Changes in Water Quality in Deckers Creek from 1974 to 1999-2000

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Abstract. The Deckers Creek drainage basin covers approximately 62.9 square miles (16,600 hectares) in Monongalia and Preston Counties of West Virginia. Throughout the twentieth century, this watershed has received high levels of pollution in several forms. A 1974 study examined the water chemistry in Deckers Creek over a six-month period at 29 sample points. Water samples from the same sites were collected and analyzed monthly from March 1999 through October 2000 for acidity, alkalinity, total iron, aluminum, manganese, and other metals, as well as for fecal coliform concentrations. Most of the tributaries sampled in 1999-2000 showed reduced metal loads and acidity as compared to 1974, as did the main stem of Deckers Creek above the town of Richard. By contrast, little improvement was detected in the portion of Deckers Creek below Richard due to the input of untreated mine water from an underground mining complex. Decreased mining activity, increased reclamation, and improved quality of deep mine discharge have led to improved water conditions in the upper portion of Deckers Creek. Improved chemical properties in the majority of the creek may, however, present more noticeable biological contamination such as fecal coliforms and could present a new water quality problem.

Introduction

The Deckers Creek watershed lies within the drainage basin of the Monongahela River in western Preston and eastern Monongalia Counties in northern West Virginia. The stream is approximately 23.6 miles (38.1 km) in length, originating in the southeast corner of Monongalia County at an elevation of 2,427 feet (737 m). The creek flows southeast to Reedsville, where it loops to the northwest (Figure 1). Relief is very gradual from the headwaters to Masontown before becoming steep from Masontown to Dellslow. After Dellslow, the creek again flows over gently sloping terrain until reaching the Monongahela River at an elevation of 793 feet (237 m) (Teti 1974).

Most of the exposed geology is part of the Pennsylvanian Period, namely the Monongahela, Conemaugh, and Pottsville Groups and the Allegheny Formation (Natural Resource Conservation Service 2000). The dominant rock types include sandstone, siltstone, shale, limestone, and coal (Teti 1974). Major soils in the area include the Gilpin and Dekalb Series in the higher elevations and the Atkins, Brinkerton, and Pope Series in the bottomlands (NRCS 2000).

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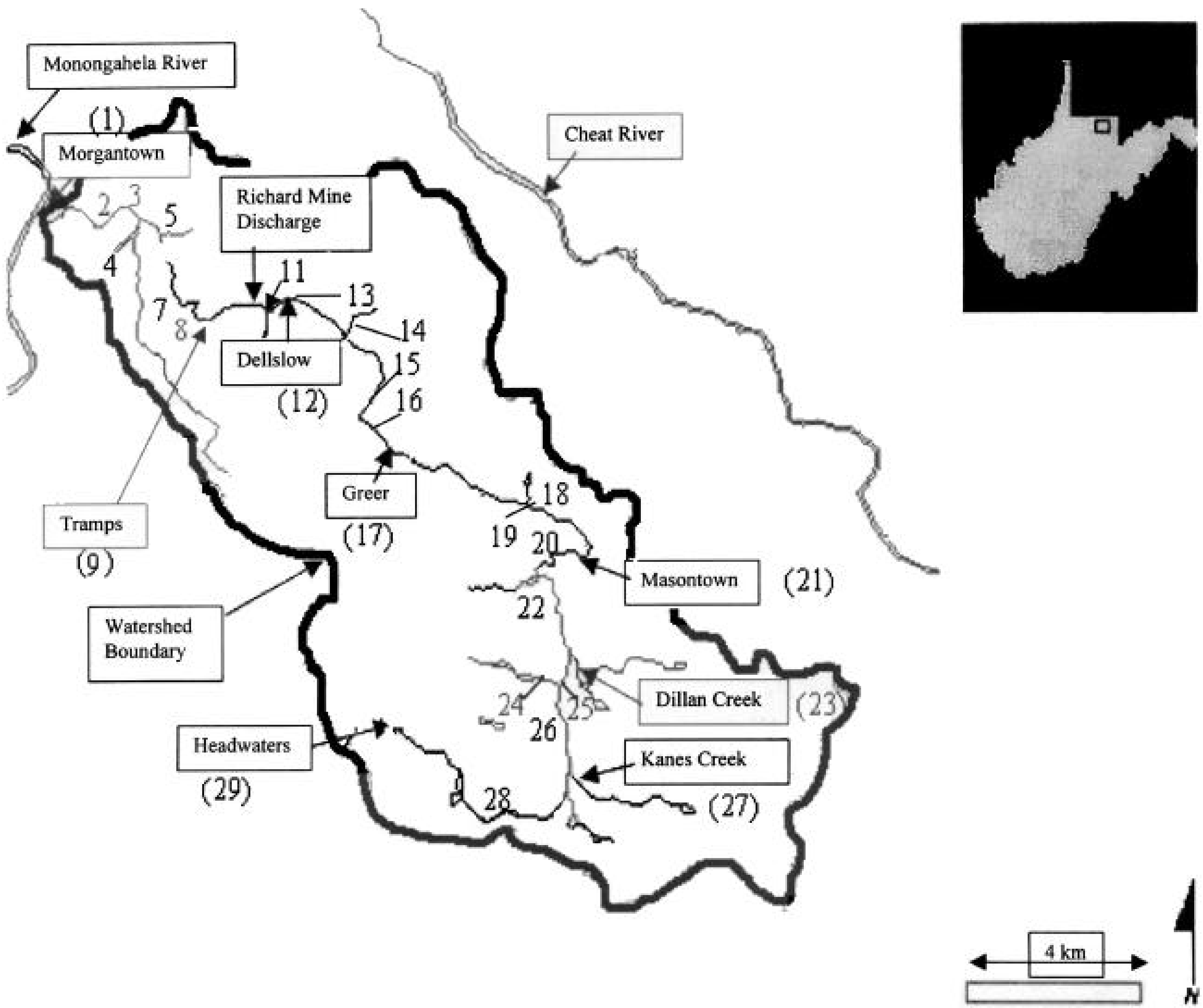


Figure 1. Deckers Creek from the headwaters to its confluence with the Monongahela River at Morgantown. The 29 sampling sites visited in 1974 and 1999-2000 are shown. Eight sampling sites, along with the Cheat and Monongahela Rivers, are named which represent different sections of the stream.

