Colorado River Water Availability Study

CWCB Board Workshop

January 26, 2010

Consulting Team

AECOM

AMEC Earth & Environmental

Canyon Water Resources

Leonard Rice Engineers

Stratus Consulting

BOYLE | AECOM

Agenda

- What we were tasked to do
- Results
- Where we go from here

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What we were tasked to do

"How much water from the Colorado River Basin System is available to meet Colorado's future water needs?"

1. What is a reasonable base of existing uses to utilize in Phase I of the Colorado River Water Availability Study (CRWAS)
2. How does historical hydrology compare to a longer hydrologic trace based on tree ring analysis
3. What is a reasonable projection for hydrology as affected by climate change
4. How much water for future use would Colorado be entitled to under the Compacts considering existing uses

1. What is a reasonable base of existing uses to utilize in Phase I of CRWAS

- **Phase I**
  Water Availability under current water supply infrastructure, currently perfected water rights, and current levels of consumptive and non-consumptive water demands

- **Phase II**
  Water Availability under projected demands from existing, conditional, and new water rights and for additional consumptive and non-consumptive water demands

Public Outreach

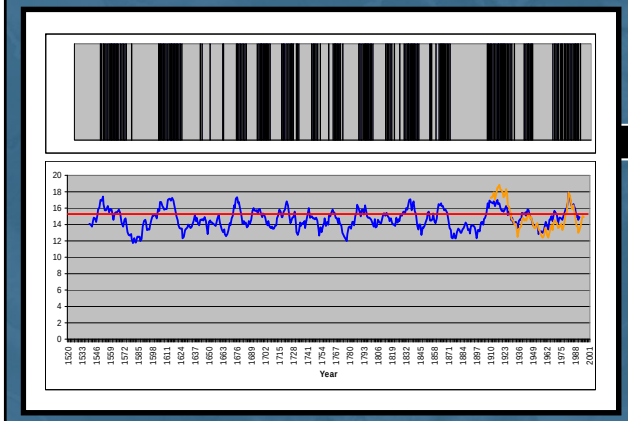
- ~30 public meetings, presentations, workshops
  - CWCB, DWR, and AG Staff
  - CWCB Board
  - CWCB Climate Change Technical Advisory Group
  - IBCC and BRTs (two more after draft report published)
  - Joint Front Range Climate Change Vulnerability Study Program
  - NOAA Regional Integrated Sciences and Assessments Program
  - University of Colorado's Western Water Assessment Program
  - Colorado River Water Conservation District Annual Seminar
  - Front Range Water Council
  - Colorado Water Congress
- Vetted through peer review groups

Overall Hydrology Approach

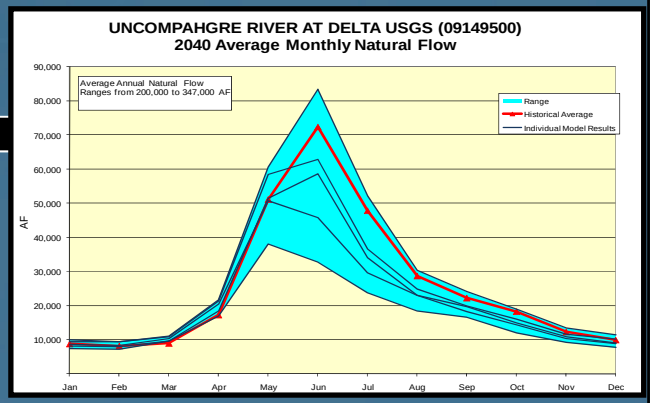
1500 1950 2005 2040 2070 2099

Observed Hydrology

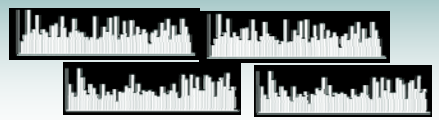
Paleohydrology



GCM's & Hydrology



Statistical Models



StateMod
StateCU

2. How does historical hydrology compare to a longer hydrologic trace based on tree ring analysis

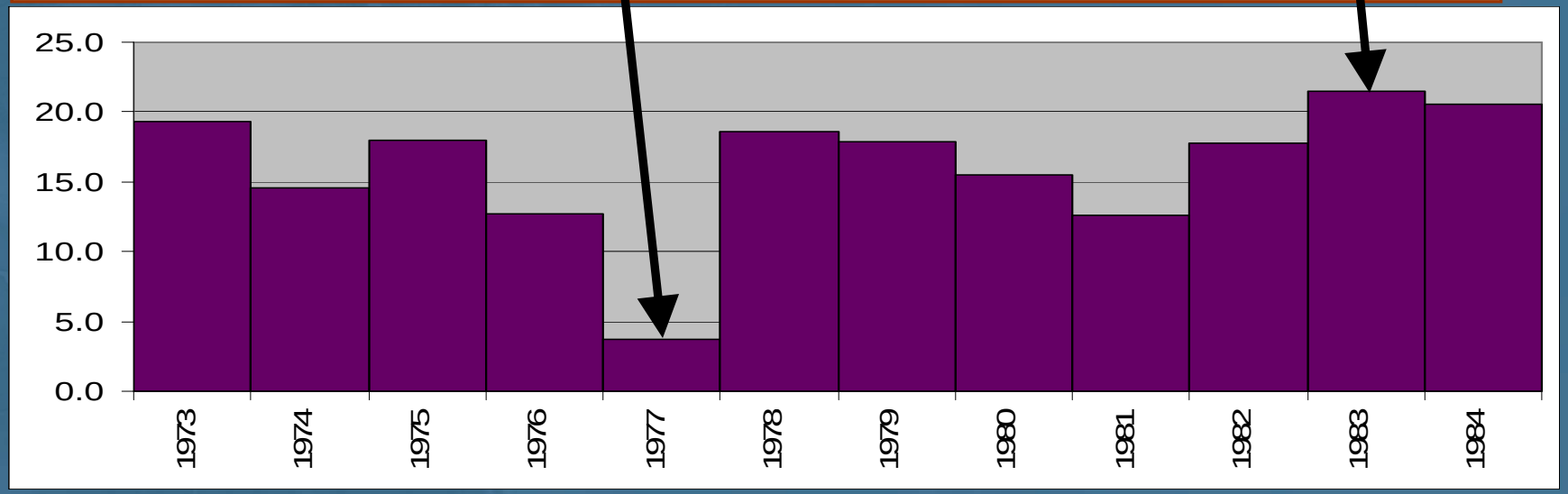
Paleo Hydrology

Douglas-fir, south-central CO

1977

1983

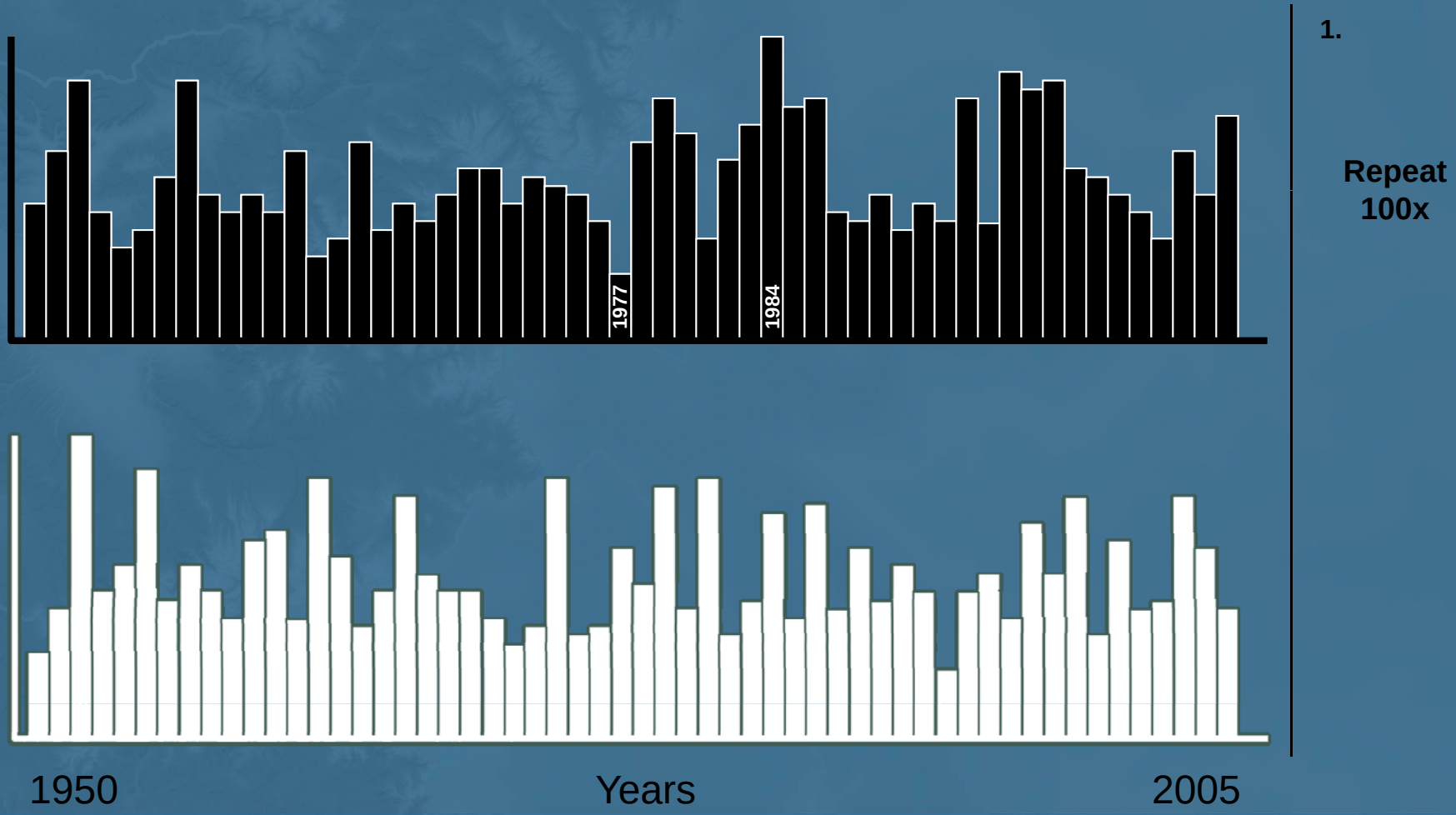
NOAA treeflow.info



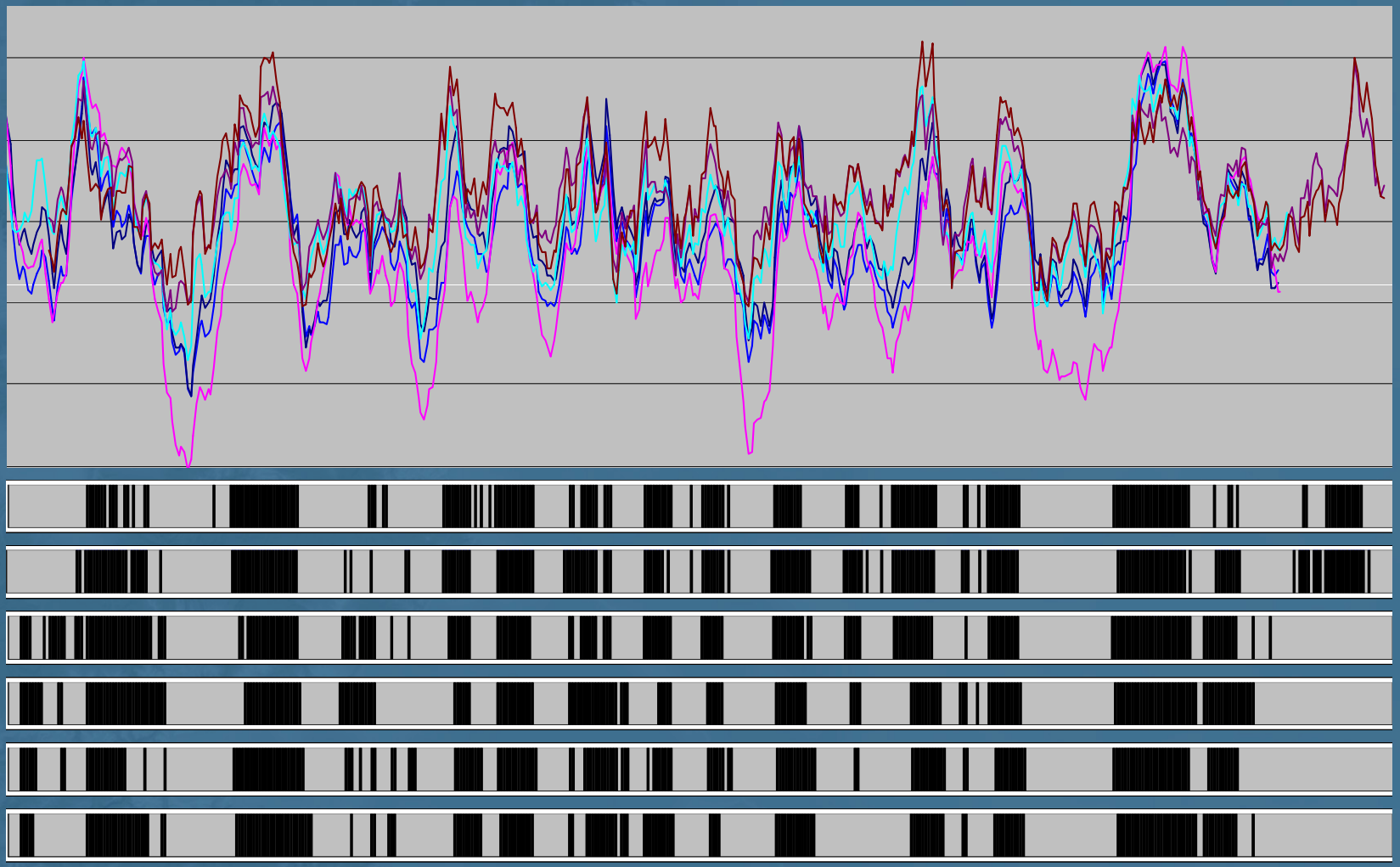
Paleo Hydrology--Approach

- Two approaches
  - Regression
    - Models flow sequences and magnitudes
    - Based on mathematical model relating tree-ring width to flow magnitude
  - Re-sequencing
    - Models flow sequences
    - Obtains magnitudes from historical record
    - Based on model of "state" transition
      - E.g. "wet-to-wet", "dry-to-wet"...

Re-sequencing – The Process



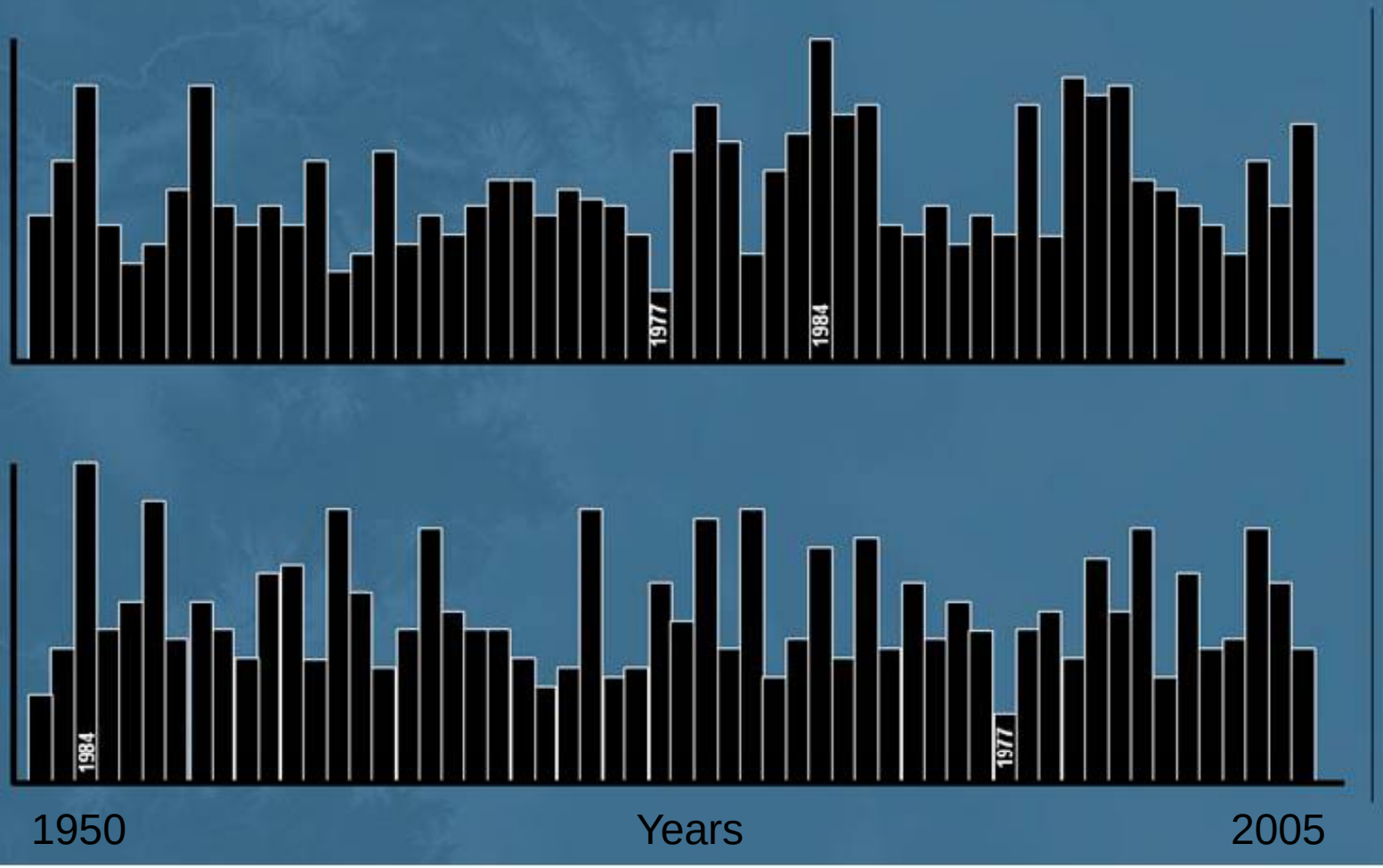
Re-sequencing – The Motivation



Paleo Hydrology--Results

- Statistics of Annual Flows
  - Median 56-year mean was slightly greater than 1950-2005 mean flow
    - Paleo record indicates slightly more wet years
- Statistics of wet spells and drought
  - Median durations were similar
  - Median surplus volumes tended lower
  - Median drought volumes often higher
- Extreme events are represented in flow data
  - This is the real benefit from using the paleo record

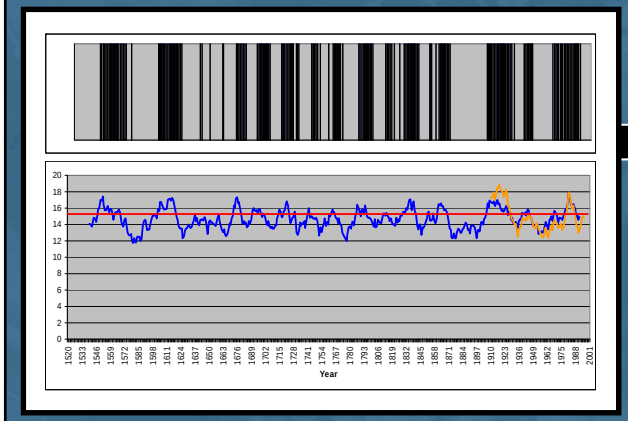
Re-sequencing – The Process



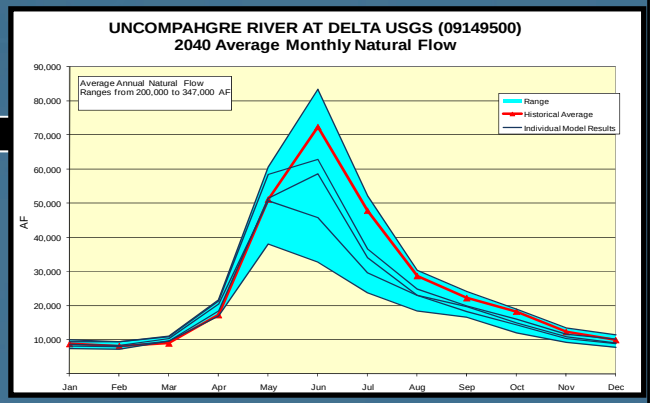
Overall Hydrology Approach

Observed Hydrology

Paleohydrology



GCM's & Hydrology



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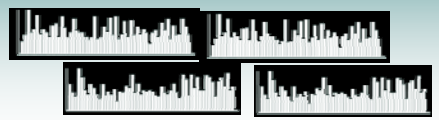

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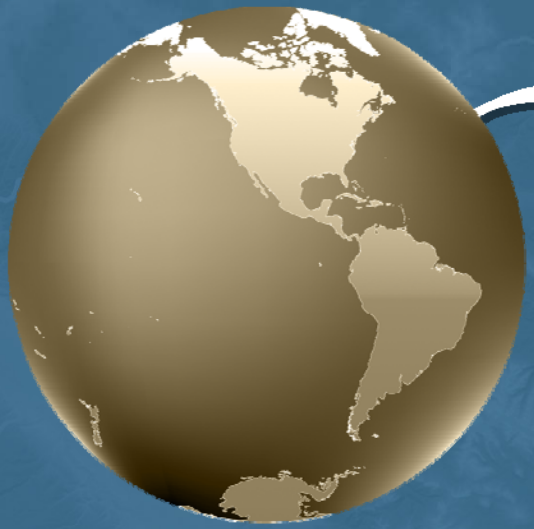
3. What is a reasonable projection for hydrology as affected by climate change



Earth

- Emissions Scenarios
- Global Climate Models

Result: *Altered Temperature and Precipitation*

Colorado River Basin

- "Down-Scaled" Projections
- Revised Basin-Wide Hydrology

Result: *Altered Stream Flows*

State of Colorado

- CDSS Modeling

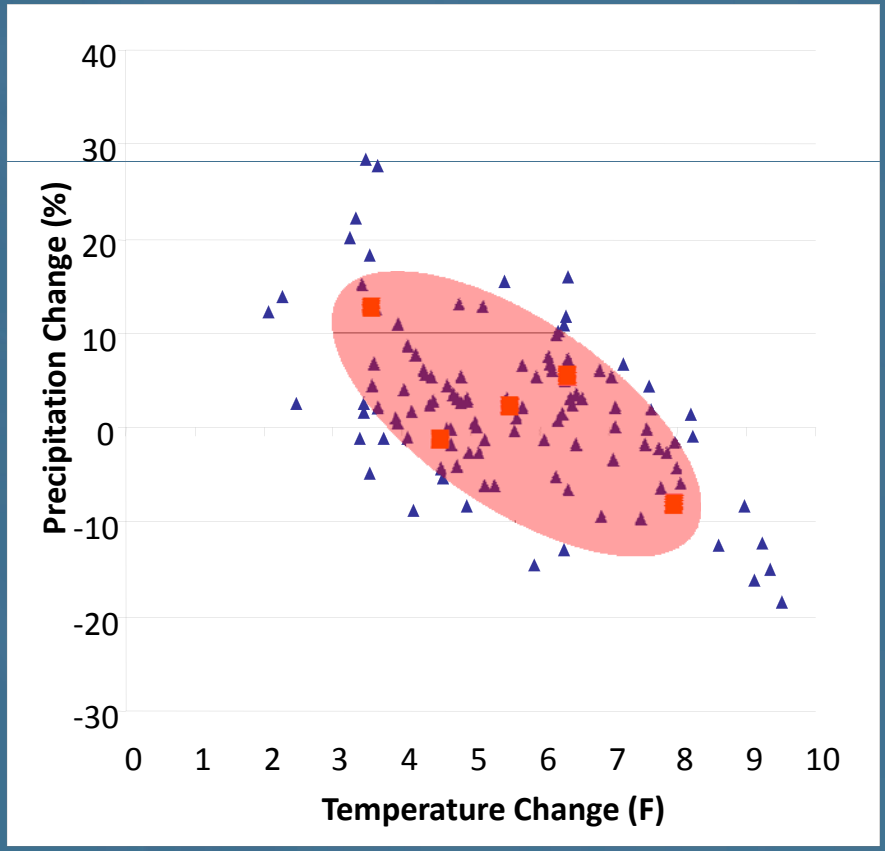
Result: *Water Availability*

Climate Change: Selection of Projections

- CRWAS coordinated with Front Range Study
- Two time frames jointly selected (2040 / 2070)
- Five projections jointly selected to characterize projected climate for each time frame

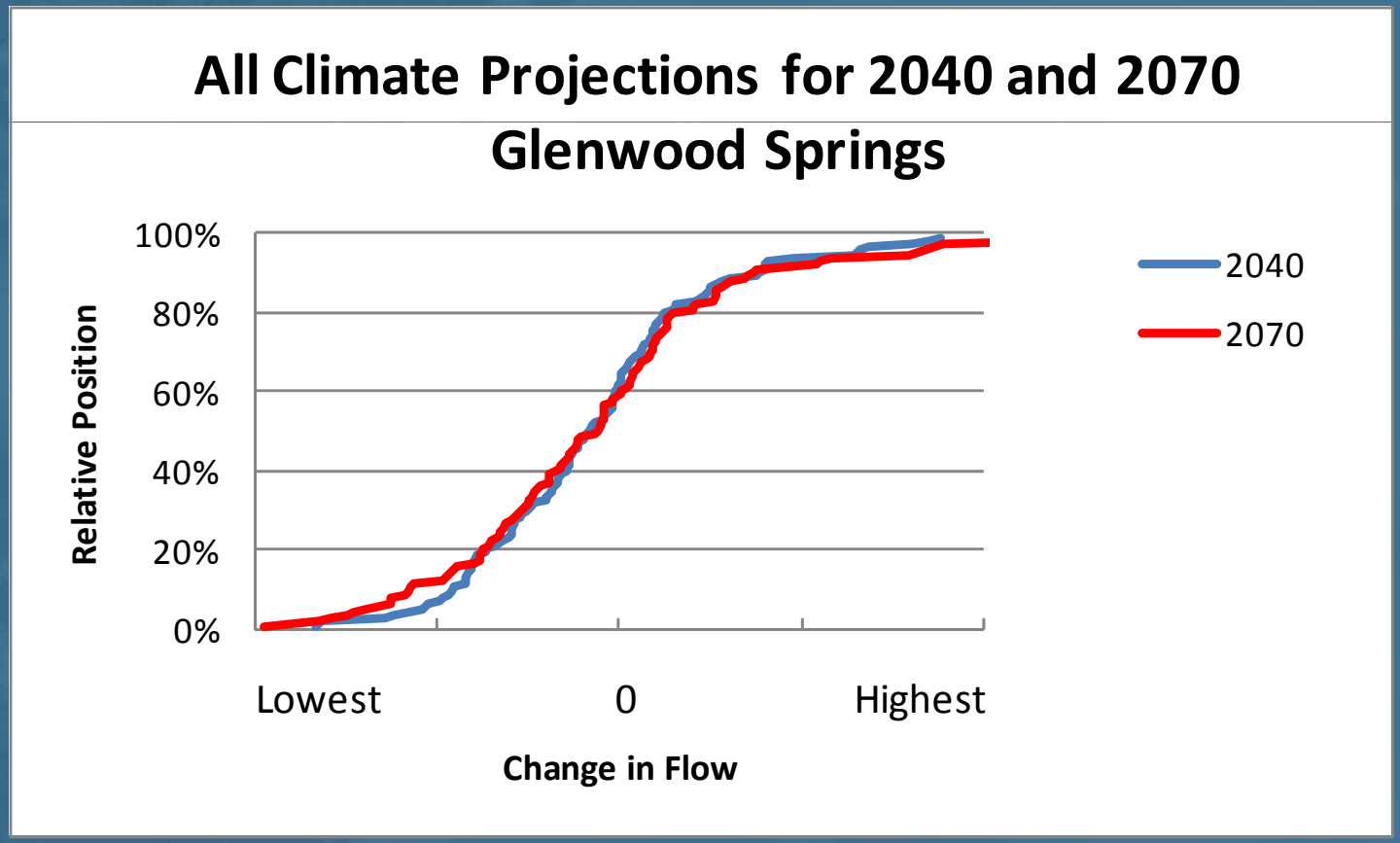
Climate Change: Selection of Projections

- Projections selected based on change in Temperature and Precipitation
- Selected projections intended to represent a region that contains approximately 80% of all projections

