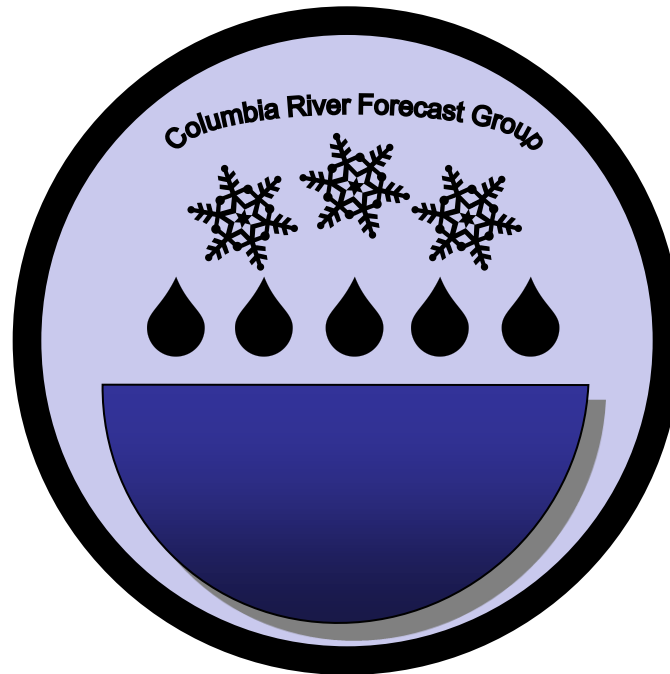


# *COLUMBIA RIVER FORECAST GROUP*

## 2016 ANNUAL REPORT



CHAIR: MARY MELLEMA, USBR  
VICE-CHAIRMAN: KYLE DITTMER, CRITFC

AUGUST 15, 2017

# COLUMBIA RIVER FORECAST GROUP

## 2016 ANNUAL REPORT

### SUMMARY

The Columbia River Forecast Group (CRFG) was created in 2009 to promote and support the advancement of water resource forecasting, products, and techniques in the Columbia River Basin. The primary group objective is to refine and improve Basin reservoir operations for the benefit of the region's water supply consistent with 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 collaborated to form the Columbia River Forecast Group (CRFG) to implement this RPA action and to meet Accord principles. To address these needs, the CRFG provided an open forum for sharing, discussing, evaluating, comparing and potentially implementing new forecasting techniques, supporting procedures, and information into the planning and operation of the Columbia River Basin reservoir system. The term “forecasting” refers to both water supply forecasting and streamflow forecasting.

The CRFG developed a charter, organizational structure, expectations, and strategies in 2009. Under the terms of the charter, the CRFG is open for participation from any Basin 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 four business meetings in 2016 which were hosted by CRITFC and NOAA Fisheries: February 18, May 19, September 15, and December 8 (annual review, conference call due to inclement weather). Each meeting provided a forum to review the current runoff forecasts (or performance), discuss topics of common interest, and to hear speakers on topics related to water supply forecasting. Meetings were attended by staff from BC Hydro and Power Authority (BC Hydro), Bonneville Power Administration (BPA), Columbia River Inter-Tribal Fish Commission (CRITFC), Colville Confederated Tribes (CCT), Corps of Engineers (COE), Fish Passage Center (FPC), Idaho Power Company (IPC), National Oceanic and Atmospheric Administration (NOAA) Fisheries, Natural Resources Conservation Service (NRCS), NOAA/NWS-Northwest River Forecast Center (NWRFC), Northwest Power Conservation Council (NWPPCC), U.S Bureau of

Reclamation (Reclamation), U.S. Geological Survey (USGS), Washington Department of Ecology, and the University of Washington Department of Hydrology and Computational Hydrology.

## TOPICS FOR DISCUSSION

Topics and discussion covered a wide range of interests and included:

- Review and discussion of current forecasts (winter/summer meetings) with a focus on forecast errors and challenges; summaries of snow and precipitation patterns
- RMJOC-II Climate Change Research Project...Hydroclimate Workshop Updates
- NWS-NWRFC Hydrologic Ensemble Forecast Service (HEFS) Initiative
- NCAR Experimental Forecasts – Hungry Horse and Dworshak
- Discussion of Salmon Manager Concerns in Columbia Basin regarding forecasts and better prediction of water temperature
- NRCS Interactive Map Demonstration
- Discussions regarding using indices for statistical volume forecasting
- Initial Control Flow Review of calculations and discussion on how to improve process
- NWRFC National River Forecast Program (NWM)
- 2017 pre-season water supply forecasts
- The 2016 wrap-up and review of runoff forecasts, comparison of results, discussion of challenges, and lessons learned
- Discussion of possible 2017 CRFG activities and work elements

Water Year 2016 began with very dry conditions which was a holdover from 2015. Fall precipitation was not impressive but conditions improved in December. This trend continued so precipitation through the season was at near normal amounts in the Pacific Northwest with the exception of the upper Snake and northeast Oregon. SWE on April 1 ranged from 90-125% but very warm temperatures and dry conditions during April caused an early runoff. Volumes were below average with runoff skewed early in the season. With the early runoff there was discussion regarding how to account for this runoff that may not be captured in the traditional periods for volume forecasts.



## P R E S E N T A T I O N   H I G H L I G H T S

Various guest speaker presentations were well received and appreciated by the group:

- ❖ Taylor Dixon, NWRFC, *Hydrologic Ensemble Forecast Service*. Presentation of a new pre/post processor interface to the existing forecast system. It has the possibility of quantifying forcing/modeling uncertainties.
- ❖ Erik Pytlak, BPA, *RMJOC-II Climate Change Research Project... Forecast/Streamflow Workshop Updates*. Discussion of issues related to the preliminary results of RMJOC-II.
- ❖ Pablo Mendoza and Andy Wood, NCAR, *NCAR Experimental Forecast*. Research project that looks at the combination of watershed and climate indicators for improving forecasts.
- ❖ Paul Wagner, NOAA-Fisheries, *Salmon Manager issues*. Can we develop early warning system to avoid warm temperatures that occurred last year. Also, is there a better early prediction for Libby that would moderate pre-season draft and allow more flexibility? Concern with having Libby as full as possible and improving refill procedure at Grand Coulee.
- ❖ Georg Jost, BC Hydro, *Upper Columbia Forecasts*. Issues with early snowmelt, February saw new record inflows. In warm years the glacial melt is bigger, there is new project by UNBC for real-time monitoring of glacial and snow-covered basins.
- ❖ Kyle Dittmer, CRITFC, *MEI Forecasting Method – Extended Dataset*. Comparison of historical and current datasets, early indication that pre-1950 data not as representative for current conditions.
- ❖ Gus Goodbody, NRCS, *NRCS Interactive Map Demonstration*. The new interactive map developed by NRCS has new features with more functionality.
- ❖ Ron Malmgren, COE – NW Division, *Initial Control Flow (ICF) -Review of the Procedure and Timing of Declaring the ICF*. Review of origin and current procedures of how ICF is calculated and declared. Generated much discussion on possible future study to improve or change procedure.
- ❖ Erik Pytlak, BPA, *RMJOC-II... Update on Modeling Progress*. Project has been extended two months because of lower Snake NRNI data problems. Data has been regenerated but bias correction will need further refinement causing the delay.
- ❖ Taylor Dixon, NWRFC, *National River Forecast Program*. Presentation on the National Water Model that is being developed by the NWS. The National Water Model is still in test mode and not interactive yet. It is in development phase and gives an idea of the possible future capability of NWS hydrologic forecasting.



