

*COLUMBIA RIVER FORECAST GROUP*

**2010  
ANNUAL  
REPORT**



**MAY 2011**

# COLUMBIA RIVER FORECAST GROUP

## 2010 ANNUAL REPORT

### 2010 ANNUAL SUMMARY

The Columbia River Forecast Group (CRFG) was formed to work to promote and support the advancement of forecasting skill, products, and techniques in the Columbia River Basin for the purpose of improving reservoir operations for the benefit of the region and as prescribed and documented in the Columbia Basin Fish Accords and 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp), Reasonable and Prudent Alternative (#7) as shown below.

***RPA Action 7 – Forecasting and Climate Change/Variability:*** The Action Agencies will hold annual forecast performance reviews looking at in-place tools for seasonal volume forecasts and to report on the effectiveness of experimental or developing/emerging technologies and procedures. As new procedures and techniques become available and are identified to have significant potential to reduce forecast error and improve the reliability of a forecast, the Action Agencies will discuss the implementation possibilities with regional interests. The purpose is to improve upon achieving upper rule curve elevations by reducing forecasts errors and thereby providing for improved spring flows...

The Action Agencies and Fish Accord partners formed the Columbia River Forecast Group (CRFG) to collaboratively implement this RPA action. To address the RPA, the CRFG has provided an open forum for sharing, discussing, evaluating and potentially implementing new forecasting techniques, supporting procedures, and information into the planning and operation of the Columbia River Basin system. The term “forecasting” refers to both water supply forecasting and streamflow forecasting.

The CRFG developed a charter and organizational structure in 2009 as well as organizing expectations and a strategy for the group. Under the terms of the charter, the CRFG is also open for participation from any representative of a governmental organization, academic institution, or invited guests of the CRFG who are willing to contribute to the effectiveness and success of the group. The CRFG conducted five business and/or workshop meetings in 2010: March 19, May 13, August 4 (webinar), October 7, and December 10. The meetings provided a forum to review the performance of the year’s forecasts and to hear speakers on various topics related to water supply forecasting. Meetings were attended by numerous agencies including the Natural Resources Conservation Service, NWRFC, NOAA Fisheries, Columbia River Inter-Tribal Fish Commission (CRITFC), Bonneville Power Administration (BPA), U.S. Army Corps of Engineers (Corps), Bureau of Reclamation (Reclamation), Northwest Power and Conservation Council (NPCC), the Fish Passage Center, and BC Hydro and Power Authority.

The March meeting/workshop included a presentation from COE on the revision of the Libby forecast equations. Reclamation provided an update on their analysis of the affects of using mid month forecasts on the operation of Hungry Horse Reservoir. BPA provided an update for an ongoing investigation for additional snow pillows in the Canadian portion of the Columbia Basin. Discussions were also held on format and content of the annual report.

At the May meeting/workshop the team reviewed their purpose in order to help stay focused on the mission, to reduce forecast errors and to better anticipate the runoff timing or water supply. The Action Agencies and the RFC use the best available science to compute water supply forecasts. COE reported on the work on updating the Libby Forecast. Some of the climate variables look promising such as QBO, along with the summer SOI and PNA. Also, the Alberta snow measurement sites are still appearing to be useful. In addition, BPA reported that progress is still being made on the study for additional snow pillows in the Canadian portion of the Columbia Basin.

In August, a webinar workshop was held for CRFG review of the proposed update to the Libby forecast procedure. The procedure was presented and explained and the individuals provided their comments to the COE.

In the October 7 meeting, representatives from multiple agencies provided a recap and review of their 2010 water supply forecasts with an assessment of the performance of the procedures during the water year. Other presentations included an update by BPA on their effort to investigate potential sites for new snow pillow stations in Canada, and updates from Reclamation and the Corps on their ongoing study of the potential benefits of performing mid month forecasts at Hungry Horse and Dworshak Reservoirs (more info on these work items will be found below).

The December meeting/workshop included a presentation from Reclamation summarizing the affects of using mid month forecasts on the operation of Hungry Horse Reservoir (more info below). BC Hydro also gave two very interesting presentations. The first was titled “A Horse-Race Intercomparison of Process-Oriented Watershed Models for Operational River Forecasting”, in which BC Hydro contracted with multiple entities for a “which model is the best” competition, where each entity used their own independent model to predict flow parameters at the same set of 4 unique projects. The results varied, but it confirmed that BC Hydro’s internal model was robust and should continue to be supported. The other BC Hydro presentation was “Multi-Thread Assessment of Hydroclimactic Change to Support Long-term Planning of Hydroelectric Resources”, which was an analytical approach to using multiple (and sometimes divergent) climate change predictions for long term planning certainty.

CRFG work accomplishments and ongoing studies in 2010 included the following:

- Working with the Corps on its efforts to improve the water supply forecast equations for Libby Dam through evaluation of various climate indices. New water supply forecast equations were developed for Libby Dam inflow during 2010. The analysis reviewed a wide pool of climate index variables, precipitation variables

and snow pillow sites and used advanced statistical methods to develop principal components regression models for producing monthly forecasts from 1-November to 1-June. The new equations make seasonal use of the SOI, QBO and PNA climate variables, along with four precipitation variables and up to nine snow pillow sites. The new equations provide improved forecasts (reduced errors) over the previous set of equations from 2004.

- Working with BPA and the Columbia River Treaty Hydrometeorological Committee to look at the benefits of additional snow pillows in the Columbia Basin in British Columbia. BPA's assessment began with a GIS-based analysis on snow course and snow pillow locations and elevations, compared to PRISM-derived precipitation volume contributed per elevation band. This was augmented by a statistical PCA analysis of which snow stations are most influential in their contribution to runoff. BPA has a short list of snow course sites to recommend, and a short list of alternative sites. The timeline for the project was to complete a draft report of the recommendations in December 2010, issue the final report in March 2011, acquire approval in April 2011, turn the permitting process over to BC Hydro in summer 2011, and install new pillows in summer 2012. The draft report is still internal to BPA, and a final report has been delayed slightly. The CRFG will continue to be engaged with the ongoing work in 2011.
- Working with the Corps and Reclamation to assess the benefits of mid-month water supply forecast updates. The effort entails looking at two test locations: Hungry Horse and Dworshak dams. Both agencies used multiple linear regression equations to hind cast mid-month forecasts going back to about 1980. At Dworshak, the Corps determined that roughly 2/3's of the cases the mid month forecast points in the right direction, and 1/3 in the wrong direction, although many of the 'trends' are not significant. Further work to analyze results is pending until completion of the Corps' system RES-SIM model. At Hungry Horse, Reclamation determined there were minimal effects to operations from producing mid month forecasts. Reclamation utilized a daily time-step operations model (Riverware) to simulate operations with and without the mid month forecasts, and found that modeled operations were essentially the same in 25 out of the 30 years, with only minor changes in the other 5 years. Other conclusions were: Impacts were not seen in most years because flood control was not forcing operations; impacts were limited to wet years with increasing or decreasing forecast trend; an increasing trend in March meant water was shifted earlier into late March from April; increasing trend after April meant shifting water into April from May; an opposite effect was caused by a decreasing forecast; any release changes would be further muted due to attenuation through downstream projects.
- Develop an Annual Report and report format for the group that includes an appendix that will track water supply forecast performance each year. The report was developed and posted in November, 2010 for the year 2009.

Previously five key work items for the 2010 work plan were established in September 2009. These included:

1. Evaluate the benefits/problems with increased frequency of water supply updates. This was discussed above.

2. Review the climate indices evaluated and selected when the Libby forecast procedure was last updated. This was discussed above.
3. Verify and track accuracy and limitations of various forecast equations and models (Volume Distribution and Calculation (VoDCA), Extended Streamflow Prediction (ESP), etc.). This was initially tabled, but tracking of forecasts at key locations in the basin is included in Appendix C. The next steps would be to compare concurrent forecast procedures from different sources (USACE, National Weather Service (NWS), etc.) to access which procedures are the most accurate over a number of years. This can be investigated during FY 2011.
4. Perform risk analysis associated with forecasts. This work item needs to be revisited and clarified.
5. Evaluate the benefits of additional snow pillow sites, particularly in the Canadian portion of the Columbia drainage, assigned to David Bright (Bonneville Power Administration (BPA)). This task is still in progress and a final report is now due in 2011.

Status of these and other action items from the 2010 calendar year are shown in the following table.

