Appendix D

Draft San Joaquin River Interim Flow Unsteady Modeling Analysis

Water Year 2011 Interim Flows Project

Administrative Draft Supplemental Environmental Assessment/Initial Study

June 2010

DRAFT
San Joaquin River Interim Flow Unsteady Modeling Analysis

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INTRODUCTION

A one-dimensional (1-D), unsteady hydraulic model of the approximately 150-mile reach of the San Joaquin River between Friant Dam [River Mile (RM) 267.6] and the confluence with the Merced River (RM 118.2) was developed by Mussetter Engineering, Inc. (MEI, 2009) [now part of the Tetra Tech Surface Water Group (Tt-MEI)] using the U.S. Army Corps of Engineers HEC-RAS computer software Version 4.0 (USACE, 2008). The model was developed to support planning and design efforts for implementation of the Settlement Agreement between the Natural Resources Defense Council (NRDC), Friant Water Users Authority (FWUA) and the Federal Government that establishes restoration guidelines for the reach (NRDC et al., 2007). The model provides a tool to route existing and potential restoration flow release hydrographs to predict the magnitude and duration of discharges and the associated hydraulic conditions at locations throughout the project reach downstream from Friant Dam.

This memorandum describes model execution and analysis of a series of hydrographs for Reaches 1a, 1b and 2a (**Figure 1**) that were provided by the California Department of Water Resources (CDWR). The primary objective of this study is to examine the sensitivity of predicted Friant-release hydrographs to the water-surface elevation at the start of the hydrograph in the eight off-channel storage areas used in the model (**Figure 2**). A secondary objective is to help identify hydrograph(s) that could be released from Friant Dam that will not exceed a peak discharge of 1,300 cfs at the Chowchilla Bypass Bifurcation Structure.

SCOPE OF WORK

The following tasks were completed by Tt-MEI to achieve the objectives of the work:

1. Initial water-surface elevations were determined for the eight storage areas for four different trial runs: (1) the water-surface elevation in the river adjacent to each storage area at a steady-state discharge of 350 cfs, with no infiltration loss, (2) all storage areas at lowest possible levels based on the 1998 mapping, (3) a steady-state discharge of 350 cfs with infiltration loss, and (4) elevations interpreted from the 2007 LiDAR mapping data.

2. The unsteady model was executed for the 15 hydrographs provided by CDWR that represent possible Friant Dam release schedules for each of the four initial condition trials.

3. Hydrographs that do not exceed a peak discharge of 1,300 cfs at the Bifurcation Structure were identified.

INITIAL CONDITIONS AND ASSUMPTIONS

CDWR provided to Tt-MEI 15 hydrographs representing possible Friant Dam release schedules (**Figures 3 through 5**). The hydrographs include a combination of five peak-flow releases (1,500, 1,660, 2,000, 2,500, and 3,000 cfs) and three different peak release durations (6-, 12- and 24-hour). All hydrographs begin and end with at discharge of 350 cfs, with identical up- and down-ramping rates that are based on guidelines established by the San Joaquin River Restoration Program (the Program).

The geometry used in the model represents existing conditions in Reaches 1a, 1b and 2a, including the eight off-channel storage areas resulting from abandoned gravel pits along the reach (Figure 2). The hydrograph were run for four different sets of initial water-surface elevations in the storage areas to study the sensitivity of flood wave celerity and attenuation (**Table 1**). Trial 1 represented the highest reasonable initial elevations, were based on the water-surface elevation in the main channel closest to each storage area at a steady-state discharge of 350 cfs and no infiltration loss. Trial 2 used the lowest possible initial elevations, under the assumption that all storage areas are empty. Trial 3 used initial elevations that incorporate groundwater losses into the 350-cfs, steady-state run. Trial 4 used elevations interpreted directly from the 2007 mapping data provided by Towill, Inc. (Towill, 2009) for each storage area when the mean daily flow release from Friant Dam was 219 cfs.

Table 1. Storage area initial water-surface elevations.

Storage Area	Trial 1: 350 cfs (no loss)	Trial 2: Storage areas empty	Trial 3: 350 cfs (with loss)	Trial 4: 2007 Mapping (219 cfs)
	(ft, NGVD29)	(ft, NGVD29)	(ft, NGVD29)	(ft, NGVD29)
A	249.6	246	249.5	248.53
B	249.6	236	249.5	248.53
C	228.03	218	227.64	226
D	272.38	266	271.05	268.21
1	233.48	225	232.41	230.95
2	249.6	246	249.5	248.53
3	249.6	246	249.5	248.53
4*	266	266	266	266

*SA-4 is disconnected from the main channel at flows below 6,000 cfs and does not influence the results of this study.

The previously developed rating curve for the Bifurcation Structure was used for the downstream boundary condition (**Figure 6**), and the previously developed groundwater loss relationship detailed in (MEI, 2009) was applied to the discharge profile (**Figure 7**).

RESULTS

The four sets of initial storage conditions were modeled for each of the 15 different hydrographs. A comparison of the resulting hydrographs at the Bifurcation Structure is presented to highlight the maximum difference between cases.

Predicted peak discharge magnitudes at the Bifurcation Structure for the 1,500-cfs peak release are shown in **Table 2**. As expected, for all durations, the highest predicted peak discharges at the Bifurcation Structure correspond with the highest initial storage-area elevations (Trial 1). Similarly, Trial 2 which assumed the storage areas are at the lowest possible elevations predicted the lowest peak discharges. Trials 3 and 4, which used initial storage elevations derived from the unsteady model and 2007 mapping data, respectively, predicted peak discharges that were nearly identical for peak release durations of 6 and 12 hours. This occurred because a similar volume of water was drawn into and permanently stored in Storage Area 1 for these hydrographs. The differences in the initial elevation between these trials had a more significant effect on the result for the 24-hour duration release. The predicted peak discharge at the Bifurcations Structure was less than 1,300 cfs for all of the simulated 1,500-cfs release hydrographs (Table 2, **Figures 8 through 10**).

Table 2. Predicted peak discharge magnitudes at Bifurcation Structure for a Friant release of 1,500 cfs.

Peak Release Duration	Trial 1 (cfs)	Trial 2 (cfs)	Trial 3 (cfs)	Trial 4 (cfs)
6-hour	801	634	768	765
12-hour	914	737	827	825
24-hour	1,073	853	942	872

Release hydrographs that peak at 1,660 cfs show a similar trend as to the 1,500-cfs releases (**Table 3**). For the 6- and 12-hour release durations, Trials 3 and 4 predicted approximately the same hydrographs at the Bifurcation Structure, and the differences were more significant for the 24-hour release (**Figures 11 throug h 13**). Trials 1 and 2 provide the bounds of the expected influence of the initial elevations in Storage Area 1, with the difference in predicted peak discharge increasing with increasing duration of the release. The predicted peak discharge was also less than 1,300 cfs for all of the 1,660-cfs release simulations.

Table 3. Predicted peak discharge magnitudes at Bifurcation Structure for a Friant release of 1,660 cfs.

Peak Release Duration	Trial 1 (cfs)	Trial 2 (cfs)	Trial 3 (cfs)	Trial 4 (cfs)
6-hour	957	766	833	831
12-hour	1,085	855	900	884
24-hour	1,258	948	1,128	928

For the 2,000-cfs release runs, the predicted peak discharge at the Bifurcation Structure was different for all trials and all duration lengths (**Table 4, Figures 14 through 16**). The 1,300-cfs threshold is exceeded with the 12-hour duration for Trial 1, with a peak discharge at the Bifurcation Structure of about 1,390 cfs. Trials 3 and 4 result in even higher peak discharges at the Bifurcation Structure (approximately 1,520 and 1,400 cfs, respectively).

Table 4. Predicted peak discharge magnitudes at Bifurcation Structure for a Friant release of 2,000 cfs.				
Peak Release Duration	Trial 1 (cfs)	Trial 2 (cfs)	Trial 3 (cfs)	Trial 4 (cfs)
6-hour	1,243	906	1,100	960
12-hour	1,389	978	1,275	1,065
24-hour	1,572	1,050	1,519	1,395

For the 2,500-cfs release, the 1,300-cfs threshold at the Bifurcation Structure was exceeded for runs except Trial 2 with 6- and 12-hour duration releases (**Table 5, Figures 17 through 19**), and the threshold is exceeded for all of the 3,000-cfs releases (**Table 6, Figures 2 0 through 22**).

Table 5. Predicted peak discharge magnitudes at Bifurcation Structure for a Friant release of 2,500 cfs.				
Peak Release Duration	Trial 1 (cfs)	Trial 2 (cfs)	Trial 3 (cfs)	Trial 4 (cfs)
6-hour	1,721	1,109	1,808	1,467
12-hour	1,882	1,149	1,814	1,686
24-hour	2,072	1,412	2,045	1,984

Table 6. Predicted peak discharge magnitudes at Bifurcation Structure for a Friant release of 3,000 cfs.				
Peak Release Duration	Trial 1 (cfs)	Trial 2 (cfs)	Trial 3 (cfs)	Trial 4 (cfs)
6-hour	2,247	1,481	2,189	2,100
12-hour	2,392	1,785	2,354	2,282
24-hour	2,571	2,226	2,555	2,521

DISCUSSION

For the cases considered in this study, the initial water-surface elevation in storage areas SA-1 and SA-C have a significant effect on downstream discharges for the lower magnitude and shorter duration release hydrographs. Except for the initial condition with the lowest possible elevations (Trial 2), four of the eight storage areas (SA-2, SA-3, SA-A, SA-B) have lateral weirs that control the off-take of flow at elevations below the local water-surface elevation in the main channel (**Table 7**). As a result, the elevation in the storage areas equalizes with the main channel elevation, effectively eliminating differences in initial conditions elevations. Two other storage areas have controlling weir elevations that are never overtopped, and therefore, do not affect any of the results (SA-B and SA-4). The remaining two (SA-1 and SA-C) have controlling weir elevations that are above the local water-surface elevation, and thus, maintain the initial condition elevation until the flood pulse causes the local water-surface elevation to rise above the weir elevation. Therefore, all differences between predicted downstream hydrographs in

Trials 1, 3 and 4 for a given release magnitude and duration can be attributed to the initial stage in these two storage areas.

Table 7. Storage area controlling weir elevations and stage differences of initial water-surface elevations.*					
Storage Area	Controlling Weir Elevation	Trial 1: 350 cfs (no loss)	Trial 2: Storage areas empty	Trial 3: 350 cfs (with loss)	Trial 4: 2007 Mapping (219 cfs)
	(ft, NGVD29)	(ft, NGVD29)	(ft, NGVD29)	(ft, NGVD29)	(ft, NGVD29)
A	248.0	1.6	(2.0)	1.5	0.5
B	254.0	(4.4)	(18.0)	(4.5)	(5.5)
C	228.0	0.0	(10.0)	(0.4)	(2.0)
D	269.0	3.4	(3.0)	2.1	(0.8)
1	234.0	(0.5)	(9.0)	(1.6)	(3.1)
2	248.0	1.6	(2.0)	1.5	0.5
3	246.0	3.6	-	3.5	2.5
4	272.4	(6.4)	(6.4)	(6.4)	(6.4)

* values in parentheses indicate initial WSEL is lower than controlling weir

This effect is most easily seen by comparing stages in the different storage areas. The stage hydrograph for a peak discharge of 1,660 cfs and duration of 6 hours is presented for each of the four initial conditions for SA-A, SA-C and SA-1 in **Figures 23 through 25**. In all four cases, the stage in SA-A quickly rises to the water-surface level in the main channel, and the stage behaves identically to the main channel throughout the hydrograph (Figure 23). IN SA-C, the difference between stages at the beginning and end of the hydrograph indicate that flow is permanently removed from the main channel (Figure 24). The most dramatic example occurs at SA-1, where different amounts of flow are removed from the channel during the hydrograph. This represents a significant flow volume due to the large size of this storage area (254 acres (Figure 25). The significance of the initial stages in storage areas SA-1 and SA-C diminishes for the releases with larger peak and longer duration (**Figure 26**).

Trials 1 and 4 can be used to gage the sensitivity of modeled results to the initial stages used in the storage areas. It is expected that the stages in Trial 1 are higher than expected because no flow is lost to groundwater infiltration. Trial 4 used stages that are lower than expected because the reported discharge at the time the mapping data was collected was 219 cfs. As discussed previously, release hydrographs with peak release magnitudes of 1,660 and 2,000 cfs showed the largest range in predicted downstream hydrographs, implying that these results are the most sensitive to initial storage area stage. The largest difference was predicted during the 1,660-cfs, 24-hour release where the predicted peaks for Trials 1 and 4 were approximately 1,260 and 930 cfs, respectively. This represents a difference of 20 percent of the peak release discharge. Differences for the 1,660-cfs, 12-hour release, 1,500-cfs, 24-hour release, 2,000-cfs, 6-hour release and 2,000-cfs, 12-hour release were 12, 13, 14 and 16 percent of peak release discharge, respectively. All other release hydrographs were expected to have downstream differences of 10 percent or less.

The initial conditions of Trial 3 represent the best approximation of water-surface elevations in the off-channel storage areas at the beginning of the Friant pulse release. For this trial, the

1,300-cfs channel capacity limit of Reach 2B is not exceeded by the 1,500- and 1,600-cfs Friant pulse releases for any duration (**Figure 27**). When the pulse is increased to 2,000 cfs, the capacity is exceeded when the duration rises above 12 hours. All durations for pulse releases of 2,500 and 3,000 cfs result in peak flows at the Bifurcation Structure that exceed the 1,300 cfs.

CONCLUSIONS

Four different sets of initial stage in the off-channel storage areas were used to run 15 different hydrographs of varying peak magnitude and duration. The results show that predicted downstream hydrographs are somewhat sensitive to the initial stages. The hydrographs in the middle range (1,660-cfs, 12- and 24-hour durations and 2,000-cfs, 6- and 12-hour durations) were most affected by the initial conditions. The results also indicate that SA-1, and to a lesser extent SA-C, has a significant effect on the magnitude of the downstream peak discharge. The initial conditions for Trial 3 represent the best estimate of initial conditions for this set of hydrographs because they correspond to the local main-channel elevation predicted by the unsteady model with groundwater loss. Trial 3 predicts that all hydrographs at 2,000 cfs, 12 hours and below will not exceed the 1,300-cfs threshold at the Bifurcation Structure.

The results of this study highlight the importance of properly modeling both the off-channel storage area size and in-let weir height. The next iteration in development of the unsteady model should focus on refining the location and inlet conditions of all potential storage areas. Given the sensitivity of predicted results to the initial stage within some of the storage areas, an effort to calibrate the relationship between main-channel water-surface elevation and storage area elevation would also be beneficial.

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U.S. Army Corps of Engineers, 2008. HEC-RAS, River Analysis System, Users Manual, Version 4.0, Hydrologic Engineering Center, Davis, California.

