Status Report

Work to Date on the Development of the VARQ Flood Control Operation at Libby Dam and Hungry Horse Dam

January 1999

Section 1

Appendix A

Appendix A

VARQ Operating Procedures

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A.1. **INTRODUCTION**. This appendix contains a description of the rules that govern the VARQ procedure at Libby and Hungry Horse Dams. Examples of the VARQ operation are presented.

A.2. **GENERAL RULES**. The general rules that govern the VARQ flood control procedure are listed below.

Rule 1. Storage Reservation Diagrams. Storage reservation diagrams (SRD) for Libby and Hungry Horse (Figures A-1 and A-2, respectively) guide the evacuation of space for flood control. Required space is a function of the April-August runoff forecast at Libby and the May-September forecast at Hungry Horse. Following evacuation (after May 1) the projects are required to maintain this space until the initiation of refill. During evacuation and up until the initiation of refill, outflows should be limited to hydraulic capacity of the powerhouse to the best extent possible. However, situations such as the loss of hydraulic capacity or rapidly changing forecasts may require spill to meet flood control requirements.

Rule 2. Initiation of Refill. Initiation of refill is determined by the operating procedures for system flood control on the lower Columbia River. These procedures are described in Columbia River Treaty, Flood Control Operating Plan, October 1972. At Libby and Hungry Horse, refill is initiated approximately ten days prior to when streamflow forecasts of unregulated flow are projected to exceed the Initial Control Flow (ICF) at The Dalles, Oregon. This criteria applies most of the time: however, if the reservoir intersects with its flood control refill curve (FCRC) prior to ICF being reached, then refill is initiated at that time. The FCRC is a refill curve that fills the reservoir with 95 percent confidence at minimum outflow.

Rule 3. Initial VARQ Outflow. Use Figure A-3 and A-4 to determine an initial VARQ outflow for Libby and Hungry Horse, respectively.

Rule 4. Adjusting VARQ Outflows for Delta Storage. Adjust the initial VARQ outflows, if necessary, to compensate for any storage difference between the actual May 1 reservoir level and the space required for flood control. This difference can reflect under or over-drafted conditions (Delta). This is done in the following manner:

Estimate the duration of the system flood control operation (Duration) using Figure A-5. Select the appropriate curve based on the level of the latest projected control flow at The Dalles (ICF). From the selected curve determine the flood control duration using the April-August runoff forecast for The Dalles.

Compute the VARQ storage adjustment:

ADJSTO = [Delta(kaf) x 0.5(ksfd/kaf)] / Duration(days)

Compute the new VARQ outflow:

VARQ(new) = VARQ(initial) + ADJSTO

If the runoff forecast at The Dalles is less than 85 million acre-feet, it is likely that system flood control of any significant duration will not be necessary for the lower Columbia River. Use streamflow forecasts to adjust VARQ outflows, if necessary, to compensate for any storage difference between the actual May 1 reservoir level and the space required for flood control. Reduce the VARQ outflows as necessary to provide protection against local flooding and to improve the likelihood of refill.

Rule 5. Adjusting VARQ Outflows for Prior VARQ Releases.

VARQ releases are seasonal in nature, generated using seasonal runoff forecasts. This rule accounts for the difference in outflows released since the initiation of refill and the new VARQ outflows developed using the updated runoff forecast:

ADJDUR = [VARQ(new) – VARQ(prior)] x [Prior Release(days) / [New Duration(days) – Prior Release(days)]]

Compute final VARQ outflow:

VARQ(final) = VARQ(new) + ADJDUR

Rule 6. Inflows Less Than VARQ Outflows. At the initiation of refill, if inflows are less than the VARQ outflow, pass inflow until inflows rise to the VARQ level. Thereafter, if inflows drop below the VARQ outflow, pass inflow until they rise again to the VARQ level.

