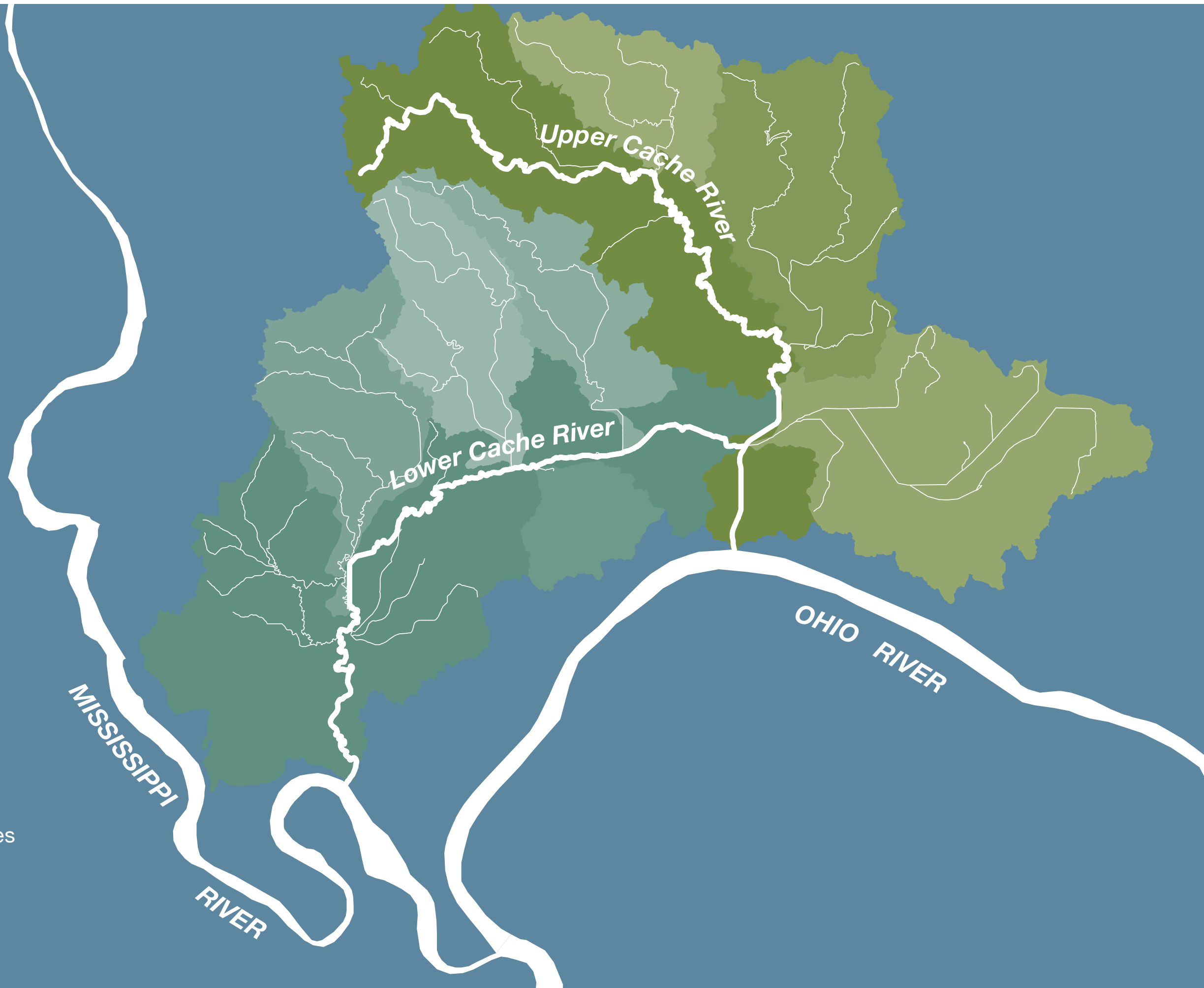
Prepared for the
Cache River Joint Venture Partnership
January 2008

Hydrologic and Hydraulic Modeling and Analyses for the Cache River for the Purposes of Evaluating Current Conditions and Alternative Restoration Measures

Misganaw Demissie, Laura Keefer, Yanqing Lian, Feng Yue, Brad Larson



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Illinois State Water Survey
Champaign, Illinois
Center for Watershed Science

A division of the Illinois
Department of Natural Resources
and an affiliated agency
of the University of Illinois

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Abstract

The Cache River basin located in southern Illinois has characteristics that are unique in the State of Illinois and the nation, with its diverse physical, chemical, and biological features that produced a great diversity of natural communities. Because of these unique characteristics, the Cache River basin contains some high quality bottomland hardwood forests and wetlands that have been recognized nationally and internationally. However, changes in land-use practices and hydraulic modifications during the last century have significantly threatened the ecological integrity of some of these valuable habitats and wetlands. To sustain their value and importance, these habitats need restoration and protection. One of the key goals of resource managers working in the area is to restore the Cache River's natural hydrology to a level that can sustain a viable ecology throughout the river corridor. To evaluate the results of different restoration measures, the Cache River Joint Venture Partnership needed reliable hydrologic and hydraulic models.

The Illinois State Water Survey developed calibrated hydrologic and hydraulic models and evaluated the hydrology under current conditions and under various restoration scenarios. Results then were compared to the reference/base condition. The reference/base condition refers to the condition when the hydrology of the Lower Cache River was controlled on the east end by Karnak Levee with two 48-inch gated culverts that prevented flow from Post Creek Cutoff into the Lower Cache River and by in-channel weirs at Route 37 and "Diehl Dam" located west of Long Reach Road. The top elevation for "Diehl Dam" was set at 328.4 feet above mean sea level.

After analyzing all the scenarios considered with different combinations of flooding conditions, structural changes, and boundary conditions, the study conclusions can be summarized as follows:

1) The current condition exposes the Lower Cache River corridor, especially the eastern portion, including the community of Karnak, to more flooding during major floods, such as 100-year or greater floods from the Upper Cache and Ohio Rivers. However, the current condition improves flood drainage for some parts of the area during more frequent 1-, 2-, and 5-year floods.

2) Installing the East Outlet Structure with stop logs and three or more 72-inch culverts will lower flood elevations from the reference/base condition for the portion of the river east of Karnak Road Bridge, including the community of Karnak, because of increased outlet capacity of the larger culverts.

3) Moving “Diehl Dam” 2,800 feet from its current location under current conditions will increase the area flooded by the 100-year flood by only 8 acres. The additional acres flooded are distributed in small increments throughout the Lower Cache River floodplain. Water levels in the stream channel between current and proposed locations will be higher than the current condition during low- and moderate-flow conditions.

4) Partially reconnecting the Lower Cache River with the Upper Cache River by diverting some flow from the Upper Cache to the Lower Cache River will not increase flood elevations from the reference/base condition during major floods such as a 100-year flood but will raise flood elevations during more frequent 1- and 2-year floods. During low- and moderate-flow conditions, reconnection will create slow-moving westerly flow in the Lower Cache River and will not cause flooding.

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Chapter 1. Introduction

The Cache River basin is located in the extreme southern part of Illinois, just north of the confluence of the Ohio and Mississippi Rivers. The basin covers parts of six southern Illinois counties: Union, Johnson, Alexander, Pulaski, Massac, and Pope. The total drainage area of the basin is 737 square miles. Since the construction of Post Creek Cutoff in 1915, the Cache River basin has been divided into two subwatersheds: the Upper and Lower Cache River watersheds (Figure 1-1). The Upper Cache River watershed consists of the eastern part of the Cache River basin with a drainage area of 368 square miles; it drains directly to the Ohio River through the Post Creek Cutoff. The Lower Cache River watershed consists of the western part of the Cache River basin with a drainage area of 358 square miles; it drains to the Mississippi River through a diversion channel at the downstream end of the river. Eleven square miles of the Lower Cache River watershed continue to drain into the Ohio River through the original channel.

Because of its unique location at a junction of major rivers and at the confluence of different topographic and physiographic regions (Figure 1-2), the Cache River basin exhibits diverse physical, chemical, and biological features resulting in a great diversity of natural communities with many plant and animal species on the edge of their geographic range. In addition, some of the natural communities within the basin are relatively undisturbed and still support the full range of species and natural character they displayed prior to human disturbance. As a result, the Cache River basin contains nationally and internationally significant habitats that merit protection and restoration. However, changes in land use practices and hydrologic modifications during the previous century have significantly threatened the ecological integrity of some of the important habitats and wetlands in the basin, which included more than 100 species considered endangered or threatened species.

Concerned citizens, nongovernmental organizations and state and federal agencies have been working together during the last 30 years to protect and restore these valuable natural resources. Because of the scale and complexity associated with successful restoration, preservation and management of natural resources within the Cache River basin, a partnership was formed among several conservation organizations in the state including the Illinois Department of Natural Resources (IDNR), The Nature Conservancy (TNC), U.S. Fish and Wildlife Service (USFWS), Ducks Unlimited, and Natural Resources Conservation Service

(NRCS) forming the nucleus of the Cache River Joint Venture Partnership (JVP). Together, the JVP partners own and manage more than 45,000 acres of land in the Cache River basin—including the Cache River State Natural Area, Cypress Creek National Wildlife Refuge, and Grassy Slough Preserve. Further, in partnership with local landowners, NRCS has completed almost 14,000 acres of wetland restoration in the basin through the Wetland Reserve Program. Other prominent contributors to this effort include the U.S. Army Corps of Engineers (USACE), St. Louis District, Citizen's Committee to Save the Cache River, local Soil and Water Conservation Districts, students and scientists from Southern Illinois University, local farmers and conservation professionals who banded together to form the Cache River Watershed Resource Planning Committee, the Friends of the Cache River Watershed, and numerous other organizations and individuals representing diverse backgrounds and interests.

Many of these conservation groups and local stakeholders have come together with the common goal of restoring the Cache River system's natural hydrology as much as possible with minimal impacts to private land. This restoration vision includes creating a managed reconnection between the Upper and Lower Cache Rivers and placing two structures in the river channel (hereafter referred as the East Outlet Structure and West Rock Weir) to sustain minimum water levels in the Lower Cache River channel. The structures will be described in detail later in the report. An essential component of this restoration effort is detailed hydrologic and hydraulic modeling to determine water levels associated with the proposed restoration measures. Hydrologic and hydraulic modeling will allow the JVP to satisfy regulatory requirements and assure no negative impacts on natural, agricultural, and social resources.

To accomplish this, the JVP funded the Center for Watershed Science at the Illinois State Water Survey (ISWS) to develop the necessary hydrologic and hydraulic models. These models will enable the JVP to evaluate benefits and potential impacts of proposed restoration alternatives objectively from both ecological and regulatory perspectives. This report presents the results of the investigation that includes development of updated hydrologic and hydraulic models, evaluation of current hydrologic conditions, and evaluation of alternative restoration measures.

Acknowledgments

The work upon which this report is based was supported in part by funds provided by the Cache River Joint Venture Partnership (JVP), which includes the Illinois Department of Natural Resources, The Nature Conservancy, the U.S. Fish and Wildlife Service, Ducks Unlimited, and the Natural Resources Conservation Service. Their support and contributions in defining the study scope and reviewing the draft reports are greatly appreciated.

Several ISWS staff contributed significantly to the completion of the project through data analysis and report preparation. We are especially grateful to Vern Knapp for preparing the flow duration curves for the Upper Cache River and reviewing the report. We also appreciate David Crowder's review of the draft report in a timely manner. Eva Kingston edited the report, and Sara Nunnery assisted in preparing the figures. Becky Howard prepared the camera-ready copy of the report.

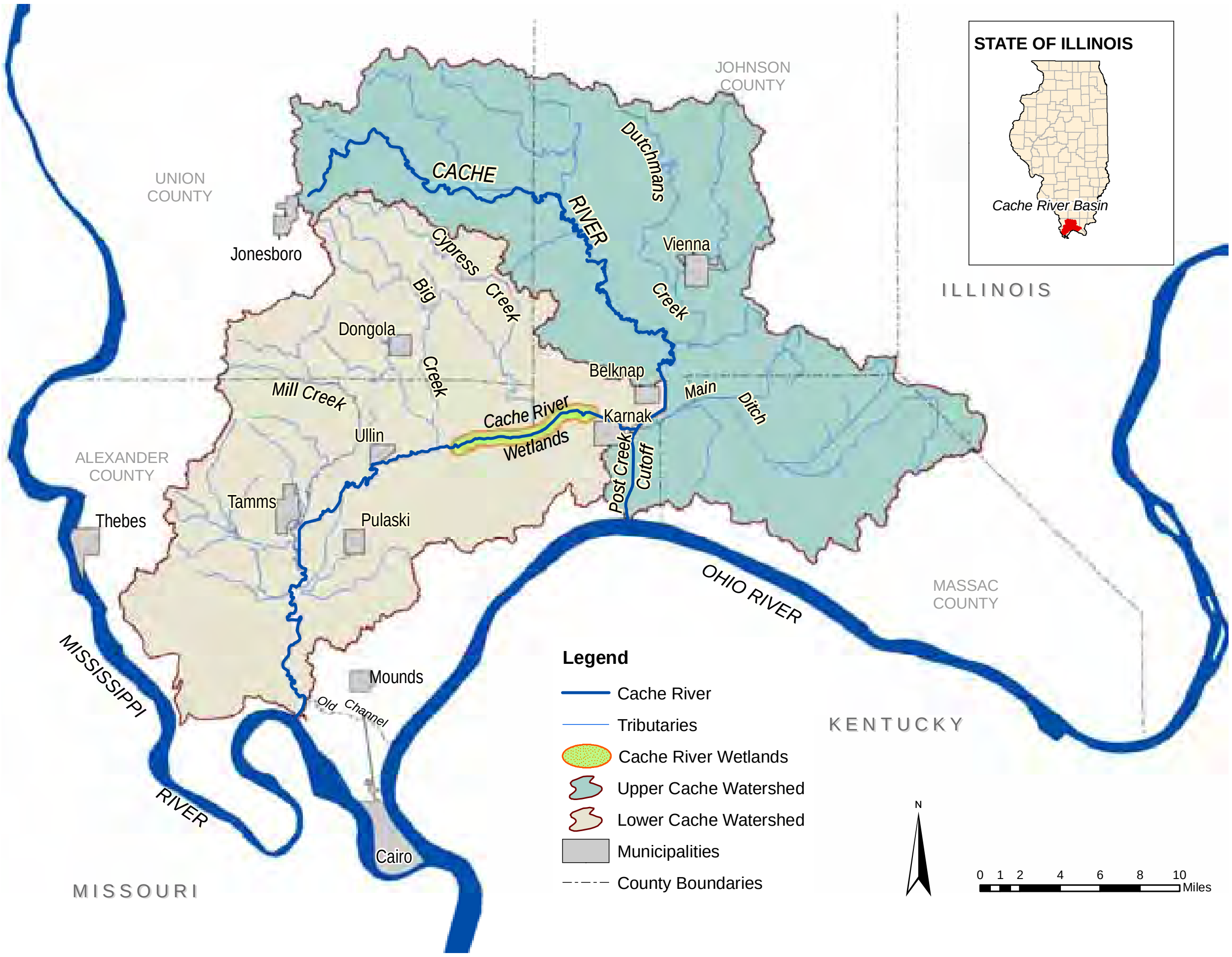


Figure 1-1. Location of Lower and Upper Cache River watersheds in southern Illinois

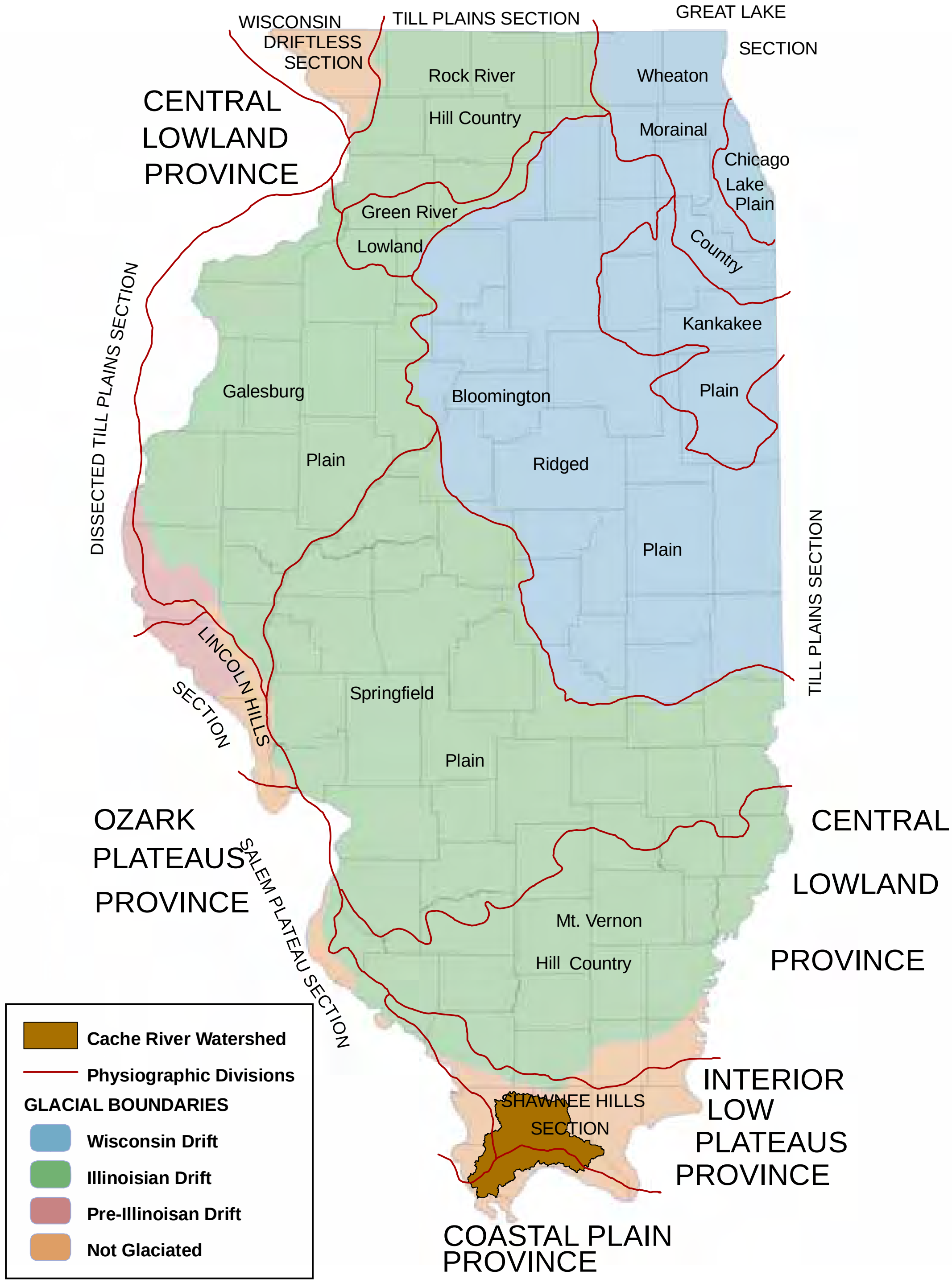


Figure 1-2. Physiographic divisions and glacial boundaries of Cache River basin in Illinois

Chapter 2. Background

The Cache River is located in extreme southern Illinois, just north of the confluence of the Ohio and Mississippi Rivers (Figure 2-1). The total drainage area of the basin was 737 square miles until the construction of Post Creek Cutoff in 1915, which divided the Cache River basin into the Upper and Lower Cache River watersheds with 368 and 358 square miles of drainage, respectively. Karnak Levee (also known as Cache River Levee), along the western bank of Post Creek Cutoff near Karnak, separates the Upper and Lower Cache River watersheds. This levee was built in 1952 across the old Cache River channel and forces drainage from the Upper Cache River to flow directly to the Ohio River through the Post Creek Cutoff. It also was designed to prevent any flood from the Upper Cache and Ohio Rivers from backing into the Lower Cache River. Karnak Levee was designed with two 48-inch gated culverts (shown in Figure 2.2) to allow local drainage along the west side of the levee to flow to Post Creek Cutoff. Drainage from the Lower Cache River watershed was assumed to flow west into the Mississippi River. However, during flood events, some drainage from the Lower Cache River flowed east to Post Creek Cutoff through the culverts in Karnak Levee.

Because of these alterations and the influence of the Ohio and Mississippi Rivers, the hydraulics of the Lower Cache River are very complex. Since the division of the Cache River basin into two watersheds, the Lower Cache River does not receive flow from the Upper Cache River to maintain a sustained flow in the downstream direction. Local tributaries are now the headwaters and the source of water for the upper portion of the Lower Cache River.

Big Creek, Cypress Creek, and Mill Creek (Figure 2-3) are the three major tributaries that drain the upper portion (headwaters) of the Lower Cache River watershed. Big Creek has a drainage area of 51.7 square miles and flows into the Cache River at River Mile (RM) 24.1. Cypress Creek has a drainage area of 46.3 square miles and flows into the east side of the wetland at RM 29.4. Mill Creek has a drainage area of 53 square miles and flows into the Lower Cache River at RM 15.0. However, low to moderate flows from the upper third of the Mill Creek watershed are diverted to Indian Camp Creek (approximately 1 mile northwest of the town of Ullin), which enters the Lower Cache River south of Ullin (RM 20.5). Several smaller tributaries also flow into the Lower Cache River. The most significant of these smaller tributaries, Limekiln Slough, has a drainage area of 22.1 square miles and flows into the west end of the Cache River Wetlands Area at RM 25.2.

Big Creek, Limekiln Slough, and Cypress Creek flow into the Lower Cache River where the channel bed elevation is the highest as shown in Figure 2-4. East of the Cypress Creek confluence, the Lower Cache River has a downward slope to the east toward Karnak Levee. During low and moderate flows, the Cache River Wetlands Area in the vicinity of Long Reach Road is normally the divide between the two portions of the Lower Cache River that flow east towards Karnak Levee and west towards the Mississippi River (Allgire, 1991). During flood conditions, all or part of the wetland flows to the west. The location where the flow divides to the east or west is not constant and varies during flood events (IDNR, 1997).

Once water from tributaries enters the Lower Cache River, it can flow in an easterly direction toward culverts in Karnak Levee or flow in a westerly direction toward the Lower

Cache River outlet on the Mississippi River. If the flows are high enough to overtop streambanks, which is the case during most flood events, then water flows into the wetland areas that have large water storage capacity. A combination of several factors determines which way water flows in upper parts of the Lower Cache River. Some of the factors are magnitude of the floods, channel capacity and slope, flood heights, floodplain storage, outlet capacity at bridge openings, and resistance to flow. At present, however, Karnak Levee has been breached and the culverts washed away (Figure 2-5). It is now possible for major floods from the Upper Cache and Ohio Rivers to back into and flood the Lower Cache River floodplain and for flood waters from the Lower Cache River to flow to Post Creek Cutoff without any control.

Demissie et al. (1990a, 2001) and IDNR (1997) provide more complete descriptions of the hydrology, land use, and climate of the Cache River, and the reader is referred to these publications for additional information.

The objective of this research was to develop hydrologic and hydraulic models that can simulate the hydrology of the tributary watersheds and the hydraulics of the Lower Cache River. The models then were used to evaluate current conditions under different flooding possibilities and future conditions under different management scenarios, including a managed reconnection with the Upper Cache River.

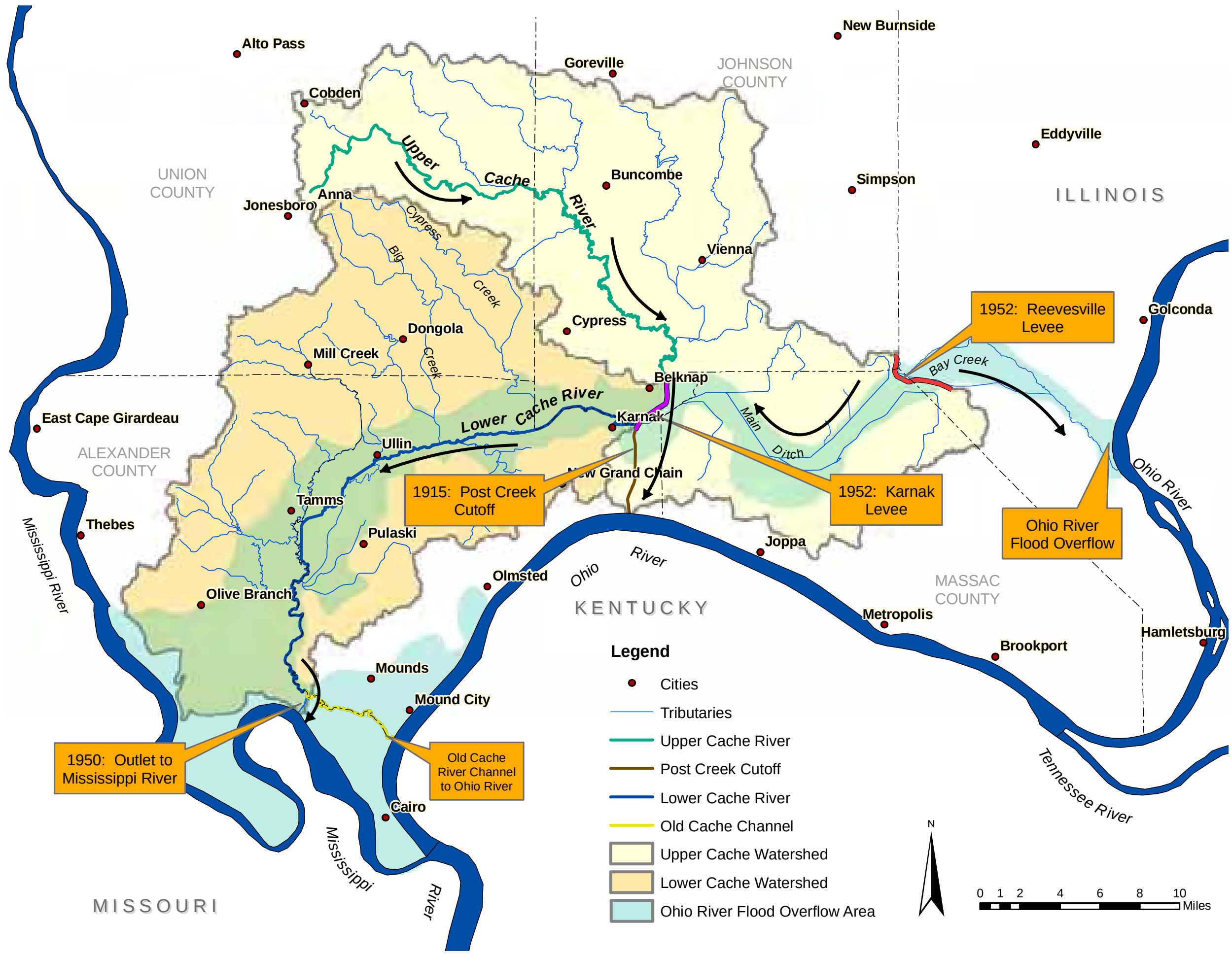


Figure 2-1. Historical major drainage alterations and current drainage pattern of Lower and Upper Cache River watersheds (Demissie et al., 1990a,b)

Figure 2-2. East side of Karnak Levee showing two gated culverts releasing water from Lower Cache River into Post Creek Cutoff

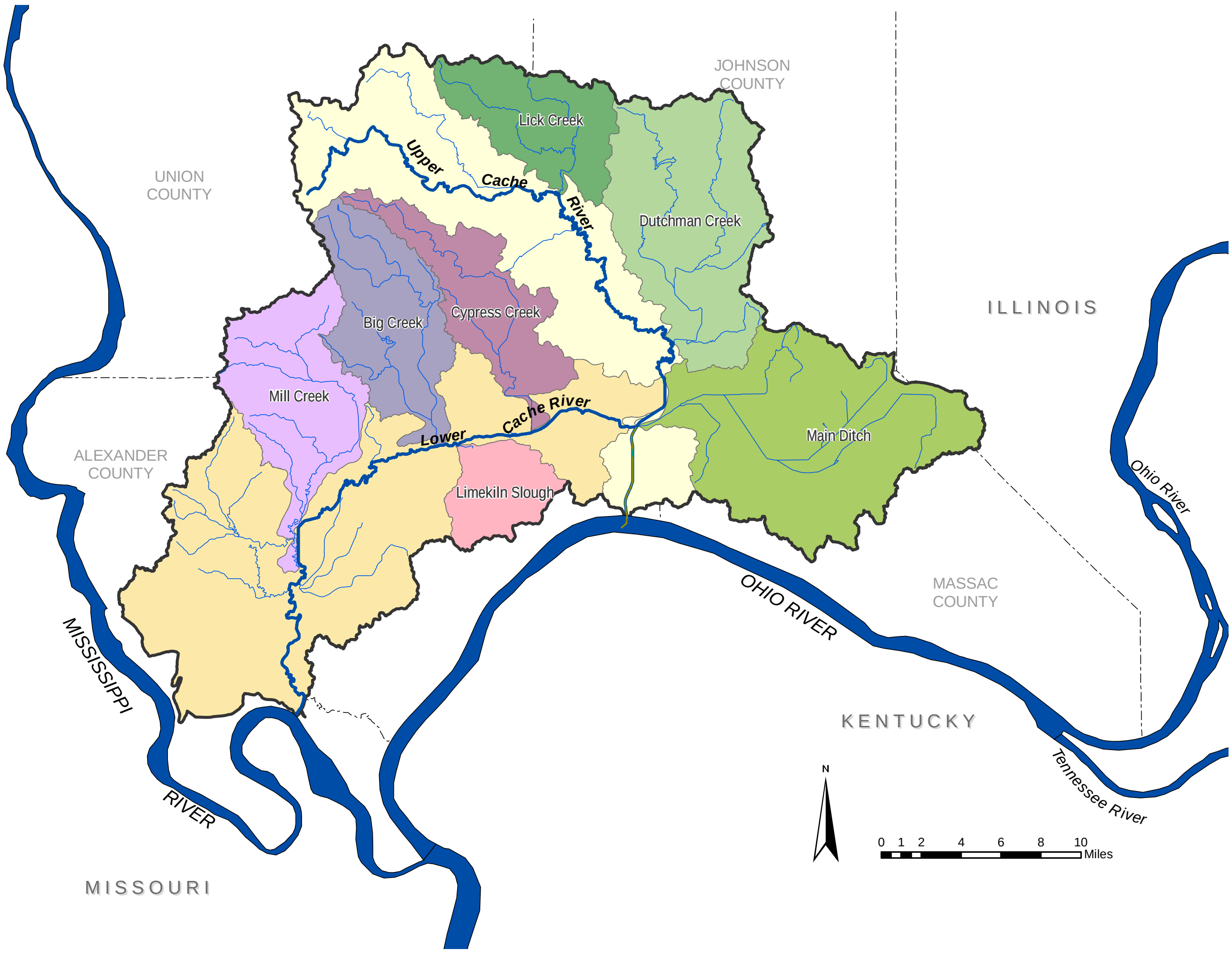


Figure 2-3. Location of major tributary watersheds in Cache River basin

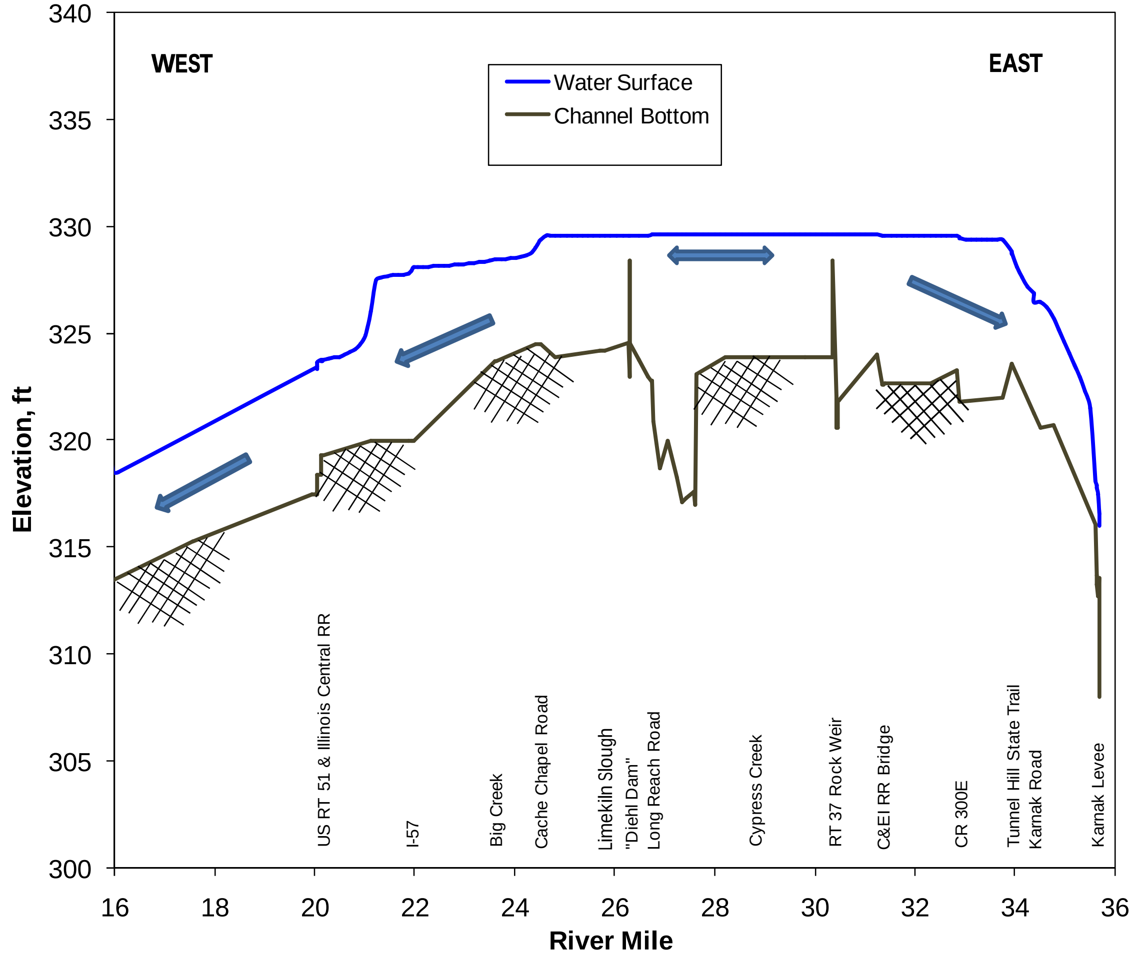


Figure 2-4. Channel bed profile of Lower Cache River and direction of flow during low- and moderate-flow conditions

a) Karnak Levee Culverts – 1991

b) Karnak Levee Breach

Figure 2-5. East side of Karnak Levee showing a) deterioration of levee embankment with loss of culvert flap gates and b) levee breach and washed out culverts looking west toward Post CreekCutoff

Chapter 3. Hydrologic and Hydraulic Modeling

The hydrology and hydraulics of the Lower Cache River were investigated intensively by updating models previously developed by the ISWS and the USACE, St. Louis District. Two models, one for hydrology and the other for hydraulic simulation, were updated and used to evaluate different scenarios that represent reference conditions, current conditions, and future alternatives.

Hydrologic models are designed to estimate the amount of runoff or streamflow generated by individual storm events or by a combination of various storm events. Hydraulic models are then used to compute streamflow characteristics, such as depth and width of water and flow velocity.

The hydrologic model computes the runoff that is generated by precipitation over a watershed, taking into consideration different topography, soil types, and land cover in that watershed. To compute flow characteristics (velocity, depth, etc.), the hydraulic model uses information on channel and floodplain geometry, stream slope, vegetation, and man-made factors such as bridges, levees, and culverts. The flow characteristics computed by the hydraulic model can also be used to estimate the amount of sediment transported by the stream. Both types of models are mathematical simplifications of the physical processes in a real stream and its watershed, and thus are estimates of what actually occurs following rainfall events.

The hydrologic modeling system (HEC-HMS) developed by the Hydrologic Engineering Center of the USACE simulates rainfall-runoff processes for the tributary watershed to the Lower Cache River. The HEC-HMS model for the Lower Cache River watershed was developed based on an earlier HEC-1 model developed by the ISWS. The present model was updated by calibrating and validating the model with recently collected ISWS hydrologic data. The model was used to compute runoff from tributary watersheds for 1- to 100-year storm events. Outputs from the HEC-HMS model for the different storm events then are used as inputs to the One-Dimensional Unsteady Flow through a Full Network of Open Channels (UNET) model. The UNET model for the Lower Cache River initially was developed by the St. Louis District and previously had been used by the ISWS for a research project on Big Creek. The UNET model is capable of modeling the complex hydraulics of the Lower Cache River where flow directions change over time. The UNET model was used to route flows through the Lower Cache River under different storm events and boundary conditions at the east and west outlets. Development of the current version of both models and their applications are discussed in this chapter.

Hydrologic Model Development and Application

The first step in the development of models for the Lower Cache River starts with the hydrologic model that will simulate rainfall-runoff processes in the whole watershed. Because of prior studies of the watershed, different versions of hydrologic models have been developed. The first hydrologic model for the Lower Cache River watershed was developed in 1990 by the ISWS based on the HEC-1 model (Demissie et al., 1990b). The HEC-1 model developed by the Hydrologic Engineering Center of the USACE was the standard hydrologic model at the time

(USACE, 1990). The Lower Cache River watershed model was updated significantly using new digital elevation model (DEM) data and more tributary watersheds than in 2001 for the Big Creek watershed study (Demissie et al., 2001). The USACE, St. Louis District further updated the model and later converted it to the HEC-HMS model for their Alexander and Pulaski Counties Study (USACE, 2000). The HEC-HMS model is an upgrade of the earlier HEC-1 model (USACE, 2001). The HEC-HMS version of the hydrologic model developed by the St. Louis District was used for the current study.

Watershed Delineations

The Lower Cache River watershed highlighted in Figure 3-1 is included in the HEC-HMS model. Figure 3-2 shows the schematic representation in the HEC-HMS model of the different tributary watersheds draining into the Lower Cache River. Three major tributary watersheds, Big Creek, Cypress Creek, and Limekiln Slough, were selected for detailed modeling to develop good representation for the whole watershed in the area of interest. Table 3-1 lists all tributary watersheds that drain into the Lower Cache River and their drainage areas. Area ratios of tributary units to the modeled watersheds (Big Creek, Cypress Creek, and Limekiln Slough) will be used to estimate lateral inflows to the Lower Cache River hydraulic model.

Table 3-1. Drainage Areas and Area Ratios of HEC-HMS Tributary Units

Tributary units shown in Figure 3.2	*Drainage area (mi^2)*	*Area ratio as compared to*		
		Big Creek	*Cypress Creek*	*Limekiln Slough*
24	0.74	0.01	0.02	0.03
25	2.58	0.05	0.06	0.12
26	0.86	0.02	0.02	0.04
27	2.52	0.05	0.06	0.12
30	2.78	0.05	0.07	0.13
15+16	3.59	0.07	0.09	0.16
17+18+19	8.98	0.18	0.21	0.41
28+29	3.35	0.07	0.08	0.15
35+36	11.63	0.23	0.28	0.53
Big Creek	50.76	1.00	1.21	2.32
Boar Creek	35.5	0.70	0.85	1.62
Cypress Creek	41.97	0.83	1.00	1.92
Hogskin Creek	7.15	0.14	0.17	0.33
Indian Camp Creek	4.06	0.08	0.10	0.19
Lake Creek	46	0.91	1.10	2.10
LD 1	8	0.16	0.19	0.37
LD 2	5.64	0.11	0.13	0.26
LD 3	9.91	0.20	0.24	0.45
Limekiln Slough	21.89	0.43	0.52	1.00
Mill Creek	57.6	1.13	1.37	2.63
Sandy Creek	28.78	0.57	0.69	1.31

Due to spatial variations or hydrologic differences in watershed characteristics, it is often necessary to subdivide a watershed into smaller homogeneous units. The ArcView-based utility HEC-GeoHMS was used for watershed delineations in this study. The HEC-GeoHMS geospatial tool kit can facilitate visualization of spatial information, document watershed characteristics, delineate the watershed, and generate input files for the HEC-HMS model. The Big Creek, Cypress Creek, and Limekiln Slough watersheds were delineated and subdivided into sub-watersheds by HEC-GeoHMS from 10-foot by 10-foot DEM data downloaded from the U.S. Geological Survey national elevation website (http://statgraph.cr.usgs.gov/viewer.htm). The watershed maps generated from DEM data for Big Creek, Cypress Creek, and Limekiln Slough are shown in Figures 3-3, 3-4, and 3-5, respectively.

In addition to the DEM data, land use and soil types are used to subdivide watersheds into homogeneous units. The Soil Conservation Service (SCS) Curve Number method is used to estimate infiltration and runoff for each sub-basin. The SCS Curve Number is an infiltration index determined from soil and land cover data for the watershed. Soils in the United States are classified into four hydraulic soil groups (HSGs), A, B, C, and D, and three dual classes, A/D, B/D, and C/D (http://wpindex.soils.wisc.edu/hydrologicsoilgroup.html). Each group indicates different minimum rate of infiltration for bare soil after prolonged wetting. The soil type data for Big Creek, Cypress Creek, and Limekiln Slough are given in Tables 3-2, 3-3, and 3-4, respectively. Land use for Big Creek, Cypress Creek, and Limekiln Slough watersheds is given in Tables 3-5, 3-6, and 3-7, respectively. As can be seen in the tables, the predominant land use is cropland and pasture covering more than 95 percent of the watersheds.

Based on DEM data, land use, and soil type, the three watersheds were subdivided into small sub-basins represented in the HEC-HMS model as shown in Figures 3-6, 3-7, and 3-8 for Big Creek, Cypress Creek and Limekiln Slough, respectively. A total of 252, 163, and 74 sub-watersheds were delineated for Big Creek, Cypress Creek, and Limekiln Slough watersheds respectively. Sub-watershed characteristics include identification number, drainage area, and average elevation, longest path to watershed outlet, and average Curve Number for each of the sub-basins for the three watersheds and are provided in Appendix A-1, and Manning' roughness coefficients for the five reaches in the Lower Cache River UNET model are listed in Appendix A-2.

Table 3-2. Soil Types for Big Creek Watershed

Soil type classification	*HSG*	*Area (mi^2)*
IL054	C	1.103
IL060	B	11.035
IL063	C	20.745
IL069	C/D	17.876

Table 3-3. Soil Types for Cypress Creek Watershed

Soil type classification	*HSG*	*Area (mi^2)*
IL054	C	1.140
IL060	B	0.912
IL063	C	21.441
IL069	C/D	18.476

Table 3-4. Soil Types for Limekiln Slough Watershed

Soil type classification	*HSG*	*Area (mi^2)*
IL054	C	0.286
IL063	C	10.015
IL069	C/D	11.589

Table 3-5. Land Use Classifications for Big Creek Watershed

Land use	*Area (mi^2)*
Commercial and services	0.008
Cropland and pasture	49.398
Deciduous forest land	0.779
Forested wetland	0.047
Industrial	0.006
Non-forested wetland	0.008
Orch, grov, vnyrd, nurs, orn	0.116
Other urban or built-up	0.017
Reservoirs	0.008
Residential	0.111
Strip mines	0.031
Trans, comm, util	0.230

Table 3-6. Land Use Classifications for Cypress Creek Watershed

Land use	*Area (mi^2)*
Cropland and pasture	40.588
Deciduous forest land	0.718
Forested wetland	0.412
Mixed forest land	0.009
Orch, grov, vnyrd, nurs, orn	0.003
Trans, comm, util	0.240

Table 3-7. Land Use Classifications for Limekiln Slough Watershed

Land use	*Area (mi^2)*
Cropland and pasture	21.058
Deciduous forest land	0.272
Forested wetland	0.533
Mixed urban or built-up	0.004
Orch, grov, vnyrd, nurs, orn	0.012
Other agricultural land	0.012

Calibration and Validation of HEC-HMS Model for Big Creek Watershed

The ISWS operates two raingages (RG 54 and RG 55) and two streamgages (STN 500 and STN 502) in the Big Creek watershed (Figure 3-3). Hourly precipitation and streamflow data since 2001 are available for calibration and validation of the Big Creek watershed HEC-HMS model using the SCS method for runoff simulation in this study. Table 3-8 is a Curve Number lookup table (U.S. SCS, 1986) for combinations of land use and hydrologic soil groups for the Big Creek watershed. Calibrated hydrologic parameter values then can be applied to other tributaries by assuming hydrologic similarities in the adjacent watersheds. A storm event in September 2001 was selected for calibration purposes, and calibration results are shown in Figure 3-9 where the simulated runoff is compared to the observed streamflow at gaging station 502 on Big Creek. The simulation matches the observed data very well with less than 1 percent error on the peakflow and less than 5 percent error on the total runoff. The hydrographs did not align perfectly because of a 1.5 hour shift in the time to peak for the simulated hydrograph.

Calibrated model parameter values including the Curve Numbers then were validated by comparing simulated runoff and observed streamflow for a rainstorm event in January 2003 (Figure 3-10). As shown in Figure 3-10, the model reproduces the observed flows with less than 5 percent error on the peakflow and less than 10 percent error on the total runoff. The calibrated and validated HEC-HMS model then was used to generate runoff hydrographs for storm events of different frequencies and durations. Table 3-9 shows design storm hyetographs generated based on the third quartile of the Huff distribution (Huff and Angel, 1989). Runoff hydrographs for Big Creek for storms with 1- to 100-year return periods are shown in Figure 3-11. Similar simulations were run for the other tributary watersheds. These results then are used as input to the UNET model.

Hydraulic Model Development and Application

In situations where the flow hydraulics are complex, resulting in reverse flows, and where the channel slopes are very low, analyses of hydraulics of flow use an unsteady flow, dynamic wave routing model. The UNET model (USACE, 1997), developed and maintained by the USACE, was chosen as the tool to analyze flow dynamics in the Lower Cache River. The USACE, St. Louis District developed several sets of data for use in UNET modeling of the Lower Cache River, including cross-sectional data of the channel and floodplain geometry (USACE, personal communication, 2000). For this study, the UNET data files from the St. Louis

Table 3-8. Curve Numbers for Combination of Land Use and Hydrologic Soil Groups (U.S. SCS, 1986)

Land use code	*Land use*	*HSG A*	*HSG B*	*HSG C*	*HSG D*
11	Residential	61	75	83	87
12	Commercial and services	89	92	94	95
13	Industrial	81	88	91	93
14	Trans, comm, util	98	98	98	98
15	Indust & commerc cmplxs	89	92	94	95
16	Mixed urban or built-up	80	86	89	92
17	Other urban or built-up	89	92	94	96
21	Cropland and pasture	77	86	91	94
22	Orch, grov, vnyrd, nurs, orn	66	77	85	89
23	Confined feeding ops	59	74	82	86
24	Other agricultural land	68	79	86	89
31	Herbaceous rangeland	70	80	87	93
32	Shrub & brush rangeland	55	67	80	85
33	Mixed rangeland	48	67	77	83
41	Deciduous forest land	55	66	74	79
42	Evergreen forest land	60	75	85	89
43	Mixed forest land	57	73	82	86
51	Streams and canals	100	100	100	100
52	Lakes	100	100	100	100
53	Reservoirs	100	100	100	100
61	Forested wetland	100	100	100	100
62	Non-forested wetland	100	100	100	100
73	Sandy area (non-beach)	25	25	25	25
76	Transitional areas	75	80	85	90
77	Mixed barren land	75	80	85	90

Table 3-9. Rainfall Depth-Duration Frequency Table for Southern Illinois

Duration	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
3-hour	1.9	2.32	2.89	3.33	3.99	4.55	5.29
6-hour	2.23	2.73	3.39	3.91	4.68	5.31	6.21
12-hour	2.59	3.15	3.93	4.53	5.42	6.19	7.20
24-hour	2.97	3.62	4.51	5.21	6.23	7.11	8.27
48-hour	3.30	4.00	5.03	5.80	6.93	7.86	8.79
72-hour	3.59	4.36	5.48	6.34	7.53	8.54	9.52
5-day	4.10	4.99	6.20	7.21	8.45	9.45	10.82
10-day	5.26	6.36	7.81	8.90	10.34	11.36	12.50

District were updated with new input hydrographs generated from the new HEC-HMS model. Even though no additional surveying was conducted outside the dredged segment of the river, some channel and floodplain cross sections have been extended based on DEM data to contain the 100-year flood elevations. New channel cross sections were used for the segment of the river dredged in 2005 based on survey data provided by Shawnee Survey and Consulting, Inc., which was contracted by the IDNR.

