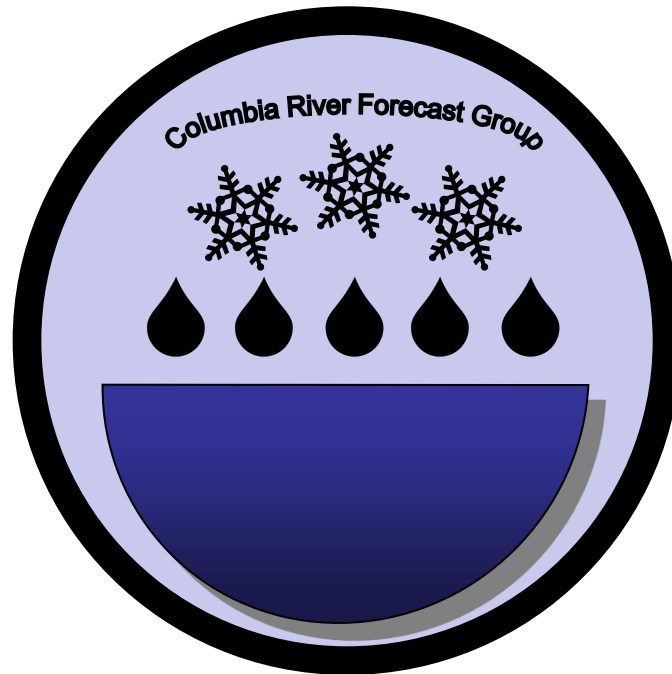


COLUMBIA RIVER FORECAST GROUP

2015 ANNUAL REPORT



CHAIRMAN: KYLE DITTMER, CRITFC
VICE-CHAIRMAN: ERIC ROTHWELL, USBR

AUGUST 11, 2016

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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 2015 and hosted by CRITFC: February 18, April 21, September 9, and December 3 (annual review). 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 Bonneville Power Administration (BPA), Columbia River Inter-Tribal Fish Commission (CRITFC), 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 (NWPC), Oregon Climate Change Research Institute, (OCCRI), U.S Bureau of Reclamation (USBR), U.S. Geological Survey (USGS), Washington Dept. of Ecology.

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
- Historical Satellite Data – WSF Improvement?
- RMJOC-II...Forecast Uncertainty and Streamflow; UW GCM Selections
- RMJOC-II...Forecast/Streamflow Workshop Update
- USBR Snow Model – Boise River Basin
- NRCS Interactive Map Tool
- Salmon Manager concerns/issues
- Update on NOAA/NWS-NWRFC Initiatives
- Idaho Power 2014-2015 Fall Chinook Spawning/Emergence
- 2016 pre-season water supply forecasts
- Summary of 23rd Annual OR-AMS Winter Weather forecast meeting
- Discussion of Verification of Forecast Methods
- The 2015 wrap-up and review of runoff forecasts, comparison of results, discussion of challenges, and lessons learned
- Discussion of possible 2016 CRFG activities and work elements

Water Year 2015 was a very unusual meteorological and hydrological year – filled with unexpected challenges and surprises. It was initially expected by most regional entities that going into the year with a weak El Niño the meteorological and hydrologic responses would be “near normal.” However, given the very warm winter, transition dominated areas (snow/rain) became rain dominated. Thus, peaks of basin freshets occurred 30-90 days earlier than normal in many parts of the basin while snow-dominated areas in Canada contributed to later peaks. This resulted in the reduction of the spring mainstem peak flow for the Columbia River at The Dalles. The summer flows occurred earlier and in some cases set new record low flows.

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:

- ❖ Phil Mote, OCCRI, *Historical Satellite Data – WSF Improvement?* Seeking to generate a new network of snow cover extent and SWE to assist predictions of streamflow and water supply forecasting.
- ❖ Erik Pytlak, BPA, *RMJOC-II...Forecast Uncertainty and Streamflow*. We assess the implications of new global climate projections, account for the uncertainties in global climate models, downscaling methods, and hydrologic models to help regional planners to make better-informed risk assessments of the range of hydro-climatic outcomes in the Columbia River Basin over the next 50 years.
- ❖ Bart Nijssen & Oriana Chegwiddden UW, Erik Pytlak, BPA, *UW GCM Selections*. Effort uses new CMIP5 results, ten Global Climate Models, three hydro models.
- ❖ Erik Pytlak, BPA, *RMJOC-II...Forecast/Streamflow Workshop Update*. RMJOC-II GCM's shows a warmer future (esp. in the interior Columbia Basin). Seasonal patterns and ranges of temperature and precipitation are captured better in RMJOC-II. Temperature distribution shows that coastal areas, west side from many of the models shows less warming than in the interior.
- ❖ Scott Havens, USDA-ARS, *USBR Snow Model – Boise River Basin*. A physically based snow model for the Boise River basin was applied to operations to predict inflows to the Boise River reservoirs using DHSVM (Distributed Hydrology-Soil-Vegetation Model) and WRF (Weather Research and Forecasting model).
- ❖ Rashawn Tama, NRCS, *NRCS Interactive Map Tool*. The NRCS mapping website now gives more utility to present snow and precipitation information spatially by filtering by conditions (e.g., records, averages, specific years). Also, it can compare the same set of stations over multiple analog years.
- ❖ Paul Wagner, NOAA-Fisheries, *Salmon Manager issues*. Was WY 2015 the lowest on record? Where there any “early warning” triggers? Will the new Libby forecast help with December pre-draft operations? April flood control targets?
- ❖ Kevin Berghoff, NWRFC, *Updates from the NWRFC*. Extended climate forcings through 2010. New monthly normals for precipitation and temperature stations are based on 1981-2010 data. New MAP/MAT forcings are for each basin, extending observed data record through 2015. ESP will increase to 63 or 64 traces.

ACCOMPLISHMENTS

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

- RMJOC-II. This is the next generation effort to evaluate new downscaled global climate model data for the Pacific Northwest.
- New forecast procedure for Libby Dam. WY 2015 was the first full year that the COE was able to use their newly revised procedure.
- NWS/NWRFC period-of-record extension for ESP model with climate forcings. How did model performance work out?
- ARS ISNOBAL modeling by USBR for the Boise River Basin.
- Historical snow satellite data – how useful is this test case for forecast procedures?
- The unusual nature of WY 2015 – what was learned in this very warm, very dry year? How will WY 2015 be reflective as an indicator of future years modified by climate change?

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 “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 - 2015 Meetings

The following meetings took place for the CRFG.

18 February 2015

21 April 2015

9 September 2015

3 December 2015 (Annual Review)

Reviewed and finalized Meeting notes are as follows:

Date: February 18, 2015, 9:00 am – 3:00 pm PST

**Location: Columbia River Inter-Tribal Fish Commission, Celilo Room (5th floor),
700 NE Multnomah Street, Suite 1200, Portland.**

Teleconference: (877) 848-7030, Access #: 3626353, Security #: 1111,
<https://www.webmeeting.att.com>

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

1. Welcome, introductions, Dec. 2014 notes – CRFG Chairman Kyle Dittmer (09:00 - 09:10)
2. Review of the 2015 Forecast Season, by agency (~ 15 min. each) (09:10 – 10:15)
 - COE: Kristian Mickelson (Libby), Steve Hall (Dworshak)
 - USBR: Eric Rothwell (Hungry Horse, Upper-Snake)
 - NRCS: Rashawn Tama (Columbia basin)
 - NWS-RFC: Kevin Berghoff (Columbia basin)
- <<<BREAK TIME>>> Refreshments (10:15 – 10:30)
2. Forecast Review (continues) (10:30 – 10:50)
 - BC Hydro: Adam Gobena (Canadian Columbia and Kootenai), *invited*
 - CRITFC: Kyle Dittmer (Columbia at The Dalles)
 - Others?
 - Discussion: current conditions/trends, forecast uncertainty, improvement(s).
3. Update on RMJOC-II Climate Change Research (Erik Pytlak, BPA) (10:50 – 11:00)
4. Historical Satellite Data – WSF Improvement? (Dr. Phil Mote, OCCRI) (11:00 – 12:00)
 - <<<LUNCH...on your own>>> see attached flyer (12:00 – 1:00)
5. Update on NWS-NWRFC Initiatives (Kevin B.) (1:00 – 1:30)
6. Review and Verification of Forecast Methods (Kyle D.) (1:30 – 1:50)
 - <<<BREAK TIME>>> Refreshments (1:50 – 2:10)
7. “The Sampler”... Status of 2014 CRFG Report (Eric R), Outstanding Issues from 2014? (Kyle), Salmon Manager Issues? (Paul W.), Upcoming WSF conferences/meetings? (all) (2:10 – 2:50)
8. Other business: future agenda items, etc. (2:50 – 3:00)
9. Meeting adjournment. (3:00 pm)

