Water Quality Studies—
Red Rock and Saylorville Reservoirs
Des Moines River, Iowa

Annual Report
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Water Quality Studies—
Red Rock and Saylorville Reservoirs
Des Moines River, Iowa

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Environmental Engineering Section
Department of Civil Engineering
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<td>64.</td>
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<td>Comparative data, length and weight of individual fish, condition factors, and subsample averages for whole carp (<em>Cyprinus carpio</em>, age class V) collected at Red Rock Reservoir in July 2006.</td>
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1. INTRODUCTION

The U.S. Army Corps of Engineers has constructed four major river impoundments in Iowa for the purposes of flood control, low flow augmentation for water quality control, and recreation. These are the Coralville Dam and Reservoir located on the Iowa River north of Iowa City, the Rathbun Dam and Reservoir located on the Chariton River in southern Iowa near Centerville, the Red Rock Dam and Reservoir, and the Saylorville Dam and Reservoir, both located on the Des Moines River. The Red Rock, Saylorville, and Coralville reservoirs are regulated by the Rock Island District Corps of Engineers, while Rathbun Reservoir is regulated by the Kansas City District. The Red Rock Dam and Reservoir are located southeast of the city of Des Moines, and the Saylorville Dam and Reservoir are located northwest of Des Moines. Red Rock Reservoir was completed March 16, 1969. When Saylorville Reservoir began to fill April 12, 1977, all projects were complete and in operation. Information regarding Saylorville and Red Rock reservoir projects and regulation is listed in Table 1.

The construction of impoundment facilities influences both the aquatic environment of the river and the surrounding terrestrial habitats. These effects are both beneficial and detrimental, depending upon the particular sites involved. The most recognized effects of storage impoundments on water quality (Churchill 1957) are

- development of thermal stratification
- buildup of free carbon dioxide at bottom
- possible dissolution of iron and manganese at bottom
- reduction of turbidity
- sedimentation in reservoirs
- possible production of H2S odor or algal odor
- reduction in bacterial populations
- effects on biochemical oxygen demand (BOD) and dissolved oxygen concentration

In addition, both Saylorville and Red Rock reservoirs have been shown to generally reduce chlorophyll concentrations (Søballe 1981). These impoundment systems were expected to have minimal adverse effects on existing aquatic and terrestrial habitats while improving the quality and quantity of low stream flow and providing downstream flood protection.

Obviously some means of assessing the environmental implications of the reservoirs’ construction and operation were imperative, because the effects of Saylorville and Red Rock reservoirs on water quality and quantity influence the use made of the Des Moines River and the operation of both reservoirs. In view of the need to know the quality of the water at any given
Table 1. Information on Saylorville and Red Rock dams and reservoirs from regulation manuals, Corps of Engineers.

<table>
<thead>
<tr>
<th></th>
<th>Saylorville Dam &amp; Reservoir</th>
<th>Red Rock Dam &amp; Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of project</strong></td>
<td>Flood control, conservation, water supply</td>
<td>Flood control, conservation, recreation</td>
</tr>
<tr>
<td><strong>Authority</strong></td>
<td>Public Law 85-500, 85th Congress</td>
<td>Public Law 534, 78th Congress</td>
</tr>
<tr>
<td><strong>Estimated total cost</strong></td>
<td>$169,790,000 (1981)</td>
<td>$93,242,484 (1986)</td>
</tr>
<tr>
<td><strong>Damage prevented (1993 only)</strong></td>
<td>$113 million</td>
<td>$58 million</td>
</tr>
<tr>
<td><strong>Drainage area</strong></td>
<td>5,823 square miles</td>
<td>12,323 square miles</td>
</tr>
<tr>
<td><strong>Channel capacity below dam</strong></td>
<td>16,000 ft³/s (w/corridor plan)</td>
<td>18,000 ft³/s to Eldon, Iowa</td>
</tr>
</tbody>
</table>

**Dam**

- **Type**: Rolled earthfill
- **Fill**: 7.6 million cubic yards
- **Length**: 6,750 ft
- **Crest elevation**: 915.5 ft NGVD
- **Date of closure**: April 1977

**Reservoir**

- **Conservation pool**
  - storage capacity: 836 ft NGVD
  - area: 90,000 acre-ft
  - length: 5,950 acres
  - Flood pool: 24 valley miles
- **Flood pool**
  - additional storage: 890 ft NGVD
  - area: 496,000 acre-ft
  - length: 16,700 acres

- **Red Rock Dam & Reservoir**

- **Type**: Rolled earthfill
- **Fill**: 6.5 million cubic yards
- **Length**: 5,841 ft
- **Crest elevation**: 797 ft NGVD
- **Date of closure**: July 1968

- **Conservation pool**
  - storage capacity: 742 ft NGVD
  - area: 189,000 acre-ft
  - length: 15,250 acres
  - Flood pool: 18 valley miles
- **Flood pool**
  - additional storage: 780 ft NGVD
  - area: 1,247,000 acre-ft
  - length: 64,680 acres

---

*Saylorville Reservoir was constructed in three phases from June 1965 through April 1977. The Des Moines River was diverted through the outlet works in July 1975. Final construction was completed and the reservoir began to fill in April 1977.*

*A seasonal increase (September-December) of two feet is part of the regulations in order to improve wildlife habitat.*

*Original conservation pool level was 833 ft NGVD, raised to 836 ft NGVD in 1983.*

*Original conservation pool level was 725 ft NGVD, raised to 728 ft NGVD in 1979, to 734 ft NGVD in 1988, and to 742 ft NGVD in 1992.*

*Water and sediment storage.*
Table 1. Continued.

<table>
<thead>
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<th>Saylorville Dam &amp; Reservoir</th>
<th>Red Rock Dam &amp; Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spillway Type</strong></td>
<td>Chute w/uncontrolled weir(^f) 430 ft long</td>
<td>Ogee weir with Tainter crest gates, 5 gates, 41 ft by 45 ft</td>
</tr>
<tr>
<td><strong>Crest elevation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Discharge capacity at flood pool</strong></td>
<td>884 ft NGVD 21,000 ft(^3)/s</td>
<td>Open 736 ft NGVD, closed 781 ft NGVD 225,000 ft(^3)/s</td>
</tr>
<tr>
<td><strong>Energy Discipator</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Outlet Facilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Circular conduit</td>
<td>Rectangular concrete conduits</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>One, 22 ft diameter</td>
<td>Fourteen, 5 ft by 9 ft</td>
</tr>
<tr>
<td><strong>Service gates</strong></td>
<td>Three, 8 ft by 19 ft sluice gates</td>
<td>Hydraulic slide gates</td>
</tr>
<tr>
<td><strong>Energy dissipator</strong></td>
<td>Stilling basin</td>
<td>Stilling basin</td>
</tr>
<tr>
<td><strong>length</strong></td>
<td>96 ft</td>
<td>180 ft</td>
</tr>
<tr>
<td><strong>width</strong></td>
<td>65 ft to 97 ft</td>
<td>241 ft</td>
</tr>
<tr>
<td><strong>floor elevation</strong></td>
<td>772.75 ft NGVD</td>
<td>654 ft NGVD</td>
</tr>
<tr>
<td><strong>end sill elevation</strong></td>
<td>778.75 ft NGVD</td>
<td>664 ft NGVD</td>
</tr>
<tr>
<td><strong>baffles</strong></td>
<td>2 rows of 5 and 6 each</td>
<td>2 rows of 6 and 7 each</td>
</tr>
<tr>
<td><strong>Design floods</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Standard project</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>maximum elevation</strong></td>
<td>783 ft NGVD</td>
<td>897.9 ft NGVD</td>
</tr>
<tr>
<td><strong>peak inflow</strong></td>
<td>273,000 ft(^3)/s</td>
<td>115,400 ft(^3)/s</td>
</tr>
<tr>
<td><strong>peak outflow</strong></td>
<td>109,000 ft(^3)/s</td>
<td>100,800 ft(^3)/s</td>
</tr>
<tr>
<td><strong>volume of runoff</strong></td>
<td>7.69 inches</td>
<td>9 inches</td>
</tr>
<tr>
<td><strong>Spillway design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maximum elevation</strong></td>
<td>908 ft NGVD</td>
<td>791.2 ft NGVD</td>
</tr>
<tr>
<td><strong>Peak inflow</strong></td>
<td>277,800 ft(^3)/s</td>
<td>613,000 ft(^3)/s</td>
</tr>
<tr>
<td><strong>Peak outflow</strong></td>
<td>213,700 ft(^3)/s</td>
<td>378,000 ft(^3)/s</td>
</tr>
<tr>
<td><strong>Volume of runoff</strong></td>
<td>13.8 inches</td>
<td>7.53 inches</td>
</tr>
</tbody>
</table>

\(^f\)A pneumatic rubber dam has been installed on weir to increase crest elevation to 890 ft NGVD.
<table>
<thead>
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<th>Regulation (^g)</th>
<th>Saylorville Dam &amp; Reservoir</th>
<th>Red Rock Dam &amp; Reservoir</th>
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<tr>
<td>Minimum release</td>
<td>200 ft(^3)/s, plus water supply demands</td>
<td>200 ft(^3)/s</td>
</tr>
<tr>
<td>Dec-Apr</td>
<td>30,000 ft(^3)/s</td>
<td>30,000 ft(^3)/s</td>
</tr>
<tr>
<td>Apr-Dec</td>
<td>12,000 ft(^3)/s</td>
<td>18,000 ft(^3)/s</td>
</tr>
<tr>
<td>Records</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average inflow (July)</td>
<td>2,420 ft(^3)/s</td>
<td>5,500 ft(^3)/s</td>
</tr>
<tr>
<td>Highest inflow recorded</td>
<td>47,000 ft(^3)/s (7/11/93)</td>
<td>134,900 ft(^3)/s (7/12/93)</td>
</tr>
<tr>
<td>Average outflow (July)</td>
<td>2,420 ft(^3)/s</td>
<td>5,500 ft(^3)/s</td>
</tr>
<tr>
<td>Highest outflow recorded</td>
<td>43,100 ft(^3)/s (7/13/93)</td>
<td>104,400 ft(^3)/s (7/15/93)</td>
</tr>
<tr>
<td>Previous high</td>
<td>29,000 ft(^3)/s (1984)</td>
<td>40,000 ft(^3)/s (1984)</td>
</tr>
<tr>
<td>Highest pool elevation</td>
<td>892.01 ft NGVD (7/13/93)</td>
<td>782.67 ft NGVD (7/13/93)</td>
</tr>
</tbody>
</table>

\(^g\) Under normal conditions; emergency regulations go into effect in the case of extreme flood or drought.
time and the changes in water quality that result from the operation of the two reservoirs, the Rock Island District of the Corps of Engineers contracted with the Engineering Research Institute of Iowa State University to design and conduct a long-term study that would permit evaluation of water quality

• in the Des Moines River above and below Saylorville Reservoir before reservoir impoundment
• in the Des Moines River above, in, and below Saylorville Reservoir after reservoir impoundment
• in the Raccoon and Des Moines rivers upon entering and after leaving the city of Des Moines, thus enabling assessment of the effects of point and nonpoint sources of pollution on the Des Moines River
• in the Des Moines River above, in, and below Red Rock Reservoir, both before and during operation of Saylorville Reservoir

In addition to the overall water quality studies, the Corps of Engineers decided to include investigations of a more specific nature that would permit

• evaluation of the effects of Whitebreast Creek, the main tributary entering Red Rock Reservoir, on the water quality in and below Red Rock Reservoir
• evaluation of the predominant biological processes occurring within Red Rock Reservoir as determined by weekly primary productivity estimates
• evaluation of the heterogeneity of water quality parameters within Saylorville and Red Rock reservoirs as determined by sampling along several transects at various depths
• evaluation of ecological stress as evidenced by macroinvertebrate populations
• evaluation of the fluctuations of bacterial populations in the reservoir areas, including recreation area beaches and adjacent river reaches
• evaluation of total gas saturation downstream from Red Rock Reservoir and examination of fish from fish kills to determine if gas saturation is a causative agent in observed fish kills
• calibration of in-situ sensors used with data collection platforms for remote sensing of water quality at locations just downstream from Saylorville and Red Rock reservoirs

Some of these objectives have been met and others continue to be addressed in the current contracts.

This report compiles data from the thirty-eighth contract period of Corps-sponsored water quality monitoring along the Des Moines River, which extended from January 10, 2006, through December 5, 2006, and encompassed 22 samplings. It is important to maintain a continuous data
record in long-term monitoring. Under the previous contract, the last sampling occurred on December 6, 2005; thus there was not more than a month between contract periods.

The Scope of Work for this contract period was identical to last period. The list of parameters analyzed was extended in 2000 with the support of the Iowa Department of Natural Resources Iowa Water Initiative (IDNR, 2000) to include total organic carbon (TOC), dissolved silica, organic nitrogen, orthophosphate, and total phosphate. These parameters were previously analyzed but had been discontinued by the Corps to address budget constraints. In 2001, bacterial monitoring was expanded to include quantification of *Escherichia coli* bacteria for the first time in the projects’ history. Also in 2001, transparency tube depths began being taken at the riverine stations. Iowa State has supported BOD testing at the reservoir sites since 2000 so that water quality indices could be calculated. The Scope of Work during this contract period continues a phased reduction in the extent of work during the winter months and concentrates more effort from April to October. Thus several of the parameters, such as the bacterial counts and chlorophyll pigments, were only analyzed on a seasonal basis.
2. BASIN CHARACTERISTICS

The Des Moines River is a mineral-laden, eutrophic river flowing primarily through agricultural lands and is the largest internal river in the state. Originating in Minnesota as two forks and converging in north central Iowa, the Des Moines River flows southeasterly to its confluence with the Mississippi River south of Keokuk, Iowa. The total length is 535 miles. The Des Moines River basin encompasses 12,884 square miles, nearly one-quarter of the state of Iowa. Saylorville Dam has a drainage area of 5,823 square miles. Large tributaries above the dam include the East Fork of the Des Moines River (1,315 square miles), the Boone River (906 square miles), and Lizard Creek (437 square miles). The channel slope between Jackson, Minnesota, and Saylorville Dam is 2 to 3 feet per mile. Lake Red Rock has a drainage area of 12,323 square miles. The major tributaries above the dam include the Raccoon River (3,441 square miles), North River (590 square miles), Middle River (558 square miles), South River (590 square miles), and Whitebreast Creek (430 square miles). Figure 1 shows the sub-basins by 8-digit HUC (hydrologic unit code). Table 2 lists by sub-basin the watershed area, use categories, and other information (IDNR 2000).

The river has been described in three zones: upper, middle, and lower (Drum 1964). The upper zone begins in the headwaters of southern Minnesota and extends to the junction of the east and west forks, about 70 river miles north of the city of Des Moines. The zone is characterized by a silt and sand-gravel bottom. The major soil association found within the watershed of this zone is the Clarion-Nicolett-Webster association with slopes ranging from one to thirty percent, portions of which are susceptible to erosion. The middle zone extends to the confluence with the Raccoon River in the city of Des Moines. Within this zone outwash deposits often project into the river, and the river bottom comprises rock rubble, sand, and sand gravel with some sand-silt bars. Much of the agricultural land in this area is tile drained. The major soil associations are Marshall, Clarion-Nicolett-Webster, and Shelby-Sharpsburg-Macksburg. The lower zone begins at the southern tip of the Wisconsin glaciation area and extends to the confluence with the Mississippi River at the southeastern tip of the state. The river meanders where not channelized, and the bottom is composed of silt or sand silt. The watershed has a slope of zero to eighteen percent and is very susceptible to erosion (Oschwald et al. 1965).
upper basin is in the ecoregion designated 47b, Des Moines Lobe, and the lower basin is
designated ecoregion 47f, Southern Iowa Rolling Loess Prairies (Griffith et al. 1994).
Table 2. Des Moines River, basin characteristics.

