Colorado River Water Availability Study

Study Overview for

Yampa and White River Basin Roundtable

March 4, 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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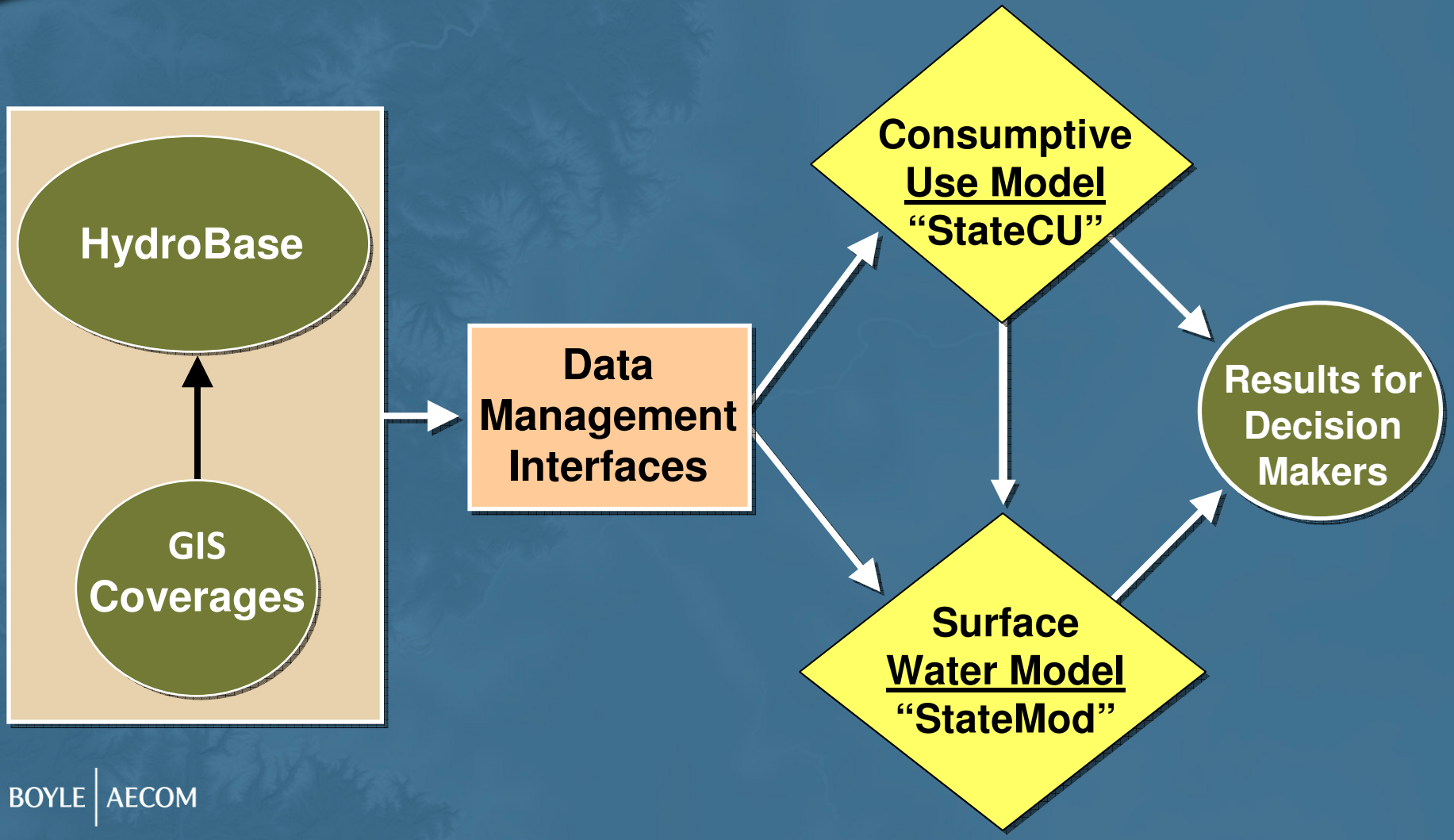
1) Historical Hydrology – Data-Centered CDSS



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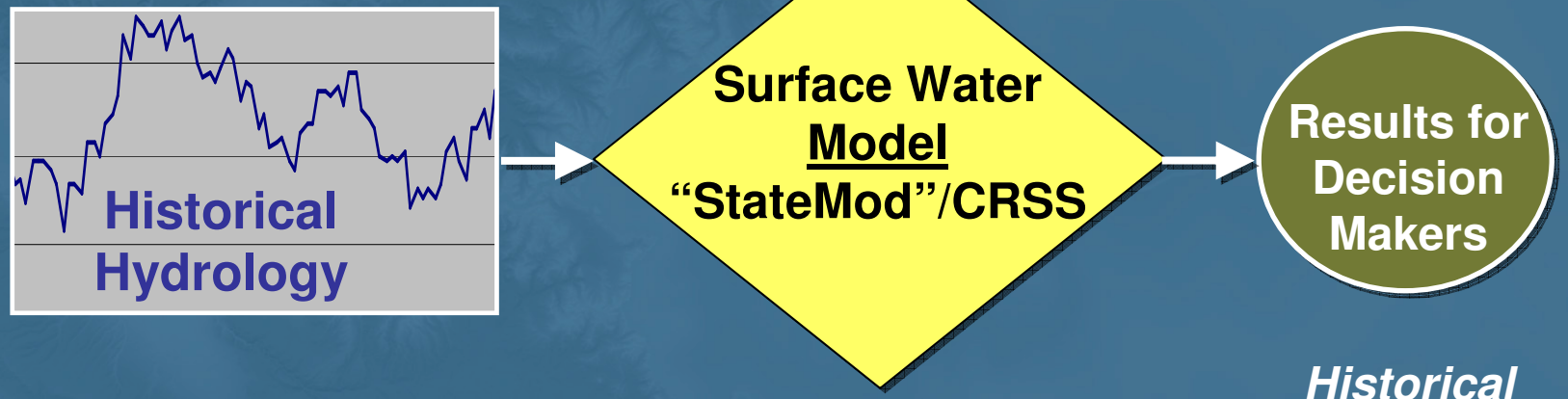
1) Historical Hydrology → Water Availability



Historical

Water Availability

Reservoir Conditions

Instream Flows

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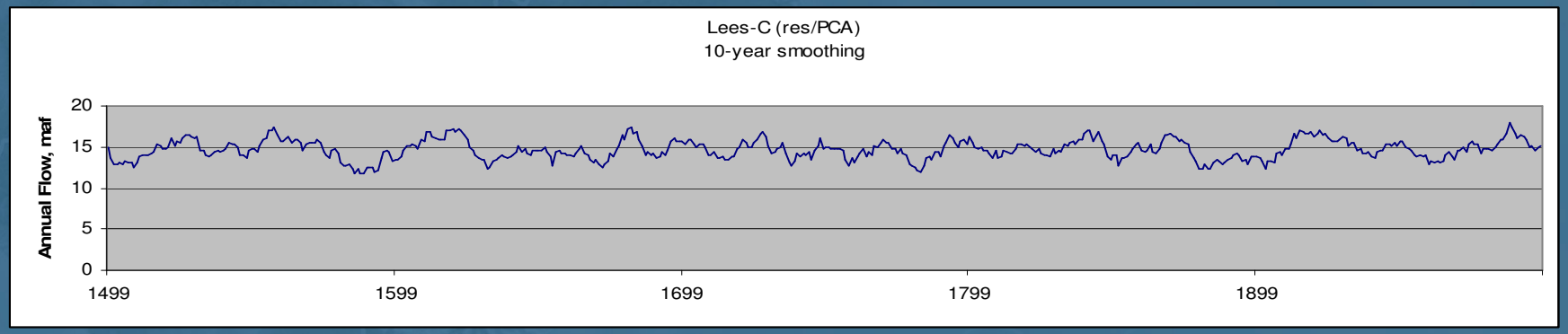
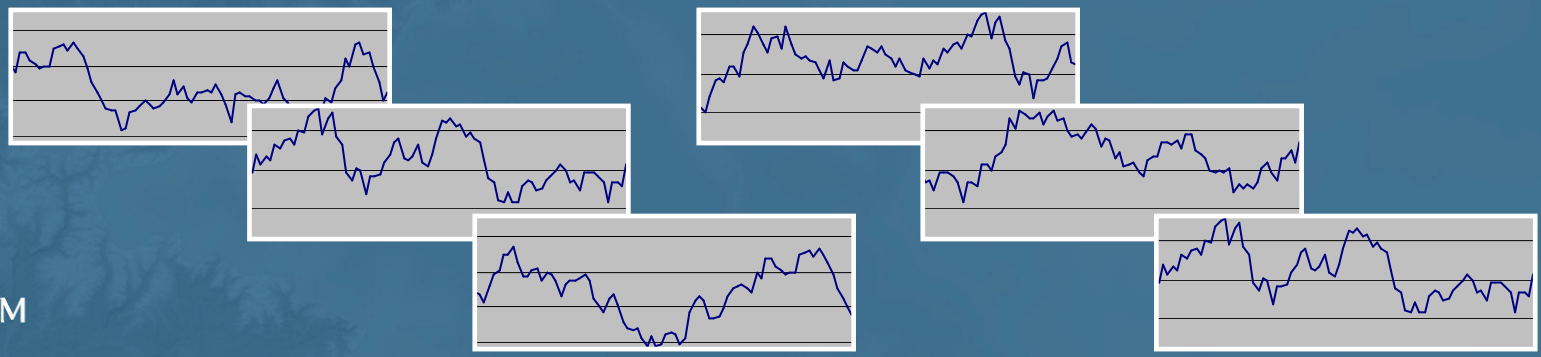
2) Alternate Historical Hydrology (Paleohydrology)

Reconstructed Flows



"Ensemble" of "Traces"



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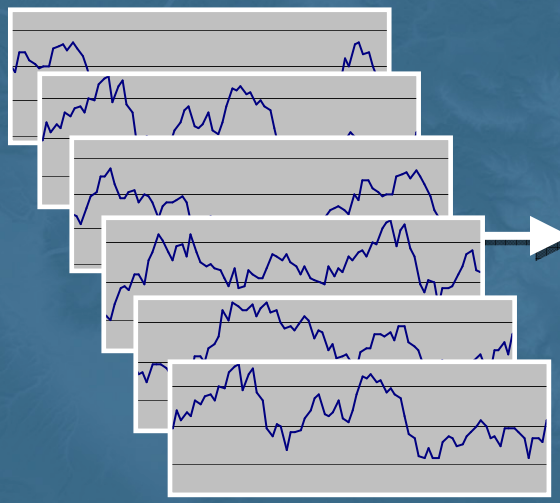
2) Alternate Historical Hydrology ➔ Water Availability

"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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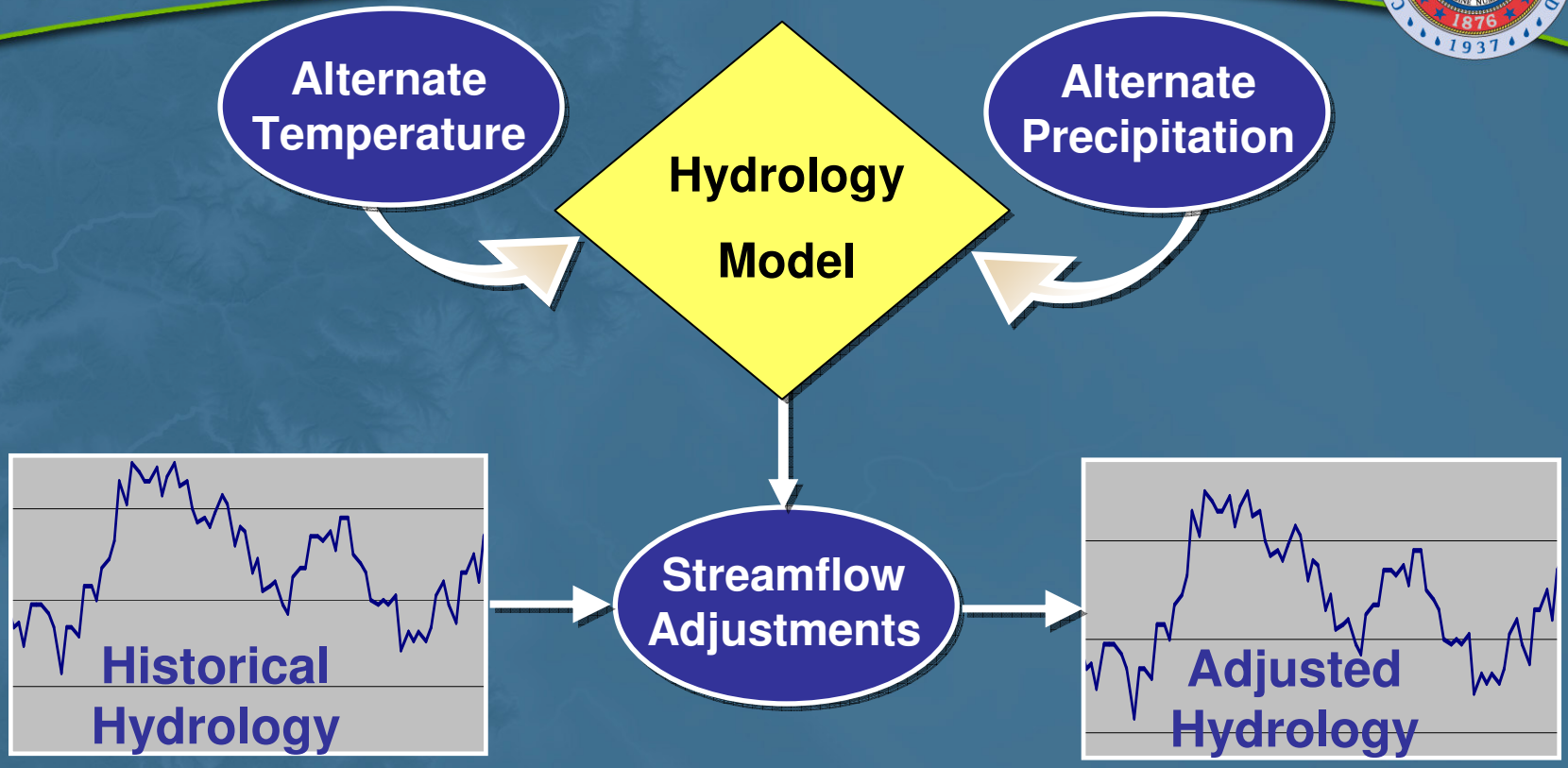
3) Alternate Hydrology of Climate Change



