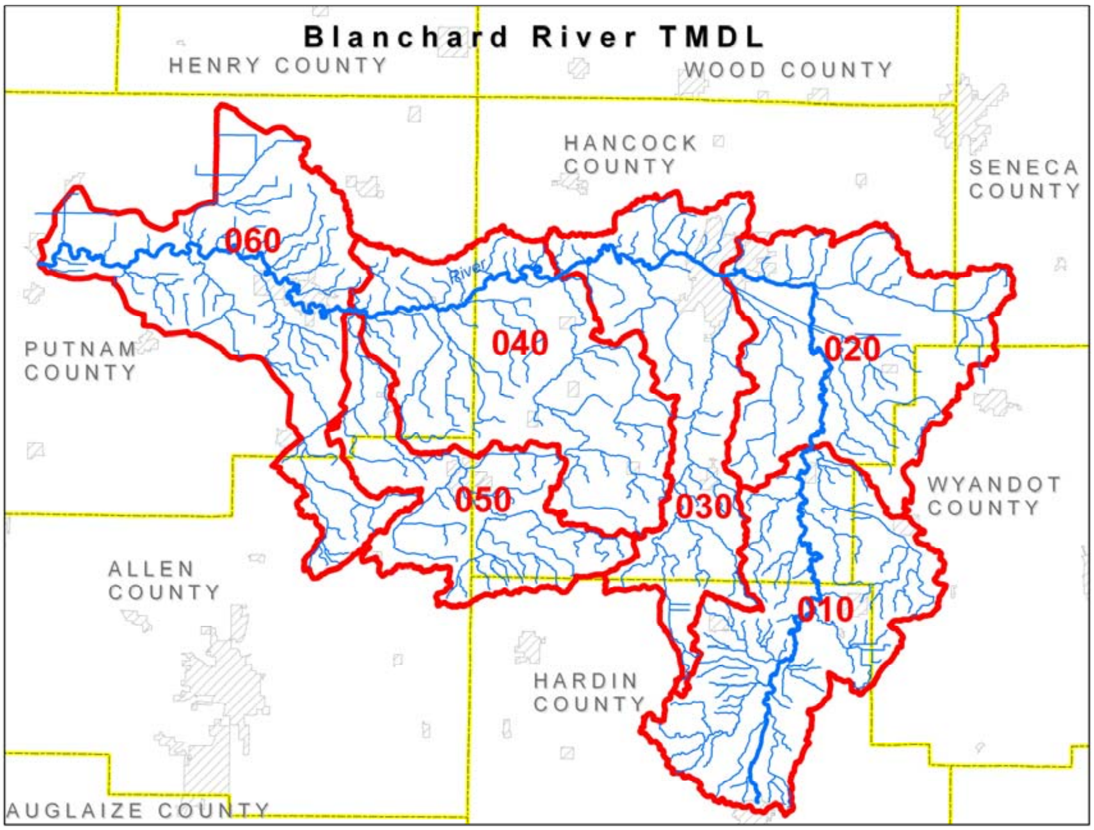
Appendix C: TMDL Modeling Information

The nutrient, dissolved oxygen, habitat and sediment, and pathogen (bacteria) modeling work was performed by multiple staff in the Ohio EPA Division of Surface Water Modeling Section**.** This Information has also been presented in an abbreviated format in Chapter 6 of the main report. Each of the following reports follows a general outline that includes.

- Selection of the water quality target values
- Method of quantifying existing loads
- Application of margins of safety to account for uncertainty
- Quantifying the needed reduction pollutant reduction

Methods of TMDL Development



Blanchard River basin with HUC 11 sub-basins.	**HUC 8 = 04100008**
HUC 010	Blanchard River Headwaters
HUC 020	Includes the Outlet (lower)
HUC 030	Includes Eagle Creek
HUC 040	Includes Ottawa Creek
HUC 050	Riley Creek
HUC 060	Lower Blanchard River, includes Cranberry Creek and various other smaller tributaries

Summary descriptions of the areas represented by sentinel sites:

The Headwaters: The headwater basin is the upper most portion of the Blanchard River and consists of 5 HUC14s above S.R. 37 and Potato Run. The HUC14s are 04100008010-010, 020, 030, 040, and 050.

HUC 04100008020: The next HUC 11 downstream of the headwater HUC. It contains the lower Outlet tributary, a tributary of which there is a local interest to improve.

The Outlet (lower): The Outlet is a tributary to the Blanchard River which drains mostly agriculture fields then enters the Blanchard River above Findlay and upstream of the Findlay drinking water intake right where the Blanchard River makes a ninety degree turn to the west. The HUC14s are 04100008020-020 and 030.

Eagle Creek: Eagle Creek is a Blanchard River tributary which begins in rural landscape and enters the Blanchard River inside of the town of Findlay. The HUC14s are 04100008030-020 and 030.

Ottawa Creek: Ottawa Creek is a Blanchard River tributary which flows through rural agricultural areas then enters the Blanchard River downstream of Findlay. The HUC14s are 04100008040-010 and 020.

Riley Creek: Riley Creek is a Blanchard River tributary which flows through the towns of Bluffton and Pandora and which enters the Blanchard River upstream of the town of Ottawa.

Cranberry Creek: Cranberry Creek is a Blanchard River tributary which flows through agriculture fields and enters the Blanchard River downstream of the town of Ottawa. Cranberry Creek was found to meet its WWH use designation (is not impaired), therefore, modeling results are not presented in this report.

Other smaller tributaries which received TMDLs but which did not directly use GWLF: These areas include; Bear Creek, Deer Creek, Caton Creek, Moffitt Ditch, Miller City Cutoff, Dukes Run, and Pike Creek. The TMDLs for these drainages were based on the GWLF outputs from the other modeled basins.

GWLF (Hydrology)

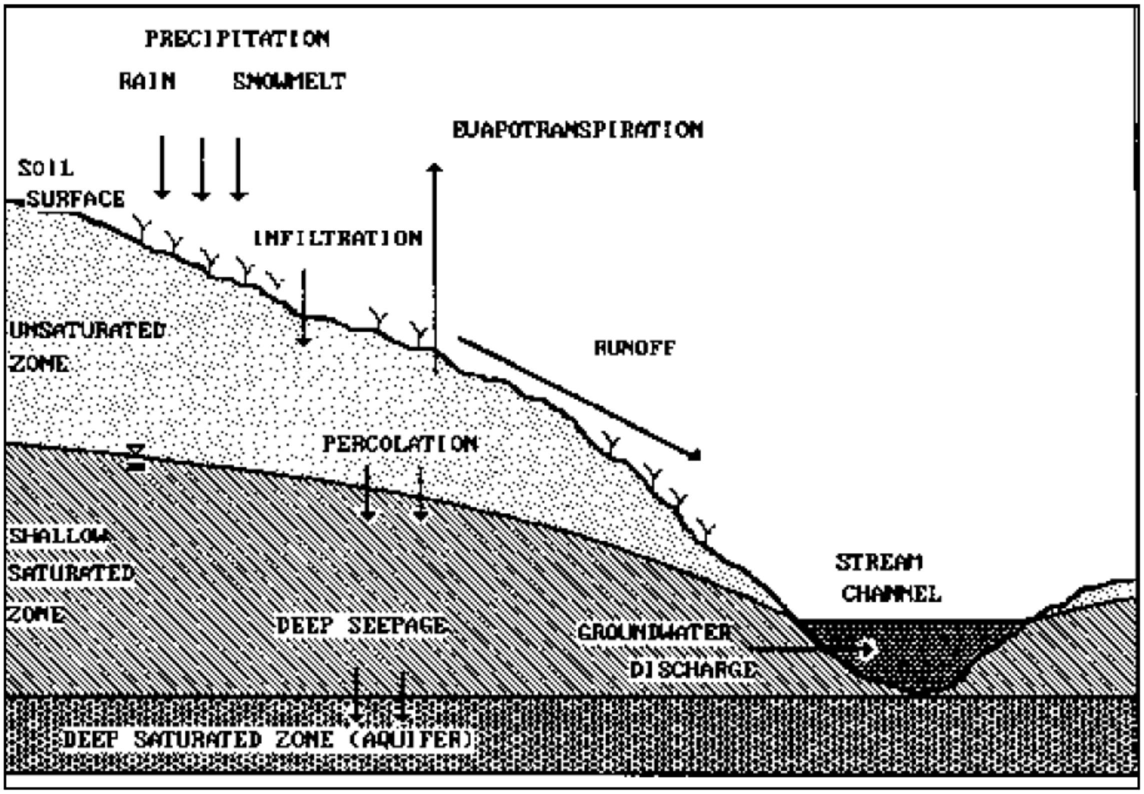
The hydrologic cycle for the subwatersheds receiving nutrient TMDLs is simulated using the GWLF model (Haith, 1992) through the desktop simulation called BasinSim 1.0 (Dai, 2000). The model predicts stream flow based on precipitation, evapotranspiration, land uses and soil characteristics. Figure 6.1 shows the hydrologic model of GWLF.

GWLF simulates runoff, groundwater recharge and stream flow by a water-balance method using measurements of daily precipitation and average temperature. Runoff is calculated using the Natural Resources Conservation Service's Runoff Curve

Number method (USDA, 1986). This method determines the amount of precipitation that runs off the surface and is adjusted for antecedent soil moisture before the precipitation event, growing or dormant season, detention potential and soil characteristics. Curve numbers vary by land cover, use and soil type; the higher the curve number the more runoff produced. The predicted surface runoff flow is the quick response flow including interflow and drainage from tiles.

Groundwater recharge is determined by tracking daily water balances in the unsaturated and shallow saturated zones. These zones act as reservoirs and have inputs and outputs. The input to the unsaturated zone is the infiltrated water calculated as the amount of the precipitation received less the surface runoff. Water leaves this zone to the atmosphere via plant root uptake through transpiration and down to the shallow saturated zone through percolation. Transpiration is grouped with evaporation to make an evapotranspiration function. GWLF determines a daily potential evapotranspiration based on day length, temperature and a cover coefficient of plant or crop in the area of interest. If there is enough available moisture in the unsaturated zone, the potential evapotranspiration will be lost to the atmosphere. If the available moisture in the unsaturated zone is less than that day's potential evapotranspiration, all water in that zone will go to the atmosphere. When the temperature is less than or equal to zero, there is no evapotranspiration. Percolation occurs daily when the unsaturated zone moisture volume exceeds the storage capacity after any evapotranspiration occurs. The shallow saturated zone receives the percolated water. This zone is treated as a linear reservoir; it can discharge water to the stream as baseflow or lose moisture to deep seepage. Each of these losses is determined by the product of the zone's moisture storage and a specific constant rate coefficient (one for baseflow and one for seepage).

Figure 6.1. GWLF Model hydrology component interaction.



Stream flow is computed as the sum of the groundwater discharge from the shallow saturated zone (baseflow) and the surface runoff. The model computes the daily water balance and resulting stream flow.

GWLF Input files, GWLF requires four input files; long term flow, weather, transport and nutrients.

<u>Long Term Flow Input File</u>
The basis of any sound nutrient modeling is a calibrated hydrologic model. To that end an effort was made to calibrate the model hydrology for each sub-basin to long term flow data based on the USGS gage in Findlay (gage number 04189000). Using the USGS tapedown program (Davis, 1982), an organic correlation program, measured flows from the various sentinel sites were curve fitted to the stage height measurements. The resultant formula was then used to calculate flows for the remaining stage height measurements for which flows were not measured. This yielded approximately 25 flow to sample pairings for each of the modeled sub basins. A long term flow data set was calculated by developing a statistical relationship between the 25 flows and the long term USGS gage at Findlay (04189000) flow dataset. The BasinSim model output for each modeled area is compared to this calculated long term flow dataset input file for calibration.

Seven sentinel sites were setup on the major tributaries to the Blanchard River to assess the major influences to the River. Sentinel sites are sites where frequent water quality chemistry samples are taken and where bridges are used to relate stream stage heights to stream flow. This allows more flow data to be collected at the site than would be possible if flows had to be measured with each visit. Six of these sites were visited between 5/31/05 and 1/09/07, with one long term Blanchard River site at CR 140 starting on 2/02/05.

Table 6.1. Summary of Sentinel Sites

Basin	STORET	RM	Area (sq mi)	No. of visits	Range of measured Qs (cfs)
Blanchard R Headwaters	P05S74	75.57	140.8	24	0.585 – 371.
Blanchard R CR 140 USGS gage	500040	55.26	346.	31	25.0 – 2260.
Eagle Cr.	P05K49	0.45	61.4	24	0.378 – 136.
Ottawa Cr.	P05P17	0.90	63.0	25	2.08 – 125.
Riley Cr.	P05K66	1.20	85.6	25	3.07 – 41.2
Cranberry Cr. *	P05S07	1.64	45.0	24	0.050 – 151.
Blanchard R SR 115 @ Cuba, USGS gage	200149	9.05	745.	24	21.0 – 8300.

* Cranberry Cr. is not impaired for nutrients, therefore, there is no further mention of it.

Weather Input File

To determine daily temperature and precipitation for each HUC 11, data from the Midwestern Regional Climate Centers (MRCC) weather stations were used. The coverage over a HUC11 study area from each weather station was weighted based on coverage over the study area. The weight was determined using the Thiessen polygon method which draws perpendicular bisecting lines at equal distances from station locations then calculates the area each station covers (Chow, Maidment, and Mays, 1988, & Linsley, Koeler, and Paulus, 1982). This method gives greater weight to the nearest station(s). From this weight based data was derived a long term, from 4/1/1991 to 2/26/2007, daily mean precipitation and temperature model input dataset. Table 6.2 shows which MRCC weather stations were used to calculate precipitation for each of the modeled areas, and Table 6.3 shows the station ID for each site.

Table 6.2. Weather station guide for HUC 11s

Basin	**HUC 11 (041000080-)**	**Weather Stations**
Blanchard R Headwaters	010	KENTON, UPPER_SANDUSKY, FINDLAY_FAA_AIRPORT
Blanchard R CR 140 USGS gage, and the Outlet	020	UPPER_SANDUSKY, FINDLAY_FAA_AIRPORT, FINDLAY_WPCC
Eagle Cr.	030	KENTON, FINDLAY_FAA_AIRPORT, FINDLAY_WPCC, PANDORA
Ottawa Cr.	040	OTTAWA
Riley Cr	050	PANDORA

Table 6.3. MRCC weather station ID key

KENTON, OH (Station ID: 334189)
UPPER_SANDUSKY, OH (Station ID: 338534)
OTTAWA, OH (Station ID: 336337)
OTTAWA, OH (Station ID: 336342)
FINDLAY_FAA_AIRPORT, OH (Station ID: 332786)
FINDLAY_WPCC, OH (Station ID: 332791)
PANDORA, OH (Station ID: 336405)

<u>Transport Input file</u>

The transport data input file supplies the model with the needed information to direct the fate of water as it travels over and through soil, some of which makes it to the stream thus adding to the stream flow, see Figure 6.1 for the hydraulic model representation. The inputs for this file were derived by calculation, adjustment during calibration, and in some cases default values were used. Table 6.4 details each input to this file with its source.

Table 6.4. Ottawa Creek Transport Input File		
Input	Source	Adjustment During Calibration
Recession coefficient	Calculated from Findlay USGS gage (04189000) data then adjusted	Yes
Seepage coefficient	Started with a default of zero, adjusted up	Yes
Initial unsaturated storage	Default = 10 cm	No
Initial saturated storage	Default = 0 cm	No
Initial snow melt	Default = 0 cm	No
Sediment delivery ratio	Calculated using model's tool	No
Unsaturated zone available capacity	Started with default of 10, adjusted up	Yes
Evapotranspiration cover coefficient	Calculated based on precipitation – stream flow	No
Day hours	Based Ohio hours	No
Growing season	Based on Ohio values	No
Erosivity coefficient	Based on BasinSim User's Guide Table B-14	No
Land Uses	Derived from National Land Cover Dataset*	No
Soil curve number	Natural Resources Conservation Service's Runoff Curve Number method (USDA, 1992).*	Yes
KLSCP	KLS from STATSGO, LS from USDA personal communication, and P from GWLF manual table B-13.	No

* Land use, soil and weather data are critical components of hydrology functions of GWLF. The National Land Cover Dataset (NLCD) is used as the land cover resource for this study. NLCD is compiled from Landsat TM satellite imagery circa 1992 and includes 23 classes of land use (USGS, 2000). Geographic Information System (GIS) data is used to determine soil properties. GIS data indicate tabular and spatial components. Soil GIS tabular or attributes data includes properties such as soil erodibility and slope. Spatial aspects indicate precisely where certain map units, which the tabular data relate to, exist. The Natural Resource Conservation Service's State Soil Geographic (STATSGO) and Soil Survey Geographic Database

(SSURGO) databases are used to learn all needed soils information. STATSGO is a generalized GIS database of soil parameters originally produced from more detailed soil survey data. The mapping scale for STATSGO is 1:250,000. The newer, high-resolution data provided by SSURGO is not available for several counties in this watershed as a spatial GIS database. However, the higher resolution SSURGO tabular or attribute data does exist statewide. Because of this situation, the SSURGO attributes are generalized to relate to the STATSGO spatial data.

<u>Nutrient Input File</u>

Input nutrient data for rural source areas are dissolved phosphorus concentrations in runoff and solid-phase nutrient concentrations in sediment. Daily nutrient accumulation rates are required for each urban landuse. Septic systems required estimates of the per capita nutrient load in septic system effluent and per capita nutrient losses due to plant uptake, as well as the number of people served by each type of system. Point sources of phosphorus are assumed to be in dissolved form and must be specified for each month. The remaining nutrient data are dissolved phosphorus concentrations in groundwater, (GWLF User's Manual, 1996).

Another important nutrient input, and one that required much attention, is manure runoff. The model requires that the number of landuses and start and stop months be input to account for the higher runoff total phosphorus concentration values. To account for this, raw data from 63 sampling efforts from local fields during runoff conditions were looked at and the average from the most appropriate sites, 1.605 mg/l, was used as the total phosphorus runoff input value. This number was applied to the number of acres found to have manure applied. To determine just how many acres received manure ArcGIS was used to calculate how much of each county was in each modeled area. Then using county livestock data from the Rapid Assessment Data Profile for the Blanchard River Watershed (NRCS, 2008), see Table 6.5, the amount of manure produced in each county was apportioned to the modeled areas. The amount of land that received applied manure was applied to both the pastured and cultivated field landuses. It was assumed that all the pasture land received manure then the remainder of manure was assumed to be applied to cultivated field, so the cultivated field landuse was divided into two landuses, one with manure application and one without.

The apportioning was done considering certain assumptions such as; how much manure each type of livestock produces, phosphorus concentrations from manure, how farmers determined how many acres are needed to dispose of/use the manure without over applying phosphorus or nitrogen, what months manure is field applied, percentage of calves VS cows, etc. Because all of these assumptions vary from farm to farm the loading from the manure applied landuses should be considered an estimate.

Table 6.5. Estimated Livestock animal units, manure production, and nutrient production.

County and Watershed Totals	AU Dairies	AU Beef	AU Swine	AU Poultry	Manure Production (tons/yr) Dairy/Beef	Swine	Poultry	Nutrient Production (1000 lbs/yr) N	P2O5	K2O
Allen	1,114	5,263	5,213	0	56,745	64,302	0	1,349	932	986
Hancock	2,897	1,645	2,661	0	51,913	32,824	0	916	579	675
Hardin	13,436	3,289	7,369	17,547	219,468	90,898	208,365	7,495	6,279	5,001
Putnam	9,360	2,763	8,311	1,451	147,459	102,513	11,873	2,965	2,028	2,142
Seneca	1,114	7,039	4,285	0	70,853	52,855	0	1,349	875	992
Wyandot	3,789	1,908	6,673	11,257	65,956	82,313	133,673	4,361	3,944	2,856
Blanchard W/S	9,022	3,945	8,100	5,390	155,056	99,913	61,947	4,014	3,053	2,794

Source: NRCS, RAPID WATERSHED ASSESSMENT - DATA PROFILE BLANCHARD RIVER WATERSHED, Table 14, January 2008

GWLF model output is reported as load in tonnes/month, our water quality data samples are reported as a concentration. The Blanchard River headwaters, HUC 041000080-010 and HUC 041000080-020 phosphorus model output was tested against long term data in nearby waters; Maumee River and Sandusky River, using Heidleberg's National Center for Water Quailty Research (NCWQR) Water Quality Laboratory data from 1997 to 2000 water years. The data from NCWQR is reported as load in lbs/acre/day, in order to make the comparison the model output was converted to match the NCWQR data units, see Table 6.6. The comparison shows that the model output is realistic and supportable.

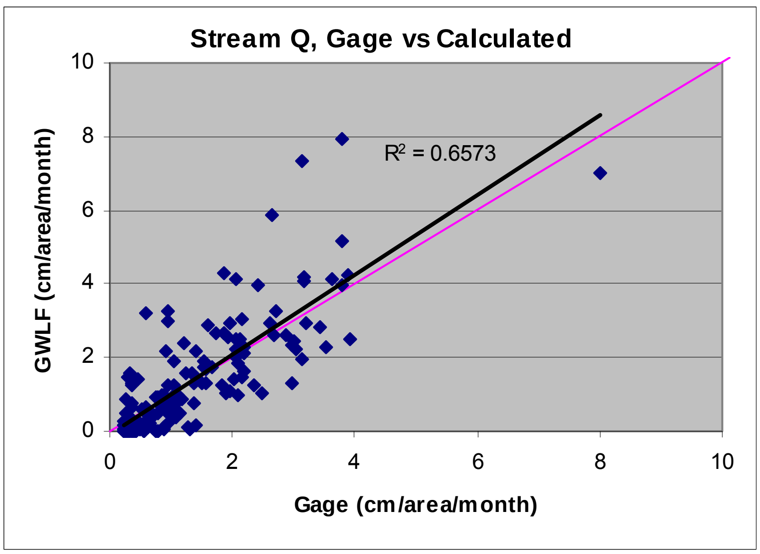
Table 6.6. Total Phosphorus Load Comparison, 1997 – 2000 Water Years

Basin	Drainage Area (sq miles)	NCWQR *	TMDL model output (average)**
		(lbs/acre/yr)	
Maumee River	6330	1.13	
Sandusky River	1253	1.07	
Blanchard R. headwater HUC 04100008010	141		.886
Blanchard R. HUC 04100008020	133		.743

* NCWQR data taken from Table 15 of the Sandusky River TMDL, 2004.
** Model output yearly data from 1997 – 2000 (not water years).

Hydrology Model Calibration:
The hydrologic inputs were calibrated for the first three of the seven areas (Ottawa Creek, HUC 020, and The Outlet) for which the GWLF model was used. Once the input files were assembled the model was run and outputs for stream flow, runoff flow and ground water flow were compared to the long term flow data, such as in Figure 6.2. In order to parse out the runoff and ground water flows from the long term flow dataset a baseflow separation program (Web-based Hydrograph Analysis tool–WHAT) developed at Purdue University was used, (Muthukrishnan, 2005). Some transport inputs, as mentioned in Table 6.4, Ottawa Creek Transport Input File, i.e. recession coefficient, seepage, and curve numbers were adjusted to improve the model output fit to the measured gage data. Once comfortable that the transport model inputs were adjusted properly, the other area models were assumed to be calibrated and were not compared to the base flow separation outputs. After the model's hydrology was suitably calibrated the nutrient inputs were assembled.

Figure 6.2. Comparison of the total stream flow model output to long term flow data for the Ottawa Creek study area.



Nutrient calibration:
Nutrient calibration is somewhat of a challenge since the field measured data is in concentration (mg/l) at a particular moment in time and the model output is in monthly load (tonnes/month). Comparability can become lost when a few samples are used to characterize a month and when a monthly value is back calculated to one concentration in time. Therefore, in order to check the model output the field data for each modeled area was compared to the flow represented as a flow duration interval percentage. This does two things; shows how total phosphorus concentrations react to flow volume, and makes it possible to see a trend which can be compared to the model output, see Figure 6.3, site FDI%, and Figure 6.4, model output FDI%.

Figure 6.3

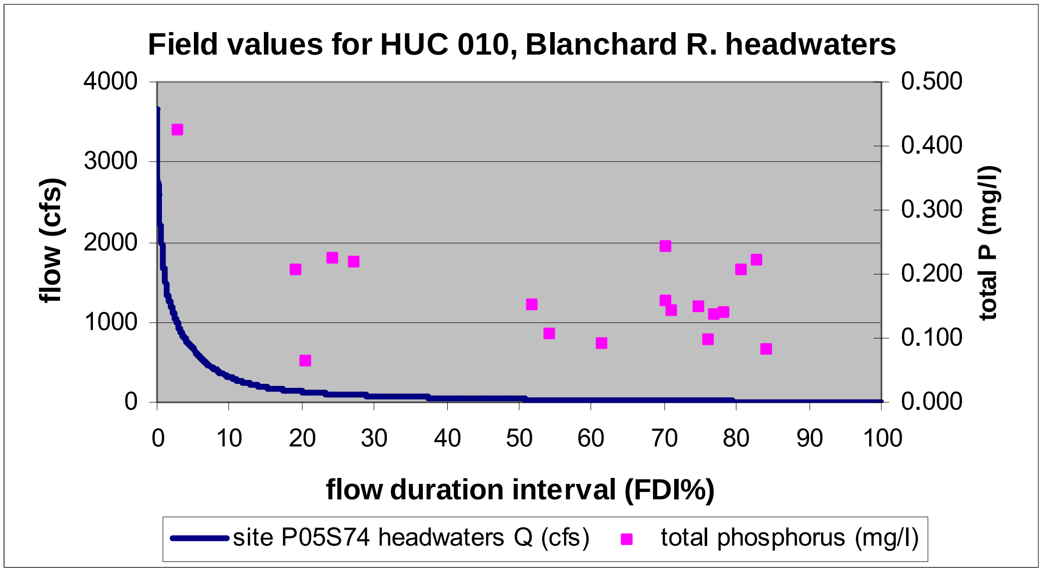
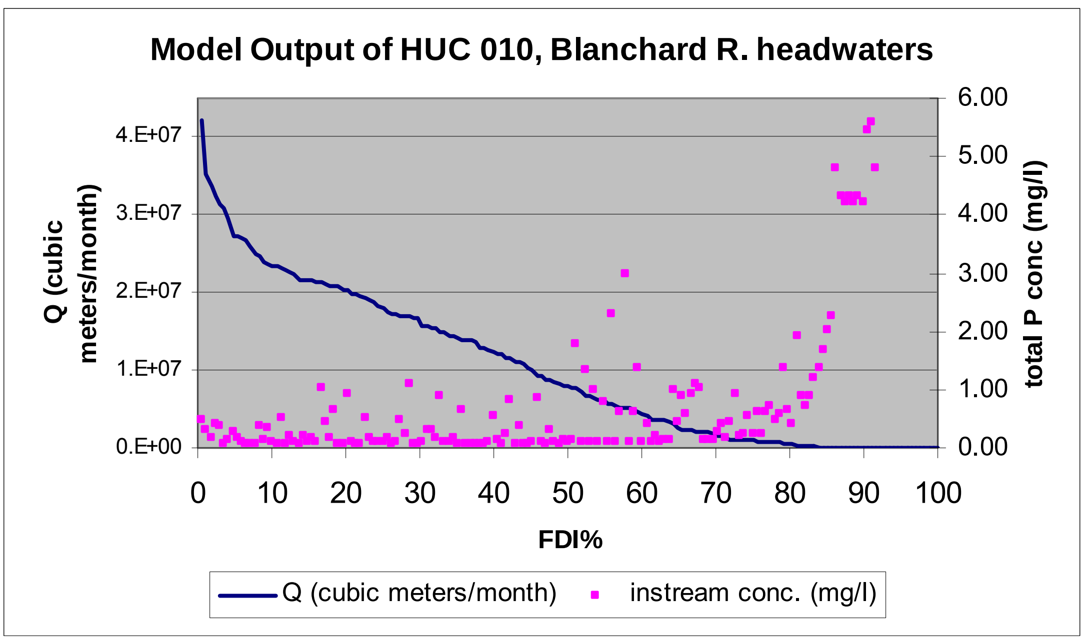
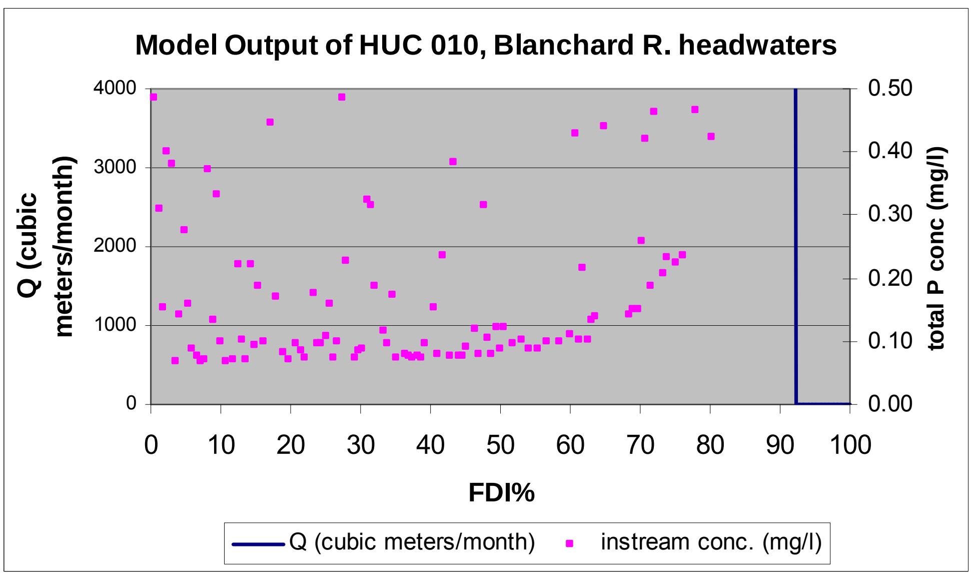


Figure 6.4.



The figures above compare total phosphorus concentration values from the field and model outputs to flow duration intervals (FDIs) for the most upstream Blanchard River HUC 11. FDIs express flow as exceedance percentages, for instance, the 70th FDI% is the flow value which is exceeded 70 % of the time. In the field data figure the flow values were paired up by date with the water quality sample values for that day at the site. By showing the field values with the FDI one can see how phosphorus reacts to changes in the flow and what, if any, trend there is with increasing flow. Using the field data figure, which lacks values from the extreme ends of the hydrograph (flow curve), there doesn't seem to be a phosphorus trend. Phosphorus concentrations are level between the 85th and 10th percentile flows. However, the figure using the model output, which does show data at the flow duration curve extreme ends, clearly reveals that phosphorus concentrations are higher at low flows and lower at high flows. Since the field values represent samples taken at a particular moment and the model output represents concentrations derived from monthly averages one cannot expect the model output to ever mimic the field value figures exactly. However, the two datasets are similar enough to show that the model is performing as needed. Because the scale is so different on the two figures they can be difficult to compare. To make this easier the scale from the model output figure has been lowered in Figure 6.5 in order to better compare the two to demonstrate the model does reflect the field data. Note; the flow units are different and thus not comparable.

Figure 6.5.



The same exercise above was done below for the next downstream sentinel site on the Blanchard River at county Road 140. It is also the site of USGS gage 04189000 from which flow values for the flow duration curve were obtained. Again, the scale on the model output file was reduced to better compare to field data, see Figure 6.7. Taking in to consideration that the model output is in monthly averages, compared to the point in time field samples, the model data does simulate the field values well.

Figure 6.6.

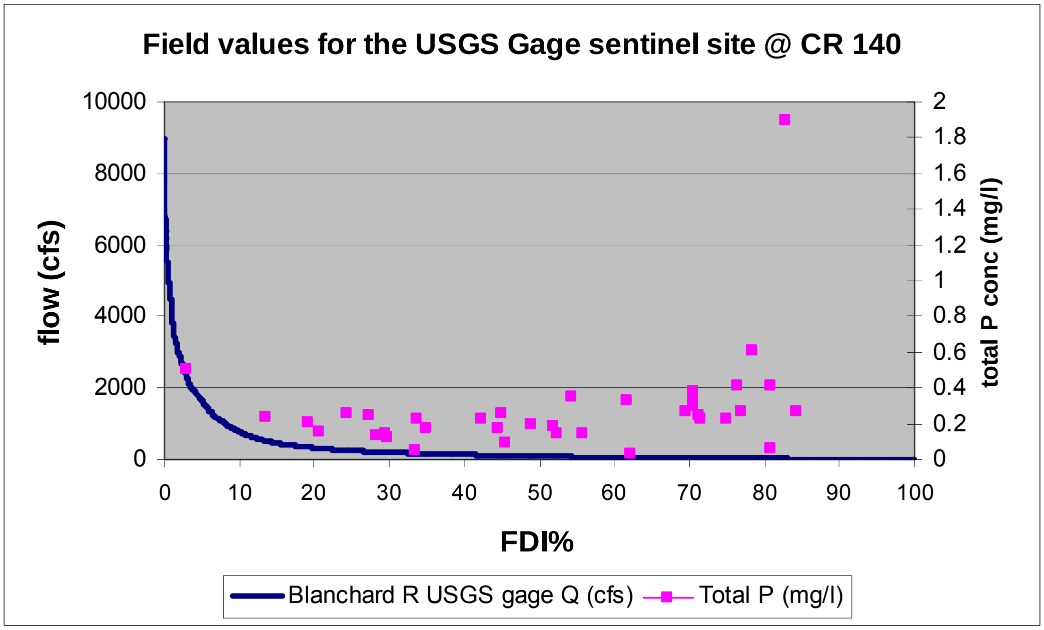


Figure 6.7.

