

COLUMBIA RIVER TREATY HYDROMETEOROLOGICAL COMMITTEE

2015 ANNUAL REPORT
OCTOBER 1, 2014 - SEPTEMBER, 2015



Photo Credit: Frank Weber

Wildcat Creek Climate Station and Snow Pillow, Mica Basin, 2122m
Installed September 15, 2014

Stephanie Smith	BC Hydro, Canadian Chair
Georg Jost	BC Hydro, Canadian Member
William Proctor	U.S. Army Corps of Engineers, U.S. Co-Chair
Ann McManamon	Bonneville Power Administration, U.S. Co-Chair

DECEMBER 2015

COLUMBIA RIVER TREATY HYDROMETEOROLOGICAL COMMITTEE 2015 ANNUAL REPORT

Introduction

The Columbia River Treaty Hydrometeorological Committee (CRTHC) was established in September 1968 by the Entities. The CRTHC is responsible for planning and monitoring the operation of the hydrometeorological data collection network in accord with the Columbia River Treaty (CRT). It also assists the Entities in matters related to hydrometeorological and water supply forecasting.

This report summarizes CRTHC activities during the 2015 water year (October 1, 2014 – September 30, 2015). The Annual Report focuses on:

- Station Adequacy
- Computer Systems and Data Acquisition and Exchange
- Forecasting Procedures
- Review of the 2015 CRT water supply forecasts
- Other activities of the Committee

The CRTHC began issuing regular Annual Reports in 2001. General background information on CRTHC activities contained in the 2001 and 2002 annual reports is now presented in a separate supplemental document. The supplement contains general information that does not typically change from year to year. Appendices in the supplemental document include:

Appendix A –	Introduction to the CRTHC terms of reference
Appendix B –	Terms of reference for the CRTHC
Appendix C –	Process for reviewing hydrometeorological data networks
Appendix D –	List of contributors of hydrometeorological data
Appendix E –	Data communication and storage systems
Appendix F –	Data exchange reports
Appendix G –	Treaty studies, models, and forecast requirements

2015 ANNUAL REPORT

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COLUMBIA RIVER TREATY
HYDROMETEOROLOGICAL COMMITTEE

2015 ANNUAL REPORT

2015 Annual Summary

The Columbia River Treaty Hydrometeorological Committee (CRTHC) was established in September 1968 by the Entities and is responsible for planning and monitoring the operation of hydrometeorological data collection network in accord with the Treaty and otherwise assisting the Entities as needed. The Committee consists of four members as follows:

UNITED STATES SECTION

William Proctor*, USACE Co-Chair

Ann McManamon, BPA Co-Chair

CANADIAN SECTION

Stephanie Smith, B.C. Hydro, Chair

Georg Jost**, B.C. Hydro, Member

* William Proctor replaced Peter Brooks as U.S. Co-chair on August 20, 2015

** Georg Jost replaced Adam Gobena as Canadian Member on January 12, 2015

The CRTHC would like to recognize Peter Brooks for his long and outstanding service to the Committee over the last 18 years.

The CRTHC conducted bi-monthly conference calls and met in person twice during the 1 October 2014 – 30 September 2015 period:

Meeting 75: 19 March, 2015, BPA

Meeting 76: 19 August, 2015, BC Hydro

In addition, the CRTHC members conducted several interim phone conference calls to discuss impending water supply forecast decisions or provide interim guidance for ongoing projects. The CRTHC maintains a list of all action items arising from these meetings and Schedule 1 attached to the end of the main body of the Annual Report details the outstanding action items, and the list of actions completed this year.

The 2014 CRTHC Annual Report was completed in December 2014, in advance of the annual Permanent Engineering Board Meeting.

Stations

The CRTHC routinely reviews the basin gauging network for adequacy and at this time believes that the station network is adequate for Treaty purposes.

The CRTHC process for reviewing proposed changes to the operation of stations within the hydrometeorological network is described in Appendix C of the Supplemental Report. The process is intended to ensure that changes made to the network do not adversely affect the monitoring, planning, and operations of Treaty facilities.

One new hydrometric station was added in 2015 to the Nordic headwater basin above Mica. There were no Treaty or Supplemental stations discontinued in 2015. The CRTHC discussed ongoing station data reliability and completeness for three Treaty stations: Fernie climate station in BC, and Porthill and Bonners Ferry stations in Idaho. BC Hydro will be installing an automated climate station at Fernie in November 2015, and have requested the observer continue to perform climate observations for a sufficient period to compare the collection characteristics of the new station are comparable to the old station. BPA provided BC Hydro with code to web scrape the Porthill and Bonners Ferry data, but the availability of data from these stations continues to be limited.

The four new snow monitoring stations installed in 2013-2014 in the Canadian section of the Columbia River Basin had their first full snow monitoring season in 2014-2015. Figure 1 below shows the snow water equivalent plots for the four new sites plus Molson Creek for the sake of comparison over the period Oct 2014 – June 15, 2015.

