APPENDIX H

SEDIMENT VOLUME DISTRIBUTION STUDY

Distribution of Sediment Deposits in the Mahoning River

PROJECT SUMMARY

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November, 1998

BACKGROUND

Past industrial use of the Mahoning River between Warren, Ohio and the Ohio-Pennsylvania (OH/PA) state line has resulted in severe contamination of the river's bottom sediments with heavy metals, PCBs, PAH, etc. The Water Resources Development Act of 1996 authorized the U.S. Army Corps of Engineers, Pittsburgh District to perform studies of the feasibility of ecosystem restoration in this section of the river. Under the Energy and Water Development Appropriations Act of 1998, $1 million was allocated for these studies. AWK Consulting Engineers, Inc. was hired by the Corps of Engineers to perform several project elements for the Reconnaissance Phase of the study, including chemical testing of sediments, estimation of sediment volume, analysis of the ecological benefits of remediation, preliminary evaluation of remediation alternatives, and development of preliminary cost estimates. The project area was defined as extending from the OH/PA state line (RM 11.9) to the navigable limit as defined by the Corps of Engineers (RM 40.7), which is about 1.9 miles below the Warren North River Road Dam (near Copperweld Steel Corp.).

In order to evaluate the feasibility and cost of various alternatives for remediation of contaminated bottom sediments in the Mahoning River, it is essential that the location and volume of sediment deposits be known with reasonable accuracy. The only previous survey of bottom sediment distribution was conducted by Havens and Emerson (1976), in a study funded by the U.S. Army Corps of Engineers, Pittsburgh District. It was estimated that the Mahoning River contained 281,000 cubic yards (CY) of sediment deposits between the Warren North River Road dam and the state line. This study also indicated that the presence of 285,000 CY of "oil-soaked banks" between RM 13.0 and RM 36.8 posed a further environmental threat to the river. To obtain an independent, updated estimate of sediment volume, AWK Consulting Engineers, Inc. contracted Youngstown State University (YSU) to perform a field survey as part of the Reconnaissance Phase study. As part of this survey, observations were also made of the presence of visible oil stains on the river banks, and the organic matter content was measured on several samples of bottom and bank sediments.

METHODS

The section of the river surveyed in this study differed somewhat from the Corps of Engineers project area. The downstream limit was the Lowellville First Street Dam. The one mile section between the Lowellville dam and the OH/PA state line was not surveyed due to time and budgetary constraints at the end of the project. The upstream limit of this survey was the Leavittsburg Leavitt Road Dam. This was initially recommended as the upstream boundary of the project area by the Steering Committee advising the Corps of Engineers.

Field Procedures:

For purposes of this study, the project area was divided into ten reaches, or "pools", defined as sections of the river between two adjacent dams. The work was performed from a canoe, beginning at the Lowellville dam (RM 13.0) and working upstream. Within each reach, the depth of sediment deposits was measured along several transects across the river. In the first seven reaches surveyed, distances along the river were measured by towing a 150 ft. nylon rope, with

buoys tied at 25 ft. intervals, behind a canoe while paddling upstream. Markers (orange tape) were tied along the river bank at intervals of 100 to 600 ft. (usually 300 ft). These markers were used to determine the location of transects. In the three uppermost reaches, the swiftness of the river current made paddling upstream impractical. So, the sediments were surveyed while paddling the canoe in the downstream direction. The location of each transect was marked on a detailed map of the river.

Transects were performed at intervals ranging from 100 ft. to 600 ft. or more. In general, where sediment deposits were heavy, an interval of 150 ft. to 300 ft. was used. Where sediment deposits were light, an interval of 300 to 600 ft. was used. In sections of the river where swift current does not permit sediment deposition to occur, intervals greater than 600 ft. were occasionally used.

The depth of bottom sediments was measured at 5 ft. intervals along each transect. In addition, since it was found that sediment deposits were often thickest at the river banks, depth measurements were also performed at a distance of 1 ft. from each bank. Measurements were performed by starting at the river bank and moving outward into the river channel until the depth of sediment deposits became insignificant. Distances from the banks were approximated by eye, using the 17 ft. length of the canoe as a guide. The depth of sediment deposit at each point was measured using two poles to locate the top and bottom of the deposit. The bottom of the deposit was first located by manually forcing a ¾ inch diameter steel pipe through the deposit until solid bottom was encountered. Next, the top of the deposit was located using a 2 inch diameter wooden pole with a 6 inch by 6 inch plywood pad fastened to the bottom. This pole was gently lowered until the pad rested on the sediment surface. Initially, both poles were marked with graduations of 0.1 ft. During the last half of the study, an interval of 0.5 ft. was used for the steel pole to save time in replacing the graduations, which were frequently worn away by abrasion. At each transect point, the depths from the water surface to the top and bottom of the sediment deposits were recorded in a field notebook to the nearest 0.1 ft., and the depth of the deposit was calculated by taking the difference between the readings. In addition, a brief description of the sediment grain size was entered.

During the field survey, unusual features of the sediment deposits that could not be captured by the data alone were described in the field notebook. In addition, the location of certain landmarks (e.g. bridges) and observations of the river banks were recorded, along with other general observations of the river (e.g. fauna).

Samples of bottom sediment and soil from the river banks were taken from several locations. Bottom sediments were collected by scooping with a plastic cup fastened to a wooden pole. Sediments were transferred to glass I-Chem jars using a stainless steel knife. Bank material was collected directly with the stainless steel knife and placed in glass I-Chem jars as well. Large leaves and sticks were excluded from the samples.

Sediment Volume Calculations:

For each transect, the cross-sectional area occupied by sediment deposits was estimated using the equation:

$$A = \frac{1}{2}\sum_{i=1}^{n}(z_i + z_{i-1})d_i$$

where:

A = cross-sectional area occupied by sediment deposits, ft^2;

z_i , z_{i-1} = depths of sediment deposits at adjacent sampling points along a transect; ft;

d_i = distance between adjacent sampling points, ft.; and

n = number of sampling points at which measurements were taken.

Then, the volume of bottom sediment deposits between two adjacent transects was estimated using the equation:

$$V = \frac{1}{2}(A_u + A_d)L$$

where:

V = volume of sediment deposits between two adjacent transects, ft^3;

A_u = cross-sectional area occupied by sediment deposits at the upstream end of the river segment, ft^2;

A_d = cross-sectional area occupied by sediment deposits at the downstream end of the river segment, ft^2; and

L = distance between adjacent transects, ft.

All volumes were converted from cubic feet to cubic yards by dividing by 27. The total sediment volume within a reach of the river was obtained by summing all volumes between transects in that reach. In the first seven reaches, a correction factor was applied to the total volume estimate to account for any discrepancy between the total length of the reach measured in the field and the actual length reported by Havens and Emerson (1976) and Ohio EPA (1996). All calculations were performed using Microsoft Excel spreadsheets.

Laboratory Procedures:

Sediment and soil samples were stored at 4 C in a refrigerator until processing. A portion of the sample was placed in an aluminum dish and water was removed by evaporation in an oven at 103 C for at least eight hours. After recording the dry weight, samples were placed in a furnace at 550 C for at least one hour. They were then removed and cooled in a desiccator, and weighed again. The organic (volatile) matter content of the sample was obtained by calculating the weight loss during combustion in the furnace.

RESULTS

Volume and Distribution of Sediment Deposits:

The estimates of total sediment volume in each reach of the Mahoning River are presented and compared to the Havens and Emerson (1976) study in Table 1 and Figure 1. Copies of the spreadsheets containing the volume calculations for all ten reaches are included in the Appendix, along with one example of a spreadsheet used to calculate the cross-sectional area occupied by bottom sediments at a particular transect. A total volume estimate of 475,775 cubic yards was obtained for the area surveyed. The total volume estimate for reaches 1-8 was 63.7% greater than

TABLE 1. Results of Mahoning River Sediment Survey and Comparison to 1976 Havens and Emerson Study.

Reach No.	Reach Name	Length (Miles)	Key	1976 Vol. (CY)	1998 Vol. (CY)	CY/Mile
10	West Leavittsburg	1.1	WL		3,636	3,305
9	Leavittsburg	2.6	LEA		12,140	4,669
8	North Warren	2.6	NW	8,700	35,021	13,470
7	South Warren	3.2	SW	5,000	7,484	2,339
6	Niles	9.8	NIL	213,800	243,137	24,810
5	Girard	3.8	GIR	11,800	78,164	20,569
4	North Youngstown	2.1	NYO	9,000	26,064	12,411
3	South Youngstown	2.9	SYO	7,600	21,437	7,392
2	Struthers/Campbell	1.9	S/C	7,600	34,166	17,982
1	Lowellville	3.3	LOW	17,500	14,526	4,402
	Total (or Ave)	**33.3**		**281,000**	**475,775**	**14,288**

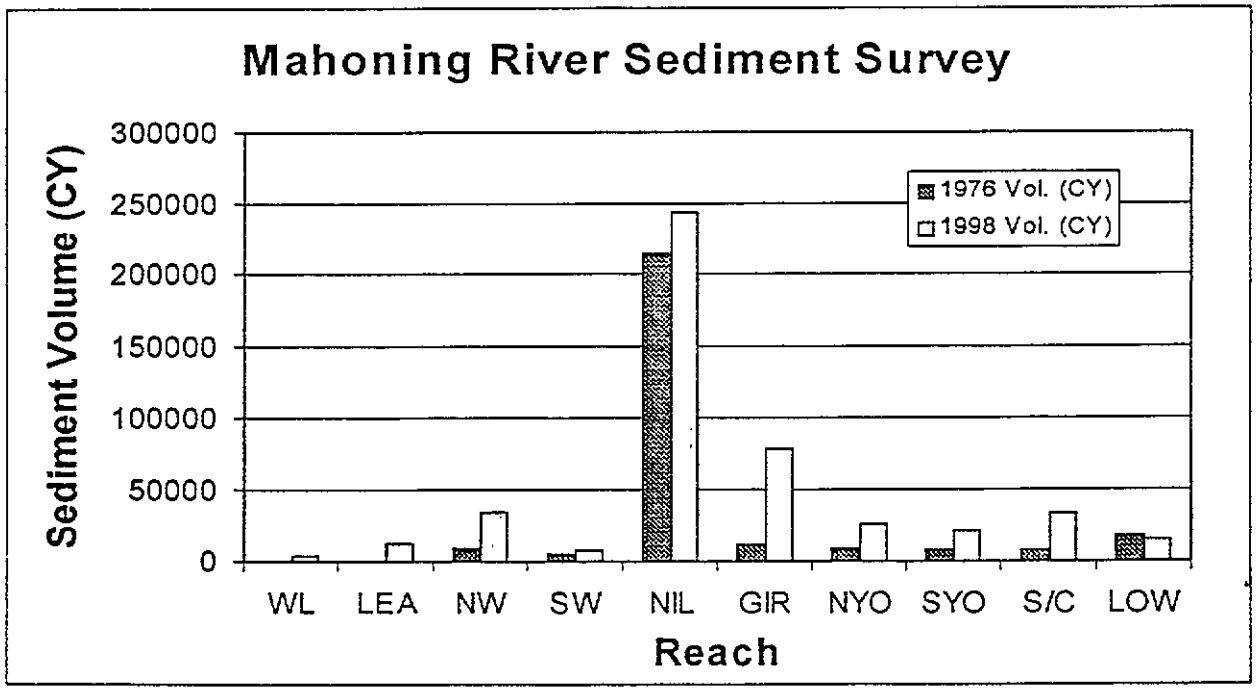

FIGURE 1. Distribution of Sediment Deposits in the Mahoning River and Comparison to 1976 Estimates by Havens and Emerson.

