Lower Red Basin Retention (LRBR) Study

Appendix E: Virtual Thaw Progression

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Virtual Thaw Progression

Through the development of the Halstead Upstream Retention Project a method to simulate the spatial variability of spring snowmelt pattern in the Red River Basin was developed called the Virtual Thaw Progression (VTP) (Houston Eng, 2013). This analysis was based on determining the thaw date at various location in the Red River Basin based on the first day of three consecutive days where the minimum daily temperature was above freezing (32 ^{O}F). This data was used to create a synthetic snowmelt event for the entire United States portion of the Red River of the North Basin. The main objective for the development of the VTP synthetic snowmelt event is to provide a consistent framework to evaluate distributed detention for the Red River of the North Basin and to determine if a viable approach to reaching the overall LTFS mainstem red River peak flow and volume reductions goal of 20% exists. This modeled synthetic hydrograph will be generated such that it conforms to the 1% annual exceedence probability (AEP) flow hydrograph at the following critical locations along the mainstem of the Red River of the North: Wahpeton, North Dakota, Hickson, North Dakota, Fargo, North Dakota, Halstad, Minnesota, Grand Forks, Minnesota, Oslo, Minnesota, Drayton, North Dakota and Emerson, Manitoba. To support this evaluation, flow-frequency analysis and balanced hydrographs are compiled for all mainstem, Red River of the North gage sites.

Synthetic Snowmelt Event Development

The Halstead Upstream Retention Project collected minimum daily temperatures at 402 locations throughout the Red River basin for years 1970-2012 between March 1st and May 31st (Houston Eng, 2013). In our updated analysis this dataset was expanded for years 2012-2017. Table 1 compared the VTP thaw dates between the original Halstead Upstream Retention study and the updated analysis which included data through 2017. The statistical values summarize the average annual values for each of the 402 locations.

Table 1 Comparison between Halstead Upstream Retention VTP dates and updated analysis

	Min	25th Percentile	Median	75th Percentile	Max
Halsted Upstream Retention Study (1970-2012)	3/18/2017	4/1/2017	4/8/2017	4/14/2017	4/30/2017
Updated Analysis (1970-2017)	3/16/2017	3/30/2017	4/5/2017	4/11/2017	4/28/2017

The comparison show a shift to an earlier date in the thaws days of 2-3 days in the statistics. However the range between statistics remains almost identical. The VTP is used to calculate progression throughout a watershed therefore the difference between values is more important than the actual data. Consequentially, the VTP products develop from the Halstead Upstream Retention Study were used in our analysis. This included the gridded precipitation HEC-DESS file derived from the TR-60 equivalent rainfall depths and VTP timing information (Houston Eng, 2013).

Model Calibration

Table 2 Change in watershed average CN values form calibration

Major Watershed	Original Average CN	Calibrated Average CN	Percent change in CN
Phase 1			
Otter-Tail	74	78	5%
BDS	76	78	5%
Buffalo South	76	83	10%
WRR-ND	74	82	10%
Buffalo North	74	82	10%
WRR-MN	73	58	-20%
Sheyenne	70	56	-20%
Maple	75	60	-20%
Rush	73	59	-20%
Elm	77	62	-20%
Phase 2			
Sand Hill	71	43	-40%
Goose	75	45	-40%
Wilson	77	46	-40%
Lower Red Lake	73	44	-40%
Clear Water	73	44	-40%
Upper Red Lake	78	47	-40%
Thief	78	47	-40%
Grand Marais	72	86	20%
Turtle	74	89	20%
Forest	75	93	25%
Snake	73	90	25%
Park	73	88	25%
Tamarac	74	91	25%
Roseaue	74	92	25%
Two Rivers	73	91	25%
Pembina	79	92	25%
Aux Marais	78	95	25%

The Phase 1 and Phase 2 Red River of the North WAT models were calibrated using the synthetic snow melt event precipitation grid and the 1% exceedance balanced hydrographs at 8 locations along the mainstem of the Red River of the North: Wahpeton, North Dakota, Hickson, North Dakota, Fargo, North Dakota, Halstad, Minnesota, Grand Forks, Minnesota, Oslo, Minnesota, Drayton, North Dakota, and Emmerson, Manitoba. The precipitation grids were applied to the HEC-HMS models for the basin and the watershed runoff flows from the model output were run through HEC-RAS to determine flows in the river. Calibration was conducted by adjusting CN value in the HMS models. CN were adjusted uniformly within each of the major watersheds boundaries until flows matched the balanced hydrographs. Table 2 shows the CN changes made in each watershed.

CN in the original model remained consistently between 71 and 77. However, in order to match the flows of the 1 % exceedance balanced hydrographs at each location CN for the calibrated model range from the 40's between Halstead and Grand Forms to around 90 between Grand Forks and Emerson.

Figures 1 – 8 show the comparison hydrographs between the 1% balances hydrographs and the calibrated model. Table 3 shows the comparison between the peak flows generated from the calibrated model and the peak flows of the 1% exceedance balanced hydrographs at the seven calibration points along the mainstem of the Red River of the North. Differences in peak flows range between -1% and 3% with the largest difference occurring at Drayton and Whapeton.

Table 3 Peak flow comparison between the balanced hydrographs (BH) and the calibrated peak flows

Calibration Location	BH Peak flows (cfs)	Calibrated Peak flows (cfs)	Percent difference
Phase 1			
Red River at Whapeton, ND	17,900	17,400	3%
Red River at Hickson, ND	23,500	23,000	2%
Red River at Fargo, ND	34,700	35,000	-1%
Phase 2			
Red River at Halstad, ND	70,300	69,800	1%
Red River at Grand Forks, ND	102,700	100,300	2%
Red River at Oslo, ND	106,500	106,300	0%
Red River at Drayton, ND	111,700	109,000	2%
Red River at Emerson, Manitoba	117,000	113,000	3%

Halstead Upstream Retention (HUR) Model

The calibrated model to the 1% exceedance balanced hydrographs was combined with the added retention in the Halstead Upstream Retention Project. The HMS models from the Halstead Upstream Retention Project were imported into the calibrated WAT models for phase I. These calibrated models included added retention designed to produce a 20% reduction in peak flows. The calibrated CNs from the VTP model were imported into the HUR HMS models so that the hydrology remained constant between the two model versions. The Phase I HMS models were rerun with the added retention areas and then routed through the existing HEC-RAS phase I model. The resulting flows from the phase I model were then run through the phase 2 HEC-RAS model. No changes were made to the phase 2 model from the calibrated VTP version. Table 4 shows the changes in peak flow at the 7 calibration locations along the mainstem of the Red River of the North. Figures 9-16 show the hydrographs at each calibration locations. Peak flow were reduced in the phase 1 portion of the model by the desired rate of 20% at Halstad, ND. However, when the flows were routed through the phase 2 portion of the model the over reduction in peak flows was reduced to 10% at Drayton, ND and 7% at Emerson, Manitoba.

Table 4 Peak flow comparison between the VTP calibrated model and the HUR model

	VTP Peak flows	HUR Peak Flows	Percent change in Peak Flow
Phase 1			
Red River at Whapeton, ND	17,400	14,600	16%
Red River at Hickson, ND	23,000	17,000	26%
Red River at Fargo, ND	35,000	28,900	17%
Phase 2			
Red River at Halstad, ND	69,800	55,900	20%
Red River at Grand Forks, ND	100,300	85,000	15%
Red River at Oslo, ND	106,300	88,000	17%
Red River at Drayton, ND	109,000	98,600	10%
Red River at Emerson, Manitoba	113,000	105,000	7%

References

Houston Eng. (2013) Red River Basin Standardized Melt Progression Event Analysis. Prepared for the Red River Basin Commission. By Houston Engineering Inc. April 2013.

