River Forecast Application for Water Management: Oil and Water?

Kevin Werner

NWS Colorado Basin River Forecast Center

Mesa State College
November 6, 2013

Outline

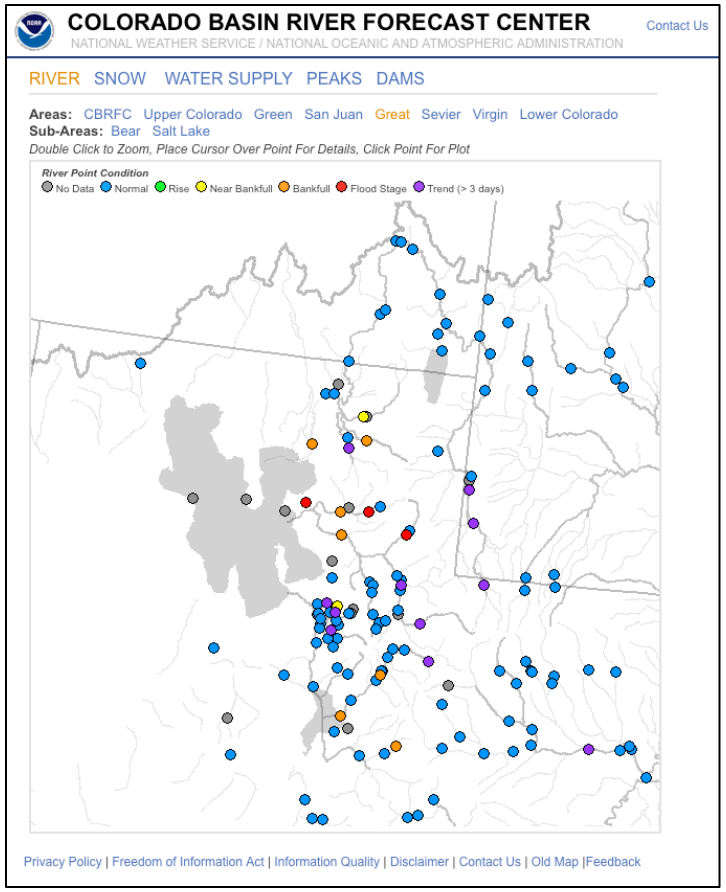
- River Forecast Center overview
- Motivation
- Ensemble Forecasts
- Ensemble Forecast Application

Colorado Basin River Forecast Center

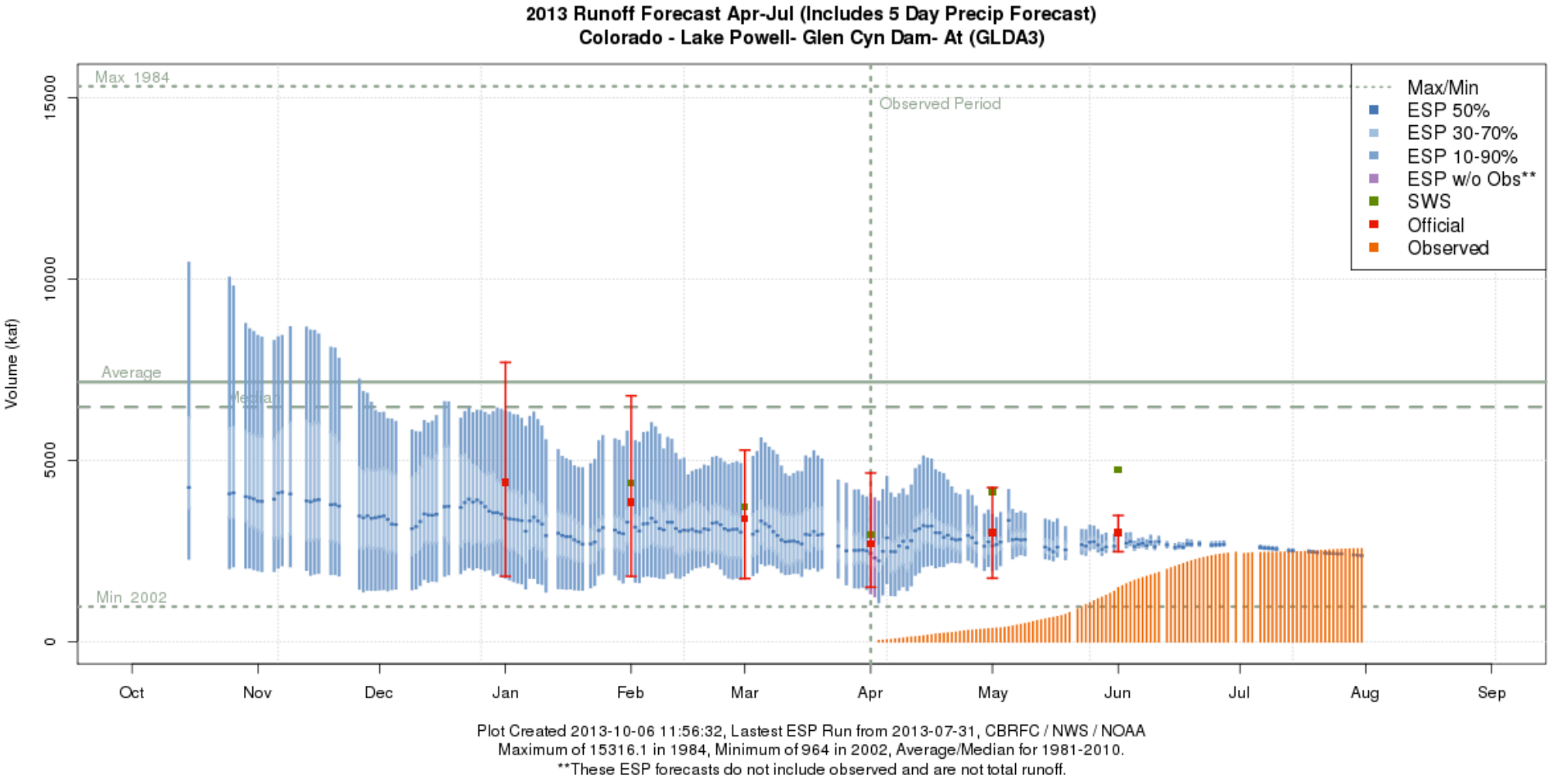
The Colorado Basin River Forecast Center (CBRFC) generates streamflow forecasts across the Colorado Basin and Utah. The latest forecasts, data, and more are available online:

- **Daily streamflow forecasts**
- **Long lead peak flow forecasts**
- **Water supply forecasts**
- **Webinar briefings**
- **Email updates**
- **And More….**

