ARCADIS
Infrastructure, environment, buildings

GPD GROUP

Akron, Ohio

Little Cuyahoga River Final Hydraulic Report

November 2009

Table of Contents

Section 1 Background

In late 2007, the City of Akron initiated a study of a 490-acre area south of I-76 which was selected as the new site for the World Headquarters of the Goodyear Tire and Rubber Co. and associated commercial/residential redevelopment adjacent to the headquarters buildings. The study, called the Eastgate Utility and Hydraulic Study, was completed by the team of GPD and ARCADIS and consisted of an evaluation and mapping of existing utilities within the redevelopment area as well as an analysis of the existing storm sewer system and a flood analysis of the streams flowing through the area. The study was completed and submitted in March 2008.

The stream analysis portion of the Eastgate Utility and Hydraulic Study, completed by ARCADIS, included an evaluation of two proposed alternates for relocating 2,900 feet of the Little Cuyahoga River upstream of Martha Avenue by up to 520 feet to the south of its current location. The project developer, Industrial Realty Group (IRG), intended to relocate the river to the south to open up additional area north of the river to redevelopment. However, subsequent to the March 2008 study, the City and IRG decided the river would be maintained in its current corridor due to environmental, utility, and construction cost constraints. ARCADIS therefore evaluated three additional alternates which would maintain the river in its current corridor. The three additional alternates differed in the modifications to the Goodyear Dam 1,900 feet downstream of Martha Avenue. (See Photo 1.) One alternate included no modifications to the dam; a second alternate included removal of the 15-foot wide gate in the existing dam; the final alternate included lowering the full 40-foot width of the dam to the bottom of gate elevation (an approximate 5-foot lowering of the dam). The three additional alternates assumed the river would be restored to a more natural condition by creating a meandering pattern through the existing river corridor and adding environmental enhancements through riffle pools, bank shaping and vegetation, floodplain design, and a multistage channel configuration.

Subsequently, GPD teamed with Enviroscience, Inc. in a project for IRG to further refine the river restoration improvements in order to obtain permit coverage and to construct the improvements through a design-build project. ARCADIS supported the design team by modeling the refinements to the restoration design and assisting the design team in floodplain permit planning. At the conclusion of this effort, the City and IRG decided that the Goodyear Dam would be lowered for the full width of the dam, which would include removal of the gate as well as lowering of the fixed concrete spillway portions on either side of the gate.

The City was then able to secure outside funding for the river restoration, and, therefore, took the lead in the river restoration effort. The river restoration was also extended downstream to include the river segment from Martha Avenue to the Goodyear Dam. This new segment is referred to as Phase 2 of the river restoration project, while the original segment upstream of Martha Avenue is referred to as Phase 1. The two phases of the river restoration will be bid separately by the City and will be constructed as separate projects. The limits of the river restoration projects are shown in Figure 1.

GPD provided the river restoration final design, and ARCADIS incorporated the final design into the hydraulic model. The modeling effort culminated in a final proposed model which reflects the final design of the proposed improvements. The final model was documented in a CLOMR application which ARCADIS submitted to FEMA in November 2009. The CLOMR specified the modifications to the floodplain limits and elevations derived from the stream restoration and will allow FEMA an opportunity to review and comment on the proposed improvements before they are constructed. A final LOMR will need to be submitted after the improvements are constructed based on as-built conditions.

Photo 1 – Goodyear Dam (at Old Kelly Ave. looking east)

Section 2 Existing Analysis

Overview

Two models were used to define the Little Cuyahoga River watershed within the study limits. A hydrologic model was developed to determine the flows within the watershed using the US Army Corps of Engineers Hydrologic Engineering Center's Hydrologic Modeling System software (HEC-HMS v. 3.1.0). Peak flows were determined at several locations along the Little Cuyahoga River. A hydraulic model was then developed to determine water surface elevations along the river using the Hydrologic Engineering Center's River Analysis System software (HEC-RAS v. 3.1.3). Limits of the water surface elevation determinations from this model are shown on Figure 1.

The Little Cuyahoga River in the project area drains 43.43 square miles in eastern Summit and western Portage counties as shown on the drainage area map in Figure 2. The watershed is predominantly covered by forests, open fields, and rural residential development with smaller areas of commercial and denser residential development in the western portion of the drainage basin. The watershed contains several large lakes which were constructed for flood control after a destructive flooding event in 1913. These lakes which include Springfield Lake, Wingfoot Lake, Hills Pond, and Mogadore Reservoir provide significant flood storage and reduction of peak flows which would otherwise not occur in the Little Cuyahoga River.

