

Water Supply Forecasting Tools and Processes

Colorado River Commission
Technical Workshop
December 5, 2008

Brenda Alcorn
Senior Hydrologist
Colorado Basin River Forecast Center

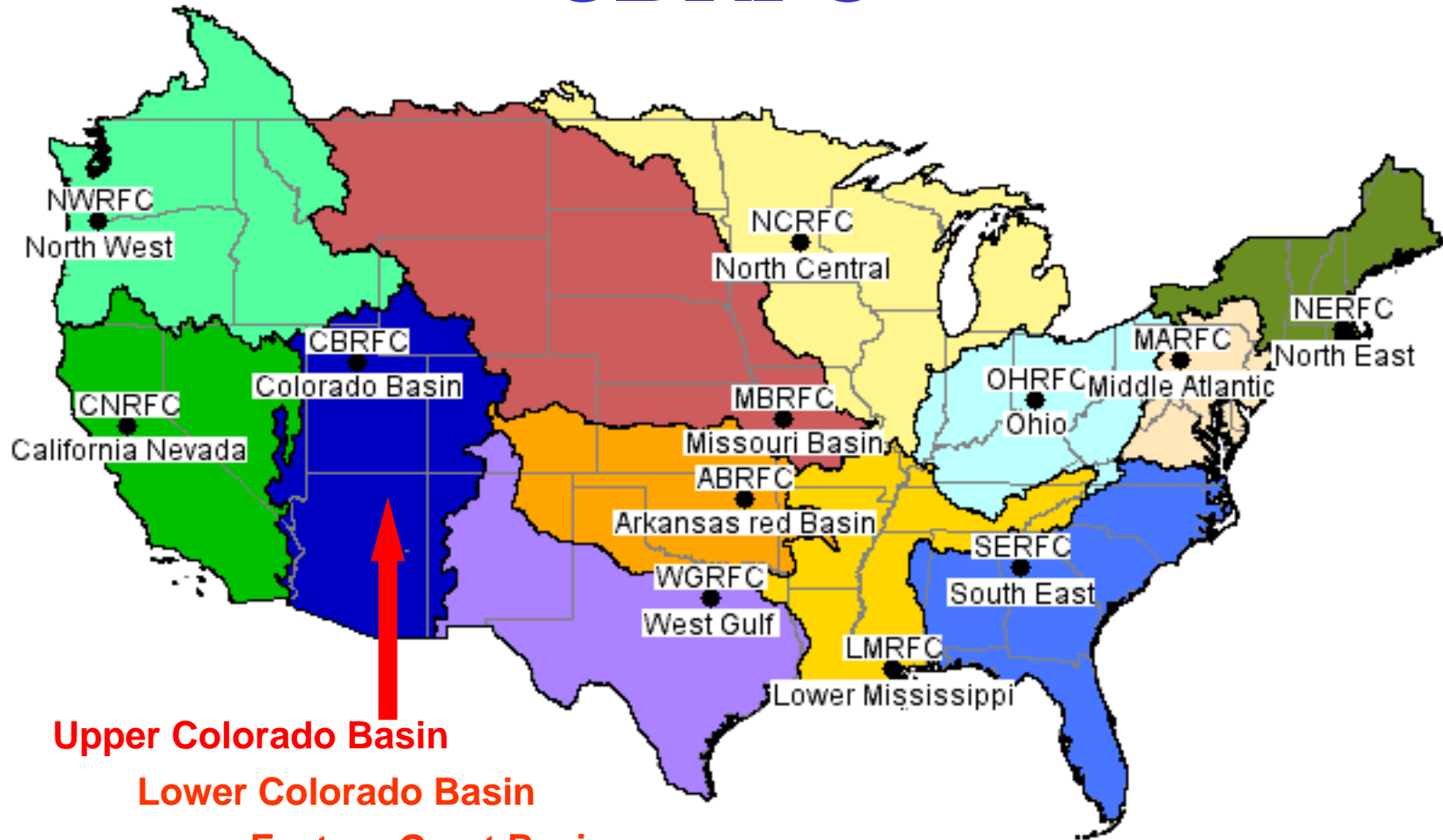


Water Supply Forecasting Tools and Processes

- CBRFC – who we are and what we do
- Statistical Water Supply (SWS)
- NWS River Forecast System - Ensemble Streamflow Prediction (ESP)
- Sources of Error
- Lake Powell and Lake Mead forecasts



CBRFC



Upper Colorado Basin

Lower Colorado Basin

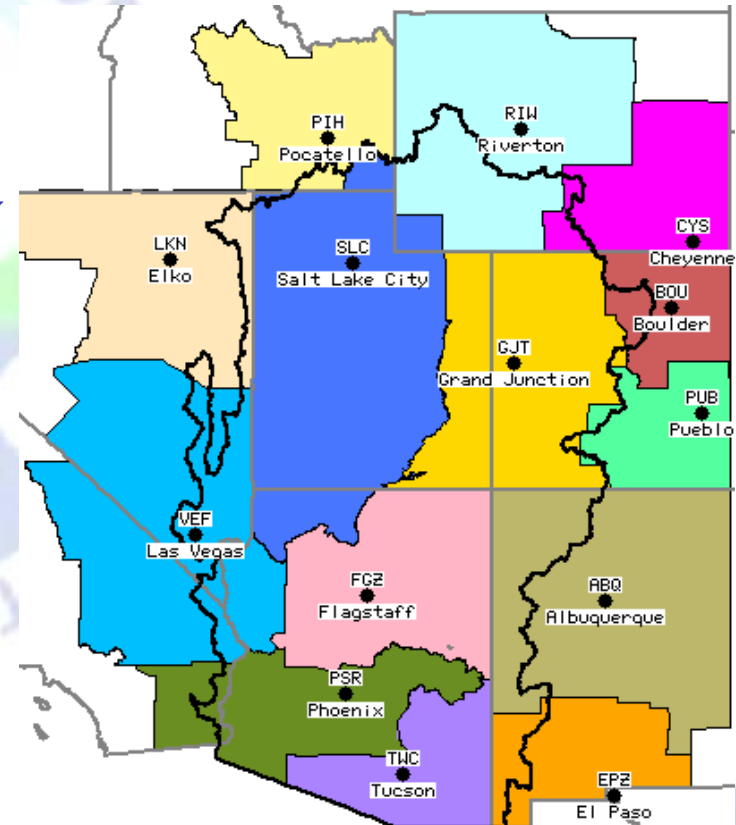
Eastern Great Basin

- One of 13 NWS River Forecast Centers
- Located in Salt Lake City, UT



CBRFC

- Mission:
 - Protect lives and property
 - Enhance national economy
- Major programs include:
 - Flood and routine river forecasts
 - Flash flood support
 - Water Supply Forecasts



