Assessment of ORSANCO Fish Population Data Using the Modified Index of Well Being (MIwb)

Ohio River Valley Water Sanitation Commission
June 1992

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ASSESSMENT OF ORSANCO FISH POPULATION DATA USING THE MODIFIED INDEX OF WELL BEING - MIwb

I. INTRODUCTION

The Ohio River Valley Water Sanitation Compact (Article I) requires efforts by member states (Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia) to ensure the waters of the Ohio River Basin are "......capable of maintaining fish and other aquatic life." The Federal Clean Water Act requires the biological integrity of the nation's surface waters to be restored and maintained. While chemical monitoring can be used to measure the suitability of water to maintain aquatic life, direct measurement of the aquatic community measures the success of restoration efforts.

Since 1957 the Ohio River Valley Water Sanitation Commission (ORSANCO) has surveyed the fish population of the Ohio River. These surveys provided "snapshots" of the relative diversity and health of the biological community of the Ohio River. Until recently few widely accepted analytical methods were available to measure the health of the community and determine any changes over time due to improved water quality conditions.

Fausch et al. (1990) emphasized the importance of using fish communities as sensitive indicators of environmental degradation and that the primary stresses on fish communities, aside from natural fluctuations, are man induced. By using community indices the data collected by ORSANCO can be analyzed for changes over time in relation to improvements in pollution control and show areas where the biological community continues to be stressed due to human influences.

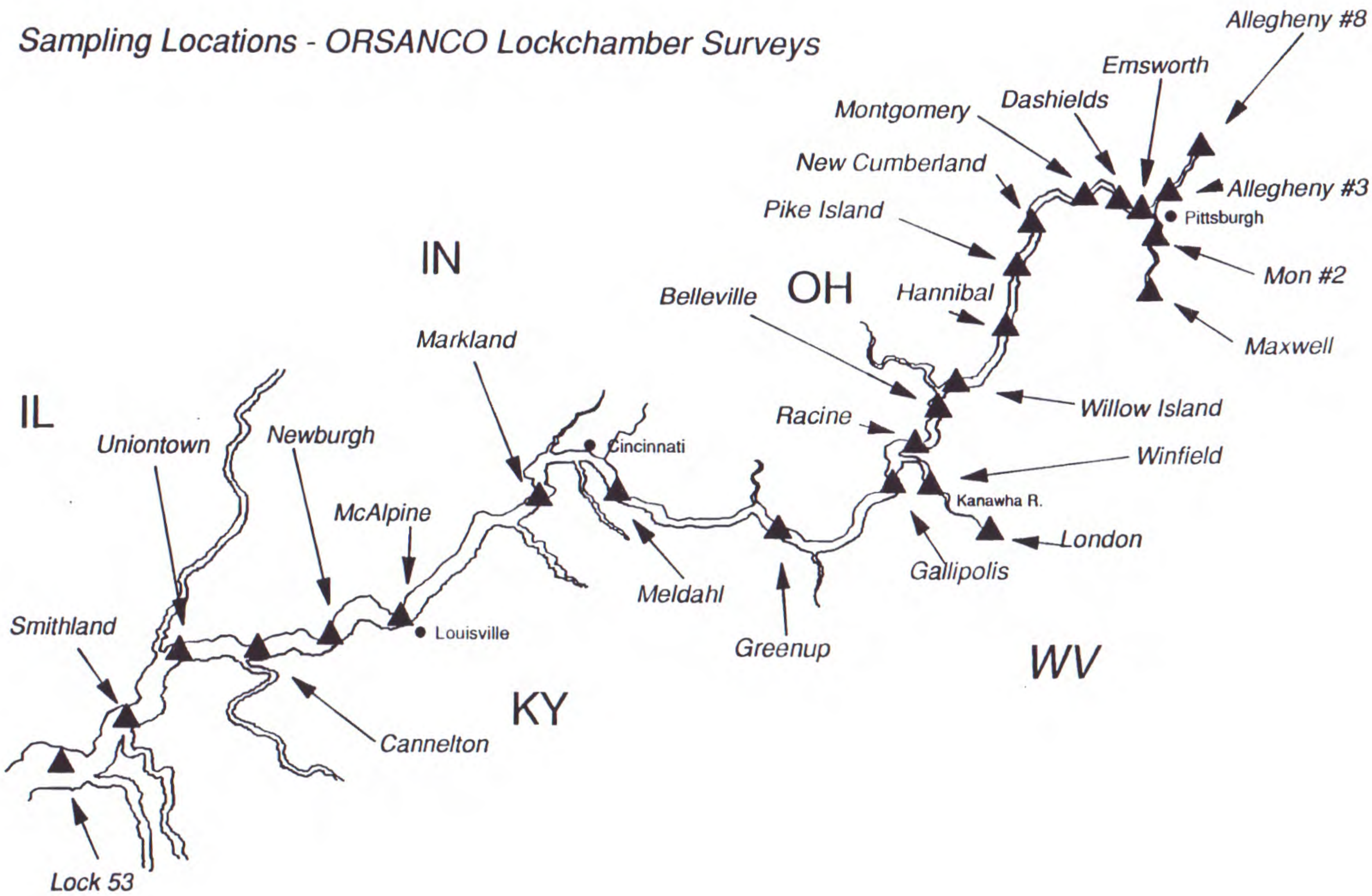
This report presents analyses of data collected by ORSANCO from 1968 through 1990 using the Modified Index of Well Being (MIwb), (Ohio EPA 1987) which is a modification of the original index of well being developed by Gammon (1976).

II. SAMPLING METHODS

The fish population data used for these analyses were collected at navigational locks along the Ohio and three major tributaries (Allegheny, Monongahela, and Kanawha). Figure 1 displays the location of the locks sampled. The lower gates and a fill valve of the lockchamber are opened starting at 12 a.m. to provide flow through the lockchamber. Once collection boats are in the lockchamber (approx. 9 a.m.) the fill valve and lower gates are closed. Basic water quality conditions (D.O. temperature, pH, conductivity, and transparency) are measured and recorded. Rotenone is then introduced to the lockchamber to achieve a final concentration of 1 ppm rotenone.

Figure 1

Sampling Locations - ORSANCO Lockchamber Surveys



The fish within the lockchamber begin to surface and all fish are collected. Once all fish are collected the lock is filled to circulate any fish off the bottom that were missed.

The fish are then taken to a processing area for sorting by species. Each species is sorted into size classes (every 3 cm). Total numbers and weight of all size classes are measured and recorded.

III. METHODS OF BIOLOGICAL ASSESSMENT

Two methods were considered to analyze the fish population data to determine quantatively the relative health of the biological community: the Index of Biotic Integrity (IBI) and the Modified Index of Well Being (MIwb). Other methods have been employed elsewhere, but these two are widely used and accepted. The U.S. EPA April 1990 document, Biological Criteria: National Program Guidance, mentions both these methods and the Ohio EPA's Biological Criteria for the Protection of Aquatic Life: Users Manual for Biological Field Assessment of Ohio Surface Waters details the methods. These references provide the following overviews of the methods.

A. Index of Biotic Integrity (IBI)

The IBI, as originally proposed by Karr in 1981, is comprised of twelve metrics. Six metrics evaluate species richness and composition, three metrics summarize trophic composition, and three metrics summarize fish abundance and condition information. Each of the metrics is based on an expected value and given a rating. The summation of the metrics provides the IBI value.

At present the IBI is the most sophisticated method for the evaluation of biological data. However to apply it to the Ohio River the reference conditions must be established. Future efforts by ORSANCO will include developing this reference information. At this time the IBI is not pursued as an analysis tool.

B. Modified Index of Well Being (MIwb)

The MIwb incorporates four measures of fish communities that have traditionally been used separately: numbers of individuals, biomass, and the Shannon Diversity index (H) based on numbers and weight (two separate calculations). The Ohio EPA recently developed a modification of the Iwb which makes the index more sensitive to a wider array of environmental disturbances, particularly those that result in shifts in community composition without large reductions in species richness, numbers, and/or biomass. The Modified Index of Well Being retains the same computational formula as the conventional Iwb, but any of the 13 highly tolerant species are eliminated from the numbers and biomass components. The tolerant species are included in the two Shannon index calculations. This modification prevents high Iwb scores from degraded sites with large numbers of pollution tolerant fish. The formulas for the Modified Index of Well Being and Shannon index are as follows:

$$MIwb = 0.5\ln N + 0.5\ln B + \overline{H}(no.) + \overline{H}(wt)$$

Where:

N = relative (number per unit distance sampled) numbers of all species - excluding those designated as highly tolerant (Appendix A)

B = relative weight of all species - excluding species designated as highly tolerant (Appendix A)

H(no.) = Shannon Diversity Index based on numbers

H(wt.) = Shannon Diversity Index based on weight

Shannon Diversity Index

$$\overline{H} = -\sum \frac{n_i}{N} \ln(\frac{n_i}{N})$$

Where:

n_i = relative number or weight of the ith species

N = Total number or weight of the sample

The results of river studies using the Iwb (or MIwb) show a positive relationship between this index and the quality of water and habitat (OEPA 1987). The MIwb relies on the assertion that least impacted stream segments support a larger variety and abundance of fish than stressed segments in the same system. This hypothesis has been tested and verified in several different situations and confirms the value that this method has for monitoring environmental quality, measuring the success of water pollution control programs, and determining attainment of Clean Water Act (CWA) goals (i.e. fishable waters, biological integrity). Appendix B shows how the Ohio EPA uses MIwb numbers to determine whether the waters meet CWA goals.[1]

An assessment of the sensitivity of the MIwb index is essential for an evaluation of the MIwb numbers. As noted by Ohio EPA, the index as a whole is much less variable than its components. Gammon (1976) found the individual variability of each of the four MIwb components to range from 20-50%, but the variability for the MIwb was approximately 7%. Ohio EPA has estimated the error in its MIwb numbers through repeat sampling of the same stream reaches. For larger Ohio streams sampled with electrofishing techniques, the MIwb from individual samples deviated less than ±0.5 MIwb units from the mean at a site about 75% of the time. The maximum deviation observed was about 0.95 MIwb units.[2] This, however, is not a reliable error estimate for the present study because the Ohio River is much larger than the streams analyzed by Ohio EPA and the collection method is different (rotenone as opposed to electrofishing).

The MIwb seemed very suitable to the lockchamber fish population data. It required only the data already contained in the database. Thus, it was but a programming task to run the MIwb on the lockchamber data. However, the MIwb was adapted from Ohio EPA without much critical assessment. Work remains to be done to ensure that the index is applicable to Ohio River fish population data.

IV. DATA ANALYSIS

A. Fish Population Data Base

All fish population data from 1978 through 1990 are in DBASE III+® data bases. ORSANCO maintains these data bases as both individual years and a composite data base of all data. A DBASE III+® routine was written to calculate the index value. The data base structure and program are included in Appendix C for reference. Pre-1978 data exist as paper files only.

B. Application of the MIwb/Iwb to the Lockchamber Data

Usual application of the MIwb/Iwb is to boat or wading electrofishing sampling. Data from these methods are used as numbers or weight per unit distance. This allows valid comparisons between sampling stations.

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[1] *Ohio EPA, Biological Criteria for the Protection of Aquatic Life: Volume II. Users Manual for Biological Assessment of Ohio Surface Waters, October 1987, p. 4-64; table from p. C-12.*

[2] *Ibid., pp. C-2, D-1.*

Some adjustment had to be made to normalize the index values between lockchambers. Adjustment of the relative numbers and weight for the total area (in acres) of each lockchamber was applied to accomplished this. Therefore the MIwb applied to the lockchamber data was as follows:

$$MIwb = 0.5\ln\frac{N}{Area} + 0.5\ln\frac{B}{Area} + \overline{H}(no.) + \overline{H}(wt.)$$

C. Comparison of Iwb to the MIwb

The exclusion of highly tolerant fish in the MIwb discounts the potential inflation of the index due to an abundance of these species. Also, as water quality conditions improve there should be a convergence of these values. The Iwb value was calculated and the values graphed against MIwb values to show this relationship.