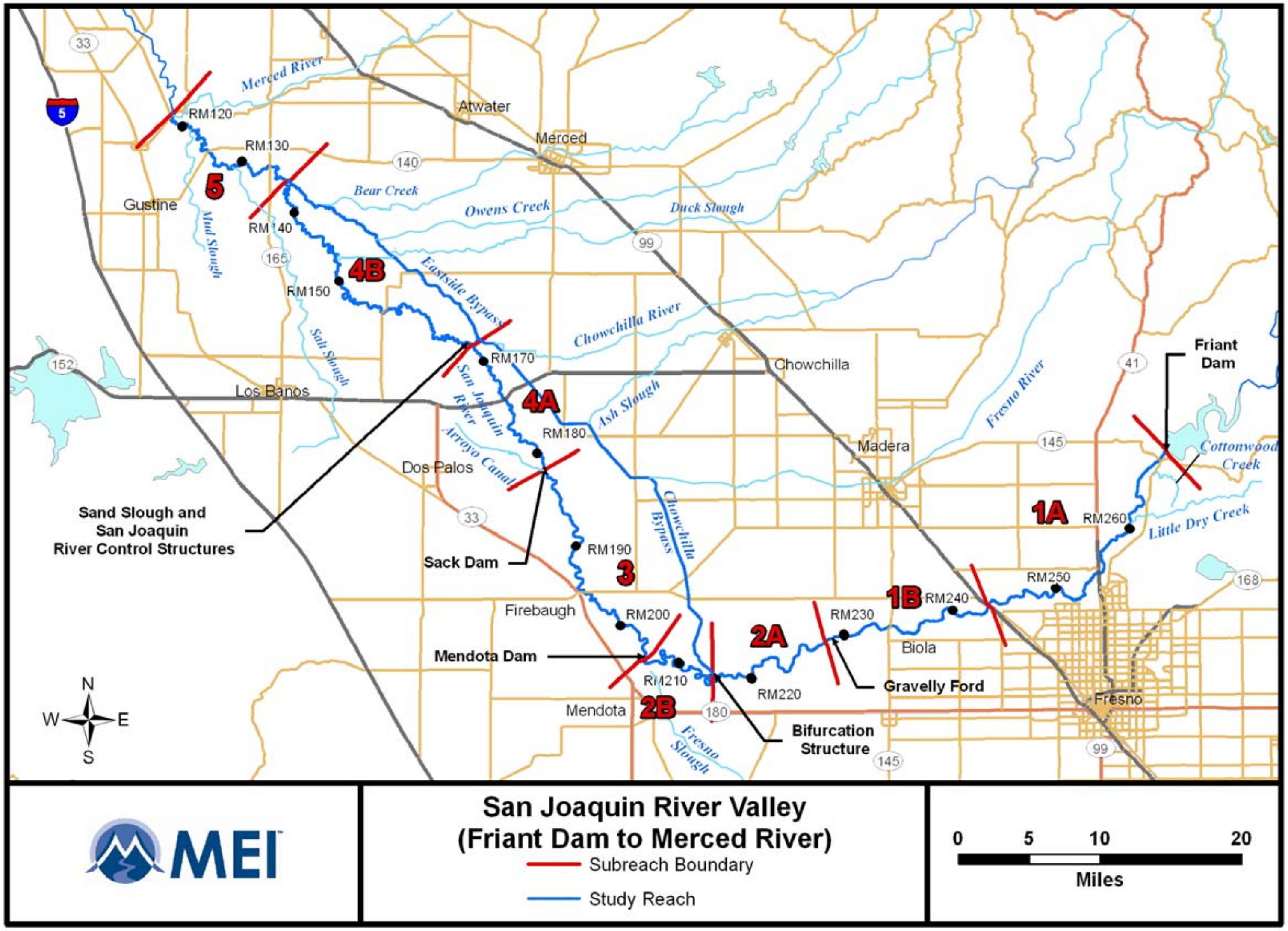

Figure 1. Plan view of San Joaquin River, Reaches 1a, 1b and 2a.

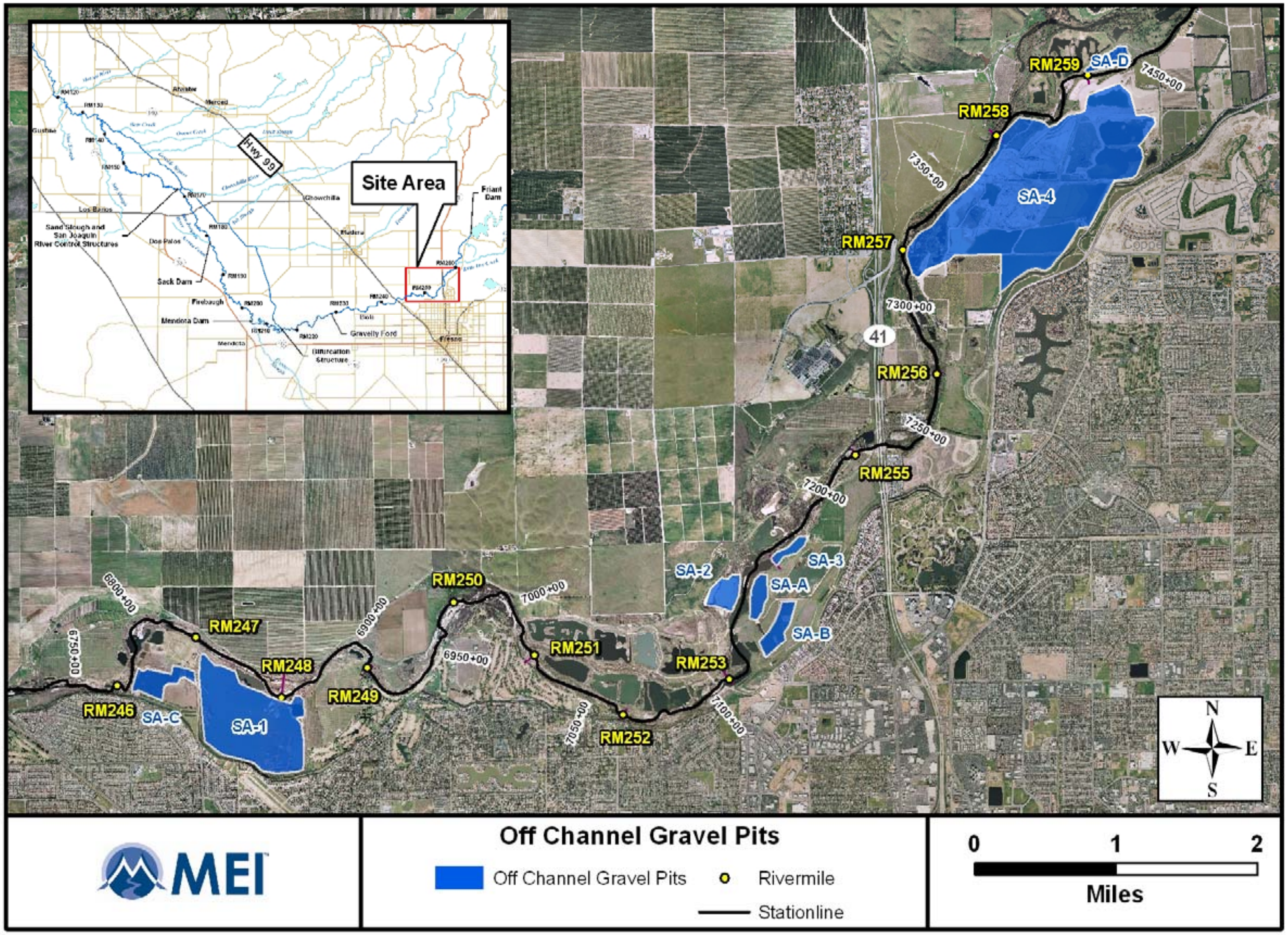

Figure 2. Plan view of off-channel storage areas.

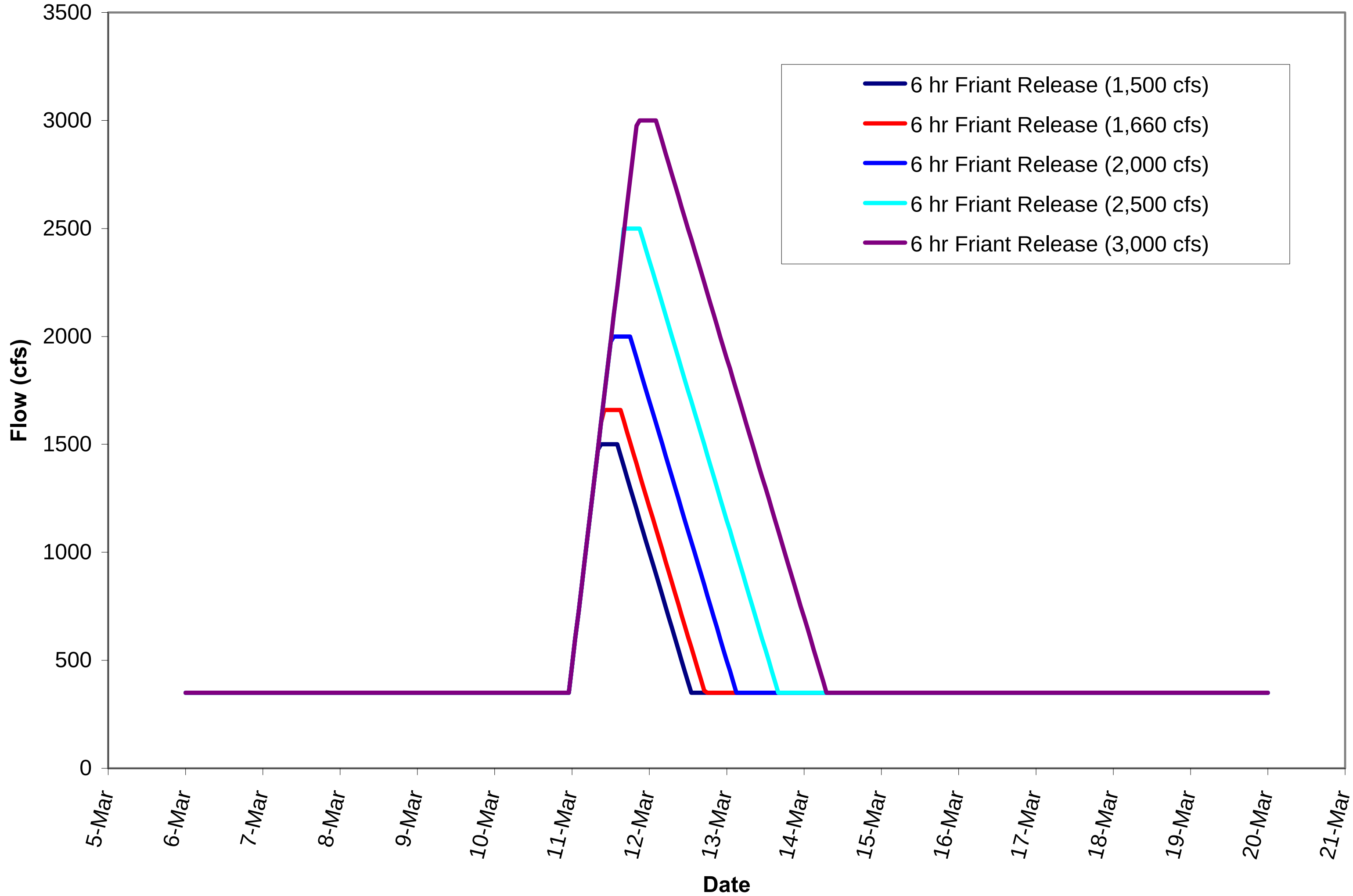

Figure 3. Friant Dam 6-hour release hydrograph of 1,500, 1,660, 2,000, 2,500 and 3,000 cfs.

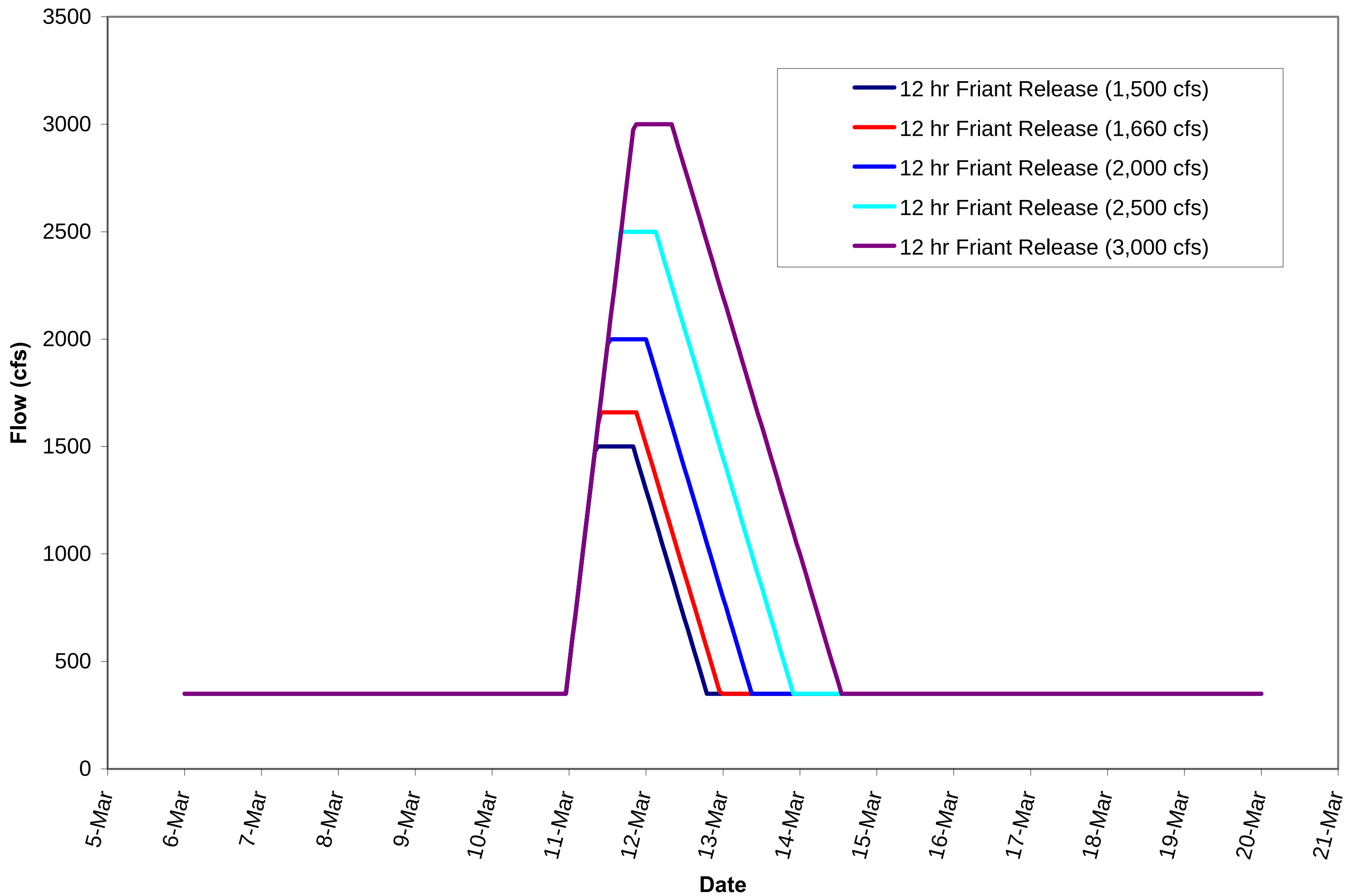

Figure 4. Friant Dam 12-hour release hydrograph of 1,500, 1,660, 2,000, 2,500 and 3,000 cfs.

