# Assessment and Comparison of Water Quality in Outlet Creek and the Storm Lake Watershed

Produced for Water for Iowans, a joint endeavor of
the Iowa Environmental Council and AgSTATE

Updated August 9, 2006

Christopher S. Jones, Ph.D.
Des Moines Water Works

# I. Background

## A. Hydrology

Storm Lake is one of largest and one of the last remaining glacial lakes in Iowa, most of the rest having been drained in the last 100 to 150 years. It is fed primarily by the perennial stream Powell Creek. Both Powell Creek and the lake itself are fed by numerous intermittent streams. The Storm Lake Watershed is part of the Des Moines Lobe, a region once dominated by the vast wet prairie/prairie pothole ecosystem that stretched from what is now Des Moines to the north and west far into Canada. This landscape had little natural drainage, and artificial drainage in the Storm Lake Watershed commenced before 1910 in the form of agricultural drain tile, so that the land could be cultivated for row crops. Thus, Powell Creek also is heavily influenced by effluent from numerous drain tiles in the watershed. Prior to entering Storm Lake, Powell Creek enters a marshy/wetland area known as Little Lake or Little Storm Lake.

Historically, Storm Lake has had dramatic fluctuations in water level corresponding to climatic conditions. A 1950 *Des Moines Register* article described Storm Lake as the “lake that died,” but lake levels rebounded to near-normal only two years later. Because of the shallow, saucer-like shape of the lake basin, drops in water level result in a dramatically receding shoreline. At least two dams have been constructed on the outlet of the lake during the past century, apparently to buffer this effect. One of these dams continues to function as intended. Water overflows the dam only intermittently and during wet climatic conditions. This overflow, when present, is the source of a stream known as Outlet Creek, which flows south and east about 10 miles to its confluence with the North Raccoon River.

The North Raccoon River is the mainstem tributary of the Raccoon River, the primary source of water for the Des Moines Water Works (DMWW). The Raccoon River watershed has the highest average nitrate-nitrogen (NO3-N) level of any of the 42 subwatersheds in the Mississippi River drainage. NO3-N is a regulated drinking water contaminant, and treated drinking water supplied by public water systems can contain no more than 10 mg/L. Raccoon River levels exceed 18 mg/L episodically. DMWW maintains the largest ion exchange nitrate removal facility in the world so that compliant water can be provided to its customers. The stream also contains high levels of *E. coli* bacteria, and the water is unsafe for recreational contact much of the year. The Raccoon River is defined as impaired for nitrate and coliform bacteria from Van Meter to Des Moines. Other smaller stretches of the North and Middle Raccoon also have defined impairments. The Raccoon River is on the Threatened and Impaired 303(d) list.

Water quality in the Raccoon River has been monitored by DMWW since 1931. In cooperation with Agriculture’s Clean Water Alliance (ACWA), a consortium of fertilizer retailers in the Raccoon Watershed, DMWW has monitored water quality in Outlet Creek and numerous other Raccoon River tributaries since 2000.

## II. Water Quality Data

### A. Storm Lake and Feeder Streams

The 2005, the Total Maximum Daily Load (TMDL) report prepared by the Iowa Department of Natural Resources identified turbidity as Storm Lake's primary impairment. The primary source of turbidity causing the impairment is the re-suspension of lake-bottom sediment by wind-induced waves. High turbidity levels impair the aesthetic value of the lake, and also adversely affect aquatic life as defined in water quality narrative criteria. Little Storm Lake acts as a sediment trap reducing the sediment delivered to Storm Lake. The focus of this report is on chemical impairments to water quality in the Storm Lake and Outlet Creek watersheds and does not address sediment delivery.

The Storm Lake Watershed can be divided in two basic ways. Firstly, Powell Creek can be divided into five separate regions; in addition, a region designated as "Marsh" (M6) supplies the Little Lake area, and Regions designated as L7 and L8 feed the southwest portion of the lake. These can be seen on the map in Figure 1.