D. Test for Relationship with Time

One of the basic questions to be answered by ORSANCO is: Is the aquatic community of the Ohio River improving over time? ORSANCO (1990) has shown water quality improvements over time applying the seasonal Kendall test for trends to eleven years of monthly monitoring data from the Ohio River and its major tributaries. Because of the frequency of sampling (at best once per year) the fish population data is not sufficient for the Kendall test. The relationship of the MIwb with time was tested using linear regression techniques. The slope of the line was tested to determine statistical significance.

The regression equation used for the analyses was:

$$MIwb = \beta_o + \beta_1 * Year$$

The slope of the line was tested using a t-statistic and testing the hypothesis that the slope is equal to zero. If the resulting t-value was greater than that found in a t-table at $p<0.05$ the hypothesis is rejected and the slope was found to be significant.

E. Test for Relationship with Flow

River flow is one factor that may influence the fish population from year to year. The USGS maintains stream gaging stations at 12 locations on the Ohio River. Of these, 7 are at or within 5 miles of lockchambers sampled and 5 had a suffcient number of data points. Flow data were retrieved and compared to MIwb values using linear regression techniques described above. Both annual average flow and spring (April, May, & June) average flows were used for the analyses.

The regression equation used for the analyses was:

$$MIwb = \beta_0 + \beta_1 * FLOW$$

The slope of the line was tested using a t-statistic and testing the hypothesis that the slope is equal to zero. If the resulting t-value was greater than that found in a t-table at $p<0.05$ the hypothesis is rejected and the slope found to be significant.

F. Comparison to Ohio EPA Electrofishing Results

In 1989 the Ohio EPA conducted a night electrofishing survey on the Ohio River from river mile 280.8 to 442.5. The Ohio EPA evaluated their data using the MIwb and the results of their work were qualitatively compared to the MIwb calculated for the 1989 lockchamber survey. The values can only be compared qualitatively due to the very different sampling methods.

V. RESULTS

A. Application of the MIwb/Iwb to the Lockchamber Data

Table 1 shows the MIwb values of Ohio River sampling locations and Table 2 shows the MIwb values of tributary sampling locations. Several comments are needed to clarify the tables.

MIwb values for data collected from 1968 to 1978 needs additional verification. These data were analyzed based on tabular data showing only total weight and numbers of each species at each lockchamber. The data need further verification and need to be entered into the Commission data base. Large changes in MIwb scores are not antcipated. This is also true for data collected before 1968 which were not used in this analysis. There is also a need to develop criteria against which to assess the MIwb values.

Minnow identifications were inconsistent over the period. Incomplete minnow identification would cause lower MIwb values due to fewer recorded species. The values calculated without thorough minnow data are identified on Tables 1 & 2.

TABLE 1
Mlwb Values - Ohio River Main Stem Locations

LOCATION	RMI	1968	1969	1970	1973	1974	1975	1976	1977	1978	1968 - 1978 MAX	MIN	AVG
EMSWORTH	6.2												
DASHIELDS	13.2	***7.7***	***7.5***	***7.7***			***9.7***	***8.2***	***7.1***	7.0	9.7	7.0	7.8
MONTGOMERY	31.7	***8.3***	***6.5***	***7.5***							8.3	6.5	7.4
NEW CUMBERLAND	54.4	***7.4***	***7.8***								7.8	7.4	7.6
PIKE ISLAND	84.2	***8.0***	***8.2***				***9.0***	***8.7***	***9.6***	6.7	9.6	6.7	8.4
HANNIBAL	126.4							***9.1***	***8.9***	7.8	9.1	7.8	8.6
WILLOW ISLAND	161.7												
BELLEVILLE	203.9	***8.3***	***8.9***	***9.2***				***9.4***	***8.9***	8.5	9.4	8.3	8.9
RACINE	237.5												
GALLIPOLIS	279.2	***9.1***	***8.0***	***8.9***				***9.3***	***8.4***	7.7	9.3	7.7	8.6
GREENUP	341.0	***9.1***	***8.5***	***9.7***							9.7	8.5	9.1
MELDAHL	436.2	***8.9***	***8.7***	***9.3***				***9.2***	***8.5***	9.3	9.3	8.5	9.0
MARKLAND	531.5	***9.0***	***8.7***	***8.0***			***8.9***	***8.3***		8.5	9.0	8.0	8.6
MCALPINE	606.8	***8.1***	***8.4***	***7.5***		***7.4***		***8.4***		8.8	8.8	7.4	8.1
CANNELTON	720.7	***9.8***	***8.6***	***8.9***		***9.0***	***9.7***	***9.9***			9.9	8.6	9.3
NEWBURGH	776.1	***8.0***	***8.2***	***8.8***		***9.4***				9.0	9.4	8.0	8.7
UNIONTOWN	846.0		***8.0***	***8.0***		***8.7***		***8.8***		9.9	9.9	8.0	8.7
SMITHLAND	918.5							***8.7***		10.4	10.4	8.7	9.5
LOCK 53	962.6												

LOCATION	RMI	1979	1980	1981	1983	1985	1987	1988	1989	1990	1979 - 1990 MAX	MIN	AVG
EMSWORTH	6.2							9.5		8.1	9.5	8.1	8.8
DASHIELDS	13.2	8.7	9.2	9.8	9.9	9.3	9.7	9.7			9.9	8.7	9.5
MONTGOMERY	31.7							10.1	9.1	9.3	10.1	9.1	9.5
NEW CUMBERLAND	54.4		8.0	8.1	***8.6***	7.6	8.7	10.4	8.8	8.6	10.4	7.6	8.6
PIKE ISLAND	84.2	8.1	7.4	***7.7***	***8.6***	***8.1***	***8.2***	9.8	9.5	8.1	9.8	7.4	8.4
HANNIBAL	126.4	8.8	8.0	***8.2***		***8.5***	***9.1***	10.2	9.0		10.2	8.0	8.8
WILLOW ISLAND	161.7		7.6	***8.5***			***9.3***	10.5	9.0	8.9	10.5	7.6	9.0
BELLEVILLE	203.9	9.4	8.9	***8.9***	***9.6***	***9.0***	***8.8***		9.9		9.9	8.8	9.2
RACINE	237.5			***8.4***	***9.6***		***9.0***	10.3	9.9	9.6	10.3	8.4	9.5
GALLIPOLIS	279.2	9.0	9.1		***9.1***		***8.4***	9.7	9.9	9.2	9.9	8.4	9.2
GREENUP	341.0		***8.1***	***9.1***			***9.5***	10.6		9.7	10.6	8.1	9.4
MELDAHL	436.2				***10.4***			***11.6***	***9.4***		11.6	9.4	10.5
MARKLAND	531.5	***10.2***					***10.0***	***10.7***		9.6	10.7	9.6	10.1
MCALPINE	606.8			***9.0***	***9.1***	8.8	***9.0***	9.5	10.3		10.3	8.8	9.3
CANNELTON	720.7	***10.1***					***10.0***		9.6	9.6	10.1	9.6	9.8
NEWBURGH	776.1					9.3	***10.3***		10.0		10.3	9.3	9.9
UNIONTOWN	846.0		8.8	***9.9***	***9.3***	9.9	***10.4***	***11.0***		9.6	11.0	8.8	9.8
SMITHLAND	918.5				***9.2***		***10.4***		10.0		10.4	9.2	9.8
LOCK 53	962.6			***8.8***							8.8	8.8	8.8

BOLD ITALICS UNDERLINE - Pre 1978 data needs to be verified
BOLD ITALICS SHADE - No minnow identifications are included

Table 2
Mlwb Values - Tributary Locations

											1968 - 1978		
LOCATION	**RMI**	1968	1969	1970	1973	1974	1975	1976	1977	1978	**MAX**	**MIN**	**AVG**
MON #2	11.2	***5.1***		***5.0***	***8.0***			***7.0***	***8.3***	6.0	8.3	5.0	6.6
MAXWELL	61.2			***2.8***	***7.7***			***8.4***	***7.5***	7.0	8.4	2.8	6.7
ALLEGHENY #3	14.5												
ALLEGHENY #8	52.6	***10.1***		***7.0***							10.1	7.0	8.6
LONDON	82.8												
WINFIELD	31.1												

											1979 - 1990		
LOCATION	**RMI**	1979	**1980**	**1981**	**1983**	**1985**	**1987**	**1988**	**1989**	**1990**	**MAX**	**MIN**	**AVG**
MON #2	11.2		7.4	8.2	8.9	7.4	8.3	10.8	7.3	7.3	10.8	7.3	8.2
MAXWELL	61.2					7.9	8.3	8.9	7.0		8.9	7.0	8.0
ALLEGHENY #3	14.5	6.9	8.6	8.1		8.5	8.7	9.1	8.1	7.1	9.1	6.9	8.1
ALLEGHENY #8	52.6	8.3				7.4	9.3				9.3	7.4	8.3
LONDON	82.8		8.9								8.9	8.9	8.9
WINFIELD	31.1		8.8								8.8	8.8	8.8

BOLD ITALICS UNDERLINE - Pre 1978 data needs to be verified
Status of Minnow Identification Unknown for Tributaries

Figures 2 & 3 display the data as maximum, minimum and average values at all locations for the periods from 1968-1978 and 1979-1990. Figure 2 shows improving conditions from Dashields (rm 13.2 to Meldahl (rm 436.2) with an apparent sag at Gallipolis (rm 279.2). MIwb values then decrease from Meldahl to McAlpine (rm 606.8) (0.9 units). Conditions recover at the remaining locations with Cannelton (rm 720.7) and Smithland showing the best conditions.

Figure 3 show the MIwb decreases from Montgomery (rm 31.7) to Pike Island (rm 84.2). Conditions then improve from Pike Island (rm 84.2) to Meldahl (rm 436.2). Again there is a slight sag at Gallipolis (rm 279.2). In both cases the difference between the Gallipolis and the next upstream location is less than 0.5 units. Sanders (1990) suggests that differences in MIwb scores of less than 0.5 are not significant. MIwb scores improve to Meldahl then decrease to McAlpine (1.2 units). Conditions are then apparently stable at the remaining locations.

B. Comparison of Iwb to the MIwb

Figure 4 shows MIwb values plotted against Iwb values for Ohio River locations for the years 1978-1990. The graph shows that as the biological community improves the indices converge. Figure 5 shows the difference between the MIwb and the Iwb versus the MIwb value. The graph shows for MIwb values greater than 9.3 the difference between the indices is less than 0.5 units.

C. Test for Relationship with Time

Figures 6 through 20 display scatter plots of MIwb values vs time for each lockchamber with at least eight data points. For those locations where the results of the regression analysis and statistical test for significance showed the slope of the regression line to be significant the regression line is also displayed. Table 3 displays the results of the regression and statistical analyses.

