CHAPTER 5

ANALYSIS OF BASELINE STUDY RESULTS AND HISTORIC INFORMATION

Results of the monitoring and land use/land cover studies were reviewed and analyzed using several methods to gain the broadest understanding of conditions in each of the three subwatersheds. The reader will first encounter a discussion of the monitoring program results, giving context to the data and initial suggestions for improvements. Next is a section describing the various methods of analysis used. Following this are the results of the analyses, combining the land use and land cover results with those of the monitoring program. These analyses give further guidance as to what actions should be taken to prevent and reduce non-point pollution, and where to concentrate those efforts. An overview of the historic conditions is then added to complete the analysis.

5.1 Discussion of Monitoring Program Results

5.1.1 Chemical, Physical and Bacteriological Analysis (by Parameter)

5.1.1.1 Stream Temperature

In seven samplings over 2002 and 2003, the maximum allowable stream temperature has not been exceeded at any site. Generally, Buck Creek had lower stream temperature in July and September than other subwatersheds. This lower temperature is likely because of a greater amount of groundwater contribution (springs) to stream flow and tree canopy cover.

The potential coldwater status of Buck Creek opens the possibility of introducing trout species. A sustainable trout population would not only provide a fishery resource that is otherwise unavailable in Delaware County, but most importantly, it would create an opportunity to provide greater protection for Buck Creek under the Indiana Administrative Code which requires streams capable of supporting the natural reproduction of trout to be maintained as such. There are no salmonid species native to the White River Watershed, therefore, and the possibility of Buck Creek successfully supporting introduced trout species would require further research. Current data suggests that the dissolved oxygen and temperature requirements of rainbow trout and brown trout would be marginally consistent with the conditions found within Buck Creek (Wehrly et al. 1999). However, given the historical difficulties with establishing persistent salmonid populations, a thorough investigation would need to be conducted by a fisheries biologist with experience specifically related to the physical habitat requirements of salmonids before stocking could be recommended.

Regardless of whether or not trout are eventually stocked, an effort should be made to maintain or decrease stream temperatures in Buck Creek. The natural structure and function of the fish communities within this cold/cool water stream are unique within Delaware County and they are likely dependent on protection of the narrow riparian corridor that remains throughout most of the length of the stream. Additional protection could be provided by increasing the width of the riparian corridor along Buck Creek and its tributaries and by limiting construction of additional impervious ground cover.

5.1.1.2 Water pH

All samples from both years have been between pH 6 and 9, which are the limits specified in IAC 327 2-1-6. Values tended to be lower in the May 2003, July 2003, September 2003, and October 2003 samplings than for July 2002 and October 2002 dates. Buck Creek had increasing water pH going downstream in the second half of 2002, but decreasing pH downstream during May 2003, July 2003, and September 2003. Killbuck Creek had lower overall values than the other subwatersheds for May 2003, July 2003, and September 2003.

5.1.1.3 Dissolved Oxygen

Levels of dissolved oxygen (DO) were lower than the 5.0 mg/L daily average IAC requirements for eleven instances (7%) in the Killbuck Creek and Prairie Creek subwatersheds. The instances include KB-1 in July 2002 and September 2003, KB-2 in July 2003 and September 2003. KB-4 in September 2003, KB-5 in July 2003 and September 2003, KB-6 in July 2003, and PC-6 in July 2003. PC-4 and PC-5 also had low levels of DO in September 2003. Note: there are no legal standards for water quality in privately owned reservoirs at this time in the state of Indiana.

Levels of DO were below the 4.0 mg/L at any time IAC requirement in three instances (2%). The instances are KB-6, PC-2 (WR-4), and PC-6 in September 2003.

BC-1 (WR-1), BC-2 (WR-2), BC-3, BC-5, BC-6, BC-7, BC-8, PC-3, PC-7, and PC-8 reported DO values that were consistent with the IAC regulation for cold water fish habitat of not less than 6.0 mg/L at any one time. Over all, sampling times twenty three instances (15%) were less than the standard of cold water fish habitat. Generally, the DO values were lower in July and September 2003.

Areas of concern include BC-4, the Mud Creek tributary to Killbuck, and PC-6. Best management practices in agricultural areas include erosion control, filter strips, and manure management. Favorable practices for urban areas include erosion control on developing areas, constructed wetlands for storm water treatment, and septic system repair and maintenance. Septic system elimination, by replacement with sanitary sewer, is also a practice that would increase DO levels. Reduction of flow from combined sewer overflow is another strategy for increasing DO (along with decreasing total suspended solids, *E. coli*, and other contaminants), but that will not be addressed in this report because it is beyond the scope of the project, which is primarily concerned with non-point pollution. Because shading lowers stream temperature, protection of riparian tree cover is appropriate for both urban and agricultural areas.

5.1.1.4 Biological Oxygen Demand

More than half of the water samples tested had Biological Oxygen Demand (BOD) values lower than the Method Detection Limit of 2.0 mg/L and only a few samples had BOD values that would be of concern (higher than 3.3 mg/L, Hoosier River Watch) In Buck Creek BOD levels tended to increase going downstream, but are mostly low. Killbuck had a more random pattern of BOD values, with high readings in the high flow events in May 2003. The Prairie Creek Subwatershed had generally low values, but registered high readings for the White River sites during flooding in October 2003 and moderately high readings in the reservoir in July 2003.

BOD is a measure of the oxygen used by microorganisms to decompose this waste. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high. As the waste is consumed or dispersed through the water, BOD levels will begin to decline. Nitrates and phosphates in a body of water can contribute to high BOD levels. Nitrates and phosphates are plant nutrients and can cause plant life and algae to grow quickly. When plants grow quickly, they also die quickly. This contributes to the organic waste in the water, which is then decomposed by bacteria. This results in a high BOD level. The temperature of the water can also contribute to high BOD levels. When BOD levels are high, dissolved oxygen levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive.

5.1.1.5 Total Suspended Solids

Thirty-one of the one hundred and fifty-four samples (20%) had total suspended solids (TSS) exceeding the guideline of 80 mg/L (Waters, 1995). All but two of the samples exceeding the guideline were from the May 2003 period. Killbuck Creek, which has more silt and sediment in the channel, had the eleven highest values (ranging from 160 to 800 mg/L). Most of the TSS in May would be soil particles transported by water erosion. TSS results in July samples were elevated as a result of algal growth. Soil particles can carry nutrients such as ammonium and phosphorus as well as pesticides.

Sites of concern are Buck Creek sampling points 3 through 7 and Killbuck 1, 2, and 5 (others also exceeded guideline). In both of these streams, there was a general tendency for TSS to increase going downstream. No Prairie Creek sites exceeded the guideline. Agricultural Best Management Practices (BMPs) would include erosion control (terraces, grass waterways, etc.), conservation tillage, and filter strips. Urban BMPs would include erosion control on construction sites and constructed wetlands for stormwater retention. Streambank restoration of degraded sites would be appropriate in both rural and urban areas.

Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organic and metals tend to bind to particles.

