MALCOLM PIRNIE

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January 16, 2008

John Owen, P.E.
Environmental Specialist
Ohio EPA CDO Division of Surface Water
50 West Town Street, Suite 700
Columbus, Ohio 43216-1049

Re: City of Lancaster
Upper Hocking Water Pollution Control Facility
Revised Upper Hocking River Water Quality Monitoring and QUAL2K Modeling Report

Dear Mr. Owen:

Enclosed are two revised copies of the above referenced report. Per you email dated 12/4/07, and the attached Ohio EPA Interoffice Communication dated 12/4/07 from Eric Pineiro, we have addressed the following:

- Enclosed is a CD containing input files for the three calibration runs and for the summer and winter 7Q10 scenarios.
- Revised the model using the reaeration coefficients per the attached Ohio EPA Interoffice Communication dated 12/4/07.
- The requested temperature and weather data is included within the model runs on the enclosed CD.

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If you have any questions regarding the enclosed information, please let us know. We would like to proceed with the NPDES Permit process as soon as possible, as our current schedule for submittal of the PTI is mid April 2008.

Very truly yours,

MALCOLM PIRNIE, INC.

Thomas J. Bulcher

Thomas J. Bulcher, P.E.
Project Manager

OEPA LOT 01 16 08

Enclosures

c: Denise Crews, City of Lancaster
Mike Nixon, City of Lancaster

0491049

OhioEPA
State of Ohio Environmental Protection Agency

INTEROFFICE COMMUNICATION

DATE December 4, 2007

TO John Owen, DSW-CDO

FROM Eric Pineiro, DSW-CO

RE: Review of Upper Hocking Water Quality Monitoring and Qual2K Modeling Report

The Upper Hocking Water Quality Monitoring /Qual2K Modeling Report has been reviewed, and the comments are summarized below.

1. The consultants (Malcolm Pirnie) used the Qual2K D.O. model to assess the impact of the Upper Hocking Water Pollution Control facility discharge to the Hocking River. The consultants should provide Ohio EPA with an electronic copy of the input data files used for the calibration and at least one of the 7Q10 scenarios.

2. According to the consultant, the reaeration coefficients for Qual2K were determined using the Owens-Gibbs reaeration equation (see page 12 in the report). Ohio EPA has a set of reaeration equations recommended for use in Ohio, based on stream slope, streamflow, velocity and depth. The simulations must be performed using the recommended equations. The attached guidance provides the necessary details. A spreadsheet to do the calculations is available upon request.

3. The report (page 13) indicates that, before running the 7Q10 models, the temperature and weather data were modified to reflect typical cloud cover, wind speed, air and dew temperatures for summer and winter. The report doesn't include the values that were used, therefore Ohio EPA cannot evaluate if these modifications are reasonable. Please provide copy of the input data sets that show the modified weather data.

If you have any questions, please call me at 644-2886.

cc: Maan Osman, DSW
Mike Gallaway, DSW-CDO
Erin Sherer, DSW-CDO

Table 6-1 . Stream Categories and Preferred K_2 Predictive Equations.

Class 1: Slope less than or equal to 3 ft/mi.

Negulescu - Rojanski (1969) $K_2 = 10.92 \ (V/H)^{.85}$

Krenkel - Orlob (1963) $K_2 = 234. \ (VS)^{.408} \ H^{-.66}$

Class 2: Slope between 3 and 10 ft/mi;
flow less than or equal to 30 cfs.

Parkhurst - Pomeroy (1972) $K_2 = 48.39 \ (1 + .17 \ F^2) \ (VS)^{.375} \ H^{-1}$

Class 3: Slope between 3 and 10 ft/mi;
flow greater than 30 cfs.

Thackston - Krenkel (1969) $K_2 = 24.94 \ (1 + F^{.5}) \ U^* \ H^{-1}$

Class 4: Slope greater than 10 ft/mi.

Tsivoglou - Neal (1976) $K_2 = C \ V \ S$

if $1 < Q \leq 10$ cfs, $C = 9500$
if $10 < Q \leq 25$ cfs, $C = 6860$
if $Q > 25$, $C = 4650$

Definition of Variables

K_2 = reaeration coefficient - base e @ 20°C (day^{-1});
V = average velocity (ft/s);
H = average hydraulic depth (ft);
S = slope of the energy gradient (ft/ft);
F = Froude number = $V \ (32.2 \ H)^{-.5}$;
U^* = average shear velocity (ft/s) = $(32.2 \ H \ S)^{.5}$; and,
C = Tsivoglou escape coefficient (ft s/day).