Figure 1: Red River of the North At Wahpeton Flow Hydrographs

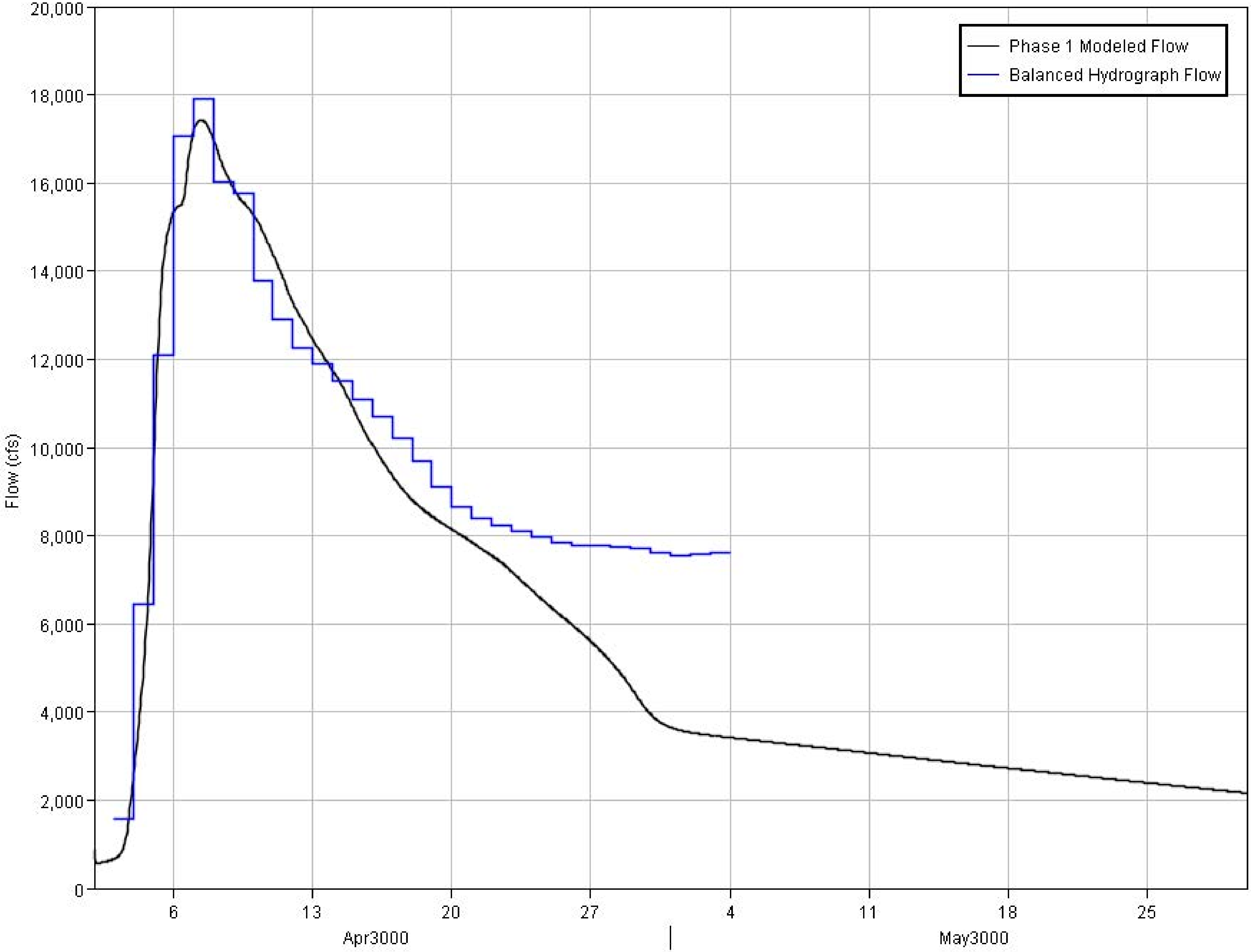

Figure 2: Red River of the North at Hickson Flow Hydrographs

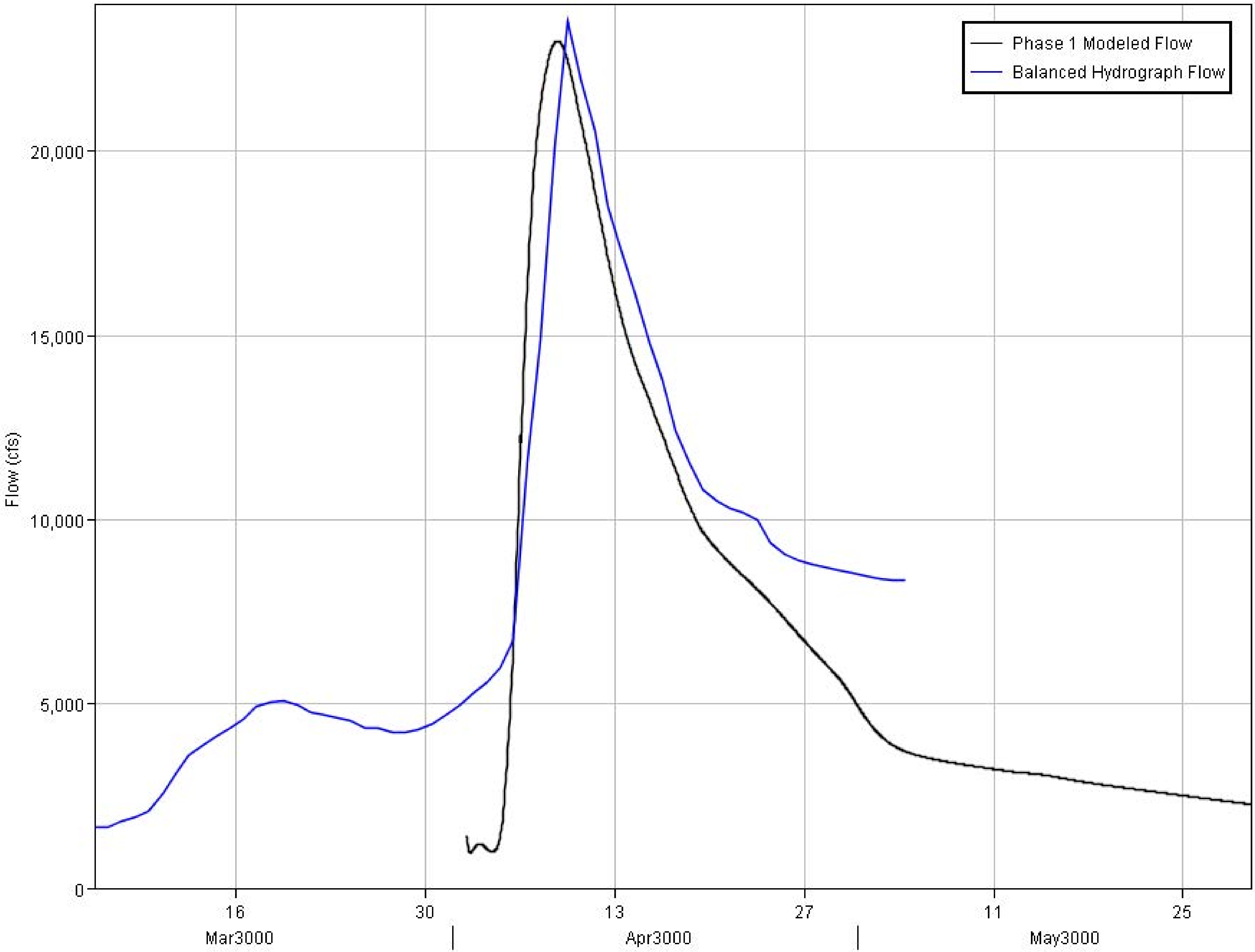

Figure 3: Red River of the North At Fargo Flow Hydrographs

