COLUMBIA RIVER TREATY

HYDROMETEOROLOGICAL COMMITTEE

2008

SUPPLEMENTAL

REPORT

Bonneville Dam – photo by James Reilly

FEBRUARY 2009

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HYDROMETEOROLOGICAL COMMITTEE

2008 SUPPLEMENTAL REPORT

Summary

The Canadian and United States Entities of the Columbia River Treaty established the Hydrometeorological Committee (CRTHC) in 1968. The mandate of the CRTHC is primarily to be responsible for ensuring that hydrometeorological data necessary for the planning and operation of Treaty project facilities are collected and communicated to the Entities. The "Introduction to the terms of reference for the CRTHC, shown in Appendix A of the 2008 Supplemental Report gives a brief history of the CRTHC. CRTHC terms of reference are included in Appendix B of the Supplemental Report.

The CRTHC Annual Reports has two parts; the first part reports on activities for the current Water Year; and the second part consists of more general background information that is organized into a Supplemental Report. The supplement contains general information that does not typically change from year to year. Appendices in this 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

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Acronyms

AEC - Actual Energy Capability
AER - Actual Energy Regulation
AOP - Assured Operating Plan
BC Hydro - British Columbia Hydro and Power Authority
BPA - Bonneville Power Administration
CBT - Columbia Basin Telecommunications
CROHMS - Columbia River Operational Hydrometeorological Management System
CRT - Columbia River Treaty
CRTHC - Columbia River Treaty Hydrometeorological Committee
CRTOC - Columbia River Treaty Operating Committee
CWMS - Corps Water Management System
CWS - Columbia Winter Specified
DOP - Detailed Operating Plan
EC - Environment Canada
ESA - Endangered Species Act
ESP - Ensemble Streamflow Prediction
FCOP - Flood Control Operating Plan
FRO - Fall runoff, used in Libby water supply forecasting procedure
FTP - File Transfer Protocol

HYDSIM - Hydrologic Simulation model

MOE - BC Ministry of Environment

MSC - Meteorological Service of Canada, Environment Canada

NRCS - Natural Resources Conservation Service

NWPP - Northwest Power Pool

NWRFC - Northwest River Forecast Center, US National Weather Service

NWSRFS - National Weather Service River Forecast System

Operating Year - October 1 to September 30 (CRTHC)

PEBCOM - Permanent Engineering Board Engineering Committee

PNCA - Pacific Northwest Coordination Agreement

POP - CRT Principles and Procedures Document

QPF - Quantitative Precipitation Forecast

RCS - Regional Climate Station

RFS - River Forecast System

RODS - BPA's Real-time Operations Dispatch and Scheduling

SNOTEL - SNOwpack TELemetry, NRCS snow pillow and climate data network

STP- Single Trace Procedure

SSARR - Streamflow Synthesis and Reservoir Regulation hydrologic model

TSR - Treaty Storage Regulation study

UBCWM - University of British Columbia Watershed Model

USACE - US Army Corps of Engineers

USBR - US Bureau of Reclamation

Water Year - August 1 to July 31 (CRTOC)

WSC - Water Survey of Canada, Environment Canada

WSF - Water Supply Forecast

COLUMBIA RIVER TREATY
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Appendix A Introduction to the CRTHC terms of reference[1]

The Columbia Treaty between Canada and the United States of America relating to cooperative development of water resources of the Columbia River Basin was jointly signed by the heads of the respective Governments on January 17, 1961. Final ratification of the Treaty occurred when Canada Ratified the Treaty on September 16, 1964.

Article XIV, Arrangements for Implementation contains:

> 2. In addition to the powers and duties dealt with specifically elsewhere in the Treaty, the powers and duties of the entities include:
>
> e. The establishment and operation of a hydrometeorological system as required by Annex A,

[1] *The text of this appendix is copied from the original 1967 document.*

Annex A, Principles of Operation states:

> 2. A hydrometeorological system, including snow courses, precipitation stations and streamflow gauges will be established and operated, as mutually agreed by the entities and in consultation with the Permanent Engineering Board, for use in establishing data for detailed programming of flood control and power operations. Hydrometeorological information will be made available to the entities in both countries for immediate and continuing use in flood control and power operations.

In March of 1965, an International Task Force on Hydrometeorological Network, Columbia River Treaty was appointed to recommend establishment and operation of the Hydrometerological Network and procedures for exchange of information between the two Entities. Each of the Entities was guided by the following instructions:

> A In collaboration with the respective Section of the task force, participate in the following activities:
>
> > 1 Recommend additions to the present hydrometeorological network to provide information essential to the operation of the Treaty storage to achieve the benefits contemplated by the Treaty which will:
> >
> > > a Provide current data on reservoir and streamflow conditions.
> > >
> > > b. Provide sufficient information for forecasting streamflow on a long-range (seasonal), medium range (10

days to a month or two), and short-range (up to 10 days) basis to meet the operational criteria of each project.

2 Recommend establishment and operation of a communication system for timely reporting of all hydrometeorological factors to meet operational and forecasting requirements.

This system should utilize existing facilities where possible, and new facilities should be recommended where needed.