**Figure 1: Storm Lake Watershed Regions**

Erosion and sediment yields for the five Powell Creek Regions were determined in 1993 by Bishop and Menzel[1]. Bishop's and Menzel's analysis showed that about 25% of the Powell Creek watershed had a high potential for nutrient and sediment (NPS) pollution. A long-term commitment between IDNR, Iowa Department of Agriculture and Land Stewardship (IDALS), Natural Resource Conservation Service (NRCS), and the Iowa Lakes Resource Conservation and Development (RCD) office has worked to significantly reduce watershed erosion and nutrient delivery to Storm Lake. The efforts of these groups have resulted in 6900 acres of conservation tillage, 7850 of terraces, 222 acres of contour farming, 7000 acres of integrated crop management, and 87 acres of filter strips and wetlands. This has reduced sediment load from Powell Creek to Little Lake by 9900 tons/ year from 1954 to 1963, to 4020 tons/year in 1999. Other estimates conclude these practices currently save up to 19,150 tons soil/year. IDNR has now concluded that sediment load from Powell Creek is not a significant factor in the elevated turbidity levels found in Storm Lake[5].

Careful analysis of the Powell Creek, M6, L7 and L8 regions results in a further division of the watershed into 18 separate sub basins. These are shown in Figure 2 below.

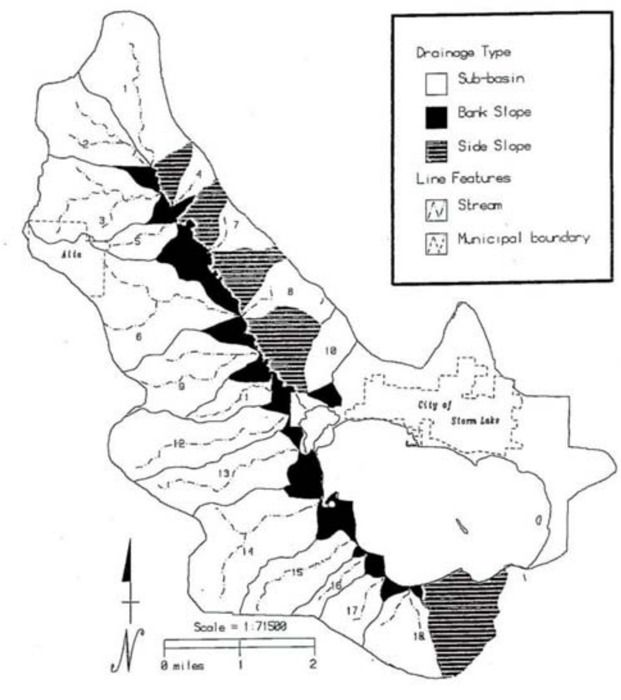


**Figure 2: Storm Lake Sub-basins**

Bishop and Menzel's analysis also quantified nitrogen and phosphorous loads delivered by each of the 18 sub-basins. Their data shows that, like many of Iowa's water resources, the Storm Lake watershed receives large inputs of nutrients due to the application of fertilizer (anhydrous ammonia and livestock manure) to row crops. The 1993 data shows that nitrogen loads delivered to the lake averaged 2.57 pounds per acre of watershed, with one sub-watershed (sub-basin 7) delivering over 7 pounds per acre. Phosphorous loads averaged 2.07 pounds per acre of watershed, with basin 7 also contributing the most at 3.6 pounds per acre. Groundwater in the area was known to be widely contaminated with nitrate, with mean concentrations about 7-8 mg/L, and some wells containing as much as 49 mg/L.[1] It must be emphasized that all this data is now 13 years old, and conditions may have changed substantially since then. Phosphorous loads likely have decreased dramatically, coincidentally with reductions in sediment. Nitrogen loads, however, have likely not seen similar reductions and may actually have increased. Nitrogen is not particularly responsive to the management practices outlined earlier that were responsible for significant reductions in sediment load. Because nitrogen is highly soluble, and because much of it enters the watershed through tile effluent, it is a more insidious problem that will not be easily solved. Table 1 below summarizes nitrogen, phosphorous, and sediment loads delivered by each of the 18 sub-basins in 1993. Again, bear in mind that phosphorous and sediment loads have almost certainly declined substantially in the 13 years since 1993.