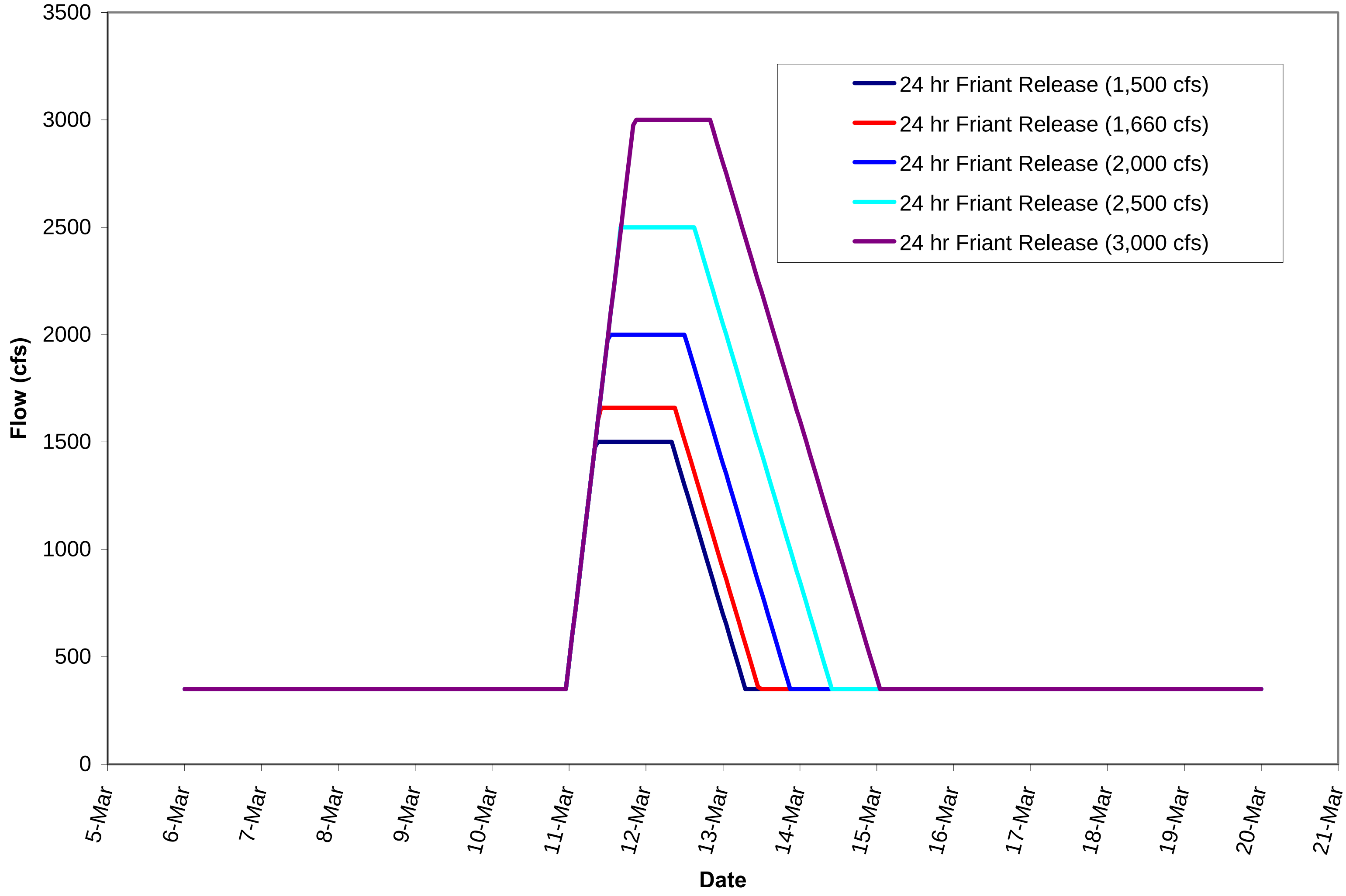

Figure 5. Friant Dam 24-hour release hydrograph of 1,500, 1,660, 2,000, 2,500 and 3,000 cfs.

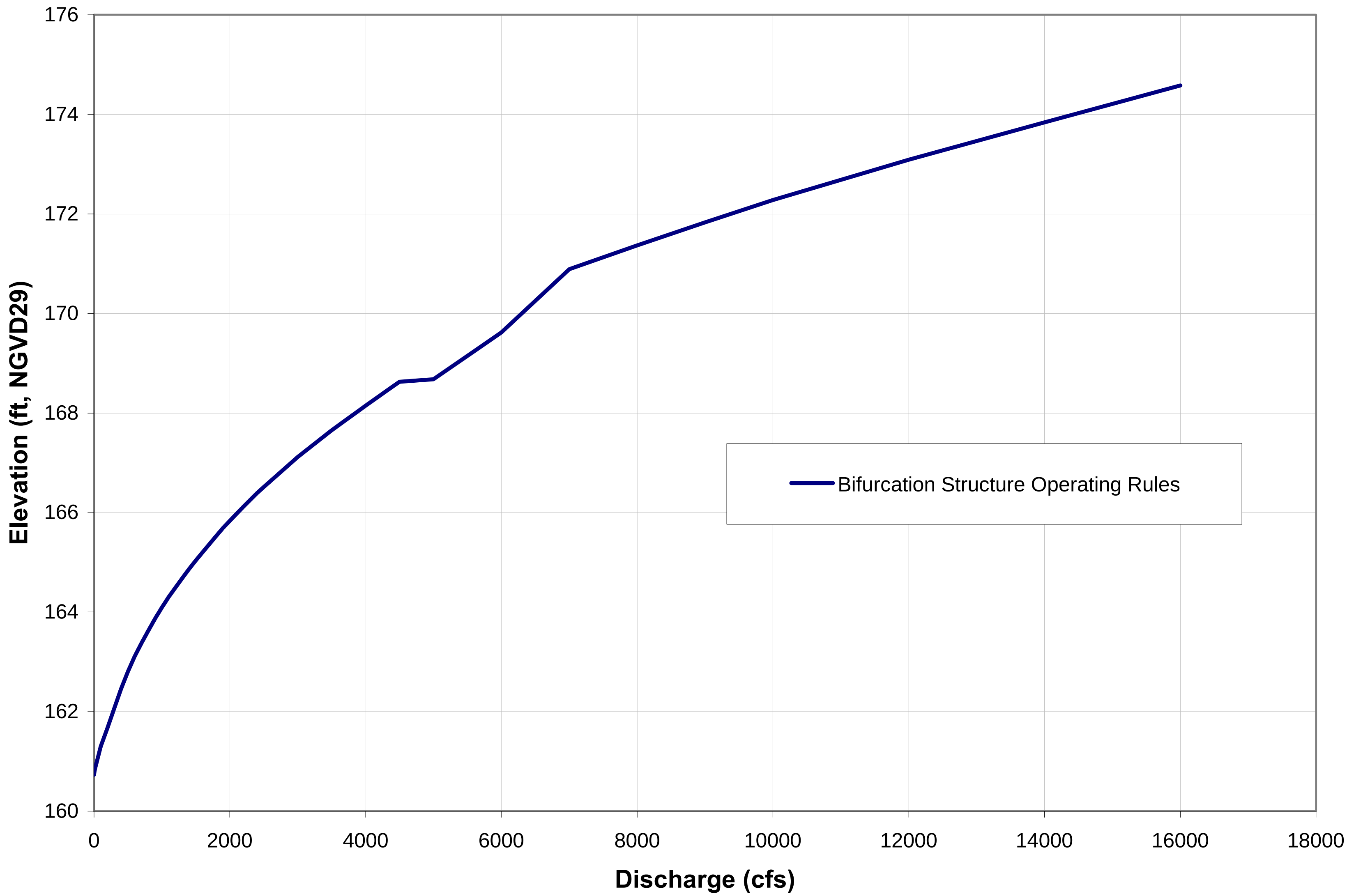

Figure 6. Rating curve defining the downstream boundary condition at the Bifurcation Structure.

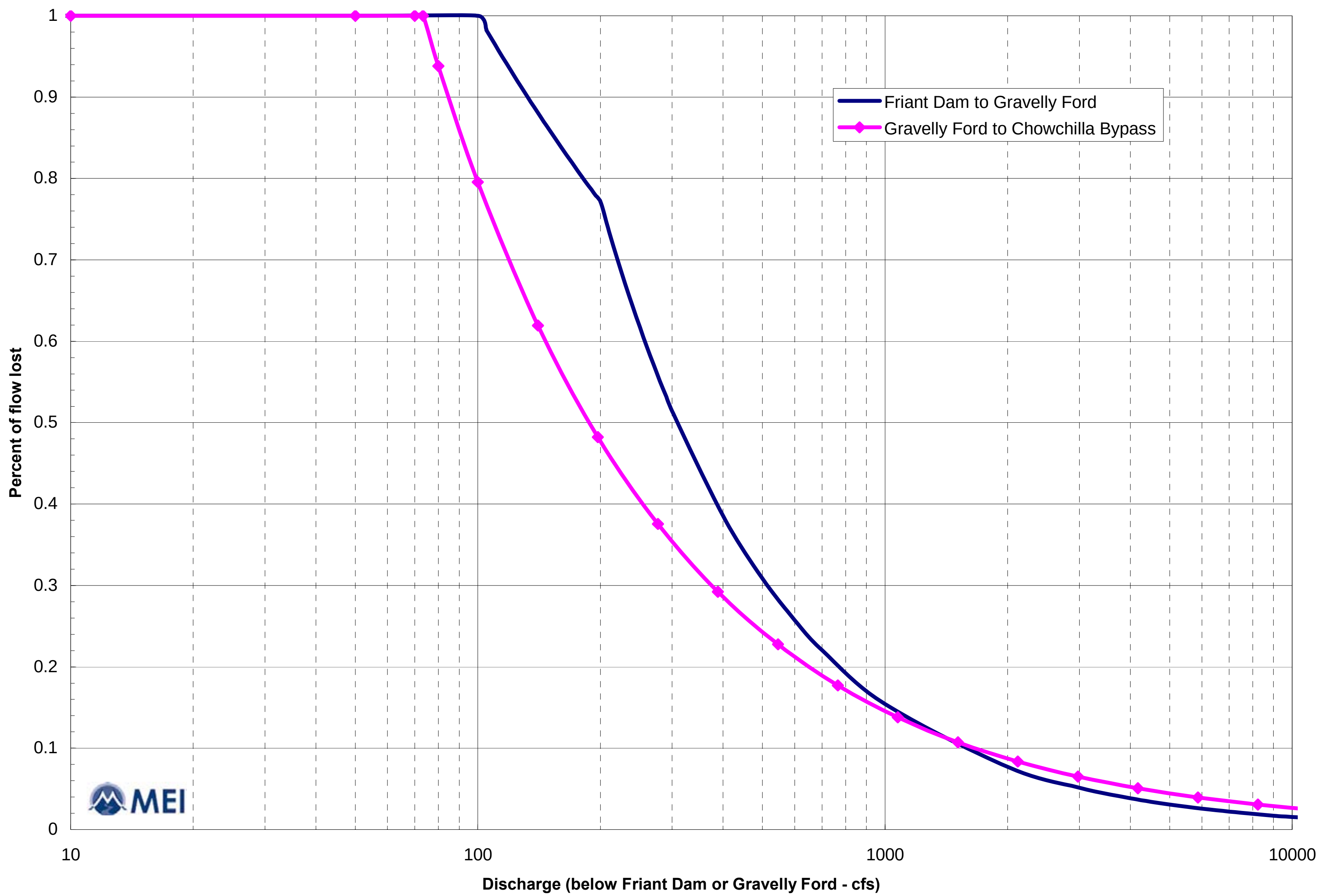

Figure 7. Groundwater loss rating curve.

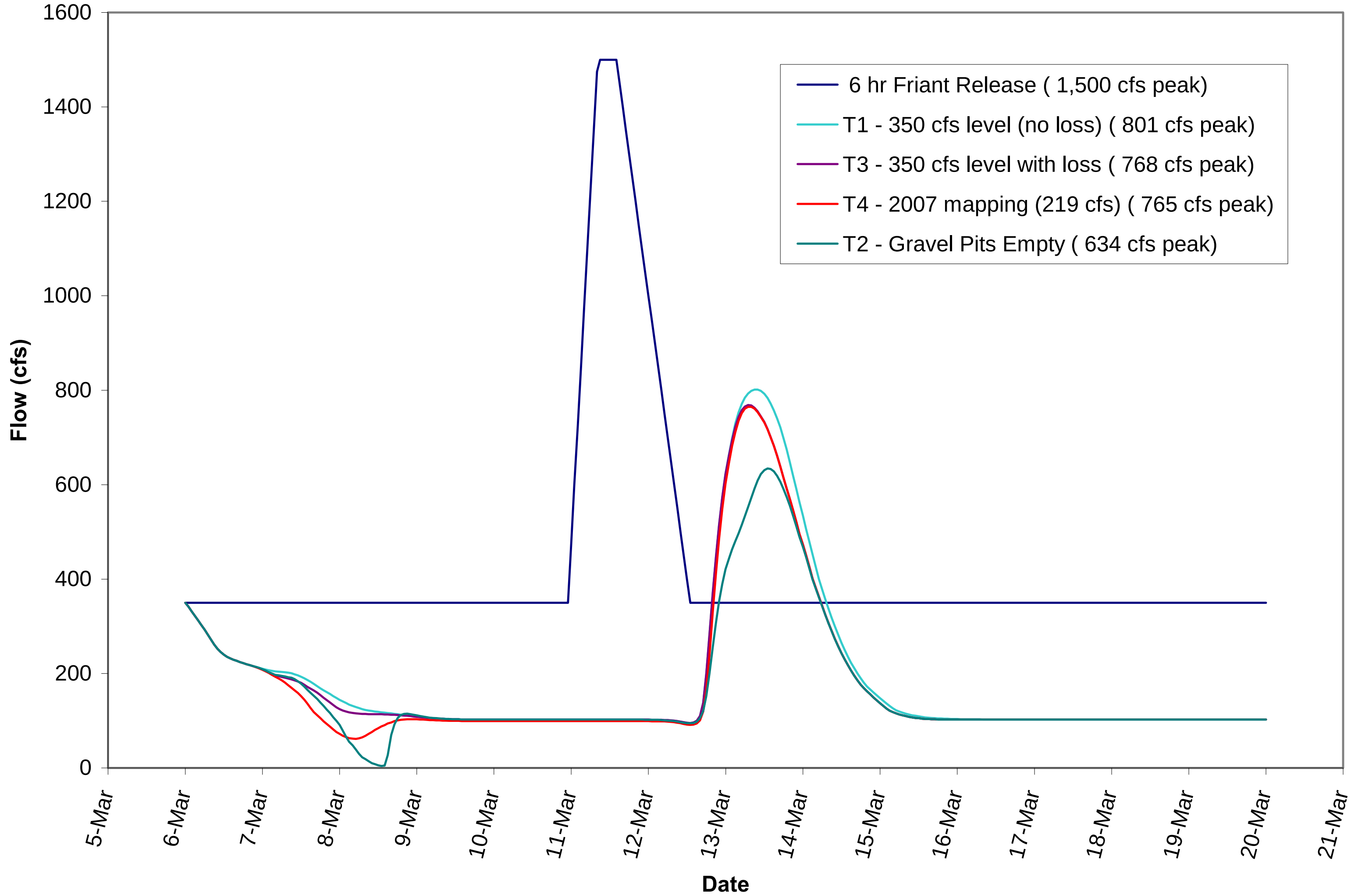

Figure 8. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 1,500-cfs, 6-hour release.