www.cbrfc.noaa.gov

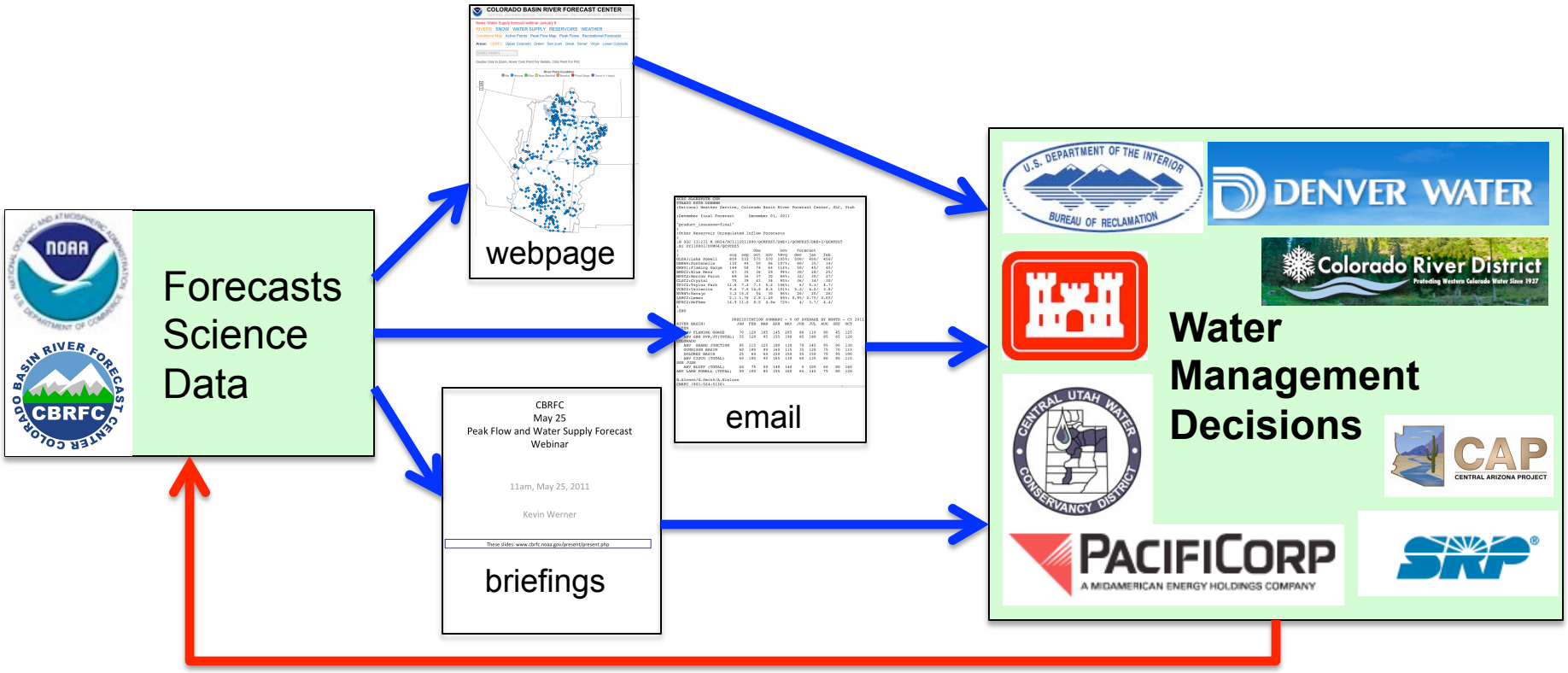


Water Supply Forecast: Lake Powell 2013



Motivating Question: How do people use these forecasts? In particular, how do people use the forecast distribution?

Motivation



How effective are forecasts in informing water management decisions?

- Forecast information transmission?
- Effective forecast products and tools?
- Meeting forecast information requirements?
- Feedback and iteration with decision makers?

Previous Research on Water Management and Forecast Usage

Forecasts generally not used. Water management agencies value reliability and quality above all else. Unless those are threatened, agencies have little incentive to use forecasts.

Forecast use correlates with perceived risk. Forecast usage not dependent on agency size or on understanding of forecast skill and reliability.

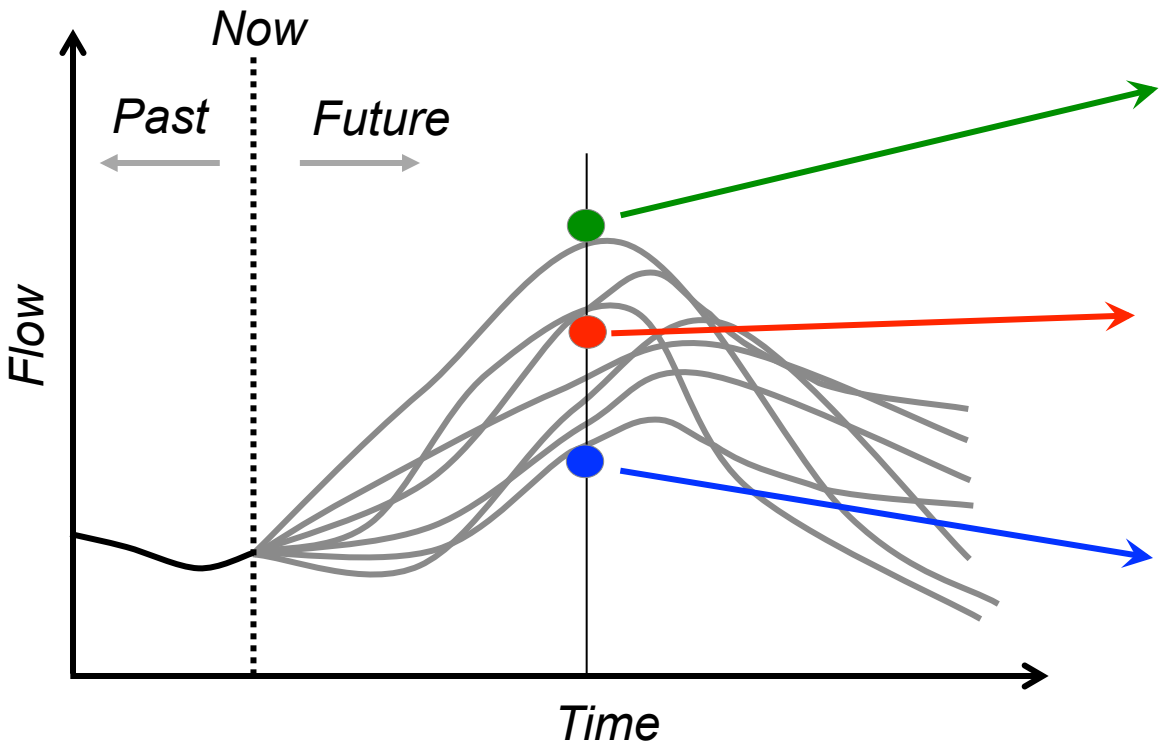
Policy and infrastructure in USA limit use of forecasts. Many operating decisions are tied to observed data and do not allow flexibility.

Hopeless?

No! Long term drought, increasing demands, and climate change projections for less water each present opportunities for increasing forecast usage.

Study	Method(s)	Geographic Area(s)
(Rayner et al., 2005)	Field Research: Semi-structured Interviews	USA: Pacific Northwest, Southern California, and Washington, DC
(O'Connor et al., 2005)	Survey	USA: South Carolina and Susquehanna River Basin of Pennsylvania
(Lemos, 2008)	Field Research: Observation of Meetings	USA and Brazil
(Dow et al., 2007)	Survey (building on earlier work (O'Connor et al., 2005))	USA: South Carolina and Susquehanna River Basin of Pennsylvania
(Callahan & Miles, 1999)	Field Research: Semi-structured interviews	USA: Pacific Northwest
(Ziervogel et al., 2010)	Case Study	South Africa
(Pulwarty & Redmond, 1997)	Field Research: Semi-structured interviews	USA: Pacific Northwest

Ensemble Streamflow Prediction (ESP)

