OVERVIEW

I. Des Moines Water Works Source Water

The Raccoon River and shallow groundwater wells heavily influenced by it are the primary water sources for the Des Moines Water Works. Approximately 500,000 people (17% of the Iowa's population) regularly consume this water, and about 15 billion gallons of it is treated annually for consumption. Lake Michigan, the Mississippi River, and the Missouri River are the only surface water sources that supply more water, and more people, in the Upper Midwest.

Des Moines Water Works (DMWW) has been using Raccoon River-influenced groundwater for more than a century at its Fleur Drive Treatment Plant. A three-mile-long infiltration gallery, 30 feet underground, runs parallel to the river and collects water as it seeps from the river through the surrounding soil structure. Direct use of river water began in the late 1940's. Collector wells adjacent to the river were constructed in 2000, and supply water to the Maffitt Treatment Plant.

Following the 1977 drought, the utility constructed a surface water intake on the Des Moines River. This is located near the intersection of Hickman Ave. and M.L. King Blvd. in Des Moines. Des Moines River water has been used regularly since about 1980.

Two radial collector wells that will use Des Moines River-influenced water are currently in the planning stages. These will be located on the east bank of the river between Interstate 80 and NW 66th Avenue between Johnston and Saylorville.

The amount of water used from the sources varies with water demand and water quality. Long term averages are 40% Raccoon River-influenced groundwater, 30% Raccoon River water, and 30% Des Moines River water. The Raccoon River is the preferred surface water source due to energy and water hardness considerations, but ice, chronically high nitrate levels, and episodically high turbidity limit its use.

Because of the buffering effect of Saylorville Reservoir, the Des Moines River is a more stable and dependable source when compared to the Raccoon. But its water has substantially higher levels of hardness, especially non-carbonate hardness, which increase costs associated with treatment.

II. Hydrology

A. Raccoon River

The Raccoon River rises in Buena Vista County, Iowa, and travels approximately 200 miles to its confluence with the Des Moines River in the city of Des Moines. The mainstem of the Raccoon River, also known as the North Raccoon in its upper stretches, has two main tributaries: the Middle and South Raccoon Rivers. The Middle Raccoon River rises in northwest Carroll County and flows 76 miles to join the South Raccoon near Redfield, IA. The South Raccoon River rises near the Guthrie-Audubon County line and flows 50 miles until its confluence with the Middle Raccoon. The combined flows of the Middle and South Raccoon join the North Raccoon near Van Meter, a few miles downstream from Redfield.

The entire Raccoon River Watershed drains 17 counties and 3600 square miles, 6.4% of Iowa's total area. The river flows through the western part of the Des Moines Lobe, a very young geological formation left behind by the last Wisconsinan ice age. All three branches of the Raccoon were influenced by glacial melt water, and the current course of the Middle Raccoon roughly traces the furthest edge of glacial advance. The landscape of this region was shaped only 12,000 to 16,000 years ago, much more recently than the rest of Iowa. Small portions of the watershed lie in the Southern Iowa Drift Plain and the Northwest Iowa Plains.

No one alive today has seen the Raccoon River in its natural state. Prior to European settlement, lands making up the watershed were largely wet prairie. Early settlers transformed the landscape into agricultural land through removal of native plants and systematic drainage, a process that continues to this day. The prairies and wetlands of the region were largely gone by 1890. This landscape modification dramatically altered the character, appearance, and water quality of the river to the extent that the river would be largely unrecognizable to people who saw it prior to 1860.

The Raccoon River Watershed includes Hydrologic Unit Codes (HUC) 07100006 (North Raccoon River) and 07100007 (combined Middle and South Raccoon Rivers).

B. Des Moines River

The Des Moines River rises from Lake Shetek near the southwestern Minnesota city of Pipestone and flows 525 miles to its confluence with the Mississippi River in southeastern Iowa. The portion upstream from its confluence with the Raccoon River drains 26 Iowa counties and over 5000 square miles of land. There are 47 significant tributaries to the Des Moines, but the river is largely fed by three main branches: the East and West Fork of the Des Moines, and the Boone River.

The Des Moines River watersheds upstream from the DMWW intake include the following HUCs: 07100004 (Middle Des Moines), 07100001 (Des Moines Headwaters), 07100003 (East Fork Des Moines), 07100002 (Upper Des Moines), and 07100005 (Boone River).

The geological history of the Des Moines River watershed mirrors that of the Raccoon watershed. Virtually the entire watershed drains areas of the Des Moines Lobe, and landscape modification over the last century has been dramatic.

As it relates to water treatment, the Des Moines River differs from the Raccoon in one dramatic way: impoundment of the river 10 miles upstream from the DMWW intake. Saylorville Dam and Reservoir constitute a buffer of sorts, and the huge changes in flow and water quality which plague the Raccoon are less dramatic in the Des Moines. Much of the sediment and turbidity in the Des Moines are deposited in the reservoir. Upstream from the reservoir, the river behaves similarly to the Raccoon. Beaver Creek, a sizable tributary entering the Des Moines downstream from Saylorville Dam, can cause significant changes in water quality after large precipitation events. Large changes in Des Moines River flow can occur during the process of lake level management by the Army Corps of Engineers. Unlike the Raccoon, however, these dramatic changes in flow do not necessarily result in water quality changes. A map depicting the locations of the Raccoon and Des Moines River watersheds is shown in Figure 1. The

Raccoon River Watershed is depicted in green, the Des Moines River Watershed in purple.

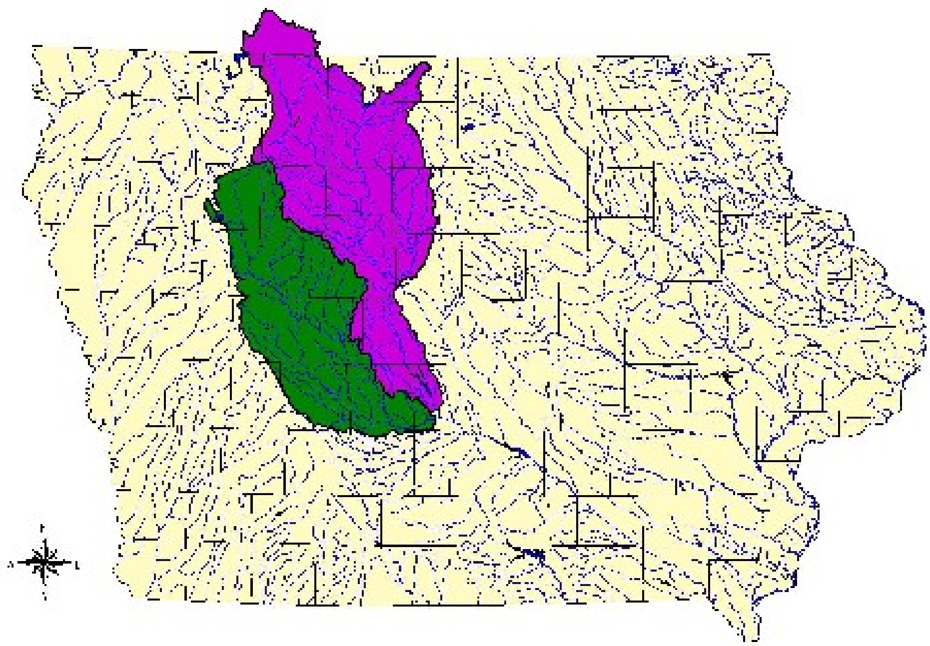


Figure 1: Des Moines and Raccoon River Watersheds

III. Sources of Water Quality Impairments

A. Agriculture

1. Nitrate

The Des Moines Lobe is one of the most productive agricultural regions on earth. Early settlers transformed the landscape into agricultural land through removal of native plants and systematic drainage, a process that continues to this day. Approximately 74% of its area is now cultivated for corn (Zea mays L.) and soybeans [Glycine max (L.) Merr.] (1). Livestock production provides an added economic benefit to the area, and millions of animals—cattle, hogs, and poultry, are raised in the region. The annual agricultural economic input to the region is estimated to be in excess of $11 billion (Iowa Soybean Association, unpublished data).

Soils in the watershed are primarily poorly-drained, fine-textured glacial deposits that supported the countless wetlands that dotted the landscape prior to settlement (2, 3, 4, 5). Large stretches of the landscape are approximately level and natural drainage is very undeveloped. In order to most efficiently cultivate the land, subterranean drainage pipes, known as tiles, were systematically installed over the last 150 years (6). In many sections of the watershed, cultivation would be impossible without these tile lines. In recent decades, however, intense tile installation has focused on not only on making land available for row crops, but also to dry out damp spots in a cultivated field. Tiles also have the effect of more rapidly increasing soil temperatures in the spring. Tiles effectively lower the water table to their elevation. Both the Des Moines and Raccoon River Watersheds, like much of the northern 2/3 of Iowa, are a maze of tile drainage networks. Collection systems are managed by county or drainage district authorities. Water from multiple tile lines is usually collected in progressively-larger pipes, which then drain into ditches and tributaries which feed the main river. Many of these ditches were formerly streams in their own right that were straightened to facilitate drainage and cultivation.

Tiles bypass nature's natural system of water transfer from the land to streams. Thus, opportunities for biological denitrification and plant uptake of natural and applied nitrogen are lost or minimized. This, coupled with intense application of nitrogen via anhydrous ammonia and animal manure, has greatly increased nitrate levels in Midwestern streams over the last 60 years (5, 7, 8, 9). There is some thought that land use practices alone hasten the transfer of naturally-mineralized nitrogen to surface waters (8).

Nitrogen application rates to cultivated fields in the U.S. increased substantially during the 1970's (7, 10, 9), but have been relatively constant since 1981 (7). The same situation holds true for Iowa. Fertilizer-N use in Iowa peaked in 1985 with average application rates to corn of 145 lbs/acre. Both application rates and total N used on corn have held steady since 1986 (Department of Agronomy, Iowa State University, unpublished data).

For the period of 1980-1996, the Raccoon River had the highest average nitrate + nitrite concentration (mg/L) and the second-highest total nitrogen yield (kg/km^2) of the 42 sub-watersheds in the Mississippi River basin (10). During the same period, the Des Moines River had the second-highest average nitrogen concentration and the 8th-highest yield (10). This of course makes both rivers significant contributors to the hypoxia condition in the Gulf of Mexico. Nitrogen supplied to the Mississippi River from sub-watersheds like the Des Moines and Raccoon have been shown to affect the seasonal hypoxia zones in the Gulf (11, 12, 13, 15).

2. *E. coli* and other pathogens

Coliform bacteria are found everywhere in the environment. Fecal coliform and *E. coli*, are found in the intestinal tract of vertebrates and their waste. Coliform bacteria are water quality indicators, and their presence is an indicator that water has been contaminated with human and animal waste. The countless millions of cattle, hogs, chickens, and turkeys contribute substantial numbers of pathogenic microorganisms to the streams when animal manure is not managed properly. Tributaries of the Raccoon have been known to contain well in excess of 1 million colonies of *E. coli* per 100 ml of water (Des Moines Water Works, unpublished data). Many of these streams receive little or no human wastewater. It should be emphasized that *E. coli*, while possibly pathogenic in its own right, can indicate the presence of other pathogenic organisms, such as *Cryptosporidium*, *Shigella*, *Salmonella*, and various other bacteria, viruses, and parasites.

3. Routes of Entry into Streams

Agricultural contaminants enter the stream through three main ways: stormwater runoff, snowmelt, and tile effluent. Tiles can be a nearly continuous source of nitrate from cultivated fields during wet years. Improperly installed tiles near animal confinements can introduce large quantities of manure, nitrogen, phosphorous, and pathogenic organisms to streams. Stormwater runoff and snowmelt can wash large quantities of manure (directly from confinements or that applied to fields) and nitrogen into the watersheds. Contrasted with tile runoff, this sort of contamination is episodic and dependent upon climatic events.

B. Human and Industrial Wastewater

There can be no doubt that human and industrial wastewater, both treated and untreated, contributes to the impairment of Raccoon and Des Moines Rivers.

There are numerous permitted (municipal and private) waste treatment facilities in both watersheds. In addition, there are numerous unsewered communities throughout the region whose untreated waste finds its way into the rivers and their tributaries. Some of this waste enters via improperly installed or malfunctioning septic tanks; some also enters through tile lines or drainage ditches which receive a community's untreated waste by way of rudimentary collection systems. Wastewater introduces a number of contaminants, including bacteria and other pathogens, nitrate, chloride, phosphorous, pharmaceuticals and byproducts, and personal care products and their byproducts. Very few wastewater treatment facilities are required to disinfect their effluent; consequently these waste streams tend to contain large numbers of microbes. Treated waste streams can also contain NO3-N concentrations in excess of 100 mg/L. These types of discharges tend to have their greatest impact at low flow or in low-flow streams, such as Outlet Creek near Storm Lake. Changes in Raccoon River chemistry that indicate WWTP influence (such as increased fluoride and *E. coli*) are episodically detected at DMWW's Fleur Drive Plant. This usually is most evident in the fall months, when flow is low and communities discharge their treatment lagoons to a stream in the watershed. Likewise, detectable Des Moines River changes occur that show the evidence of human wastewater. These could originate from the Grimes WWTP, or from malfunctioning home septic systems in the Johnston area. The portion of total coliforms that is *E. coli* tends to be higher in the Des Moines River than the Raccoon River. DMWW believes this is an indication that *E. coli* levels in the Des Moines River are likely influenced by human wastewater more than livestock waste; contrastingly, DMWW believes the preponderance of *E. coli* in the Raccoon River likely originate from livestock. Urban stormwater runoff likely also contributes to *E. coli* loads in both streams, especially in Polk County.

Experiments in DMWW's testing laboratory show that about 80% of *E. coli* in cold (40F) river water die within three days. This suggests two conclusions: most of the *E. coli* seen at DMWW's intakes enter the watershed within three days river travel time; and/or the numbers of *E. coli* in the upper reaches of the watershed are enormous, and many times that seen at the DMWW intake.

C. Urban Stormwater

DMWW has monitored tributaries within Polk County during four snapshot events that have taken place since May of 2004. These results generally show that urban areas are significant sources of *E. coli* bacteria, but are not large contributors of nitrate. Nitrate concentrations tend to decrease as streams enter and flow through metropolitan Des Moines; however, the opposite is true for some, but not all streams for *E. coli*. This is an indication the strormwater runoff from urban areas is a significant source of microbiological pathogens. This also could indicate leaking or malfunctioning septic tanks in the metro area, or leaking sanitary sewer lines. To summarize, urban stormwater runoff is a significant and measurable contributor to the impairment of both the Des Moines and Raccoon Rivers.

REVIEW OF HISTORICAL DATA

I. Des Moines Water Works Finished Drinking Water

A. Fleur Drive Plant Nitrate

DMWW has been monitoring nitrate at its Fleur Drive facility since 1931. Prior to 1974, monitoring frequency was low and irregular, but most years finished water nitrate was evaluated at least quarterly. Beginning with the safe drinking water act of 1974, nitrate has been monitored much more frequently, and in recent years has been monitored daily. The filtered effluent water has been automatically and continuously monitored since 2004. Figure 2 below charts average annual nitrate levels leaving the plant since 1931.