3 Review the network from time to time and recommend additions to or deletions from facilities to ensure peak network efficiency.

4 Prepare reports and recommendations to the entities from time to time as appropriate.

B. In addition, the Entities shall be responsible for the following:

1 Prepare such interim or supplemental reports as may be needed to adequately inform the Entities on significant developments, alternative considerations, and progress.

2 Coordinate activities as needed with the other task forces.

3 In developing the required network facilities, seek technical advice and obtain technical assistance, as necessary, from Canadian and other United States Agencies such as the Geological Survey,

Soil Conservation Service, and the National Weather Service as well as within your own agencies, B.C. Hydro and Power Authority, the Bonneville Power Administration, and the Corps of Engineers.

4 Provide the Entities with copies of all correspondence, reports and drafts of reports, minutes of meetings, and distribution of all material.

The International Task Force was in operation from 1965 through September 19, 1968. During this period, recommendations were prepared and subsequently adopted by the Entities with the concurrence of the Permanent Engineering Board. These recommendations established the basic hydrometeorological network of stations required by the Entities under the Treaty to provide data necessary for the operation of the Treaty projects. These were termed “Treaty facilities.”

The Entities agreed on October 23, 1967, to a definition for other hydrometeorological stations and communications not considered elements of the Treaty hydromet system but necessary for operational forecasting for the Columbia River. These were termed “supporting facilities.”

On September 19, 1968, the United States and Canadian Entities agreed to abolish the Task Force. The CRTHC was established at the same time. The terms of reference that follow outline the responsibilities given to the CRTHC at that time.

This document will be updated from time to time as changes occur in hydrometeorological requirements or facilities listings.

Appendix B Terms of reference for the CRTHC

May 20, 1968

1 - GENERAL

The CRTHC will be composed of representatives of each Entity. The CRTHC will recommend the establishment of the Columbia River Treaty Hydrometeorological System. This system (hereinafter called "Treaty facilities") and the supporting facilities thereto are defined in an agreement between the Canadian and United States Entities dated October 23, 1967, as follows:

a Treaty facilities

1 The Columbia River Treaty Hydrometeorological System shall consist of new and existing streamflow and reservoir gauges, snow courses, meteorological stations, and other related hydrometeorological data-collecting facilities a plan for methods and frequency of reporting, and a communication system to provide information for the operation of Duncan, Arrow, Mica and Libby reservoirs. It shall include hydrometeorological

stations which provide operational and forecasting data relevant to the flow of the Columbia River at Birchbank, British Columbia, or at an equivalent streamflow gauge, and in addition, certain key streamflow and reservoir gauges on the Columbia River downstream from Birchbank and [certain key streamflow and reservoir gauges] on the Clark Fork - Pend Oreille tributary.

2 All stations included in the System will be as agreed from time to time by the Entities in consultation with the Permanent Engineering Board.

3 Additions to or deletions from the System will be subject to mutual agreement by the Entities with the objective of assuring continued operation of the system.

b Supporting facilities

1 It is desirable to identify other hydrometeorological stations and communications, not considered as elements of the system, which provide information for operational forecasting for the Columbia River.

2 A list of the hydromet stations and communications referred to in (1) above will be maintained by the Entities and all elements included in the list will be identified as “supporting facilities.”

3 Each Entity will make reasonable effort to assure the continued operation of supporting facilities located in its own country.

c Supplemental data

Available hydrometeorological data from any part of the Basin required by either Entity from time to time will be provided by the other Entity on request.

2 – COMPOSITION OF THE CRTHC

The CRTHC will be composed of a United States Section and a Canadian Section. The members of each Section will be designated by their respective Entity. One member of each Section will be formally designated as chairman of the Section.

3 – DUTIES OF THE CRTHC

The duties of the CRTHC will include the following, subject to modification and addition as may be deemed appropriate by the Entities from time to time.

i Governing Treaty facilities:

a Review existing hydrometeorological facilities and where necessary recommend additions and improvements in order to develop a hydrometeorological system which will:

1 Provide current data on reservoir streamflow conditions.

2 Provide sufficient information for forecasting streamflow to determine operation of the Treaty projects.

b Recommend establishment of communication for timely reporting of hydrometeorological information to meet operation and forecasting requirements. Existing communication facilities should be used where adequate and new facilities should be recommended where needed.

c Recommend a plan for methods and frequency of reporting.

d Review the system from time to time and recommend additions or deletions of Treaty facilities and to insure peak network efficiency.

ii Governing supporting facilities:

Recommend other existing hydrometeorological stations and communications not considered as Treaty facilities for inclusion by the Entities in a list of “supporting facilities.”

iii Prepare annual reports reviewing the CRTHC’s activities for the preceding year and such other reports and recommendations to the entities from time to time as appropriate.

iv In the event of any substantial disagreement between the United States Section, the Chairmen of the Canadian and United States Sections will immediately refer the matter to the respective Entities through the Manager, Canadian Entity Services and the Staff Coordinators for instructions.

v Consult, and coordinate its work, with the Columbia River Treaty Operating Committee.