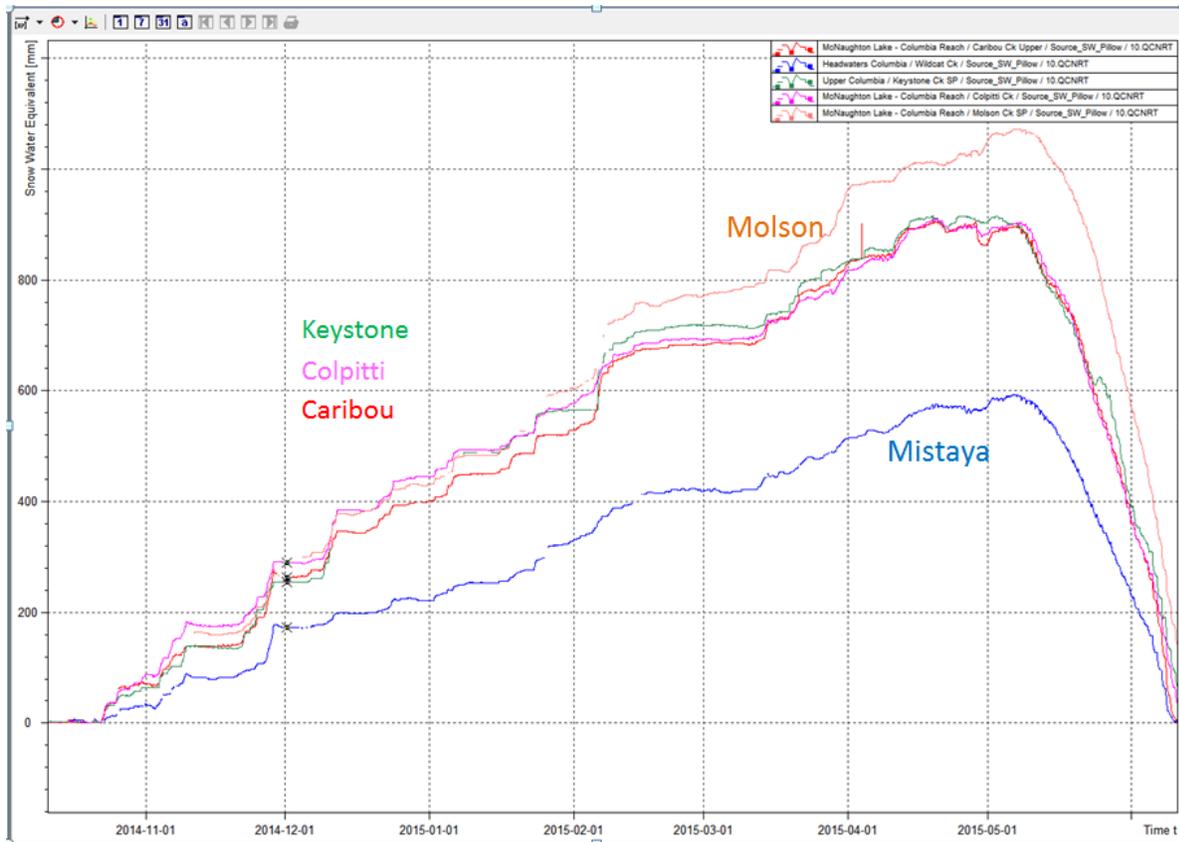


Figure 1 Snow measurements from new Canadian snow pillows in 2015

The CRTHC continues to add to and re-shape its station database for use primarily in monitoring station adequacy, tracking station changes, and visualization of basin coverage. A significant amount of metadata has been added; and all stations are placed in one of three categories: Treaty, supplemental, and informational¹. This

¹ Definitions of these categories are described in Appendix B of the Supplemental Report.

database can now be used to generate maps of the Treaty station network like the example in Figure 2, and easily track changes to the network over time.