UPPER HOCKING RIVER WATER QUALITY MONITORING AND QUAL2K MODELING REPORT

STREAM SAMPLING AND MODELING FOR THE UPPER HOCKING RIVER
LANCASTER, OHIO

July 2007
Revised January 2008
Project No. 0491-049

MALCOLM PIRNIE, INC.
1900 Polaris Parkway, Suite 200
Columbus, Ohio 43240

CITY OF LANCASTER, OHIO
UPPER HOCKING RIVER
WATER QUALITY MONITORING AND QUAL2K MODELING

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1.0 SUMMARY

A QUAL2K model of the Upper Hocking River was developed to estimate the effects of a discharge from the proposed Upper Hocking Water Pollution Control Facility (WPCF) on the stream water quality. The model was calibrated utilizing water quality and physical data collected on the Hocking River and its tributaries during the summer of 2005. The field effort included continuously monitoring sondes, grab sample data, flow measurements, time of travel studies, and stream surveys. The calibrated parameters in the model included temperature, CBOD, DO, nitrogen, phosphorus, suspended algae and benthic algae.

The model was developed using data collected between August 16th and September 16th 2005. In particular, three dry weather days during this period were sampled for calibration purposes. The continuous data for these particular dates were also used for calibration. The flow measurements and time of travel information were used globally, for both the calibration models and the validation model. The model was calibrated by adjusting the temperature, CBOD, DO, SOD, nutrient and algae routines in the model.

The calibrated model was then lowered to 7Q10 flow and run with several flow rates from the proposed Upper Hocking WPCF in summer and winter conditions. The flow rates used in the model were 2, 3, 4, 6, and 8 MGD. With the BADCT limits used for the facility effluent (see below), the model predicted DO levels that were above the modified warm water habitat criteria of 4 mg/L for all of the proposed flow rates. The model also supports a higher winter permit limit for ammonia.

- Flow = 2, 3, 4, 6, and 8 MGD
- Temperature = 24°C (summer) 14°C (winter) (75°F, 57°F respectively)
- $CBOD_{fast}$ = 10 mg/L ($CBOD_5$ = 10 mg/L)
- Dissolved Oxygen = 6 mg/L
- Organic Nitrogen = 1.0 mg/L
- Ammonia = 1.0 mg/L (summer), 3.0 mg/L (winter)
- Nitrate + Nitrite = 10.5 mg/L
- Total Phosphorus = 1.0 mg/L

2.0 STREAM SAMPLING AND MONITORING PROGRAM

Data were collected from August 16th through September 16th of 2005 in order to develop and calibrate a QUAL2K model for the Upper Hocking River.

2.1 SAMPLE LOCATIONS

Eight continuous monitoring locations were selected on the Hocking River. Figure A.1 in APPENDIX A shows these site locations. The upper part of the study area drains mostly agricultural areas as seen by the large fields surrounding the tributaries. After Site 5 the stream becomes more urban with combined sewer overflows (CSOs) and tributaries that drain less agricultural areas. However, the entire stream is very channelized in both the agricultural and urban areas.

2.2 CONTINUOUSLY MONITORED DATA

YSI model 6920 sondes were installed at Sites 1 through 8 on the Hocking River. The sondes continuously measured and logged the dissolved oxygen (DO) concentration, temperature, pH and specific conductivity in the stream. The in-stream sensors recorded each parameter on 15 minute intervals during the water quality study. Graphs of the continuous data collected using the sondes are located in APPENDIX B. Each time a sonde site was visited, instantaneous discrete measurements were taken for DO, temperature, pH, and specific conductivity, with hand-held meters. These discrete data points are plotted next to the continuous data in APPENDIX B.

