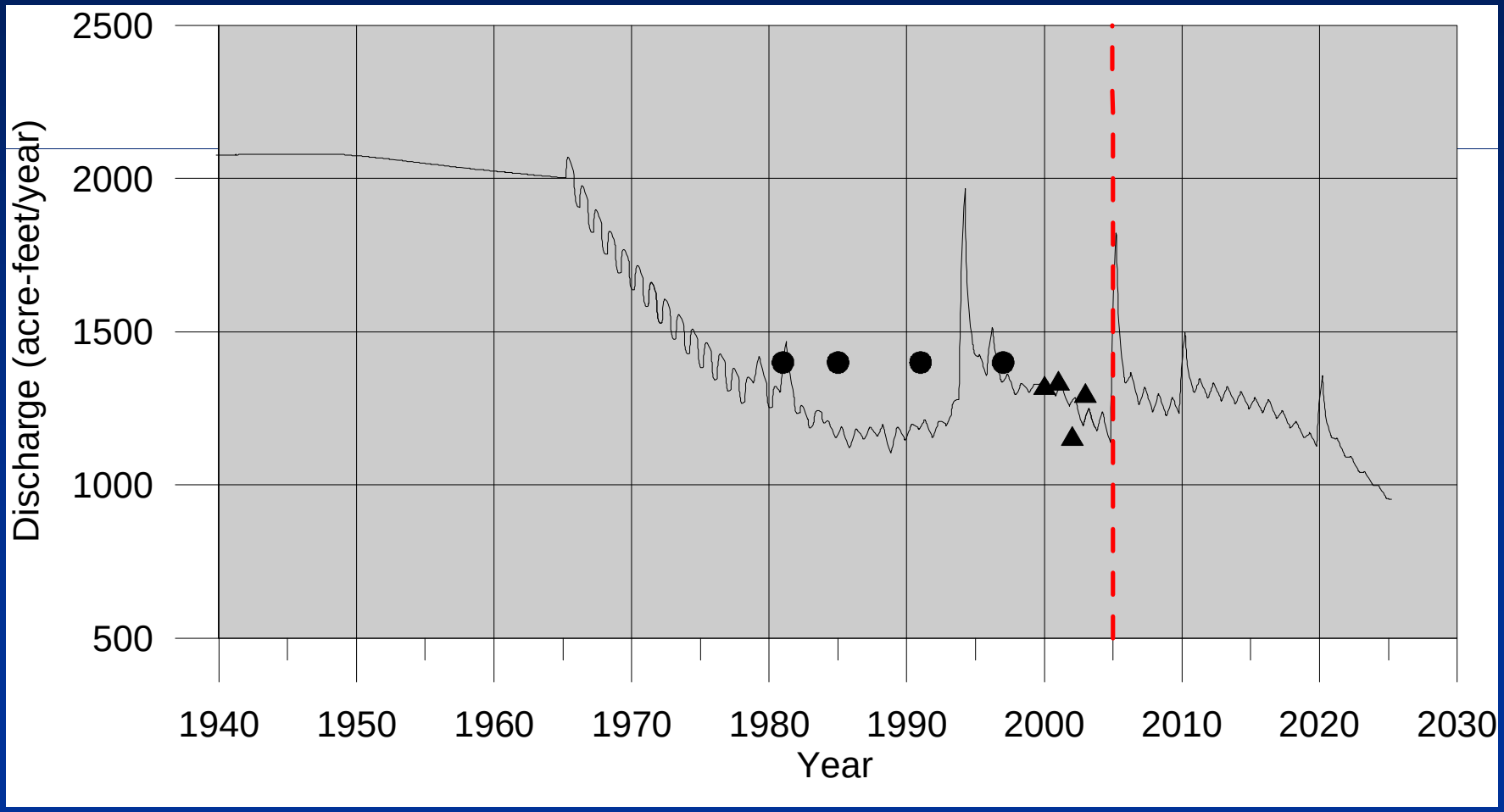
Projected Growth with Conservation Scenario

- Population growth rates 2005 - 2024
  - City of Prescott: 2.5%
  - Town of Prescott Valley: 4.5%
  - Town of Chino Valley: 7%
  - Dewey-Humboldt / Unincorporated: 5%
- Conservation Factor
  - 2010 - 2014: 10%
  - 2015 - 2019: 15%
  - 2020 - 2024: 20%

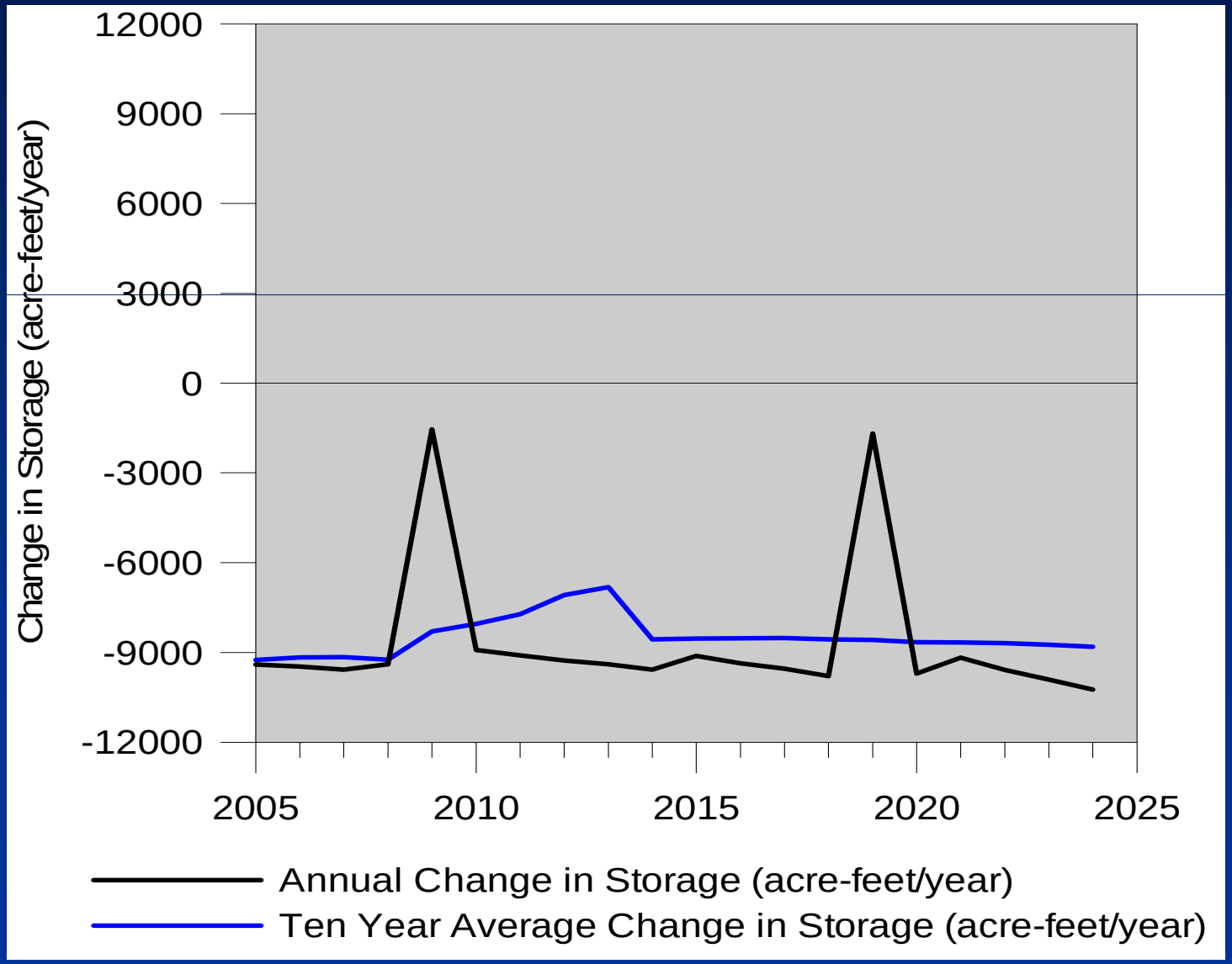
Simulated Discharge at Del Rio Springs: Projected Growth with Conservation Scenario