Flood Forecasts / Routine Forecasts

NATIONAL WEATHER SERVICE
Colorado Basin River Forecast Center

Home News Organization Search

River Conditions

Zoom to: -Cities-

Points: Search | Show All
Data Type: River | Snow
Click: Select | Zoom
Zoom: 1x | 4x | 8x | 16x
Zoom Mode: Topography | Satellite

Display Options

- Topography
- States
- RFC
- Rivers
- HSAs
- Basins
- Basins Above Normal
- Data Points
- Forecast Points
- AHPS Points
- Stations Above Normal
- Station Labels

Apply

Quick Plot

NWS ID:
Open

Legend

Basin in Conditions (0-3 days)

Peak Flow Forecasts, Latest for 2008

NOAA, National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
www.cbrfc.noaa.gov

Contents

- Introduction
- Upper Colorado Peak Flow Forecasts
- Great Salt Lake Peak Flow Forecasts
- Lower Colorado Peak Flow Forecasts
- River Running Permits/Information
- Definitions
- Additional Information

Introduction

Streamflow varies dramatically over the course of the snowmelt season. To characterize the magnitude of a year with a single seasonal peak sometimes can be an oversimplification. Hydrographs (or graphs of mean daily flow versus time) for each site can be viewed by clicking on the site name. The hydrographs include an example high and low year alongside last year and this year.

River recreationists often ask what are the high and low years. Rankings of a sites peak flows can be viewed by clicking the site name below. Reservoir regulation plays a major role in determining observed peak flows. As would be expected, higher (but more short-lived) peaks are generally observed in the pre-regulatory era (before 1960).

Upper Colorado Peak Flow Forecasts (mean daily cfs)

Prepared by: Alcorn, Clark, Lhotak

2008 Forecast Exceedance Probability

National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
APR 3, 2008

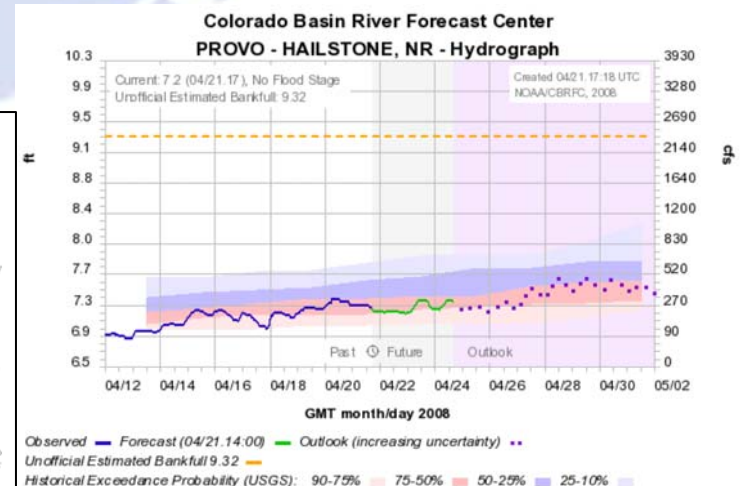
FLOOD POTENTIAL OUTLOOK
UTAH

Snowpack conditions across the Great Salt Lake region range from average to above average. Current temperatures are cool and weather models are forecasting active conditions with cool temperatures over the next 10 days. Stream flow models are indicating less than a 10% chance of flood flows, however the potential for reaching bankfull is currently above average. Streams will most likely run high and cold this spring and areas with small ungaged streams may see an elevated threat of bankfull or overbank conditions. The onset of conditions that will raise the threat of flooding will be monitored closely and this product will be updated as needed.

Snowpack decreased in the Duchesne Basin due to well below average precipitation in March and is now 110 percent of average. At this time, the potential for Spring flooding due to snowmelt is not high. ESP NWS models indicates peaks flows due to snowmelt will be near average for points in the basin.

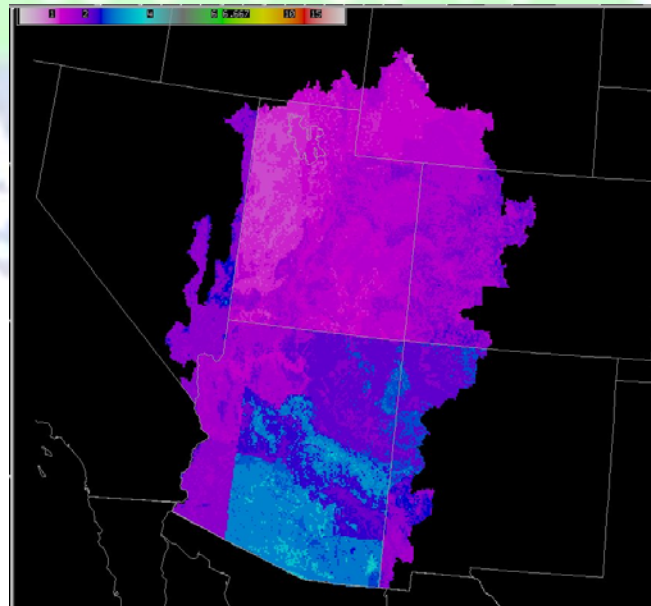
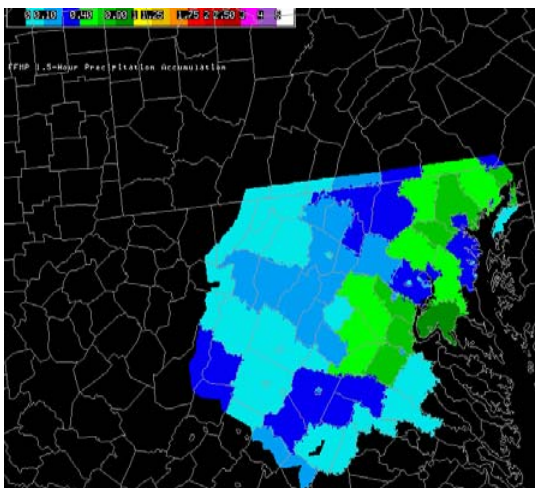
The potential for Spring flooding due to snowmelt is not high in the lower Green basin. Much below average precipitation in March decreased the percent average snowpack from 115 percent of average on March 1st to 105 percent of average on April 1st. Peaks flows are expected to be near average for streams in the San Rafael basin.