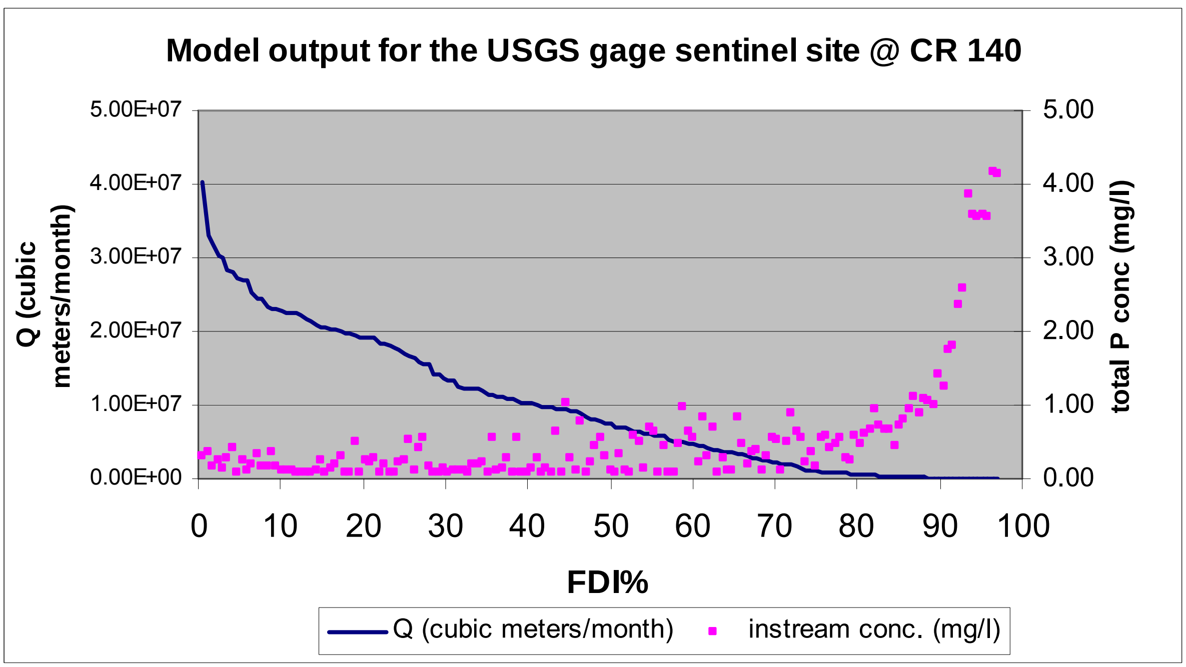
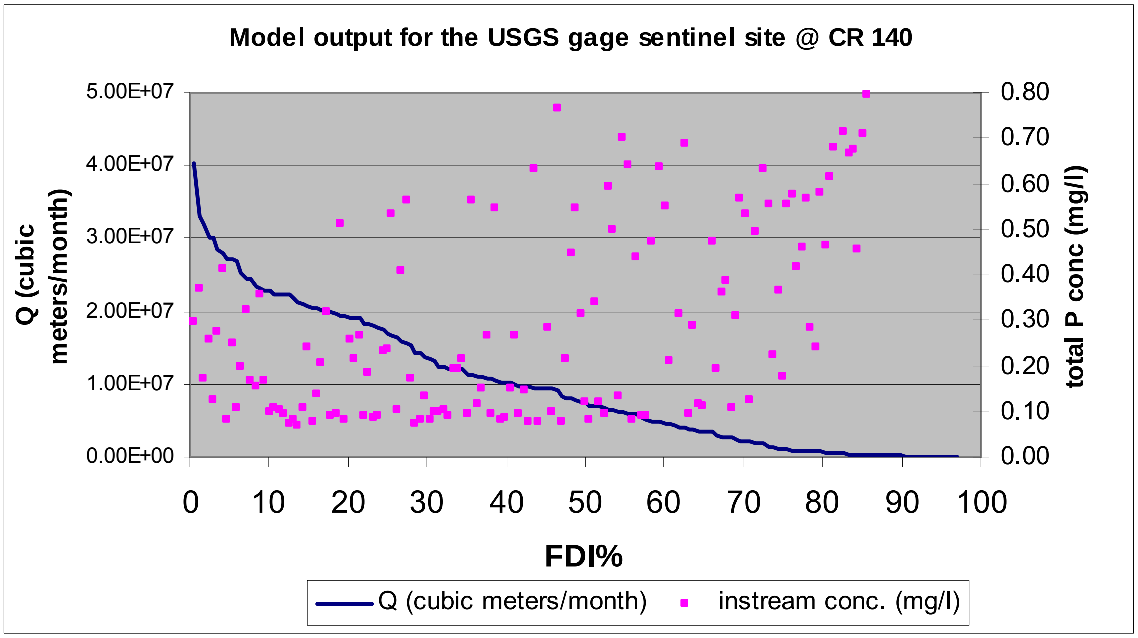


Figure 6.8.



6.1 Selection of water quality target values

6.1.1 Target: average needed reduction (%)

The percent needed reduction was calculated for the modeled areas by using the model output stream flow for each modeled area and the appropriate target concentration based on the Nutrient Association document (OhioEPA, 1999) to create a target load. The monthly calculations for fourteen years were then averaged for each month. Then the average monthly target load was divided by the average monthly model output existing load to derive the difference. The target as a needed percent reduction is calculated using, target = (1-X/Y)*100, where X is the target load and Y is the existing load. The result is a monthly needed percent reduction. The targets were grouped by season and the average calculated to derive the average seasonal target.

The percent needed reduction for the small un-modeled basins were derived by changing the recommended nutrient criteria (OhioEPA, 1999) in the spreadsheets used to calculate the needed reductions for four of the modeled basins (Ottawa Cr., The Outlet, Eagle Cr., Cranberry Cr.) to derive target percent needed reductions. These basins were selected because they had the smallest drainage areas of all the modeled basins and therefore are most closely matched to the un-modeled basins. The target reductions from the four basins were then averaged and any negative target values, which indicates existing conditions do not need to be reduced, were set to zero. The averages were then applied to the un-sampled basins based on basin size and use designation.

6.1.2 Target: average needed reduction (kg/d)

For both the modeled and un-modeled areas (smaller tributaries) the needed reduction loads are simply calculated from the existing conditions and needed reduction percentage, i.e. existing condition (kg/d) times needed percent reduction (%) = average needed reduction (kg/d). For the summer calculations the margin of safety (MOS) percentage is added to the needed reduction before being multiplied by the existing condition.

6.2 Methods of Quantifying Existing Loads

GWLF model output is reported monthly in units of tonnes. The scenarios for the Blanchard River areas were for 15 years, the first year of which was eliminated since the model hydrology was stabilizing. In order to reduce the 14 years of monthly GWLF output into a presentable fashion the monthly output values were summarized into seasonal data by grouping the months into seasons, i.e. winter, spring, summer, and fall. Average and maximum values were then derived from this data.

The Blanchard River basin TMDL effort can be divided into two types of areas, the modeled sub-basins and the un-modeled sub-basins. Sentinel sites were established on the major tributaries and the mainstem in order to gather chemistry and flow data for model support. These sentinel sites, synonymous with the modeled areas, covered most of the Blanchard River drainage area, around 87%. Some smaller tributaries towards the more downstream portion of the basin were not sampled and therefore not modeled; these un-modeled areas makeup 13% of the Blanchard River basin. The methods used to derive TMDLs for both these areas are explained below.

6.2.1 Average of existing conditions (kg/day)

For the modeled areas: Blanchard River headwaters, HUC 04100008-020, the Outlet, Eagle Creek, Ottawa Creek, and Riley Creek.

The GWLF model output for total phosphorus was used to derive the existing conditions. The output was sorted by month using a pivot table, and the averages of four seasons; winter, spring, summer, and fall were taken. The seasons were broken down as such, winter (Dec., Jan., Feb.), spring (Mar., Apr., May), summer (Jun., Jul., Aug.), and fall (Sep., Oct., Nov.). The GWLF output is monthly (tonnes/month) so in order to reduce it to daily loads (kg/day) the seasonal monthly averages were divided by the number of days in the season divided by 3, i.e. spring has 92 days/3 = 30.66 days, then multiplied by 1000 to convert tonnes (metric tons) to kilograms. The result is an average seasonal load in kg/d.

For the un-modeled areas: Bear Creek, Deer Creek, Caton Creek, Moffitt Ditch, Miller City Cutoff, Dukes Run, and Pike Creek.

Existing total phosphorus is a function of area, see Figure 6.9.

Figure 6.9. Existing total phosphorus values for the modeled Blanchard River basins.

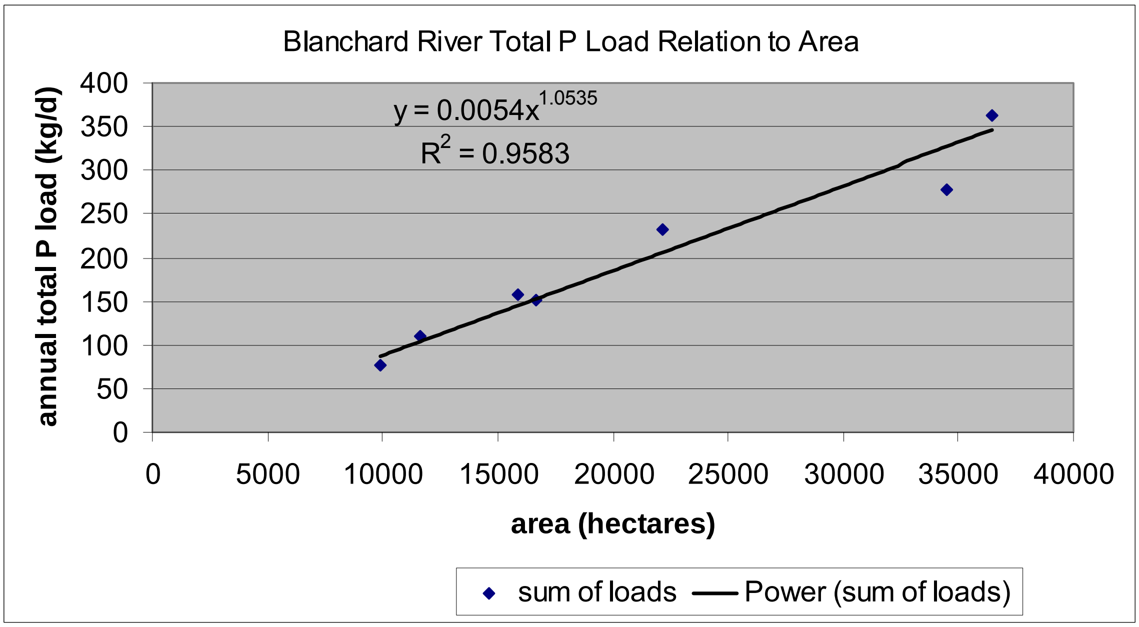
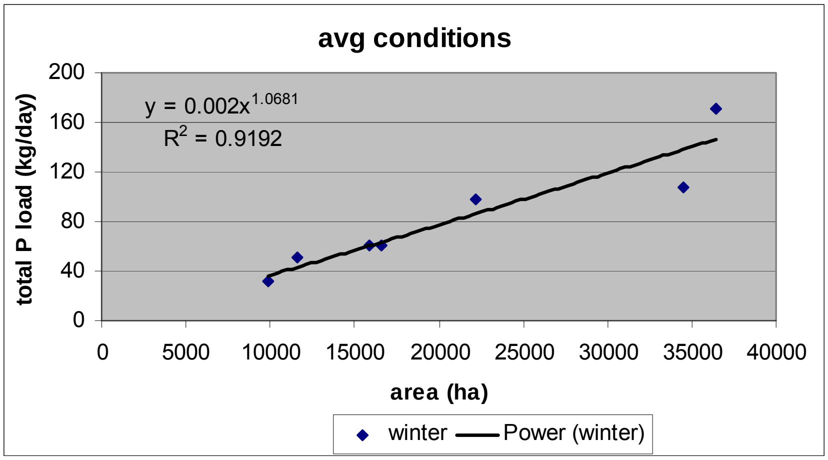


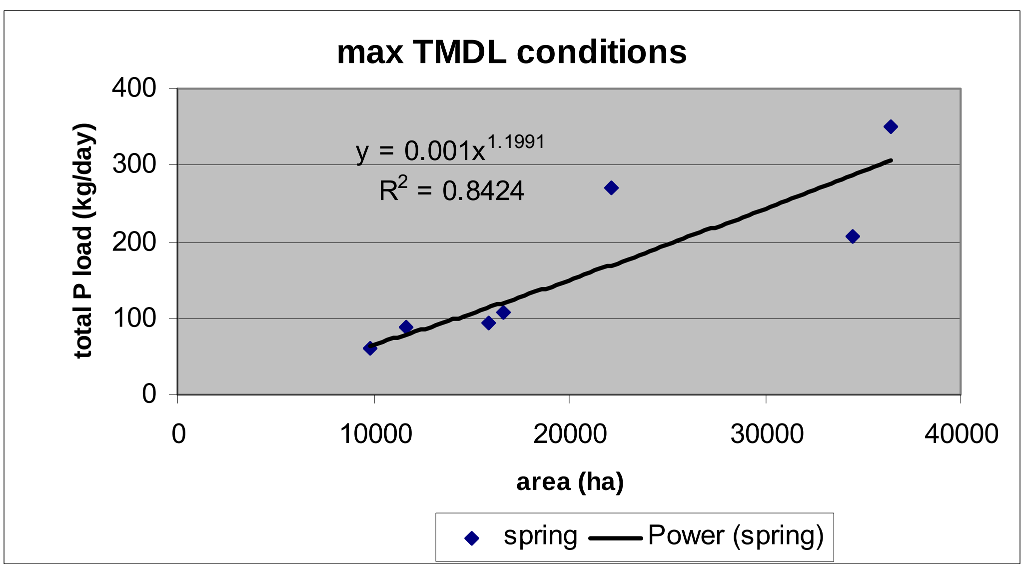
Figure 6.10 shows that the sum of the seasonal average daily loads is related to area. The sum was derived by adding the seasonal average daily existing total phosphorus loads, i.e. average winter (kg/d) + avg. spring (kg/d), avg. summer (kg/d) + avg. fall (kg/d). The sum for each modeled area was then matched to the respective drainage area. With this information it made sense that existing conditions for the un-modeled areas could be derived from the modeled areas. To do this a regression was built for each season using the existing total daily phosphorus loads for each of the modeled areas. The associated regression equation was then used to calculate seasonal daily loads for the un-modeled tributaries. Figure 6.10 is an example. From this formula, $Y = 0.002*X^{1.0681}$, where Y is load (kg/d) and X is drainage area (ha), a load can be developed for winter. Formulas were derived for each season.

Figure 6.10. Regression formula to calculate average conditions in un-modeled tributaries.



For LAs the maximum TMDLs were calculated the same way as existing conditions were, by relating the maximum TMDLs for the modeled areas to their respective drainage areas. Then the resultant regression formula was used to determine the maximum TMDLs for the un-modeled tributaries. Figure 6.11 is an example.

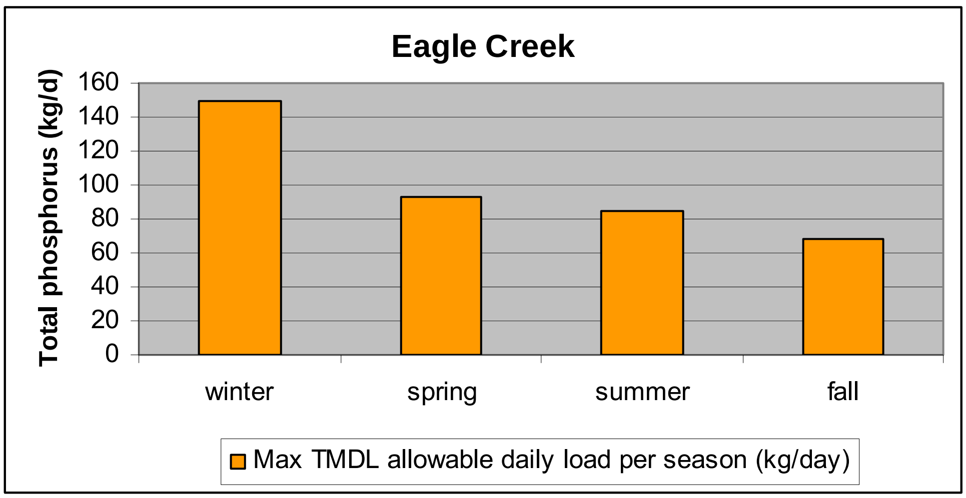
Figure 6.11. Maximum TMDLs related to drainage area.



Average TMDL: average daily load (kg/day)
The average TMDL (kg/d) is simply calculated by subtracting the needed reduction (kg/d) from the existing condition (kg/d).

Maximum TMDL: maximum daily load (kg/day)
The maximum load allocation (LA) TMDLs for the modeled basins were calculated by using the 95th percentile of existing data, following USEPA draft guidance, Options for Expressing Daily Loads in TMDLs, (USEPA, 2007). The model outputs consisted of 15 years of monthly simulations, from 1991 to 2006. The first year was omitted to allow the model to stabilize, therefore only 168 monthly results were used. These 168 values were separated into seasons then the 95th percentile was calculated for each seasons, see Figure 6.12. The 95th percentile was selected because of high confidence in the model outputs. There is high confidence in the model inputs because of familiarity and similarity in the various modeled areas within the Blanchard River basin.

Figure 6.12. Eagle Creek seasonal maximum TMDL.



The maximum WLAs (point sources) for the same basins were calculated by using the 95th percentile of the monthly WLA model inputs. The GWLF nutrient input file requires a point source load (kg/month) for each month. The 95th percentile from these 12 inputs was taken and converted to kg/day and used as the maximum WLA. If there were no dischargers in the basin the result is zero, and if there is no discharger permit data then one assumed value was used for each month resulting in a 95th P equal to that number, i.e. for the Ottawa Cr. basin there were no discharger data for the point source, so a value of 71.51 kg/month derived from a facility similar in size and operation which had monthly operating report data, was used for each month. The resulting 95th P was then 71.51.

For both the modeled and un-modeled areas septic systems are considered to be a point source (WLA) in this TMDL. Because the model input is simply the number of house septic systems for 4 categories of system functionality (normal, short circuited, ponded, and direct discharge), and because the model output is simply summarized annually and is equal for each year, the maximum TMDL calculation is rather simple. It is calculated as the average daily load times 0.95. Because of its proximity to the City of Findlay, and therefore higher density of houses, the total phosphorus contribution from septic systems, for Eagle Creek, is higher at 23% than any other of the modeled basins. The next highest is the HUC 04100008010-020 basin, at 5%.

Calculations for the maximum TMDLs for the un-modeled areas is explained above in the chapter, Average of existing conditions (kg/d): For the un-modeled areas.

6.3 Accounting for uncertainty: application of margins of safety

There is a strong built in implicit MOS in the GWLF total phosphorus modeling for the Blanchard River. The target was calculated by taking a protective phosphorus concentration based on use designation and stream size and the GWLF hydrologic output and a conversion factor to derive the target load. The total phosphorus target concentration was taken from the Nutrient Associations Document (OEPA, 1999) and is appropriate for summer values. However, it was also applied to the other three seasons; fall, winter, and spring. Phosphorus is less problematic when water temperatures are cooler so by using the summer target for the other seasons there is an implicit MOS.

Also, an explicit MOS was added by increasing the summer needed percent reduction by 3%. As mentioned above the other seasons have a MOS due to the use of the summer target being applied to cooler seasons. The 3% addition to the summer season covers the summer season.

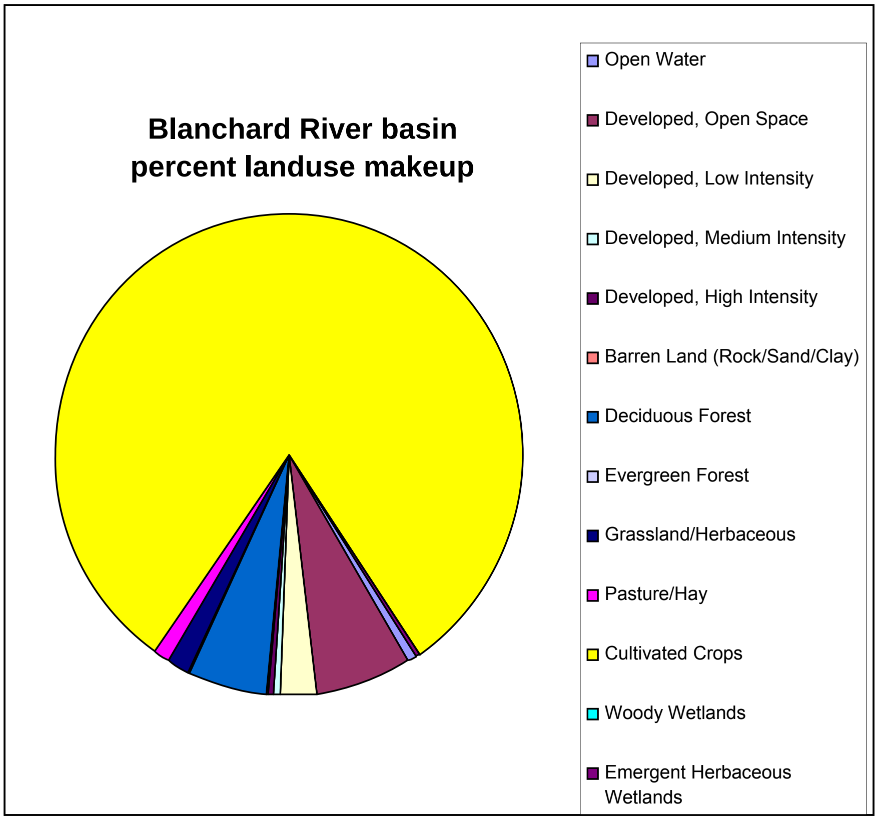
6.4 Quantifying needed abatement

The GWLF landuse summary for all modeled years, except for year one, is handy for use in determining how implementation efforts should be prioritized. Appendix A, Landuse Summary for All Modeled Basins is a collection of the summaries for each modeled basin. This can be used by water quality groups to determine how much phosphorus is coming from each of the landuses and point sources.

Appendix A Land Use Summary for All Modeled Basins Manured.xls

A major cause of impairment in the Blanchard River basin is excessive nutrients (total phosphorus), the source is mainly non point in nature, and essentially agriculture since 80.9% of the basin is made up of cultivated crop fields, Figure 6.13. There is also a contribution from point sources, such as discharges from schools, highway roadside rests, waste water treatment plants, failing home sewage treatment systems, etc. In most cases in the Blanchard River basin, with the exception of the City of Findlay, Pandora and Bluffton, these are small discharges, which are generally not issued permit limits for phosphorus, and result in a small percentage of the total phosphorus load over the course of a year. However, their effects to the streams can be damaging and are felt during periods of low flow when runoff from the agriculture fields is essentially nonexistent, therefore, they are important because they make up a large percentage of the total phosphorus load during these periods. Repair of failing home sewage treatment systems (HSTS) would help reduce both total phosphorus and instream bacteria.

Figure 6.13. Blanchard River percent landuse makeup



Far and away the biggest bang for the buck regarding total phosphorus reduction is through care at the agricultural field level. Volumes have been written on this subject but suffice it to say that conservation methods to avoid erosion, with soil sampling and proper fertilizer application is the key in the Blanchard River basin.

<u>Municipal Separate Storm Sewer System Calculation</u>
Method: In order to calculate the total phosphorus contribution from the MS4 area the transport and nutrient model input files were adjusted to reflect the hardened conditions of the urban area. The point source dischargers and failing septic systems were set to zero (it was determined there were not many houses with septic systems in the area). Using National Land Cover Database data the land use and areas, within the MS4 area, were determined and all other inputs from the Eagle Creek model set up were left unchanged. This setup allowed the model to calculate only the urban landuse contribution. The MS4 area includes the metropolitan Findlay area minus the area covered by CSOs, since that area is not part of the separated storm sewer area. The dissolved phosphorus portion of the model output was almost entirely (97%) from groundwater, so it was subtracted from the total

phosphorus output in order to calculate just the runoff load. Also, only the runoff flow was used to calculate the load, the ground water portion was excluded. This allowed for the calculation of phosphorus from just the urban landuse area. Then, as with the other modeled areas, the target concentration of 0.1 and 0.17 mg/l, for wadable streams and small rivers respectively, were multiplied by the output flows to determine the target load. That target load was then calculated as a percentage of the existing phosphorus load to obtain the needed percent reduction.

Results: The results of the MS4 modeling show that reductions are needed for average TMDL conditions in the spring and fall seasons, and maximum conditions should not be exceeded. See Appendix B for values.

3.1 Habitat Alteration and Sedimentation

Habitat TMDL targets and the Qualitative Habitat Evaluation Index (QHEI)

Habitat alteration is a significant cause of impairment throughout the Blanchard River basin. Poor habitat quality is an environmental condition, rather than a pollutant load, so development of a load-based TMDL for habitat is not possible. Nonetheless, habitat is an integral part of stream ecosystems and has a significant impact on aquatic community assemblage and consequently on the potential for a stream to meet the bio-criteria within Ohio's water quality standards (see Section 2.3). In addition, U.S. EPA acknowledges that pollutants, conditions or other environmental stressors can be subject to the development of a TMDL to abate those stressors in order to meet water quality standards (***USEPA TMDL reference on pollution vs. pollutant***). Thus, sufficient justification for developing habitat TMDLs is established.

The Qualitative Habitat Evaluation Index (QHEI) was developed by the Ohio EPA (OEPA 1987) with one of the objectives being to create a means for distinguishing impacts to the aquatic community from pollutant loading versus poor stream habitat. The design of the QHEI in conjunction with its statistically strong correlation to the bio-criteria makes it an appropriate tool for developing habitat TMDLs.

The QHEI assigns a numeric value to an individual stream segment (typically 150-200 m in length) based on the quality of its habitat. The actual number values of the QHEI scores do not represent the quantity of any physical properties of the system but provide a means for comparing the relative quality of stream habitat. However, even though the numeric value is derived qualitatively, subjectivity is minimized because scores are based on the presence and absence and relative abundance of unambiguous habitat features. Reduced subjectivity was an important consideration in developing the QHEI and has since been evidenced through minimal variation between scores from various trained investigators at a given site as well as consistency with repeated evaluations (Rankin 1989).

The QHEI evaluates six general aspects of physical habitat that include channel substrate, instream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient. Within each of these categories or sub-metrics, points are assigned based on the ecological utility of specific stream features as well as their relative abundance in the system. Demerits (i.e., negative points) are also assigned if certain features or conditions are present which reduce the overall utility of the habitat (e.g., heavy siltation and embedded substrate). These points are summed within each of the six sub-metrics to give a score for that particular aspect of stream habitat. The overall QHEI score is the sum of all of the sub-metric scores.

Since its development the QHEI has been used to evaluate habitat at most biological sampling sites and currently there is an extensive database that includes QHEI scores and other water quality variables. Strong correlations exist between QHEI scores and some its component sub-metrics and the biological indices used in Ohio's water quality standards such as the Index of Biotic Integrity (IBI). Through statistical analyses of data for the QHEI and the biological indices, target values have been established for QHEI scores with respect to the various aquatic life use designations (Ohio EPA 1999). For the aquatic life use designation of warm water habitat (WWH) an overall QHEI score of 60 is targeted to provide reasonable certainty that habitat is not deficient to the point of precluding attainment of the bio-criteria. An overall score of 75 is targeted for streams designated as exceptional warm water habitat (EWH) and a minimum score of 45 is targeted for modified warm water habitat (MWH) streams.

One of the strongest correlations found through these statistical analyses described above is the negative relationship between the number of "modified attributes" and the IBI scores. Modified attributes are features or conditions that have low value in terms of habitat quality and therefore are assigned relatively fewer points or negative points in the QHEI scoring. A sub-group of the modified attributes shows a stronger impact on biological performance; these are termed "high influence modified attributes".

In addition to the overall QHEI scores, targets for the maximum number of modified and high influence modified attributes have been developed. For streams designated as WWH, there should no more than 4 modified attributes of which no more than 1 should be a high influence modified attribute. Table 3.1 lists modified and high influence modified attributes and provides the QHEI targets used for this habitat TMDL. For simplicity, a pass/fail distinction is made telling whether each of the three targets are being met. Targets are set for: 1) the total QHEI score, 2) maximum number of all modified attributes, and 3) maximum number of high influence modified attributes only. If the minimum target is satisfied, then that category is assigned a "1", if not, it is assigned a "0". To satisfy the habitat TMDL, the stream segment in question should achieve a score of three.

Table 3.1. QHEI targets for the habitat TMDL.

	Overall QHEI Score	All Modified Attributes	
		High Influence Modified Attributes	All Other Modified Attributes
Range of Possibilities	12 to 100 points	- Channelized or No Recovery - Silt/Muck Substrate - Low Sinuosity - Sparse/No Cover - Max Pool Depth < 40 cm (wadeable streams only)	- Recovering Channel - Sand Substrate (boat sites) - Hardpan Substrate Origin - Fair/Poor Development - Only 1-2 Cover Types - No Fast Current - High/Moderate Embeddedness - Ext/Mod Riffle Embeddedness - No Riffle
Target	Overall score >= 60	Total number < 2	Total number < 5[a]
TMDL Points if Target Satisfied	+ 1	+ 1	+ 1

[a] Total number of modified attributes includes those counted towards the high influence modified attributes.

Sediment TMDL targets and the Qualitative Habitat Evaluation Index (QHEI)

The QHEI is also used in developing the sediment TMDL for this project. Numeric targets for sediment are based upon sub-metrics of the QHEI. Although the QHEI evaluates the overall quality of stream habitat, some of its component sub-metrics consider particular aspects of stream habitat that are closely related to and/or impacted by the sediment delivery and transport processes occurring in the system.

The QHEI sub-metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion and riparian zone. Table 3.2 lists targets for each of these metrics.

- The substrate sub-metric evaluates the dominant substrate materials (i.e., based on texture size and origin) and the functionality of coarser substrate materials in light of the amount of silt cover and degree of embeddedness. This is a qualitative evaluation of the amount of excess fine material in the system and the degree to which the channel has assimilated (i.e., sorts) the loading.
- The channel morphology sub-metric considers sinuosity, riffle, and pool development, channelization, and channel stability. Except for stability each of these aspects are directly related to channel form and consequently how sediment is transported, eroded, and deposited within the channel itself (i.e., this is related to both the system's assimilative capacity and loading rate). Stability

reflects the degree of channel erosion which indicates the potential of the stream as being a significant source for the sediment loading.

- The bank erosion and riparian zone sub-metric also reflects the likely degree of in-stream sediment sources. The evaluation of floodplain quality is included in this sub-metric which is related to the capacity of the system to assimilate sediment loads.

Table 3.2. QHEI targets for the sediment TMDL.

Sediment TMDL =	Substrate	+	Channel Morphology	+	Riparian Zone/Bank Erosion	
For WWH >=	13	+	14	+	5	>= 32

The rationale for using the QHEI for development of the sediment TMDL is largely due to the fact that other measures and/or methods of evaluating sediment loading are problematic and have limited reliability. For example, total suspended solids (TSS) is commonly used as a modeling parameter, however gathering data that is reliable for calibration and validation is often uncertain. This uncertainty rests in the fact that TSS demonstrates a high degree of variability both over space and time and is also very sensitive to local disturbances. Additionally, models that adequately account for in-stream sediment dynamics (e.g., erosion and deposition processes) are lacking or require very high resource expenditures (e.g., much data collection) that often are not feasible.