Simulated Discharge as Baseflow in the Agua Fria River: Projected Growth with Conservation Scenario



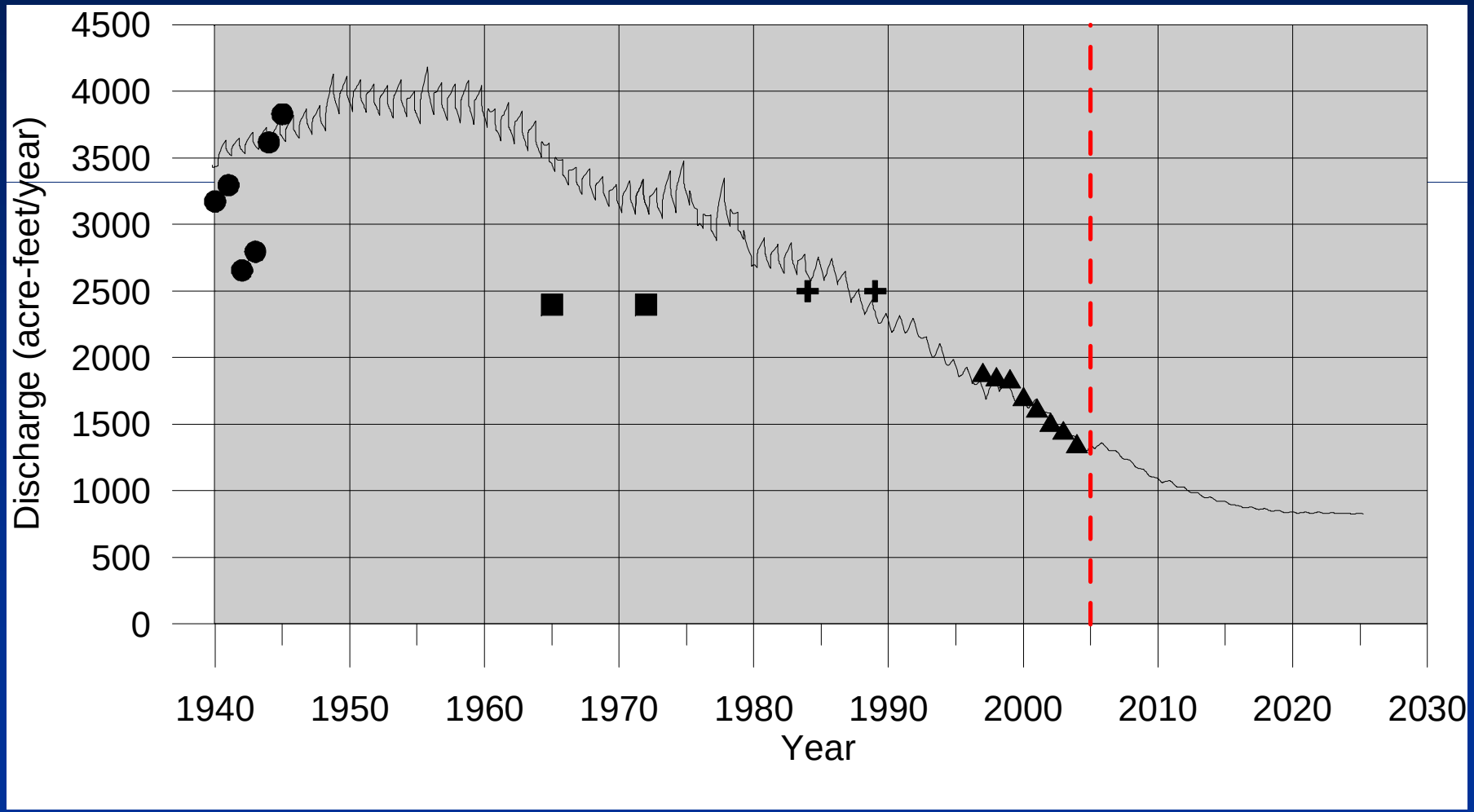
Change in Storage: Projected Growth with Conservation Scenario



