PREPARED BY

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Initial Study Report

Hydrologic and Hydraulic Modeling: Upstream Hydraulic Model

Pensacola Hydroelectric Project
Project No. 1494

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Executive Summary

Mead & Hunt is assisting Grand River Dam Authority (GRDA) with its intent to relicense the Pensacola Hydroelectric Project (Project), which is regulated by the Federal Energy Regulatory Commission (FERC). Flood control operations at the Project are regulated by the United States Army Corps of Engineers (USACE). This Initial Study Report (ISR) documents the findings of Hydrologic and Hydraulic (H&H) modeling upstream of the Project.

The Proposed Study Plan (PSP) and Revised Study Plan (RSP) recommended the development of a Comprehensive Hydraulic Model (CHM). The model upstream of the Project is referred to as the Upstream Hydraulic Model (UHM). Mead & Hunt used a Hydrologic Engineering Center River Analysis System (HEC-RAS) model, previously developed by Tetra Tech, as the base for UHM development. Mead & Hunt conducted a detailed review of Tetra Tech's model and identified ways in which the model should be improved (Mead & Hunt, 2016). As part of this study, Mead & Hunt transformed the Tetra Tech model by updating the version of HEC-RAS from a beta version to a full release version, modifying the geometry to contain larger flood events and to improve model stability and accuracy, updating bridge geometry, adding the Spring River and the Elk River, replacing the reservoir bathymetry to reflect newly surveyed conditions, and by using computational parameters recommended by the HEC-RAS development team. This resulted in an improved hydraulic model of Grand Lake and the river system upstream of Pensacola Dam.

Mead & Hunt calibrated the UHM using measured data, including United States Geological Survey (USGS) gage elevations, high water marks, and recorded data from loggers installed by the project team. Six historical events were used to calibrate the model. Manning's n-values were adjusted until simulated water surface elevations reasonably matched measured data. Flow roughness factors were used to fine-tune the model.

A flood frequency analysis was performed for the study area using data from USACE. Data from 1940 (dam construction date) to 2019 (latest available data at time of data delivery from USACE) were used and a graphical frequency analysis of peak inflows was performed. The analysis estimated a 100-year event flow at Pensacola Dam of approximately 300,000 cubic feet per second (cfs). The largest events of recent record did not meet or exceed the 100-year event threshold at Pensacola Dam. The July 2007 event was scaled so the peak flow at Pensacola Dam approximately matched the estimated 100-year event, with a daily inflow volume to Pensacola Dam that approximately matched the results of a statistical analysis of historical inflow volumes.

The calibrated UHM was used to analyze five historical inflow events and one synthetic event with a range of starting pool elevations at Pensacola Dam. Maximum water surface elevation (WSEL) values and inundation extents were extracted from HEC-RAS and analyzed.

The results of the UHM demonstrate that the initial stage at Pensacola Dam has an immaterial impact on upstream WSELs and inundation. Only a different inflow event caused an appreciable difference in maximum WSEL and maximum inundation extent. The differences in WSEL and inundation extent due to the size of the inflow event were an order of magnitude greater than the differences in WSEL and inundation extent due to the initial stage at Pensacola Dam.

List of Abbreviations and Terms

1D	One-Dimensional
2D	Two-Dimensional
2DFA	Two-Dimensional Flow Area
CFS	Cubic Feet Per Second
CHM	Comprehensive Hydraulic Model
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GEV	Generalized Extreme Value
GRDA	Grand River Dam Authority
H&H	Hydrologic and Hydraulic
ISR	Initial Study Report
HEC	Hydrologic Engineering Center
LiDAR	Light Detection and Ranging
MISR	Model Input Status Report
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NED	National Elevation Dataset
NWIS	National Water Information System
OM	Operations Model
PD	Pensacola Datum
Project	Pensacola Hydroelectric Project
PSP	Proposed Study Plan
RAS	River Analysis System
RM	River Mile
RSP	Revised Study Plan
SPD	Study Plan Determination
SSP	Statistical Software Package
UHM	Upstream Hydraulic Model
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WSEL	Water Surface Elevation

1. Introduction and Background

1.1 Project Description

The Pensacola Hydroelectric Project is owned and operated by GRDA and regulated by the FERC. The Pensacola Dam is in Mayes County, Oklahoma on the Grand-Neosho River. Pensacola Dam impounds Grand Lake. Construction of Pensacola Dam was completed in 1940. **Figure 1** displays the study area. Downstream of Pensacola Dam, GRDA also owns and operates the Robert S. Kerr Dam as the Markham Ferry Hydroelectric Project. Kerr Dam is also in Mayes County and impounds Lake Hudson, also known as Markham Ferry Reservoir. Flood control operations at both Pensacola Dam and Kerr Dam are regulated by USACE.

1.2 Study Plan Proposals and Determination

GRDA is currently relicensing the Project. The timeline of study plan proposals and determination is as follows:

1. On April 27, 2018, GRDA filed its PSP to address hydrologic and hydraulic modeling in support of its intent to relicense the Project.
2. On September 24, 2018, GRDA filed its RSP.
3. On November 8, 2018, the FERC issued its Study Plan Determination (SPD) for the Project.
4. On January 23, 2020, the FERC issued an Order on the Request for Clarification and Rehearing, which clarified the timeline for certain milestones applicable to the relicensing study plan.

The PSP and RSP recommended the development of a CHM. This report discusses the UHM. As stated in the RSP, the objectives of the H&H modeling study are to:

1. Determine the duration and extent of inundation under the current license operations of the Project during several measured inflow events.
2. Determine the duration and extent of inundation under any proposed change in these operations that occurs during several measured or synthetic inflow events.
3. Provide the model results in a format that can inform other analyses (to be completed separately) of Project effects, if any, in several resource areas.
4. Determine the feasibility of implementing alternative operations scenarios, if applicable that may be proposed by GRDA as part of the relicensing effort.

The FERC's SPD and Order on Request for Clarification and Rehearing included direction to provide a model input status report by March 30, 2021, and hold a conference call on model inputs and calibration within 30 days of the input status report. The Upstream Hydraulic Model Input Status Report was filed with FERC and shared with stakeholders on March 30, 2021 (Mead & Hunt, 2021). A Technical Conference was held on April 21, 2021, to allow relicensing participants to ask questions regarding the Model Input Status Report (MISR).

This report is a continuation of the MISR and incorporates comments provided on the MISR as addressed in **Appendix A**. It documents the development of the UHM and findings from the analyses of historical and synthetic flow events with different initial stages at Pensacola Dam.

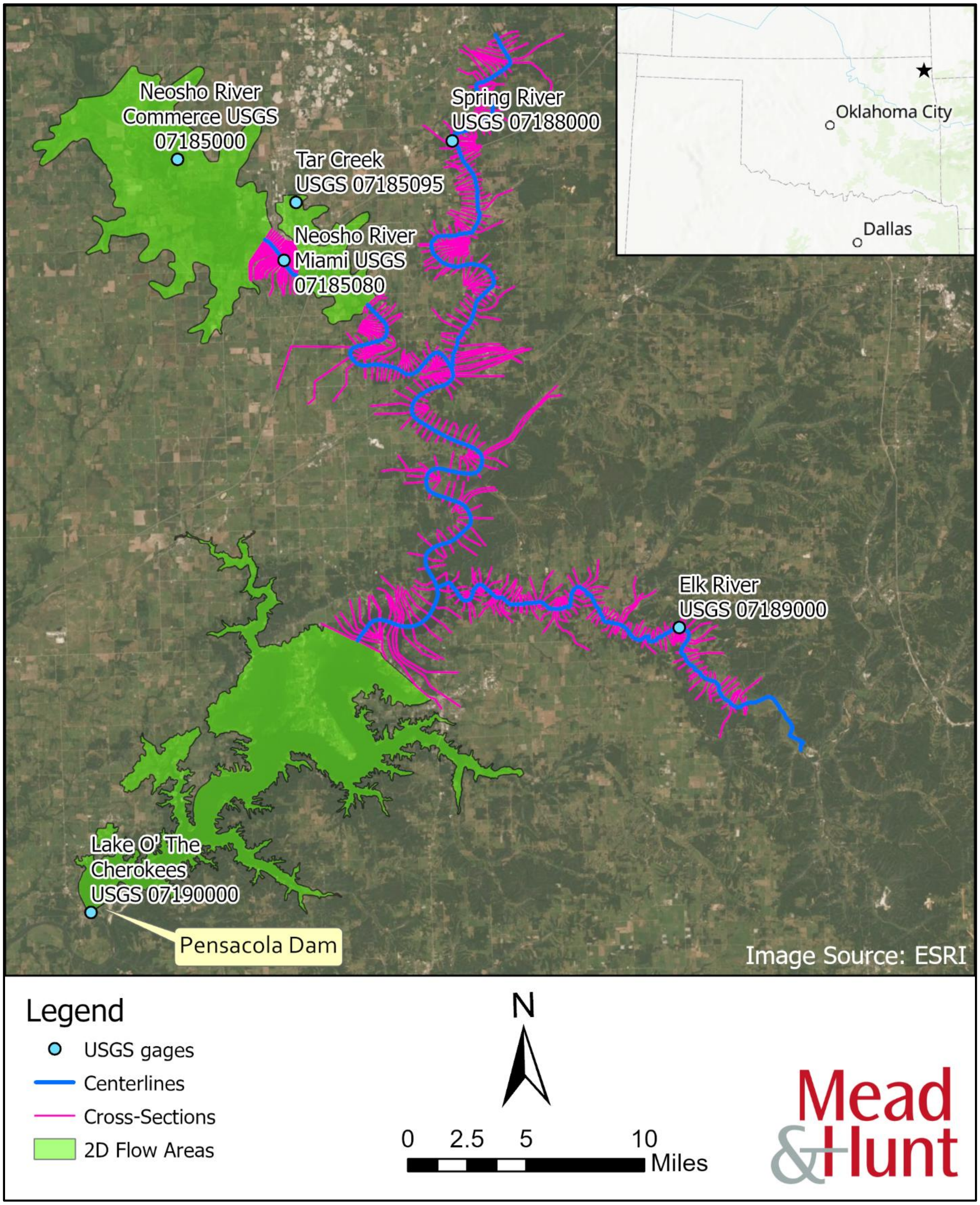
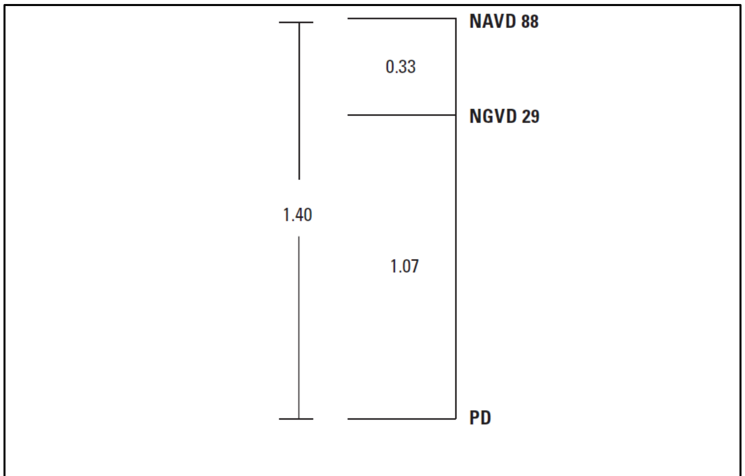


Figure 1. UHM study area.

1.3 Vertical Datums

Data sources for this study use a variety of vertical datums. Unless otherwise noted, data are presented in the Pensacola Datum (PD). To convert from PD to the National Geodetic Vertical Datum of 1929 (NGVD29), add 1.07 feet. To convert from NGVD29 to the North American Vertical Datum of 1988 (NAVD88), add 0.33 feet. **Figure 2** displays datum transformations and conversions (Hunter, Trevisan, Villa, & Smith, 2020). The HEC-RAS model discussed in this report was developed in NGVD29.



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

Figure 2. Datum transformations and conversions.
Source: (Hunter, Trevisan, Villa, & Smith, 2020).

2. Model Development

Tetra Tech previously developed a HEC-RAS model of the study area (Tetra Tech, 2015, 2016). Mead & Hunt used Tetra Tech's model as the base for UHM development. After a detailed review, the Tetra Tech model was transformed in the following ways, resulting in an improved comprehensive hydraulic model of Grand Lake and the river system upstream of Pensacola Dam.

1. Model was converted from a beta version of HEC-RAS to version 5.0.7.
2. Two-dimensional (2D) flow area (2DFA) was added for Grand Lake, replacing cross-sections.
3. 2DFAs in the vicinity of Miami, Oklahoma were expanded to fully contain inundation from larger flow events.
4. Mesh cell centers within 2DFAs were reviewed and adjusted in accordance with USACE guidance (USACE, 2016a).
5. Cross-sections were extended to fully contain the inundation from larger flow events.
6. 1D/2D flow boundaries were reviewed and adjusted in accordance with USACE guidance (USACE 2016a, USACE 2016b).
7. Bridge geometries were updated to reflect current conditions.
8. Bank stations and ineffective flow areas were reviewed and adjusted in accordance with USACE guidance (USACE, 2016b).
9. Elk River was added to the model.
10. Spring River was added to the model.
11. Recently published USGS Grand Lake bathymetry data were incorporated into model geometry (Hunter, Trevisan, Villa, & Smith, 2020).
12. Computational parameters were reviewed and adjusted in accordance with USACE guidance (USACE, 2016a).

UHM improvements are discussed in detail below.

2.1 HEC-RAS Version

Tetra Tech performed hydraulic modeling with the August 2016 5.0 beta version of HEC-RAS (Tetra Tech, 2015; Tetra Tech 2016). At the time of Mead & Hunt's RSP and the FERC's SPD, the current version of HEC-RAS was 5.0.7. Therefore, Mead & Hunt used HEC-RAS 5.0.7 for analysis.

2.2 Grand Lake 2DFA

Tetra Tech used cross-sections to represent Grand Lake. Mead & Hunt replaced the cross-sections downstream of River Mile (RM) 100 with a 2DFA. The 2DFA better accounts for the volume in Grand Lake. **Figure 3** displays a comparison of Tetra Tech's model geometry to Mead & Hunt's geometry.

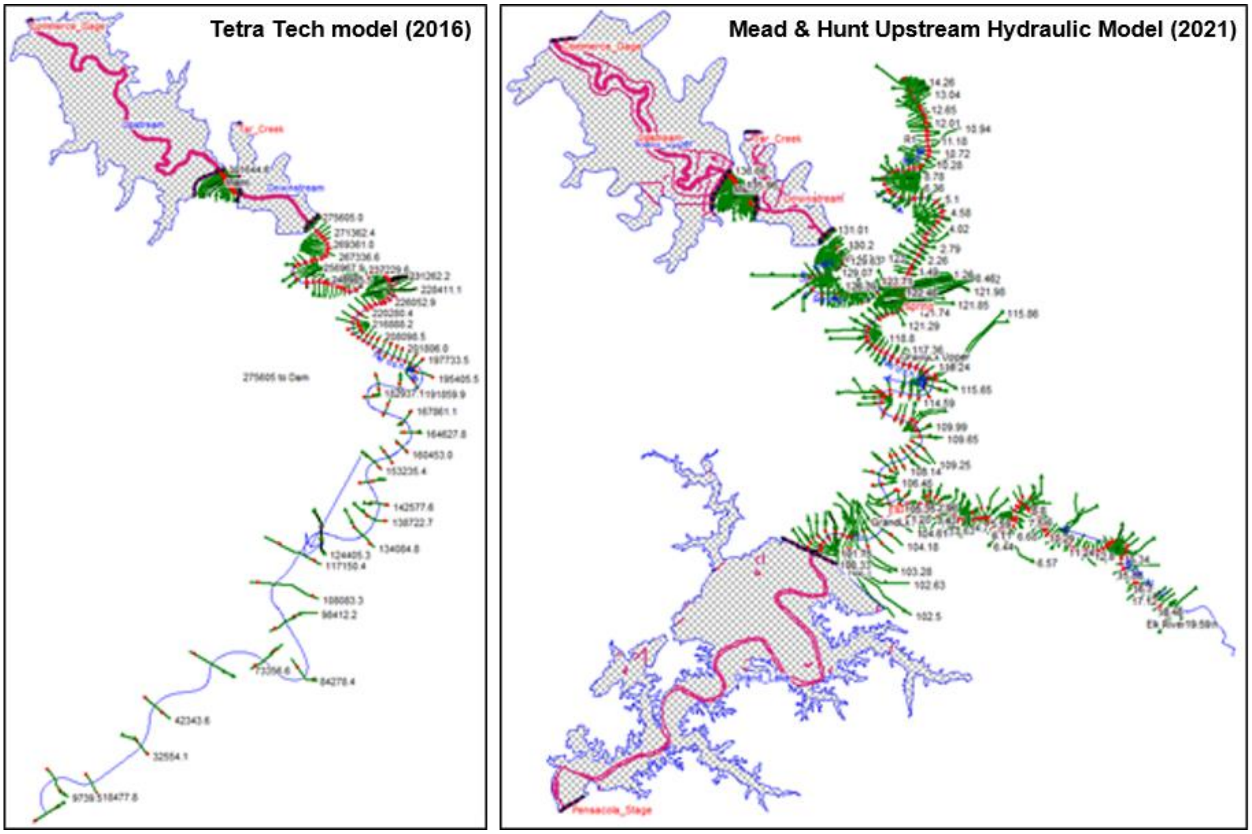


Figure 3. Comparison of model geometries.

2.3 Upstream 2DFAs

Tetra Tech included two 2DFAs in their HEC-RAS model: one just downstream of the City of Miami and one upstream of the City of Miami. Preliminary simulations showed that large flow events (e.g., the 100-year event) were not contained within the 2DFAs. Mead & Hunt expanded the 2DFAs so large flow events could be contained within the model boundaries. The expanded 2DFAs are displayed in **Figure 3**. In Mead & Hunt's model, the most upstream 2DFA is named "Miami_Upper" and the next 2DFA downstream is named "Miami_Lower".

The upstream boundary of the model along the Neosho River was not modified. Tetra Tech determined that it takes 4 hours for a flood wave to travel from the upstream end of the model (RM 152.2) to the Commerce gage (Tetra Tech, 2015). Mead & Hunt's preliminary simulations confirmed the 4-hour travel time. Therefore, Mead & Hunt applied a negative 4.0 hour offset to the USGS flow hydrographs, which were used as inflows at the upstream end of the Neosho River 2DFA. Flow data are further discussed in **Section 3.1**.

2.4 2DFA Cell Refinement

Tetra Tech included some refinement of 2DFA cells. However, cell faces were not aligned to the top of the river channel. Mead & Hunt refined cell alignments to follow the banks of the Neosho River in accordance with USACE guidance (USACE, 2016a). **Figure 4** displays an example comparison of Tetra Tech's 2DFA cell alignment to Mead & Hunt's cell alignment.

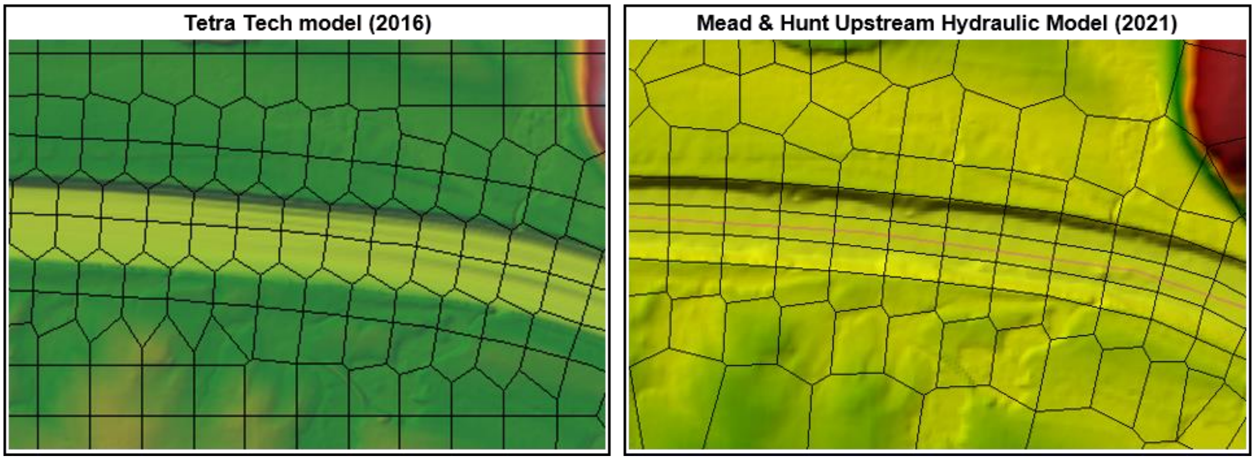


Figure 4. Comparison of 2DFA cells.

2.5 Cross-Section Adjustments

Like the 2DFAs, preliminary simulations showed large flow events (e.g., 100-year event) were not contained within the cross-sections. Mead & Hunt extended the cross-sections laterally so large flow events were contained within the cross-sections. An example of extended cross-sections is displayed in **Figure 5**.

2.6 1D/2D Boundaries

Mead & Hunt reviewed the 1D/2D boundaries in the Tetra Tech model and moved the boundaries to determine if model stability could be improved. Moving the most upstream 1D/2D boundary further upstream resulted in a more stable, accurate model. The adjusted boundary was placed in accordance with USACE guidance (USACE, 2016a; USACE 2016b). The revised location of the 1D/2D model boundary is displayed in **Figure 5**.

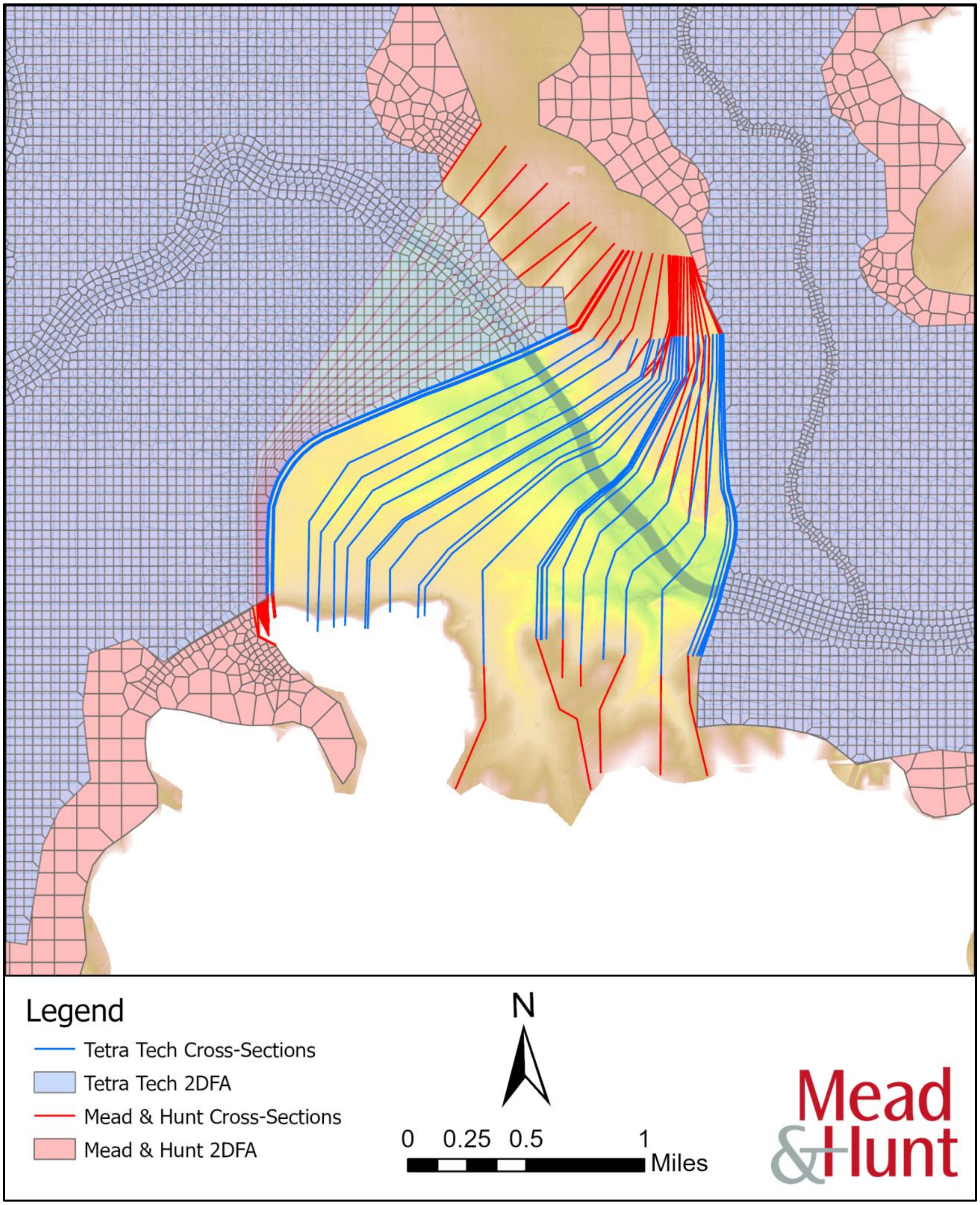


Figure 5. Comparison of cross-sections and most upstream 1D/2D boundary.

2.7 Bridge Geometries

Tetra Tech (2016) stated bridge geometry in their HEC-RAS model was primarily obtained from a Simons & Associates HEC-2 model (Simons & Associates, Inc., 1996). Mead & Hunt updated roadway bridge geometry using as-built drawings obtained from the Oklahoma Department of Transportation, Missouri Department of Transportation, and local/county road commissions. Railroad bridge geometries were updated using measurements provided by GRDA. An example of the updated bridge geometry at the Old Highway 69 Bridge in Miami, OK (RM 135.941) is displayed in **Figure 6**.

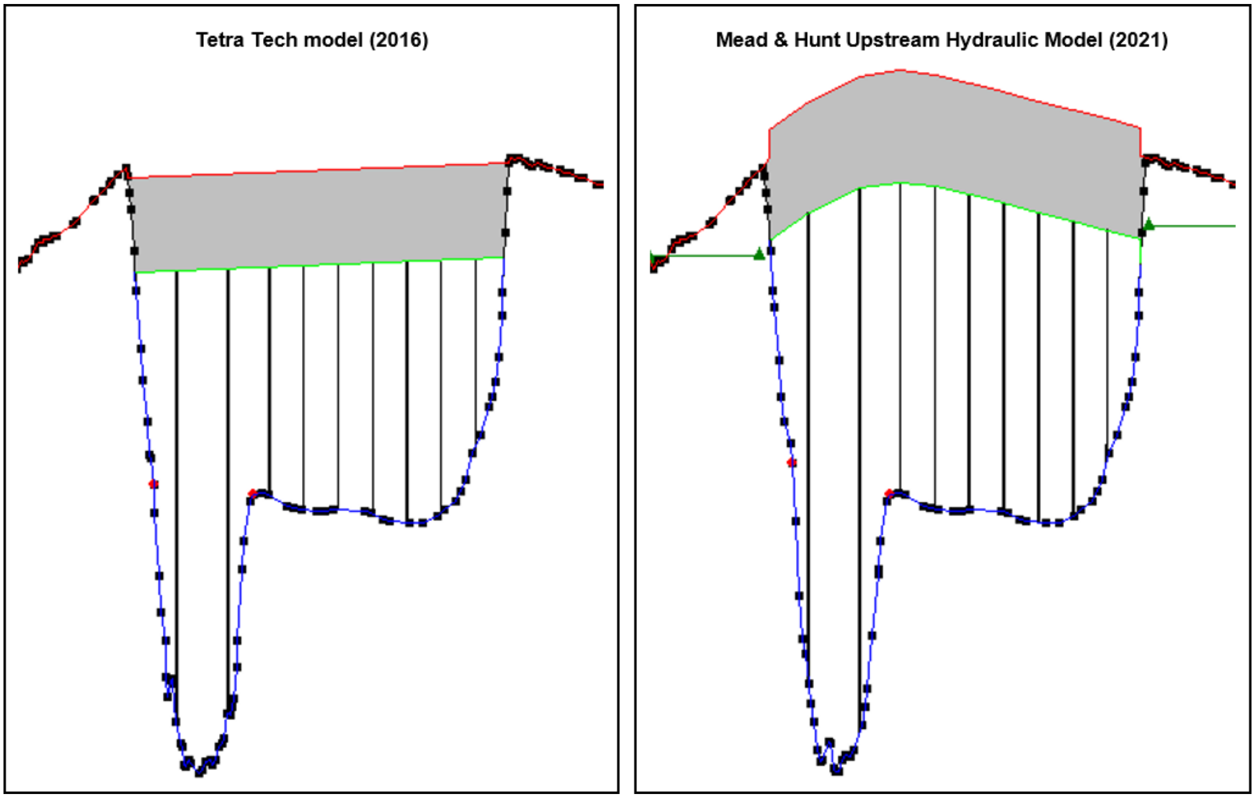


Figure 6. Example comparison of bridge geometry.

2.8 Bank Stations and Ineffective Flow Areas

Mead & Hunt reviewed and adjusted the bank stations and ineffective flow areas in the UHM according to best practices and the HEC-RAS Reference Manual (USACE, 2016b). Most adjustments to ineffective flow areas were upstream and downstream of bridges and were due to the updated bridge geometry. An example comparison of ineffective flow areas is displayed in **Figure 7**.

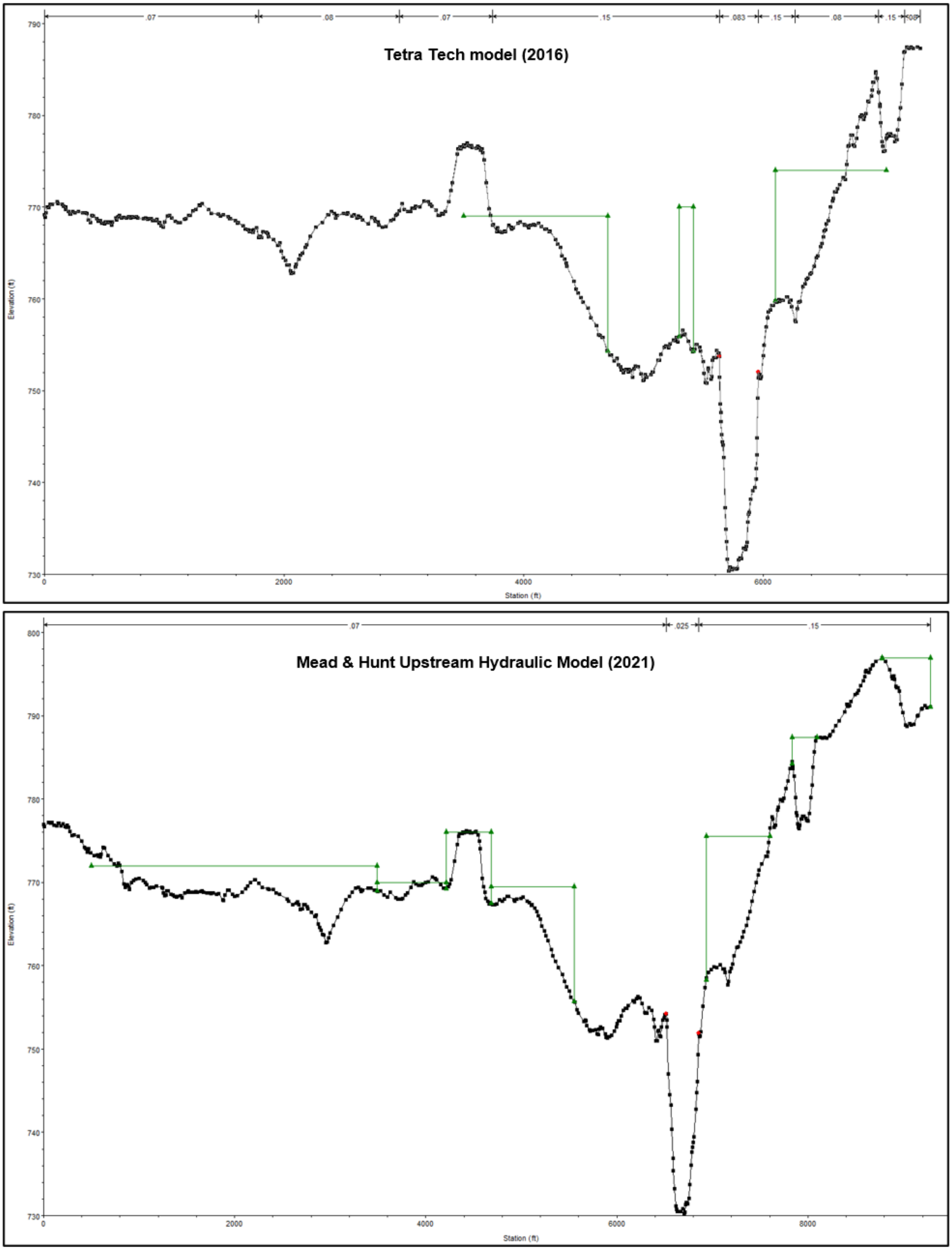


Figure 7. Example comparison of modified ineffective flow areas.

2.9 Spring River

Mead & Hunt added the Spring River to the UHM. The portion of the Spring River modeled by Mead & Hunt extended from the confluence with the Neosho River at the downstream end to RM 21.0 at the upstream end. The river centerline was digitized, and cross-sections were drawn perpendicular to the flow. Cross-sections were extended laterally far enough to contain large flow events (e.g., 100-year event). Bank stations were digitized and then adjusted in HEC-RAS. Ineffective flow areas were defined using guidance from the HEC-RAS Reference Manual (USACE, 2016b). **Figure 8** displays the riverbed profile of the Spring River. There are four bridges within the modeled reach:

1. E 57 Road (RM 14.16),
2. Interstate 44 Will Rogers Turnpike (RM 13.50),
3. OK 100 / E 10 Road (RM 8.01), and
4. US Highway 60 (RM 0.57).

There is one stream gage within the reach: Spring River near Quapaw, OK (USGS Gage No. 07188000). The gage is at E 57 Road (RM 14.16). Preliminary simulations indicated it takes 2.5 hours for a flood wave to travel from RM 21.0 (upstream end of the Spring River reach) to the USGS gage. Therefore, a negative 2.5-hour offset was applied to the USGS flow hydrographs, which were used as inflows at the upstream end of the Spring River.

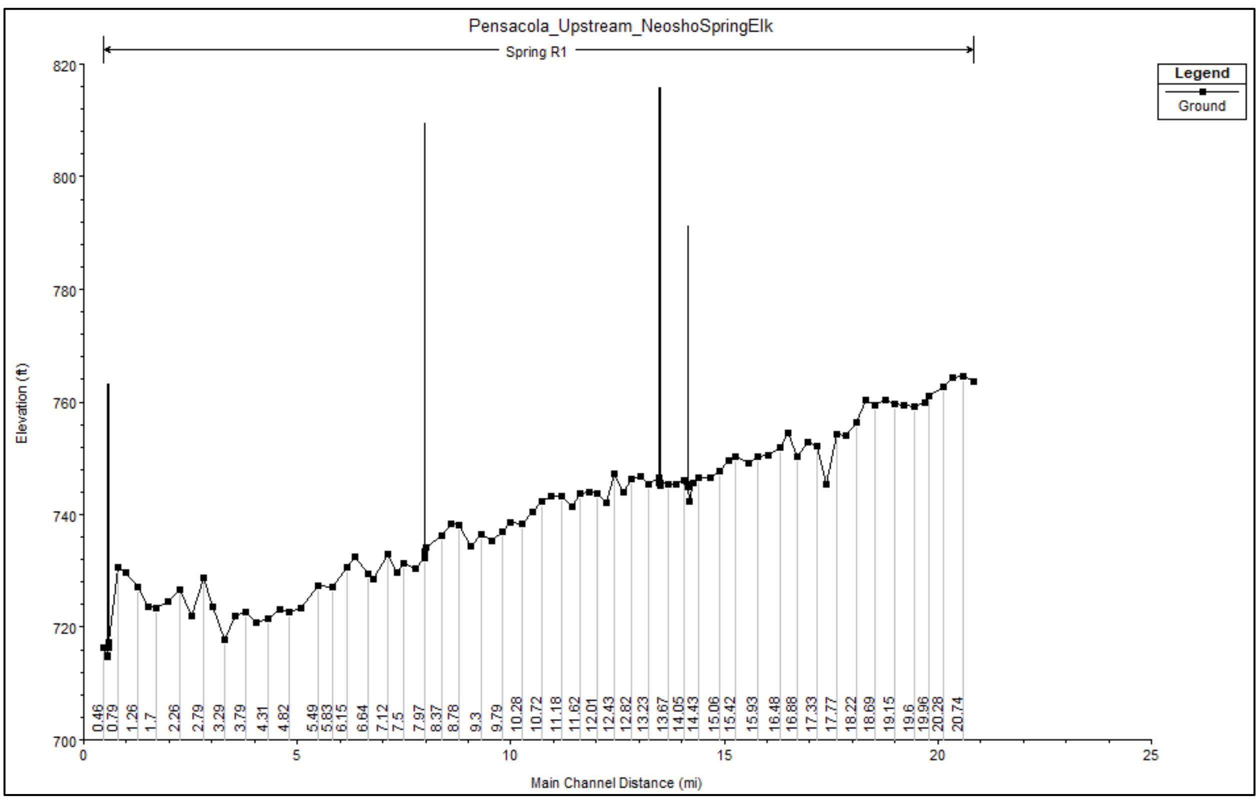


Figure 8. Riverbed profile of the Spring River.

2.10 Elk River

Mead & Hunt added the Elk River to the UHM. The portion of the Elk River modeled by Mead & Hunt extended from the confluence with Grand Lake at the downstream end to RM 19.59 at the upstream end. The river centerline, cross-sections, bank stations, and ineffective flow areas were defined with the same methodology used for the Spring River. **Figure 9** displays the riverbed profile of the Elk River. There are two bridges within the modeled reach:

1. Highway 10 (RM 4.67) and
2. Highway 43 (RM 14.22).

There is one stream gage within the reach: Elk River near Tiff City, MO (USGS Gage No. 07189000). The gage is at Highway 43 (RM 14.22). Preliminary simulations indicated that it takes 2 hours for a flood wave to travel from RM 19.59 (upstream end of the Elk River reach) to the USGS gage. Therefore, a negative 2.0-hour offset was applied to the USGS flow hydrographs, which were used as inflows at the upstream end of the Elk River.

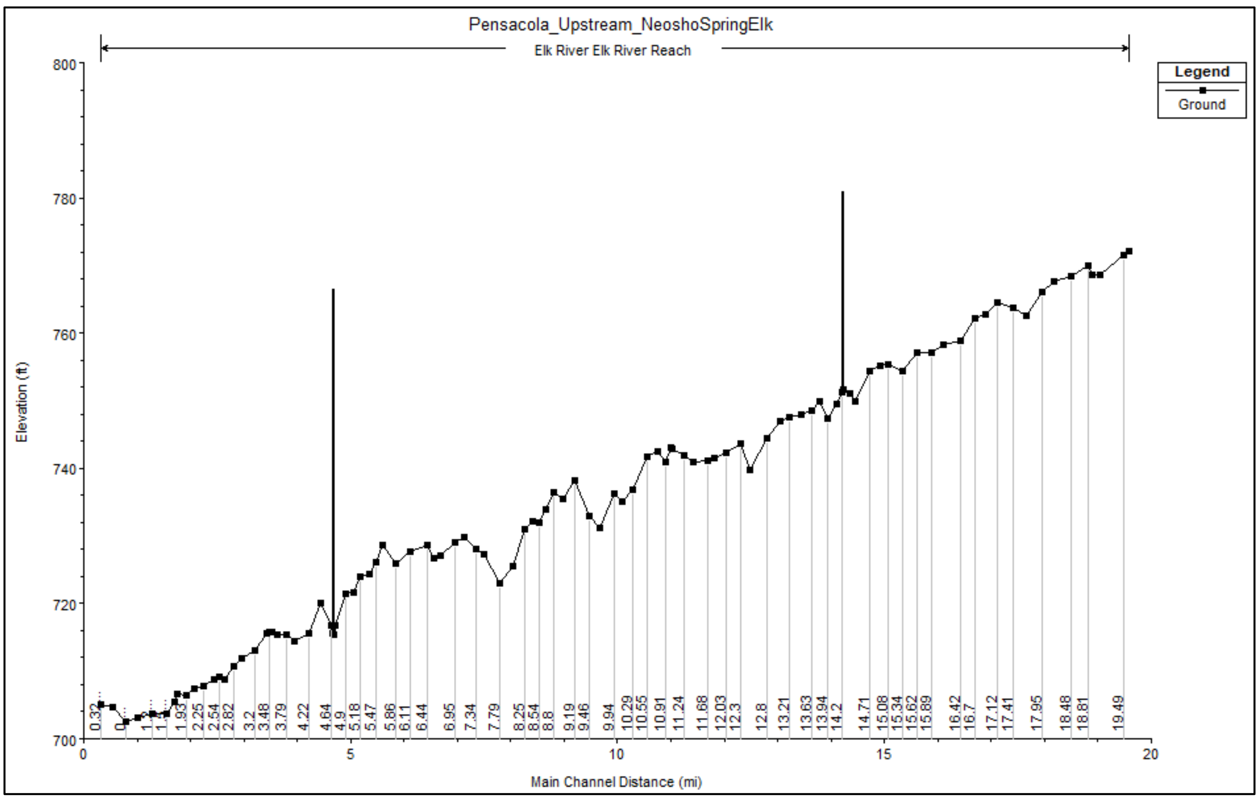


Figure 9. Riverbed profile of the Elk River.

2.11 Updated Bathymetry

In response to the FERC's SPD, GRDA enlisted USGS to perform a bathymetric survey of Grand Lake (Hunter, Trevisan, Villa, & Smith, 2020). Mead & Hunt integrated the Grand Lake bathymetry with a combined Digital Elevation Model (DEM) of the study area. The DEM was created with the following data, in descending order of priority:

1. USGS 2020 bathymetry, representing Grand Lake (Hunter, Trevisan, Villa, & Smith, 2020).
2. USGS 2017 bathymetry, representing the Neosho River, Spring River, and Elk River (Smith, Hunter, & Ashworth, 2017).
3. Federal Emergency Management Agency (FEMA) 2016 bathymetry from cross-section data, representing Tar Creek (FEMA, 2019).
4. Dewberry 2011 Light Detection and Ranging (LiDAR) overbank area (Dewberry, 2011).
5. USGS National Elevation Dataset (NED) 1/3 arc-second elevation layer, representing the overbank area in areas where no LiDAR data were available (USGS, 2017).

Figure 10 displays bathymetric and topographic data sources. USGS's 2020 report compared the capacity of Grand Lake, based on 2020 bathymetry, to previous capacity curves. **Figure 11** displays the capacity curves presented in USGS's report (Hunter, Trevisan, Villa, & Smith, 2020).

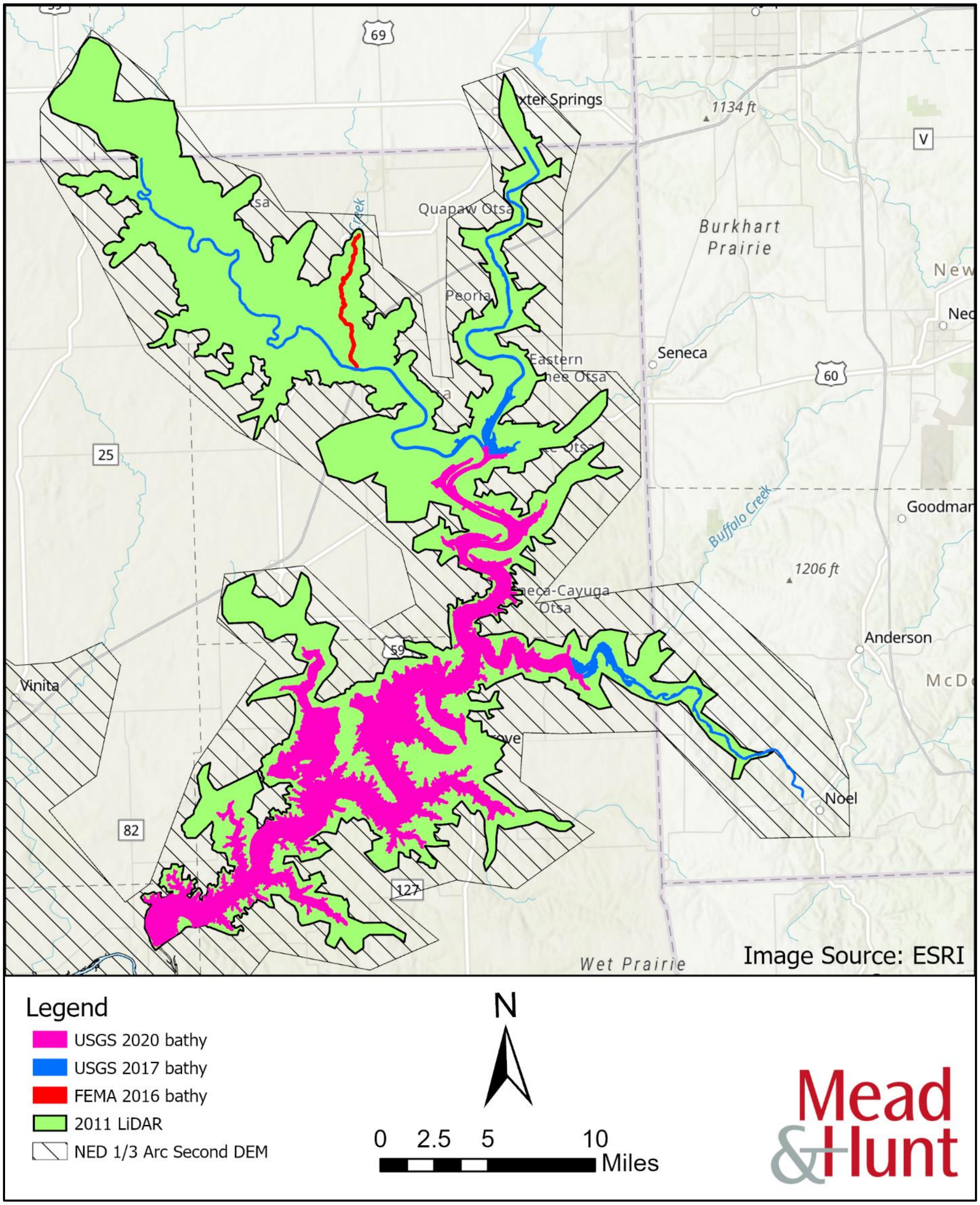


Figure 10. Bathymetric and topographic data sources.

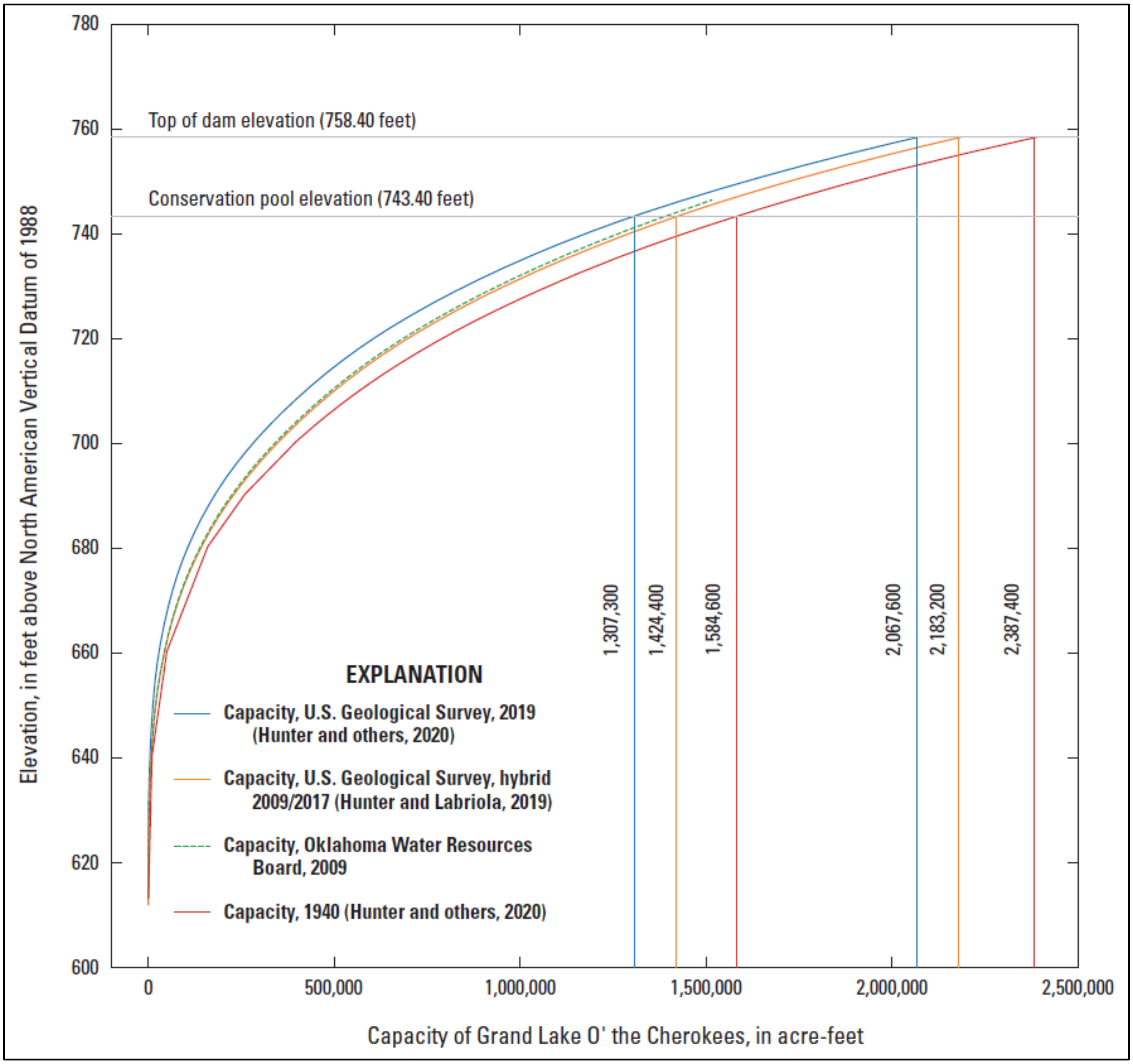


Figure 11. Grand Lake capacity curves.
Source: (Hunter, Trevisan, Villa, & Smith, 2020).

2.12 Computational Parameters

Tetra Tech's simulations all used the Diffusion Wave equation set. The HEC-RAS 2D Modeling User's Manual states the Diffusion Wave equations can be used while developing the model, but the Full Momentum equations should always be tested:

> *Once the model is in good working order, then make a second HEC-RAS Plan and switch the computational method to the Full Momentum equation option… Run the second plan and compare the two answers throughout the system. If there are significant differences between the two runs, the user should assume the Full Momentum (Saint Venant equations) answer is more accurate, and proceed with that equation set for model calibration and other event simulations* (USACE, 2016a).

Mead & Hunt ran preliminary simulations of the UHM with both Diffusion Wave and Full Momentum equation sets. Results from one simulation are displayed in **Figure 12**. The displayed reach (RM 131 to RM 151) approximately covers the two upstream 2DFAs and the 1D reach between the two upstream 2DFAs. Based on the WSEL differences in the test results, Mead & Hunt used Full Momentum for the two most upstream 2DFAs: Miami Upper and Miami Lower (see again **Figure 12**).

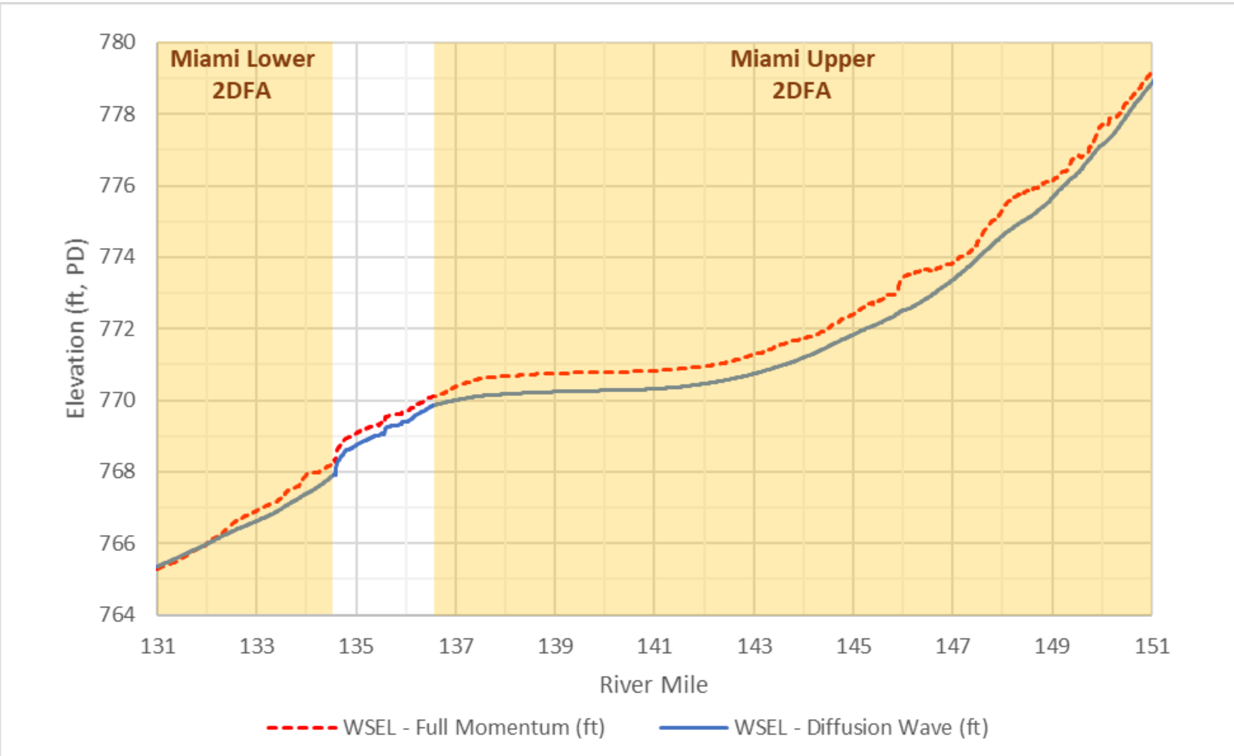


Figure 12. Simulation results from preliminary comparison of Diffusion Wave to Full Momentum equation sets.

Test results showed very little difference in WSEL in the Grand Lake 2DFA. Therefore, Mead & Hunt used the Diffusion Wave equation set for the Grand Lake 2DFA.

3. Model Calibration

The UHM was calibrated using several historical inflow events that represented a range of flows. Stream gage data were used for model boundary conditions and to compare measured WSEL to simulated values. High water marks and loggers installed by the project team were also used to compare measured and simulated WSEL.

3.1 Stream Gage Data

Data from the following stream gages were used for calibration:

1. Neosho River near Commerce, OK (USGS Gage No. 07185000)
2. Neosho River at Miami, OK (USGS Gage No. 07185080)
3. Tar Creek at 22nd Street Bridge at Miami, OK (USGS Gage No. 07185095)
4. Spring River near Quapaw, OK (USGS Gage No. 07188000)
5. Elk River near Tiff City, MO (USGS Gage No. 07189000)
6. Lake O' the Cherokees at Langley, OK (USGS Gage No. 07190000)

Details regarding the individual stream gages are discussed below. Stream gage data were obtained from the USGS National Water Information System (NWIS).

3.1.1 Neosho River near Commerce, OK

The Neosho River near Commerce, OK (USGS Gage No. 07185000) stream gage is at the Stepps Ford Bridge, approximately 6.7 miles downstream of the upper boundary of the model. Discharge data were available in hourly increments from April 1990 onward and stage data were available in hourly increments from October 2007 onward. The gage datum is 748.97 feet above NGVD29 (USGS, 2021a). Stage data at the gage were used in calibration.

Flow data were used as an upstream boundary condition for the Neosho River. Tetra Tech determined that it takes 4 hours for a flood wave to travel from the upstream end of the model (RM 152.2) to the Commerce gage (Tetra Tech, 2015). Mead & Hunt's preliminary simulations confirmed the 4-hour travel time. Therefore, Mead & Hunt applied a negative 4.0 hour offset to the USGS flow hydrographs, which were used as inflows at the upstream end of the Neosho River 2DFA.

3.1.2 Neosho River at Miami, OK

The Neosho River at Miami, OK (USGS Gage No. 07185080) stream gage is at the Highway 125 Bridge (RM 135.46) in the City of Miami. Stage data were available in hourly increments from October 2007 onward. Daily minimum, maximum, and mean stage data were available from October 1994 onward (USGS, 2021b). Stage data at the gage were used in calibration. Regarding the gage datum, Tetra Tech concluded that:

> *Although the NWIS website indicates that the datum for the Miami gage is referenced to NGVD29, field surveys to support this and previous Tetra Tech studies indicate that the datum is actually reported in the GRDA Pensacola Datum (PD). The reported values were, therefore, converted to NGVD29 for use in this analysis by adding 1.07 feet so that they are consistent with the Commerce data and the mapping and other data used for the modeling.*

Mead & Hunt analyzed the gage data and came to the same conclusion. Mead & Hunt contacted Scott Strong from the USGS Tulsa Field Office; Scott confirmed that the datum of the Miami gage is indeed in the Pensacola Datum.

3.1.3 Tar Creek at 22nd Street Bridge at Miami, OK

The Tar Creek at 22nd Street Bridge at Miami, OK (USGS Gage No. 07185095) stream gage had stage data available in hourly increments from October 2007 onward and had discharge data available in hourly increments from October 1989 onward. The gage datum is 762.23 feet above NGVD29 (USGS, 2021c).

Flow data were used as an upstream boundary condition for Tar Creek. No time offset was necessary because the gage is located at the upstream end of the model.

3.1.4 Spring River near Quapaw, OK

The Spring River near Quapaw, OK (USGS Gage No. 07188000) stream gage is at E 57 Road (RM 14.16). Stage data were available in hourly increments from October 2007 onward and discharge data were available in hourly increments from October 1989 onward. The gage datum is 746.25 feet above NGVD29 (USGS, 2021d).

Stage data at the gage were used in calibration. Flow data were used as an upstream boundary condition for the Spring River. As discussed in **Section 2.9**, a negative 2.5-hour offset was applied to flow hydrographs to account for flood wave travel time.

3.1.5 Elk River near Tiff City, MO

The Elk River near Tiff City, MO (USGS Gage No. 07189000) stream gage is at Highway 43 (RM 14.22). Stage data were available in hourly increments from October 2007 onward and discharge data were available in hourly increments from May 1990 onward. The gage datum is 750.61 feet above NGVD29 (USGS, 2021e).

Stage data at the gage were used in calibration. Flow data were used as an upstream boundary condition for the Elk River. As discussed in **Section 2.10**, a negative 2.0-hour offset was applied to flow hydrographs to account for flood wave travel time.

3.1.6 Lake O' the Cherokees at Langley, OK

The Lake O' the Cherokees at Langley, OK (USGS Gage No. 07190000) gage measures Grand Lake stage levels. Hourly stage data were available from October 2010 onward (USGS, 2021f). Stage data prior to October 2010 were provided by GRDA. Stage data were used as the downstream boundary condition for the model.

3.2 Historical Events

The following historical inflow events were used for calibration of the UHM.

1. July 2007
2. October 2009
3. December 2015
4. January 2017
5. April 2017
6. May 2019

Details regarding the individual inflow events are discussed below. For all historical events used in calibration of the UHM, USGS gage data were used for the upstream inflow boundaries and WSELs at Pensacola Dam were used for the downstream stage boundary. **Table 1** lists a summary of the historical event boundary conditions.

Table 1. Summary of historical event boundary conditions

Historical Event	Peak Inflow (cfs)				Pensacola Peak Stage (feet, PD)
	Neosho River	Tar Creek	Spring River	Elk River	
July 2007	141,000	726	33,300	1,190	754.53
October 2009	46,100	4,630	66,200	39,300	749.59
December 2015	45,400	4,710	151,000	107,000	754.93
January 2017	10,200	678	15,900	1,140	742.82
April 2017	58,100	3,550	114,000	107,000	754.59
May 2019	91,400	6,410	109,000	66,500	755.08

3.2.1 July 2007

For the July 2007 event, hourly flow data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Daily minimum, mean, and maximum WSELs were available for the Neosho River at Miami gage. Grand Lake stage data were provided by GRDA. High water marks, compiled by Tetra Tech (2016), were available for this inflow event. Of the selected calibration events, the July 2007 event had the highest recorded flow on the Neosho River at the Commerce gage.

3.2.2 October 2009

For the October 2009 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. High water marks, compiled by Tetra Tech (2016), were available for this inflow event.

3.2.3 December 2015

For the December 2015 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. High water marks, compiled by Tetra Tech (2016), were available for this inflow event. Of the selected calibration events, the December 2015 event had the highest recorded flow on the Spring River at Quapaw gage. The peak flow at the Elk River near Tiff City gage was 107,000 cfs, which is equal to the peak flow that occurred at this gage during the April 2017 event. This flow is the highest recorded flow on the Elk River for the selected calibration events.

3.2.4 January 2017

For the January 2017 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. Hourly WSEL logger data throughout the study area were collected by the project team for this event. Of the selected calibration events, the January 2017 event had the lowest recorded flow on all gages.

3.2.5 April 2017

For the April 2017 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. Hourly WSEL logger data throughout the study area were collected by the project team for this event. The peak flow at the Elk River near Tiff City gage was 107,000 cfs, which is equal to the peak flow that occurred at this gage during the December 2015 event. This flow is the highest recorded flow on the Elk River for the selected calibration events.

3.2.6 May 2019

For the May 2019 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. Hourly WSEL logger data throughout the study area were collected by the project team for this event. Of the selected calibration events, the May 2019 event had the highest recorded flow at the Tar Creek at Miami gage.

3.3 Methodology

The goal of model calibration was to create a single geometry file that could be used for a variety of synthetic/hypothetical simulations. Simulated WSEL values were compared to stream gage elevations within the study area, high water marks, and WSEL logger data collected by the project team.

Tetra Tech previously digitized land cover along the Neosho River from the confluence with the Spring River to the upstream end of the model (Tetra Tech, 2015). Mead & Hunt expanded the coverage, digitizing land cover in the following areas:

1. Neosho River, downstream of the confluence with the Spring River
2. Grand Lake
3. Elk River
4. Spring River

Tetra Tech assigned Manning's n-values to land cover categories (Tetra Tech, 2015). Tetra Tech's work relied on commonly used guidance (Arcement & Schneider, 1989) and area-specific investigation (Mussetter, 1998). Mead & Hunt continued to use the same Manning's n-values in overbank areas. Mead & Hunt digitized two new categories of land cover: field crops and dense urban areas. Manning's n-values were assigned to these categories based on other n-values and engineering judgement. Horizontal variation in n-values was applied to the cross-sections and spatially varied n-values were applied to the 2DFAs. **Table 2** lists the overbank Manning's n-values.

Table 2. Overbank Manning's n-values.

Land Cover	n-Value
Field crops	0.040
Pasture	0.080
Urban	0.070
Urban, dense	0.090
Water	0.040
Woody vegetation	0.100
Woody vegetation, dense	0.150

Manning's n-values in the main channel were iteratively adjusted until simulated WSELs reasonably agreed with measured data. **Table 3** lists the in-channel Manning's n-values that resulted from model calibration.

Table 3. Channel Manning's n-values.

Reach	n-Value
Grand Lake (reservoir, up to RM 121.29)	0.020
Neosho River (RM 121.51 up to RM 128.81)	0.035
Neosho River (RM 129.07 up to RM 135.44)	0.037
Neosho River (RM 135.47 up to RM 152.2)	0.025
Elk River (full reach)	0.042
Spring River (full reach)	0.038

After the base n-values were determined, flow roughness factors were iteratively applied to further decrease the differences between simulated and measured WSELs. **Table 4** lists the flow roughness factors that resulted from model calibration.

Table 4. Flow roughness factors.

Neosho River		Spring River		Elk River	
Flow (cfs)	Roughness Factor	Flow (cfs)	Roughness Factor	Flow (cfs)	Roughness Factor
0	0.60	0	0.79	0	1.15
20,000	0.60	20,000	0.79	40,000	1.15
40,000	0.70	40,000	0.94	60,000	0.80
45,000	0.70	60,000	0.94	80,000	0.80
50,000	1.00	80,000	0.94	100,000	1.00
55,000	1.25	100,000	1.00	120,000	1.00
60,000	1.25	120,000	1.00	140,000	1.00
80,000	1.25	140,000	1.10	160,000	1.00
90,000	1.30	160,000	1.10	350,000	1.00
110,000	1.30	180,000	1.00		
140,000	1.30	350,000	1.00		
150,000	1.30				
160,000	1.00				
350,000	1.00				

3.4 Results

The results from the model calibration are discussed in the following paragraphs. **Figure 13** displays the over/underprediction of peak simulated WSEL at USGS gages. The average difference between simulated WSELs and measured USGS gage WSELs is -0.1 feet; the model is slightly underpredicting the WSEL at USGS gages.

UHM results were also compared to the high water marks compiled by Tetra Tech (2016). **Figure 14** compares model results to the July 2007 high water marks, **Figure 15** compares results to the October 2009 marks, and **Figure 16** compares results to the December 2015 marks. The average underprediction of simulated WSEL is 0.5 feet for the July 2007 event, the average overprediction is 0.4 feet for the October 2009 event, and the average underprediction is 0.1 feet for the December 2015 event.

The project team installed WSEL loggers throughout the study area. Loggers were in place during three calibration events: January 2017, April 2017, and May 2019. **Figure 17** displays the logger locations. Not all logger locations have data for a given event; some loggers were missing when the project team visited to perform maintenance and download data. Loggers 3, 4, 11, and 12 were missing for the May 2019 event. Logger 9 was missing for all three events. Data from loggers 7, 8, 13, 14, and 15 were not included in calibration because the logger WSEL was influenced by incoming, un-gaged streams not modeled in the UHM. The loggers were placed in support of the Sedimentation Study, early in the pre-study period before model parameters were fully defined. **Figure 18** displays the over/underprediction of peak simulated WSEL at the loggers used for model calibration for the three events. The average difference between simulated WSELs and measured WSELs is -0.6 feet; the model is underpredicting the WSEL at the loggers.

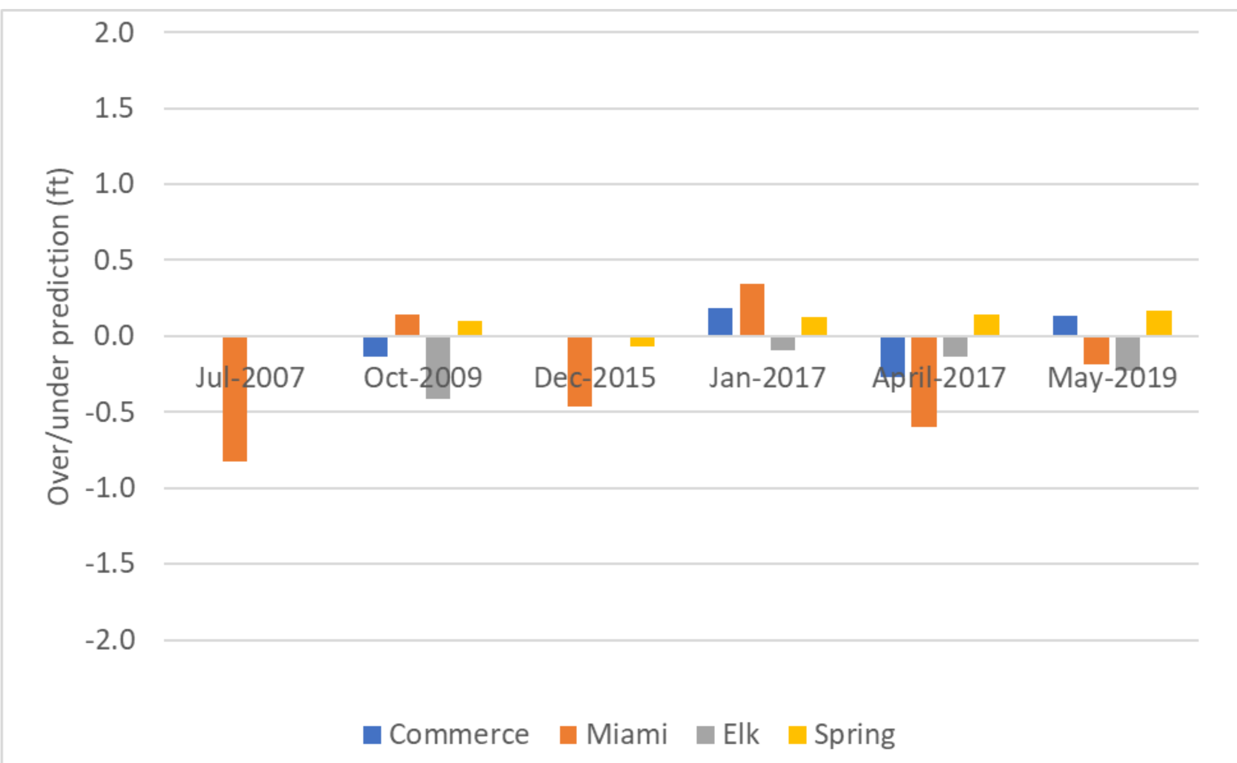


Figure 13. Over/underprediction of simulated WSEL at USGS gages.

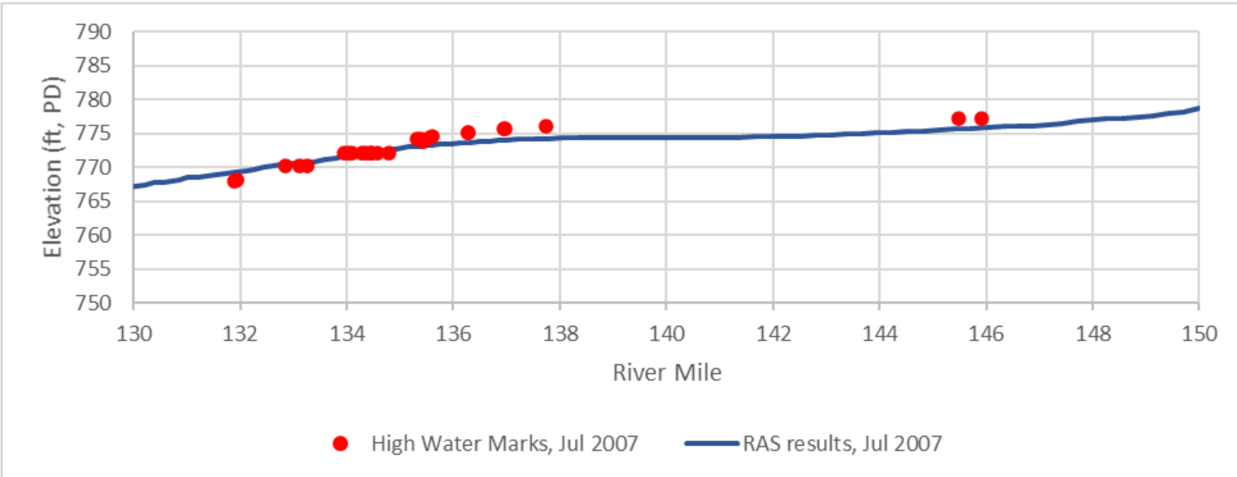


Figure 14. Comparison of UHM results to July 2007 high water marks.

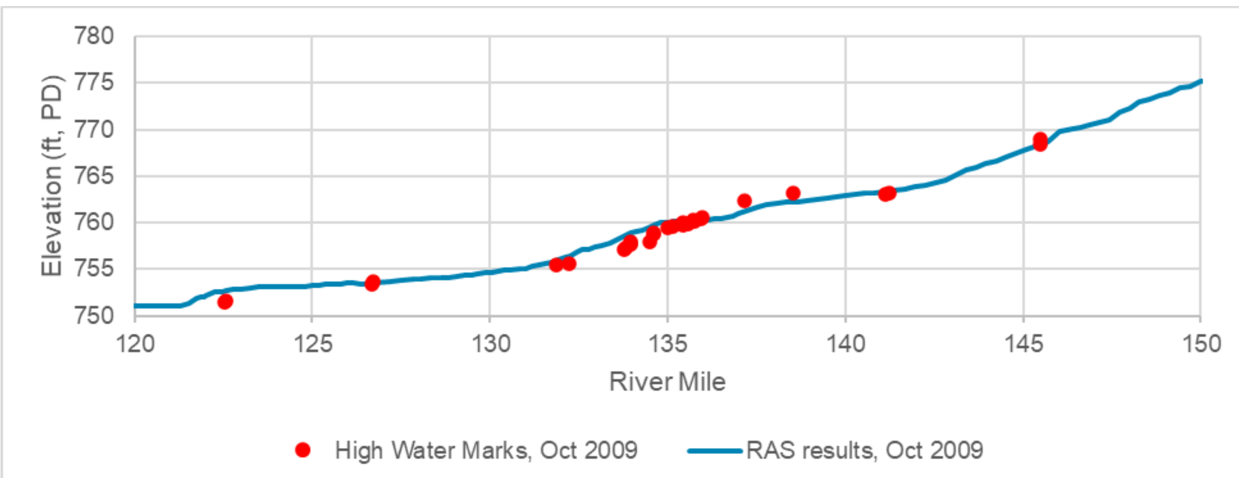


Figure 15. Comparison of UHM results to October 2009 high water marks.

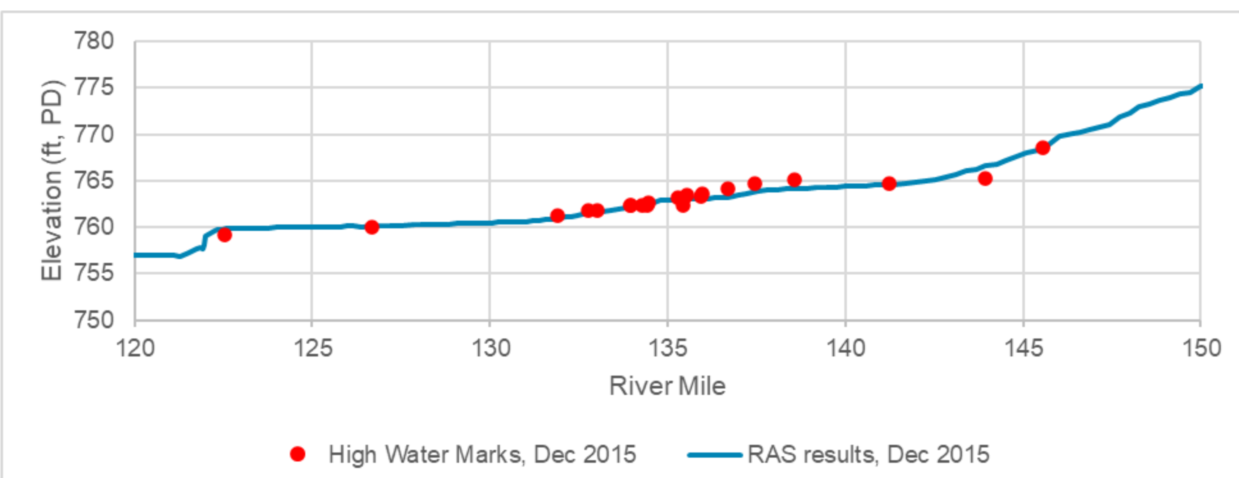


Figure 16. Comparison of UHM results to December 2015 high water marks.

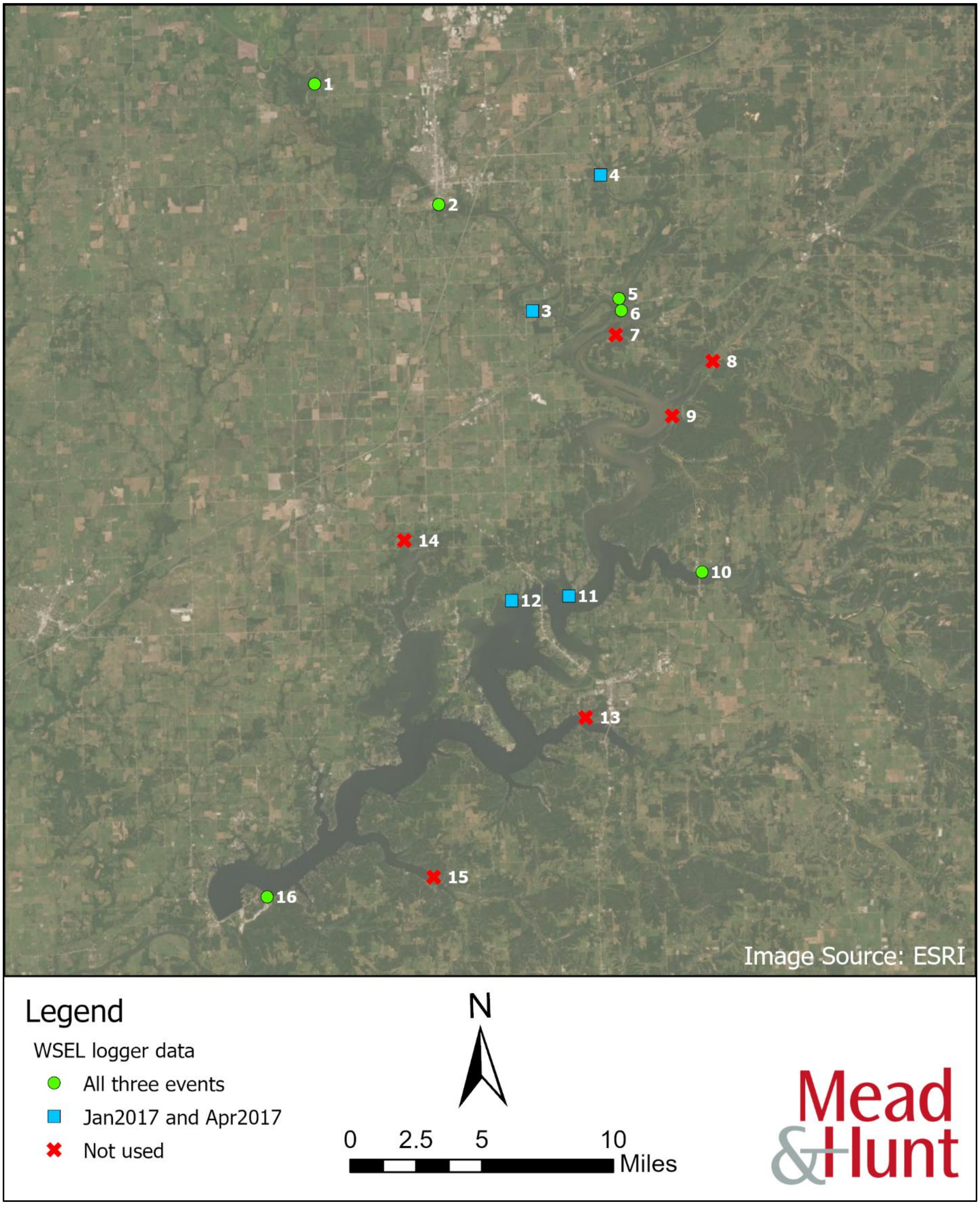


Figure 17. Locations of WSEL loggers installed by project team.

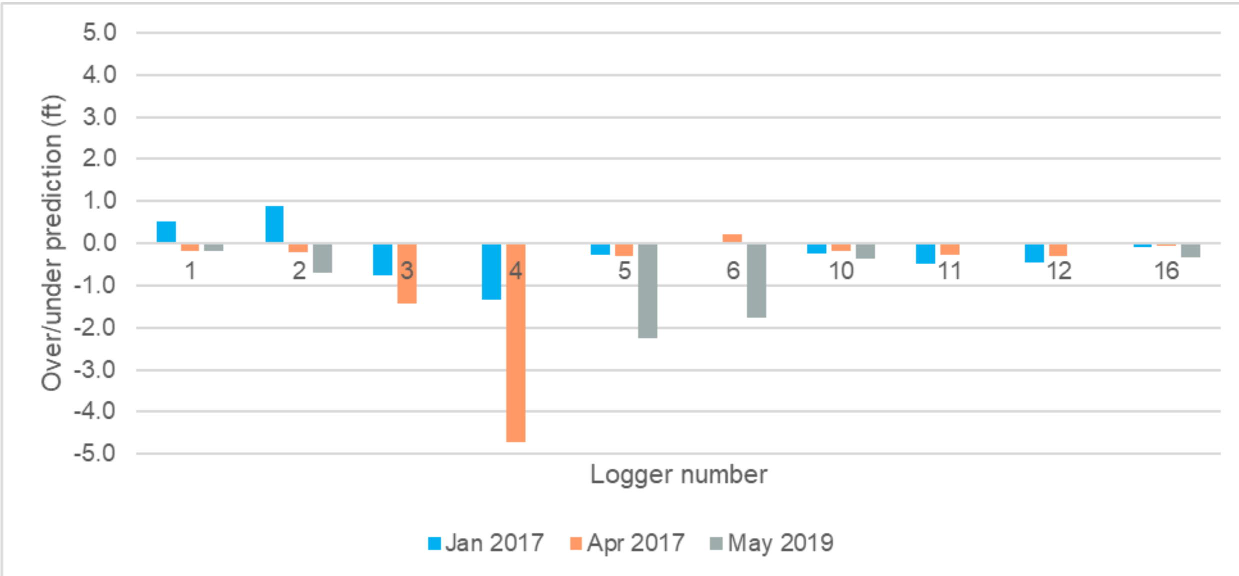


Figure 18. Over/underprediction of simulated WSEL at loggers installed by project team.

3.5 July 2007 Additional Data

As noted in **Section 3.1**, for gages where inflow hydrographs were defined, stage data were available in hourly increments from October 2007 onward. After the Technical Conference on April 21, 2021, the City of Miami, Oklahoma, provided comments regarding the Upstream MISR (City of Miami, 2021). The City of Miami noted that stage data for the Commerce gage from circa 1990 to October 2007 were not published online but were available upon request from USGS. The City of Miami recommended obtaining the data from USGS and using it in the calibration process.

Mead & Hunt contacted USGS and requested the pre-October 2007 hourly stage data for the Commerce gage on the Neosho River, the Miami gage on the Neosho River, the Tiff City gage on the Elk River, and the Quapaw gage on the Spring River. Scott Strong, from the USGS Tulsa Field Office, provided the pre-October 2007 hourly stage data for the gages to Mead & Hunt with the following disclaimer (USGS disclaimer):

> *Please note that prior to October 2007, instantaneous stage values were not considered a reportable data product. A small possibility exists that some of the data provided in this email was not processed in accordance with current USGS standards and could contain errors.*

Because of this disclaimer, Mead & Hunt compared the pre-October 2007 USGS data to other publicly available USGS data:

1. Peak streamflow is the maximum flow that occurred during the USGS water year. Stage associated with the peak streamflow is reported by USGS and was converted to WSEL (feet, PD datum) by Mead & Hunt for analysis. For the Miami gage, USGS reports maximum stage that occurred during the USGS water year because streamflow is not reported at the gage.
2. Streamflow measurements are USGS field measurements and are independent of gage-recorded values. USGS reports flow and gage height for streamflow measurements. Stage was converted to WSEL (feet, PD datum) by Mead & Hunt for analysis.

USGS data for the July 2007 event are discussed below.

3.5.1 Neosho River near Commerce, OK

For the Commerce gage, Mead & Hunt also reviewed USGS data available from the gage Peak Streamflow webpage (USGS, 2021g) and the gage Streamflow Measurements webpage (USGS, 2021h). These data, along with the pre-October 2007 USGS data and results from the HEC-RAS model, are presented in **Table 5**.

Mead & Hunt analyzed the difference between the USGS measurements and the HEC-RAS model results. The WSEL for the peak streamflow value is 0.15 feet lower than the maximum WSEL caculated by the HEC-RAS model. The WSELs from the streamflow measurements range from 0.58 feet to 1.29 feet higher than the HEC-RAS maximum WSEL. The maximum WSEL of the pre-October 2007 hourly time series data provided by USGS is 1.45 feet higher than the HEC-RAS maximum WSEL.

USGS measurements were also compared against each other. The highest USGS streamflow measurement is 0.16 feet lower than the maximum WSEL of the pre-October 2007 hourly time series data provided by USGS. The peak streamflow WSEL is 1.60 feet lower than the maximum WSEL of USGS hourly time series. The peak streamflow WSEL is reported on July 3, 2007. Compared to the two streamflow measurements collected on July 3, 2007, the peak streamflow WSEL ranges from 0.73 feet to 1.13 feet lower than the streamflow measurements.

