APPENDIX B – HYDRAULIC EVALUATION RESULTS

Appendix B – Hydraulic Evaluation Results
June 27, 2012

B.1 General Overview

The Federally Recommended Plan (FRP) was designed to reduce the 100-year flood level at the Fargo Gage from RS 42.4 feet to approximately RS 31 feet.

In addition to the base plan of RS 31 feet, seven additional residual flood stage options were evaluated between RS 30 feet and RS 37 feet using the US Army Corps of Engineers' Unsteady HEC-RAS (River Analysis System) model developed for the Fargo-Moorhead Metro Flood Risk Reduction Feasibility Study (FM Metro) Phase 5, October 2011. Table B1 shows the resultant 100-year peak discharge and corresponding existing condition frequency of this peak discharge.

Table B-1

Residual Peak 100-yr Flood Stage, Discharge, and Approximate Existing Frequency		
Residual 100-yr Flood Stage	**Residual 100-yr Peak Discharge (cfs)**	**Approximate Existing Condition Frequency (yr)**
RS30	10,700	3.6
RS31	11,900	4.8
RS32	13,300	6.0
RS33	14,600	7.1
RS34	15,900	8.4
RS35	17,500	10.2
RS36	19,200	11.4
RS37	21,000	12.9

These results allow for the comparison of the resultant impacts, required operation and maintenance, and potential needed mitigation measures.

B.2 Summary of Model Sources

The hydraulic analyses for the "Flow Through Damage Reduction Area" study were completed using the US Army Corps of Engineer's Unsteady HEC-RAS (River Analysis System, version 4.2 beta) model developed for the Fargo-Moorhead Metro Flood Risk Reduction Feasibility Study (FM Metro) Phase 5, October, 2011. The model consists of river cross sections and storage areas (sections of land) that provide representation of existing condition and with project flood routing through the various river

corridors. The Phase 5 model used in this analysis was the latest available at the beginning of this project task.

B.3 Event Frequency

The Phase 4 modeling effort was completed for the Fargo-Moorhead Metro Flood Risk Management Project Feasibility Study in April, 2011. Following the feasibility study, several additional hydrologic and hydraulic assessments were made to assist the U.S. Army Corps of Engineers and the local decision makers in the transition to final design. The additional analyses were conducted within Phase 5. Previous phases included synthetic design events of the 10-, 2-, 1-, and 0.2-percent chance of occurrence, also commonly referred to as the 10-, 50-, 100-, and 500-year events. The 2-percent chance event (50-year) was not included in the Phase 5 analysis due to the limited available time for alternative evaluation. Therefore, only the 10-, 1-, and 0.2-percent chance events were utilized for the Phase 5 evaluations. The flow through town analysis only included the 10-percent and 1-percent chance events producing through town stages ranging from 30 feet to 37 feet as measured at USGS Streamgage 05054000 at Fargo (13th Avenue South). The gage zero is referenced to elevation 862.74 using NAVD 88. The 0.2-percent chance event requires a flood stage of approximately 40.8 feet at the Fargo Gage for design operation. Therefore, increasing flows through the flood damage reduction area was not applicable for this event.

B.4 General Project Operation Approach

The primary mechanism built into the flood risk reduction project is the diversion channel itself. Early hydraulic evaluation of this stand-alone feature produced impacts that could not be completely defined within the United States. To mitigate the effects of the lost floodplain storage and the diverted flood water, an upstream staging and storage area was incorporated into the design. The diversion channel and staging area, along with a unique gate operation produced definable downstream impacts.

Flood water is regulated from the upstream staging area through a combination of weirs and gates. Currently, the discharge to the diversion channel occurs through a passive weir in the northwest corner of the staging area. Discharges through town are regulated through gate structures on the Wild Rice River, Red River, and on Wolverton Creek. As the gates begin to close preventing water from entering the flood risk management area (protected area), the staging area begins to fill and subsequently discharges occur into the diversion channel. In general, the downstream impacts occur because of the lost floodplain storage and because the diversion is moving flood waters downstream faster than during existing conditions. This produces a downstream hydrograph that is different than that of existing conditions. To reduce the downstream impacts, the concept has been to “de-couple” or offset the peaks of the hydrographs between the diversion flows and the flows through town. Since the flows through the diversion are relatively uncontrolled, the only active operation available is to regulate the flows through town. To offset the peak discharges between the diverted flow and the flows through town, the operation requires the gates to be closed through town during the peak of the flood hydrograph. This allows the only discharge in the downstream direction to be that of the diversion. As

soon as the peak passes, the gates can be opened and discharges through town released to meet the designed target flows.

B.5 Increased Water through Town Gate Operation

The original feasibility study gate operation required minimal discharge through town during the peak of the hydrograph followed by an increase in discharges as the diverted flows began to recede. The target flow through town during feasibility was approximately 9,600 cfs which equates to a flood stage of approximately 30 feet. The discharge that produced this elevation came after the peak of the main hydrograph because of the decoupling operation. Figures B-1 through B-8 show the discharge hydrograph at the Red River Control Structure as well as the stage hydrograph representing the staging area elevations.

For the flows through the flood damage reduction area analysis, the target flows were increased to produce incrementally increasing stages of 30 feet through 37 feet at USGS Gage 05054000 at Fargo. This was completed for the 10-year and the 100-year events. The existing condition 10-year event produces a maximum stage of 34.8 feet through town. Executing a 10-year project operation with 30, 31, 32, or 33 feet through town is not as simple as restricting a minimal amount of water to reduce the stage accordingly. This is because the diversion is also providing benefit from the Sheyenne, Maple, Rush and Lower Rush Rivers. The adverse effect of diverting flow from these rivers must also be mitigated via the upstream staging area. For example, to reduce the flows through town to produce a stage of 32 feet, the gates on the Red River must be completely closed during the peak to allow the diverted water to pass. After the peak of the hydrograph passes, the gates would then be opened to produce incrementally higher discharges through town to match the intended target stage. All of the targeted stages would be met (if the inflow volume allows) after the hydrograph peak. Figure B-9 displays the various target stages through town for the 1-percent chance event. Notice the timing of the target stage hydrograph compared to the existing hydrograph.