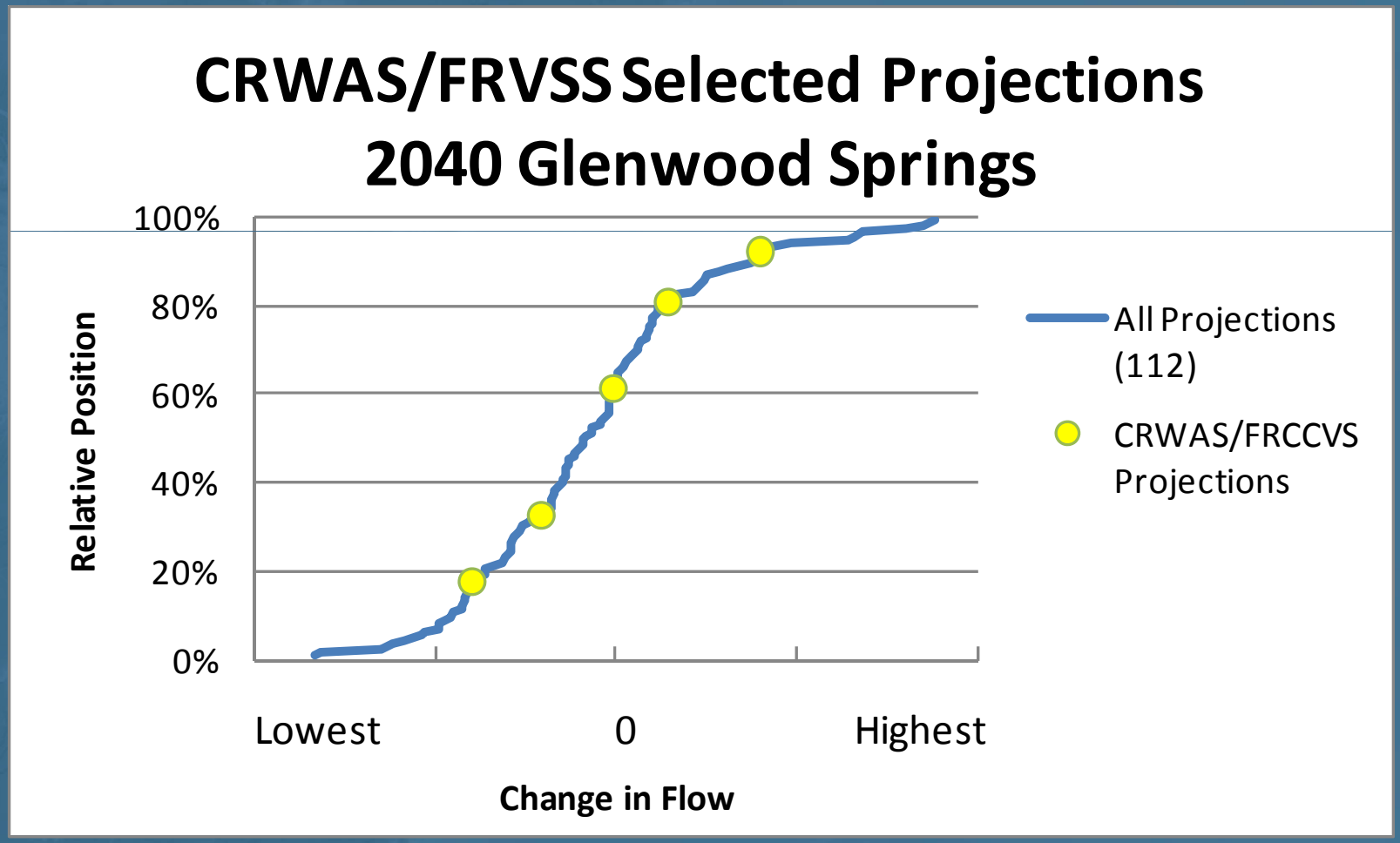


Climate Change: Range of Projections

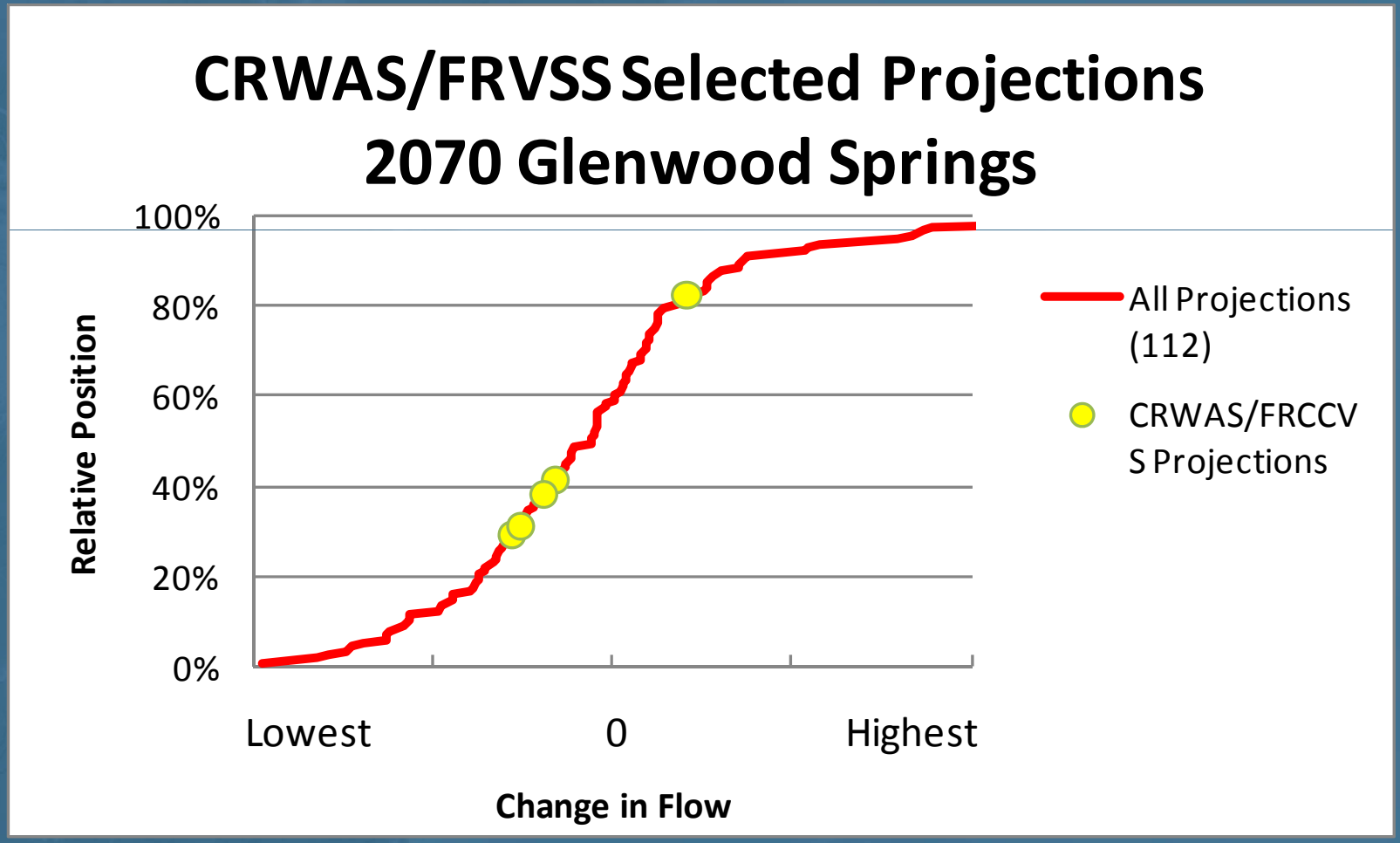
Projections for 2040 and 2070 not very different



Climate Change: 2040 Selected Projections

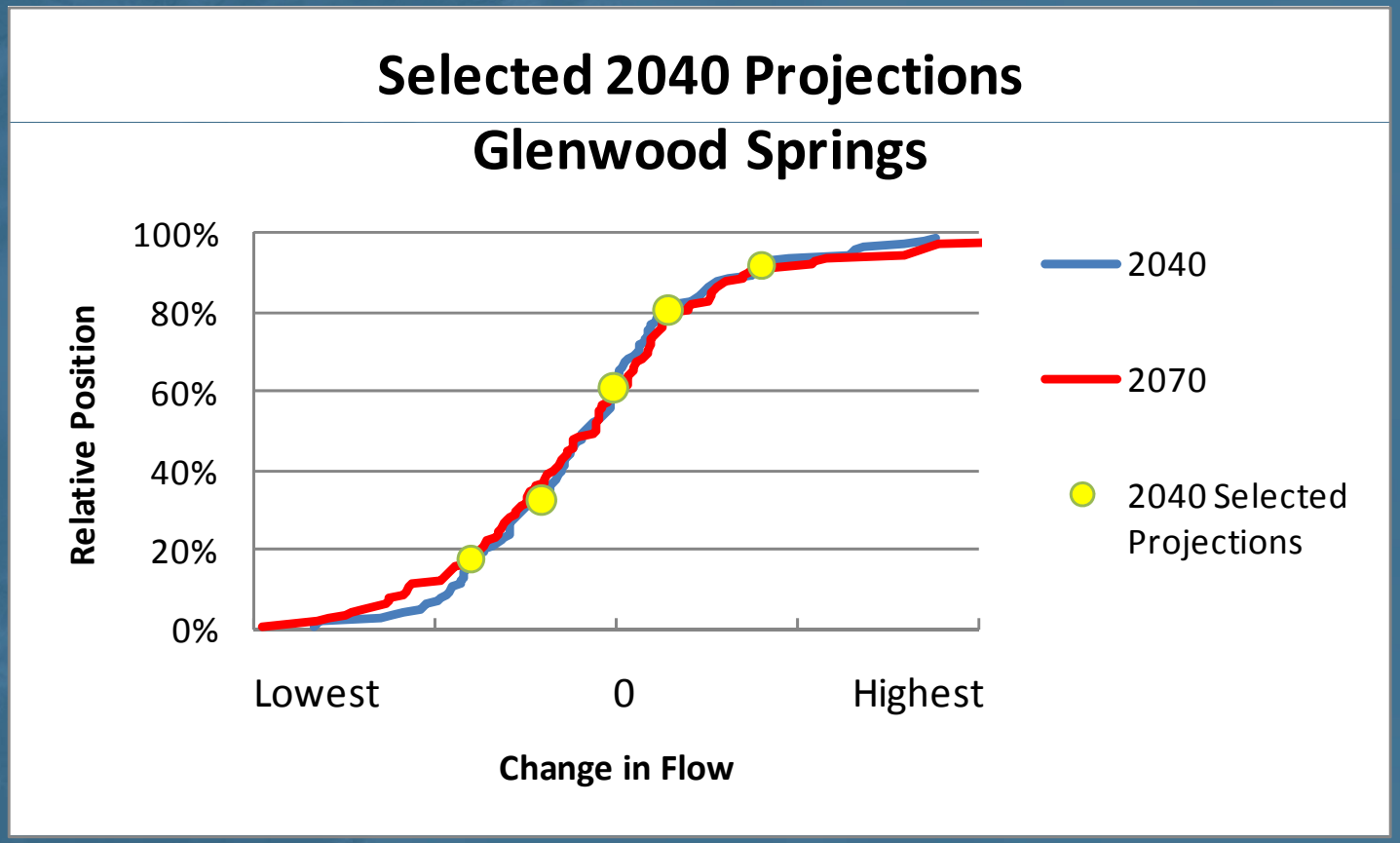


Climate Change: 2070 Selected Projections

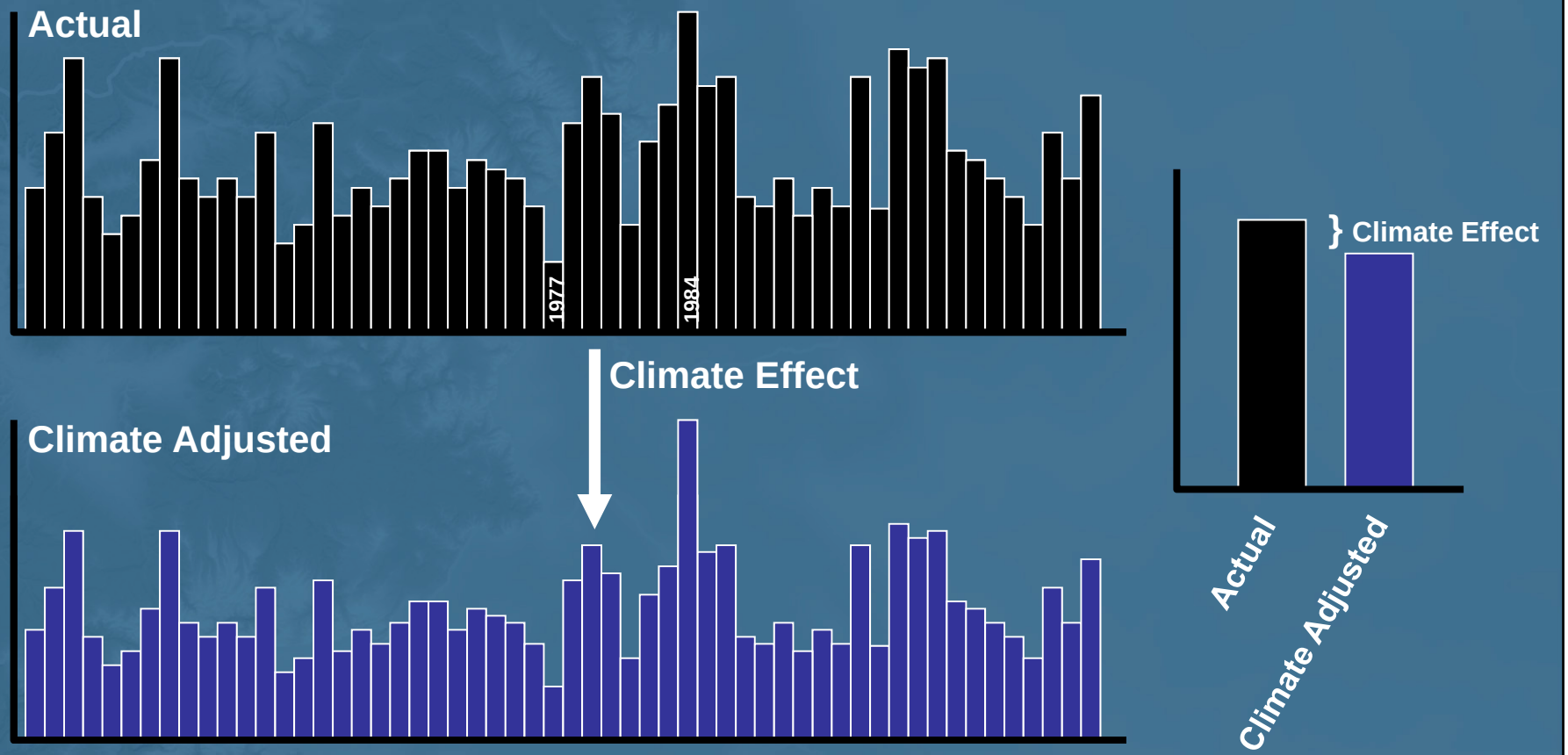


Climate Change: 2040 and 2070 Projection Comparison

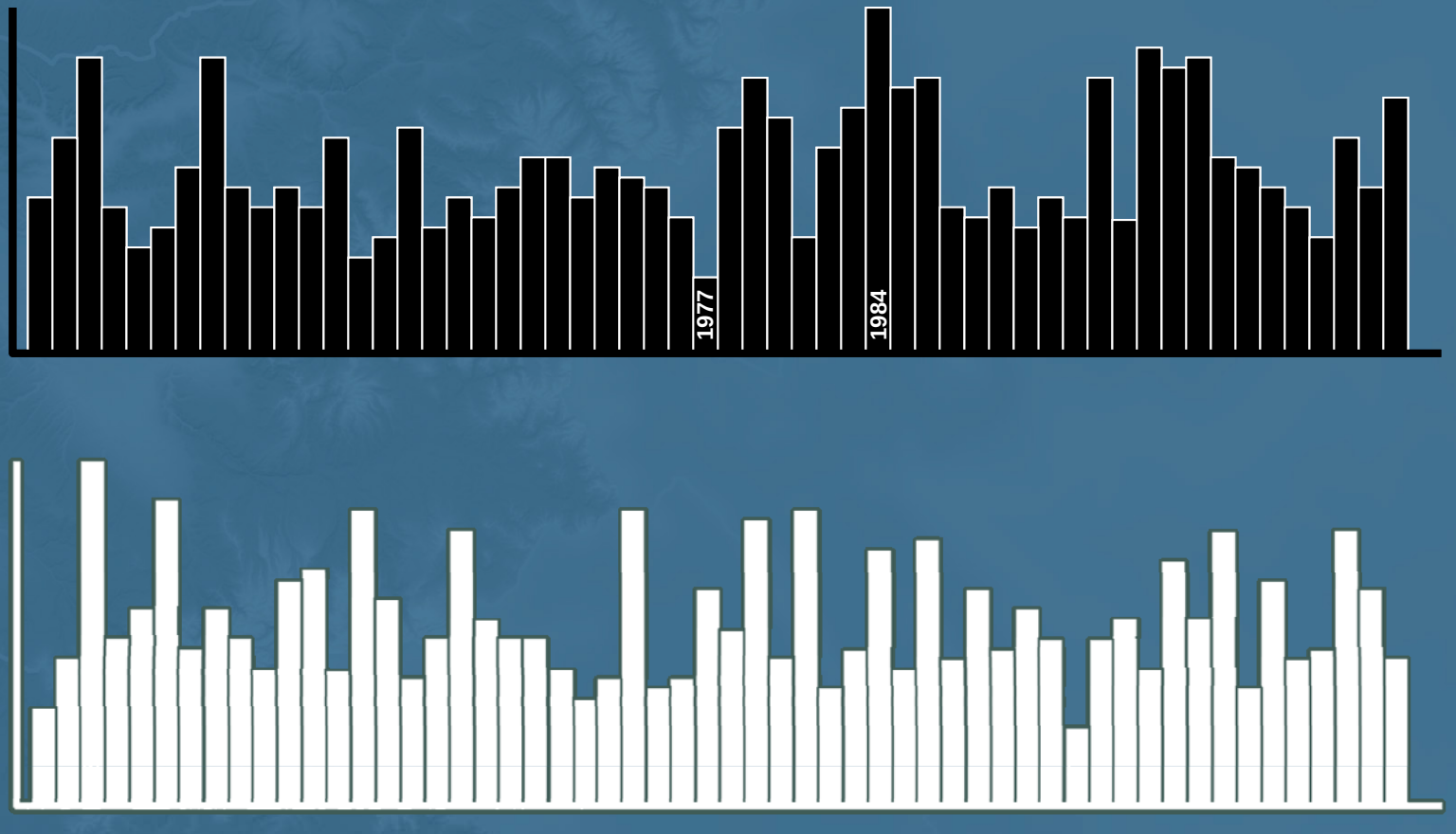
- The selected projections for 2040 are representative of both periods



GCM Hydrology Process



Re-sequencing Climate Adjusted Hydrology



1.

Repeat 100x

Forest Change Hydrology

- Forest Change Due to Fire
  - Localized
  - Relatively small except for very rare cases.
  - Occurrence is substantially random over long periods.
- Forest Change Due to Insect Infestation
  - Data Availability
  - Forest Recovery Timeframe
  - Water Supply Impact Detection Threshold

Forest Change due to Insect Infestation

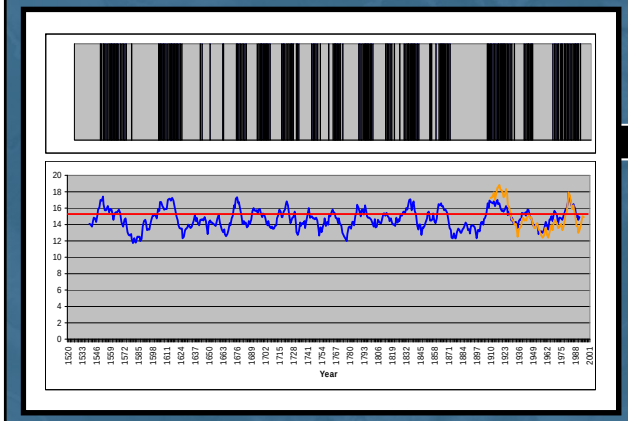
- Data Availability
  - Tree and beetle science is changing rapidly
  - USFS and participating agencies have ongoing studies in North Platte Basin
  - Re-growth, snow studies, and new hydrologic data
- Forest Recovery Timeframe:
  - Re-growth begins immediately via immature trees and understory vegetation
  - ET reduction offset quickly by grass / shrub regrowth
  - Evaporation reduction offset by tree re-growth (before 2040)
- Water Supply Impact Detection Threshold:
  - Most flow volume from sub-alpine forest (elevations >8,000 feet)
  - 20%-30% watershed must be cleared before detectable flow change
  - Stream flow impact from forest disturbance <<< Impacts from climate change

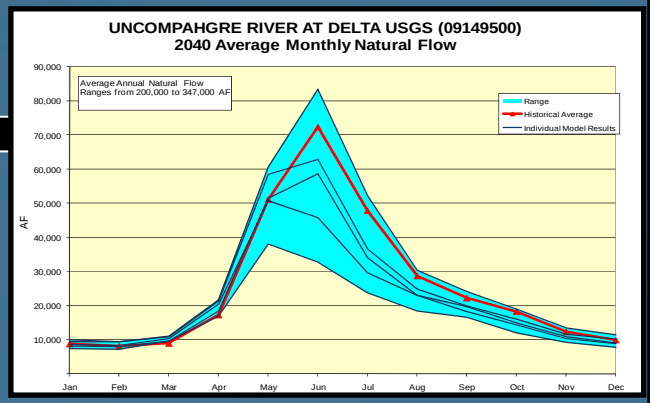
Overall Hydrology Approach

Paleohydrology

Observed Hydrology

GCM's & Hydrology





Statistical Models

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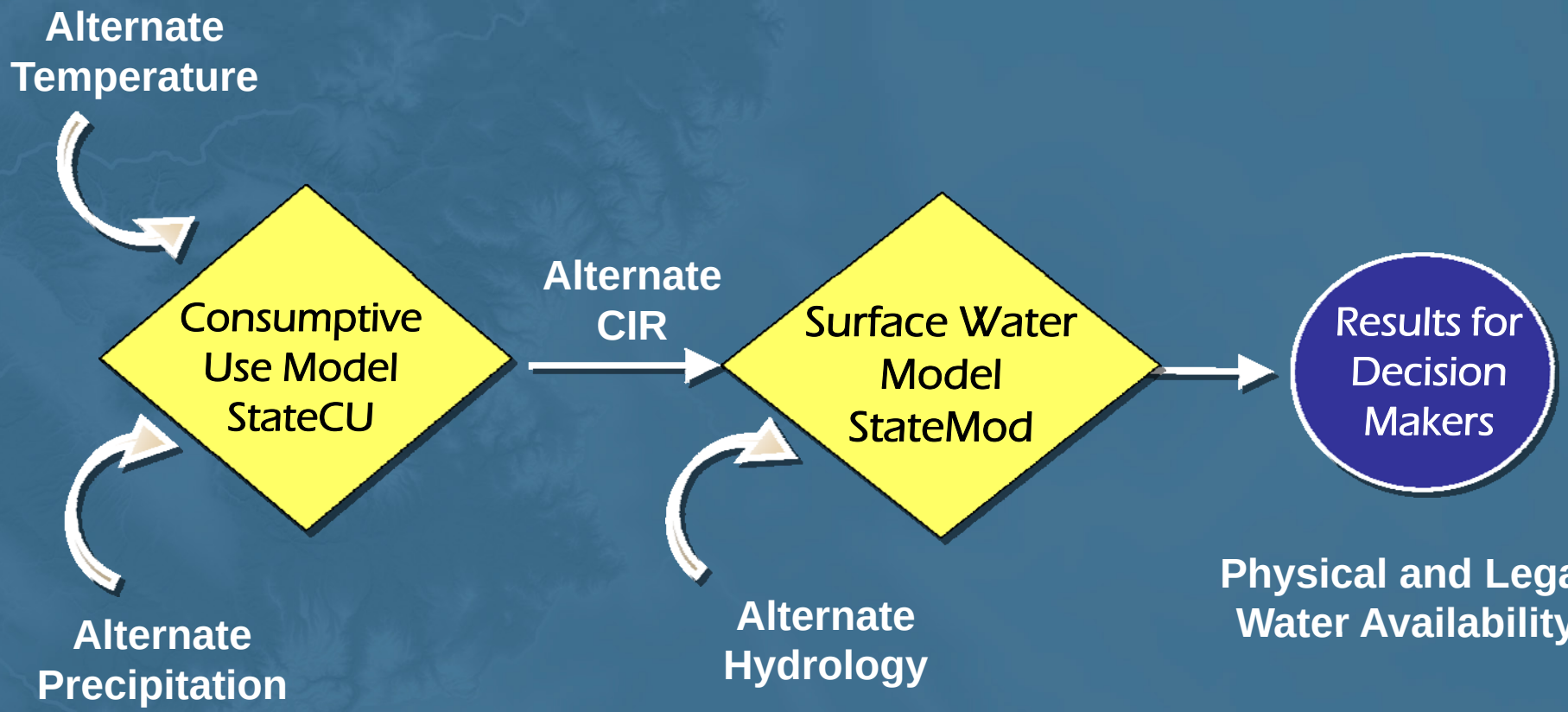
StateCU

Final Step – Estimating Water Availability



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- Results
- Where we go from here

Results from Climate Adjusted Hydrology

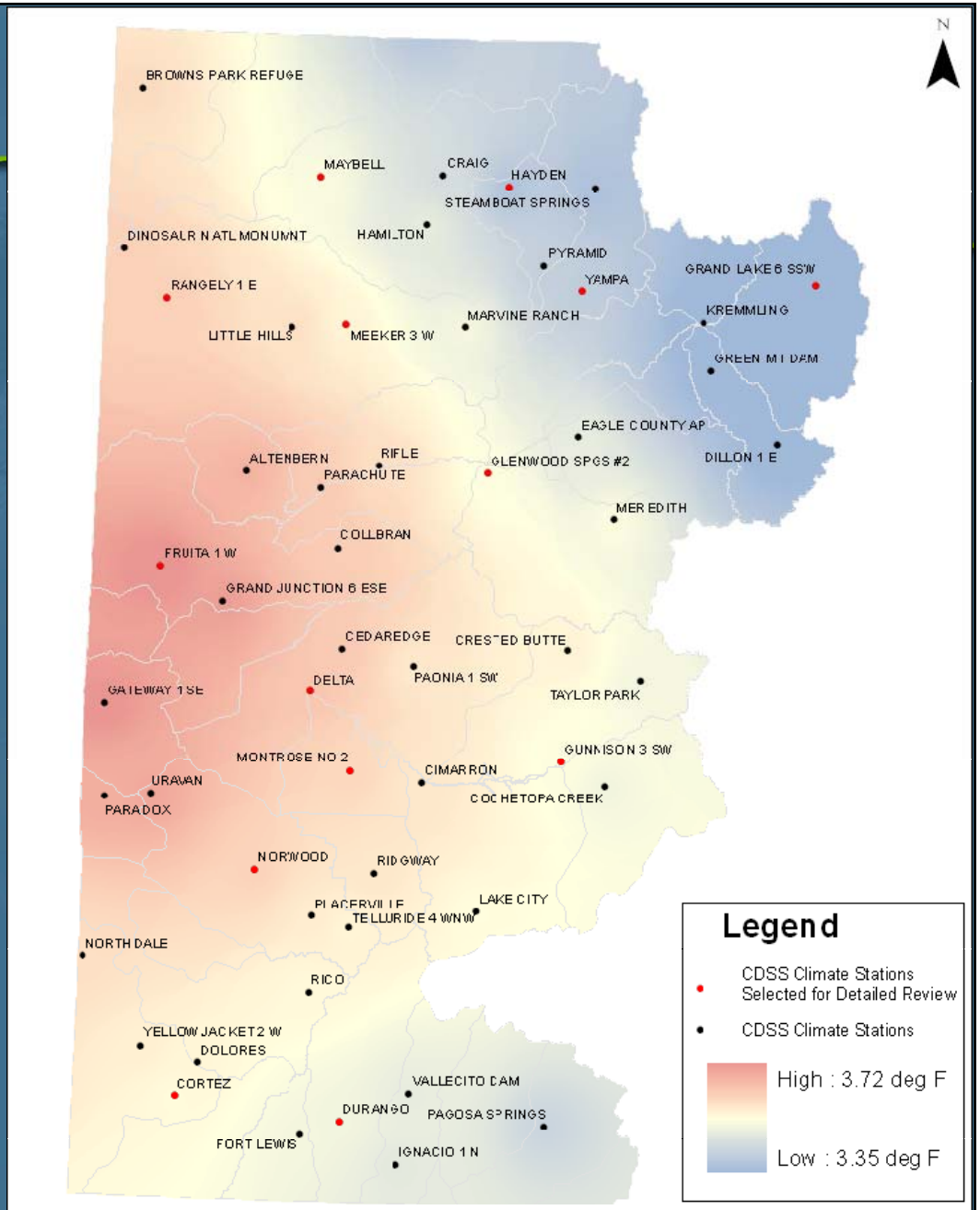
- Temperature
- Precipitation
- Crop Irrigation Requirement
- Natural Flow
- Modeled Streamflow
- Water Available to Meet Future Demands
- Modeled Consumptive Use
- Modeled Reservoir Storage