While there are differences between the HEC-RAS results and the USGS measurements, there are also differences between the various USGS measurements. The magnitude of the differences between HEC-RAS results and USGS measurements is similar to the magnitude of differences between the various USGS measurements.

Table 5. Comparison of additional data for the Neosho River near Commerce, OK.

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	7/3/2007 (no time listed)	775.55
USGS Streamflow Measurements	7/3/2007 1615 hours	776.28
	7/3/2007 1930 hours	776.68
	7/4/2007 1222 hours	776.99
Pre-October 2007 USGS Data Maximum WSEL	7/3/2007 2300 hours	777.15
HEC-RAS Maximum WSEL	7/4/2007 1200 hours	775.70

3.5.2 Neosho River at Miami, OK

For the Miami gage, Mead & Hunt also reviewed the USGS data available from the gage Peak Streamflow webpage (USGS, 2021i). No data were available for the July 2007 event on the gage Streamflow Measurements webpage (USGS, 2021j). The gage peak streamflow value, along with the pre-October 2007 USGS data, USGS daily maximum (see **Section 3.1.2**) and results from the HEC-RAS model, are presented in **Table 6**.

The WSELs for the peak streamflow, the pre-October 2007 USGS data, and the USGS daily maximum are all 774.05 ft. Because the values are exact matches, the peak streamflow value and daily maximum were potentially based on the pre-October 2007 data that USGS delivered to Mead & Hunt. The USGS WSELs are 0.83 feet higher than the maximum WSEL in the HEC-RAS model.

Table 6. Comparison of additional data for the Neosho River at Miami, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	7/4/2007 (no time listed)	774.05
USGS Streamflow Measurements	*No data*	
Pre-October 2007 USGS Data Maximum WSEL	7/4/2007 0300 hours	774.05
USGS Daily Maximum WSEL	7/4/2007 (no time listed)	774.05
HEC-RAS Maximum WSEL	7/4/2007 1800 hours	773.22

3.5.3 Elk River near Tiff City, OK

For the Tiff City gage on the Elk River, Mead & Hunt also reviewed USGS data available from the gage Peak Streamflow webpage (USGS, 2021k) and the gage Streamflow Measurements webpage (USGS, 2021l). These data, along with the pre-October 2007 USGS data and results from the HEC-RAS model, are presented in **Table 7**.

The WSEL for the peak streamflow matches the WSEL for the pre-October 2007 USGS data. Because the values are exact matches, the peak streamflow value was potentially based on the pre-October 2007 data that USGS delivered to Mead & Hunt. The streamflow measurement occurred six days after the peak had passed and thus is not a good point for comparison. The WSEL for the peak streamflow is 0.58 feet lower than the maximum WSEL in the HEC-RAS model.

Table 7. Comparison of additional data for the Elk River near Tiff City, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	6/13/2007 (no time listed)	758.32
USGS Streamflow Measurements	6/19/2007 1107 hours	754.20
Pre-October 2007 USGS Data Maximum WSEL	6/13/2007 0100 hours	758.32
HEC-RAS Maximum WSEL	6/13/2007 0300 hours	758.90

3.5.4 Spring River near Quapaw, OK

For the gage near Quapaw on the Spring River, Mead & Hunt also reviewed USGS data available from the gage Peak Streamflow webpage (USGS, 2021m) and the gage Streamflow Measurements webpage (USGS, 2021n). These data, along with the pre-October 2007 USGS data and results from the HEC-RAS model, are presented in **Table 8**.

The WSEL for the peak streamflow matches the WSEL for the pre-October 2007 USGS data. Because the values are exact matches, the peak streamflow value was potentially based on the pre-October 2007 data that USGS delivered to Mead & Hunt. Comparing USGS measurements to HEC-RAS, the WSEL for the peak streamflow is 0.63 feet higher than the maximum WSEL in the HEC-RAS model. The streamflow measurement is 0.97 feet lower than the maximum WSEL in the HEC-RAS model.

Comparing USGS measurements against each other, the peak streamflow WSEL is 1.60 feet higher than the streamflow measurement. The difference between the USGS measurements exceeds the difference between the HEC-RAS results and either of the USGS measurements.

Table 8. Comparison of additional data for the Spring River near Quapaw, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	6/13/2007 (no time listed)	779.21
USGS Streamflow Measurements	6/13/2007 1218 hours	777.61
Pre-October 2007 USGS Data Maximum WSEL	6/13/2007 0400 hours	779.21
HEC-RAS Maximum WSEL	6/13/2007 0700 hours	778.58

3.5.5 Summary of Findings and Conclusions Regarding Additional Data

Mead & Hunt considered the following factors when determining if the model should be recalibrated to match the pre-October 2007 USGS data for the July 2007 event:

1. USGS included a disclaimer for the pre-October 2007 data, noting that the data may not have been processed in accordance with current USGS standards and could contain errors.
2. Differences between various USGS measurements are similar to or greater than differences between HEC-RAS results and USGS measurements.
    a. For the Neosho River near Commerce gage, the magnitude of the differences between HEC-RAS results and USGS measurements is similar to the magnitude of differences between the various USGS measurements.
    b. For the Spring River near Quapaw gage, the difference between the USGS measurements exceeds the difference between the HEC-RAS results and either of the USGS measurements.
3. In the HEC-RAS User's Manual, USACE states that a ± 5% flow measurement, which may be "optimistic," translates into a stage error of ±1.0 feet (USACE, 2016c). Considering the differences between the various USGS measurements at the gage locations, there may be errors for the July 2007 event flow measurement that result in stage errors of 1.0 feet or more.
4. In their comments on the Upstream MISR, the City of Miami recommended reducing the Commerce gage peak flow for the July 2007 event hydrograph. The City of Miami's lack of comfort using publicly available USGS flow data for the July 2007 event further reinforces the recommendation against recalibrating the model to match the pre-October 2007 USGS data (which was delivered by USGS with a data accuracy disclaimer).

The goal of UHM development and calibration is to create a single geometry file that could be used for a variety of synthetic/hypothetical simulations. Adjusting model calibration to match a dataset suspected to have accuracy issues contradicts that goal. Considering the factors listed above, it is inadvisable to recalibrate the model to match the pre-October 2007 USGS data for the July 2007 event.

4. Flood Frequency Analysis

Mead & Hunt performed a flood frequency analysis for the study area. USACE has developed a period of record RiverWare model that includes Pensacola Dam. Mead & Hunt extracted the total inflow at Pensacola Dam from 1940 (dam construction date) to 2019 (latest available data at time of data delivery from USACE) from the RiverWare model.

Annual peak inflows at Pensacola Dam were extracted using HEC's Statistical Software Package (SSP) version 2.2. The full inflow time series was imported into HEC-SSP and the annual peaks were automatically filtered. Water years were set to start at October 1st to align with USGS water years (USGS, 2016). One manual adjustment was necessary for an event that occurred in September and October 1986. HEC-SSP automatically selected September 30, 1986 for the peak of water year 1986 and October 2, 1986 for the peak of water year 1987, as displayed in **Figure 19**. The September 30th peak is not hydrologically independent of the October 2nd peak. Mead & Hunt manually selected the next highest peak for water year 1986: November 19, 1985. Manually correct flood peaks were re-imported and a Graphical Frequency Analysis of Peak Inflows was performed in HEC-SSP. Weibull plotting positions were used and a best-fit was digitized through the peak flows. Annual recurrence interval flows were rounded to the nearest thousand cubic feet per second (cfs).

Tabular results of flood frequency analysis are presented in **Table 9** and graphical results are presented in **Figure 20**. **Figure 20** also displays the exceedance curve from the Real Estate Adequacy Study (USACE, 1998), which was developed using similar methodology as Mead & Hunt's analysis. At lower recurrence intervals (2-year through 10-year), the new analysis resulted in higher flows. At higher recurrence intervals (20-year through 500-year), the new analysis resulted in lower flows. Differences between the Mead & Hunt analysis and the Real Estate Adequacy Study Analysis are primarily due to the additional two decades of data used in the new analysis.

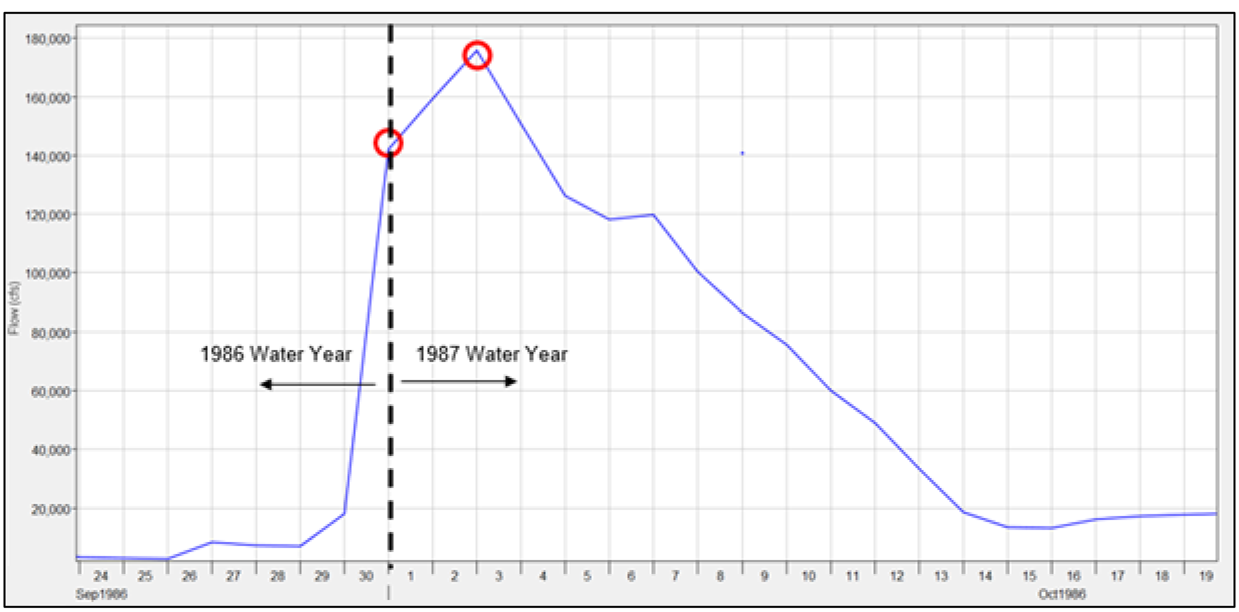


Figure 19. 1986 and 1987 water years in HEC-SSP.

Table 9. Flood frequency analysis tabular results.

Annual Recurrence Interval	Flow (cfs)
2	90,000
5	152,000
10	192,000
20	225,000
50	266,000
100	299,000
200	330,000
500	375,000

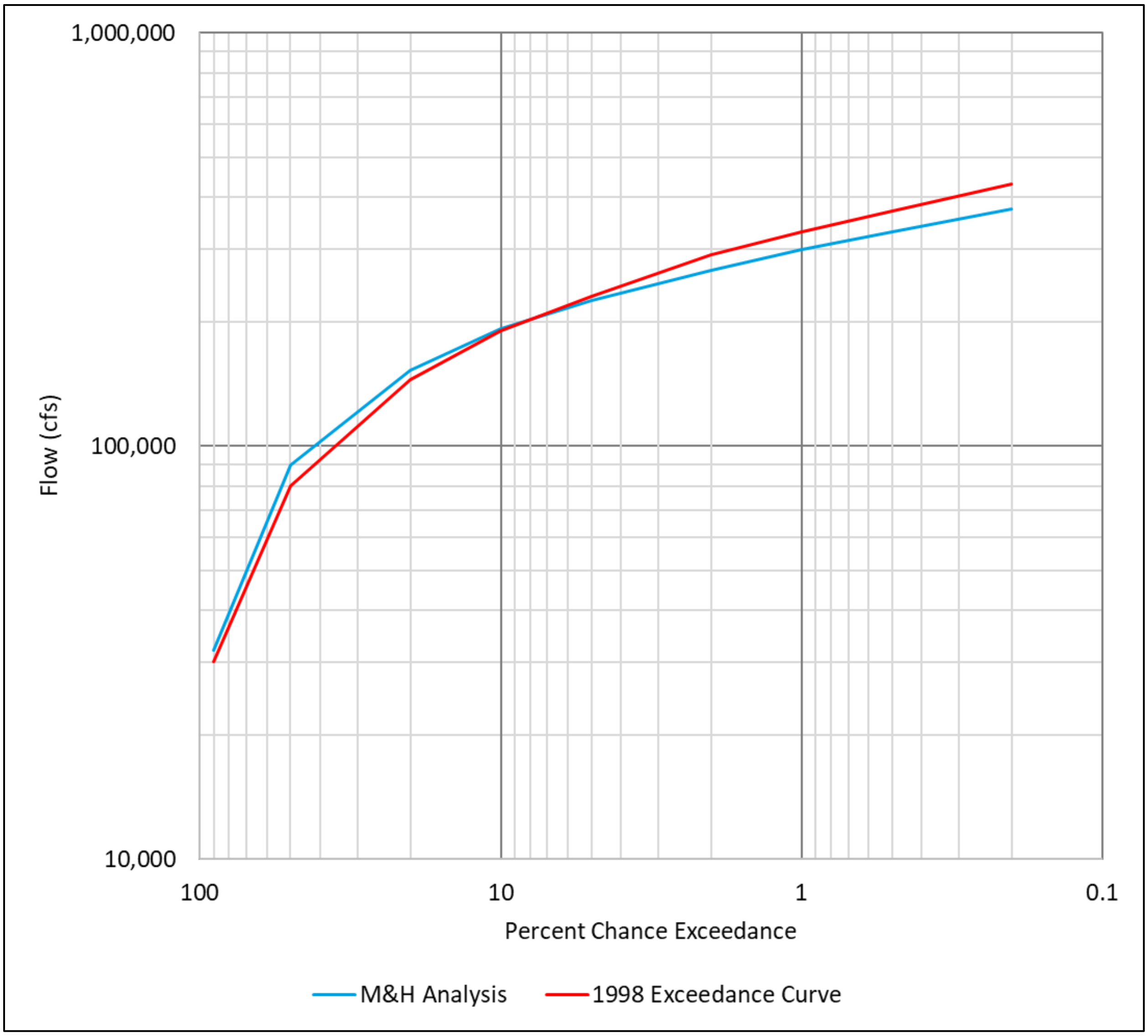


Figure 20. Flood frequency analysis graphical results.

5. Inflow Event Analysis

The flood frequency analysis estimated that the 100-year event flow at Pensacola Dam is approximately 300,000 cfs. The July 2007 event is the largest event of recent record on the Neosho River, with a peak flow of 141,000 cfs at the Commerce gage. Simulation results estimated a total peak inflow of approximately 130,000 at Pensacola Dam, which includes inflow from Tar Creek, the Elk River, and the Spring River. It also includes attenuation of the flood peaks as they travel to Pensacola Dam. When flood frequency at Pensacola Dam is considered, the July 2007 event is a 4-year return period event.

Three other recent events resulted in a large inflow at Pensacola Dam: September 1993, December 2015, and May 2019. Simulation results estimated a total peak inflow at Pensacola Dam of 226,000 cfs for the September 1993 event; 210,000 cfs for the December 2015 event; and 190,000 cfs for the May 2019 event. The peak inflow for the September 1993, July 2007, December 2015, and May 2019 events are listed in **Table 10**, along with the estimated return period.

The FERC's SPD stated that "If the flood frequency analysis shows that the selected historical inflow events do not exceed a 100-year recurrence interval, inflow events up to and including the 100-year recurrence interval would be evaluated." Therefore, Mead & Hunt iteratively scaled the events listed in **Table 10** until the total peak inflow at Pensacola Dam was approximately 300,000 cfs. The scaling factors are listed in **Table 10**. The scaled events were simulated in the UHM.

Table 10. Peak inflows at Pensacola Dam for four recent events.

Event	Peak Inflow[1] at Pensacola Dam (cfs)	Estimated Return Period	Scaling Factor to Estimate 100-year Return Period
September 1993	226,000	21 years	1.17
July 2007	130,000	4 years	2.26
December 2015	210,000	15 years	1.50
May 2019	190,000	9 years	1.70

1 Peak inflow rounded to the nearest 10,000 cfs

Mead & Hunt selected the scaled July 2007 event to represent the 100-year inflow to Pensacola Dam. Mead & Hunt used a statistical analysis of historical inflow volumes and peak flows to adjust the inflow hydrograph volume for the scaled July 2007 event. For each 24-hour period of the hydrograph, the total volume to Pensacola Dam was estimated using a modeled volume vs. peak flow relationship. The statistical model was developed based on a coefficient of determination (R^2) best-fit calculation assuming the Generalized Extreme Value (GEV) distribution (Bolívar, Díaz-Francés, Ortega, & Vilchis, 2010.; Takara, 2009). The GEV distribution is a family of distributions (Gumbel, Frechét, and Weibull) commonly used to model infrequent (extreme) random variables, including wind speed, precipitation, and stream flow.

Pensacola Dam inflow for 24-hour periods was extracted from the USACE RiverWare model. Inflow by 24-hour duration was converted to volume. Volumes were placed into bins with D+0 representing the day when the peak inflow occurred, D-1 representing the day before the peak, D+1 representing the day after the peak, and so on. The outermost bins included the average over three days: D-8 to D-10, and D+7 to D+9. Thus, the full set of bins is as follows: D-8 to D-10, D-7, D-6, D-5, D-4, D-3, D-2, D-1, D+0, D+1, D+2, D+3, D+4, D+5, D+6, and D+7 to D+9.

Sets of bins were calculated for the day within each USGS water year for which the annual maximum inflow to Pensacola Dam occurred (one set of bins per USGS water year). Bins were then ordered according to maximum inflow to Pensacola Dam and used to calculate the GEV distribution parameters.

First, the 100-year inflow to Pensacola Dam was predicted using the GEV distribution parameters and the annual peak inflow values from RiverWare. The reduced variate was calculated for each ordered peak inflow value, and the shape parameter was adjusted to maximize the R^2 correlation of the GEV-linearized discharges (peak inflow vs. reduced variate of peak inflow). This resulted in a 100-year inflow to Pensacola Dam of 306,317 cfs, which is within 3 percent of the value calculated in Mead & Hunt's flood frequency analysis using the Graphical Frequency Analysis of Peak Inflows method, which validates the flood frequency analysis results. The shape parameter was then adjusted so the 100-year inflow would match the value of 299,000 cfs from the flood frequency analysis, for consistency. **Table 11** presents the GEV distribution parameters and flow results for both cases. Note that the R^2 value was very high for both the original and adjusted cases.

Table 11. GEV distribution parameters and results.

Parameter	Prediction of 100-year Inflow	Adjusted to Match Flood Frequency Analysis 100-year Inflow
shape parameter, k (approximate)	0.01	-0.02
scale parameter, σ (linear slope, m)	49703	51076
location parameter, μ (linear intercept, b)	73193	73586
coefficient of determination, R^2	0.991	0.990
reduced variate for 100-year event, y	4.69	4.41
100-year inflow (cfs)	306,317	299,000

For each volume bin (D-8 to D-10, D-7… D+0… D+6, and D+7 to D+9), the binned daily volumes were plotted as a function of the reduced variates for the corresponding peak inflow values, using the same adjusted shape parameter (k) used to predict the 100-year inflow. A linear trend line for each volume bin (e.g., D+0) was calculated to obtain the scale parameter σ (linear slope, m) and a location parameter μ (linear intercept, b) for each volume bin. The reduced variate for the 100-year peak inflow (4.41), along with the scale and location parameters were then used to calculate the daily inflow volumes for each bin that are predicted to correspond to a 100-year peak inflow event. **Table 12** displays the results of the statistical analysis. Additional information including correlation plots can be found in **Appendix B**.

Table 12. Results of historical inflow volume statistical analysis.

Volume Bin	Scale Parameter, σ (m)	Location Parameter, μ (b)	100-Year Inflow Volume (acre-feet)
D-8 to D-10 avg.	13701	15500	75,966
D-7	13651	15589	75,835
D-6	10187	18852	63,810
D-5	7285	23100	55,249
D-4	6811	28286	58,344
D-3	16733	34613	108,461
D-2	38161	50607	219,023
D-1	77487	93430	435,403
D+0	101308	145956	593,058
D+1	88088	115917	504,675
D+2	61232	85512	355,747
D+3	40672	57248	236,745
D+4	27591	39800	161,567
D+5	20812	33485	125,334
D+6	15887	30527	100,641
D+7 to D+9 avg.	11578	30060	81,157

The resulting volume curve at Pensacola Dam was used as a goal for the volume at Pensacola Dam in HEC-RAS. In HEC-RAS, variable factors were applied at different times along the inflow hydrographs iteratively until the resulting daily inflow volume at Pensacola Dam closely matched the results of the statistical analysis. The peak flow at Pensacola Dam is still scaled to approximately match the predicted 100-year peak flow at the dam, calculated in the flood frequency analysis. **Figure 21** presents the results graphically and **Table 13** presents the results in tabular format.

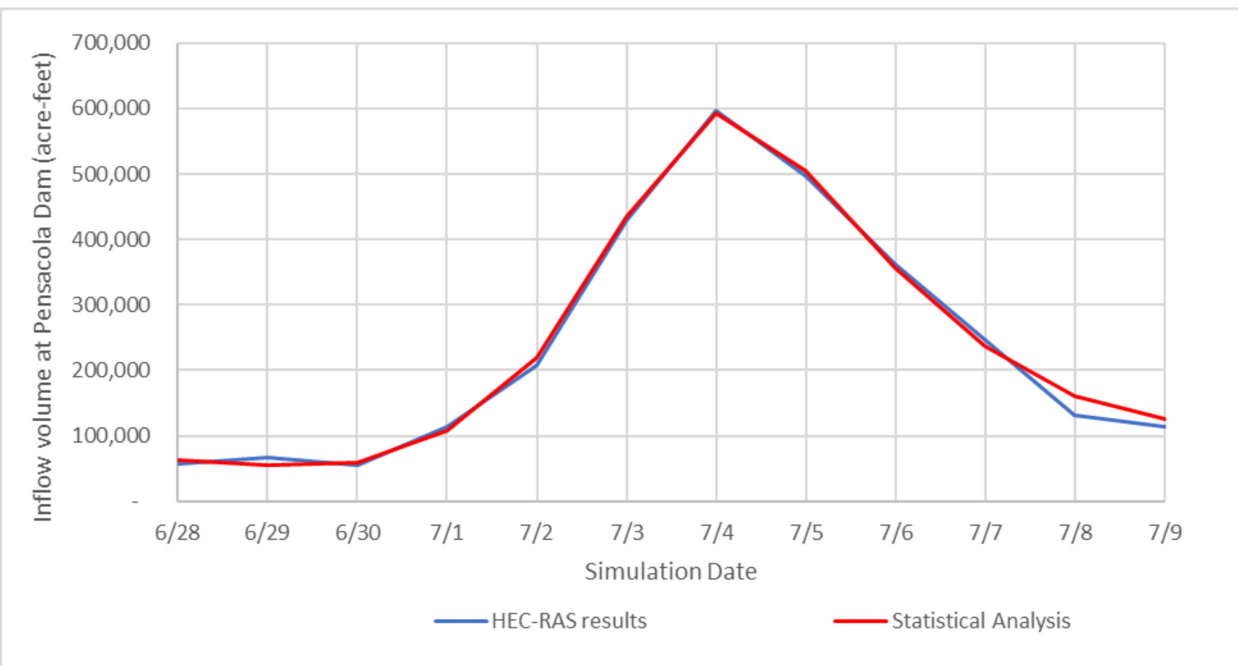


Figure 21. Graphical comparison of HEC-RAS results to statistical analysis for the 100-year flood event.

Table 13. Tabular comparison of HEC-RAS results to statistical analysis for the 100-year flood event.

Simulation Date	Volume (acre-feet)	
	Statistical Analysis	HEC-RAS Results
6/28/2007	63,810	57,073
6/29/2007	55,246	67,085
6/30/2007	58,345	55,453
7/1/2007	108,461	114,053
7/2/2007	219,027	207,606
7/3/2007	435,403	429,269
7/4/2007	593,058	596,025
7/5/2007	504,674	496,290
7/6/2007	355,747	361,363
7/7/2007	236,745	246,033
7/8/2007	161,566	130,901
7/9/2007	125,335	113,355

6. Definition of "Material Difference"

The RSP states that:

> *The H&H study area will encompass the channel and overbank areas of the Grand/Neosho River watershed that have a material difference in water surface elevation due to Project operation during the measured inflow events of the H&H Study. A material difference in water surface elevation due to Project operations will be based on professional judgment.*

In the SPD, the FERC recommended GRDA propose a definition of "material difference." On GRDA's behalf, Mead & Hunt reviewed how various government entities quantify difference in WSEL, and the findings are as follows:

1. FEMA requires base flood elevations, which is commonly the 100-year event WSEL, to "match within one-half foot" at the transition between a revised study and the study it is replacing (Office of the Federal Register, 2021).
2. USACE published an engineering manual for the Hydrologic Engineering Requirements for Reservoirs (USACE, 2018). The manual dictates the point of intersection between pre-project and post-project WSEL profiles is established where the profiles are within one foot of each other.
3. USGS defines field measurements of discharge as "excellent" if the flow measurement is within 2% of the actual value and as "good" if the measurement is within 5% of the actual value. Mead & Hunt ran all the calibration simulations with the gage inflows increased and decreased by 2%. WSELs between the two sets of simulations were compared at the USGS gages within the study area. There was a difference in WSEL of approximately one-half foot between the simulation results.

In an effort to follow generally accepted scientific practice, Mead & Hunt completed a review of how government agencies approach differences in WSEL. Material difference represents expected precision when comparing model results for the sole purpose of determining areas to be included in the model. Mead & Hunt is defining material difference as 0.5 feet of WSEL for out of bank events or 0.5 feet of WSEL within the banks where inundation impacts infrastructure or other sensitive resources. The study results (**Section 8**) confirmed that WSEL differences at the upstream ends of the model did not exceed 0.5 feet for either in bank or out of bank events.

7. Simulated Scenarios

The calibrated HEC-RAS model was used to analyze a range of operating conditions at Pensacola Dam. Five historical inflow events and one synthetic inflow event were analyzed for a range of starting pool elevations at Pensacola Dam. The inflow events and starting pool elevations are listed in **Table 14**. The Operations Model (OM) was used to calculate stage hydrographs at Pensacola Dam for the various starting pool elevations. The starting pool elevations ranged from 734 feet up to 757 feet, which is the elevation of the crest of the dam.

Table 14. List of inflow events and initial stages simulated.

Inflow Event	Type	Estimated Return Period[1]	Pensacola Dam Starting Pool Elevation (ft, PD)	Simulation Start/End Date
Sept. 1993	Historical	21 years	743.85[2], 742, 743, 744, 745	9/24/1993 – 10/2/1993
June 2004	Historical	1 year	743.42[2], 742, 743, 744, 745	6/13/2004 – 6/18/2004
July 2007	Historical	4 years	745.69[2], 742, 743, 744, 745	6/28/2007 – 7/10/2007
Oct. 2009	Historical	3 years	740.98[2], 742, 743, 744, 745	10/8/2009 – 10/16/2009
Dec. 2015	Historical	15 years	742.86[2], 742, 743, 744, 745	12/26/2015 – 1/2/2016
100-year	Synthetic	100 years	734, 740, 742, 743, 744, 745, 757[3]	N/A[4]

1 Return period for peak inflow at Pensacola Dam.

2 Historical pool elevation of Pensacola Dam.

3 Crest elevation of Pensacola Dam.

4 Because the 100-year event is synthetic, there is no historical start or end date. The duration of simulation is 12.5 days, which is consistent with the simulated duration of the July 2007 event upon which it was based.

USGS flow data were used to define inflow hydrographs at the upstream ends of the model for the historical inflow events. The development of the inflow hydrographs for the synthetic 100-year event is discussed in **Section 5**. Peak inflows for the various inflow locations and inflow events are listed in **Table 15**. The flow hydrographs for the inflow events are included in **Appendix C**. Of the inflow events:

1. The September 1993 event had the highest recorded flow on the Spring River gage near Quapaw.
2. The June 2004 event had the lowest recorded flow on the Neosho River at the Commerce gage, the Spring River at the Quapaw gage, and the Elk River at the Tiff City gage.
3. The July 2007 event had the highest recorded flow on the Neosho River at the Commerce gage.
4. The October 2009 event had the second highest recorded flow on Tar Creek at the 22nd Street gage.
5. The December 2015 event had the highest recorded flow on the Elk River at the Tiff City gage.

Table 15. Summary of peak inflows.

Inflow Event	Peak Inflow (cfs)			
	Neosho River	Tar Creek	Spring River	Elk River
September 1993	75,600	8,200	230,000	18,100
June 2004	24,800	749	10,500	577
July 2007	141,000	726	33,300	1,190
October 2009	46,100	4,630	66,200	39,300
December 2015	45,400	4,710	151,000	107,000
100-year	308,264	1,641	74,975	2,689

The inflow hydrographs and the Pensacola Dam starting pool elevations were input into the OM, which calculated the stage hydrographs at Pensacola Dam for the various scenarios. The OM ISR, filed simultaneously with this report, discusses the development and results of the OM. **Table 16** summarizes, by inflow event, the lowest and highest peak elevation of the Pensacola Dam pool for the simulations with various Pensacola Dam starting pool elevations. The stage hydrographs at Pensacola Dam for the various starting pool elevations are included in **Appendix C**.

For the 100-year event, the highest maximum pool elevation is 757 feet, which is the starting pool elevation for one of the 100-year scenarios simulated. Because an elevation of 757 feet PD is equal to the crest of the dam, the OM immediately begins reducing the pool elevation after the start of the simulation. The maximum pool elevation for this simulation is thus a function of the initial Pensacola Dam pool condition.

Table 16. Summary of peak pool elevations for Pensacola Dam.

Event	Pensacola Dam Pool Elevation (ft, PD)		Difference (ft)
	Lowest Peak	Highest Peak	
September 1993	754.93	754.93	0.00
June 2004	744.71	745.14	0.43
July 2007	754.23	754.96	0.73
October 2009	750.27	750.84	0.57
December 2015	754.34	754.82	0.48
100-year	754.90	757.00	2.10

8. Study Results

Maximum WSELs and maximum inundation extents were extracted from HEC-RAS for each simulation. Maximum WSELs are presented in **Appendix D** (tabular format) and **Appendix E** (graphical format), and maximum inundation extents are presented in **Appendix F**.

Tabulated results of maximum WSEL and maximum WSEL differences are presented in **Appendix D**. Within a set of tables, there is one table per modeled inflow source: the Neosho River, the Spring River, the Elk River, and Tar Creek. In **Appendix D.1** through **Appendix D.6**, tables are organized by inflow event. For example, the set of tables in **Appendix D.1** report maximum WSEL for the September 1993 event with starting pool elevations of 742-, 743-, 744-, and 745-feet PD. Each table in **Appendix D.1** through **Appendix D.6** includes the maximum difference in peak WSEL between the various starting pool elevation scenarios. **Appendix D.7** presents a set of tables for simulations that used historical starting pool elevations. Maximum WSEL profiles are compared for the various inflow events. Each table in **Appendix D.7** includes the maximum difference in peak WSEL between the various inflow scenarios.

Plots of maximum WSEL profiles are presented in **Appendix E**. Like the tabulated results, **Appendix E.1** through **Appendix E.6** present profiles organized by inflow event, with simulation results from various starting pool elevations compared against each other. Each plot in **Appendix E.1** through **Appendix E.6** includes a profile of the maximum difference in peak WSEL between the various starting pool elevation scenarios. **Appendix E.7** presents maximum WSEL profiles for simulations that used historical starting pool elevations. Maximum WSEL profiles are compared for the various inflow events. Each plot in **Appendix E.7** includes a profile of the maximum difference in peak WSEL between the various inflow scenarios. **Appendix E.8** presents a comparison of maximum WSEL differences. Maximum WSEL differences due to change in starting pool elevation are compared to maximum WSEL differences due to inflow event.

Maps of maximum inundation extent are presented in **Appendix F**. **Appendix F.1** through **Appendix F.6** present mapped inundation extent organized by inflow event, with mapped results from various starting pool elevations compared against each other. **Appendix F.7** presents mapped inundation extent for simulations that used historical starting pool elevations, with mapped results from various inflow events compared against each other.

9. Discussion of Results

Maximum WSELs and maximum inundation extents were analyzed to determine the upstream impacts, if any, of various initial stages at Pensacola Dam. **Table 17** presents a summary of maximum WSEL differences along the modeled inflow reaches. The first six rows in the table present maximum WSEL differences for the various starting pool elevations for a given inflow event. The last row in the table presents maximum WSEL differences for the various inflow events, using the historical starting pool elevations. The maximum WSEL differences for a given inflow event due to a change in starting pool elevation are an order of magnitude smaller than the maximum differences when inflow events are compared against each other, and the historical starting pool elevation is used.

Table 18 presents a summary of smallest and largest maximum inundation areas. The first six rows in the table present smallest and largest maximum inundation areas for simulations with various starting pool elevations for a given inflow event. For example, for the September 1993 event, the maximum inundation areas for simulations with starting pool elevations of 742-, 743-, 744-, and 745-feet PD were all compared against each other; the simulation with the smallest inundation area and the simulation with the largest inundation area were then determined. The last row in the table presents smallest and largest maximum inundation areas for the various inflow events, using the historical starting pool elevations. The maximum inundation area differences for a given inflow event due to a change in starting pool elevation are an order of magnitude smaller than the maximum differences when inflow events are compared against each other, and the historical starting pool elevation is used.

Figure 22 through **Figure 33** display examples of maximum WSEL profiles and maximum inundation extent organized by inflow event, as presented in **Appendix E.1** through **Appendix E.6** (WSEL profiles) and **Appendix F.1** through **Appendix F.6** (maximum inundation extent). **Figure 34** and **Figure 35** display examples of maximum WSEL profiles and maximum inundation extents, respectively, for simulations that used historical starting pool elevations for various inflow events, as presented in **Appendix E.7** and **Appendix F.7**.

Figure 22 through **Figure 35** are representative of the data presented in **Table 17** and **Table 18**. The magnitude of the incoming flow event is the primary determining factor of maximum WSEL and maximum inundation extent upstream of Pensacola Dam. For the historical inflow events, a difference of 3 feet in starting pool elevation (742 feet vs. 745 feet) resulted in little difference in maximum WSEL and little difference in maximum inundation extent. For the 100-year inflow event, a difference of 23 feet in starting pool elevation (734 feet vs. 757 feet) resulted in little difference in maximum WSEL and little difference in maximum inundation extent.

To show this more explicitly, **Figure 36** and **Figure 37** display examples of maximum WSEL profiles and maximum inundation extents, respectively, for simulations that used a starting pool elevation of 742 feet PD for various inflow events. **Figure 38** and **Figure 39** display results for simulations that used a starting pool elevation of 745 feet PD for various inflow events. With the same starting pool elevation, there are large differences in maximum WSEL and maximum inundation extent due to the magnitude of the incoming flow event.

Comparing **Figure 22** through **Figure 33**, which show the impact of the starting pool elevation on inundation, to **Figure 34** through **Figure 39**, which show the impact of the inflow event on inundation, the magnitude of the inflow event is the primary determining factor of maximum WSEL and maximum inundation extent.

A final comparison is presented to show how the magnitude of the inflow event is the primary determining factor of maximum WSEL, as opposed to the starting pool elevation. **Figure 40** displays an example comparison of maximum WSEL differences, as presented in **Appendix E.8**. Maximum differences in WSEL due to a change in starting pool elevation are compared to maximum differences in WSEL due to inflow event. **Figure 40** shows how the magnitude of the inflow event is the primary determining factor of maximum WSEL.

Table 17. Summary of maximum WSEL differences.

Event(s)	Maximum WSEL Difference (ft)			
	Neosho River	Spring River	Elk River	Tar Creek
September 1993	0.36	0.12	0.04	0.15
June 2004	0.69	0.92	0.42	0.32
July 2007	1.40	1.22	0.75	0.13
October 2009	0.84	0.48	0.62	0.06
December 2015	0.49	0.32	0.54	0.18
100-year	2.10	0.33	1.91	0.05
Historical Starting Elevation	20.95	36.78	26.84	20.54

Table 18. Summary of smallest and largest maximum inundation areas.

Event	Maximum Area of Inundation (acres)		Difference (%)
	Smallest	Largest	
September 1993	82,007	82,093	0.1%
June 2004	49,743	50,469	1.4%
July 2007	80,257	81,148	1.1%
October 2009	70,648	70,985	0.5%
December 2015	78,020	78,473	0.6%
100-year	92,525	94,141	1.7%
Historical Starting Stage	50,551	82,029	47.5%

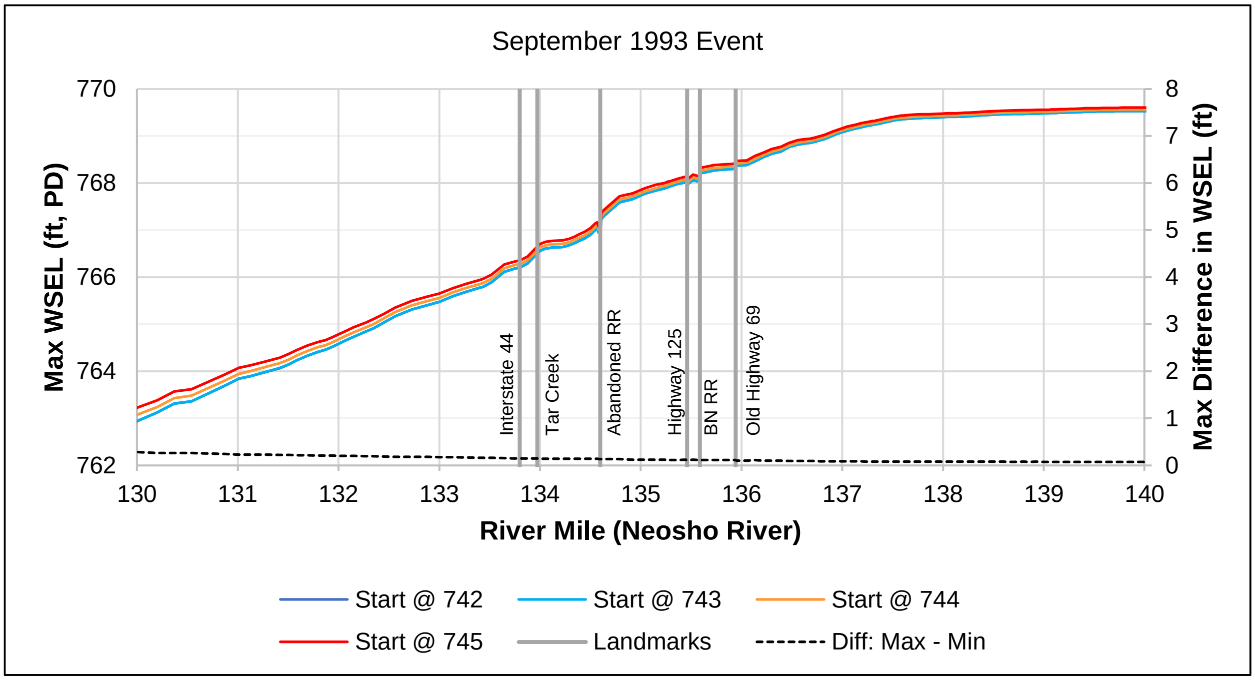


Figure 22. Maximum WSELs near Miami, OK for the September 1993 event.

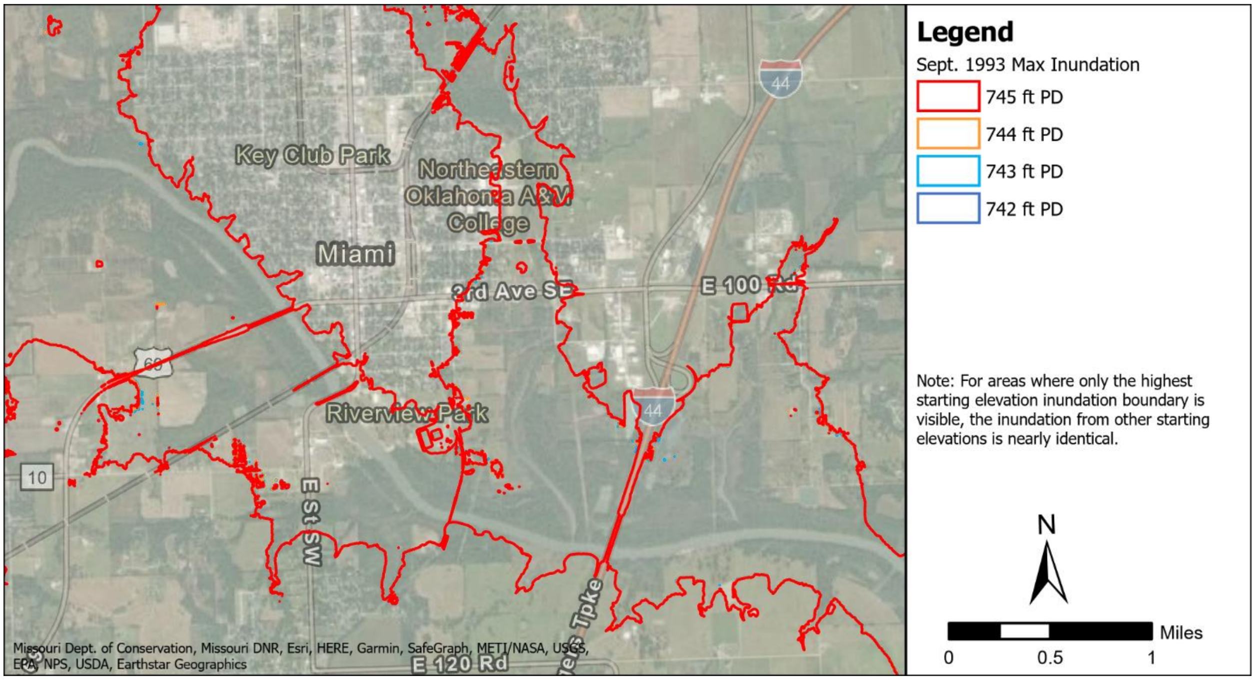


Figure 23. Maximum inundation extents near Miami, OK for the September 1993 event.

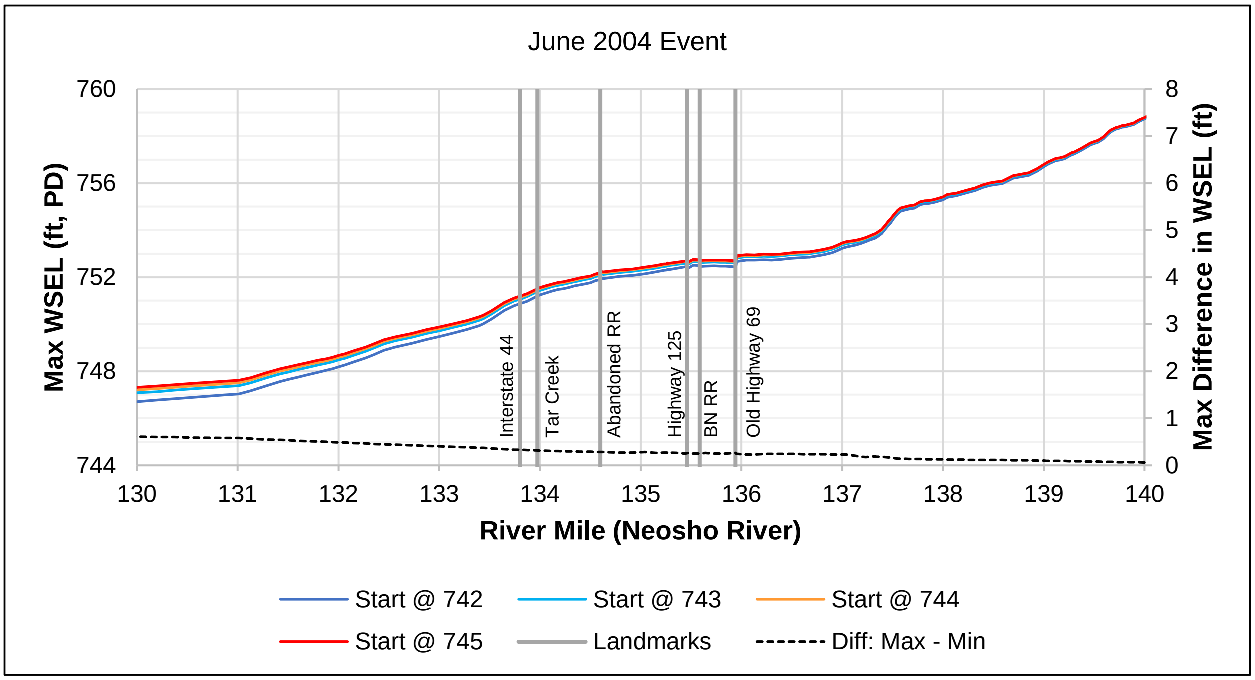


Figure 24. Maximum WSELs near Miami, OK for the June 2004 event.

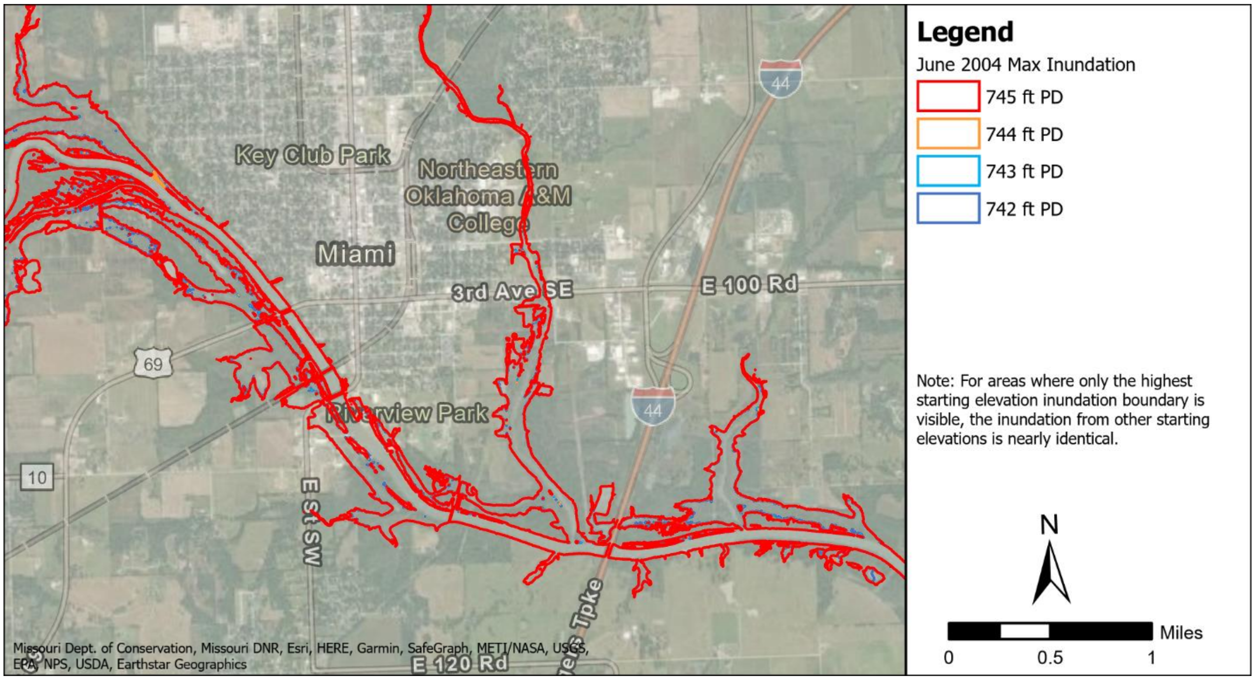


Figure 25. Maximum inundation extents near Miami, OK for the June 2004 event.

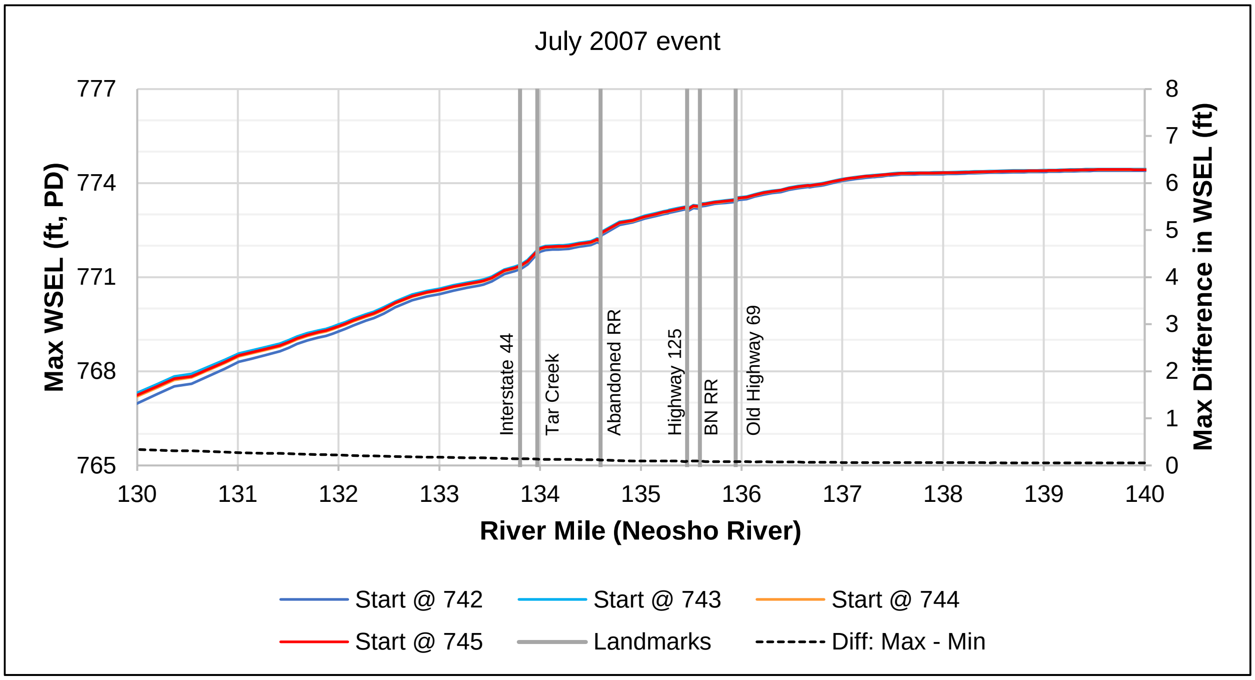


Figure 26. Maximum WSELs near Miami, OK for the July 2007 event.

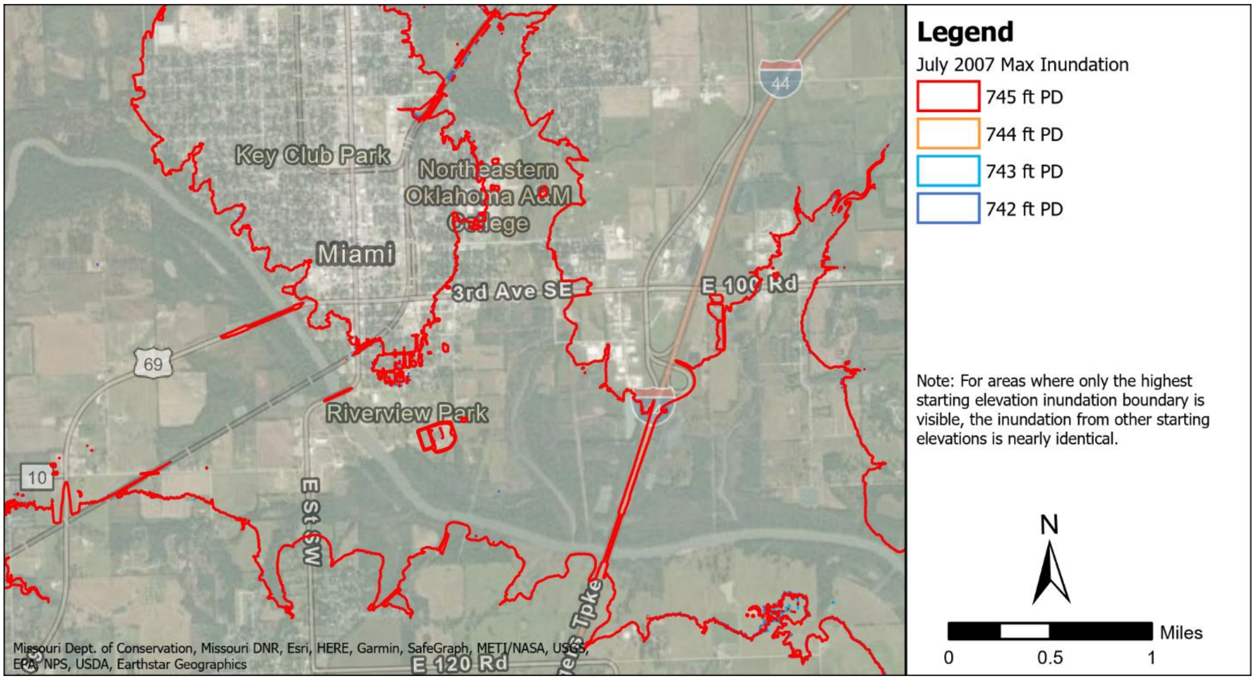


Figure 27. Maximum inundation extents near Miami, OK for the July 2007 event.

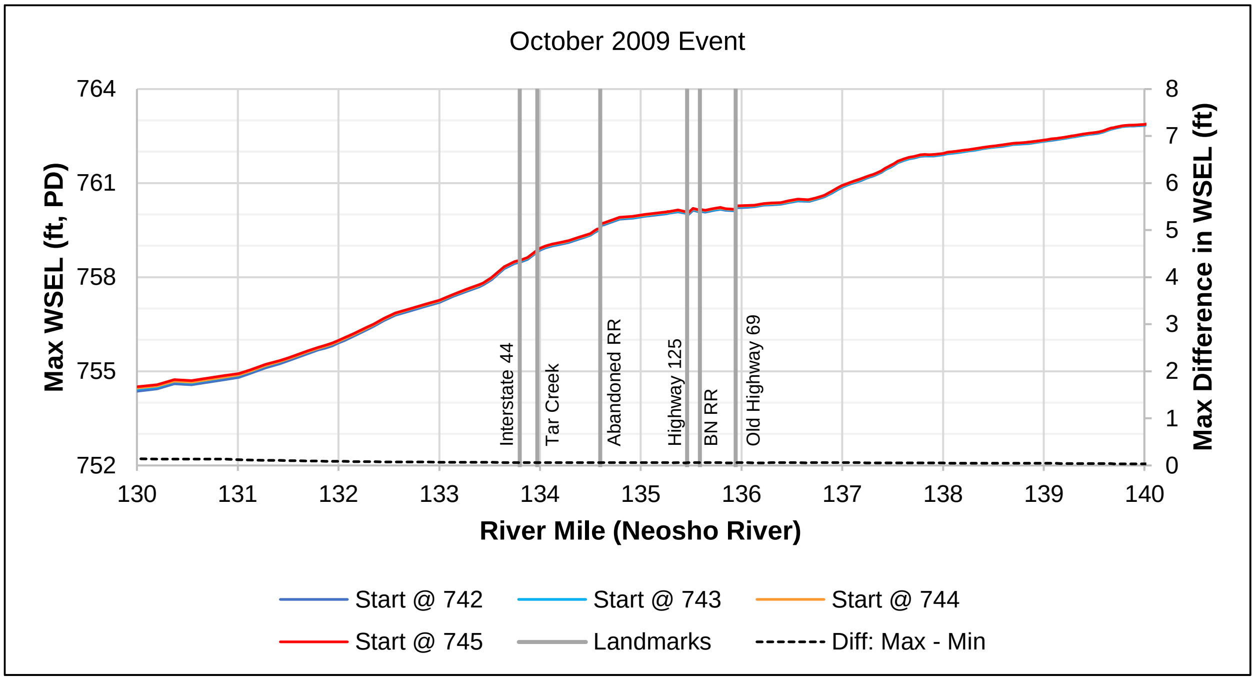


Figure 28. Maximum WSELs near Miami, OK for the October 2009 event.

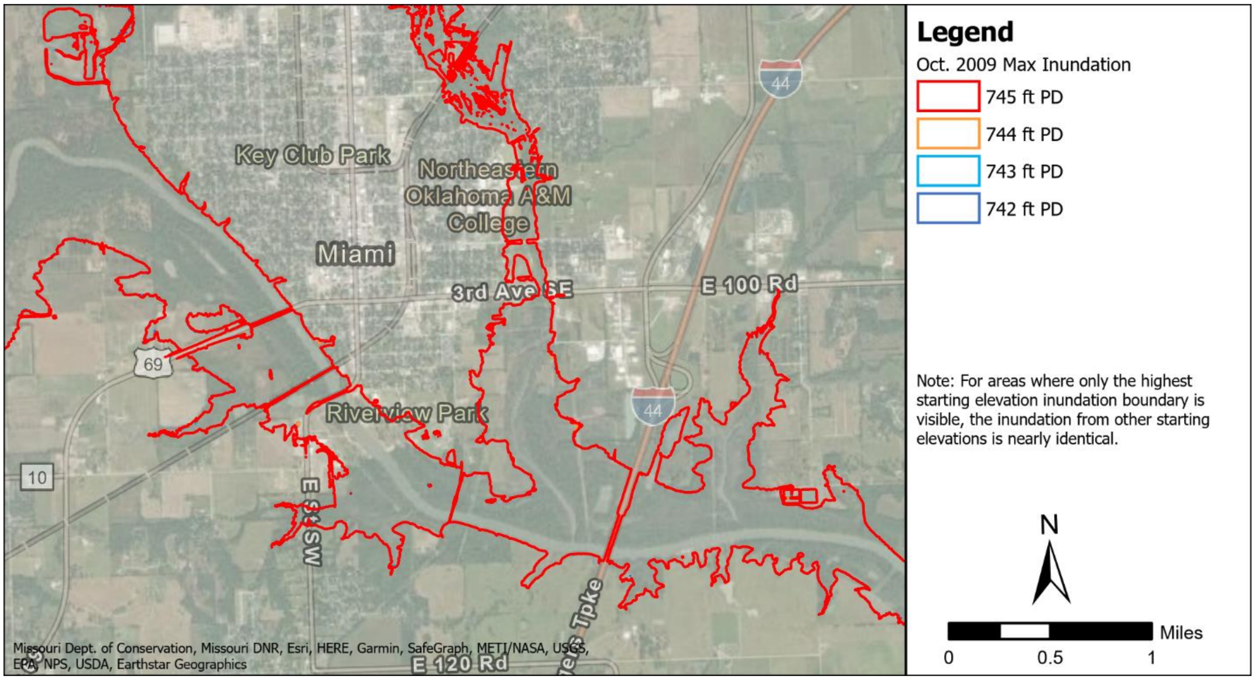


Figure 29. Maximum inundation extents near Miami, OK for the October 2009 event.

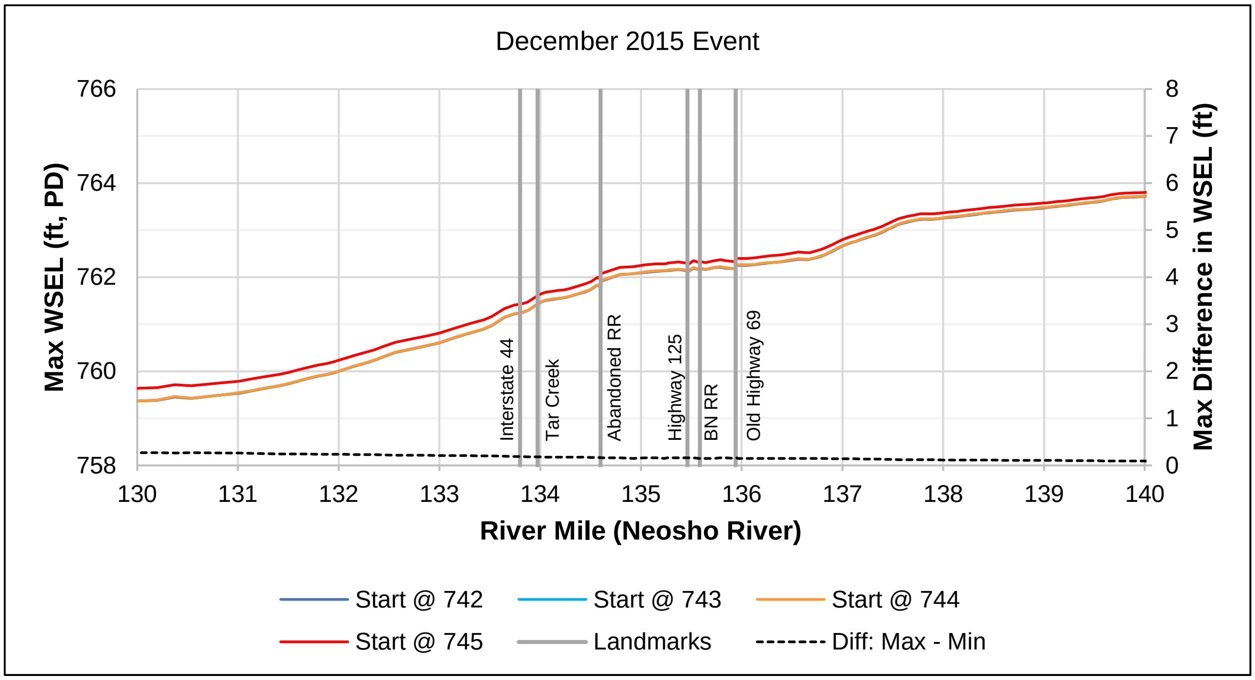


Figure 30. Maximum WSELs near Miami, OK for the December 2015 event.

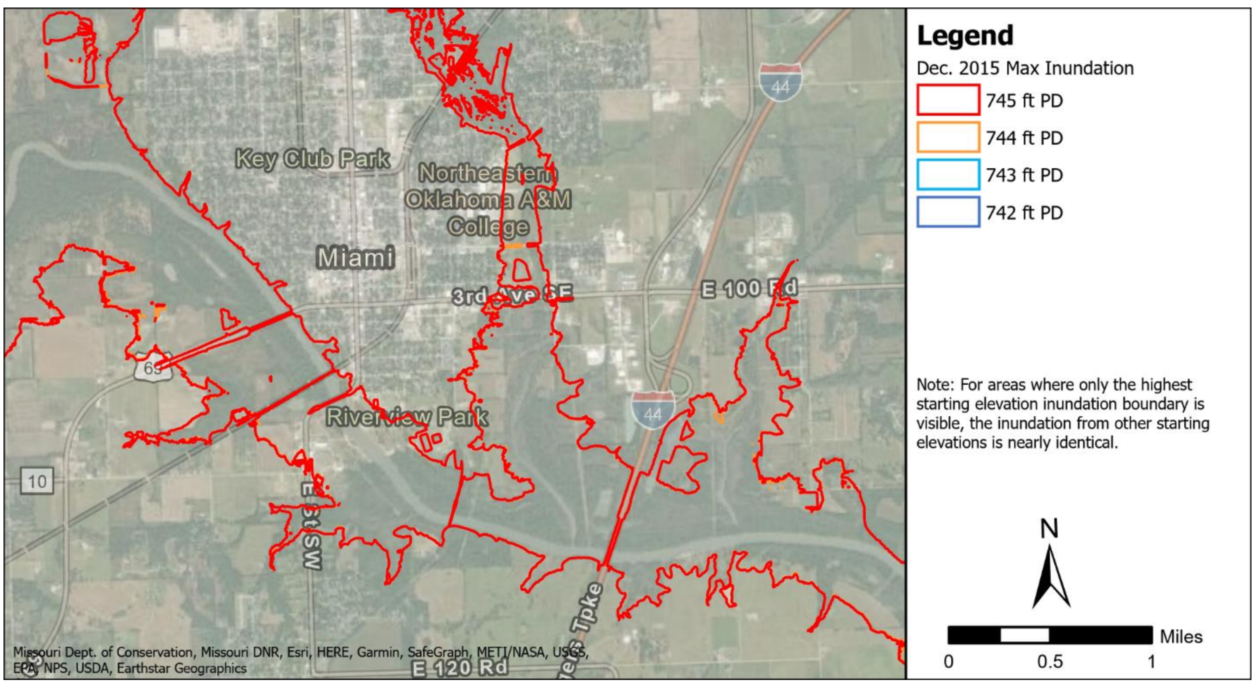


Figure 31. Maximum inundation extents near Miami, OK for the December 2015 event.

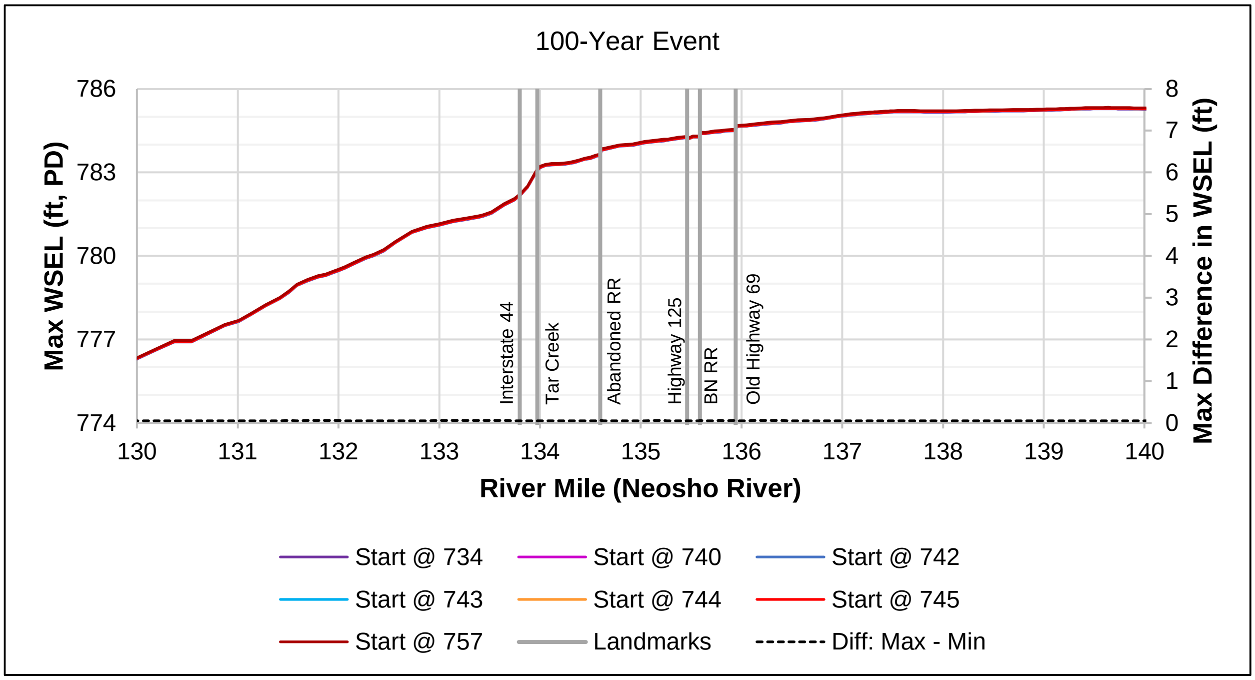


Figure 32. Maximum WSELs near Miami, OK for the 100-year event.

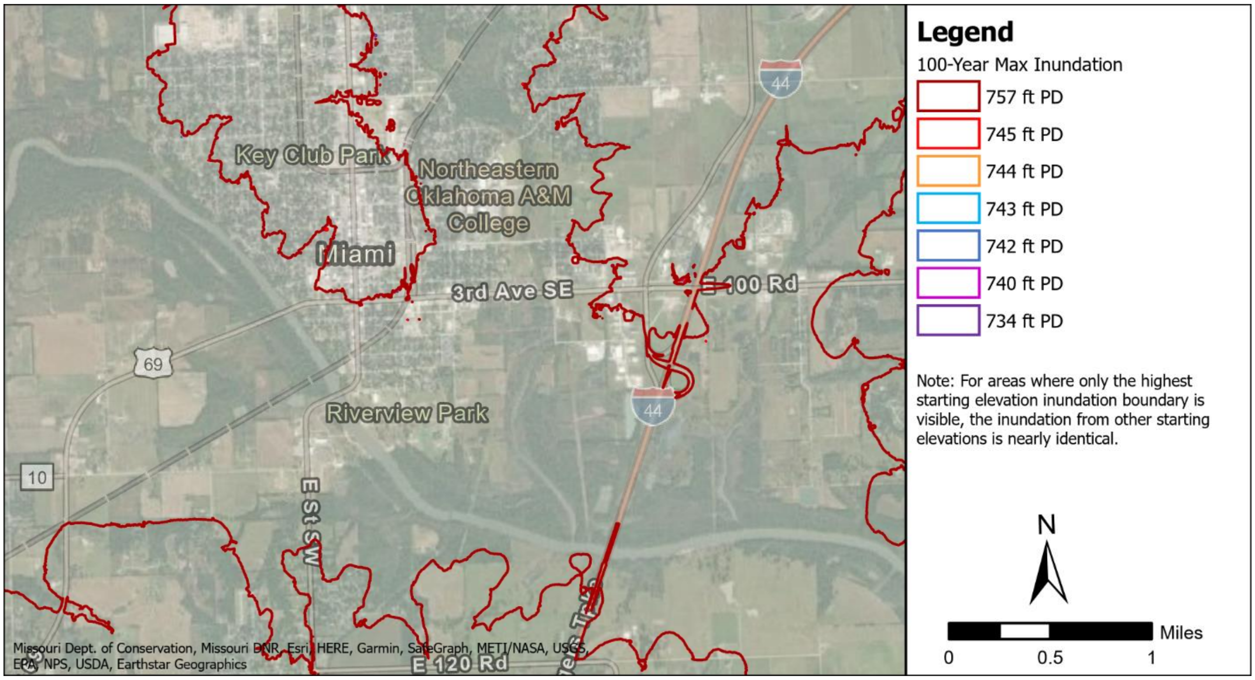


Figure 33. Maximum inundation extents near Miami, OK for the 100-year event.

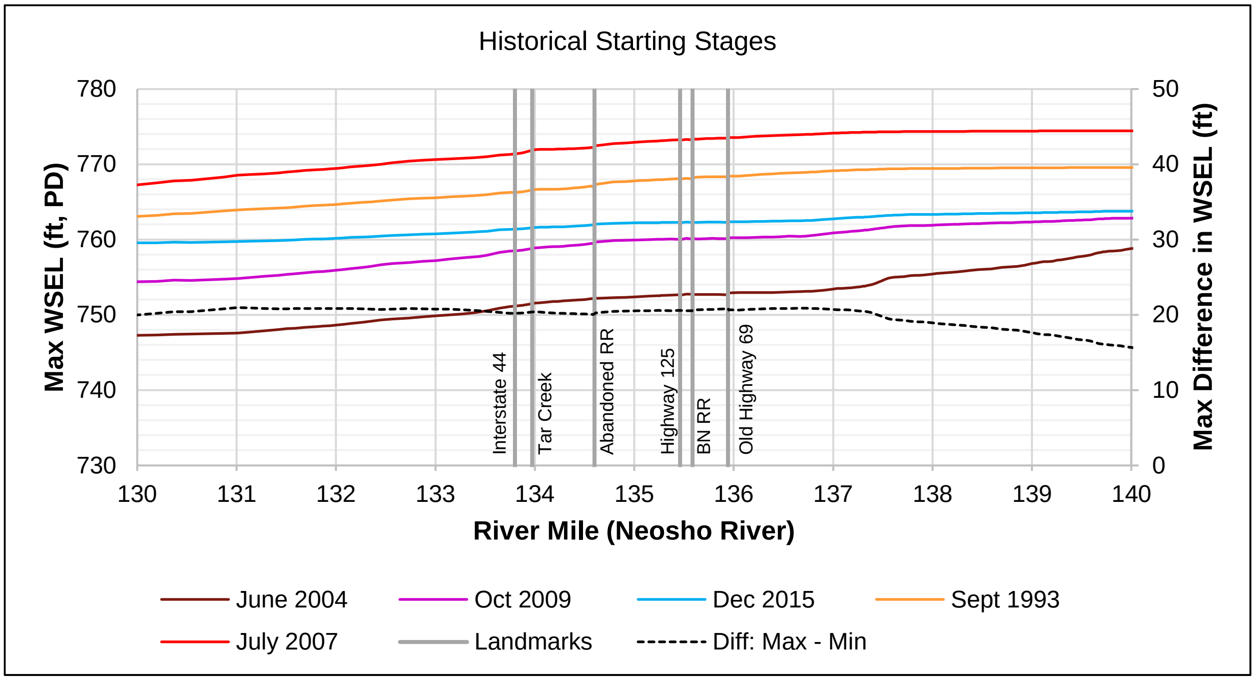


Figure 34. Maximum WSELs near Miami, OK for simulations with historical starting stages.

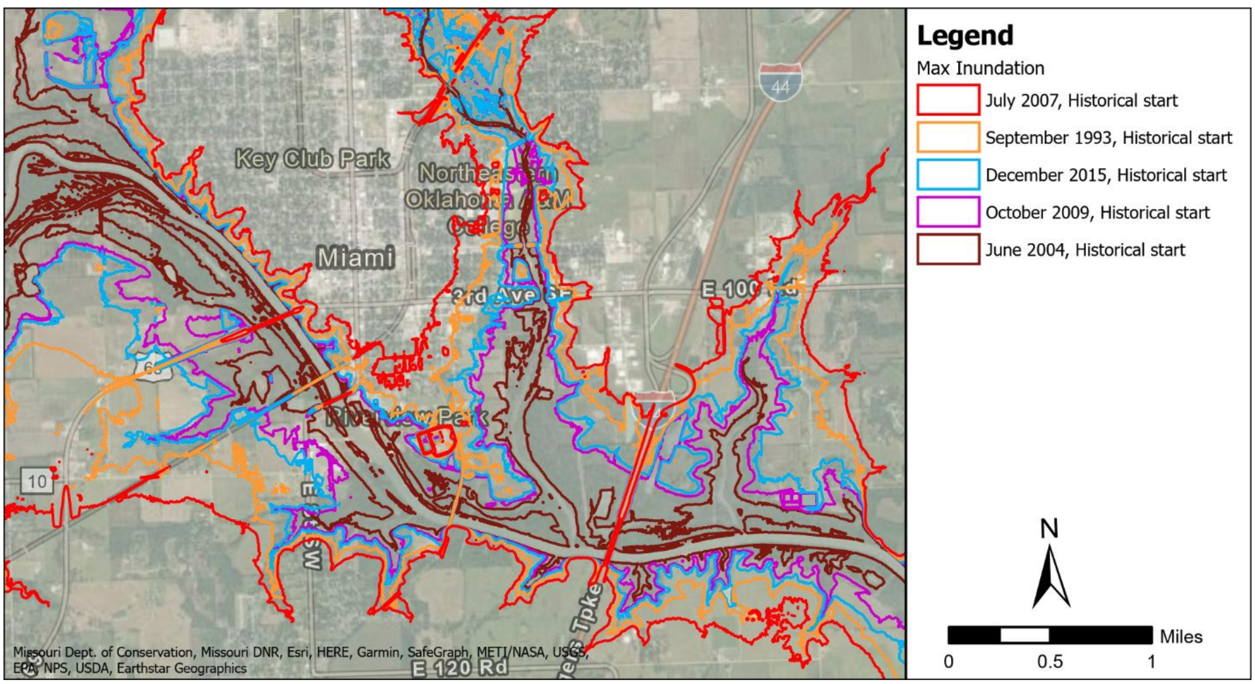


Figure 35. Maximum inundation extents near Miami, OK for the simulations with historical starting stages.

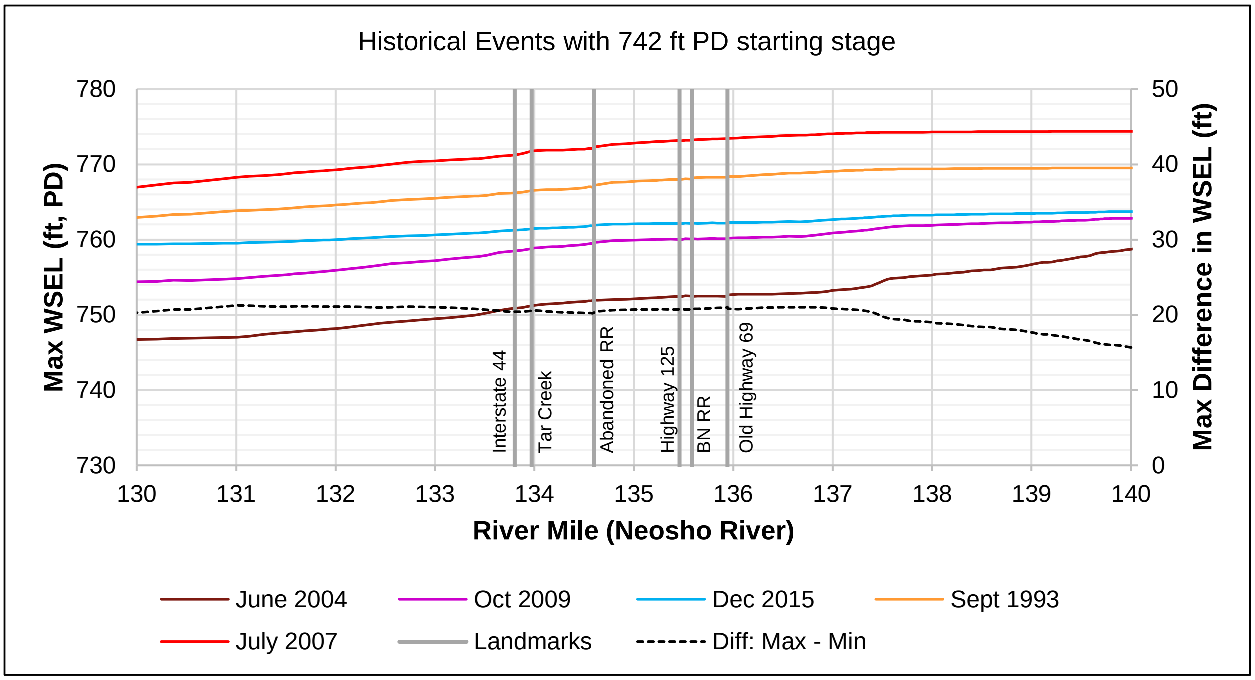


Figure 36. Maximum WSELs near Miami, OK for the historical inflow events, using a starting pool elevation of 742 feet.

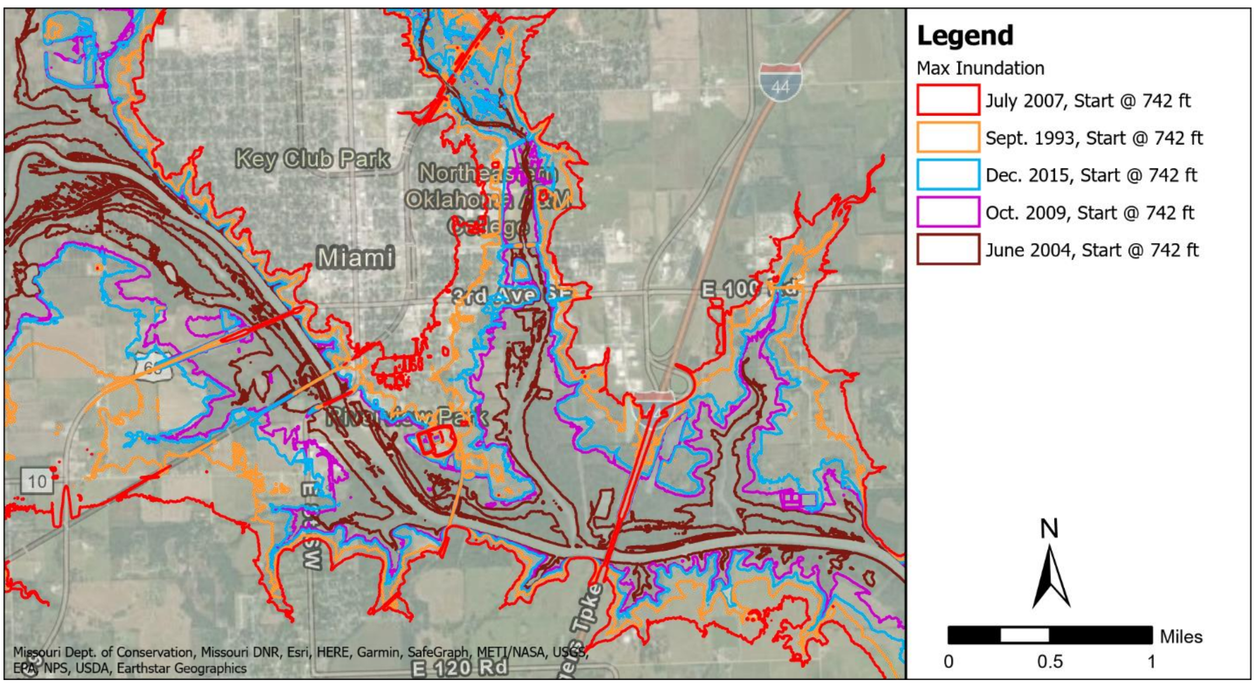


Figure 37. Maximum inundation extents near Miami, OK for the historical inflow events, using a starting pool elevation of 742 feet.

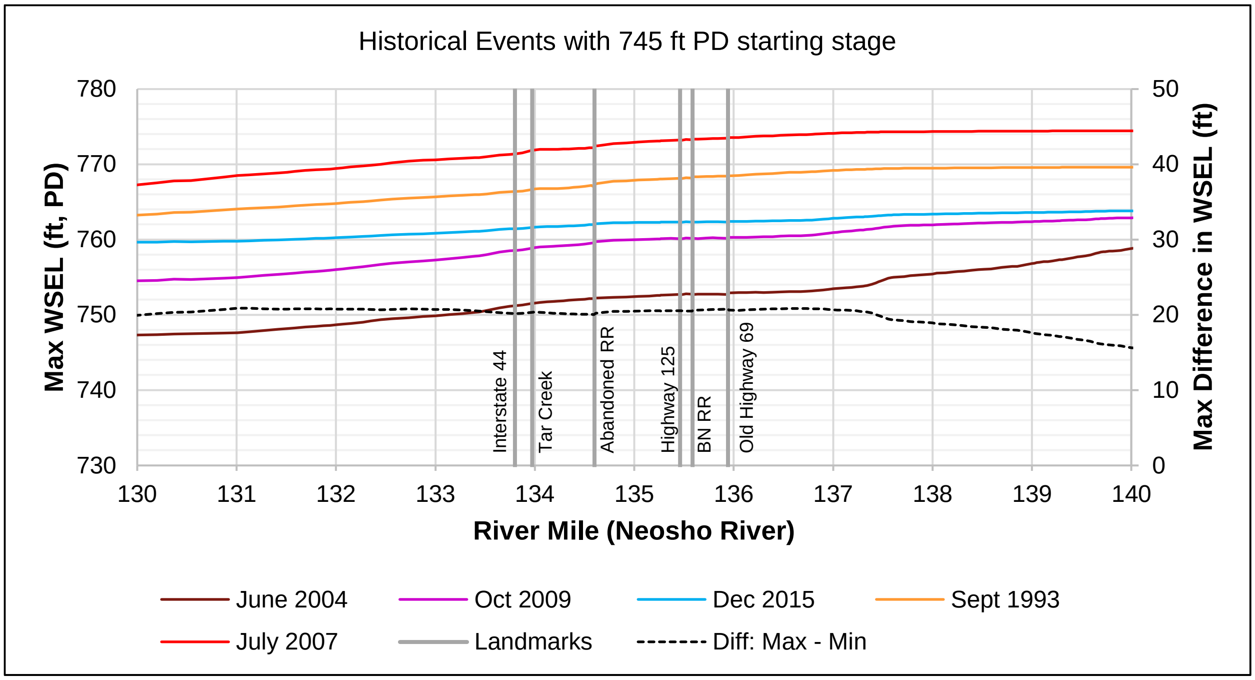


Figure 38. Maximum WSELs near Miami, OK for the historical inflow events, using a starting pool elevation of 745 feet.