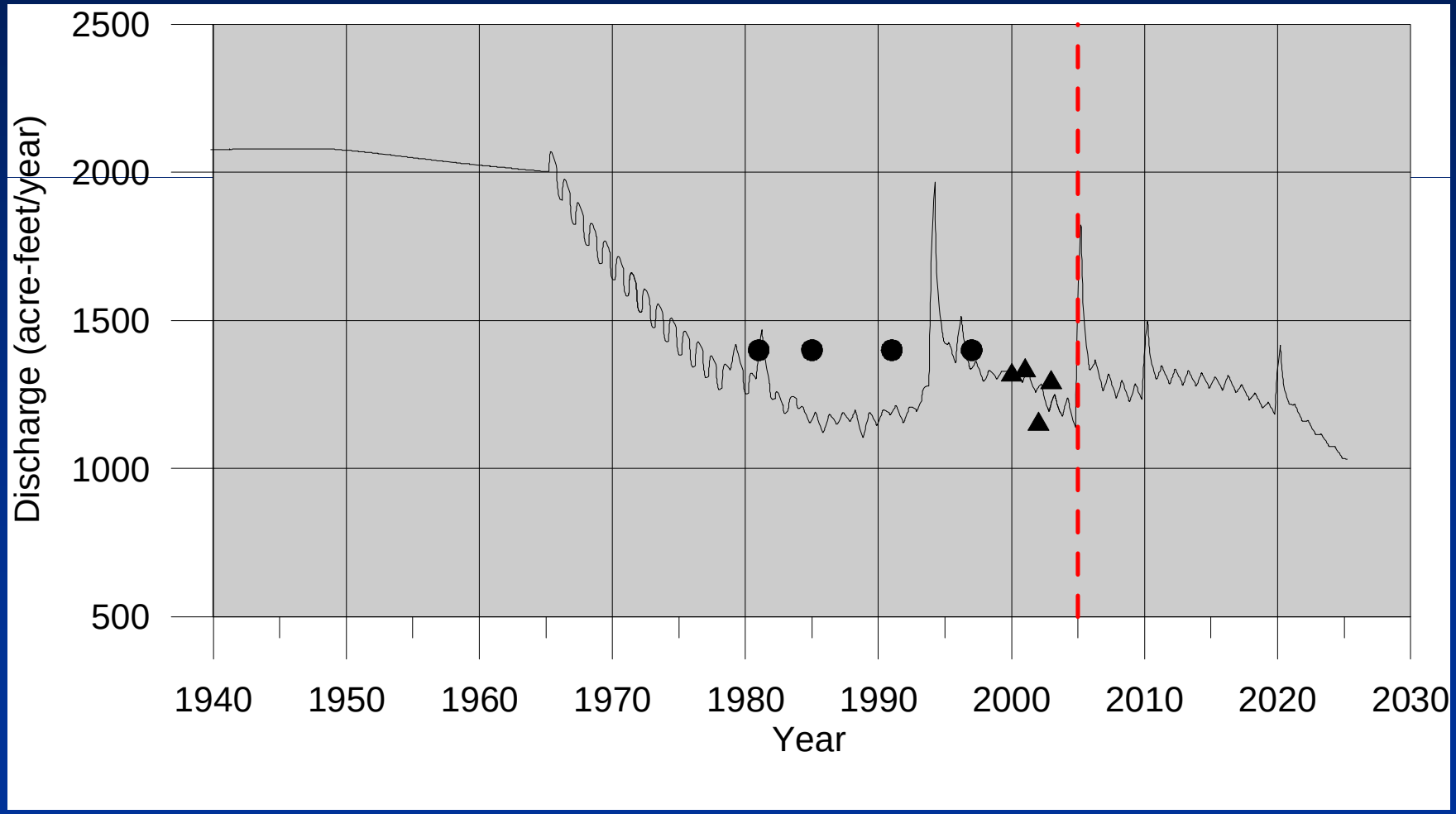
Projected Growth with Conservation and Augmentation Scenario

- Equivalent demand to Projected Growth with Conservation Scenario
- Importation Rates
  - Town of Chino Valley begins importing 600 ac-ft in 2009, increases to 1800 ac-ft by 2014
  - City of Prescott begins importing 4717 ac-ft in 2010, continues through 2024
  - Town of Prescott Valley begins importing 4000 ac-ft in 2010, continues through 2024

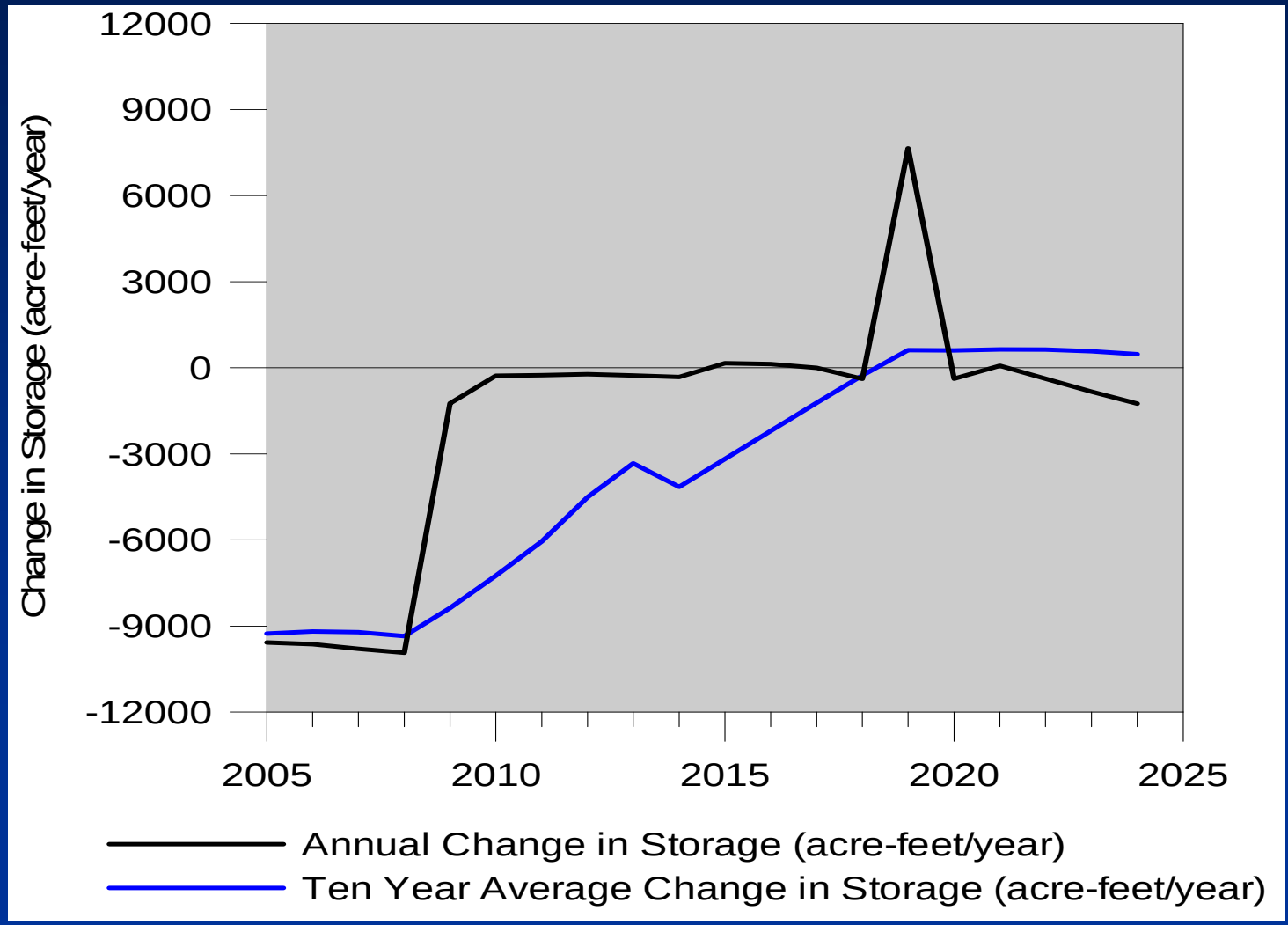
Simulated Discharge at Del Rio Springs: Projected Growth with Conservation and Augmentation Scenario



