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Cuyahoga River HEC-RAS Study

Janaury 2007

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James S. Bowling, PE 1/15/07

Julie A. Lawson, PE 1-15-07

Cuyahoga River
HEC-RAS Study

Prepared for:
Friends of the Crooked River

Prepared by:
ARCADIS U.S., Inc.
520 South Main Street
Suite 2400
Akron
Ohio 44311-1010
Tel 330.434.1995
Fax 330.374.1095

Our Ref.:
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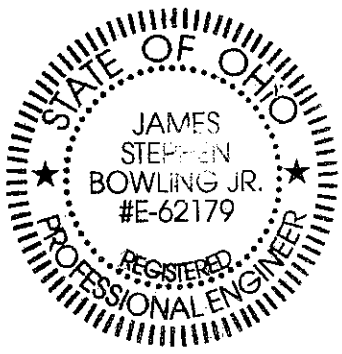
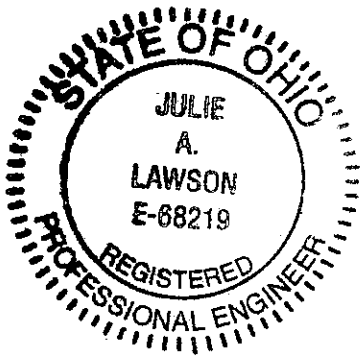
January 2007





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ARCADIS U.S., Inc.
520 South Main Street
Suite 2400
Akron
Ohio 44311-1010
Tel 330 434 1995
Fax 330 374 1095
www.arcadis-us.com

WATER RESOURCES
BUSINESS PRACTICE

Mr. William J. Zawiski
Environmental Scientist
Ohio Environmental Protection Agency
Northeast District Office
2110 East Aurora Road
Twinsburg, Ohio 44087

Subject:
Friends of the Crooked River
Cuyahoga River HEC-RAS Study

Date:
15 January 2007

Contact:
Thomas E. Hall, PE
James S. Bowling, PE

Phone:
330.434.1995

Email:
tom.hall@arcadis-us.com
james.bowling@arcadis-us.com

Our ref:
CL000386.R001

Dear Mr. Zawiski:

Enclosed please find two copies of the draft report for the Cuyahoga River HEC-RAS Study for your review. After completion of your review, we will address your comments and finalize the report.

Should you have questions or require additional information, please contact us at your convenience.

Sincerely,

ARCADIS U.S., Inc.

Thomas E. Hall, PE

James S. Bowling, PE

TEH/JSB/lmd

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Section 1 Introduction

The Brecksville Dam is being considered for removal in response to the Total Maximum Daily Load (TMDL) analysis performed by the Ohio Environmental Protection Agency (OEPA). The dam, shown in Photo 1, is located in the Cuyahoga River on the border of Brecksville (Cuyahoga County) and Sagamore Hills (Summit County) as shown in Figure 1. The dam is approximately 163 feet long and nearly eight feet high and serves to feed water to the Ohio and Erie Canal by gravity through Canal Feeder Gates, shown in Photo 2. The purpose of this study is to determine the hydraulic impacts of removing the Brecksville Dam for incorporation into the Environmental Impact Statement being completed by the OEPA.

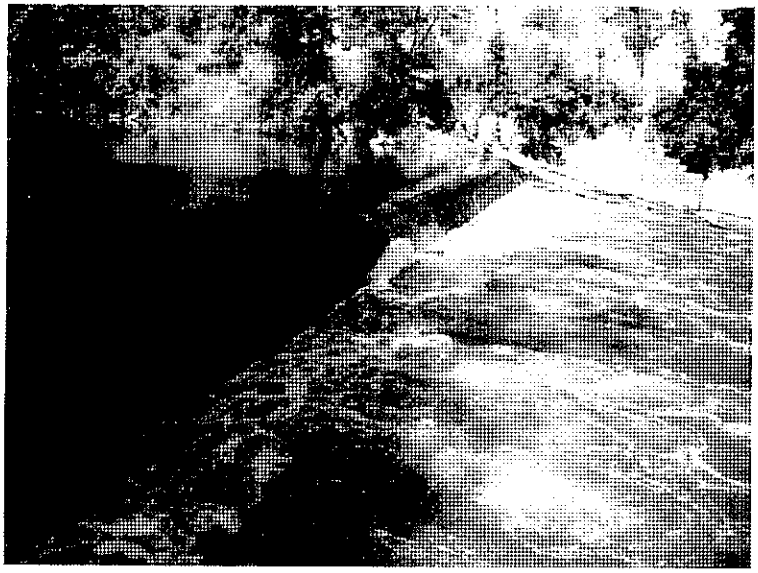

Photo 1:
Brecksville Dam in the Cuyahoga River.