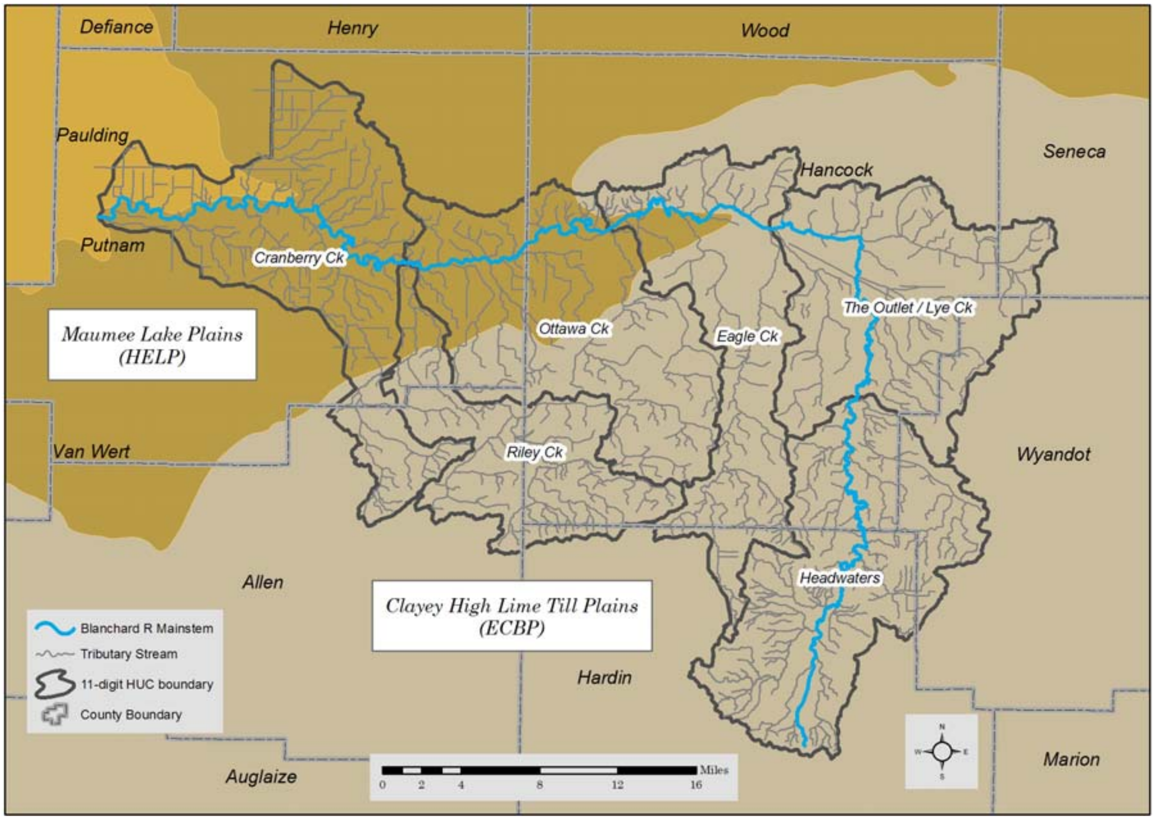
Finally, the QHEI has such a strong relationship with the bio-criteria in Ohio's water quality standards whereas, TSS has a relatively weak correlation with biological performance, which is probably related to the variability and unreliability of TSS measures. The QHEI represents the end result of high sediment loading (either from the landscape of in-stream sources) as it impacts the biological community.

4.1 TMDL for Sediment and Stream Habitat

Tables 4.1 and 4.2 reflect a quantification of sediment-induced and habitat-induced cause of impairment. Every site should be considered in a strata consisting of the same ALU designation (i.e., EWH vs. WWH vs. MWH) and ecoregion. Based on existing ALU designation, all sites with QHEI assessments were WWH though proposed ALU designation would relegate some of the sites to MWH. Currently, no targets exist for the MWH ALU designation. Sediment and habitat TMDL targets for the WWH ALU designation appear at the bottom of Tables 4.1 and 4.2

Two ecoregions – ECBP and HELP – exist in the Blanchard River watershed (Figure 4.1). However, stratification by ecoregion was not performed because the ECBP Level-4 subregion 55a (Clayey High Lime Till Plains) within the Blanchard watershed is very similar to the HELP Level-4 57a subregion (Maumee Lake Plains), especially along the northern edge of the 55a boundary (R. Miltner 2007, personal communication).

Figure 4.1. Distribution of Level-4 ecoregions (subregions) in the Blanchard River watershed along with boundaries of watershed assessment units.



In quantifying the Bedload and Habitat TMDLs for the Blanchard River watershed, only sites with either ALU partial- or non-attainment were considered. Sites having full attainment or those with insufficient data (i.e., no attainment status defined) were excluded and hence do not appear in Tables 4.1 and 4.2. Further, of these sites, only those with causes identified as siltation and sedimentation were considered for a Bedload TMDL (Table 4.1). Correspondingly, only those sites with habitat alteration or flow alteration were considered for a Habitat TMDL (Table 4.2). These causes were assigned by site in Tables 1a-7a in the 2007 TSD (Ohio EPA 2007).

By far the Riley Creek assessment unit (0410008-050) contains the greatest frequency of sites below the sediment target of 32 (Table 4.1; Figure 4.2). In particular the upper portions of mainstem Riley Creek (at river mile 24.9, 22, and 19.5) have significant deviations from the sediment target owing to low scores on the substrate and riparian/bank erosion metrics. When considering tributaries within this assessment unit, Little Riley Creek (both upper and lower sub-watersheds bearing the same name) also has significant deviations from the sediment target. Here low channel morphology and substrate metrics are responsible for the deficit. The Ottawa Creek assessment unit (0410008-040) contains a few tributaries that are below the sediment target – at the lower length of Dukes Run and Tiderishi Creek. Both deviations were caused by low metric scores for channel morphology. Concluding the sediment TMDL analysis is one site each within the Eagle Creek (0410008-030) and Cranberry Creek (0410008-060) assessment units. The mainstem Blanchard River (river mile 57.8) has a significant deviation from the target (40.6%) and mainly due to substrate issues. Within the Cranberry Creek assessment unit, Caton Ditch has not met the sediment target (low substrate metric).

Figure 4.2. Depiction of <u>Bedload Scores</u> at QHEI assessment sites for impaired sites having sedimentation or siltation causal factors.

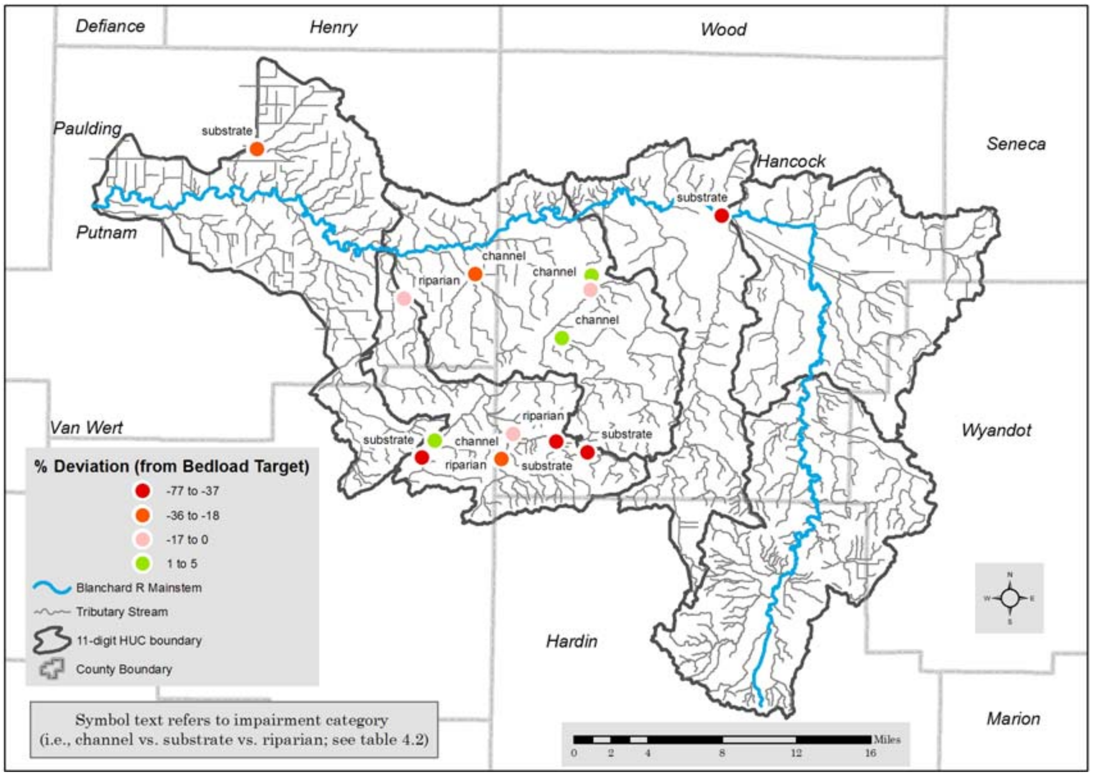
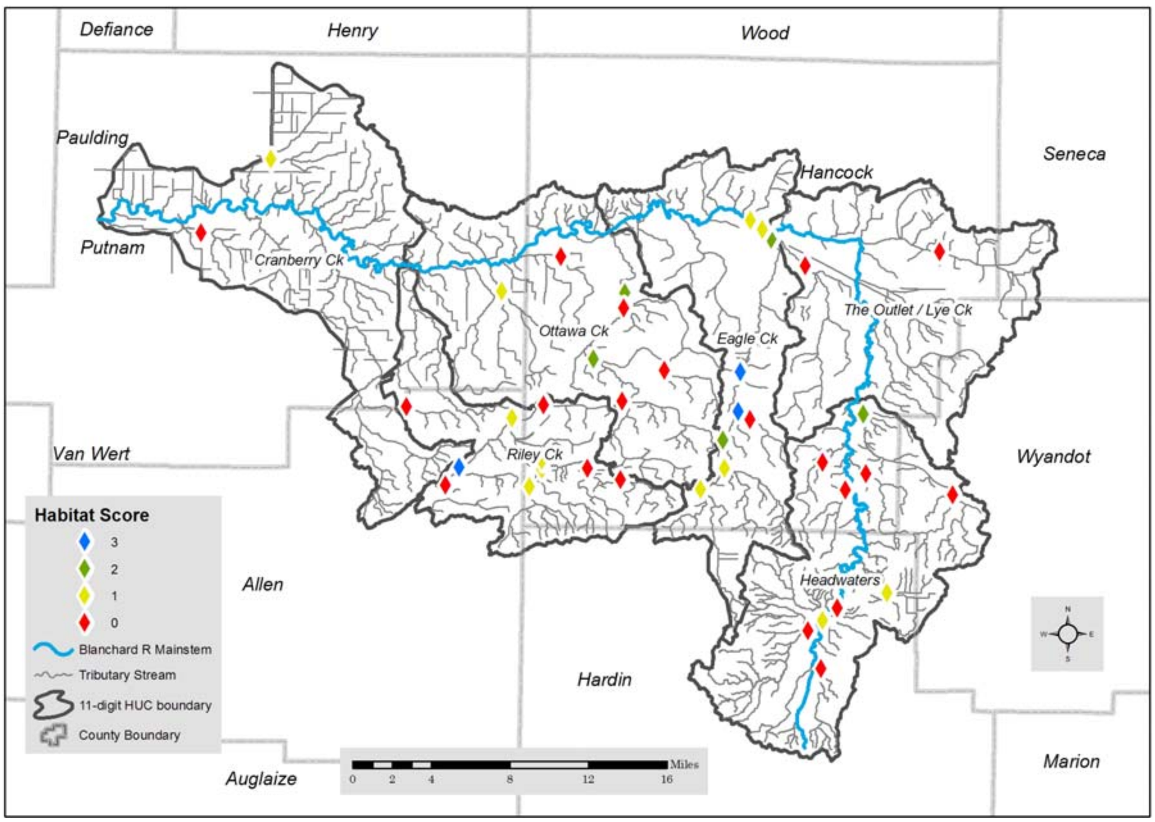


Table 4.1. Characterization of the Sediment TMDL using QHEI metrics for impaired sites with sedimentation and siltation causes in the Blanchard River watershed. All sites are ALU-designated as WWH.

Stream/River (-0n0 = HUC 14)	River Mile	QHEI Categories			Total Sediment Score	Deviation from target (%)	Main impairment category
		Substrate	Channel	Riparian			
WAU: Eagle Creek (04100008-030)							
-030 Blanchard River (below Eagle Creek to above Aurand Run)							
Blanchard River	57.8	6.5	8.5	4	19	40.6	substrate
WAU: Ottawa Creek (04100008-040)							
-010 Ottawa Creek (except Tiderishi Creek)							
Ottawa Creek	10.1	14	12	6.5	32.5	meets	channel
Ottawa Creek	4.8	13.5	13	7	33.5	meets	channel
-020 Tiderishi Creek							
Tiderishi Creek	0.1	13.5	11.5	4.5	29.5	7.8	channel
-060 Dukes Run							
Dukes Run	1.9	12	7.5	4.5	24	25.0	channel
WAU: Riley Creek (04100008-050)							
-010 Riley Creek (headwaters to above Little Riley Creek [upper])							
Riley Creek	24.9	3	9	4.5	16.5	48.4	substrate
Riley Creek	22	6	7.5	5.5	19	40.6	substrate
-020 Little Riley Creek (upper)							
Little Riley Creek (upper)	2.6	10	10.5	5	25.5	20.3	channel
-030 Riley Creek (below Little Riley Creek [upper] to above Little Riley Creek [lower])							
Riley Creek	19.5	13	11.5	3	27.5	14.1	riparian
-040 Little Riley Creek (lower)							
Little Riley Creek (lower)	5.4	1	4	2.5	7.5	76.6	substrate
Little Riley Creek (lower)	4.2	13.5	15	4.5	33	meets	riparian
-050 Riley Creek (below Little Riley Creek [lower] to Blanchard River [except Cranberry Run])							
Riley Creek	4.4	16.5	11	3.5	31	3.1	riparian
WAU: Cranberry Creek (04100008-060)							
-040 Miller City Cutoff							
Caton Ditch	3	5	12	4	21	34.4	substrate
Target (WWH)		≥ 13	≥ 14	≥ 5	≥ 32		

As described in Chapter 3, the Habitat TMDL considers the final QHEI score and the frequency of modified attributes for a given site. For the Blanchard River watershed both the Headwaters (04100008-010) and Riley Creek (04100008-050) assessment units have the greatest frequency of habitat-induced impairment. Specifically, the upper Blanchard River mainstem and several single sites on smaller tributaries have low habitat scores (Table 4.2; Figure 4.3). These smaller tributaries include Ripley Rum, The Outlet (upper sub-watershed), and Cessna Creek. Two sites on Potato Run fail to meet the habitat target and one of these fails miserably. For the Riley Creek assessment unit, both upper and lower sub-watersheds named Little Riley Creek have multiple failure sites (Table 4.2). The upper part of the Riley Creek mainstem fails significantly in meeting the habitat target.

Figure 4.3. Depiction of Habitat Scores at QHEI assessment sites for impaired sites having flow alteration or habitat alteration causal factors.



The Eagle Creek (04100008-030) and Ottawa Creek (04100008-040) assessment units contain the second highest frequency of sub-target habitat scores. The entire length of Eagle Creek mainstem falls below the target – besides agricultural-related habitat destruction, the lower portion of the mainstem is impaired by urbanization as it enters the City of Findlay. The Blanchard River mainstem is also below the habitat target and, in this section, induced by reservoir-impoundment, dam tailrace, and urban development (Table 4.2). With the removal of the Liberty Street dam in the summer of 2007 and subsequent installation of four riffle structures in the near area, it is possible that the target could be reached at river-mile 56.9. At the upper river-mile (57.8), there is small likelihood of improvement as long as the City Park (Findlay) dam and upstream impoundment remain intact. In the Ottawa Creek assessment unit, the mainstem Ottawa Creek barely fails at the lower reach but, in contrast, fails significantly towards its upper segment (Table 4.2; Figure 4.3). Two sites on Tiderishi Creek fail miserably.

The Outlet/Lye Creek (04100008-020) and Cranberry Creek (04100008-060) assessment units have the fewest sub-target habitat scores. One site in each of the lower portions of Lye Creek and The Outlet sub-watersheds fail miserably. Two sites in the Cranberry Creek assessment unit – Caton Ditch and Deer Creek – also have significant below target habitat scores.

Table 4.2. Characterization of the Habitat TMDL using QHEI metrics for impaired sites having causes of either habitat alteration or flow alteration (or both) in the Blanchard River watershed. All sites are ALU-designated as WWH. UNT = un-named tributary with mainstem river-mile at confluence in parenthesis.

Stream/River (-0n0 = HUC 14)	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore			Total Habitat Score
					QHEI	High Influence	Modified	
WAU: Headwaters (04100008-010)								
-010 Blanchard River: headwaters to above Cessna Creek								
UNT to Blanchard River (RM 100.38)	**0.7**	**34.5**	**4**	**10**	**0**	**0**	**0**	**0**
-020 Cessna Creek								
Cessna Creek	**0.5**	**42**	**2**	**11**	**0**	**0**	**0**	**0**
-030 Blanchard River: below Cessna Creek to below The Outlet (upper)								
Blanchard River	**97.5**	**46**	**1**	**8**	**0**	**1**	**0**	**1**
Blanchard River	**96**	**46**	**2**	**8**	**0**	**0**	**0**	**0**
The Outlet (Blanchard R RM 90.94)	**3.6**	**52**	**1**	**8**	**0**	**1**	**0**	**1**
-040 Blanchard River: below The Outlet (upper) to above Potato Run								
UNT to Blanchard River (RM 79.75)	**2.2**	**40**	**4**	**9**	**0**	**0**	**0**	**0**
UNT to Blanchard River (RM 80.53)	**1.8**	**33.5**	**4**	**11**	**0**	**0**	**0**	**0**
Ripley Run	**0.1**	**50**	**2**	**9**	**0**	**0**	**0**	**0**
-050 Potato Run								
Potato Run	**9.6**	**39**	**3**	**10**	**0**	**0**	**0**	**0**
Potato Run	**1.8**	**63.5**	**0**	**6**	**1**	**1**	**0**	**2**

Stream/River (-0n0 = HUC 14)	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore			Total Habitat Score
					QHEI	High Influence	Modified	
WAU: The Outlet / Lye Creek (04100008-020)								
-030 The Outlet (lower)								
The Outlet (Blanchard R RM 63.63)	**4.5**	**38.5**	**2**	**9**	**0**	**0**	**0**	**0**
-050 Lye Creek								
Lye Creek	**2.6**	**39.5**	**2**	**8**	**0**	**0**	**0**	**0**
WAU: Eagle Creek (04100008-030)								
-010 Eagle Creek: headwaters to below Flat Branch								
Eagle Creek	**17.7**	**55.5**	**1**	**7**	**0**	**1**	**0**	**1**
Flat Branch	**0.1**	**54**	**1**	**7**	**0**	**1**	**0**	**1**
-020 Eagle Creek: below Flat Branch to Blanchard River								
Eagle Creek	**14**	**66**	**0**	**5**	**1**	**1**	**0**	**2**
Eagle Creek	**11.6**	**60.5**	**0**	**3**	**1**	**1**	**1**	**meets**
Eagle Creek	**9.1**	**64.5**	**0**	**2**	**1**	**1**	**1**	**meets**
Buck Run	**0.6**	**47**	**2**	**6**	**0**	**0**	**0**	**0**
Eagle Creek	**0.5**	**62.5**	**0**	**5**	**1**	**1**	**0**	**2**
-030 Blanchard River: below Eagle Creek to above Aurand Run								
Blanchard River	**57.8**	**46**	**1**	**8**	**0**	**1**	**0**	**1**
Blanchard River	**56.9**	**56.5**	**0**	**7**	**0**	**1**	**0**	**1**
WAU: Ottawa Creek (04100008-040)								
-010 Ottawa Creek: except Tiderishi Creek								
Ottawa Creek	**14.7**	**52**	**2**	**8**	**0**	**0**	**0**	**0**
Ottawa Creek	**10.1**	**62.5**	**0**	**7**	**1**	**1**	**0**	**2**
Ottawa Creek	**4.8**	**67**	**0**	**5**	**1**	**1**	**0**	**2**
-020 Tiderishi Creek								
Tiderishi Creek	**7.3**	**40**	**3**	**9**	**0**	**0**	**0**	**0**
Tiderishi Creek	**0.1**	**58**	**2**	**7**	**0**	**0**	**0**	**0**
-040 Moffitt Ditch								
Moffitt Ditch	**2.4**	**21**	**4**	**9**	**0**	**0**	**0**	**0**
-060 Dukes Run								
Dukes Run	**1.9**	**51**	**2**	**4**	**0**	**0**	**1**	**1**
WAU: Riley Creek (04100008-050)								
-010 Riley Creek: headwaters to above Little Riley Creek (upper)								
Riley Creek	**24.9**	**32.5**	**3**	**10**	**0**	**0**	**0**	**0**
Riley Creek	**22**	**22**	**3**	**10**	**0**	**0**	**0**	**0**
-020 Little Riley Creek (upper)								
Little Riley Creek (upper)	**2.6**	**50**	**1**	**8**	**0**	**1**	**0**	**1**

Stream/River (-0n0 = HUC 14)	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore			Total Habitat Score
					QHEI	High Influence	Modified	
Little Riley Creek (upper)	1	53.5	0	7	0	1	0	1
-030 Riley Creek: below Little Riley Creek [upper] to above Little Riley Creek (lower)								
Riley Creek	19.5	55.5	0	7	0	1	0	1
Marsh Run	1.7	33	4	11	0	0	0	0
-040 Little Riley Creek (lower)								
Little Riley Creek (lower)	5.4	25.5	5	10	0	0	0	0
Little Riley Creek (lower)	4.2	64.5	0	3	1	1	1	meets
Little Riley Creek (lower)	0.1	61	2	6	1	0	0	1
-060 Cranberry Run								
Cranberry Run	6.7	31.5	4	10	0	0	0	0
WAU: Cranberry Creek (04100008-060)								
-040 Miller City Cutoff								
Caton Ditch	3	47.5	1	7	0	1	0	1
-060 Deer Creek								
Deer Creek	1.6	32	5	11	0	0	0	0
Target (WWH)		≥60 = 1 pt	<2 = 1 pt	<5 = 1 pt				3 pts

4.2 Addressing Impairments on the Blanchard River Mainstem (Findlay)

The Blanchard River mainstem is not attaining aquatic life use (ALU) from RM 97.5 to 55.2 due to a suite of causes defined as organic enrichment and dissolved oxygen, nutrients, thermal modification, and habitat alteration. For the segment of mainstem traversing through the urban corridor of the City of Findlay (approximate RM 62 to 55), an instream-kinetics water quality model (Qual-2K) was constructed to simulate critical stream conditions and compare strategies for remediation. This Qual-2K model was implemented to address these specific urban-related, point-source and impoundment-related causes: thermal modification, nutrients, and organic enrichment and dissolved oxygen (Table 4.1). Some sources of aquatic life use impairment (related to the causes of nutrients and organic enrichment) are associated with crop production, combined sewer overflows (CSOs), and urban runoff. Crop production and urban runoff sources are addressed elsewhere in this chapter using the Generalized Watershed Loading Function (GWLF) model (Table 4.1). Allocations for point-source nutrient loads emanating from Findlay Water Pollution Control Facility (WPCF) as generated from the Qual-2K simulations (see S4-scenario results below) are described here.

The following conclusions can be made with respect to meeting water quality criteria/targets and possible restoration scenarios:

1) Water temperature: Increase the amount of woody vegetation in the form of tall, high canopy density deciduous trees along the entire course of the study area where feasible to reduce water temperature below the water quality standard of 27.8 °C. Further, temperature reductions will also be encouraged by the removal of the Findlay City Park dam and subsequent reforestation of the former reservoir basin.
2) Dissolved oxygen: Average dissolved concentrations are above the average criterion for the entire stretch of the study area with the exception of a very large drop at the City Park dam pool. By removing the Findlay City Park dam and reservoir, the average criterion is then met for the entirety of the study area. Concomitantly, the expansion of woody riparian vegetation along the length of th study area would reduce phytoplankton growth and thus increase minimum (diurnal) dissolved oxygen values.
3) Total Phosphorus: Reduce the effluent concentration from Findlay WPCF for total phosphorus from the current 1.0 mg-P/L NPDES monthly average limit to a 0.3 mg-P/L monthly average to meet an instream target 0.16 mg-P/L approximately 2 miles downstream.

Description of Qual-2K Model

Qual-2K is a one-dimensional, steady-state model which is used to simulate dissolved oxygen (DO), carbonaceous BOD (CBOD), algae as chlorophyll-a, organic and inorganic phosphorus, and the nitrogen series. The model considers stream reaeration from the atmosphere and sediment oxygen demand among other processes. Qual-2K is supported and distributed by US EPA and has been widely used for studying the impact of conventional pollutants on streams. The study area is divided into a sequence of reaches (Figure 4.1) and within each reach there exists 1-to-4 elements where physical/chemical processes are simulated as a steady-state (invariant with time) phenomenon. The Blanchard River (Findlay) study area was divided into 18 reaches with a headwater boundary established just upstream of the Findlay PWS (public water supply) intake (RM 62.6) and a downstream boundary established just upstream of the confluence with Oil Ditch (RM 54.05) (Figure 4.2). Each reach represents a stretch of river that has constant hydraulic characteristics (e.g., slope, velocity, bottom width, among others). While both the mainstem and tributaries can be modeled as interacting segments, for the Blanchard River (Findlay) model the tributaries were considered as fixed inputs (Figures 4.2 and 4.3). The entire course of elements for all reaches is considered a series of linked, “completely mixed reactors”. Each element, though, is a separate system which has an initial external input (from just upstream and/or laterally from seepage or tributary and wastewater inflow) and internal chemical reaction which either increase or decrease the parameter of concern (e.g., DO or temperature). The outflow from one element represents the inflow into the next downstream element.

For calibrating the Blanchard Qual-2K model, a field survey was conducted on August 1-3, 2006 where flow, bulk water chemistry, grab-sample water chemistry, composite-sample water chemistry, and cross-sectional profiles were measured over multiple locations of the mainstem and all significantly flowing incoming tributaries. The Qual-2K model was developed for August 2, 2006 when the streamflow at the USGS gauge (Figure 4.3) was 49.0 cfs. For developing the TMDL, the Qual-2K model was developed for critical stream conditions using a flow return interval of ${}_7Q_{10}$ (8.89 cfs). Critical stream conditions imply summer low stream flow and warm water temperatures, and wastewater effluent set to NPDES permit limits and design flow. A ${}_7Q_{10}$ flow is statistical value representing the minimum average 7-day flow with a recurrence-interval of 10 years. The ${}_7Q_{10}$ flow was calculated at the USGS gauge location using DFLOW (v. 3.1) for the period 1982-2007.

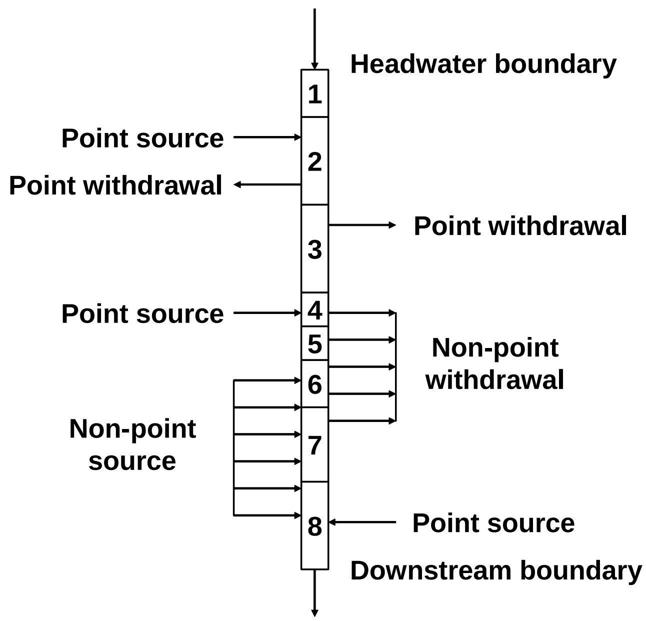


Figure 4.1. General segmentation scheme for the Qual-2K model showing reaches (numbered), boundary locations, and lateral inputs (or withdrawals). In this simplified scheme, tributaries are considered as fixed, point source inputs.

The Blanchard Qual-2K model uses two rating curves to describe two stream hydraulic characteristics – velocity and depth – as a function of channel flow (Q). The functional relationship for velocity (U) and depth (H) is described as:

$$U = aQ^b$$

$$H = \alpha Q^\beta$$

The coefficients (a and α) and exponents (b and β) are established from field survey. At a minimum, three field surveys are needed to establish reliable coefficients and exponents through a linear, least-squares regression analysis. Each survey produces one plotting point for fitting a linear model. Because only one time-of-travel field survey was performed for this TMDL, the exponents b (0.45) and β (0.55) were established near the midpoints of ranges provided in Chapra (1996). The leading coefficients (a and α) were then fixed to a single flow value measured on August 3, 2006 for a given Qual-2K reach. Results for the August 2006 time-of-travel survey show significant velocity decline in the reaches upstream of dam heads (Figure 4.3). A historical time-of-travel survey in 1983 produced comparable magnitudes of velocity. Field estimates of average channel width and depth for the same day were taken from three cross-sectional measurements – at the downstream end of reaches #4, #16, and #18 (Figure 4.4). The remaining 16 widths were measured from high resolution aerial photography from the Ohio Statewide Imagery Program (OSIP) using a LiDAR sensor for the period March-April 2006 (Ohio DAS 2006). The longitudinal slope of the water surface was estimated from USGS 1:24,000 topographic quadrangles where contour lines cross the mainstem (Figure 4.3).

The physical, chemical, and biological processes simulated by Qual-2K are represented by a set of equations that contain many parameters. Some parameters are established globally (applied to all of the 18 reaches) whereas other parameters are established locally and are unique for each reach. Appendix A and B contain the global rate constants and local reach rate constants, respectively. Description of these parameters and associated processes are defined in the Qual-2K model documentation (Chapra et al. 2006).

Upstream boundary conditions for the Qual-2K model were characterized by using monitoring data (flow and water chemistry) collected at RM 62.6 (Figure 4.4) during the August 1-3 2006 survey. Downstream boundary conditions were not established for the Blanchard Qual-2K model.

Diffuse sources are allowed in the Qual-2K model as uniformly distributed flow over the entire length of a reach. Often these are included in the simulation to ensure better balancing of flow and water chemistry at each monitoring station. For the Blanchard Qual-2K model, the flow and water chemistry balance for each monitoring station was satisfactory. No known evidence of distributed inflow (from groundwater and subsurface bank flow) was observed or documented. Hence, no diffuse sources were recognized in this modeling effort.

Point sources are recognized in the Qual-2K model as wastewater effluent and incoming tributaries (where they themselves are not simulated but considered as a fixed input). The sole wastewater source in the Blanchard Qual-2K model is the Findlay WPCF at RM 56.42 (within reach #16; Figure 4.4). Tributary inputs are defined in Table 4.3

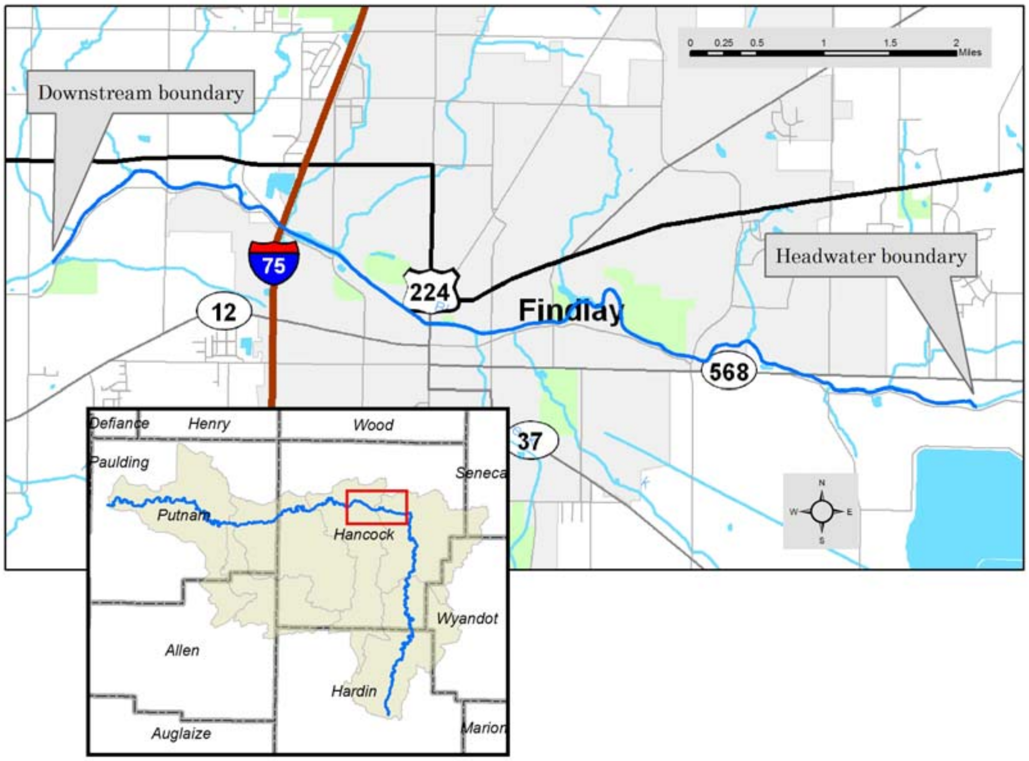


Figure 4.2. Longitudinal extent of Qual-2K modeling analysis with respect to City of Findlay and Blanchard River watershed.