Figure 2 - Mlwb Values 1968-1978

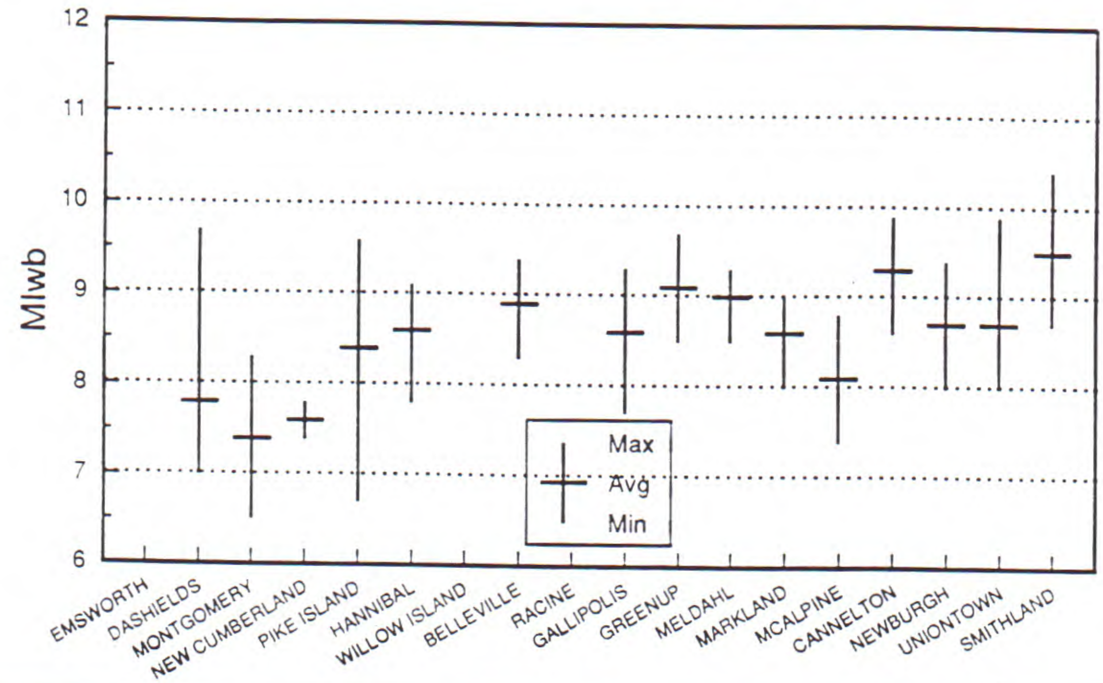


Figure 3 - Mlwb Values - 1979-1990

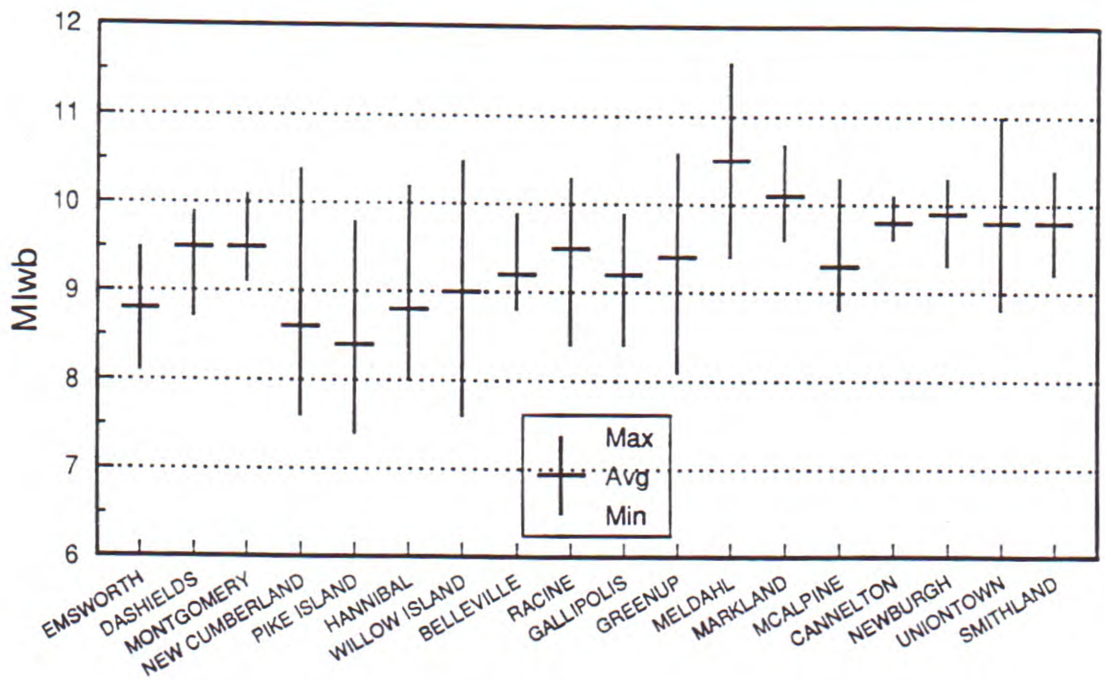


Figure 4 - Comparison of Mlwb to lwb

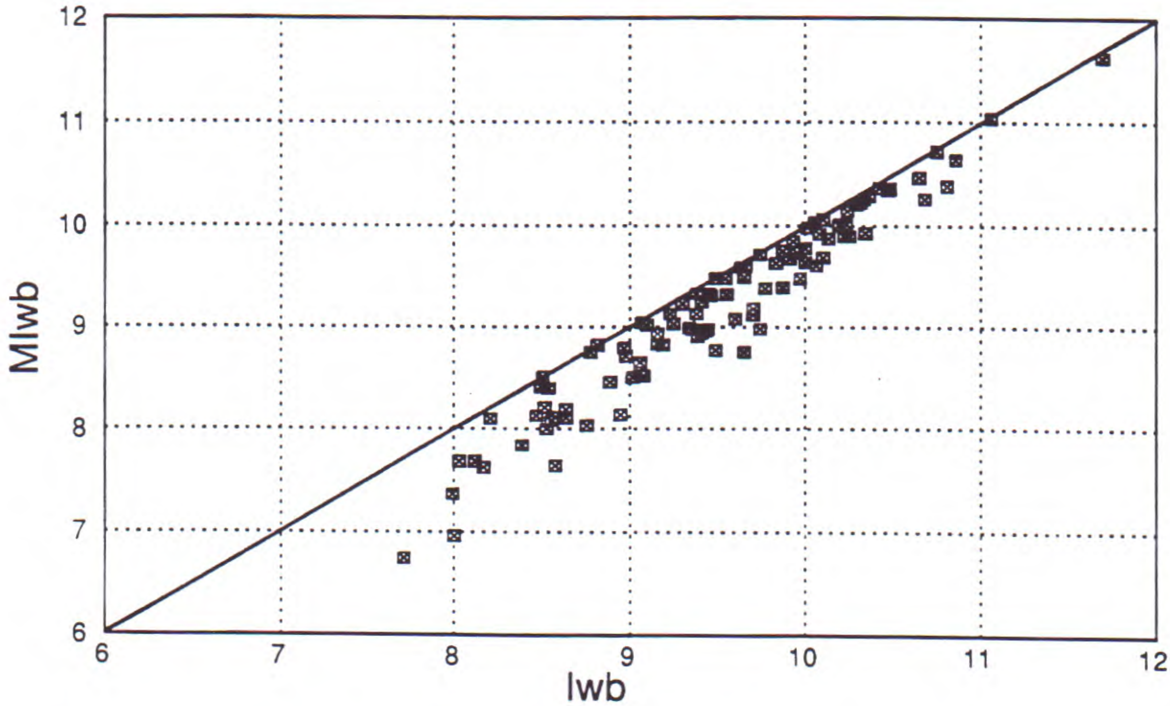
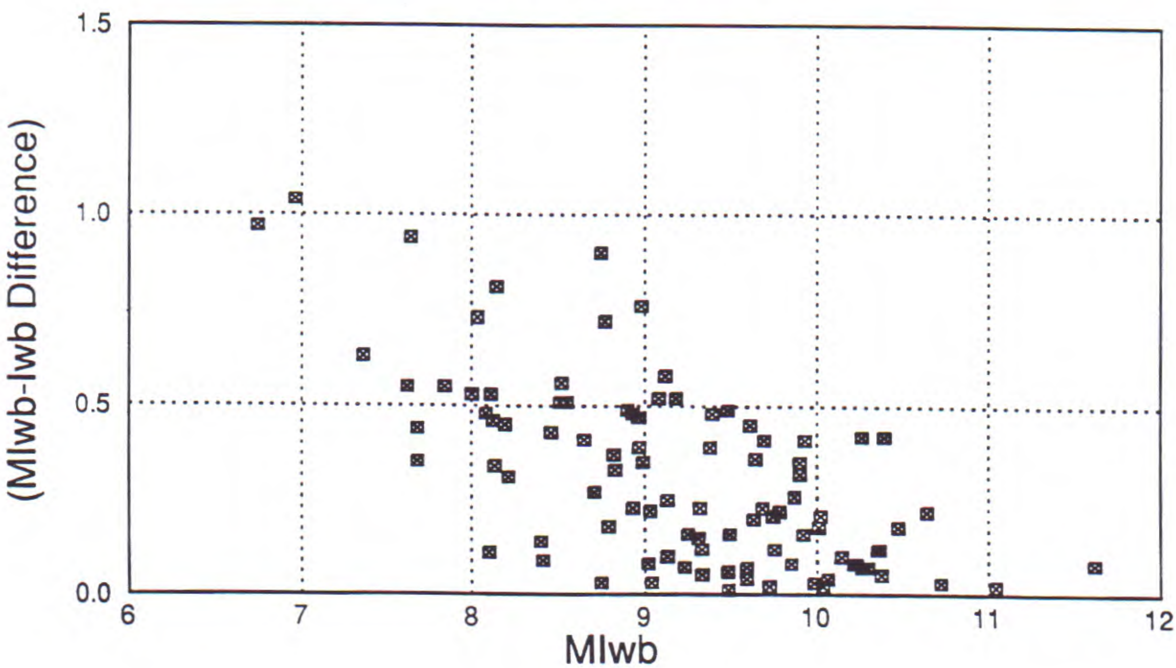


Figure 5 - (Mlwb-lwb Difference) vs Mlwb

Ohio River Locations



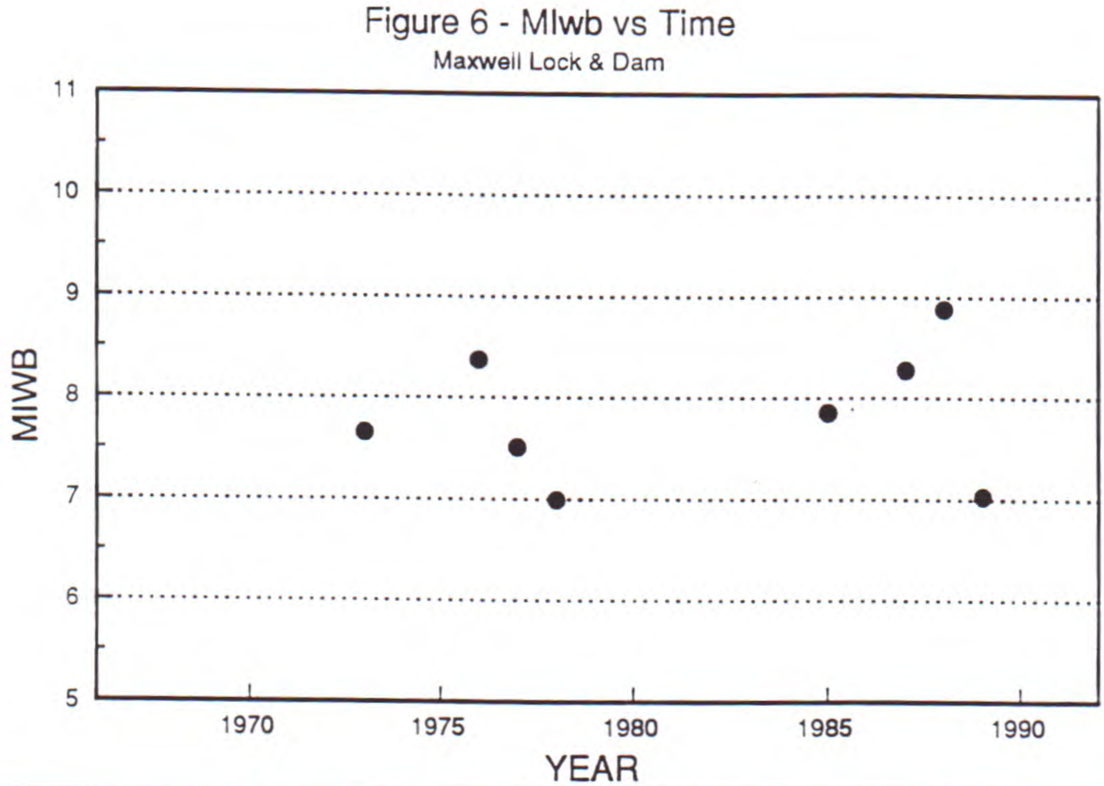


Figure 6 - MIwb vs Time
Maxwell Lock & Dam
11
10
9
8
7
6
5
MIWB
1970
1975
1980
1985
1990
YEAR