Rule 7. Updating VARQ Outflows During Refill Season. Update VARQ outflows throughout the refill season, May through June, as new runoff forecasts are developed. Use streamflow forecasts to evaluate the performance of the VARQ outflows in meeting system and local flood control objectives. Reduce VARQ outflows if necessary to provide protection from local flooding. Return to VARQ outflows once local flooding is over.

Rule 8. Final Stages of Refill. Adjust VARQ outflows during the final stages of refill to avoid overfilling and unwanted spill. Use streamflow forecasts and engineering judgement to select the appropriate outflows.

Optional Fish/Spill Adjustments. For Libby Dam regulation, Seattle District has proposed making an additional adjustment to lower the likelihood of spill during refill. This adjustment is a function of the runoff forecast at Libby and would be added directly onto VARQ outflows that are computed for flood control (Rules 3,4, and 5). This is an optional adjustment made after evaluating the volume and distribution of the projected runoff and the likelihood of future spill based on the level of the reservoir and condition of the powerplant.

A.3. **LIBBY DAM EXAMPLE.**

Water Year: 1997
Condition: High runoff, 7852 kaf for Apr-Aug, 123% of 1961-1990 normal.
Figure A-6 shows the daily reservoir operation.

January 1 – April 30:

Ops: Evacuation of flood control space.

April Apr-Aug Runoff Forecast for Libby	7610 kaf
Rule 1. Flood Control Space Requirement (Figure A-1)	4215 kaf
Flood Control Elevation	2329.6 ft
Observed Space	3902.8 kaf
Observed Pool Elevation	2343.8 ft
April Apr-Aug Runoff Forecast for The Dalles	125 maf
Initial Control Flow at The Dalles	494 kcfs

May 1:

Ops: Operate in accordance with IJC criteria for Kootenay Lake and continue to draft to flood control requirements, if possible.

May 2:

Ops: Refill begins (Rule 2). IFC is reached in unregulated streamflow forecast ten days out on May 11.

Rule 3. Initial VARQ Outflow (Figure A-3)	5.0 kcfs
Rule 4. Delta Storage (4215-3902.8=312.2)	312.2 kaf
Rule 4. Duration (Figure A-5)	63 days
Rule 4. Delta Storage Adjustment (312.2*.504)/63=2.5	2.5 kcfs
Rule 4. Final VARQ Outflow (5+2.5=7.5)	7.5 kcfs

May 9:

Ops: May runoff forecast issued. Determine lookback adjustment to flood control space requirement for May 1 and, if necessary, adjust VARQ outflows.

May Apr-Aug Runoff Forecast for Libby	7665 kaf
Rule 1. May 1 Flood Control Space Requirement (Figure A-1)	4323 kaf
May 1 Flood Control Elevation	2324.4 ft
Rule 3. Initial VARQ Outflow (Figure A-3)	5.0 kcfs
Rule 4. Delta Storage (4323-3902.8=420.2)	420.2 kaf
May Apr-Aug Runoff Forecast for The Dalles	130 maf
Initial Control Flow at The Dalles	518 kcfs
Rule 4. New Duration (Figure A-5)	67 days
Rule 4. VARQ Storage Adjustment (420.2*0.504)/67=3.16	3.16 kcfs
Rule 4. New VARQ Outflow (5.0+3.16=8.16)	8.16 kcfs
Rule 5. Prior Release Duration	7 days
Rule 5. Duration Adjustment (8.16-7.50)*(7/(67-7))=0.08	0.08 kcfs
Rule 5. Final VARQ Outflow (8.16+0.08=8.24)	8.24 kcfs

May 15 – 18:

Ops: Reduce outflows to minimum for local flood control at Bonners Ferry (Rule 7).

May 19 – June 7:

Ops: Resume VARQ outflows of 8.24 kcfs.

June 8 – 14:

Ops: June runoff forecast issued. Use new runoff forecast and latest streamflow forecast to adjust VARQ outflow. Determine regulation that provides protection against flooding and limits unnecessary spill.