CRDSS Natural Flows
CRSS Natural Flows

CRDSS Adjusted Flows
CRSS Adjusted Flows

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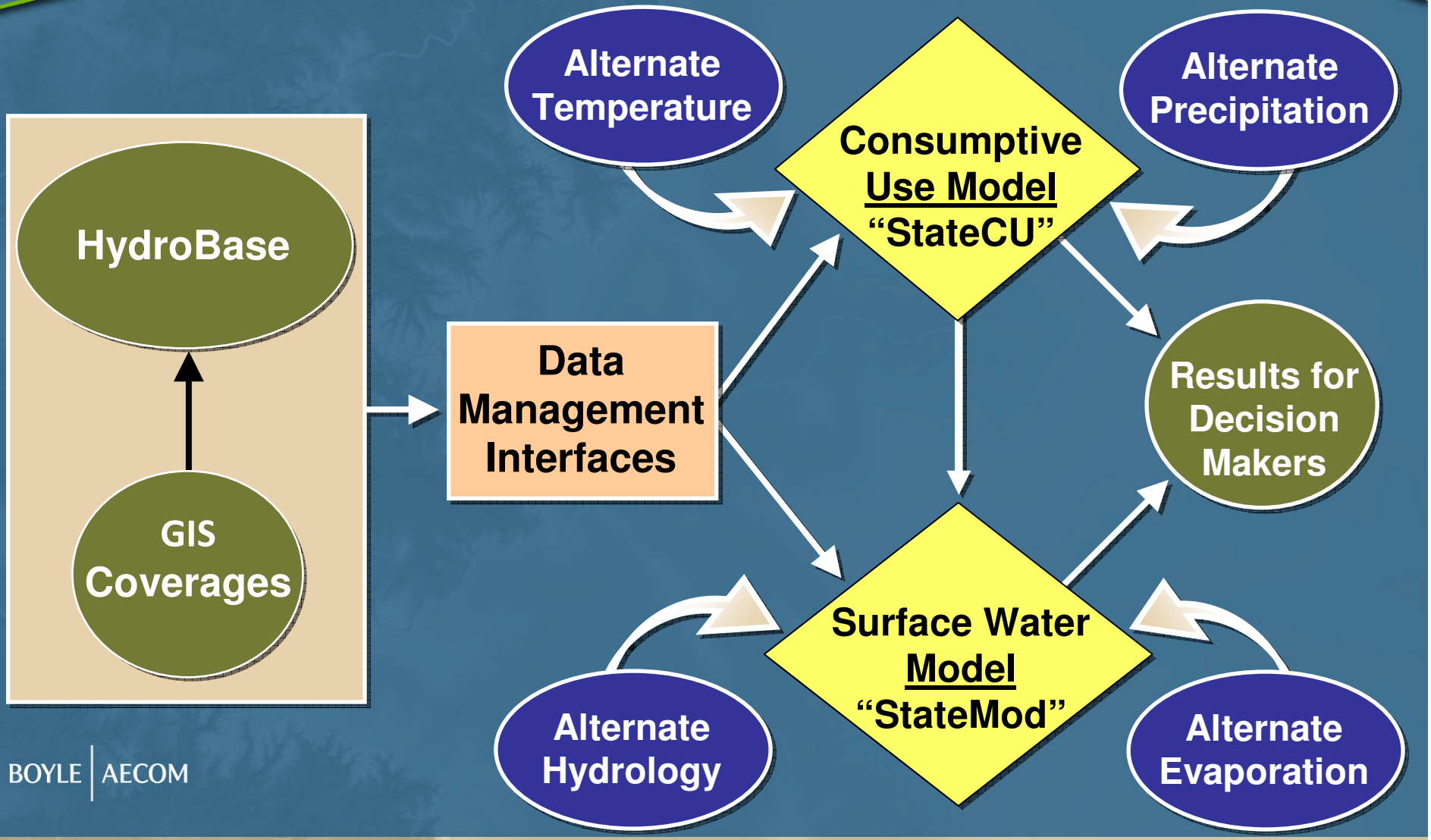
3) Alternate Hydrology of Climate Change



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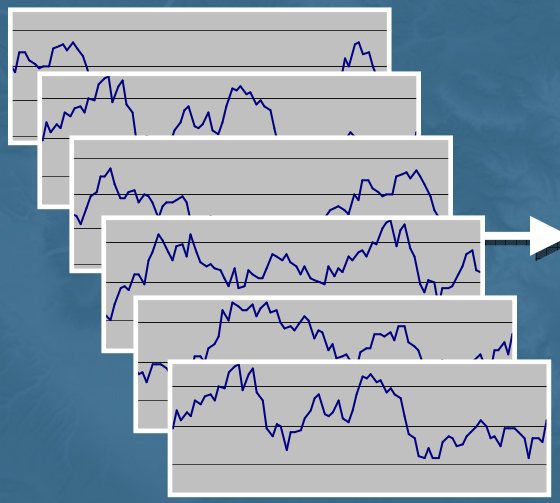
3) Alt. Hydrology / Climate Change → Water Availability

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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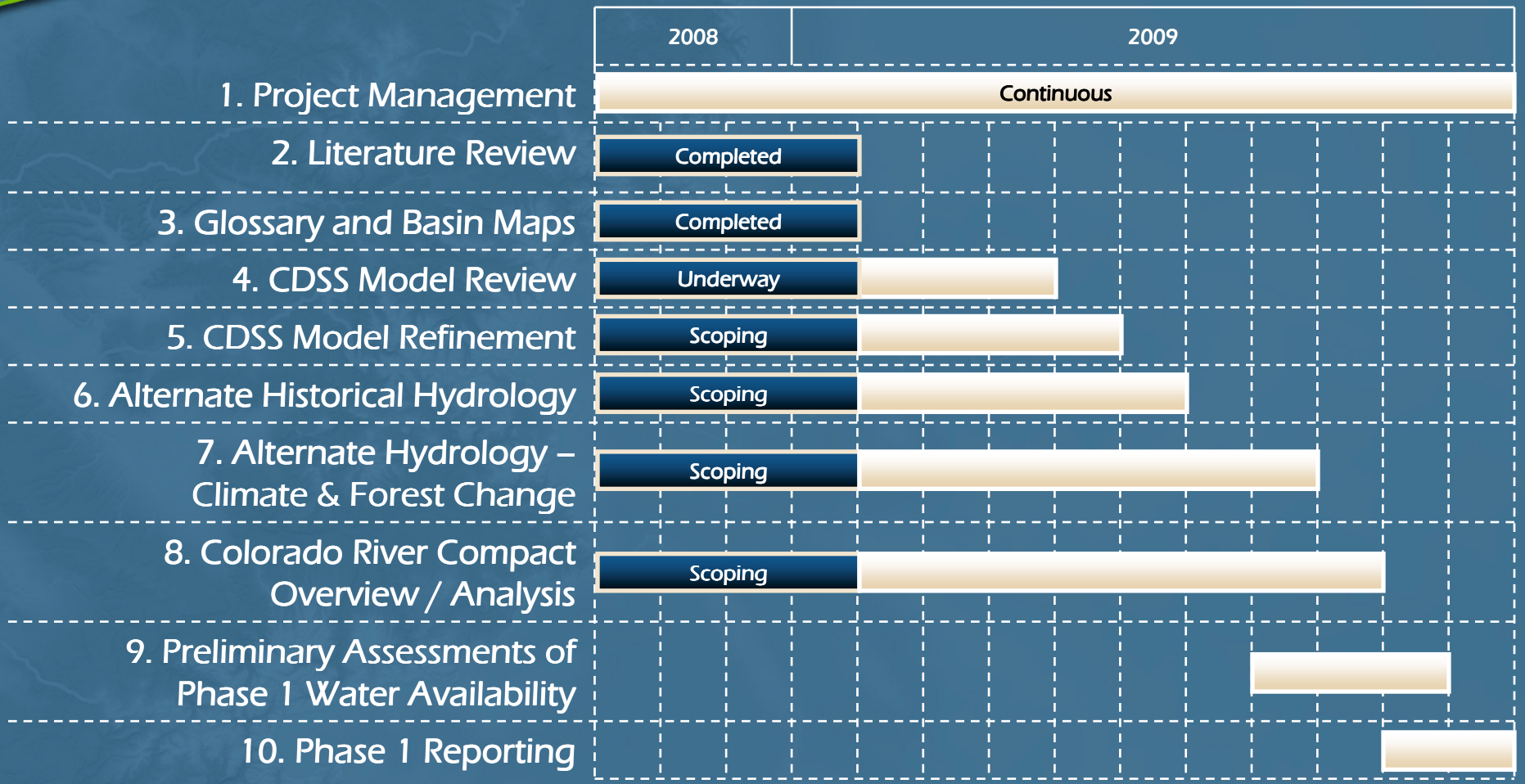
Study Status – Phase I



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CDSS Discussion - Purpose

- Present CDSS Information Specific to Yampa and White Basins
- Increase Comfort with CDSS Models and Procedures
- Provide Context for Review of Model Briefs
- Generate Discussion of Potential Model Enhancements

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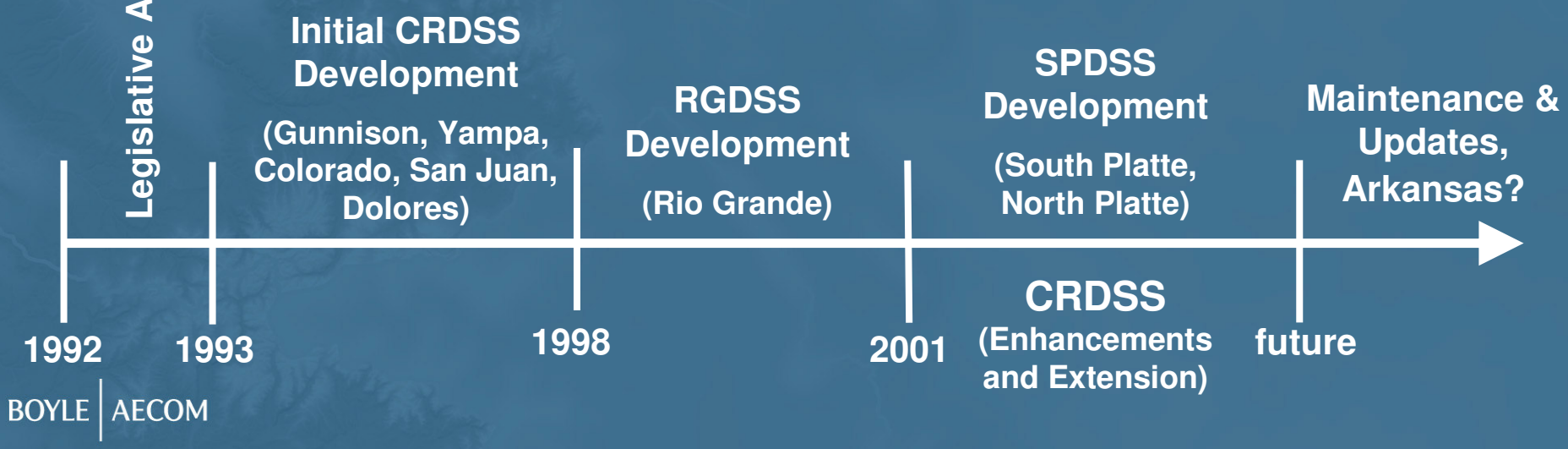
CDSS Overview

- 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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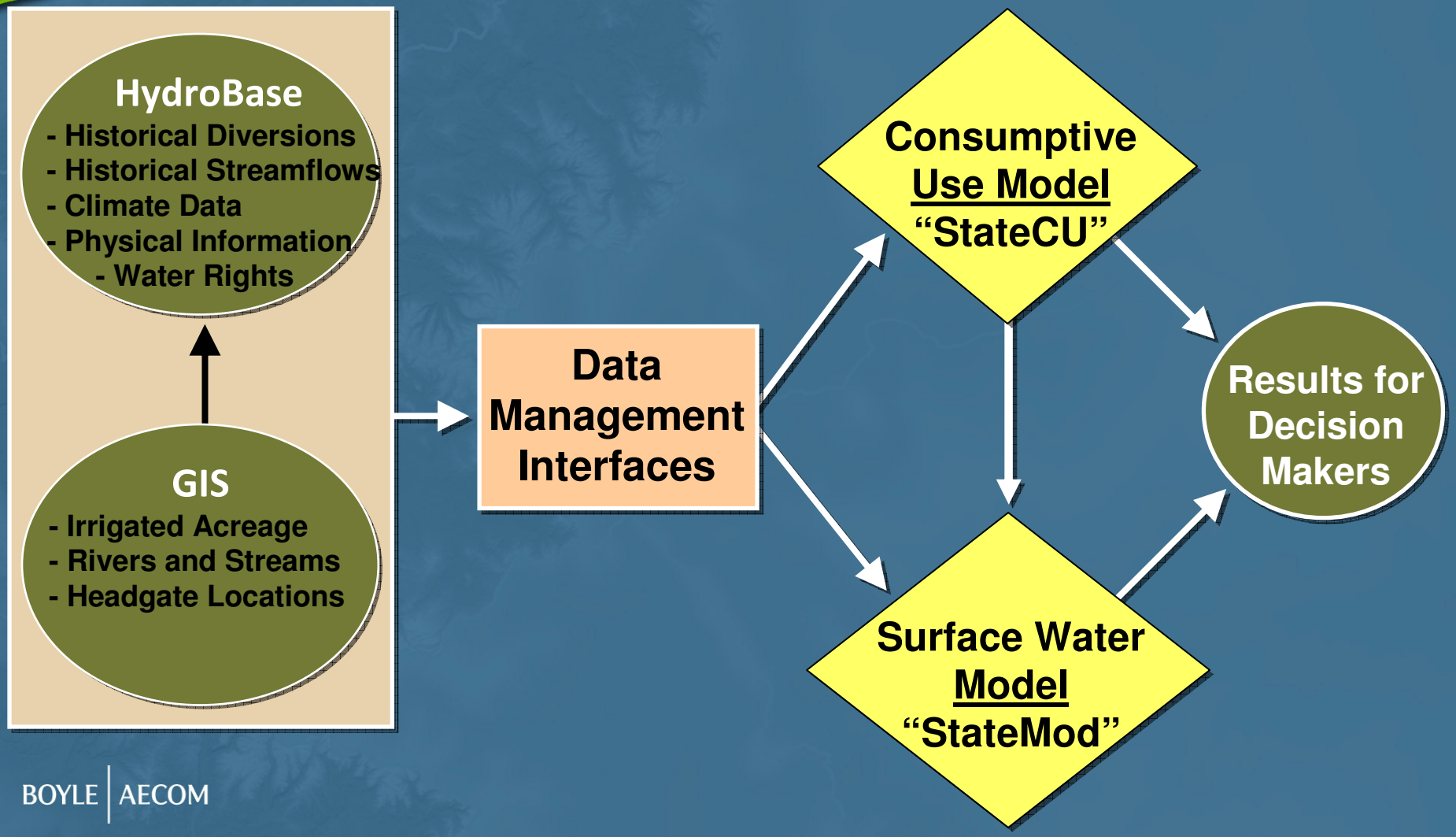
CDSS Overview - Data-Centered Approach



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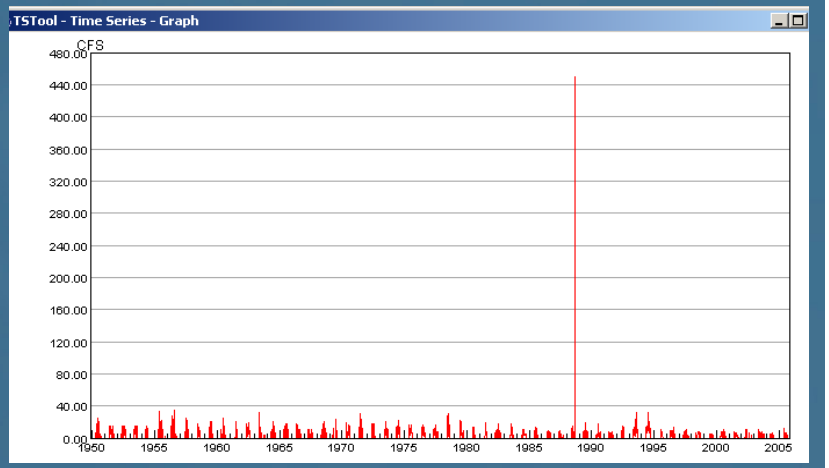
CDSS Overview – Data Collection

- Digitized Water Commissioner Diversion Records to include in HydroBase
- Reviewed WISP Data and Water Rights Information to Identify errors
- Worked with Reservoir Operators to provide Historical Storage Data
- Reviewed Data from other Sources to "Approve" including in HydroBase



