Table 1.5

Critical Thermal Thresholds for Key Species						
Species	Optimum		MAWT For Growth		UAT	
	°F	°C	°F	°C	°F	°C
Northern Pike[2]	71.2	21.8	77.5	25.3	84.0	28.9
Walleye[4 & 5]	73.0	22.8	88.9	31.6	86.0	30.0
Muskellunge	75.6	24.2	80.6	27.0	84.6	29.2
Smallmouth Bass	86.0	30.0	89.6	32.0	89.6	32.0

Optimum - the temperature at which an organism can most efficiently perform a specific physiological or ecological function

MAWT for Growth - the mean weekly average temperature for growth (Brungs and Jones 1976). The MAWT is calculated based on a formula that requires an optimum and upper lethal temperature.

UAT - upper avoidance temperature. A sharply defined upper temperature at which an organism at a given acclimation temperature will avoid (Coutant 1977)

References:

1. Brungs, W.A. and B.R. Jones. 1977. Temperature Criteria for freshwater fish: protocol and procedures, EPA-600/3-77-061. U.S. EPA Ecological Research Series.

2. Carlander, K. D. 1969. Handbook of freshwater fishery biology. 3rd Edition,. 752 pp. Ames, Iowa; Iowa State University Press

3. Coutant, C. C. 1977. Compilation of temperature preference data. J. Fish. Res. Bd. Can. 34, no. 5: 739-45.

4. Hokanson, K. E. F. 1977. Temperature requirements of some percids and adoptions to the seasonal temperature cycle. J. Fish. Res. Bd. Can. 34, no. 10: 1524-50.

5. Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184-966 pp.

The District requires:

The water temperature criteria for the hydropower plant outfall are based on existing maximum water temperatures, which are similar to PA's TSF water temperature criteria except during August and September, when water temperatures are cooler (<80°F or 26.7°C). The hydropower operator (assumed to be the Mahoning Creek Hydroelectric Company, MCHC) will monitor the outflow, using data collected at their real-time, continuously recording water quality monitors located in the stilling basin, the lake, and just downstream of the hydropower plant, and will operate to maintain water temperatures at all monitors at or below appropriate criteria (see Chart 1 for monthly or bi monthly criteria). MCHC's data will be provided real-time and continuously on the USGS' public website throughout the duration of the FERC license. When the temperature at any of these monitors is higher than the date specific criteria and higher than the water temperature in the lake near the lake bottom (dam intake elevation), MCHC will reduce flow through the turbine and/or the District will increase bypass flow sufficient to meet water temperature criteria. The District's water quality monitor located on Mahoning Creek at the McCrea Furnace Bridge will be utilized to evaluate the effectiveness of, and possibly modify, the WT criteria for MCHC's WQ monitors.

A summary of requirements for Mahoning Creek Lake outflow and stilling basin, compared to PA specific water temperature criteria and MCHP's proposal[10], are presented in Tables 2 and 3.

Action Plan:

When the hydroelectric plant is operating, if the water temperature (measured at the hydropower outfall) rises above the applicable water temperature criteria, the bypass flow rate will be increased and/or flow through the turbine reduced to bring water temperatures back into compliance. Effectiveness of bypassing flow will be apparent immediately, and bypass flow will be increased until criteria are met. Immediate response time will be required during working hours. After working hours, a logistically reasonable response time will be determined by USACE project personnel, optimally, not to exceed 2 -hours. Verification of the accuracy of the real-time monitor will be at the discretion of the hydropower plant operator, and will have no impact response time. If the WT rises above 80 °F more than 1% of the time during the summer/fall season at the McCrea Furnace Bridge gauge, than the WT criteria forthe hydropower tailrace outfall and/or the lake will be lowered.

4.b. Mahoning Creek Lake Water Temperature

While the District's 1993 CE_QUAL-R1[5] model run showed only a mild warming in outflow water temperatures during August with all alternatives, this model underestimated the cumulative impacts of season long lake stratification. Therefore, it is possible that predicted outflow water temperatures will also be warmer than estimated.

Grab water temperature data were collected randomly in the lake between 1973 and 2010. In 2006, the District began collecting real-time, April – October water temperature data in the lake just upstream of the dam, at depths every 3 feet from the lake surface to bottom.

Chart 1 compares the PA WWF, CWF, and TSF water temperature criteria with the District's nondegradation water temperature criteria for Mahoning Creek Lake directly upstream of the dam at 24 feet deep. The PA WWF, CWF, and TSF and the District's nondegradation lake water temperature criteria are also presented in tabular format in Table 1.

Chart 8 shows real-time water temperature data collected at the approximate elevation of the existing dam intakes by year (2006 – 2010), along with the PA DEP WWF, CWF, and TSF and District nondegradation water temperature criteria.

Chart 9 shows the real-time water temperature data collected in the lake near the elevation of the new hydropower intake (1054 ft NAVD88 invert) by year along with the PA DEP WWF, CWF, and TSF and District nondegradation water temperature criteria.

Chart 10 shows real-time water temperature data collected 24 feet below the lake surface by year (2006 – 2010). This depth was selected because historically, waters shallower than 25 feet deep when Mahoning Lake is at summer pool elevation have rarely been anoxic.

Chart 8.