that reported by Havens and Emerson (1976) for the same eight reaches. It is believed that this discrepancy is due mainly to differences in the field methods employed. Havens and Emerson (1976) measured sediment depth at a distance of 20 ft. from the river banks. If sediment was found, they assumed that the depth was uniform over the entire 20 ft. distance. The 1998 survey revealed that the depths of sediment deposits at distances of 1 ft., 5 ft., 10 ft., and 15 ft. from the banks were almost always greater, and often much greater, than at 20 ft.

With the exception of a large sediment deposit (about 22,000 CY) near Packard Park in Warren, the volume of sediment deposits in the upper four reaches (9.5 miles) was very low (less than 5,000 CY/mile). The slope of the river and swiftness of the current are greater here than in the lower reaches, providing little opportunity for sediment deposition. Not surprisingly, the heaviest sediment deposits were found in the Girard and Niles pools, with sediment volume exceeding 20,000 CY/mile. Most of the sediment load accumulated by the river in the Warren area is deposited in these reaches. In the lower reaches of the project area (Youngstown, Campbell/Struthers and Lowellville), the volume of deposits is variable, but generally falls between these two extremes. Since the current is fairly swift in the one mile section between the Lowellville First Street Dam and the OH/PA state line, it is expected that the volume of sediment deposits is fairly low, most likely less than 2,000 CY.

The total volume of sediment deposits within the Corps of Engineers project area defined by the navigable limit of the Mahoning River can also be calculated from the results of this survey. The estimated sediment volume in reaches 1 to 7 (i.e. from the Lowellville First Street dam to the Warren Summit Street dam) is 424,978 CY. Of the estimated 35,021 CY of sediment deposits in reach 8 (North Warren pool), 6,693 CY is located above the navigable limit and 28,329 CY is located downstream of the navigable limit. Thus, the estimated total sediment volume within the Corps of Engineers project area is 453,306 CY, excluding the one mile section between the Lowellville First Street dam and the OH/PA state line. Adding 1,000 to 2,000 CY for this section results in a total sediment volume estimate of approximately 455,000 CY.

To provide greater detail on the location of sediment deposits within each reach, plots of the cumulative volume of deposits versus river mile were developed. These plots are presented for the ten reaches surveyed in Figures 2 through 11. All ten reaches are shown on one plot in Figure 12. The areas of heaviest sediment deposits are indicated by a steep slope of the cumulative volume curve. Examination of these plots reveals four distinctly different patterns. In three reaches, most of the sediment (over 70%) is contained in a fairly short length of the river within 0.5 mile of the downstream dam. These are the West Leavittsburg pool, the North Warren pool, and the South Warren pool. Three other reaches have a relatively uniform distribution of sediment deposits over their entire length, as indicated by a constant slope to the cumulative volume curve. These are the Leavittsburg, Niles, and Lowellville pools. A third pattern is characterized by significant and fairly uniform sediment deposits over most of the reach, with heavier deposits (accounting for about 40% of the total) within 0.1 to 0.5 miles of the downstream dam. Three adjacent reaches – the Girard, North Youngstown and South Youngstown pools – exhibit this pattern. The Struthers/Campbell pool shows a unique pattern of sediment deposition. Most of the sediment volume in this reach is located in the middle of the pool, with very little deposited in the first 0.5 mile of the reach or in the last 0.3 mile above the downstream dam.

Figure 2
Mahoning River
West Leavittsburg Pool
Cumulative Volume -vs- Distance

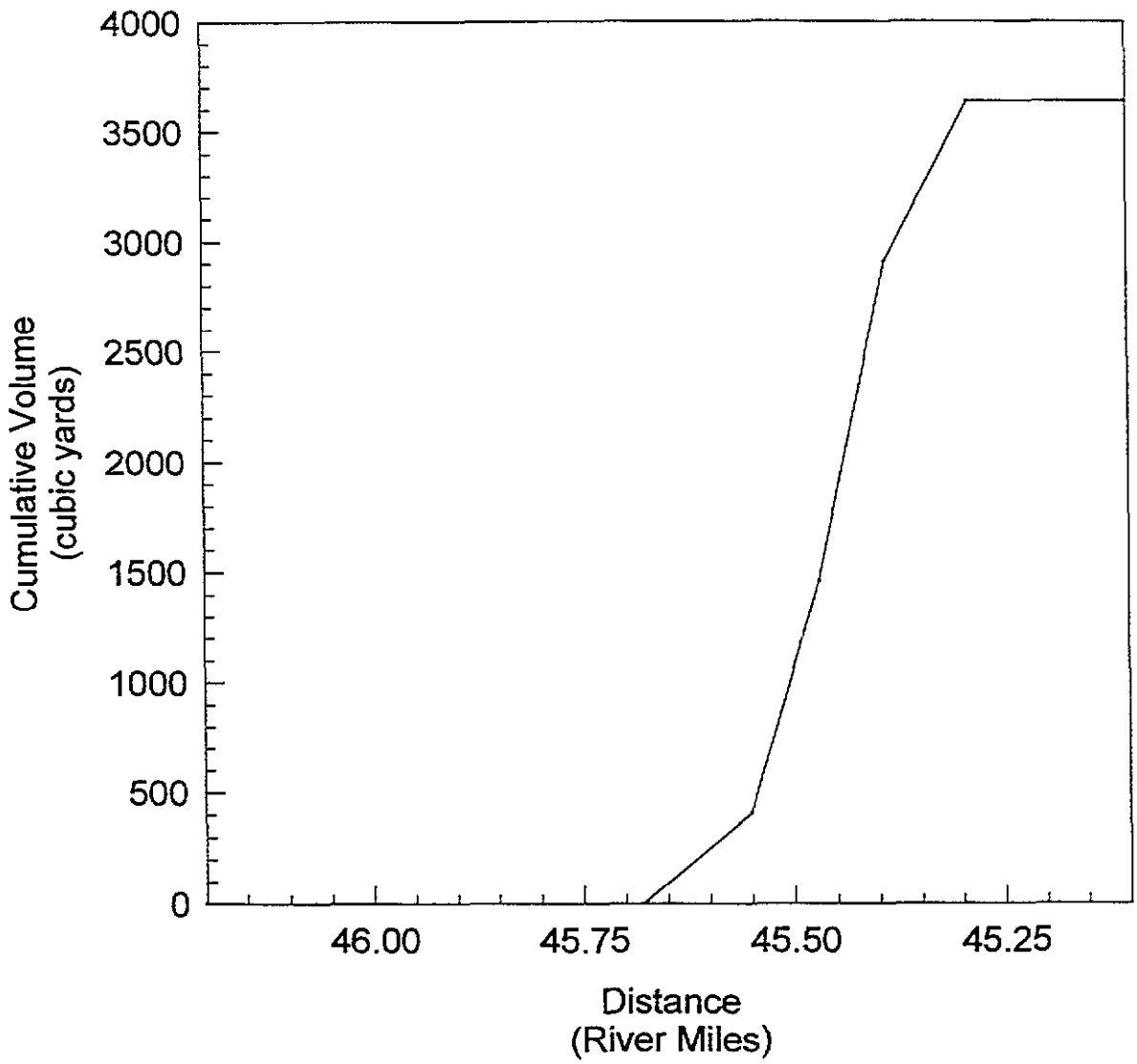

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Figure 3
Mahoning River
Leavittsburg Pool
Cumulative Volume -vs- Distance