The three storm frequencies used for the hydrologic and hydraulic analyses were the 10, 25, and 100-year storm events. The 10 and 25-year events were selected, because these storm frequencies are frequently used in the design of storm water infrastructure including culverts and bridges. The 100-year event was chosen, because the 100-year frequency is used to establish base flood elevations and floodplains for the FEMA flood insurance program. For the river restoration portion of the Little Cuyahoga River, the 2-year and 500-year flow rates were estimated and used in the HEC-RAS analysis as well. The 2-year flow rate was used to evaluate the bank-full design. The 500-year flow rate was included in the CLOMR analysis as required by FEMA.

Hydrologic Model

<u>Methodology</u>

In order to create a hydrologic model of the watershed, the existing watershed was divided into 15 subareas. The factors taken into consideration for subdividing the watershed included size, homogeneous land use, soil types and key inflow locations along the Little Cuyahoga River and its tributaries. Based on the recommended application of various hydrologic methods, we determined that the most appropriate method to determine runoff hydrographs and peak flow rates is the United States Geologic Survey (USGS) regression based method described in *Water-Resource Investigation Report 93-4080* for rural watersheds. A few of the subareas in the western portion of the watershed have significant developed areas, so the USGS *Open-File Report 93-135* for urban watersheds was used to develop runoff hydrographs for these subareas. Because this hydrologic method is not embedded in the HEC-HMS software, runoff hydrographs had to be developed remotely using spreadsheets and then copied into the HEC-HMS model.

Hydrologic parameters used in both sets of USGS regression equations include drainage area and main channel slope. The urban equations also use basin development factor and annual precipitation while the rural equations use forested area and storage area as additional parameters. From these hydrologic parameters, the lag time and peak flow rates for each subarea were calculated which were used to develop runoff hydrographs for the 15 subareas following USGS hydrograph generation methodology. The rural regression equations were used for 11 of the 15 subareas, whereas the urban equations were used for the four most developed subareas in the western portion of the watershed. A table providing the pertinent parameters for the 15 subareas as well as calculated lag times and peak flow values is included in the Appendix.

The runoff hydrographs developed using spreadsheets were then copied into the HEC-HMS model. While the HEC-HMS model was not used to develop the hydrographs, other important capabilities of the model were used to determine how the runoff hydrographs are routed, combined and translated downstream. The larger lakes and ponds with significant storage capacity were included in the model as well as river reaches. The Ohio Department of Natural Resources provided stage-storage-discharge data for Springfield Lake, Wingfoot Lake, Hills Pond, and Mogadore Reservoir. As the runoff hydrographs are routed through these features, the hydrograph peaks are attenuated and hydrograph durations are extended. The model also combines hydrographs at defined junctions to create composite hydrographs which provide the peak flow rates that were entered into the hydraulic model. Table 1 lists the flow rates generated by the HEC-HMS model as well as the junction names and locations. Due to attenuation of the hydrographs through the river, the model actually predicted lower flows for a downstream junction (J1) in the Little Cuyahoga River than an upstream junction (J3). The higher values from junction J3 were used in HEC-RAS for the entire downstream reach of the Little Cuyahoga River. Figure 3 provides a schematic of the existing HEC-HMS model representing the Little Cuyahoga River watershed.

Table 1 Peak Flow Rates (cfs)							
Location	HEC-HMS Junction	HEC-RAS River Sta.	2-year Peak Flow	10-year Peak Flow	25-year Peak Flow	100-year Peak Flow	500-year Peak Flow
Little Cuyahoga River							
E. Market St. (SR 18)	J4	7.351	-	881	1134	1527	-
Confluence with Springfield Lake Outlet	J3	7.160	670	1285	1704	2296	2632
Middlebury Run Park	J1	6.573	670	1278	1646	2285	2646
Springfield Lake Outlet							
Massillon Road (SR 241)	J8	36.75	-	452	580	775	-
Confluence with Haley's Ditch	J9	1519	-	513	643	884	-
Haley's Ditch							
Seiberling St.	S-4B	4368	-	264	340	468	-
Confluence with Adam's Ditch	J7	2240	-	445	515	714	-
Adam's Ditch							
Hobart Ave.	S-4A	1216	-	181	264	370	-