| Sub Basin | Acres | N conc (ppm) | N load (lbs/acre) | P conc (ppm) | P load (lbs/acre) | Sediment Yield (tons/acre) |
|---|---|---|---|---|---|---|
| 1 | 1018 | 3.69 | 1.96 | 0.71 | 2.02 | 1.36 |
| 2 | 709 | 3.64 | 1.95 | 0.7 | 2.06 | 1.39 |
| 3 | 914 | 3.74 | 2.09 | 0.7 | 1.74 | 1.13 |
| 4 | 146 | 3.07 | 1.66 | 0.57 | 1.67 | 1.07 |
| 5 | 242 | 3.27 | 1.94 | 0.61 | 1.77 | 1.15 |
| 6 | 1389 | 2.79 | 1.47 | 0.5 | 1.24 | 0.74 |
| 7 | 203 | 12.21 | 7.11 | 2.14 | 3.6 | 2.8 |
| 8 | 351 | 3.53 | 2.03 | 0.68 | 2.57 | 1.84 |
| 9 | 744 | 3.95 | 2.24 | 0.77 | 2.21 | 1.52 |
| 10 | 289 | 3.56 | 1.96 | 0.68 | 1.72 | 1.11 |
| 11 | 235 | 3.42 | 2.03 | 0.65 | 2.42 | 1.7 |
| 12 | 917 | 3.63 | 2.1 | 0.7 | 1.99 | 1.33 |
| 13 | 739 | 3.49 | 2.05 | 0.67 | 1.55 | 0.97 |
| 14 | 1179 | 3.51 | 1.93 | 0.67 | 2.18 | 1.49 |
| 15 | 576 | 3.37 | 1.84 | 0.64 | 2.15 | 1.47 |
| 16 | 163 | 4.04 | 2.12 | 0.79 | 2.23 | 1.53 |
| 17 | 316 | 9.55 | 5.29 | 1.75 | 2.47 | 1.75 |

**Table 1 : Nitrogen, Phosphorous, and Sediment Delivery by the 18 Storm Lake Sub-basins in 1993**

Nitrate levels in the lake itself have not been chronically high, either in 1993 or the present day. Except near the Little Lake outlet, concentrations below 1 mg/L are common.[2] Nitrate levels in close proximity to the mouth of other feeder streams can be higher than the main body of the lake. Nitrate levels generally decrease as water flows through Little Lake, into the main lake, and finally toward the Storm Lake outlet. This process takes 2.6 years on average, plenty of time for organisms in Little

Lake and the main lake to either assimilate nitrogen as plant protein, or to convert nitrogen to gaseous forms ($N_2$, $NO_x$) which escape to the atmosphere. This effect was observed locally in 1993 by Pleasants[3], who remarked that "The effect of ponded water (Marsh and Lake sites) in reducing nitrate concentrations is quite evident." Furthermore, Lehtinen and Menzel stated in 1993 that "ponding of the water in marsh and lake greatly reduces nitrate-N concentration."[4] A snapshot of this is evidenced in the Buena Vista University (BVU) data from May 21, 2003. Powell Creek had a NO3-N concentration of 7.7 mg/L, while the sample from the dam area of the lake contained only 0.4 mg/L. In fact, none of the many samples taken during the spring/summer of 2003 near and below the dam exceeded 1 mg/L NO3-N. Much of the Powell Creek nitrate is likely consumed in Little Lake, with its shallow, fertile environment, before this nitrogen can ever enter the main body of Storm Lake. This is depicted in Figure 3, which shows NO3-N data for Powell Creek, Little Lake, and the Storm Lake inlet in 2003. It's apparent that much of the Powell Creek nitrate never makes it into main body of Storm Lake. Of course, some of this nitrogen could have been assimilated as plant protein and is indeed still part of the total nitrogen load in the lake. Episodes when the inlet NO3-N exceeds that of Little Lake likely reflect storm events where the nitrate in Little Lake has been diluted by high flows from the Powell Creek.