The aerial view of the upper part of the Lower Cache River that is modeled by UNET is shown in Appendix A-3 and identifies significant features, including tributary streams, bridges, and control structures. A schematic of the whole Lower Cache River as represented in the UNET model is shown in Figure 3-12 and includes the important features of the UNET model listed in Table 3-10. Flood stages in the five reaches identified in Figure 3-12 are affected by different control structures and flow inputs.

Due to the high density of vegetation in the Lower Cache River, channel and floodplain areas have high resistance to the flow. The Manning's roughness coefficients are typically high as compared to rivers of average vegetation condition (Chow, 1988). The Manning's roughness coefficients for the five reaches in the Lower Cache River UNET model are listed in Appendix A-2.

Boundary Conditions for UNET Model

Boundary conditions for the Lower Cache River UNET model have to be defined for the confluence of Lower Cache River with the Mississippi River and the junction of the Lower Cache River with the Upper Cache River at Karnak Levee. Table 3-11 gives water surface elevations for 2-, 10-, and 100-year floods for the Mississippi River from the USACE Upper Mississippi River flood frequency study (USACE, 2004). In order to obtain the water surface elevations for different frequency floods at the junction of the Upper and Lower Cache River, flood frequency analysis was conducted for the Upper Cache River. Table 3-11 gives water surface elevations for the 2-, 10-, and 100-year floods at the junctions of the Lower Cache River with the Upper Cache River at Karnak Levee outlet/breach.

Critical Rainstorm Durations

Critical storm duration is defined as the duration of a specified rainstorm event (design rainstorm) that produces the highest streamflow or highest flood stage in the stream. Critical storm durations for the Lower Cache River were identified through simulation runs from 10- and 100-year rainstorms of 3-, 6-, 12-, 18-, 24-, 48-, 72-, 120-, and 240-hour durations. Both 2-year and 1-year stage boundary conditions were used for the confluence of Lower Cache River and Mississippi River and the junction of Lower and Upper Cache Rivers in the UNET model, respectively.

The analysis from a combination of 16 runs showed that 10- and 100-year rainstorms with 120-hour duration produced the highest water surface elevations in the Lower Cache River. Based on the critical duration analysis, design rainstorms with 120-hour duration were used in the subsequent analyses.

Table 3-10. Locations of Major Features Included in Cache River UNET Model

River Mile	*Feature*
35.631	Karnak Levee
34.379	Karnak Road
33.942	Tunnel Hill State Trail
33.771	Lateral inflow from Subarea 27
32.901	CR 300E
32.841	Lateral inflow from Subarea 26
31.415	Lateral inflow from Subarea 25
31.347	C&EI Railroad
31.241	Lateral inflow from Subarea 24
30.445	U.S. Rt. 37
30.373	Rt. 37 Rock Weir
29.803	Lateral inflow from Subareas 35 and 36
28.788	Lateral inflow from Cypress Creek
27.610	Dredging from RM 26.786
26.786	Lateral inflow from Subareas 17, 18, and 19
26.744	Long Reach Road
26.307	"Diehl Dam"
24.823	Lateral inflow from Limekiln Slough and Subareas 15 and 16
24.503	Cache Chapel Road
23.599	Lateral inflow from Big Creek
21.978	Lateral inflow from Subareas 28 and 29
21.926	U.S. I-57
21.887	Lateral inflow from Subareas 30
20.151	U.S. Rt. 51 and Illinois Central Railroad
19.948	Lateral inflow from Indian Camp Creek
14.361	Lateral inflow from Mill Creek
12.560	Sandusky Road
12.274	Lateral inflow from Sandy Creek
10.627	Lateral inflow from Boar Creek
9.711	Lateral inflow from Hogskin Creek
4.590	Olive Branch Road
4.007	Lateral inflow from Lake Creek
0.545	Illinois Rt. 3 and Mississippi River

Table 3-11. Boundary Conditions for UNET Model

Return period	*Mississippi River elevation at confluence with Lower Cache River*	*Upper Cache River elevation at Karnak Levee outlet/breach*
2-year	318.20	319.00
10-year	325.20	334.05
100-year	331.40	341.51

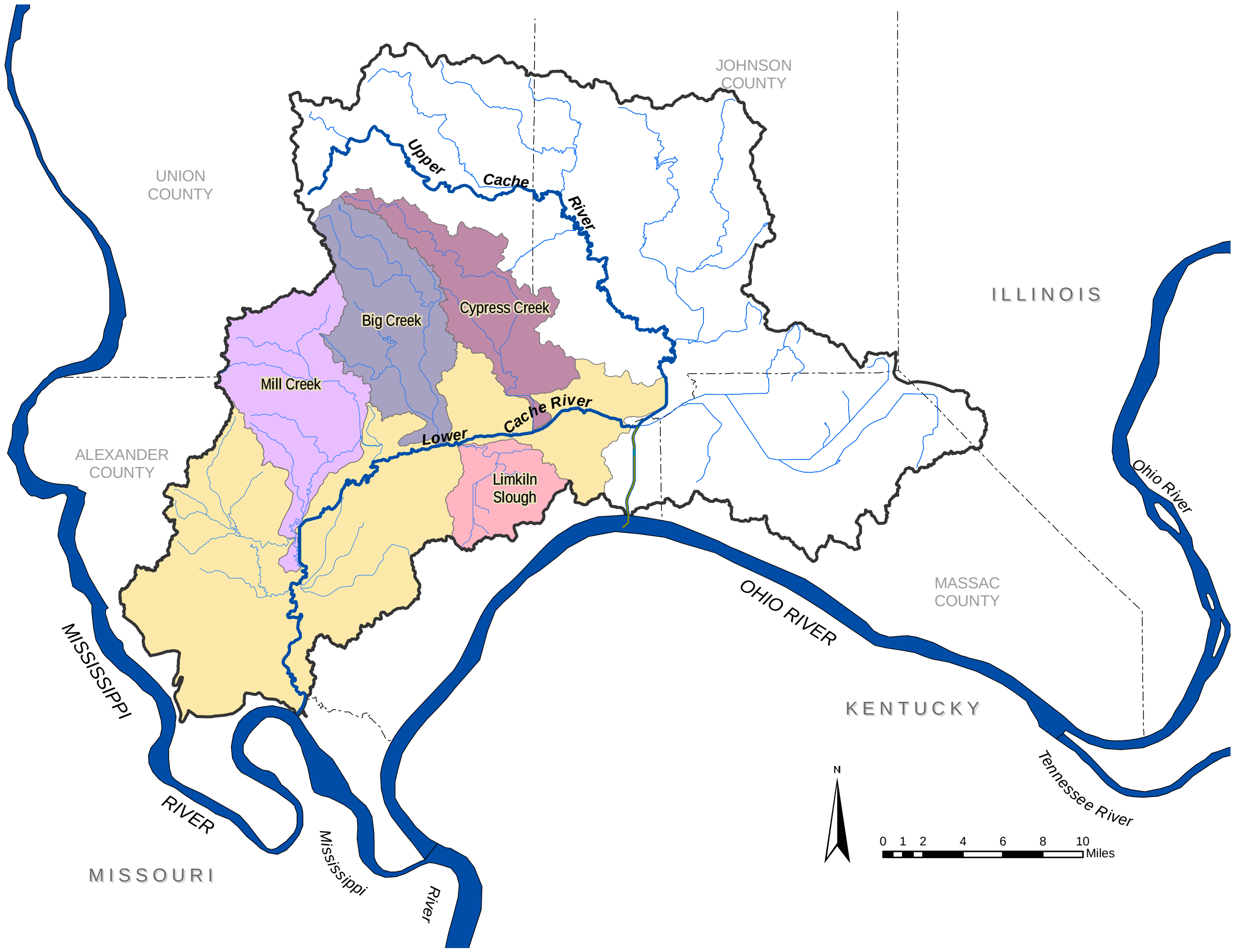


Figure 3-1. Lower Cache River and its major tributary watersheds

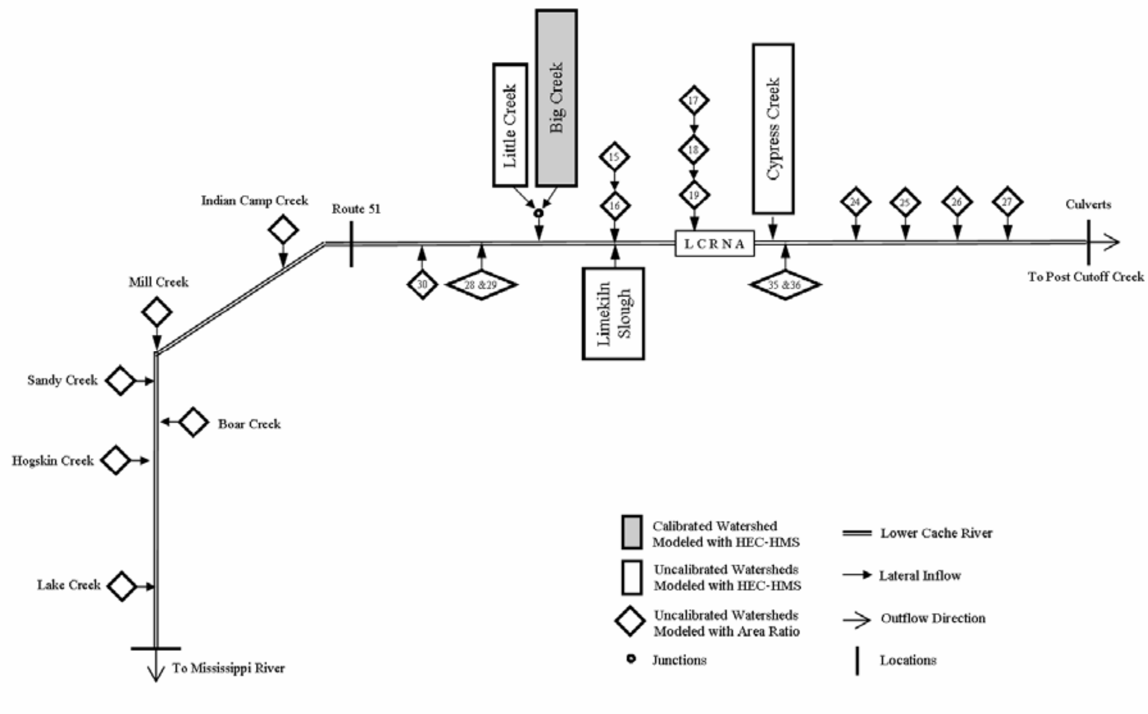


Figure 3-2. Schematic representation of HEC-HMS hydrologic model of Lower Cache River and its tributary watersheds

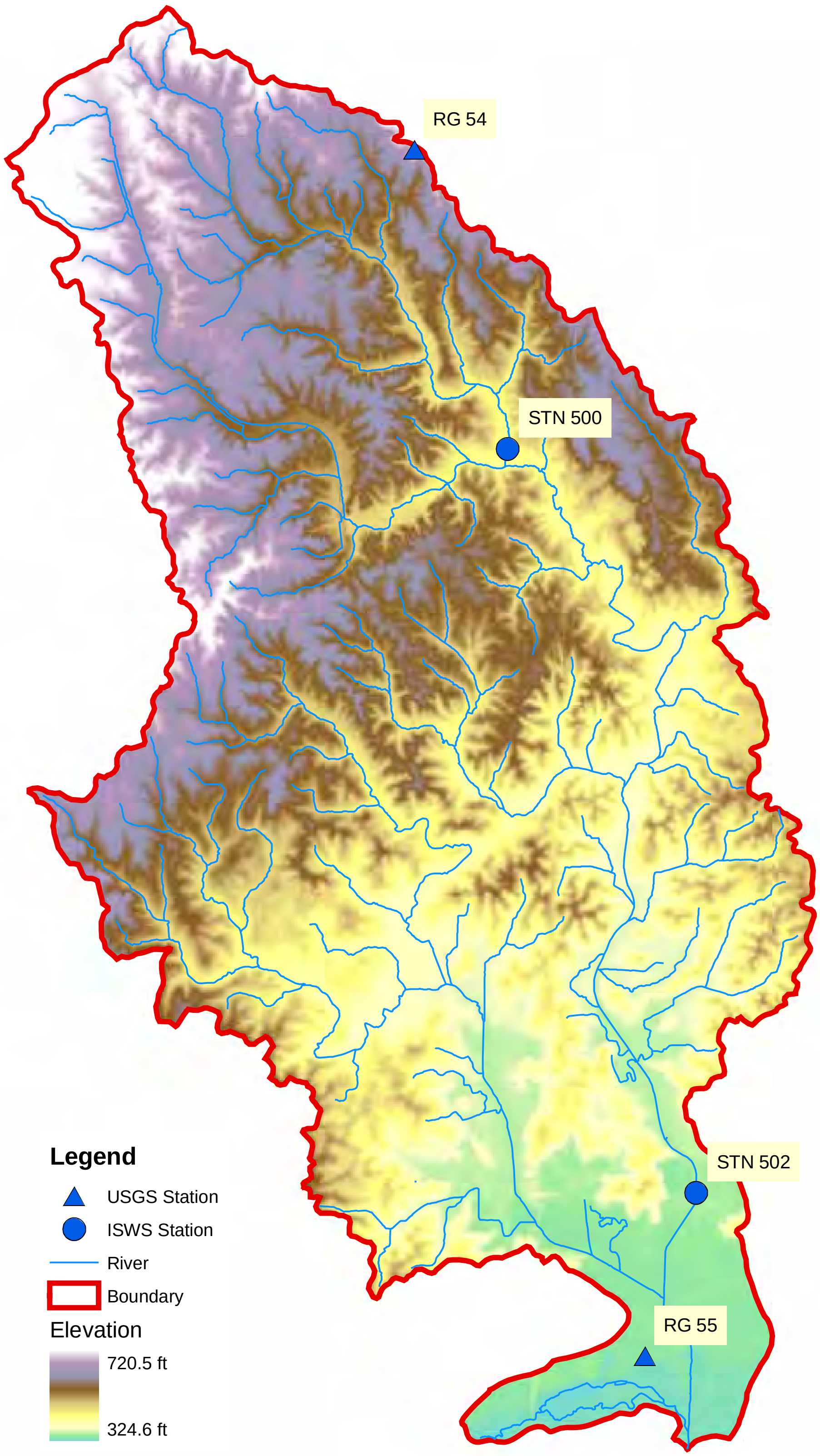


Figure 3-3. DEM and stream network data, Big Creek watershed

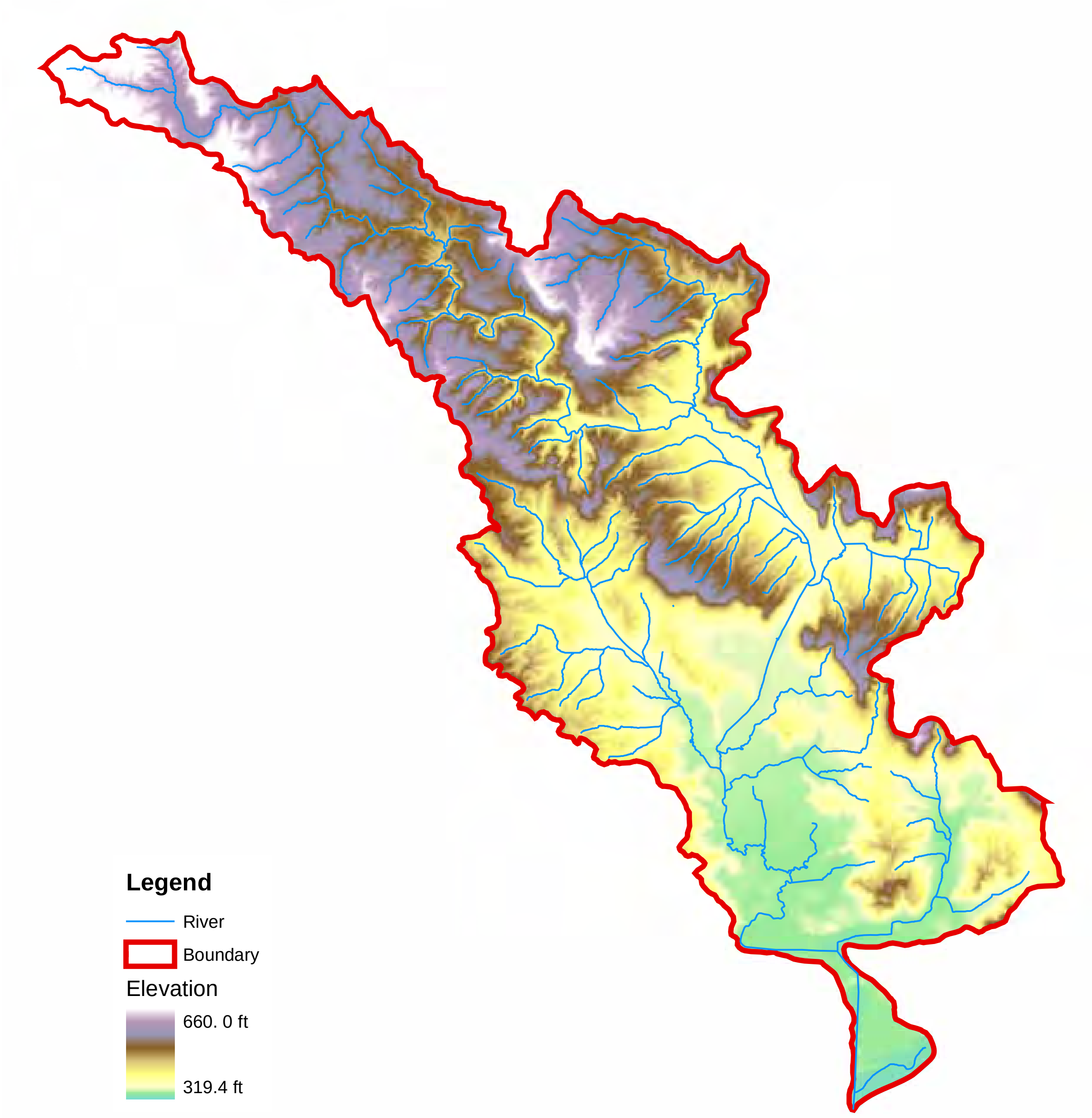


Figure 3-4. DEM and stream network data, Cypress Creek watershed

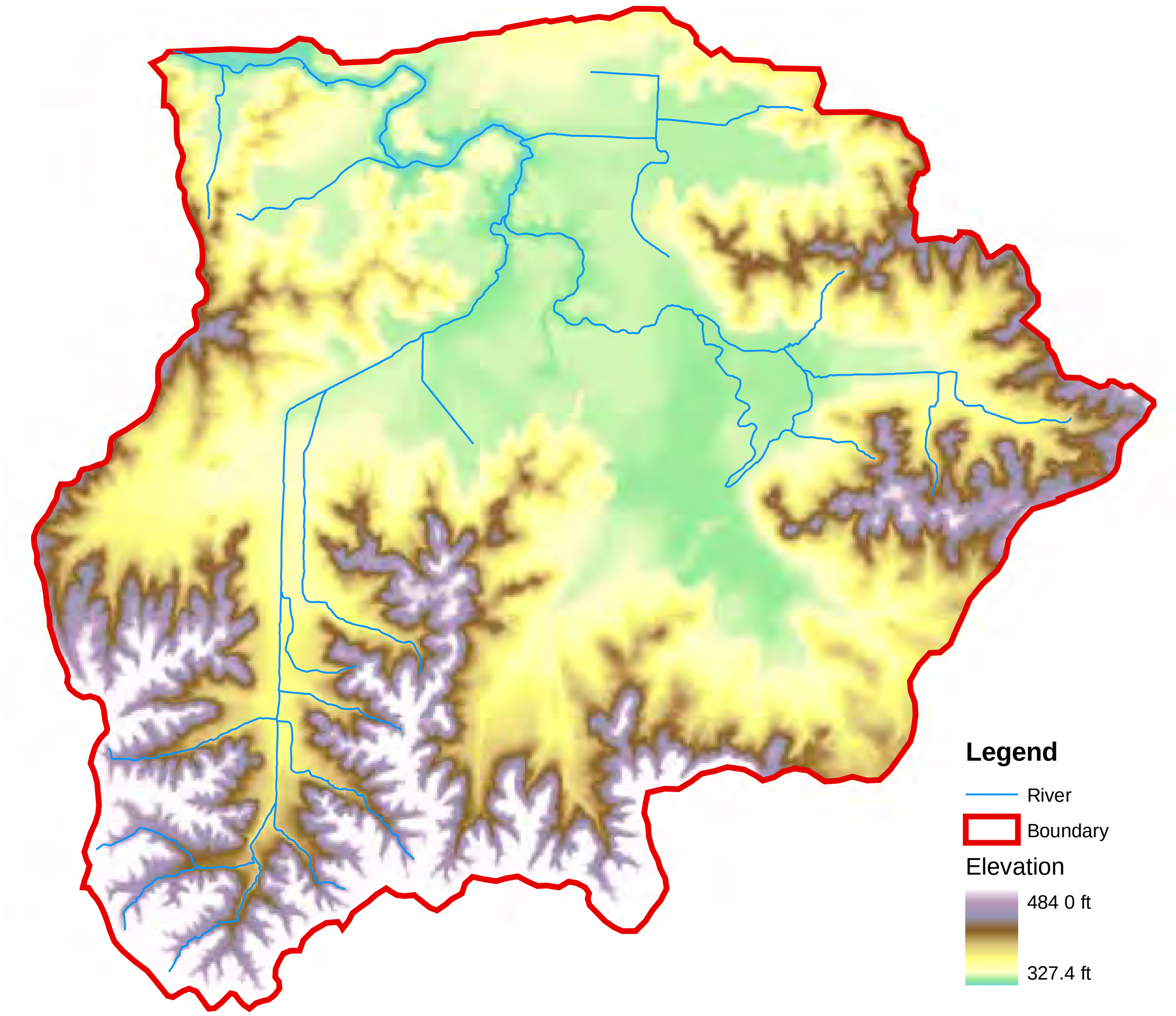


Figure 3-5. DEM and stream network data, Limekiln Slough watershed

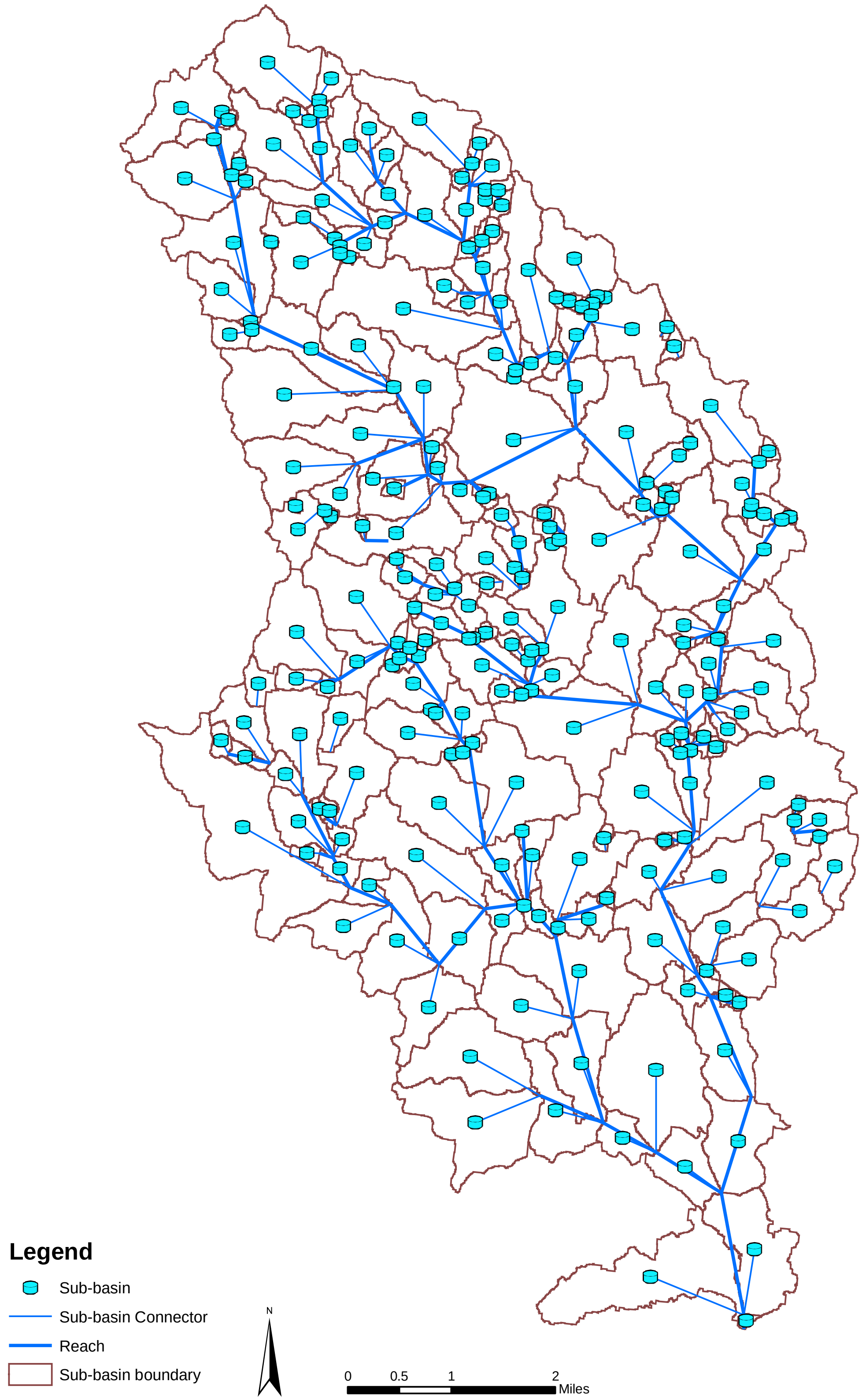


Figure 3-6. Sub-basins and flow connections used in HEC-HMS model of Big Creek watershed

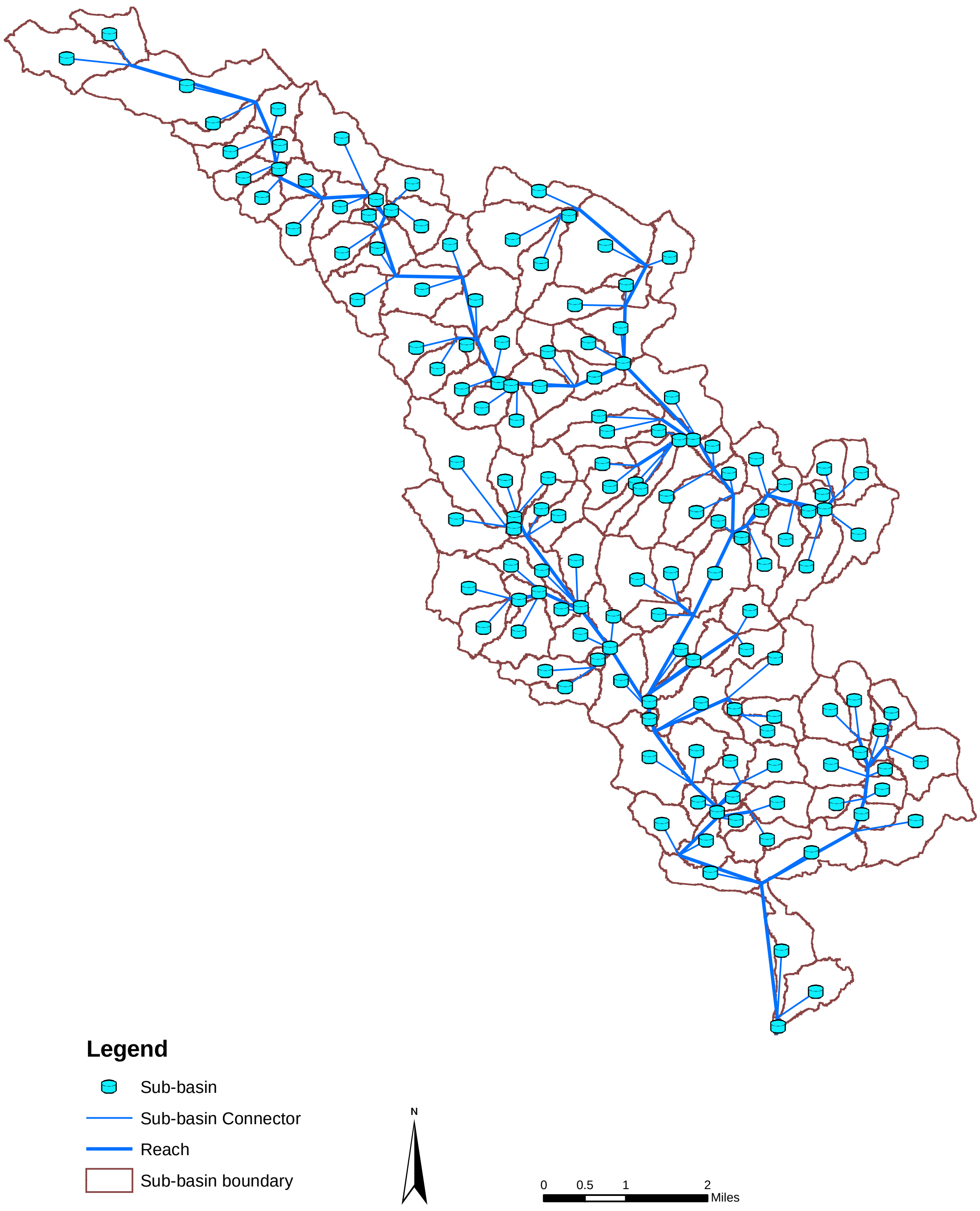


Figure 3-7. Sub-basins and flow connections used in HEC-HMS model of Cypress Creek watershed

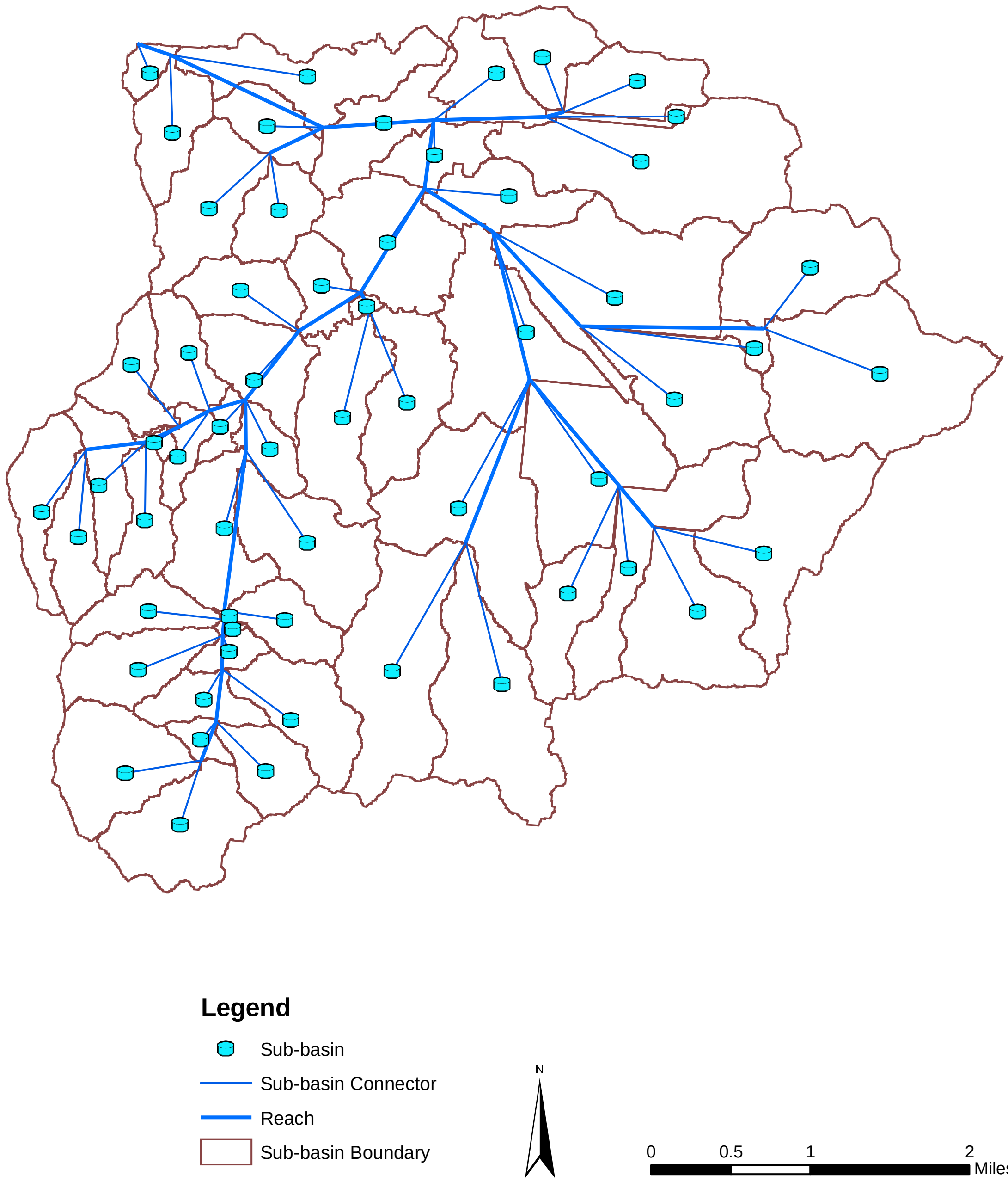


Figure 3-8. Sub-basins and flow connections used in HEC-HMS model of Limekiln Slough watershed

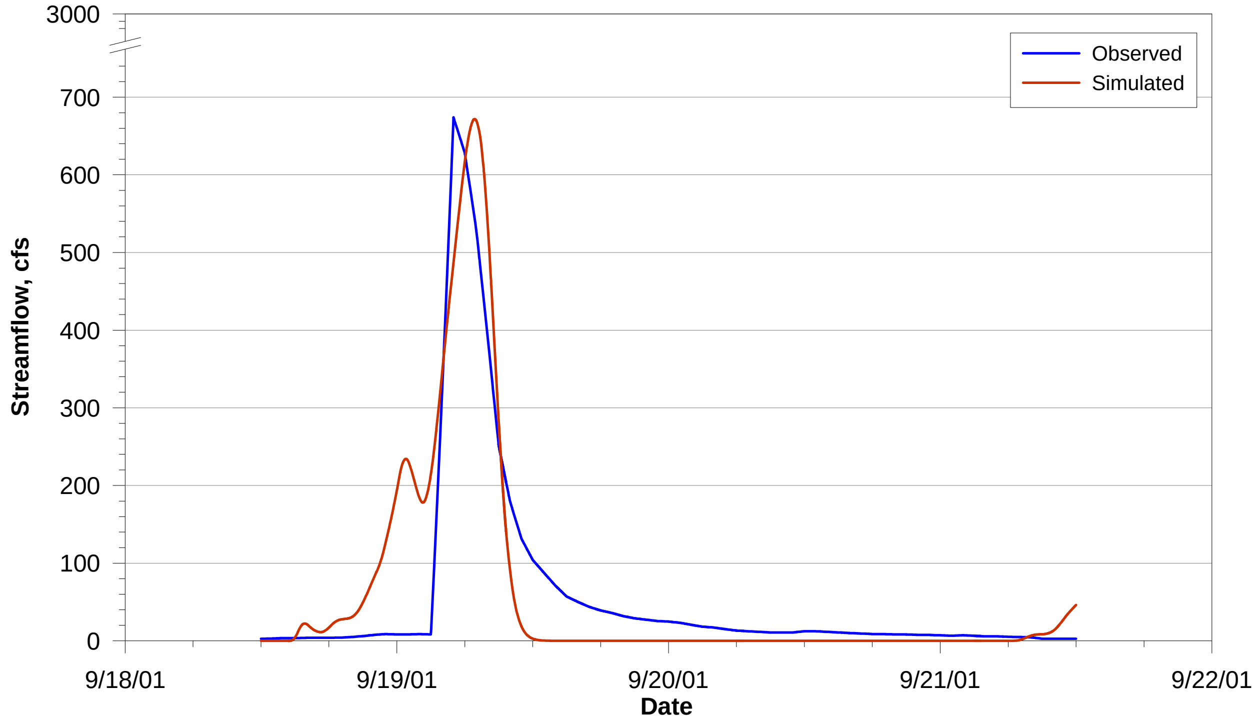


Figure 3-9. Comparison of simulated and observed flows at gaging station 502 of Big Creek for storm event in September 2001 for calibration of HEC-HMS model

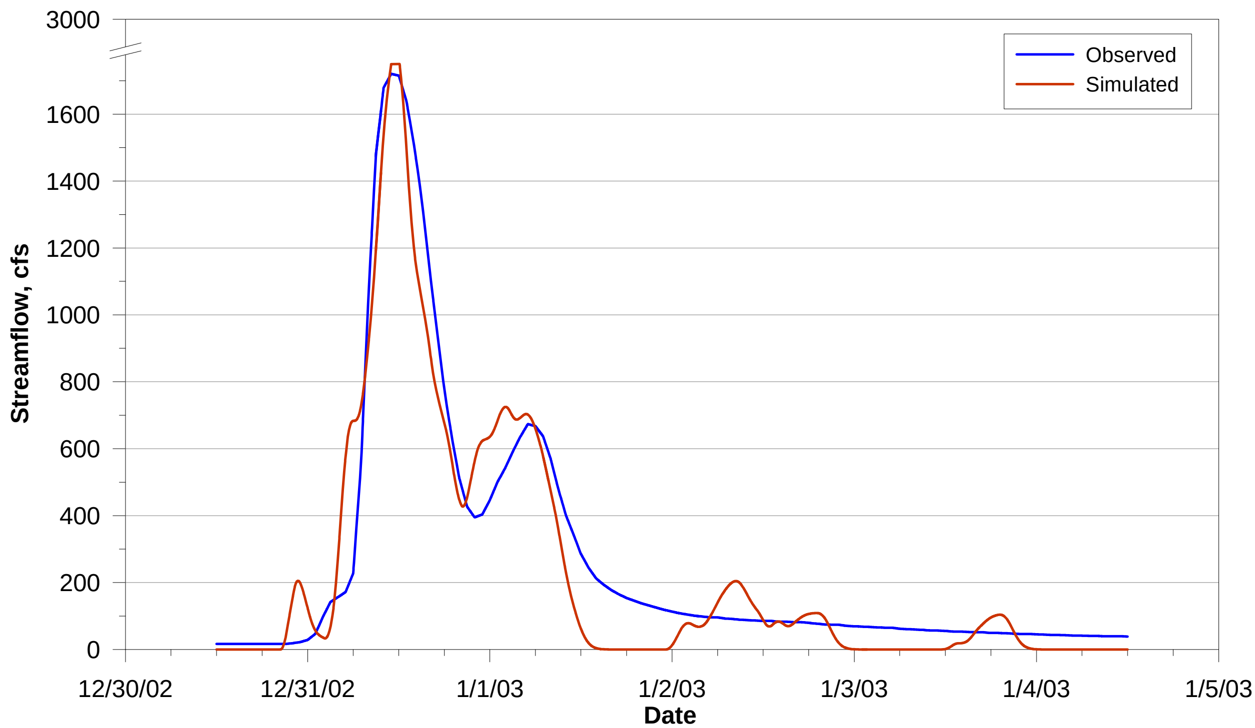


Figure 3-10. Comparison of simulated and observed flows at gaging station 502 of Big Creek for storm event in January 2003 for validation of HEC-HMS model

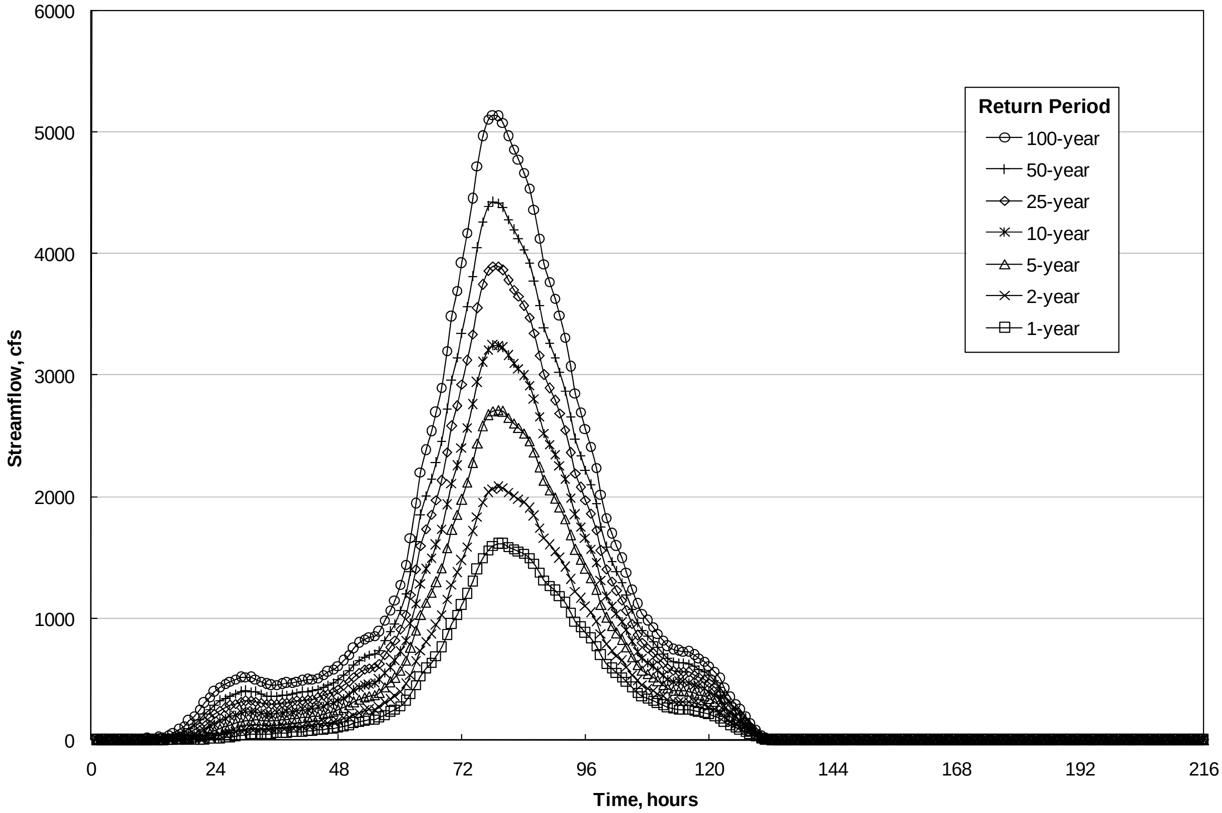


Figure 3-11. Flood hydrographs for Big Creek watershed for storm events of 1-, 2-, 5-, 10-, 25-, 50-, and 100-year return periods and 120-hour duration

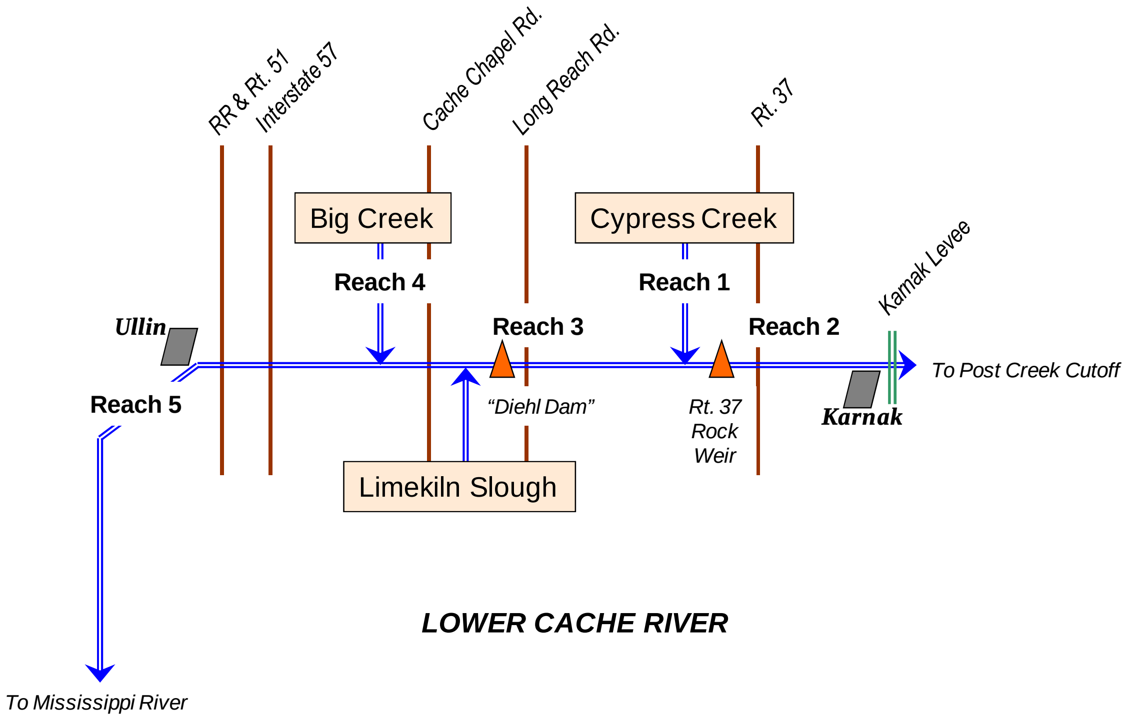


Figure 3-12. Schematic of UNET model for Lower Cache River

Chapter 4. Evaluation of Reference Conditions, Current Conditions, and Alternative Future Scenarios

The main objective of this project was to develop the tools and information necessary to evaluate the current conditions and future alternatives to manage the hydrology of the Lower Cache River so that nationally and internationally significant wetlands can be maintained and restored without increasing flooding potential for private property owners within the Lower Cache River floodplain. The critical step in achieving this objective was development of hydrologic and hydraulic models described in the previous section. The models then were used to evaluate a list of scenarios developed after extensive discussions with the JVP and the Office of Water Resources, IDNR, during the project. A complete list of scenarios is provided in Table 4-1. Scenarios are grouped into four categories: 1) reference/base condition (prior to the Karnak Levee breach); 2) current condition (with the Karnak Levee breach); 3) future alternatives; and 4) future alternatives with reconnection of the Lower Cache River with the Upper Cache River.

Reference/Base Condition

The reference/base condition refers to the condition when the hydrology of the Lower Cache River was controlled on the east end by Karnak Levee with two 48-inch gated culverts that prevented flow from Post Creek Cutoff into the Lower Cache River and by in-channel structures at Route 37 and “Diehl Dam” west of Long Reach Road. All these control structures are shown on the map in Appendix A-3 and on the schematic in Figure 3-12. This condition is used as a reference for comparison with various scenarios because it had been in existence for many years and agreed to by the Big Creek drainage district and State of Illinois as the acceptable drainage and water level management in the Lower Cache River. Eight different combinations of flooding scenarios were evaluated: 1A) 100-year flood in the Lower Cache River and 10-year flood conditions in the Mississippi, Upper Cache, and Ohio Rivers (this is the standard protocol required by the Federal Emergency Management Agency (FEMA) for floodplain mapping for the Lower Cache River); 1B) 100-year flood in the Lower Cache River and 2-year flood conditions in the Mississippi, Upper Cache, and Ohio Rivers (this represents conditions only with a major flood in the Lower Cache River but no major flooding in all other rivers); 1C) 100-year flood in the Lower and Upper Cache Rivers and 2-year flood conditions in the Mississippi and Ohio Rivers; 1D) 100-year floods in all rivers (this is rare but still possible and represents one of the worst possible flooding conditions); 1E) 100-year flood in the Lower and Upper Cache Rivers and 10-year flood in the Mississippi and Ohio Rivers (this is also highly probable as major storm events in the region would cover both the Upper and Lower Cache River watersheds); 1F) 100-year flood in the Upper Cache River and 2-year flood in other rivers (this scenario evaluates the impact of flooding from the Upper Cache River in the Lower Cache River); 1G) 100-year flood in the Upper Cache and Ohio Rivers and 2-year flood in the Lower Cache and Mississippi Rivers (this scenario represents the impact of 100-year floods on the Lower Cache from the Upper Cache and Ohio Rivers happening together); 1H) 100-year flood in the Ohio River only with a 2-year flood for other rivers (this scenario represents the impact of a major flood in the Ohio River on the Lower Cache River). The 100-year flood profiles in the Lower Cache River were computed and mapped for all eight reference conditions for comparison with flood profiles for similar conditions under current conditions and future alternatives.