GCM's Effect On Temperature

Lower Elevations Show Largest Absolute Temperature Increase

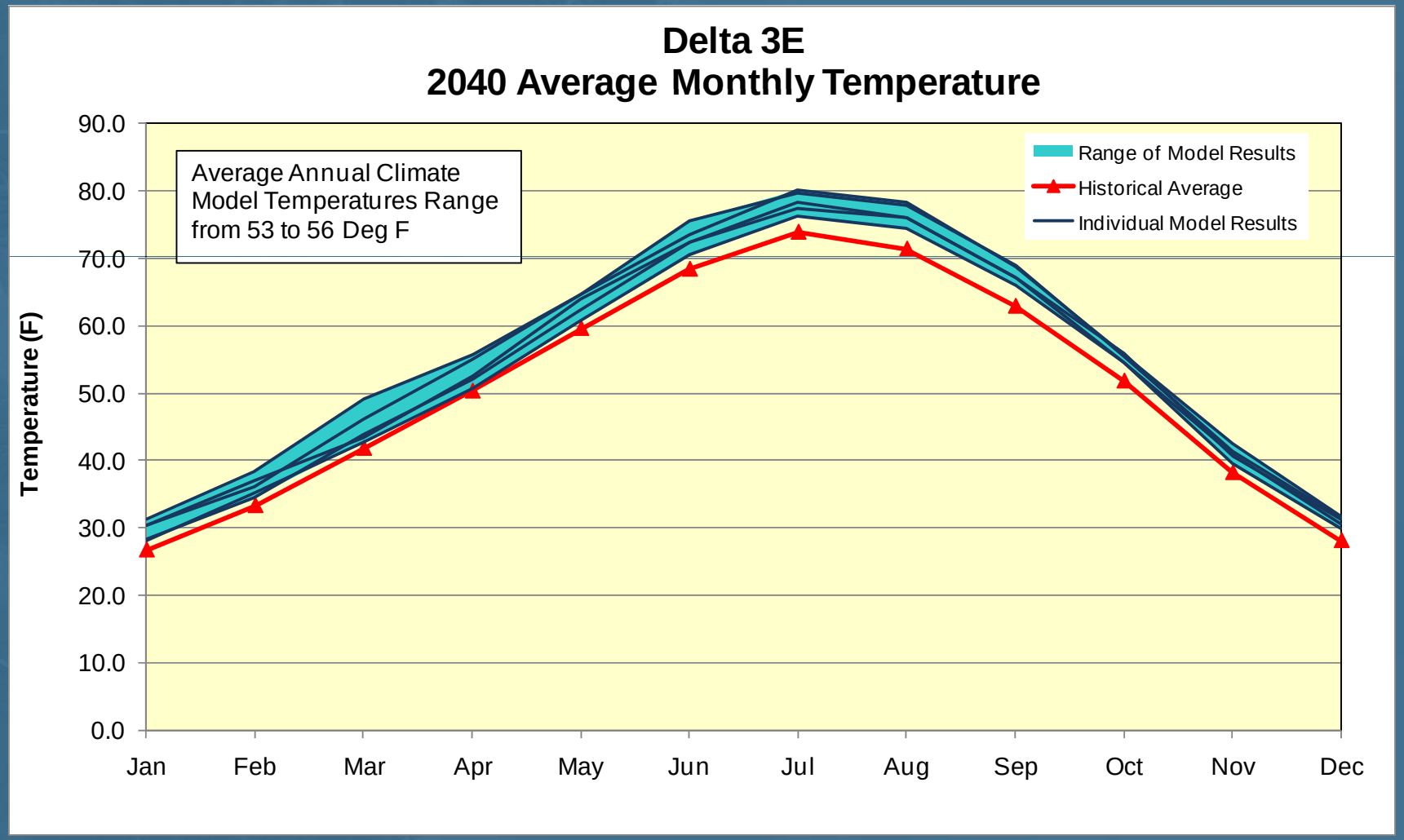
Basin Wide 2040 Average Increase Ranges from 3.3 to 3.7 deg F

Increase is Consistent Each Month



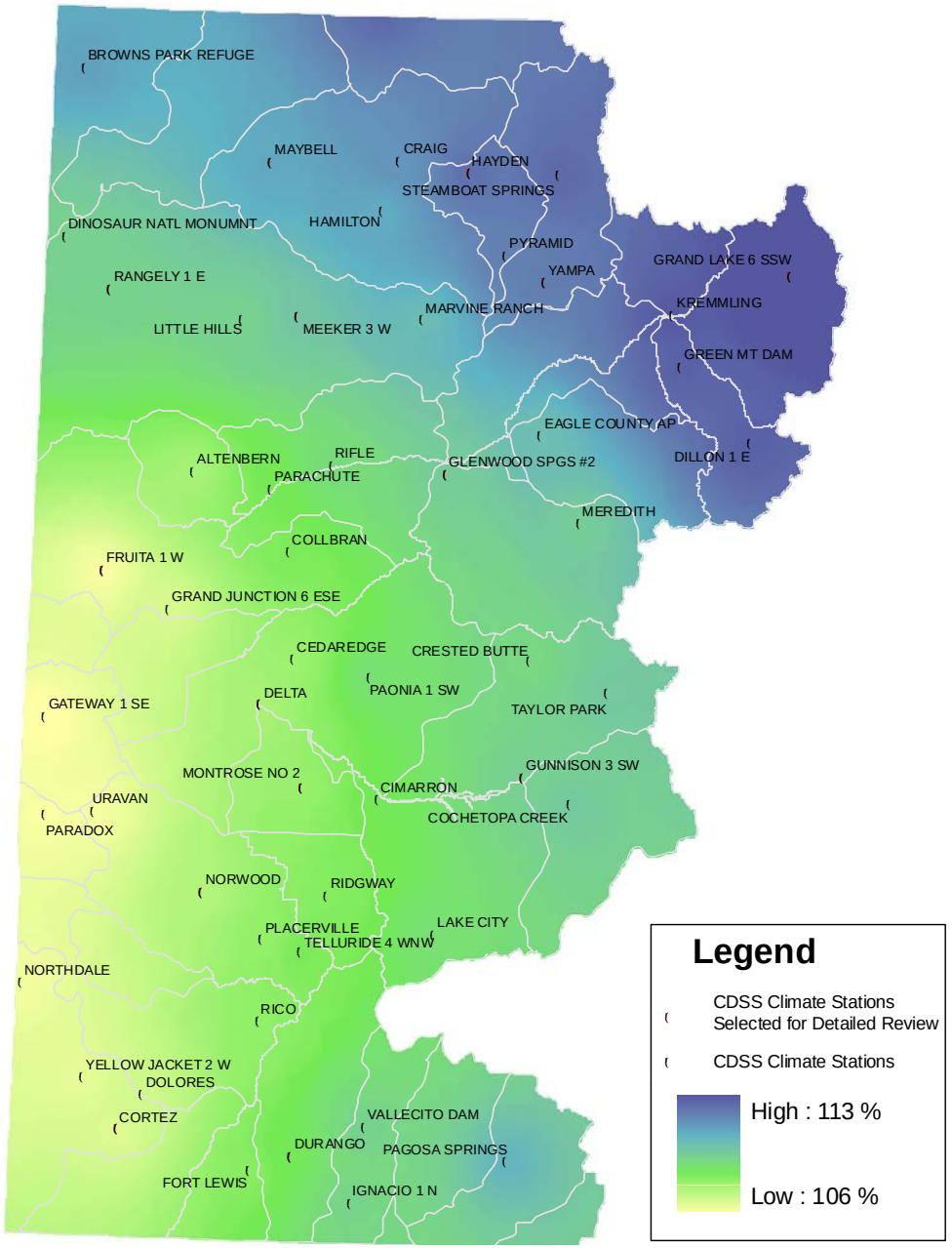
2040 Annual Increase in Temperature from Historical

GSM's Effect on Temperature



GCM's Effect On Winter Precipitation

- Winter Precipitation (Nov-Mar) Increases Basin-Wide
- Ranges from 106 to 113 Percent of Historical
- Shift from Snow to Rain in Shoulder Months
- Increases More Compared to Historical in Northern CO
- Increases More Compared to Historical at Higher Elevations



2040 Percent of Historical Winter Precipitation

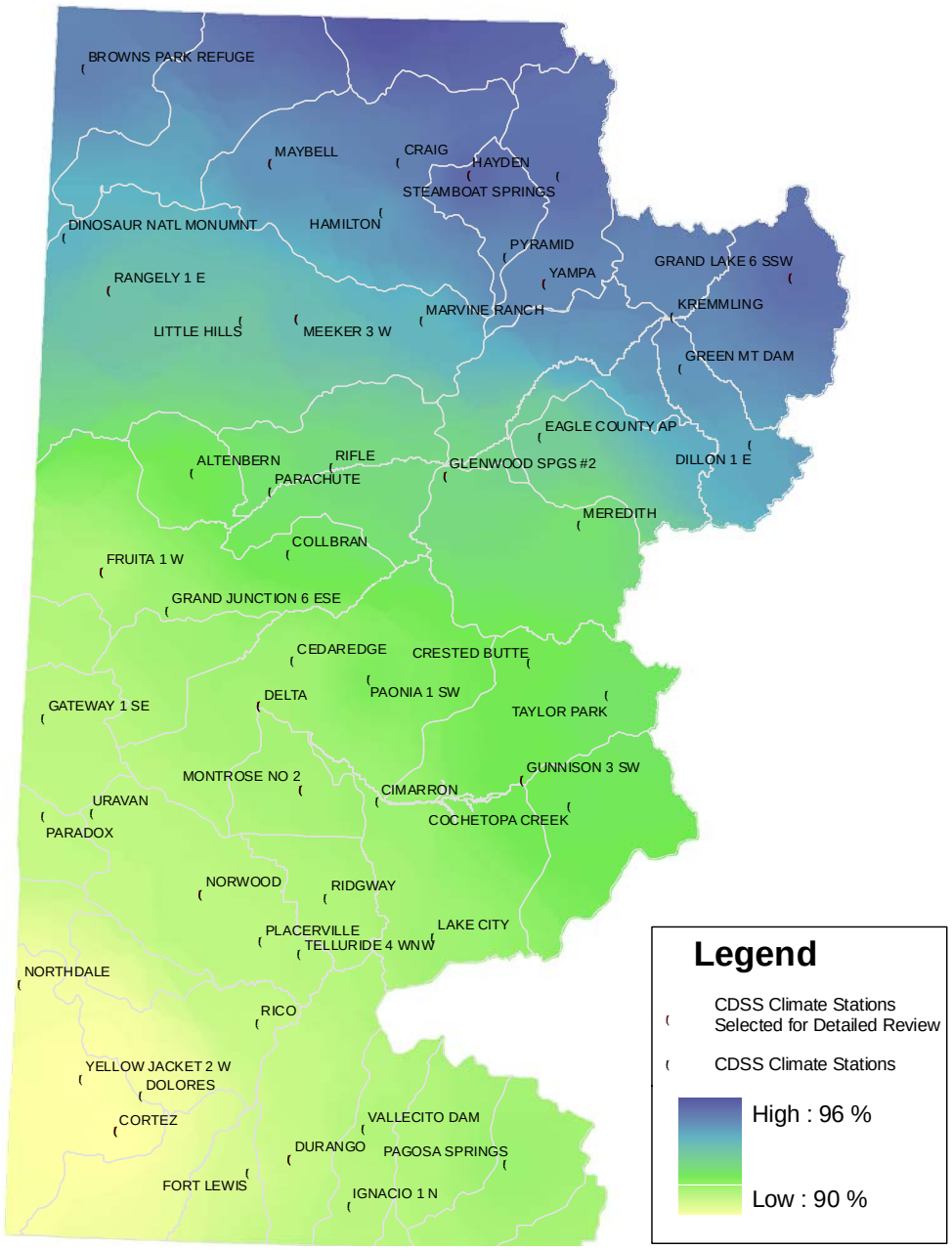
GCM's Effect On Irrigation Season Precipitation

Summer Precipitation (Apr-Oct) Decreases Basin-wide

Ranges from 90 to 96 Percent of Historical

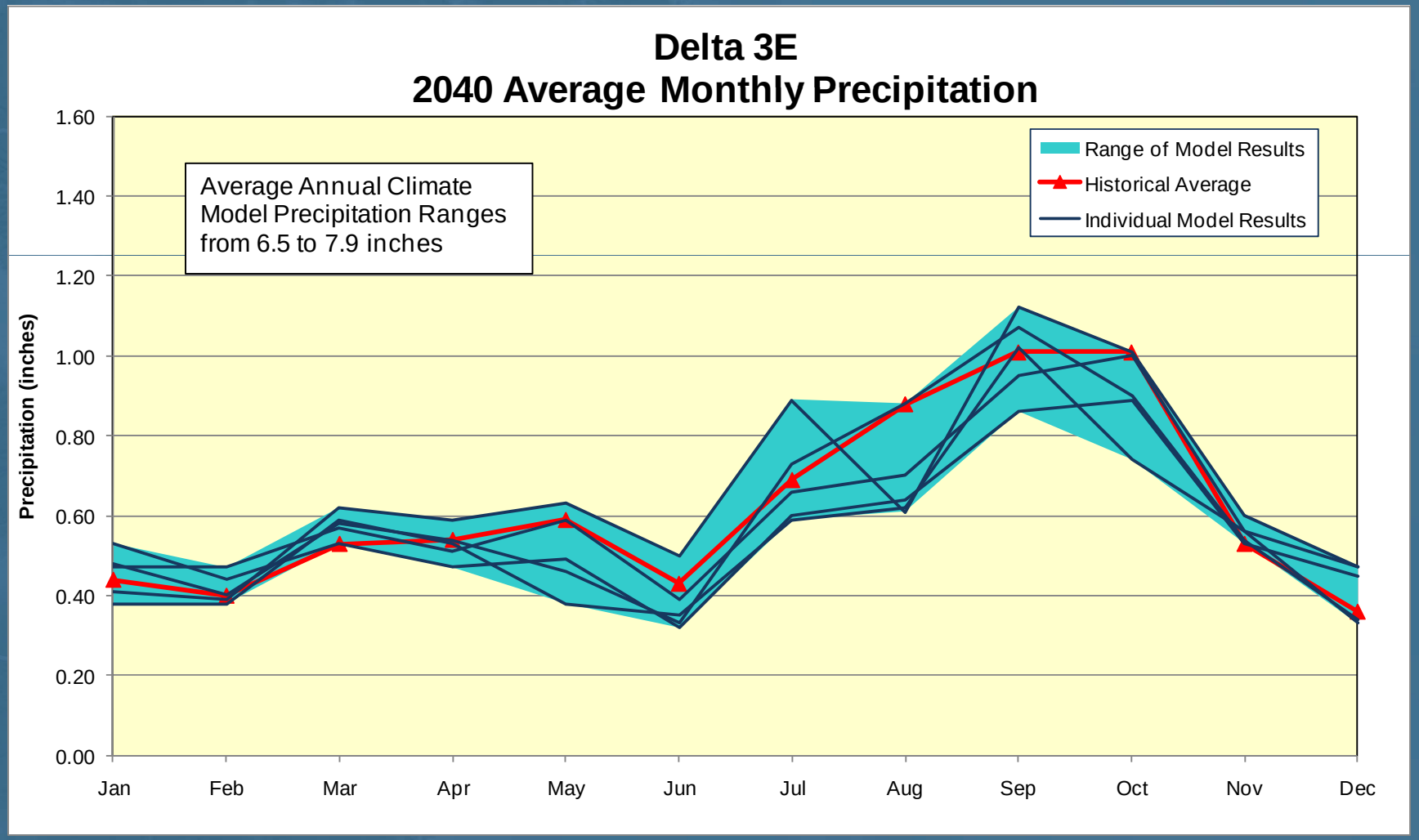
Decreases More Compared to Historical in Southern CO

Decreases Less Compare to Historical at Higher Elevations



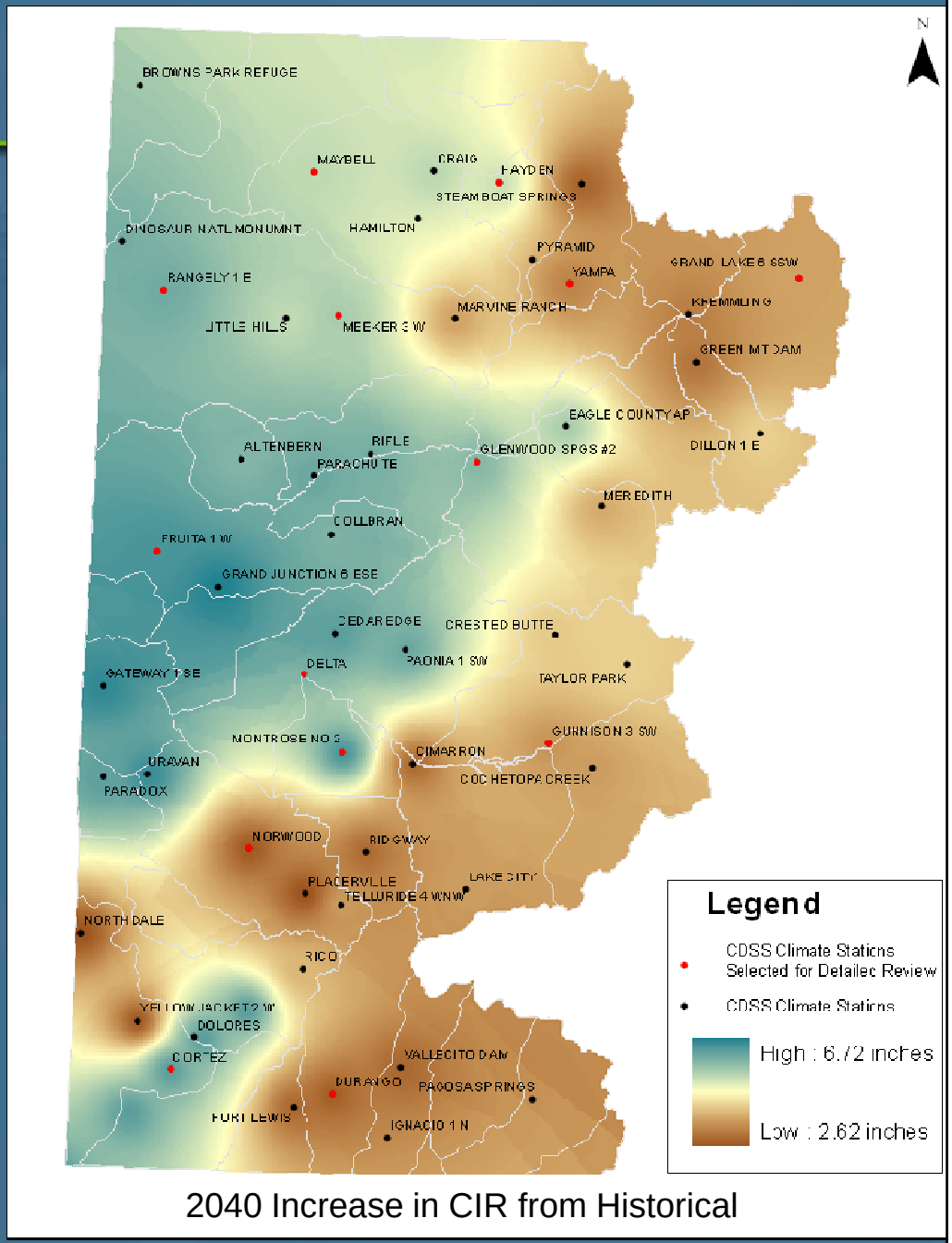
2040 Percent of Historical Summer Precipitation

GCM's Effect on Precipitation



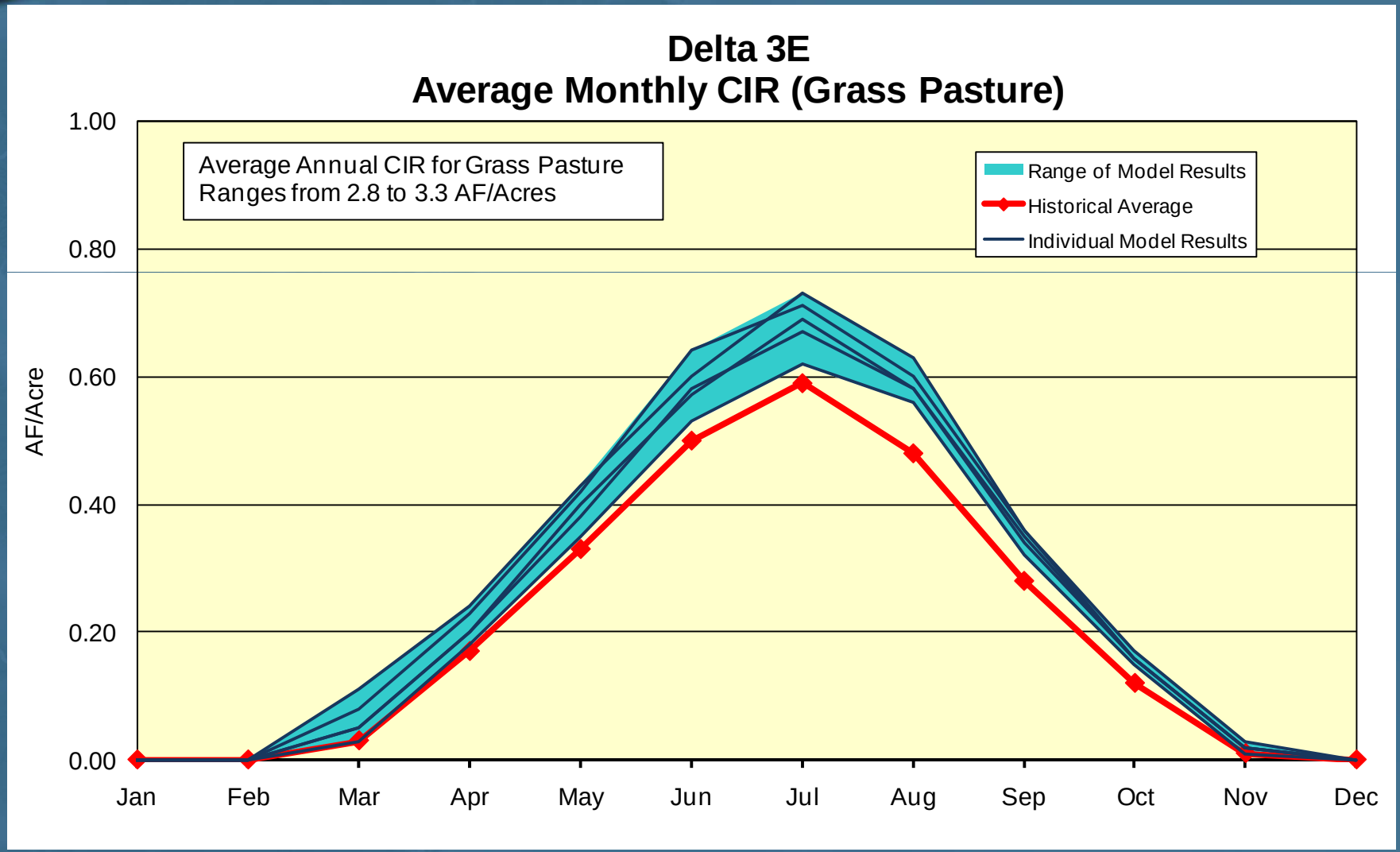
GCM's Effect On Crop Irrigation Requirement

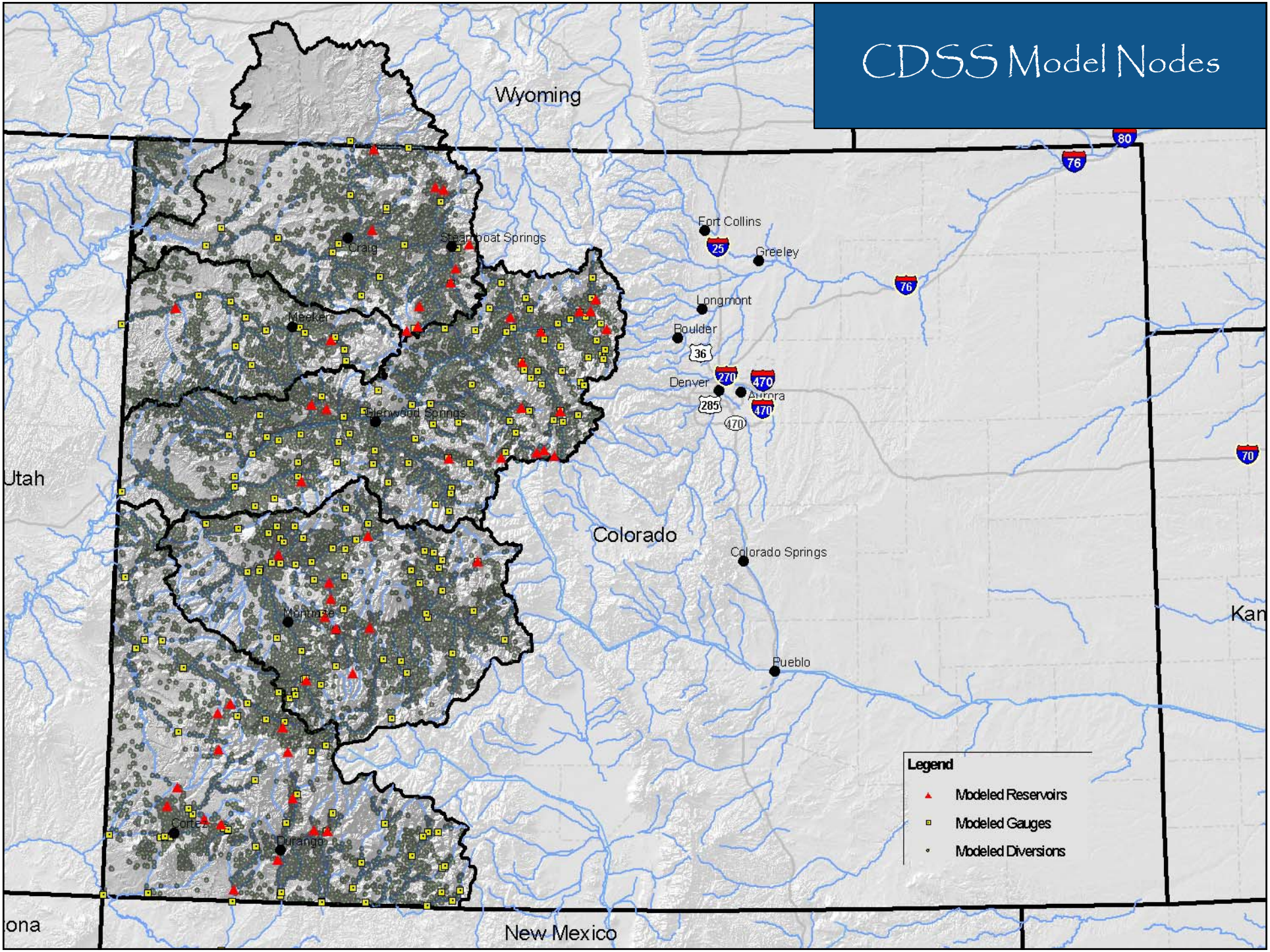
- Crop Irrigation Requirement Increases Basin-wide
- CIR Increase Ranges from 2.6 to 6.7 inches per Year
- Growing Season for Perennial Crops Increases Basin-wide
- Growing Season Increase Ranges from 15 to 22 days
- Lower Elevations Show Largest Increase from Historical