5.1.1.6 Ammonia Nitrogen

The maximum permissible ammonia nitrogen level allowed under Indiana Administrative Code varies with pH and water temperature. For example, a sample with a pH of 7.5 and temperature of 15 °C should not exceed a concentration level of 0.1054 mg/L of unionized NH_3-N. One hundred fourteen of the one hundred fifty-four samples (74%) had values exceeding the standard with the highest levels observed in Killbuck Creek. As temperature decreases the allowable concentration of NH_3 also decreases (down to 0.0746 mg/L at 10 °C). Several additional samples (from each subwatershed) had values above the standard at the lower temperatures. Only one sample was below the detection limit of 0.040 mg/L for Ammonia-N.

A note of caution with regard to this finding is that the method used also detects NH_4 because the samples are elevated to a high pH prior to analysis. The measurement of NH_3 in situ would be very difficult, so the laboratory method is used. However, many of the samples tested would have lower NH_3 concentrations than what the results reported indicate.

Areas of concern (ranked within subwatershed) include BC-4, 7 and 3; KB-2, 4, and 5; and PC-3,5, 4, 8, and 7. Note that PC-3 is below and PC-4 and 5 are in the reservoir and would be influenced by other drainage areas as well as the three tributaries that we are monitoring (Prairie Creek, Cunningham, and Huffman). Agricultural best management practices for reducing N loading are erosion control, conservation tillage, filter strips, and incorporation of manure. Favorable practices for urban areas include erosion control on developing areas, constructed wetlands for storm water treatment, and septic system repair, maintenance or elimination. About three-fourths of the ammonia produced in the United States is used in fertilizer either as the compound itself or as ammonium salts such as sulfate and nitrate. Large quantities of ammonia are used in the production of nitric acid, urea and nitrogen compounds. Since ammonia is a decomposition product from urea and protein, it is found in domestic wastewater. Fish and other aquatic organisms also contribute to ammonia levels in streams. NH_3 is toxic to aquatic organisms at relatively low concentrations.

5.1.1.7 Nitrate + Nitrite Nitrogen

Only one sample (KB-6, May 2003) had a nitrate + nitrite level exceeding the IAC drinking water standard of 10 mg NO_3-N/ L. However, sixty four samples (42%) contained NO_3 above the 1.6 mg/L guideline for modified warm water habitat (Ohio EPA, 1999). All three subwatersheds evidenced nitrates above the 1.6 mg/L guideline, but Killbuck Creek tended to have the highest levels in the May sampling. Despite potential dilution, nitrate levels were generally higher during high flows in May than during low flows observed in the second half of 2002. However, values reported from the high flow event in September 2003 were all below the 1.6 mg/L guideline. The September 2003 lower results were due to the fact that sampling occurred three days after the beginning of the high flow event, and therefore the pollutants which ran off of the landscape and into the waterways were already flushed downstream. Whereas, the May 2003 high flow sampling event took place during the first flush of the high flow event, and therefore sampling captured the complete picture of what pollutants ran off of the surrounding subwatershed. The White River watershed sites (WR-1, WR-2, WR-3, and WR-4) and four of the six sites in the Buck Creek subwatershed exceeded the guideline in July 2003. In October of 2003, the White River sites, PC-6, PC-7, PC-8 and five out of the six Buck Creek sites exceeded the guideline, but none of the Killbuck sites were above the modified warm water habitat guideline.

Areas of concern are all of the Buck Creek sites, especially BC-7; KB-6, 4, and 5; and PC-7, 8, and 6. Best management practices in agricultural areas include nutrient and manure management, constructed wetlands, and retrofitting of tile drains to manage flow. Favorable practices for urban areas include nutrient management of turf grass areas, constructed wetlands for storm water treatment, and septic system repair, maintenance or elimination.

Nitrogen is one of the most abundant elements and composes about 80 percent of the air. It is found in the cells of all living things and is a major component of proteins. Inorganic nitrogen may exist in the free-state as a gas, N_2, or as nitrate NO_3-, nitrite NO_2- or ammonia NH_3.

Organic nitrogen is found in proteins and is continually recycled by plants and animals. Nitrogen-containing compounds acts as nutrients in streams, rivers and reservoirs. The major routes of entry for nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes, runoff from fertilized agricultural fields and lawns and discharges from car exhausts. Bacteria in water quickly convert nitrites [NO_2] to nitrates [NO_3] and the process can deplete the oxygen supply. The major impact of nitrites/nitrates on fresh water bodies is eutrophication. Nitrates stimulate the growth of algae and other plankton which provide food for higher organisms, such as invertebrates and fish; however an excess of nitrogen can cause overproduction of plankton and as they die and decompose they use up the oxygen which causes other oxygen-dependent organisms to die.

Note: In most natural systems, nitrite is rapidly converted to nitrate. Nitrite tends to be more toxic to organisms than nitrate.

5.1.1.8 Orthophosphate -Phosphorus

Orthophosphate as P was found to be greater than or equal to the guideline for water quality of 0.1 mg/L (Pierzynski *et al*., 2000) in fifty five samples (36%) with two of the four highest values associated with the White River (WR-2 in July 2002 and October 2002, due to treatment plant discharge). During the high flow sampling events, May and September 2003, all sites exceeded the guideline because P tends to be attached to soil particles.

Killbuck Creek subwatershed had the most frequent occurrence of exceedance of this guideline. There were particularly high P levels in May 2003, with KB-3 and KB-2 having highest readings. However, no Killbuck sites exceeded the guideline in October of 2003. Buck Creek had many readings above the guideline in the high flow periods of May and Sept. 2003 with BC-3, 4, and 5 showing high levels. The Huffman Creek (PC-7) tributary in the Prairie Creek subwatershed had the highest P values followed by PC-8 and 6.

Areas of concern are all Buck Creek sites; Killbuck Creek (KB-3, 2, and 1); and PC-7, 8, and 6. Best management practices in agricultural areas include conservation tillage, erosion control, filter strips, nutrient and manure management. Favorable practices for urban areas include erosion control on construction sites, nutrient management of turfgrass areas, and septic system repair, maintenance or elimination.

There is not a specific state standard for phosphorus, but levels as low as 0.005 mg/L have been found to cause eutrophication (Correll, 1998). Similar to nitrate + nitrite, phosphates negatively impact water quality by causing accelerated rates of eutrophication. Phosphates naturally found in water are derived from decomposing organic material and leaching of phosphorus-rich bedrock. Sources of elevated readings could come from fertilizer runoff, human and animal waste from failing septic systems, sewage treatment plants, livestock confinement areas, mass quantities of decomposing organic matter, industrial effluent, and detergent wastewater.

5.1.1.9 *E. coli*

The *E. coli* standard (235 colony forming units per 100mL for a single sample: 327 IAC 2-1-6) was frequently exceeded. One hundred and thirty-eight of the one hundred and fifty-four samples (90%) contained *E. coli* above the standard with the top four sites being in urban areas (BC-2, BC-3, BC-4, and BC-5) that were sampled during the high flow period (May 5, 2003).