The continuous DO data collected by the sondes at the sites agreed with the discrete readings collected in the field. At many sites, large diurnal variations in the concentration of DO were noticed, likely due to the presence of algae. In particular, the sonde at Site 4 recorded elevated DO concentrations as well as extreme diurnal variations in DO compared to other sites. Site 4 was located just downstream of the confluence of Lateral C with the Hocking River. This tributary contained large amounts of suspended algae, based on visual inspection.

Continuous temperature readings from the sondes closely matched the discrete readings taken in the field. The average daily temperature in the Hocking River generally decreased over the study period. The figures in APPENDIX B show the continuous temperature data from each site.

The pH in the streams generally remained between 7.6 and 8.8, which is within the expected range. The greatest difference in pH values occurred at Site 4. This is most likely due to algae interactions, as algal respiration affects pH. Continuous pH data for each site is shown in APPENDIX B.

The continuous specific conductivity reported by the sondes at each site closely matched the discrete readings collected using hand held meters, and are within the expected range. The specific conductivity data for each site is shown in APPENDIX B.

2.3 GRAB SAMPLE DATA

Grab samples were collected at Sites 1, 3, 4, 6, and 8, as well as the Hunters Run and Tarhe Run tributaries. In addition, samples were taken at the current WPCF sampling locations including upstream at Broad Street, the WPCF effluent, and downstream at Sugar Grove Road. All of the sampling locations are indicated on Figure A.1 in APPENDIX A. All of the samples were taken during dry weather conditions. The grab sample data can be found in APPENDIX C. The samples were analyzed for the following parameters:

- $CBOD_5$
- $CBOD_{20}$
- TKN
- NH_3-N
- NO_3-N
- NO_2-N
- Total Phosphorus
- Total Organic Phosphorus
- Total Dissolved Organic Phosphorus
- Dissolved Phosphorus
- TDS
- TSS
- Alkalinity
- Fecal Coliform

Carbonaceous Biological Oxygen Demand (CBOD) was analyzed to determine if a high concentration or source of CBOD could be found in the stream system. High concentrations of CBOD will decrease the concentration of DO in the stream. The results of the 5-day CBOD analyses were generally less than the detection limit of 2 mg/L and the 20-day CBOD test results were all less than 4 mg/L for stream samples. The CBOD is not significantly different between the agricultural and urban areas of the stream. Natural decay of organic matter such as plants, leaves and algae are the most likely sources of CBOD in agricultural areas. In the urban areas the City's CSOs are a likely source of some CBOD. The current WPCF also is a source of CBOD to the stream.

Nitrogen and phosphorus, both nutrients, were generally low given the observed conditions in and near the stream. Nutrient levels were expected to be higher because much of the land drained by the Hocking River is used to grow crops. The in-stream algae most likely have a portion of the available nutrients bound up in cellular matter. However, in-stream concentrations of most nutrients increased at Site 4, after the confluence with Lateral C. It was observed visually that Lateral C contained significant amounts of suspended algae, and the increased nutrient levels were not unexpected, since it drains a significant area of agricultural land.

2.4 FLOW MEASUREMENT DATA

Flow rates were measured at Sites 1, 3, 6, 7, and 8 and on all 7 tributaries using a Sontek acoustic flow measurement device. The Sontek device recorded the data from the acoustic meter and then calculated the discharge using standard USGS methodology. Each flow measurement on the Hocking River and each of the tributaries included readings at a minimum of 15 points, with 40 second averages at each point to ensure that the flow calculated at a single point did not exceeded 10-percent of the total flow. Flow measurements were taken at each of the locations on at least three different occasions. Tabular results of the flow measurements can be seen in APPENDIX D. APPENDIX D also shows the average flow for each flow measurement location, an average of the bold discrete values. These averages were used in the calibration of the model because the flow rates were generally stable throughout the period of study.

2.5 ALGAE SAMPLING

QUAL2K simulates suspended algae and benthic algae. For this reason, sampling for both algal communities was completed September 14th, 2005 at Sites 2, 4, 6, and 7. The water column sample was taken in a similar manner as the grab samples. Stream water was simply placed in the sample bottle, and filtering of the sample was completed by the laboratory. The benthic sampling was completed using Ohio Environmental Protection Agency (OEPA) developed methods. At each of the four sampling sites 25 rocks from the bottom of the channel were collected. These rocks were then scraped to collect algae growing on the rock in a specific area measured on the surface of the rock. The scraped algae was collected in a basin, transferred into a sample bottle, and later filtered by the laboratory for analysis.

