Colorado River Water Availability Study

Study Overview for

Southwest Basin Roundtable

March 11, 2009

Consulting Team

Boyle - AECOM Water
AMEC Earth & Environmental
Canyon Water Resources
Leonard Rice Engineers
Stratus Consulting

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Agenda

- Introductions
- Study Purpose and BRT Involvement
- Approach
  - Two-Phase Study
  - Three-Step Hydrologic Analysis
- Study Limitations
- Status
- CRDSS Overview
- StateCU Model
- StateMod Model
- Comments, Questions, Model Enhancements?

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Study Team – Management

CWCB Board of Directors

Ray Alvarado
Ross Bethel
Eric Hecox
Veva Deheza
CWCB & DWR Staff

Department of Natural Resources

Attorney General's Office

IBCC - Basin Roundtables

Boyle Management

Blaine Dwyer, P.E.
Project Manager

Matt Brown, P.E.
Assistant P.M.

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Study Team – Technical

Blaine Dwyer	Project Manager
Matt Brown	Assistant Project Manager
Ben Harding	Paleo, Stochastic, and Big River hydrology / operations
Erin Wilson	CDSS applications
Meg Frantz	StateMod refinements / execution
Jim Pearce	Review - Water Management issues
Joel Smith	Guidance - Climate Change approaches

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Study Purpose – State-Wide Sponsorship

Interstate Issues

Information for the entire state to use in relation to current and future water management

Intrastate Issues

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Basin Roundtable Involvement

- BRT Workshops on Model Briefs for each Basin
  - Colorado – February 23
  - Gunnison – March 2
  - White/Yampa – March 4
  - Southwest – March 11
- BRT input on CDSS Model Refinements
- BRT input on other Study products as developed

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Two-Phase Study

- 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

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Study Approach – Three Step Hydrologic Analysis

1) **Historical Hydrology**

- To be used for comparative analysis
- 1950's forward (most reliable data)

2) **Alternate Historical Hydrology** | Extend Records with Tree-Rings & Stochastic Methods

3) Climate Change and Forest Change

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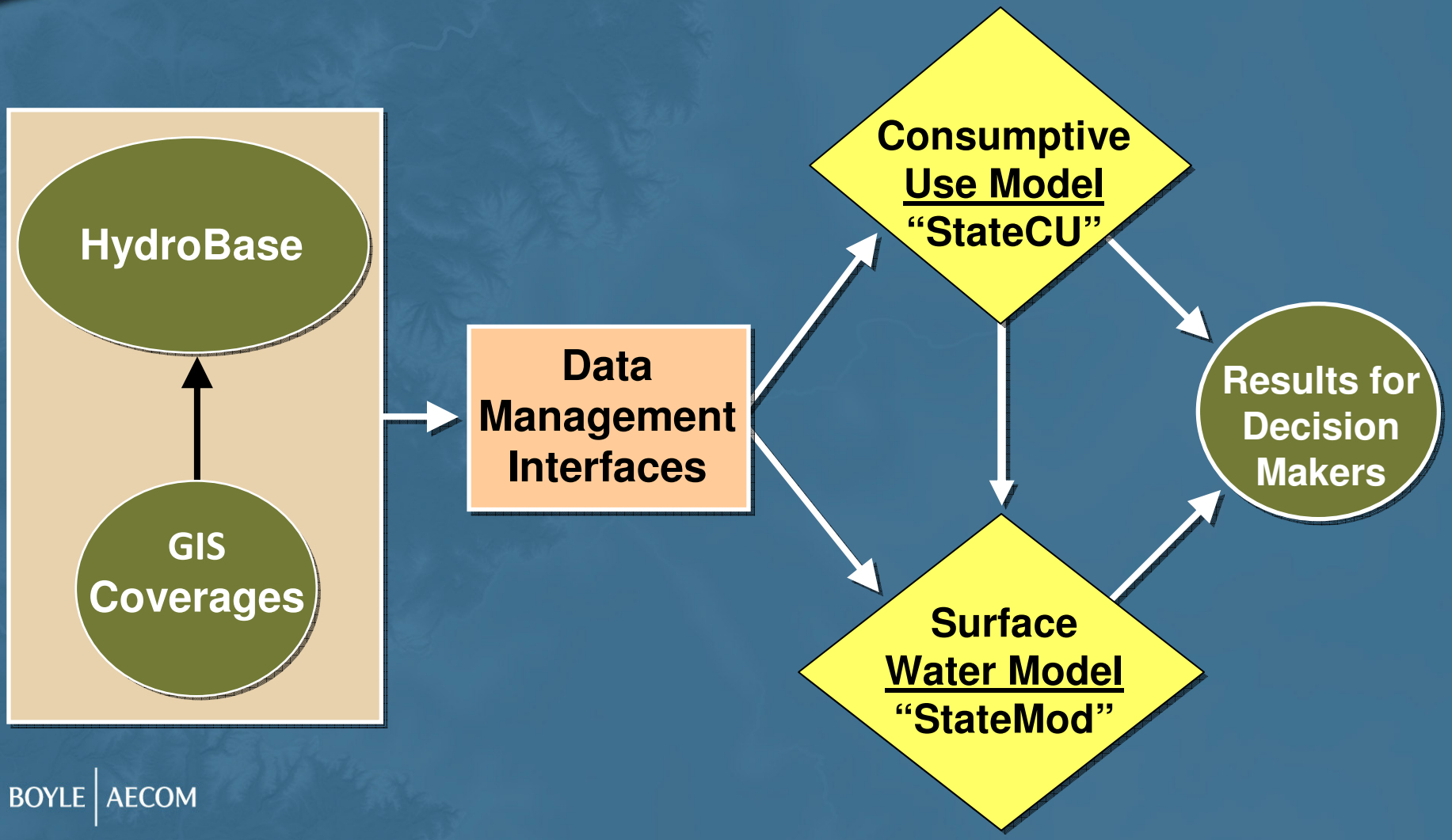
1) Historical Hydrology – Data-Centered CDSS



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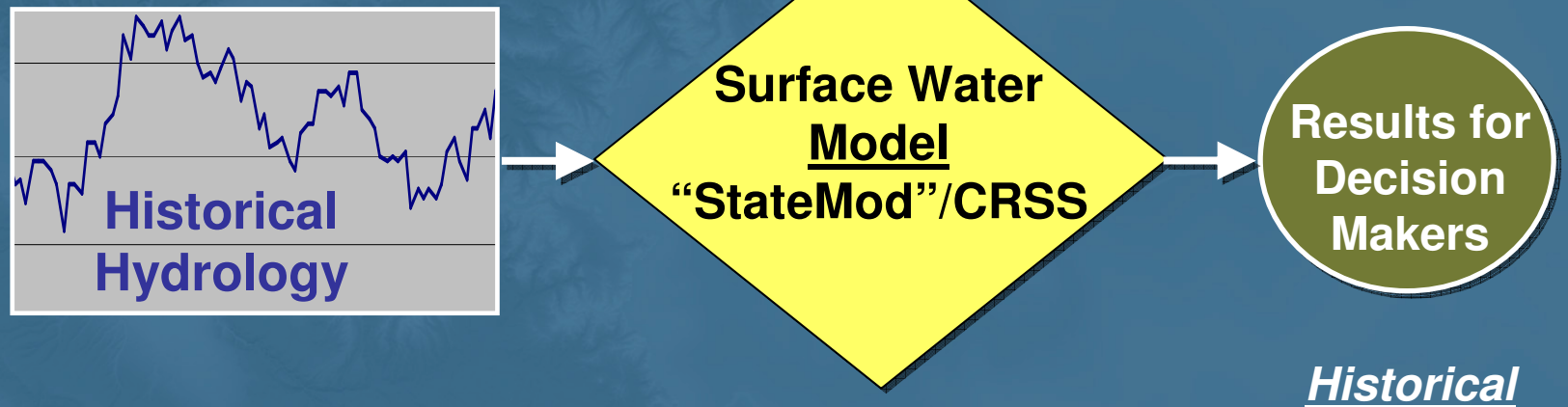
1) Historical Hydrology → Water Availability



Historical

Water Availability

Reservoir Conditions

Instream Flows

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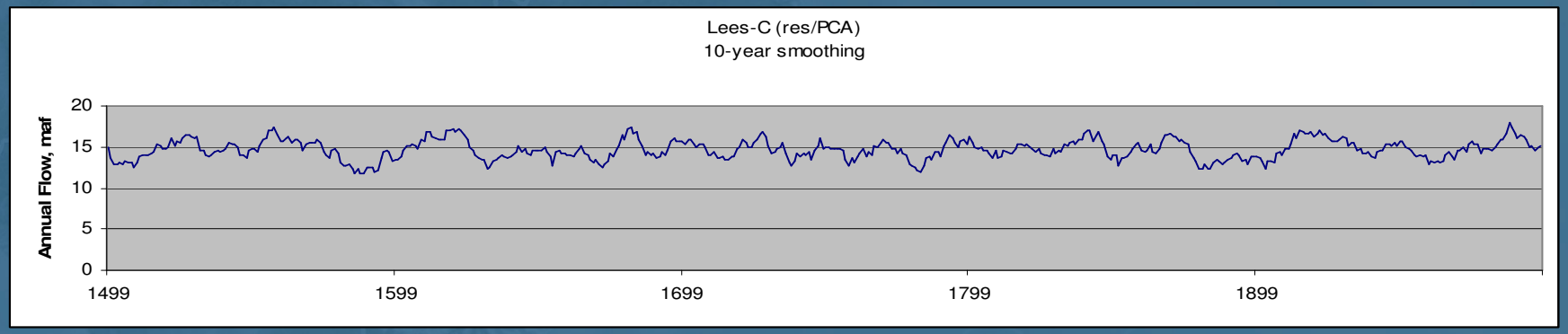
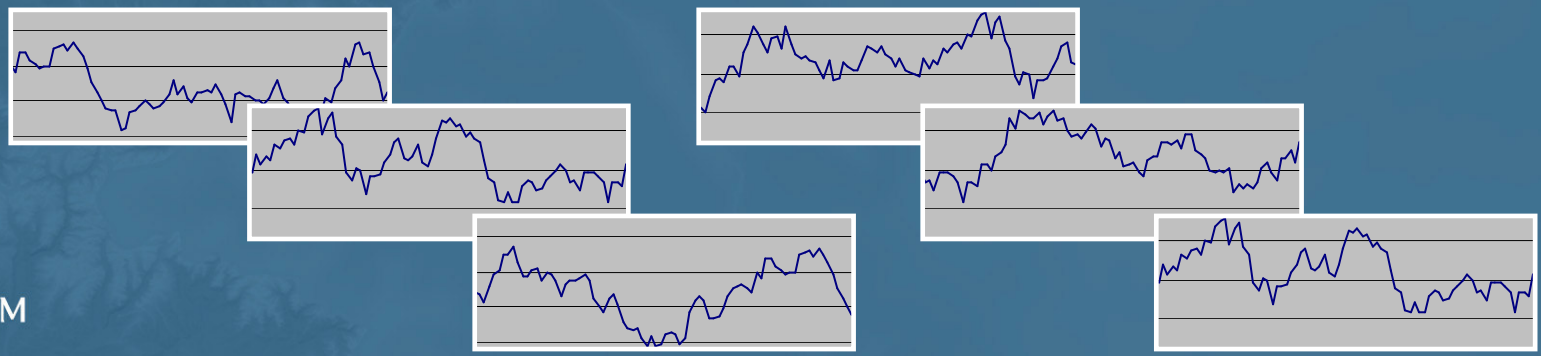
2) Alternate Historical Hydrology (Paleohydrology)

Reconstructed Flows



"Ensemble" of "Traces"



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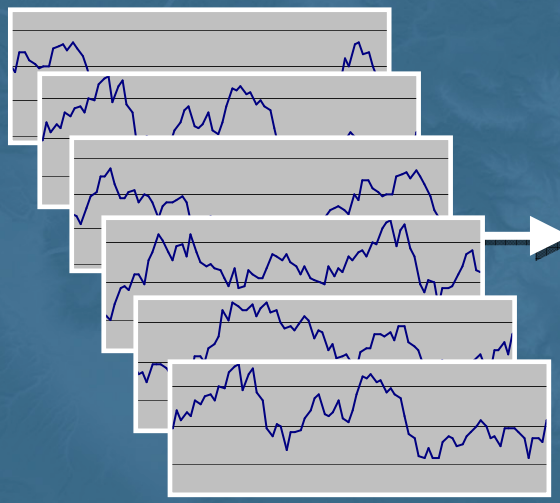
2) Alternate Historical Hydrology ➔ Water Availability

"Ensemble" of "Traces"



Surface Water Model "StateMod"/CRSS

Results for Decision Makers

Alternate Historical

Water Availability

Reservoir Conditions

Instream Flows

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3) Climate Change & Down - Scaling

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*

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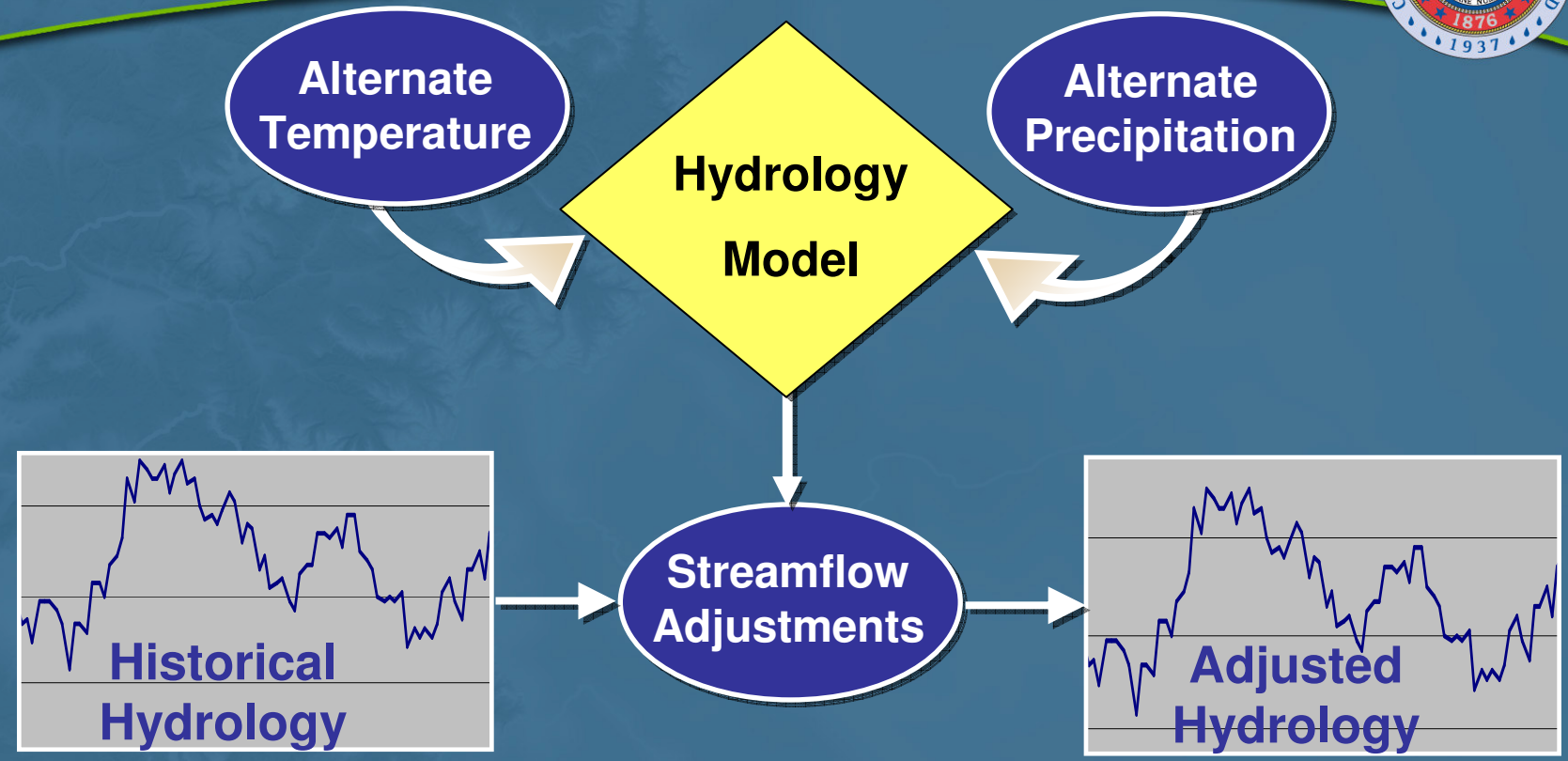
3) Alternate Hydrology of Climate Change



CRDSS Natural Flows
CRSS Natural Flows

CRDSS Adjusted Flows
CRSS Adjusted Flows

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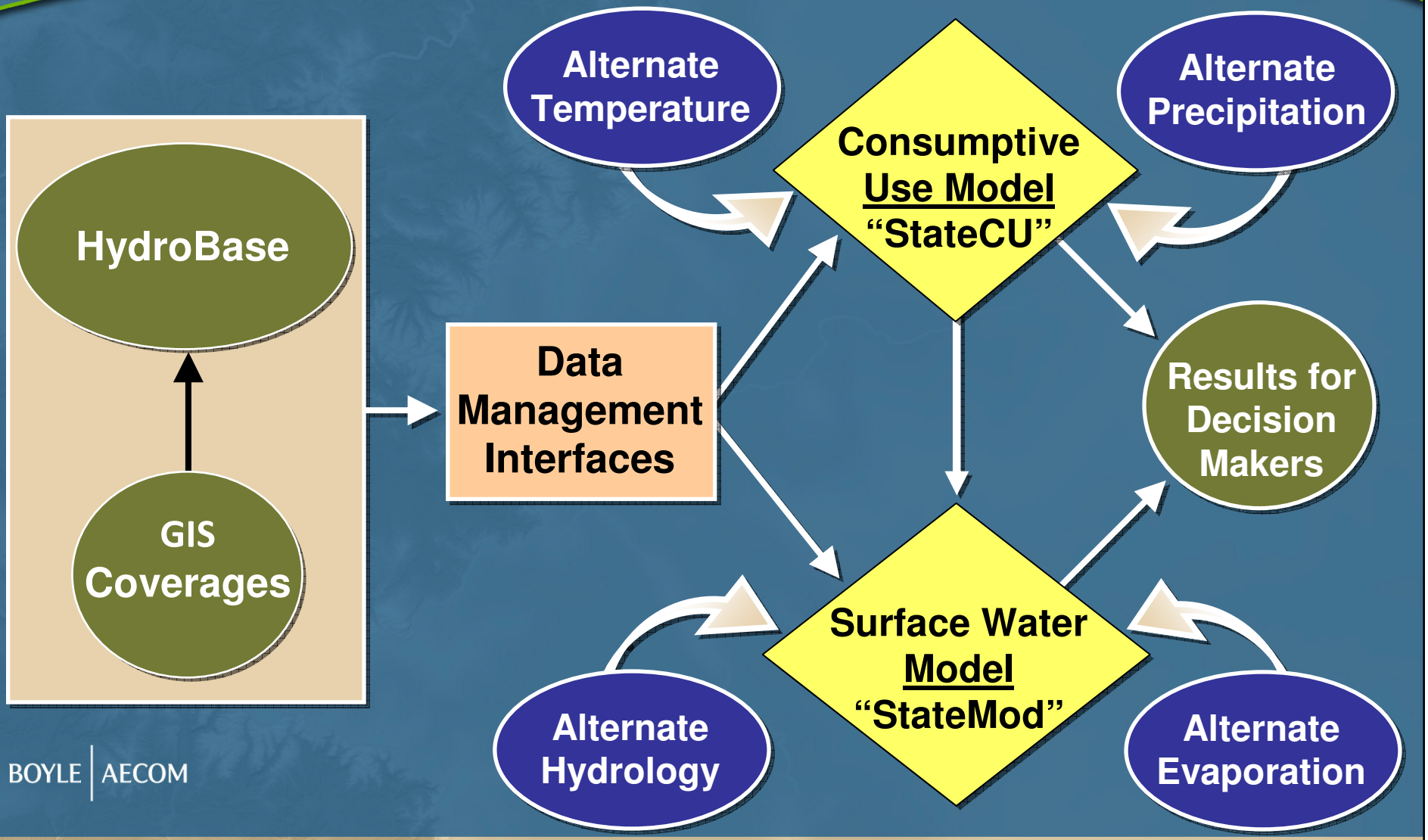
3) Alternate Historical Hydrology