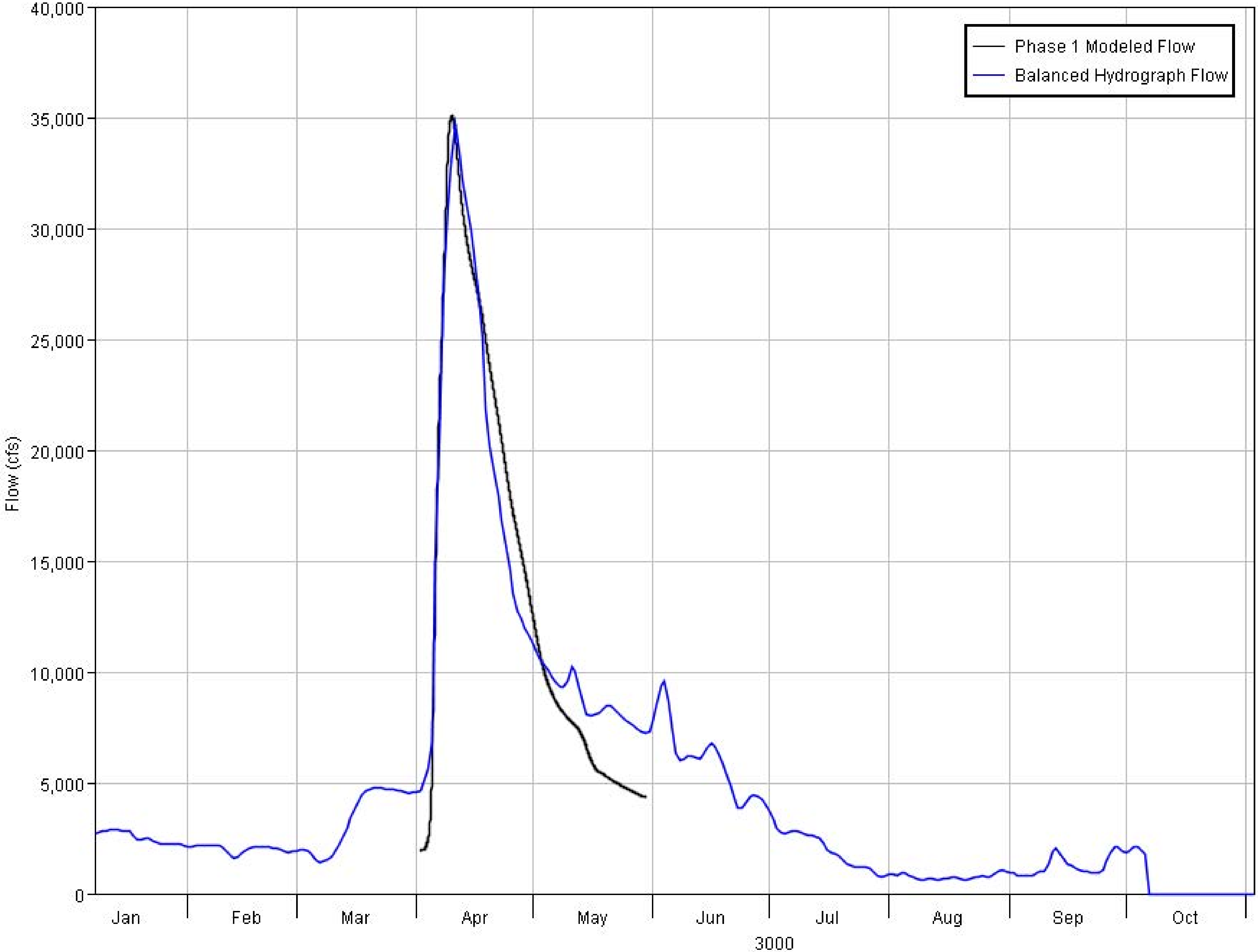

Figure 4: Red River of the North At Halstad Phase II Flow Hydrographs

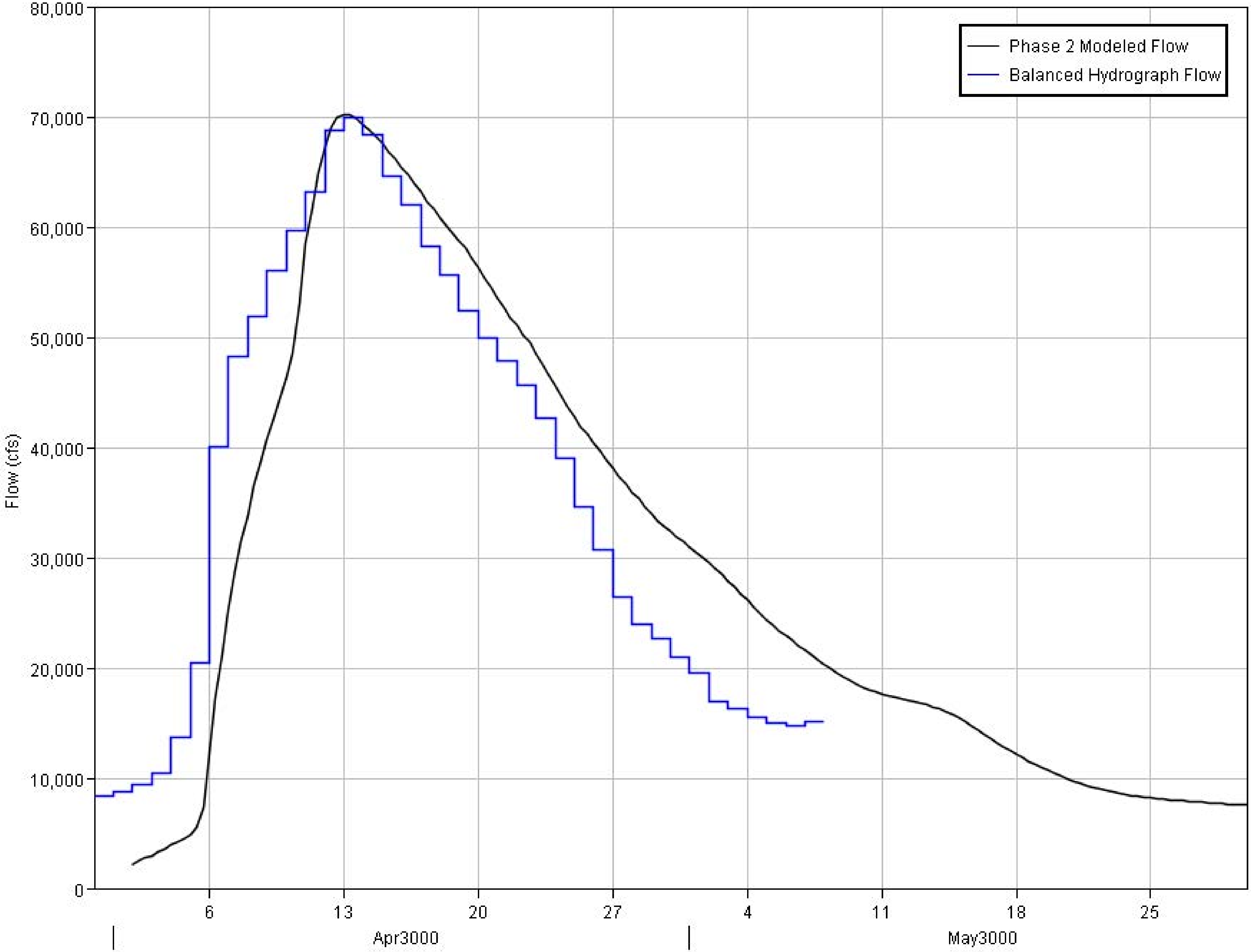

Figure 5: Red River of the North At Grandforks Flow Hydrographs