As expected the suspended algae concentration at Site 4 was much higher than at other sites. Site 4 is downstream of the confluence with Lateral C which contained large amounts of suspended algae based on visual inspection. However, at this site and at Site 2 the benthic community was not as strong. This is most likely due to the fact that these stretches are somewhat slow moving and as a result, have more silt and fewer exposed rocks in the substrate. The other locations (especially Site 6 and Site 7) contained an adequate riffle section and a number of appropriate sized rocks for the benthic analysis due to the presence of a bridge. The suspended and benthic algae sampling results can be found in APPENDIX E.

The benthic algae concentrations were reviewed by the OEPA. The sampling results were found to be "anomalously low." It was learned that the benthic algae concentrations observed in Ohio streams are rarely less than 40 milligrams of algae per square meter. It is unknown whether laboratory or sampling error caused this discrepancy in the benthic algae data.

2.6 STREAM SURVEYING DATA

At each of the eight Hocking River sites stream surveys were conducted using a level, rod, and a fiberglass tape measure. Using the level and the rod, a channel profile was determined for each site by measuring relative vertical heights upstream and downstream of the site. The tape was placed through the thalweg of the channel so that the distances associated with the relative vertical elevations could be measured. Cross sections were measured at locations along the river that appeared to be typical or average for the area, and at each sonde location. This survey data was used to develop the hydraulic coefficients for QUAL2K. APPENDIX F summarizes the surveying data.

2.7 WEATHER DATA

Climatological data from the Fairfield County Airport was downloaded from the National Climactic Data Center (NCDC). Hourly observations of air temperature, dew point temperature, cloud cover and wind speed data were included in the dataset. The weather parameters were used as a direct input into the QUAL2K model. For each dry weather sampling event, the hourly weather values for that day were added to the model. APPENDIX G summarizes the weather data.

2.8 TIME OF TRAVEL STUDY

In order to perform the time of travel study in an accurate and timely manner, the river was divided into multiple segments. To determine the time of travel between the sampling sites, rhodamine WT fluorescent dye was injected and monitored using four sondes with optical rhodamine sensors. Dye was injected into the stream at Sites 1, 2, 4, and 6. The sondes were located at Sites 2, 4, 6 and 8 to capture the dye plume as it traveled downstream. Refer to Figure A.1 in APPENDIX A for the site locations. The sensors were used to determine the time at which the peak dye concentration reached the monitoring point.

APPENDIX H has plots of the time of travel study dye concentrations versus time after injection. It can be seen that the concentration curves are very smooth and the curves are not that wide. This indicates that the channel is very uniform, and there is little dispersion in the channel. A table summarizing the average velocity for each time of travel study is presented in APPENDIX H. The summary results were used to develop the hydraulic coefficients of the QUAL2K model and for hydraulic calibration.

3.0 QUAL2K WATER QUALITY MODELING

QUAL2K was used to predict the impacts of the proposed Upper Hocking WPCF effluent discharge on the Upper Hocking River. The process involved four primary steps: 1) Analysis of the field data; 2) Determination of the hydraulic coefficients for QUAL2K; 3) Calibration of QUAL2K; and 4) Alternative analysis of the Upper Hocking WPCF in QUAL2K.

3.1 ANALYSIS OF FIELD DATA

Much of the data analysis is addressed in SECTION 2.0. It should be noted that the data gathered on the grab sample collection dates were used to develop the QUAL2K model boundary conditions and calibration points. In general, the weather data, grab sample data and the continuous sonde data for each of the grab sample collection events were used to calibrate the model.

The initial step in the data analysis was the formation of the QUAL2K model structure. QUAL2K breaks a stream down into reaches and elements. Reaches were made up with 1 to 20 elements. An element is the smallest computational portion of the model. Unlike QUAL2E, QUAL2K allows elements of various sizes. Reaches are selected based on stream characteristics. Reaches should have fairly constant hydraulic characteristics, such as slope and bottom width. All elements in a single reach are divided into equal spaces within the specific reach. Digital orthophotography was used along with survey data and field observations to break the stream into 10 separate reaches. These segments were based on both field observed and measured channel hydraulic features, as well as the percent of channel shading from surrounding vegetation. Since the river is channelized and the hydraulics are fairly constant, shading and vegetation cover were the driving factors in creating the reaches for the model. Selection criteria included tree cover, slope, and observations of stream flow regimes; i.e. width, depth, and observed velocities. The reaches are shown in Figure I.1 in APPENDIX I.