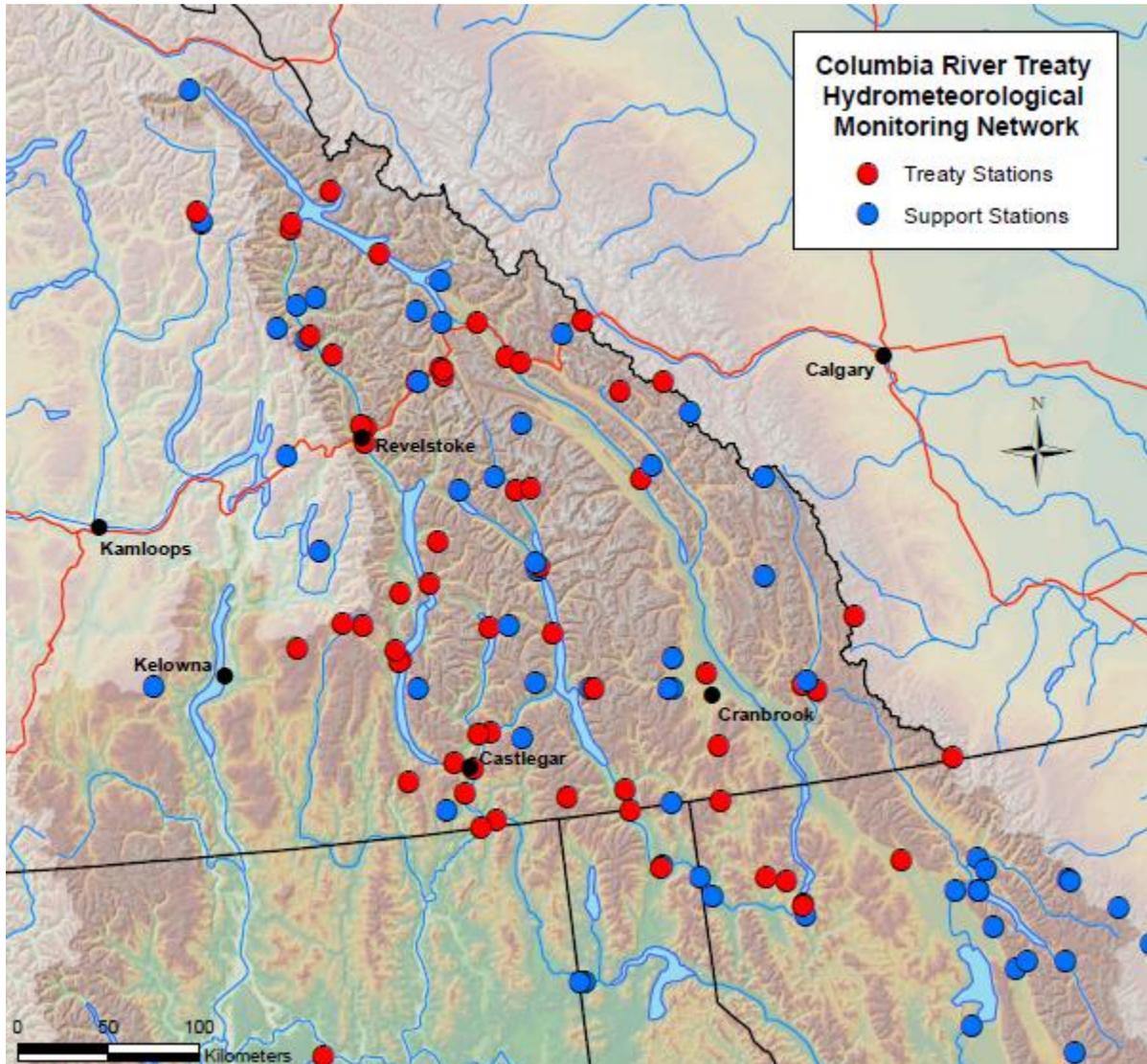


Figure 2 Sample map of Treaty and Support stations for the Upper Columbia basin

Computer Systems and Data Acquisition and Exchange

B.C. Hydro completed their transition to secure FTP and all agencies are now receiving Canadian CROHMS data through this more secure channel.

BPA reported having some issues with their THOR server syncing across multiple CBT servers at the USACE. BPA and the USACE are investigating.

Another continuing issue is regional access to the hydrometeorological data through CROHMS. It is the mission of USACE to provide data in a timely manner to the Treaty Entities to execute the terms and conditions of the Treaty, including support and maintenance of an adequate hydrometeorological network. Higher Army authority sometimes places additional security requirements that may impair the timely delivery of said data. Therefore USACE must be diligent in assessing and addressing IT security requirements in order to continue to provide adequate data dissemination to the region. In 2016 the CRTHC and the USACE will focus on trying to find a lasting solution to these communications issues.

Forecasting

2015 Forecasting Deviations

The CRTHC can agree to alter inputs to the prescribed Treaty water supply forecasting procedures if there is a strong justification and agreement that one of the inputs is unduly influencing the forecast results. The committee has a procedure to review any proposed changes and decide whether the change is considered to be justified. There was one deviation requested by BC Hydro in the May 2015 forecast for Revelstoke to better reflect the basin conditions at the time. By May 1st, Columbia region snow pack based on 12 stations above 1550m (roughly the snowline at the time of the survey) was 78% of normal. Fall and Winter precipitation at one station (Blue River) caused a change of +6% on the Revelstoke May forecast although above normal winter precipitation did not translate into above normal snowpack due to the anomalously warm winter. CRTHC agreed that the Blue River Fall and Winter precipitation input should be set to 100% of normal in the equations in the final 01 May Treaty forecast.

POP Appendix 8 Update

New water supply forecasting procedures for Libby were implemented in 2015. The CRTHC submitted a new version of POP Appendix 8 for approval at the September 22, 2015 CRTOC meeting and incorporated the following changes:

- The hedges were updated to reflect the new Libby Water Supply Forecast procedure AND early season statistics (Table 1) for all projects were re-examined to make sure that they correctly reflected the root mean square error (RMSE) around the median. This impacted the hedge computation for many of the projects for the Aug-Nov time frame.
- Background documentation was combined into Appendix 8 for easier tracking, and a Table of Contents was added to make the longer document easier to navigate.
- There was clarification in the wording describing the computation of hedges and error statistics, and in the section describing the creation of January-July Volumes from Statistical Forecast periods.
- There was a clarification in the TSR section of Appendix 8 to reflect that for the second TSR in June, the TSR submittal needs to extend past the end of July and to include the two halves of August. This brings this section into alignment with POP section 4.4B.

While CRTOC agreed to all the changes submitted for POP Appendix 8 at the September 22, 2015 meeting, CRTOC wanted to consider adopting additional December water supply forecasts particularly for The Dalles. This issue identified several additional implementation impacts on the use of early season forecasts and was still under review at the end of the 2015 water year.

2016 NWS ESP Water Supply Forecasts

The Northwest River Forecast Center (NWRFC) continues to produce water supply forecasts using the Ensemble Streamflow Prediction (ESP) procedure which includes a 5-day short term weather forecast for its ESP.

CRTHC completed a comparison of the WY2015 forecasts produced using a 5-day and a 10-day short term weather forecast and concluded that the 10-day short term forecast provided little additional value in The Dalles forecast for this past water supply season, and almost no difference from the 5 day forecast from April onwards. The CRTHC continues to advise using the water supply ESP forecasts incorporating the 5 day short term forecast.

The CRTHC provided the recommendation for forecast dates (typically the 5th working day of the month) for the upcoming year; and the recommendation was approved by the CRTOC at their September 22, 2015 meeting.

The approved official forecast dates are:

- December 7, 2015
- January 8, 2016
- February 5, 2016
- March 7, 2016
- April 7, 2016
- May 6, 2016
- June 7, 2016
- July 8, 2016

The December 2015 forecast date was added by CRTOC.

Forecast Verification

The water supply forecasts and information on the hydrometeorology for the year are presented in the 2015 Annual Report of the Columbia River Treaty by the Entities (Section IV), and will not be repeated here. This section gives a brief overview of the forecasts and focuses on the results of the verification of the Treaty project forecasts and any lessons learned.

The Dalles

The Columbia Basin watershed experienced very warm temperatures this past year that persisted during the winter and spring. The very warm winter caused an unusual percentage of the winter precipitation to fall as rain rather than snow (see Figure 3) causing winter and early spring flows to be above average. The ESP model that is used by the NWRFC to generate its water supply forecasts maintains an account of the current hydrologic states as starting points, which includes snow cover, soil moisture and channel storage for subsequent forecasts. From this basin state, ESP produces probabilistic forecasts of stream flow and other hydrological variables. The ESP forecasts assume that historical meteorological data are representative of possible future conditions and uses these potential outcomes as input data to hydrologic models along with the current states of the models obtained from the forecasting component. This past year, the typical precipitation that was expected in the NWRFC ESP forecasts simply never materialized, and forecasts for the expected runoff continued to degrade throughout the later winter and early spring.