In addition, each Section will be responsible to its respective Entity for the following:

a Prepare such interim or supplemental reports as may be needed to keep the appropriate Entity informed on significant developments, alternative considerations, progress, and operation of the Treaty facilities and supporting facilities.

b Coordinate activities as needed with the appropriate Section of other Columbia River Treaty committees.

c In determining and reviewing the required Treaty facilities and supporting facilities, seek technical assistance as necessary from other agencies in the appropriate country.

d Provide the appropriate Entity with copies of all correspondence, reports, and drafts or reports, minutes of meetings, and the distribution of all material.

Appendix C Process for reviewing hydrometeorological data networks

The CRTHC ensures that the integrity of hydrometeorological stations that are required to monitor, plan, and operate Treaty facilities is maintained by following a prescribed process. The process involves several steps, as described below.

STEP 1. COMMUNICATE WITH DATA COLLECTION AGENCIES

Each year, the CRTHC formally reminds each contributing data collection agency or utility to inform the CRTHC of any impending changes in its operation of hydrometeorologic stations near or within the Columbia River basin. Most hydrometeorological data required for the operation of the Columbia River Treaty are collected by Canadian federal and provincial state agencies. Data collection agencies and electrical utilities contacted are included in Appendix D.

STEP 2. DETERMINE TREATY STATUS OF STATIONS SUBJECT TO OPERATIONAL CHANGES

If informed of a proposed change to the operation of any hydrometeorological station, the Canadian and United States Sections of the CRTHC both determine if the change affects the ability to monitor, plan, or operate a Treaty facility. Specifically, the CRTHC will designate a station as Treaty or support if data from it are required:

- as input to the AOP
- as input to the DOP
- as input to TSR studies
- as input to HYDSIM
- as input to the NWSRFS or UBCWM models for Columbia River sub-basins
- as input to seasonal water supply forecasting procedures required by the FCOP
- to monitor or operate Treaty facilities, including daily and additional seasonal forecasts for Treaty facilities

Brief descriptions of Treaty planning processes and models are included in Appendix E.

STEP 3. RESPOND TO DATA AGENCIES WHEN A CHANGE IN STATION OPERATION AFFECTS TREATY OPERATIONS

Where a change in the operation of a designated Treaty or support station is proposed, the Canadian and United States Sections of the CRTHC will explore several options:

- If the change in station operation compromises monitoring, planning for, or operating a Treaty facility, the appropriate Section of the CRTHC will urge data collection agencies on its respective side of the border to continue the current operation of the station.
- Where data collection agencies are unable to continue the current operation of a Treaty or support station, the CRTHC will examine the impact that the proposed station change has on monitoring or operating a Treaty project. The CRTHC will also examine the practicality of modifying planning models to accept the proposed station change. The impact of the change in operation of the station should not, in the view of the CRTHC, deteriorate the accuracy of model results significantly. If the change does not significantly affect the ability to monitor, plan, or operate a Treaty facility, the CRTHC will not object to the proposed change.
- Where changes to a Treaty or support station are detrimental to Treaty monitoring, planning, or operations, the CRTHC will attempt to fund and arrange other resources required to continue the operation of the station. Alternatively, a suitable replacement station may be investigated.

STEP 4. DOCUMENT CRTHC WORK

The CRTHC will document the following:

- CRTHC activity during the operating year, which is defined as October 1 to September 30
- changes to the operation of Treaty or support stations proposed within the CRTHC's operating year
- the CRTHC's response to the proposed changes
- resolution of proposed changes to the hydrometeorological network
- processes to communicate and exchange hydrometeorological data.

STEP 5. REGULARLY REVIEW HYDROMETEOROLOGICAL DATA REQUIREMENTS FOR TREATY MODELS

As required, the CRTHC will review existing and proposed models used for CRT planning studies and operations to assess hydrometeorological data requirements. The CRTHC will recommend preferred daily and seasonal forecasting models to be used in CRT operations to the CRTOC.

Appendix D List of contributors of hydrometeorological data

The Canadian Section of the CRTHC typically writes letters to selected agencies at the beginning of each operating year requesting notification of changes to station networks. Data collection agencies contacted include;

- Alberta Environment
- BC Ministry of Environment
- Meteorological Service of Canada – Atmospheric Monitoring Division
- Meteorological Service of Canada – Applications and Services
- Meteorological Service of Canada – Water Surveys Division

Other agencies and electrical utilities contributing data for Treaty purposes include;

- US Army Corps of Engineers
- US Bureau of Reclamation
- US Geological Survey
- US Northwest River Forecast Center
- US Natural Resources Conservation Service
- Fortis BC

- Avista
- BC Hydro
- Bonneville Power Administration
- CASSO Corporation
- Chelan PUD
- Douglas PUD
- Grant PUD
- Idaho Power
- PacifiCorp
- Pennsylvania Power and Light
- Pend Oreille PUD

Appendix E Data communication and storage systems

CBT and other communications systems administered by the CRTHC are described in the following sections.