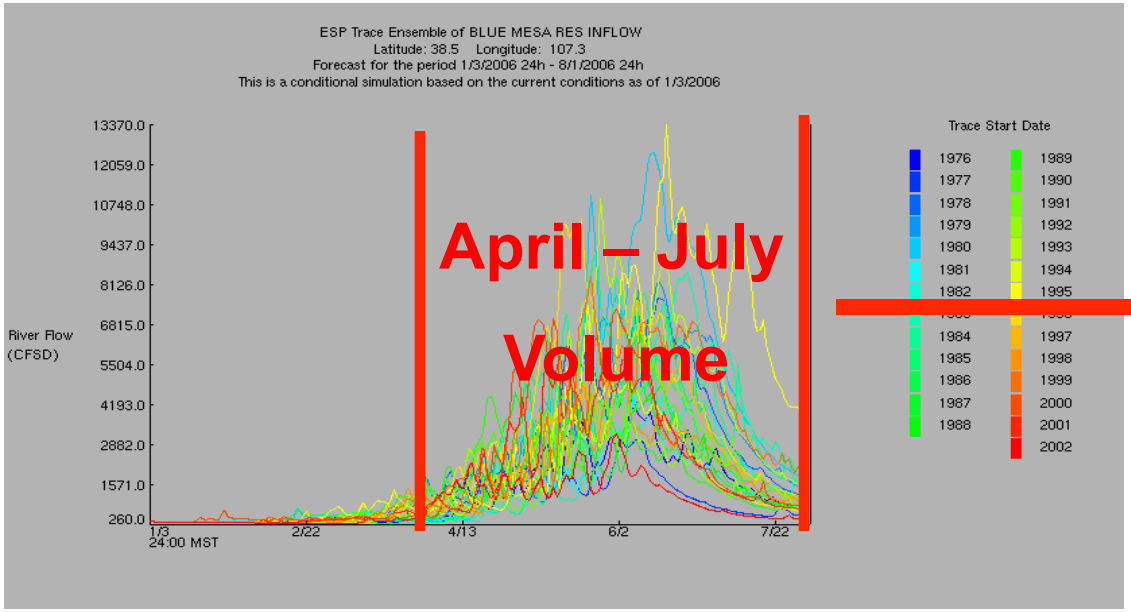


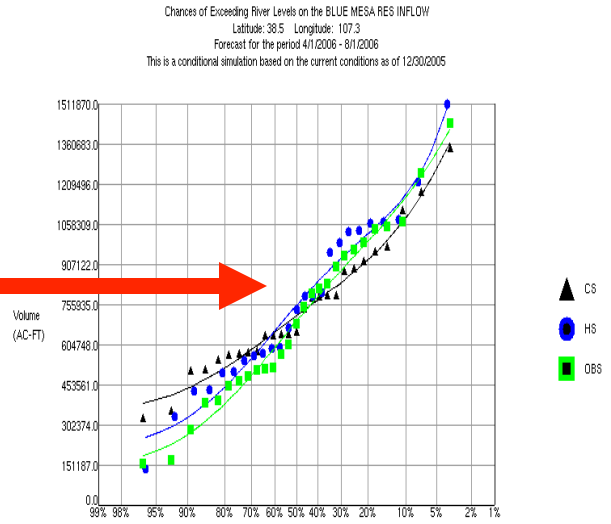
Low chance of this level flow or higher

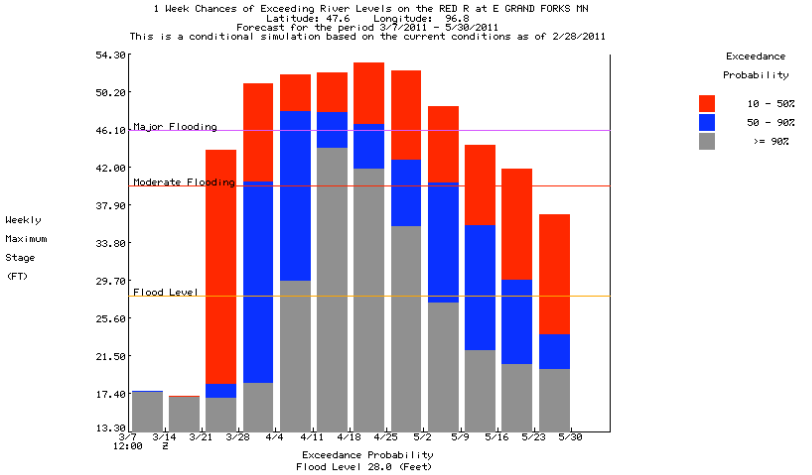
Medium chance of this level flow or higher

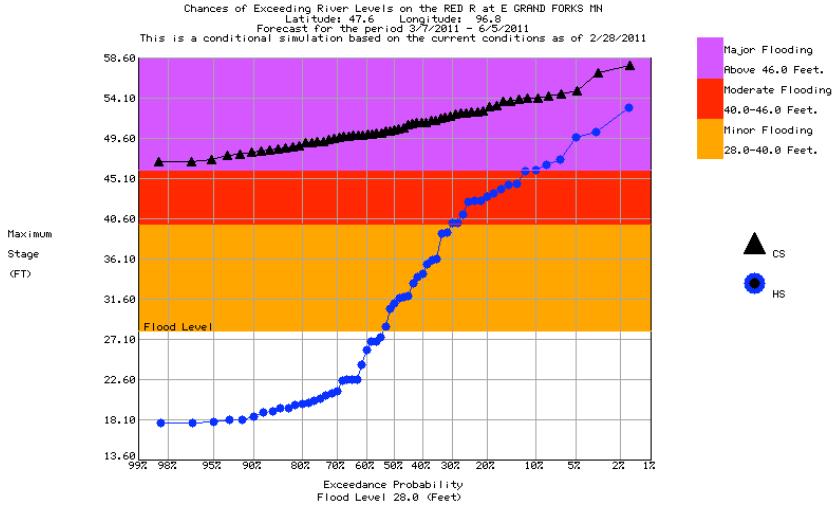
High chance of this level flow or higher

ESP Analysis









National Weather Service

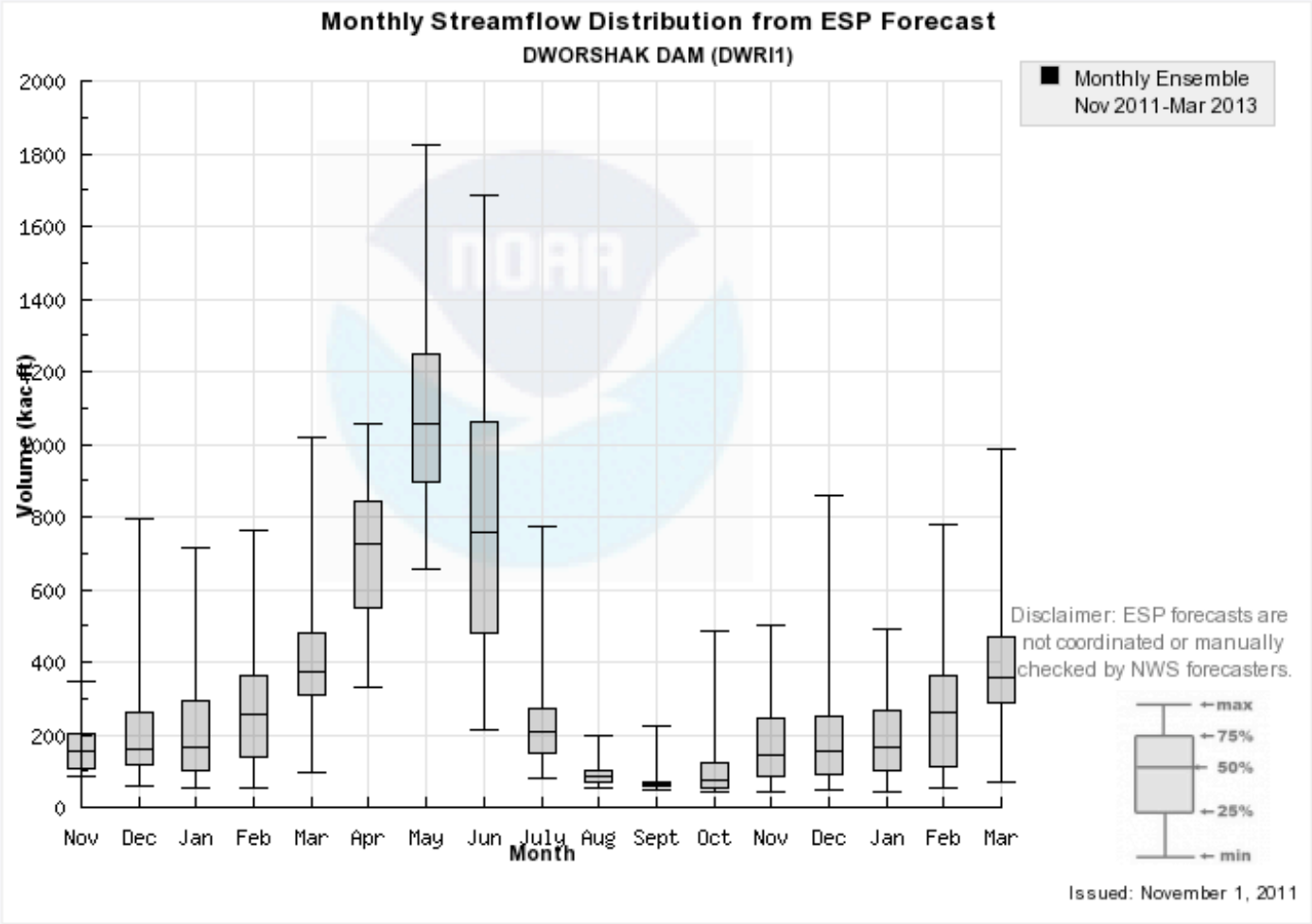
National Water Resources Outlook

Home | Maps | **Points** | Help

Summary | **Ensemble Plot** | Forecast Evolution Plot | Forecast Ranking Table | Climate Variability | Forecast Verification | Data Checkout

Ensemble Plot

Nf Clearwater River at Dworshak Dam, Idaho (DWRI1 / NWRFC)



Need Help?