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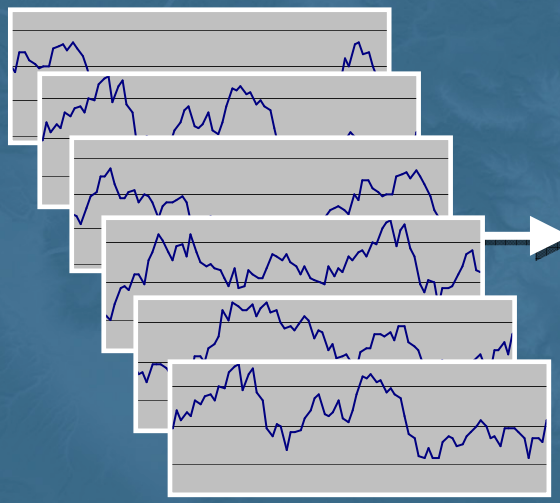
3) Alt. Hydrology / Climate Change → Water Availability

Ensemble of Traces
Adjusted Streamflows



Surface Water Model "StateMod"/CRSS

Results for Decision Makers

Climate Change

Water Availability
Reservoir Conditions
Instream Flows

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Study Limitations – Scope

- No assessment of compact call administration or potential for curtailments

- Phase I only considers current levels of water demands and current infrastructure
  (Phase II considers potential future water demands)

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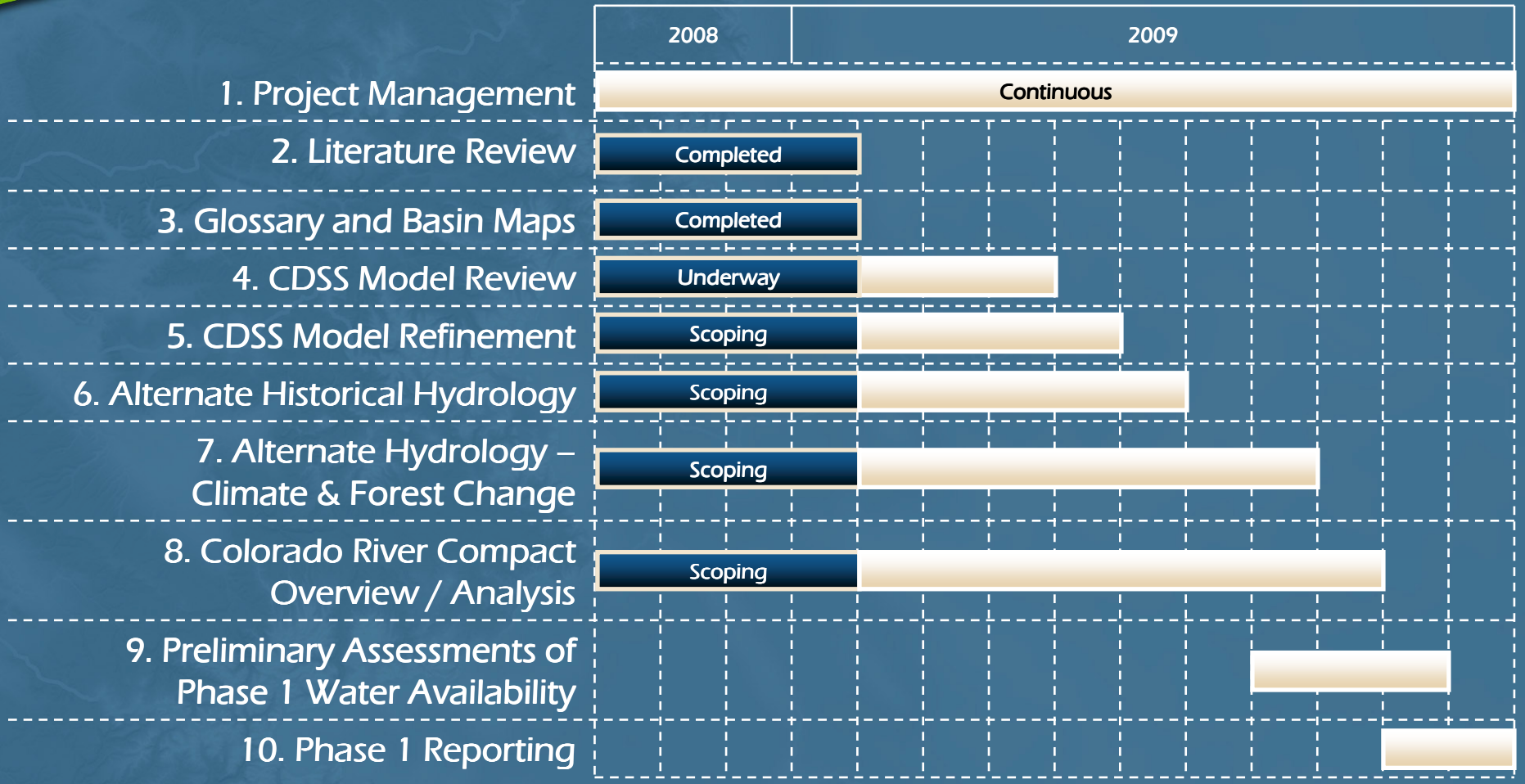
Study Status – Phase I



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CDSS Discussion - Purpose

- Present CDSS Information Specific to San Juan and Dolores Basins
- Increase Comfort with CDSS Models and Procedures
- Provide Context for Review of Model Brief
- Generate Discussion of Potential Model Enhancements

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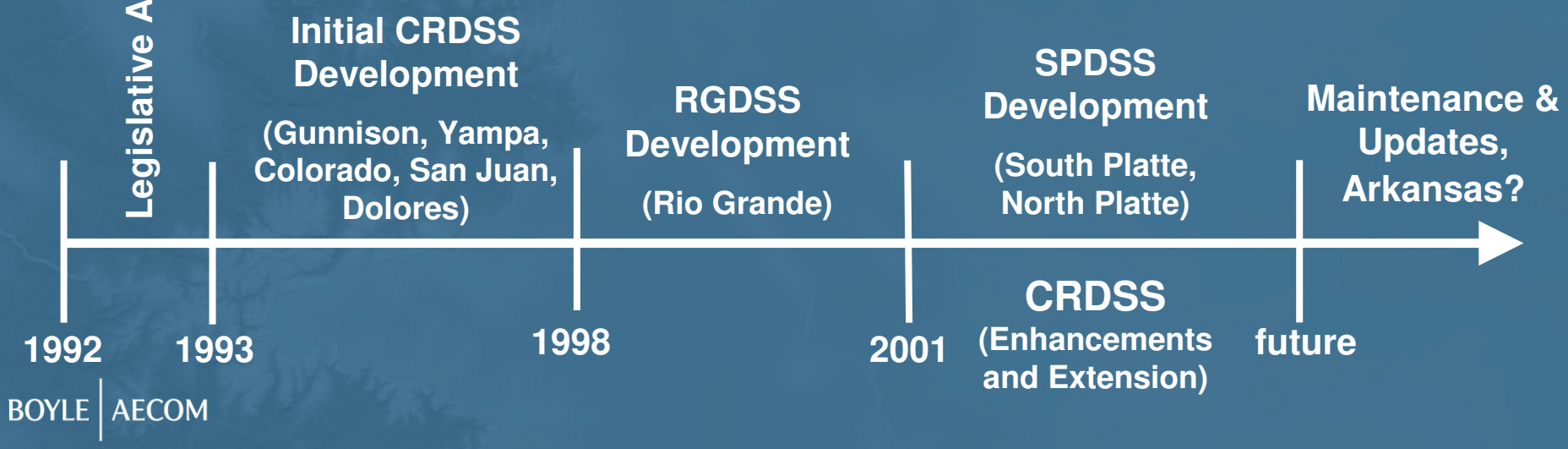
CDSS Overview

- Water Management System
- Developed by CWCB and Division of Water Resources
- Goal is to provide data/tools to assist in making informed decisions regarding historic and future use of water



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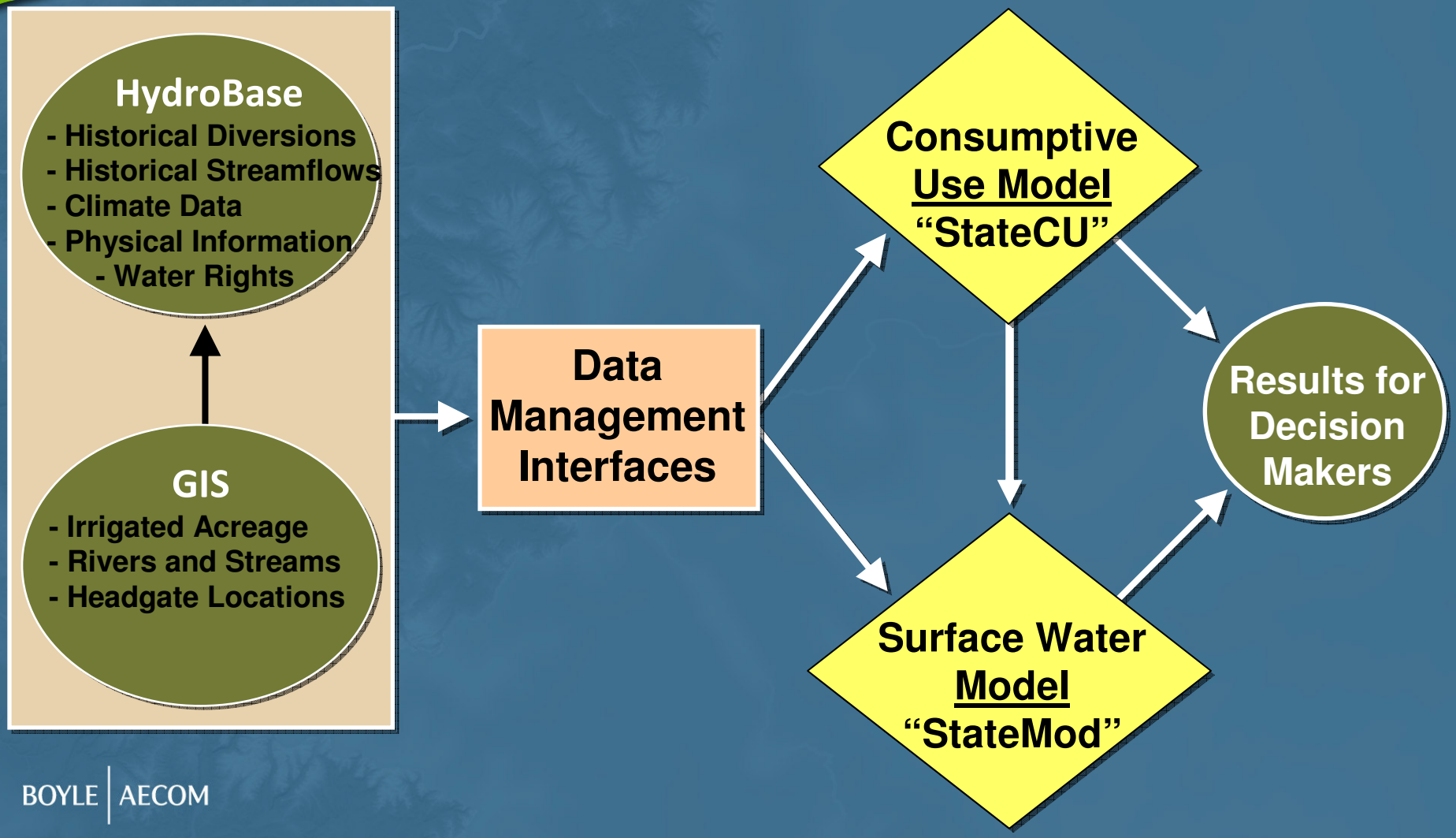
CDSS Overview - Data-Centered Approach



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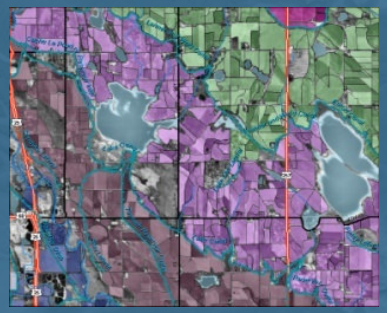
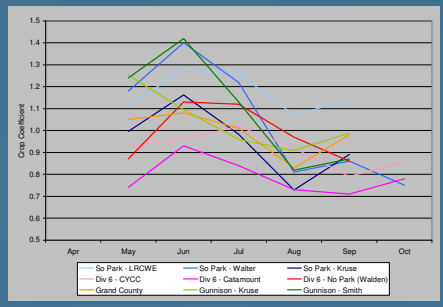
StateCU Overview

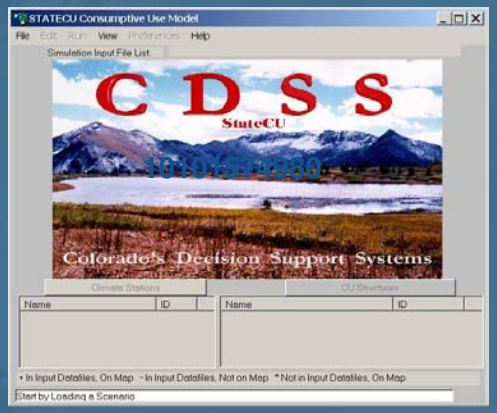
Supplemental Sources User Info

Irrigated Acreage, Crop Type, Irrigation Method

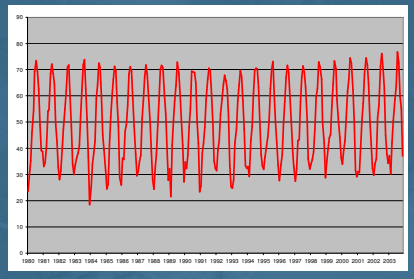




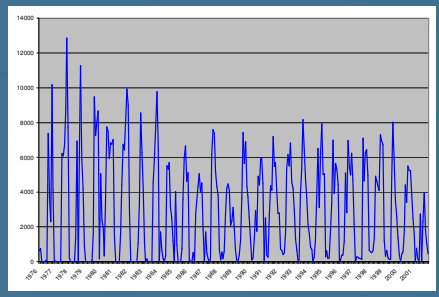
CU Method Review and Selection



Climate Data



Water Supply Data



Irrigation Efficiencies

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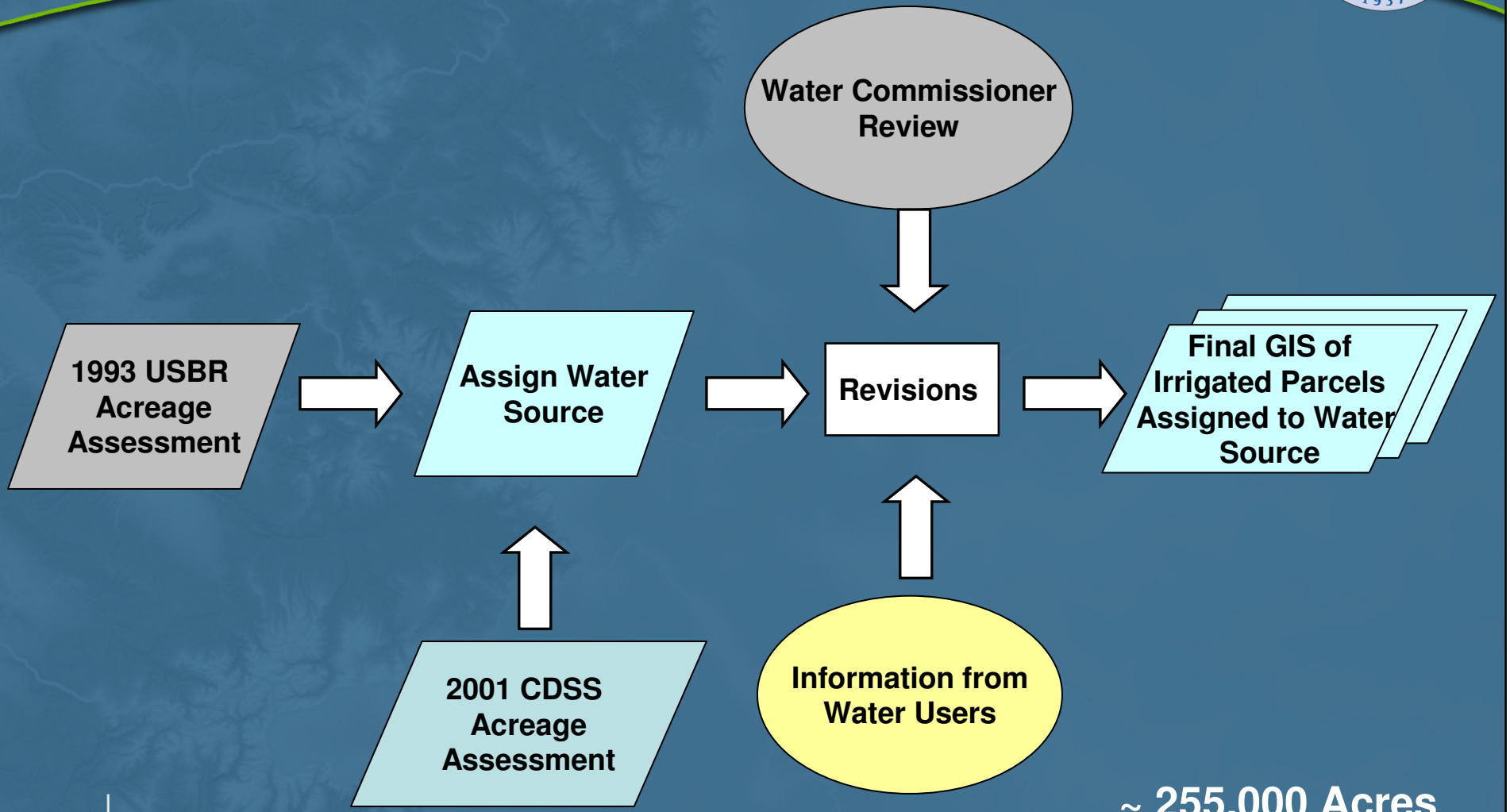
StateCU Overview – Data Collection