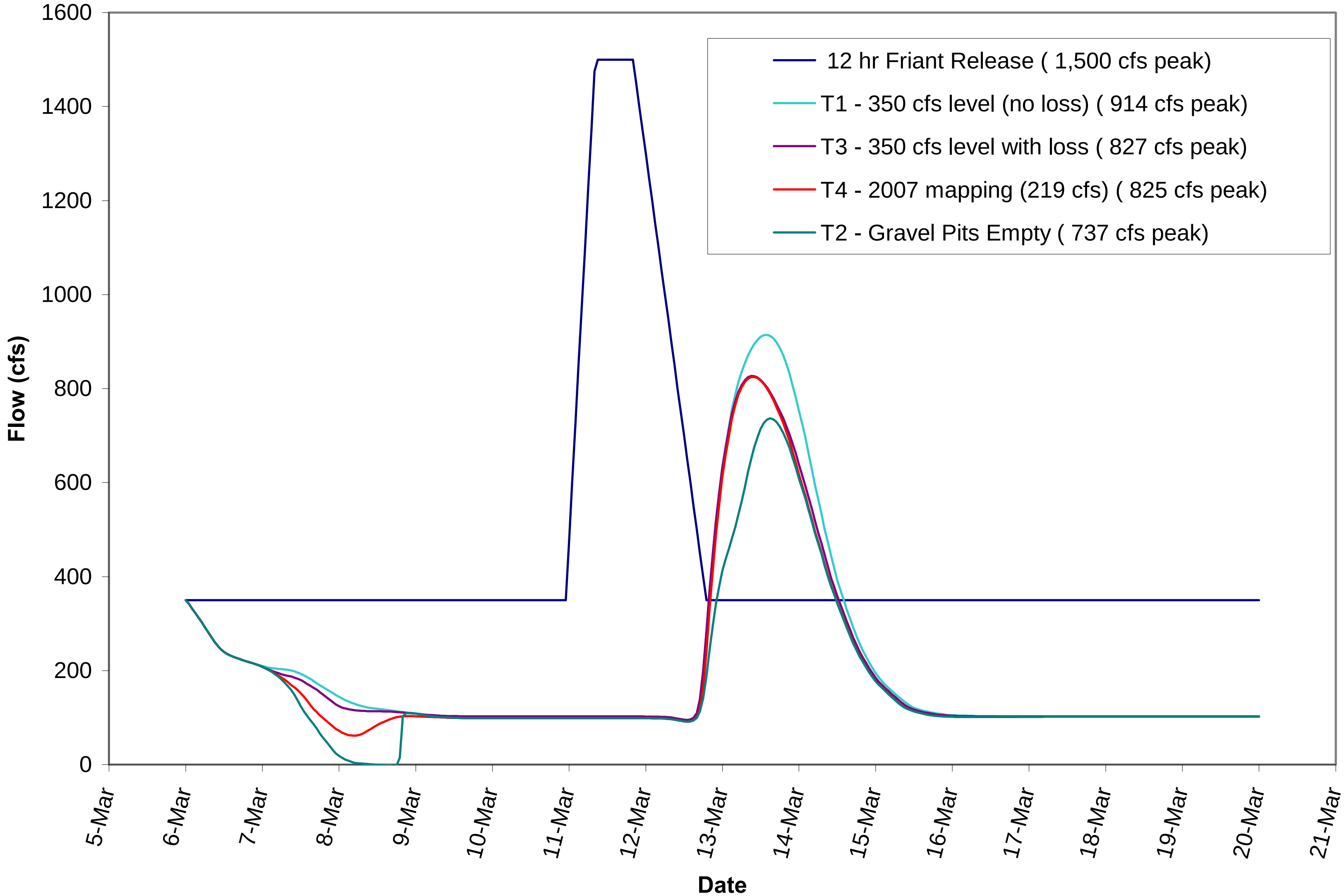

Figure 9. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 1,500-cfs, 12-hour release.

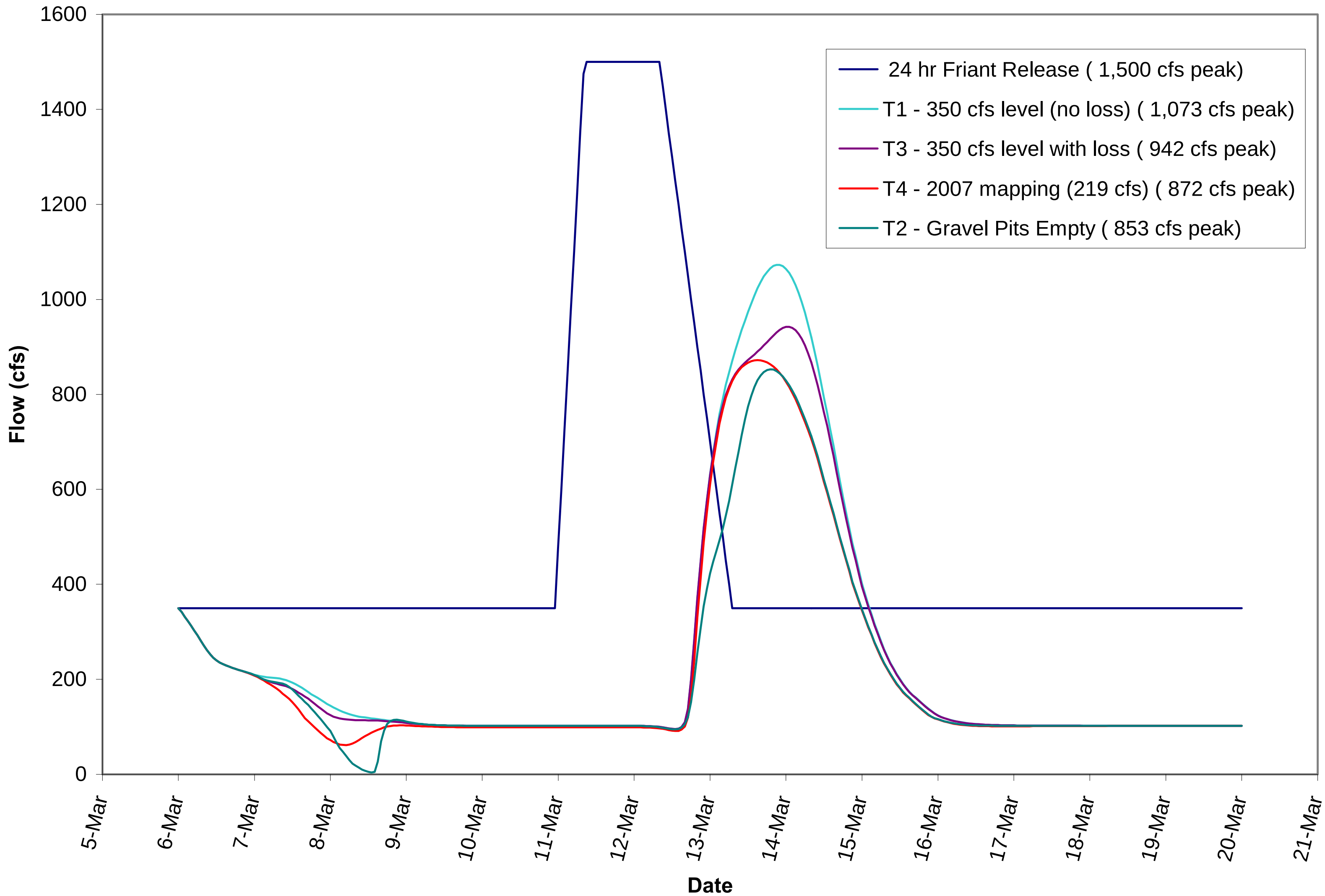

Figure 10. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 1,500-cfs, 24-hour release.

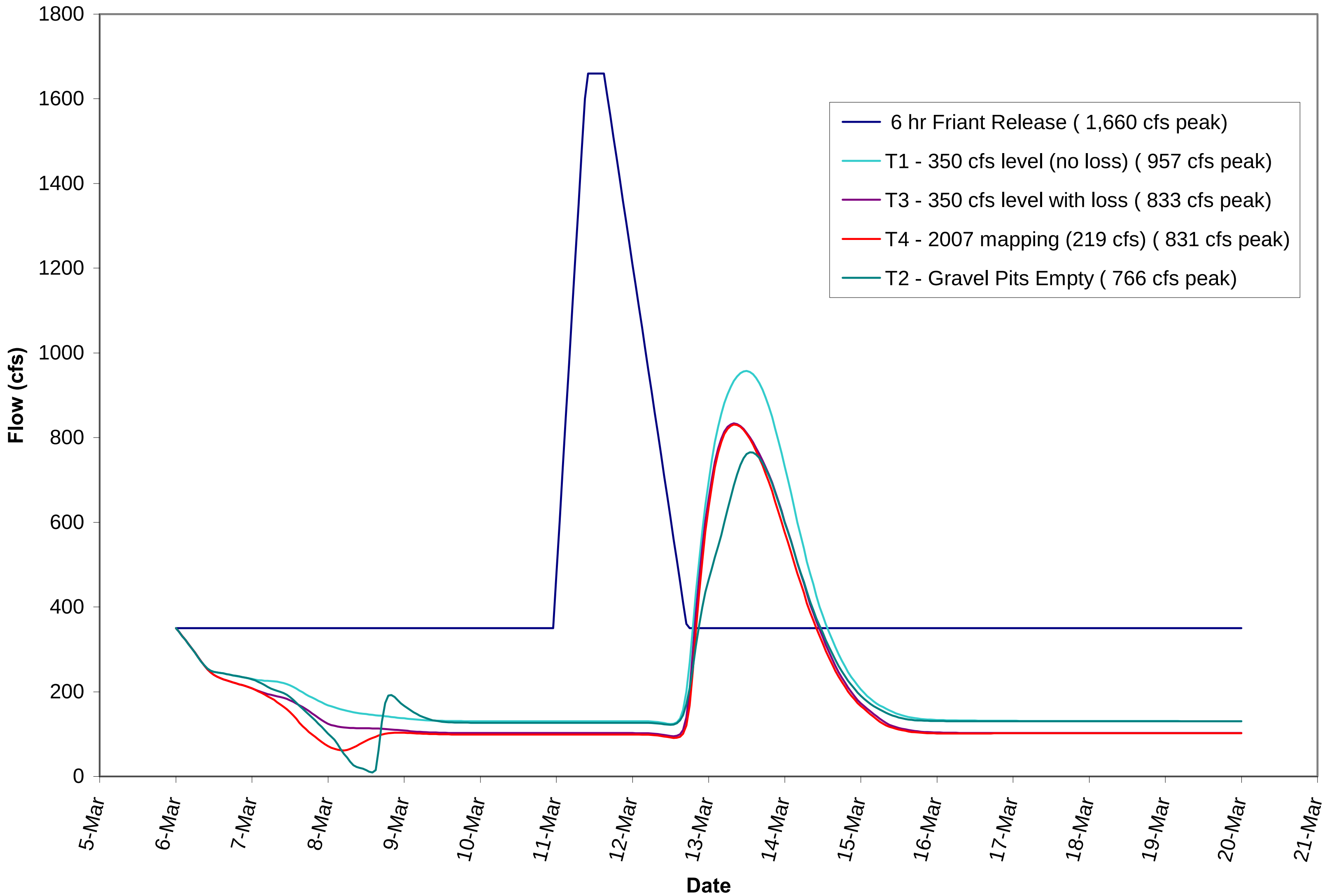

Figure 11. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 1,660-cfs, 6-hour release.

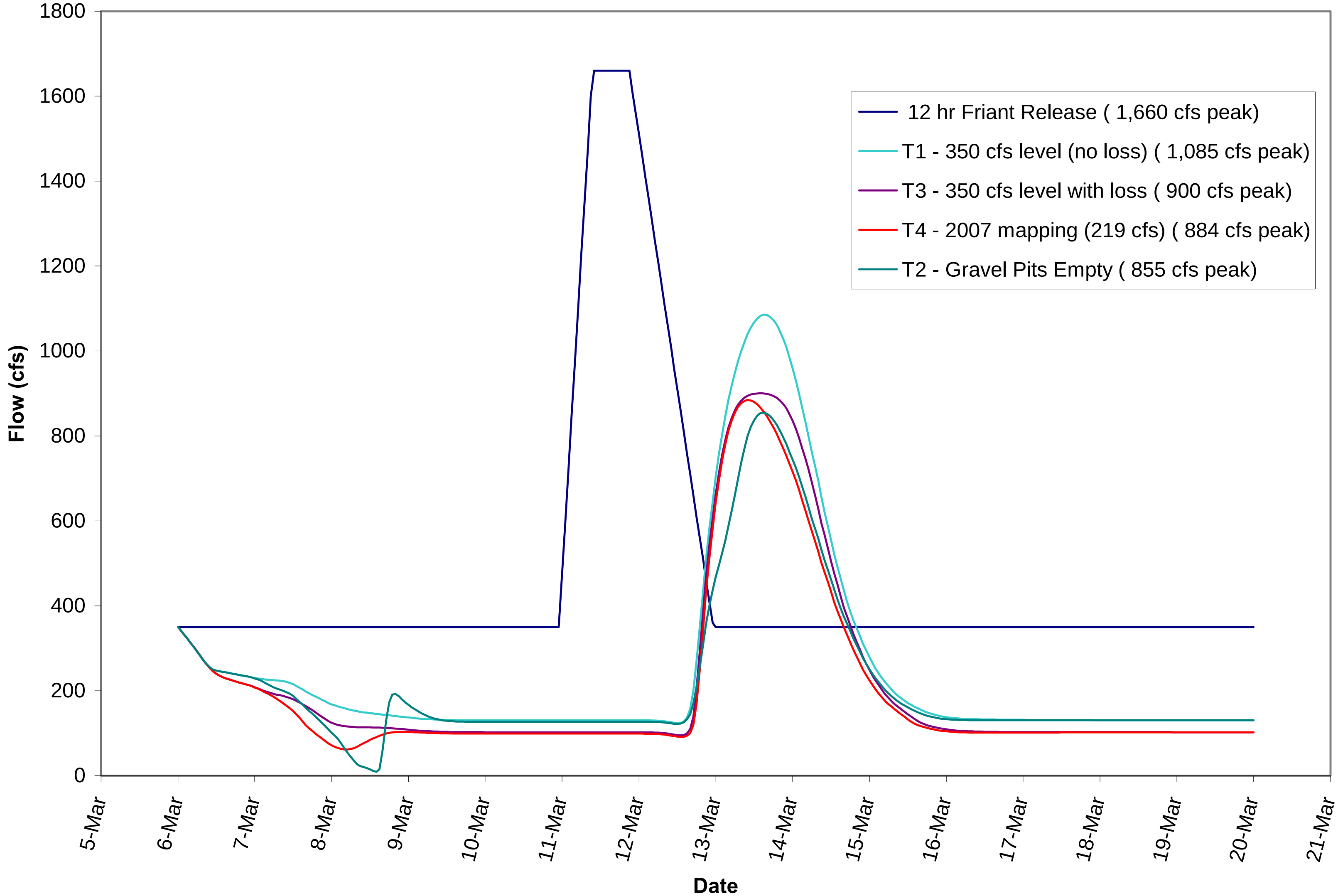

Figure 12. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 1,660-cfs, 12-hour release.

