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MIDDLE CREEK WATER ASSESSMENT USING WATER QUALITY INDEX (WQI)†

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ABSTRACT

Water quality Index (WQI) provides a single value to express overall quality of water which is calculated based on a number of measurable parameters. WQI was calculated based on 10 parameters that were determined during the period between June and July of 2012 and July of 2013 in an effort to assess the water quality of Middle Creek (MC) (Snyder, CO. PA). The Middle Creek (MC) is a 2nd order tributary stream flowing into Penn's Creek before joining the Susquehanna River. In this study, eleven sites were selected along MC between the head waters and its confluence with Penn's Creek. Physical properties were measured in the field, and grab-samples were tested for P, NO_2^-, NO_3^-, NH_3, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). The Composite WQI for all sites along MC was calculated to be 89.71, indicating that MC is in good condition regarding water quality and is capable of buffering nutrient and chemical runoff. Results have shown that certain parameters, such as temperature (T°), COD or BOD, can be used as proxies for predicting the WQI. Due to good correlation with WQI values, T°, COD or BOD can be used to assess water quality within a short period of time. In this study, T° and COD were found to give the best forecasting parameters, followed by BOD. The relationships found between WQI and these three parameters, allow for a simple test to provide an adequate assessment of the water quality of a given stream system. [J PA Acad Sci 88(1): 4-12, 2014]

INTRODUCTION

The Middle Creek (MC) is located in Snyder County, Pennsylvania and is bordered by a large farmland region. Snyder County is comprised of 332 square miles and has a population of 39,702 (Figure 1). The headwater of this small stream starts as two separate branches, which merge and flow into Penn's Creek and eventually into Susquehanna River. It is recognized that high levels of pollution in the Susquehanna River and the Chesapeake Bay are caused by runoff from smaller upstream tributaries. Because it is difficult to tackle the cleanup of the water in The Susquehanna River and Chesapeake Bay, there is a need to address these issues at their sources. Runoff into Middle Creek comes mainly from agricultural non-point sources, such as animal facilities, grazing, pesticide spraying, plowing, planting, irrigation, fertilizing, and harvesting. The presence of non-point sources of pollution makes cleanup very challenging even towards the headwaters. In Snyder County, farmlands have been proven to be the cause of non-point source of pollution infiltrating into the MC via land runoff and improper drainage (Edwards and Seay 1987). In this study, a Water Quality Index along Middle Creek extension was calculated based on water quality analyses of all chemical and physical properties.

Water quality Index (WQI) is measured based on a number of parameters, which provides a single value that is used to express the overall quality of water. Each parameter is important in determining the Water Quality Index (WQI) of Middle Creek and its overall impact. While this is true, certain parameters tend to influence the water quality more significantly than others. A heavily weighted parameter with a small standard deviation will not have as drastic of an effect on the WQI as a lower weighted parameter with a high standard deviation. The WQI is a mathematical equation that combines many water parameters into a single number to represent the water quality of a water body. The use of WQI is a simple practice, which allows adequate classification of water quality. The determination of WQI requires a normalization step in which each parameter is arranged on a scale from 1-100; 1 being the worst quality and 100 being the best. Lastly, a weighting factor is applied in accordance to the importance of each parameter as an indicator of water quality (Nives, 1999; Pesce and Wunderlin, 2000; Jonnalagadda and Mhere, 2001). Due to the fact that there are hundreds of individual parameters involved in water quality assessment which are generally not always represented within the WQI equation, WQI may not be the most precise technique if the individual parameters are not well selected. If these parameters are well selected;

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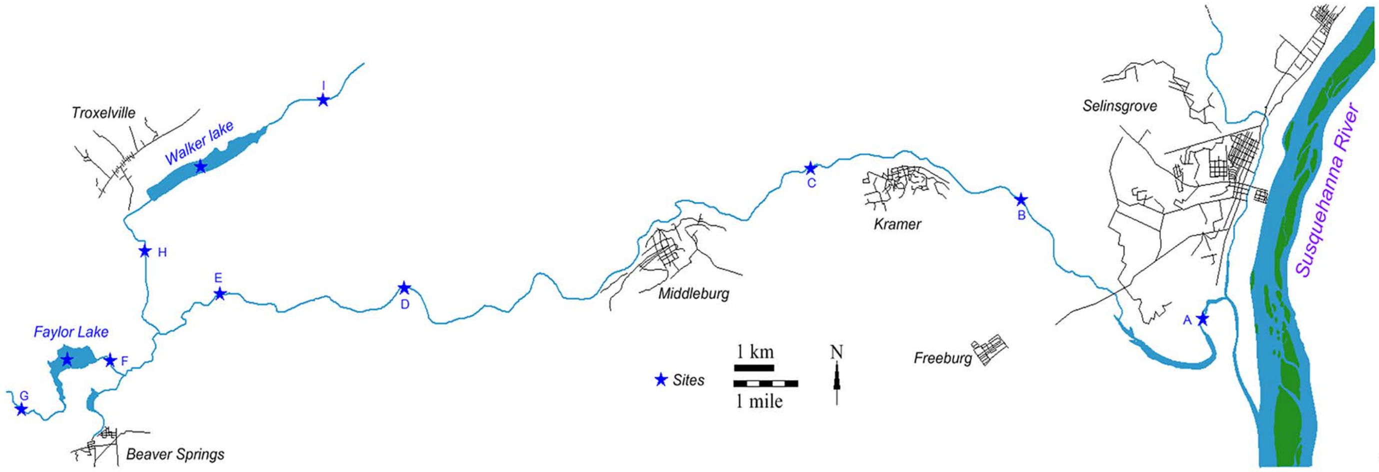