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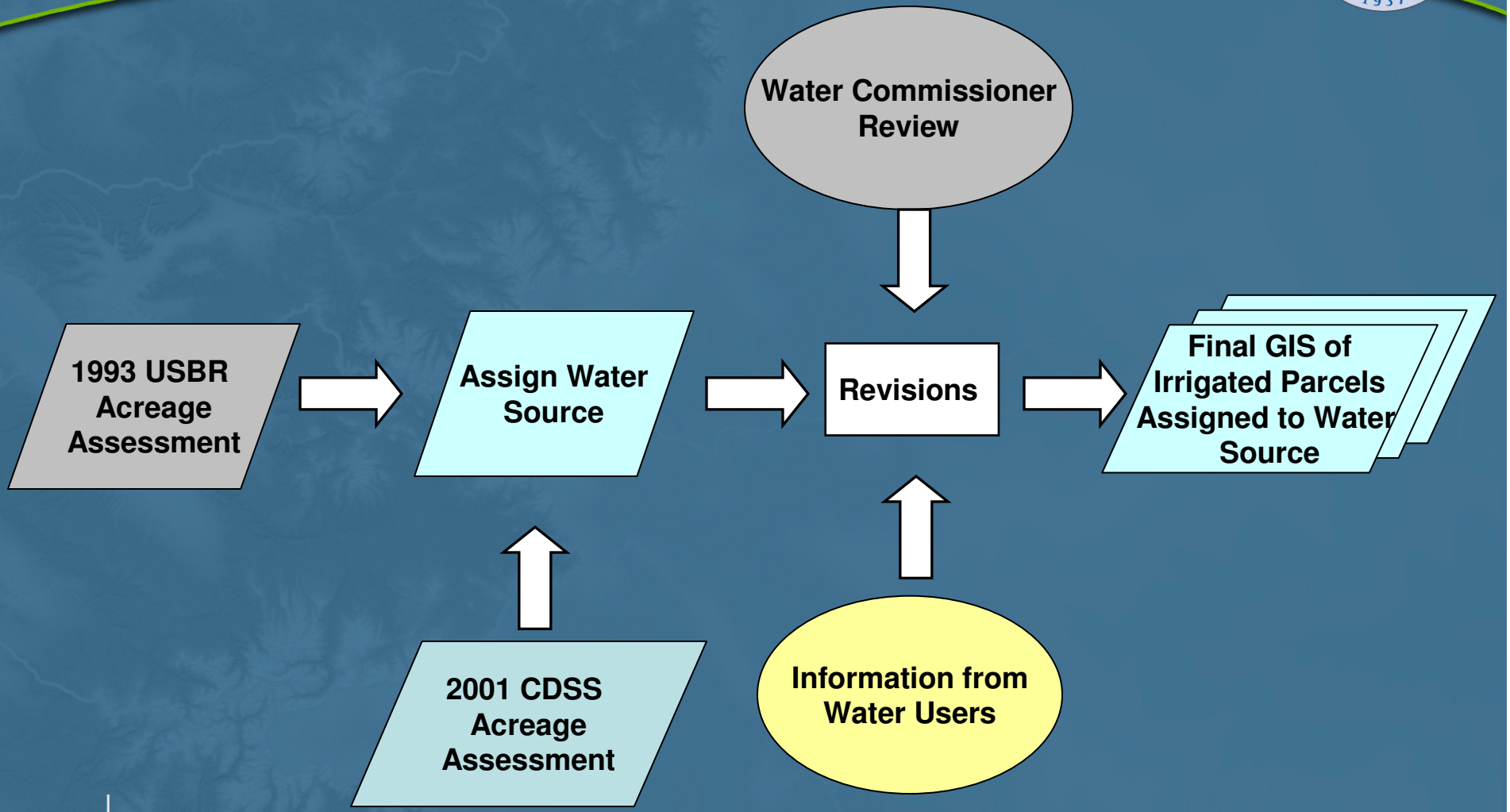
CDSS Overview – Data Collection



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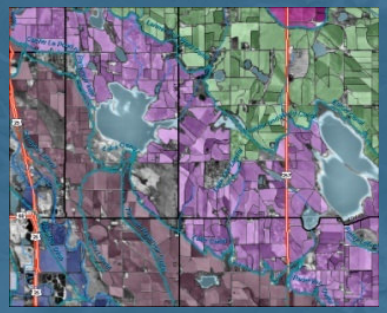
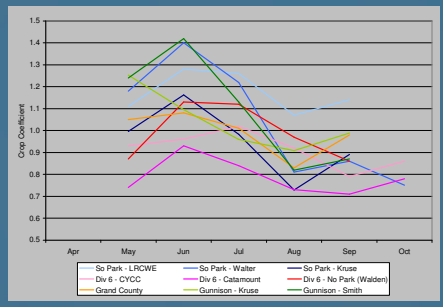
Consumptive Use Analysis (StateCU)

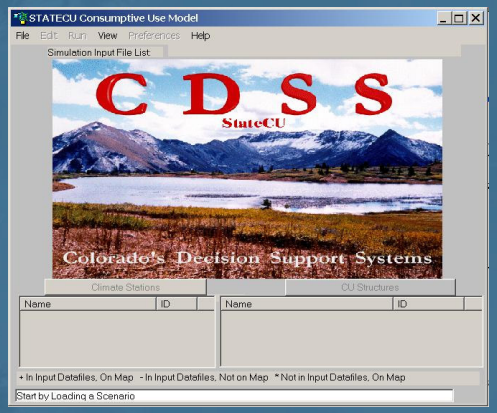
Supplemental Sources User Info

Irrigated Acreage, Crop Type, Irrigation Method

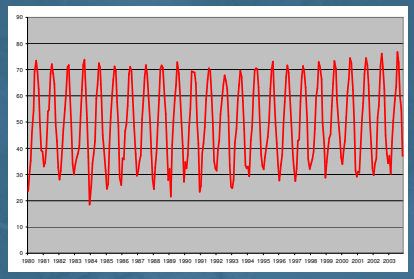


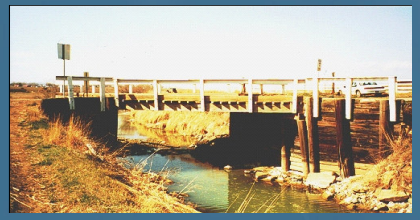


CU Method Review and Selection



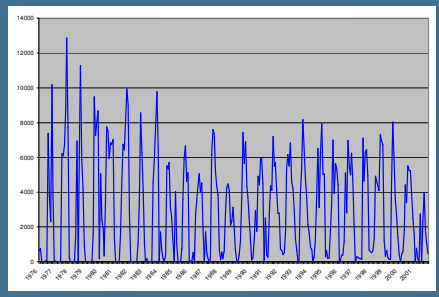
Climate Data





Irrigation Efficiencies

Water Supply Data



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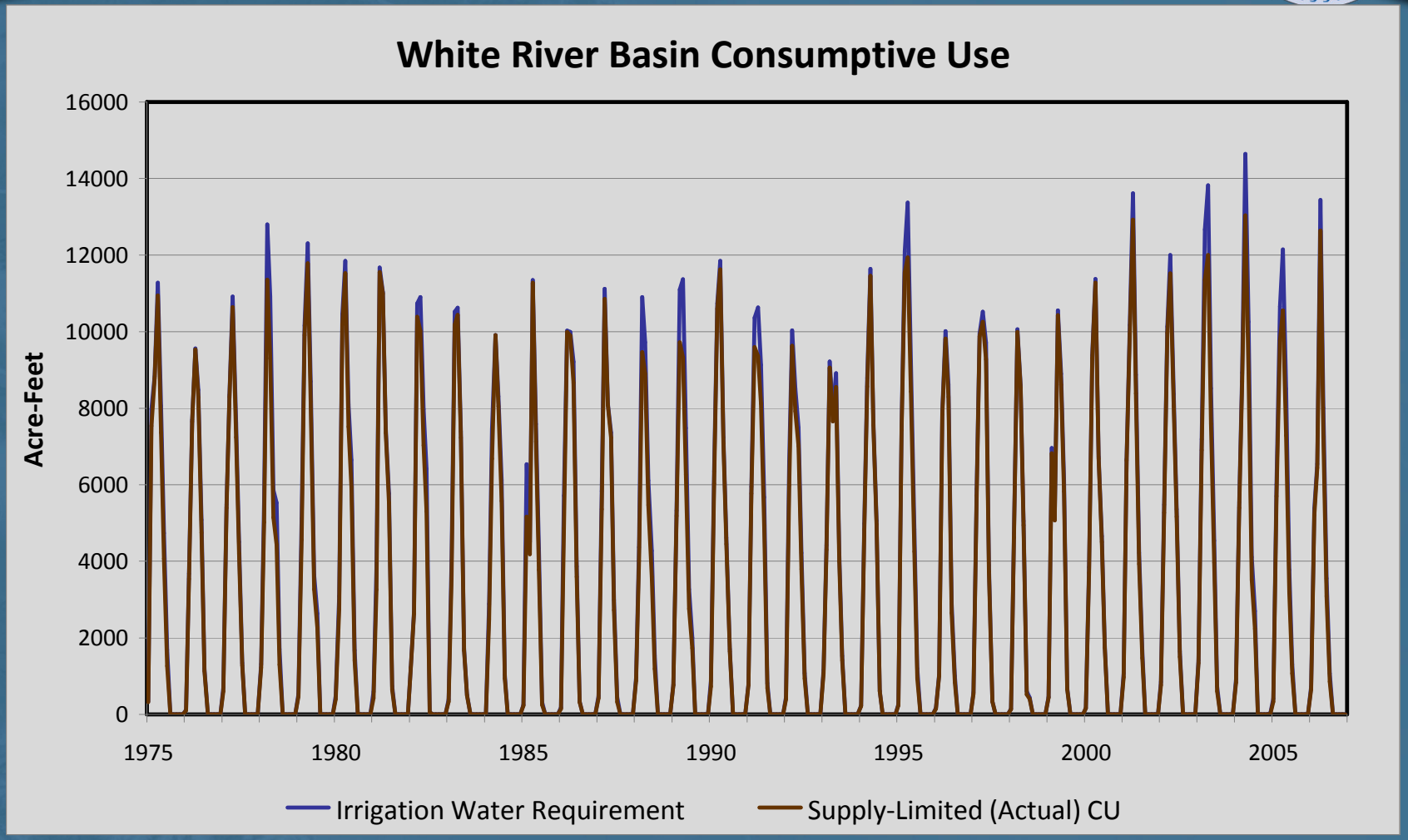
Consumptive Use Analysis



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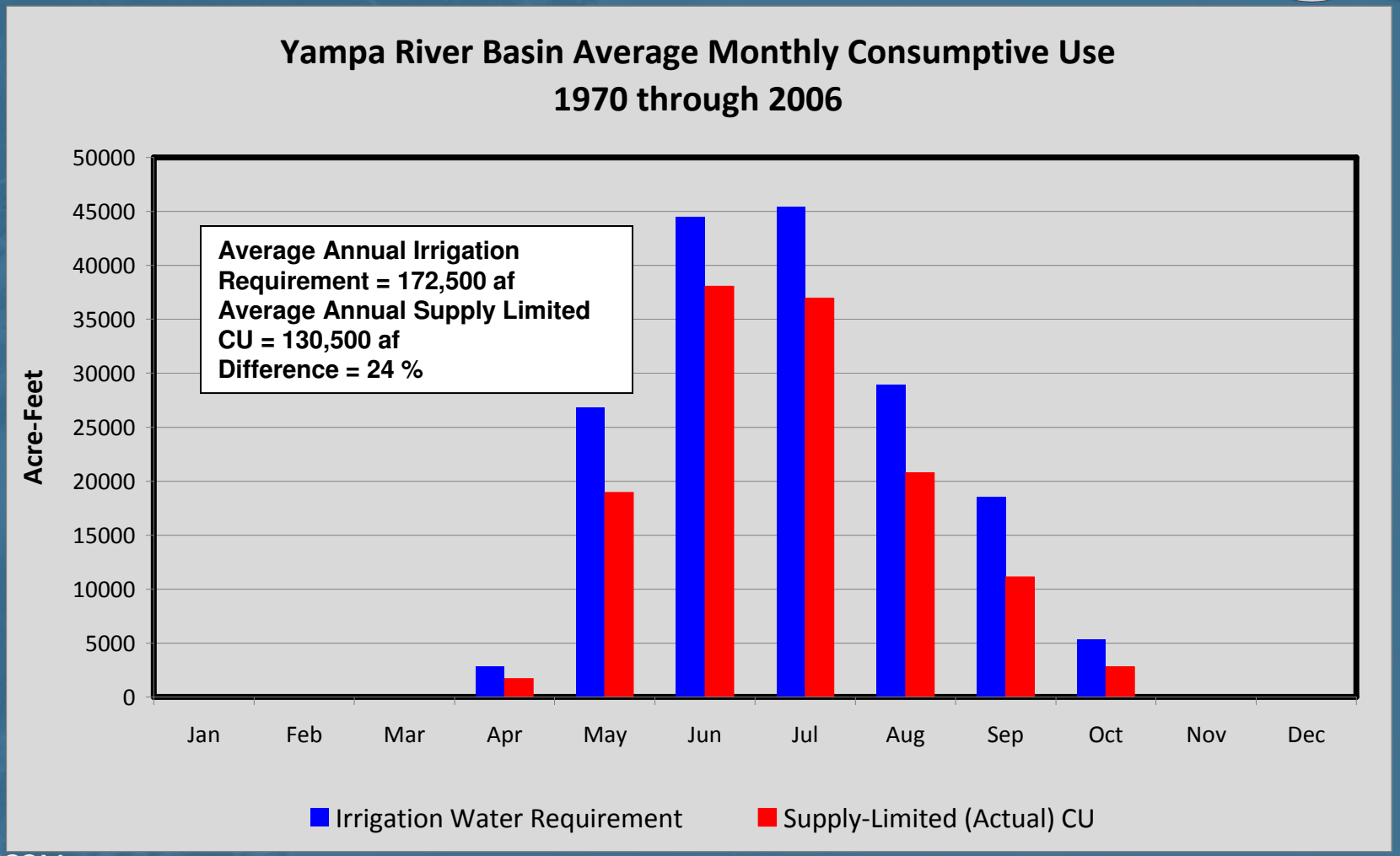
Consumptive Use Analysis



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Consumptive Use Analysis

- CDSS Method Compared to USBR Method for Upper Basin Compact Consumptive Uses and Losses Reporting

	USBR Method	CDSS Method
Irrigated Acreage	1993 USBR GIS	1993 USBR GIS
Potential Crop CU Method	Blaney-Criddle, Coefficients Developed at Lower Elevations	Blaney-Criddle, High-Altitude Coefficients
Shortage Methods	Reduce CU Based on Indicator Gages	Supply-Limited CU Based on Actual Diversions