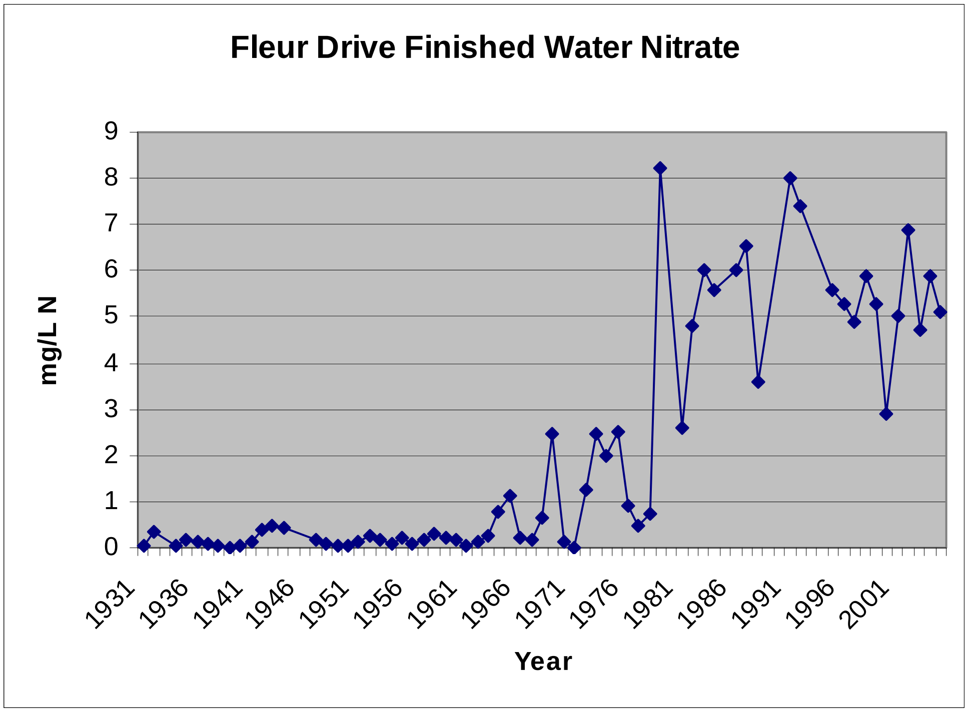


Figure 2: Fleur Drive Finished Water Nitrate

Figure 2 shows that nitrate was never much of a problem for DMWW until 1979. In fact, annual average finished water nitrate never exceeded 1 mg/L until the late 1960's. Once can see that nitrate levels didn't change much even after DMWW started using water directly from the Raccoon River in 1950. DMWW finished construction on its nitrate removal facility in 1992, and since then the facility has been used an average 41 days per year to keep finished water nitrate below 10 mg/L. The nitrate removal facility is used as a last resort, and other strategies, mainly source water blending, are used to keep finished water nitrate below 10 mg/L. Use of the facility is expensive due to energy and chemical requirements, and waste brine from the facility is discharged to the Raccoon River. DMWW maintains an NPDES permit for this discharge, which contains fairly high levels of chloride, TDS, sodium, sulfate, and nitrate. The discharge is diluted with large amounts of unchlorinated, treated water, but otherwise is untreated. The facility is usually discharging into the very high river flows seen in the spring and early summer, and so the environmental impact of the discharge is thought to be low. Nonetheless, DMWW is seeking ways to eliminate or reduce this discharge.

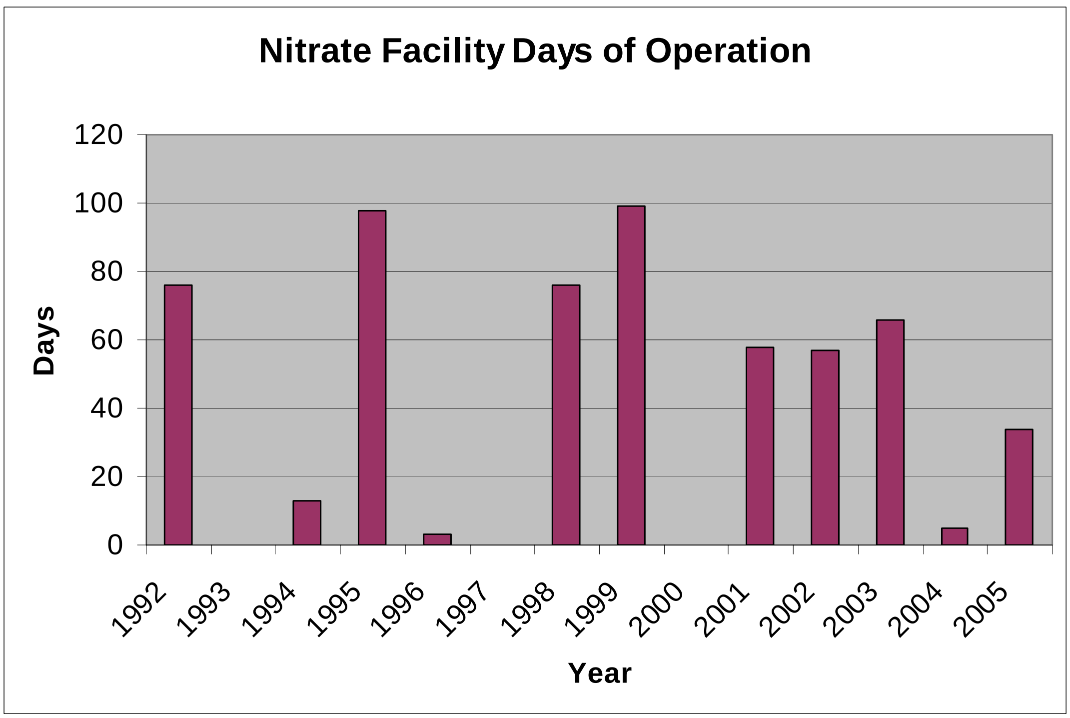


Figure 3: Nitrate Removal Facility, Days of Operation

B. Maffitt Plant Nitrate

The Maffitt Plant began producing water in April of 2000, and by early 2001 it was apparent that the radial collector wells, which were the primary source of water for the plant, would be plagued by high nitrate levels. Lacking the capacity to remove nitrate, finished water nitrate is kept below the 10 mg/L limit by diluting the high-nitrate well water with low-nitrate water from Maffitt Reservoir. At times, not enough lake water can be used, and in this situation water flow from the wells must be reduced. It is very expensive to operate the treatment facility in this manner. In recent years, water from the Raccoon River has been diverted into a gravel pit known as Crystal Lake, where natural denitrification takes place, and this water has been used as low-nitrate dilution water for the plant.

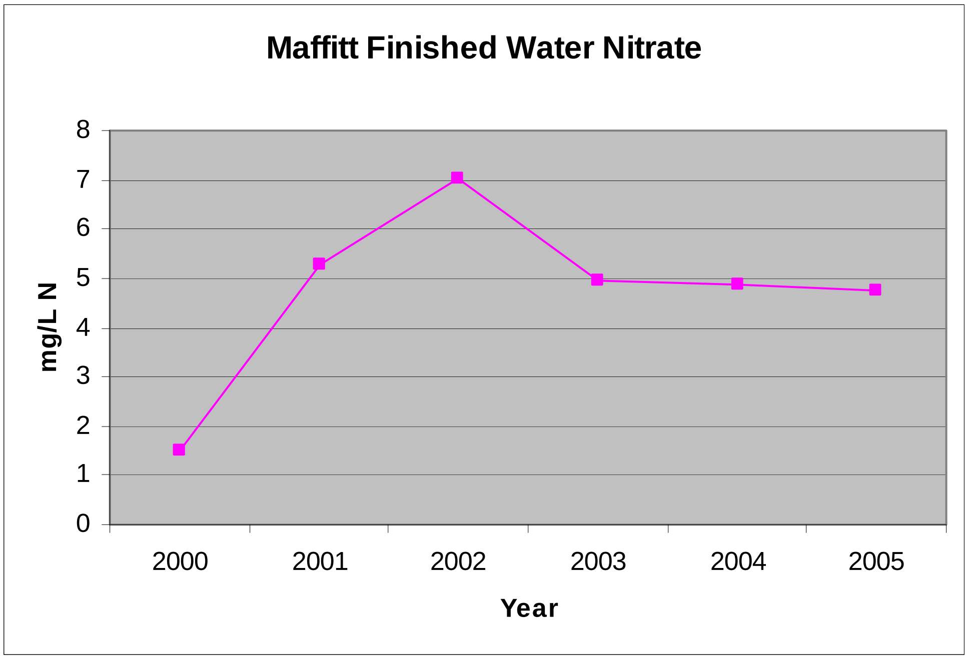


Figure 4: Maffitt Finished Water Nitrate

C. *E. coli* Bacteria

Coliform bacteria are completely eliminated during the treatment processes at both Maffitt and Fleur Drive plants. Sedimentation and lime softening physically remove these organisms from the treatment train, and the high pH levels of lime softening also provide toxicity. The few remaining live organisms that penetrate the rapid sand filters are easily killed by chlorine in the finished water storage reservoir. DMWW has never detected coliform bacteria in water leaving either plant since 1993. This fact should not diminish the importance of reducing coliform bacteria levels in the source waters. The presence of *E. coli* in the source waters is an indicator of other disease-causing organisms and chemical contaminants, such as antibiotics, hormones, and personal care products. It is unclear whether or not conventional water treatment removes many of these substances prior to the water being delivered to the customers.

II. DMWW Fleur Drive Raccoon River Intake Data (Water Works Park)

A. Nitrate

Spotty DMWW data exists for the period of 1934 to 1973. Some researchers have speculated that both the Raccoon and Des Moines Rivers saw episodic nitrate concentrations of 8 mg/L during the 1940's (14), but DMWW data indicates that the annual arithmetic average NO3-N concentration never exceeded 5 mg/L until 1973. The first year that DMWW saw monthly averages exceed the drinking water maximum contaminant level (MCL) of 10 mg/L was 1972. The chronically-high nitrate levels seen in the present day first appeared in 1979. Figure 5 below shows arithmetic annual average nitrate values for the period 1974 through 2005.

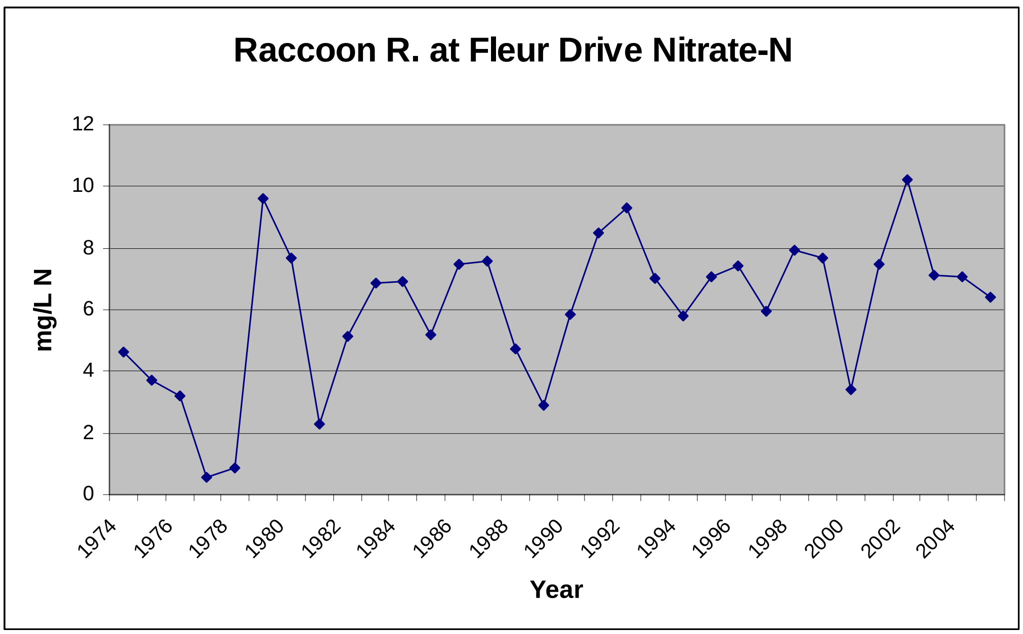


Figure 5: Raccoon River Annual Arithmetic Nitrate-N

Average nitrate concentrations tend to follow a predictable "S" curve as the year progresses, with nitrate concentrations peaking in late spring, and a secondary peak occurring in early winter. This is depicted in Figure 6 on the next page.

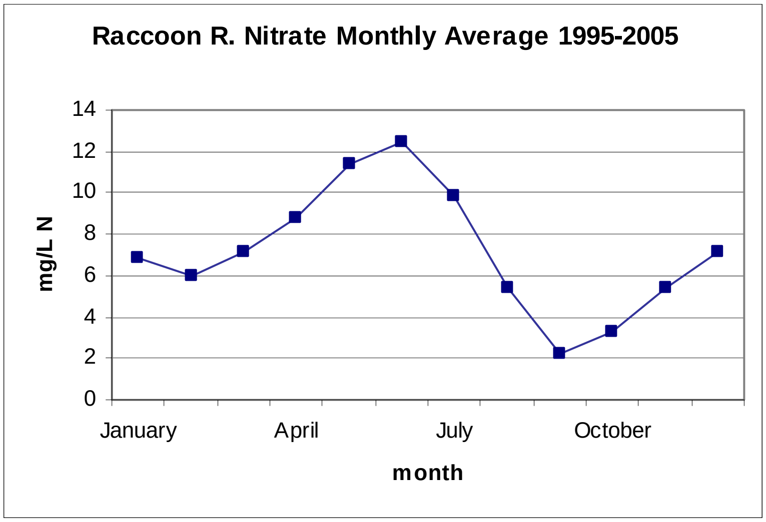


Figure 6: Raccoon River Monthly Average Nitrate Concentrations

As practical operation of a water treatment facility, arithmetic average nitrate concentrations are what determine necessary water treatment. However, the true assessment of nitrate levels in the river must take river flow into consideration. Nitrate measurements can be correlated with flow measurements to produce flow-weighted averages (FWAs).

Figure 7 below depicts Raccoon River FWA at DMWW's Fleur Drive location since 1996. The five highest FWA-N years on the Raccoon River have all occurred since 1998.