### Action Items for CRFG 2010

Meeting	Item	Final Status	Complete
From 2009	Mid-Month Forecasts	Decision was to table this exercise until the new ResSim model is complete and then run simulations to determine the impacts of using a mid month forecast on final water availability.	Tabled until ResSim model is ready.
From 2009	Libby	Updated Libby using new/additional climate indices.	Complete
From 2009	Verify and track accuracy and limitations of various forecast equations and models	From March Meeting, "Should National Resource Conservation Service (NRCS) be involved in the comparison with NWS and the USACE to see whose procedures are most accurate?"	Final action item was to add tables of forecasts for key sites, preferably for the last 10 years.
March 2010	Should NRCS be involved in the comparison with NWS and the USACE to see whose procedures are most accurate?	Study of comparing different forecasts for a given region has not yet been done.	Study on this issue has not been issued yet.
March 2010	Annual Report	Annual report for 2009 was finally drafted and posted on the Salmon Recovery web site in November 2010.	Complete
May 2010	NWS and discussion of impacts of 10-day forecast on ESP process.	Discuss with the NWS about using less than the 10 day deterministic forecast as part of the ESP process. Would a 3 day or 5 day be better and then shift to ESP traces instead of 10 days out?	Will try and have this presentation at meeting in 2011.
March 2010	Review of forecast procedures and accuracy	Reports from each station were presented at the October and December meetings.	Complete
May 2010	Discussion of 30 year data sets that are used by the Action Agencies (AA).	A sub group needs to be put together to review and discuss the 30 year data sets that are utilized by the AAs.	Part of the issue is who should take the lead on this?

## A P P E N D I X A

### Columbia River Forecast Group (CRFG)

The following pages document the CRFG Charter approved on July 21, 2009.

#### CRFG CHARTER

##### I. Purpose

**The Columbia River Forecast Group will work to promote and support the advancement of forecasting skill, products, and techniques in the Columbia River Basin for the purpose of improving reservoir operations for the benefit of the region and as prescribed and documented in the Columbia Basin Fish Accords and 2008 FCRPS Biological Opinion, Reasonable and Prudent Alternative (#7).** It will also provide an open forum for sharing, discussing, evaluating and potentially implementing new forecasting techniques, supporting procedures, and information into the planning and operation of the Columbia River Basin system. The term forecasting will refer to both water supply forecasting and streamflow forecasting.

##### II. Composition

The CRFG will be composed of technical representatives from the AAs, namely the BPA, the USACE, and the USBR, as well as the parties to the Fish Accords. The CRFG will also be open for participation from any representative of a governmental organization, academic institution or invited guests of the CRFG, who are willing to contribute to the effectiveness and success of the group.

The Chair of the CRFG will be a representative from the three AAs or Fish Accord Tribes. The Chair position will rotate annually among these four representative organizations or groups following the Fall Workshop.

##### III. Meetings and Workshops

A general business meeting will occur no less than quarterly but more frequently if workload and projects require it. Meetings and workshops will be called at the discretion of the Chair.

In addition to business meetings, there will be an Annual CRFG Meeting in the fall to review the performance of various operational and experimental forecast procedures over the previous water year, to report on any new approved procedures being implemented in the next year, and to plan committee work for the coming year.

#### IV. Functions

1. Facilitate the sharing of information and research pertinent to the improvement of forecasting for the Columbia River Basin, namely in the areas of water supply forecasting, operational streamflows forecasting, data quality and availability, weather forecasting (as it pertains to improving water supply and streamflow forecasting), and climate change.
2. Track and review the performance of current forecasting procedures and techniques, as well as sharing, discussing, and investigating the potential of new forecasting techniques and modeling.
3. When promising research or techniques are discovered and introduced for consideration, the CRFG will develop a strategy for either investigating the potential improvement with available technical staff within the CRFG or provide recommendations or proposals to the AAs for possible funding and support for further research and development.
4. The group will participate in the evaluation of proposed new forecast procedures, models, and techniques and provide recommendations on the incorporation of new procedures into the planning and operation of the Columbia River system.
5. Facilitate the sharing of data, where possible, and the monitoring of the data network and systems which enhance and support the forecasting capabilities of the region. When necessary, the group will provide recommendations on improvements and enhancements to the network.
6. When necessary, the group will plan and facilitate workshops with presenters speaking on current research and forecast projects. The group will also have a role in educating users on forecasting products and on specific focus areas, providing the technical expertise and platform for conducting seminars and workshops on various topics pertinent to the group's purpose.

#### V. Reporting

1. The CRFG will produce minutes of each official meeting for distribution to the group and for the purpose of summarizing the group's activities and achievements at the end of the year.
2. The CRFG will produce an annual summary of the group's activities, achievements, and recommendations no later than 4 months after the end of the water year. This report will be the basis for annual reporting required for the Biological Opinion and Fish Accord records.
3. The organization chairing the CRFG will be responsible for meeting notes and annual reporting at the end of the water year.



## **A P P E N D I X B**

### **Columbia River Forecast Group**

Meeting notes. The following meetings took place for the CRFG. Meeting notes are attached where available:

19 March 2010

13 May 2010

4 August 2010 (Libby Forecast Webinar)

7 October 2010

10 December 2010

**Subject: Columbia River Forecasting Group**  
**Location: Columbia River Inter-Tribal Fish Commission (CRITFC) Building,**  
**Columbia Room (upstairs)**  
**Time: 0900-1200, 19 March 2010**

Current Agenda: Please be prepared to address your action items below and let me know how long do you need for your section (5 min, 15 min, 30 min). I like to set times in place. If there is additional discussion required, we will table it and come back to it at the end.

1. Introductions (0900-0910)
2. Review purpose of CRFG (0910-0915)
3. Status of 2010 Workplan (0915-0930)
  - a) Workplan development (B. Proctor/N. Stephan) (0915-0930)
  - b) Status of work (0930-0945)
    - 1) R. Wortman: Libby Forecast Procedure Update (0930-0945)
    - 2) J. Roache: HGH mid-month forecast update evaluation (0945-1000)
    - 3) S. Hall: DWR mid-month forecast update evaluation (1000-1015)
    - 4) D. Bright: Snow Pillow investigation in British Columbia (B.C.) (1015-1030)
    - 5) N. Stephan: Set up and develop format for annual report including annual record of forecast performance (1030-1045)
4. Status of 2009 Annual Report (Bill Proctor) (1045-1050)
5. Break (1050-1100)
6. Round Robin on CRFG focus areas: (All)
  - a) Seasonal Water Supply Forecasting (1100-1110)
  - b) Operational Streamflow Forecasting (1110-1120)
  - c) Data Quality and Availability (1120-1130)
  - d) Weather Forecasting (1130-1140)
  - e) Climate Change (1140-1150)
  - f) Workshops and Events (1150-1200)
6. Meeting schedule
  - a) Next meeting, 20 or 21 May 2010, Columbia River Room, 4<sup>th</sup> Floor, Northwestern Division (NWD), USACE.
  - b) Setting up a set date every other month
7. Parking Lot for Unfinished Discussion

## Columbia River Forecasting Group Meeting of 19 March 2010

### Meeting Minutes

#### Attendees

Bill Proctor, USACE	Joel Fenolio, USACE	Kyle Dittmer, CRITFC
Stephen Hall, USACE	Paul Wagner, National Oceanic and Atmospheric Administration (NOAA)	Jolyne Lea, U.S. Department of Agriculture (USDA), NRCS
David Bright, BPA	Jon Lea, USDA NRCS	Jim Ruff, Northwest Power and Conservation Council (NWPPCC)
Randy Wortman, USACE	Rashawn Tama, USDA NRCS	David Benner, Fish Passage Center (FPC)
Ken Soderlind, USACE	David Garen, USDA NRCS	Chris Karafotias, BPA
Tom Herrett, USGS	Nancy Stephan, BPA	Ted Day, USBR

1. **Introductions.** Bill Proctor introduced as new chair of the committee.
2. **Review purpose of CRFG.** This is documented in the 2009 Annual Report outline.
3. **Status of 2010 Workplan:**
  - a) Workplan development (B. Proctor/N. Stephan)
  - b) Status of work

1) **R. Wortman: Libby Forecast Procedure Update.** The work in reviewing and updating the Libby water supply forecast is in full swing. A review of the long term streamflow records for Libby inflow discovered that the streamflow displays a distinct shift toward lower flows following the mid-1970s (Libby began filling in 1973). Due to this non-stationarity in flow, the new analysis will include data only from 1975 to 2009. New to the forecast development is consideration of 10 climate variables (Pacific North American (PNA) Index, Western Pacific (WP) Index, Oceanic Nino Index (ONI), Bivariate El Nino/La Nina Oscillation (ENSO) Timeseries (BEST), Quasi-Biennial Oscillation (QBO), Northern Oscillation Index (NOI), Pacific Decadal Oscillation (PDO), Nina34, Southern Oscillation Index (SOI), and Multivariate ENSO Index (MEI)). Three of these climate variables (PNA, PDO, QBO) appear to be showing helpful early-season predictive power. Also new is consideration of the eight Alberta Environment snow pillow stations situated along the crest of the Rocky Mountains on the eastern edge of the Kootenay basin. These snow pillows, with 1-January and 1-February correlations with Libby inflow similar to (or better than) the few available B.C. Automated Snow Pillow (ASP) stations, will be included in the analysis. Data fill-in is a huge chore, and is almost completed for the snow data. Data fill-in for the precipitation stations will begin shortly.

The principle component regression analysis and equation development should be underway before the end of April and completed during May.