Seventy percent of the land surface in the watershed is covered by forest. Oak-hickory and northern hardwoods are the dominant timber types. Farmland comprises 15% of the watershed, with nearly all of the active farming occurring in the upper portions of the watershed in Preston County. Urban land, found in the lower half of the watershed near Morgantown, makes up roughly 10% of the area. Mined lands account for the remaining 5% (NRCS 2000).

Deckers Creek and its tributaries flow through a high-sulfur coal region of West Virginia, where the coal and associated strata contain high levels of sulfur in the mineral form of pyrite. When exposed to water and oxygen, pyrite undergoes a series of chemical reactions, ultimately resulting in the release of sulfate, proton acidity, and iron (Banks et al. 1997). This phenomenon may be observed throughout Appalachia. Thirty-five percent and twenty-two percent of 318 stream sites sampled in Pennsylvania, Kentucky, West Virginia, and Ohio in the mid 1960's had higher iron and sulfate, respectively, than U.S. Public Health Services drinking water standards (National Research Council 1979).

Acidity and iron serve to accelerate normal geochemical weathering in a self-perpetuating sequence of reactions, and much of the metal oxyhydroxides precipitate out of solution upon contacting natural waters (Younger 1998). These precipitates form coatings in stream channels, smothering native biology (Gray 1995). The accompanying increase in weathering can also lead to the dissolution of silicate minerals, causing the release of metals such as aluminum and manganese into the environment in more reactive forms (Younger 1998). Tests on the short-term toxicity of coal mine drainage water to two species of sunfish (*Lepomis machrochirus* and *Lepomis gibbosus)* have shown that the fish experience respiratory distress within a few hours after being introduced into water having pH values between 3.0 and 3.5 and total acidity values of 50 mg/L (Pegg 1984). A large-volume input of untreated mine water enters Deckers Creek near the town of Richard (Figure 1). The pH of the Richard mine water is usually less than 3.5 and the acidity values are much higher (1200 mg/L) than these waters tested for fish, rendering the creek unfit for fish over its remaining four miles to the confluence with the Monongahela River in Morgantown.

Numerous small acid mine drainage inputs can be located throughout the Deckers Creek watershed, but the discharge flowing from the Richard Mine, a large abandoned underground mining complex, dominates any examination of other deleterious impacts to the stream due to its volume, chemistry, and proximity to population centers.

Another source of pollution in Deckers Creek is the input of fecal bacteria from agricultural fields and bordering residential areas. The extent to which natural waters have been impacted by fecal matter from warm-blooded organisms may be determined through the isolation and subsequent enumeration of indicator bacteria. High counts of fecal coliforms are directly linked to sewage inputs and indicate the possible presence of other, more harmful bacteria and viruses (Edwards et al. 1997). Surface run-off from agricultural fields can also carry harmful microbes into stream water. Fecal material from grazing livestock and the land application of sewage-sludge increase the levels of indicator organisms in streams and may create bacterial reservoirs in soils. These reservoirs could possibly serve as sources of bacterial contamination when temperature and moisture conditions are favorable (Hunter et al. 1999).

In 1974, James Teti, a graduate student in the Geology Department of West Virginia University, conducted a water quality study of Deckers Creek (Teti 1974). He located 29 sampling points along the creek and collected water samples during a six-month period. The purpose of this study was to revisit the sites that were sampled 27 years ago and, after conducting water quality analyses, determine changes in water quality between 1974 and 1999-2000.

Methods

1974 Sampling Procedures

Samples were collected in collapsible, plastic 1-quart bags at 29 established sample sites along Deckers Creek and its tributaries (Figure 1) on eight occasions between January 1974 and June 1974. Teti (1974) reports withdrawing each sample from a flowing part of the stream in order to avoid any increases in ionic concentrations due to evaporation from standing pools. Sample containers were filled completely to minimize any reaction between the water and atmospheric gases trapped in the container. Water samples were put on ice and later analyzed in the laboratory for total acidity, total alkalinity, specific conductance, and dissolved metals (total iron, calcium, magnesium). Teti did not measure flow when he collected water samples during the 1974 sampling period.

1999-2000 Sampling Procedures

Beginning in March of 1999, water samples were collected at 29 sites along Deckers Creek and several of its tributaries on a monthly basis, corresponding to sites originally sampled by Teti (Figure 1). A YSI 3500 Water Quality Meter was used to measure temperature, electrical conductivity, and pH in the field. Two water samples were collected at each site. Each sample was collected from the same point in the creek each month. The water bottles were filled completely to eliminate interactions between the sample and any air left in the head space. The first sample was collected in a 250-ml plastic bottle and was neither filtered, nor acidified. A second sample of 20 ml was filtered with a 0.45um filter and acidified to pH 2.0 with 0.5 ml of concentrated hydrochloric acid. Both samples were placed on ice and transported to the laboratory. The first sample was analyzed for pH, acidity, and alkalinity using a TitraLab autotitrator (Radiometer/Copenhagen, Denmark), while the second sample was analyzed for Fe, Al, Mn, Mg, Zn, Ba and Ca using an Inductively Coupled Spectrophotometer, Plasma 400 (Perkin Elmer, Norwalk, CT). All titrations were performed within six hours of sample collection. Alkalinity titrations were carried to an endpoint pH of 4.2, while acidity titrations proceeded to an endpoint pH of 8.2.

Flow determinations were also made at the same time water samples were taken. At the beginning of the study at each point, the bottom of the stream channel was delineated from the high water mark on one bank to the corresponding mark on the opposite bank. A reference point was chosen near the center of this transect in the stream. The point was marked either by driving a steel post into the streambed or by placing a brightly colored brick. At subsequent sampling times, the depth of the water was measured at this reference point and used to calculate depths across the stream transect and a water velocity measurement was taken.