Simulated Discharge as Baseflow in the Agua Fria River: Projected Growth with Conservation and Augmentation Scenario



Change in Storage: Projected Growth with Conservation and Augmentation Scenario



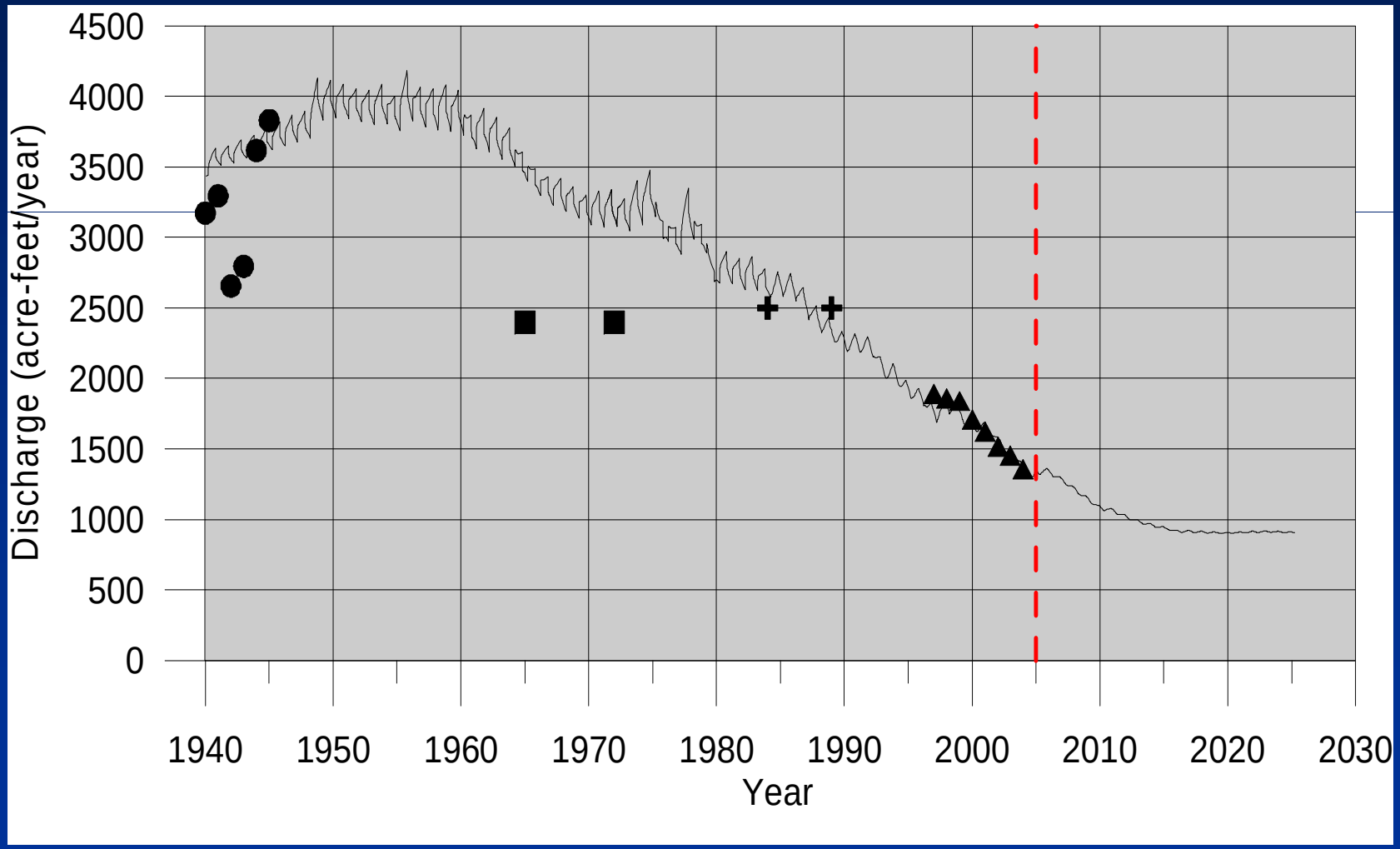
Low Growth with Conservation and Augmentation Scenario