There is no official Corps record for the historical Libby inflow. Pre-project inflow has been computed several ways, from several gages. Post-project records are not exactly consistent, but are very, very close. The Libby inflow series shows a 20-year upward shift, from approximately mid-1940s to mid-1970s, followed by a return to the previous regime. The shift is about 1.5 Million Acre Feet (MAF) and is statistically significant. Forecast development will only use data from 1975 to 2009. Snow data in the east Kootenay basin is fairly sparse, especially snow pillow sites. The four Montana snow pillows are generally not well correlated with Libby inflow. The newly discovered snow pillows along the B.C./Alberta border may be able to help improve the forecast. These are **just east of the Libby basin and look very promising on helping with the predictions.** Report can be found at: [http://www.nwd-wc.usace.army.mil/report/libf/lib\\_wsf\\_2010.pdf](http://www.nwd-wc.usace.army.mil/report/libf/lib_wsf_2010.pdf)

### **2) J. Roache/Ted Day: HGH mid-month forecast update evaluation.**

USBR is not as far along on the project as we'd like to be, but we are making progress in putting together the necessary data and should be able to gain momentum over the next month. We already have a spreadsheet built that we can use for making the mid-month forecasts, with minor modifications. We will be using our current multiple linear regression equation, which is a single equation for January-July runoff that we use for the entire season; this equation necessarily relies on assumption of future subsequent conditions. This way, we will have consistency between first of month and mid-month forecasts. Depending on the outcomes, we would consider building new principle component mid-month equations in the future, and these would not rely on subsequent conditions.

USBR and the USACE will work together to determine the best way to display and analyze results. USBR plans to insert the mid-month forecast results into its daily time-step operations model (Riverware) to analyze impacts/improvements to operations, compared to using first of month forecasts alone.

USBR has been preparing informal mid-month forecasts in 2010, and these results were shown. The mid-month forecasts have shown the correct trend so far this season, particularly with a precipitous drop in forecast from the 1 February issuance to the 15 February issuance.

**3) S. Hall: DWR mid-month forecast update evaluation.** DWR is not really done yet and still needs some internal review. Roughly in two-thirds of cases, the mid-month forecast points you in the right direction and one-third in the wrong direction, but often this might not be a very big difference.

**Action Item:** USACE Walla Walla District (NWW) will relook at this using a criteria of +/- 200 Thousand Acre Feet (KAF) to see how this impacts the indicator.

**Action Item:** NWW will write a white paper in the future and provide it first for internal review and then share the results with the CRFG.

Potential issues:

- (1) If the next 2 weeks are a wet or dry cycle, then you could over correct.
- (2) Next phase needs rules. For example, when the mid-month tells you to change direction, use only a 50% change in the required storage volume or elevation.
- (3) This could affect system flood control and shift operations, but would need to be looked at in a separate study.
- (4) Note this is based on the current equations and Sno-Tel sites.

**4) D. Bright: Snow Pillow investigation in B.C.** Topic: An Investigation for Additional Snow Pillows in the Canadian Portion of the Columbia Basin.

Minutes: The Columbia River Treaty Operating Committee (CRTOC) tasked the Hydromet Committee (October 2009) to look into the need for additional snow pillows in the Canadian portion of the Columbia Basin. A work plan was finalized in December, 2009 and calls for a Geographic Information System (GIS) analysis of the Basin, a statistical assessment as needed, and then recommendations for an additional three-five snow pillows. More than likely, these pillows will be located at existing snow course sites. The timeline for the project is to complete a draft report of the recommendations in December 2010; issue the final report in March 2011; acquire CRTOC approval in April, 2011; turn the permitting process over to BC Hydro in summer 2011; and install the new snow pillows in summer 2012. The presentation showed GIS work to date, specifically the contributions of the major Canadian sub-basins to Columbia River runoff with respect to elevation and existing gauges. Following the GIS analysis, the BPA group plans to tap into the NRCS expertise later this spring. Finally, a reference was mentioned to a review article on network gauging optimization. That article is: Mishra, A. K., and P. Coulibaly (2009), Developments in hydrometric network design: A review, Rev. Geophys., 47, RG2001, doi:10.1029/2007RG000243.

**5) N. Stephan: Set up and develop format for annual report including annual record of forecast performance.** Format for the annual report is attached. Summary graphs should track the error bands or spread for the 10% to 90% error bands for different forecasting procedures.

**Action Item:** Technical Management Team (TMT) already shows charts for the Columbia at The Dalles forecast. Compare the End of Year (EOY) plots. Eventually use consistent forecast data sets.

**Action Item:** Randy is already working on the update to the Libby Forecast. David Garen was willing to assist. David Bright indicated said he did not have time. Randy was to provide Nancy a link to the forecast comparison graphics that he produces for TMT.

**Action Item:** Outline for reporting work for the annual report

**Action Item:** Go back 10 years on the data comparison tables. Look at the blue book summaries. 2010 Report is only going back to 2005 forecasts.

**4. Status of 2009 Annual Report (Bill Proctor).** Nancy is working on this document to be completed later this year. If you have submittals for 2009 work, please send to Nancy Stephan by 31 May.

**5. Round Robin on CRFG focus areas: (All)**

a) Seasonal Water Supply Forecasting. Should NRCS be involved in the comparison with NWS and the USACE to see whose procedures are most accurate? Jim Ruff asked, “Can anything be done to hedge on forecasts before 31 December to avoid digging a deep hole in the reservoir based on not very good information?” Part of the problem is that the climate indices developed late. October was predicted to be a weak El Nino; now it is the fifth strongest.

**Action Item:** Look at El Nino – El Nina Presentation; this website is fairly good. <http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html>

b) Operational Streamflow Forecasting.

c) Data Quality and Availability. Discussion on 30-year data sets starts in 2011. Note was about putting together a subgroup on this and who should be included.

**Action Item:** Please think about this and we’ll have more discussion at the next CRFG meeting.

d) Weather Forecasting.

**Action Item:** Analyses on NWS ESP traces and the effect that the 10-day deterministic forecast has on them. Could Harold from River Forecast Center (RFC) do presentation on the 10 day as well as the 3 day and 5 day?

e) Climate Change.

f) Workshops and Events. Workshop scheduled for 19 April, River Management and Joint Operation Committee (RMJOC) Climate Change Workshop.

**6. Meeting schedule.** Next meeting is 13 May 2010, Columbia River Room, 4<sup>th</sup> Floor, NWD, USACE.

**a. May Agenda Items:**

- 1) International Joint Commission (IJC) Rules and Operations – Joel Fenolio
- 2) HGH and DWR Mid-Month Update – Ted Day and Steve Hall
- 3) Libby Forecast Equation Update – Randy Wortman

4) Status of submittals for the 2009 Annual Report. *(Note my guess is that nothing has been submitted yet. Please remember this task and remit a short write up to Nancy Stephan by 31 May on any 2009 work on this topic. Thank you.)*

5) Any other topics for May meeting

**b. Future Agenda Items:**

1) (July) IJC Rules and Operations – Joel Fenolio

2) (July) Report of a trend analysis of flow data within our region of interest including the Columbia River. (Frank Weber)

3) (September or November) Results from climate change studies (Frank Weber)

4) Others??

**Action Item:** I seem to remember a July meeting being discussed, but no firm date yet.

**Action Item:** Volunteer for a location?

**Action Item:** Meeting scheduled for 4 November 2011

**Action Item:** Volunteer for a location?

5) Setting up a set date every other month, currently planning for May, July, and November. On every other month schedule, we could have a September meeting as well; however, this tends to be very difficult. Charter only requires quarterly meetings.

**7. Parking Lot for Unfinished Discussion.**

Corrections: With Action Items, need to assign person responsible for each item. Correct at next meeting.

**Subject: Columbia River Forecasting Group**  
**Date: 13 May 2010, 0900-1000 Conference Call**

**Location: Willamette River Room, 4th Floor, NWD, USACE; 1125 NW Couch Street, Suite 500; Portland, OR, 97208.**

**Contact: Bill Proctor: 503-808-3952 Office, 865-898-6238 Cell**

1. Introductions - Bill Proctor (0900-0905)
2. Status of 2010 Workplan
  - a) Workplan development (B. Proctor/N. Stephan) (0905-0920)
  - b) Status of work (0920-0930)
3. HGH Update – Jon Roache (USBR) – Nothing new to report, target July meeting.
4. DWR Mid-Month Update – Steve Hall - Nothing new to report, target July meeting.
5. Libby Forecast Equation Update – Randy Wortman (0930-0940)
6. Status of submittals for the 2009 Annual Report (0940-0950)
7. Review Action Items (0950-1000)
8. Any other topics for July Meeting. (1000-1010)



# Columbia River Forecasting Group Meeting of May 13, 2010

## Meeting Minutes

**Date: 13 May 2010, 0900-1000, Conference Call**

### Attendees

USACE – NWD	USACE - NWS	CRITFC
USACE – NWW	NOAA	USDA NRCS
BPA	Fish Passage Center	

1. Introductions - Bill Proctor. Reminder of Purpose: In an effort to reduce forecast error and to better anticipate the runoff timing or water supply, the AAs and the RFC use the best available science to compute water supply forecasts. An annual forecast review will occur each fall by the CRFG to evaluate the performance of the current forecast procedures. The CRFG will evaluate new forecasting techniques for potential implementation.
  