Graph Options

Forecasts

Current Forecast: November 1, 2011

☐ Forcing Year

☐ ENSO Biased Forecast

Archives

☐ Average Runoff

☐ Historical Observations

Season Options

Seasonal Constraints: Sept 12 to Mar 13

◉ Monthly

○ Accumulation

Link to this page/plot

Source: wateroutlook.nwrfc.noaa.gov

National Weather Service

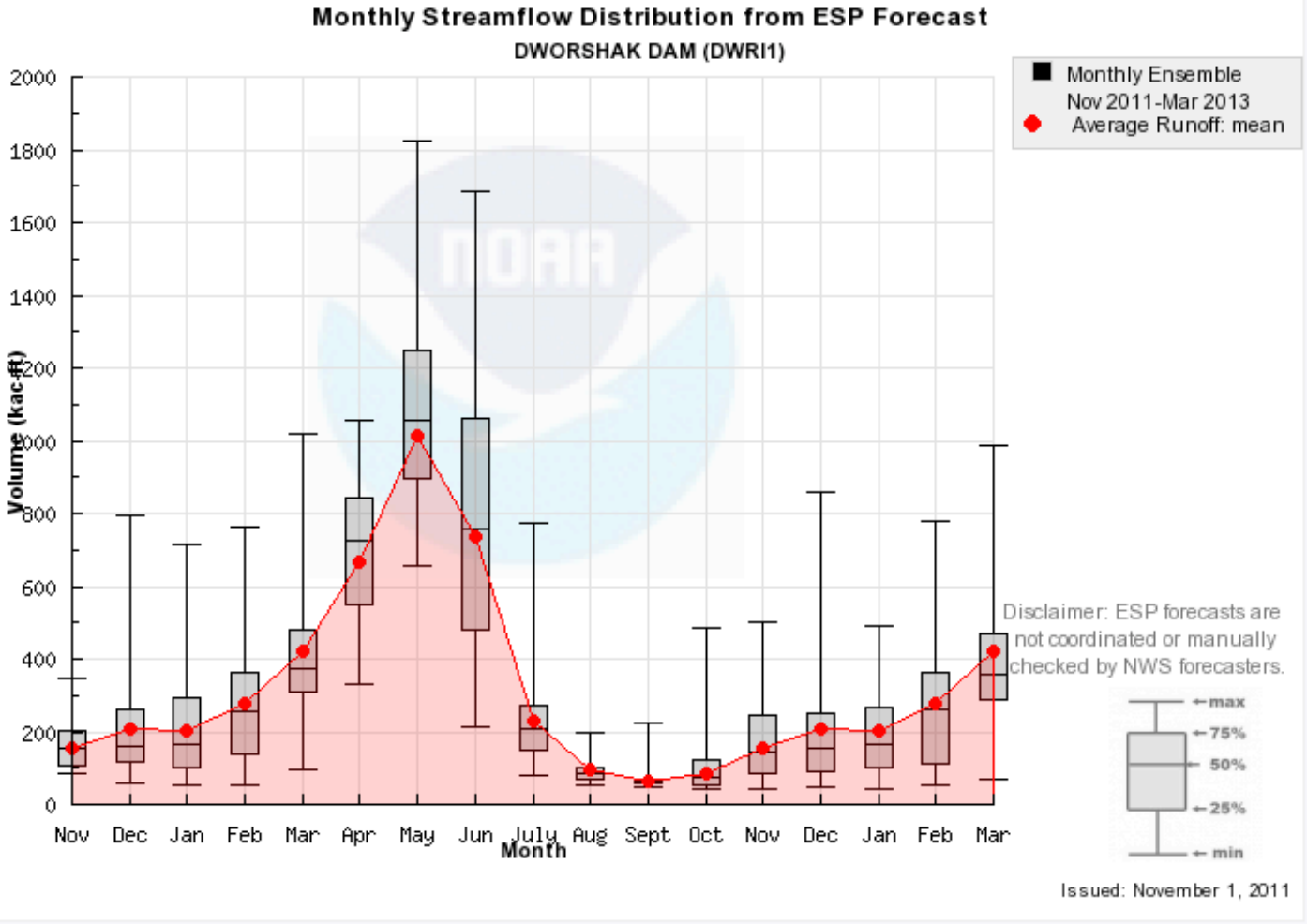
National Water Resources Outlook

Home | Maps | **Points** | Help

Summary | **Ensemble Plot** | Forecast Evolution Plot | Forecast Ranking Table | Climate Variability | Forecast Verification | Data Checkout

Ensemble Plot

Nf Clearwater River at Dworshak Dam, Idaho (DWRI1 / NWRFC)



Link to this page/plot

Need Help?

Graph Options

Forecasts

Current Forecast: November 1, 2011

☐ Forcing Year

☐ ENSO Biased Forecast

Archives

☑ Average Runoff: Mean

☐ Historical Observations

Season Options

Seasonal Constraints: Nov 11 to Mar 13

◉ Monthly

○ Accumulation

National Weather Service

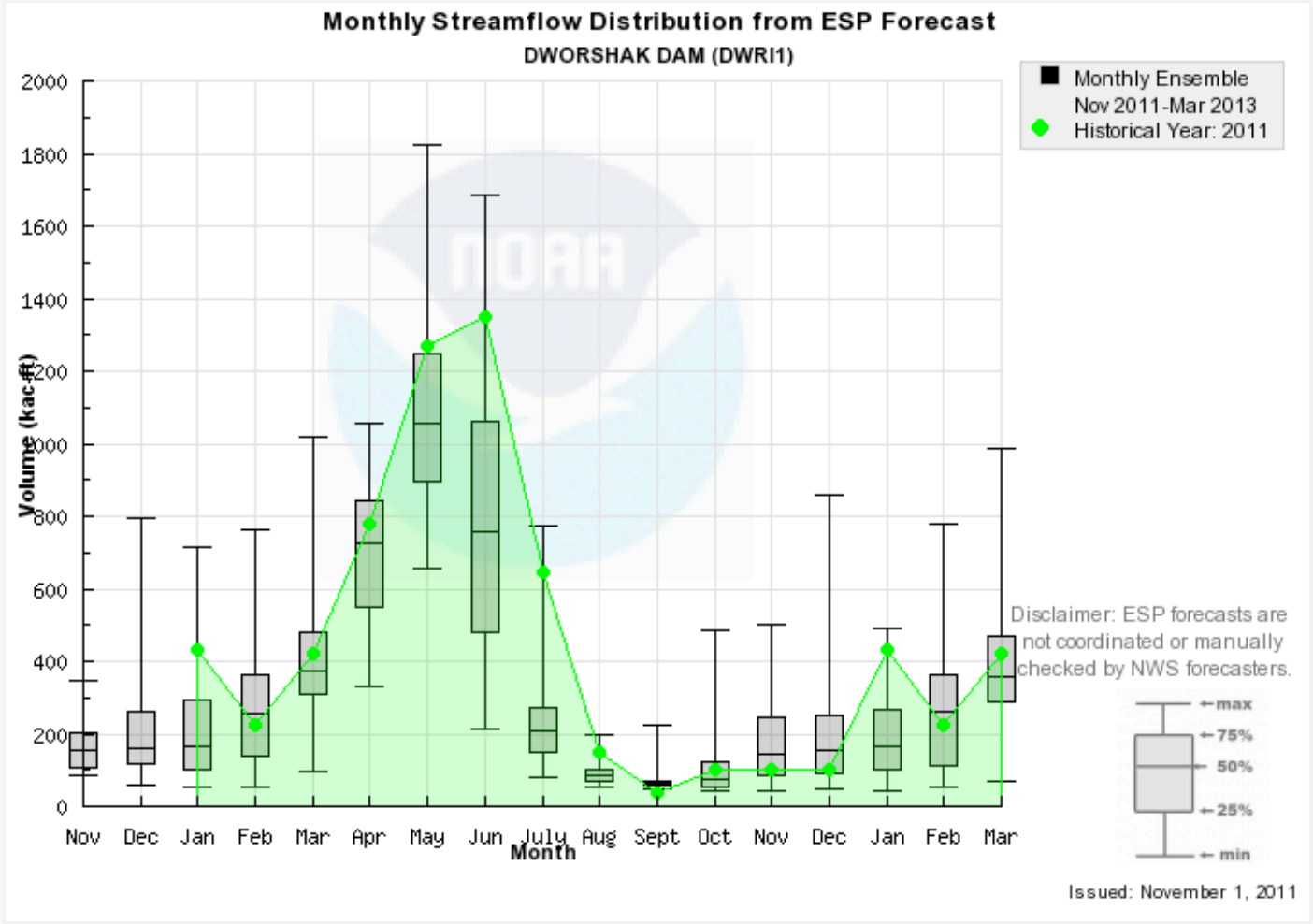
National Water Resources Outlook

Home | Maps | **Points** | Help

Summary | **Ensemble Plot** | Forecast Evolution Plot | Forecast Ranking Table | Climate Variability | Forecast Verification | Data Checkout

Ensemble Plot

Nf Clearwater River at Dworshak Dam, Idaho (DWRI1 / NWRFC)



Need Help?