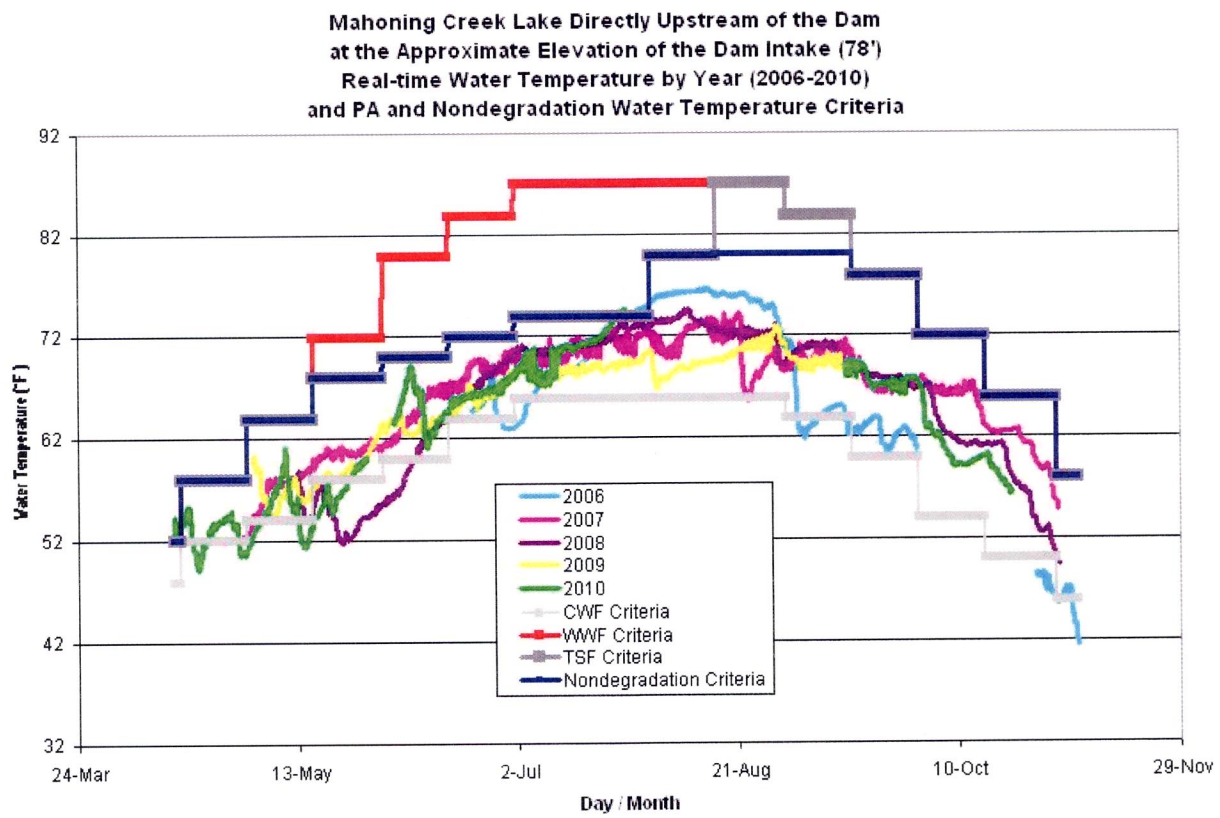

Mahoning Creek Lake Directly Upstream of the Dam
at the Approximate Elevation of the Dam Intake (78')
Real-time Water Temperature by Year (2006-2010)
and PA and Nondegradation Water Temperature Criteria
92
82
72
62
52
42
32
Water Temperature (°F)
24-Mar
13-May
2-Jul
21-Aug
10-Oct
29-Nov
Day / Month
2006
2007
2008
2009
2010
CWF Criteria
WWF Criteria
TSF Criteria
Nondegradation Criteria

Chart 9.

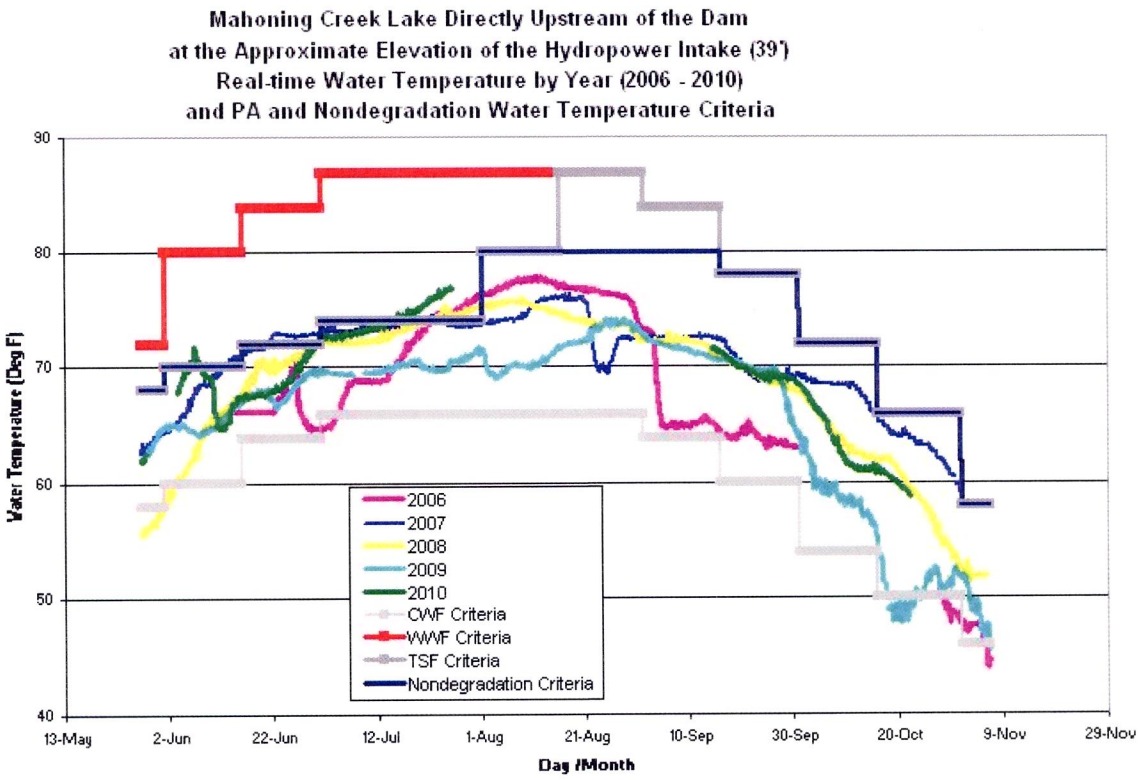
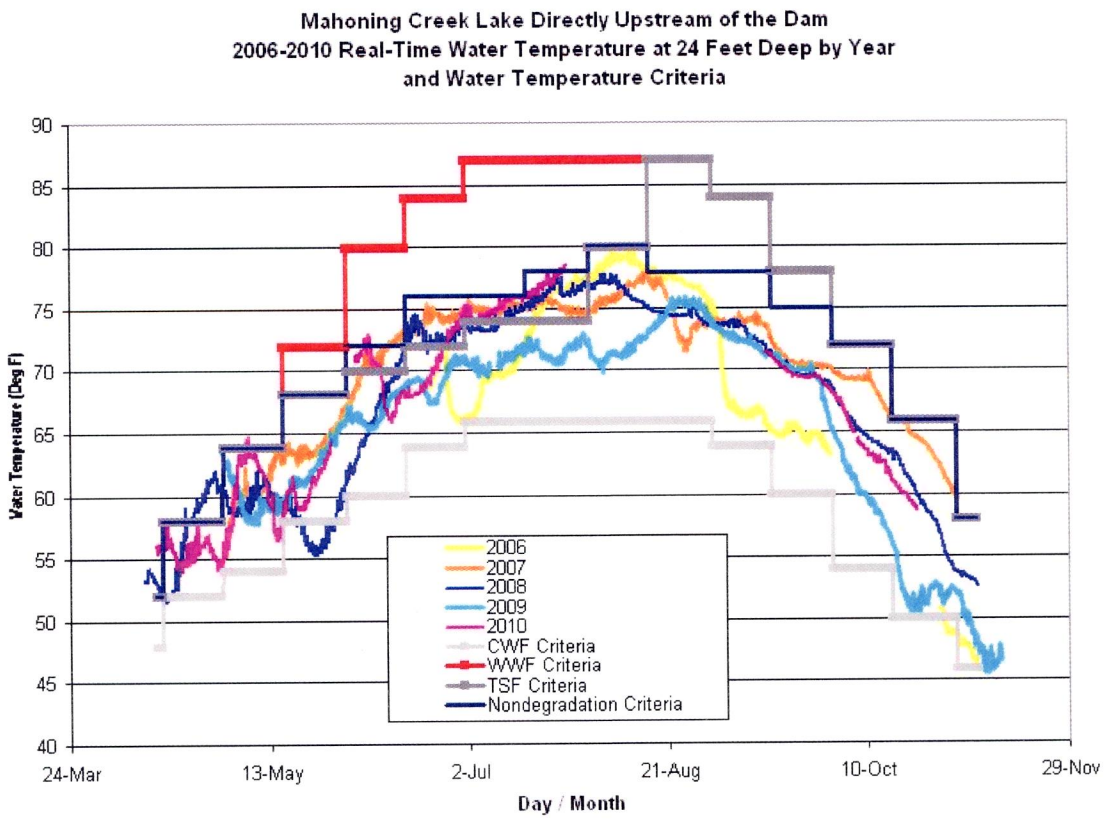