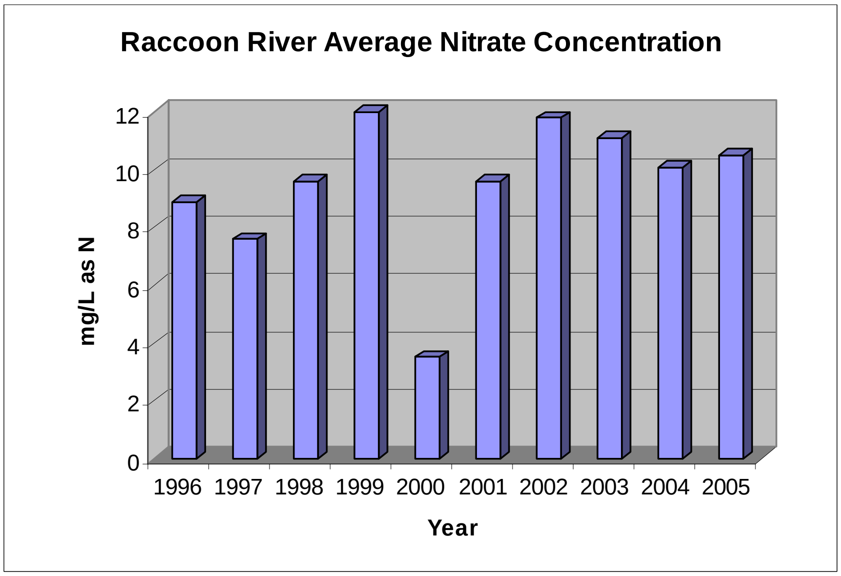


Figure 7: Raccoon River FWA Nitrate-N

High nitrate levels are closely tied to high river flows. Figures 5 and 7 show that the year 2000 had the lowest FWA N and the lowest arithmetic average nitrogen concentration since 1988. That calendar year was also very dry with drought or near-drought conditions found throughout the watershed. Figure 8 shows FWA N compared to annual average river flow for the period 1996-2005.

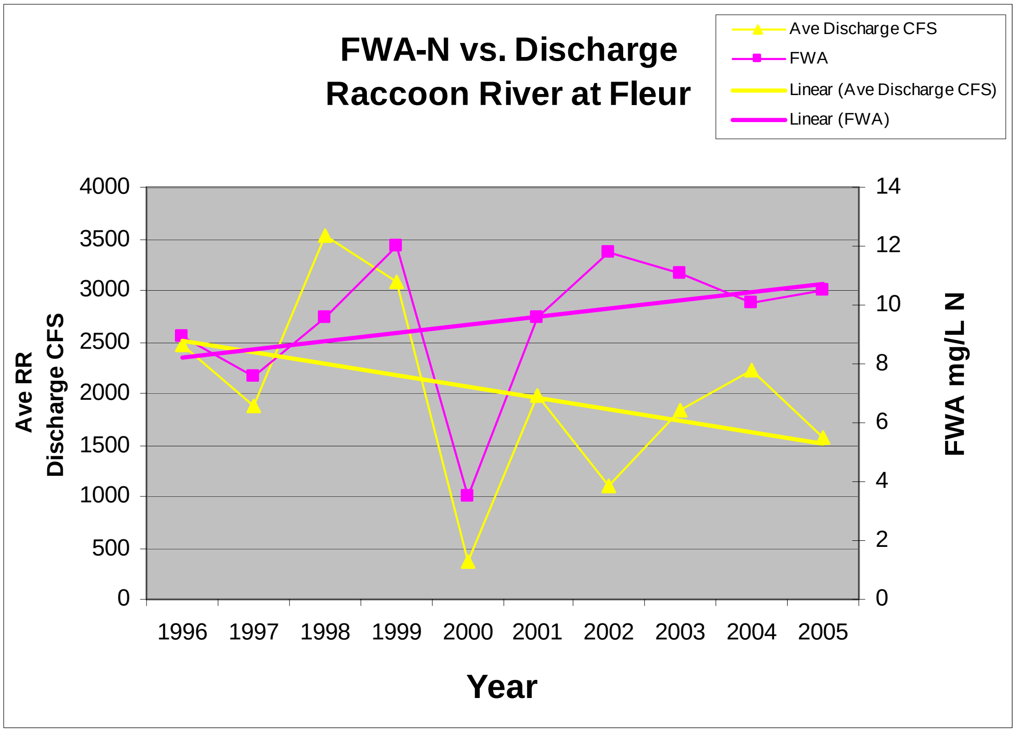


Figure 8: FWA Nitrogen vs. Average Discharge, Raccoon River at Fleur

One can see that flow is very closely connected to the amount of nitrate in the river. One can also see that the while flow is trending down over the last decade, the FWA-N continues to trend up. This implies that the water traveling down the Raccoon River is increasingly concentrated with nitrate, even though the total load may be decreasing. DMWW staff believe this indicates the portion of river flow that begins as tile effluent (versus runoff or groundwater seeping into the river through the alluvium) is increasing. Even though flows have trended down by about 40% over the last decade, nitrate loads have trended down by a lesser amount—25%—over the same period, as shown in Figure 9 on the next page.

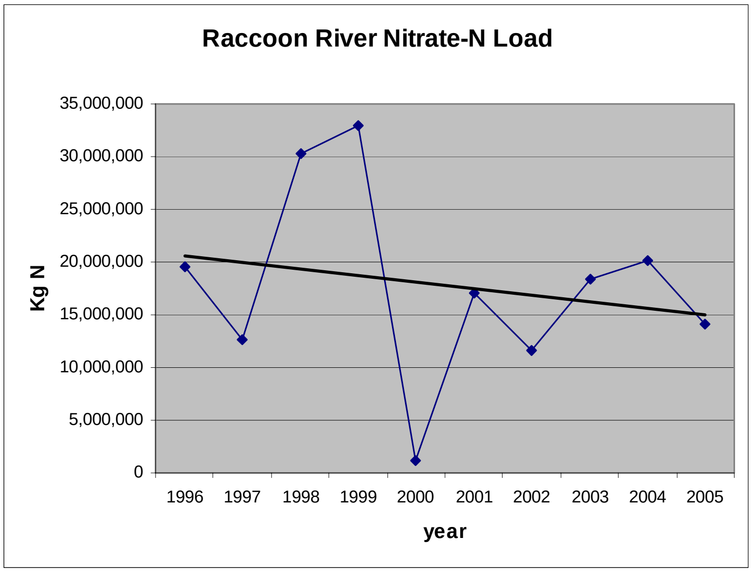
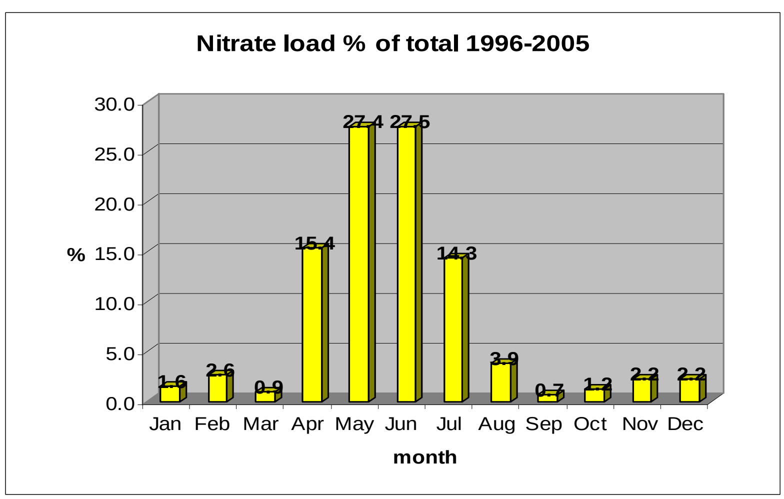


Figure 9: Raccoon River Nitrate Load 1996-2005

Because of Iowa's seasonal precipitation patterns and the timing of anhydrous ammonia application to cultivated fields, the bulk of the nitrogen load traveling down the Raccoon River occurs during the April through July time period, as depicted in Figure 10. For the 10-year period beginning in 1996, almost 85% of the nitrate load occurs during these four months. Another factor here may be that during late summer and early fall, much of the nitrogen is tied up as organic nitrogen in the form of plant proteins within algal cells in the river, and this phenomenon might be reflected in total nitrogen values. The die-off of these organisms with the onset of winter could also be the cause of the secondary nitrate peak seen in early winter.

Figure 10: Temporal Distribution of Raccoon R. N Loads



Maximum NO3-N concentrations seen in the Raccoon River approach 16 mg/L in most years, and have peaked at just over 18 mg/L in 2002. These maximum concentrations can be seen in Figure 11.

Average nitrate concentrations for a calendar month routinely exceed 10 mg/L, and the river can stay above this level for several consecutive months. Unwaveringly high nitrate levels in the Raccoon not only preclude its use as a water source, but also tend to elevate the NO3-N in DMWW's groundwater sources. Once the groundwater nitrate (gallery and Maffitt wells) approaches 10 mg/L, then nitrate removal at Fleur, or dilution with reservoir water at Maffitt, becomes necessary. The worst arithmetic average NO3-N months are shown in Figure 12. Ten out the worst 13 months have occurred since 1999.

Figure 11: Raccoon River Monthly Maximum NO3-N

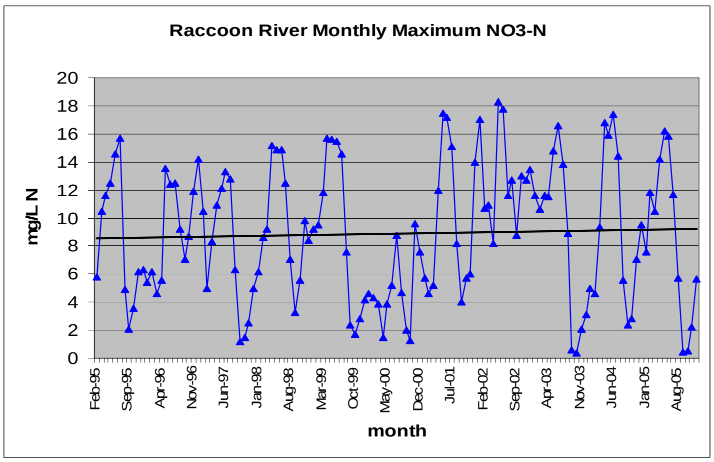
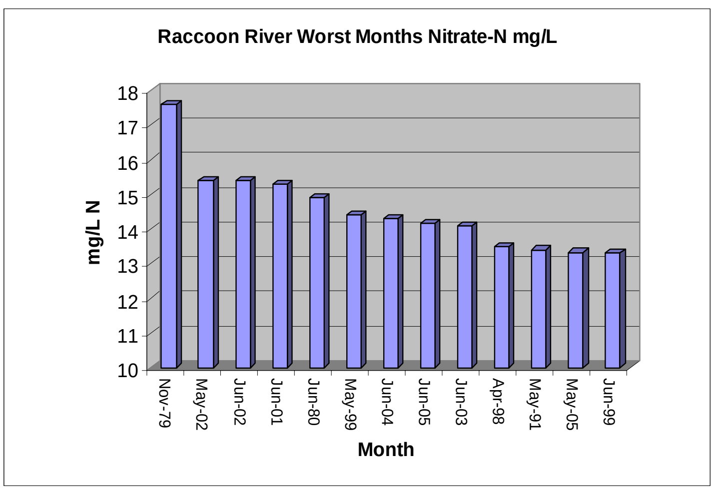


Figure 12: Raccoon River Worst Average NO3-N Months



B. *E. coli*

DMWW has been regularly monitoring *E. coli* and total coliforms in its source waters since mid-1996. No colony-forming units of *E. coli* can legally be present in finished drinking water, and DMWW monitors every step in the treatment train, including the source and finished water, to ensure that safe water is being delivered to customers. The sedimentation-lime softening-rapid sand filtration-disinfection treatment easily kills and/or deactivates coliform bacteria, and no *E. coli* have ever been detected in water leaving the plant. That said, the presence of *E. coli* in the source water is an indication that other disease-causing organisms and chemical contaminants, such as antibiotics, hormones, and personal care products, are present in the source water. It is unclear whether or not conventional water treatment removes many of these substances prior to the water being delivered to the customers. For this reason, mitigation of *E. coli* levels in the Raccoon River and DMWW's other source waters is a priority for the utility.

The presence of *E. coli* also has ecological and recreational consequences for Iowa's residents. The EPA standard for safe recreational contact is *E. coli* levels of 200 colony forming units (CFU) per 100 ml. The annual average *E. coli* level found in the Raccoon River at Fleur Drive has never met the 200 CFU/100 ml standard, and in fact these organisms populate the river at many times this level, as shown in Figure 13.

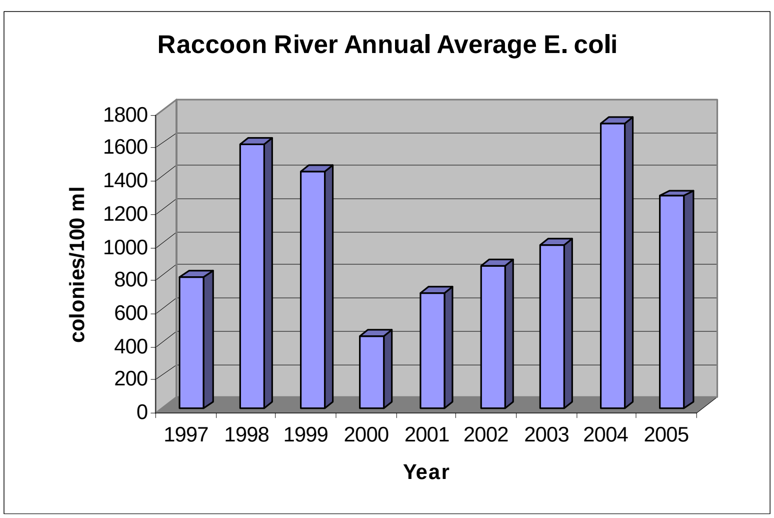


Figure 13: Raccoon River Annual Average *E. coli*

E. coli levels in the river tend to be highest in the high flow months of spring and early summer. At least anecdotally, this implies that most of these organisms are originating from animal waste in storm runoff. These sources could be both agricultural (livestock) and urban. Figure 14 below shows the monthly variation of *E. coli* in the river. Once can see that only the non-recreational winter months see *E. coli* levels low enough for safe contact.

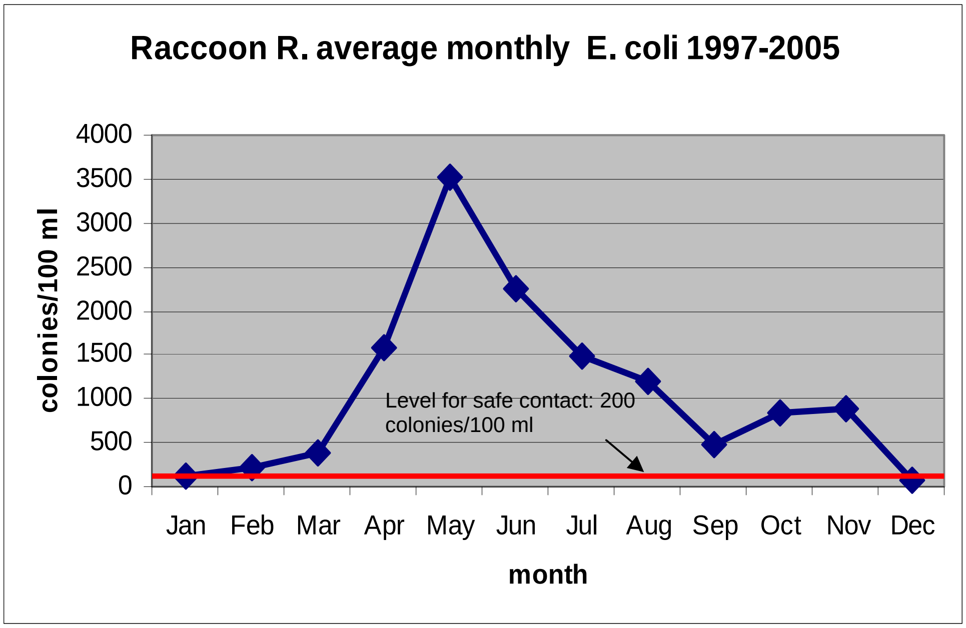


Figure 14: Raccoon River Average Monthly *E. coli*

The secondary peak in *E. coli* levels seen in November is likely due to human wastewater. It is known that small communities with lagoon waste treatment frequently release the lagoon in fall prior to freeze-over, and DMWW staff speculate this is the origin of the secondary fall peak.