Water velocity readings were taken using a Global Water Flow Probe FP101 (Global Water, Gold River CA). This probe features a function that computes an average velocity over a ten-second period. The probe was moved vertically through the creek at the reference point to compute an average velocity for the entire stream column. Multiplying the cross-sectional area of the water in the stream by velocity provided a good estimate of flow.

1974 Flow Estimation

In order to accurately compare stream quality data sets from two different time periods, the flow levels during each sampling phase should be comparable. If flows vary greatly between sampling phases, any observed differences in chemical parameters may be due to localized dilution or concentration effects rather than changes in baseline conditions (Skousen 2000). As no flow data was collected during the 1974 study, it was necessary to make an estimation of stream flow to determine whether or not data from the two studies could be compared. Monthly stream flow at Morgantown for the entire year of 1974 was calculated using the following equation:

(rainfall inches/month)(1month/2592000s)(1 ft/12 inches)(area of watershed in ft^2) = total amount of water hitting the surface of the watershed each month in cubic feet per second X a seasonal runoff factor (0.4) = calculated stream flow at the outlet of the watershed (Morgantown).

Table 1 lists the calculated monthly flows for the mainstem of Deckers Creek at Morgantown in 1974 and 1999-2000, as well as measured monthly flows for the 1999-2000 period. Table 2 shows calculated versus measured flows for three other years (1946-1948) for which both monthly rainfall and monthly flow data were available at the Morgantown site. While monthly rainfall amounts were quite variable across months, the 1974 and 1999-2000 average monthly rainfalls were quite similar (4.06 in vs 3.77 in). The average monthly measured flow (84.3 cfs) by our method compared to the average monthly estimated flow (82.6 cfs) was also very similar in 1999-2000. However, there was generally a poor match between monthly values of estimated flow and measured flow. For example, the measured flow during May-June 1999 was roughly 26 cfs. Estimated flows during this period were nearly three times higher than measured flows. Further, monthly estimated flows during 1946-1948 did not compare closely to the monthly measured flows. Nevertheless, monthly rainfall was used as an indicator of the high or low flow conditions when water samples were collected during 1974. The high or low flow conditions as calculated by our estimation technique were then tied to our measured flow conditions in 1999-2000 to coordinate data. Reasons for these discrepancies are relatively obvious. Average rainfall may have been distributed unevenly across the watershed. Variable slopes, seasonal changes in both antecedent soil moisture conditions and amount of vegetative ground cover, and snow melt events may account for varying runoff rates. Increases in the proportion of impervious ground surface throughout the watershed over the last 50 years may also explain inconsistencies in flow calculation.

Table 1. Comparison of rainfall, streamflow, and estimated stream flow for 1974 and 1999-2000.

Year	***Month***	Measured average rainfall (inches)	Estimated flow at Morgantown (cfs)	Measured flow at Morgantown (cfs)
1974	Jan	5.27	115.6	*
1974	Feb	2.06	45.2	*
1974	Mar	3.16	69.3	*
1974	Apr	3.37	73.9	*
1974	May	6.3	138.2	*
1974	Jun	8.33	182.7	*
1974	Jul	3.94	86.4	*
1974	Aug	4.67	102.4	*
1974	Sep	3.87	84.9	*
1974	Oct	1.53	33.6	*
1974	Nov	2.47	54.2	*
1974	Dec	3.69	80.9	*
	Average	**4.06**	**88.92**	
1999	Jan	5.84	128.1	*
1999	Feb	2.53	55.5	*
1999	Mar	4.52	99.1	*
1999	Apr	2.99	65.6	*
1999	May	3.69	80.9	26.7
1999	Jun	2.17	47.6	26.4
1999	Jul	3.09	67.8	19.4
1999	Aug	2.75	60.3	11.3
1999	Sep	2.85	62.5	5.9
1999	Oct	3.7	81.1	10.5
1999	Nov	4.18	91.7	29.9
1999	Dec	3.1	68.0	142.5
2000	Jan	1.87	41.0	99.3
2000	Feb	5.16	113.2	117.7
2000	Mar	2.89	63.4	259
2000	Apr	4.81	105.5	116.9
2000	May	4.6	100.9	121
2000	Jun	6.01	131.8	225.6
2000	Jul	4.6	100.9	94.3
2000	Aug	3.96	86.8	42.7
	Average	**3.77**	**82.58**	**84.32**

Table 2. Comparison of rainfall, streamflow, and estimated stream flow for 1946-1948.

Year	Month	Measured average rainfall (inches)	Estimated flow at Morgantown (cfs)	Measured flow at Morgantown (cfs)
1946	Jan	2.03		*
1946	Feb	3.44	77.57	131
1946	Mar	4.02	90.65	70
1946	Apr	1.73	39.01	109
1946	May	5.61	126.51	70
1946	Jun	6.03	135.98	65
1946	Jul	2.65	59.76	10
1946	Aug	2.6	58.63	4
1946	Sep	3	67.65	1.5
1946	Oct	3.09	69.68	2.7
1946	Nov	1.83	41.27	7
1946	Dec	2.61	58.86	6
	average	**3.22**	**63.54**	**43.29**
1947	Jan	4.31	97.19	*
1947	Feb	1.63	36.76	70
1947	Mar	2.09	47.13	75
1947	Apr	1.87	42.17	97
1947	May	4.24	95.62	121
1947	Jun	3.7	83.44	*
1947	Jul	5.92	133.50	52
1947	Aug	3.32	74.87	41
1947	Sep	4.07	91.78	7.3
1947	Oct	1.42	32.02	4.3
1947	Nov	2.99	67.43	82
1947	Dec	1.65	37.21	*
	average	**3.10**	**69.93**	**61.07**
1948	Jan	4.03	90.88	122
1948	Feb	3.99	89.98	35
1948	Mar	4.32	97.42	214
1948	Apr	6.63	149.51	108
1948	May	4.48	101.03	455
1948	Jun	5.95	134.18	23
1948	Jul	7.24	163.27	138
1948	Aug	3.87	87.27	*
1948	Sep	3.66	82.54	4.2
1948	Oct	1.92	43.30	4.6
1948	Nov	4.11	92.68	7.3
1948	Dec	5.13	115.69	11
	average	**4.61**	**103.98**	**102.01**