Columbia River Forecast Group – Winter Meeting, CRITFC, Portland, Feb. 18, 2015. Participants in person: Kyle Dittmer (CRITFC), Steve Hall (USACE – Walla Walla), Wayne Jousma (USACE – Walla Walla), Jason Ward (USACE – Portland), Rashawn Tama (NRCS), Phil Mote (OCCRI), Kristian Mickelson (USACE – Seattle), Erik Pytlak (BPA), Kara McCarthy (NRCS), Gus Goodbody (NRCS), Eric Rothwell (USBR) Participants by phone Bob Heinith (CRITFC contractor), Steve King (NWS NWRFC), Dave Robinson (Rutgers University)

Introductions and Roll Call (Dittmer)

Review of 2015 Forecast Season

COE Seattle (Kristian Mickelson): Libby

This is the first year Corps is using their new water supply forecast equations, and they seem to be tracking well. The new equations do not incorporate climate indices in January, they rely on precipitation and snow water equivalent (SWE). The preseason, December, forecast does still use SOI (Southern Oscillation Index).

January and February have been wet and warm. SWE is well below average. Despite the low SWE the water supply forecast is trending towards normal. December forecast was high due to precipitation. January/February forecast is falling with lack of snow. Corps will operate to release minimums for now. The March-August forecast is 5523 KAF.

COE Walla Walla (Steve Hall): Dworshak

The Dworshak water supply forecast is trending well below normal, due to lack of snow accumulation. Snow is ranging from 40-70% of normal but low elevation snow is lacking. Basins to the northwest of the basin are well below average for SWE but the southeast basin snow is near average. Z-score forecast is coming in even lower than their PCA forecast. The inclusion of a three month SOI is forecasting a declining forecast. Forecast is 1922 KAF, 79% of normal. Z-score was 1355 KAF.

Kyle Dittmer asked about the Corps use of aerial surveys, which sparked a lengthy discussion on how aerial surveys are used, and how others use remote sensing to qualify their forecasts. Steve stated that the Corps Walla Walla uses the flights opportunistically during final refill. If there is a lopsided distribution the flights are valuable to verify what is happening with snow distribution.

USBR (Eric Rothwell): Hungry Horse, Upper Snake

Many of the Reclamation projects water supply forecasts are doing much worse than the upper Snake River system and the S.F. Flathead River at Hungry Horse Dam. Our January water supply forecast for the Upper Snake was above average (109% of average, coordinated with the Corps) driven by a healthy snowpack, the forecast dropped slightly in February (101% of average, coordinated with the Corps) and we expect it to continue to drop because the snowpack is not building. Despite the relatively dry period in January the forecast is near average, but with strong carryover prospects are good to fill the system. On the S.F. Flathead River the snowpack is above average, unlike many of the basins in the region. The combination of a good snowpack and early season precipitation project a water supply forecast for February of 114% of average. With the dry period in early

February we expect the water supply forecast to fall in March, our unofficial midmonth forecast came in at 107% (the same as the NWRFC 0-day on February 16).

NRCS (Rashawn Tama): Columbia Basin

During the NRCS introduction Rashawn wanted to remind the group that NRCS is not trying to predict what is going to happen, we are trying to provide an envelope of possibilities. He also reminded that although snow pack is low for much of the basin there is some time and potential for change.

WSF Daily Forecasts (http://www.wcc.nrcs.usda.gov/wsf/daily_forecasts.html): Rashawn presented NRCS's daily forecast products. These waters supply forecasts (WSF) use current data and are useful to show trend that are occurring season to date. The daily WSF use Z-score, while most of the NRCS monthly regressions are principal component. He then presented several basins as examples. Specifically, the overall trend for water supply for Flathead Lake and Dworshak is trending down from earlier forecasts; these examples seemed to typify much of the Columbia River Basin. For more info: (www.wcc.nrcs.usda.gov/ftpref/data/water/wcs/daily_forecast/charts).

NOAA/NWS/NWRFC (Kevin Berghoff): Columbia Basin

Kevin gave an overview of the regional precipitation and temperatures for the 2015 Water Year with a comparison of 2014 to illustrate how warm the last couple of months have been. The precipitation this year has been robust in comparison to 2014, particularly October through January. The forecast in mid-February for the Columbia River above Grand Coulee Dam is 106% of average this year compared to ~60% this time last year. Last year precipitation in February and March were very strong (near record levels in many areas), turning around an otherwise dismal water supply forecast. This year the February precipitation is near average, but is lower than last year.

Although the precipitation has been decent this year, this winter has been much warmer than last winter, and much warmer than normal throughout the region. Specifically December, January and February have been very warm, which are the months that snow typically accumulates. The Cascades are in especially bad shape, more rain than snow this year. Eastern Oregon and Washington also have thin snowpacks. The Upper Snake River basin and Western Montana are looking near average. The April to September water supply forecast for Grand Coulee (10-day QPF) is 93%, same as last year at this time. The Lower Granite water supply forecast has been dropping since early January, currently 87% compared to 100% at this time last year. At The Dalles the forecast is 89% this year compared to 93% of average last year at this time.

Another key note from the NWRFC was that the January to July water supply forecasts are stronger than the April to September forecasts because of likelihood over earlier runoff. Smaller tributaries could be very dry in the later summer. The next 10-days (2/17 – 2/27) look very dry, we should expect a much drier period than average.

CRITFC (Kyle Dittmer): Columbia River at The Dalles

CRITFC uses the Multivariate ENSO Index (MEI) regressed against The Dalles historical flows to project water supply. Their February forecast is 95.7 MAF Jan-July (94%), and

April-August is 83.8 MAF (95%). The PDO is strongly positive, with a weak El Niño, potentially a reason for the warm season. CRITFC is optimistic that we might see some slight improvements in the water supply (weather) in the near future.

BPA (Erik Pytlak): RMJOC-II Climate Change Research

BPA is hosting the second Columbia River Management Joint Operating Committee (RMJOC-II) Transboundary Climate Change Workshop on the February 19th and 20th. This workshop will coordinate and communicate ongoing research on climate change implications for Columbia Basin hydrology, and will focus on the two ongoing RMJOC climate change studies commissioned by BPA and others in late 2013 led by University of Washington and Portland State University. These studies will assess the implications of the latest global climate projections, but to also better account for the uncertainties in global climate models, downscaling methods, and hydrologic models. It is our hope that by understanding these uncertainties will allow regional planners to make better-informed risk assessments, and yield a better understanding of the possible range of hydro-climatic outcomes in the Columbia River Basin over the next 50 years. Over 60 attendees are expected, including researchers, agencies, and tribes from upper and lower basin.

On January 26th both the University of Washington and Portland State University climate change projects went before the BPA review board to defend their research. Specifically they were asked to present their performance, and met required benchmarks. Results of the reviews are expected later in February. Climate change projected stream flow forecasts (associated with RMJOC-II) are expected by the end of 2016.