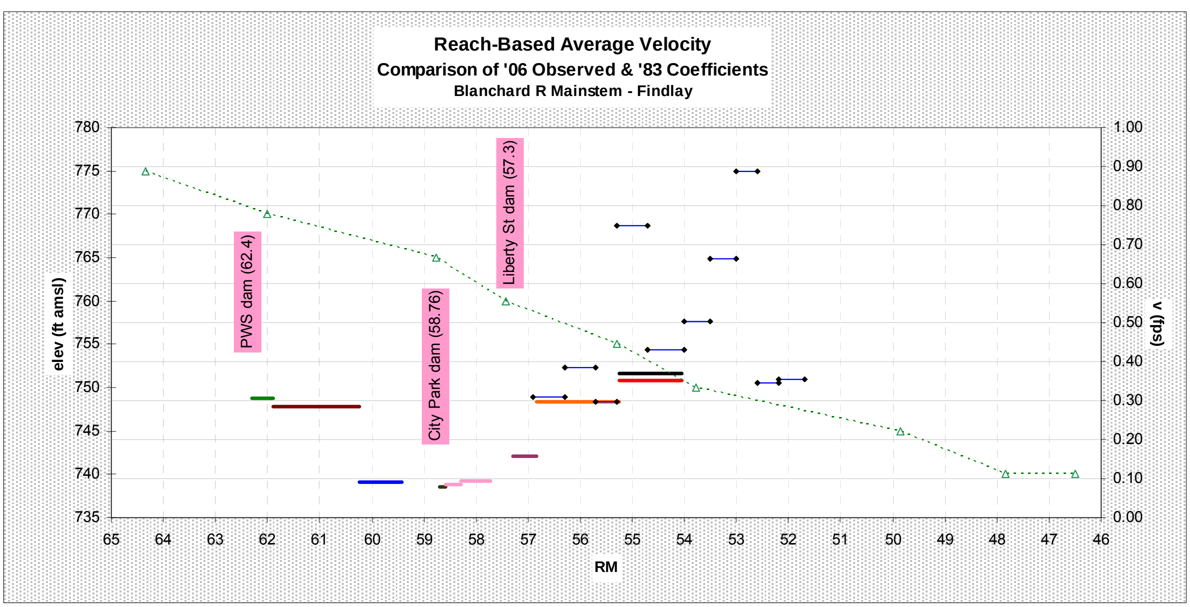


Figure 4.3. Determination of average reach velocity (ft/s) from field-based survey for August 2006 conditions (multi-color) and a 1983 historical survey (thin blue). Topographic elevation derived from 1:24,000 USGS quadrangles depicted in dashed-green.

Table 4.1. Causes of ALU impairment (as listed in 2007 TSD) within the Qual-2K modeled river segment of the Blanchard R mainstem and corresponding approaches for TMDL development.

HUC	Description	River Mile	Causes	TMDL Development			
				Qual-2K nutrient/DO /temp	GWLF nutrient	QHEI habitat/flow	QHEI sediment
-020-040	Blanchard R mainstem	61.7/61.9	organic enrichment		x		
			nutrients		x		
			thermal modification	x			
-030-030		57.8/57.9	thermal modification	x			
			organic enrichment/DO	x			
			habitat alteration (development-related)			x	
			siltation				x
		57.3	habitat alteration				
			thermal modification	x		x	
			nutrients		x		
			organic enrichment/DO	x			
		56.9/56.8	thermal modification	x			
			nutrients		x		
			habitat alteration (development-related)			x	
		55.2/54.7	nutrients	x	x		
			organic enrichment/DO	x			
			thermal modification	x			

Table 4.2. Description of the 18 Qual-2K reaches used in the Blanchard River (Findlay) simulation.

Reach#	Description	Downstream End	Length (m)	Length (ft)
1	PWS reservoir	PWS dam head (RM 62.4)	322	1056
2	DST PWS dam	Harold Shafer Ditch (RM 61.9)	805	2640
3	Rush Ck inflow	RM 60.25	2655	8712
4	Upper City Park reservoir	RM 59.4	1368	4488
5	Lower City Park reservoir	RM 58.97	692	2270
6	City Park dam vestibule	City Park dam head (RM 58.76)	338	1109
7	DST City Park reservoir	Lye Ck (RM 58.3)	740	2429
8	Riffle #1 vestibule	R1 (RM 58.24)	97	317
9	Lye Ck & Eagle Ck intervening	Eagle Ck (RM 58.1)	225	739
10	Upper Liberty St dam pool	RM 57.73	595	1954
11	Riffle #2 vestibule	Riffle #2 (RM 57.45)	451	1478
12	Lower Liberty St dam pool	RM 57.42	48	158
13	Liberty St dam vestibule	Liberty St dam head; Riffle #3 (RM 57.3)	193	634
14	Riffle #4 vestibule	Riffle #4 (RM 57.0)	483	1584
15	Downstream Liberty St dam	UST Howard Run (RM 56.83)	274	898
16	Findlay WPCF; Howard Run	I-75 bridge (RM 56.3)	853	2798
17	Downstream I-75 bridge	USGS gauge (RM 55.26)	1674	5491
18	Upstream Oil Ditch	Oil Ditch (RM 54.0)	2028	6653

Table 4.3. Definition of tributary inputs (considered as fixed point sources) into the Blanchard Qual-2K model.

Tributary (monitoring location)	Reach #	RM	Drainage Area (mi^2)
Harold Shafer Ditch @ SR 568	2	61.99	4.9
Un-named Tributary @ Saratoga Dr (Rush Ck)	3	60.75	1.8
Hagerman's Run	5	58.97	1.1
Lye Ck	7	58.38	27.9
Eagle Ck @ Lincoln St	9	58.10	61.0
Howard Run	15	56.80	4.8
Dalzell Ditch	16	56.35	1.1
Un-named Tributary @ US 224 (W of River Rd)	17	55.76	1.6
Un-named Tributary @ US 224 (W of CR 140)	18	54.96	1.7
Un-named Tributary downstream CR 139	18	54.30	4.2

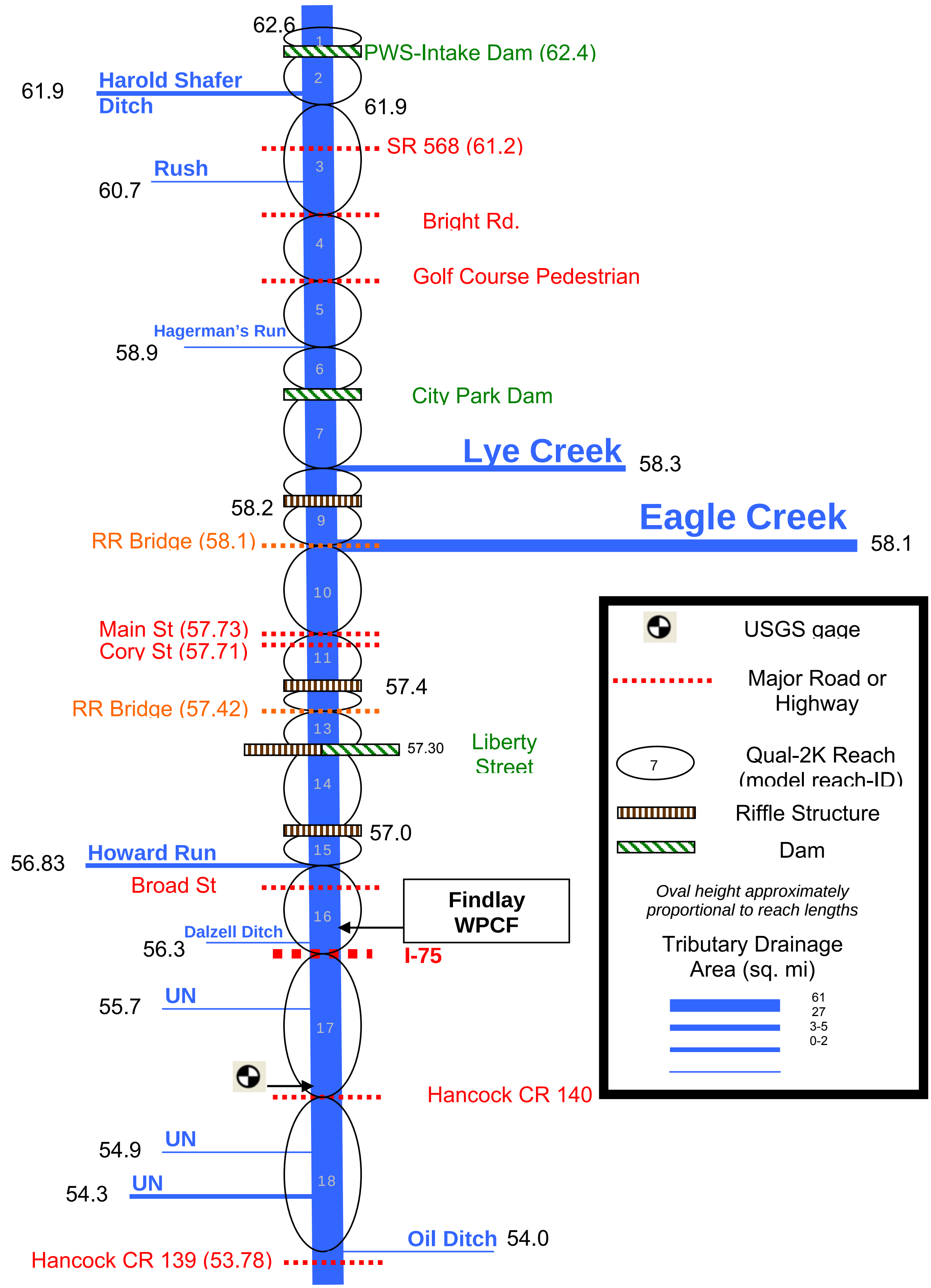


Figure 4.4. Schematic showing Qual-2K reach segments (ovals) for the Blanchard

River mainstem (Findlay), locations of existing dams and 2007-installed riffle structures, road crossings, tributaries, and corresponding river mile-markers.

Calibration of Qual-2K Model for the Blanchard River (Findlay) Mainstem

The Blanchard Qual-2K model was calibrated for flow, water temperature, dissolved oxygen, phytoplankton, nitrate, and phosphorus species (both total and inorganic) from measurements taken during the August 2006 field survey. These measurements included instream mainstem and tributaries, and Findlay WPCF effluent. Model calibration results for water temperature (Figure 4.6), dissolved oxygen (Figure 4.8), phytoplankton (Figure 4.9), phosphorus species (Figure 4.10), and nitrate (Figure 4.11) are discussed below. Model predicted average values are presented as a solid line whereas model minimum and maximum values are shown as red-dashed lines. Observed values are shown as single point icons.

Longitudinal nitrate concentrations were calibrated very well (Figure 4.11) showing a decline in a downstream direction until a large dose is presented by the Findlay WPCF into the mainstem. Nitrate target values for meeting the aquatic life beneficial use are not available for Ohio at this time so no criterion is shown. Also, evidence of nutrient co-limitation (phosphorus and nitrogen) was not demonstrated by field biologists for the Blanchard River mainstem; hence, no restoration scenarios for nitrate reduction will be presented.

A critical factor in simulating the longitudinal distribution of water temperature in the Qual-2K model is an accurate depiction of shading of solar radiation on the water surface. The effective shade of a water surface is defined as the fraction of solar radiation that is blocked because of shade from topography and vegetation. High resolution digital topography (1 m) and aerial photography (1 m) data was processed to more accurately depict the longitudinal pattern of shade along the Blanchard River (Findlay) mainstem. Both data sources were obtained from OSIP (Ohio DAS 2006). Vegetation classes were manually digitized within a 91 m (300 ft) buffer from each left and right bank according to the classification shown in Table 4.4 (Figures 4.20 and 4.21). An additional class entitled “bridge deck” was added to simulate 100% shade on road crossings over the Blanchard River mainstem.

Hourly effective shade was built from an algorithm developed by State of Washington Department of Environmental Quality (2007) for processing vegetation height, canopy density, bank overhand, and topographic elevation. Latitude, compass direction, day of year, and time of day are also incorporated into the algorithm. Typical mid-day effective shade is below 25% whereas dawn-dusk shading increases to 50-90% (Figure 4.5.). Reach #12 and #18 produce the highest mid-day effective shade at 20-25%.

The water temperature simulation also involved hourly weather data (including air and dewpoint temperature, wind speed, and cloud cover); this information obtained from Weather Underground (2007). For times of day when cloud cover was listed as cloudy or partly cloudy, the METAR[a] code was used. For example, FEW034 is defined as 1/8 to 2/8 cloud cover at 3400 ft and the midpoint was calculated as 3/16 or 18.8%.

Calibration of the longitudinal distribution of water temperature was fit very closely (Figure 4.6). The trace shows a general increase in temperature within the dam pool regions (both City Park and Liberty Street dams) between RM 60.2 and RM 56.6, and then a sudden decline in temperature once Findlay WPCF effluent enters the mainstem at RM 56.32. The average temperature criterion (27.8 °C) was violated throughout the upper two-thirds of the study area, but especially in the reservoir portions of the mainstem. The criterion was nearly met between the headwaters and RM 60.3, and this is mainly attributed to an established wooded riparian corridor with large deciduous trees (Figure 4.5; reach #1 through #3). The maximum temperature criterion (29.4 °C) was violated throughout the study area (except at the Findlay WPCF mixing zone) compared to model maximum simulations, though these values may be less reliable than model averages.

When examining observed values (Figure 4.6), the monitoring results at RM 59.4 and 59.0 are not representative of ambient conditions as the multi-parameter datasondes were placed near the bottom of the dam pool. Instantaneous measurements of water temperature measured at mid-depth showed much higher values for the same date. Instrument error was associated with the low value realized at RM 57.42.

[a] METAR is the aviation routine weather report and is a contraction of MÉTéorologique ("Weather") Aviation Régulière ("Routine").

Table 4.4. Land-cover classes defined by height, canopy density, and bank overhang used in computing hourly effective shade.

Land-Cover Description	Height (m)	Density (%)	Overhang (m)
Water	0	0%	0.0
River Bottom – Floodplain	0	0%	0.1
Pastures/Cultivated Field/Lawn	0	0%	0.1
Young Orchard	3	75%	0.5
Mature Orchard	12.2	75%	1.9
Barren – Embankment	0	0%	0.0
Barren – Clearcut	0	0%	0.0
Clearcut, below 50% dense regeneration	4.6	25%	0.2
Lumber Yard	0	0%	0.0
Barren – Road	0	0%	0.0
Barren – Railroad	0	0%	0.0
Barren - Agr Road	0	0%	0.0
Large Hardwood	22.9	75%	6.8
Small Hardwood	12.2	75%	3.2
Large Hardwood	22.9	25%	6.8
Small Hardwood	12.2	25%	2.7
Large Conifer	27.4	75%	5.3
Small Conifer	12.2	75%	1.5
Large Conifer	27.4	25%	5.3
Small Conifer	12.2	25%	1.5
Shrubs	4.6	75%	0.2
Shrubs	4.6	25%	0.2
Grasses	1	75%	0.1
Developed – Residential buildings	6.1	100%	0.0
Developed – Industrial buildings	9.1	100%	0.0
Dam	0	0%	0.0
Pipeline	0	0%	0.0
WWTP	0	0%	0.0
Bridge Deck	10	100%	30.0

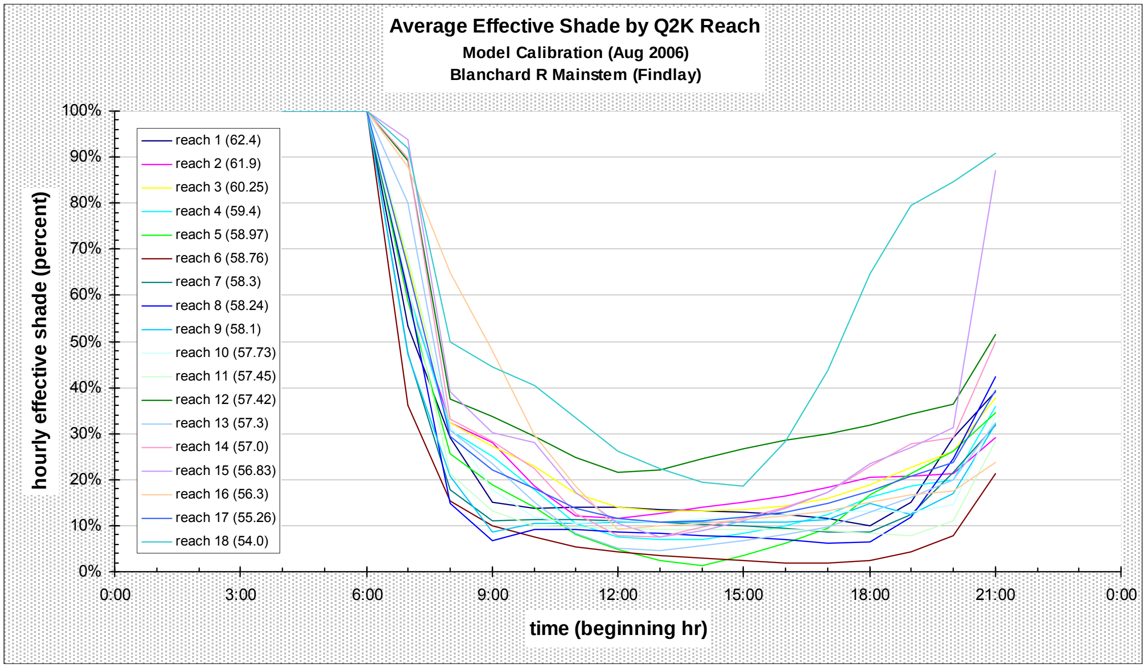


Figure 4.5. Hourly distribution of effective shade for each of the 18 Qual-2K reaches that extend through the Blanchard River (Findlay) study area.

Calibration of the longitudinal distribution of dissolved oxygen (DO) was fit reasonably well (Figure 4.7). There was difficulty in fitting the model to the observed concentration at RM 54.05, even after increasing the sediment oxygen-demand rate in the Qual-2K model. The observed low value at RM 54.05 was confirmed by the average of 2005 summer sampling (the average of instantaneous measurements was 5.48 mg/L). DO concentrations decline progressively from the headwater boundary downstream into the City Park dam pool. Within this pool and slightly upstream (RM 60.4 to RM 59.0), violations of average and minimum water quality criteria occur. Concentrations subsequently increase as flow moves over the 7.6 ft City Park dam head and remain high through the Liberty Street dam pool and Findlay WPCF mixing zone. Values of the reaeration constant contribute to this increase in DO concentration (Figure 4.8) and are discussed below. Observed values for DO were obtained from multi-parameter datasondes. Values at all locations are valid with the exception of instrument error for the sample at location RM 55.26.

Reaeration constants (k_a) that govern the mass transfer of oxygen between the atmosphere and the water column were generated from typical equations customized for Ohio conditions. When two choices for a prescribed k_a were valid given discharge, depth and velocity conditions, the smaller magnitude was chosen given that very low values were measured in 1983 Ohio EPA field surveys. For reaches that contained dam heads at their downstream boundary (reach #1, #6, and #13), k_a was set artificially high (Figure 4.8). By default (and apparently not modifiable in Qual-2K, v. 2.04), values of the water-quality coefficient (a_d) and dam type (b_d) were set at 1.25 (moderate pollution) and 0.9 (flat broad-crested irregular step), respectively. Physical dimensions of the three dam structures and the four recently installed riffle structures are shown in Table 4.5. The largest structure is City Park dam whereas the Liberty Street dam has since been removed (Spring-Summer 2007) and replaced with a lower height structure (see riffle #3 in model application section).

Table 4.5. Physical dimensions and information sources of instream impoundment structures for the Blanchard River mainstem within the Qual-2K study area.

Location	Height (ft)	Width (ft)	Information Source
PWS-intake	4.0	66.0	PWS facility
City Park	7.6	190.3	Findlay City Engineer
Liberty Street	8.75	101.5	Findlay City Engineer
Riffle #1	5.0	115.0	NRCS construction drawings
Riffle #2	4.5	117.5	NRCS construction drawings
Riffle #3 (former Liberty Street dam)	4.15	101.5	NRCS construction drawings
Riffle #4	3.5	28.0	NRCS construction drawings; width estimated from OSIP aerial photography

Model simulation of phytoplankton (measured as a concentration of chlorophyll-a) was fit reasonably well to observed data (Figure 4.9). Water column concentrations of chlorophyll-a were analyzed from filter bioassays where the resultant slurry was read by Turner Designs Model TD-700 fluorometer. The longitudinal trace of phytoplankton increases with downstream distance and shows marked increases within the dam pools (both Liberty Street and City Park reservoirs) and beyond the Findlay WPCF mixing zone (RM 56.0 to RM 54.0). Increases in phytoplankton growth are representative of an enhanced nutrient supply (both inorganic-P and nitrate) and light availability caused by reduced effective shade.

Inorganic phosphorus concentrations simulated by the Qual-2K model closely matched observed concentrations (Figure 4.10). However, total phosphorus concentrations (TP) (which is a combination of inorganic-P, organic-P, and chlorophyll-a) were not simulated correctly in the middle portion of the study area. However, TP concentrations were simulated exactly near the headwaters and downstream portions of the mainstem. This inexact fit stems from the inability of the Qual-2K model to capture organic-P variation (results not shown). The pooled area between RM 60.0 and RM 56.5 is likely generating phosphorus *internally* - from algal growth, distributed sources (groundwater), or sediment. It is likely Qual-2K cannot simulate these lentic processes correctly.

A sharp increase in both total and inorganic phosphorus was realized once Findlay WPCF effluent enters the mainstem. The target concentration (0.16 mg/L) of total phosphorus was exceeded from this point downstream (RM 56.3 to RM 54.0 and beyond). The target value was derived from Ohio EPA (1999) for the Eastern Cornbelt Plains Ecoregion (ECBP), small-river drainage systems, and for achieving an IBI score above 40 units.

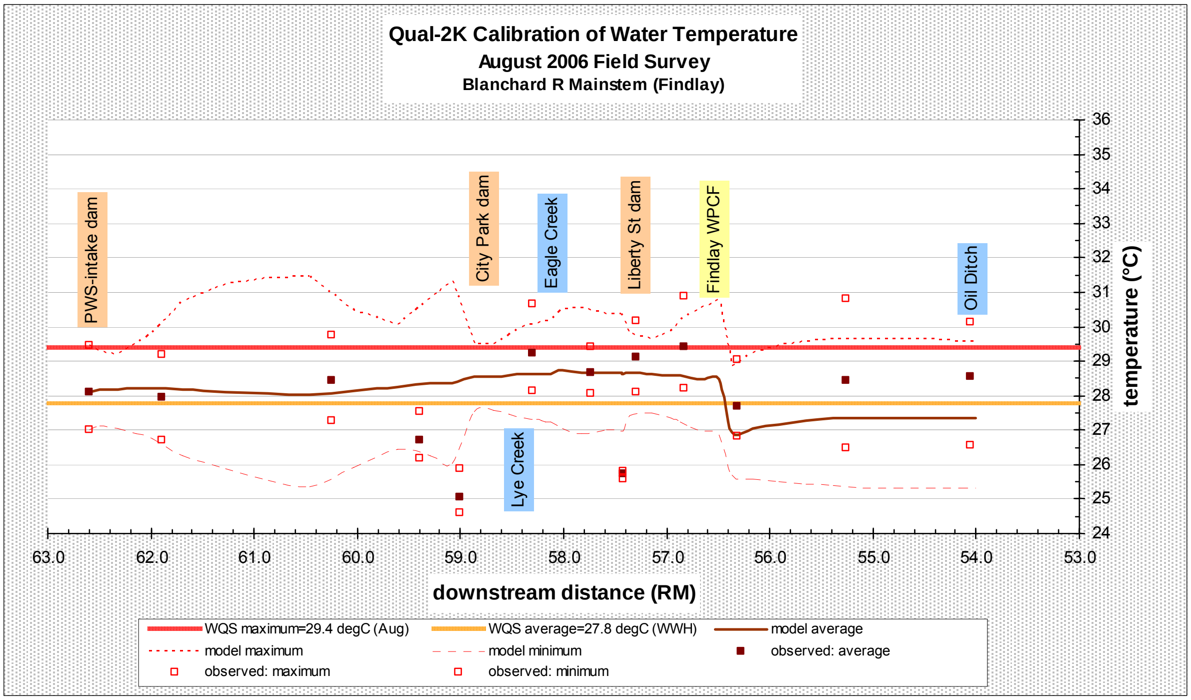


Figure 4.6. Longitudinal distribution of model-predicted water temperature (average, minimum, maximum) compared to observed temperature and average/maximum temperature criteria.

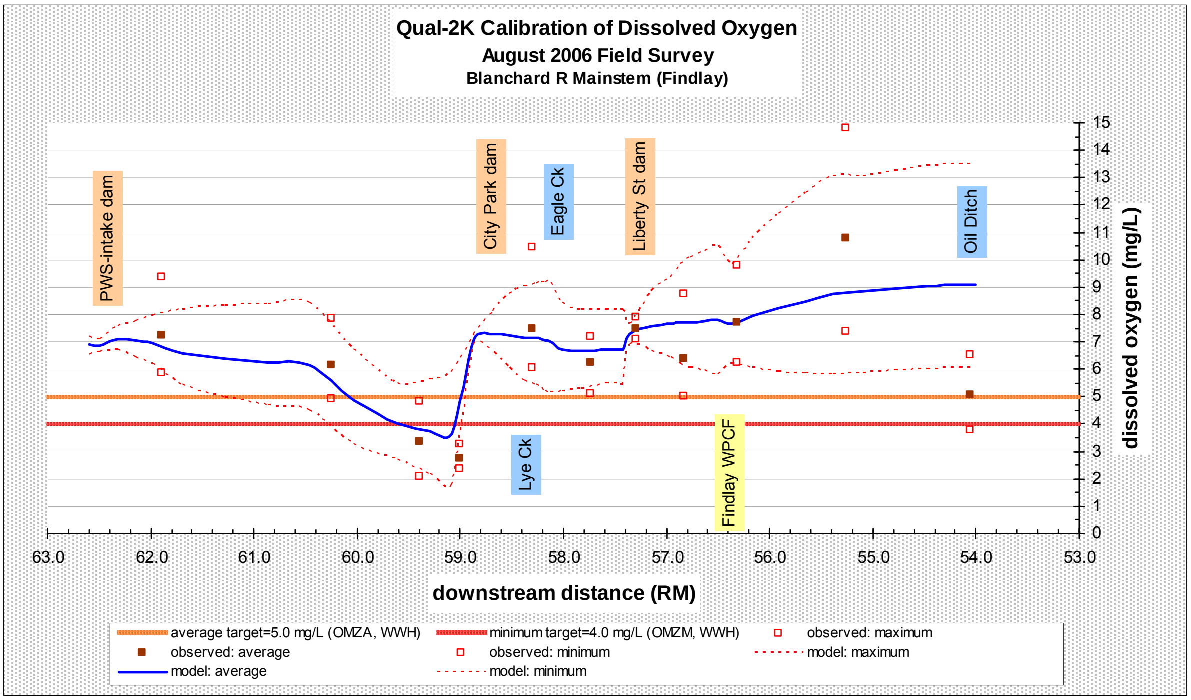


Figure 4.7. Longitudinal distribution of average and minimum/maximum model-predicted dissolved oxygen concentrations compared to observed concentrations and average/minimum water quality criteria.

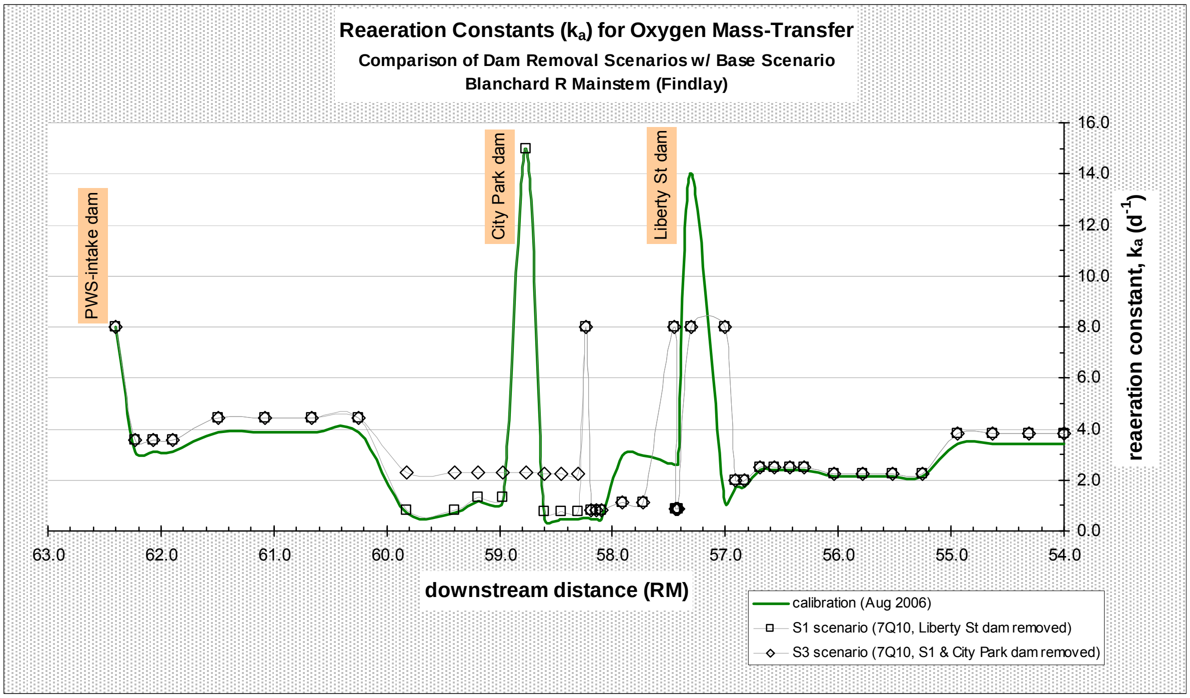


Figure 4.8. Longitudinal distribution of reaeration constant (k$_a$) as function of model scenario and location of dam heads.