Data analysis and field observations were also used to identify which components of the QUAL2K model would be necessary. The continuous DO data and pH data showed diurnal swings which are indicative of algae growth and respiration. Field observations over the study period also suggested attached algae growth was occurring on the channel bottom during extended periods of dry weather. The algae were washed away during a mid-study heavy rain event, and gradually grew back in the following days. Given the conditions observed and the data analysis, the following components were considered necessary in QUAL2K: temperature routine, CBOD routine, DO routine, nitrogen routine, phosphorus routine, and algae routine.

3.2 HYDRAULIC COEFFICIENTS

QUAL2K is not a hydraulic model. Instead, QUAL2K requires the user to input hydraulic coefficients that estimate the average velocity and depth for a given flow rate. Hydraulic coefficients for the Upper Hocking River QUAL2K model were determined using the data generated from the flow measurements. The functions governing the development of the hydraulics and their relationship are shown below.

$$v = a*Q^b \quad \text{(eq. 1)}$$

$$d = \alpha*Q^\beta \quad \text{(eq. 2)}$$

$$Q = v*A \quad \text{(eq. 3)}$$

$$w = A/d \quad \text{(eq. 4)}$$

Where:

- v = velocity (m/s)
- Q = flow (cms)
- d = depth (m)
- A = area (m^2)
- w = width (m)
- a & b = velocity hydraulic coefficients
- α & β = depth hydraulic coefficients
- $b + \beta = 1$ for rectangular channels

As was described in SECTION 2.0, and mentioned in SECTION 3.1, the Upper Hocking River is channelized, in both the agricultural and urban areas of the stream. In general, the stream is lined with very high, steep banks, and though there are bends (mostly due to property lines and channelization through town) the overall channelized rectangular shape dominates the channel. For this reason the hydraulic coefficients for b and β were set to 0.4 and 0.6, respectively. These generalizations are supported by the measured cross sections presented in APPENDIX F, as well as field observations and the time of travel study (APPENDIX H).

Next, the coefficient values (a and α) were determined. First, the flow rate versus the stage height from the various flow measurements was plotted. Then flow versus velocity from the time of travel data was added. Since the channel exponents (b and β) were set because of the rectangular channel shape, curves were added to the charts. The curves were developed from eq.1 and eq.2 above, and allowed coefficient values to be adjusted so that a best fit could be determined. The coefficient values (a and α) were then finalized based on modeler judgment so that there was a good fit the field data. Plots of the resulting coefficients are included in APPENDIX J.

These coefficients (a, b, α, and β) were then added to the model so that the predicted hydraulics could be tested against the measured hydraulic data. With the selected coefficients the model predicted the time of travel very closely. In addition, the flow and depths matched very closely. The velocities predicted by the model were not as close to the measured values. Since the time of travel was the most important parameter to satisfy, however, velocity coefficients were not modified. Model calibration results for the hydraulics are presented in APPENDIX L.

3.3 CALIBRATON OF THE HOCKING RIVER QUAL2K MODEL

The necessary routines for the QUAL2K model were identified during data analysis. The first parameter to be calibrated was temperature, followed by CBOD, and finally by the combination of DO, nitrogen, phosphorus and algae.

Temperature was calibrated first since it affects every other process in the model. Temperature is used to adjust the kinetic rates from a base of 20 degrees Celsius to complement the in-stream temperature predicted by the model. Temperature is also the primary factor used to calculate the saturation level of DO in water. The temperature calibration was accomplished making small adjustments to the model. First, the shortwave and longwave radiation models used in QUAL2K were selected. The shortwave radiation model atmospheric transmission coefficient was adjusted (within the accepted range) to bring the model prediction closer to observed values in the calibration events. Finally, the stream percent shade readings were adjusted (within the range observed in the field) to achieve temperature calibration.