Mahoning Creek Lake Directly Upstream of the Dam
at the Approximate Elevation of the Hydropower Intake (39')
Real-time Water Temperature by Year (2006 - 2010)
and PA and Nondegradation Water Temperature Criteria
Water Temperature (Deg F)
90
80
70
60
50
40
13-May
2-Jun
22-Jun
12-Jul
1-Aug
21-Aug
10-Sep
30-Sep
20-Oct
9-Nov
29-Nov
Day /Month
2006
2007
2008
2009
2010
CWF Criteria
WWF Criteria
TSF Criteria
Nondegradation Criteria

Chart 10.


Mahoning Creek Lake Directly Upstream of the Dam
2006-2010 Real-Time Water Temperature at 24 Feet Deep by Year
and Water Temperature Criteria
Water Temperature (Deg F)
90
85
80
75
70
65
60
55
50
45
40
24-Mar
13-May
2-Jul
21-Aug
10-Oct
29-Nov
Day / Month
2006
2007
2008
2009
2010
CWF Criteria
WWF Criteria
TSF Criteria
Nondegradation Criteria

As can be seen in Charts 8, 9, and 10, respectively, during the District's 2006 – 2010 real-time lake water temperature monitoring period, maximum water temperature at the approximate elevation of the dam intakes was 73°F (22.8 °C), maximum water temperature at the approximate elevation of the hydropower penstock was 78°F (25.6 °C), and maximum water temperature at 24 feet below the lake surface was about 79°F (26.1 °C). It is therefore likely that with use of a higher elevation intake, hydropower plant outflow water temperatures will be at least 5 °F warmer than existing conditions. In addition, because withdrawal from a higher elevation for hydropower generation will create strong summer thermal stratification near the intake, plant outflow water temperatures may be even higher. Even a slight increase in outflow water temperatures could negatively impact the existing downstream coolwater fishery.

The District requires:

> The Mahoning Creek Lake water temperature criteria are based on the existing monthly or bimonthly maximum water temperatures recorded during the District's period of record in the lake at a depth of 24 feet when the lake is at its summer pool elevation (1073 ft NAVD). Maximum lake water temperatures at 24 feet deep are currently similar to PA's TSF water temperature criteria[4] except during June - July, when temperatures are slightly warmer and during August and September, when temperatures are cooler (<80°F or 26.7°C).
>
> MCHC will monitor water temperature using data collected at their real-time, continuously recording water quality monitors located in the lake. If the lake water temperatures at 24 ft exceed monthly / bimonthly criteria, then bypassed flow will be increased to modify lake stratification and lower water temperatures (See Table 1, maximum 80°F (26.7°C)).
>
> A summary of requirements for Mahoning Creek Lake, compared to PA specific water temperature criteria and MCHP's adaptive management proposal[10], is presented in Table 4.Action Plan:
>
> When the hydroelectric plant is operating, if the water temperature (measured in the lake) rises above 80°F, the bypass flow rate will be increased and/or flow through the turbine reduced to bring water temperatures back into compliance. Effectiveness of bypassing flow will be apparent within 24 hours, and bypass flow will be increased until the criterion is met. Immediate response time will be required during working hours. After working hours, a logistically reasonable response time will be determined by USACE project personnel, optimally, not to exceed 2 -hours. Verification of the accuracy of the real-time monitor will be at the discretion of the hydropower plant operator, and will have no impact response time.