Microbiological procedures

A separate water sample was collected at a later date each month and tested for the presence of fecal coliform bacteria by the membrane filtration technique. All 29 sites were sampled at least once until it was determined which sites warranted further monitoring. Eight representative sites were chosen and re-sampled monthly beginning in June 1999. The tests were done with 0.7 um filters instead of 0.045 um filters, as the larger filter size allows for improved recovery of organisms possibly damaged by acidic conditions in the stream (Bissonnette 1999). The filters were then plated onto membrane-fecal coliform (mfc) media and incubated at 44.5 C for 24 hours. The plates were then counted to determine the number of colony forming units (CFU's) per 100 ml.

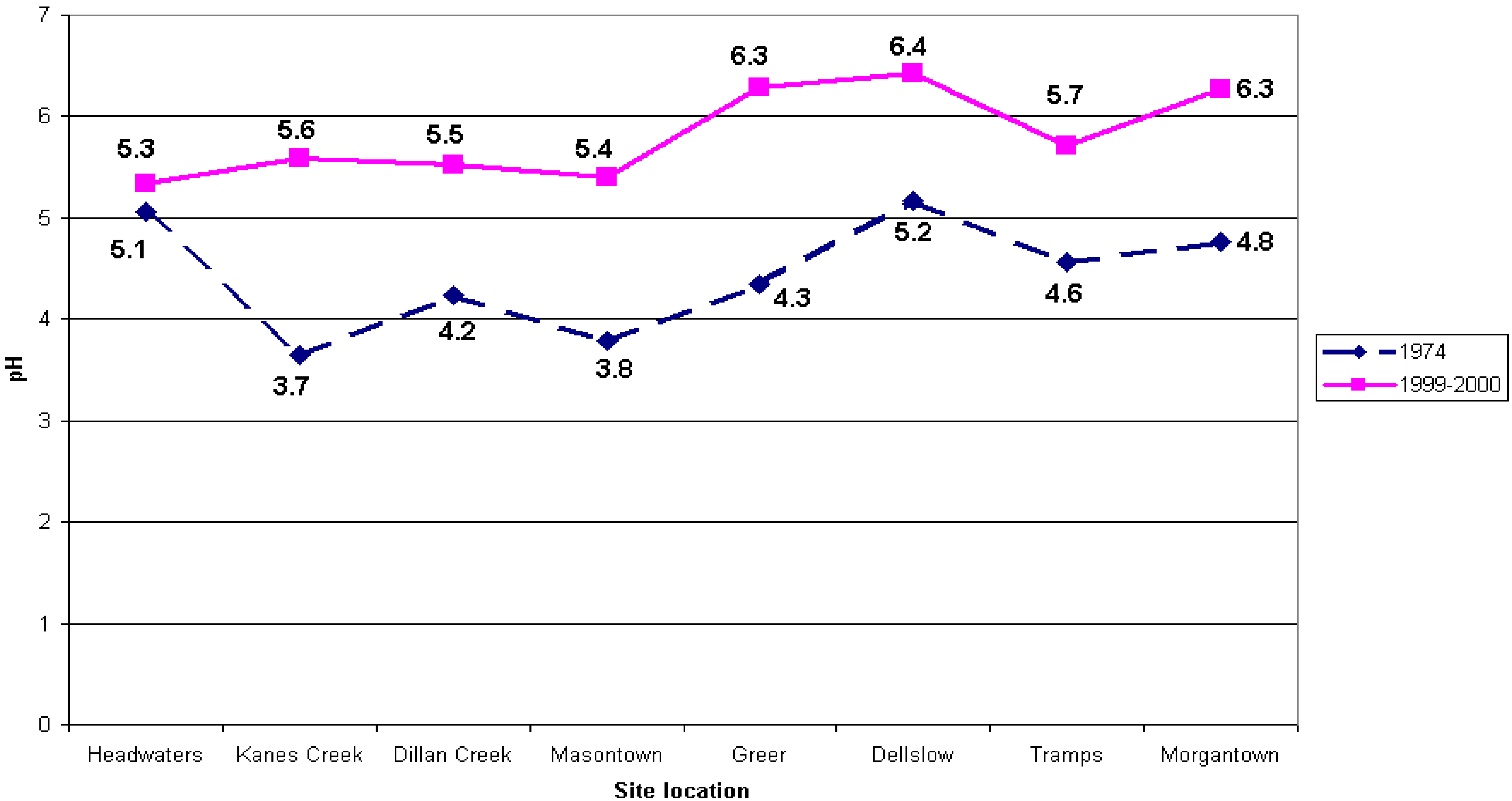
Results and Discussion

Based on estimated and measured flows as previously described, the 1974 and the 1999-2000 monthly data were divided into low flow (June, July, August, September, and October), medium flow (November, December, and January), and high flow (February, March, April, and May) conditions. Only one month of data existed in the low and medium flow classes for the 1974 study. Data from eight of the 29 sites were selected to represent specific sections of the stream. The Headwater sampling location was the most upstream sampling point and represented an area of limited pollution from households and land disturbances. Two sampling locations were located below the inflow of two major tributaries draining areas heavily surface mined in the 1970's and 80's (Kanes and Dillan Creek). The Masontown site was just below the town of Masontown where a low-flow acid mine drainage input occurs. Greer is the location of a large limestone aggregate mine. Limestone materials of various sizes are introduced into the stream at this point. At Dellslow, the limestone and water have mixed and several more relatively good quality tributaries have entered the creek. But most important, this site is upstream from a major acid mine drainage input from the Richard underground mine complex. Tramps is immediately downstream from the Richard acid mine drainage input to Deckers Creek, while the Morgantown site is near the mouth just before Deckers Creek enters the Monongahela River.