Annual average *E. coli* levels are very closely linked to average river discharge, as shown in Figure 15, further evidence that most of these organisms get into the Raccoon and tributaries through runoff. Tests in DMWW's laboratory show that about 80% of *E. coli* perish in river water within three days. This would indicate one of two things, or both: levels upstream of DMWW are many times higher than measured at Fleur Drive, and/or most of the organisms enter the river within three days' travel time of DMWW's intake.

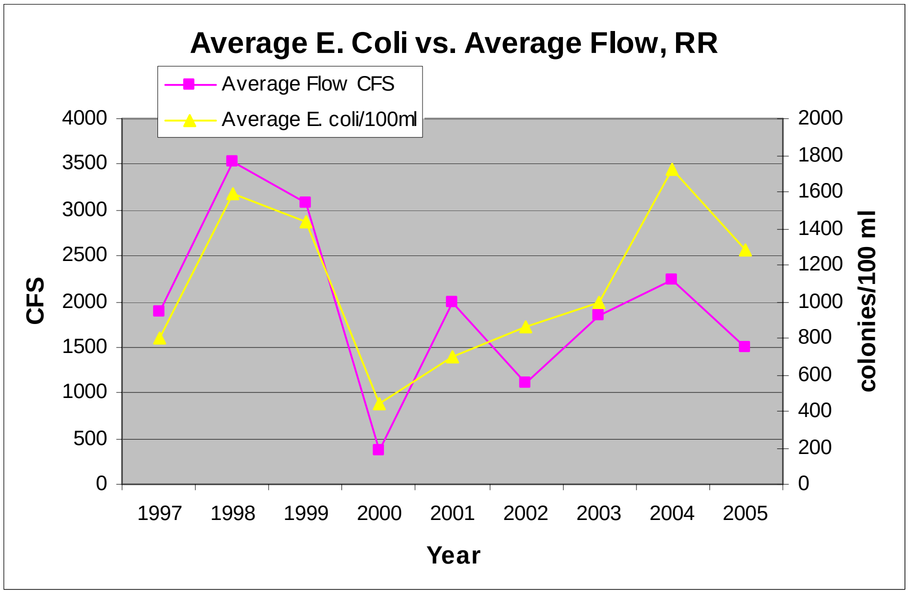


Figure 15: Raccoon River *E. coli* vs. Flow

Levels of *E. coli* can change dramatically within a short period of time, usually around storm events. Large episodes of 100,000 CFU/100 ml or more skew the mean well above the median (also of interest, median flow closely mirrors median *E. coli* levels). Nonetheless, the river is nothing short of chronically impaired for recreation, as shown in Figure 16 below. Even in 2000, when the annual average was a relatively low 440 CFU/100ml, the river still exceeded the safe contact standard on 88 calendar days.

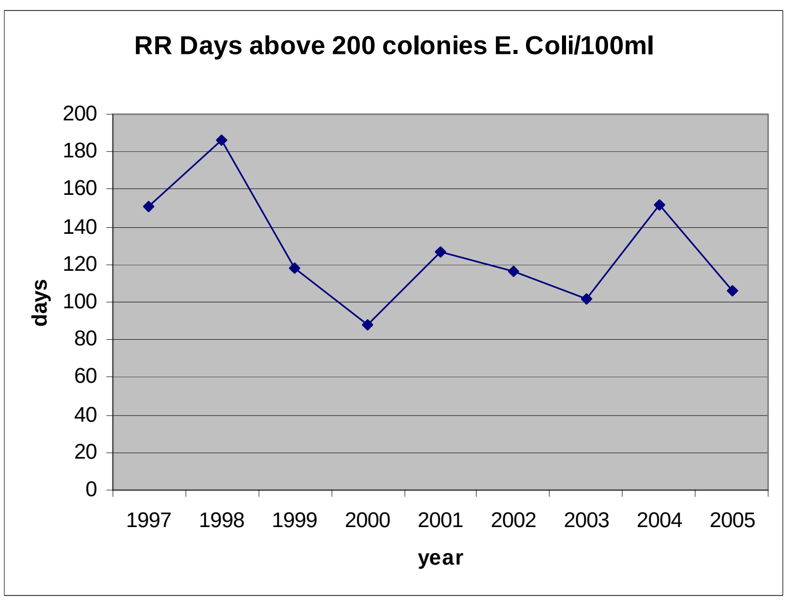


Figure 16: Raccoon River, days with *E. coli* above 200 CFU/100 ml

III. DMWW Des Moines River Intake Data (Hickman/MLKing)

A. Nitrate

Although extensive, DMWW data for the Des Moines River is not equal to that for the Raccoon River for the simple reason that the Des Moines River has not been used as a water source for as long. Furthermore, all of DMWW's ground water sources are Raccoon River-influenced, so interest in the Raccoon historically has been keener. Nitrate levels in the Des Moines tend to be more stable due to the buffering effect of Saylorville Reservoir, approximately 8 miles upstream from DMWW's intake. Beaver Creek, which enters the river about halfway between Saylorville Dam and the DMWW intake, can occasionally cause fluctuations in river nitrate—both up and down. But because its flow typically is many times less than that in the Des Moines, its effect on nitrate concentrations is usually minimal and short-lived. High nitrate peaks on the Des Moines River are lower than those seen in the Raccoon, but otherwise Des Moines River average nitrate does not differ dramatically from levels seen in the Raccoon. Figure 17 below shows monthly average nitrate in both rivers, and one can see that the Raccoon is slightly higher in each month except for the period of July through October, when levels in both rivers are virtually identical.

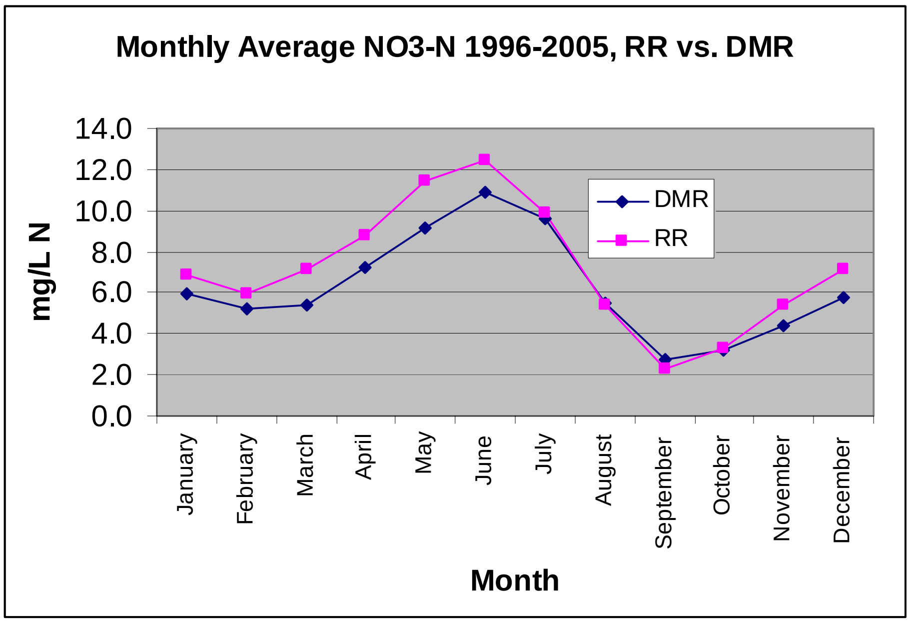
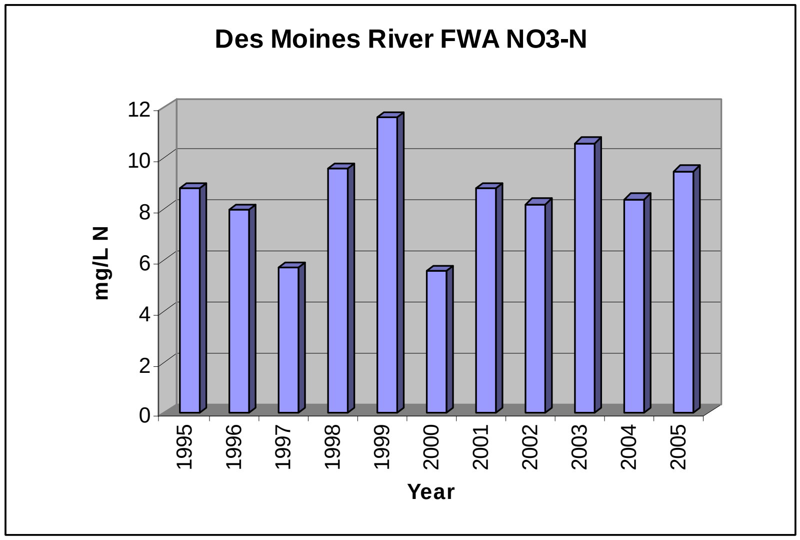


Figure 17: Des Moines River vs. Raccoon River NO3-N

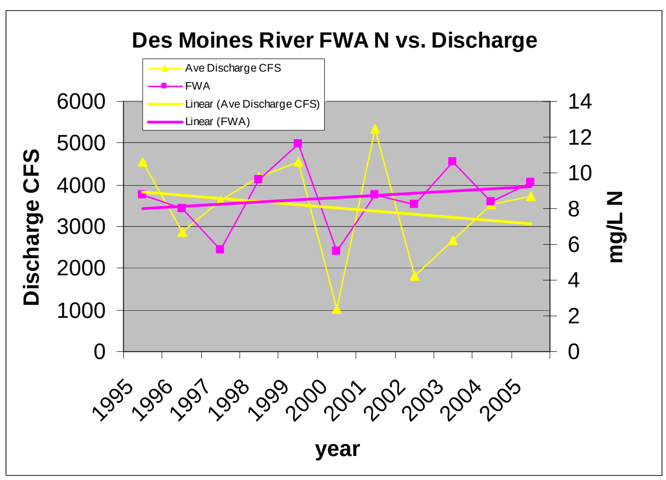
Figure 18 below depicts Des Moines River FWA NO3-N at DMWW's intake since 1995. Like the Raccoon River, the two worst years in recent history were 1999 and 2002. The dry year of 2000 was the only year of the last 11 where FWA nitrate in the Des Moines exceeded that of the Raccoon.

Figure 18: Des Moines River FWA Nitrate



Like the Raccoon, nitrate levels in the Des Moines tend to be highest when flows are high. Also like the Raccoon, FWA NO3-N is trending up over the last 10 years, while flows are trending down. The flow decreases are manifesting themselves in a slight downward trend for total NO3-N load delivered by the river. Figures 19 and 20 depict these trends. The combined NO3-N loads traveling past DMWW's two surface water intakes since 1995 total 477 million Kg, a figure approaching what is applied to land in all of Iowa in a typical year (1985-2003 average: 646 million Kg).

Figure 19: Des Moines River FWA Nitrate vs. Flow



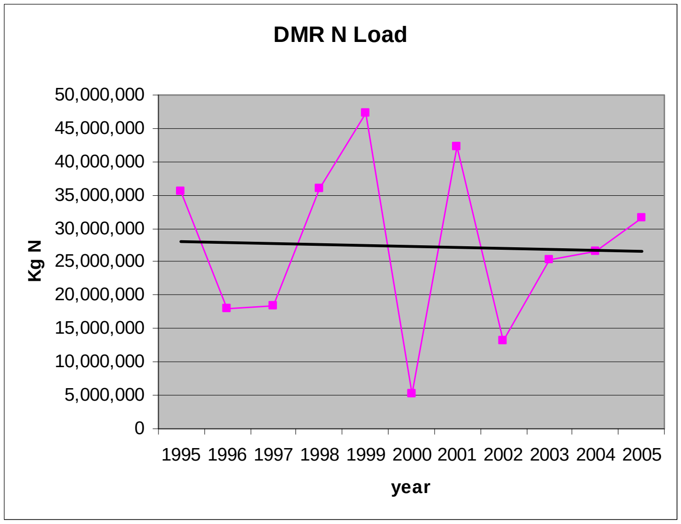
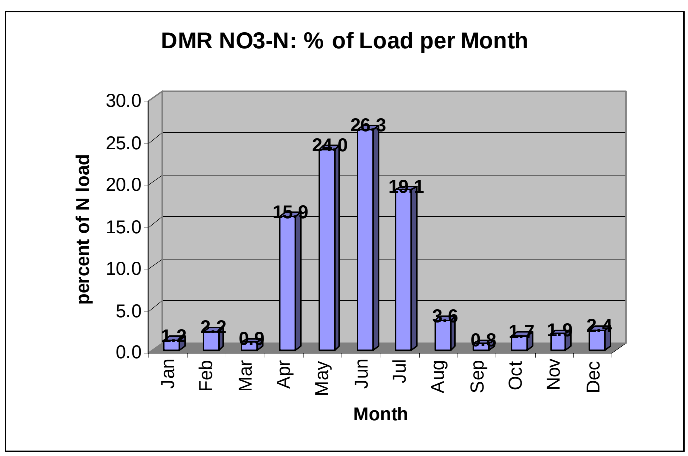


Figure 20: Des Moines River Nitrate Load, 1995-2005

When the bulk of the nitrate load travels down the Des Moines River is amazingly similar to the Raccoon River. The reader might recall that 84.6% of the NO3-N load in the Raccoon occurs in the April through July time period. The figure for the Des Moines River is 85.3%. This implies that for the purpose of evaluating nitrate, Saylorville Reservoir is basically a riverine system where little of the nitrate is consumed, at least during the nitrate peak of spring and early summer when water temperatures are relatively low. There can be no doubt that sediment, phosphorous, bacteria, and other particulates remain in the reservoir; however, nitrate concentrations likely are not affected much by the short (11 days approximately) detention time in the lake. Figure 21 below depicts the temporal distribution of the nitrate load in the Des Moines River throughout a typical calendar year (1995-2005 averages).