- Nominally provided at ~400 points every 6 hours out to 10 days.
- Flexible web interface to forecasts and data
- Requires large amounts of data (e.g. snow, precip, streamflow)



Flash Flood

- Support NWS flash flood program at WFOs through innovative flash flood guidance and (eventually) distributed model



FFMP Basin Table for NMO

file config layer zoom cwa click

Time Duration(hrs.)
1.5

0.0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0

Refresh D2D May 16 07 20:55:00 GMT

NAME	RATE	PRECIP	RFCFFG GUID	RFCFFG RATIO	RFCFFG DIFF
MD,CHARLES	3.37	0.82	1.50	55	-0.68
MD,BALTIMORE	2.05	0.80	1.50	53	-0.70
VA,PRINCE WILLIAM	0.31	0.72	1.50	48	-0.78
VA,STAFFORD	3.22	0.71	1.50	47	-0.79
MD,CECIL	0.31	0.68	1.50	45	-0.82
VA,SPOTSVLVANIA	1.70	0.65	1.50	44	-0.85
MD,HOWARD	0.98	0.60	1.50	40	-0.90
VA,CULPEPER	0.25	0.59	1.50	40	-0.91
VA,ORANGE	0.12	0.59	1.50	39	-0.91
MD,MONTGOMERY	0.40	0.59	1.50	39	-0.91
Potomac River	2.23	0.82	1.50	55	-0.68

Water Supply

- **WHEN:**
 - At the beginning of each month January-May.
 - Mid-month updates for some points.
- **WHAT:**
 - Seasonal volume (April-July most common).
 - “Natural” flow.
 - Flow that would be expected given no water management activities.
 - We attempt to account for all known and measured diversions and reservoir regulation upstream for which data is available.
 - Many unknown/unmeasured diversions.
 - Sometimes hard to get all adjustment data in real-time.
 - Adjustments we account for available at:
<http://www.cbrfc.noaa.gov/wsup/guide/>
- **WHERE to find it:**
 - <http://www.cbrfc.noaa.gov/wsup/wsup.cgi>

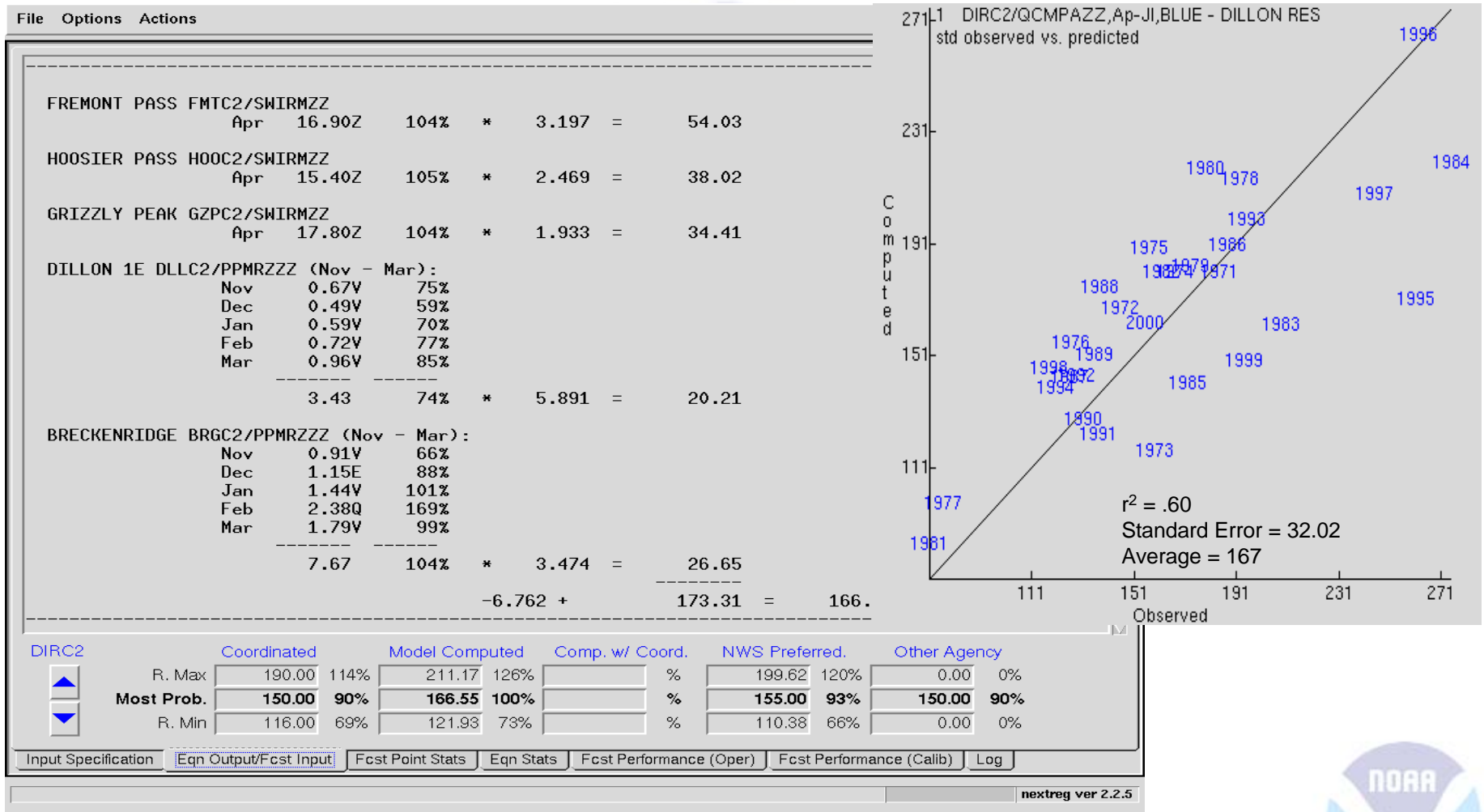


Statistical Water Supply (SWS)

- Regression equations that relate observed data to future seasonal streamflow volume.
- Inputs are monthly values.
 - Total precipitation (can be multiple months)
 - First of month snow water equivalent
 - Monthly flow volume
 - Climate indices (SOI)
- Output is a seasonal volume (i.e. April-July).
 - It is really a conditional probability distribution, not a single value; the equation result is the 50% exceedance.
 - Other exceedance levels (10%, 90%, etc.) can be calculated by using the standard error.