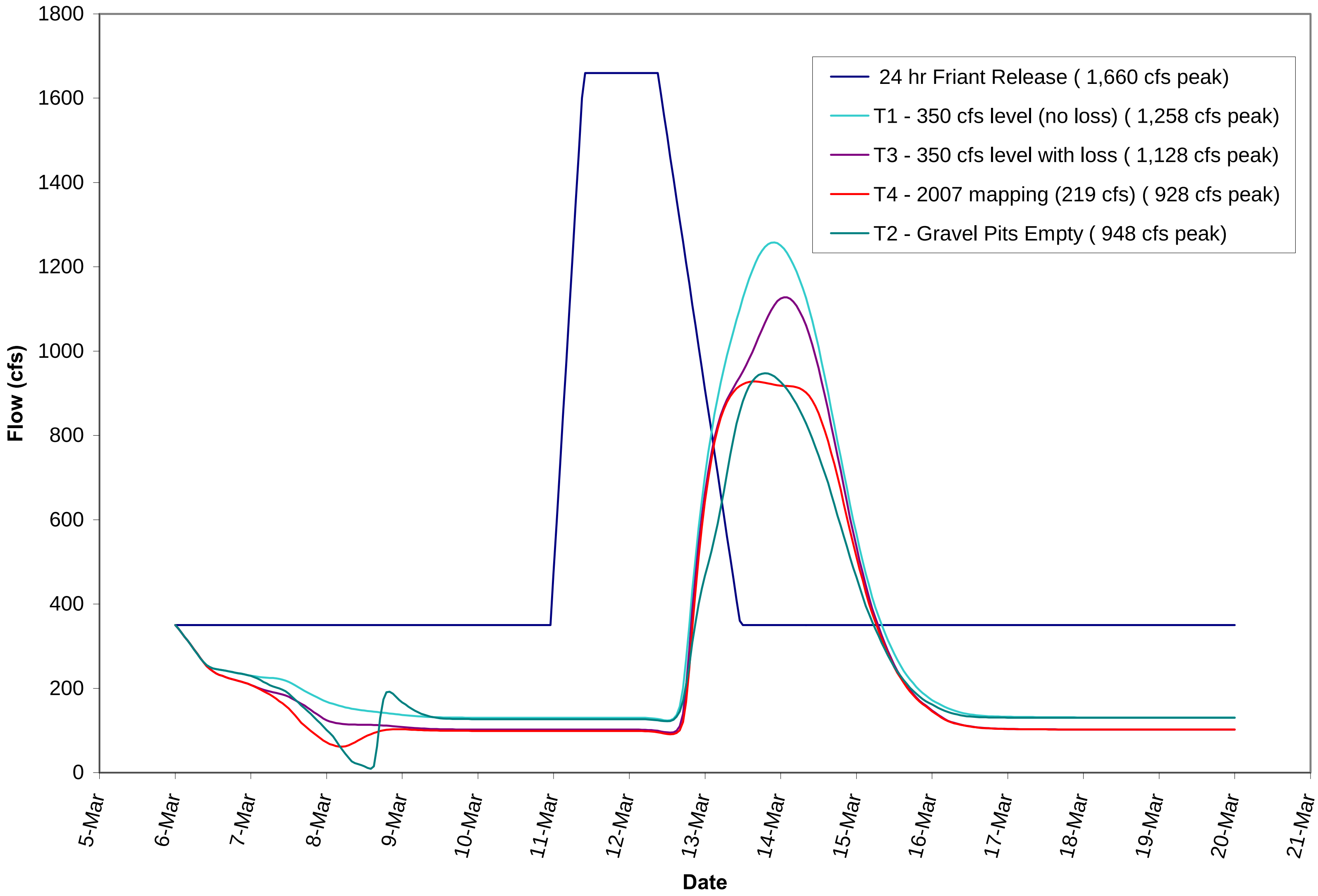

Figure 13. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 1,660-cfs, 24-hour release.

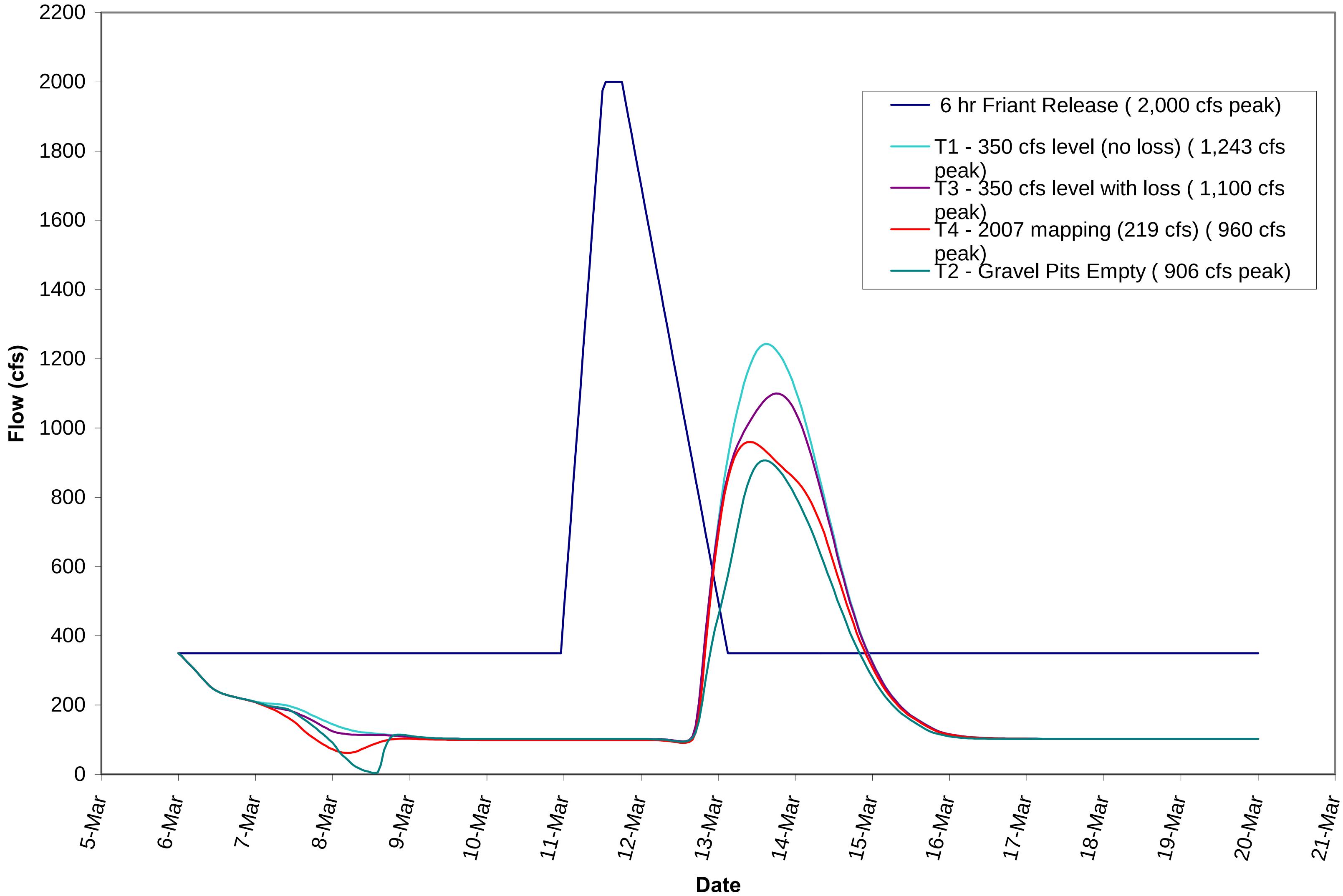

Figure 14. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 2,000-cfs. 6-hour release.

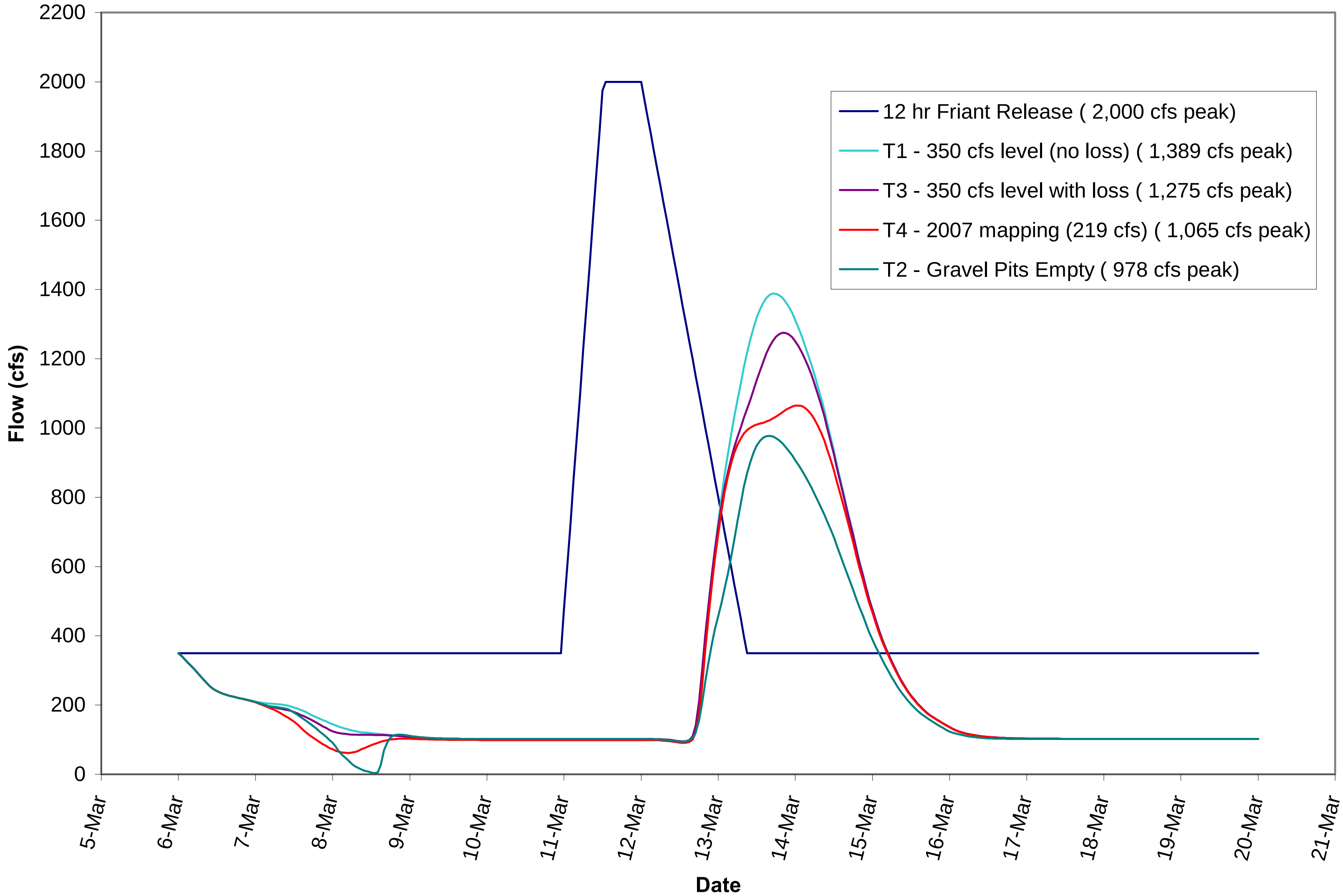

Figure 15. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 2,000-cfs, 12-hour release.

