TECHNICAL MEMORANDUM

Prineville Reservoir – Operating Rule Curve Memo

PREPARED BY: Chris Runyan, P.E.
River and Reservoir Operations Group
Bureau of Reclamation, Pacific Northwest Regional Office

DATE: August 13, 2018

1.0 INTRODUCTION

The purpose of this Technical Memorandum (TM) is to provide an overview of the existing reservoir rule curve that Prineville Reservoir currently operates from as well as provide a conceptual level investigation of potential benefits of updating the existing rule curve. This TM was completed as part of the Upper Deschutes Basin Study and addresses the following topics:

- Crooked River Project Description
- Summary of Reservoir Operations
- Current Performance of Existing Rule curve
- Overview of Implementation Process
- Future Actions

2.0 Crooked River Project Description

The Crooked River is a regulated system controlled by the Arthur R. Bowman Dam. The dam impounds streamflow from the Crooked River and a small tributary (Bear Creek) to create Prineville Reservoir. The dam serves many purposes, including providing Section 7 flood control, water supply (irrigation and municipal and industrial (M&I)), fish and wildlife benefits, and recreational opportunities. Section 7 flood control obligations refer to projects that were partially funded by Federal dollars with the requirement that once constructed, the reservoir would be operated to provide flood control benefits for public infrastructure located downstream. During the non-irrigation season, water is released primarily for fish and wildlife purposes (excluding flood control releases); outside of this season, additional releases are made to meet irrigation and M&I demand.

Arthur R. Bowman Dam (Figure 1) is an earthfill structure on the Crooked River about 20 miles upstream from the City of Prineville, Oregon. The dam has a height of 240 feet, crest length of 790 feet, and a volume of 1.42 million cubic yards of material. The spillway consists of an uncontrolled crest inlet structure, chute, and stilling basin. The capacity of the spillway is 8,120 cfs at maximum water surface elevation of 3257.9 ft and results in a flood surcharge storage of 80,330 acre-feet. The outlet works has an intake structure with an 11-foot-diameter circular tunnel upstream from the gate chamber, an 11-foot modified horseshoe tunnel downstream from the gate chamber, and a stilling basin, which is shared with the spillway. The capacity of the outlet works is 3,300 cfs at normal water surface elevation of 3234.8 ft. Based on a reservoir sedimentation survey completed in 1998, the total active storage capacity of Prineville Reservoir was estimated at 148,560 acre-feet.