However, the top four sites, in decreasing order, during the high flow period of September 2003 were KB-6, KB-2, KB-1, and BC-4. Nine out of the fifteen samples that were less than the standard were located in Prairie Creek subwatershed, but six of the reservoir samples were also above the limit. Buck Creek tended to have the highest *E. coli* numbers, followed by Killbuck Creek in 2002 and May 2003 sampling events. In July and September of 2003, Killbuck Creek tended to have the highest E. coli numbers followed by Buck Creek. However, the White River watershed sites PC-2 (WR-4) and PC-1 (WR-3) had the highest E. coli numbers in October of 2003. Also, the Killbuck subwatershed reported the highest numbers followed by the Prairie Creek subwatershed and Buck Creek subwatershed in October of 2003.

Areas of concern are BC-3, 4, 5, and 8; KB-6, 2, and 1; and PC-7, 6, and 8. Best management practices in agricultural areas include filter strips, manure management, and fencing for exclusion of livestock from streams. Appropriate practices for urban areas include septic system repair /maintenance or elimination, proper handling of pet wastes, and constructed wetlands for pretreatment of combined sewer overflow.

5.1.1.10 Atrazine

Atrazine concentrations of four out of five samples taken in May of 2003 exceeded the drinking water and aquatic life standards for the pesticide. Only PC-3 had an Atrazine concentration below the standard and that may reflect biological decomposition or sedimentation of the chemical in the reservoir, which is immediately upstream of that sampling point. The Atrazine concentrations taken in November of 2002 and October 2003 were below the standard. Readers should be aware that concentrations in source water are normally higher than those in the drinking water supply distributed by Indiana American Water Company. This is because the company uses activated charcoal to filter out pesticides and other harmful chemicals before pumping water into the distribution system. BMPs include Integrated Pest Management, low application rates, incorporation of herbicides, filter strips, alternative products, mechanical cultivation, and organic production.

5.1.1.11 Diazinon

Diazinon concentrations taken were reported by Environmental Chemical Consulting Service Inc.(Madison, WI) in October of 2003 and reported to be below the method detection limit of 0.0084 ug/L. Samples analyzed in the NREM Department had a high concentration of 70 ng/L, which is less than the aquatic life standard and the drinking water guideline of 100 ng/L (0.1 ug/L).

5.1.2 Biological and Stream Habitat Analysis (by Subwatershed)

5.1.2.1 Killbuck Creek Subwatershed

Poor habitat quality results in low biological index scores for Killbuck and Mud Creek. QHEI scores were less than 40 for each site indicating very little habitat diversity. Under these conditions, healthy biological integrity is unattainable. Contributing sources to habitat impairment include stream channelization and degraded riparian zones. The extensive silt/muck substrates and the absence of lithophilic species suggest that sedimentation is a primary cause of impairment. Dense algal mats were found at each site indicating high nutrient loads from fertilizers, high sunlight intensity from canopy removal, and low flow velocities due to naturally low gradients, inappropriate channel modifications, or a combination of the two.

5.1.2.2 Buck Creek Subwatershed

The Buck Creek Subwatershed is defined by good habitat quality and underachieving biological communities. The headwaters of Buck Creek possess good habitat quality and biological integrity. The groundwater discharge from springs near the headwaters of Buck Creek has a strong influence on the fish community, depressing IBI scores at BC-8 and BC-7. This is a limitation of the IBI and not an indication of poor fish communities. Both the habitat and biological communities in these areas seem to be of fair quality.

Buck Creek at C.R. 400 S. (BC-6) shows an unusual dip in both habitat quality and biological integrity. The stream has been impounded near the bridge crossing, essentially creating a dammed area within the sample reach. The impact on the habitat and biota is evident in the scores, but the extent of impact is probably limited to a relatively small area in the stream. Removal of the dam would likely be sufficient to restore much of the habitat and biological quality at this United States Geological Survey (USGS) gaging station site. Buck Creek at 23rd St. (BC-5) scored consistently high for all indices. BC-5 is located at the upstream border of the influence of the city of Muncie. Buck Creek at Tillotson Ave. (BC-4) and C.R. 325 W. (BC-3) have the largest disparity between habitat quality and biological index scores.

While habitat quality is good at these sites, the macroinvertebrate communities have declined substantially. Fish communities do show a slight improvement, but this is due to increasing water temperatures as the influence of the springs become less significant. IBI scores are still lower than expected given the good habitat quality. These results suggest that BC-4 and BC-5 may be under the influence of chemical stressors. Possible influences include the combined sewer overflows (CSOs) located upstream from these sites or watershed runoff influences such as the highly urbanized nature of this subwatershed.

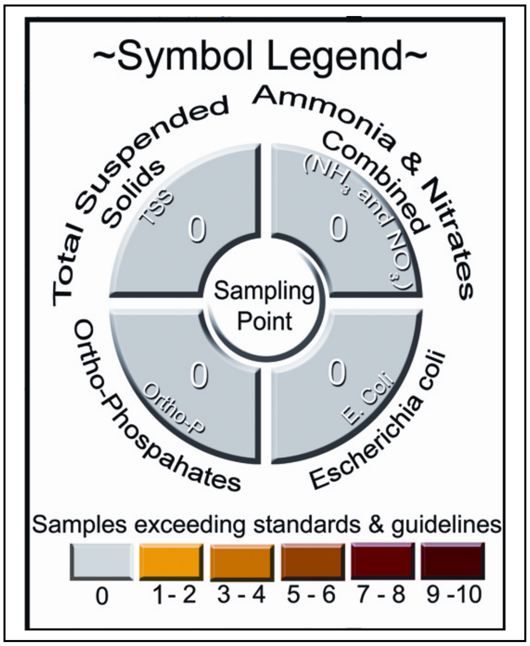
5.1.2.3 Prairie Creek Subwatershed

Prairie Creek (PC-6) had unusually low in-stream habitat quality and biological integrity scores given the fair condition of the floodplain. Due to the fact that there is almost no detectable flow, Prairie Creek appears to function more as an arm of the reservoir than as a lotic (flowing) water body. The biological communities found within PC-6 are typical of lake habitats which would support this assumption and make our biological criteria inappropriate for making water quality determinations. As there are no biological criteria for lentic (lake-type environment), only a generalized assumption about biological integrity can be made.