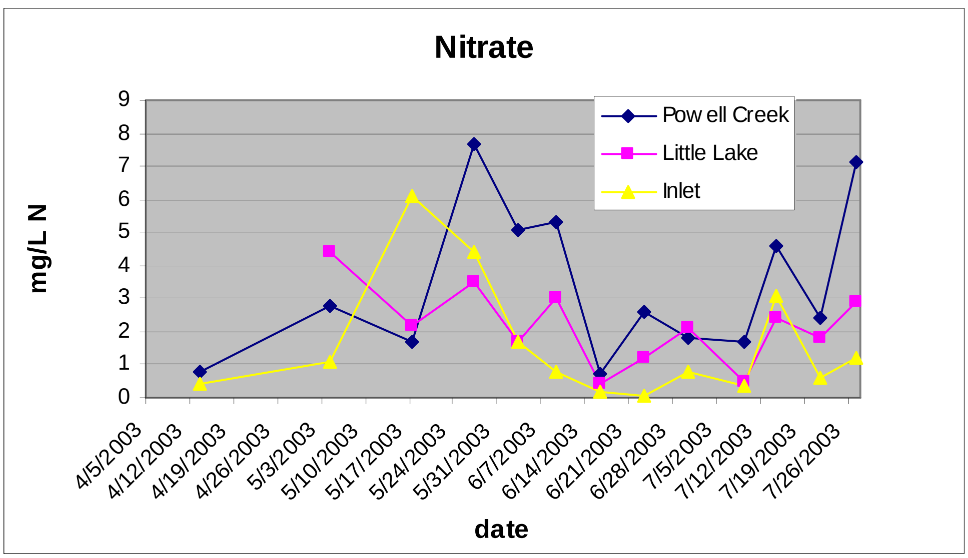


**Figure 3: Nitrate in Powell Creek, Little Lake, and the Storm Lake Inlet**

Other streams directly feeding the lake likely contribute significant loads of nitrate, but organisms in the lake consume most of this before it reaches the overflow. It is probably safe to conclude that water entering Outlet Creek via the Storm Lake overflow never contains more than 1 mg/L NO3-N.

Because of its conservative nature, phosphorous entering Storm Lake by-and-large remains there. Monitoring data supports this. Sub-watershed stream data from 1993 shows phosphorous levels from 0.5 to 2.14 mg/L.[1] The BVU data shows phosphorous levels sometimes exceeding 500 ppb.[2] Figure 4 depicts the conservative nature of phosphorous.[2] One can see that phosphorous levels in the incoming water of Powell Creek are significantly lower than that of Little Lake and the Storm Lake inlet. This is to be expected. Most of the phosphorous entering the lake surely gets immediately consumed by organisms, and then becomes part of the sediment of the lake as the organisms die. Unfortunately, the 2003 BVU data contains only one phosphorous measurement from a sample in close proximity to the outlet. This sample contained 21.7 ppm of total phosphorous. Once again, it is important to recognize that the management practices implemented since 1989 in the Powell Creek basin have likely reduced phosphorous loads to the lake from Powell Creek. But because of the conservative nature of phosphorous, most of it remains there, except that removed through dredging.

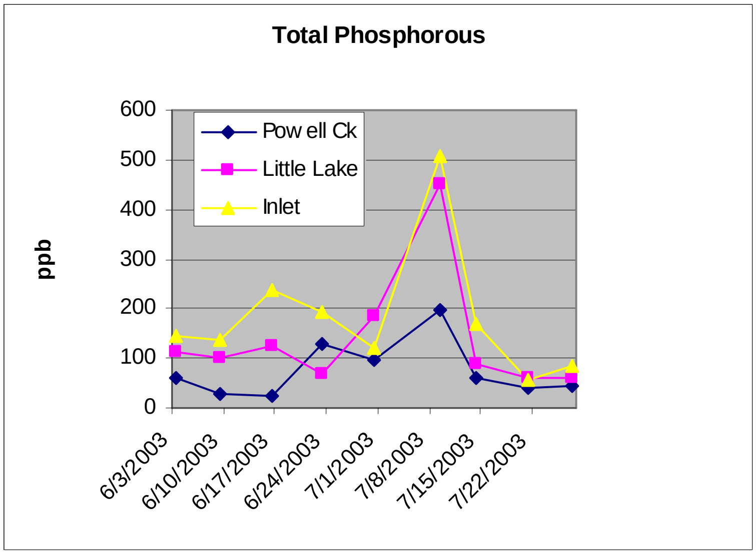


**Figure 4: Phosphorous in Powell Creek, Little Lake, and the Storm Lake Inlet**

## B. Outlet Creek

As mentioned earlier, the DMWW/ACWA team has monitored water quality in Outlet Creek since 2000. The DMWW/ACWA sampling location is near Outlet Creek's confluence with the North Raccoon River. Results of the monitoring have shown Outlet Creek to contain the highest NO3-N levels of any stream in the Raccoon River watershed in 5 of the 6 monitoring years (2004 was the exception). Figure 5 shows average nitrate levels since 2000 for the April-August monitoring period.