## ACCOMPLISHMENTS

CRFG work accomplishments and ongoing studies or issues the CRFG will continue to address:

- RMJOC-II. Continue monitoring of progress in evaluating the new downscaled global climate model data for the Columbia Basin.
- Recognition of the difficulty in using the current forecasting procedures in years with early runoff patterns – an interest in looking at new approaches to adapt to these changes.
- Continued discussions regarding the volume forecast periods, with the early runoff experienced in 2015 and 2016 – should we shift the periods to better account for the early runoff?
- ICF – Continue reviewing how it is calculated and used and the need for adaptive management in-season.
- Continued discussions on snow data – Implementation of using new procedures in model to get areal extent by elevation of snow water.
- Historical snow satellite data – how useful is this for forecast procedures?
- The unusual nature of WY 2015 and WY 2016 – what was learned in both of these years? 2016 was not as bad as 2015 but runoff was shifted earlier than “normal”. This seems to be a trend – how does reservoir management adapt?

## APPENDIX 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 “Action Agencies” (i.e., 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 Autumn 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 streamflow 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 four 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 - 2016 Meetings**

The following meetings took place for the CRFG.

18 February 2016

19 May 2016

15 September 2016

8 December 2016 (Annual Review)

Reviewed and finalized Meeting notes are as follows:

**Date: February 18, 2016, 9:00 am – 12:00 pm PST**

**Location: Columbia River Inter-Tribal Fish Commission (Columbia Room, 12<sup>th</sup> Floor), 700 NE Multnomah Street, Portland**

**Teleconference:** (877) 848-7030, Access #: 3626353, Security #: 9915,  
<https://www.webmeeting.att.com>

Contacts: Eric Rothwell, USBR (208) 378-5273; Kyle Dittmer, CRITFC (503) 731-1314;

1. Welcome, introductions, Dec. 2015 minutes – CRFG Chairman Eric Rothwell (09:00 – 09:10)
2. Draft 2015 CRFG Annual Report, Kyle Dittmer (09:10 – 09:20)
3. Review of the 2016 Forecast Season by agency (~10 minutes each) (09:20 – 10:00)
  - USACOE: Seattle District (LIB), Steve Hall (DWR)
  - USBR: Eric Rothwell (HGH, Upper-Snake)
  - NRCS: Rashawn Tama
  - NWS-RFC: Kevin Berghoff
- <<<BREAK TIME>>> (10:00 – 10:15)
4. Review of 2016 Forecast Season (continues) (10:15 – 10:30)
  - BC Hydro: Adam Gobena (UC points) or Georg Jost
  - CRITFC: Kyle Dittmer (TDA)
  - Discussion: Current conditions
5. Update on NWS-NWRFC HEFS Initiative (Dixon) (10:30 – 11:00)
6. RMJOC-II...Forecast/Streamflow Workshop Updated (Erik Pytlak, BPA) (11:00 – 11:30)
7. NCAR Experimental Forecast – Hungry Horse, Dworshak (Andy Wood and Pablo Mendoza) (11:30 – 12:00)
8. “The Sampler”...Salmon Manager Issues? (Paul W.), Upcoming WSF meetings? (all) (12:00 – 12:20)
9. Other business: future agenda items, set next meeting date, etc. (12:20 – 12:30)
10. Meeting adjournment (12:30)

**Columbia River Forecast Group–Winter Meeting, CRITFC, Portland; February 18, 2016**

*Introductions:*

Chairman Eric Rothwell welcomed everyone at 9:05 am. The attendees introduced themselves. The December notes were reviewed. Send your comments to Eric or Kyle.

*Draft 2015 CRFG Annual Report, Kyle Dittmer (CRITFC):*

Bob Heinith offered up edits on the intro-section of the newly released draft. Others will review. Kyle is requesting “big picture” comments in the next two-weeks.

*Review and Discussion of the 2016 Forecast Season:*

COE (Kristian Mickelson)...The latest Libby forecast is at 6.3 MAF (a slight bump up from January). Paul Wagner asked about the expected March forecast? That is uncertain due to the near term dry-spell. Paul asked about the differences with the COE vs. NWRFC forecast? Main difference is the nature of the model – ESP vs. SOI-flavored regression. The snow information is similar but no SOI usage in the RFC forecast. Kevin said that it was “a good thing” that we get to see how model performance can differ (presumably to look at the driving elements). We should look at verification values. Libby is on minimum flows now.

COE (Steve Hall)...The forecast (April-July) for Dworshak moved from 1740 KAF (October) to 2000 KAF (February) or 82%. The Z-score forecast was 2400 KAF (95%). The Z-score method is still in the experimental stage and run in parallel with the official forecast. Maybe we can revise in one year? It may be wise to drop the SOI component by February. Taylor asked what was driving the “average” in the forecast? Steve said this was the default condition without anything odd observations. The Z-score uses a vertical distribution, PCA (i.e., Principal Component Analysis), small error, and favors the mean. Eric asked can one use PCA but use a select sub-set (e.g., high, low) of years? Kristian said that the Seattle-COE has talked about doing such a test-study but has not done so. Erik reported that SOI, MEI are falling out of favor with forecasters *in lieu* of ONI, Oceanic Nino Index (<https://www.climate.gov/news-features/understanding-climate/climate-variability-oceanic-ni%C3%B1o-index>). ONI data goes back to 1948. Steve speculates that the Dworshak forecast could decline and will have to closely monitor operations. DWR outflows are at minimum now.

USBR (Eric Rothwell)... Snake River at Heise: February forecast 94% (MLR model); 3200 KAF, 89% (coordinated). USBR presented multiple forecast results, and for the Upper Snake they agreed well with the USBR-ACOE coordinated forecast. January precipitation was 86% for the Upper Snake and the snow is lower than last year, but there is more low elevation snow which may decrease or at least delay the onset of irrigation demand. Hungry Horse 97% (MLR); 1837 KAF, 90% (coordinated). The January precipitation for Hungry Horse was 102%, but the February 1st snowpack was 89% of normal. The February MLR forecast for Hungry Horse was much higher than other USBR forecast products (PCA and an experimental PCA) and other agency (NRCS and NWS-NWRFC) forecasts. Jason asked how the adopted forecast reconciles discrepancies

between forecast results, and the response was using the best available information to select and support the adopted forecast from available USBR forecasts.

NRCS (Rashawn Tama)...A map of PNW forecasts was displayed. Will values in the Rockies drop? March 1<sup>st</sup> will likely be similar to February 1<sup>st</sup> values.

BC Hydro...no report was offered. No BC Hydro representative was present.