Population growth rates 2005 – 2024

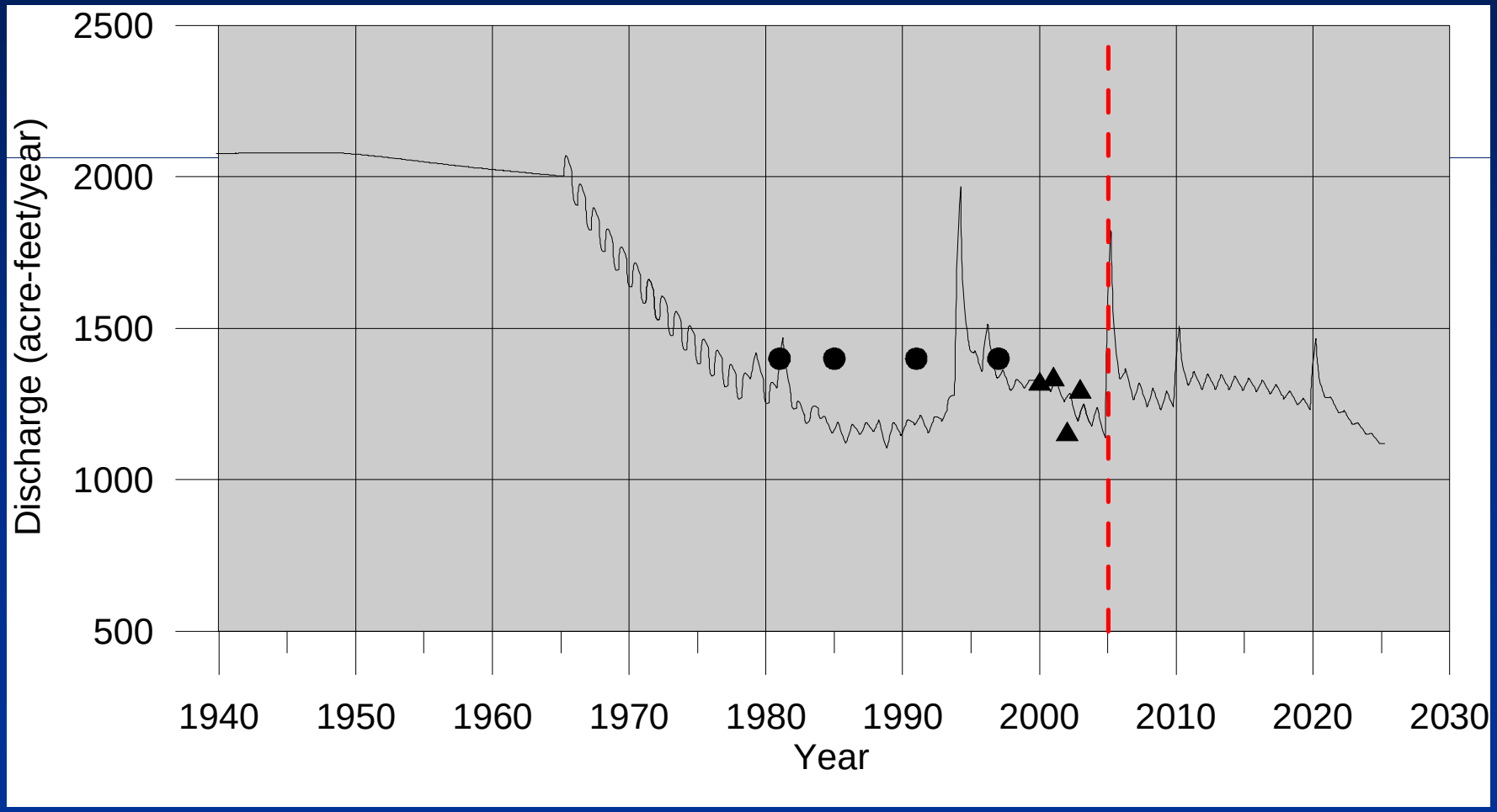
- City of Prescott: 2.0%
- Town of Prescott Valley: 3.5%
- Town of Chino Valley: 5%
- Dewey-Humboldt / Unincorporated: 3%

- Conservation Factor
  - 2010 - 2014: 10%
  - 2015 - 2019: 15%
  - 2020 - 2024: 20%
- Importation rates same as PG ConAug Scenario

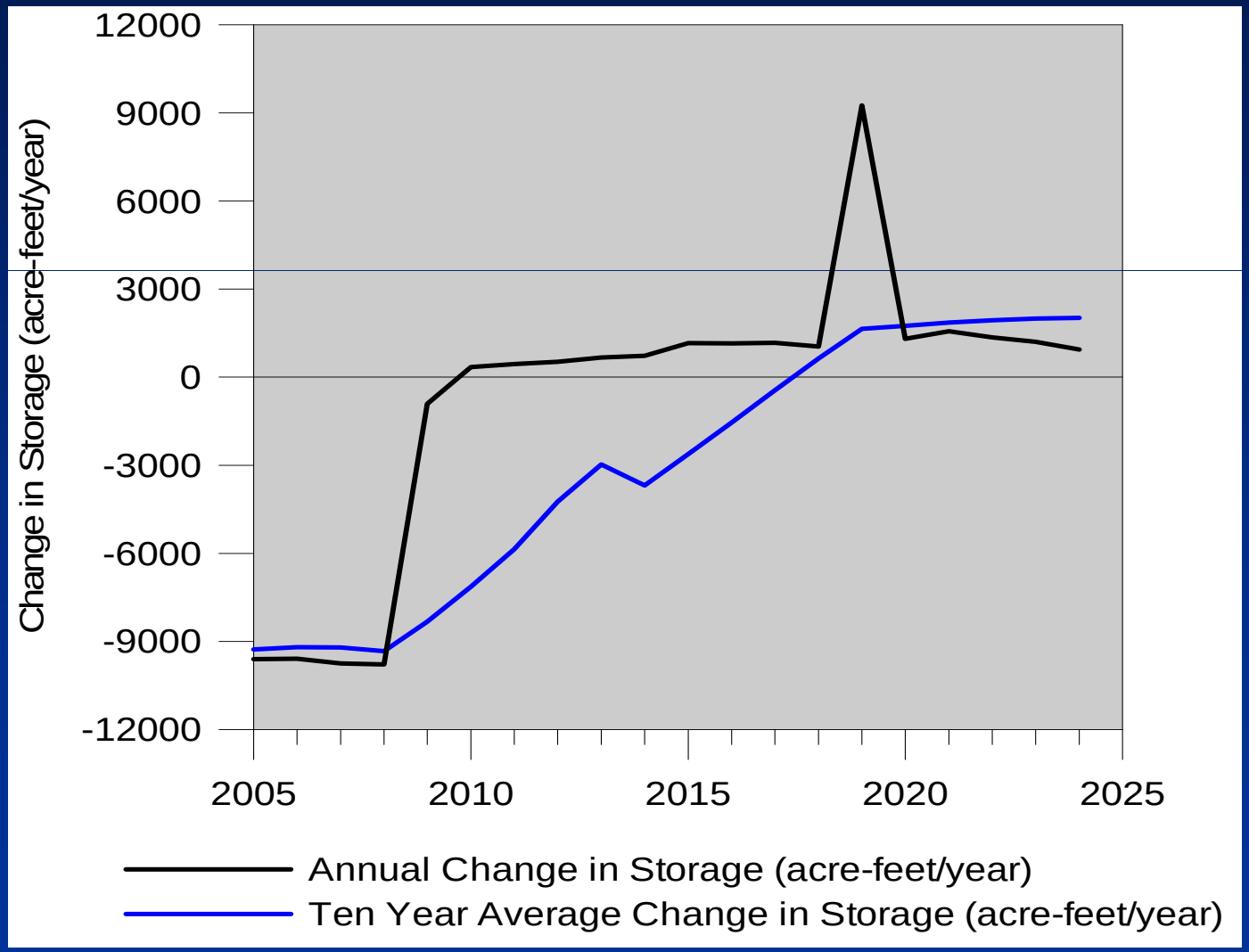
Simulated Discharge at Del Rio Springs: Low Growth with Conservation and Augmentation Scenario