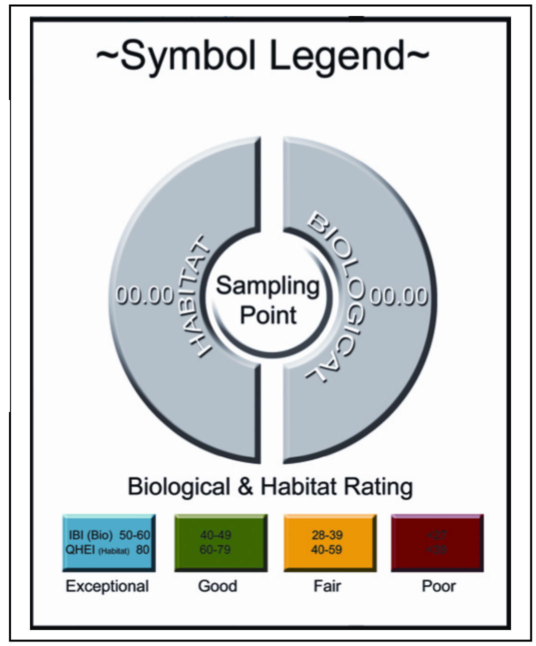
Huffman Creek (PC-7) had relatively high habitat scores considering its size. Typically streams of this size have been highly modified (like those in the Killbuck/Mud Creek Subwatershed) and have correspondingly low biological integrity scores. PC-7, however, has good habitat quality and fair biological index scores. The habitat scores of Cunningham Ditch (PC-8) were poor due to channelization, riparian removal, and livestock access. Like PC-6, the habitat and fish communities of PC-8 were also more typical of a lentic (lake-type environment) during the August 2002 sample. However, due to the lowering of the reservoir, the flow velocity of Cunningham Ditch visibly increased by the September sample. Habitat scores and biological index scores increased as the stream assumed the characteristics more typical of lotic (flowing) waters.

5.1.3 Monitoring Program Visual Summary (by Subwatershed)

The following four maps were used to summarize the plethora of data that was delivered by the monitoring program. These maps were instrumental in assisting the Technical Committee in explaining and gathering input from other members of the public.



Figures 5.1: Symbol Legend for Monitoring Program Results Summary Maps



The above numeric values were derived by quantifying the number of times (from all sampling sessions) a result for a given parameter (chemical or biological) exceeded state standards or scientific guidelines used in the original analysis.

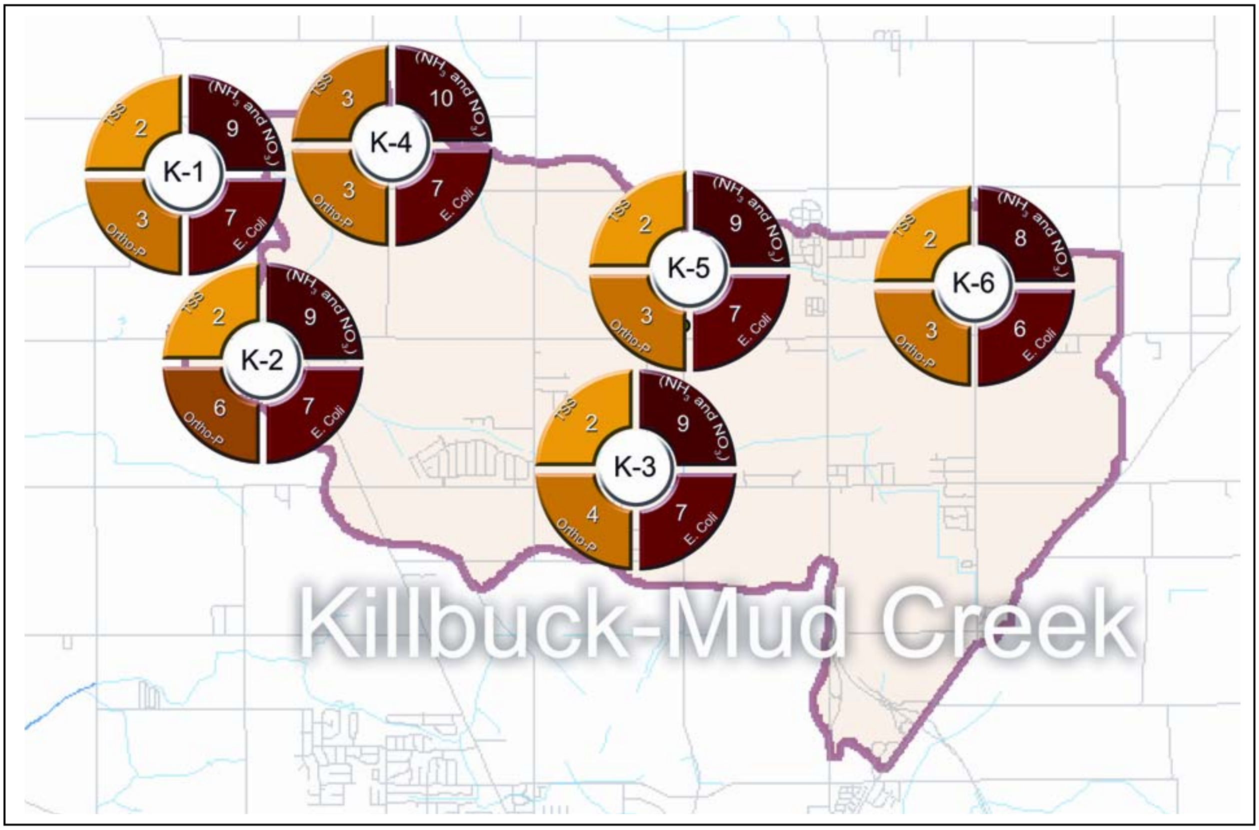


Figure 5.2: Killbuck/Mud Creek Subwatershed Chemical and *E. coli* Results Summary