OCCRI (Phil Mote): Snow Ablation Characteristics and Melt-discharge Relationships in Columbia Basin. (in collaboration with Rutgers University and University of Georgia) Researchers– Phil Mote, Dave Robinson (RU), Tom Mote (UG), coordinated with NCDC. Objectives:

- generate snow cover extent, and SWE (NOAA satellite SCE climate data record);
- utilize SCE CDR and other data, decision tools, to predict streamflow associated with snowmelt within the Columbia Basin;
- make recommendations for additional observations to create a network to fully characterize the basin snowpack.

Using visible satellite imagery (IMS) 4km, AVHRR (SWE), DayMet (similar to PRISM but on a daily time step), USGS river discharge, and in situ observations (SNOTEL, etc.), reanalysis products NCAR/NCEP Reanalysis and NOAA Climate Forecast System Reanalysis (CFSR).

By end of March 2016 they will deliver a project database, climatology summary, evaluation of pre-existing forecast models with and without SCE CDR input, decision support system. The researchers are hoping to have interaction with stakeholders to improve and test the study products.

Gus Goodbody and Rashawn Tama (NRCS) compared snow covered area and SNOTEL measurements. They found strong correlations over a 15-year period. Problem with snow covered area is that it may not tell you more about the water supply. This sparked a long conversation about the quality and usefulness of current snow distribution information.

NOAA/NWS/NWRFC (Kevin Berghoff): **NWRFC Water Supply Web Products**

Gave an overview of the NWRFC's Water supply products on their public website; daily forecast are available from <<http://www.nwrfc.noaa.gov/rfc/>> a clickable map of the Columbia basin, water supply archives, ranking, data, etc. are available from each of the site pages. Coming soon: water supply graphics for individual months, entire water year.

ESP Natural Water Supply Forecasts are available from another tab on the main map site. All of the adjustments (consumptive use and storage) are removed, resulting in a total water supply to the forecast point that represents a potentially 'natural' discharge time series. Kevin also displayed an ESP Interactive Ensemble Analyzer which allows for customizable data displays to tailor water supply products to users need, for example displaying specific time ranges that are relevant to the end user's concerns.

Over the last 2-3 years NWRFC has developed a snow update system, this includes a PCA within the framework of CHPS, a PCA stand-alone R-scripts, SNOTEL weighted average, NOHRSC, and historical information. All of these snow data summaries are available on one plot to see simulated and estimated SWE for the water year. NWRFC uses this information to update the snow states in their model, rather than just relying on modeled snow states. Upper zones of basin models are typically well represented by most of the snow state models, but the lower zones have less success. NOHRSC tends to be an outlier for the lower zones.

Hydrologic Ensemble Forecast Service (HEFS) - the NWRFC is integrating HEFS into their forecasting workflow. HEFS will be able to generate a seamless probabilistic forecast, with a forecast period of up to a year. Similar to ESP, HEFS quantifies the uncertainty into the future (unlike the current deterministic products that do not represent the uncertainty inherent in forecast products).

Other topics:

- 1) Review and verification of forecast methods. Kyle Dittmer (CRITFC) suggested that a discussion on verification methods should be reinitiated. Every agency has their method for conducting a forecast. This group is charged with improving water management techniques. Past review & verification efforts have been sidelined due to staffing changes.
- 2) Steve Hall (USACE) past efforts of reviewing Dworshak WSF used CSVE. There should be other metrics. They have looked at total error, CSVE, station continuity. Rashawn Tama (NRCS) – we should refine what we want to get out of a verification process and who has the resources to actually do this.
- 3) 2014 CRFG Report. Steve Hall (USACE) said a draft will be available by the next meeting, waiting on final December meeting minutes.

Next meeting – Tuesday, April 21, with potentially a field trip on the day before or after.

Note-taker: Eric Rothwell, US Bureau of Reclamation, Boise, Idaho.

Revised April 21, 2015

Date: April 21, 2015, 9:00 am – 3:00 pm PDT

**Location: Columbia River Inter-Tribal Fish Commission, Celilo Room (5th floor),
700 NE Multnomah Street, Suite 1200, Portland**

Teleconference: (877) 848-7030, Access #: 3626353, Security #: 1111,
<https://www.webmeeting.att.com>

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

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 - USBR: Eric Rothwell (Hungry Horse, Upper-Snake)
 - NRCS: Rashawn Tama (Columbia basin)
 - NWS-RFC: Steve King (Columbia basin)

<<<BREAK TIME>>> Refreshments (10:30 – 10:50)
2. Forecast Review (continues) (10:50 – 11:20)
 - BC Hydro: TBA Rep. (Canadian Columbia and Kootenai), *invited*
 - CRITFC: Kyle Dittmer (Columbia at The Dalles)
 - Others?
 - Discussion: current conditions/trends, forecast uncertainty, improvement(s).
3. Draft 2014 CRFG Annual Report (Stephen Hall, COE) (11:20 – 11:40)
4. Idaho Power 2014-15 Fall Chinook Spawning/Emergence (Kresta DB, IPC) (11:40 – 12:00)
 - <<<LUNCH...on your own>>> see attached flyer (12:00 – 1:00)
5. USBR Snow Model – Boise River Basin (Scott Havens) (1:00 – 1:30)
6. NRCS Interactive Map Tool (Rashawn) (1:30 – 1:50)
 - <<<BREAK TIME>>> Refreshments (1:50 – 2:10)
7. “The Sampler”...Forecast Verification-thoughts? (Kyle), Outstanding Issues from 2014? (Kyle), Salmon Manager Issues? (Paul W.), Upcoming WSF conferences/meetings? (all) (2:10 – 2:50)
8. Other business: future agenda items, etc. (2:50 – 3:00)
9. Meeting adjournment. (3:00 pm)

Columbia River Forecast Group - Spring Meeting, CRITFC, April 21, 2015

Participants in person: Kyle Dittmer (CRITFC), Stephen King (NWRFC), Kresta Davis-Butts (IPCo), Steve Hall (USACE – Walla Walla), Rashawn Tama (NRCS), Eric Rothwell (USBR), Erik Pytlak (BPA), Paul Wagner (NOAA-NMFS). On the Phone: Jason Ward (USACE – Portland), Kristian Mickelson (USACE – Seattle), Paul Pickett (WA Department of Ecology), Bob Heinith (CRITFC contractor), Scott Havens (USDA-ARS)

Introductions and Roll Call (Dittmer). Review February meeting minutes and update.

Review of 2015 Forecast Season

COE Seattle (Kristian Mickelson): Libby

The April-August forecast for Libby is 5804 KAF. Because of the type of year, and specifically because of the lack of low elevation snow, this forecast maybe overestimating. Bob asked about inclusion of summer convective, thunder-storms being included in forecast. Kristian replied that during equation development they looked for indices for summer rain events – but none of them performed well. It is indirectly incorporated through an intercept value. Bob asked if there has been more often summer precipitation events than in the past. Kristian recounted that in the last few years, he doesn't think that there has been a significant change.

COE Walla Walla (Steve Hall): Dworshak

The April through July forecast is 1.7 MAF, 77% of normal. Steve expressed some suspicion of this forecast, thinks it is trending high based on precipitation but the snowpack are ranging from 0 – 77% of normal. The low snow values create issues in the model. NRCS has been in the basin a couple of times this year, typically they go in late March but this year they went in early April. This April, the snow-line was approximately 5600 feet, which is not well represented by the SNOTEL data (most in that elevation range are on northern aspects). Snow cover currently looks more like early June. April is typically the peak accumulation period. Crater Meadows SNOTEL, in the southeast corner of the basin, is the highest at 77% of normal but this site doesn't represent the basin well. Kyle identified that February flows were high and appear to be the peak flow event. Steve agreed with that assertion and noticed that we really haven't had a dry year. We've had a warm year – plenty of precipitation but not as snow. He doesn't expect a large peak, but should see a significant volume of runoff from the remaining snow.

USBR (Eric Rothwell): Hungry Horse, Upper Snake

Both the Flathead and Upper Snake started off with strong precipitation and snow. In the Flathead, the precipitation remained relatively high but warm, resulting in record high March inflows and a falling forecast in April.