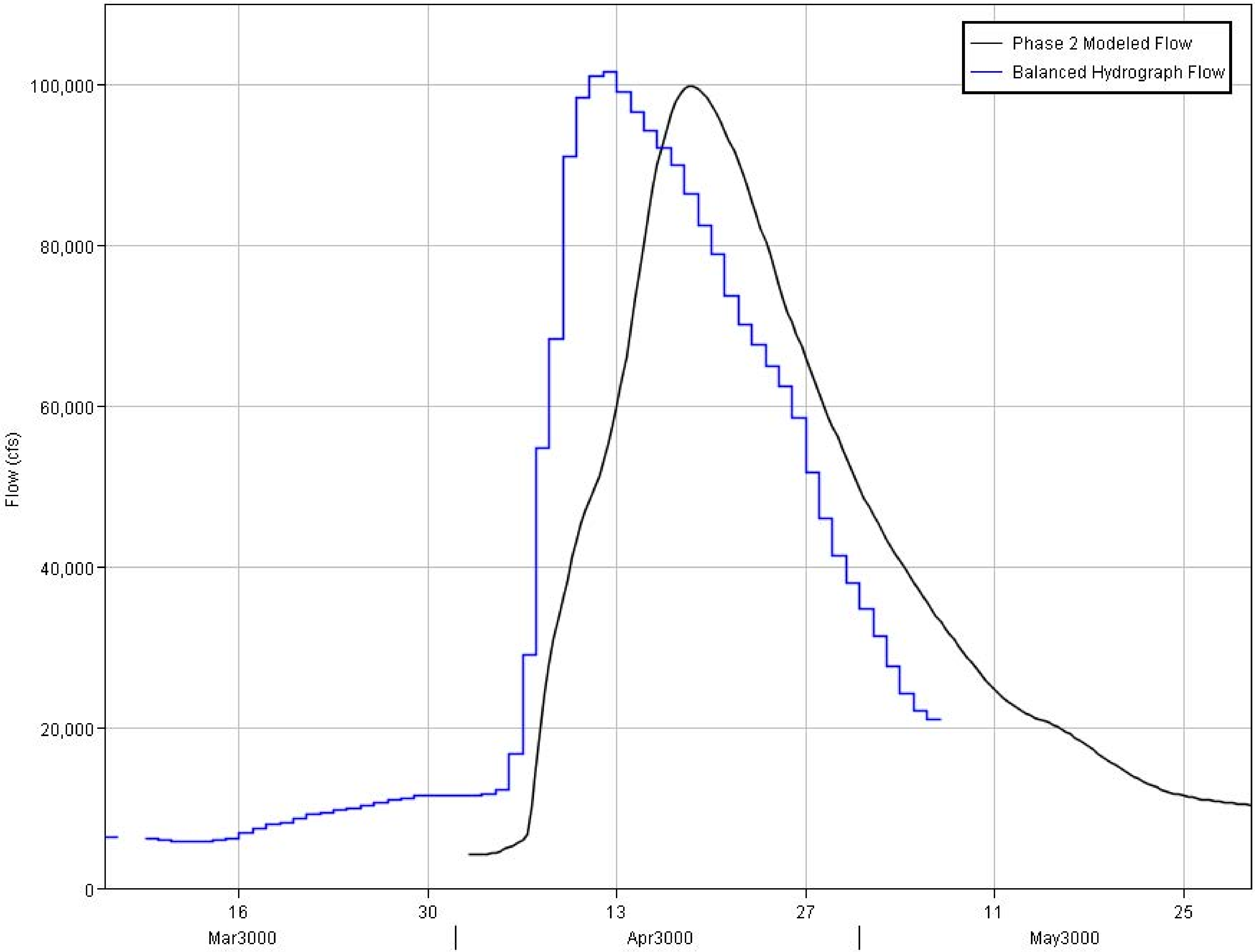

Figure 6: Red River of the North At Oslo Flow Hydrographs

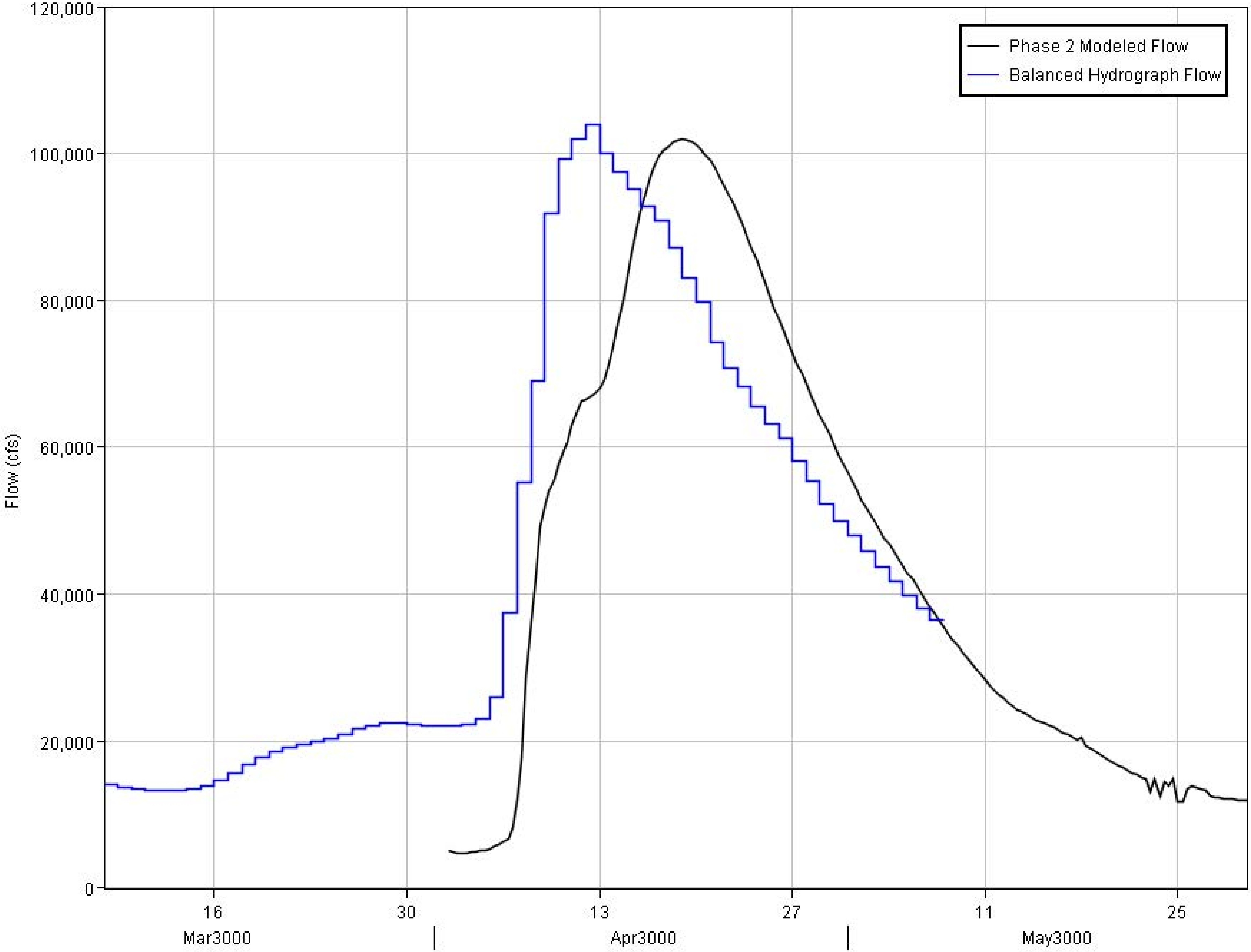

Figure 7: Red River of the North at Drayton Flow Hydrographs

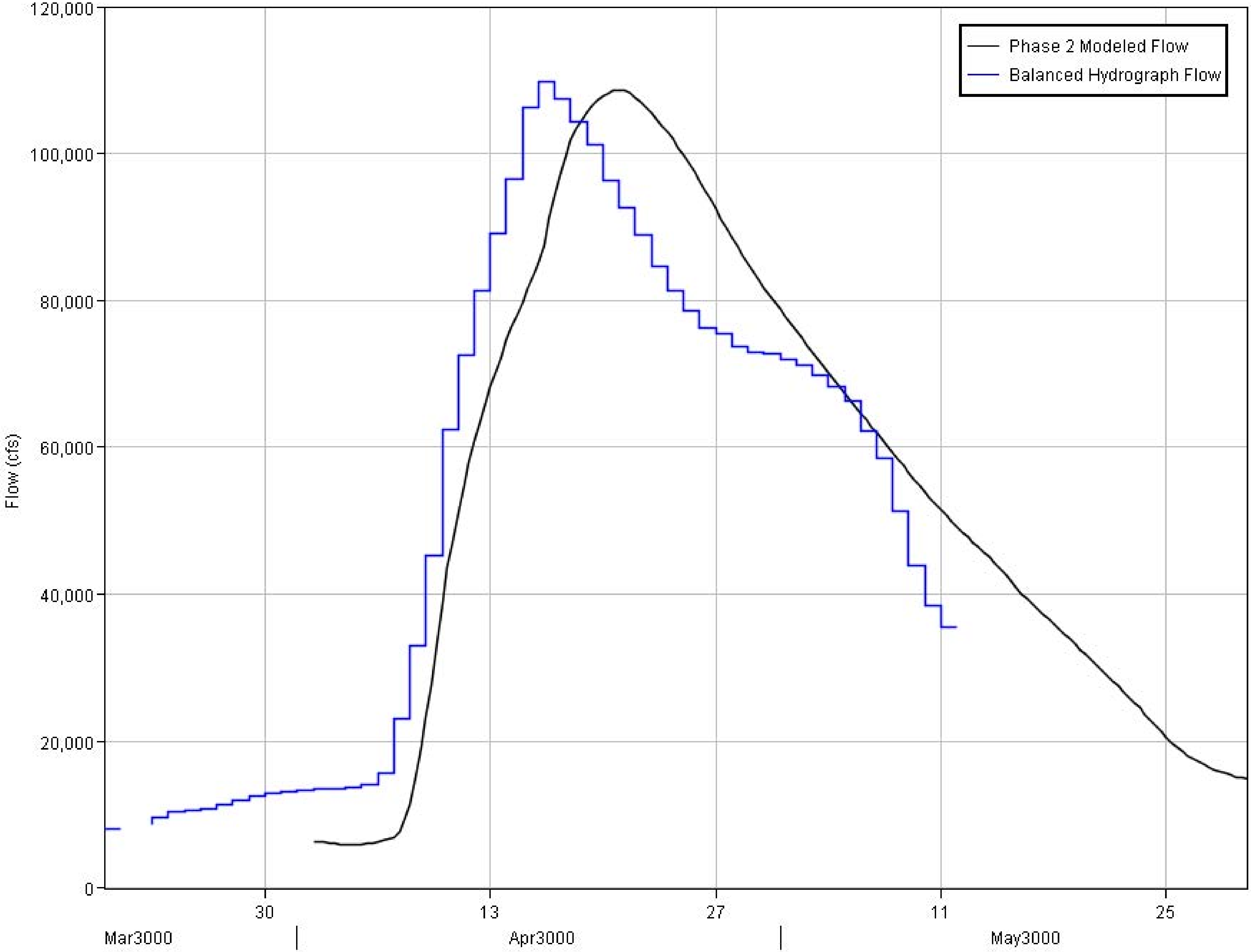