5. Dissolved Oxygen

5.a. Mahoning Creek Outflow Dissolved Oxygen

While waters are currently withdrawn from anoxic strata near the bottom of the lake during the summer season, the dam is a very effective aerator and the waters discharged are consistently circumsaturated with dissolved oxygen. In addition, cool bottom releases from the dam assure a coolwater downstream fishery. Based on the District's CE-QUAL-R1 water quality model simulation[5], turbine discharges of the proposed hydropower project will severely depress the dissolved oxygen concentration of the Mahoning Creek downstream of the power plant for most of the summer season. Hydropower generation will also create relatively strong summer thermal stratification near the intake elevation, leaving anoxic, dead storage in the deeper strata of the lake below the intake elevation.

The District began collecting real-time dissolved oxygen data at the McCrea Furnace Bridge (Mahoning Creek mile 22) in 2008. Chart 11 shows unedited real-time DO data, collected at this station, from 2008 – 2010, along with the PA WWF, CWF, and TSF DO criteria[7]. Edited 2008 – 2009 DO data are presented in Chart 12. Chart 13 shows grab DO data collected from Mahoning Creek downstream of the stilling basin weir for the District's period of record (1973 – 2011).

Chart 14 shows grab DO data collected in the stilling basin weir between 1989 and 1995. The 1992 stilling basin DO data are questionable because they were collected by project staff with a meter that was not calibrated regularly. Because stilling basin data are limited, Project staff occasionally collected grab DO, water temperature, and % DO saturation data in and downstream of the stilling basin from February through July 2011.

Chart 11.

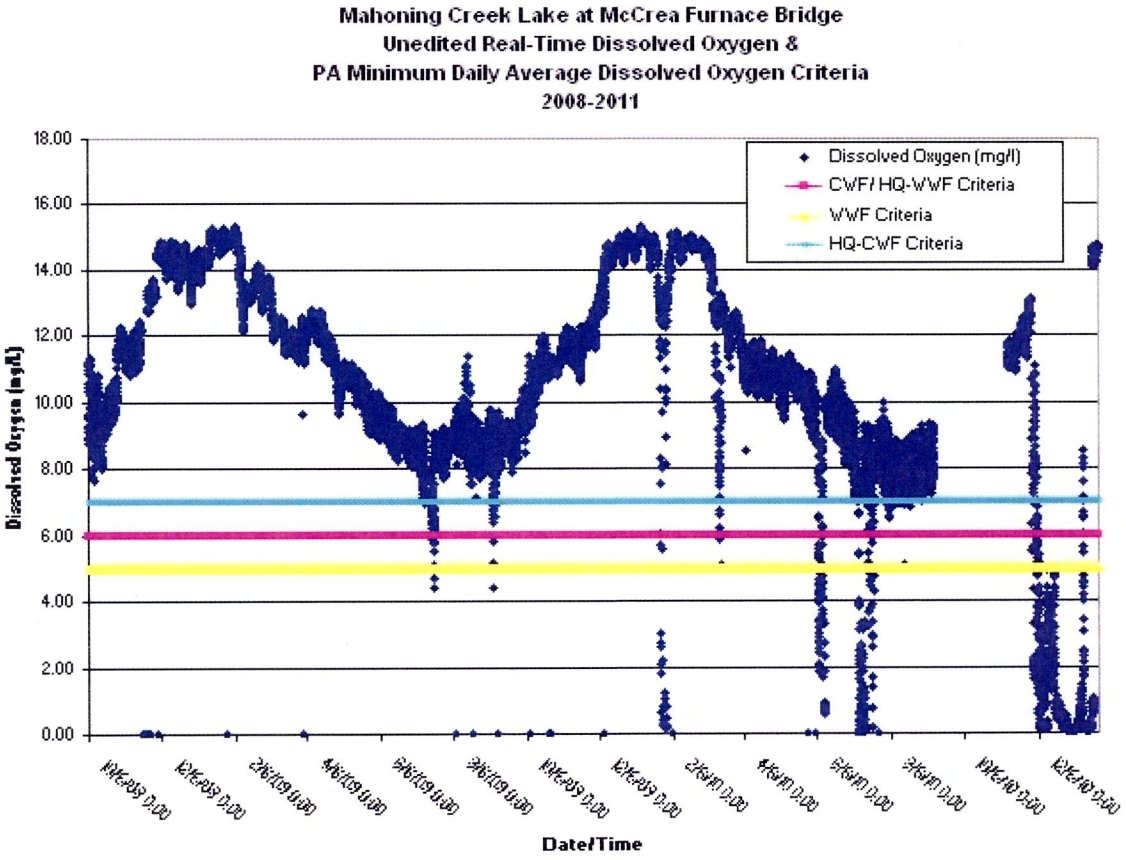

Mahoning Creek Lake at McCrea Furnace Bridge
Unedited Real-Time Dissolved Oxygen &
PA Minimum Daily Average Dissolved Oxygen Criteria
2008-2011
Dissolved Oxygen (mg/l)
CWF/ HQ-WWF Criteria
WWF Criteria
HQ-CWF Criteria
Dissolved Oxygen (mg/L)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Date/Time

Chart 12.