The high flow averages (February through May data) for these eight representative sites are presented for four parameters: pH, alkalinity, acidity, and total iron (Figures 2-5). Data from 1999-2000 and 1974 are plotted on the same graph for each parameter to illustrate the change in water quality over time. The graphs indicate that levels of acidity and total iron have significantly decreased ($P<.0001$ and $P<.0027$, respectively) throughout the stream, while alkalinity and pH have significantly increased ($P<.0001$).

Water pH at all sites was higher during the present study than in 1974 (Figure 2). The present pH levels are in most cases 1 to 2 pH units greater than in 1974. In 1974, the average pH in Deckers Creek was never above 5.2 (Teti 1974). Prolonged periods of low pH water in a stream are detrimental for several reasons. When the pH of a sample is below 5.5, aluminum can exist in solution in its highly toxic Al^{3+} form. Trivalent aluminum and free protons interfere with oxygen absorption in benthic macroinvertebrates and fish. Aluminum also binds phosphorus in less available forms

Figure 2. Average pH from February-May (high flow conditions) at eight selected sites for 1974 and 1999-2000.



and interferes with the uptake, transport, and use of nutrients and water by plants. When pH is above 5.5, as during the 1999-2000 sampling period, aluminum will bind with hydroxides and precipitate out of solution, causing less damage to aquatic life.

Alkalinity levels have increased throughout the entire watershed, with the largest average alkalinity levels coming below Greer Limestone (Figure 3). Alkalinity is a measure of the ability to neutralize acidity and dissolved metals. A stream with high alkalinity levels will be able to supply adequate amounts of carbonate, bicarbonate, and hydroxide ions in solution to bind up free protons and heavy metals. Several factors are responsible for the increase from 1974 to 1999-2000. In the late 1970's, an active treatment system was constructed on Kanes Creek. This facility intermittently pumps and treats water from a nearby deep mine using ground calcium carbonate. The treated water is passed through a series of settling ponds before being discharged into Deckers Creek. When operating, this system adds 1000 to 2000 gallons per minute of high pH, high alkalinity water to the creek. Tables 3 and 4 show the effects of this treatment on both Kanes Creek and the mainstem of Deckers Creek. Levels of iron, aluminum, manganese, and acidity were all reduced, while pH, alkalinity, and calcium were all increased. In Kanes Creek, acidity was reduced by 97%.

Acidity levels have declined, averaging a 62% decrease across all sites, with the smallest decrease occurring below the Richard Mine discharge (21%) (Figure 4). It is interesting that the worst acidity levels are at two different locations for the two sampling periods. Kanes Creek had the highest acidity during the 1974 study, while Tramps had the highest numbers during 1999-2000. This indicates improvements in the upper half of the watershed and continued inputs of mine water in the lower part of Deckers Creek. Reducing water acidity has multiple benefits, and is consequentially a main goal of all acid mine drainage remediation measures. Acid water irritates the gills and eyes of fish and insects. Elevated acidity levels also lead to accelerated weathering of clay minerals and pyrite. Clay minerals may break down quicker, releasing metals from their crystal lattices such as aluminum and iron, while the weathering of pyrite has been identified by numerous researchers as the biggest source of acidic mine drainage.

Figure 5 shows the decrease in total iron concentrations over the past 25 years. Total iron levels dropped as much as 87% at Kanes Creek, with an average decrease of 53% across the eight sites (Figure 5). Elevated pH and reduced acidity are both partially responsible for this decrease. During both studies, Tramps had the highest iron levels, due to inputs of untreated mine drainage at Richard. Iron is less toxic than aluminum, but will readily combine with hydroxide ions to form stream bottom-coating precipitates.

Decreased mining activity, higher additions of alkaline materials to the creek, and reclamation of abandoned mines in the Dillan and Kanes Creek areas have led to improved chemical quality of Deckers Creek. Possibly the most important factor behind the water quality improvements in Deckers Creek is natural healing that comes with time. Wood et al. (1999) indicates that minewater pollution is most severe in the first few decades after a discharge begins and that water, even from large mining complexes, improves in quality after 40 years. As oxidizable pyrite supplies diminish, the overall quality of mine drainage improves, contributing to improvements in receiving streams. With less mining activity in the watershed and improved

Figure 3. Average alkalinity levels from February-May (high flow conditions) at eight selected sites for 1974 and 1999-2000.