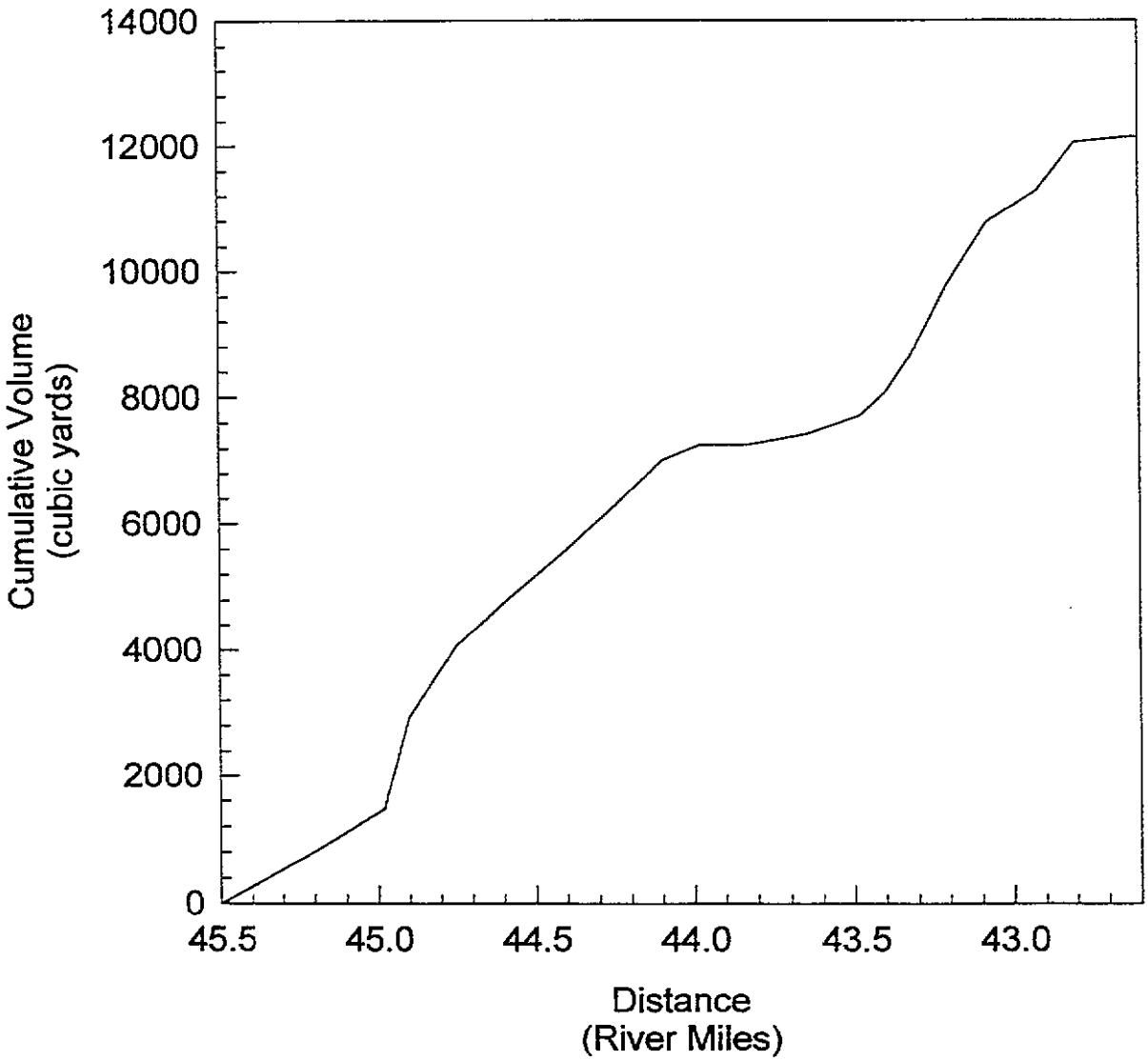

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Figure 4
Mahoning River
North Warren Pool
Cumulative Volume -vs- Distance

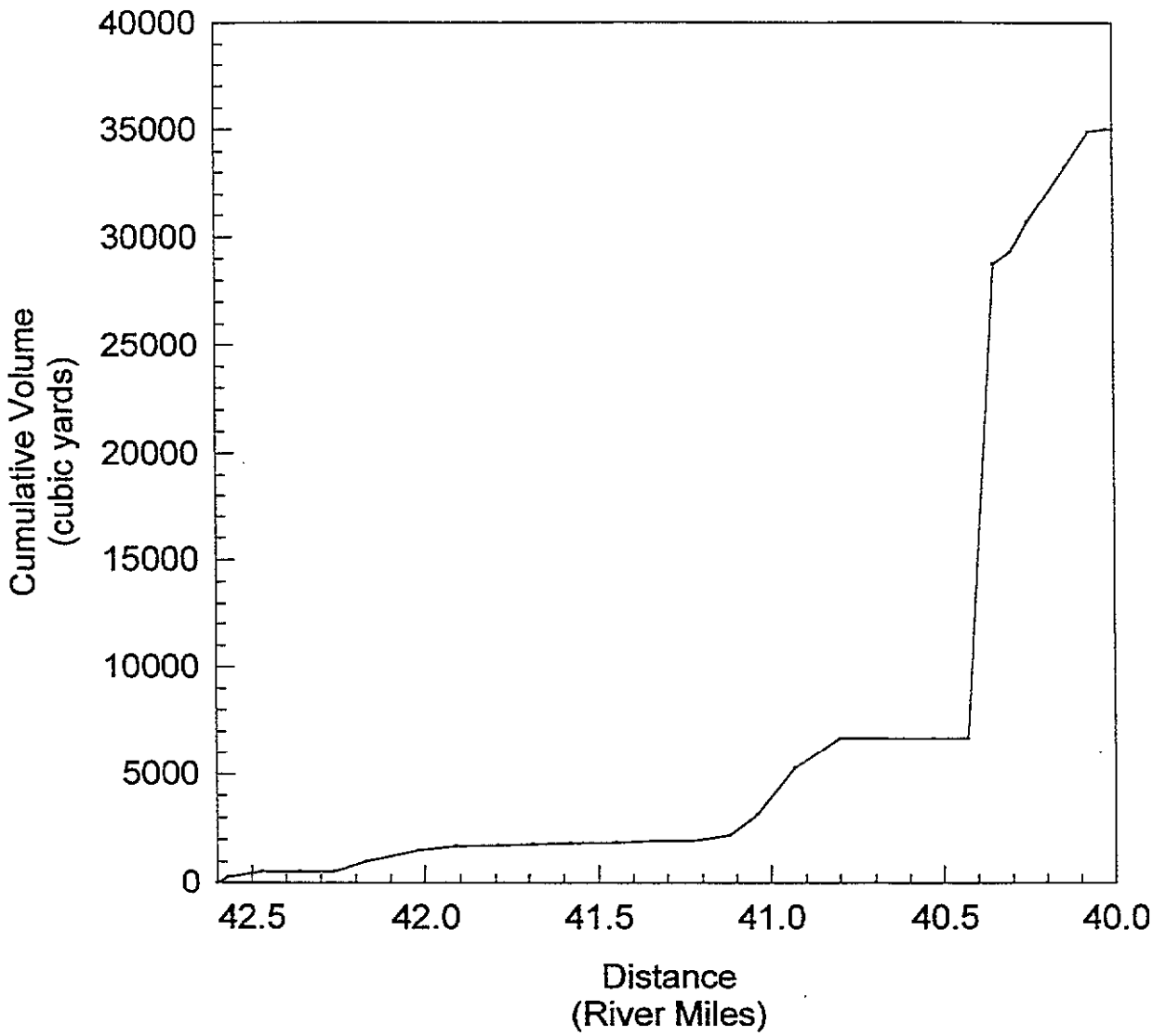

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Figure 5
Mahoning River
South Warren Pool
Cumulative Volume -vs- Distance

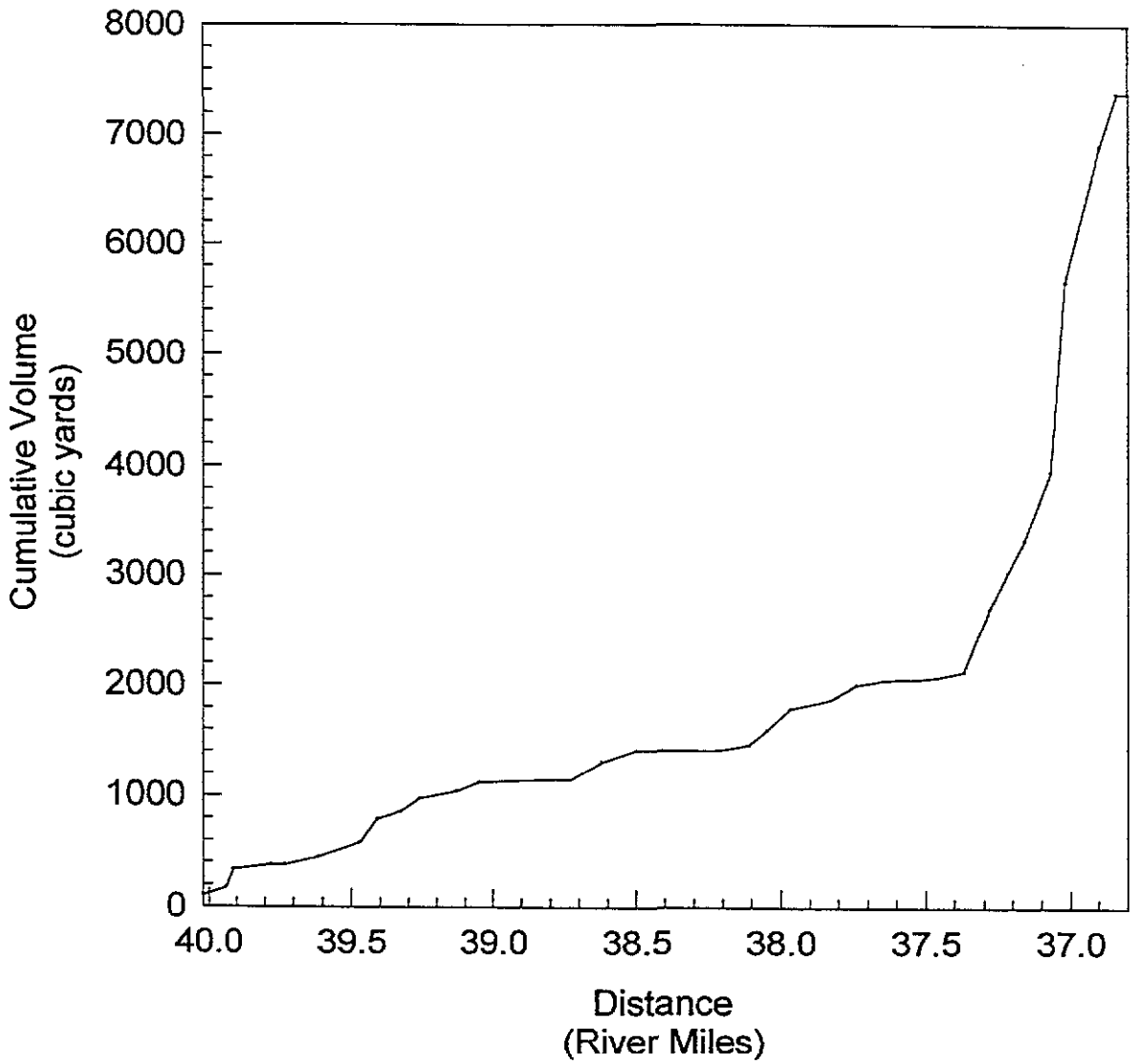

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Figure 6
Mahoning River
Niles Pool
Cumulative Volume -vs- Distance