~ 255,000 Acres

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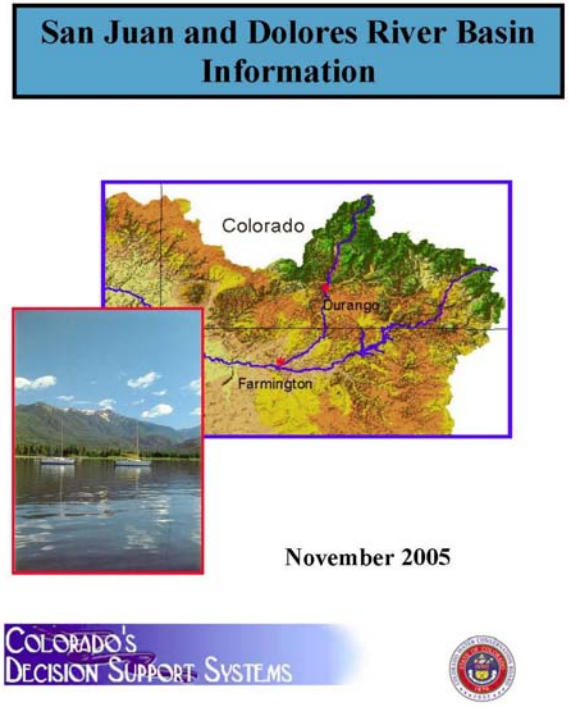
StateCU Overview – Data Collection

- Interviewed water administrators and project operators
- Reviewed and summarized published data on basin water use and project operations
- Identified Irrigation Practices and supplemental sources
- Basin Information Report Available at

  http://cdss.state.co.us/



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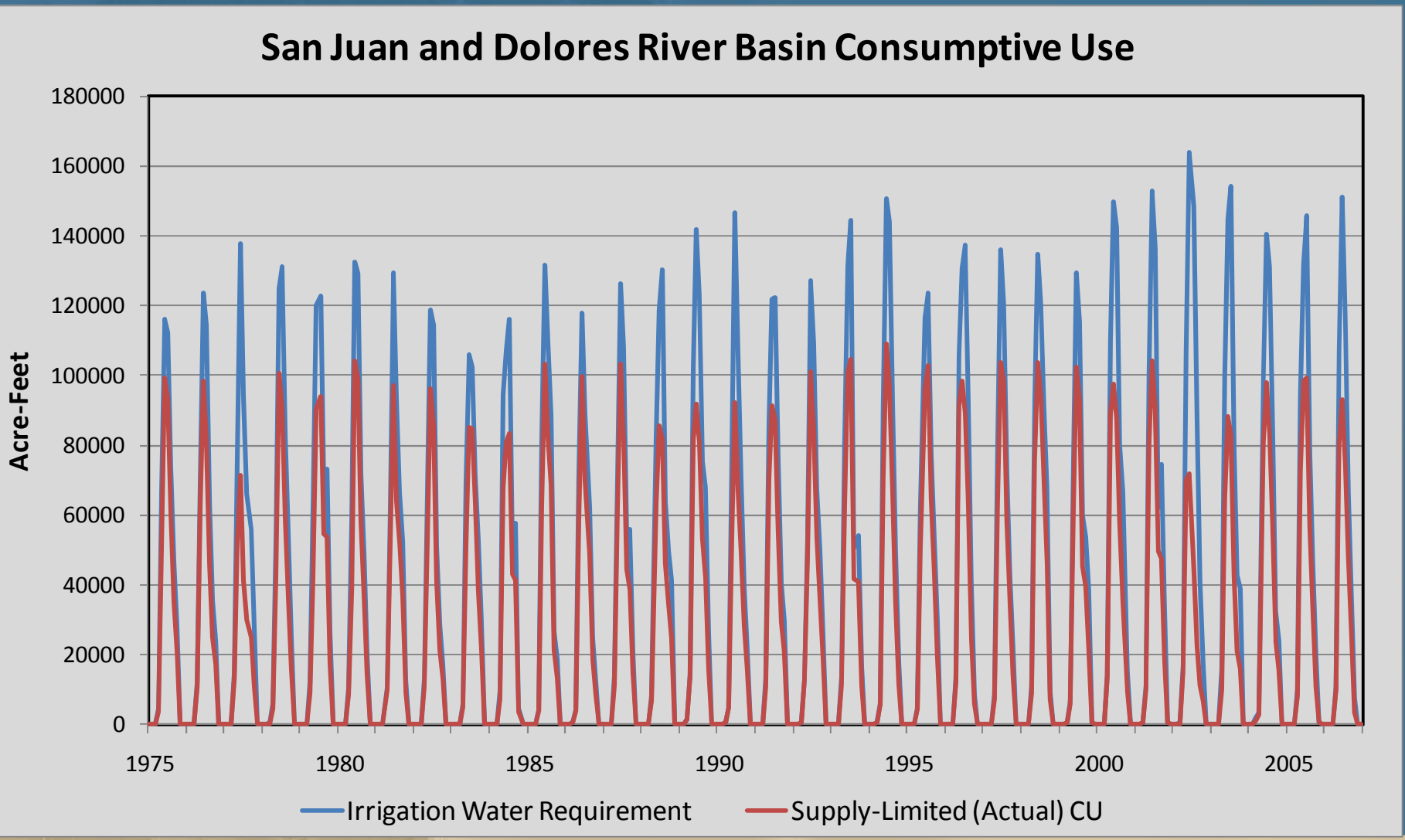
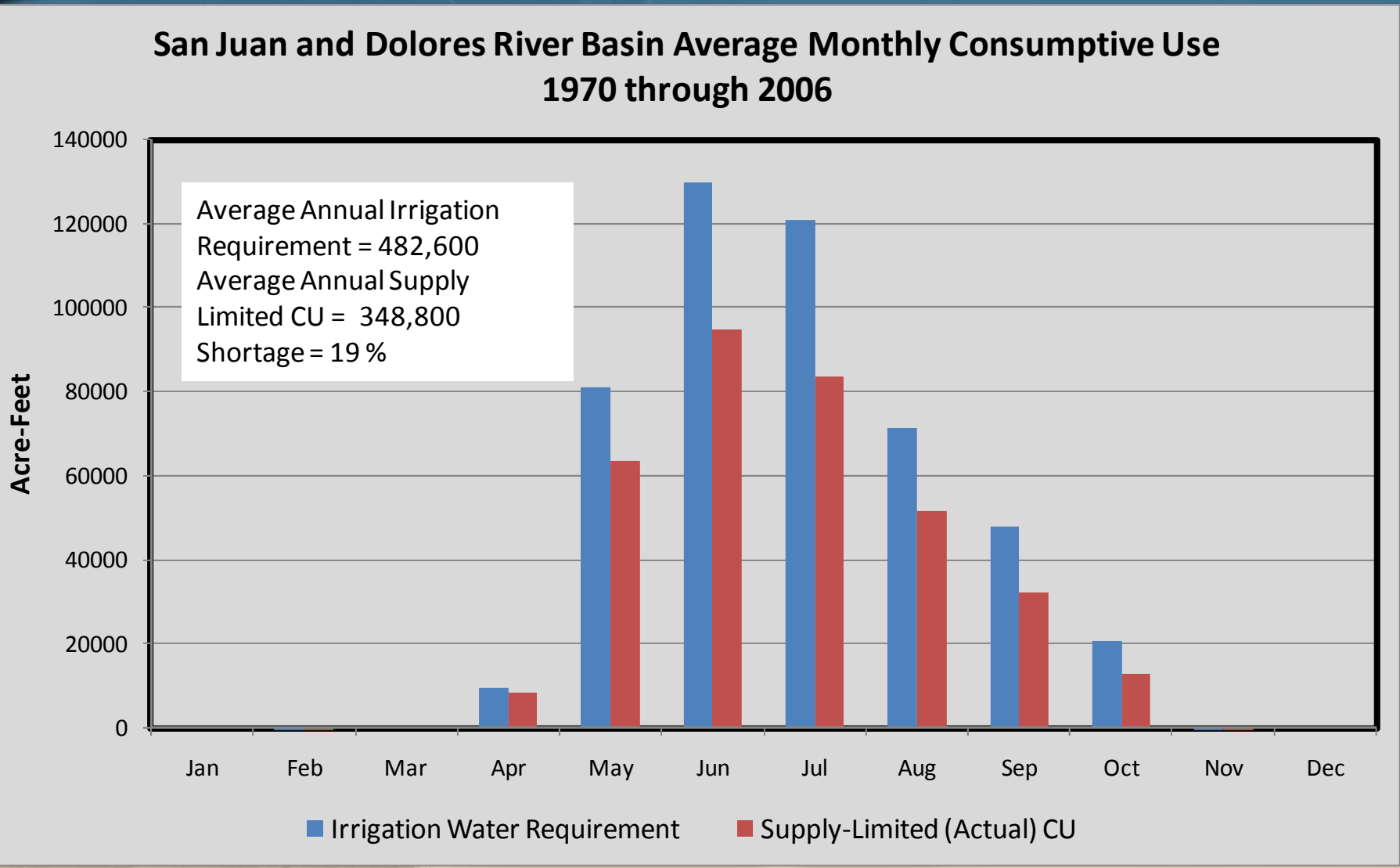
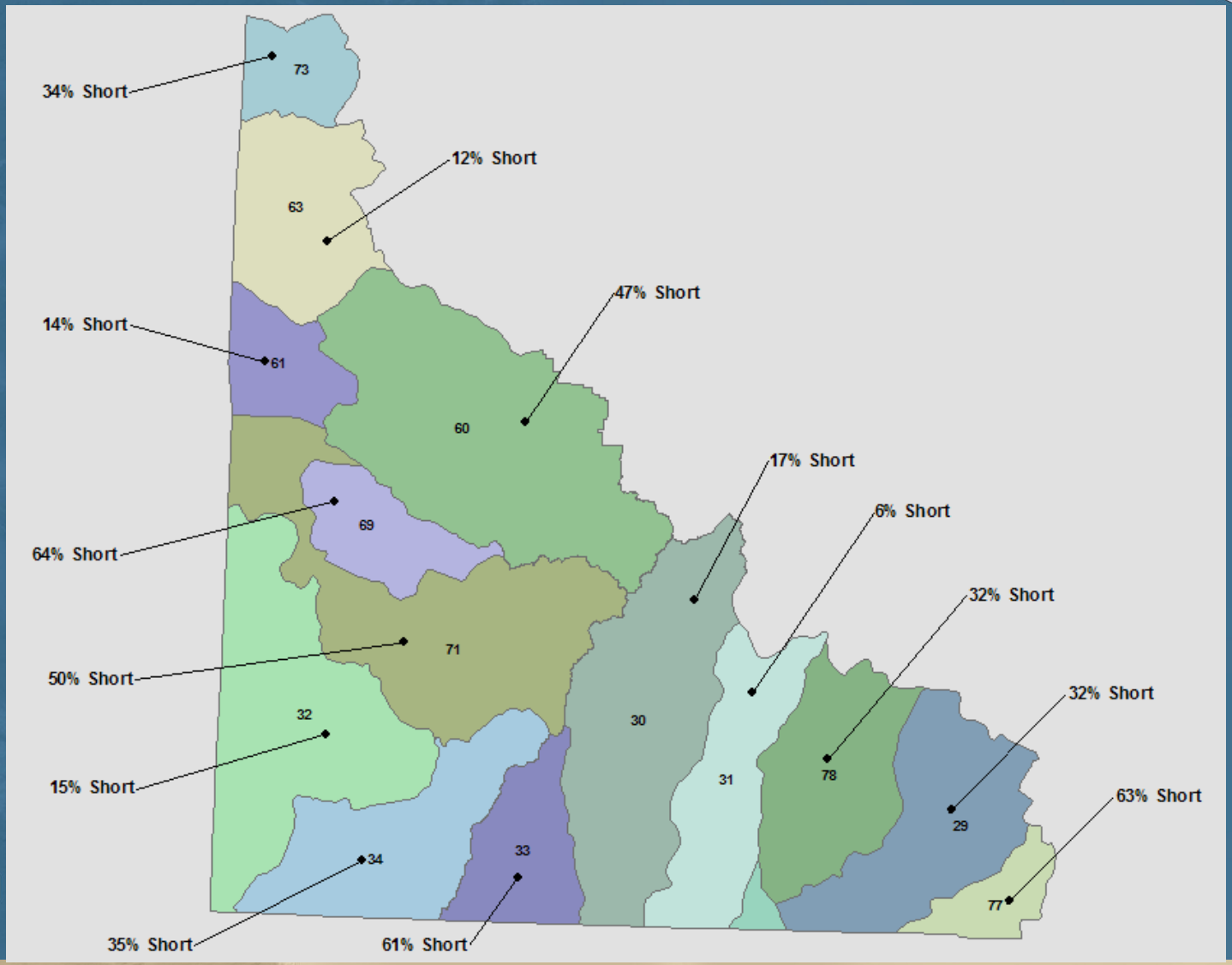
StateCU Summary



StateCU Summary



Consumptive Use Analysis



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Consumptive Use Analysis

- Crop Requirements Used in StateMod to Determine Irrigation Return Flow Amounts
- Crop Requirements Used in StateMod to Determine Baseline Demands
- Consumptive Use Analysis Identifies Shortages. StateMod Identifies "Why"
  - Physical water limitation
  - Legal limitation (downstream senior right)
  - Irrigation practices

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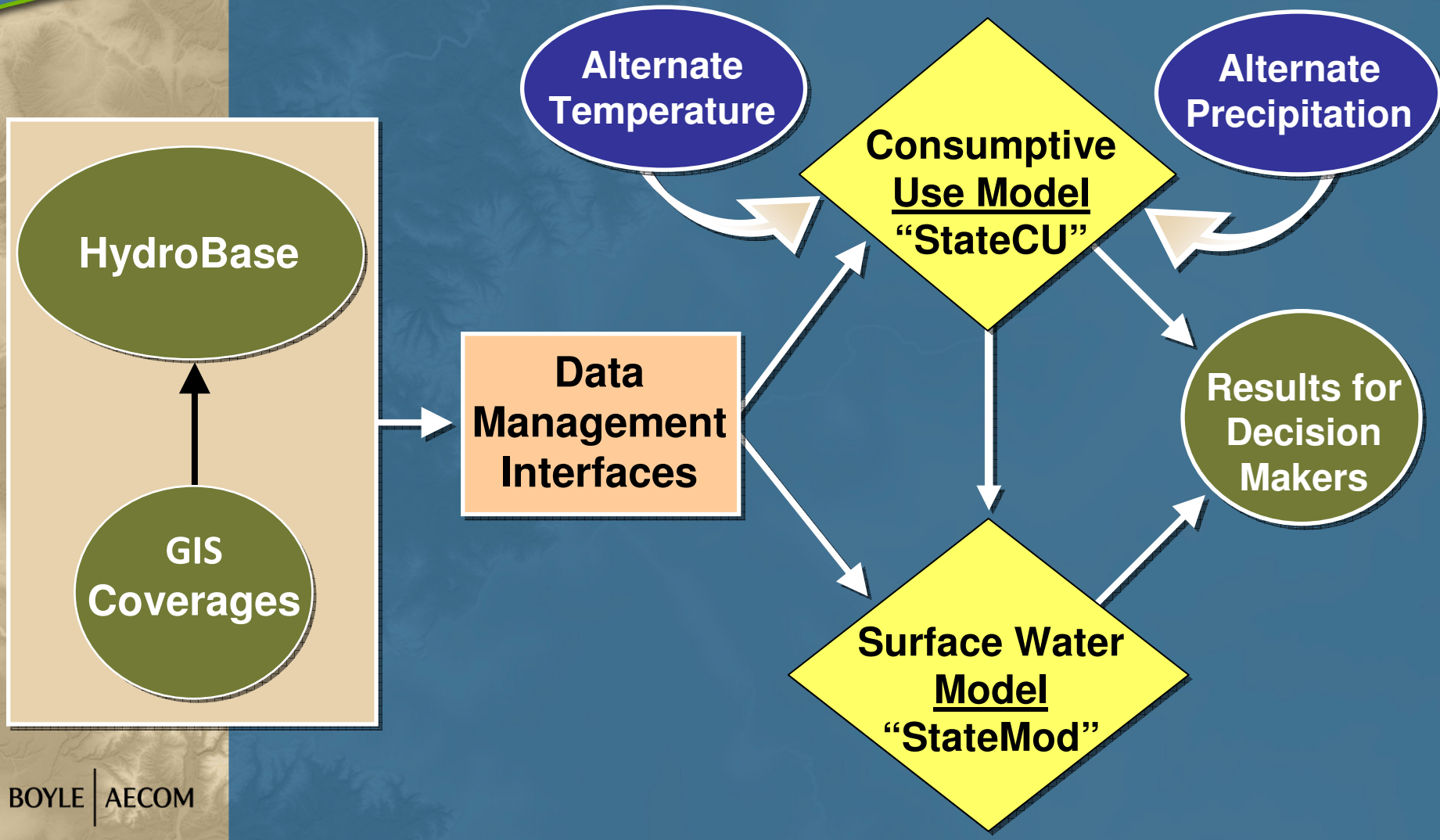
StateCU - Alternate Historical Hydrology



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StateMod Introduction

- General–Purpose Water Allocation Model
- Can be Adapted to Any River Basin through Unique Data Sets
- Data Sets Define Basin
- StateMod Operates Based on Colorado's Water Right System

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StateMod Introduction

- Linked-Node Model
- Nodes are Locations Where you Have or Need Information
  - Stream Gages
  - Diversion Locations
  - Reservoirs
  - Beginning/End of Instream Flow Segments
  - Return Flow/Discharge Locations