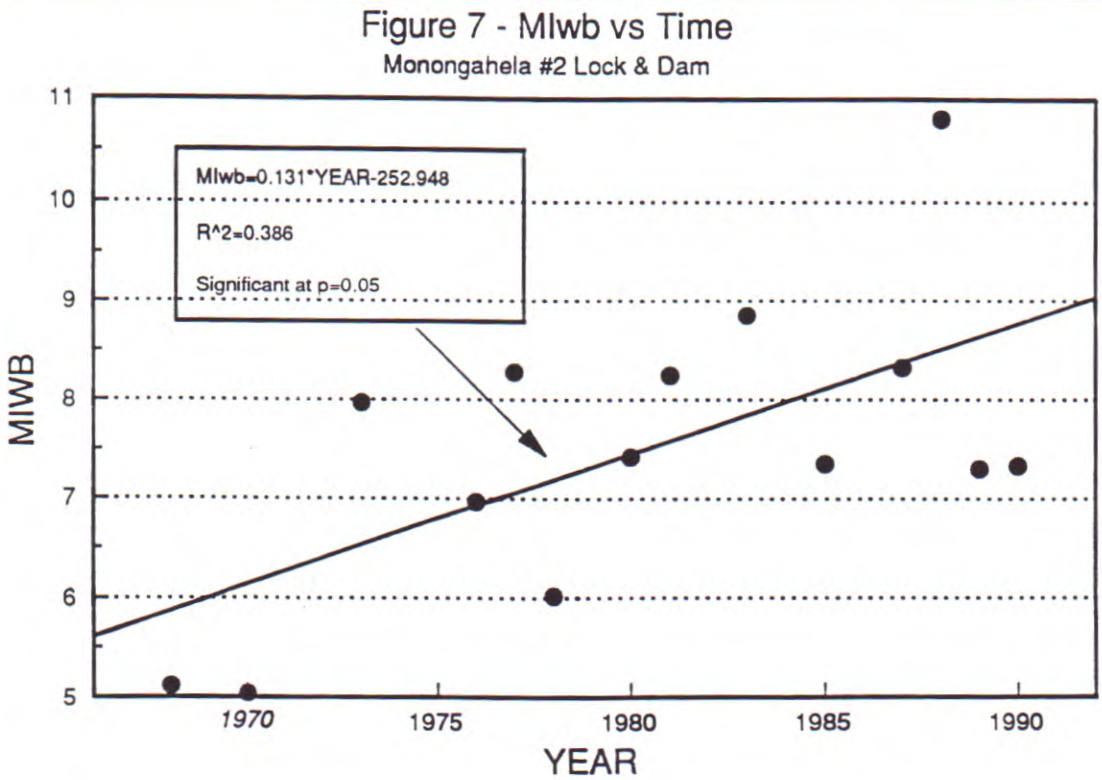


Figure 7 - MIwb vs Time
Monongahela #2 Lock & Dam
MIwb=0.131*YEAR-252.948
R^2=0.386
Significant at p=0.05
11
10
9
8
7
6
5
MIWB
1970
1975
1980
1985
1990
YEAR