NWS-NWRFC (Kevin Berghoff)...Seasonal precipitation is 101-109%. We're dry in the Upper-Middle Snake right now. The Dec-Jan. temperatures were relatively cooler but February is warmer. The Upper Columbia SWEs are 100-130%; Upper-Snake 70-100%, Middle-Snake 100-130%. Latest WSF: TDA 97%, LWG 95%, DWR 95%. ESP using 1949-2015 climate forcings. Website now has ONI vs. historical runoff plots. Data downloads available now, too.

CRITFC (Kyle Dittmer)...Based on the Multivariable ENSO Index (MEI), the El Niño event peaked in November and has trailed off slightly. The February forecast for the Columbia River at The Dalles (TDA): Jan.-July, 96 MAF (94%); April-July, 75 MAF (94%); April-Aug., 83 MAF (94%). Erik noted that this forecast was elevated, given the strength of the El Niño.

*RMJOC-11...update on Forecast Workshop, Erik Pytlak (BPA):*

We are planning for the next workshop on May 20 (tentative). We expect to complete the final tasks #8 - #10 in 2016. There was a UW-OSU presentation of their preliminary results to the BPA Technology and Innovation group on January 26. For the 2040s, there is a large range of temperature/precipitation values. We are not going to do water temperature modeling. One trend is a wetter winter (mean values) and a dryer summer. The first provisional flow data-set is ready (using VIC hydro model, RCP 8.5 data). There is a data format issue to be resolved. By April, expect the PRMS data, then MACA data in July, and ORNL data by September. The flow scenarios cover 1970-99 (baseline), 2040-69, and 2070-99. A second peak flow is appearing in winter – most likely caused by early snowmelt of the tributaries. The summer flow pattern is similar to that of the RMJOC-I results. Forecast procedure – 30-year normals (but changing), with little change in the standard error. How do we select 10-12 scenarios? Need two high-low “bookend” runs from Batch 2, 3 (RCP 8.5). The criteria list (obtained by Cluster Analysis) has range, timing, winter volume, refill risk. Bob asked about the time needed for conversion of data-sets? Erik said weeks-to-months.

*NWS-NWRFC HEFS Initiative, Taylor Dixon (NWRFC):*

The Hydrologic Ensemble Forecast Service is a new pre/post processor interface to the existing forecast system. Each ESP ensemble member is just one possible outcome. ESP is simple, objective, and can assess uncertainty, risk. The probability is based on historical observations. HEFS quantifies forcing/model uncertainties. Forecast time: hours to seasons. Components: GEFS forecast (1-15 days), CFSv2 (16-270 days), Climatology (271+ days). A Meteorological Ensemble Forecast Processor corrects forcing bias, merges times, and downscales. Then MEFP is fed into the CHPS hydro model (and ensemble post-processing). HEFS has 47 forecast points (west/east side split), 13 reservoir inflow points, and all operational. Example graphs included the Santiam

River at Detroit Lake, Snoqualmie River at Snoqualmie, Anderson Ranch Dam. Kyle asked if there is a west/east side bias? Atmospheric River events are under-forecasted.

*NCAR Experimental Forecast*, Pablo Mendoza and Andy Wood (NCAR):

What value is there to adding more complexity to a forecast scheme? Focus is on hydro and meteorological predictability. How to best combine watershed and climate predictability? Data requirements: regression, statistical, dynamic. Goals: (1) Systematic inter-comparison of dynamic/statistical methods, comparison maps of weather/ocean variables and runoff. The SHERPA (System for Hydromet Ensemble Research and Prediction Applications) interface helps run and manage the study. (2) Hindcasts...and how to transition to real-time forecasts. Summary: (1) Hybrid of climate and watershed predictability is best. (2) Standard climate indices do outperform custom/reanalysis indices. Next steps: (1) Operationalize non-WSF predictands (1, 3-month), (2) Diagnostics to understand forecast discrepancies. (3) Add new basins. Bob asked about snow-rain transition basins, like Yakima? We need to do more studies.

For more info: [www.ral.ucar.edu/staff/wood/case\\_studies\\_wr/](http://www.ral.ucar.edu/staff/wood/case_studies_wr/)

“The Sampler”

*Salmon Manager concerns*, Paul Wagner (NOAA-Fisheries): (1) Summer Temperature. Can we develop an early warning system? The sockeye got cooked last year. (2) Better early prediction for Libby? The pre-season draft is an ongoing issue. *Low elevation snow gages*, Kresta (IPCo): can we add gages? How do we properly measure low elevation snow?

*Upcoming WSF conferences/meetings?*: none.

*Other Business*: Our next meeting is set for **May 19<sup>th</sup>** (confirmed) at CRITFC’s Columbia Room. Eric adjourned the meeting at 1:00 pm and thanked all for coming and participating.

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Attendance:

Berghoff, Kevin – NWS/NWRFC (Portland)  
Davis-Butts, Kresta – IPCo (Boise)  
Dittmer, Kyle – CRITFC (Portland)  
Dixon, Taylor – NWS/NWRFC (Portland)  
Hall, Steve – COE (Walla Walla)  
Pytlak, Erik – BPA (Portland)  
Rothwell, Eric – USBR (Boise)  
Skiles, Tom – CRITFC  
Wagner, Paul – NOAA-Fisheries

On the phone:

Heinith, Bob – CRITFC contractor  
Mendoza, Pablo – NCAR (Boulder, CO)  
Mickelson, Kristian – COE (Seattle)  
Pickett, Paul – WA Dept. of Ecology

Stephan, Nancy – BPA (Portland)  
Tama, Rashawn – NRCS (Portland)  
Ward, Jason – COE (NW Division)  
Wood, Andy – NCAR (Boulder, CO)

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**Date: May 19, 2016, 9:00 am – 12:00 pm PDT**

**Location: Columbia River Inter-Tribal Fish Commission (Columbia Room, 12<sup>th</sup> Floor), 700 NE Multnomah Street, Portland**

**Teleconference:** (877) 848-7030, Access #: 3626353, Security #: 9915,  
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2. Draft 2015 CRFG Annual Report, Kyle Dittmer (09:10 – 09:20)
3. Review of the 2016 Forecast Season by agency (~10 minutes each) (09:20 – 10:15)
  - USACOE: Kristian M. or Joel F. (LIB), Steve Hall (DWR)
  - USBR: Mary Mellema (HGH, Upper-Snake)
  - NWS-RFC: Kevin Berghoff
  - BPA: Erik Pytlak (seasonal review and RMJOC-II update)
- <<<BREAK TIME>>> (10:15 – 10:30)
4. Review of 2016 Forecast Season (continues) (10:30 – 10:45)
  - BC Hydro: Georg Jost (UC points)
  - CRITFC: Kyle Dittmer (TDA)
  - Discussion: Current conditions
5. MEI Forecasting Method – Extended Data Set (Kyle Dittmer) (10:30 – 10:45)
6. NRCS – Interactive Map Demonstration (Gus Goodbody) (10:45 – 11:10)
7. “The Sampler”...Salmon Manager Issues? (Paul W.),  
Upcoming WSF meetings? (all) (11:10 – 11:40)
8. Other business: chair transition, future agenda items, set next meeting date, etc.(11:40 – 12:00)
9. Meeting adjournment (12:30)



## **Columbia River Forecast Group–Spring Meeting, CRITFC, Portland; May 19, 2016**

### *Introductions:*

Chairman Eric Rothwell welcomed everyone at 9:05 am. The attendees introduced themselves. Kristian introduced Chris Frans who will be taking over representing the Seattle COE from Kristian and Joel starting next meeting. The February notes were reviewed. Send additional comments to Kyle before the next meeting.