2. Status of 2010 Workplan - not much progress on this item yet. We have a set of action items that are being tracked and progress on the various projects is continuing. Need to develop a work plan for future items. (B. Proctor/N. Stephan)
  
3. HGH Update – Jon Roache (USBR). Data available for mid months. Looking at the results, the April official forecast was 71%; the mid month was 74%; and the official May forecast was 74%. Target presenting some results at the July meeting.
  
4. DWR Mid-Month Update – Steve Hall. Nothing new to report due to the loss of staff member(s), target July meeting to present results.
  
5. Libby Forecast Equation Update – Randy Wortman. Some of the climate variables look promising. QBO is one. *[The Bios a quasi-periodic oscillation of the equatorial zonal wind between easterlies and westerlies in the tropical stratosphere with a mean period of 28 to 29 months. The alternating wind regimes develop at the top of the lower stratosphere and propagate downwards at about 1 km (1 mi) per month until they are dissipated at the tropical tropopause. Downward motion of the easterlies is usually more irregular than that of the westerlies. The amplitude of the easterly phase is about twice as strong as that of the westerly phase. At the top of the vertical QBO domain, easterlies dominate; while at the bottom, westerlies are more likely to be found.]* Wikipedia. And it can have a 14-18 month lead. However, Matt Newman, NOAA Climate Diagnostics Center pointed out that the QBO long lead might not make it a good fit when comparing to a shorter term data base and to be aware of that. Randy is also looking at the Summer SOI and the PNA Also, the Alberta snow measurement sites are still appearing to be useful and would provide the potential for doing mid-month forecasts as they are all snow pillows. Also, for precipitation, a multi-month accumulation appears more factor rather than just for 1 month.

6. Status of submittals for the 2009 Annual Report. At the July meeting, need to further discuss the plan for formatting the 2009 report and what should be included. Also need to review the performance of the 2009 forecasts and begin preparing performance comparisons of the 2010 forecasts.

7. Review Action Items.

a. Want to discuss with the NWS about using less than the 10-day deterministic forecast as part of the ESP process. Would not a 3 day or 5 day be better and then shift to ESP traces instead of 10 days out?

b. David Bright is still on track on the Snow Pillow Investigation.

c. Need to put together a sub group to review and discuss the 30-year data sets that are utilized by the AAs. Part of the issue is who should take the lead on this??

8. Any other topics for July Meeting.

a. NWS is proposing to end the STP forecasts.

b. Predictors of North-West weather patterns.

9. Next meeting is 13 July, in the Columbia River Room, USACE Northwestern Division Office. Meeting is later deferred until September and then again until 7 October 2010.

**Date: 4 August 2010, 13:00-14:30 (Final Agenda)**

**Location: Willamette Room, 4th Floor, NWD, USACE; 1125 NW Couch Street, Suite 500; Portland, OR, 97208.**

**Note: You will have to go to the 5<sup>th</sup> Floor to check in.**

**Contact: Bill Proctor: 503-808-3952 Office, 865-898-6238 Cell**

**DATE and TIME:**

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Start Date/Time: 4 August 2010, 1300 PDT, Wednesday

End Date/Time: 4 August 2010, 1430 PDT, Wednesday

Duration: 1 hour, 30 minutes

Total Ports: 30

- 2004 Model Status
- Stationarity concerns
- Predictor variables – concepts
- Predictor variables
  - Climate variables (accumulation, lags, correlation)
  - Precipitation variables
  - Snow variables
- Regression models
  - “Goodness of Fit” statistics (Root Mean Square Error (RMSE), Standard Error (SE), Cross Validation Standard Error (CVSE))
  - 2004 Model and 2010 Model statistics
  - 2010 Model equations

Review of Libby Forecast Equation Report report can be found at [http://www.nwd-wc.usace.army.mil/report/libf/lib\\_wsf\\_2010.pdf](http://www.nwd-wc.usace.army.mil/report/libf/lib_wsf_2010.pdf)

**Date: 7 October 2010, 0830 – 1300 (Final Agenda)**

**Location: Columbia River Room, 4th Floor, NWD, USACE; 1125 NW Couch Street, Suite 500; Portland, OR, 97208**

**Note: You will have to go to the 5<sup>th</sup> Floor to check in.**

**Contact: Bill Proctor: 503-808-3952 Office, 865-898-6238 Cell**

1. Introductions - Bill Proctor (0830-0835)
2. Status of 2010 Workplan
  - a) Workplan development from 2009 (B. Proctor/N. Stephan) (0835-0855)
    - 1) Evaluate the benefits/problems with increased frequency of water supply updates. A preliminary study at Hungry Horse (USBR, Ted Day) and Dworshak (USACE, Steve Hall) are being conducted in 2010.
    - 2) Review the climate indices evaluated and selected when the Libby forecast procedure was last updated. Assess and the need and/or merit of updating the procedure with other climate indices such as the Trans-Niño Index. A reassessment of the forecast is to be conducted by Randy Wortman (USACE) in 2010.
    - 3) Verify and track accuracy and limitations of various forecast equations and models (VoDCA, ESP, etc.), addressed by adding tables of history of Water Supply Forecasts (WSFs) in Appendix C.
    - 4) Risk analysis associated with forecasts. (Who and What is this work objective?)
    - 5) Evaluate the benefits of additional snow pillow sites, particularly in the Canadian portion of the Columbia drainage, originally assigned to David Bright (BPA)
  - b) Status of work (0855-0900)
3. HGH Update – Ted Day (USBR) (0900-0920)
4. DWR Mid-Month Update – Steve Hall (0920-0940)
5. Libby End of December Variable Draft – Joel Fenolio (0940-1020)
6. Review of the 2009 Annual Report (1020-1040)
7. Break (1040-1100)
8. NWS Status of adding Pillows at existing snow course sites in B.C. – BPA Representative (1110-1140)
9. Forecast Procedure Review and 2010 performance (1140-1240)  
(approximately 10 min. each)
  - a. NRCS – ReShawn Tama
  - b. NWRFC – Tom Fero or representative
  - c. USACE – Ken Soderlind/Maler Annamalai
  - d. USBR – Ted Day, Hungry Horse

- e. BC-Hydro – Frank Weber, Duncan
- f. CRITFC – Kyle Dittmer

10. Parking Lot.

(1240-1300)

Data Quality and Availability. Discussion on 30-year data sets starts in 2011. Note was about putting together a subgroup on this and who should be included.

**Action Item:** Please think about this and we'll have more discussion at the next CRFG meeting

11. Topics for 5 November Meeting:

- Intercomparison Study of Process-Oriented Watershed Models, Frank Weber (40 Min)
- Probabilistic capabilities of BCH forecasting system for Short and long term forecasts, Frank Weber
- Trend Analysis of BC Hydro Reservoir Inflows, Frank Weber
- Mid month forecasts, final presentations, USBR and Walla Walla
- Informal update on ensemble forecast system and forecast verification system design, 15 min.
- Below are suggestions for additional topics covered by the Annual Report:
  - List of key forecasting-related accomplishments by group members; here, I would limit the definition of accomplishments to project work
  - Technical publications by group members
- Analyses on NW Service ESP traces and the effect that the 10-day deterministic forecasts has on them vs. the 3 and 5 day forecast, Harold Opitz
- IJC Rule Curve presentation, Fenolio (Due to full agenda, could slip to December)

12. Topics for December meeting:

- Resolution of Comments from the Libby Forecast Report, Wortman and Fenolio (1 hour)
- PSU Research Water Resource Management, Hydro Forecasts, and Climate Change, from Kyle Dittmer, Dr. Hamid Moradkhani
- Schedule for meeting 2011. (would first Fridays of the month work--February, April, June, September, October, December?)
- NWS Status of adding Pillows at existing snow course sites in B.C.

13. Meeting Adjourned.

(1300)

**Next Meeting 10 December 2010, NWD Office, USACE**

# **Columbia River Forecasting Group**

## **Meeting of 7 October 2010**

Meeting Minutes (DRAFT) – by Randy Wortman

Attendance list (Partial): Bill Proctor, Randy Wortman, Frank Weber, Steve Hall, Ted Day, Rashawn Tama, Jim Ruff, Ken Soderlind, Dave Benner, Kyle Dittmer, Cara McCarthy, Paul Wagner, Margaret Filardo, Jolyne Lea, Phil Butcher, Tom Fero; with Joel Fenolio, Sara Marxen, Kristian Mickelson via conference call.

### **1. Introductions**

**2. Status of 2010 Workplan.** Bill Proctor, NWD USACE, reviewed the 2010 workplan and discussed each of the five items. No one could provide an explanation for what was desired for task #4, “Risk analysis associated with forecasts,” so it was the consensus that this item be dropped and not forwarded to the 2011 workplan.

**3. HGH Update.** Ted Day, USBR, provided an update on the Bureau’s work on developing trail mid-month forecasts Hungry Horse Dam. They have first-of-month forecast equations updated through 2009, and also have new mid-month forecast equations, both utilizing standard regression techniques. Ted presented charts showing several examples of how the forecasts progressed through the runoff season, with occasional examples showing misdirected mid-month forecasts. USBR will be proceeding to develop and test operations that would utilize the trail mid-month forecasts.