Figure 21: Temporal Distribution of Des Moines River N load



As mentioned previously, nitrate peaks in the Des Moines River tend to be slightly lower than those in the Raccoon. These can be seen in Figure 22 below. Like the Raccoon, the nitrate maximums in the Des Moines show a slight upward trend over the last decade, this while the total load trends down slightly. DMWW staff interprets this to mean that both rivers are increasingly influenced by high-nitrate sources, i.e. tile effluents. Figure 23 below lists the worst FWA NO3-N months for the Des Moines River.

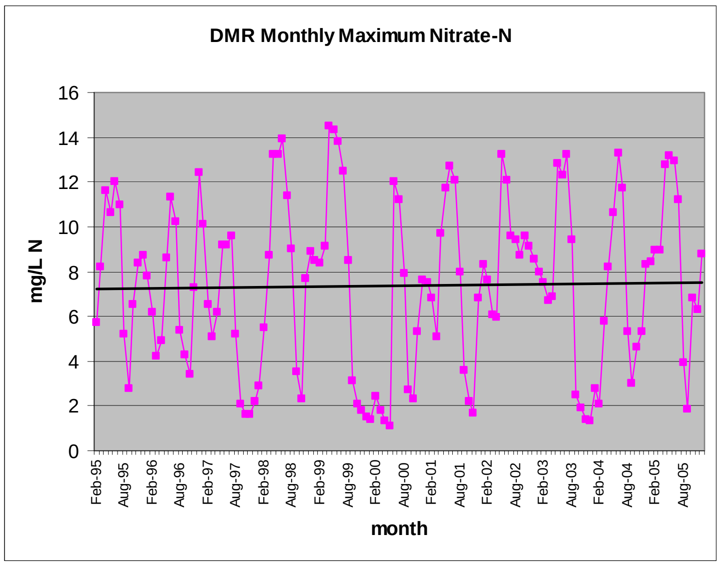


Figure 22: Des Moines River Monthly Maximum Nitrate-N

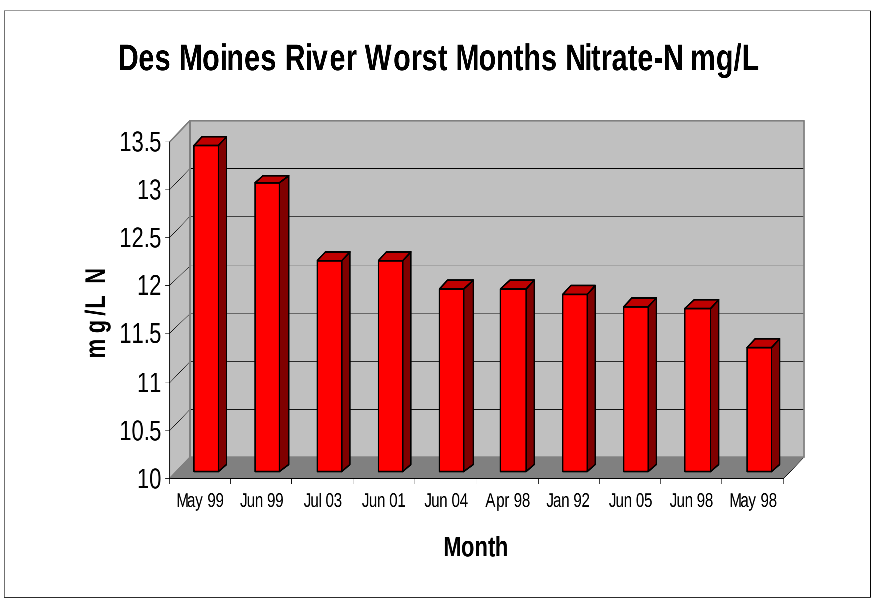


Figure 23: Des Moines River, Highest FWA NO3-N Months

B. *E. coli*

Like the Raccoon, the Des Moines River has been monitored for *E. coli* by DMWW since 1996. As a general rule, *E. coli* levels in the Des Moines are far lower than those seen in the Raccoon, especially during the cold-weather months. This is thought to be the result of particulate materials settling out of the river as it travels through Saylorville Reservoir. Unlike the Raccoon, most years see the annual average *E. coli* level in the Des Moines below the safe contact standard of 200 CFU/100 ml, as shown below in Figure 24.

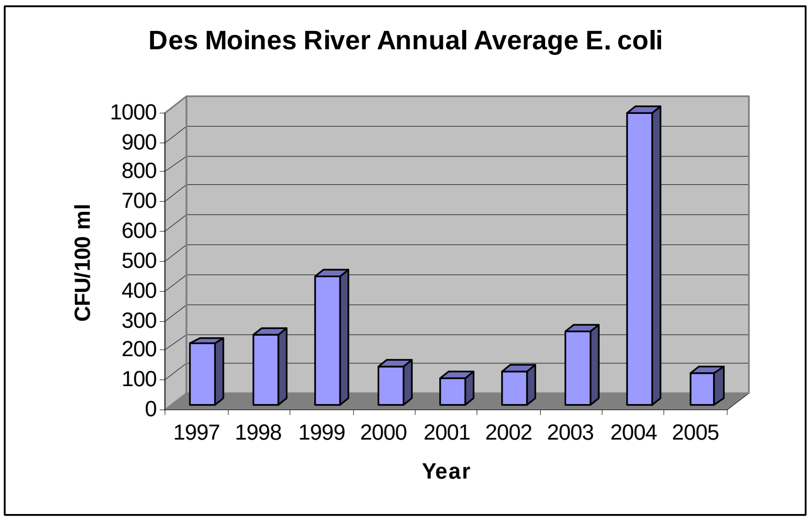


Figure 24: Des Moines River Annual Average *E. coli*

The warm-weather months do typically see *E. coli* levels above the safe contact standard, shown in Figure 25 below.

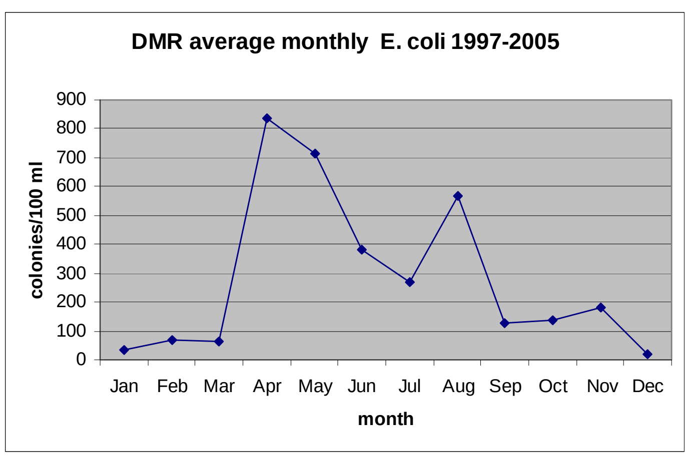


Figure 25: Des Moines River Average Monthly *E. coli*

The river is typically above the safe standard for at least two months per year (Figure 26). Interestingly, annual average *E. coli* levels in the Des Moines River do not correlate with annual average flows, quite the opposite of the Raccoon (Figure 27). This likely is the result of the settling influences of the reservoir. Another interesting aspect of Des Moines River coliforms is the proportion of total coliform that is *E. coli*. Although both absolute total coliform and *E. coli* numbers are lower in the Des Moines than the Raccoon, the *E. coli*/total coliform ratio tends to be quite a bit higher in the Des Moines River. For example, Figure 28 shows this phenomenon for a brief period during 2004.

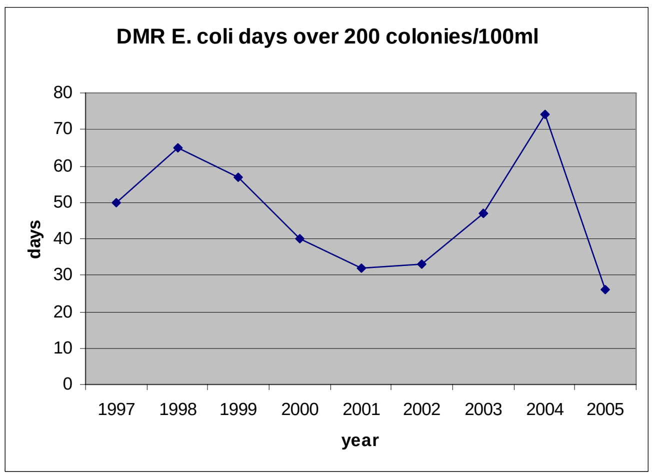


Figure 26: Des Moines *E. coli*, days above 200 CFU/100ml

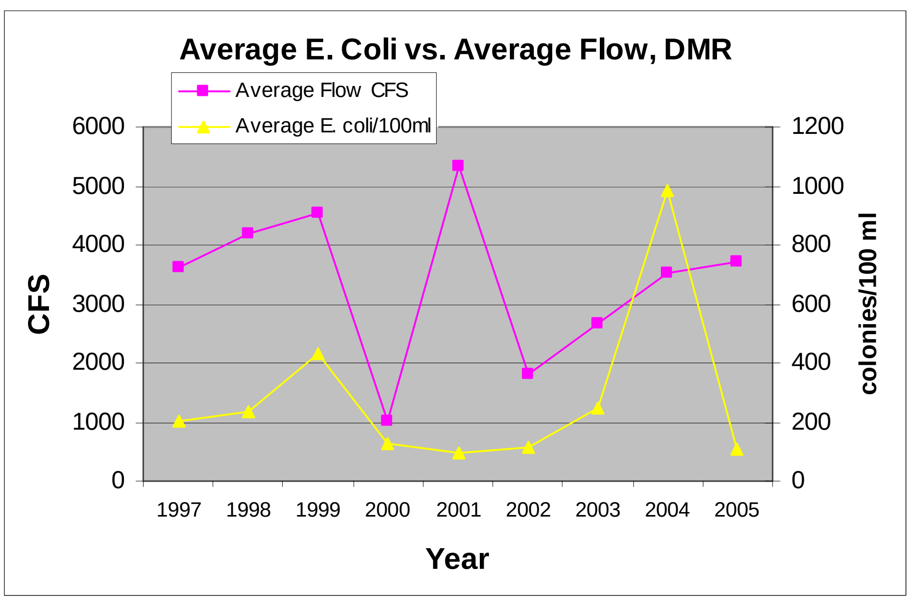


Figure 27: Des Moines River *E. coli* vs. Average Flow

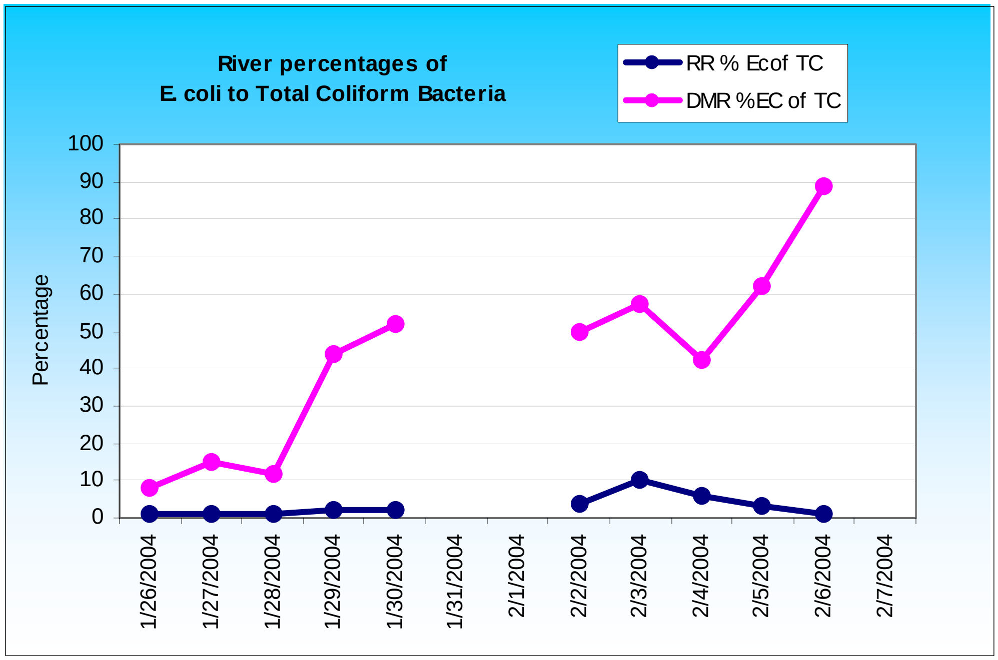


Figure 28: % *E. coli* of Total Coliforms, Des Moines and Raccoon Rivers

DMWW staff believes the phenomenon depicted by Figure 28 implies a measurable amount of human wastewater, either treated or untreated, is entering the Des Moines River within a few miles of DMWW's intake. The City of Grimes is known to have a WWTP on Beaver Creek; this effluent is about 10 to 15 stream miles from the DMWW intake. It is also known that a number of private septic systems in and around the City Johnston, near the Des Moines River and Saylorville Lake, have leaked or are currently leaking into the river. To summarize this point, although absolute numbers of *E. coli* and total coliforms are far lower in the Des Moines River, the preponderance of *E. coli* in proportion to total coliforms implies a serious situation may exist with human waste entering the Des Moines River near DMWW's water intake.

IV. Agriculture's Clean Water Alliance (ACWA) Data

A. Overview

ACWA is a consortium of fertilizer retailers doing business in the Raccoon River Watershed. Growing out of the Raccoon River Watershed Association in the 1990's, ACWA has funded a volunteer monitoring and testing program in the Raccoon River Watershed since 2000. Roger Wolf of the Iowa Soybean Association (ISA) has been the executive director of the group since its inception. A network of volunteers has collected samples throughout the watershed every other week during the April through August time period, and these samples have been evaluated in DMWW's testing laboratory for various water quality parameters. This program has produced a substantial data base for the Raccoon River and its tributaries, and has enabled DMWW and ISA scientists to characterize many of the subwatersheds delivering nitrate to the mainstem river.

B. Nitrate Data

The ACWA nitrate data is so extensive that only large (but informative nonetheless) generalizations will be made in the text of this report.

Firstly, the highest nitrate concentrations and nitrogen loads are coming from the North Raccoon Subwatershed. This could be characterized as the mainstem of the river and its tributaries upstream from Van Meter. This stands to reason, since this portion of the watershed lies almost exclusively in the Des Moines Lobe, and is therefore the area with the most intense row crop cultivation. This portion of the watershed also contains the greatest proportion of artificially-drained land. It is not at all unusual to see nitrate concentrations in excess of 30 mg/L in many tributaries of the North Raccoon. The North Raccoon Watershed also has several significant point sources of nitrate, most notably two treated wastewater discharges from the City of Storm Lake—on municipal, one industrial. These discharge into Outlet Creek, which ACWA/DMWW monitoring shows NO3-N levels exceeding 60 mg/L at times. There are also several other municipal WWTP discharges in the North Raccoon watershed, including the Cities of Perry, Rockwell City, Lake City, and Jefferson, to name a few.