<u>Calibration</u>

The hydrologic model was calibrated by comparing the results from the HEC-HMS program to the flow rates determined from the USGS Streamstats application, the FEMA Flood Insurance Study (FIS), Ohio Bulletin No. 45, and historic peak flow rates measured at the USGS flow gage near Massillon Road. Streamstats is a web-based application which uses a state-wide digital terrain model to determine drainage areas and other hydrologic data to predict peak flow rates based on regression equations similar to Report 93-4080. Although Streamstats uses a similar method to the method used for the HEC-HMS model, the Streamstats output was valuable as a comparison tool, because the storage potential in the watershed is evaluated differently. While the HEC-HMS model explicitly analyzes hydrograph attenuation through major ponds and lakes through a routing analysis, Streamstats accounts for storage by measuring the portion of the watershed area where storage would occur and reducing the peak flows by a regression factor. As expected, the flows predicted by the model are lower than those calculated by Streamstats, because the model explicitly accounts for the artificial storage of the watershed, which is a significant feature of this watershed as previously discussed. The HEC-HMS model and Streamstats flow values are presented in Tables 2 and 3.

The HEC-HMS results were also compared to record flow data for the Little Cuyahoga River at Massillon Road collected by USGS. The USGS measured daily mean flows and peak flows at this location from November 1945 to September 1974. The highest flow rate during this record period measured 891 cfs which occurred on January 21, 1959 which the FIS identified as having a 15-year recurrence interval. This flow rate is slightly more than the 10-year flow rate of 881 cfs predicted by the HEC-HMS model at this location. The record event of January 1959, however, was likely a combination of rainfall and snowmelt, which generally produces lower peak flow rates that are maintained for longer durations.

Tables 2 and 3 show that the FEMA FIS flow rates are considerably lower than the flows generated by the HEC-HMS model or predicted by Streamstats or the Bulletin 45 method. According to the FIS, these flows were calculated by straight line extrapolation of flow gage measurements. Based on observed stream levels within the study limits, the FIS flow rates seem to be unreasonably low and the HEC-HMS model appears to provide more reasonable estimates of design storm peak flow rates.

Table 2
10-Year Peak Flow Comparison

Location	HEC-HMS (USGS)	USGS Streamstats	FEMA FIS	Ohio Bulletin No. 45
Little Cuyahoga River				
E. Market St. (SR 18)	881	1350	-	1190
Confluence with Springfield Lake Outlet	1285	1780	640	1264
Middlebury Park	1278	1890	640	1328
Springfield Lake Outlet				
Massillon Road (SR 241)	452	740	213	-
Confluence with Haley's Ditch	513	940	250	-
Haley's Ditch				
Seiberling St.	264	180	-	-
Confluence with Adam's Ditch	445	430	-	1010
Adam's Ditch				
Hobart Ave.	181	340	-	-

Table 3 100-Year Peak Flow Comparison				
Location	HEC-HMS (USGS)	USGS Streamstats	FEMA FIS	Ohio Bulletin No. 45
Little Cuyahoga River				
E. Market St. (SR 18)	1527	2000	-	3010
Confluence with Springfield Lake Outlet	2296	2660	1060	1799
Middlebury Run Park	2285	2830	1060	1894
Springfield Lake Outlet				
Massillon Road (SR 241)	775	1180	398	-
Confluence with Haley's Ditch	884	1500	470	-
Haley's Ditch				
Seiberling St.	468	340	-	-
Confluence with Adam's Ditch	714	760	-	2590
Adam's Ditch				
Hobart Ave.	370	580	-	-

Hydraulic Model

The next stage of the watershed model development consisted of creating an existing hydraulic model of the Little Cuyahoga River. The Hydrologic Engineering Center's River Analysis System (HEC-RAS v. 3.1.3) program was used for the hydraulic model. The Springfield Lake Outlet within the study limits and the Little Cuyahoga River downstream of the Springfield Lake Outlet are included in the FEMA Flood Insurance Study (FIS) and have 100-year base flood elevations established.