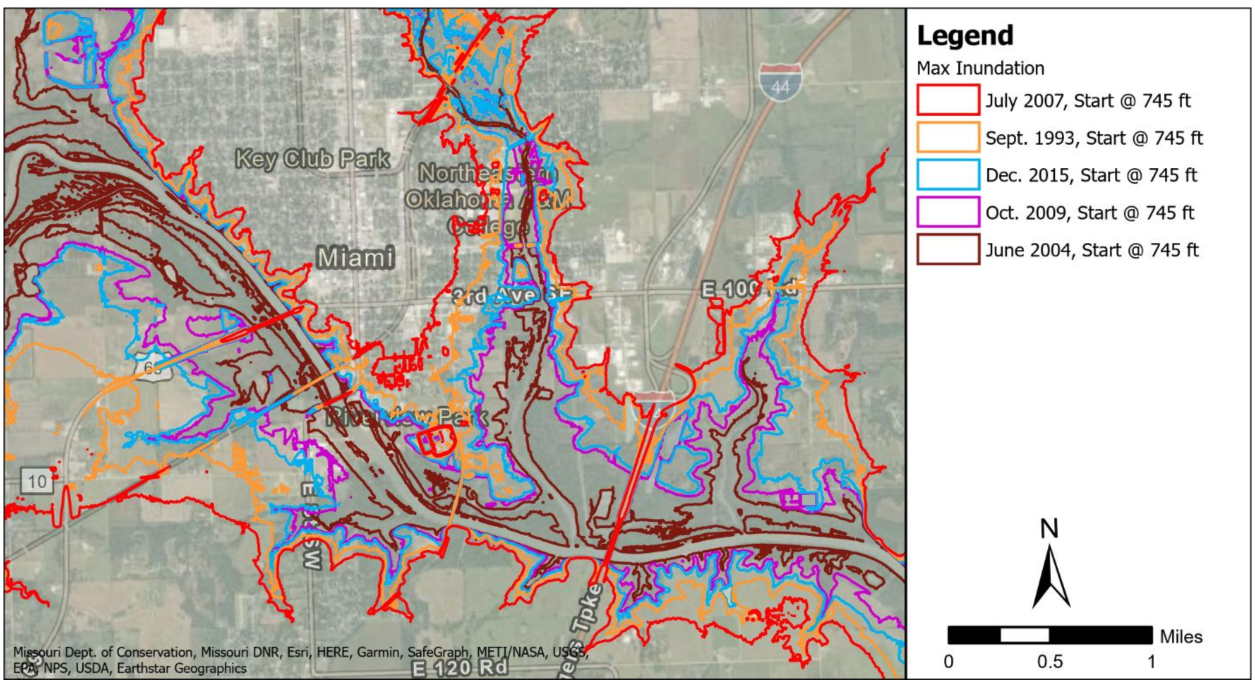


Figure 39. Maximum inundation extents near Miami, OK for the historical inflow events, using a starting pool elevation of 745 feet.

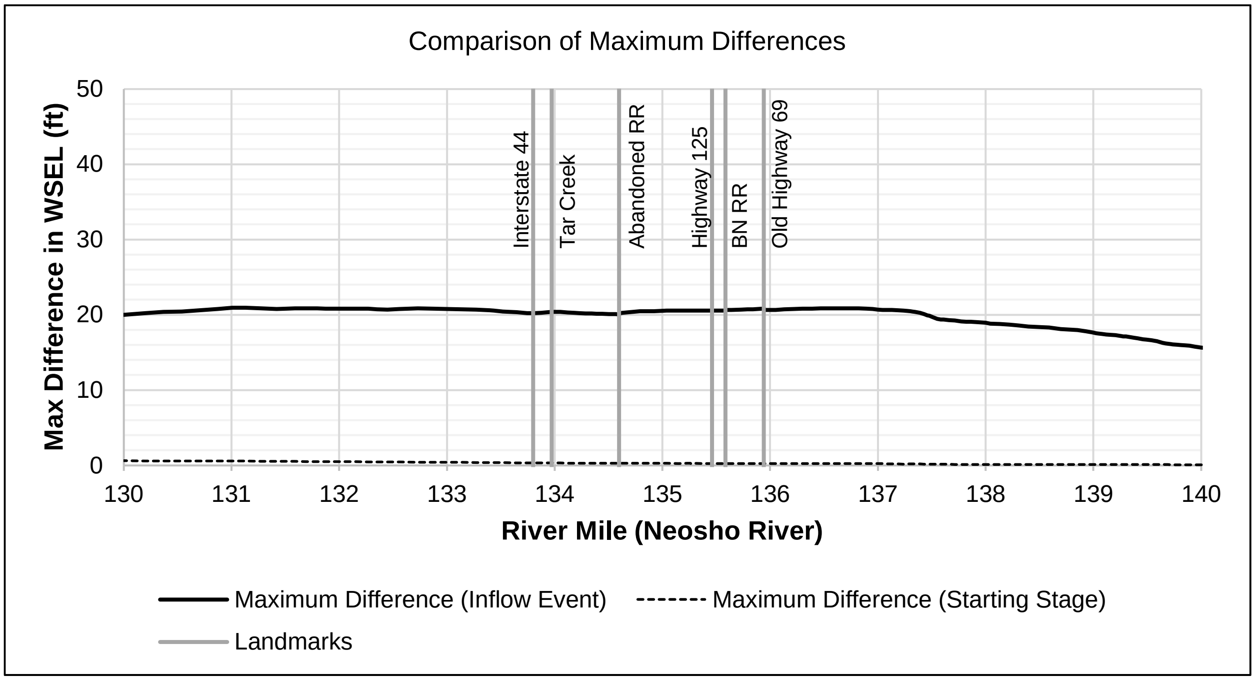


Figure 40. Comparison of maximum WSEL differences near Miami, OK.

10. Conclusions

The results of the UHM demonstrate that the initial stage at Pensacola Dam has an immaterial impact on upstream WSELs and inundation. Only a different inflow event caused an appreciable difference in maximum WSEL and maximum inundation extent. The differences in WSEL and inundation extent due to the size of the inflow event were an order of magnitude greater than the differences in WSEL and inundation extent due to the initial stage at Pensacola Dam.

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USGS. (2021n, August 17). *Streamflow Measurements for the Nation: USGS 07188000 Spring River near Quapaw, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/measurements/?site_no=07188000

APPENDIX A:
RESPONSE TO CITY OF MIAMI COMMENTS

This document compiles comments received on *H&H Modeling: Upstream Hydraulic Model – Model Input Status Report*, filed with FERC on March 30, 2021. The City of Miami was the only entity to file comments; their comments were filed with FERC on June 23, 2021. After each comment, Mead & Hunt has provided a response. Page numbers listed below reference the *Model Input Status Report*.

Comment No. 1, Section 2.1, page 4

City of Miami Comment

The USACE's Hydrologic Engineering Center (HEC) has recently released HEC-RAS Version 6.0. This model has several improvements over Version 5.0.7, including the ability to represent bridges within a 2-D area. Tetra Tech recommends developing and calibrating a fully 2-D hydraulic model using HEC-RAS Version 6.0.

Mead & Hunt Response to Comment No. 1

The FERC-approved Revised Study Plan states that HEC-RAS version 5.0.3 or later will be used. Consistent with this requirement, the model was developed in HEC-RAS version 5.0.7. Version 6.0 includes an expanded set of features. The ability to represent bridges within a 2D Flow Area is new to version 6.0. The engineering community has not yet extensively tested this, or other new features. It is inadvisable to move the model to this new version at this time.

Comment No. 2, Section 2.2, page 4

City of Miami Comment

Because the 2DFA better accounts for the volume in Grand Lake, it should be applied to the entire area of the lake.

Mead & Hunt Response to Comment No. 2

The cross-sections upstream of River Mile 100 extend across the reservoir and thus properly account for the volume.

Comment No. 3, Section 2.2, page 4

City of Miami Comment

The River Miles along Grand Lake and the Neosho River are different by approximately 8 miles compared to previous studies (Holly, 2001; Tetra Tech, 2015). For comparative purposes with previous studies, Tetra Tech recommends using the original river mile stationing.

Mead & Hunt Response to Comment No. 3

Mead & Hunt used USGS river miles because it is a publicly available dataset.

Comment No. 4, Section 2.4, page 6

City of Miami Comment

The Mead & Hunt hydraulic model has many areas where the cell alignments do not follow the top of banks, as shown in Figure A. Mead & Hunt should therefore review the cell alignments in its model and refine them to ensure that they meet Mead & Hunt's stated goal of matching cell alignments to waterway banks.

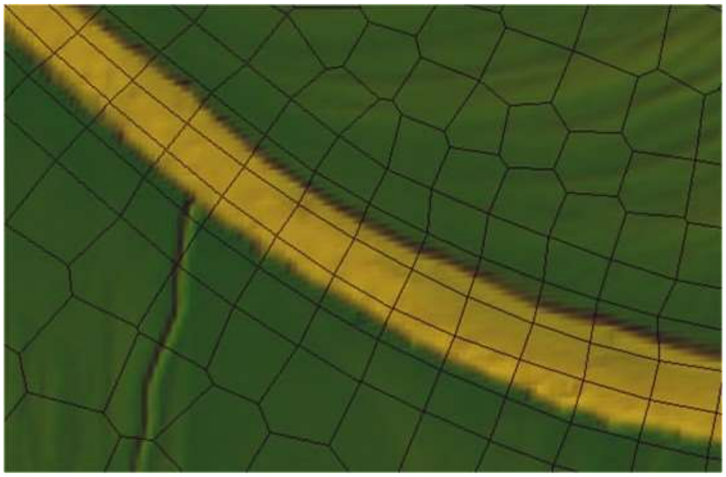


Figure A. Example of 2DFA mesh of the Mead & Hunt model where the cell alignments do not follow the top of banks. This section of mesh is located on the Neosho River upstream from the City of Miami.

Mead & Hunt Response to Comment No. 4

Mead & Hunt followed USACE guidance in the 2D Modeling User's Manual when aligning cell faces near the Neosho River banks (USACE, February 2016). USACE provides the following guidance in the 2D Modeling User's Manual:

> "*Break lines can… be placed along the main channel banks in order to keep flow in the channel until it gets high enough to overtop any high ground berm along the main channel*" (page 3-3).

Mead & Hunt followed this guidance and aligned the cell faces so that faces did not go into the channel.

Secondly, Mead & Hunt followed the guidance in the 2D Modeling User's Manual by not placing the break lines too close to each other. The 2D Modeling User's Manual states:

> *"[Cells with collinear faces are] generally caused by placing two or more break lines parallel to each other, and **close together**, such that the creation of cells along one break line can create problems with cells along the other break line*" (page 3-18, emphasis added).

The 2D Modeling User's Manual warns:

> "*If cells end up [with collinear faces], **the software will run, but the computation across cell faces that are like this will not be correct***" (page 3-17, emphasis added).

Tetra Tech's recommendation would not improve model performance and may result in a degraded computational mesh, which could result in incorrect computations. It is more important for the cell face to represent a consistent overbank elevation than be as close to the bank as possible. Mead & Hunt's cell face alignment follows USACE guidance.

Comment No. 5, Section 2.11, page 12
City of Miami Comment

In reviewing the Mead & Hunt model input status report, Tetra Tech developed bed elevation profiles along the centerline of the historic Grand and Neosho Rivers using the 2008 OWRB, 2015 Tetra Tech, 2017 USGS, and 2019 USGS hydrographic data; the following observations were made about the profiles (**Figure B**):

- Bed elevations from the 2015 Tetra Tech and 2017 USGS surveys along the centerline of the channel between Twin Bridges and Miami are in good agreement.
- Upstream of Twin Bridges, there is significant variability in the 2017 USGS profile. The model input status report indicates that Mead & Hunt used the 2017 USGS survey of the Neosho River to represent the channel from Twin Bridges to approximately the Kansas border. From Twin Bridges to about 3 miles upstream of the City of Miami, the USGS surveyed cross-sections approximately perpendicular to the flow. From 3 miles upstream of the City to the Kansas border, the USGS surveyed the channel in a zig-zag pattern (**Figure C**). The resulting interpolation of the survey points provides a poor representation of the channel topography, as indicated by the variability in the bed profile and bed elevations shown in Figure C. The interpolation method applied by the USGS is not known. Tetra Tech recommends re-evaluating the USGS survey data to develop representative channel conditions. Tetra Tech recommends using the Tetra Tech survey data, where available, to supplement the USGS data.
- The 2008 OWRB and 2019 USGS surveys show similar amounts of aggradation between about the Elk River and Twin Bridges; however, elevations from the 2019 USGS surveys are typically higher. From Pensacola Dam to about 30 miles upstream, the 2019 USGS survey is 5 to 8 feet higher than 2008 OWRB survey. The nearby upstream tributaries are relatively small and likely do not contribute enough sediment to cause this amount of aggradation. Tetra Tech would expect minor aggradation in this area between construction of the dam and the present, therefore, the differences are likely due to differences in surveying equipment and method, an error in one (or both) of the surveys, or a combination of both.

For this review, Tetra Tech also developed a comparison of the 2008 OWRB and 2019 USGS digital elevation models (surfaces) of Grand Lake, shows that:

- The differences are larger at the downstream end (near Pensacola Dam) compared to upstream (Figure D); this is consistent with the centerline profiles in Figure B but is an unexpected result. Typically, it would be expected that there would be relatively little difference between the surveys near Pensacola Dam and larger differences near Twin Bridges due to sedimentation at the head of Grand Lake.
- The USGS (2019) report presents an elevation-volume rating curve (Figure 11) that indicates a reduction in volume at the dam crest elevation (755 feet) of about 10 percent between 2008 and 2019 and about 17 percent between 1940 and 2019 (USGS Figure 5). The USGS (2019) attributes the difference to survey methods and equipment but does not provide either profile or planform comparisons of the two surveys to allow independent evaluation of this conclusion.

Tetra Tech recommends that Mead and Hunt perform an analysis of the differences between the OWRB and USGS surveys and substantiate why the USGS survey is being used for the study. Tetra Tech would support Mead & Hunt collecting spot elevations of the lake bed in the vicinity of the dam to confirm that the USGS survey is correct.

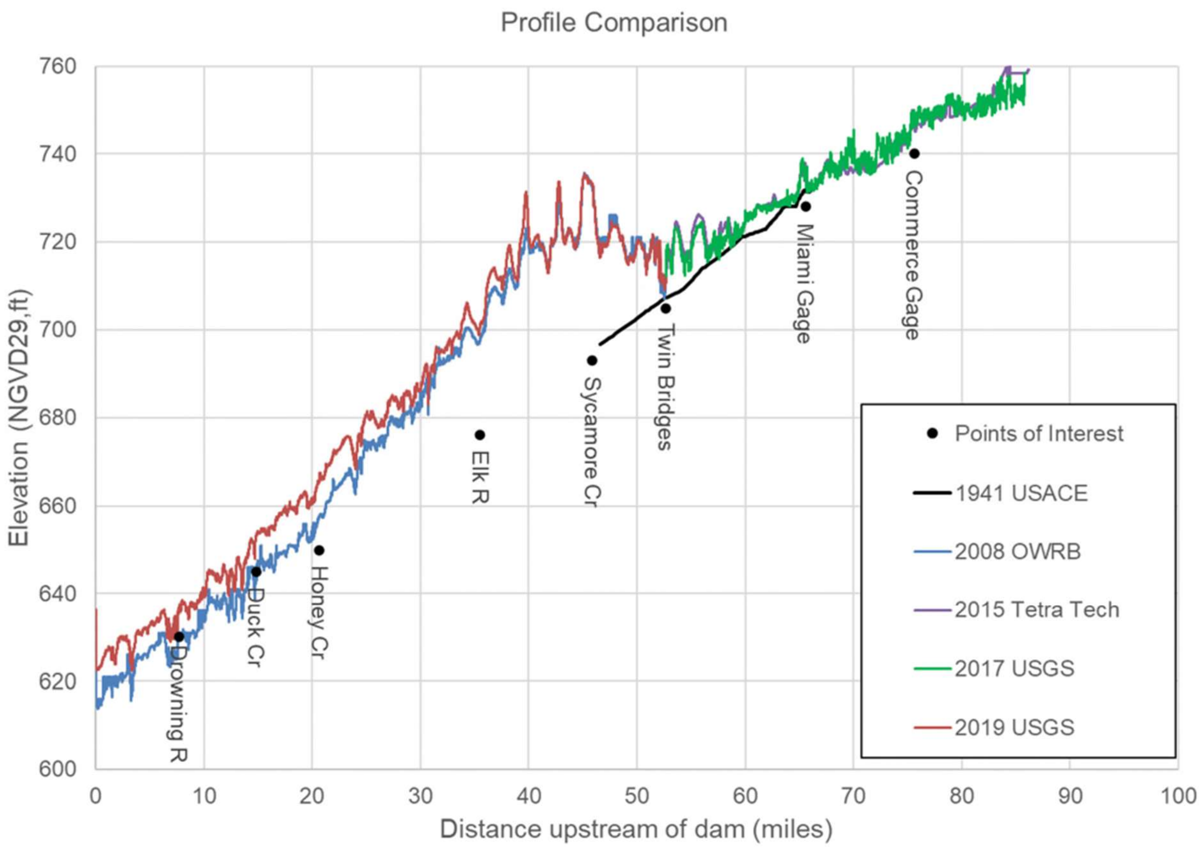


Figure B. Comparison of the 1941 USACE, 2008 OWRB, 2015 Tetra Tech, 2017 USGS and 2019 USGS profiles along the centerline of the historic Grand River and Neosho River.

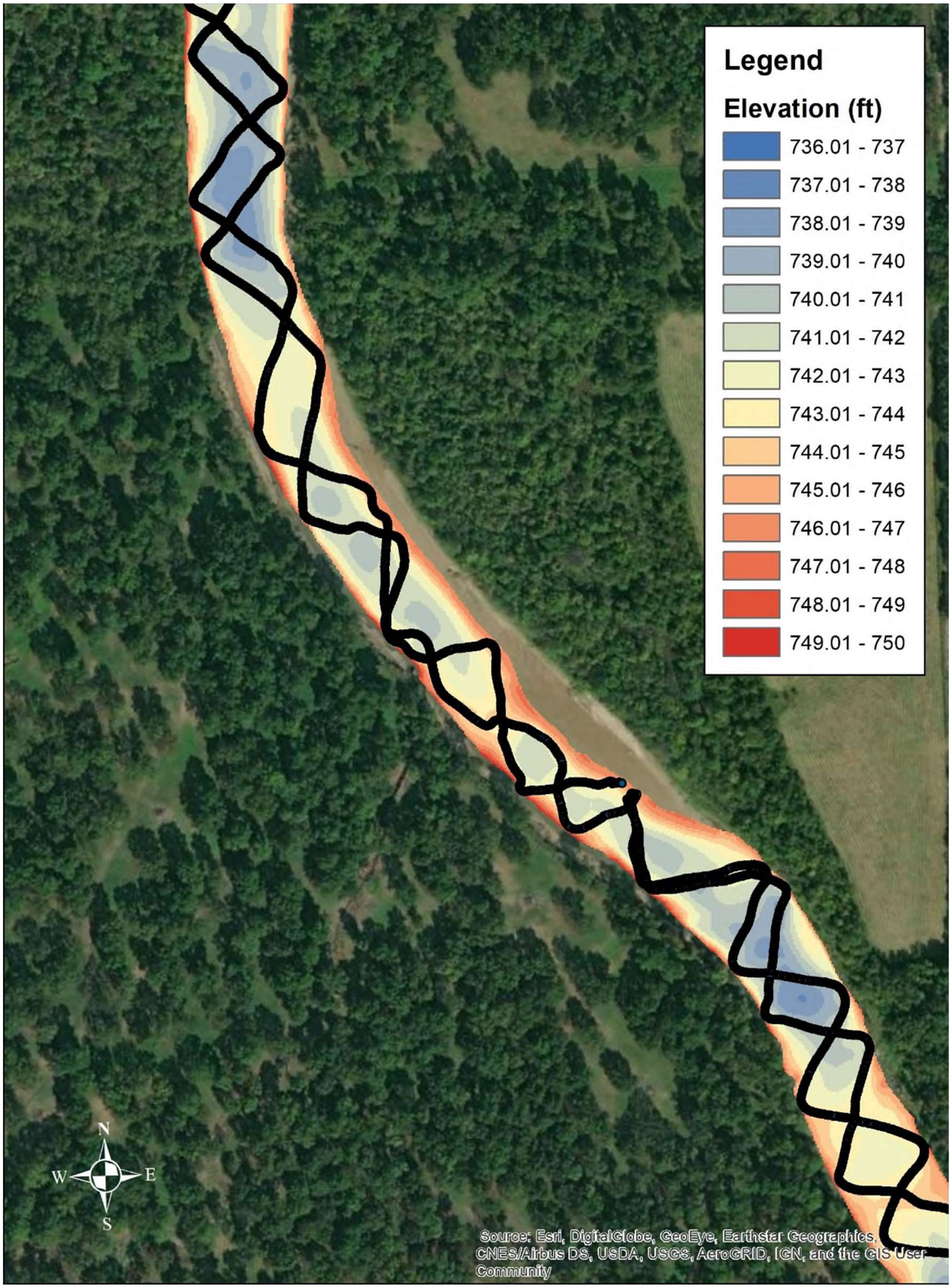


Figure C. Example of survey points collected by the USGS (2017) and overlaying the Digital Elevation Model developed by the USGS. The irregular bed elevations are due to the surface development method and are not representative of actual conditions.

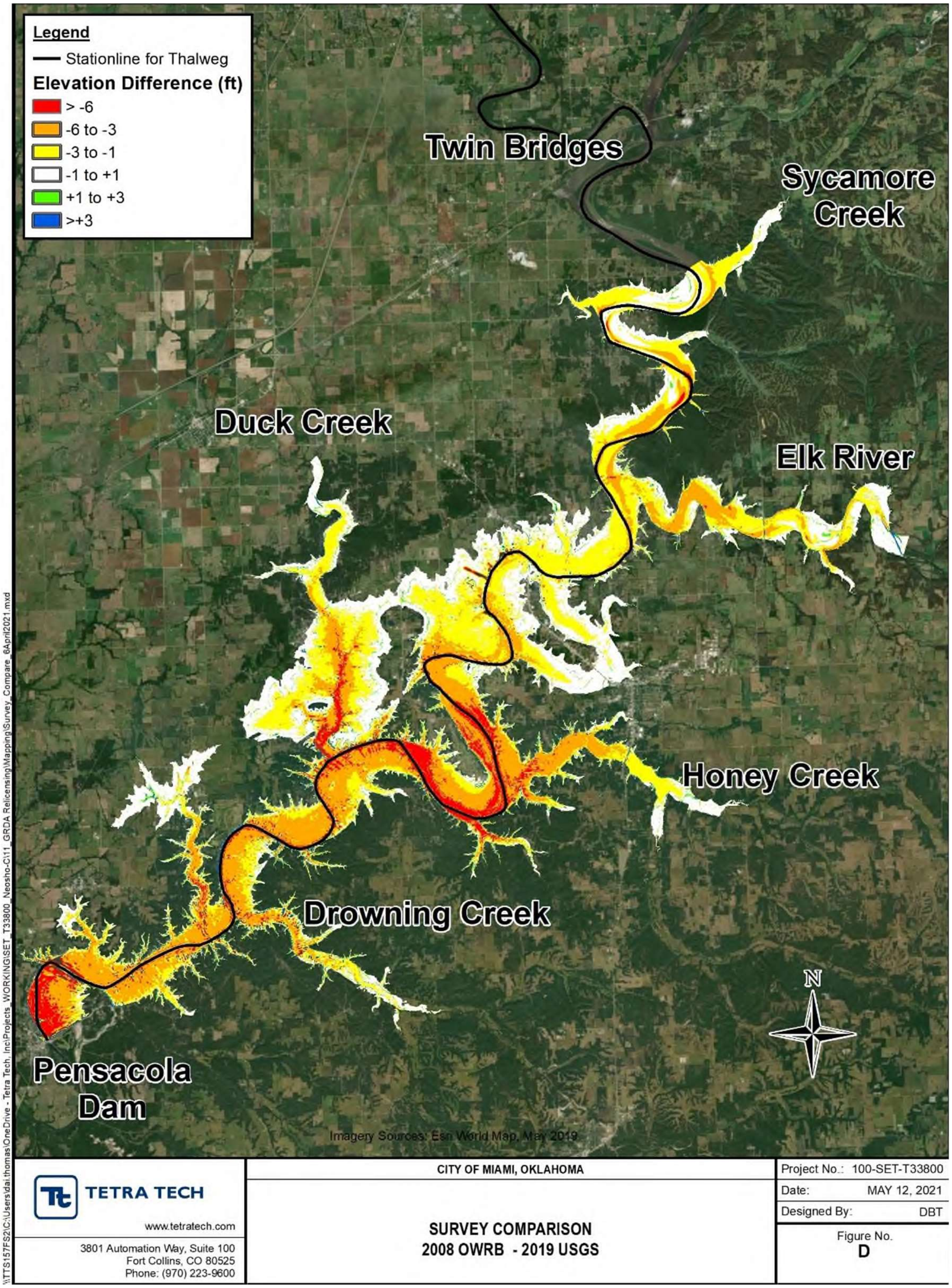


Figure D. Difference in elevation between the 2008 OWRB and 2019 USGS surveys.

Mead & Hunt Response to Comment No. 5

There is no basis to question the accuracy of the 2017 or 2019 bathymetry data collected by USGS for the following reasons:

1. The 2019 bathymetry was completed at the City of Miami's request and at FERC's direction in the Study Plan Determination. USGS is a nationally recognized agency for their expertise in data collection. USGS was selected as a non-biased, objective entity for bathymetric data collection. USGS performed the data collection in accordance with the Study Plan Determination.
2. USGS's 2019 report documents the use of industry standard practices for multi-beam bathymetric data collection quality assurance, namely beam-angle checks and patch tests. USGS also documented the use of industry standards when estimating uncertainty in the collected data.
3. USGS's 2017 report documents the use of industry standard practices for single-beam bathymetric data collection quality assurance, namely independent speed of sound measurements and bar checks at depths that spanned the range of measured depth. USGS also documented the use of industry standards when estimating uncertainty in the collected data.
4. USGS's 2017 bathymetry data was officially released in September 2017. The Proposed Study Plan (April 2018) and the Revised Study Plan (September 2018) both discussed the proposed use of USGS's 2017 bathymetry data. Tetra Tech had ample time to review USGS's data prior to and during the study planning process and did not object to the use of the USGS 2017 bathymetry during the study planning process. Raising issues with the 2017 data at this point in the relicensing process is not appropriate.

GRDA and Mead & Hunt have followed City of Miami and Tetra Tech recommendations regarding bathymetric data collection. Further inquiries regarding USGS data should be directed to USGS.

Comment No. 6, Section 2.12, page 15
City of Miami Comment

Figure 12 indicates up to 5 feet of difference in water-surface elevation between the full momentum and diffusion wave methods. Tetra Tech ran Mead & Hunt's model applying the diffusion wave method. Comparison of the water-surface elevations between the two methods showed differences of up to 0.8 feet (Figure E), significantly less than the 5-feet reported by Mead and Hunt.

Tetra Tech also ran its own 2015 model for the 2007 flood and found differences in the water-surface elevation of less than 0.5 feet. Therefore, it appears to Tetra Tech that the Mead & Hunt model results presented in this section and Figure 12 are wrong. Tetra Tech has encountered this issue before and recommends deleting the output files (including the dss file) and re-running the model. Tetra Tech would be pleased to discuss these results with Mead & Hunt to identify and eliminate the discrepancy.

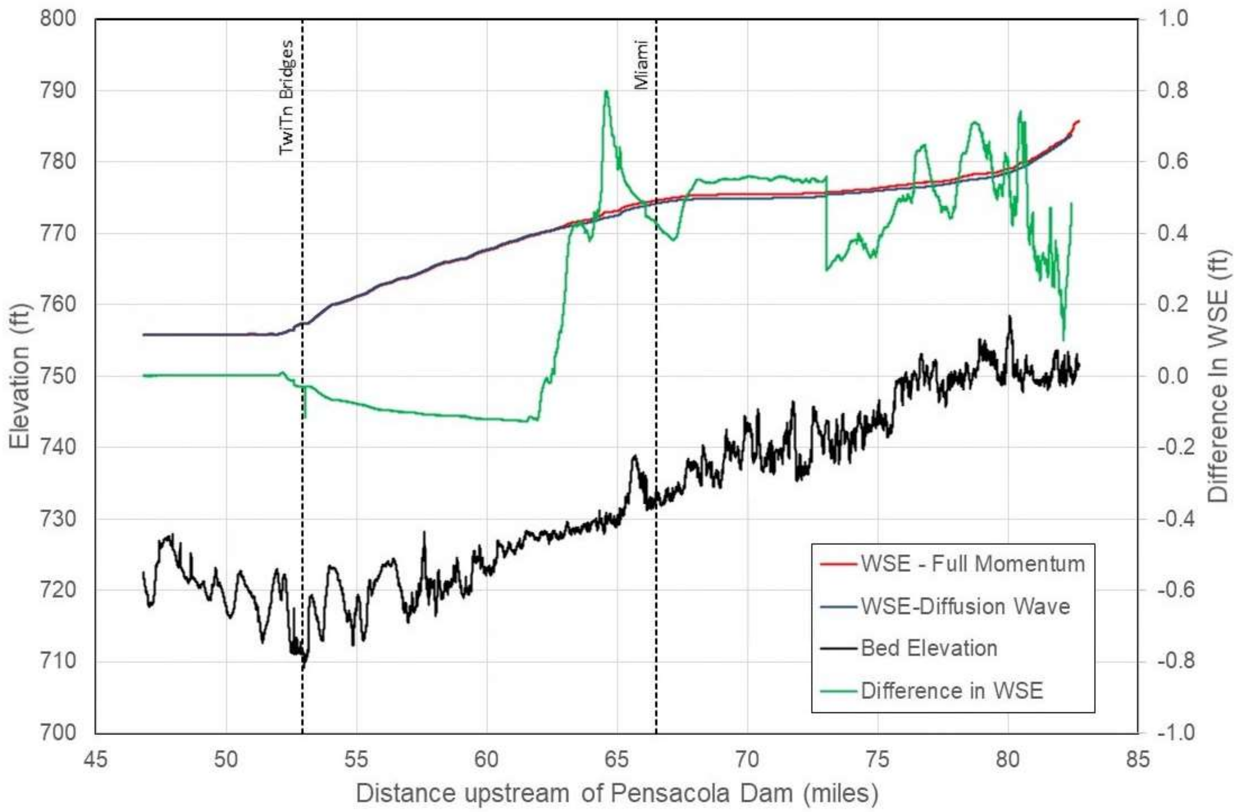


Figure E. Comparison of the predicted water-surface elevation profiles by the Mead & Hunt model applying the full momentum and diffusion wave equations for the June 2007 flood.

Mead & Hunt Response to Comment No. 6

The results displayed in Figure 12 are from a preliminary simulation, as stated in the report. Part of the process that FERC recommended in the Study Plan Determination is the presentation of preliminary results in the Model Input Status Report.

The Manning's n-values used in the calibrated model were not yet applied when this simulation was performed, so differences between the figure and Tetra Tech's re-run of the model are to be expected. Updated results are presented in the Initial Study Report.

Comment No. 7, Section 3.1.1, page 16

City of Miami Comment

Stage data for the period from c1990 to October 2007 are not published online but are available upon request from the USGS. Tetra Tech received the data from:
Scott Strong sstrong@usgs.gov
Jason Lewis jmlewis@usgs.gov
U.S. Geological Survey
Oklahoma City, OK 73116
(405) 810-4404
Tetra Tech recommends obtaining that data from USGS and using it in the calibration process.

Mead & Hunt Response to Comment No. 7

Discussion of data availability for the July 2007 event has been updated in Mead & Hunt's report.

Comment No. 8, Section 3.1.2, page 16

City of Miami Comment

The Neosho River at Miami, OK (USGS Gage No. 07185080) started operating in 1994. Hourly gage data are available from the USGS upon request. Tetra Tech recommends obtaining these data and using them in calibration.

Mead & Hunt Response to Comment No. 8

In general, Mead & Hunt looked at hourly time series data when calibrating. For the 2007 event, Mead & Hunt used the daily maximum values at the Miami gage because hourly data was not publicly available. Because the flood event occurred over multiple days, the publicly available daily maximum values were sufficient.

Comment No. 9, Section 3.2.1, page 18

City of Miami Comment

The spike in flow near the peak of the 2007 flood is likely an anomaly, as it does not occur in the stage data (Figure F). The USGS measured the flow near the peak of the 2007 flood and applied a shift to the rating-curve for the data collected after the measurement. As a result, the USGS applied two rating curves to the 2007 flood, which has led to the downward shift in the flow hydrograph. Tetra Tech recommends that Mead and Hunt re-calculate the flows prior to the peak using the stage-versus-discharge rating-curve reported near the peak.

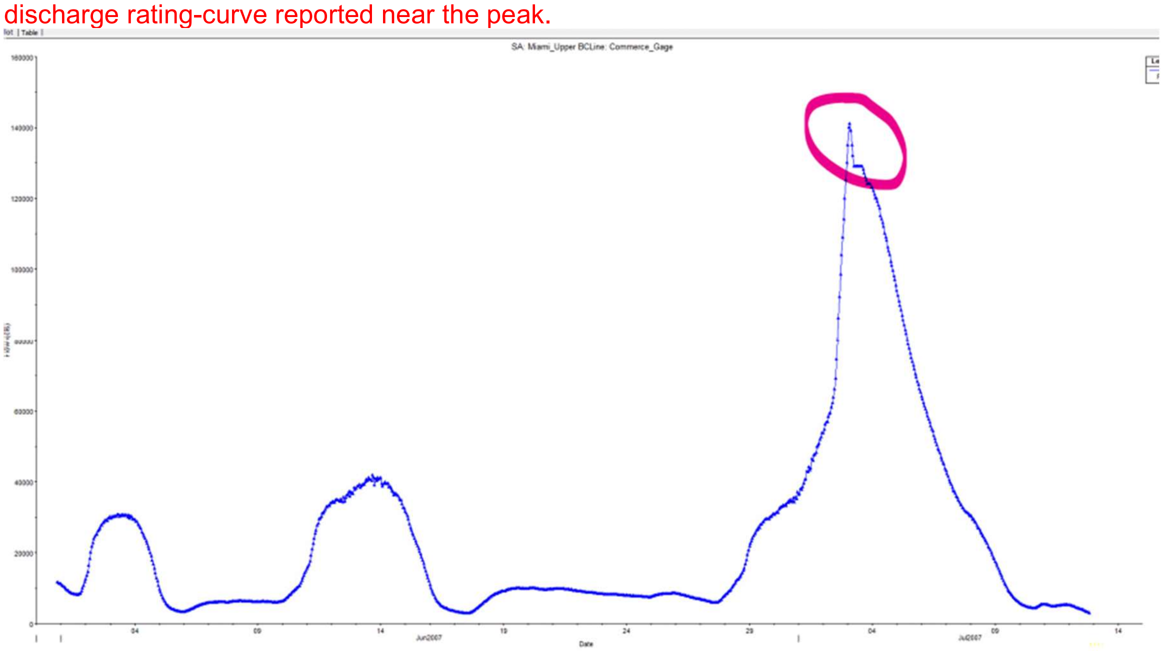
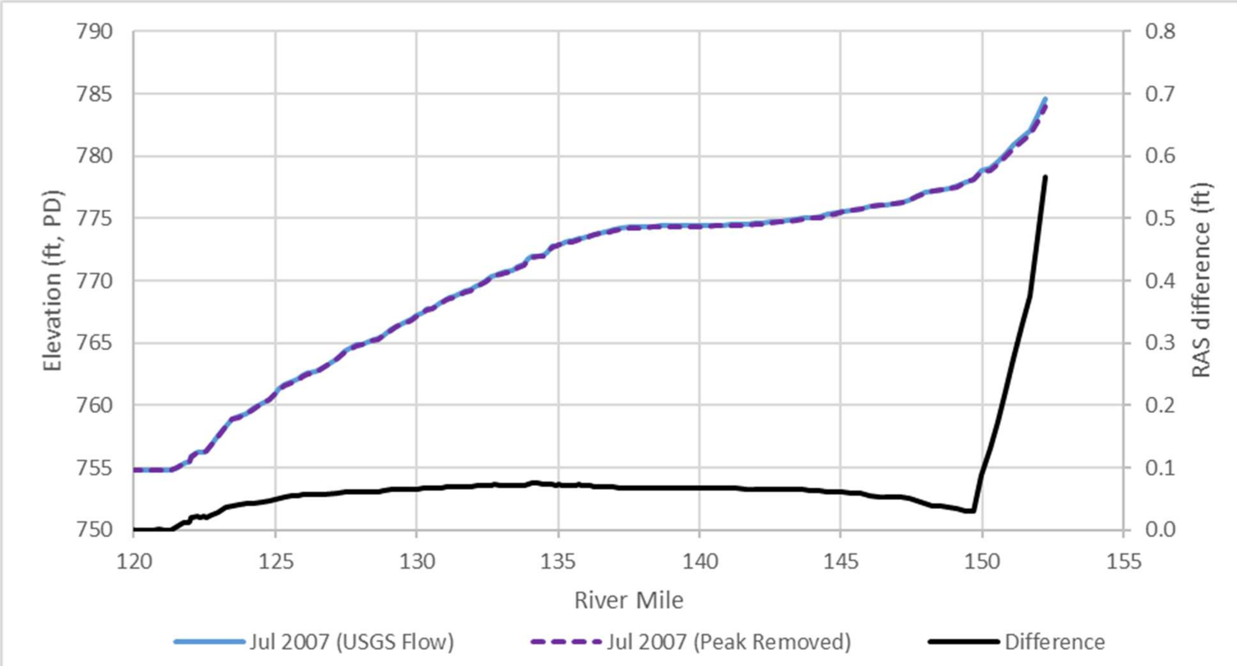


Figure F. The highlighted section represents a spike in the hydrograph that is not representative of the actual flows.

Mead & Hunt Response to Comment No. 9

Mead & Hunt simulated the July 2007 event with the spike at the peak of the hydrograph removed. The results from the simulation with the peak removed were compared to results from the simulation using the publicly available USGS flow hydrograph. See the figure below. The difference in water surface elevation is less than 0.6 feet at the very upstream end of the model, and quickly drops to less than 0.1 feet. Given the choice between (1) using USGS flow data directly and (2) manipulating the flow data using the second rating curve, it is best to use the USGS data directly.



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775
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765
760
755
750
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
120
125
130
135
140
145
150
155
Elevation (ft, PD)
RAS difference (ft)
River Mile
Jul 2007 (USGS Flow)
Jul 2007 (Peak Removed)
Difference

Comment No. 10, Section 3.3, page 21

City of Miami Comment

HEC-RAS has the ability to simulate vertically varied Manning's n-values for 1-D areas but not for 2-D areas. In general, the Manning's n-values increase at higher flows due to the increased roughness of the tree canopy. The application of the roughness factors only to 1-D areas does not make physical sense. There could be a difference in Manning's n value by a factor of 0.6 or 1.3 on either side of the 1D/2D boundary. For example, the Manning's n roughness value in the 2-D area is 0.037, while the n-value in the 1-D area varies from 0.022 to 0.047. Also, it does not make physical sense to increase the Manning's n values in the lake. Since the lake is deep, the model is likely to be relatively insensitive to the Manning's n (within a reasonable range of n-values). Tetra Tech recommends performing a sensitivity analysis of the effects of changing Manning n-values in the lake as well as along the Neosho, Spring and Elk Rivers.

For the Neosho River, the roughness factor in the Mead & Hunt model decreases from 1.3 at 150,000 cfs to 1.0 at flows greater than 160,000 cfs. This does not make physical sense as there is no obvious reason why the roughness would decrease at greater discharges. If Mead & Hunt continue using this method, Tetra Tech recommends keeping the roughness factor the same at the larger flow events.

Mead & Hunt Response to Comment No. 10

USACE recommends the use of flow roughness factors in model calibration (HEC-RAS User's Manual, page 8-65). By using flow roughness factors, Mead & Hunt is following USACE guidance.

Tetra Tech raises a concern with the discontinuity in n-values at the 1D/2D boundary. Tetra Tech notes that the Mead & Hunt model has a difference in n-value at the 1D/2D boundary of 0.037 (2D) and a range from 0.022 to 0.047 (1D). In the same area, Tetra Tech's 2016 analysis used n-values of 0.037, then 0.083, then 0.035, then 0.043, with abrupt transitions between these values (Tetra Tech, 2016). Mead & Hunt's approach results in less abrupt changes in n-values.

Regarding increasing n-values in the lake, there were no flow roughness factors applied to Grand Lake. Flow roughness factors were not applied below River Mile 121.51.

Regarding the suggestion of a sensitivity analysis, Mead & Hunt tested the sensitivity to Manning's n-values early in our modeling and found that the Neosho River, the Spring River, and the Elk River were relatively sensitive to changes in n-values. Grand Lake was relatively insensitive to n-values.

Regarding the flow roughness factor of 1.0 for flows higher than those used in calibration, there is no available, comprehensive set of observed data collected at higher flows to justify the application of flow roughness factors at higher flows.

Comment No. 11, Section 3.4, page 21

City of Miami Comment

Based on the Mead & Hunt model output for the October 2009 flood, the average of the absolute differences between the predicted maximum water-surface elevations and measured high-water marks is 0.57 feet.

For the 2007 flood, the average of the absolute differences between the predicted maximum water-surface elevations and measured high-water marks is 1.19 feet. As shown in Figure 13, the greatest calibration differences occur at the Miami Gage, which is a key area of interest to the City of Miami.

In general, the Mead & Hunt model is underpredicting the measured water-surface elevations for the larger flood events. Because much of the flood plain upstream of Grand Lake is relatively flat, small underpredictions of water surface elevation translate into much greater underpredictions in the lateral extent of flooding in many areas. Therefore, Tetra Tech supports calibrating the individual high-water marks to an absolute difference of less than 0.5 feet, and not the average of all the differences to less than 0.5 feet, which can under-represent the differences.

Mead & Hunt Response to Comment No. 11

Mead & Hunt followed USACE guidance in the HEC-RAS User's Manual when calibrating (USACE, February 2016).

1. USACE states that a ± 5% flow measurement, which may be "*optimistic*", "*translates into a stage error of ±1.0 feet*" (page 8-54). It is inadvisable to further modify the model to force the water surface elevation profiles to match each high-water mark within 0.5 feet.
2. USACE states that "*high water marks in the overbank area are often higher than in the channel*" (page 8-55). Because many of the high-water marks were collected in the overbank area, a slight model underprediction is expected when compared to measured water surface elevations.
3. USACE recommends the user to "*not force a calibration to fit with unrealistic Manning's n-values*" (page 8-65). Rather than force the water surface elevation to match each high-water mark within 0.5 feet by aggressively modifying n-values, Mead & Hunt followed USACE guidance and accomplished the goal of a water surface elevation profile that passes through or near the high-water marks.

Mead & Hunt's report has been updated with a comparison of measured water surface elevations for the July 2007 event.

Comment No. 12, Section 3.4, page 21

City of Miami Comment

Tetra Tech's review of the predicted flow hydrograph neat the mouth of the Elk River indicated probable model instability for the 2007 flood (Figure G). Tetra Tech recommends reviewing the model output and adjusting the model to prevent model instability.

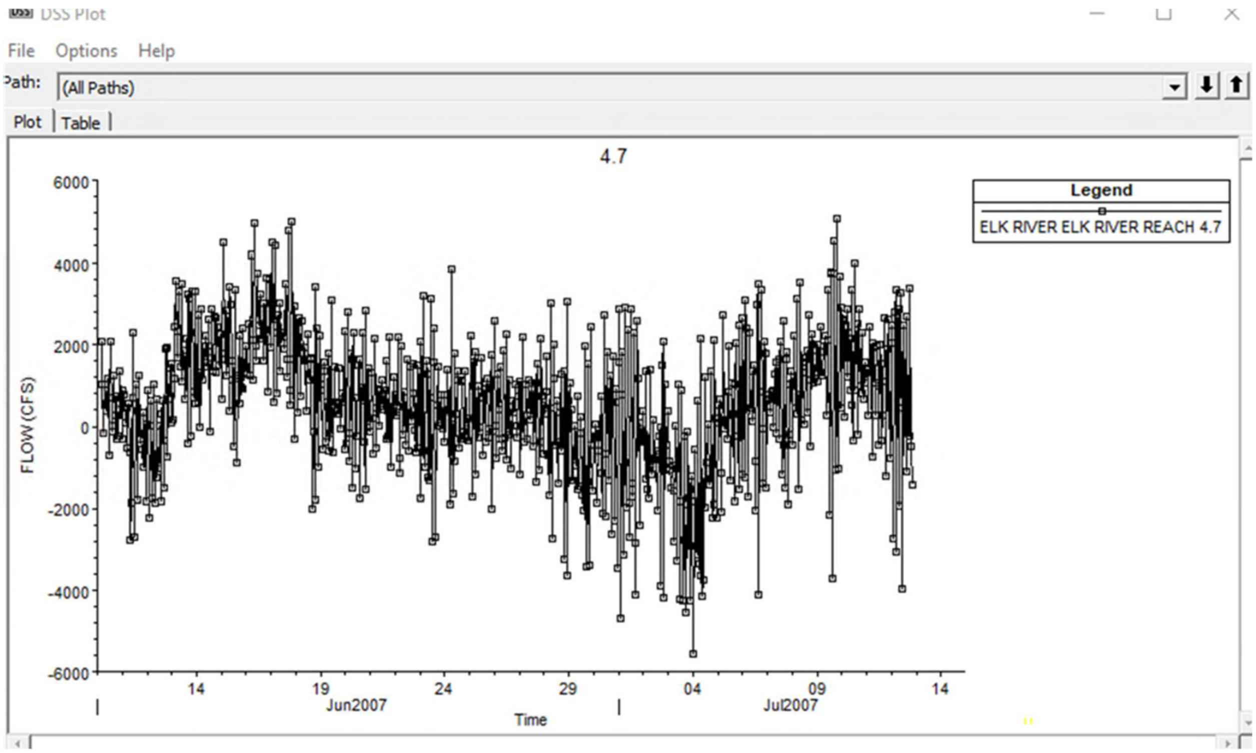


Figure G. Screen capture from HEC-RAS showing the predicted flow for the 2007 flood at cross- section 4.7 on the Elk River. The variability in the predicted flow indicates numerical instability in the model.

Mead & Hunt Response to Comment No. 12

The fluctuating flow, which is different than model instability, is due to the use of recorded historical stage hydrograph as the downstream boundary. The recorded stage hydrograph includes fluctuations which create fluctuating flow toward the downstream end of the model. Synthetic or smoothed stage boundary conditions, which are used for the operational scenario simulations, result in less flow fluctuation.

Comment No. 13, Section 3.4, page 22

City of Miami Comment

Figure 13 does not show the calibration of the 2007 flood at Commerce gage. Tetra Tech recommends obtaining the hourly stage data from the USGS and calibrating the Mead & Hunt Model to the Commerce gage.

Mead & Hunt Response to Comment No. 13

Peak stage at the Commerce gage for the July 2007 event is discussed in Mead & Hunt's Initial Study Report.

Comment No. 14, Section 3.4, page 23

City of Miami Comment

Figure 16 shows a significant drop in water-surface elevation near RM 123. Mead & Hunt should explain the reason for the drop, and why it does not call into question Mead & Hunt's modeling results.

Mead & Hunt Response to Comment No. 14

The decrease in water surface elevation occurs at the downstream face of the Burlington Northern Railroad Bridge and is a function of bridge hydraulics.

Comment No. 15, Section 4, page 26

City of Miami Comment

Tetra Tech recommends a comparison between the peak flows reported by the RiverWare and gage records to ensure the data sets match by a reasonable amount. Tetra Tech recommends a flood-frequency and/or partial duration flood-frequency analysis for all the gages contributing to Grand Lake, including the Neosho, Spring, and Elk Rivers and Tar Creek.

Mead & Hunt Response to Comment No. 15

By using RiverWare for the flood frequency analysis, Mead & Hunt is following the City's recommendation.

Comment No. 16, Section 4, page 26

City of Miami Comment

Tetra Tech understands that the Real Estate Adequacy Study (U.S. Army Corps of Engineers, 1998) may have significant problems in terms of both the methods and results. The report was admitted into evidence in the 1998 state civil trial, Dalrymple et al v. Grand River Dam Authority, CJ 94-444, regarding the question of "'to what extent' Pensacola Dam causes backwater effects in the subject reach." Dr. Forrest Holly, the Referee agreed to by all parties, placed little weight in the study, making no reference to it in coming to his conclusions (Referee Report, February 15, 1999). Further, Holly (2001) concluded that there was substantially more backwater effect in the Miami reach than the Corps concluded in its September 1998 Real Estate Adequacy Study. Tetra Tech recommends independently verifying any methods or results presented in the study.

Mead & Hunt Response to Comment No. 16

Mead & Hunt's objective is not to verify previous studies, including the 1998 REAS. The flood frequency curve from the 1998 REAS is only presented in the report for comparative purposes. Mead & Hunt's methodology for the flood frequency analysis follows best practices (USGS Bulletin 17C, USACE EM 1110-2-1415).

Comment No. 17, Section 5, page 28
City of Miami Comment

In addition to the peak flow, the hydrograph volume has an important impact on the lake elevation and outflow operations during flood events. The Mead & Hunt (2021) report does not provide any analysis of the inflow flood volume.

During flood events, the USACE attempts to limit the outflow to 100,000 cfs to prevent downstream flooding. During large floods, such as the 2019 flood, the lake reached its highest level in history at 755.1 feet Pensacola Datum and the outflow peaked at approximately 180,000 cfs.

A large inflow volume can result in a significant increase in Grand Lake's water-surface elevation and an associated increase in flooding along the Neosho, Spring, and Elk Rivers.

The application of the scaling number to determine the 100-year inflow to Grand Lake is not appropriate, as it may result in unrealistic peak flows and flow volumes. For example, FEMA developed the 100-year peak flow hydrograph for the Neosho River by performing a flood-frequency analysis (using the HEC-SSP software) to estimate the peak flow, then performing hydrologic (rainfall/runoff) modeling (using the HEC-HMS software) to estimate the flood volume. The resulting hydrograph had a peak flow of about 165,000 cfs and volume of about 1,424,000 ac-ft (Figure H). In comparison, multiplying the 2007 flood hydrograph by scaling factor of 2.15 produces a peak flow of about 319,000 cfs and volume of 2,884,300 cfs; both the peak flow and volume are far in excess of FEMA's 100-year peak flow and volume, and physically unrealistic for the 100-year event (Figure H).

The flood-frequency curve for the Neosho River at Commerce Gage is shown in Figure I. The 100-year peak flow is approximately 165,000 cfs. The 100-year peak flow applied by Mead & Hunt plots well outside the 95th percentile confidence limit.

Tetra Tech recommends that Mead & Hunt perform a basin-wide hydrologic analysis to develop flood hydrographs at each of the inflow locations that have physically based rationale for predicting the peak flow and volume.

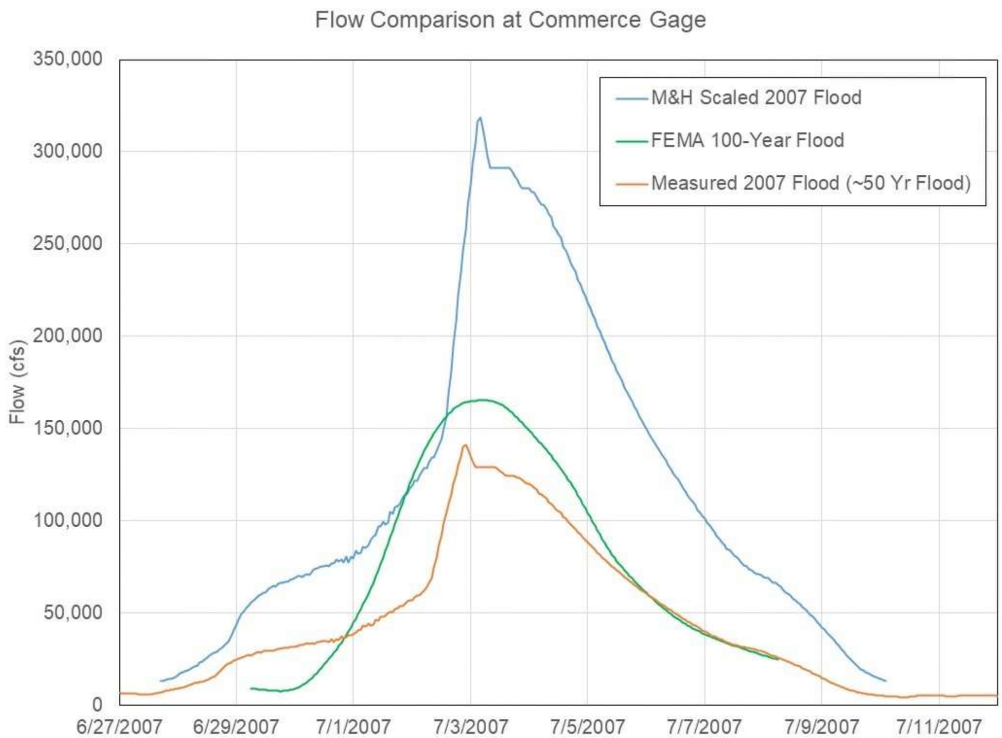


Figure H. Comparison of the measured 2007 flood at Commerce Gage, FEMA 100-year flood hydrograph, and scaled 2007 flood in the Mead & Hunt model used to represent the 100-year inflow to Grand Lake.

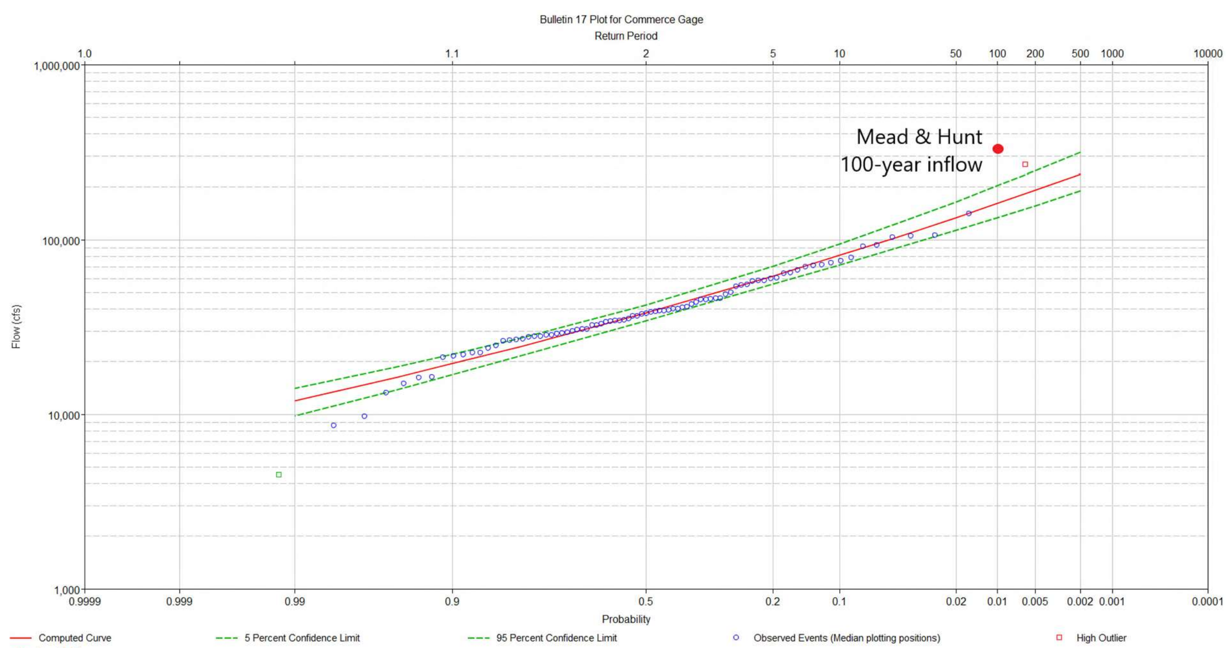


Figure I. Flood-frequency curve for the Neosho River at Commerce gage. Note that the scaled 100-year peak flow predicted by the Mead & Hunt model falls well outside the confidence limits of the flood-frequency curve.

Mead & Hunt Response to Comment No. 17

A basin-wide hydrologic analysis was not recommended in the Revised Study Plan, nor required in FERC's Study Plan Determination.

The FEMA flood-frequency analysis referenced by Tetra Tech was performed using a HEC-HMS model. A single sub-basin was used to represent the 5,927 square miles that drain to the Commerce gage and the model did not include John Redmond Reservoir. Model calibration was performed using the 2007 event and model validation was performed using a flood frequency curve computed using statistical methods in USGS's PeakFQ software. FEMA's approach includes the following deficiencies:

1. Not including John Redmond Reservoir (thus treating a regulated system like an unregulated system) and then calibrating to historic data from the regulated system will result in inaccurate model parameters, which will decrease the predictive capability of the model.
2. Statistical methods should not be used to estimate flood frequency for regulated basins. Using statistical methods within PeakFQ to validate the HEC-HMS model does not follow best practices (USGS Bulletin 17C).

Regarding the inflow volume, Mead & Hunt used a statistical analysis of historic inflow volume to better estimate the hydrograph volume.

Comment No. 18, Section 6, page 29

City of Miami Comment

This method is for determining the Guide Take Line for real estate takings. It should not be used to define the "material difference" for calibration purposes.

Adjusting the flows by ±2% and comparing the difference in water-surface elevations is essentially a sensitivity analysis. The results are valid only for the selected site and for the modeled flood event. This method should not be evaluated for determining the "material difference".

Mead & Hunt Response to Comment No. 18

Mead & Hunt reviewed how various government entities quantify difference in water surface elevation. We understand that the scenarios for which these quantifications are applied are not exactly like the scenario at hand. However, they are still instructive for the purpose of defining material difference.

Comment No. 19, Section 6, page 29

City of Miami Comment

In addition to the "out of bank events", the "material difference" criterion of 0.5 feet should be applied to the calibration for the within bank flows.

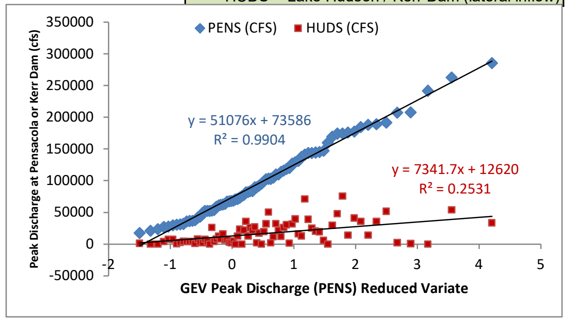
Mead & Hunt Response to Comment No. 19

Mead & Hunt is considering 0.5 feet of difference in water surface elevation within banks where it is required to meet the objectives of the study. Specifically, we are considering 0.5 feet of water surface elevation difference within the banks where the inundation impacts infrastructure or other sensitive resources.

APPENDIX B:

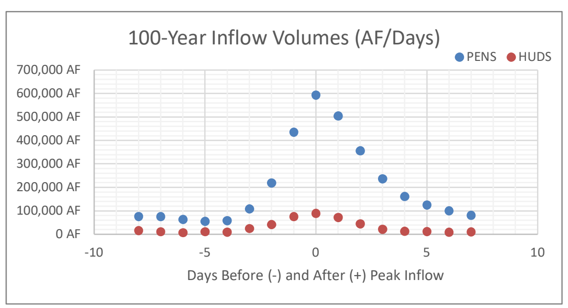
HISTORICAL INFLOW VOLUME STATISTICAL ANALYSIS

PENS = Pensacola Dam / Grand Lake (total inflow)
HUDS = Lake Hudson / Kerr Dam (lateral inflow)

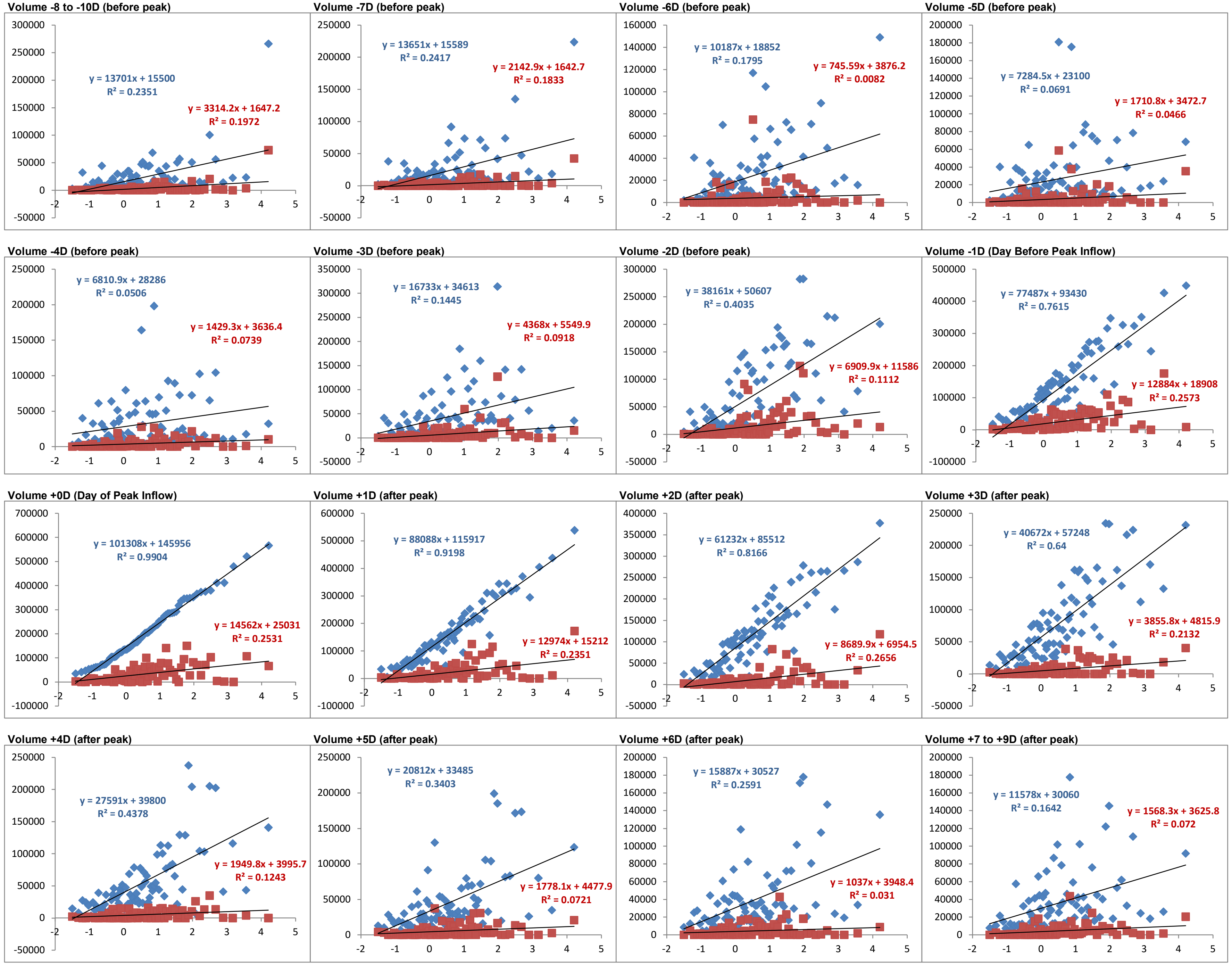


reduced variate for 100-year event, y = 4.41

	scale, σ (m)	location, μ (b)	100-year
PENS (CFS)	51076	73586	299,000 cfs
HUDS (CFS)	7342	12620	45,021 cfs
PENS D–8 to –10 (AF)	13701	15500	75,966 AF
PENS D–7 (AF)	13651	15589	75,835 AF
PENS D–6 (AF)	10187	18852	63,810 AF
PENS D–5 (AF)	7285	23100	55,249 AF
PENS D–4 (AF)	6811	28286	58,344 AF
PENS D–3 (AF)	16733	34613	108,461 AF
PENS D–2 (AF)	38161	50607	219,023 AF
PENS D–1 (AF)	77487	93430	435,403 AF
PENS D+0 (AF)	101308	145956	593,058 AF
PENS D+1 (AF)	88088	115917	504,675 AF
PENS D+2 (AF)	61232	85512	355,747 AF
PENS D+3 (AF)	40672	57248	236,745 AF
PENS D+4 (AF)	27591	39800	161,567 AF
PENS D+5 (AF)	20812	33485	125,334 AF
PENS D+6 (AF)	15887	30527	100,641 AF
PENS D+7 to +9 (AF)	11578	30060	81,157 AF
HUDS D–8 to –10 (AF)	3314	1647	16,274 AF
HUDS D–7 (AF)	2143	1643	11,100 AF
HUDS D–6 (AF)	746	3876	7,167 AF
HUDS D–5 (AF)	1711	3473	11,023 AF
HUDS D–4 (AF)	1429	3636	9,944 AF
HUDS D–3 (AF)	4368	5550	24,827 AF
HUDS D–2 (AF)	6910	11586	42,081 AF
HUDS D–1 (AF)	12884	18908	75,769 AF
HUDS D+0 (AF)	14562	25031	89,297 AF
HUDS D+1 (AF)	12974	15212	72,470 AF
HUDS D+2 (AF)	8690	6955	45,306 AF
HUDS D+3 (AF)	3856	4816	21,833 AF
HUDS D+4 (AF)	1950	3996	12,601 AF
HUDS D+5 (AF)	1778	4478	12,325 AF
HUDS D+6 (AF)	1037	3948	8,525 AF
HUDS D+7 to +9 (AF)	1568	3626	10,547 AF



Average Daily Volume (AF) vs GEV Peak Discharge (PENS) Reduced Variate Correlation Plots



APPENDIX C:
HYDROGRAPHS

APPENDIX C.1:
INFLOW HYDROGRAPHS

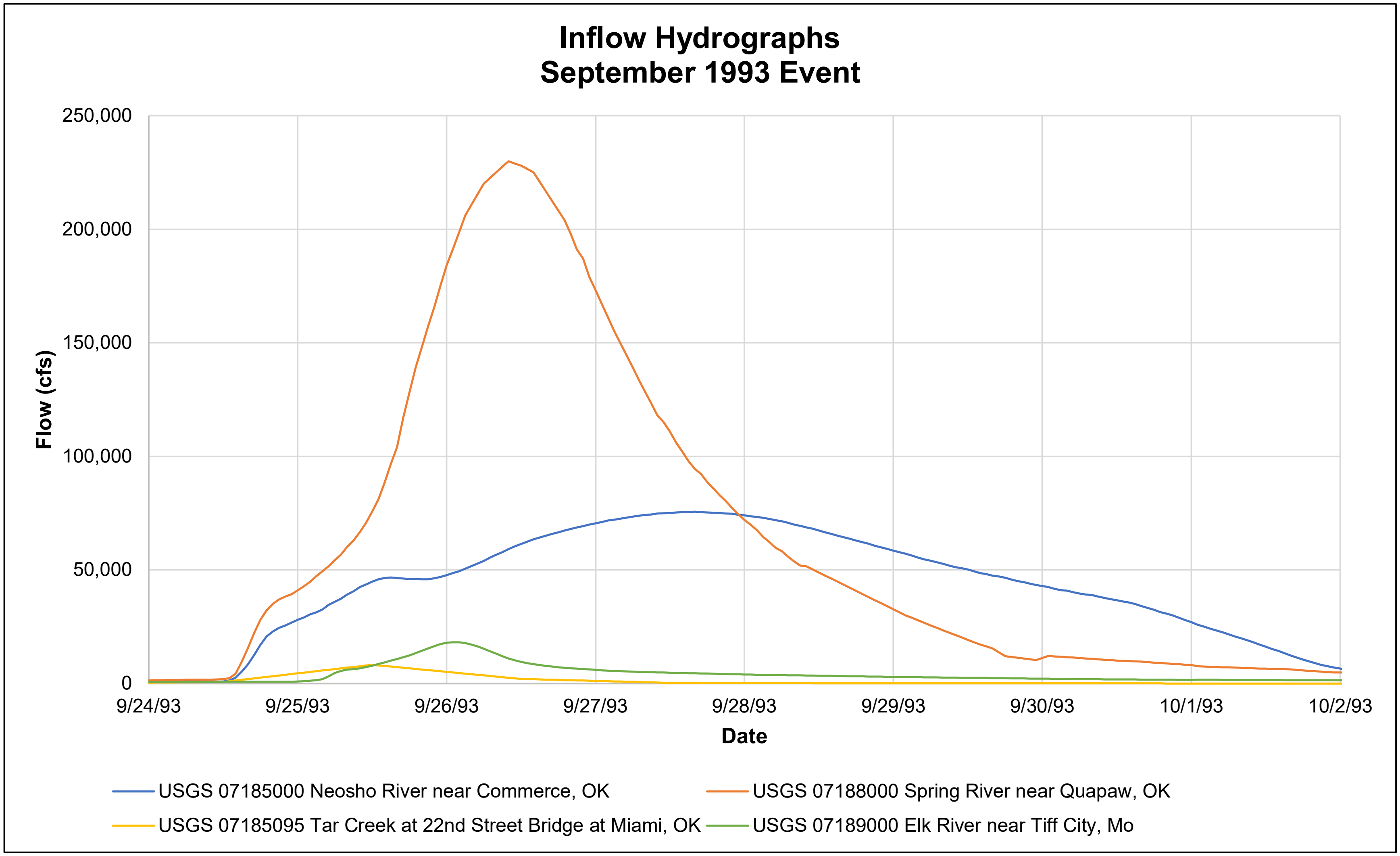


Figure C.1. Inflow hydrographs for the September 1993 event upstream of Pensacola Dam.

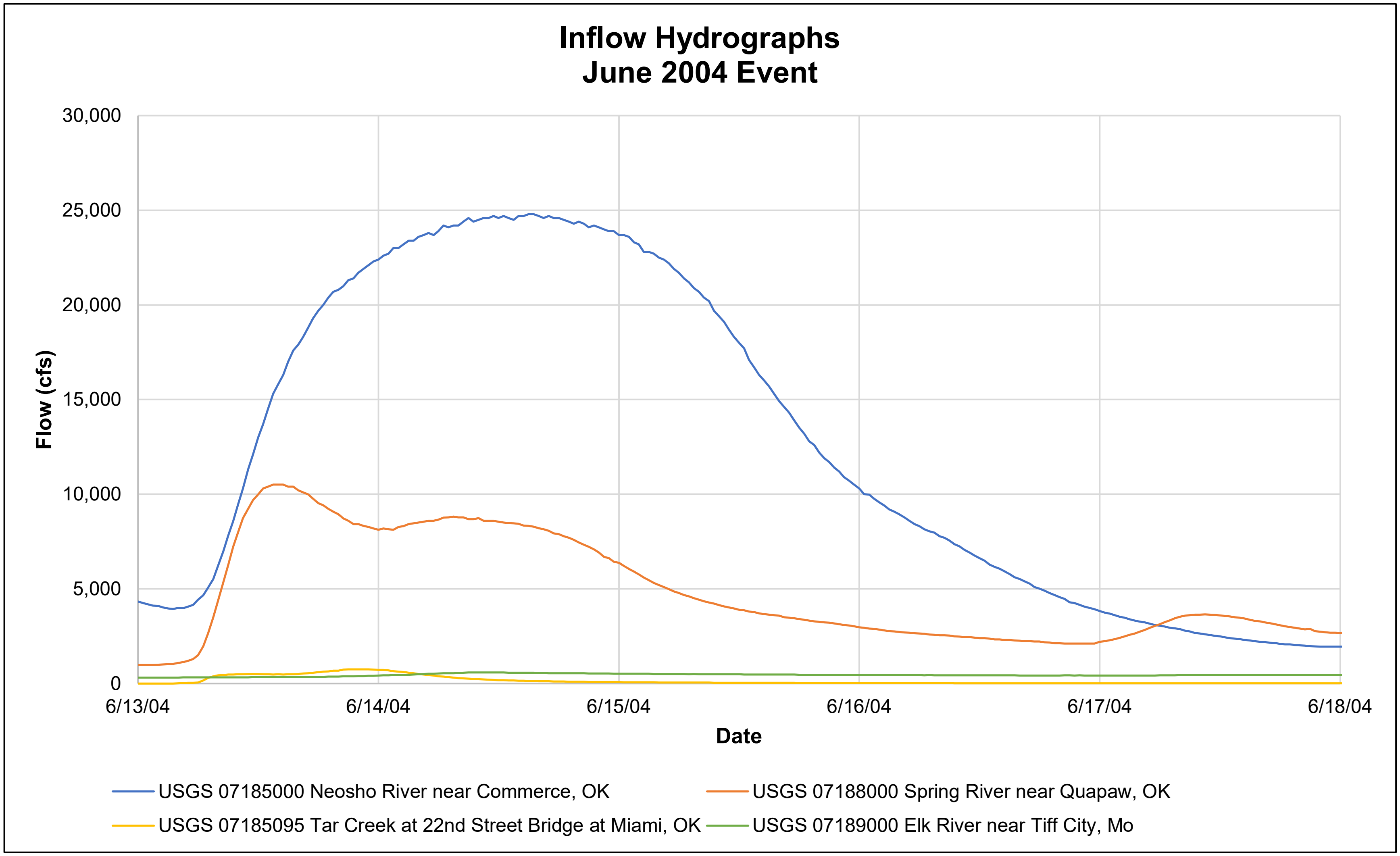


Figure C.2. Inflow hydrographs for the June 2004 event upstream of Pensacola Dam.

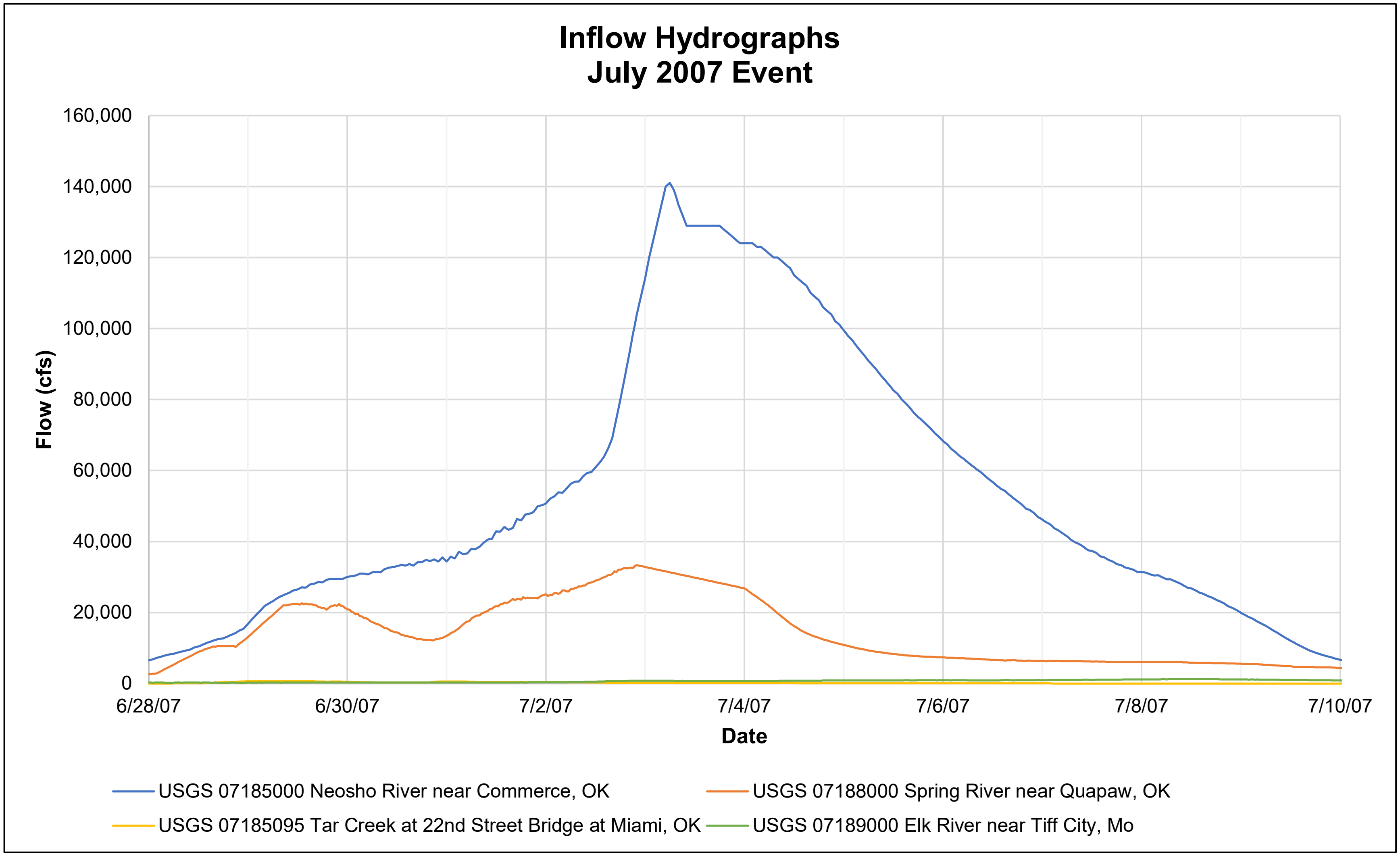


Figure C.3. Inflow hydrographs for the July 2007 event upstream of Pensacola Dam.

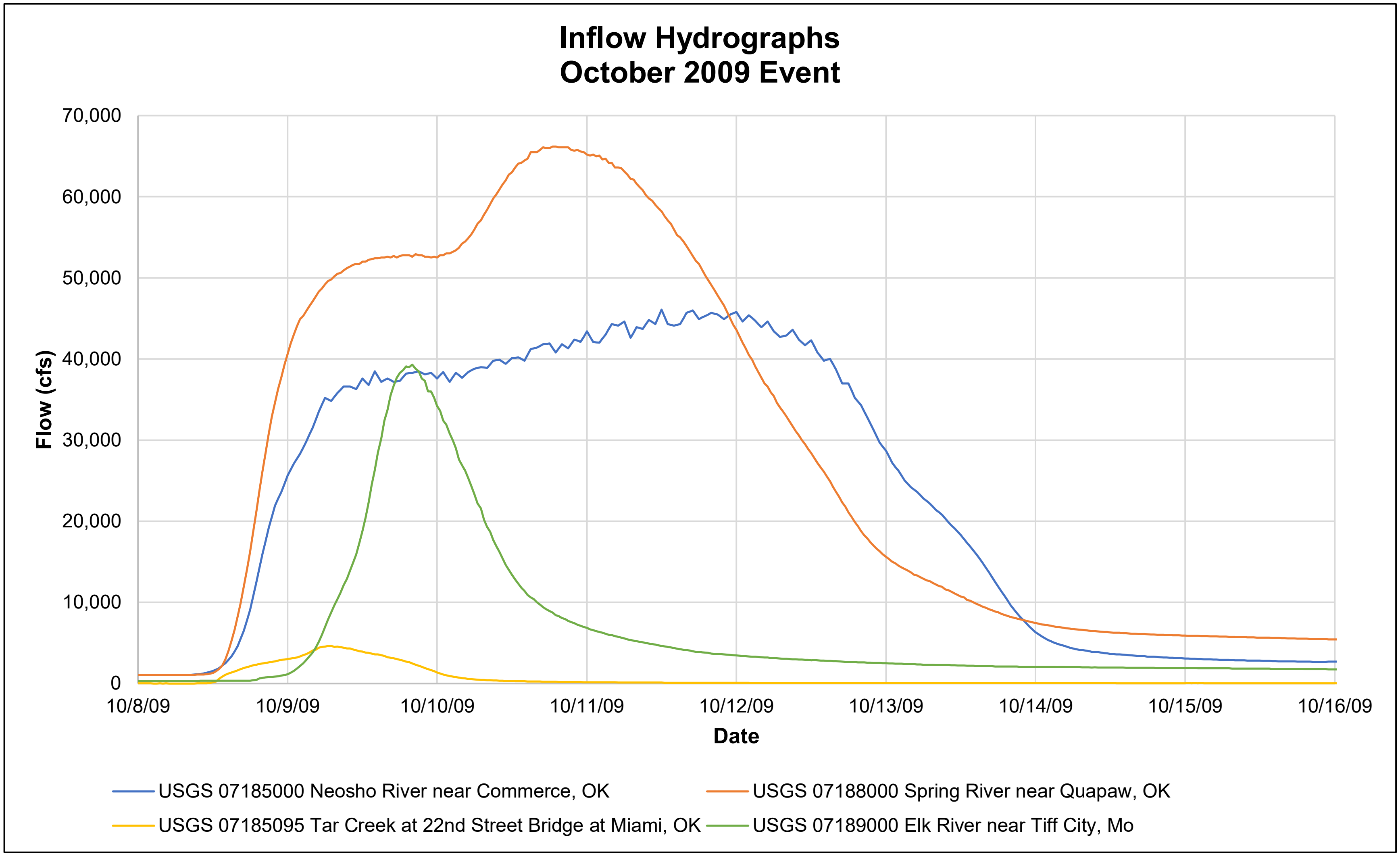


Figure C.4. Inflow hydrographs for the October 2009 event upstream of Pensacola Dam.

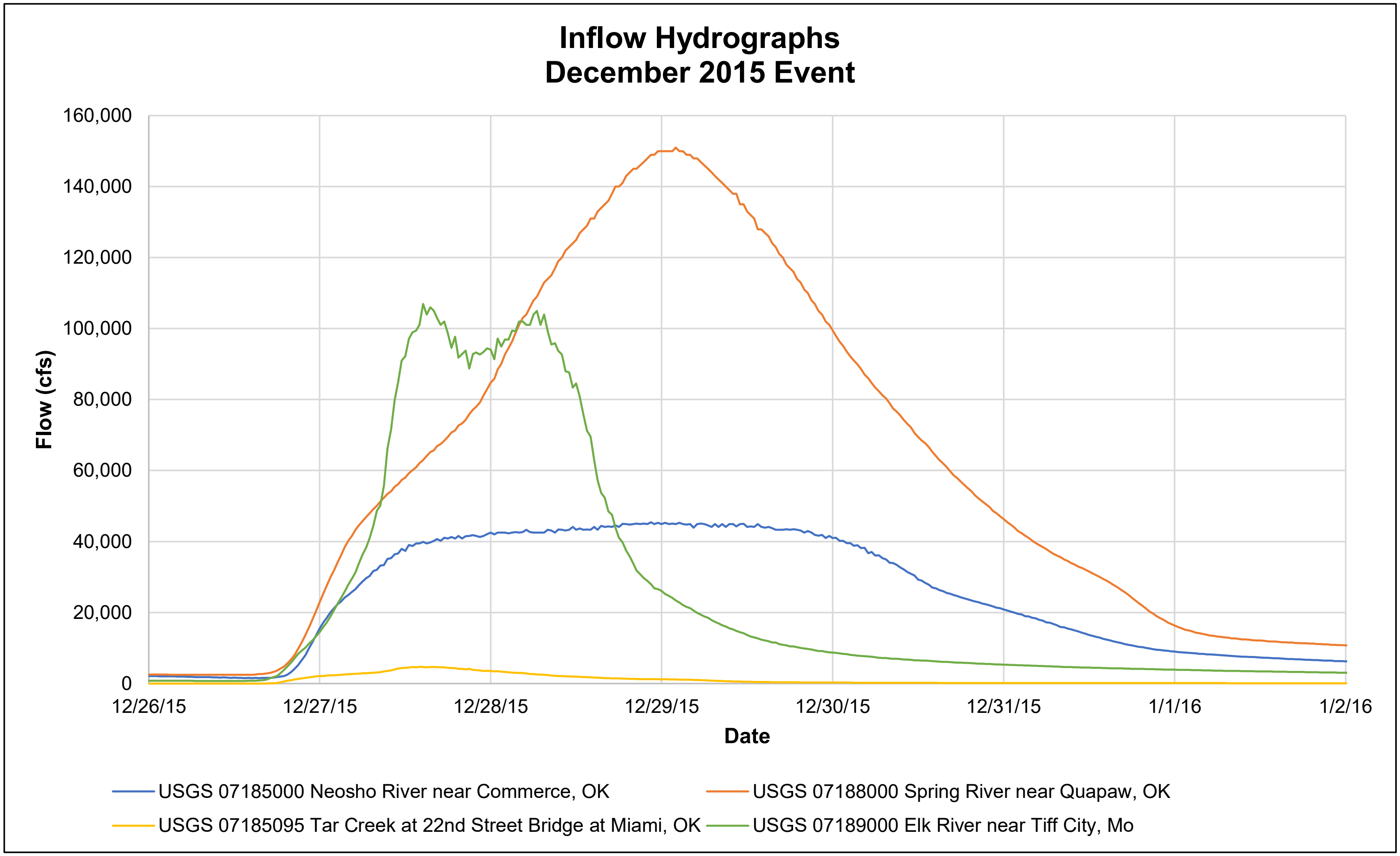


Figure C.5. Inflow hydrographs for the December 2015 event upstream of Pensacola Dam.