A separate stream flow trace is simulated for each year of historical data using the current basin state conditions as the starting point for each simulation. The stream flow traces are analyzed for flow volumes, for a series of different seasonal periods. A statistical analysis is performed using the values obtained from each year's simulation to produce a probabilistic forecast for each seasonal volume.

The April-August ESP forecasts for February 2015 (Figure 4) were still roughly average at 83 Maf, but by the March forecast, the dry February conditions resulted in a lower forecast (72 Maf, ~ 82 percent of average). In addition, much of the precipitation which occurred in February and March was rain and the above average observed streamflows were not included in the April-August time period. Forecasts essentially remained unchanged by April 1 (72 Maf), but the expected spring precipitation in the April never materialized, and the water supply forecasts rapidly deteriorated during April and May. Since any forecast will have to assume some level of future precipitation, this issue will arise with any forecast procedure.

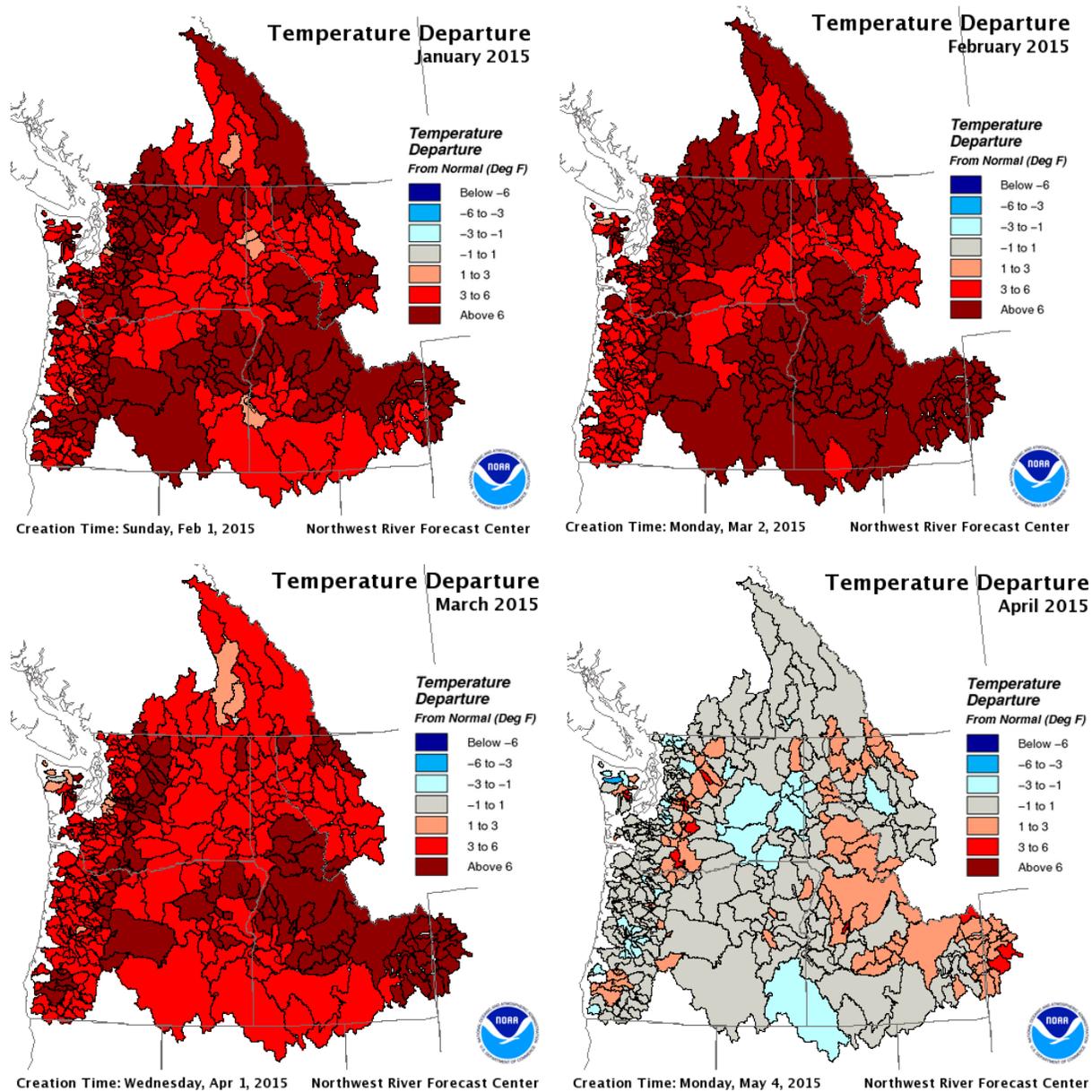


Figure 3 Pacific Northwest Mean Temperature departure January - April 2015

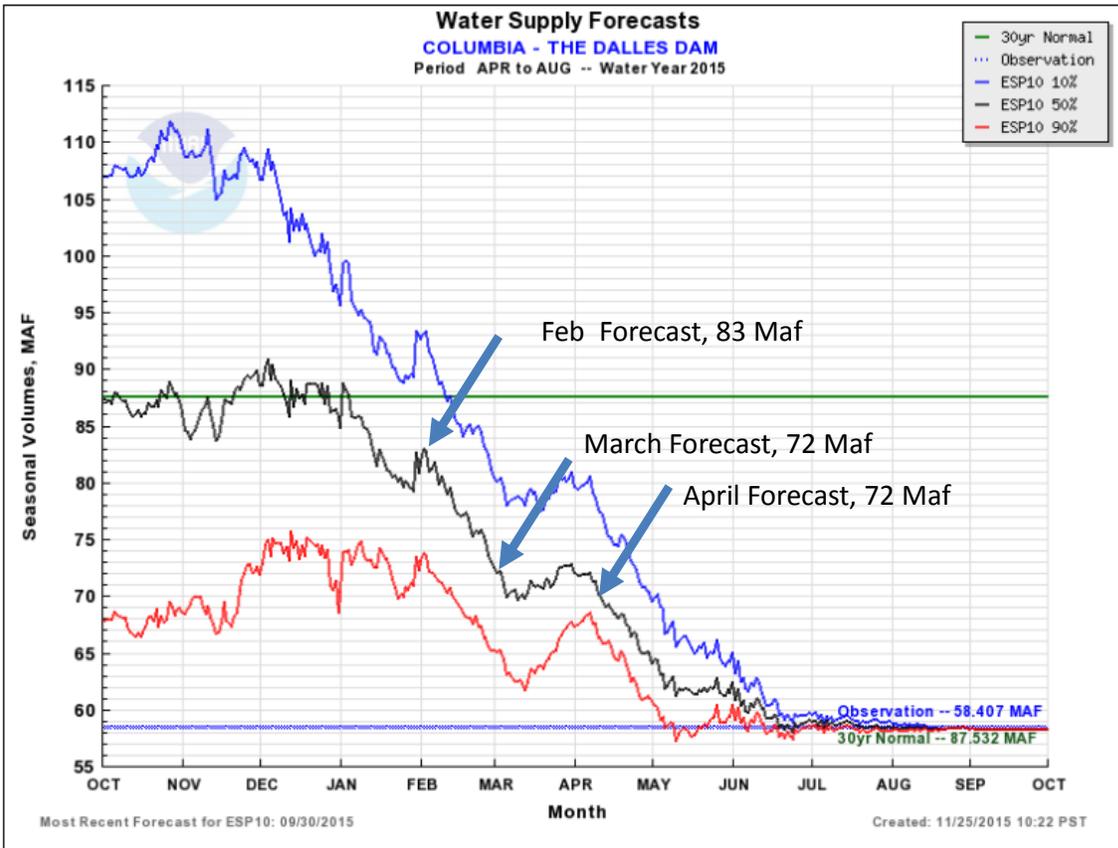


Figure 4 NWRFC 2015 Water Supply Forecasts for The Dalles

The NWRFC is currently working on several issues that may help reduce the several sources of error.

- Recalibrating the model to include last year. Each year can now be added going forward.
- Adding more current years through 2015, more modern and more recent variability.
- Continuing to provide each of the individual ensembles. Forecasts are starting with soil moisture, snow pack and the 10 day QPF, then the ensembles providing the range of historical occurrences.
- Reducing the number of traces, instead of using 67 traces just use the last 30 years is an option

- Working on a new model, a dynamic climate model, called the HEFS (Hydrologic Ensemble Forecast Service). It is similar to ESP, but it takes into account a climate-guided ensemble. Limited testing is being done at this time.