The hydraulic analysis followed FEMA required procedures where applicable, so the analysis could be used as part of a future LOMR submittal to FEMA. After creating the duplicate effective model (DEM) for the FEMA studied area from the backup data, it was determined that a corrective effective model (CEM) was needed primarily to update the method of analyzing dams in the Little Cuyahoga River. This was accomplished by using HEC-RAS' capability to directly analyze inline structures which was not available in its precursor program, HEC-2, which was used to create the original FIS model.

The next step in the analysis was to create an existing model from the CEM. We used available plan information supplemented by survey data to revise channel, overbank and structure data for changes which have occurred. These changes included a new pedestrian bridge in Middlebury Run Park (See Photo 2), new bridges at 3rd Avenue (See Photo 3) and relocated Kelly Avenue (See Photo 4), a bridge replacement at Seiberling Street (See Photo 5), and the removal of two railroad bridges and three pedestrian bridges over the Little Cuyahoga River. The existing model also incorporated the relocation of the river in Middlebury Run Park (see Photo 6) and the stretch between I-76 and Martha Avenue. After the CEM was updated to existing conditions, the existing model was extended to include the full study limits.

The results of the HEC-RAS analysis show that the existing 100-year flood elevations are higher than the corresponding duplicate effective elevations, predominately because the existing model uses a 100-year flow rate that is more than double the FIS flow rate. As discussed in Section 3, the proposed river restoration project would significantly lower the 100-year flood elevations. At the upstream end of the studied portion of the river (at the Springfield Lake Outlet confluence), the proposed 100-year flood elevation is within 0.5 feet of the effective flood elevation (regulatory base flood elevation).

Photo 2 – Downstream Side of Pedestrian Bridge (looking east)

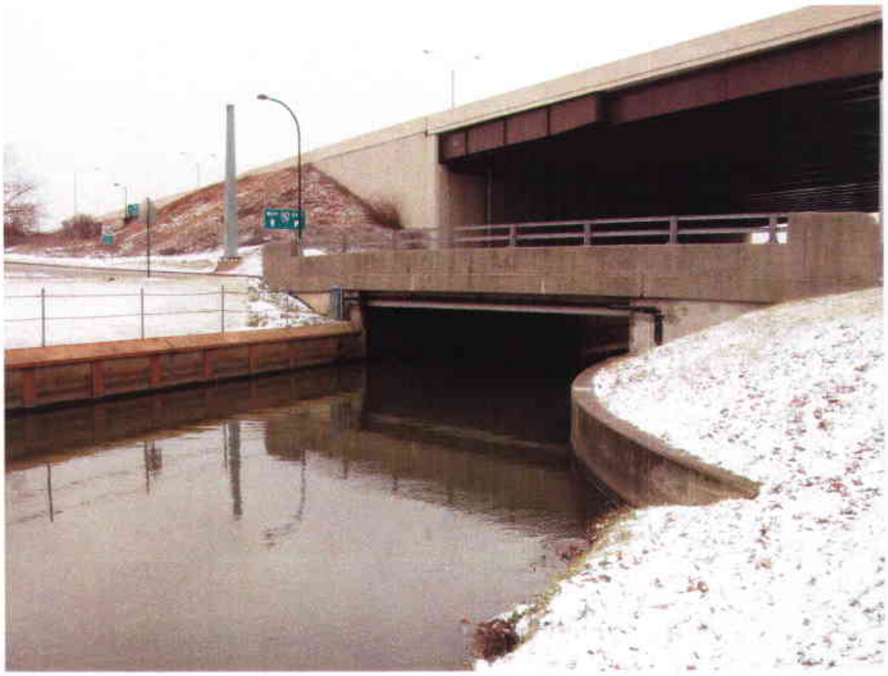


Photo 3 – Downstream Side of 3rd Avenue Bridge (looking southeast)

Photo 4 – Downstream Side of Kelly Avenue Bridge (looking southeast)

Photo 5 – Downstream Side of Seiberling Street Bridge (looking east)

Photo 6 – Relocated River in Middlebury Run Park (at Martha Ave. looking east)

Section 3 Proposed Analysis

In order to facilitate redevelopment of the area and to restore a portion of the Little Cuyahoga River to a more natural condition, the City of Akron has undertaken a river restoration project as previously discussed. The limits of the river restoration are from just upstream of the Martha Avenue culvert to 2,400 feet upstream. The river restoration will essentially maintain the river through its existing corridor; however, the proposed alignment of the low flow channel will meander through this corridor.