### *Draft 2015 CRFG Annual Report, Kyle Dittmer (CRITFC):*

Jason and Erik offered up edits. Jason did give Kyle the updated Forecast/Observed table, which will be incorporated in draft #3. We hope to finalize the Report by next the meeting.

### *Review and Discussion of the 2016 Forecast Season:*

COE (Kristian Mickelson)...The latest Libby forecast is at 5.8 MAF, or 99%, which dropped after a hot dry April. Bob Heinith - what about the need to have more snow-pillows for mid-elevation sites? BC Hydro did recently install more high-elevation snow-pillows. Erik Pytlak - water supply forecasts were not designed to forecast the shape of the runoff. How do we incorporate temperature info? Maybe we invite Dan Isaac to present the stream temperature data warehouse: [http://www.fs.fed.us/rm/boise/AWAE/projects/stream\\_temp/maps.html](http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/maps.html). An ESP forecast is most valuable in that regard. Steve Hall – a snow model is built into ESP but there is room for improvement. Kevin Berghoff – we’re blind to low-to-mid elevation snow, so any extra data is good. Kresta – the Boise NRCS office is seeking to obtain low-elevation snow data. Mary Mellema – the USBR AgriMet system was not designed for snow but the RAWS network (4000-5000 feet elevation) may be appropriate. What is the best way to resolve the water supply volume vs. timing issue? Paul Wagner – we need to account for early runoff in our water supply forecast methods. “Why aren’t we refilling...capture the start of refill?” was his main point. Discussion was on a review of ICF this year, lessons learned, and potential to make process better. Kristian – how does early runoff impact refill and how to improve on the process (“capture the start of refill”)?

COE (Steve Hall)...The forecast (April-July) for Dworshak is 2090 KAF or 86%. The ESP traces performed a little better. The COE does mid-month snow flights. The budget for data collection is decreasing – a national problem. The initial state of the snow model should be high priority. A national Corps effort is looking at distributed snow modeling. Is there an opportunity to summarize the finds at CRFG in the future? Georg – model grid-spacing and observed site spacing needs to be better aligned.

USBR (Mary Mellema)...the Boise and Hungry Horse basins saw similar patterns of early snow-melt. The coordinated Upper Snake Heise May forecast was 2450 KAF (or 86%) compared to a drop from the 99% April forecast. We do expect to have full water supply for irrigators this summer. April runoff for Heise was 130% of normal. The coordinated Hungry Horse May forecast was 1164 KAF (or 74%) compared to a drop from the 90% April forecast. The April runoff was 167%. We saw big early peak flows.

NWS-NWRFC (Kevin Berghoff)...WY 2016 is not as bad as WY 2015. April and May were very warm and often dry. Latest forecast shows a return to cool, wet air flow. Current snow pack is 25-50% of normal. Latest WSF: Columbia at Mica, Grand Coulee 100%; Columbia at The Dalles 97%. Lower elevation basins are taking a big hit now. ESP – what can be done to shape the forecast? Go to NWRFC's water supply page: <<http://www.nwrhc.noaa.gov/ws>>. Paul – how does ESP perform vs. regression WSF? Georg – for BC basins, ESP is better.

BPA (Erik Pytlak)...Strong El Nino events may fail in a regression analysis. Step-wise may work better for such non-linear fits. He showed a graph of a curved fit with ENSO data that worked better than a classic linear fit. Strong ENSO events do behave differently than weak events. Big recent events can complicate the analysis. It is worth noting that the BPA Weather Office forecasted a near normal precipitation and slightly warmer than normal 2015-16 winter.

*RMJOC-II Meeting* (Erik P.)...the May 20<sup>th</sup> meeting will give you the latest updates on the hydro modeling efforts. Please come if you can.

BC Hydro (Georg Jost)...BC Hydro does forecasts for 20 basins using Statistical Water Supply equations for the Feb.-Sept. period. The Upper Columbia basins was slightly warm (+2 degC) in December but April was dry, hot. The April 1<sup>st</sup> Snow Water Equivalent was near normal. Early onset of snowmelt was problematic: February saw new record inflows; April saw >150% runoff. For the Mica basin, a glacial component represents 5% of the average runoff. For warm years, the glacial melt is bigger. MODIS (or Moderate Resolution Imaging Spectroradiometer; [https://en.wikipedia.org/wiki/Moderate-resolution\\_imaging\\_spectroradiometer](https://en.wikipedia.org/wiki/Moderate-resolution_imaging_spectroradiometer)) images suggests that there is enough snow for a second freshet peak. Stephanie added that there is a new project by UNBC for real-time monitoring of glacial and snow-covered basins.

CRITFC (Kyle Dittmer)...The Multivariable ENSO Index (MEI) has been consistent this season – Columbia River at The Dalles (TDA) forecasts: Jan.-July, 92-96 MAF (90-94%); April-July, 72-75 MAF (90-94%); April-Aug., 80-83 MAF (91-94%). MEI has fluctuated very little.

*MEI Forecasting Method – Extended Dataset*, Kyle Dittmer (CRITFC)...The historical dataset spans 1950-present. The experimental dataset spans 1871 to 2005. The current MEI combines sea-level Pressure and Temperature plus zonal (east-west) and meridional (north-south) surface wind, air temperature, and fraction cloud cover. The experimental MEI only includes the sea-level P and T variables. Three-month moving average of MEI is inserted into a regression. The hindcast regression equation used 1950-2015 data. Forecasts were computed for all pre-season (i.e., Sept.-Dec.) and in-season months (i.e., Jan.-April). The operational dataset outperformed the test dataset for the pre-season months (65% of forecasts) and in-season months (95%). There is no bias (pro/con) for ENSO years. Implication: pre-1950 data may not be as representative of current hydro-met conditions. Would like to run analysis on ONI data and compare with MEI.

*NRCS-Interactive Map Demonstration*, Gus Goodbody (USDA/NRCS):

The interactive map contains new features with more functionality. Map accessing Air/Water database, USGS streamflow data, BC's Environment Canada data (snow, precip, etc.). Menu displays many elements. Customization and filtering is now possible. New features: on-demand basin index, select reference period, color keys, export data from the map (stationary inventory too). Caution – this is raw data with minimal-to-no quality control. Map goes live June 2016.