Statistical Water Supply (SWS)



nextreg ver 2.2.5

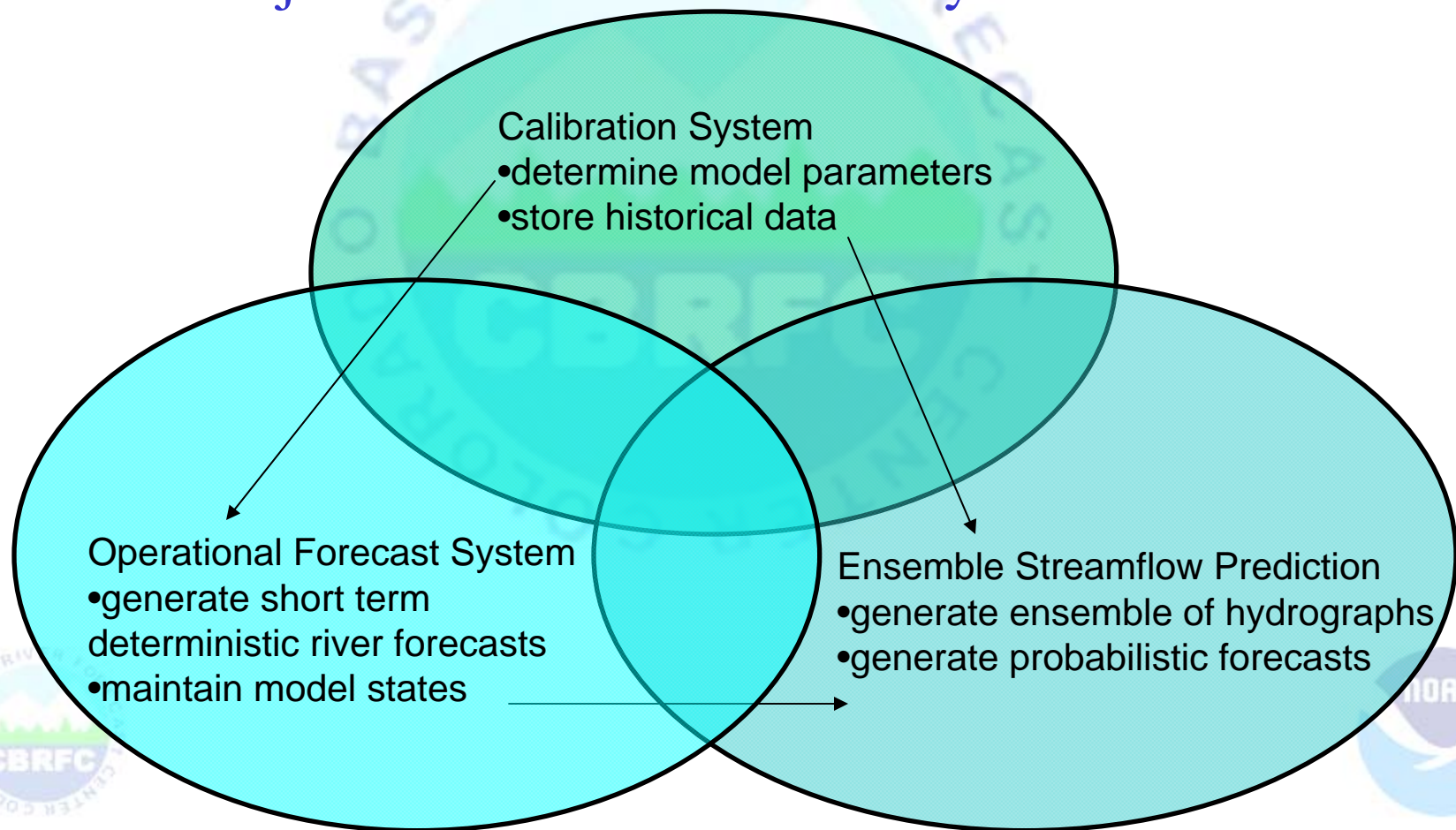
Statistical Water Supply (SWS)

- Headwater vs. local/routed forecast point
 - For downstream points the regression equation ‘routes’ the upstream volume forecast; it’s input is the upstream forecast volume(s).
 - If there is significant ‘local’ contribution between the points, an equation can be created for the local volume and is then included in the routed equation.
- Example: Lake Powell inflow
 - Too big an area to be handled by a headwater equation.
 - Good correlation with upstream volumes:
 - Green at Green River + Colorado nr Cisco + San Juan nr Bluff
 - $r^2 = .994$ for observed data



NWS River Forecast System

- Continuous, conceptual hydrologic model composed of three major interrelated functional systems.



Calibration System (CS)

- Choose from a variety of models and processes that can:
 - Simulate snow accumulation and ablation.
 - Compute runoff using a soil moisture model.
 - Time the distribution of runoff from the basin to the outlet.
 - Perform channel routing.
 - Model reservoir operations.
- Determine the optimal set of parameters for each model to best simulate flow.
- Store historical precipitation, temperature and flow time series for the basin.



Operational Forecast System (OFS)

- Keeps track of model states, including soil moisture and snowpack.
- Inputs are:
 - Observed precipitation, temperature, and streamflow (which have been quality controlled before input).
 - Forecast precipitation (5 days) and temperature (10 days).
 - **Note: snow/swe is not a direct input, the snow model within each segment builds and melts its own snowpack based on precipitation and temperature inputs.
- Segments/states can be adjusted by forecasters in real time.
 - Snow states are updated at the beginning of each winter month by comparing model simulated snowpack to SNOTEL site data (not a one to one relationship).
- Run multiple times per day so there is continual quality control, updating and adjusting.