June Apr-Aug WSF for Libby	7840 kaf
Rule 1. May 1 Lookback Flood Control Space Requirement	4666 kaf
Rule 3. Initial VARQ Outflow (Figure A-3)	5.0 kcfs

Rule 4. Delta Storage (4666.4-3902.8=763.6)	763.6 kaf
June Apr-Aug WSF for The Dalles	136 maf
Initial Control Flow at The Dalles	530 kcfs
Rule 4. New Duration (Figure A-5)	68 days
Rule 4. VARQ Storage Adjustment (763.6 x 0.504)/68=5.66	5.66 kcfs
Rule 4. New VARQ Outflow (5.0+5.66=10.66)	10.66 kcfs
Rule 5. Prior Release Duration	37 days
Rule 5. VARQ Duration Adjustment (10.66-Average Previous VARQ Outflows)*(37/(68-37))=3.60	3.60 kcfs
Rule 5. Final VARQ Outflow (10.66+3.60=14.26)	14.26 kcfs

June 21 – 30:

Ops: VARQ outflows adjusted during the final stages of refill to avoid overfilling and unwanted spill (Rule 8). Outflows selected using streamflow forecasts and engineering judgement.

A.4. **HUNGRY HORSE EXAMPLE**.

Water Year: 1997
Condition: High runoff year, 2932 kaf, 153% of the 1961-1990 normal.
Figure A-7 shows the daily reservoir operation.

January 1 – April 30:

Ops: Evacuation of flood control space.

April May-Sep Runoff Forecast for Hungry Horse	2371 kaf
Rule 1. Flood Control Space Requirement (Figure A-2)	2049 kaf
Flood Control Elevation	3445.6 ft
Observed Space	2049 kaf
Observed Pool Elevation	3445.6 ft
April Apr-Aug Runoff Forecast for The Dalles	125 maf
Initial Control Flow at The Dalles	494 kcfs

May 1:

Ops: Maintain Pool at 3445.6 ft until initiation of refill.

May 2:

Ops: Refill begins (Rule 2). IFC is reached in unregulated streamflow forecast ten days out on May 11.

Rule 3. Initial VARQ Outflow (Figure A-4)	1.78 kcfs
Rule 4. Delta Storage (2049–2049=0)	0 kaf
Rule 4. Duration (Figure A-5)	63 days
Rule 4. VARQ Delta Storage Adjustment	0 kcfs
Rule 4. Final VARQ Outflow (1.78+0=1.78)	1.78 kcfs

May 9:

Ops: May runoff forecast issued. Determine lookback adjustment to flood control space requirement for May 1 and, if necessary, adjust VARQ outflows.

May May-Sep Runoff Forecast for Hungry Horse	2861 kaf
Rule 1. May 1 Flood Control Space Requirement (Figure A-2)	2179 kaf
May 1 Flood Control Elevation	3424.5 ft
Rule 3. Initial VARQ Outflow (Figure A-4)	0.99 kcfs
Rule 4. Delta Storage (2179–2049=130)	130 kaf
May Apr-Aug Runoff Forecast for The Dalles	130 maf
Initial Control Flow at The Dalles	518 kcfs
Rule 4. New Duration (Figure A-5)	67 days
Rule 4. VARQ Storage Adjustment (130*0.504)/67=0.98	0.98 kcfs
Rule 4. New VARQ Outflow (0.99+0.98=1.97)	1.97 kcfs
Rule 5. Prior Release Duration	7 days
Rule 5. Duration Adjustment (1.97-1.78)*(7/(67-7))=0.02	0.02 kcfs
Rule 5. Final VARQ Outflow (1.97+0.02=1.99)	1.99 kcfs

May 16 – 18:

Ops: Reduce outflows to minimum for local flood control at Columbia Falls (Rule 7).

May 19 – 31:

Ops: Resume VARQ outflows of 1.99 kcfs.

June 1 –2:

Ops: Reduce outflows to minimum for local flood control at Columbia Falls (Rule 7).

June 3 – 7:

Ops: Resume VARQ outflows of 1.99 kcfs.