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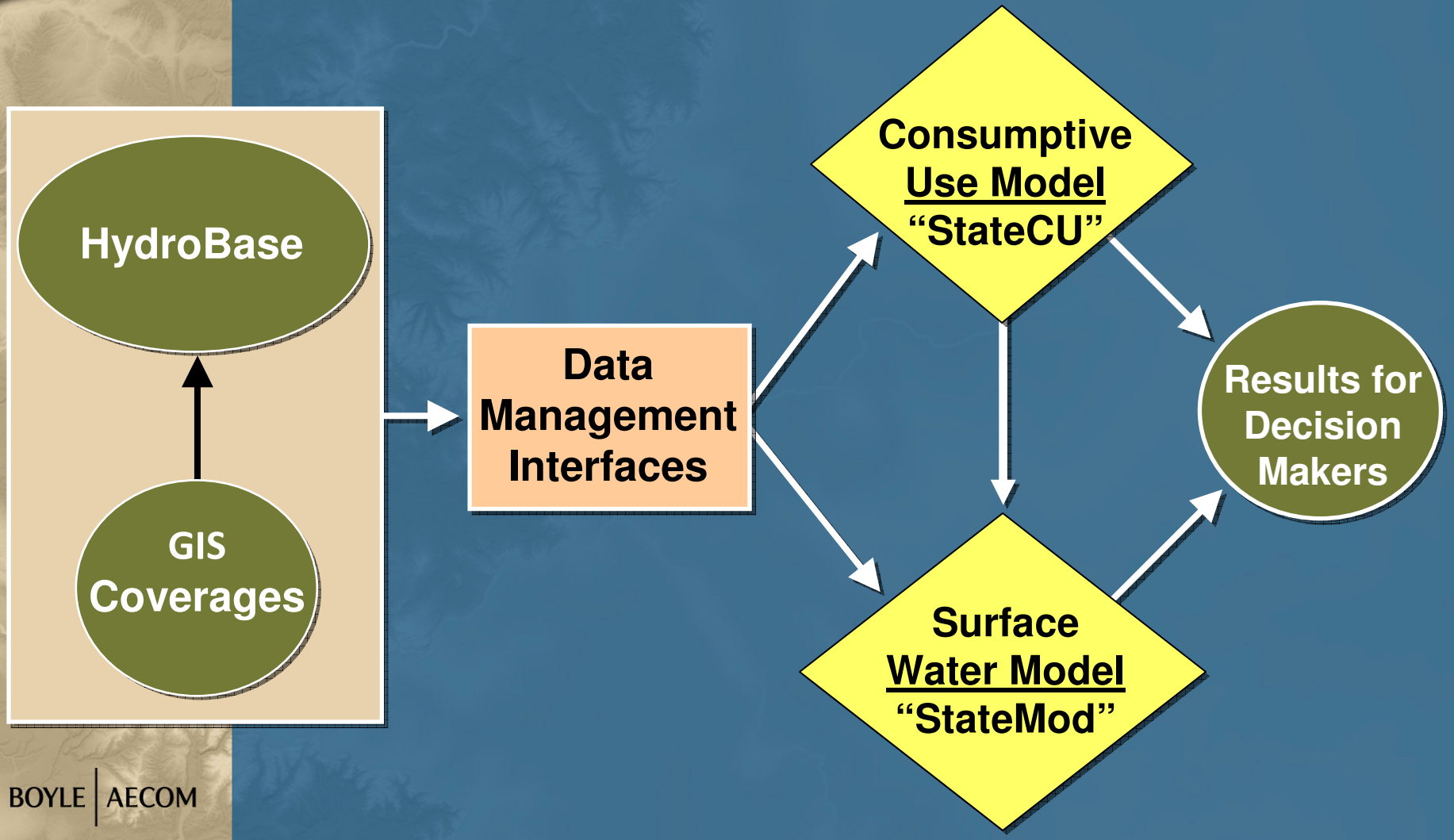
Consumptive Use Analysis



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StateCU and StateMod

- 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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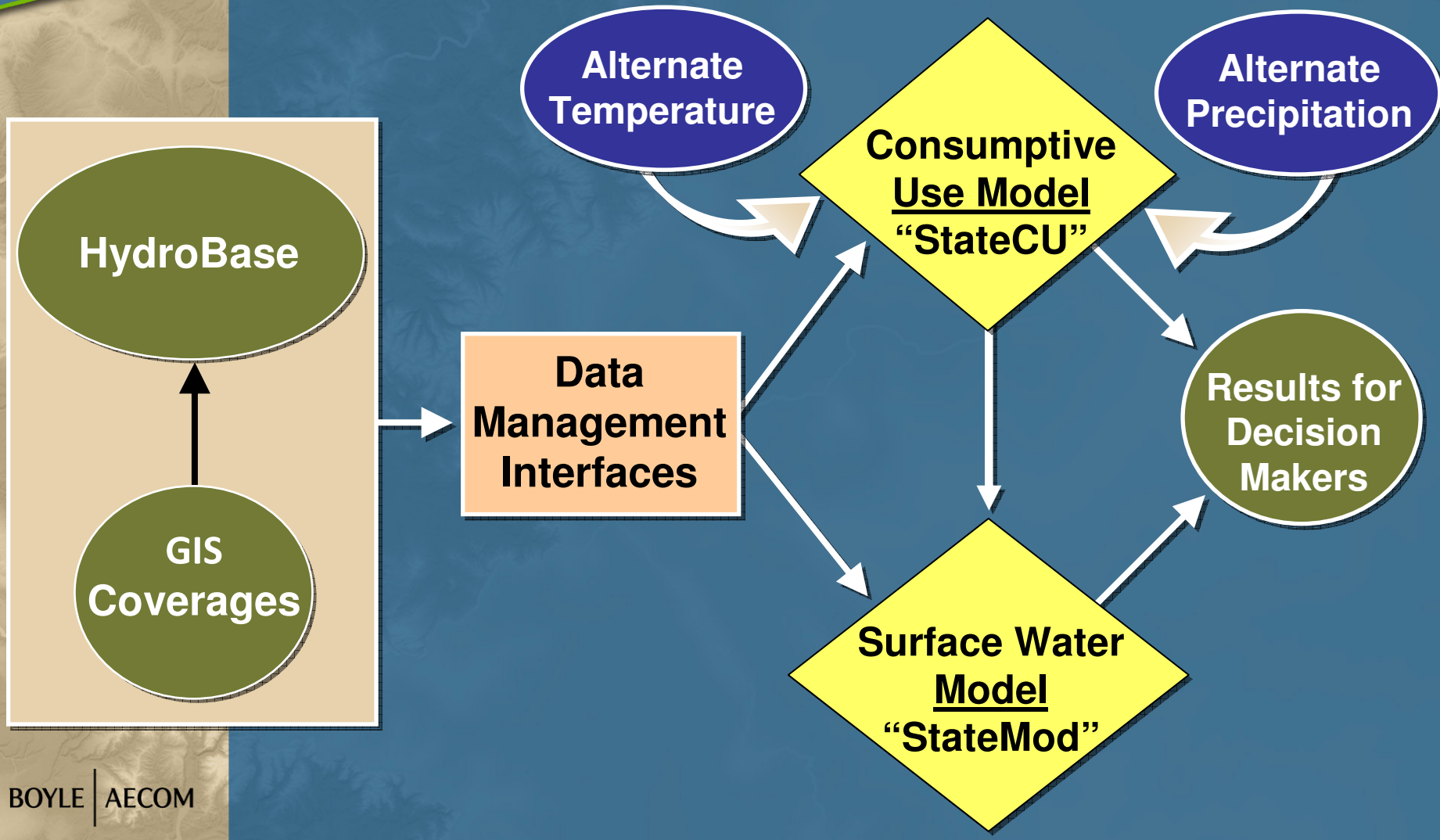
StateCU - Alternate Hydrology of Climate Change



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StateMod Overview

- 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 Overview

- 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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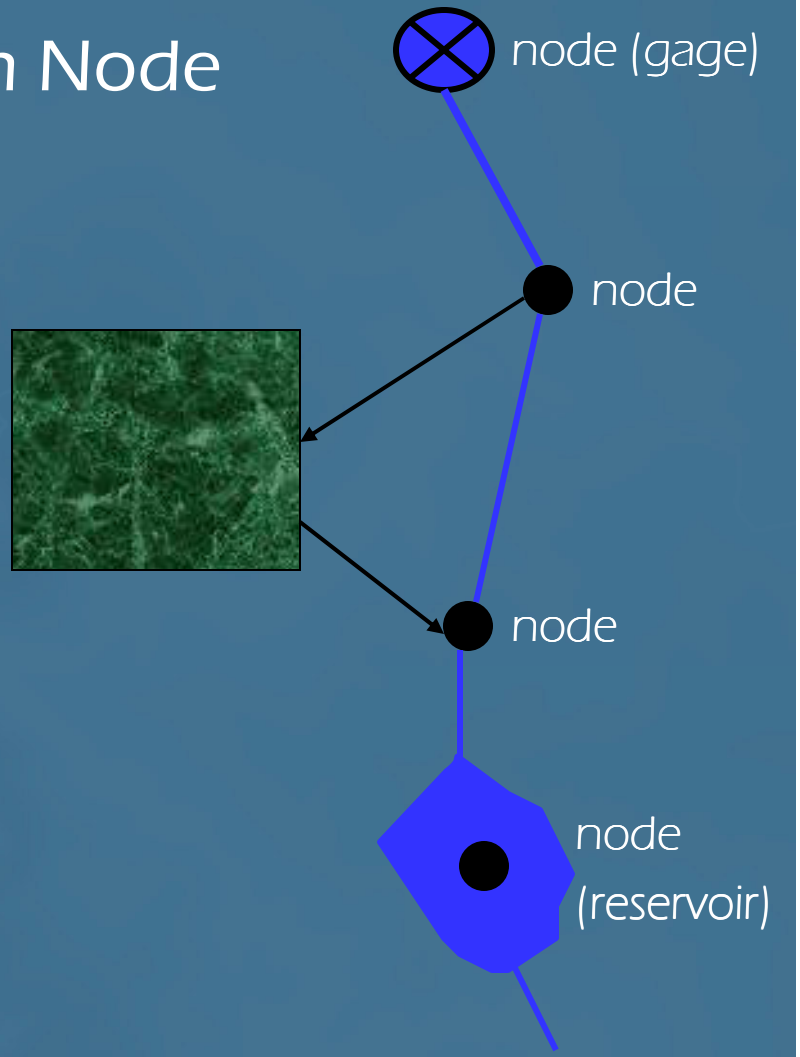
StateMod Overview

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



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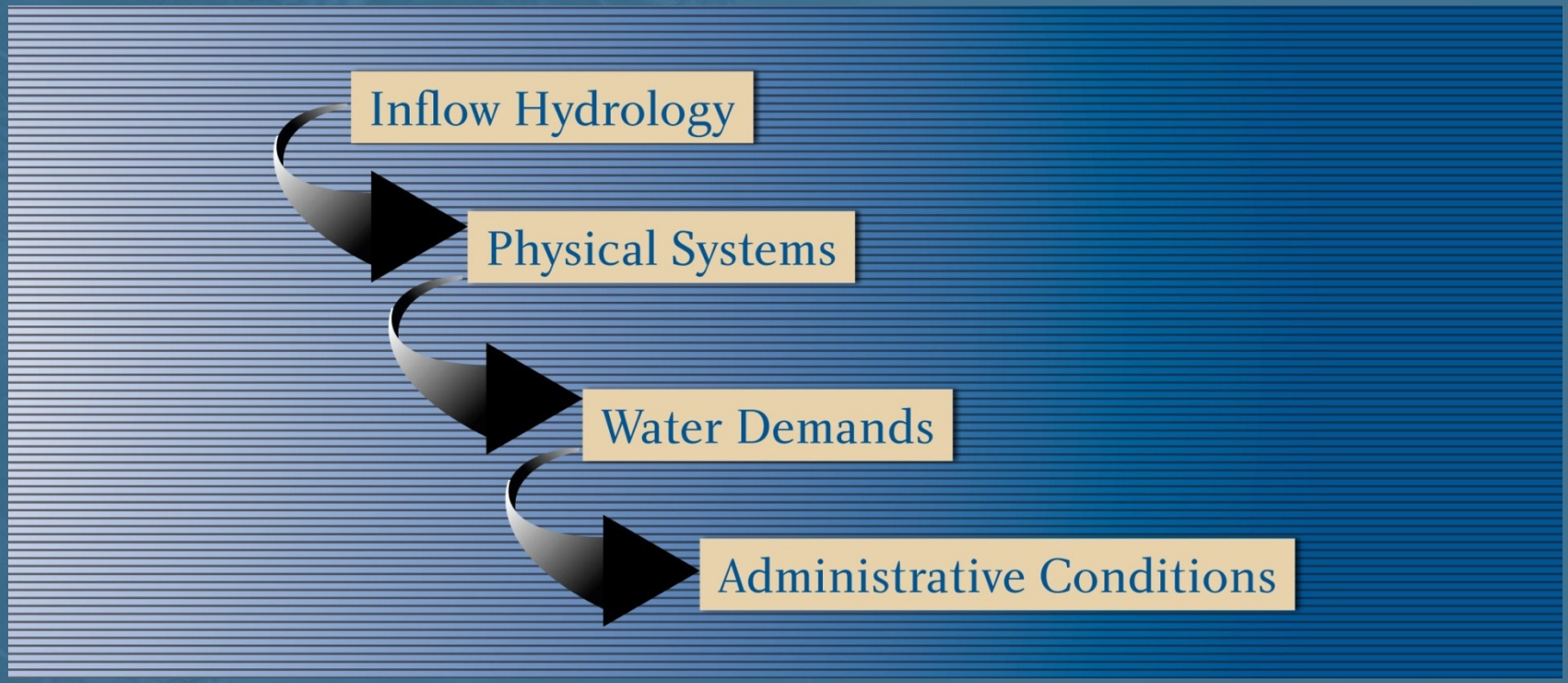
StateMod Model Components



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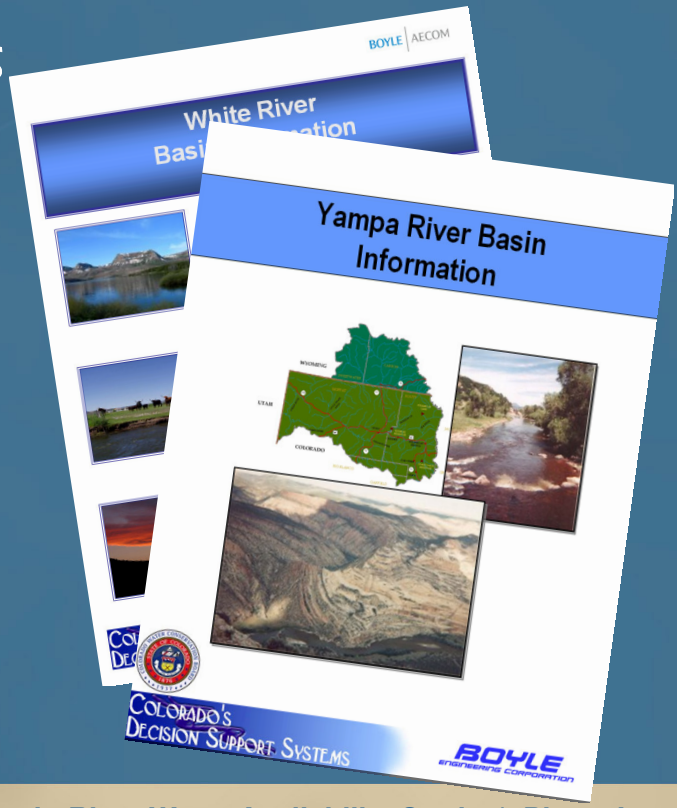
StateMod – Data Collection

- Interviewed water administrators and project operators
- Reviewed and summarized published data
- Identified Irrigation Practices and supplemental sources
- Not model-specific
- Available at http://cdss.state.co.us/ (Products, Surface Water Model)



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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
- Yampa Model includes Little Snake basin in Wyoming – data from Wyoming's Green River Basin Plan