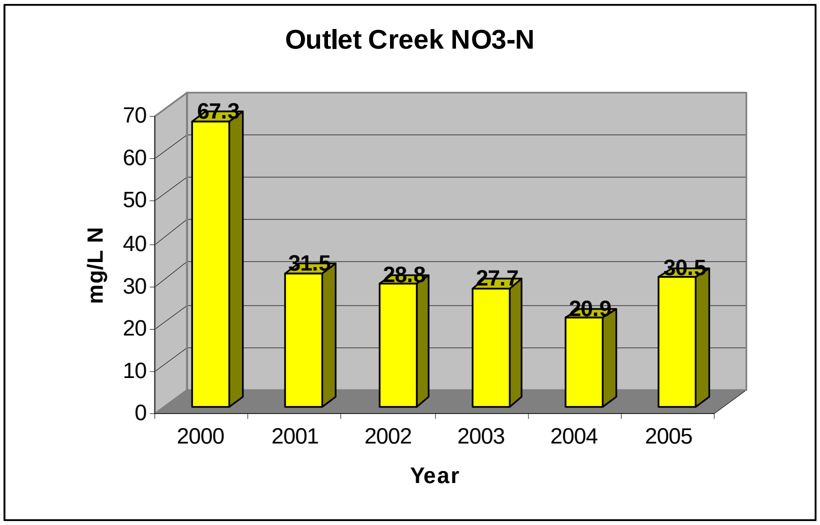


**Figure 5: Outlet Creek Nitrate 2000-2005**

Because the Storm Lake overflow contains little or no nitrate, it is apparent that Outlet Creek is receiving large inputs of nitrogen between the lake and the Raccoon River. Just downstream from the lake, the stream is known to receive at least two significant point source discharges: the City of Storm Lake Wastewater Treatment Plant (WWTP) effluent and treated effluent from the Tyson Foods (formerly IBP) processing plant. The WWTP receives effluent from at least one large industrial discharger: the Bil-Mar/Sara Lee food processing plant. The Tyson hog slaughterhouse processes about 14,000 hogs per day, and the Bil-Mar plant processes several million turkeys per year. Tyson and Bil-Mar account for about 70% of the water use in the City of Storm Lake, and provide about ¼ of all the county's jobs. Waste from animal processing is known to contain high amounts of nitrogen and phosphorous. Table 2 illustrates nitrate levels at various locations along Outlet Creek, and one can see that inputs to the stream can contain enormous amounts of nitrogen.[6]

| Site | 3/27/01 | 4/16/01 | 6/26/01 | 7/24/01 |
|---|---|---|---|---|
| Outlet Creek at the Lakeside Blacktop | 9.1 | 9.7 | 14 | 5.6 |
| Storm Lake Wastewater Effluent | 29 | 20 | 24 | 11 |
| Outlet Creek between Storm Lake and IBP Outfalls | 26 | 19 | 22 | |
| IBP Wastewater Effluent | 130 | 130 | 150 | 140 |
| Outlet Creek at Hwy 71 Culvert | 52 | 44 | 68 | 71 |
| Outlet Creek at 140th Ave Culvert | 41 | 35 | 53 | 42 |
| Outlet Creek at 150th Ave Bridge | 38 | 35 | 53 | 38 |
| Outlet Creek at 640th St Bridge W of Co.Rd M50 | 35 | 31 | 48 | 40 |
| Outlet Creek at 170th Ave Bridge | 34 | 30 | 45 | 37 |

**Table 2: 2001 Outlet Creek Nitrate Levels**

It is interesting to note the high- and low-nitrate years for Outlet Creek (From Figure 5). Year 2000 was known to be a very dry year with drought conditions experienced over a large portion of Iowa. The overflow of Storm Lake was minimal or non-existent for much of the year. Since the overflow water has been shown to contain little nitrate, it stands to reason that the point sources' effect was magnified during 2000 without the above-mentioned dilution water from the lake. Likewise, the summer of 2004 was known to be very wet in northwest Iowa, leading to a large overflow condition on the lake. This provided substantial dilution water, lowering the nitrate concentration and buffering the impact of the point sources.