The Middle Raccoon River typically has the second-highest nitrate concentrations and loads of the three branches of the Raccoon. It also drains Des Moines Lobe land, with the course of the river tracing the southern-most edge of glacial advance. Water entering the Middle Raccoon from the south drains land lying in the Southern Iowa Drift Plain—hillier, with less artificial drainage. Nitrate concentrations in the Middle Raccoon and its tributaries typically exceed 10 mg/L through the ACWA monitoring period of April through August. The

Middle Raccoon is heavily influenced by high concentrations of livestock in Carroll County, and so the proportion of NO3-N entering the watershed that is animal-borne may be higher in the Middle Raccoon than what is seen in the North Raccoon.

The South Raccoon River has had the lowest nitrate levels of the three branches, except for one year (2001). The South Raccoon River drains landscape that lies entirely in the Southern Iowa Drift Plain, so this branch has the least amount of tile effluent in its flow. This is the logical explanation for the lower nitrate levels. Nonetheless, nitrate levels in the South Raccoon and its tributaries frequently exceed the drinking water standard of 10 mg/L. Figure 29 below shows the 6-year averages generated through the ACWA monitoring of the three subwatersheds. Data in the graph represents all the sampling locations in the watersheds, and not only the three main branches.

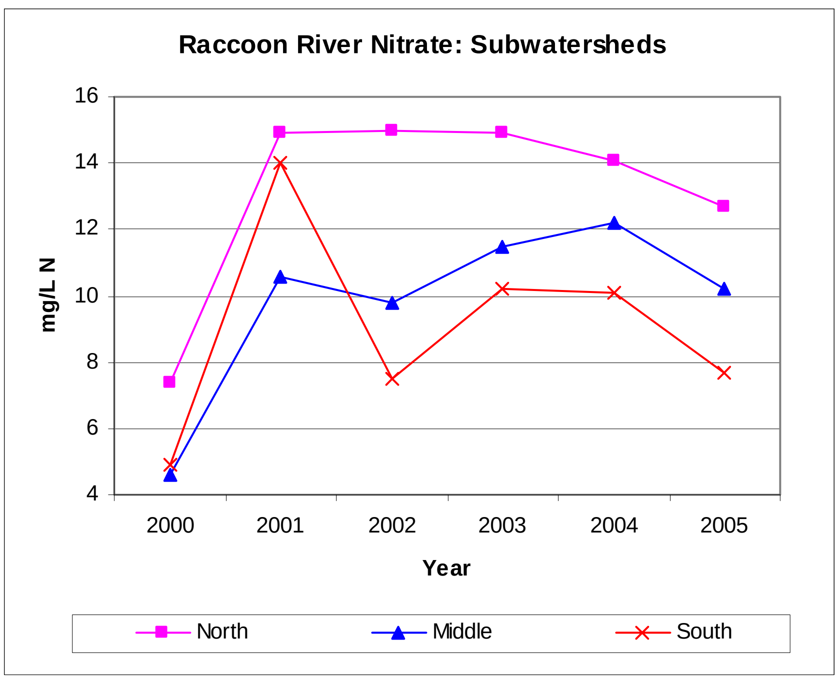


Figure 29: Raccoon River Subwatershed Nitrate, April-August

As mentioned, Figure 29 represents all the sites within the three individual watershed. Each of the three main branches has been monitored just upstream from the point of confluence with the other two branches. This data is represented Figure 30. If flow data for the three branches was known (DMWW does not currently have this data), then relative loads from the three main subwatersheds could be calculated.

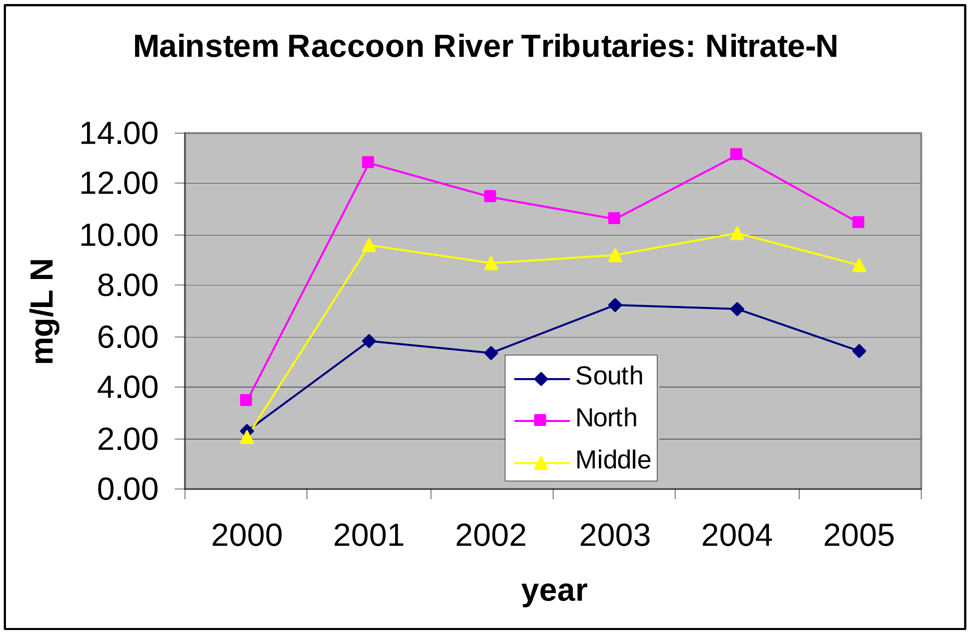


Figure 30: Nitrate in the North, Middle, and South Raccoon Mainstems

ACWA sampling locations have varied slightly over the years. In some cases, this variation was due to practical considerations, i.e. access to a sample site may have become impractical or unsafe. In other instances, it was decided that a site was no longer interesting from a scientific perspective, and that resources could be used better by evaluating alternative sites. About 30 sites have been evaluated every year since 2001. The median nitrate value for each of these sites is shown in Figure 31. One can see from Figure 31 that, with a few exceptions, there is nearly widespread uniformity in the concentrations of the individual tributaries. This reflects what must be similar land use, hydrology, and nitrogen inputs throughout the entire Raccoon River Watershed.

The exceptions are interesting. Outlet Creek has been discussed previously as being heavily impacted by point sources. These two point sources likely contain NO3-N at levels far above 100 mg/L. Furthermore, these point sources are contributing nitrate 365 days per year, as opposed to non-point source contamination which tends to be seasonal and dependent on precipitation events.

Elk Run Creek clearly stands out as the second-most nitrate-impaired tributary. In fact in 2004, Elk Run average nitrate exceeded that of Outlet Creek.

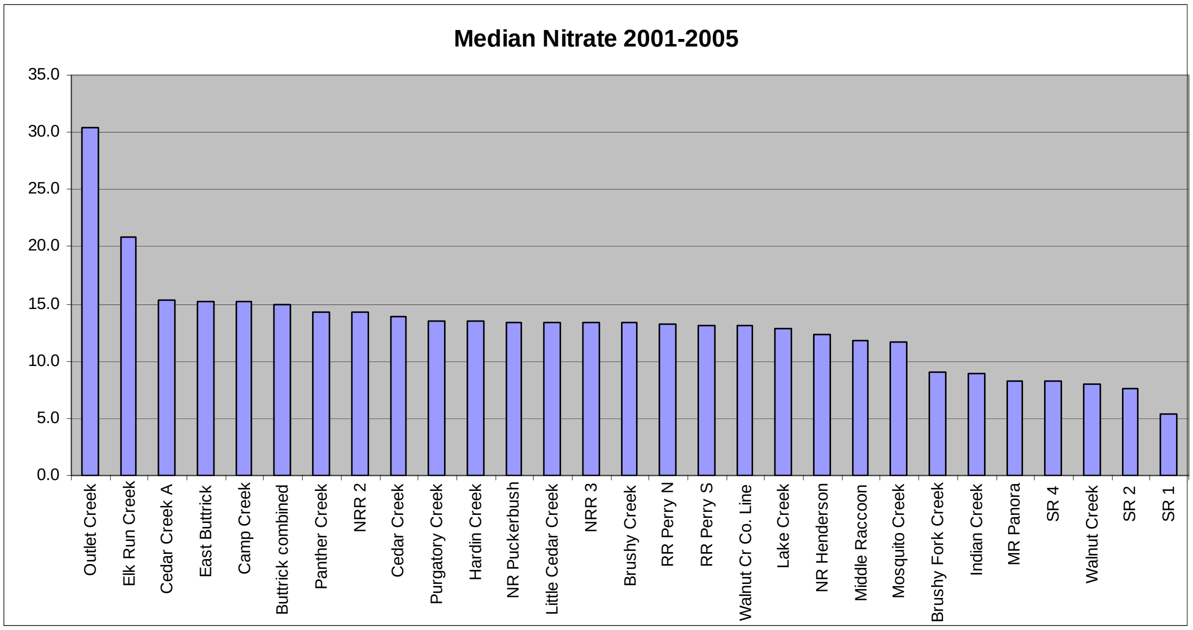


Figure 31: Median Nitrate, 2001-2005, ACWA Sites

Elk Run Creek, whose course lies mainly in Carroll County, is known to be heavily affected by livestock waste, and this could be the reason this stream stands out from others. Further evidence that livestock may have an out-of-proportion affect on some streams is Brushy Creek. This stream, also flowing through Carroll County, has the highest nitrate levels in the South Raccoon Watershed. It is also known to be influenced by large amounts of livestock manure. DMWW staff have concluded that it is likely that every stream flowing through the Des Moines Lobe landform contains between 12 and 15 mg/L NO3-N in the April through August time period, unless it is affected by point sources or extreme numbers of livestock that increase nitrate levels beyond 15 mg/L.

C. *E. coli*

DMWW monitored *E. coli* in ACWA samples for the first time in 2005. As one might expect, there can be some extreme episodes of *E. coli* contamination on small tributaries that almost always are connected to precipitation events. Because some of these episodes are so high (in some cases, more than 1 million CFU/100ml are present), a more accurate depiction of chronic impairment is median levels. Figure 32 depicts median *E. coli* levels at the *E. coli*-monitored sites during 2005. The striking thing about Figure 32 is the large variability from site to site. This is in contrast to the nitrate data, where most of the tributaries fall within a rather narrow range of 12-15 mg/L. It's apparent from Figure 32 that mitigation of *E. coli* impairment in the Raccoon River may take place with more of a targeted approach on a few streams, whereas nitrate impairment is relatively uniform throughout the watershed.

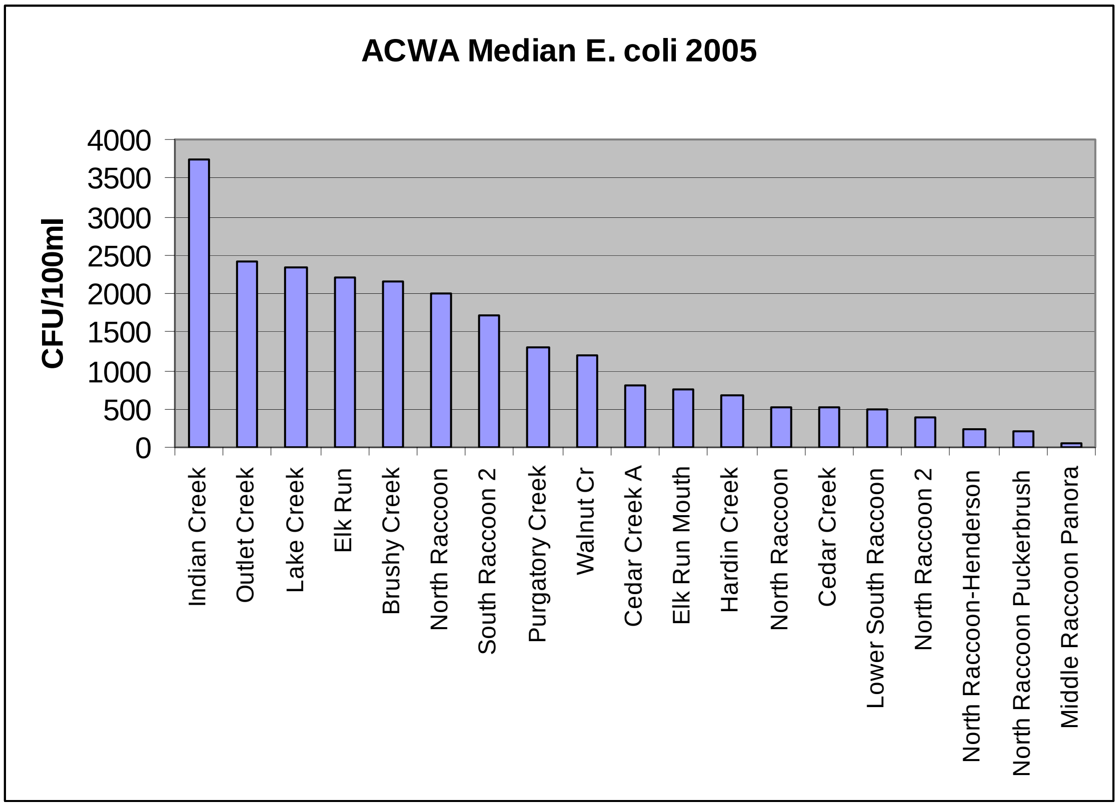


Figure 32: *E. coli* at ACWA Sample Sites, 2005

V. IGSB Fecal Coliform and *E. coli* Data

A. Overview

The Iowa Geological Survey Bureau has monitored fecal coliform and *E. coli* in at five sites in DMWW's watershed approximately monthly since late 1999. These sites include Beaver Creek near Grimes (Storet 10770001), the North Raccoon River near Jefferson (Storet 10370001), the South Raccoon River near Redfield (Storet 10250001), the Des Moines River just upstream from Des Moines (10770002); and the Raccoon River just upstream from Des Moines

(Storet 10250002). This data was quantified as both *E. coli* and fecal coliform until mid-2004; after that date it has been quantified as *E. coli*. For the purposes of discussion here, only the *E. coli* data will be addressed, although the fecal data is available electronically to the user of this report.

B. Summary of Data

Table 1 below summarizes the data from the five sites.

Site	Events	Average *E. coli* CFU/100 ml	Max. Event CFU/100 ml	Events with CFU/100ml > 200
Beaver Creek near Grimes	72	1280	39000	30
N. Raccoon River Near Jefferson	76	1427	70000	22
Des Moines R. upstream from Des Moines	62	52	710	6
S. Raccoon R. Near Redfield	79	5953	240000	26
Raccoon R. upstream from Des Moines	66	2018	50000	22

Table 1: Summary of IGSB *E. coli* Data, 1999-2005

Although the number of sampling events is far less, DMWW staff believes the IGSB data correlates well with data obtained at DMWW's Raccoon and Des Moines River intakes. The IGSB data from the South Raccoon Redfield site also would seem to be consistent with the *E. coli* impairment of Brushy Creek (the major tributary of the South Raccoon) revealed by the DMWW/ACWA testing of 2005. One can also see that there is a severe *E. coli* impairment in all the streams tested during the IGSB testing, except for the Des Moines River upstream from Des Moines. Figures 33 through 37 below show data for the five sampling sites, and indicate the highly variable data for each sampling location. Presumably this variability is dependent upon precipitation events.