2040 Increase in CIR from Historical

GCM's Effect on Crop Irrigation Requirement




CDSS Model Nodes
Wyoming
Utah
Colorado
New Mexico
Kan
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Fort Collins
Greeley
Longmont
Boulder
Denver
Aurora
Colorado Springs
Pueblo
Steamboat Springs
Craig
Meeker
Glenwood Springs
Montrose
Cortez
Durango
80
76
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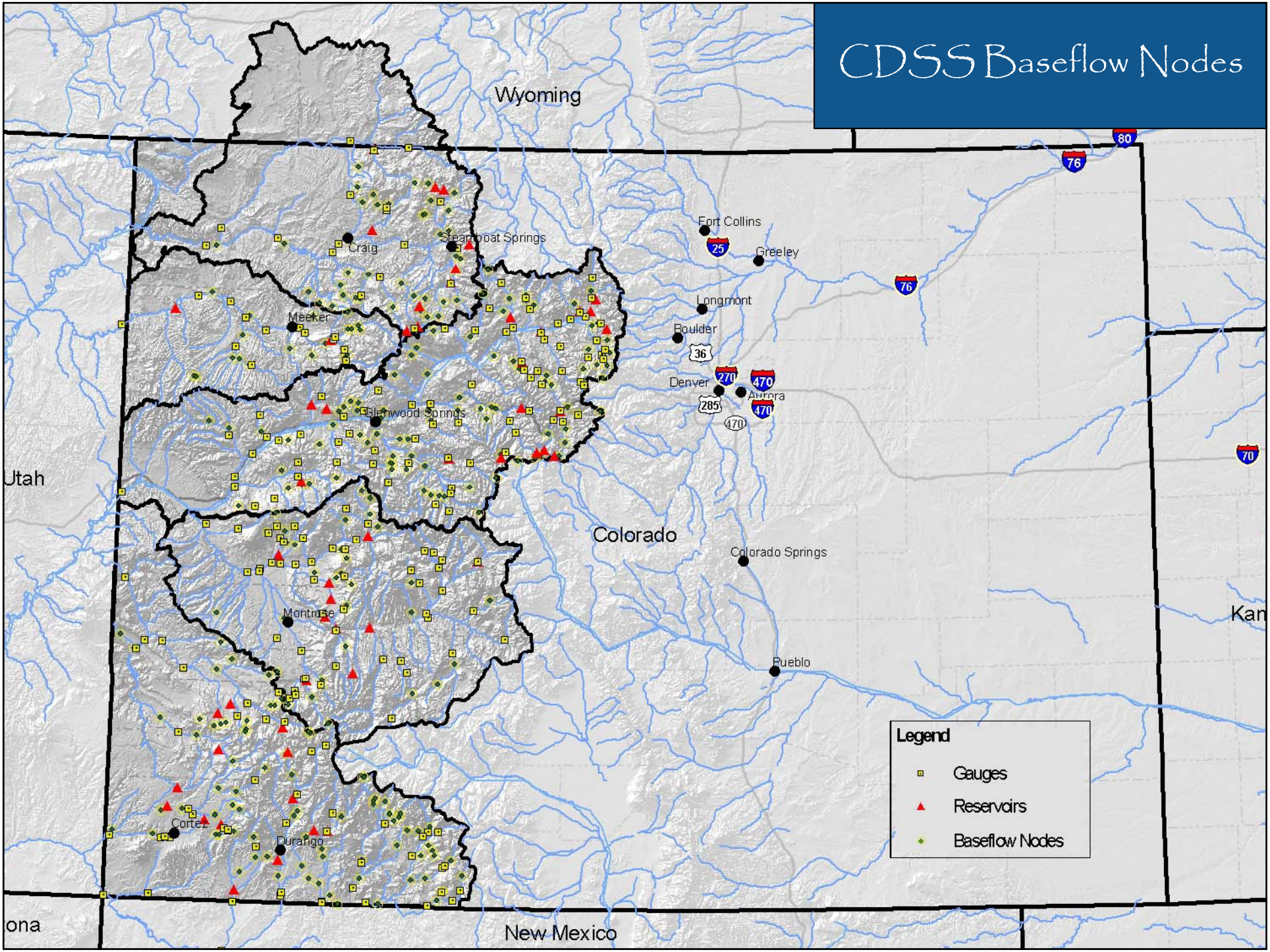
470
285
70
Legend
Modeled Reservoirs
Modeled Gauges
Modeled Diversions


CDSS Baseflow Nodes
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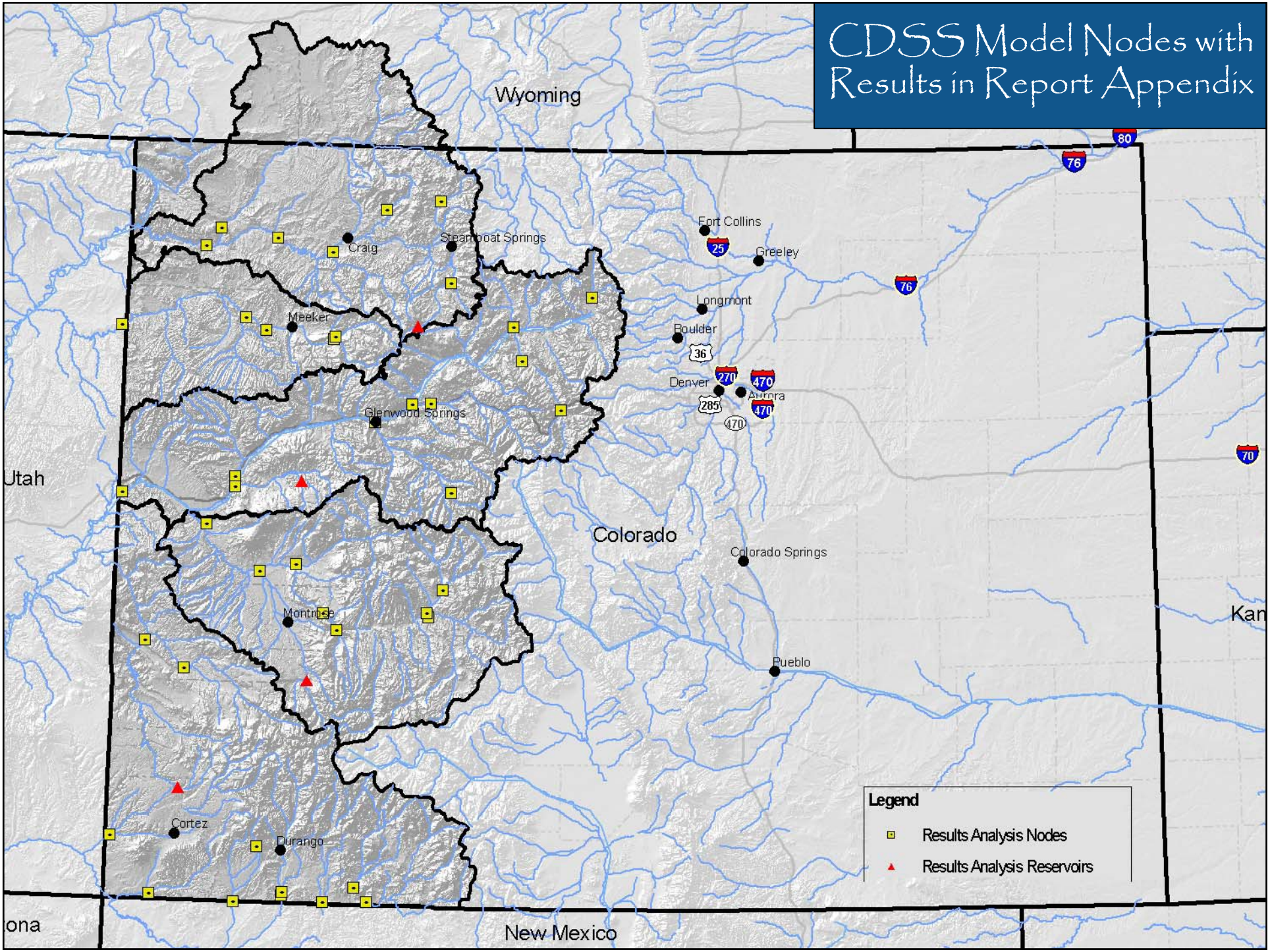
Baseflow Nodes


CDSS Model Nodes with Results in Report Appendix
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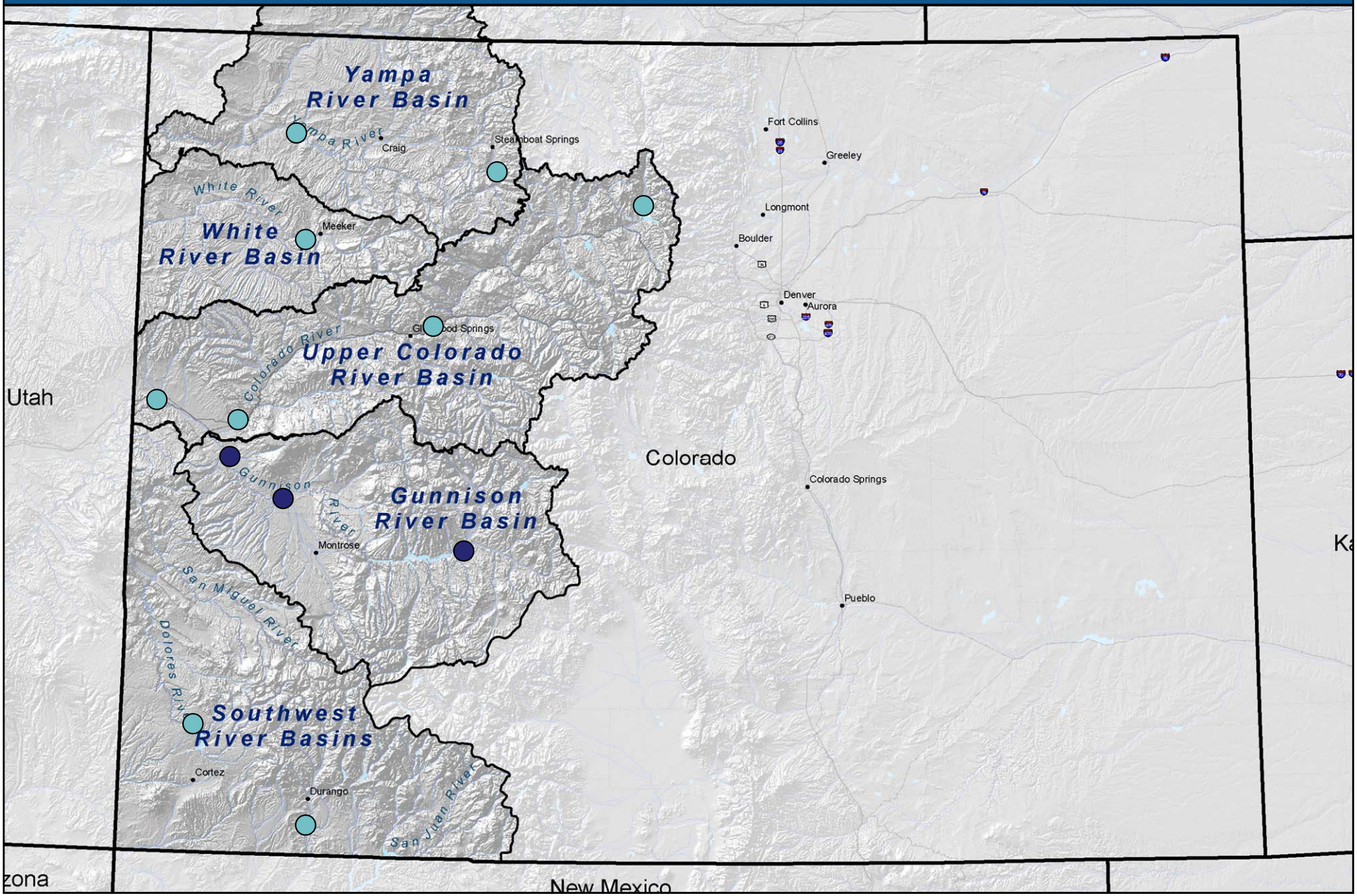
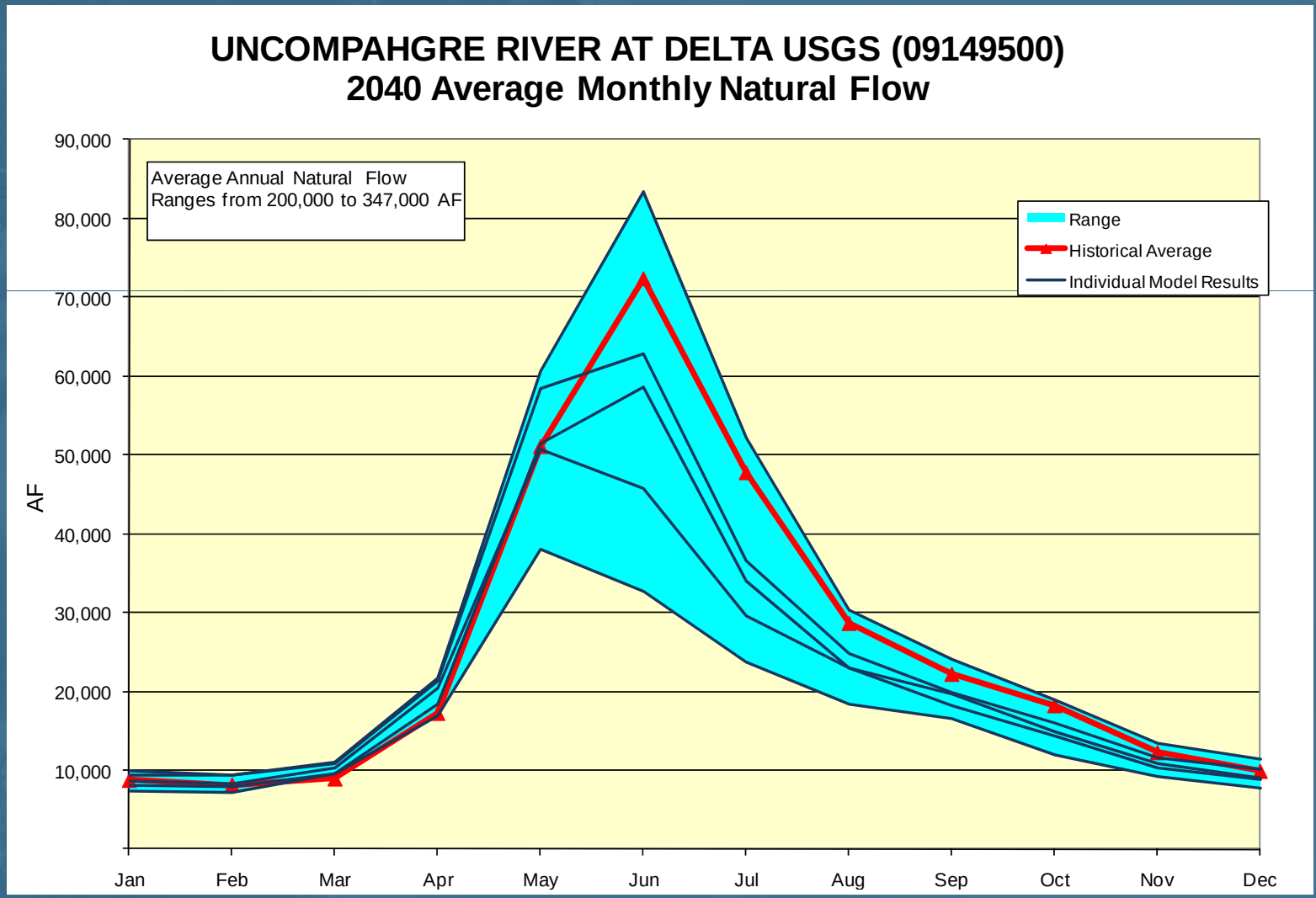
Results Analysis Nodes
Results Analysis Reservoirs

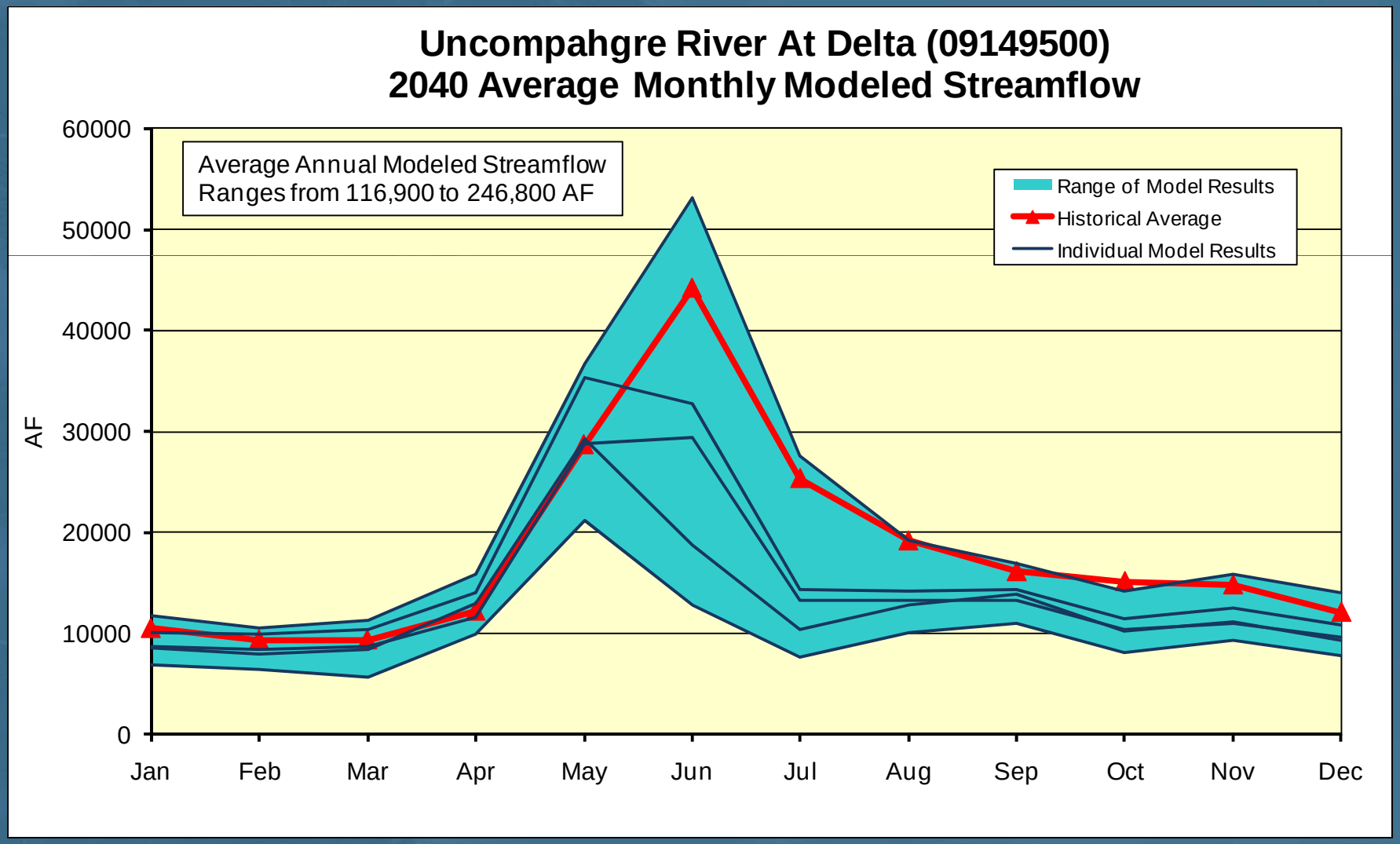
Water Availability Results: Focus on Gunnison Basin



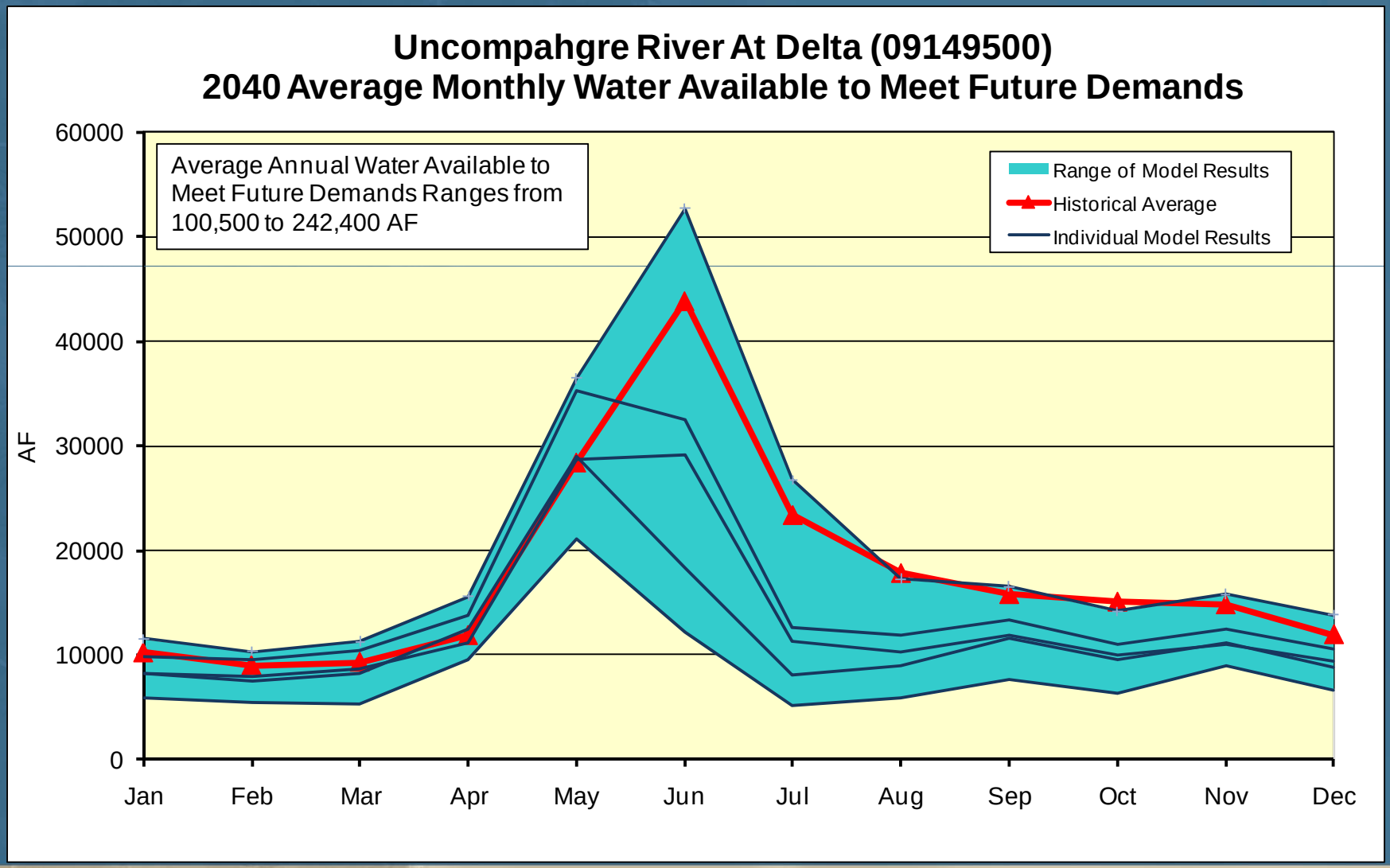
Natural Flow



Modeled Streamflow



Water Availability



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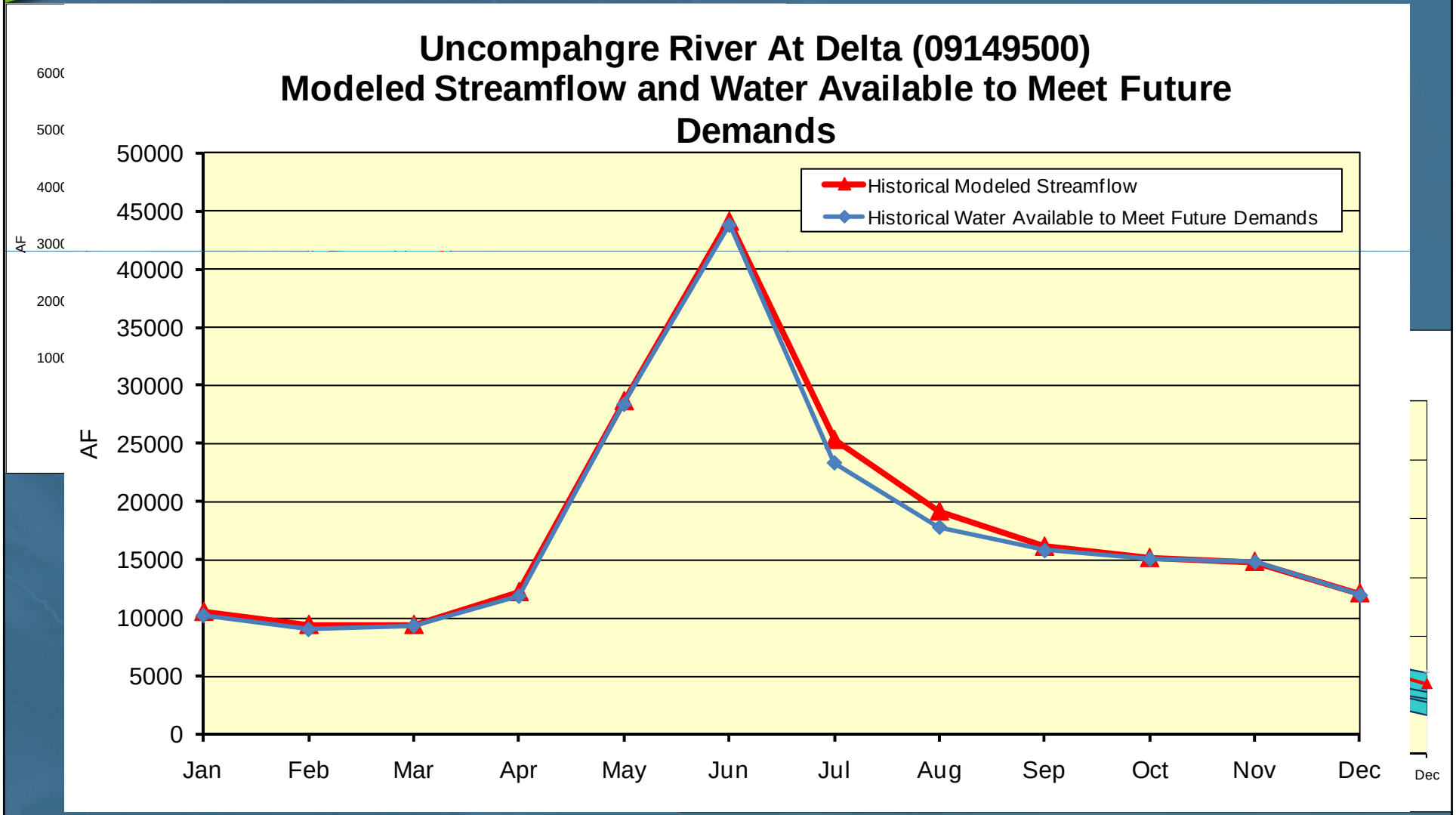