B.6 Staging/Storage Area Variation

The peak elevation of the staging/storage area is driven by the volume and timing of the inflow hydrograph in combination with the discharges through the diversion, through town, and the volume in the staging/storage area. As expected, the timing of the peak stage coincides with the timing of the peak inflow hydrograph. Since the increasing flow through town occurs on the receding limb of the typical existing conditions hydrograph for the proposed operating scenario, it does not affect the staging elevation. Increasing the flows through town does however reduce the duration at which the staging area is inundated. Figure B-10 shows a plot of the staging area flooding durations with respect to the increased flows through town.

For the 100-year event, the maximum water surface elevation observed in Storage Area 1 is equivalent to the maximum staging area elevation. This is because the water surface elevation of 923.2 is well above most existing roadways allowing interconnect and water surface equalization between rivers and within the flood pool. However, the 10-year produces different water surface elevations between Storage Area 1 and the staging area for the various through town operations. This is in part due to the

interconnecting hydraulic effects between the Wild Rice River, the diversion channel, and Storage Area 1 in the Phase 5 model. The difference is also attributed to the current gate operation and the inflow hydrology.

B.7 Variation in Diversion Channel Wetted Perimeter

To effectively compare the various flows through the damage reduction area alternatives, costs associated with each alternative must be differentiated. Maintenance costs for the diversion channel were estimated using the frequency, duration and elevation of flow through the diversion channel for each given event and operational scheme. To accomplish this, the wetted perimeter was obtained from each alternative model run. Because the increased flow through town was only changed on the receding limb of the hydrograph, all of the analyzed alternatives produced the same discharge through the diversion, resulting in the same water surface profile and the same wetted perimeter (for each event). The only combination of event and alternative that produced a different wetted perimeter was the 10-year, 33 foot stage because there wasn't enough volume available in the hydrograph to produce the same peak discharges through the diversion and through town. Tables B-1 and B-2 display the wetted surface of the diversion channel in acres used to assist in estimating the maintenance costs for each alternative.

Table B-2

Diversion Channel Wetted Surface for Analysis of O&M Costs				
	10-yr Flood Stages at the Fargo Gage - Diversion Wetted Surface (acres)			
Area	**30'**	**31'**	**32'**	**33'**
Red to WR	124.70	124.69	124.66	96.57
WR to Red	1841.96	1840.43	1837.68	1620.50
Total	1966.67	1965.12	1962.33	1717.07

Table B-3

Diversion Channel Wetted Surface for Analysis of O&M Costs								
	100-yr Flood Stages at the Fargo Gage - Diversion Wetted Surface (acres)							
Area	**30'**	**31'**	**32'**	**33'**	**34'**	**35'**	**36'**	**37'**
Red to WR	128.40	128.40	128.40	128.40	128.40	128.40	128.40	128.40
WR to Red	2688.42	2688.42	2688.42	2688.42	2688.42	2688.42	2688.42	2688.42
Total	2816.83	2816.83	2816.83	2816.83	2816.83	2816.83	2816.83	2816.82

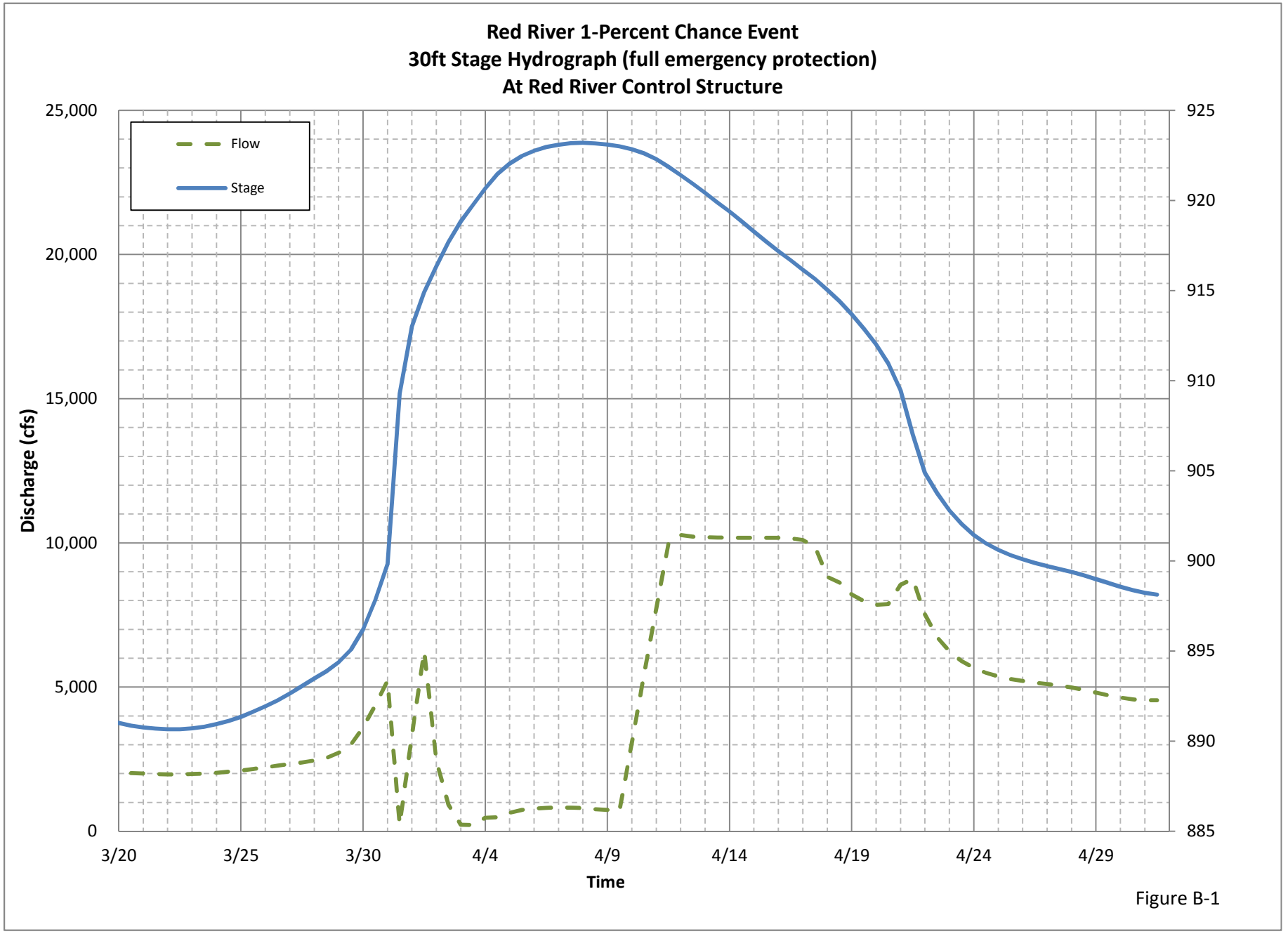
Red River 1-Percent Chance Event
30ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-1

