2012 Drought Exercise Report

Summary and Lessons Learned

September 2013

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ICPRB Report No. 13-9

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This report was prepared by the Interstate Commission on the Potomac River Basin, Section for Cooperative Water Supply Operations on the Potomac. Funds were provided for this report by the Washington Suburban Sanitary Commission, the Washington Aqueduct Division of the U.S. Army Corps of Engineers, and the Fairfax County Water Authority. The opinions expressed are those of the authors and should not be construed as representing the opinions or policies of the United States or any of its agencies, the several states, the Commissioners of the Interstate Commission on the Potomac River Basin, or the water suppliers.

The report is available online at www.PotomacRiver.org as ICP13-9_Ahmed.pdf.

Introduction

The Washington, D.C., metropolitan area (WMA) relies on the Potomac River to supply approximately three quarters of the water it uses. The region's three major water suppliers, Fairfax Water, the Washington Suburban Sanitary Commission, and the Washington Aqueduct Division of the U.S. Army Corps of Engineers (the "CO-OP suppliers"), participate in a unique cooperative management system that is designed to optimize use of available resources and ensure that ample water is available during periods of drought. This system includes joint funding of water supply storage in reservoirs located upstream of the CO-OP suppliers' Potomac River intakes and coordinated operations when flows in the river fall below specified thresholds.

The Section for Cooperative Water Supply Operations on the Potomac (CO-OP) of the Interstate Commission on the Potomac River Basin (ICPRB) helps manage this system by coordinating WMA water withdrawals from the Potomac River and off-river reservoirs during droughts. CO-OP also recommends releases from upstream reservoirs when forecasted flow in the river is not sufficient to meet expected needs. These needs include WMA demands and an environmental flow-by of 100 million gallons per day (MGD) on the Potomac River at Little Falls dam near Washington, D.C.[1]

Each year when flows are at or above normal, CO-OP conducts a drought exercise. These exercises allow participants to practice and improve communication procedures among organizations. They also provide ICPRB's CO-OP staff with an opportunity to practice using operational tools and making management decisions, and to explore the effects of different management strategies. This ensures that during an actual drought all stakeholders are properly trained and key operational strategies have been discussed and tested beforehand.

This report describes activities and results of the 2012 drought exercise, which took place from September 26 through October 2. Participants in this year's exercise include staff from:

- ICPRB CO-OP Section
- The Washington Aqueduct – a Division of the U.S. Army Corps of Engineers (Aqueduct), which supplies water to the District of Columbia via DC Water, and to parts of Virginia
- The Washington Suburban Sanitary Commission (WSSC), which supplies water to Montgomery and Prince Georges counties in Maryland, and on a limited basis to other parts of Maryland
- Fairfax County Water Authority (Fairfax Water), which supplies water to Fairfax County, Virginia, and provides wholesale water to other suppliers in northern Virginia
- Loudoun County Water Authority (Loudoun Water), a wholesale customer of Fairfax Water with plans to construct a Potomac River intake and water treatment plant to provide a portion of its future supply

[1] A complete discussion of CO-OP drought operations can be found in the report, 2010 Washington Metropolitan Area Water Supply Reliability Study; Part 1: Demand and Resource Availability Forecast for the Year 2040, S.N. Ahmed, K.R. Bencala, and C.L. Schultz, ICPRB Report No. 10-01, May 2010, available at www.potomacriver.org under "Publications."

- U.S. Army Corps of Engineers (USACE), Baltimore District
- Metropolitan Washington Council of Governments (MWCOG)

This year's exercise included simulated operations of planned Loudoun Water facilities for the first time. While currently a wholesale customer of Fairfax Water, Loudoun Water has received a Virginia water appropriations permit and plans to construct a water treatment plant and Potomac River intake and to re-purpose a quarry for water supply storage (referred to as Quarry A). Depending on the extent of future participation by Loudoun Water in CO-OP operations, the proposed quarry could significantly increase the reliability and flexibility of the region's water supply system.

This year's exercise included the following elements:

- A conference call of the regional Drought Coordination Technical Committee to discuss potential water use restrictions.
- Use of CO-OP's daily flow prediction tool to determine the need for releases from Little Seneca Reservoir.
- Communication and coordination with Loudoun Water on simulated withdrawals, discharges, and storage, under the exercise scenario assumption that Loudoun had become a signatory to a set of agreements making them a full participant in the region's cooperative water supply management system.
- Development of a preliminary relationship between Edwards Ferry (EF) water level data and Little Falls flow data for future use in flow prediction tools.

CO-OP System

The Potomac River is the primary source of raw water for the CO-OP suppliers, who each have an intake on the river upstream of Little Falls dam. Fairfax Water also relies on stored water in the Occoquan Reservoir. Likewise, WSSC relies on water from a pair of reservoirs in the Patuxent River watershed: Rocky Gorge and Tridelphia (see map in Figure 1). Aqueduct has intakes at two locations on the Potomac River: Little Falls and, several miles upstream, at Great Falls. In addition, these three suppliers jointly own storage in two reservoirs located upstream of their Potomac River intakes: Jennings Randolph (JRR), which is operated by the U.S. Army Corps of Engineers, and Little Seneca, operated by WSSC. They pay a portion of the operations and maintenance costs of a third upstream reservoir, Savage. This storage is available to augment Potomac River flow during low-flow periods.

The CO-OP suppliers participate in a cooperative system of water supply planning and management that is based on a set of agreements entered into more than 30 years ago. The Low Flow Allocation Agreement (LFAA) of 1978 provides for the allocation of water during shortages. The Water Supply Coordination Agreement (WSCA) of 1982 commits the three suppliers to operate "in a coordinated manner" to optimize the use of available resources and specifies that water demand and availability forecasts be conducted every five years. Also in 1982, the water suppliers signed a set of agreements that provide for joint funding of water supply storage in upstream reservoirs.