Figure 8 - Mlwb vs Time

Dashields Lock & Dam

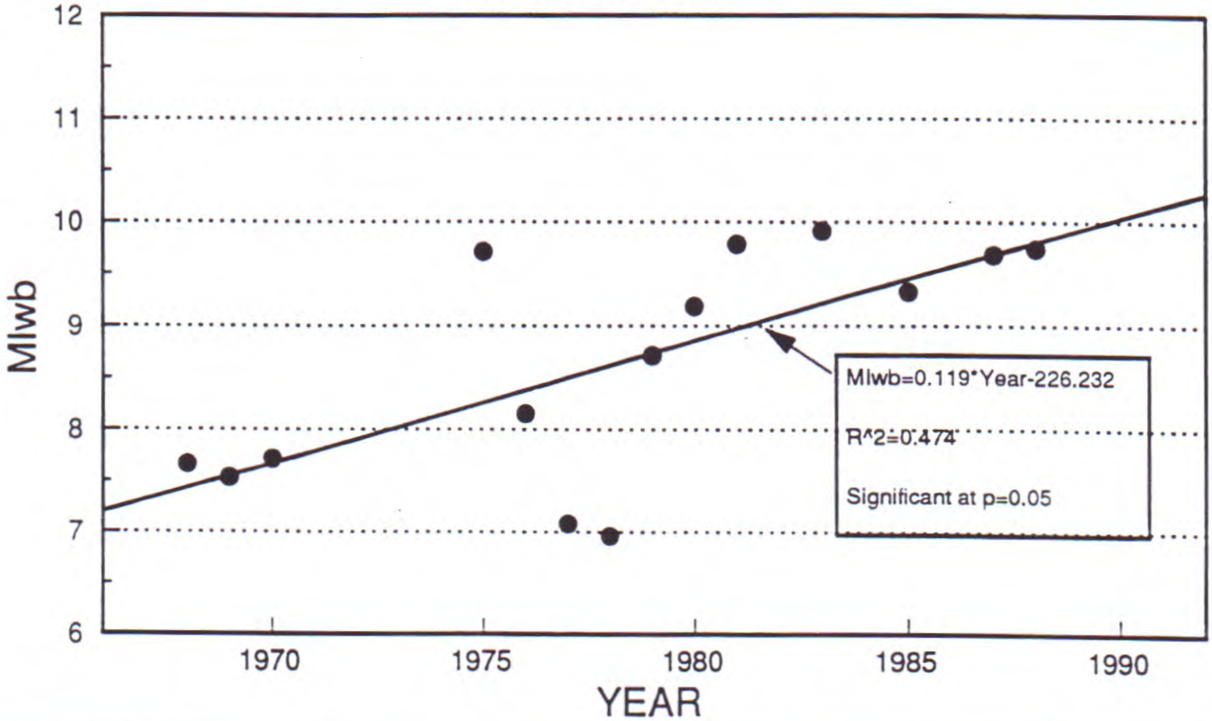


Figure 9 - Mlwb vs Time

New Cumberland Lock & Dam

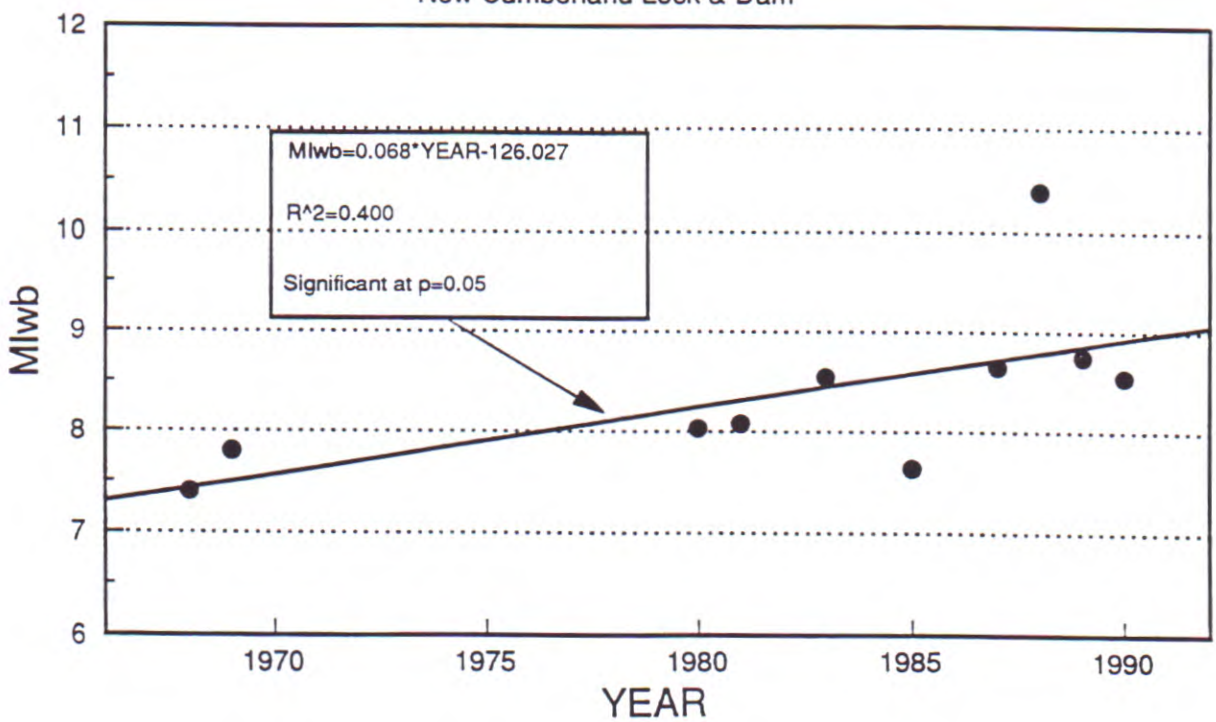


Figure 10 - Mlwb vs Time
Pike Island Lock & Dam

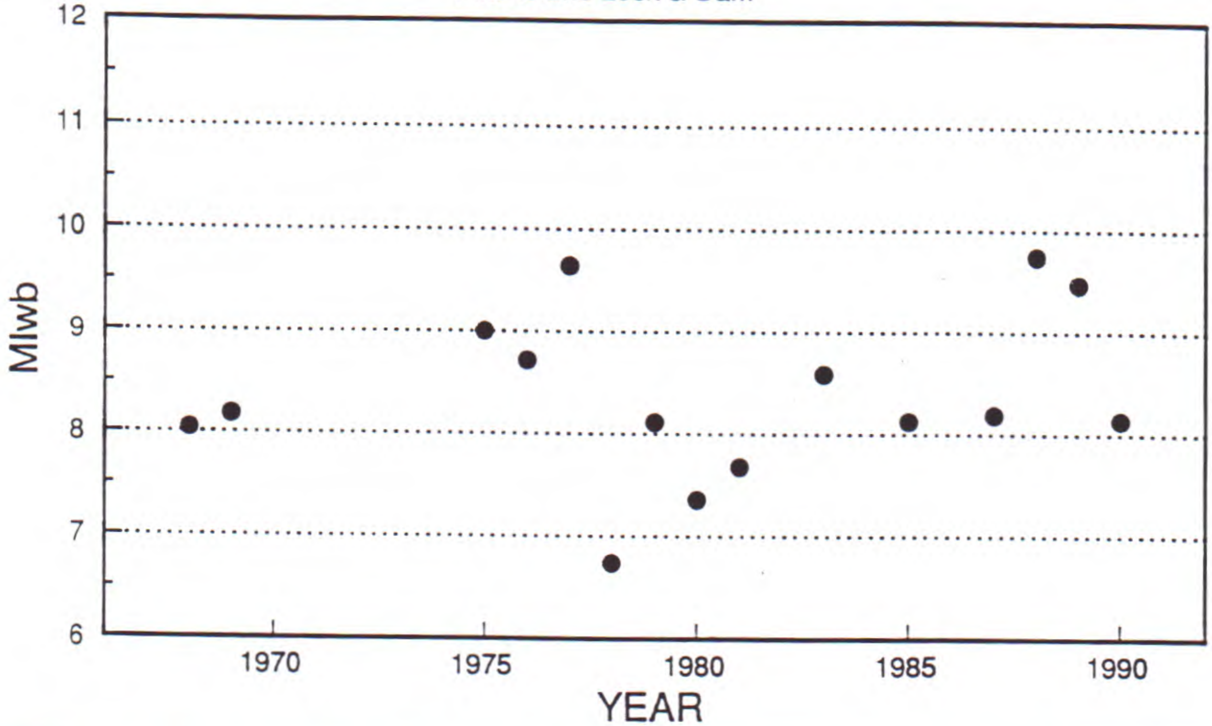


Figure 11 - Mlwb vs Time
Hannibal Lock & Dam

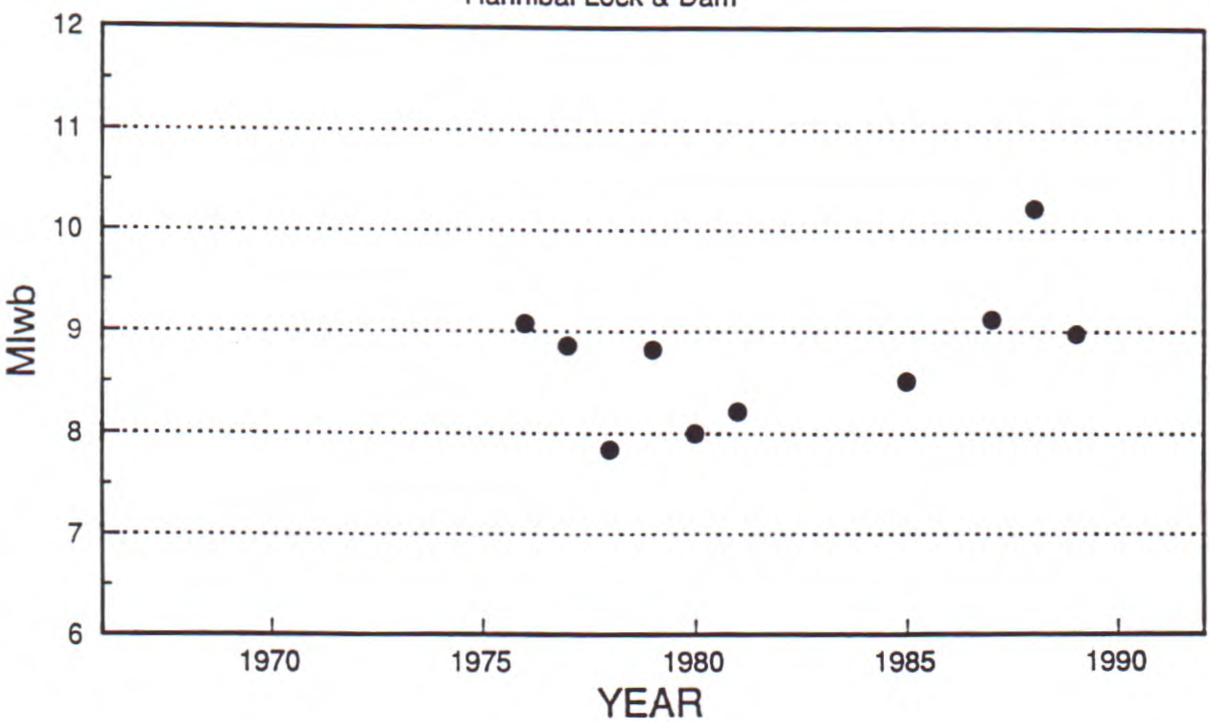


Figure 12 - Mlwb vs Time
Belleville Lock & Dam

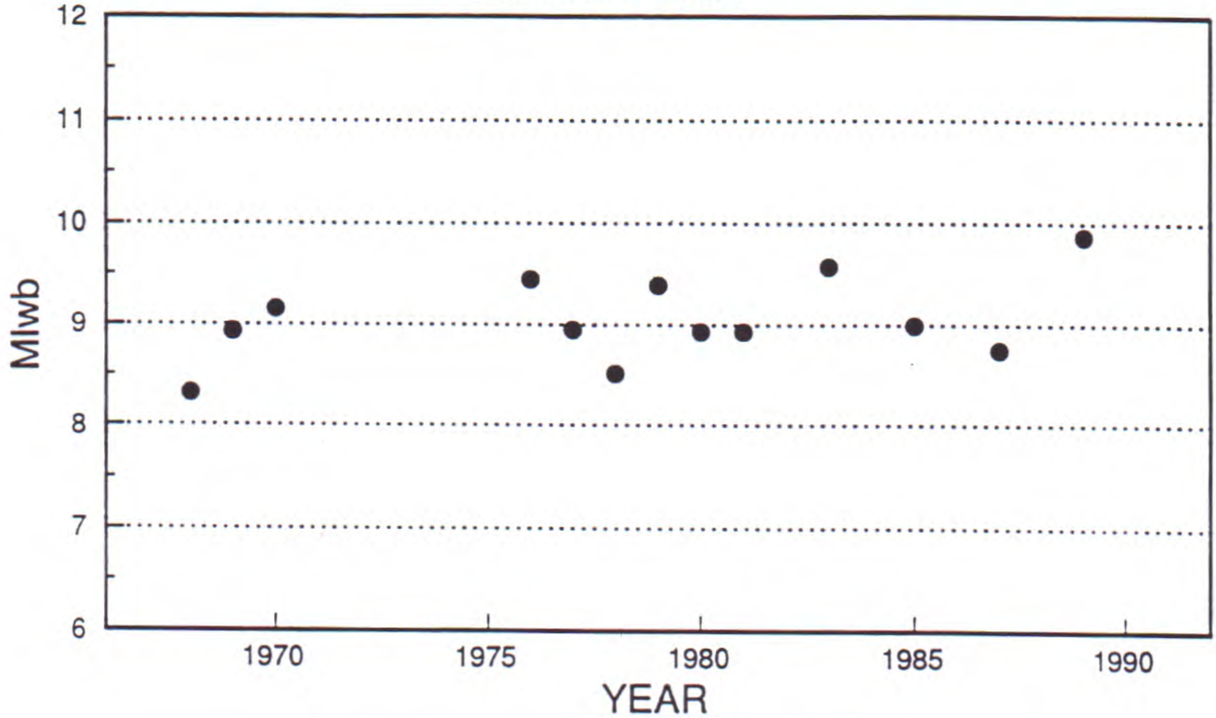


Figure 13 - Mlwb vs Time
Gallipolis Lock & Dam

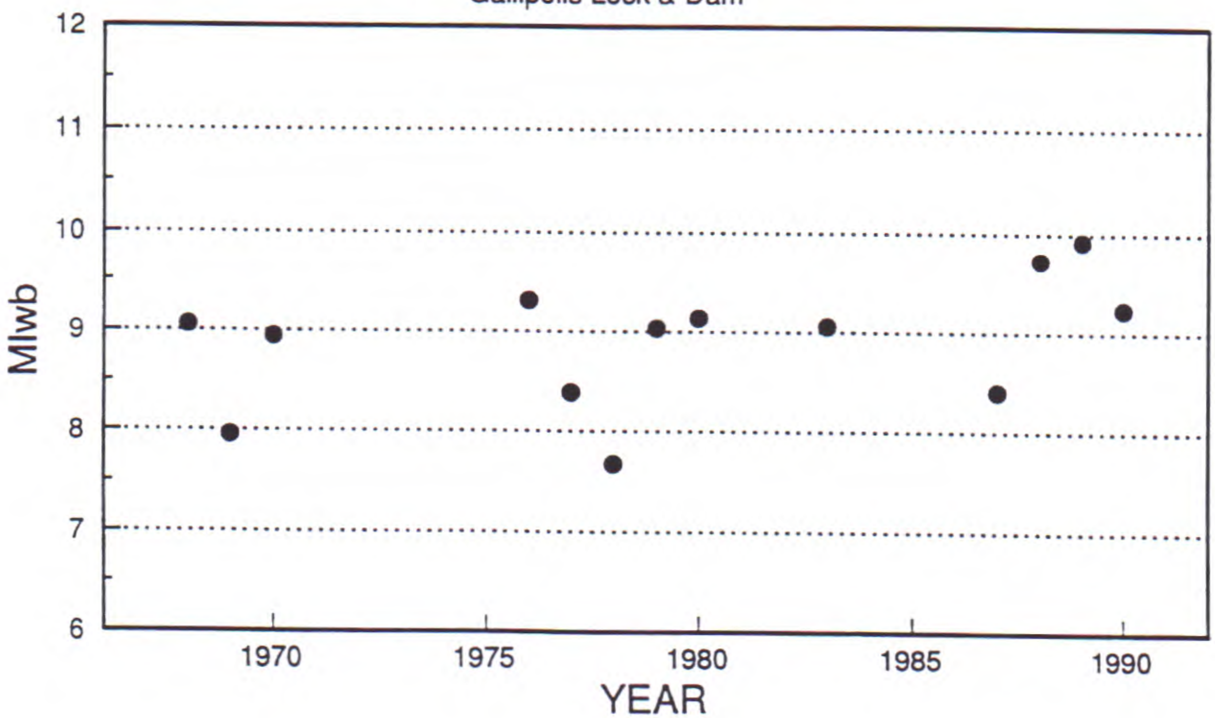


Figure 14 - Mlwb vs Time
Greenup Lock & Dam

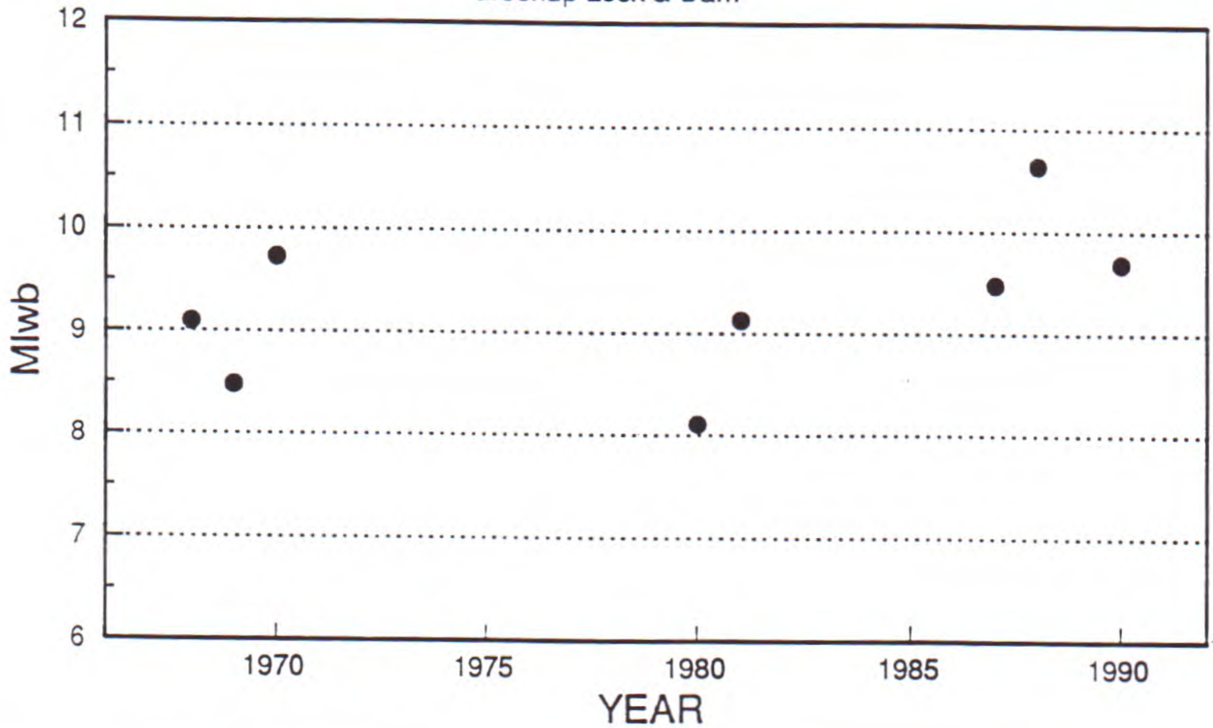
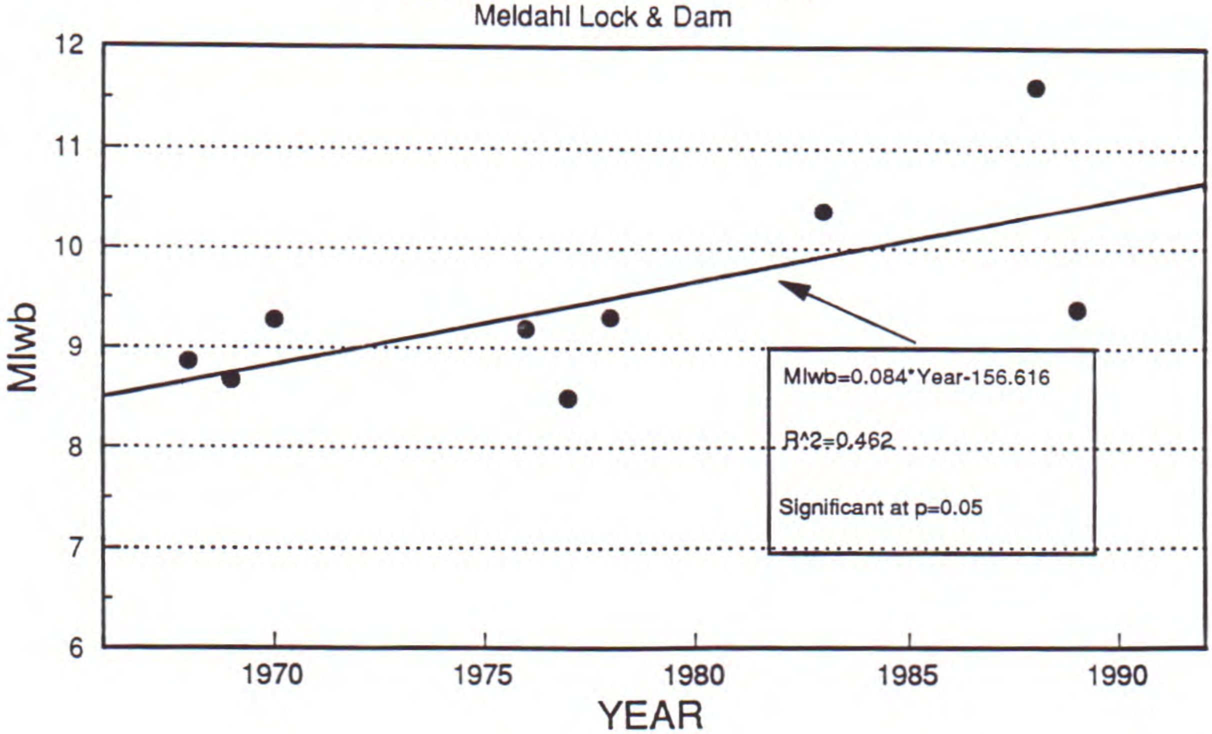