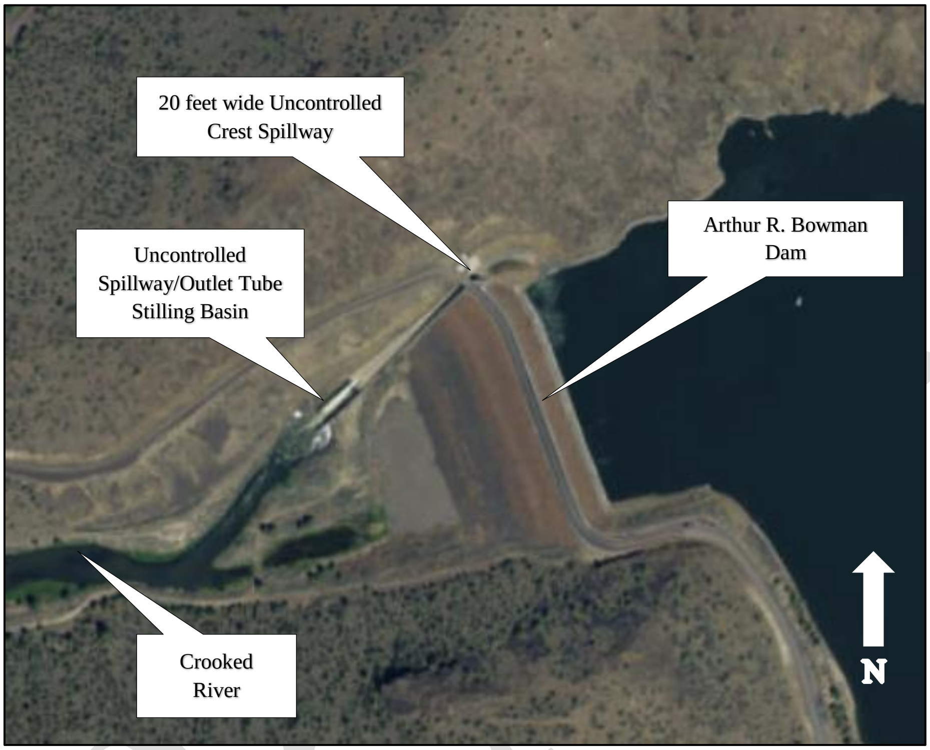

Figure 1. Arthur R. Bowman Dam Overview

3.0 SUMMARY OF RESERVOIR OPERATIONS

The following section provides a description of a typical operations season for Prineville Reservoir. For discussion purposes of this TM, a typical year will be broken into two periods that include the irrigation season and non-irrigation season. It is important to note that certain operational objectives at Prineville reservoir such as providing Flood Risk Management (FRM) or releasing water for fish and wildlife purposes can overlap both irrigation and non-irrigation seasons.

3.1 Non-Irrigation Season

The non-irrigation season typically starts around the beginning of November after all diversions from the Crooked River have ceased. During the non-irrigation season water released from the reservoir is typically from either flood control operations if required by the rule curve or for fish and wildlife purposes.

A typical flood season (time of year when reservoir inflows experience the largest variability) for Prineville Reservoir is from November 15 through the month April. During this period, the reservoir is regulated based on a two-part rule curve that includes a static space requirement and a dynamic Storage Reservation Diagram (dSRD) (Figure 2).