Ensemble Streamflow Prediction (ESP)

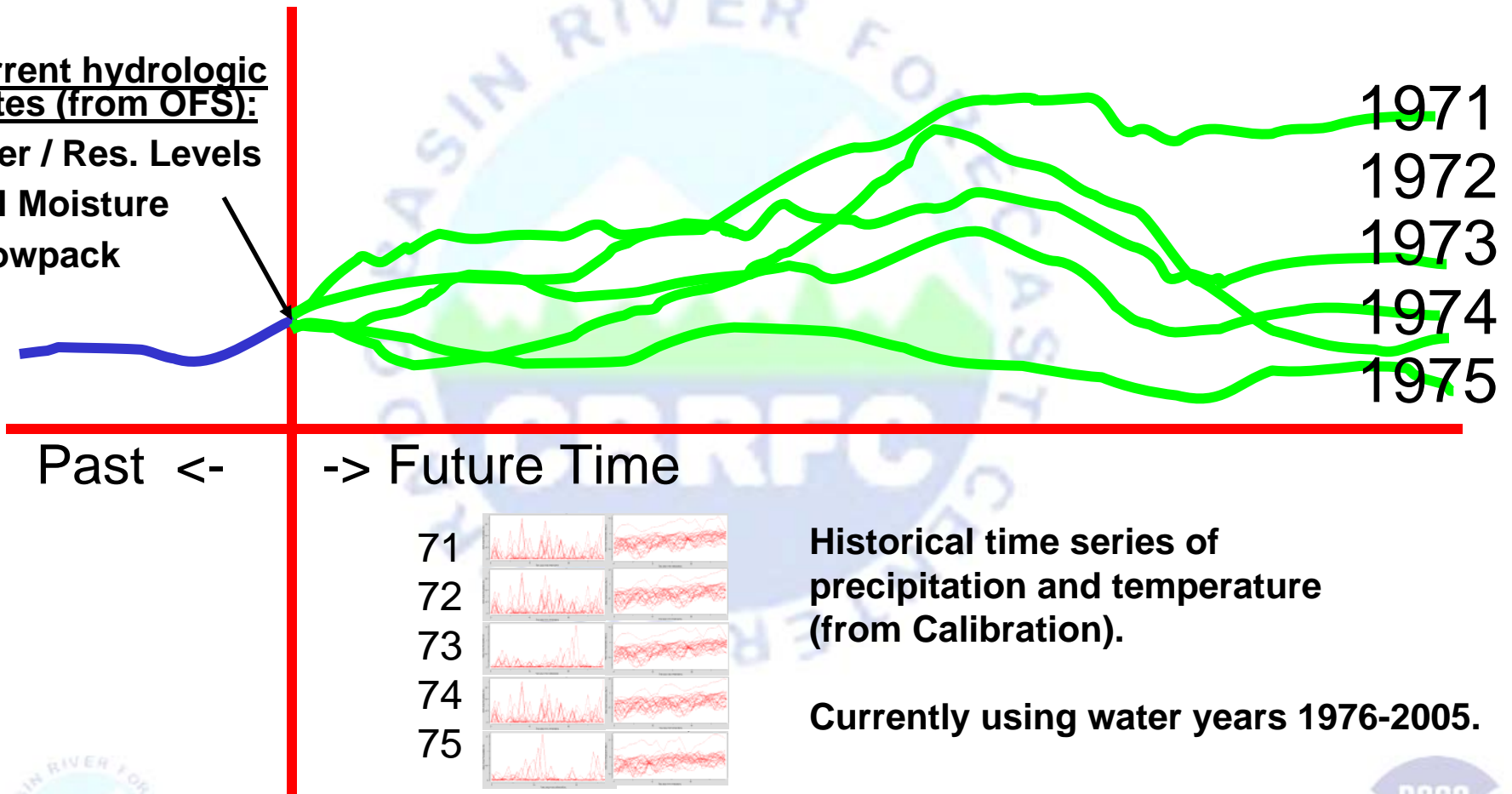
- Uses model states from OFS as starting point and can also use the QPF (5 days) and QTF (10 days) inputs.
- Uses historical precipitation and temperature time series from CS and statistical distributions to derive probabilistic flow forecasts.
 - Can choose different probability distributions (e.g. empirical, log, wakeby).
 - Can display any exceedance levels wanted.
- Can be pre- or post- adjusted with climate forecasts.
- Can adjust output for model (calibration) bias.



Ensemble Streamflow Prediction (ESP)

Current hydrologic states (from OFS):

River / Res. Levels
Soil Moisture
Snowpack



Start with current conditions – Apply each year of historical climate – Create several possible future streamflow patterns



Ensemble Streamflow Prediction (ESP)

5 days forecast precipitation

10 days forecast temperature

Current hydrologic states (from OFS):
River / Res. Levels
Soil Moisture
Snowpack



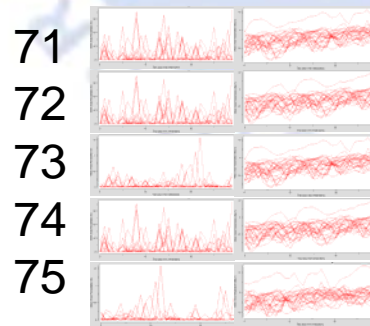
Past <-

-> Future Time

Climate Forecasts:

1) Pre-adjust: input time series are shifted based on the CPC forecast probability anomalies.

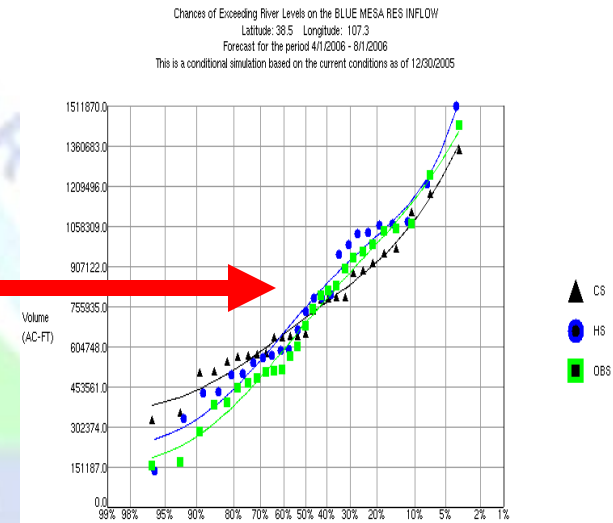
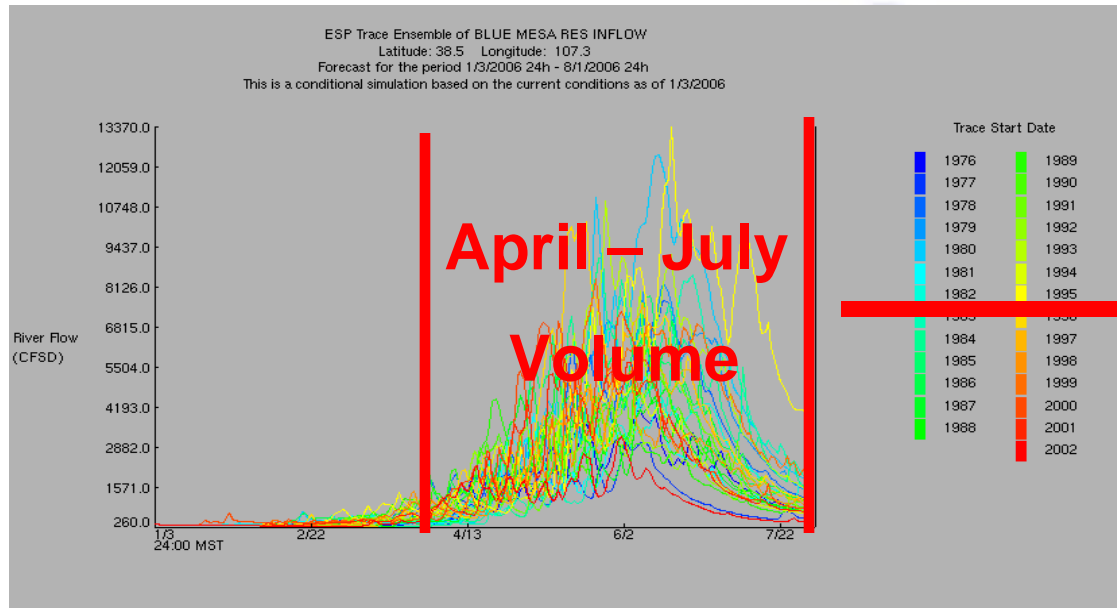
2) Post-adjust: output traces are weighted by year; alters the likelihood (probability) of a value occurring, not the individual ensemble values.