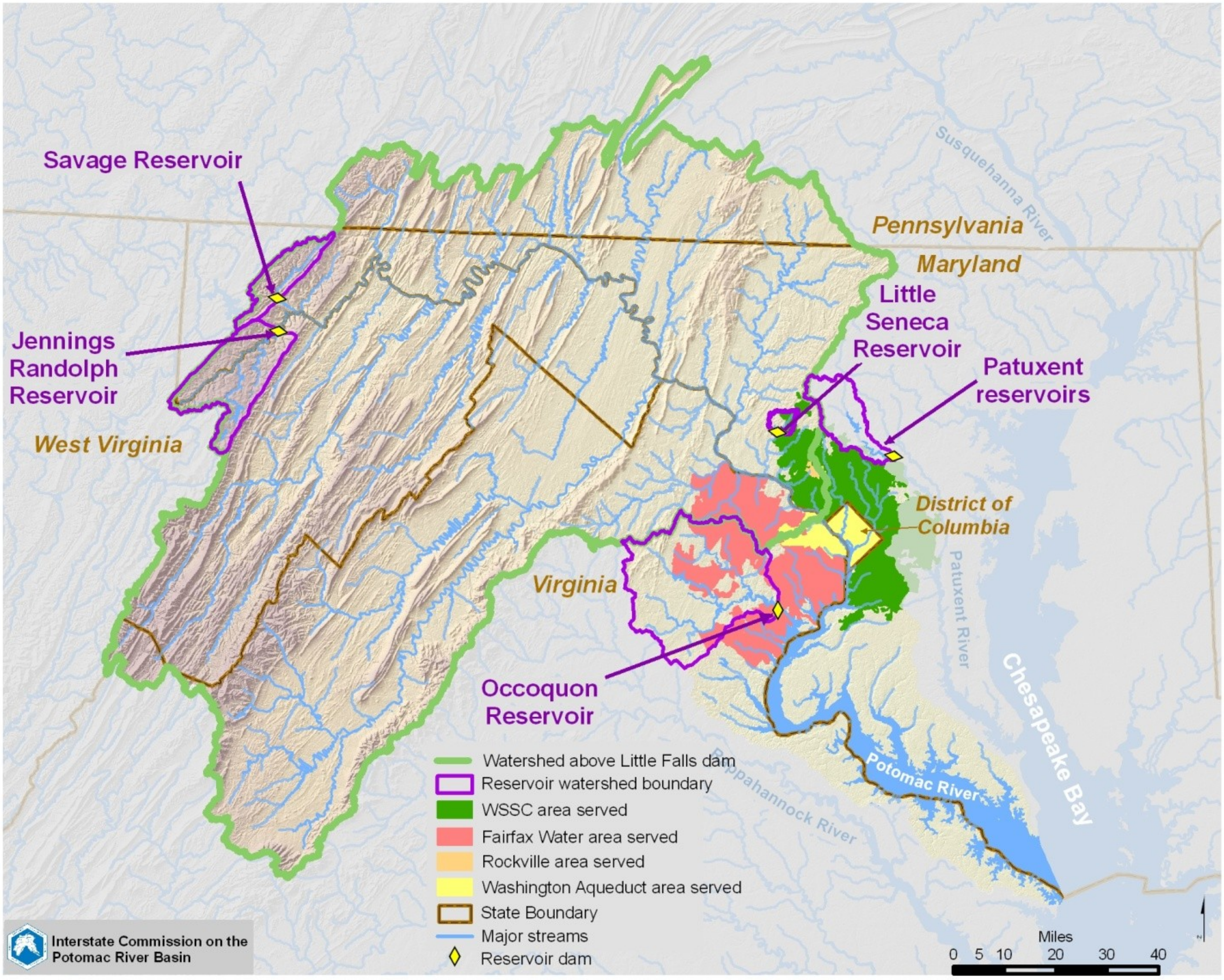

Figure 1 – WMA water supplies

Exercise Scenario

The exercise scenario was based on the drought of 1930, which is the historical drought of record for the CO-OP system. CO-OP's Potomac Reservoir and River Simulation Model (PRRISM) was used to simulate Potomac River flows for use in CO-OP's daily flow prediction tool. Historic flow data and CO-OP forecasts of demands in the year 2022 were used as inputs for the simulation. The following description was distributed to exercise participants to set the stage for the exercise:

Today's date is August 21, 2022. A widespread and severe drought is gripping much of the nation, including the mid-Atlantic region. A dry winter and spring were followed by an extremely dry summer, with precipitation in the basin over past three months totaling only 55% of normal. In the first three weeks of August, the basin has received only half of an inch of rain. Total July and August demands of the *four[2] CO-OP utilities have ranged from 630 to 780 million gallons per day (MGD). Below is a timeline of CO-OP-related activities and events over the course of the drought:*

1. *July 8: CO-OP began drought operations, including twice daily reporting of recent withdrawals and forecasted demands, when adjusted flow at Little Falls (observed flow plus Washington metropolitan area Potomac withdrawals) minus the 100 MGD Little Falls flow-by fell below twice Potomac withdrawals.*
2. *July 15: Water supply releases were initiated from Jennings Randolph and Savage reservoirs.*
3. *July 17: Flow at Little Falls fell below the threshold for the LFAA Restriction Stage. A conference call took place between the General Managers of the CO-OP utilities. On that call, the General Manager of Washington Aqueduct, in consultation with the General Managers of WSSC, Fairfax Water, and Loudoun Water, decided not to declare a Restriction Stage. However, it was agreed that this decision would be reviewed if and when reservoir storages fell to a level triggering the "Warning Stage" of the Metropolitan Washington Water Supply and Drought Awareness Response Plan, which calls for voluntary restrictions in the Washington metropolitan area.*
4. *July 27: First release was made from Little Seneca Reservoir. Prior to this date, the Montgomery County Executive and County Council, the Maryland-National Capital Region Park and Planning Commission, and staff at Black Hill Regional Park were informed that reservoir releases would likely occur in the coming weeks.*
5. *August 21 – Day 1 of the exercise: Yesterday's release from Jennings Randolph Reservoir water supply was approximately 180 MGD, with a corresponding Luke flow target of 400 cubic feet per second (cfs). No releases have been made from Little Seneca Reservoir in the past several days. Combined Jennings Randolph and Little Seneca water supply storage is approaching 60% capacity, the threshold for the Washington metropolitan area drought plan "Warning Stage." This morning's system storages are reported to be as follows:*

Beginning Reservoir Storages (usable)

Reservoir	Capacity* (BG)	Current (BG)	% Full
Jennings Randolph – Water quality storage	14.2	9.9	70%
Jennings Randolph – Water supply storage	11.4	7.0	61%
Savage	5.9	3.0	51%
Little Seneca	3.5	2.5	71%
Quarry A	1.02	0.66	65%
Occoquan	7.3	4.6	63%
Patuxent	9.8	5.0	51%

**Year 2022 reservoir storage capacities reflect projected losses due to sedimentation, as estimated in 2010 Washington Metropolitan Area Drought Operations - Summary and Lessons Learned, S.N. Ahmed, K.R. Bencala and C.L. Schultz, Interstate Commission on the Potomac River Basin, Rockville, Maryland, 2011, ICPRB Report No. 11-04.*

Simulated Drought Operations

Simulated drought operations were conducted over a seven-day period, including weekends. The actual dates of the exercise were Wednesday, September 26, through Tuesday, October 2, 2012; the simulated dates were August 21 through August 28, 2022. Data used to construct the simulated flow were taken from one of the most severe weeks of the drought of 1930. Simulated operations included twice daily

[2] *Loudoun Water became a signatory of a new regional water supply coordination agreement and the Low Flow Allocation Agreement in 2019. Quarry A went into service in January of 2021.*

reports from CO-OP utilities and from Loudoun Water on recent withdrawal rates, forecasted demands, and reservoir storage levels. CO-OP distributed morning and afternoon e-mail updates on flow conditions, actual and estimated withdrawal rates, and operational recommendations for each utility and reservoir.