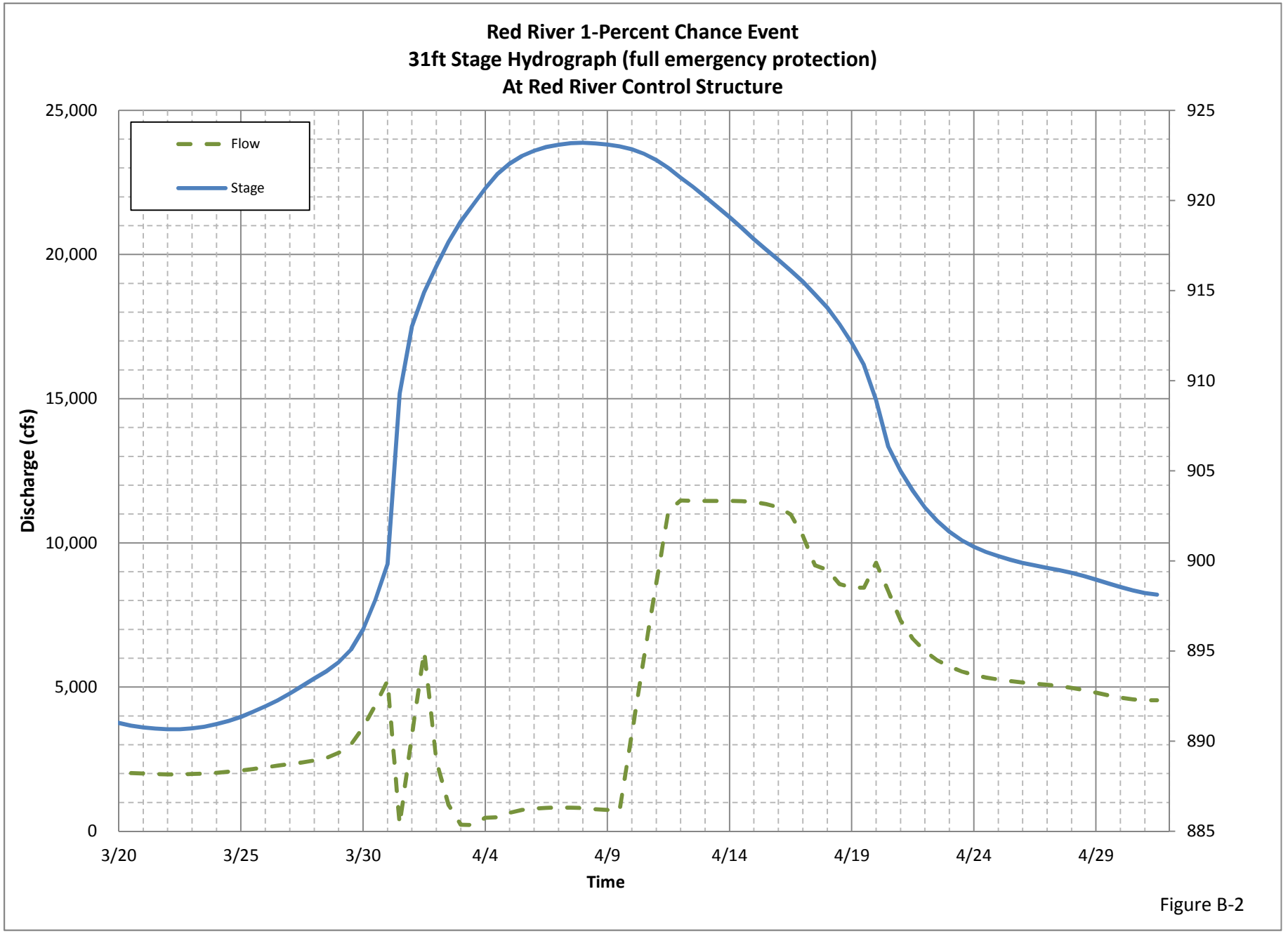
Red River 1-Percent Chance Event
31ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-2