Historical time series of precipitation and temperature (from Calibration).



Ensemble Streamflow Prediction (ESP)



1. Select a forecast window
2. Select a forecast variable
3. Model derives a distribution function
4. 50% exceedance value = most probable forecast
5. Correct for model bias

Statistics based on all years.

# Exceedance Probabilities	Conditional Simulation	Historical Simulation	Historical Observed
0.900	438320.500	328520.656	262730.375
0.750	552369.562	499977.531	435810.375
0.500	711742.375	751782.938	691946.625
0.250	877104.812	973699.188	935549.938
0.100	1080490.375	1170393.125	1157333.250

SWS

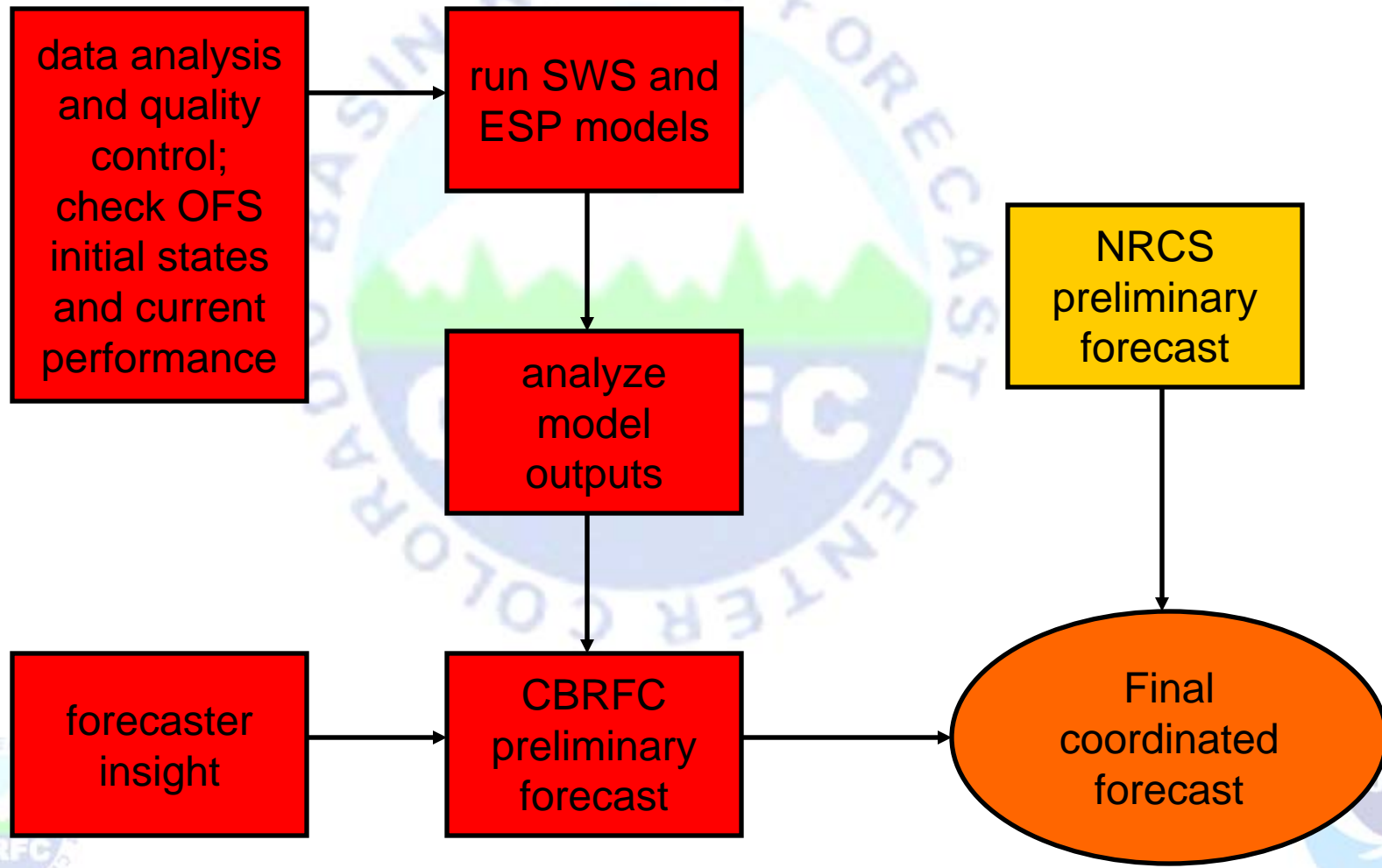
vs.

ESP

- Easy to calibrate, maintain and run.
- Works only for seasonal volumes.
- Equations are made to be run only at specific times (i.e. first of month) for a specific period.
- Requires extensive calibration and maintenance.
- Can compute many hydrologic variables over any period.
- Can be run at any time for any period.
- Keeps track of soil moisture.