The Upper Snake had a dry February and very dry March and the water supply forecast continued to fall. Specifically lower and mid-elevation snow and precipitation station, incorporated in the USBR's forecasts, had no snow accumulation and well below average precipitation. Eric presented the trends of two trial principal component regression forecasts, these are in development but they show promise in providing another check for Reclamation's existing methods.

NOAA/NWS/NWRFC (Steve King): Columbia Basin

Northern part of basin had stronger seasonal precipitation than the south and eastern portion of the basin. Temperatures have been very warm through most of the water year, throughout the basin. The only cool month was November. Storms might otherwise produce snowpack, but in this warm situation resulted in runoff and very little low elevation snowpack.

Snowpack, most of the basin is well below normal. Slightly better conditions exist in British Columbia and western Montana, but those conditions have been eroded as well this spring. In British Columbia, there was a slight snowpack rebound in March.

Runoff is occurring early, largely due to mid and low elevations receiving precipitation as rain - not as snow. Rivers have had stronger early flows than usual. The early forecast periods, or if considering the entire water year, will show a higher percent of average than later forecast periods that cover the summer.

The Grand Coulee April-September forecast has fallen from above 60 MAF to 52 MAF, 87% of average. However, the January-July forecast is currently 100% of average, which is misleading because this includes runoff to date.

Lower Granite – the April to September forecast is at 64% today. Similar to Grand Coulee, this forecast stated the year near normal, then it dried out in February and March and the forecast has fallen steadily. January to July is also dropping and is currently at 75% of normal. The Columbia at The Dalles – 79% of average for the April-September period – has dropped off from a near normal forecast in December.

Natural flow forecast on the NWRFC forecasts, www.Nwrfc.noaa.gov/natural/, is an attempt to come up with an unregulated flow, so that regulated and unregulated basins can be compared. The natural forecasts take into consideration consumptive use, regulation. The natural flows page presents many more forecast locations. These are calibrated to the short-term, calculating a flow and routing downstream. The routing component provides a conceptually more realistic forecast. The consumptive use relies on a natural normal, so that the consumptives are consistent with the hydrologic state of the natural flow forecasts. ESP natural forecasts, has additional periods including October – September, and January-month. One can also download the Forecast Ensemble (CSV for accessibility).

Beta-monthly Natural forecast – shows a monthly runoff volume against averages and ESP forecast going forward. The forecast is deterministic and considers runoff to date. It is the ESP version that uses the 10-day forecast. This product does not conserve volume, so don't use to sum for period runoff.

CRITFC (Kyle Dittmer): The Columbia at The Dalles

The MEI (Multivariate ENSO Index) based forecast for The Dalles for January - July forecast is 96 MAF at 95%, April – July 77 MAF 96%, and the April-August period is 77 MAF at 88%. There was some discussion between Kyle, Paul and Erik about this year's El Niño – specifically, that it was a weak or pseudo El Niño event.

NOAA/NWS/NWRFC (Steve King): NOAA climate forecasts

The latest guidance

(http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf) suggests that there is a 70% chance that the current El Niño will continue through this summer. The Modoki El Niño

(http://www.jamstec.go.jp/frcgc/research/d1/iod/enmodoki_home_s.html.en) differs from a classic El Niño in that the strong surface warming is focused in the **central** tropical Pacific and not the eastern Pacific, which will affect the direction of the Trade Winds and Westerlies plus the moisture delivery (amount, timing) to our west coast.

CRFG 2014 Annual Report (Steve Hall):

He would prefer comments back by May 15th. This information goes into the FCRPS Annual Report to NOAA but has been integrated already.

Idaho Power 2014-2015 Fall Chinook Spawning/Emergence (Kresta Davis-Butts):

Idaho Power's Fall Chinook Program began in 1991 and is a voluntary operations plan for the Hells Canyon Complex. The program provides a stable river flow level during the fall Chinook salmon spawning period, generally from mid-October to early December. The flow level provided during the fall Chinook salmon spawning period generally establishes what the minimum flow from Hells Canyon Dam will be once spawning is complete. The operations plan looks at the space needed in Brownlee to plan for a flat outflow during the spawning period in October-December, and hold those flows through incubation until emergence. In the fall of 2014 there wasn't a significant draft required. Minor drafted occurred in August through early October, then a precipitation event increased inflows requiring an operation adjustment. On October 15, flat flows were targeted at around 8500 cfs. The winter was wet and warm, so the flat flows increased through the winter, and ended at 9500 cfs, dropping to 9200 cfs based on information to protect critical redd locations. Similar to air temperatures, water temperatures have been warmer, decreasing the incubation period and the emergence is occurring several weeks early. This may influence the timing of the operations. Kresta also displayed the redd counts being conducted on the lower Snake River and tributaries, that show a steady and positive trend since early 1990s.

Forecast Verification (Kyle Dittmer):

Erik – verification is not a trivial matter. BPA is first looking at precipitation verification, with a focus in the headwaters. Then we look at WSF in headwater locations, upstream of regulation. Suggest focusing on headwater locations. Also verifying ESP is difficult, because verification relies on one number whereas the ESP provides multiple answers. Steve – at NWRFC verification is important, but agrees that it isn't easy. Focus is to look at locations where performance is low. Agrees that precipitation is important to examine, and forecasts are constantly changing so without a history with a method it is hard to verify. Kyle – should we have a consistent verification scheme? Or is it agency and location specific? Erik – is not a bad idea, with flexibility. Notice that ESP is going to be different than statistical methods. Verification – what have agencies done to verify?

USDA ARS ISNOBAL Modeling in the Boise River Basin (Scott Havens):

The ARS is conducting basin snow modeling for the BRB. This effort is a partnership with the Bureau of Reclamation through their Science and Technology program. The purpose is to present a proof of concept of using a physically based snow model for the Boise River basin, and applying this to operations. This project is using ISNOBAL to model snow, then predict inflows to the Boise River reservoirs using DHSVM (Distributed Hydrology-Soil-Vegetation Model) and WRF (Weather Research and Forecasting model). Currently ARS is providing weekly snow pack reports to USBR throughout the spring runoff period.

NRCS Interactive Map Tool (Rashawn Tama):

The NRCS is updating their mapping website to provide more utility to present snow and precipitation information spatially. The interactive station map allows for filtering by conditions, such as records, averages, or specific years. Also, it can compare the same set of stations over multiple analog years.

Rashawn presented a beta version of the website to demonstrate the new mapper tools. For example, the mapper allows for filtering sites by records for specific date ranges. The new mapper allows for answering relative station, state, and basin conditions quickly. The beta version of NRCS's new web-mapper can be found here:

<http://www.wcc.nrcs.usda.gov/webmap_beta/>.

FPAC/Salmon Manager Review (Paul Wagner):

FPAC continues to be concerned with the December Libby operations, which is drafted to 2411 feet by the end of the month. Once the project is drafted this low, it puts the project well below the April 10 flood control level with the exception of average or above average years. For example this year's end of March flood control level turned out to be 2434 feet and the project is at 2413 feet - well below the flood control rule curve. The 2434 feet flood control elevation is based on the Corps' volume forecast which is 99% of average for the period April - August. This gets worse when the forecasts diverge. The RFC forecast is presently 90% of average or 5.3 MAF which equates to an end of month flood control elevation of 2443 feet.

FPAC was overall satisfied with the spring operations at Hungry Horse, but is concerned with the forced draft at Grand Coulee for drum-gate maintenance. The concern is largely due to the maintenance occurring and this being a lower forecast year, but they recognize that drum-gate maintenance is necessary and unavoidable this year.

Upcoming Meetings

HOPIG Conference – Inflow Forecasting: Uncertainties of Forecasting Water. November 19-20, Indian Wells, CA. More information can be found here:

<<http://www.ceati.com/event/HOP2015/>>.

Note-taker: Eric Rothwell, US Bureau of Reclamation, Boise, Idaho.