Additional influences on the temperature model include point sources (tributary streams) and groundwater flow. Tributary flows, based on actual field measurements, were incorporated into the model. Temperatures for the point sources were based on field observations and any data collected on the tributary. For example, Tarhe Run was observed to be consistently colder than the other streams, and was believed to be mainly groundwater fed. Also, most of the tributaries were slow and would heat-up during the day due to limited shading. Groundwater flows were added to the model to match the actual main stream flow measurements. The groundwater was assigned a temperature of 16°C (approximately 61°F). After the calibration process, the model slightly under-predicted temperature for the 8/22 event, and slightly over-predicted the 9/6 calibration event. The model slightly over-predicted the temperature for the 9/12 validation event. Overall the fit was very good across the calibration events and the validation event.

It should be noted that no continuously monitoring sondes were installed in any of the tributaries, and only a few discrete measurements and grab samples were taken from the tributaries. This lack of data on the tributaries made it difficult to calibrate when keeping the water quality similar amongst the tributaries. However, it became clear that the tributaries in the agricultural areas and the urban areas had different qualities. For this reason the tributaries were assigned reasonable concentrations according to surrounding land use, field observations and Hocking River observations.

CBOD was the second parameter to be calibrated, since temperature impacts CBOD and CBOD impacts DO. In the QUAL2K model there are two types of CBOD that can be simulated, fast and slow. Fast reacting CBOD is a result of human or animal waste. Slow reacting CBOD is from tertiary waste water treatment facilities and forests. The grab samples identified low concentrations of $CBOD_5$ and $CBOD_{20}$ in the stream. In the river there were no detectable levels of $CBOD_5$ (APPENDIX C). Detailed information was recorded during the $CBOD_{20}$ analysis for all three dry weather events.

Graphs were created from this data and exponential curves were fitted to the points to determine the laboratory decay rates. The graphs of the decay rates are located in APPENDIX K. The $CBOD_{20}$ decay rates show that there is little CBOD in the system, and that there is a slow decay rate in the stream. The data did not leave much of an option for the model calibration. Therefore, the calibration involved lowering the default rates enough to better fit the grab data without going beyond published values.

The next calibration step involved simulation of DO, nitrogen, phosphorus, suspended algae and benthic algae. In order to determine the correct hydraulic-based reaeration equation to use for each reach of the model, a spreadsheet provided by the OEPA was used. The spreadsheet utilized the river hydraulics and temperature for each reach to determine the temperature corrected reaeration rate to add to the model. Because the reaeration equation selection in the spreadsheet was based on channel slope there were a variety of equations used in the model. Below is a table listing the channel reach and the reaeration equation used in the model.

Reach Name	**Hydraulic Reaeration Used**
Reach 1 – Collins	Tsivoglou-Neal
Reach 2 – Kark	Tsivoglou-Neal
Reach 3 – Ety	Parkhurst-Pomeroy
Reach 4 – Band Camp	Parkhurst-Pomeroy
Reach 5 – Wetland	Parkhurst-Pomeroy
Reach 6 – Mall/Residential	Negulescu-Rojanski
Reach 7 – Fair	Parkhurst-Pomeroy
Reach 8 – Park	Parkhurst-Pomeroy
Reach 9 – Tarhe	Parkhurst-Pomeroy
Reach 10 – WPCF	Parkhurst-Pomeroy

The nutrients and algae were also added at the same time as the DO. Concentrations of phosphorus and nitrogen were low; therefore calibration to these parameters involved lowering some of the rates associated with the various nutrient species. In addition, the suspended algae growth rate was maximized to capture the high concentrations observed in the agricultural areas, especially near Lateral C. The benthic algae growth rate was decreased in order to better estimate the typical concentrations found in Ohio streams. These modifications to the model resulted in a good match to the nutrient and algae data, and a close calibration to the DO in the agricultural area. All of the adjustments made to the model rates were within published values.

The final step in the calibration dealt with the over-prediction of DO near the end of the model, in the urban portion of the stream. A small sediment oxygen demand (SOD) was added to the urban reaches 7 through 10 to bring the DO prediction close to observed levels. The presence SOD is likely in reaches 7, 8, 9, and 10 since these reaches are the only ones in the Upper Hocking River model that receive CSOs. All of the model results for the calibration and validation events are presented in APPENDIX L.