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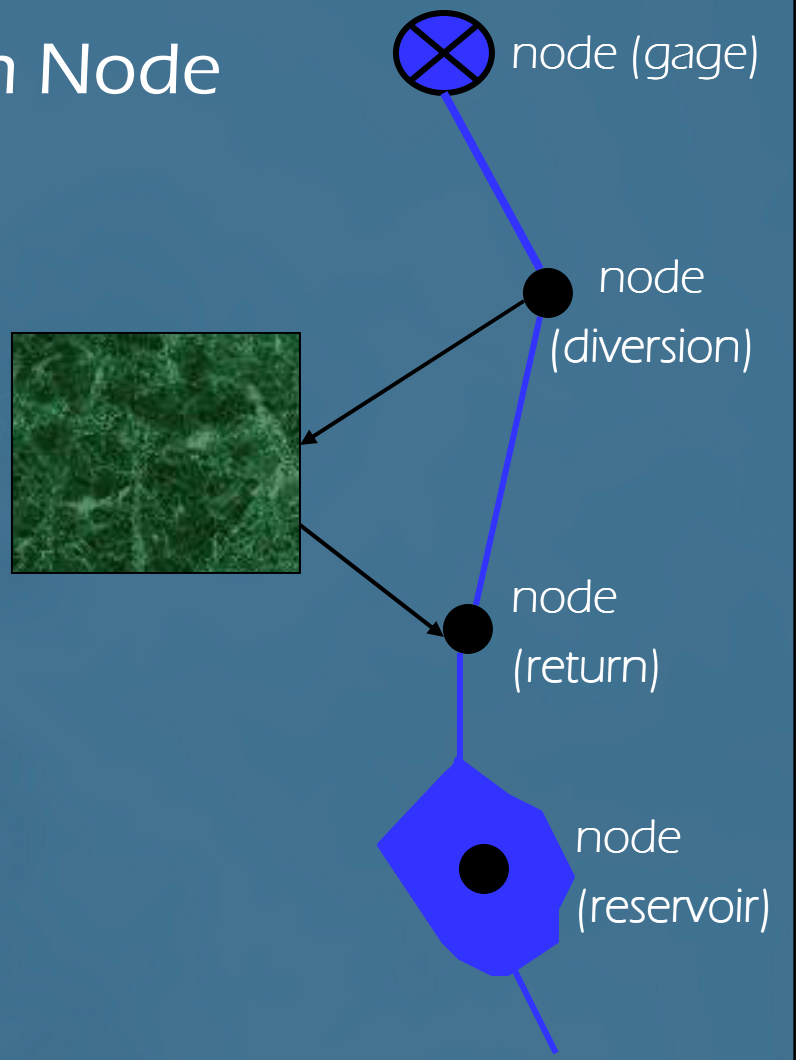
StateMod Introduction

- Water is Carried from Node to Node via
  - Rivers
  - Canals
  - Pipelines



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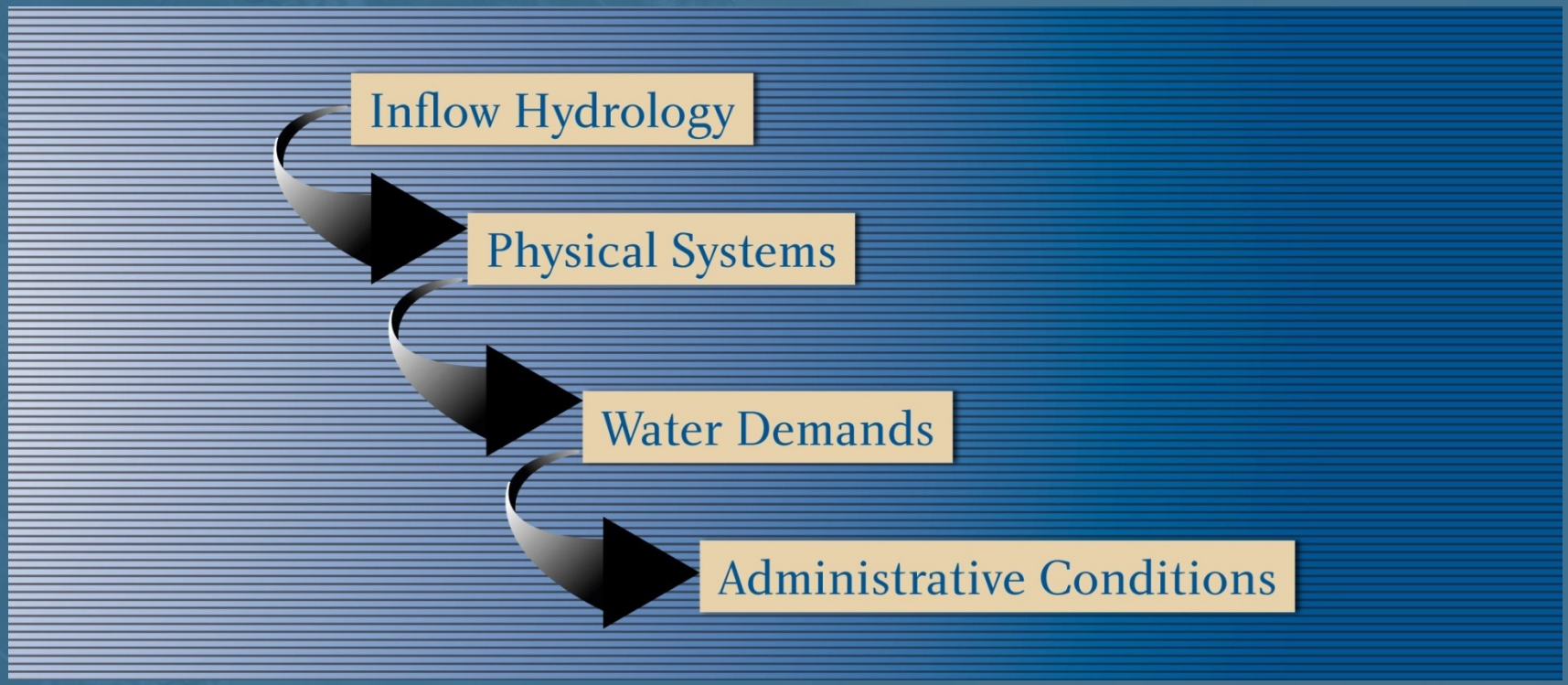
Model Components



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Inflow Hydrology

- CRWAS Model Period - 1950 through 2005
  - Represents Wet/Dry/Average Periods
  - Minimized Data Filling
  - Sufficiently Long to look at Water Availability over time
- Model Represents more than 80 San Juan and Dolores River Tributaries

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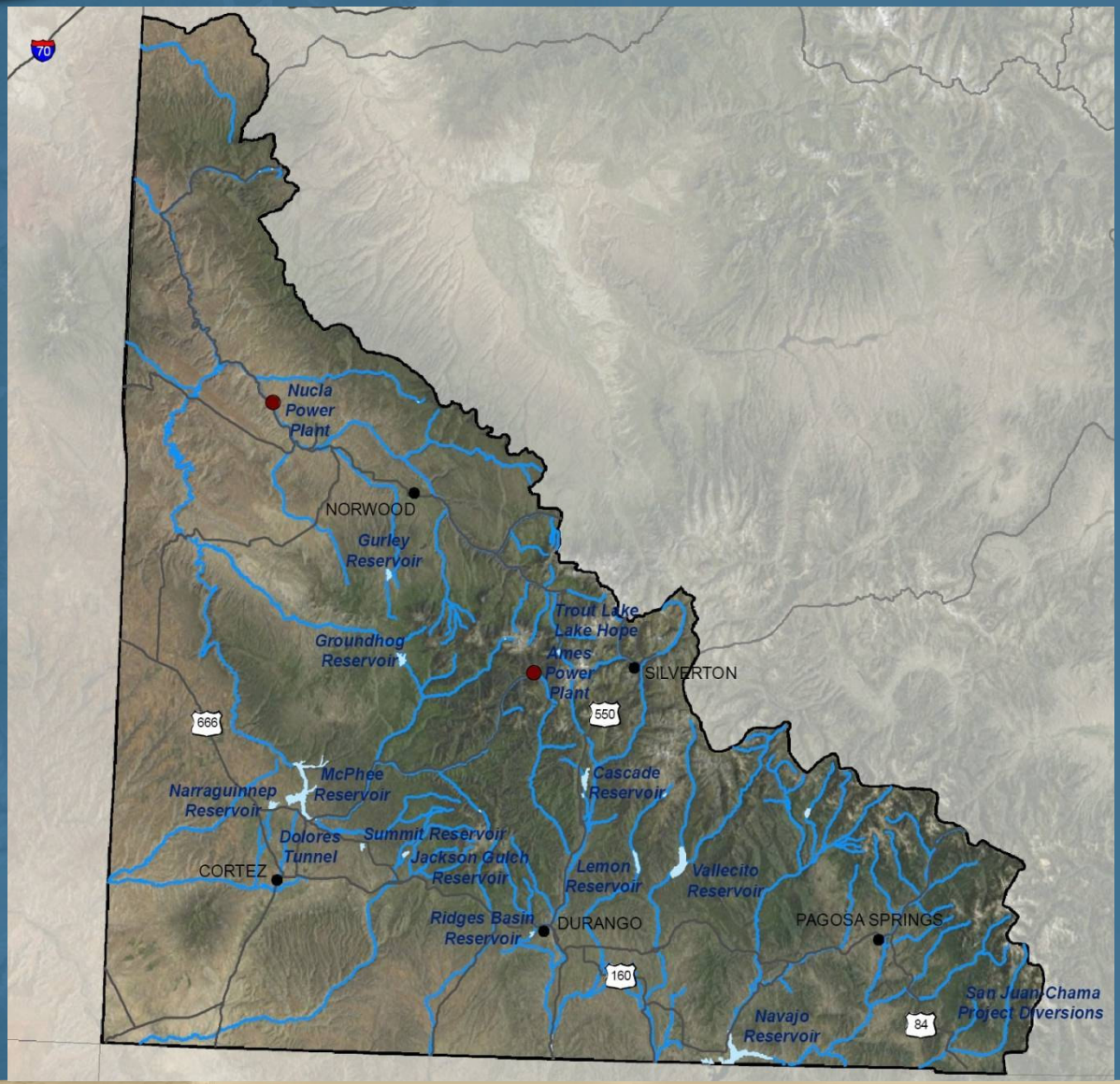
Inflow Hydrology



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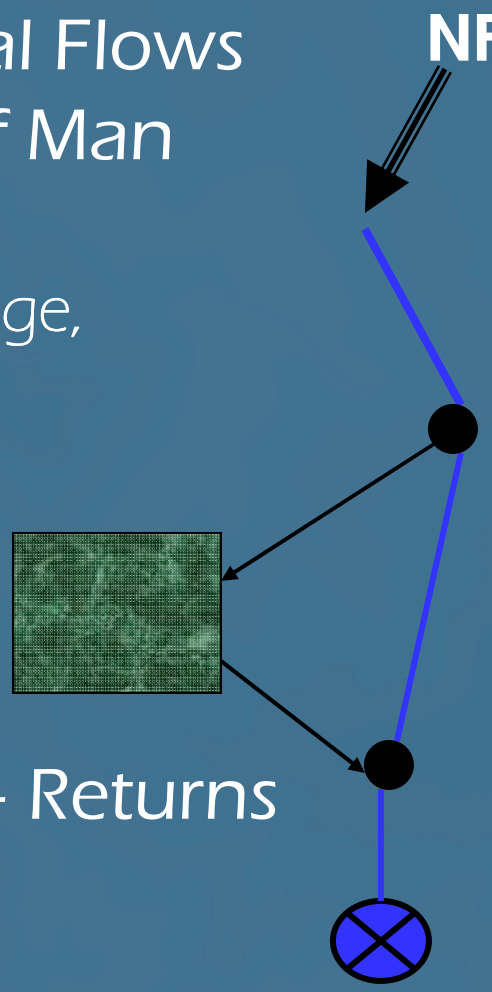
Inflow Hydrology – Natural Flow Development

- StateMod estimates Natural Flows by Removing the Effects of Man
  - Diversions, Return Flows, Changes in Reservoir Storage, Evaporation



- NF = Gaged + Diversions – Returns +/- change in storage

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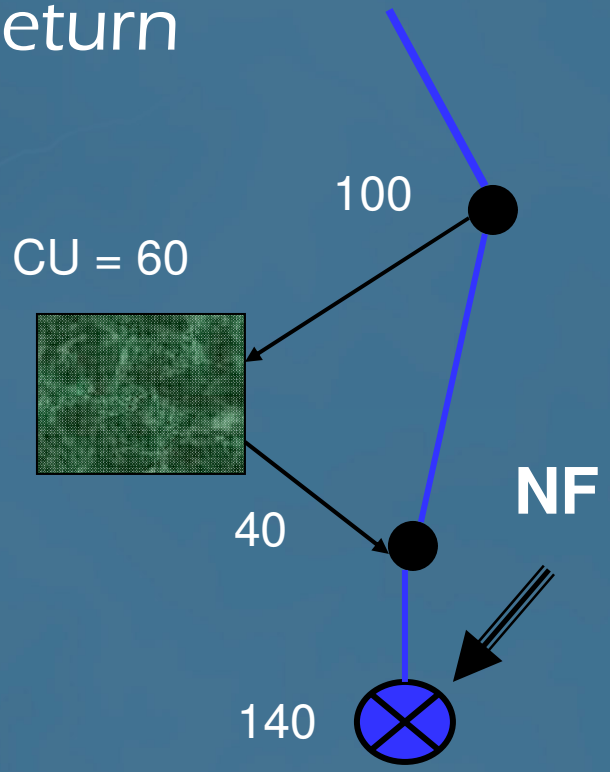
Inflow Hydrology – Natural Flow Development

- Develop NF at Gaged Locations
- NF = Gaged + Divert – Return



NF = 140 + 100 – 40

NF = 200

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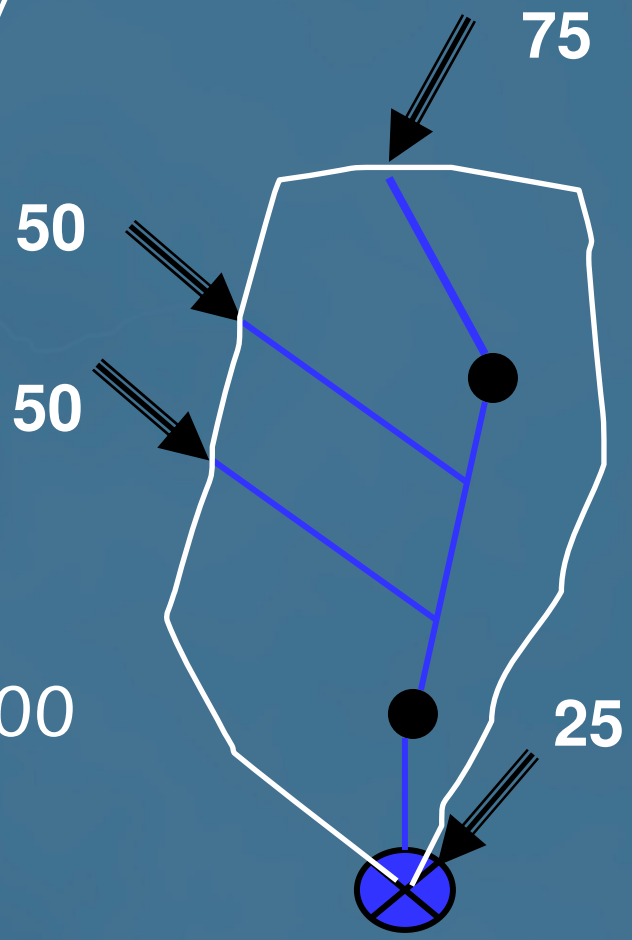
Inflow Hydrology – Natural Flow Development

- Distribute Natural Flow Gains to ungaged tributaries



NF at Gage = 200

Overall Gain at Gage = 200

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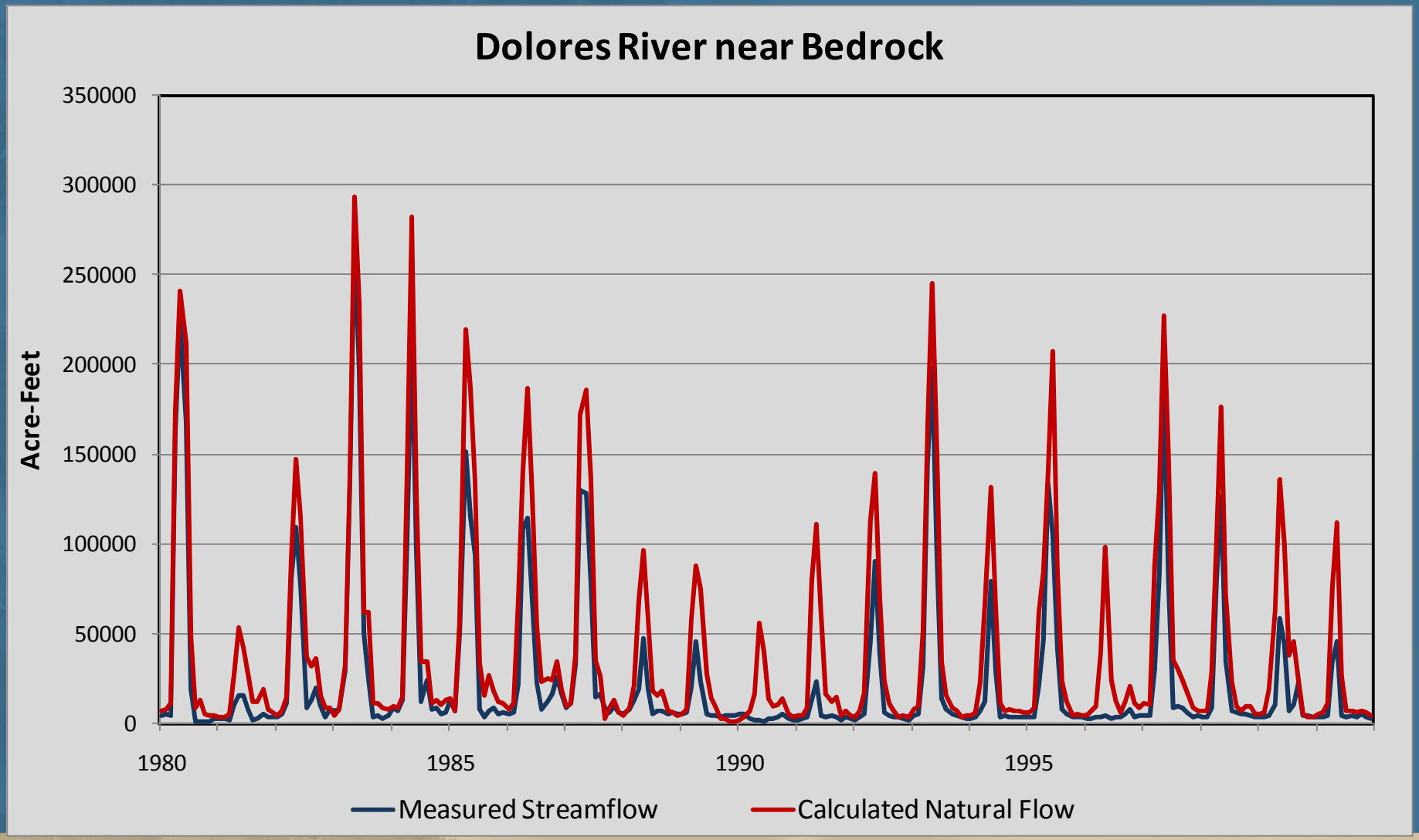
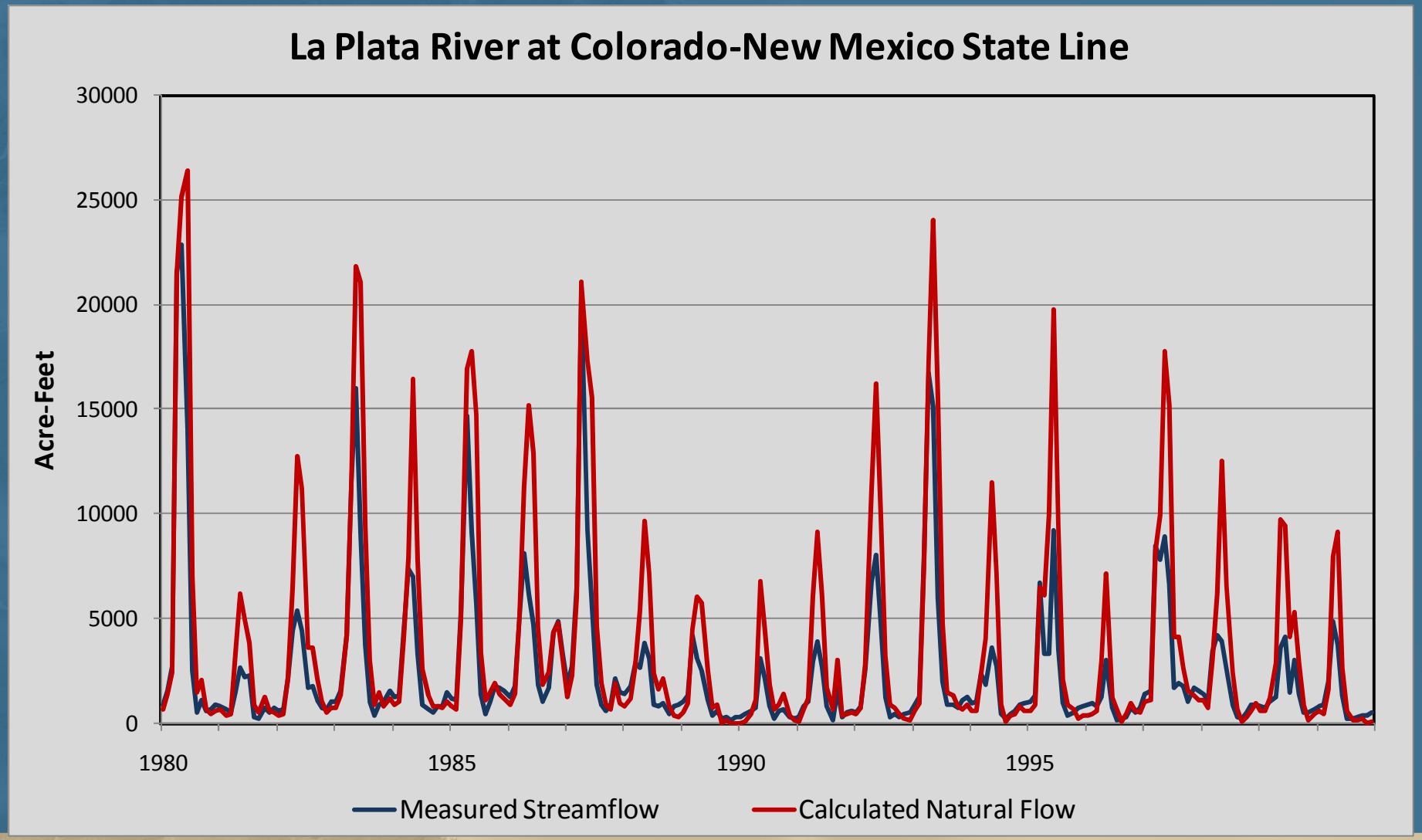
Inflow Hydrology