Graph Options

Forecasts

Current Forecast: November 1, 2011

☐ Forcing Year

☐ ENSO Biased Forecast

Archives

☐ Average Runoff

☑ Historical Observations: 2011 | Off

Season Options

Seasonal Constraints: Nov 11 to Mar 13

◉ Monthly

○ Accumulation

Link to this page/plot

National Weather Service

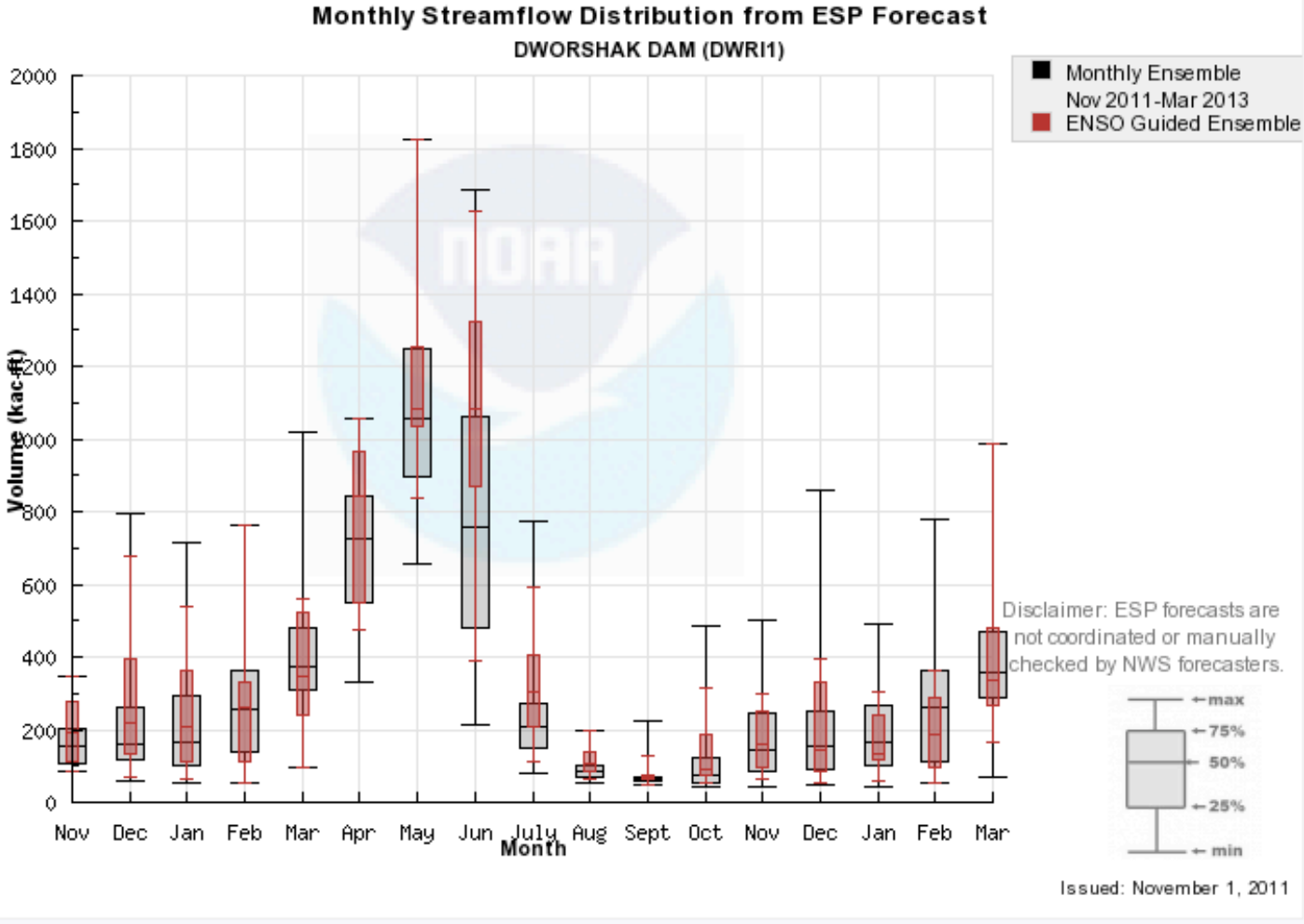
National Water Resources Outlook

Home | Maps | **Points** | Help

Summary | **Ensemble Plot** | Forecast Evolution Plot | Forecast Ranking Table | Climate Variability | Forecast Verification | Data Checkout

Ensemble Plot

Nf Clearwater River at Dworshak Dam, Idaho (DWRI1 / NWRFC)



Need Help?

Graph Options

Forecasts

Current Forecast: November 1, 2011

☐ Forcing Year

☑ ENSO Biased Forecast: La Nina | All

Archives

☐ Average Runoff

☐ Historical Observations

Season Options

Seasonal Constraints: Nov 11 to Mar 13

◉ Monthly

○ Accumulation

Link to this page/plot

Forecast Application

- Previous research and personal experience show forecasts, especially ensemble forecasts, are seldom used
- When used, forecasts use is motivated more by risk perception than forecast skill or applicability

- **Question: How do decision makers incorporate forecast uncertainty?**

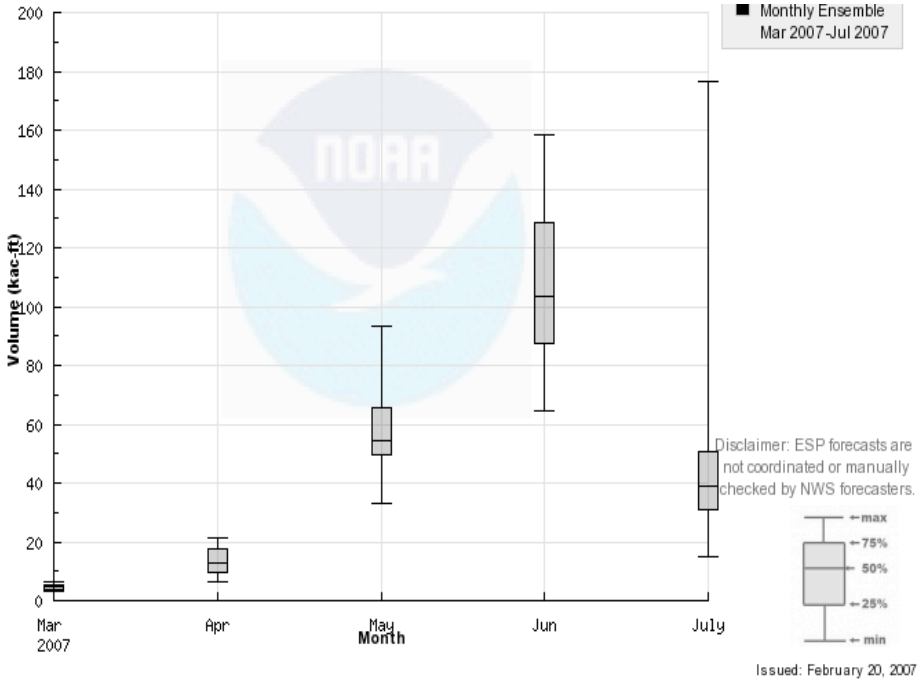
Reservoir Operation Scenario: Method

- Participants given a series of forecasted monthly reservoir inflows (i.e. on right)