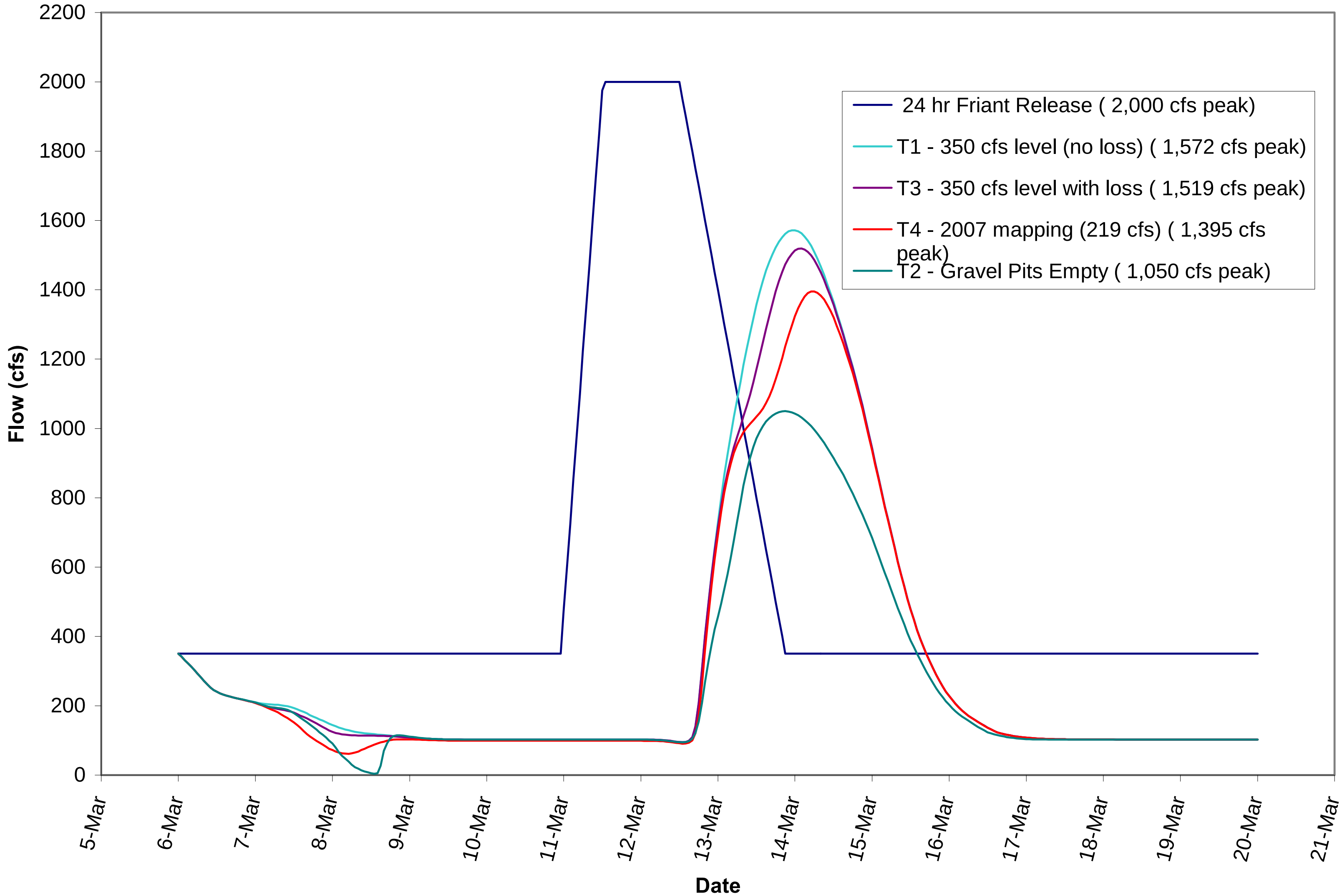

Figure 16. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 2,000-cfs, 24-hour release.

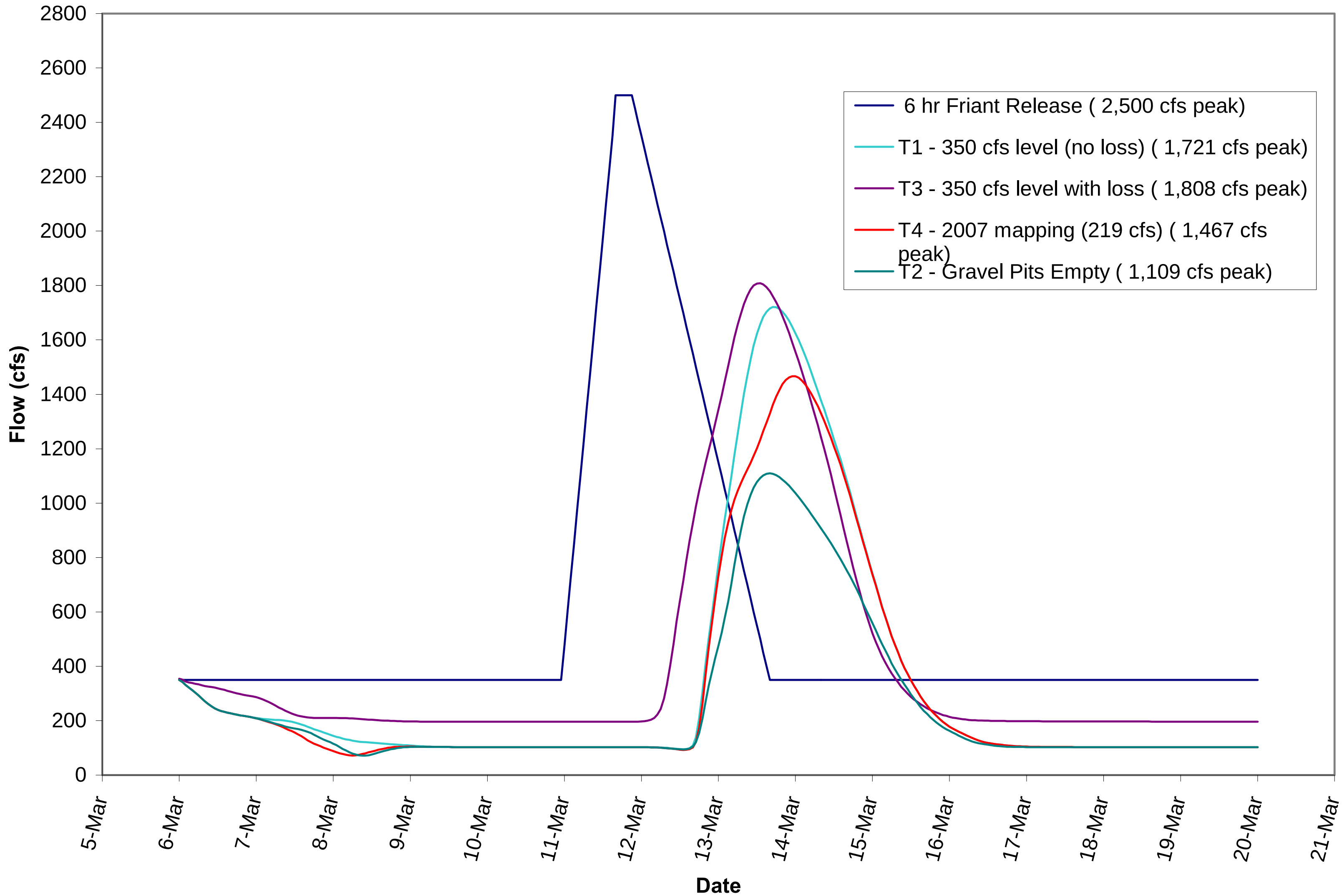

Figure 17. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 2,500-cfs, 6-hour release.

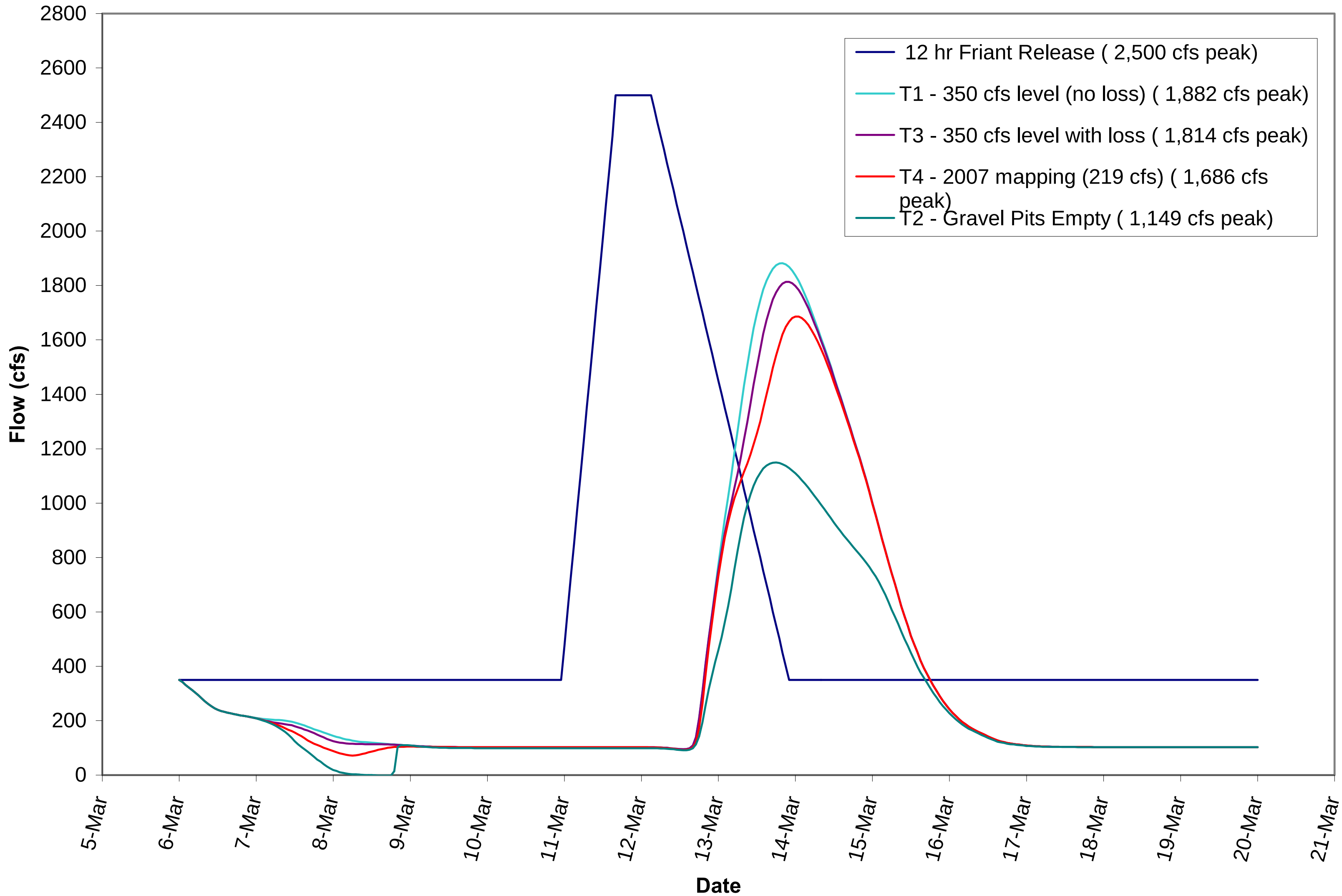

Figure 18. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 2,500-cfs, 12-hour release.

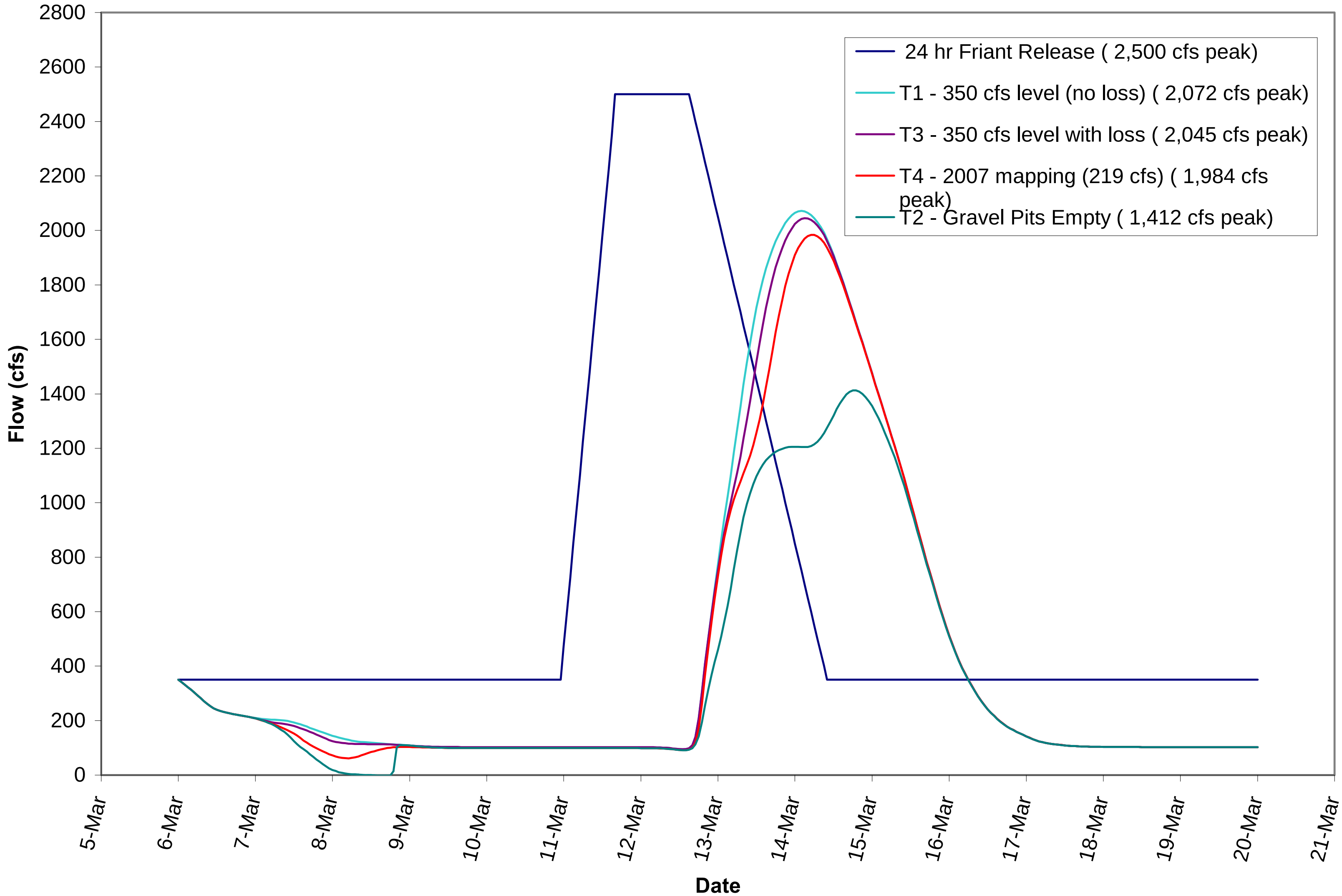

Figure 19. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 2,500-cfs, 24-hour release.