Key operational goals for CO-OP staff during droughts are:

- Maintaining Potomac River flow at Little Falls dam, as measured by the U.S. Geological Survey (USGS) gage (Station ID 01646500), at or above the 100 MGD (155 cfs) environmental flow-by.
- Maintaining estimated flow at Great Falls, located approximately 9.3 river miles upstream of Little Falls, at or above the recommended minimum flow of 300 MGD (464 cfs). Estimated travel time between Great Falls and Little Falls during extremely low flow conditions is nine hours.
- Balancing use of storage in system reservoirs to ensure that adequate storage is maintained in each reservoir to sustain expected withdrawals throughout the remainder of a severe drought, and to ensure a 95 percent probability of refill to 90 percent capacity by June 1 of the following year.

To estimate future Potomac withdrawals for input into flow prediction tools, CO-OP staff develops withdrawal scenarios for both the Potomac River and off-Potomac reservoirs. These scenarios may require load shifts by the water suppliers to and from Potomac River and reservoir intakes. Scenarios are based on estimates of near-term demands, estimates provided by the water suppliers, and historic data for the month of August.[3]

Load shifting, that is, the shifting of some portion of a supplier's withdrawal from one intake to another, is sometimes requested by CO-OP staff during droughts to help meet operational goals. Each of the WMA suppliers has two intakes. Fairfax Water and WSSC both have one intake on the Potomac River and one off-Potomac intake (at the Occoquan and the Patuxent reservoirs, respectively). Aqueduct has two intakes on the Potomac River: one at Great Falls and one at Little Falls. Load shifting requires close communication between ICPRB CO-OP and water supplier staff.

Load-shifting by Fairfax Water

Fairfax Water has two water supply sources, the Potomac River and Occoquan Reservoir. Fairfax Water's Potomac and Occoquan supplies are treated and feed into a single interconnected transmission and distribution system. The Potomac source primarily feeds northern and western areas while the Occoquan supplies the south and east. Available transmission capacity defines the amount of water that may be transferred between the different areas.Raw water withdrawn from the Potomac River is treated by Fairfax Water's Corbalis water treatment plant (WTP) which has a maximum capacity of 225 MGD. Raw water withdrawn from Occoquan Reservoir is treated by their Griffith treatment plant, which has a maximum capacity of 120 MGD. The Corbalis plant supplies treated water primarily to the Potomac service area, but up to 65 MGD of this water can be fed into the distribution system of the Occoquan service area. Conversely, the Griffith plant supplies treated water primarily to the Occoquan service area, but up to 35 MGD can be pumped to the Potomac service area. In 2012 the Corbalis plant

[3] However, for the 2012 drought exercise CO-OP flow prediction tools were loaded with 2002 withdrawal data for consistency with Potomac-OASIS model results.

provided 58% of Fairfax Water's total production and the Griffith plant provided 42%. This split is also reflective of the last 5-year period (private communication, Greg Prelewicz, Aug 19, 2013).

At the start of the exercise, the simulated production at Fairfax Water's Griffith plant was 100 MGD, with a corresponding withdrawal from Occoquan Reservoir of 112 MGD, accounting for production losses. In the afternoon of Day 1 of the exercise, CO-OP staff requested that Fairfax Water shift additional demand from its Corbalis WTP to its Griffith WTP in order to reduce Potomac River withdrawals. CO-OP was informed by Joel Thompson, Fairfax Water's Director of Production, that actual Occoquan service area demand was about 70 MGD, so if Griffith was producing 100 MGD this implied that the full 30 MGD shift from Griffith to the Potomac service area was already occurring, and no further shift was possible. However, it was agreed that since the exercise scenario month was August, Occoquan service area demands would likely be closer to 80 MGD, and a shift of an additional 10 MGD from Corbalis to Griffith was reasonable. Thompson also mentioned that Fairfax Water is planning to make improvements to its distribution system that would potentially allow greater shifts by the year 2022.

Load-shifting by WSSC

WSSC's distribution system has considerable flexibility and can implement load shifts between its Potomac and Patuxent WTPs quickly. Though, the load shifts are subject to the constraints of the Patuxent plant's minimum and maximum production rates of 30 and 65 MGD, respectively. At the start of the exercise, simulated storage in the Patuxent reservoirs, at 51 percent capacity, was significantly lower than in most other system reservoirs, and CO-OP staff recommended that Patuxent withdrawals be maintained at the minimum rate of 30 MGD to preserve storage. During several days of the exercise, due to falling flows in the Potomac River, WSSC was asked to temporarily shift an additional 30 MGD of demand to the Patuxent in order to help maintain the Great Falls flow-by.

Load-shifting by Washington Aqueduct

One of CO-OP's operational targets is a recommended flow minimum of 300 MGD (464 cfs) between Great Falls and Little Falls. This stretch of the river, approximately 9.3 miles in length, contains relatively unique and rare biological communities.[4] During droughts, CO-OP staff may request that Washington Aqueduct shift part or all of its withdrawal from its Great Falls intake downstream to its Little Falls intake in order to maintain flow at or above this minimum level. Because there is no stream gage at Great Falls, flow between Great Falls and Little Falls is estimated to be the sum of observed flow at Little Falls and Washington Aqueduct's withdrawal at Little Falls, with an adjustment made to account for the travel time between Great Falls and Little Falls (which has been estimated to be nine hours during very low flow conditions). CO-OP drought operation spreadsheets include computations and graphs of estimated flow at Great Falls.

[4] Cummins, J.D., Claire Buchanan, Carlton Haywood, Heidi Moltz, Adam Griggs, R. Christian Jones, Richard Kraus, Nathaniel Hitt, Rita Villella Bumgardner. 2011. "Potomac Basin Large River Environmental Flow Needs" prepared for The Nature Conservancy of Maryland and the District of Columbia and the National Park Service. ICPRB Report 10-3.

Simulated flow at Little Falls during the drought exercise ranged from 130 to 200 MGD. Therefore, throughout the exercise Washington Aqueduct was requested to withdraw the majority of its water from Little Falls. Because there are pumping costs associated with water withdrawals from Little Falls, Washington Aqueduct prefers under normal conditions to withdraw water from Great Falls.

CO-OP operational spreadsheets contain an empirical formula relating Great Falls intake gate settings to flow through the Great Falls conduit. During the exercise, Washington Aqueduct staff was asked if there were any constraints on withdrawals at Great Falls or Little Falls during low flow conditions. We were informed that the lowest gate setting they can use is 0.5 feet. Beyond that, they would just close both of the gates and meet all demands from Little Falls (Ricky Davie, September 27, 2012). A note of this constraint was made on the "OperationsGuide" page of the daily operations tool. The gate setting formula will be adjusted to reflect this constraint.

Little Seneca Release

A simulated release from Little Seneca was initiated on the third day of the exercise, August 23, 2022. Contact was made with Black Hills Regional Park staff to remind them of potential releases during low flows and to verify contact information.