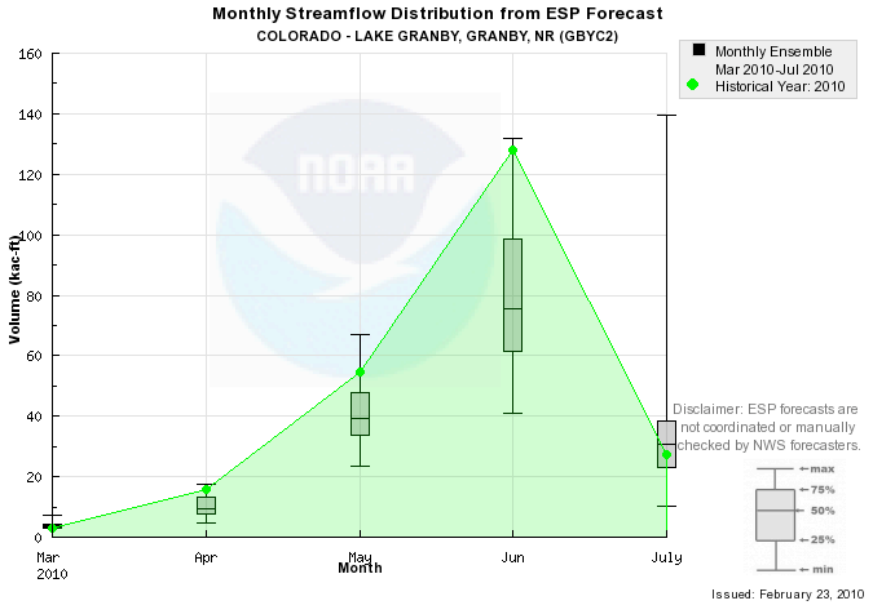
- As simulated time passes, participants given monthly observed inflow and new forecast each month

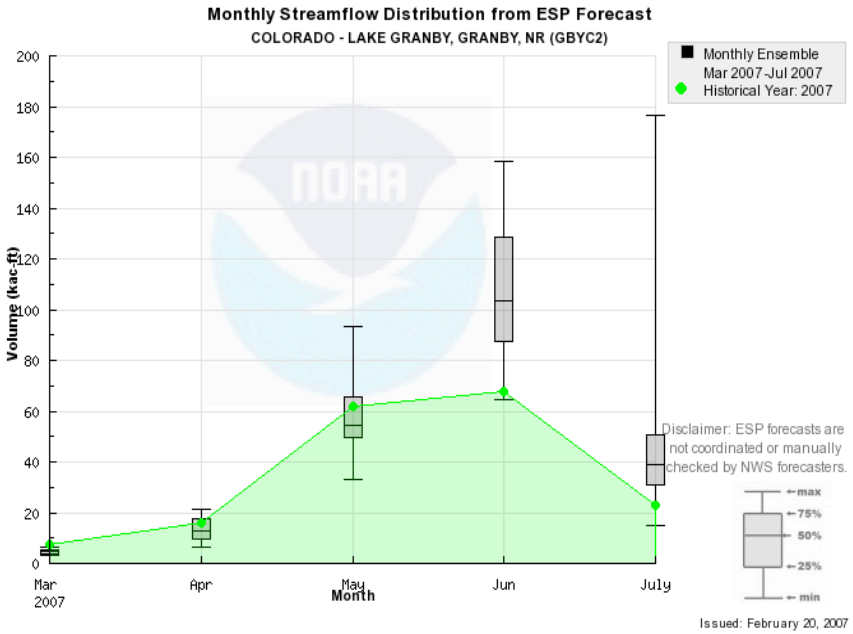
- Participants generate new release schedule each month:
  - Must release between 15 and 60 kac-ft per month
  - Reservoir must not overtop
  - "Winner" has highest ending level without overtopping

- Conducted at workshops:
  - AMS Annual Meeting Short course
  - Utah Stakeholder Meeting
  - NWS Training



Reservoir Operations Scenario

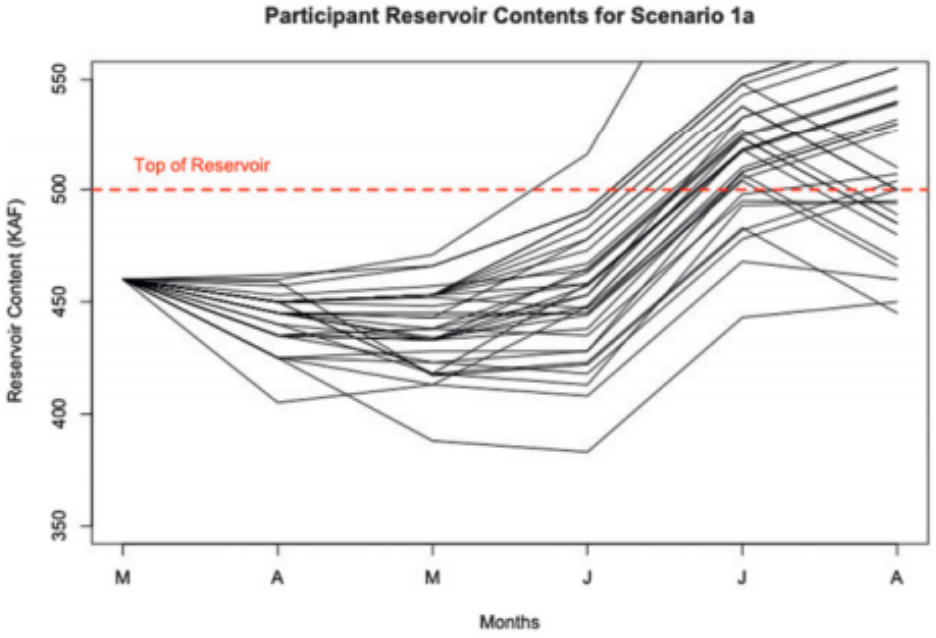


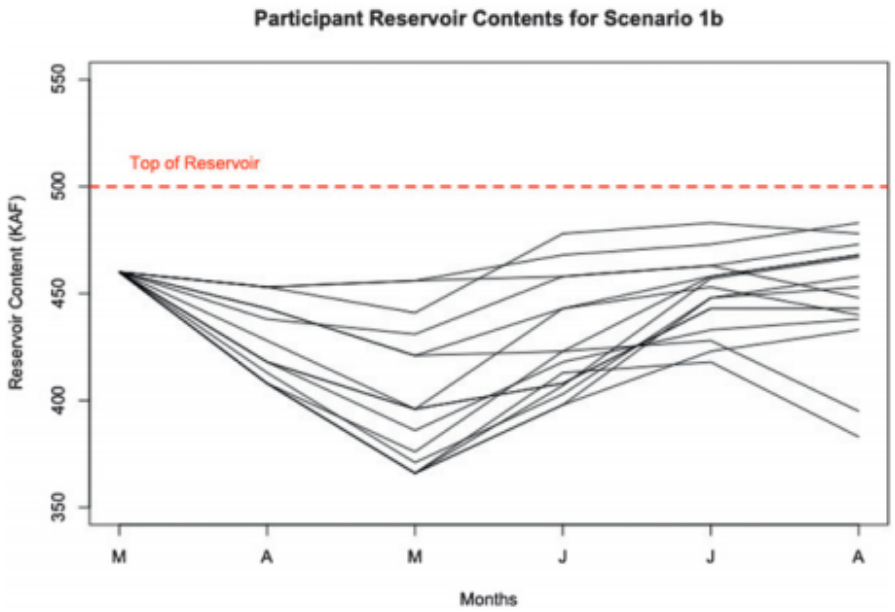


Group 1a:
Actual forecasts for Lake Granby 2010
Underforecast peak flow (June)

Group 1b:
Actual forecasts for Lake Granby 2007
Overforecast June and July volumes