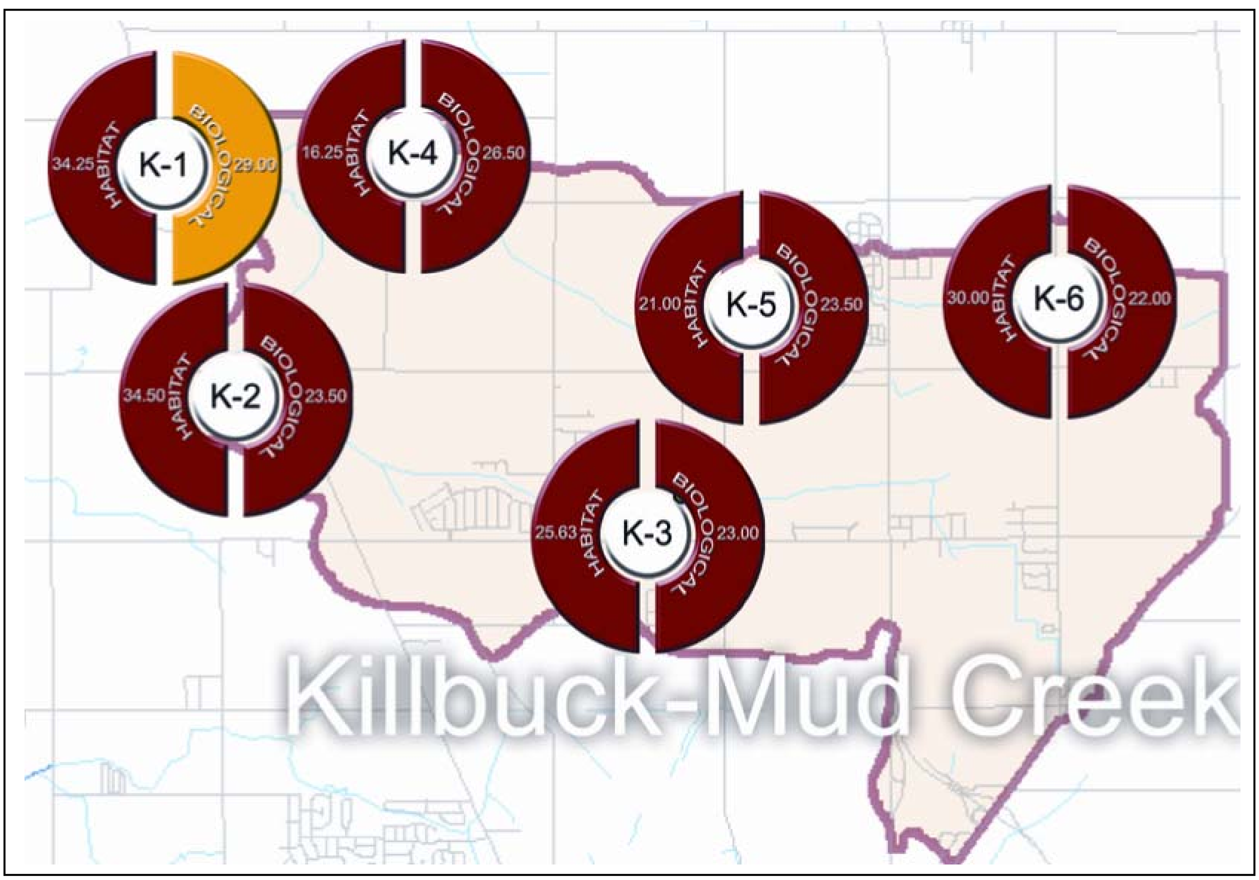


Figure 5.3: Killbuck/Mud Creek Subwatershed Biological and Stream Habitat Results Summary