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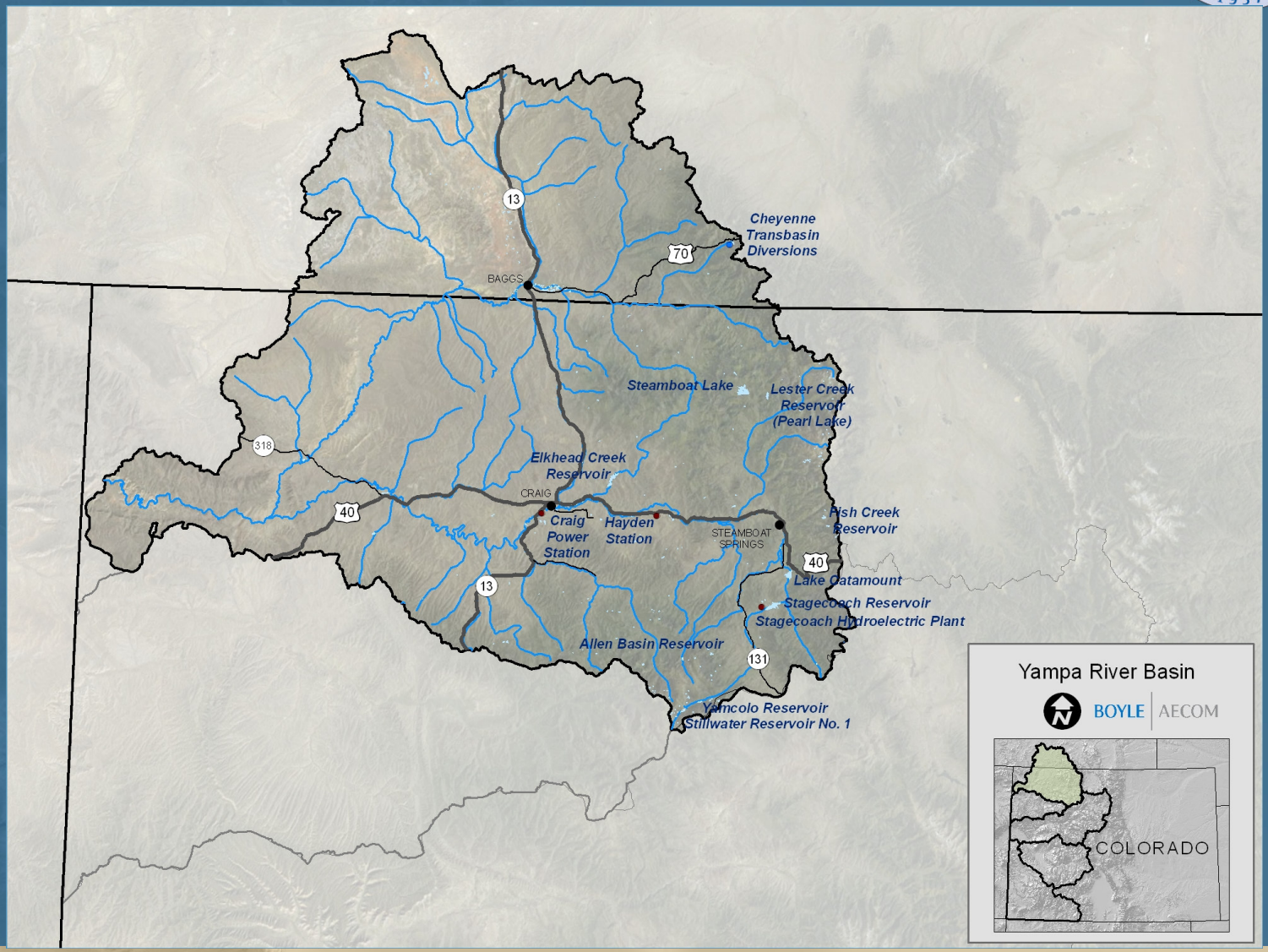
Inflow Hydrology – Yampa River Basin



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Inflow Hydrology – White River Basin

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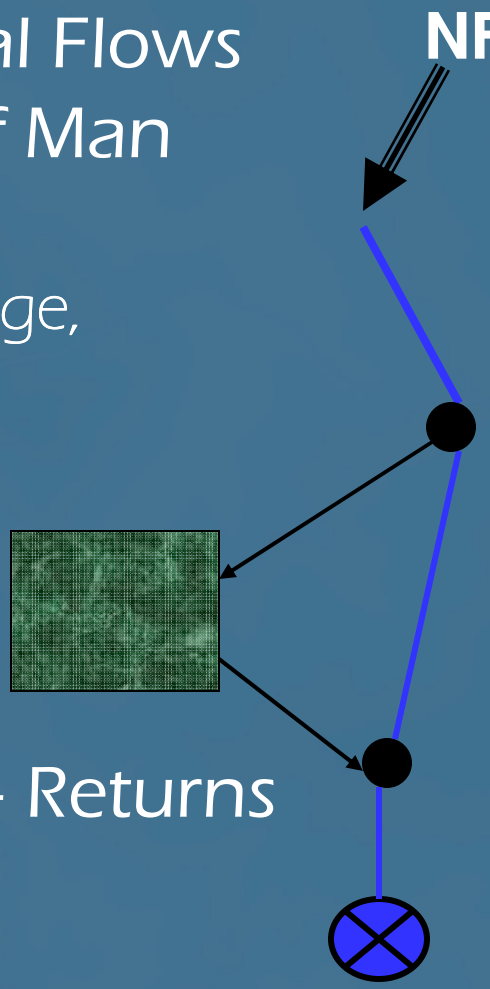
Inflow Hydrology – Natural Flow Development

- 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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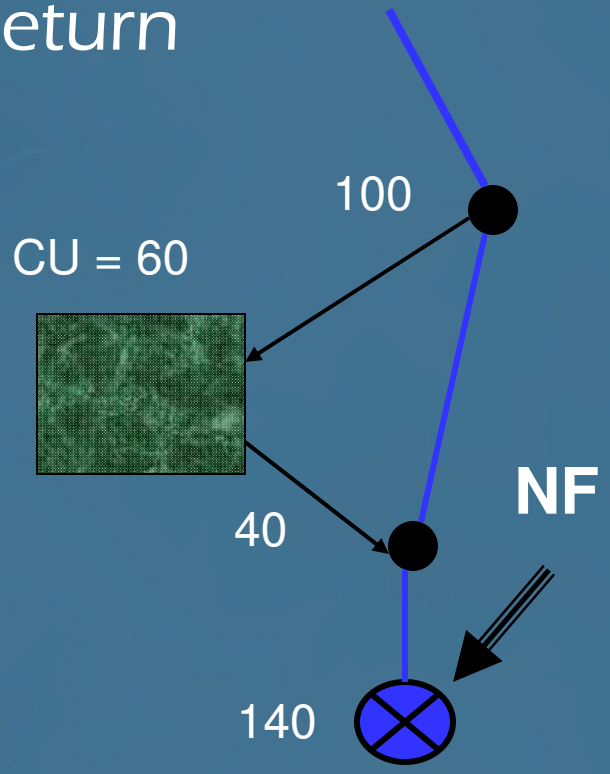
Inflow Hydrology – Natural Flow Development

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



NF = 140 + 100 – 40

NF = 200

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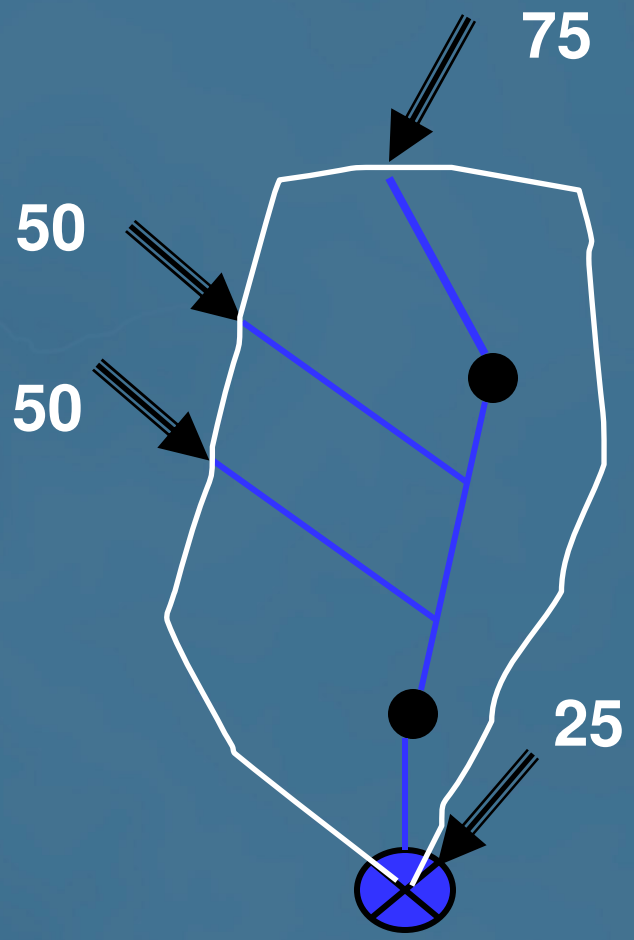
Inflow Hydrology – Natural Flow Development

- Distribute Natural Flow Gains to ungaged tributaries



Overall Gain = 200

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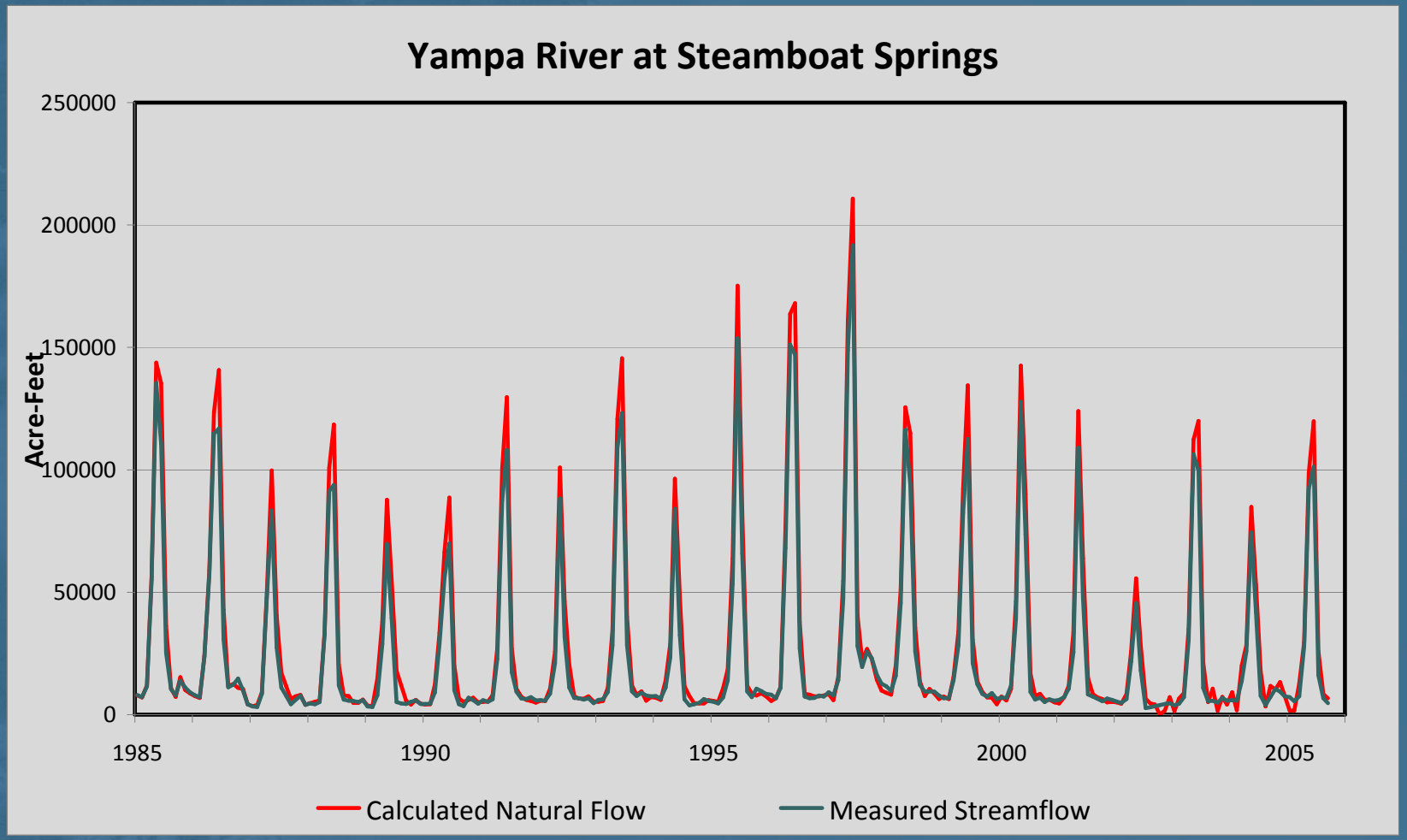
Inflow Hydrology



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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

- Yampa River – 235 Key Diversions representing
  - ~ 63,000 Irrigated Acres
  - Large/ "important" irrigation structures (calling or swing structures, structures with reservoir water
  - 7 Municipal and Industrial Diversions
- White River – 96 Key Diversions representing
  - ~ 23,000 Irrigated Acres
  - Large/ "important" irrigation structures (calling or swing structures, structures with reservoir water
  - 4 Municipal and Industrial Diversions

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Physical Systems

- Remaining Structures are Represented in Aggregates
  - Grouped by Location
  - Structures on Smaller Tributaries not Represented in the Model; Structures without Diversion Records, most Wyoming structures (Yampa)
  - Yampa aggregated irrigation: ~ 29,000 acres
  - White aggregated irrigation: ~ 6,000 acres

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Physical Systems

- 11 Key Reservoirs
  - 130,000 Acre-feet Combined Storage

Elkhead	Steamboat Lake	Stagecoach
Allen Basin	Yamcolo	Fish Creek
Pearl Lake	Stillwater	Lake Catamount
Kenney Reservoir (aka Taylor Draw Reservoir)	Big Beaver (aka Lake Avery)	

- 23 Instream Flow Segments, plus Kenney Reservoir bypass Requirement

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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 Demands Average Monthly Diversions from recent period
  - Yampa:1999 - 2004
  - White: 1998 - 2006
- Reservoir "Demands"
  - Reservoir Capacities or Operational Targets