Figure 1. Site locations along Middle Creek.

WQI can be a good indicator of water quality. In this study, the parameters used to determine the WQI of MC and the corresponding values for each parameter and their weight are listed in Table 1. Among all the parameters measured in this study, temperature (T°), chemical oxygn demand (COD) and biochemical oxygen demand (BOD) were found to exhibit strong correlation in regards to WQI. Based on data collected during this study, a correlation was established between WQI and these three parameters, allowing for one to estimate water quality in a straightforward method.

METHODS

This study focuses on the analysis of water quality using Water Quality Index (WQI) at 11 sites along MC. The 11 sites were labeled as A, B, C, D, E, F, G, H, I, Walker Lake (WL) and Faylor Lake (FL). The selection of these sites was made to collect a dataset capable of fully representing MC. One site was selected upstream from both WL and FL, namely the site H and site I, respectively; and one site was selected on each branch downstream from the lakes, namely the site F and site G, respectively. Five additional sites were selected between the merging point of the two branches of MC and Penn's Creek near Susquehanna River (A, B, C, D, and E) (Figure 1). Samples were collected between June and July of 2012 and July of 2013. All sites were sampled ten times over this time period.

Physical properties including T°, pH, electrical conductivity (K_E) and dissolved oxygen (DO) were measured in the field using a YSI 556 MPS multi-probe meter. Three sets of samples were collected and tested to determine nutrients and ion levels, as well as COD, BOD_5 and total suspended solids (TSS). Two nutrients were measured using a DR2800 spectrophotometer; nitrite (NO_2^-) and ammonia (NH_3). Two anions were measured using Dionex ICS-2000; nitrate (NO_3^-) and phosphorus (P).

Samples were placed into an incubator for five days at 20 °C to measure the BOD_5 of each site. Each site was sampled and preserved by acidification to pH $\leq$ 2 using concentrated H_2SO_4 (Rice et al. 2012) for the measurement of their COD concentrations. The TSS was calculated based on an additional 250 mL sample filtered through a weighted standard glass-fiber, heated at 103-105 °C for one hour.

With all of the measured parameter concentrations, the WQI for Middle Creek was determined using the following equation:

$$\mathrm{WQI} = \frac{(\Sigma i\, Pi\, Ci)}{(\Sigma i\, Pi)}$$

Pi represents the relative weight of each parameter and *Ci* is the normalized value of each parameter given in Table 1. WQI allows one to classify a given water system into several quality levels. A weighting factor is applied depending on the importance of each parameter as an indicator of water quality (Nives, 1999; Pesce and Wunderlin, 2000; Jonnalagadda and Mhere, 2001). The final value that is obtained from the equation is a value from 0-100. There are five water quality classifications ranking from poor water quality to excellent water quality (Table 2).

Table 1. Values for Pí and Cí pertain to the parameters used to determine WQI of MC (J. Vicente et al., 2009) K_E (mS/cm); TSS (mg/l); P (mg/l); COD (mg/l); BOD_5 (mg/l); DO (mg/l); T° (°C); NO_2^- (mg/l); NO_3^- (mg/l); Amm (mg/l) and pH.

		Cí										
	Pí	100	90	80	70	60	50	40	30	20	10	0
pH	1	7	7.0 - 8.0	7.0 - 8.5	7.0 - 9.0	6.5 - 7.0	6.0 - 9.5	5.0 - 10	4.0 - 11	3.0 - 12	2.0 - 13	1.0 - 14
K_E	2	< 0.75	< 1.00	< 1.25	< 1.50	< 2.00	< 2.50	< 3.00	< 5.00	< 8.00	< 12.00	> 12.00
TSS	4	< 20	< 40	< 60	< 80	< 100	< 120	< 160	< 240	< 320	< 400	> 400
NO_2-	2	< 0.005	< 0.01	< 0.03	< 0.05	< 0.10	< 0.15	< 0.20	< 0.25	< 0.50	< 1.00	> 1.00
NO_3-	2	< 0.5	< 2.0	< 4.0	< 6.0	< 8.0	< 10.0	< 15.0	< 20.0	< 50.0	< 100.0	> 100.0
NH_4	3	< 0.01	<.05	< 0.10	< 0.20	< 0.30	< 0.40	< 0.50	< 0.75	< 1.00	< 1.25	> 1.25
P	1	< 0.2	< 1.6	< 3.2	< 6.4	< 9.6	< 16.0	< 32.0	< 64.0	< 96.0	< 160.0	> 160.0
COD	3	< 5	< 10	< 20	< 30	< 40	< 50	< 60	< 80	< 100	< 150	> 150
BOD_5	3	< 0.5	< 2.0	< 3	< 4	< 5	< 6	< 8	< 10	< 12	< 15	> 15
DO	4	≥ 7.5	> 7.0	> 6.5	> 6.0	> 5.0	> 4.0	> 3.5	> 3.0	> 2.0	> 1.0	< 1.0
T° (°C)	1	21/16	22/15	24/14	26/12	28/10	30/5	32/0	36/-2	40/-4	45/ -6	> 45/< -6