Canadian Projects

The Arrow local drainage is defined as the sum of the Arrow, Revelstoke, and Whatshan basins, while the Arrow total drainage is defined as the sum of the Arrow, Revelstoke, Whatshan, and Mica basins. Arrow local and total forecasts are aggregates of sub-basin forecasts.

Columbia River Treaty forecasts for Mica, Revelstoke, Arrow local and Duncan are based solely on statistical forecast model (i.e., principal component regression). For early-season (December) forecasts, total Feb-Jul forecast volumes are disaggregated into monthly volumes using the monthly runoff distribution from the 80-year mean. For consecutive forecast dates, total Feb-Jul volumes, or the residual thereof, are calculated by aggregating BC Hydro's monthly forecast volumes and disaggregated using the monthly runoff distribution from the 80-year mean. January forecasts are naïve (climatology, 80-year mean) forecasts. August forecasts are the difference between Apr-Aug forecasts and the Apr-Jul volume of the disaggregated Feb-Jul forecasts.

2015 HIGHLIGHTS FOR CANADIAN PROJECTS

Precipitation, temperature, and snow

- Winter precipitation in the Upper Columbia region was generally above normal.
- With the exception of November, monthly temperature anomalies during the winter months were 1.5 to 3.5 degrees Celsius above normal.
- The above normal temperatures resulted in below average peak snow accumulation, despite the above normal precipitation during the winter months (note that snow accumulation statistics are based on short to medium length time

series at medium to low elevations – the high elevation snow pack might have looked different).

Inflows

- Above normal winter temperature caused elevated inflows during the winter months into all Columbia and Kootenay projects up to the start of the freshet.
- The snow melt started early and a big portion of the water stored in the snowpack was already in the reservoirs by the end of May.
- The seasonal peak occurred at the beginning of June.
- By July the inflows were already much below normal. Inflows stayed much below normal up until a heavy rainfall event at the end of August.