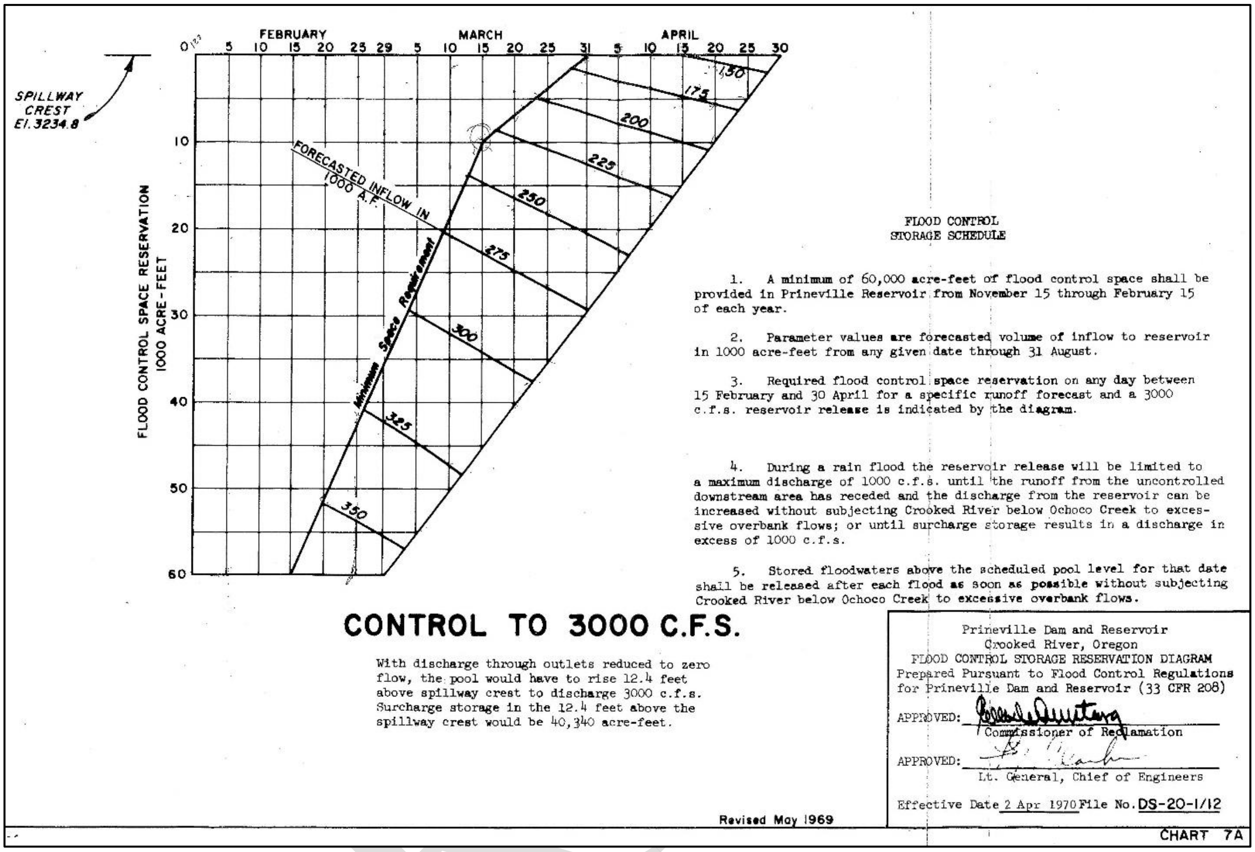

Figure 2. Prineville Reservoir dynamic Storage Reservation Diagram (dSRD) for a maximum regulated discharge of 3,000 cfs.

The static flood control period begins on November 15th and ends on February 15th, after which point reservoir refill into the winter flood space requirement can begin. During the static flood control period, a minimum of 60,000 acre-feet of reservoir space must be made available to provide protection against winter rain-on-snow type flood events.

After February 15th, the refill of the reservoir is operated based on the dSRD, which provides refill curves based on the forecasted runoff, projected fill date around the end of April, and a maximum allowable reservoir discharge target of 3,000 cfs. The dSRD part of the curve is utilized to determine the reservoir space required based on the volume of runoff projected from the current date through the end of August. The dSRD curve was developed utilizing the available surcharge storage (40,330 acre-feet) at Prineville Reservoir to control to the maximum allowable reservoir discharge target of 3,000 cfs while also providing a high probability of reservoir refill for water supply. To utilized the available surcharge, when water begins to discharge over the uncontrolled spillway, the discharge through the outlet tube is reduced so that the total discharge below the dam is still 3,000 cfs or less and the reservoir is allowed to fill. Using this operation provides 12.4 feet of surcharge (40,330 acre-feet) to attenuate reservoir inflows before flow over the uncontrolled spillway exceeds 3,000 cfs. The use of surcharge space allows for the release of stored water later and greatly increases the operational flexibility for keeping flows below the maximum allowable discharge of 3,000 cfs.

3.2 Irrigation Season

The second period of the reservoir operations season is the irrigation season. Depending on weather trends, irrigation can start anywhere from the middle of March to the middle of April with an average season starting around the first of April. The irrigation season typically lasts until the end of October to early November depending on how extended the growing season is. During this time, water is primarily released from Prineville Reservoir for a combination of irrigation demands and fish and wildlife purposes. Irrigation demands along the Crooked River are met through a combination of natural flow rights and the release of storage water from Prineville Reservoir. The start of the irrigation season can also coincide with active flood operations and it is not uncommon for flood control operations to continue through the month of May. After flood control operations cease, outflows are reduced to meet irrigation demand and fish and wildlife purposes.

4.0 CURRENT PERFORMCE OF EXISITING RULE CURVE

The current rule curve for Prineville Reservoir was developed to provide both FRM and a high probability of reservoir refill for water supply. The rule curve was developed using the stream gauge record at that time and was finalized in 1969. Before considering modification of an existing rule curve, it is important to first determine how it is performing at meeting the current operational objectives. For the case of Prineville Reservoir, modification of the rule curve may be advantageous if the current curve has resulted in an unacceptable number of instances when reservoir outflows exceeded the maximum flood control discharge target of 3,000 cfs. On the water supply side, another reason modification may be advantageous is if the probability of reservoir refill is less than originally designed.

For purpose of the TM, the 1981-2017 period (37 years) was analyzed to determine if 1) the curve is providing FRM consistent with the original project purpose, and 2) the curve is providing a high reliability in reservoir refill.