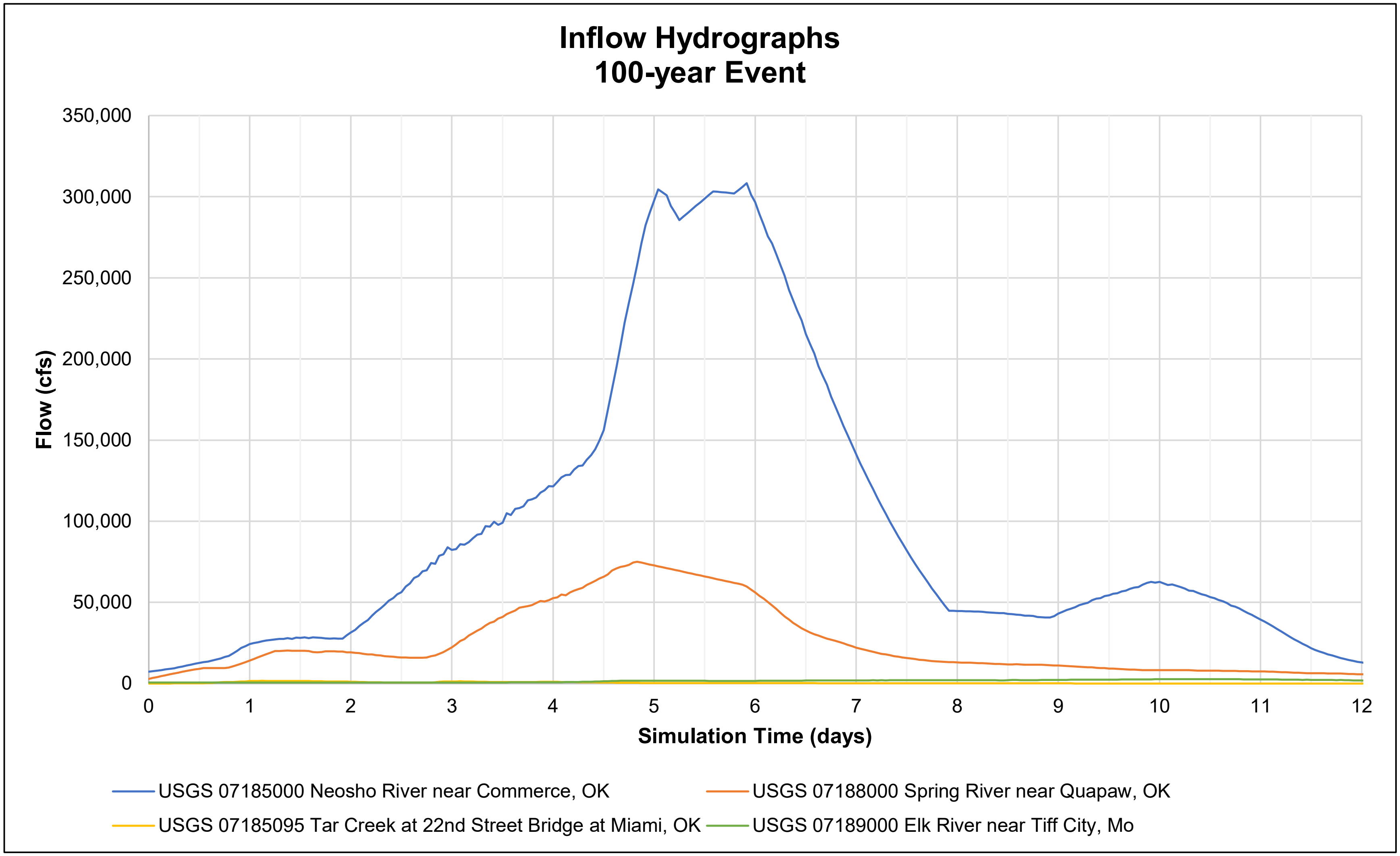


Figure C.6. Inflow hydrographs for the 100-year event upstream of Pensacola Dam.

Note: Because the 100-year event is synthetic, there is no historical start or end date, so stage hydrographs for the 100-year event are presented as a function of simulation time rather than date.

APPENDIX C.2:
STAGE HYDROGRAPHS

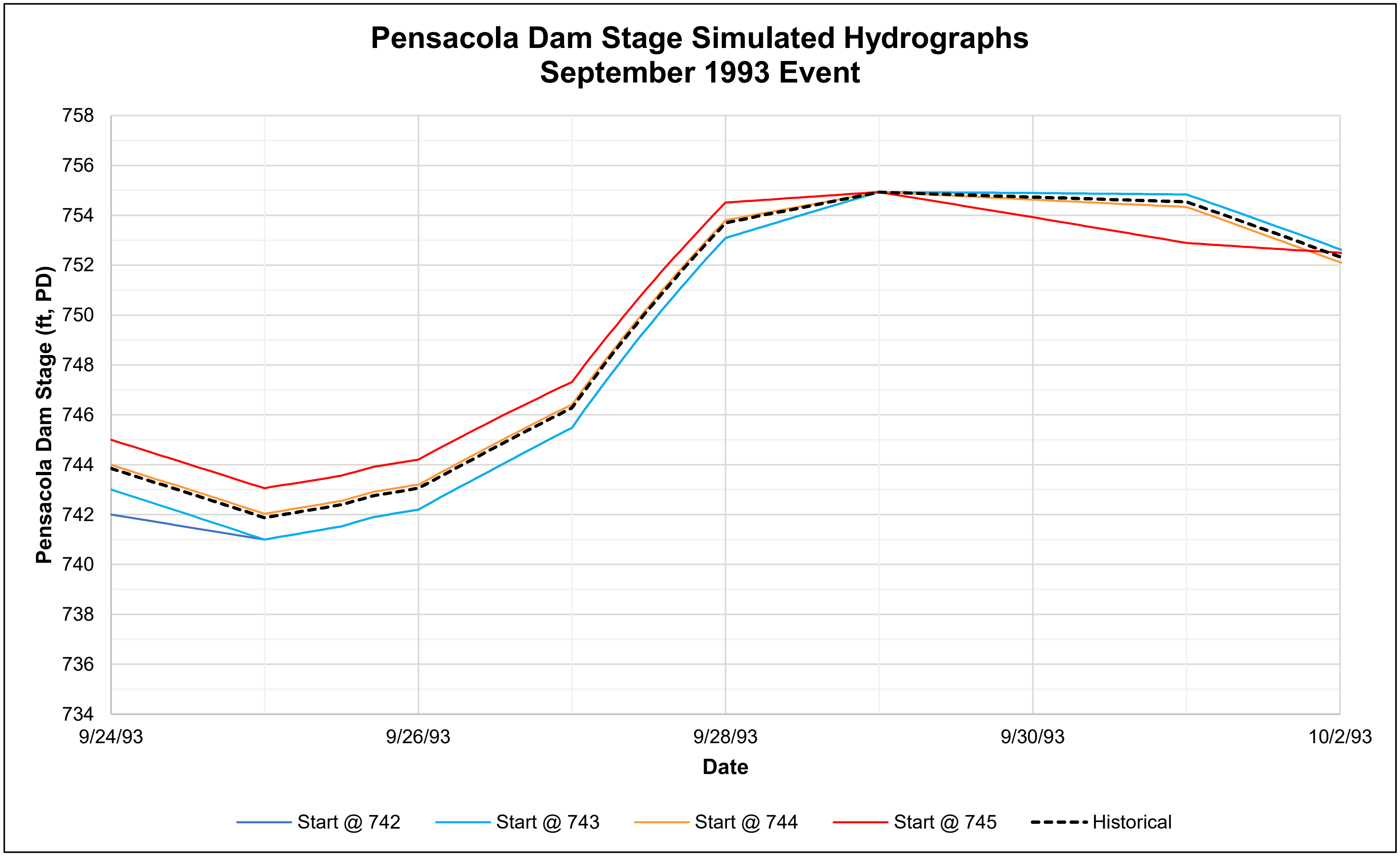


Figure C.7. Simulated stage hydrographs for the September 1993 event upstream of Pensacola Dam.

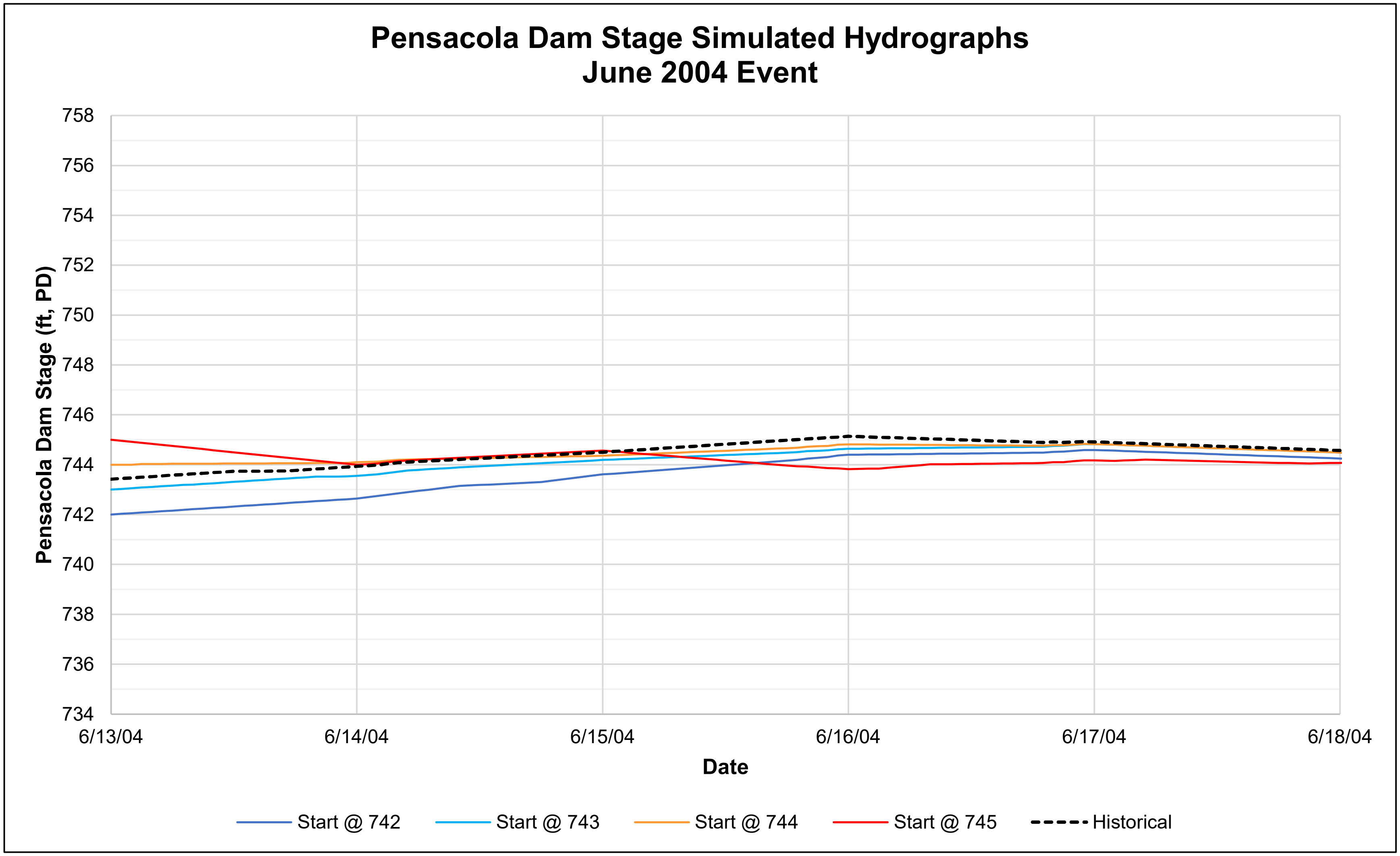


Figure C.8. Simulated stage hydrographs for the June 2004 event upstream of Pensacola Dam.

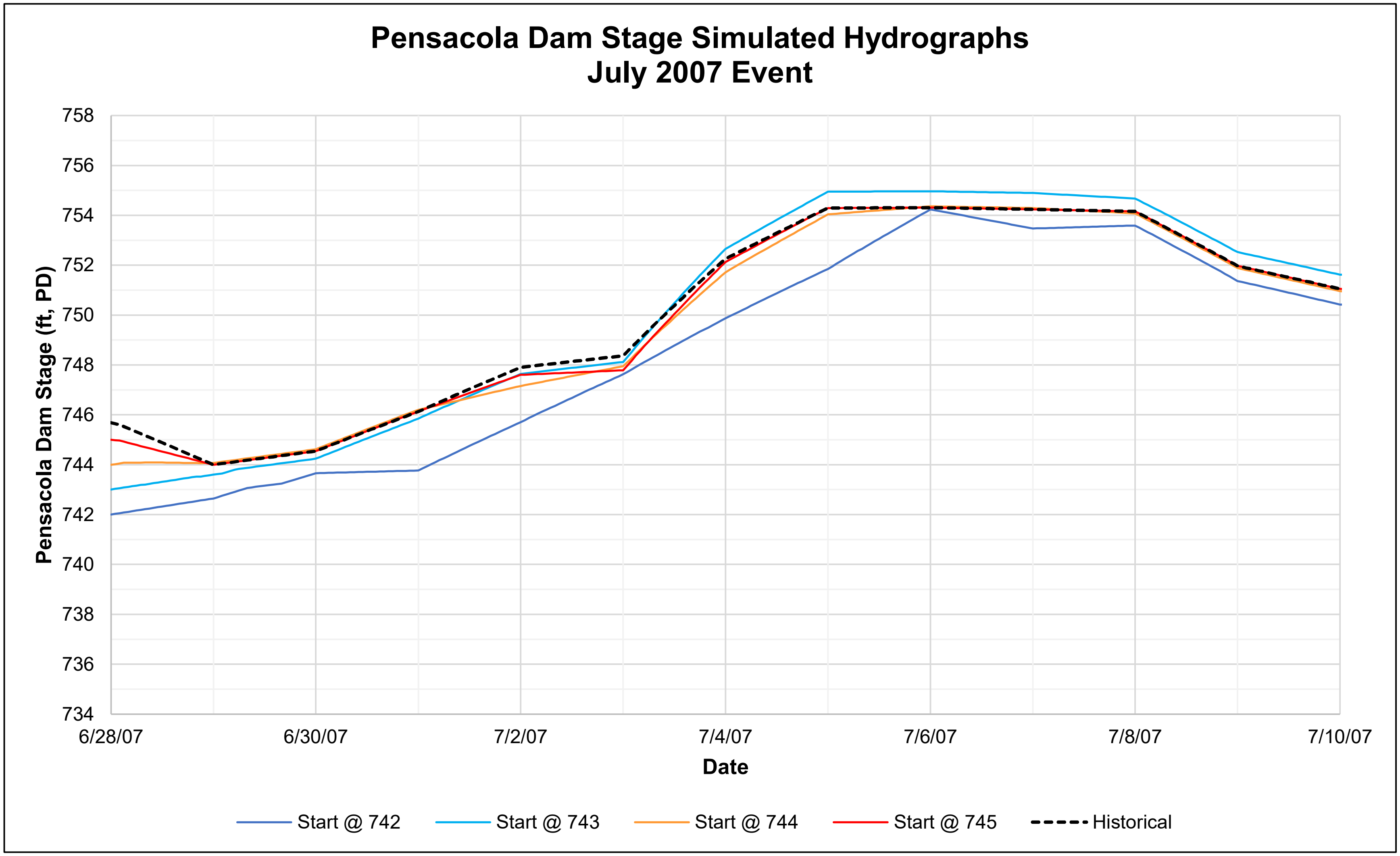


Figure C.9. Simulated stage hydrographs for the July 2007 event upstream of Pensacola Dam.

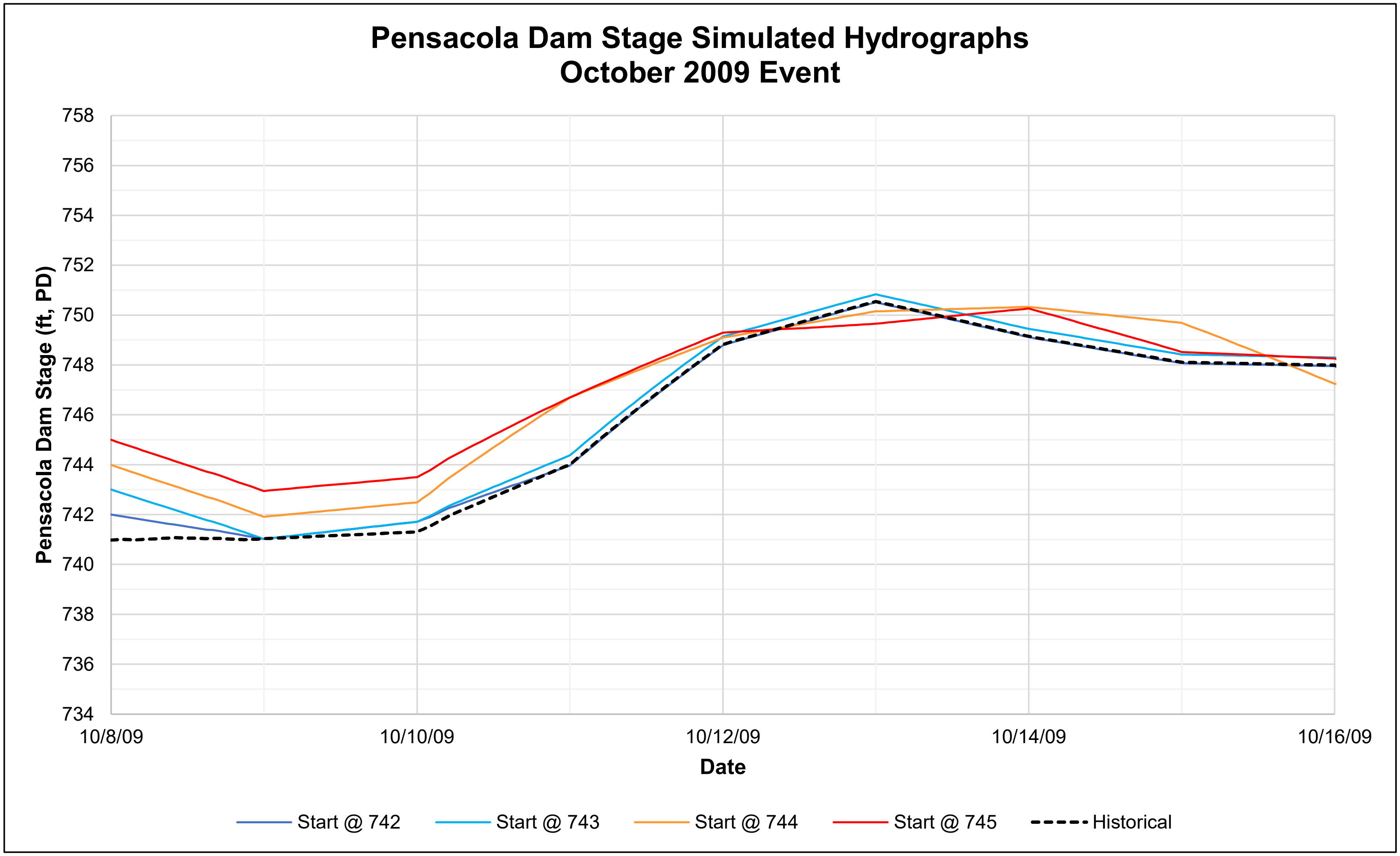


Figure C.10. Simulated stage hydrographs for the October 2009 event upstream of Pensacola Dam.

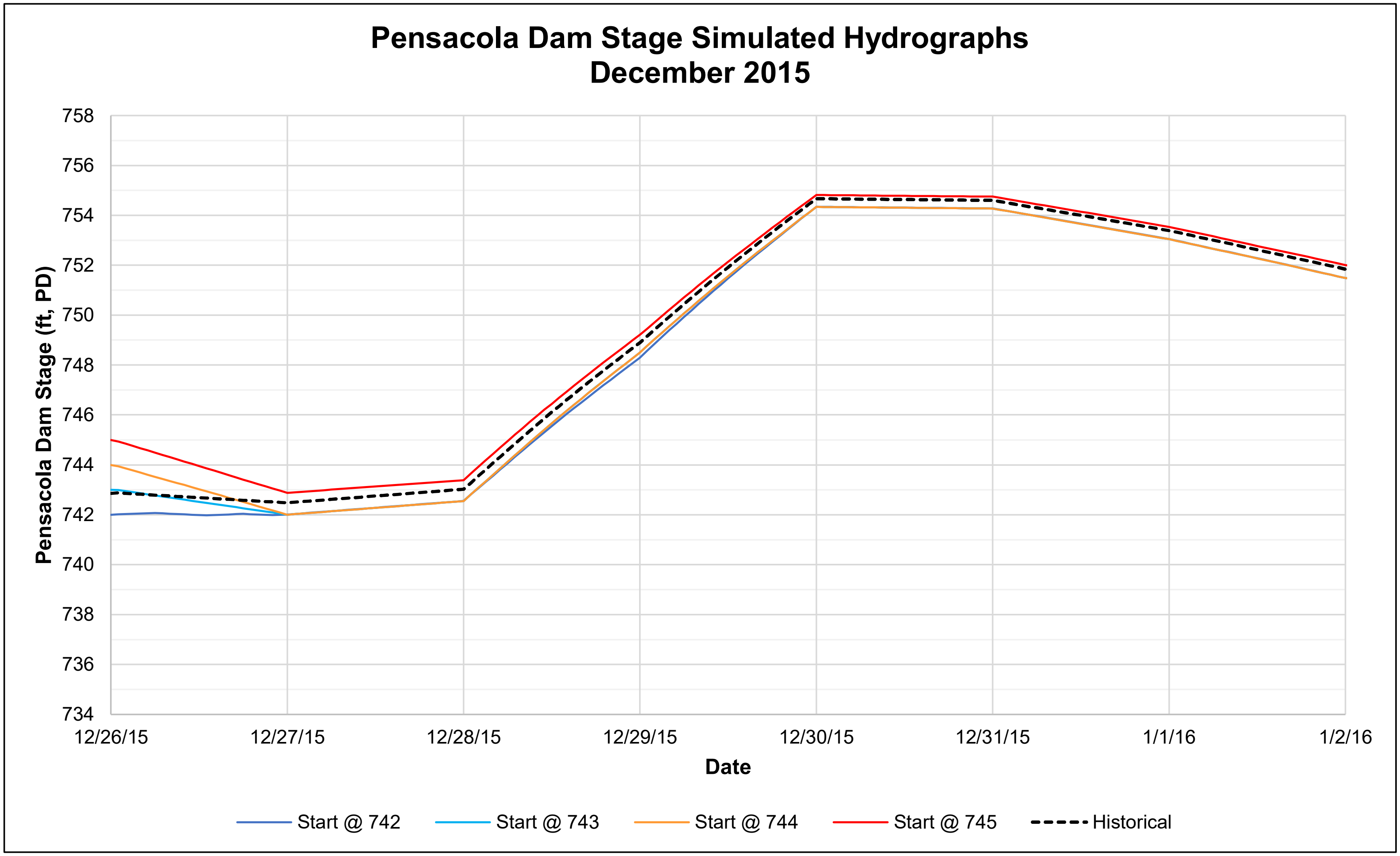


Figure C.11. Simulated stage hydrographs for the December 2015 event upstream of Pensacola Dam.

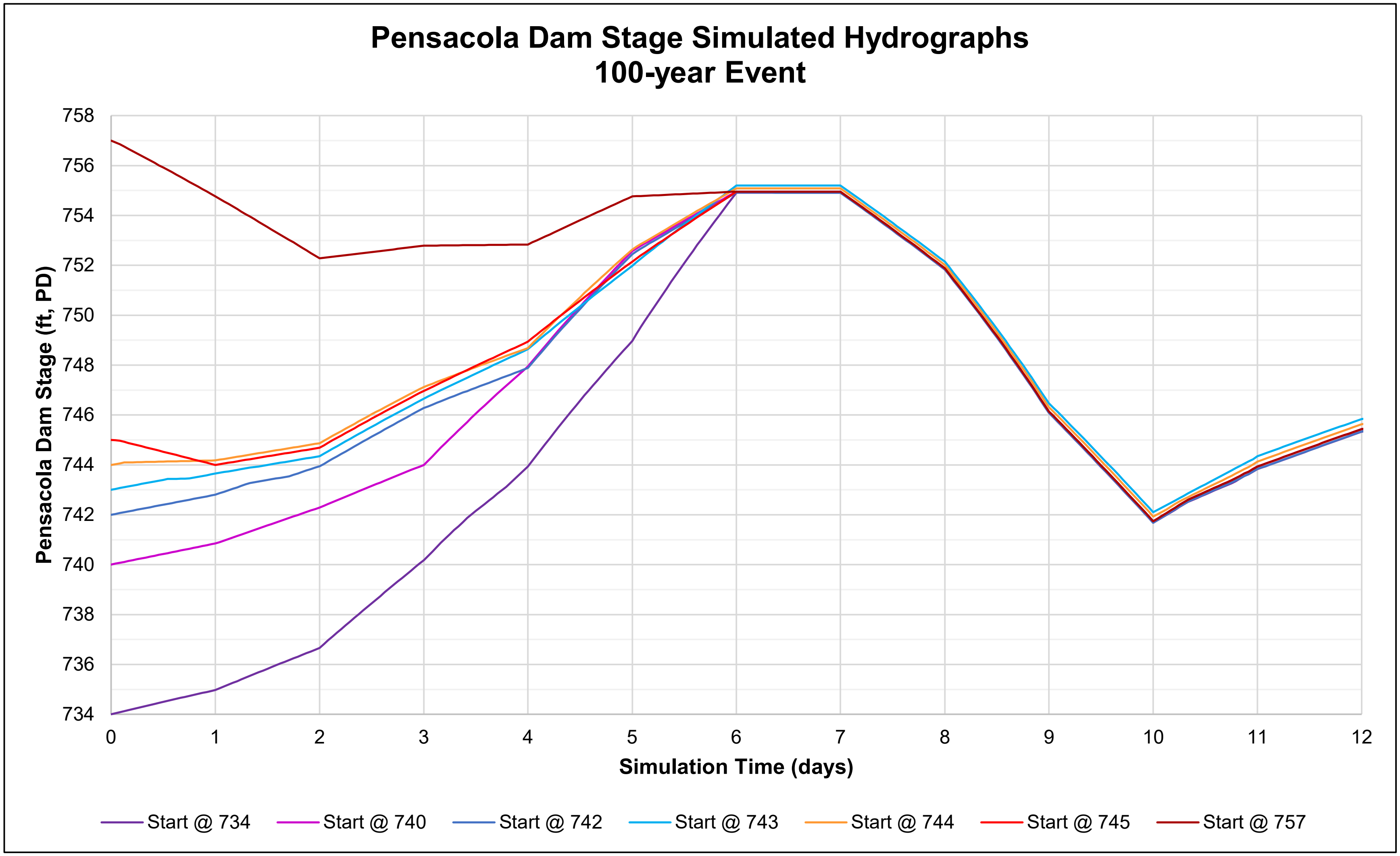


Figure C.12. Simulated stage hydrographs for the 100-year event upstream of Pensacola Dam.

Note: *Because the 100-year event is synthetic, there is no historical start or end date, so stage hydrographs for the 100-year event are presented as a function of simulation time rather than date.*

APPENDIX D:
MAX WATER SURFACE ELEVATIONS

APPENDIX D.1:
SEPTEMBER 1993 EVENT MAX WATER SURFACE ELEVATIONS

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
152.175	Upstream end of model					
152.175	752.29	780.71	780.71	780.71	780.71	0.00
152.000	749.79	779.82	779.82	779.82	779.82	0.00
151.000	748.53	777.94	777.94	777.94	777.94	0.00
150.000	748.47	776.66	776.66	776.66	776.66	0.00
149.000	750.14	775.12	775.12	775.12	775.12	0.00
148.000	749.29	774.25	774.25	774.25	774.25	0.00
147.000	747.76	772.71	772.71	772.72	772.72	0.01
146.000	747.81	772.32	772.32	772.33	772.34	0.02
145.500	745.12	771.62	771.62	771.63	771.65	0.03
145.480	E 60 Road Bridge					
145.400	748.01	771.55	771.55	771.56	771.58	0.03
145.000	741.47	771.22	771.22	771.24	771.26	0.03
144.000	743.43	770.54	770.54	770.56	770.59	0.05
143.000	737.95	770.07	770.07	770.10	770.13	0.06
142.000	742.91	769.71	769.71	769.74	769.78	0.07
141.000	741.01	769.57	769.57	769.61	769.64	0.07
140.000	736.33	769.53	769.53	769.56	769.60	0.07
139.000	743.99	769.48	769.48	769.52	769.56	0.07
138.000	736.48	769.40	769.40	769.43	769.48	0.08
137.000	733.33	769.08	769.08	769.12	769.17	0.09
136.000	731.75	768.37	768.37	768.42	768.47	0.10
135.950	731.18	768.37	768.37	768.42	768.47	0.10
135.941	Old Highway 69 Bridge					
135.940	731.21	768.36	768.36	768.41	768.47	0.11
135.590	731.77	768.21	768.21	768.26	768.32	0.11
135.586	BN RR Bridge					
135.580	731.07	768.03	768.03	768.08	768.14	0.11
135.470	732.63	767.98	767.98	768.03	768.09	0.11
135.460	Highway 125 Bridge					
135.440	731.60	768.01	768.01	768.07	768.13	0.12
135.000	732.64	767.73	767.73	767.79	767.85	0.12
134.610	728.75	767.23	767.23	767.29	767.36	0.13
134.599	Abandonded RR Bridge					
134.595	728.58	766.93	766.93	766.99	767.06	0.13
134.000	727.23	766.56	766.56	766.63	766.70	0.14
133.973	Tar Creek					
133.900	727.72	766.34	766.35	766.41	766.49	0.15
133.800	Interstate 44 Bridge					
133.700	728.57	766.15	766.15	766.22	766.30	0.15
133.000	727.70	765.47	765.47	765.56	765.65	0.18
132.000	727.96	764.58	764.58	764.68	764.79	0.20
131.000	726.82	763.83	763.83	763.93	764.06	0.23
130.000	723.18	762.94	762.94	763.07	763.22	0.28
129.000	719.79	762.08	762.08	762.24	762.41	0.33
128.000	719.69	761.71	761.71	761.76	761.82	0.11
127.000	716.37	761.58	761.58	761.62	761.69	0.11
126.710	715.94	761.55	761.55	761.60	761.66	0.11
126.700	S 590 Road Bridge					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
126.670	715.61	761.53	761.53	761.58	761.64	0.11
126.000	720.35	761.50	761.50	761.55	761.61	0.11
125.000	717.08	761.41	761.41	761.46	761.52	0.11
124.000	715.62	761.36	761.36	761.41	761.48	0.12
123.000	713.34	761.28	761.28	761.33	761.40	0.11
122.580	711.08	761.23	761.24	761.28	761.35	0.12
122.570	Highway 60 Bridge					
122.550	709.97	761.23	761.23	761.28	761.34	0.11
122.350	Spring River					
122.000	710.64	760.13	760.13	760.18	760.26	0.13
121.980	709.90	759.66	759.66	759.72	759.79	0.13
121.970	BN RR Bridge					
121.960	710.89	756.93	756.93	756.99	757.07	0.14
121.000	712.79	755.68	755.68	755.69	756.04	0.36
120.000	717.63	755.67	755.67	755.68	756.03	0.36
119.000	714.29	755.52	755.52	755.53	755.73	0.22
118.000	720.29	755.45	755.45	755.45	755.59	0.14
117.000	717.29	755.37	755.37	755.37	755.44	0.07
116.000	725.99	755.34	755.34	755.34	755.38	0.04
115.000	726.26	755.28	755.28	755.28	755.28	0.00
114.000	718.27	755.17	755.17	755.16	755.16	0.01
113.000	720.74	755.16	755.16	755.16	755.16	0.00
112.000	714.31	755.08	755.08	755.07	755.06	0.02
111.000	718.94	755.03	755.03	755.02	755.01	0.02
110.000	719.24	755.04	755.04	755.03	755.02	0.02
109.000	712.29	754.99	754.99	754.98	754.97	0.02
108.000	710.68	754.98	754.98	754.97	754.96	0.02
107.000	711.95	754.97	754.97	754.97	754.96	0.01
106.000	700.35	754.97	754.97	754.96	754.96	0.01
105.350	Elk River					
105.000	701.60	754.97	754.97	754.96	754.96	0.01
104.000	696.61	754.96	754.96	754.96	754.96	0.00
103.000	694.22	754.96	754.96	754.96	754.95	0.01
102.000	688.58	754.96	754.96	754.95	754.95	0.01
101.000	684.72	754.93	754.93	754.93	754.93	0.00
101.750	685.91	754.95	754.95	754.95	754.94	0.01
101.730	Highway 59 (Sailboat Bridge)					
101.710	682.31	754.94	754.94	754.94	754.93	0.01
100.000	702.62	754.94	754.94	754.94	754.94	0.00
99.000	714.86	754.94	754.94	754.94	754.94	0.00
98.000	701.83	754.94	754.94	754.94	754.94	0.00
97.000	689.54	754.94	754.94	754.94	754.94	0.00
96.000	672.30	754.94	754.94	754.94	754.94	0.00
95.000	669.27	754.94	754.94	754.94	754.94	0.00
94.000	686.65	754.94	754.94	754.93	754.94	0.00
93.000	693.39	754.94	754.94	754.93	754.93	0.00
92.000	692.74	754.93	754.93	754.93	754.93	0.00
91.000	657.21	754.93	754.93	754.93	754.93	0.00
90.000	681.52	754.93	754.93	754.93	754.93	0.00

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - SEPT 1993 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
89.000	674.45	754.93	754.93	754.93	754.93	0.00
88.000	672.60	754.93	754.93	754.93	754.93	0.00
87.000	674.44	754.93	754.93	754.93	754.93	0.00
86.000	671.68	754.93	754.93	754.93	754.93	0.00
85.000	665.48	754.93	754.93	754.93	754.93	0.00
84.000	669.51	754.93	754.93	754.93	754.93	0.00
83.000	656.25	754.93	754.93	754.93	754.93	0.00
82.000	632.89	754.93	754.93	754.93	754.93	0.00
81.000	631.68	754.93	754.93	754.93	754.93	0.00
80.000	657.03	754.93	754.93	754.93	754.93	0.00
79.000	649.03	754.93	754.93	754.93	754.93	0.00
78.000	653.11	754.93	754.93	754.93	754.93	0.00
77.000	Pensacola Dam					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.2**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - SEPT 1993 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
21.000	Upstream end of model					
21.000	762.67	805.10	805.10	805.10	805.10	0.00
20.000	760.13	804.41	804.41	804.41	804.41	0.00
19.000	759.04	803.09	803.09	803.09	803.09	0.00
18.000	753.18	800.93	800.93	800.93	800.93	0.00
17.000	750.54	799.10	799.10	799.10	799.10	0.00
16.000	749.28	796.17	796.17	796.17	796.17	0.00
15.000	746.37	794.15	794.15	794.15	794.15	0.00
14.170	741.32	791.71	791.71	791.71	791.71	0.00
14.160	E 57 Road					
14.120	744.21	789.81	789.81	789.81	789.81	0.00
14.000	744.86	789.14	789.14	789.14	789.14	0.00
13.510	744.59	786.79	786.79	786.79	786.79	0.00
13.500	Interstate 44 Bridge					
13.450	745.52	784.91	784.91	784.91	784.91	0.00
13.000	745.56	783.01	783.01	783.01	783.01	0.00
12.000	742.72	780.13	780.13	780.13	780.13	0.00
11.000	742.23	778.45	778.45	778.45	778.45	0.00
10.000	737.62	776.97	776.97	776.97	776.97	0.00
9.000	733.92	774.02	774.02	774.02	774.02	0.00
8.020	733.14	772.73	772.73	772.73	772.73	0.00
8.010	OK Highway 10 Bridge					
7.970	731.28	771.29	771.29	771.30	771.31	0.02
7.000	730.33	769.23	769.23	769.24	769.26	0.03
6.000	727.95	767.88	767.88	767.89	767.92	0.04
5.000	722.10	766.52	766.53	766.55	766.57	0.05
4.000	720.00	765.63	765.63	765.65	765.68	0.05
3.000	723.22	764.36	764.36	764.39	764.43	0.07
2.000	723.73	763.50	763.50	763.54	763.58	0.08
1.000	728.44	762.64	762.64	762.68	762.73	0.09
0.580	716.17	760.67	760.67	760.71	760.78	0.11
0.570	Highway 60 Bridge					
0.560	713.76	760.18	760.18	760.24	760.30	0.12
0.460	715.35	760.83	760.83	760.88	760.95	0.12
0.000	Downstream end of Spring River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
19.590	Upstream end of model					
19.590	771.15	787.52	787.52	787.52	787.52	0.00
19.000	767.51	785.42	785.42	785.42	785.42	0.00
18.000	765.41	781.77	781.77	781.77	781.77	0.00
17.000	762.53	777.78	777.78	777.78	777.78	0.00
16.000	756.63	773.42	773.42	773.42	773.42	0.00
15.000	754.26	769.55	769.55	769.55	769.55	0.00
14.240	750.52	766.33	766.33	766.33	766.33	0.00
14.220	Highway 43 Bridge					
14.200	750.12	766.08	766.08	766.08	766.08	0.00
14.000	747.07	764.91	764.91	764.91	764.91	0.00
13.000	745.41	760.77	760.77	760.77	760.77	0.00
12.000	741.15	757.41	757.41	757.41	757.41	0.00
11.910	OK/MO State Line					
11.000	741.93	755.03	755.03	755.01	754.99	0.04
10.000	734.62	755.02	755.02	755.00	754.98	0.04
9.000	734.66	755.01	755.01	754.99	754.97	0.04
8.000	724.21	755.00	755.00	754.99	754.97	0.03
7.000	728.21	755.00	755.00	754.98	754.97	0.03
6.000	727.13	754.99	754.99	754.98	754.96	0.03
5.000	721.05	754.99	754.99	754.98	754.96	0.03
4.700	716.13	754.99	754.99	754.97	754.96	0.03
4.670	OK Highway 10 Bridge					
4.640	715.21	754.99	754.99	754.97	754.96	0.03
4.000	716.61	754.98	754.98	754.97	754.96	0.02
3.000	714.74	754.98	754.98	754.97	754.96	0.02
2.000	709.09	754.98	754.98	754.97	754.96	0.02
1.000	705.82	754.97	754.97	754.96	754.96	0.01
0.320	706.36	754.97	754.97	754.96	754.96	0.01
0.000	Downstream end of Elk River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.4**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - SEPT 1993 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model					
4.152	762.17	776.77	776.77	776.77	776.77	0.00
3.900	760.10	775.76	775.76	775.76	775.76	0.00
3.840	22nd Ave Bridge					
3.800	762.30	774.50	774.50	774.50	774.50	0.00
3.300	759.46	772.27	772.27	772.27	772.27	0.00
2.800	756.73	768.46	768.46	768.46	768.46	0.00
2.710	BN RR Bridge					
2.700	755.72	767.11	767.11	767.11	767.11	0.01
2.500	754.95	766.47	766.47	766.53	766.61	0.15
2.300	754.15	766.47	766.47	766.53	766.61	0.15
2.200	Rockdale Blvd Bridge					
2.100	751.51	766.47	766.47	766.53	766.61	0.15
1.900	750.02	766.47	766.47	766.53	766.61	0.14
1.700	749.58	766.47	766.47	766.53	766.61	0.15
1.660	Central Ave Bridge					
1.600	746.47	766.47	766.47	766.53	766.61	0.15
1.500	744.29	766.47	766.47	766.53	766.61	0.14
1.400	OK Highway 10 Bridge					
1.300	742.00	766.47	766.47	766.53	766.61	0.14
1.000	739.34	766.46	766.47	766.53	766.61	0.15
0.700	737.06	766.47	766.47	766.53	766.61	0.14
0.300	736.42	766.47	766.47	766.54	766.62	0.15
0.041	735.85	766.45	766.46	766.52	766.60	0.15
0.000	Downstream end of Tar Creek					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

APPENDIX D.2:

JUNE 2004 EVENT MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUNE 2004 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
152.175	Upstream end of model					
152.175	752.29	773.78	773.79	773.79	773.79	0.00
152.000	749.79	773.47	773.48	773.48	773.48	0.00
151.000	748.53	772.52	772.52	772.52	772.52	0.01
150.000	748.47	771.81	771.82	771.82	771.82	0.01
149.000	750.14	770.44	770.44	770.44	770.44	0.00
148.000	749.29	768.75	768.76	768.76	768.76	0.01
147.000	747.76	766.93	766.93	766.94	766.94	0.01
146.000	747.81	766.06	766.07	766.08	766.08	0.02
145.500	745.12	764.70	764.71	764.72	764.72	0.02
145.480	E 60 Road Bridge					
145.400	748.01	764.60	764.61	764.61	764.62	0.02
145.000	741.47	764.15	764.16	764.17	764.17	0.02
144.000	743.43	763.33	763.34	763.35	763.35	0.02
143.000	737.95	762.16	762.18	762.19	762.19	0.03
142.000	742.91	761.24	761.26	761.27	761.27	0.03
141.000	741.01	760.07	760.10	760.11	760.12	0.04
140.000	736.33	758.73	758.77	758.79	758.79	0.06
139.000	743.99	756.70	756.76	756.79	756.80	0.10
138.000	736.48	755.29	755.37	755.41	755.41	0.12
137.000	733.33	753.23	753.37	753.43	753.46	0.23
136.000	731.75	752.70	752.84	752.90	752.93	0.24
135.950	731.18	752.63	752.78	752.84	752.87	0.24
135.941	Old Highway 69 Bridge					
135.940	731.21	752.39	752.55	752.62	752.65	0.26
135.590	731.77	752.46	752.62	752.68	752.71	0.25
135.586	BN RR Bridge					
135.580	731.07	752.49	752.65	752.71	752.74	0.25
135.470	732.63	752.38	752.54	752.60	752.64	0.26
135.460	Highway 125 Bridge					
135.440	731.60	752.44	752.59	752.66	752.69	0.25
135.000	732.64	752.13	752.30	752.37	752.40	0.28
134.610	728.75	751.96	752.14	752.20	752.24	0.28
134.599	Abandonded RR Bridge					
134.595	728.58	751.87	752.05	752.11	752.15	0.28
134.000	727.23	751.25	751.44	751.52	751.56	0.31
133.973	Tar Creek					
133.900	727.72	751.03	751.23	751.31	751.35	0.32
133.800	Interstate 44 Bridge					
133.700	728.57	750.69	750.90	750.98	751.03	0.34
133.000	727.70	749.47	749.72	749.81	749.88	0.40
132.000	727.96	748.18	748.48	748.59	748.67	0.49
131.000	726.82	747.03	747.38	747.51	747.61	0.58
130.000	723.18	746.70	747.07	747.20	747.31	0.61
129.000	719.79	746.17	746.56	746.70	746.81	0.64
128.000	719.69	746.05	746.44	746.59	746.71	0.65
127.000	716.37	745.78	746.18	746.33	746.45	0.67
126.710	715.94	745.75	746.15	746.30	746.42	0.67
126.700	S 590 Road Bridge					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
126.670	715.61	745.74	746.14	746.28	746.41	0.67
126.000	720.35	745.62	746.03	746.18	746.30	0.68
125.000	717.08	745.43	745.83	745.99	746.11	0.68
124.000	715.62	745.29	745.69	745.85	745.98	0.69
123.000	713.34	745.17	745.56	745.72	745.85	0.68
122.580	711.08	745.14	745.52	745.68	745.81	0.67
122.570	Highway 60 Bridge					
122.550	709.97	744.69	745.08	745.24	745.38	0.69
122.350	Spring River					
122.000	710.64	744.68	745.07	745.23	745.36	0.68
121.980	709.90	744.68	745.06	745.22	745.35	0.67
121.970	BN RR Bridge					
121.960	710.89	744.67	745.04	745.20	745.34	0.67
121.000	712.79	744.66	744.93	745.07	745.22	0.56
120.000	717.63	744.65	744.89	745.02	745.15	0.50
119.000	714.29	744.65	744.89	744.96	745.07	0.42
118.000	720.29	744.65	744.88	744.95	745.02	0.37
117.000	717.29	744.65	744.88	744.94	745.02	0.37
116.000	725.99	744.64	744.88	744.93	745.01	0.37
115.000	726.26	744.64	744.88	744.90	745.00	0.36
114.000	718.27	744.63	744.87	744.88	745.00	0.37
113.000	720.74	744.63	744.87	744.87	745.00	0.37
112.000	714.31	744.63	744.86	744.86	745.01	0.38
111.000	718.94	744.62	744.86	744.86	745.01	0.39
110.000	719.24	744.62	744.86	744.86	745.01	0.39
109.000	712.29	744.62	744.86	744.85	745.01	0.39
108.000	710.68	744.61	744.85	744.85	745.01	0.40
107.000	711.95	744.61	744.85	744.85	745.02	0.41
106.000	700.35	744.61	744.85	744.85	745.02	0.41
105.350	Elk River					
105.000	701.60	744.61	744.85	744.85	745.02	0.41
104.000	696.61	744.61	744.85	744.84	745.02	0.42
103.000	694.22	744.60	744.84	744.84	745.03	0.43
102.000	688.58	744.60	744.84	744.84	745.03	0.43
101.000	684.72	744.59	744.83	744.83	745.04	0.45
101.750	685.91	744.60	744.84	744.84	745.04	0.44
101.730	Highway 59 (Sailboat Bridge)					
101.710	682.31	744.60	744.84	744.84	745.04	0.44
100.000	702.62	744.59	744.83	744.83	745.01	0.42
99.000	714.86	744.59	744.83	744.83	745.01	0.42
98.000	701.83	744.59	744.83	744.83	745.01	0.42
97.000	689.54	744.59	744.83	744.83	745.01	0.42
96.000	672.30	744.59	744.83	744.83	745.01	0.42
95.000	669.27	744.59	744.83	744.83	745.01	0.42
94.000	686.65	744.59	744.83	744.83	745.01	0.42
93.000	693.39	744.59	744.83	744.83	745.01	0.42
92.000	692.74	744.59	744.83	744.83	745.01	0.42
91.000	657.21	744.59	744.83	744.83	745.01	0.42
90.000	681.52	744.59	744.83	744.83	745.01	0.42

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUNE 2004 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
89.000	674.45	744.59	744.83	744.83	745.01	0.42
88.000	672.60	744.59	744.83	744.83	745.01	0.42
87.000	674.44	744.59	744.83	744.83	745.01	0.42
86.000	671.68	744.59	744.83	744.83	745.01	0.42
85.000	665.48	744.59	744.83	744.83	745.00	0.41
84.000	669.51	744.59	744.83	744.83	745.00	0.41
83.000	656.25	744.59	744.83	744.83	745.00	0.41
82.000	632.89	744.59	744.83	744.83	745.00	0.41
81.000	631.68	744.59	744.83	744.83	745.00	0.41
80.000	657.03	744.59	744.83	744.83	745.00	0.41
79.000	649.03	744.59	744.83	744.83	745.00	0.41
78.000	653.11	744.59	744.83	744.83	745.00	0.41
77.000	Pensacola Dam					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
21.000	Upstream end of model					
21.000	762.67	773.88	773.88	773.88	773.88	0.00
20.000	760.13	771.04	771.04	771.04	771.04	0.00
19.000	759.04	768.52	768.52	768.52	768.52	0.00
18.000	753.18	764.57	764.57	764.57	764.57	0.00
17.000	750.54	762.75	762.75	762.75	762.75	0.00
16.000	749.28	760.33	760.34	760.34	760.34	0.01
15.000	746.37	758.33	758.33	758.34	758.34	0.02
14.170	741.32	757.45	757.46	757.47	757.47	0.02
14.160	E 57 Road					
14.120	744.21	757.48	757.48	757.49	757.50	0.02
14.000	744.86	757.37	757.37	757.38	757.39	0.02
13.510	744.59	756.83	756.84	756.85	756.86	0.03
13.500	Interstate 44 Bridge					
13.450	745.52	756.57	756.57	756.59	756.60	0.03
13.000	745.56	755.42	755.44	755.46	755.48	0.05
12.000	742.72	753.26	753.31	753.36	753.41	0.15
11.000	742.23	751.58	751.69	751.81	751.90	0.32
10.000	737.62	750.11	750.31	750.51	750.65	0.54
9.000	733.92	749.11	749.40	749.65	749.83	0.72
8.020	733.14	747.99	748.38	748.68	748.91	0.92
8.010	OK Highway 10 Bridge					
7.970	731.28	745.77	746.16	746.42	746.65	0.88
7.000	730.33	745.29	745.74	745.96	746.09	0.80
6.000	727.95	744.89	745.40	745.63	745.67	0.78
5.000	722.10	744.80	745.29	745.51	745.57	0.78
4.000	720.00	744.77	745.21	745.41	745.50	0.73
3.000	723.22	744.76	745.18	745.38	745.48	0.72
2.000	723.73	744.74	745.15	745.34	745.45	0.71
1.000	728.44	744.74	745.14	745.31	745.44	0.70
0.580	716.17	744.73	745.13	745.30	745.43	0.70
0.570	Highway 60 Bridge					
0.560	713.76	744.73	745.12	745.29	745.42	0.69
0.460	715.35	744.73	745.12	745.29	745.42	0.69
0.000	Downstream end of Spring River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
19.590	Upstream end of model					
19.590	771.15	774.17	774.17	774.17	774.17	0.00
19.000	767.51	772.64	772.64	772.64	772.64	0.00
18.000	765.41	769.18	769.18	769.18	769.18	0.00
17.000	762.53	766.13	766.13	766.13	766.13	0.00
16.000	756.63	761.16	761.16	761.16	761.16	0.00
15.000	754.26	757.92	757.92	757.92	757.92	0.00
14.240	750.52	753.18	753.18	753.18	753.18	0.00
14.220	Highway 43 Bridge					
14.200	750.12	753.10	753.10	753.10	753.10	0.00
14.000	747.07	752.78	752.78	752.78	752.78	0.00
13.000	745.41	749.01	749.01	749.01	749.01	0.00
12.000	741.15	746.06	746.02	746.01	746.01	0.05
11.910	OK/MO State Line					
11.000	741.93	744.90	745.07	745.08	745.16	0.26
10.000	734.62	744.66	744.89	744.87	745.07	0.41
9.000	734.66	744.65	744.89	744.87	745.05	0.40
8.000	724.21	744.64	744.88	744.87	745.04	0.40
7.000	728.21	744.64	744.88	744.87	745.02	0.38
6.000	727.13	744.64	744.87	744.86	745.01	0.37
5.000	721.05	744.63	744.87	744.86	745.01	0.38
4.700	716.13	744.63	744.87	744.86	745.01	0.38
4.670	OK Highway 10 Bridge					
4.640	715.21	744.63	744.87	744.86	745.01	0.38
4.000	716.61	744.62	744.86	744.86	745.01	0.39
3.000	714.74	744.62	744.86	744.86	745.01	0.39
2.000	709.09	744.62	744.86	744.85	745.02	0.39
1.000	705.82	744.61	744.85	744.85	745.02	0.41
0.320	706.36	744.61	744.85	744.85	745.02	0.41
0.000	Downstream end of Elk River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model					
4.152	762.17	768.17	768.17	768.17	768.17	0.00
3.900	760.10	767.29	767.29	767.29	767.29	0.00
3.840	22nd Ave Bridge					
3.800	762.30	766.05	766.05	766.05	766.05	0.00
3.300	759.46	764.09	764.09	764.09	764.09	0.00
2.800	756.73	760.95	760.95	760.95	760.95	0.00
2.710	BN RR Bridge					
2.700	755.72	760.45	760.45	760.45	760.45	0.00
2.500	754.95	759.30	759.30	759.30	759.30	0.00
2.300	754.15	757.47	757.47	757.47	757.47	0.00
2.200	Rockdale Blvd Bridge					
2.100	751.51	754.83	754.84	754.84	754.84	0.00
1.900	750.02	753.21	753.22	753.23	753.23	0.02
1.700	749.58	751.24	751.40	751.47	751.50	0.26
1.660	Central Ave Bridge					
1.600	746.47	751.17	751.37	751.44	751.49	0.31
1.500	744.29	751.17	751.37	751.44	751.49	0.31
1.400	OK Highway 10 Bridge					
1.300	742.00	751.17	751.37	751.44	751.49	0.31
1.000	739.34	751.17	751.37	751.44	751.49	0.31
0.700	737.06	751.17	751.37	751.44	751.49	0.31
0.300	736.42	751.17	751.37	751.44	751.49	0.31
0.041	735.85	751.17	751.36	751.44	751.48	0.31
0.000	Downstream end of Tar Creek					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

APPENDIX D.3:
JULY 2007 EVENT MAX WATER SURFACE ELEVATIONS

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
152.175	Upstream end of model					
152.175	752.29	784.43	784.43	784.43	784.43	0.00
152.000	749.79	783.27	783.27	783.27	783.27	0.00
151.000	748.53	780.33	780.33	780.33	780.33	0.00
150.000	748.47	778.90	778.90	778.90	778.90	0.00
149.000	750.14	777.45	777.46	777.45	777.45	0.01
148.000	749.29	777.08	777.09	777.09	777.09	0.01
147.000	747.76	776.21	776.23	776.22	776.22	0.02
146.000	747.81	775.99	776.01	776.00	776.00	0.02
145.500	745.12	775.71	775.74	775.73	775.73	0.03
145.480	E 60 Road Bridge					
145.400	748.01	775.67	775.70	775.69	775.69	0.03
145.000	741.47	775.49	775.52	775.51	775.51	0.03
144.000	743.43	775.07	775.11	775.09	775.10	0.04
143.000	737.95	774.79	774.84	774.82	774.82	0.05
142.000	742.91	774.55	774.60	774.58	774.59	0.05
141.000	741.01	774.43	774.48	774.46	774.47	0.05
140.000	736.33	774.39	774.44	774.42	774.43	0.05
139.000	743.99	774.36	774.41	774.39	774.40	0.06
138.000	736.48	774.29	774.34	774.32	774.33	0.06
137.000	733.33	774.07	774.13	774.10	774.11	0.06
136.000	731.75	773.47	773.55	773.52	773.53	0.08
135.950	731.18	773.41	773.49	773.46	773.47	0.08
135.941	Old Highway 69 Bridge					
135.940	731.21	773.43	773.51	773.48	773.49	0.08
135.590	731.77	773.25	773.34	773.30	773.31	0.09
135.586	BN RR Bridge					
135.580	731.07	773.18	773.27	773.23	773.25	0.09
135.470	732.63	773.11	773.20	773.16	773.17	0.09
135.460	Highway 125 Bridge					
135.440	731.60	773.16	773.24	773.21	773.22	0.08
135.000	732.64	772.83	772.92	772.88	772.89	0.09
134.610	728.75	772.35	772.46	772.42	772.43	0.11
134.599	Abandonded RR Bridge					
134.595	728.58	772.09	772.20	772.16	772.17	0.11
134.000	727.23	771.81	771.94	771.89	771.91	0.13
133.973	Tar Creek					
133.900	727.72	771.49	771.63	771.57	771.59	0.14
133.800	Interstate 44 Bridge					
133.700	728.57	771.15	771.29	771.23	771.25	0.14
133.000	727.70	770.46	770.63	770.57	770.59	0.17
132.000	727.96	769.27	769.49	769.41	769.43	0.22
131.000	726.82	768.28	768.56	768.46	768.49	0.27
130.000	723.18	766.97	767.31	767.19	767.23	0.34
129.000	719.79	765.71	766.14	765.99	766.04	0.43
128.000	719.69	764.59	765.11	764.93	764.99	0.53
127.000	716.37	763.14	763.84	763.59	763.66	0.70
126.710	715.94	762.67	763.42	763.17	763.24	0.75
126.700	S 590 Road Bridge					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
126.670	715.61	762.61	763.38	763.12	763.20	0.77
126.000	720.35	761.95	762.81	762.52	762.61	0.86
125.000	717.08	760.36	761.45	761.10	761.19	1.09
124.000	715.62	758.71	760.07	759.64	759.76	1.36
123.000	713.34	757.20	758.49	757.94	758.08	1.29
122.580	711.08	756.23	757.34	756.73	756.88	1.11
122.570	Highway 60 Bridge					
122.550	709.97	756.18	757.35	756.71	756.88	1.17
122.350	Spring River					
122.000	710.64	755.93	757.07	756.40	756.57	1.14
121.980	709.90	755.81	756.92	756.25	756.41	1.11
121.970	BN RR Bridge					
121.960	710.89	755.48	756.42	755.77	755.92	0.94
121.000	712.79	755.02	755.88	755.17	755.32	0.86
120.000	717.63	755.01	755.87	755.17	755.31	0.86
119.000	714.29	754.85	755.68	754.99	755.10	0.84
118.000	720.29	754.77	755.59	754.91	755.00	0.82
117.000	717.29	754.69	755.49	754.82	754.89	0.80
116.000	725.99	754.66	755.46	754.80	754.86	0.80
115.000	726.26	754.60	755.38	754.72	754.77	0.78
114.000	718.27	754.48	755.25	754.60	754.61	0.76
113.000	720.74	754.47	755.24	754.60	754.60	0.77
112.000	714.31	754.39	755.14	754.50	754.49	0.74
111.000	718.94	754.34	755.07	754.45	754.42	0.73
110.000	719.24	754.34	755.08	754.46	754.43	0.74
109.000	712.29	754.30	755.03	754.41	754.37	0.73
108.000	710.68	754.29	755.01	754.40	754.35	0.72
107.000	711.95	754.28	755.01	754.39	754.35	0.73
106.000	700.35	754.27	755.00	754.39	754.34	0.73
105.350	Elk River					
105.000	701.60	754.27	755.00	754.39	754.34	0.73
104.000	696.61	754.27	754.99	754.39	754.34	0.72
103.000	694.22	754.26	754.99	754.39	754.34	0.73
102.000	688.58	754.26	754.98	754.38	754.33	0.72
101.000	684.72	754.23	754.96	754.36	754.31	0.73
101.750	685.91	754.25	754.98	754.38	754.33	0.73
101.730	Highway 59 (Sailboat Bridge)					
101.710	682.31	754.24	754.97	754.37	754.32	0.73
100.000	702.62	754.24	754.97	754.37	754.32	0.73
99.000	714.86	754.23	754.97	754.37	754.32	0.74
98.000	701.83	754.23	754.97	754.37	754.32	0.73
97.000	689.54	754.23	754.97	754.37	754.32	0.73
96.000	672.30	754.23	754.97	754.37	754.32	0.73
95.000	669.27	754.23	754.97	754.37	754.32	0.73
94.000	686.65	754.23	754.97	754.37	754.32	0.73
93.000	693.39	754.23	754.97	754.36	754.32	0.73
92.000	692.74	754.23	754.97	754.36	754.31	0.73
91.000	657.21	754.23	754.96	754.36	754.31	0.73
90.000	681.52	754.23	754.96	754.36	754.31	0.73

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
89.000	674.45	754.23	754.96	754.36	754.31	0.73
88.000	672.60	754.23	754.96	754.36	754.31	0.73
87.000	674.44	754.23	754.96	754.36	754.31	0.73
86.000	671.68	754.23	754.96	754.36	754.31	0.73
85.000	665.48	754.23	754.96	754.36	754.31	0.73
84.000	669.51	754.23	754.96	754.36	754.31	0.73
83.000	656.25	754.23	754.96	754.36	754.31	0.73
82.000	632.89	754.23	754.96	754.36	754.31	0.73
81.000	631.68	754.23	754.96	754.36	754.31	0.73
80.000	657.03	754.23	754.96	754.36	754.31	0.73
79.000	649.03	754.23	754.96	754.36	754.31	0.73
78.000	653.11	754.23	754.96	754.36	754.31	0.73
77.000	Pensacola Dam					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.10**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - JULY 2007 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
21.000	Upstream end of model					
21.000	762.67	783.49	783.49	783.49	783.49	0.00
20.000	760.13	780.70	780.70	780.70	780.70	0.00
19.000	759.04	777.52	777.52	777.52	777.52	0.00
18.000	753.18	774.20	774.20	774.20	774.20	0.00
17.000	750.54	772.20	772.20	772.20	772.20	0.00
16.000	749.28	770.00	770.00	770.00	770.00	0.00
15.000	746.37	767.51	767.51	767.51	767.51	0.01
14.170	741.32	765.96	765.96	765.96	765.96	0.00
14.160	E 57 Road					
14.120	744.21	766.18	766.18	766.18	766.18	0.00
14.000	744.86	766.01	766.01	766.01	766.01	0.00
13.510	744.59	765.30	765.30	765.30	765.30	0.00
13.500	Interstate 44 Bridge					
13.450	745.52	764.98	764.98	764.98	764.98	0.00
13.000	745.56	763.85	763.85	763.85	763.85	0.00
12.000	742.72	762.16	762.17	762.16	762.16	0.01
11.000	742.23	760.39	760.40	760.39	760.39	0.01
10.000	737.62	758.86	758.87	758.87	758.87	0.01
9.000	733.92	757.53	758.65	758.07	758.23	1.12
8.020	733.14	757.49	758.60	758.02	758.17	1.11
8.010	OK Highway 10 Bridge					
7.970	731.28	756.30	757.52	756.88	757.05	1.22
7.000	730.33	756.27	757.49	756.84	757.01	1.22
6.000	727.95	756.26	757.47	756.82	756.99	1.21
5.000	722.10	756.25	757.46	756.81	756.98	1.21
4.000	720.00	756.24	757.45	756.81	756.97	1.21
3.000	723.22	756.24	757.45	756.80	756.97	1.21
2.000	723.73	756.23	757.45	756.80	756.96	1.22
1.000	728.44	756.23	757.44	756.80	756.96	1.21
0.580	716.17	756.23	757.44	756.79	756.96	1.21
0.570	Highway 60 Bridge					
0.560	713.76	756.22	757.43	756.78	756.95	1.21
0.460	715.35	756.22	757.43	756.79	756.95	1.21
0.000	Downstream end of Spring River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.11**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - JULY 2007 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
19.590	Upstream end of model					
19.590	771.15	775.57	775.57	775.57	775.57	0.00
19.000	767.51	774.03	774.03	774.03	774.03	0.00
18.000	765.41	770.46	770.46	770.46	770.46	0.00
17.000	762.53	767.01	767.01	767.01	767.01	0.00
16.000	756.63	762.78	762.78	762.78	762.78	0.00
15.000	754.26	759.23	759.23	759.23	759.23	0.00
14.240	750.52	755.03	755.52	755.21	755.25	0.49
14.220	Highway 43 Bridge					
14.200	750.12	755.00	755.49	755.18	755.22	0.49
14.000	747.07	754.87	755.38	755.00	755.04	0.51
13.000	745.41	754.41	755.13	754.49	754.47	0.72
12.000	741.15	754.35	755.09	754.42	754.42	0.74
11.910	OK/MO State Line					
11.000	741.93	754.33	755.08	754.41	754.40	0.75
10.000	734.62	754.32	755.06	754.40	754.39	0.74
9.000	734.66	754.32	755.06	754.40	754.38	0.74
8.000	724.21	754.31	755.05	754.40	754.38	0.74
7.000	728.21	754.31	755.04	754.40	754.37	0.73
6.000	727.13	754.30	755.03	754.40	754.37	0.73
5.000	721.05	754.30	755.03	754.40	754.36	0.73
4.700	716.13	754.29	755.02	754.40	754.36	0.73
4.670	OK Highway 10 Bridge					
4.640	715.21	754.29	755.02	754.40	754.36	0.73
4.000	716.61	754.29	755.02	754.39	754.35	0.73
3.000	714.74	754.29	755.01	754.39	754.35	0.72
2.000	709.09	754.28	755.01	754.39	754.35	0.73
1.000	705.82	754.28	755.00	754.39	754.34	0.72
0.320	706.36	754.27	755.00	754.39	754.34	0.73
0.000	Downstream end of Elk River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.12**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - JULY 2007 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model					
4.152	762.17	771.89	772.02	771.97	771.99	0.13
3.900	760.10	771.89	772.02	771.97	771.99	0.13
3.840	22nd Ave Bridge					
3.800	762.30	771.89	772.02	771.97	771.99	0.13
3.300	759.46	771.89	772.02	771.97	771.99	0.13
2.800	756.73	771.89	772.02	771.97	771.99	0.13
2.710	BN RR Bridge					
2.700	755.72	771.89	772.02	771.97	771.99	0.13
2.500	754.95	771.89	772.02	771.97	771.99	0.13
2.300	754.15	771.89	772.02	771.97	771.99	0.13
2.200	Rockdale Blvd Bridge					
2.100	751.51	771.89	772.02	771.97	771.99	0.13
1.900	750.02	771.89	772.02	771.97	771.99	0.13
1.700	749.58	771.89	772.02	771.97	771.99	0.13
1.660	Central Ave Bridge					
1.600	746.47	771.89	772.02	771.97	771.99	0.13
1.500	744.29	771.89	772.02	771.97	771.99	0.13
1.400	OK Highway 10 Bridge					
1.300	742.00	771.89	772.02	771.97	771.98	0.13
1.000	739.34	771.88	772.01	771.96	771.98	0.13
0.700	737.06	771.87	772.00	771.95	771.97	0.13
0.300	736.42	771.81	771.94	771.89	771.91	0.13
0.041	735.85	771.72	771.85	771.80	771.82	0.13
0.000	Downstream end of Tar Creek					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

APPENDIX D.4:

OCTOBER 2009 EVENT MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - OCT 2009 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
152.175	Upstream end of model					
152.175	752.29	778.47	778.47	778.47	778.47	0.00
152.000	749.79	777.86	777.86	777.86	777.86	0.00
151.000	748.53	776.35	776.35	776.35	776.35	0.00
150.000	748.47	775.17	775.17	775.17	775.17	0.00
149.000	750.14	773.78	773.78	773.78	773.78	0.00
148.000	749.29	772.40	772.40	772.40	772.40	0.00
147.000	747.76	770.52	770.52	770.52	770.52	0.00
146.000	747.81	769.75	769.75	769.75	769.75	0.00
145.500	745.12	768.34	768.34	768.35	768.35	0.00
145.480	E 60 Road Bridge					
145.400	748.01	768.23	768.23	768.24	768.24	0.00
145.000	741.47	767.66	767.66	767.66	767.66	0.00
144.000	743.43	766.46	766.46	766.46	766.46	0.00
143.000	737.95	765.01	765.01	765.02	765.02	0.01
142.000	742.91	763.83	763.84	763.85	763.85	0.02
141.000	741.01	763.18	763.19	763.20	763.21	0.03
140.000	736.33	762.84	762.85	762.86	762.87	0.03
139.000	743.99	762.32	762.34	762.36	762.37	0.04
138.000	736.48	761.90	761.91	761.94	761.95	0.05
137.000	733.33	760.87	760.89	760.91	760.92	0.06
136.000	731.75	760.21	760.24	760.26	760.27	0.06
135.950	731.18	760.20	760.23	760.25	760.26	0.06
135.941	Old Highway 69 Bridge					
135.940	731.21	760.17	760.19	760.21	760.22	0.05
135.590	731.77	760.10	760.13	760.15	760.16	0.06
135.586	BN RR Bridge					
135.580	731.07	760.08	760.10	760.12	760.14	0.06
135.470	732.63	759.99	760.02	760.04	760.05	0.06
135.460	Highway 125 Bridge					
135.440	731.60	760.04	760.06	760.08	760.09	0.05
135.000	732.64	759.92	759.94	759.96	759.98	0.06
134.610	728.75	759.65	759.68	759.70	759.71	0.06
134.599	Abandonded RR Bridge					
134.595	728.58	759.47	759.50	759.52	759.53	0.06
134.000	727.23	758.86	758.90	758.91	758.93	0.06
133.973	Tar Creek					
133.900	727.72	758.62	758.66	758.67	758.69	0.06
133.800	Interstate 44 Bridge					
133.700	728.57	758.36	758.39	758.41	758.42	0.06
133.000	727.70	757.19	757.24	757.24	757.26	0.07
132.000	727.96	755.90	755.95	755.96	755.99	0.08
131.000	726.82	754.80	754.87	754.88	754.92	0.12
130.000	723.18	754.36	754.43	754.46	754.50	0.14
129.000	719.79	753.68	753.82	753.88	753.95	0.27
128.000	719.69	753.41	753.55	753.61	753.68	0.27
127.000	716.37	752.95	753.09	753.17	753.25	0.30
126.710	715.94	752.87	753.01	753.09	753.17	0.30
126.700	S 590 Road Bridge					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
126.670	715.61	752.85	752.99	753.07	753.15	0.30
126.000	720.35	752.81	752.96	753.04	753.12	0.31
125.000	717.08	752.50	752.66	752.75	752.83	0.33
124.000	715.62	752.32	752.48	752.58	752.66	0.34
123.000	713.34	752.08	752.24	752.35	752.42	0.34
122.580	711.08	751.98	752.15	752.27	752.33	0.35
122.570	Highway 60 Bridge					
122.550	709.97	751.74	751.91	752.03	752.11	0.37
122.350	Spring River					
122.000	710.64	751.49	751.70	751.75	751.85	0.36
121.980	709.90	751.38	751.65	751.60	751.71	0.33
121.970	BN RR Bridge					
121.960	710.89	751.35	751.63	751.53	751.63	0.28
121.000	712.79	751.05	751.35	750.75	750.82	0.60
120.000	717.63	751.04	751.34	750.74	750.79	0.60
119.000	714.29	750.94	751.24	750.63	750.52	0.72
118.000	720.29	750.89	751.19	750.57	750.39	0.80
117.000	717.29	750.83	751.14	750.50	750.33	0.81
116.000	725.99	750.81	751.12	750.48	750.33	0.79
115.000	726.26	750.76	751.07	750.42	750.32	0.75
114.000	718.27	750.68	751.00	750.36	750.30	0.70
113.000	720.74	750.67	750.99	750.36	750.30	0.69
112.000	714.31	750.61	750.94	750.35	750.29	0.65
111.000	718.94	750.58	750.91	750.34	750.28	0.63
110.000	719.24	750.58	750.91	750.34	750.28	0.63
109.000	712.29	750.55	750.88	750.34	750.28	0.60
108.000	710.68	750.55	750.88	750.33	750.28	0.60
107.000	711.95	750.54	750.87	750.34	750.28	0.59
106.000	700.35	750.54	750.87	750.34	750.28	0.59
105.350	Elk River					
105.000	701.60	750.54	750.87	750.34	750.28	0.59
104.000	696.61	750.53	750.86	750.34	750.28	0.58
103.000	694.22	750.53	750.86	750.34	750.28	0.58
102.000	688.58	750.52	750.85	750.34	750.27	0.58
101.000	684.72	750.51	750.84	750.33	750.27	0.57
101.750	685.91	750.52	750.85	750.33	750.27	0.58
101.730	Highway 59 (Sailboat Bridge)					
101.710	682.31	750.52	750.85	750.33	750.27	0.58
100.000	702.62	750.51	750.84	750.33	750.27	0.57
99.000	714.86	750.51	750.84	750.33	750.27	0.57
98.000	701.83	750.51	750.84	750.33	750.27	0.57
97.000	689.54	750.51	750.84	750.33	750.27	0.57
96.000	672.30	750.51	750.84	750.33	750.27	0.57
95.000	669.27	750.51	750.84	750.33	750.27	0.57
94.000	686.65	750.51	750.84	750.33	750.27	0.57
93.000	693.39	750.51	750.84	750.33	750.27	0.57
92.000	692.74	750.51	750.84	750.33	750.27	0.57
91.000	657.21	750.51	750.84	750.33	750.27	0.57
90.000	681.52	750.51	750.84	750.33	750.27	0.57

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - OCT 2009 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
89.000	674.45	750.51	750.84	750.33	750.27	0.57
88.000	672.60	750.51	750.84	750.33	750.27	0.57
87.000	674.44	750.51	750.84	750.33	750.27	0.57
86.000	671.68	750.51	750.84	750.33	750.27	0.57
85.000	665.48	750.51	750.84	750.33	750.27	0.57
84.000	669.51	750.51	750.84	750.33	750.27	0.57
83.000	656.25	750.51	750.84	750.33	750.27	0.57
82.000	632.89	750.51	750.84	750.33	750.27	0.57
81.000	631.68	750.51	750.84	750.33	750.27	0.57
80.000	657.03	750.51	750.84	750.33	750.27	0.57
79.000	649.03	750.51	750.84	750.33	750.27	0.57
78.000	653.11	750.51	750.84	750.33	750.27	0.57
77.000	Pensacola Dam					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
21.000	Upstream end of model					
21.000	762.67	790.77	790.77	790.77	790.77	0.00
20.000	760.13	788.92	788.92	788.92	788.92	0.00
19.000	759.04	785.68	785.68	785.68	785.68	0.00
18.000	753.18	782.60	782.60	782.60	782.60	0.00
17.000	750.54	780.53	780.53	780.53	780.53	0.00
16.000	749.28	778.12	778.12	778.12	778.12	0.00
15.000	746.37	775.15	775.15	775.15	775.15	0.00
14.170	741.32	772.81	772.81	772.81	772.81	0.00
14.160	E 57 Road					
14.120	744.21	773.22	773.22	773.22	773.22	0.00
14.000	744.86	772.99	772.99	772.99	772.99	0.01
13.510	744.59	772.08	772.08	772.08	772.08	0.00
13.500	Interstate 44 Bridge					
13.450	745.52	771.61	771.61	771.61	771.61	0.00
13.000	745.56	770.16	770.16	770.17	770.17	0.01
12.000	742.72	767.89	767.89	767.89	767.89	0.00
11.000	742.23	765.98	765.98	765.98	765.99	0.01
10.000	737.62	764.46	764.46	764.47	764.47	0.01
9.000	733.92	762.28	762.28	762.30	762.31	0.03
8.020	733.14	760.75	760.76	760.79	760.80	0.05
8.010	OK Highway 10 Bridge					
7.970	731.28	759.44	759.45	759.49	759.50	0.06
7.000	730.33	757.04	757.06	757.16	757.17	0.13
6.000	727.95	755.50	755.52	755.70	755.71	0.20
5.000	722.10	754.25	754.27	754.53	754.55	0.30
4.000	720.00	753.47	753.51	753.82	753.84	0.37
3.000	723.22	752.77	752.83	753.18	753.20	0.43
2.000	723.73	752.26	752.38	752.70	752.73	0.48
1.000	728.44	752.02	752.18	752.37	752.42	0.40
0.580	716.17	751.81	751.99	752.08	752.17	0.36
0.570	Highway 60 Bridge					
0.560	713.76	751.78	751.95	752.04	752.13	0.35
0.460	715.35	751.80	751.97	752.07	752.16	0.36
0.000	Downstream end of Spring River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
19.590	Upstream end of model					
19.590	771.15	793.77	793.77	793.77	793.77	0.00
19.000	767.51	791.13	791.13	791.13	791.13	0.00
18.000	765.41	787.17	787.17	787.17	787.17	0.00
17.000	762.53	783.91	783.91	783.91	783.91	0.00
16.000	756.63	779.22	779.22	779.22	779.22	0.00
15.000	754.26	775.00	775.00	775.00	775.00	0.00
14.240	750.52	771.70	771.70	771.70	771.70	0.00
14.220	Highway 43 Bridge					
14.200	750.12	771.20	771.20	771.20	771.20	0.00
14.000	747.07	770.02	770.02	770.02	770.02	0.00
13.000	745.41	764.84	764.84	764.84	764.84	0.00
12.000	741.15	761.15	761.15	761.15	761.15	0.00
11.000	741.93	755.17	755.17	755.17	755.18	0.01
11.910	OK/MO State Line					
10.000	734.62	750.88	751.05	750.91	750.96	0.17
9.000	734.66	750.58	750.91	750.34	750.30	0.61
8.000	724.21	750.57	750.90	750.34	750.29	0.61
7.000	728.21	750.56	750.89	750.34	750.29	0.60
6.000	727.13	750.56	750.89	750.34	750.29	0.60
5.000	721.05	750.56	750.89	750.34	750.28	0.61
4.700	716.13	750.55	750.88	750.34	750.28	0.60
4.670	OK Highway 10 Bridge					
4.640	715.21	750.55	750.88	750.34	750.28	0.60
4.000	716.61	750.55	750.88	750.34	750.28	0.60
3.000	714.74	750.55	750.88	750.34	750.28	0.60
2.000	709.09	750.54	750.87	750.34	750.28	0.59
1.000	705.82	750.54	750.87	750.34	750.28	0.59
0.320	706.36	750.54	750.87	750.34	750.28	0.59
0.000	Downstream end of Elk River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.16**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - OCT 2009 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model					
4.152	762.17	775.04	775.04	775.04	775.04	0.00
3.900	760.10	774.11	774.11	774.11	774.11	0.00
3.840	22nd Ave Bridge					
3.800	762.30	772.86	772.86	772.86	772.86	0.00
3.300	759.46	770.57	770.57	770.57	770.57	0.00
2.800	756.73	766.52	766.52	766.52	766.52	0.00
2.710	BN RR Bridge					
2.700	755.72	765.50	765.50	765.50	765.50	0.00
2.500	754.95	764.13	764.13	764.13	764.13	0.00
2.300	754.15	762.23	762.23	762.23	762.23	0.00
2.200	Rockdale Blvd Bridge					
2.100	751.51	759.50	759.50	759.50	759.51	0.01
1.900	750.02	758.75	758.79	758.80	758.81	0.06
1.700	749.58	758.75	758.79	758.80	758.81	0.06
1.660	Central Ave Bridge					
1.600	746.47	758.75	758.79	758.80	758.81	0.06
1.500	744.29	758.75	758.79	758.80	758.81	0.06
1.400	OK Highway 10 Bridge					
1.300	742.00	758.75	758.79	758.80	758.81	0.06
1.000	739.34	758.75	758.79	758.80	758.81	0.06
0.700	737.06	758.75	758.79	758.80	758.81	0.06
0.300	736.42	758.76	758.79	758.81	758.82	0.06
0.041	735.85	758.75	758.78	758.79	758.81	0.06
0.000	Downstream end of Tar Creek					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

APPENDIX D.5:

DECEMBER 2015 EVENT MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - DEC 2015 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
152.175	Upstream end of model					
152.175	752.29	778.38	778.38	778.38	778.38	0.00
152.000	749.79	777.79	777.79	777.79	777.79	0.00
151.000	748.53	776.27	776.27	776.27	776.27	0.00
150.000	748.47	775.15	775.15	775.15	775.15	0.00
149.000	750.14	773.76	773.76	773.76	773.76	0.00
148.000	749.29	772.37	772.37	772.37	772.37	0.00
147.000	747.76	770.50	770.50	770.50	770.50	0.00
146.000	747.81	769.75	769.75	769.75	769.75	0.00
145.500	745.12	768.34	768.34	768.34	768.34	0.00
145.480	E 60 Road Bridge					
145.400	748.01	768.23	768.23	768.23	768.23	0.00
145.000	741.47	767.66	767.66	767.66	767.67	0.00
144.000	743.43	766.51	766.51	766.51	766.52	0.01
143.000	737.95	765.23	765.23	765.23	765.26	0.03
142.000	742.91	764.30	764.30	764.30	764.36	0.06
141.000	741.01	763.88	763.89	763.89	763.96	0.08
140.000	736.33	763.71	763.72	763.72	763.80	0.09
139.000	743.99	763.47	763.48	763.48	763.58	0.11
138.000	736.48	763.25	763.26	763.26	763.37	0.12
137.000	733.33	762.66	762.67	762.67	762.80	0.14
136.000	731.75	762.25	762.26	762.26	762.40	0.15
135.950	731.18	762.24	762.25	762.25	762.40	0.16
135.941	Old Highway 69 Bridge					
135.940	731.21	762.22	762.23	762.23	762.37	0.15
135.590	731.77	762.18	762.19	762.19	762.33	0.15
135.586	BN RR Bridge					
135.580	731.07	762.16	762.17	762.17	762.31	0.15
135.470	732.63	762.11	762.12	762.12	762.27	0.16
135.460	Highway 125 Bridge					
135.440	731.60	762.14	762.15	762.15	762.30	0.16
135.000	732.64	762.09	762.10	762.10	762.25	0.16
134.610	728.75	761.92	761.93	761.93	762.08	0.16
134.599	Abandonded RR Bridge					
134.595	728.58	761.79	761.80	761.80	761.96	0.17
134.000	727.23	761.46	761.47	761.47	761.64	0.18
133.973	Tar Creek					
133.900	727.72	761.32	761.33	761.33	761.50	0.18
133.800	Interstate 44 Bridge					
133.700	728.57	761.19	761.19	761.19	761.37	0.19
133.000	727.70	760.60	760.61	760.61	760.81	0.21
132.000	727.96	760.00	760.01	760.01	760.23	0.23
131.000	726.82	759.53	759.54	759.54	759.79	0.26
130.000	723.18	759.37	759.37	759.37	759.64	0.27
129.000	719.79	759.21	759.21	759.21	759.49	0.28
128.000	719.69	759.11	759.11	759.11	759.40	0.30
127.000	716.37	758.96	758.97	758.97	759.27	0.30
126.710	715.94	758.93	758.94	758.94	759.24	0.31
126.700	S 590 Road Bridge					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
126.670	715.61	758.91	758.92	758.92	759.22	0.31
126.000	720.35	758.89	758.89	758.89	759.19	0.30
125.000	717.08	758.79	758.80	758.80	759.10	0.31
124.000	715.62	758.74	758.75	758.75	759.06	0.32
123.000	713.34	758.67	758.68	758.68	758.98	0.31
122.580	711.08	758.63	758.64	758.64	758.95	0.32
122.570	Highway 60 Bridge					
122.550	709.97	758.62	758.63	758.63	758.93	0.31
122.350	Spring River					
122.000	710.64	758.10	758.11	758.11	758.43	0.33
121.980	709.90	757.86	757.86	757.86	758.19	0.33
121.970	BN RR Bridge					
121.960	710.89	756.95	756.96	756.96	757.27	0.32
121.000	712.79	756.18	756.18	756.18	756.53	0.35
120.000	717.63	756.17	756.17	756.17	756.53	0.35
119.000	714.29	755.81	755.81	755.81	756.18	0.37
118.000	720.29	755.62	755.64	755.64	756.01	0.39
117.000	717.29	755.44	755.44	755.44	755.83	0.39
116.000	725.99	755.37	755.37	755.37	755.77	0.40
115.000	726.26	755.24	755.24	755.24	755.66	0.42
114.000	718.27	754.96	754.95	754.95	755.40	0.45
113.000	720.74	754.95	754.94	754.94	755.38	0.44
112.000	714.31	754.73	754.74	754.74	755.19	0.46
111.000	718.94	754.63	754.62	754.62	755.08	0.45
110.000	719.24	754.64	754.63	754.63	755.09	0.46
109.000	712.29	754.53	754.52	754.52	754.98	0.45
108.000	710.68	754.50	754.48	754.48	754.95	0.47
107.000	711.95	754.48	754.47	754.47	754.95	0.48
106.000	700.35	754.46	754.45	754.45	754.94	0.48
105.350	Elk River					
105.000	701.60	754.46	754.46	754.46	754.94	0.48
104.000	696.61	754.45	754.44	754.44	754.92	0.48
103.000	694.22	754.43	754.43	754.43	754.90	0.47
102.000	688.58	754.41	754.40	754.40	754.88	0.48
101.000	684.72	754.36	754.36	754.36	754.84	0.48
101.750	685.91	754.40	754.39	754.39	754.87	0.48
101.730	Highway 59 (Sailboat Bridge)					
101.710	682.31	754.38	754.38	754.38	754.86	0.48
100.000	702.62	754.37	754.36	754.36	754.84	0.48
99.000	714.86	754.36	754.36	754.36	754.84	0.48
98.000	701.83	754.36	754.36	754.36	754.84	0.48
97.000	689.54	754.36	754.36	754.36	754.83	0.48
96.000	672.30	754.36	754.36	754.36	754.83	0.48
95.000	669.27	754.36	754.36	754.36	754.83	0.48
94.000	686.65	754.36	754.35	754.35	754.83	0.48
93.000	693.39	754.36	754.35	754.35	754.83	0.48
92.000	692.74	754.36	754.35	754.35	754.83	0.48
91.000	657.21	754.35	754.35	754.35	754.83	0.48
90.000	681.52	754.35	754.35	754.35	754.83	0.48

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - DEC 2015 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
89.000	674.45	754.35	754.35	754.35	754.83	0.48
88.000	672.60	754.35	754.35	754.35	754.83	0.48
87.000	674.44	754.35	754.35	754.35	754.83	0.48
86.000	671.68	754.35	754.35	754.35	754.82	0.48
85.000	665.48	754.35	754.34	754.34	754.82	0.48
84.000	669.51	754.35	754.34	754.34	754.82	0.48
83.000	656.25	754.35	754.34	754.34	754.82	0.48
82.000	632.89	754.35	754.34	754.34	754.82	0.48
81.000	631.68	754.35	754.34	754.34	754.82	0.48
80.000	657.03	754.35	754.34	754.34	754.82	0.48
79.000	649.03	754.35	754.34	754.34	754.82	0.48
78.000	653.11	754.35	754.34	754.34	754.82	0.48
77.000	Pensacola Dam					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
21.000	Upstream end of model					
21.000	762.67	800.69	800.69	800.69	800.69	0.00
20.000	760.13	799.50	799.50	799.50	799.50	0.00
19.000	759.04	797.69	797.69	797.69	797.69	0.00
18.000	753.18	795.45	795.45	795.45	795.45	0.00
17.000	750.54	793.52	793.52	793.52	793.52	0.00
16.000	749.28	790.74	790.74	790.74	790.74	0.00
15.000	746.37	788.26	788.26	788.26	788.26	0.00
14.170	741.32	785.82	785.82	785.82	785.82	0.00
14.160	E 57 Road					
14.120	744.21	784.97	784.97	784.97	784.97	0.00
14.000	744.86	784.49	784.49	784.49	784.49	0.00
13.510	744.59	783.32	783.32	783.32	783.32	0.00
13.500	Interstate 44 Bridge					
13.450	745.52	782.64	782.64	782.64	782.63	0.01
13.000	745.56	780.13	780.13	780.13	780.13	0.00
12.000	742.72	777.94	777.94	777.94	777.93	0.01
11.000	742.23	776.26	776.26	776.26	776.26	0.00
10.000	737.62	775.15	775.15	775.15	775.15	0.00
9.000	733.92	773.56	773.56	773.56	773.56	0.00
8.020	733.14	772.72	772.72	772.72	772.72	0.00
8.010	OK Highway 10 Bridge					
7.970	731.28	767.86	767.86	767.86	767.90	0.04
7.000	730.33	765.24	765.25	765.25	765.31	0.07
6.000	727.95	763.72	763.74	763.74	763.83	0.11
5.000	722.10	762.30	762.33	762.33	762.44	0.14
4.000	720.00	761.34	761.37	761.37	761.51	0.16
3.000	723.22	760.18	760.21	760.21	760.39	0.21
2.000	723.73	759.62	759.61	759.61	759.88	0.27
1.000	728.44	759.18	759.18	759.18	759.46	0.28
0.580	716.17	758.42	758.43	758.43	758.74	0.32
0.570	Highway 60 Bridge					
0.560	713.76	758.29	758.29	758.29	758.60	0.31
0.460	715.35	758.48	758.49	758.49	758.80	0.32
0.000	Downstream end of Spring River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.19**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - DEC 2015 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	
19.590	Upstream end of model					
19.590	771.15	800.12	800.12	800.12	800.12	0.00
19.000	767.51	797.92	797.92	797.92	797.92	0.00
18.000	765.41	794.01	794.01	794.01	794.01	0.00
17.000	762.53	790.87	790.87	790.87	790.87	0.00
16.000	756.63	786.22	786.22	786.22	786.22	0.00
15.000	754.26	782.38	782.38	782.38	782.38	0.00
14.240	750.52	779.28	779.28	779.28	779.28	0.00
14.220	Highway 43 Bridge					
14.200	750.12	776.85	776.85	776.85	776.85	0.00
14.000	747.07	775.82	775.82	775.82	775.82	0.00
13.000	745.41	769.73	769.73	769.73	769.73	0.00
12.000	741.15	765.86	765.86	765.86	765.86	0.00
11.910	OK/MO State Line					
11.000	741.93	760.18	760.18	760.18	760.18	0.00
10.000	734.62	756.38	756.38	756.38	756.41	0.03
9.000	734.66	754.57	754.53	754.53	755.07	0.54
8.000	724.21	754.55	754.51	754.51	755.04	0.53
7.000	728.21	754.53	754.50	754.50	755.02	0.52
6.000	727.13	754.53	754.50	754.50	755.01	0.51
5.000	721.05	754.51	754.49	754.49	755.00	0.51
4.700	716.13	754.51	754.49	754.49	754.99	0.50
4.670	OK Highway 10 Bridge					
4.640	715.21	754.51	754.48	754.48	754.99	0.51
4.000	716.61	754.50	754.48	754.48	754.97	0.49
3.000	714.74	754.49	754.47	754.47	754.96	0.49
2.000	709.09	754.48	754.47	754.47	754.96	0.49
1.000	705.82	754.47	754.46	754.46	754.94	0.48
0.320	706.36	754.46	754.46	754.46	754.94	0.48
0.000	Downstream end of Elk River					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.20**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - DEC 2015 EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)				Max WSEL Difference El. 742 to 745* (ft)
		El. 742	El. 743	El. 744	El. 745	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model					
4.152	762.17	775.09	775.09	775.09	775.09	0.00
3.900	760.10	774.16	774.16	774.16	774.16	0.00
3.840	22nd Ave Bridge					
3.800	762.30	772.90	772.90	772.90	772.90	0.00
3.300	759.46	770.62	770.62	770.62	770.62	0.00
2.800	756.73	766.58	766.58	766.58	766.58	0.00
2.710	BN RR Bridge					
2.700	755.72	765.54	765.54	765.54	765.54	0.00
2.500	754.95	764.16	764.16	764.16	764.16	0.00
2.300	754.15	762.24	762.24	762.24	762.24	0.01
2.200	Rockdale Blvd Bridge					
2.100	751.51	761.40	761.41	761.41	761.58	0.18
1.900	750.02	761.40	761.41	761.41	761.58	0.18
1.700	749.58	761.40	761.41	761.41	761.58	0.18
1.660	Central Ave Bridge					
1.600	746.47	761.40	761.41	761.41	761.58	0.18
1.500	744.29	761.40	761.41	761.41	761.58	0.18
1.400	OK Highway 10 Bridge					
1.300	742.00	761.40	761.41	761.41	761.58	0.18
1.000	739.34	761.40	761.41	761.41	761.58	0.18
0.700	737.06	761.40	761.41	761.41	761.58	0.18
0.300	736.42	761.40	761.41	761.41	761.58	0.18
0.041	735.85	761.39	761.40	761.40	761.57	0.18
0.000	Downstream end of Tar Creek					

*Difference between the highest and lowest Max WSELs from the simulations with El. 742 to El. 745 Pensacola Dam starting stages.