CBT

The USACE operates the CBT system. CBT is one of several major subsystems of CROHMS. The CBT system provides the primary communications system between the hydropower projects and the operating agencies. The CBT system receives data directly from both the USACE and the USBR projects and consolidates project data collected by other agencies. A list of the current "members" of the CBT system include:

- Avista Corporation, Spokane, WA
- BC Hydro, Vancouver, B.C.
- Bonneville Power Administration, Portland, OR and Vancouver, WA
- Constellation Energy Commodity Group
- Controlled Area Scheduling Service, Spokane, WA
- Eugene Water and Electric Board, Eugene, OR
- PacifiCorp, Portland, OR
- Portland General Electric, Portland, OR
- PP&L Montana, Butte, MT

- Public Utility District No. 1 of Chelan County, WA
- Public Utility District No. 1 of Douglas County, WA
- Public Utility District No. 1 of Pend Oreille County, Newport, WA
- Public Utility District No. 2 of Grant County, WA
- Puget Sound Energy, Redmond, WA
- Seattle City Light, Seattle, WA
- Tacoma Power and Light, Tacoma, WA
- USACE, Portland, OR, Seattle & Walla Walla, WA
- USBR, Boise, ID

Typically, data collection agencies transmit hourly data from their respective systems to the CBT system in one of two ways. Data are transmitted either via the CBT web page (HTTPS protocols) or direct file transfer (FTP protocol). Specifically;

- BPA and NWRFC have direct private circuits to the USACE in Portland to transmit data for the Grand Coulee and Hungry Horse projects. They may use the Internet as an alternative circuit.
- BC Hydro uses the Internet as its primary telecommunications circuit. Data from Canadian locations are first retrieved through a DOMSAT satellite downlink and are then forwarded to CBT via the Internet.

Data collection agencies are also provided with dial-up accounts to the USACE. These accounts allow access the CBT system over standard public telephone circuits in the event that the private circuits and the Internet are unavailable. Information posted to the CBT web pages for retrieval by the CBT community is accessible only through secure, encrypted transmissions. Public access to the CBT system is not permitted.

The CBT system operates much like an e-mail server. Each arriving message is coded with a list of addressees targeted to receive the message. The content of the message is a text field containing the data coded in “CBT Format”, a convention adapted and used by the operating agencies across the Pacific Northwest since 1957. The CBT computer in Portland re-posts each message to the appropriate CBT web page of each agency. It simultaneously forwards the data to CROHMS and to BPA’s RODS system.

OTHER COMMUNICATIONS SYSTEMS

Other communications systems and networks transmit data into CROHMS. The NRCS transmits data from SNOTEL stations to the NWRFC in Portland. The NWRFC then forwards these data to the USACE’s CROHMS system.

Streamflow data for sites in the United States are retrieved from the USACE’s DOMSAT satellite downlink and input directly to the CROHMS system.

Some data collection agency or other data sources have expanded their communications systems to include Web pages, anonymous FTP, and NOAA Port satellite downlinks to supplement communication through the traditional CBT and CROHMS systems.

Appendix F Data exchange reports

The following contains a summary of CRT hydrometeorological hourly, daily, monthly, and other reports:

HOURLY PROJECT DATA REPORTS

These reports include hourly project data for the following hydropower projects:

- Libby
- Albeni Falls
- Grand Coulee
- Hungry Horse
- Dworshak
- The Dalles

The CBT system is used to send the following data to CROHMS each hour.

- Inflow
- Outflow
- Spillway flow
- Reservoir and tailwater elevations
- Generation

DAILY PROJECT DATA REPORTS

Daily project data reports are sent to CROHMS just after midnight using the CBT system. The reports include project data for the following hydropower projects:

- Libby
- Albeni Falls
- Grand Coulee
- Hungry Horse
- Dworshak
- The Dalles

Reports include the following data:

- Instantaneous and daily average inflow
- Daily average outflow
- Daily average spillway flow
- Day-end reservoir and tailwater elevations
- Daily total generation data

Upon referral with the US Entity Section during the year, BC Hydro discontinued sending 8 a. m. streamflow data for the Similkameen River at Hedley, Okanagan River at Penticton, South Slocan River at Crescent City, and Columbia River at Birchbank in November 2001. These data are available directly from the Water Survey of Canada at URL http://scitech.pyr.ec.gc.ca/waterweb/.

METEOROLOGICAL DATA REPORTS

Meteorological data reports, sent to CROHMS by mid-morning each day, typically include the following:

- Maximum daily temperature
- Minimum daily temperature
- Instantaneous temperature
- Incremental or accumulated precipitation

Weather data from hydropower projects and Canadian stations are sent to CBT. Alberta Environment sends precipitation data for one station directly to the USACE via e-mail. Weather data for other stations in the United States are collected by the NWRFC and transferred to the USACE using FTP over a dedicated circuit.

SNOW DATA REPORTS

Daily SNOTEL data and monthly snow course data for United States stations are collected by the NRCS and transmitted to the NWRFC.

The NWRFC pulls snow pillow data for Canadian sites from British Columbia's MOE web site. The USACE accesses snow data directly through its circuit to the NWRFC.