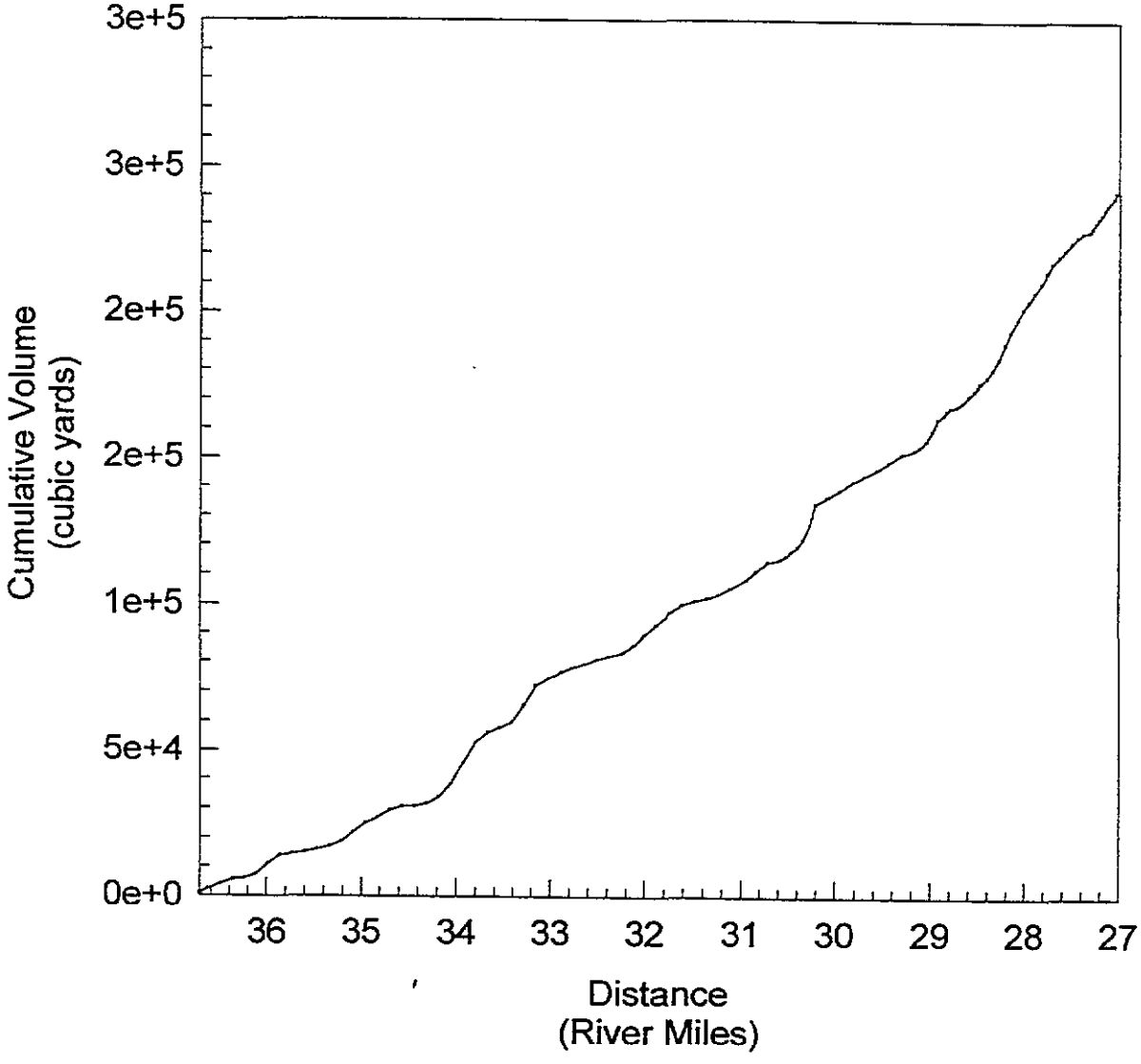

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Figure 7
Mahoning River
Girard Pool
Cumulative Volume -vs- Distance

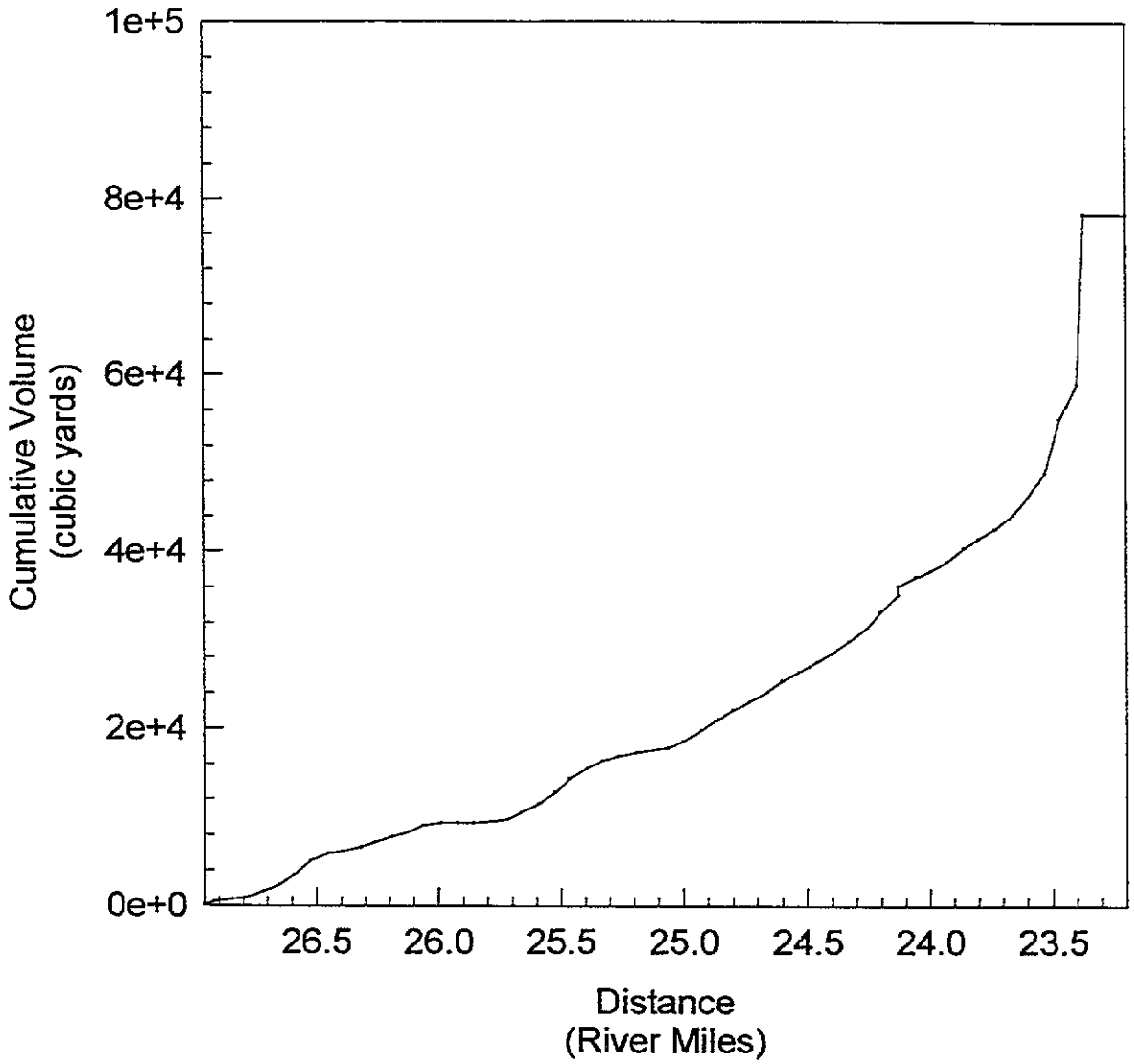

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Figure 8
Mahoning River
North Youngstown Pool
Cumulative Volume -vs- Distance

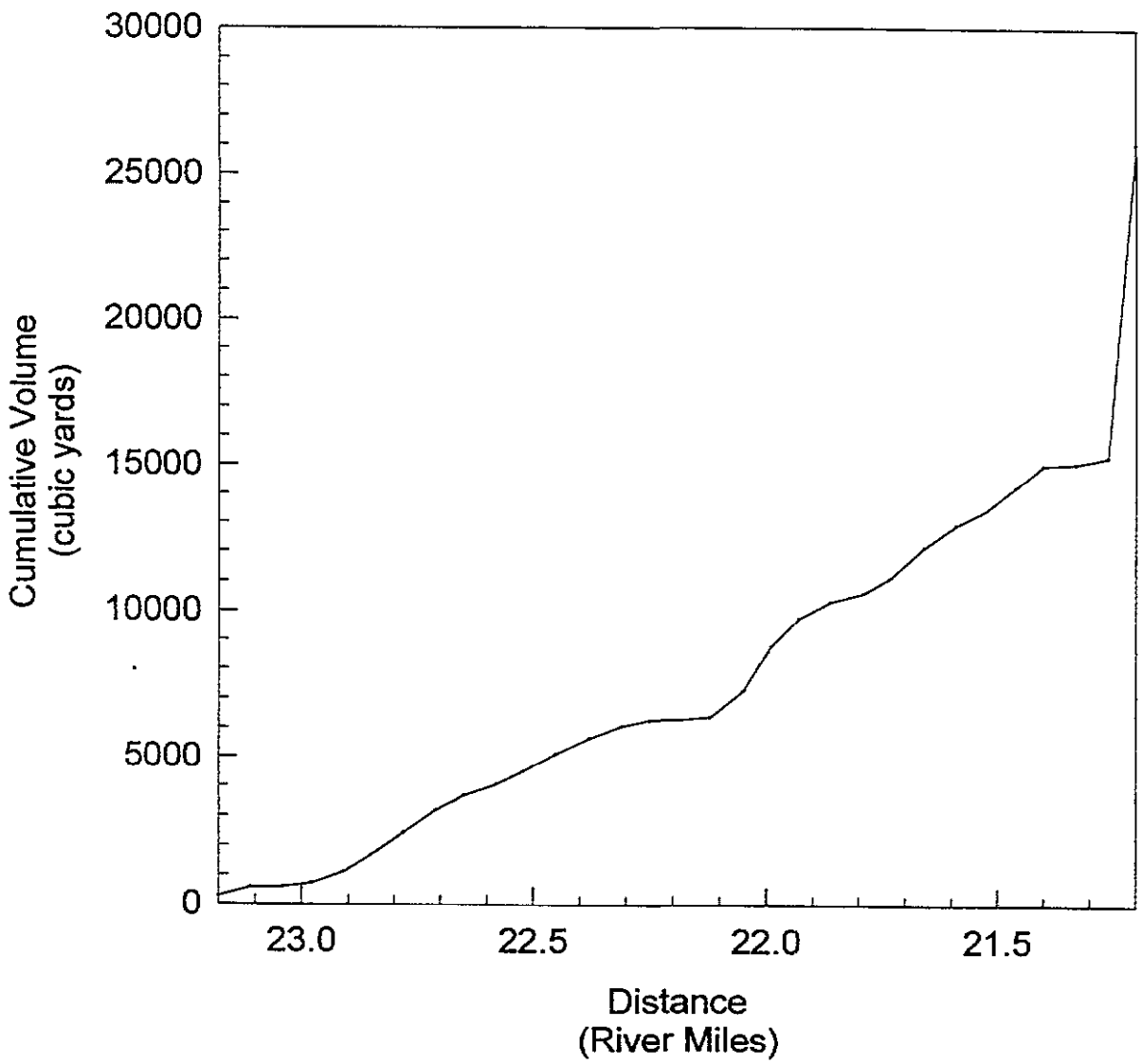

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Figure 9
Mahoning River
South Youngstown Pool
Cumulative Volume -vs- Distance