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Water Demands – Sources

- Reservoir "Demands"
  - Only place operational targets used is Lake Catamount

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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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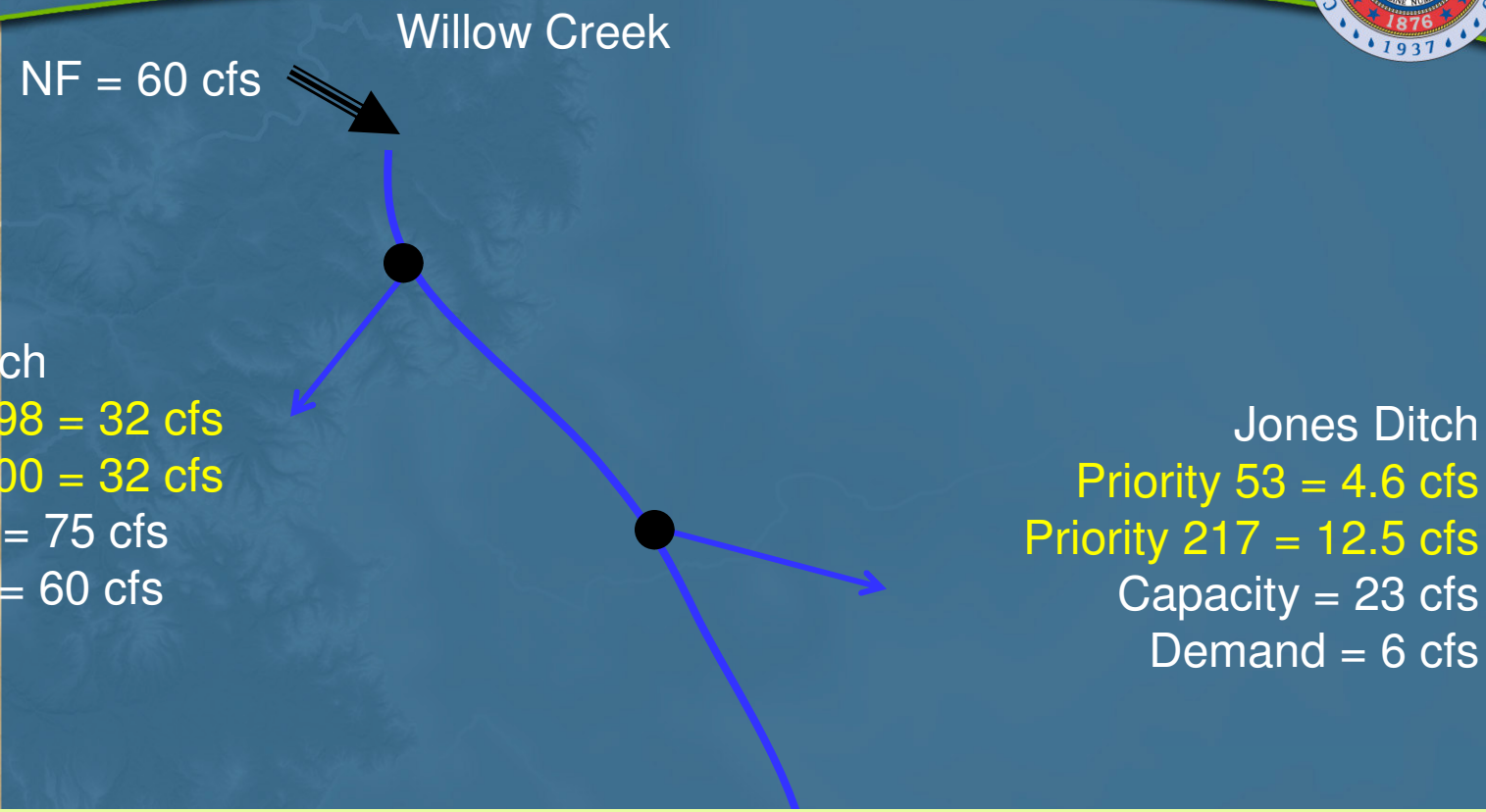
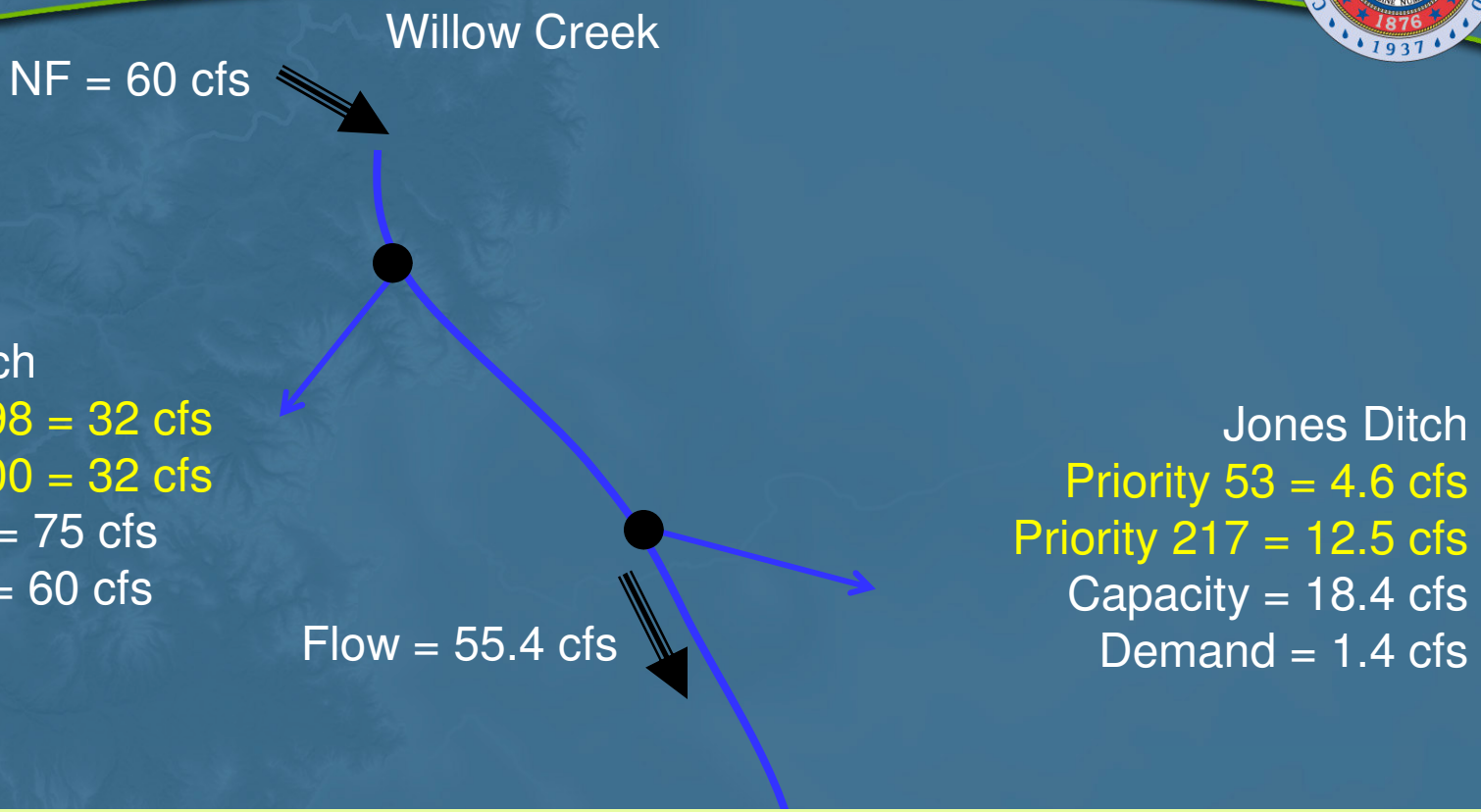
Model Operations



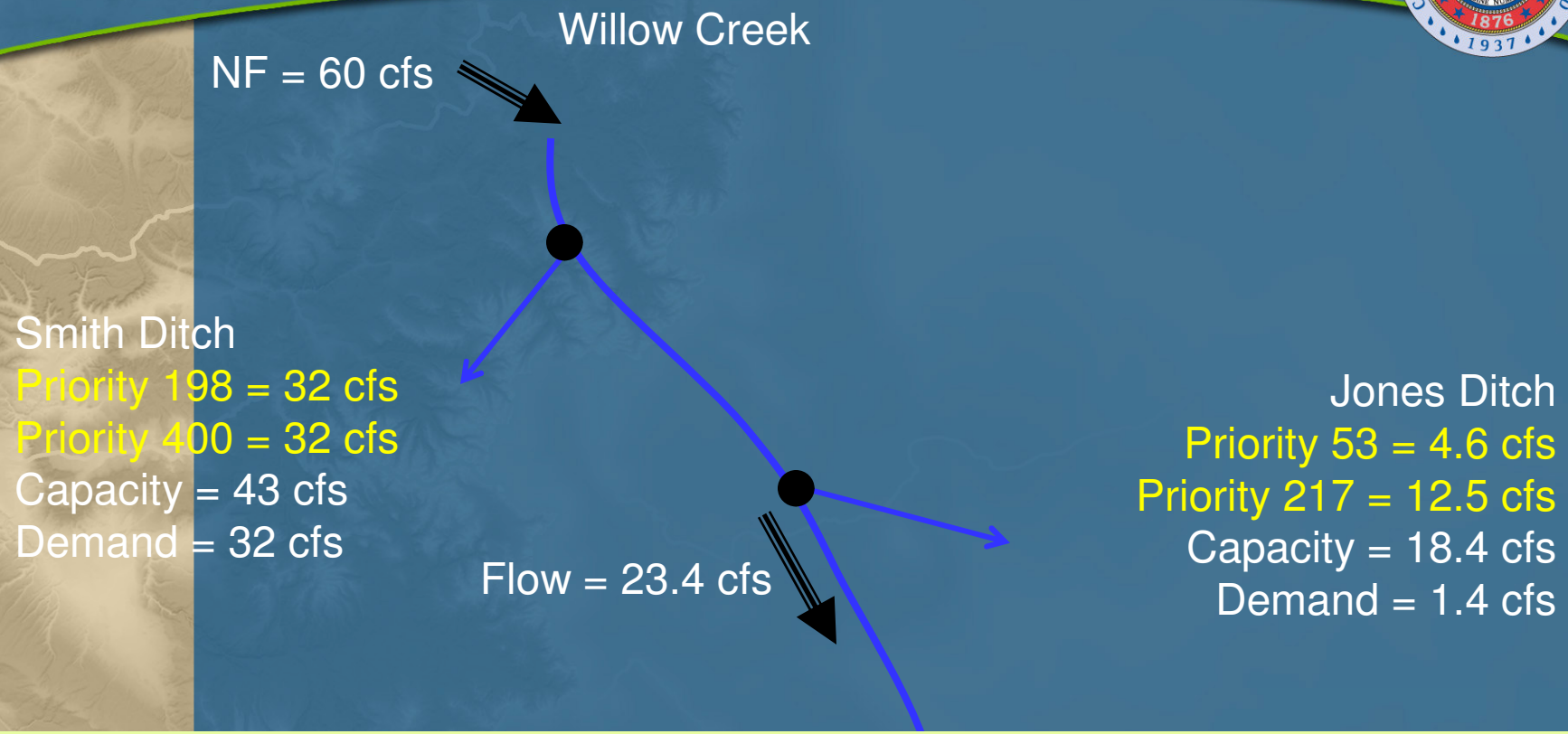
1) Priority 53: Direct Diversion = min (demand, water right, capacity, physical flow) = min(6, 4.6, 23, 60) = 4.6
2) Demand is decreased to 6 - 4.6 = 1.4
3) Diversion structure capacity is decreased to 23 - 4.6= 18.4
4) Flow Downstream is Decreased to 60 - 4.6 = 55.4

Model Operations



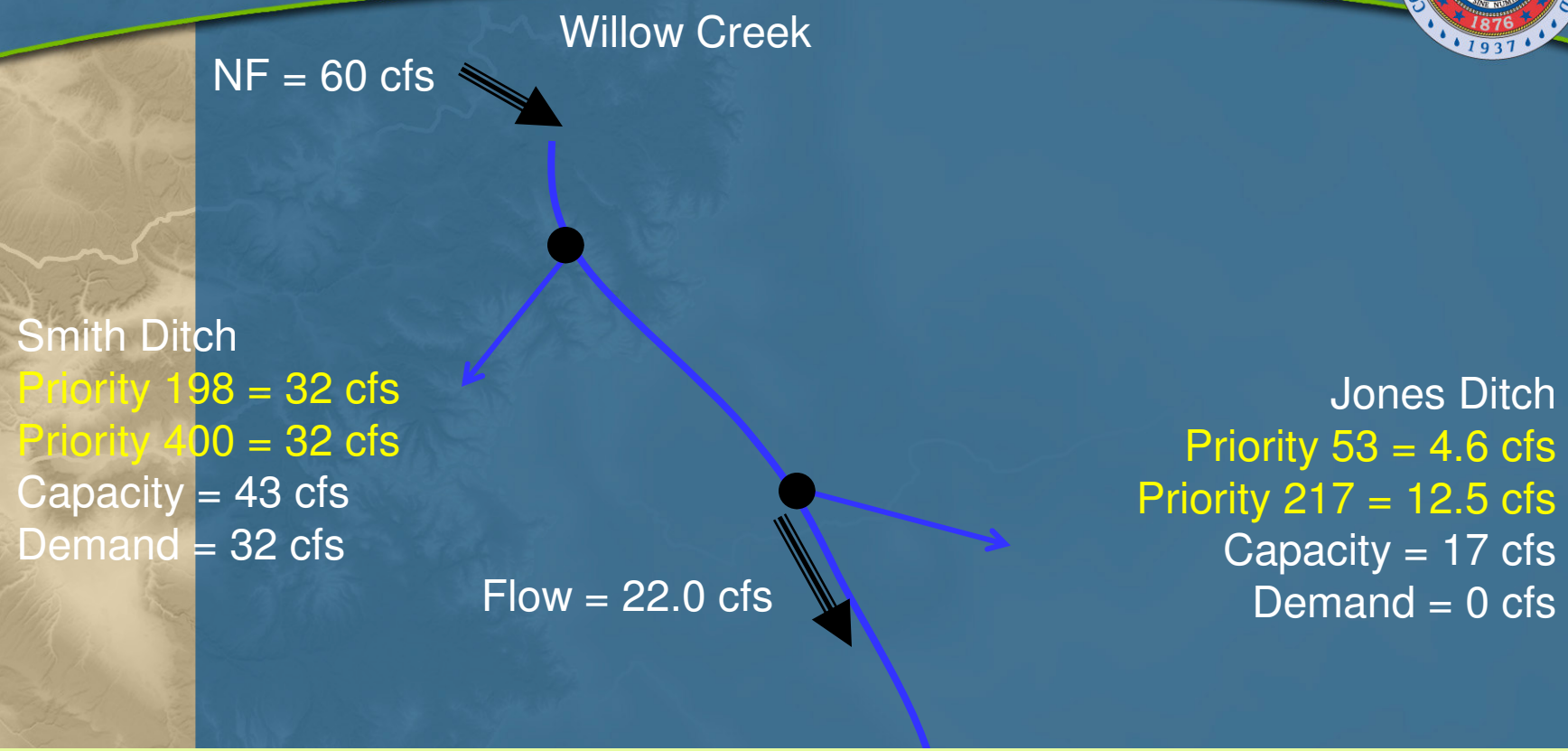
5) Priority 198: Direct Diversion = min (demand, water right, capacity, physical flow) = min(60, 32, 75, 55.4) = 32
6) Demand is decreased to 60 - 32 = 28
7) Diversion structure capacity is decreased to 75 - 32= 43
8) Flow Downstream is Decreased to 55.4 - 32 = 23.4

Model Operations



9) Priority 217: Direct Diversion = min (demand, water right, capacity, physical flow) = min(1.4, 12.5, 18.4, 23.4) = 1.4
10) Demand is decreased to 1.4 – 1.4 = 0
11) Diversion structure capacity is decreased to 18.4 – 1.4= 17.0
12) Flow Downstream is Decreased to 23.4 – 1.4 = 22.0

Model Operations



13) Priority 400: Direct Diversion = min (demand, water right, capacity, physical flow)
    = min(32, 32, 43, 22.0) = 22.0
14) Demand is decreased to 28 – 22.0 = 6.0 **Demand is Shorted**
15) Diversion structure capacity is decreased to 43 – 22.0 = 21.0
16) Flow Downstream is Decreased to 21.9 – 21.9 = 0

Administrative Conditions

- Model "Operating Rules" Define:
  - How Water is "Carried" to Off-Channel Reservoirs (e.g. Allen Basin Supply)
  - How Demands are Satisfied From Reservoirs and in What "Priority" (e.g., Yamcolo, Stagecoach, Elkhead)
  - How Water is "Carried" to Collection Systems and Common Demands and in What "Priority"

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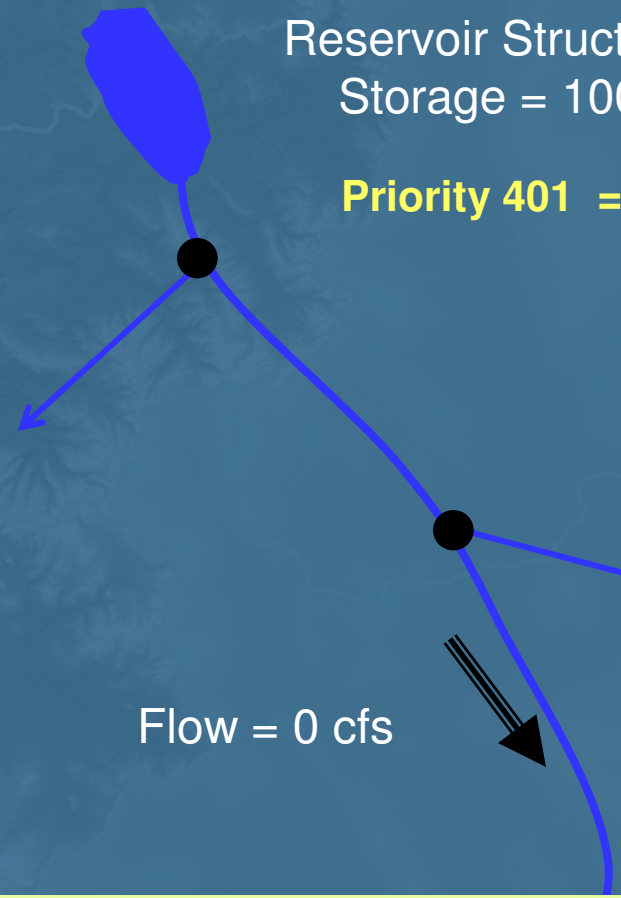
Model Operations



17) Priority 401: Reservoir Release Operating, Reservoir Release = min (demand, carrier capacities, reservoir storage) =min(6.0, 21,100) = 6.0
18) Demand is decreased to 6.0 – 6.0 = 0 **Demand is Satisfied**

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
  - Reservoirs Store and Release Based on Historical contents
  - 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
  - No STEP 2 Calibration For White River

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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
    - Extraordinary releases from Lake Avery in 2002