Use of Loudoun Water's Quarry A

Because Loudoun Water is not actually part of the CO-OP system, operating policies for use of Quarry A in conjunction with other CO-OP system resources have not been developed. However, preliminary simulations with ICPRB's PRRISM model indicate that restricting use of Quarry A to times when flows drop to levels that require, or are close to requiring, a Little Seneca Reservoir release provides benefits to both Loudoun Water and to the CO-OP utilities. CO-OP staff used this as a guideline for simulated operation of Quarry A in the 2012 drought exercise.

Based on input from Loudoun Water, CO-OP assumed that 15 MGD was the production rate of the planned Loudoun Water WTP in the year 2022, and that Loudoun's Broad Run water reclamation plant was discharging 6 MGD. During the exercise Loudoun Water also estimated that a load shift from the Potomac River to Quarry A would take approximately four hours to implement (Thom Lipinski, 9/28/12).

On Day 2 of the exercise, because simulated flow at Little Falls was near the level requiring a release from Little Seneca, CO-OP requested a withdrawal of 5 MGD from Quarry A. On Day 3, simulated flow at Little Falls had fallen further, to approximately 130 MGD, which is equal to the Little Falls flow-by plus 30 MGD. CO-OP's flow forecast model, based on data from the Point of Rocks and other upstream gages, predicted that flow would continue to fall over the next several days. Therefore, CO-OP initiated a Little Seneca release of 30 MGD. At the same time, Loudoun Water was requested to increase their water treatment plant production from 15 MGD to 20 MGD, their maximum capacity, and increase their withdrawal from Quarry A from 5 to 20 MGD. These actions would provide an additional 15 MGD increase in flow at Little Falls, and would reduce the amount of Loudoun's purchased water (from Fairfax) by 5 MGD.

This request to maximize use of Quarry A was consistent with simulated efforts being made by the other utilities. WSSC and Fairfax Water had increased their off-Potomac withdrawals to the maximum rates feasible: WSSC producing 60 MGD from its Patuxent plant and Fairfax Water producing 110 MGD from its Griffith plant. Also, Washington Aqueduct had shifted all of its withdrawals to Little Falls in order to preserve the Great Falls flow-by. It was emphasized by CO-OP staff that these operations were expected to be temporary and that forecasted precipitation should allow a shift of more load back to the Potomac River, and to Great Falls, sometime in the next several days.

This exercise demonstrated that Quarry A could provide benefits to the CO-OP system by helping meet operational goals. Under the drought exercise assumption that Loudoun's WTP would typically operate at a rate of 15 MGD and withdraw approximately 15 MGD from the river, purchasing the remainder of their demand from Fairfax Water, a request to cease withdrawals from the river and increase production from 15 to 20 MGD would provide a net change in flow of 20 MGD. Thus, use of the quarry, coordinated with use of other off-Potomac resources, could provide significant assistance in meeting the Potomac River minimum flow target of 100 MGD at Little Falls and the Great Falls recommended minimum of 300 MGD.

Institutional Responses

Washington Metropolitan Area Drought Plan

The Washington metropolitan area developed a coordinated drought response plan, the *Metropolitan Washington Water Supply and Drought Awareness Response Plan: Potomac River System* (MWCOG, 2000) following the 1999 drought. During this drought, messages between states, local jurisdictions, and water suppliers were not coordinated which led to much confusion on the part of the public about drought conditions and water use restrictions. The various jurisdictions and suppliers addressed this problem with a regional response plan that is coordinated by the Metropolitan Washington Council of Government. This plan details various triggers, actions, and messages for three water restriction stages (Watch, Warning, and Emergency) to be implemented in the MWCOG region covering the Maryland and Virginia suburbs of Washington.

Drought stages are declared by the Drought Coordination Committee (DCC), whose members consist of Chief Administrative Officers from MWCOG's 21 member governments, the general managers of area water utilities, water supply officials from the Maryland Department of the Environment (MDE) and the Virginia Department of Environmental Quality (DEQ), and ICPRB CO-OP staff. The DCC is supported by staff from MWCOG, NOAA's Climate Prediction Center (CPC), and the USGS. Technical support for DCC decisions is provided by the DCC's Drought Coordination Technical Committee (DCTC), which consists of staff from the DCC member agencies.

The Watch stage can be declared when the NOAA CPC indicates D1 drought intensity level (moderate drought) for most of the Potomac basin. The Warning stage can be declared when the combined water supply storage at Jennings Randolph and Little Seneca reservoirs has dropped to 60 percent of capacity for five consecutive days with five percent probability of not being able to meet unrestricted water supply demands over the next one to two months. The Emergency stage is declared when there is a 50 percent probability of not being able to meet water supply demands over the next month. The drought response plan calls for voluntary reductions in water use during the Watch and Warning stages and mandatory restrictions in the Emergency stage. A table detailing each of the stages can be found at http://www.mwcog.org/pdf/drought-plan-response_plan.pdf.

Application to 2012 Drought Exercise

On the first day of this year's exercise, combined water supply storage at Jennings Randolph and Little Seneca reservoirs was 63 percent of capacity. This level is close to the 60 percent trigger for the Warning stage in the regional drought response plan. These simulated conditions prompted Fairfax Water General Manager Charles Murray to request a call of the DCTC. This call, coordinated by COG, was held on the third day of the exercise as simulated storage continued to drop in all the region's reservoirs.

On the DCTC call, updates on conditions and operations were given by ICPRB CO-OP, water utilities, state agencies, and USGS. Both MDE and DEQ reported that given the severe conditions of the exercise scenario, their states would already be in an emergency stage with mandatory water use restrictions in place. For Maryland this would cover western and central portions of the state. WSSC would be exempt from these restrictions since they are part of the regional MWCOG plan.

The discussion on the states' declaration of drought stages pointed to a need for future discussion on how drought response activities under the Washington metropolitan area regional plan and under Virginia's drought plan can be coordinated. In 2003, a Drought Response Technical Advisory Committee, chaired by the Virginia Department of Environmental Quality, developed a statewide drought plan which was accepted by the Commonwealth's Administration in 2004.[5] According to this plan, drought stages may be declared either state-wide or by region by the Virginia Drought Coordinator, or, in the case of a Drought Emergency, by the Governor, under recommendation by the Virginia Drought Monitoring Task Force.

Another issue raised on the call for further consideration is whether or not the Little Falls flow-by buffer would be reduced when flows get very close to 130 MGD, acknowledging that this would make it more likely that the flow-by could be missed. The time period over which the flow should be calculated is not clear. In the LFAA, the flow-by requirement refers to a 100 MGD flow-by, but does not specify if this is an instantaneous rate or a daily average.

There was a brief discussion of whether or not the Restriction Stage of the LFAA should be declared. It was generally agreed that because Maryland and Virginia would already be under mandatory restrictions, declaration of the Restriction Stage would not have much of an impact on river flows.

The outcome of the DCTC call was a simulated recommendation to the DCC that a Warning stage be declared after combined water supply storage at Jennings Randolph and Little Seneca reservoirs had

[5] Virginia Drought Assessment and Response Plan, Virginia Department of Environmental Quality, 2004.

remained below 60 percent capacity for five days. In practice, this decision would be accompanied by a press release and media call.