Forecasts

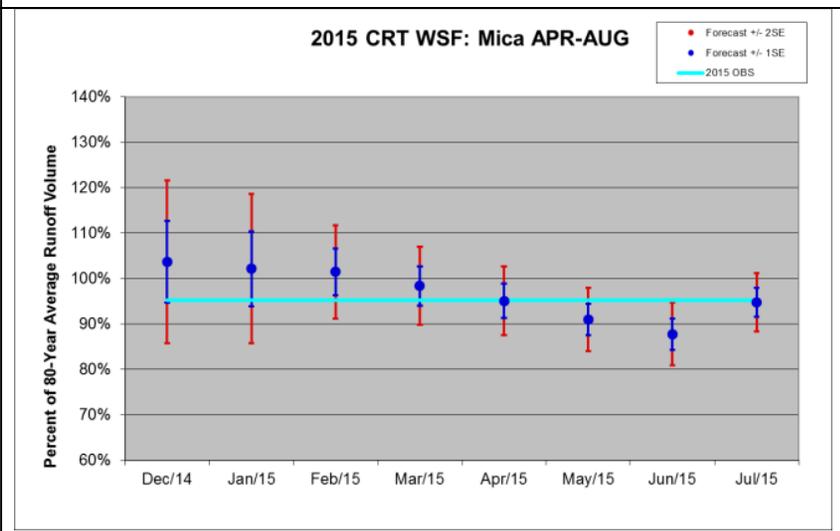
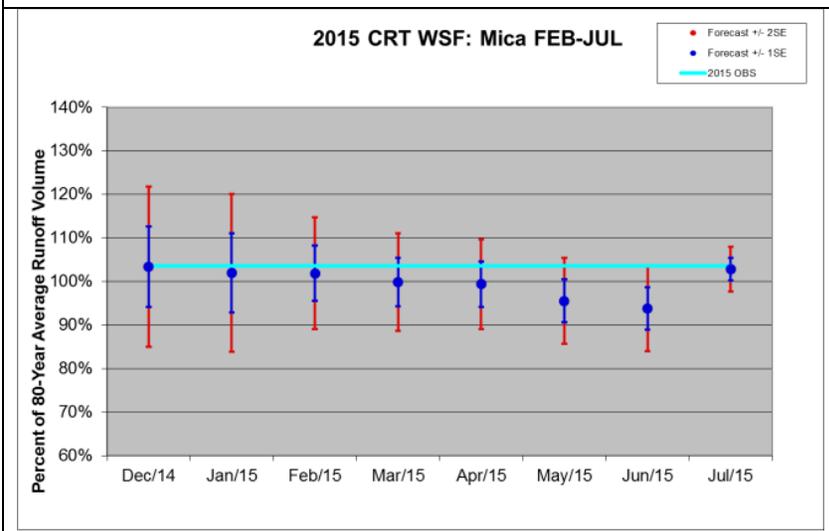
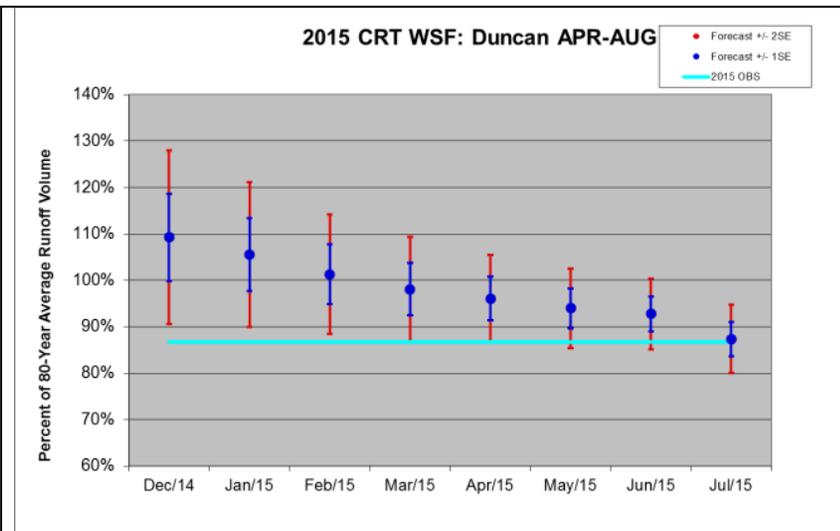
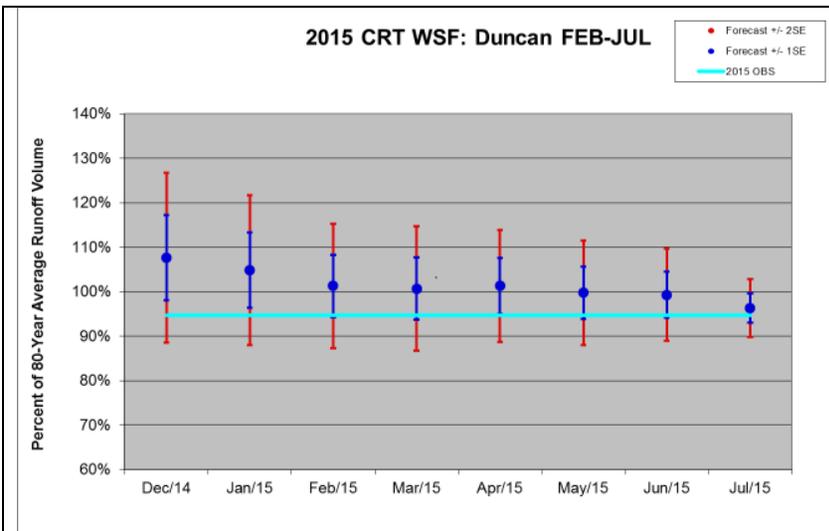
- Figure 5 shows the evolution of the 2015 forecasts for Canadian Treaty projects
- Early season forecasts (December) for Mica, Arrow, and Duncan were all above normal.
- All forecasts gradually trended downwards to below normal as the forecast season progressed, except for Mica. Mica trended to above normal until June but the July forecast for the FEB-JUL volume (and also the observed) was above normal.
- There were no abrupt changes in the forecast except for a 9% increase in the Mica forecast between June and July.
- The highest decrease in the forecast from the initial December forecast occurred at Duncan, the smallest at Mica. The decrease is more pronounced in the APR-AUG forecasts than it is in the FEB-JUL forecasts.
- Treaty forecast for Mica worked out well. The final observed inflows for Mica in the FEB-JUL and APR-AUG periods were within ± 2 standard errors of the forecast for all months. FEB-JUL observed inflows were within ± 1 standard error of the forecast in all months but May and June.
- Most of the FEB-JUL forecasts at Duncan also enclosed the observed inflows by ± 1 standard error. APR to AUG forecasts did poorly in enclosing the observed

inflows. For most months the final observed inflow volumes was outside the ± 2 standard errors of the forecasts.