The retail portion of the proposed development covers an area now occupied by Middlebury Run Park and several businesses along the south side of Englewood Avenue. As shown on Figure 5, much of this area is contained within the existing 100-year floodplain. In order to lower flood elevations in the area of the redevelopment, the Goodyear Dam downstream of Kelly Avenue will also be modified. The dam modifications will consist of lowering the full 40-foot width of the dam, which would include removal of the 15-foot wide gate as well as lowering of the fixed concrete spillway portions on either side of the gate. This will result in lowering the normal water elevation upstream of the dam by approximately 5 feet.

One objective of the river restoration and dam modification projects is to contain the 100-year flood limits within a 150-corridor. In order to accomplish this, the river restoration design included raising the elevation of the northern edge of the 150-foot corridor to provide sufficient depth of flow for the 100-year storm event. As shown on Figure 5, raising the grade adjacent to the river would create two low areas to the north which are lower than the adjacent 100-year flood elevations. It was not the intent of the river restoration project to design and construct a levee along the north side of the river which would satisfy ODNR and US Army Corps of Engineers requirements. Accordingly, the low areas are not considered to be protected by the northern embankment and are, therefore, included in the proposed 100-year flood limits. This is intended to be a temporary condition as the low areas will be filled above the 100-year flood elevations when this area is redeveloped and will then be removed from the 100-year flood limits. In the HEC-RAS analysis, the 100-year flood peak flow was maintained within the 150-foot river corridor and the low areas to the north were not assumed to convey any portion of the 100-year flow. Subsequent filling of this area will therefore not impact the proposed 100-year flood elevations.

Field survey and visual observations of the river revealed that a significant amount of sediment has been deposited upstream of the dam particularly west of Martha Avenue. If the dam were removed, several feet of sediment would have to be dredged from the river in this area, or it would be naturally removed by the river over time.

Removal of the river bed material could expose the foundations of the bridges at 3rd Avenue and relocated Kelly Avenue and the existing soldier pile walls at various locations between the dam and Martha Avenue. The City is investigating the need for modifications to these structures and will proceed with design and construction of any necessary modifications. A preliminary evaluation has indicted that the Kelley Avenue bridge will be replaced, and the foundation of the 3rd Avenue bridge will be protected with rock channel protection, neither of which is anticipated to have a significant impact to flood elevations upstream of Martha Avenue.

The proposed HEC-RAS model includes the river restoration, lowering of the Goodyear Dam, and removal of the sediment upstream of the dam. The results of the proposed analysis reveal that the 100-year peak flow would be contained within the proposed 150-foot river corridor for the entire length of the relocation. The 100-year flood limits for the proposed river improvements are shown on Figure 5 along with the existing and effective 100-year flood limits (FEMA special flood hazard area).

The proposed 100-year flood elevations are considerably lower than the existing flood elevations within the area of the river restoration. The proposed 100-year flood elevation is within 0.5 feet of the effective flood elevation at the upstream end of the studied portion of the river.