<table>
<thead>
<tr>
<th>Basin Name</th>
<th>8-dig HUC</th>
<th>Area</th>
<th>Counties Included</th>
<th>Surface Water Supply Intakes</th>
<th>Public Water Supply Wells</th>
<th>Ag, Drainage Wells</th>
<th>% Cropland</th>
<th>% Pasture</th>
<th>%Crop/Pasture Erosion&gt;2T&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Animal Units/sq mi&lt;sup&gt;b&lt;/sup&gt;</th>
<th>DMRWQN Sites Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Moines River</td>
<td>7100002</td>
<td>1,000 sq mi</td>
<td>Dickinson, Emmet, Palo Alto, Pochahontas, Humbolt</td>
<td>2</td>
<td>27</td>
<td>147</td>
<td>87.1</td>
<td>1.9</td>
<td>2.2</td>
<td>151.7</td>
<td></td>
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<tr>
<td>East Fork Des Moines River</td>
<td>7100003</td>
<td>1,107 sq mi</td>
<td>Emmet, Kossuth, Winnegbago, Hancock, Humbolt</td>
<td>34</td>
<td>22</td>
<td>90.6</td>
<td>1.9</td>
<td>2.8</td>
<td>100.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Des Moines River</td>
<td>7100004</td>
<td>1,719 sq mi</td>
<td>Pocahontas, Humbolt, Webster, Greene, Boone, Dallas, Polk</td>
<td>1</td>
<td>75</td>
<td>40</td>
<td>81.4</td>
<td>2.7</td>
<td>1.1</td>
<td>105.9</td>
<td>Stations 0, 1, 2, 3, 4 and 5</td>
</tr>
<tr>
<td>Boone River</td>
<td>7100005</td>
<td>908 sq mi</td>
<td>Kossuth, Hancock, Humbolt, Wright, Hamilton</td>
<td>26</td>
<td>19</td>
<td>88.7</td>
<td>1.3</td>
<td>1.4</td>
<td>285.5</td>
<td></td>
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</tr>
</tbody>
</table>

<sup>a</sup>Greater than twice the tolerable soil loss rate, from 1992 National Resources Inventory, NRCS.

<sup>b</sup>Unit of measurement of animal capacity, from 1996 NRCS.
Table 2. Continued.

<table>
<thead>
<tr>
<th>Basin Name</th>
<th>8-dig HUC</th>
<th>Area</th>
<th>Counties Included</th>
<th>Surface Water Supply Intakes</th>
<th>Public Water Supply Wells</th>
<th>Ag, Drainage Wells</th>
<th>% Cropland</th>
<th>% Pasture</th>
<th>%Crop/Pasture Erosion&gt;2T&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Animal Units/sq mi&lt;sup&gt;b&lt;/sup&gt;</th>
<th>DMRWQN Sites Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Raccoon River</td>
<td>7100006</td>
<td>2,482 sq mi</td>
<td>Buena Vista, Pocahontas, Sac, Calhoun</td>
<td>2</td>
<td>131</td>
<td>1</td>
<td>86.1</td>
<td>2.9</td>
<td>2.6</td>
<td>140.9</td>
<td>Station 10</td>
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<td></td>
<td></td>
<td></td>
<td>Webster, Carroll, Greene, Dallas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Raccoon River</td>
<td>7100007</td>
<td>1,138 sq mi</td>
<td>Carroll, Guthrie, Dallas</td>
<td>1</td>
<td>48</td>
<td>0</td>
<td>79.3</td>
<td>6.0</td>
<td>11.7</td>
<td>165.1</td>
<td></td>
</tr>
<tr>
<td>Des Moines River</td>
<td>7100008</td>
<td>2,437 sq mi</td>
<td>Polk, Guthrie, Adair, Madison, Warren, Marion, Clarke, Lucas</td>
<td>2</td>
<td>61</td>
<td>0</td>
<td>62.7</td>
<td>11.6</td>
<td>10.7</td>
<td>102.6</td>
<td>Stations 6, 7, 8, and 9</td>
</tr>
<tr>
<td>Des Moines River</td>
<td>7100009</td>
<td>2,093 sq mi</td>
<td>Marion, Mahaska, Lucas, Monroe, Wapello, Appanoose, Davis, Van Buren</td>
<td>6</td>
<td>24</td>
<td>0</td>
<td>57.4</td>
<td>13.0</td>
<td>12.5</td>
<td>103.7</td>
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</tbody>
</table>
3. PROJECT SCOPE

When first conceived, the Des Moines River Water Quality Network (DMRWQN) was intended to monitor preimpoundment water quality in the Saylorville Reservoir area of the Des Moines River upstream of the city of Des Moines. Interpretation of the data collected in the early years of the study indicated that the water quality at Station 1 (near Boone) was a good predictor of the water quality at Station 5 (near Saylorville) before impoundment. This resulted in the elimination of some sampling sites located between Stations 1 and 5 and the addition of new sites at several downstream locations on the Des Moines River, as well as at a single location on the Raccoon River. In August 1971, monitoring was extended downstream to encompass Red Rock Reservoir, which had been in operation since May 1969, and its tailwater. Saylorville Reservoir was completed in April 1977. In addition, because waters of the maximum flood pool of Saylorville Reservoir extend upstream beyond the regular upstream sampling station (Station 1), an alternative station (Station 0) was added upstream of the influences of the Saylorville Reservoir flood pool waters. Station 0 is normally monitored whenever Saylorville Lake level exceeds 870 feet NGVD (National Geodetic Vertical Datum of 1929). The geographical scope of this project normally extends from Station 1 near Boone, Iowa, to Station 9 near Pella, Iowa, encompassing approximately 116 river miles, or about 134 miles when the alternative upstream location (Station 0) is monitored. Each sampling site and its significance are identified in the following section and in Table 3. The location of each regular sampling station is shown in Fig. 2.

Thus, sampling stations for the current contract year were now located above, within, and below Saylorville Reservoir; on the Raccoon River (the major tributary joining the Des Moines River at Des Moines); on the Des Moines River below the city of Des Moines; and on the Des Moines River above, within, and below Red Rock Reservoir. Water samples were collected and tested for various physical, chemical, and biological parameters on 22 occasions between January 10, 2006, and December 5, 2006. In addition to the routine sampling, additional studies were supported. Studies examined gas saturation downstream from both reservoirs and bacteria populations at each reservoir’s recreational area beaches. Support from the Iowa Department of Natural Resources allows the analyses of total organic carbon, dissolved silica, organic nitrogen, orthophosphate and total phosphate.

All data collected were submitted in weekly and monthly reports to the Corps of Engineers and other cooperating groups. This annual report summarizes the data from these weekly and monthly reports and corrects any errors appearing in those reports. Data for the period of record (since July 1967) are maintained as a Paradox database (DMRWQN), which is annually
<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Des Moines River, State Route 175 bridge near Stratford, Webster County, 276.7 mi from upstream mouth. Latitude: 42.252392°N Longitude: 93.9960°W</td>
<td>Upstream of maximum Saylorville Reservoir flood pool</td>
</tr>
<tr>
<td>1</td>
<td>Des Moines River, near Boone Water Plant, County Road E-26 bridge, just above low-head dam, Boone County, 258.8 mi upstream from mouth. Latitude: 42.080660°N Longitude: 93.937821°W</td>
<td>Upstream of Saylorville Reservoir conservation pool</td>
</tr>
<tr>
<td>4&lt;sup&gt;b&lt;/sup&gt;5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Saylorville Reservoir, 0.15 mi upstream from the dam, 213.9 mi upstream from mouth. Latitude: 41.708387°N Longitude: 93.683294°W</td>
<td>Saylorville Reservoir conservation pool</td>
</tr>
<tr>
<td>5</td>
<td>Des Moines River, 66th Street bridge at the Sycamore Recreation Area and near the town of Saylorville, 2.3 mi downstream from Saylorville Dam, 211.4 mi upstream from mouth. Latitude: 41.677917°N Longitude: 93.668470°W</td>
<td>Downstream from Saylorville Reservoir, upstream of the city of Des Moines</td>
</tr>
<tr>
<td>10</td>
<td>Raccoon River, County Road R-16 bridge at the town of Van Meter, Dallas County, 1.1 mi downstream from confluence of North and South Raccoon Rivers, 29.0 mi upstream from mouth. Latitude: 41.534199°N Longitude: 93.950349°W</td>
<td>Upstream of the city of Des Moines and the confluence with the Des Moines River</td>
</tr>
<tr>
<td>6&lt;sup&gt;c&lt;/sup&gt; (through 04Aug98)</td>
<td>Des Moines River, State Route 46 bridge near Iowa Power and Light Company, Des Moines, Polk County 200.7 mi upstream from mouth. Latitude: 41.550792°N Longitude: 93.524761°W</td>
<td>5-1/2 mi downstream from the confluence of the Raccoon River and 2-1/2 mi downstream from the Des Moines Water Pollution Control Plant</td>
</tr>
</tbody>
</table>

<sup>a</sup>Alternative upstream station, to be sampled in place of Station 1 whenever Saylorville Lake elevation exceeds 870 ft NGVD.

<sup>b</sup>S: surface sample.

<sup>c</sup>M: mid-depth sample.

<sup>d</sup>B: bottom sample.

Coordinates are decimal degrees, North American Datum 1927.
<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Des Moines River, Highway 65N, Polk County,</td>
<td>6 mi downstream from the confluence of the Raccoon River and 3 mi downstream from the Des Moines Regional Wastewater Treatment Plant</td>
</tr>
<tr>
<td></td>
<td>Latitude: 41.5388°N Longitude: 93.4843°W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 mi downstream from the confluence of the Raccoon River and 3 mi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>downstream from the Des Moines Regional Wastewater Treatment Plant</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Des Moines River, County Road S35 south of Runnells, Warren County,</td>
<td>Upstream of the conservation pool of Red Rock Reservoir but in the flood pool area and downstream from the confluences of the North, Middle, and South rivers</td>
</tr>
<tr>
<td></td>
<td>37.2 mi upstream from Red Rock Dam, 179.5 mi upstream from mouth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latitude: 41.488626°N Longitude: 93.338831°W</td>
<td></td>
</tr>
<tr>
<td>8SB</td>
<td>Red Rock Reservoir, 0.15 mi upstream of the Red Rock Dam over the thalweg,</td>
<td>Red Rock Reservoir conservation pool just upstream of the dam</td>
</tr>
<tr>
<td>8MC</td>
<td>143.1 mi upstream from the mouth</td>
<td></td>
</tr>
<tr>
<td>8BD</td>
<td>Latitude: 41.374339°N Longitude: 92.978369°W</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Des Moines River, 0.7 mi downstream from Red Rock Dam, Marion County,</td>
<td>Downstream from Red Rock Dam</td>
</tr>
<tr>
<td></td>
<td>Howell Station Landing recreation area, second jutty on northeast bank,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>142.2 mi upstream from mouth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latitude: 41.361773°N Longitude: 92.972264°W</td>
<td></td>
</tr>
</tbody>
</table>
archived on a CD-ROM. Also, the Iowa Department of Natural Resources adds the data yearly to the new Iowa STORET water quality computer system (http://wqm.igsb.uiowa.edu/iastoret/). The database generated from these water quality contracts is periodically verified for completeness and accuracy. If errors are discovered, they are immediately corrected. In addition, a World Wide Web site is maintained by the Des Moines River Water Quality Monitoring Network. General project information, as well as weekly, monthly, and annual reports, are available on the site. Data may also be downloaded from the Web site. The URL is http://www.cce.iastate.edu/research/lutz/dmrwqn/dmrwqn.html.
4. HISTORY OF THE DATABASE

The thirty-nine-year history of the Des Moines River water quality studies is summarized in Tables 4 through 9. Table 4 lists the sampling periods and the number of samplings during each contract period, and Table 5 breaks this information down into water-year periods. Table 6 identifies the location for each sampling station. Table 7 summarizes the history of the database for each sampling station. (Please note that Stations 2, 3-RIVER, and 4-RIVER were preimpoundment sampling stations and that the location of Station 4-RIVER along the Des Moines River roughly corresponds to the location of Station 4 in Saylorville Reservoir. Station 2 was located two miles west of Madrid on Route 89. Station 3-RIVER was located five miles southeast of Madrid on County Road X.) Table 8 documents the period of record for each parameter analyzed and illustrates the fluctuation in parameters sampled from contract to contract. Table 9 lists the additional studies that were supported under several of the contracts.
Table 4. History of the database—contract periods.

<table>
<thead>
<tr>
<th>Contract Period</th>
<th>Sampling Dates</th>
<th>Number of Samplings</th>
<th>Cumulative Number of Samplings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>06Jul67–28Jun68</td>
<td>52</td>
<td>52</td>
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<tr>
<td>2</td>
<td>05Jul68–09Jul69</td>
<td>54</td>
<td>106</td>
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<td>3</td>
<td>18Jul69–11Jul70</td>
<td>52</td>
<td>158</td>
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<td>17Jul70–13Jul71</td>
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<td>5</td>
<td>21Jul71–12Jul72</td>
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<td>19Jul72–27Jul73</td>
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<td>02Aug73–24Jul74</td>
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<td>01Aug74–29Jul75</td>
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<td>05Aug75–21Jul76</td>
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<td>04Aug76–26Jul77</td>
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<td>Contract Period</td>
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<td>10Jan06–05Dec06</td>
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Table 5. History of the database—sampling frequency.

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</tr>
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<td>1991–92</td>
<td>20</td>
</tr>
<tr>
<td>1992–93</td>
<td>22</td>
</tr>
<tr>
<td>1993–94</td>
<td>22</td>
</tr>
<tr>
<td>1994–95</td>
<td>22</td>
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<td>1995–96</td>
<td>22</td>
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<td>1996–97</td>
<td>22</td>
</tr>
<tr>
<td>1997–98</td>
<td>22</td>
</tr>
</tbody>
</table>
Table 5. Continued.

<table>
<thead>
<tr>
<th>Water Year (Oct.–Sept.)</th>
<th>Number of Samplings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–99</td>
<td>22</td>
</tr>
<tr>
<td>1999–00</td>
<td>22</td>
</tr>
<tr>
<td>2000–01</td>
<td>22</td>
</tr>
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<td>2001–02</td>
<td>22</td>
</tr>
<tr>
<td>2002–03</td>
<td>22</td>
</tr>
<tr>
<td>2003–04</td>
<td>22</td>
</tr>
<tr>
<td>2004–05</td>
<td>22</td>
</tr>
<tr>
<td>2005–06</td>
<td>22</td>
</tr>
</tbody>
</table>
Table 6. History of the database—sampling station locations.