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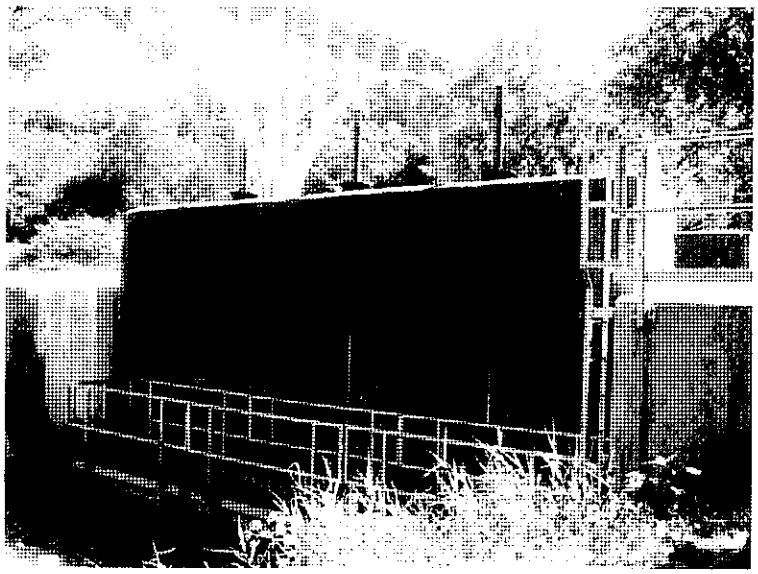

Photo 2:
Canal Feeder Gates connect the Cuyahoga River to the Ohio and Erie Canal.

The study area, shown in Figure 1, extends along the Cuyahoga River from Highland (Vaughn) Road to approximately 600 feet downstream of the dam, including the Ohio and Erie Canal from the Canal Feeder Gates to approximately 600 feet downstream of the dam. The study area also includes Chippewa Creek for approximately 3,000 feet upstream of its confluence with the Cuyahoga River, as it is located in the backwater from the dam. This portion of the Cuyahoga River, which flows north into Lake Erie, is surrounded by the Cuyahoga Valley National Park. To achieve the goals of this study, hydrology calculations were completed, field inspections were performed, and hydraulic analyses for existing and proposed conditions were developed.

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Section 2 Hydrologic Analysis

The average, 10-year and 100-year peak flows were calculated so that they could be modeled in the hydraulic analysis. The investigation of these storm events reveal the impacts that the dam removal will have to the aesthetics enjoyed by park patrons, potential scour at bridges and base flood elevations.

The United States Geological Survey (USGS) Water-Resources Investigations Report 89-4126, "Techniques for Estimating Flood-Peak Discharges of Rural, Unregulated Streams in Ohio", was used to calculate the 10- and 100-year peak discharges. Hydrologic calculations may be found in Appendix A.

The Cuyahoga River is a gaged stream, with the nearest USGS gaging station being in Independence (Station #0420800), approximately six miles downstream. Therefore, to determine the peak discharge in the Cuyahoga River, the technique for estimating flood-peak discharge for an ungaged site on a gaged stream was applied. Chippewa Creek is not a gaged stream, therefore the multiple-regression equations were used for estimating the peak discharges.

The average discharge was calculated for the Cuyahoga River and Chippewa Creek by scaling the average streamflow measured at the Independence gaging station based on drainage areas, as shown in Appendix A. The calculations yielded an average discharge of 703 cfs in the Cuyahoga River and 21 cfs in Chippewa Creek.