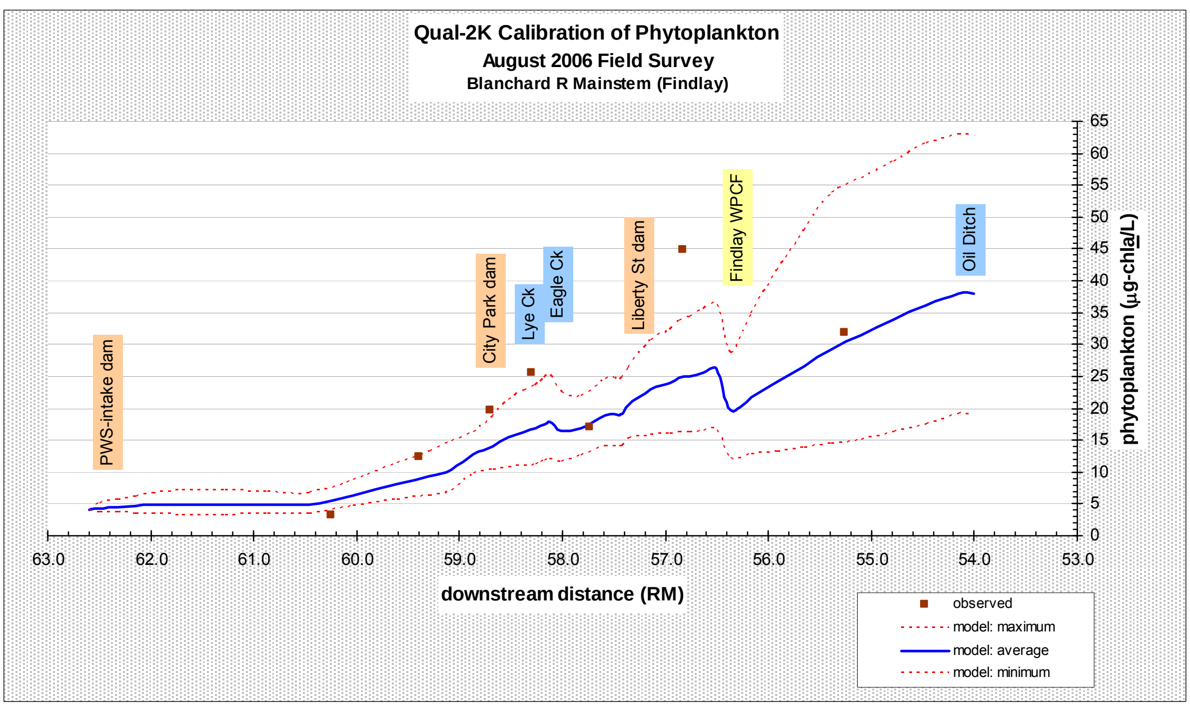


Figure 4.9. Longitudinal distribution of model-predicted phytoplankton concentration compared to observed values.

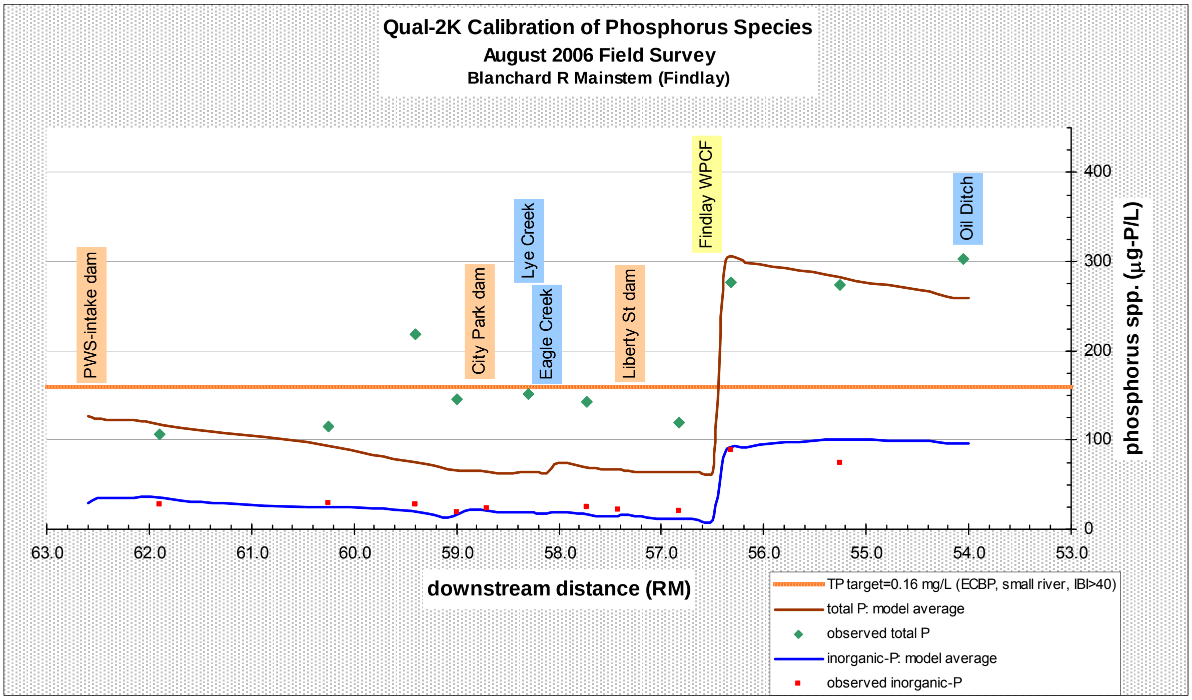


Figure 4.10. Longitudinal distribution of model-predicted total phosphorus and inorganic phosphorus (ortho-phosphate) concentrations compared to observed values and total phosphorus water quality criterion.

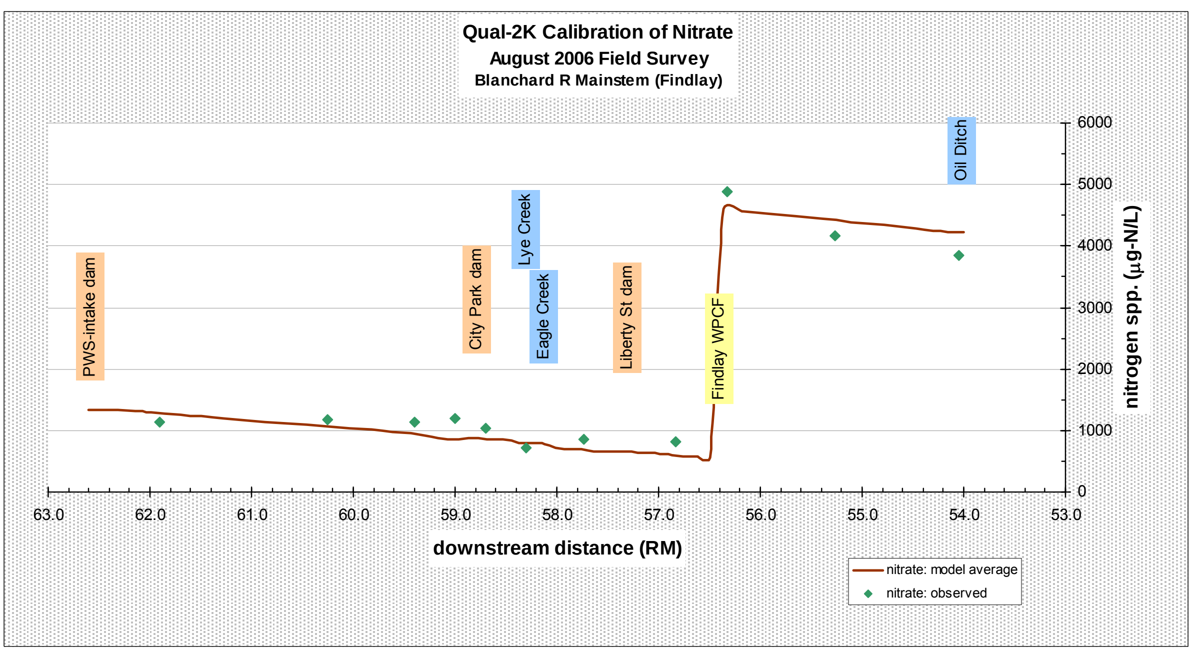


Figure 4.11. Longitudinal distribution of model-predicted nitrate concentration compared to observed values.

Restoration Scenarios Generated from Blanchard Qual-2K Modeling

Calibrated model rates were used with August 2006 water chemistry data for tributaries to simulate water quality conditions for the Blanchard River (Findlay) mainstem during the critical summer-month, low flow period. It is assumed that summer critical streamflow is at ${}_{7}Q_{10}$ levels, and tributary flow inputs were adjusted accordingly. Water temperature, daylight length, and sun angle reflect August conditions.

The first model scenario (S1) was constructed to match existing conditions (2007 and beyond). During the August 2006 Ohio EPA survey, the Liberty Street dam was intact. In the period following, the dam was cut in half vertically (from 8.75 ft to 4.15 ft) (Table 4.5) and an additional three riffle structures were installed on the mainstem (Figure 4.4). Physical dimensions for these four recently (Spring-Summer 2007) installed riffle structures were obtained from construction drawings for the Upper Blanchard River Watershed Project (USDA Natural Resources Conservation Service 2001) (Table 4.5). Wooded bank vegetation was also cleared on the downstream, right edge-of-water (north bank). Thus, the S1-scenario includes the above changes but also is simulated at conservative stream conditions (Table 4.5). Critical stream conditions are defined here as a critical low flow (${}_{7}Q_{10}$) for the mainstem and tributaries, effluent flow at design conditions for the Findlay WPCF, an upstream boundary water quality at background concentrations. For estimating background concentrations of total phosphorus, the average of six grab samples from 2005 was used.

Three other model scenarios (named S2, S3, and S4) were generated to explore water quality improvements. One scenario (S2) expanded the amount of riparian wooded vegetation along the entire mainstem corridor where feasible (Figure 4.20). The S2-scenario expands the area of high canopy density (>75%), tall (22.9 m or 75 ft) hardwood with large bank overhang (6.9 m or 22 ft) along a 15 m buffer from each bank of the Blanchard River mainstem. Some existing land uses were excluded from this riparian reforestation scenario including roads, buildings, and developed infrastructure. The hourly distribution of effective shade for reach #14 (Figure 4.4) decreases slightly for the S1-scenario (bank clearing) but increases considerably for the S2-scenario (Figure 4.13). Overall, the effective shade improves remarkably (typically from 15% to 50%) over the entire mainstem for S2-scenario (Figure 4.15).

The approach in the S3-scenario was to explore an alternative to S2-scenario (15 m forest buffer) by removing the City Park dam (RM 58.76) – thereby removing the instream reservoir and reducing upstream channel width and subsequently providing increased shading, increased flow velocity, and decreased channel depth (Figure 4.21). Like the S2-scenario, the goal in the S3-scenario is to reduce water temperature below the average and maximum criteria and increase DO above the average and minimum criteria. Hourly distribution of effective shade for reaches #5 and #6 (Figure 4.4) increases considerably for the S3-scenario (Figure 4.14). Phytoplankton growth would likely be reduced when moving from a reservoir (lentic) to a channel (lotic) environment and thereby improve DO minimum concentrations. This scenario was implemented mechanistically by adjusting the Qual-2K model by setting velocity to 0.0914 m/s (0.3 fps) and water depth to 0.5791 m (1.9 ft) for reach #4 through #7 (Figure 4.4). Given these changes in velocity and depth, reaeration constants for these same reaches were adjusted from 0.42-15.0 d^{-1} in S1 to 2.23-2.27 d^{-1} in S3 (Figure 4.8). Hence the average of the reaeration constants for these four reaches was increased to 2.27 d^{-1} from 0.58 d^{-1}.

The S2-scenario reduces the average water temperature remarkably below the water quality criterion of 27.8 °C (Figure 4.12). The criterion is met in nearly 100% of the length. The S3-scenario also reduces water temperature below the criterion but, as expected, not as widespread as the S2-scenario (Figure 4.12). The reduction in water temperature is evident at the former City Park reservoir of S3-scenario (RM 60.5 to RM 58.5) and the water quality criterion is now met there.

Under critical streamflow conditions, model simulated average DO remains above the average water quality criterion of 5.0 mg/L in the S1-scenario (Figure 4.16). Criterion exceedence also occurs downstream of the Findlay WPCF (RM 56.42). The facility has relatively high DO and acceptable CBOD NPDES permit limits so it is unlikely any gains can be met through effluent adjustments. The biggest gain in meeting the criterion occurs with the removal of City Park dam and reservoir (S3-scenario) where, using estimated reaeration coefficients, DO concentrations fall drastically in S1 and S2 (Figure 4.16; RM 60.6 to RM 59.1). Once the dam and reservoir are removed, DO concentrations remain above the 5.0 mg/L criterion. These predictions would likely improve by incorporating a river hydraulics model, like HEC-RAS, to simulate stream velocity and depth where instream structures have been hypothetically removed.

The S2-scenario (wooded riparian) does little to improve DO concentrations as its longitudinal trace follows that of the S1-scenario (Figure 4.16). However, the S2-scenario is more effective at reducing phytoplankton growth (Figure 4.17) and the subsequent diurnal variation in DO.

Based on the simulations generated in Scenario 2 and Scenario 3 to improve temperature and DO conditions in the Blanchard R mainstem, an ideal restoration scenario would include characteristics of both. Though this scenario was not simulated and thus results not presented here, the highest improvement in temperature and DO conditions would result from removing the City Park dam and subsequently reforesting the former reservoir area along with reforesting a 15 m buffer along the mainstem where ever feasible.

Scenario 4 (S4) was constructed to examine alternative concentrations of total phosphorus from the City of Findlay wastewater effluent in meeting the downstream target of 0.16 mg/L (Table 4.5). The downstream target was arbitrarily set at RM 54.05 which is just upstream of the Oil Ditch-Blanchard River confluence. The S1-scenario considers a total phosphorus effluent concentration of 1 mg/L, the current NPDES permit limit for a monthly average. S4-scenario also considers effluent concentrations of 0.5 and 0.3 mg/L, which could likely represent a monthly average permit limit. As seen in Figure 4.18, the downstream target is met only with the simulation using a 0.3 mg/L total phosphorus effluent concentration. At critical streamflow conditions, the total phosphorus load from Findlay WPCF dominates the instream load because the upstream (background) concentration is small and effluent flow is large (Figure 4.19).

Nitrate reduction scenarios were not generated because evidence of nutrient co-limitation on aquatic plant growth (including algae) was not substantiated (R Miltner 2007, personal communication).

Table 4.5. Description of alternative scenarios for TMDL allocation employed to address ALU impairment and WQS violations for temperature, dissolved oxygen, and total phosphorus.

Scenario Description	Q (cfs)	Instream Structures	Floodplain Vegetation	Findlay (2PD0008) WWTP Effluent		Upstream Boundary	Stream Characteristics: velocity (U), depth (H), temperature, and reaeration
				Q (mgd)	Parameter Concentration (mg/L)	TP (mg/L)	
Calibration	● mainstem (USGS gauge): 49 (Aug 2006) ● Eagle Ck: 4.17 (Aug 2006) ● Lye Ck: 1.23 (Aug 2006) ● other tributaries: varies (Aug 2006)	● PWS dam ● City Park dam ● Liberty St dam	● OSIP data (Mar-Apr 2006)	9.45 (14.6 cfs)	TP=0.871 (Aug 2006)	0.127 (Aug 2006)	velocity, depth, temperature (Aug 2006)
S1: Modify instream structures; vegetation clearing; conservative stream conditions	● mainstem (USGS gauge): 8.89 ($_7Q_{10}$; 1982-2007) ● Eagle Ck: 1.57 ($_7Q_{10}$ area-yield) ● Lye Ck: 0.72 ($_7Q_{10}$ area-yield) ● tributaries: varies ($_7Q_{10}$ area-yield)	● Liberty St dam removed ● 4 riffle structures installed	● same as calibration stage but trees cleared and replaced w/ grass on N bank DST Liberty St dam; 1.84 ha (4.55 Ac) removed	15.0 (23.21 cfs) (design flow)	● TP(monthly) = 1.0 ● DO(summer) = 6.7 ● $CBOD_{20}$(summer) = 22 ● NH_3(summer)= 1.4	0.081 (Jun-Aug 2005)	● increase U and decrease H for reaches #13 and #14 (near Liberty St dam) ● velocity and depth dependent on Q as: $U=aQ^b$ (b=0.45) $H=\alpha Q^\beta$ (β=0.55) ● temperature maintained as Aug 2006 ● reaeration adjusted dependent on U, H, and Q.
S2: Increase shading near stream by tree planting (medium and tall height) ; conservative stream conditions	● same as S1	● same as S1	● same as S1 and replace non-forested floodplain w/ forest; 35.0 ha (85.4 Ac) added; 15 m setback from each bank	● same as S1	● same as S1	● same as S1	● same as S1

Scenario Description	Q (cfs)	Instream Structures	Floodplain Vegetation	Findlay (2PD0008) WWTP Effluent		Upstream Boundary	Stream Characteristics: velocity (U), depth (H),
S3: Remove City Park dam; increase shading at former reservoir; conservative stream conditions	● same as S1	● same as S1 and remove City Park dam	● replace former City Park reservoir and L/R bank for 600 m UST w/ forested floodplain; 5.0 ha (12.4 Ac) added ● reduce channel width UST of City Park dam ● all other floodplain conditions same as S1	● same as S1	● same as S1	● same as S1	● same as S1 and increase U and decrease H for reaches #6 and #7 (near City Park dam); reaeration adjusted for same
S4: Reduce total phosphorus concentration in Findlay WWTP effluent to 0.3 mg/L.	● same as S1	● same as S1	● same as S1	● same as S1	● TP(monthly)=0.3 and 0.5 ● all other parameters same as S1	● same as S1	● same as S1

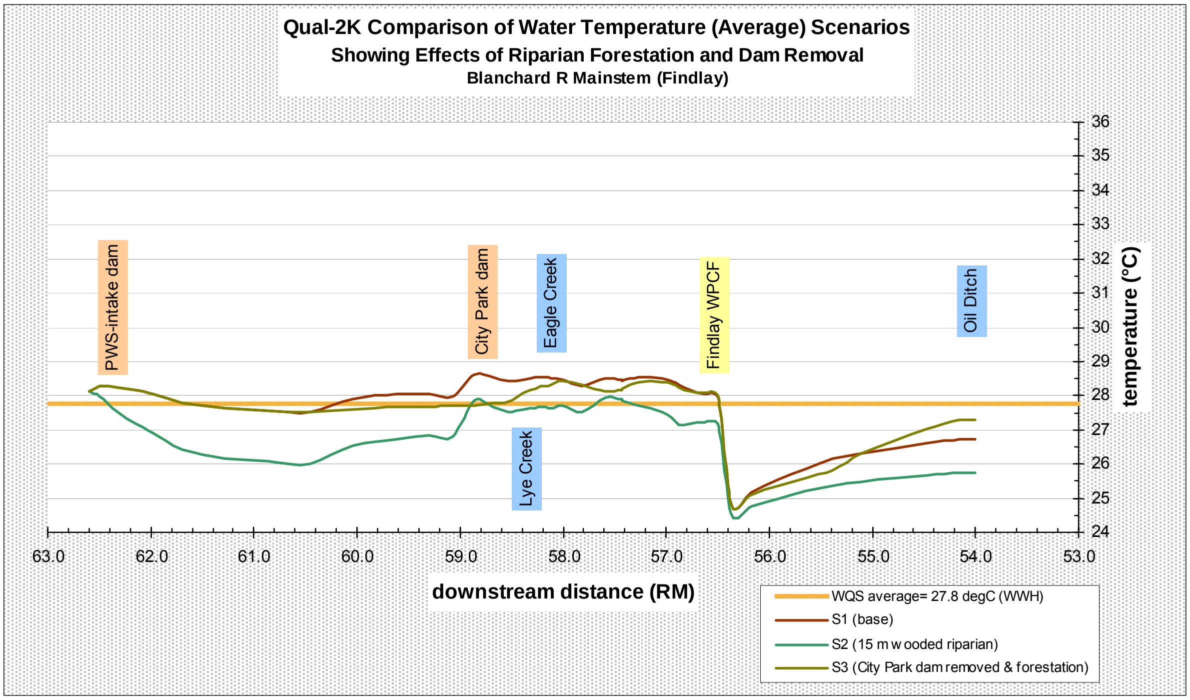


Figure 4.12. Longitudinal distribution of average water temperature generated by three Qual-2K scenarios: S1 (base scenario), S2 (15 m reforestation on each bank where feasible), and S3 (removal of City Park dam and subsequent reforestation of reservoir area).

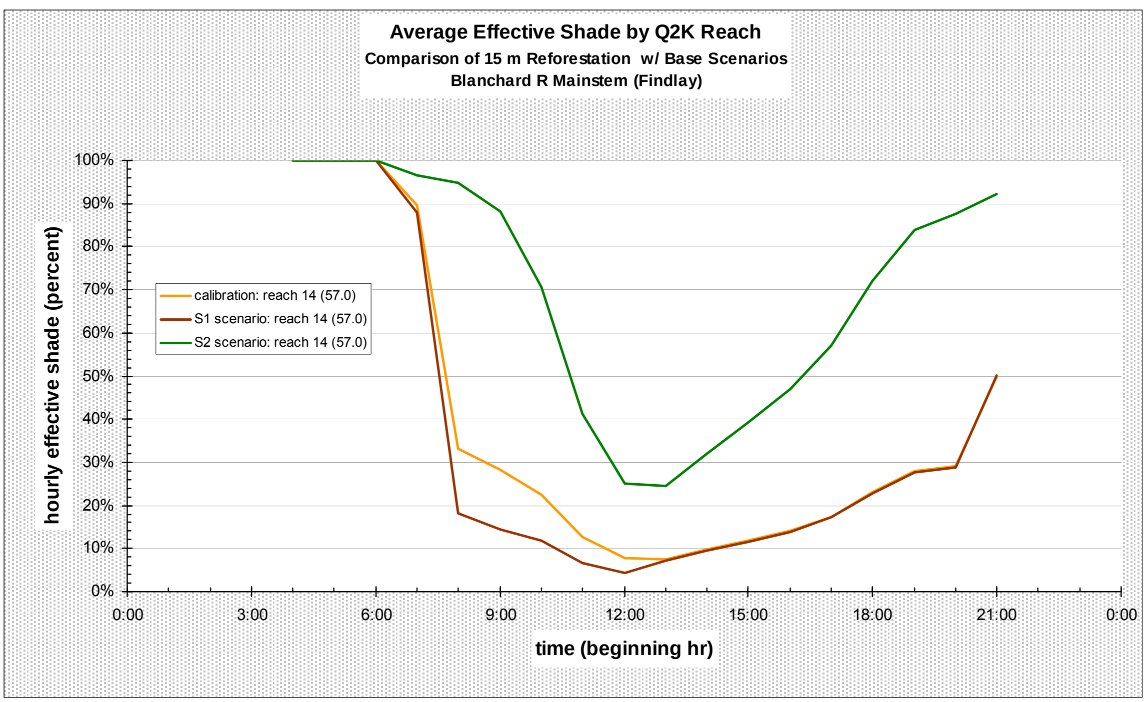


Figure 4.13. Comparison of average (daily) effective shade for reach #14 which is just downstream of the former Liberty Street dam. The longitudinal trace shows the calibration simulation where the north bank just downstream of Liberty Street dam as

fully wooded, S1 scenario with the same bank vegetation removed, and S2 scenario with 15 m wooded vegetation each bank.

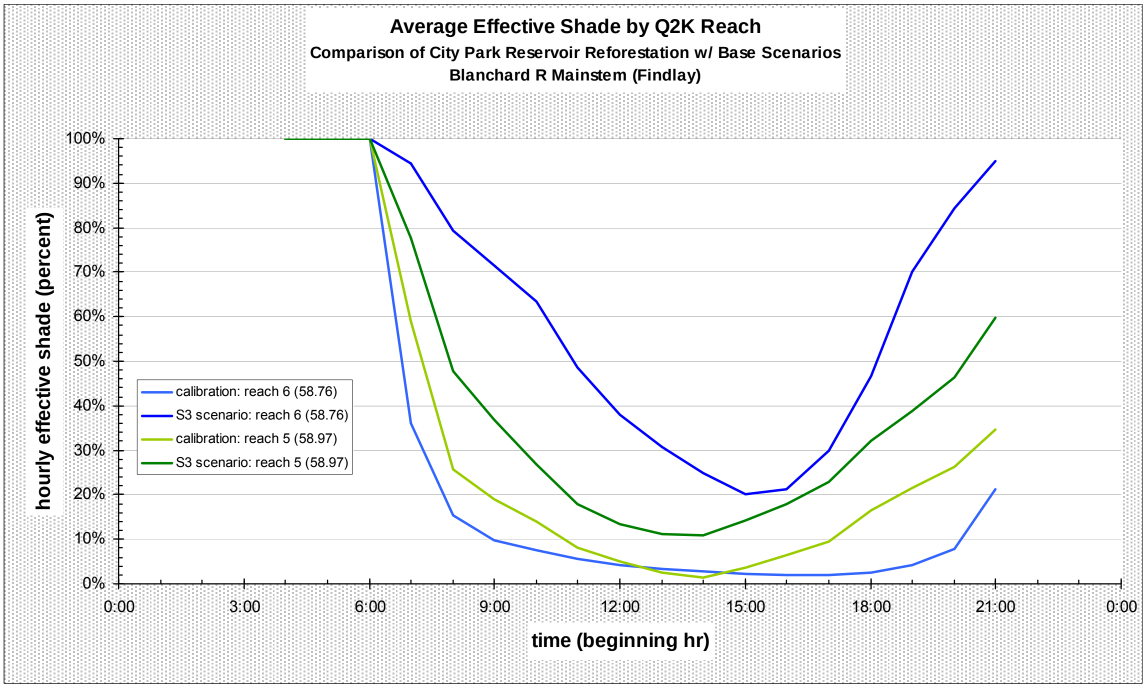


Figure 4.14. Hourly distribution of effective shade (as a percent of total incoming solar radiation reduced by topography and vegetation) for Qual-2K reaches #5 and #6 showing base scenario (calibration) and City Park dam removal and reforestation (S3-scenario).

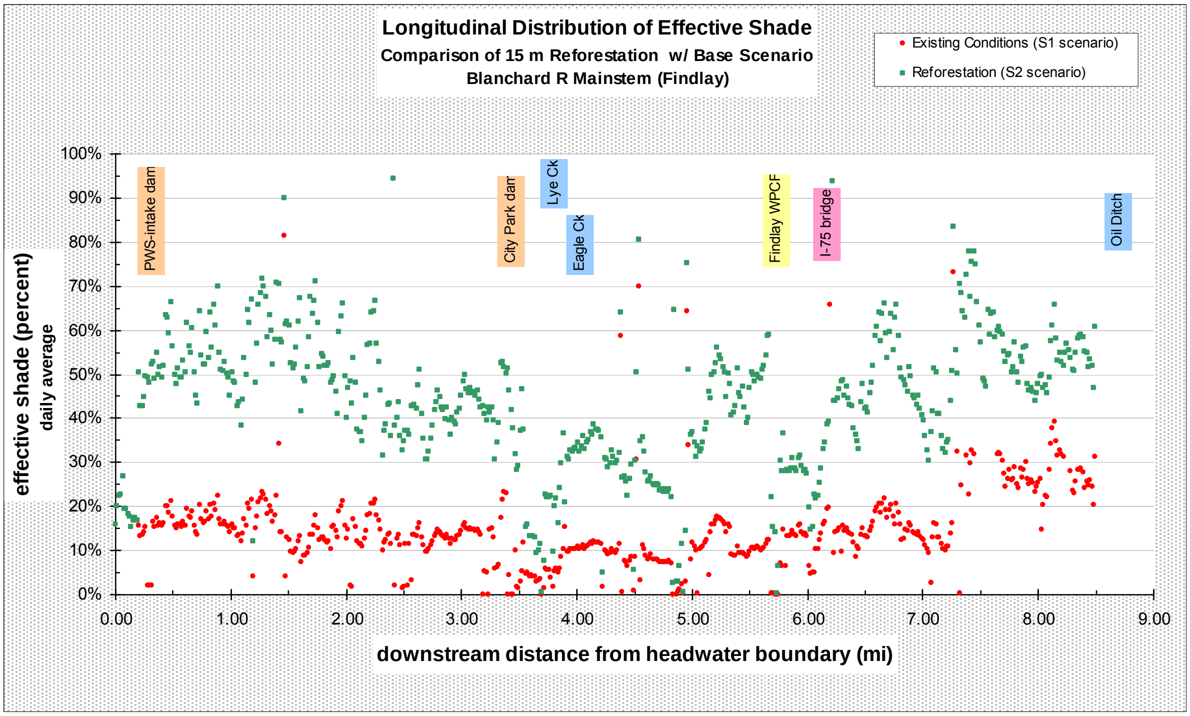


Figure 4.15. Longitudinal distribution of average daily effective shade (as a percent of total incoming solar radiation reduced by topography and vegetation) upon the water surface of the Blanchard River mainstem. Plot shows comparison of S1-scenario (existing conditions) to a proposed riparian reforestation scenario (S2).

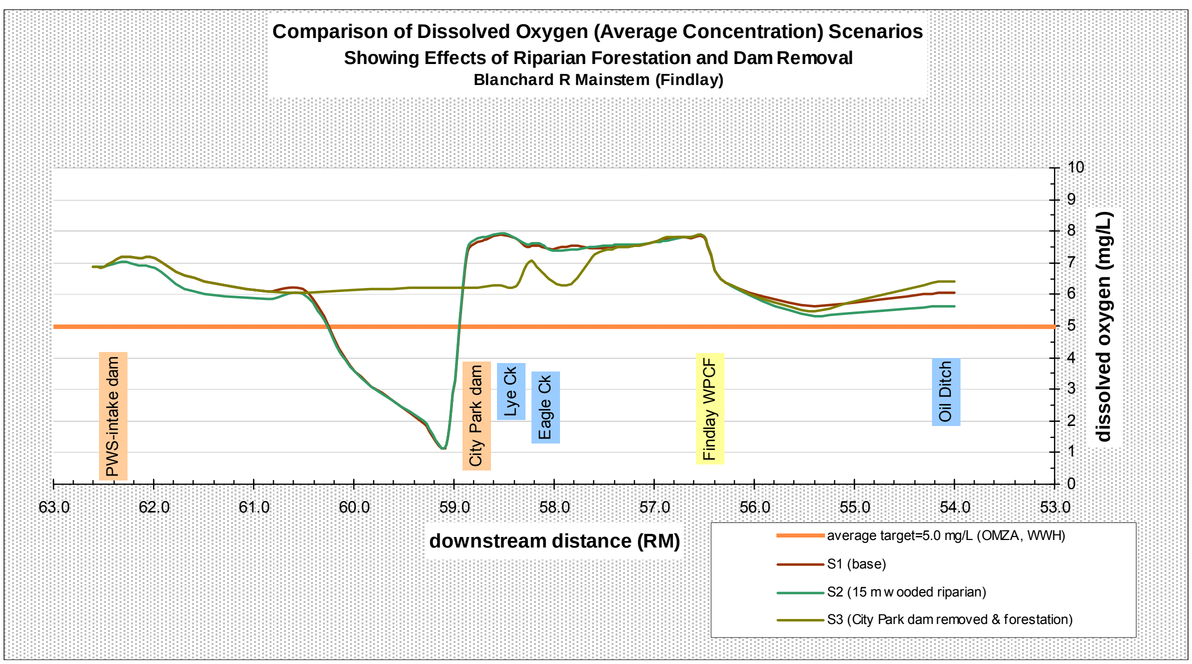


Figure 4.16. Longitudinal distribution of average dissolve oxygen concentration generated by three Qual-2K scenarios: S1 (base scenario), S2 (15 m reforestation on each bank where feasible), and S3 (removal of City Park dam and subsequent reforestation of reservoir area).

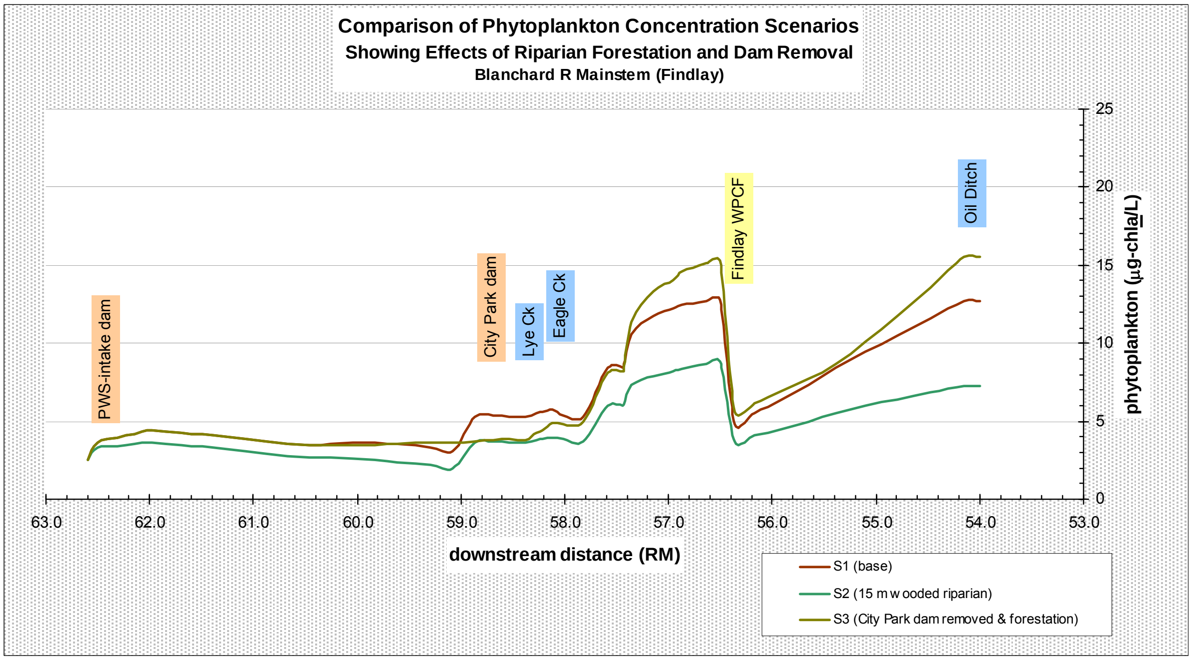


Figure 4.17. Longitudinal distribution of model-predicted average phytoplankton concentration generated by three Qual-2K scenarios: S1 (base scenario), S2 (15 m reforestation on each bank where feasible), and S3 (removal of City Park dam and subsequent reforestation of reservoir area).