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Model Calibration

- Streamflow Average Annual Calibration Within 1 Percent on Yampa River
- Streamflow Average Annual Calibration within 0.5 Percent on White River

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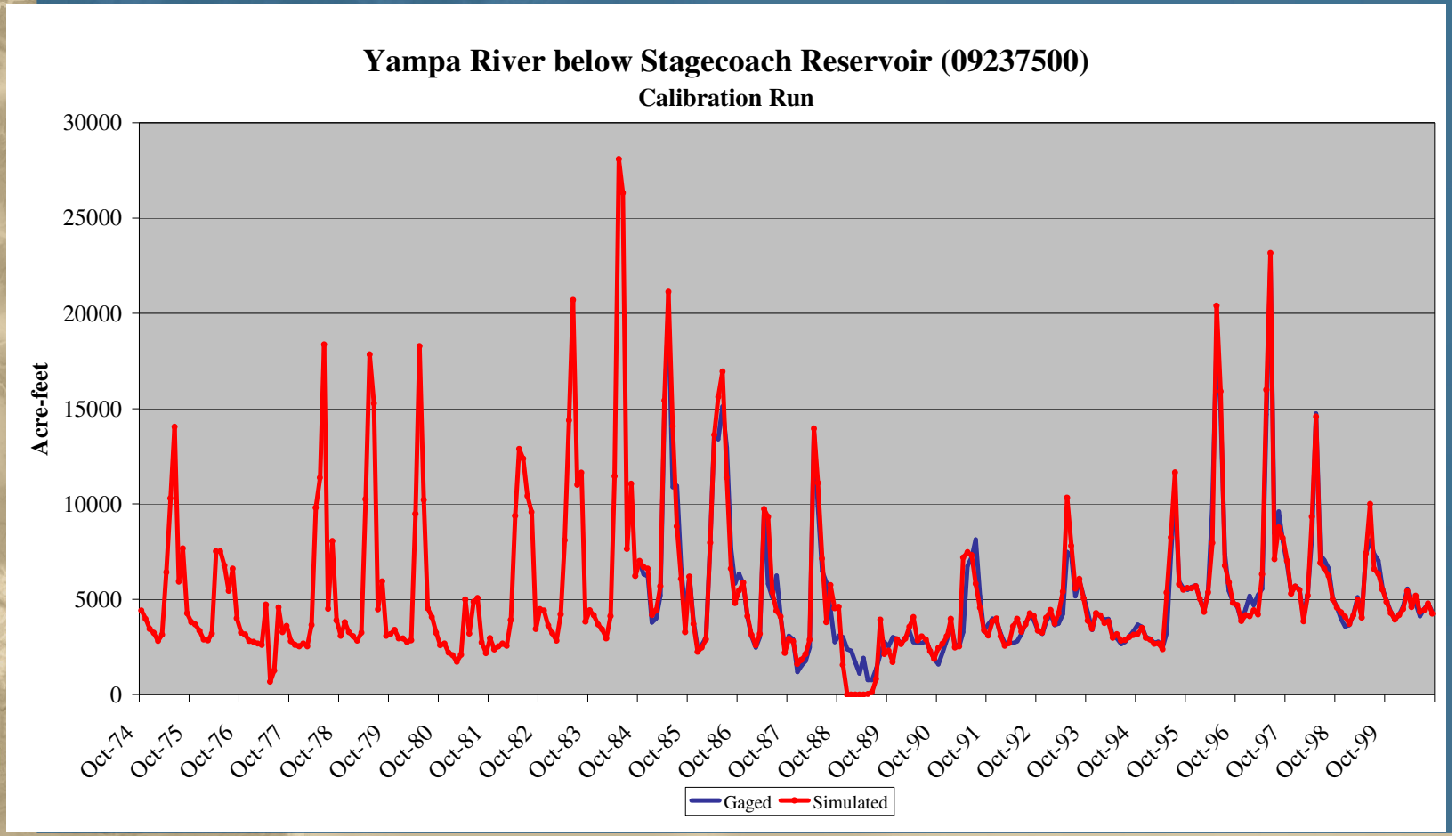
Model Calibration

- Streamflow Calibration below Reservoirs showed most error



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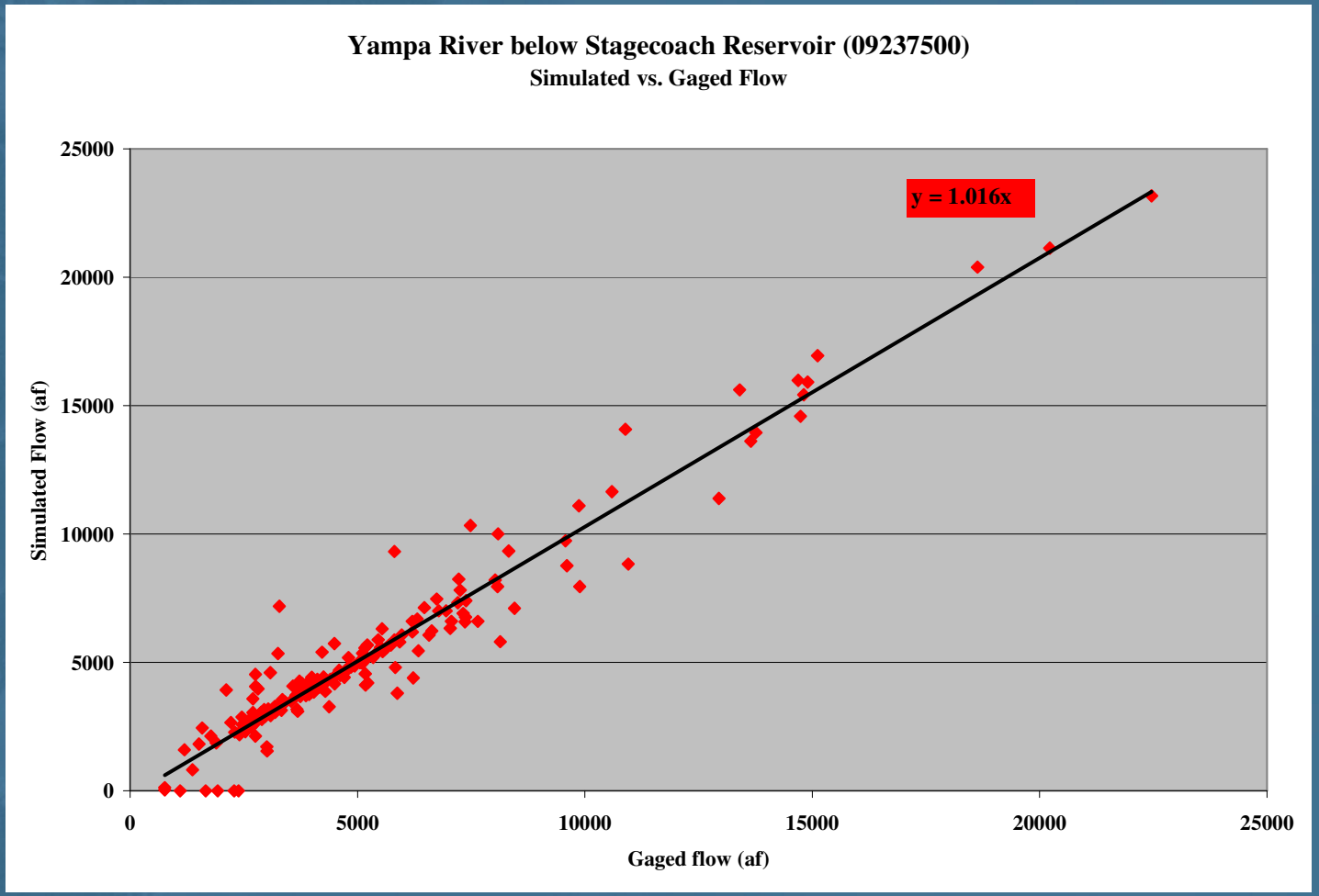
Model Calibration

- Another view…



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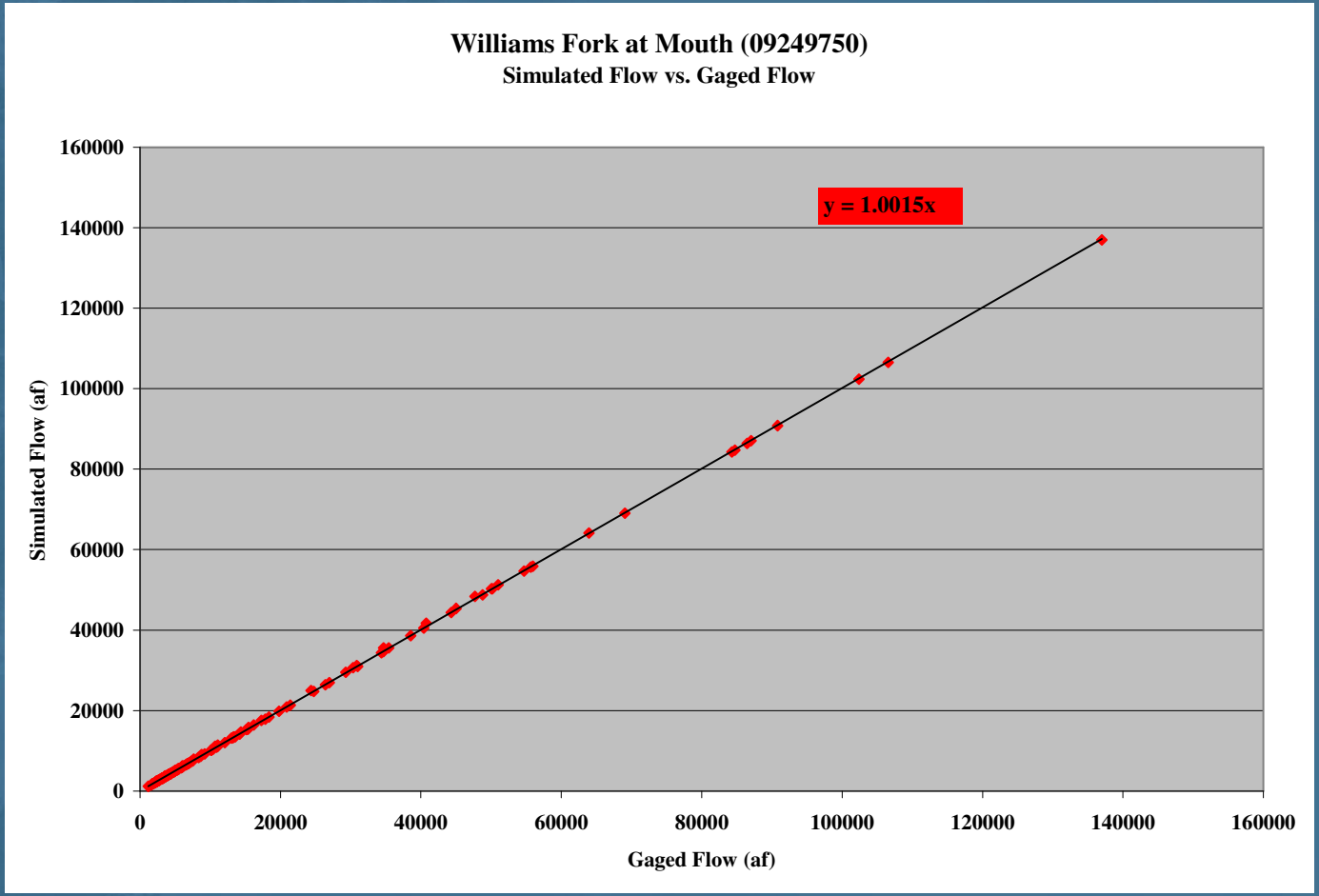
Model Calibration

- Calibration on Mainstem and Larger Tributaries Generally Very Good



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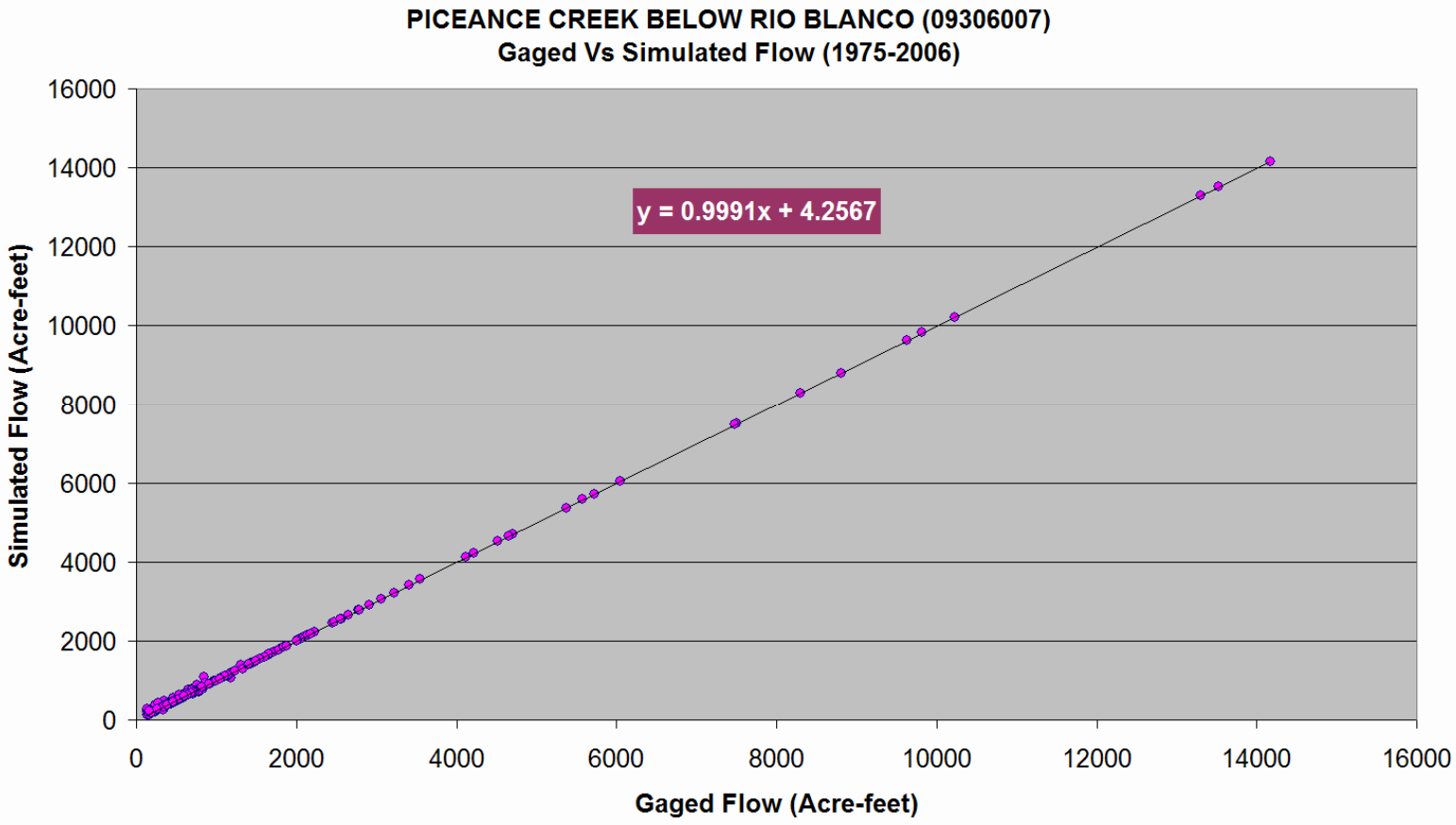
Model Calibration

- Calibration on Mainstem and Larger Tributaries Generally Very Good



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Model Calibration

- Yampa: Basin Wide Total Simulated Diversions are within 2 percent of Total Historical Diversions
  - Fortification Creek diversions short by 9% – short gage record there, lack measured hydrology
  - Williams Fork diversions short by 4.9% - baseflows pro-rated across four ungaged headwaters (?)
- White: Basin Wide Total Simulated Diversions are within 1 percent of Total Historical Diversions
  - Piceance Creek Aggregated Diversions are Shorted Likely Because they Historically Re-Divert each other's Return Flows