Table 4-1. Different Scenarios Evaluated for Cache River Using Hydrologic and Hydraulic Models

Scenarios	*"Diehl Dam"/ West Rock Weir*	*Long Reach dredging*	*Rt. 37 Rock Weir*	*Condition at Karnak Levee*	*Opening size at East Outlet Structure*	*Flood conditions in major rivers (return period, years)*			
						Mississippi	*Lower Cache*	*Upper Cache*	*Ohio*
1. Reference/base condition (prior to levee breach)									
A. 100-year flood (Lower Cache); 10-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	10	100	10	10
B. 100-year flood (Lower Cache); 2-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	2	100	2	2
C. 100-year flood (Lower and Upper Cache); 2-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	2	100	100	2
D. 100-year flood for all rivers	Yes		Yes	No breach	2 x 48 in	100	100	100	100
E. 100-year flood (Lower and Upper Cache); 10-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	10	100	100	10
F. 100-year flood (Upper Cache); 2-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	2	2	100	2
G. 100-year flood (Upper Cache and Ohio); 2-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	2	2	100	100
H. 100-year flood (Ohio); 2-year flood (other rivers)	Yes		Yes	No breach	2 x 48 in	2	2	2	100
2. Current condition (with levee breach)									
A. 100-year flood (all rivers)	Yes	Yes	Yes	Breach	Breach	100	100	100	100
B. 100-year flood (Lower Cache); 10-year flood (other rivers)	Yes	Yes	Yes	Breach	Breach	10	100	10	10
C. 100-year flood (Lower Cache); 2-year flood for other rivers)	Yes	Yes	Yes	Breach	Breach	2	100	2	2
D. 100-year flood (Lower and Upper Cache); 10-year flood (other rivers)	Yes	Yes	Yes	Breach	Breach	10	100	100	10
E. 100-year flood (Upper Cache); 2-year flood (other rivers)	Yes	Yes	Yes	Breach	Breach	2	2	100	2
F. 100-year flood (Upper Cache and Ohio); 2-year flood (other rivers)	Yes	Yes	Yes	Breach	Breach	2	2	100	100
G. 100-year flood (Ohio); 2-year flood (other rivers)	Yes	Yes	Yes	Breach	Breach	2	2	2	100
H. 100-year flood (Lower and Upper Cache); 2-year flood (other rivers)	Yes	Yes	Yes	Breach	Breach	2	100	100	2
3. Future alternatives									
A. West Rock Weir ("Diehl Dam" moved)	2,800 ft west	Yes	Yes	Repair	2 x 48 in	10	100	10	10
B. East Outlet Structure (drop structure without stop logs)	2,800 ft west	Yes	Yes	Repair	3 x 72 in	10	100	10	10
C. East Outlet Structure (drop structure with stop logs @ 330 ft)	2,800 ft west	Yes	Removed	Repair	3 x 72 in	10	100	10	10
D. West Rock Weir ("Diehl Dam" moved)	2,800 ft west	Yes	Yes	Repair	2 x 48 in	2	100	2	2
E. East Outlet Structure (drop structure without stop logs)	2,800 ft west	Yes	Yes	Repair	3 x 72 in	2	100	2	2
F. East Outlet Structure (drop structure with stop logs @ 330 ft)	2,800 ft west	Yes	Removed	Repair	3 x 72 in	2	100	2	2
G. East Outlet Structure (drop structure without stop logs)	2,800 ft west	Yes	Yes	Breach	Breach	2	100	2	2
H. Impacts of "Diehl Dam" at 328.4 ft	Yes	Yes	Yes	Breach	Breach	2	1-100	2	2
I. Impacts of West Rock Weir at 328.4 ft	2,800 ft west	Yes	Yes	Breach	Breach	2	1-100	2	2
4. Future alternatives with reconnection (Diversion of 200, 400, 800 cfs)									
A. Reference/base conditions and diversion	Yes		Yes	No breach	2 x 48 in	2	1-100	2	2
B. Current conditions and diversion	Yes	Yes	Yes	Breach	Breach	2	1-100	2	2
C. Future alternatives and diversion (drop structure with stop logs)	2,800 ft west	Yes	Removed	No breach	3 x 72 in	2	1-100	2	2
D. Future alternatives and diversion (drop structure with stop logs)	2,800 ft west	Yes	Removed	No breach	3 x 72 in	10	1-100	10	10

Current Condition

The current condition refers to conditions as they are now where a major change from the reference/base condition is the breach at Karnak Levee and the absence of the two 48-inch culverts. This condition allows floodwaters from Post Creek Cutoff to flow into the Lower Cache River. Both “Diehl Dam” and Route 37 Rock Weir are assumed to be in place. Under this current condition, eight different combinations of flooding and boundary conditions were considered and evaluated, including scenario 2A, one of the worst case scenarios with all major rivers at 100-year flood conditions, a rare but possible condition. Even higher floods are possible in the area if floods with a return period greater than 100 years occur in one of the rivers.

The 100-year flood profiles in the Lower Cache River and corresponding flood boundaries for the area for scenario 2A are compared with reference condition 1D in Figures 4-1 and 4-2. As shown in Figure 4-1, the flood profile for scenario 2A is consistently higher than reference condition 1D except for the area near the junction with the Mississippi River. Scenario 2A floods about 19,949 acres compared to 15,611 acres for reference condition 1D (Table 4-2). A total of 4,338 more acres of private and conservation lands are flooded under scenario 2A than under reference condition 1A.

Scenario 2B represents a 100-year flood in the Lower Cache River and a 10-year flood for other rivers, similar to reference condition 1A. The 100-year flood profiles in the Lower Cache River and corresponding flood boundaries for the area for scenario 2B are compared to reference condition 1A in Figures 4-3 and 4-4. As shown in Figure 4-3, flood profiles for current condition 2B are slightly lower than for reference condition 1A for the middle segment of the Lower Cache River and significantly lower for the eastern end, east of Karnak Road Bridge, and about the same for the western part of the Lower Cache River. A total of 11,620 acres of land are flooded under this scenario compared to 12,370 acres for reference condition 1A (Table 4-2). In this case, 750 fewer acres, mostly in the eastern part of the area, are flooded than under reference condition 1A.

Scenario 2C represents a 100-year flood in the Lower Cache River and 2-year flood conditions for the other rivers similar to reference condition 1B. The 100-year flood profiles in the Lower Cache River and corresponding flood boundaries for the area for scenario 2C are compared to reference condition 1B in Figures 4-5 and 4-6. As shown in Figure 4-5, flood profiles for scenario 2C are slightly lower than for reference condition 1B for the middle segment of the Lower Cache River and significantly lower for the eastern end, east of Karnak Road Bridge, and about the same for the western part of the Lower Cache River. A total of 10,477 acres of land are flooded under this scenario compared to 11,693 acres of land flooded than under reference condition 1B (Table 4-2).

Scenario 2D represents a 100-year flood in the Lower and Upper Cache Rivers and 10-year flood conditions in the Mississippi and Ohio Rivers, similar to reference condition 1E. The 100-year flood profiles for the Lower Cache River and corresponding flood boundaries for the area for scenario 2D are compared to reference condition 1E in Figures 4-7 and 4-8. As shown in Figure 4-7, flood profiles for scenario 2D are consistently higher than for reference condition 1E. A total of 16,245 acres of land are flooded under scenario 2D compared to 14,588 acres flooded for reference condition 1E (Table 4-2). Approximately 1,657 more acres of land are flooded under scenario 2D than under reference condition 1E.

The next three scenarios represent a 100-year flood in the Upper Cache and/or the Ohio Rivers and 2-year floods in the Lower Cache and Mississippi Rivers. Comparison of the scenarios and their corresponding reference conditions illustrates the effects of the levee breach on flooding in the Lower Cache River area induced by backwater from the Upper Cache and the Ohio Rivers even with no major flood in the Lower Cache River.

Scenario 2E represents flooding conditions in the Lower Cache River when only the Upper Cache River is at 100-year flood conditions. The Lower Cache, Mississippi, and Ohio Rivers are under 2-year flood conditions. The flood profile for scenario 2E is compared to the profile for reference condition 1F in Figure 4-9, and the corresponding flood boundaries are shown in Figure 4-10. As shown in Figure 4-9, flood elevations for scenario 2E are consistently higher than the 100-year flood elevation for reference condition 1F except for the reach near the junction with the Mississippi River. A total of 12,083 acres of land are flooded under scenario 2E compared to 9,303 acres for reference condition 1F. Approximately 2,780 more acres of land are flooded under scenario 2E than under reference condition 1F, as shown in Figure 4-10.

Scenario 2F represents flooding conditions in the Lower Cache River when the Upper Cache and Ohio Rivers are at 100-year flood conditions and the Lower Cache and Mississippi Rivers are at 2-year flood conditions. The flood profile for scenario 2F is compared to the profile for reference condition 1G in Figure 4-11, and corresponding flood boundaries are shown in Figure 4-12. As shown in Figure 4-11, flood elevations for scenario 2F are significantly higher than those for reference condition 1G throughout the Lower Cache River except for the reach close to the junction with the Mississippi River. The effect of the levee breach is significantly higher in the eastern part of the Lower Cache River because the constrictions at the Karnak Road and Tunnel Hill State Trail bridges act as dams preventing more flooding to the west. A total of 13,503 acres of land are flooded under scenario 2F compared to 9,440 acres for reference condition 1G. Approximately 4,063 more acres of land are flooded under scenario 2F than under reference condition 1G, as shown in Figure 4-12.

Scenario 2G represents flooding conditions in the Lower Cache River when only the Ohio River is at 100-year flood conditions. The Mississippi, Lower Cache, and Upper Cache Rivers are at 2-year flood conditions. The flood profile for scenario 2G is compared to the profile for reference condition 1H in Figure 4-13, and corresponding flood boundaries are shown in Figure 4-14. As shown in Figure 4-13, the flood elevations for scenario 2G are slightly higher than those for reference condition 1H for most of the area except for the reach east of Karnak Road Bridge where it is slightly lower. A total of 8,115 acres of land are flooded under scenario 2G compared to 7,686 acres for reference condition 1H. Approximately 429 more acres of land are flooded under scenario 2G than under reference condition 1H, as shown in Figure 4-14.

Future Alternatives

Future alternatives refer to water level management scenarios under consideration by the JVP. The two main features that are integral to these scenarios include:

1) Replacing “Diehl Dam” (Figure 4-15) with another rock weir that would be known as West Rock Weir. The “Diehl Dam” is a rock weir located on private land that maintains low water levels in the Lower Cache Wetlands. West Rock Weir will be located approximately 2,800 feet to the west of “Diehl Dam” and within the Cypress Creek National Wildlife Refuge managed by the U.S. Fish and Wildlife Service. West Rock Weir will be an in-channel rock weir similar to “Diehl Dam” (as shown in Figure 4-16) with the top elevation to be selected based on water depth requirements of the Cache River wetlands east of the structure. The top elevation for “Diehl Dam” was set at 328.4 feet above mean sea level. Moving the weir from its current location to the proposed location on public land would transfer the responsibility of operation and maintenance from a private land owner to the U.S. Fish and Wildlife Service.

2) Installation of an East Outlet Structure at the Karnak Levee breach. The East Outlet Structure would maintain low water elevations at desirable levels for the wetlands, allow increased outflow to Post Creek Cutoff during flood events, and prevent backflow from Post Creek Cutoff into the Lower Cache River. The East Outlet Structure is assumed to include a box-type stop log drop structure in front of three or four 72-inch culverts with flap-gates that will be installed through Karnak Levee, as shown in the conceptual illustration in Figure 4-17. The structure will be designed to allow placement of stop logs up to desired elevations to maintain low water levels in the Cache River wetlands. Flap gates on the east side of the culverts would prevent floodwaters from the Upper Cache and the Ohio Rivers from backing into the Lower Cache River.

After considering different future scenarios, the results of five scenarios considered feasible (3C, 3F, 3H, 3I, and 4C) are discussed and included in the report.

Scenario 3C represents flooding conditions in the Lower Cache River under similar conditions as for reference condition 1A, with the Lower Cache River at 100-year flood conditions and the other rivers at 10-year flood conditions. For scenario 3C, it is assumed that “Diehl Dam” will move west, the Karnak Levee will be repaired, and the East Outlet Structure with stop logs at top elevation of 330 feet will be built in front of three 72-inch culverts with flap gates at Karnak Levee. The 100-year flood profile and corresponding flood boundaries are compared to those of reference condition 1A in Figures 4-18 and 4-19. As shown in Figure 4-18, the flood profile for scenario 3C is slightly below that of reference condition 1A throughout the Lower Cache River. The difference is higher east of Karnak Road Bridge. The total area flooded under scenario 3C is 12,070 acres as compared to 12,370 acres for reference condition 1A (Table 4-2). Scenario 3C floods 300 less acres than reference condition 1A, and most of the area not flooded is located east of Karnak Road.

Scenario 3F represents flooding conditions in the Lower Cache River under similar conditions as for reference condition 1B, with the Lower Cache River under 100-year flood conditions and the rest of the rivers under 2-year flood conditions. The same assumptions made for scenario 3C about “Diehl Dam” and the East Outlet Structure also are made for scenario 3F. The 100-year flood profile and corresponding flood boundaries are compared to those of reference condition 1B in Figures 4-20 and 4-21, respectively. As shown in Figure 4-20, flood profiles are almost identical except on the eastern end where the profile for scenario 3F is lower than for reference condition 1B. The total area flooded under scenario 3F is 11,364 acres as compared to 11,693 acres for reference condition 1B (Table 4-2). Scenario 3F floods 275 less acres than reference condition 1B. Most of the area not flooded under scenario 3F is located east of Karnak Road.

Two scenarios (3H and 3I) were developed to investigate the impact of moving "Diehl Dam" approximately 2,800 feet west from its current location under present conditions with the levee breach. Scenario 3H represents flooding conditions in the Lower Cache River for 1- to 100-year flood events in the Lower Cache River and 2-year flood events for all other rivers, with "Diehl Dam" at its present location. Scenario 3I represents the same conditions as 3H, but "Diehl Dam" is assumed to be replaced by the West Rock Weir with a top elevation of 328.4 feet and 2,800 feet west of its current location. The 100-year flood profiles and boundaries under both scenarios are compared in Figures 4-22 and 4-23. As shown in Figure 4-22, both profiles are almost identical with a maximum difference of only 0.02 feet. As a result, areas flooded by both scenarios are very close: 10,477 acres flooded under scenario 3H and 10,485 acres flooded under scenario 3I (Table 4-2). The eight additional acres flooded under scenario 3I (less than 1/10th of a percent of the total area flooded) are distributed in small increments along the fringe of the floodplain. Similar comparisons were made for more frequent floods than a 100-year flood (Figures 4-24 through 4-29), with Figure 4-24 representing a 50-year flood and Figure 4-29 representing a 1-year flood. In all cases, there is no significant difference between the two scenarios. It should however, be recognized that the stream channel between "Diehl Dam" and the proposed West Weir Structure will experience higher water levels than the present condition during low- and moderate-flow conditions in the Lower Cache River.

Acres of land flooded under different scenarios under consideration for this report are summarized in Table 4-2. Flooded acres are divided into private lands and conservation lands so that the information can be used for planning and evaluating alternative restoration measures.

Future Alternatives with Reconnection

Future alternatives with reconnection are similar to future alternatives already discussed, but with the important difference of reconnection of the Lower Cache River with the Upper Cache River diverting water into the Lower Cache River from the Upper Cache River. Only results for scenario 4C are presented in this report. Both scenario 4A, reconnection under the reference condition with levee repair and two 48-inch culverts, and scenario 4B, reconnection under the current condition with levee breach, are very unlikely future alternatives. Scenario 4C assumes that West Rock Weir is 2,800 feet west of "Diehl Dam" and the East Outlet Structure with stop logs will be built in front of three 72-inch gated culverts through Karnak Levee. Three different diversion amounts were considered: 200, 400, and 800 cubic feet per second (cfs). Flooding conditions are the same as in reference/base condition 1B: Lower Cache River at 100-year flood and the other rivers at 2-year floods. Therefore, results of hydraulic modeling for scenario 4C are compared to results from 1B for flooding comparisons. The most important consideration for reconnection, however, is to sustain flow in the Lower Cache River during low-flow conditions. Therefore, the discussion that follows evaluates the impact of reconnection on flooding and on moderate and low flows.

Table 4-2. Acres of Land Flooded by 100-Year Floods in Lower Cache River under Selected Scenarios

Scenario	*Acres flooded* Private	Conservation	Total
Reference/base condition			
1A. 100-year flood (Lower Cache); 10-year flood (other rivers)	5,039	7,331	12,370
1B. 100-year flood (Lower Cache); 2-year flood (other rivers)	4,672	7,021	11,693
1C. 100-year flood (Lower and Upper Cache); 2-year flood (other rivers)	4,961	7,281	12,242
1D. 100-year flood (all rivers)	7,199	8,412	15,611
1E. 100-year flood (Lower and Upper Cache); 10-year flood (other rivers)	6,278	8,310	14,588
1F. 100-year flood (Upper Cache); 2-year flood (other rivers)	3,121	6,182	9,303
1G. 100-year flood (Upper Cache and Ohio); 2-year flood (other rivers)	3,213	6,227	9,440
1H. 100-year flood (Ohio); 2-year flood (other rivers)	2,345	5,341	7,686
Current condition			
2A. 100-year flood (all rivers)	10,530	9,419	19,949
2B. 100-year flood (Lower Cache); 10-year flood (other rivers)	4,822	6,798	11,620
2C. 100-year flood (Lower Cache); 2-year flood (other rivers)	4,435	6,042	10,477
2D. 100-year flood (Lower and Upper Cache); 10-year flood (other rivers)	7,526	8,719	16,245
2E. 100-year flood (Upper Cache); 2-year flood (other rivers)	4,683	7,400	12,083
2F. 100-year flood (Upper Cache and Ohio); 2-year flood (other rivers)	5,354	8,149	13,503
2G. 100-year flood (Ohio); 2-year flood (other rivers)	2,543	5,540	8,115
Future alternatives			
3C. East Outlet Structure (drop structure with stop logs @ 330 ft)	4,898	7,172	12,070
3F. East Outlet Structure (drop structure with stop logs @ 330 ft)	4,633	6,731	11,364
3H. Impacts of “Diehl Dam” at 328.4 ft	4,435	6,042	10,477
3I. Impacts of West Rock Weir at 328.4 ft	4,441	6,044	10,485
Future alternatives with reconnection			
4C-200. Future alternatives and diversion of 200 cfs (drop structure with stop log at 330 ft)	4,701	6,967	11,668
4C-400. Future alternatives and diversion of 400 cfs (drop structure with stop log at 330 ft)	4,745	7,032	11,777
4C-800. Future alternatives and diversion of 800 cfs (drop structure with stop log at 330 ft)	4,848	7,159	12,007

An important consideration in planning for reconnection is the variability of streamflow in the Upper Cache River. The flow duration curve for the Upper Cache River near Forman is shown in Figure 4-30 and data given in Table 4-3. The flow duration curve provides information on the distribution of streamflow by giving estimates of the percent chance that a certain flow amount will be exceeded. To show the range of variability from year to year, three curves are shown in Figure 4-30, one based on the long-term record (1924–2006), one for 1987, a low flow year, and another for 2002, a wet year. For example, the flow expected to be exceeded 50 percent of the time ranges from a low of 25 cfs for a dry year to a high of 99 cfs for a wet year. Similar estimates can be made for different exceedence probabilities using Figure 4-30 and Table 4-3.

Reconnection during Flood Conditions in Lower Cache River

Figures 4-31 and 4-32 compare 100-year flood profiles and corresponding flood boundaries for scenario 4C with 200 cfs diversion (4C-200) from the Upper Cache River reference condition 1B, respectively. As shown in Figure 4-31, flood profiles are almost identical except for the east end where the profile for 4C-200 is lower than for reference condition 1B. The total area flooded under scenario 4C-200 is 11,668 acres as compared to 11,693 acres for reference condition 1B (Figure 4-32 and Table 4-2). Therefore, scenario 4C-200 floods about 25 less acres than reference condition 1B.

Table 4-3. Flow Duration Data for Upper Cache River near Forman

Percent time exceedence probability	*Long-term record (cfs)*	*Dry year, 1987 (cfs)*	*Wet year, 2002 (cfs)*
99	0.1	0.06	0.5
98	0.2	0.16	0.7
95	0.8	0.33	1.1
90	1.9	0.45	2.5
85	3.3	0.74	4.7
80	5.4	1.3	9.8
75	8	2.4	18
70	12	4.2	23
60	26	12	53
50	55	25	99
40	110	42	218
30	220	65	568
25	312	94	796
20	445	124	1050
15	612	181	1400
10	858	259	1830
5	1350	621	2680
2	2110	1060	3640
1	2980	2010	4930

Figures 4-33 and 4-34 compare 100-year flood profiles and corresponding flood boundaries for scenario 4C with 400 cfs diversion (4C-400) from the Upper Cache River and reference condition 1B. As shown in Figure 4-33, the two flood profiles are about the same for the segment from Cache Chapel Road to Karnak Road, and the profile for scenario 4C-400 is less than for reference condition 1B east of Karnak Road and higher west of Cache Chapel Road. The total area flooded under scenario 4C-400 is 11,777 acres as compared to 11,693 acres for reference condition 1B (Figure 4-34 and Table 4-2). Scenario 4C-400 floods about 84 more acres than reference condition 1B.

Figures 4-35 and 4-36 compare 100-year flood profiles and corresponding flood boundaries for scenario 4C with 800 cfs diversion (4C-800) from the Upper Cache River to those of reference condition 1B, respectively. As shown in Figure 4-35, the profile for scenario 4C-800 is slightly higher than that for reference condition 1B for most of the area except for the segment east of Karnak Road where they are about the same. The total area flooded under scenario 4C-800 is 12,007 acres as compared to 11,693 acres for reference condition 1B (Figure 4-36 and Table 4-2). Scenario 4C-800 floods about 314 more acres than reference condition 1B.

Comparison of 50-, 25-, 10-, 5-, 2-, and 1-year flood profiles for future alternatives with reconnection 4C with 200 cfs diversion (4C-200) and reference condition 1B are shown in Figures 4-37 through 4-42, respectively. The figures show the difference between profiles increases as the flood return period decreases from 50-year to 1-year. The diversion has more impact on more frequent floods than on major floods. While scenario 4C-200 floods less area than reference condition 1B for the 100-year flood, it floods more area than the reference condition for the 1-year flood. This is because of two factors: 1) adding 200 cfs during a major flood is less significant than adding the same amount during lesser floods, and 2) the larger culverts at the East Outlet Structure consistently lowered flood elevations on the east end during major floods.

Reconnection during Low and Moderate Flows in Lower Cache River

To evaluate flow directions, profiles, and velocities during low- and moderate-flow conditions in the Lower Cache River under various reconnection scenarios, a combination of elevations at the West Rock Weir and East Outlet Structure were considered. East Outlet Structure elevations of 330.0 and 330.4 feet were combined with West Rock Weir elevations of 328.4, 327.4, and 326.4 feet, as shown in Table 4-4. Flow profiles for the different combination of elevations at the East Outlet Structure and West Rock Weir for 200 cfs diversion are shown in Figures 4-43 through 4-54. The water surface elevation on the east end ranged from a low of 330.1 feet for the combination of 330.0 feet at the East Outlet Structure and 326.4 feet at West Rock Weir. In the central area, elevations ranged from 329.6 to 331.47 feet. Combinations of different elevations at the East Outlet Structure and West Rock Weir also created different splits in flows going west and east. Table 4-4 summarizes results when westerly and easterly flows for different combinations are provided. The main observation from Table 4-4 is for some elevation combinations and diversion amounts, most of the water flows east toward the East Outlet Structure and Post Creek Cutoff. The preferred condition is for most of the water to flow in a westerly direction.

Table 4-4. Flow Directions and Amounts in Lower Cache River for Future Alternatives with Reconnection during Low- and Moderate-Flow Periods

Elevation, East Outlet Structure (feet)	*Elevation, West Rock Weir (feet)*	*200 cfs*		*400 cfs*		*800 cfs*	
		Westerly (cfs)	*Easterly (cfs)*	*Westerly (cfs)*	*Easterly (cfs)*	*Westerly (cfs)*	*Easterly (cfs)*
330.0	328.4	77	121	82	316	354	447
330.0	327.4	174	26	246	153		
330.0	326.4	176	23	246	153	355	444
330.4	328.4	77	122	85	313	403	398
330.4	327.4	196	5	267	132		
330.4	326.4	195	5	268	131	402	398

Figure 4-55 to 4-58 show computed velocity profiles along the Lower Cache River during low- and moderate-flow periods with 200 cfs diversion for different combinations of elevations at the East Outlet Structure and West Rock Weir. One of the impacts of flow diversion into a stream is an increase in flow velocities. While moderate increases in flow velocities are desirable for the river ecosystem, excessive increases could have undesirable consequences such as streambank erosion. For these reasons, the change in flow velocities due to diversion of flow from the Upper Cache to the Lower Cache River were evaluated. Velocities east of West Rock Weir are very low, in most cases less than 0.1 feet per second. Velocities increase west of West Rock Weir, almost reaching 2 feet per second in some cases. It should be recognized that these estimates are based on existing cross-sectional data that are extremely important in modeling low-flow conditions. More accurate estimates require more detailed and current cross-sectional data of the Lower Cache River.

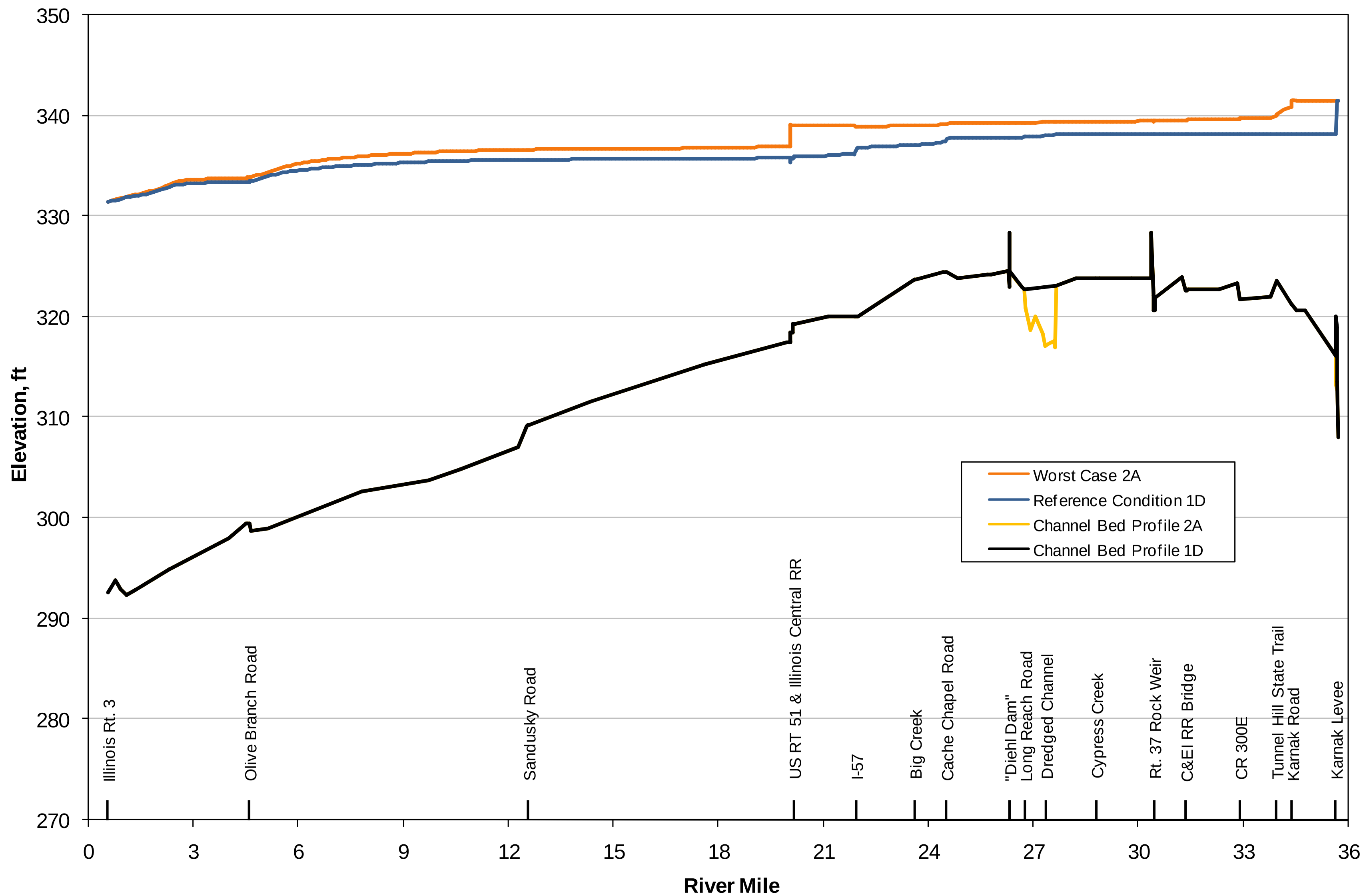
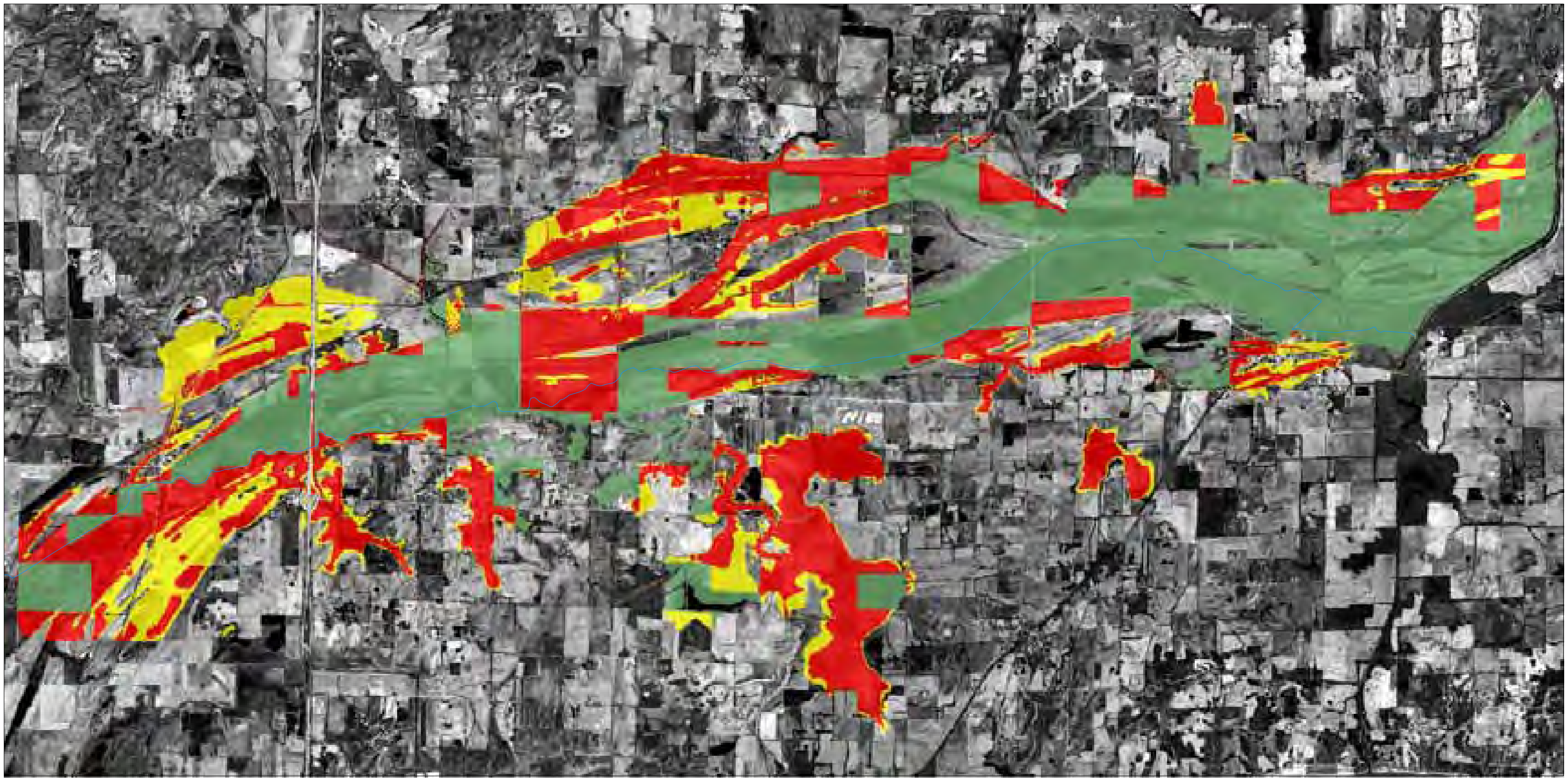


Figure 4-1. 100-year flood profiles for Lower Cache River: comparing current to reference conditions
(all rivers at 100-year flood condition)



Summary

	Flooded Acres	
	Private	Cons.
Reference Condition (**1D**):	7199	8412
Current Condition (**2A**):	10530	9419
Flooded area reduced by:	-0	-0
Flooded area increased by:	+3331	+1007
Net Change:	+3331	+1007

Figure 4-2. 100-year flood boundaries for Lower Cache River: comparing current to reference conditions (all rivers at 100-year flood condition)

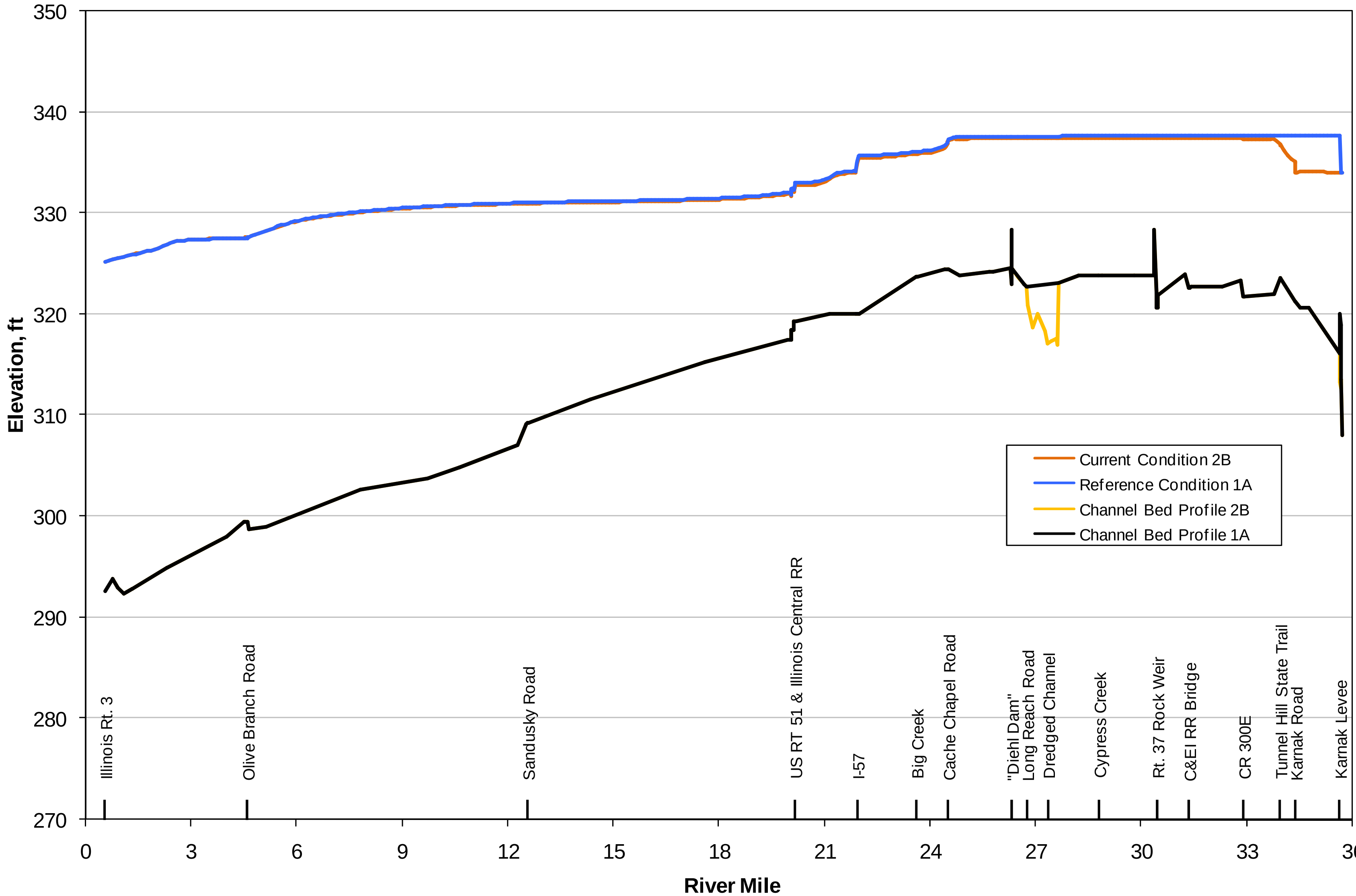
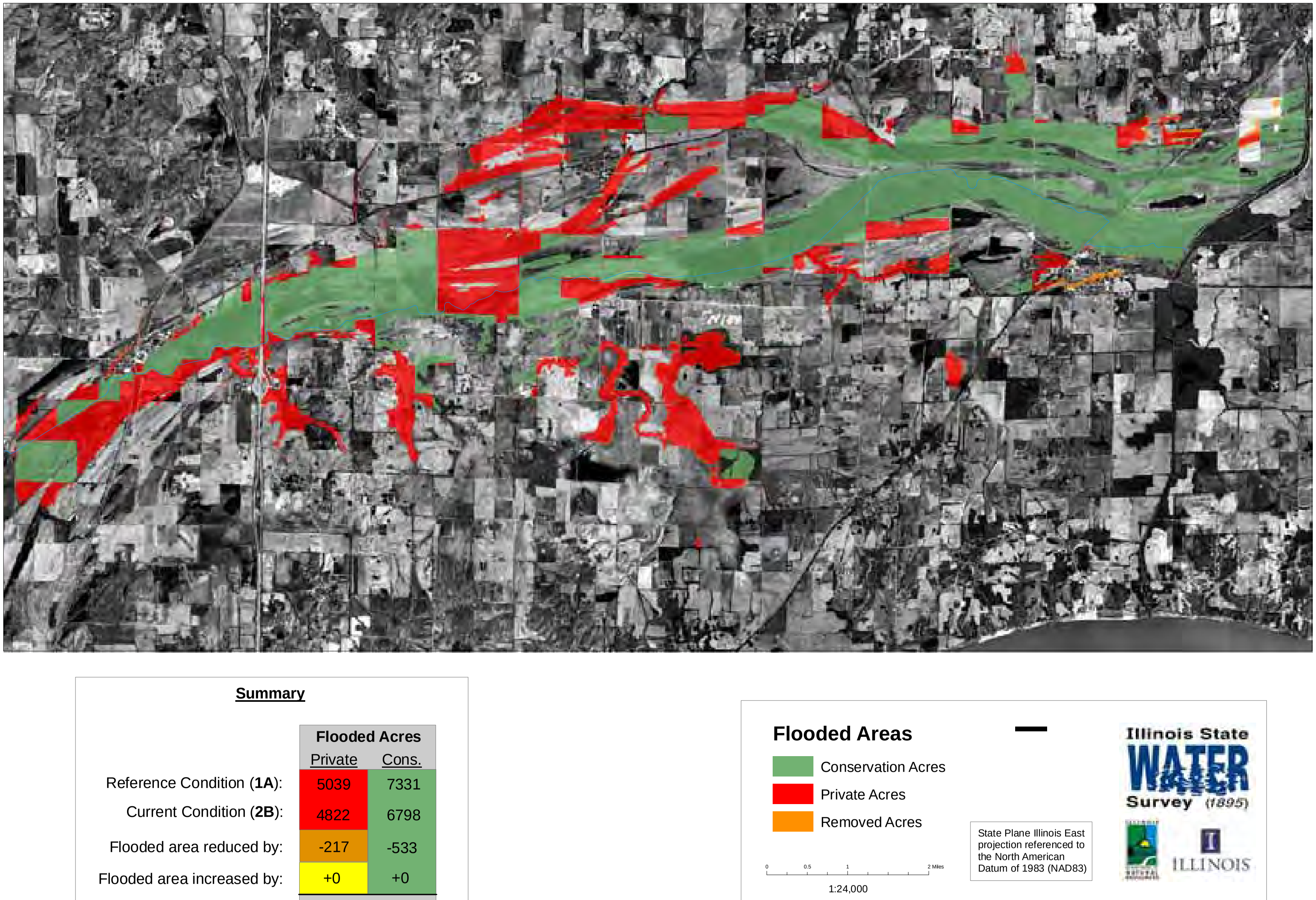


Figure 4-3. 100-year flood profiles for Lower Cache River: comparing current to reference conditions
(Lower Cache at 100-year flood condition; Mississippi, Upper Cache, and Ohio Rivers at 10-year flood condition)



Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1A**):	5039	7331
Current Condition (**2B**):	4822	6798
Flooded area reduced by:	-217	-533
Flooded area increased by:	+0	+0
Net Change:	-217	-533

Figure 4-4. 100-year flood boundaries for Lower Cache River: comparing current to reference conditions (Lower Cache at 100-year flood condition; Mississippi, Upper Cache, and Ohio Rivers at 10-year flood condition)

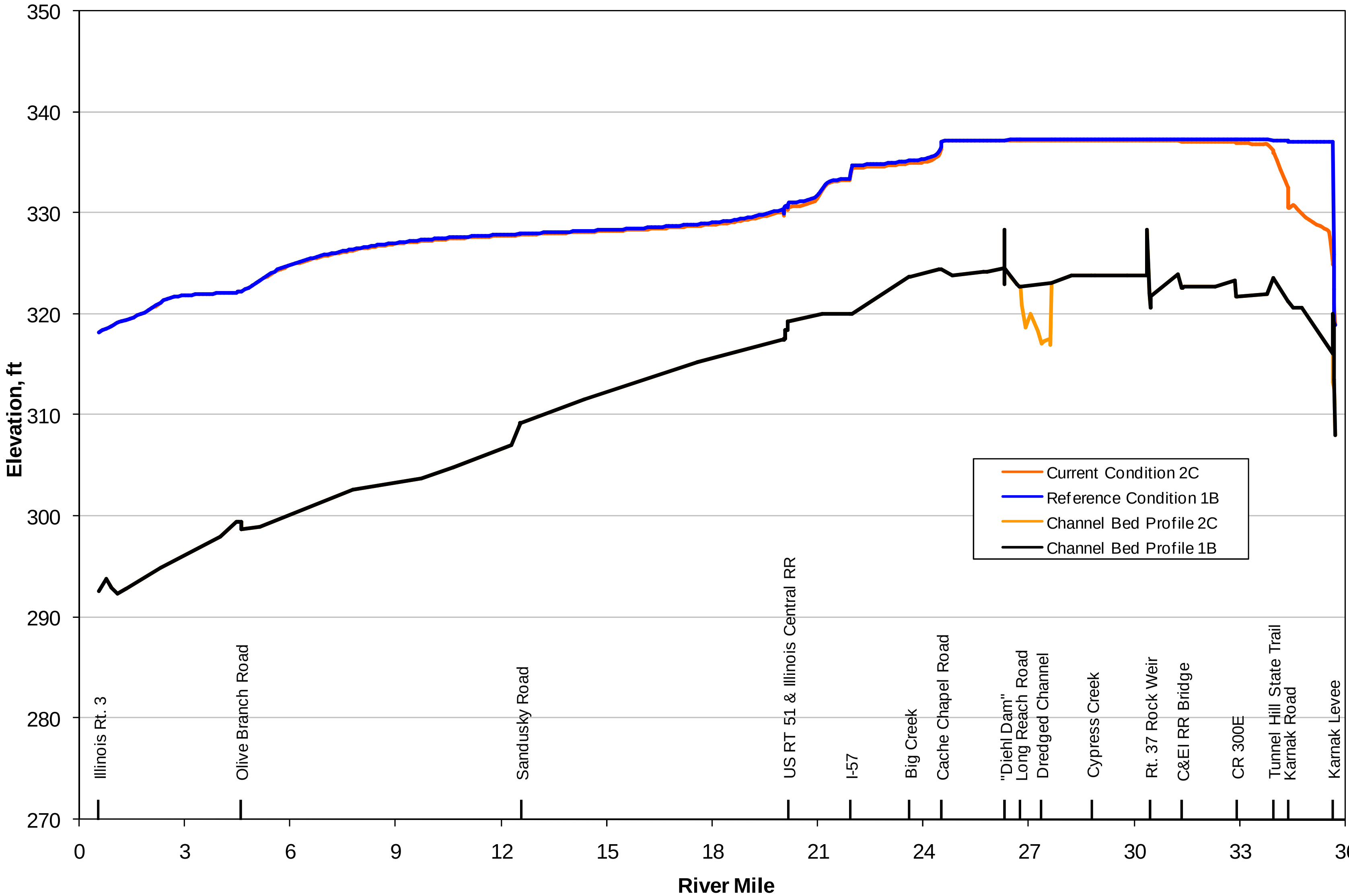


Figure 4-5. 100-year flood profiles for Lower Cache River: comparing current to reference conditions
(Lower Cache at 100-year flood condition; Mississippi, Upper Cache, and Ohio Rivers at 2-year flood condition)

Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1B**):	4672	7021
Current Condition (**2C**):	4435	6042
Flooded area reduced by:	-237	-979
Flooded area increased by:	+0	+0
Net Change:	-237	-980

Flooded Areas

- Conservation Acres
- Private Acres
- Removed Acres

0 0.5 1 2 Miles

1:24,000

State Plane Illinois East projection referenced to the North American Datum of 1983 (NAD83)

Illinois State WATER Survey (1895)

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Figure 4-6. 100-year flood boundaries for Lower Cache River: comparing current to reference conditions (Lower Cache at 100-year flood condition; Mississippi, Upper Cache, and Ohio Rivers at 2-year flood condition)