**4. DWR Mid-Month Update.** Steve Hall, Walla Walla District-USACE, provided a recap of his prior presentation on the Corps’ work with developing mid-month forecasts for Dworshak Dam. They are also using standard regression techniques to develop their equations. Steve reports that their mid-month equations are correct approximately two-thirds of the time, and incorrect approximately one-third of the time. He reports that filtering out the inconsequential changes would improve the performance metric. There was general discussion regarding “frequency” of forecasts (e.g., monthly, mid-monthly, weekly) and benefit/disbenefit, along with discussion on how best to incorporate external information (e.g., weather forecasts) that could influence a decision on whether to accept, reject, or modify a mid-month forecast.

**5. Libby End of December Variable Draft.** Joel Fenolio, Seattle District-USACE, presented a webcast presentation on the End-of-December Variable Draft operation at Libby Dam, MT.

**6. Review of the 2009 Annual Report.** Bill Proctor handed out a draft copy of the 2009 Annual Report (this would be the first ever annual report for the CRFG), discussed the contents and asked for comments. Several suggestions were made for additions to “Appendix C – Historical Forecast Results” (include 3-year averages; include an additional forecast period for The Dalles). He will add these changes and finalize the 2009 report.

## **7. Break**

**8. NWS Status of adding Pillows at existing snow course sites in B.C.** Phil Butcher, BPA, presented work done at the request of the Treaty Hydromet Data Committee to investigate potential sites for new snow pillow stations. Their assessment began with a GIS-based analysis based on snow-course and snow pillow locations and elevations, compared to Parameter-elevation Regressions on Independent Slopes Model (PRISM)-derived precipitation volume contributed per elevation band. This was augmented by a statistical Principal Components Analysis (PCA) of which snow stations are most influential in their contribution to runoff. They have a short list of snow course sites to recommend, and a short list of alternative sites. Representatives from the Corps and BC Hydro discussed that current water supply forecast equations include consideration of snow stations close-by, but outside the watershed boundaries, and suggested that the current study may benefit by extending consideration to sites near, but outside, the basin boundaries.

**9. Reviewing forecast procedures and performance.** Representatives from multiple agencies provided a recap and review of their 2010 water supply forecasts:

a. Rashawn Tama, NRCS WCC, provided an overview of NRCS water supply forecasts at 32 forecast points across the Northwest. He reported that 22 out of 32 basins were greatly under-forecasted, due largely to an unusually dry start to the winter months, followed by extremely high spring precipitation amounts. The 1-April forecast at several locations predicted runoff in the range of 50% to 70% of average, whereas the observed runoff ended up in the 100% to 116% range; however, there were still several basins that had less than a 10% increase in runoff.

b. Tom Fero, NWRFC, reported on his agency's water supply forecasts for Grand Coulee, Lower Granite and The Dalles for issue dates of 1-January, 1-April, and 1-June.

c. Ted Day provided a report on the Bureau's inflow forecasts for Hungry Horse Dam. Similar to the NRCS forecasts, their forecasts through 1-April were for well below average runoff, and were substantially low due to the unusually high spring precipitation.

d. Frank Weber, BC Hydro, discussed his agencies water supply forecasts, which utilize both PCA regression forecasts and ESP streamflow forecast models. Most of the Canadian basin showed a response to the moderately strong El Nino condition that sets up circulation patterns that produce above average temperatures and below average precipitation. Frank reported that Mica basin, the largest contributor to Columbia River runoff of any of the Canadian basins, was at near-record low flow throughout the year

(ending up with the 4<sup>th</sup> lowest volume of historic record). In several basins, the ESP forecasts matched or exceeded the performance of the VoDCa statistical forecasts.

e. Kyle Dittmer, CRITFC, provided a brief summary of his MEI forecast for 2010. The Columbia at The Dalles pre-season forecast error was +12%. He reported that his “correction-curve” forecast procedure had problems and would not likely be used next year.

f. Dworshak (Walla Walla District) and Libby (Seattle District) will be presented at the December meeting.

10. Bill Proctor reviewed topics and discussed dates for the next CRFG meeting. Following discussion, Bill is reconsidering the initial proposed date of 5-November, with consideration now being given to a combined November-December 2-day meeting during the week that ends November and starts December.

11. The Chair of the CRFG will be a representative from the three AAs (BPA, USACE, USBR) or the Fish Accord Tribes. The Chair position will rotate annually among these four representative organizations or groups following the Fall Workshop. So USBR would have the next chair followed by one of the Fish Accord Tribes representatives.

**For Copies of presentations, see folder for Meeting, 7 October 2010.**



**Date: 10 December 2010, 0800 – 1400 (Final Agenda)**

**Location: Columbia River Room, 4th Floor, NWD, USACE; 1125 NW Couch Street, Suite 500; Portland, OR, 97208**

**Note: You will have to go to the 5<sup>th</sup> Floor to check in.**

**Contact: Bill Proctor: 503-808-3952 Office**

1. Introductions - Bill Proctor (0800-0805)
2. HGH Mid-Month Final Report – Ted Day (USBR) (0805-0835)
3. DWR Mid-Month Final Report – Steve Hall (0835-0905)
4. Resolution of Comments from the Libby Forecast Report Update on Libby Forecast – Wortman and Mickelson (0905-1000)
5. Break (1000-1015)
6. A “Horse Race” Intercomparison of Process-Oriented Watershed Models for Operational River Forecasting – Sean Fleming (1015-1055)
7. Multi-Thread Assessment of Hydroclimatic Change to Support Long-term Planning of Hydroelectric Resources - Sean Fleming (1055-1125)
8. LUNCH (1125-1210)
9. Forecast Procedure Review and 2010 performance (approximately 15 min. each) DWR, Steve Hall; Kristian Mickelson – LIB (1210-1240)
10. New Chairman – USBR (1240-1250)  
Schedule for meeting 2011, New Chairman
11. Topics for Future meetings (1250-1310)
  - Informal update on ensemble forecast system and forecast verification system design, 15 min
  - NWS Analyses on NW Service ESP traces and the effect that the 10-day deterministic forecasts has on them vs. the 3 and 5 day forecast, Harold Opitz
  - PSU Research Water Resource Management, Hydro Forecasts, and Climate Change, from Kyle Dittmer, Dr. Hamid Moradkhani. This could be a Webinar in November or December 2010.
  - Final Report on NW Service adding Pillows at existing snow course sites in B.C.

- Below are suggestions for additional topics covered by the Annual Report:
  - List of key forecasting-related accomplishments by group members; here, I would limit the definition of accomplishments to project work. Is there anything for 2010 Report?
  - Technical publications by group members

12. Meeting Adjourned.

(1310)

# Columbia River Forecasting Group

## Meeting of 10 December 2010

### Meeting Minutes

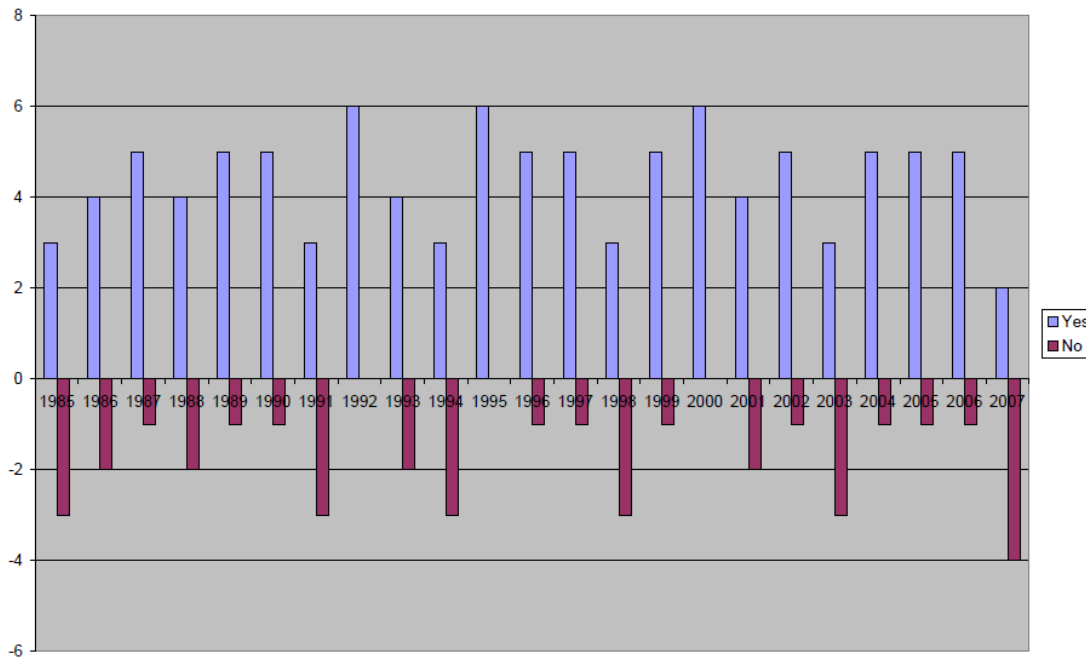
#### 1. Introductions - Bill Proctor.