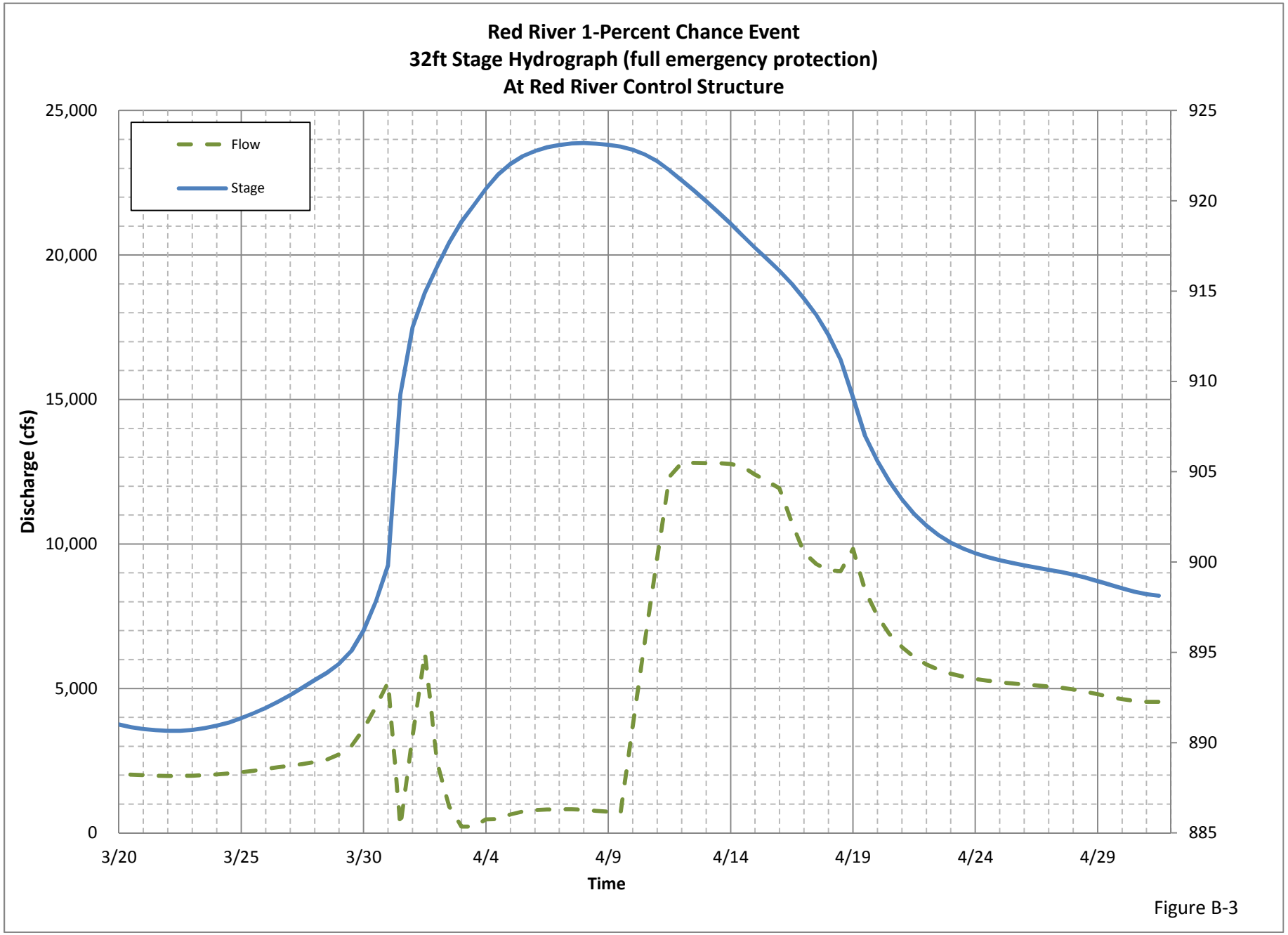
Red River 1-Percent Chance Event
32ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-3

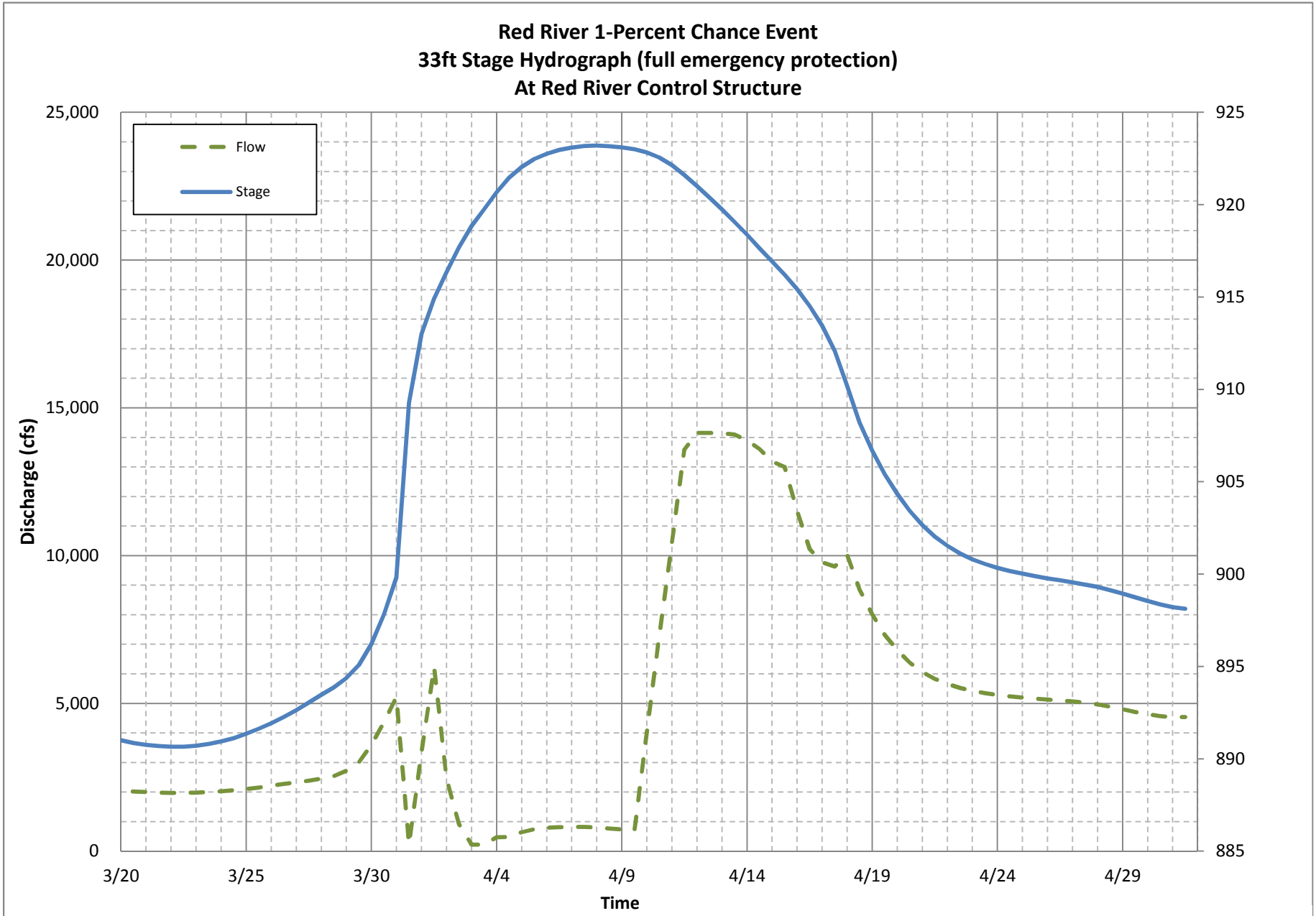
Red River 1-Percent Chance Event
33ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-4