NO3-N traditionally has been a desirable endpoint for nitrogen leaving the waste treatment process. It should be said that DMWW's testing shows that the nitrite-nitrogen ($NO_2$-N) concentration in Outlet Creek is relatively low—usually less than 1 mg/L. This indicates near-complete oxidation of nitrogen to nitrate—a traditional goal of waste treatment. Current acceptable waste treatment processes that produce large amounts of nitrate are considered to be working properly. Contrasted with ammonia-nitrogen ($NH_3$-N), NO3-N has little acute effect on macro-aquatic life. However, because of the severe nitrate impairment in the Raccoon River, and the connected hypoxia problem in the Gulf of Mexico, some policy-makers are revisiting how waste nitrogen should be managed. It is obvious the point-source effluents on Outlet Creek contain high concentrations of nitrate—possibly well over 100 mg/L as N. From the perspective of watershed improvement, it would be prudent to explore ways to reduce this nitrogen input.

Dissolved phosphorous concentrations in Outlet Creek are also elevated. Figure 6 shows the results of DMWW phosphorous testing.

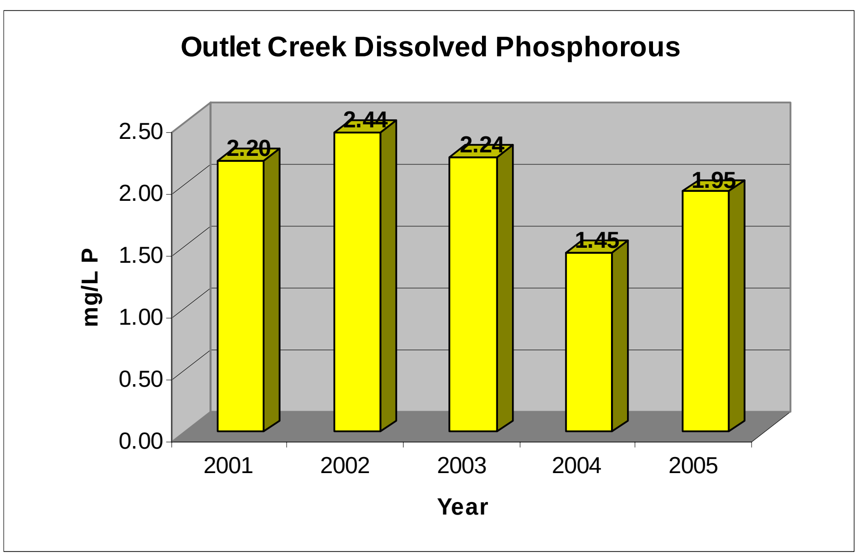


**Figure 6: Outlet Creek Dissolved Phosphorous**

No standard exists, but dissolved phosphorous levels above 0.5 mg/L can seriously impair a water body with excess nutrients. Although it is known that waste from animal processing and treated municipal wastewater contains high levels of phosphorous, it is less apparent that Outlet Creek phosphorous is due primarily to the point source discharges. This is because Storm Lake itself is a huge reservoir of phosphorous. During the wet year of 2004, however, phosphorous levels were at their lowest, indicating the lake overflow was serving as dilution water to the point source discharges and also indicating the point sources are indeed adding a significant amount of phosphorous to Outlet Creek.

Chloride is an important water quality indicator, and levels above 1000 mg/L can be acutely harmful to aquatic life. DMWW monitoring indicates that Outlet Creek chloride levels are not elevated, as shown in Figure 7. This is not to say that chloride levels couldn't be elevated, either chronically or episodically, in close proximity to the point source discharges.