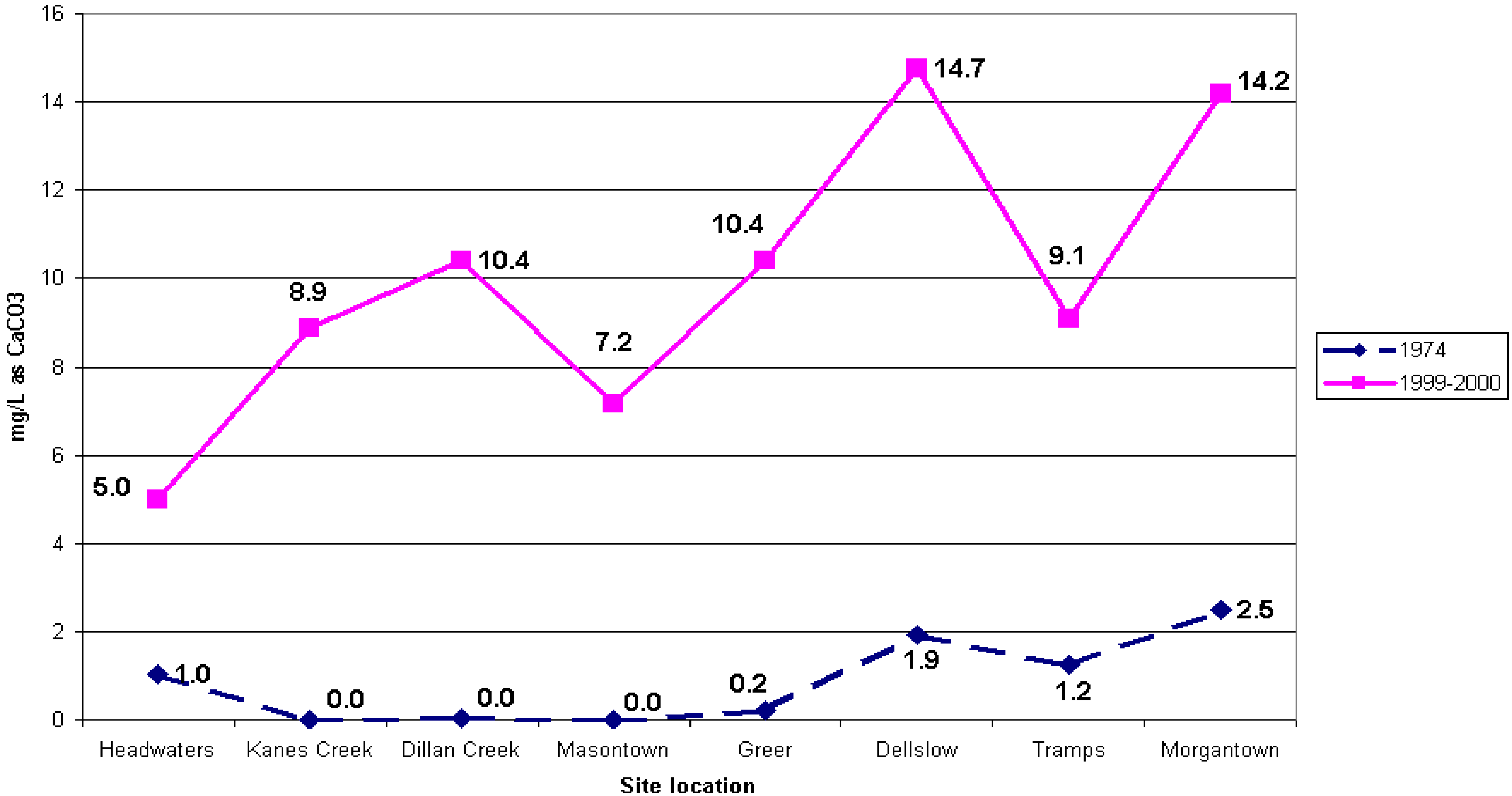


Table 3. Conditions in Kanes Creek (site 27) during a period of AMD treatment versus a period of no AMD treatment.

Parameter	**With Treatment (August 2000)**	**Without Treatment (September 2000)**
pH	6.24	3.82
Acidity	3.99	143.3
Alkalinity	11.07	0
Total iron	.13	27.4
Aluminum	.16	3.72
Calcium	211.4	107.7
Manganese	.73	1.96

Table 4. Conditions 1500 m downstream from Kanes Creek during a period of AMD treatment versus a period of no AMD treatment.

Parameter	**With Treatment (August 2000)**	**Without Treatment (September 2000)**
pH	6.43	5.84
Acidity	5.32	30.17
Alkalinity	28.66	20.95
Total iron	.07	5.84
Aluminum	.16	.39
Calcium	142.28	78.13
Manganese	.54	1.17

Figure 4. Average acidity levels from February-May (high flow conditions) at eight selected sites for 1974 and 1999-2000.