Figure 8: Red River of the North at Emerson Flow Hydrographs

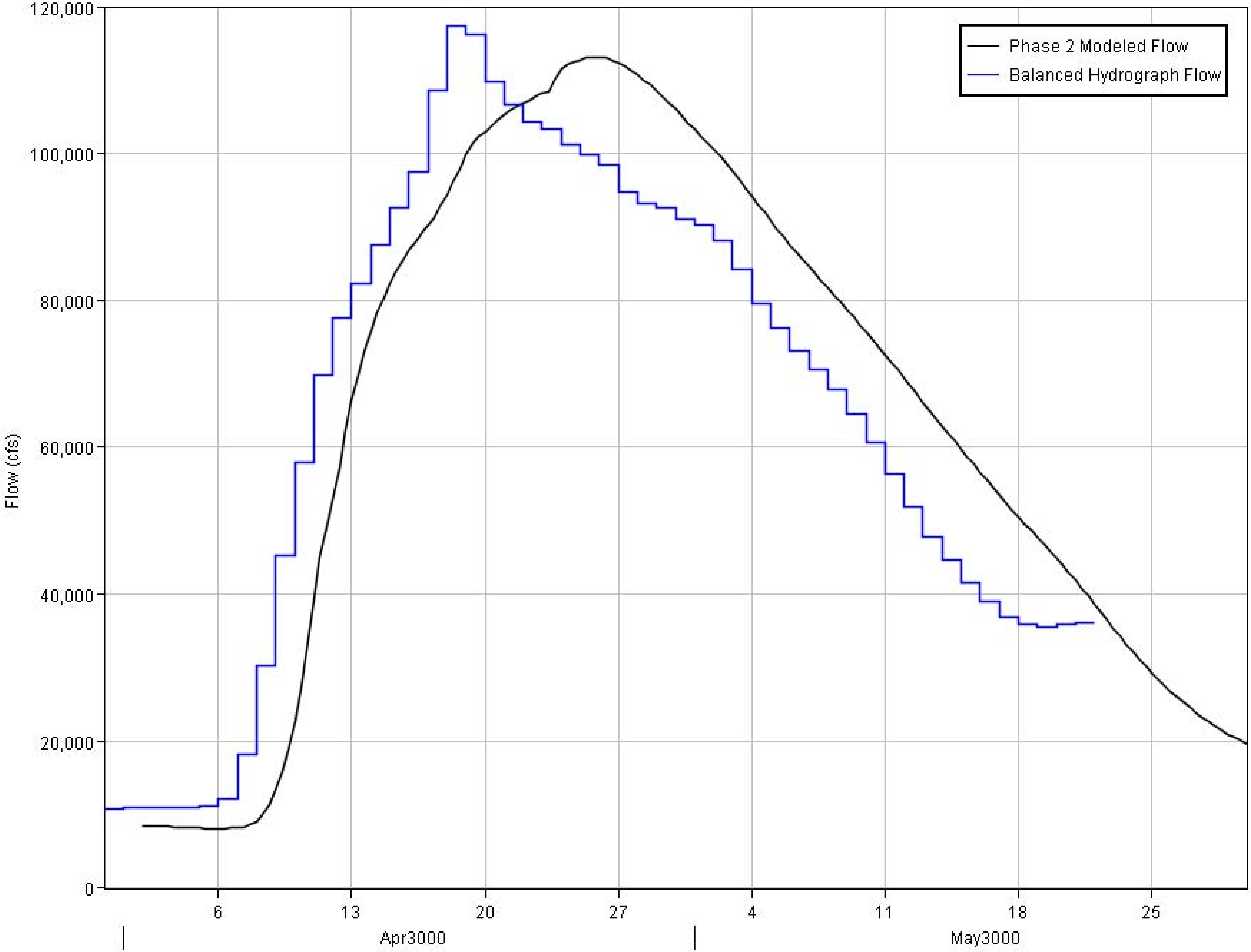

Figure 9: HUR Red River of the North At Wahpeton Flow Hydrographs

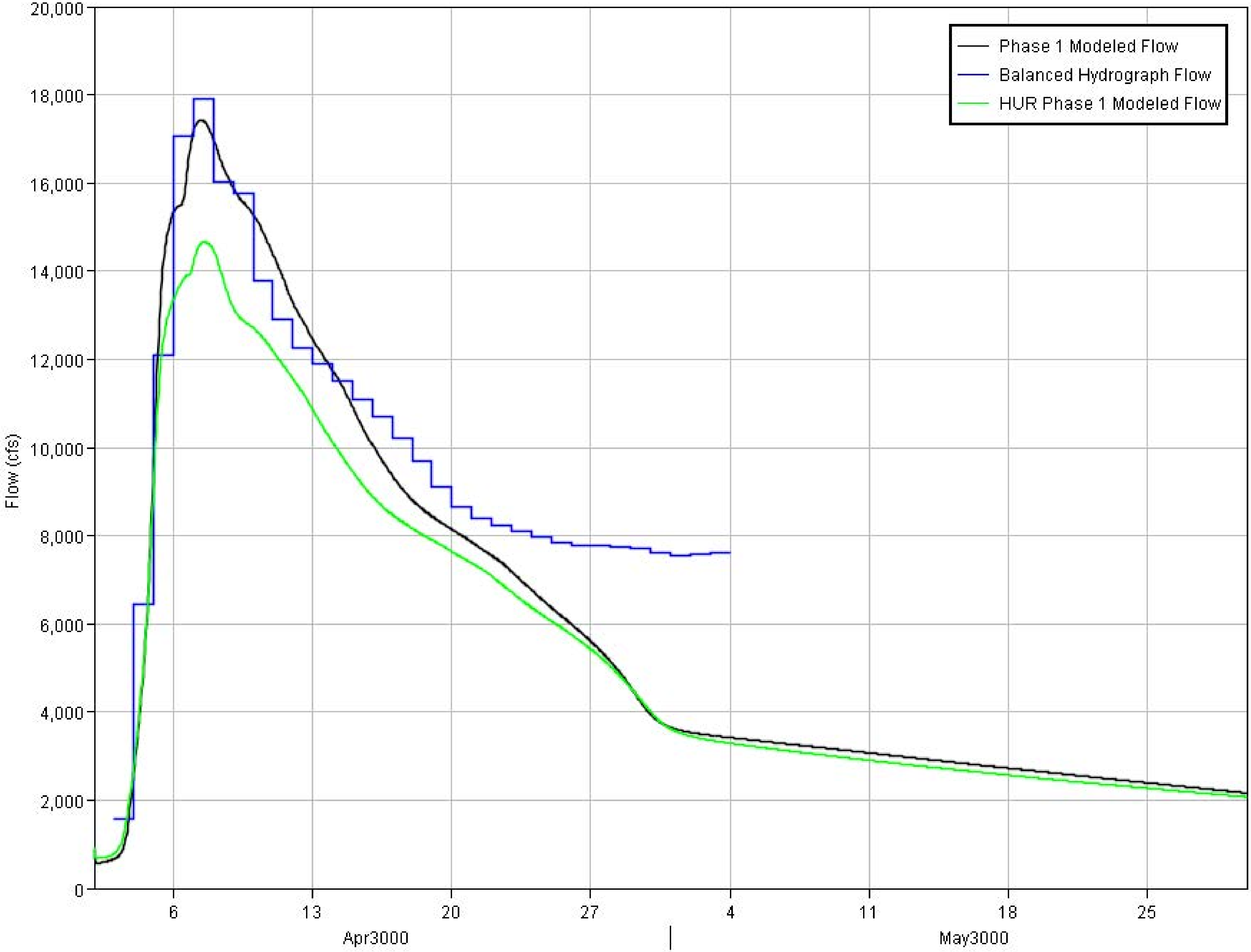