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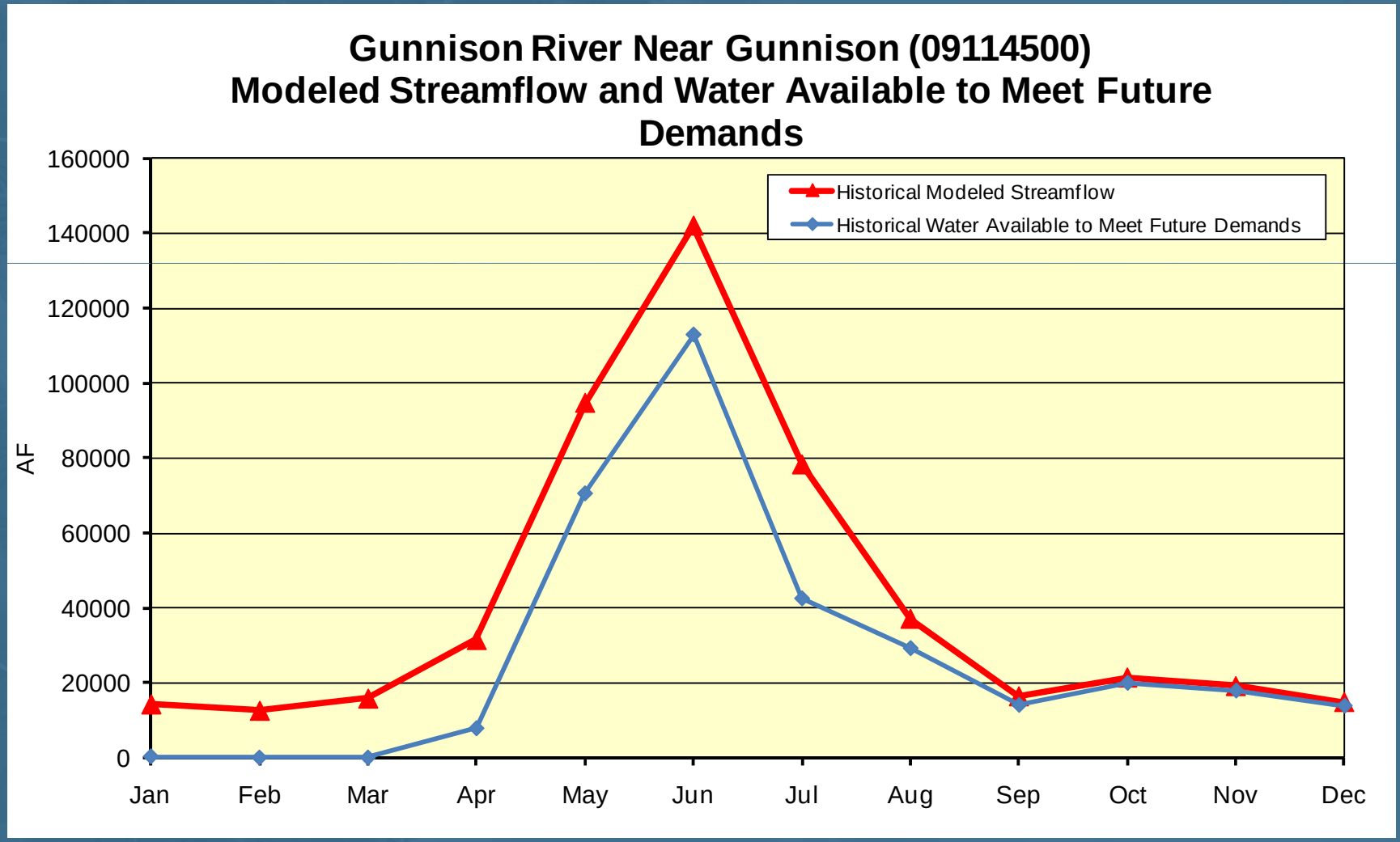
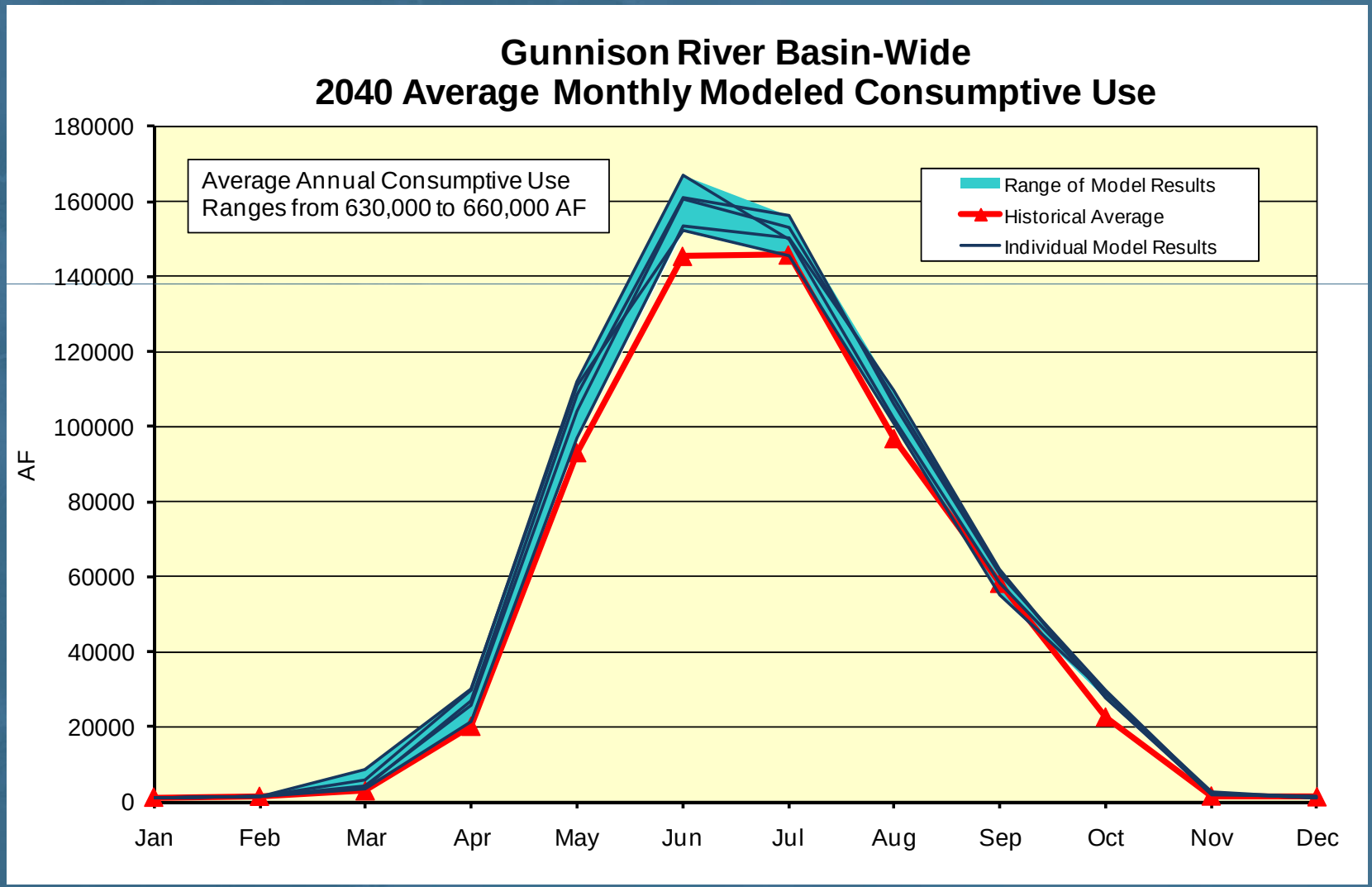
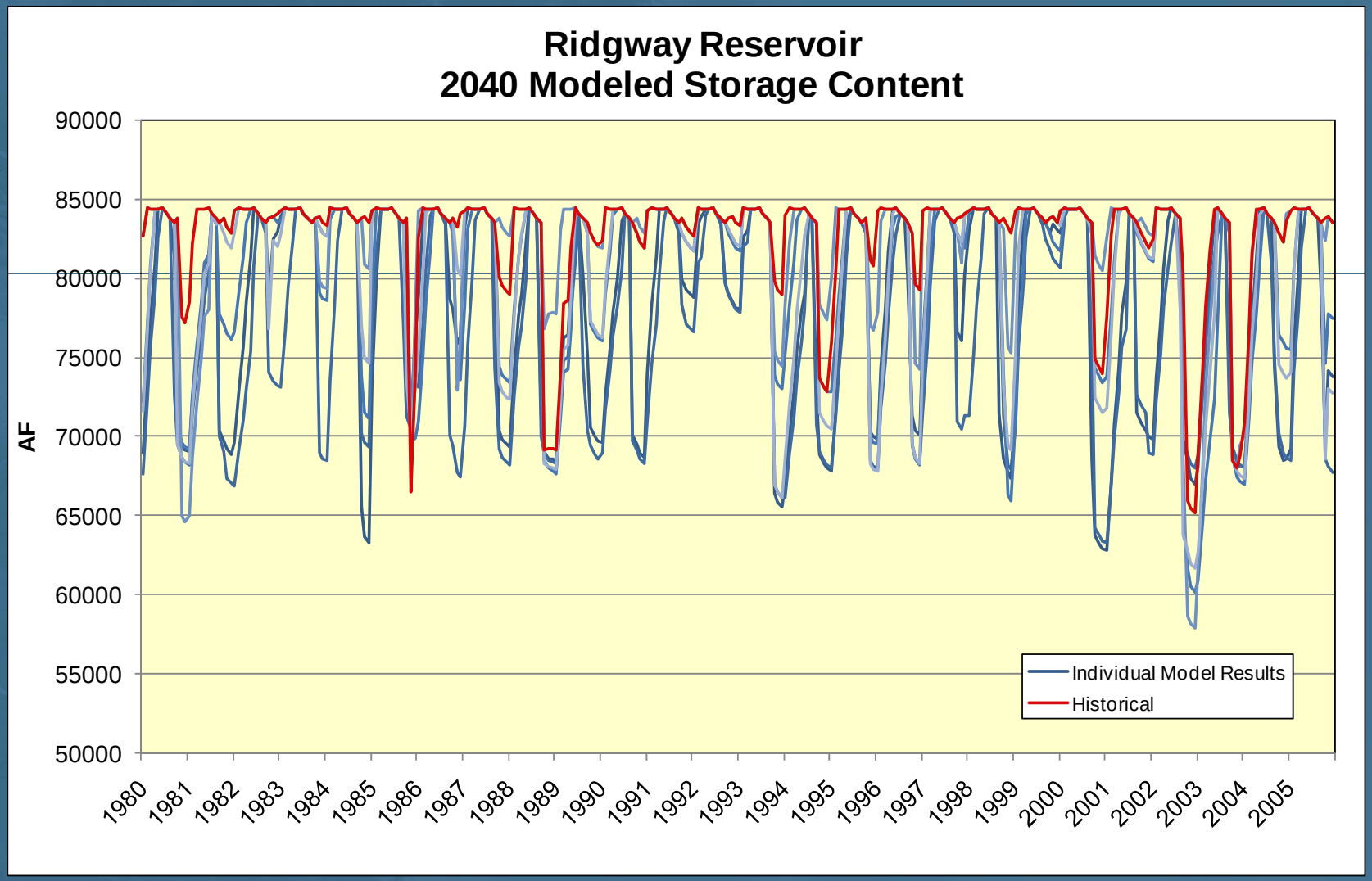


Modeled Consumptive Use



Modeled Reservoir Storage



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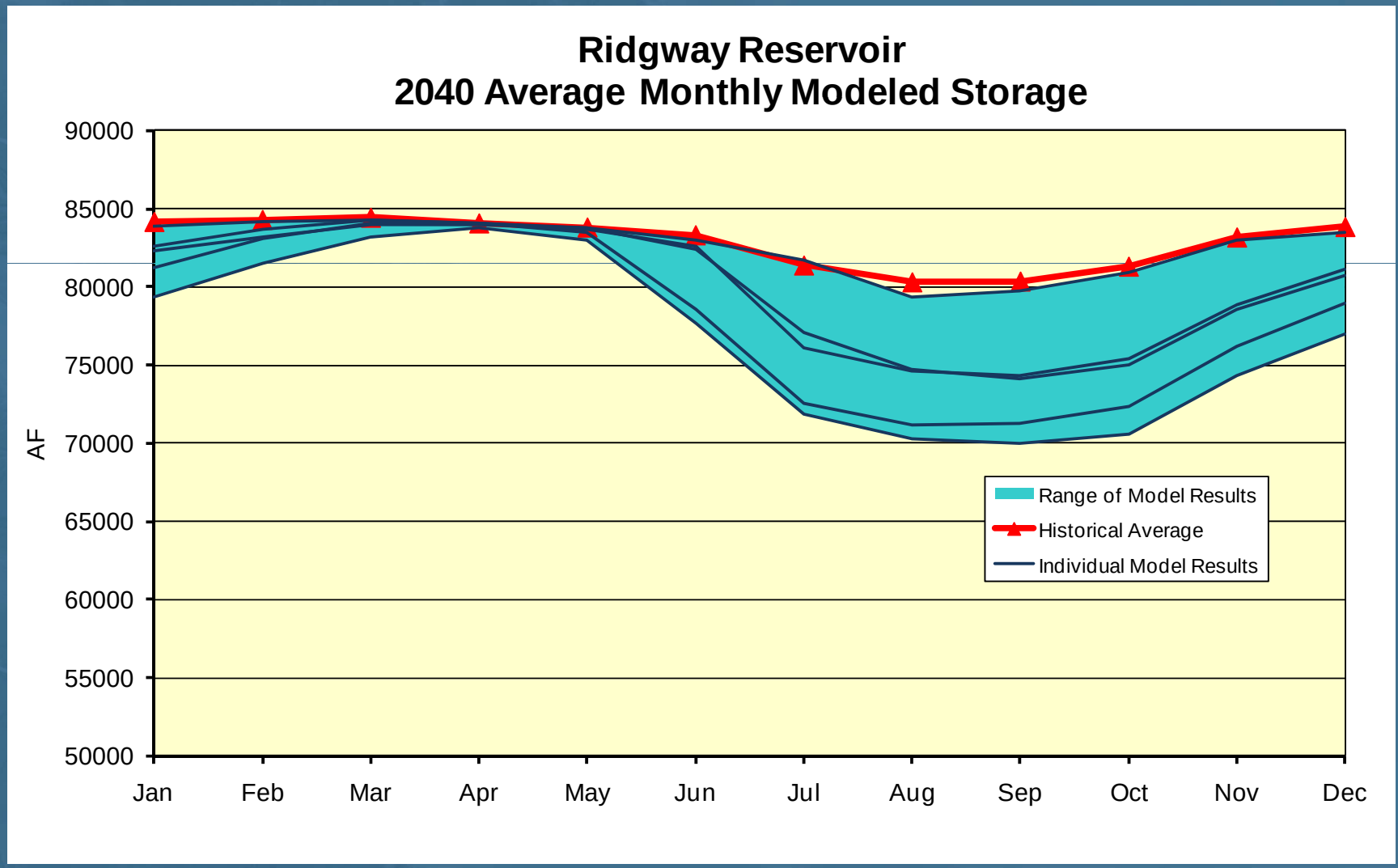


Water Availability Results – Breakdown

- Natural Flow Decreases

  = Less Physical Flow in the Basin

- Crop Irrigation Requirement Increases

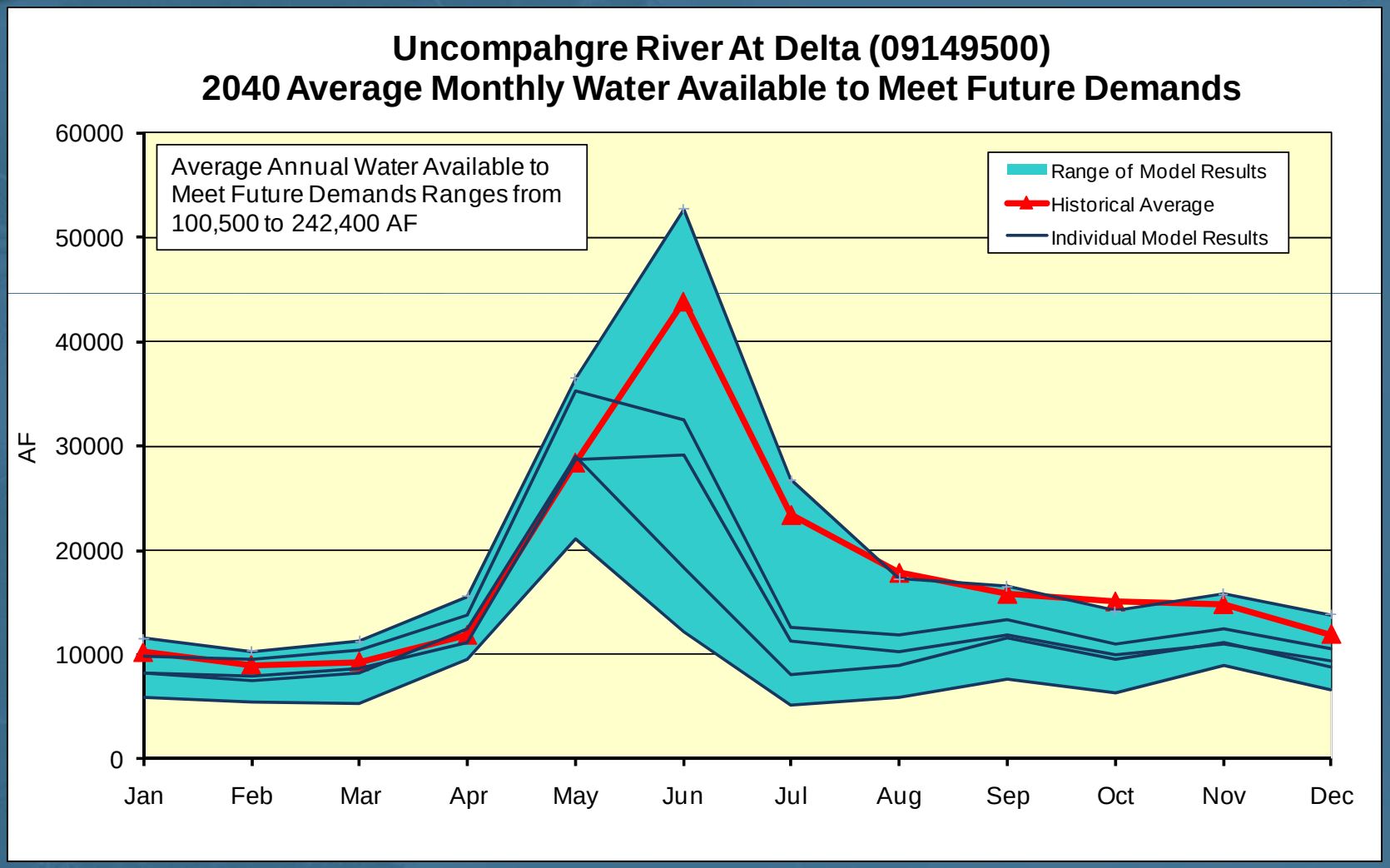
  = More Demand on the System

- Modeled Results

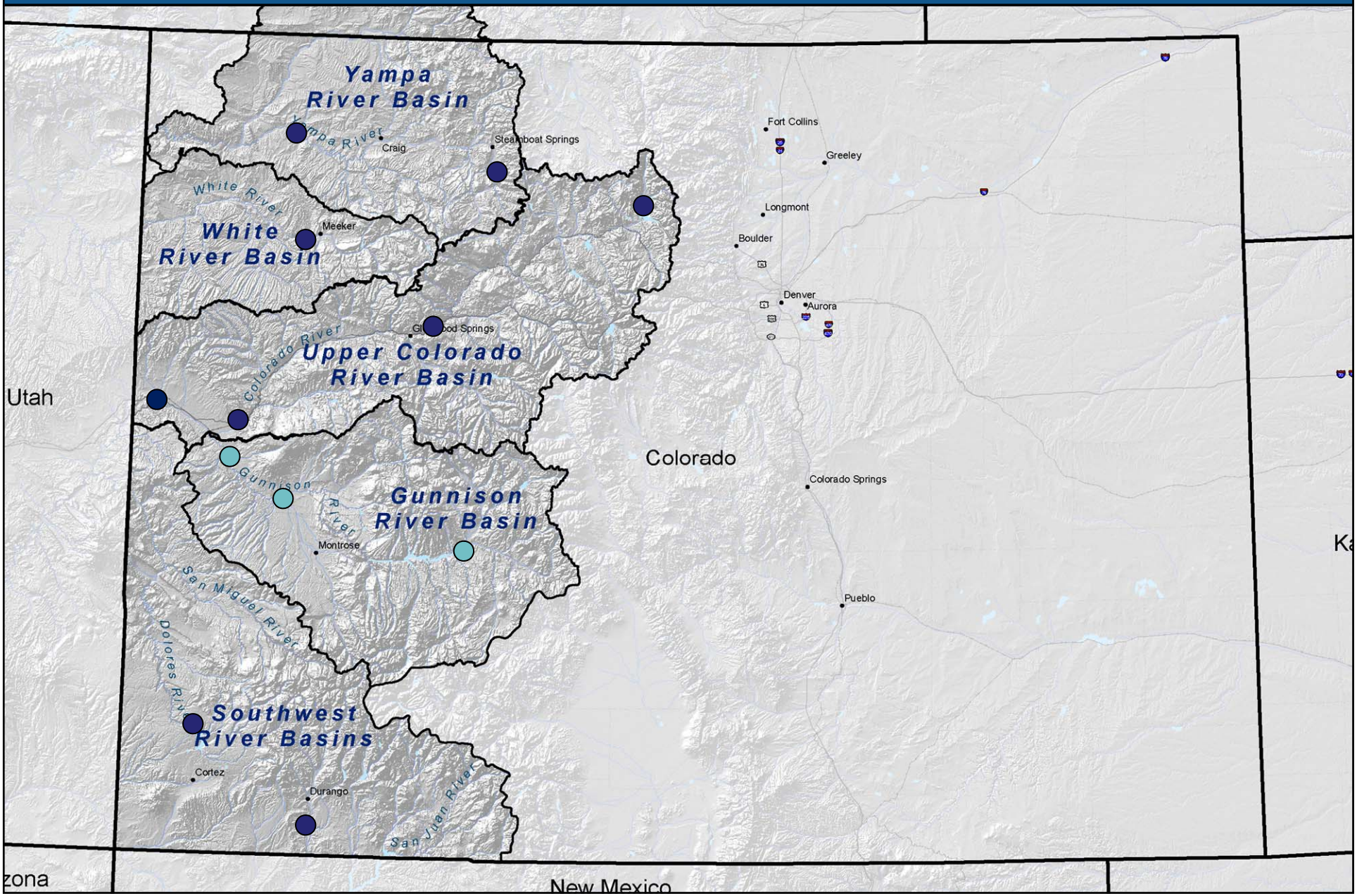
  = Less Water Available to Meet Future Demands

  = Increased Use of Reservoirs

Water Availability



Water Availability Results: Yampa, White, Colorado, Southwest



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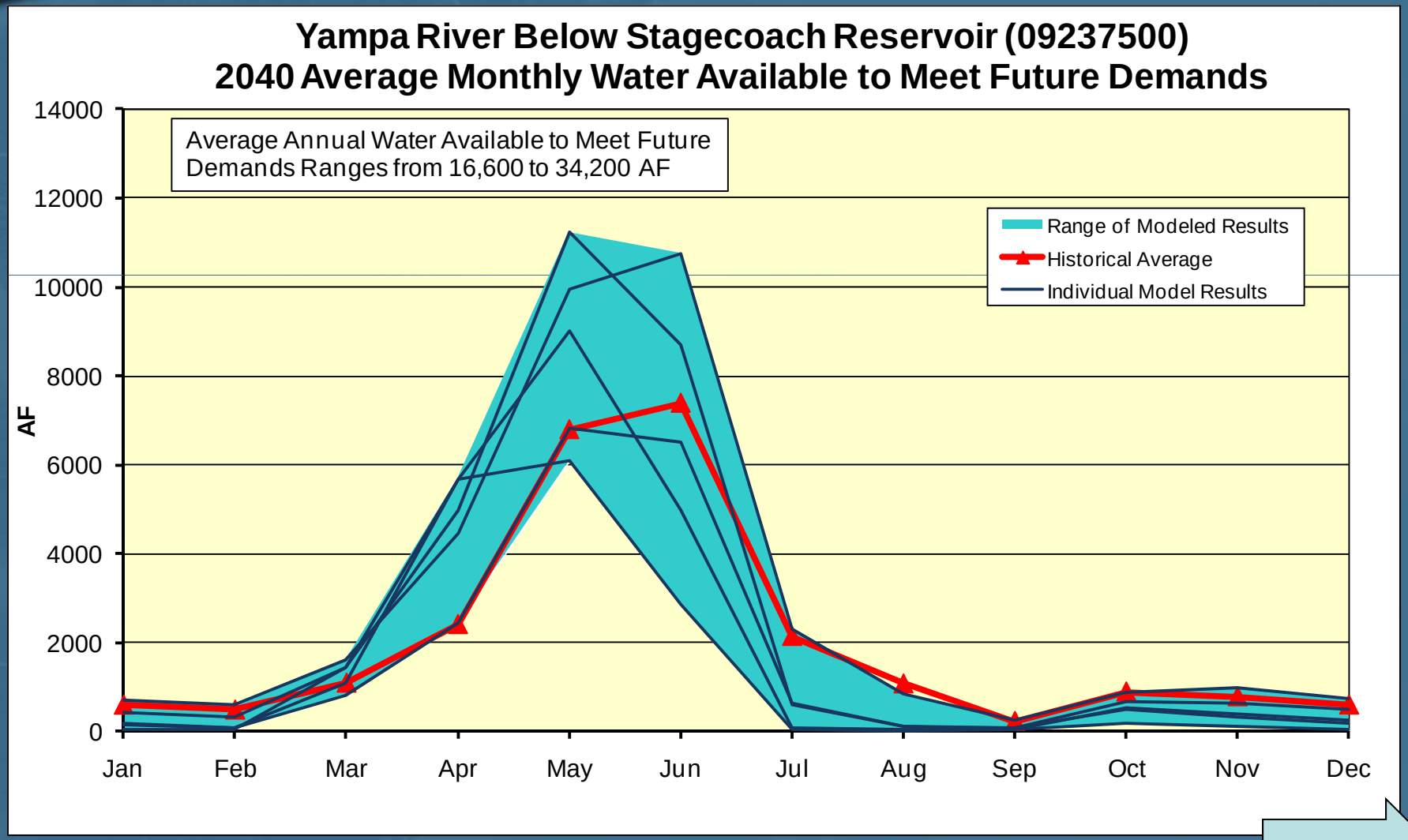
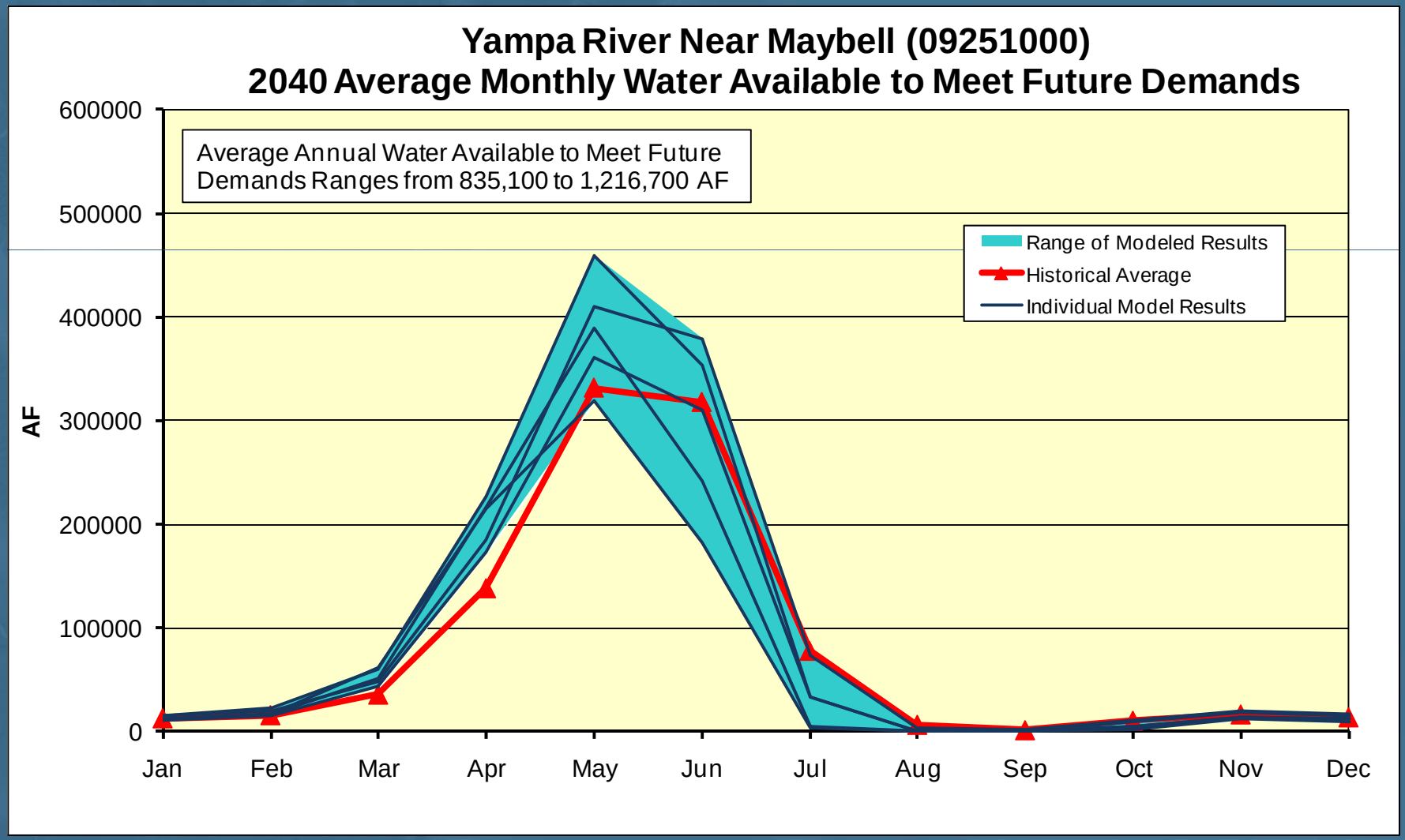
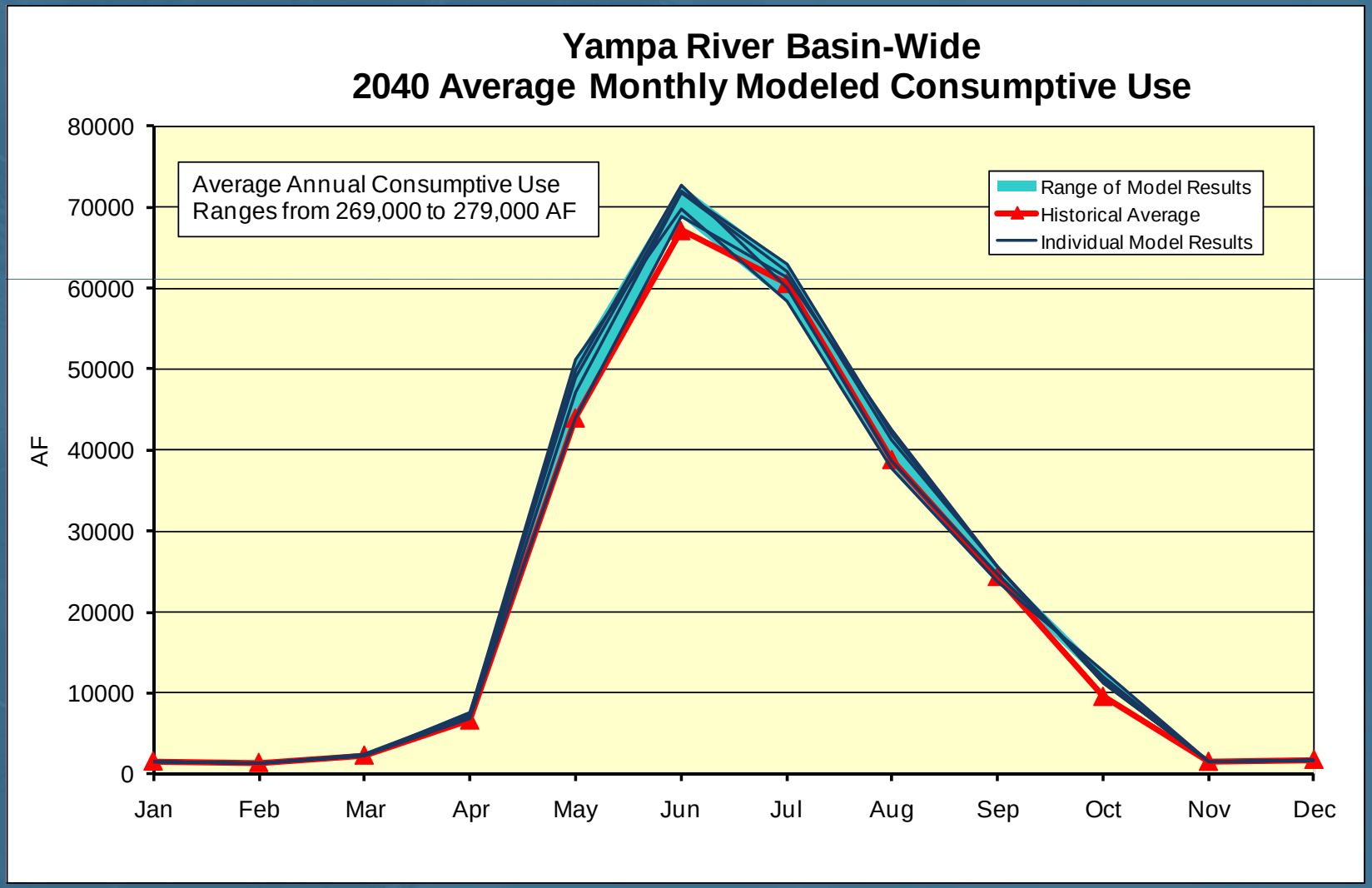