3.4 7Q10 SIMULATIONS

The critical conditions models were run using the 7-day average, 10 year recurrence interval (7Q10) flow for the stream. The 7Q10 flow is determined by the USGS at a gauging station where flow data is continuously monitored for a number of years. The gauging station nearest to the modeled portion of the Upper Hocking River is at Enterprise, Ohio. At this station the average flow measured during the 2005 sampling events was approximately 2 cms (70.7 cfs). The 7Q10 for the Enterprise site on the Hocking River is 0.91 cms (32 cfs). The 7Q10 value is 45.5% of the average 2005 dry weather event flow. Because none of the streams showed evidence of being ephemeral, each of the flow inputs into the model was decreased by 54.5% to determine the 7Q10 flow for the model. These calculated values are very similar to those published by the USGS for Hunters Run and for the Hocking River near Columbus Street. The calculated values were used to build the 7Q10 models because the USGS published values for the Lancaster area are based on data collected over 25 years ago while the Enterprise data is current.

Under the 7Q10 conditions the model predicted the stream response to various flows from the proposed Upper Hocking WPCF. The 7Q10 simulations consist of 10 separate scenarios. The first 5 scenarios are for summer conditions, while the second 5 investigate the river response during winter. For each season the modeled flow rates are 2, 3, 4, 6, and 8 MGD from the Upper Hocking WPCF. The flow inputs included in all the 7Q10 models were the headwater, the point source from the Upper Hocking WPCF, point sources from the seven tributary streams, and minor incremental inflow (groundwater).

Before running the 7Q10 models, temperature and weather data were updated based on the season. The changes to the temperature and weather were determined using past models completed by Malcolm Pirnie, Inc. and the OEPA. Specifically, models on Mill Creek near Marysville were reviewed to determine typical cloud cover, wind speed, air and dew point temperatures as well as Julian date for the 7Q10 models.

The proposed Upper Hocking WPCF load was placed in the model at river kilometer 152.15 (river mile 94.54) which is just upstream of Collins Road and the first continuous monitoring location (Site 1). The following treated effluent concentrations were input into the model for the summer simulations. These effluent concentrations correspond to the Best Available Demonstrated Control Technology (BADCT) limits:

- Temperature = 24°C (75°F)
- $CBOD_{fast}$ = 10 mg/l ($CBOD_5$ = 10 mg/l)
- Dissolved Oxygen = 6.0 mg/l
- Organic Nitrogen = 1 mg/l
- Ammonia = 1.0 mg/l
- Nitrate + Nitrite = 10.5 mg/l
- Total Phosphorus = 1.0 mg/l
  - Inorganic Phosphorus = 0.9 mg/L
  - Organic Phosphorus = 0.1 mg/L

APPENDIX M shows the results from the BADCT simulations for summer-time 7Q10 low flow model. The stream maintains DO levels above the 4 mg/l, 24 hour average.

Finally, the 7Q10 winter runs were simulated with varying flows from the proposed Upper Hocking WPCF. Using an instream temperature of 10.5°C (51° F), the following treated effluent parameter concentrations were used for the model runs:

- Temperature = 14°C (57 °F)
- $CBOD_{fast}$ = 10 mg/l ($CBOD_5$ = 10 mg/l)
- Dissolved Oxygen = 6.0 mg/l
- Organic Nitrogen = 1 mg/l

- Ammonia = 3.0 mg/l
- Nitrate + Nitrite = 10.5 mg/l
- Total Phosphorus = 1.0 mg/l
    - Inorganic Phosphorus = 0.9 mg/L
    - Organic Phosphorus = 0.1 mg/L

All runs maintained the modified warm-water habitat criteria of 4 mg/l of DO, 24-hour average. The results from the winter scenarios are shown in APPENDIX N.

Following these results, a benthic algae sensitivity analysis was completed to determine if the 7Q10 DO concentrations could be maintained with low concentrations of benthic algae. The sensitivity analysis found that the benthic algae growth rate could be decreased by over 70% in the summer, and decreased over 50% in the winter without depressing the DO concentration below 4 mg/l. These rates produce benthic algae concentrations at or below 40 milligrams of algae per square meter, which is considered low for Ohio streams.