Figure 10: HUR Red River of the North at Hickson Flow Hydrographs

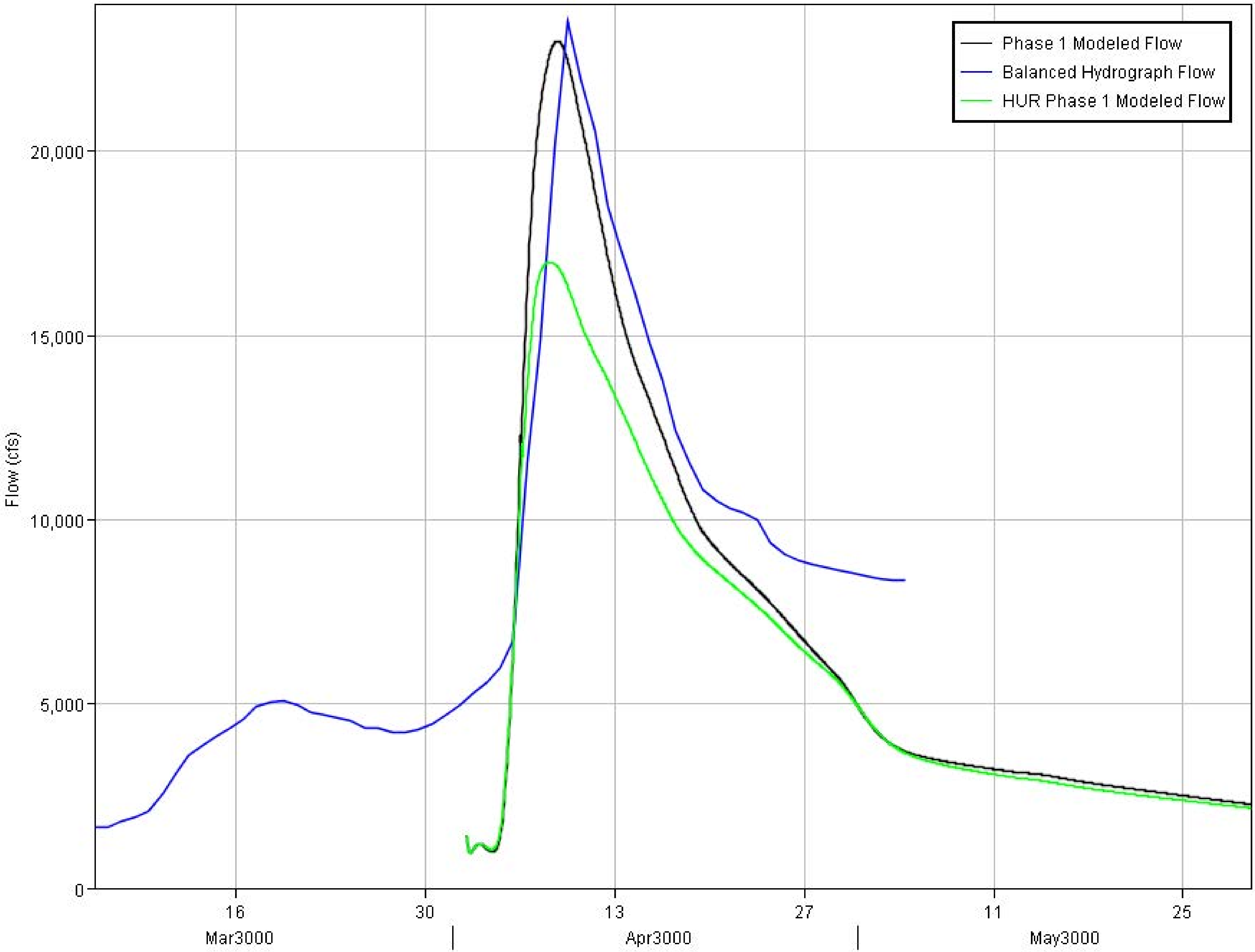

Figure 11: HUR Red River of the North At Fargo Flow Hydrographs

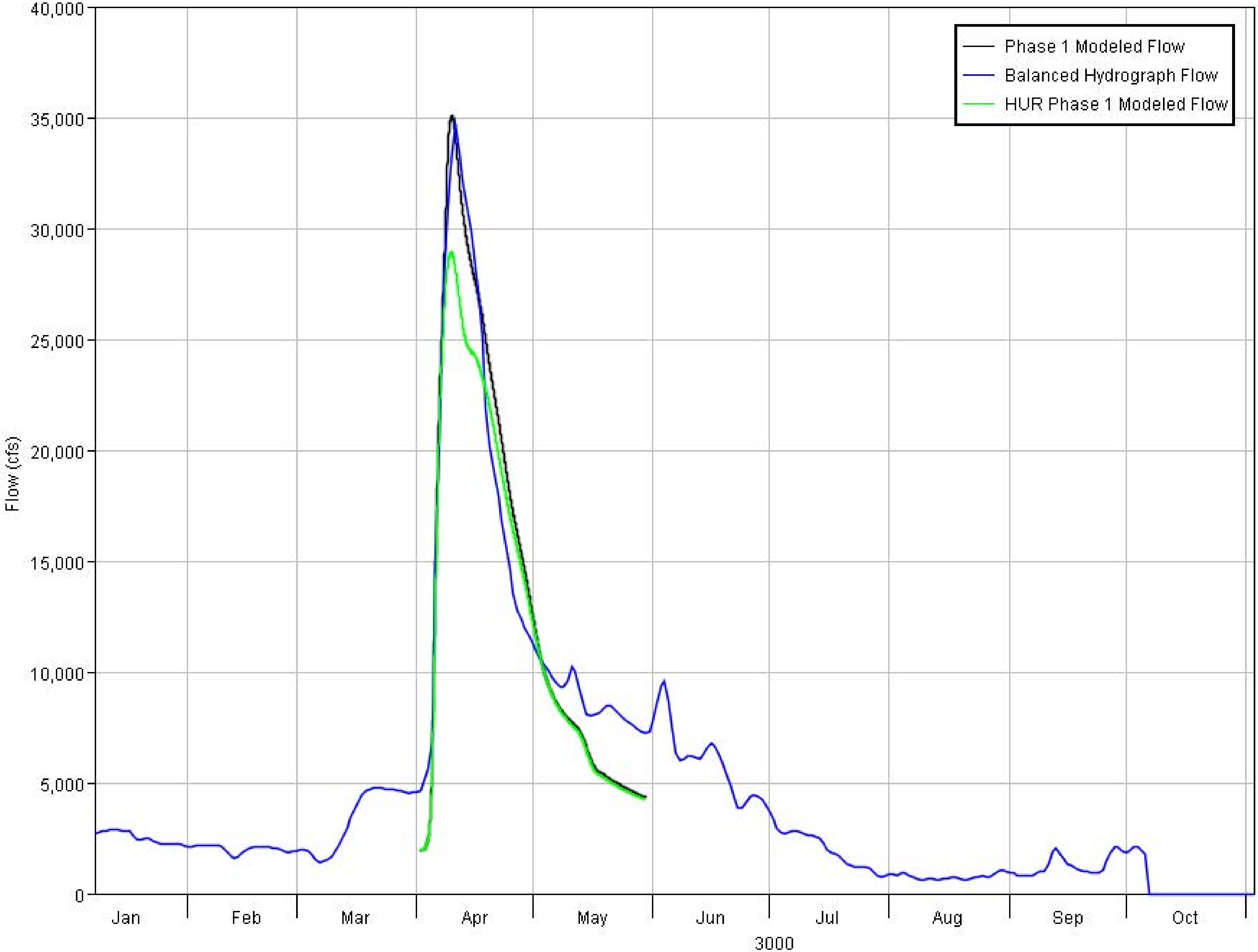