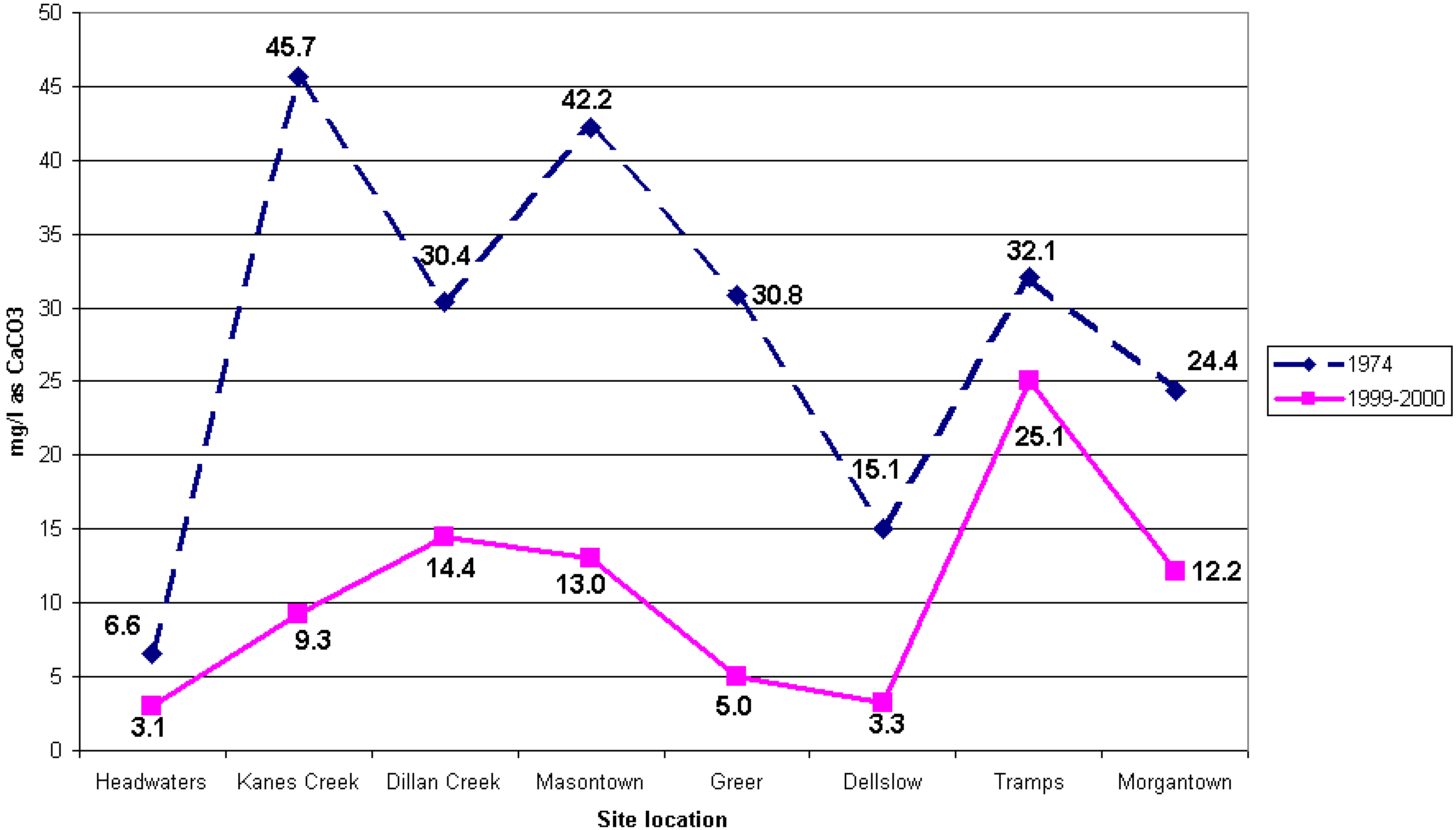
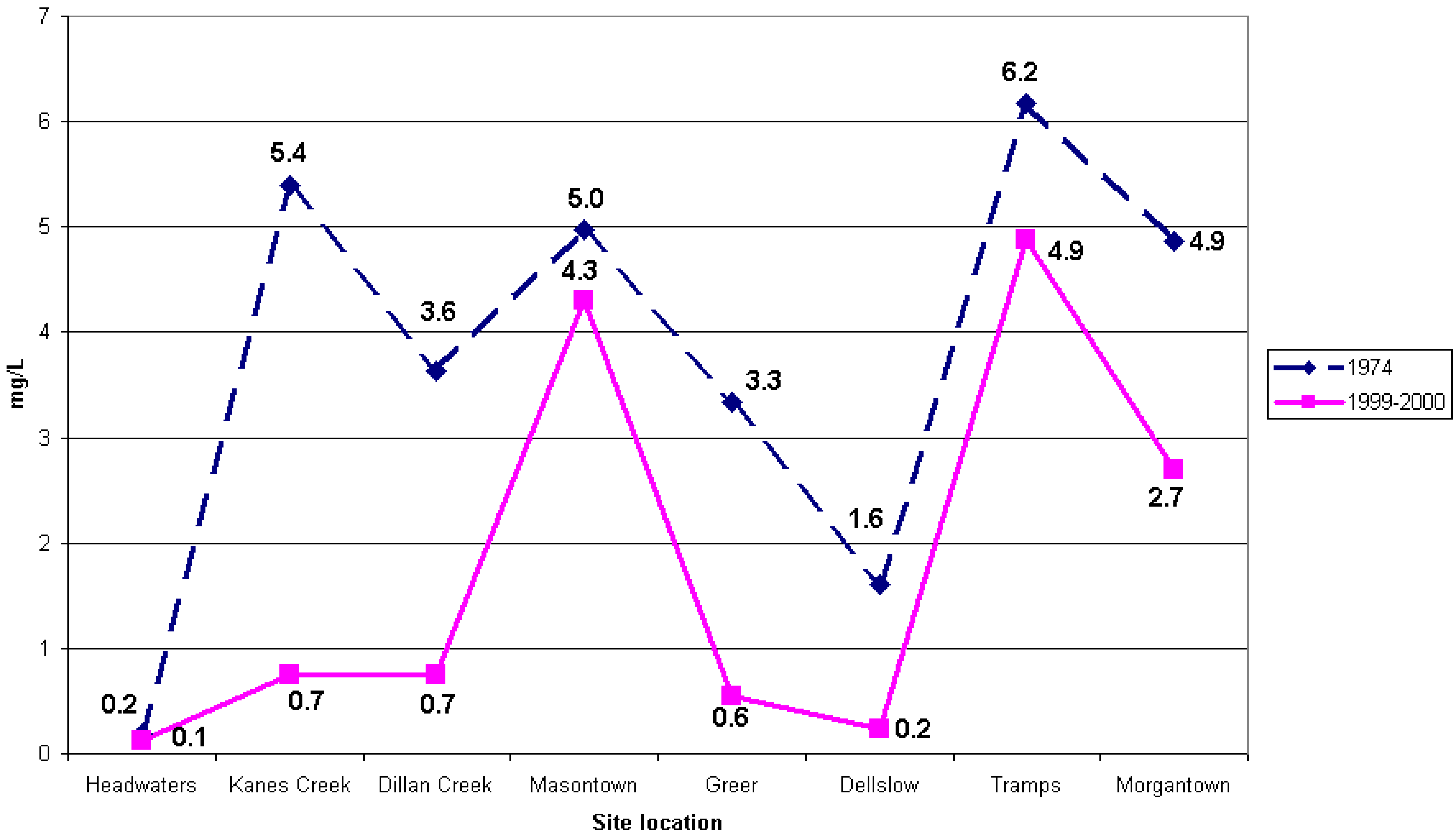


Figure 5. Average total iron levels from February-May (high flow conditions) at eight selected sites for 1974 and 1999-2000.



reclamation on the few remaining active mining sites, water quality has improved. Natural reclamation and reclamation projects conducted by the state on abandoned sites, and better treatment and control of water on active sites also enhances this improvement.