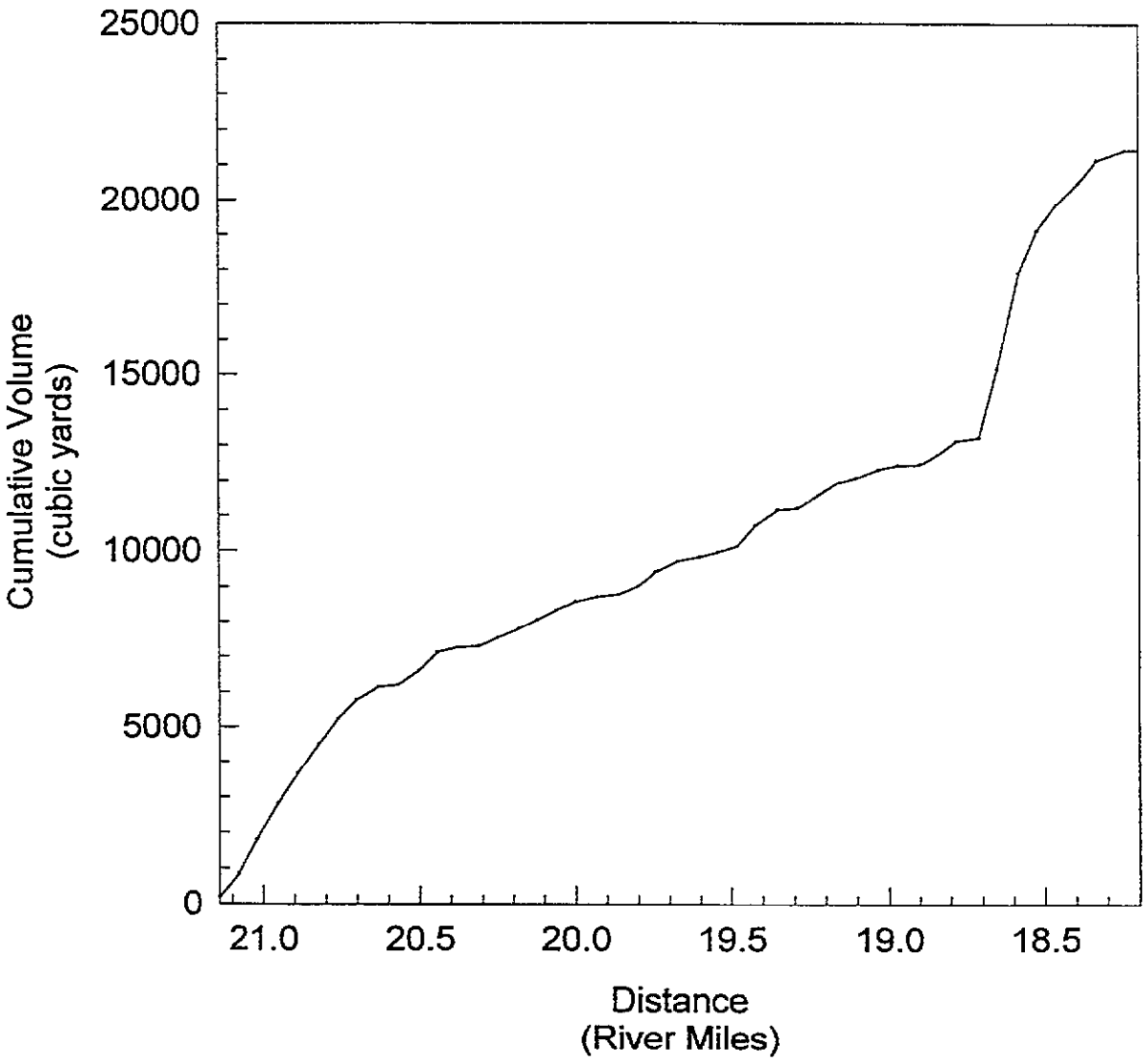

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Figure 10
Mahoning River
Struthers/Campbell Pool
Cumulative Volume -vs- Distance

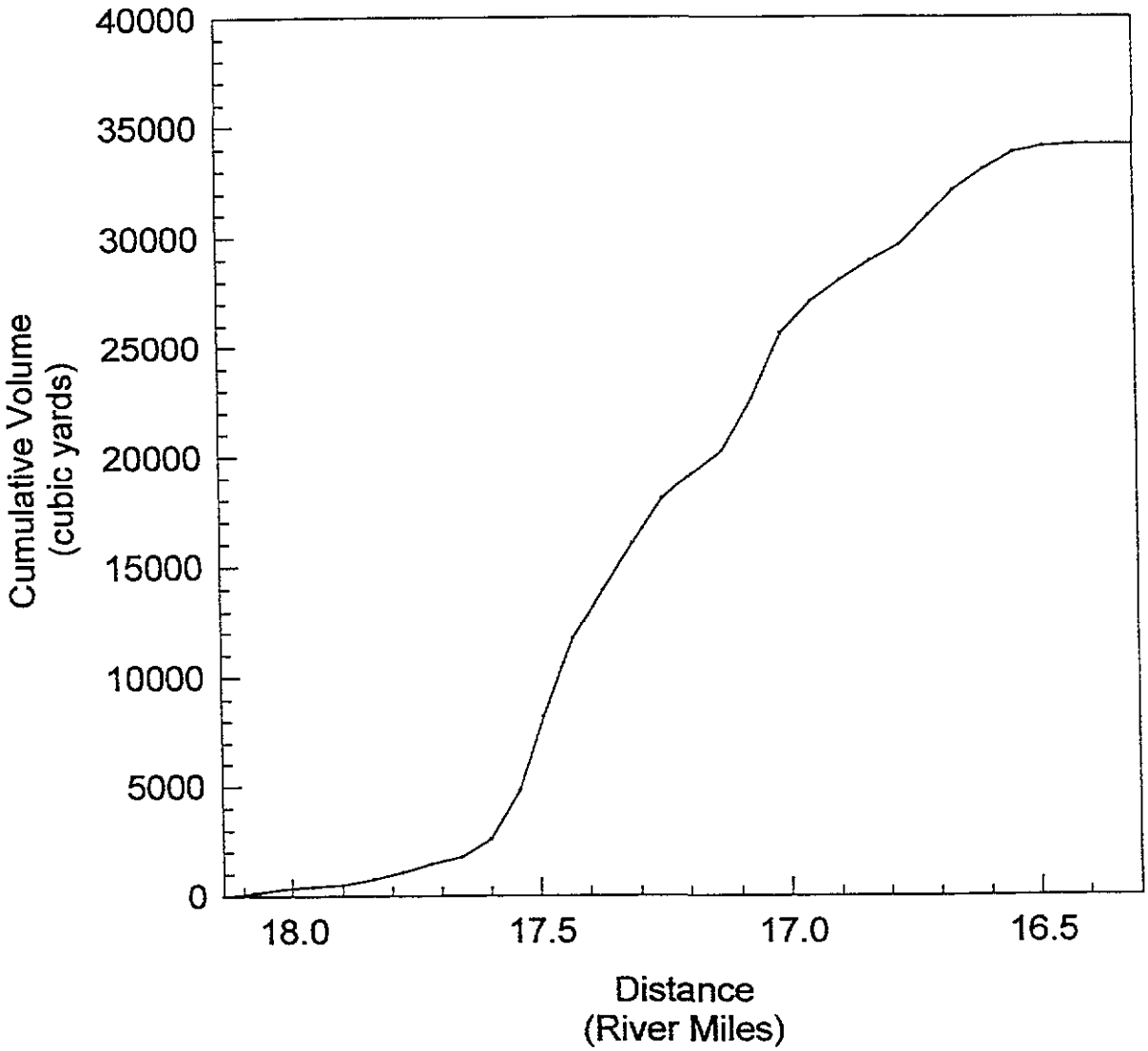

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Figure 11
Mahoning River
Lowellville Pool
Cumulative Volume -vs- Distance