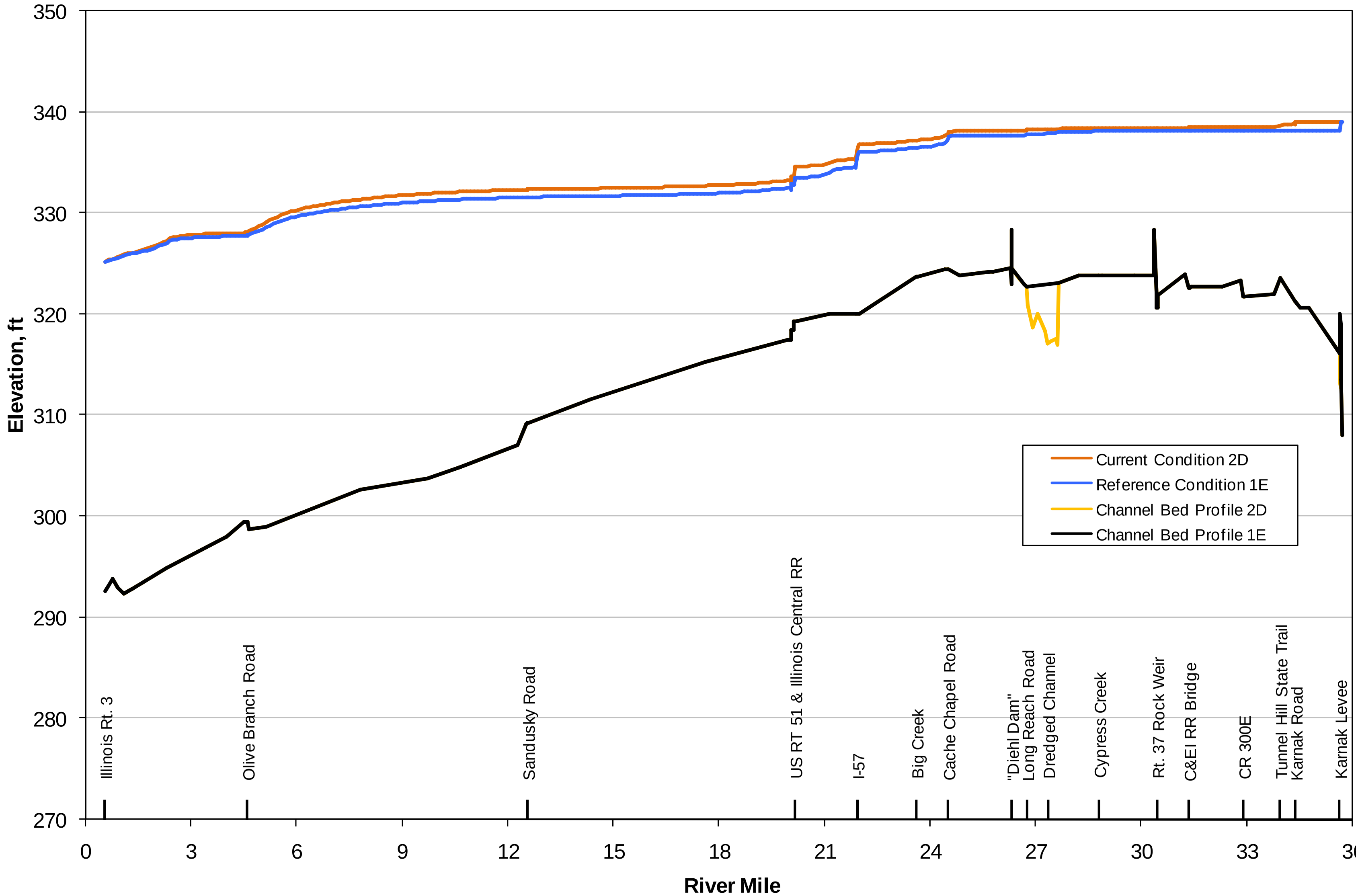
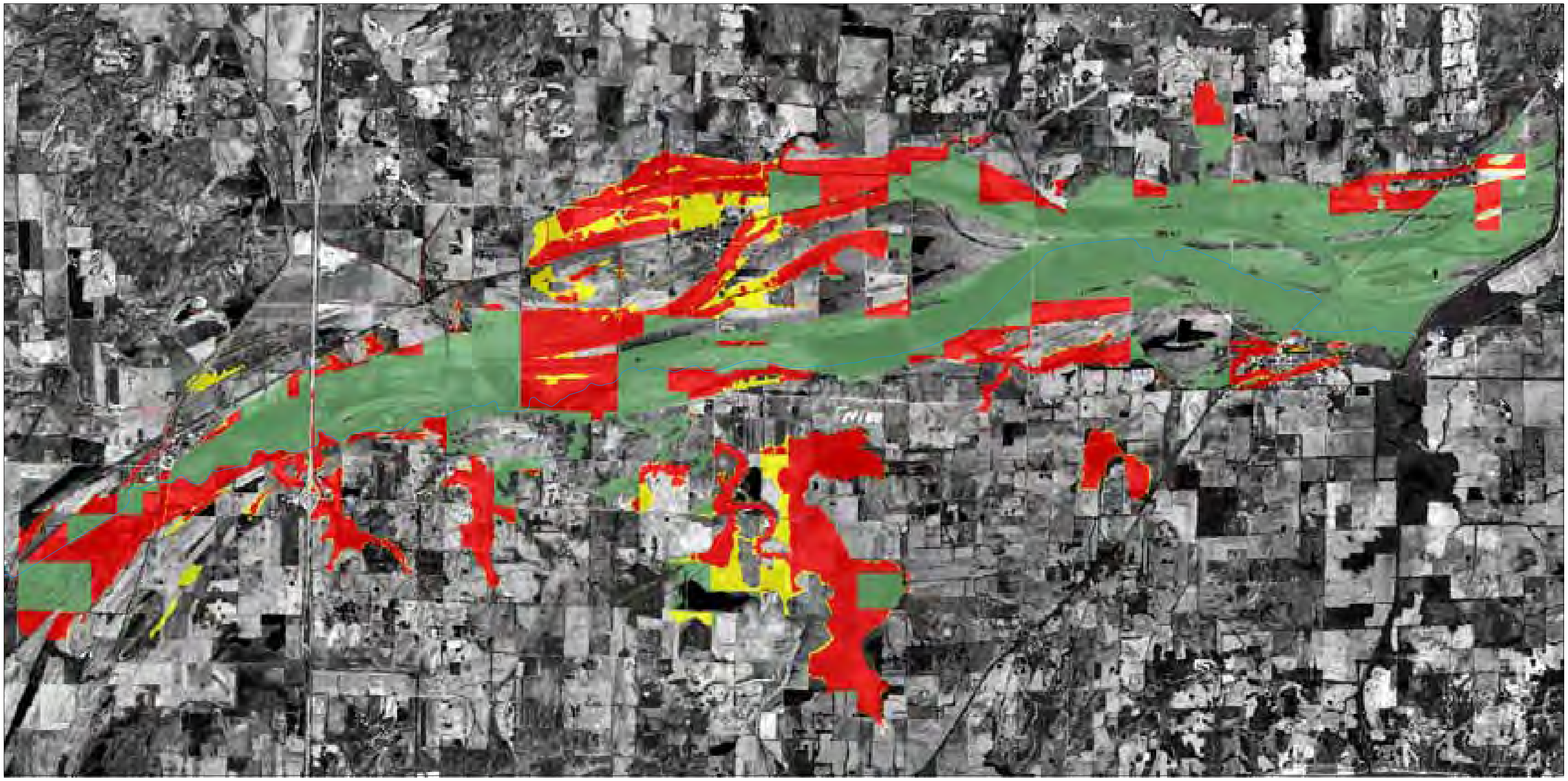


Figure 4-7. 100-year flood profiles for Lower Cache River: comparing current to reference conditions
(Lower and Upper Cache Rivers at 100-year flood condition and Mississippi and Ohio Rivers at 10-year flood condition)



Summary

	Flooded Acres	
	Private	Cons.
Reference Condition (**1E**):	6278	8310
Current Condition (**2D**):	7526	8719
Flooded area reduced by:	-0	-0
Flooded area increased by:	+1248	+409
Net Change:	+1248	+409

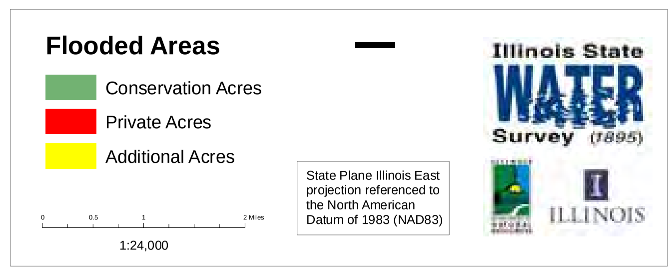


Figure 4-8. 100-year flood boundaries for Lower Cache River: comparing current to reference conditions
(Lower and Upper Cache Rivers at 100-year flood condition and Mississippi and Ohio Rivers at 10-year flood condition)

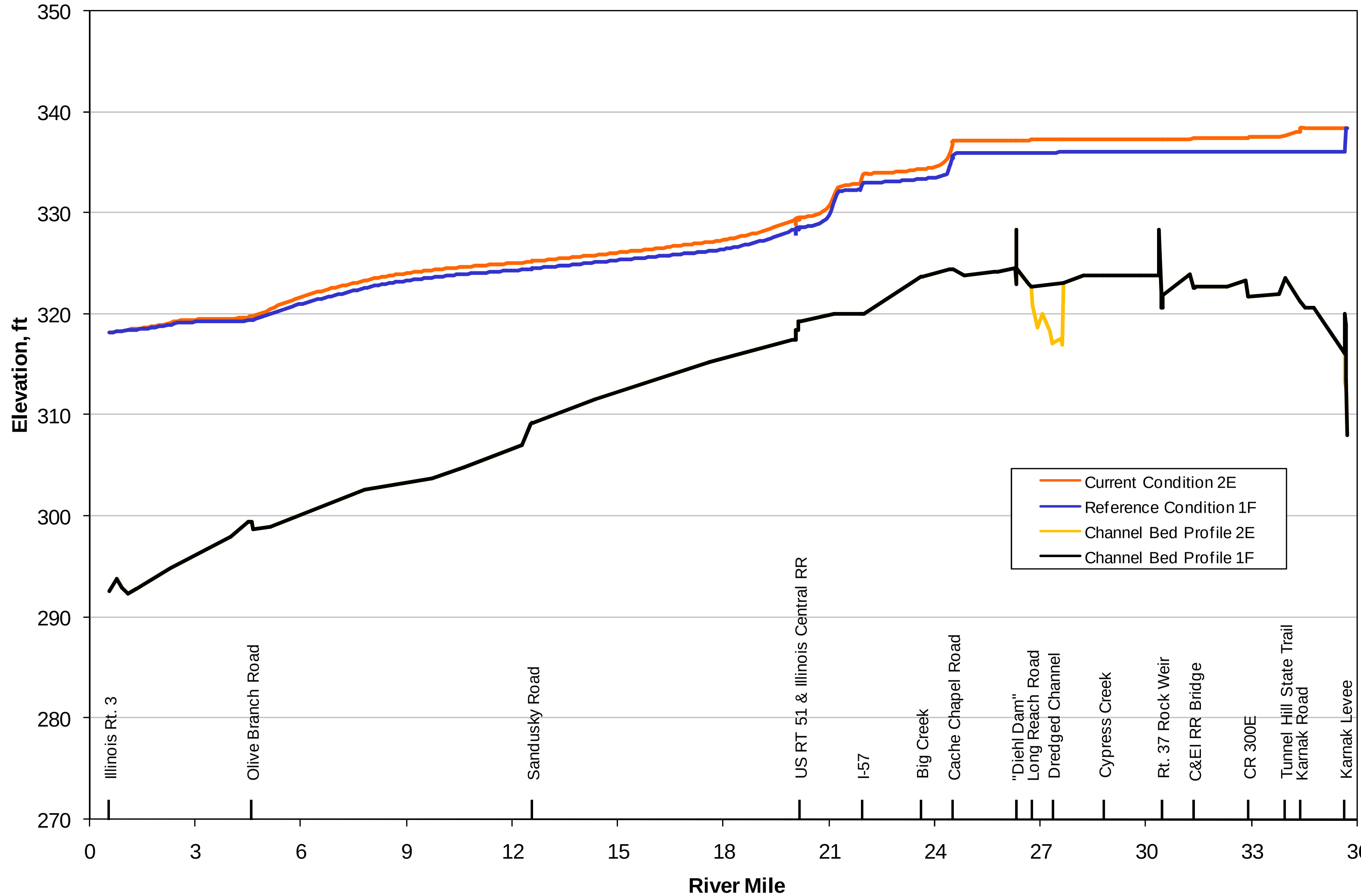
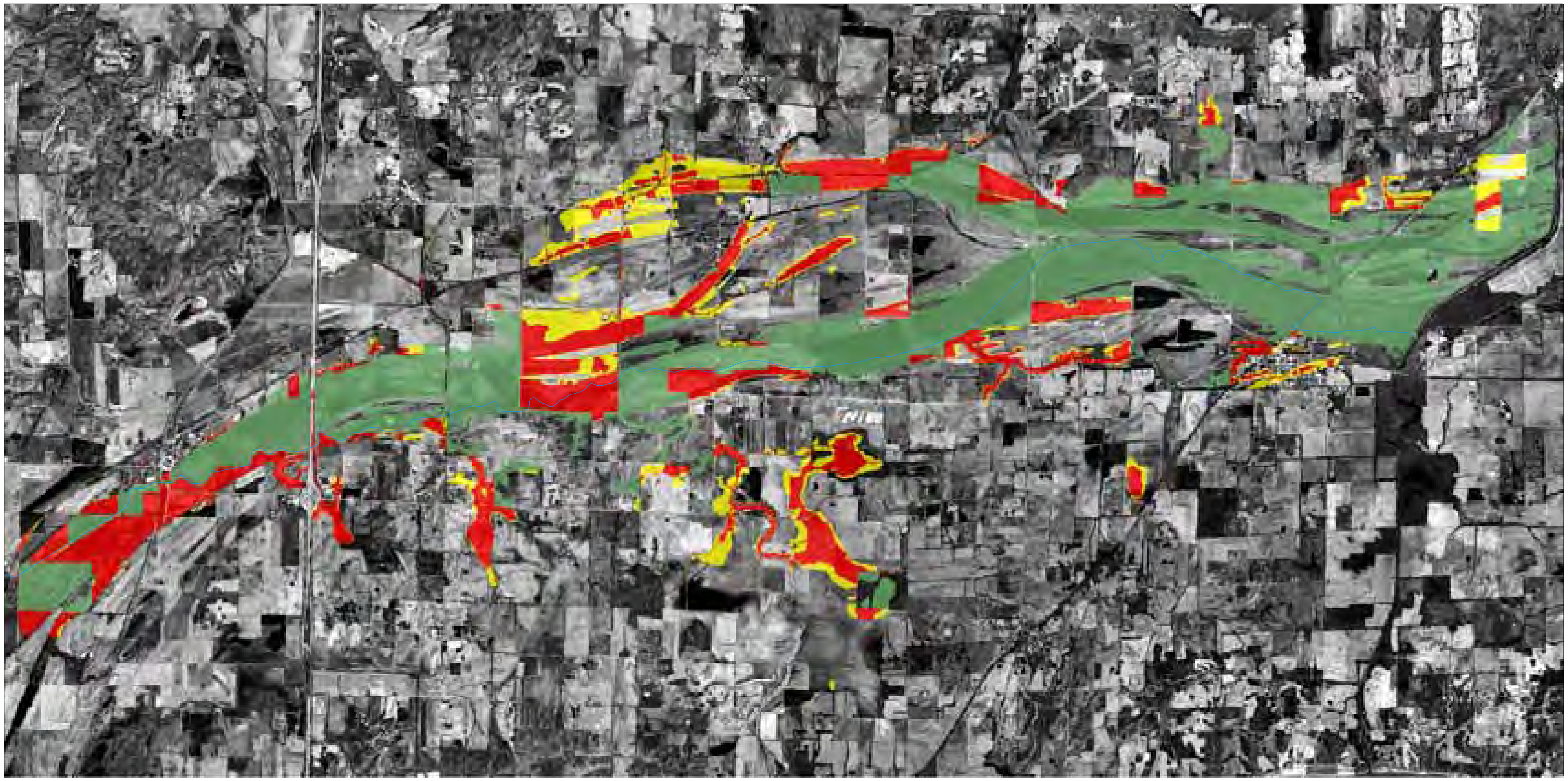


Figure 4-9. Flood profiles in Lower Cache River: comparing current to reference conditions (Upper Cache River at 100-year flood condition and Lower Cache, Mississippi, and Ohio Rivers at 2-year flood condition)



Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1F**):	3121	6182
Current Condition (**2E**):	4683	7400
Flooded area reduced by:	-0	-0
Flooded area increased by:	+1562	+1218
Net Change:	+1562	+1218

Flooded Areas

Conservation Acres

Private Acres

Additional Acres

0 0.5 1 2 Miles

1:24,000

State Plane Illinois East projection referenced to the North American Datum of 1983 (NAD83)

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Figure 4-10. 100-year flood boundaries for Lower Cache River (Upper Cache River at 100-year flood condition and Lower Cache, Mississippi, and Ohio Rivers at 2-year flood condition)

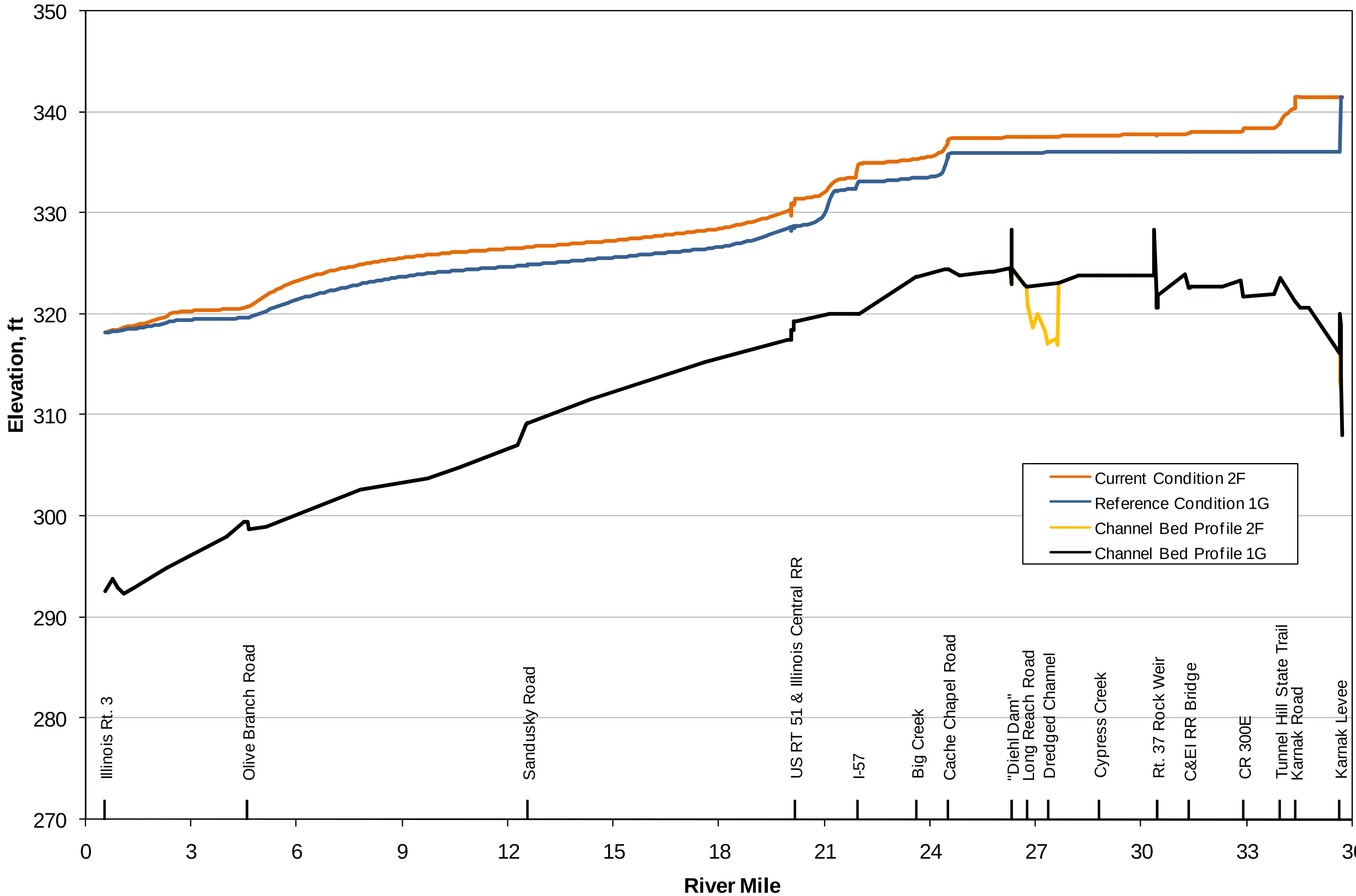
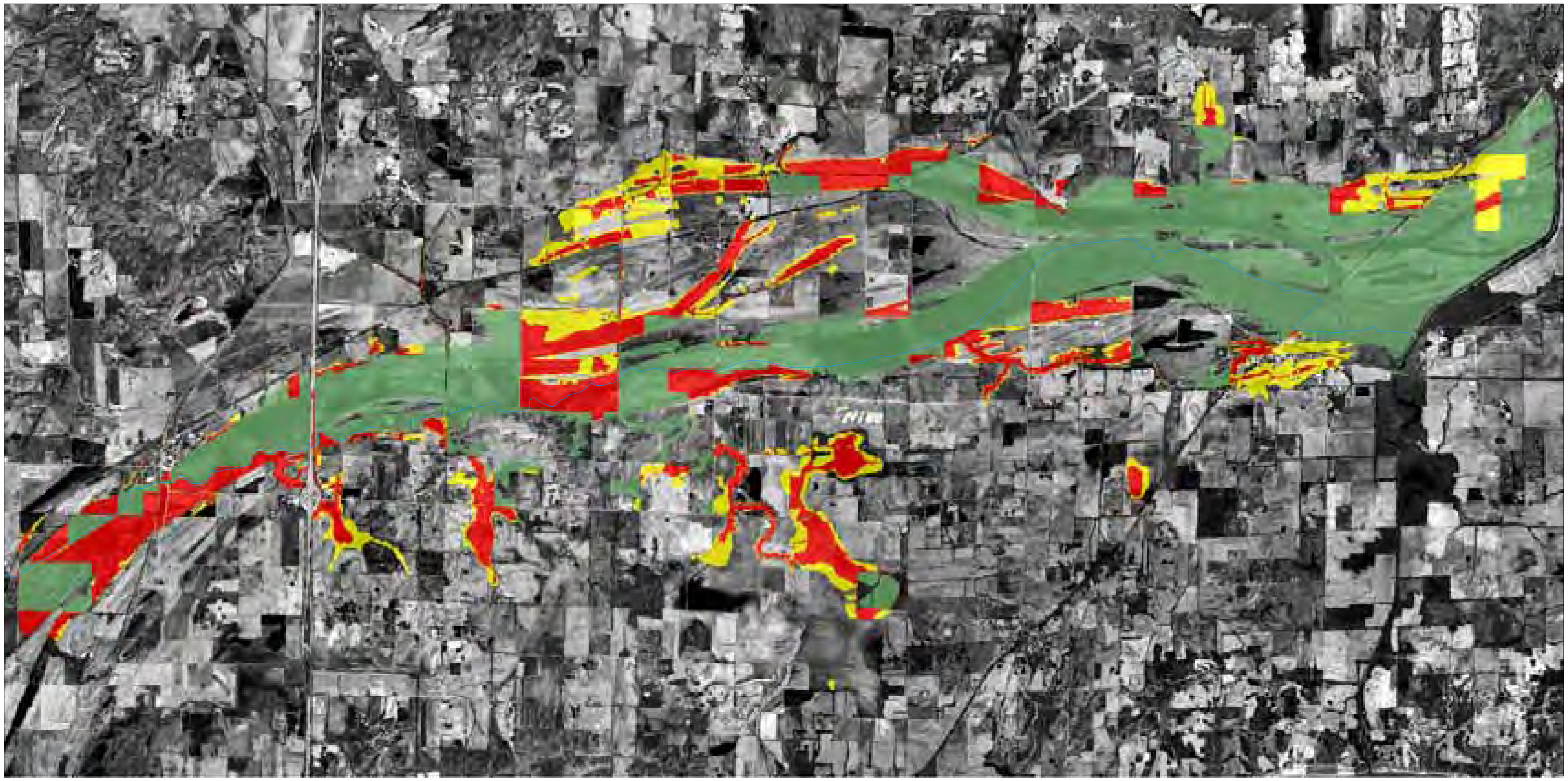


Figure 4-11. Flood profiles in Lower Cache River: comparing current to reference conditions (Upper Cache and Ohio Rivers at 100-year flood condition and Lower Cache and Mississippi Rivers at 2-year flood condition)



Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1G**):	3213	6227
Current Condition (**2F**):	5354	8149
Flooded area reduced by:	-0	-0
Flooded area increased by:	+2141	+1922
Net Change:	+2141	+1922

Flooded Areas

Conservation Acres

Private Acres

Additional Acres

0 0.5 1 2 Miles

1:24,000

State Plane Illinois East projection referenced to the North American Datum of 1983 (NAD83)

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Figure 12. 100-year flood boundaries for Lower Cache River (Upper Cache and Ohio Rivers at 100-year flood condition and Lower Cache and Mississippi Rivers at 2-year flood condition)

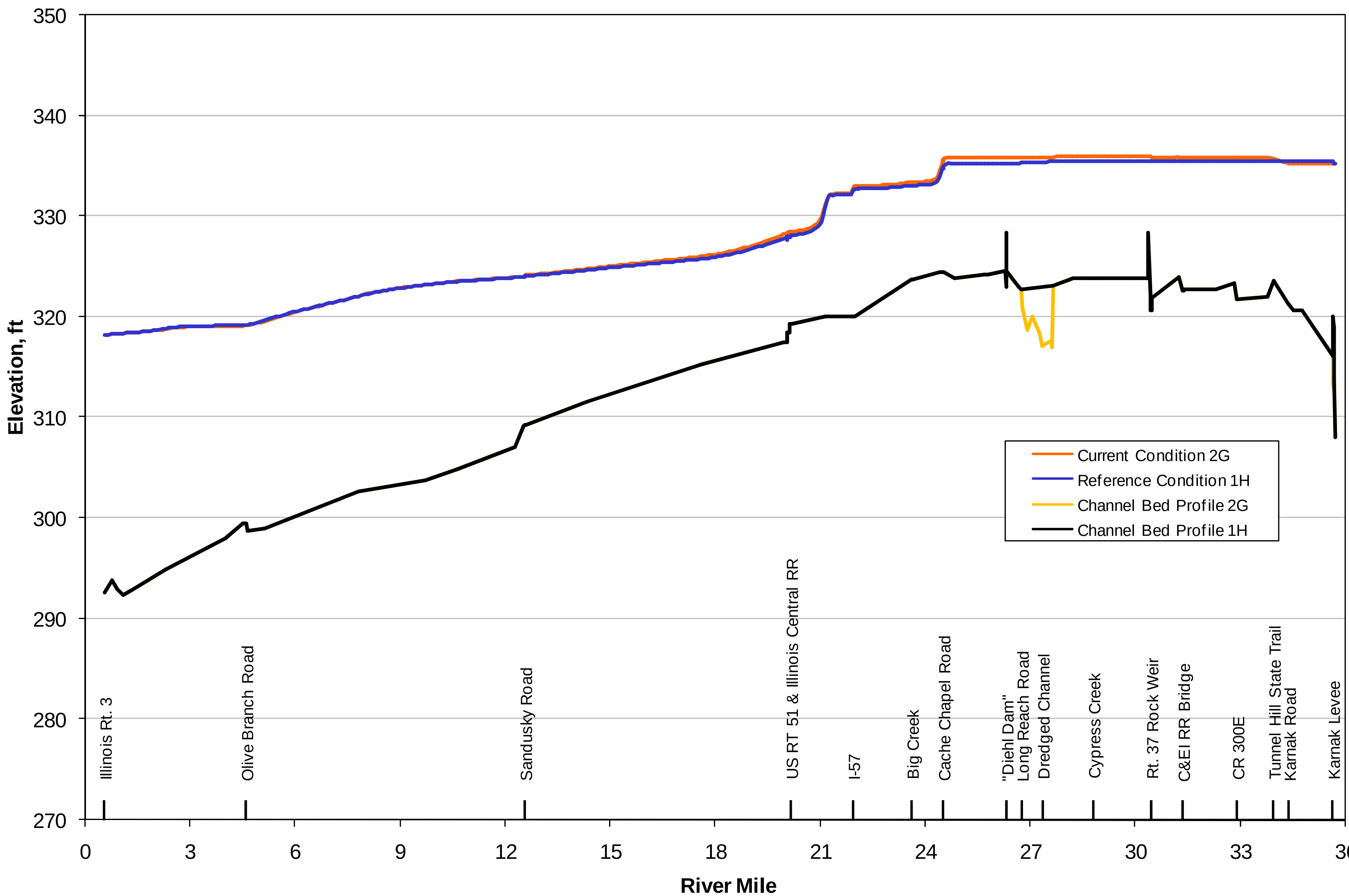
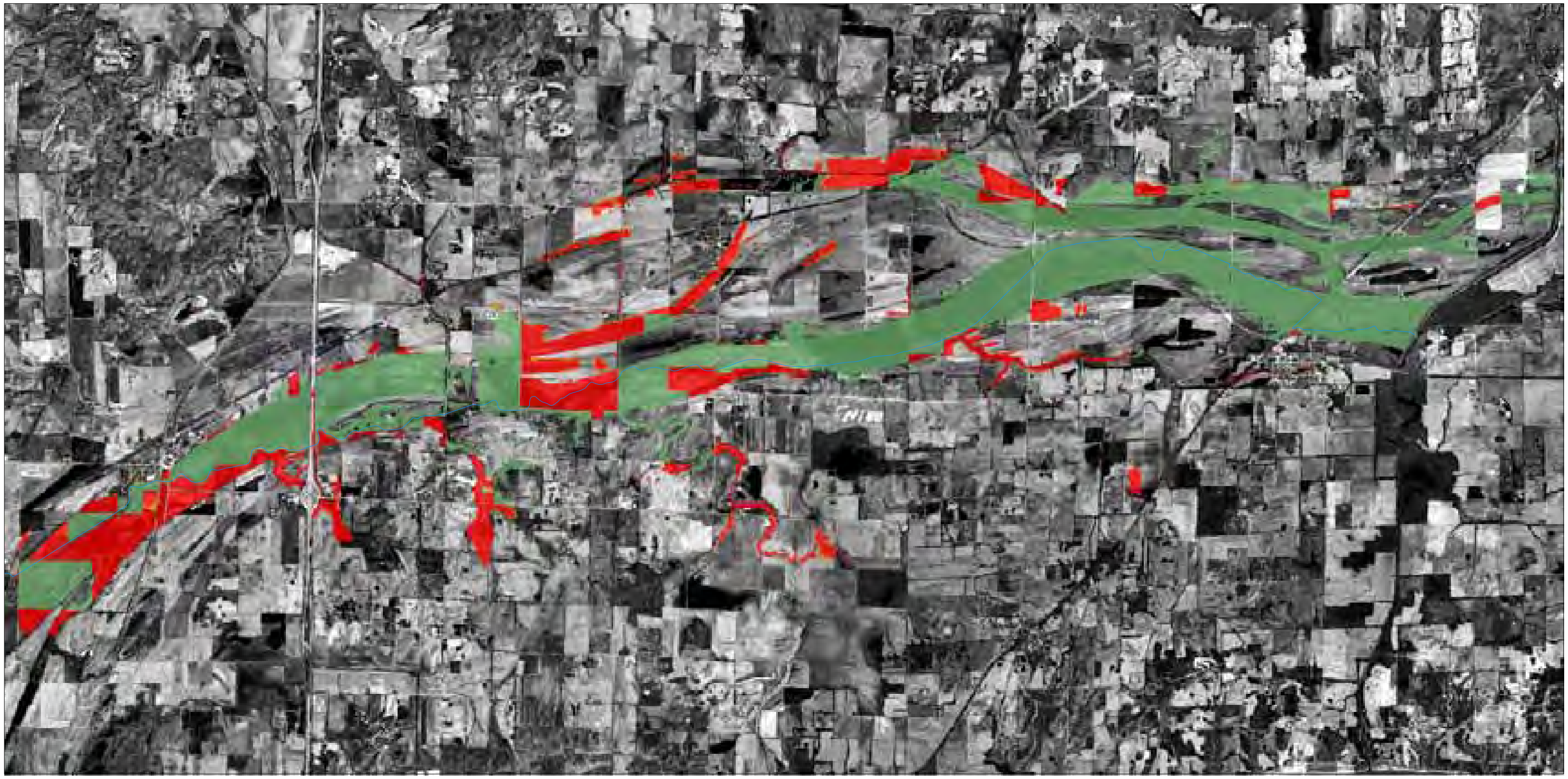


Figure 4-13. Flood profiles in Lower Cache River: comparing current to reference conditions (Ohio River at 100-year flood condition and Lower Cache, Upper Cache, and Mississippi Rivers at 2-year flood condition)



Summary

	Flooded Acres	
	Private	Cons.
Reference Condition (**1H**):	2345	5341
Current Condition (**2G**):	2543	5540
Flooded area reduced by:	-1	-13
Flooded area increased by:	+199	+212
Net Change:	+198	+199

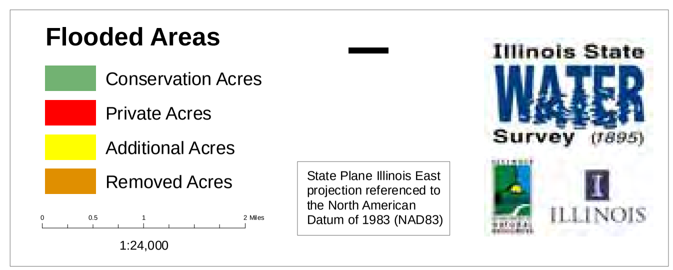


Figure 4-14. 100-year flood boundaries for Lower Cache River (Ohio River at 100-year flood condition and Lower Cache, Upper Cache, and Mississippi Rivers at 2-year flood condition)

a) Low-flow conditions

b) Overtopped condition (note flow direction is west to east)

Figure 4-15. “Diehl Dam” during a) low-flow conditions and b) when overtopped

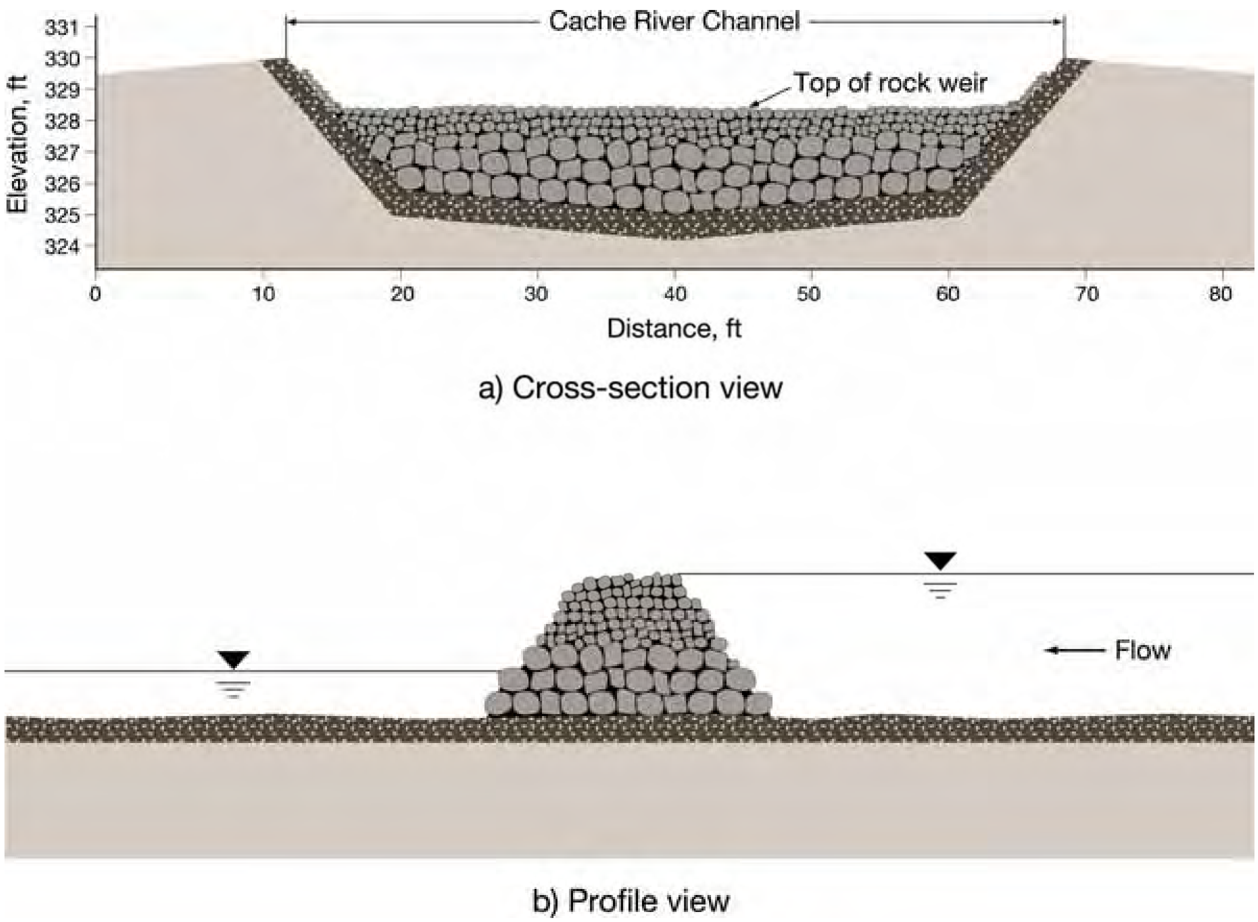
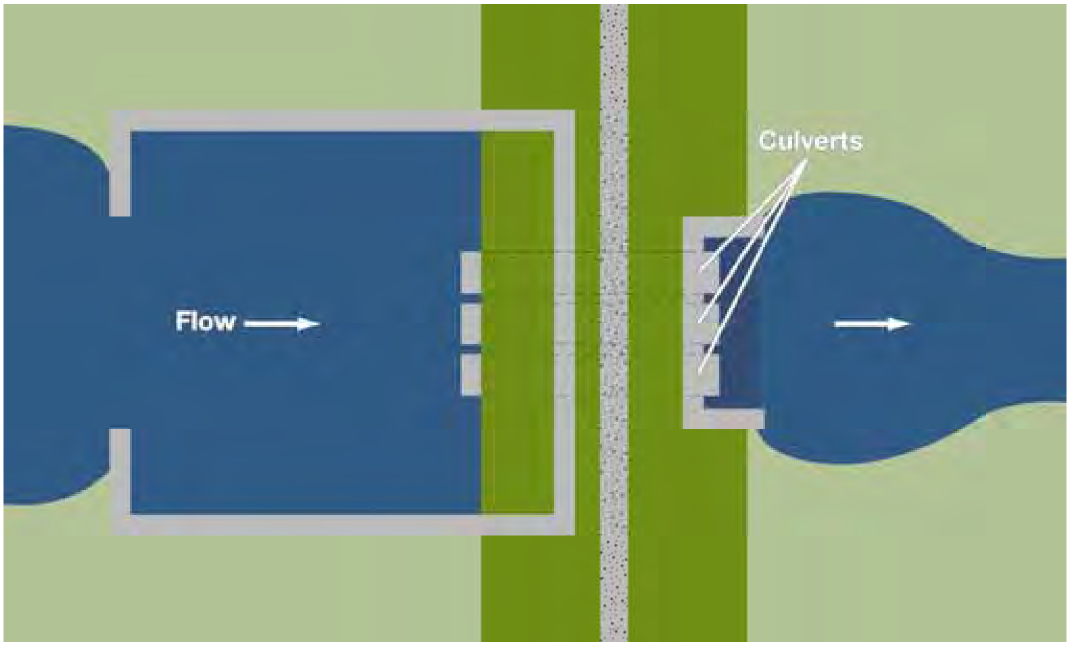
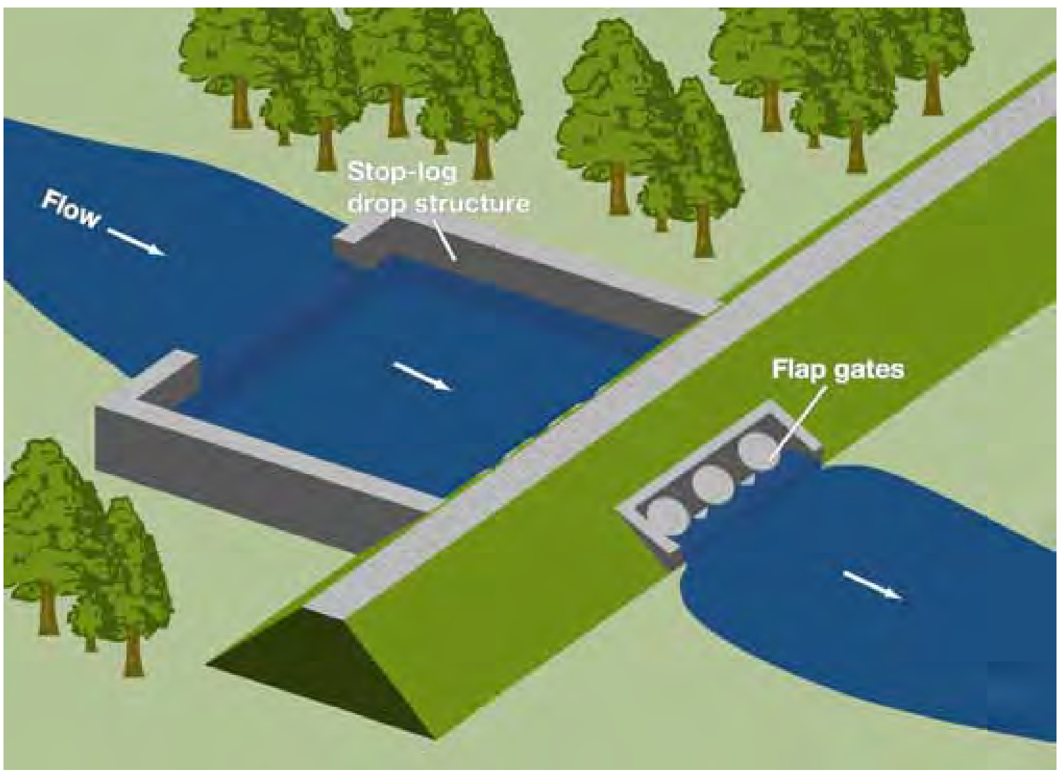


Figure 4-16. Conceptual design for proposed West Rock Weir



a) Plan view



b) 3-D view

Figure 4-17. Conceptual design for proposed East Outlet Structure

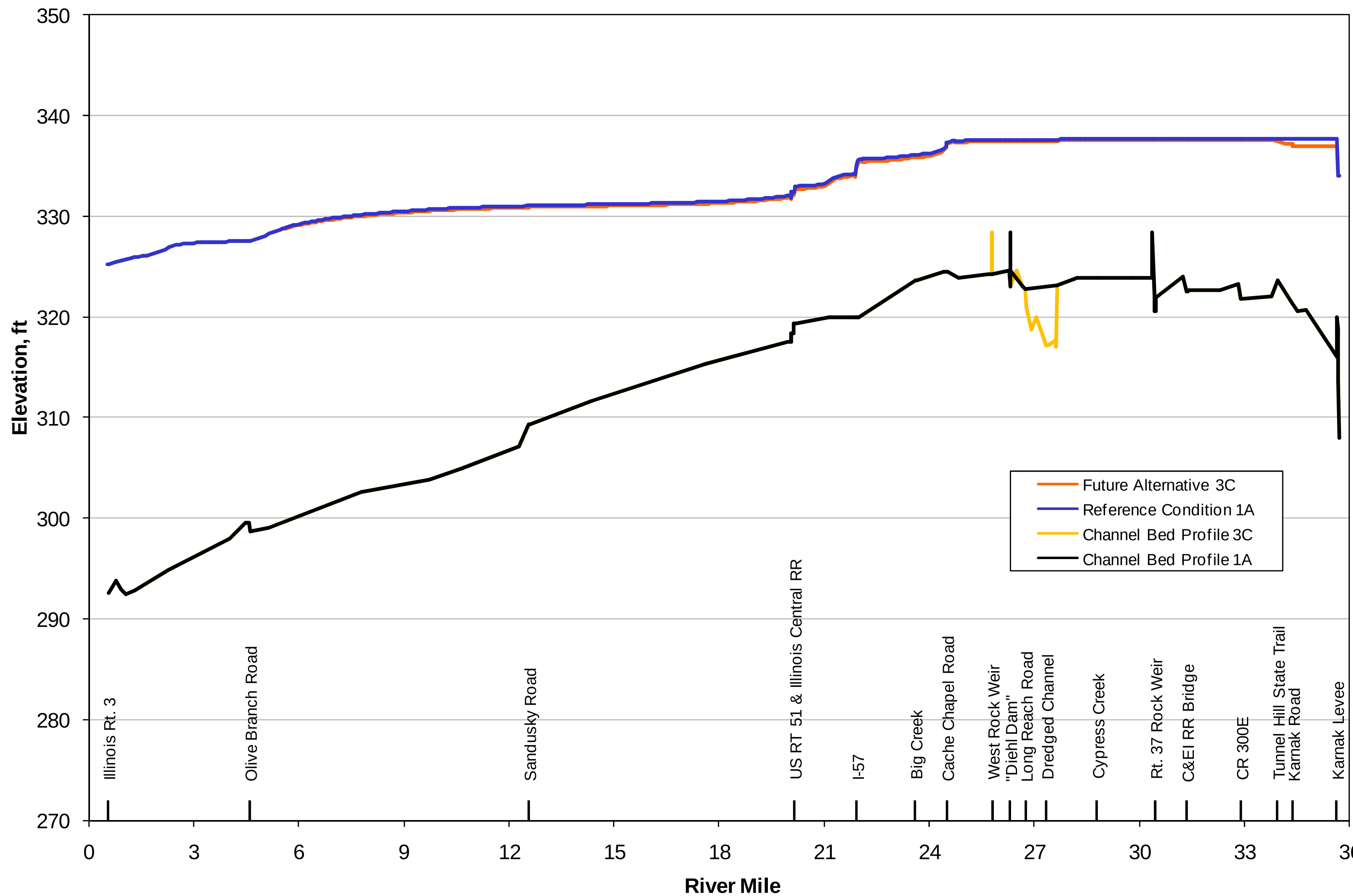


Figure 4-18. 100-year flood profiles for Lower Cache River (with Mississippi, Upper Cache, and Ohio Rivers at 10-year flood condition) for future alternative 3C (with East Outlet Structure control set at 330 feet elevation and three 72-inch culverts) compared to reference condition

Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1A**):	5039	7331
Alternative Condition (**3C**):	4898	7172
Flooded area reduced by:	-141	-159
Flooded area increased by:	+0	+0
Net Change:	-141	-159

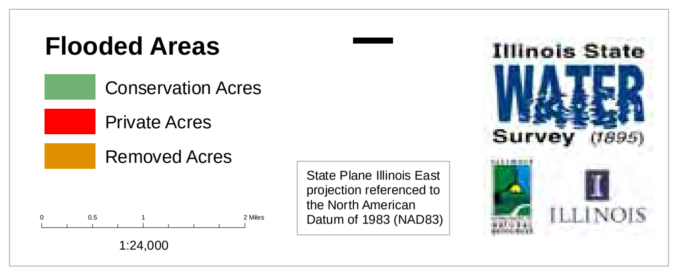


Figure 4-19. 100-year flood boundaries for Lower Cache River (with Mississippi, Upper Cache, and Ohio Rivers at 10-year flood condition) for future alternative 3C (with East Outlet Structure control set at 330 feet elevation and three 72-inch culverts) compared to reference condition