June 8 – 14:

Ops: June runoff forecast issued. Use new runoff forecast and latest streamflow forecast to adjust VARQ outflow. Determine regulation that provides protection against flooding and limits unnecessary spill.

June May-Sep WSF for Hungry Horse	2901 kaf
Rule 1. May 1 Lookback Flood Control Space Requirement	2221 kaf
Rule 3. Initial VARQ Outflow (Figure A-4)	0.75 kcfs
Rule 4. Delta Storage (2221-2049=172)	172 kaf
June Apr-Aug WSF for The Dalles	136 maf
Initial Control Flow at The Dalles	530 kcfs
Rule 4. New Duration (Figure A-5)	68 days
Rule 4. VARQ Storage Adjustment (172 x 0.504)/68=1.28	1.28 kcfs
Rule 4. New VARQ Outflow (0.75+1.28=2.03)	2.03 kcfs
Rule 5. Prior Release Duration	37 days
Rule 5. VARQ Duration Adjustment (2.03-Average Previous VARQ Outflows)*(37/(68-37))=0.39	0.39 kcfs
Rule 5. Final VARQ Outflow (2.03+0.39=2.42)	2.42 kcfs

June 15 – 30:

Ops: VARQ outflows adjusted during the final stages of refill to avoid overfilling and unwanted spill (Rule 8). Outflows selected using streamflow forecasts and engineering judgement.

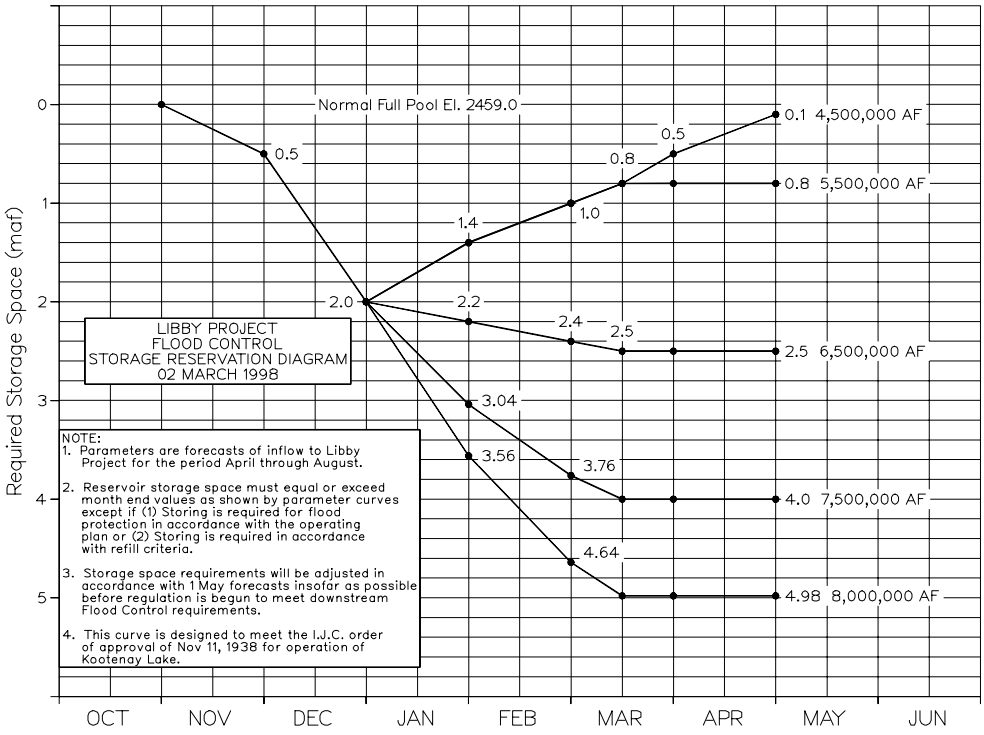

Figure A-1. VARQ Storage Reservation Diagram for Libby.