APPENDIX D.6:
100-YEAR EVENT MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734 Max WSEL (ft, PD)	El. 740 Max WSEL (ft, PD)	El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	El. 757 Max WSEL (ft, PD)	
152.175	Upstream end of model								
152.175	752.29	791.90	791.91	791.91	791.91	791.91	791.91	791.93	0.02
152.000	749.79	790.66	790.67	790.67	790.67	790.67	790.67	790.69	0.03
151.000	748.53	788.12	788.13	788.13	788.13	788.13	788.13	788.16	0.04
150.000	748.47	787.42	787.44	787.44	787.44	787.44	787.44	787.47	0.05
149.000	750.14	786.89	786.91	786.91	786.91	786.91	786.91	786.94	0.05
148.000	749.29	786.82	786.84	786.84	786.84	786.84	786.84	786.87	0.05
147.000	747.76	786.45	786.47	786.47	786.47	786.47	786.47	786.50	0.05
146.000	747.81	786.31	786.33	786.33	786.33	786.33	786.33	786.37	0.05
145.500	745.12	786.21	786.23	786.23	786.23	786.23	786.23	786.26	0.05
145.480	E 60 Road Bridge								
145.400	748.01	786.19	786.21	786.21	786.20	786.21	786.20	786.24	0.05
145.000	741.47	786.08	786.10	786.10	786.10	786.10	786.10	786.13	0.05
144.000	743.43	785.80	785.82	785.82	785.81	785.82	785.81	785.85	0.05
143.000	737.95	785.60	785.62	785.63	785.62	785.62	785.62	785.66	0.05
142.000	742.91	785.44	785.46	785.46	785.45	785.46	785.45	785.49	0.05
141.000	741.01	785.31	785.33	785.33	785.33	785.33	785.33	785.36	0.05
140.000	736.33	785.27	785.29	785.29	785.28	785.29	785.28	785.32	0.05
139.000	743.99	785.22	785.25	785.25	785.24	785.24	785.24	785.28	0.05
138.000	736.48	785.16	785.18	785.18	785.18	785.18	785.18	785.21	0.05
137.000	733.33	785.02	785.04	785.04	785.03	785.04	785.03	785.07	0.05
136.000	731.75	784.65	784.67	784.67	784.66	784.67	784.66	784.70	0.05
135.950	731.18	784.61	784.63	784.63	784.62	784.63	784.62	784.66	0.05
135.941	Old Highway 69 Bridge								
135.940	731.21	784.50	784.52	784.52	784.52	784.52	784.52	784.55	0.05
135.590	731.77	784.39	784.41	784.41	784.41	784.41	784.41	784.45	0.06
135.586	BN RR Bridge								
135.580	731.07	784.26	784.28	784.28	784.27	784.28	784.27	784.31	0.05
135.470	732.63	784.19	784.21	784.21	784.21	784.21	784.21	784.24	0.05
135.460	Highway 125 Bridge								
135.440	731.60	784.24	784.26	784.26	784.25	784.26	784.25	784.29	0.05
135.000	732.64	784.03	784.05	784.05	784.04	784.05	784.04	784.08	0.05
134.610	728.75	783.79	783.81	783.81	783.81	783.81	783.81	783.85	0.06
134.599	Abandonded RR Bridge								

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734 Max WSEL (ft, PD)	El. 740 Max WSEL (ft, PD)	El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	El. 757 Max WSEL (ft, PD)	
134.595	728.58	783.59	783.61	783.61	783.61	783.61	783.61	783.65	0.06
134.000	727.23	783.17	783.19	783.19	783.18	783.19	783.18	783.22	0.05
133.973	Tar Creek								
133.900	727.72	782.61	782.63	782.63	782.63	782.63	782.63	782.67	0.05
133.800	Interstate 44 Bridge								
133.700	728.57	781.92	781.94	781.95	781.94	781.94	781.94	781.98	0.06
133.000	727.70	781.10	781.12	781.12	781.12	781.12	781.12	781.16	0.06
132.000	727.96	779.46	779.48	779.48	779.48	779.48	779.48	779.52	0.06
131.000	726.82	777.63	777.65	777.65	777.65	777.65	777.65	777.68	0.05
130.000	723.18	776.29	776.31	776.31	776.31	776.31	776.31	776.34	0.05
129.000	719.79	775.16	775.18	775.18	775.18	775.18	775.18	775.21	0.05
128.000	719.69	774.10	774.12	774.12	774.12	774.13	774.12	774.16	0.06
127.000	716.37	772.96	772.98	772.98	772.98	772.98	772.97	773.01	0.05
126.710	715.94	772.60	772.62	772.62	772.62	772.62	772.62	772.66	0.06
126.700	S 590 Road Bridge								
126.670	715.61	772.24	772.26	772.26	772.26	772.26	772.26	772.30	0.06
126.000	720.35	771.56	771.58	771.58	771.59	771.59	771.58	771.62	0.06
125.000	717.08	769.64	769.66	769.66	769.66	769.67	769.66	769.69	0.05
124.000	715.62	767.95	767.97	767.97	767.98	767.97	767.96	768.00	0.05
123.000	713.34	765.51	765.52	765.52	765.53	765.53	765.51	765.56	0.05
122.580	711.08	762.55	762.55	762.55	762.55	762.55	762.55	762.55	0.00
122.570	Highway 60 Bridge								
122.550	709.97	762.31	762.37	762.36	762.42	762.40	762.36	762.44	0.13
122.350	Spring River								
122.000	710.64	762.38	762.47	762.46	762.54	762.51	762.46	762.57	0.19
121.980	709.90	761.85	761.95	761.93	762.04	762.01	761.93	762.07	0.22
121.970	BN RR Bridge								
121.960	710.89	761.14	761.17	761.16	761.28	761.23	761.17	761.19	0.14
121.000	712.79	759.80	759.83	759.81	759.94	759.89	759.83	759.84	0.14
120.000	717.63	759.84	759.88	759.86	759.98	759.93	759.87	759.89	0.14
119.000	714.29	758.98	759.01	758.99	759.13	759.08	759.01	759.02	0.15
118.000	720.29	758.54	758.58	758.55	758.70	758.64	758.57	758.59	0.16
117.000	717.29	758.04	758.07	758.05	758.21	758.15	758.07	758.08	0.17
116.000	725.99	757.89	757.93	757.91	758.08	758.01	757.93	757.94	0.18

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.21**
GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734 Max WSEL (ft, PD)	El. 740 Max WSEL (ft, PD)	El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	El. 757 Max WSEL (ft, PD)	
115.000	726.26	757.50	757.54	757.52	757.70	757.63	757.54	757.55	0.20
114.000	718.27	756.64	756.68	756.65	756.86	756.78	756.68	757.00	0.36
113.000	720.74	756.65	756.69	756.66	756.87	756.79	756.69	757.00	0.35
112.000	714.31	755.97	756.01	755.98	756.21	756.12	756.01	757.00	1.03
111.000	718.94	755.54	755.58	755.55	755.80	755.70	755.58	757.00	1.46
110.000	719.24	755.61	755.66	755.62	755.88	755.78	755.66	757.00	1.39
109.000	712.29	755.22	755.25	755.21	755.49	755.37	755.25	757.00	1.79
108.000	710.68	755.14	755.16	755.13	755.41	755.29	755.17	757.00	1.87
107.000	711.95	755.13	755.15	755.12	755.39	755.28	755.16	757.00	1.88
106.000	700.35	755.08	755.11	755.07	755.35	755.24	755.12	757.00	1.93
105.350	Elk River								
105.000	701.60	755.09	755.13	755.09	755.37	755.26	755.13	757.00	1.91
104.000	696.61	755.07	755.11	755.07	755.35	755.24	755.11	757.00	1.93
103.000	694.22	755.05	755.09	755.05	755.33	755.22	755.09	757.00	1.95
102.000	688.58	755.02	755.06	755.02	755.30	755.19	755.06	757.00	1.98
101.000	684.72	754.92	754.97	754.93	755.21	755.10	754.97	757.00	2.08
101.750	685.91	754.98	755.02	754.98	755.26	755.15	755.02	757.00	2.02
101.730	Highway 59 (Sailboat Bridge)								
101.710	682.31	754.95	754.99	754.95	755.23	755.12	754.99	757.00	2.05
100.000	702.62	754.97	755.02	754.98	755.26	755.15	755.02	757.00	2.03
99.000	714.86	754.97	755.02	754.98	755.26	755.15	755.02	757.00	2.03
98.000	701.83	754.96	755.01	754.97	755.25	755.14	755.01	757.00	2.04
97.000	689.54	754.96	755.01	754.97	755.25	755.14	755.01	757.00	2.04
96.000	672.30	754.95	755.00	754.96	755.24	755.13	755.00	757.00	2.05
95.000	669.27	754.95	755.00	754.96	755.24	755.13	755.00	757.00	2.05
94.000	686.65	754.94	754.99	754.95	755.23	755.12	754.99	757.00	2.05
93.000	693.39	754.94	754.99	754.95	755.23	755.12	754.99	757.00	2.06
92.000	692.74	754.94	754.99	754.95	755.22	755.11	754.99	757.00	2.06
91.000	657.21	754.93	754.98	754.94	755.22	755.11	754.98	757.00	2.07
90.000	681.52	754.93	754.98	754.94	755.22	755.11	754.98	757.00	2.07
89.000	674.45	754.92	754.97	754.93	755.21	755.10	754.97	757.00	2.07
88.000	672.60	754.92	754.97	754.93	755.21	755.10	754.97	757.00	2.08
87.000	674.44	754.92	754.97	754.93	755.21	755.10	754.97	757.00	2.08
86.000	671.68	754.92	754.97	754.93	755.21	755.10	754.97	757.00	2.08

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734	El. 740	El. 742	El. 743	El. 744	El. 745	El. 757	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
85.000	665.48	754.91	754.96	754.92	755.20	755.09	754.96	757.00	2.09
84.000	669.51	754.91	754.96	754.92	755.20	755.09	754.96	757.00	2.09
83.000	656.25	754.91	754.96	754.92	755.20	755.09	754.96	757.00	2.09
82.000	632.89	754.91	754.96	754.92	755.20	755.09	754.96	757.00	2.09
81.000	631.68	754.90	754.95	754.91	755.19	755.08	754.95	757.00	2.09
80.000	657.03	754.90	754.95	754.91	755.19	755.08	754.95	757.00	2.10
79.000	649.03	754.90	754.95	754.91	755.19	755.08	754.95	757.00	2.10
78.000	653.11	754.90	754.95	754.91	755.19	755.08	754.95	757.00	2.10
77.000	Pensacola Dam								

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

PENSACOLA DAM | **TABLE D.22**
GRAND RIVER DAM AUTHORITY | SPRING RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734 Max WSEL (ft, PD)	El. 740 Max WSEL (ft, PD)	El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	El. 757 Max WSEL (ft, PD)	
21.000	Upstream end of model								
21.000	762.67	791.80	791.80	791.80	791.80	791.80	791.80	791.80	0.00
20.000	760.13	790.14	790.14	790.14	790.14	790.14	790.14	790.15	0.01
19.000	759.04	786.91	786.91	786.91	786.91	786.91	786.91	786.91	0.01
18.000	753.18	783.88	783.88	783.88	783.88	783.88	783.88	783.89	0.01
17.000	750.54	781.90	781.91	781.91	781.91	781.91	781.91	781.92	0.02
16.000	749.28	779.42	779.43	779.43	779.43	779.43	779.43	779.45	0.03
15.000	746.37	776.44	776.46	776.46	776.46	776.46	776.46	776.50	0.06
14.170	741.32	773.95	773.98	773.98	773.98	773.99	773.98	774.04	0.09
14.160	E 57 Road								
14.120	744.21	774.41	774.44	774.44	774.44	774.44	774.44	774.49	0.08
14.000	744.86	774.17	774.21	774.21	774.21	774.21	774.21	774.26	0.09
13.510	744.59	773.23	773.26	773.26	773.26	773.27	773.26	773.33	0.10
13.500	Interstate 44 Bridge								
13.450	745.52	772.71	772.75	772.75	772.74	772.75	772.75	772.82	0.11
13.000	745.56	771.21	771.28	771.27	771.27	771.28	771.28	771.37	0.15
12.000	742.72	768.84	768.97	768.96	768.94	768.97	768.95	769.14	0.30
11.000	742.23	767.46	767.60	767.60	767.57	767.60	767.58	767.76	0.29
10.000	737.62	766.63	766.69	766.68	766.68	766.69	766.68	766.79	0.16
9.000	733.92	765.62	765.68	765.67	765.68	765.69	765.67	765.73	0.11
8.020	733.14	765.18	765.22	765.22	765.25	765.24	765.22	765.28	0.10
8.010	OK Highway 10 Bridge								
7.970	731.28	764.51	764.56	764.55	764.58	764.58	764.55	764.62	0.11
7.000	730.33	764.19	764.25	764.24	764.28	764.27	764.24	764.31	0.12
6.000	727.95	764.07	764.13	764.12	764.16	764.15	764.12	764.19	0.12
5.000	722.10	763.98	764.03	764.03	764.07	764.06	764.02	764.10	0.12
4.000	720.00	763.93	763.98	763.98	764.02	764.01	763.97	764.05	0.12
3.000	723.22	763.87	763.92	763.92	763.96	763.95	763.91	763.99	0.12
2.000	723.73	763.83	763.89	763.88	763.92	763.91	763.88	763.95	0.12
1.000	728.44	763.80	763.86	763.85	763.89	763.88	763.85	763.92	0.12
0.580	716.17	763.73	763.78	763.78	763.82	763.81	763.77	763.85	0.12
0.570	Highway 60 Bridge								
0.560	713.76	763.70	763.76	763.75	763.80	763.78	763.75	763.82	0.12

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734	El. 740	El. 742	El. 743	El. 744	El. 745	El. 757	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
0.460	715.35	763.72	763.78	763.77	763.81	763.80	763.77	763.84	0.12
0.000	Downstream end of Spring River								

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

PENSACOLA DAM **TABLE D.23**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734 Max WSEL (ft, PD)	El. 740 Max WSEL (ft, PD)	El. 742 Max WSEL (ft, PD)	El. 743 Max WSEL (ft, PD)	El. 744 Max WSEL (ft, PD)	El. 745 Max WSEL (ft, PD)	El. 757 Max WSEL (ft, PD)	
19.590	Upstream end of model								
19.590	771.15	777.77	777.77	777.77	777.77	777.77	777.77	777.77	0.00
19.000	767.51	776.22	776.22	776.22	776.22	776.22	776.22	776.22	0.00
18.000	765.41	772.64	772.64	772.64	772.64	772.64	772.64	772.64	0.00
17.000	762.53	768.77	768.77	768.77	768.77	768.77	768.77	768.77	0.00
16.000	756.63	764.95	764.95	764.95	764.95	764.95	764.95	764.95	0.00
15.000	754.26	761.27	761.27	761.27	761.27	761.27	761.27	761.27	0.00
14.240	750.52	756.89	756.89	756.89	756.89	756.89	756.89	757.07	0.18
14.220	Highway 43 Bridge								
14.200	750.12	756.83	756.83	756.83	756.83	756.83	756.83	757.07	0.24
14.000	747.07	756.37	756.37	756.37	756.45	756.41	756.37	757.05	0.68
13.000	745.41	755.38	755.36	755.31	755.60	755.47	755.35	757.01	1.70
12.000	741.15	755.26	755.24	755.19	755.49	755.36	755.23	757.00	1.81
11.910	OK/MO State Line								
11.000	741.93	755.22	755.20	755.15	755.45	755.32	755.19	757.00	1.85
10.000	734.62	755.20	755.18	755.14	755.44	755.31	755.18	757.00	1.86
9.000	734.66	755.19	755.18	755.13	755.43	755.30	755.18	757.00	1.87
8.000	724.21	755.17	755.17	755.13	755.42	755.30	755.17	757.00	1.87
7.000	728.21	755.16	755.16	755.12	755.41	755.29	755.17	757.00	1.88
6.000	727.13	755.15	755.16	755.12	755.41	755.29	755.16	757.00	1.88
5.000	721.05	755.14	755.15	755.11	755.40	755.28	755.16	757.00	1.89
4.700	716.13	755.14	755.15	755.11	755.40	755.28	755.16	757.00	1.89
4.670	OK Highway 10 Bridge								
4.640	715.21	755.14	755.15	755.11	755.40	755.28	755.16	757.00	1.89
4.000	716.61	755.13	755.14	755.11	755.39	755.27	755.15	757.00	1.89
3.000	714.74	755.12	755.14	755.10	755.39	755.27	755.15	757.00	1.90
2.000	709.09	755.11	755.14	755.10	755.38	755.27	755.14	757.00	1.90
1.000	705.82	755.10	755.13	755.09	755.38	755.26	755.14	757.00	1.91
0.320	706.36	755.10	755.13	755.09	755.37	755.26	755.13	757.00	1.91
0.000	Downstream end of Elk River								

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

PENSACOLA DAM | **TABLE D.24**

GRAND RIVER DAM AUTHORITY | TAR CREEK MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)							Max WSEL Difference El. 734 to 757* (ft)
		El. 734	El. 740	El. 742	El. 743	El. 744	El. 745	El. 757	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model								
4.152	762.17	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
3.900	760.10	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
3.840	22nd Ave Bridge								
3.800	762.30	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
3.300	759.46	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
2.800	756.73	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
2.710	BN RR Bridge								
2.700	755.72	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
2.500	754.95	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
2.300	754.15	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
2.200	Rockdale Blvd Bridge								
2.100	751.51	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
1.900	750.02	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
1.700	749.58	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
1.660	Central Ave Bridge								
1.600	746.47	783.59	783.61	783.61	783.60	783.61	783.60	783.64	0.05
1.500	744.29	783.58	783.60	783.60	783.60	783.60	783.60	783.63	0.05
1.400	OK Highway 10 Bridge								
1.300	742.00	783.56	783.58	783.58	783.58	783.58	783.58	783.62	0.05
1.000	739.34	783.52	783.54	783.54	783.54	783.54	783.54	783.57	0.05
0.700	737.06	783.48	783.50	783.50	783.49	783.50	783.49	783.53	0.05
0.300	736.42	783.25	783.27	783.27	783.26	783.27	783.26	783.30	0.05
0.041	735.85	783.04	783.07	783.07	783.06	783.06	783.06	783.10	0.05
0.000	Downstream end of Tar Creek								

*Difference between the highest and lowest Max WSELs from the simulations with El. 734 to El. 757 Pensacola Dam starting stages.

APPENDIX D.7:

HISTORICAL STARTING STAGE MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
152.175	Upstream end of model						
152.175	752.29	780.71	773.79	784.43	778.47	778.38	10.65
152.000	749.79	779.82	773.48	783.27	777.86	777.79	9.79
151.000	748.53	777.94	772.52	780.33	776.35	776.27	7.81
150.000	748.47	776.66	771.82	778.90	775.17	775.15	7.09
149.000	750.14	775.12	770.44	777.46	773.78	773.76	7.01
148.000	749.29	774.25	768.76	777.09	772.40	772.37	8.33
147.000	747.76	772.72	766.94	776.23	770.52	770.50	9.29
146.000	747.81	772.33	766.08	776.01	769.75	769.75	9.93
145.500	745.12	771.63	764.71	775.74	768.34	768.34	11.03
145.480	E 60 Road Bridge						
145.400	748.01	771.56	764.61	775.70	768.23	768.23	11.08
145.000	741.47	771.23	764.17	775.52	767.66	767.67	11.35
144.000	743.43	770.56	763.34	775.11	766.46	766.52	11.76
143.000	737.95	770.09	762.18	774.83	765.01	765.25	12.65
142.000	742.91	769.74	761.27	774.60	763.83	764.34	13.33
141.000	741.01	769.60	760.11	774.48	763.18	763.94	14.37
140.000	736.33	769.56	758.78	774.44	762.84	763.77	15.65
139.000	743.99	769.51	756.79	774.40	762.33	763.54	17.62
138.000	736.48	769.43	755.40	774.34	761.90	763.33	18.93
137.000	733.33	769.11	753.44	774.12	760.87	762.76	20.68
136.000	731.75	768.41	752.91	773.54	760.22	762.35	20.63
135.950	731.18	768.41	752.85	773.48	760.21	762.35	20.63
135.941	Old Highway 69 Bridge						
135.940	731.21	768.40	752.63	773.50	760.17	762.33	20.87
135.590	731.77	768.25	752.69	773.33	760.11	762.29	20.64
135.586	BN RR Bridge						
135.580	731.07	768.07	752.72	773.26	760.08	762.26	20.54
135.470	732.63	768.02	752.61	773.18	760.00	762.22	20.57
135.460	Highway 125 Bridge						
135.440	731.60	768.06	752.67	773.23	760.04	762.25	20.56
135.000	732.64	767.78	752.38	772.91	759.92	762.20	20.53
134.610	728.75	767.28	752.22	772.44	759.66	762.03	20.22

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 Max WSEL (ft, PD)	June 2004 Max WSEL (ft, PD)	July 2007 Max WSEL (ft, PD)	Oct 2009 Max WSEL (ft, PD)	Dec 2015 Max WSEL (ft, PD)	
134.599	Abandonded RR Bridge						
134.595	728.58	766.98	752.13	772.19	759.47	761.90	20.06
134.000	727.23	766.62	751.53	771.92	758.87	761.58	20.39
133.973	Tar Creek						
133.900	727.72	766.40	751.32	771.60	758.63	761.44	20.28
133.800	Interstate 44 Bridge						
133.700	728.57	766.21	751.00	771.27	758.36	761.31	20.27
133.000	727.70	765.54	749.84	770.60	757.20	760.74	20.76
132.000	727.96	764.66	748.63	769.45	755.91	760.16	20.82
131.000	726.82	763.92	747.57	768.50	754.81	759.71	20.94
130.000	723.18	763.05	747.26	767.24	754.38	759.55	19.98
129.000	719.79	762.22	746.77	766.06	753.69	759.40	19.29
128.000	719.69	761.75	746.66	765.00	753.42	759.31	18.34
127.000	716.37	761.62	746.42	763.68	752.96	759.18	17.27
126.710	715.94	761.59	746.39	763.26	752.88	759.15	16.87
126.700	S 590 Road Bridge						
126.670	715.61	761.57	746.37	763.21	752.86	759.12	16.84
126.000	720.35	761.54	746.27	762.62	752.82	759.10	16.35
125.000	717.08	761.45	746.09	761.21	752.52	759.01	15.36
124.000	715.62	761.40	745.97	759.77	752.34	758.96	15.43
123.000	713.34	761.32	745.86	758.09	752.09	758.89	15.46
122.580	711.08	761.28	745.84	756.89	752.00	758.85	15.44
122.570	Highway 60 Bridge						
122.550	709.97	761.27	745.40	756.88	751.76	758.84	15.87
122.350	Spring River						
122.000	710.64	760.17	745.40	756.58	751.51	758.33	14.77
121.980	709.90	759.71	745.39	756.42	751.41	758.09	14.32
121.970	BN RR Bridge						
121.960	710.89	756.98	745.38	755.92	751.38	757.17	11.79
121.000	712.79	755.69	745.30	755.32	751.09	756.42	11.12
120.000	717.63	755.68	745.29	755.31	751.08	756.41	11.13
119.000	714.29	755.53	745.27	755.10	750.98	756.06	10.79
118.000	720.29	755.45	745.25	755.00	750.93	755.89	10.64

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
117.000	717.29	755.37	745.24	754.89	750.87	755.70	10.46
116.000	725.99	755.35	745.23	754.86	750.85	755.64	10.41
115.000	726.26	755.28	745.21	754.77	750.79	755.52	10.31
114.000	718.27	755.16	745.19	754.61	750.72	755.26	10.08
113.000	720.74	755.16	745.18	754.60	750.71	755.25	10.07
112.000	714.31	755.07	745.16	754.49	750.65	755.05	9.91
111.000	718.94	755.02	745.16	754.42	750.62	754.93	9.86
110.000	719.24	755.03	745.16	754.43	750.62	754.94	9.87
109.000	712.29	754.98	745.15	754.37	750.59	754.83	9.83
108.000	710.68	754.97	745.15	754.35	750.59	754.80	9.82
107.000	711.95	754.97	745.15	754.35	750.58	754.80	9.82
106.000	700.35	754.96	745.15	754.34	750.58	754.79	9.81
105.350	Elk River						
105.000	701.60	754.96	745.15	754.34	750.58	754.79	9.81
104.000	696.61	754.96	745.14	754.34	750.57	754.77	9.82
103.000	694.22	754.96	745.14	754.34	750.57	754.75	9.82
102.000	688.58	754.95	745.14	754.33	750.56	754.73	9.81
101.000	684.72	754.93	745.14	754.31	750.55	754.69	9.79
101.750	685.91	754.95	745.14	754.33	750.56	754.72	9.81
101.730	Highway 59 (Sailboat Bridge)						
101.710	682.31	754.94	745.14	754.32	750.56	754.71	9.80
100.000	702.62	754.94	745.14	754.32	750.55	754.69	9.80
99.000	714.86	754.94	745.14	754.32	750.55	754.69	9.80
98.000	701.83	754.94	745.14	754.32	750.55	754.69	9.80
97.000	689.54	754.94	745.14	754.32	750.55	754.68	9.79
96.000	672.30	754.94	745.14	754.32	750.55	754.68	9.79
95.000	669.27	754.94	745.14	754.32	750.55	754.68	9.79
94.000	686.65	754.93	745.14	754.32	750.55	754.68	9.79
93.000	693.39	754.93	745.14	754.32	750.55	754.68	9.79
92.000	692.74	754.93	745.14	754.31	750.55	754.68	9.79
91.000	657.21	754.93	745.14	754.31	750.55	754.68	9.79
90.000	681.52	754.93	745.14	754.31	750.55	754.68	9.79
89.000	674.45	754.93	745.14	754.31	750.55	754.68	9.79

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
88.000	672.60	754.93	745.14	754.31	750.55	754.68	9.79
87.000	674.44	754.93	745.14	754.31	750.55	754.68	9.79
86.000	671.68	754.93	745.14	754.31	750.55	754.67	9.79
85.000	665.48	754.93	745.14	754.31	750.55	754.67	9.79
84.000	669.51	754.93	745.14	754.31	750.55	754.67	9.79
83.000	656.25	754.93	745.14	754.31	750.55	754.67	9.79
82.000	632.89	754.93	745.14	754.31	750.55	754.67	9.79
81.000	631.68	754.93	745.14	754.31	750.55	754.67	9.79
80.000	657.03	754.93	745.14	754.31	750.55	754.67	9.79
79.000	649.03	754.93	745.14	754.31	750.55	754.67	9.79
78.000	653.11	754.93	745.14	754.31	750.55	754.67	9.79
77.000	Pensacola Dam						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 Max WSEL (ft, PD)	June 2004 Max WSEL (ft, PD)	July 2007 Max WSEL (ft, PD)	Oct 2009 Max WSEL (ft, PD)	Dec 2015 Max WSEL (ft, PD)	
21.000	Upstream end of model						
21.000	762.67	805.10	773.88	783.49	790.77	800.69	31.22
20.000	760.13	804.41	771.04	780.70	788.92	799.50	33.37
19.000	759.04	803.09	768.52	777.52	785.68	797.69	34.58
18.000	753.18	800.93	764.57	774.20	782.60	795.45	36.37
17.000	750.54	799.10	762.75	772.20	780.53	793.52	36.34
16.000	749.28	796.17	760.34	770.00	778.12	790.74	35.83
15.000	746.37	794.15	758.34	767.51	775.15	788.26	35.81
14.170	741.32	791.71	757.46	765.96	772.81	785.82	34.25
14.160	E 57 Road						
14.120	744.21	789.81	757.49	766.18	773.22	784.97	32.32
14.000	744.86	789.14	757.38	766.01	772.99	784.49	31.76
13.510	744.59	786.79	756.84	765.30	772.08	783.32	29.95
13.500	Interstate 44 Bridge						
13.450	745.52	784.91	756.58	764.98	771.61	782.64	28.33
13.000	745.56	783.01	755.45	763.85	770.16	780.13	27.56
12.000	742.72	780.13	753.34	762.17	767.89	777.93	26.80
11.000	742.23	778.45	751.76	760.40	765.98	776.26	26.70
10.000	737.62	776.97	750.42	758.87	764.46	775.15	26.55
9.000	733.92	774.02	749.54	758.23	762.28	773.56	24.49
8.020	733.14	772.73	748.55	758.18	760.75	772.72	24.18
8.010	OK Highway 10 Bridge						
7.970	731.28	771.30	746.33	757.06	759.44	767.88	24.97
7.000	730.33	769.24	745.93	757.02	757.04	765.28	23.31
6.000	727.95	767.89	745.62	757.00	755.49	763.79	22.27
5.000	722.10	766.54	745.52	756.99	754.24	762.39	21.01
4.000	720.00	765.65	745.47	756.98	753.47	761.45	20.18
3.000	723.22	764.39	745.46	756.98	752.77	760.31	18.93
2.000	723.73	763.53	745.45	756.97	752.26	759.80	18.08
1.000	728.44	762.67	745.45	756.97	752.03	759.38	17.22
0.580	716.17	760.71	745.44	756.96	751.83	758.64	15.27
0.570	Highway 60 Bridge						
0.560	713.76	760.23	745.44	756.96	751.80	758.50	14.79

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
0.460	715.35	760.87	745.44	756.96	751.82	758.70	15.43
0.000	Downstream end of Spring River						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.27**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
19.590	Upstream end of model						
19.590	771.15	787.52	774.17	775.57	793.77	800.12	25.95
19.000	767.51	785.42	772.64	774.03	791.13	797.92	25.28
18.000	765.41	781.77	769.18	770.46	787.17	794.01	24.83
17.000	762.53	777.78	766.13	767.01	783.91	790.87	24.74
16.000	756.63	773.42	761.16	762.78	779.22	786.22	25.06
15.000	754.26	769.55	757.92	759.23	775.00	782.38	24.46
14.240	750.52	766.33	753.18	755.25	771.70	779.28	26.10
14.220	Highway 43 Bridge						
14.200	750.12	766.08	753.10	755.22	771.20	776.85	23.75
14.000	747.07	764.91	752.78	755.04	770.02	775.82	23.04
13.000	745.41	760.77	749.01	754.47	764.84	769.73	20.72
12.000	741.15	757.41	746.01	754.41	761.15	765.86	19.85
11.910	OK/MO State Line						
11.000	741.93	755.01	745.33	754.40	755.17	760.18	14.85
10.000	734.62	754.99	745.18	754.39	750.89	756.40	11.22
9.000	734.66	754.99	745.17	754.38	750.62	754.92	9.82
8.000	724.21	754.98	745.17	754.37	750.61	754.89	9.81
7.000	728.21	754.98	745.16	754.37	750.61	754.87	9.82
6.000	727.13	754.98	745.16	754.37	750.60	754.86	9.82
5.000	721.05	754.98	745.15	754.36	750.60	754.85	9.83
4.700	716.13	754.98	745.15	754.36	750.59	754.84	9.83
4.670	OK Highway 10 Bridge						
4.640	715.21	754.97	745.15	754.36	750.59	754.84	9.82
4.000	716.61	754.97	745.15	754.35	750.59	754.83	9.82
3.000	714.74	754.97	745.15	754.35	750.59	754.82	9.82
2.000	709.09	754.97	745.15	754.35	750.58	754.81	9.82
1.000	705.82	754.97	745.15	754.34	750.58	754.80	9.82
0.320	706.36	754.96	745.15	754.34	750.58	754.79	9.81
0.000	Downstream end of Elk River						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model						
4.152	762.17	776.77	768.17	772.00	775.04	775.09	8.60
3.900	760.10	775.76	767.29	772.00	774.11	774.16	8.47
3.840	22nd Ave Bridge						
3.800	762.30	774.50	766.05	772.00	772.86	772.90	8.45
3.300	759.46	772.27	764.09	772.00	770.57	770.62	8.18
2.800	756.73	768.46	760.95	772.00	766.52	766.58	11.04
2.710	BN RR Bridge						
2.700	755.72	767.11	760.45	772.00	765.50	765.54	11.54
2.500	754.95	766.52	759.30	772.00	764.13	764.16	12.70
2.300	754.15	766.52	757.47	772.00	762.23	762.24	14.53
2.200	Rockdale Blvd Bridge						
2.100	751.51	766.52	754.84	772.00	759.50	761.52	17.16
1.900	750.02	766.52	753.22	772.00	758.76	761.52	18.78
1.700	749.58	766.52	751.47	772.00	758.76	761.52	20.53
1.660	Central Ave Bridge						
1.600	746.47	766.52	751.46	772.00	758.76	761.52	20.54
1.500	744.29	766.52	751.46	772.00	758.76	761.52	20.54
1.400	OK Highway 10 Bridge						
1.300	742.00	766.52	751.46	772.00	758.76	761.52	20.54
1.000	739.34	766.52	751.46	771.99	758.76	761.52	20.53
0.700	737.06	766.52	751.46	771.98	758.76	761.52	20.53
0.300	736.42	766.53	751.46	771.92	758.76	761.52	20.46
0.041	735.85	766.51	751.45	771.83	758.75	761.51	20.38
0.000	Downstream end of Tar Creek						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

APPENDIX E:
WATER SURFACE ELEVATION PROFILES

APPENDIX E.1:
SEPTEMBER 1993 EVENT PROFILES

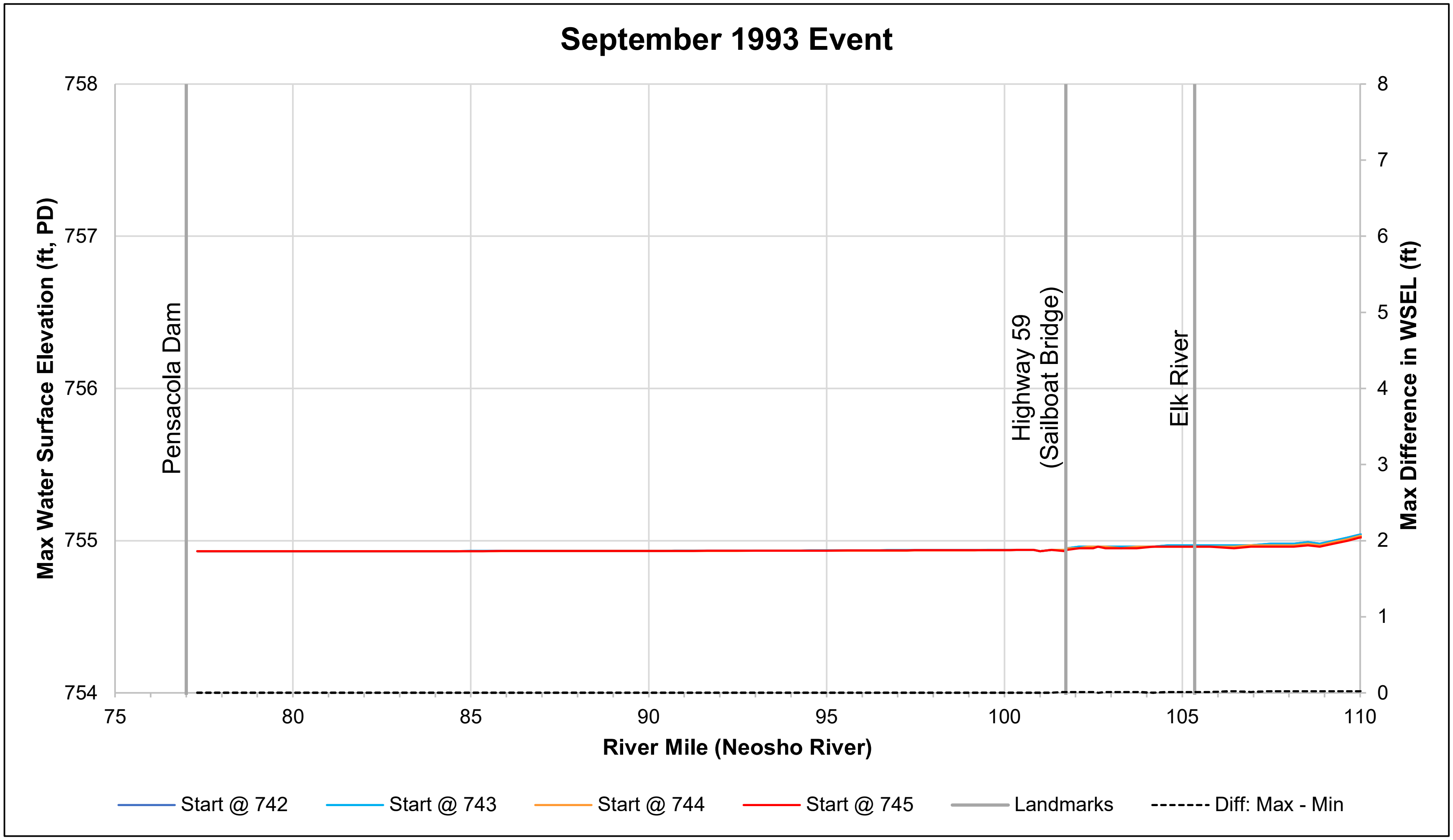


Figure E.1. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

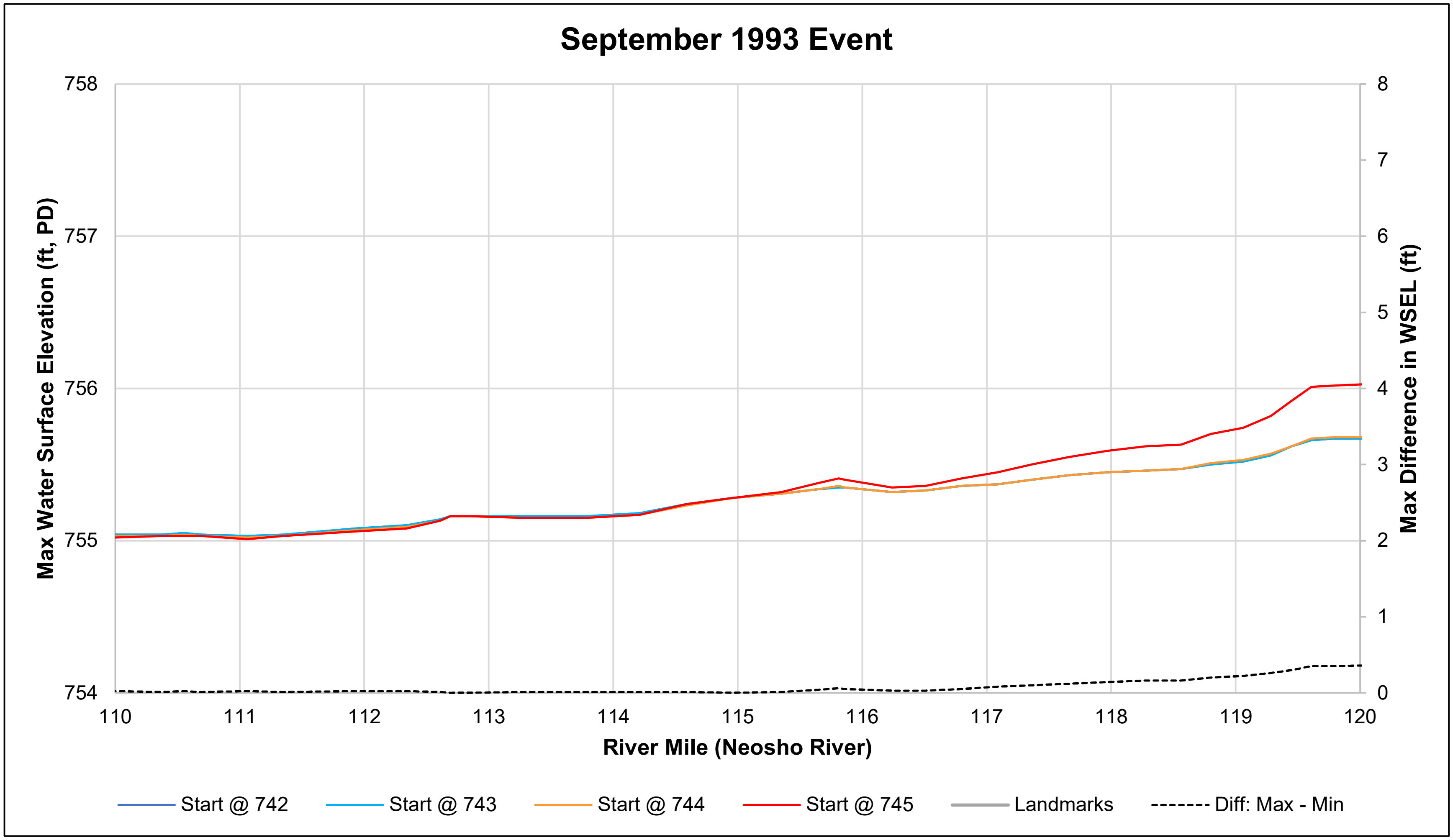


Figure E.2. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

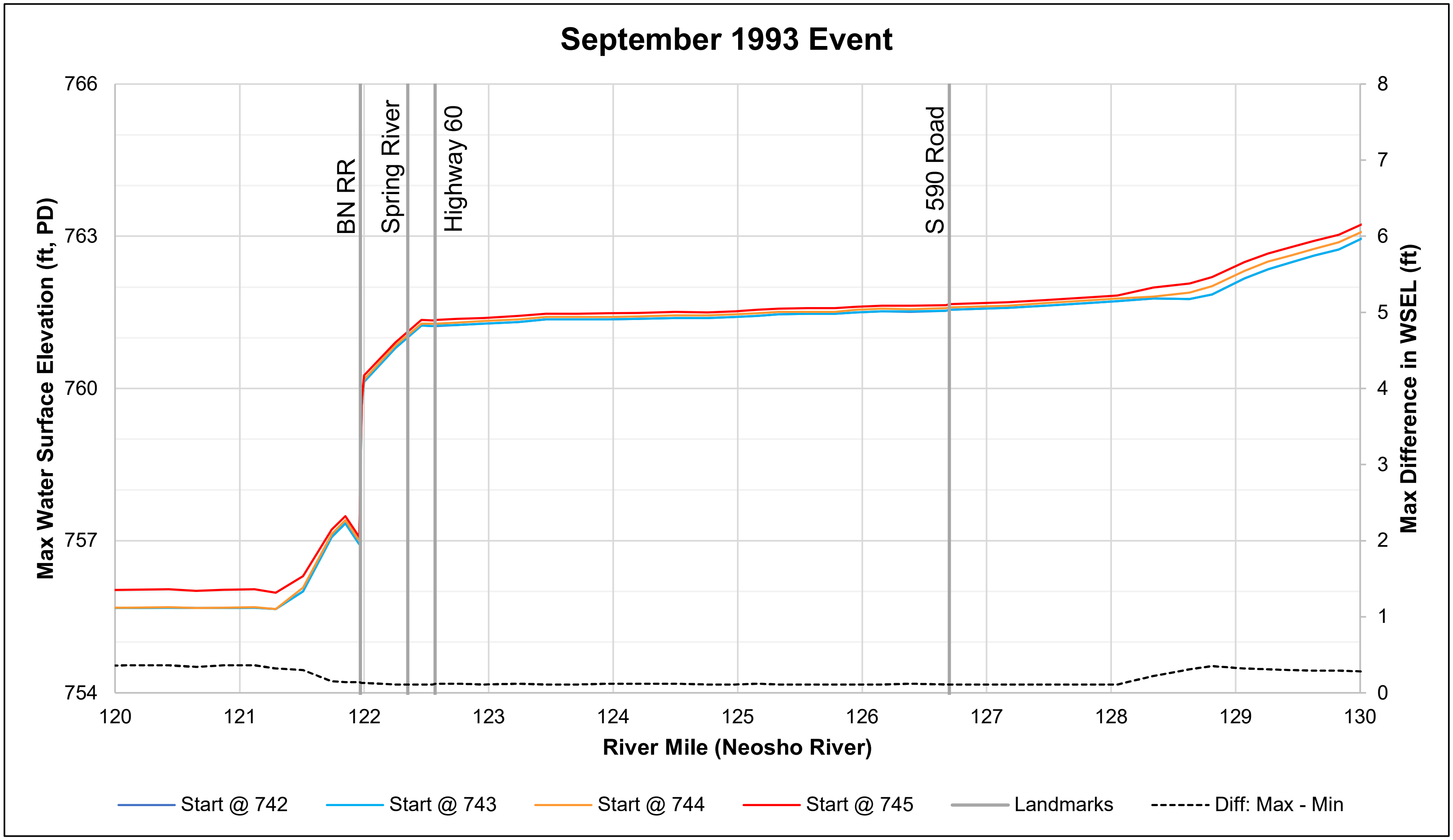


Figure E.3. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

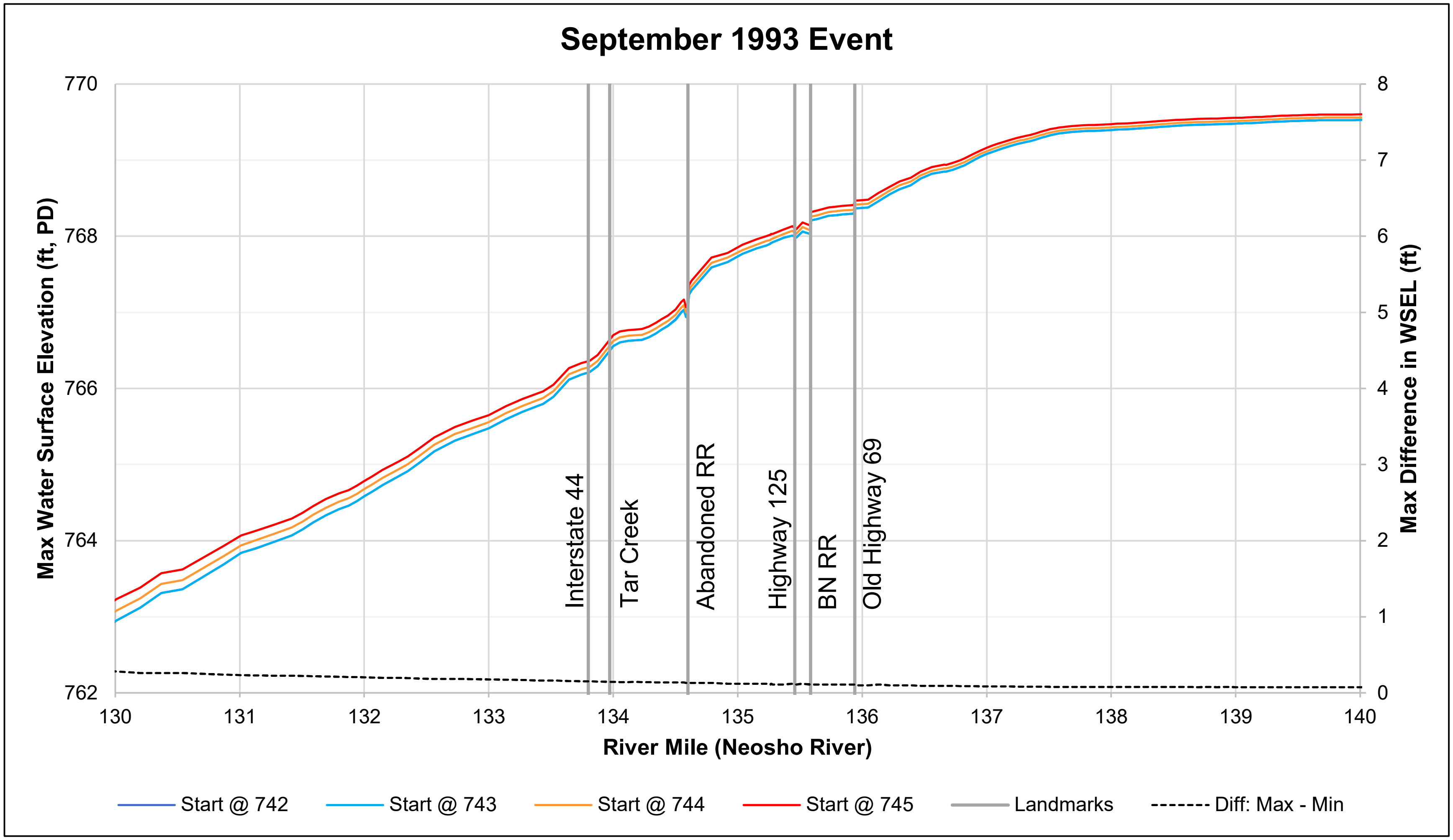


Figure E.4. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

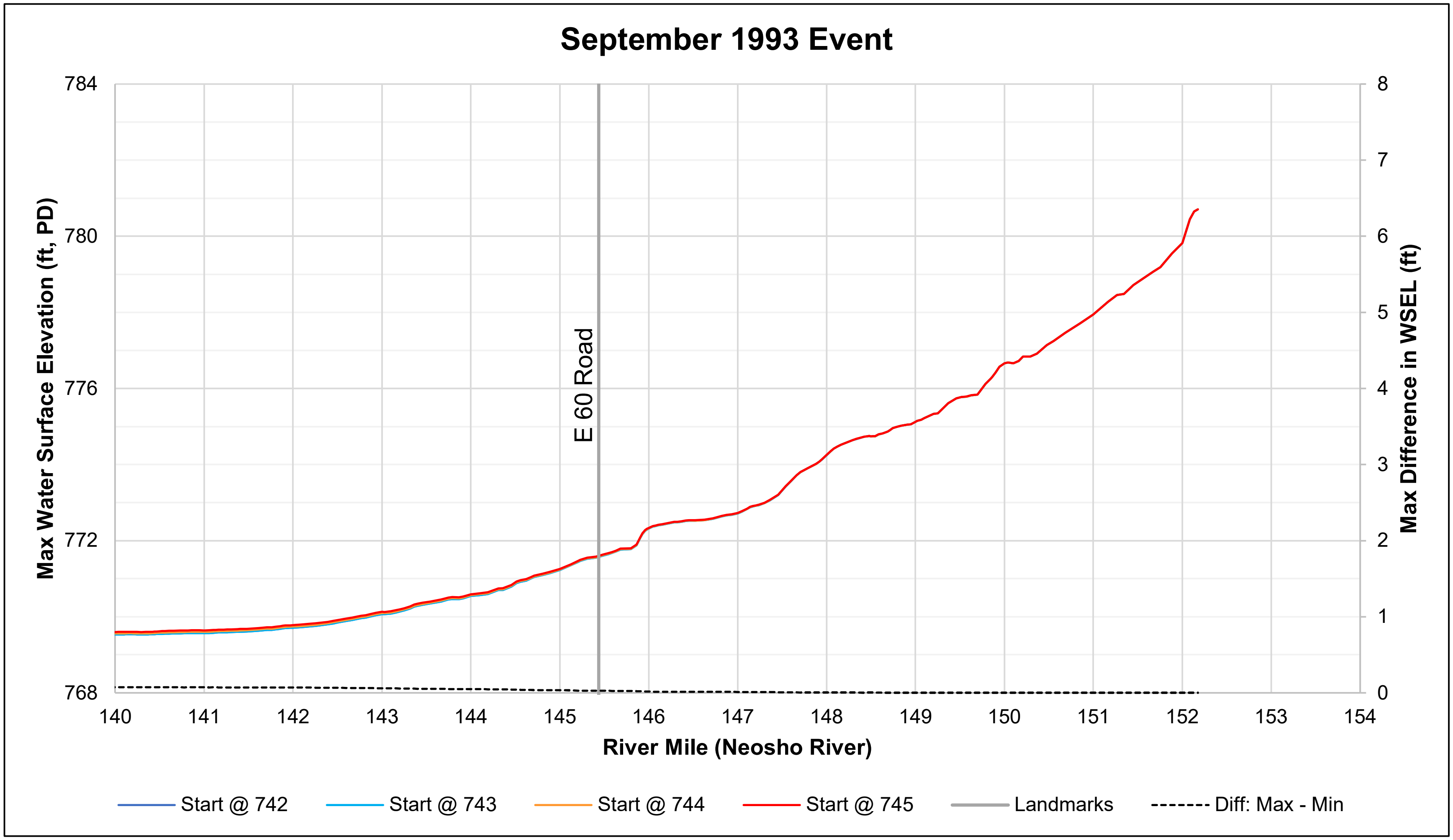


Figure E.5. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

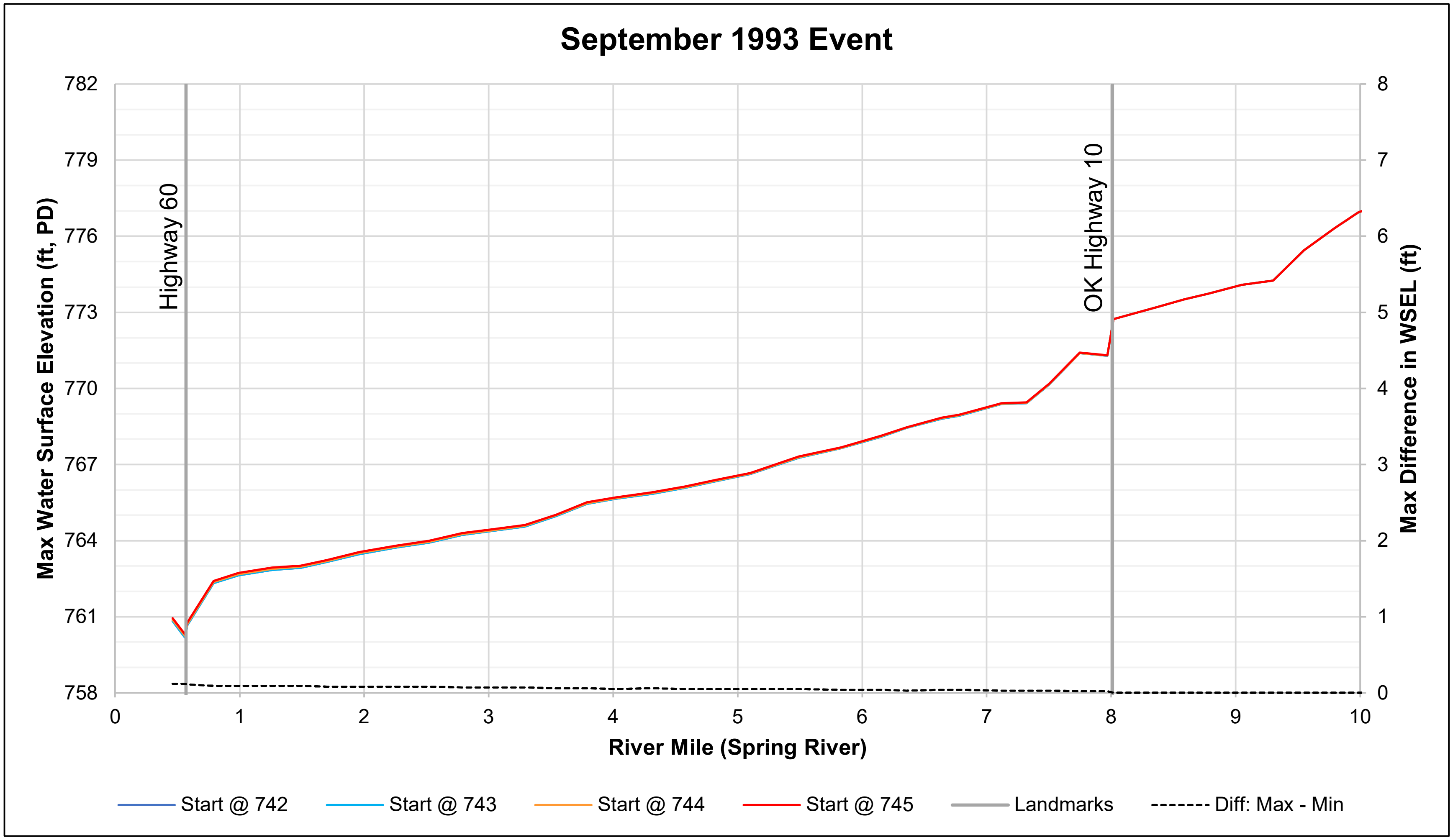


Figure E.6. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

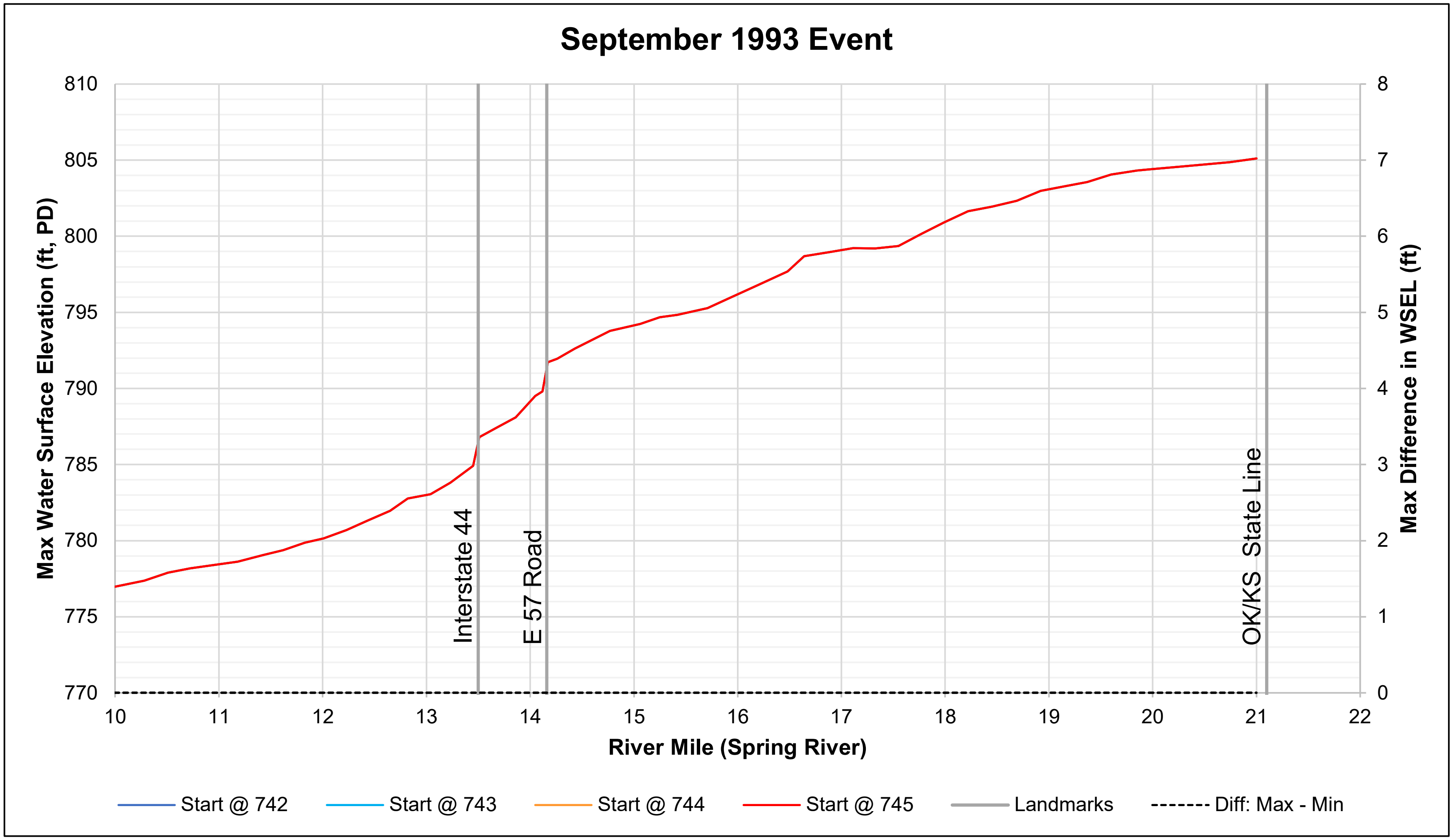


Figure E.7. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

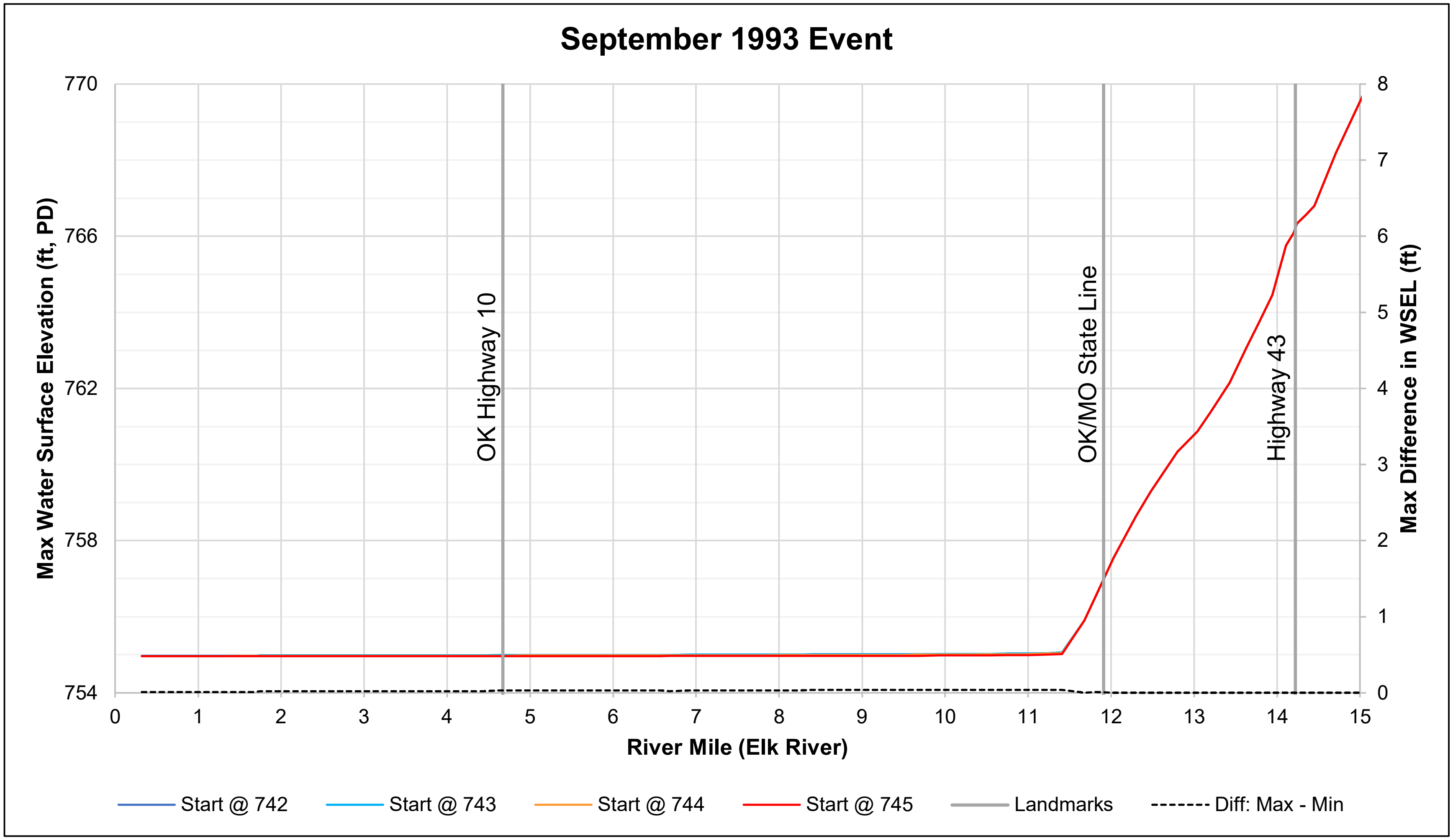


Figure E.8. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

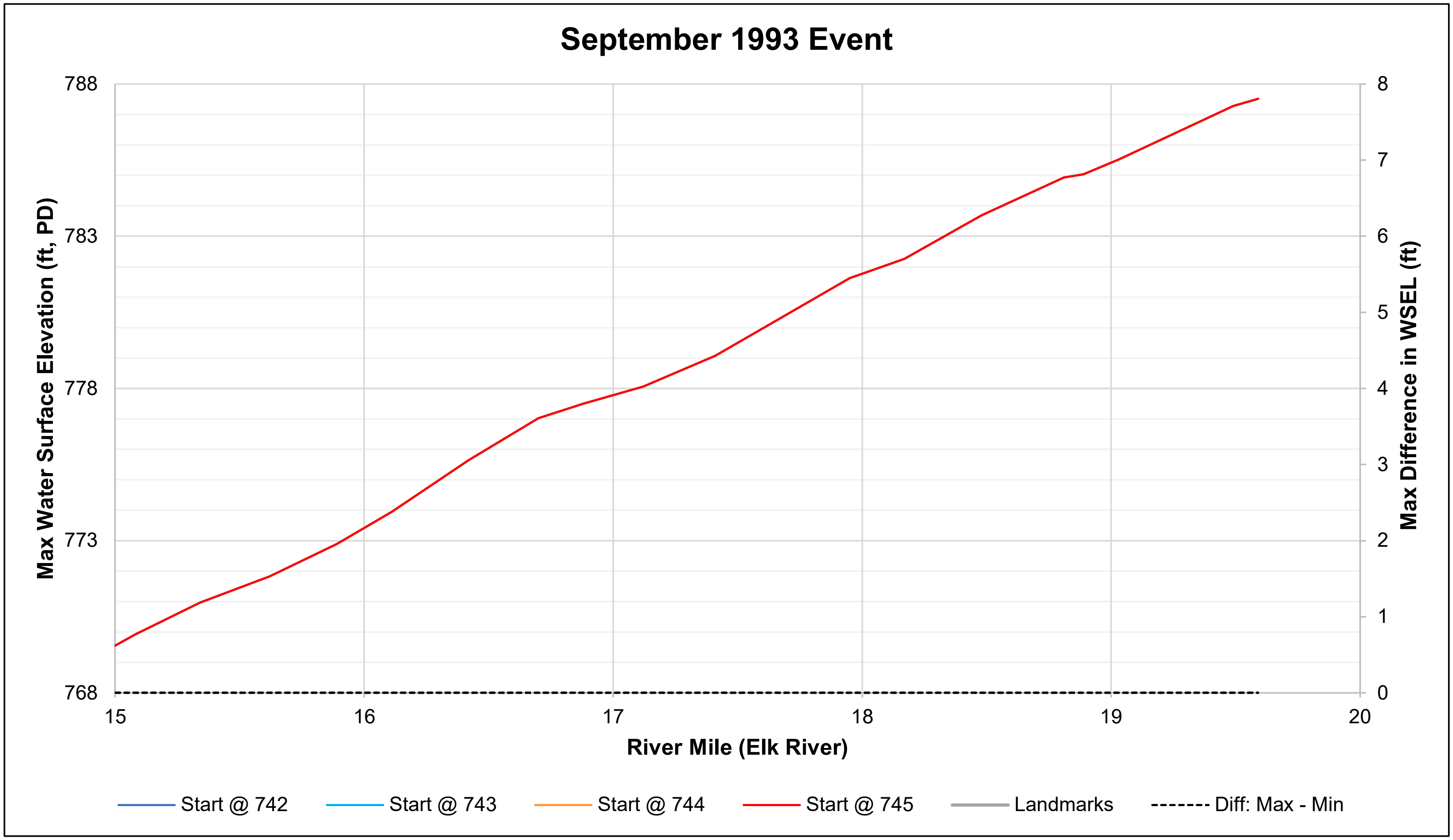


Figure E.9. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

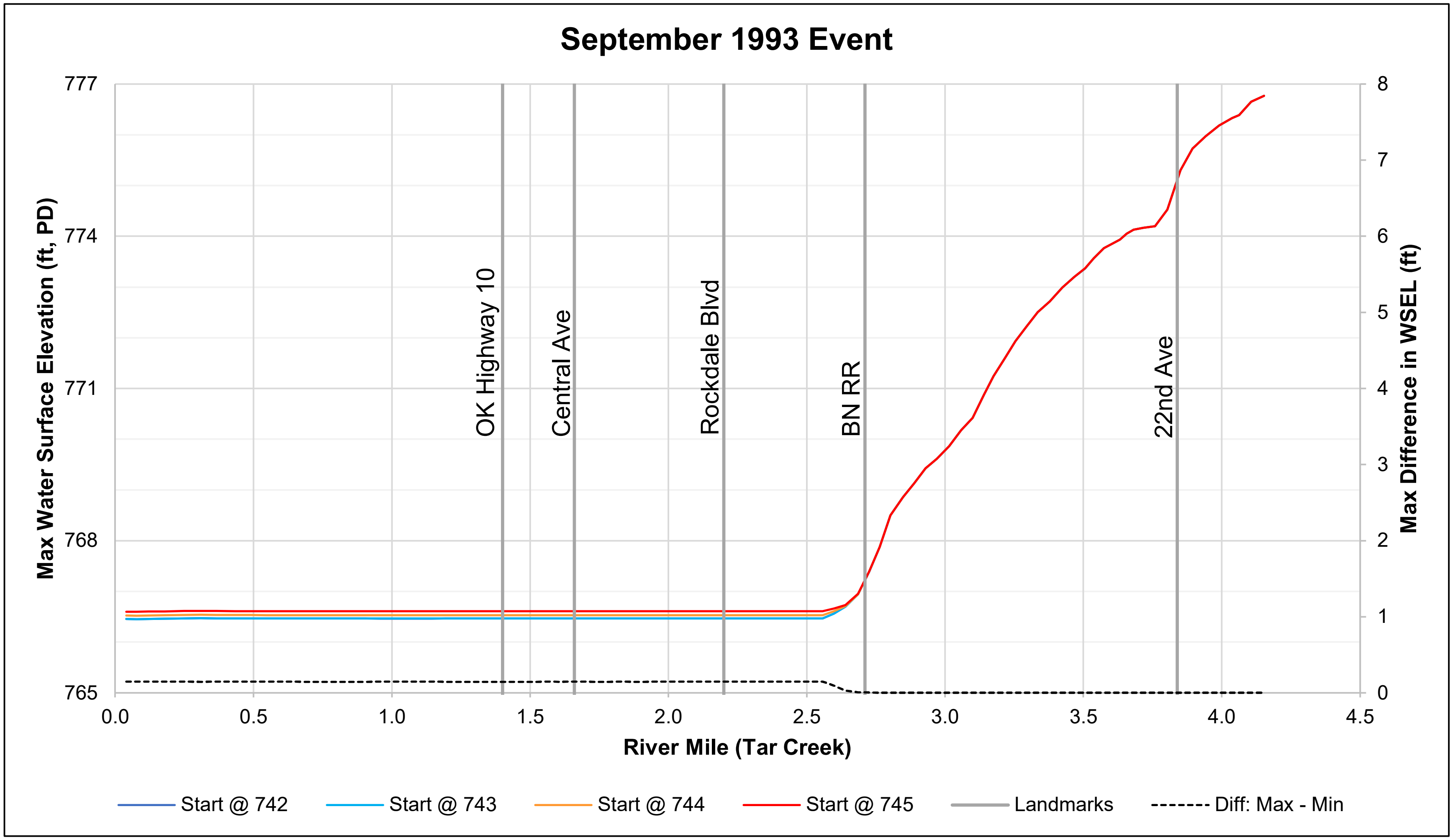


Figure E.10. Water surface elevations for the September 1993 event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

APPENDIX E.2:
JUNE 2004 EVENT PROFILES

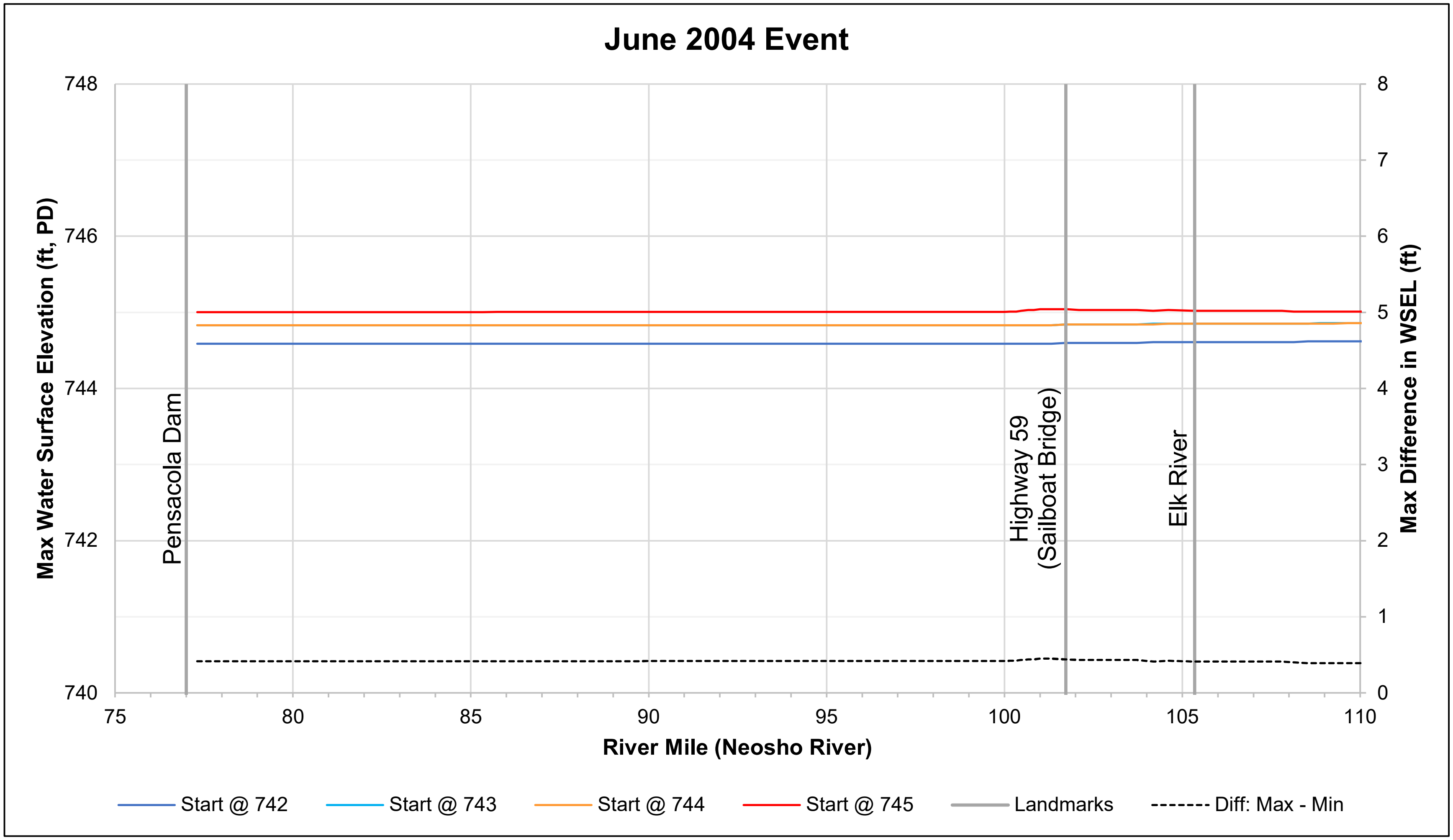


Figure E.11. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:
1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