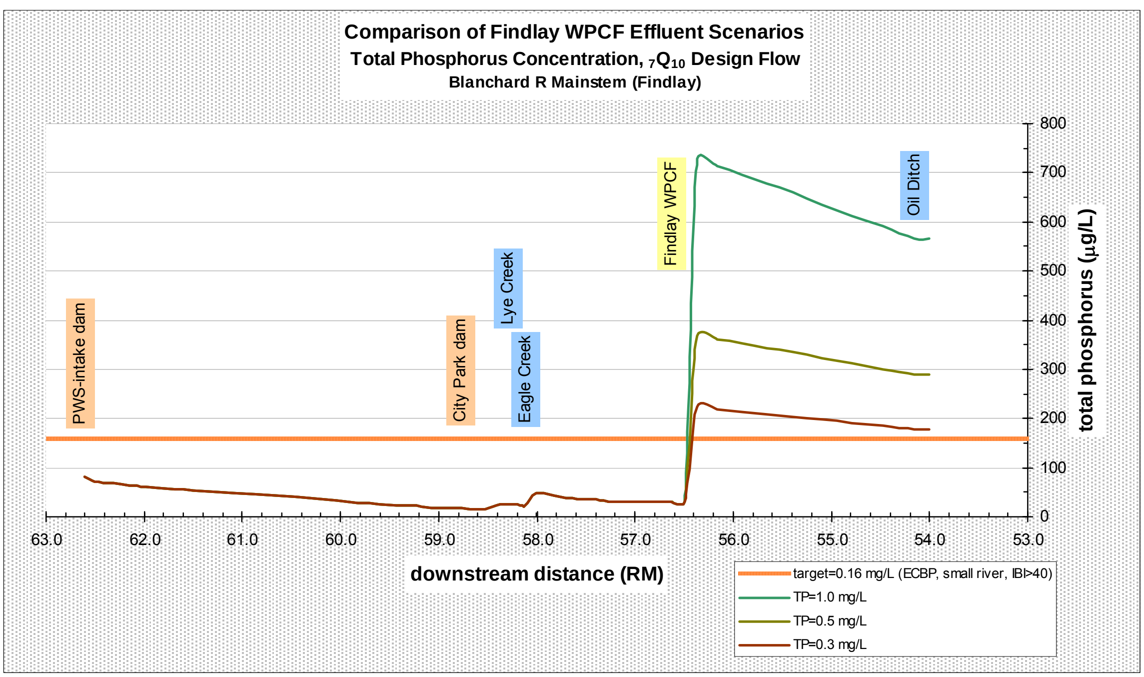


Figure 4.18. Longitudinal distribution of total phosphorus generated by three Qual-2K simulations involving varying Findlay WPCF effluent concentration.

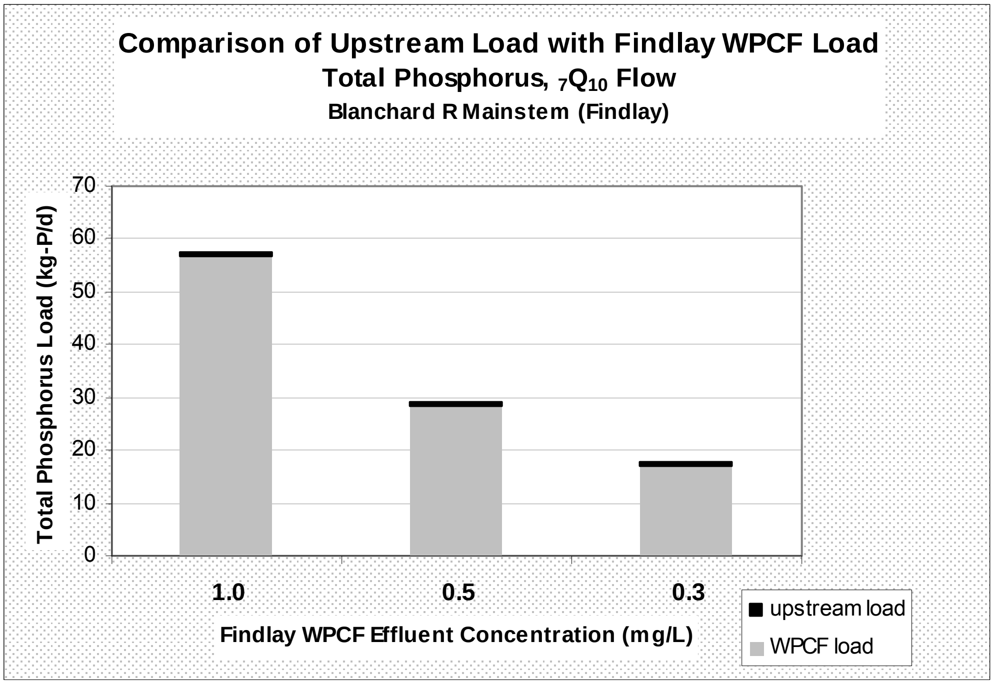


Figure 4.19. Comparison of total phosphorus load (kg-P/d) for Findlay WPCF effluent at three different effluent concentrations and that just upstream of effluent pipe on the Blanchard River mainstem at a $_7Q_{10}$ flow (less than 1 kg-P/d). The target load downstream of the WPCF mixing zone is 12.4 kg/d (at $_7Q_{10}$ flow for the ECBP ecoregion and to meet an IBI>40).

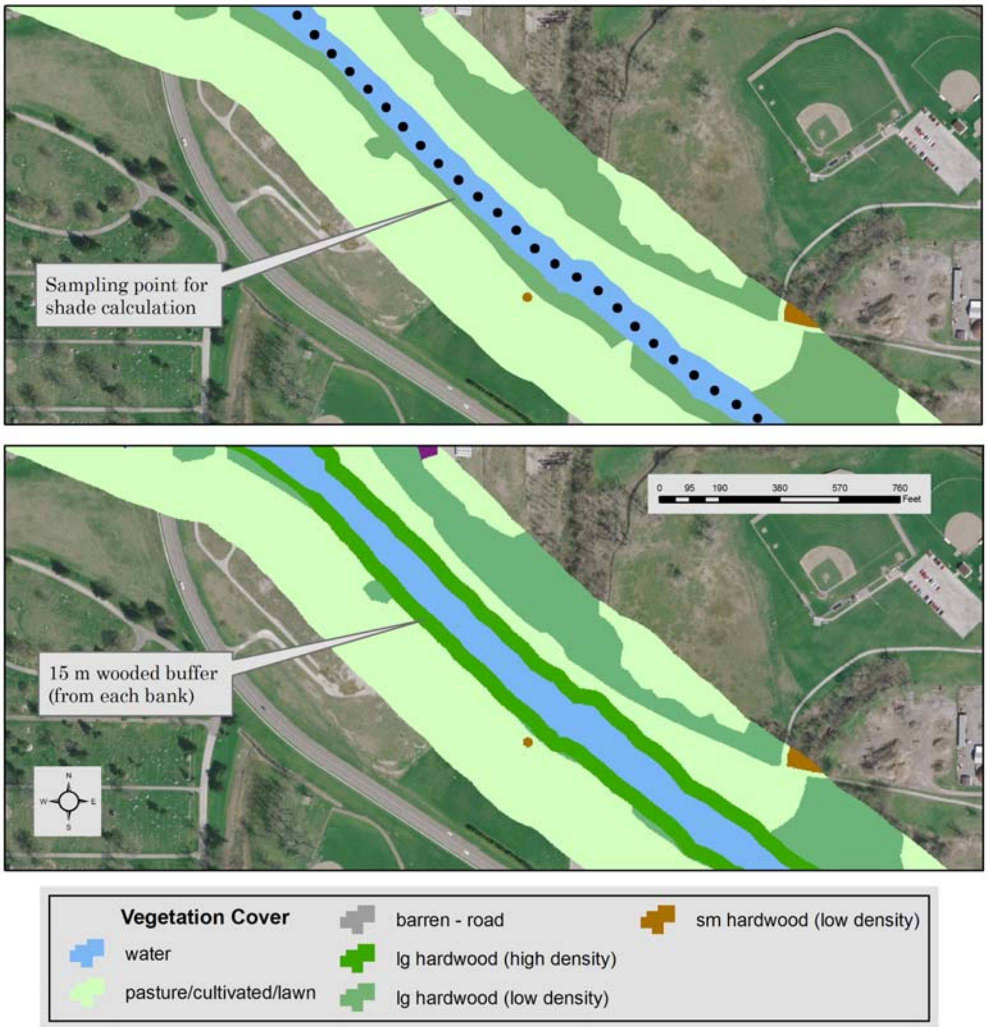


Figure 4.20. Comparison of vegetation cover between existing conditions (calibration and S1-scenario) and proposed (S2-scenario) 15 m (49 ft) wooded buffer (high canopy density, tall hardwood) just downstream of the former Liberty Street dam (Qual-2K reach #14, RM 57.0).

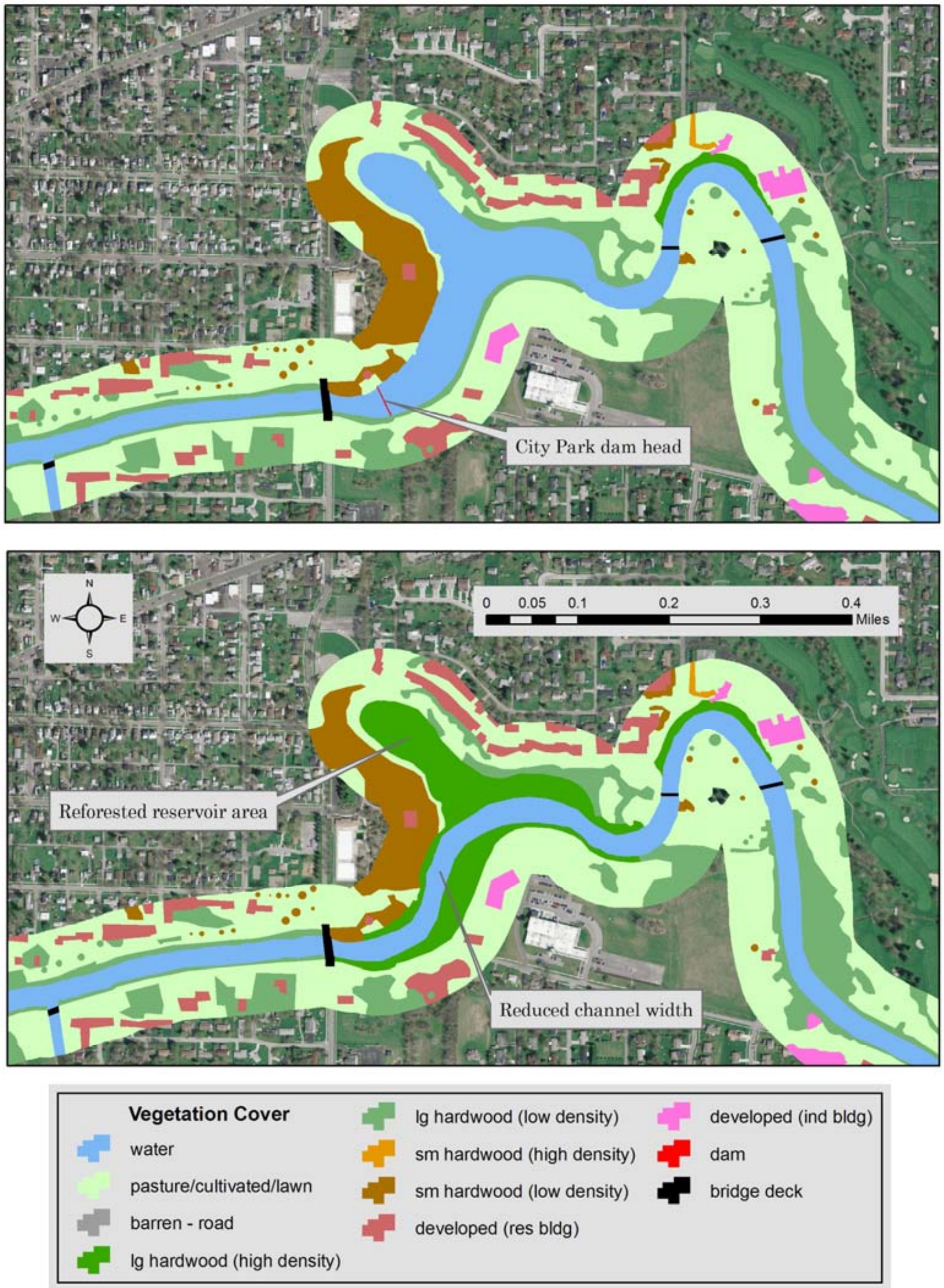


Figure 4.21. Comparison of vegetation cover and channel or reservoir extent between existing conditions and proposed conditions (S3-scenario) at Findlay City Park (Qual-2K reaches #5-6, RM 58.76). Vegetation cover was demarcated within a 91 m (300 ft) buffer on each bank.

References Cited

Chapra SC, Pelletier, GJ and Tao H (2006) *QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.04: Documentation and Users Manual*. Civil and Environmental Engineering Department, Tufts University, Medford, MA.

Chapra (1996) *Surface Water Quality Modeling,* McGraw-Hill (p. nn-nn).

Ohio DAS (2006) Ohio Statewide Imagery Program http://ogrip.oit.ohio.gov/ServicesData/StatewideImagery/tabid/86/Default.aspx

Ohio EPA (1999) *Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams*. Technical Bulletin MAS/1999-1-1.

Washington State Department of Ecology (2007) *tTools for ArcGIS* (http://www.ecy.wa.gov/programs/eap/models.html) [An ArcGIS project with tools for sampling geospatial data to obtain input data for the calculator for shade from riparian vegetation and topography.]

Weather Underground (2007) http://www.wunderground.com/

Appendix

Figure A.1. Boxplots showing statistical summary of hourly dissolved oxygen measurements from multi-parameter datasondes for each river-mile location.

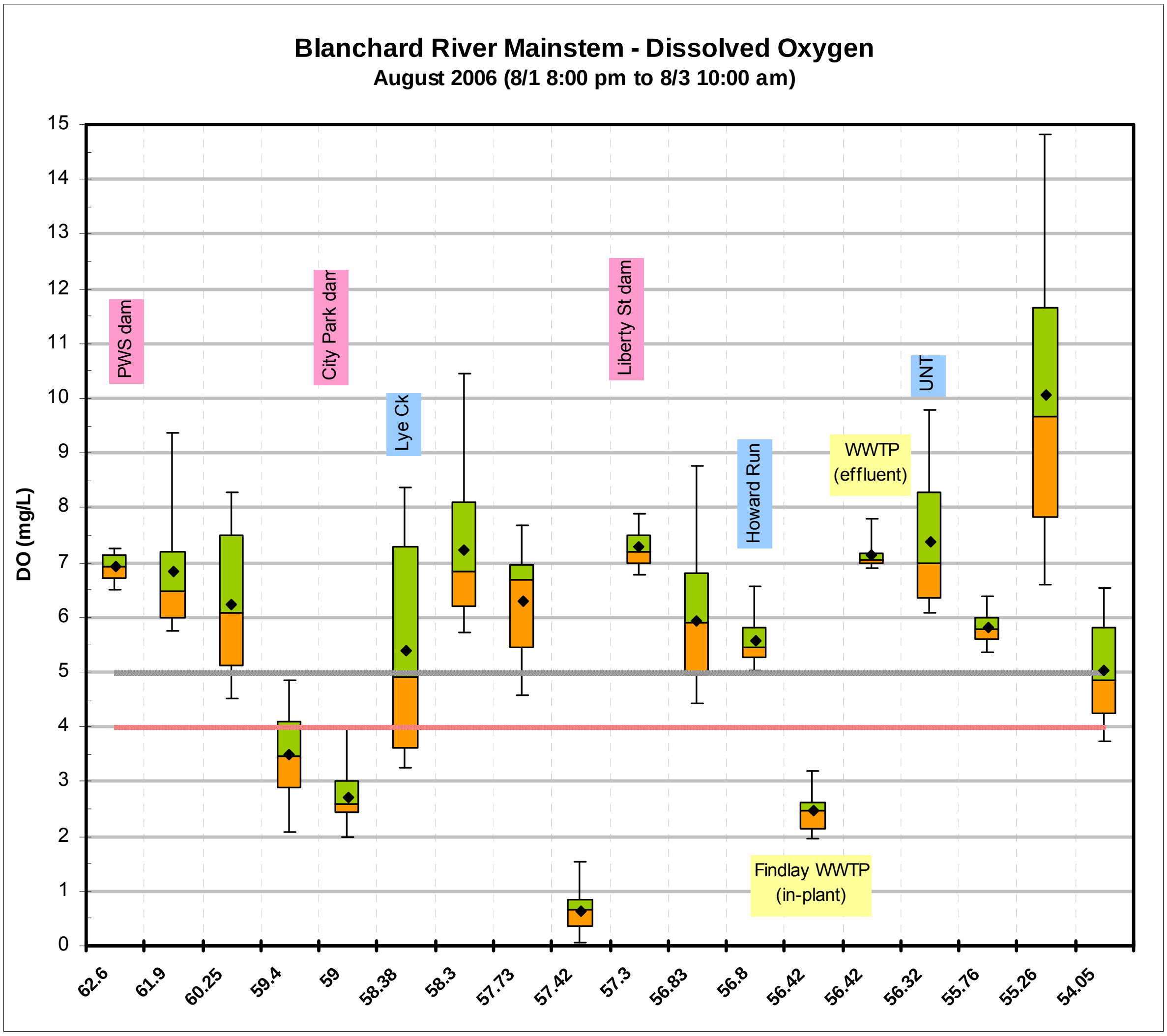
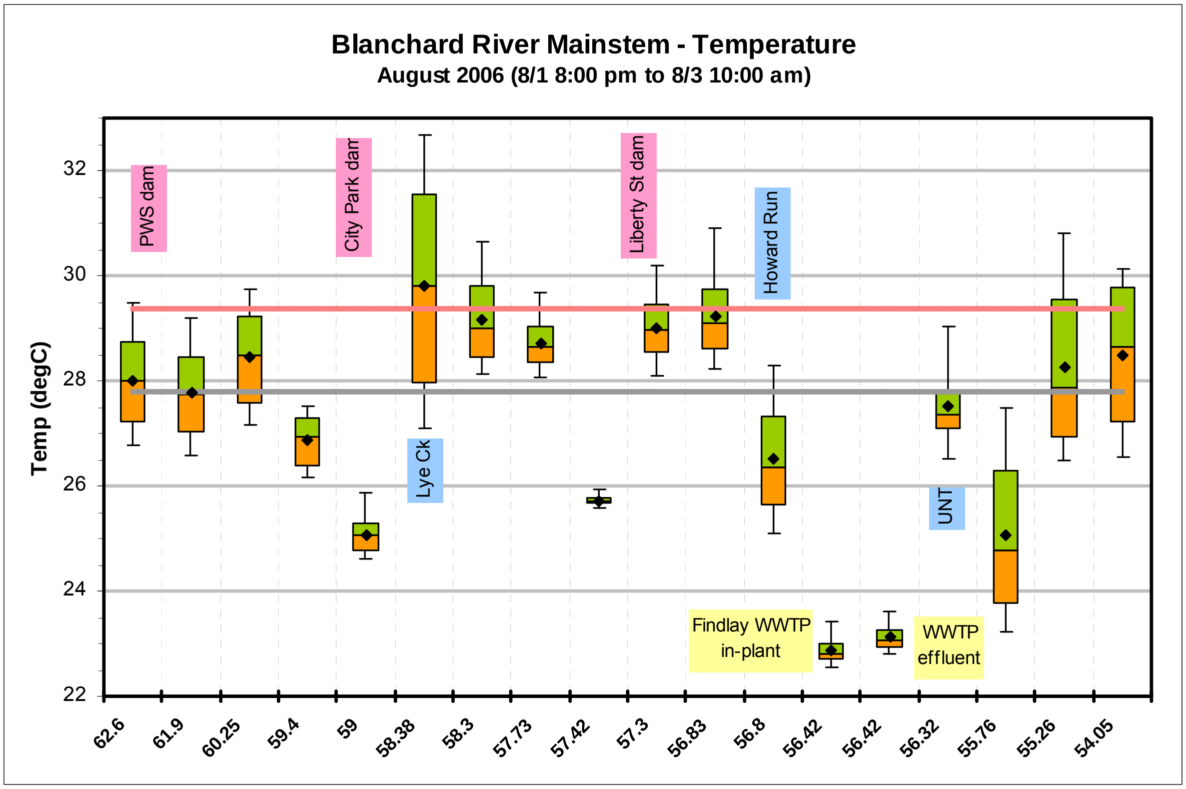


Figure A.2. Boxplots showing statistical summary of hourly temperature measurements from multi-parameter datasondes for each river-mile location.



Adjustments to Rate Constants for Model Calibration

1. Oxygen reaeration rate: k_2 [d^{-1}]
    a. Prescribe for each reach segment using Ohio EPA-specific computation as a function of bed slope and discharge; then compute as a function of stream velocity and depth.
    b. At locations of dam heads (i.e., PWS dam, City Park dam, and Liberty St dam), set hypothetically high reaeration rate but not greater than 20 d^{-1}.

2. Organic-phosphorus
    a. Increased the general hydrolysis rate to 0.5 d^{-1} (from the default is 0.2 d^{-1}) for specific reaches (reach #15 through #18).
    b. The settling velocity (general setting) was decreased to 0.05 m/d (from a default of 0.1 m/d).
    c. The reach-specific settling velocity was subsequently changed (for all reaches) and decreased further to: 10 d^{-3} m/d (reach #1 through #3 and reach #11 through #15), $5 \cdot 10^{-4}$ m/d (reach #4 through #10), and $1.5 \cdot 10^{-3}$ m/d (reach #15 through #18).

3. Phytoplankton
    a. The general maximum growth rate was increased to 3 d^{-1} (from a default of 2.5 d^{-1}).
    b. The reach-specific maximum growth rate was modified for specific reaches:
        i. An increase to 4.0 d^{-1} for reach #13 through #18 (except an increase to 4.5 d^{-1} for reach #15).
        ii. A decrease to 1.5 d^{-1} for reach #3 and to 2.0 d^{-1} for reach #10.
    c. The reach-specific settling velocity was decreased to 0.005 m/d for reach #13 through #18 (from the default of 0.05 m/d).

4. Inorganic-phosphorus
    a. The general settling velocity was decreased to 1.2 m/d (from a default of 2.0 m/d).

5. Bottom algae
    a. The general maximum growth rate was increased to 250 mg-chla/m^2/d in a zero-order growth model (from the default of 50 mg-chla/m^2/d).

6. Sediment oxygen demand (SOD)
    a. The percent area of bottom coverage was upward/downward adjusted based on anecdotal field evidence and observed stream velocity (see Table A.1).
    b. The percent area of bottom coverage was hypothetically upward adjusted for scenarios in which in-stream dam heads and reservoirs were removed (scenarios S1, S2, and S4 for one dam and scenario S3 for two dams).
    c. The prescribed SOD rate was set to 2.0 g/m^2/d for all reach segments.

Table A.1. Assigned rates for reach segments for calibrating the Blanchard-Findlay Qual-2K model. All rates were used in S1, S2, S3, and S4 simulation scenarios with the exception of bottom SOD coverage. Bottom SOD coverage (percent area) varies with simulation scenario.

Reach Description	*Reach Number*	*Bottom Algae Coverage (% area)*	*Bottom SOD Coverage (% area)*			*Prescribed SOD* $g\text{-}O_2/m^2/d$	*Organic P*		*Phytoplankton*	
			Calibration	S1, S2, and S4	S3		*Hydrolysis Rate /d*	*Settling Velocity m/d*	*Maximum Growth Rate /d*	*Settling Velocity m/d*
PWS reservoir	1	20.00	75.00	75.00	75.00	2.00		0.0010		
Downstream PWS dam	2	20.00	30.00	30.00	30.00	2.00		0.0010		
Rush Ck inflow	3	20.00	50.00	50.00	50.00	2.00		0.0010	1.5000	
Upper City Park reservoir	4	20.00	75.00	75.00	40.00	2.00		0.0005		
Lower City Park reservoir	5	20.00	75.00	75.00	40.00	2.00		0.0005		
City Park dam vestibule	6	20.00	75.00	75.00	40.00	2.00		0.0005		
Downstream City Park reservoir	7	20.00	30.00	30.00	30.00	2.00		0.0005		
Riffle #1 vestibule	8	20.00	30.00	30.00	30.00	2.00		0.0005		
Lye Ck & Eagle Ck intervening	9	20.00	50.00	40.00	40.00	2.00		0.0005		
Upper Liberty St dam pool	10	20.00	75.00	40.00	40.00	2.00		0.0005	2.0000	
Riffle #2 vestibule	11	20.00	75.00	40.00	40.00	2.00		0.0100		
Lower Liberty St dam pool	12	20.00	75.00	40.00	40.00	2.00		0.0100		
Liberty St dam vestibule	13	20.00	75.00	40.00	40.00	2.00		0.0100	4.0000	0.0050
Riffle #4 vestibule	14	20.00	45.00	40.00	40.00	2.00		0.0100	4.0000	0.0050
Downstream Liberty St dam	15	20.00	45.00	40.00	40.00	2.00	0.8000	0.0150	4.5000	0.0050
Findlay WPCF; Howard Run	16	20.00	40.00	40.00	40.00	2.00	0.8000	0.0150	4.0000	0.0050
Downstream I-75 bridge	17	30.00	40.00	40.00	40.00	2.00	0.8000	0.0150	4.0000	0.0050
UST Oil Ditch	18	30.00	40.00	40.00	40.00	2.00	0.8000	0.0150	4.0000	0.0050

Figure A.3. ArcInfo macro-language (AML) code used to reclassify the land cover and land use within the 15 m buffer.

```
*****************************************************************************
*
setwindow gs1scenario
setmask gs1scenario
setcell 1.0
DOCELL
gs2scenario = gs1scenario
if (forest15m eq 600)
  {    if (gs1scenario eq 301) gs2scenario = gs1scenario
       else if (gs1scenario eq 304) gs2scenario = gs1scenario
       else if (gs1scenario eq 321) gs2scenario = gs1scenario
       else if (gs1scenario eq 400) gs2scenario = gs1scenario
       else if (gs1scenario eq 402) gs2scenario = gs1scenario
       else if (gs1scenario ge 3248 and gs1scenario le 3255) gs2scenario = gs1scenario
       else gs2scenario = forest15m
       endif
  }
endif
```

6.0 Pathogen analysis

1) Fecal Coliform: Importance of Indicator Organisms

The proportion of pathogenic organisms present in assessed waters is generally small compared to non-pathogenic organisms. For this reason most pathogenic bacteria are difficult to isolate and identify. Additionally, pathogenic organisms are highly varied in their characteristics and type which also makes them difficult to measure. Non-pathogenic bacteria that are associated with pathogens transmitted by fecal contamination are more abundant and can be used as surrogates because of the greater ease in sampling and measuring. These bacteria are called indicator organisms; a class of indicator bacteria called fecal coliforms was monitored in the Blanchard River watershed to assess recreational-use impairment. There are promulgated water quality standards for the maximum geometric mean concentration and the ninetieth percentile concentration for fecal coliform bacteria (§OAC 3745-1-07). These values serve as the targets used in the development of the TMDLs that address recreation use impairments.

Numeric targets for fecal coliform are derived from bacteriological water quality standards. The criterion for fecal coliform specified in §OAC 3745-1-07 are applicable outside the mixing zone and apply to waters determined for primary contact recreation (PCR) and secondary contact recreation (SCR). There are several streams or segments of rivers currently designated secondary contact recreation in the Blanchard River watershed (Table 6.1). For PCR the standard states that the geometric mean, based on not less than five samples within a thirty-day period, shall not exceed 1000 counts per 100 ml and shall not exceed 2000 counts per 100 ml in more than 10 percent of the samples taken during any thirty-day period. Hence, both conditions must be met for non-exceedence of the standard. If one condition is violated at a sampling station, then recreation-use impairment exists at that location. As written the standards effectually establish both chronic and acute permissible instream fecal coliform concentrations. The SCR standard varies in that it requires fecal coliform not to exceed the geometric mean value of 5000 per 100 ml in more than ten percent of the samples taken during any thirty-day period. There is no geometric mean component of the standard for SCR designated waters.

2) Establishment of Target

Elevated bacteria loading is the cause of recreational-use impairment in the Blanchard River basin. Violations of both chronic and acute criteria exist at multiple sites within each WAU, though more sites fail by the acute criterion than do by the chronic criterion (Figure 6.2; Table A6-1). Both the chronic and acute criteria were applied to the outlet of the six watershed assessment units (WAUs) and the MS4 region (Figure 6.1). The WAUs correspond to 11-digit USGS HUC (now 10-digit code) are named: The Headwaters, The Outlet / Lye Creek, Eagle Creek, Ottawa Creek, Riley Creek, and Cranberry Creek. In addition, a 14-digit (presently 12-digit) HUC subwatershed of The Outlet / Lye Creek WAU, entitled The Outlet (lower), received a loading assessment and allocation. Because only a few segments under

SCR criteria exist within each WAU, only the PCR chronic criterion was applied to a TMDL load allocation.

A flow-exceedence analysis of the USGS continuous stream flow gauge at Findlay (station ID = 0326000) found no bacteria sampling events with flows above a 10 percent exceedence. Hence, all sampling events were kept in determining the average (geometric mean) and maximum (90th percentile) recreation season concentrations.

Table 6.1. Streams and river segments designated as Secondary Contact Recreation (SCR) within the Blanchard River watershed.

Description	River Mile(s)	WAU	HUC 14
Blanchard River	101.03, 100.05, 97.42	Headwaters	04100008-010-010, -030 (97.42)
Forest-Simpson Ditch	0.8	Headwaters	04100008-010-030
Shallow Run	4.7, 4.0	Headwaters	04100008-010-030
Rickenbach Ditch	4.98, 4.93, 1.18	Headwaters	04100008-010-050
Buck Run	3.57, 0.56	Eagle Creek	04100008-030-020
Higbie-Redick Ditch	0.76	Ottawa Creek	04100008-040-010

Figure 6.1. Location of MS4 (municipal separate storm-sewer system) under Phase II stormwater management program for Findlay, Ohio.