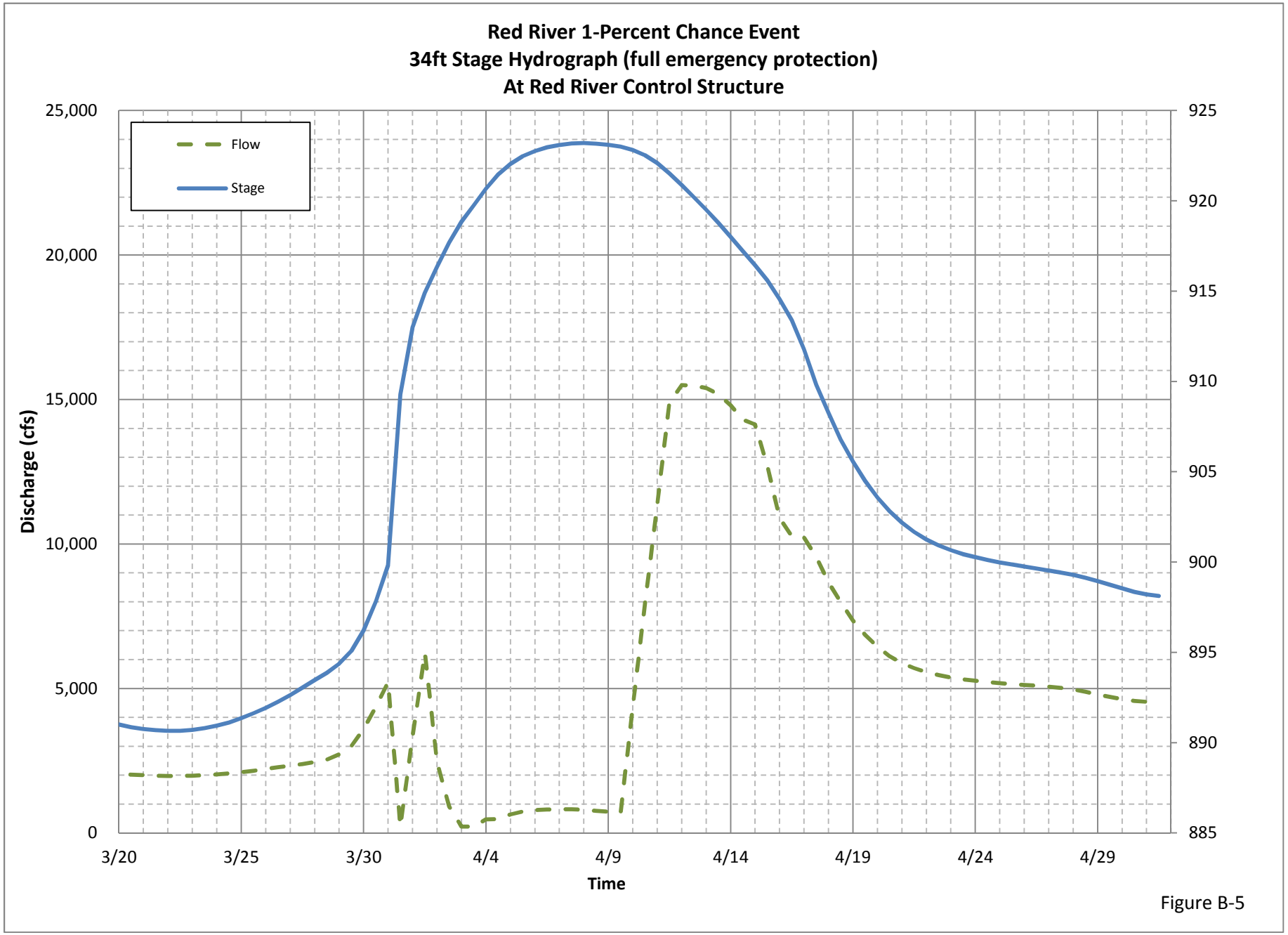
Red River 1-Percent Chance Event
34ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-5

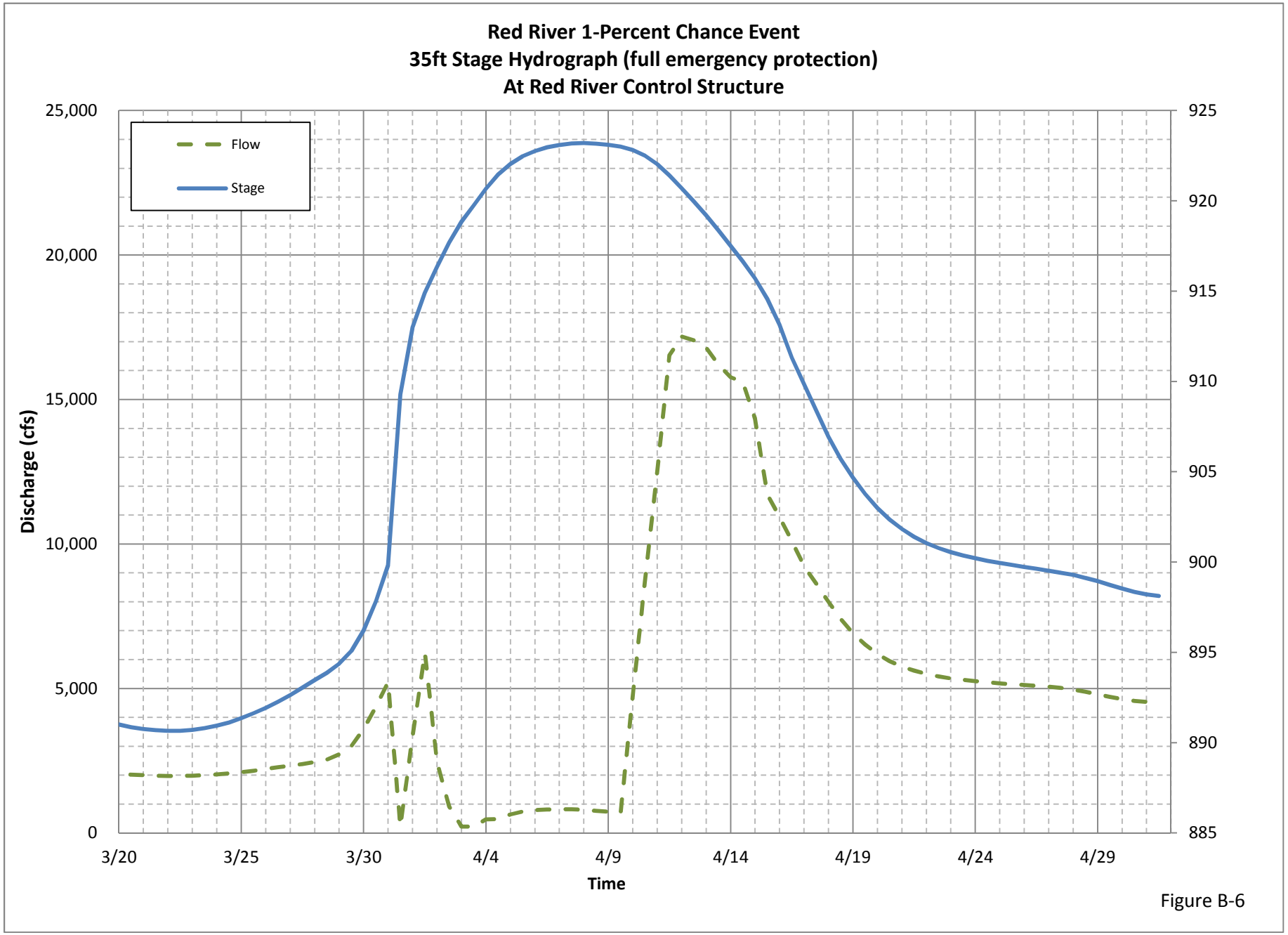
Red River 1-Percent Chance Event
35ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-6