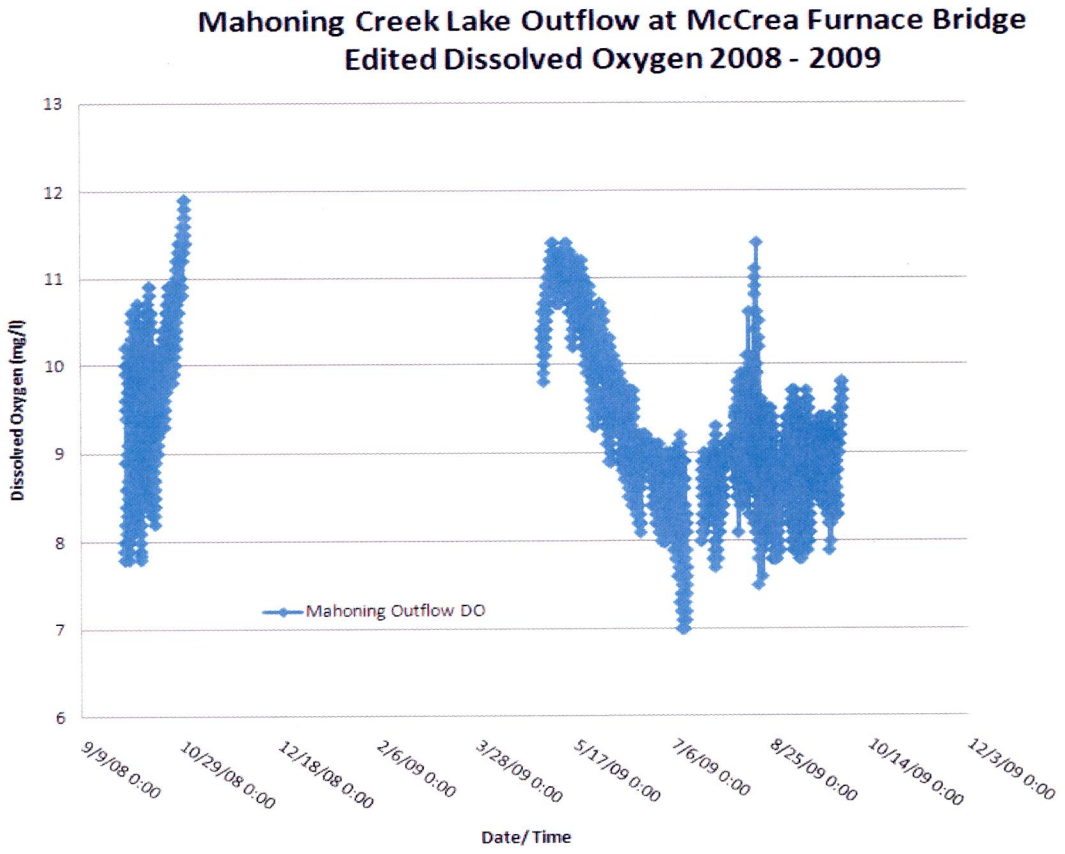

Mahoning Creek Lake Outflow at McCrea Furnace Bridge
Edited Dissolved Oxygen 2008 - 2009
Dissolved Oxygen (mg/l)
13
12
11
10
9
8
7
6
Mahoning Outflow DO
9/9/08 0:00
10/29/08 0:00
12/18/08 0:00
2/6/09 0:00
3/28/09 0:00
5/17/09 0:00
7/6/09 0:00
8/25/09 0:00
10/14/09 0:00
12/3/09 0:00
Date/ Time

Chart 13.

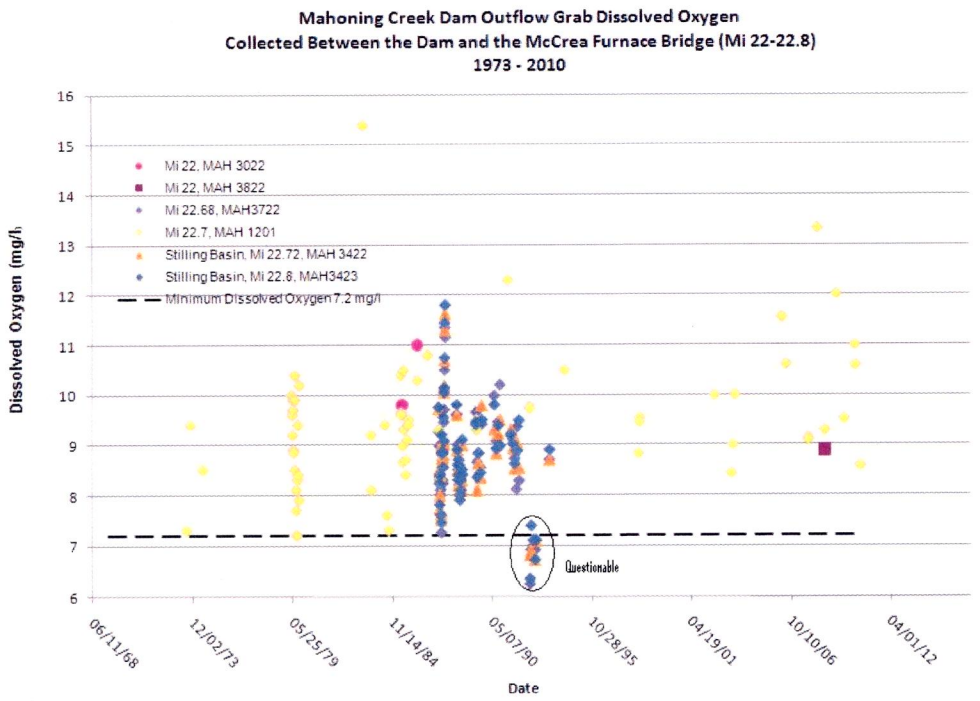

Mahoning Creek Dam Outflow Grab Dissolved Oxygen
Collected Between the Dam and the McCrea Furnace Bridge (Mi 22-22.8)
1973 - 2010
Dissolved Oxygen (mg/l)
16
15
14
13
12
11
10
9
8
7
6
Mi 22, MAH 3022
Mi 22, MAH 3822
Mi 22.68, MAH3722
Mi 22.7, MAH 1201
Stilling Basin, Mi 22.72, MAH 3422
Stilling Basin, Mi 22.8, MAH3423
Minimum Dissolved Oxygen 7.2 mg/l
Questionable
06/11/68
12/02/73
05/25/79
11/14/84
05/07/90
10/28/95
04/19/01
10/10/06
04/01/12
Date