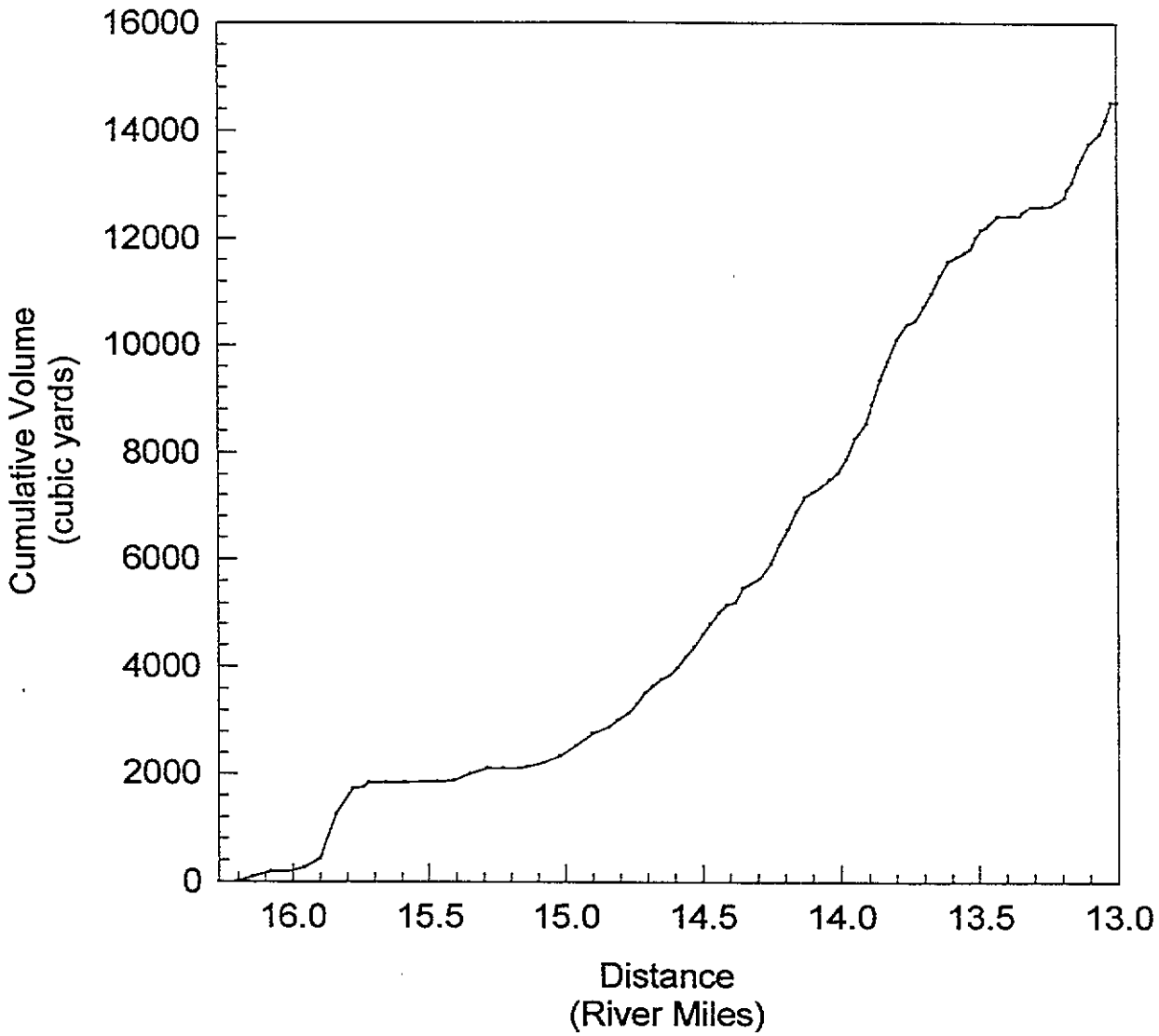

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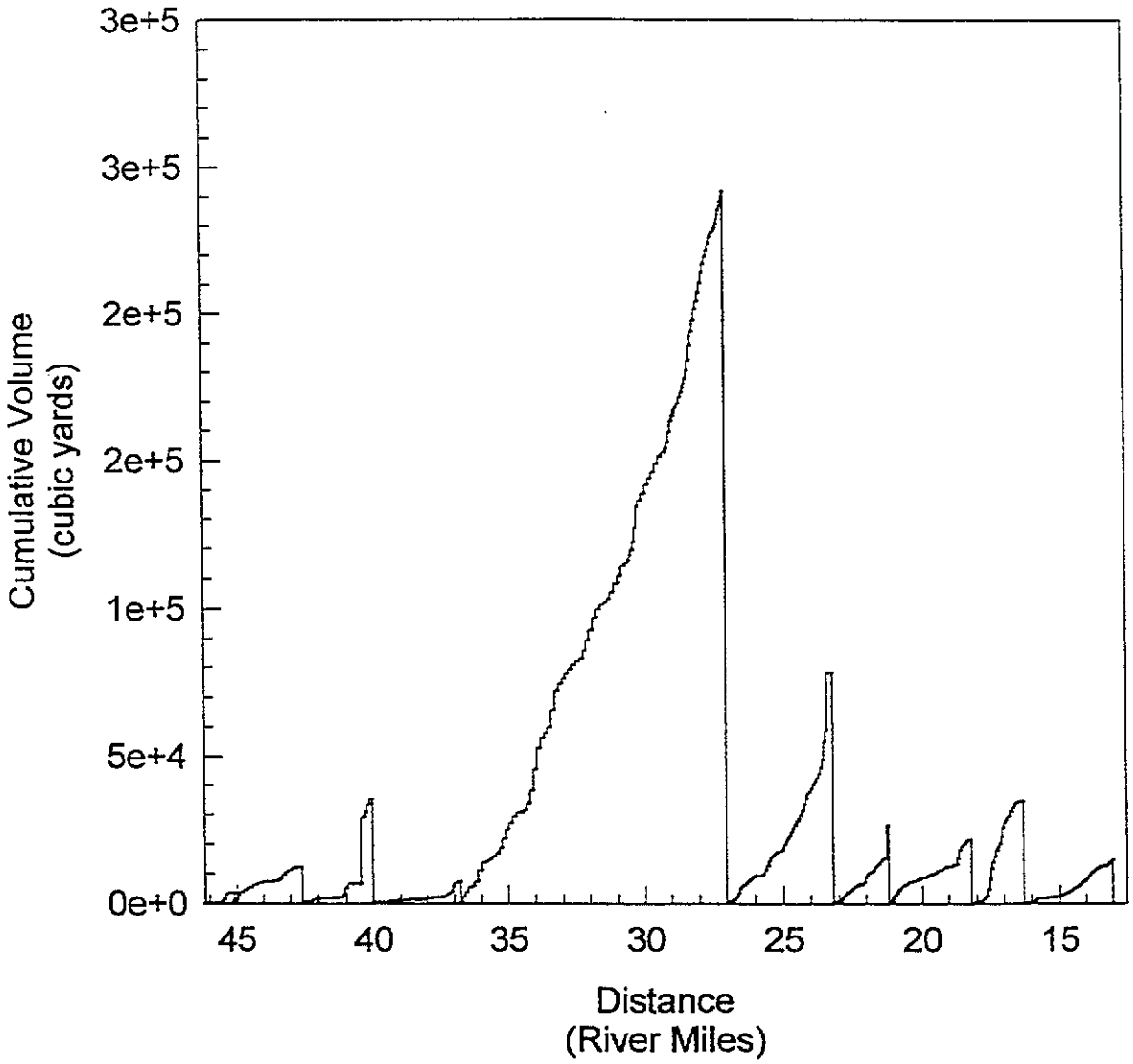
Figure 12
Mahoning River
Cumulative Volumes -vs- Reach Distance



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The difference between sediment volume estimates obtained by Havens and Emerson (1976) and this study is substantial. Using the sediment depth data collected at each transect in this study, it was possible to estimate the contribution of field methods to this difference. The following procedure was used to calculate the sediment cross-sectional area that would have been obtained at each transect if the field methods of Havens and Emerson (1976) had been used instead of those described previously:

1) If no sediment deposits were found at a distance of 20 ft. or greater from the river bank, the cross-sectional area occupied by sediments was set to zero.
2) If sediments were found at a distance of 20 ft. from the bank, the depth of sediment deposits between 0 and 20 ft. were assumed to be equal to the depth at 20 ft. Sediment depths at distances greater than 20 ft. from the bank were set at measured values.

Using this approach, the sediment volume was calculated using 1998 data with 1976 methods for reaches 1 to 6. The results are summarized in Table 2. In all cases, using the 1976 methods results in a much lower estimate of sediment volume than this study. However, the volumes obtained by this procedure are not well correlated with the results reported by Havens and Emerson (1976) for individual reaches. For example, in the Niles pool, the procedure yielded a sediment volume estimate 77,715 CY (or 36%) less than that reported by Havens and Emerson, while in the Girard pool, it yielded a volume 32,745 CY (or 277.5%) greater than reported by Havens and Emerson. The total volume for all six reaches agree reasonably well. One possible explanation for this result is that some of the sediment deposits in the Niles pool (and perhaps also the North Youngstown and Lowellville pools) were resuspended during high flow events and deposited further downstream during the 21 years between the two field studies. Despite some inconsistencies in this comparison, it nevertheless serves to emphasize that the sediment volume estimates of Havens and Emerson (1976) are most likely low since their field methods would not accurately account for deeper sediment deposits commonly found within 20 ft. of the river banks.

TABLE 2. The Effect of Field Methods on Sediment Volume Estimates.

Reach	1976 Volume (H & E) (CY)	1998 Volume (YSU) (CY)	1998 Vol. by 1976 Method (CY)
Niles	213,800	243,137	136,085
Girard	11,800	78,164	44,545
North Youngstown	9,000	26,064	2,906
South Youngstown	7,600	21,437	10,243
Struthers/Campbell	7,600	34,166	26,775
Lowellville	17,500	14,526	3,767
Total	**267,300**	**417,494**	**224,321**

Sediment Characteristics:

The results of organic (volatile) matter content measurements performed on several bottom sediment and bank samples are presented in Table 3. The mean organic matter content for all 18 samples was 8.7%, with a range of 1.6% to 19.8% and standard deviation of 4.8%. There was no appreciable difference between the mean for bank samples (8.2%) and that for bottom sediments (9.0%). However the organic matter measurements were more variable for the bottom sediments (std. dev. = 5.8%) than for the bank sediments (std. dev. = 1.6%). These results indicate that river bottom and bank sediments are composed predominately of inorganic material. However, considering the strong tendency of many hydrophobic compounds (e.g. PCBs) to adsorb to organic matter, the organic fraction of the bottom sediments may play an key role in the partitioning, transport, and fate of several important pollutants in the Mahoning River.

TABLE 3. Organic Matter Content of Mahoning River Bottom and Bank Sediments.