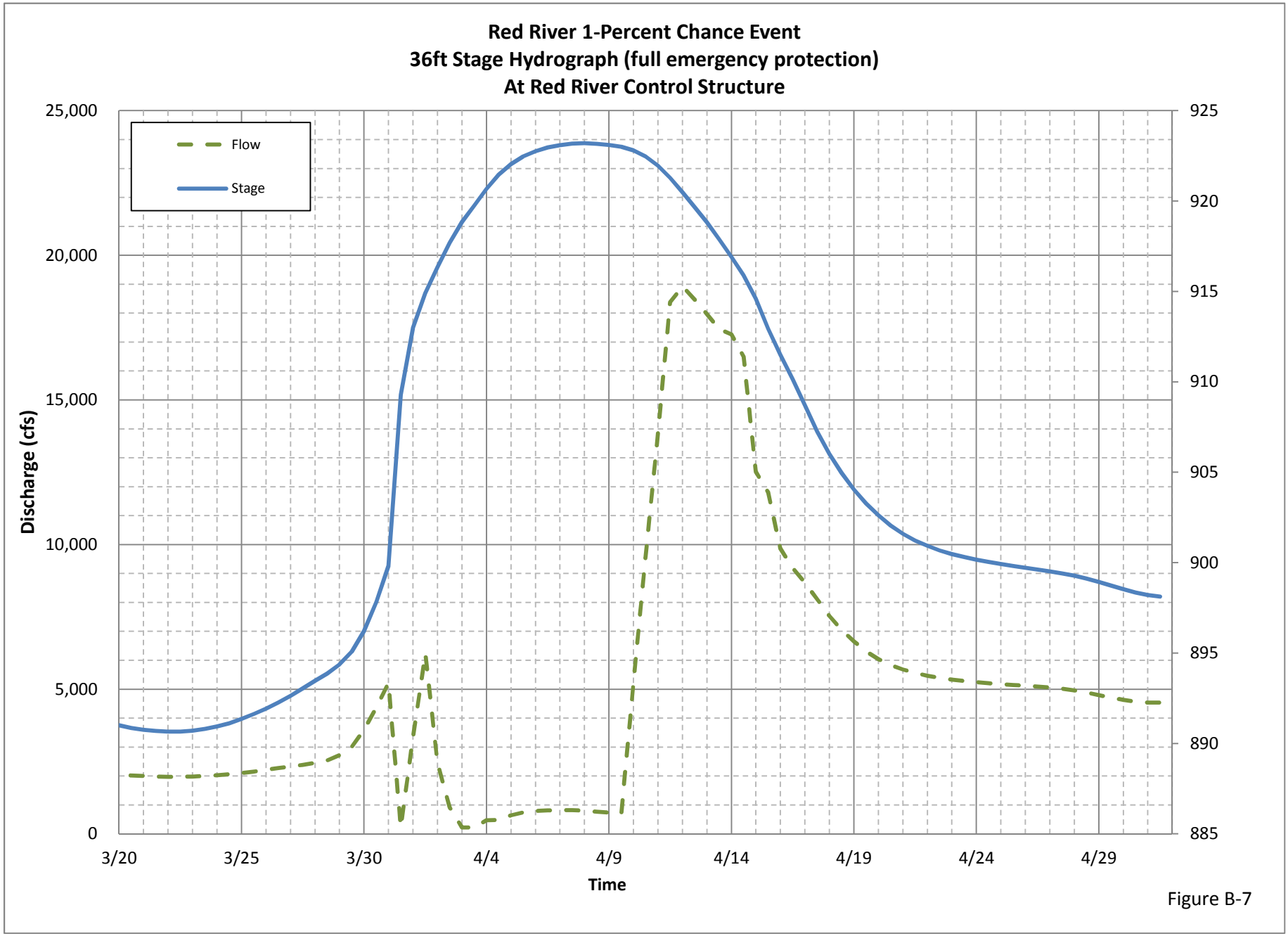
Red River 1-Percent Chance Event
36ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-7