Table 2. Scale from 0-100 representing the quality of water in accordance to WQI.

Water Quality Index Quality Scale	
91-100	Excellent water quality
71-90	Good water quality
51-70	Average water quality
26-50	Fair water quality
0-25	Poor water quality

RESULTS & DISCUSSION

Physico-chemical parameters of the Middle Creek water quality are shown in Tables 3, 4 and 5. In this study, the Middle Creek was divided in three segments. These segments were selected to address the existing differences due to the impact of two water impoundments located along the two head water branches of Middle Creek. Segment one represents the downstream main branch starting from Site A near the confluence with Penn's Creek to site E near the merging point of the two head water branches. Table 3 characterizes the main branch represented by 5 sampling sites (A, B, C, D and E). Table 4 corresponds to Walker Lake extension along the North Branch of the Middle Creek and is represented by 3 sites (H, WL and I). Table 5 characterizes Faylor lake extension represented by 3 sites (G, FL and F).

Sites A through E (Figure 1)

Table 3 displays the average values (Avg), standard deviation (STD), minimum values (Min) and maximum values (Max) for sites A through E. The pH values remained between 7.66 and 8.92 and decreased slightly downstream. K_E shows a gradual increase downstream probably due to runoff from farmland along MC. TSS values ranged from 0 to 31 mg/l. Sites D and C had the highest overall concentrations of TSS. The concentration of NO_2^- was insignificant and no true pattern was visible in concentration. The concentration of NO_3^- increased downstream with the exception of site A. The range of NO_3^- concentrations was found to be between .529 and 10.205 mg/l. NH_3 concentrations were found to be very low in MC. The standard deviation of NH_3 was the second lowest for all parameters indicating a constant level of NH_3 throughout. The lack of NO_2^- and NH_3 is most likely due to the short lived life of the two due to their rapid conversion to NO_3^- from bacteria (BASIN, 2012). Phosphorus concentrations were very low with a slight increase downstream. The low concentrations of phosphorus are most likely due to the consumption of the phosphorus by plants and its tendency to cling to soil particles (BASIN, 2012), as well as continuous base flow discharge diluting the stream water. COD had its highest concentration at site C with 21 mg/l and fell to 0 mg/l at site A. Increases in COD can be attributed to an increase in chemical pollutants from farmland runoff. BOD decreased from site E to site B, and then encountered a slight increase at site A. The maximum value was 2.7 mg/l at site E. Unpolluted streams tend to have a BOD of 5 mg/l or less making this stream very clean in respect to the amount of oxygen used by aerobic bacteria during decomposition. DO levels were quite high at all sites

Table 3. Summary of Avg, STD, Max and Min of MC main extension (A, B, C, D, E). K_E (mS/cm); TSS (mg/l); P (mg/l); COD (mg/l); BOD_5 (mg/l); DO (mg/l); T° (°C); NO_2^- (mg/l); NO_3^- (mg/l); Amm (mg/l) and pH.