Figure 3 shows a plot of storage content at Prineville Reservoir and discharge below the dam for the 1981-2017 period. In general, any discharges above approximately 280 cfs can be considered releases caused due to flood control operations while reservoir content above 148,560 acre-feet can be considered a full reservoir. Looking at the discharge below the dam for all years (1981-2017), discharges remained below 3,000 cfs for most years while 8 years had discharges over

3,000 cfs but remained less than 3,300 cfs which is considered within the inherent error of river gauging of the 3,000 cfs target.

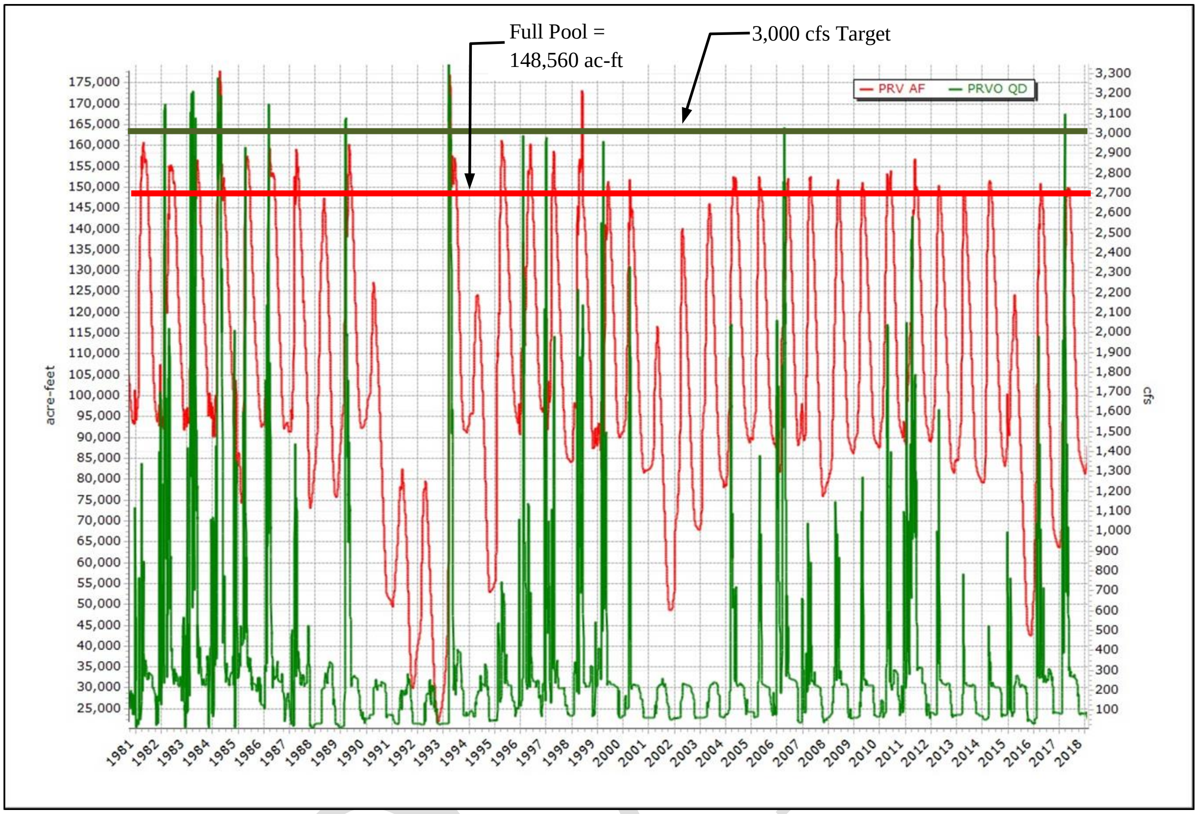

Figure 3. Prineville Reservoir content (red line, left axis) and discharge below the reservoir (green line, right axis) for the 1980-2017 period.

On the reservoir refill side, there are 8 years when complete reservoir refill was not obtained (Table 1). Impacts to reservoir refill caused directly by flood control releases are limited to only those years when there were flood control releases and the reservoir missed complete refill. To identify this type of scenario, flood control discharges were identified as both discharges required to maintain the static winter space requirement of 60,0000 acre-feet during the November 15th-through-February15th period and discharges greater than irrigation demand (i.e discharges greater than 280 cfs) during the refill period. By using this criterion, 2 of the 8 years (1994 and 2015) were identified as years when reservoir refill was impacted by releases for flood control. All other years that did not completely refill were a result of inadequate runoff volume and not a result of flood control operations or forecast error.