**2. HGH Mid-Month Final Report – Ted Day (USBR).** USBR ran the mid month forecasts through daily Riverware model to look at operations with and without them. Basically, it just does not make much difference at HGH, at least not with the 1980-2009 dataset. It takes a wet year when flood control is driving the operations, along with a significant increasing or decreasing trend to the forecast, to have an impact, and even then is probably not too significant. There were only 5 years where differences showed up. I could find no example of a “wrong trend” in the mid-month forecast that caused a modified operation.

**3. DWR mid Month Final Report – Steve Hall.** The objective was to analyze the effect of a mid-month forecast relative to first of month forecasts by use existing forecasts methods and equations. Determine frequency and amount of forecast error compared to first of month forecasts (how often and how much can the forecast miss-lead) and then scope subsequent phases if needed. Analysis was done using simple linear regression forecast equations updated in 2008. Current Dworshak Principle Components forecast equations are not designed for mid-month analysis and the analysis was done using historical data from 1985 to 2007 for months between 1 January and 15 June.

The results were that out of 23 years analyzed, all 23 had at least two mid-month forecasts that led in the right direction. But out of 23 years, 20 had a least one mid-month forecast that misled (moved in the wrong direction). The average number of wrong or miss-leading mid-month forecasts was 1.6 forecasts per year.

Mid Month Forecast leads in the right direction



The conclusion was that the frequency of mid month leading in the right direction (compared to subsequent first of month forecast) is more often than not an improvement. The magnitude of the forecast errors is approximately equal. NWW's recommendation is continuing with the analysis to include an analysis of flood control effects. NWW also recommends considering limiting the impact of the mid-month forecast by considering partial flood control operational adjustments. Further analysis of this method was tabled pending completion of the new model currently under development. When complete, model simulations of this approach could be more easily conducted and further analysis would be done at that time.

**4. Resolution of Comments from the Libby Forecast Report. Update on Libby Forecast – Wortman and Mickelson.** The procedure was briefed on 4 August 2010 and comments from CRFG received. Comments were substantially addressed and then the final document was approved in November 2010. The new procedure went into use for December forecast of 2010.

## 5. Break

## 6. A 'Horse Race' Intercomparison of Process-Oriented Watershed Models for Operational River Forecasting - Sean Fleming

### WATERSHED MODELS FOR OPERATIONAL FORECASTING IN B.C.

The vast majority of the province's power comes from hydroelectric generation. Reservoir inflow forecasts thus are key to the efficient, safe, and responsible provision of electricity to B.C. Therefore, it is important to periodically review technologies available

vs. those currently in use. This process was for the inter-comparison of process-oriented watershed models for operational river forecasting in B.C. Unusual technical and managerial organization of project – “horse race” format (managed competition). There were some hiccups along the way, but overall an unequivocal success. Models were rated according to specific performance criteria and a concrete recommendation was achieved.

For the horse race approach, would need to have the same experience and objective measurement procedure.

- Each modelling team has very high expertise and experience with its own model
- Each modelling team uses only its own model
- Each modelling team given same data
- Each modelling team given same time
- Each modelling team given same goal
- But each team uses its own approaches and experience as appropriate to each model

Not a closed-book exam: considerable back and forth between teams, PM, and BCH. Overall environment of mutual support + friendly competition between teams.

The lead consultant actively orchestrated the project under guidance from BCH. Consultant provided objective project management-direction, facilitation, integration-but did not perform any modelling. Results were distilled into coherent final message. Four different models were used to generate the forecast for both hydrologic performance and operational logistics performance, with the current modeling approach winning out by a nose.

## **7. Multi-Thread Assessment of Hydroclimatic Change to Support Long-term Planning of Hydroelectric Resources - Sean Fleming**

CLIMATE VARIABILITY and CHANGE. Long-term anthropogenic climate changes are being investigated due to population and economic growth, generating increased fossil fuel combustion and deforestation resulting in intensified greenhouse gases. General circulation models (GCMs) of global climate suggest for most of British Columbia over most the year:

- Substantial increase in temperature
- Some increase in precipitation

Historical trends are generally consistent with these projections. Concerns are that future climatic changes may affect demand and water supply. Hydrology & Technical Services Group has undertaken studies to assess water supply implications with a goal to support long-term system planning and optimization by other BC Hydro groups. This is a large and complicated problem with no standard engineering/geoscience code of practise. Thus, it is prudent to pursue several scientific threads in parallel.

BC Hydro modeled three different regions across British Columbia, the Upper Campbell Reservoir on Victoria Island. Study considered 15 GCMs, three emissions scenarios, statistical downscaling, Variable Infiltration Capacity (VIC) distributed macro scale hydrologic model. As the VIC model was used, no glacial melt component, was included – loosely, emulate glacial melt via a forced locally permanent snowpack. These study results found that there was a smaller and earlier summer freshet due to more rain and earlier runoff for Upper Campbell. To address the projects on the interior, for the Peace, Frazer, and Upper Columbia Basins, a new procedure was developed to include the impacts of glacier/snow capped mountains on runoff (WC<sup>2</sup>N Study). This included multi-criteria selection of specific combinations of six GCMs and three emissions scenarios. Preliminary results found that there was a slightly higher winter flow release, with larger and earlier summer freshet, and then lower flows in late summer. Higher precipitation is counterbalanced by loss of glacier melt production, but there was no indication of declining annual water supply.

## SYNTHESIS

- None of the three studies are fully complete yet, but...
- Multi-thread approach appears to provide more complicated, but more useful, picture
- Avoids putting all one's eggs in one basket – more defensible final conclusions (e.g., no water supply decline)
- Points of consensus between studies/methods: climatic change features with high confidence
- Points of disagreement: specific directions for future work

## 8. LUNCH (skipped)

**9. Reviewing forecast procedures and performance. Forecast Procedure Review and 2010 performance (approximately 15 minutes each), USACE, Steve Hall – DWR; Kristian Mickelson – LIB.**

Libby – December forecast for April-August runoff was 6544 KAF, which would require a full drawdown. In addition, it would exceed the criteria for 4800 KAF to initiate a turbine pulse. May forecast was lower, at 4887 KAF, but still a sufficient volume to provide the sturgeon pulse. Throughout the winter, the NWRFC forecasts were significantly lower than the official USACE forecasts. The final actual inflow volume for April was 4540 KAF, which is 77% of normal for the previous 35 years. Even though fall precipitation was 101% of average, December-April was only about 54% of average. Given the loss of data collection platforms on this basin, the forecast procedure was updated for water year (WY) 2011 by Wortman.

**10. New Chairman – USBR.** Schedule for meeting 2011, new Chairman, Ted Day, USBR.

## **11. Topics for future meetings**

- Informal update on ensemble forecast system and forecast verification system design, 15 minutes.
- NWS Analyses on Northwest (NW) Service ESP traces and the affect that the 10-day deterministic forecasts has on them vs. the 3 and 5 day forecast, Harold Opitz
- Portland State University (PSU) Research Water Resource Management, Hydro Forecasts, and Climate Change from Kyle Dittmer, Dr. Hamid Moradkhani. This could be a Webinar in November or December 2010.
- Final Report on NW Service adding Pillows at existing snow course sites in B.C.
- Below are suggestions for additional topics covered by the Annual Report:
  - List of key forecasting-related accomplishments by group members; here, I would limit the definition of accomplishments to project work. Is there anything for 2010 Report?
  - Technical publications by group members

**12. Meeting Adjourned. For Copies of presentations, see folder for Meeting, December 10 2010.**

## Appendix C Historical forecast results

### Columbia River Forecast Group 2010

Historic forecast results:

Period Forecasts for different months = from

<http://www.nwd.usace.army.mil/report/colriverflood.htm>

Observed KAF = from runoff processor

Duncan: (Apr – Aug)											
Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
2005	2003	<u>109%</u>	2013	<u>110%</u>	1972	<u>108%</u>	1968	<u>107%</u>	1876	<u>102%</u>	1834
2006	1839	<u>87%</u>	1906	<u>90%</u>	1946	<u>92%</u>	1922	<u>91%</u>	1932	<u>91%</u>	2120
2007	2087	<u>88%</u>	2122	<u>90%</u>	2096	<u>88%</u>	2221	<u>94%</u>	2257	<u>95%</u>	2370
2008	2202	<u>113%</u>	2091	<u>107%</u>	2091	<u>107%</u>	2059	<u>105%</u>	1985	<u>101%</u>	1957
2009	2003	<u>123%</u>	1945	<u>120%</u>	1866	<u>115%</u>	1859	<u>114%</u>	1787	<u>110%</u>	1627
2010	2030	<u>125%</u>	1962	<u>121%</u>	1825	<u>113%</u>	1817	<u>112%</u>	1813	<u>112%</u>	1621

Libby: (Apr – Aug)											
Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
2005	5786	<u>104%</u>	5630	<u>101%</u>	5371	<u>97%</u>	5401	<u>97%</u>	5096	<u>92%</u>	5564
2006	5487	<u>83%</u>	6186	<u>93%</u>	6350	<u>96%</u>	6076	<u>92%</u>	6179	<u>93%</u>	6629
2007	6955	<u>102%</u>	6582	<u>96%</u>	6516	<u>96%</u>	6847	<u>100%</u>	6990	<u>102%</u>	6822
2008	6282	<u>113%</u>	6498	<u>117%</u>	6435	<u>116%</u>	6387	<u>115%</u>	6166	<u>111%</u>	5539
2009	5526	<u>125%</u>	5436	<u>123%</u>	5296	<u>120%</u>	5672	<u>128%</u>	5209	<u>118%</u>	4425
2010	5682	<u>126%</u>	5478	<u>121%</u>	5084	<u>113%</u>	5103	<u>113%</u>	4887	<u>108%</u>	4517