Revised April 23, 2015

Date: September 9, 2015, 9:00 am – 12:00 pm PDT

Location: TELECONFERENCE MEETING, Columbia River Inter-Tribal Fish Commission, 700 NE Multnomah Street, Suite 1200, Portland

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

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

1. Welcome, introductions, April 2015 notes – CRFG Chairman Kyle Dittmer (09:00 - 09:15)
2. RMJOC-II...Forecast Uncertainty and Streamflow (Erik Pytlak, BPA) (09:15 – 10:00)
3. RMJOC-II...UW GCM Selections (UW Rep. or Erik P.?) (10:00 – 10:45)
- <<<BREAK TIME>>>
4. Forecast Verification...Next Steps? (Kyle D., CRITFC) (11:00 – 11:20)
5. Updates from the NWRFC (Kevin B.) (11:20 – 11:30)
6. Draft 2014 CRFG Annual Report...progress? (Stephen Hall, COE) (11:30 – 11:40)
7. “The Sampler”...Salmon Manager Issues? (Paul W.), Upcoming WSF meetings? (all) (11:40 – 11:50)
8. Other business: future agenda items, etc. (11:50 – 12:00)
9. Meeting adjournment (12:00 pm)

Columbia River Forecast Group - Summer Meeting, CRITFC, September 9, 2015. Participants in person: Kyle Dittmer (CRITFC), Steve Hall (COE Walla Walla), Jason Ward (COE Portland), Ron Thomason (COE Seattle), Kristian Mickelson (COE Seattle), Erik Pytlak (BPA), Bob Henith (CRITFC contractor). On the phone: Dave Benner (FPC), Sherri Sears (Colville Tribe), Jim Ruff (NWPPC), John Fazio (NWPPC), Nancy Stephan (BPA), Paul Pickett (WA Department of Ecology), Kevin Berghoff (NWS-NWRFC), Eric Rothwell (USBR), Chris Rans (COE Seattle), Bart Nijssen (UW), Oriana Chegwidan (UW), Tim Brewer (IPCo), Cara McCarthy (NRCS).

Introductions and Roll Call (Dittmer). We'll resend February and April meeting minutes for final revisions.

Proposed RMJOC-II Workshop (Erik Pytlak):

Last two weeks of October (W-F) meeting workshop on RMJOC-II with UW. Review schedules. Provide Erik your preferred timing. Choice: Oct 21-23; Oct 28-30 (preferred).

RMJOC-II...Forecast Uncertainty and Streamflow (Erik Pytlak, and Nancy Stephan):

We anticipate over 120 streamflow climate change traces- much more than RMJOC-I. Eventually we will want 6-10 regulation scenarios that envelope the range of climate change uncertainty. The unregulated streamflows is just the beginning. Then we have to operate the system (e.g., flood operations, water supply, BiOp requirements, and Treaty operations). To operate the system we need water supply forecasts.

Last time we used a statistical regression forecast, which was criticized by taking a 2D field and extracting points, which introduced a large uncertainty (off one grid-cell which could mean a difference between rain/snow due to elevation). It was very labor intensive – successful but was very labor intensive. We were also using historical errors in those forecasts. The forecast errors may be rather small compared to the large uncertainties with climate change itself. Hydrologic modeling differences are properly accounted for in RMJOC-II efforts. Also, we now use ESP forecast for Brownlee, TDA, and GCL.

Urgency is placed on this study because of the 2018 BiOp. Results are required from this study by late FY2016 or early FY2017 to be able to incorporate in the BiOp studies.

Two initial approaches to forecasting for RMJOC-II were proposed (with the acknowledgement that in the future more sophisticated approaches may be necessary):

- Option 1: Perfect Trend (interpolation from climatology to known volume)
 - Starting 'forecast' (Dec. or Jan.) is 1981-2010 climatology for each project.
 - Subsequent months: forecasts step toward a final volume in each climate change scenario.
 - June 1 and July 1 forecasts assumed "perfect"
 - Pros: early to implement, follows current WSF trends, we don't need SWE or precipitation, changes can be quickly evaluated.
 - Cons: forecast changes from Jan-April would be too smooth, wouldn't help answer questions whether more frequent forecast updates would assist/impair operations.

- Option 2: Climate change volume with current forecast variances/errors.
 - Starting with climate change volume for each scenario.
 - Randomly select ‘forecast’ within the current forecast variance.
 - Pros: rather straightforward to implement, allows for forecast ‘yo-yos’ (reality), already being done for other Corps work.
 - Cons: assumes similar forecast variance/errors in the future, could end up with biases at a few locations, random forecast generator means that we would get very different reservoir operations for the same climate change streamflow trace.
- Other options were considered including: perfect forecasts; Update the RMJOC-I Equations; downscaled GCM (Corps) and use existing equations; SWE trend.

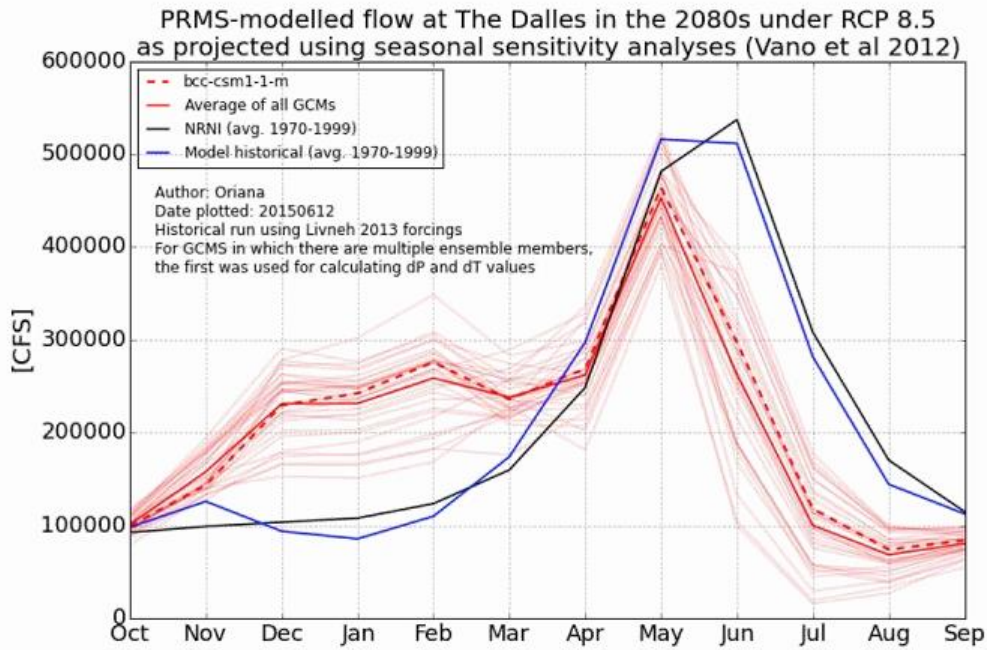
Comments/Discussion – Maybe a blend of Option 1 and 2 can work? Option 1 is the central tendency with a randomly selected variance selected at each forecast to simulate the reality of in-season variability. We’re looking to other national experts (NCAR). Contact Erik with additional comments and questions.

RMJOC-II...UW GCM Selections (Bart Nijssen, Oriana Chegwiddden, Erik Pytlak): Update to previous RMJOC-I using CMIP5 instead of CMIP3. We’re also looking at multiple hydrologic models, downscaling methods, and global climate models. Period 1950-2100 (1950-2006 control), ten global climate models, three hydrologic models, two representative concentration pathways = 120 future scenarios. Global climate models were selected and working on downscaling and bias correction. Next year – hydrologic simulations, streamflow routing, and dissemination of final results. BPA has requested that timeline is reorganized to provide streamflows earlier to support 2018 BiOp.