Figure 15 - Mlwb vs Time
Meldahl Lock & Dam



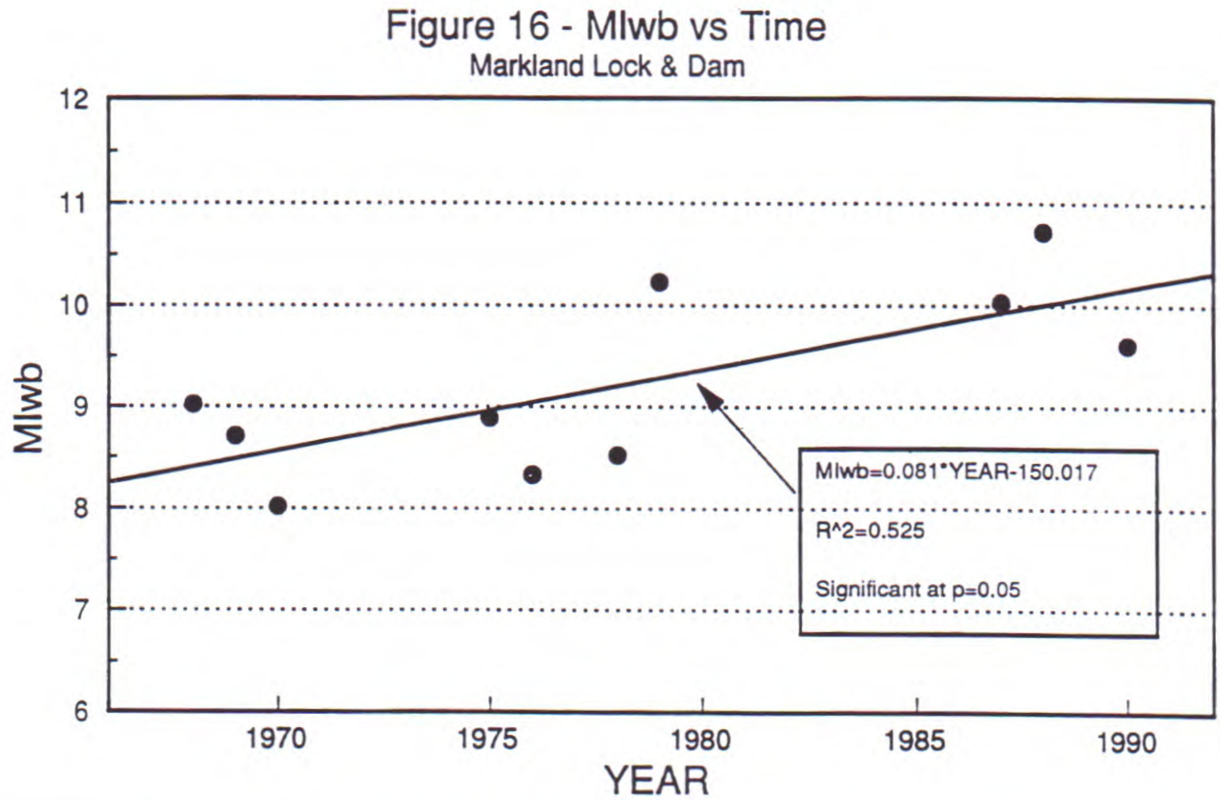


Figure 16 - Mlwb vs Time
Markland Lock & Dam
12
11
10
9
8
7
6
Mlwb
Mlwb=0.081*YEAR-150.017
R^2=0.525
Significant at p=0.05
1970
1975
1980
1985
1990
YEAR

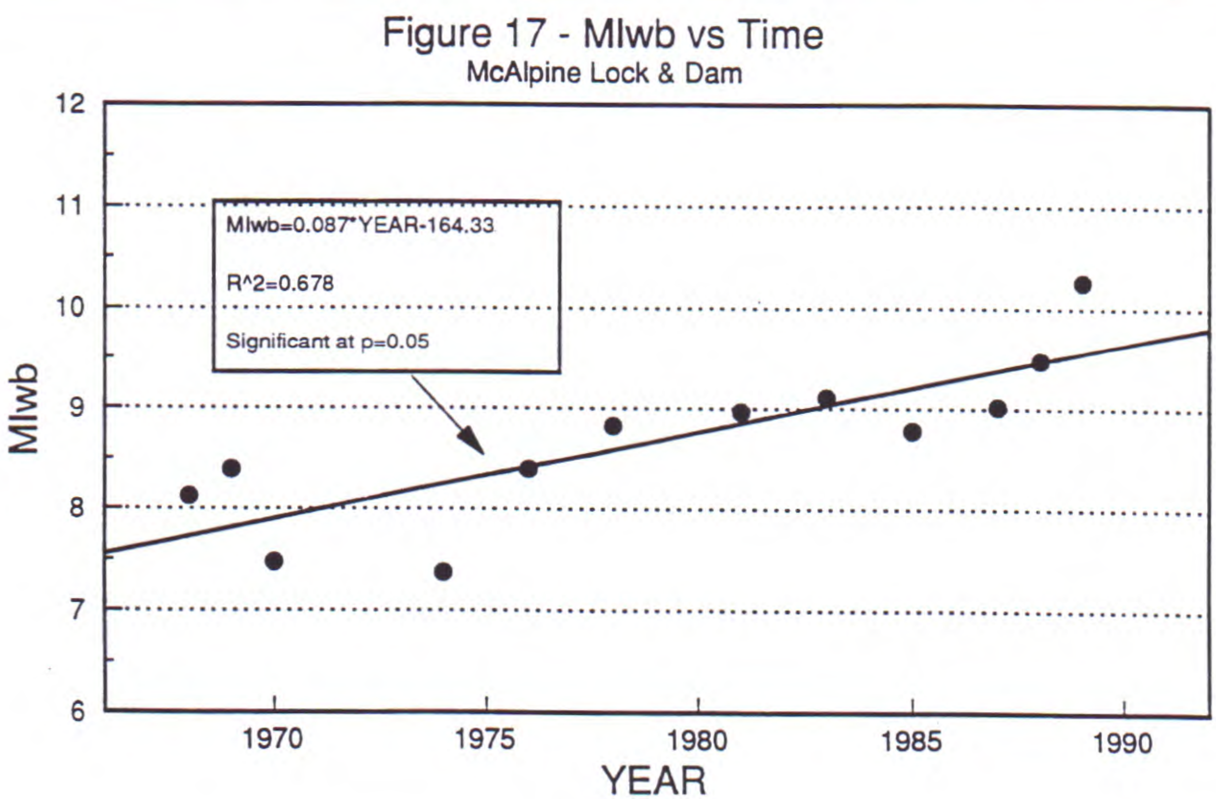


Figure 17 - Mlwb vs Time
McAlpine Lock & Dam
12
11
10
9
8
7
6
Mlwb
Mlwb=0.087*YEAR-164.33
R^2=0.678
Significant at p=0.05
1970
1975
1980
1985
1990
YEAR