<table>
<thead>
<tr>
<th>Station</th>
<th>Station Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Des Moines River, State Route 175 bridge near Stratford, Iowa, Webster County. Alternate Site. Mile 276.7. (lat. 42.252392°N, long. 93.9960°W).</td>
</tr>
<tr>
<td>1</td>
<td>Des Moines River, near Boone Water Plant, County Rd E–26 bridge, Boone County. Mile 258.8. (lat. 42.080660°N, long. 93.937821°W).</td>
</tr>
<tr>
<td>2</td>
<td>Des Moines River, State Route 89, near Madrid, Iowa, Boone County. Mile 235.4.</td>
</tr>
<tr>
<td>3–RIVER</td>
<td>Des Moines River, County Road X, SE of Madrid, Polk County. Mile 227.0.</td>
</tr>
<tr>
<td>3B</td>
<td>Saylorville Reservoir, County S&amp;V bridge, headwaters–bottom depth.</td>
</tr>
<tr>
<td>3M</td>
<td>Saylorville Reservoir, County S&amp;V bridge, headwaters–middle depth.</td>
</tr>
<tr>
<td>3S</td>
<td>Saylorville Reservoir, County S&amp;V bridge, headwaters–surface depth. (lat. 41.759953°N, long. 93.741015°W).</td>
</tr>
<tr>
<td>4–RIVER</td>
<td>Des Moines River, near Polk City, Iowa, County S&amp;V bridge, Polk County. Mile 218.4.</td>
</tr>
<tr>
<td>4B</td>
<td>Saylorville Reservoir, main basin, 0.15 miles upstream of the dam–bottom depth.</td>
</tr>
<tr>
<td>4M</td>
<td>Saylorville Reservoir, main basin, 0.15 miles upstream of the dam–middle depth.</td>
</tr>
<tr>
<td>4S</td>
<td>Saylorville Reservoir, main basin, 0.15 miles upstream of the dam–surface depth. (lat. 41.708387°N, long. 93.683294°W).</td>
</tr>
<tr>
<td>5</td>
<td>Des Moines River, 2.3 mi below Saylorville Dam, 66th St. bridge, Polk County. Mile 211.4. (lat. 41.67917°N, long. 93.66847°W).</td>
</tr>
<tr>
<td>5A</td>
<td>Des Moines River, City of Des Moines at Euclid Ave. bridge.</td>
</tr>
<tr>
<td>6</td>
<td>Des Moines River, State Route 46 bridge near Iowa Power and Light Company, Des Moines, Polk County 200.7 miles upstream from mouth. (lat. 41.550792°N, 93.524761°W).</td>
</tr>
<tr>
<td>6 (through 04Aug98)</td>
<td>Des Moines River, Highway 65 North (lat. 41.5388°N, long. 93.4843°W).</td>
</tr>
<tr>
<td>7</td>
<td>Red Rock Reservoir, 0.15 mile upstream of dam–bottom depth</td>
</tr>
<tr>
<td>8B–HEAD WATER</td>
<td>Red Rock Reservoir, State Route 14 bridge, Marion County–bottom depth.</td>
</tr>
<tr>
<td>8M</td>
<td>Red Rock Reservoir, 0.15 mile upstream of dam–middle depth.</td>
</tr>
<tr>
<td>8M–HEADWATER</td>
<td>Red Rock Reservoir, State Route 14 bridge, Marion County–middle depth.</td>
</tr>
<tr>
<td>8S</td>
<td>Red Rock Reservoir, 0.15 mile upstream of dam–surface depth. (lat. 41.374339°N, long. 92.978369°W).</td>
</tr>
<tr>
<td>8S–HEAD WATER</td>
<td>Red Rock Reservoir, State Route 14 bridge, Marion County–surface depth. (lat. 41.41917°N, long. 93.1161°W).</td>
</tr>
<tr>
<td>Station</td>
<td>Station Location</td>
</tr>
<tr>
<td>---------</td>
<td>------------------</td>
</tr>
<tr>
<td>9</td>
<td>Des Moines River, 2&lt;sup&gt;nd&lt;/sup&gt; jutty NE bank, 0.7 mile downstream of Red Rock Dam (9/3/91–current). (lat. 41.361773°N, long. 92.972264°W). [Previously, County Road T–15 bridge till collapse.]</td>
</tr>
<tr>
<td>11</td>
<td>Des Moines River below Red Rock Reservoir, at County Road T17, Near Harvey, Marion County. (lat. 41.34639°N, long. 92.9455°W).</td>
</tr>
<tr>
<td>12</td>
<td>Des Moines River below Red Rock Reservoir, State Route 92 bridge, Marion County. Mile 131.0, 12.0 miles downstream from Red Rock Dam. (lat. 41.31083°N, long. 92.88028°W).</td>
</tr>
<tr>
<td>13</td>
<td>Des Moines River below Red Rock Reservoir, at County Road T39, near Beacon, Marion County. (lat. 41.24833°N, long. 92.76056°W).</td>
</tr>
</tbody>
</table>
Coordinates are decimal degrees, North American Datum 1927.
Table 7. History of the database—sampling station activity.

<table>
<thead>
<tr>
<th></th>
<th>Contract Period&lt;sup&gt;a&lt;/sup&gt;</th>
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</thead>
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<tr>
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<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3–RIVER</td>
<td></td>
</tr>
<tr>
<td>4–RIVER</td>
<td></td>
</tr>
<tr>
<td>3 S,M,B</td>
<td></td>
</tr>
<tr>
<td>4 S,M,B</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>5A</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8–HEAD WATER</td>
<td></td>
</tr>
<tr>
<td>8 S,M,B</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Dates corresponding to contract periods are listed in Table 4.
Table 8. History of the database—parameters.

<table>
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<tr>
<th>Parameter</th>
<th>Contract Period\textsuperscript{a}</th>
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</thead>
<tbody>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>Time</td>
<td>x</td>
</tr>
<tr>
<td>Secchi depth</td>
<td></td>
</tr>
<tr>
<td>Transparency tube depth</td>
<td></td>
</tr>
<tr>
<td>Water temperature</td>
<td>x</td>
</tr>
<tr>
<td>Cloud cover</td>
<td></td>
</tr>
<tr>
<td>Ice cover</td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td>x</td>
</tr>
<tr>
<td>Elevation</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>x</td>
</tr>
<tr>
<td>Solids</td>
<td></td>
</tr>
<tr>
<td>Suspended</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Volatile</td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>Total filterable</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>x</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td></td>
</tr>
<tr>
<td>Total alkalinity</td>
<td></td>
</tr>
<tr>
<td>Phenol. alkalinity</td>
<td></td>
</tr>
<tr>
<td>Total hardness</td>
<td></td>
</tr>
<tr>
<td>Calcium hardness</td>
<td></td>
</tr>
<tr>
<td>Soluble calcium</td>
<td></td>
</tr>
<tr>
<td>Soluble magnesium</td>
<td></td>
</tr>
<tr>
<td>Specific conductance</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td></td>
</tr>
<tr>
<td>Inorganic</td>
<td>x</td>
</tr>
<tr>
<td>Total organic</td>
<td>x</td>
</tr>
<tr>
<td>Soluble organic</td>
<td>x</td>
</tr>
<tr>
<td>Tot. particulate</td>
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</tr>
<tr>
<td>COD</td>
<td>x</td>
</tr>
<tr>
<td>BOD</td>
<td>x</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>x</td>
</tr>
<tr>
<td>D.O. saturation</td>
<td>x</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
</tr>
<tr>
<td>Organic</td>
<td>x</td>
</tr>
<tr>
<td>Nitrite</td>
<td>x</td>
</tr>
<tr>
<td>Nitrate</td>
<td>x</td>
</tr>
<tr>
<td>Nitrite+nitrate</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>x</td>
</tr>
<tr>
<td>Total</td>
<td>x</td>
</tr>
<tr>
<td>Un-ionized ammonia</td>
<td>x</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Dates corresponding to contract periods are listed in Table 3.
<table>
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<tr>
<th>Parameter</th>
<th>Contract Period&lt;sup&gt;a&lt;/sup&gt;</th>
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</thead>
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<tr>
<td>Time</td>
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<tr>
<td>Secchi depth</td>
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<td>Transparency tube depth</td>
<td></td>
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<tr>
<td>Water temperature</td>
<td>x</td>
</tr>
<tr>
<td>Cloud cover</td>
<td>x</td>
</tr>
<tr>
<td>Ice cover</td>
<td>x</td>
</tr>
<tr>
<td>Flow</td>
<td>x</td>
</tr>
<tr>
<td>Elevation</td>
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<td>Turbidity</td>
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<td>Solids</td>
<td>Total</td>
</tr>
<tr>
<td>Volatile</td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
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<tr>
<td>Total filterable filter</td>
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<tr>
<td>pH</td>
<td>x</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>x</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>x</td>
</tr>
<tr>
<td>Phenol. alkalinity</td>
<td>x</td>
</tr>
<tr>
<td>Total hardness</td>
<td>x</td>
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<tr>
<td>Calcium hardness</td>
<td>x</td>
</tr>
<tr>
<td>Soluble calcium</td>
<td></td>
</tr>
<tr>
<td>Soluble magnesium</td>
<td></td>
</tr>
<tr>
<td>Specific conductance</td>
<td></td>
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<tr>
<td>Carbon</td>
<td>Inorganic</td>
</tr>
<tr>
<td></td>
<td>Total organic</td>
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<tr>
<td>Soluble organic</td>
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<td>COD</td>
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</tr>
<tr>
<td>BOD</td>
<td>x</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>x</td>
</tr>
<tr>
<td>D.O. saturation</td>
<td>x</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Organic</td>
</tr>
<tr>
<td></td>
<td>Nitrite</td>
</tr>
<tr>
<td>Nitrate</td>
<td></td>
</tr>
<tr>
<td>Nitrite+nitrate</td>
<td>x</td>
</tr>
<tr>
<td>Ammonia</td>
<td>x</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Un-ionized ammonia</td>
<td>x</td>
</tr>
</tbody>
</table>

*Note: x indicates data is available for that period.*
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Contract Period(^a)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17</td>
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<tr>
<td><strong>Phosphate</strong></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total soluble</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble unreactive</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Particulate</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td><strong>Silica</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td><strong>Oil and grease</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
</tr>
<tr>
<td>Total arsenic</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble arsenic</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total barium</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble barium</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total cadmium</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble cadmium</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total chromium</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble chromium</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble copper</td>
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</tr>
<tr>
<td>Iron</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total lead</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble lead</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total manganese</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble manganese</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Total silver</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble silver</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Soluble zinc</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td><strong>Mercury in fish</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td><strong>Ion balance (quarterly)</strong></td>
<td></td>
</tr>
<tr>
<td>Sulfate</td>
<td>x x x x x x x x x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Chloride</td>
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</tr>
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<td>Potassium</td>
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</tr>
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<td>Sodium</td>
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<tr>
<td><strong>Bacteria</strong></td>
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<td>Total coliform</td>
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<td>Fecal coliform</td>
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<td>Fecal streptococcus</td>
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</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td></td>
</tr>
</tbody>
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\(^a\) Contract period.
Table 8. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Contract Perioda</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
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<td>Phosphate</td>
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</tr>
<tr>
<td>Total</td>
<td>X</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>X</td>
</tr>
<tr>
<td>Total soluble</td>
<td></td>
</tr>
<tr>
<td>Soluble unreactive</td>
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</tr>
<tr>
<td>Particulate</td>
<td></td>
</tr>
<tr>
<td>Silica</td>
<td></td>
</tr>
<tr>
<td>Oil and grease</td>
<td>X</td>
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<tr>
<td>Metals</td>
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</tr>
<tr>
<td>Total arsenic</td>
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<tr>
<td>Soluble arsenic</td>
<td>X</td>
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<td>Total barium</td>
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<td>Soluble barium</td>
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<td>Total cadmium</td>
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<td>Soluble chromium</td>
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<td>Iron</td>
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<td>Total lead</td>
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<tr>
<td>Soluble lead</td>
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<td>Total manganese</td>
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<td>Soluble manganese</td>
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<td>Total silver</td>
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</tr>
<tr>
<td>Soluble silver</td>
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</tr>
<tr>
<td>Soluble zinc</td>
<td>X</td>
</tr>
<tr>
<td>Mercury in fish</td>
<td>X</td>
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<tr>
<td>Ion balance (quarterly)</td>
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</tr>
<tr>
<td>Sulfate</td>
<td>X</td>
</tr>
<tr>
<td>Chloride</td>
<td>X</td>
</tr>
<tr>
<td>Potassium</td>
<td>X</td>
</tr>
<tr>
<td>Sodium</td>
<td>X</td>
</tr>
<tr>
<td>Bacteria</td>
<td></td>
</tr>
<tr>
<td>Total coliform</td>
<td>X</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>X</td>
</tr>
<tr>
<td>Fecal streptococcus</td>
<td>X</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>X</td>
</tr>
</tbody>
</table>

b Only on a quarterly basis for ion balance.

c Reduced from monthly to quarterly frequency.

d Analysis with S-H (Smith-Hieftje) background correction.

e Analysis with deuterium background correction.
Table 8. Continued.

| Parameter | | | | | | | | | | | | | | | |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | Contract Period<sup>a</sup> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Algae     | | | | | | | | | | | | | | | |
| Blue-green| x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Flagellates| x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Diatoms   | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Green     | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Total plankton | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Pigments  | | | | | | | | | | | | | | | |
| Chlorophyll<sub>a</sub> | x | x | x | | | | | | | | | | | | | x | x | x | x | x |
| Chlorophyll<sub>b</sub> | x | x | x | | | | | | | | | | | | | x | x | x | x | x |
| Chlorophyll<sub>c</sub> | x | | | | | | | | | | | | | | | x | x | x | x | x |
| Pheophytin<sub>a</sub> | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Corr. chloro<sub>a</sub> | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Benthic organisms | | | | | | | | | | | | | | | |
| No. of organisms | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| No. of species | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Diversity index | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Redundancy index | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Pesticides | | | | | | | | | | | | | | | |
| Water | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Fish (carp, fillets) | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Fish (carp, whole) | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Fish (multispecies, fillets) | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Sediment | x | | | | | | | | | | | | | | | | | | | |
| Transport | | | | | | | | | | | | | | | |
| Sus solids <sup>f</sup> | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NH<sub>4</sub> <sub>3</sub> | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NO<sub>2</sub> + NO<sub>3</sub> <sub>3</sub> | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| T. phosphate transpt | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| T. nitrogen transpt | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |

<sup>f</sup>Nitrite and nitrate were analyzed separately.
Table 8. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Contract Perioda</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Algae</td>
<td></td>
</tr>
<tr>
<td>Blue-green</td>
<td></td>
</tr>
<tr>
<td>Flagellates</td>
<td></td>
</tr>
<tr>
<td>Diatoms</td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>Total plankton</td>
<td></td>
</tr>
<tr>
<td>Pigments</td>
<td></td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>x</td>
</tr>
<tr>
<td>Chlorophyll b</td>
<td>x</td>
</tr>
<tr>
<td>Chlorophyll c</td>
<td>x</td>
</tr>
<tr>
<td>Pheophytin a</td>
<td>x</td>
</tr>
<tr>
<td>Corr. chloro a</td>
<td>x</td>
</tr>
<tr>
<td>Benthic organisms</td>
<td></td>
</tr>
<tr>
<td>No. of organisms</td>
<td></td>
</tr>
<tr>
<td>No. of species</td>
<td></td>
</tr>
<tr>
<td>Diversity index</td>
<td></td>
</tr>
<tr>
<td>Redundancy index</td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Fish (carp, fillets)</td>
<td>x</td>
</tr>
<tr>
<td>Fish (carp, whole)</td>
<td></td>
</tr>
<tr>
<td>Fish (multispecies, fillets)</td>
<td></td>
</tr>
<tr>
<td>Sediment</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td></td>
</tr>
<tr>
<td>Sus solids transp</td>
<td>x</td>
</tr>
<tr>
<td>NH₄ transp</td>
<td>x</td>
</tr>
<tr>
<td>NO₂ + NO₃ transp</td>
<td>x</td>
</tr>
<tr>
<td>T. phosphate</td>
<td>x</td>
</tr>
<tr>
<td>T. nitrogen transp</td>
<td></td>
</tr>
</tbody>
</table>

^gLimited support from ISU.
Table 9. History of the database—additional studies.