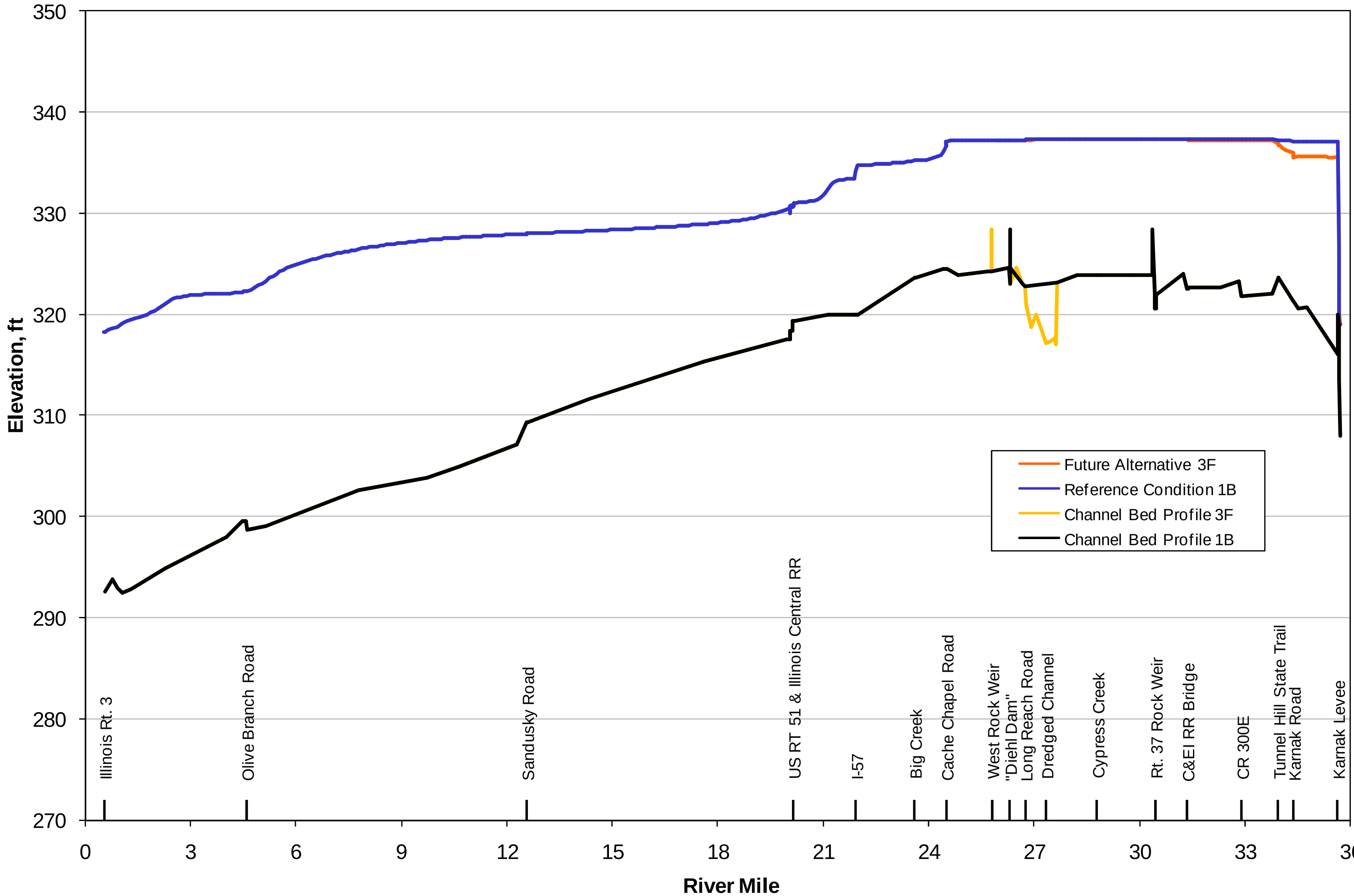
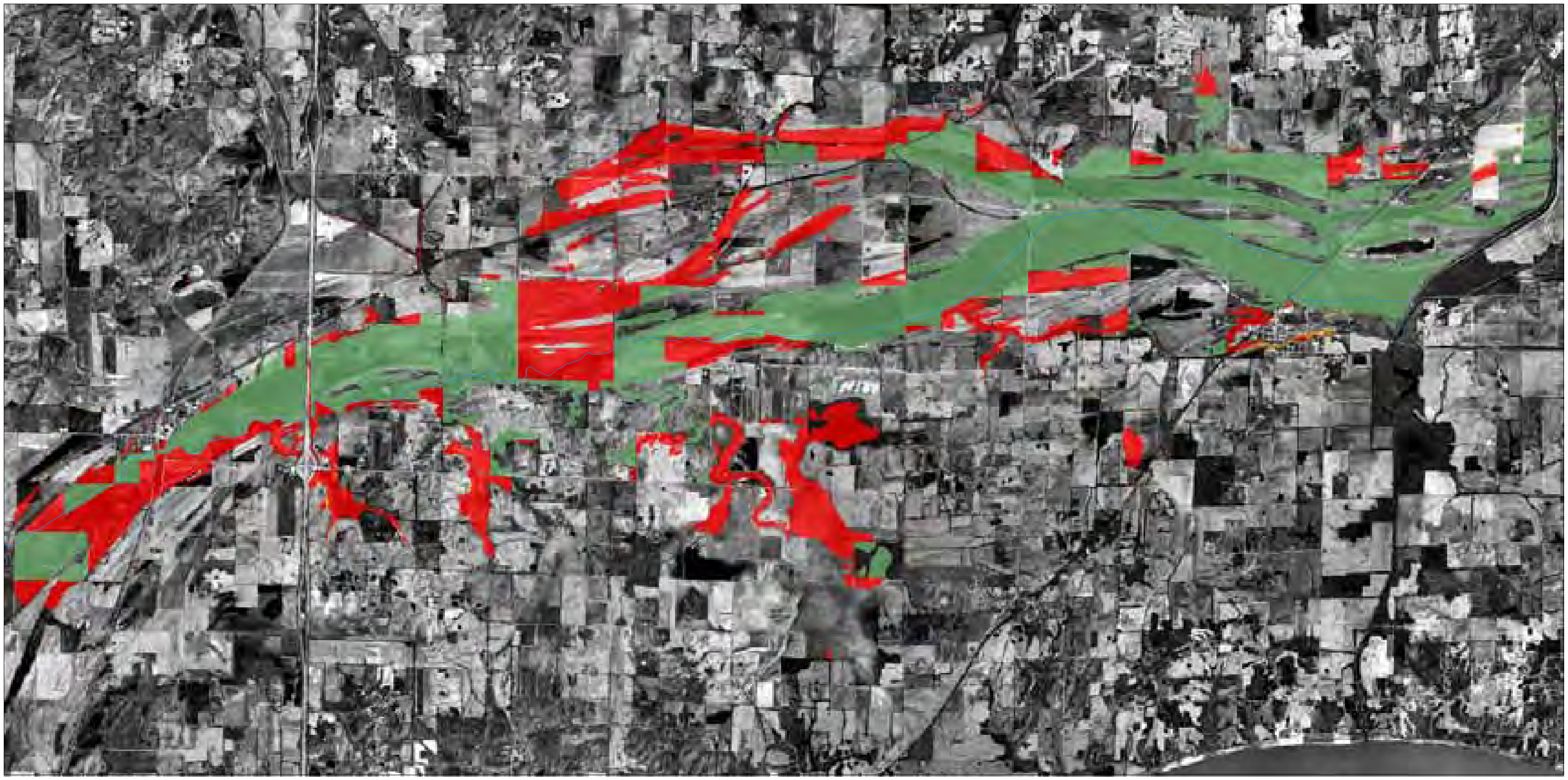


Figure 4-20. 100-year flood profiles for Lower Cache River (with Mississippi, Upper Cache, and Ohio Rivers at 2-year flood condition) for future alternative 3F (with East Outlet Structure control set at 330 feet elevation and three 72-inch culverts) compared to reference condition



Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1B**):	4672	7021
Alternative Condition (**3F**):	4633	6731
Flooded area reduced by:	-48	-294
Flooded area increased by:	+9	+4
Net Change:	-39	-290

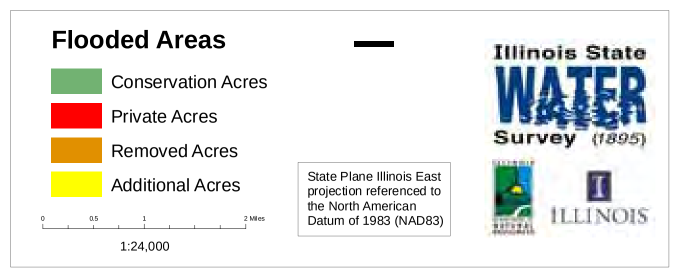


Figure 4-21. 100-year flood boundaries for Lower Cache River (with Mississippi, Upper Cache, and Ohio Rivers at 2-year flood condition) for future alternative 3F (with East Outlet Structure control set at 330 feet elevation and three 72-inch culverts) compared to reference condition

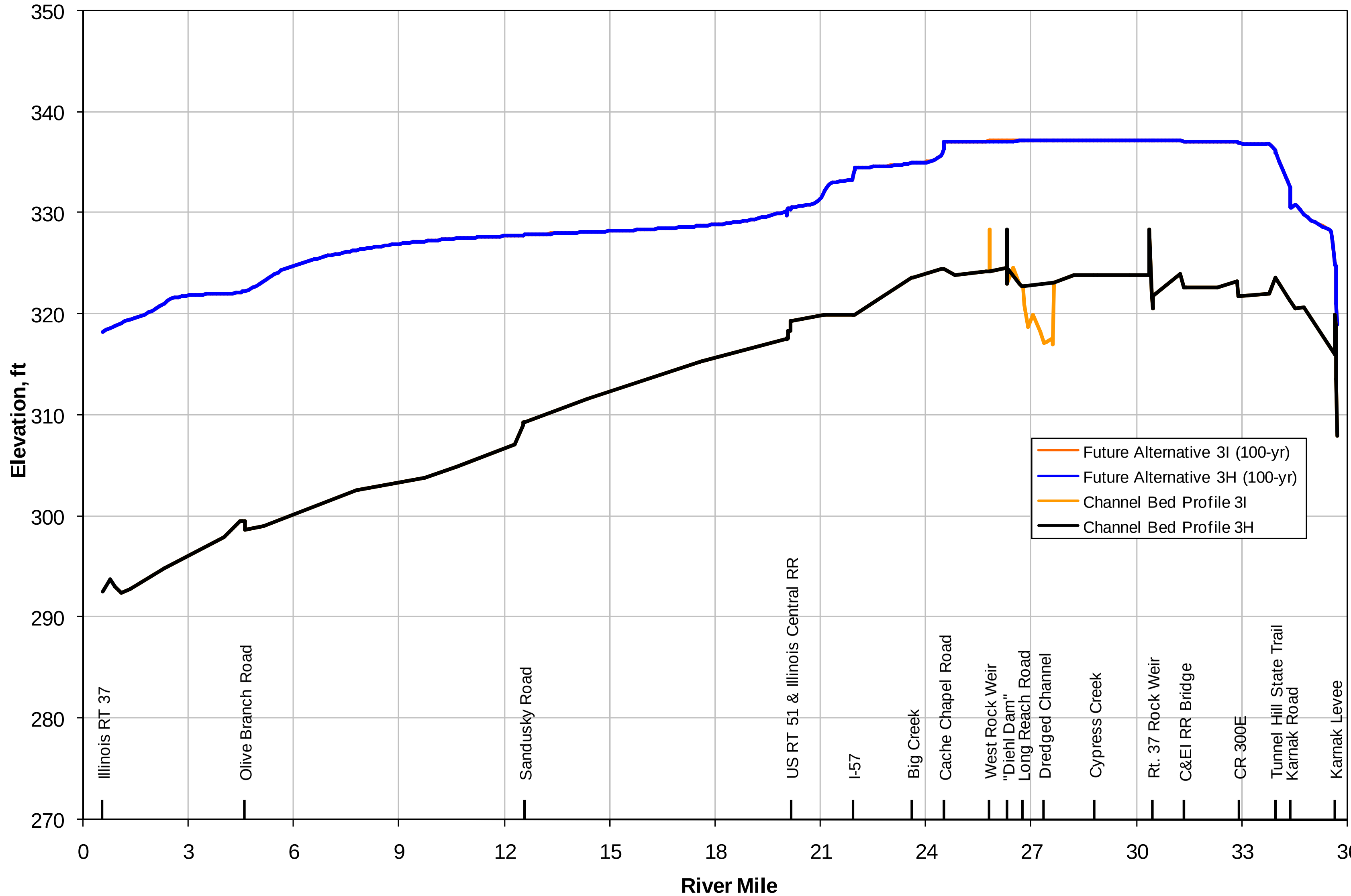
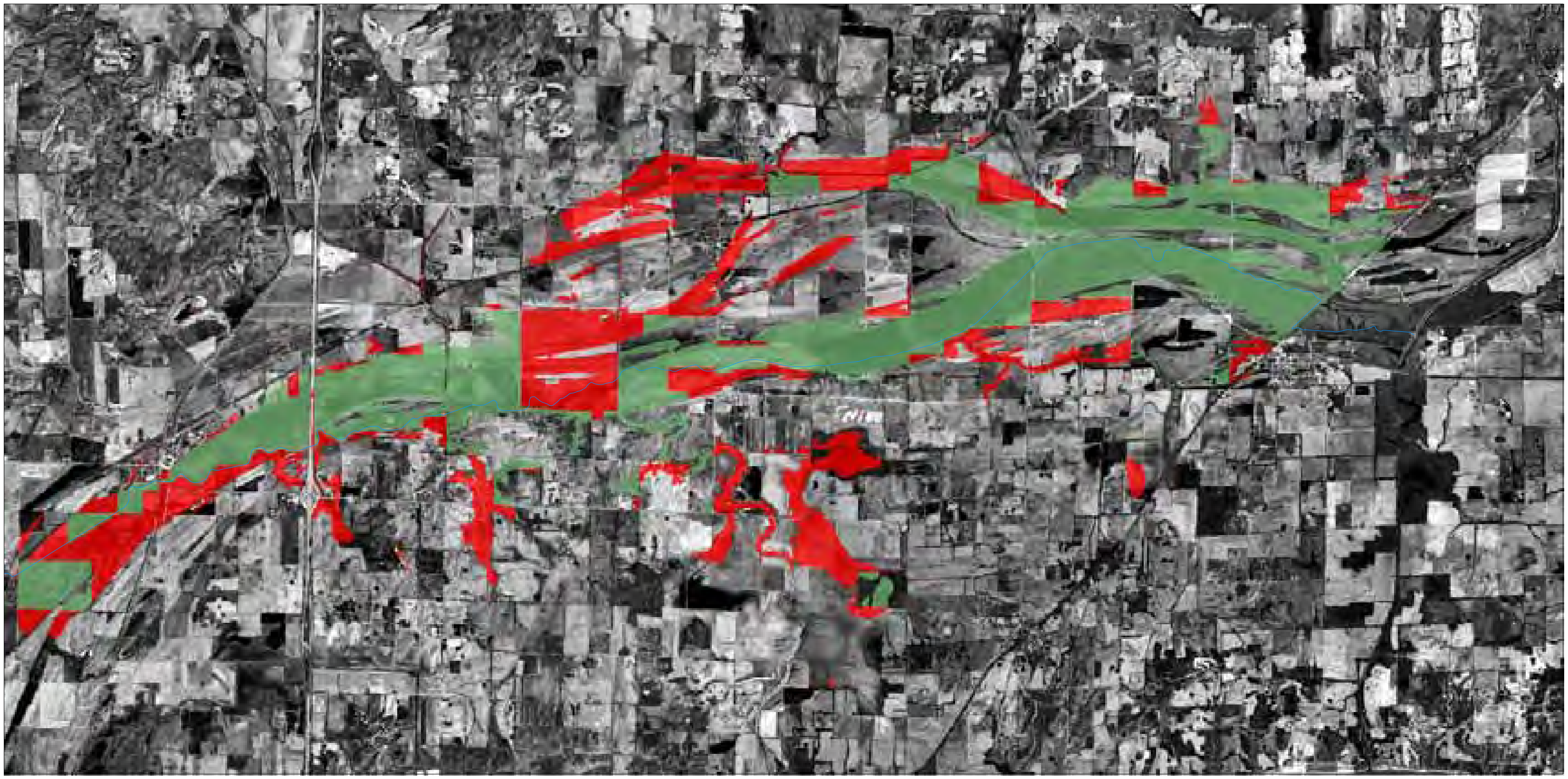


Figure 4-22. 100-year flood profiles in Lower Cache River assuming “Diehl Dam” is moved 2,800 feet to the west of its current location compared to current condition



Summary

	Flooded Acres Private	Flooded Acres Cons.
Alternative Condition (**3H**):	4435	6042
Alternative Condition (**3I**):	4441	6044
Flooded area reduced by:	-0	-0
Flooded area increased by:	+6	+2
Net Change:	+6	+2

Flooded Areas

Conservation Acres
Private Acres
Additional Acres

0 0.5 1 2 Miles
1:24,000

State Plane Illinois East projection referenced to the North American Datum of 1983 (NAD83)

Illinois State WATER Survey (1895)

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Figure 4-23. 100-year flood boundaries for Lower Cache River assuming “Diehl Dam is moved 1,000 feet to the west of its current location compared to current condition

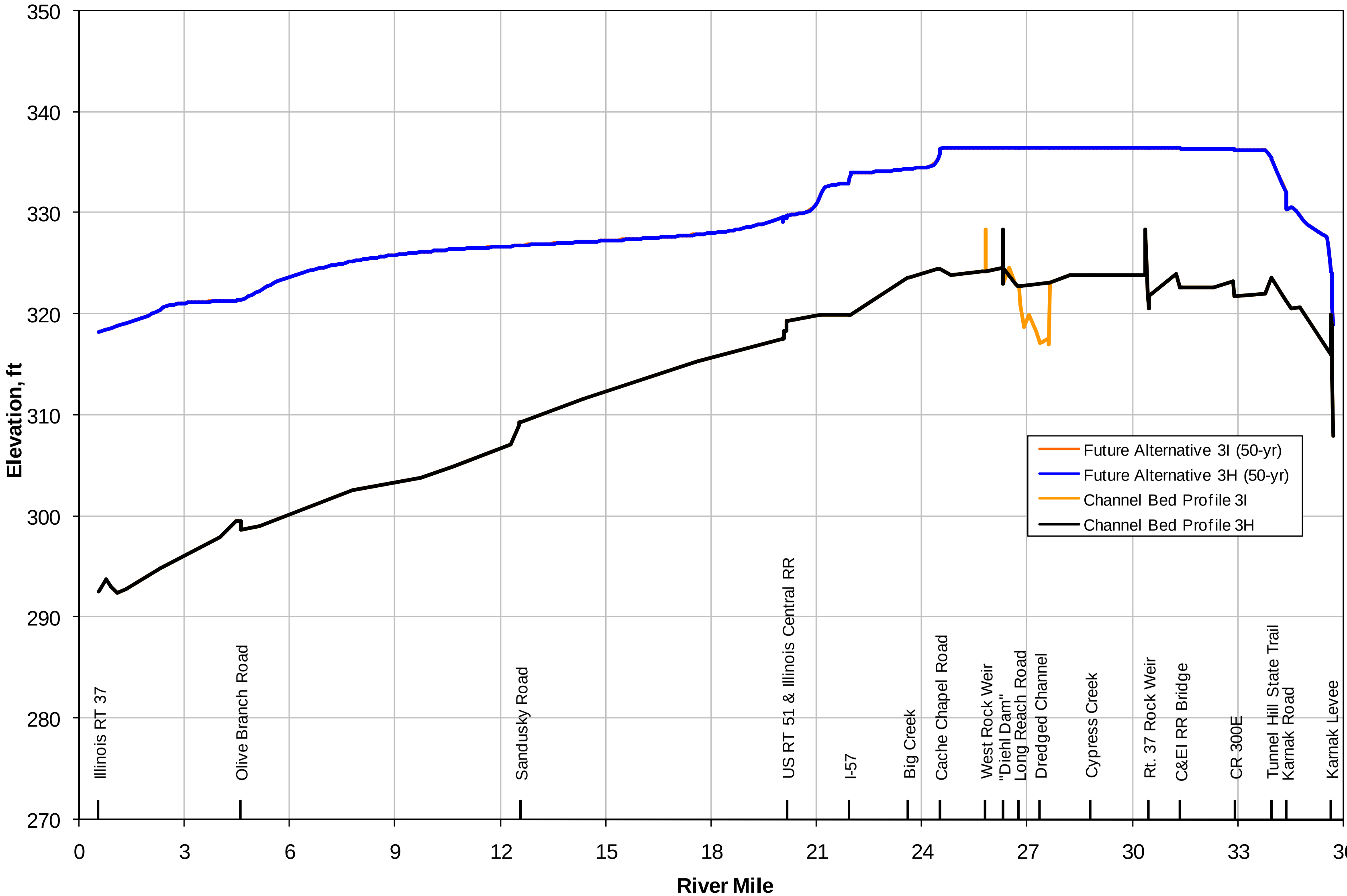


Figure 4-24. 50-year flood profiles in Lower Cache River assuming "Diehl Dam" is moved 2,800 feet to the west of its current location compared to current condition

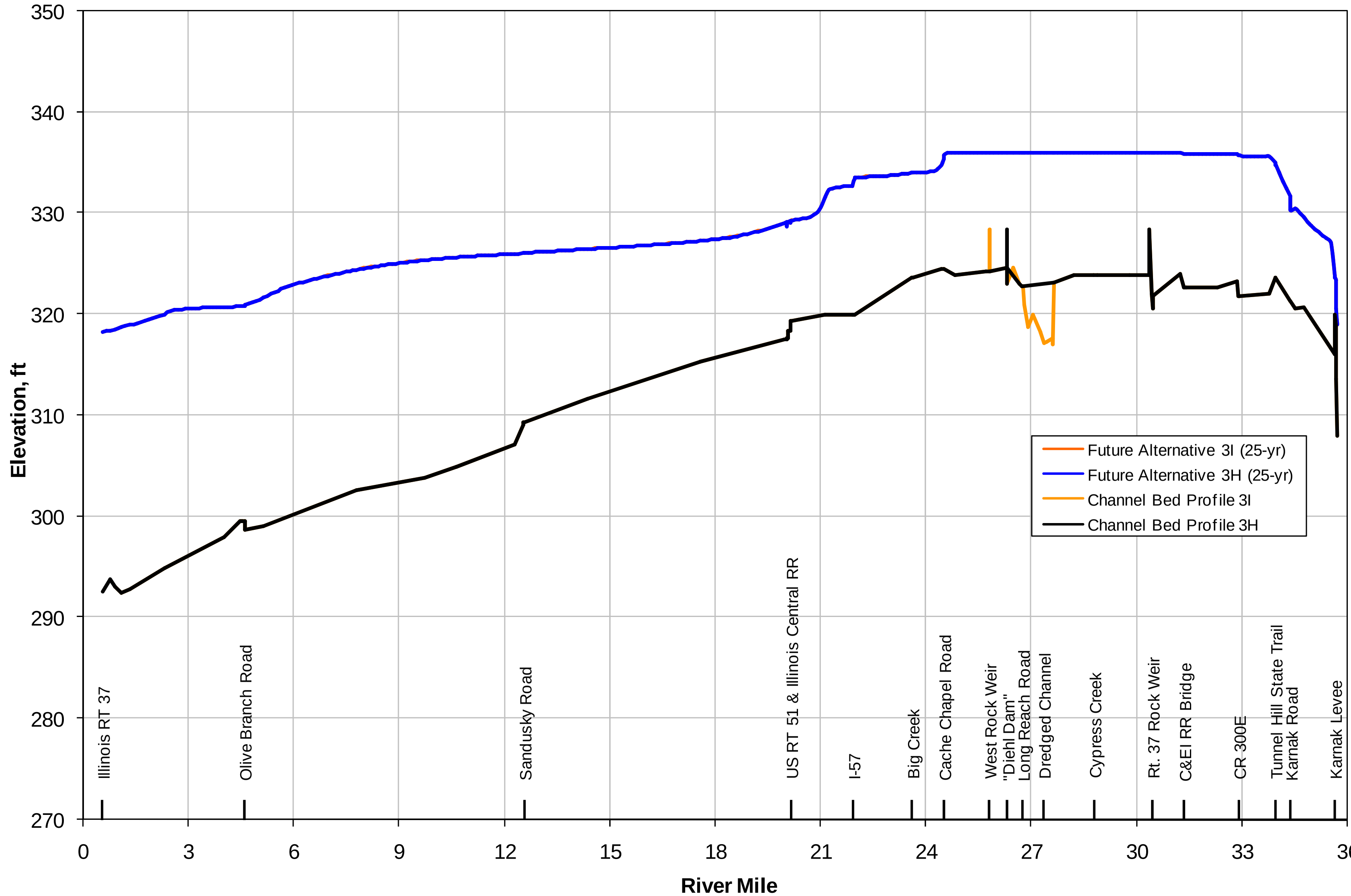


Figure 4-25. 25-year flood profiles in Lower Cache River assuming "Diehl Dam" is moved 2,800 feet to the west of its current location compared to current condition

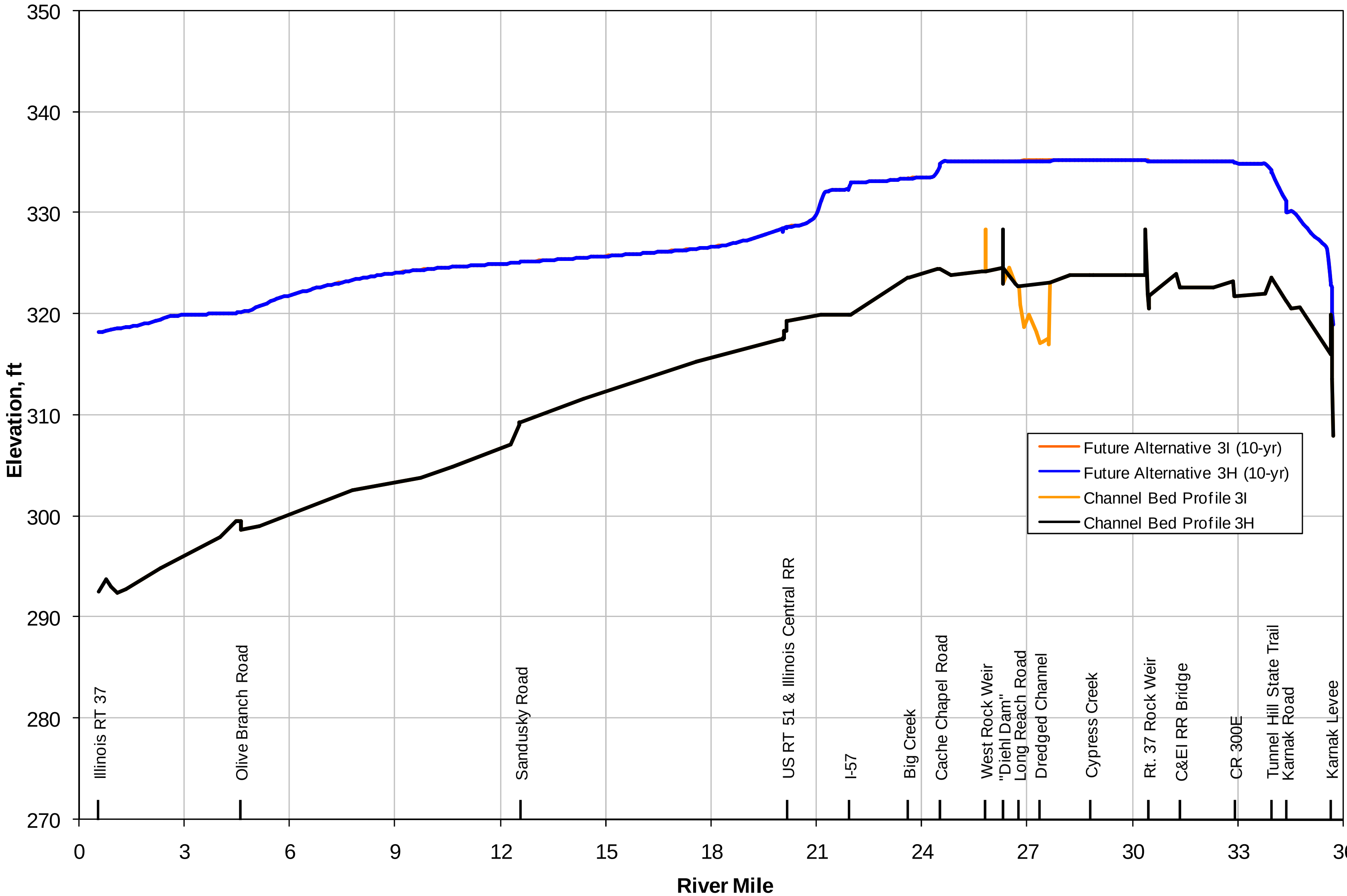


Figure 4-26. 10-year flood profiles in Lower Cache River assuming “Diehl Dam” is moved 2,800 feet to the west of its current location compared to current condition

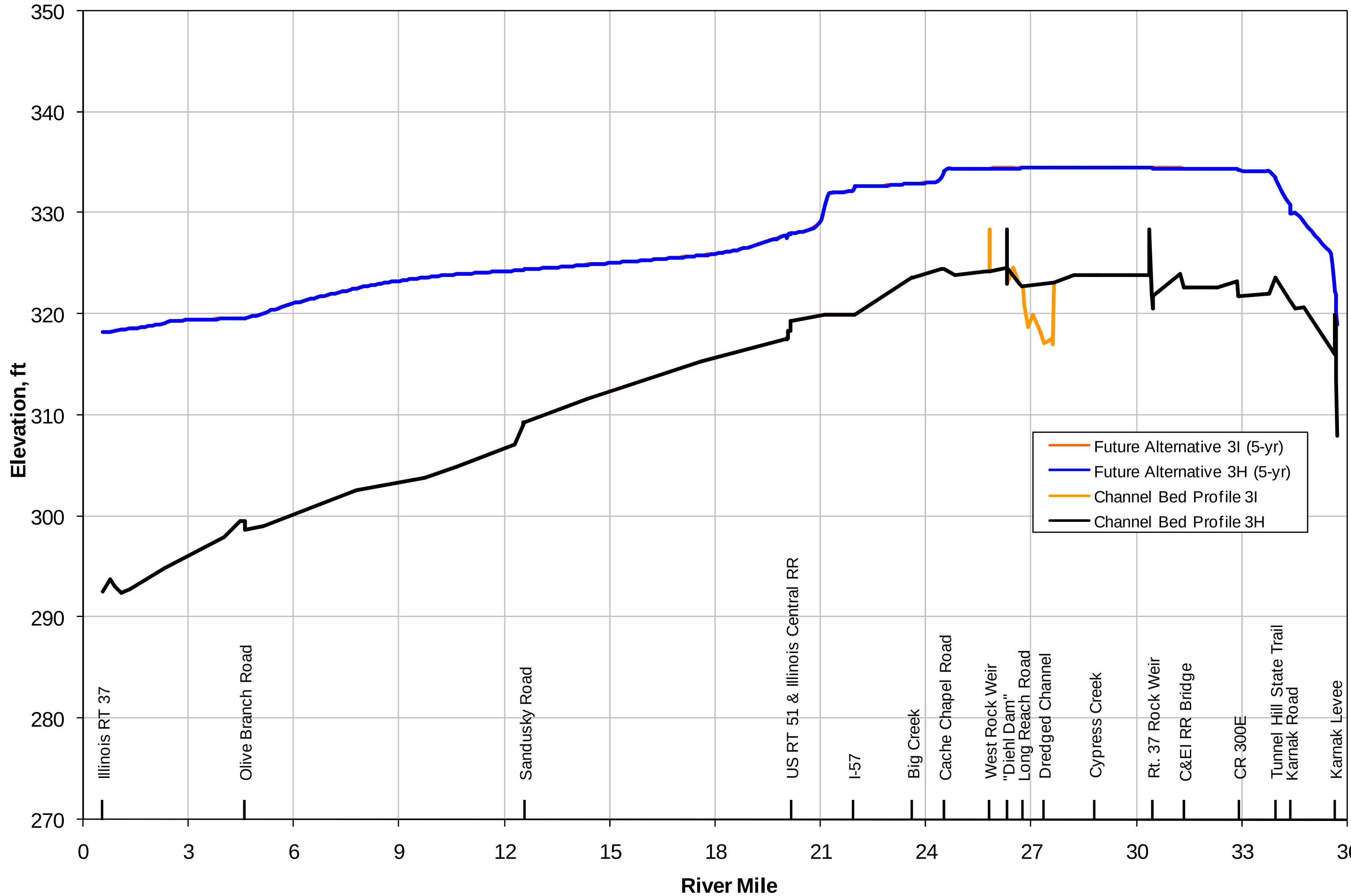


Figure 4-27. 5-year flood profiles in Lower Cache River assuming "Diehl Dam" is moved 2,800 feet to the west of its current location compared to current condition

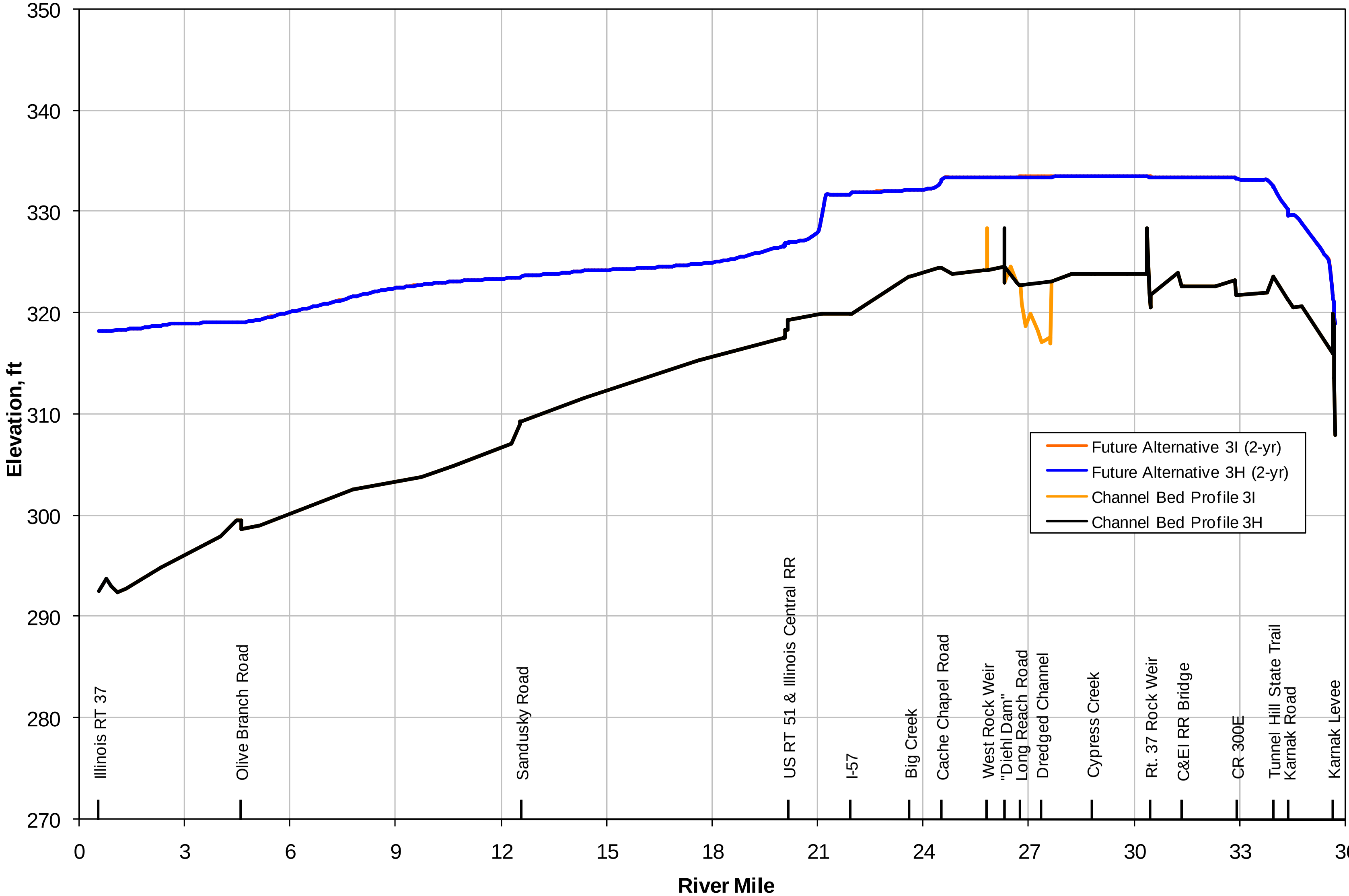


Figure 4-28. 2-year flood profiles in Lower Cache River assuming “Diehl Dam” is moved 2,800 feet to the west of its current location compared to current condition

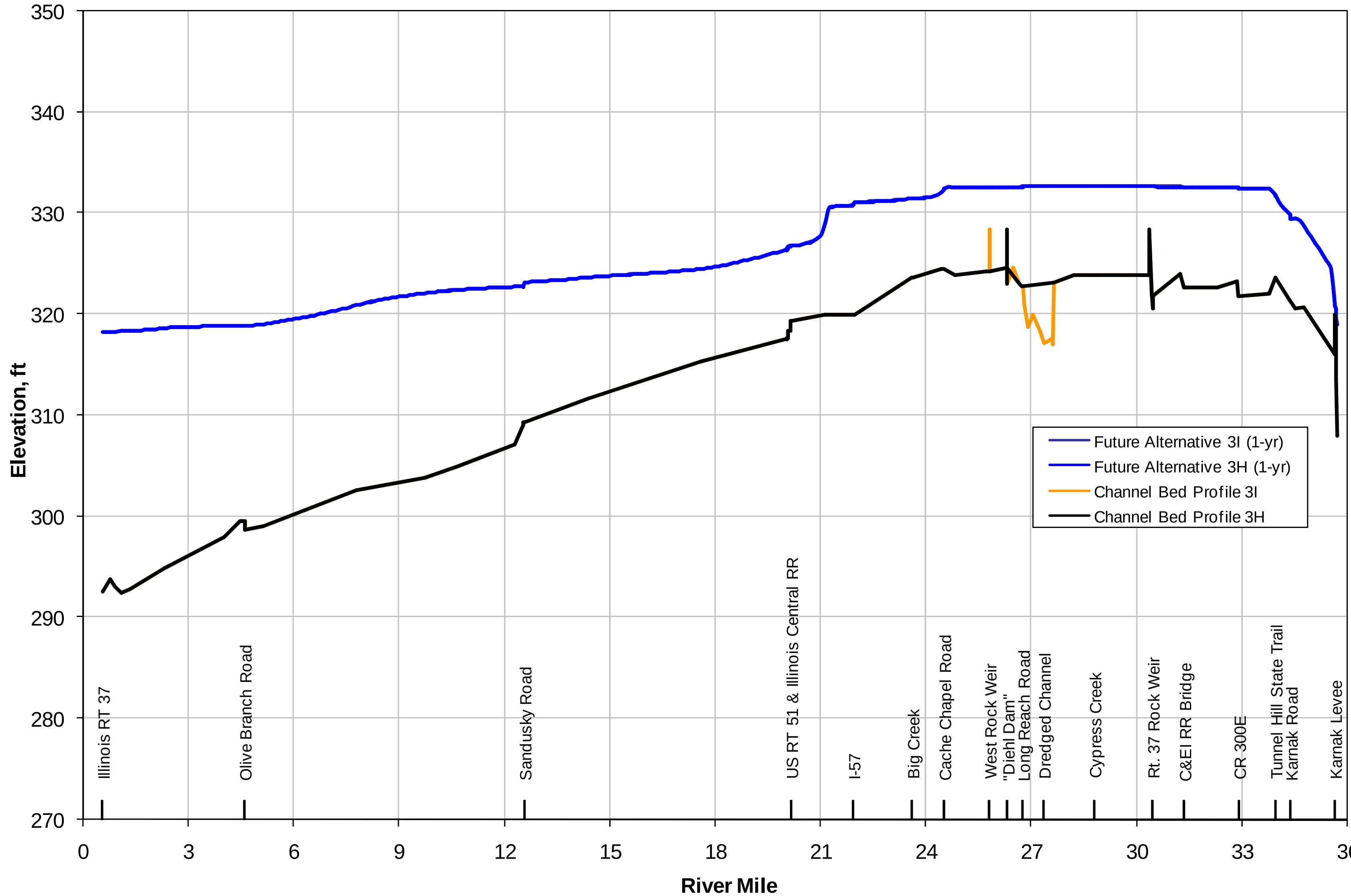


Figure 4-29. 1-year flood profiles in Lower Cache River assuming “Diehl Dam” is moved 2,800 feet to the west of its current location compared to current condition

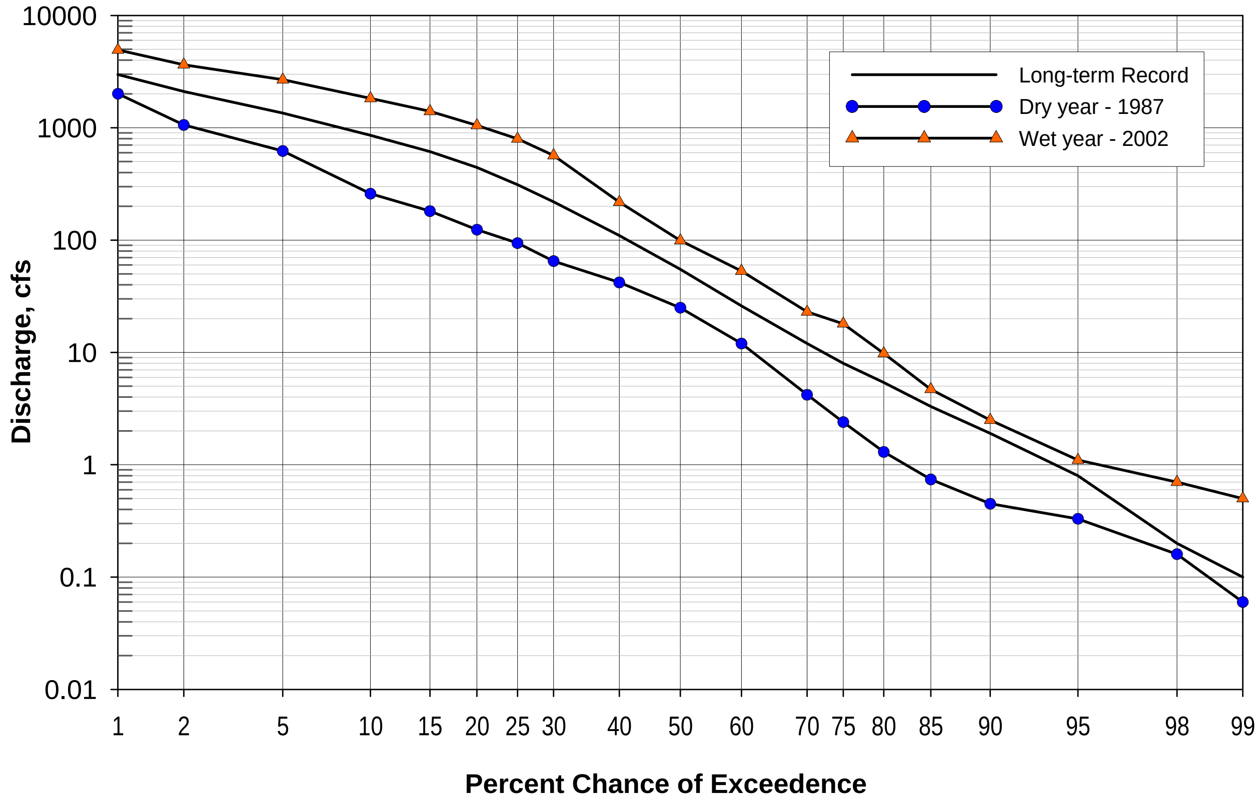


Figure 4-30. Flow duration curves for Upper Cache River at Forman

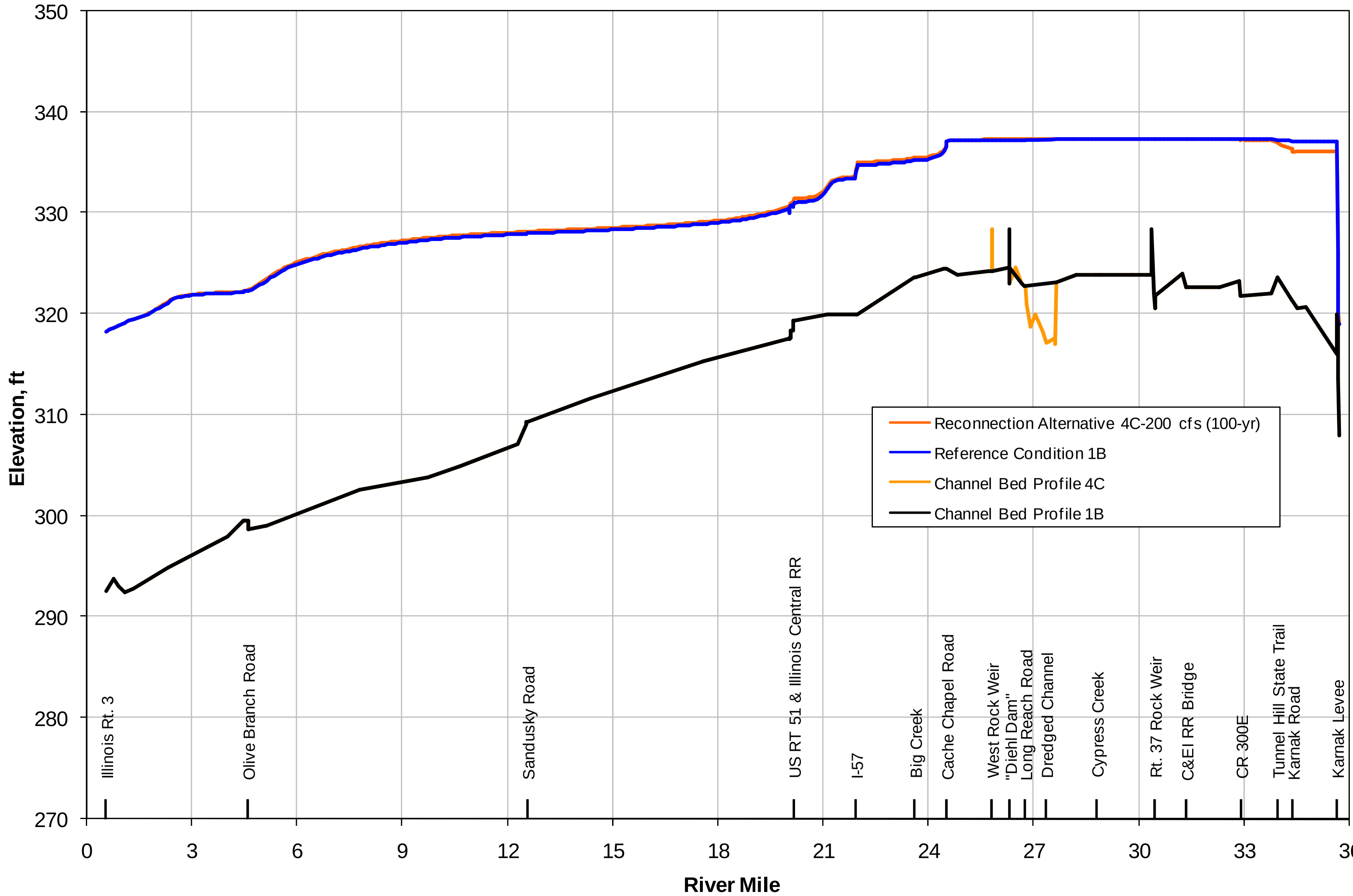
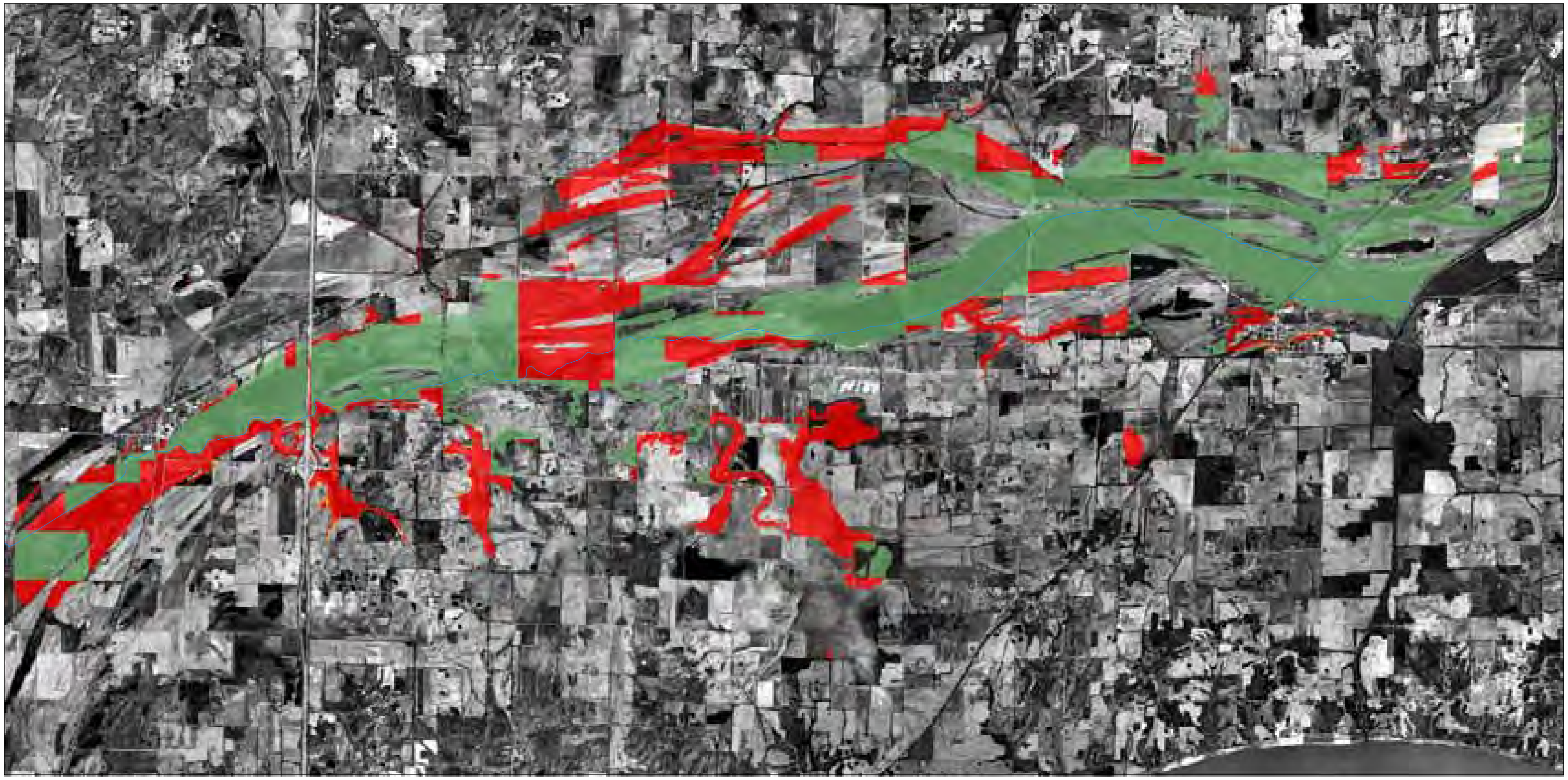