Low Flow Water Use Restrictions

The scenario used for this exercise assumed that the region was in the grip of a prolonged and serious drought, with flows in the Potomac River comparable to those experienced during the drought of record. Hydrologic conditions of this severity have not been experienced since the current cooperative water supply system was put in place 30 years ago, so the exercise provided an opportunity to explore other institutional responses that would likely be triggered during such a drought. CO-OP and the member utilities developed a table of all the various thresholds, subsequent actions, and responsible parties that may apply during low flow conditions (see Appendix A). In order to complete this table a number of agreements and state regulations were reviewed. Highlights of this review are below.

Low Flow Allocation Agreement Restriction Stage and the C & O Canal

The exercise scenario specifically noted that the threshold for the Restriction Stage of the LFAA had been crossed on July 17, 2022, but that the general managers of the WMA water suppliers had decided not to declare the Restriction Stage at that time. A review of this decision was a topic for discussion on the DCTC call. Modification 2 of the LFAA states that when the Restriction Stage is declared Washington Aqueduct "will request the U.S. Park Service to discontinue putting Potomac River water into the C&O Canal." However, it should also be noted that the LFAA Memorandum of Intent[6] states that "In recognition of the need of the C & O Canal National Historic Park for minimal amounts of water to maintain the integrity of structures, the National Park Service will not be obligated to consider a complete cutoff of its intakes until such time as the Washington Aqueduct determines it necessary to invade the environmental flow-by amount. Whenever the Restriction Stage is in effect and following a request by the Washington Aqueduct, the National Park Service will consider means of reducing the demand for water withdrawal by the C & O Canal National Historic Park from the subject portion of the river consistent with the preservation of the Park's resources."

CO-OP staff contacted Superintendent Kevin Brandt of the C & O Canal National Historical Park to learn about how and where the canal is watered and how this might be reduced if the Restriction Stage were declared (September 27, 2012). The canal is watered in six locations along its 184.5 mile length from Washington to western Maryland. These locations, along with the methods of diverting water from the river to the canal and information on consumptive losses due to these diversions, are described in Appendix B.

Preliminary Stage-Discharge Relationship for Edwards Ferry Water Level Monitor

During droughts, CO-OP staff must forecast flow in the Potomac River in order to make the operational decisions necessary to meet demands and environmental flow needs. However, flow forecasting is

[6] Memorandum of Intent. From Drake Wilson, Brigadier General, USA, Acting Director of Civil Works. To James A. Joseph, Under Secretary of the Interior. July 20, 1978.

challenging during low flow conditions. CO-OP's flow forecasts rely on measurements of flow, also referred to as discharge, at stream gage stations operated by the USGS. Flow is only measured at a limited number of locations on the river. These measurements are often subject to increasing errors as flows fall due to the growth of submerged aquatic vegetation and other factors. Also, physical processes which may have a significant effect on flow during periods of drought, such as water losses, are poorly understood. For these reasons, CO-OP staff has an interest in increasing the amount and quality of flow data available upstream of the WMA water supply intakes.

A new station on the Potomac River was established by the USGS on August 24, 2011, at Edwards Ferry near Poolesville, Maryland, with funding from the CO-OP water suppliers (USGS Station Number 01644148). The location of this station is shown on the map in Figure 2. Edwards Ferry is currently a stage-only station. That is, it measures stage, or water level, in the river, but the data is not used by the USGS to estimate discharge. In order to develop relationships allowing a conversion of stage measurements to discharge values, the USGS typically collects stage and discharge data for a range of flow conditions. This is currently not done at the Edwards Ferry station due to uncertainty about the potential quality of the low flow portion of a stage-discharge relationship. However, if analyses of the Edwards Ferry stage data indicate that useful stage-discharge tables can be developed, the station may in the future be converted to a station which reports both stage and discharge.

One of the tasks of the 2012 drought exercise was to analyze available data from the Edwards Ferry station and develop a preliminary stage-discharge relationship for potential use in CO-OP flow forecast tools. Unfortunately, from the point of view of this analysis, flows in the river have been for the most part in the moderate to high range since the establishment of the USGS's Edwards Ferry station in August of 2011. Therefore, the analysis below provides only a very approximate relationship between stage and discharge during low flow periods.

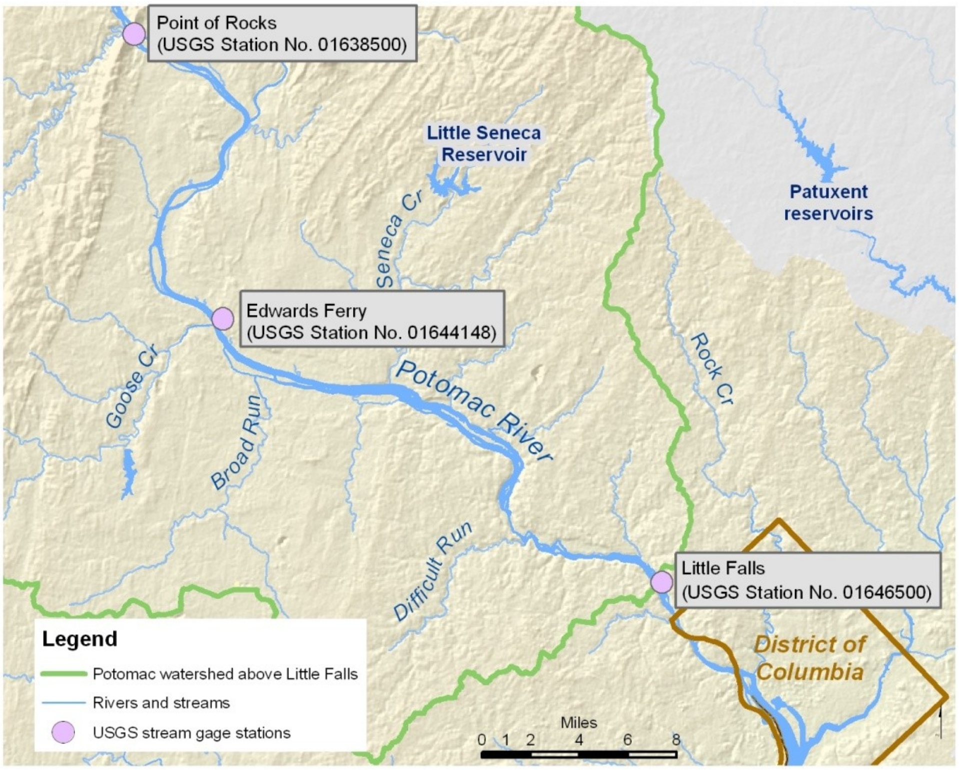

Figure 2 – Map showing USGS stream gage stations on the Potomac River upstream of the District of Columbia

The relationships developed below were based on stage measurements at Edwards Ferry and corresponding discharges reported at a downstream location, Little Falls dam near Washington, D.C (USGS Station Number 01646500). Hydrographs at the two locations were reviewed, corresponding peaks were identified, and travel times of these peaks from Edwards Ferry to Little Falls were computed. The distance in river miles from Edwards Ferry to Little Falls is approximately 26.3 miles. Observed travel times were computed as the difference between the times of the corresponding peaks at Edwards Ferry and Little Falls. Table 1 below contains data and results from this analysis. The modeled travel times are based on the empirical relationship between travel time (days) and flow (cfs), Q (see Figure 3),

$$\text{Travel time} = 17.7\, Q^{-0.41}$$

where the exponent and multiplicative factor were determined by finding the best fit of the above functional form to the data, using Microsoft Excel's Solver package.