<table>
<thead>
<tr>
<th>Contract Period</th>
<th>Additional Studies Supported by Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diurnal studies. Continuous water quality monitoring at Station 1.</td>
</tr>
<tr>
<td>3</td>
<td>Continuous water quality monitoring at Station 1.</td>
</tr>
<tr>
<td>9</td>
<td>Diurnal studies. Profile studies downstream from Des Moines Water Pollution Control Plant.</td>
</tr>
<tr>
<td>10</td>
<td>Profile studies downstream from Des Moines Water Pollution Control Plant.</td>
</tr>
<tr>
<td>11</td>
<td>Transect study at Red Rock Reservoir. EWQOS(^a) supplemental sampling at Red Rock Reservoir.</td>
</tr>
<tr>
<td>12</td>
<td>EWQOS supplemental sampling at Red Rock Reservoir. Transect studies at Red Rock Reservoir. Storm event sampling.</td>
</tr>
<tr>
<td>13</td>
<td>EWQOS primary productivity study at Red Rock Reservoir. Period of record data analysis.</td>
</tr>
<tr>
<td>16</td>
<td>Transect study at Saylorville Reservoir. Gas saturation study and fish kill evaluation downstream from Red Rock Reservoir.</td>
</tr>
<tr>
<td>17</td>
<td>Transect study at Saylorville Reservoir. Gas saturation study at Red Rock Reservoir. Evaluation of bacterial populations at recreational area swimming beaches at both reservoirs.</td>
</tr>
<tr>
<td>18</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas saturation study at Red Rock Reservoir. Calibration of remote-sensing equipment at locations just downstream from each reservoir.</td>
</tr>
<tr>
<td>19</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas saturation study at Red Rock Reservoir. Calibration of remote-sensing equipment at locations just downstream from each reservoir. Imagery transect study at Saylorville Reservoir for remote-sensing applications.</td>
</tr>
<tr>
<td>20</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas saturation study at Red Rock Reservoir. Calibration of remote-sensing equipment at locations just downstream from each reservoir.</td>
</tr>
<tr>
<td>21</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas saturation study at Red Rock Reservoir.</td>
</tr>
<tr>
<td>22</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Two studies of bacterial populations at selected sites along Whitebreast and Compentine creeks. Gas saturation study at Red Rock Reservoir.</td>
</tr>
<tr>
<td>24</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas saturation studies below Saylorville and Red Rock reservoirs.</td>
</tr>
</tbody>
</table>

\(^a\)Supported by Corps of Engineers’ Environmental and Water Quality Operational Studies.
<table>
<thead>
<tr>
<th>Contract Period</th>
<th>Additional Studies Supported by Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas saturation studies below Saylorville and Red Rock reservoirs. Wastewater lagoon study at Wallashuck, North Overlook, and Whitebreast Recreation Areas.</td>
</tr>
<tr>
<td>32–38</td>
<td>Evaluation of bacterial populations at recreational area swimming beaches. Gas supersaturation studies below Saylorville and Red Rock reservoirs. IDNR support of TOC, silica, organic nitrogen, orthophosphate and total phosphate.</td>
</tr>
</tbody>
</table>
5. PARADOX DATABASE: RIVER WATER QUALITY MONITORING (DMRWQN)

All data is maintained on a personal computer as a Paradox data set named DMRWQN (Des Moines River Water Quality Network). This data set consists of five Paradox tables: isudates.db, isuparam.db, isusites.db, isumethods.db, and isudata.db. The first four files are informational files that describe the location of the sampling stations, list the parameter information, assign event numbers to sampling dates, and document the methods of analysis. The last file, isudata.db, contains the individual data records. Table 10 gives the table structure for these four files that comprise the DMRWQN data set.

The data from this contract period have been entered into the DMRWQN data set. There are now 476,794 individual data records in the DMRWQN data set spanning the period from July 6, 1967, through December 5, 2006. This year, additions to the database included results from two special studies at the swimming beaches performed in 2005. This required the addition of 45 sites, as there were nine separate locations at each of four beaches and also nine duplicates. Also, solar radiation averages and peak values since 2004 were added for beach sampling. This required the addition of two new parameters. Wind direction during beach monitoring since 2004 was also included. This year, to facilitate comparative long-term data at the swimming beaches, historical data from original beach sampling protocol using three sites per beach were averaged to obtain one value per beach per sampling. This required the addition of two parameters—260 (fecal coliform, average) and 261 (E. coli, average). Also added to the database was historical gas pressure data collected in 1993 at Stations 0 and 1. And finally, three Carlson Tropic State Indices (TSI) were calculated for historical data and added to the Paradox database. This required the addition of three parameter identifications—TSI (Chlorophyll), TSI (Phosphorus), and TSI (Secchi). The current data set encompasses information from regular sampling locations (many of which have been discontinued), beach sampling locations, and locations used earlier for transect and storm event studies. There are now 261 parameter identifications in the data set. These include physical, chemical, and biological parameters as well as calculated parameters such as transports. There are separate parameter identifications for each medium or target species.

Data was added to the DMRWQN database as soon as verified. Custom Paradox programs were developed to facilitate data entry into DMRWQN and to compile data from DMRWQN for reports. Visual basic programs were written to compile monthly mean data and to compose long-term record summaries. Updated Paradox files were available for download from
the project’s Web site. With this annual report, the updated DMRWQN database is sent to the Corps on CD-ROM.
Table 10. Structure of the five individual Paradox tables in the DMRWQM data set.

a. Paradox table isudates.db structure:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Type</th>
<th>Size</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATES_SAMPLED</td>
<td>D</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>CONT_PERIOD</td>
<td>N</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>WEEK_NUMBER</td>
<td>N</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

b. Paradox table isuparam.db structure:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Type</th>
<th>Size</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARAM_NUM</td>
<td>N</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>PARAM_NAME</td>
<td>A</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>UNITS</td>
<td>A</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>SIG_NO</td>
<td>A</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

c. Paradox table isusites.db structure:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Type</th>
<th>Size</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NO</td>
<td>A</td>
<td>15</td>
<td>*</td>
</tr>
<tr>
<td>SITE_LOCATION</td>
<td>A</td>
<td>200</td>
<td>*</td>
</tr>
</tbody>
</table>

d. Paradox table isumethods.db structure:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Type</th>
<th>Size</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARAMETER</td>
<td>A</td>
<td>60</td>
<td>*</td>
</tr>
<tr>
<td>METHOD</td>
<td>A</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>REFERENCE</td>
<td>A</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>COMMENTS</td>
<td>A</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td>A</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

^aField type: D=date, N=number, A=alpha.
^bField size in characters.
^c* indicates keyed data for sorting.
Table 10. Continued.

e. Paradox table isudata.db structure:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Type a</th>
<th>Size b</th>
<th>Key c</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARAM_NUM</td>
<td>N</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>SITE</td>
<td>A</td>
<td>15</td>
<td>*</td>
</tr>
<tr>
<td>DATE_OF_SAMPLE</td>
<td>D</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>SIGN</td>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SAMPLE_VALUE</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. FIELD OPERATIONS

6.1. Sampling Stations

The 2006 contract specified the use of 13 regular sampling stations as described in Table 3. The locations of these sampling stations are indicated in Fig. 2. Water samples were collected on 22 occasions at most locations, four of which did not involve sampling on Saylorville or Red Rock reservoirs because of seasonal cuts in project scope and ice cover. Station 0 was not used as an alternative site upstream from Saylorville Reservoir this year.

6.2. Sampling Methods

In order to maintain consistency, the method of collecting water samples at the sampling stations has remained essentially the same from year to year. Grab samples of river water were collected in a sampling bucket lowered from a bridge. The sampling bucket used for sample collection was a dissolved oxygen dunker as described in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 2005). The bucket held two BOD bottles that were filled for dissolved oxygen and alkalinity determinations. The bucket was lowered twice to get a sample sufficient for replicates of the two tests. Additional collections with a Nalgene polyethylene pail were used for the remaining tests. Water for bacterial analyses was collected using autoclaveable pitchers, one for each site. Water for metal analyses was collected with the polyethylene pail only.

Stations 4 and 8 are located in Saylorville and Red Rock conservation pools, respectively, and sampling at these stations was primarily conducted from a motorboat. Sites at the reservoirs were not accessed during the winter months when ice covered, as set out in the Scope of Work. At the riverine locations, when ice first began to cover the river, a concrete block was lowered down to break a hole in the ice. When the ice thickness increased, a hole was drilled in the ice with a gasoline-powered auger.

Samples taken from various depths at Saylorville and Red Rock reservoirs were obtained by using a Van Dorn sampler. The Van Dorn water sampler consisted of a polyvinyl chloride cylinder with two rubber end caps attached to a length of rope. After this sampler was lowered to the appropriate depth, a messenger was sent down the rope to trigger the end caps to close, thus capturing a water sample in the cylinder. The sampler had a drain valve that allowed for collection of dissolved oxygen samples without agitation.
All samples not required for field analysis were placed in polyethylene bottles. Sample treatment and preservation methods followed procedures outlined in the contracts and in *Standard Methods* (American Public Health Association 2005). Samples used for ammonia, nitrite plus nitrate, Kjeldahl, and total phosphate were acidified in the field with sulfuric acid. TOC samples were acidified in the field with phosphoric acid. Samples to be used for bacterial counts were placed in sterile, 500-ml bottles. Samples used for metals analyses were placed in large, trace-metal-grade, nitric-acid-washed bottles. Metals bottles were prudently cleaned with detergent, rinsed many times, and bathed in 1:5 trace-metal-grade nitric acid overnight. All samples were transported on ice to the laboratory to slow biological activity. Water samples, especially bacterial samples, were analyzed as soon as possible upon return to the Department of Civil, Construction, and Environmental Engineering’s (CCEE) Environmental Engineering Research Laboratory (EERL).

6.3. Field Analyses

A truck-mounted mobile laboratory was used for travel between stations and as a base for sample collection, analysis, and any other field work. Analyses of several of the least conservative parameters were performed in the mobile laboratory. These parameters included water temperature, pH, carbon dioxide, phenolphthalein alkalinity, total alkalinity, calcium hardness, and total hardness. Dissolved oxygen samples were fixed in the field, water sealed, and then titrated in the laboratory the next day. Secchi disk or transparency tube depths were taken at each site, as appropriate.

6.4. Safety

Riverine water samples were collected from bridges with extreme caution. Emergency flashers and warning beacons on the mobile laboratory were turned on while approaching a bridge. When the truck stopped, field personnel exited from the truck through the back or nontraffic side doors, orange traffic control cones were set out behind the truck, and water samples were collected expediently—usually requiring a stop of only two to five minutes.

Access to the reservoir stations was by motorboat, with at least two field personnel present during the sampling. The boat, a 1990 Spectrum, provided a safe, stable platform for conducting sampling activities. A life preserver was provided for each crew member, and a floatable throw ring also was available. The boat was equipped with a horn and a fire
extinguisher. When sufficient ice covered the riverine stations, access to the sampling stations was by foot, and extreme care was used when crossing over ice. Safety equipment used during winter sampling included life preservers, a floatable throw ring, and thermal emergency blankets. Sampling was not performed in the dark or during extreme storms. In addition, reservoir sampling was not attempted during wind warnings.

The truck-mounted mobile laboratory was equipped with a spare tire and jack, flares, fire extinguisher, first-aid kit, lab spill kit, and eye wash. All field personnel wore safety glasses when working in the laboratory. All reagent containers were labeled with identity and hazard warnings (modified National Firefighters Protection Association ratings) as required by law. Field personnel maintained Material Safety Data Sheets (MSDSs) of all chemicals involved at both the base and mobile laboratories for easy reference. The truck also was equipped with a radio, which was useful for weather updates. In addition, two-way radios were available in the mobile laboratory and sampling boat, and these radios allowed for constant communication between sampling personnel.
7. LABORATORY ANALYSES

7.1. Participating Laboratories

Besides field parameters, all physical, chemical, environmental, and bacteriological analyses were performed by Iowa State’s CCEE EERL. Use of electroshock equipment for the collection of fish for pesticide analyses was coordinated with Dr. Clay Pierce of the Fisheries Ecology and Management section of Iowa State’s Department of Natural Resource Ecology and Management.

7.2. Quality Assurance

The following quality assurance measures were used by the laboratory:

1. Replicate Determinations. Usually one determination was made on each sample, although multiple determinations were normally made for BOD, trace metals, and bacteria analyses.

2. Internal Standardization. All standard solutions and reagents were registered in permanent record books listing the composition, serial number, and date of preparation. Commercially prepared 1,000-mg/l stock solutions were used for most metals during this contract period. Stock solutions and working dilutions prepared from these standards were assigned fixed expiration dates according to written laboratory policy. Storage times ranged from one month for low-range ammonia standards to one year for some heavy-metal stock solutions. A few standard solutions were prepared fresh for each use. All test instruments were standardized each day. As a minimum, standard curves were run before each set of samples. Standard curves were computer-generated by a best-fit procedure. Computer printouts served as documentation for the raw data, the calculated equation, and the deviations of the individual points from the curve. The calibration, maintenance, and performance of all critical equipment are documented in equipment logbooks, on data sheets, or both. All calibrations are traceable to National Institute of Standards and Technology standards.

3. Duplicate Samples. Each week the laboratory analyzed a duplicate sample provided by the field crew. The duplicate sample was collected at a different location each week, and laboratory personnel were not informed of the location until after the analyses were completed and reported. The results were used as a subjective means of evaluating technician performance and the precision of the sampling and analytical techniques. The difference between duplicate
samples was plotted on control charts constructed using ProPlus software, which utilized the Shewhart Method outlined in the *Handbook for Analytical Quality Control in Water and Wastewater*, Environmental Protection Agency (EPA). Depending on the parameter, the control chart was based on the absolute difference or percentage difference between samples. Table 11 summarizes the control charts used and lists the warning and control limits at two and three standard deviations from the mean difference. Results falling outside of the warning limits were monitored as possible indications of problems in test conditions. When possible, the analytical test was redone if the differences fell outside the control limits. Table 12 tabulates the number of samples in each range, the average value, and the absolute difference between duplicate samples and their standard deviations.

4. **External Standardization.** Commercially available quality control standards were analyzed periodically as an independent means of checking the accuracy of the laboratory’s standards.

5. **Spiked Samples.** For most parameters, the laboratory analyzed samples spiked with known additions of analyte with every analytical batch. The percentage of the known addition recovered was plotted on control charts in a manner similar to the duplicate sample data. The warning and control limits used for the percentage recovery of spiked samples are listed in Table 13.

### 7.3. Analytical Methods

Table 14 lists the source and method for the analysis of each parameter included in this report. The reference sources discuss the precision and accuracy of each method. In addition, there is an informational file in the database entitled isumethods.db that details the methods of analysis used during the entire period of record. Most methods have remained fairly stable over the life of the project. The most variable methods were those used for metals, as both techniques and instrumentation changed over time. The current methods are listed in Table 14.
Table 11. Duplicate sample, quality-assurance-control chart information, 2006 contract period.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rangea</th>
<th>Chart Used</th>
<th>Warning Limitb</th>
<th>Control Limitb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (as N)</td>
<td>all</td>
<td>absolute difference</td>
<td>±0.05 mg/l</td>
<td>±0.06 mg/l</td>
</tr>
<tr>
<td>NO₂ + NO₃ (as N)</td>
<td>&lt;10</td>
<td>absolute difference</td>
<td>±0.11 mg/l</td>
<td>±0.14 mg/l</td>
</tr>
<tr>
<td>NO₂ + NO₃ (as N)</td>
<td>&gt;10</td>
<td>absolute difference</td>
<td>±0.83 mg/l</td>
<td>±1.09 mg/l</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>all</td>
<td>absolute difference</td>
<td>±8.7 mg/l</td>
<td>±11.8 mg/l</td>
</tr>
<tr>
<td>Total phosphorus (as P)</td>
<td>all</td>
<td>absolute difference</td>
<td>±0.04 mg/l</td>
<td>±0.06 mg/l</td>
</tr>
<tr>
<td>Orthophosphorus (as P)</td>
<td>all</td>
<td>absolute difference</td>
<td>±0.03 mg/l</td>
<td>±0.04 mg/l</td>
</tr>
<tr>
<td>Kjeldahl nitrogen (as N)</td>
<td>all</td>
<td>absolute difference</td>
<td>±0.23 mg/l</td>
<td>±0.30 mg/l</td>
</tr>
<tr>
<td>TOC</td>
<td>all</td>
<td>absolute difference</td>
<td>±1.31 mg/l</td>
<td>±1.73 mg/l</td>
</tr>
<tr>
<td>Silica</td>
<td>all</td>
<td>absolute difference</td>
<td>±0.41 mg/l</td>
<td>±0.54 mg/l</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>all</td>
<td>absolute difference</td>
<td>±7.6 mg/m³</td>
<td>±10.0 mg/m³</td>
</tr>
</tbody>
</table>

aAll are mg/l, except chlorophyll a, mg/m³.