	NO_2^-	Amm	COD	BOD_5	T°	K_E	DO	pH	NO_3^-	P	TSS
A											
Avg	0.007	0.048	6.800	0.979	24.034	0.242	9.226	8.161	4.853	0.078	3.100
Max	0.009	0.100	10.50	1.820	26.760	0.284	11.480	8.480	5.769	0.228	8.000
Min	0.005	0.030	0.000	0.150	20.460	0.221	7.000	7.820	3.830	0.006	0.000
STD	0.001	0.022	2.877	0.549	1.806	0.019	1.259	0.212	0.716	0.072	2.889
B											
Avg	0.008	0.039	7.160	0.771	23.922	0.229	8.995	8.068	10.205	0.060	5.600
Max	0.012	0.080	9.000	1.770	27.040	0.276	11.300	8.450	5.892	0.204	16.00
Min	0.004	0.010	3.000	0.030	21.270	0.209	6.340	7.660	3.680	0.000	0.000
STD	0.003	0.021	1.755	0.574	1.624	0.020	1.411	0.248	0.698	0.064	5.774
C											
Avg	0.007	0.049	8.770	0.958	23.568	0.219	8.688	7.982	10.067	0.066	12.800
Max	0.009	0.080	21.00	1.750	26.560	0.263	10.750	8.300	5.818	0.372	27.600
Min	0.004	0.020	5.000	0.170	20.240	0.197	6.740	7.680	3.520	0.000	0.400
STD	0.001	0.017	4.416	0.490	1.830	0.020	1.381	0.226	0.728	0.104	10.037
D											
Avg	0.006	0.053	8.410	1.637	25.003	0.205	10.941	8.542	8.685	0.057	13.000
Max	0.013	0.150	13.20	2.340	28.450	0.283	12.850	8.920	4.869	0.204	31.200
Min	0.003	0.010	6.000	1.050	21.350	0.165	8.880	7.970	3.210	0.000	0.400
STD	0.003	0.037	2.066	0.485	2.157	0.030	1.368	0.315	0.529	0.060	10.469
E											
Avg	0.041	0.037	8.280	1.600	24.716	0.174	10.601	8.633	7.569	0.056	6.200
Max	0.360	0.050	13.50	2.700	27.890	0.205	12.820	8.870	3.666	0.132	13.200
Min	0.003	0.010	1.000	1.020	21.480	0.156	9.190	8.290	2.220	0.001	0.400
STD	0.106	0.013	3.570	0.480	2.020	0.013	1.029	0.190	0.535	0.038	4.803

but were the highest at sites D and E. Sites D and E are both downstream from the lakes and are fairly close to the lakes. The increase of DO concentration in these two sites is due to the fast flow condition downstream from the dam and the turbulent system caused by the multiple riffles areas. The highest T° was at site D while the lowest T° was at site C. The T° fluctuation is most likely related to baseflow contribution, spring water and relative distance from the two lake extensions. Overall, the WQI for sites A through E was determined to be 90.95 ranking the quality of this water as good.

Walker Lake Extension (H, WL, I)

The minimum pH value was 7.62, while the maximum pH value was 9.99. The pH was higher at WL than at the other two sites. Site H had a higher pH than site I most likely because site H is downstream from WL. The highest K_E was found at site I, dropped by approximately half at WL and increased at site H to a similar concentration as in site I. The increase in K_E in both sites H and I is caused by groundwater influx to the stream. Site H is usually colder than any other site and the existence of several wetlands not far from this site is strong evidence of existing base flow discharge to MC. WL's low reading of K_E is most probably caused by the impoundment characteristics of the lake. The lack of turbulence does not allow for sediment to be stirred and causes much of the ions and nutrients to be settled at the bottom of the lake. TSS data set yielded a range from

0 to 65.2 mg/l. Site I had the highest concentration of NO_2^- while WL had the lowest concentration. The concentration of NO_3^- was the highest at site I and the lowest at WL. NH_3 concentrations were very similar at all three sites but proved to be the highest at site H and the lowest at site WL. There was no apparent trend between concentrations of NO_2^-, NO_3^- and NH_3 at these three sites. Total phosphorus concentration was found at low concentration in WL extension. This is most likely due to the large amount of plant life that inhabits the lake and the settling of the nutrients due to a lack of turbulence. COD had its highest concentration at WL with a value of 35.2 mg/l. Sites H and I had maximum values of 21.1 mg/l and 15.1 mg/l respectively. WL's elevated level of COD is most likely caused by the large amounts of organic matter that is present. The oxidation of this organic matter requires large amounts of oxygen. BOD was the lowest at site H and increases at WL before it returns to a similar concentration at site I. Organic matter decaying at the bottom of WL is presumably the cause for the increased BOD concentrations due to its breakdown from aerobic bacteria. As aerobic bacteria decompose this organic matter, they require oxygen to proceed with this process (BASIN, 2012). DO levels were high at these three sites. Site I had a concentration of 9.15 mg/l, WL had a concentration of 11.81 mg/l and site H had a concentration of 9.03 mg/l. WL's high level of DO is believed to be caused from the release of oxygen during photosynthesis from the large amount of plants that inhabit the lake. WL had the highest T° by almost 8 °C. The lack of high discharge flow into WL and the direct insolation allow for excessive heating. Overall, the WQI for the WL extension was determined to be 87.89 classifying the water quality as good. Walker Lake extension has a lower WQI than sites A through E. WL is the main reason for this decrease. The highest WQI of WL was 88.08 and the lowest was 81.54. These scores bring down the overall WQI of Walker Lake extension. The results showed that pH, T^o, COD and BOD_5 are the main parameters that diminish WL's WQI.