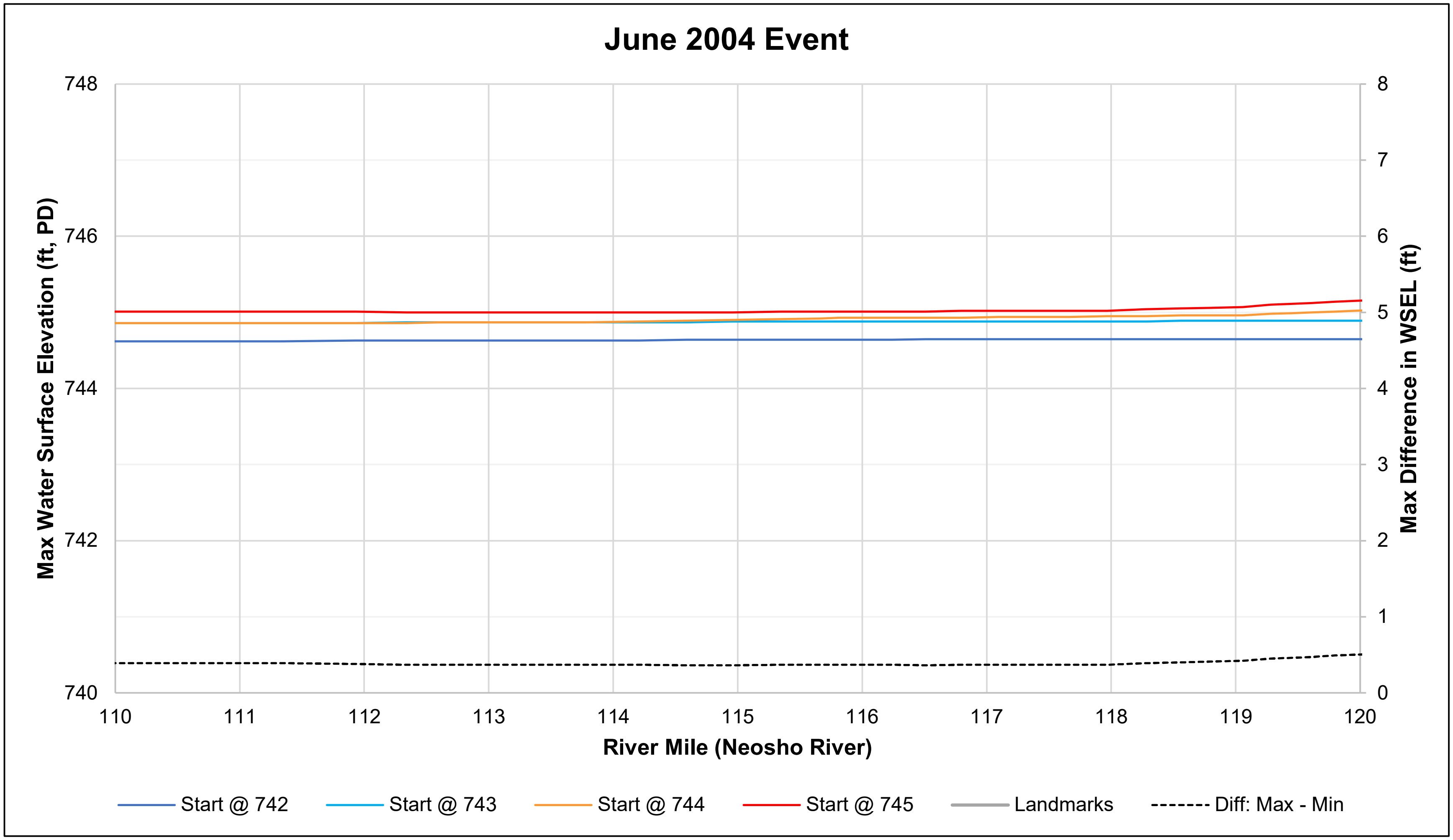


Figure E.12. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

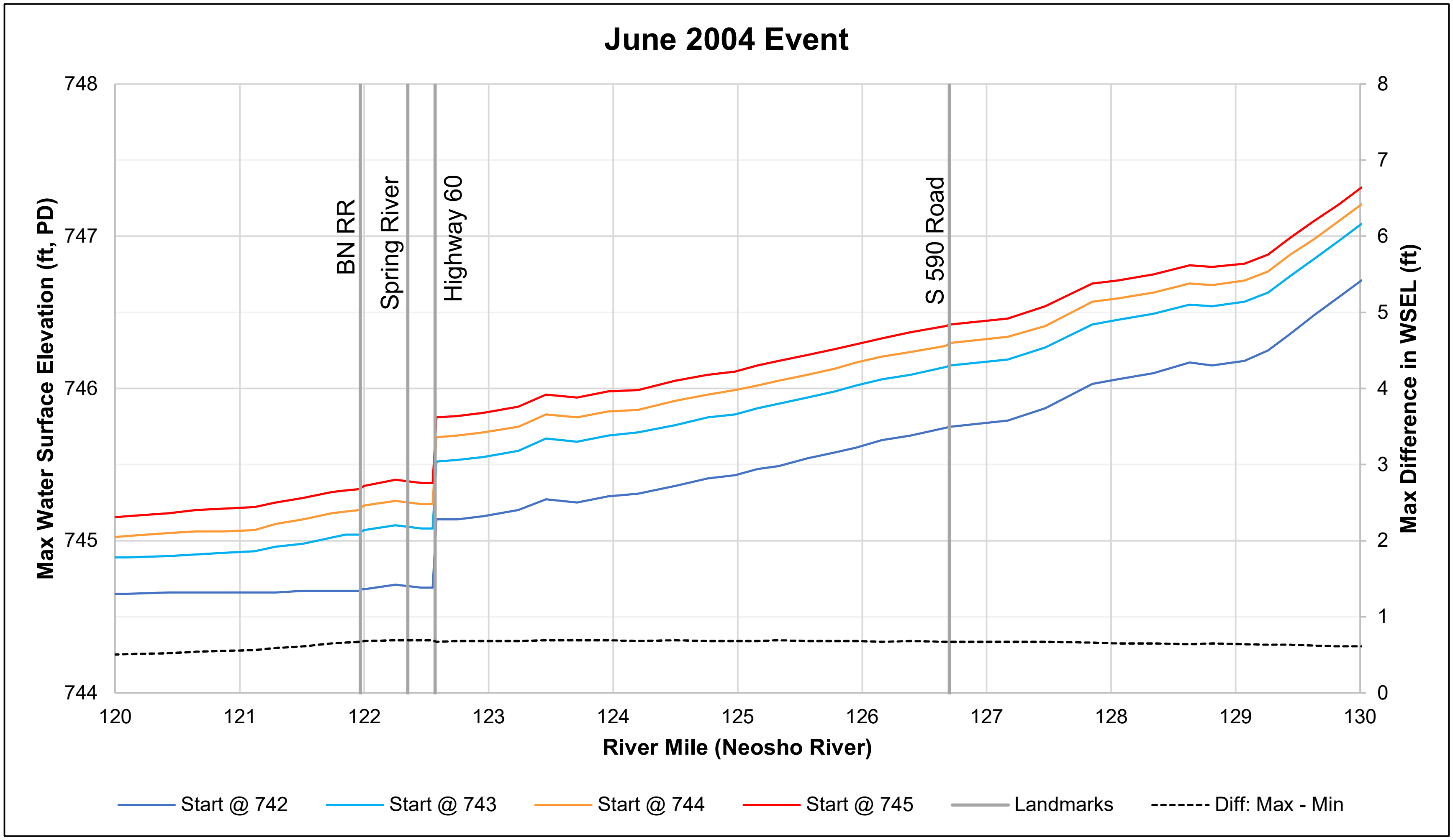


Figure E.13. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

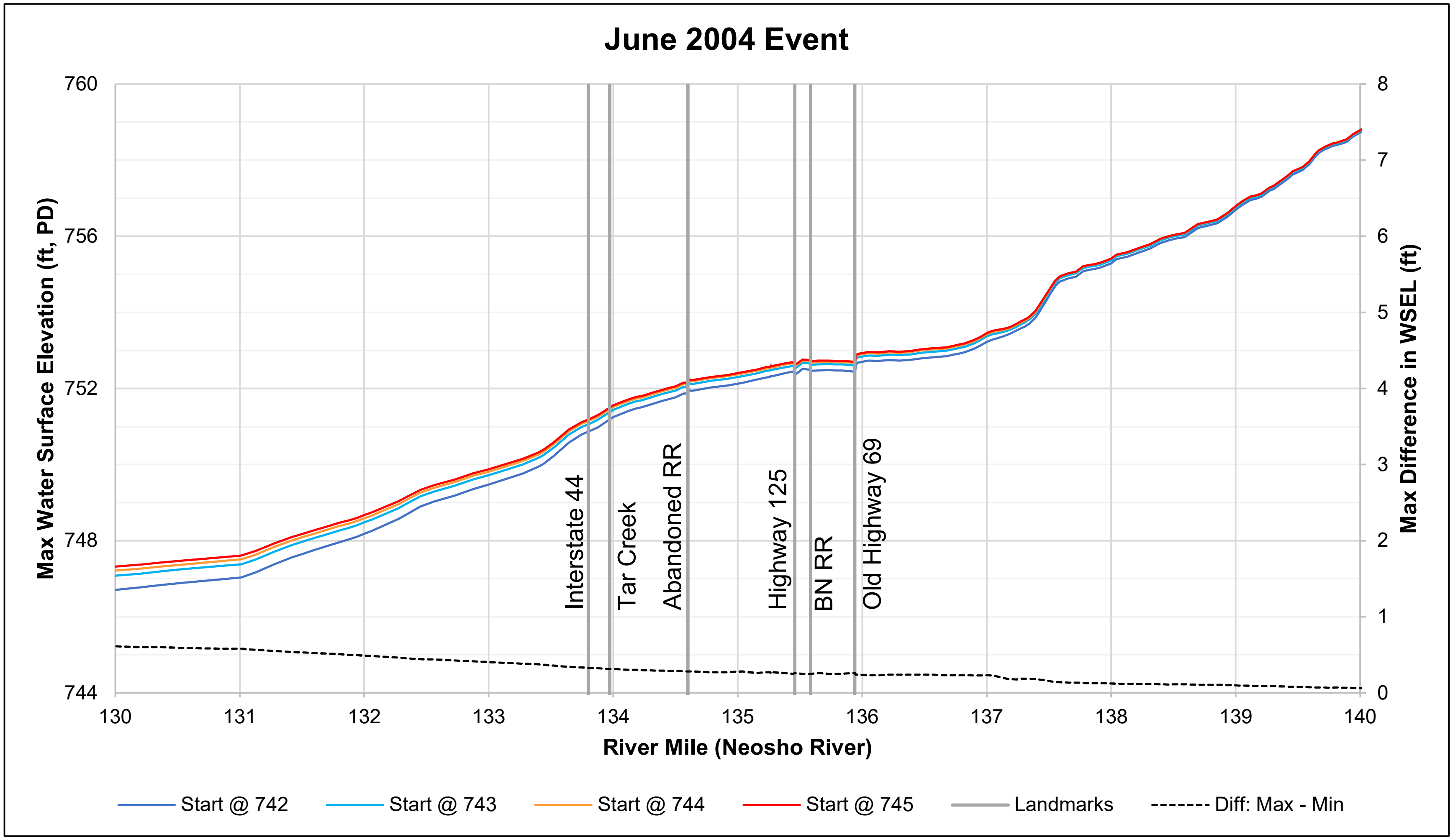


Figure E.14. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

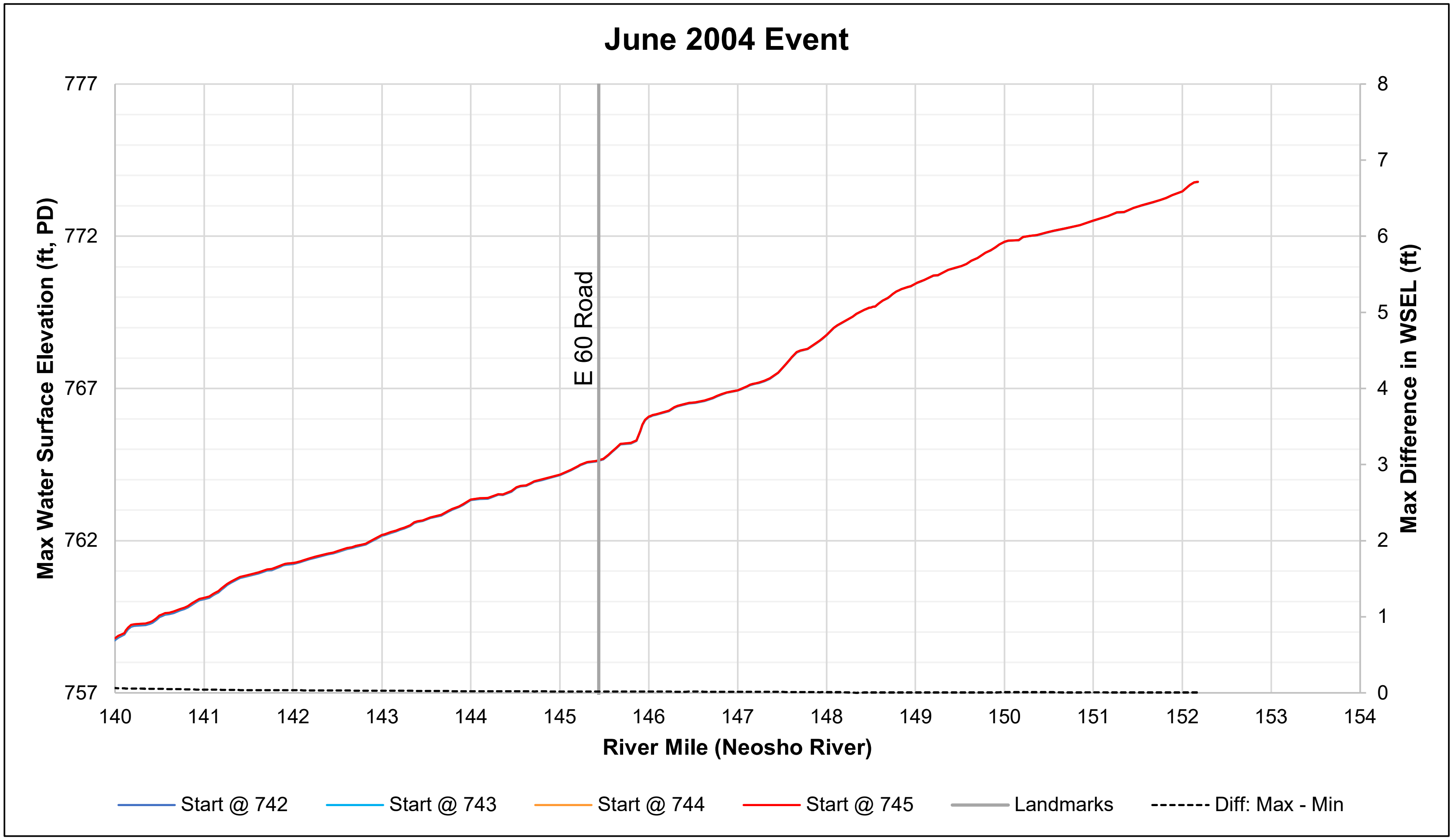


Figure E.15. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

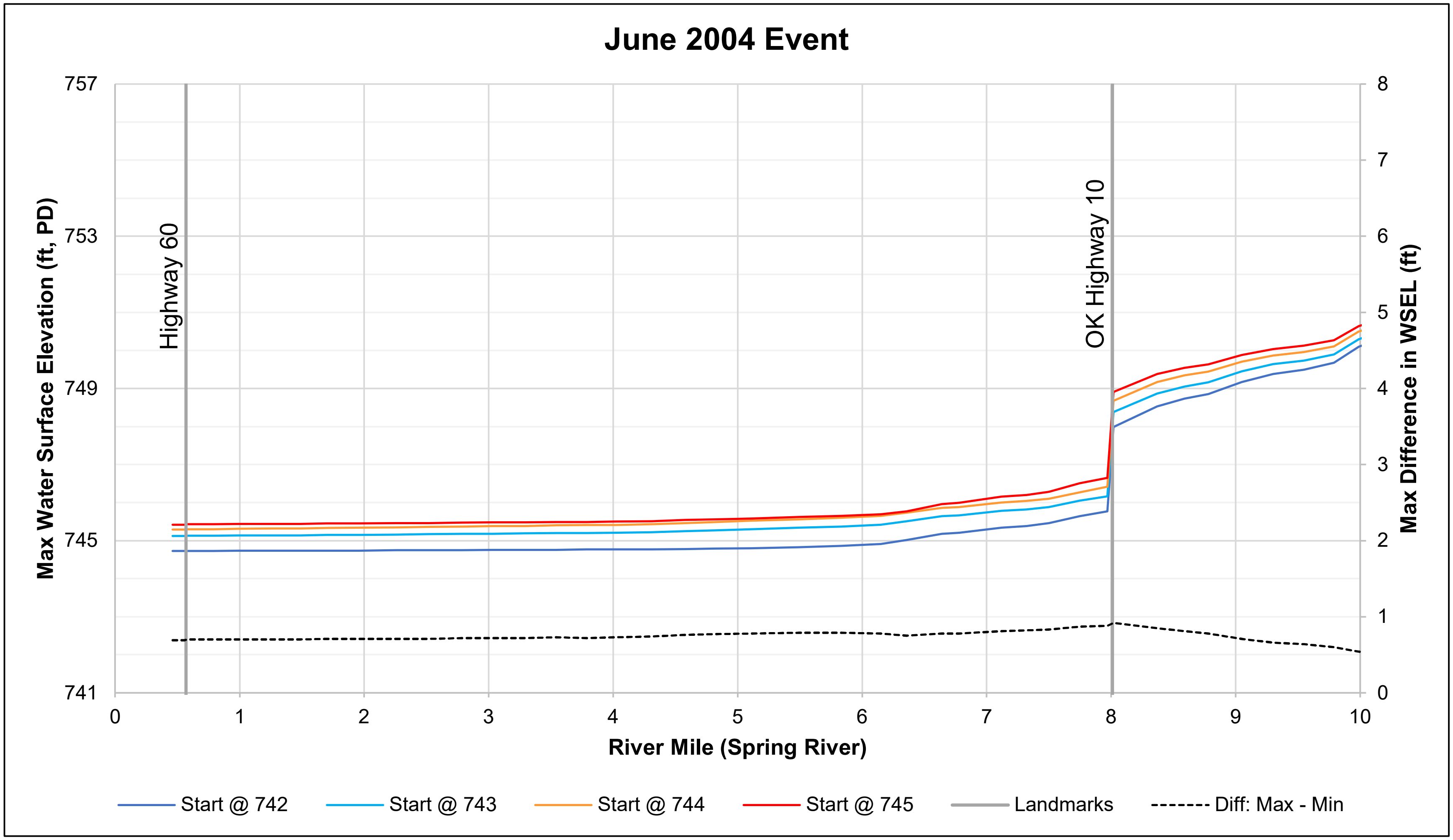


Figure E.16. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

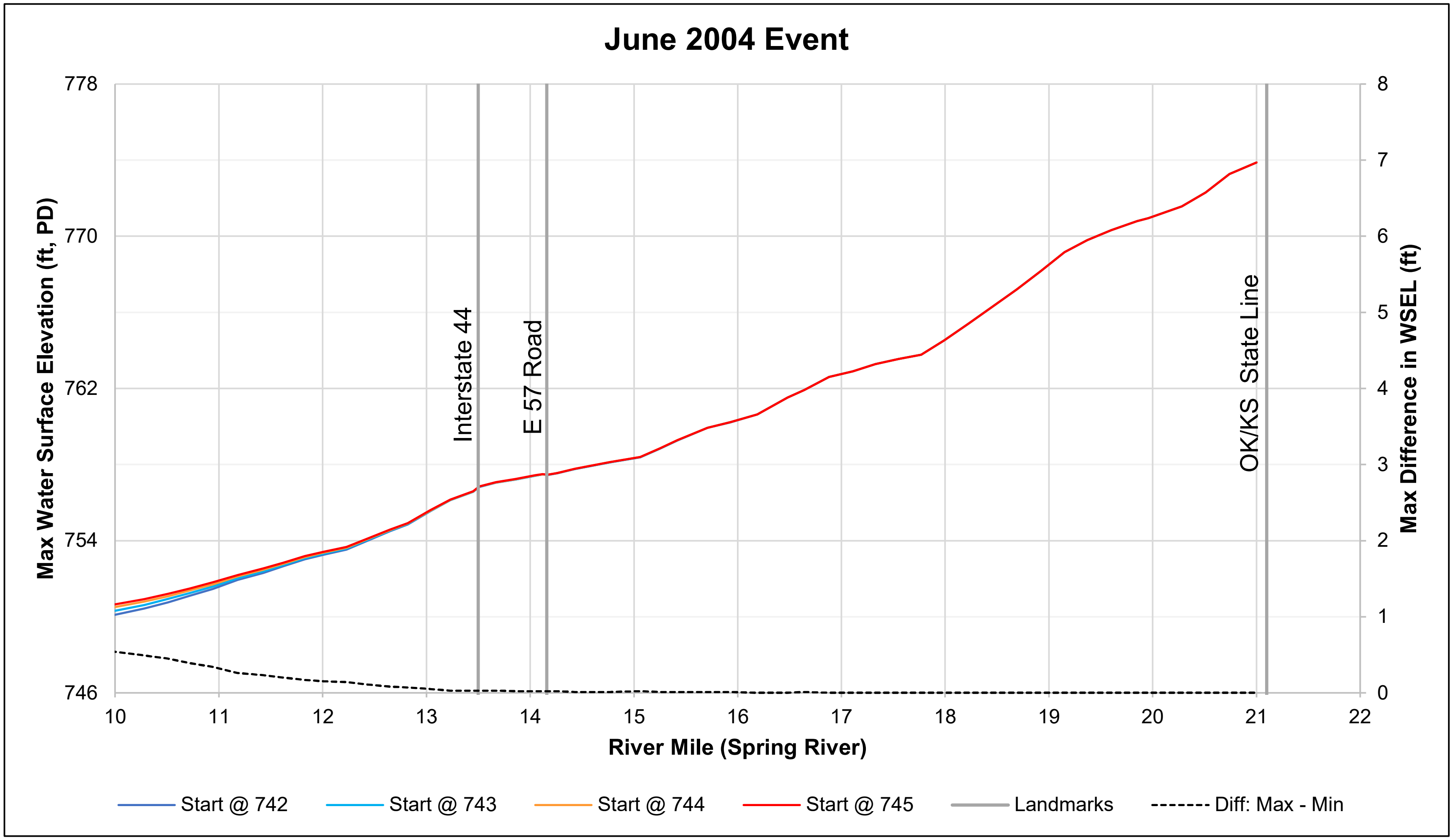


Figure E.17. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

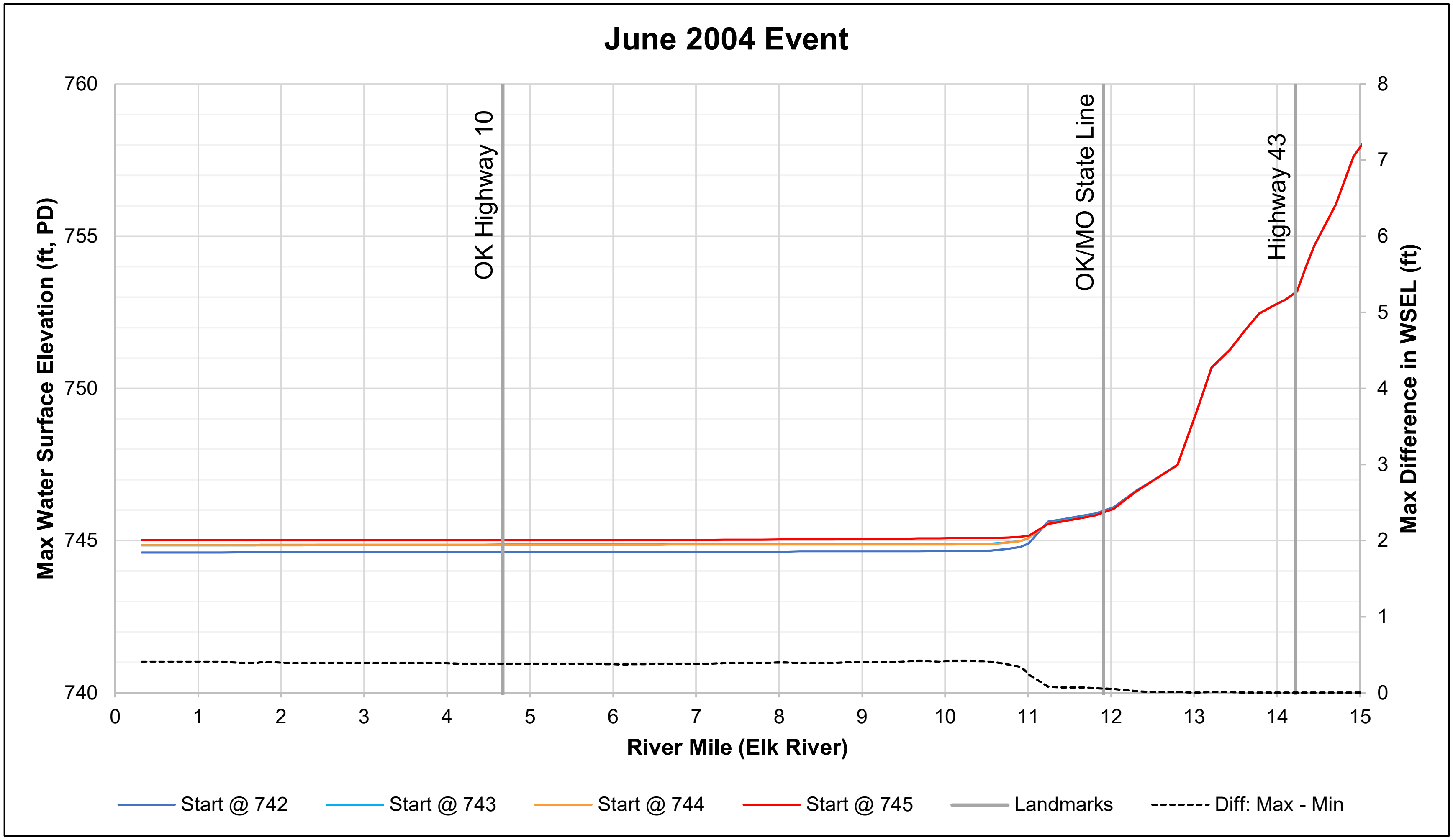


Figure E.18. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

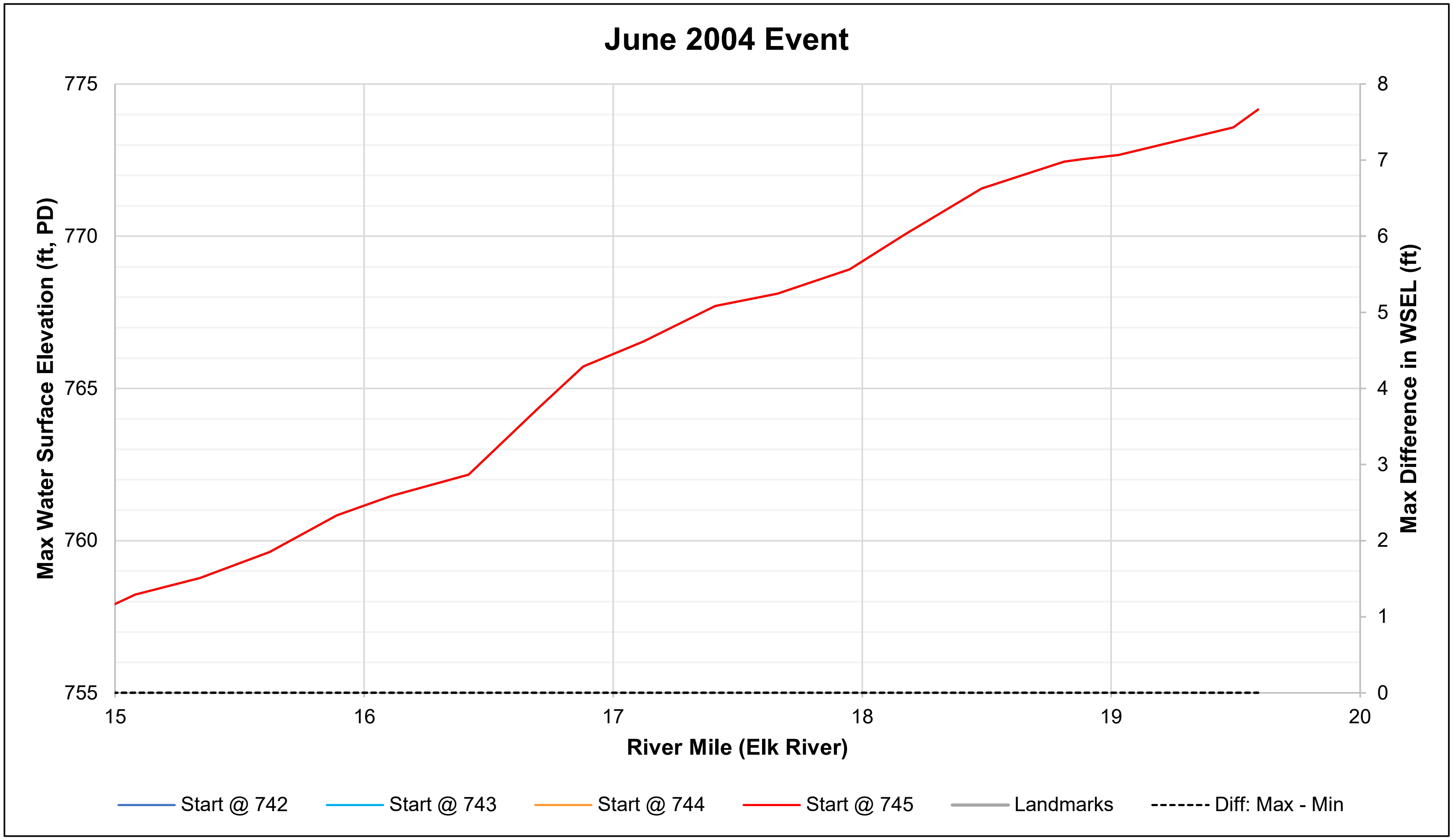


Figure E.19. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:
1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

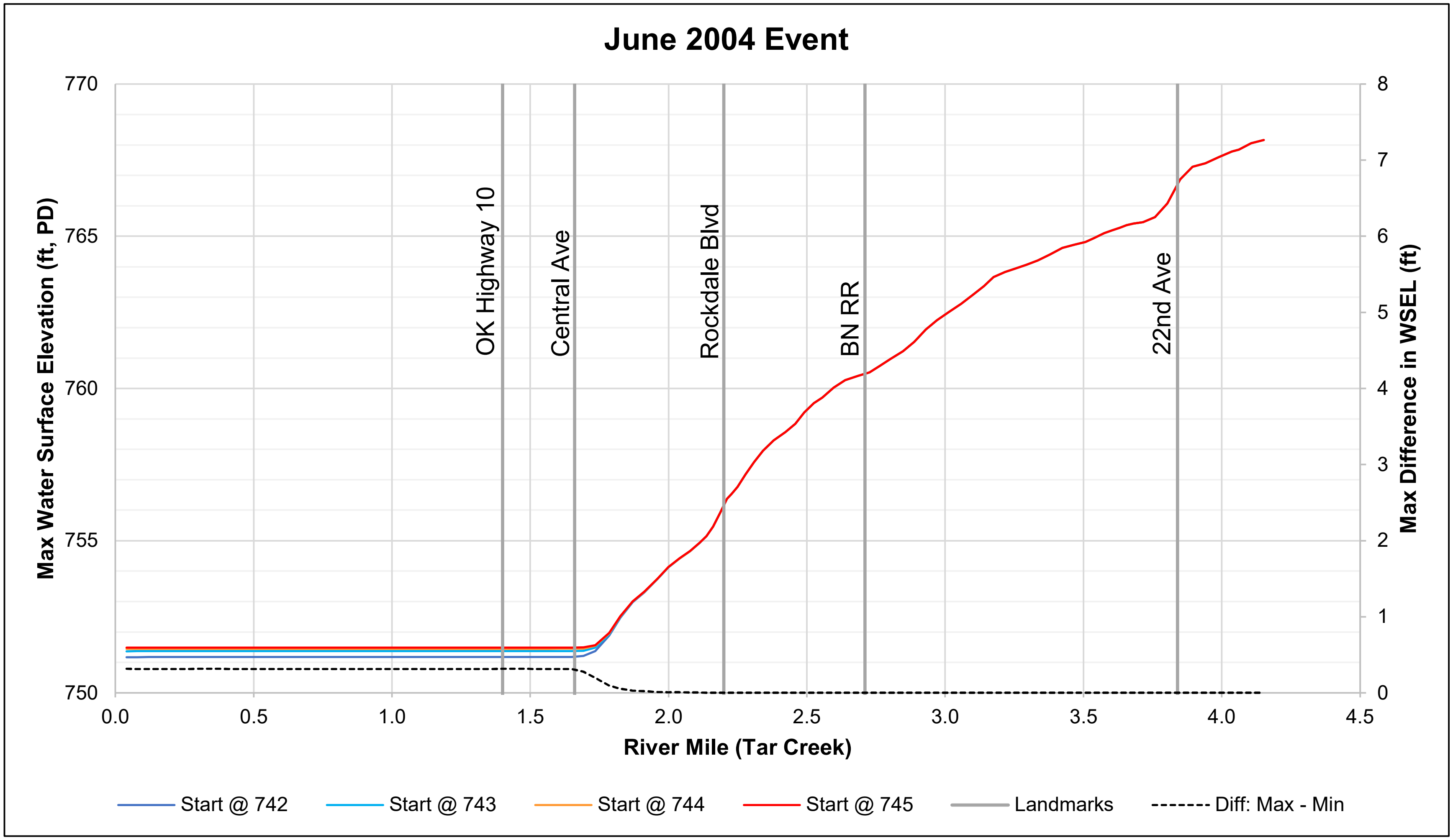


Figure E.20. Water surface elevations for the June 2004 event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

APPENDIX E.3:
JULY 2007 EVENT PROFILES

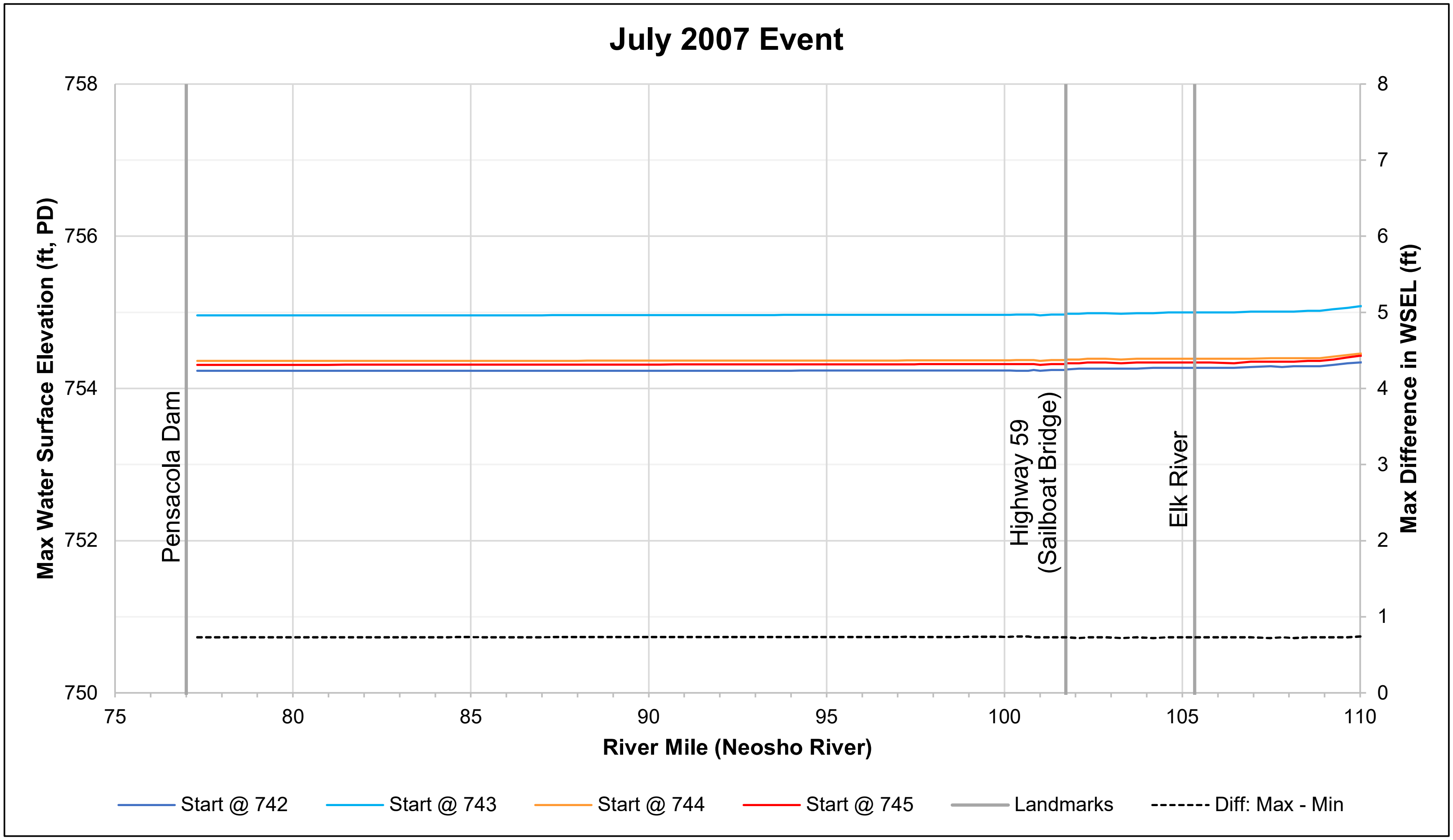


Figure E.21. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

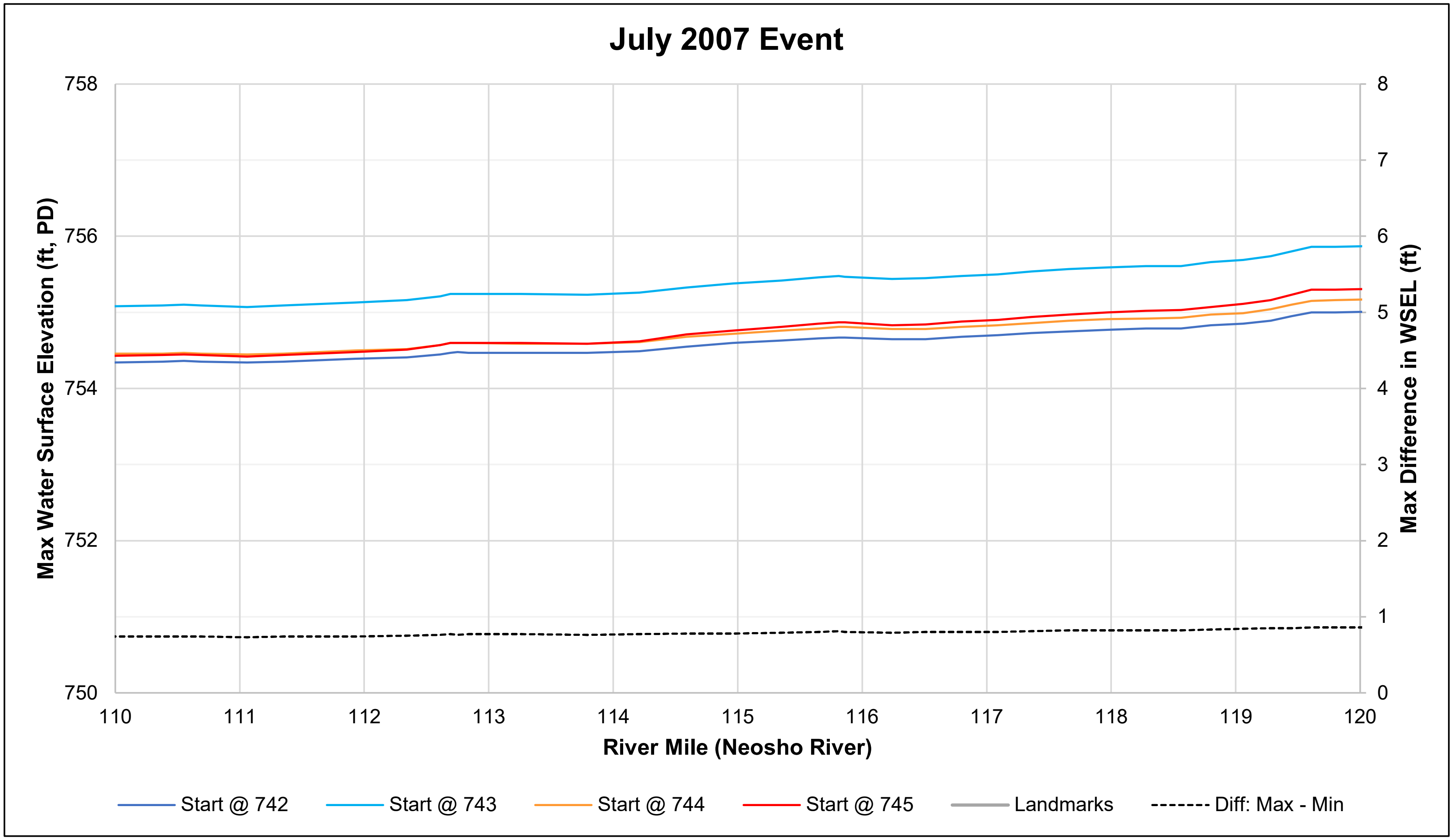


Figure E.22. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

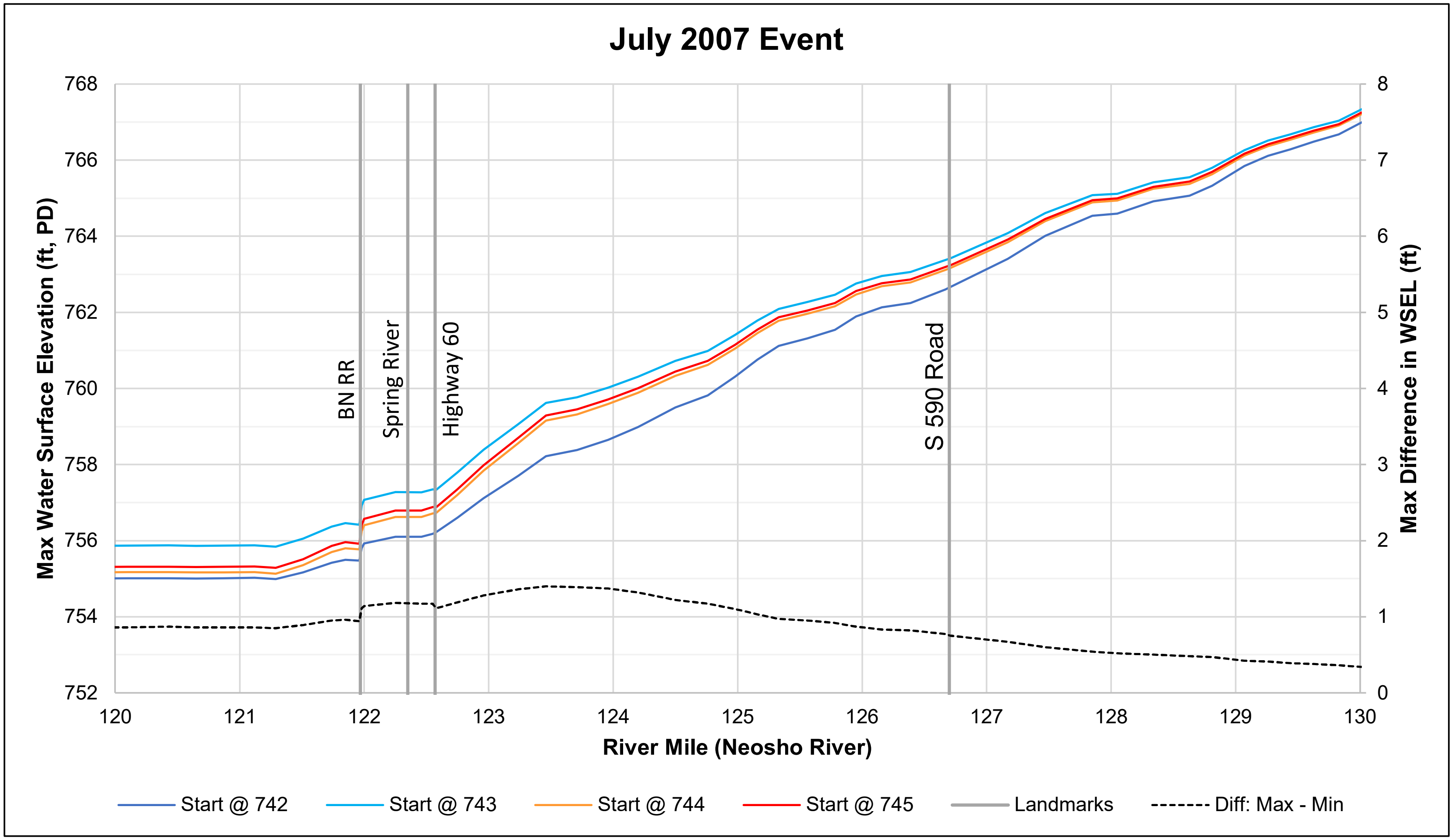


Figure E.23. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

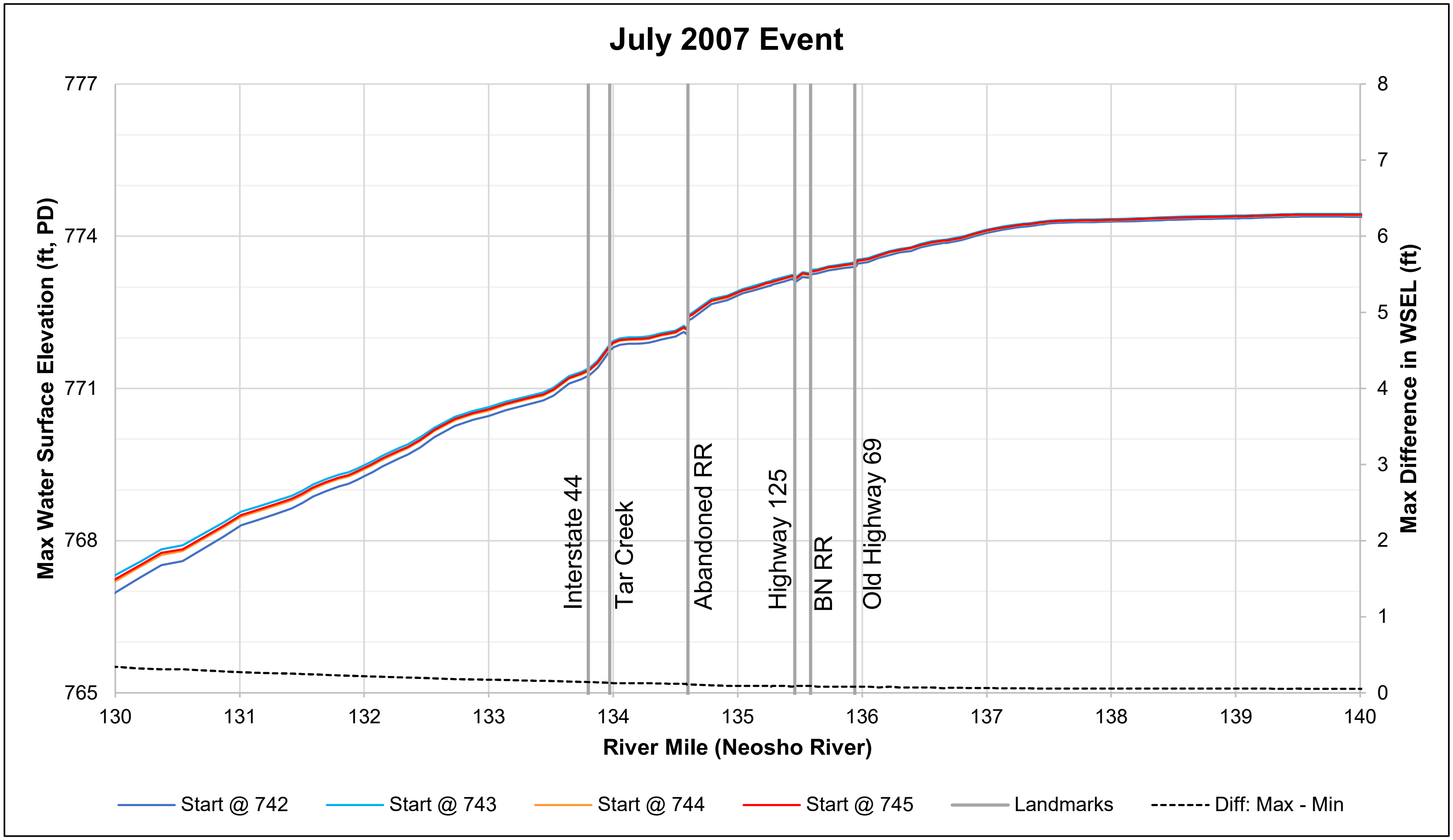


Figure E.24. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

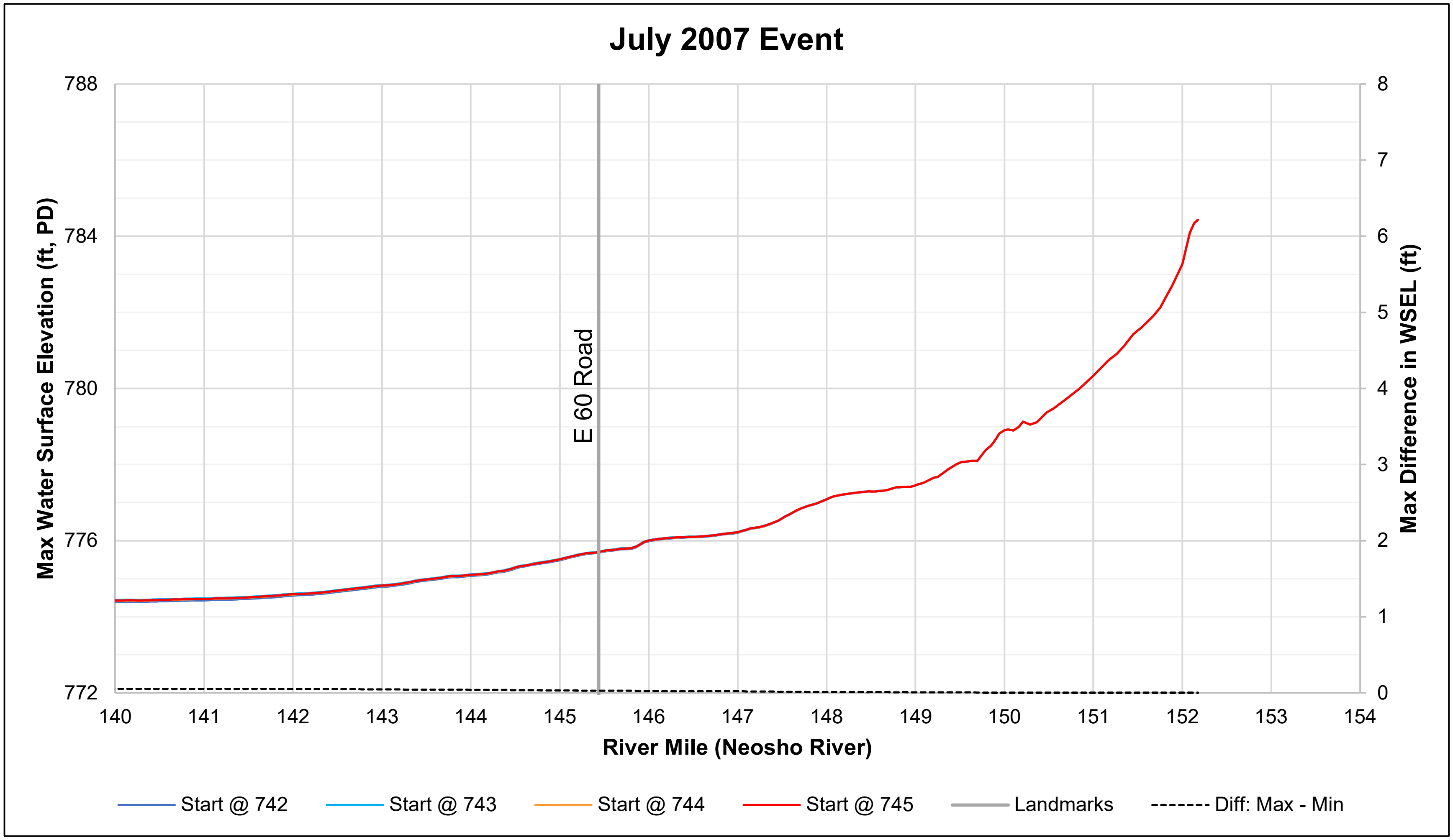


Figure E.25. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

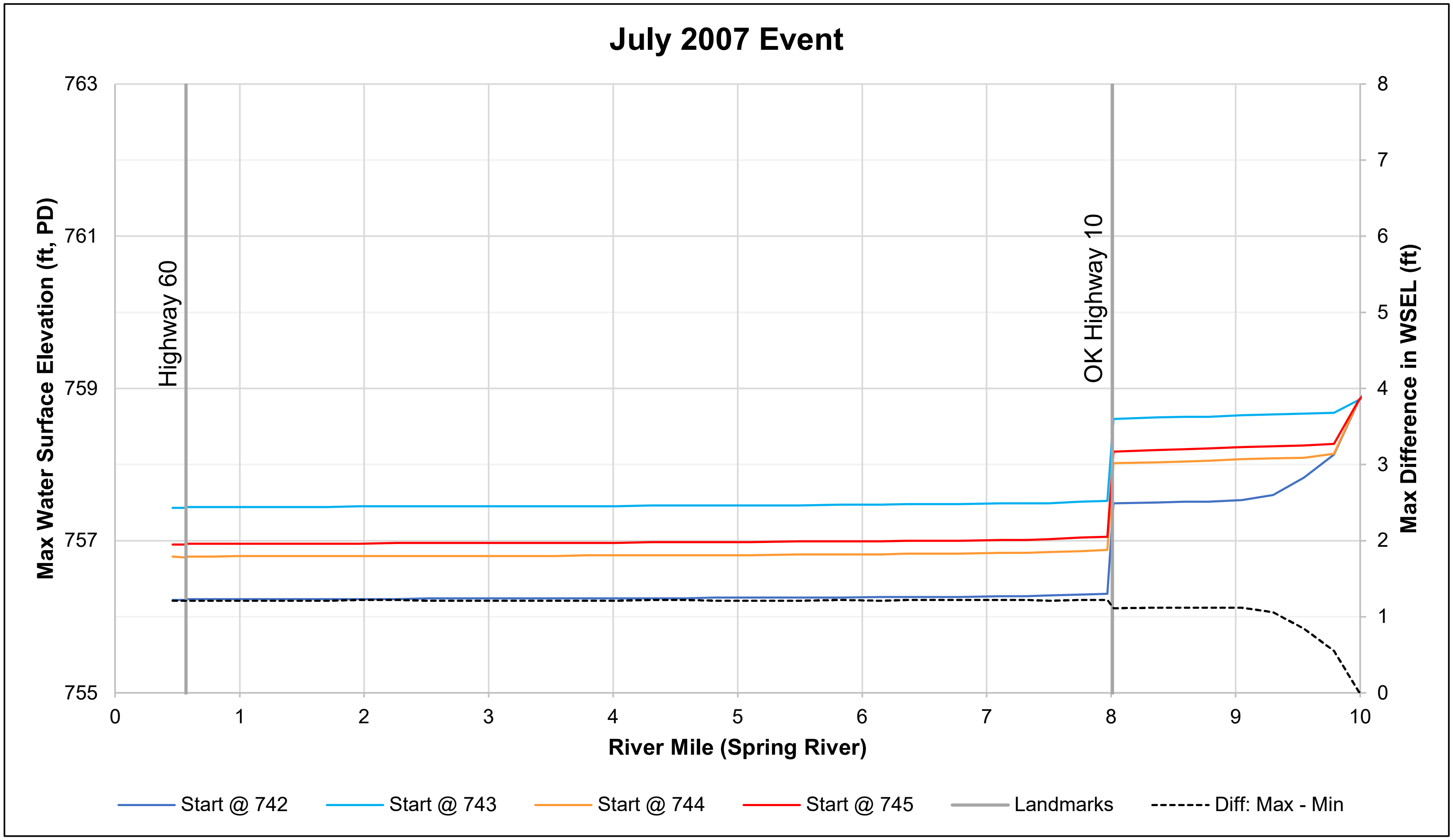


Figure E.26. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

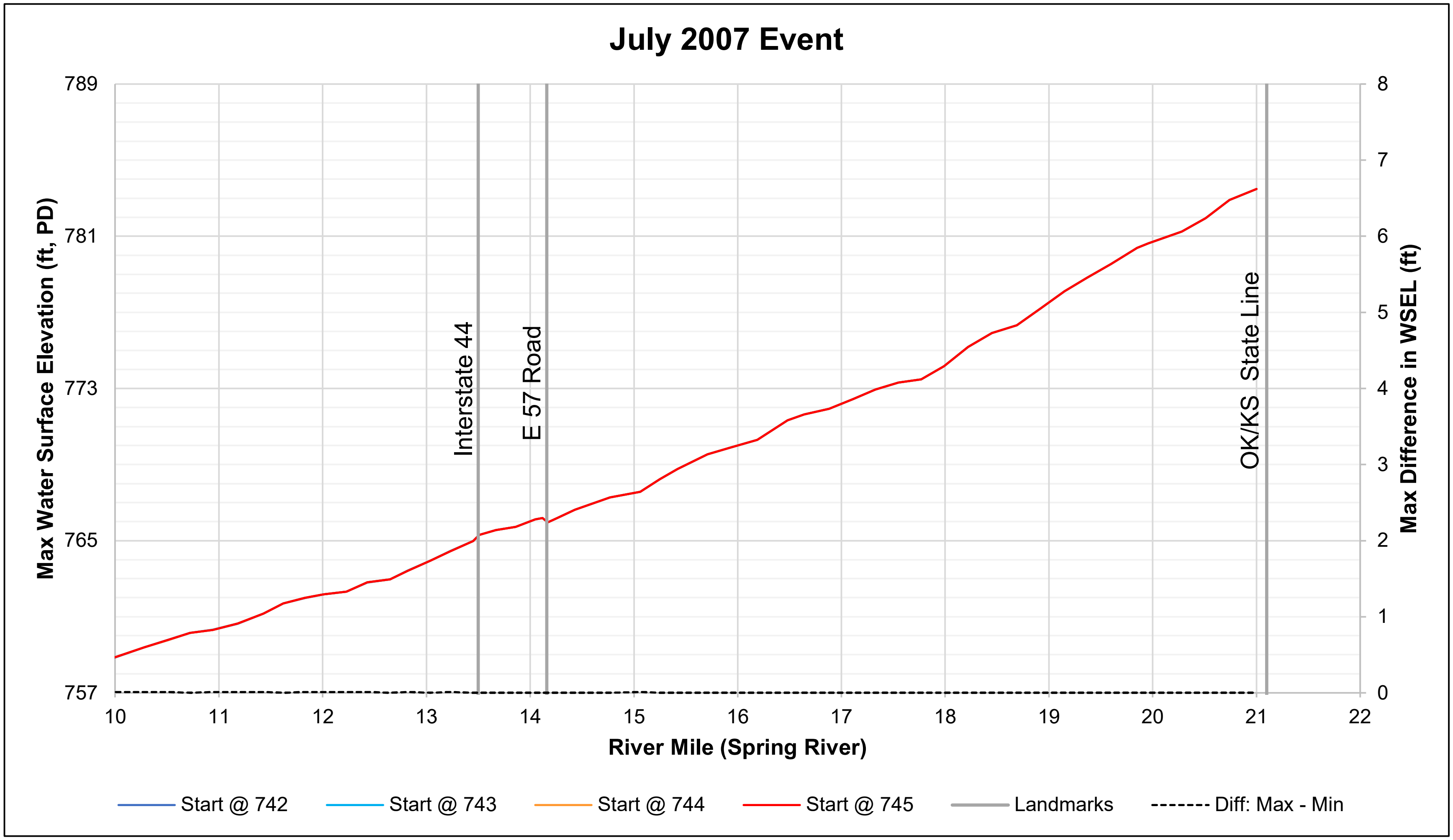


Figure E.27. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

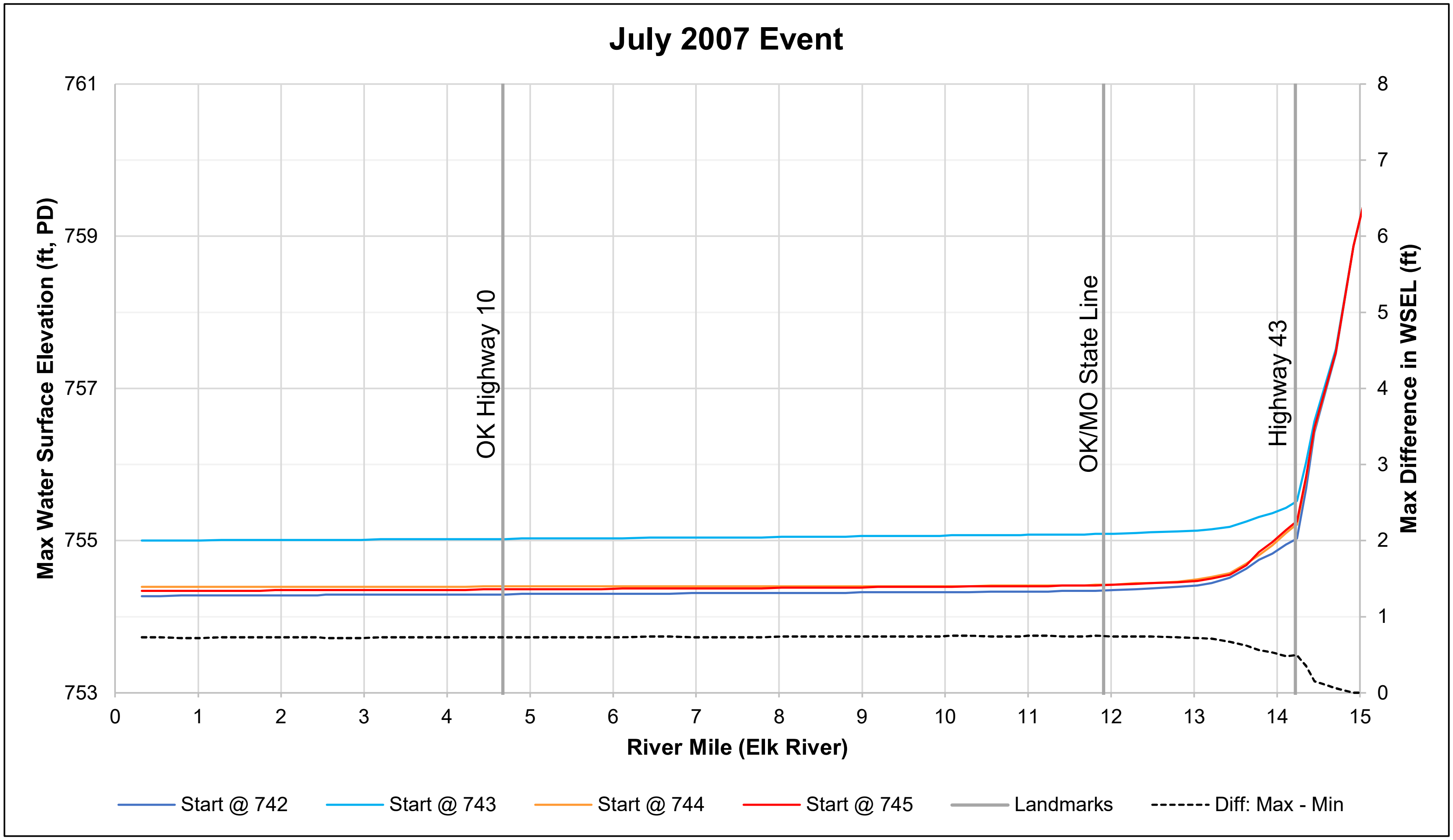


Figure E.28. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

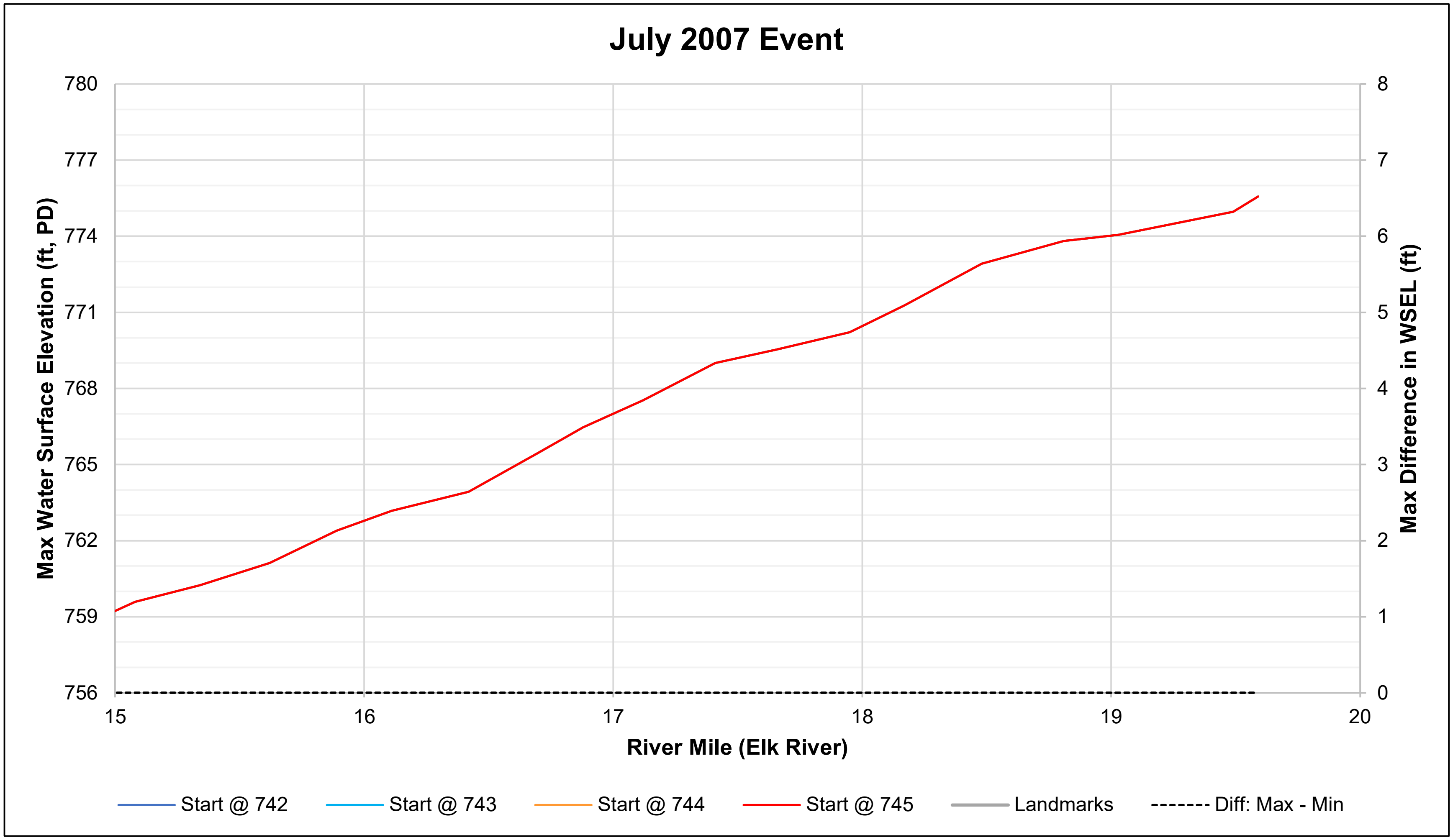


Figure E.29. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

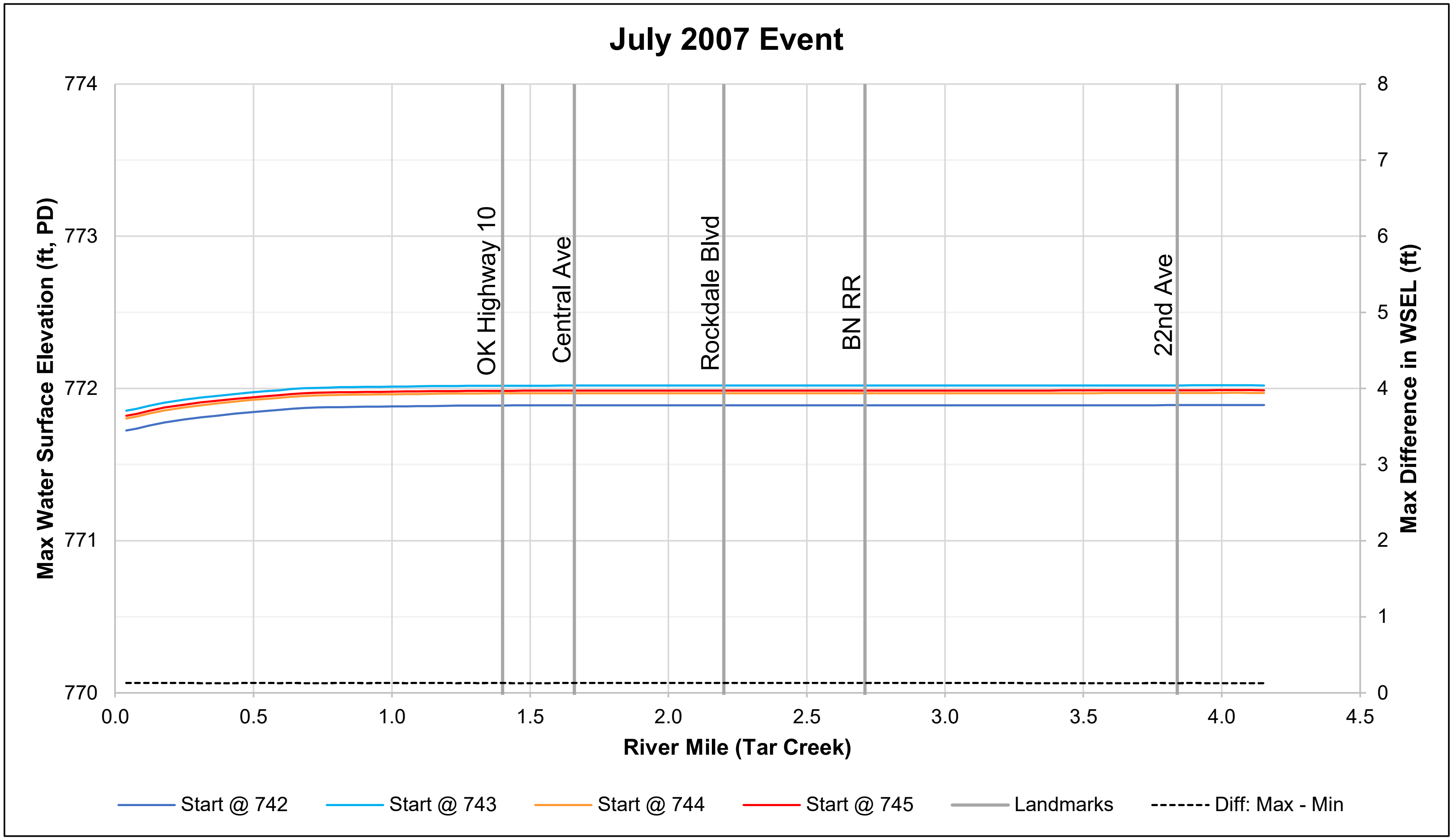


Figure E.30. Water surface elevations for the July 2007 event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

APPENDIX E.4:
OCTOBER 2009 EVENT PROFILES

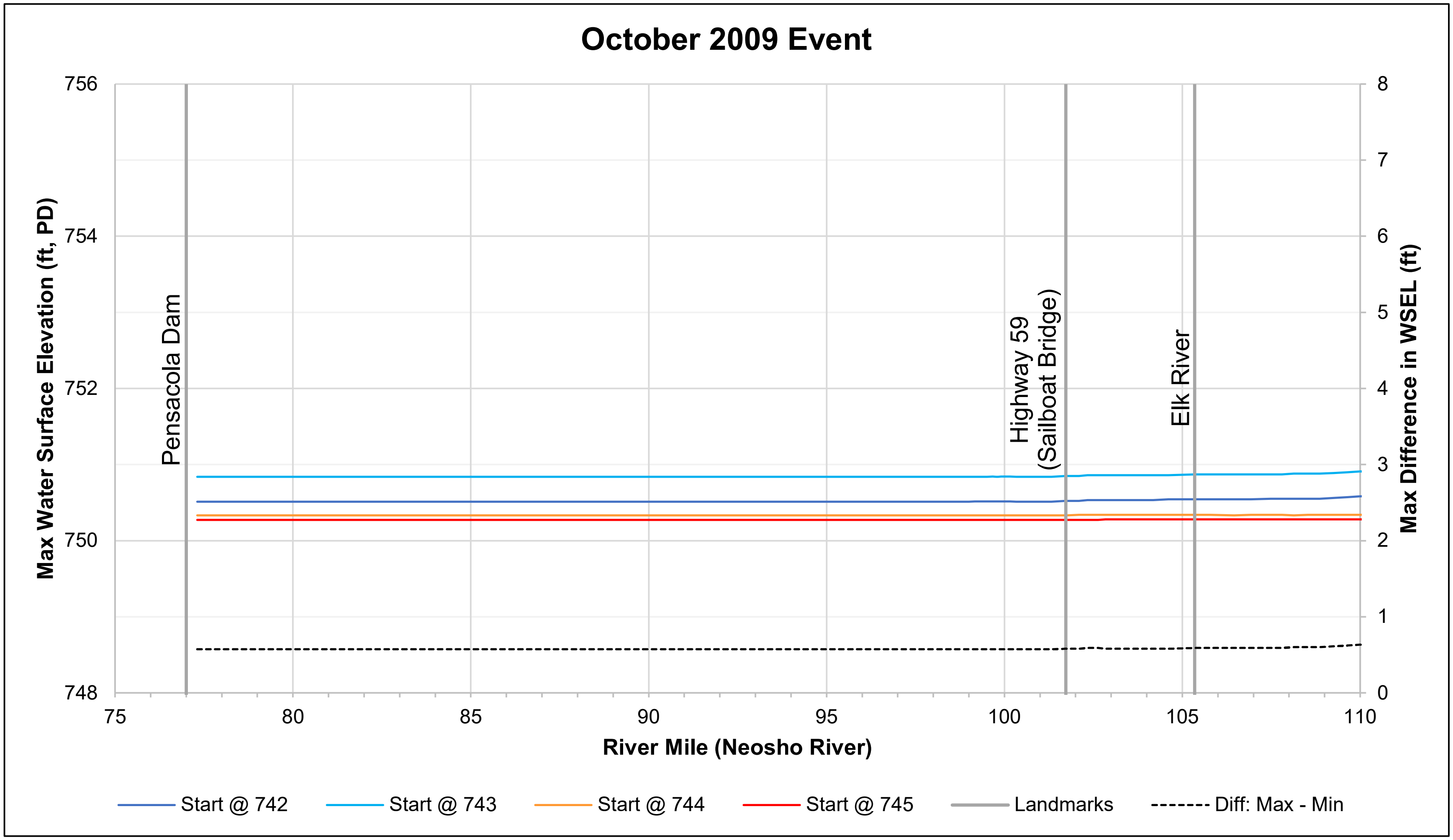


Figure E.31. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:
1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