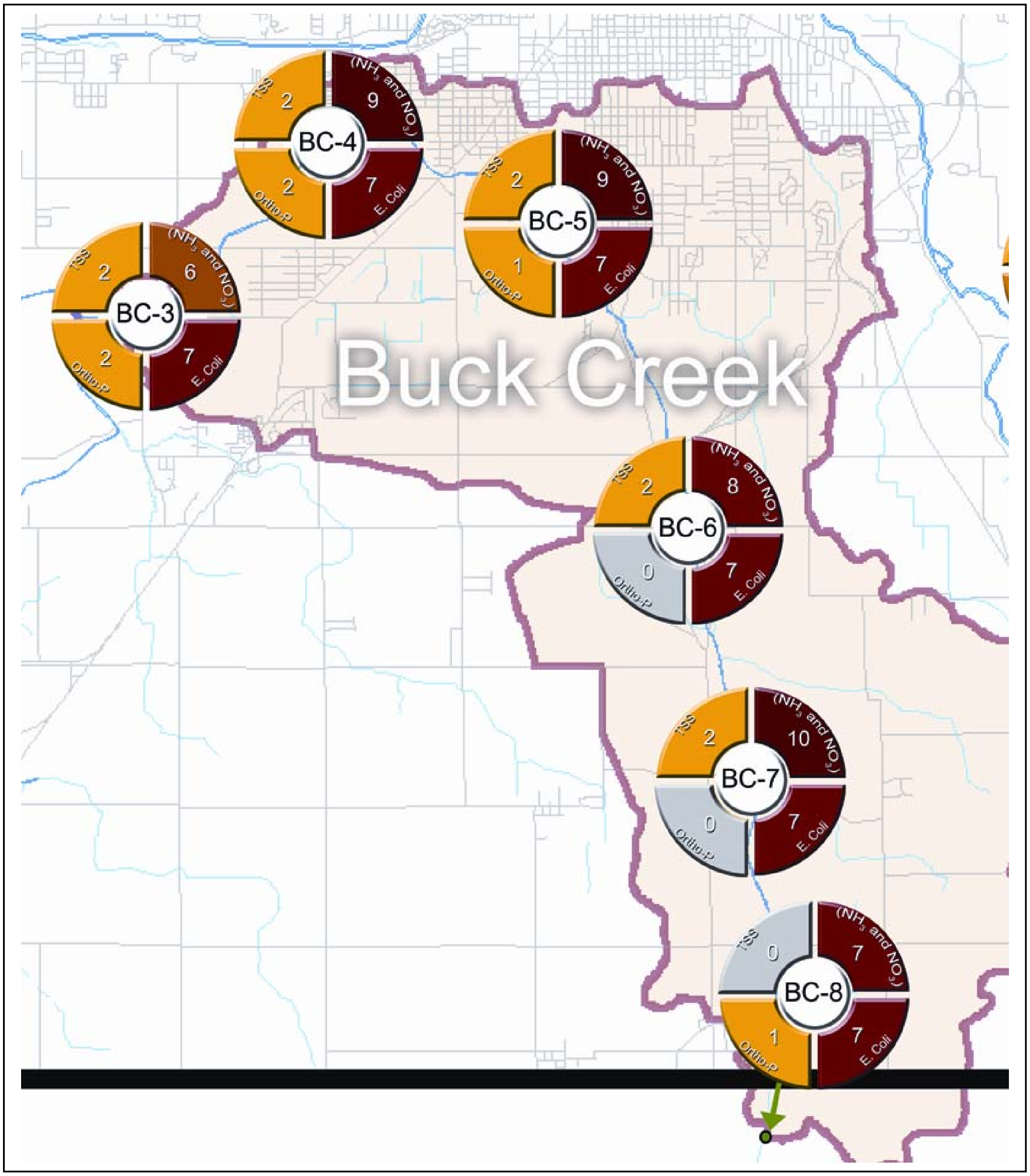


Figure 5.4: Buck Creek Subwatershed Chemical and *E. coli* Results Summary

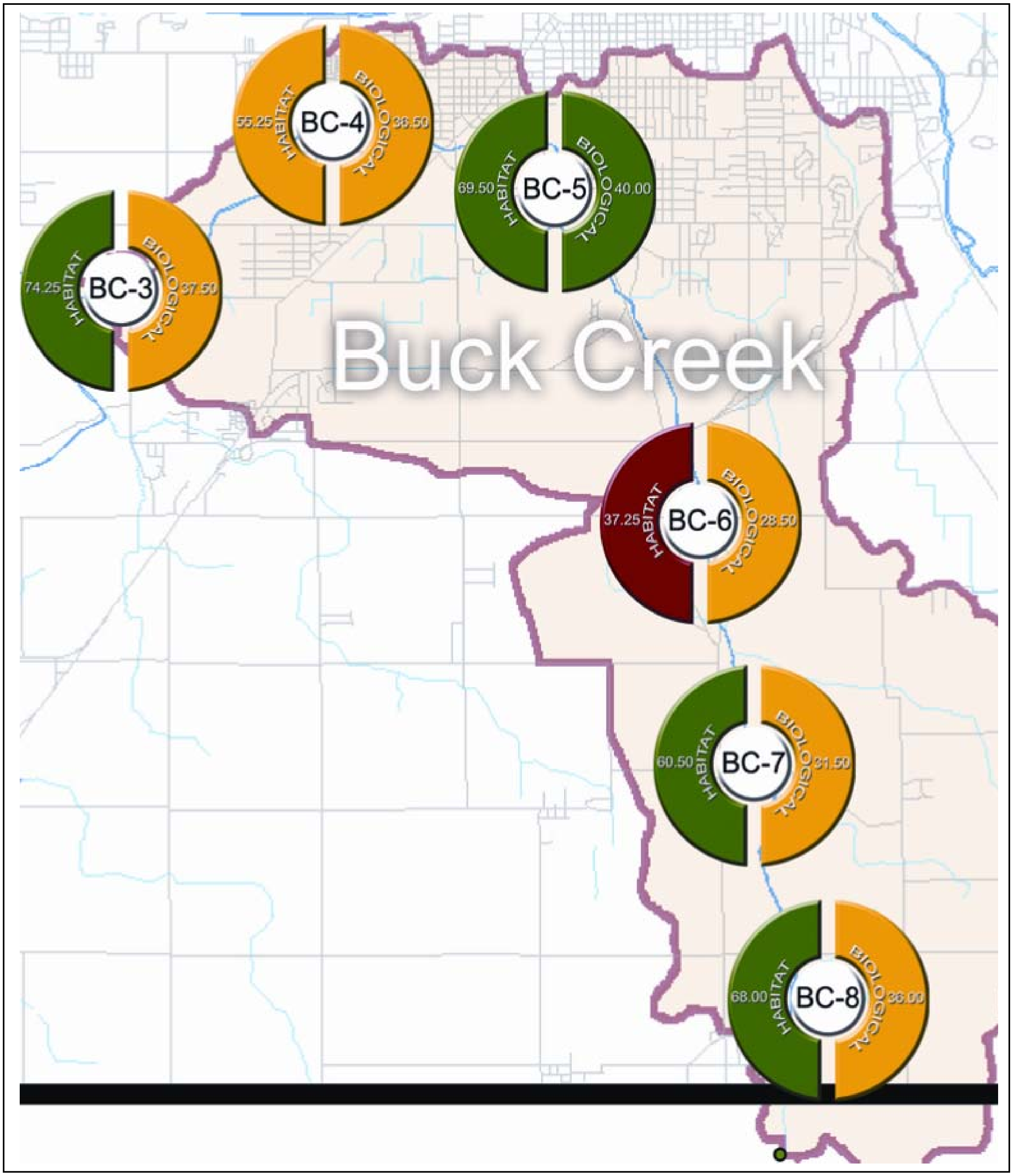


Figure 5.5: Buck Creek Subwatershed Biological and Stream Habitat Results Summary