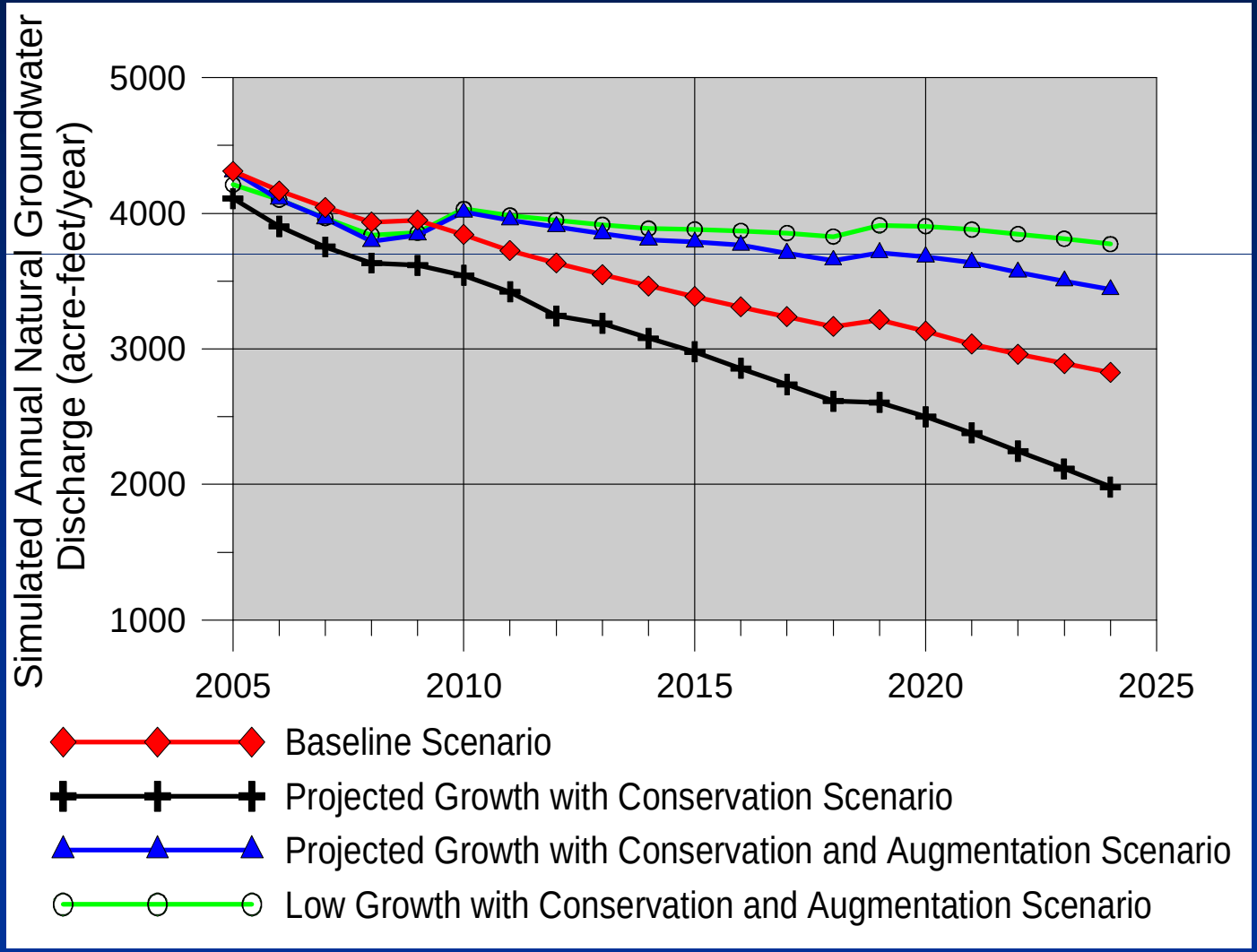
Simulated Discharge as Baseflow in the Agua Fria River: Low Growth with Conservation and Augmentation Scenario