Summary of Water Supply Forecast Process



Sources of Error

- Data
 - Undetected errors in historical as well as current observations
 - Errors in streamflow measurements due to poor channel ratings/controls
 - Lack of data in some areas
 - Ungaged/unknown diversions (especially in low years)
 - Consumptive use
 - Distribution of snow vs. point measurements
- Model
 - Initial conditions (see data errors)
 - Calibration error (bias)
- Future weather
 - QPF (accuracy, distribution in space & time)
 - Spring temperatures affect melt/runoff pattern
 - Climate outlooks

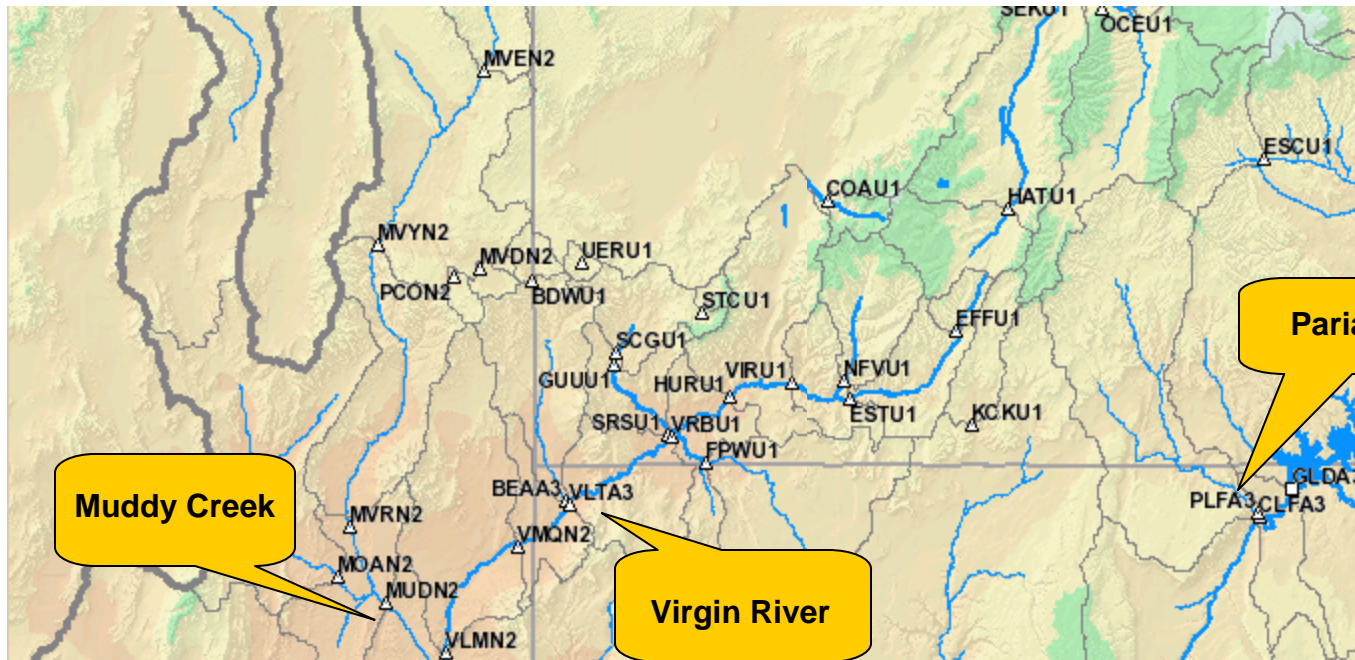


Lake Powell and Lake Mead

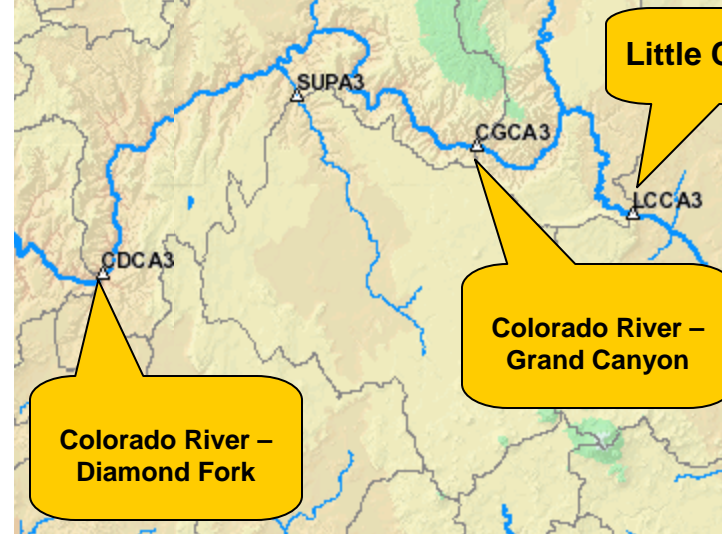
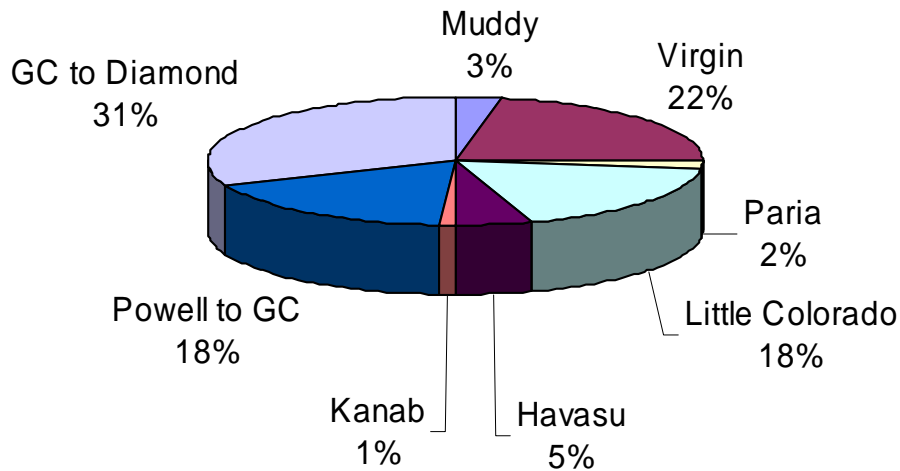
- Issued twice each month year-round.
 - First of month.
 - Mid-month.
- Monthly volumes for next three months.
 - Lake Powell values are the total ‘unregulated’ inflow.
 - Lake Mead values are the observed intervening (‘local’) flow between Lake Powell and Lake Mead.
- Based entirely on ESP (no SWS)
 - For months that are within the seasonal water supply window, it does take into account the official seasonal forecast volumes.