Faylor Lake Extension (G, FL, F)

The pH values were in the range of 7.76 and 9.99. There were greater pH values at FL than at sites G and F. Site F had a higher pH than site G most likely due to its location downstream from FL. K_E was high in site G and low in FL. TSS values ranged from 1.6 mg/l at site F, to 60.4 mg/l at site G. NO_2- concentrations were very low at all three sites. Site F had the highest concentration with a value of 0.023 mg/l. The low concentration of NO_2^- is most likely caused by the rapid conversion to NO_3^- by bacteria. NO_3^- had the highest concentrations at site G, while FL and site F had lower concentrations compared to site G. NH_3 concentrations at all three sites were very low. Site F had the highest concentration followed by FL. NH_3 is rapidly converted to either NO_3^- or nitrogen gas depending on the concentration of DO in the water. Since all three sites have high concentrations of DO, the NH_3 is most likely being converted into NO_3^- which would explain the higher concentrations of NO_3^-. Low concentrations of phosphorous were found within the FL extension. COD was relatively low at each site. Site G had the lowest concentration with 0 mg/l and FL and site F had similar concentrations of 13.32 and 13.46 mg/l, respectively. BOD was the highest at FL with a concentration of 3.18 mg/l and the lowest at site G with a concentration of 1.23 mg/l. Unpolluted streams should have a BOD of 5 mg/l or less, making this a healthy stream in regard to BOD. DO was very high at all three sites. FL had the highest DO concentration of 12.05 mg/l, while site F had the lowest concentration of 8.52 mg/l. FL had the highest T° of 28.9 °C, followed closely by site F with a T° of 28.05 °C. Site G had the lowest T° of 22.9 °C. The high T° level in FL is most likely caused by the lack of flowing water and the shallow depth of the lake. Site F experiences increased T°s due to its proximity to FL. Overall, the WQI for the FL extension was determined to be 89.44 making this water a good water quality. FL extension has a lower WQI than the main branch of MC but a slightly higher WQI than Walker Lake extension. The best WQI that Faylor Lake had was 91.92 and the lowest was 86.92. These low scores for FL bring down the overall WQI of the Faylor Lake extension. pH, To and COD are the main parameters that diminish Faylor Lake's WQI.

WQI Analyses

WQI values varied from site to site due to the concentration and weight of each parameter tested. The overall WQI value for each day was determined to be in the range of good water to excellent water (Figure 2).

Data was collected during the month of June and July in 2012 and 2013 to allow for an in-depth WQI analysis. This large data set allowed for trends to be identified and analyzed. The WQI remained fairly consistent over the two testing periods suggesting that Middle Creek's environment has remained for the most part unchanged. This consistency was important in determining which parameters were the driving forces of the WQI. The five most heavily weighted parameters used to calculate the WQI are TSS, DO, COD, BOD and NH_3. TSS and DO are the most heavily weighted by a factor of 4, while COD, BOD and NH_3 are weighted by a factor of 3 (Table 1). These heavily weighted parameters did not prove to influence the WQI as significantly as their relative weight would suggest. DO levels were above the maximum WQI range of 7.5 mg/l for each site, causing DO to be a constant within the WQI and thus not useful for water quality analysis. Even though DO may carry a higher weight in the WQI equation; it does not express itself in the final value as strongly as other, less weighted parameters. Due to the lack of variation and minute concentrations of NH_3,

Table 4. Summary of Avg, STD, Max and Min of WL Extension (H, WL, J). K_E (mS/cm); TSS (mg/l); P (mg/l); COD (mg/l); BOD_5 (mg/l); DO (mg/l); T° (°C); NO_2^- (mg/l); NO_3^- (mg/l); Amm (mg/l) and pH.

	NO_2^-	Amm	COD	BOD_5	T°	K_E	DO	pH	NO_3^-	P	TSS
H											
Avg	0.009	0.066	10.140	1.351	21.349	0.183	9.033	8.120	7.839	0.071	5.500
Max	0.014	0.130	20.100	2.790	22.530	0.232	11.600	8.690	6.700	0.264	11.200
Min	0.006	0.030	5.400	0.480	19.100	0.160	7.520	7.620	2.760	0.003	0.000
STD	0.003	0.027	3.973	0.757	0.990	0.020	1.042	0.345	1.192	0.085	4.144
WL											
Avg	0.004	0.050	26.310	5.928	28.905	0.121	11.814	9.773	4.821	0.055	38.700
Max	0.007	0.080	35.200	12.92	31.970	0.142	13.640	9.990	1.029	0.360	65.200
Min	0.001	0.010	16.800	3.820	25.810	0.109	9.090	9.500	0.000	0.000	22.800
STD	0.002	0.019	5.685	2.948	1.948	0.011	1.266	0.142	0.359	0.107	14.289
J											
Avg	0.009	0.047	8.670	1.409	20.779	0.185	9.151	8.021	8.312	0.054	20.100
Max	0.025	0.090	15.100	3.200	23.260	0.241	11.650	8.220	6.370	0.300	42.400
Min	0.002	0.013	3.000	0.230	17.440	0.162	7.340	7.730	2.500	0.012	10.400
STD	0.007	0.026	4.162	0.872	1.793	0.023	1.147	0.157	1.164	0.081	11.589

this parameter yielded inconclusive results. When analyzed using the WQI, concentrations of NH_3 corresponded to the maximum value of 100. Even though this parameter carries a weight of 3, it can be ignored due to the lack of variation between values.