- Arrow local forecasts, in line with Mica and Duncan forecasts, overestimated both the final FEB-JUL and APR-AUG volumes for all forecast months. The forecast errors for both periods were outside ± 1 standard error for all but the June and July forecasts.

Analysis and conclusions

- While the forecasts for Mica worked out for most of the forecast season, there was a sudden increase in the July forecast that is worth exploring. Because of the early melt, snow courses that are used as predictors in the May and June forecast equations had much below normal snow in the May 1st snow surveys. The statistical models consequently predicted a much below normal residual volume. However, despite a very dry June, inflows came in at about 20% higher than predicted in the June (and May) forecast, leading to a sudden increase in the July forecast. The most plausible explanation for this is that the high elevation snowpack wasn't accounted for properly by the mid elevation snow courses in the forecast equations.
- Errors in the FEB to JUL volume forecasts were much lower than in the APR to AUG volume forecasts. The reason for that can be found in the early melt. The inflows coming from the earlier than normal melt and a big portion of the high inflows during the winter months are still within the FEB-JUL period. These inflows are missing from the APR to AUG period. Hence the steeper (but still gradual) decline in all the APR to AUG forecasts.



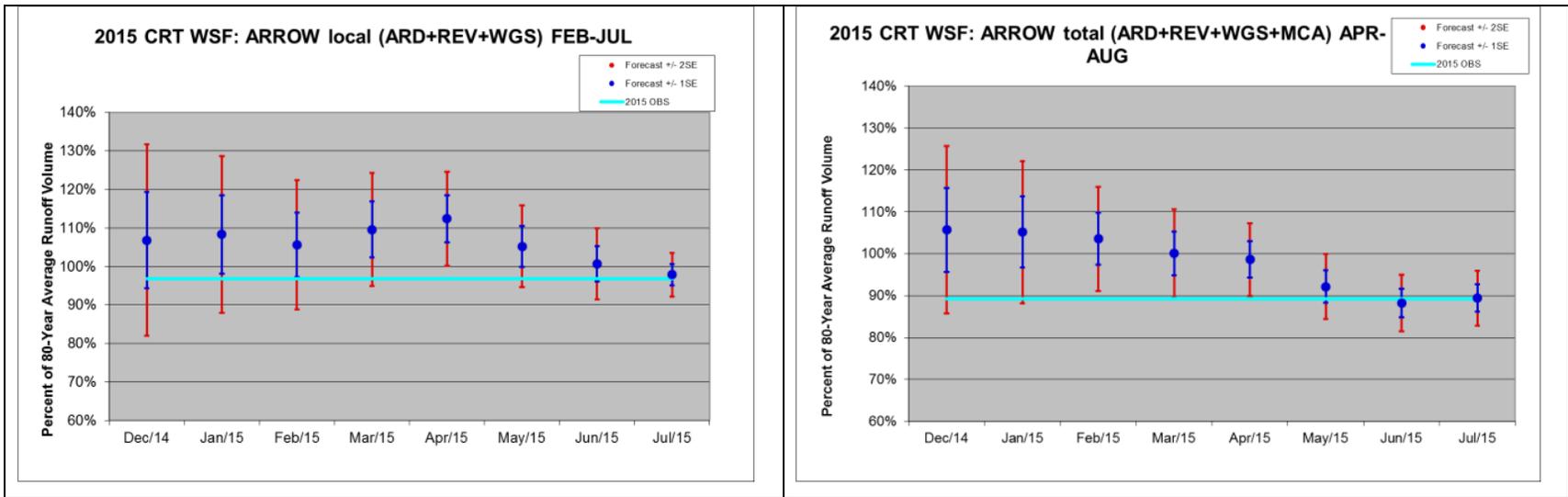


Figure 5 Seasonal forecast evolution including standard errors for Mica, Duncan, and Arrow local during the 2015 forecast season.

Libby

The Libby 2015 water supply forecast was heavily influenced by the warm wet winter. The precipitation in the Libby watershed through the fall and early winter (October – December) was above normal at about 126% of average. Figure 3 shows the temperature departures from normal from January to April of 2015. Throughout the winter and early spring the precipitation amounts remained well above average at stations through January and March with the percent of average at 136%. The snow accumulation was below average through these months due to the warm temperatures and high freezing elevations during February and March with the 1st of March snowpack being 81 percent of average. March was a big precipitation month with 200 percent of average rainfall in the Kootenai Basin but the snow pack percentage stayed the same at about 80 percent of average on the 1 April due to unusually warm temperatures. The snowpack continued to deteriorate through the month of April with the 1 May snowpack at 60 percent of average. Not only did the temperatures stay warm in April but the precipitation totals dropped off significantly to 28 percent of average for the month. May continued the April trend with low precipitation totals and well above average temperatures. By the 1 June, 3 of the 8 SWE sites in the forecasts were depleted of snow and the other 5 stations had only 35 percent of average SWE totals. The observed April-August seasonal average snowpack was 73% of average. As seen in Table 1 below, Libby Dam was over-forecasted for the seasonal volume forecasts issued from December through June. The over-forecasting was due to the high precipitation totals that did not translate to above average snowpack due to the well above average temperature this last winter.