Chart 13.a

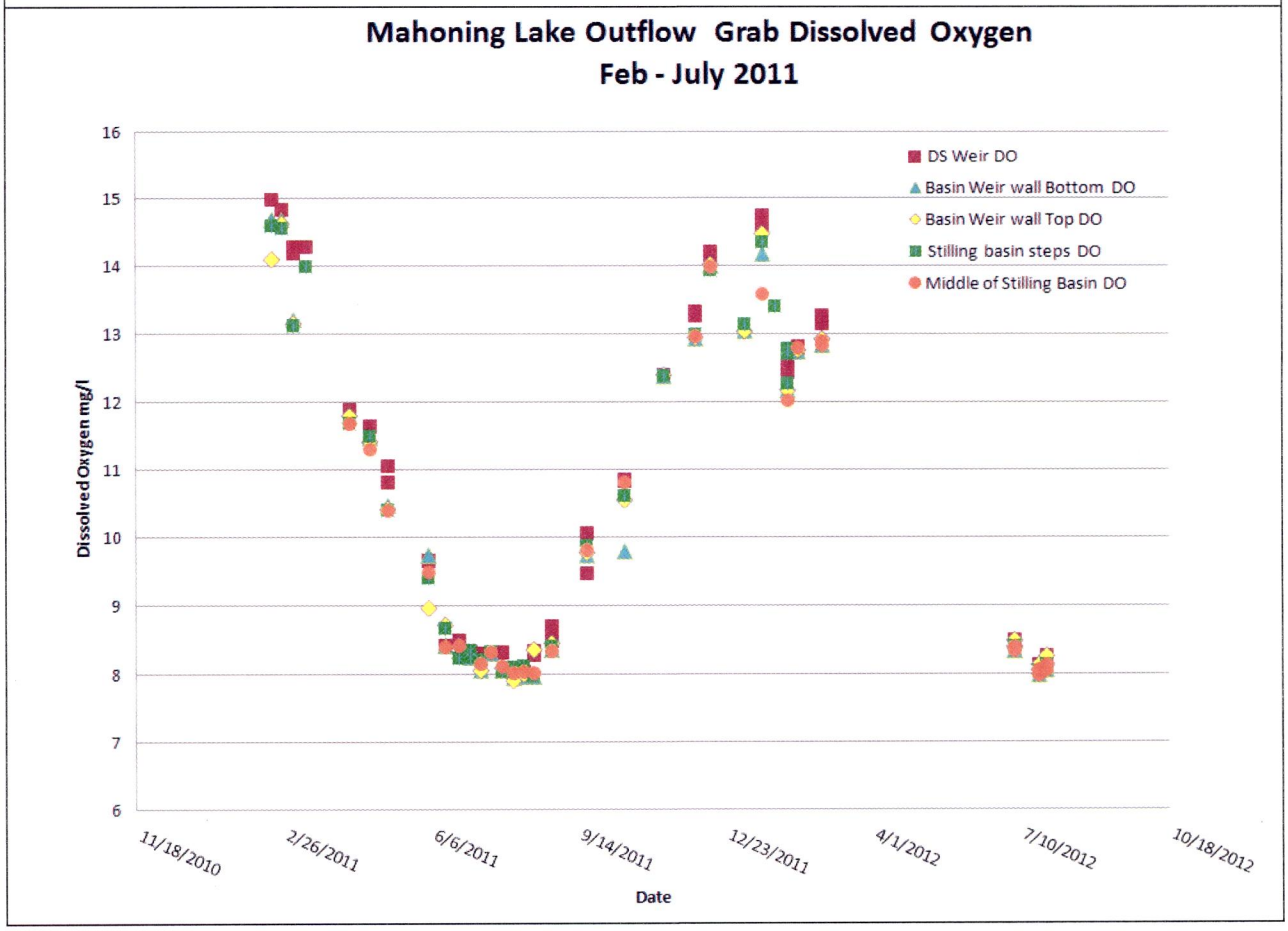

Mahoning Lake Outflow Grab Dissolved Oxygen
Feb - July 2011
DS Weir DO
Basin Weir wall Bottom DO
Basin Weir wall Top DO
Stilling basin steps DO
Middle of Stilling Basin DO
Dissolved Oxygen mg/l
16
15
14
13
12
11
10
9
8
7
6
11/18/2010
2/26/2011
6/6/2011
9/14/2011
12/23/2011
4/1/2012
7/10/2012
10/18/2012
Date

Chart 13.b.