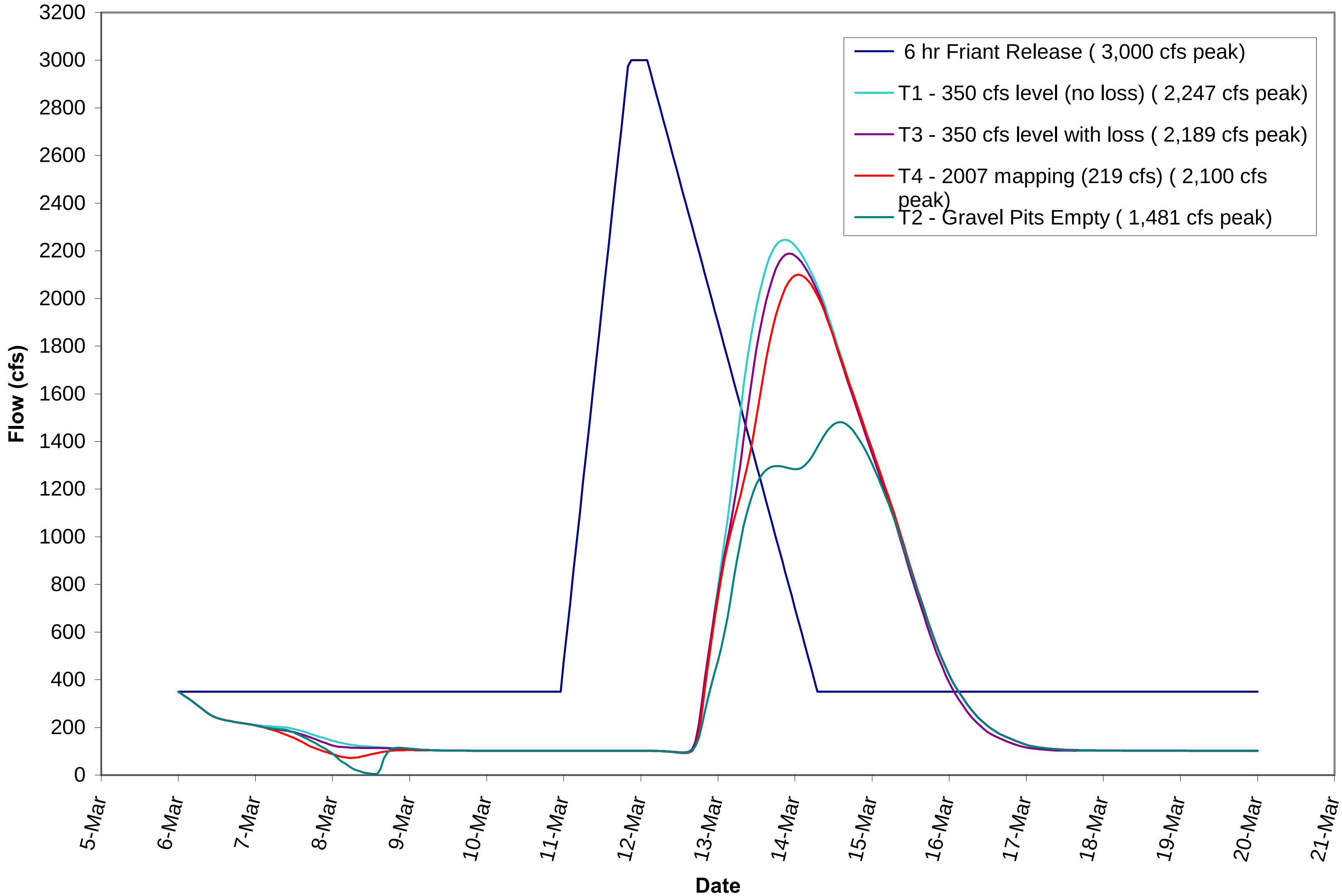

Figure 20. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 3,000-cfs, 6-hour release.

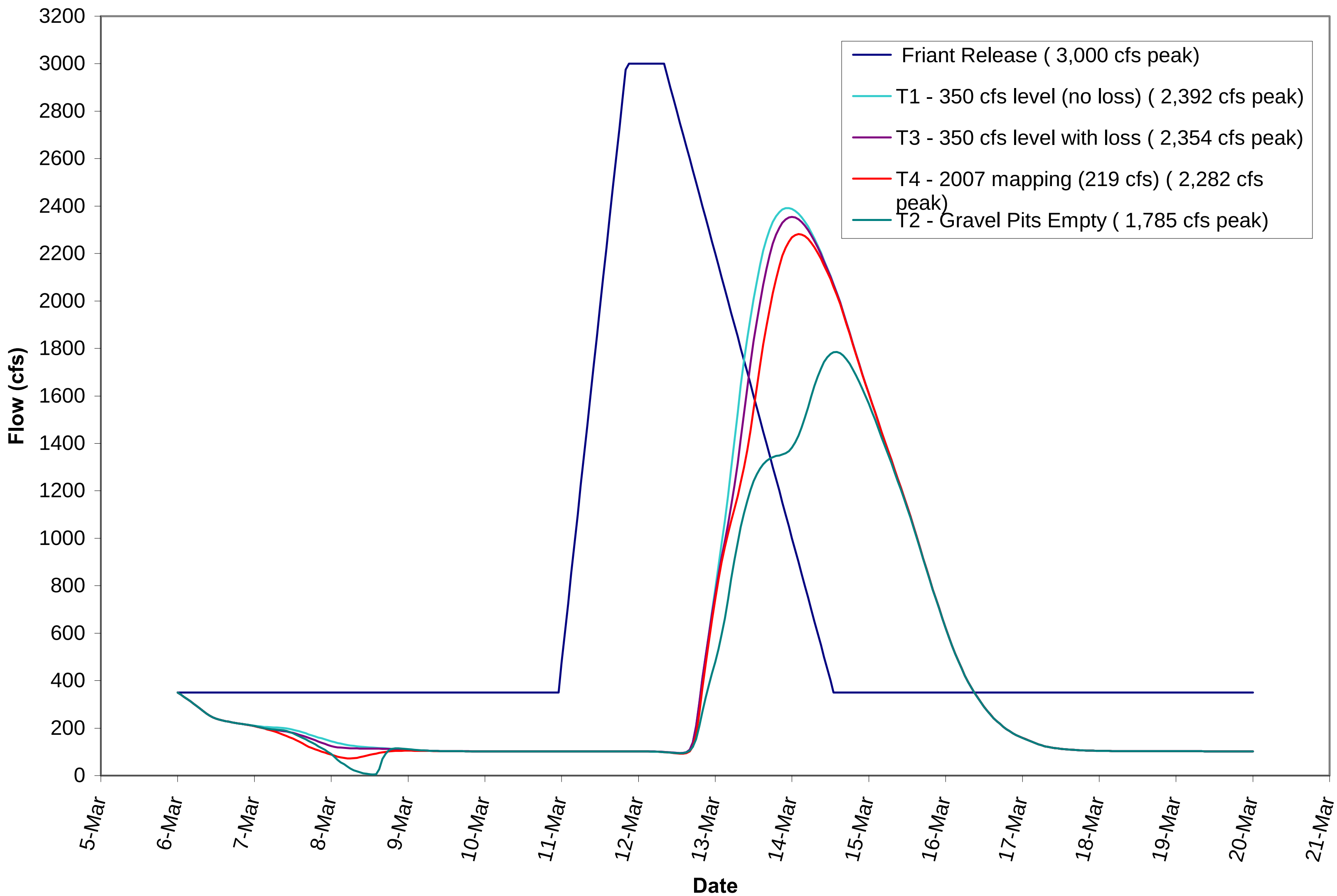

Figure 21. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 3,000-cfs, 12-hour release.

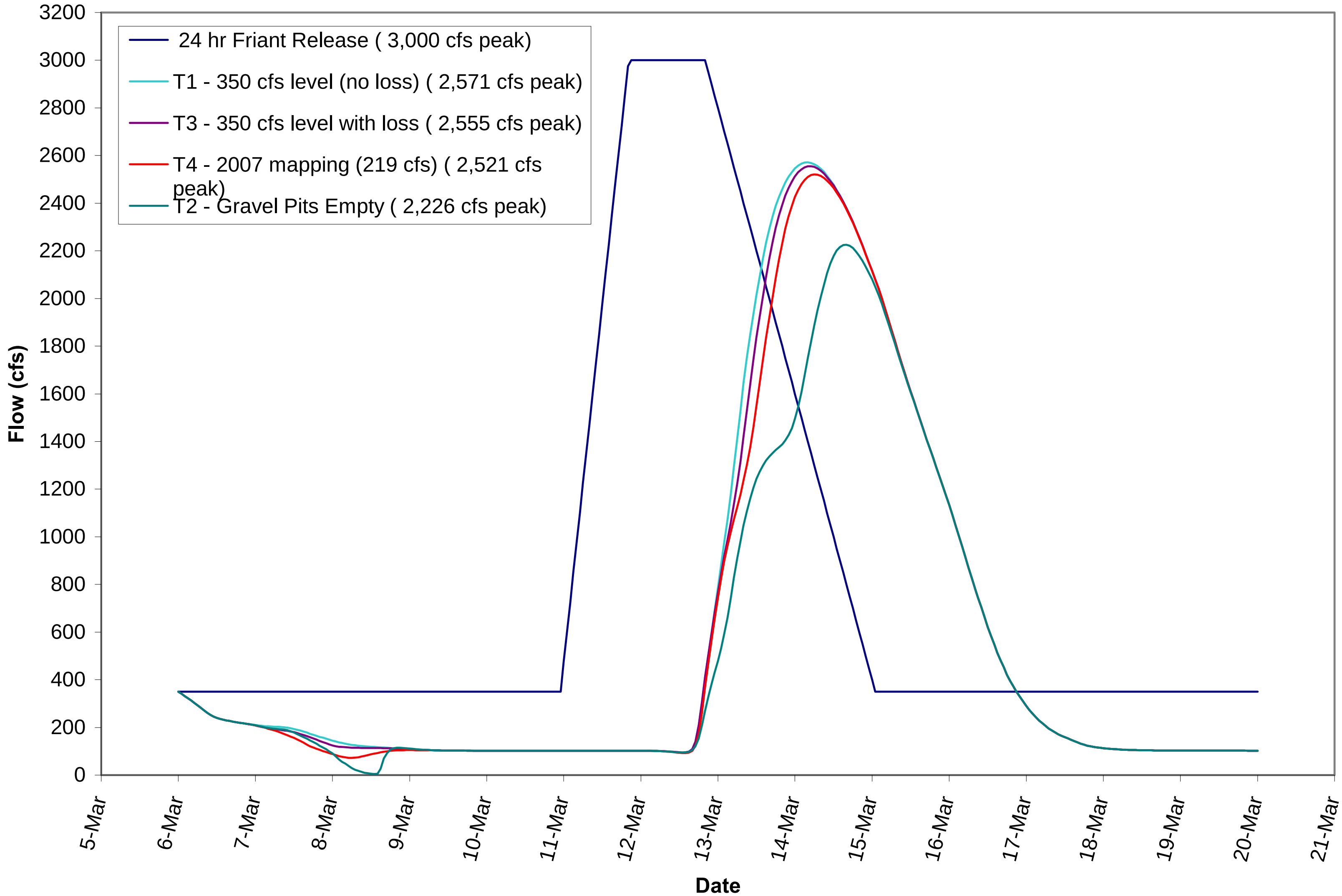

Figure 22. Predicted hydrographs for the four initial conditions at the Bifurcation Structure for a 3,000-cfs, 24-hour release.

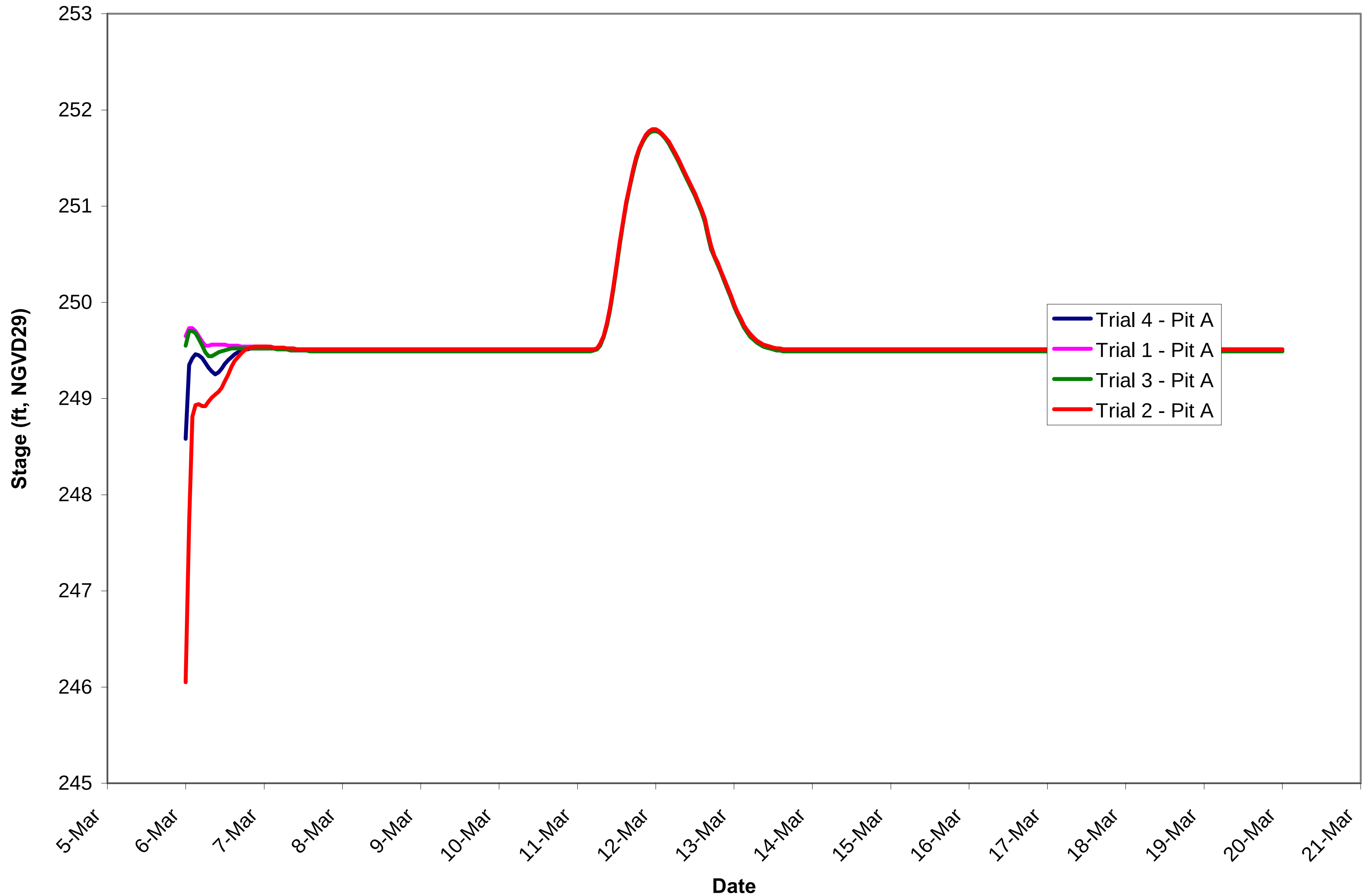

Figure 23. Predicted stage of storage area SA-A versus time for a Friant Dam release of 1,600 cfs for 6 hours.