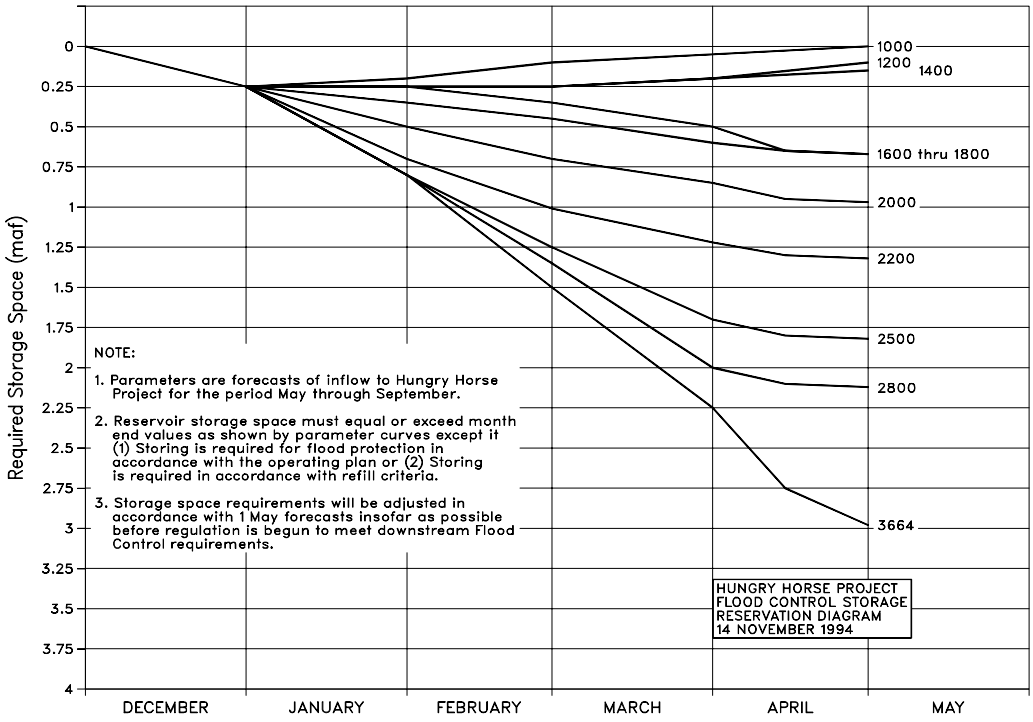

Figure A-2. VARQ Storage Reservation Diagram for Hungry Horse.

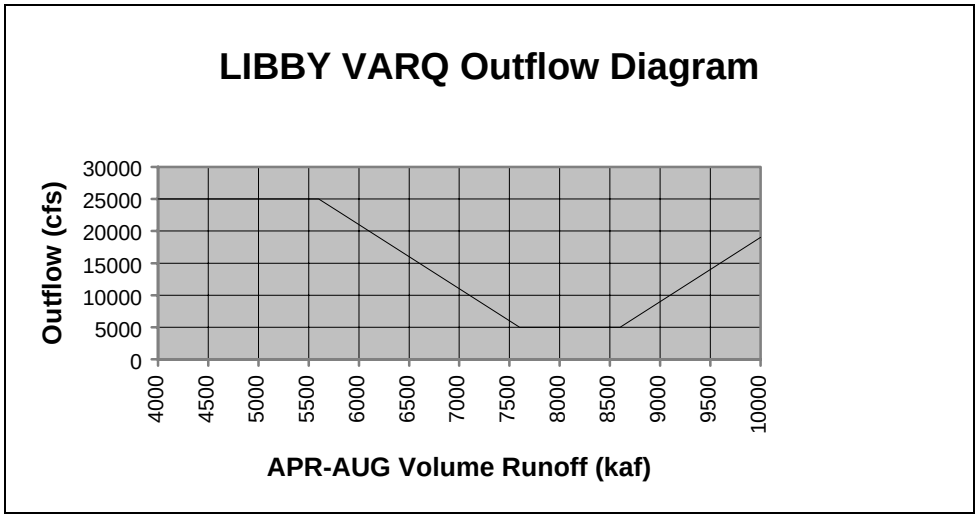

Figure A-3. VARQ Outflows at Libby.