Sample #	River Mile	Location	% Organic Matter
1	14.2	Bank	9.3
2	13.7	Bottom	8.0
3	13.6	Bank	6.7
4	13.5	Bottom	1.6
5	13.5	Bottom	8.0
6	16.4	Bottom	4.6
7	16.7	Bank	10.9
8	17.4	Bottom	4.2
9	17.5	Bank	7.0
10	18.5	Bottom	11.2
11	18.5	Bank	7.3
12	22.0	Bottom	3.1
13	22.0	Bank	8.2
14	23.4	Bottom	4.5
15	25.0	Bottom	16.0
16	28.3	Bottom	10.3
17	30.0	Bottom	19.8
18	30.2	Bottom	16.0
		Mean (St. Dev.)	**8.7 (4.8)**

The following additional observations of bottom sediment and river bank characteristics were also made during the course of the field study:

- For most transects, sediment deposits are deeper and more fine-grained (silt) near the river banks, and gradually (or sometimes abruptly) become shallower and more coarse-grained (sand or gravel) as distance away from the banks increases. In most cases, the sediment depth tapers to zero within 30 ft. of the banks. This is to be expected since current velocities increase with distance from the bank, resulting in the scouring of progressively larger sediment particles.
- A wide variety of sediment types were observed. Those that account for the greatest sediment volume include the following: very soft silt/clay deposits with high water content and black color; silt with lower water content and a grey or reddish brown color that required some effort to penetrate with the 3/4 inch pole; and thick deposits of sand "armored" by a surface layer of tightly packed sand.
- Some unusual sediment types were also observed, including a reddish brown concretion that appeared to be at least partly anthropogenic material (Campbell/Struthers pool), and a mixture of sediment and a tar-like substance that could only be removed from the 3/4 inch pole by washing with a solvent (Niles pool).
- Oil was frequently released from the sediment deposits during depth measurements, indicating that industrial contamination from the past remains.
- Gas bubbles were often released when the sediments were disturbed, indicating that biological decomposition of organic matter is occurring.
- No evidence of oil stains was found on the surface of the river banks. However, a significant depth of soft sediment deposits was often found within 1 ft. of the bank. This would tend to support the observation by Michael Koryak of the U.S. Army Corps of Engineers, Pittsburgh District (unpublished) that soft sediment is present beneath the river banks in some locations.

SUMMARY AND CONCLUSIONS

Based on this study, it is estimated that the Mahoning River contains 475,775 CY of bottom sediment deposits between RM 13.0 (the Lowellville First St. dam) and RM 46.2 (the Leavittsburg Leavitt Rd. dam). It is estimated that the total bottom sediment volume contained within the Corps of Engineers project area (from the OH/PA state line at RM 11.9 to the limit of navigation at RM 40.7) is about 455,000 CY. In most reaches, the heaviest accumulation of sediment deposits is located within 0.5 mile of the downstream dam. However, the remainder of the reach usually also contains significant sediment deposits as well. Thus, if the sediment is to be removed by dredging, there are only a few areas (totaling four to five river miles) that could be skipped. It appears that soft sediments are also present beneath the river banks (i.e. "oil-soaked banks"). Further work is needed to determine the extent of these deposits.

ACKNOWLEDGEMENT

Field work for this project was performed by Robert Williamson, Sean Sweeney, Wade Robinson, and Dean Palumbo, all students at Youngstown State University. The project could not have been completed without their hard work and dedication.

REFERENCES

Havens and Emerson, Ltd., 1976. Feasibility Study on the Removal of Bank and River Bottom Sediments in the Mahoning River. Report submitted to U.S. Army Corps of Engineers, Pittsburgh District.

Ohio EPA, 1996. Biological and Water Quality Study of the Mahoning River Basin. OEPA Technical Report MAS/1995-12-14, Ohio Environmental Protection Agency, Columbus, OH.

APPENDIX

- **Spreadsheets for Sediment Volume Calculations**
- **Sample Spreadsheet for Sediment Area Calculation**

Lowellville First Street Dam Section
Lowellville Pool

Dam Designation	Distance (ft)	Area 1 (ft^2)	Area 2 (ft^2)	Area (ft^2)	Volume (ft^3)
LFD+					
	0	81.2	0	81.2	0
	100	81.2	0	81.2	8120
	200	43.5	0	43.5	6235
	300	52.4	0	52.4	4795
	500	51	0	51	10340
	700	21.1	0	21.1	7210
	800	52.7	0	52.7	3690
	900	18.55	0	18.55	3562.5
	1000	31.4	0	31.4	2497.5
	1100	0	0	0	1570
	1200	6.55	0	6.55	327.5
	1300	0	0	0	327.5
	1500	25.7	0	25.7	2570
	1650	0	0	0	1927.5
	1700	0	0	0	0
	1800	0	0	0	0
	1900	0	0	0	0
	2100	23.85	0	23.85	3577.5
	2250	0	0	0	1788.75
	2300	39.5		39.5	987.5
	2400	31.8	0	31.8	3565
	2500	32.3	0	32.3	3205
	2550	50.1	0	50.1	2060
	2600	19.3	0	19.3	1735
	2700	22.8	0	22.8	2105
	2850	4	0	4	2010
	3000	15.7	71.45	87.15	6836.25
	3150	17.95	0	17.95	7882.5
	3300	26.7	40.9	67.6	6416.25
	3450	20.9	C	20.9	6637.5
	3600	2.6	0	2.6	1762.5
	3750	73.3	19.45	92.75	7151.25
	3900	22.5	20.4	42.9	10173.75
	4050	65.5	8.25	73.75	8748.75
	4200	71.85	7.25	79.1	11463.75
	4350	11.95	27.85	39.8	8917.5
	4500	37.2	14.85	52.05	6888.75
	4650	29.95	44.5	74.45	9487.5
	4800	12.75	0	12.75	6540
	4950	26.9	0	26.9	2973.75
	5100	12.8	11.15	23.95	3813.75
	5250	5.95	3	8.95	2467.5
	5400	7.35	16.05	23.4	2426.25
	5550	26.8	38.85	65.65	6678.75
	5700	42.1	6.65	48.75	8580
	5850	18.1	24.8	42.9	6873.75
	6000	28.6	47.05	75.65	8891.25
	6150	12.1	0	12.1	6581.25
	6300	45.45	0	45.45	4316.25

6600	0	0	0	6817.5
6750	12	0	12	900
6900	39.95	0	39.95	3896.25
7050	31.85	0	31.85	5385
7200	37.95	0	37.95	5235
7350	23.7	14.6	38.3	5718.75
7500	11.1	14.15	25.25	4766.25
7650	13.75	27.45	41.2	4983.75
7800	4.45	0	4.45	3423.75
7950	4.2	18.2	22.4	2013.75
8100	5.85	10.75	16.6	2925
8250	21.45	4.5	25.95	3191.25
8400	25.2	14.45	39.65	4920
8550	7.75	13.25	21	4548.75
8700	9.25	12.1	21.35	3176.25
8850	8.95	12.5	21.45	3210
9000	5	13.4	18.4	2988.75
9300	8.05	11.45	19.5	5685
9600	14.9	0	14.9	5160
9900	7.5	0	7.5	3360
10200	5.1	0	5.1	1890
10500	0	0	0	765
10620	0	0	0	0
10920	0	0	0	0
11220	16.95	0	16.95	2542.5
11520	4.15	0	4.15	3165
11820	0	0	0	622.5
12120	0	0	0	0
12420	0.5	0	0.5	75
12720	0	0	0	75
13020	0	0	0	0
13320	13.85	0	13.85	2077.5
13420	0	0	0	692.5
13620	118.05	0	118.05	11805
13920	3.25	14.55	17.8	20377.5
14220	12.1	0	12.1	4485
14520	0	0	0	1815
14820	0	0	0	0
15120	15.85	0	15.85	2377.5
15420	0	0	0	2377.5
15720	0	0	0	0
16020	0	0	0	0

Lowellville Pool

length 3.034091 *miles*

scale factor for variation in length of reach 1.077

Volume		calculated	corrected
total in ft^3	=	364162.5	392203.01
total in yd^3	=	13487.5	14526.038
average yd^3 per mile		4445.318	4787.6079

Struthers Bridge St. Dam Section
Struthers/Campbell Pool

Dam Designation	Distance (ft)	Area (ft^2)	Volume (ft^3)
Struthers Bridge St. Dam	0	0	0
	150	0	0
	300	0	0
	450	0	0
	600	32	2400
	900	12.5	6675
	1200	117.15	19447.5
	1500	45.2	24352.5
	1800	153.55	29812.5
	2100	79.95	35025
	2400	38.35	17745
	2700	110.2	22282.5
	3000	57.15	25102.5
	3300	194.9	37807.5
	3600	326.55	78217.5
	3900	88.25	62220
	4200	93	27187.5
	4500	99.85	28927.5
	4800	248.975	52323.75
	5100	111.2	54026.25
	5400	267.85	56857.5
	5700	340.45	91245
	6000	247.4	88177.5
	6300	135.2	57390
	6600	8.45	21547.5
	6900	44.8	7987.5
	7200	24.35	10372.5
	7500	28.8	7972.5
	7800	14.45	6487.5
	8100	0	2167.5
	8400	15.4	2310
	8700	19.5	5235
	9000	0.7	3030
	9300		105
		total volume in ft^3	884437.5
		total volume in yds^3	32756.94
		correction factor	1.043
		CORRECTED VOLUME (yds^3)	**34165.49**
		average sediment (CY/mile)	**18618.8**

Haselton Center Street Dam Section
Sorth Youngstown Pool

Dam Designation HCD+	Distance (ft)	Area (ft^2)	Volume (ft^3)
	0	34.75	0
	200	34.75	6950
	600	42.05	15360
	900	56.15	14730
	1200	65.75	18285
	1500	128.85	29190
	1800	309.4	65737.5
	2100	0	46410
	2400	16.15	2422.5
	2700	44.25	9060
	3000	0.75	6750
	3300	4.35	765
	3600	12.9	2587.5
	3900	24.15	5557.5
	4200	0.5	3697.5
	4500	55.95	8467.5
	4800	4	8992.5
	5100	4	1200
	5400	68.75	10912.5
	5700	23.75	13875
	6000	4.25	4200
	6300	15.75	3000
	6600	3.35	2865
	6900	41.6	6742.5
	7200	26.15	10162.5
	7500	11.05	5580
	7800	0	1657.5
	8100	22	3300
	8400	15.95	5692.5
	8700	29.75	6855
	9000	13.25	6450
	9300	29.8	6457.5
	9600	6.45	5437.5
	9900	0	967.5
	10200	21.7	3255
	10500	59.95	12247.5
	10800	7.5	10117.5
	11100	0	1125
	11400	55.9	8385
	11700	30.25	12922.5
	12000	86.95	17580
	12300	49.95	20535
	12600	80.15	19515
	12900	85.7	24877.5
	13200	70.4	23415
	13500	30.55	15142.5
	13800	0	4582.5
		total volume in ft^3	514017.5
		total volume in yd^3	19037.69
		correction factor	1.126
		CORRECTED VOLUME	21436.43
		average sediment (CY/mile)	**7266.588**