BOD vs. WQI

BOD's data set had a large standard deviation between sites. This deviation causes the BOD to be a moderately accurate predictor in regards to the WQI. Along the main extension of MC, BOD was not an accurate predictor of the WQI (Figure 3). The addition of spring water to MC as well as the presence of few waste water treatment facilities along MC causes inconsistencies in BOD concentrations and its relation to WQI. As BOD increases, the WQI should decreases. Figure 3 shows a horizontal line's trend which falsely indicate that an increase in BOD is not causing any increase in WQI. The relationship between WQI and BOD is not as apparent in this section of MC as it is in the other two extensions.

Along the Walker Lake extension, BOD has been found to be an accurate predictor of the WQI. The negative trend line indicates any decrease in WQI is caused by an increase in BOD concentration. Trend lines were created for each site to verify that this relationship remained constant throughout this extension. Along this extension, data points closely fit the trend line providing a more accurate approximation of the water quality classification. BOD's relationship with the WQI is best displayed within the Walker Lake extension, most likely, due to its proximity to the headwater and lack of infiltration from external water sources, such as springs and runoff streams.

The FL extension follows a similar trend of WL extension. Site F and FL show very similar negative trends due to their proximity to one another, while site G shows a positive trend line and a large deviation of data (Figure 3). This positive trend found at site G eliminates some confidence in the BOD parameter as a predictor of the WQI. COD may be used with more confidence to predict the WQI in this site.

COD vs. WQI

COD was the only heavily weighted parameter that was capable of accurately predicting the quality of water using the WQI along the Middle Creek. All eleven sites displayed negative trends correlating the COD and the WQI. As COD concentrations increased, the WQI values decreased (Figure 4). Figure 4 shows the trend of the relationship between WQI and COD along the main section of MC. Trend lines were created for each site to verify that this relationship remained constant throughout the main section. Due to the large number of parameters involved in the WQI, this trend may not be as extreme at certain sites as the WQI and COD concentrations would indicate. Site C for instance has a small negative slope in respect to other sites located along the main section of MC. This is mainly due to the single outlying data point located at approximately 22 mg/l. The

Table 5. Summary of Avg, STD, Max and Min of FL Extension (G, FL, F). K_E (μS/cm); TSS (mg/l); P (mg/l); COD (mg/l); BOD_5 (mg/l); DO (mg/l); T° (°C); NO_2^- (mg/l); NO_3^- (mg/l); Amm (mg/l) and pH.

	NO_2^-	Amm	COD	BOD_5	T°	K_E	DO	pH	NO_3^-	P	TSS
G											
Avg	0.006	0.039	6.700	1.231	22.911	0.183	10.237	8.322	7.660	0.050	22.000
Max	0.010	0.140	23.600	2.560	25.740	0.213	12.770	8.550	5.510	0.192	60.400
Min	0.002	0.010	0.000	0.270	19.650	0.155	9.120	7.760	3.599	0.004	2.400
STD	0.003	0.036	6.060	0.717	1.939	0.018	1.124	0.221	0.745	0.062	21.107
FL											
Avg	0.009	0.048	13.320	3.184	28.907	0.165	12.046	9.366	4.554	0.032	12.500
Max	0.023	0.080	17.400	6.710	32.180	0.185	14.360	9.990	1.384	0.168	28.800
Min	0.000	0.020	9.500	0.770	25.170	0.155	10.000	8.950	0.000	0.000	2.000
STD	0.007	0.021	2.977	1.592	2.327	0.011	1.466	0.274	0.486	0.054	9.544
F											
Avg	0.011	0.052	13.460	1.996	28.047	0.166	8.515	9.044	4.801	0.030	8.700
Max	0.023	0.080	19.000	4.190	30.020	0.189	9.610	9.670	1.494	0.168	27.600
Min	0.003	0.010	8.000	0.670	24.920	0.155	7.880	8.550	0.000	0.000	1.600
STD	0.006	0.024	3.616	1.076	1.662	0.011	0.525	0.322	0.517	0.052	9.799

same trend can be found along the Walker Lake and Faylor Lake extensions.

Along the Walker Lake extension, data points closely fit the trend line providing a more accurate approximation of the water quality classification. COD versus WQI relationship is best expressed within the Walker Lake extension due to its proximity to the headwater and lack of input from external water sources, such as runoff from streams.