Figure 4-31. Comparison of 100-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B



Summary

	Flooded Acres	
	Private	Cons.
Reference Condition (**1B**):	4672	7021
Alternative Condition (**4C**):	4701	6967
Flooded area reduced by:	-25	-97
Flooded area increased by:	+54	+43
Net Change:	+29	-54

Flooded Areas

- Conservation Acres
- Private Acres
- Removed Acres
- Additional Acres

0 0.5 1 2 Miles

1:24,000

State Plane Illinois East projection referenced to the North American Datum of 1983 (NAD83)

Illinois State Water Survey (1895)

ILLINOIS

Figure 4-32. Comparison of 100-year flood boundaries along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

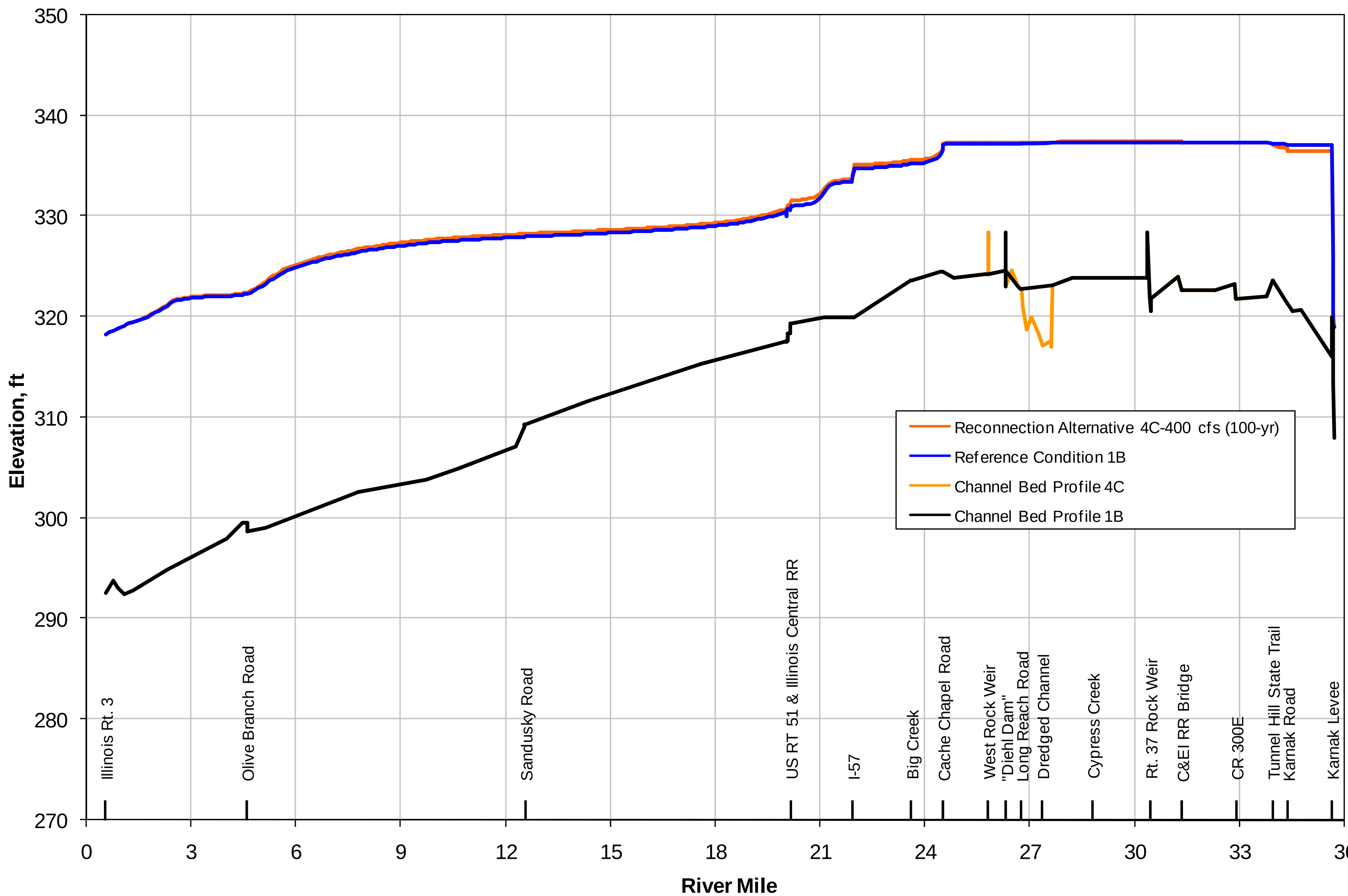


Figure 4-33. Comparison of 100-year flood profiles along Lower Cache River for reconnection alternative 4C with 400 cfs diversion from Upper Cache River with reference condition 1B

Summary

	Flooded Acres Private	Flooded Acres Cons.
Reference Condition (**1B**):	4672	7021
Alternative Condition (**4C**):	4745	7032
Flooded area reduced by:	-13	-55
Flooded area increased by:	+86	+66
Net Change:	+73	+11

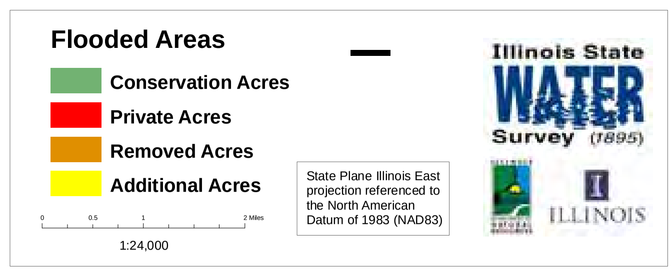


Figure 4-34. Comparison of 100-year flood boundaries along Lower Cache River for reconnection alternative 4C with 400 cfs diversion from Upper Cache River with reference condition 1B

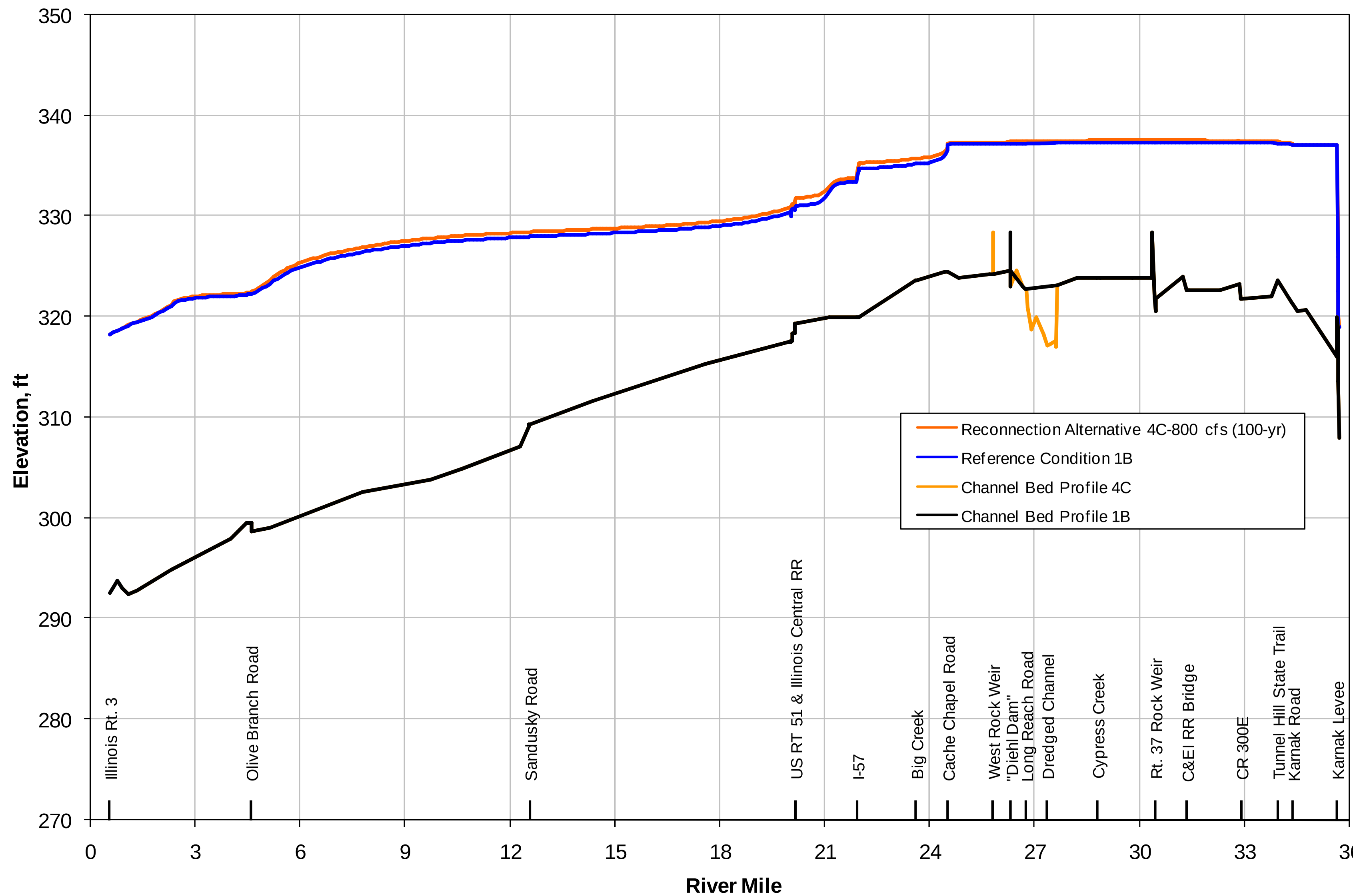
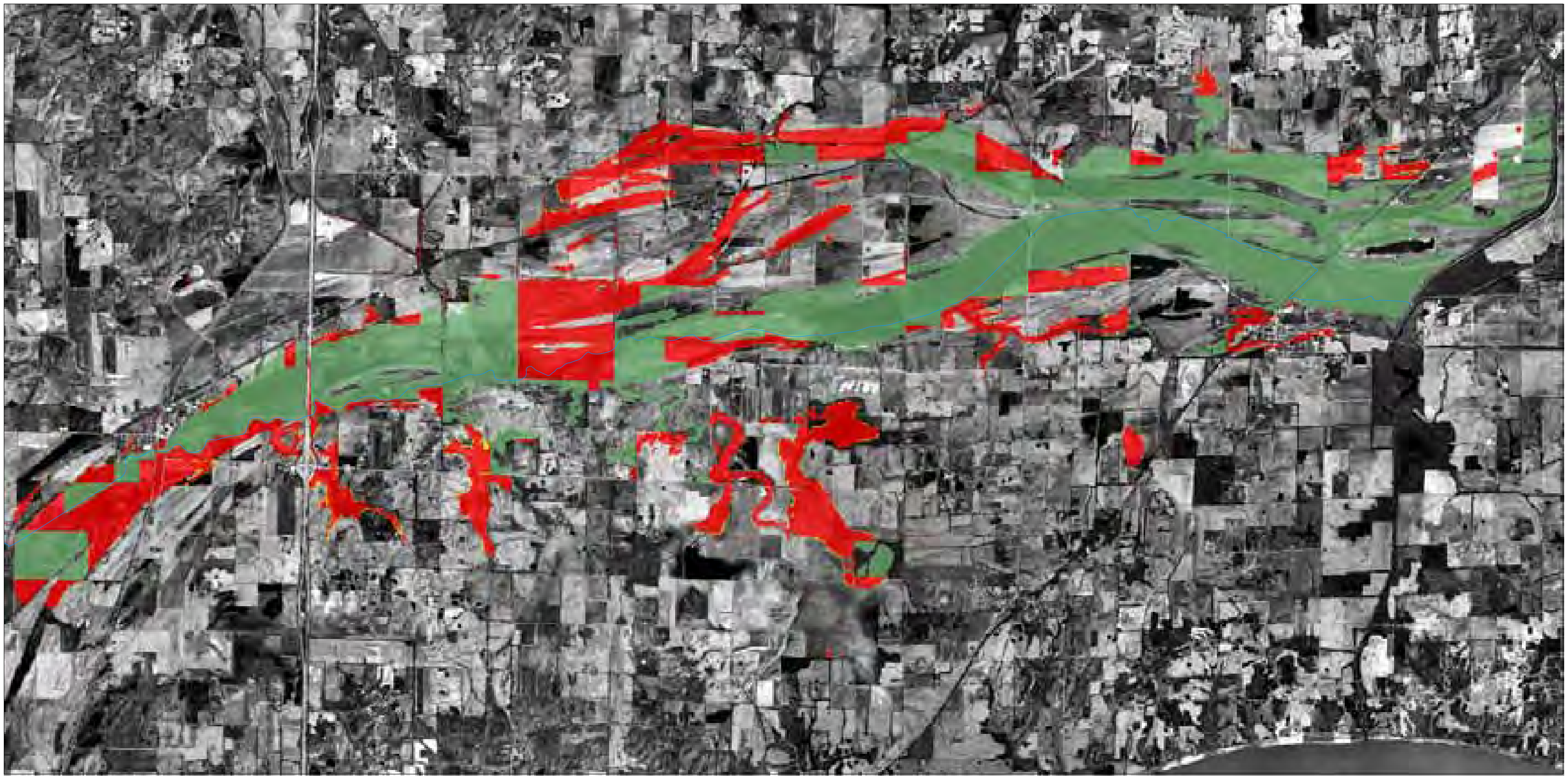


Figure 4-35. Comparison of 100-year flood profiles along Lower Cache River for reconnection alternative 4C with 800 cfs diversion from Upper Cache River with reference condition 1B



Summary

	Flooded Acres	
	Private	Cons.
Reference Condition (**1B**):	4672	7021
Alternative Condition (**4C**):	4848	7159
Flooded area reduced by:	-0	-0
Flooded area increased by:	+176	+138
Net Change:	+176	+138

Flooded Areas

Conservation Acres

Private Acres

Additional Acres

0 0.5 1 2 Miles

1:24,000

State Plane Illinois East projection referenced to the North American Datum of 1983 (NAD83)

Illinois State WATER Survey (1895)

ILLINOIS

Figure 4-36 Comparison of 100-year flood boundaries along Lower Cache River for reconnection alternative 4C with 800 cfs diversion from Upper Cache River with reference condition 1B

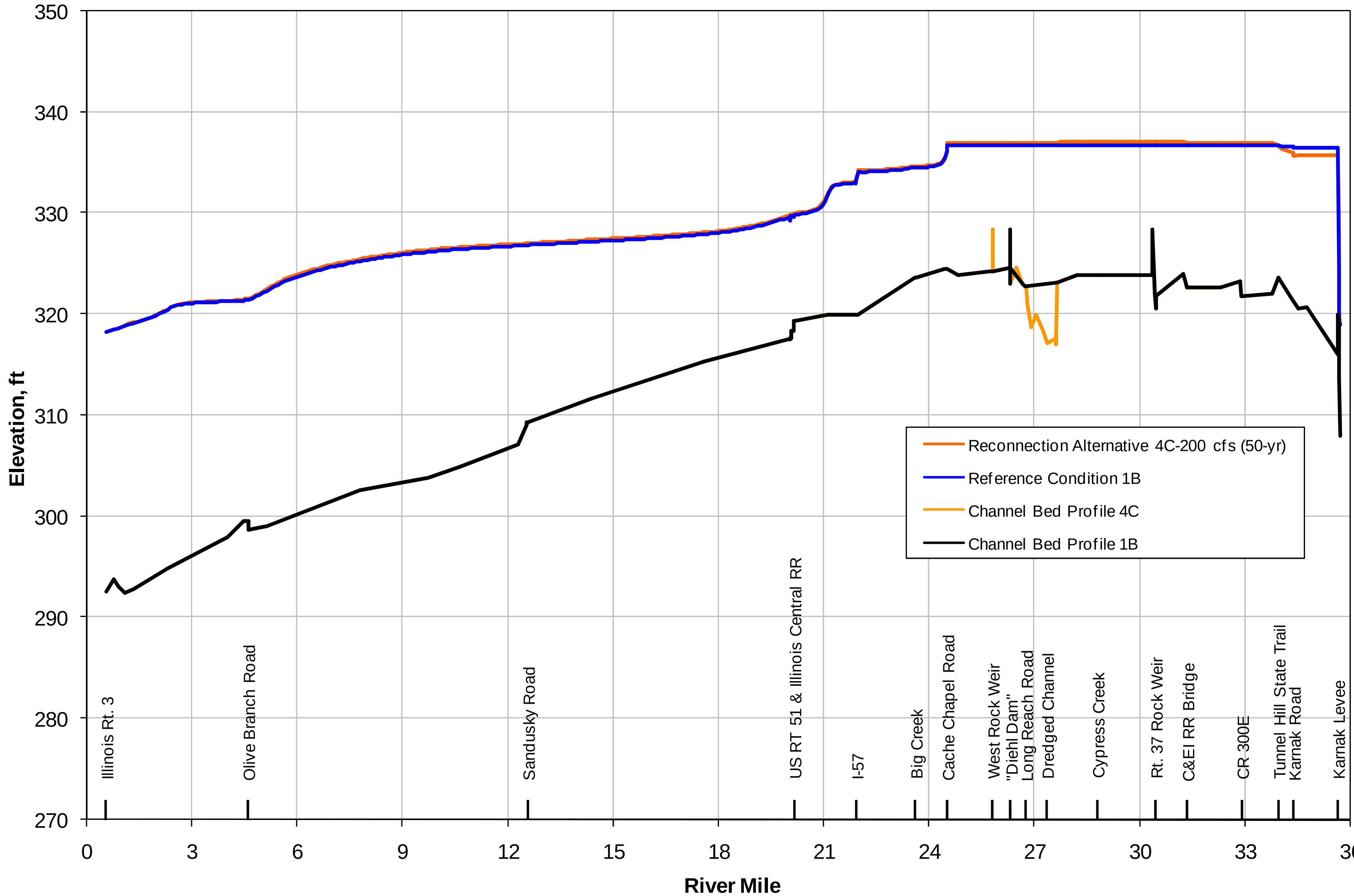


Figure 4-37. Comparison of 50-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

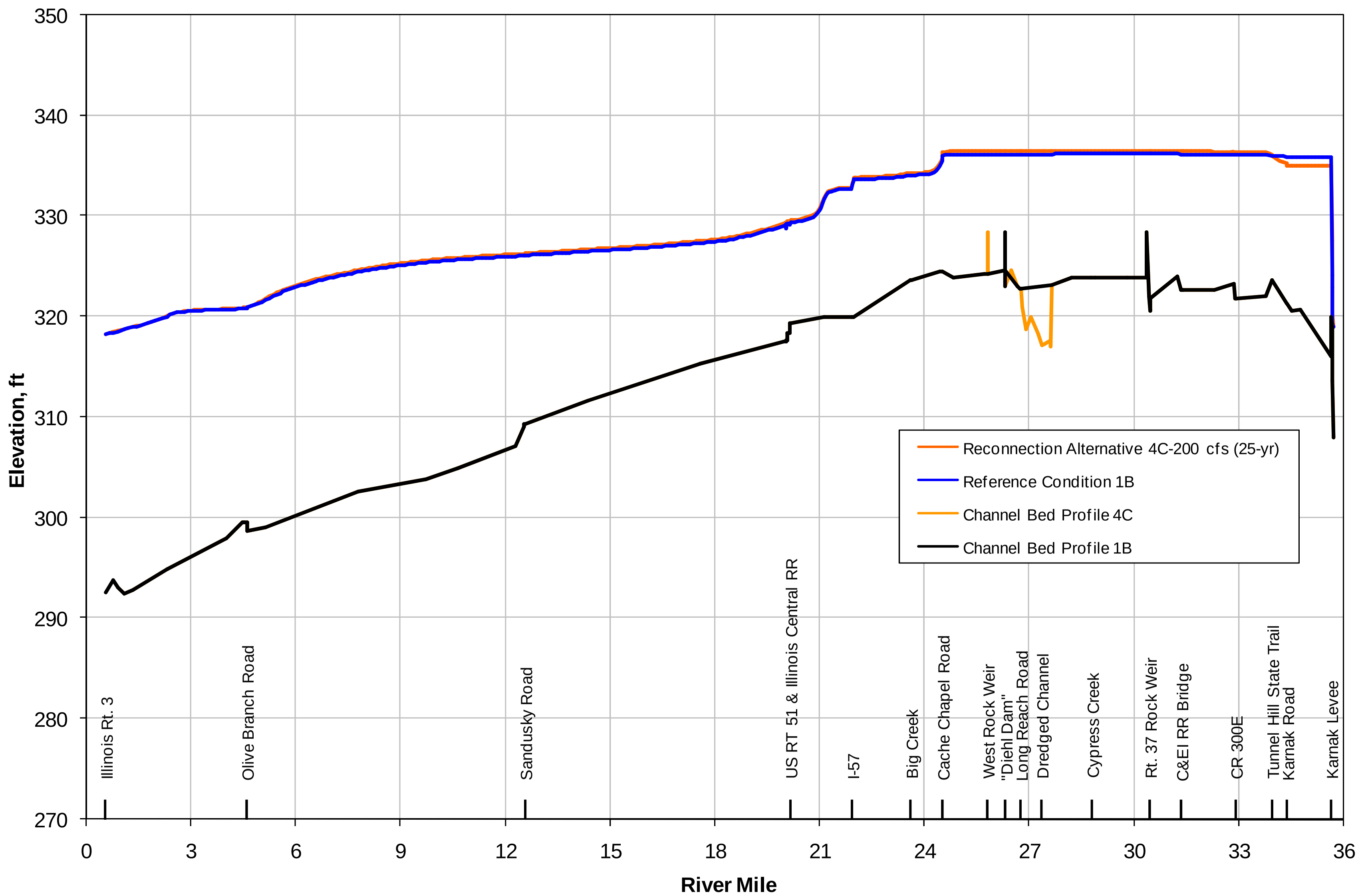


Figure 4-38. Comparison of 25-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

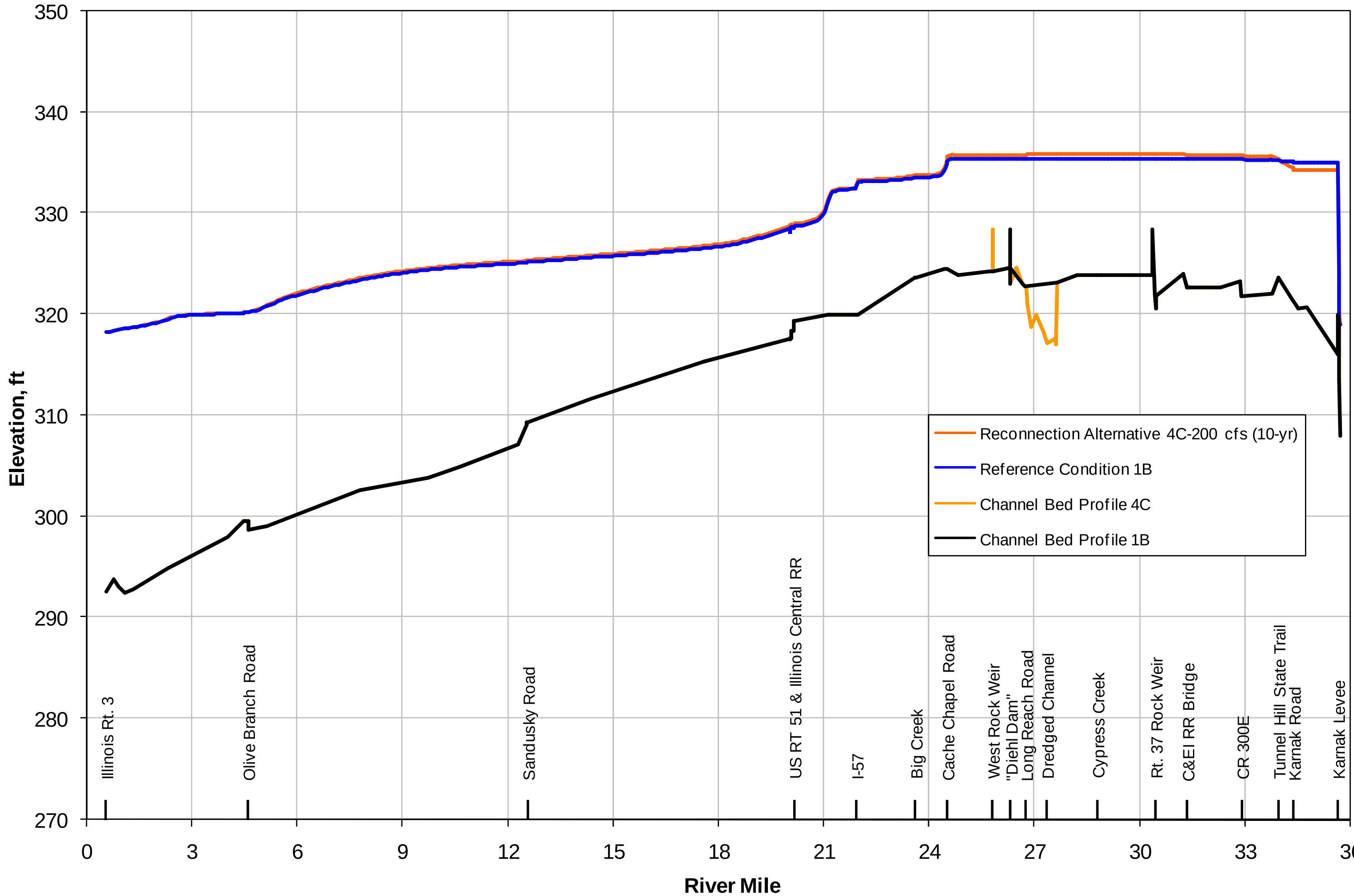


Figure 4-39. Comparison of 10-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

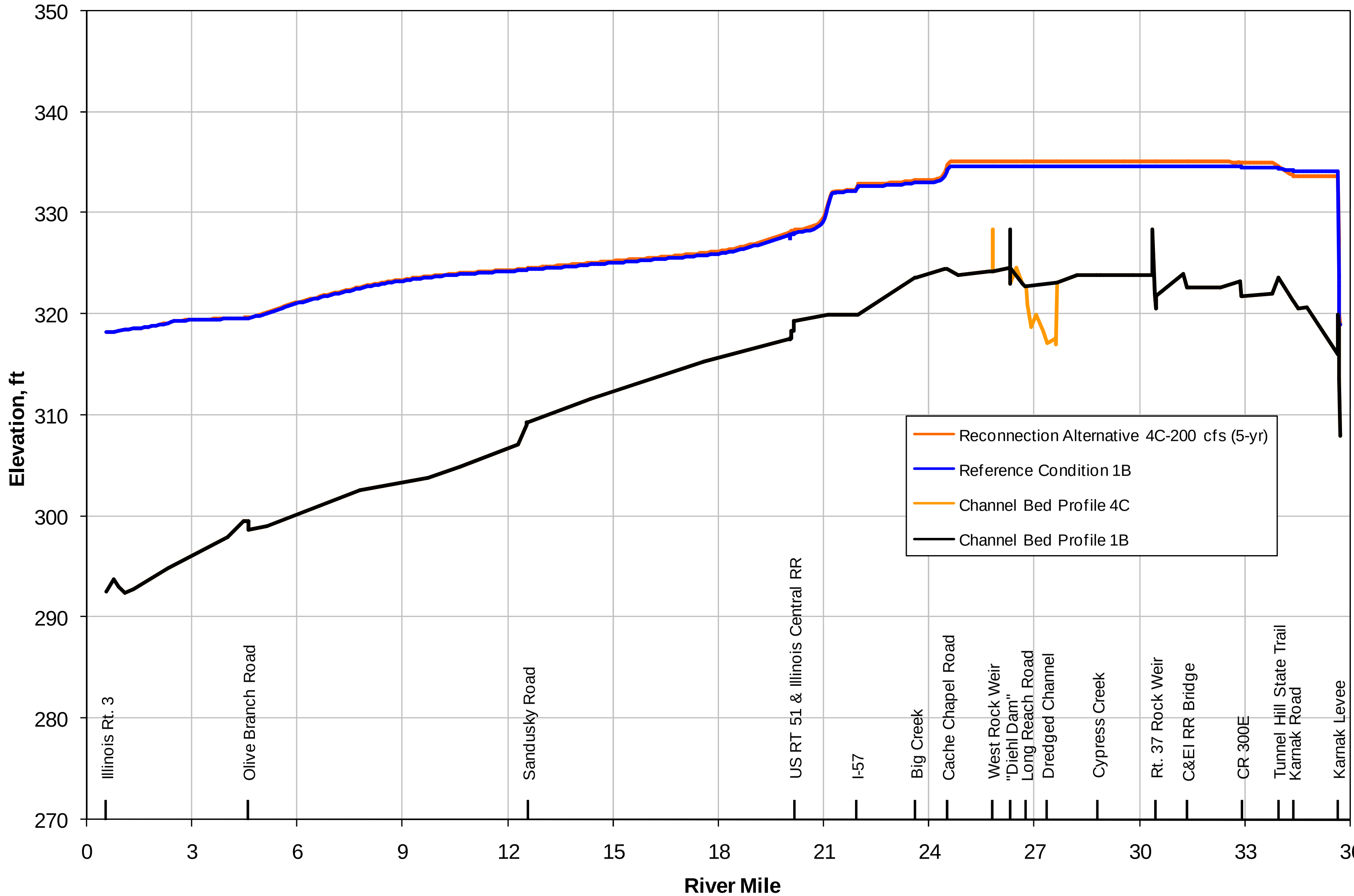


Figure 4-40. Comparison of 5-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

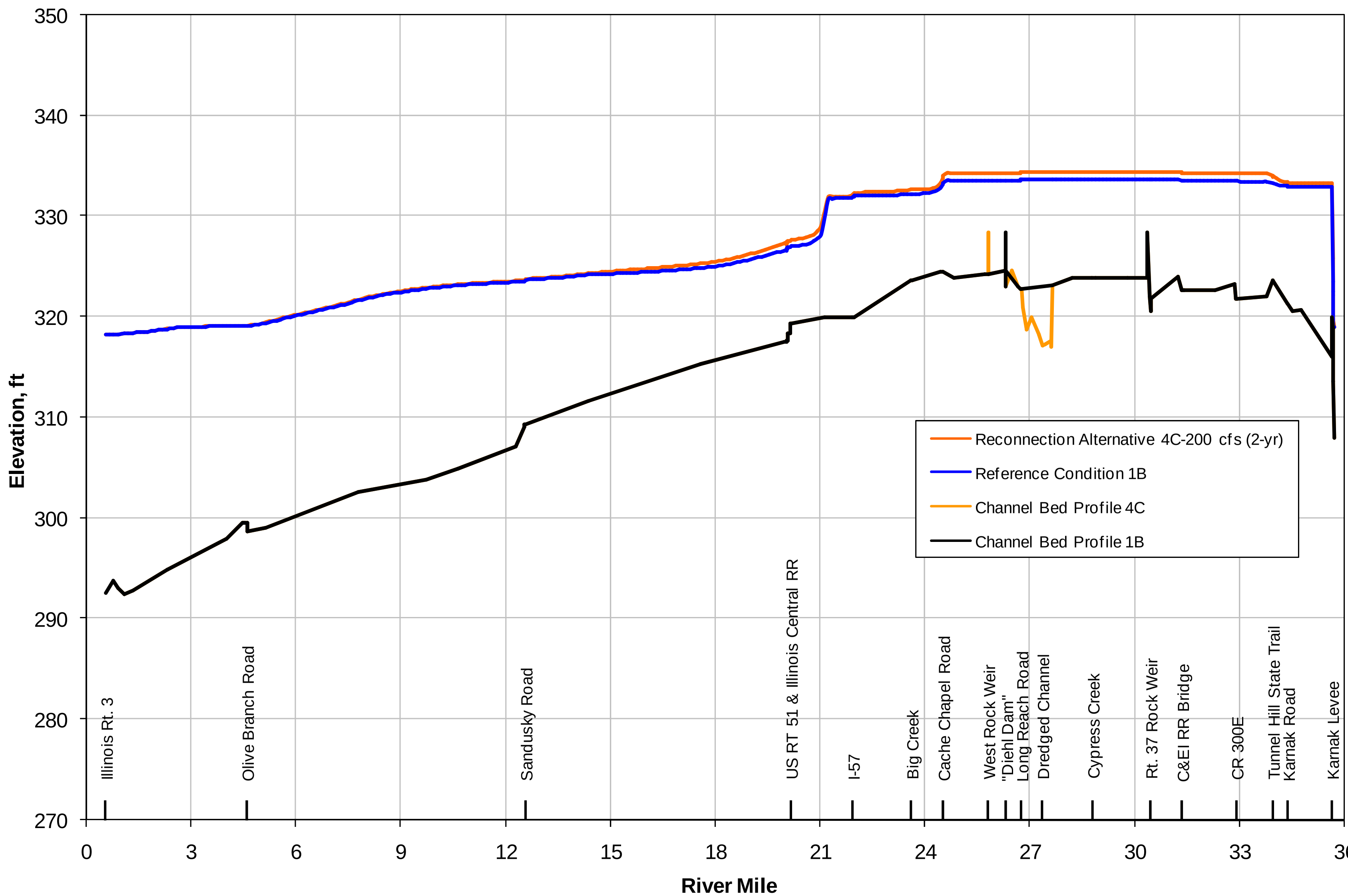


Figure 4-41. Comparison of 2-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

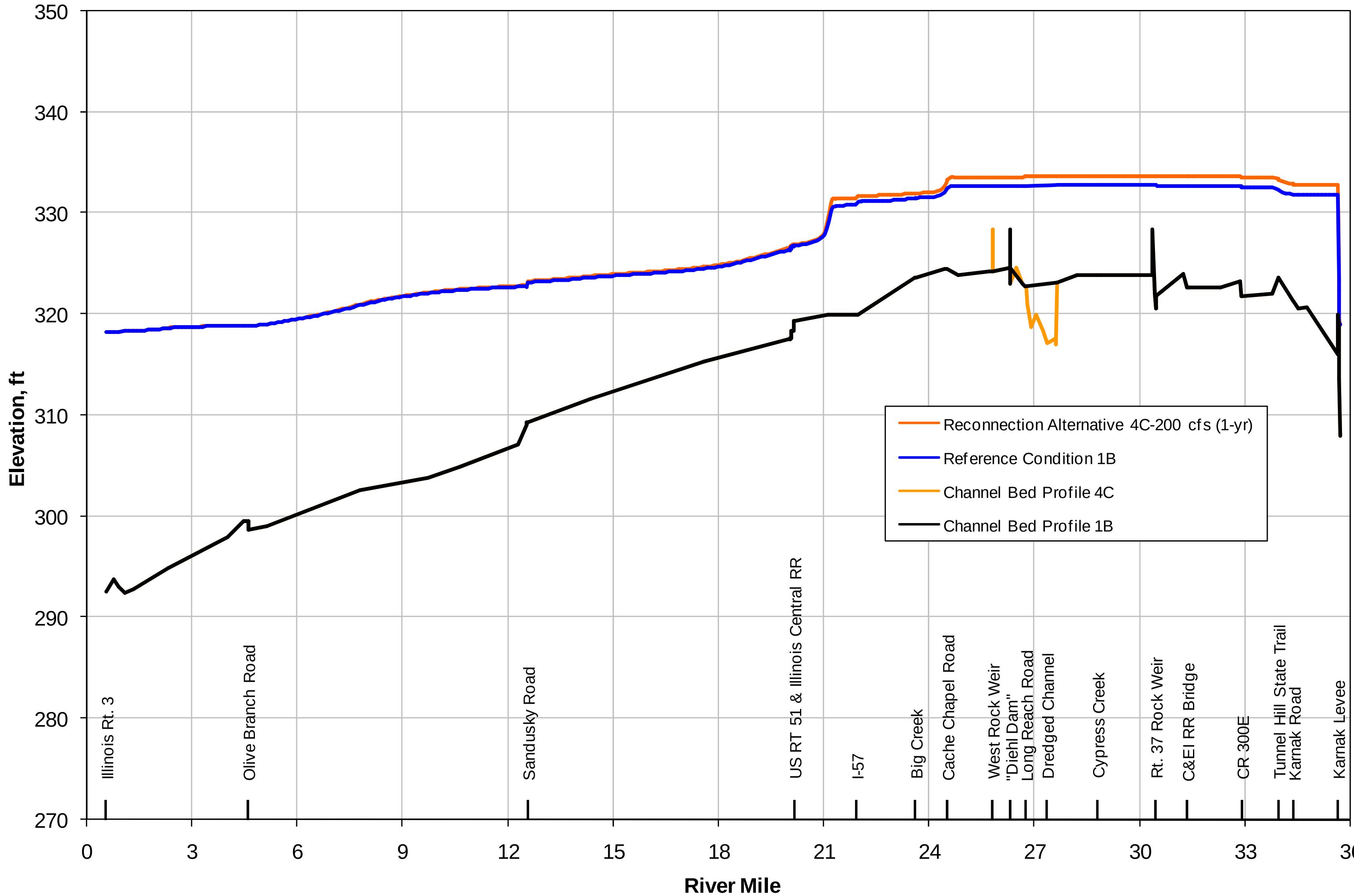


Figure 4-42. Comparison of 1-year flood profiles along Lower Cache River for reconnection alternative 4C with 200 cfs diversion from Upper Cache River with reference condition 1B

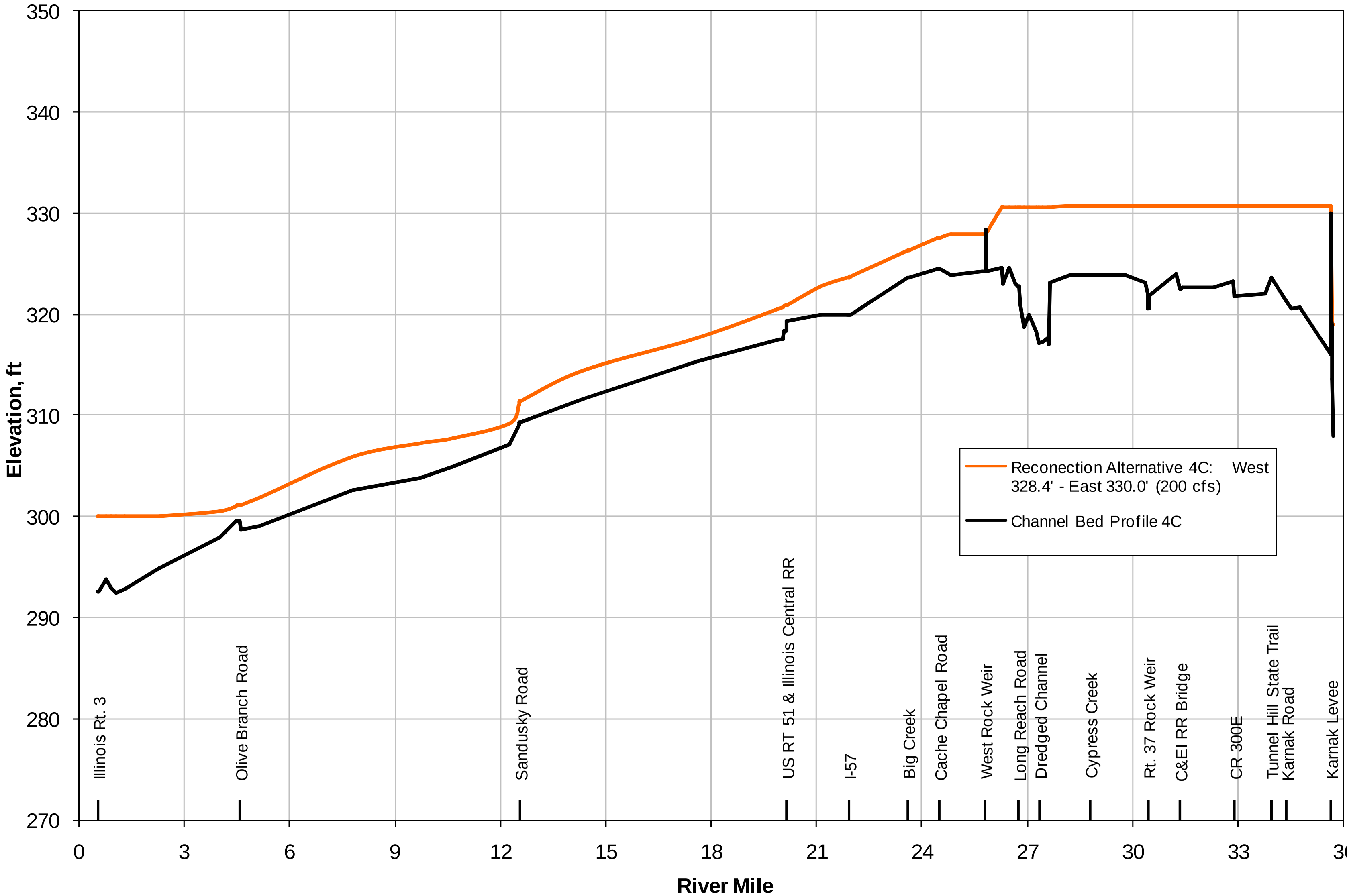


Figure 4-43. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 328.4 feet, and 200 cfs diversion)

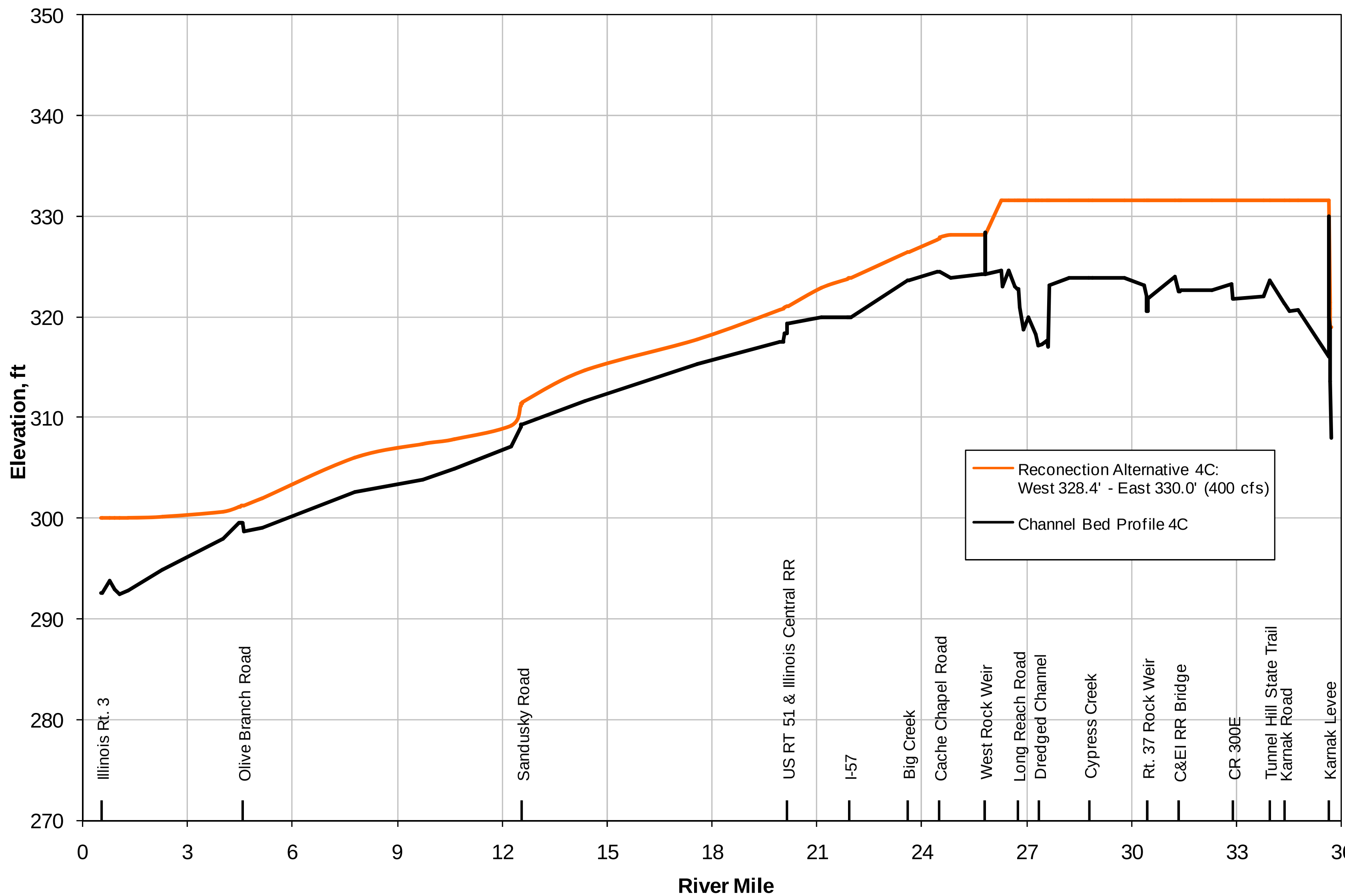


Figure 4-44. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 328.4 feet, and 400 cfs diversion)