bHistorical laboratory performance.
Table 12. Analysis of results from duplicate samples collected January 10, 2006, through December 5, 2006.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number of Samples</th>
<th>Range</th>
<th>Average Value</th>
<th>Average Absolute Difference</th>
<th>Standard Deviation</th>
<th>Average Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>22</td>
<td>1–45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.2</td>
<td>5.5</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>22</td>
<td>3–83&lt;sup&gt;b&lt;/sup&gt;</td>
<td>43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Ammonia (as N)</td>
<td>22</td>
<td>&lt;0.01–0.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.01</td>
<td>16.0</td>
</tr>
<tr>
<td>NO&lt;sub&gt;2&lt;/sub&gt; + NO&lt;sub&gt;3&lt;/sub&gt; (as N)</td>
<td>22</td>
<td>&lt;0.01–13.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.06</td>
<td>0.8</td>
</tr>
<tr>
<td>Kjeldahl (as N)</td>
<td>22</td>
<td>0.38–2.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.61</td>
<td>7.8</td>
</tr>
<tr>
<td>Orthophosphorus (as P)</td>
<td>22</td>
<td>&lt;0.01–0.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;0.01</td>
<td>3.7</td>
</tr>
<tr>
<td>Total phosphorus (as P)</td>
<td>22</td>
<td>&lt;0.01–0.25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.06</td>
<td>21.4</td>
</tr>
<tr>
<td>Silica (as SiO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>22</td>
<td>6.79–23.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.11</td>
<td>0.8</td>
</tr>
<tr>
<td>TOC</td>
<td>22</td>
<td>3.5–9.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.0</td>
<td>12.8</td>
</tr>
<tr>
<td>BOD</td>
<td>22</td>
<td>0.9–8.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.5</td>
<td>13.0</td>
</tr>
<tr>
<td>Chlorophyll &lt;i&gt;a&lt;/i&gt;</td>
<td>13</td>
<td>8–176&lt;sup&gt;c&lt;/sup&gt;</td>
<td>77&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Fecal coliform bacteria</td>
<td>12</td>
<td>1–610&lt;sup&gt;d&lt;/sup&gt;</td>
<td>182&lt;sup&gt;d&lt;/sup&gt;</td>
<td>38&lt;sup&gt;d&lt;/sup&gt;</td>
<td>54</td>
<td>21</td>
</tr>
<tr>
<td>&lt;i&gt;Escherichia coli&lt;/i&gt;</td>
<td>12</td>
<td>1–590&lt;sup&gt;d&lt;/sup&gt;</td>
<td>169&lt;sup&gt;d&lt;/sup&gt;</td>
<td>46&lt;sup&gt;d&lt;/sup&gt;</td>
<td>67</td>
<td>27</td>
</tr>
</tbody>
</table>

<sup>a</sup>NTU.  
<sup>b</sup>mg/l.  
<sup>c</sup>mg/m³.  
<sup>d</sup>organisms/100 ml.
Table 13. Spike-recovery, quality-control chart information, 2006 contract period.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Spike Concentration</th>
<th>Mean Recovery</th>
<th>Warning Limit</th>
<th>Control Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (as N)</td>
<td>0.20 mg/l</td>
<td>104%</td>
<td>±24.1%</td>
<td>±36.1%</td>
</tr>
<tr>
<td>NO\textsubscript{2} + NO\textsubscript{3} (as N)</td>
<td>2.00 mg/l</td>
<td>99.5%</td>
<td>±15.0%</td>
<td>±22.6%</td>
</tr>
<tr>
<td>Kjeldahl nitrogen (as N)</td>
<td>2 mg/l</td>
<td>100%</td>
<td>±17.1%</td>
<td>±25.6%</td>
</tr>
<tr>
<td>Total phosphorus (as P)</td>
<td>0.65 mg/l</td>
<td>101%</td>
<td>±19.4%</td>
<td>±29.0%</td>
</tr>
<tr>
<td>Orthophosphorus (as P)</td>
<td>0.06 mg/l</td>
<td>104%</td>
<td>±15.3%</td>
<td>±22.9%</td>
</tr>
<tr>
<td>Silica (as SiO\textsubscript{2})</td>
<td>5.0 mg/l</td>
<td>100%</td>
<td>±6.7%</td>
<td>±10.0%</td>
</tr>
<tr>
<td>Soluble cadmium</td>
<td>250 µg/l</td>
<td>107%</td>
<td>±10.9%</td>
<td>±16.4%</td>
</tr>
<tr>
<td>Soluble copper</td>
<td>250 µg/l</td>
<td>99.5%</td>
<td>±13.3%</td>
<td>±20.0%</td>
</tr>
<tr>
<td>Soluble lead</td>
<td>250 µg/l</td>
<td>101%</td>
<td>±9.9%</td>
<td>±14.9%</td>
</tr>
<tr>
<td>Soluble mercury</td>
<td>0.3 µg/l</td>
<td>104%</td>
<td>±19.6%</td>
<td>±29.4%</td>
</tr>
</tbody>
</table>

\textsuperscript{a} From a check sample the recovery for TOC was 101\% with warning and control limits of ±13.6\% and ±20.4\%, respectively.
Table 14. Methods of analysis of water quality parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Type K digital thermometer or mercury-filled Celsius thermometer, 2550</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Nephelometric method, 2130 B</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>Glass fiber filter dried at 103–105°C, 2540 D</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>Iodometric, Winkler, azide modification, 4500–O C</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Percent saturation of dissolved oxygen</td>
<td>Calculation using solubility constant</td>
<td>Colt</td>
</tr>
<tr>
<td>Biochemical oxygen demand (BOD)</td>
<td>Incubation, 20°C, 5 days, nitrification suppressed, 5210 B</td>
<td>SMEWW</td>
</tr>
<tr>
<td></td>
<td>DO Winkler azide modification, 4500–O C</td>
<td>SMEWW</td>
</tr>
<tr>
<td>pH</td>
<td>Electrometric, 4500–H⁺ B</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Potentiometric titration, 4500–CO₂ C</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Phenolphthalein alkalinity</td>
<td>Potentiometric titration, 2320 B</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>Potentiometric titration, 2320 B</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Total hardness</td>
<td>EDTA titration, 2340 C</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Calcium hardness</td>
<td>EDTA titration, 3500–Ca D</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Total organic carbon (TOC)</td>
<td>Persulfate-UV oxidation, 5310 C</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Ammonia nitrogen</td>
<td>Phenate method, automated, 4500–NH₃ G</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Un-ionized ammonia nitrogen</td>
<td>Ammonia calculation</td>
<td>ERLT</td>
</tr>
<tr>
<td>Nitrite + nitrate nitrogen</td>
<td>Cadmium reduction method, automated, 4500–NO₃⁻ F</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen (TKN)</td>
<td>Semi-automated colorimetry</td>
<td>MGAW, sec. 351.2</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Atomic absorption spectrophotometry</td>
<td>SMEWW</td>
</tr>
<tr>
<td></td>
<td>Direct air–acetylene flame method, 311B</td>
<td>SMEWW</td>
</tr>
<tr>
<td></td>
<td>Nitric acid digestion, 3030E</td>
<td>SMEWW</td>
</tr>
</tbody>
</table>

References:
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Atomic absorption spectrophotometry</td>
<td>SMEWW</td>
</tr>
<tr>
<td></td>
<td>Direct air–acetylene flame method, 311B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitric acid digestion, 3030E</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>Atomic absorption spectrophotometry</td>
<td>SMEWW</td>
</tr>
<tr>
<td></td>
<td>Direct air–acetylene flame method, 311B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitric acid digestion, 3030E</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>Manual cold vapor technique</td>
<td>MGAW, sec. 245.1</td>
</tr>
<tr>
<td>Sulfate</td>
<td>Methylthymol blue, automated, 4500–SO_4^2^- F</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Sodium</td>
<td>Flame emission photometric, 3500–Na</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Potassium</td>
<td>Flame photometric, 3500–K B</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Chloride</td>
<td>4500–Cl^- E</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Total phosphate</td>
<td>Colorimetric, automated, block digester AAII</td>
<td>MGAW, sec. 365.4</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>Automated ascorbic acid reduction, 4500–P F</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Dissolved silica</td>
<td>Automated molybdate reactive, 4500–SiO_2^2 E</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Phytoplankton pigments</td>
<td>Spectrophotometric determination, 10200 H</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Fecal coliform bacteria</td>
<td>Membrane filter, 9222 D</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>Membrane filter, 9222 G</td>
<td>SMEWW</td>
</tr>
<tr>
<td>Pesticides (fish flesh)</td>
<td>Extraction, gas chromatography</td>
<td>AOAC, pp. 466–472, 480–481 FDA, sec. 201–A, 211.1</td>
</tr>
</tbody>
</table>


8. DISCUSSION OF DATA

8.1. Data Presentation

Samples were collected at most stations on 22 occasions during the contract period. In the past, data for Station 1 (Boone) and Station 0 (Stratford) have shown that the water quality at these stations is similar, especially under normal flow conditions. Thus, Station 1 served as the upstream station representing water quality before impoundment. Station 0 was used as the upstream location when Saylorville Reservoir was high enough to inundate Station 1. Sampling was never conducted at Station 0 during this contract period. Samples collected at Station 4 within the Saylorville Reservoir conservation pool are representative of the impounded Des Moines River water. Comparison of the water quality at Station 1 with that of Station 5 represents the influence of Saylorville Reservoir. The water quality at Station 10 on the Raccoon River at Van Meter, Iowa, represents the effects from a drainage basin subject to relatively large variations in flow, as well as water quality, in comparison with the Des Moines River. A composite of data from Stations 5 and 10 represents the water quality of the Des Moines River before the impact of the city of Des Moines and the surrounding drainage area. The order in which the data are presented allows the reader to determine the effects of the city of Des Moines easily by comparing the water quality of the Des Moines River above the city (Station 5) and of the Raccoon River as it entered the city (Station 10) with the quality of the combined Des Moines-Raccoon rivers below the Des Moines Integrated Community Area (ICA) Regional Wastewater Treatment Plant (Station 6). Because of the capacity of the river to assimilate wastes and to recover from their effects, the water quality may improve significantly between Station 6 and Station 7 near Runnells, Iowa, except during extreme low flows. The water quality at Station 7 often may be dramatically affected (especially during storm events) by the input from the small tributaries (North, Middle, and South rivers) that empty into the Des Moines River between Stations 6 and 7. Under maximum flood pool conditions, the Station 7 location may become impounded, lowering water velocity and prompting deposition of suspended material. Station 8 is located within the conservation pool of Red Rock Reservoir. By comparing the water quality at Stations 6, 7, and 8 with Station 9 immediately downstream from the dam, one can determine the effects of the reservoir on water quality.

The discussions of individual parameters found in the following sections are intended to summarize the major trends observed during the study. Table 15 lists the expected concentrations for selected parameters and gives an explanation for observance of extreme values. For
comparison, Table 16 summarizes extreme values observed over the entire period of record for selected parameters. The maximum and minimum concentrations observed for each parameter during this contract period are listed in Table 17. Tabular and graphical presentations of all data collected are presented in Appendix A, which includes several graphs for most parameters. Data tables include the summary statistics mean, minimum, and maximum for each station, as well as the overall mean. For most parameters, results that were greater or lesser than a particular value were set to that value to calculate the statistics. For metals, however, results less than detection limits were not included when calculating these statistics. To aid in comparisons between graphs, all graphs for river stations have the same y-axis range and interval for each parameter. The graphs for reservoir stations may differ in scale from the river stations but are comparable between reservoirs. The first graph for most parameters includes Stations 1, 4S, and 5 to illustrate the effect of Saylorville Reservoir on water quality in the Des Moines River. Graphs of data from Stations 4S and 4B are included to show differences within Saylorville Reservoir and the effects of stratification. Results from Stations 5, 10, and 6 are illustrated in another graph, showing how the Raccoon River and the city of Des Moines influence the water quality in the Des Moines River. A graph of results from Stations 6 and 7 illustrates the effects of the North, Middle, and South rivers. Another graph of data from Stations 8S and 8B illustrates the effect of stratification in Red Rock Reservoir on water quality. Values from Stations 7, 8S, and 9 were often graphed to show the influence of the Red Rock Reservoir on water quality downstream. Not all of these graphs are included for each parameter. For bacteria results, all data estimated as less than or greater than a particular value were graphed as missing values.

Appendix B contains long-term data for most parameters. Data are compiled as tables of the monthly means for the period of record. Summary statistics from monthly and annual means are listed.

8.2. Water Quality Standards and Criteria

8.2.1. Federal

The U.S. Environmental Protection Agency was directed in the Clean Water Act to establish water quality criteria (Federal Register, Chapter 40, Part 131.11) to form the basis for enforceable standards to be developed by the states. These criteria are periodically expanded and updated to reflect the latest scientific knowledge on the identifiable effects of pollutants on public health and welfare, aquatic life, and recreation. The EPA’s ambient water quality criteria were
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Range(^a)</th>
<th>Extreme Minimum(^a)</th>
<th>Extreme Maximum(^a)</th>
<th>Significance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temperature</td>
<td>0–30°C (32–90°F)</td>
<td>-0.4°C (31.6°F)</td>
<td>38°C (100.4°F)</td>
<td>Excessive high temperature or rapid changes in temperature may adversely affect aquatic life; temperature affects metabolisms, chemical reactions and solubilities.</td>
<td>Statification occurs at reservoirs; diurnal warming or effluent inputs may increase temperatures downstream.</td>
</tr>
<tr>
<td>pH</td>
<td>7.5–8.5</td>
<td>6.00</td>
<td>9.90</td>
<td>pH can determine ionic species present and affect toxicity (IA std pH 6-9).</td>
<td>High pH is usually due to excessive algal growth; low pH could be due to cloudy conditions and less photosynthetic activity, precipitation effects or runoff (especially from acid mine drainage).</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0–20 mg/l</td>
<td>0 mg/l</td>
<td>94 mg/l</td>
<td>High CO(_2) is usually due to decomposition of organic matter; moderate levels can be due to respiration especially on cloudy days; low CO(_2) is usually due to algal utilization of CO(_2) as carbon source.</td>
<td>High total alkalinity is seen during low flows due to groundwater inputs; low values are associated with storm events, ice and snowmelt, and algal growth as algal use of CO(_2) raises pH and precipitates calcium carbonate.</td>
</tr>
<tr>
<td>Phenolphthalein alkalinity</td>
<td>0–10 mg/l as CaCO(_3)</td>
<td>0 mg/l as CaCO(_3)</td>
<td>59 mg/l as CaCO(_3)</td>
<td>Alkalinity is an index to the nature of the rocks in a drainage basin and how much they are weathered. Higher alkalinitities are seen with watersheds containing carbonate rock. Alkalinity also defines the buffering capacity.</td>
<td>High values indicate excessive algal growth.</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>200–400 mg/l as CaCO(_3)</td>
<td>67 mg/l as CaCO(_3)</td>
<td>589 mg/l as CaCO(_3)</td>
<td>Alkalinity is an index to the nature of the rocks in a drainage basin and how much they are weathered. Higher alkalinitities are seen with watersheds containing carbonate rock. Alkalinity also defines the buffering capacity.</td>
<td>High total alkalinity is seen during low flows due to groundwater inputs; low values are associated with storm events, ice and snowmelt, and algal growth as algal use of CO(_2) raises pH and precipitates calcium carbonate.</td>
</tr>
<tr>
<td>Calcium hardness</td>
<td>200–300 mg/l as CaCO(_3)</td>
<td>58 mg/l as CaCO(_3)</td>
<td>493 mg/l as CaCO(_3)</td>
<td>Hardness can affect water uses and determine toxicity of metals to aquatic organisms.</td>
<td>Same notes as for total alkalinity.</td>
</tr>
</tbody>
</table>