ARCADIS

Infrastructure, buildings, environment, communications

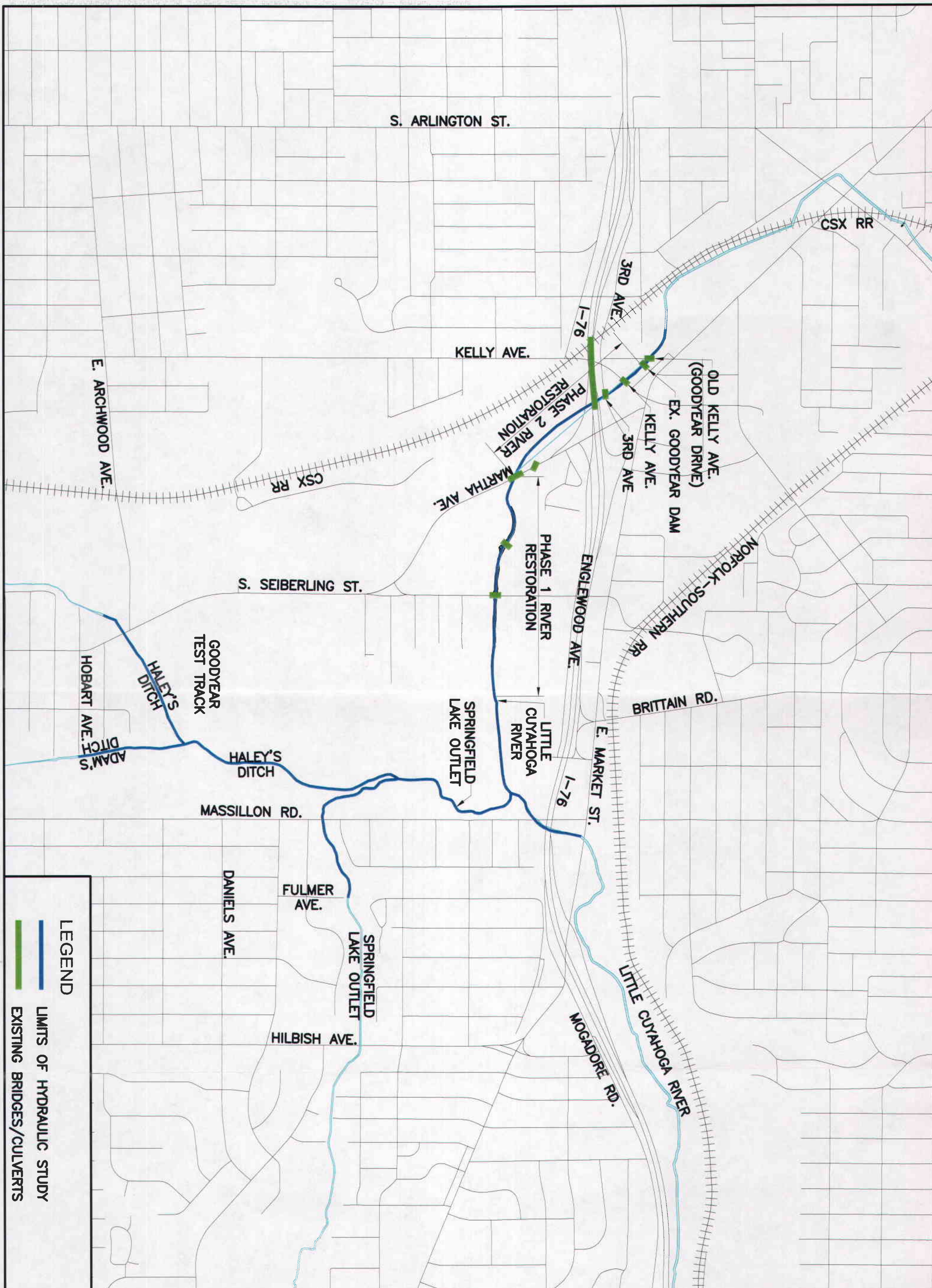
Date: 11/25/09

Analyst: PSB

Project: Little Cuyahoga River CLOMR

Drainage Area Reference No.	Type of Drainage Area (Urban or Rural)	Drainage Area (Mi^2)	Drainage Area (Ac)	Main Channel Length (Ft)	Main Channel Length (Mi)	Amount of Storage (Ac)	Storage as a % of Total Area (%)	Stream Elev. @ 10% Length of Main Channel (Ft)	Stream Elev. @ 85% Length of Main Channel (Ft)	Main Channel Slope (SL) (Ft/Mile)	Rural Basin Lag Time (LT) (Hr)	Amount of Forested Area (Ac)	Amount of Forested Area (%)
1	Urban	1.86	1190.4	9400	1.780	0.918	0.08	1021.0	1111.0	67.4			
2	Urban	0.36	230.4	5800	1.098	3.874	1.68	1020.0	1148.0	155.4			
3	Urban	1.80	1152.0	14000	2.652	1.406	0.12	1021.0	1155.0	67.4			
4A	Rural	0.73	467.2	7300	1.383	0.918	0.20	1015.0	1065.0	48.2	2.30	14.23	3.05
4B	Rural	1.49	953.6	12000	2.273	9.000	0.94	1037.0	1090.0	31.1	3.46	5.00	0.52
4C	Rural	5.31	3398.4	31000	5.871	148.600	4.37	1027.0	1124.0	22.0	7.99	345.76	10.17
5 (W/O Springfield Lake for Storage)	Rural	3.23	2067.2	11700	2.216	117.670	5.69	1078.0	1107.0	17.4	9.64	148.99	7.21
6	Rural	2.00	1280.0	12700	2.405	9.580	0.75	1050.0	1170.0	66.5	2.41	136.70	10.68
7	Rural	3.64	2329.6	14400	2.727	31.440	1.35	1026.0	1048.5	11.0	10.76	252.67	10.85
8	Rural	4.50	2880.0	21800	4.129	187.590	6.51	1081.0	1152.0	22.9	10.46	674.83	23.43
9	Rural	1.34	857.6	9300	1.761	59.640	6.95	1052.0	1068.0	12.1	15.65	128.90	15.03
10	Rural	2.83	1811.2	19000	3.598	11.780	0.65	1085.0	1158.0	27.0	5.14	273.13	15.08
11 (W/O Mogadore Reservoir for Storage)	Rural	13.73	8787.2	15200	2.879	372.930	4.24	1110.0	1180.0	32.4	7.02	1935.20	22.02
12 (W/O Wingfoot Lake for Storage)	Rural	2.83	1811.2	3000	0.568	158.070	8.73	1155.0	1176.0	49.3	5.59	274.45	15.15
13	Urban	0.05	32.0	1800	0.341	0.000	0	995.4	996.4	3.9			