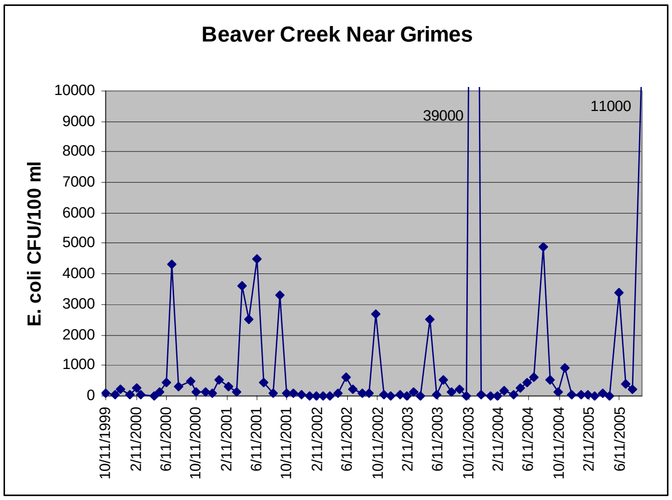


Figure 33: IGSB *E. coli* data for Beaver Creek near Grimes

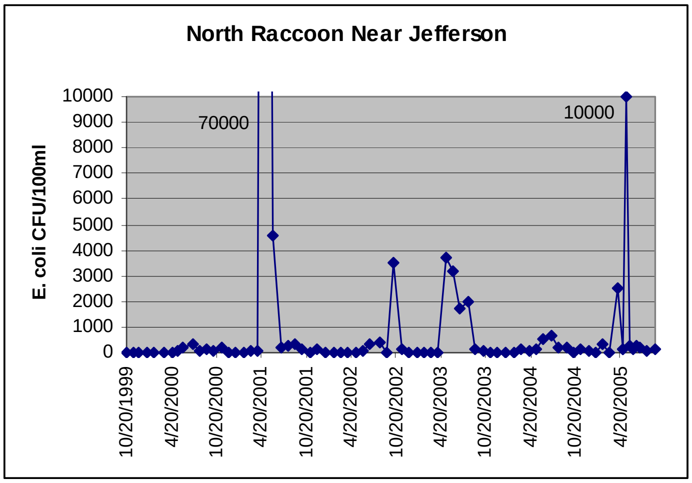


Figure 34: IGSB *E. coli* data for the North Raccoon R. near Jefferson

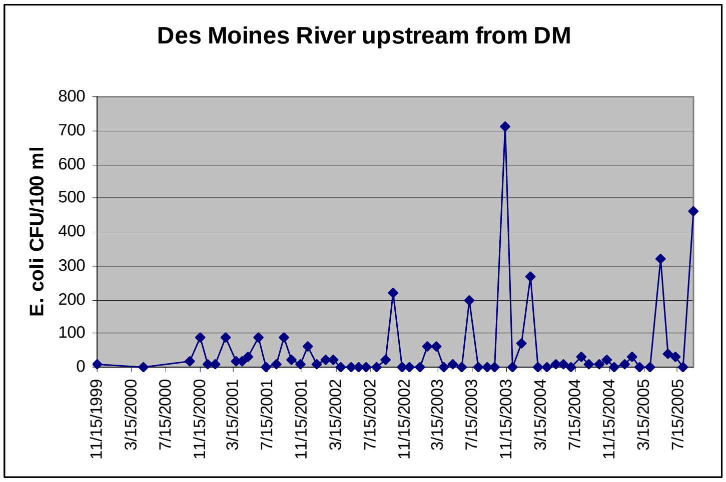


Figure 35: IGSB *E. coli* data for the Des Moines R. upstream from DM

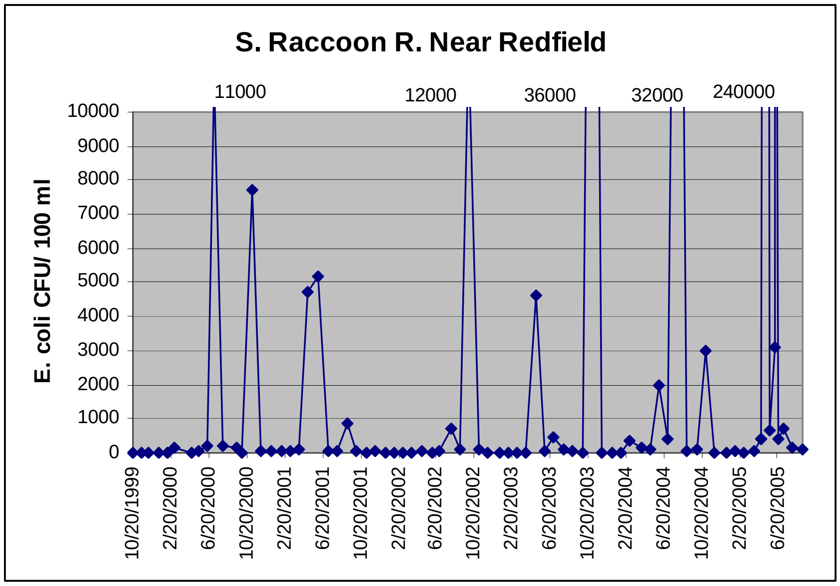


Figure 36: IGSB *E. coli* data for the S. Raccoon River near Redfield

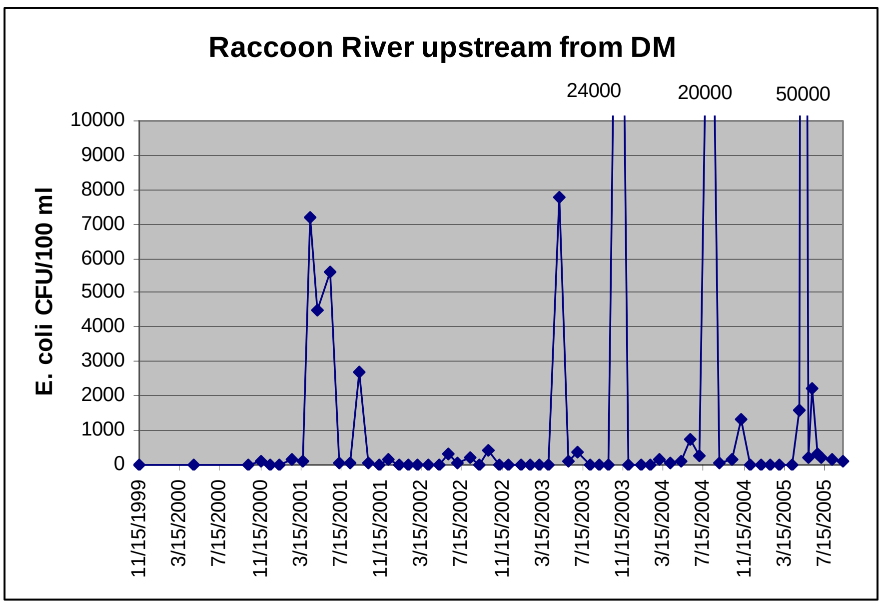


Figure 37: IGSB *E. coli* data for the Raccoon River upstream from DM

VI. Des Moines River Water Quality Network Data

A. Background

The Des Moines River Water Quality Network (DMRWQN) is a surface water quality project sponsored by the US Army Corps of Engineers that collects water samples year-round at locations along the Des Moines and Raccoon Rivers and Saylorville and Red Rock Reservoirs. The purpose of the project is to evaluate the affects of the Saylorville and Red Rock Dams on downstream river quality and to characterize upstream water quality. The project was initiated in 1967 as a preimpoundment study of the Saylorville Reservoir reach and has evolved over its 38 year history to include Red Rock Reservoir.

As it relates to this report, significant findings of the study have been:

- that non-point sources are the main component to contamination, especially by particulate parameters, and;
- that there appears to be no overall trend (either decreasing or increasing) in nitrate nitrogen concentrations over the 38 year period; however, from 1967-82 an increasing trend was observed.

Data are available through STORET and project annual reports.

B. Data Review

The DMRWQN data is organized around “water years” which run from October until September. This is skewed slightly from the DMWW data which is organized around the calendar year of January 1 to December 31. DMWW converted the DMRWQN data to a calendar year format, and both electronic files are included with this report.

The DMRWQN has monitored about 30 sites over its nearly 40-year history. Two of the sites are of particular interest to this report. The first site, designated as Station 5, is on the Des Moines River, 2.3 miles downstream from the Saylorville Dam at the NW 66th Ave. bridge. The second site of interest, Station 10, is at the Raccoon River bridge at Van Meter, just downstream from the confluence of the North Raccoon and Middle-South Raccoon Rivers. This is the only DMRWQN site on the Raccoon River. Extensive nitrate data is available for each of these locations.

Station 10 has exhibited the highest average Nitrate + Nitrite concentration of all the DMRWQN sites over the historical record (7.02 mg/L). Station 5 had the fourth-highest average nitrate concentration (5.94 mg/L).

Statistical analysis (Seasonal Kendall Tau) of the flow-weighted NO3-N average showed an increasing trend of 0.36 mg/year for the period of 1967 until 1982 for Station 10. No trend has been observed since 1982. This is consistent with historical rates of nitrogen application to row crop in Iowa, i.e. increasing rates of application during the 1970's and relatively constant rates of application since the mid-1980's. Rates of nitrogen application from 1985 until 1993 actually decreased from 145 lb/acre to 114 lb/acre, with no decreasing trend seen in NO3-N concentrations at either Station 5 or 10. Table 2 below is a summary of the DMRWQN nitrite plus nitrate data for the period of record.

Parameter	**Station 5**	**Station 10**
Data Points	1329	1072
Years of Record	37	32
Highest Monthly NO3-N	13.7 mg/l	15.8 mg/l
Overall mean	5.94	7.02
Records > 10 mg/l	154	284
% of samples > 10 mg/l	12	26

Table 2: Summary of DMRWQN NO3-N Data

The DMRWQN database provides a good check of the historical DMWW data, even though the sample locations are slightly different. For the Raccoon data, the DMWW and DMRWQN sample locations are about 20 river miles apart, while the Des Moines River sample locations differ by about 6 river miles. In addition, Beaver Creek enters the Des Moines River between the two sample locations, so the DMWW data should reflect this influence. Also, for any given year, the DMWW database contains far more data points than the DMRWQN record. The sampling frequency for the DMRWQN project has averaged about two samples per month for the past several years; the DMWW sampling frequency averages varies from 5 to 30 samples per month, depending on nitrate levels.

Figures 38 and 39 below compare the annual arithmetic averages for the period of 1995-2003. One can see that there is extremely good agreement on the long-term average NO3-N data for the two monitoring projects, even with the differences in sampling frequency and sample locations. The Des Moines River data would seem to imply that the influence of Beaver Creek on Des Moines River nitrate is not significant from a long-term perspective.

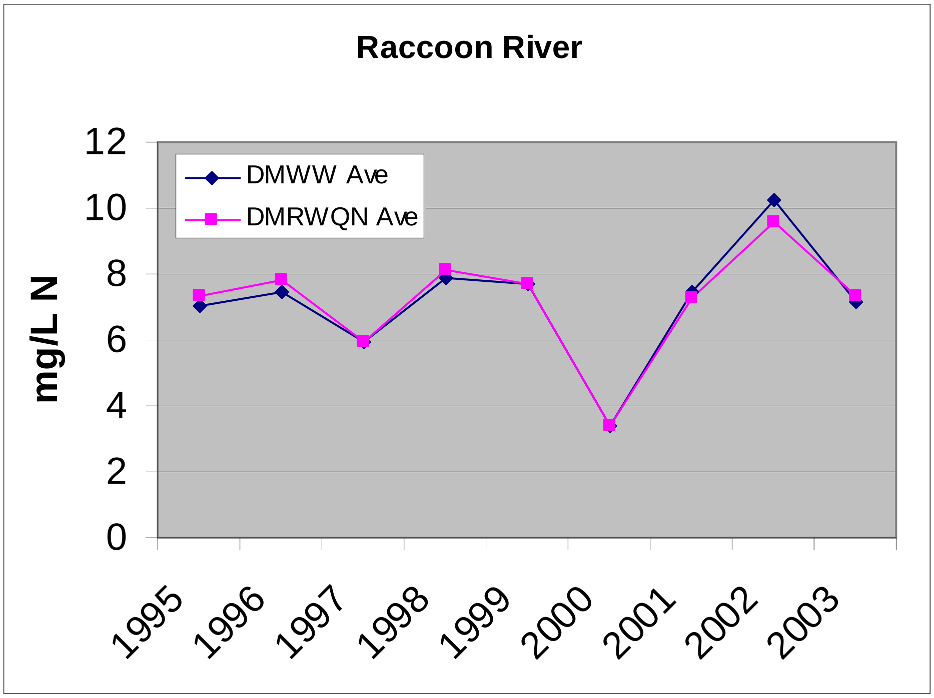


Figure 38: Comparison of DMWW and DMRWQN NO3-N data for the Raccoon River

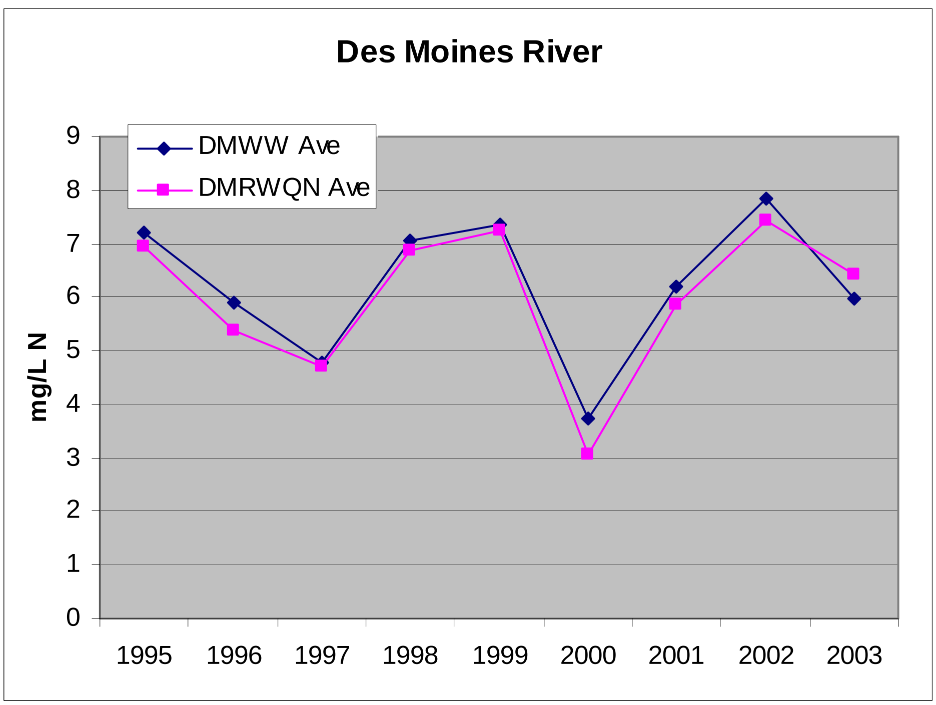


Figure 39: Comparison of DMWW and DMRWQN NO3-N data for the Des Moines River

Monthly DMWW and DMRWQ averages for the 1995-2004 time period are also remarkably similar. This would seem to indicate that the extra data points provided by the DMWW database do not largely increase the accuracy of the long-term historical record. Figures 40 and 41 below show the comparison of monthly averages for the two databases.