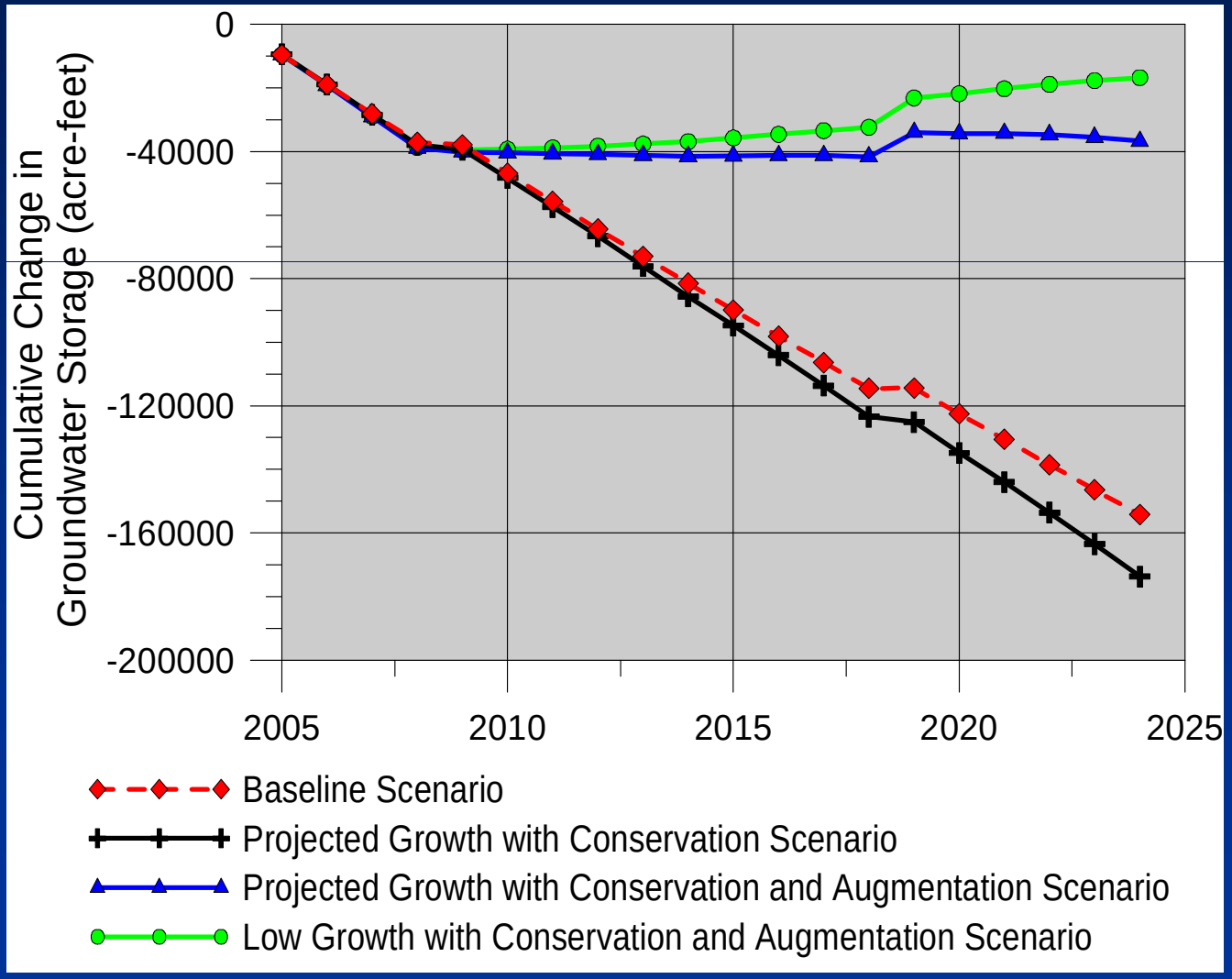
Change in Storage: Low Growth with Conservation and Augmentation Scenario



Simulated Annual Natural Groundwater Discharge



Simulated Change in Groundwater Storage for the Four Scenarios



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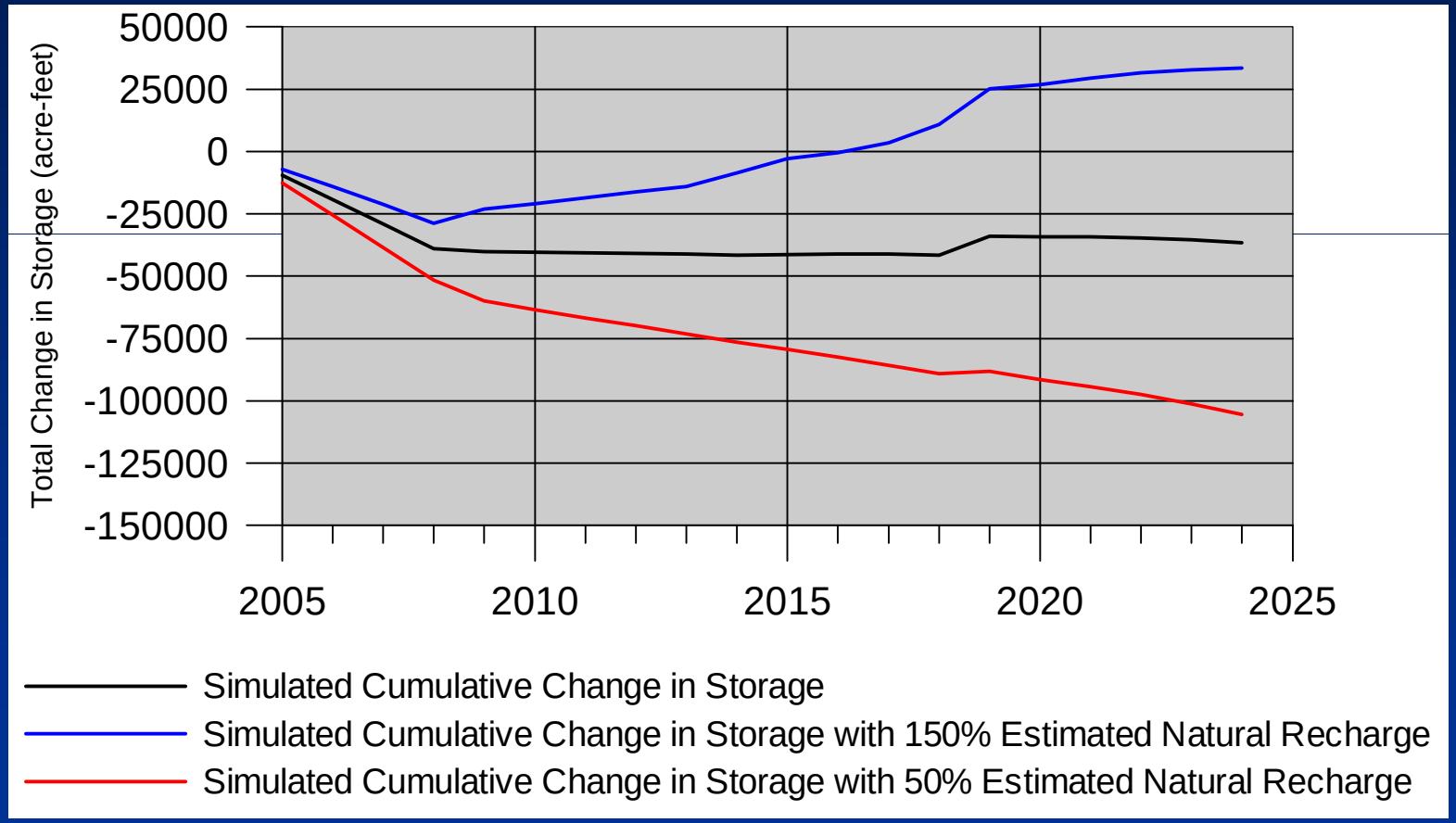
Other Scenarios are Possible

- Rate of Growth
- Importation Schedule
  - Timing and Amounts
- Conservation Potential
  - What is really possible?
- What do we do with our effluent?
  - Use it, or lose it?
- What about recharge?