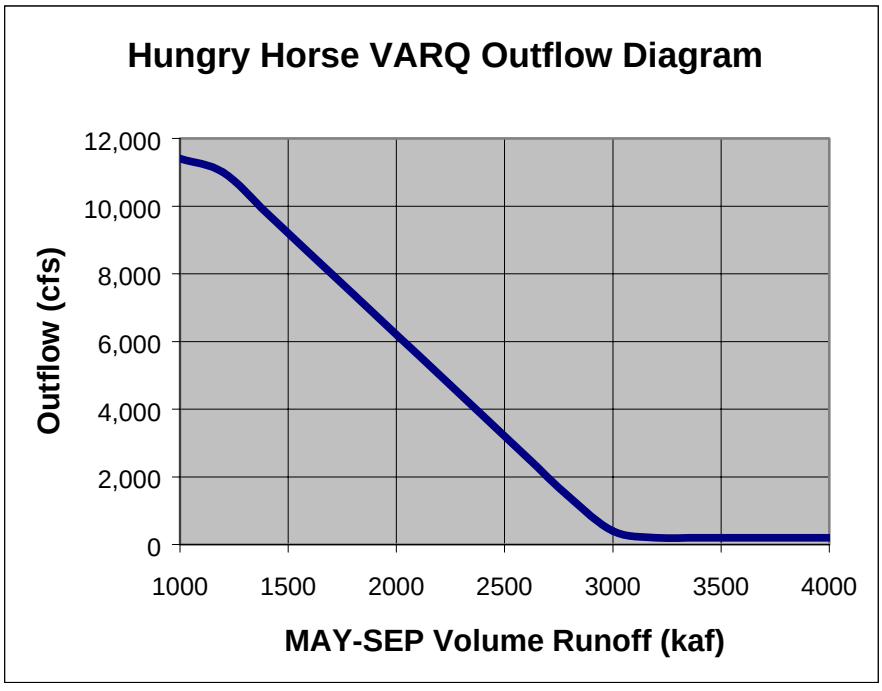

Figure A-4. VARQ Outflows at Hungry Horse.