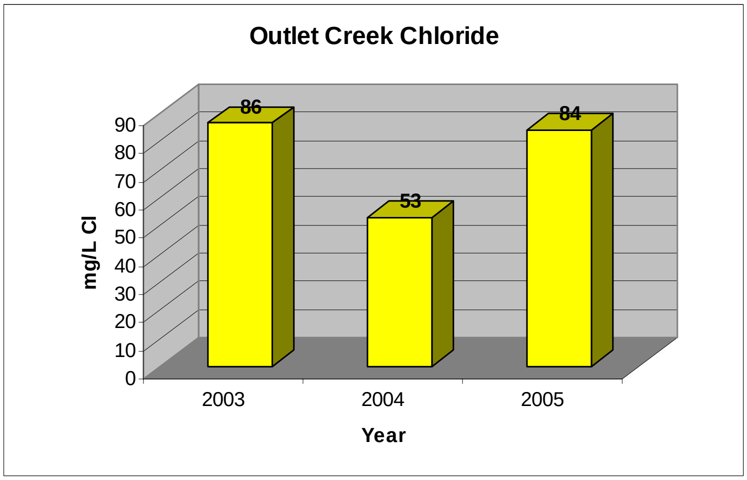


**Figure 7: Outlet Creek Chloride**

DMWW monitored *E. coli* bacteria levels in Outlet Creek for the first time in 2005. The level of *E. coli* in water deemed safe for contact is 235 colonies per 100 ml. Outlet Creek *E. coli* levels exceeded this level for each sampling event of 2005. The average level detected was 2377 colonies/100 ml, with a maximum of 4020 on July 21. Figure 8 illustrates Outlet Creek *E. coli* levels compared to levels safe for recreational contact. The source of these organisms could and probably does include Storm Lake, the City of Storm Lake WWTP, urban stormwater from the City of Storm Lake, the Tyson Foods effluent, and livestock manure downstream from the City of Storm Lake. According to current Iowa law, Outlet Creek is not protected as a recreational stream or a drinking water source, so these bacteria levels in and of themselves do not constitute a water quality violation. It is obvious, however, that Outlet Creek is a contributing factor to the *E. coli* impairment of the Raccoon River. The Storm Lake WWTP is not disinfected so it must be assumed that many of these organisms originate from this source. It must be said that disinfection is not required by IDNR for this effluent.

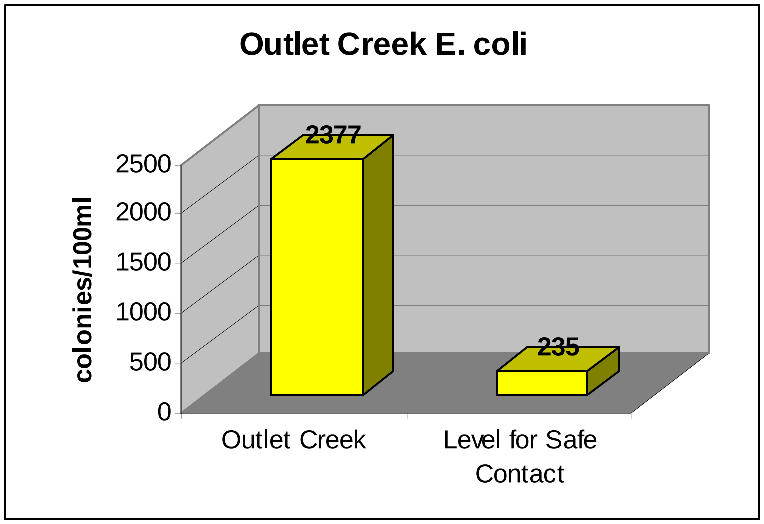


**Figure 8: Outlet Creek *E. coli***

## III. Possible Solutions to Improved Water Quality

**Storm Lake's** primary impairment is turbidity caused by sediment re-suspension within the lake. A long-term program of dredging is currently increasing the depth of Storm Lake. IDNR believes the current dredging program will provide significant improvement to water clarity and significantly reduce total phosphorus concentrations. Watershed land use will, however, continue to impact the water quality in Storm Lake for the long term. This will be particularly true as high phosphorus concentrations begin to cause algal blooms that were suppressed because of light limitations in the water column.

**Little Storm Lake** and its future capacity to trap sediment should be assessed. If its ability to capture sediment lessens, then Storm Lake will again be susceptible to siltation. Land use in the Storm Lake/Little Storm Lake watershed is 75% row crop. Managing agricultural land use in the watershed for water quality is imperative. Identifying key contribution locations and encouraging the adoption of practices to improve, manage and minimize the potential losses of soil and nutrients is critical.

Additional **monitoring** is needed in Storm Lake and Little Storm Lake to provide ongoing data assessment and communication of water quality. IDNR, Buena Vista College, IOWATER volunteers and others conducting water monitoring in the watershed should combine their monitoring resources into a comprehensive monitoring and communication plan. This will be a more effective use of resources and will avoid duplication.