“The Sampler”

*Salmon Manager concerns*, Paul Wagner (NOAA-Fisheries): (1) Libby Dam Dec. 31 draft – can more flexible be achieved than current procedure? We want the reservoir as full as possible. (2) Grand Coulee refill procedure could be better – more water and cooler. (3) Bob Heinith mentioned a new USGS study to look at *Hyporheic Zone* seeps and flow (<https://riverrestoration.wikispaces.com/Hyporheic+zones>) in the mainstem Columbia River. Goal is to map out the cool water refugia that may benefit salmon redds (i.e., egg nests) especially in a future of global warming driven water temperatures. Erik P. – we need more current water temperature modeling (like the Yearsley model) concurrent with water temperature monitoring. Chris Frans mentioned that the Yearsley model has been revamped to take smaller scale processes into account.

*Oregon AIH* (Kyle). He mentioned that OR-AIH recently elected new officers and wants to be a professional resource association for local water managers. A newly created info-pamphlet was handed out. Kyle encouraged the group to pass along this info to co-workers. AIH wants to target/recruit younger professionals to keep our profession strong.

*Upcoming WSF conferences/field meetings?*: There will be a tour of the Upper Columbia basin and its projects on Sept. 18-20.

*Other Business*: Eric is switching to a new job at the USBR. Mary Mellema (USBR) will fulfill the role of the role of the CRFG Chair until the end of 2016. Then we begin a new cycle: BPA will be the Chairman (Erik Pytlak) with the COE (Steve Hall?) as Vice-Chairman.

Our next meeting is set for **September 15<sup>th</sup>** (confirmed) at CRITFC's Columbia Room. Eric adjourned the meeting at 12 noon and thanked all for coming and participating.

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Attendance:

Berghoff, Kevin – NWS/NWRFC (Portland);  
Davis-Butts, Kresta – IPCo (Boise);  
Dittmer, Kyle – CRITFC (Portland);  
Frans, Chris – COE (Seattle);  
Gillies, Brad – NWS/NWRFC (Portland);  
Giovando, Jeremy – COE (Walla Walla);  
Goodbody, Gus – NRCS (Portland);  
Gorg, Atousa – PSU-Civil Engineering (Portland)  
Hall, Steve – COE (Walla Walla);

Heinith, Bob – CRITFC contractor;  
Jost, Georg – BC Hydro

**Date: September 15, 2016, 9:00 am – 11:15 am PDT**

**Location: Teleconference. Columbia River Inter-Tribal Fish Commission (Columbia Room, 12<sup>th</sup> Floor), 700 NE Multnomah Street, Portland**

**Teleconference and Webinar: Web Meeting Address: <https://www.webmeeting.att.com>**

Meeting Numbers: (877) 848-7030 or (404) 443-2170

Access Code: 3626353

**Teleconference:** (404) 443-2170 Toll Free: (877) 848-7030

Access Code: 3626353

Security Code: 0915

Contact Info: Mary Mellema, USBR (208) 378-5118; Kyle Dittmer, CRITFC (503) 731-1314;

1. Welcome, Introductions,  
Approval of May 2016 minutes – CRFG Chair Mary Mellema (09:00 – 09:10)
2. Approval of 2015 CRFG Annual Report, Final Revisions - All (09:10 – 09:20)
3. ICF Issues. Review of the Timing of calling the ICF. 2016 lessons learned, discussion on how to make process better. Ron Malmgren, Corps Water Management Branch (09:20 – 10:15)
4. Update on RMJOC II Modeling Progress – Erik Pytlak (10:15 – 10:30)
5. Other business: Agenda items for November meeting, set meeting date, etc. (10:30 – 11:00)
6. Meeting adjourned (11:15)

## **Columbia River Forecast Group – Summer Meeting** (conf. call); September 15, 2016

### *Introductions:*

Chairwoman Mary Mellema welcomed everyone at 9:05 am. The attendees introduced themselves. The May meeting notes were reviewed and approved.

### *Draft 2015 CRFG Annual Report, Kyle Dittmer (CRITFC):*

Steve Hall moved to approve and finalize the draft. Motion seconded. Draft now finalized. Erik Pytlak will upload to the Federal salmon website <  
<https://www.salmonrecovery.gov/>>.

### *ICF Issues. Review of the Timing of calling the ICF. 2016 lessons learned, discussion on how to make process better, Ron Malmgren (COE - NW Division):*

Objectives – minimize damage in BC, U.S.; ensure refill (3 BC, 5 PNW dams).  
Evacuation: October (earliest) but usually starts in January then ends April 30. Draft requirement depends on dam, WSF (and Storage Reservation Diagram). GCL uses the TDA – upstream adjustment (space available). Refill is triggered when the unregulated flow (NWRFC forecast) exceeds the **Initial Control Flow** (i.e., theoretical hydrograph).  
Calculation: May-Aug forecast volume – upstream storage corrections. Erik – ESP may help with early peak flows. Tracy – how about a May-July volume? Ron will do follow-up. Cyclical project: variable SRD and may or may not refill (fixed URC). Non-cyclical: variable URC. Use the 1972 FCOP Chart to determine refill. Mary – why the differing periods of runoff? Kevin – different seasonal snow melt periods (north vs. south) have required different runoff periods. Headwater projects fill first up to 10 days before ICF date by dropping to min-flow. TDA controlled flow can vary- depends on forecast error, unexpected weather events, runoff shape. Ending controlled flow: flood is ending, reservoir space vs. inflow. Lessons learned in 2016: little change or flexibility was possible. Mary – issues at the COE, how is ICF is calculated? Any changes to FCOP need to have BC Hydro review and approval via the CRT Hydromet Committee. ICF is guidance but not absolute rule for operations. May-July vs. May-August volume shift would see a 10-15 kcfs increase. Steve – CC impacts show early runoff timing more frequently. Need to adaptively manage. Erik – build up more resiliencies to buffer against 2015 type seasonal events.

### *Update on RMJOC II Modeling Progress, Erik Pytlak (BPA):*

In June, issues discovered with NRI flow (error above BRN- too much water for inflows) and the COE found lower Snake flows are too low. Second set of CIG flow – bias correction was not working well as intended. Two additional months of funding by USBR was granted to help CIG to finish flow calibration effort (w/o excessive bias corrected flow). The Flow set (now better quality) with 172 points is likely to be ready in OCT or NOV. Public meeting now pushed back to January 2017 given the unexpected data issues.

*Other Business:* Need to move our meeting about TMT YER. Try for Thursday, Dec. 8. Kyle will check. Send agenda topics to Mary. Kevin – RFC to end forecast point Snake at Milner.

Mary adjourned the meeting at 10:20 am. She thanked all for dialing in and participating.