Results





Underforecast scenario

30 of 35 overtopped reservoir

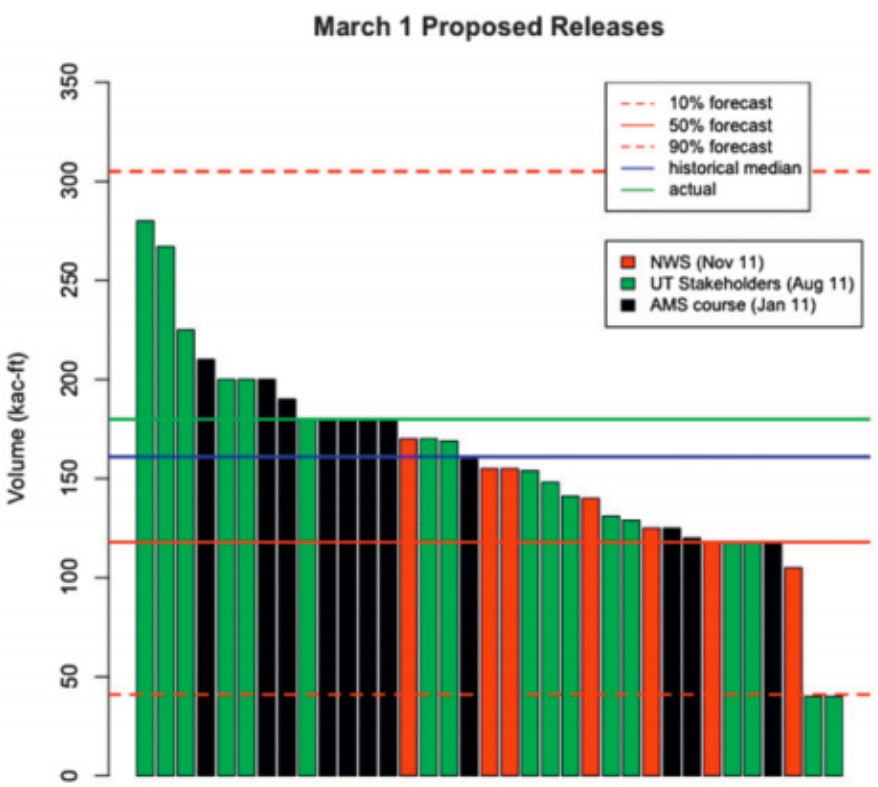
Participant who drew down reservoir early was not familiar with water management or probabilistic forecasts

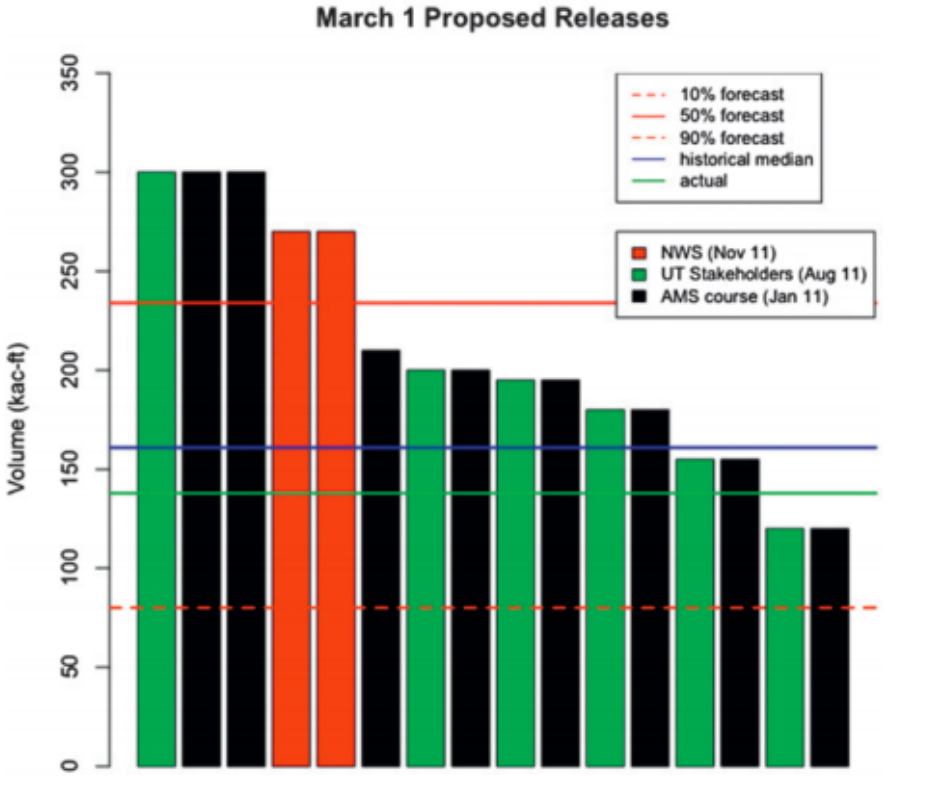
Overforecast scenario

No one overtopped

Participants most familiar with water management drew down reservoir early

Results





Tendency for participants to operate to either the median forecast or the historical flows

Participants largely ignore 10%/90% forecast even though the risk structure of the exercise would suggest participants avoid overtopping at all costs (e.g. plan for 10% forecast).

Conclusions

- Forecast agencies cannot take for granted that forecasts are understood or applied in appropriate ways
- People generally do not use information in the tails of the forecast distribution
- Extreme events are disproportionately responsible for major impacts. They are also often represented in the tails of the forecast distribution
- Forecast agencies and forecast users should collaborate on forecast application including development of decision support systems.

Decision Support System

ESP output increasingly available for stakeholders

- AHPS pages
- Wateroutlook pages
- Experimental RFC websites
- “Raw” ESP output used by some water management agencies to optimize operations

RFC ESP Forecasts

Results of Dillon ESP Simulations

Date of Traces: 4/7/08

Note: When elevations correspond to a specific date, the elevation occurs at the end of that date.

Trace	Elev < 9002 Date	Elev > 9002 Date	# Days < 9002	Elev = 9011 Date	Elev = 9017 Date	Elev May 26	Elev June 30	Peak Comp Inflow cfs	Peak Comp Inflow Date	Peak Outflow cfs	Peak Outflow Date	From May 26 - September 3. Days <450 out	Days 450-699	Days 700-1199	Days 1200-1399	Days >= 1400 out
1976	n/a	n/a	0	6/2	6/8	9006.60	9017.99	2266	6/6	1747	6/13	0	71	19	7	4
1977	n/a	n/a	0	5/24	6/4	9011.70	9017.23	1990	6/6	1432	6/9	0	83	11	4	3
1978	5/10	5/23	14	6/12	6/18	9002.70	9018.20	2539	6/15	1591	6/24	0	76	16	4	5
1979	5/12	5/20	9	6/6	6/13	9004.30	9018.60	2735	6/15	2173	6/18	0	69	12	2	18
1980	n/a	n/a	0	6/9	6/16	9004.40	9017.94	2226	6/12	1321	6/22	0	79	17	5	0
1981	n/a	n/a	0	6/2	6/8	9006.80	9017.82	2857	6/9	2219	6/13	0	66	21	6	8
1982	5/14	5/28	15	6/17	6/25	9001.10	9018.73	2033	6/18	1702	7/2	0	79	13	3	6
1983	5/10	6/9	31	6/20	6/23	8999.00	9019.29	3384	6/24	2781	6/28	0	55	25	2	19
1984	5/7	5/20	14	5/31	6/8	9006.10	9018.55	2549	6/15	2311	6/17	0	55	20	4	22
1985	n/a	n/a	0	6/2	6/8	9006.30	9017.83	2877	6/9	1935	6/12	0	71	16	4	10
1986	n/a	n/a	0	6/5	6/13	9005.70	9017.90	2349	6/9	1515	6/19	0	75	17	6	3
1987	n/a	n/a	0	5/25	6/8	9011.10	9017.88	2107	6/8	1331	6/16	0	76	19	6	0
1988	5/11	5/16	6	6/8	6/15	9003.80	9018.15	2357	6/9	1875	6/21	0	76	13	3	9
1989	n/a	n/a	0	5/29	6/9	9008.80	9017.70	1912	5/30	1331	6/22	0	76	19	6	0
1990	5/13	5/23	11	6/7	6/12	9002.80	9018.17	2926	6/10	1971	6/16	0	71	15	3	12
1991	5/8	5/19	12	6/3	6/10	9005.40	9018.10	2395	6/12	1959	6/15	0	71	15	3	12
1992	n/a	n/a	0	5/18	5/27	9016.20	9017.81	1875	5/21	1391	6/14	0	60	32	9	0
1993	5/11	5/15	5	6/3	6/12	9005.10	9018.40	2789	6/18	2404	6/19	0	69	10	7	15
1994	n/a	n/a	0	6/2	6/8	9006.50	9017.62	2241	6/7	1442	6/16	0	77	14	7	3
1995	5/8	6/10	34	4/8	6/21	9000.00	9019.96	3843	7/9	3613	7/10	0	48	18	3	32
1996	n/a	n/a	0	5/24	6/3	9012.60	9017.91	2273	5/25	1840	6/11	0	68	16	5	12
1997	5/13	5/16	4	6/6	6/12	9004.30	9018.52	2535	6/19	2311	6/23	0	69	11	4	17
1998	n/a	n/a	0	6/2	6/13	9005.40	9017.89	2122	6/3	1054	6/24	0	72	29	0	0
1999	5/12	5/23	12	6/6	6/12	9003.70	9019.05	2854	6/21	2559	6/22	0	56	19	2	24
2000	n/a	n/a	0	5/22	5/28	9014.60	9017.46	2736	5/31	2334	6/2	0	72	14	3	12
2001	n/a	n/a	0	5/25	6/1	9011.40	9017.64	2292	6/3	1759	6/5	0	70	17	3	11
2002	n/a	n/a	0	5/31	6/8	9006.20	9017.24	2465	6/1	1169	6/13	0	87	14	0	0
2003	5/11	5/21	11	5/30	6/3	9005.10	9018.26	3180	5/31	2139	6/19	0	62	13	6	20
2004	n/a	n/a	0	5/27	6/6	9010.40	9017.52	1836	6/8	1311	6/11	0	85	13	3	0
2005	5/12	5/20	9	5/29	6/8	9007.80	9017.89	2074	5/24	1679	6/21	0	72	18	4	7
	n/a	n/a														
Min	5/7	5/15	0	4/8	5/27	8999.00	9017.23	1836	5/21	1054	6/2	0	48	10	0	0
Max	5/14	6/10	34	6/20	6/25	9016.20	9019.96	3843	7/9	3613	7/10	0	87	32	9	32
Avg	5/10	5/23	6	5/31	6/9	9006.53	9018.11	2487	6/9	1873	6/17	0	71	17	4	9
90% Ex	8-May	16-May	0	5/23	6/2	9002.54	9017.51	1983	5/29	1320	6/10	0	56	12	2	0
70% Ex	10-May	19-May	0	5/29	6/8	9004.37	9017.83	2236	6/5	1493	6/13	0	69	14	3	3
50% Ex	11-May	20-May	0	6/2	6/8	9005.90	9017.93	2376	6/9	1799	6/17	0	71	16	4	9
30% Ex	12-May	23-May	10	6/5	6/12	9007.10	9018.22	2736	6/12	2149	6/21	0	76	18	5	12
10% Ex	13-May	5-Jun	14	6/9	6/18	9011.79	9018.76	2951	6/19	2420	6/24	0	79	21	7	20