Total Change in Storage: PG ConAug Scenario



Conclusions

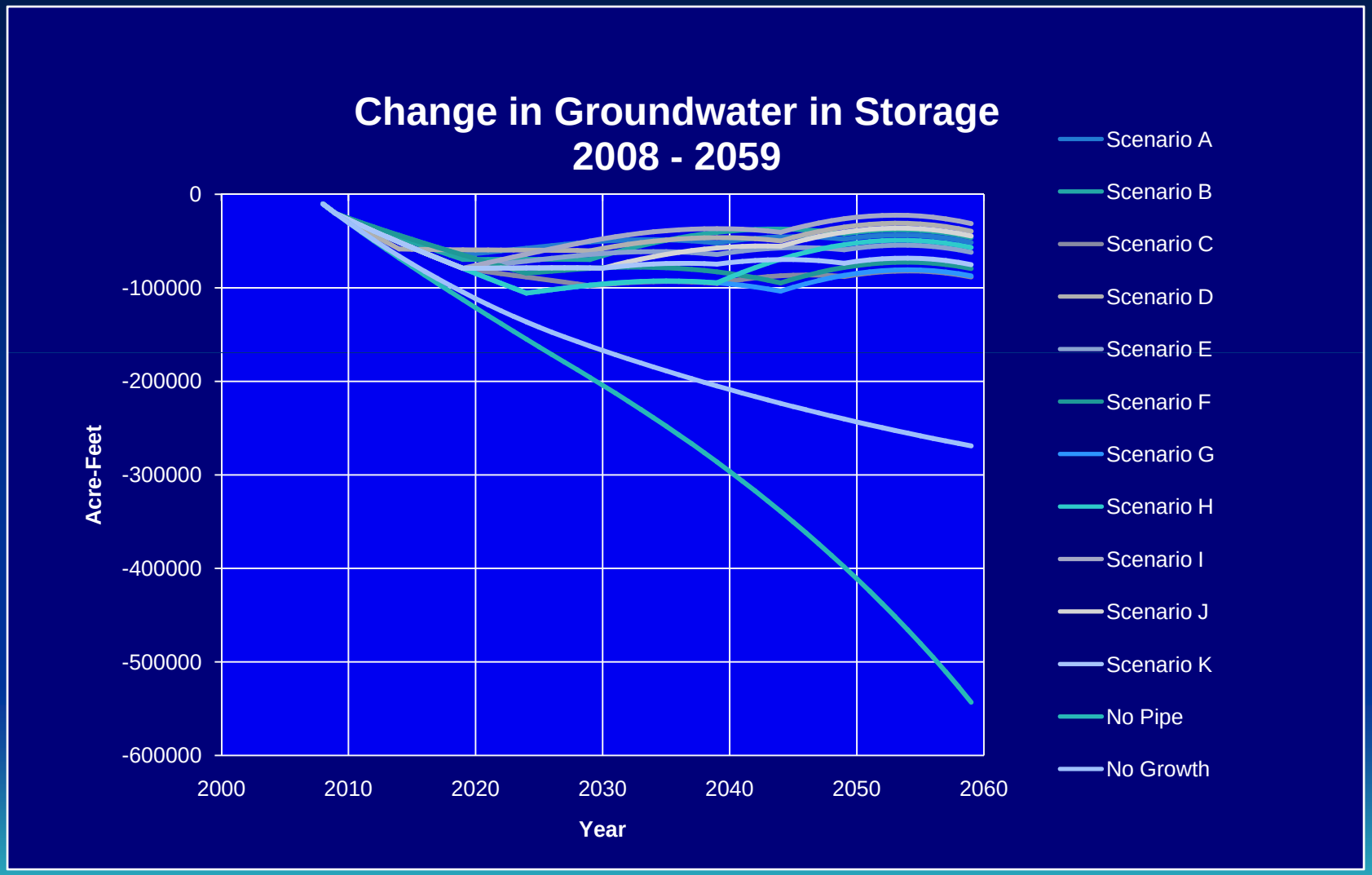
- Conservation alone is insufficient for the achievement of safe-yield.
- Achievement of safe-yield is possible through a combination of conservation and supply augmentation.
- Achievement of safe-yield is possible with projected population growth rates, but likely only temporarily and at a cost to natural groundwater discharge.

Conclusions

- The successful achievement and maintenance of a safe-yield condition in the Prescott AMA will likely require a combination of growth planning, conservation strategies, and supply augmentation.
- Enhanced natural recharge and additional conservation may provide opportunities for higher growth within a state of safe-yield.

Conclusions

- Even with zero growth and additional conservation, safe-yield will not be achieved in the absence of an additional water supply…
- The Big Chino aquifer presents the only legally, physically available water supply.
- Therefore, a Big Chino pipeline is necessary for the achievement of safe-yield.


Change in Groundwater in Storage
2008 - 2059
0
-100000
-200000
-300000
-400000
-500000
-600000
Acre-Feet
2000
2010
2020
2030
2040
2050
2060
Year
Scenario A
Scenario B
Scenario C
Scenario D
Scenario E
Scenario F
Scenario G
Scenario H
Scenario I
Scenario J
Scenario K
No Pipe
No Growth

Acknowledgments

Abe Springer, Zachary Smith, Keith Nelson, ADWR, Prescott AMA GUAC, City of Prescott, Town of Prescott Valley, Town of Chino Valley, Arizona Water Institute, Yavapai County WAC, USGS, Frank Corkhill, Dale Mason, Wesley Hipke, Gerry Wildeman, Leslie Graser, Amy Levy, Crystal Frost, Gordon Wahl, Bill Remick, Frank Putman, Carol Johnson, Mark Holmes, Chris Bartels, John Munderloh, John Rasmussen, Kathy Jacobs, Jim Holway, NAU Watershed Research and Education Program, Achievement Rewards for College Scientists, Decision Center for the Desert City, Global Water, UVRWPC


Questions?
For more information, please visit:
http://www.watershed.nau.edu/Research/Timmons/Timmons.htm