An assumed base flow of 1 cfs was used in the Ohio and Erie Canal for existing conditions since most of the flow is contributed from the Canal Feeder Gates instead of direct runoff and the program requires some initial flow to run. According to the study performed by Bergmann Associates for the National Park Service entitled "Hydrologic Study and Design Alternatives: Watered Section of the Ohio and Erie Canal – Brecksville Feeder Dam to Rockside Road", the Canal Feeder Gates are kept 50% open under average operating conditions. To avoid canal flooding, the gates are lowered to 25% open for wet weather conditions. Therefore this study assumed that each of the three gates would be 50% open for the average flow condition and 25% open for the 10- and 100-year events. The hydraulic model took these operating conditions into account and calculated the existing flow that enters the canal from the Cuyahoga River under each of these three conditions as shown in Table 1. A flow of 21 cfs was used for the proposed model of the Ohio and Erie Canal since that is the design flow rate in the canal per the Bergmann Associates study. Since it will no longer be feasible to water the canal by gravity at this location once the dam is removed, it is

assumed that a pumping station will be used to convey 21 cfs into the canal under proposed conditions and that the gates would be closed. Therefore 21 cfs was removed from the Cuyahoga River at the likely location of the pumping station, adjacent to the Canal Feeder Gates.

The flow rates calculated for each river section studied are presented below in Table 1.

Table 1
Summary of Flows

	Average Flow (cfs)		10-year Peak Flow (cfs)		100-year Peak Flow (cfs)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Chippewa Creek	21	21	2,500	2,500	4,650	4,650
Ohio and Erie Canal	66*	21	152*	21	165*	21
Cuyahoga River – Upstream of Canal Feeder Gates	703	703	13,055	13,055	20,370	20,370
Cuyahoga River – Downstream of Canal Feeder Gates	638*	682	12,904*	13,034	20,206*	20,349

* Flows calculated in HEC-RAS

Section 3 Hydraulic Analysis

A hydraulic model was developed with the calculated flow rates from the hydrologic analysis to determine water surface elevations using the Hydrologic Engineering Center's River Analysis System software (HEC-RAS v. 3.1.3). The main project area was modeled as three river reaches, the Cuyahoga River downstream of Chippewa Creek, "Lower", the Cuyahoga River upstream of Chippewa Creek, "Upper", and Chippewa Creek, "Tributary". The Ohio and Erie Canal was also modeled as a separate reach. The Canal was connected to the other three reaches via the Canal Feeder Gates modeled as a lateral structure. The Brecksville Dam was modeled as an inline weir.

To represent the geometry of the river, cross sections of the channel were surveyed and Cuyahoga County GIS information was used to complete each cross section's geometry in the floodplain. An engineering field visit was performed by ARCADIS personnel to determine Manning's Roughness Coefficients, evaluate the hydraulic characteristics of existing structures, and verify cross section geometry. The following photos show the representative Manning's 'n' values along the Cuyahoga River, Chippewa Creek and the Ohio and Erie Canal.

Photo 3:
Looking downstream at the Ohio and Erie Canal downstream of the Canal Feeder Gates.

Photo 4:
Looking upstream from the lower project limits. The towpath trail serves as the left overbank of the Ohio and Erie Canal and the right overbank of the Cuyahoga River.

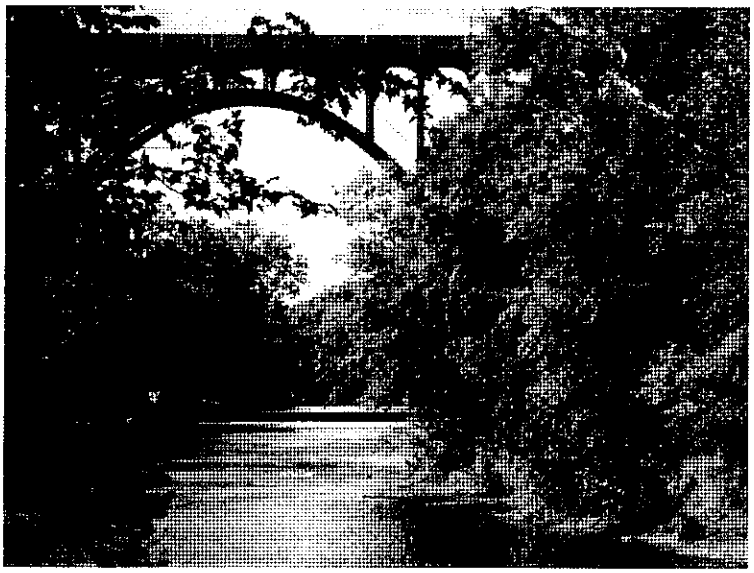

Photo 5:
Looking upstream at the lower reach of the Cuyahoga River downstream of the Brecksville Dam.