Lake Mead 'local' inflow forecasts



Annual Inflow Powell to Mead Tributary Distribution

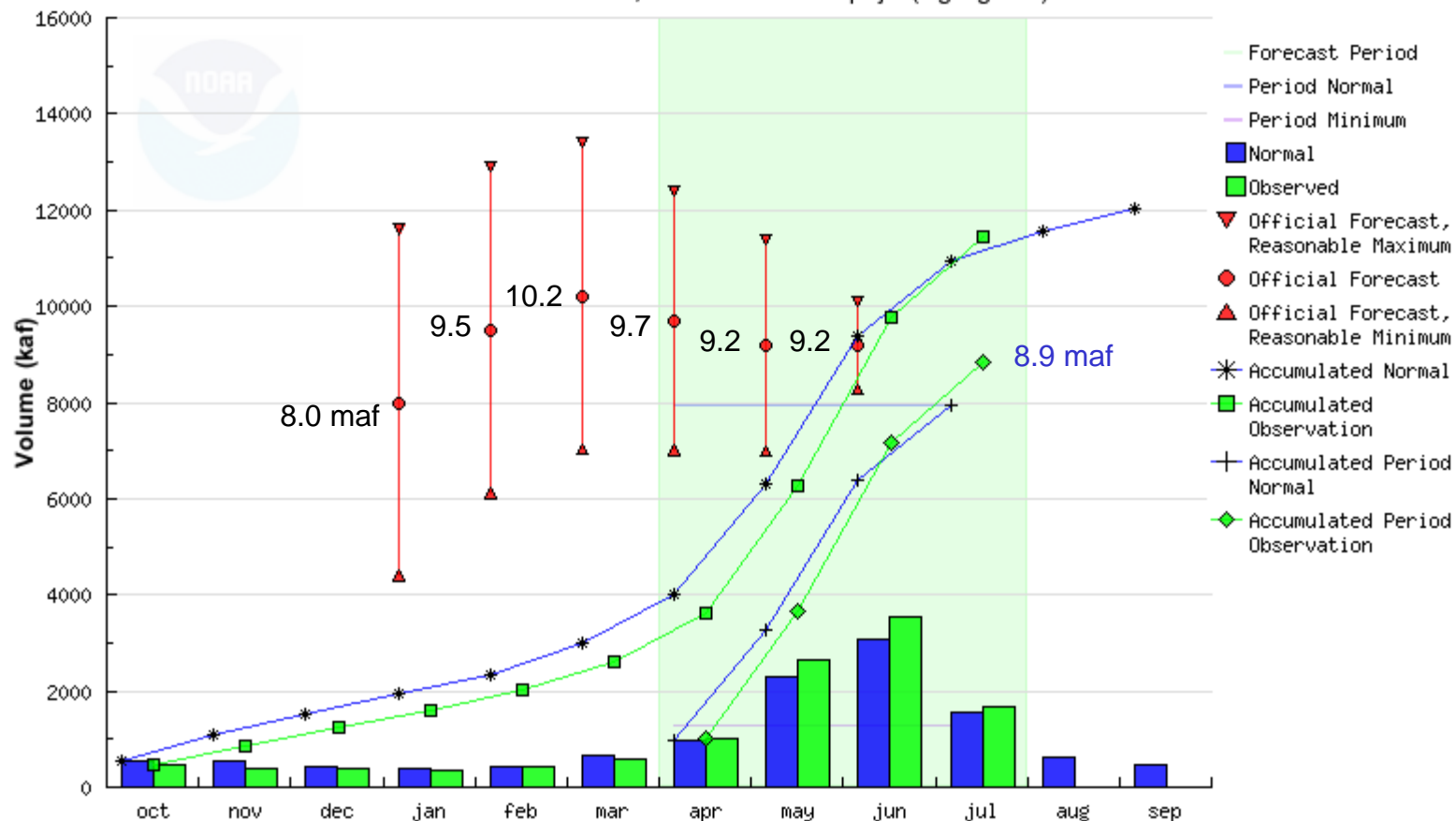


Contact: Greg Smith (greg.smith@noaa.gov)



COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)

Water Year 2008, Forecast Period apr-jul (highlighted)



CBRFC/NWS/NOAA 12/03/08 08:56:57 MST



Apr-Jul 2008 8.9 maf /112%



Thank You!

www.cbrfc.noaa.gov

(801) 524-5130

brenda.alcorn@noaa.gov



Address <http://www.cbrfc.noaa.gov/>

NOAA's National Weather Service
Colorado Basin River Forecast Center

News Organization Search Go

Water
Schedule
Operations
River Forecasts & Data
River Watches & Warnings
Internal Forecast Products
Flood Outlook & Guidance
Recreational Forecasts
Advanced Hydrologic Prediction Service
Reservoirs
Water Supply
Snowmelt Peak Flow
Data
Webcat
DamBreak

Weather
Snow
Precipitation
Temperature
Freezing Level
Soil Moisture
Discussions
Text Data Products
Warnings & Watches
Forecasts
Radar
Satellite

Climate
Data and Indices
Forecasts
El Nino and MJO
Hydroclimatology

About the CBRFC
Visitor Information
Visitor Information (local)
Address
Staff
History
Papers
Presentations

River Forecasts & Data
Forecasts on this web page are not official and should be used only as guidance. Official warnings and forecasts can be found here.
Legend. Map data updated 10/13/2012 12:12 GMT, 10/13/14:12 MDT. Click map to zoom.
Data Type: [River Forecasts](#) | [Reservoirs](#) | [Recreational](#) | [Snow Conditions](#)
Click to: [Select](#) [Zoom](#) Zoom to: [1x](#) [4x](#) [8x](#) [Help](#)

Legend
Basin Conditions (0-3 days)
 1 = Normal, 0 = No Data
 2 = Significant Rise
 3 = Near Bankfull
 4 = Above Bankfull
 5 = Above Flood Stage
 Observed (Solid)
 Simulated (Striped)
 Outlook (beyond 3 days)

Station Types
 AHPS Point
 Forecast Point
 Data Point

Quick Plot
NWS ID

Display Options
 Topography
 States
 RFC
 Rivers
 HSAs
 Basins
 Basins Above Normal
 Data Points
 Forecast Points
 AHPS Points
 Stations Above Normal
 Station Labels

A topographic map of the Colorado Basin showing river networks and numerous data points. The map is overlaid with a grid. The data points are represented by various symbols and colors, corresponding to the legend. The map shows the Colorado River and its tributaries, with a focus on the central and southern parts of the basin.