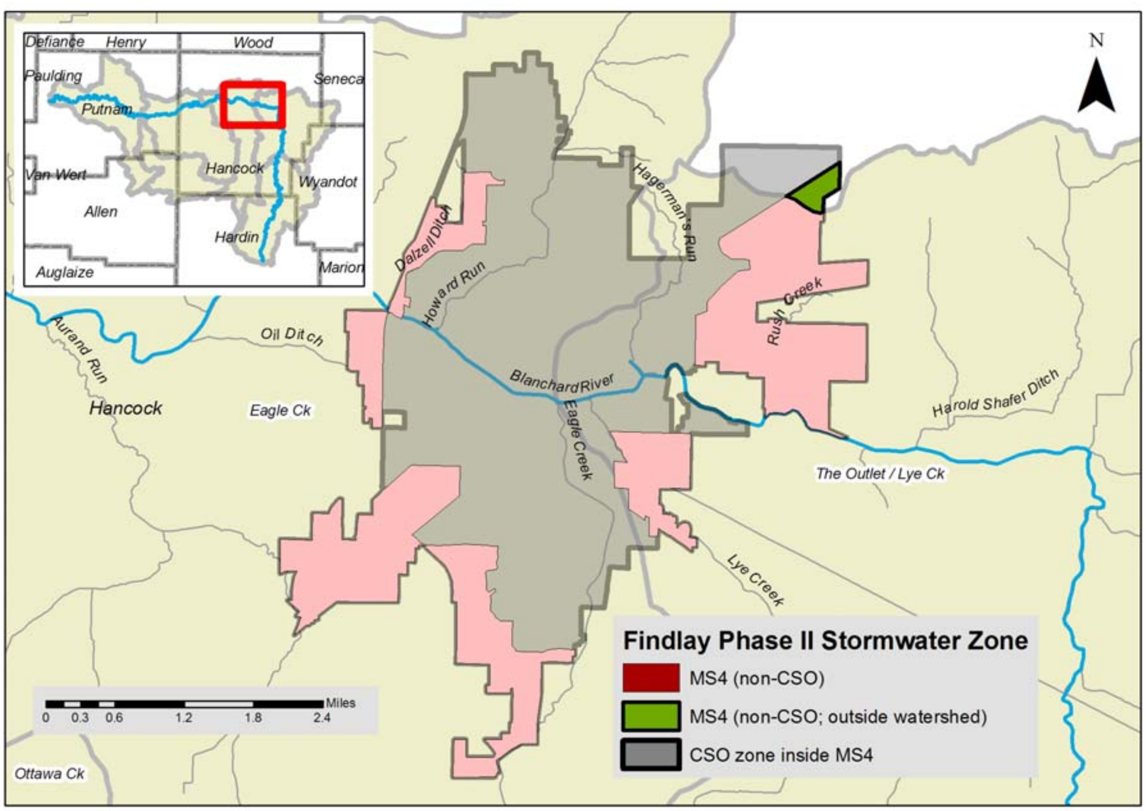
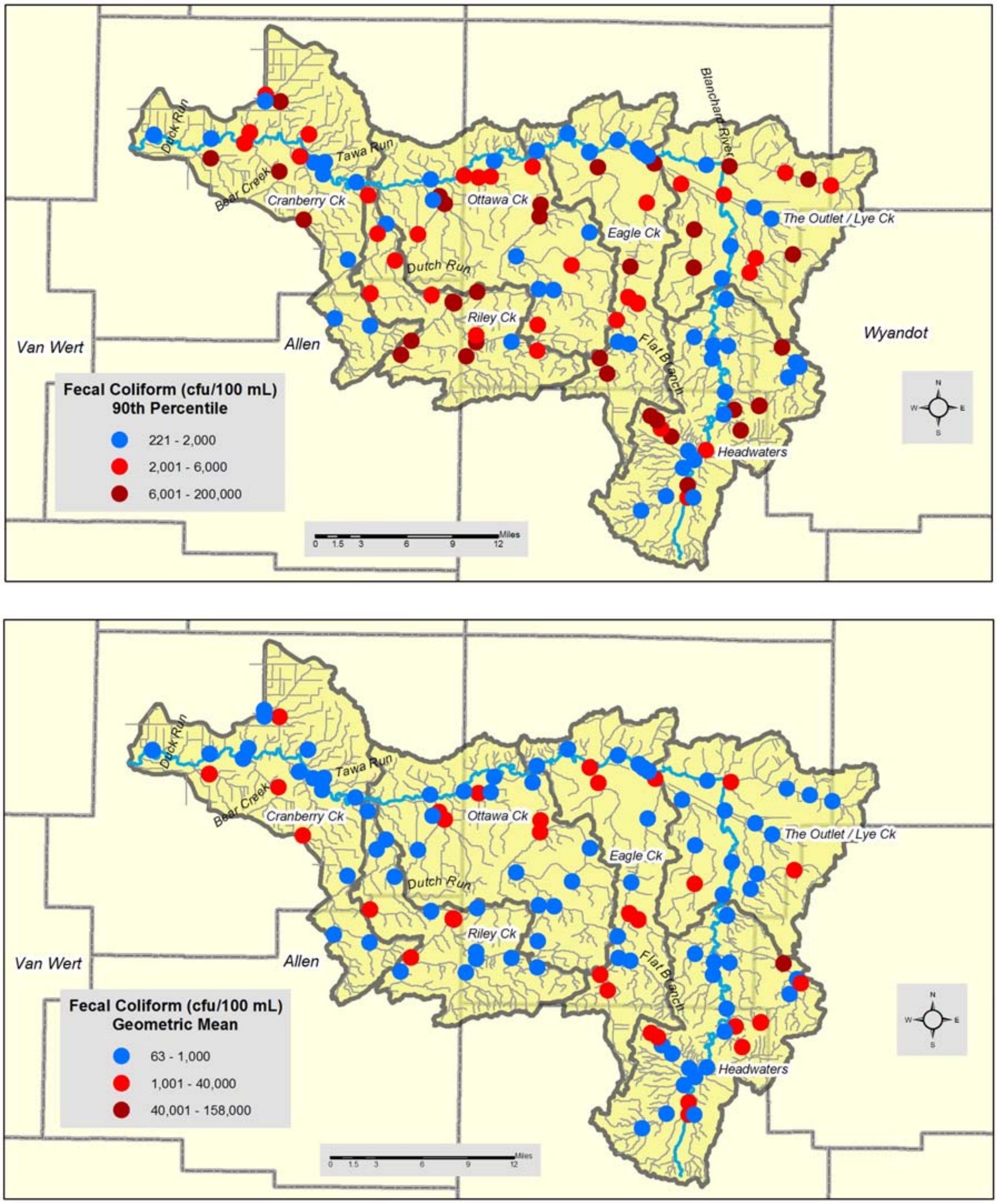


Figure 6.2. Map showing geometric mean (upper) and 90th percentile (lower) fecal coliform concentrations (in units of cfu/100 mL) at sampling locations monitored in 2005. Internal lines refer to WAU boundary.



3) Approach: Estimation of Existing Loads and Sources

The pathogen simulation period extended from April 1999 to February 2007. TMDL allocations were computed over the period – May 2000 to February 2007, which is 1.1 years shorter than the simulation period. Allocations were completed for the six watershed assessment units and the MS4 region in Finday. The MS4 region does not contain drainages maintained by combined sewer overflows (Figure 6.1).

Determination of nonpoint and point loading sources was determined through direct inputs to streams (point) and surface runoff/washoff (nonpoint) (Table 6.2). Target loads (TMDL) are simply a product of streamflow (volumetric flow rate) and the water quality criterion.

Daily surface runoff was determined from the NRCS curve-number method. This method requires daily precipitation depth, land cover type, and soil hydrologic group. Precipitation input was generated from the method described above. Land use was determined from the National Land Cover Dataset (Homer et al. 2001) and soil hydrologic group was determined from NRCS SSURGO (Soil Survey Staff 2005) digital soil layers. Both factors determine the curve number, which was areally-weighted within each assessment unit.

Total daily precipitation was synthesized from a collection of six gauges (Table 6.3). Each gauge's contribution to the HUC-11 area was determined by Theissen polygon weighting. Data was produced from the Midwestern Regional Climate Center in Champaign IL.

Total streamflow was estimated as the sum of surface runoff, baseflow, flow from residential septic systems, and waste flow from cattle in-stream. Surface runoff was determined from the curve-number technique described above. Baseflow was determined from hydrograph separation using the USGS PART method (Rutledge 1998). Daily streamflow from the USGS Blanchard River at Findlay gauge (346 sq.mi) was partitioned into storm and baseflow using PART. The baseflow for each assessment unit was proportioned by area.

To estimate manure production, numbers of livestock distributed by animal type were taken from the Ohio Department of Agriculture 2004 Annual Report and Statistics (Ohio Department of Agriculture 2004). The report provides numbers aggregated by Ohio County. Values by watershed assessment unit were derived from spatial overlay of the watershed assessment unit boundary onto the county boundary. Thus, an areal proportion of livestock number can be assigned to each assessment unit (Table 6.4).

One direct contribution of pathogens to the stream system occurs from livestock access to the stream. Using Bacteria Indictor Tool (BIT) (U.S. Environmental Protection Agency 2000) assumptions, only beef cattle have access to streams. Beef cattle are assumed to be either kept in feedlots or allowed to graze (depending on the season). When grazing, a certain proportion is assumed to have direct access to streams. An assumption is made that all beef cattle are confined from December through March, inclusive. Then from April through November, only 15 percent of the total number in the watershed can graze, and half of this amount has direct access to streams. Thus, about 8 percent of the total number of livestock in the watershed has direct access to the stream. BIT assumes that dairy cattle are only kept in feedlots. Therefore all of their waste is used for manure application (divided between Cropland and Pastureland).

NPDES permittees are assumed to be discharging effluent with fecal coliform concentrations at or below their permit limit of 1000 cfu/100 mL. Accounting for NPDES loads was achieved by taking their design flow and allowance of the full permit limit (i.e., 1000 cfu/100 mL). Any permittee discharging above the permit limit (results summarized in Table 6.5) will be managed through the NPDES compliance program where efforts are made to assist the permittee in meeting the fecal coliform criterion.

An assessment of CSO discharges was made for the communities with recognized CSO outfalls. Findlay, Bluffton, Pandora, Forest, and Dunkirk are recognized in Ohio EPA (2007) as having discharges from these sources. CSO discharges were not accounted for in the current pathogen model because either discharge information has not been reported and/or the community is under a long-term control plan (LTCP) or is in the process of reconstructing their sewer infrastructure for separation. Further, CSO discharges occur on an intermittent basis and would not contribute substantially to the total pathogen load of the assessment unit. A summary of known CSO information on these communities is presented in Table 6.6. Concentrations of fecal coliforms from CSO discharges have been reported nationally at $4.2 \cdot 10^6$ cfu/100 mL (Dorian et al. 1981) and from 10^5-10^7 cfu/100 mL (Water Environment Federation 1999).

The number of people using a household septic system was determined from several sources. Initial estimates of population were extracted from the US Census 2000 block enumerations for specific 11-digit HUCs (those used in the GWLF nutrient model described elsewhere in this report). The HUC total was then decremented by the number of people in a sewer service-area to yield an unsewered population estimate. For areas outside the HUC but still included in the WAU, the US Census 1990 block group enumeration was employed and sewage treatment attributes (i.e., public, septic tank or cesspool, and other) were assessed.

For Hancock County, residential septic systems were estimated to have a failure rate of 50 percent (Hancock County Health Department 2004). The report states, "based on the number of household sewage treatment systems in Hancock County that are older than 30 years, it is assumed that the majority of the systems in Hancock County are discharging off-lot, installed in unsuitable soils, and have little or no maintenance." A 50 percent failure rate was applied to all septic systems in the Blanchard River watershed. Hancock County occupies approximately 50 percent of the total Blanchard watershed area and it is assumed that the remaining counties that comprise a large percentage of the watershed (Putnam and Hardin counties) have a similar failure rate.

Table 6.2. Characterization of existing loads, target loads, and load allocation for the Blanchard River pathogen analysis.

<table>
<tr><th>Development Step</th><th colspan="2">Source</th><th>Approach</th></tr>
<tr><td rowspan="4">Determination of Existing Load</td><td colspan="2">Point Source (NPDES)</td><td>Product of design flow and the fecal coliform average standard currently in place for a given permittee.</td></tr>
<tr><td colspan="2">Washoff from Land</td><td>Livestock manure and wildlife fecal exports distributed by land cover type and transported to stream via surface runoff. This approach encompasses the MS4 Zone in the City of Findlay.</td></tr>
<tr><td colspan="2">HSTS</td><td>Population served by failing HSTS estimated via US Census Bureau. Failure rate identified by Hancock County Health Department. Fecal coliform load based upon population estimates and a per capita loading rate.</td></tr>
<tr><td colspan="2">Beef Cattle in Stream</td><td>Proportion of beef cattle that are estimated to graze, then a sub-set that are expected to have stream access.</td></tr>
<tr><td colspan="3">TMDL: Calculation of Target Load (Loading Capacity)</td><td>Product of daily discharge at the outlet of each watershed assessment unit (WAU) and the chronic criterion for fecal coliform (i.e., geometric mean concentration).</td></tr>
<tr><td rowspan="5">Proposed Allocation</td><td rowspan="2">WLA</td><td>Point Source (NPDES)</td><td>Product of design flow and the fecal coliform average standard currently in place for a given permittee (same as existing load determination).</td></tr>
<tr><td>MS4</td><td>The allocation for the MS4 Zone (City of Findlay) is computed exactly as in the Washoff from Land (LA) (see below).</td></tr>
<tr><td rowspan="3">LA</td><td>Washoff from Land</td><td>The washoff allocation is the residual loading capacity once the NPDES WLA and 5% HSTS have been allocated.</td></tr>
<tr><td>HSTS</td><td>Failing HSTS are allocated a fecal coliform load equal to a 5% failure rate.</td></tr>
<tr><td>Beef Cattle in Stream</td><td>A 100% removal of beef cattle in streams is proposed so that a zero loading is authorized.</td></tr>
<tr><td colspan="4">Definitions
LA: load allocation
WLA: wasteload allocation
HSTS: home sewage treatment systems (i.e., residential septic systems)
MS4: municipal separate storm sewer system</td></tr>
</table>

Table 6.3. NOAA station list used for Blanchard River pathogen model precipitation data. Data source is NCDC climate-radar data inventories.

Station Name	Station ID
Kenton, Ohio	334189
Upper Sandusky, Ohio	338534
Ottawa, Ohio	336342
Findlay FAA Airport, Ohio	332786
Findlay WPCC, Ohio	332791
Pandora, Ohio	336405

Table 6.4. Assigned livestock number by type for each assessment unit.

Assessment Unit	cattle & calves	milk cows	hogs & pigs	stock sheep	hens & pullets of laying age
Headwaters (-010)	2,795	737	14,689	409	35,599
The Outlet / Lye Ck (-020)	1,768	445	7,535	356	33,736
The Outlet (lower) (-020-030)	620	149	2,369	135	9,918
Eagle Ck (-030)	1,507	387	6,119	277	29,083
Ottawa Ck (-040)	2,588	767	70,111	391	37,647
Riley Ck (-050)	1,586	451	23,705	252	21,654
Cranberry Ck (-060)	4,136	1,355	181,352	483	37,233
MS4 (non-CSO)	0	0	0	0	0

Table 6.5. Existing and allocated fecal coliform loads for NPDES dischargers (organized by assessment unit and facility).

Facility Name	OEPA#	Existing Load (cfu/day)	% Reduction	Allocated Load (cfu/day)
The Headwaters 04100008-010				
Claradan Count Sr Housing Complex	2PW00008	6.81E+07	0	6.81E+07
Mt Blanchard WWTP	2PA00045	*under construction*		
Dunkirk WWTP	2PB00061	5.19E+09	0	5.19E+09
Forest WWTP	2PB00044	7.57E+09	0	7.57E+09
Hardin Northern School	2PT00043	3.79E+08	0	3.79E+08
Shelly Materials (Forest Quarry)	2IJ00046		na	
Triumph Thermal Systems	2IS00001		na	
Duff Quarry	2IJ00022		na	
The Outlet / Lye Ck 04100008-020				
Vanlue WWTP	2PA00016	2.65E+09	0	2.65E+09
Heritage Springs Campgrounds	2PR00182	4.73E+08	0	4.73E+08
The Outlet (lower) 04100008-020-030				
none				
Eagle Ck 04100008-030				
Findlay WWTP	2PD0008	5.68E+11	0	5.68E+11

Facility Name	OEPA#	Existing Load (cfu/day)	% Reduction	Allocated Load (cfu/day)
National Lime & Stone	2IJ00081		na	
BP Oil Findlay Bulk Plant	2IN00176	5.72E+06	0	5.72E+06
Eagle Ck Utility Co	2PU00004	*tie-into Findlay WWTP*		
Camp Berry	2PR00146	5.68E+08	0	5.68E+08
Arlington WWTP	2PA00050	6.36E+09	0	6.36E+09
Arlington WTP	2IZ0000		na	
Sycamore Springs Golf Course	2PR00098	1.51E+08	0	1.51E+08
Ottawa Ck 04100008-040				
Tawa Ridge Estates	2PW00003	1.06E+08	0	1.06E+08
Ohio DOT I-75 Rest Area	2PP00019	3.79E+08	0	3.79E+08
Rawson WWTP	2PA00039	5.75E+09	0	5.75E+09
Cory Rawson High School	2PT00031	4.73E+08	0	4.73E+08
Riley Ck 04100008-050				
Putnam Stone	2IJ00057		na	
Pandora WWTP	2PB00029	1.27E+10	0	1.27E+10
Bluffton WWTP	2PC00005	7.19E+10	0	7.19E+10
Ridge Rd MHP	2PY00046	1.32E+08	0	1.32E+08
Mast Estates	2PG00038	3.41E+08	0	3.41E+08
Beaverdam WWTP	2PB00018	3.79E+09	0	3.79E+09
Richland Manor	2PR00199	7.04E+08	0	7.04E+08
Speedway Super America (#3547)	2PR00109	5.68E+08	0	5.68E+08
Cranberry Ck 04100008-060				
Country Acres	2PG00083	1.14E+09	0	1.14E+09
Miller City High School	2PT00025	3.03E+08	0	3.03E+08
Putnam Co Landfill	2IN00122		na	
Putnam Co Board of MRDD	2PG00112	3.79E+08	0	3.79E+08
MS4 Zone (City of Findlay)				
Enelco, Inc Quarry (Tarbox-McCall)	2IJ00064		na	

Table 6.6. Summary of CSO outfall and correction efforts within the Blanchard River watershed.

Facility	Remediation Plan	Flow Discharge 2000-2007		WAU
		Frequency (% of days)	Median Flow Volume (MGD)	
Forest	LTCP approved 1997; in progress	26.4	0.050	Headwaters
Dunkirk	no LTCP; submitted plans for separating sewers; in progress	5.1	0.002	Headwaters
Findlay†	actively completing LTCP	3.7	1.82	Eagle Ck
Pandora	no LTCP; General Plan 1986; per Administrative Orders are actively separating sewers; deadline 12/28/2010	no reporting	--	Riley Ck
Bluffton	LTCP approved 1997; in progress	no reporting	--	Riley Ck

Findlay†: Flow record extends from 2003-2006 due to facility reporting requirement. For 2007, high rainfall produced several flooding events which in turn prevented monitoring of CSO overflows. The exception was December 2007 which reported a median of 5.25 MGD.

4) Critical Condition and Seasonality

The critical condition for pathogens is the summer dry period when flows are lowest, and thus the potential for dilution is the lowest. Summer is also the period when the probability of recreational contact is the highest. For these reasons recreational use designations are only applicable in the period May 1 to October 15. Pathogen TMDLs are developed for the same May to October 15 time-period in consideration of the critical condition, and for agreement with Ohio WQS. For temporal variation within the recreation season, loading quantities (existing, target, and reductions) are characterized by month.

5) Margin-of-Safety

An explicit margin-of-safety of 4% was incorporated into the maximum allowable load. A value of 4% is reflective of other Ohio EPA load allocations for pathogens and uncertainty in model representation of pathogen origin and transport. An implicit margin-of-safety was considered in developing runoff generated loads arising from land application of manure. Another implicit consideration was establishing NPDES pathogen loads at design flow of the effluent.

Loading capacity is calculated as the product of the seasonal flow volume and the fecal coliform target concentration. No attempt is made to link downstream loading capacity with upstream loading via instream processing. Only die-off of land accumulated bacteria prior to wash off is considered in the BIT method. In reality, considerable die-off occurs between the source of loading and the TMDL endpoint, and this loss represents in an additional implicit margin of safety.

6) Future Growth

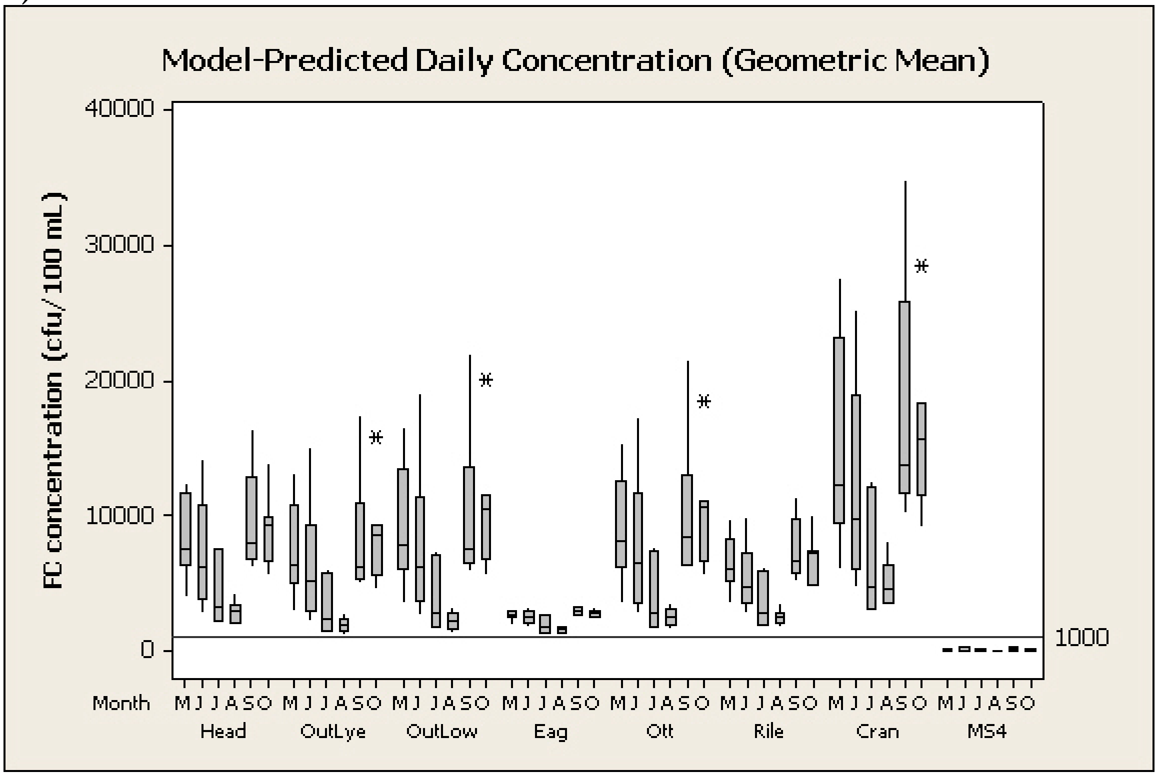
No adjustments for future growth were considered in the pathogen model given the less than vigorous anticipated population increases for Hancock, Putnam, and Allen counties within the Blanchard River watershed.

7) Estimation of Existing Loads

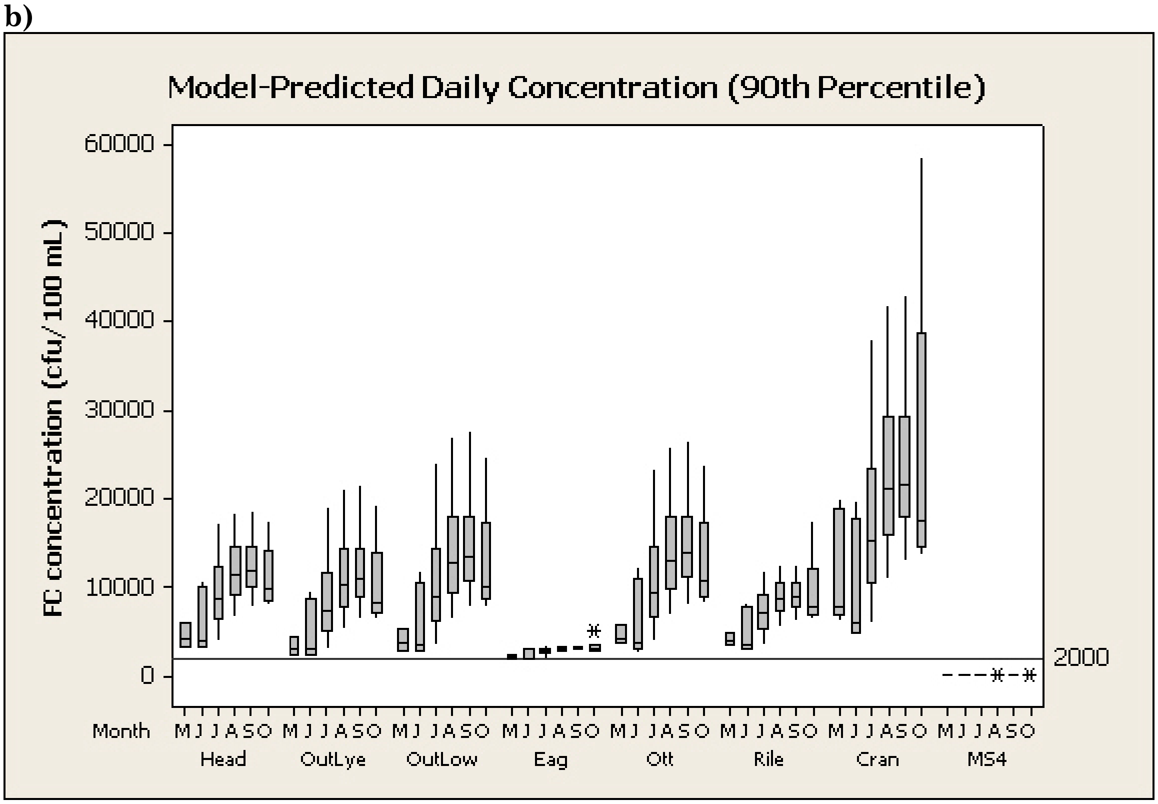
The concentrations derived from model-predicted daily loads show that all WAU exceed the chronic criterion by significant margins (Figure 6.3a). The exception is the MS4 Zone where it meets the chronic criterion for each of the six months in the recreation season. In terms of meeting the acute criterion, the same exceedences appear (Figure 6.3b). The Eagle Creek WAU (-030) is only slightly above the chronic and acute criteria whereas Cranberry Creek WAU (-060) significantly exceeds both criteria. In general a decline in the geometric mean exists as the recreation season elapses from May to October; the reverse is true for the 90th percentile concentration.

Figure 6.3. Distribution of geometric mean (a) and 90th percentile (b) model-predicted fecal coliform concentrations by month of recreation season. The sequence "M J J A S O" represents May 1 through October 15 by month (e.g., M = May). Water quality criteria are depicted by horizontal line for both chronic (1000 cfu/100 mL) and acute (2000 cfu/100 mL) conditions. The distribution is composed of 7 monthly geometric means for the period 2000-2006 and portrayed by assessment unit: Head=The Headwaters, OutLye=The Outlet/Lye Ck, OutLow=The Outlet (lower), Eag=Eagle Ck, Ott=Ottawa Ck, Rile=Riley Ck, Cran=Cranberry Ck, and MS4=MS4 Zone (Findlay). For each icon, the central bar represents the median value (n = 6), the upper grey and lower grey box edges represent the 75th and 25th percentiles, respectively, and the whiskers represent the highest/lowest data value within 1.5 times the inter-quartile range. Asterisks represent upper and lower outliers.

a)


Model-Predicted Daily Concentration (Geometric Mean)
FC concentration (cfu/100 mL)
40000
30000
20000
10000
0
1000
Month
M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O
Head
OutLye
OutLow
Eag
Ott
Rile
Cran
MS4

b)


Model-Predicted Daily Concentration (90th Percentile)
FC concentration (cfu/100 mL)
60000
50000
40000
30000
20000
10000
0
2000
Month
M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O
Head
OutLye
OutLow
Eag
Ott
Rile
Cran
MS4

For each assessment unit (WAU) and the MS4 Zone in Finday, a TMDL was computed as a function of total streamflow generated by each unit and the chronic fecal coliform criterion (Table 6.7). For each day within the recreation season and over a 7-year period of record (2000-2006), the daily allowance (TMDL) was subtracted from the existing (model-predicted) daily load. If the TMDL was less than the existing load, a daily reduction was computed. Subsequently a geometric mean of each month of daily reductions was computed and then the median of these 7 means (2000-2006) was compiled. The median reduction and percent reduction are shown in Table 6.7; the range of reductions is from 43% to 95% of the existing load. Aside from the MS4 Zone (which has no required reduction), the lowest percent reduction is needed for Eagle Creek WAU (-030) whereas the highest is needed for Cranberry Creek WAU (-060) (Figure 6.4). The largest range in percent reduction exists for the The Outlet/Lye Creek WAU (-020) and its subwatershed (The Outlet – lower). The percent reduction needed generally decreases as the recreation season progresses from May to October.

The median loads presented in Table 6.7 are also shown along with corresponding distributional statistics (e.g., 75th and 25th percentiles, highest/lowest data value within 1.5 times the inter-quartile range, and upper/lower outliers) in Figure 6.5 for each assessment unit.

Table 6.7. Quantification of daily model-predicted existing load, NPDES load (WLA), TMDL, required load reduction and equivalent percent, and maximum allocated load (cfu/day). The maximum allocated load applies to the LA for all assessment units excluding the MS4 Zone (Findlay). For the MS4 Zone, the maximum allocated load applies to the WLA only. Values represent the median of 7 geometric means for each month during the recreation season for the period 2000-2006. October geometric means are based on a 15-day period of record.

Month	N	Exist Total	Exist NPDES	TMDL	Reduction	% Reduction	Max Allocation
		median (10^9 cfu/day)					
The Headwaters (04100008-010)							
May	7	4,129	13	1,431	2,254	67%	1,418
Jun	7	3,477	13	1,074	2,429	73%	1,061
Jul	7	3,911	13	667	2,934	87%	654
Aug	7	3,781	13	489	2,994	88%	476
Sep	7	3,949	13	412	3,029	91%	399
Oct	7	3,331	13	538	2,915	88%	524
The Outlet / Lye Ck (04100008-020)							
May	7	2,555	3	1,363	1,165	55%	1,360
Jun	7	2,420	3	1,024	1,359	64%	1,020
Jul	7	2,407	3	508	1,813	85%	505
Aug	7	2,443	3	387	1,895	89%	384
Sep	7	2,446	3	306	1,907	90%	303
Oct	7	2,232	3	430	1,803	85%	427
The Outlet (lower) (04100008-020-030)							

May	7	876	0	389	451	62%	389
Jun	7	833	0	293	507	69%	293
Jul	7	829	0	144	639	87%	144
Aug	7	843	0	109	664	91%	109
Sep	7	838	0	85	666	92%	85
Oct	7	766	0	122	636	87%	122
Eagle Ck (04100008-030)							
May	7	2,968	575	1,814	1,085	43%	1,240
Jun	7	2,843	575	1,564	1,235	49%	989
Jul	7	2,812	575	1,216	1,623	64%	641
Aug	7	2,818	575	1,051	1,693	68%	477
Sep	7	2,852	575	1,086	1,705	68%	511
Oct	7	2,768	575	1,020	1,614	64%	445
Ottawa Ck (04100008-040)							
May	7	4,022	7	1,641	1,995	64%	1,634
Jun	7	3,590	7	1,283	2,243	72%	1,276
Jul	7	3,451	7	591	2,762	88%	584
Aug	7	3,531	7	441	2,834	90%	434
Sep	7	3,579	7	388	2,871	92%	381
Oct	7	3,135	7	498	2,750	88%	491
Riley Ck (04100008-050)							
May	7	2,359	90	964	1,231	63%	874
Jun	7	2,100	90	830	1,215	62%	740
Jul	7	2,118	90	520	1,663	84%	430
Aug	7	2,370	90	391	1,731	88%	301
Sep	7	2,353	90	341	1,738	88%	251
Oct	7	1,967	90	378	1,667	85%	288
Cranberry Ck (04100008-060)							
May	7	8,154	2	1,597	3,961	78%	1,595
Jun	7	6,385	2	1,432	4,113	82%	1,431
Jul	7	6,436	2	737	4,628	92%	735
Aug	7	6,220	2	468	4,719	93%	466
Sep	7	6,500	2	454	4,727	95%	452
Oct	7	4,970	2	471	4,603	93%	469
MS4 Zone (City of Findlay)							
May	7	1	0	75	0	0%	75
Jun	7	2	0	67	0	0%	67
Jul	7	4	0	53	0	0%	53
Aug	7	4	0	50	0	0%	50
Sep	7	3	0	46	0	0%	46
Oct	7	3	0	51	0	0%	51

Figure 6.4. Distribution of percent load reduction needed to meet chronic TMDL target (1000 cfu/100 mL) by month of recreation season. The sequence "M J J A S O" represents May 1 through October 15 by month (e.g., M = May). The distribution is composed of 7 monthly geometric means for the period 2000-2006 and portrayed by assessment unit; assessment unit codes defined in Figure 6.3 above. Icons are identified in Figure 6.3 (above).