Similarly, modeled travel times as a function of gage height, D (feet), are given by (see Figure 4)

$$\text{Travel time} = 15.0\, D^{-2.0}$$

Finally, based on the data in Table 1, the empirical relationship between gage height at Edwards Ferry and flow at Little Falls (appropriately lagged) is (see Figure 5)

$$\text{Little Falls flow} = 3619 - 2155\, D + 513\, D^2$$

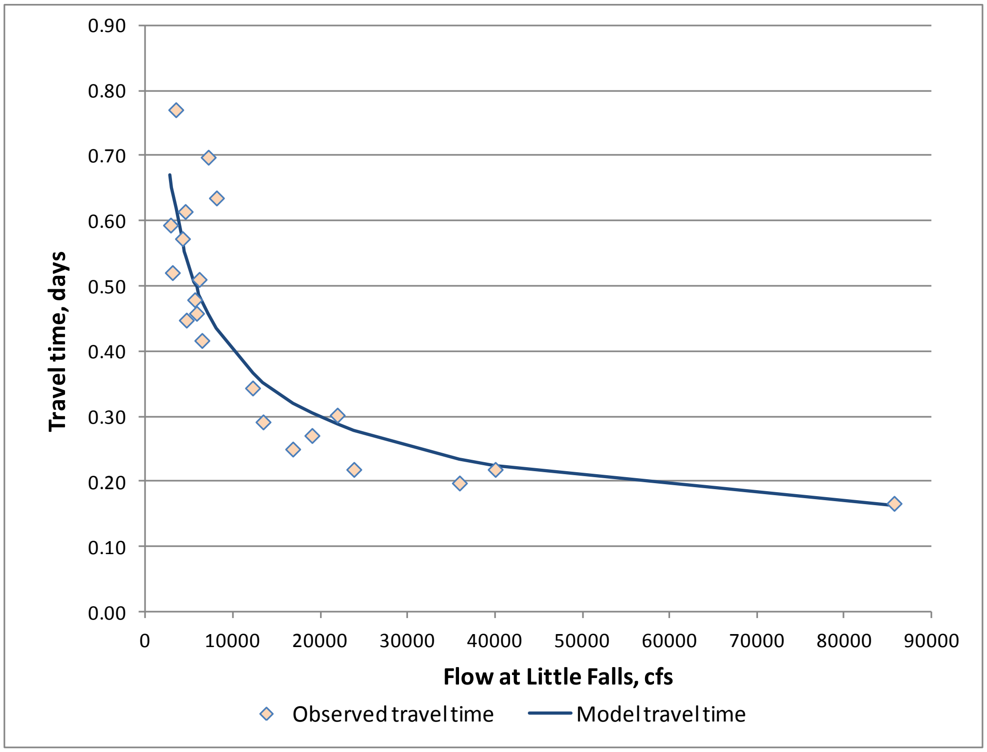

Figure 3 – Observed and modeled travel times as a function of flow at Little Falls.

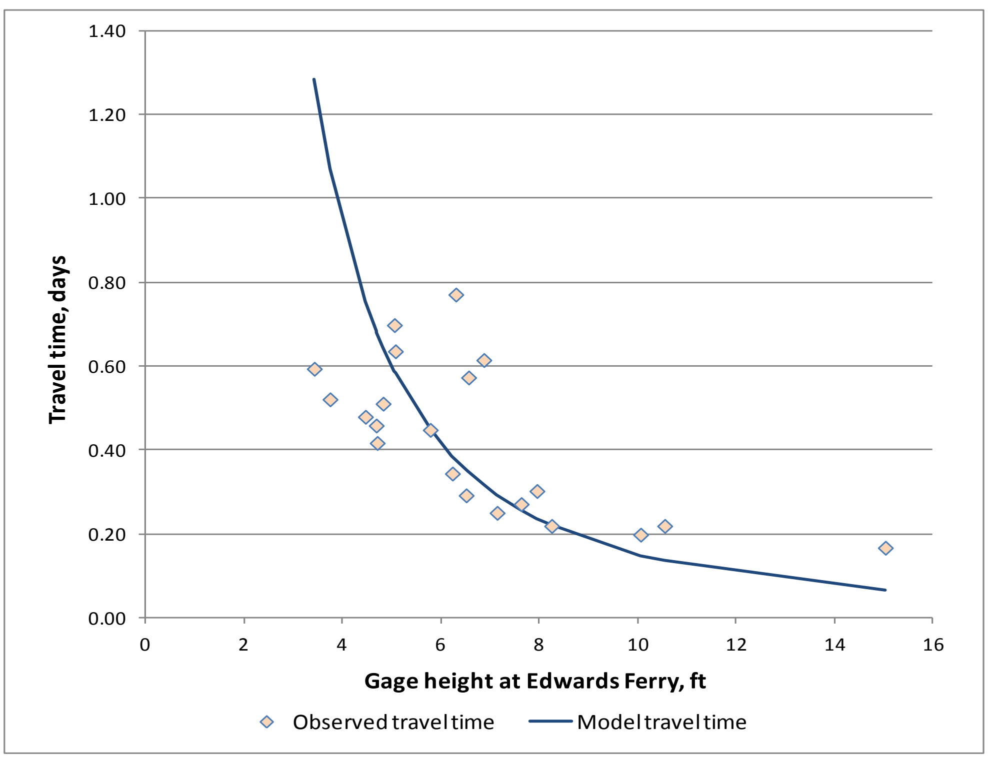

Figure 4 - Observed and modeled travel times as a function of water level at Edwards Ferry.