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Attendance:

- Berghoff, Kevin – NWS/NWRFC (Portland)
- Davis-Butts, Kresta – IPCo (Boise)
- Dittmer, Kyle – CRITFC (Portland)
- Frans, Chris – COE (Seattle)
- Gobena, Adam – BC Hydro
- Hall, Steve – COE (Walla Walla)
- Malmgren, Ron (COE)
- Mellema, Mary – USBR (Boise)
- Pytlak, Erik – BPA (Portland)
- Sears, Sheri (Colville Tribe)
- Schwarz, Tracy COE (Walla Walla)
- Thomasson, Ron – COE

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Note-taker: Kyle Dittmer, Columbia River Inter-Tribal Fish Commission, Portland, Oregon

**December 8<sup>th</sup>, 2016**

**Meeting time:** 8:30 am – 1:45 pm PST

**Location:** **Columbia Room**, NOAA Fisheries, 1201 NE Lloyd Blvd, Ste 1100.

**Teleconference:** USA Toll-Free: (877)848-7030

USA Caller Paid/International Toll: (404)443-2170

ACCESS CODE: 3626353 SECURITY CODE: 1208

Web Meeting Address: <https://www.webmeeting.att.com> <<https://www.webmeeting.att.com>>

Meeting Number(s): (877)848-7030 or (404)443-2170

ACCESS CODE: 3626353

**Contact Info:** Mary Mellema (208-378-5118)  
Kyle Dittmer (503-731-1314)

**8:30 am** **Welcome and Introductions** (Mary)

**8:40** **Approval Minutes:** September 15, 2016 (all)

**8:45 – 10:00** **2016 Water Year Forecasts in Review by agency (~ 15 minutes each)**

USACE: Joel Fenolio or Kristy Riley (LIB)

Steve Hall (DWR)

Reclamation: Mary Mellema (HGH, upper Snake)

NRCS: Rashawn Tama

NWS-NWRFC: Kevin Berghoff

**10:00- 10:15** <<<BREAK>>>

**10:15-11:00** **2016 Forecast Review Continues**

BPA: Rick van der Zweep

BC Hydro: Georg Jost - Canadian Columbia and Kootenai

CRITFC: Kyle Dittmer (TDA)

Others?

**11:00-11:15** **Discussion: Forecast verification. 2016 Forecast Issues**

**11:15-11:30** **RMJOC-II Climate Change Research Update:** Rick van der Zweep

**11:30-12:30** <<Break/Lunch – on your own>>

**12:30-1:00** **NWRFC Presentation on National River Forecast Program – Taylor Dixon**

**1:00-1:30** **2016 Initiatives and Chair selection:** all

**1:30** **Other items:** 2016 report and set next meeting dates

**1:45** **Adjourn**



**Columbia River Forecast Group – Annual Forecast Review Meeting** (conf. call);  
December 8, 2016

*Introductions:*

Chairwoman Mary Mellema welcomed everyone at 8:30 am. The attendees introduced themselves. It was decided on short notice to hold a webinar as a snow-storm was expected to hit Portland that day and make face-to-face attendance difficult. The September meeting notes, updated by Kyle with some edits from Erik Pytlak, were reviewed by Mary but not sent out to the Group. Mary asked the members present to approve the revised notes and we did so.

*Review of the 2016 Forecasts:*

Libby, Logan Osgood-Zimmerman, COE-Seattle. Forecast was 5.8 MAF, 99% of normal. Forecast diverged (ESP vs. regression) by December 2015. Observed was 5.4 MAF. April had the highest Standard Error. Basin precipitation (Oct.-Dec. 2015) was 90-110%. Conditions through March were good: high winter precipitation, good snowfall through March. Record breaking warmth and dryness came in April, which caused rapid snowmelt. The inflow timing shifted 4-6 weeks earlier.

Dworshak, Steve Hall, COE-Walla Walla. The January through June COE forecasts: 1900-2300 KAF (86% of normal). The NWRFC forecasts were 2200-2750 KAF. The official COE forecast performed slightly better than the Z-score forecasts.

Upper Snake, HGH, Mary Mellema, USBR. The Upper Snake, as noted at the Snake River at Heise, saw a long dry autumn season. Heise runoff was only 70% of normal. The Flathead basin had a wet autumn-winter season. Hungry Horse (HGH) had its monthly inflow shift a month early, as noted by the April data. The forecasts closely tracked during February and March with the NWRFC a little lower than the USBR forecast. HGH ran on minimum flows all during winter-spring. Jason – How many years do you need to see a shift in flows due to climate change? Mary – We are looking at pre/post 1950 data for indicators or trends. Steve – We need a longer range data review. Kyle – What about the impact of a strong El Niño event vs. the moderate-to-weaker events on a forecast? Mary – We have not reviewed it yet. Paul – Does Heise drive Upper Snake operations? Mary – Heise is only part of the package. We use the Boise and Payette flow data too.

Columbia Basin, NRCS, no report, no representative.

Columbia Basin, Kevin Berghoff, NWRFC. The strong El Niño signal showed up in the ONI data: NDJ (2015-16) = 2.3 (“very strong”) which ties with the 1997-98 peak value. Current ONI = -0.5. Seasonal precipitation was near normal through most of the region but somewhat dry in the Upper Snake and northeast Oregon. Temperature departures in February and April were very warm: +4 to +6 degF while December-January was only +0.5 to +3 degF. The April 1<sup>st</sup> SWE was 90-125% but saw a rapid (and record) drop by May 1<sup>st</sup>. Observed runoff (April-Sept.): LWG 83%, TDA 89%. The ESP forecasts were 85-90%. Plots of the historical runoff vs. ONI are available at the NWRFC website.

Columbia Basin, Rick Vanderzweep, BPA. BPA forecast was similar to the NWS/NWRFC, as they track similar basins. Starting conditions were dry. Model uses 66 ensemble traces instead of 49. Early runoff was widely observed due to warm conditions. Upper Columbia runoff was fairly good. Paul – Do we account for early runoff in the forecast? It depends on the runoff period – January-July vs. April-September. Trial runs are starting for the new Climate Index ESP model for basin-wide areas (with a post-processing method). Paul – Can the model be adjusted to account for early runoff? Bill – There is no accumulation method to capture “lost volume” due to an early warming episode. Mary – What is the risk to management for highly variable weather patterns?

Upper Columbia Basin, BC Hydro, no report, no representative.

Columbia River at The Dalles, Kyle Dittmer, CRITFC. For WY 2016, the error was -0.5% (January-July), 4% (April-July), and 6% (April-August) – among the best errors for the MEI method. The 2008-2016 average error: 6% (January-July), 4% (April-July), 3% (April-August).

The 2017 Pre-season forecast: The Multivariable ENSO Index, MEI, moved into La Niña two months ago. The sunspot pattern, sea-surface temperature departures, and MEI all suggest a La Niña winter. Government Camp: November-May season: -3.2 degF departure, 250-inch snow base (107%). Expect four snow events for Portland – two moderate (3-4 inch each), two minor (1-inch). CRITFC’s MEI forecast (with the Sept-Oct.-Nov. index): expect above normal flow at TDA, 111 MAF  $\pm$  12 MAF, January to July period, or 109% of the 1981-2010 period. Other forecast runoff periods of note: April-July 85 MAF, 106% and April-Aug. 93 MAF, 106%.

*Update on RMJOC II Modeling Progress, Rick van der Zweep (BPA):*

The UW was done by October. The USBR contract will fund extra work. There is a problem with the Bias Correction (BC) for some winter flows in the Snake basin. UW wants to use a different BC technique – annual vs. monthly – and is a work-in-progress. Next meeting Jan. 20. Mary – Will the BC be for the Snake or entire Columbia River basin? New BC will apply to entire CR basin. Bob – How will Water Supply Forecasts be used in modeling efforts? Jason – Jeromy Giovando (WW-COE) is working on the new dataset but still waiting for UW data.