\(^a\)Based on data from this project and applicable to study area.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Rangea</th>
<th>Extreme Minimuma</th>
<th>Extreme Maximuma</th>
<th>Significance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC</td>
<td>5–15 mg/l</td>
<td>&lt;1 mg/l</td>
<td>341 mg/l</td>
<td>Indicator of organic pollution. Higher the TOC the greater the oxygen demand.</td>
<td>High TOC can indicate wastewater effluent or feedlot runoff; moderate values can be associated with algal growth.</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>6–13 mg/l</td>
<td>0 mg/l</td>
<td>50 mg/l</td>
<td>Adequate dissolved oxygen is required for healthy environments (IA std 5 mg/l).</td>
<td>High D.O. can result from algal production of oxygen under sunny conditions or from air entrapment below dams; low values result from stratification in reservoirs and decomposition of organic matter.</td>
</tr>
<tr>
<td>BOD</td>
<td>1–5 mg/l</td>
<td>&lt;0.1 mg/l</td>
<td>32 mg/l</td>
<td>Oxygen demand lowers DO concentration which can cause oxygen depletion and adversely affect aquatic communities.</td>
<td>High BOD values result from decomposition of organic matter or effluent inputs; low values result from clear water and limited runoff.</td>
</tr>
<tr>
<td>Suspended Solids</td>
<td>5–70 mg/l</td>
<td>&lt;1 mg/l</td>
<td>12,490 mg/l</td>
<td>Solids can increase turbidity and inhibit photosynthesis, disturb behaviors and impair reproduction. Siltation of solids can impair resource.</td>
<td>High suspended solids concentrations are associated with storm events, moderate concentrations can be due to storm events or algal growth, low values result from clear water and limited runoff.</td>
</tr>
<tr>
<td>Turbidity</td>
<td>5–50 NTU</td>
<td>1 NTU</td>
<td>20,000 NTU</td>
<td>Same as above.</td>
<td>Same notes as for suspended solids.</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>0.1–0.5 mg/l</td>
<td>&lt;0.01 mg/l</td>
<td>22.4 mg/l</td>
<td>Ammonia is toxic to aquatic organisms. It also is a nutrient and can contribute to eutrophication (IA std variable).</td>
<td>High ammonia concentrations are due to decomposition of organic matter or presence of effluent; low values result from algal utilization of ammonia for nitrogen source.</td>
</tr>
</tbody>
</table>
Table 15. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Range&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Extreme Minimum&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Extreme Maximum&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Significance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Un-ionized ammonia N</td>
<td>0.001–0.010 mg/l</td>
<td>&lt;0.001 mg/l</td>
<td>1.06 mg/l</td>
<td>The most toxic form.</td>
<td>Same notes as for ammonia.</td>
</tr>
<tr>
<td>Nitrite plus nitrate N</td>
<td>2–8 mg/l</td>
<td>&lt;0.01 mg/l</td>
<td>18.2 mg/l</td>
<td>Nitrite in drinking water can cause methemoglobinemia. As a nutrient, excessive levels can accelerate eutrophication (IA std drinking water 10 mg/l).</td>
<td>High values can result from runoff or subsurface flow from nonpoint sources of fertilizer, from sewage and from feedlot effluents; low values indicate intense algal growth and utilization of nitrate for nitrogen source.</td>
</tr>
<tr>
<td>Organic nitrogen</td>
<td>0.5–2.0 mg/l</td>
<td>&lt;0.01 mg/l</td>
<td>13 mg/l</td>
<td>An indicator of nutrient enrichment of surface waters.</td>
<td>High organic nitrogen concentrations are associated with wastewater discharge, feedlot runoff, or algal blooms.</td>
</tr>
<tr>
<td>Total phosphate</td>
<td>0.2–1.0 mg/l</td>
<td>&lt;0.01 mg/l</td>
<td>17.3 mg/l</td>
<td>Often the most important nutrients controlling plant growth in lakes.</td>
<td>High total phosphate concentrations are usually associated with organic pollution or runoff of fertilizers.</td>
</tr>
<tr>
<td>Chlorophyll&lt;sub&gt;a&lt;/sub&gt; -reservoir -river</td>
<td>5–50 mg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1 mg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>300 mg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Indirect measure of algal biomass.</td>
<td>High pigment concentrations obviously indicate algal blooms; low concentrations are usually due to storm events and dilution.</td>
</tr>
<tr>
<td>Fecal coliform bacteria</td>
<td>10–1,000/100ml</td>
<td>&lt;1/100ml</td>
<td>207,000/100ml</td>
<td>Indicates the probability of contamination by microbial pathogens. (IA std for primary contact is 200 organisms/100ml, in waters not affected by surface runoff).</td>
<td>High FC bacteria indicate contamination either from human sewage or animal waste.</td>
</tr>
</tbody>
</table>
Table 15. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Range(^a)</th>
<th>Extreme Minimum(^a)</th>
<th>Extreme Maximum(^a)</th>
<th>Significance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total gas saturation</td>
<td>95–102%</td>
<td>88%</td>
<td>134%</td>
<td>Measures the amount of atmospheric gas dissolved in water, as compared to ambient air pressure.</td>
<td>High TGP is sometimes seen below dams and can cause gas bubble trauma in aquatic organisms. Intermittent elevated TGP is less lethal and may be a result of algal production of oxygen gas.</td>
</tr>
<tr>
<td>Water quality index</td>
<td>70–85</td>
<td>30</td>
<td>90</td>
<td>A rating based on many different water quality parameters.</td>
<td>WQI is often lowered because of increases in suspended solids, ammonia or nitrate, and decreases in dissolved oxygen; WQI is highest when concentrations are nearest optimum concentrations.</td>
</tr>
<tr>
<td>(DMRWQI)</td>
<td></td>
<td></td>
<td></td>
<td>Excellent 91–100 Good 71–90 Fair 70–51 Bad 50–26 Very bad 25–0</td>
<td></td>
</tr>
</tbody>
</table>
Table 16. Extreme values over the entire period of record for selected parameters, from Paradox data set.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Station</th>
<th>Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>River Flow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Des Moines River</td>
<td>102,000 ft³/s</td>
<td>7</td>
<td>13Jul93</td>
<td>flood event</td>
</tr>
<tr>
<td></td>
<td>56,700 ft³/s</td>
<td>6</td>
<td>19Jun84</td>
<td>pre-1993 maximum</td>
</tr>
<tr>
<td></td>
<td>13 ft³/s</td>
<td>5</td>
<td>25Jan77</td>
<td>drought conditions</td>
</tr>
<tr>
<td>Racoon River</td>
<td>31,500 ft³/s</td>
<td>10</td>
<td>19Jun90</td>
<td>flood event</td>
</tr>
<tr>
<td></td>
<td>30,200 ft³/s</td>
<td>10</td>
<td>13Jul93</td>
<td>flood event</td>
</tr>
<tr>
<td></td>
<td>53 ft³/s</td>
<td>10</td>
<td>12Jan68</td>
<td>drought conditions</td>
</tr>
<tr>
<td><strong>Elevation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saylorville Lake</td>
<td>891.78 ft NGVD</td>
<td>4S</td>
<td>13Jul93</td>
<td>high flow</td>
</tr>
<tr>
<td></td>
<td>888.59 ft NGVD</td>
<td>4S</td>
<td>11Jun91</td>
<td>high flow</td>
</tr>
<tr>
<td></td>
<td>832.61 ft NGVD</td>
<td>4S</td>
<td>17Jan79</td>
<td>low flow</td>
</tr>
<tr>
<td>Lake Red Rock</td>
<td>782.63 ft NGVD</td>
<td>8S</td>
<td>13Jul93</td>
<td>high flow</td>
</tr>
<tr>
<td></td>
<td>779.60 ft NGVD</td>
<td>8S</td>
<td>26Jun84</td>
<td>high flow</td>
</tr>
<tr>
<td></td>
<td>720.00 ft NGVD</td>
<td>8S</td>
<td>08Feb77</td>
<td>drought conditions</td>
</tr>
<tr>
<td><strong>Secchi Disc Depth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saylorville Lake</td>
<td>2.33 m</td>
<td>4S</td>
<td>13Jun84</td>
<td>data available from 1980</td>
</tr>
<tr>
<td></td>
<td>0.10 m</td>
<td>4S</td>
<td>28Apr87</td>
<td></td>
</tr>
<tr>
<td>Lake Red Rock</td>
<td>4.80 m</td>
<td>8S</td>
<td>21Jun84</td>
<td>data available from 1980</td>
</tr>
<tr>
<td></td>
<td>0.06 m</td>
<td>8S</td>
<td>19Jun90</td>
<td></td>
</tr>
<tr>
<td><strong>Transparency</strong></td>
<td>&gt;120 cm</td>
<td>several</td>
<td>periodically</td>
<td>parameter began 2001</td>
</tr>
<tr>
<td>tube depth</td>
<td>1.6 cm</td>
<td>7</td>
<td>12Apr05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.3 cm</td>
<td>10</td>
<td>25May04</td>
<td></td>
</tr>
<tr>
<td><strong>Water temperature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>38.0°C (100.4°F)</td>
<td>6</td>
<td>24Aug71</td>
<td>thermal pollution</td>
</tr>
<tr>
<td></td>
<td>-0.4°C (31.6°F)</td>
<td>7 &amp; 10</td>
<td>10Feb97 &amp; 11Jan00</td>
<td>severe cold</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.90</td>
<td>1</td>
<td>11Dec69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.00</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12Feb71</td>
<td>Station 2 was near Madrid</td>
</tr>
</tbody>
</table>

When two or more values are listed for a maximum or minimum, it means the value and the next highest or lowest unrelated value, or else it lists values attributed to different mechanisms (i.e., point source versus nonpoint source) or ecosystems (i.e., river versus reservoir).

<sup>a</sup>Discontinued parameter or station.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Station</th>
<th>Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>94.0 mg/l</td>
<td>4B</td>
<td>24 Jul 84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>when pH &gt; 8.30</td>
</tr>
<tr>
<td>Phenolphthalein alkalinity</td>
<td>59 mg/l</td>
<td>4-RIVER</td>
<td>11 Dec 69</td>
<td>Station 4-RIVER was near Polk City</td>
</tr>
<tr>
<td></td>
<td>0 mg/l</td>
<td>several</td>
<td>often</td>
<td>when pH &lt; 8.30</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>589 mg/l as CaCO₃</td>
<td>1</td>
<td>18 Jan 77</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>67 mg/l as CaCO₃</td>
<td>7</td>
<td>07 Jul 87</td>
<td>high flow</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>50.08 mg/l</td>
<td>8S</td>
<td>20 Jan 76</td>
<td>376% of saturation (reservoir)</td>
</tr>
<tr>
<td></td>
<td>28.90 mg/l</td>
<td>5</td>
<td>23 Feb 68</td>
<td>203% of saturation (river)</td>
</tr>
<tr>
<td></td>
<td>0.65 mg/l</td>
<td>0</td>
<td>25 Jan 77</td>
<td>4.6% of saturation (river)</td>
</tr>
<tr>
<td></td>
<td>0.00 mg/l</td>
<td>4B</td>
<td>30 Jul 79</td>
<td>0% of saturation (reservoir)</td>
</tr>
<tr>
<td>Calcium hardness</td>
<td>493 mg/l as CaCO₃</td>
<td>5</td>
<td>02 Jan 85</td>
<td>low flow (winter)</td>
</tr>
<tr>
<td></td>
<td>58 mg/l as CaCO₃</td>
<td>1</td>
<td>25 Jul 89</td>
<td>intense productivity</td>
</tr>
<tr>
<td>Total hardness</td>
<td>766 mg/l as CaCO₃</td>
<td>5</td>
<td>02 Jan 85</td>
<td>low flow (winter)</td>
</tr>
<tr>
<td></td>
<td>108 mg/l as CaCO₃</td>
<td>9</td>
<td>30 Aug 77</td>
<td>high flow</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>341 mg/l</td>
<td>10</td>
<td>02 Jun 80</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>&lt;1 mg/l</td>
<td>several</td>
<td>periodically</td>
<td></td>
</tr>
<tr>
<td>Specific conductance</td>
<td>1,827 µmhos/cm</td>
<td>1</td>
<td>18 Jan 77</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>236 µmhos/cm</td>
<td>10</td>
<td>19 Mar 79</td>
<td>high flow</td>
</tr>
<tr>
<td>Inorganic carbon</td>
<td>148 mg/l</td>
<td>1</td>
<td>18 Jan 77</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>13 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>high flow</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>12,490 mg/l</td>
<td>10</td>
<td>30 May 89</td>
<td>high flow (Raccoon River)</td>
</tr>
<tr>
<td></td>
<td>10,200 mg/l</td>
<td>7</td>
<td>06 Jul 82</td>
<td>high flow (Des Moines River)</td>
</tr>
<tr>
<td></td>
<td>&lt;1 mg/l</td>
<td>several</td>
<td>a few</td>
<td>low flow (winter)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Station</td>
<td>Date</td>
<td>Remarks</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Turbidity</td>
<td>20,000 NTU</td>
<td>10</td>
<td>15Jun82</td>
<td>high flow (Raccoon River)</td>
</tr>
<tr>
<td></td>
<td>6,400 NTU</td>
<td>7</td>
<td>06Jul82</td>
<td>high flow (Des Moines River)</td>
</tr>
<tr>
<td></td>
<td>1 NTU</td>
<td>several</td>
<td></td>
<td>ice cover; high elevation</td>
</tr>
<tr>
<td>BOD</td>
<td>32.0 mg/l</td>
<td>6</td>
<td>23Feb77</td>
<td>low flow (waste)</td>
</tr>
<tr>
<td></td>
<td>30.2 mg/l</td>
<td>5</td>
<td>03May68</td>
<td>low flow (plankton)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.1 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>under ice cover</td>
</tr>
<tr>
<td>COD&lt;sup&gt;a&lt;/sup&gt;</td>
<td>553 mg/l</td>
<td>10</td>
<td>16May74</td>
<td>high flow</td>
</tr>
<tr>
<td></td>
<td>0.0 mg/l</td>
<td>5</td>
<td>14Feb69</td>
<td>low flow</td>
</tr>
<tr>
<td>Organic nitrogen</td>
<td>13.0 mg/l</td>
<td>4</td>
<td>12Sep68</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>&lt;0.01 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>–</td>
</tr>
<tr>
<td>Ammonia nitrogen</td>
<td>22.4 mg/l</td>
<td>6</td>
<td>08Feb77</td>
<td>low flow (waste)</td>
</tr>
<tr>
<td></td>
<td>11.9 mg/l</td>
<td>1</td>
<td>01Feb77</td>
<td>low flow (waste)</td>
</tr>
<tr>
<td></td>
<td>4.17 mg/l</td>
<td>6</td>
<td>16Jan90</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>3.65 mg/l</td>
<td>4B</td>
<td>23Jul96</td>
<td>stratification</td>
</tr>
<tr>
<td></td>
<td>&lt;0.01 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>algal utilization</td>
</tr>
<tr>
<td>NO&lt;sub&gt;2&lt;/sub&gt; (as N)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.62 mg/l</td>
<td>3-RIVER&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16Oct68</td>
<td>data from 1967–1976 only</td>
</tr>
<tr>
<td></td>
<td>&lt;0.01 mg/l</td>
<td>many</td>
<td>often</td>
<td>–</td>
</tr>
<tr>
<td>NO&lt;sub&gt;2&lt;/sub&gt; + NO&lt;sub&gt;3&lt;/sub&gt; (as N)</td>
<td>18.2 mg/l</td>
<td>10</td>
<td>18Jun02</td>
<td>flow increase (Raccoon River)</td>
</tr>
<tr>
<td></td>
<td>18.1 mg/l</td>
<td>1</td>
<td>12Jun90</td>
<td>high flow (Des Moines River)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.01 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>low flow, algal utilization</td>
</tr>
<tr>
<td>Un-ionized ammonia (as N)</td>
<td>1.06 mg/l</td>
<td>1</td>
<td>29Mar68</td>
<td>low flow, high pH</td>
</tr>
<tr>
<td></td>
<td>0.742 mg/l</td>
<td>6</td>
<td>25Jan77</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>0.200 mg/l</td>
<td>8B</td>
<td>16Mar81</td>
<td>stratification</td>
</tr>
<tr>
<td></td>
<td>&lt;0.001 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>high flow, low pH</td>
</tr>
<tr>
<td>Total nitrogen (as N)</td>
<td>27.9 mg/l</td>
<td>6</td>
<td>08Feb77</td>
<td>low flow (waste)</td>
</tr>
<tr>
<td></td>
<td>17.2 mg/l</td>
<td>10</td>
<td>26Jun01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.20 mg/l</td>
<td>10</td>
<td>16May01</td>
<td></td>
</tr>
</tbody>
</table>
Table 16. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Station</th>
<th>Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthophosphate</td>
<td>14.7 mg/l</td>
<td>6</td>
<td>08Feb77</td>
<td>low flow (waste)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.03 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>algal utilization</td>
</tr>
<tr>
<td>Total phosphate</td>
<td>17.3 mg/l</td>
<td>6</td>
<td>08Feb77</td>
<td>low flow (waste)</td>
</tr>
<tr>
<td></td>
<td>13.2 mg/l</td>
<td>10</td>
<td>19Mar79</td>
<td>high flow (runoff)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.03 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>low flow</td>
</tr>
<tr>
<td>Dissolved silica (as SiO₂)</td>
<td>59.6 mg/l</td>
<td>9</td>
<td>23Aug72</td>
<td>diatom growth</td>
</tr>
<tr>
<td></td>
<td>50.7 mg/l</td>
<td>5</td>
<td>05Jul68</td>
<td>storm event</td>
</tr>
<tr>
<td></td>
<td>&lt;0.01 mg/l</td>
<td>several</td>
<td>periodically</td>
<td>algal utilization</td>
</tr>
<tr>
<td>Soluble arsenic&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.3 µg/l</td>
<td>5</td>
<td>10Jul90</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>LTDL&lt;sup&gt;b&lt;/sup&gt;</td>
<td>many</td>
<td>10Jul90</td>
<td>often</td>
</tr>
<tr>
<td>Soluble cadmium</td>
<td>6.4 µg/l</td>
<td>5</td>
<td>09Jul91</td>
<td>since May 1988 method change</td>
</tr>
<tr>
<td></td>
<td>LTDL</td>
<td>most</td>
<td>09Jul91</td>
<td>since May 1988 method change</td>
</tr>
<tr>
<td>Soluble chromium&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20 µg/l</td>
<td>1</td>
<td>13Jan87</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>LTDL</td>
<td>many</td>
<td>13Jan87</td>
<td>–</td>
</tr>
<tr>
<td>Soluble copper</td>
<td>72 µg/l</td>
<td>1</td>
<td>11Oct94</td>
<td>initiated in WY91</td>
</tr>
<tr>
<td></td>
<td>LTDL</td>
<td>a few</td>
<td>11Oct94</td>
<td>–</td>
</tr>
<tr>
<td>Soluble lead</td>
<td>22 µg/l</td>
<td>9</td>
<td>05Oct95</td>
<td>since May 1988 method change</td>
</tr>
<tr>
<td></td>
<td>LTDL</td>
<td>most</td>
<td>05Oct95</td>
<td>since May 1988 method change</td>
</tr>
<tr>
<td>Soluble mercury</td>
<td>2.5 µg/l</td>
<td>10</td>
<td>28Apr82</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>LTDL</td>
<td>many</td>
<td>28Apr82</td>
<td>–</td>
</tr>
<tr>
<td>Soluble zinc&lt;sup&gt;a&lt;/sup&gt;</td>
<td>479 µg/l</td>
<td>9</td>
<td>05Oct95</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>LTDL</td>
<td>a few</td>
<td>05Oct95</td>
<td>–</td>
</tr>
<tr>
<td>Chlorophyll &lt;i&gt;a&lt;/i&gt;</td>
<td>880 mg/m³</td>
<td>1</td>
<td>16Nov67</td>
<td>river</td>
</tr>
<tr>
<td></td>
<td>297 mg/m³</td>
<td>3B</td>
<td>25Nov80</td>
<td>reservoir</td>
</tr>
<tr>
<td></td>
<td>0 mg/m³</td>
<td>several</td>
<td>periodically</td>
<td>high flow, turbid</td>
</tr>
</tbody>
</table>