RESERVOIR CONTROL CENTER MESSAGES

Operational messages and instructions for project operations are sent out to the projects from the USACE Reservoir Control Center throughout the day or night as needed. Daily flow forecasts submitted by the NWRFC are also included. These messages are distributed using the CBT system.

BPA MESSAGES

Dedicated circuits between USACE and BPA use FTP to send and receive BPA messages on the CBT. Messages include:

- Operational messages
- Generation schedules
- Grand Coulee forecasts
- PNCA Entitlements

WATER SUPPLY FORECASTS

Volume runoff forecasts are exchanged by e-mail and posted to the web sites of the originating agencies for review and coordination with other Treaty participants.

Appendix G Treaty studies, models, and forecast requirements

Several forecasting and operational models require the input of hydrometeorological data. These models are used to forecast seasonal water supply or daily inflows, or to plan the operation of Treaty facilities for power production or flood control. The following sections briefly describe these studies, models, and related forecasting requirements.

ASSURED OPERATING PLAN

The Entities jointly prepare an Assured Operating Plan (AOP) each year for the sixth succeeding "operating year". For purposes of the AOP, the operating year is defined as August 1 to July 31. The AOP optimizes the system generation potential, with and without Treaty storage considered. The AOP also provides the Entities with essential information for effective operational planning of their respective power systems that are dependent on or coordinated with the operation of Canadian storage.

Downstream benefit computations are prepared in conjunction with the AOP. The computations define the downstream power benefits in the United States from Canadian storage five years in advance for each year in which the Treaty is in force.

DETAILED OPERATING PLAN

Each year, the US Entity, in consultation with the Canadian Entity, performs system regulation studies to develop a Detailed Operating Plan (DOP) for Canadian Treaty storage reservoirs, the whole of Canadian Treaty storage, and for Libby reservoir. The DOP is normally developed based on the respective AOP for that operating year. Planning for the DOP begins in the fall, with the final Canadian Entity data submittal made by 01 February, prior to the start of the next August-to-July operating year.

ACTUAL ENERGY REGULATION

The Pacific Northwest Coordination Agreement (PNCA) was created in 1964 to coordinate the utilities and agencies controlling generating facilities in the region for the purpose of optimizing power production while fulfilling project constraints and non-power uses of the system.

The PNCA requires each party to determine their Actual Energy Capability (AEC) given their short-term operations. The party's AEC determines each party's interchange, in-lieu, or provisional storage-draft rights or obligations.

Beginning in 1977, PNCA parties decided to have the Northwest Power Pool (NWPP) use a single hydro model to simulate the coordinated hydro system to determine each parties AEC and rights and obligations. This hydro model is called the Actual Energy Regulation (AER). The AER is run at least twice a month and may be run more often at the request of a PNCA party.

The AER uses the following input to determine the desired storage operation and to specify the hydroelectric component of each party's AEC:

- planned loads
- resources
- operating criteria, including Endangered Species Act (ESA) operations

- current unregulated streamflow forecasts
- flood control rule curves
- and operating rule curves

Only unregulated streamflow forecasts, hydro-independent generation, variable refill curves, and upper rule curves are changed. All other operating data in the AER study, including firm and secondary loads, thermal and miscellaneous resources, non-power requirements, other plant and operating data, and other applicable rule curves, come from the applicable Assured Operating Plan, as modified by the Detailed Operating Plan or other agreement of the Operating Committee.

The USACE submits monthly streamflow forecasts for their projects to the NWPP and BPA provides all other Federal/Canadian project monthly streamflow forecasts. During the January-July period, all monthly shaping of the streamflow forecasts maintain the forecast seasonal volumes supplied by the project owners. The NWPP then combines the USACE and BPA forecasts with other non-Federal project streamflow forecasts for use in the AER model.

The draft rights and obligations of the Canadian projects at Mica, Arrow, and Duncan are determined through the Treaty Storage Regulation (TSR) process and then inserted into the AER studies. While the TSR is very similar to the AER, it does not incorporate ESA operations.

TREATY STORAGE REGULATION

The Columbia River Treaty was implemented in 1964 to coordinate the operation of Canadian Columbia basin reservoirs for optimum power and flood control benefits downstream in Canada and the United States. A Detailed Operating Plan (DOP) is prepared annually according to the Treaty for this purpose.

The DOP requires a TSR study as input to determine the monthly storage rights and obligations for the Canadian reservoirs Mica, Arrow, and Duncan. The TSR also provides mid-month storage rights and obligations for the months of April and August. The TSR is similar to the AER, except that ESA-related operating constraints are not considered and hydro system power loads are estimated slightly differently. The TSR uses the following input to determine basic operating requirements for Canadian Treaty reservoirs:

- DOP operating criteria for 76 coordinated system projects in the United States and Canada
- current unregulated streamflow forecasts
- flood control curves
- refill curves

Only unregulated streamflow forecasts, hydro-independent generation, variable refill curves, and upper rule curves are changed. All other operating data in the TSR study, including firm and secondary loads, thermal and miscellaneous resources, non-power requirements, other plant and operating data, and other applicable rule curves, come from the applicable Assured Operating Plan, as modified by the Detailed Operating Plan or other agreement of the Operating Committee.