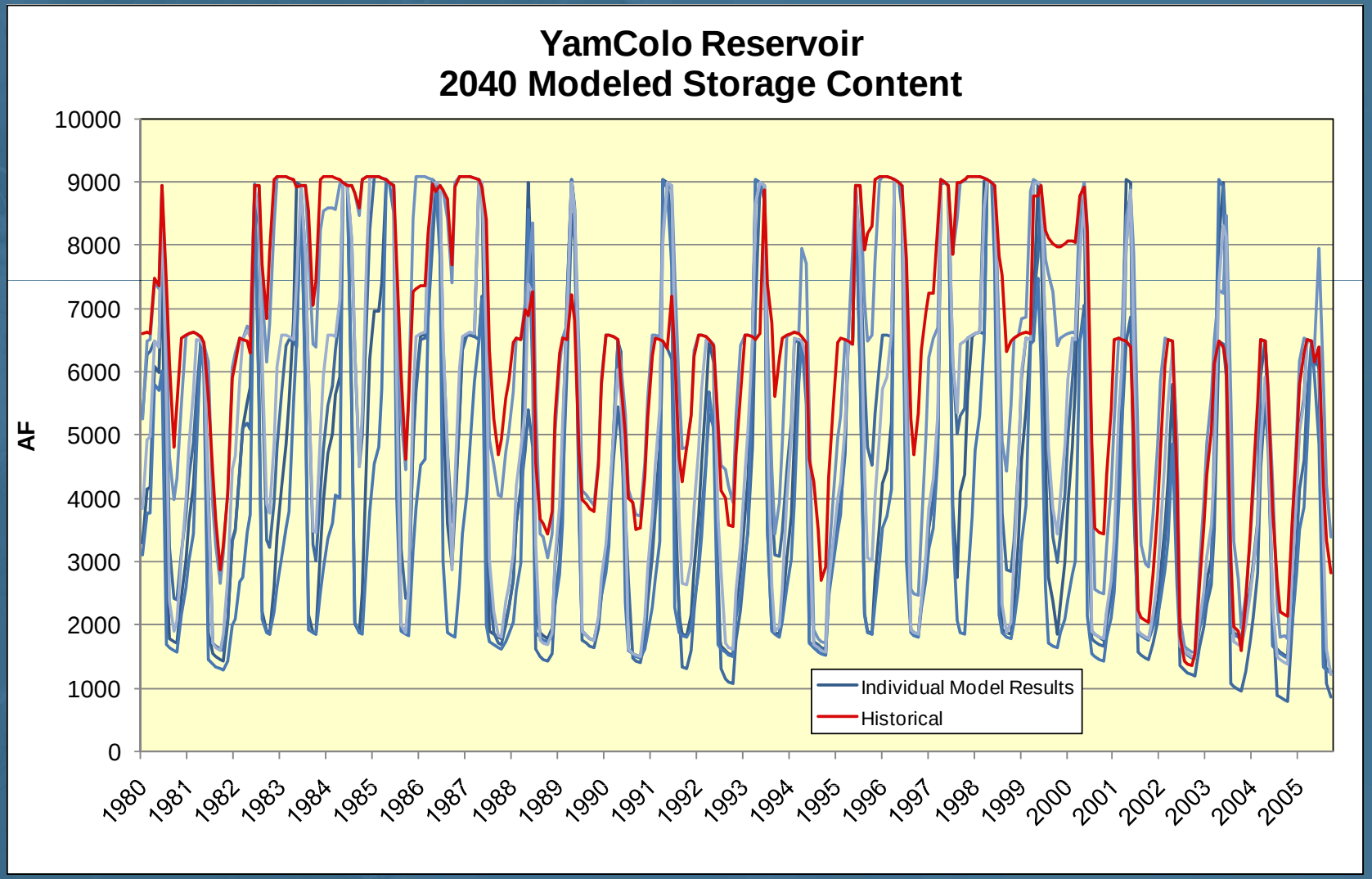
Water Availability



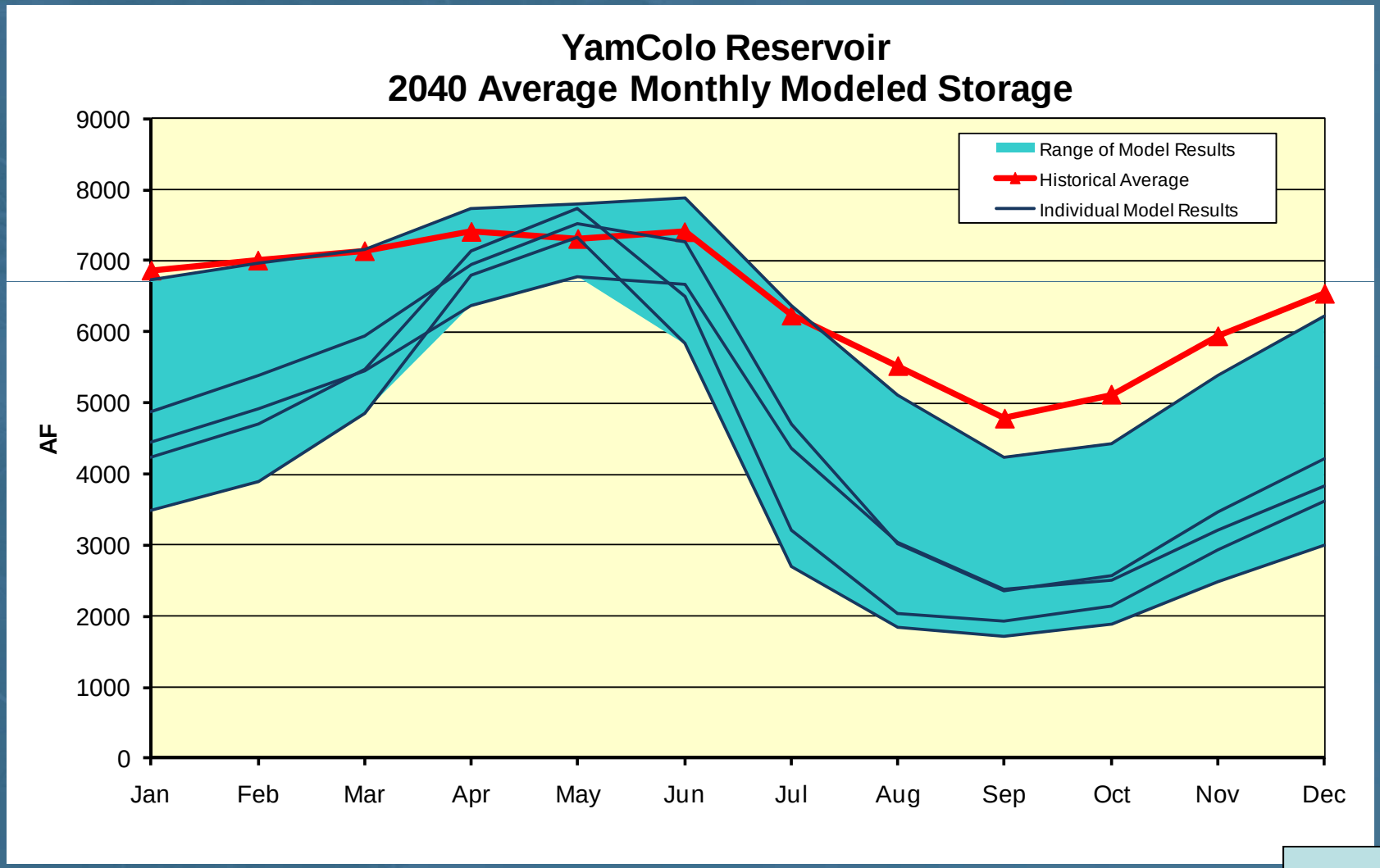
Modeled Consumptive Use



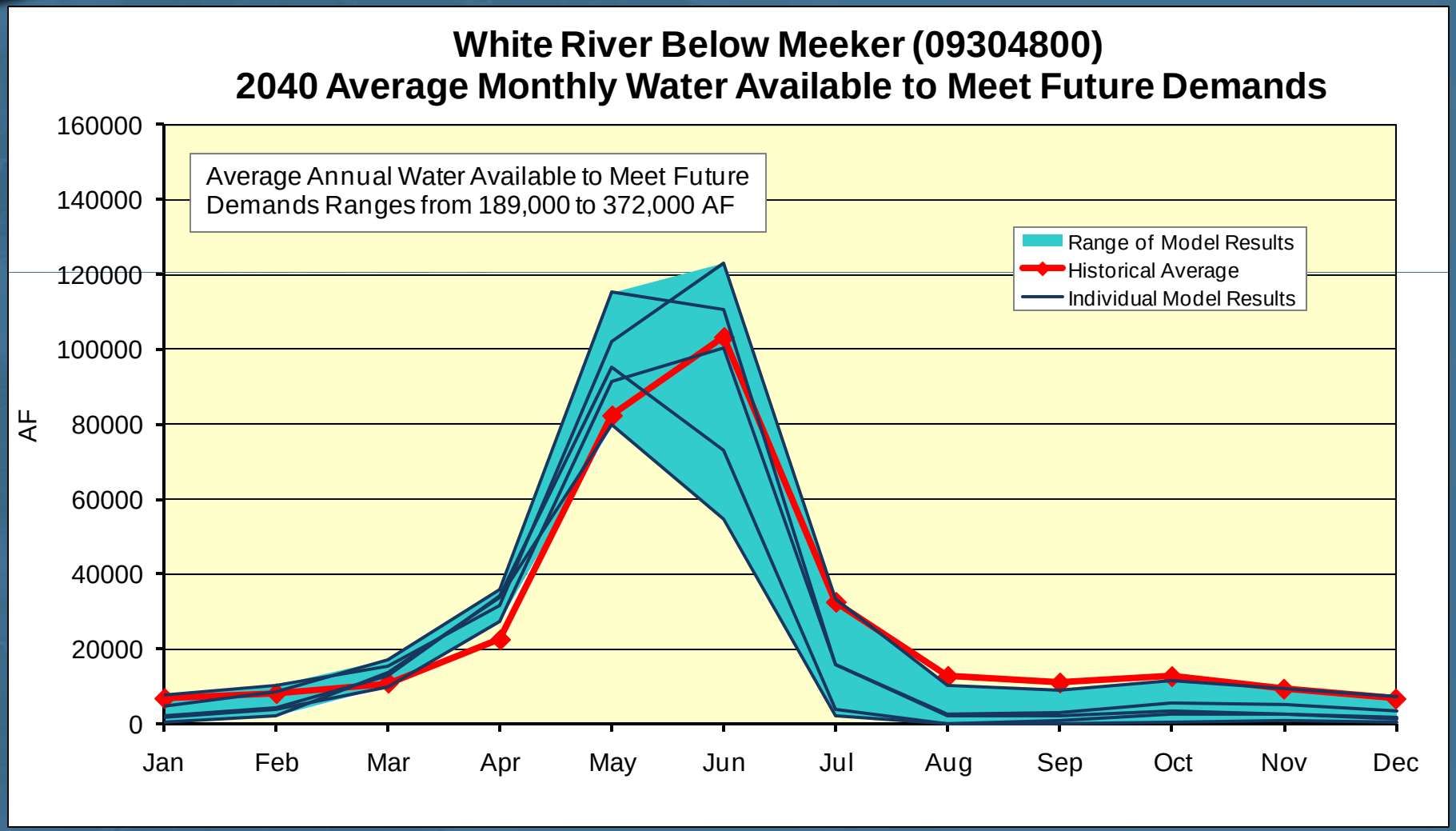
Modeled Reservoir Storage



Modeled Reservoir Storage



Water Availability



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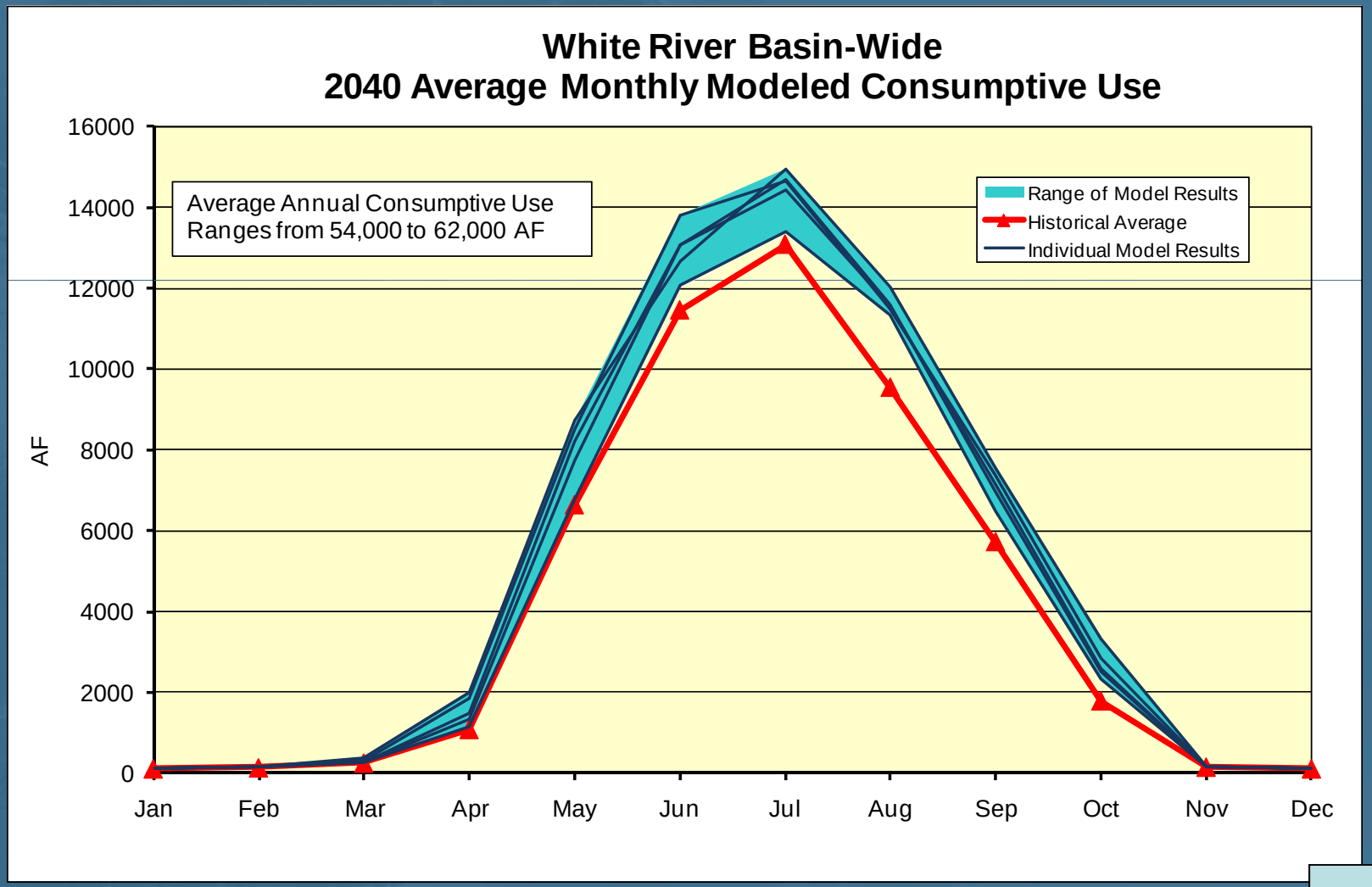
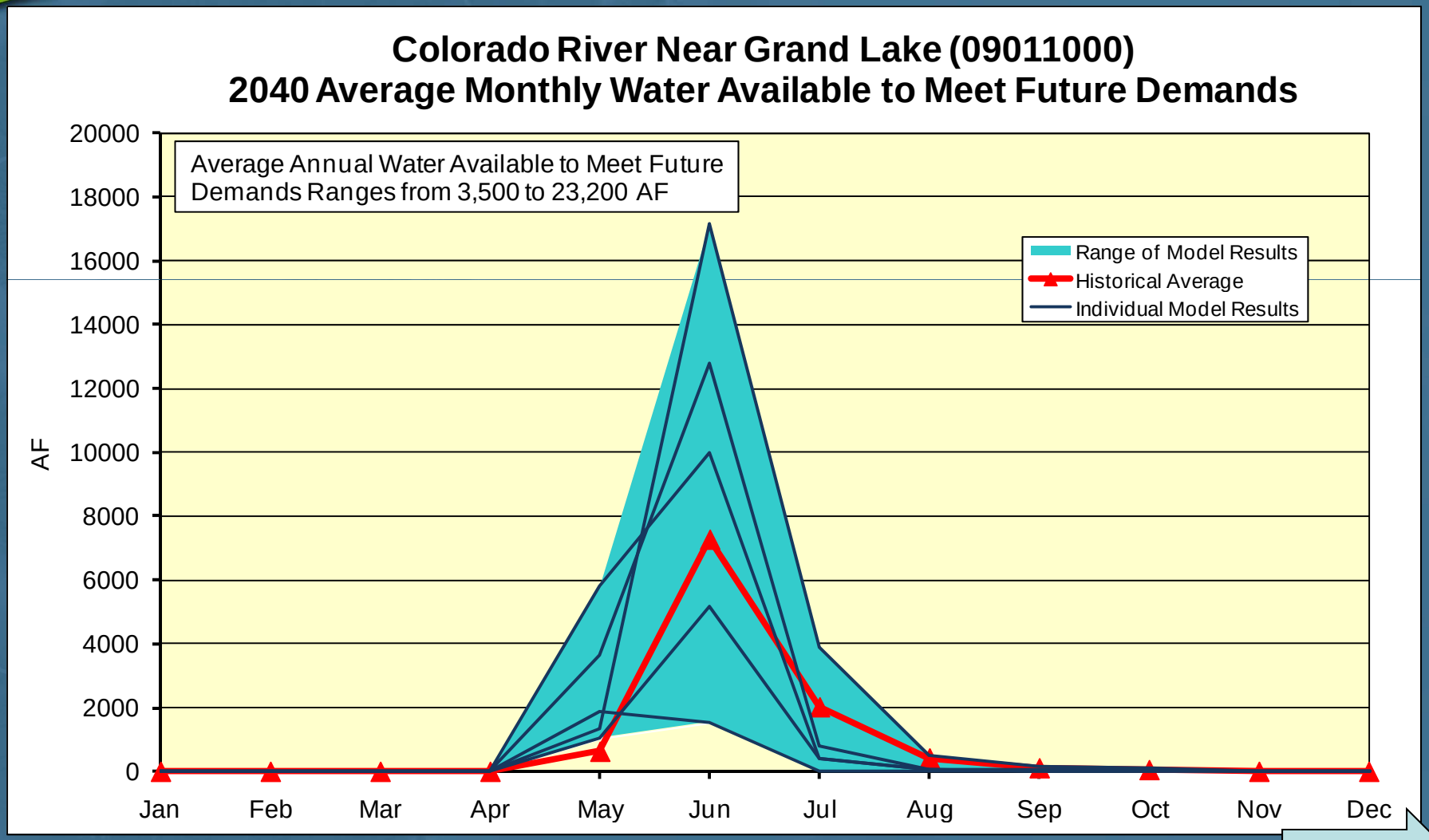


Water Availability



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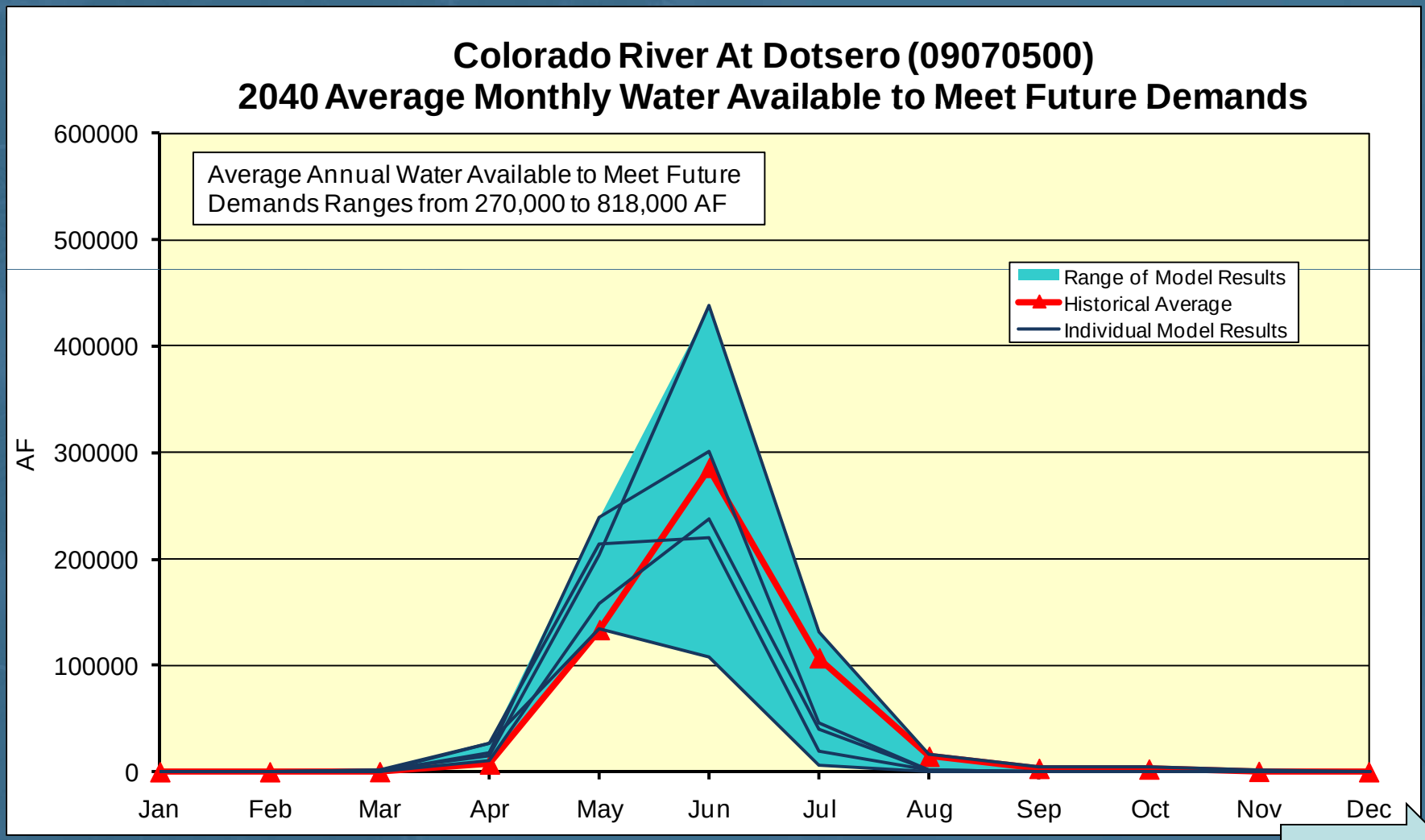