Table 1. Years when Reservoir did not Refill Completely

Year	Ac-ft from Full	Reason for not Refill
1990	21,327	Inadequate Runoff Volume
1991	66,235	Inadequate Runoff Volume
1992	68,862	Inadequate Runoff Volume
1994	24,295	Inadequate Runoff Volume, Flood Control
2001	31,952	Inadequate Runoff Volume
2002	8,508	Inadequate Runoff Volume
2003	2,507	Inadequate Runoff Volume
2015	24,372	Inadequate Runoff Volume, Flood Control

Complete reservoir refill was not reached in 1994 (Figure 4) due to a combination of inadequate runoff volume and flood control releases that occurred during the winter static space requirement period. The reservoir ended up reaching a maximum content that was 24,295 acre-feet less than full. Due to the persistent low snow pack from November-through February 15th of that year, and due to following back to back drought conditions from 1990-1992, the reservoir was operated within the 92,000 to 96,000 acre-feet of content range and only required outflows to be increased from minimums up to approximately 100 cfs for a short duration. Operating the reservoir to maintain the winter static space requirement during the November 15th-through-Februray 15th period resulted in the release of approximately 2,300 acre-feet water over minimum flows. With perfect hindsight, had the winter static space requirement been abandoned in late November, the maximum content reached would have increased from 124,265 acre-feet to 126,565 acre-feet, but this small increase would have required the operators to know that dry conditions would persist for the remainder of the season, which is not realistic.