The USACE submits monthly streamflow forecasts for their projects to the NWPP and BPA provides all other Federal/Canadian project monthly streamflow forecasts. During the January-July period, all monthly shaping of the streamflow forecasts maintain the forecast seasonal volumes supplied by the project owners. The NWPP then combines the USACE and BPA forecast with other non-Federal project streamflow forecasts and makes the data available for use in the TSR model.

The TSR is normally run twice per month to provide the operation of Canadian reservoirs for the AER. Either of the Canadian or United States Entities may request that the TSR be run more often.

Actual operation of the Canadian Treaty storage projects is established by weekly Entity agreements that are based on the TSR end-of-month storage results, combined with supplemental operating agreements or flood control requirements. TSR operating information for Libby is provided at the weekly meeting for coordinating operations on the Kootenay, but is not used for Libby's actual operation.

HYDSIM

HYDSIM is a reservoir simulation model that was developed for planning the seasonal operation of the Northwest hydropower system. The Canadian and United States Entities use HYDSIM for developing the AOP, DOP, and TSR studies carried out throughout the year. HYDSIM regulations are divided into 14 intervals during the water year; twelve monthly periods, with both April and August divided into two. Input to the model includes plant characteristics, operational data, historic streamflows and rule curves that guide the operation.

HYSSR

HYSSR is a US Army Corps of Engineers reservoir simulation model that was developed for planning the seasonal operation of the Northwest hydropower system. USACE uses HYSSR for developing the AOP, DOP, and PNCA studies carried out throughout the year. HYSSR regulations are divided into 14 intervals during the water year; twelve monthly periods, with both April and August divided into two. Input to the model includes plant characteristics, operational data, historic streamflows and rule curves that guide the operation.

FLOOD CONTROL OPERATING PLAN

The USACE is responsible for Columbia River Treaty flood control operations. The FCOP was developed under provisions of the Columbia River Treaty. It prescribes criteria and procedures by which the Canadian Entity will operate Mica, Duncan, and Arrow Reservoirs. Libby Reservoir is included in the FCOP to meet the Treaty requirement to coordinate its operation for flood control protection in Canada. The operation of Treaty storage reservoirs is intended to reduce stages at all potential flood damage areas in Canada and the United States to non-damaging levels where possible. During large flood events where flood damage cannot be avoided, the plan aims to control levels to minimize damage.

The FCOP addresses both local and system flood control requirements. Local flood control relates to areas immediately downstream of project reservoirs. System flood control relates to overall system storage operations that reduce flood potential in the Portland, Oregon / Vancouver, Washington river reach. Flows on the Columbia River at The Dalles are used to prescribe system flood control requirements. The operation of Canadian storage for system flood control requirements is integral and has been factored into the FCOP.

The plan develops operations for the evacuation and refill phases through the winter and spring. Operational requirements for system flood control are determined through the use of storage reservation diagrams, current operations guidance, and flood stage levels at damage centers. The USACE uses self-generated seasonal water supply forecasts for Libby and Dworshak. Other water supply forecasts are provided as follows for the USACE to determine upper rule curves:

- BC Hydro provides water supply forecasts for Mica, Arrow, and Duncan.
- The USBR provides forecasts for Hungry Horse.
- The NWRFC provides forecasts for all remaining points.

The NWRFC provides real-time in-season forecasts to assist the USACE refill project reservoirs.

The FCOP was initially developed in 1965 and first published in 1972. Changes to the Libby evacuation flood control curve were made in 1989. The USACE, Northwestern Division, North Pacific Region recently published a revised plan in May 2003, entitled “Columbia River Treaty Flood Control Operating Plan”. Revisions were made in response to changes in flood control criteria and development of new evaluation procedures.

WATER SUPPLY FORECASTING

Columbia River Treaty seasonal water supply forecasts are required for two reasons. First, the forecasts are required to plan the evacuation of storage space from Treaty reservoirs for flood control purposes prior to the onset of the spring freshet (USACE, 2003). Second, they are required to plan reservoir operations to ensure a reasonable likelihood of refill following the spring freshet.

Seasonal water supply forecasts are generally made over a period of time when snowmelt runoff predominates. Common forecast periods for Treaty projects are from the forecast date to the end of July, or to the end of September. Forecasts are made on the first of each month, usually starting 01 January[2]. The last seasonal inflow forecasts are made on 01 August of each year for Canadian projects and 01 July for US projects. Seasonal water supply forecasts can be based on either statistical procedures or conceptual hydrological model simulations. Currently, seasonal water supply forecasts used for calculating upper rule curves are based on statistical procedures.

STATISTICAL PROCEDURES

Statistical procedures are usually developed using multiple linear regression techniques. Forecast water supply to a reservoir over the coming spring and summer period is regressed against a variety of predictor variables. These

2 The NWRFC prepares three forecasts each month between late December and June. These forecasts include early-bird, final, and mid-month forecasts. The early-bird and mid-month forecasts use preliminary data from a subset of stations as input. Final forecasts use observed data through the end of the previous month for all stations in the forecast procedure. The USACE uses final forecasts to develop flood control operations and modify reservoir elevation targets each month. Other groups use the water supply forecasts to plan power production and irrigation needs.

variables typically include data from a number of hydrometeorologic stations. Data are used to compute predictor variables, such as mountain snow water equivalent and accumulated valley-bottom precipitation. In addition, antecedent conditions, such as fall precipitation or winter base flow, are commonly used as predictor variables.