Hungry Horse: (May – Sep)											
Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
2005	1647	<u>132%</u>	1418	<u>114%</u>	1144	<u>92%</u>	1217	<u>98%</u>	1173	<u>94%</u>	1245
2006	1826	<u>101%</u>	2024	<u>112%</u>	1958	<u>108%</u>	1912	<u>106%</u>	1824	<u>101%</u>	1811
2007	1823	<u>136%</u>	1803	<u>135%</u>	1786	<u>134%</u>	1495	<u>112%</u>	1425	<u>107%</u>	1337
2008	1840	<u>76%</u>	1859	<u>77%</u>	1876	<u>78%</u>	1913	<u>79%</u>	2131	<u>88%</u>	2410
2009	1809	<u>112%</u>	1864	<u>115%</u>	1697	<u>105%</u>	1817	<u>112%</u>	1816	<u>112%</u>	1618
2010	1654	<u>103%</u>	1429	<u>89%</u>	1284	<u>80%</u>	1305	<u>81%</u>	1345	<u>84%</u>	1608



## Grand Coulee: (Apr – Aug)

Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF
2005	54863	<u>112%</u>	53657	<u>110%</u>	45820	<u>94%</u>	47628	<u>98%</u>	47628	<u>98%</u>	48807
2006	55466	<u>91%</u>	58480	<u>96%</u>	57877	<u>95%</u>	57275	<u>94%</u>	58500	<u>96%</u>	61189
2007	60000	<u>105%</u>	61600	<u>107%</u>	61200	<u>107%</u>	61600	<u>107%</u>	61000	<u>106%</u>	57350
2008	59300	<u>99%</u>	59200	<u>99%</u>	61300	<u>103%</u>	61600	<u>103%</u>	60000	<u>100%</u>	59739
2009	55800	<u>116%</u>	54600	<u>113%</u>	53100	<u>110%</u>	55400	<u>115%</u>	54000	<u>112%</u>	48186
2010	54000	<u>113%</u>	49100	<u>103%</u>	45800	<u>96%</u>	44900	<u>94%</u>	45300	<u>95%</u>	47711

## Brownlee: (Apr – Jul)

Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF
2005	3170	<u>88%</u>	2590	<u>72%</u>	1740	<u>48%</u>	2180	<u>60%</u>	2440	<u>68%</u>	3612
2006	6690	<u>75%</u>	8016	<u>89%</u>	6940	<u>77%</u>	8380	<u>93%</u>	9020	<u>101%</u>	8975
2007	5200	<u>185%</u>	3630	<u>129%</u>	3760	<u>134%</u>	3300	<u>118%</u>	3040	<u>108%</u>	2807
2008	4390	<u>101%</u>	5260	<u>120%</u>	5500	<u>126%</u>	5400	<u>124%</u>	4860	<u>111%</u>	4368
2009	4260	<u>76%</u>	4020	<u>72%</u>	3350	<u>60%</u>	4970	<u>89%</u>	5000	<u>90%</u>	5575
2010	3300	<u>72%</u>	3020	<u>66%</u>	2470	<u>54%</u>	2590	<u>56%</u>	2780	<u>61%</u>	4586

## Dworshak: (Apr – Jul)

Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF
2005	1914	<u>116%</u>	1642	<u>100%</u>	1423	<u>87%</u>	1321	<u>80%</u>	1344	<u>82%</u>	1643
2006	2601	<u>97%</u>	2707	<u>101%</u>	2612	<u>98%</u>	2593	<u>97%</u>	2626	<u>98%</u>	2677
2007	2905	<u>161%</u>	2126	<u>118%</u>	2192	<u>122%</u>	1982	<u>110%</u>	1868	<u>104%</u>	1799
2008	2717	<u>79%</u>	2738	<u>80%</u>	2810	<u>82%</u>	3010	<u>88%</u>	3003	<u>87%</u>	3434
2009	3075	<u>121%</u>	2681	<u>106%</u>	2461	<u>97%</u>	2662	<u>105%</u>	2631	<u>104%</u>	2539
2010	2174	<u>114%</u>	1742	<u>91%</u>	1571	<u>82%</u>	1398	<u>73%</u>	1526	<u>80%</u>	1906

## Lower Granite: (Jan – Jul)

Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF
2005	20700	<u>114%</u>	18000	<u>99%</u>	14600	<u>81%</u>	15700	<u>87%</u>	16500	<u>91%</u>	18134
2006	31600	<u>98%</u>	34500	<u>107%</u>	31900	<u>99%</u>	33200	<u>103%</u>	34900	<u>108%</u>	32194
2007	28200	<u>149%</u>	23000	<u>122%</u>	23500	<u>124%</u>	21400	<u>113%</u>	20600	<u>109%</u>	18887
2008	27200	<u>99%</u>	29500	<u>107%</u>	29200	<u>106%</u>	28000	<u>102%</u>	26500	<u>96%</u>	27522
2009	25700	<u>89%</u>	25100	<u>87%</u>	22400	<u>78%</u>	26400	<u>91%</u>	26900	<u>93%</u>	28899
2010	22400	<u>100%</u>	19300	<u>86%</u>	17000	<u>76%</u>	16600	<u>74%</u>	17000	<u>76%</u>	22460

## The Dalles: (Jan – Jul)

Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF
2005	85600	<u>105%</u>	82400	<u>101%</u>	70700	<u>87%</u>	73800	<u>91%</u>	74700	<u>92%</u>	81349
2006	101000	<u>88%</u>	111000	<u>97%</u>	107000	<u>93%</u>	107000	<u>93%</u>	110000	<u>96%</u>	114672
2007	105000	<u>110%</u>	101000	<u>105%</u>	100000	<u>104%</u>	100000	<u>104%</u>	99100	<u>104%</u>	95738
2008	102000	<u>103%</u>	103000	<u>104%</u>	103000	<u>104%</u>	101000	<u>102%</u>	97300	<u>98%</u>	99209
2009	94700	<u>105%</u>	92900	<u>103%</u>	86200	<u>96%</u>	92000	<u>102%</u>	91100	<u>101%</u>	90244
2010	88500	<u>104%</u>	79200	<u>93%</u>	71800	<u>85%</u>	69700	<u>82%</u>	70900	<u>84%</u>	84718

The Dalles: (Apr – Aug)											
Year	Jan		Feb		Mar		Apr		May		Observed
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF
2005	74300	<u>109%</u>	69200	<u>101%</u>	57200	<u>84%</u>	60800	<u>89%</u>	61900	<u>90%</u>	68452
2006	87500	<u>90%</u>	94300	<u>97%</u>	91200	<u>93%</u>	92700	<u>95%</u>	95600	<u>98%</u>	97541
2007	91300	<u>116%</u>	88200	<u>112%</u>	88300	<u>112%</u>	85200	<u>108%</u>	84200	<u>107%</u>	78939
2008	88200	<u>95%</u>	91800	<u>98%</u>	94300	<u>101%</u>	94700	<u>102%</u>	90900	<u>98%</u>	93198
2009	82100	<u>102%</u>	79700	<u>99%</u>	74800	<u>93%</u>	82400	<u>102%</u>	81400	<u>101%</u>	80771
2010	76700	<u>99%</u>	68500	<u>88%</u>	62100	<u>80%</u>	60900	<u>79%</u>	62200	<u>80%</u>	77410