Inflow Hydrology



Inflow Hydrology – Data Sources

- Gaged Data recorded by USGS and DWR, stored in HydroBase
- Diversions Recorded by DWR, Stored in HydroBase
- Reservoir Contents Provided by Reservoir Owners/Operators , Stored in HydroBase
- Return Flows Are the Portion of Diverted Water not Required by the Crops, as Determined by StateCU

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Physical Systems

- Diversion Structures
  - Location on the River
  - Headgate and Canal Capacities
  - Return Flow Locations
- Reservoirs
  - Location on River or Off-Channel
  - Location of Carrier Ditches
  - Storage Volume, Outlet Capacities, Account Size, Area/Capacity Tables
- Instream Flow Reaches
  - Beginning/Ending of Reach

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Physical Systems

- Over 300 Diversion Structures Explicitly Represented
  - 222,000 Irrigated Acres
  - Larger Structures; Structures that are Important in Administration (Per Water Commissioner); Structures Receiving Reservoir Water
  - 7 Trans-basin Diversions (out of Colorado Basin)
  - 11 Trans-tributary Diversions
  - 10 Municipal and Industrial Diversions

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Physical Systems

- Remaining Structures are Represented in 25 Aggregates
  - 33,000 acres
  - Grouped by Location
  - Structures on Smaller Tributaries not Represented in the Model; Structures without Diversion Records

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Physical Systems

- 12 Key Reservoirs in Colorado (>3000 af)
  - 650,000 Acre-feet Combined Storage

Vallecito	Lemon	Cascade
Jackson Gulch	Summit	Narraguinnep
Groundhog	McPhee	Gurley
Lake Hope	Trout	Miramonte
Navajo (New Mexico)	Ridges Basin (Future)	Long Hollow (Future)

- 54 CWCB Instream Flow Segments
- 11 Minimum Bypass Locations

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Physical Systems – Data Sources

- Physical Structure Location Based on GIS, Available Straight-line Diagrams, and Water Commissioner Input
- Return Flow Locations Based on GIS
- Ditch and Reservoir Capacity Information is Stored in HydroBase (If Available)
- Additional Reservoir Capacities, Account Information, and Area Capacity Curves Obtained from Reservoir Owners/Operations

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Water Demands

- Irrigation Demands
  - Full Irrigation Water Requirements from StateCU
- Municipal and Industrial Demands
  - 1998 to 2005 Average Monthly Diversions
- Trans-basin Demands
  - 1975 to 1991 Average Monthly Diversions
- Reservoir "Demands"
  - Reservoir Capacities or Operational Targets

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Water Demands – Sources

- Reservoir and Trans-basin Bypass Requirements based on Operational Agreements
- Reservoir "Demands"
  - Reservoir Capacities or Operational Targets
  - Operational Targets for Lemon and Vallecito Reservoirs Provided by USBR/Operators

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Administrative Conditions

- Water Rights (Direct, Storage, Instream Flow)
- Reservoir and Carrier Operations
- Policies and Agreements (Such as Minimum Bypasses, Fish Flows, etc)

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Model Operations

1. Based on Natural Inflow and Return Flows from Previous Time Steps
2. Identifies Most Senior Water Right
3. Estimates Diversion = min (Demand, Water Right, Headgate Capacity, Available Flow)
4. Adjusts Downstream Flows to Reflect Senior Diversions and Immediate Return Flows
5. Future Returns are Calculated
6. Repeated for Next Junior Water Right

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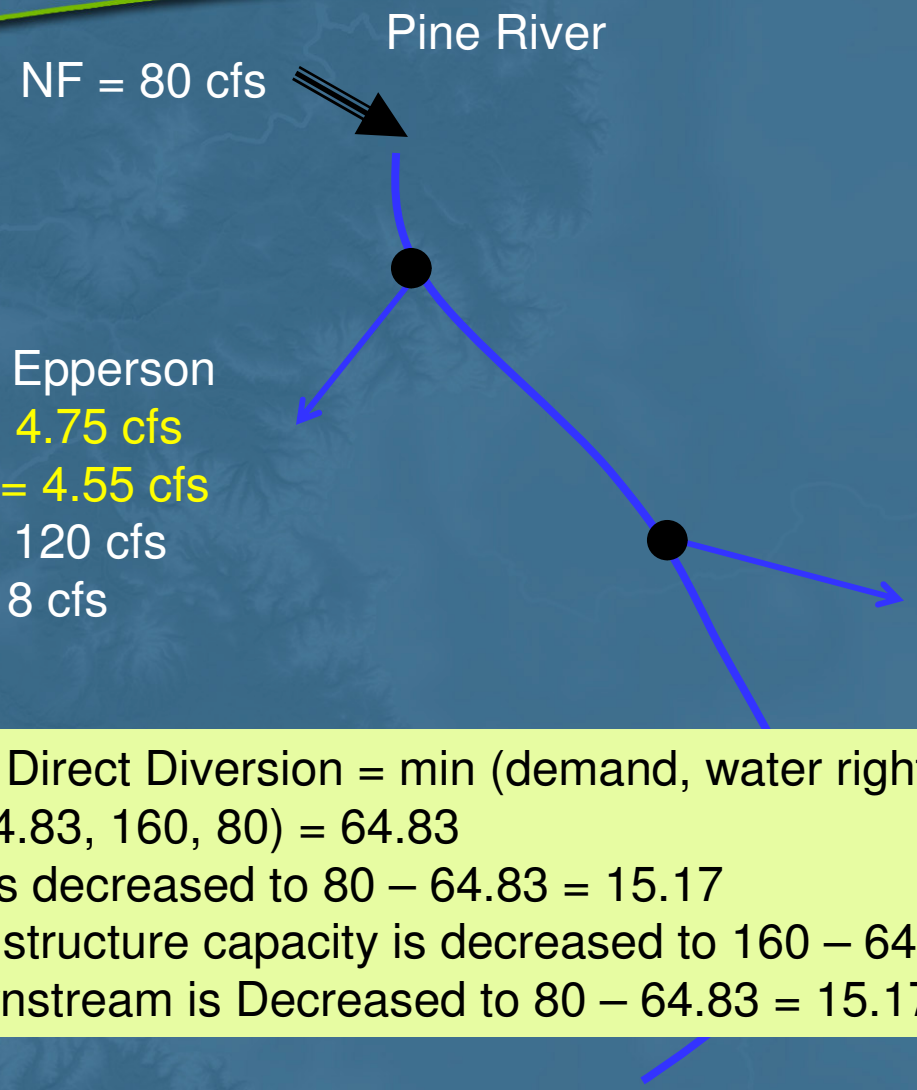
Model Operations



1) Priority 1: Direct Diversion = min (demand, water right, capacity, physical flow) = min(80, 64.83, 160, 80) = 64.83
2) Demand is decreased to 80 – 64.83 = 15.17
3) Diversion structure capacity is decreased to 160 – 64.83= 95.17
4) Flow Downstream is Decreased to 80 – 64.83 = 15.17

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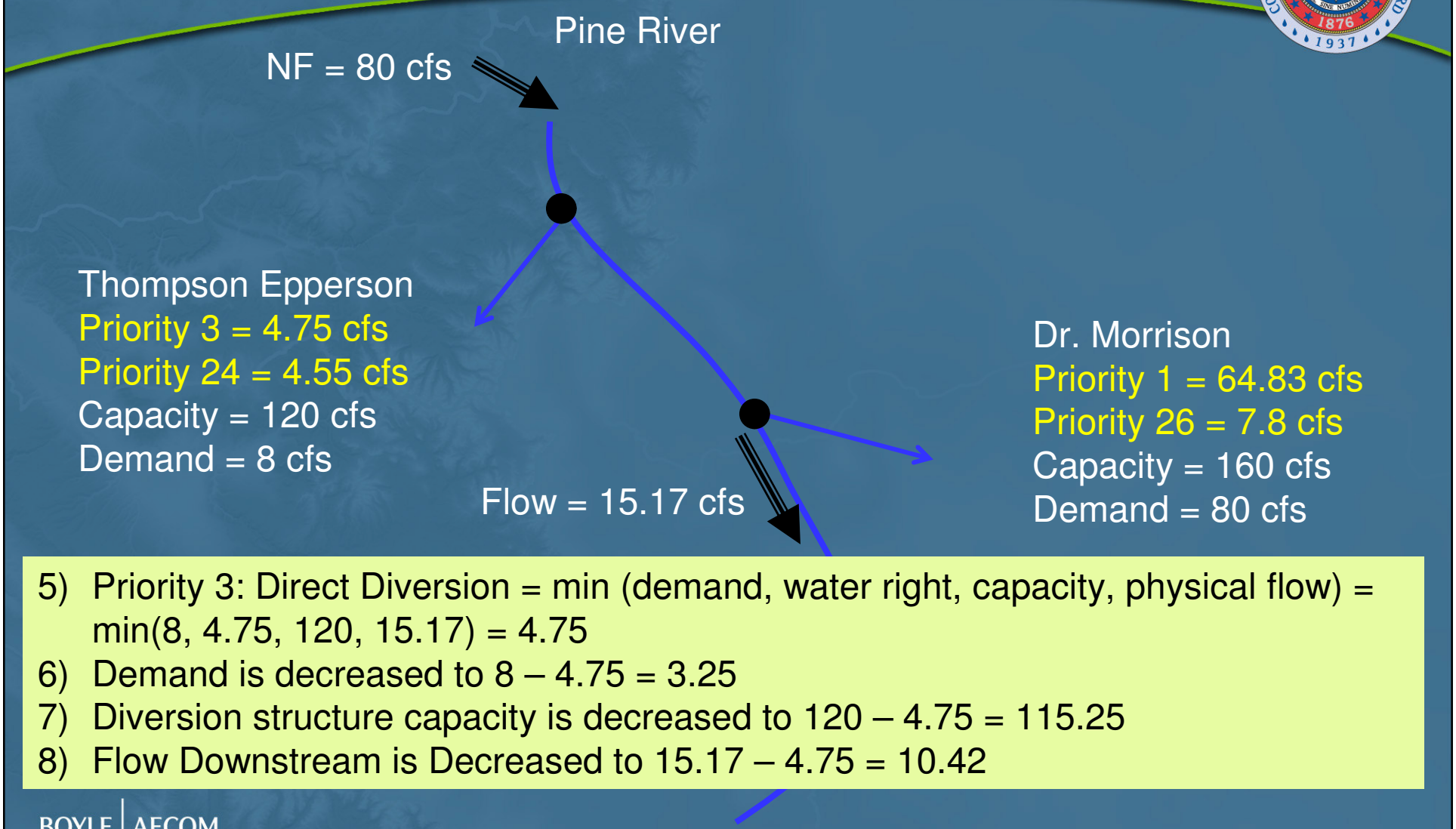
Model Operations



5) Priority 3: Direct Diversion = min (demand, water right, capacity, physical flow) = min(8, 4.75, 120, 15.17) = 4.75
6) Demand is decreased to 8 – 4.75 = 3.25
7) Diversion structure capacity is decreased to 120 – 4.75 = 115.25
8) Flow Downstream is Decreased to 15.17 – 4.75 = 10.42

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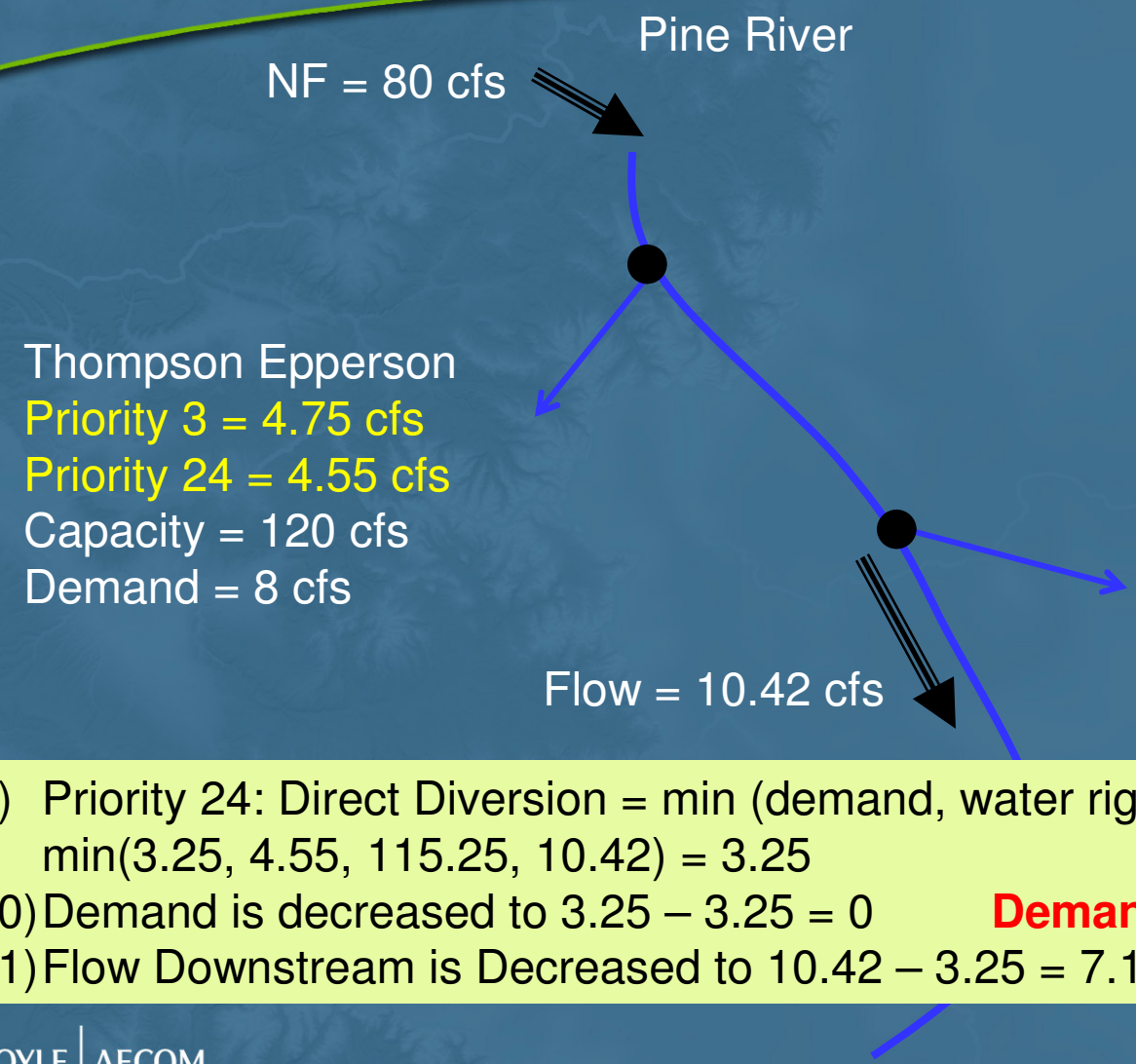
Model Operations



9) Priority 24: Direct Diversion = min (demand, water right, capacity, physical flow) = min(3.25, 4.55, 115.25, 10.42) = 3.25
10) Demand is decreased to 3.25 – 3.25 = 0 **Demand is Satisfied**
11) Flow Downstream is Decreased to 10.42 – 3.25 = 7.17