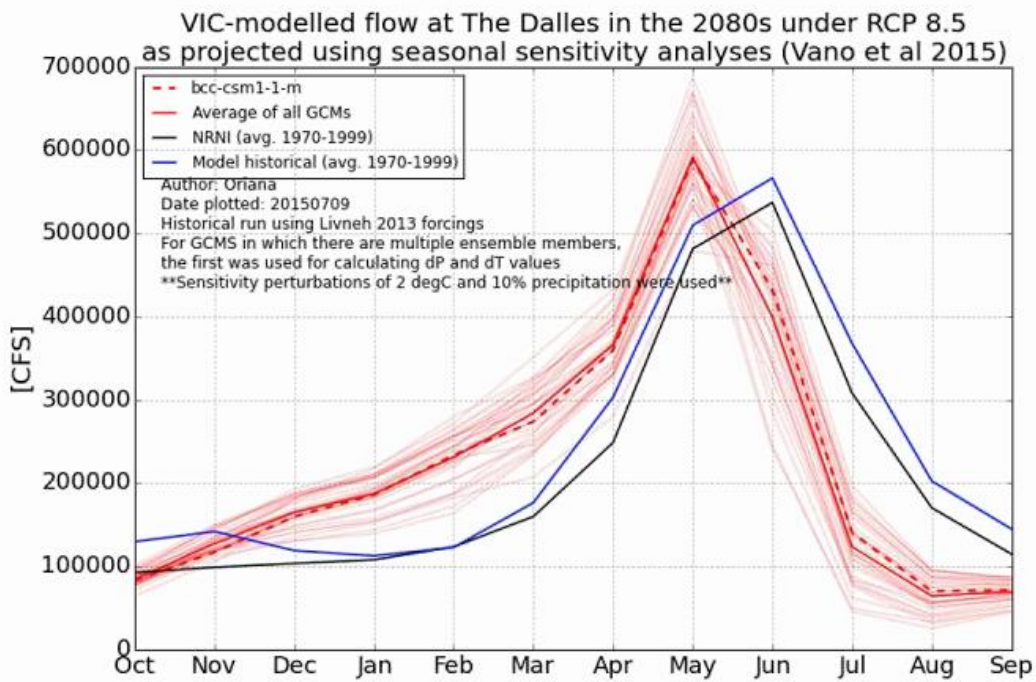
Hydrologic models: VIC, PRMS, ULM (a NOAA model, Unified Land Model). All models are setup with 1/16 degree resolution. UW is unsatisfied with the ULM performance (snow performance and hydrologic generation). Adjustments have been labor intensive and largely unsuccessful. The bias correction could make the flows work but wouldn’t really fit the processes that are likely to be occurring under climate change. UW is proposing (request to BPA) to drop ULM and to look at different hydrologic parameters and how that will impact VIC and PRMS. Uncertainty is inherent in the choice of calibration methods. Use VIC parameter sets to produced form two parameter sets. We could use this approach to compare UW VIC calibration, Oakridge National Lab (for SECURE report), and NCAR (Martyn Clark) approaches to calibrating VIC.

Both PRMS and VIC perform well with UW calibration techniques, except in small basins in the Deschutes. The third model calibration was problematic. The results did not give confidence that we were capturing climate change or bias correction. The introduction of different calibration approaches is seen as an enhancement of the study.

Examples of initial results of PRMS and VIC hydrologic model calibration at TDA:



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Global Climate Model Selection (work done by David Rupp at OSU) approach was to look at performance of GCM based on model ranking over PNW to come up with a preliminary GCM list (10 models). These models were presented at Transboundary Climate Workshop at BPA, stakeholders ask OSU to re-compare (observations) to NCEP-20CR by plotting differences in means and standard deviations to assess how well the models are emulating the jet-stream patterns. This comparison removed some of the (two) of the GCM (right for the wrong reasons) and added two better performing GCMs (emulated the jet-stream better). We removed bcc-csm1-1-m and NorESM1-M, and added GFDL-ESM2M and HadGEM2-CC.

Final list of GCM's that are being downscaled:

Selection of 10 GCMs

Preliminary list (April 2014)	Final list (August 2015)
CCSM4	CCSM4
CNRM-CM5	CNRM-CM5
HadGEM2-ES	HadGEM2-ES
CanESM2	CanESM2
IPSL-CM5A-MR	IPSL-CM5A-MR
MIROC5	MIROC5
CSIRO-Mk3-6-0	CSIRO-Mk3-6-0
Inmcm4	Inmcm4
bcc-csm1-1-m	HadGEM2-CC
NorESM1-M	GFDL-ESM2M

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Downscaled methods/datasets: Hybrid delta method (consistent with RMJOC-I), Multivariate adaptive constructed analogs (MACA), and dynamically downscaled data from Oak Ridge National Laboratory for SECURE Report (through 2050). The target is to have initial flow results to present at the BPA Transboundary Climate Workshop in January 2017.

Forecast Verification (Kyle Dittmer):

General thoughts:

Decide what you are verifying on, what time periods to look at vs. which runoff periods, also want to put into context of what the weather was (much drier than average – so not a failure of the forecast more a result in a shift in weather). Models change over time – updated so the verification may not be representative. Focus on headwater operations – Dworshak, Libby, etc.

Kyle proposed having this subject brought up at FPAC (will do a follow-up) to help guide forecasters as to what information/verification in particular fish managers would find most useful. Bob Heinith – comparison of methods would be useful. He suggests bi-monthly forecasts. What is the objective? Use caution with using one year (e.g., weather changes – dry or wet – could be the reason for poor forecast performance).

Updates from the NWRFC (Kevin Berghoff):

We use extended climate forcings through 2010. New monthly normals for precipitation and temperature stations are based on 1981-2010 data. New MAP/MAT forcings are for each basin, extending observed data record through 2015. This process will be done each year to extend the record with the most recent data. ESP will increase to 63 or 64 traces.

For traditional and ESP Natural there will be a monthly volume forecast and summary. The old ESP (beta site) will be replaced with the new natural ESP page. There will be new methods for downloading information (the FTP site is being closed). The new format will be in a csv format. The forcing files will be available as an xml format.

Draft 2014 CRFG Annual Report...progress? (Stephen Hall):

Final comments are due in two weeks by September 25th. Please review document.

Upcoming Meetings

- Oregon Chapter of The American Meteorological Society Annual meeting – Saturday, October 24th
- HOPIG Conference – Inflow Forecasting: Uncertainties of Forecasting Water. November 19-20, Indian Wells, CA. More information can be found here: <http://www.ceati.com/event/HOP2015/>
- PNW Climate Workshop – November 5-6, Coeur d'Alene. More information can be found here: <http://pnwclimateconference.org/>

Next meeting – tentatively December 3rd to coordinate with the TMT Year-End Review.

Note-taker: Eric Rothwell, US Bureau of Reclamation, Boise, Idaho.

Revised September 24, 2015

Date: December 3, 2015, 8:30 am – 3:00 pm PST

**Location: Columbia River Inter-Tribal Fish Commission (Celilo Room, 5th Floor),
700 NE Multnomah Street, Portland**

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

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

1. Welcome, Introductions, Sept. 2015 notes, Phone List (CRFG Chairman Kyle Dittmer)
(08:30 - 08:50)
2. Draft 2014 CRFG Annual Report...finalize? (Stephen Hall, COE) (08:50 – 09:00)
3. Review of 2015 Forecast Season, by agency (~ 20 min. each) (09:00 – 10:20)
USA-COE: Joel F. (LIB), Steve Hall (DWR)
USBR: Eric Rothwell (HGH, Upper-Snake)
NRCS: Rashawn Tama
NWS-NWRFC: Kevin Berghoff
- <<<BREAK TIME>>> Refreshments (10:20 – 10:30)
3. Review of 2015 Forecast Season (continues) (10:30 – 11:20)
BPA: Erik Pytlak
BC Hydro: Adam Gobena (UC points) or Georg Jost
CRITFC: Kyle Dittmer (TDA)
Discussion: Forecast verification. Suggested forecast improvement(s)? (11:20 – 11:30)
4. 2016 Pre-season Forecasts (NWS, CRITFC, and others ???) (11:30 – 11:55)
5. Summary of 23rd Annual Oregon-AMS Winter Weather meeting (Kyle) (11:55 – 12:00)
- <<<LUNCH...on your own>>> (12:00 – 01:00)
6. RMJOC-II...Forecast/Streamflow Workshop Update (Erik Pytlak, BPA) (01:00 – 01:40)
7. NWS-NWRFC Water Supply Forecasts – Extended Forcings (Kevin B.) (01:40 – 02:00)
8. “The Sampler”...Salmon Manager Issues? (Paul W.), Upcoming WSF meeting? (all)
(02:00 – 02:20)
9. Other business: 2016 Initiatives, Chairman selection, set next meeting date, etc.(02:20 – 03:00)