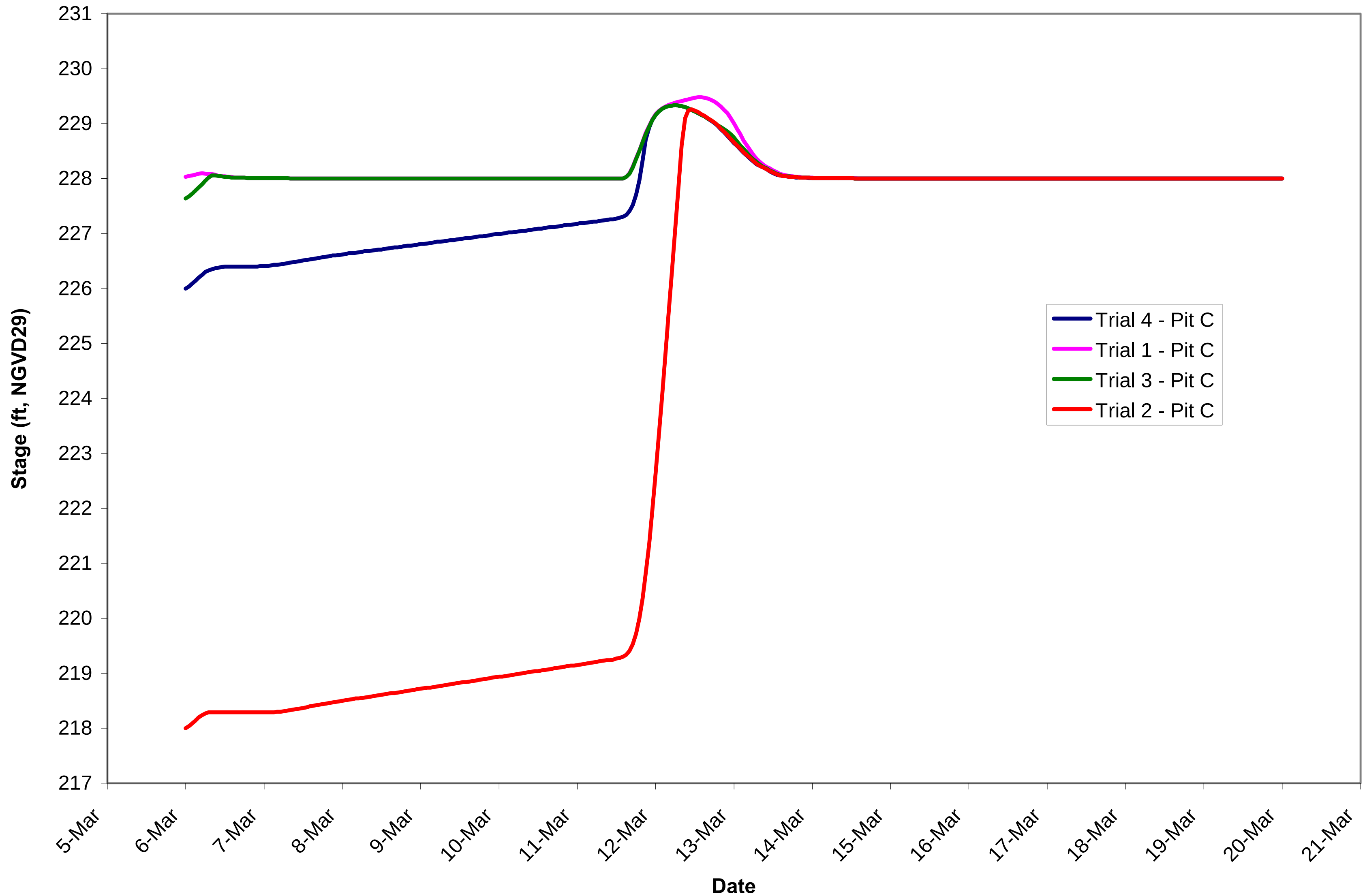

Figure 24. Predicted stage of storage area SA-C versus time for a Friant Dam release of 1,600 cfs for 6 hours.

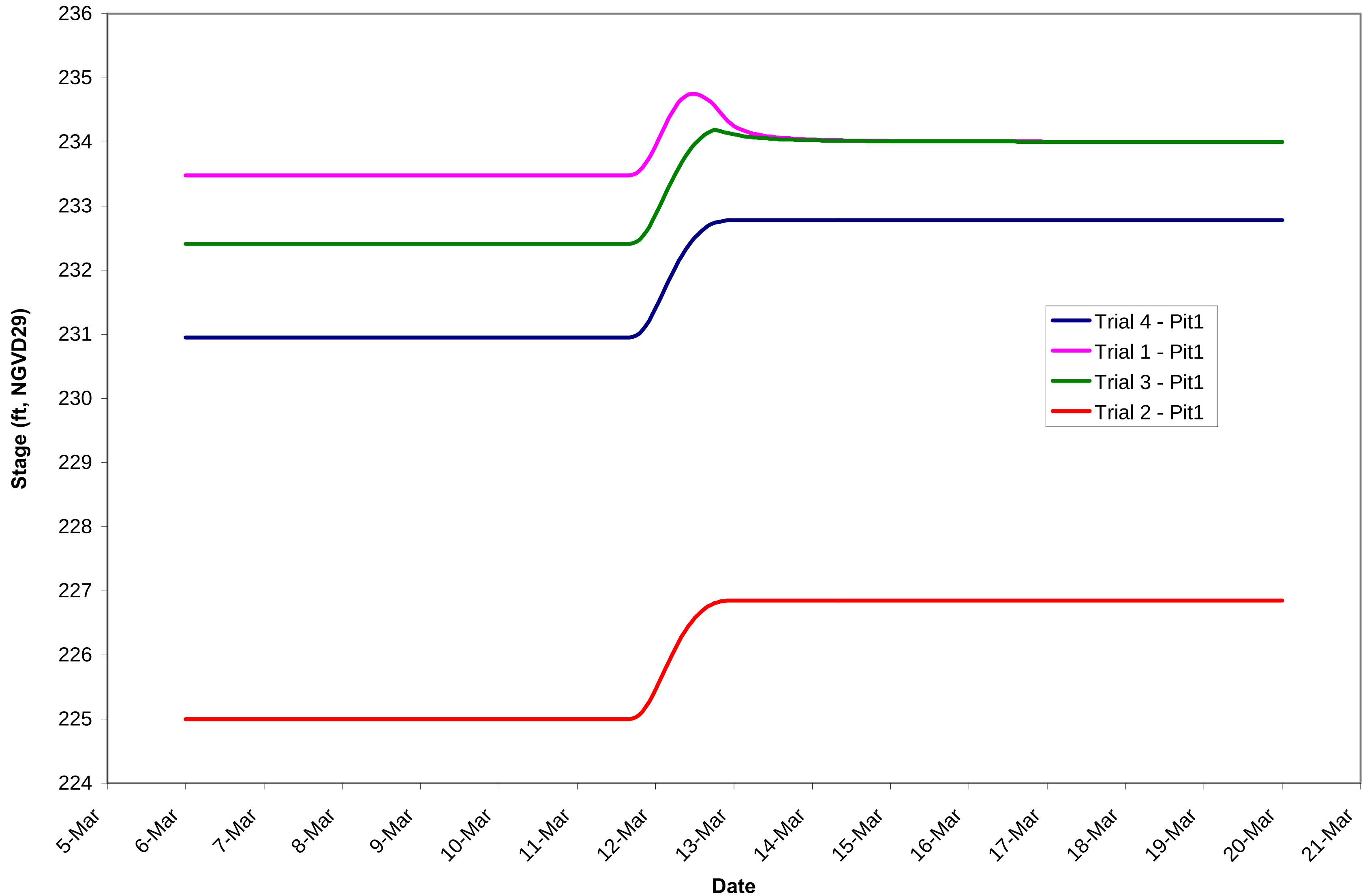

Figure 25. Predicted stage of storage area SA-1 versus time for a Friant Dam release of 1,600 cfs for 6 hours.

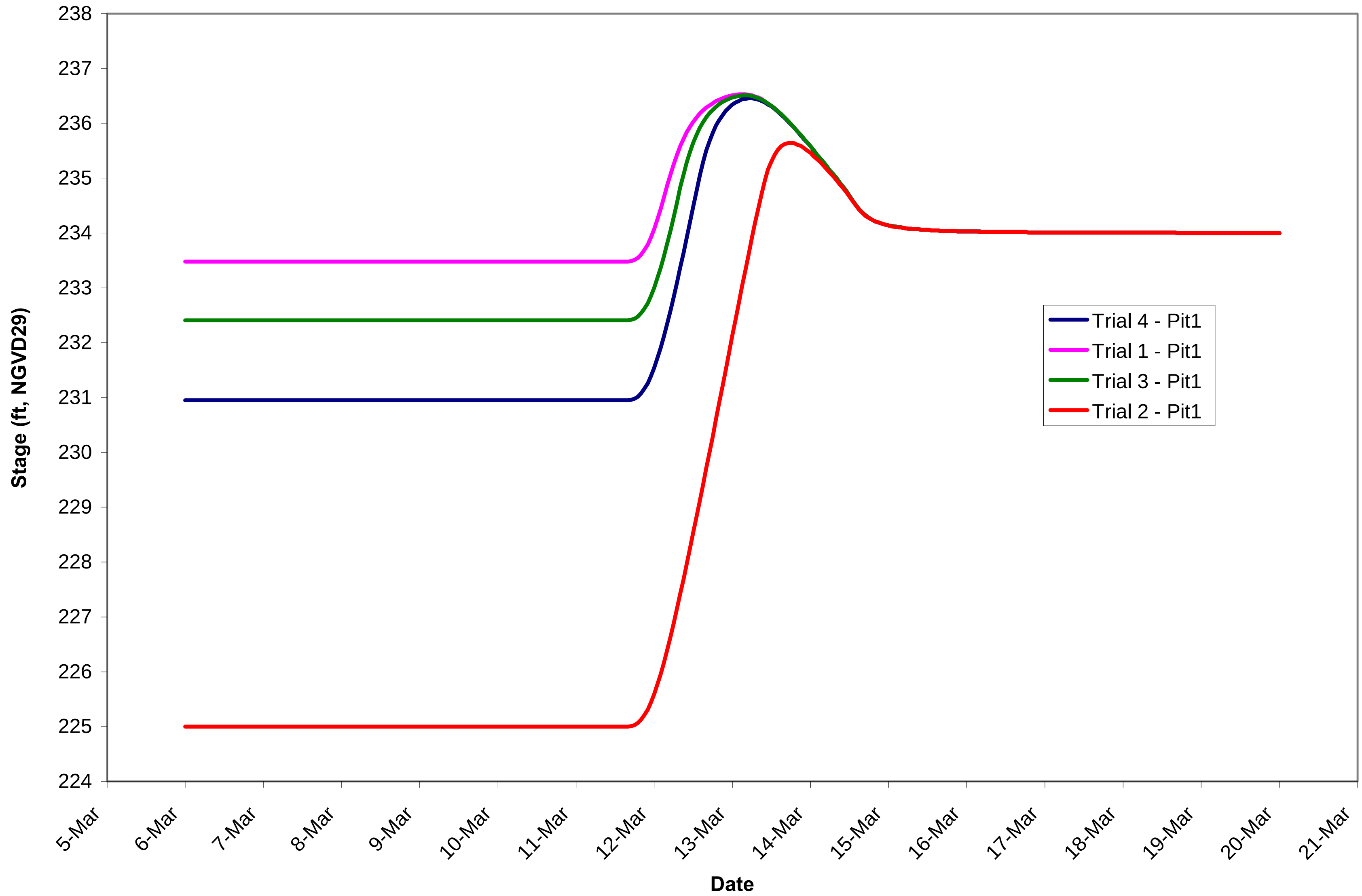

Figure 26. Predicted stage of storage area SA-1 versus time for a Friant Dam release of 2,500 cfs for 24 hours.

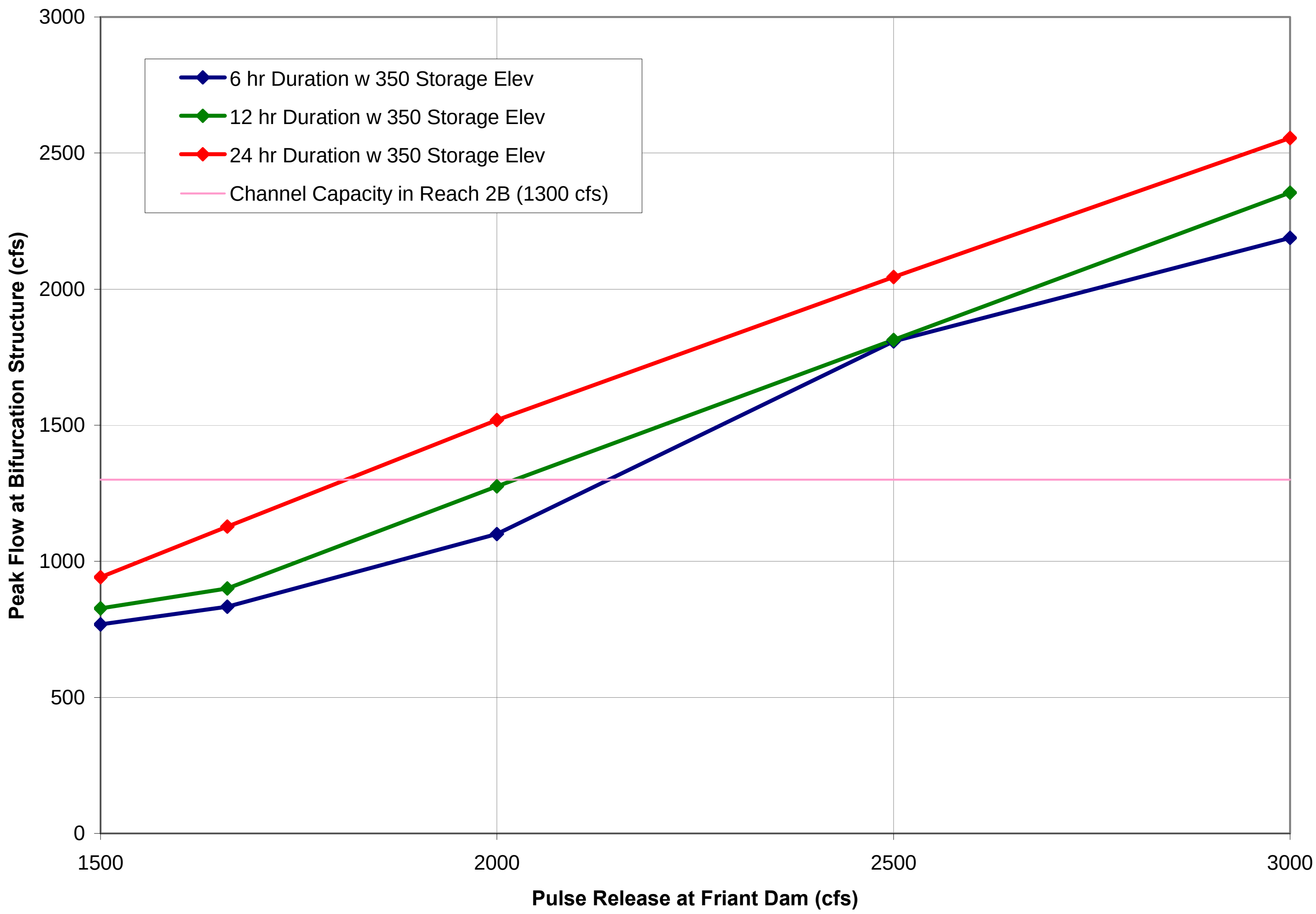

Figure 27. Predicted peak discharge at the Bifurcation Structure for each Friant pulse magnitude and duration.