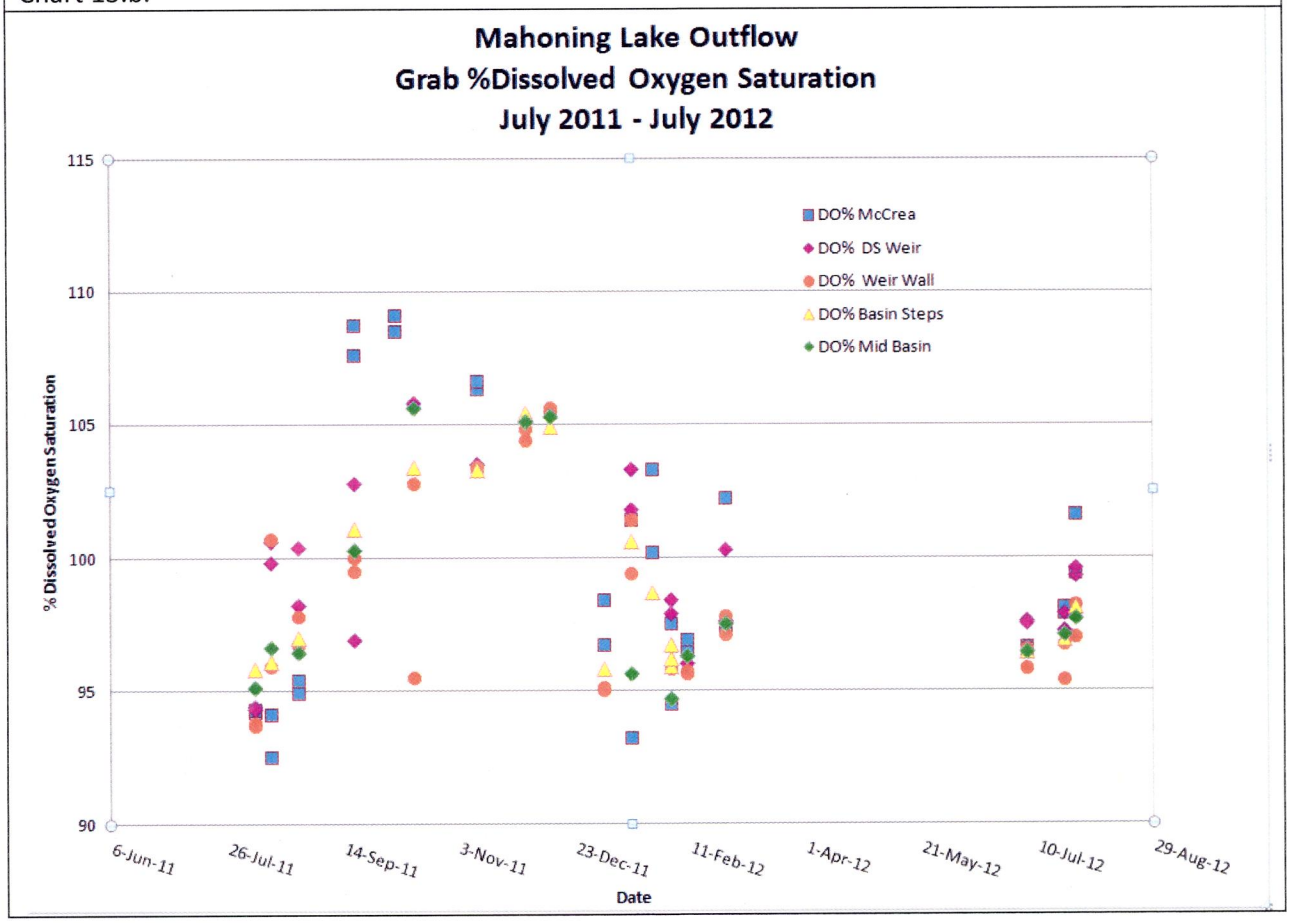
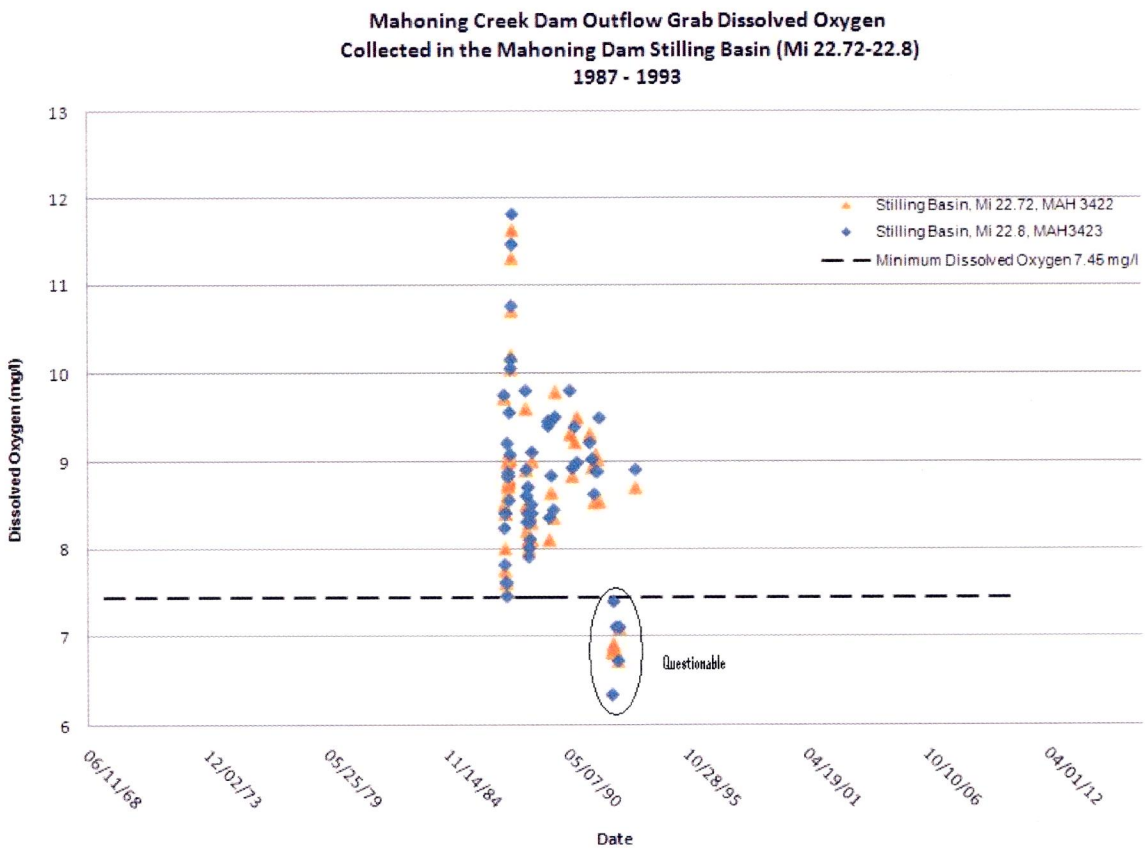

Mahoning Lake Outflow
Grab %Dissolved Oxygen Saturation
July 2011 - July 2012
% Dissolved Oxygen Saturation
115
110
105
100
95
90
DO% McCrea
DO% DS Weir
DO% Weir Wall
DO% Basin Steps
DO% Mid Basin
6-Jun-11
26-Jul-11
14-Sep-11
3-Nov-11
23-Dec-11
11-Feb-12
1-Apr-12
21-May-12
10-Jul-12
29-Aug-12
Date

Chart 14.