<sup>b</sup>LTDL—less than detection limit.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Station</th>
<th>Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorophyll b</td>
<td>354 mg/m³</td>
<td>4–RIVER</td>
<td>05Jan68</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>90 mg/m³</td>
<td>7</td>
<td>21Jun88</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>0 mg/m³</td>
<td>several</td>
<td>periodically</td>
<td>–</td>
</tr>
<tr>
<td>Chlorophyll c</td>
<td>77 mg/m³</td>
<td>1</td>
<td>24Aug81</td>
<td>river</td>
</tr>
<tr>
<td></td>
<td>64 mg/m³</td>
<td>4S</td>
<td>28Jan80</td>
<td>reservoir</td>
</tr>
<tr>
<td></td>
<td>0 mg/m³</td>
<td>several</td>
<td>periodically</td>
<td>–</td>
</tr>
<tr>
<td>Pheophytin a</td>
<td>264 mg/m³</td>
<td>1</td>
<td>30Mar81</td>
<td>river</td>
</tr>
<tr>
<td></td>
<td>73 mg/m³</td>
<td>3B</td>
<td>22Sep80</td>
<td>reservoir</td>
</tr>
<tr>
<td></td>
<td>0 mg/m³</td>
<td>several</td>
<td>periodically</td>
<td>–</td>
</tr>
<tr>
<td>Fecal coliform bacteria</td>
<td>207,000/100 ml</td>
<td>10</td>
<td>12Sep78</td>
<td>high flow</td>
</tr>
<tr>
<td></td>
<td>200,000/100 ml</td>
<td>6</td>
<td>01Feb77</td>
<td>low flow</td>
</tr>
<tr>
<td></td>
<td>17,000/100 ml</td>
<td>WBB3</td>
<td>23Sep86</td>
<td>beach</td>
</tr>
<tr>
<td></td>
<td>&gt;12,000/100 ml</td>
<td>3B</td>
<td>08Nov77</td>
<td>reservoir</td>
</tr>
<tr>
<td></td>
<td>&lt;1/100 ml</td>
<td>several</td>
<td>periodically</td>
<td>in the reservoirs</td>
</tr>
<tr>
<td>Escherichia coli bacteria</td>
<td>16,700/100 ml</td>
<td>10</td>
<td>15Jun04</td>
<td>began 2001</td>
</tr>
<tr>
<td></td>
<td>4,700/100 ml</td>
<td>SPB</td>
<td>18Aug04</td>
<td>beach</td>
</tr>
<tr>
<td>Total gas saturation</td>
<td>132%</td>
<td>8S</td>
<td>13Aug91</td>
<td>St. 8S began 1988</td>
</tr>
<tr>
<td></td>
<td>88.2%</td>
<td>8S</td>
<td>09Jun88</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>134%</td>
<td>9</td>
<td>24Aug93</td>
<td>St. 9 began 1983</td>
</tr>
<tr>
<td></td>
<td>98.5%</td>
<td>5</td>
<td>11Jan00</td>
<td>St. 5 began 1989</td>
</tr>
<tr>
<td>Nitrogen gas saturation</td>
<td>136%</td>
<td>9</td>
<td>25Apr06</td>
<td>St. 8S began 1988</td>
</tr>
<tr>
<td></td>
<td>61.8%</td>
<td>8S</td>
<td>25Jul00</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>156%</td>
<td>9</td>
<td>06Jun95</td>
<td>St. 9 began 1983</td>
</tr>
<tr>
<td></td>
<td>99%</td>
<td>5</td>
<td>09Dec97</td>
<td>St. 5 began 1989</td>
</tr>
</tbody>
</table>

<sup>c</sup>from Stations 5, 8S and 9 only.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Station</th>
<th>Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSI (chlorophyll)</td>
<td>31</td>
<td>8S</td>
<td>13Feb79</td>
<td>ice cover</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>4S</td>
<td>06Jun89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>86</td>
<td>8S</td>
<td>16May89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>88</td>
<td>4S</td>
<td>17Mar97</td>
<td></td>
</tr>
<tr>
<td>TSI (phosphorus)</td>
<td>31</td>
<td>4S</td>
<td>27Mar02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>53</td>
<td>8S</td>
<td>27Jul99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>93</td>
<td>4S</td>
<td>10Mar80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>114</td>
<td>8S</td>
<td>14Dec76</td>
<td></td>
</tr>
<tr>
<td>TSI (Secchi)</td>
<td>37</td>
<td>8S</td>
<td>21Jun83</td>
<td>high reservoir pool</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>4S</td>
<td>13Jun84</td>
<td>high reservoir pool</td>
</tr>
<tr>
<td></td>
<td>93</td>
<td>4S</td>
<td>28Apr87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>101</td>
<td>8S</td>
<td>19Jun90</td>
<td></td>
</tr>
<tr>
<td>Water quality index</td>
<td>30</td>
<td>7</td>
<td>01Nov83</td>
<td>high suspended solids</td>
</tr>
<tr>
<td></td>
<td>94</td>
<td>4S &amp; 6</td>
<td>27Mar02</td>
<td></td>
</tr>
</tbody>
</table>
Table 17. Maximum and minimum values observed for each parameter for the period January 10, 2006, through December 5, 2006.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum</th>
<th>Station/Date</th>
<th>Minimum</th>
<th>Station/Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>River Flow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Des Moines River</td>
<td>16,600 ft³/s</td>
<td>7/11Apr06</td>
<td>3,980 ft³/s</td>
<td>10/19Sep06</td>
</tr>
<tr>
<td>Raccoon River</td>
<td>289 ft³/s</td>
<td>5/05Dec06</td>
<td>179 ft³/s</td>
<td>10/07Aug06</td>
</tr>
<tr>
<td><strong>Lake Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saylorville Lake</td>
<td>838.97 ft NGVD</td>
<td>4S/22May06</td>
<td>835.29 ft NGVD</td>
<td>4S/26Jun06</td>
</tr>
<tr>
<td>Lake Red Rock</td>
<td>744.61 ft NGVD</td>
<td>8S/10Oct06</td>
<td>742.12 ft NGVD</td>
<td>8S/11Apr06</td>
</tr>
<tr>
<td><strong>Secchi Disc Depth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saylorville Lake</td>
<td>1.02 m</td>
<td>4S/15May06</td>
<td>0.27 m</td>
<td>4S/11Apr06</td>
</tr>
<tr>
<td>Lake Red Rock</td>
<td>1.45 m</td>
<td>8S/07Aug06</td>
<td>0.39 m</td>
<td>8S/19Sep06</td>
</tr>
<tr>
<td><strong>Transparency tube depth</strong></td>
<td>&gt;120 cm</td>
<td>10/07Nov06</td>
<td>3.7 cm</td>
<td>7/14Aug06</td>
</tr>
<tr>
<td><strong>Water temperature</strong></td>
<td>32.5°C</td>
<td>10/17Jul06</td>
<td>−0.1°C</td>
<td>1/05Dec06</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>8.91</td>
<td>10/05Sep06</td>
<td>7.13</td>
<td>8B/07Aug06</td>
</tr>
<tr>
<td><strong>Carbon dioxide</strong></td>
<td>21.4 mg/l</td>
<td>5/26Jun06</td>
<td>0.0 mg/l</td>
<td>Many</td>
</tr>
<tr>
<td>Phenolphthalein alkalinity</td>
<td>14 mg/l as CaCO₃</td>
<td>8S/28Mar06</td>
<td>0 mg/l as CaCO₃</td>
<td>Most</td>
</tr>
<tr>
<td><strong>Total alkalinity</strong></td>
<td>316 mg/l as CaCO₃</td>
<td>10/05Dec06</td>
<td>137 mg/l as CaCO₃</td>
<td>1/17Jul06</td>
</tr>
<tr>
<td><strong>Dissolved oxygen</strong></td>
<td>19.38 mg/l</td>
<td>8S/10Jul06</td>
<td>0.25 mg/l</td>
<td>8B/24Jul06</td>
</tr>
<tr>
<td><strong>D.O. saturation</strong></td>
<td>253% of saturation</td>
<td>8S/10Jul06</td>
<td>3% of saturation</td>
<td>8B/24Jul06</td>
</tr>
<tr>
<td><strong>BOD</strong></td>
<td>10.1 mg/l</td>
<td>8S/10Jul06</td>
<td>0.7 mg/l</td>
<td>5/14Aug06</td>
</tr>
<tr>
<td><strong>Calcium hardness</strong></td>
<td>293 mg/l as CaCO₃</td>
<td>1/14Feb06</td>
<td>83 mg/l as CaCO₃</td>
<td>10/14Aug06</td>
</tr>
<tr>
<td><strong>Total hardness</strong></td>
<td>485 mg/l as CaCO₃</td>
<td>7/10Jan06</td>
<td>184 mg/l as CaCO₃</td>
<td>10/14Aug06</td>
</tr>
<tr>
<td><strong>Turbidity</strong></td>
<td>1,020 NTU</td>
<td>7/14Aug06</td>
<td>1 NTU</td>
<td>Several/10Jan06</td>
</tr>
<tr>
<td><strong>Suspended solids</strong></td>
<td>1,808 mg/l</td>
<td>7/14Aug06</td>
<td>3 mg/l</td>
<td>9/05Dec06</td>
</tr>
<tr>
<td><strong>Ammonia (as N)</strong></td>
<td>0.53 mg/l</td>
<td>8B/05Jun06</td>
<td>0.01 mg/l</td>
<td>Many</td>
</tr>
<tr>
<td><strong>Un-ionized ammonia (as N)</strong></td>
<td>0.032 mg/l</td>
<td>8S/12Jun06</td>
<td>&lt;0.001 mg/l</td>
<td>Several</td>
</tr>
</tbody>
</table>
Table 17.  Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum</th>
<th>Station/Date</th>
<th>Minimum</th>
<th>Station/Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{NO}_2 + \text{NO}_3$ (as N)</td>
<td>16.0 mg/l</td>
<td>10/15May06</td>
<td>&lt;0.01 mg/l</td>
<td>1/A few</td>
</tr>
<tr>
<td>Organic nitrogen (as N)</td>
<td>2.95 mg/l</td>
<td>7/14Aug06</td>
<td>0.28 mg/l</td>
<td>5/14Aug06</td>
</tr>
<tr>
<td>Total nitrogen (as N)</td>
<td>16.9 mg/l</td>
<td>10/15May06</td>
<td>1.20 mg/l</td>
<td>10/07Aug06</td>
</tr>
<tr>
<td>TOC</td>
<td>14 mg/l</td>
<td>4S/05Jun06</td>
<td>3 mg/l</td>
<td>10/22May06</td>
</tr>
<tr>
<td>Dissolved silica (as SiO$_2$)</td>
<td>24.4 mg/l</td>
<td>1/07Aug06</td>
<td>4.70 mg/l</td>
<td>8S/10Jul06</td>
</tr>
<tr>
<td>Total phosphate (as PO$_4$)</td>
<td>4.17 mg/l</td>
<td>7/14Aug06</td>
<td>&lt;0.03 mg/l</td>
<td>5/05Dec06</td>
</tr>
<tr>
<td>Orthophosphate (as PO$_4$)</td>
<td>2.82 mg/l</td>
<td>6/05Sep06</td>
<td>&lt;0.03 mg/l</td>
<td>Many</td>
</tr>
<tr>
<td>Soluble cadmium</td>
<td>LDTLa</td>
<td>–</td>
<td>LDTLa</td>
<td>–</td>
</tr>
<tr>
<td>Soluble copper</td>
<td>7 µg/l</td>
<td>5/22May06</td>
<td>LDTLa</td>
<td>–</td>
</tr>
<tr>
<td>Soluble lead</td>
<td>LDTLa</td>
<td>–</td>
<td>LDTLa</td>
<td>–</td>
</tr>
<tr>
<td>Soluble mercury</td>
<td>0.08 µg/l</td>
<td>6/07Aug06</td>
<td>LDTLa</td>
<td>–</td>
</tr>
<tr>
<td>Chlorophyll $a$</td>
<td>283 mg/m$^3$</td>
<td>1/22Aug06</td>
<td>3 mg/m$^3$</td>
<td>8S/12Jun06</td>
</tr>
<tr>
<td>Chlorophyll $b$</td>
<td>20 mg/m$^3$</td>
<td>10/14Aug06</td>
<td>0 mg/m$^3$</td>
<td>Many</td>
</tr>
<tr>
<td>Chlorophyll $c$</td>
<td>27 mg/m$^3$</td>
<td>10/14Aug06</td>
<td>0 mg/m$^3$</td>
<td>A few</td>
</tr>
<tr>
<td>Pheophytin $a$</td>
<td>39 mg/m$^3$</td>
<td>7/24Jul06</td>
<td>0 mg/m$^3$</td>
<td>A few</td>
</tr>
<tr>
<td>Corrected chlorophyll $a$</td>
<td>256 mg/m$^3$</td>
<td>1/22Aug06</td>
<td>2 mg/m$^3$</td>
<td>8S/14Aug06</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>3,800 /100 ml</td>
<td>7/19Sep06</td>
<td>&lt;1/100 ml</td>
<td>A few</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>3,700 /100 ml</td>
<td>7/19Sep06</td>
<td>&lt;1/100 ml</td>
<td>A few</td>
</tr>
<tr>
<td>Total gas saturation $^b$</td>
<td>131% of saturation</td>
<td>9/25Apr06</td>
<td>90.6% of saturation</td>
<td>8S/19Sep06</td>
</tr>
<tr>
<td>Nitrogen gas saturation $^b$</td>
<td>136% of saturation</td>
<td>9/25Apr06</td>
<td>98% of saturation</td>
<td>8S/10Jul06</td>
</tr>
<tr>
<td>TSI (chlorophyll)</td>
<td>81</td>
<td>8S/10Jul06</td>
<td>41</td>
<td>8S/12Jun06</td>
</tr>
</tbody>
</table>

$^a$LDTLa—less than detection limit.