Figure 12: HUR Red River of the North At Halstad Phase II Flow Hydrographs

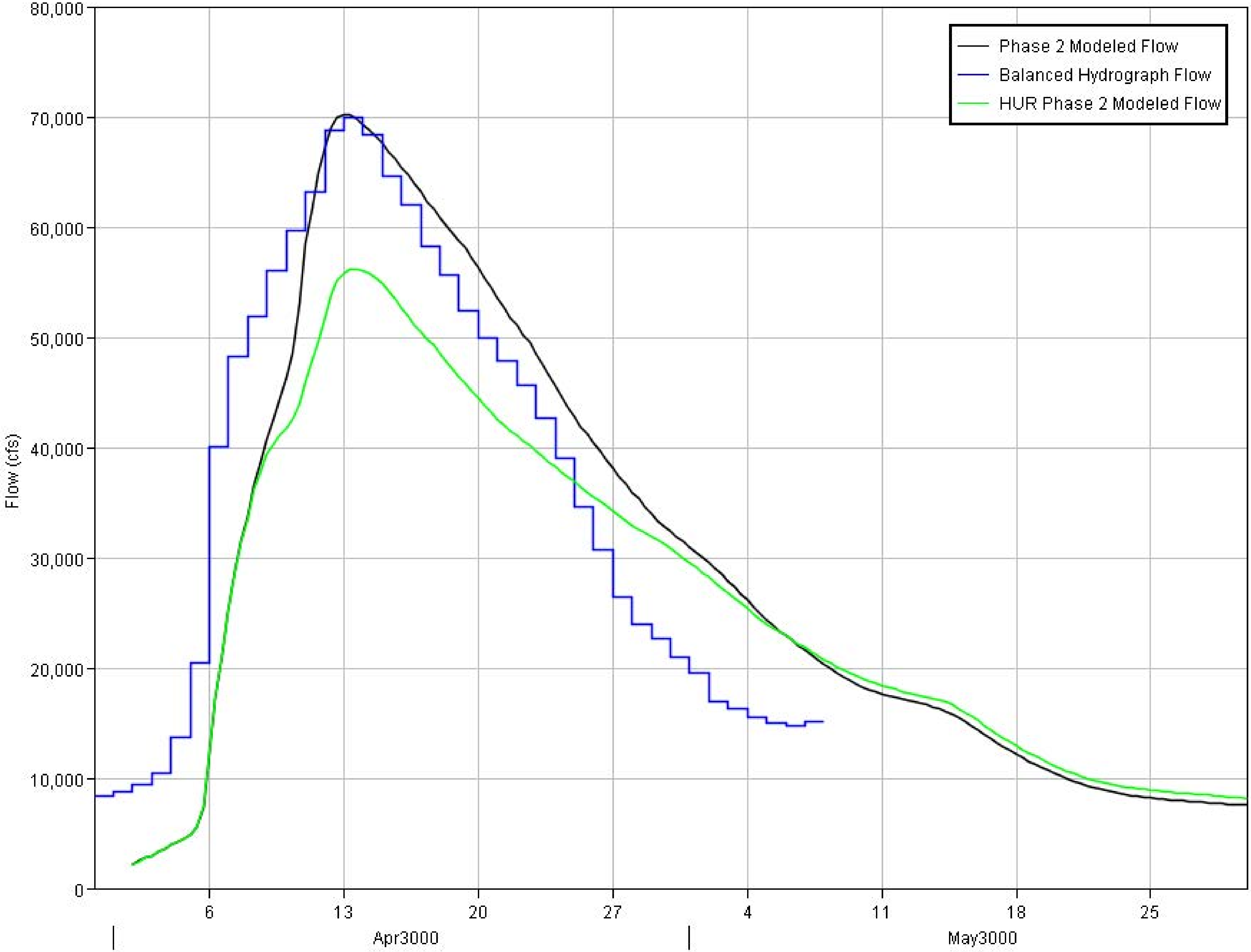

Figure 13: HUR Red River of the North At Grandforks Flow Hydrographs

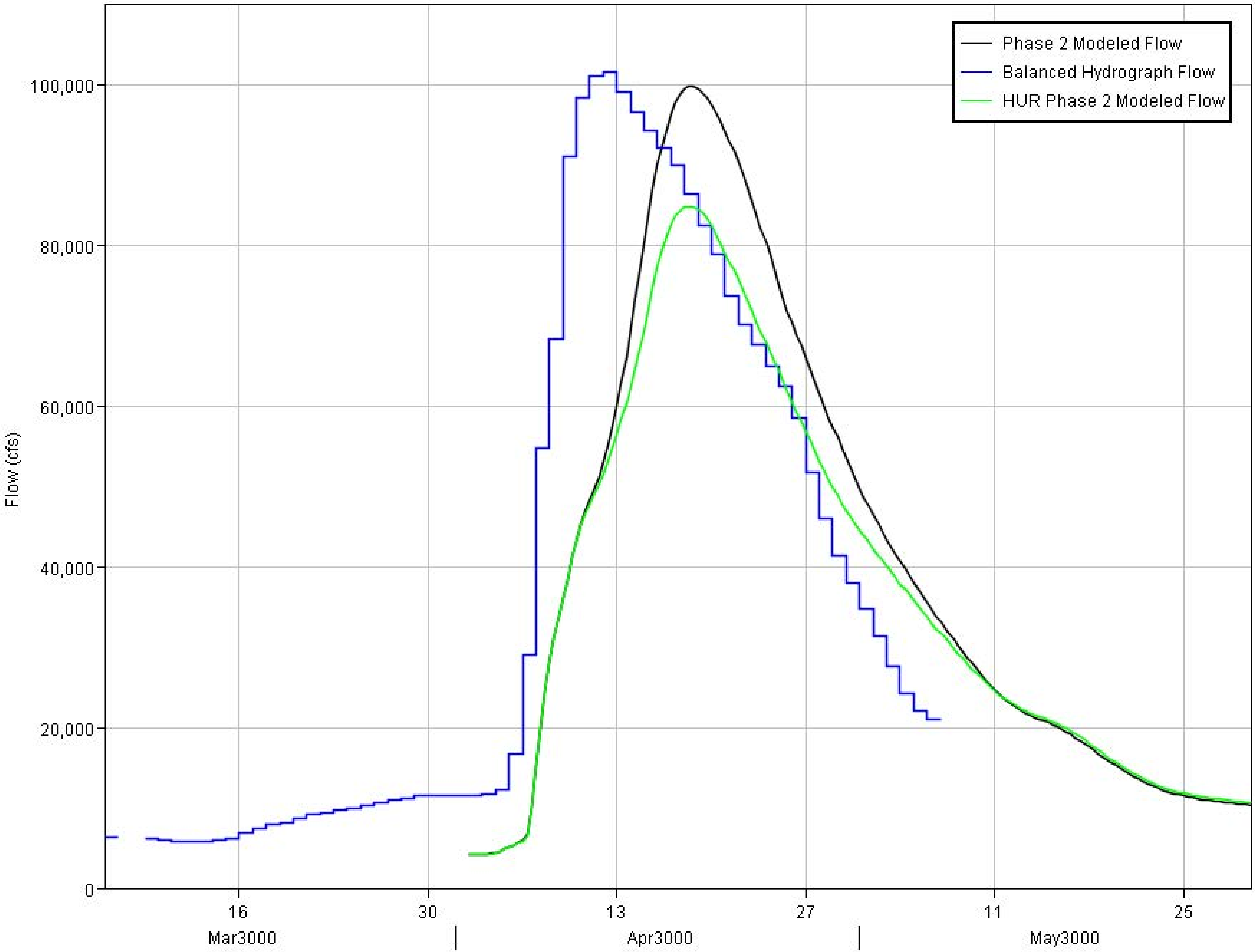

Figure 14: HUR Red River of the North At Oslo Flow Hydrographs