Photo 6:
Looking upstream at the left overbank in the lower reach of the Cuyahoga River near the Station Road Bridge.

Photo 7:
Looking upstream in the lower reach of the Cuyahoga River from the Station Road Bridge.

Photo 8:
Looking upstream at the left overbank in the upper reach of the Cuyahoga River.

Photo 9:
Looking downstream at the upper reach of the Cuyahoga River.

Photo 10:
Looking upstream at the right overbank on the upper reach of the Cuyahoga River.

Photo 11:
Looking upstream at Chippewa Creek.

Photo 12:
Looking downstream at the left overbank of Chippewa Creek.

Photo 13:
Looking upstream at the right overbank of Chippewa Creek.

Three bridges were analyzed within the study area: the Station Road pedestrian bridge over the lower reach of the Cuyahoga River, the railroad bridge over Chippewa Creek tributary, and the Riverview Road bridge over Chippewa Creek tributary. The State Route 82 bridge, which is a high level bridge above the Cuyahoga River valley downstream of the dam, was not analyzed as a bridge for the hydraulic model; however, piers within the floodplain were modeled to accurately represent its impact. Photos of each bridge are shown below.

Photo Credit: Jonathan Maxwell

Photo 14:
Downstream face of the Station Road Pedestrian Bridge over the lower reach of the Cuyahoga River.

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Photo 15:
Upstream face of the railroad bridge over Chippewa Creek Tributary.

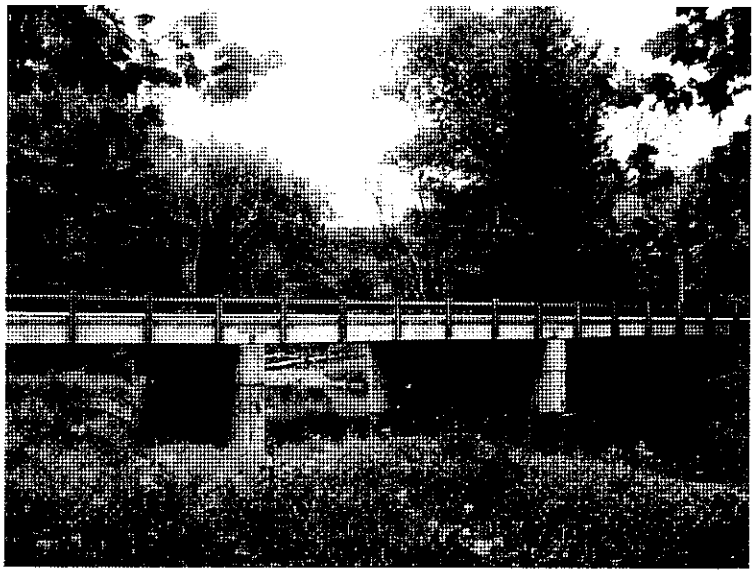

Photo 16:
Upstream face of the Riverview Road Bridge over Chippewa Creek Tributary.

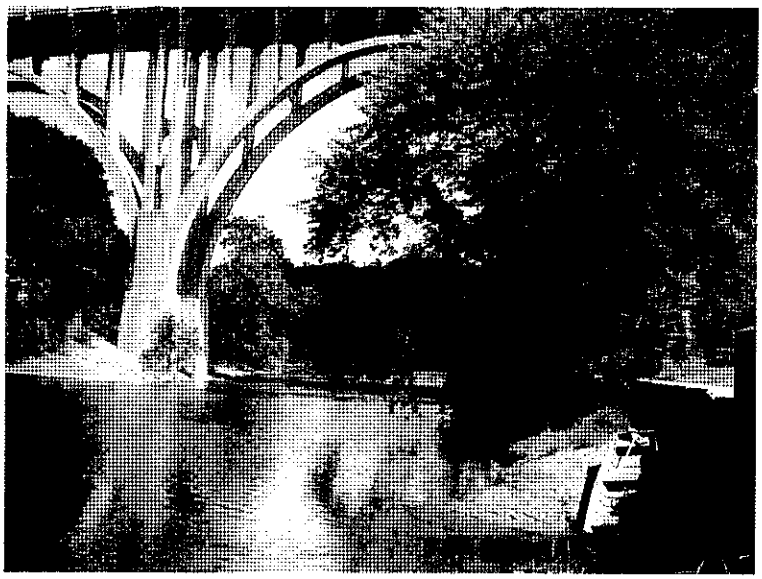

Photo 17:
Upstream face of the State Route 82 piers impacted by the lower reach of the Cuyahoga River.