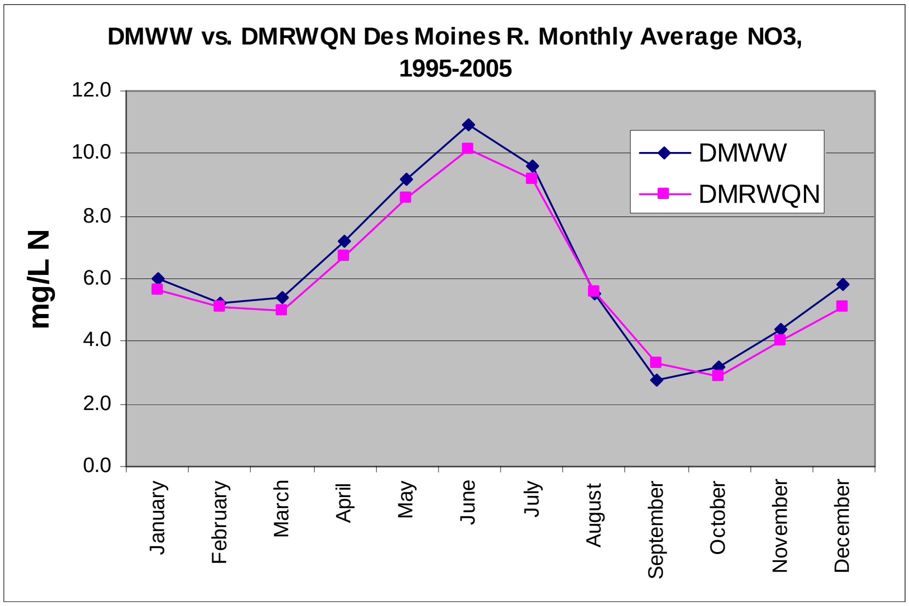


Figure 40: Comparison of Monthly Averages, DMWW vs. DMRWQN, Des Moines River Nitrate

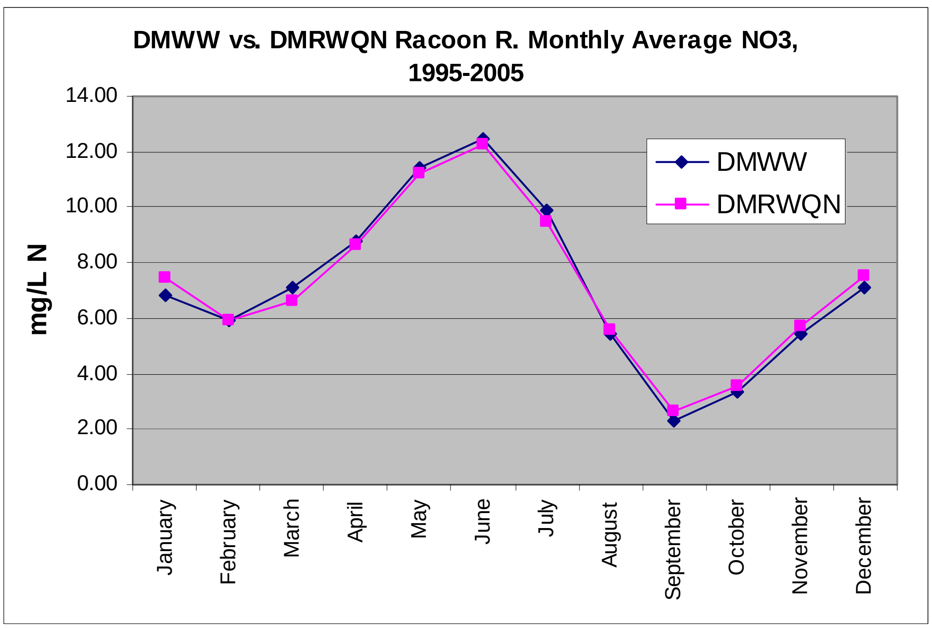


Figure 41: Comparison of Monthly Averages, DMWW vs. DMRWQN, Raccoon River Nitrate

The data similarity extends beyond simple average NO3-N concentrations to also include annual NO3-N loads delivered by each river. Figures 42 and 43 compare nitrogen loads, and the reader can see the striking similarity between the two databases.

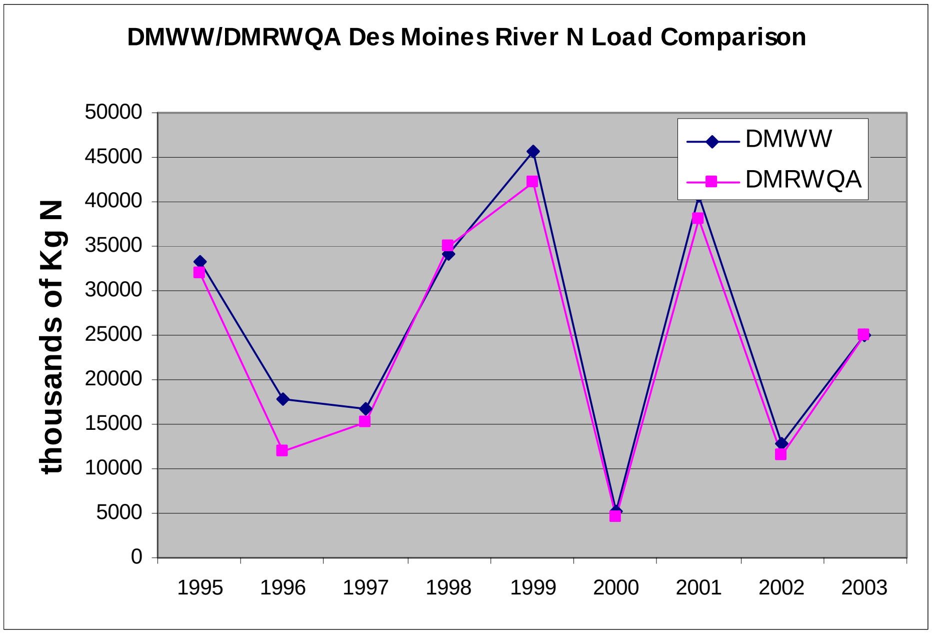


Figure 42: Comparison of Annual N Loads, DMWW vs. DMRWQN, Des Moines River Nitrate

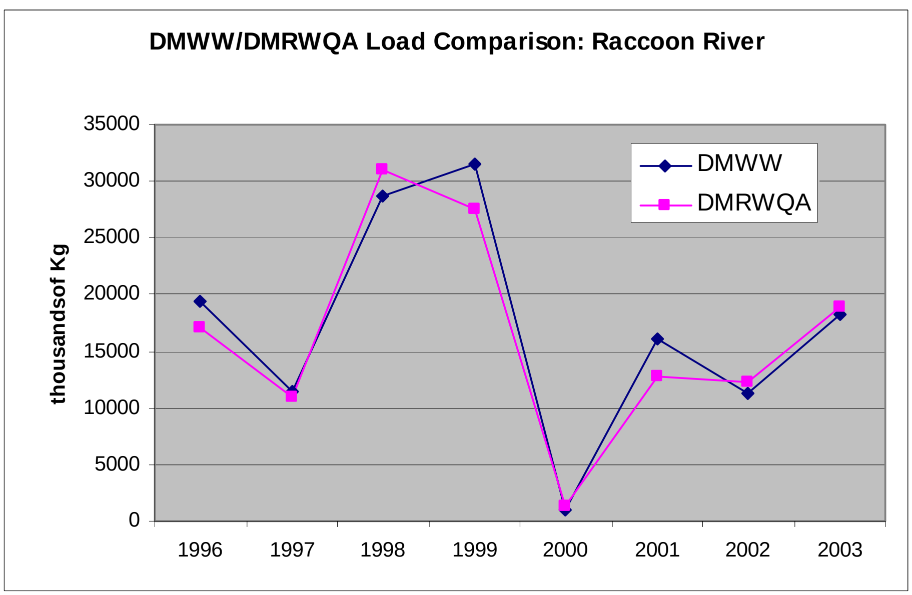


Figure 43: Comparison of Annual N Loads, DMWW vs. DMRWQN, Raccoon River Nitrate

The favorable comparisons of DMWW with DMRWQN data show that, at least for the mainstem rivers, twice per month monitoring really presents an accurate assessment of long-term nitrate-nitrogen levels and trends, and that the two databases are practically equal in their utility, even though the DMWW monitoring occurs at a frequency many times that of the DMRWQN monitoring.

VII. DMWW Creek Studies

A. Overview

DMWW lab staff have conducted several “creek studies” over the years since 1998. These primarily have focused on Walnut Creek in Dallas and Polk Counties, but also include one study of Beaver Creek in Polk County and one of Lake Creek in Pocahontas and Calhoun Counties. Some of these have been “snapshot” studies, which are one-day sampling events that characterize water quality on that given day at one or several locations on the stream. Other studies, notably the Walnut Creek studies, have evaluated samples collected at intervals over period of several weeks or months.

The reader of this report will have to assess the value of this data and come to conclusions of their own as to its usefulness. In general, the data shows relatively uniform nitrate impairment within a stream, but highly variable *E. coli* levels, largely dependent on location, flow, and precipitation events. Textual descriptions of these creek studies are fairly extensive in their own right, and are included with this report, both in paper and electronic form.

ANALYTICAL METHODS

I. Nitrate

A. DMWW Data (Including ACWA and Creek Studies)

The DMWW Laboratory has been analyzing nitrate in its source and finished waters since 1931. What these early procedures may have been is not known with any certainty. But data generated during period of 1931 to 1974 likely was done so using both electrochemical/ion selective electrode and wet chemistry procedures. Data generated from 1974 to 1987 is thought to have been generated almost exclusively with ion selective electrode procedures, which were and are well-established as viable procedures for the analysis of nitrate-nitrogen.

To the best of this author's knowledge, data generated since 1987 has used ion chromatography procedures almost exclusively. In the present day, and for the past several years, the procedure that has been followed is EPA Method 300.0 A and B (17). This technique provides for simultaneous, multi-ion analysis including fluoride, nitrate, nitrite, sulfate, and others. Detection is accomplished using a conductivity cell.

B. DMRWQN Data

DMRWQN data is currently generated using the Automated Cadmium Reduction procedure, which is Standard Methods Procedure 4500-NO_3^- (18). From 1998 until November 2002, DMRWQN data was generated using EPA method 300.0 described above. As mentioned previously in this report, the DMRWQN data compares very favorably with the DMWW data.

II. Bacteria

A. DMWW Data (including ACWA and Creek Studies)

All *E. coli* data generated by the DMWW laboratory was done so using SM 9223B (18), colilert/Quantitray procedure for the quantification of *E. coli* in surface waters. This procedure uses the colilert presence/absence medium in a series of incubation wells. The number of wells indicating the presence of *E. coli,* along with the sample volume used, enable the laboratory worker to quantify *E. coli* numbers in a surface water sample. This otherwise would be impractical using the membrane filter technique due to matrix complexities and the large numbers of coliform bacteria frequently found in watershed samples.

B. IGSB Data

The most recent IGSB data was generated using EPA method 1603: *E. coli* in Water by Membrane Filtration Using Modified membrane-Thermotolerant *E. coli* Agar (Modified mTEC) (19). Prior to 2002, the IGSB data was generated by following SM 9222, Membrane Filter Technique for Members of the Coliform Group (18). SM 9213 for Recreational Waters was also used for some samples. This information is all included in the electronic file containing the IGSB data.

III. Discussion of Data Comparability

As mentioned previously in this report, DMWW nitrate data compares extremely favorably with DMRWQN data for the average nitrate levels and nitrate loads in both the Raccoon and Des Moines River Watersheds. This data comparability transcends the analytical method used, i.e. similar data was produced using different analytical procedures. It is the opinion of this author that the two main sources of nitrate data are rock-solid.

Because there is much less bacteria data for the IGSB coliform monitoring project, a lower level of certainty is inherent when comparing it with the DMWW data. However, the overall maximum and average levels of *E. coli* found during the IGSB monitoring are very comparable with those produced by DMWW monitoring.

It is the opinion of this author that all the data included with this report is accurate, defensible, and depictive of the impairments in the Raccoon and Des Moines River Watersheds.

Finally, it should be said that the DMWW laboratory is certified by the State of Iowa for analysis of nitrate and coliform bacteria, and the laboratory undergoes an audit conducted by the University of Iowa Hygienic Laboratory every two years.

DATA GAPS

I. Nitrate

DMWW staff believes the mainstem rivers (Raccoon and Des Moines) have been very thoroughly characterized for nitrate impairment. Much of this data includes simultaneous flow measurements. The user could easily connect precipitation events with historical nitrate data for the mainstem river. A lesser, but still substantial level of nitrate characterization has been achieved for the three main tributaries of the Raccoon (North, Middle, South).

Most of the main tributaries of the Raccoon River Watershed have been characterized for the April through August time period, without flow measurements. Additional flow data could be correlated with the average nitrate levels of the past 5 years to ascertain the relative loads being delivered by each of these tributaries. In addition, future lab data could be generated simultaneously with flow measurements. Most of the tributary data is for samples collected at the mouth of the stream. Each individual tributary could be further investigated to identify “hot spots” of nitrate input.

No rain or snowmelt event data exists with this report. This type of data might give a picture of the relative proportions of the nitrate load that are due to runoff, shallow groundwater infiltration into the river, tile effluent, and wastewater effluent.

How these gaps in the data will addressed is outlined in the QAPP portion of this report.

II. *E. coli*

Far less data exists for *E. coli* than for nitrate. That said, the mainstem rivers are highly characterized for *E. coli* impairment over the last eight years. For all practical purposes, only about four months of extensive tributary data exists, and this for less than 20 streams in the Raccoon River Watershed. Other spotty data is available through the IGSB database and the DMWW creek studies. Nonetheless, some conclusions can be reached.

Probably the most important conclusion about *E. coli* inputs is that they are much more acute and much less widespread than those for nitrate. It can be confidently stated that virtually every tributary in the North Raccoon Watershed is highly and chronically impaired for nitrate. The same cannot be said for *E. coli*. DMWW staff feel that the *E.*

coli impairment in the Raccoon River is likely due to a handful of tributaries which contribute the lion's share of the load. Once these streams are identified, extensive investigation and sampling of possible hotspots, followed by mitigation, may result in a reasonable likelihood of success in correcting this impairment. It must be said that mitigation likely will result in financial hardships for both livestock producers and individual homeowners with illegal or malfunctioning septic systems. How these streams and hotspots will be investigated is outlined in the QAPP.

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