*NWRFC Presentation on National River Forecast Program, Taylor Dixon (NWS/NWRFC):*

The National Water Model (NWM) is a community coupled-based model, like their current CHPs platform, but has super-computer driven capabilities, extensive features, multi-scale, and multi-physics processes. It can assimilate major hydro elements – precipitation, soil moisture, groundwater, streamflow, etc. - on small-to-large spatial scales (down to 1-km resolution). NWM is a physical distribution platform, flexible with an interwoven collection of physical and conceptual modules. Version 1.0 was launched in August 2016: stream guidance for new locations, modeling architecture (new science), a foundation/interface with surface and groundwater flow for operational forecasting. NWM is not interactive (yet), uncalibrated (parameters only), a final product, nor a replacement for current RFC forecasts. Much testing will occur – runs in four modes.

Kyle – Will test runs be done in parallel with current RFC forecasts? Expect a users meeting soon – in January. Bob – Will the AR5 climate projections be integrated? We will only do 30-day forecast periods, for now. It will take a few years to integrate any new climate projections.

*2017 Initiatives and Chair selection, Mary Mellema (USBR):*

Our solicited list: NWM, RMJOC-II, Andy Wood’s climate change work. Other suggestions? Bob – How can we entice BC Hydro to be more engaging with the CRFG? Kyle – What about low-to-mid elevation snow gages? How can we slow/stop the decline of the hydromet network?

According to the rotation schedule it is BPA’s turn for the Chair, then the COE for the vice-chair. We presume that Erik Pytlak will fill the role as Chair but not confirmed yet. We thanked Mary for her six-months of service as CRFG Chair.

*Other Business:* Need to dovetail our meeting next to the RMJOC meeting. Next meeting set for January 19 (Thursday) at CRITFC’s Columbia Room (confirmed).

Mary adjourned the meeting at 11:20 am. She thanked all for dialing in and participating.

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Attendance:

- Berghoff, Kevin – NOAA NWS/NWRFC (Portland)
- Cooper, Peter – USBR (Boise)
- Dittmer, Kyle – CRITFC (Portland)
- Gariglio, Frank – Idaho Power Company
- Hall, Steve – COE (Walla Walla)
- Heinith, Bob – CRITFC Consultant
- Malmgren, Ron – COE (NW Division)
- Mellema, Mary – USBR (Boise)
- Proctor, Bill – COE (NW Division)
- Runyan, Chris – USBR (Boise)
- Schwarz, Tracy COE (Walla Walla)
- Thomasson, Ron – COE (NW Division)
- Wagner, Paul (NOAA Fisheries)
- Ward, Jason, (COE – NW Division)
- van der Zweep, Rick – BPA (Portland)

Logan Osgood-Zimmerman, COE (Seattle)

Alfredo Rodriguez, COE (Walla Walla)

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Note-taker: Kyle Dittmer, Columbia River Inter-Tribal Fish Commission, Portland, Oregon

*Revised December 15, 2016*

## Appendix C

### Historical forecast results

#### Columbia River Forecast Group 2016

Historic forecast results: [http://www.nwd-wc.usace.army.mil/report/flood\\_risk](http://www.nwd-wc.usace.army.mil/report/flood_risk)

Historical Jan-Jul Results for The Dalles and Lower Granite and Observed KAF:

<http://www.nwrfc.noaa.gov/ws>

1. Use the interactive map at the web address above.
2. Go to the forecasting map for TDA and LWG or the runoff map for Observed results.
3. Click on the dam needed and for TDA and LWG, look up the appropriate archive data. For the observed runoff, click on the dam needed and add up the observed for the months stated in the tables below.
- 4.

In 2012, the official Water Supply Forecasts used for FCRPS operations for Grand Coulee, Brownlee, Lower Granite, and The Dalles changed to the NWRFC ESP median issued on certain days of the month, and based on different lead times on future precipitation:

- 2012: 4<sup>th</sup> working day of the month, 10 days of future precipitation  
 2013: 5<sup>th</sup> working day of the month, 3 days of future precipitation  
 2015: 5<sup>th</sup> working day of the month, 5 days of future precipitation  
 2016: 5<sup>th</sup> working day of the month, 5 days of future precipitation

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	109%	2013	110%	1972	108%	1968	107%	1876	102%	1834
2006	1839	87%	1906	90%	1946	92%	1922	91%	1932	91%	2120
2007	2087	88%	2122	90%	2096	88%	2221	94%	2257	95%	2370
2008	2202	113%	2091	107%	2091	107%	2059	105%	1985	101%	1957
2009	2003	123%	1945	120%	1866	115%	1859	114%	1787	110%	1627
2010	2030	125%	1962	121%	1825	113%	1817	112%	1813	112%	1621
2011	1846	82%	1942	86%	1912	85%	1997	89%	2057	91%	2251
2012	1987	77%	2039	79%	2015	78%	2138	83%	2227	87%	2571
2013	2283	105%	2079	96%	1975	91%	2061	95%	2094	96%	2172
2014	1785	86%	1728	83%	1761	85%	1891	91%	1903	91%	2081
2015	2148	122%	2061	117%	1995	113%	1958	111%	1912	108%	1766
2016	2063	106%	1978	101%	1961	101%	1972	101%	2063	106%	1951

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	KAF
2005	5786	104%	5630	101%	5371	97%	5401	97%	5096	92%	5564
2006	5487	83%	6186	93%	6350	96%	6076	92%	6179	93%	6629
2007	6955	102%	6582	96%	6516	96%	6847	100%	6990	102%	6822
2008	6282	113%	6498	117%	6435	116%	6387	115%	6166	111%	5539
2009	5526	125%	5436	123%	5296	120%	5672	128%	5209	118%	4425
2010	5682	126%	5478	121%	5084	113%	5103	113%	4887	108%	4517
2011	5610	73%	6656	86%	7111	92%	7191	93%	8165	106%	7729
2012	5524	69%	5714	62%	5635	61%	6872	75%	7159	78%	9185
2013	6898	96%	6384	89%	6315	88%	6189	86%	6535	91%	7173
2014	5432	81%	5192	78%	5505	82%	6868	103%	6996	105%	6673
2015	6297	148%	5523	130%	5683	134%	5808	137%	4826	114%	4250
2016	6249	115%	6318	117%	6472	120%	6681	123%	5831	108%	5414

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	KAF
2005	1647	132%	1418	114%	1144	92%	1217	98%	1173	94%	1245
2006	1826	101%	2024	112%	1958	108%	1912	106%	1824	101%	1811
2007	1823	136%	1803	135%	1786	134%	1495	112%	1425	107%	1337
2008	1840	76%	1859	77%	1876	78%	1913	79%	2131	88%	2410
2009	1809	112%	1864	115%	1697	105%	1817	112%	1816	112%	1618
2010	1654	103%	1429	89%	1284	80%	1305	81%	1345	84%	1608
2011	1944	61%	2139	67%	2222	69%	2357	73%	2798	87%	3212
2012	1691	80%	1781	85%	1739	83%	1906	91%	1680	80%	2102
2013	1968	106%	1877	102%	1743	94%	1750	95%	1789	97%	1849
2014	1787	73%	1819	75%	2142	88%	2204	90%	2400	99%	2436
2015	1977	214%	1927	208%	1678	181%	1496	162%	1499	162%	925
2016	1629	135%	1531	127%	1573	131%	1556	129%	1251	104%	1203