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Model Calibration

- Reservoir Calibration Results
  - Reservoir Calibration Fair to Good with Some Exceptions
  - Stagecoach Reservoir – difficulty predicting hydropower demand
  - Yamcolo Reservoir generally "underutilized" in model, lacking information on historical contents
  - Elkhead Reservoir underutilized, lacking information on historical contents

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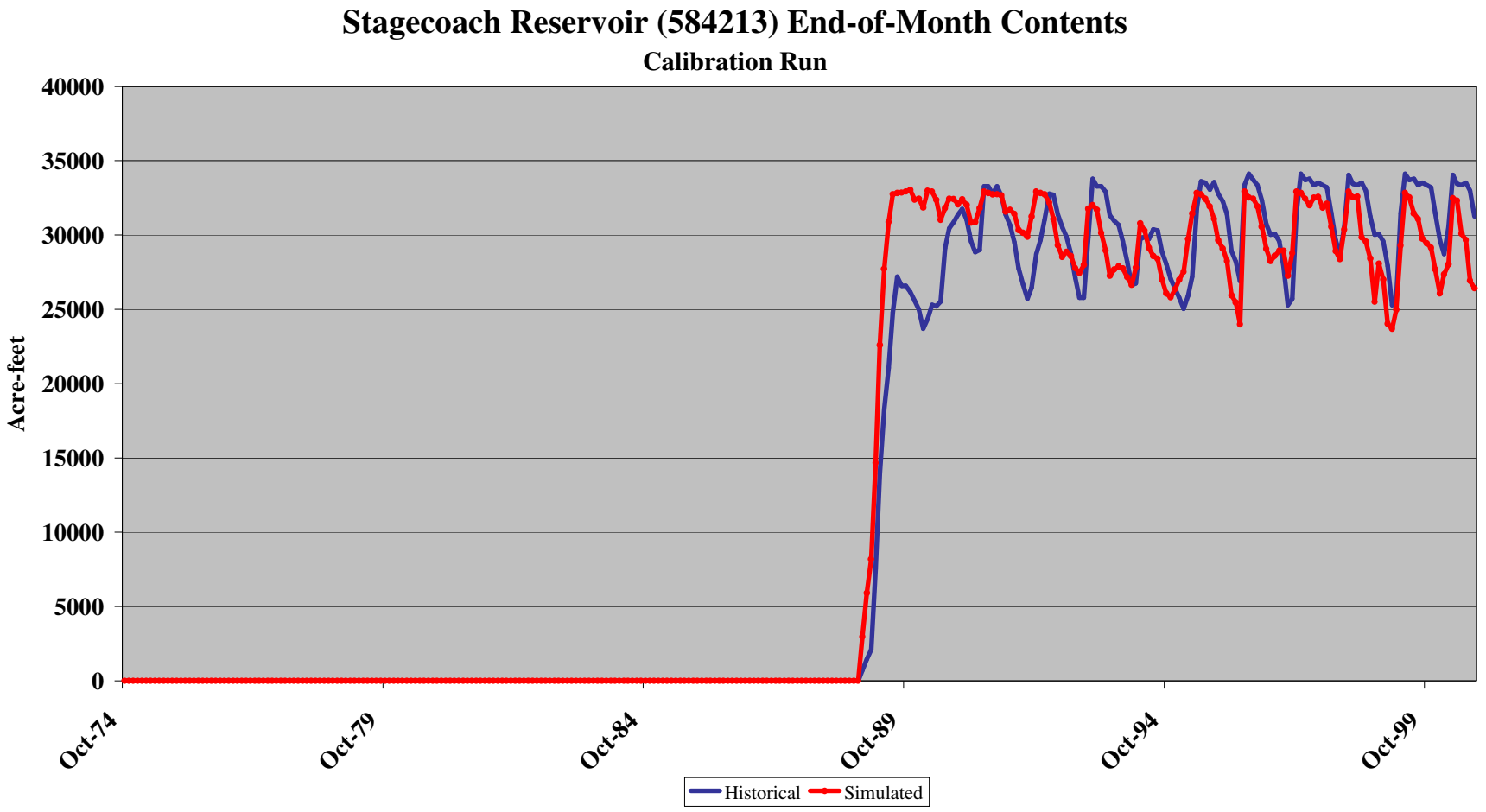
Model Calibration



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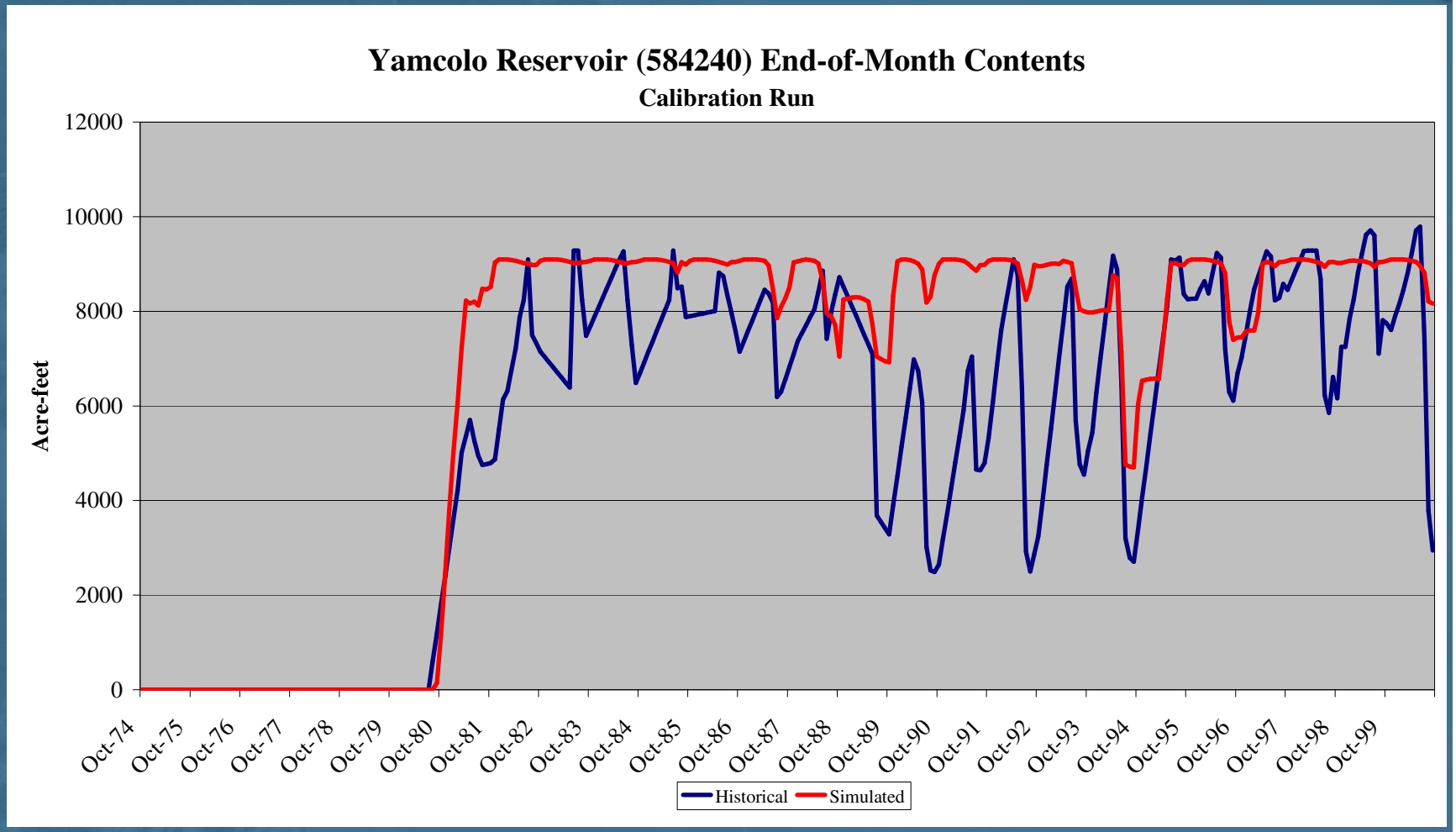
Model Calibration



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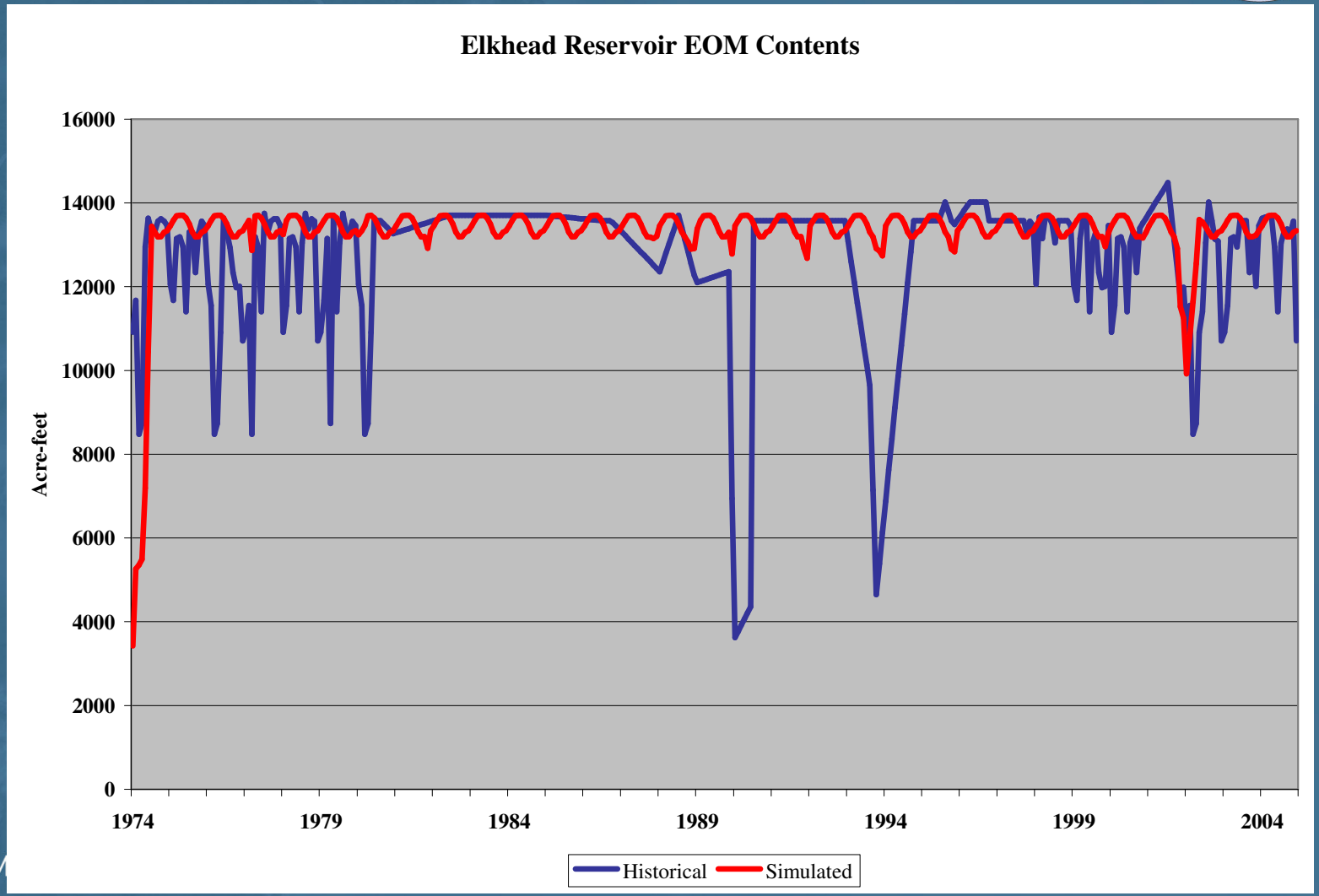
Model Calibration



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Model Calibration

- Basin-wide Calibration Results are Good
- Understanding and Representation of Basin Operations is Good
- Yampa and White River StateMod Models are Appropriate Prediction Tool to Consider Effects of Basin Climate Variability

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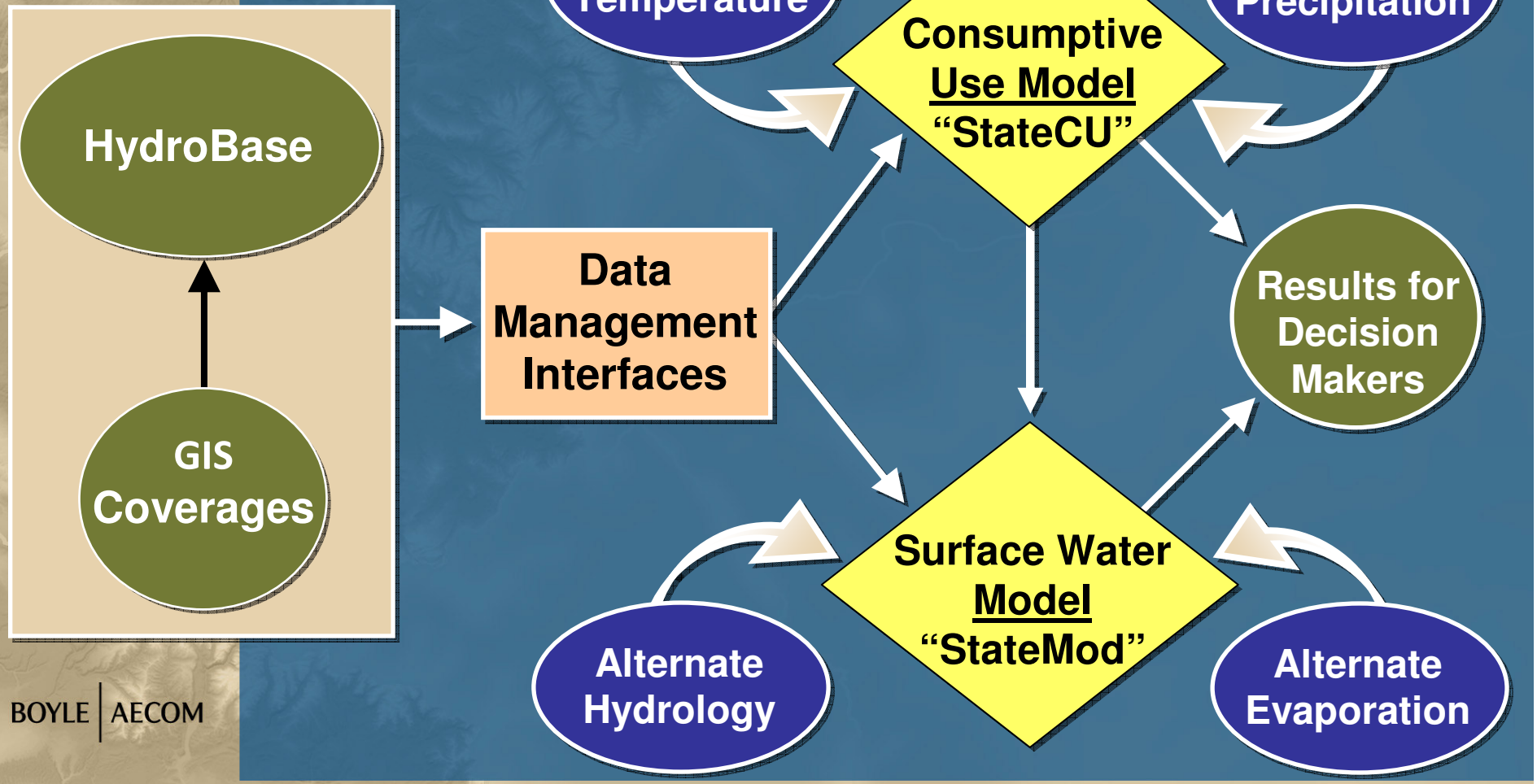
StateMod - Alternate Historical Hydrology



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Questions, Comments, Suggested Model Enhancements?

Website:

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

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