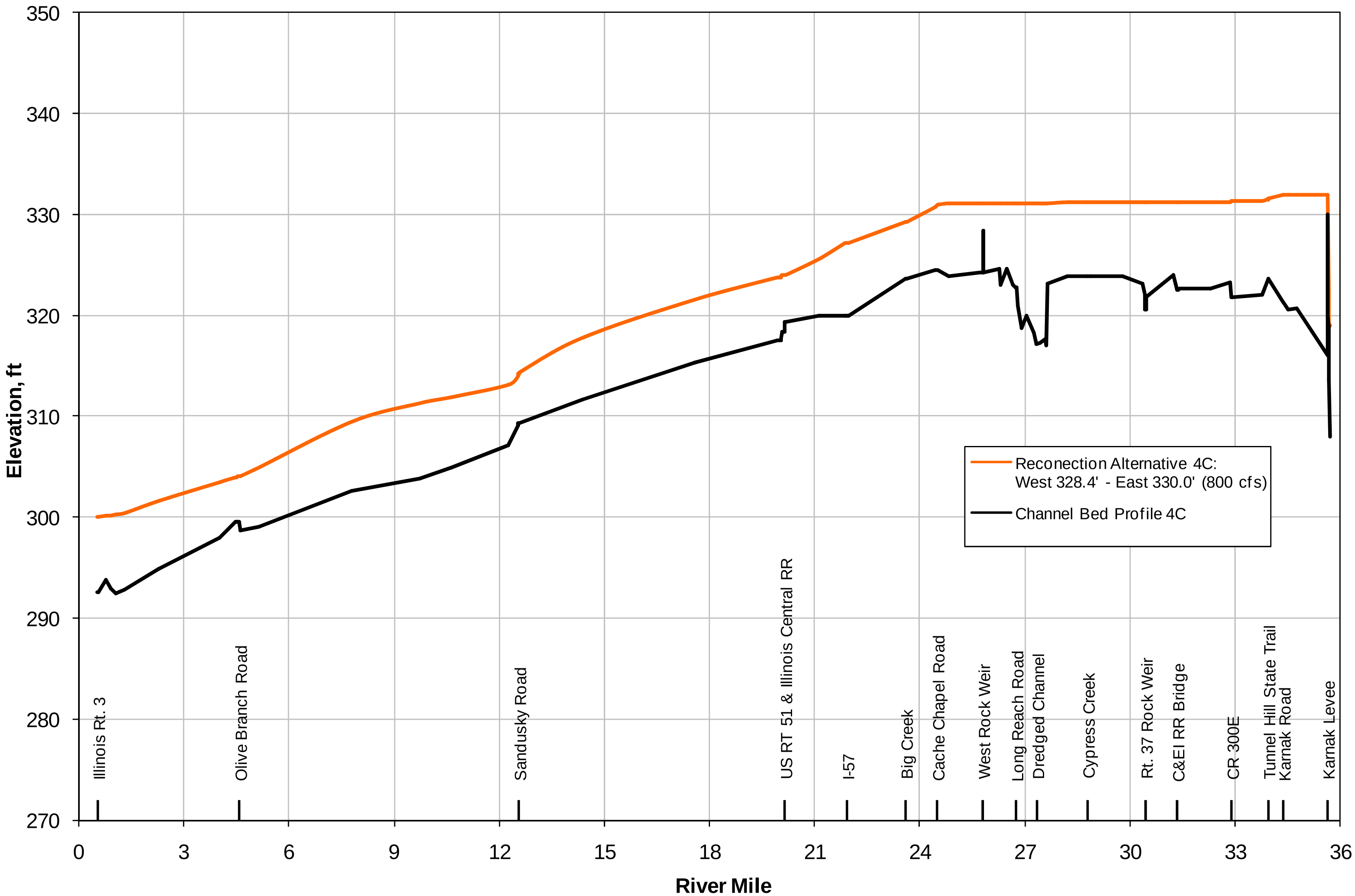


Figure 4-45. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 328.4 feet, and 800 cfs diversion)

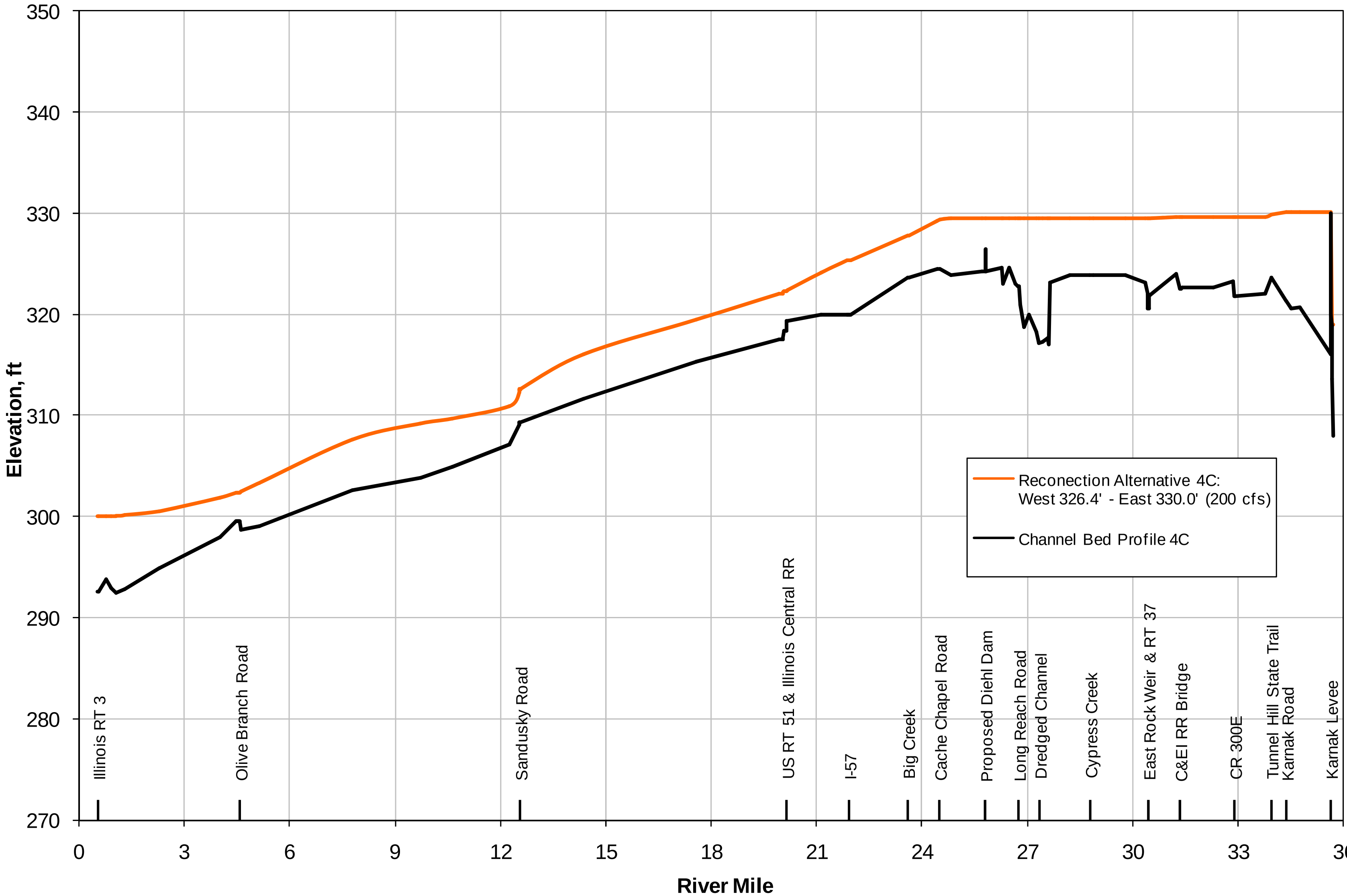


Figure 4-46. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 326.4 feet, and 200 cfs diversion)

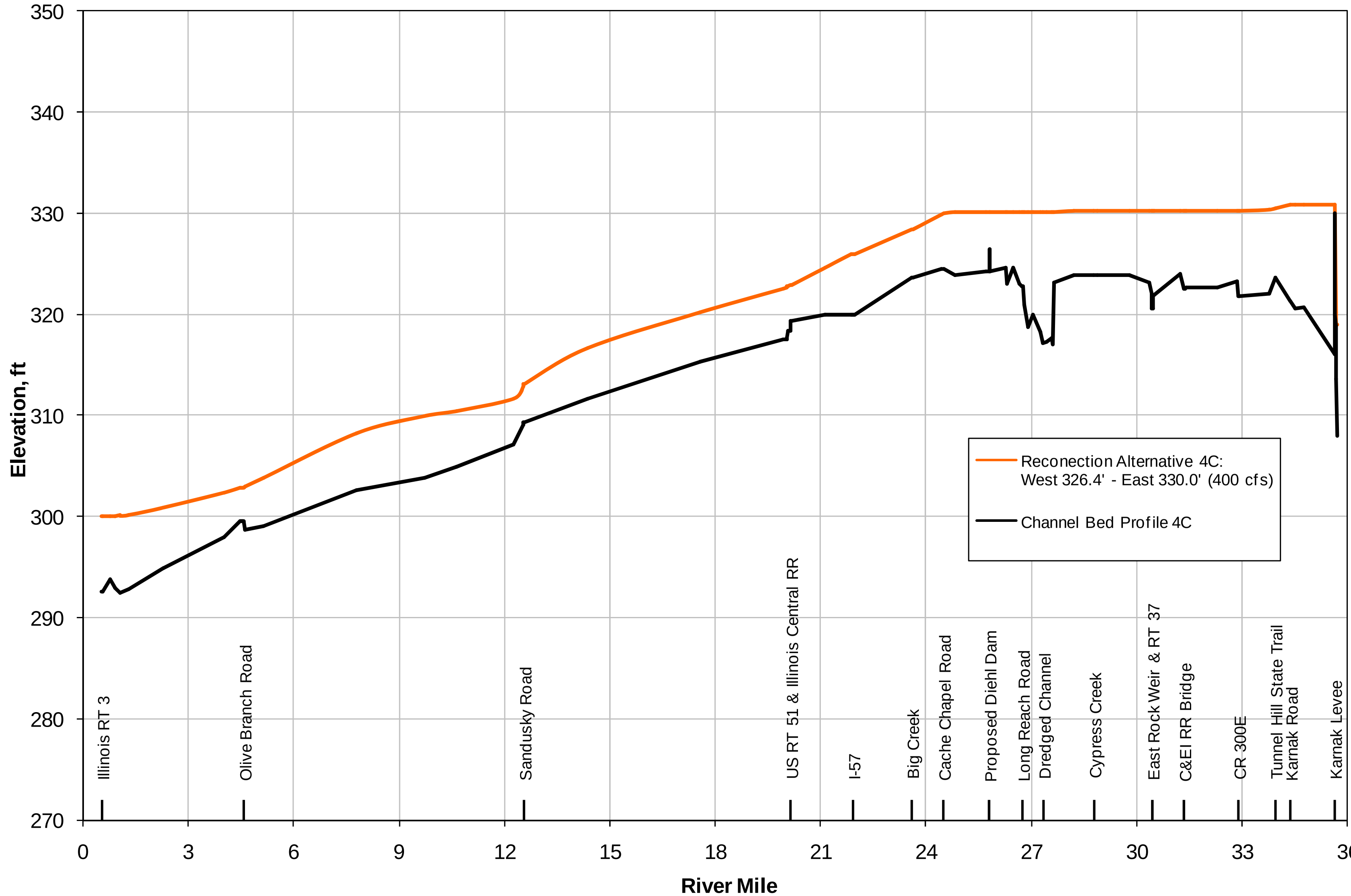


Figure 4-47. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 326.4 feet, and 400 cfs diversion)

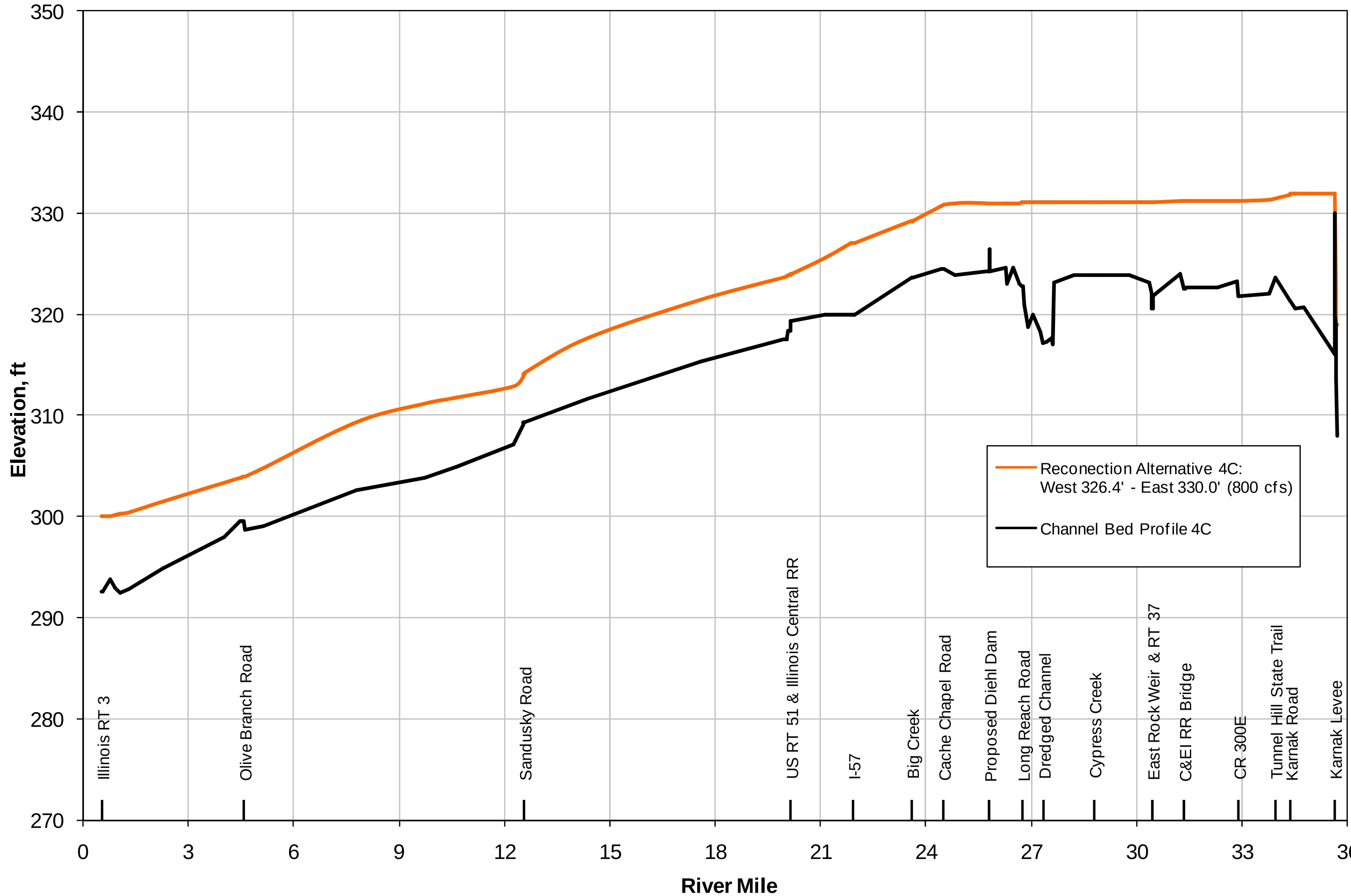


Figure 4-48. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 326.4 feet, and 800 cfs diversion)

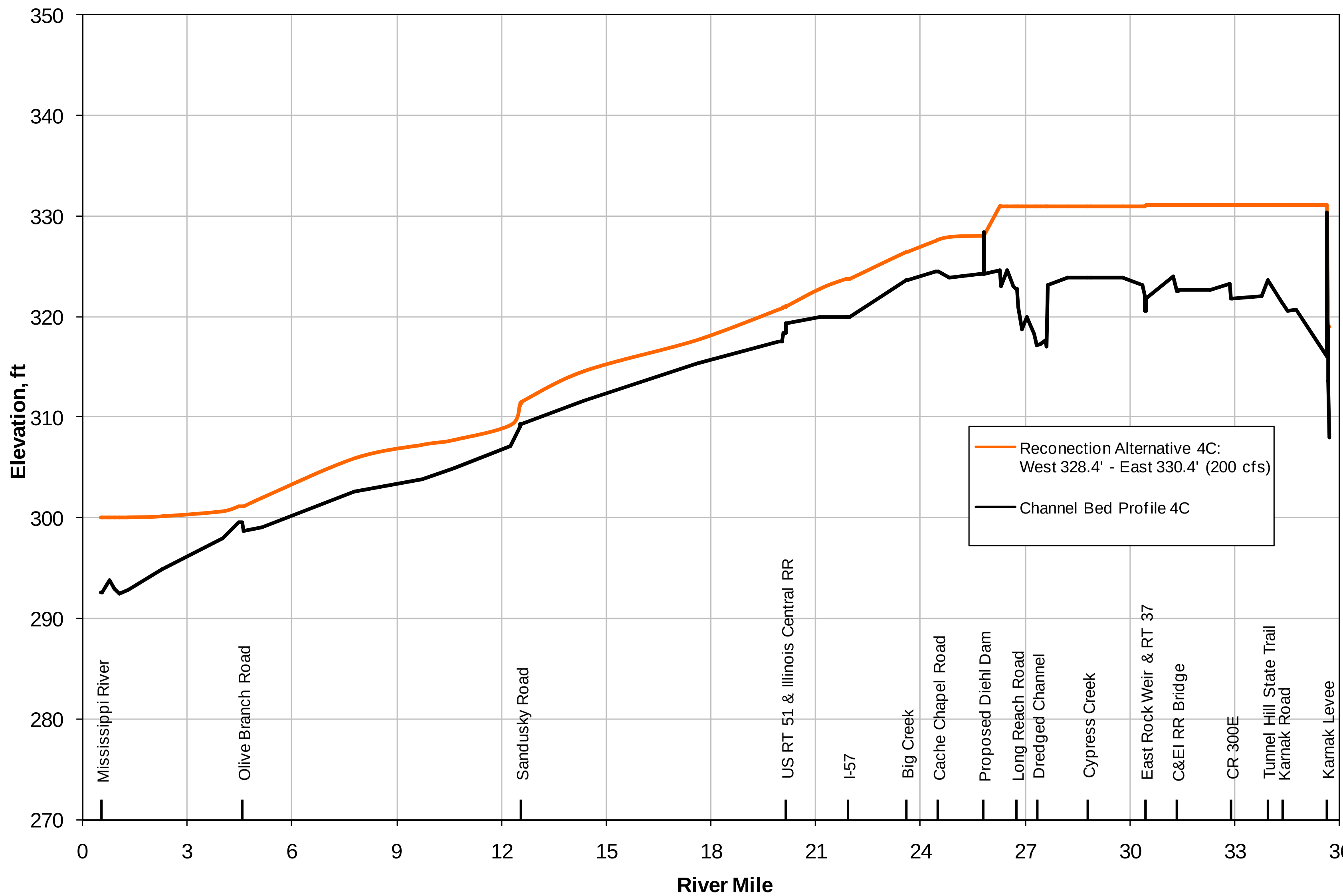


Figure 4-49. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 328.4 feet, and 200 cfs diversion)

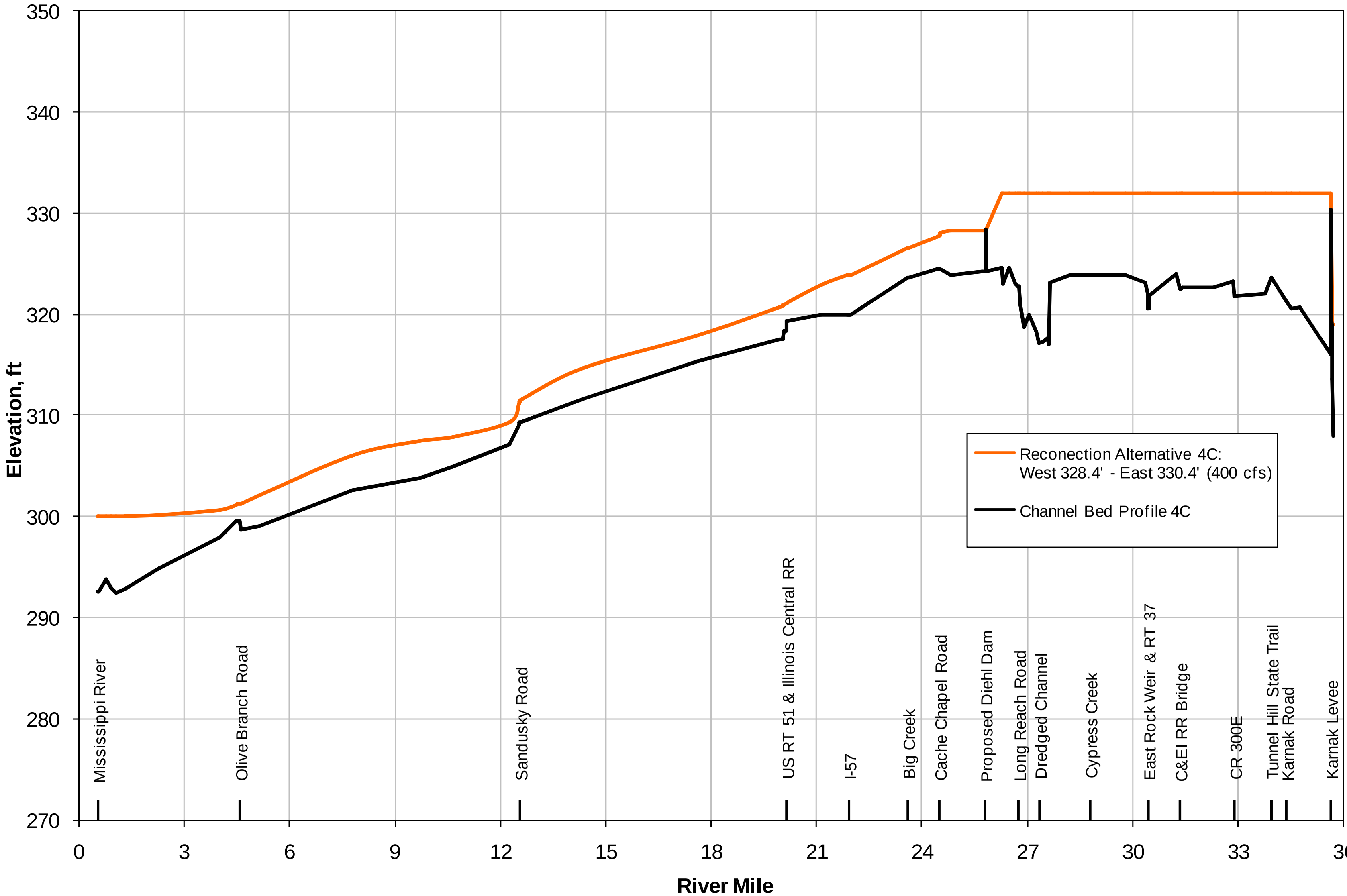


Figure 4-50. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 328.4 feet, and 400 cfs diversion)

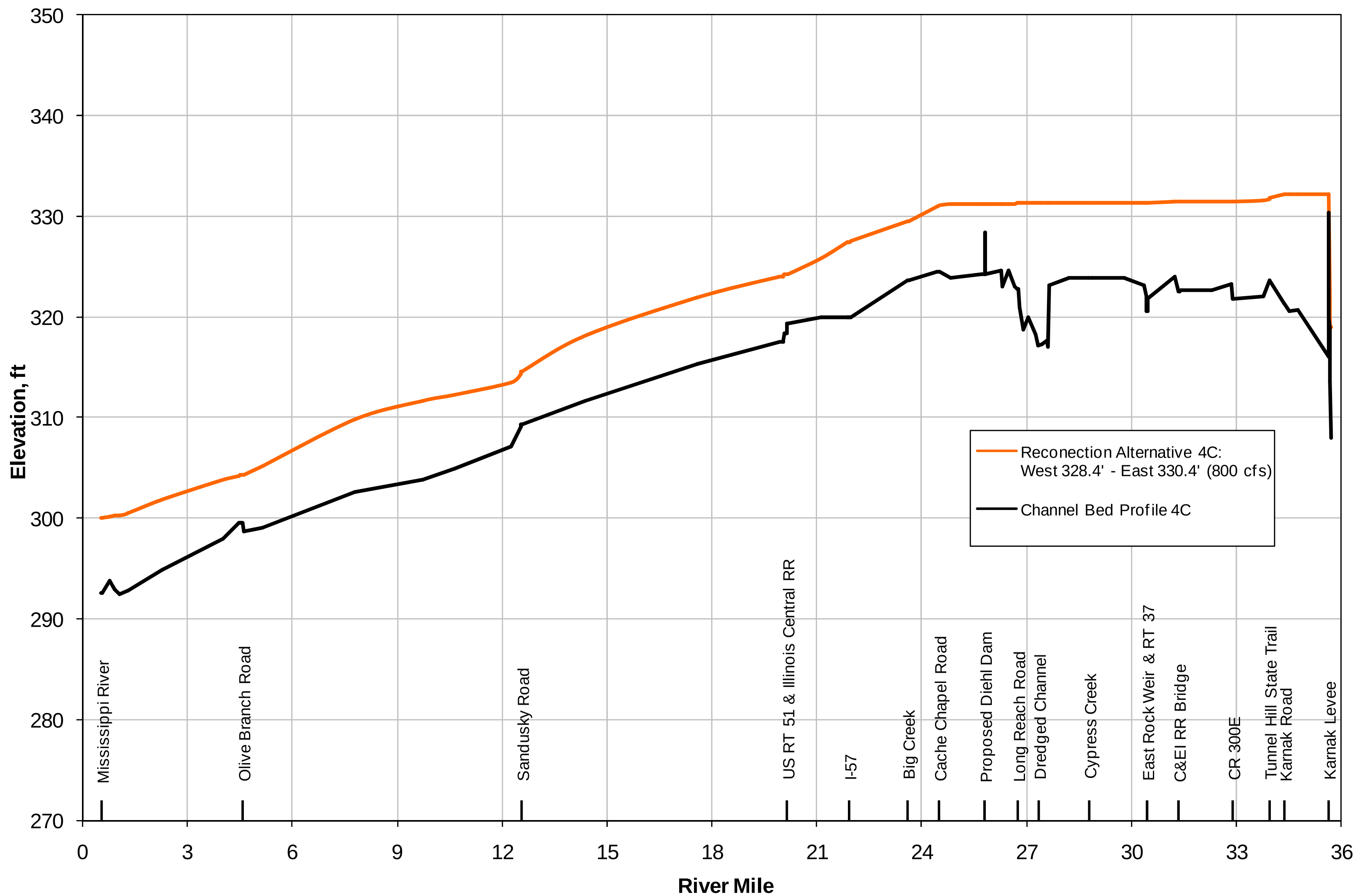


Figure 4-51. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 328.4 feet, and 800 cfs diversion)

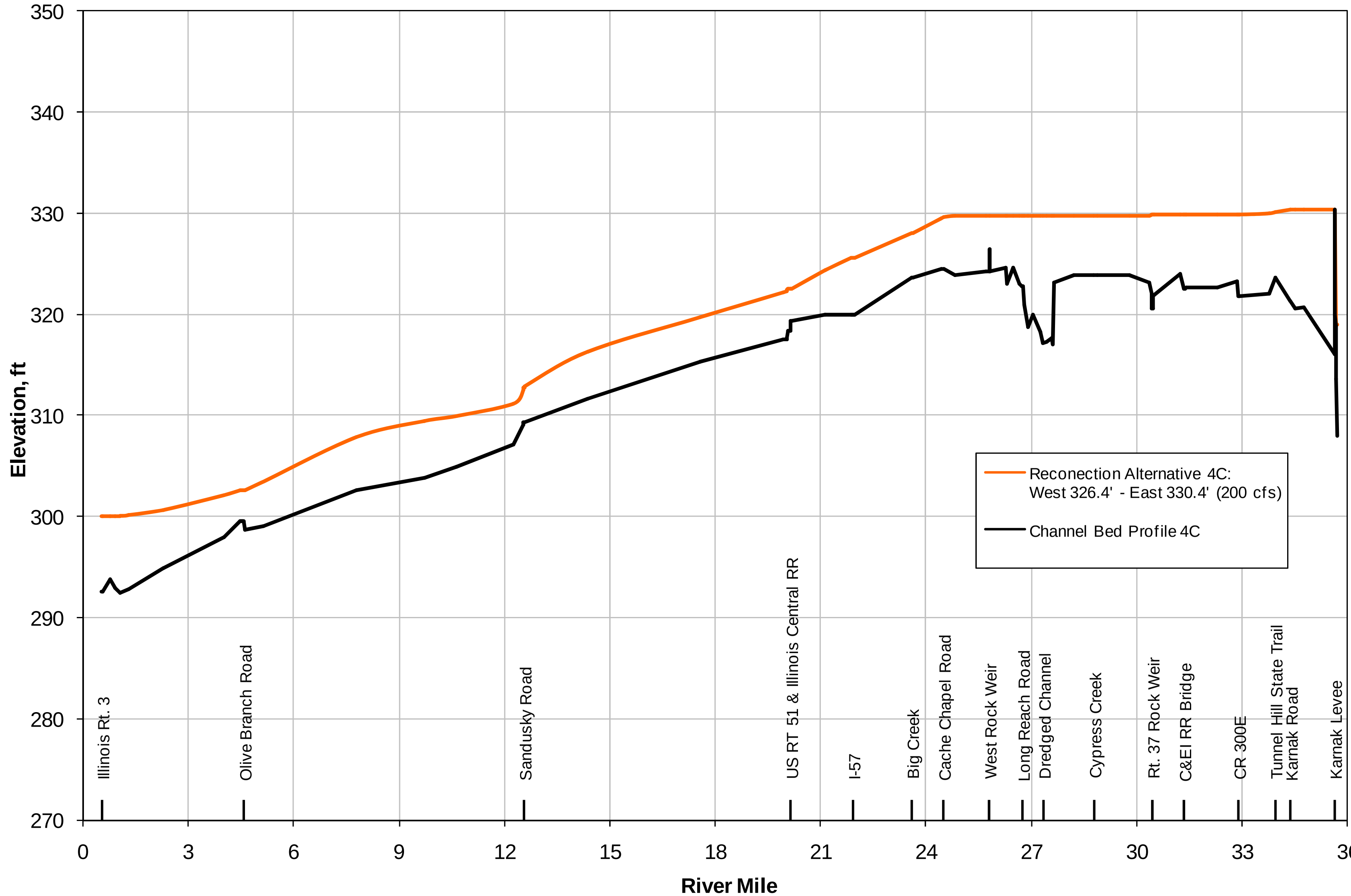


Figure 4-52. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 326.4 feet, and 200 cfs diversion)

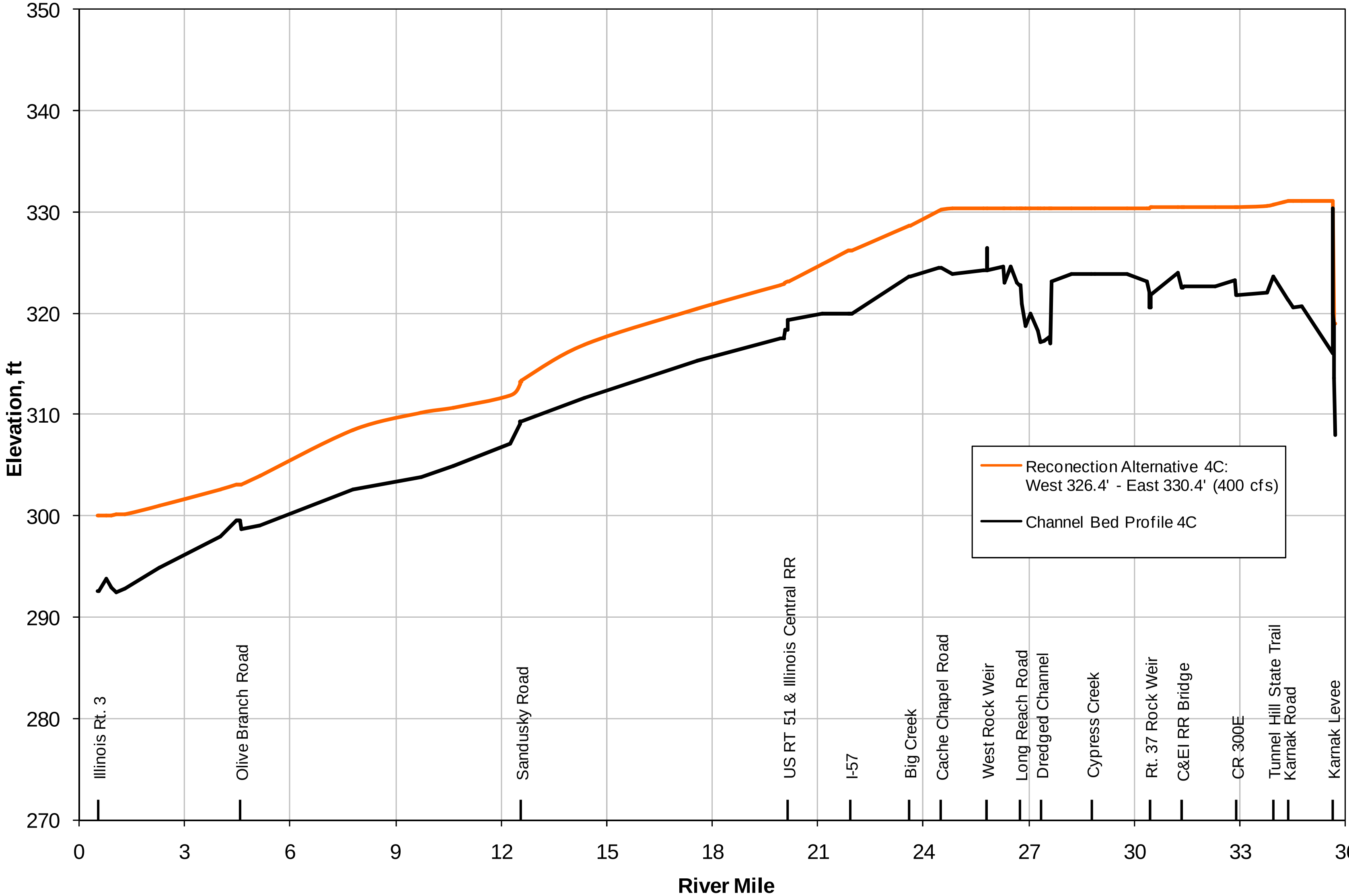


Figure 4-53. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 326.4 feet, and 400 cfs diversion)

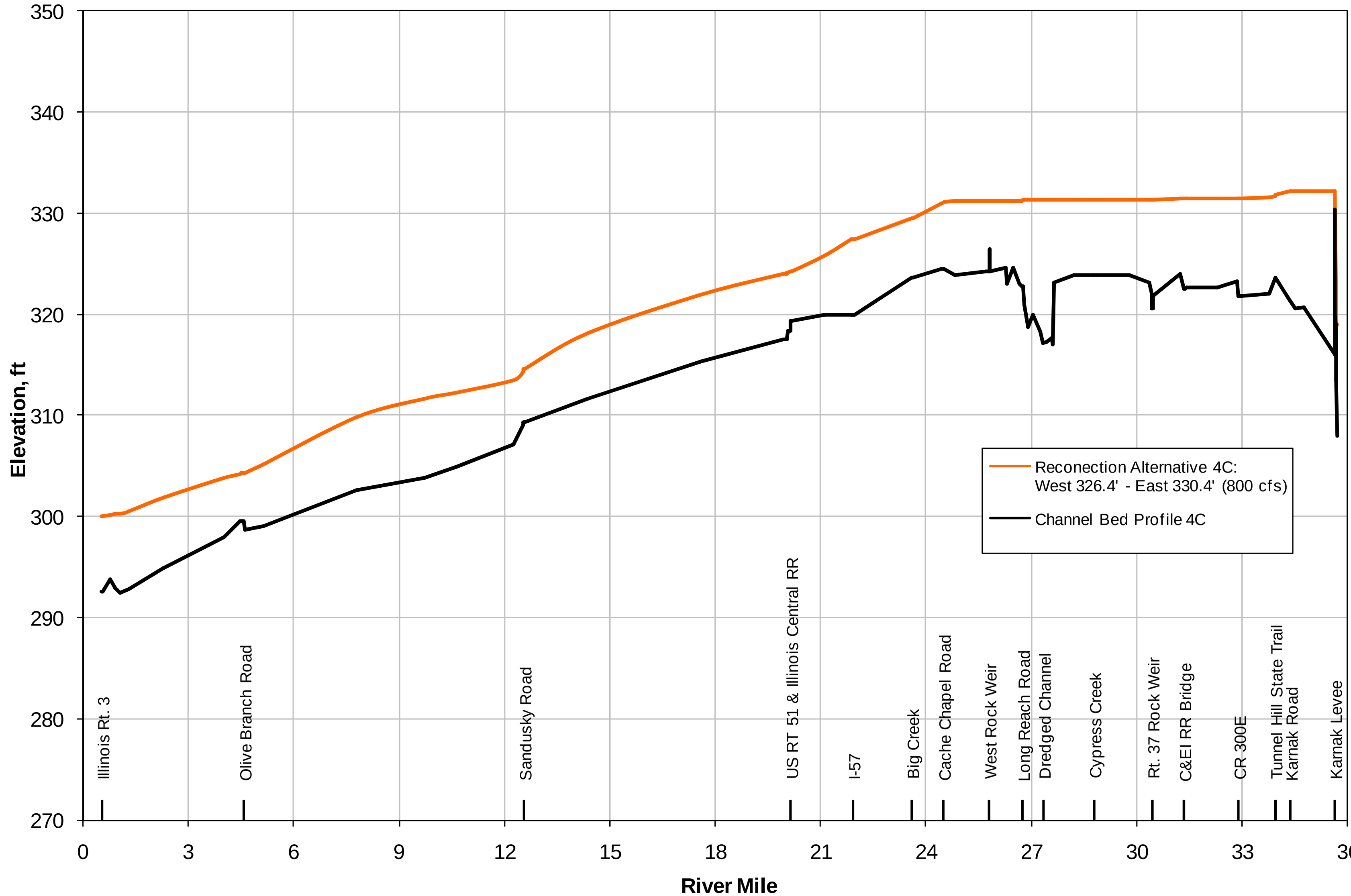


Figure 4-54. Moderate flow water surface profile in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 326.4 feet, and 800 cfs diversion)

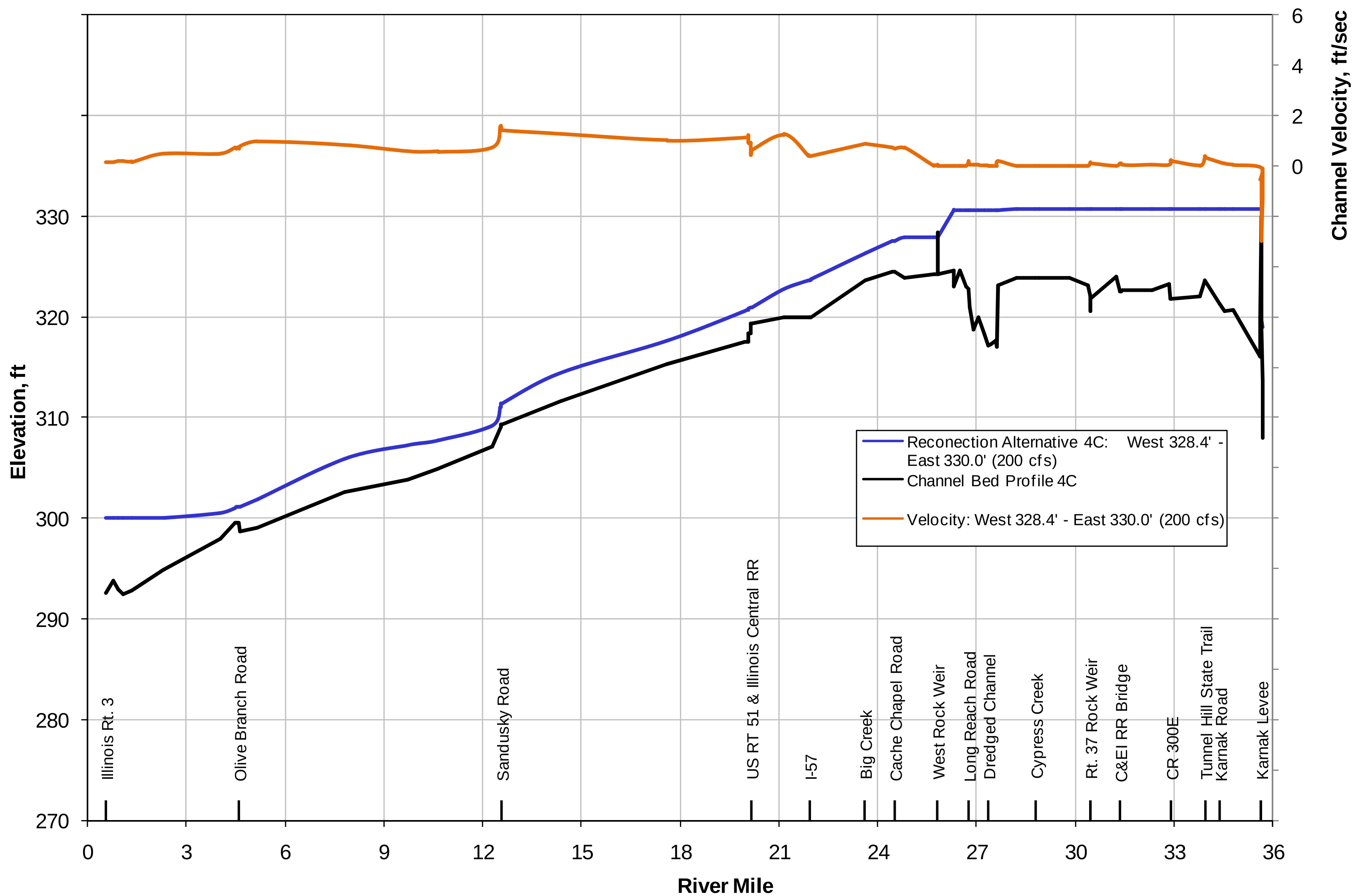


Figure 4-55. Average channel velocities in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 328.4 feet, and 200 cfs diversion)

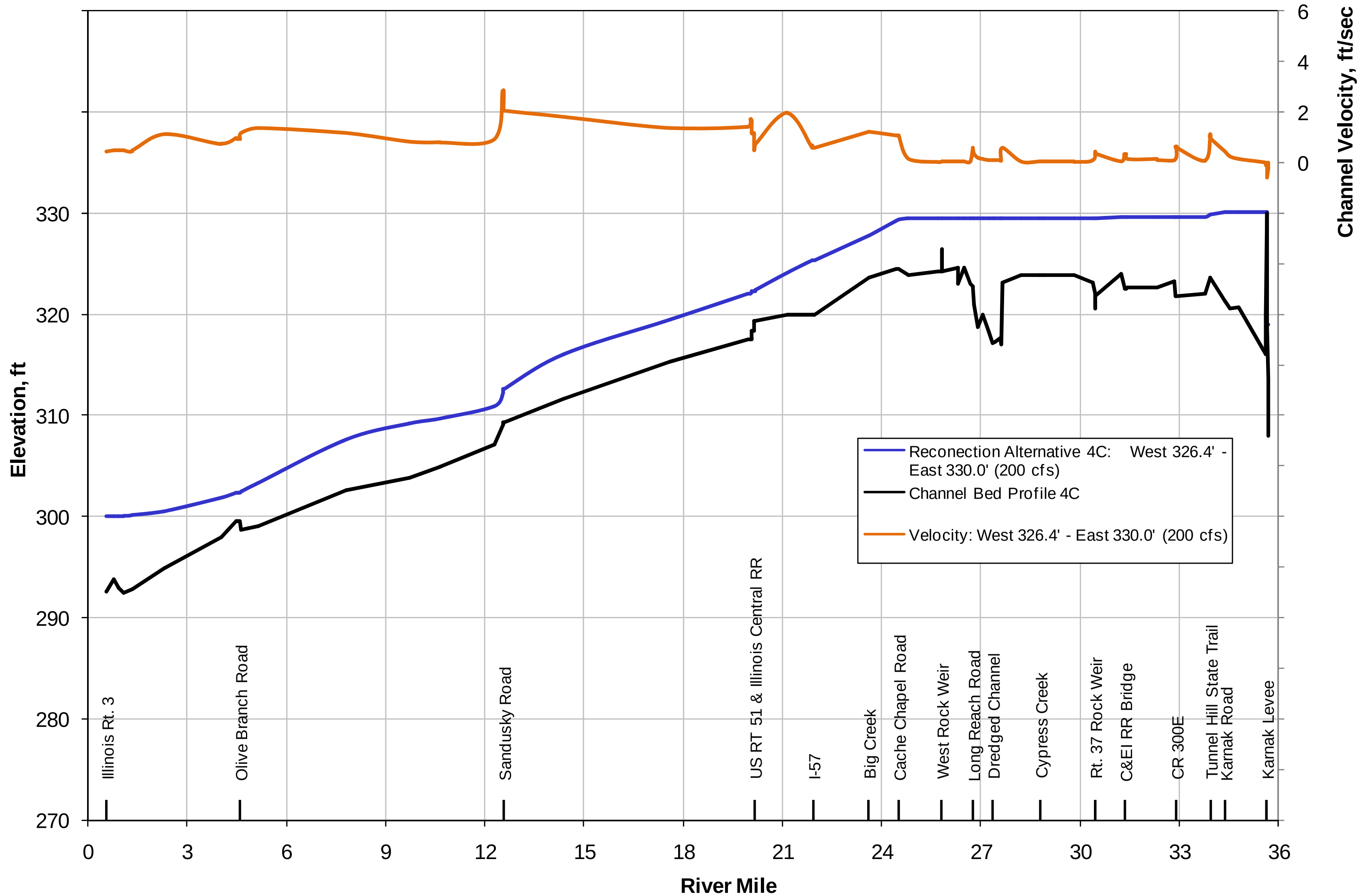


Figure 4-56. Average channel velocities in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.0 feet, West Rock Weir at 326.4 feet, and 200 cfs diversion)

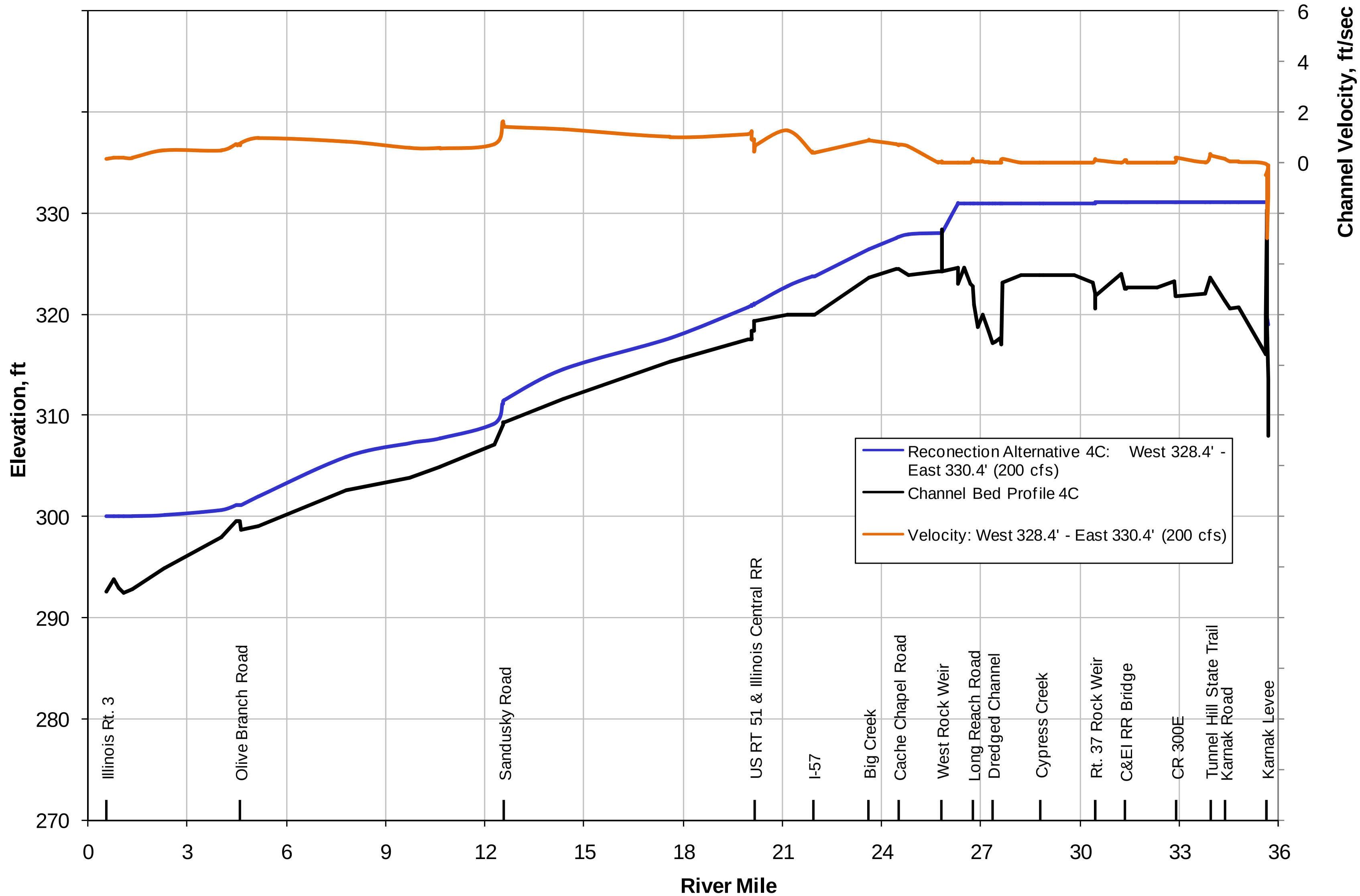


Figure 4-57. Average channel velocities in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 328.4 feet, and 200 cfs diversion)

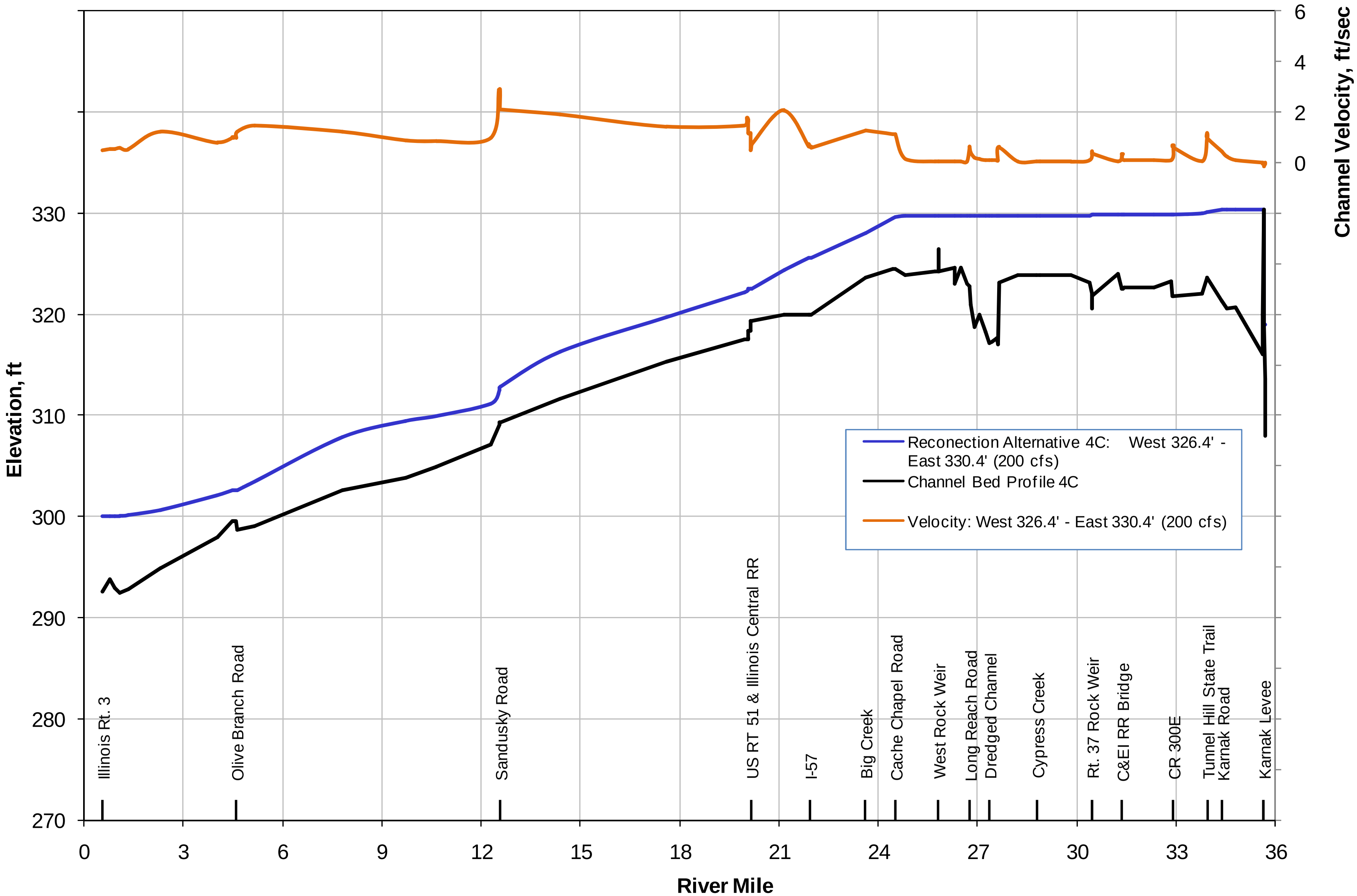


Figure 4-58. Average channel velocities in Lower Cache River with reconnection to Upper Cache River (scenario 4C, with stop log at East Outlet Structure set at 330.4 feet, West Rock Weir at 326.4 feet, and 200 cfs diversion)

Chapter 5. Summary and Conclusions

Hydrology and hydraulics of the Lower Cache River were investigated intensively by updating hydrologic and hydraulic models previously developed by the ISWS and the USACE, St. Louis District.