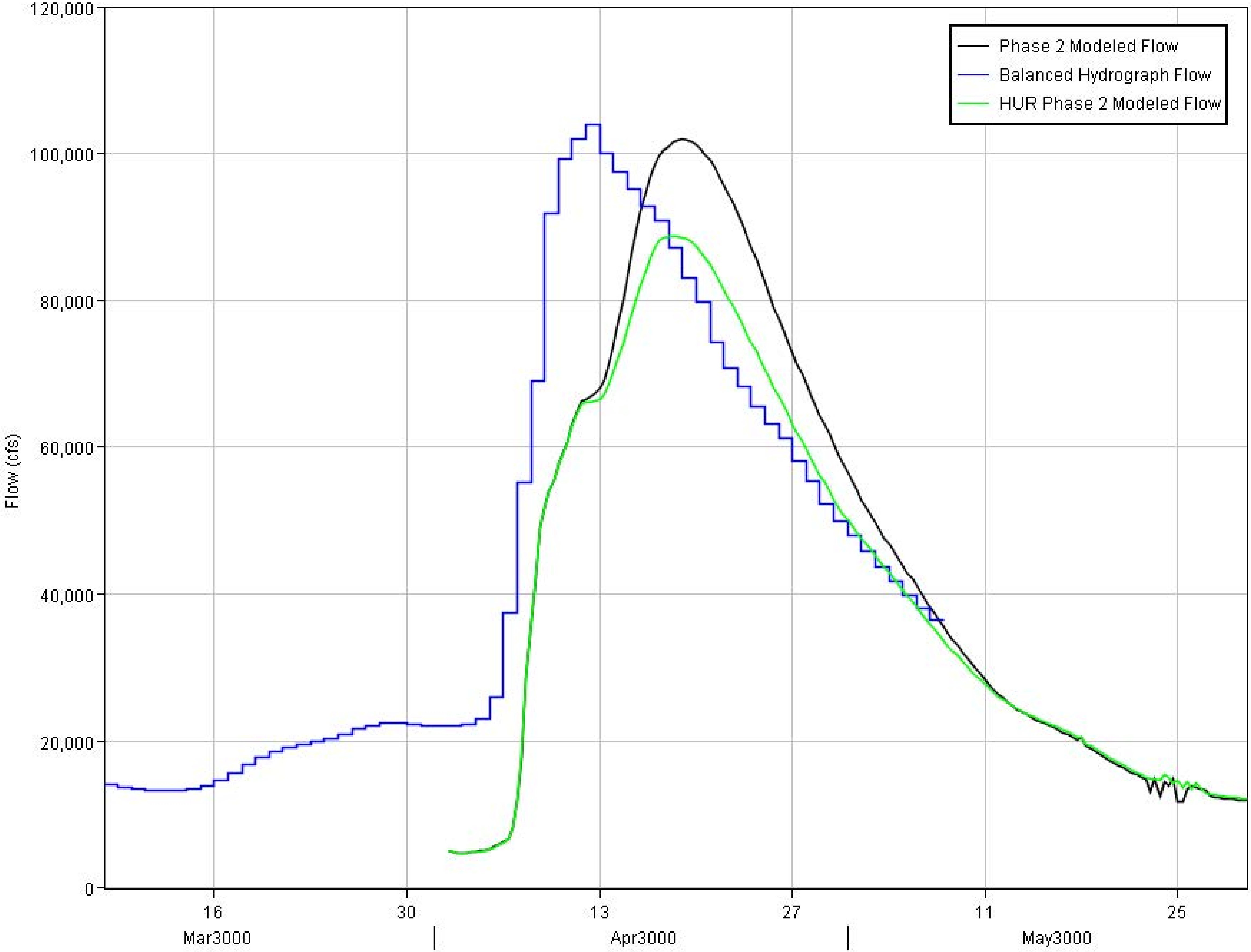

Figure 15: HUR Red River of the North at Drayton Flow Hydrographs

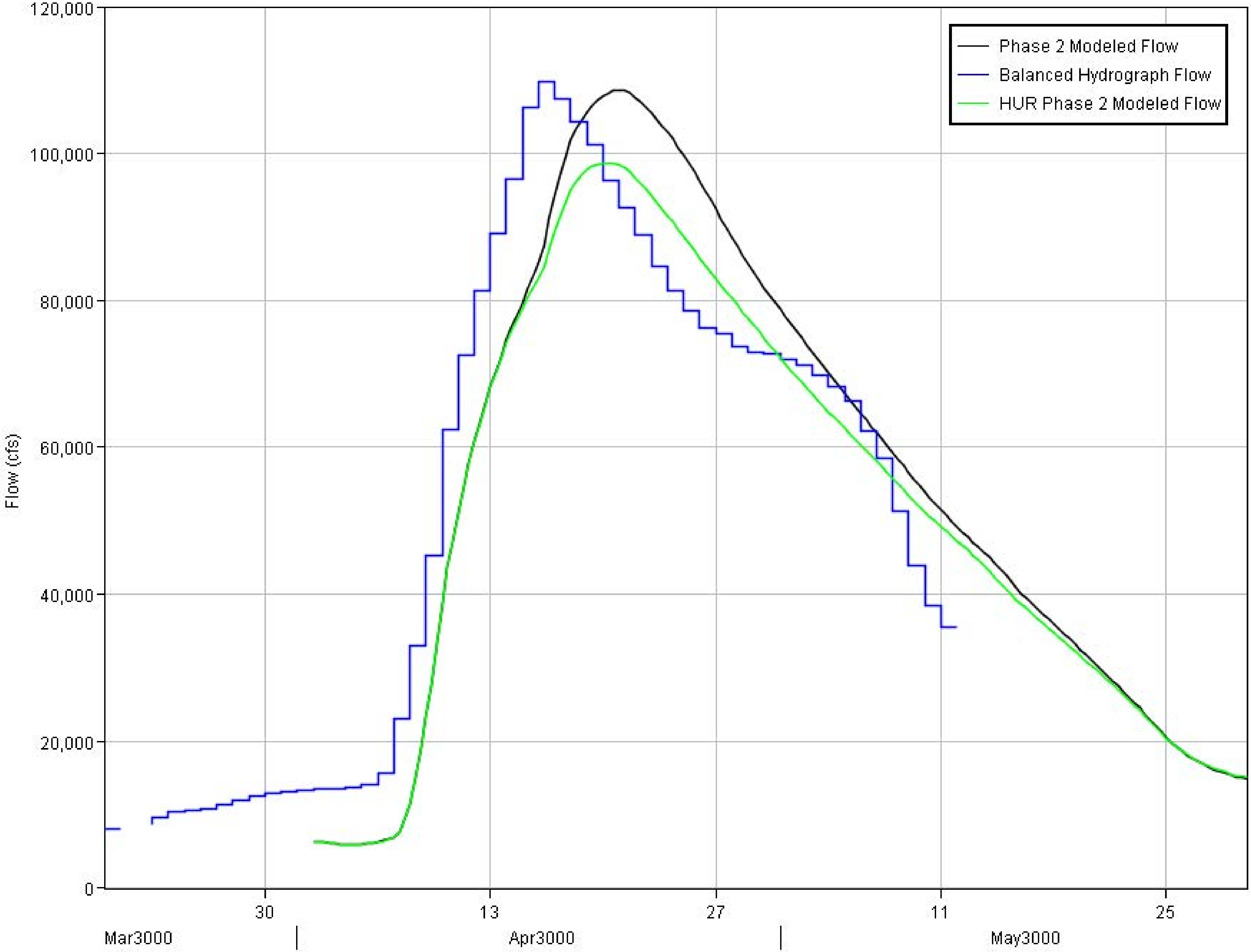

Figure 16: HUR Red River of the North at Emerson Flow Hydrographs