BC Hydro revised the statistical forecast methodology in 2008 and implemented early season forecasts in December (BC Hydro, 2008)[3]. The USACE recently revised statistical forecast procedures for Libby Reservoir (USACE, 2004)[4]. The NWRFC in Portland, Oregon prepares water supply forecasts for sub-basins throughout the Columbia River Basin during the winter and early spring in cooperation with the NRCS, USACE, and others. Agencies rely on hydrometeorological and snow survey station data throughout the United States and Canadian portions of the basin. Statistical procedures produce "official" forecasts used to determine storage space evacuation from Treaty reservoirs required for flood control and refill criteria.

ENSEMBLE STREAMFLOW PREDICTION

A conceptual hydrological model may be used to forecast water supply using a procedure known as Ensemble Streamflow Prediction, or ESP. Once initial watershed conditions, such as snowpack and groundwater storage, are determined on the forecast date, historical weather data are input to the conceptual model, one year at a time, beginning each time with the current initial basin-state conditions. A series of synthetic hydrographs, as shown in Figure 1, is produced. By assuming that each hydrograph simulation has an equal likelihood of occurring in the coming season, the synthetic series

[3] *BC Hydro (Luo) 2008. BC Hydro VoDCA Statistical Volume Forecast Models for Canadian Columbia River Treaty Projects*

[4] *USACE (Wortman) 2004. Water Supply Forecasting Models for Libby, MT.*

generated is analyzed to produce a probabilistic forecast of seasonal water supply over the coming season.

BC Hydro uses the UBC Watershed Model (UBCWM) to simulate flows required for the ESP procedure, whereas BPA and NWRFC use the NWS River Forecast System (NWSRFS). Forecasts produced using ESP techniques are generally used by utilities as input to other models to determine probable outcomes of operations on hydro generation and fisheries operations. They also provide a valuable comparison to forecasts produced using statistical procedures.

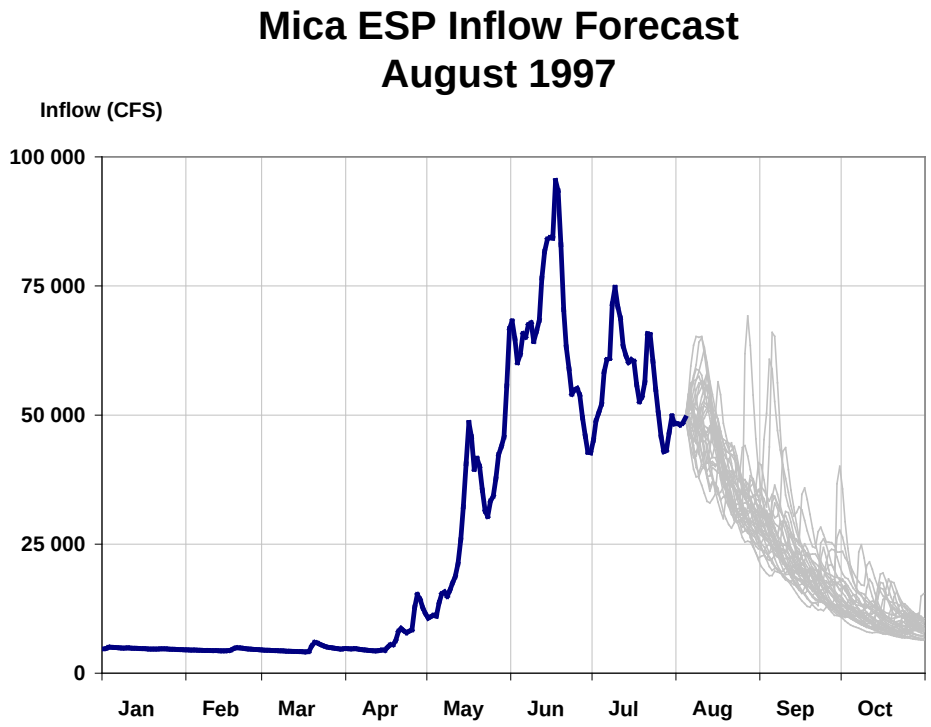

Figure 1 *Series of synthetic hydrographs produced using the ESP forecasting procedure. Forecast date is 01 August in the example*

The two forecasting methods have advantages and disadvantages over each other. One advantage of statistical procedures is that they are relatively easy to develop. They are also entirely objective; that is, forecasts are deterministic and consistent, regardless who prepares them. ESP forecasts produced by conceptual models may be subjective. For example, individual forecasters may adjust a model's basin state conditions differently in order to get the model to "track" observed flows to the forecast date. The subjective adjustments to basin state conditions can lead to different water supply forecasts. However, forecasts produced using conceptual models provide the best means available today for disaggregating seasonal runoff volumes into daily runoff distributions over the forecast period. These distributions are invaluable input to operational models required for Treaty projects.