Once the cross sections, lateral structure, inline weir and bridges were input into the geometric file, the program was run and calibrated. First the program was calibrated based on hydraulic principles. A complexity was discovered at the confluence of Chippewa Creek and the Cuyahoga River. This complexity was caused by the 100-year water surface leaving the banks of Chippewa Creek at this location, which created a different flow path than the average and 10-year flow paths took, both remaining within the banks at the confluence of these rivers. To address this situation, a separate model was created for the 100-year peak flow. This allowed the calculations to be accurate for each scenario.

With the program calibrated based on hydraulic principles, published and observed conditions were considered for additional calibration. While the Cuyahoga River has been studied by the Federal Emergency Management Agency (FEMA) downstream of the study area, this portion of the river has not been studied, so no published 100-year water surface elevations were available. Therefore, final calibration of the existing model was based on observed conditions from recent floods provided by the OEPA. The calibrated model approximately met these conditions except for the Riverview Road crossing of Chippewa Creek, where floods were reported to have overtopped Riverview Road and the model does not show overtopping. This could be explained by the observed water surface elevation occurring during a different storm recurrence than

was modeled, from debris in the channel around the bridge, or from the calculated peak discharge in Chippewa Creek being slightly low. When the standard error of prediction specified in USGS Report 89-4126 was added to the peak discharge calculated using the USGS method, Riverview Road did overtop in the model, indicating that the standard error present in hydrologic analysis could explain the difference. Since the water surface elevation is not impacted at this location due to the proposed dam removal, no further calibration was performed to the model due to this difference in observed water surface elevation.

The proposed model represents the project area after the Brecksville Dam is removed. To create the proposed model, the inline structure was removed, as well as the cross section immediately upstream of the dam. This was done to simulate some sediment redistribution after the dam is removed. As can be seen in the water surface profiles, the channel elevation is significantly higher behind the dam, indicating sediment build-up. Once the dam is removed, it is anticipated that the sediment will either be removed as a part of construction, or gradually transported downstream. Sediment transport was not analyzed as a part of this study.

The Canal Feeder Gates (lateral structure) were kept in the proposed model, but the gates were closed for all flow conditions. As was previously stated, it was assumed that a pumping station will provide 21 cfs to the canal, and no change in channel or floodplain geometry will result from the construction of the pumping station.

The detailed input and results of the existing hydraulic analysis are shown in Appendix B for the Average and 10-year peak flows and in Appendix C for the 100-year peak flow. The detailed input and results of the proposed hydraulic analysis are shown in Appendix D for the Average and 10-year peak flows and in Appendix E for the 100-year peak flow. Electronic files of the HEC-RAS program are included in Appendix H.

Based on the results of the existing and proposed model, removing the Brecksville Dam will lower the base flood (100-year) elevation (BFE) up to 0.26 feet in the Cuyahoga River and will not impact Chippewa Creek's BFE. The Ohio and Erie Canal BFE will drop nearly two feet due to the lower proposed flow rate. The impact to the Average water surface elevation will drop the water surface elevation up to 3.58 feet immediately upstream of the dam. The results are summarized in Table 2 and show that the removal of the dam will not cause any additional flood hazards and meets FEMA requirements for work in Zone A Flood Zones. The table also shows that the water surface elevation downstream of the Canal Feeder Gates will increase slightly

after the dam is removed since water will no longer be diverted from the Cuyahoga River into the canal through the gates. The 21 cfs that will be pumped from the Cuyahoga River into the canal at this location under proposed conditions is less than the 65, 151, and 164 cfs that is diverted under existing conditions for the Average, 10-year and 100-year flows as calculated in HEC-RAS. Therefore the higher proposed flow rate through this portion of the Cuyahoga River will result in a modestly higher water surface elevation as well. The 0.71 foot increase in water surface elevation for the 100-year event shown in Table 2 immediately downstream of the dam in the Cuyahoga River represents a slight difference in the location of a drop in the water surface profile. This increase in water surface elevation reflects the modeling approach and not an appreciable change in site conditions.