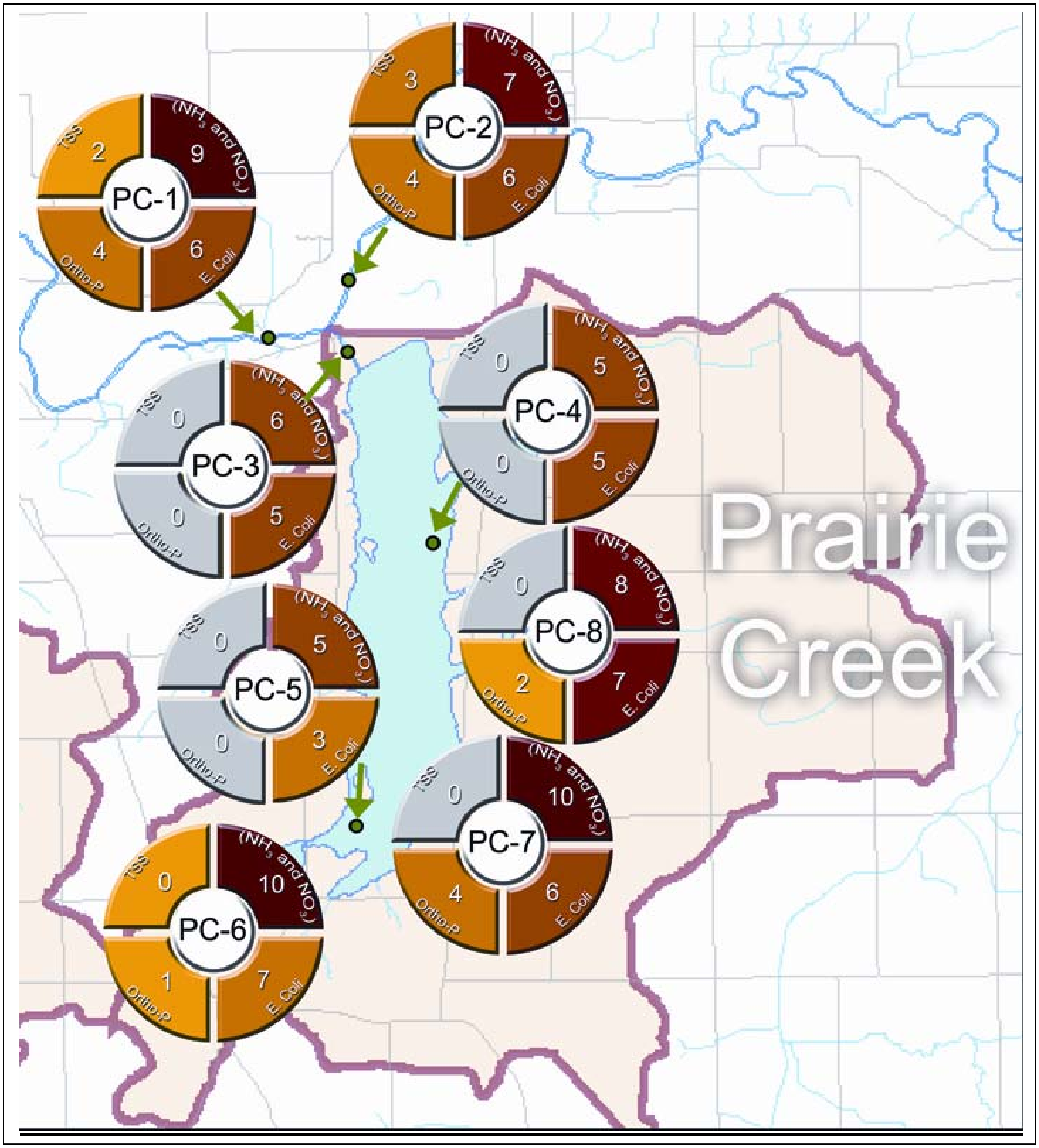


Figure 5.6: Prairie Creek Subwatershed Chemical and *E. coli* Results Summary

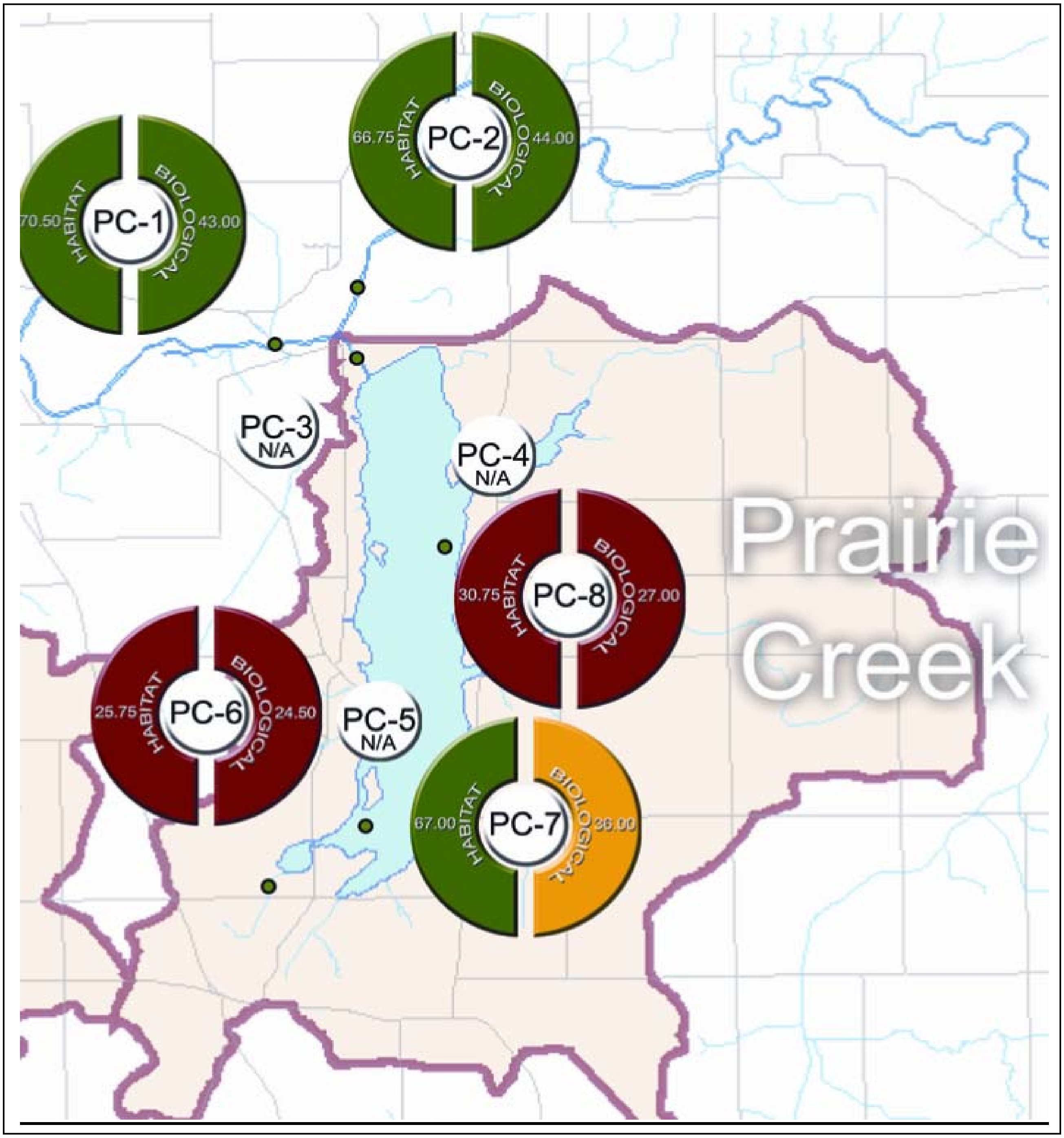


Figure 5.7: Prairie Creek Subwatershed Biological and Stream Habitat Results Summary

5.1.4 Sub-Subwatershed Rankings (by Subwatershed)

Table 5.1: Killbuck Creek Subwatershed Average Rank for Chemical and Biological Parameters Over All Sampling Dates

Subwatershed	Site	TSS Rank	NH_3 Rank	NO_3 Rank	Ortho-P Rank	*E. coli* Rank	QHEI Rank	IBI Rank	Overall Ranking
KB	2	2	1	6	1	3	5	3	3
KB	5	3	2	3	5	4	2	3	3.14
KB	6	5	4	1	6	1	4	1	3.14
KB	4	4	3	2	4	5	1	4	3.29
KB	1	1	5	4	3	2	6	5	3.71
KB	3	6	6	5	2	6	3	2	4.29

Note: Low rankings indicate most impaired sites

Table 5.2: Buck Creek Subwatershed Average Rank for Chemical and Biological Parameters Over All Sampling Dates

Subwatershed	Site	TSS Rank	NH_3 Rank	NO_3 Rank	Ortho-P Rank	*E. coli* Rank	QHEI Rank	IBI Rank	Overall Ranking
BC	4	2	1	4	1	1	2	4	2.14
BC	6	4	5	2	4	6	1	1	3.29
BC	7	5	2	1	5	5	3	2	3.29
BC	3	1	3	5	2	2	6	5	3.43
BC	5	3	4	3	3	3	5	6	3.86
BC	8	6	6	6	6	4	4	3	5.00

Note: Low rankings indicate most impaired sites

Table 5.3: Prairie Creek Subwatershed Average Rank for Chemical and Biological Parameters Over All Sampling Dates

Subwatershed	Site	TSS Rank	NH_3 Rank	NO_3 Rank	Ortho-P Rank	*E. coli* Rank	Overall Ranking
PC	7	3	5	2	1	1	2.40
PC	6	3	4	4	3	2	3.20
PC	8	3	6	3	2	3	3.40
PC	3	5	1	5	4	4	3.80
PC	5	4	2	6	6	5	4.60
PC	4	6	3	5	5	6	5.00

Note: Low rankings indicate most impaired sites

5.2 Statistical and Computer Analysis Methodology

5.2.1 Subwatershed Ranking System Analysis

To analyze problem locations within the subwatersheds, a ranking system was employed for assessing areas that could benefit from implementation of Best Management Practices. The chemical parameters used were TSS, NH_3, NO_3, P, and *E. coli*. Biological parameters including Qualitative Habitat Evaluation Index (QHEI) and the Index of Biological Integrity (IBI) were also incorporated into the ranking system; Invertebrate Community Index (ICI) was intentionally excluded on account of missing data. This list contains the variables that were most commonly above legal limits or guidelines. For each chemical parameter, measured concentrations for each sampling event at each location were ranked with the highest level assigned a rank of one. Ranks for a given location were then averaged (across date) for each parameter. The five rankings for each site were then averaged (across parameters) and the locations re-ranked based on the overall average (of date and parameter).

5.2.2 GIS and Regression Analysis

Regression analysis was used to determine significant relationships between parameters. Regression analysis evaluates the strength and nature of linear association between independent and dependent variables. Scatterplots were used to graphically display the association between the variables used in the regression analysis. The regression equation obtained from this analysis can be used to predict values for one variable based on values for an associated variable if a significant relationship exists. The first column in the following regression statistics tables indicate the independent variable and the second column indicates the dependent variables used in the analysis. The Probability>F (p-value) column indicates the statistical association that exists between the two variables. An association is considered to be significant if $p<0.05$, highly significant if $p<0.01$ and very highly significant if $p<0.001$. The R^2 column shows the "goodness of fit", or how close the individual points are to the trend line. The slope of the trendline is given by the "Slope" column. The sign (positive or negative) indicates whether there is a proportional or inversely proportional association between the variables. The final column, "Intercept", reveals where the trendline crosses the y-axis.