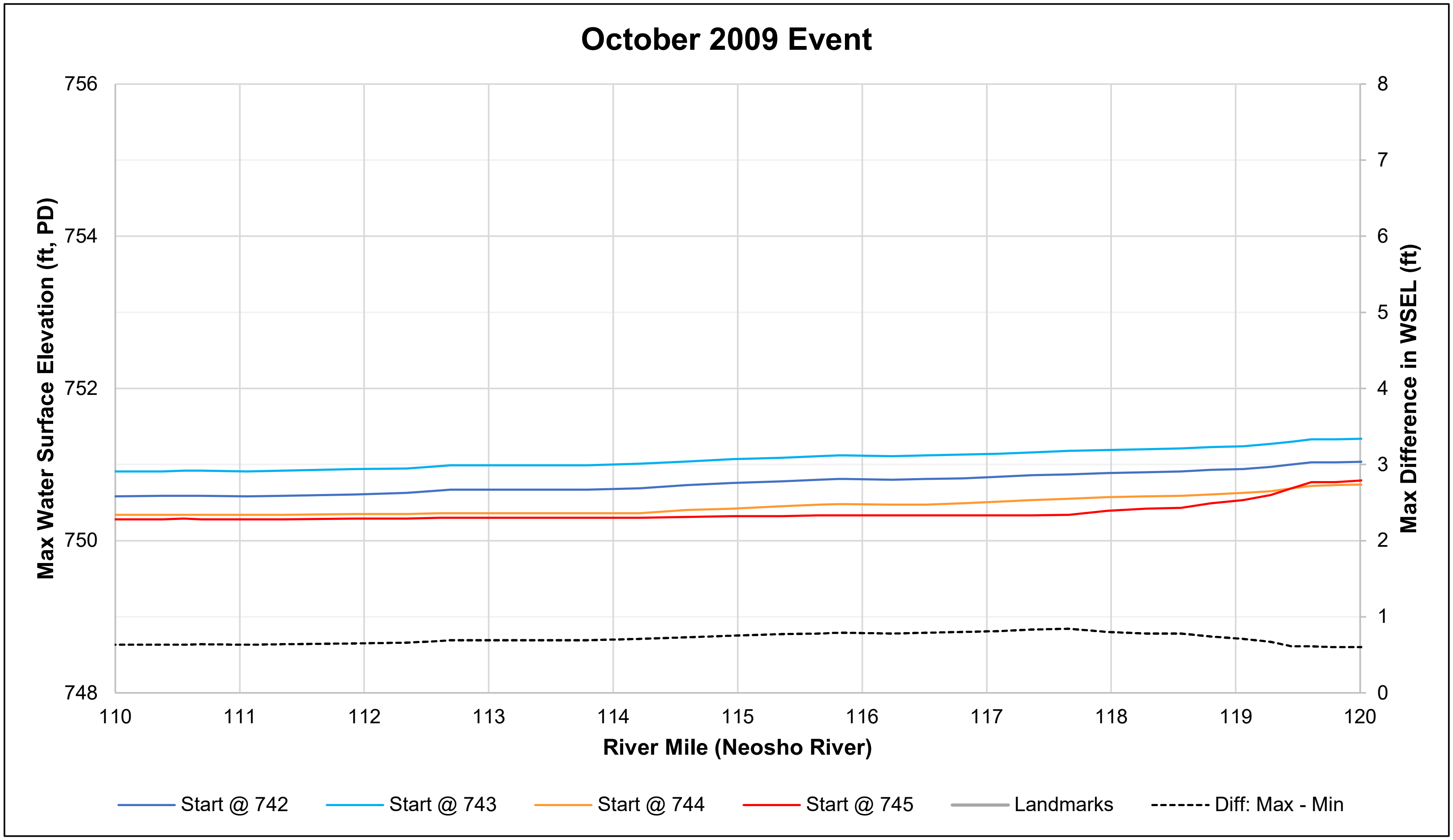


Figure E.32. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

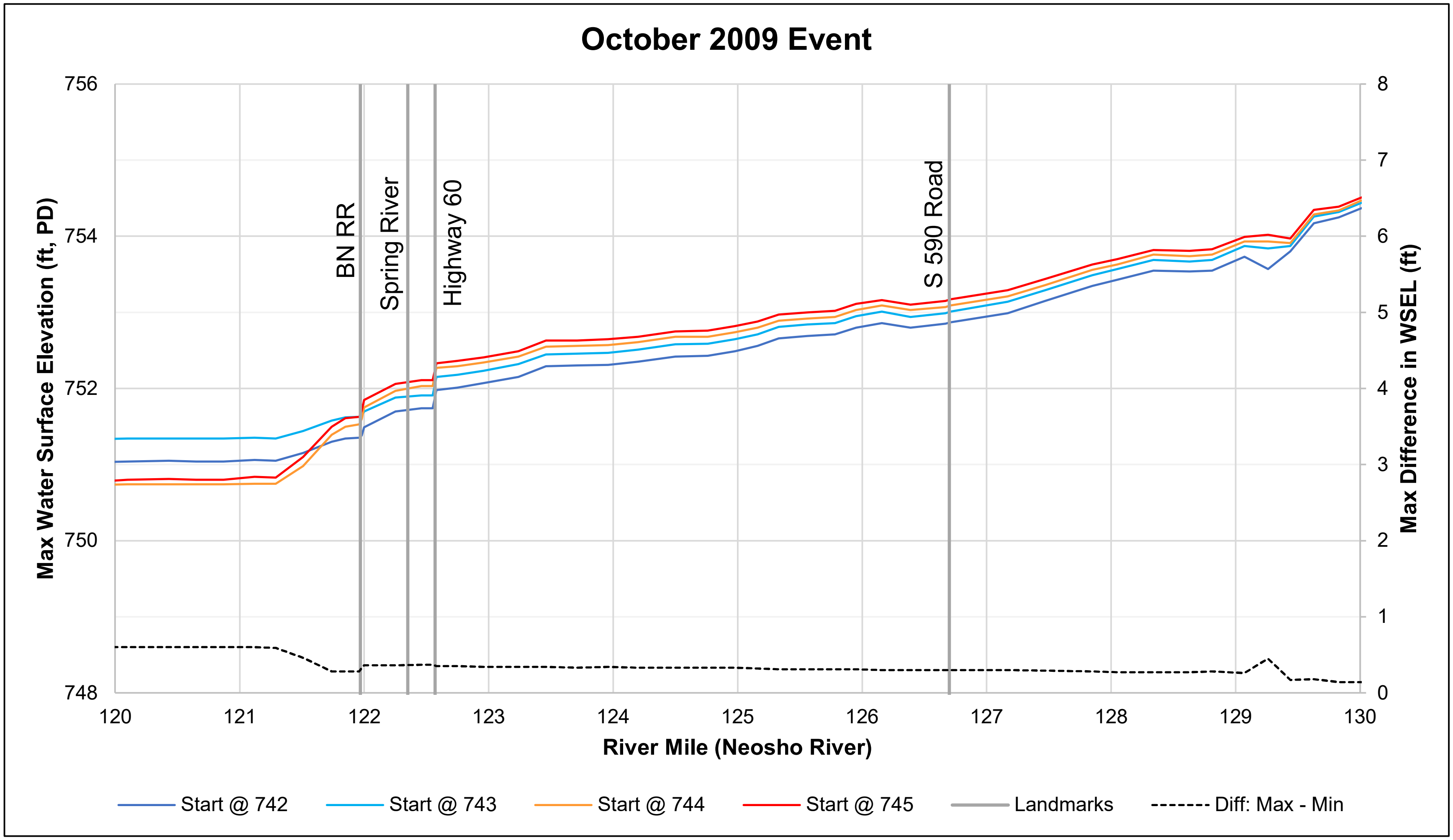


Figure E.33. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

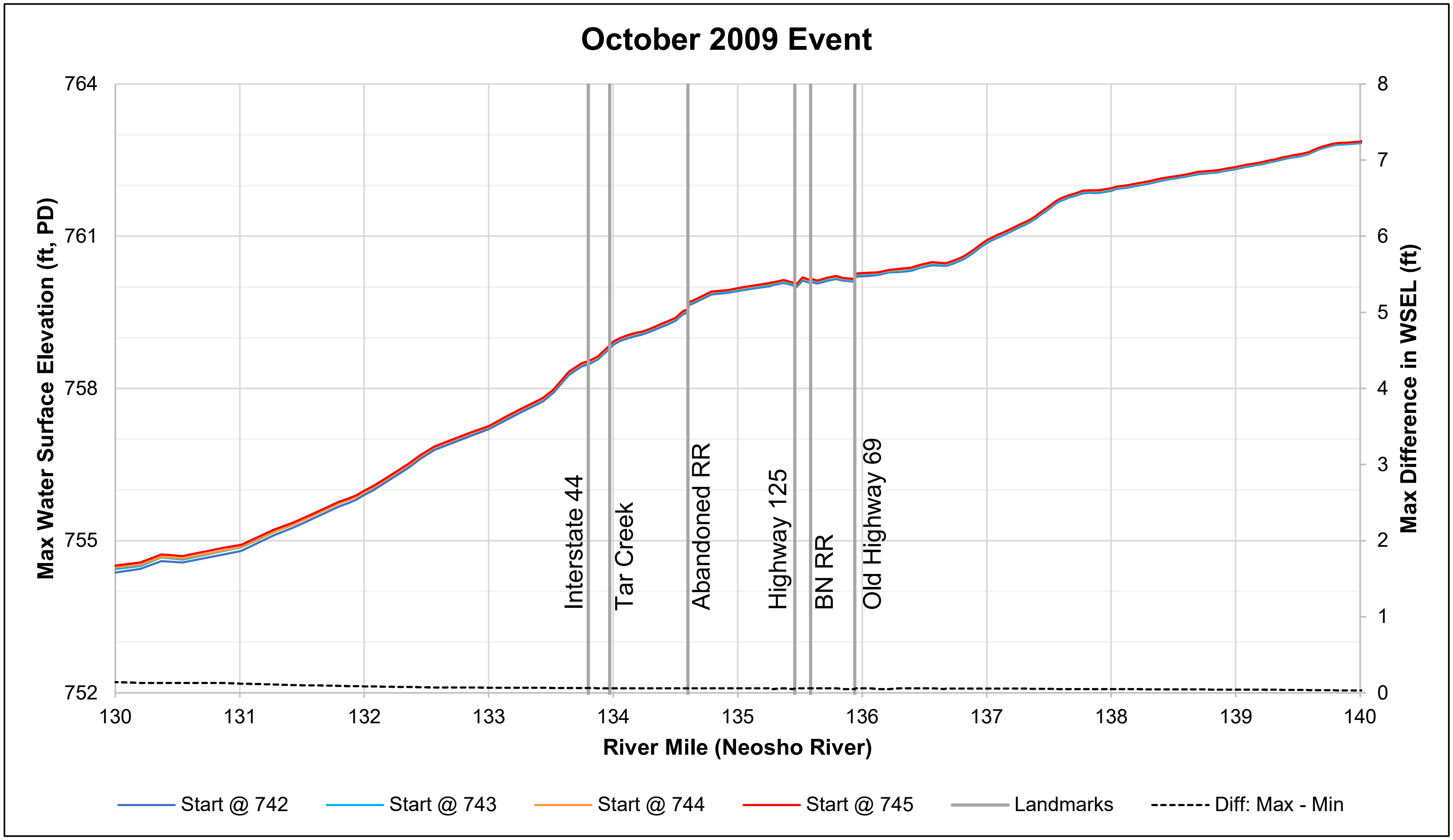


Figure E.34. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

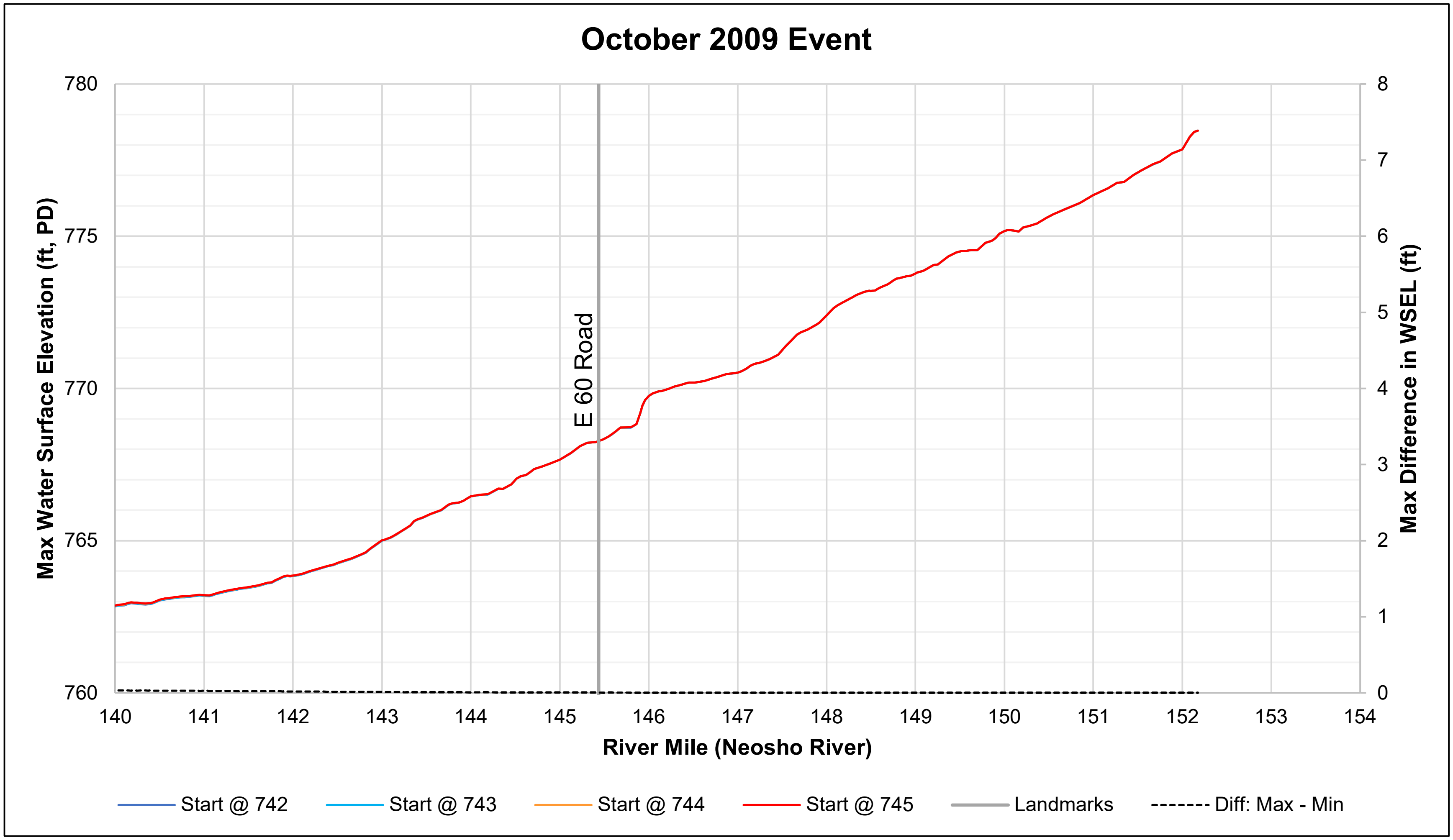


Figure E.35. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

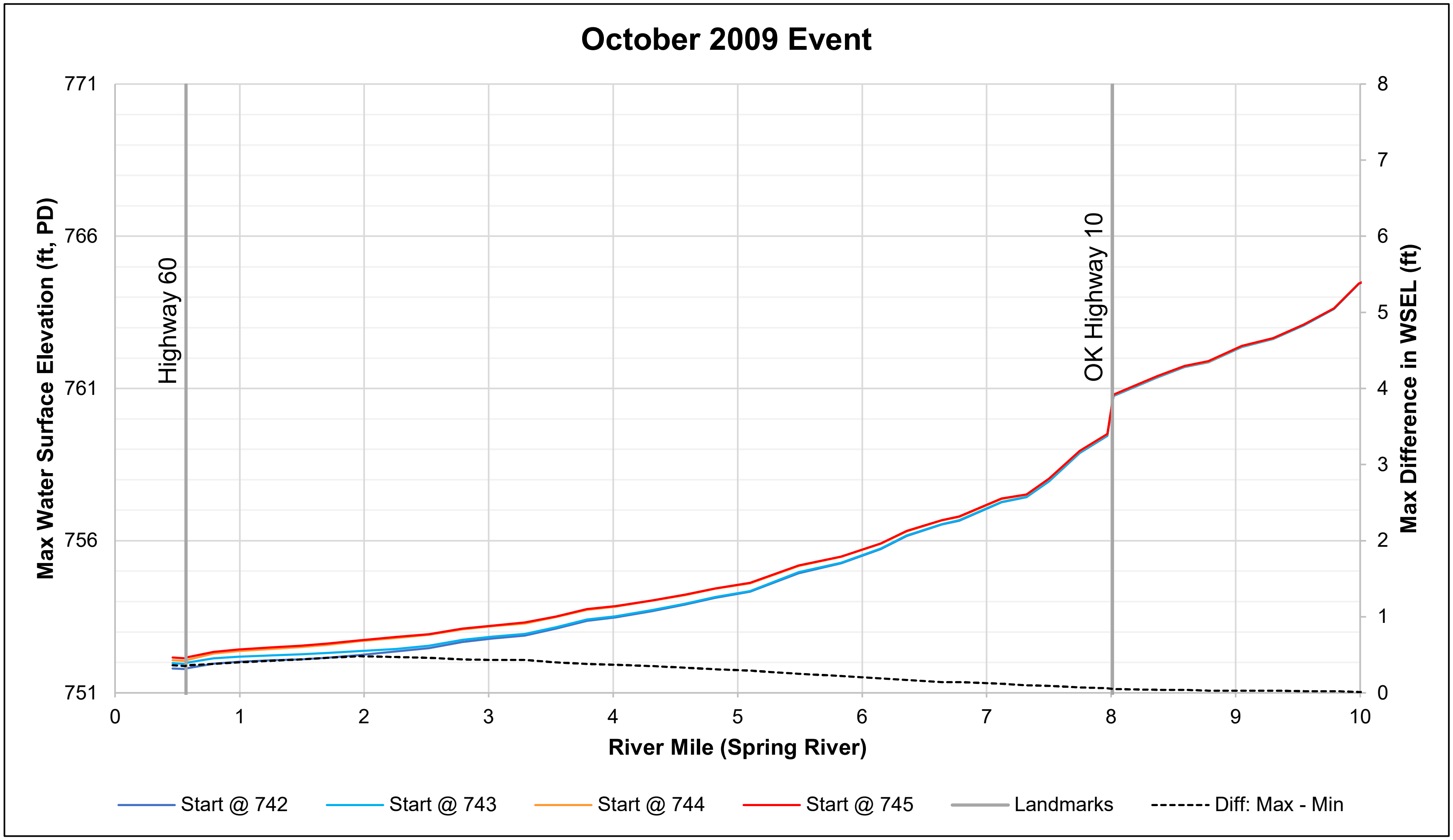


Figure E.36. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

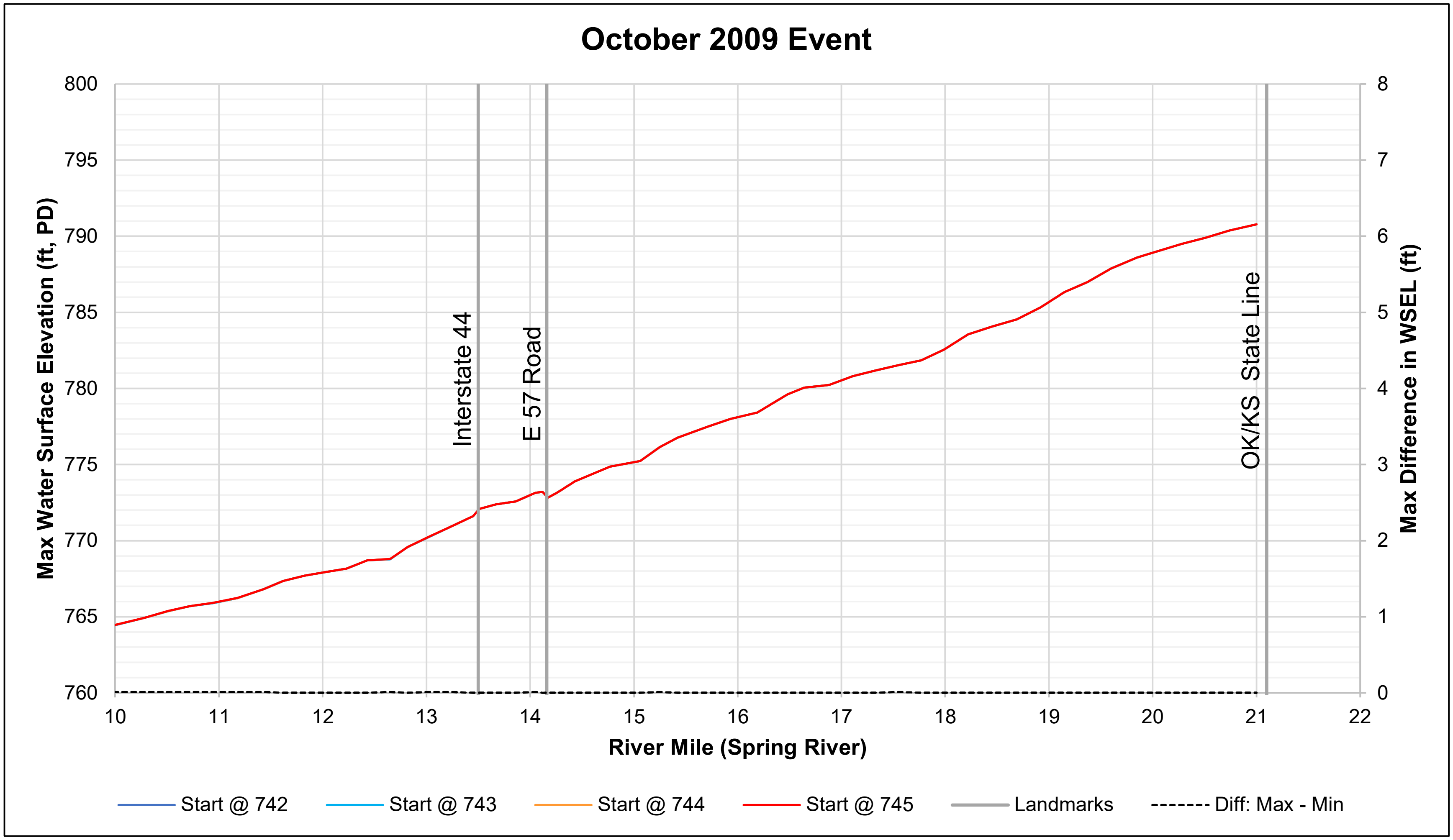


Figure E.37. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

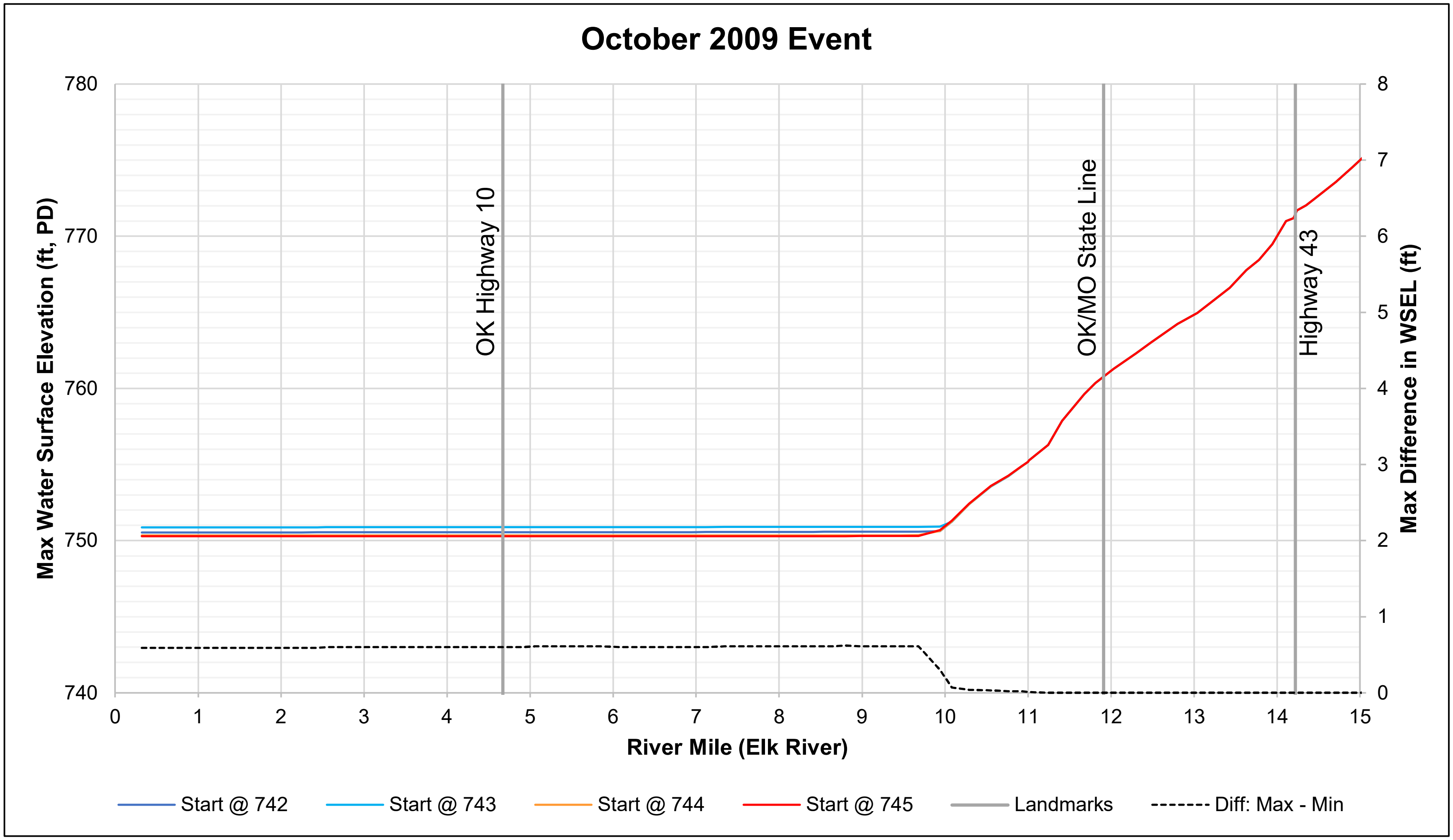


Figure E.38. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:
1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.
2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.
4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

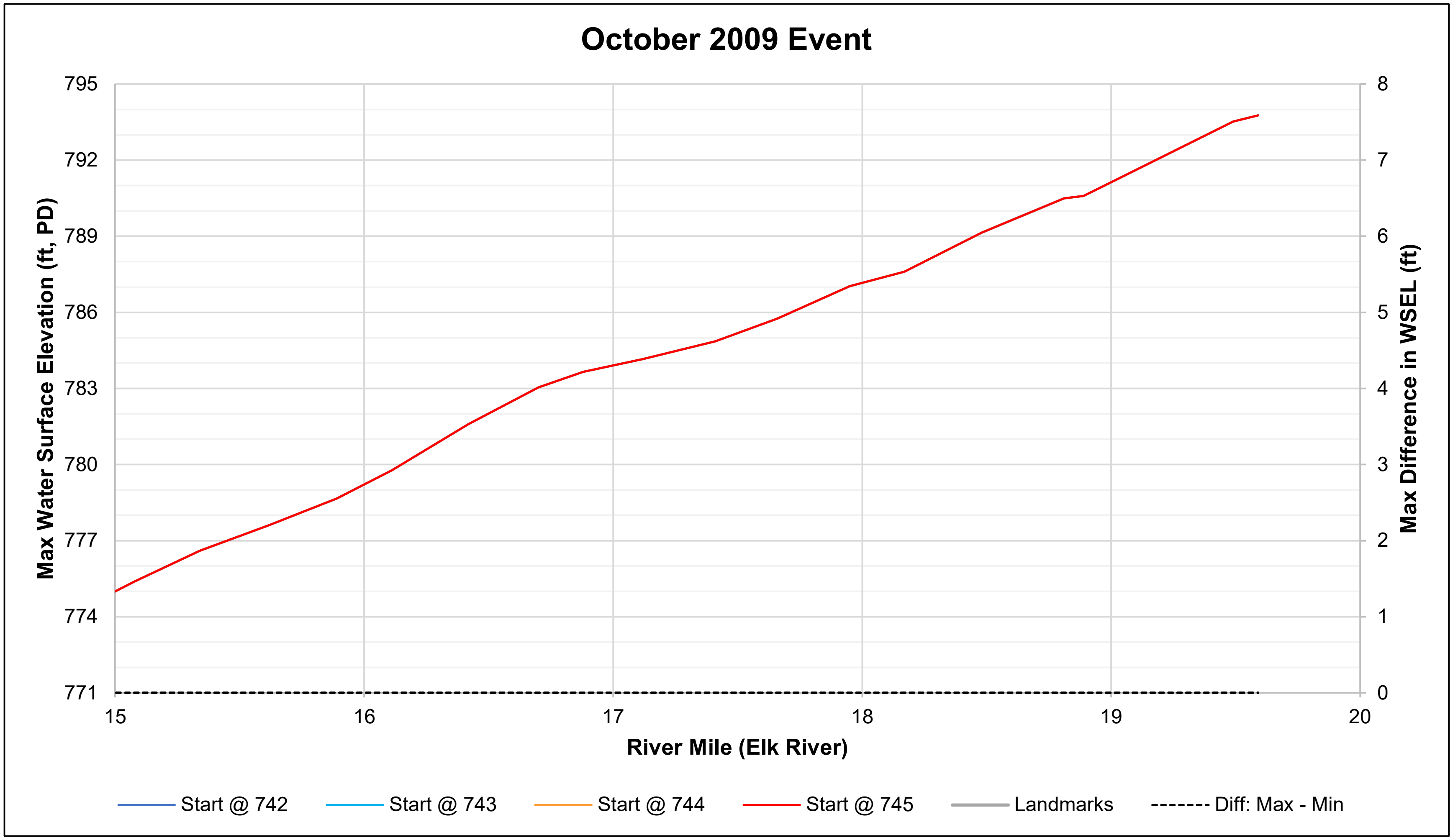


Figure E.39. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

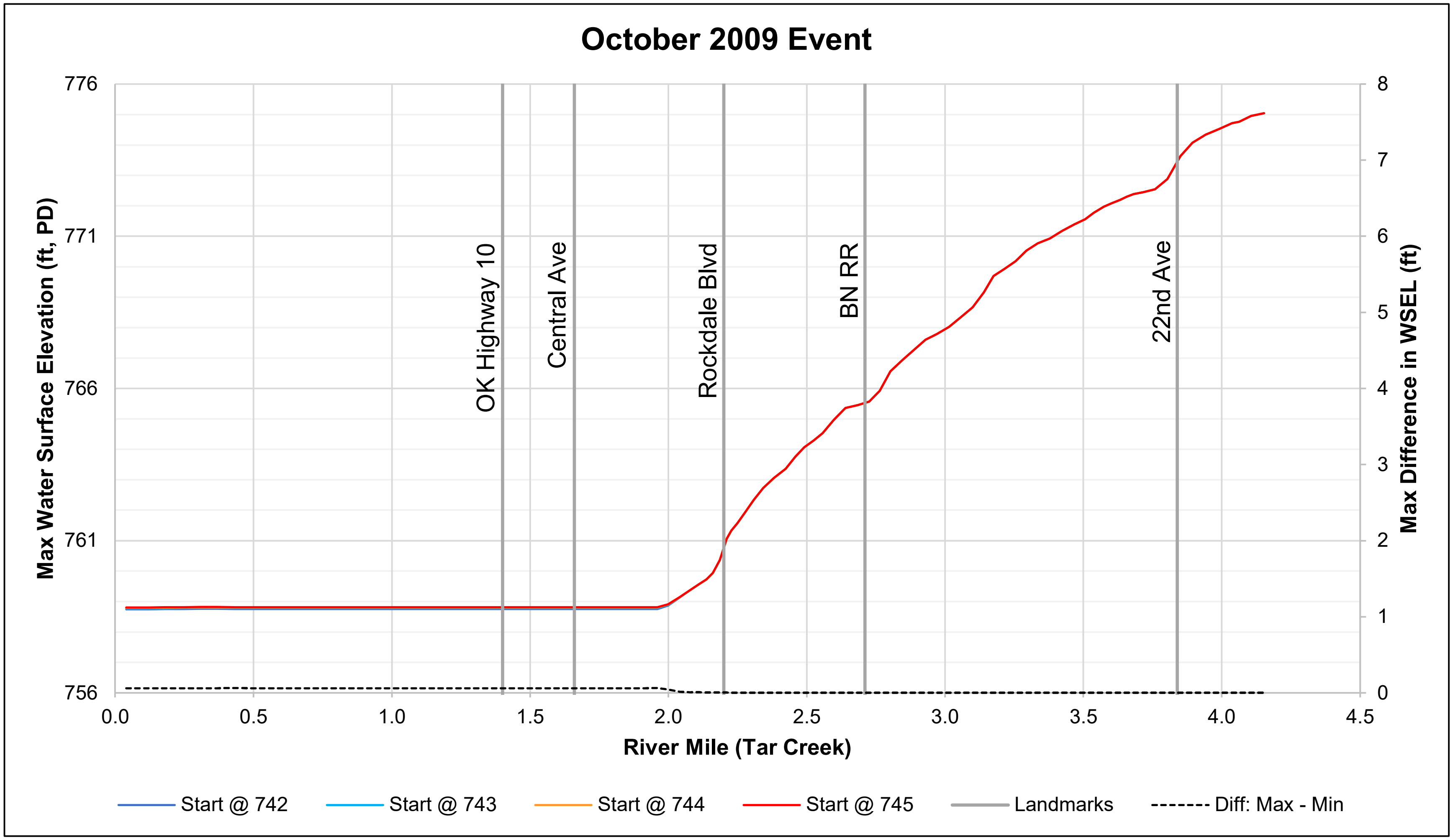


Figure E.40. Water surface elevations for the October 2009 event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

APPENDIX E.5:
DECEMBER 2015 EVENT PROFILES

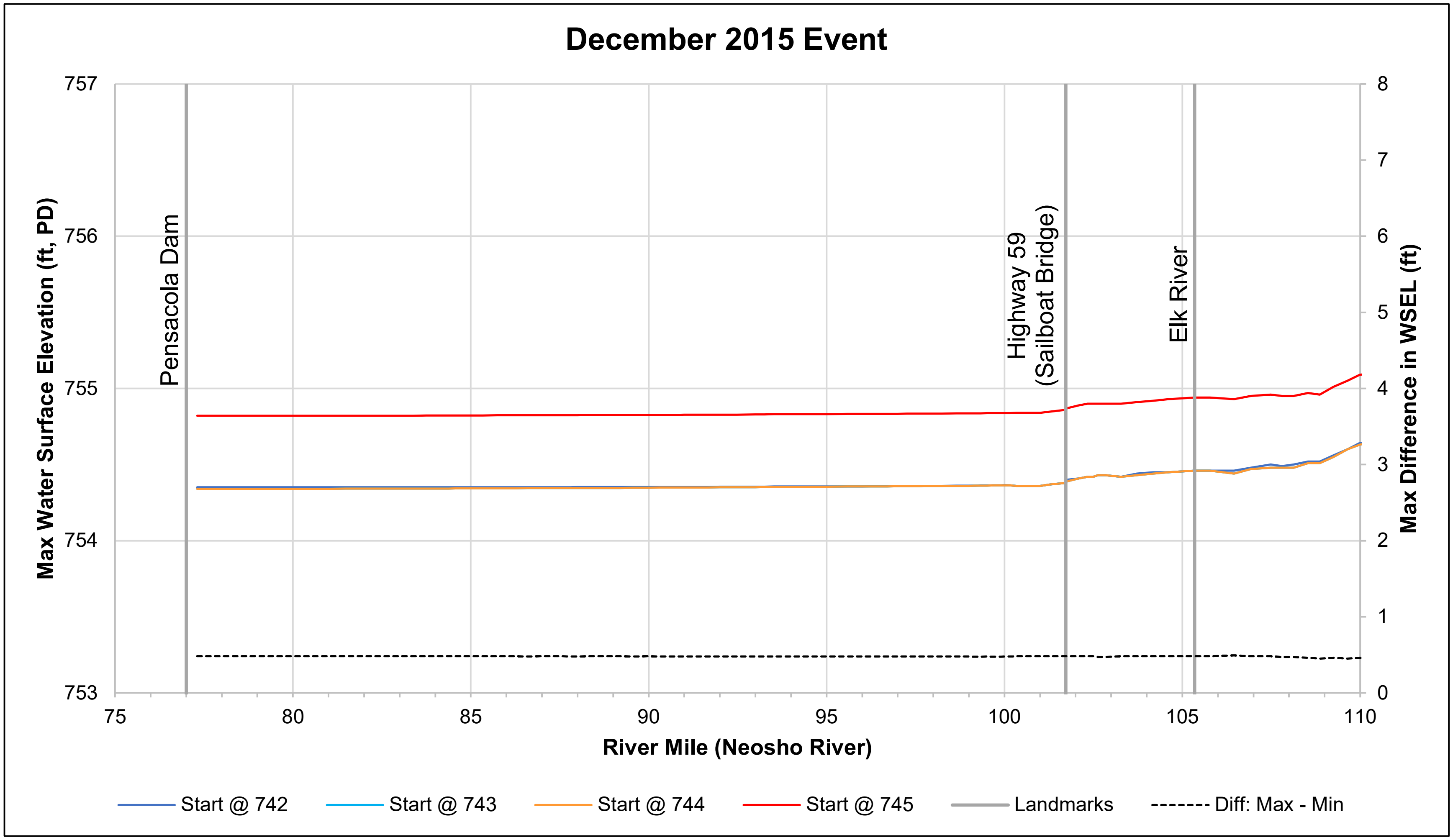


Figure E.41. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

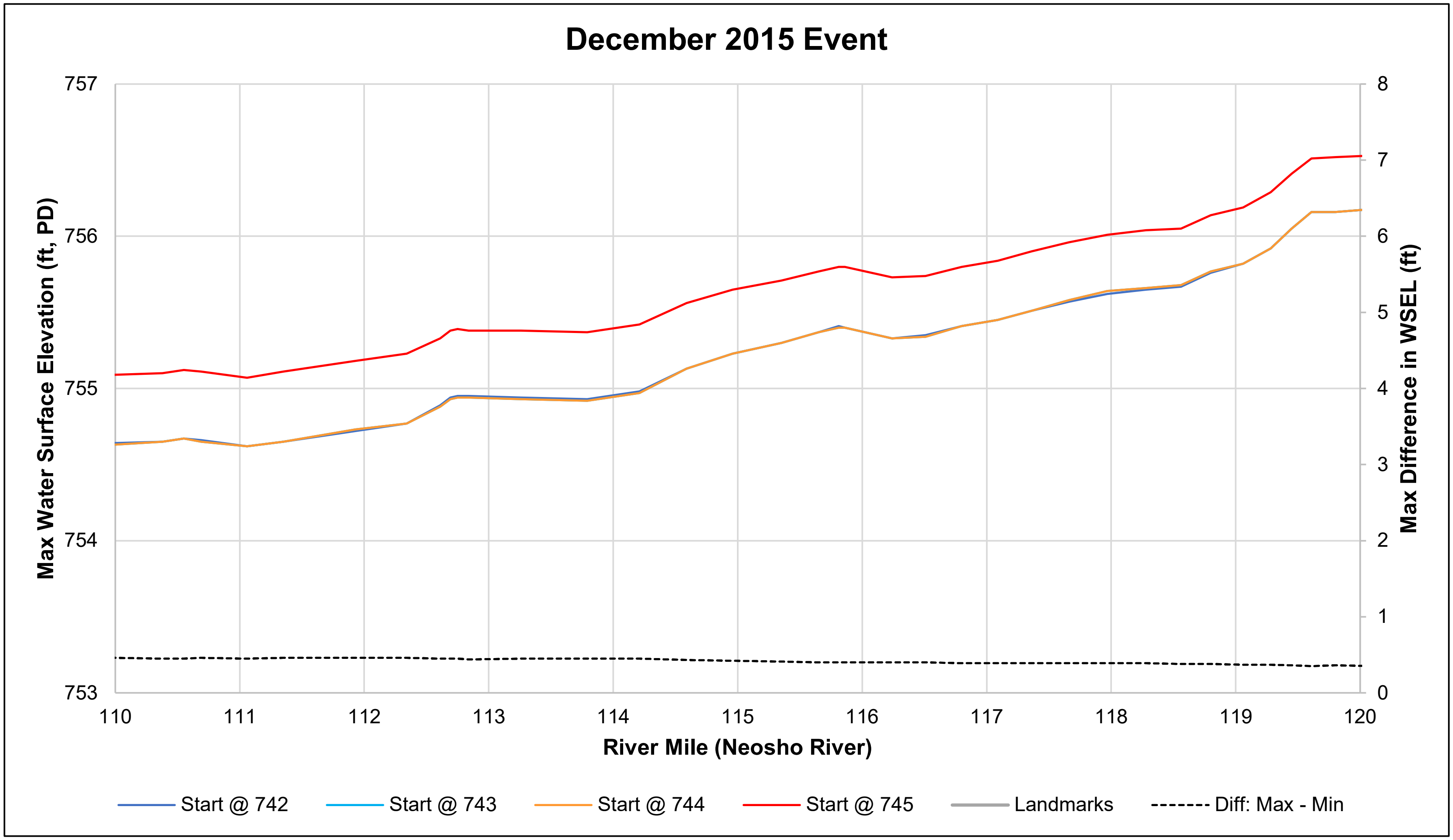


Figure E.42. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

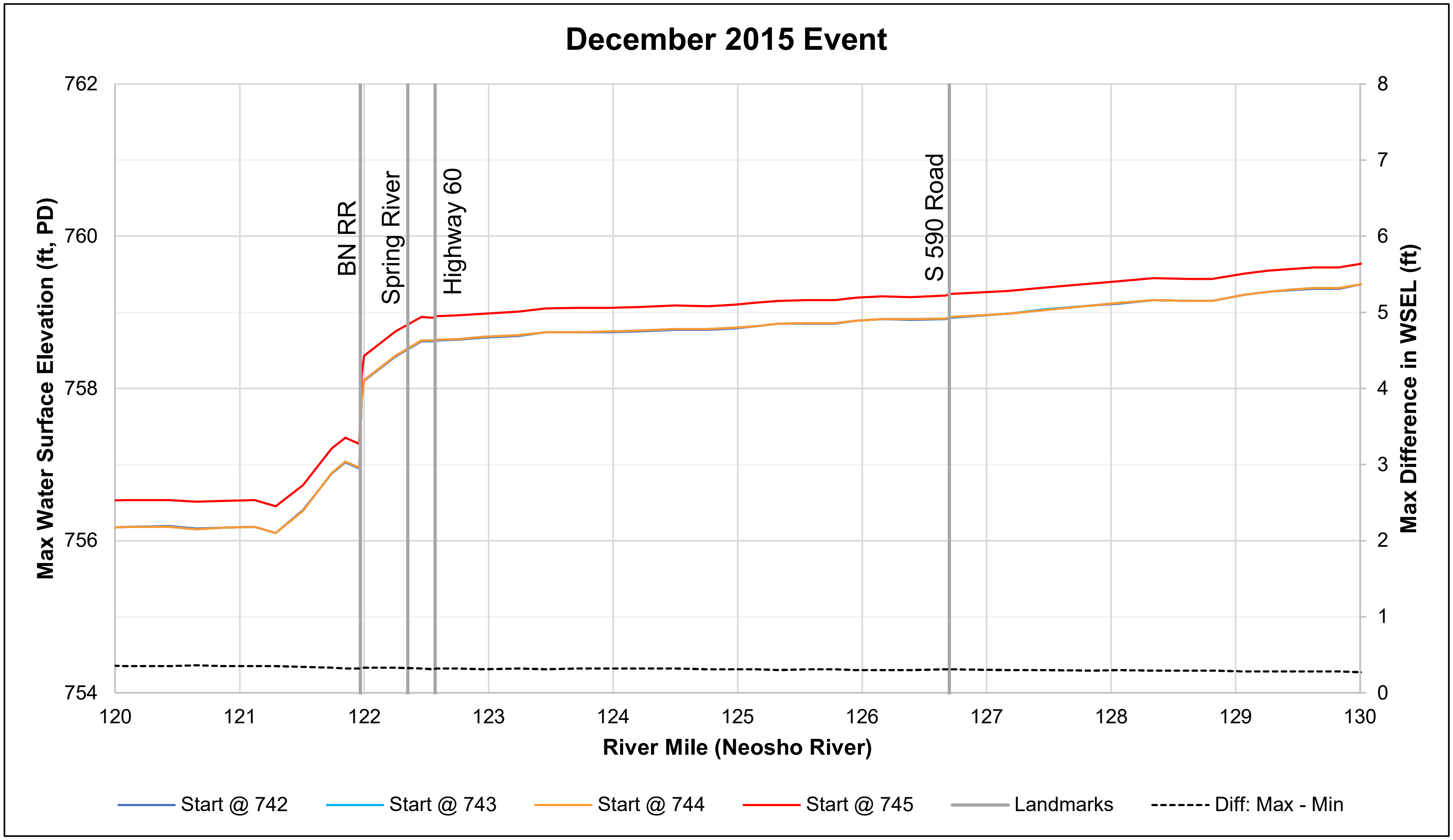


Figure E.43. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

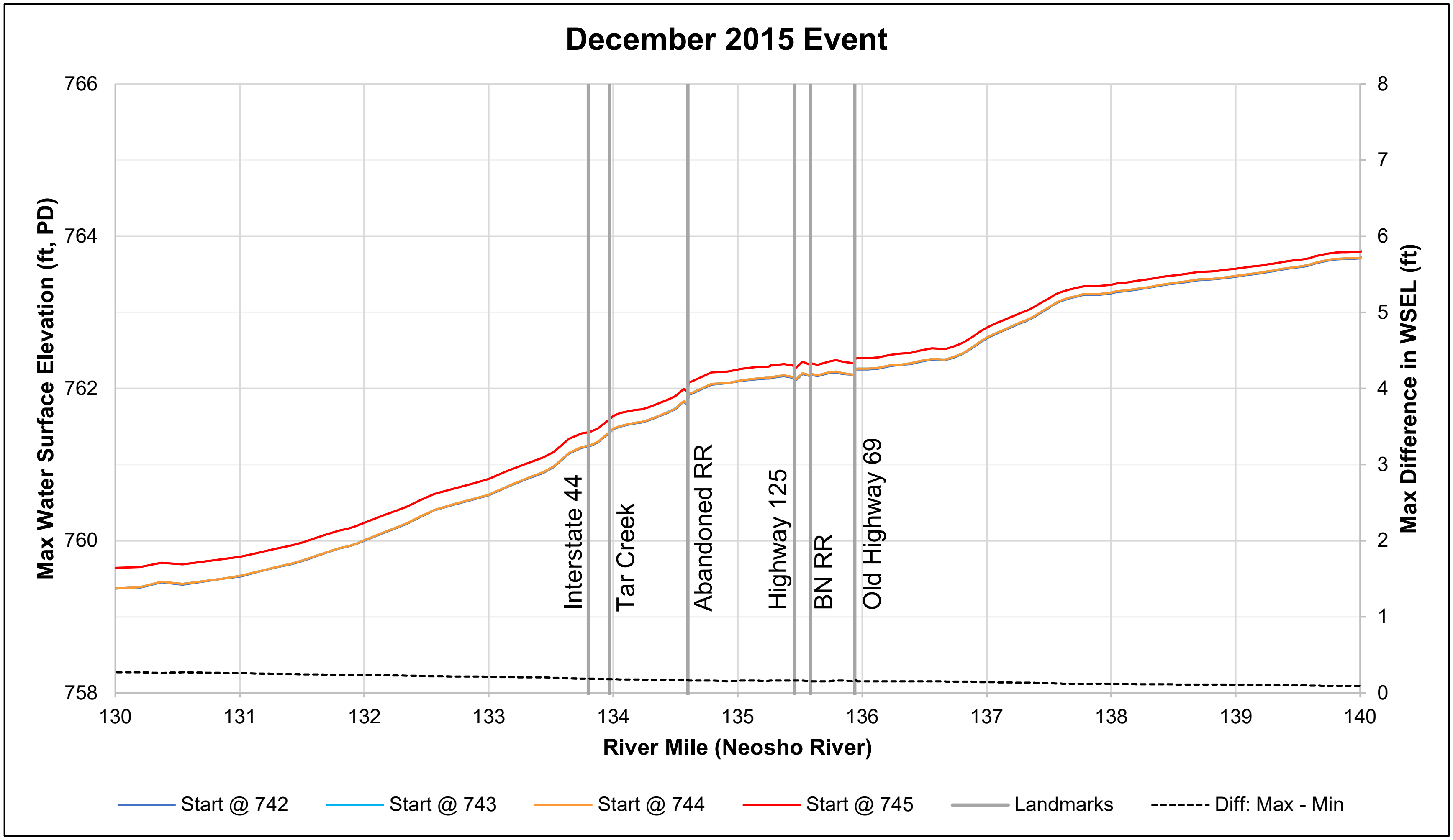


Figure E.44. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

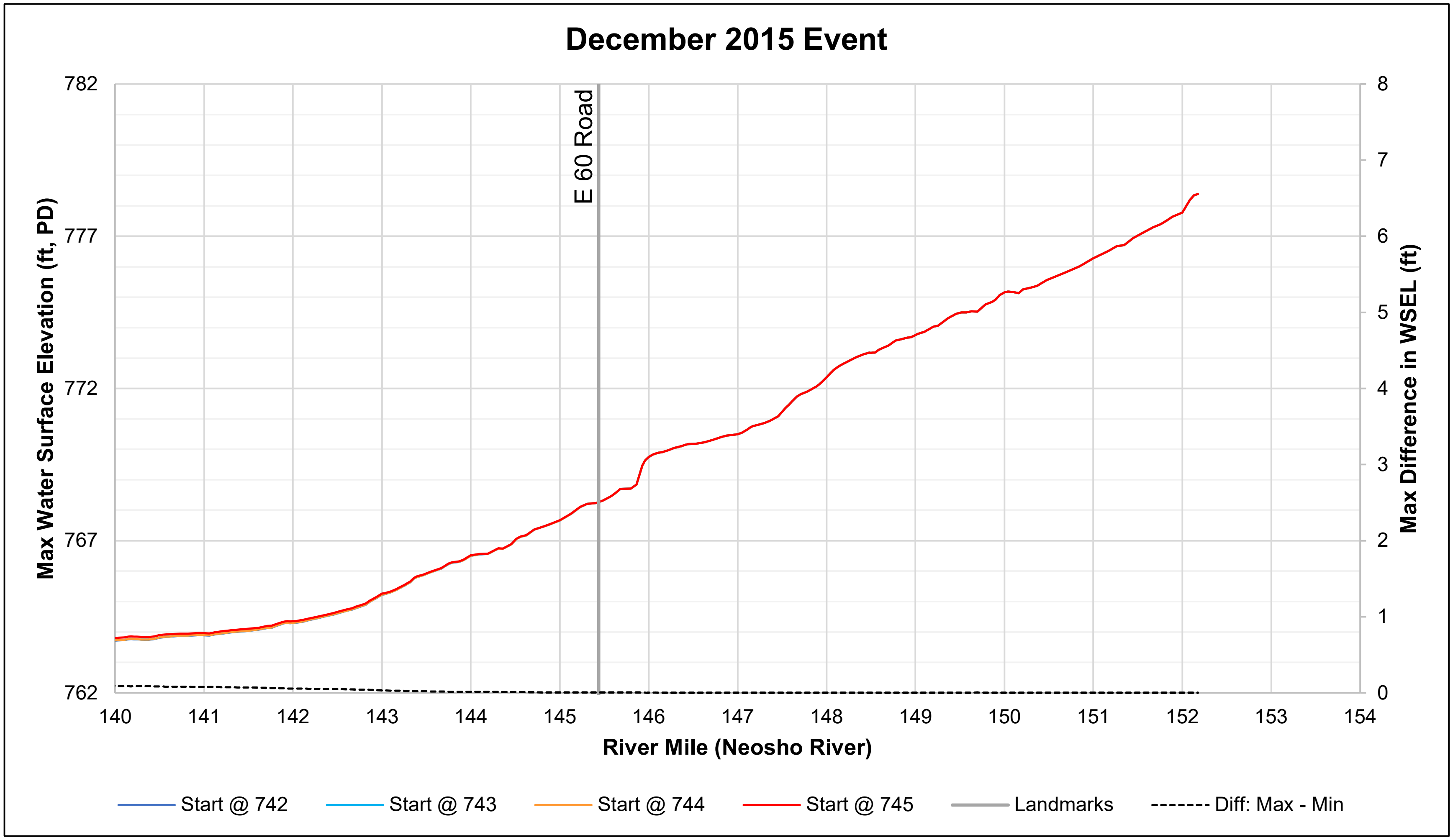


Figure E.45. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

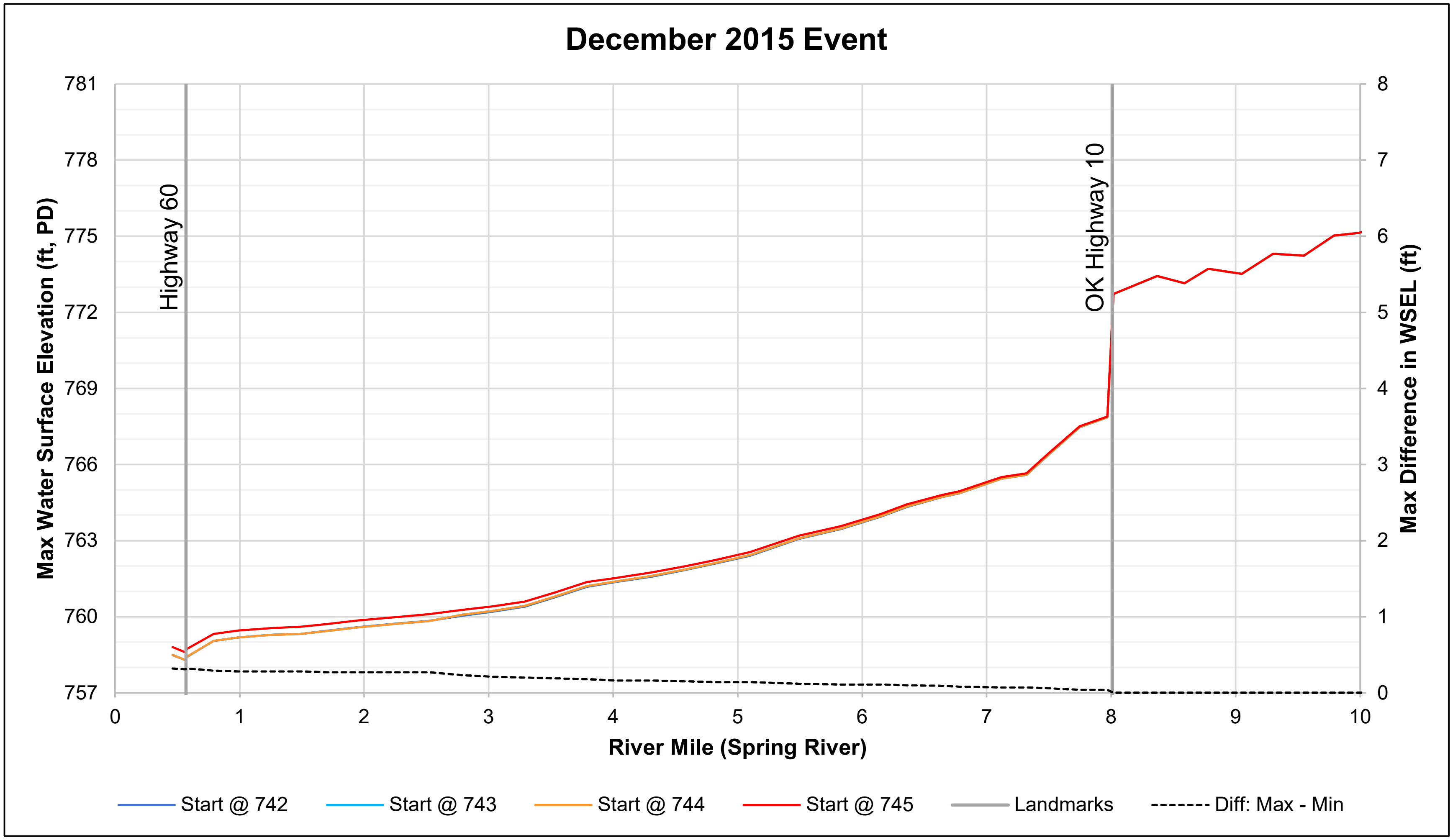


Figure E.46. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

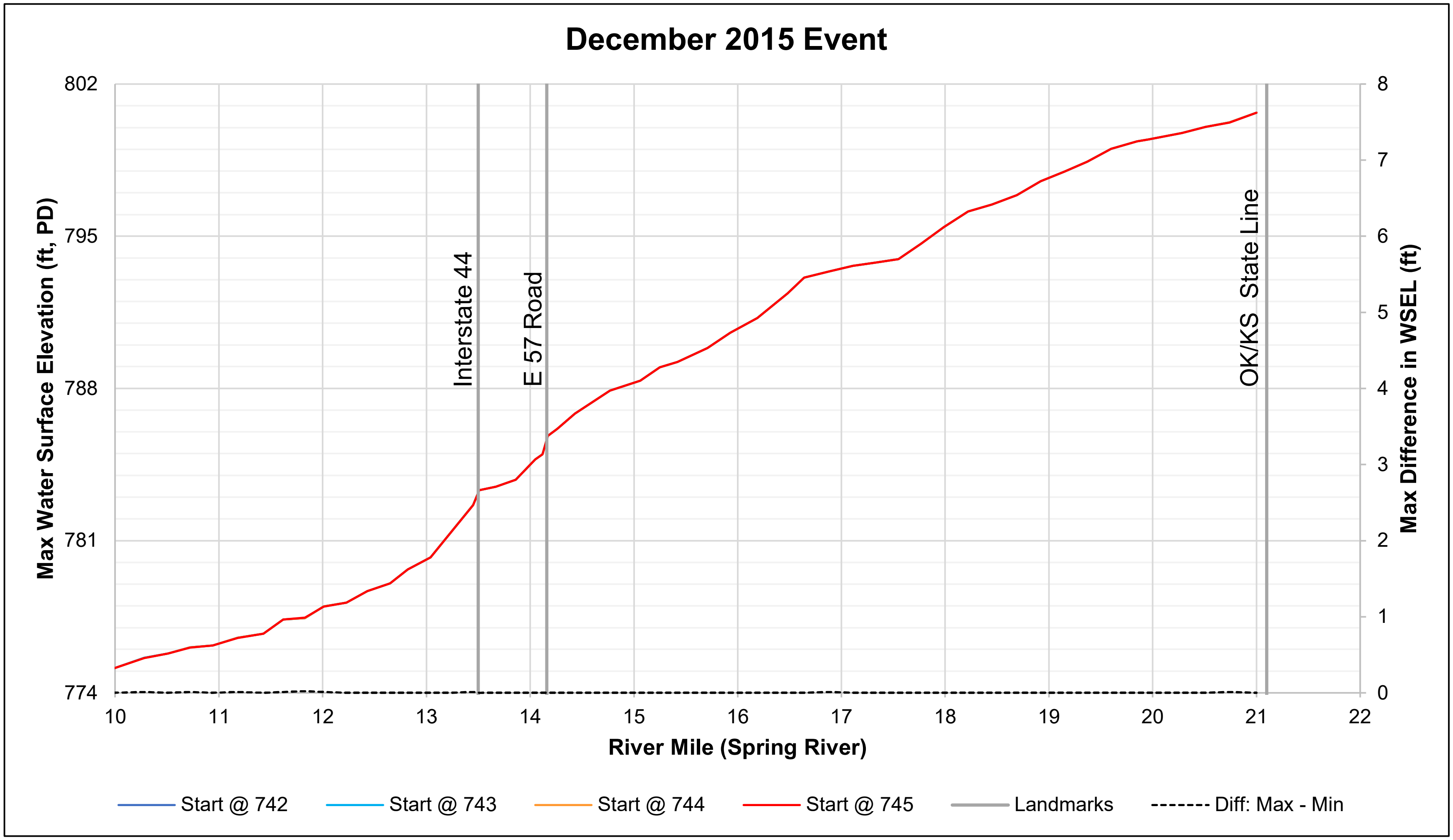


Figure E.47. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

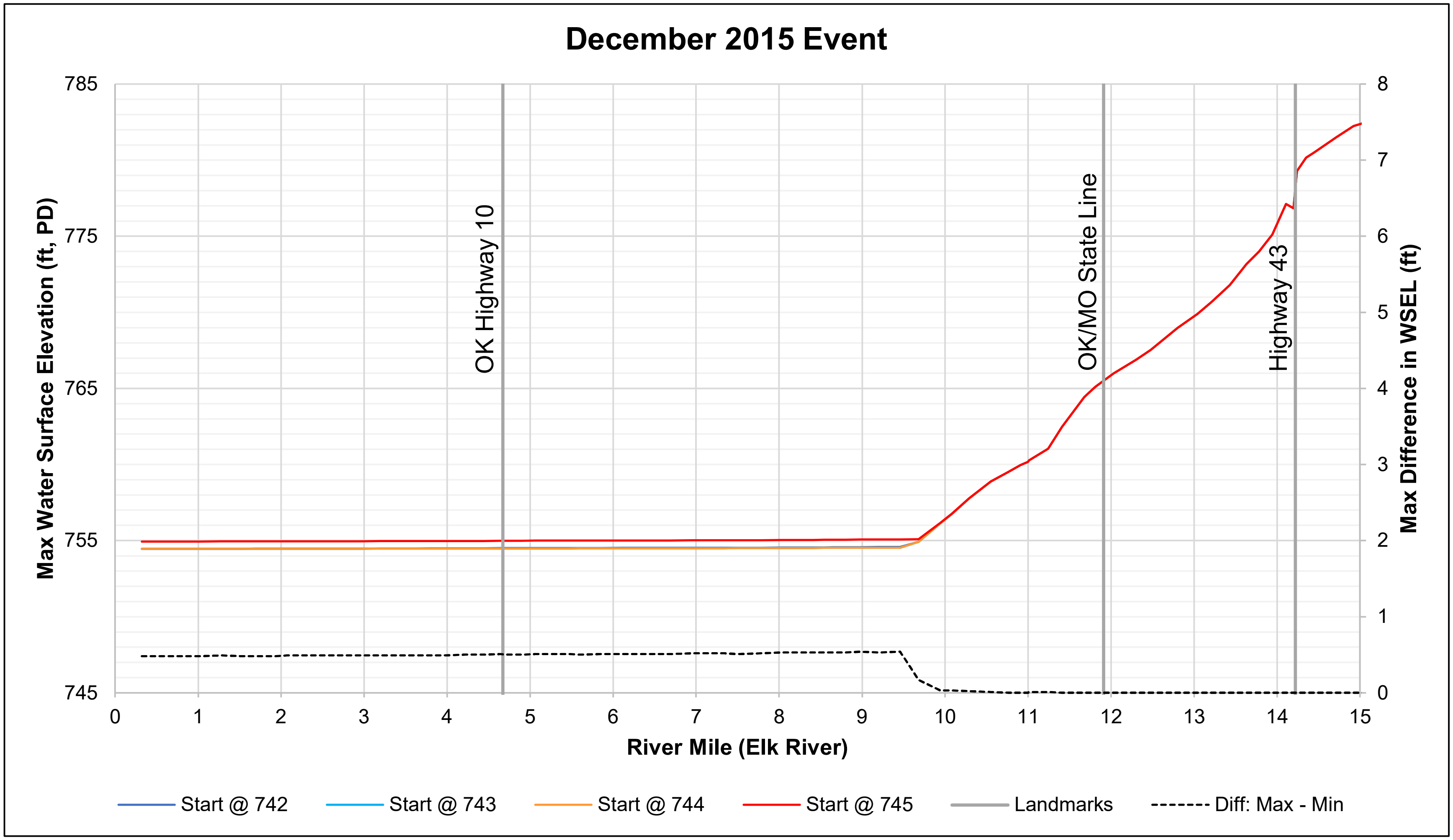


Figure E.48. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

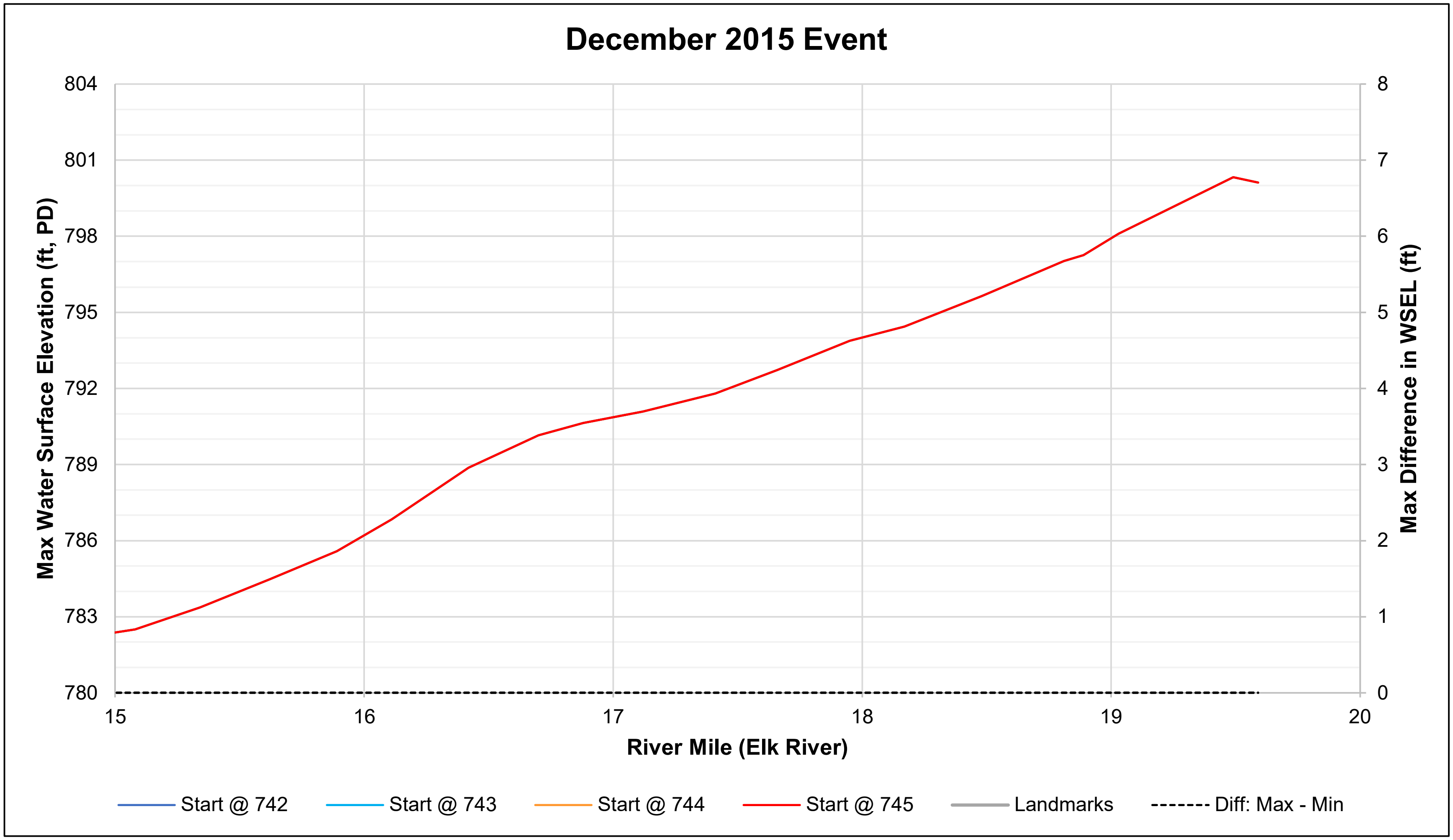


Figure E.49. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:
1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

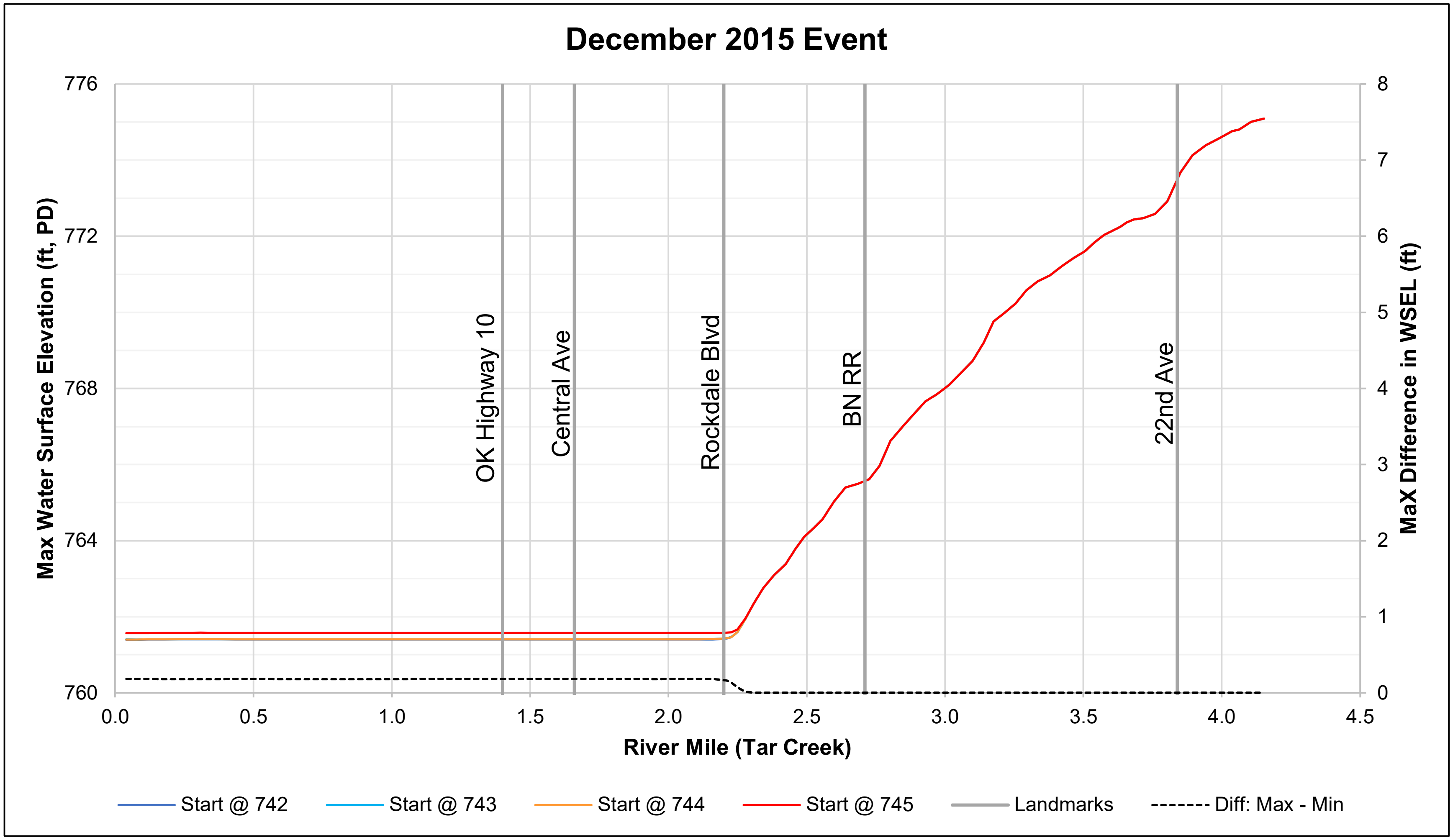


Figure E.50. Water surface elevations for the December 2015 event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

APPENDIX E.6:
100-YEAR EVENT PROFILES

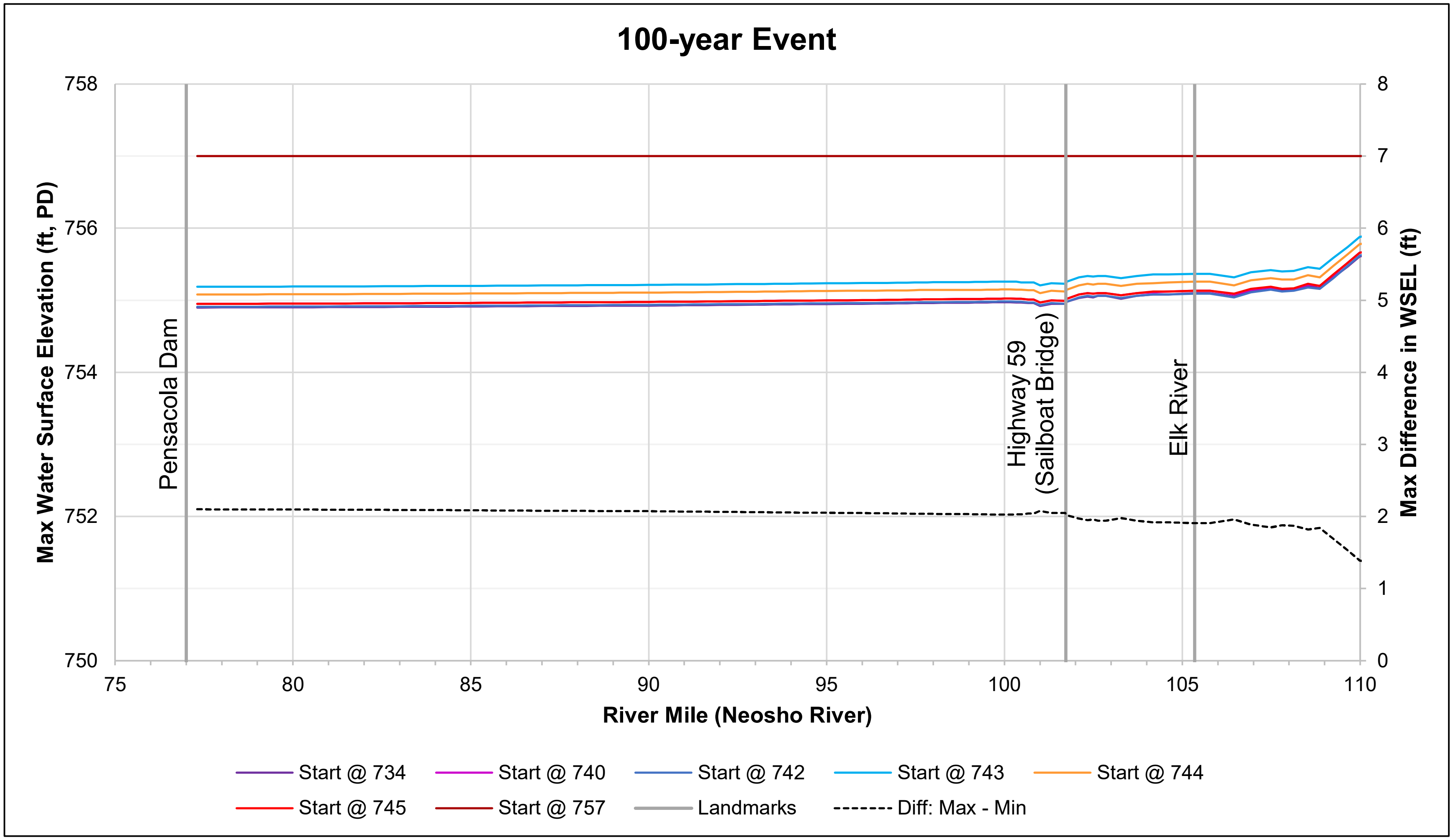


Figure E.51. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

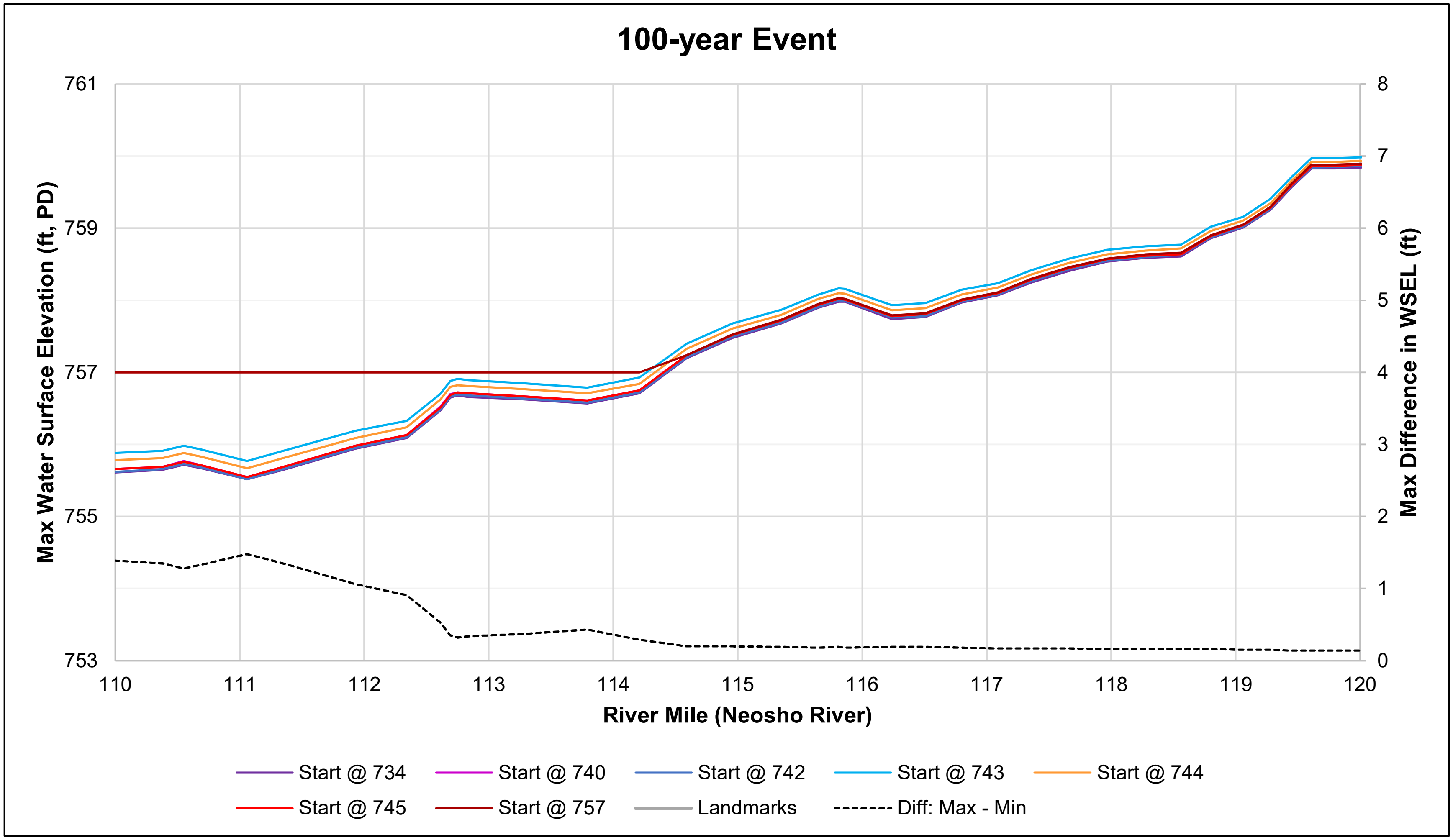


Figure E.52. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

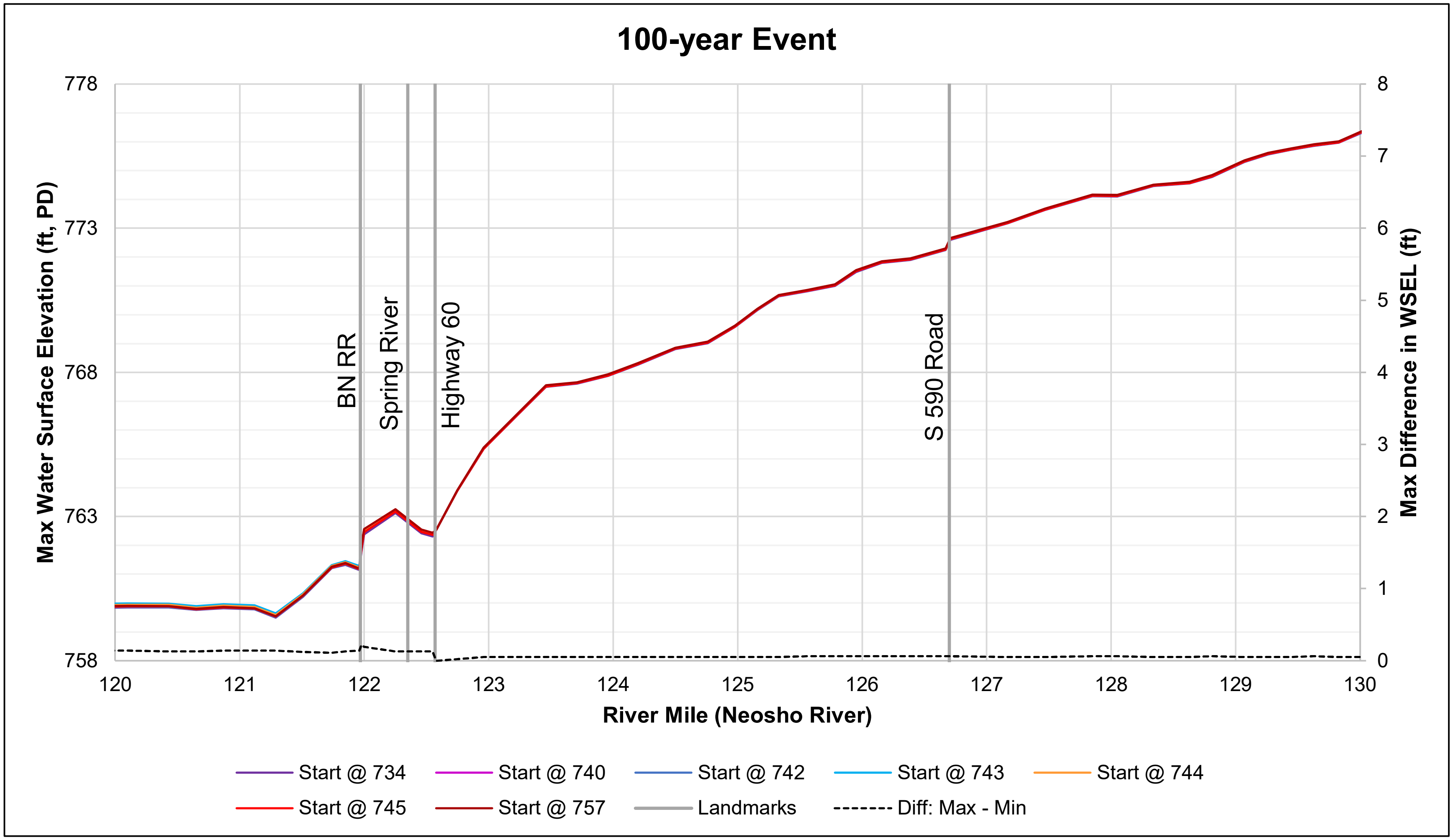


Figure E.53. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

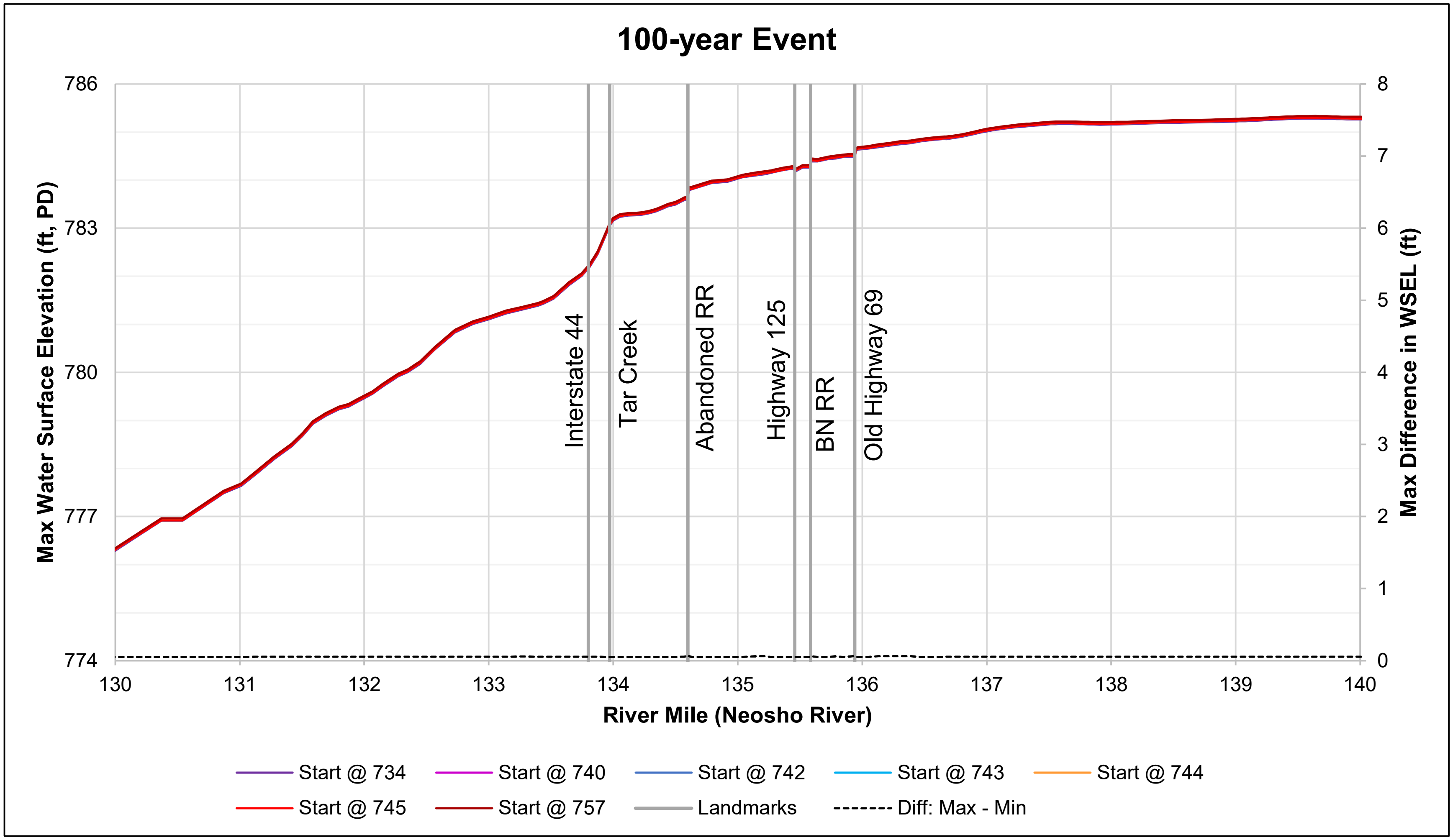


Figure E.54. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: 1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

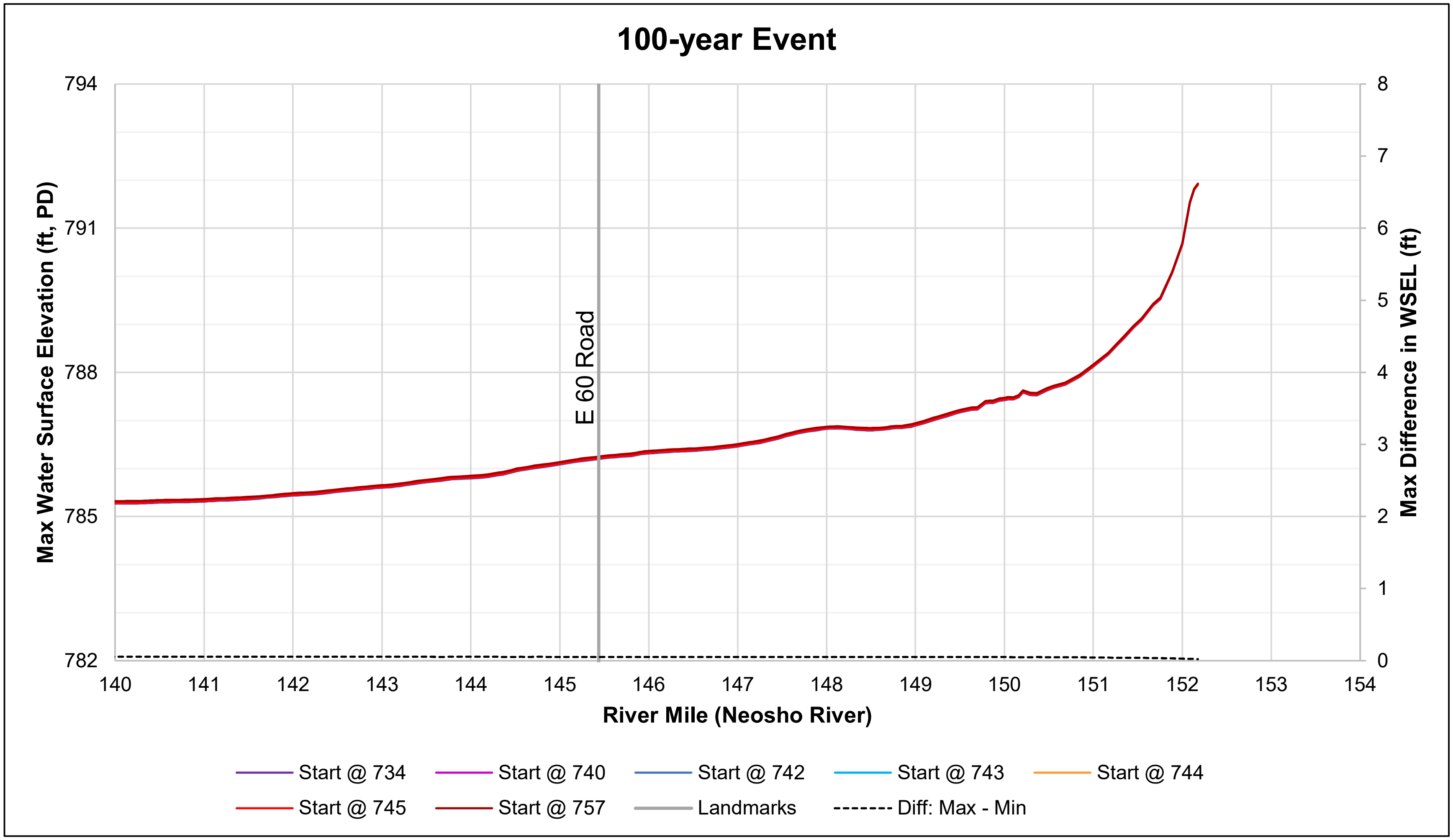


Figure E.55. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

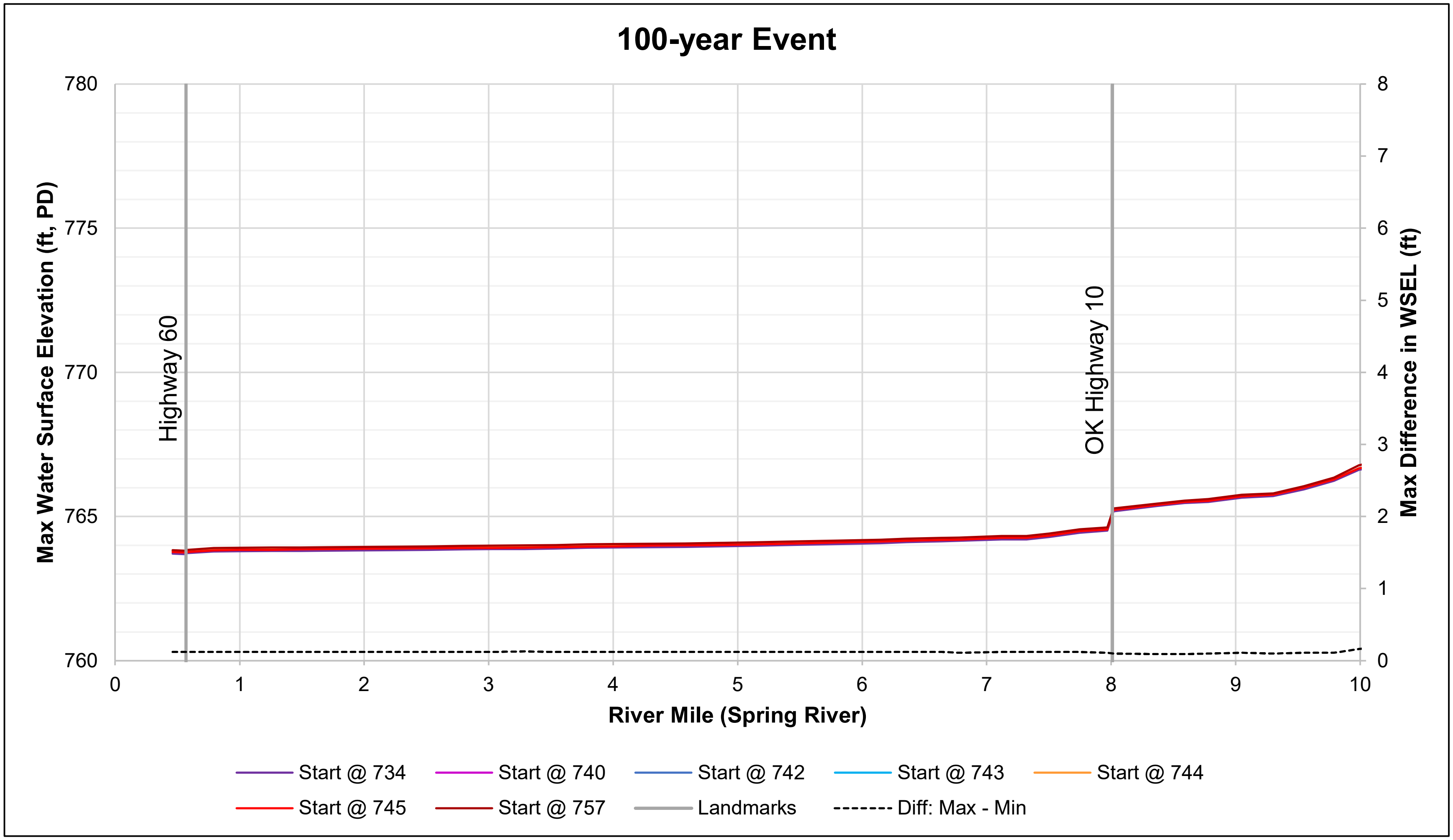


Figure E.56. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

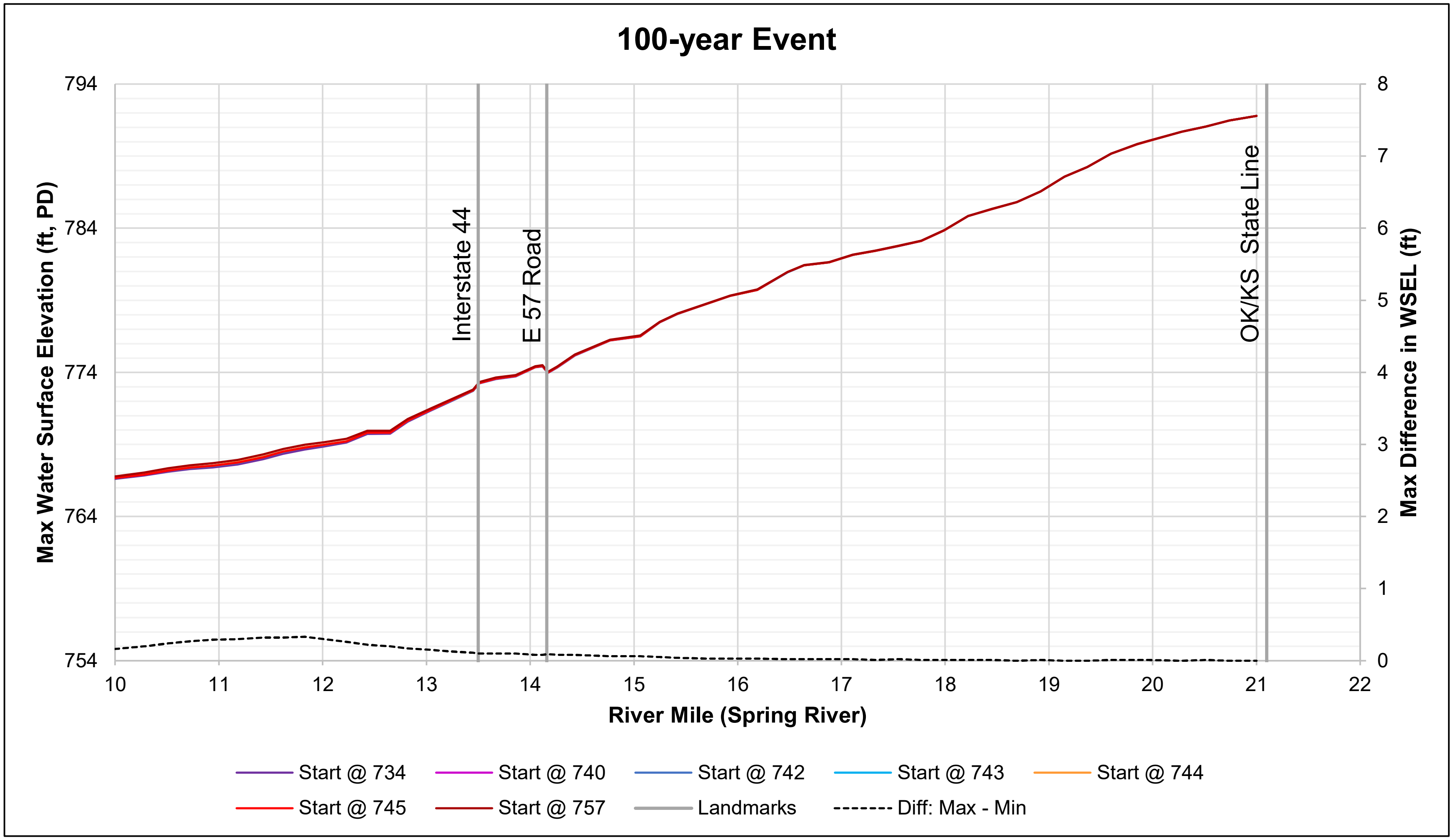


Figure E.57. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:
1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

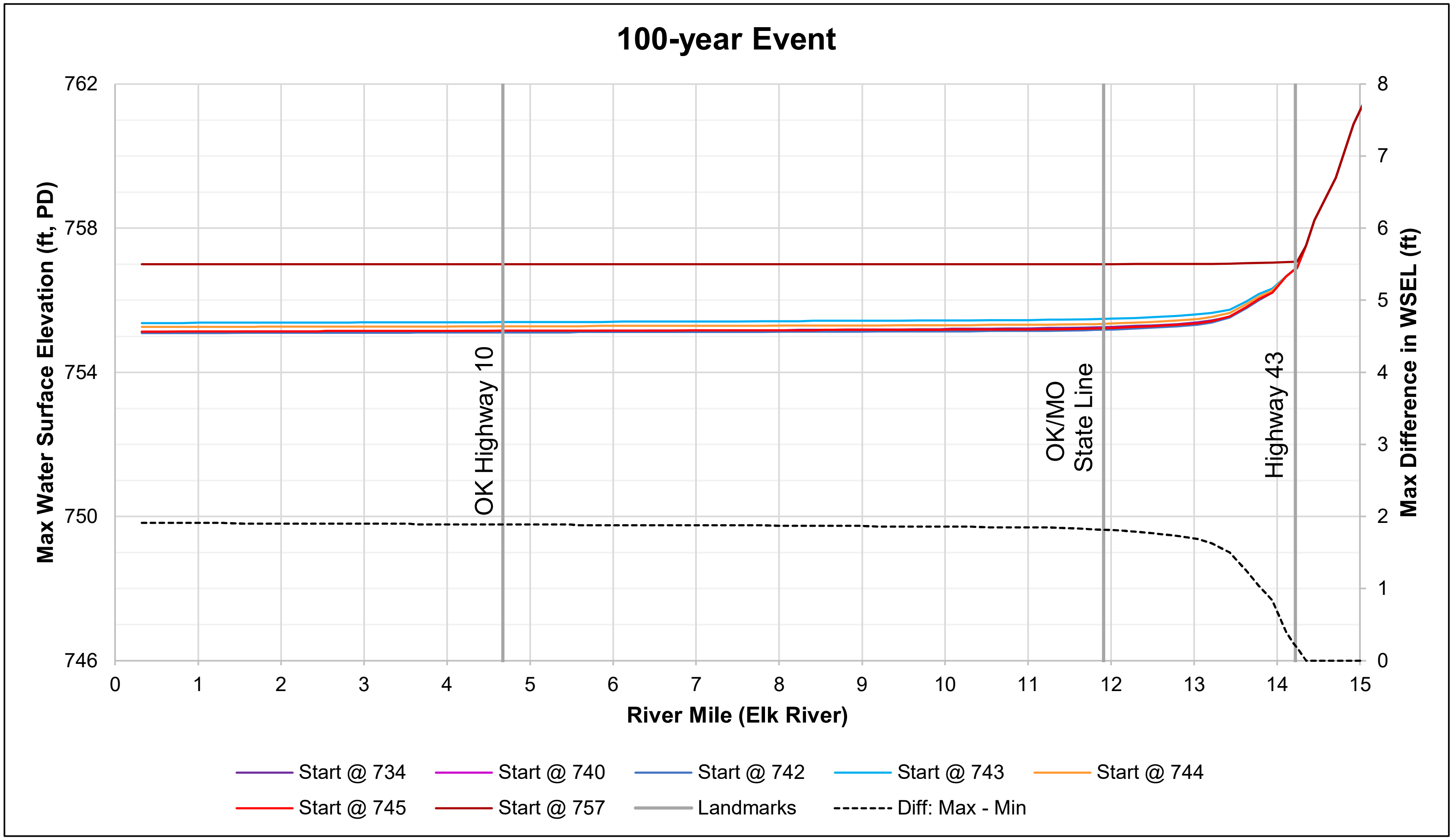


Figure E.58. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

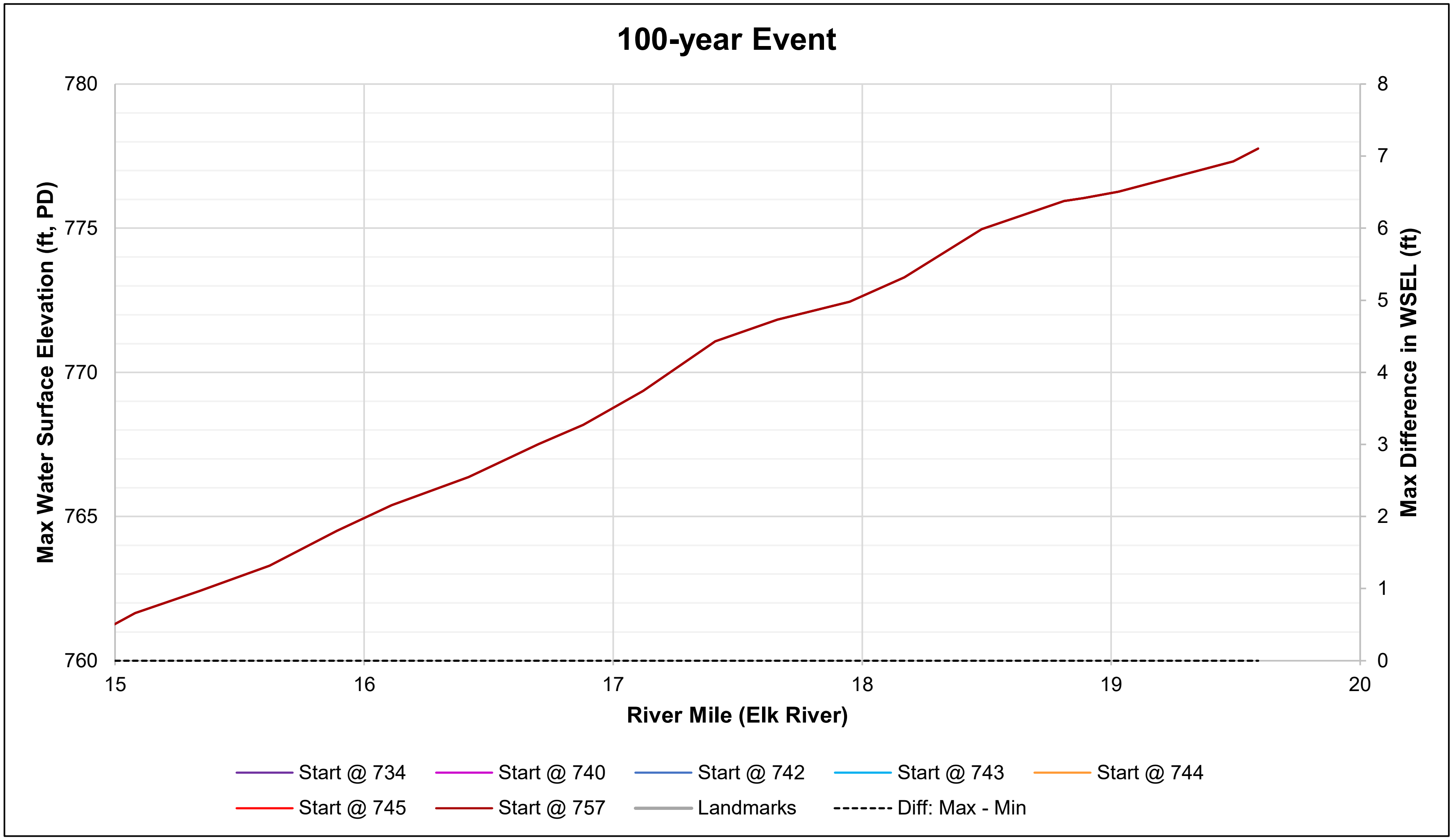


Figure E.59. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.

2. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.

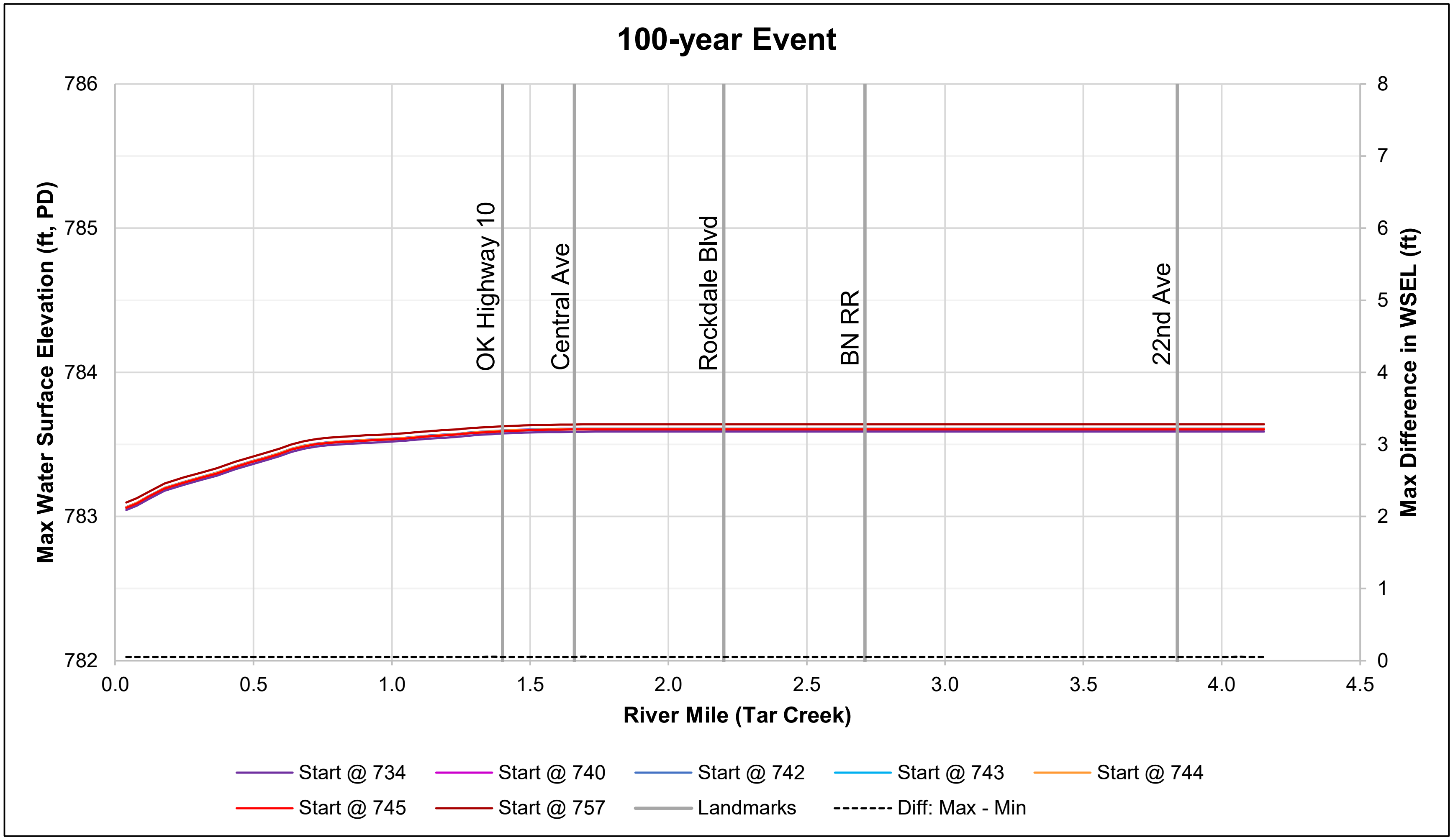


Figure E.60. Water surface elevations for the 100-year event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes:

1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profile for the other starting elevations is nearly identical.*

APPENDIX E.7:
HISTORICAL STARTING STAGE PROFILES

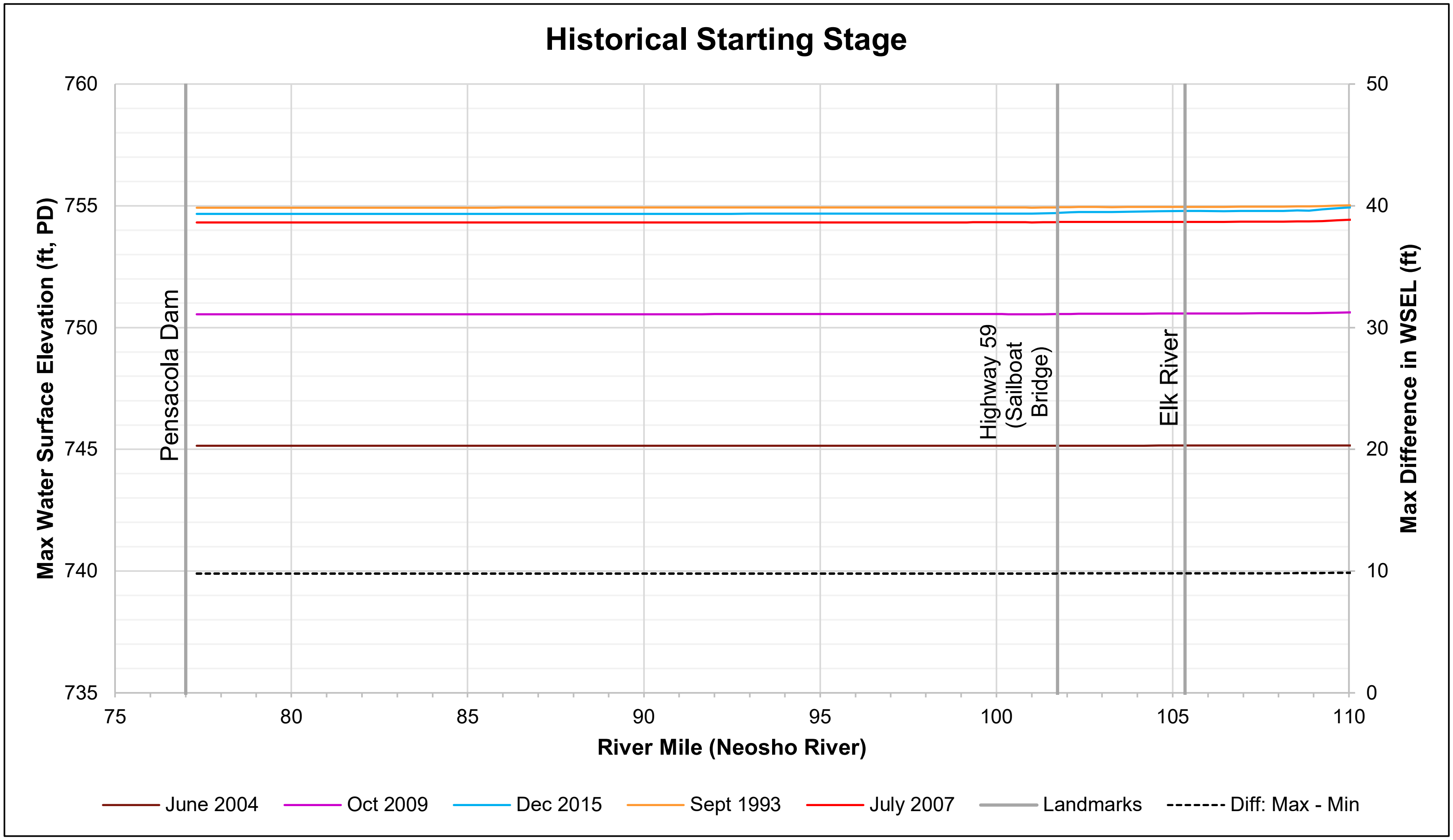


Figure E.61. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

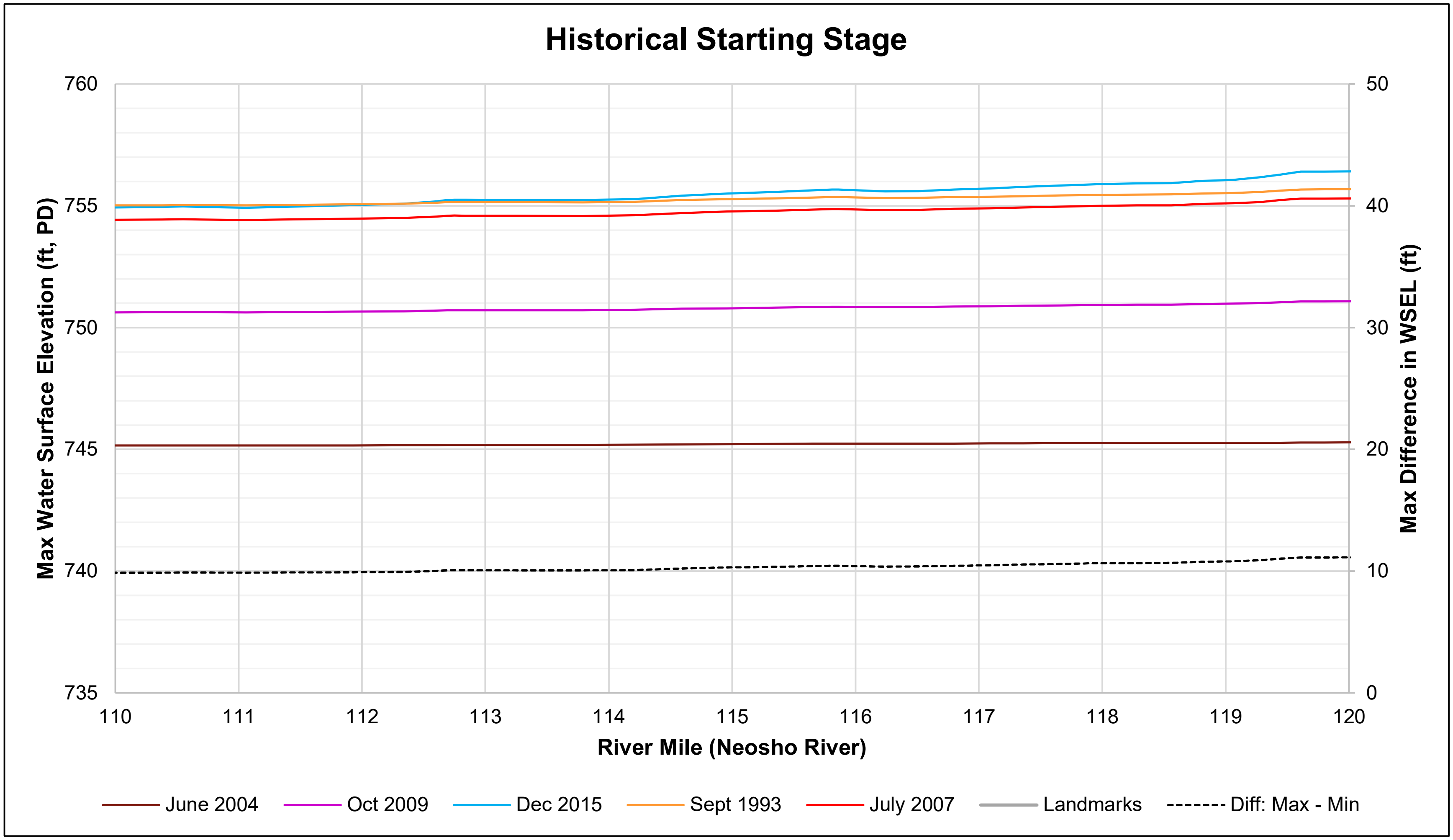


Figure E.62. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

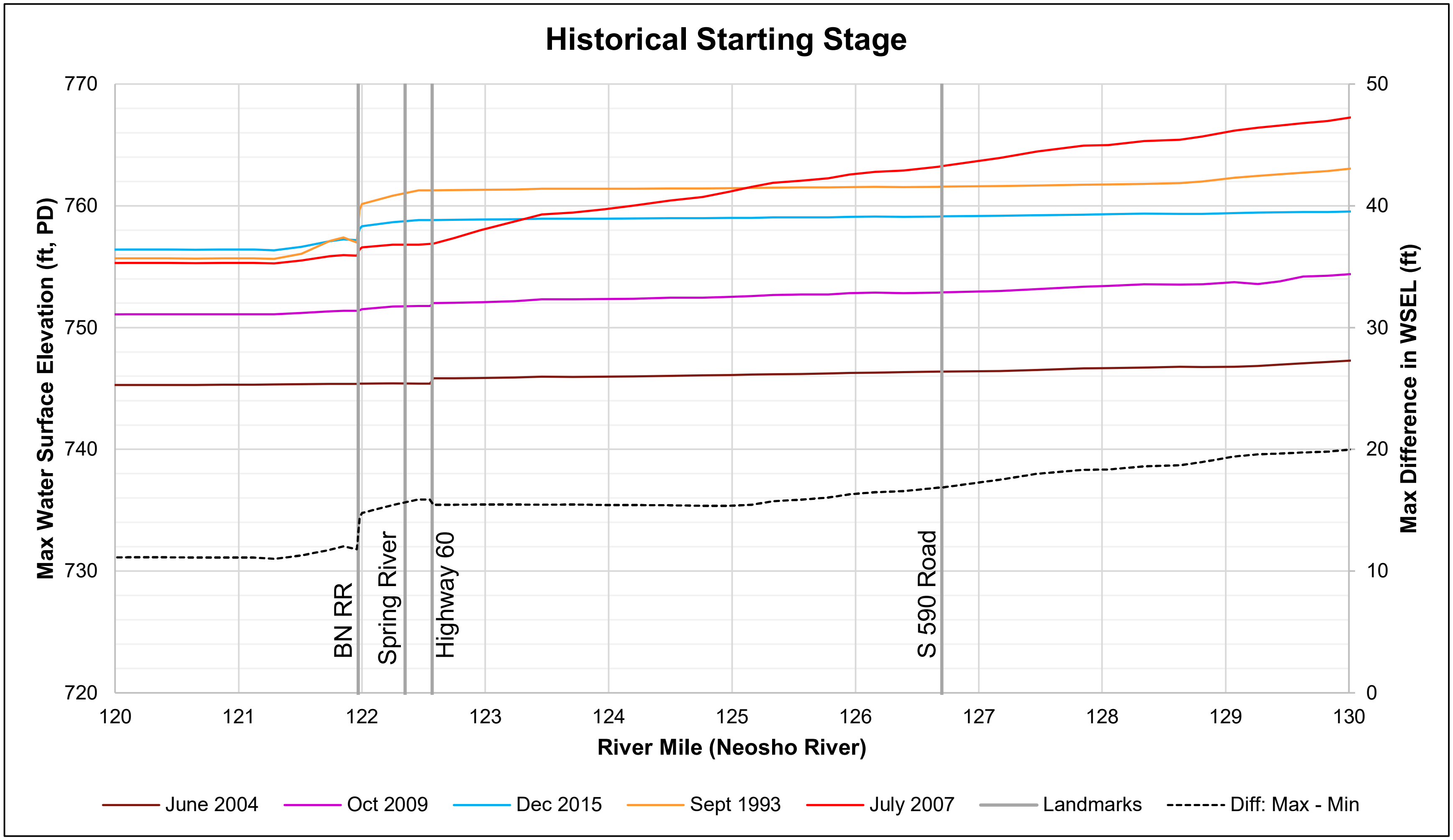


Figure E.63. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

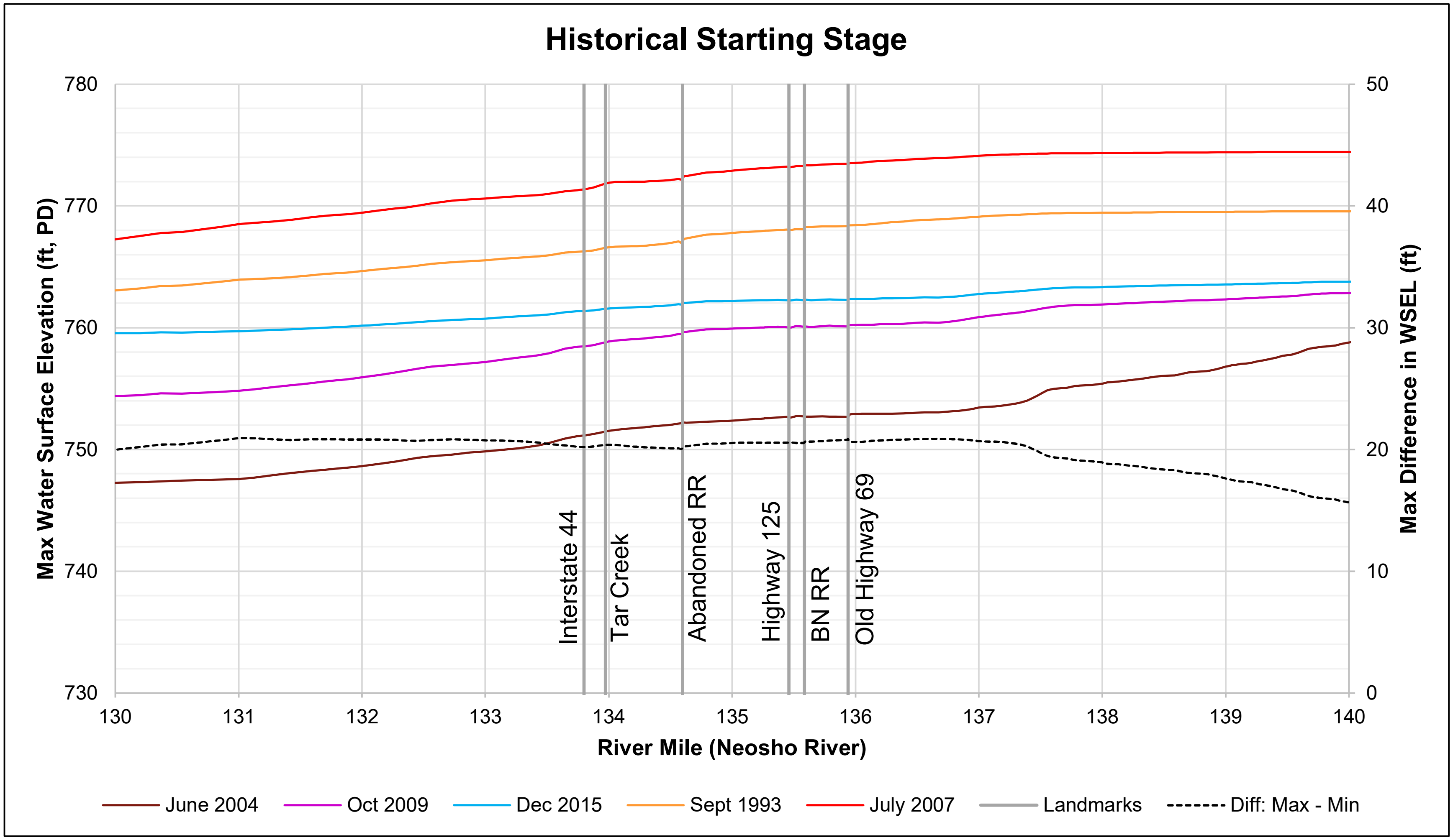


Figure E.64. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

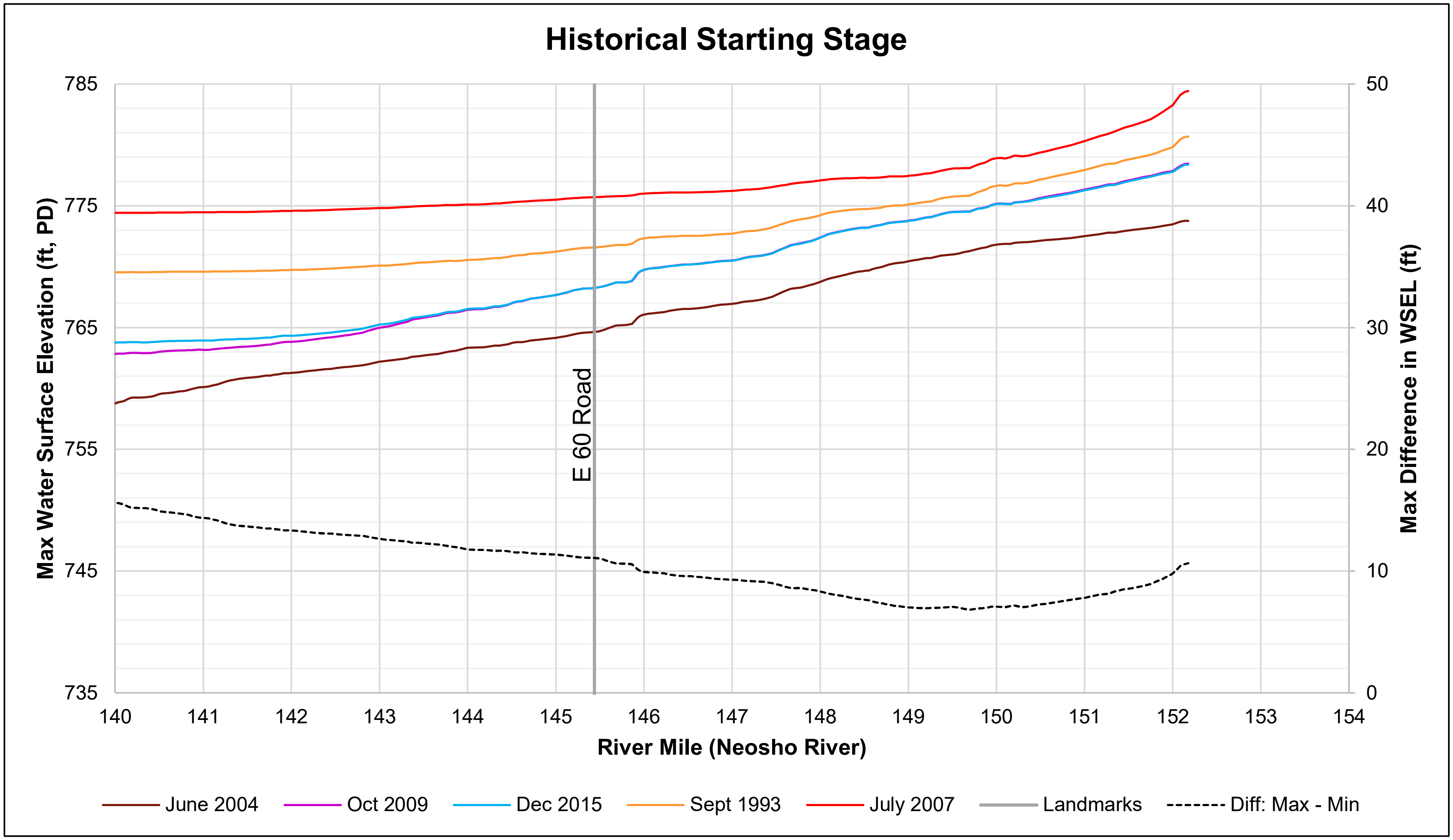


Figure E.65. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

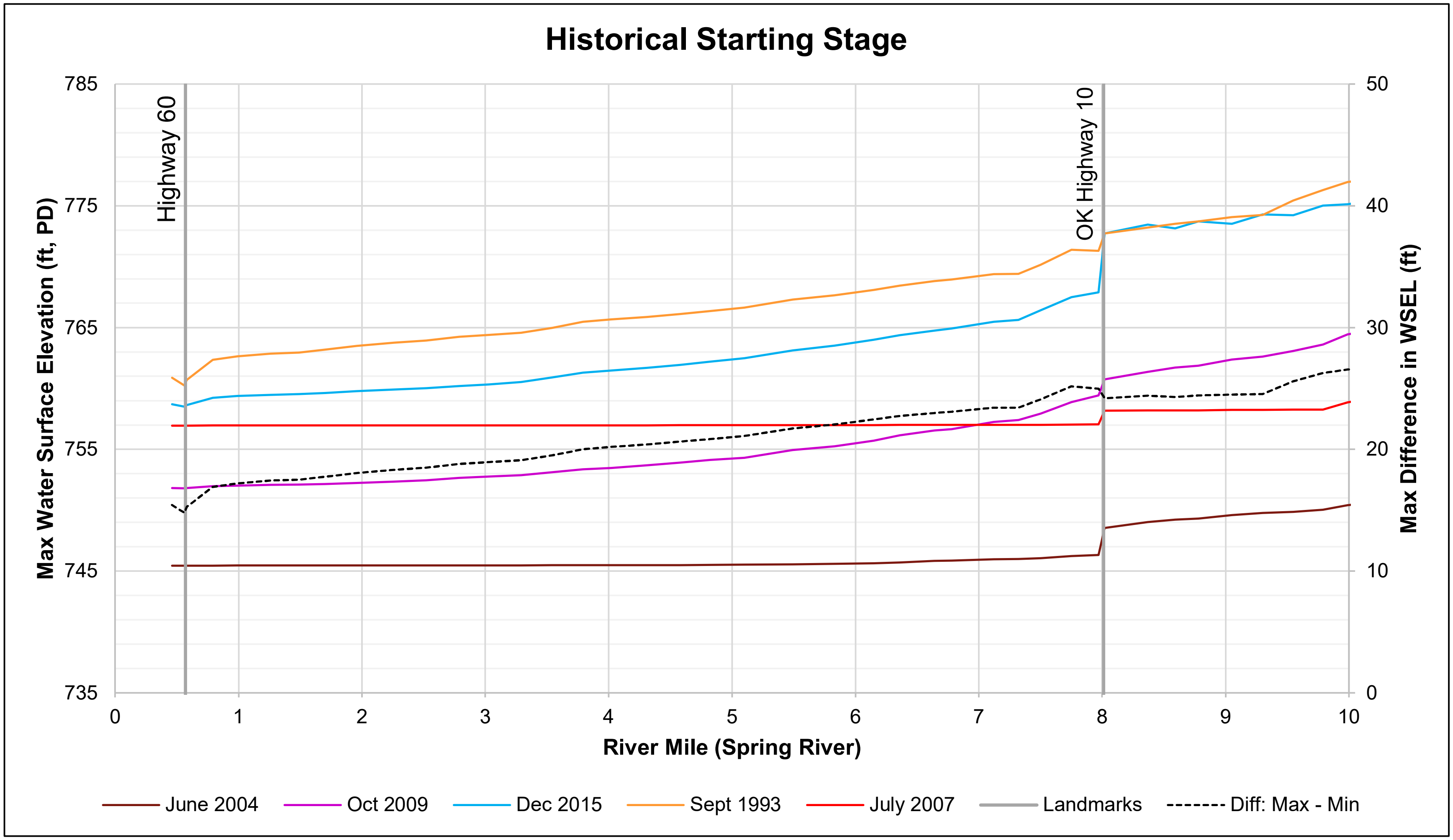


Figure E.66. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: 1. *The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.*
2. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.*

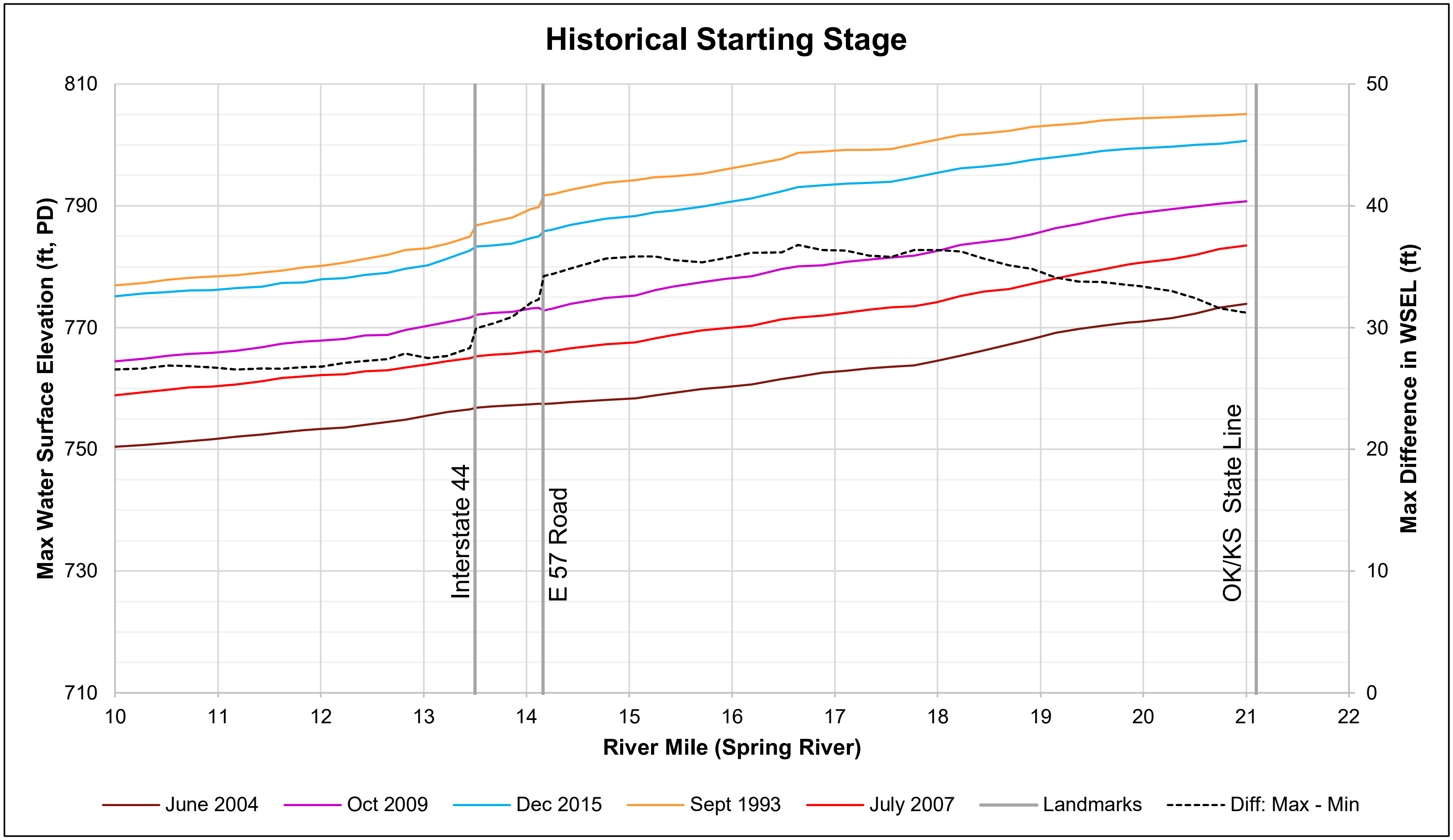


Figure E.67. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

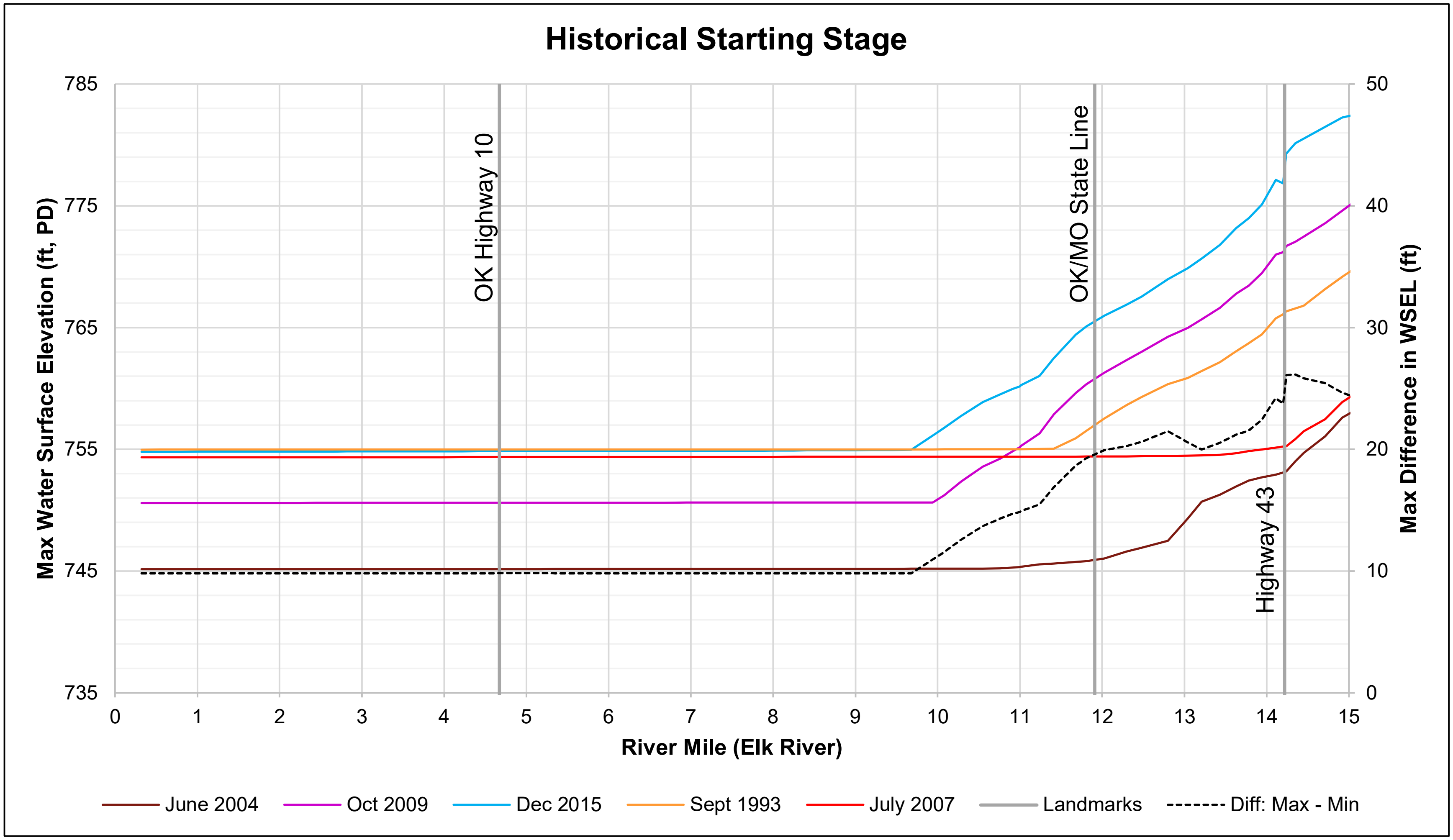


Figure E.68. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

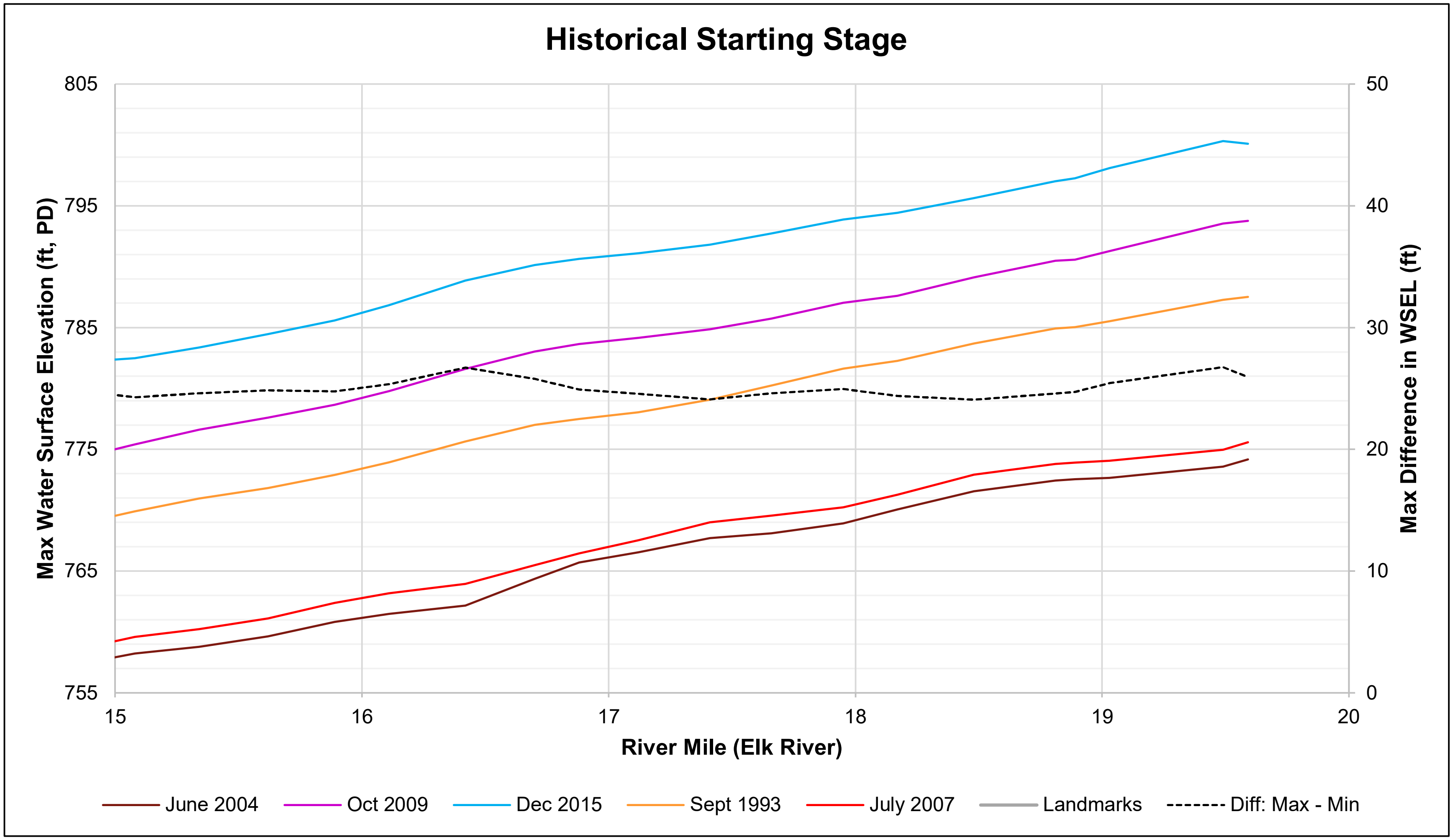


Figure E.69. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

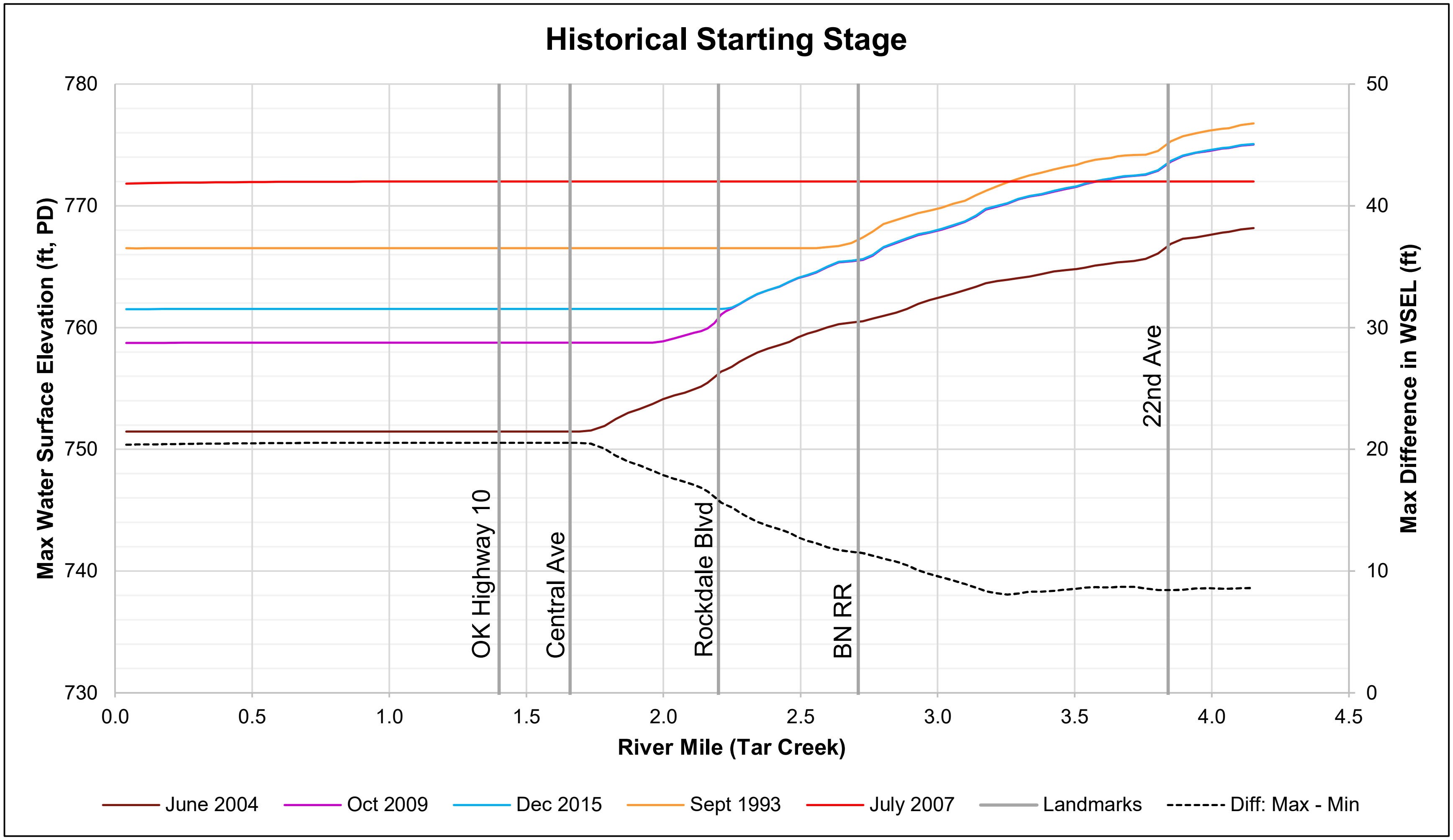


Figure E.70. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

APPENDIX E.8:
COMPARISON OF MAXIMUM DIFFERENCES

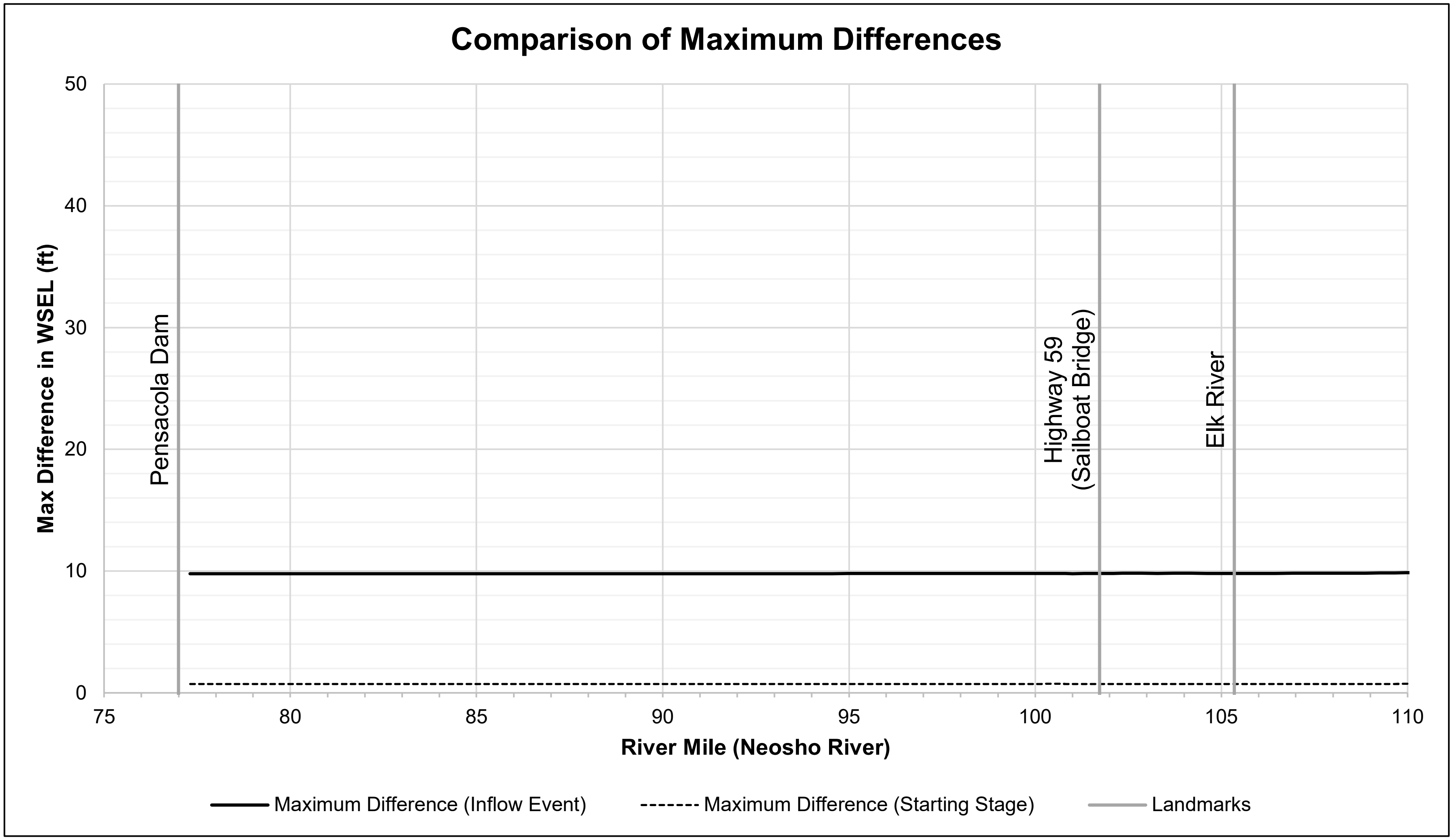


Figure E.71. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Neosho River profile (1 of 5).

Notes:

1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.

2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

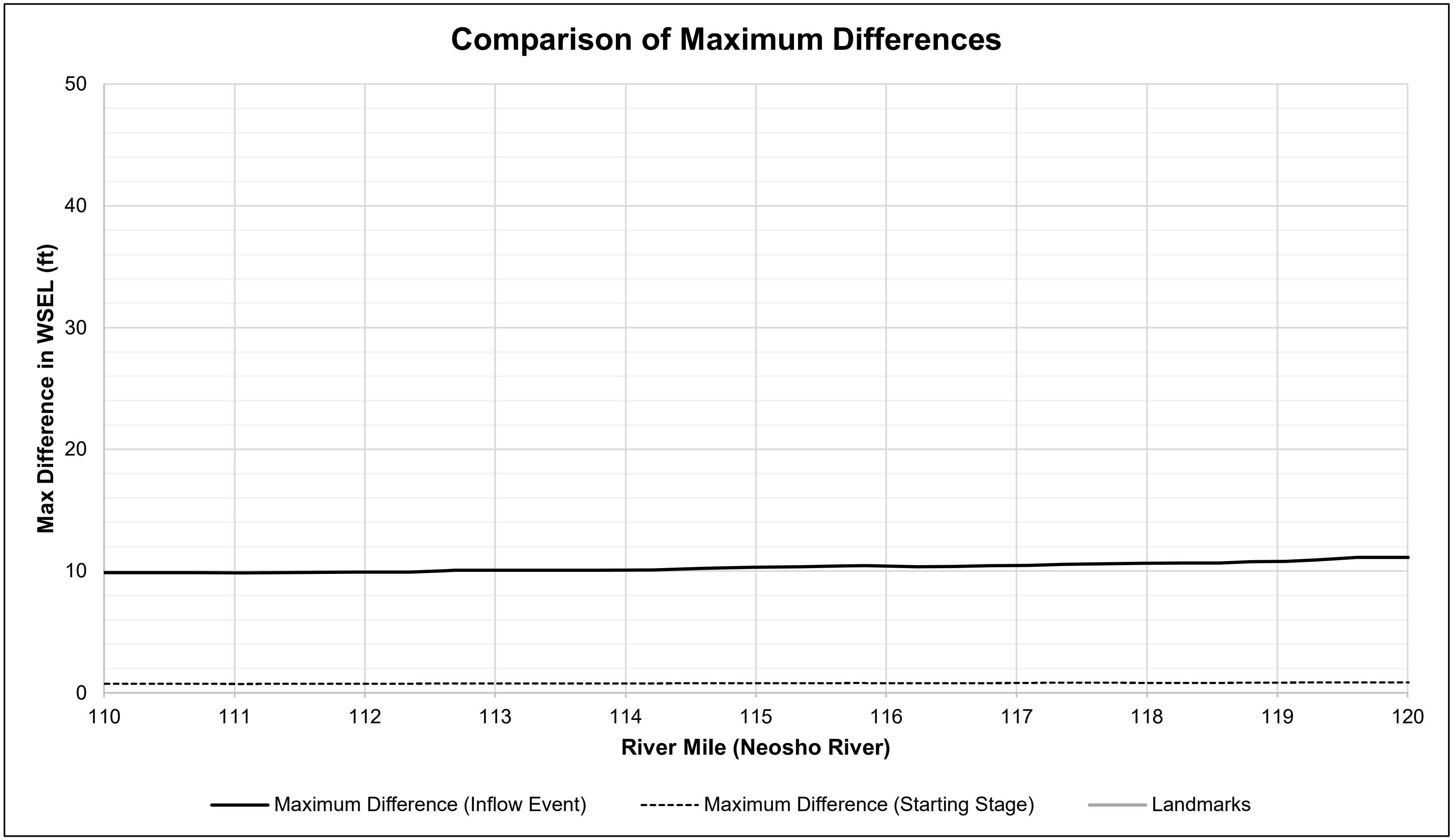


Figure E.72. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Neosho River profile (2 of 5).

Notes:

1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.

2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

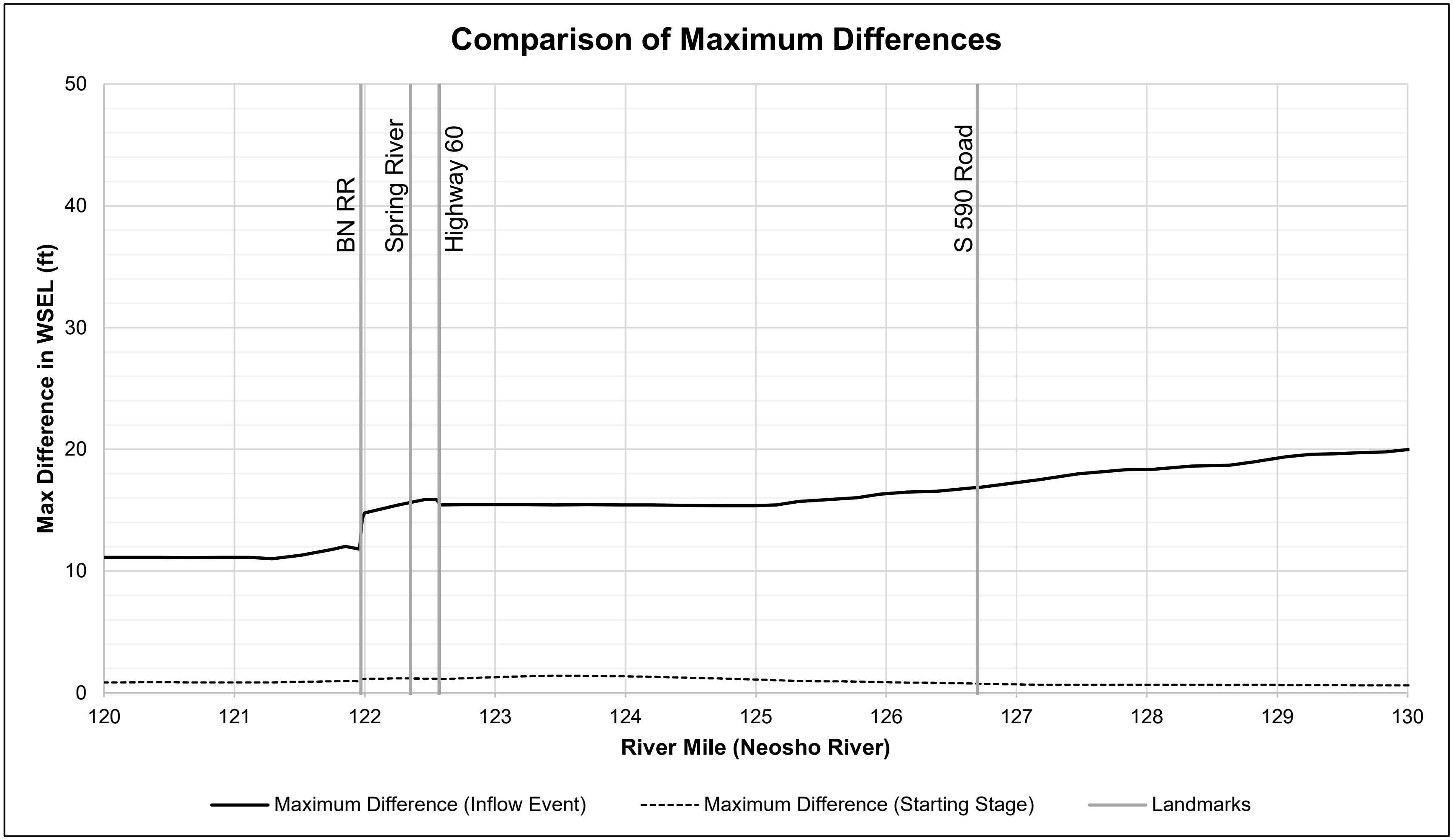


Figure E.73. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Neosho River profile (3 of 5).

Notes: 1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.
2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

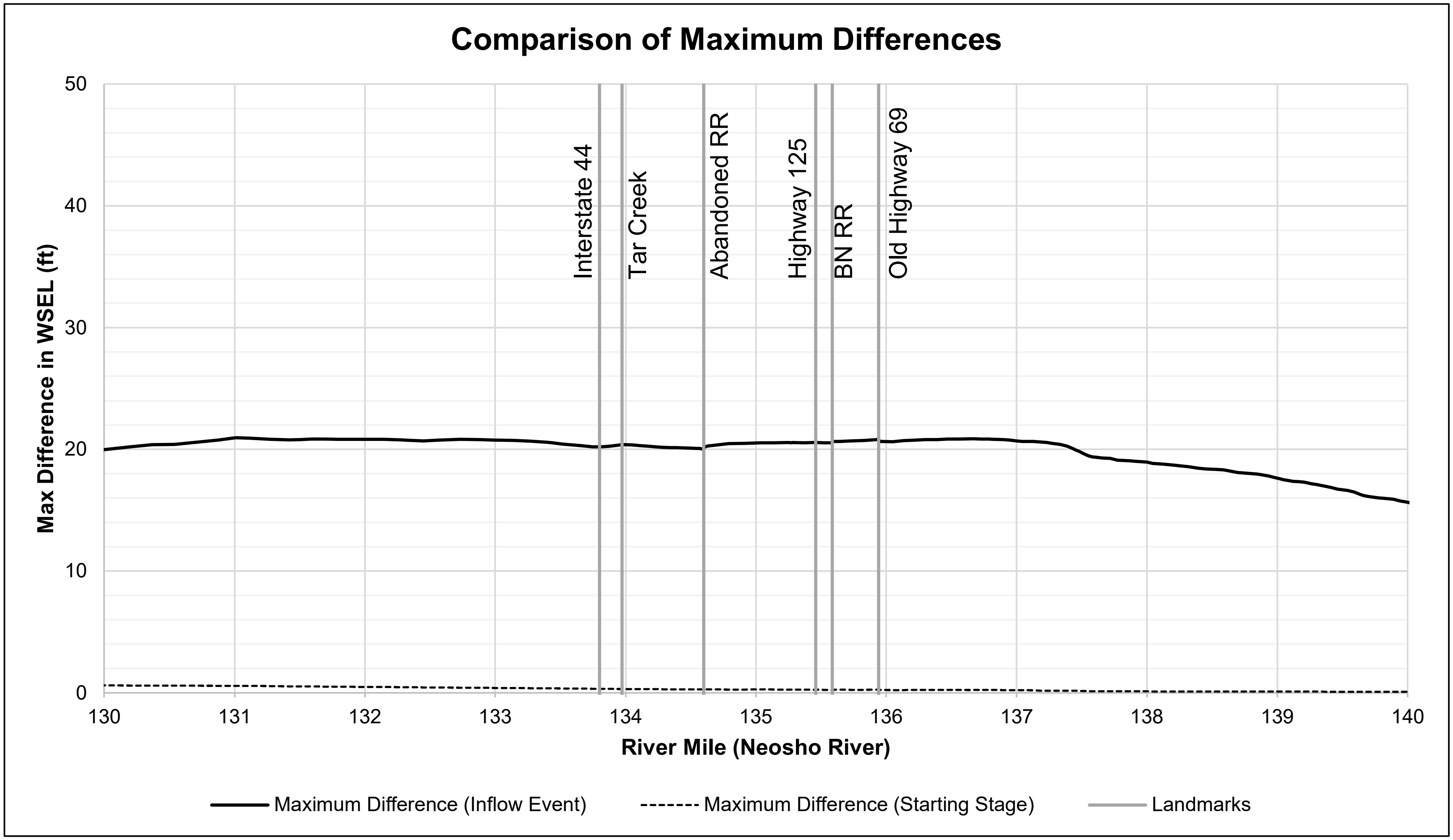


Figure E.74. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Neosho River profile (4 of 5).

Notes: 1. *The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.*
2. *The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.*

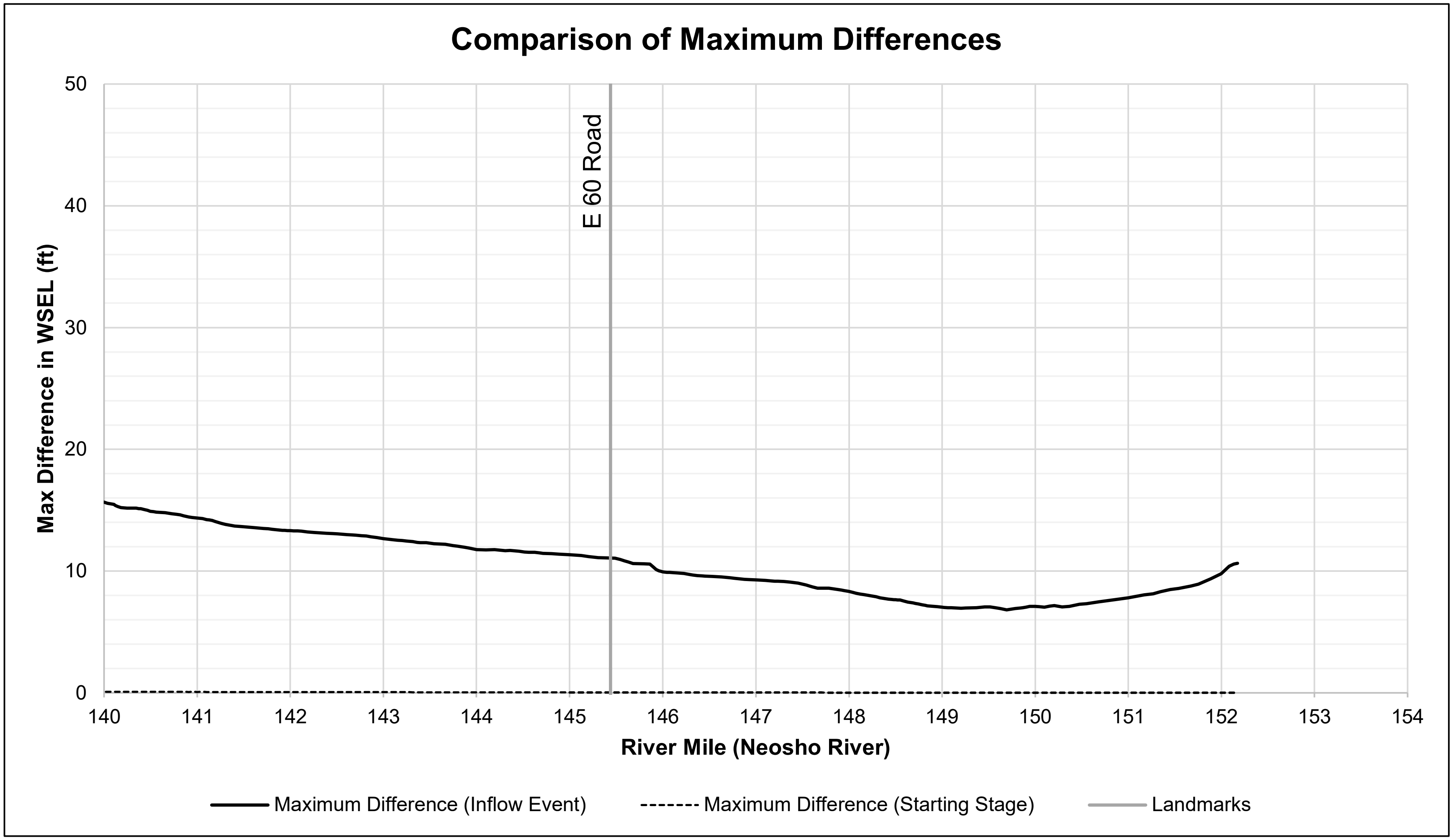


Figure E.75. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Neosho River profile (5 of 5).

Notes:

1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.

2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

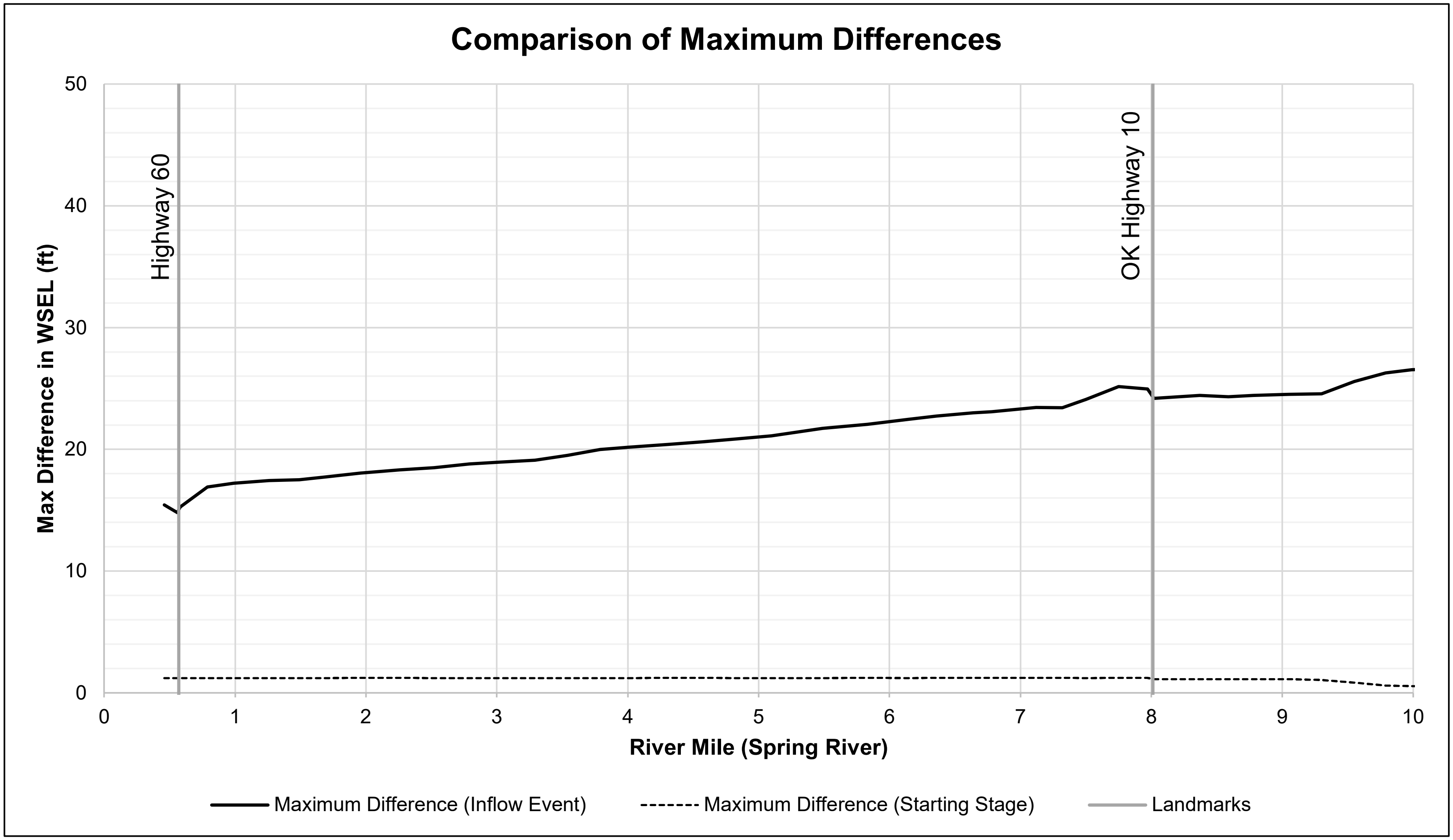


Figure E.76. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Spring River profile (1 of 2).

Notes:
1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.
2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

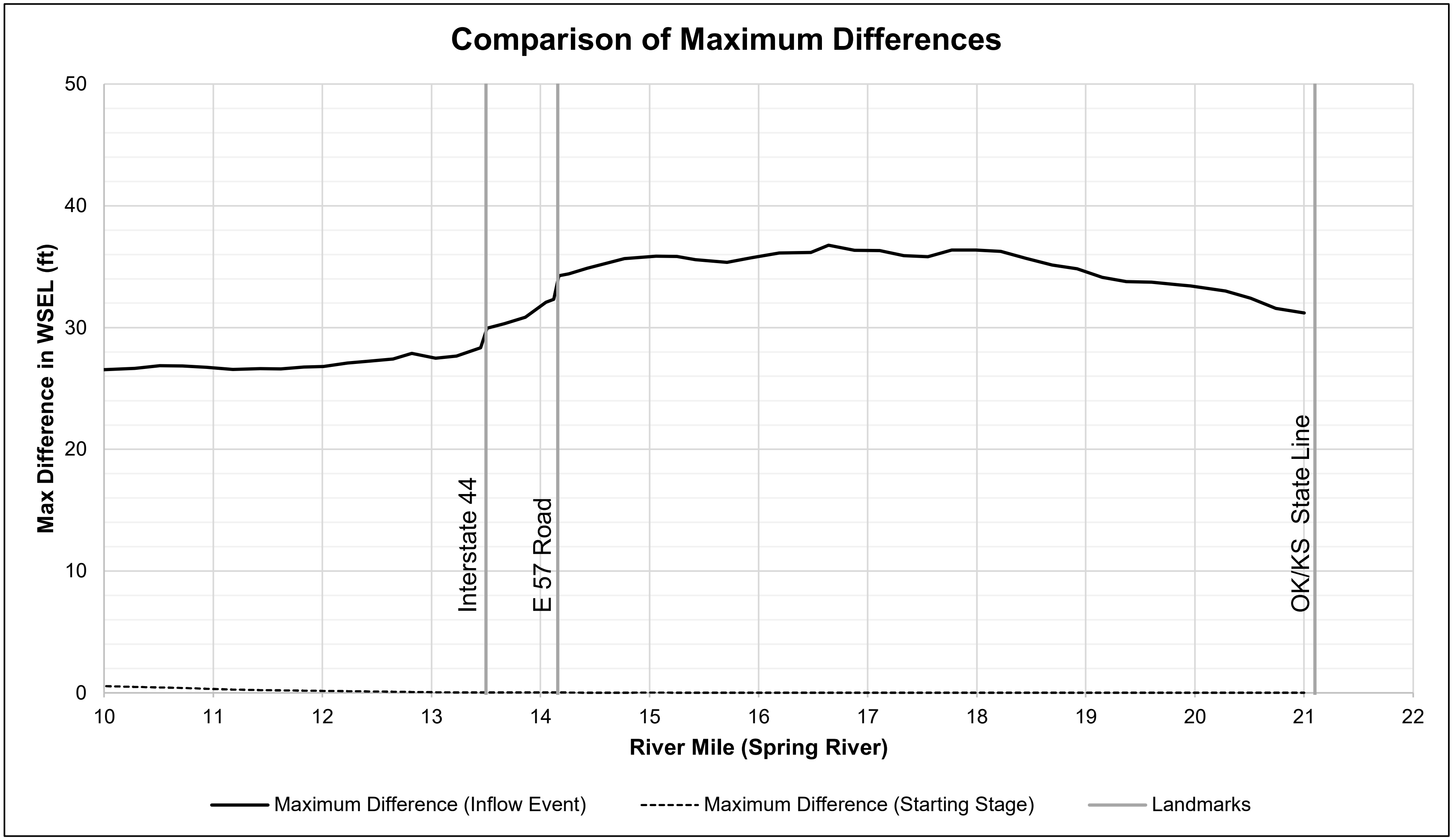


Figure E.77. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Spring River profile (2 of 2).

Notes:
1. *The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.*
2. *The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.*

Figure E.78. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Elk River profile (1 of 2).

Notes: 1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.
2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

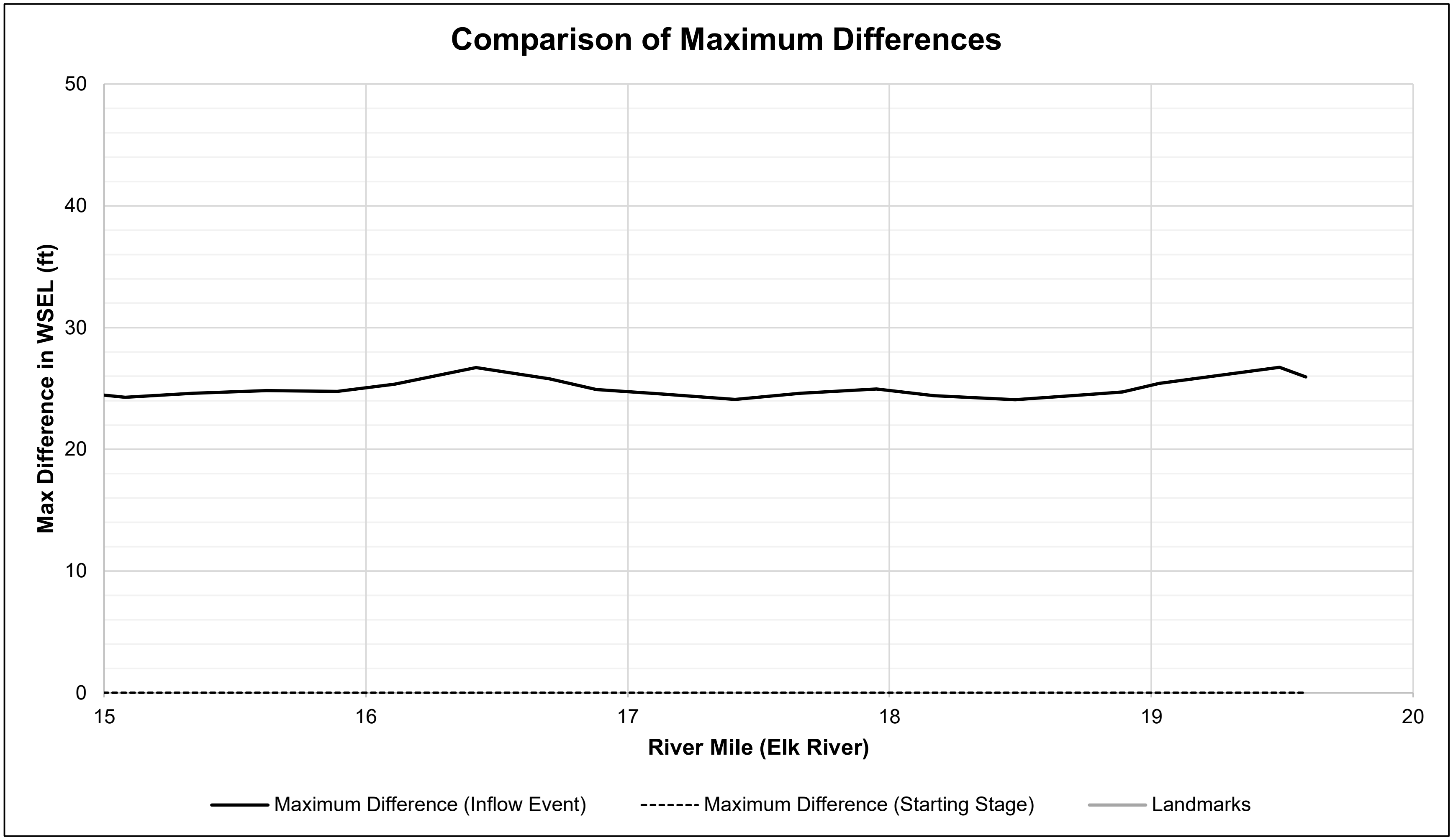


Figure E.79. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Elk River profile (2 of 2).

Notes:
1. *The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.*
2. *The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.*

Figure E.80. Maximum water surface elevation differences due to a change in starting pool elevation compared to maximum water surface elevation differences due to inflow event along the Tar Cree profile (1 of 1).

Notes: 1. The solid line, Maximum Difference (Inflow Event), plots the maximum difference in WSEL when the various inflow events are compared against each other.

2. The dashed line, Maximum Difference (Starting Stage), plots the maximum difference in WSEL due to change in starting pool elevation.

APPENDIX F:
INUNDATION MAPS

Due to the size of inundation map files, each set of maps is included as a separate PDF.