Columbia River Forecast Group - Autumn Meeting, CRITFC, December 3, 2015. Participants in person: Kyle Dittmer CRITFC, Steve Hall USACE-Walla Walla, Alfredo Rodriguez USACE – Walla Walla, Kevin Berghoff NWRFC, Erik Pytlak BPA, Katharine Rowden NWS Spokane, Eric Rothwell USBR, Jason Ward USACE – Portland, Paul Wagner NOAA-NMFS, Atousa Gorg PSU student, Jennifer Mora PSU student, Kresta Davis-Butts IPCo, Rich Domingue NOAA-NMFS. Phone: Kevin Shaffer USACE-Seattle, Nancy Stephen BPA, Bob Heinith CRITFC contractor, Jim Ruff NWPC, Charles Morrill WDFW.

Introductions and Roll Call (Kyle Dittmer)

Chairman Kyle welcomed members and guests. We reviewed and voted to accept the February, April and September meeting minutes prepared by Vice-Chairman Eric.

Updated phone/email list – members please review the revised list. Erik also suggested that RMJOC-II participants be added to the CRFG list, as there is strong overlap of the two groups.

Draft 2014 CRFG Annual Report (Kyle Dittmer)

Review of 2014 CRFG Annual Report. We made minor edits. We moved and voted to finalize the Report written by Steve Hall (COE).

Review of 2015 Forecast Season

Libby (Kevin Shaffer)

The inflow forecast equations, for the April to August period, was updated in 2014. This updated regression was first used in 2015. For the December and January forecasts the equations include the SOI (Southern Oscillation Index). The initial forecasts were above average, based on fall precipitation, until snow information became available in January. The forecast trended down in the spring, and the observed runoff for the April to August period was below average. The forecasts were: December 6899, January 6297, February 5523, March 5683, April 5808, May 5396, and June 5090 (KAF).

The forecasts were too high due to unusual runoff conditions. While upper elevation snow in the areas of the SNOTEL gages was 80 percent of normal, the lower and middle elevation snowpack was relatively low due to consistent warm temperatures. Additionally, above normal fall precipitation which fell as rain, not snow, pushed up the forecast but did not result in as much April-August runoff as the forecast anticipated. Mid-to-lower elevation snow condition information is not readily available. Potential ways to improve forecasts under these conditions would include additional information at those mid and lower elevations. Additional gages have been added in the Kootenai River basin, although that information will not be usable until many years of record are established.

Members suggested that by including a temperature index in the forecast for years like WY 2015, when warm temperatures caused higher winter runoff and little snow in the lower elevations. However, accommodating extreme or unusual years in a regression forecast can be difficult, since it often reduces forecast accuracy during the more normal runoff years.

Dworshak (Steve Hall)

Steve presented a comparison of the NRCS Z-score forecast, ESP range and median, official Corps WSF, and the actual runoff through the runoff season. The early forecasts are driven by the SOI. All of the forecasts fell through the season. The official forecast over-corrected in June, probably due to the very low snow amounts being reported in the basin. The June forecast doesn't typically drive any forecast decisions. Final observed runoff was close to 1.1MAF. Walla Walla uses NOHRSC¹ snow distribution both qualitatively to compare to forecast trends and quantitatively as a requirement for operations.

Hungry Horse and Upper Snake (Eric Rothwell)

Above normal precipitation and near normal snow in the Upper Snake and Hungry Horse lead to an above average forecast to start the forecast season in January. February weather throughout the region was much drier and warmer than normal. For the Upper Snake the next several months were warm and dry, with little snow accumulation. With very little accumulation of snow and dry conditions, the March runoff forecasts decreased significantly from the February forecasts. The Upper Snake water supply forecasts fell every month, but water supply conditions partially recovered with a very wet May.

The SF Flathead River basin experienced similar conditions, except for a warm wet March which lead to high March runoff and a deterioration of the snowpack and loss of water available for later runoff. The seasonal precipitation from April to June was 35% of normal. Discussion about missed forecasts included examination of the forecast assumptions including average subsequent conditions, limitations of using precipitation data without considering temperature impacts (snow drought).

NWS-NWRFC (Kevin Berghoff)

Overview of the entire basin, the basin was out of balance. Above Mica the water supply was above normal, but as you head south the water supply for the water year was progressively worse. If you look at the entire year the runoff wasn't horrible, but if you focus on summer runoff it was much lower. Above GCL the precipitation was 93%, above TDA 84% of normal for the water year, but the timing and temperature drove the water supply issues. The December to March period (critical snowpack building months) was extremely warm in comparison to normal leading to snowpack accumulation much lower than normal. In January most of the basin had a strong start to snow accumulation (except for the Cascades). The warmer temperatures in subsequent months resulted in lower accumulation or even depletion of the snowpack. The Canadian portion of the basin still had cold enough temperatures to build a snowpack, but the rest of the basin had very low snowpacks (due to early melt out or record low snowpacks).

The ESP forecasts all started near normal in January then depleted rapidly through the next several months. The ESP did capture the decreasing water supply trend and

¹ <http://www.nohrsc.noaa.gov/interactive/html/map.html>

accounted for some of the early runoff. The exception of this decreasing trend was the basin above Mica.

As an example of deteriorating water supply conditions Kevin examined was Dworshak. Temperature departures for Dworshak were around 6-7 degF above normal for the February to March period. Although the October to March cumulative precipitation for 2015 was near normal, the Apr-Sep observed runoff volume was substantially less than many years that had much less precipitation. As an example, in 1977 the Dworshak basin had 19 inches less precipitation than 2015, but still had 238 KAF greater Apr-Sept. runoff. This was due to the excessively warm temperatures resulting in early snowmelt runoff as well as below normal precipitation during the Apr-Sep period in 2015.

Last year El Niño was not a factor. The winter was really a temperature-driven issue.

Preview of 2016 ESP forecasts:

Mica and Libby basins are projected to be near normal. Forecast conditions deplete southward, but should be close to normal. Early forecasts are good for comparison of initial states of the models and as starting point to view water supply trends through the year. However, most of what will decide the water supply will be determined by what happens in the future.

Tools available on the website – ESP volume forecast products, archive, and ranking tool. Seasonal ESP forecast are broken into monthly segments. ESP custom forecasts – users can download daily data and focus on specific years or products.

BPA (Pytlak)

BPA shared their after-the-fact forecasts and lessons learned from WY 2015. One year is not climate change, but it was very warm in the west and very cold in the east. Taken as a whole across CONUS, it was only slightly warmer than normal. However, temperatures in the Pacific Northwest in 2015 were similar to projections for the 2040s in RMJOC-I. So the year may serve as a good case study for what climate change could do to with respect to streamflows and system operations.

Using 500mb heights as a proxy for the jet stream in the January to March period, the strong ridge remained offshore/west of California, but just onshore in the Pacific Northwest. That was particularly bad for California, but good for northern part of Columbia River Basin. In short, WY 2015 was not a typical drought for the basin because of near normal precipitation. However, as was discussed at the Pacific Northwest Climate Workshop in November, it was a snow drought driven by the high temperatures, which was then exacerbated by an unusually dry spring.