## CRFG Mailing List December 10, 2010

Name	Agency	Phone	E-mail
<a href="#">Richard Domingue</a>	NOAA/NMFS	503-231-6858	<a href="mailto:richard.domingue@noaa.gov">richard.domingue@noaa.gov</a>
<a href="#">Paul Wagner</a>	NOAA/NMFS	503-231-2316	<a href="mailto:paul.wagner@noaa.gov">paul.wagner@noaa.gov</a>
<a href="#">Harold Opitz</a>	NOAA - NWRFC	503-326-7291	<a href="mailto:harold.opitz@noaa.gov">harold.opitz@noaa.gov</a>
<a href="#">Tom Fero</a>	NOAA - NWRFC	503-326-7291	<a href="mailto:Thomas.fero@noaa.gov">Thomas.fero@noaa.gov</a>
<a href="#">Roger Pulwarty</a>	NOAA - Western Water Assessment	303-497-4425	<a href="mailto:roger.pulwarty@noaa.gov">roger.pulwarty@noaa.gov</a>
<a href="#">Matt Newman</a>	NOAA CIRES Climate Diagnostics Center	303-497-6233	<a href="mailto:matt.newman@noaa.gov">matt.newman@noaa.gov</a>
<a href="#">Steve King</a>	NOAA - NWRFC		
<a href="#">Thomas Herrett</a>	USGS	503-251-3239	<a href="mailto:herrett@usgs.gov">herrett@usgs.gov</a>
<a href="#">Jim O'Conner</a>	USGS	503-251-3222	<a href="mailto:joconnor@usgs.gov">joconnor@usgs.gov</a>
<a href="#">Kathy Peter</a>	USGS	208-387-1300	<a href="mailto:dpeter@usgs.gov">dpeter@usgs.gov</a>
<a href="#">Dennis Lynch</a>	USGS	503-251-3200	<a href="mailto:dlynch@usgs.gov">dlynch@usgs.gov</a>
<a href="#">Cynthia Barton</a>	USGS	252-552-1600	<a href="mailto:cbarton@usgs.gov">cbarton@usgs.gov</a>
<a href="#">John Risley</a>	USGS	503 251-3279	<a href="mailto:irisley@usgs.gov">irisley@usgs.gov</a>
<a href="#">Mark Mastin</a>	USGS	253-552-1609	<a href="mailto:mcmastin@usgs.gov">mcmastin@usgs.gov</a>
<a href="#">Erik Pytlak</a>	BPA		<a href="mailto:espytlak@bpa.gov">espytlak@bpa.gov</a>
<a href="#">Cara McCarthy</a>	BPA	503-230-5046	<a href="mailto:cmccarthy@bpa.gov">cmccarthy@bpa.gov</a>
<a href="#">Ann McManamon</a>	BPA		<a href="mailto:anmanamon@bpa.gov">anmanamon@bpa.gov</a>
<a href="#">Chris Karafotias</a>	BPA		<a href="mailto:ckarafotias@bpa.gov">ckarafotias@bpa.gov</a>
<a href="#">Phillip Butcher</a>	BPA	503-230-3850	<a href="mailto:pibutcher@bpa.gov">pibutcher@bpa.gov</a>
<a href="#">Tom Perkins</a>	NRCS - National Water and Climate Center	503-414-3059	<a href="mailto:tom.perkins@por.usda.gov">tom.perkins@por.usda.gov</a>
<a href="#">Angus Goodbody</a>	NRCS - National Water and Climate Center	503-414-3033	<a href="mailto:angus.goodbody@por.usda.gov">angus.goodbody@por.usda.gov</a>
<a href="#">Sheila Strachan</a>	NRCS - National Water and Climate Center		<a href="mailto:Sheila.Strachan@or.usda.gov">Sheila.Strachan@or.usda.gov</a>
<a href="#">Dave Garen</a>	NRCS - National Water and Climate Center	503-414-3017	<a href="mailto:david.garen@por.usda.gov">david.garen@por.usda.gov</a>
<a href="#">Michael Strobel</a>	NRCS - National Water and Climate Center	503-414-3055	<a href="mailto:michael.strobel@por.usda.gov">michael.strobel@por.usda.gov</a>
<a href="#">Jolyne Lea</a>	NRCS - National Water and Climate Center	503-414-3040	<a href="mailto:jllyne.lea@por.usda.gov">jllyne.lea@por.usda.gov</a>
<a href="#">Jon Lea</a>	USDA NRCS Snow Surveys/Nat Res Invent	(503) 414-3267	<a href="mailto:jon.lea@or.usda.gov">jon.lea@or.usda.gov</a>
<a href="#">Rashawn Tama</a>	USDA-NRCS	503-414-3010	<a href="mailto:rashawn.tama@por.usda.gov">rashawn.tama@por.usda.gov</a>
<a href="#">Ron Abramovich</a>	USDA - Boise		<a href="mailto:Ron.Abramovich@id.usda.gov">Ron.Abramovich@id.usda.gov</a>
<a href="#">Ted Day</a>	BOR - Boise	208-378-5273	<a href="mailto:tday@usbr.gov">tday@usbr.gov</a>
<a href="#">Mary Mellema</a>	BOR - Boise	208-378-5118	<a href="mailto:mmellema@usbr.gov">mmellema@usbr.gov</a>
<a href="#">Pat McGrane</a>	BOR - Boise	208-378-5215	<a href="mailto:pmcgrane@usbr.gov">pmcgrane@usbr.gov</a>
<a href="#">Levi Brekke</a>	BOR - Technical Service Center	303-445-2494	<a href="mailto:lbrekke@do.usbr.gov">lbrekke@do.usbr.gov</a>
<a href="#">John Roache</a>	BOR - Boise		<a href="mailto:jroache@usbr.gov">jroache@usbr.gov</a>
<a href="#">Jeremy Giovando</a>	USACE - Walla Walla District	509-527-7053	<a href="mailto:Jeremy.i.Giovando@usace.army.mil">Jeremy.i.Giovando@usace.army.mil</a>
<a href="#">Randy Wortman</a>	USACE - Portland District	503-808-4837	<a href="mailto:Randal.T.Wortman@usace.army.mil">Randal.T.Wortman@usace.army.mil</a>
<a href="#">Peter Brooks</a>	USACE - NW Division	503-808-3954	<a href="mailto:peter.f.brooks@usace.army.mil">peter.f.brooks@usace.army.mil</a>
<a href="#">Ken Soderlind</a>	USACE - NW Division	503-808-3950	<a href="mailto:kenneth.r.soderlind@usace.army.mil">kenneth.r.soderlind@usace.army.mil</a>
<a href="#">Joel Fenolio</a>	USACE - Seattle District	206-764-6683	<a href="mailto:joel.m.fenolio@usace.army.mil">joel.m.fenolio@usace.army.mil</a>
<a href="#">Kristian Mickelson</a>	USACE - Seattle District	206-764-6927	<a href="mailto:Kristian.E.Mickelson@usace.army.mil">Kristian.E.Mickelson@usace.army.mil</a>
<a href="#">Steve Hall</a>	USACE - Walla Walla District	509-527-7550	<a href="mailto:stephen.c.hall@usace.army.mil">stephen.c.hall@usace.army.mil</a>
<a href="#">Jim Barton</a>	USACE - NW Division	503-808-3930	<a href="mailto:James.D.Barton@usace.army.mil">James.D.Barton@usace.army.mil</a>
<a href="#">Bill Proctor</a>	USACE - NW Division	503-808-3952	<a href="mailto:William.D.Proctor@usace.army.mil">William.D.Proctor@usace.army.mil</a>
<a href="#">Rick Roeder</a>	Washington Department of Ecology	509-454-4238	<a href="mailto:rroeder@ecy.wa.gov">rroeder@ecy.wa.gov</a>
<a href="#">Barry Norris</a>	Oregon Water Resources Dept	503-986-0828	<a href="mailto:barrv.f.norris@wrdr.state.or.us">barrv.f.norris@wrdr.state.or.us</a>
<a href="#">Margaret Filardo</a>	Fish Passage Center	503-230-4286	<a href="mailto:mfilardo@fpc.org">mfilardo@fpc.org</a>
<a href="#">David Benner</a>	FPC		<a href="mailto:dbenner@fpc.org">dbenner@fpc.org</a>
<a href="#">Kyle Dittmer</a>	CRITFC	503-731-1314	<a href="mailto:DITK@critfc.org">DITK@critfc.org</a>
<a href="#">Bob Heinith</a>	CRITFC	503-731-1289	<a href="mailto:HEIB@critfc.org">HEIB@critfc.org</a>
<a href="#">Steve Smith</a>	CCT	503-263-1253	<a href="mailto:huntersmith@canby.com">huntersmith@canby.com</a>
<a href="#">Dennis Lettenmaier</a>	UW Dept of Civil & Environmental Engr	206-543-2532	<a href="mailto:dennisl@u.washington.edu">dennisl@u.washington.edu</a>
<a href="#">Alan Hamlet</a>	UW Climate Impacts Group	206-616-9361	<a href="mailto:hamleaf@u.washington.edu">hamleaf@u.washington.edu</a>
<a href="#">Hamid Moradkhani</a>	PSU - Civil and Environmental Engineering	503-725-2436	<a href="mailto:hamidm@cecs.pdx.edu">hamidm@cecs.pdx.edu</a>
<a href="#">Phillip Mote</a>	OSU - Director OCCRI	541-737-5694	<a href="mailto:pmote@coas.oregonstate.edu">pmote@coas.oregonstate.edu</a>
<a href="#">Jim Ruff</a>	NW Power and Conservation Council	503-222-5161	<a href="mailto:jruff@nwcouncil.org">jruff@nwcouncil.org</a>
<a href="#">Dave Rodenhuis</a>	Pacific Climate Impacts Consortium	250-472-5174	<a href="mailto:dhuis@uvc.ca">dhuis@uvc.ca</a>
<a href="#">Stephanie Smith</a>	B.C. Hydro	604-528-2219	<a href="mailto:Stephanie.Smith@bchydro.com">Stephanie.Smith@bchydro.com</a>
<a href="#">Frank Weber</a>	B.C. Hydro	604-528-8329	<a href="mailto:frank.weber@bchydro.com">frank.weber@bchydro.com</a>
<a href="#">Sean Fleming</a>	B.C. Hydro		<a href="mailto:sean.fleming@bchydro.com">sean.fleming@bchydro.com</a>
<a href="#">Paul Whitfield</a>	Environment Canada	604-664-9238	<a href="mailto:Paul.Whitfield@ec.gc.ca">Paul.Whitfield@ec.gc.ca</a>