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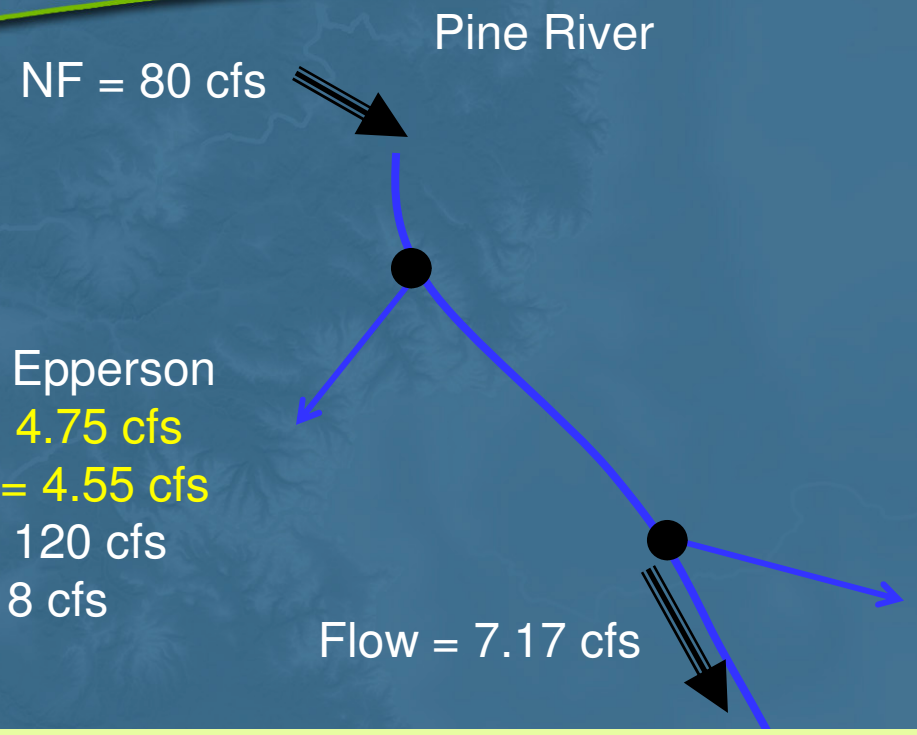
Model Operations



12) Priority 26: Direct Diversion = min (demand, water right, capacity, physical flow) = min(15.17, 7.8, 95.17, 7.17) = 7.17
13) Demand is decreased to 15.17 – 7.17 = 8.0 **Demand is Shorted**
14) Diversion structure capacity is decreased to 95.17 – 7.17 = 88
15) Flow Downstream is Decreased to 7.17 – 7.17 = 0

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Administrative Conditions

- Model "Operating Rules" for the San Juan/Dolores Model Define:
  - How Water is "Carried" to Off-Channel Reservoirs
  - How Demands are Satisfied From Reservoirs and in What "Priority"
  - How Water is "Carried" to Common Demands and in What "Priority"

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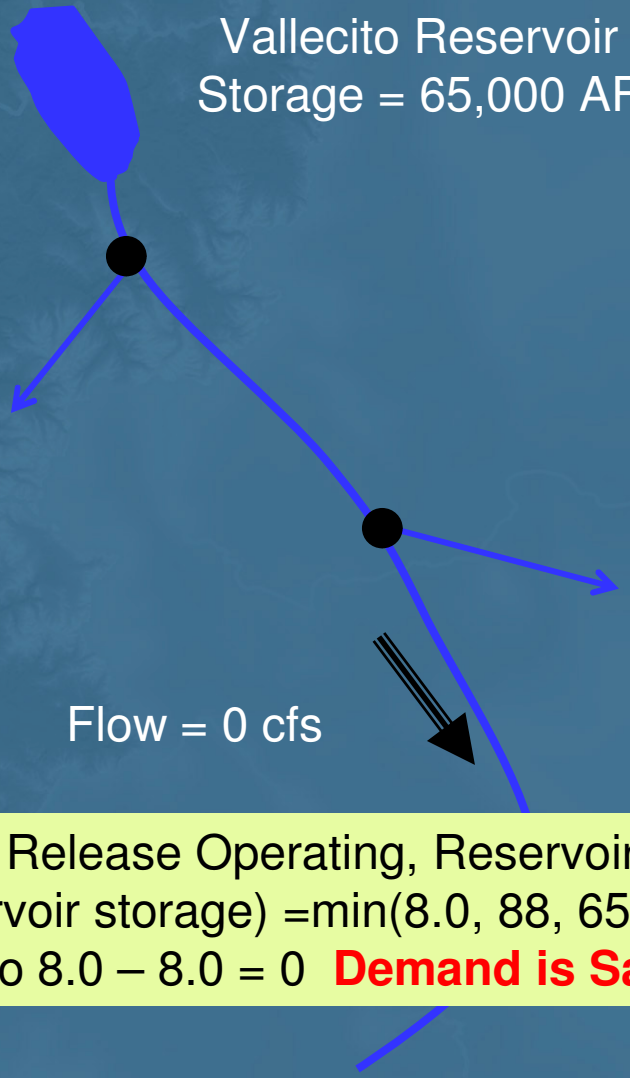
Model Operations



17) Priority 26.1: Reservoir Release Operating, Reservoir Release = min (demand, carrier capacities, reservoir storage) =min(8.0, 88, 65000) = 8.0
18) Demand is decreased to 8.0 – 8.0 = 0 **Demand is Satisfied**

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Administrative Conditions

- Model "Operating Rules" for the Following Project Operations:
  - San Juan-Chama Project
  - Pine River Project (Vallecito Reservoir)
  - Florida Project (Lemon Reservoir)
  - Cascade Reservoir
  - La Plata Compact
  - Jackson Gulch Reservoir
  - Summit Reservoir System

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Administrative Conditions

- Model "Operating Rules" for the Following Project Operations:
  - MVIC/Dolores Project (McPhee, Groundhog, and Narraguinnep Reservoirs
  - Gurley Reservoir
  - Trout Lake and Lake Hope Reservoirs
  - Navajo Reservoir

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Administrative Conditions – Sources

- Water Rights Directly From HydroBase
- Reservoir and Carrier Operations Based on Information from Reservoir Owners and Water Administrators
- Priorities for Operations Assigned to Represent "Order" with Other Rights
  - Ex: Reservoir Release to a Ditch would be Assigned a Priority Junior to the Ditch's Direct Flow Right

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Model Calibration

- Step 1 Calibration - Simulate with Calibration Data Set
  - Demands = Historical Diversions; Including Carriers to Reservoirs or other Demands
  - Reservoir "Targets" = Historical Contents; Reservoirs Store and Release Based on Historical
  - Objective to Refine Natural Flow Hydrology and Return Flow Locations

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Model Calibration

- Do Simulated Results = Historical Measurements? Compare:
  - Diversions
  - Streamflows
  - Reservoir Contents

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Model Calibration

- Calibration "Knobs"
  - Return Flow Locations (Ex. More Return Flows above Shorted Diversions, Around Gage)
  - Natural Flow Distribution to Ungaged Tributaries; Need Enough Physical Flow to Meet Historical Diversions

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Model Calibration

- Step 2 Calibration - Simulate with Calibration Data Set and Operational Data
  - Direct Demands = Historical Diversions
  - Carrier Diversions Driven by Destination Demand via Operating Rules
  - Reservoir "Targets" = Capacity or Operational Targets
  - Objective to Refine Operational Parameters

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Model Calibration

- Calibration "Knobs"
  - Revise "Priorities" Assigned to Operating Rules
  - Change Operating Rule Types
  - Continued Coordination with Reservoir Operators and Water Administrators
  - "Explain" Unresolved Issues with Calibration
    - Ex. Model Simulates Full Reservoir, However Historical Contents were Low due to Maintenance

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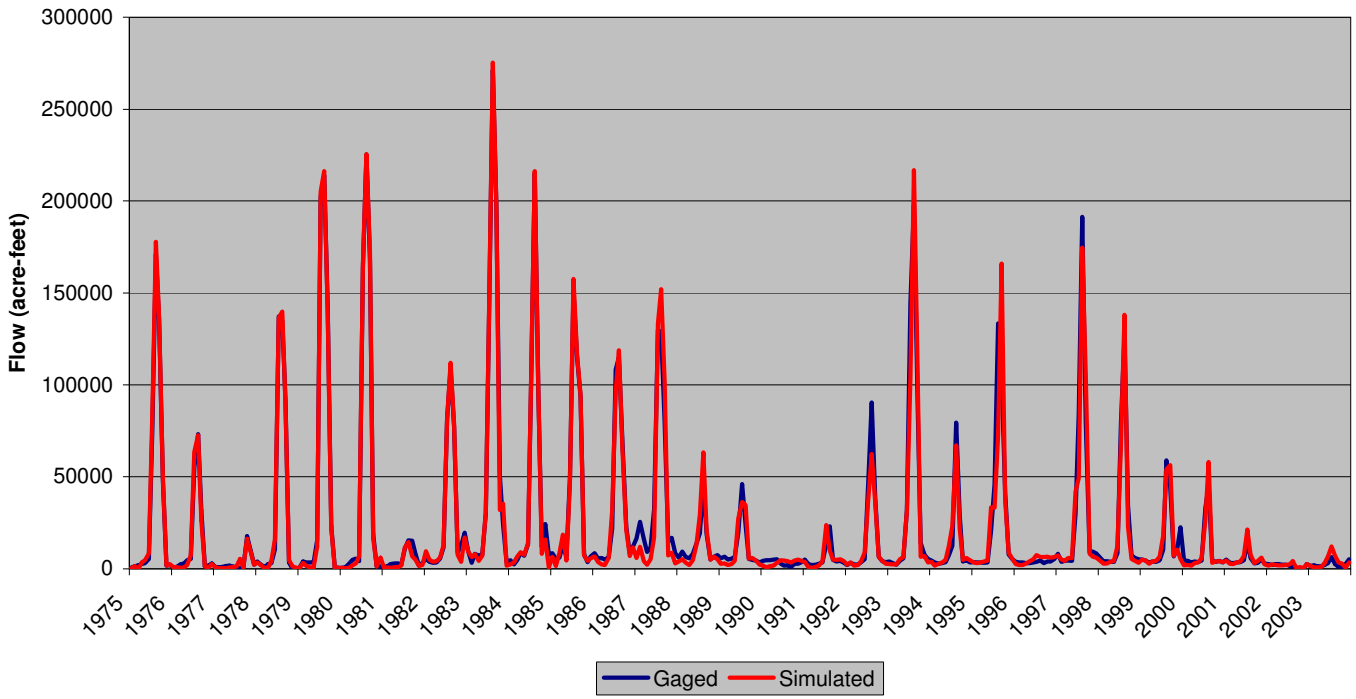
Model Calibration

- Streamflow Average Annual Calibration Within 1 Percent with Exception
  - Dolores River near Bedrock simulated, on average, within 2%



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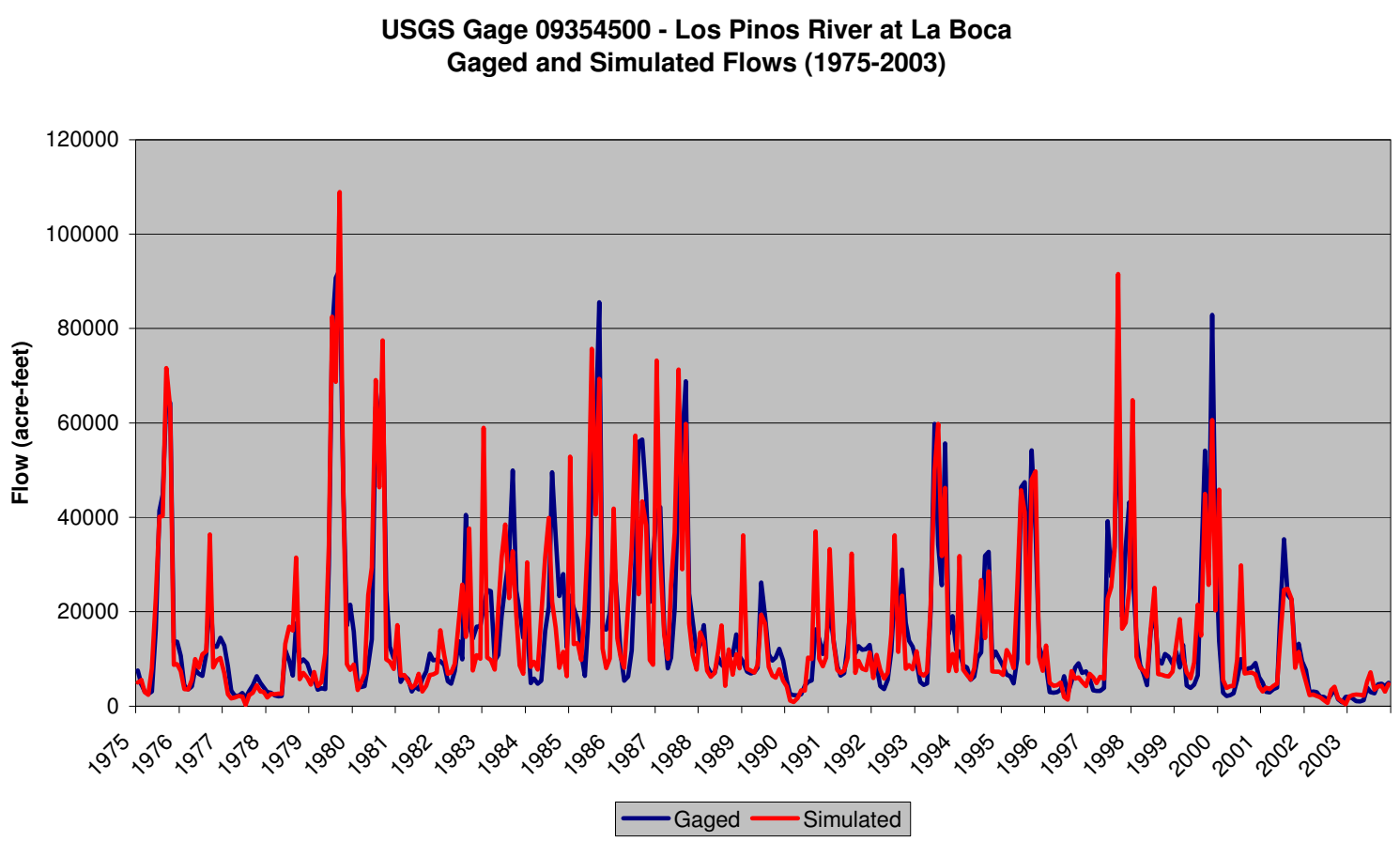
Model Calibration

- Streamflow Calibration below Reservoirs with Operational Targets Reflect that Operational Targets are "Guidelines"



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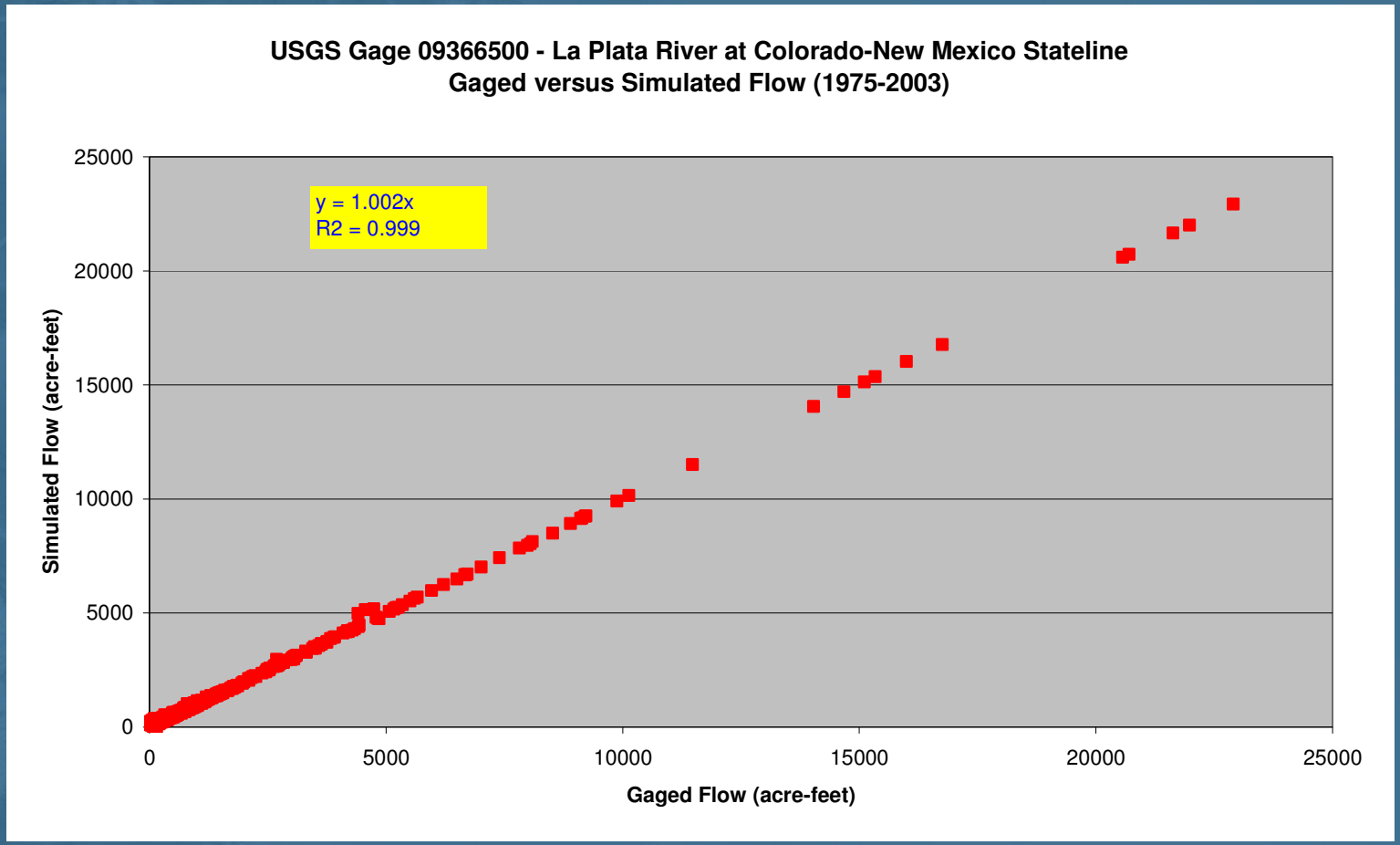
Model Calibration