North Youngstown Pool

	Distance (ft)	Area (ft^2)	Volume (ft^3)
HCD +	14100	35.5	250275
	14400	0	5325
	14700	10.25	1537.5
	15000	108.65	17835
	15300	24.3	19942.5
	15600	47.6	10785
	15900	71.35	17842.5
	16200	84.15	23325
	16500	0	12622.5
	16800	42.2	6330
	17100	46.95	13372.5
	17400	105.35	22845
	17700	128	35002.5
	18000	11.2	20880
	18300	1.95	1972.5
	18600	0	292.5
	18900	33.05	4957.5
	19200	33.15	9930
	19500	48.9	12307.5
	19800	44.9	14070
	20100	26	10635
	20400	31.5	8625
	20700	45.75	11587.5
	21000	69.5	17287.5
	21300	50.5	18000
	21600	38.75	13387.5
	21900	20.3	8857.5
	22200	0	3045
	22500	2.75	412.5
	22800	43.2	6892.5
	23100	0	6480

total volume in ft^3	606660
total volume in yds^3	22468.89
correction factor	1.16
VOLUME (yds^3)	26063.91
avg yds^3 per mile	**12839.37**

Youngstown Cresent Street Dam Section
Girard Pool

Dam esignation	Distance (ft)	Area (ft^2)	Volume (ft^3)
YCD+			
	0	600	0
	750	581.65	443118.8
	900	626.05	90577.5
	1200	301.5	139132.5
	1500	143.95	66817.5
	1800	161.1	45757.5
	2100	91.4	37875
	2400	77.1	25275
	2700	95.85	25942.5
	3000	134.05	34485
	3300	34.5	25282.5
	3600	61.6	14415
	3900	89.4	22650
	4200	63	22860
	4500	214.95	41692.5
	4800	91.2	45922.5
	5100	146.15	35602.5
	5400	58.8	30742.5
	5700	88.45	22087.5
	6000	80	25267.5
	6300	82.25	24337.5
	6600	106.1	28252.5
	6900	69	26265
	7200	75.2	21630
	7500	82.5	23655
	7800	107.5	28500
	8100	74.35	27277.5
	8400	47.6	18292.5
	8700	27.65	11287.5
	9000	35.8	9517.5
	9300	50	12870
	9600	73.85	18577.5
	9900	118.25	28815
	10200	125.5	36562.5
	10500	68.2	29055
	10800	80.35	22282.5
	11100	35.35	17355
	11400	12.8	7222.5
	11700	0	1920
	12000	0	0
	12300	0	0
	12600	48.35	7252.5

12900	58.4	16012.5
13200	31.8	13530
13500	55.3	13065
13800	32.25	13132.5
14100	38.25	10575
14400	0	5737.5
14700	119.25	17887.5
15000	126.75	36900
15300	54.35	27165
15600	69.9	18637.5
15900	25.25	14272.5
16200	12	5587.5
16500	27.15	5872.5
16800	25.8	7942.5
17000	0	2580

total volume ft^3	1805329
total volume yds^3	66864.03
correction factor	1.169
VOLUME (yds^3)	**78164.05**
average sediment yds^3 per m	**20515.5**

Girard Liberty Dam
i.e Niles Pool

Dam Designation GLD+	Distance (ft)	Area (ft^2)	Volume (ft^3)
	0	283.85	0
	150	283.85	42577.5
	300	229.95	38535
	450	198.4	32126.25
	600	280.55	35921.25
	750	210.1	36798.75
	900	219.6	32227.5
	1050	294.9	38587.5
	1200	235	39742.5
	1350	110.25	25893.75
	1500	120.2	17283.75
	1800	103.35	33532.5
	2100	216.15	47925
	2400	181.25	59610
	2700	128.15	46410
	3000	254.5	57397.5
	3300	249.4	75585
	3600	295.65	81757.5
	3900	247.75	81510
	4200	218.45	69930
	4500	213.9	64852.5
	4800	350.05	84592.5
	5100	317.95	100200
	5400	410.05	109200
	5700	375.45	117825
	6000	236.7	91822.5
	6300	189.5	63930
	6600	115.1	45690
	6900	114.25	34402.5
	7050	273.65	29092.5
	7200	263	40248.75
	7500	112.5	56325
	7800	87.8	30045
	8100	17.65	15817.5
	8400	118.75	20460
	8550	259.55	28372.5
	8700	293.75	41497.5
	9000	351.2	96742.5
	9300	174.35	78832.5
	9600	133.3	46147.5
	9900	89.6	33435
	10200	113.85	30517.5
	10800	101.7	64665
	11400	111.75	64035
	12000	51.95	49110
	12600	129	54285
	13200	105.7	70410
	13800	81	56010
	14400	110.95	57585
	15000	460.45	171420
	15300	321.2	117247.5

15600	101.75	63442.5
15900	159.9	39247.5
16200	114.4	41145
16500	30.55	21742.5
16800	122.05	22890
17400	128.25	75090
18000	91.05	65790
18600	126.65	65310
19200	47.7	52305
19800	47.3	28500
20400	18.45	19725
21000	95.65	34230
21600	135.15	69240
22200	185.75	96270
22800	101.95	86310
23400	192.2	88245
24000	31.45	67095
24600	48.1	23865
25200	51.05	29745
25800	65.2	34875
26400	39.5	31410
27000	84.35	37155
27600	73.4	47325
28200	98.95	51705
28800	424.75	157110
29400	43.55	140490
30000	92.55	40830
30600	35.85	38520
31200	236.65	81750
31800	350.2	176055
32400	246.25	178935
33000	109.2	106635
33600	63.65	51855
34200	1.9	19665
34800	0	570
35400	112.35	33705
36000	77.2	56865
36600	73.1	45090
37200	168.45	72465
37800	84.2	75795
38400	54.2	41520
39000	35.5	26910
39600	46.6	24630
40200	0	13980
40800	26.8	8040
41400	196.6	67020
42000	108.3	91470
42600	0.5	32640
43200	41.7	12660
43800	80.2	36570
44400	38.9	35730
45000	88.8	38310
45450	0	19980

total volume in ft^3	5776620.00
total volume in yd^3	213948.89
correction factor	1.13
Volume (yds^3)	**241762.24**
avg sediment yds^3 per mile	**24872.66**

APPENDIX H

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Warren Main Street Dam
South Warren Pool

Dam Designation WMD+	Distance (ft)	Area (ft^2)	Volume (ft^3)
	0	56	0
	230	56	12880
	630	111.6	33520
	1120	77.25	46268.25
	1430	31.5	16856.25
	1850	47.85	16663.5
	2480	2.5	15860.25
	2960	2.6	1224
	3440	0	624
	3830	0	0
	4160	1.25	206.25
	4400	7.5	1050
	4900	7	3625
	5360	2.5	2185
	6100	11.6	5217
	6490	8	3822
	6820	0	1320
	7390	0	0
	7860	0	0
	8440	0	0
	8840	14	2800
	9470	0	4410
	10190	0	0
	10470	3.5	490
	11710	0	2170
	12130	8.2	1722
	12810	1.25	3213
	13180	9.3	1951.75
	13590	17.85	5565.75
	13900	5.6	3634.75
	14610	0	1988
	15240	0	0
	15540	7	1050
	16180	7	4480
	16350	13	1700
	16780	0	2795
		total volume in ft^3	199291.8
		total volume in yd^3	**7381.176**
		average sediment yds^3 per mile	**2321.125**

Warren Summit Street Dam Section
North Warren Pool

Dam Designation WSD+	Distance (ft)	Area (ft^2)	Volume (ft^3)
	0	30	0
	100	30	3000
	350	327.75	44718.75
	740	18	67421.25
	1310	116	38190
	1570	0	15080
	1870	0	0
	2250	0	0
	2810	0	0
	3520	0	0
	4220	107	37450
	4920	59	58100
	5470	33	25300
	5930	0	7590
	6490	0	0
	7120	5	1575
	7640	0	1300
	8330	2.5	862.5
	8940	2.5	1525
	9470	0	662.5
	10080	17	5185
	10650	32	13965
	11450	0	12800
	11940	0	0
	12450	0	0
	13020	25.5	7267.5
	13580	0	7140
	13730	0	0
		total volume in ft^3	349132.5
		total volume in yd^3	**12930.83**
		large sediment deposit at Packard Park(est yd^3)	**22090**
		total volume in yd^3	**35020.83**
		average sediment yds^3 per mile	**13467.59**

APPENDIX H
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Warren North River Road Dam Section
Leavittsburg Pool

Dam Designation WND+	Distance (ft)	Area (ft^2)	Volume (ft^3)
	0	13.5	0
	150	13.5	2025
	1070	32	20930
	1700	11.25	13623.75
	2530	56	27908.75
	3240	27	29465
	3820	26.9	15631
	4200	24.4	9747
	4660	10.15	7946.5
	5520	0	4364.5
	6500	0	0
	7260	17.75	6745
	7930	36.85	18291
	8640	26.45	22471.5
	9600	11	17976
	10430	39	20750
	11340	28.3	30621.5
	12130	71	39223.5
	12580	16.5	19687.5
	13815	16.5	20377.5
		total volume in ft^3	327785
		total volume in yd^3	**12140.19**
		average sediment yds^3 per mile	**4639.897**

Leavittsburg Lovers Lane Dam Section
West Leavittsburg Pool

Dam Designation LLD+	Distance (ft)	Area (ft^2)	Volume (ft^3)
	0	0	0
	440	0	0
	1010	68.85	19622.25
	1530	81.5	39091
	1960	50.45	28369.25
	2400	0	11099
	3060	0	0
	3710	0	0
	4370	0	0
	5130	0	0
	5620	0	0
	5785	0	0
		total volume in ft^3	98181.5
		total volume in yd^3	**3636.352**
		average sediment yds^3 per mile	**3318.918**

Cross-Sectional Area Occupied by Bottom Sediments

Station (ft)	Da (ft)	Dt (ft)	Db (ft)	Ds (ft)	Area (ft^2)	BOTTOM
GLD+600 north	1	0.4	12.4	12	6	sand
	5	0.5	12.4	11.9	47.8	sand
	10	0.5	7.4	6.9	47	sand
	15	0.5	12.4	11.9	47	sand
	20	2.3	12.4	10.1	55	sand
	25	8	12.6	4.6	36.75	silt
	30	10.7	12.6	1.9	16.25	silt
	35	11.5	12.8	1.3	8	silt
	40	12.2	12.9	0.7	5	silt
	45	12.1	12.7	0.6	3.25	silt
	50			0.8	3.5	silt
	55			0	2	rock
GLD+600 south	1	0.3	1.5	1.2	0.6	silt
	5	0	0	0	2.4	rock
	10	0	0	0	0	rock
				Total	280.55	