Mahoning Creek Dam Outflow Grab Dissolved Oxygen
Collected in the Mahoning Dam Stilling Basin (Mi 22.72-22.8)
1987 - 1993
Dissolved Oxygen (mg/l)
13
12
11
10
9
8
7
6
Stilling Basin, Mi 22.72, MAH 3422
Stilling Basin, Mi 22.8, MAH3423
Minimum Dissolved Oxygen 7.46 mg/l
Questionable
06/11/68
12/03/73
05/25/79
11/14/84
05/07/90
10/28/95
04/19/01
10/10/06
04/01/12
Date

As demonstrated in charts 11 & 12, during the District's 2001-2011 real-time monitoring period, DO levels at the McCrea Furnace Bridge, which is located about 1 mile downstream of the dam, were generally higher than 7.2 mg/l, dropping below 7.0 mg/l only on one day, July 11, 2009, for 4 hours.

Chart 13 shows that the lowest grab DO for the District's period of record in the dam outflow (the reach of Mahoning Creek between the toe of the dam and the McCrea Furnace Bridge mi 22 – 22.8), was 7.2 mg/l. Charts 13.a and 13.b show the grab DO and % DO saturation data, respectively, collected in the stilling basin, below the stilling basin weir, and at the McCrea Furnace Bridge during 2011 and 2012. The minimum DO documented in the stilling basin during this period was 7.92 mg/l on 31 July, and below the weir it was 8.02 mg/l on the same day. The minimum % DO Saturation documented during this period in the stilling basin was 93.7% and downstream of the weir it was 94.3%

Chart 14 shows that, excluding the questionable 1992 data, the lowest DO recorded in the stilling basin during the period of record was 7.45 mg/l.

The effects of low dissolved oxygen concentrations on fish have been well documented in scientific literature (i.e. Doudoroff & Shumway (1970)[1] and Davis (1975)[2]). "Usually, dissolved oxygen levels in excess of 7.0 mg/l are desired to maintain aquatic ecosystem health.... For maintenance of aquatic health, dissolved oxygen concentrations should approach saturation, that concentration which is in equilibrium with the partial pressure of atmospheric oxygen."[8] According to Davis (1975), dissolved oxygen % saturation needed for "Level A" protection or ideal conditions for mixed freshwater fisheries with salmonids is 87%, or about 7.1 mg/l DO at 80 °F and 1 atmosphere pressure. As noted above, Mahoning Dam tailwaters are currently >93% saturated with dissolved oxygen, which translates to a dissolved oxygen level of 8.1 mg/l at 80 degrees Fahrenheit and 1 atmosphere pressure. With the proposed 7.0 mg/l dissolved oxygen criterion, at 80 °F and 1 atmosphere pressure, % dissolved oxygen saturation will be reduced to 86.4%.

The District Requires:

> The hydropower operator (assumed to be the Mahoning Creek Hydroelectric Company, MCHC) will monitor the outflow, using data collected at their real-time, continuously recording dissolved oxygen monitors located in the stilling basin and the hydropower discharge, maintaining a minimum dissolved oxygen level of 7.0 mg/l. The District's water quality monitor located on Mahoning Creek at the McCrea Furnace Bridge will be utilized to evaluate the effectiveness of, and possibly modify, the DO criterion for MCHC's WQ monitors. A summary of requirements for Mahoning Creek Lake outflow and stilling basin, compared to PA specific dissolved oxygen criterion and MCHP's adaptive management proposal[10], is presented in Tables 2 and 3.
>
> Action Plan:

When the hydroelectric plant is operating, if dissolved oxygen levels drop below 7.0 mg/l at either of MCHC's the real-time, continuously recording water quality monitors located in the Dam outflow, then the hydropower plant will immediately increase aeration of their discharge without causing nitrogen supersaturation and/or the District will immediately increase bypass flow until dissolved oxygen levels are in compliance. Effectiveness of reaeration and/or bypassing flow will be apparent immediately, and will continue until criteria are met. Immediate response time will be required during working hours.

After working hours, a logistically reasonable response time will be determined by USACE project personnel, optimally, not to exceed 2 -hours. Verification of the accuracy of the real-time monitor will be at the discretion of the hydropower plant operator, and will have no impact response time. If the DO drops below 7.0 mg/l more than 1% of the time during the summer/fall season at the District's water quality monitor located at the McCrea Furnace Bridge than the DO criterion for MCHC's WQ monitors will be lowered. 7.45 mg/l is the lowest DO ever recorded in the stilling basin and 7.2 mg/l is the lowest DO ever recorded at the dam outflow over the entire period.

5.b. Mahoning Creek Lake Dissolved Oxygen

The District conducted about 30 Mahoning Creek Lake limnological surveys during the period of summer thermal and chemical stratification. These surveys consist of intensive vertical sampling of reservoir stations for approximately 80 different parameters including dissolved oxygen, nutrients, metals, chlorophyll, and phytoplankton composition and concentration. In addition, from May through October 2010, the District continuously monitored dissolved oxygen in the lake at a depth of 24 feet .

Grab dissolved oxygen vertical profile data for Mahoning Lake, collected at the deepest location just upstream of the dam for the District's period of record are presented in Chart 15, and the same data sorted by depth are presented in Chart 16.

As can be seen in Charts 15 & 16, lake dissolved oxygen levels are generally > 5 mg/l at depths < 24 feet although there is a general trend towards decreasing DO levels in the lake at depths between 30 and 50 ft over the period of record. The average lake surface DO (0 to 5 ft) is 8.9 mg/l, the average mid-depth DO (10 to 25 ft) is 7.0 mg/l, and the average lake bottom DO (30 to 100 ft) is 5.7 mg/l.

Chart 17 shows the District's real-time, continuous dissolved oxygen data collected in the lake near the dam, at a depth of 24 feet during 2010. DO levels dropped as low as 1.5 mg/l during the period before the monitor failed, so it is likely that the minimum DO was closer to 3.5 mg/l..