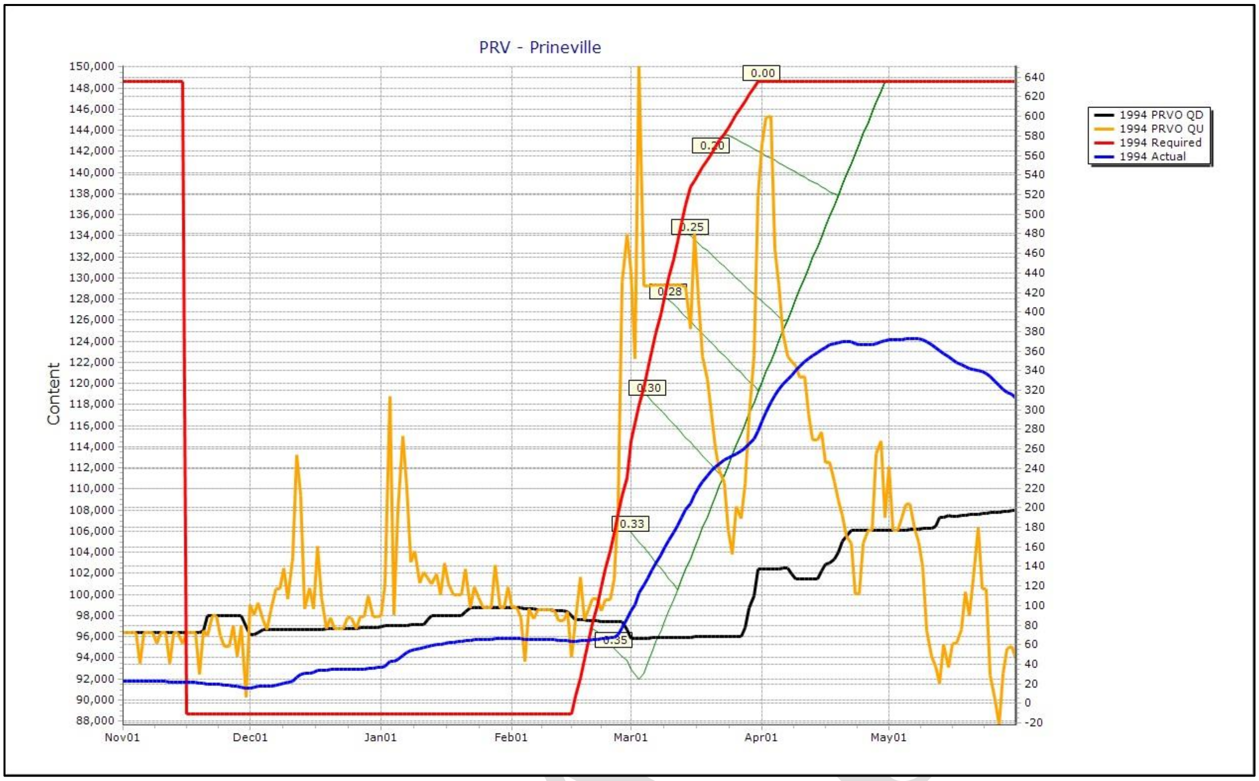

Figure 4. Operations of 1994 showing reservoir inflow (orange line, right axis), reservoir discharge (black line, right axis), reservoir storage (blue line, left axis) and maximum reservoir content allowed by the rule curve (red line, left axis).

In water year 2015 (Figure 5) up until January 1st, snowpack at the Derr Snotel (good indicator of higher elevation snowpack) located at elevation 5,670 feet was near average. The first flood control release occurred in late December when inflows into the reservoir went from 150 cfs to 3,760 cfs over the course of 3 days. This event filled the reservoir into the static winter space requirement and required that the reservoir be drafted back down to a content of approximately 90,000 acre-feet. During the remainder of December and into January, the reservoir was operated to maintain the static winter space requirement. During this period, the snowpack in the basin transitioned from average to below average and a deviation to the winter space requirement was justified to allow the reservoir to fill into the required winter static flood space. Conditions remained dry in the basin for the remainder of the runoff season and the reservoir was operated to maximize refill for water supply. Had the reservoir been operated strictly to the winter space requirement without professional judgment of the current basin conditions and low risk of a large rain-on-snow type event (i.e. minimal snowpack in the basin at that time), the maximum reservoir refill would have been reduced by 18,500 acre-feet than what occurred. Deviating from the winter space requirement sooner is not realistic due to the snowpack present in the basin in early December and the risk of a large rain-on-snow type as shown by the runoff event that actually occurred in late December of that year.