Faylor Lake extension follows a similar trend as seen in Walker Lake extension. Site F and FL show very similar trends due to their proximity to one another, while site G located near the headwater showed a large array of data. The same trends were found at Faylor Lake extension and Walker Lake extension due to their similar locations in the watershed both in the headwaters. Given the results in the above figures, a single COD test is capable of approximating

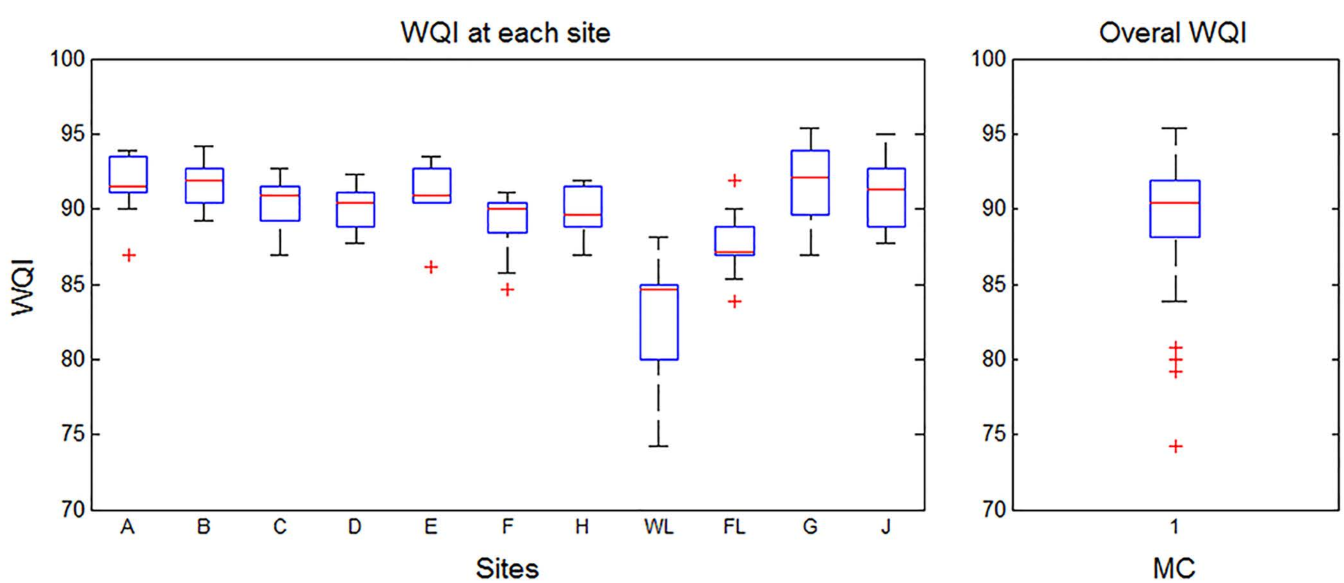

Figure 2. WQI values of MC averaged over ten sampling days taken between June July of 2012 and 2013, and the overall WQI of MC.

the water quality classification. Although COD is weighted much heavier in the WQI, the T° parameter can more accurately predict the WQI along various locations of MC.

T° vs. WQI

T°s varied significantly along the main section of MC. Although there is a large variation in the T° data, all of the sites display a negative trend indicating as T° increases the WQI values decrease (Figure 5). Many of the sites in the main extension of MC encounter environmental changes due to waste treatment facilities, agricultural runoff and natural spring infiltration. This variation in environments causes a large degree of change of the T° parameter. The deviation in trend line slopes can also be attributed to other parameters influencing the WQI as well. The overall trend line profile of the WQI and T° relationship in figure 5 allows T° to be considered a reasonable predictor of the WQI classification. Similar trends can be found along both WL and Faylor Lake extensions (Figure 5). Along the Walker Lake extension, T° has been determined to be a moderately accurate indicator of WQI. Sites I and WL exhibit very comparable environments this can be seen by their very similar negative trend lines in figure 5. These trend lines provide confidence in the ability to use T° as a predictor of WQI values. Site H has a positive trend line most likely caused by the presence of a spring. This positive trend line reduces the confidence of the T° parameter as an accurate predictor of the WQI. Although, T° can still be a very valuable forecasting parameter if the testing site's local water source is known. The Faylor Lake extension is very similar to the Walker Lake extension and provides comparable trends. Along the Faylor Lake extension all sites possess a similarly slopped negative trend (Figure 5). These similar slopes suggest that these three sites have comparable environments. These trend lines offer confidence in the ability to use T° to predict the values of WQI along the Faylor Lake extension. Given the results in the above figures, a single T° reading can give an approximation of the water quality classification along MC. Although T° is weighted much lower than COD and BOD in the WQI equation, it proves that it is capable of accurately predicting the WQI along various locations in MC.

The ability to be able to use one or two parameters to predict the quality of water in a given system has numerous benefits. The use of a forecasting parameter such as T°, COD or BOD, allows one to assess water quality in a short period of time. In this study, it was determined that T° and COD are the best forecasting parameters, followed by BOD. The relationships found between WQI and Temperature, COD and BOD, allow