- Calibration on Larger Tributaries Generally Very Good



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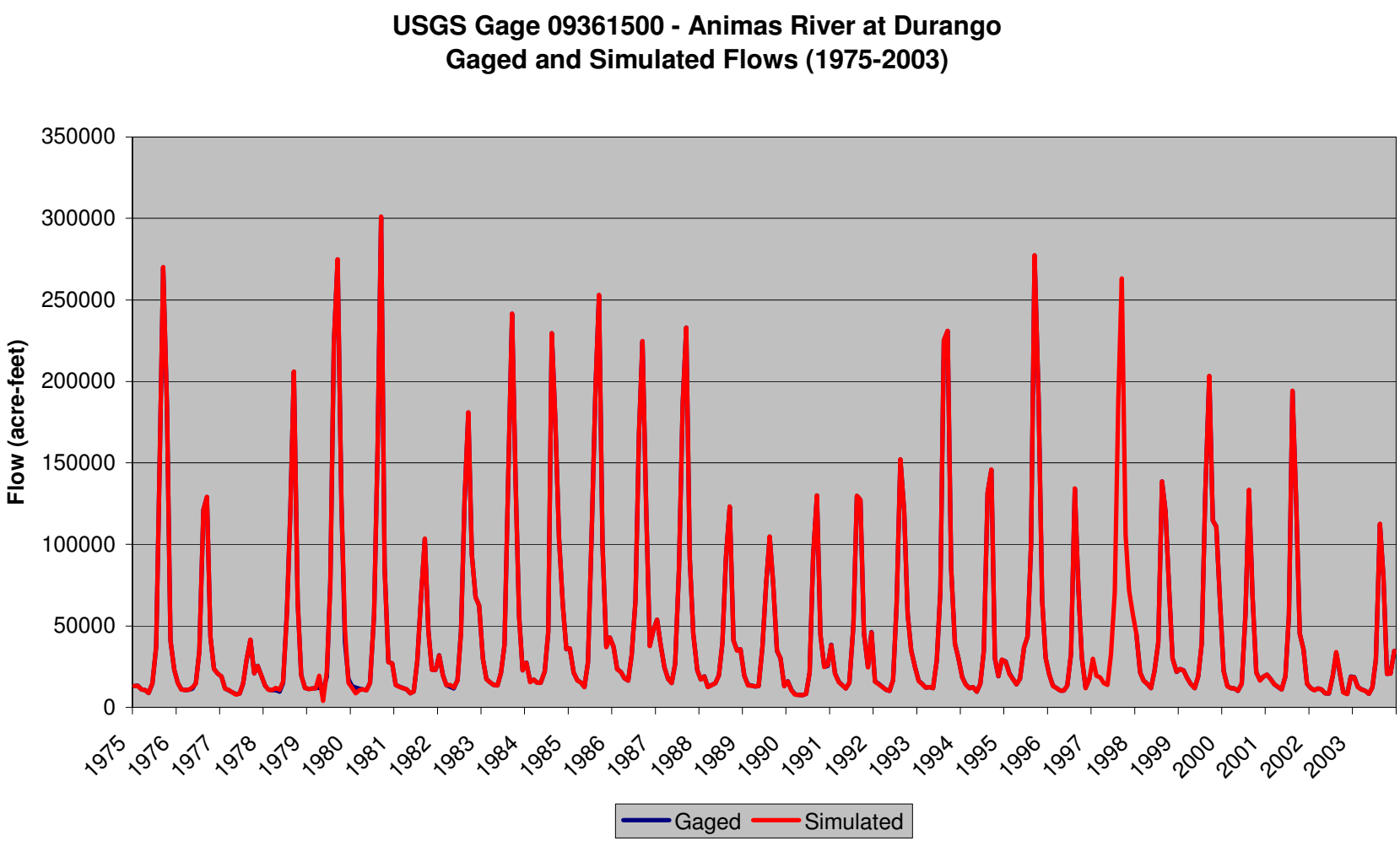
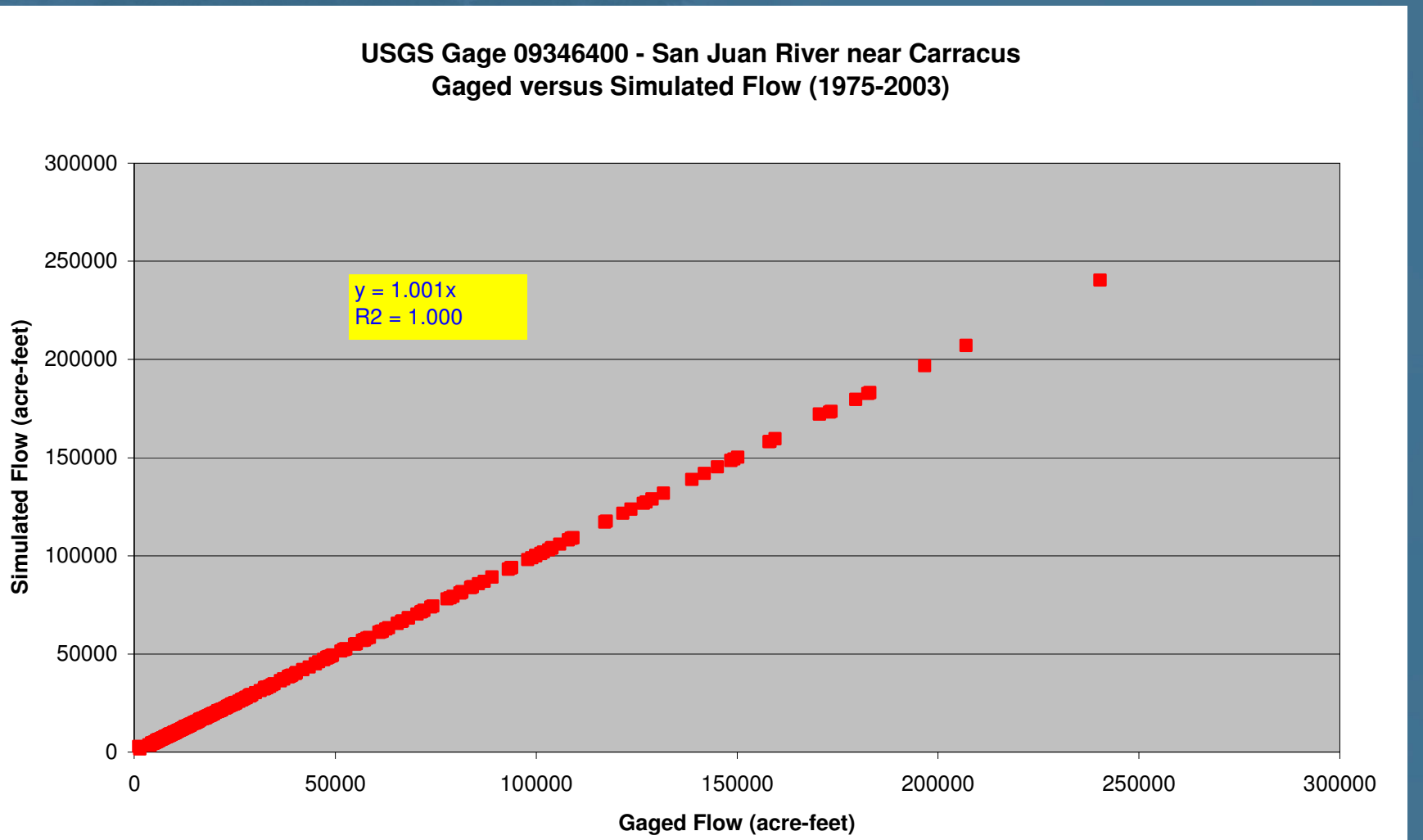
Model Calibration



Model Calibration



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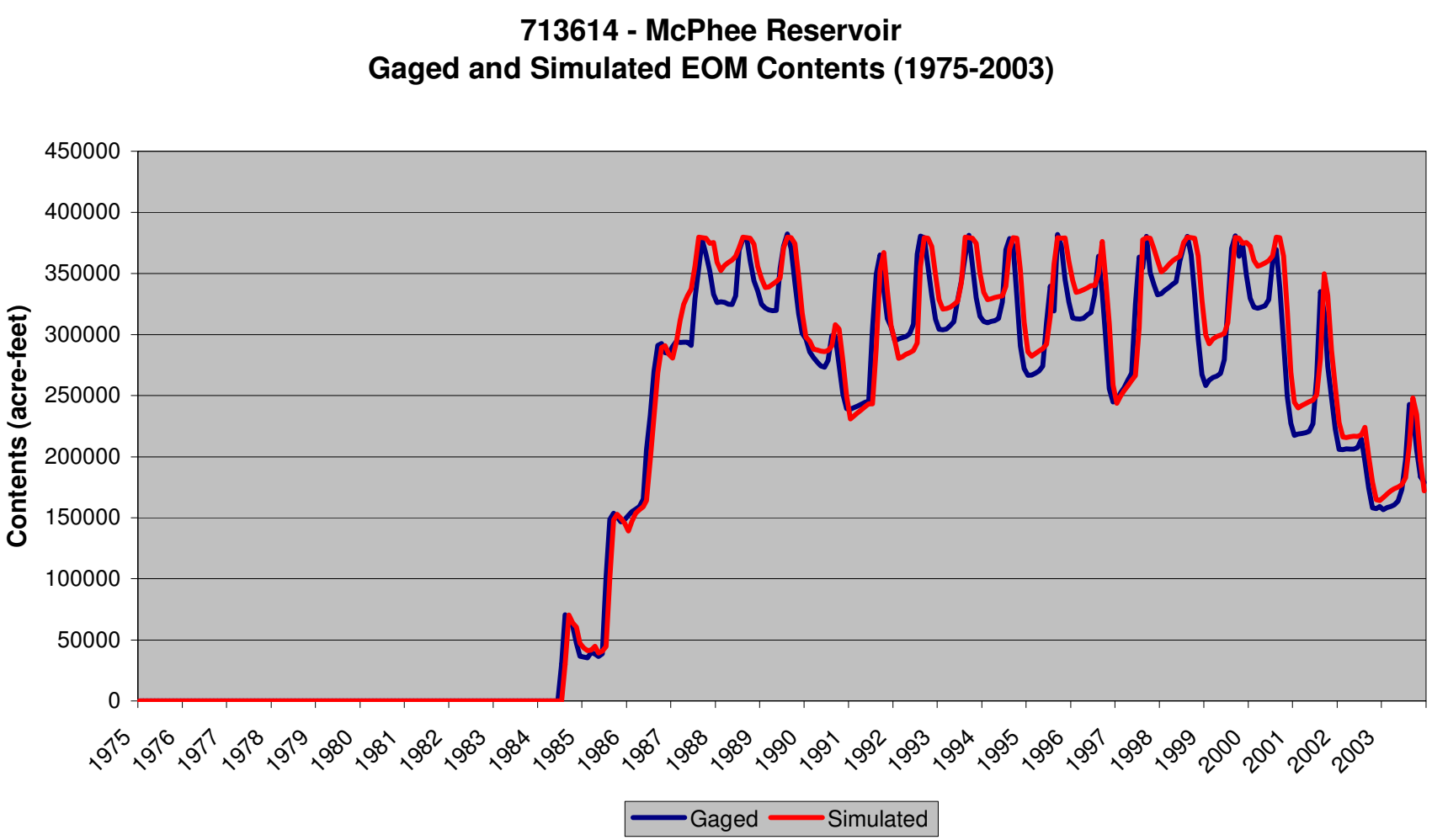

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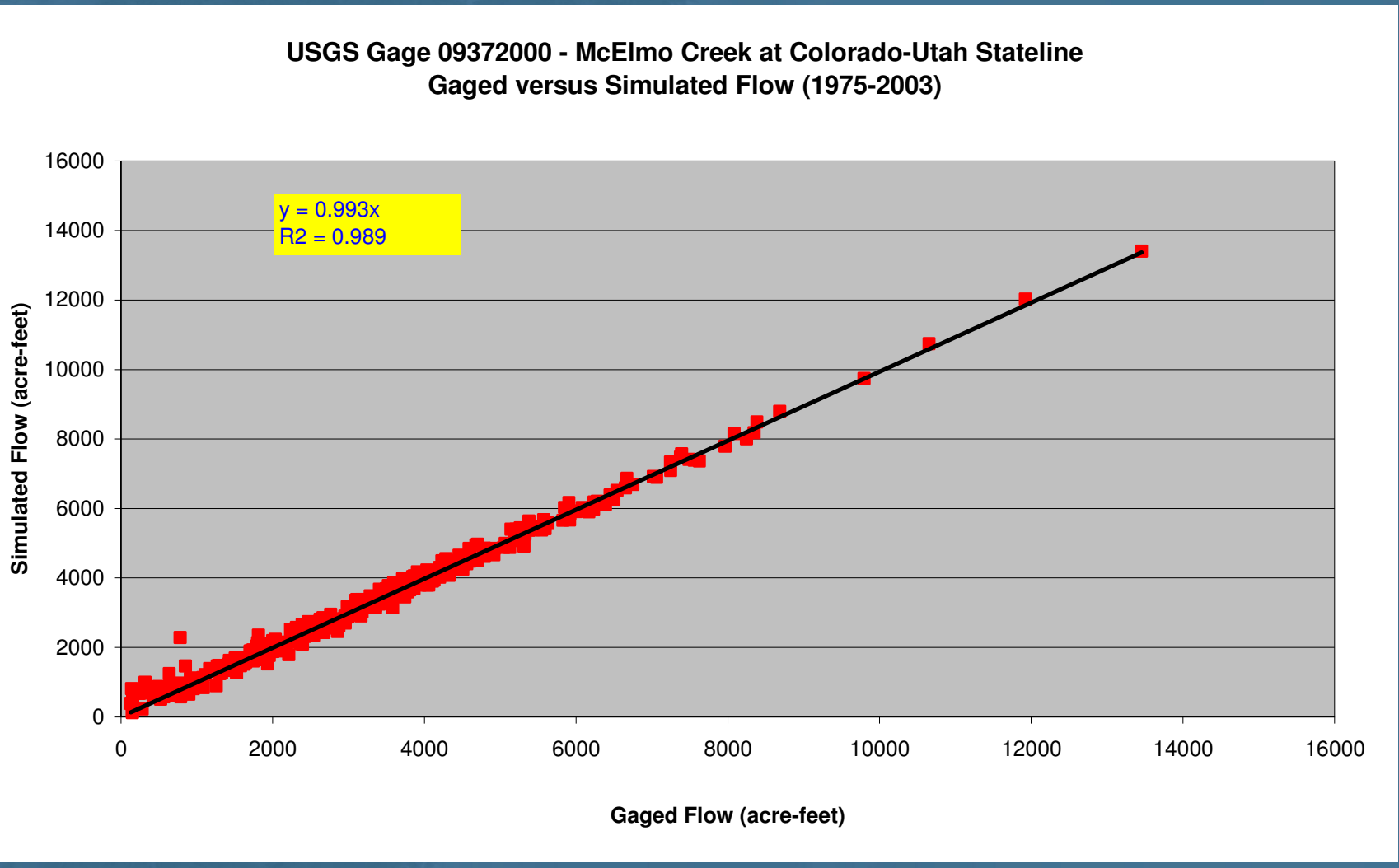

Model Calibration

- Basin Wide Total Simulated Diversions are within 1 percent of Total Historical Diversions
  - *Dolores River main stem irrigation demands are generally met, shortages occur on West Fork and Fish Creek tribs where gage data and historical diversion records are limited*

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Table 3.2
Historical and Simulated Average Annual Diversions by Sub-basin (1975-2003)
Calibration Run (acre-feet/year)

Tributary or Sub-basin	Historical	Simulated	Historical minus Simulated	
			Volume	Percent
Navajo-Blanco Rivers	109,866	109,698	168	0%
San Juan	44,906	43,900	1,006	2%
Piedra River	29,636	29,341	296	1%
Los Pinos River	201,279	200,649	630	0%
Animas and Florida Rivers	178,259	176,184	2,075	1%
La Plata River	32,185	31,546	639	2%
Mancos River (includes MVIC/Dolores Project and Summit Irrigation Use)	35,449	35,000	448	1%
McElmo Creek	204,795	203,962	833	0%
San Miguel River	119,088	117,860	1,229	1%
Dolores River	51,624	48,671	2,954	6%
Basin Total	**1,007,087**	**996,810**	**10,277**	**1%**

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Model Calibration

- Reservoir Calibration Results
  - Calibration of Off-Channel Reservoirs Used for Irrigation is Good
  - Vallecito Reservoir simulated Using Operational Storage Targets – Appear to be General Guideline and don't accurately represent flood control releases
  - Lemon Reservoir simulated Using Operational Releases – Again appear to be General Guideline
  - Calibration of Off-Channel Reservoirs Used for Irrigation is Good

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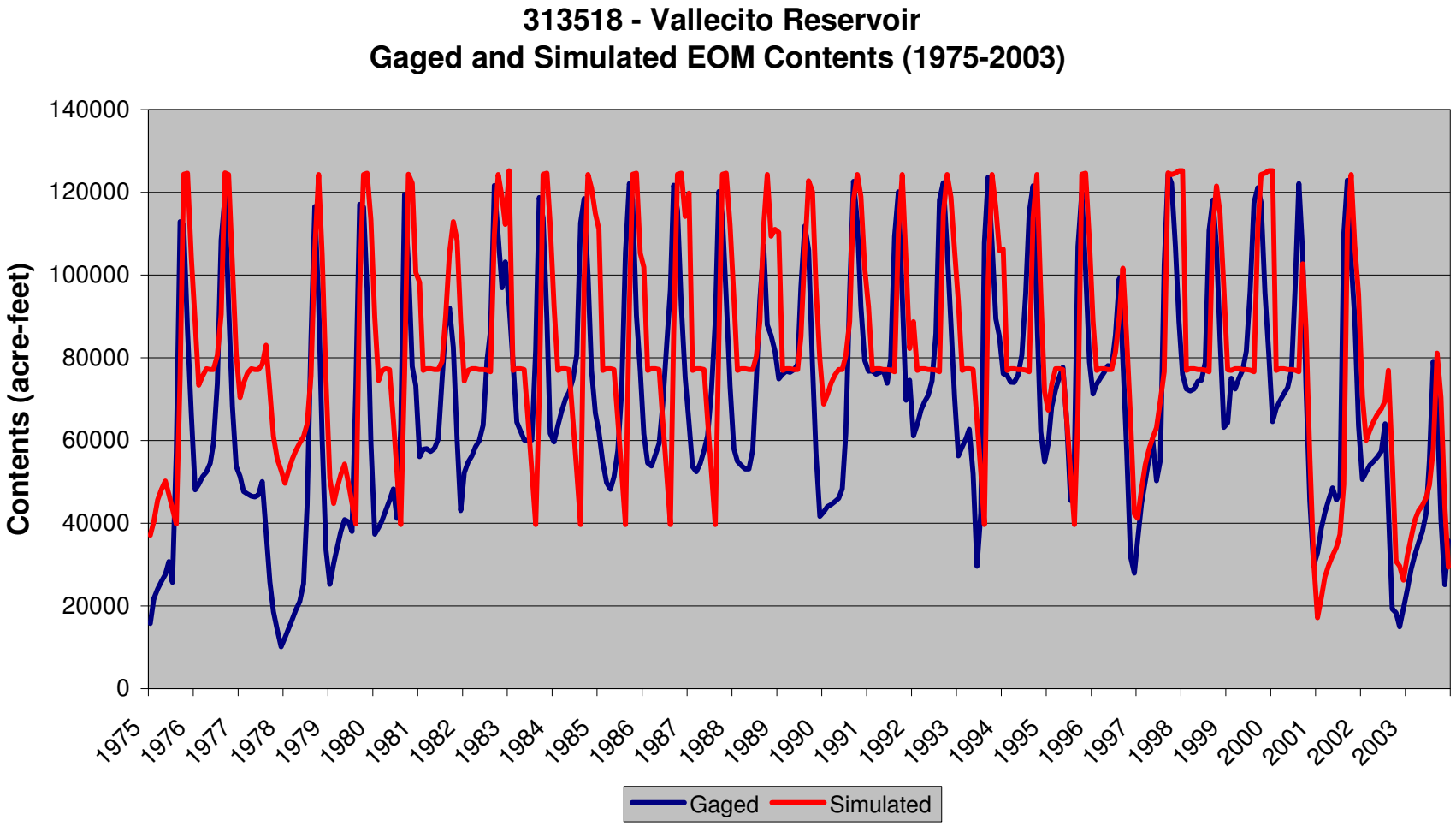
Model Calibration