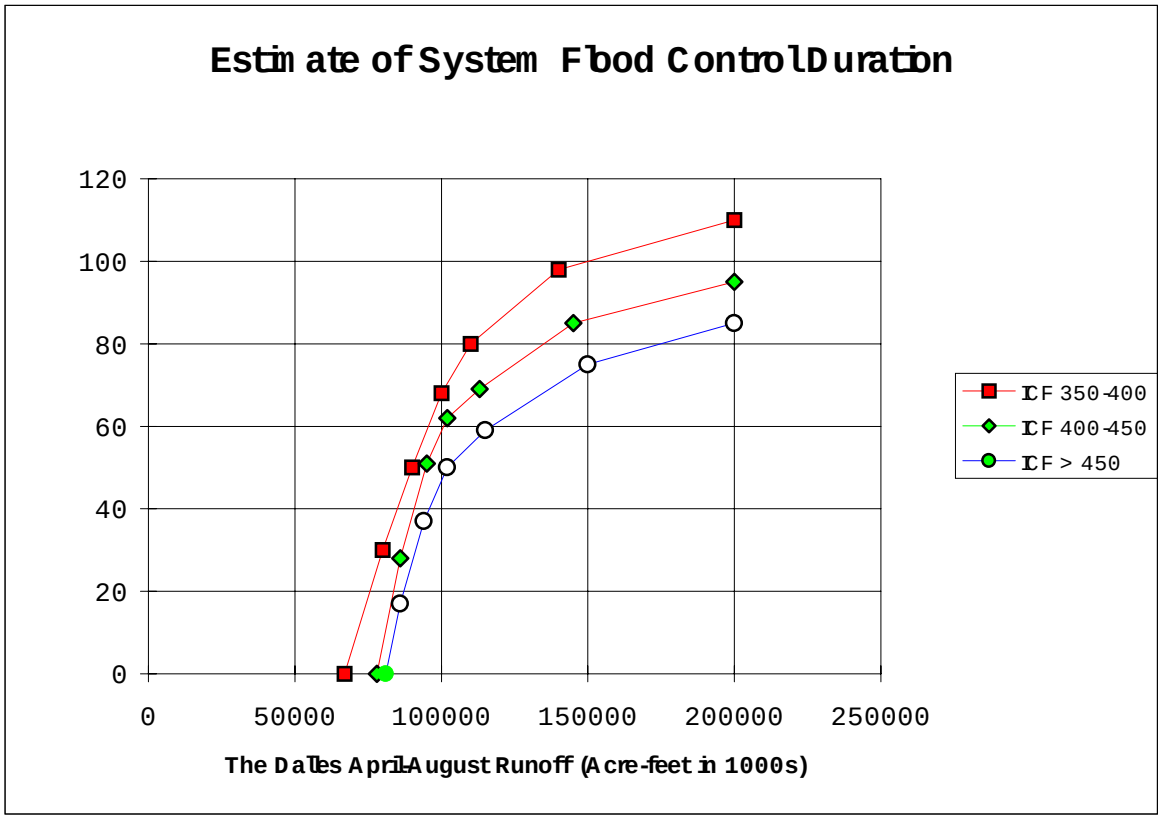

Figure A-5. Estimate of System Flood Control Duration.