Table 1 Libby 2015 Volume Forecast and Error Summary

	1st of Month Apr-Aug Volume Forecast (KAF)	Model Standard Error (KAF)	Number of Standard Errors Different than Observed	End of Month Flood Risk Management Target (ft)
Dec	6899	1076	2.5	2411.0
Jan	6297	1087	1.9	2410.0
Feb	5523	875	1.4	2435.7
Mar	5683	836	1.7	2433.8
Apr	5808	620	2.5	2428.6
May	5396	611	1.9	
June	5090	618	1.4	
Observed	4255			

Schedule 1 CRTHC Action Items

Table 2 New / Outstanding Action Items 2015

Meeting Source	Description	Notes/Updates	Assigned To	Due Date
OUTSTANDING ACTION ITEMS				
70.4.d	Find individually archive CRTHC documents and upload to SharePoint site	Peter provided Stephanie with download of old site. Stephanie to arrange to have those files uploaded once CRTHC finalizes design of new Sharepoint site hosted by BCH	all	ongoing
74.4.d	Corps to populate station list with US contact information	Dworshak (DWR) and its control point Spalding (SPDI) and Hungry Horse (HGH) and its control point Columbia Falls (CFMM) are classified as supplemental. Contact information for those sites will be added. Brownlee (BRN) and Albeni Falls (ALF) and its control point Newport (ALFI) are classified as informational. Run of river projects, e.g., Noxon, Cabinet Gorge, Thompson Falls, Boundary, Waneta, Seven-mile, etc. are classified as informational	Peter/Bill	Sep-15
75.5.a/c	Station data reliability @ Fernie BC	BCHydro automating the Fernie and Kootenay West Gate stations to improve data availability and reliability.	Stephanie	Fall 2015
75.5.d	Station Database spreadsheet	Add the Libby Forecast sites based upon the new procedures	Peter/Allan Furlow	May-15
76.5.b	BC Hydro has been replacing all climate / snow station towers that are >10' in height, including a number of stations in the Columbia basin.	BCH to send list of all towers that have been replaced / to be replaced in the Columbia region.	Stephanie	Fall 2015
76.5.b	BC Hydro has prepared one page station summary sheets for all climate / snow monitoring stations they manage.	BCH to provide BPA with the station summary sheets for BPA-funded stations once the sheets are finalized	Stephanie	Mar-16
76.5.c.iii	New hydrometric station called Nordic added to the Canadian Columbia to support glacier monitoring research study.	Send out information on the new station and how to access the data from the station to CRTHC	Stephanie	Fall 2015
76.5.c.iii	Stations database has some additional headers added into the US part of the database - which makes filtering the stations problematic.	Ann to removed extra headers from US stations list and ensure the header data is captured in the appropriate columns	Ann	Oct-15

Meeting Source	Description	Notes/Updates	Assigned To	Due Date
OUTSTANDING ACTION ITEMS				
76.7.b.i	BPA/BCH exploring options to simplify exchange of TSR forecast data between their two FEWS forecasting systems	Need to determine if BPA can post files to BCH sFTP site. BPA IT folks to connect with Charles Wong at BCH	Ann / Georg	Mar-16
76.7.b.ii	Document and share support personnel changes at each agency.	BCH to develop support "org" chart and contact information document and post on SharePoint for each agency to update.	Stephanie	Sep-15
76.7.c	BPA having issue with their THOR server syncing to multiple CBT servers at Corps	Bill to follow up	Bill	2016
76.7.d	Sharepoint - check versioning is working on Extranet		Stephanie	Mar-16
76.7.d	Check with PEB (Jerry Webb) on whether CRTHC annual reports should be posted on PEB website, and if yes, bring up to date, if no - have them removed. Request removal of May 2005 report which was not intended as public document	Bill confirmed they are supposed to be posted on PEB site, so CRTHC will need to provide PEB webmaster with to date reports and ensure all reports are in PDF format	Bill	Jan-16

Table 3 Completed Action Items 2015

Meeting Source	Description	Notes/Updates	Assigned To	Due Date	Completed
WY 2015 COMPLETED ACTION ITEMS					
71.2.f	Status of Fernie BC precipitation gage	Peter to query how Seattle District obtains the data. Stephanie to contact Environment Canada and see if station can be automated. BCH adding DCP autostation in September 2015	Peter/Stephanie	Sep-15	picked up in 75.5a
72.2.e	Develop list of specific contacts to send letters to in US for Hydromet data needs	Peter working on USGS and Corps contacts, Ann working on NRCS and NWS contacts	Peter/Ann		Superseded by 74.4.d
73.5.a	prepare content to go into guidance document for preparation of new WSF procedures	ongoing	all	30-Jun	done
75.4.a	Update POP for Libby forecast procedure	Update Appendix 8 text, hedge tables and Appendix 8 Table 1 with error information	Peter	To CRTC for review by April 25, present for adoption April 2, 2015	done
75.4.b	Create table detailing what different forecast periods are used to make which decisions throughout the year	responding to request from PEB for more information on how forecasts are used. This may be included in the CRTC annual report where the forecast and observed are often published	Ann	Fall 2015	Done
75.5.b	Add Brenda Mines to Station database	Not currently on station list. Not a treaty station, but supported by BPA and maintained by BCH. Add as Supplemental station	Stephanie/ Ann	Jun-15	done

Meeting Source	Description	Notes/Updates	Assigned To	Due Date	Completed
WY 2015 COMPLETED ACTION ITEMS					
75.5.f	Update Supplemental Report detailing our decision process for determining the sufficiency of the station network	Part of that review process includes a post-mortem on forecasts, both daily and seasonal; trends in station availability both historically and real-time; specific mentions of station discontinuation and an overall review of the network occurs whenever the seasonal forecasts are updated.	Stephanie	Fall 2015	Done
76.5.c.iii	Stations database list of agency contacts needs to be changed to a list in the database to make it easier to search and update		Bill	Oct-15	Done
76.5.d	BCH continues to have issues accessing Porthill and Bonners Ferry data from US.	Phil B can provide a query to webscrape these data	Phil	Oct-15	Done
76.6.a	Finalize POP Appendix 8 changes and send to CRTOC		Ann	Aug-15	done
76.6.b	Update distribution lists for water supply forecasts	Stephanie to ensure Bill on distribution for Cdn Treaty WSF, and review Libby forecast distribution for BCH changes	Georg	Oct-15	Done