Drainage Area Reference No.	Q_{10} (Rural 10-Year Peak Discharge) (CFS)	Q_{10} (Rural 10-Year Peak Discharge Per Ohio Bulletin # 45) (CFS)	Q_{50} (Rural 50-Year Peak Discharge) (CFS)	Q_{50} (Rural 50-Year Peak Discharge Per Ohio Bulletin # 45) (CFS)	Q_{100} (Rural 100-Year Peak Discharge) (CFS)	Q_{100} (Rural 100-Year Peak Discharge Per Ohio Bulletin No. 45) (CFS)	Q_{500} (Rural 500-Year Peak Discharge) (CFS)	Urban Basin Lag Time (LT) (Hr)	Average Annual Precipitation (In)	Basin Development Factor (BDF) = Use of Storm Sewers, Curbed Pavt Sections, Lined Channels, Channel Improvements (Rank on Scale of 1 to 12)	UQ_{10} (Urban 10-Year Peak Discharge) (CFS)	UQ_{50} (Urban 50-Year Peak Discharge) (CFS)	UQ_{100} (Urban 100-Year Peak Discharge) (CFS)	UQ_{500} (Urban 500-Year Peak Discharge) (CFS)
1								0.8946	37	9	767.7	1235.2	1455.5	1892.2
2								0.5355	37	9	227.7	343.1	397.7	517.0
3								1.4524	37	6	595.7	989.8	1179.1	1532.9
4A	198.3	182.2	318.9	287.7	372.2	337.8	439.2							
4B	261.1	241.4	408.2	365.7	472.4	422.8	549.6							
4C	450.9	411.3	677.0	580.0	773.7	654.1	1005.8							
5 (W/O Springfield Lake for Storage)	270.7	248.9	403.1	346.3	459.1	387.6	596.8							
6	407.9	364.3	653.3	564.2	761.6	660.2	990.1							
7	376.3	362.3	563.3	525.7	644.2	597.4	837.5							
8	358.6	324.1	536.1	450.1	611.4	504.6	794.8							
9	119.3	111.5	176.1	153.5	199.8	170.4	259.7							
10	435.3	405.6	676.5	614.3	782.4	711.3	1017.2							
11 (W/O Mogadore Reservoir for Storage)	1032.2	921.7	1559.5	1303.9	1787.1	1478.8	2323.2							
12 (W/O Wingfoot Lake for Storage)	278.1	241.4	425.3	338.5	487.6	381.2	633.8							
13								0.8698	37	8	48.2	68.0	77.7	101.0