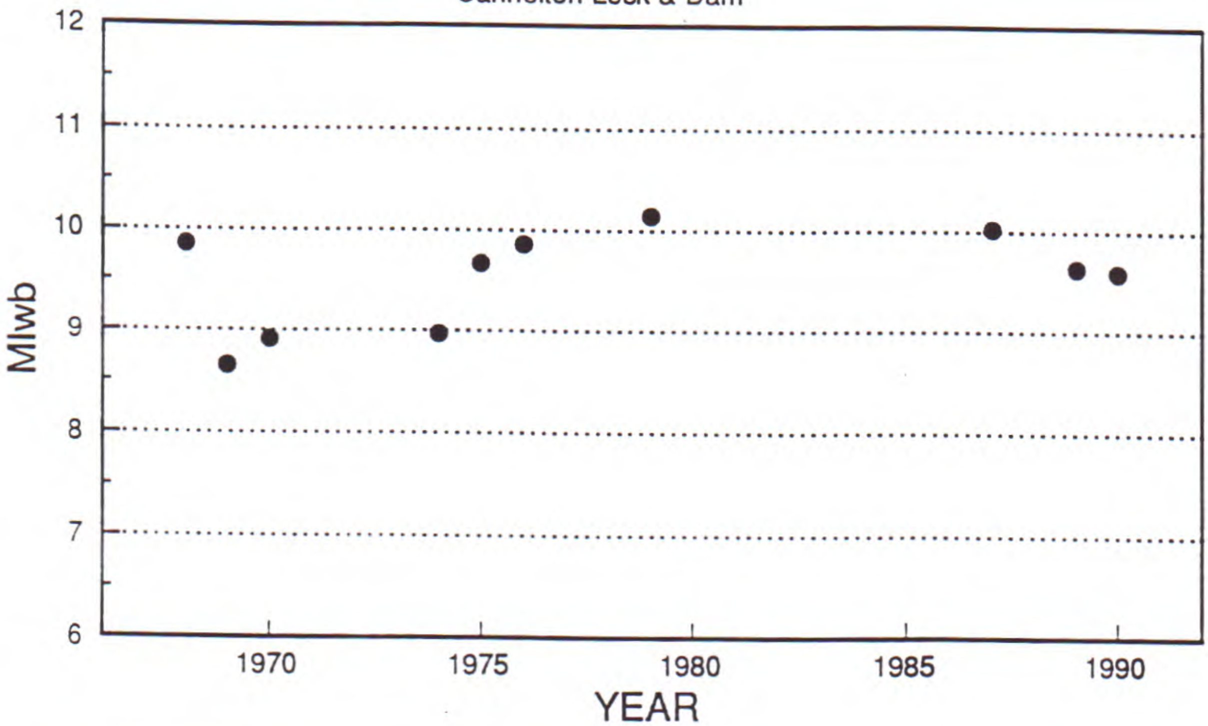


Figure 18 - Mlwb vs Time
Cannelton Lock & Dam

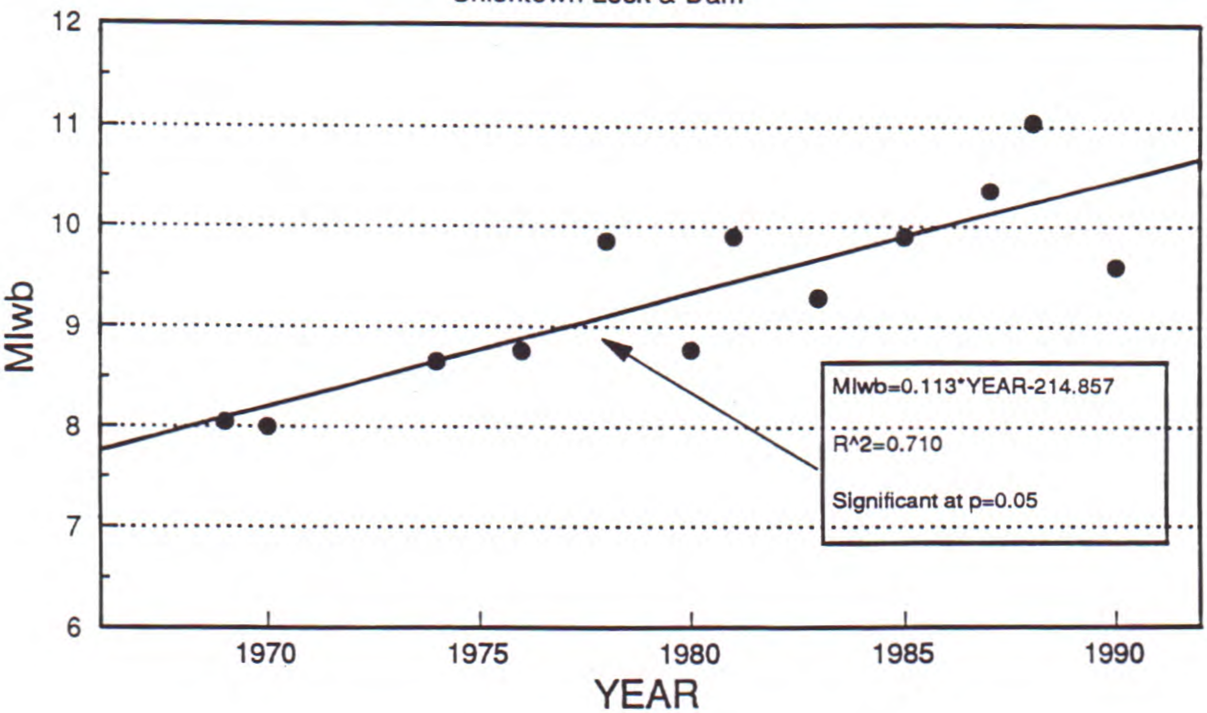


Figure 19 - Mlwb vs Time
Uniontown Lock & Dam

Figure 20 - Mlwb vs Time

Newburgh Lock & Dam

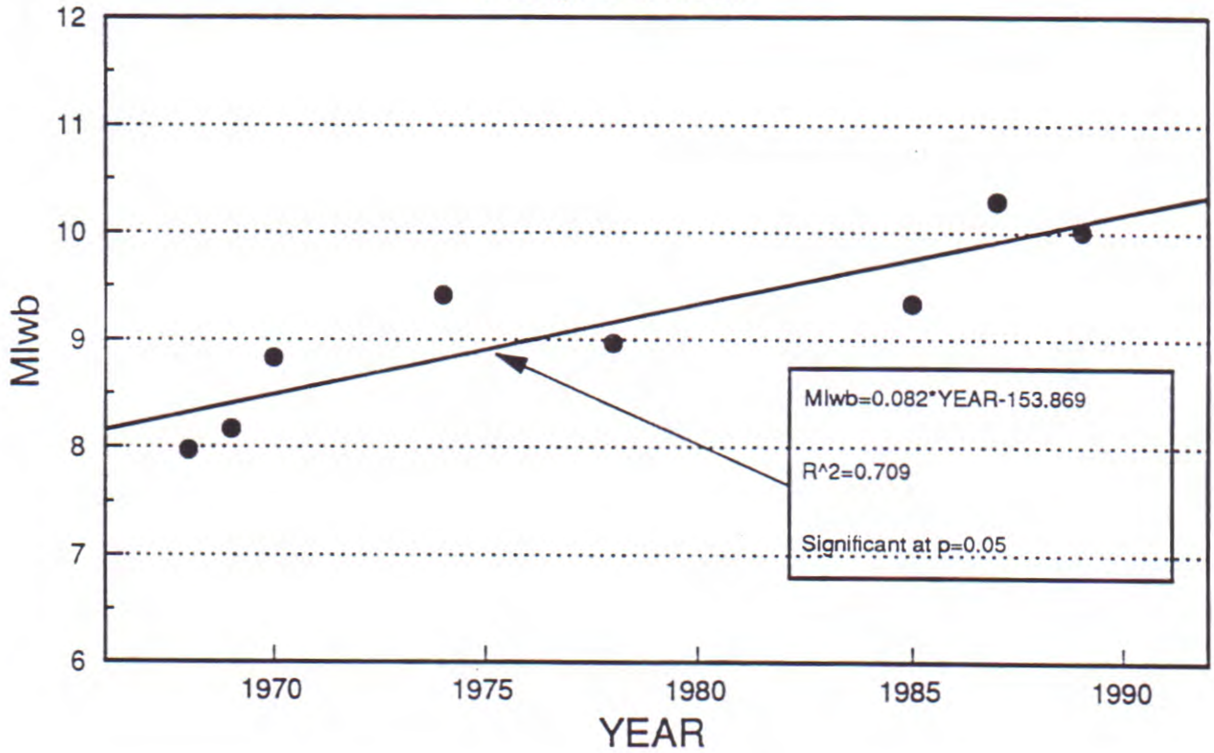


TABLE 3 RESULTS OF REGRESSION ANALYSES - Mlwb vs Year							
Location	RM*	N	B_0	B_1	R^2	t	H_o
Maxwell	61.2	9	-281.06	0.146	0.335	1.880	Accept
Monongahela #2	11.2	14	-252.95	0.131	0.386	2.746	Reject
Allegheny #3	52.6	8	-50.338	0.029	0.027	0.410	Accept
Dashields	13.2	14	-226.23	0.119	0.474	3.290	Reject
New Cumberland	54.4	10	-126.03	0.068	0.400	2.311	Reject
Pike Island	84.2	15	-44.79	0.027	0.047	0.805	Accept
Hannibal	126.4	10	-127.87	0.689	0.238	1.583	Accept
Belleville	203.9	13	-47.18	0.028	0.197	1.642	Accept
Gallipolis	279.2	13	-66.48	0.038	0.203	1.673	Accept
Greenup	341.0	8	-69.77	0.040	0.212	1.270	Accept
Meldahl	436.2	9	-156.62	0.581	0.462	2.450	Reject
Markland	531.5	10	-150.02	0.081	0.525	2.971	Reject
McAlpine	606.8	12	-164.33	0.087	0.678	4.589	Reject
Cannelton	720.7	10	-47.26	0.029	0.218	1.493	Accept
Newburgh	776.1	8	-153.87	0.082	0.709	3.819	Reject
Uniontown	846.0	8	-214.86	0.113	0.710	4.952	Reject

H_o - Null Hypothesis slope = 0 - Rejected for $p < 0.05$ - Slope is Significant

H_a - Alternate Hypothesis slope < > 0

N - Number of Data Points

*RM - River Mile * - Tributary mile points are miles from the confluence with the Ohio River*

The results show that for eight sampling locations (out of 16 assessed) there was a significant increase in the Mlwb value over time. The locations showing an increase are: Monongahela #2, Dashields, New Cumberland, Markland, Meldahl, McAlpine, Newburgh and Uniontown. All other locations did not show a significant change over time, using the methods described in section IV. None showed a declining trend over time.

D. Test for Relationship with Flow

Table 4 shows the data and locations used in this analysis. Table 5 shows the results of the analyses. It is clear from Table 5 that Mlwb values are not related to annual average flow or average spring (April-June) flow as the null hypothesis (i.e., regression line=0).

TABLE 4

FLOW DATA FOR REGRESSION ANALYSES

LOCATION	YEAR	Mlwb	ANNUAL MEAN FLOW - cfs	AP-MA-JU MEAN FLOW-cfs
Mon #2	1968	5.1	10400	15623
	1970	5.0	11600	14790
	1973	8.0	14400	18122
	1976	7.0	10100	6342
	1977	8.3	10700	9789
	1978	6.0	14300	15237
	1980	7.4	16100	20797
	1981	8.2	13200	23165
	1983	9.0	11000	20182
	1985	7.4	12400	12952
	1987	8.3	11300	13580
	1988	10.8	9160	9725
Dashields	1978	7.1	38400	43636
	1979	8.0	39200	37473
	1980	9.0	38800	49150
	1981	9.0	35500	52077
	1983	9.9	30500	51765
	1985	9.3	32500	30851
	1987	9.7	34300	40288
	1988	9.7	26700	27848
Pike Island	1979	8.1	47800	46706
	1980	7.4	46600	58891
	1981	7.7	41500	62507
	1983	8.6	36600	66581
	1985	8.1	38300	38266
	1987	8.2	38800	47127
	1988	9.8	30500	30285
	1989	9.5	48000	84686
	1990	8.1	43195	45249
Belleville	1978	8.5	68100	85419
	1979	9.4	67500	63403
	1980	8.9	69200	85850
	1981	8.9	58200	97536
	1985	9.0	50700	52664
McAlpine	1978	8.8	144000	160648
	1981	9.0	108000	205768
	1985	8.8	105000	105510
	1987	9.0	112000	145542
	1988	9.5	68700	72060
	1989	10.3	159000	253964

TABLE 5 RESULTS OF REGRESSION ANALYSIS - MIwb vs Flow							
Location	RM*	N	B_0	B_1	R^2	t	H_o
Monongahela #2 - Annual	11.2	12	9.71	$-1.8x10^{-4}$	0.052	-0.738	Accept
Monongahela #2 - Spring	11.2	12	7.79	$-1.6x10^{-5}$	0.002	-0.158	Accept
Dashields - Annual	13.2	8	13.64	$-1.3x10^{-4}$	0.352	-1.806	Accept
Dashields - Spring	13.2	8	9.08	$-1.9x10^{-6}$	0.0003	0.050	Accept
Pike Island - Annual	84.2	9	10.64	$-5.5x10^{-5}$	0.167	-1.184	Accept
Pike Island - Spring	84.2	9	8.32	$1.1x10^{-6}$	0.0005	0.060	Accept
Belleville - Annual	203.9	5	9.15	$-3.2x10^{-6}$	0.007	-0.146	Accept
Belleville - Spring	203.9	5	9.58	$-8.2x10^{-6}$	0.241	-0.975	Accept
McAlpine - Annual	606.8	6	8.56	$4.1x10^{-6}$	0.105	0.684	Accept
McAlpine - Spring	606.8	6	8.58	$5.7x10^{-6}$	0.232	1.098	Accept

H_o - Rejected for $p<0.05$ (two tailed test) - Slope is Significant
N - Number of Data Points
*RM - River Mile * - Tributary river mile are miles from the confluence with the Ohio River*

E. Comparison to Ohio EPA Electrofishing Results

In 1989 the Ohio EPA conducted a night electrofishing survey on the Ohio River from river mile 280.8 to 442.5. The Ohio EPA included 18 sites using standard methods established by the Ohio EPA for electrofishing (Sanders 1990). MIwb values were determined by the Ohio EPA and the results are presented in Table 6 along with 1989 MIwb values for Gallipolis and Meldahl.

TABLE 6

RESULTS OF OHIO EPA 1989 ELECTROFISHING SURVEY AND ORSANCO LOCKCHAMBER STUDIES

Sampling Location - River Mile	Collection Agency	Sampling Method	MIwb
Gallipolis Lock & Dam - 279.2	ORSANCO	Rotenone	9.92
River Mile 280.8	Ohio EPA	Electrofishing	9.20
River Mile 292.4	Ohio EPA	Electrofishing	8.22
River Mile 306.3	Ohio EPA	Electrofishing	7.47
River Mile 327.5	Ohio EPA	Electrofishing	8.83
River Mile 339.3	Ohio EPA	Electrofishing	7.49
River Mile 345.5	Ohio EPA	Electrofishing	8.64
River Mile 346.1	Ohio EPA	Electrofishing	8.50
River Mile 355.4	Ohio EPA	Electrofishing	8.92
River Mile 356.0	Ohio EPA	Electrofishing	9.10
River Mile 363.5	Ohio EPA	Electrofishing	8.92
River Mile 374.9	Ohio EPA	Electrofishing	9.12
River Mile 386.2	Ohio EPA	Electrofishing	8.66
River Mile 387.7	Ohio EPA	Electrofishing	8.33
River Mile 393.9	Ohio EPA	Electrofishing	9.33
River Mile 406.6	Ohio EPA	Electrofishing	7.79
River Mile 413.9	Ohio EPA	Electrofishing	9.88
River Mile 425.0	Ohio EPA	Electrofishing	9.72
Meldahl Lock & Dam 436.2	ORSANCO	Rotenone	9.39
River Mile 442.5	Ohio EPA	Electrofishing	8.28

The table shows similar index values obtained using both methods. Some caution is needed in interpreting these values. The sampling methods are very different and quantitative comparisons are not valid. It should be noted that electrofishing is a more resource efficient method for characterizing the fish community. More sampling stations can be covered with less personnel and the fish are not destroyed.