Figure 2 shows the differences in water surface elevations for all three storms analyzed through Cuyahoga River's lower and upper reach. Figure 3 displays the water surface profile for the Average and 10-year flows from the lower reach of the Cuyahoga River upstream through Chippewa Creek, and Figure 4 shows the same reaches with the 100-year flow. The Ohio and Erie Canal water surface profiles are shown in Figure 5. These figures show that the dam removal will result in a lower 100-year water surface elevation only up to the Station Road Bridge, while the average water surface elevation will be lowered nearly two miles upstream in the Cuyahoga River and to the upstream face of the railroad bridge in Chippewa Creek.

Cross sections illustrating the existing and proposed water surface elevations can be found in Appendix F for the Average and 10-year flows and Appendix G for the 100-year flow. Very little additional bank width will be exposed by the anticipated drop in water surface elevation for most of the Cuyahoga River and Chippewa Creek, as can be seen in the average flow cross sections. Since the banks are steep in most of the cross sections impacted by the dam removal, slope stabilization may need to be considered. The greatest bank width exposed will occur immediately upstream of the dam (up to 30 feet), where the water surface elevation will drop the most and the banks are less steep. Revegetation may need to be investigated. With any necessary enhancements made to the banks, the overall aesthetic qualities of the river should not change significantly for park patrons due to the slightly lower average water surface elevation.

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Table 2
Summary of HEC-RAS Results

Reach	River Station	100-year Water Surface Elevation (ft)			Average Water Surface Elevation (ft)		
		Existing	Proposed	Difference	Existing	Proposed	Difference
Ohio and Erie Canal							
Canal	100.133	627.70	625.87	-1.83	626.65	625.87	-0.78
	100.132	627.67	625.87	-1.80	626.63	625.87	-0.76
	100.111	627.64	625.86	-1.78	626.61	625.86	-0.75
	100.061	627.53	625.82	-1.71	626.53	625.82	-0.71
	100.028	627.44	625.76	-1.68	626.46	625.76	-0.70
	100.000	627.35	625.70	-1.65	626.38	625.70	-0.68
Cuyahoga River							
Upper	24.361	646.08	646.08	0.00	634.66	634.66	0.00
	24.301	646.08	646.08	0.00	634.47	634.47	0.00
	23.741	644.53	644.53	0.00	633.13	633.13	0.00
	23.411	643.40	643.39	-0.01	632.24	632.24	0.00
	23.052	643.03	643.02	-0.01	631.18	631.17	-0.01
	22.441	642.64	642.62	-0.02	629.42	629.38	-0.04
	22.224	642.12	642.10	-0.02	628.61	628.49	-0.12
	22.033	642.03	642.01	-0.02	627.87	627.29	-0.58
	21.329	641.48	641.46	-0.02	627.35	626.01	-1.34
	21.107	640.77	640.75	-0.02	627.22	625.68	-1.54
	21.022	640.06	640.02	-0.04	627.16	625.45	-1.71
Lower	20.963	--	--	--	627.13	625.33	-1.80
	20.814	638.08	638.03	-0.05	627.05	625.03	-2.02
	20.802	636.83	636.77	-0.06	627.04	624.97	-2.07
	20.800	Station Road Bridge					
	20.798	636.82	636.75	-0.07	627.04	624.97	-2.07
	20.7891*	636.73	636.65	-0.08	627.03	624.93	-2.10
	20.7802*	636.61	636.53	-0.08	627.02	624.89	-2.13
	20.7713*	636.48	636.39	-0.09	627.02	624.84	-2.18
	20.7624*	636.34	636.25	-0.09	627.01	624.77	-2.24
	20.7535*	636.18	636.08	-0.10	627.00	624.70	-2.30
	20.7446*	636.01	635.90	-0.11	626.99	624.60	-2.39
	20.7357*	635.81	635.68	-0.13	626.98	624.47	-2.51
	20.7268*	635.57	635.38	-0.19	626.97	624.27	-2.70
	20.718	635.26	635.00	-0.26	626.96	623.38	-3.58