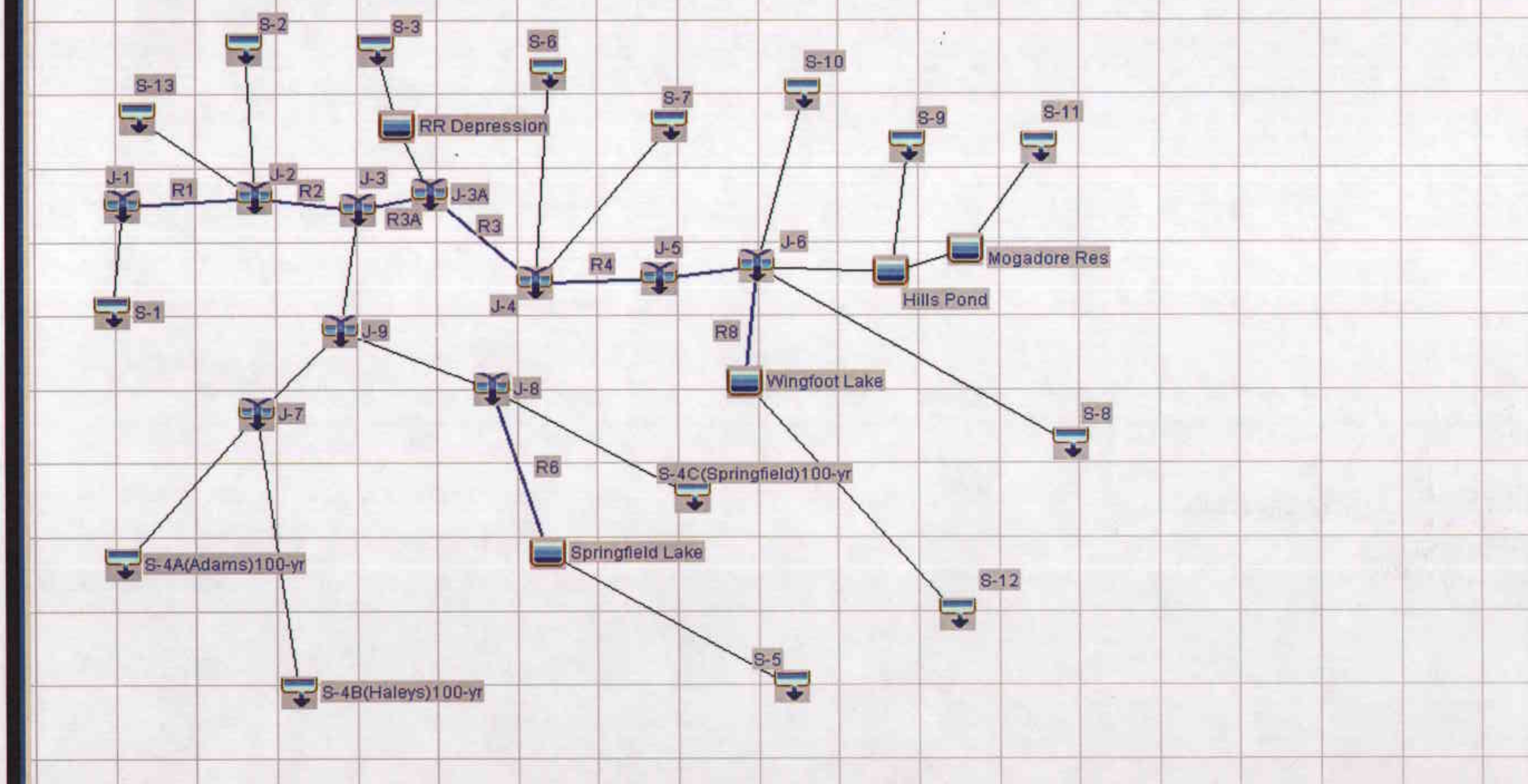
ARCADIS
ARCADIS U.S., Inc.
520 South Main Street, Suite 2400
Akron, Ohio 44311
Tel: 330-434-1995 Fax: 330-374-1095
www.arcadis-us.com

LITTLE CUYAHOGA RIVER
FINAL HYDRAULIC STUDY
AKRON, OHIO
FIGURE 1 - STREAM SCHEMATIC PLAN

0 500 1000 1500 2000
1" = 1000 FT.

N

FIGURE 3



S-2
S-3
S-6
S-13
S-10
S-7
S-9
S-11
RR Depression
J-1
R1
J-2
R2
J-3
J-3A
R3A
R3
J-5
J-6
R4
Mogadore Res
J-4
Hills Pond
S-1
J-9
R8
J-8
Wingfoot Lake
J-7
S-8
R6
S-4C(Springfield)100-yr
Springfield Lake
S-4A(Adams)100-yr
S-12
S-5
S-4B(Haleys)100-yr