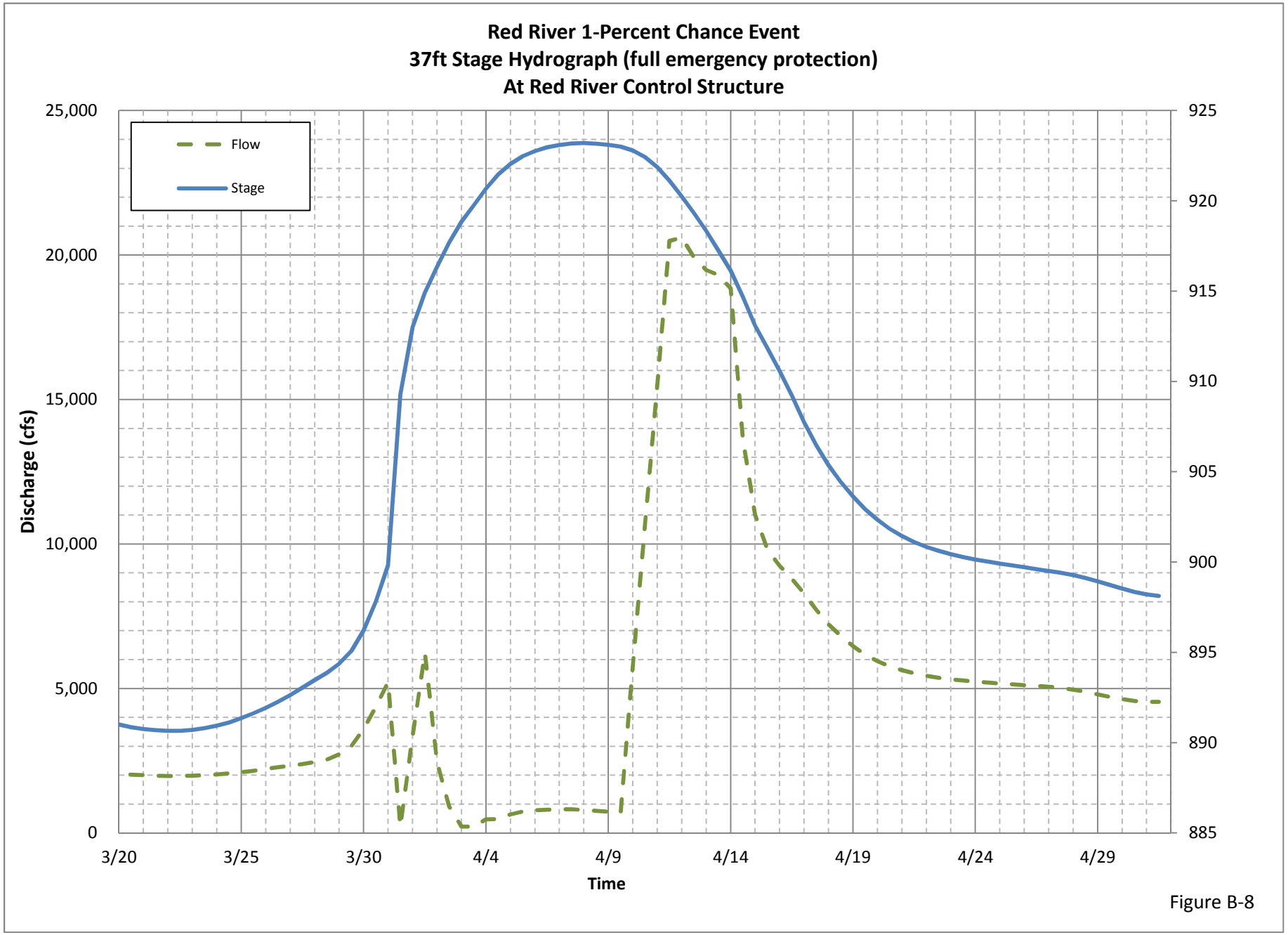
Red River 1-Percent Chance Event
37ft Stage Hydrograph (full emergency protection)
At Red River Control Structure
Flow
Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
920
915
910
905
900
895
890
885
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-8

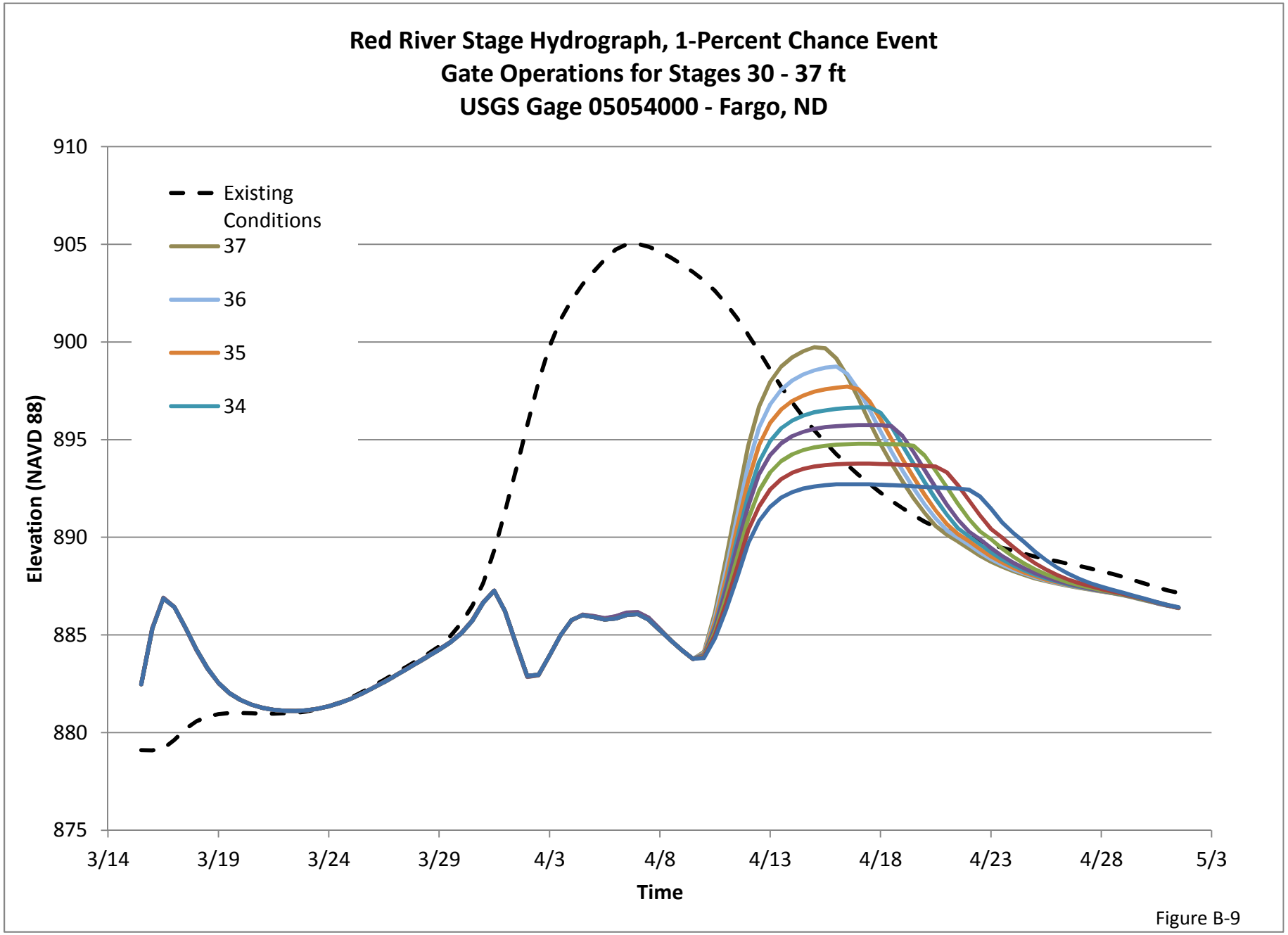
Red River Stage Hydrograph, 1-Percent Chance Event
Gate Operations for Stages 30 - 37 ft
USGS Gage 05054000 - Fargo, ND
Existing Conditions
37
36
35
34
Elevation (NAVD 88)
910
905
900
895
890
885
880
875
3/14
3/19
3/24
3/29
4/3
4/8
4/13
4/18
4/23
4/28
5/3
Time