Unregulated flows remained persistently above the long-term normal at Grand Coulee, Lower Granite, and The Dalles for the October to March period, but below average for April-June. Very low or record low flows were seen in July and August.

Prolonged runoff in January through March was sustained, which was indicative of early snowmelt and rain on snowpack events. BPA ESP forecast tracked well with NWRFC ESP forecasts, with the exception of one large deviation in early February caused by a missed weather forecast. However, the BPA forecast dropped along with NWRFC's in February due to early snowmelt, then again in April due to the dry spring.

BPA also compared WY 2015's monthly flows to the RMJOC-I mean climate streamflows. The early runoff was consistent with the RMJOC-I projections, but were lower than the RMJOC-I mean flows in May-July. One has to keep in mind that the RMJOC-I scenarios were mean cases. However the comparison does suggest that the RMJOC-I scenarios may be under dispersed for a variety of reasons. Getting a better sense of the range of possible streamflow outcomes in climate change is one of the key goals for RMJOC-II.

Lessons learned – ESPs gave early warning that was missing in most of the statistical forecasts. Examining different time steps was also helpful in seeing the impacts from melt events and early runoff, BPA runs their ESPs weekly, but keeps an eye on the daily NWRFC forecasts. Persistent jet stream pattern increased confidence that dry spring/summer was likely.

CRITFC (Kyle Dittmer)

CRITFC's forecast equation between ENSO and flow indices, relying on the teleconnection between the Multivariable ENSO Index, MEI (composite of sea-level pressure, sea-surface and air temperatures, surface wind, and cloud cover) regressed against historical TDA flows. This year the MEI peaked about two months ago – associated with the strong El Niño similar to 1997. Method uses a 3-month moving average of MEI. After each forecast season, the past year's data is added to the regression each year. R2 is about 0.3 now. For WY 2015, the error was 14% (Jan.-July), 43% (Apr-July), and 30% (Apr-Aug.).

Pro/con – good preseason tool but not statically robust – more data is needed. Kyle plans to run retrospective tests in 2016 – to do hindcasts to test current model performance.

2016 Pre-season Forecasts

Major El Niño event – nicknamed 'Godzilla' – is occurring. Expect that the El Niño state will slowly decay through the spring. Jet stream will split to the north and south of much of the basin. Expect relatively warm and dry conditions in the PNW based on NOAA's CPC 3-month forecast. Still in the cold phase PDO – but currently in a warm excursion. Water Year 1998 is a good analog to this year's El Niño state, which was on the dry side over the winter but had a wet spring. Using CRITFC's MEI forecast (using the Sept-Oct.-Nov. index) expect a slightly below normal flow at TDA, 94 MAF January to July period, or 93% of the 1981-2010 period. Other forecast runoff periods of note: April-July 74 MAF, 93% and April-Aug. 82 MAF, 93%.

RMJOC-II Forecast/Streamflow Workshop (Erik Pytlak)

At the third year of the project, the team is close to producing actual streamflows using the downscaled GCMs. RMJOC-I and II GCM's have similar temperature and precipitation ranges, but RMJOC-II GCM's does represent a warmer future. The seasonal patterns and ranges of temperature and precipitation are captured better in RMJOC-II. Temperature distribution shows that coastal areas, west side from many of the models shows less warming than in the interior. The GCMs also show a wide range of warming in the interior as well. In contrast to the statistical downscaling being done by University of Washington (UW) RMJOC-II will have dynamical downscaled GCM's available from Oakridge National Lab, which show less warming. Precipitation projections have a wide range from wetter to drier. Some forecasts show a decrease in precipitation in winter.

Hydrologic simulations and rough delivery dates – UW will deliver flow data sets sequentially rather than all at once, allowing initiation of hydro-regulation modelling. The first flows (VIC model) should be available in late January, allowing corrections if a problem is found and allows some review of delivery format. The first set of flows will be provisional. They may be revised based on review. Second set of data should be available in April- the set will likely be a larger set of flows. The third set will be ready sometime in July. The Oakridge National Lab dynamical downscaled data will be last, if it is available.

Hydro-regulation study progress since the October workshop includes: conversion from NRNI back to modified flows, forecast procedure selection progress, setting up scenario selection framework (still in progress), and finalizing work plan and staffing. Forecast procedure selection process – suggestions from SCIATA? There is a gradual trend for each month from Dec. (climate) to May (final scenario volume). For the 2040s use the 2010-2040 “mean” for each streamflow set as the ‘new normal’ allows the mean to change with climate change. Option 2 – Option 1, but with a random selection each month within the current forecast standard error as we don't know what “future” standard error will be.

Scenario framework – The scenarios will be selected as the sequential hydrologic flows become available. The following approach was identified from the October 30 RMJOC-II workshop:

- 2 to be selected from January “batch”;
- 2-6 from “batch 2 and 3”;
- 2 after all streamflows scenarios are received;
- and hold 2-4 from specific “case studies”.

More workshops are likely in 2016. We will let the CRFG members know of upcoming events.

NWS-NWRFC Water Supply Forecasts – Extended Forcings (Kevin Bergoff)

In collaboration with BPA, the period used for ESP forcing years will extend to Water Year 2015. The 1949-2010 MAP and MAT climate forcings are based on the observed precipitation and temperature data acquired from several different agencies that were Quality Control checked (“QC'd”) by the source agency. The 2011-2015 forcings are based on observed data that the RFC acquires near real-time for daily forecast operations. These data are QC'd internally at the RFC and will be appended to the historic MAP and MAT climate forcings annually in an effort to keep our climate forcings as current as possible.

ESP volume forecasts currently use the 1949-2010 data, but very soon will use 1949-2015. The 30-year normals are based on 1981-2010. Group conversation then revolved around the difference that normal period makes to perceived water year volumes (i.e. % of normal). For example observed runoff volume is greater in the 30-year period prior to 1980, which if a normal was calculated from the entire period of record for many locations would end up with higher normals.

On the horizon – Hydrologic Ensemble Forecast System (HEFS). HEFS is a probabilistic hydrologic modeling platform that the RFC is focusing energy to expanding and improving runoff and volume forecast products. HEFS may better capture uncertainty in future conditions, not current conditions; NWSRFS models will remain at the core for foreseeable future.

Salmon Managers Issues (Wagner)

Questions brought up by the Salmon Managers included:

- Was WY 2015 the lowest on record?
- Where there any “early warning” triggers?
- Will the new Libby forecast help with December pre-draft operations?
- April flood control targets.

Libby forecast is the one that is most relevant at this time of year, as often Libby has to draft based on this pre-season forecast. The new early season forecast incorporates climate variables, but admittedly the early forecasts do not have a lot of skill. Can there be more flexibility to not draft this time of year?

Other business

AGU- week of December 13th, 2015

Idaho Department of Water Resources starting in January 15th

Next meeting – tentatively set for February 18th at CRITFC. Meeting adjourned at 2:45 pm.

Note-taker: Eric Rothwell, US Bureau of Reclamation, Boise, Idaho.

Revised December 14, 2015

Appendix C

Historical forecast results

Columbia River Forecast Group 2015

Historic forecast results: 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.

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: 4th working day of the month, 10 days of future precipitation

2013: 5th working day of the month, 3 days of future precipitation

2015: 5th working day of the month, 5 days of future precipitation

Duncan: (Apr-Aug)											
Year	Jan		Feb		Mar		Apr		May		Observed KAF
	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

Libby: (Apr-Aug)											
Year	Jan		Feb		Mar		Apr		May		Observed KAF
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
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

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

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

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%	3052	125%	2289	93%	2449

Dworshak: (Apr-Jul)											
Year	Jan		Feb		Mar		Apr		May		Observed KAF
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
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

Lower Granite: (Jan-Jul)											
Year	Jan		Feb		Mar		Apr		May		Observed KAF
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
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

The Dalles: (Jan-Jul)											
Year	Jan		Feb		Mar		Apr		May		Observed KAF
	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	KAF	% of OBS	
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

<end of tables>

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Revised Aug. 11, 2016			
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