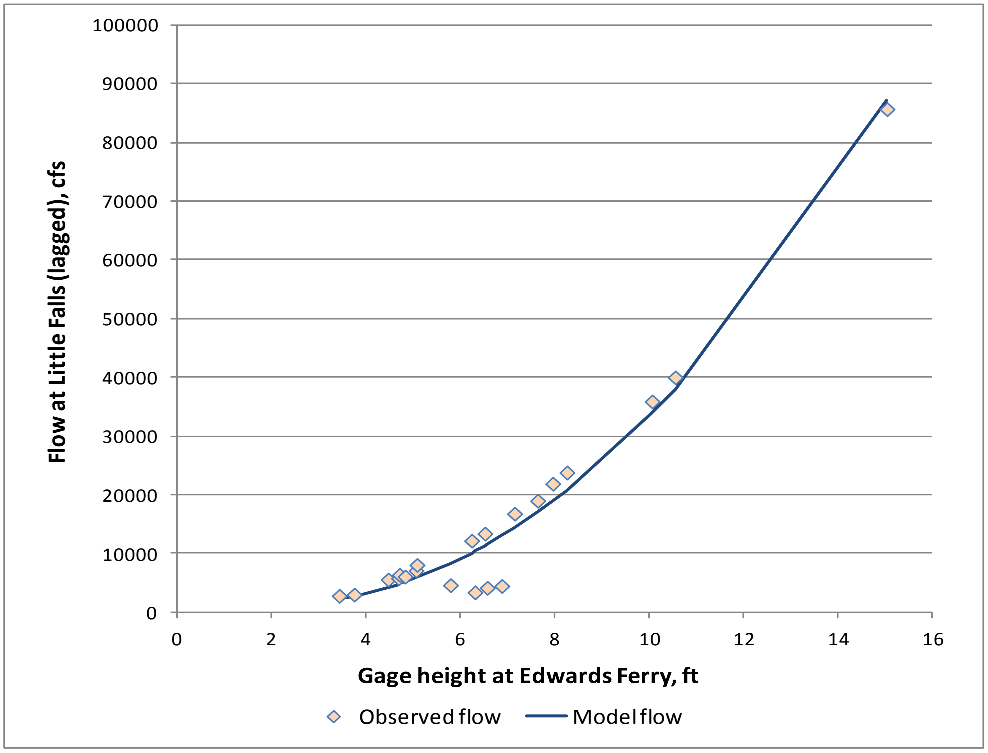

Figure 5 – Observed and modeled relationship between Edwards Ferry stage and flow at Little Falls.

Table 1 – Data for Edwards Ferry analysis

Edwards Ferry peak		Little Falls peak		Observed travel time, days	Modeled travel time, days	Comment on identification of corresponding peaks
Date and Time	Gage ht., feet	Date and Time	Discharge, cfs			
8/30/2011 1:15	3.42	8/30/2011 15:30	2800	0.59	0.67	
9/11/2011 5:30	10.06	9/11/2011 10:15	35900	0.20	0.23	
9/16/2011 23:45	6.51	9/17/2011 6:45	13400	0.29	0.35	
9/19/2011 5:00	5.05	9/19/2011 21:45	7120	0.70	0.46	rough estimate - really flat
9/20/2011 8:15	4.70	9/20/2011 18:15	6390	0.42	0.48	rough estimate - really flat
9/21/2011 10:15	4.46	9/21/2011 21:45	5570	0.48	0.51	rough estimate - really flat
9/23/2011 0:00	6.23	9/23/2011 8:15	12200	0.34	0.37	good
9/24/2011 17:15	7.14	9/24/2011 23:15	16800	0.25	0.32	good
9/30/2011 1:15	7.63	9/30/2011 7:45	19000	0.27	0.30	
11/24/2011 13:00	15.04	11/24/2011 17:00	85700	0.17	0.16	
1/14/2012 16:00	10.55	1/14/2012 21:15	40000	0.22	0.22	
1/28/2012 16:15	7.95	1/28/2012 23:30	21900	0.30	0.29	
5/9/2012 20:00	5.07	5/10/2012 11:15	8060	0.64	0.43	
6/14/2012 10:15	4.68	6/14/12 21:15	5780	0.46	0.50	rough estimate - really flat
6/2/12 12:30	8.25	6/2/12 17:45	23800	0.22	0.28	poor
7/1/2012 0:45	3.74	7/1/12 13:15	3010	0.52	0.65	
7/20/2012 18:30	4.82	7/21/12 6:45	6080	0.51	0.49	
9/4/2012 7:30	6.30	9/5/12 2:00	3400	0.77	0.62	rough estimate - really flat
7/29/12 6:15	5.78	7/29/12 17:00	4610	0.45	0.55	no peaks in Monocacy, Goose, Seneca
8/29/12 6:00	6.56	8/29/12 19:45	4170	0.57	0.57	
9/6/10 21:30	6.87	9/7/10 12:15	4480	0.61	0.55	

Lessons Learned and Action Items

The following is a list of lessons learned and action items from the exercise. Most of the action items are tasks for ICPRB staff. However, the last item on this list falls under the purview of the MWCOG.

- ICPRB: Adjust the empirical formula relating Great Falls intake gate settings to flow through the Great Falls conduit in CO-OP operational spreadsheets to reflect the minimum gate setting of 0.5 feet. (Beyond that level, Aqueduct staff has said they would just close both of the gates and meet all demands from Little Falls.) Also, note this constraint on the "OperationsGuide" page of the daily operations tool.
- ICPRB: Continue to discuss with suppliers the potential constraints on load shifting and strategies for reducing variability in Potomac River withdrawals during drought operations.
- ICPRB: Re-evaluate the 30 MGD buffer at Little Falls, and in particular, the relationship between the value of the buffer and the risk of flow dropping below the 100 MGD flow-by.
- ICPRB: Design a future drought exercise to focus on water use reduction requirements in current state water appropriation permits and potential impact on drought flows.
- ICPRB: Add combined Jennings Randolph water supply and Little Seneca storage to email report template.
- ICPRB: Add C&O Canal Superintendent Kevin Brandt to daily and enhanced monitoring email lists.
- ICPRB: When low flow conditions arise, add data points to the Edwards Ferry stage-discharge analysis and refine the low flow portion of the travel time curve.
- MWCOG: Organize and facilitate discussions with Virginia DEQ about the Governor-approved Virginia Drought Assessment and Response Plan and steps needed to assure Virginia's continued participation in the Washington metropolitan area drought plan.

Appendix A – List of Low Flow Triggers and Response Actions

Triggers			Agency	Action	Reference Documents
Flow at Point of Rocks	Daily flow[7] at Little Falls	Other			
< 2,000 cfs			ICPRB /CO-OP	Monitor Point of Rocks & Little Falls flows and withdrawals	1
			MDE	WSSC is "authorized to determine their own water supply needs, and to assess and respond to drought conditions"	7
	Withdrawals >= 50% daily flow		Aqueduct	May declare LFAA Alert Stage	2
			MDE	WSSC is "authorized to determine their own water supply needs, and to assess and respond to drought conditions"	7
	Daily flow < 100 MGD + 2x CO-OP withdrawal next 5 days	or, significant chance that releases willbe needed from JRR &/or Little Seneca in next 10 days	ICPRB /CO-OP	Full drought operations: Monitor one day past and forecast CO-OP production and reservoir storage, CO-OP to recommend source allocation	1
			VA DEQ	Reduce withdrawals from the Potomac River (CO-OP determines when, by how much, and for how long)	5
	Withdrawal + flow-by > 80% daily flow		ICPRB /CO-OP	If Restriction Stage is declared, allocation ratio of LFAA goes into effect	1
			Aqueduct	May declare LFAA Restriction Stage; If Restriction Stage declared, the NPS will consider reducing withdrawal	2
			MDE	MDE may reduce withdrawals from the Potomac River based on previous winter use rates	3
			MDE	Municipal residential permitees to reduce withdrawals from Potomac & tributaries to rates of previous winter	4
			VA DEQ	Reduce withdrawals from the Potomac River (CO-OP determines when, by how much, and for how long)	5
	Withdrawal + flow-by > daily flow any day over next 5 days		ICPRB /CO-OP	If Emergency Stage is declared, allocation ratio of LFAA goes into effect	1
			Aqueduct	May declare LFAA Emergency Stage	2
			MDE	MDE may reduce withdrawals from the Potomac River based on previous winter use rates	3
			MDE	Municipal residential permitees to reduce withdrawals	4