INFLOW FORECASTS

DAILY AND WEEKLY

BC Hydro, BPA, and NWRFC independently produce daily inflow forecasts to assist in planning daily and weekly operations of Treaty facilities. The NWRFC provides the unregulated inflow forecasts to the USACE.

BC Hydro uses the UBC watershed model to produce daily reservoir inflow forecasts. The UBCWM is built into BC Hydro's River Forecast System (RFS) that was put into operation in 2002. Basin-state conditions, such as snow water equivalent and groundwater, are simulated in both models up to the day before the forecast date. Daily total precipitation, maximum temperature, and maximum freezing level are the model's forcing variables. Observed forcing variables over the past five days and quantitative precipitation, temperature, and freezing level forecasts (QPFs) over the coming five days are input to the model to forecast reservoir inflows over the combined ten-day period. At BC Hydro,

hydrologists produce five-day inflow forecasts for Mica, Arrow, and Duncan Reservoirs by noon of each working day.

The US Entities produce independent daily forecasts for Canadian and US projects from Mica to Bonneville Dam and on the Willamette River. BPA and NWRFC use the NWSRFS model to produce daily reservoir inflow forecasts.

The NWSRFS is a lumped physically-based model that uses mathematical equations to represent physical processes of the hydrologic cycle. The system consists of components that model snowpack, soil moisture, time of concentration of flow, reservoir operations, and river routing. The NWRFS has been calibrated for 178 sub-basins in the Columbia River basin above The Dalles. During calibration, as many as 40 years of mean areal precipitation and temperature data were used to develop model parameters.

In operational use, both the NWRFC and BPA use the NWSRFS independently. Observed and forecast weather data are input to the model. Precipitation and temperature data over the past 5 to 10 days are input. Hydrologists may make minor adjustments to model states and inputs to improve the simulated streamflow to better match observed flows. BPA meteorologists forecast future precipitation and temperature that hydrologists input to the model to generate streamflow forecasts. BPA produces daily forecasts in 6-hour time steps out 9 days into the future. The NWRFC forecast period from 3 to 10 days, depending on the time of year and circumstances.

Hydrologists use model output as primary guidance when issuing an inflow forecast. However, forecasters often use other available information and data, as well as their own experience, to adjust model output before issuing a forecast. The USACE accepts streamflow forecasts from the NWRFC and regulates inflows to meet project objectives.

MONTHLY

Monthly inflow forecasts are required for the AER and TSR models.

Currently, the USACE and BPA provide these forecasts to the AER and TSR modelers. During the January-to-July period, these monthly forecasts preserve the official water supply volume forecasts. In addition, the USACE and BPA submit the monthly hydrograph shape. The hydrograph shape is subject to coordination with the Entities. During the August-to-December period, the monthly shape and overall volume is provided by the submitting agency in coordination with the Entities.

Preparing monthly inflow forecasts is more subjective in many respects than preparing daily or water supply forecasts. The monthly shape is derived using various tools and models. The USACE uses a combination of the NWRFC's models and historic percentages. From January into the early spring, the USACE uses the unregulated inflows provided by the NWRFC for the first 45 days, then enters the residual volume into a spreadsheet, which evenly applies the same percentage to the remaining months through the end of July to derive the correct overall volume. Beginning in the early spring, the NWRFC provides an unregulated inflow forecast through the runoff season. The NWRFC forecast is generated using the National Weather Service's River Forecasting System (NWSRFS) model for the short (10-day) and longer-term (45-day) forecasts. The short-term forecasts utilize current antecedent conditions throughout the basin combined with 10-day precipitation and temperature forecasts. The longer-term forecasts are generated using the Ensemble Streamflow Predictor (ESP) component of the NWRFS model. With ESP, the current antecedent conditions are combined with historical meteorological data (temperatures and precipitation from 1948 to 1993) to generate a suite of 43 hydrographs. Statistics can then be applied to the hydrographs to look at potential water scenarios. In 2003, the NWRFC began providing the region a single hydrograph, nicknamed the Single Trace Procedure (STP), which used the 10-

day forecast plus mean temperature and precipitation generated from the historical meteorological data along with the observed antecedent conditions. The STP model run is usually designated for a minimum of 45 days into the future, but can be taken out 120 days if forecasters require it.

BPA also uses a combination of models and tools to arrive at a monthly hydrograph shape. During the January-through-July period, BPA updates a weekly time-step spreadsheet with observed flows on a weekly or semi-weekly basis. Forecasters may then distribute the residual volumes for each sub-basin in one of several ways:

- Apply a historical average shape
- Apply the average shape of NWSRFS ESP traces
- Extend the current hydrograph trend of observed flows
- Use historical month-to-month serial relationships
- Use a blend of the above procedures

Whichever method is used, the overall volume is maintained to match the official water supply forecasts. During the August-to-December period, monthly shaping only needs to be extended about two months into the future. Therefore, trending, historical month-to-month serial relationships, and ESP traces are usually used.