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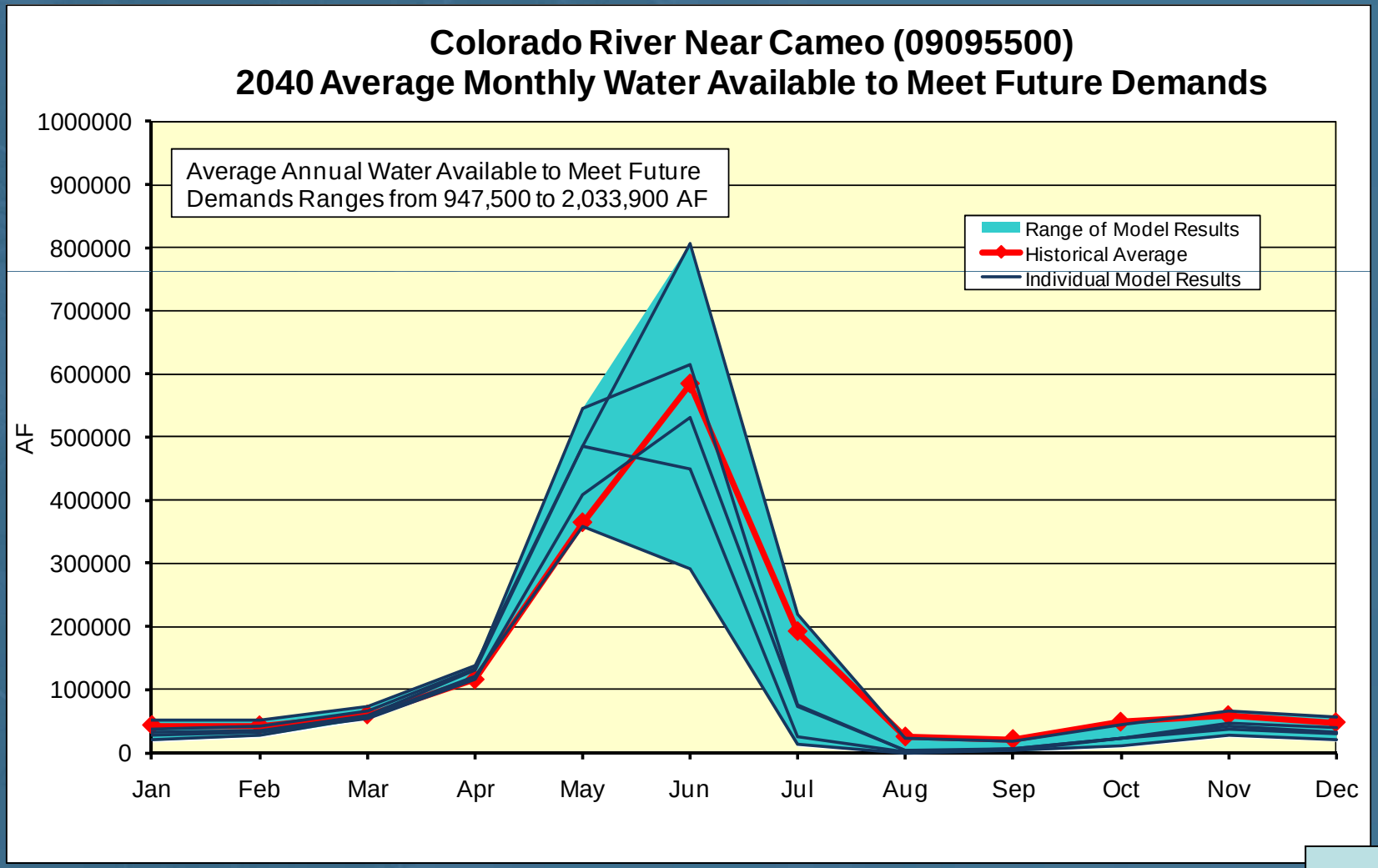

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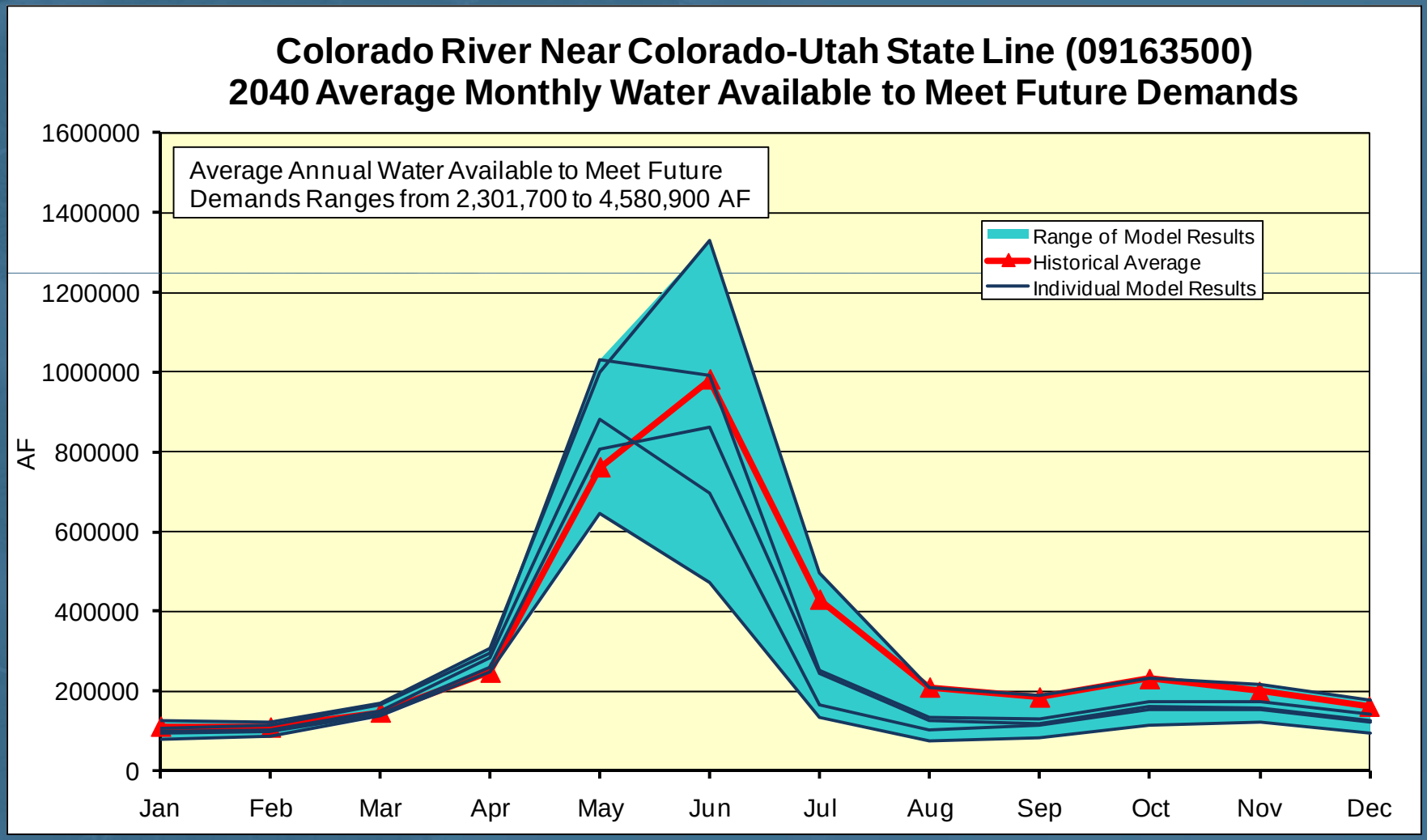

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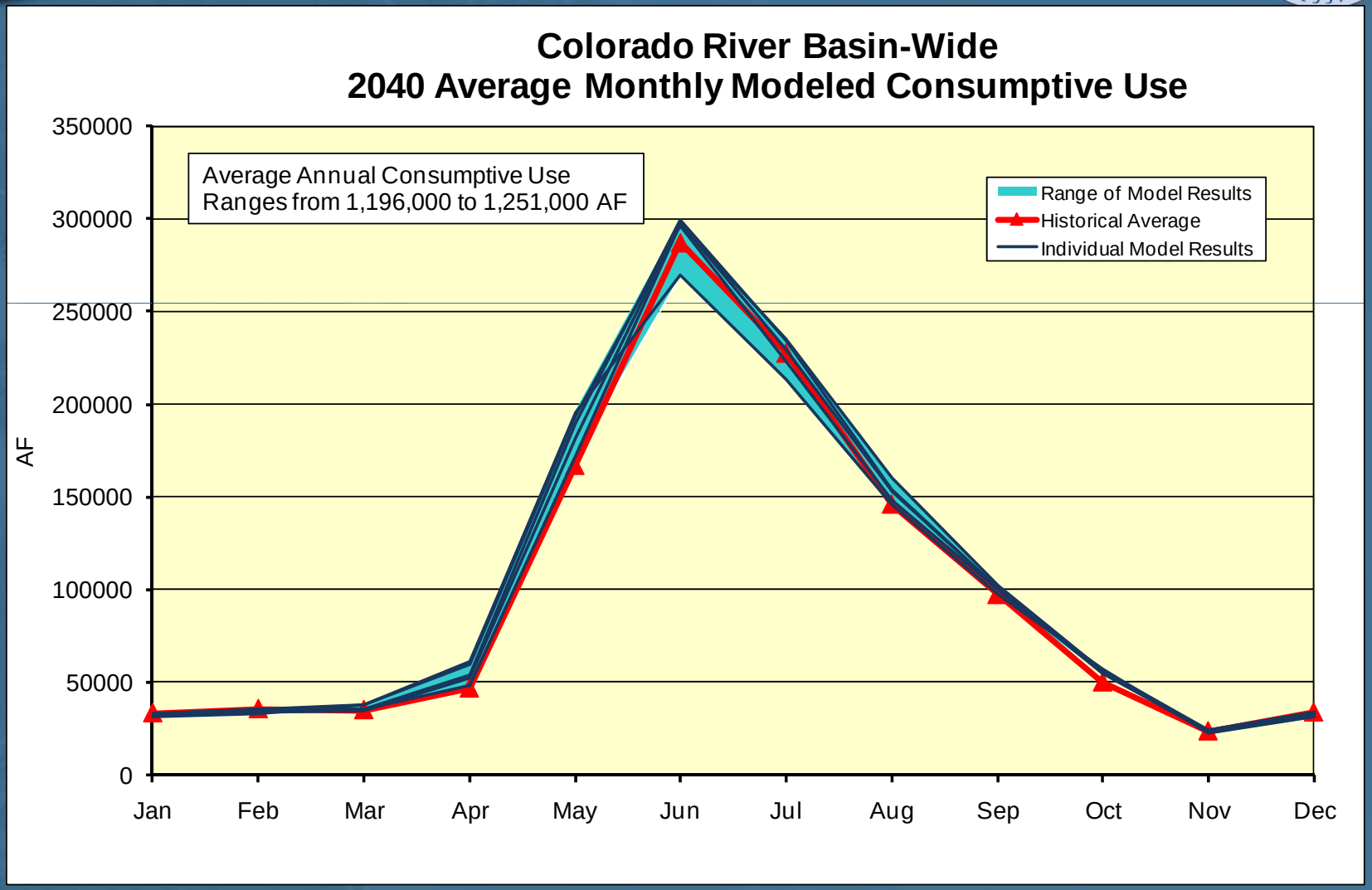
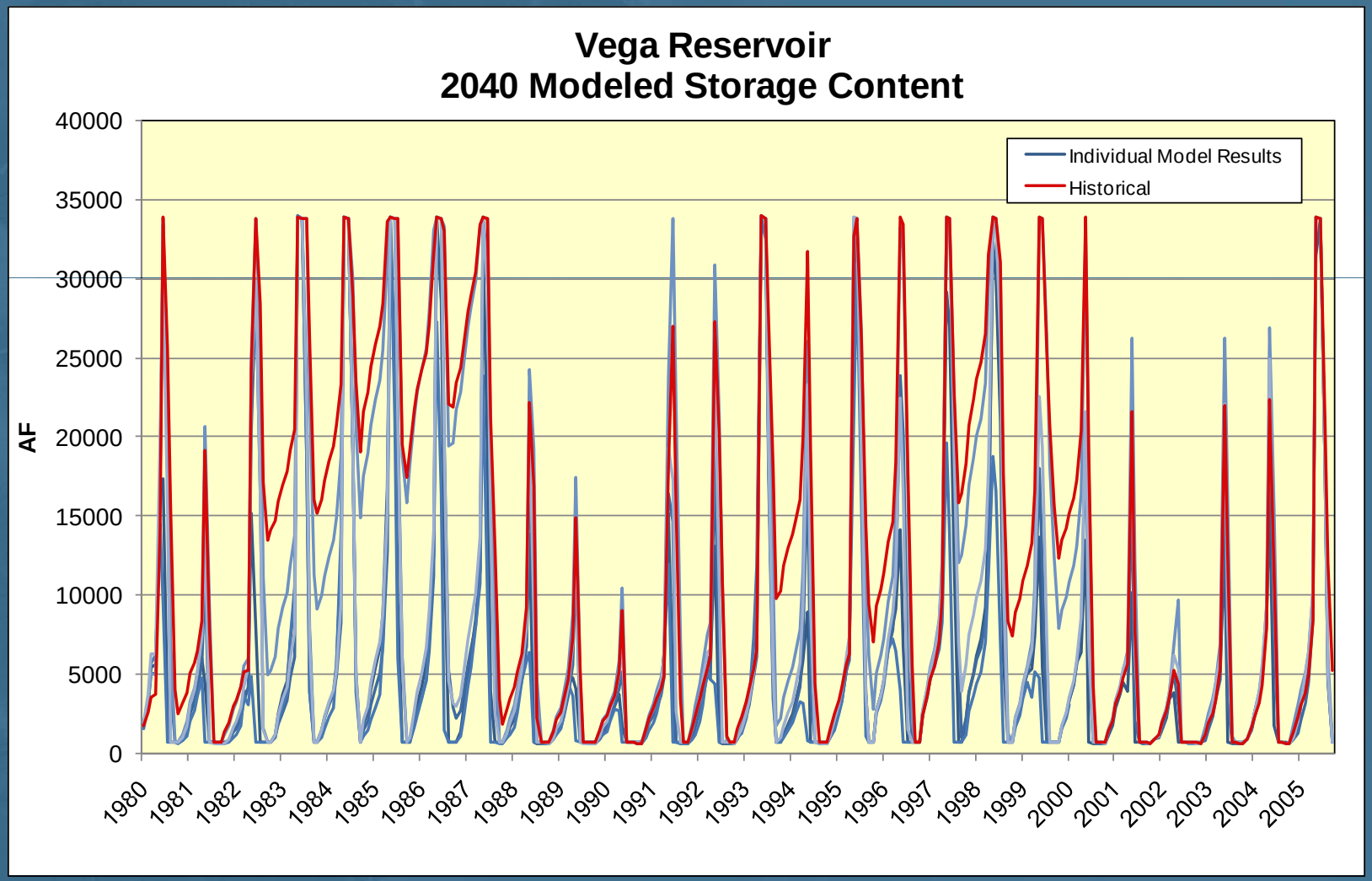
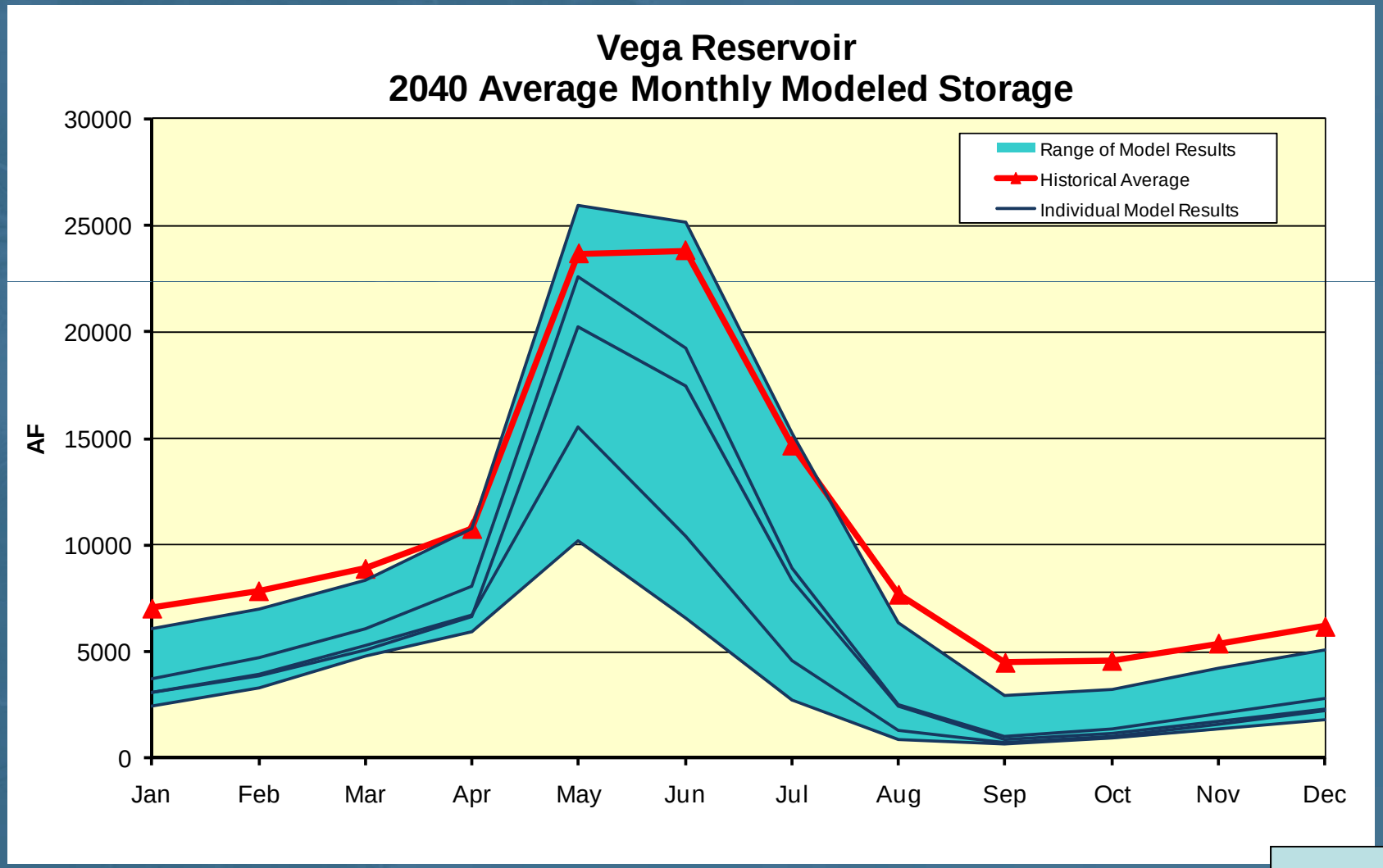


Modeled Reservoir Storage



Modeled Reservoir Storage



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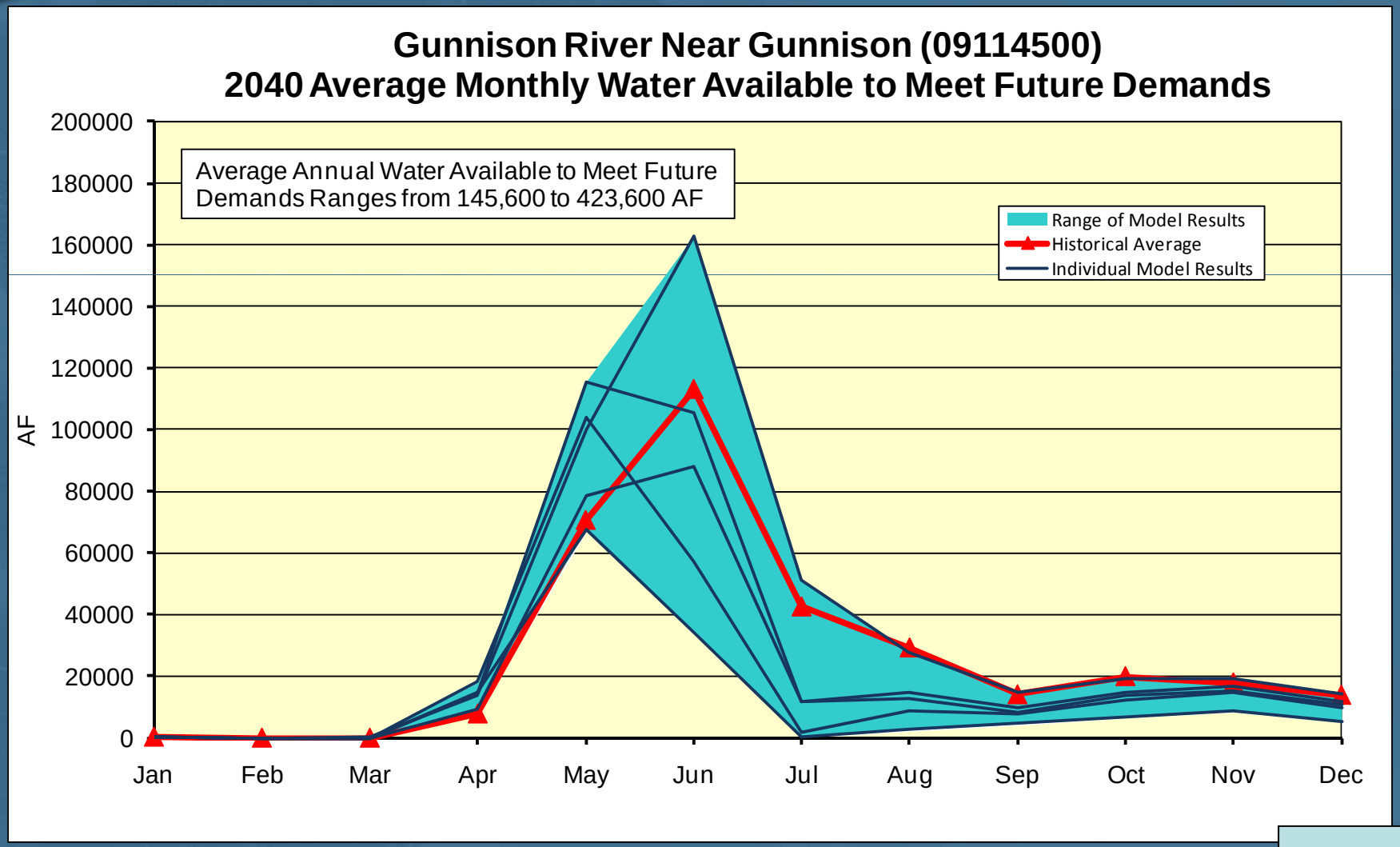
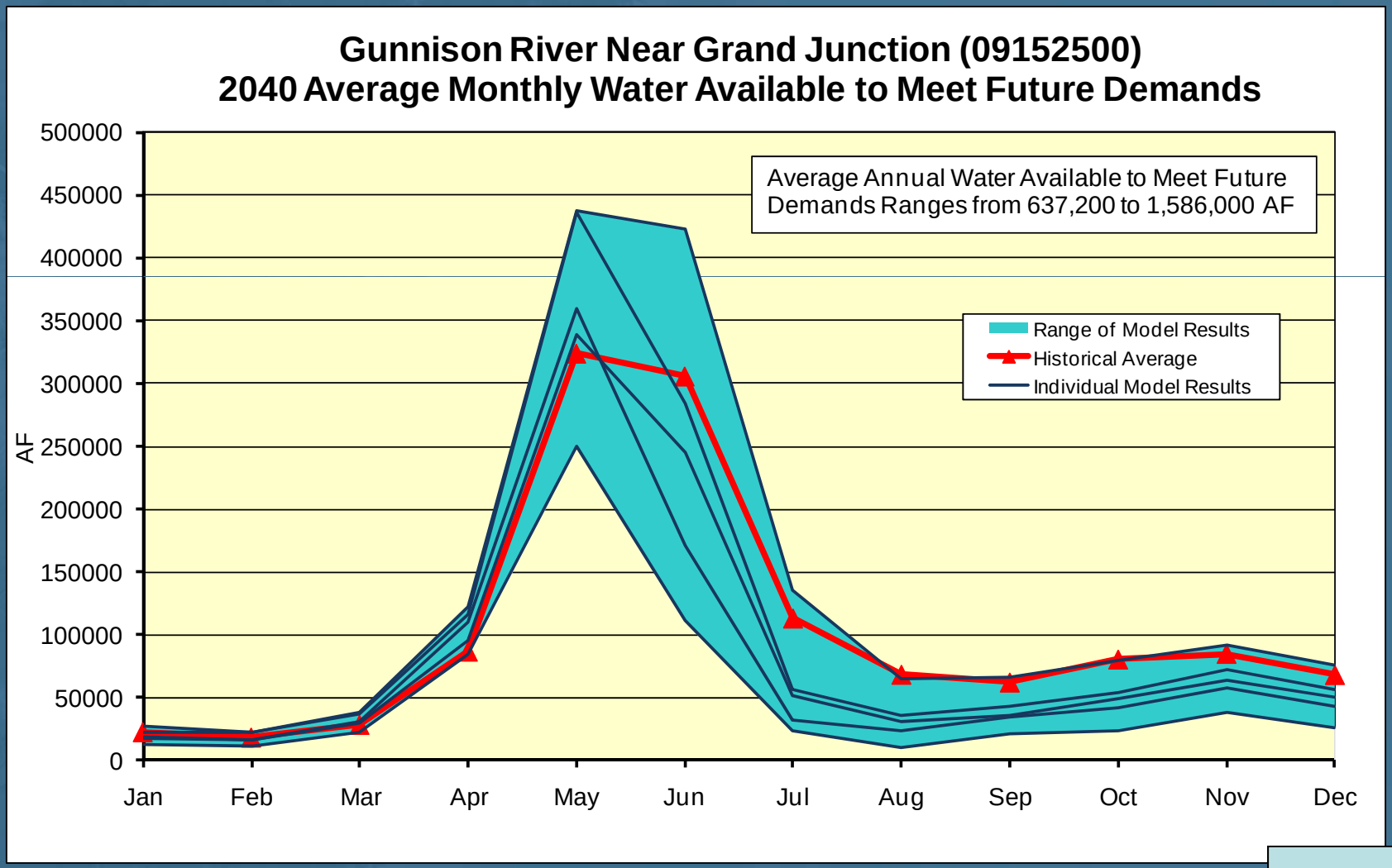
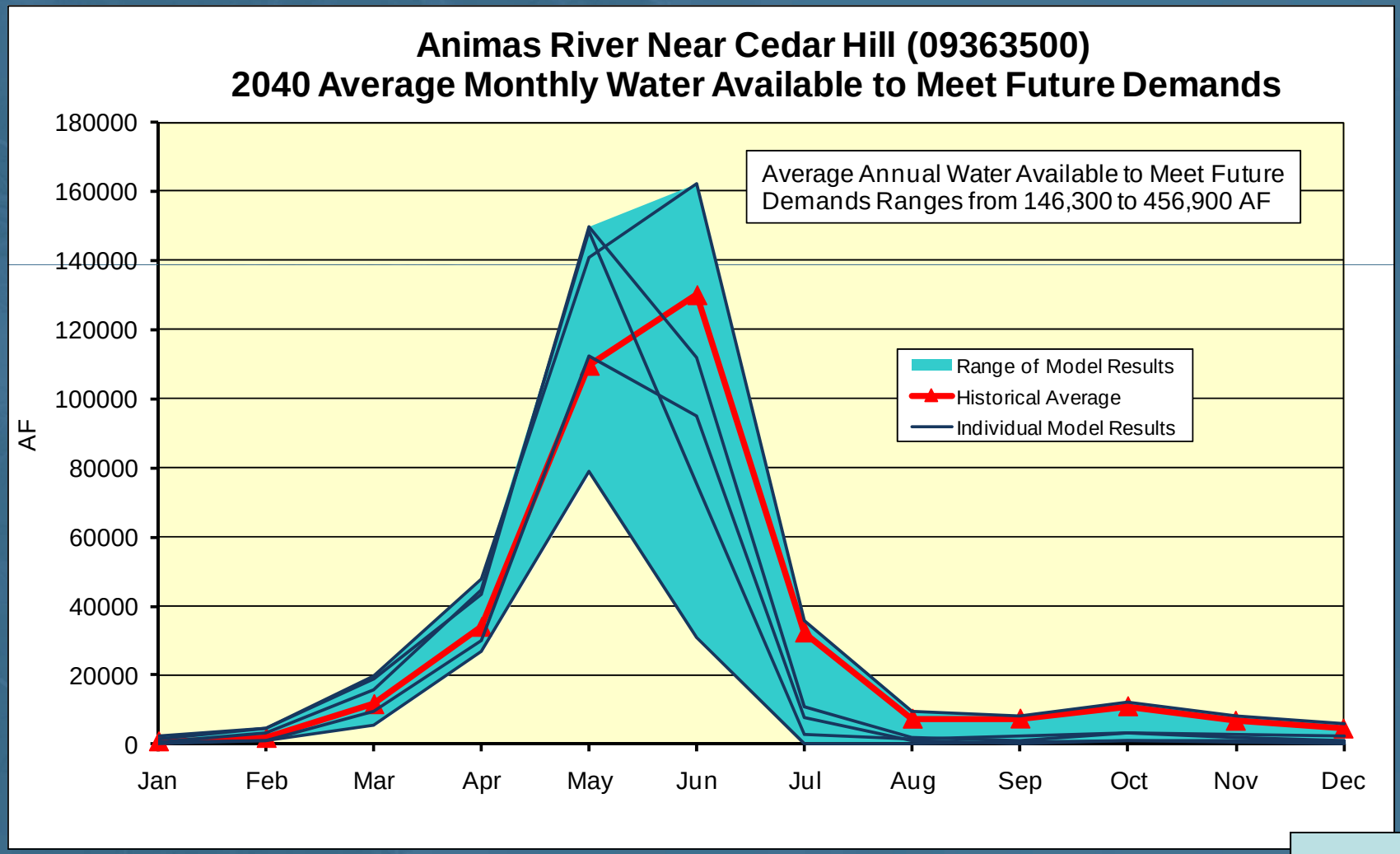