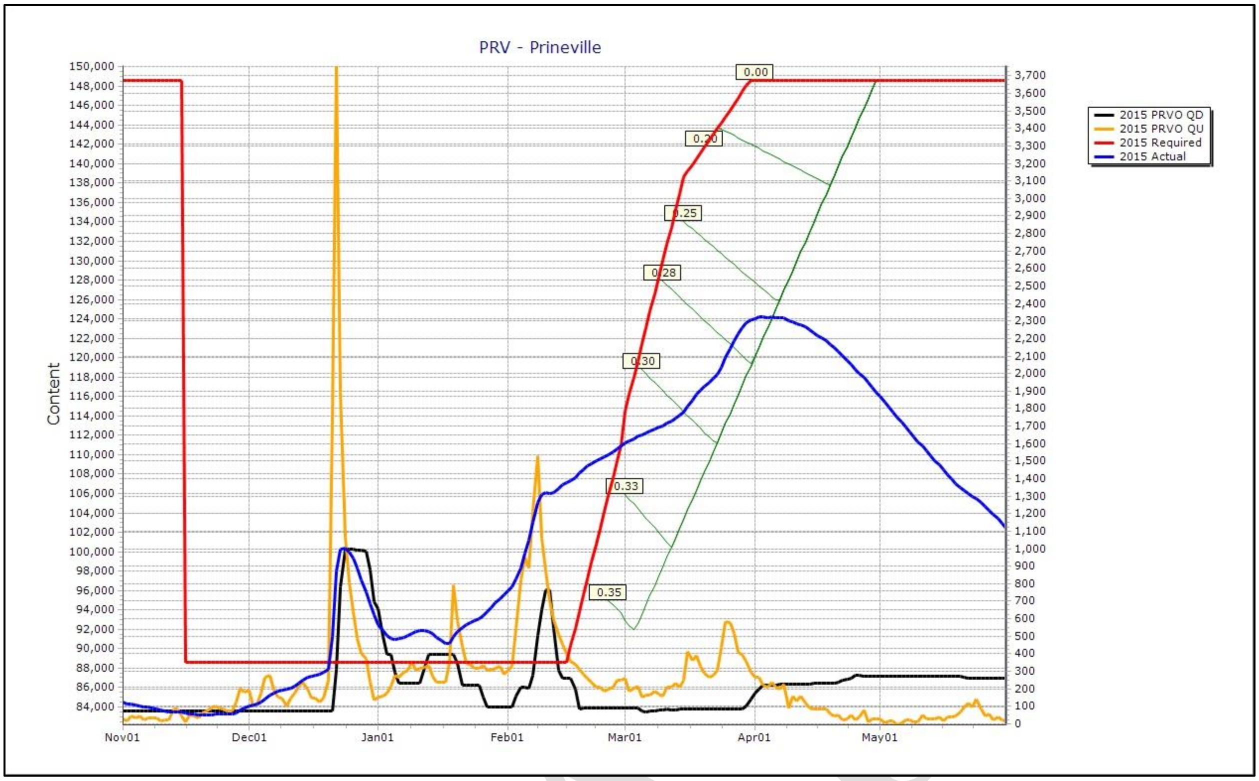

Figure 5. Operations of 2015 showing reservoir inflow (orange line, right axis), reservoir discharge (black line, right axis), reservoir storage (blue line, left axis) and maximum reservoir content allowed by the rule curve (red line, left axis).

4.0 OVERVIEW OF IMPLEMENTATION PROCESS

The current rule curve was revised in May of 1969 and was developed to balance both FRM and water supply refill criteria. The rule curve was developed pursuant to Flood Control Regulations for Prineville Dam and Reservoir (33 CFR 208). Approval of the rule curve was provided by both the Commissioner of Reclamation and the Lieutenant General of the Army Corp of Engineers. Due to the inherent complexities in developing a rule curve, acceptance of a final operating rule curve is only obtained after significant amounts of analysis, multi-agency review and revisions.

If an existing rule curve was identified as being one that may need to be updated, a similar stringent analysis process would be required. The new rule curve would need to be developed using the best available data including any additional hydrologic information since the original curve was developed. During this process, FRM would take priority and winter space requirements and runoff volume space requirement would need to be re-calculated. The new curve would also need to meet any revised or additional FRM policies including any revisions to the maximum flood discharge based on current land use practices.

Based on information documenting the revision of the Boise System rule curve and discussion around revising the Ririe Reservoir Curve, the process of updating a rule curve is a multi-year process with multi-agency oversight and review. For example, when the Boise System flood control curve was modified it required more than 5 years of analysis before the curve was adopted. For context, the intent of modifying the Boise System rule curve was to provide a higher degree of flood protection after the basin experienced a very large water year and flooding occurred.

5.0 FUTURE ACTIONS

The current performance (1981-2017 period) of the existing rule curve summarized in Section 4 of this TM found that the existing rule curve is both effectively regulating to the maximum flood discharge of 3,000 cfs as well as providing a high probability of reservoir refill for water supply.

At this point, future actions could include continuing to monitor how well the current curve is operating. For example, if the project begins to experience hydrologic events that require discharges to be greater than the 3,000 cfs target then the rule curve may need to be modified. Additionally, if the reservoir experiences events when reservoir refill is reduced (specifically during dry years) then the curve may also need to be looked at. Based on the record of operations over the last 37 years, the rule curve appears to be performing well at both providing flood control and reservoir refill per the design objectives.

It should be noted that since the passage of the Crooked River Collaborative Water Security and Jobs Act of 2014 (CRCWA), the Prineville Reservoir operations have changed, most notably by how water is carried over from one water year to the next as well as the amount of water released for fish and wildlife purposes. In general, the change in operations resulting from the CRCWA have not impacted flood control operations although the reservoir is drafting lower due to the increased release of water for fish and wildlife purposes which may impact reservoir refill on years when runoff is inadequate to completely refill the reservoir. Due to the change in reservoir operations resulting from the CRCWA, it is recommended that the probability of reservoir refill should continue to be monitored.