**Outlet Creek** water contains an enormously high concentration of nitrate—the highest concentration in a watershed that has the highest nitrate levels in the entire Mississippi Drainage. Unlike other Iowa streams, where nitrate levels vary widely with precipitation and season, Outlet Creek likely carries this high nitrate concentration 365 days a year. This is because the biggest sources are point sources, relatively unusual in Iowa. But because the sources are point sources, this presents opportunities for control and mitigation.

As previously mentioned, microorganisms and algae consume nitrate rapidly in the relative tranquil and fertility of a wetland, marsh, or lake. Assuming sufficient property is available, this process could be simulated at the site of the point source discharges. Lagooning of the waste would provide time for microorganisms to consume and convert nitrate to nitrogen gas, which would escape harmlessly to the atmosphere. Because denitrification is especially rapid when nitrate concentrations are high, a few days' lagoon detention could dramatically decrease the NO3-N concentration by 50% or more in the point source effluents and subsequently in Outlet Creek.

Tyson Foods currently uses a lagoon system in their waste treatment process. Waste first is detained in an anaerobic lagoon, which is then followed by an activated sludge process. Then the waste is transferred to a three-stage stabilization lagoon system. It is known that Tyson Foods is currently making a modification to its waste treatment process that incorporates an anoxic zone prior to the three stabilization zones. This potentially could reduce the amount of nitrate-nitrogen in Tyson's waste effluent. Proactive steps such as these lend hope that the nitrate impairment of Outlet Creek can be addressed.

If sufficient space is available, parties might also consider the creation of an artificial wetland that would serve the same purpose as the lagoon, but would also provide habitat for native species such as waterfowl, in addition to obvious aesthetic advantages over a lagoon. Dr. William Crumpton at Iowa State University could provide guidance to this endeavor should the parties deem this solution practical.

Lagoons and wetlands also serve to capture phosphorous in the discharges. It is true that unlike nitrogen, phosphorous and solids will accumulate in the sediment of the lagoon or wetland, and would likely need to be addressed at some point. Whatever mechanism is selected, however, would likely provide many years of effective and environmentally-friendly treatment before solids/phosphorous removal was necessary.

It is unfortunate that Outlet Creek, like so many Iowa streams, is contaminated with pathogenic organisms like *E. coli* simply because the stream is not protected by law. We cannot turn a blind eye to small tributaries like Outlet Creek and expect our larger rivers like the Raccoon to be healthy and usable. One simple step would be for the point source waste discharges to disinfect and then dechlorinate their effluents prior to discharge. Lagoon or wetland treatment would also likely reduce the number of *E. coli* entering Outlet Creek. Investigation of possible manure inputs may uncover sources of *E. coli* other than the point source discharges.

It seems apparent that great strides have been made in addressing two of the water quality issues in the Storm Lake watershed, sediment and phosphorous. This took an enormous amount of effort and resources. However, the nitrogen and bacteria impairments in the Outlet Creek and Raccoon River Watersheds are much more insidious and not as responsive to the types of changes that reduced phosphorous and sediment loads upstream of Storm Lake. High nitrate concentrations also can be a conundrum from the waste treatment perspective. Historically, waste treatment plants with high-nitrate effluents (compared to ammonia) were doing their job as designed. So addressing high nitrate and bacteria concentrations will require a new toolbox of potential solutions. It will also require a new mindset from the region's stakeholders. That mindset will have to be that the watershed does not end in Storm Lake; rather it continues into the Raccoon River—Iowa's largest source of drinking water, and indeed, into the Mississippi River and the Gulf of Mexico.

**ACKNOWLEDGEMENT**

Information and consultation provided by Gordon Brand proved invaluable in production of this document. Missy Sharer assisted in the production of the maps.

**REFERENCES**

1) Bishop and Menzel, Iowa State University, 1993, unpublished data.

2) Buena Vista University 2003 monitoring, unpublished data.

3) J. Pleasants, Iowa State University, 1993, unpublished data.

4) Lehtinen and Menzel, "Storm Lake Watershed Geophysical Survery," 1993, Iowa State University and Buena Vista College, unpublished data.

5) Total Maximum Daily Load for Turbidity, Storm Lake, Buena Vista County, Iowa, Iowa Department of Natural Resources, 2005.

6) Julie Sievers, IDNR, personal communication.