[7] "Daily flow" is defined at the end of Article 2.A of the LFAA as withdrawals plus observed flow at Little Falls. This quantity is sometimes referred to in CO-OP documents as “adjusted” flow at Little Falls.

Triggers			Agency	Action	Reference Documents
Flow at Point of Rocks	Daily flow[7] at Little Falls	Other			
				from Potomac & tributaries to rates of previous winter (use since 1985)	
			VA DEQ	Reduce withdrawals from the Potomac River (CO-OP determines when, by how much, and for how long)	5
		NOAA "D1" drought in Potomac River Basin	COG /CO-OP	May declare "Watch" -- Meeting of COG Drought Ops Committee, media briefing, press release when first reservoir release occurs, press release when JRR and Little Seneca storage drops below 75%	6
		JRR + Little Seneca storage < 60% of capacity; or Probability of not meeting unrestricted demand ≥ 5%	COG /CO-OP	May declare "Warning" -- Meeting of Drought Coordination Committee, weekly media briefing, voluntary water use restrictions, detailed WSO, daily water supply report from ICPRB	6
			ICPRB /CO-OP	(Note: ICPRB planning model (PRRISM) assumes 5% reduction in demand Jun - Sep; 3% reduction other months)	8
		JRR + Little Seneca storage < 25% of capacity	ICPRB /CO-OP	(Note: ICPRB planning model (PRRISM) assumes 9.2% reduction in demand Jun - Sep; 5% reduction other months)	8
		JRR + Little Seneca storage < 5% of capacity	ICPRB /CO-OP	(Note: ICPRB planning model (PRRISM) assumes 15% reduction in demand Jun - Sep; 15% reduction other months)	8
		Probability of meeting demand $\leq$ 50%	COG /CO-OP	May declare "Emergency" -- Meeting of Drought Coordination Committee, LFAA allocations, daily press conference, daily water supply reports by ICPRB, mandatory restrictions	6
		Probability of meeting unrestricted demand ≤ 95%	ICPRB /CO-OP	Suppliers advise jurisdictions and recommend restrictions	1
		Release from JRR or Little Seneca	MDE	GenOn must restrict maximum daily consumptive use to 1 MGD or less at Dickerson plan (scrubber and combustion turbine)	3
		Certain low flow periods specified by MDE	MDE	Non-residential permittees with no means of low flow augmentation will reduce consumptive use to 1 MGD (use since 1985)	4

Low Flow Triggers and Response Actions Reference Documents

1 WSCA Drought Related Operations Manual (7/22/1982)

2 LFAA Mod. #2 (4/19/1985) combined with Memorandum of Intent (7/20/1978)

3 Maryland Water Appropriation and Use Permits

4 Maryland Consumptive Use of Surface Water in the Potomac River Basin COMAR 26.17.07

5 (Virginia) 9VAC 25-210-110 A (2)

6 COG Drought Awareness Response Plan (6/07/2000)

7 Maryland State Water Conservation Advisory Committee (Nov 2000)

8 Assumptions used in CO-OP long-term planning model, PRRISM

Appendix B – C & O Canal National Historical Park Withdrawals

CO-OP staff contacted Superintendent Kevin Brandt of the C&O Canal National Historical Park to learn about how and where the canal is watered (September 27, 2012).The canal is watered in six locations along its 184.5 mile length from Washington to western Maryland. A list of these locations, along with information on the methods of diverting water from the river to the canal and on potential consumptive losses due to these diversions is given below.

Cumberland Dam

There are two 75 horse power pumps that transfer water into the canal here, though they are not used at their full capacity. This fills a quarter-mile long section of the canal. Here, the canal is lined with a geo-synthetic liner so there is little to no infiltration. There is likely some evaporation. The pumps can be turned off and on. The water that is pumped into the canal overflows back into the Potomac. If the pumps were turned off and no water was put into the canal there would be some aquatic resource and aesthetic impacts. This is not a recreation area so there would be no recreational impacts. There may be a flow meter on the pumps. It is feasible that the Park could work with the Army Corps to figure out how much water was being pumped into the canal.

Oldtown, Maryland

The water enters the canal from a tributary and subsequently flows into the Potomac.

Hancock

Water is pumped from the Potomac using a much smaller pump system than that used at Cumberland to fill a half-mile long section of the canal. This used to be the water supply system for Hancock and is still a backup for them. The pump can be turned on and off. There is no flow meter on this pump. Half of the canal here has a natural clay liner and the other half has a PVC liner so there is little infiltration. From the canal, water overflows into another portion of the canal downstream and through a wetland and eventually returns to the Potomac. Approximately 65 percent of what is pumped in is likely to make it back into the Potomac.

Williamsport

The canal is watered with a duplex pumping station through a sand infiltration intake system located in Conococheague Creek. This system is unreliable because the intake clogs very easily. Right now stormwater running into the canal keeps it near operating levels, but there are plans, but no current funding, to install a new intake a pump system. This would return this system to its former operating level that would be similar to that of Cumberland and Hancock.

Violette's Lock- below Seneca Creek at canal mile 23

Water enters the canal through Historic Inlet Lock Number 2. The remnants Dam 2, a severely breached historic dam, still let small amounts of water into the canal. The amount of water that enters the canal is directly related to the flow level in the mainstem Potomac. If flows dropped so low that the Restriction Stage was declared, there would likely be very little water making it into the canal at all. There are gates that could be closed to keep water from the Potomac from entering the canal. This would lead to severe impacts on aquatic life in the canal. The Park would like to keep the canal water at a minimum level to maintain aquatic health. The water from this portion of the canal overflows back into the Potomac.

Lock 5 to Georgetown

The canal is watered at Lock 5 (at mile 5) through Historic Inlet Lock Number 1, the remainder of flow passed downstream from Inlet Lock 2, and from overland flow of tributaries entering the canal. This portion of the canal goes down below Little Falls all the way to Rock Creek and then back into the Potomac. Water comes in from the Potomac when flows are high. When flows are low there is not enough water to run the tourist boats, but there is enough to maintain aquatic life. New, lower gates were constructed and installed in May 2011. These gates serve to let water into the canal as well as keep flood water out.