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	112%	53657	110%	45820	94%	47628	98%	47628	98%	48807
2006	55466	91%	58480	96%	57877	95%	57275	94%	58500	96%	61189
2007	60000	105%	61600	107%	61200	107%	61600	107%	61000	106%	57350
2008	59300	99%	59200	99%	61300	103%	61600	103%	60000	100%	59739
2009	55800	116%	54600	113%	53100	110%	55400	115%	54000	112%	48186
2010	54000	113%	49100	103%	45800	96%	44900	94%	45300	95%	47711
2011	56500	75%	61400	82%	62200	83%	64700	86%	70800	94%	75107
2012	44509	56%	56788	71%	60853	76%	68525	86%	72812	91%	79874
2013	58230	89%	54536	84%	54020	83%	55882	86%	57373	88%	65121
2014	54683	87%	48197	77%	57818	92%	60382	96%	64683	103%	62620
2015	56539	134%	55845	133%	49419	117%	51165	121%	45498	108%	42145
2016	52783	102%	54491	105%	56411	109%	57009	110%	56763	110%	51836

## 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	88%	2590	72%	1740	48%	2180	60%	2440	68%	3612
2006	6690	75%	8016	89%	6940	77%	8380	93%	9020	101%	8975
2007	5200	185%	3630	129%	3760	134%	3300	118%	3040	108%	2807
2008	4390	101%	5260	120%	5500	126%	5400	124%	4860	111%	4368
2009	4260	76%	4020	72%	3350	60%	4970	89%	5000	90%	5575
2010	3300	72%	3020	66%	2470	54%	2590	56%	2780	61%	4586
2011	7230	69%	6280	60%	5690	54%	7510	71%	9060	86%	10549
2012	4783	86%	4986	90%	5211	94%	6388	115%	6162	111%	5535
2013	4650	178%	4229	162%	3744	144%	3478	133%	2673	102%	2609
2014	3723	108%	3246	94%	3861	112%	3934	114%	3519	102%	3436
2015	4831	197%	4665	190%	3738	153%	2052	125%	2289	93%	2249
2016	4693	118%	4689	118%	4623	116%	4767	120%	4373	110%	3969

## 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	116%	1642	100%	1423	87%	1321	80%	1344	82%	1643
2006	2601	97%	2707	101%	2612	98%	2593	97%	2626	98%	2677
2007	2905	161%	2126	118%	2192	122%	1982	110%	1868	104%	1799
2008	2717	79%	2738	80%	2810	82%	3010	88%	3003	87%	3434
2009	3075	121%	2681	106%	2461	97%	2662	105%	2631	104%	2539
2010	2174	114%	1742	91%	1571	82%	1398	73%	1526	80%	1906
2011	3340	83%	3142	78%	3329	82%	3387	84%	3772	93%	4042
2012	2473	74%	2504	75%	2585	77%	2966	89%	3226	97%	3343
2013	2587	123%	2202	105%	2128	101%	2036	97%	2296	109%	2105
2014	2296	78%	2274	77%	2701	92%	3111	106%	3183	108%	2943
2015	2136	198%	1922	178%	1815	168%	1709	158%	1325	123%	1081
2016	1913	93%	1986	96%	2025	98%	2308	112%	2090	101%	2068

## 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	114%	18000	99%	14600	81%	15700	87%	16500	91%	18134
2006	31600	98%	34500	107%	31900	99%	33200	103%	34900	108%	32194
2007	28200	149%	23000	122%	23500	124%	21400	113%	20600	109%	18887
2008	27200	99%	29500	107%	29200	106%	28000	102%	26500	96%	27522
2009	25700	89%	25100	87%	22400	78%	26400	91%	26900	93%	28899
2010	22400	100%	19300	86%	17000	76%	16600	74%	17000	76%	22460
2011	31253	75%	30439	73%	30676	74%	32924	79%	36291	87%	41610
2012	23497	79%	25598	86%	26022	87%	29996	100%	30266	101%	29893
2013	27769	147%	24052	127%	21683	114%	20774	110%	19130	101%	18948
2014	23024	85%	23286	86%	27967	104%	29328	109%	28629	106%	26942
2015	27621	146%	28729	152%	23125	122%	21906	116%	18856	100%	18882
2016	24286	101%	25579	106%	25886	107%	26440	110%	25401	105%	24116

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	105%	82400	101%	70700	87%	73800	91%	74700	92%	81349
2006	101000	88%	111000	97%	107000	93%	107000	93%	110000	96%	114672
2007	105000	110%	101000	105%	100000	104%	100000	104%	99100	104%	95738
2008	102000	103%	103000	104%	103000	104%	101000	102%	97300	98%	99209
2009	94700	105%	92900	103%	86200	96%	92000	102%	91100	101%	90244
2010	88500	104%	79200	93%	71800	85%	69700	82%	70900	84%	84718
2011	99041	71%	105851	73%	111213	72%	119785	79%	126943	89%	142616
2012	86041	66%	93781	72%	98799	76%	114135	88%	120043	93%	129441
2013	102470	105%	92040	94%	89674	92%	90972	93%	92870	95%	97709
2014	90334	84%	79222	73%	95865	87%	105424	98%	105513	98%	108082
2015	102646	193%	103786	195%	91678	172%	96005	180%	86396	162%	53245
2016	94084	87%	95160	88%	102918	96%	104709	97%	104704	97%	107605

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	109%	69200	101%	57200	84%	60800	89%	61900	90%	68452
2006	87500	90%	94300	97%	91200	93%	92700	95%	95600	98%	97541
2007	91300	116%	88200	112%	88300	112%	85200	108%	84200	107%	78939
2008	88200	95%	91800	98%	94300	101%	94700	102%	90900	98%	93198
2009	82100	102%	79700	99%	74800	93%	82400	102%	81400	101%	80771
2010	76700	99%	68500	88%	62100	80%	60900	79%	62200	80%	77410
2011	90600	71%	92500	73%	92300	72%	101000	79%	113000	89%	127378
2012	77041	65%	84454	71%	90604	76%	103726	87%	110762	93%	119127
2013	92030	105%	81863	94%	80372	92%	81811	94%	82502	95%	87052
2014	84888	90%	72458	77%	88832	94%	92057	97%	96741	102%	94548
2015	87324	149%	83108	142%	71784	123%	72233	124%	62113	106%	58449
2016	82621	105%	83221	106%	86527	110%	86867	111%	86841	111%	78329

### CRFG Mailing List -- 2017

CRFG Mailing List -- 2017			
<i>Revised August, 2017</i>			
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