The HEC-HMS model was used to simulate rainfall-runoff processes for the tributary watersheds to the Lower Cache River. The hydrologic model, HEC-HMS was developed by the St. Louis District based on an earlier HEC-1 model previously developed by the ISWS. The present model was updated by calibration and validation with recently collected ISWS hydrologic data. The model was used to compute runoff from tributary watersheds for 1- to 100-year storm events. Outputs from the HEC-HMS model for the different storm events then were used as inputs to the hydraulic model, UNET. The UNET model for the Lower Cache River initially was developed by the St. Louis District, and the ISWS previously had used the model for a research project on Big Creek. The UNET model, a one-dimensional unsteady flow dynamic wave routing model, is capable of modeling the complex hydraulics of the Lower Cache River with changing flow directions over time. The UNET model was used to route flows through the Lower Cache River under different storm events and boundary conditions at the east and west boundaries.

The two models then were used to evaluate all scenarios outlined in Table 4-1 in four categories: 1) reference/base condition (prior to levee breach); 2) current condition (with levee breach); 3) future alternatives; and 4) future alternatives with reconnection. The reference/base condition refers to the condition when the hydrology of the Lower Cache River was controlled on the east end by Karnak Levee with two 48-inch gated culverts that prevented flow from Post Creek Cutoff into the Lower Cache River and by in-channel structures at Route 37 and "Diehl Dam" west of Long Reach Road. Because this condition was in existence for many years and had been agreed to by the drainage district and State of Illinois as acceptable drainage and water level management in the Lower Cache River, it was used as a reference for all other conditions and alternatives. The current condition refers to conditions as they are now where a major change from the reference/base condition is the breach at Karnak Levee and the absence of the two 48-inch culverts. The current condition will allow floodwaters from Post Creek Cutoff to flow back into the Lower Cache River. Both "Diehl Dam" and Route 37 Rock Weir are assumed to be in place. Future alternatives refer to management alternatives under consideration by the JVP. The two main features include moving "Diehl Dam" 2,800 feet west of its current location and installation of an East Outlet Structure with stop logs in front of three 72-inch gated culverts through Karnak Levee. This outlet structure will maintain low water elevations at desirable levels, allow increased outflow to Post Creek Cutoff during flood events, and prevent flow from Post Creek Cutoff into the Lower Cache River. Partial reconnection alternatives refer to future alternatives that re-establish the connection between the Upper and Lower Cache Rivers by diverting some flow from the Upper Cache River into the Lower Cache River. Under each of these four major categories, several different scenarios with different combinations of boundary conditions were evaluated.

For the reference/base condition, 100-year flood profiles were computed and mapped for eight conditions: 100-year flood in the Lower Cache River with other rivers at 10- or 2-year flood levels; both the Lower and Upper Cache Rivers under 100-year flood conditions, with the

Mississippi and Ohio Rivers at 10- or 2-year flood levels; all rivers under 100-year flood conditions; both the Upper Cache and Ohio Rivers under 100-year flood conditions, with other rivers at 2-year flood levels; only the Upper Cache River under 100-year flood conditions, with other rivers at 2-year flood levels; and only the Ohio River under 100-year flood conditions, with other rivers at 2-year flood levels. These results are used as reference to compare flooding under current and future conditions.

For current conditions, the major feature is the Karnak Levee breach. Different combinations of flood events and boundary conditions were evaluated and compared to the reference/base condition.

For future alternatives, the main features considered were moving "Diehl Dam" approximately 2,800 feet west of its current location and building an East Outlet Structure with stop log and larger culverts at Karnak Levee. Repairing the levee with the original 48-inch culverts and leaving the levee breach as is also were evaluated.

Reconnection alternatives evaluated diverting water from the Upper Cache River under the reference, current, and future alternatives. Diversion of 200, 400, and 800 cfs was considered, and a combination of elevations for the East Outlet Structure and West Rock Weir were evaluated.

Based on analysis of all of these scenarios with different combinations of flooding, structural changes, and boundary conditions, the findings can be summarized as follows:

1) The current condition exposes the Lower Cache River corridor, especially the eastern portion, including the community of Karnak, to more flooding during major floods, such as 100-year or greater floods from the Upper Cache and Ohio Rivers. However, the current condition improves flood drainage for some parts of the area during more frequent 1-, 2-, and 5-year floods.

2) Installing the East Outlet Structure with stop logs and three or more 72-inch culverts will lower flood elevations from the reference condition for the portion of the river east of Karnak Road Bridge, including the community of Karnak, because of increased outlet capacity of the larger culverts.

3) Moving "Diehl Dam" 2,800 feet from its current location under current conditions will increase the area flooded by the 100-year flood by only 8 acres. The additional acres flooded are distributed in small increments throughout the Lower Cache River floodplain. Water levels in the stream channel between current and proposed locations will be higher than the current condition during low- and moderate-flow conditions.

4) Partially reconnecting the Lower Cache River with the Upper Cache River by diverting some flow from the Upper Cache to the Lower Cache River will not increase flood elevations during major floods such as a 100-year flood but will raise flood elevations during more frequent 1- and 2-year floods. During low- and moderate-flow conditions, reconnection will not cause flooding, but will create slow-moving westerly flow in the Lower Cache River. More detailed cross-sectional surveys will be necessary to model low- and moderate-flow conditions more accurately, and the reconnection option should use an adaptive management approach that allows adjustments based on observations.

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Appendix A-1. Watershed Properties for HEC-HMS Model

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
Big Creek Watershed					
1	R1000W1010	0.057	544.024	2142.138	86
2	R100W1650	0.127	541.860	2966.890	90
3	R1010W2330	0.235	529.708	5517.548	86
4	R1020W2320	0.059	508.529	2852.688	86
5	R1030W1020	0.028	410.913	1854.950	89
6	R1040W2090	0.143	381.605	3584.222	92
7	R1050W2080	0.112	430.229	3504.455	91
8	R1060W1030	0.083	547.152	2970.250	83
9	R1070W2360	0.541	547.195	8379.337	83
10	R1080W2350	0.041	470.825	1782.313	77
11	R1090W1040	0.093	571.360	2939.180	90
12	R10W1480	0.132	538.713	4263.292	89
13	R1100W1780	0.015	547.673	1122.432	91
14	R110W1710	0.108	435.143	3957.902	86
15	R1110W1770	0.002	543.614	626.432	91
16	R1120W1050	0.029	604.548	1507.589	86
17	R1130W1440	0.150	595.880	4952.277	90
18	R1140W1470	0.001	587.273	456.810	85
19	R1150W1060	0.004	613.376	668.982	91
20	R1160W1460	0.471	616.544	7269.775	88
21	R1170W1450	0.024	617.137	1473.157	91
22	R1180W1070	0.044	587.694	2075.242	87
23	R1190W1520	0.037	564.561	1930.951	89
24	R1200W1490	0.007	563.624	1055.533	85
25	R120W120	0.536	498.114	11218.577	87
26	R1210W1080	0.096	540.007	2807.760	91
27	R1220W1570	0.264	459.317	6516.677	91
28	R1230W1560	0.104	521.926	3351.063	90
29	R1240W1090	0.093	564.898	3915.353	89
30	R1250W1660	0.002	499.339	370.318	91
31	R1260W1690	0.010	456.036	943.709	91
32	R1270W1100	0.016	550.982	1094.722	91
33	R1280W1680	0.466	561.417	5973.374	91
34	R1290W1670	0.004	554.552	832.866	91
35	R1300W1110	0.051	553.003	2323.240	91
36	R130W1790	0.007	406.167	819.011	86
37	R1310W1640	0.576	517.220	9286.642	90
38	R1320W1630	0.007	501.463	785.563	91
39	R1330W1120	0.036	520.599	1411.995	89
40	R1340W1600	0.036	505.652	1378.547	87

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
41	R1350W1590	0.124	508.596	3652.106	91
42	R1360W1130	0.006	546.230	832.866	87
43	R1370W1620	0.043	518.464	2289.789	90
44	R1380W1610	0.002	526.123	568.637	91
45	R1390W1140	0.037	501.206	1526.198	86
46	R1400W1750	0.037	383.857	2247.240	86
47	R140W140	0.584	583.430	9880.203	88
48	R1410W1740	0.026	477.489	2270.196	86
49	R1420W1150	0.093	520.824	2317.502	86
50	R1430W1720	0.163	455.233	4152.859	86
51	R1440W1730	0.061	492.029	2696.920	86
52	R1450W1160	0.032	485.387	1669.098	86
53	R1460W1800	0.017	414.041	1058.896	86
54	R1470W1830	0.012	473.147	1137.271	86
55	R1480W1170	0.007	520.012	537.565	86
56	R150W150	0.476	514.877	6320.329	89
57	R1510W1180	0.007	472.431	743.998	85
58	R1520W1820	0.446	504.667	6129.145	87
59	R1530W1810	0.004	462.182	523.710	86
60	R1540W1190	0.034	522.269	1529.561	91
61	R1550W1920	0.597	499.220	9096.442	88
62	R1560W1910	0.002	471.527	476.403	91
63	R1570W1200	0.003	476.124	637.912	86
64	R1580W1890	0.255	484.974	3984.221	86
65	R1600W1210	0.226	458.828	6238.590	80
66	R160W160	0.148	442.698	4337.321	82
67	R1610W1960	0.886	422.675	9388.958	85
68	R1620W1950	0.011	397.385	1203.187	93
69	R1630W1220	0.013	416.970	1049.794	90
70	R1640W2020	0.020	395.957	1777.559	93
71	R1650W2010	0.020	420.491	1907.995	89
72	R1660W1230	0.005	487.578	504.113	86
73	R1670W1860	0.196	479.117	4573.843	86
74	R1680W1850	0.003	458.320	626.432	86
75	R1690W1240	0.068	418.985	2648.630	73
76	R1700W2120	0.016	374.161	1236.635	93
77	R170W170	0.906	488.288	12116.951	89
78	R1710W2110	0.142	429.025	4817.494	75
79	R1720W1250	0.030	397.628	1226.139	71
80	R1730W2170	0.042	366.204	1880.285	81
81	R1740W2160	0.049	378.302	2460.399	90
82	R1750W1260	0.029	395.044	1659.997	77

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
83	R1760W2140	0.008	349.081	785.563	93
84	R1770W2150	0.009	374.476	1058.896	91
85	R1780W1270	0.021	391.000	1133.908	77
86	R180W180	0.273	609.507	5839.171	90
87	R1810W1280	0.025	405.181	1234.256	88
88	R1820W2290	0.622	363.021	7846.530	87
89	R1830W2280	0.143	364.300	4941.781	91
90	R1840W1290	0.014	456.152	1248.111	86
91	R1850W2470	0.034	411.112	1492.750	89
92	R1860W2460	0.004	420.339	774.086	86
93	R1870W1300	0.011	467.584	947.068	86
94	R1880W2390	0.321	480.341	5949.027	84
95	R1890W2440	0.005	466.592	1063.649	86
96	R1900W1310	0.016	378.951	838.607	85
97	R190W190	0.060	414.573	2426.947	86
98	R1910W2260	0.157	351.177	4123.177	93
99	R1920W2250	0.032	356.860	1961.036	89
100	R1930W1320	0.005	420.275	813.273	93
101	R1940W2530	0.003	342.519	409.507	93
102	R1950W2520	0.164	308.398	5596.911	91
103	R1960W1330	0.040	451.311	1819.124	86
104	R1990W1340	0.033	489.971	1616.053	76
105	R2000W2400	0.055	466.760	2989.846	86
106	R200W1840	0.081	400.262	3298.018	86
107	R2010W2430	0.005	448.899	854.838	86
108	R2020W1350	0.014	476.715	1000.113	86
109	R2030W2420	0.049	460.374	2264.457	86
110	R2050W1360	0.017	575.130	1604.574	86
111	R2080W1370	0.033	491.797	1496.112	86
112	R20W1580	0.146	494.617	3665.961	86
113	R210W210	0.266	385.220	5572.561	79
114	R2110W1380	0.010	503.739	1122.432	86
115	R2120W1990	0.154	493.153	3370.656	77
116	R2130W1980	0.030	483.805	2258.719	86
117	R2150W2580	0.236	501.618	5364.159	86
118	R2160W2650	0.023	427.164	1490.371	86
119	R2170W1400	0.060	435.618	1850.196	66
120	R2180W2500	0.010	334.645	793.680	69
121	R2190W2490	0.013	401.986	1261.966	66
122	R2200W1410	0.043	446.879	2244.864	67
123	R220W220	0.258	532.809	5987.229	91
124	R2210W2600	0.037	432.371	1785.676	79

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
125	R2220W2560	0.005	413.602	899.765	72
126	R2230W1420	0.019	601.396	983.879	86
127	R2240W2900	0.245	590.255	4682.307	86
128	R2250W2890	0.001	566.330	336.869	86
129	R2260W1510	0.113	602.537	2727.990	91
130	R2270W1540	0.658	608.168	7746.182	90
131	R2280W1530	0.004	565.131	646.029	91
132	R2290W1700	0.011	600.755	880.172	91
133	R2300W1870	0.019	558.733	1493.734	91
134	R230W2040	0.297	453.657	5303.001	87
135	R2310W1930	0.048	533.714	1927.588	90
136	R2320W2030	0.015	451.856	1000.113	91
137	R2330W2060	0.093	457.351	2821.615	87
138	R2340W2050	0.003	441.679	690.953	90
139	R2350W2180	0.229	410.341	4573.843	79
140	R2360W2190	0.015	429.042	1136.287	86
141	R2390W2200	0.010	426.456	813.273	66
142	R2400W2230	0.007	403.326	1147.763	86
143	R240W1760	0.475	569.370	10141.072	91
144	R2410W2220	0.159	375.778	3542.657	74
145	R2420W2300	0.033	409.600	1643.763	86
146	R2430W2370	0.098	561.639	2869.902	86
147	R2440W2590	0.159	445.723	4970.886	86
148	R2450W2620	0.534	476.977	6985.951	86
149	R2460W2610	0.005	391.278	629.795	86
150	R2470W2630	0.044	503.238	1925.213	86
151	R2480W2640	0.065	524.718	2386.777	86
152	R2490W1390	0.003	488.244	746.373	86
153	R2500W2660	0.150	410.104	3512.568	86
154	R250W250	0.002	465.878	334.491	91
155	R2510W2680	0.030	494.843	1579.242	86
156	R2540W2690	0.007	504.350	618.316	86
157	R2550W2720	0.055	479.119	2158.372	83
158	R2560W2710	0.008	492.158	693.332	85
159	R2570W2730	0.031	485.637	1459.302	77
160	R2580W2780	0.003	424.619	498.375	66
161	R2590W2750	0.001	437.458	309.159	66
162	R2600W2770	0.018	523.079	1100.460	72
163	R260W260	0.451	497.807	7063.342	90
164	R2620W2790	0.123	468.503	3709.904	75
165	R2630W2810	0.119	558.176	3000.338	82
166	R2650W2840	0.114	483.237	3685.554	85

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
167	R2660W2830	0.116	483.942	3771.062	86
168	R2670W2860	0.072	456.692	2601.327	74
169	R2680W2850	0.010	445.537	947.068	79
170	R2690W2870	0.017	551.124	1058.896	86
171	R270W270	0.832	545.631	11624.721	88
172	R2720W2910	0.014	611.465	1019.706	86
173	R2730W2920	0.009	537.223	952.810	73
174	R280W1940	0.075	390.987	2783.413	93
175	R290W1970	1.229	394.025	9558.583	86
176	R300W300	0.409	482.493	8247.917	89
177	R30W1430	0.058	600.403	2523.935	85
178	R310W310	0.057	477.870	3421.322	88
179	R320W2880	0.142	549.514	3668.336	86
180	R330W330	0.371	517.764	5885.490	87
181	R340W340	0.046	450.612	2328.978	78
182	R350W350	0.437	561.899	7072.443	86
183	R360W360	0.535	514.116	9346.408	86
184	R370W2000	0.869	397.543	13137.064	88
185	R380W2700	0.733	467.753	9096.032	85
186	R390W2070	0.022	345.720	1258.606	93
187	R400W2540	0.125	452.300	3878.132	84
188	R40W40	0.447	600.533	7425.953	90
189	R410W410	0.502	398.947	8225.948	87
190	R420W420	0.596	506.762	7551.632	83
191	R430W430	0.121	379.016	3780.163	92
192	R440W440	0.521	438.413	7977.947	82
193	R450W450	0.336	407.590	6798.126	87
194	R460W2340	0.219	503.335	4342.075	79
195	R470W2380	0.190	466.943	3909.612	86
196	R480W2740	0.310	417.464	6314.590	68
197	R490W2100	0.186	381.178	4320.103	90
198	R500W2480	0.851	397.903	10473.595	75
199	R50W1550	0.129	532.255	3341.962	86
200	R510W510	0.309	389.955	6635.226	79
201	R520W2130	0.213	377.438	5721.606	91
202	R530W530	0.335	491.715	6644.327	86
203	R540W540	1.010	416.916	11775.327	79
204	R550W2450	0.786	406.733	13328.658	87
205	R560W970	0.056	433.824	2061.384	86
206	R570W570	0.439	511.010	7764.791	84
207	R580W580	0.605	379.446	7772.908	84
208	R590W2310	0.088	474.115	3168.977	86

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
209	R600W2210	0.329	368.020	6195.634	81
210	R60W60	0.528	633.608	7416.442	87
211	R610W610	0.026	369.865	1384.285	90
212	R620W620	0.326	369.946	5787.521	90
213	R630W630	0.614	407.063	7340.445	84
214	R640W640	0.242	360.892	5913.200	86
215	R650W650	0.535	364.300	10384.727	88
216	R660W2270	0.008	342.519	997.734	93
217	R670W670	0.186	343.921	5571.987	93
218	R680W680	0.240	360.038	4863.406	75
219	R690W690	0.681	419.851	11500.026	89
220	R700W700	0.444	368.975	7105.314	93
221	R70W70	0.549	449.062	6918.067	84
222	R710W710	0.229	291.994	5957.144	89
223	R720W720	0.096	420.097	3345.325	86
224	R730W730	1.415	463.288	17177.111	82
225	R740W740	0.132	400.407	3900.104	86
226	R750W2510	0.089	334.079	3369.672	93
227	R760W760	0.168	371.454	4343.059	92
228	R770W770	0.433	374.026	6110.532	87
229	R780W780	0.323	445.800	6511.923	85
230	R790W790	0.807	354.604	8527.975	93
231	R800W800	0.334	346.790	5477.955	87
232	R80W80	0.067	464.355	2930.079	86
233	R810W810	0.026	330.765	1951.938	93
234	R820W2240	0.934	348.117	12816.021	92
235	R830W830	0.516	422.114	9295.743	86
236	R840W840	0.390	395.012	6732.211	87
237	R850W850	0.412	330.952	8657.424	93
238	R860W860	0.443	357.751	7859.397	90
239	R870W870	1.128	351.176	12589.991	93
240	R880W880	0.692	394.241	9205.480	88
241	R890W890	0.407	348.061	9083.161	93
242	R900W900	0.797	358.465	10318.811	82
243	R90W90	0.284	570.281	7892.848	90
244	R910W910	0.166	341.335	4289.030	94
245	R920W920	0.312	335.211	5372.276	92
246	R930W930	0.636	334.783	8870.583	92
247	R940W940	0.999	324.930	14973.815	90
248	R950W950	0.018	318.241	1607.936	99
249	R960W960	0.018	459.231	1372.809	86
250	R970W990	0.424	431.473	7102.532	86

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
251	R980W980	0.032	448.269	2340.458	86
252	R990W1000	0.158	484.822	4027.177	82
Cypress Creek Watershed					
1	R10W10	0.333	602.751	6987.496	91
2	R20W20	0.705	597.093	9564.295	91
3	R50W50	0.285	522.756	4932.539	91
4	R30W30	1.340	564.283	17144.247	90
5	R40W40	0.248	600.042	7529.535	91
6	R70W70	0.159	519.526	4910.158	91
7	R100W100	0.025	467.191	1658.675	91
9	R270W270	0.377	415.249	4862.300	88
11	R60W60	0.287	545.406	6292.989	91
12	R80W80	0.783	494.941	10387.827	90
13	R110W110	0.382	487.204	8206.030	90
14	R210W210	0.021	446.418	1259.833	91
15	R140W140	0.308	478.103	5298.976	85
16	R150W150	0.026	473.846	1638.478	91
17	R120W120	0.220	477.086	4994.944	84
18	R90W90	0.210	533.424	5468.024	91
19	R190W190	0.063	423.227	2780.588	91
21	R230W230	0.084	460.570	2614.102	91
22	R130W130	0.229	518.361	4035.146	86
23	R160W160	0.284	512.202	6206.018	92
24	R200W200	0.319	487.438	6123.413	88
25	R170W170	0.640	543.255	8144.531	85
26	R290W290	0.295	487.532	5942.911	88
27	R220W220	0.334	529.555	6806.463	87
28	R240W240	0.941	453.522	9073.578	88
30	R260W260	0.326	471.034	7566.842	78
31	R280W280	0.171	408.576	3981.108	85
32	R250W250	0.326	555.157	6484.948	90
33	R180W180	0.365	541.337	7740.411	91
34	R330W330	0.398	487.077	7399.076	79
35	R300W300	0.483	417.184	9907.287	82
36	R310W310	0.561	441.555	6486.230	79
37	R320W320	0.401	506.491	5828.279	84
38	R400W400	0.000	357.611	122.998	93
39	R340W340	0.495	386.312	7968.396	86
40	R390W390	0.239	384.326	5824.283	89
41	R370W370	0.303	374.837	6208.203	83
42	R350W350	0.078	489.894	1941.604	78

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
44	R420W420	0.268	436.080	6912.355	90
45	R450W450	0.026	369.629	1978.910	87
46	R410W410	0.225	383.983	5159.245	92
47	R360W360	0.461	506.258	6676.909	85
48	R470W470	0.015	369.629	1149.571	90
49	R380W380	0.309	457.727	5641.970	77
50	R440W440	0.319	474.515	5262.952	90
51	R490W490	0.628	357.611	9071.393	88
52	R430W430	0.245	452.522	4946.181	80
53	R540W540	0.013	346.556	957.613	90
54	R530W530	0.020	349.645	1397.756	91
55	R500W500	0.259	432.214	5462.371	78
56	R520W520	0.130	377.208	5207.102	84
57	R460W460	0.489	439.880	10902.206	90
58	R510W510	0.371	434.023	7934.558	91
59	R550W550	0.150	365.896	3662.155	92
60	R480W480	0.279	369.629	5403.057	78
61	R620W620	0.233	413.169	5609.034	86
62	R610W610	0.130	364.191	4268.784	93
63	R590W590	0.320	395.340	6477.487	85
64	R630W630	0.196	488.378	5493.122	91
65	R650W650	0.250	416.796	5619.211	85
66	R670W670	0.135	370.817	3195.256	91
67	R680W680	0.056	395.095	2777.498	91
68	R750W750	0.000	337.926	30.751	91
69	R640W640	0.235	425.571	4737.491	91
70	R700W700	0.094	357.884	3553.704	93
71	R730W730	0.157	363.888	4161.235	91
75	R690W690	0.334	404.580	6319.745	91
76	R770W770	0.248	384.594	5110.482	91
77	R560W560	0.303	404.221	8876.718	90
78	R810W810	0.022	369.394	1901.584	91
79	R570W570	0.205	426.196	8734.425	90
80	R600W600	0.979	429.789	12695.336	90
81	R790W790	0.040	362.832	1825.160	92
82	R660W660	0.410	381.983	6923.280	92
83	R840W840	0.022	347.768	1403.032	86
84	R580W580	0.455	415.203	10320.675	91
85	R830W830	0.162	375.486	5707.840	91
86	R710W710	0.307	430.236	8319.757	91
87	R820W820	0.284	390.326	6100.126	87
88	R720W720	0.281	414.832	5367.939	91

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
89	R740W740	0.516	417.846	6948.004	91
90	R850W850	0.590	403.648	8850.868	86
91	R780W780	0.282	425.566	6323.741	90
93	R960W960	0.466	331.364	9203.134	80
95	R920W920	0.006	347.768	885.563	93
98	R900W900	0.274	360.250	4718.196	95
99	R890W890	0.223	380.090	6480.578	90
101	R990W990	0.006	345.017	731.813	93
102	R760W760	0.464	456.748	9829.961	91
103	R870W870	0.409	401.421	6545.167	89
104	R800W800	0.544	352.483	8352.316	82
105	R860W860	0.219	331.364	7296.649	92
107	R880W880	0.536	361.758	7779.528	91
108	R1000W1000	0.282	366.516	4365.933	87
109	R910W910	0.196	362.459	5242.752	91
110	R940W940	0.119	370.265	3697.804	91
111	R930W930	0.127	357.649	3454.898	93
112	R970W970	0.568	396.356	8247.329	86
113	R1040W1040	0.235	397.790	5318.270	95
114	R1050W1050	0.000	318.241	61.499	100
115	R1010W1010	0.270	356.406	5039.337	94
116	R1030W1030	0.272	353.046	4273.682	92
117	R980W980	0.278	438.337	5566.452	86
118	R1060W1060	0.054	343.081	2383.932	93
119	R950W950	0.430	399.369	6259.151	88
120	R1080W1080	0.655	397.556	11038.472	89
121	R1090W1090	0.292	361.548	6760.416	88
122	R1020W1020	0.313	333.195	9590.142	82
124	R1130W1130	0.019	327.413	1451.795	93
125	R1120W1120	0.050	314.960	1939.793	99
126	R1100W1100	0.241	389.064	5990.769	90
127	R1140W1140	0.294	357.731	6723.487	84
128	R1160W1160	0.228	352.558	6207.826	90
129	R1170W1170	0.390	378.837	6592.119	90
130	R1150W1150	0.207	371.001	5696.009	94
131	R1190W1190	0.037	343.204	2025.488	91
132	R1070W1070	0.518	328.820	7594.499	95
133	R1110W1110	0.531	334.741	8668.555	84
134	R1180W1180	0.198	344.956	4498.577	93
135	R1210W1210	0.132	351.148	6546.824	94
138	R1200W1200	0.066	320.880	2578.079	94
139	R1280W1280	0.168	353.962	4041.327	93

Appendix A-1. Continued

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
140	R1240W1240	0.068	377.440	3660.875	96
141	R1250W1250	0.389	369.797	7157.072	93
142	R1220W1220	0.505	371.076	6491.129	92
143	R1270W1270	0.303	348.843	5933.266	93
144	R1290W1290	0.215	343.059	4517.872	93
145	R1260W1260	0.362	341.026	5139.950	89
147	R1230W1230	0.666	335.301	10043.927	93
148	R1310W1310	0.127	311.679	4308.804	93
149	R1300W1300	0.200	378.539	5405.242	93
150	R1360W1360	0.009	321.036	839.890	93
151	R1320W1320	0.236	322.083	4551.336	92
152	R1350W1350	0.346	334.841	5573.913	92
153	R1330W1330	0.166	311.679	5348.113	93
154	R1370W1370	0.107	340.258	3016.034	93
155	R1340W1340	0.736	360.828	10931.674	91
156	R1410W1410	0.345	343.494	5993.859	93
157	R1380W1380	0.317	344.970	5175.072	90
158	R1390W1390	0.264	327.987	6584.659	92
159	R1400W1400	0.579	343.599	10030.817	90
160	R1420W1420	0.354	339.050	8350.662	91
161	R1430W1430	0.445	311.610	10159.996	92
162	R1440W1440	0.397	298.556	8099.232	98
163	R1450W1450	0.020	306.430	1365.726	100
Limekiln Slough Watershed					
1	R50W50	0.271	340.099	5929.270	92
2	R30W30	0.316	338.462	5473.299	90
3	R60W60	0.048	347.591	5028.409	96
4	R70W70	0.288	341.687	7060.452	93
5	R20W20	0.075	340.177	2624.654	91
6	R10W10	0.499	330.709	12321.593	92
7	R110W110	0.216	343.823	5140.328	85
8	R100W100	0.205	329.819	4503.853	93
9	R90W90	0.338	329.925	6397.071	92
10	R80W80	1.071	346.931	10470.583	93
11	R150W150	0.298	340.046	6914.166	92
12	R40W40	0.276	340.256	5862.118	91
13	R130W130	0.248	340.853	4185.431	91
14	R170W170	0.604	358.938	6820.104	92
15	R140W140	0.549	341.547	6643.973	90
16	R120W120	0.439	349.336	7279.165	91
18	R210W210	0.022	337.044	1221.625	77

Appendix A-1. Concluded

Sub-basin ID	*Sub-basin name*	*Sub-basin area (mi^2)*	*Average elevation (ft-msl)*	*Longest flow path (ft)*	*Average curve number*
19	R270W270	0.333	343.238	6267.517	86
20	R250W250	0.257	352.417	5127.591	91
21	R190W190	0.067	348.370	7639.046	93
22	R200W200	0.194	338.046	3441.256	88
23	R160W160	0.966	340.046	12027.364	93
24	R180W180	1.099	359.060	9707.490	91
25	R360W360	0.243	368.001	5566.078	92
26	R260W260	0.683	340.046	9494.427	91
27	R300W300	0.237	354.983	5181.627	92
28	R220W220	0.593	342.778	8238.963	90
29	R330W330	0.119	356.999	4060.622	93
31	R350W350	0.029	349.928	1958.713	93
32	R340W340	0.249	361.236	6471.837	92
36	R310W310	0.071	345.404	3207.996	93
37	R240W240	0.448	349.207	8208.215	91
38	R320W320	0.146	378.670	4422.157	93
40	R230W230	0.516	347.039	9081.944	92
41	R290W290	0.734	340.046	7371.790	93
42	R380W380	0.321	356.984	9027.531	92
44	R400W400	0.229	391.930	5936.356	92
45	R370W370	0.402	349.999	6887.411	92
46	R470W470	0.519	370.049	8930.911	90
47	R280W280	0.825	374.358	10177.102	91
48	R480W480	0.004	362.001	986.176	93
49	R430W430	0.759	361.423	9862.146	91
50	R510W510	0.013	365.201	1513.294	93
55	R410W410	0.299	389.219	7199.654	91
57	R420W420	0.243	385.982	6369.941	88
58	R440W440	0.625	350.999	7510.618	91
60	R490W490	0.230	389.050	4839.915	90
61	R500W500	0.224	386.157	5864.303	88
62	R390W390	0.541	345.009	8162.169	92
63	R540W540	0.384	432.609	7053.365	86
65	R530W530	0.087	360.999	2470.907	93
66	R520W520	0.334	392.648	7072.286	85
67	R550W550	0.188	378.113	4504.758	90
68	R570W570	0.071	380.304	2437.065	91
70	R450W450	0.832	379.832	10496.432	89
71	R460W460	0.789	389.632	11297.205	84
72	R560W560	0.240	447.237	4880.312	78
73	R580W580	0.494	407.483	6428.724	91
74	R590W590	0.493	399.507	5780.796	82

Appendix A-2. Manning's Roughness Coefficients for Channel Cross Sections

<table>
<tr><th></th><th colspan="2">Left floodplain</th><th>Channel</th><th colspan="2">Right floodplain</th></tr>
<tr><th>River station</th><th>Segment 1</th><th>Segment 2</th><th>Segment 3</th><th>Segment 4</th><th>Segment 5</th></tr>
<tr><td>Reach 1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8.00</td><td>0.077</td><td>0.075</td><td>0.04</td><td>0.075</td><td>0.077</td></tr>
<tr><td>7.00</td><td>0.069</td><td>0.075</td><td>0.04</td><td>0.069</td><td></td></tr>
<tr><td>6.00</td><td>0.069</td><td>0.075</td><td>0.04</td><td>0.075</td><td>0.069</td></tr>
<tr><td>5.00</td><td colspan="2">0.075</td><td>0.04</td><td colspan="2">0.075</td></tr>
<tr><td>4.00</td><td>0.077</td><td>0.075</td><td>0.04</td><td colspan="2">0.075</td></tr>
<tr><td>3.00</td><td colspan="2">0.08</td><td>0.04</td><td colspan="2">0.08</td></tr>
<tr><td>2.40</td><td colspan="2">0.08</td><td>0.04</td><td colspan="2">0.08</td></tr>
<tr><td>2.30</td><td colspan="2">0.08</td><td>0.04</td><td colspan="2">0.08</td></tr>
<tr><td>2.25 (Bridge)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.20</td><td colspan="2">0.08</td><td>0.04</td><td colspan="2">0.08</td></tr>
<tr><td>2.10</td><td colspan="2">0.08</td><td>0.04</td><td colspan="2">0.08</td></tr>
<tr><td>2.00</td><td colspan="2">0.08</td><td>0.04</td><td colspan="2">0.08</td></tr>
<tr><td>1.00</td><td colspan="2">0.069</td><td>0.04</td><td colspan="2">0.069</td></tr>
<tr><td>Reach 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>28.875</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>29.803</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>30.371</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>30.372</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>30.443</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>30.445</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>Bridge</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>30.465</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>30.467</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>30.484</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.077</td></tr>
<tr><td>31.241</td><td colspan="2">0.077</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>31.346</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>31.347</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>Bridge</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>31.349</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>31.351</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>31.376</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>31.415</td><td>0.077</td><td>0.075</td><td>0.06</td><td>0.075</td><td>0.077</td></tr>
<tr><td>32.31</td><td>0.077</td><td>0.075</td><td>0.06</td><td>0.075</td><td>0.077</td></tr>
<tr><td>32.841</td><td>0.077</td><td>0.075</td><td>0.06</td><td>0.075</td><td>0.077</td></tr>
<tr><td>32.899</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>32.901</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>Bridge</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>32.904</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>32.906</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>32.919</td><td colspan="2">0.075</td><td>0.06</td><td colspan="2">0.075</td></tr>
<tr><td>33.771</td><td>0.077</td><td>0.075</td><td>0.06</td><td colspan="2">0.069</td></tr>
</table>

Appendix A-2. Continued

	Left floodplain		*Channel*	*Right floodplain*	
River station	*Segment 1*	*Segment 2*	*Segment 3*	*Segment 4*	*Segment 5*
33.941	0.075		0.06	0.075	
33.942	0.075		0.06	0.075	
14.5					
33.944	0.075		0.06	0.075	
33.945	0.075		0.06	0.075	
34.378	0.075		0.06	0.075	
34.379	0.075		0.06	0.075	
Bridge					
34.383	0.075		0.06	0.075	
34.384	0.075		0.06	0.075	
34.516	0.077	0.075	0.06	0.077	
34.771	0.077	0.075	0.06	0.077	
35.623	0.077		0.06	0.077	
35.631	0.077		0.06	0.08	
35.646	0.077		0.06	0.08	
35.665	0.085		0.06	0.085	
35.684	0.085		0.06	0.085	
35.697	0.085		0.06	0.085	
Reach 3					
28.788	0.075		0.052	0.075	
28.22	0.069		0.052	0.08	0.077
27.652	0.06		0.052	0.06	
27.61	0.06		0.052	0.06	
27.591	0.06		0.052	0.06	
27.44	0.06		0.052	0.06	
27.345	0.06		0.052	0.06	
27.25	0.06		0.052	0.06	
27.061	0.06		0.052	0.06	
26.919	0.06		0.052	0.06	
26.786	0.06		0.052	0.06	
26.749	0.055		0.052	0.055	
26.7465 (Bridge)					
26.744	0.055		0.052	0.055	
26.742	0.055		0.052	0.055	
26.666	0.08		0.052	0.08	0.069
26.496	0.069		0.052	0.075	0.077
26.307	0.069		0.052	0.075	0.077
26.306	0.08		0.052	0.08	0.069
26.29	0.069		0.052	0.075	0.077
25.8	0.08		0.052	0.08	
25.694	0.08		0.052	0.08	
24.823	0.08		0.052	0.08	0.077
24.52	0.075		0.052	0.075	

Appendix A-2. Continued

River station	Left floodplain Segment 1	Left floodplain Segment 2	Channel Segment 3	Right floodplain Segment 4	Right floodplain Segment 5
24.505	0.06		0.052	0.06	
24.503	0.06		0.052	0.06	
24.5015 (Bridge)					
24.5	0.06		0.052	0.06	
24.497	0.055		0.052	0.055	
24.431	0.055		0.052	0.055	
23.629	0.08		0.052	0.08	
Reach 4					
2.36	0.08		0.04	0.08	
2.331	0.08		0.04	0.08	
2.33	0.08		0.04	0.08	
2.326 (Bridge)					
2.322	0.08		0.04	0.08	
2.321	0.08		0.04	0.08	
2.297	0.99	0.08	0.04	0.08	0.99
1.312	0.08		0.04	0.08	
1.256	0.07		0.04	0.07	
1.254	0.06		0.04	0.06	
1.252 (Bridge)					
1.25	0.06		0.04	0.06	
1.248	0.07		0.04	0.07	
1.247	0.07		0.04	0.07	
1.212	0.077	0.08	0.035	0.08	0.077
0.53	0.077		0.035	0.077	
0.076	0.077		0.035	0.077	
Reach 5					
23.599	0.08		0.052	0.08	
21.978	0.069	0.05	0.069	0.05	0.069
21.957	0.069	0.05	0.069	0.05	0.069
21.926	0.069	0.05	0.069	0.05	0.069
21.9115 (Bridge)					
21.897	0.069	0.05	0.069	0.05	0.069
21.895	0.069	0.05	0.069	0.05	0.069
21.887	0.069	0.05	0.069	0.05	0.069
21.13	0.055	0.05	0.055		
20.183	0.055	0.035	0.055	0.035	0.055
20.16	0.055	0.035	0.055	0.035	0.055
20.151	0.077	0.03	0.055	0.065	0.065
20.143 (Bridge)					
20.135	0.077	0.03	0.055	0.065	0.065
20.13	0.077	0.03	0.055	0.03	0.055

Appendix A-2. Concluded

<table>
<tr><th rowspan="2">River station</th><th colspan="2">Left floodplain</th><th>Channel</th><th colspan="2">Right floodplain</th></tr>
<tr><th>Segment 1</th><th>Segment 2</th><th>Segment 3</th><th>Segment 4</th><th>Segment 5</th></tr>
<tr><td>20.064</td><td>0.077</td><td>0.03</td><td>0.055</td><td>0.03</td><td>0.055</td></tr>
<tr><td>20.054</td><td colspan="2">0.07</td><td>0.03</td><td colspan="2">0.07</td></tr>
<tr><td>20.052</td><td colspan="2">0.07</td><td>0.03</td><td colspan="2">0.07</td></tr>
<tr><td>20.0505 (Bridge)</td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td>20.049</td><td colspan="2">0.07</td><td>0.03</td><td colspan="2">0.07</td></tr>
<tr><td>20.047</td><td colspan="2">0.065</td><td>0.03</td><td colspan="2">0.065</td></tr>
<tr><td>20.028</td><td>0.077</td><td>0.069</td><td>0.03</td><td colspan="2">0.069</td></tr>
<tr><td>19.948</td><td>0.077</td><td>0.069</td><td>0.03</td><td colspan="2">0.069</td></tr>
<tr><td>17.581</td><td colspan="2">0.07</td><td>0.03</td><td colspan="2">0.07</td></tr>
<tr><td>14.361</td><td colspan="2">0.08</td><td>0.03</td><td colspan="2">0.08</td></tr>
<tr><td>12.581</td><td colspan="2">0.07</td><td>0.028</td><td colspan="2">0.07</td></tr>
<tr><td>12.562</td><td colspan="2">0.08</td><td>0.03</td><td colspan="2">0.08</td></tr>
<tr><td>12.56</td><td colspan="2">0.08</td><td>0.03</td><td colspan="2">0.08</td></tr>
<tr><td>12.554 (Bridge)</td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td>12.548</td><td colspan="2">0.08</td><td>0.03</td><td colspan="2">0.08</td></tr>
<tr><td>12.546</td><td colspan="2">0.07</td><td>0.05</td><td colspan="2">0.07</td></tr>
<tr><td>12.531</td><td colspan="2">0.08</td><td>0.045</td><td colspan="2">0.08</td></tr>
<tr><td>12.274</td><td colspan="2">0.077</td><td>0.045</td><td colspan="2">0.07</td></tr>
<tr><td>10.627</td><td colspan="2">0.077</td><td>0.045</td><td colspan="2">0.08</td></tr>
<tr><td>9.711</td><td colspan="2">0.077</td><td>0.045</td><td colspan="2">0.07</td></tr>
<tr><td>7.789</td><td colspan="2">0.077</td><td>0.045</td><td colspan="2">0.07</td></tr>
<tr><td>5.135</td><td>0.08</td><td>0.045</td><td>0.08</td><td colspan="2">0.077</td></tr>
<tr><td>4.621</td><td>0.069</td><td>0.035</td><td>0.069</td><td colspan="2">0.077</td></tr>
<tr><td>4.592</td><td colspan="2">0.069</td><td>0.03</td><td colspan="2">0.069</td></tr>
<tr><td>4.59</td><td colspan="2">0.069</td><td>0.03</td><td colspan="2">0.069</td></tr>
<tr><td>4.5635 (Bridge)</td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td>4.537</td><td colspan="2">0.07</td><td>0.033</td><td colspan="2">0.07</td></tr>
<tr><td>4.518</td><td colspan="2">0.07</td><td>0.038</td><td colspan="2">0.07</td></tr>
<tr><td>4.48</td><td colspan="2">0.069</td><td>0.045</td><td>0.069</td><td>0.077</td></tr>
<tr><td>4.007</td><td colspan="2">0.069</td><td>0.045</td><td>0.069</td><td>0.077</td></tr>
<tr><td>2.302</td><td colspan="2">0.069</td><td>0.045</td><td>0.069</td><td>0.077</td></tr>
<tr><td>1.318</td><td colspan="2">0.069</td><td>0.045</td><td>0.069</td><td>0.077</td></tr>
<tr><td>1.071</td><td colspan="2">0.069</td><td>0.045</td><td>0.069</td><td>0.077</td></tr>
<tr><td>0.92</td><td colspan="2">0.069</td><td>0.045</td><td>0.069</td><td>0.077</td></tr>
<tr><td>0.768</td><td colspan="2">0.06</td><td>0.04</td><td>0.06</td><td>0.077</td></tr>
<tr><td>0.56</td><td colspan="2">0.06</td><td>0.04</td><td>0.06</td><td>0.077</td></tr>
<tr><td>0.545</td><td colspan="2">0.055</td><td>0.03</td><td>0.055</td><td>0.077</td></tr>
</table>

Appendix A-3. Aerial View of the Lower Cache River Modeled by UNET, Identifying Important Features, Including Tributary Streams, Bridges, and Control Structures

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