VI. CONCLUSIONS

Based on the results presented, the Modified Index of Well Being (MIwb) is a valuable tool for evaluating fish population data collected by ORSANCO. Of the sites with sufficient data 50% showed statistically significant improvements in the fish community over time. The analyses suggest stable conditions at the other locations. This shows pollution control efforts to date have had a positive impact in many locations. Recent work by ORSANCO (ORSANCO 1990a) showed significant decreasing trends in water quality of the Ohio River and major tributaries indicating improving water quality conditions.

Examining the results spatially, there are reaches of the river showing possible problems. In general there are improving conditions from upstream to downstream, reflecting less concentrated human activity and improved habitat. Several reaches show sags in MIwb values which warrant attention. These are:

- From Montgomery (rm 31.7) to Pike Island (rm 84.2)
- From Racine (rm 237.5) to Gallipolis (rm 279.2)
- From Meldahl (436.2) to McAlpine (606.8)

Many factors could explain these sags. In the reach from Montgomery to Pike Island there is a high concentration of heavy industry. ORSANCO (1988a) identified the reaches from rm 25.5 to 40.1 and from 40.1 to 85.0 as affected by point sources and having regular violations of in-stream chemical criteria established to protect aquatic life in the period from 1980 - 1987. Acid mine drainage also contributes pollutants detrimental to aquatic life in these reaches.

The major water quality influence in the reach from Racine to Gallipolis is the Kanawha River. The Kanawha River has a heavy industrial base. The combined effect from these discharges may be influencing the aquatic community of the Ohio River.

In the reach from Meldahl to McAlpine there are several inputs that may influence the water quality and, therefore, the fish community. ORSANCO (1989b, 1990b) has shown the greatest input to this reach of the Ohio River is from nonpoint source pollution. In particular is the input from urban runoff and combined sewer overflows from the greater Cincinnati area and the Great Miami Basin (11% urban land use). Another factor in this reach of the river is the chronic operation problems at the Cincinnati Metropolitan Sewer District Mill Creek Plant.

Based on regression analysis of MIwb vs Flow (annual average and spring average) there is no statistically significant ($p<0.05$) relationship with stream flow. Future analysis may need to examine this question further.

The adjustment of the MIwb for lockchamber area allows valid comparisons of lockchambers of different sizes. The MIwb is adjusted for lockchamber area as described in section IV(B) of this report. The adjustment was needed to allow comparison of lockchambers of different sizes. The approach outlined in section IV(B) is reasonable and is consistent with the application of the MIwb by Ohio EPA. Once pre-1968 data are entered into the ORSANCO data base valid comparisons can be made over time.

V. RECOMMENDATIONS FOR ADDITIONAL WORK

The analyses and results presented indicate improving biological conditions since 1968 for the Ohio River at eight locations and stable conditions at eight other locations. Problems were noted in the spatial variation of the data indicating additional pollution control activities are needed to improve conditions. Also several problems are identified with the data and assessment of the data.

The following recommendations are offered for future analyses:

- Develop assessment criteria for the Ohio River - The FY1992 ORSANCO Program Plan addresses this issue with the formation of a work group of biological experts. This should also include development of IBI reference expectations.

- Comparison of water quality trends with changes in fish population. This is outlined in the ORSANCO FY92 Program Plan to be completed by January 1993.

- Investigate a more rigorous test for trends in the MIwb scores. Simple regression analysis was applied to the data in this report to test for trends. The adequacy of this should be determined.

- Additional field work is needed in the reaches of the Ohio River identified as having "sags" in the fish community quality. The use of intensive electrofishing surveys in these reaches would allow better definition of problem areas.

- Data collected prior 1978 needs to be checked and entered into an in-house data base. Analysis of data from 1968-1977 is presented with this report on a limited basis. Data collected prior to 1968 must be analyzed to provide a perspective of the current condition of the aquatic life.

- Future lockchamber surveys should include complete minnow identification.

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APPENDIX A

TOLERANT SPECIES

TOLERANT SPECIES

From: "Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters", Ohio EPA, October 1987.

Central Mudminnow

White Sucker

Common Carp

Goldfish

Golden Shiner

Blacknose Dace

Creek Chub

Fathead Minnow

Bluntnose Minnow

Yellow Bullhead

Brown Bullhead

Eastern Banded Killfish

Green Sunfish

APPENDIX B

OHIO EPA ASSESSMENT CRITERIA FOR MIwb

Conceptual response of fish community structural and functional attributes as portrayed by Modified Index of Well Being (MIwb). Narrative descriptions of fish community condition for good, fair, poor, and very poor ranges are indicated. Used by Ohio EPA 1980-1987, replaced by ecoregional biocriteria.

	MEETS CWA GOALS		DOES NOT MEET CWA GOALS		
Category	Exceptional	Good	Fair	Poor	Very Poor
1.[a]	Exceptional, or unusual assemblage of species	Unusual association of expected species	Some expected species absent, or in low abundance	Many expected species absent, or in low abundance	Most expected species absent
2.	Sensitive species abundance	Sensitive species present	Sensitive species absent, or in very low abundance	Sensitive species absent	Only most tolerant species remain
3.	Exceptionally high species richness	High species richness	Declining species richness	Low species richness	Very low species richness
4.[b]	Composite indes Greater than 9.5	Composite index Greater than 7.4-8.6[b]	Composite index Greater than 5.3-6.3[b], Less than 7.4-8.6[b]	Composite index Greater than 4.5-5.0[b], Less than 5.3-6.3[b]	Composite index Less than 4.5 or 5.0[b]
5.	Outstanding recreational fishery		Tolerant species increasing, beginning to predominate	Tolerant species predominate	Community organization lacking
6.	Species with an endangered, threatened, or special concern status are present				

a. Conditions: Categories 1,2,3 and 4 (if data is available) must be met and 5 or 6 must also be met in order to be designated in that particular class.

b. Encompasses range of ecoregional values: area of insignificant departure is -0.5 from ecoregional criterion. See reference for ecoregion differences.

From: "Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters", Ohio EPA, October 1987.

APPENDIX C

DATABASE PROGRAMS

```
* Program: MIWB_AR.PRG  -  Normalizes MIwb for area
* Author.: Lesley Barnhorn
* Date...: August 23, 1990
* Notes..: Analyzes fish database with the Modified Index of Well Being
*   (Iwb). Two files are used: A is database file from which
*   data is taken. B is database file to which results are
*   written.  Applicable for a database in which there are
*   multiple records for a given species (as in FISH89.DBF).

CLEAR ALL
SET TALK OFF
SELECT B
USE <1>
* ATTN: Replace <1> with appropriate output file, i.e. IWBOUT
SELECT A
USE <2>
* ATTN: Replace <2> with appropriate fish datafile, i.e. FISH89
* Since records with count or kgweight of "0" are incomplete and
*    may cause the program to fail, these are deleted.
DELETE ALL FOR COUNT=0
DELETE ALL FOR KGWEIGHT=0
DELETE ALL FOR SPECIES="CYPRINIDAE"
COPY TO DELETED FOR DELETED()
PACK
INDEX ON LOCATION+SPECIES TO <3>
* ATTN: Replace <3> with a name for the fishdata index file

* F1-F13 are tolerant species
F1="CENTRAL MUDMINNOW"
F2="WHITE SUCKER"
F3="COMMON CARP"
F4="GOLDFISH"
F5="GOLDEN SHINER"
F6="BLACKNOSE DACE"
F7="CREEK CHUB"
F8="FATHEAD MINNOW"
F9="BLUNTNOSE MINNOW"
F10="YELLOW BULLHEAD"
F11="BROWN BULLHEAD"
F12="EASTERN BANDED KILLIFISH"
F13="GREEN SUNFISH"

DO WHILE .NOT. EOF()
   * Store values for first record at given location.
   *    and initialize variables
   STORE LOCATION TO MLOC
```

```
STORE RMI TO MRMI
STORE YEAR TO MYEAR
STORE AREA TO MAREA
STORE RECNO() TO MREC
MMODCT=0
MMODWT=0
MTOTWT=0
MTOTCT=0
MSPECNUM=0
HNO=0
HWT=0

DO WHILE LOCATION = MLOC
   * Calculate total weights and fish counts, with and
   *   without tolerant species, for each location.
   MTOTCT=MTOTCT+COUNT
   MTOTWT=MTOTWT+KGWEIGHT
   * Set up logical conditions for exclusion of tolerant
   *   species.
   MCOND1=SPECIES=F1 .OR. SPECIES=F2 .OR. SPECIES=F3 .OR. SPECIES=F4
.OR. ì
speCIES=F5 .OR. SPECIES=F6 .OR. SPECIES=F7
   MCOND2=SPECIES=F8 .OR. SPECIES=F9 .OR. SPECIES=F10 .OR.
SPECIES=F11 ì
.OR. SPECIES=F12 .OR. SPECIES=F13
   IF .NOT. MCOND1 .AND. .NOT. MCOND2
      MMODCT=MMODCT+COUNT
      MMODWT=MMODWT+KGWEIGHT
   ENDIF
   SKIP
ENDDO

* Return to first record at location and calculate
*   Shannon Diversity Indices (HNO and HWT)
GO MREC
DO WHILE LOCATION=MLOC
   STORE SPECIES TO MFISH
   MSPECNUM=MSPECNUM+1
   MSPECCT=0
   MSPECWT=0
   DO WHILE SPECIES=MFISH
      MSPECCT=MSPECCT+COUNT
      MSPECWT=MSPECWT+KGWEIGHT
      SKIP
   ENDDO
   HNO=HNO+(MSPECCT/MTOTCT)*LOG(MSPECCT/MTOTCT)
```

```
    HWT=HWT+(MSPECWT/MTOTWT)*LOG(MSPECWT/MTOTWT)
  ENDDO

  * Put it together into Iwb equation
  EL1=.5*LOG(MMODCT/MAREA)
  EL2=.5*LOG(MMODWT/MAREA)
  HNO=-(HNO)
  HWT=-(HWT)
  IWBNUM=EL1+EL2+HNO+HWT
  SELECT B

  * Write results to IWB.DBF
  APPEND BLANK
  REPLACE YEAR WITH MYEAR
  REPLACE LOCATION WITH MLOC
  REPLACE RMI WITH MRMI
  REPLACE ELEMENT1 WITH EL1
  REPLACE ELEMENT2 WITH EL2
  REPLACE HNUMBER WITH HNO
  REPLACE HWEIGHT WITH HWT
  REPLACE SPECIES WITH MSPECNUM
  REPLACE FISH WITH MTOTCT
  REPLACE IWB WITH IWBNUM
  SELECT A
ENDDO

* The records that were deleted are restored to the file to
* maintain database integrity
APPEND FROM DELETED
CLOSE DATABASES
RETURN
```

APPENDIX D

LOCKCHAMBERS SAMPLED BY ORSANCO

Lockchamber Location and Surface Area

Lockchamber	River	River Mile	Surface Area Acres
Maxwell	Monongahela	61.2	1.39
Monongahela #2	Monongahela	11.2	0.46
Allegheny #8	Allegheny	52.6	0.46
Allegheny #3	Allegheny	14.5	0.46
London	Kanawha	82.8	0.46
Winfield	Kanawha	31.1	0.46
Emsworth	Ohio	6.2	0.46
Dashields	Ohio	13.2	0.46
Montgomery	Ohio	31.7	0.46
New Cumberland	Ohio	54.4	1.51
Pike Island	Ohio	84.2	1.51
Hannibal	Ohio	126.4	1.51
Willow Island	Ohio	161.7	1.51
Belleville	Ohio	203.9	1.51
Racine	Ohio	237.5	1.51
Gallipolis	Ohio	279.2	0.91
Greenup	Ohio	341.0	1.51
Maldahl	Ohio	436.2	1.51
Markland	Ohio	531.5	1.51
McAlpine	Ohio	606.8	1.51
Cannelton	Ohio	720.7	1.51
Newburgh	Ohio	776.1	1.51
Uniontown	Ohio	846.0	1.51
Smithland	Ohio	918.5	3.03
Lock 53	Ohio	962.6	1.51