The biological index scores (IBI and QHEI) were averaged across date and regressed against the spatial land use and hydrologic soil groups parameters obtained from the GIS attribute table summarizations. The spatial land use of 5 meter, 30 meter, and sub-subwatershed areas were summarized by the ratio of area/total area at each sampling location. The soil hydrologic soils for each sub-subwatershed were also summarized by area/total area for each hydrological soil group. The hydrologic soil groups A and B areas were grouped together into a low runoff soils category. The hydrologic soil groups C and D areas were also grouped together into a high runoff soils category. The regression analysis between hydrologic soil groups and the biological parameters were not separated by subwatershed and were grouped together. The averaged biological index scores were also regressed against the chemical parameters data values. The chemical parameters were not averaged across date in this analysis and were not separated out by subwatershed. In addition, the chemical parameters concentration data values were also not averaged for the regression analysis between chemical parameter values. Only the estimates of stream discharge (Q) at BC-6 and the chemical parameters were used in regression analysis because of the accuracy the predicted values of Q on days that the sampling occurred and no Q data was collected.

5.3 Statistical and Computer Analysis Results

5.3.1 Subwatershed Ranking System Analysis

The differences in rankings are primarily based on land use patterns in the subwatersheds. Killbuck/Mud Creek has the highest percentage of agricultural land (73.4%), but that is nearly equivalent to Prairie Creek at 72.2%. Buck Creek has the lowest agricultural use at 53%. Thus, agricultural land use is not necessarily a good predictor of water quality.

A more consistent explanation for the ranking of subwatersheds comes from an evaluation of greenspace. The percentage of greenspace is as follows: 7.0% for Killbuck Creek 12.6% for Buck Creek, and 18.2% for Prairie Creek. A similar pattern holds for the 30 meter (almost 100 feet) buffer that border the streams in each subwatershed. Those values are 17.7% for Killbuck Creek 43.3% for Buck Creek, and 71% for Prairie Creek. Thus the ranking of subwatersheds based on high nutrient, sediment, and bacterial concentrations appears to be associated with the extent of woodlands, especially those near the stream. Forested riparian areas help reduce the transport of sediment and nutrients into the stream by creating a natural filter to overland flows and reducing stream bank erosion.

Land use for the main stem portions of the White River watershed has not been analyzed at this point. That analysis is complicated by the fact that a substantial portion of the watershed is located in Randolph County and we do not have the same information on land use for that area. Readers should also be aware that information on PC-3, 4 and 5 is not directly comparable to other sites because those locations are in Prairie Creek Reservoir.

5.3.2 GIS and Regression Analysis

(For detailed graphs and tables of regression analysis, see Appendix F.)

The Qualitative Habitat Evaluation Index (QHEI) and Index of Biological Integrity (IBI) scores were significantly correlated with the five-meter and thirty-meter woodland riparian buffer area. These correlations indicate that increasing wooded areas along the stream banks increases the QHEI and IBI scores. The five-meter riparian woodland buffer was more significant than the thirty meter riparian woodland buffer suggesting that wooded area adjacent to the stream are more critical to the fish communities than woodland further away from the streams. The QHEI and IBI were inversely correlated with the five-meter agricultural buffer, meaning that score decreased (became less favorable) with increasing agricultural land use in the narrow area next to the stream. The associations in the results section above demonstrate the importance of land use adjacent to the stream. The associations were found to be more significant in the five meter buffers. The thirty meter buffers and sub-subwatersheds associations were also found to be significant. However, these associations were less significant than the five-meter buffer. Having greenspace (woodlands and non-agricultural areas) close to the stream helps reduce soil erosion and nutrient loading. This doesn’t mean that there is no relationship between watershed quality and land use, it just indicates that the strongest relationship is between biological indicators and the woodlands that border streams.

The relationship between the NRCS hydrologic soil groups and the biological parameters indicated significant negative linear associations. The high runoff soils (hydrologic soil groups C and D) were found to have a negative influence on the IBI and QHEI index scores. In other words, as the amount of area of these soils increased the IBI and QHEI scores tended to decrease. This would suggest that as high soil runoff potential increases the probability of more sediment, nutrients, and contaminants would enter into the streams and thus have negative impacts on fish communities.

Several significant relationships were found between the chemical parameters and the biological parameters. It was found that as TSS, NH_3, and orthophosphate results increased the IBI and QHEI scores tended to decrease. This would suggest that these chemical parameters have a negative linear relationship with these biological parameters. Also, as the DO results increased the IBI and QHEI scores tended to increase, which would indicate a positive linear association. These results suggest that the amount of sediment and sediment that has contaminants bound to its matrix negatively affect fish communities at our sampling points. Also, as the concentration of DO increases it positively affects our fish communities. The results also indicated several significant relationships between chemical parameters. For example, as TSS data values increased so did NH_3, NO_3, Orthophosphate, and *E. coli* concentrations. Some of these relationships can offer suggestions why they occur but others are more complex and beyond the sampling design of this project. However, as sediment transport and/or erosion process are increased by anthropogenic activities we have found that more contaminants can be deposited in our streams. Ammonia as N (NH_3) and orthophosphate can become attached to sediments and readily deposited into local and eventually regional and national water bodies. Nitrate + Nitrite (NO_3) tends to leach through the soil profile and contaminate underground water supplies or aquifers.

5.4 Recap of Historic Conditions

Summarizing the historic conditions described in Chapter 3, the following are known to be issues related to non-point source pollution in the Upper White River Watershed:

- Herbicides, notably Atrazine
  Source: corn and soybean agriculture; high presence of drainage tiles
  Seasonal: late May, early June

- Pesticides
  Source: agricultural uses and urban lawn care
  tied to high presence of drainage tiles
  Note: pesticide pollution rates highest in the nation;
  mainly a surface water problem

- Nutrients
  - General Sources: urban (impervious surface runoff, municipal sewage treatment, CSOs); agricultural uses; high presence of drainage tiles
    - Ammonia
      - Seasonal: higher in summer and fall
      - Note: levels decrease with increased stream flow; levels higher downstream from Muncie
    - Phosphorus
      - Seasonal: higher in winter
      - Note: levels higher downstream from Muncie
    - Nitrates
      - Source: agricultural use; high presence of drainage tiles
      - Note: problem for both surface and ground water;
        levels higher than other areas around the country;
        levels below drinking water standards

- *E. coli*
  - Sources: urban (CSOs, municipal wastewater treatment plants); residential (septic systems); agricultural (livestock, specifically cattle in streams)
  - Seasonal: CSOs = rainfall events;
    septic systems, livestock and wastewater = continual
  - Note: impairment for all 14-digit subwatersheds (except for Prairie Creek) in the Upper White River Watershed, within Delaware County

- Impaired Biotic Communities
  - Note: impairment in Buck Creek and Killbuck/Mud Creek Subwatersheds

- PCBs and Mercury
  - Note: impairment for West Fork of White River