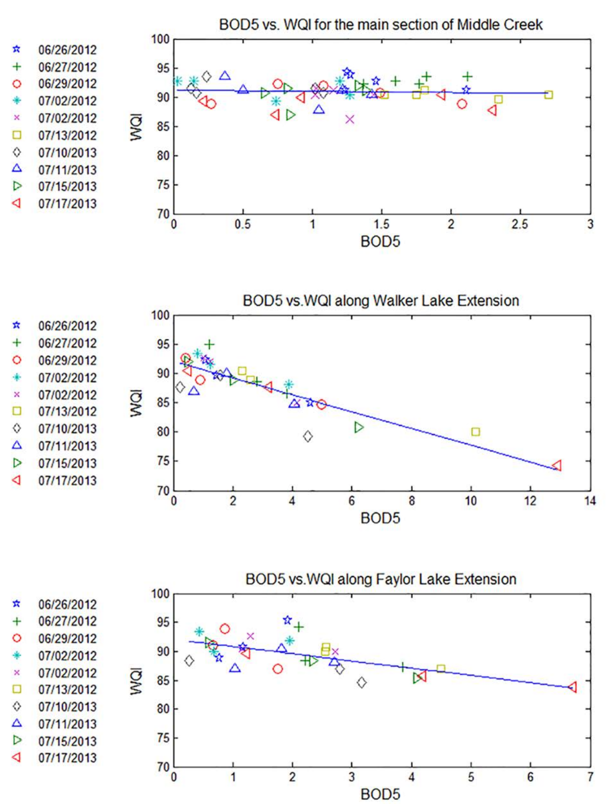

Figure 3. Relationship between BOD5 and WQI along all three extensions (Main, Walker and Faylor).

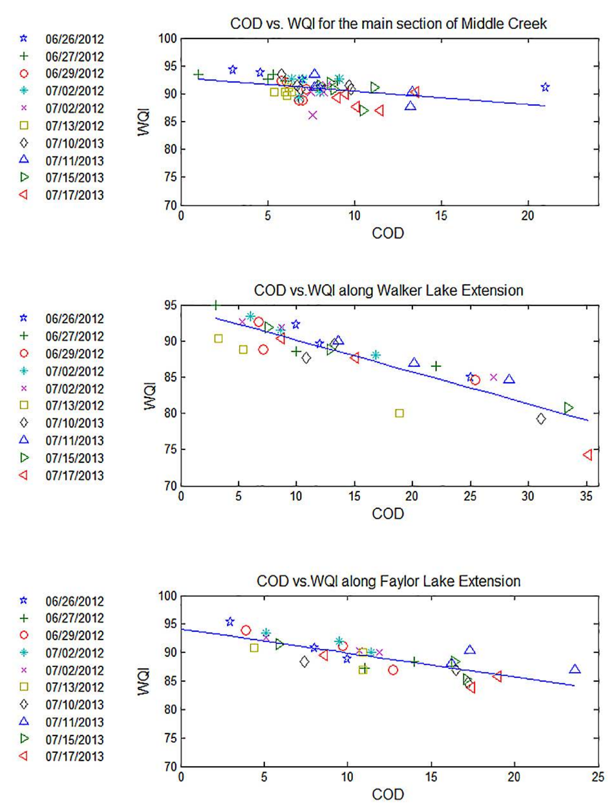

Figure 4. Relationship between COD and WQI along all three extensions (Main, Walker and Faylor).

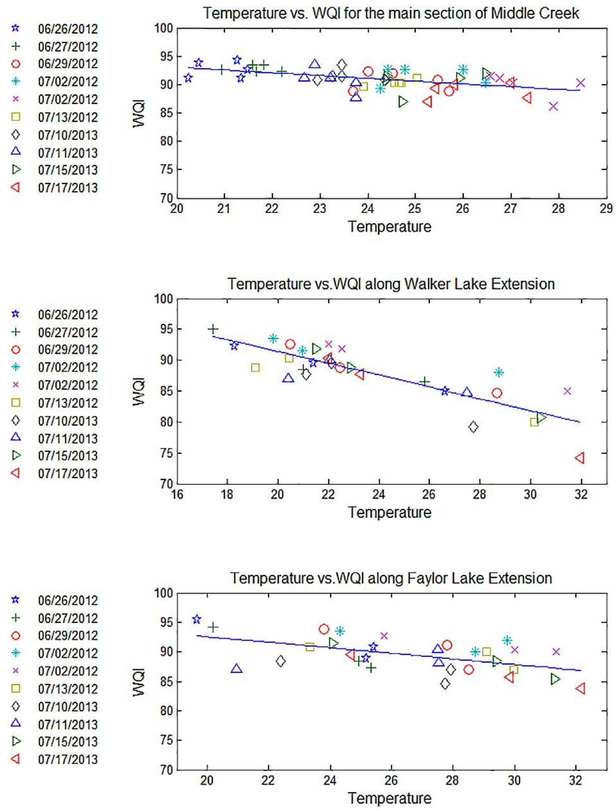

Figure 5. Relationship between T° and WQI along all three extensions (Main, Walker and Faylor).

a simple test to provide a good estimate of the water quality of a given water system. This can help reduce the cost of the methodology generally used in water quality studies and potentially decrease the number of persons conducting the water quality of a given stream. Although, it is not evident whether similar relationships between T°, COD and BOD, and WQI, can be found in other water ways, the wide spread use of WQI would provide sufficient data to determine the accuracy of the WQI along MC.

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