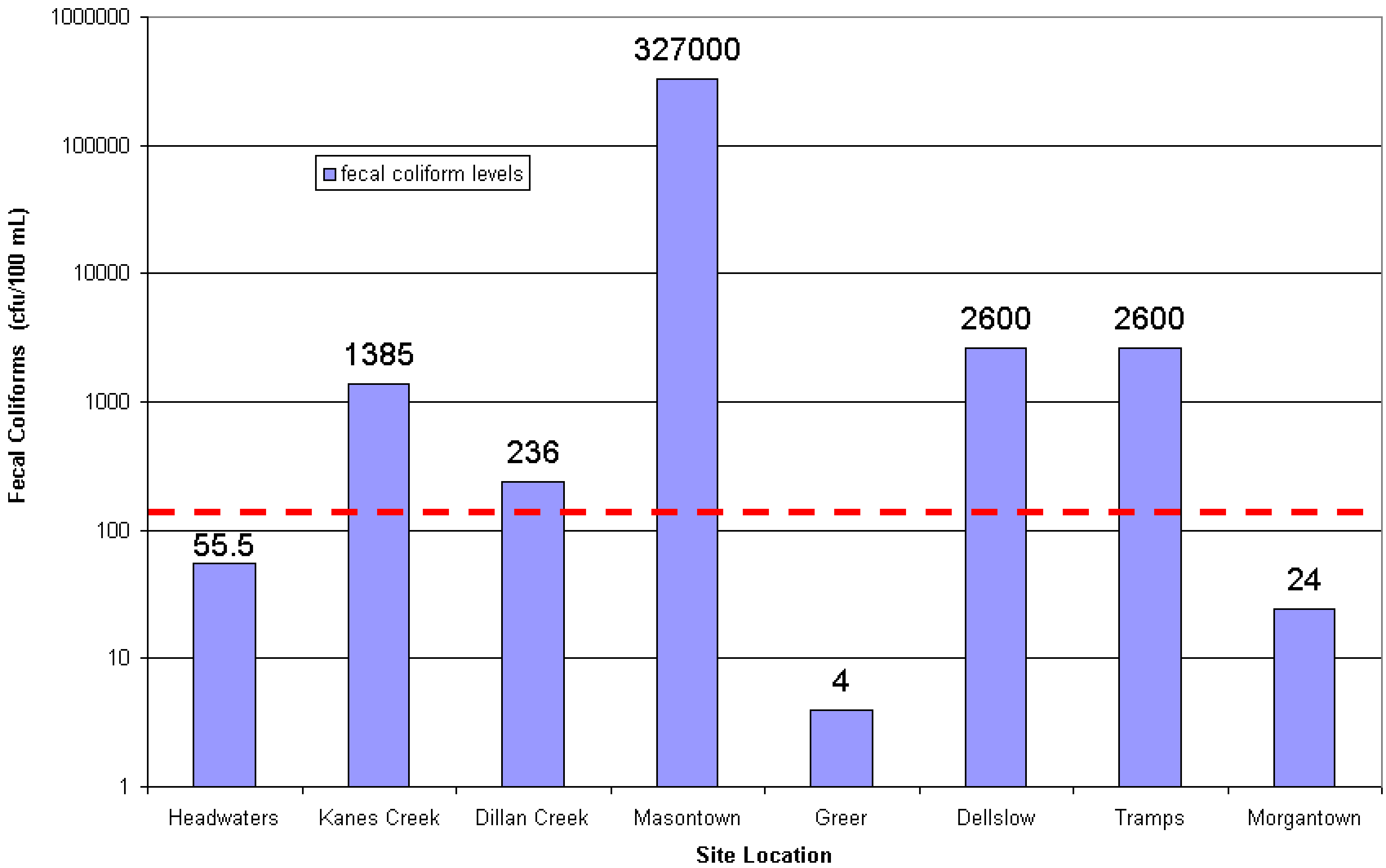
In contrast to improved water quality for the above conditions, a new water pollution problem is becoming apparent. Fecal coliform bacteria populations are very high in some parts of the watershed due to inadequate sewage treatment. Figure 6 shows the average fecal coliform counts for the Spring of 1999. No data is available from the 1974 study, but it is hypothesized that the harsh conditions in the creek during 1974 would have masked any bacterial problems. Of the eight sites shown, five had average fecal coliform counts higher than the West Virginia standard for secondary use waters of 200 colony forming units per 100 ml sample (Figure 6, dashed line). Masontown was by far the most heavily impacted site in the watershed. During the summer months of 1999, low stream flow, sustained sewage flow, and elevated temperatures led to fecal coliform levels as high as 9.0×10^6. Coyne et al. (1994) made similar observations, noting that warm, shallow streams, high in organic carbon, permit fecal coliform regrowth.

The present data help highlight some environmental laws and regulations enacted and enforced in the state which have led to the improvement of water quality in Deckers Creek. In 1977, the Surface Mining Control and Reclamation Act (SMCRA) was passed by the federal government. This law enhanced already existing efforts to make coal operators reclaim mine sites and to control the quality of the drainage coming from active mining sites. Operators are required to treat their wastewater if necessary before discharging it into receiving streams. Reclamation is mandatory, and more effective methods of backfill handling and placement are now required, thereby reducing the potential for acid mine drainage discharge. This legislation has had the effect of protecting existing environments and ensures that mine sites will not degrade the environment for future generations. The present study illustrates the long-term benefits that have been realized by requiring compliance with these laws. This study also shows that as the chemistry of Deckers Creek returns to pre-mining ranges, sewage input will become an increasingly noticeable problem.

Conclusions

Based on high flow averages for the data shown for 1974 and 1999-2000, water quality has improved in Deckers Creek during the past 27 years. The four chemical parameters measured indicate that conditions have become more favorable for aquatic life in Deckers Creek, with the greatest recovery occurring in the upper half of the watershed. Below the town of Richard, less improvement has been seen due to the massive inflow of untreated mine drainage. Sewage inputs will become a more noticeable problem as the acid inputs into Deckers Creek continue to decline.

Figure 6. Spring average Fecal Coliform counts at indicated locations (1999).



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