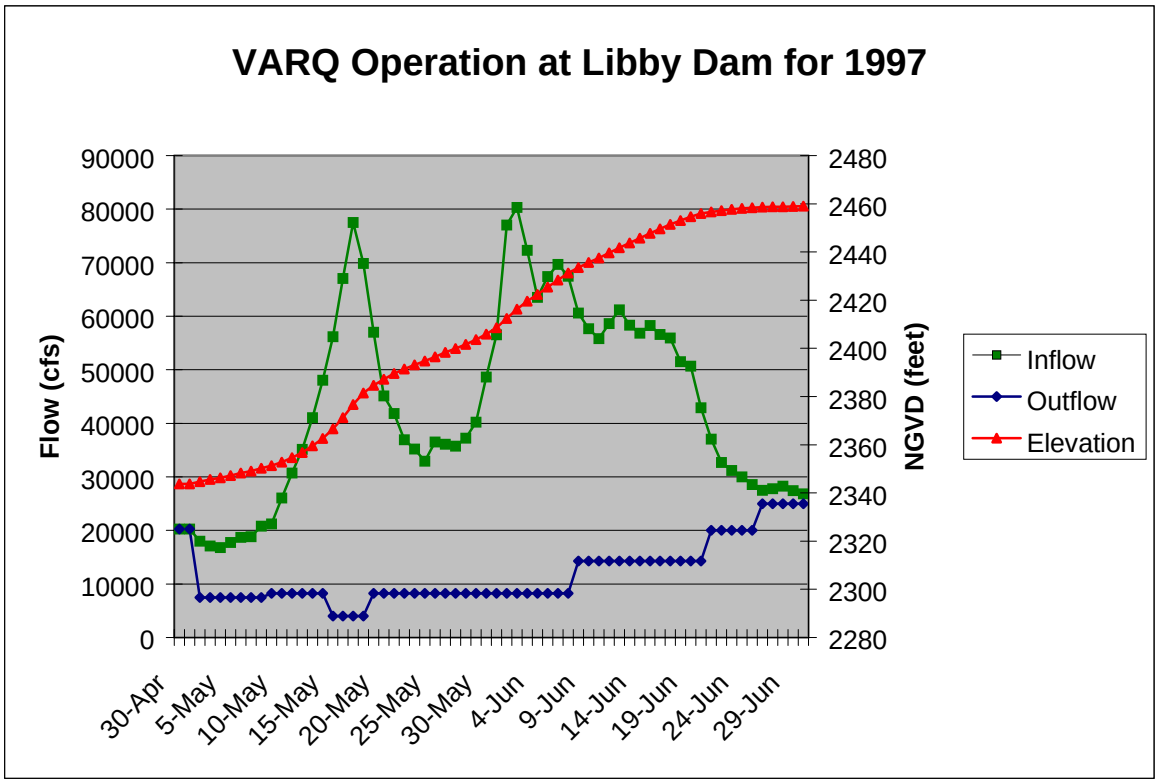

Figure A-6. Example of VARQ Operation at Libby Dam for the Spring of 1997.

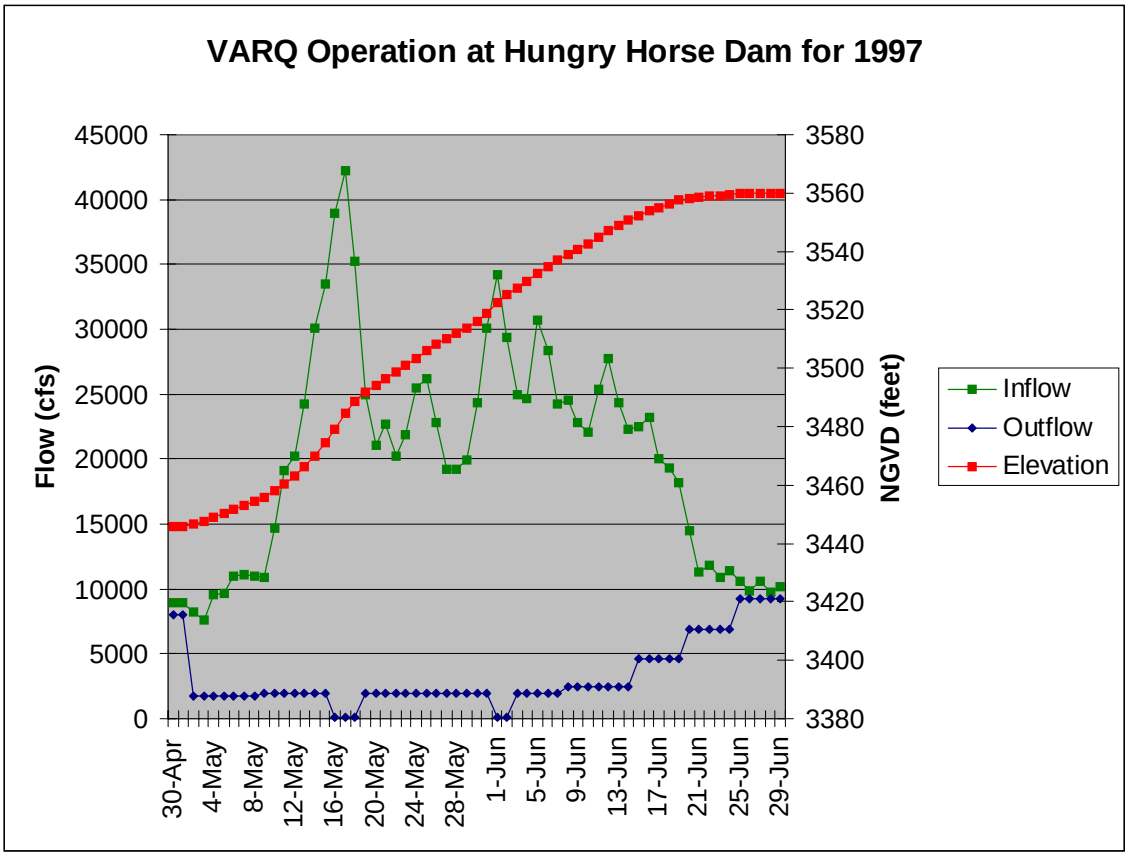

Figure A-7. Example of VARQ Operation at Hungry Horse for the Spring 1997.