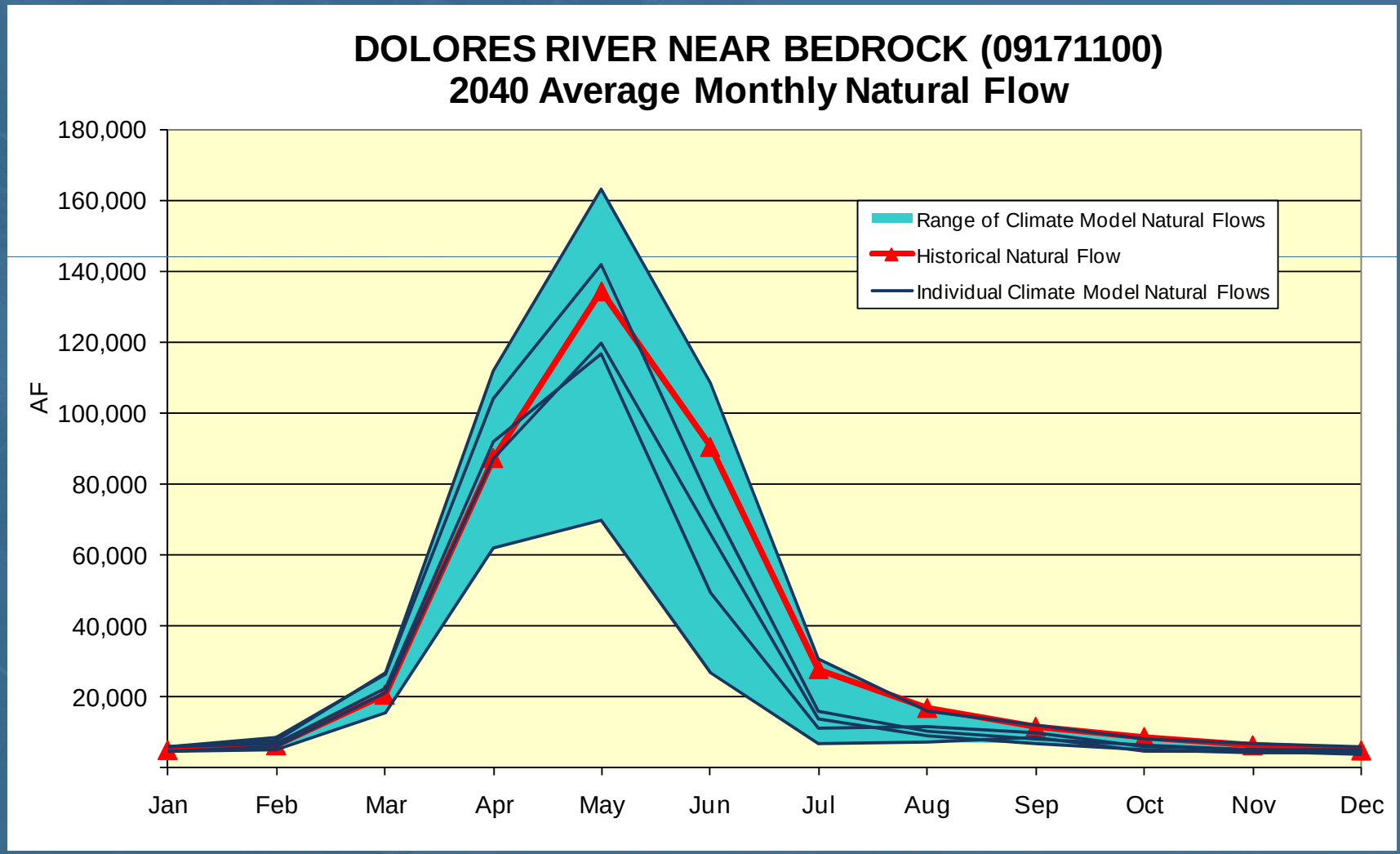
Water Availability



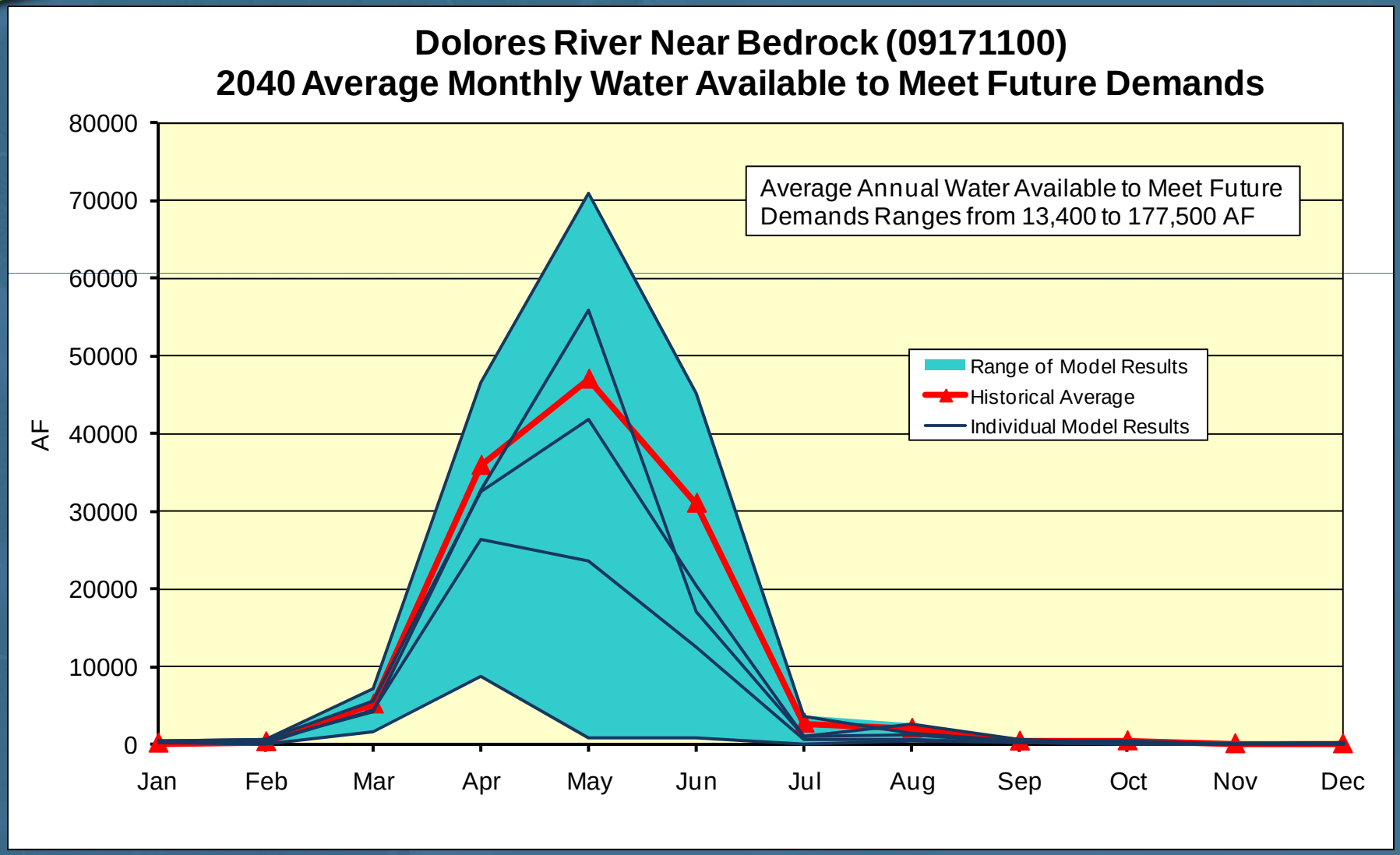
Water Availability



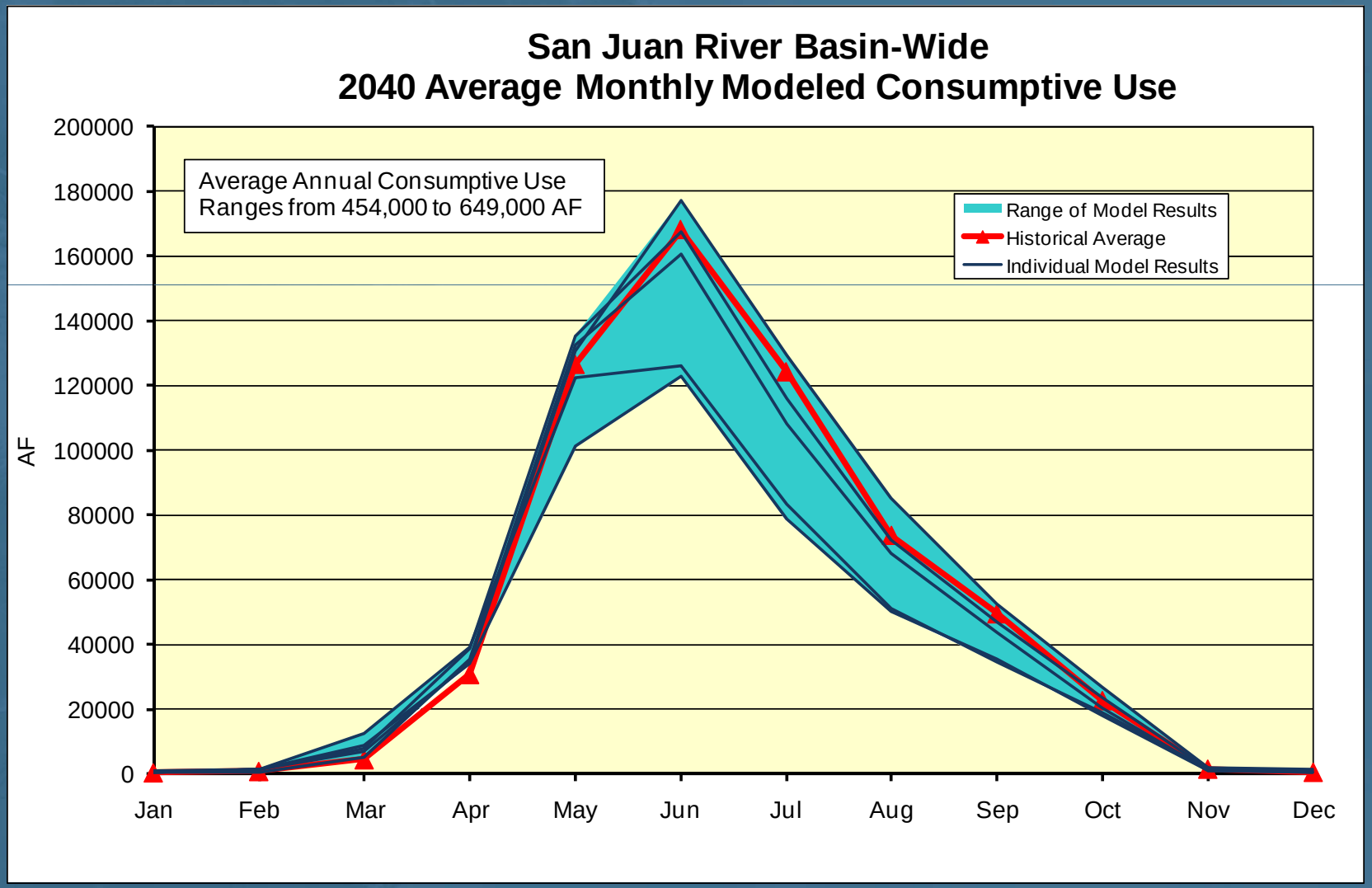
Natural Flow



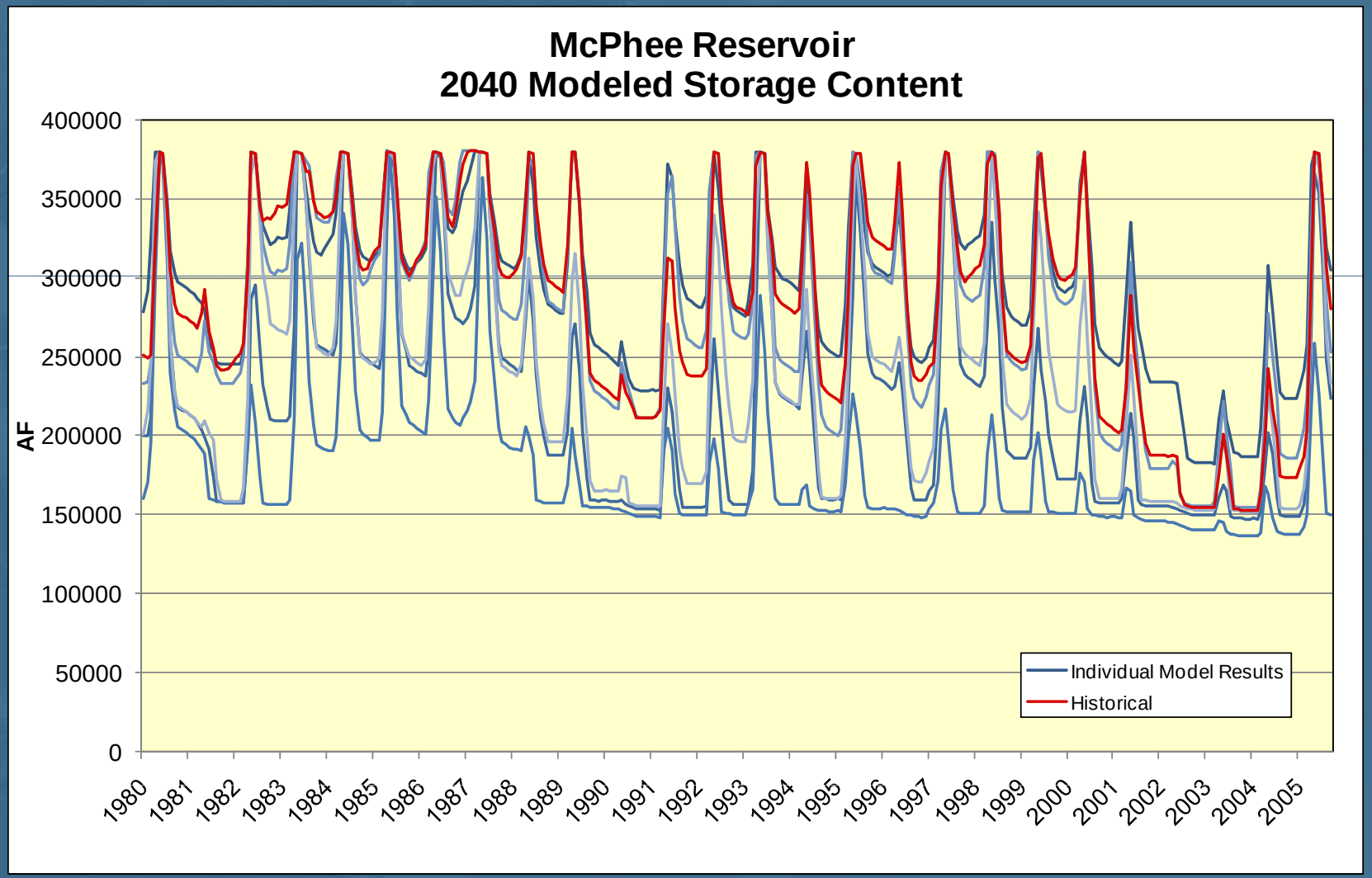
Water Availability



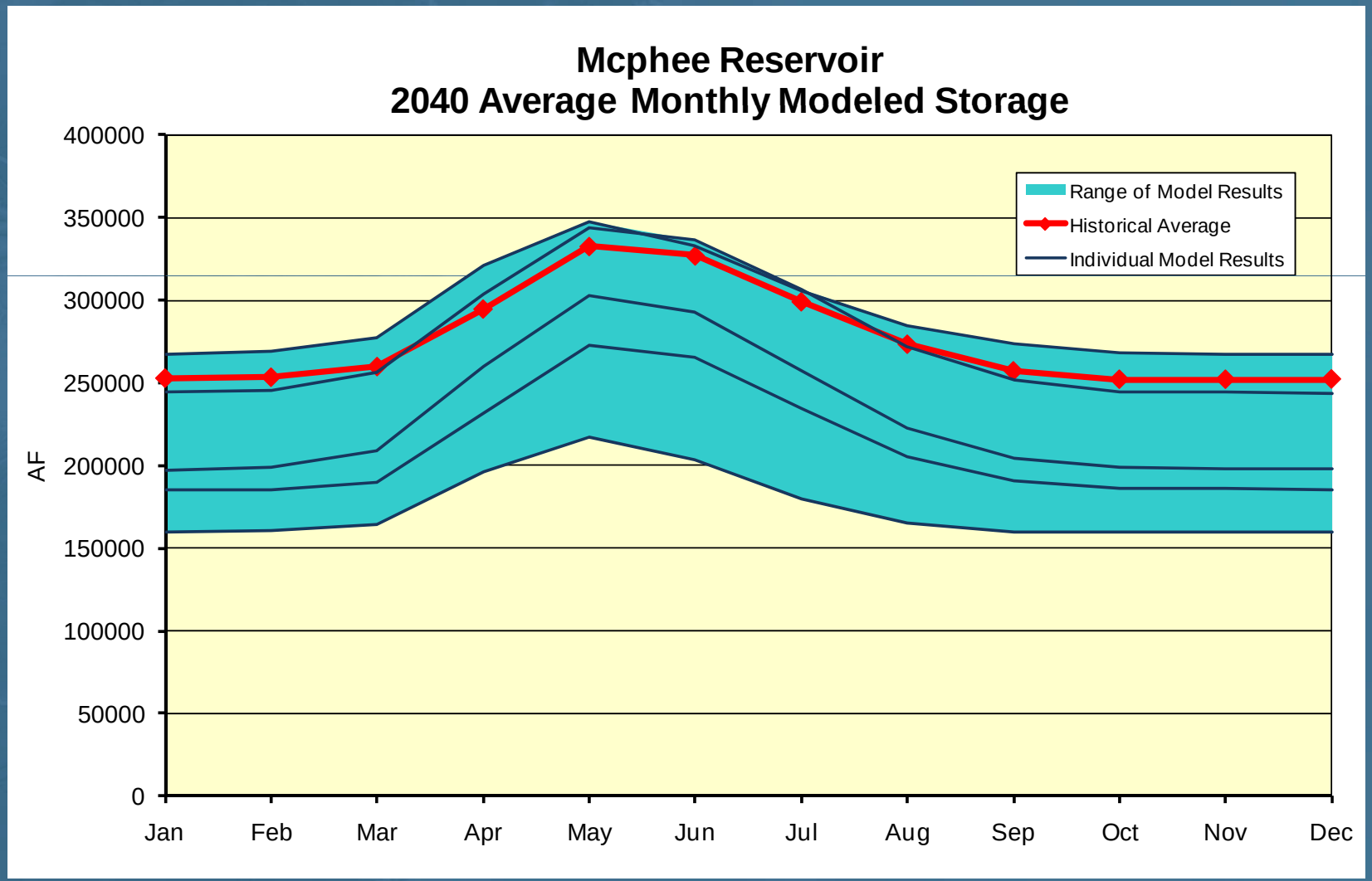
Modeled Consumptive Use



Modeled Reservoir Storage



Modeled Reservoir Storage



4. How much water for future use would Colorado be entitled to under the Compacts considering existing uses

Approach

- Simulated full-development water use requests in upper basin
- Calculated 10-year cumulative flow at Lee Ferry.
- Calculated upper basin consumptive use that will maintain Colorado River Compact compliance.

Compact Analysis: Simulation Approaches

- CRSS
  - Bureau of Reclamation model used for Federal planning and recent negotiations.
- Hydrologic Determination
  - Implementation of mass balance analysis used in 2007 Hydrologic Determination

Compact Analysis: Uncertainties

- Both approaches have limitations
  - Spatial and temporal scale
  - Don't represent in-state storage
- The bottom line:
  - CRSS may understate physical water use and legal water availability.
  - Mass balance analysis may overstate physical water use but not legal availability
- Estimates of water use by CDSS models are more reliable

Compact Analysis: Selected Approach

- Mass Balance Analysis
  - Based on 2007 Hydrologic Determination
  - Added simulation of 10-year cumulative flow provision of Colorado River Compact
- Initial Conditions
  - Reservoir contents, 10-year cumulative flow
  - Starting conditions set equal to ending conditions
  - No water added or taken away by this assumption

Compact Analysis: Selected Approach

- Reservoirs
  - Simulated major federal reservoirs
  - Capacity as of 2060 per Hydrologic Determination
  - Allowed use of CRSP minimum power pools
- Evaporation per Hydrologic Determination
  - Includes Powell, Flaming Gorge and Aspinall
  - Other evaporation chargeable to states

Compact Analysis: Assumptions

- Lee Ferry 10-year Cumulative Flow
  - 75 MAF
  - 82.5 MAF
- Inflow Assumption
  - Mass balance analysis is conducted at Lee Ferry
  - Hydrologic Determination used total inflow above Lees Ferry (does not include Paria River inflow).
  - CRWAS used total inflow above Lee Ferry (includes Paria River inflow).

Compact Analysis: Assumptions

- Depletions
  - Adopted Upper Basin water use requests used in 2007 Hydrologic Determination:

Lee Ferry Flow Obligation	Upper Basin Water Use
75 MAF	6.76 MAF
82.5 MAF	5.98 MAF

  - Assumed that all Upper Basin states are physically using their full apportionments.

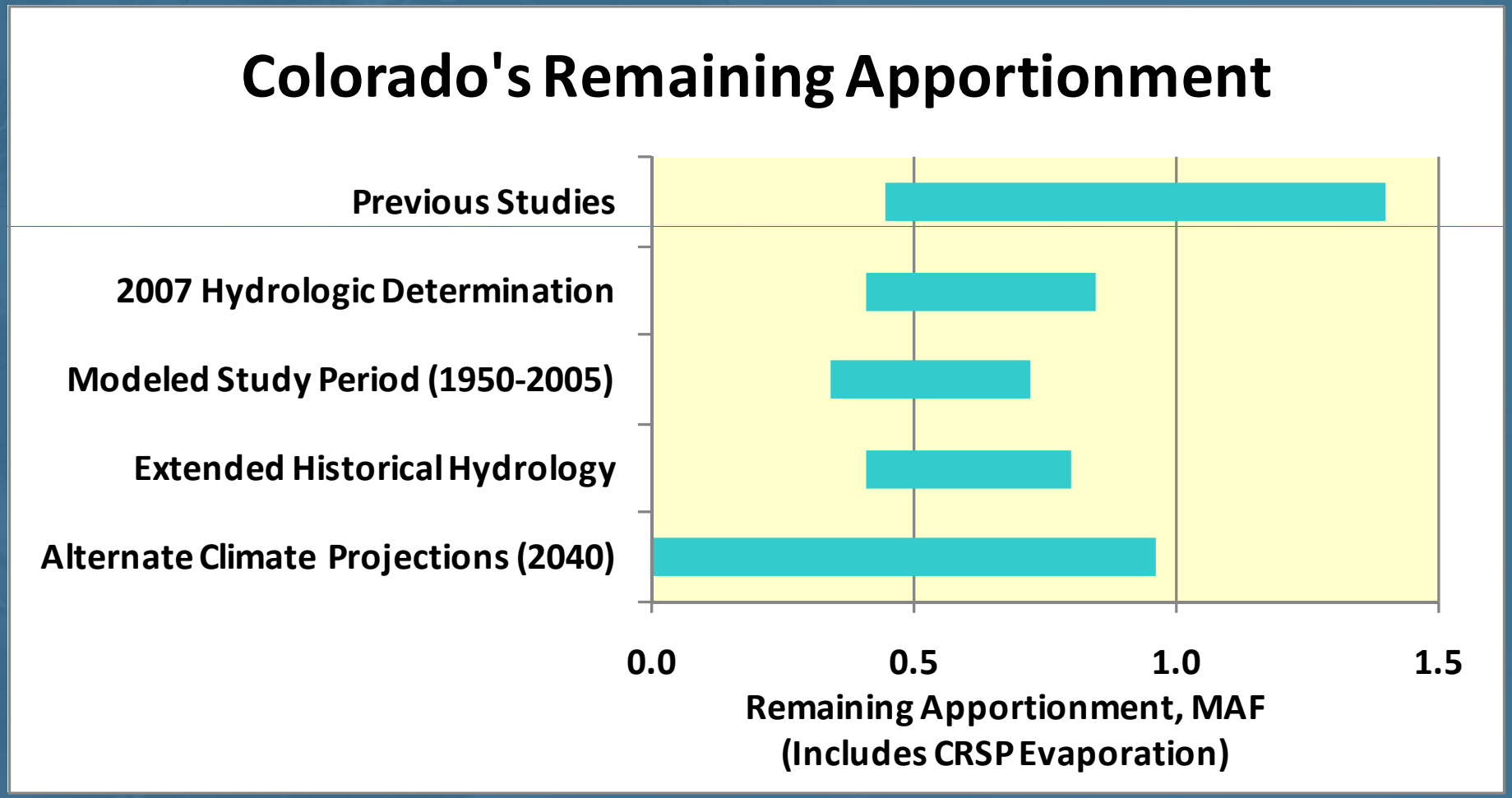
Compact Analysis: Hydrology Cases

- 1906 – 2000 (Hydrologic Determination)
- 1950 – 2005 Study Period
- Extended Historical Hydrology
  - 100 traces of re-sequenced study-period flows
  - Demonstrates more extreme wet and dry traces
- Climate Impacted Hydrology
  - Focus on 2040 time frame
  - Five projections for the time frame
  - 100 traces of re-sequenced flows for each projection

Compact Analysis: Current Consumptive Use

- Estimated by StateMod
  - 1950-2005 natural flows
  - 1950-2005 weather
  - Current irrigated acreage
  - Current M&I demands
  - Simulates diversions, crop CU, evaporation
  - Excludes evaporation from Aspinall Unit and Navajo evaporation chargeable to New Mexico
  - Excludes exports to New Mexico
- Estimated CU = 2.69 MAF

Compact Analysis: Results



Agenda

- What we were tasked to do
- Results
- Where we go from here

Completion of Phase I & Scoping for Phase II

- Prepare *Internal Draft* Phase I Report
- Issue Public *Draft* Phase I Report
- Phase I completion and Phase II scoping
  - Coordination with on-going studies and programs including:
    - Front Range Climate Change Vulnerability Study
    - Basin Needs Decision Support System (IPP)
    - State Drought Mitigation Plan
    - Consumptive & Non-consumptive Needs Assessments
    - Energy Needs Assessment (Phase II)
    - Yampa/White Agricultural Needs Assessment
    - Colorado & Yampa/White Nonconsumptive Quantification Studies
    - Colorado & Yampa/White Energy Needs Assessment (Phase II)
  - CWCB Board, IBCC and/or BRT meetings as needed
- Start Phase II of the CRWAS

Phase II

- Three primary components
  1. Refinements to the Phase I results

     (potential sensitivity analyses for alternative modeling approaches and operational interpretations — still for Phase I's current demands, operating conditions and water rights)

  2. Strategies for CO's Water Supply Future

     (modeling to support the Portfolio / Scenario Building process – a two-step process is envisioned in Phase II so that CWCB, IBCC and BRT's will have feedback loop and opportunity to refine strategies and model simulations)

  3. Support other CWCB activities – studies, programs and initiatives *(see following slides)*

Support other CWCB activities

- CRWAS refines the CDSS data and models

- *Ranges of historical and potential future:*
  1. Streamflows and reservoir levels
  2. Drought and flood magnitudes and durations
  3. Diversions, consumptive use and return flows

Comments and Questions?

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