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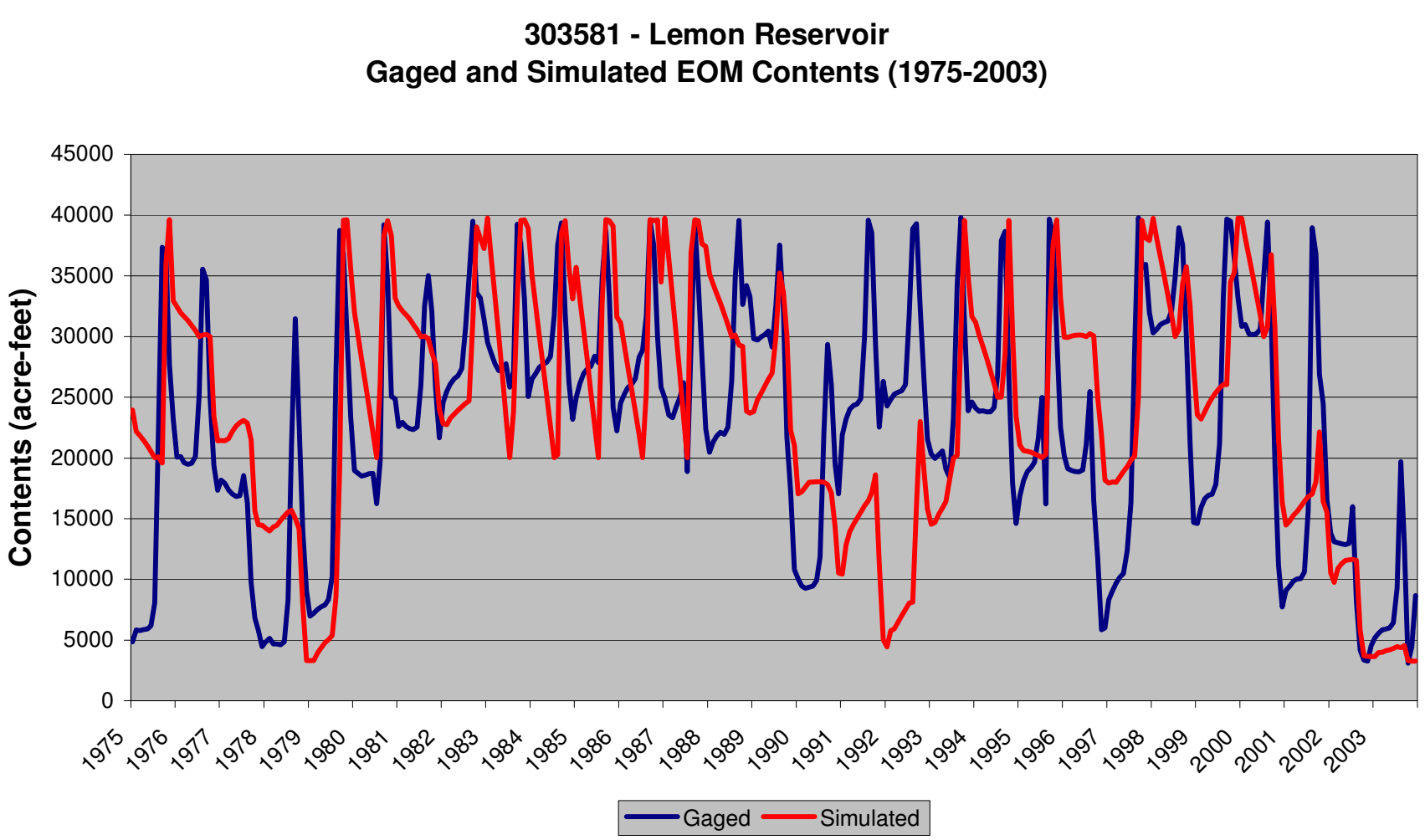
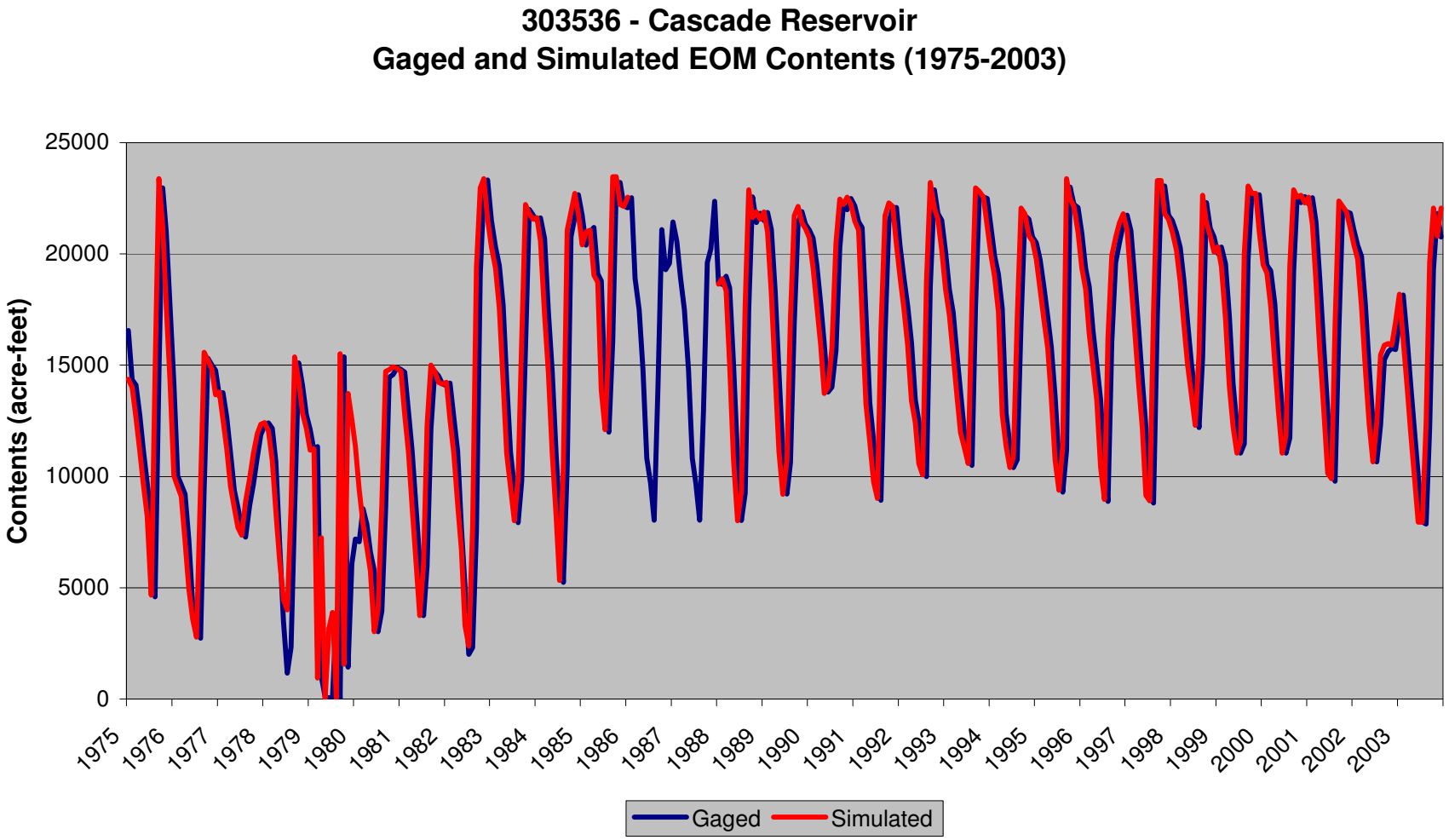


Model Calibration



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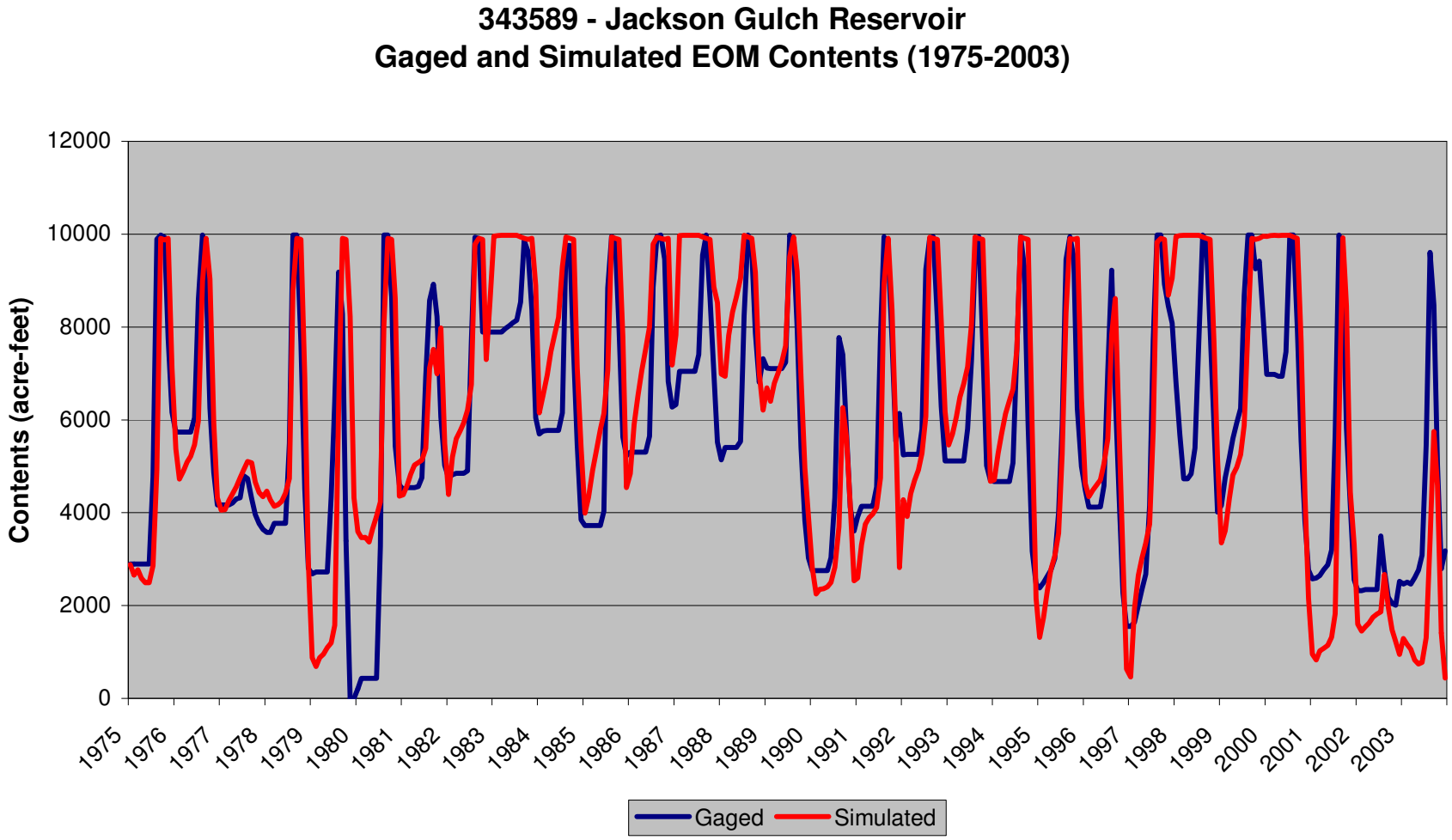
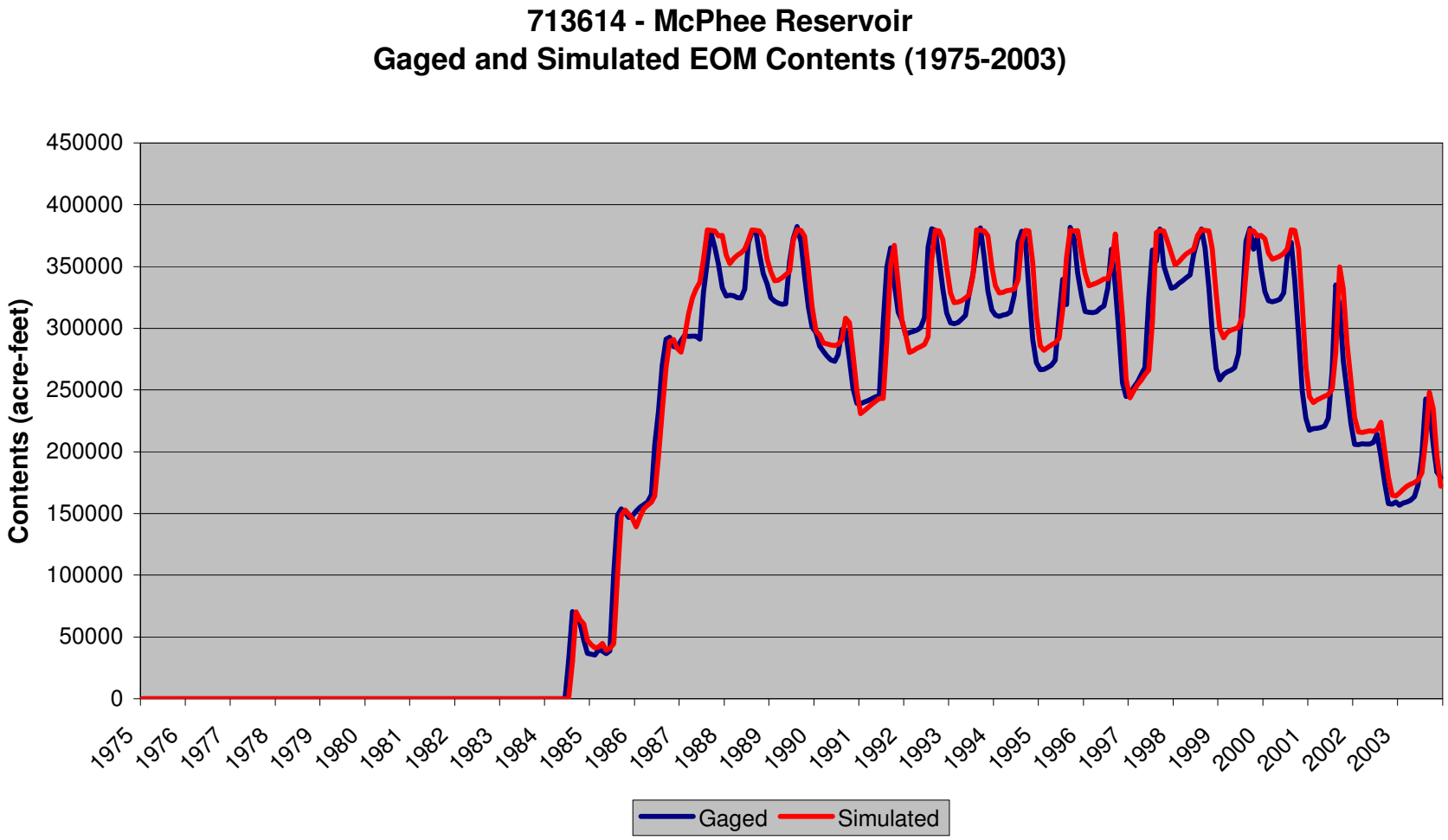


Model Calibration



Model Calibration

- Basin-wide Calibration Results are Good
- Understanding and Representation of Basin Operations is Good
- San Juan/Dolores StateMod Model is Appropriate Prediction Tool to Consider Effects of Basin Climate Variability

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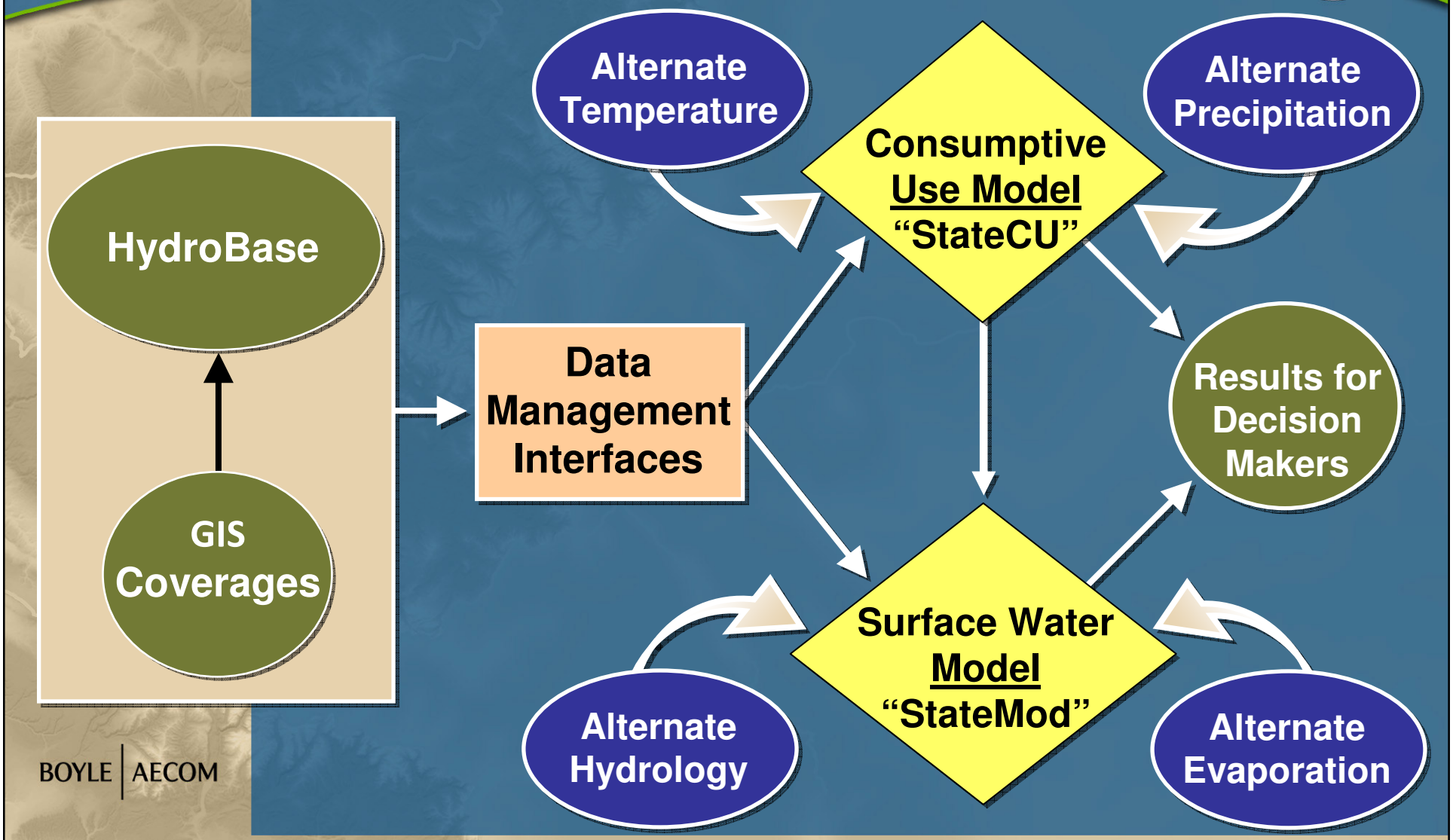
StateMod - Alternate Historical Hydrology



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Questions, Comments, Suggested Model Enhancements?

Website:

http://cwcb.state.co.us/WaterInfo/CRWAS

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