Figure B-9

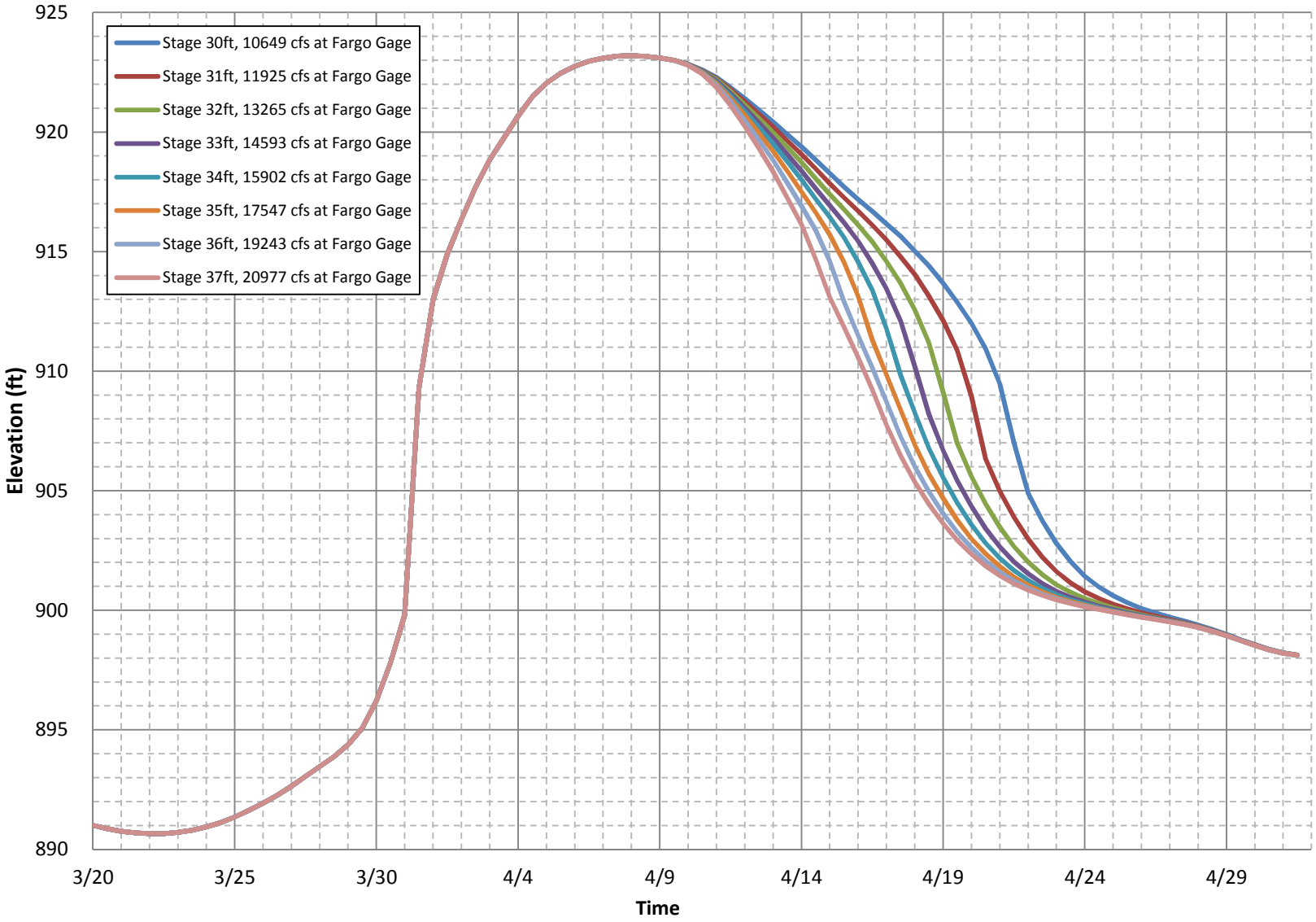
Red River 1-Percent Chance Event
30ft-37ft Stage Hydrographs (full emergency protection)
At Red River Control Structure
Stage 30ft, 10649 cfs at Fargo Gage
Stage 31ft, 11925 cfs at Fargo Gage
Stage 32ft, 13265 cfs at Fargo Gage
Stage 33ft, 14593 cfs at Fargo Gage
Stage 34ft, 15902 cfs at Fargo Gage
Stage 35ft, 17547 cfs at Fargo Gage
Stage 36ft, 19243 cfs at Fargo Gage
Stage 37ft, 20977 cfs at Fargo Gage
Elevation (ft)
925
920
915
910
905
900
895
890
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure B-10