Table 2 (con't)
Summary of HEC-RAS Results

Reach	River Station	100-year Water Surface Elevation (ft)			Average Water Surface Elevation (ft)		
		Existing	Proposed	Difference	Existing	Proposed	Difference
Cuyahoga River (con't)							
Lower (con't)	20.716	Canal Feeder Gates					
	20.685	Brecksville Dam					
	20.684	634.13	634.84	0.71	622.19	622.27	0.08
	20.674	632.85	632.93	0.08	622.15	622.22	0.07
	20.6678	632.67	632.72	0.05	622.14	622.21	0.07
	20.6661	632.32	632.36	0.04	622.14	622.20	0.06
	20.6655	632.26	632.30	0.04	622.14	622.20	0.06
		State Route 82 Bridge Piers					
	20.6584	632.35	632.39	0.04	622.12	622.18	0.06
	20.6579*	632.36	632.40	0.04	622.12	622.18	0.06
	20.6526	632.53	632.57	0.04	622.10	622.17	0.07
	20.630	632.52	632.57	0.05	621.95	622.01	0.06
	20.598	631.53	631.57	0.04	621.21	621.27	0.06
	20.574	630.86	630.90	0.04	620.67	620.73	0.06
Chippewa Creek							
Tributary	0.743	645.71	645.72	0.01	640.37	640.37	0.00
	0.617	643.66	643.65	-0.01	636.05	636.05	0.00
	0.477	643.09	643.08	-0.01	634.82	634.82	0.00
	0.433	642.52	642.51	-0.01	634.82	634.82	0.00
	0.424	Riverview Road Bridge					
	0.416	641.66	641.65	-0.01	632.89	632.89	0.00
	0.410	641.26	641.24	-0.02	632.84	632.84	0.00
	.3385*	641.37	641.35	-0.02	631.65	631.65	0.00
	0.267	641.34	641.31	-0.03	630.27	630.27	0.00
	0.169	641.29	641.27	-0.02	627.35	627.29	-0.06
	0.160	Railroad Bridge					
	0.158	640.95	640.92	-0.03	627.27	626.95	-0.32
	0.152	640.95	640.93	-0.02	627.27	626.81	-0.46
	0.109	--	--	--	627.24	626.55	-0.69

* Interpolated sections

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A scour analysis was not performed as a part of this study, and should not be necessary based on the results of the hydraulic analysis. The Ohio Department of Transportation's Bridge Design Manual requires scour analysis for "all bridges not founded on scour resistant shale or bedrock." Further, this requirement is for bridges undergoing major rehabilitation. No work is proposed to any of the bridges within the study area. Plans of the bridges were not available to be reviewed to examine their foundations. Finally, as shown in Table 3, there is minimal change (max 0.29 fps) in velocity through the bridges.

Table 3
Summary of Bridge Data

	Available Waterway Opening (sq ft)	Drainage Area (sq mi)	Water Surface Elevation				Bridge Velocity		Low Chord Elevation (ft)
			Bridge		Approach				
			10-year (ft)	100-year (ft)	10-year (ft)	100-year (ft)	10-year (fps)	100-year (fps)	
Cuyahoga River: Station Road (River Station 20.800)									
Existing	1941.5	581	634.52	636.83	635.24	638.08	9.61	12.52	639.04
Proposed	1941.5	581	634.18	636.76	634.98	638.03	9.91	12.59	639.04
Chippewa Creek: Railroad (River Station 0.160)									
Existing	1056.5	17.5	638.21	641.29	638.35	641.34	3.12	3.88	639.73
Proposed	1056.5	17.5	638.10	641.27	638.24	641.31	3.17	3.90	639.73
Chippewa Creek: Riverview Road (River Station 0.424)									
Existing	1020.0	17.5	641.45	642.52	641.70	643.09	3.85	6.39	644.11
Proposed	1020.0	17.5	641.45	642.51	641.68	643.08	3.85	6.41	644.11
Cuyahoga River: State Route 82 (River Station 20.6584)									
Existing	n/a	581	n/a	n/a	n/a	n/a	9.43	11.65	n/a
Proposed	n/a	581	n/a	n/a	n/a	n/a	9.47	11.69	n/a