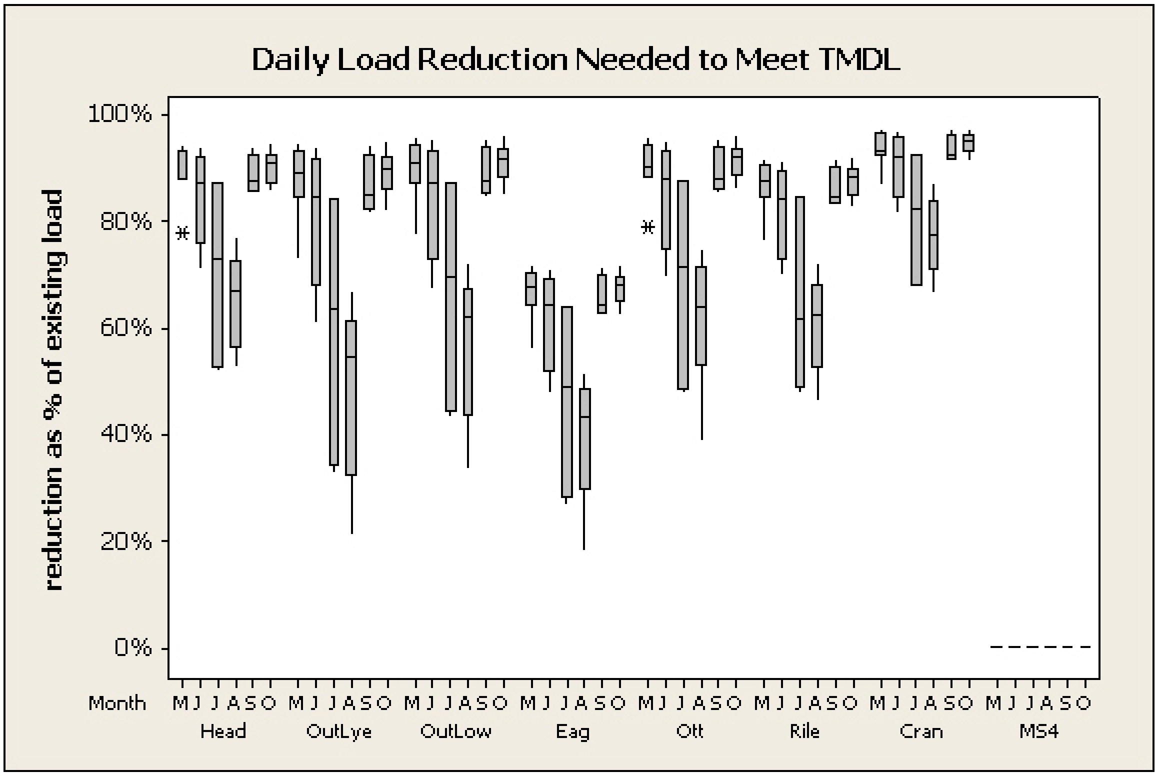
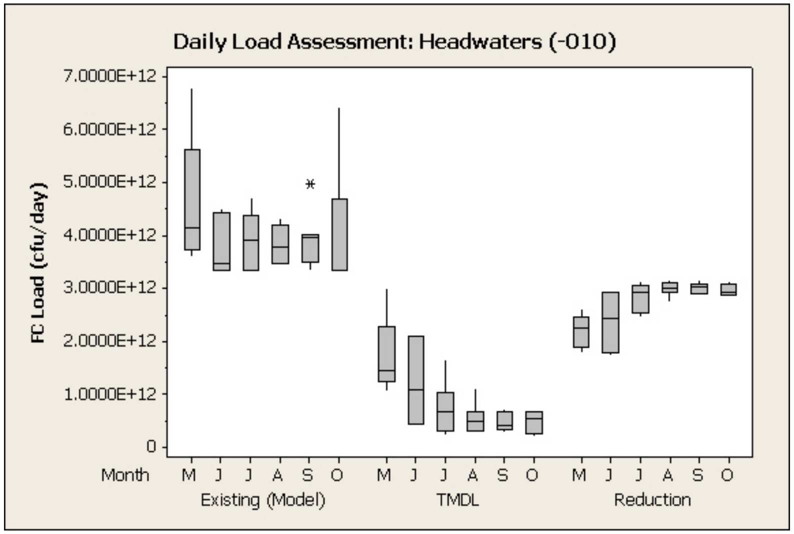
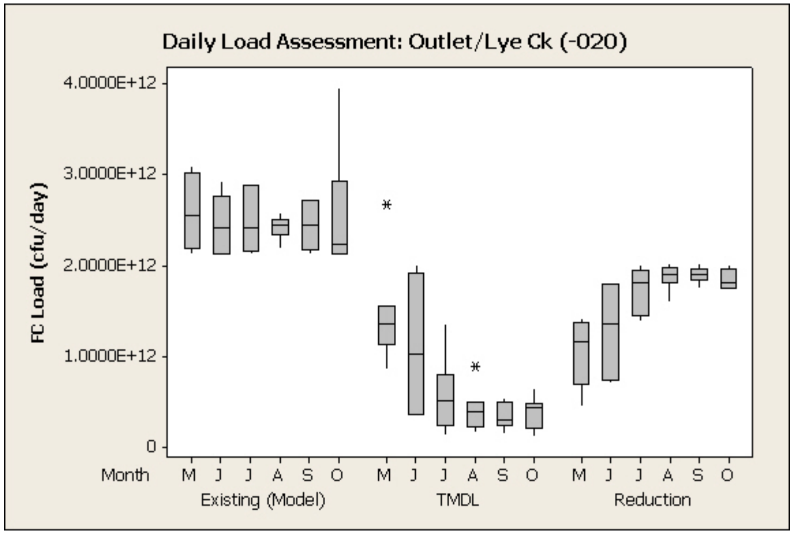


Figure 6.5. Distribution of model-predicted fecal coliform loads, allowable load (TMDL), and required load reduction (all in cfu/day) by month of recreation season. The distribution is composed of 7 monthly geometric means for the period 2000-2006 and portrayed by assessment unit: The Headwaters (a), The Outlet/Lye Ck (b), The Outlet (lower) (c), Eagle Ck (d), Ottawa Ck (e), Riley Ck (f), Cranberry Ck (g), and MS4-Findlay Zone (h). Icons are identified in Figure 6.3 (above).

a


Daily Load Assessment: Headwaters (-010)
FC Load (cfu/day)
7.0000E+12
6.0000E+12
5.0000E+12
4.0000E+12
3.0000E+12
2.0000E+12
1.0000E+12
0
Month
M J J A S O M J J A S O M J J A S O
Existing (Model)
TMDL
Reduction

b


Daily Load Assessment: Outlet/Lye Ck (-020)
FC Load (cfu/day)
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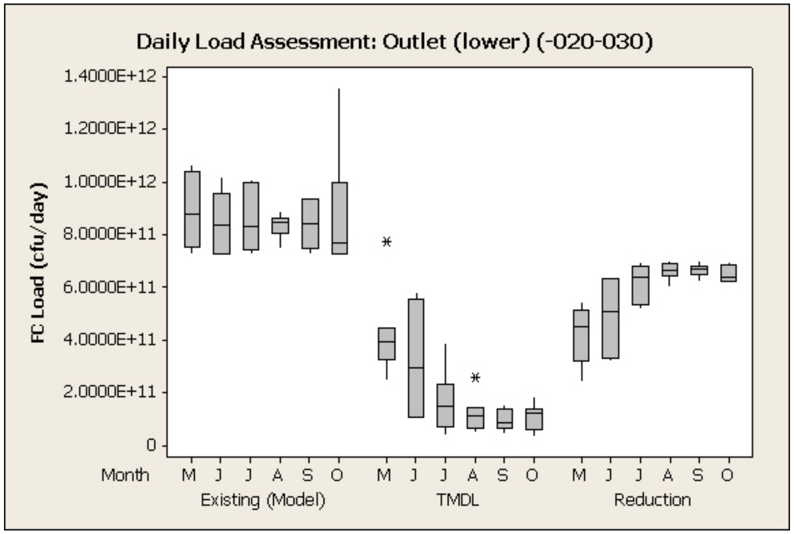
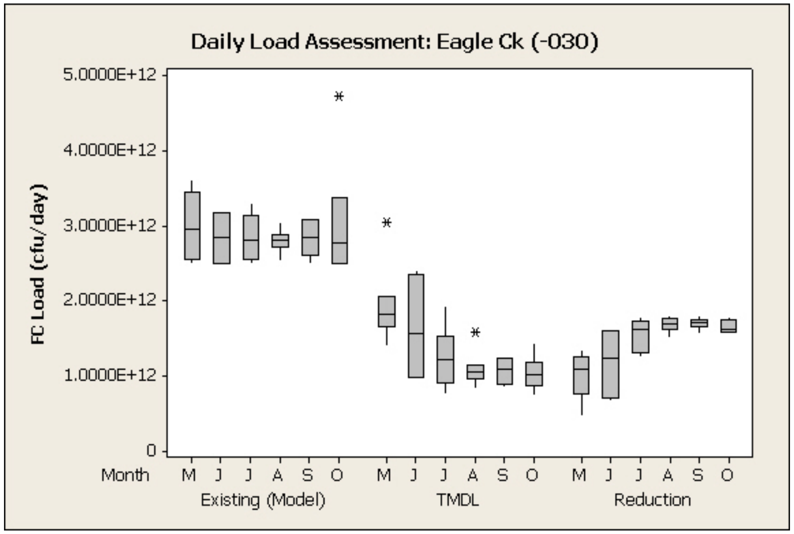
1.0000E+12
0
Month
M J J A S O M J J A S O M J J A S O
Existing (Model)
TMDL
Reduction

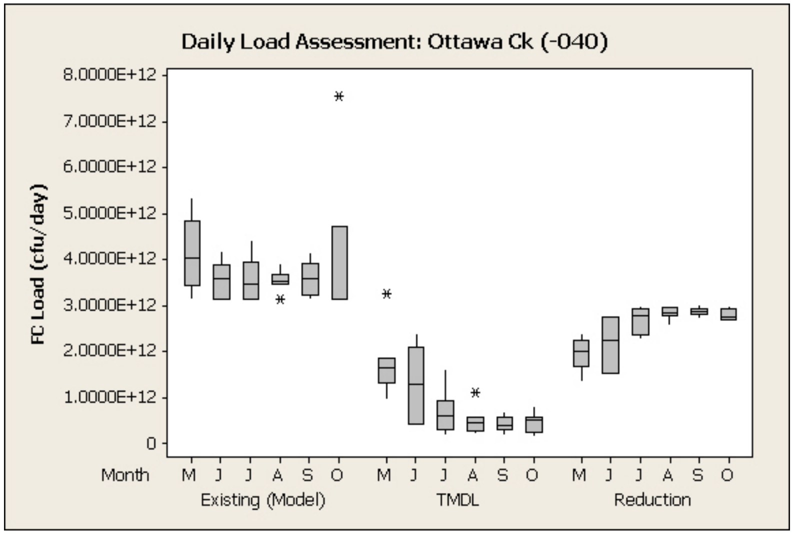
c


Daily Load Assessment: Outlet (lower) (-020-030)
FC Load (cfu/day)
1.4000E+12
1.2000E+12
1.0000E+12
8.0000E+11
6.0000E+11
4.0000E+11
2.0000E+11
0
Month
M J J A S O M J J A S O M J J A S O
Existing (Model)
TMDL
Reduction

d


Daily Load Assessment: Eagle Ck (-030)
FC Load (cfu/day)
5.0000E+12
4.0000E+12
3.0000E+12
2.0000E+12
1.0000E+12
0
Month
M J J A S O M J J A S O M J J A S O
Existing (Model)
TMDL
Reduction

e


Daily Load Assessment: Ottawa Ck (-040)
FC Load (cfu/day)
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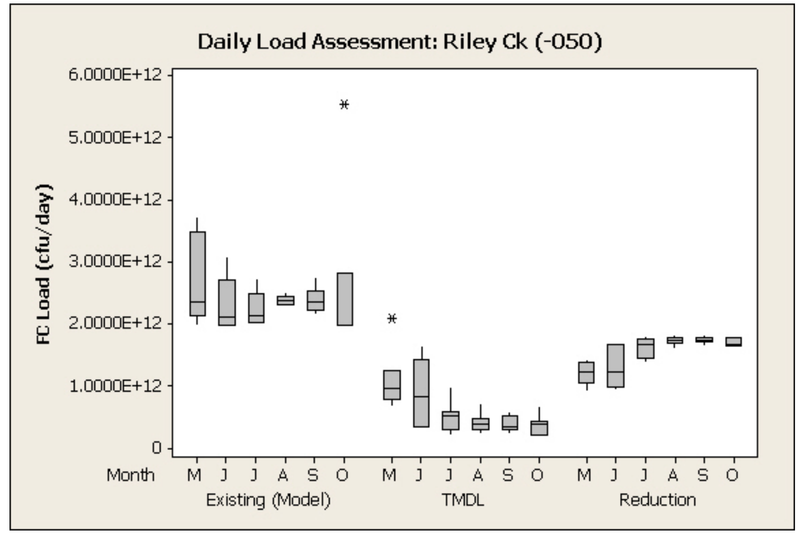
6.0000E+12
5.0000E+12
4.0000E+12
3.0000E+12
2.0000E+12
1.0000E+12
0
Month
M J J A S O
Existing (Model)
M J J A S O
TMDL
M J J A S O
Reduction

f


Daily Load Assessment: Riley Ck (-050)
FC Load (cfu/day)
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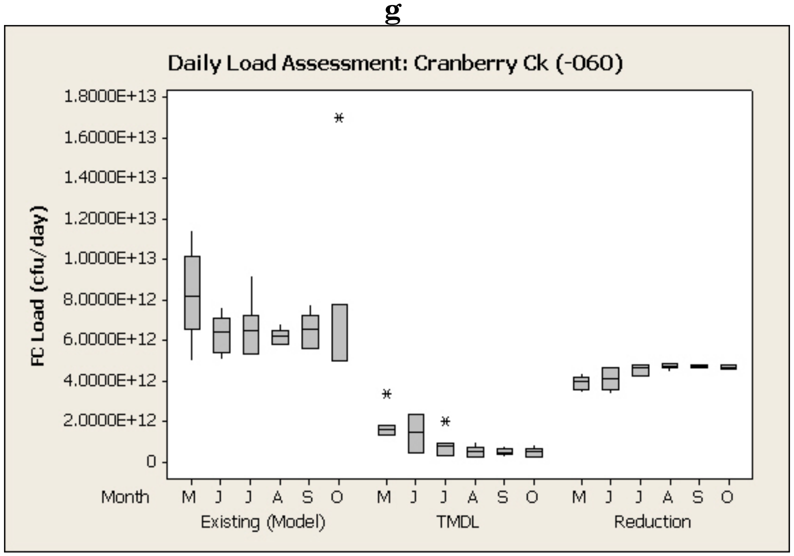
4.0000E+12
3.0000E+12
2.0000E+12
1.0000E+12
0
Month
M J J A S O
Existing (Model)
M J J A S O
TMDL
M J J A S O
Reduction

g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FC Load (cfu/day)
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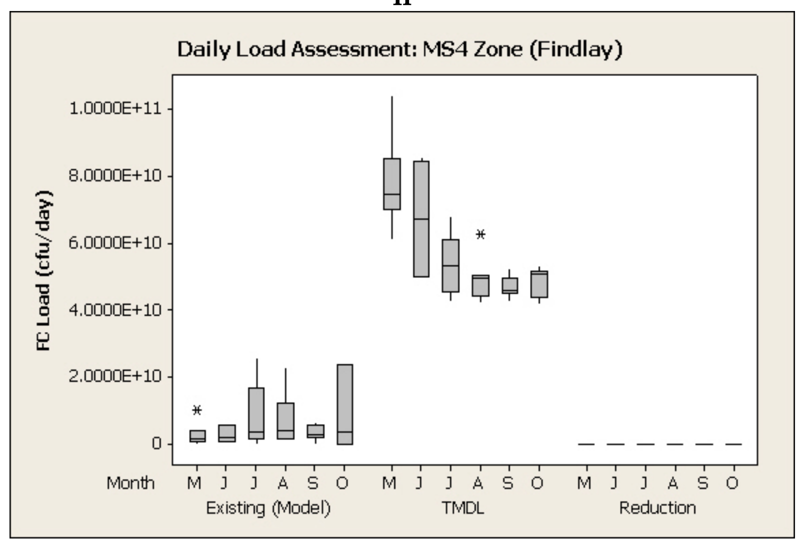
1.4000E+13
1.2000E+13
1.0000E+13
8.0000E+12
6.0000E+12
4.0000E+12
2.0000E+12
0
Month
M J J A S O
Existing (Model)
M J J A S O
TMDL
M J J A S O
Reduction

h


Daily Load Assessment: MS4 Zone (Findlay)
FC Load (cfu/day)
1.0000E+11
8.0000E+10
6.0000E+10
4.0000E+10
2.0000E+10
0
Month
M J J A S O
Existing (Model)
M J J A S O
TMDL
M J J A S O
Reduction

8) Load Allocation Scenario

The pathogen load allocation strategy required that a portion of the loading capacity be reserved for NPDES effluent meeting the fecal coliform permit limit (Table 6.2). The residual capacity was allocated to nonpoint sources that contributed pathogens to the stream system through surface washoff.

Based on amounts defined in Table 6.7, reductions in pathogen origin and transport to meet the chronic TMDL of 1000 cfu/100 mL and acute TMDL of 2000 cfu/100 mL were achieved through adjustments to point and non-point source entities. Pathogen inputs were decreased until the monthly geometric mean concentration was equal to or below the chronic criterion. Concomittantly, the 90th percentile was checked to ensure non-exceedence of the acute criterion.

A primary focus to reduce pathogens was through livestock manure production and transport. Manure enters the watershed system through direct contributions from beef cattle in streams, direct contributions from livestock in pasture due to grazing activity, application onto fields from livestock in confinement, and through presence of wildlife.

a) Management of Livestock Manure: Direct Stream Inputs
All beef cattle were excluded from streams through fencing to produce a direct zero-export of pathogens into the channel. For all livestock types, only beef cattle were permitted to access streams. However, once beef cattle were eliminated from streams, their presence in the pasture would increase albeit at a lesser loading rate than direct access to streams.

b) Management of Livestock Manure: Pasture and Land Application
Manure from cattle (both beef and dairy) and sheep is assumed to be contributed to pastureland in proportion to time spent grazing. For confined animals, manure from cattle (both beef and dairy), swine, and poultry are assumed to be collected and applied to cropland. Two restoration approaches were implemented. The first was to reduce poultry numbers by 40% and thus transport this same percentage of poultry litter outside the watershed. Transport of this manure type is the most feasible compared to all others and reduces the land application contribution. The 40% reduction, or a subset of, could also correspond to improved land management practices that would reduce the runoff transport to the stream system. The second approach was to increase the runoff coefficient within the washoff function for both urban (0.5 in) and non-urban (0.65 in) land uses to 0.8 in and 0.95 in, respectively. The runoff coefficient affects both pasture and land application components of manure export. Increasing the runoff coefficient mimics the installation of land management practices in the upland watershed areas to reduce transport of pathogens at the point of generation. The runoff coefficient represents the depth of runoff required to transport 90% of the pathogen load downslope.

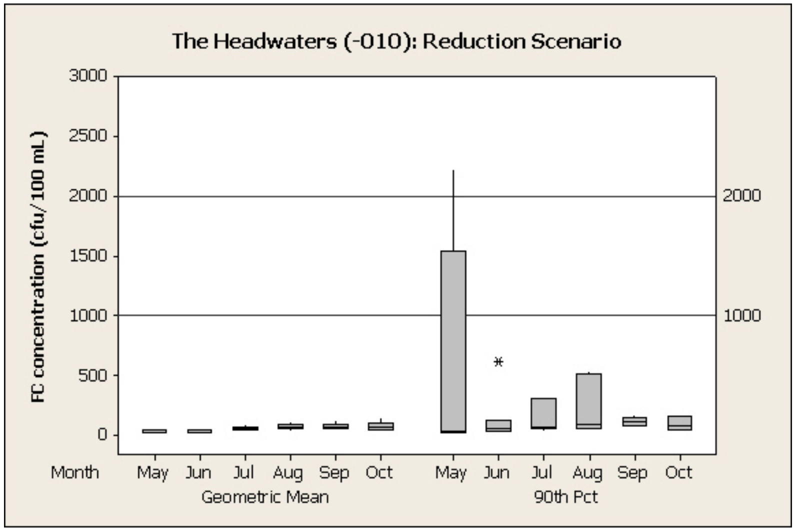
c) Residential Septic Systems
The failure rate was reduced from 50% to 5% over each of the six assessment units to reflect strong, consistent, and widespread enforcement of the Ohio HSTS rule (Ohio Department of Health 2006).

d) NDPES wastewater effluent
Because inputs to the pathogen model for wastewater sources were established at the legal permit limit of 1000 cfu/100 mL, no adjustments to NPDES loads were considered.

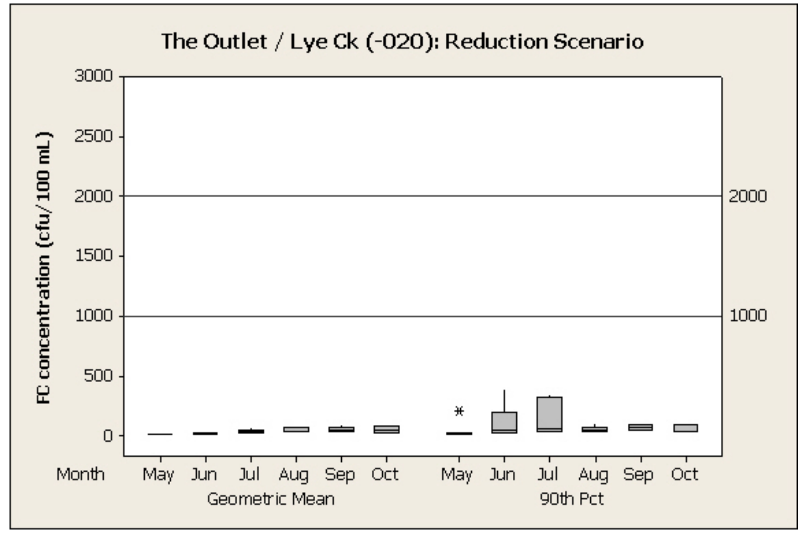
Using the strategies defined in a-c above, all fecal coliform concentrations are now below the chronic and acute TMDL for each assessment unit and each month of the recreation season (Figure 6.6). However, one should note that attainment of the chronic criterion for recreation use can not be achieved alone by eliminating cattle in streams and reducing failure rate of home septic systems. Even when the failure rate was reduced to 0%, exceedences of the chronic criterion still occur. Some form of land management practice or manure export is required to bring the existing load at or below the fecal coliform TMDL.

Figure 6.6. Distribution of geometric mean and 90^{th} percentile model-predicted fecal coliform concentrations by month of recreation season in response to the restoration scenario portrayed above. Water quality criteria are depicted by horizontal line and defined in Figure 6.3. The distribution is composed of 7 monthly geometric means for the period 2000-2006 and portrayed by assessment unit: The Headwaters (a), The Outlet/Lye Ck (b), The Outlet (lower) (c), Eagle Ck (d), Ottawa Ck (e), Riley Ck (f), Cranberry Ck (g), and MS4-Findlay Zone (h). Icons are identified in Figure 6.n (above). The upper outlier for October concentration (90^{th} percentile) has been omitted for all assessment units so that a smaller y-scale may be displayed.

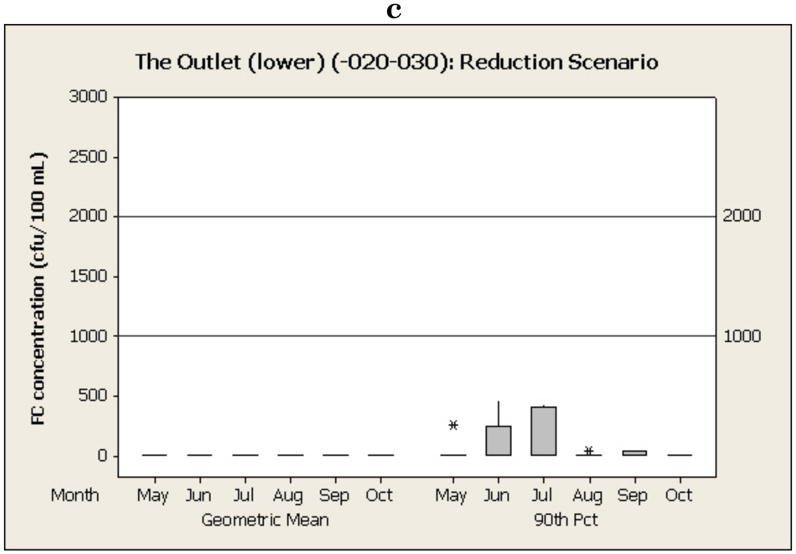
a


The Headwaters (-010): Reduction Scenario
FC concentration (cfu/100 mL)
3000
2500
2000
1500
1000
500
0
2000
1000
Month
May Jun Jul Aug Sep Oct
Geometric Mean
May Jun Jul Aug Sep Oct
90th Pct

b


The Outlet / Lye Ck (-020): Reduction Scenario
FC concentration (cfu/100 mL)
3000
2500
2000
1500
1000
500
0
2000
1000
Month
May Jun Jul Aug Sep Oct
Geometric Mean
May Jun Jul Aug Sep Oct
90th Pct

c


The Outlet (lower) (-020-030): Reduction Scenario
FC concentration (cfu/100 mL)
3000
2500
2000
1500
1000
500
0
2000
1000
Month
May Jun Jul Aug Sep Oct
Geometric Mean
May Jun Jul Aug Sep Oct
90th Pct

d

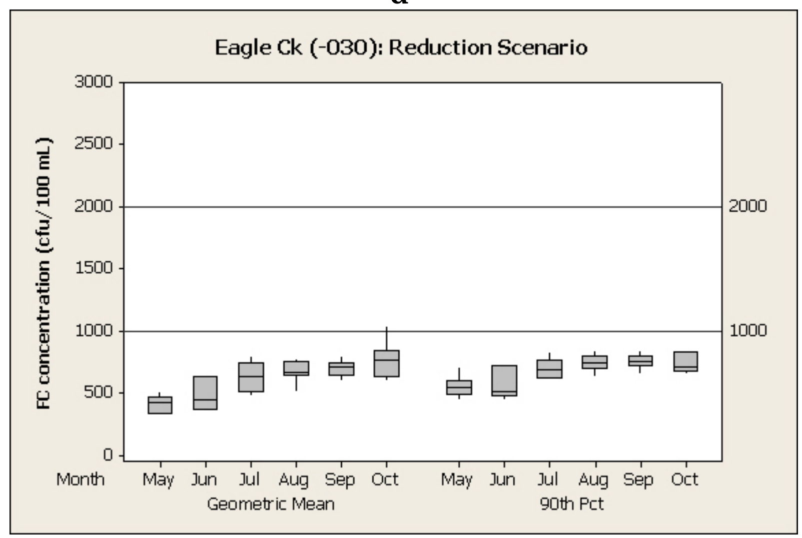
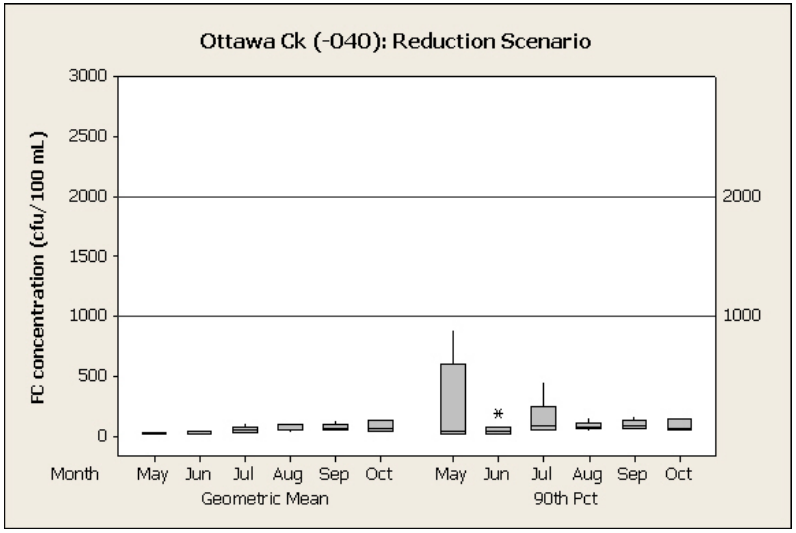
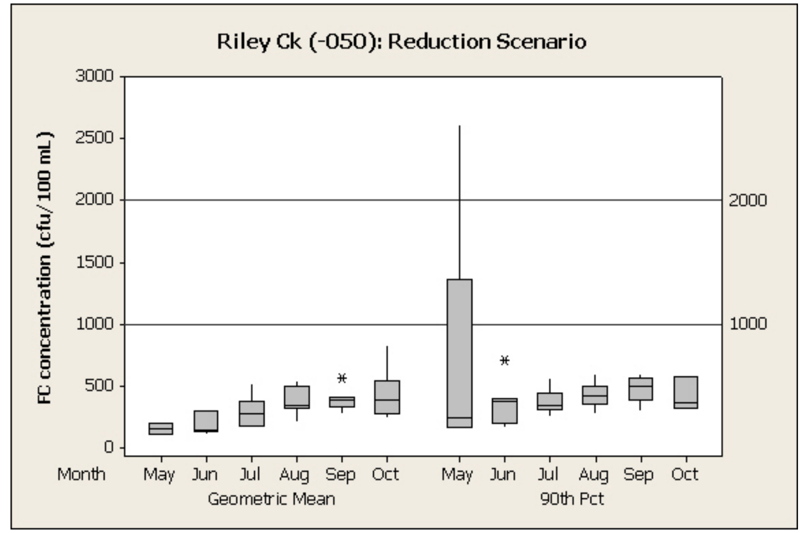

Eagle Ck (-030): Reduction Scenario
FC concentration (cfu/100 mL)
3000
2500
2000
1500
1000
500
0
2000
1000
Month
May Jun Jul Aug Sep Oct
Geometric Mean
May Jun Jul Aug Sep Oct
90th Pct

Figure 6.6. *(continued)*

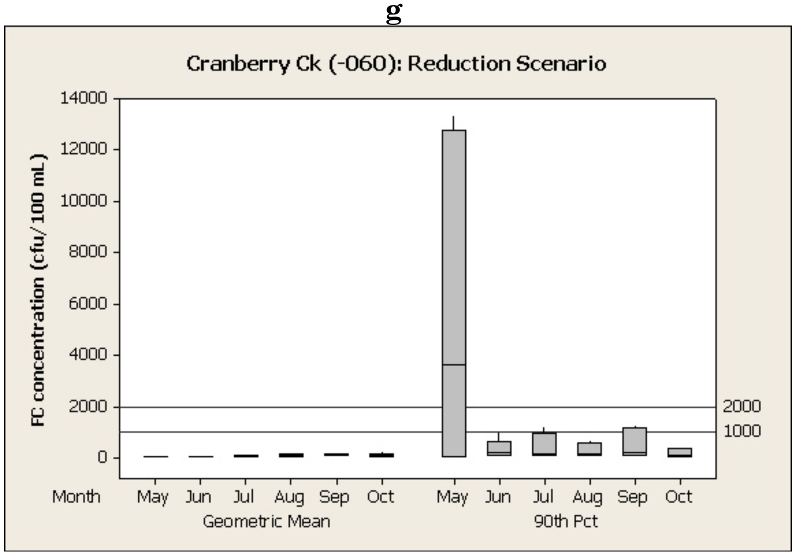
e



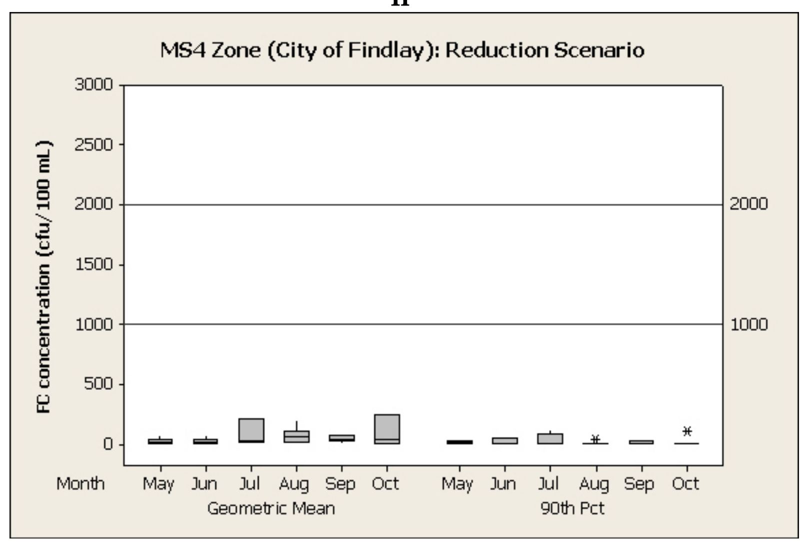
f



g



h



9) References

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