Assumed RT off until June 1 and April "normal" operating plan thereafter. Took HT from April "normal" plan.
Assumed Fernandez' suggestion and then held the 470 release.

Raftable flows approx 450 - 1800 cfs. Optimum for commercial approx 700 - 1400 cfs.
Good stream fishing approx 450 cfs and below. Marginal fishing 450 - 700 cfs.

Reservoir Management

Summary / Future Steps

- Forecast usage and awareness is growing
- Applying forecasts to decision making is non-trivial
- Investments in decision support important but need to (re)focus on:
  - Objective decision support systems
  - Better understanding decision making process

COLORADO BASIN RIVER FORECAST CENTER

NATIONAL WEATHER SERVICE / NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

News: 2013 Stakeholder Forum has been Rescheduled for Feb 25-26.

CBRFC Conditions

Double Click Map to Zoom, *Data Queried: Tue, 05 Nov 2013 14:35:01 -0700, Lat: 37.6 Lng: -110.5, Zoom: 6*

Data Types
- [ ] River
- [x] Snow
- [ ] Water Supply

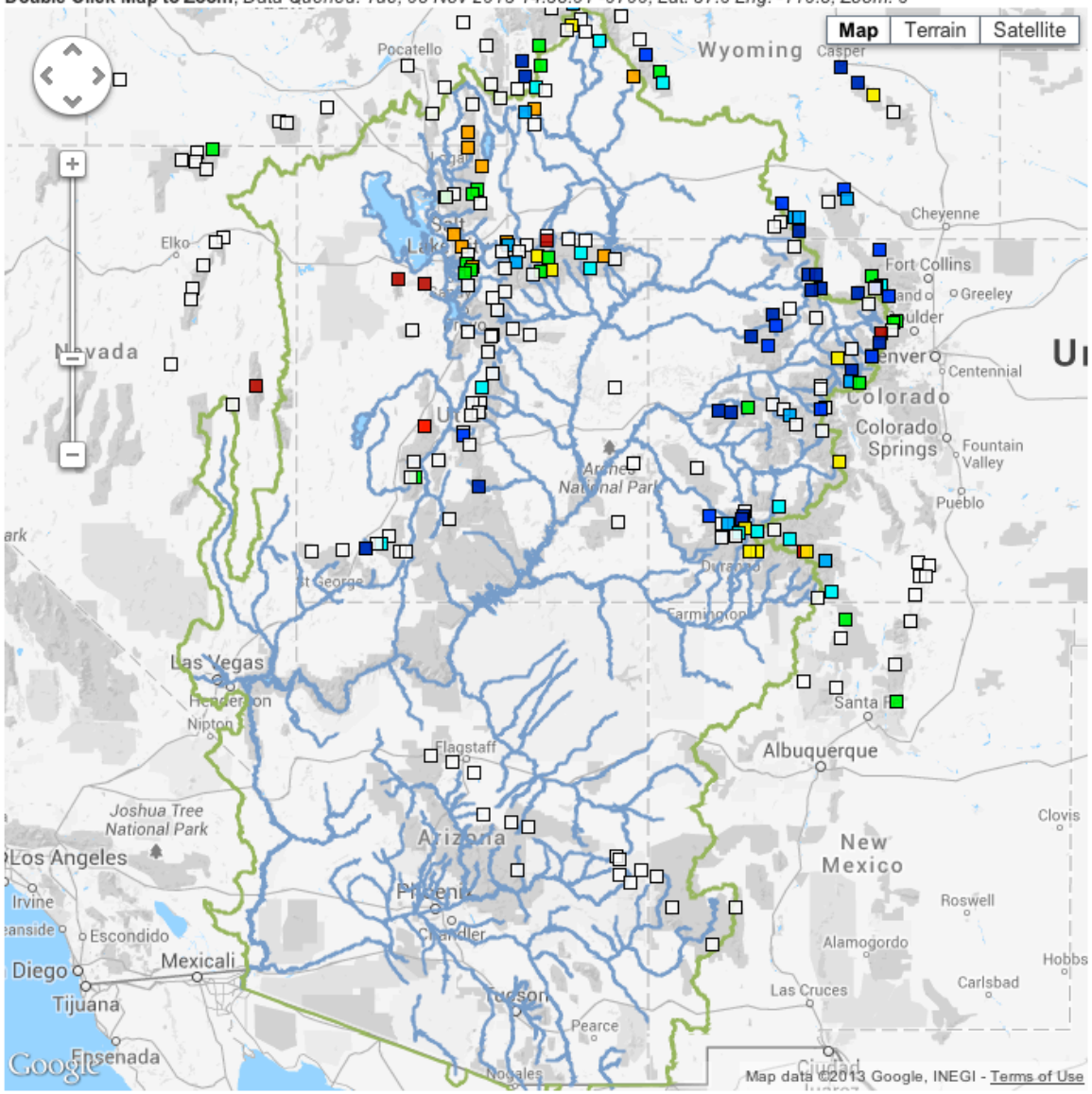
Snow (%Avg SWE)
- No Data
- < 25
- 25-50
- 50-75
- 75-90
- 90-110
- 110-125
- 125-150
- 150-175
- >175

Overlays
- [x] Rivers
- [x] RFC Boundary
- [ ] Forecast Groups
- [ ] Basins

Choose Data Type to Configure

Snow

Point Types
- [ ] All
- [ ] No Data
- [ ] No Average
- [x] < 7000 ft
- [x] 7000-8000 ft
- [x] 8000-9000 ft
- [x] 9000-10000 ft
- [x] > 10000 ft



Select Points by Forecast Group

CBRFC

Select Points by River, Location or ID

Search Points

Feedback, Questions, Concerns always welcome….

Kevin Werner

CBRFC Service Coordination Hydrologist
Phone: 801.524.5130
Email: kevin.werner@noaa.gov

Acknowledgements and Further Resources

- Co-Authors:
  - Kristen Averyt (WWA)
  - Gigi Owen (CLIMAS)
- Paper is available here:
  - http://www.cbrfc.noaa.gov/papers/papers.cgi