$^b$ From Stations 5, 8S and 9 only.
Table 17. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum</th>
<th>Station/Date</th>
<th>Minimum</th>
<th>Station/Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSI (phosphorus)</td>
<td>85</td>
<td>8S/19Sep06</td>
<td>47</td>
<td>4S/22May06</td>
</tr>
<tr>
<td>TSI (Secchi)</td>
<td>79</td>
<td>4S/11Apr06</td>
<td>55</td>
<td>8S/22May06</td>
</tr>
<tr>
<td>Water quality index</td>
<td>87</td>
<td>5/14&amp;22Aug06</td>
<td>54</td>
<td>7/14Aug06</td>
</tr>
</tbody>
</table>

Since 2002, EPA’s Water Quality Standards Web site (http://www.epa.gov/ostwater/standards) and Water Quality Criteria Web site (http://www.epa.gov/waterscience/criteria) have been effective transfer tools for this information. The current EPA criteria, along with revised methodology for human health criteria and other comments, were listed in the most recent compilation, entitled Current National Recommended Water Quality Criteria (2006) (http://www.epa.gov/waterscience/criteria/nrwqc-2006.pdf).

In July 2004, the EPA announced the intention to re-evaluate the aquatic life ambient water quality criteria for ammonia to determine whether they should be revised based on new toxicity data for aquatic organisms. In particular, recent studies on freshwater mussels suggest that some mussels may be more sensitive than the aquatic organisms used to determine the current ammonia criteria. A mussel toxicity testing workshop was held in August 2005. For more information, see EPA’s Web site, Ammonia Aquatic Life Criteria Re-Evaluation (http://www.epa.gov/waterscience/criteria/ammonia/index.html).

Revised recommendations for bacteria monitoring at swimming beaches were published by the EPA in the 1986 document Ambient Water Quality Criteria for Bacteria. Enterococci and Escherichia coli were recommended to be the basis for bacterial water quality standards because they are considered to have a higher degree of association with outbreaks of certain diseases than fecal coliforms. The EPA criteria for recreational contact are 33 organisms/100 ml Enterococci or 126 organisms/100 ml Escherichia coli (E. coli). In June 2003, the state of Iowa switched from bacteria standards based on total fecal coliform to E. coli and also divided class “A” waters into classes A1, A2, and A3 (Table 18).

EPA developed nutrient criteria for the nation’s ecoregions that were first published in the Federal Register on January 9, 2001. The appropriate EPA criteria documents for areas in the
Table 18. State of Iowa criteria for *Escherichia coli* (*E. coli*) bacteria in class A waters.

<table>
<thead>
<tr>
<th>Use</th>
<th>Geometric Mean&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Sample Maximum&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/15–11/15</td>
<td>126</td>
<td>235</td>
</tr>
<tr>
<td>11/16–3/14</td>
<td>Does not apply</td>
<td>Does not apply</td>
</tr>
<tr>
<td>Class A2 (Only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/15–11/15</td>
<td>630</td>
<td>2880</td>
</tr>
<tr>
<td>11/16–3/14</td>
<td>Does not apply</td>
<td>Does not apply</td>
</tr>
<tr>
<td>Class A2 and B(CW) or HQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year round</td>
<td>630</td>
<td>2880</td>
</tr>
<tr>
<td>Class A3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/15–11/15</td>
<td>126</td>
<td>235</td>
</tr>
<tr>
<td>11/16–3/14</td>
<td>Does not apply</td>
<td>Does not apply</td>
</tr>
</tbody>
</table>

Class A1—Primary contact recreational use, Class A2—Secondary contact recreational use, Class A3—Children’s recreational use.

<sup>a</sup>Organisms/100 ml.
Des Moines River Water Quality Network are *Ambient Water Quality Criteria Recommendations: Lakes and Reservoirs in Nutrient Ecoregion VI* (EPA 822 B-00-008) and *Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion VI* (EPA 822-B-00-017), which were released in December 2000. EPA has indicated that states should have nutrient water quality standards in place by the end of 2004 (EPA Memorandum WQSP-01-01, November 2001). A Region VII technical advisory group has proposed benchmarks for nutrient parameters. To date, Iowa has not adopted nutrient water quality standards.

In addition to the criteria established by the EPA, the Food and Drug Administration (FDA), under Section 408 of the Federal Food, Drug, and Cosmetic Act, has developed enforceable action limits for pesticide residues in food. Also, the National Academy of Sciences and the National Academy of Engineering in 1972 jointly published guidelines for pesticide and mercury residues in whole fish. In January 2001 the FDA announced an advisory on methylmercury in fish, alerting pregnant women and women of childbearing age of the hazard of eating fish containing high levels of methylmercury. Recently, revised consumption advice was jointly released by the FDA and EPA. The advisory (EPA 2004) emphasizes the positive benefits of eating fish and states the following three recommendations for women and young children to reduce their exposure to the harmful effects of mercury:

- Do not eat shark, swordfish, king mackerel, or tilefish.
- Eat up to 12 ounces (two average meals) a week of a variety of fish and shellfish that are lower in mercury (shrimp, canned light tuna, salmon, pollock, and catfish).
- Check local authorities for safety of fish locally caught. If no advice is available, eat up to six ounces (one meal) per week of fish from local waters, but don’t consume any other fish that week.

More information can be found at the EPA’s fish advisory Web site (http://www.epa.gov/ost/fish).

Since about 40% of the nation’s assessed waters did not meet water quality goals and about half of the 2,000 major watersheds had water quality problems, EPA proposed a plan in April 1998 to enhance and improve water quality criteria and standards programs. The plan, called the “Water Quality Criteria and Standards Plan—Priorities for the Future,” described six new criteria and standards program initiatives for the next decade. These six priority areas were

- maintaining and strengthening the existing “Ambient Water Quality Criteria” for water and sediments
- developing “Nutrient Criteria” and assessment methods to better protect aquatic life and human health
- developing criteria for “Microbial Pathogens” to better protect human health during water recreation
- completing the development of “Biocriteria” as an improved basis for aquatic life protection
- developing improved methods for “TMDLs (total maximum daily loads) and Modeling” to better translate water quality standards into implementable control strategies
- evaluating possible criteria initiatives for “Sedimentation, Flow, and Wildlife”
- ensuring “Implementation of These New Initiatives and Improvements by the EPA in Partnership with States and Tribes”

Work in these six priority areas supported goals of the Clean Water Action Plan and the Government Performance Results Act. Specific planned actions of the EPA that were of specific interest to this study were
- updating methodology for deriving aquatic life criteria
- proposing two to five new or revised aquatic life criteria each year
- publishing a criteria table on the Internet to post updates
- expanding water column aquatic life and human health criteria to include sediment bed criteria
- publishing updated human health criteria for mercury
- proposing three to five human health criteria each year
- establishing nutrient criteria by water body type and ecoregion
- developing improved bacterial indicators of recreational waters
- developing biological assessment methods for all types of waterbodies
- investigating optimal flow criteria to protect waterways from excessive flows and lack of base flows
- investigating the feasibility of developing sedimentation water quality criteria

The EPA revised its strategic plan, which charted its course over the period 2004–2008. Two of its five main goals involve water resources—clean and safe water, and healthy communities and ecosystems. In September 2006, the final Strategic Plan for 2006–2011 was announced. The objective and strategic targeted goals can be found at http://www.epa.gov/water/waterplan/.
In 2002 the National Water Quality Inventory was replaced by an interactive Web-based National Assessment Database (http://epa.gov/waters/reporting). In the past, states prepared water quality reports (305b) and also a prioritized list of waters that were impaired and required pollution controls (303d). Beginning with the 2002 reporting cycle, the EPA urged states to combine these two reporting requirements into one integrated report and to submit their reports electronically. The National Assessment Database is a first step toward more consistent national reporting.

8.2.2. State

The state of Iowa has designated its streams, rivers, lakes, and impoundments into different water-use categories. Class A waters are to be protected for primary contact water use. In 2004, class A waters were split into class A1, primary contact recreational use; class A2, secondary contact recreational use; and class A3, children’s recreational use, in order to assign appropriate bacterial standards. Waters that are designated as class B waters are to be protected for wildlife, fish, aquatic and semiaquatic life, and secondary contact water uses. Class C waters are to be protected as raw water sources for potable water supplies. Water quality standards are then applied to protect the associated water uses (Iowa Administrative Code, Chapter 61, http://www.legis.state.ia.us/ACO/IAChtml/567.htm).

HQ and HQR are designations that are given to surface waters that are specifically protected in the anti-degradation policy. HQ waters possess qualities that are above the state’s criteria. HQR waters possess exceptional qualities but are only held to the state’s water quality standards. In April 1990, the Environmental Protection Commission of the State of Iowa adopted major changes in Chapters 60, 61, and 62 of the Iowa Administrative Code, which involve state surface water designations, surface water quality standards, and effluent quality standards. These changes involved modifications in water-use classifications (the addition of two classes: B [LR] limited resource warm water and B [LW] lakes and wetlands), the formation of acute and chronic state criteria, and an expanded definition of mixing zones and waste load allocations. In November 2004, two new subclasses were added to class B—class B (CW1) waters are protected for the ability to maintain a variety of cold water species, including reproducing and non-reproducing; class B (CW2) includes small, channeled streams, headwaters, and spring runs that possess natural cold water attributes of temperature and flow but do not support consistent populations of trout. In September 2006, major changes were made to make designations more consistent with the Clean Water Act. These amendments
• eliminated the exceptions of the design flow requirements
• revised general use classification
• designated as class B (WW-1) all of Iowa’s perennial rivers and streams as well as intermittent streams with perennial pools
• designated as Class A1 all of Iowa’s perennial rivers and streams as well as intermittent streams with perennial pools

However, designated uses of segments are subject to change based on use attainability analyses (Iowa Administrative Code, Chapter 61, amendments 4504B and 4505B).

Concurrently
• class B (LR) use designation changed from limited resource warm water to warm water-type 2 (class B [WW-2])
• class B (WW) use designation changed from significant resource warm water to warm water-type 1 (class B [WW-1])
• a new designated use entitled warm water-type 3 (class B [WW-3]) was added
• a new designation titled human health (class HH) was added

Previously, in August 1991, August 1992, June 1996, June 2003, and December 2004, revised water use designations for particular streams, river reaches, and lakes were promulgated in the Iowa Administrative Code. In 2006 Stations 1 and 5 were re-assigned to class A1–primary contact water use; in 2004 they had been designated A2–secondary contact recreation use. In addition, all study sites were classified as under the new human health designation, which covers waters in which fish are routinely harvested for human consumption (IDNR 2006). Therefore, all of this project’s sampling sites are currently listed as waters with use designations class A1 (primary contact), class B (WW-1) (warm water significant resource), and class HH (human health). In addition, Station 0, the alternative upstream location on the Des Moines River, and Station 10 on the Raccoon River are located on river segments designated HQR (high quality resource). Also, although not strictly in study areas, the Des Moines River is designated class C (drinking water) near the Des Moines and Ottumwa water works intakes.

In 1999 the Iowa DNR began reviewing Iowa’s water quality standards to identify needed changes. Identified for review were the designation of class A waters and updates to ammonia, lead, mercury, and bacteria standards. In October 2000, the state of Iowa revised the class B water quality standards for ammonia to include acute and chronic values based not only on pH and temperature, but also life stage, and revised the mercury standards to include not only acute and chronic water quality standards, but also two human health standards. In June 2003, the state moved to using *Escherichia coli* as its bacteria indicator species. Also, the state has been
working with others in Region VII to establish nutrient criteria. Other recent issues in the state include reviewing dissolved solids and chloride criteria and designation of cold water uses. In November 2003, Governor Vilsack convened the Iowa Water Summit at Iowa State University. The goal of the summit was to establish a plan to address impaired waters in Iowa.

The Federal Clean Water Act Section 303(d) requires that each state establish a list of impaired waters for which existing required pollution controls are not stringent enough to implement state water quality standards. The state is required to establish TMDLs for waters on the list according to priority ranking. Iowa’s first impaired waters list (1998) was expanded by EPA from 54 waters to 157 waters.

A draft 2002 list identified 158 water bodies as impaired, and although this number is similar to the 1998 listing, the composition of the 2002 list differed significantly. There were 111 waterbodies from the 1998 list that were not on the draft 2002 list, and 113 waterbodies that did not appear on the 1998 list appeared on the draft 2002 list. The addition of these waters was a result of water quality monitoring and assessment activities conducted over the last five years. One third of the impairments removed from the list resulted from Iowa’s “credible data” law. Iowa’s final 2002 list, approved by the EPA, contained 205 waterbodies and 286 impairments. In addition, a separate list of waters that require further investigative monitoring was developed that included 171 waterbodies—including 108 river/stream segments, 23 lakes, and 40 wetlands.

The 2004 list of impaired water was part of IDNR’s “integrated report” activities (IDNR/IGS 2006). There were significant changes in the methodology used between the 2002 and 2004 reporting cycles. The five general categories in the integrated assessment report were as follows:

1. All designated uses are met.
2. Some of the uses are met, but there are insufficient data to determine if all uses are met.
3. There are insufficient data to determine whether any uses are met.
4. The water is impaired, but a TMDL is not needed.
5. The water is impaired, and a TMDL is needed (the Section 303[d] list).

Impaired waters in need of a TMDL were further divided into category 5a (those impaired or threatened by a pollutant stressor) and category 5b (those whose impairment is based on results from biological monitoring or a fish kill investigation where specific causes and/or sources of impairment have not been identified). The EPA-approved 2004 list contained 278 impairments on 225 waterbodies (one waterbody may have several reasons of impairment). This list included 116 waterbodies with 155 impairments categorized as 5a (impaired by pollutant
stressor, TMDL required), 102 waterbodies with 110 impairments categorized as 5b (cause of impairment unknown), and 6 impairments were dual listed as 5a and 5b. Also, there were 88 waterbodies listed for category 4 (water impaired but TMDL not needed), 26 of which are on the list because a TMDL had been established.

In addition, as provided in Iowa’s credible data law, the department maintains a separate list of waters that require further investigative monitoring. Iowa’s 2004 list of waters in need of further investigation includes 101 waterbodies (categories 2b and 3b). If the results of further investigative monitoring demonstrate that a water quality impairment exists, the affected waterbody can be added to Iowa’s impaired waters list. Table 19 lists impaired waters in DMRWQN project areas, and Table 20 lists impaired waters that are adjacent to project locations.

8.2.3. Compilation of Standards and Criteria

National and state water quality criteria and standards are constantly being reviewed, updated, and changed. Applicable state standards, EPA criteria, and FDA action levels for individual parameters are summarized in Table 21. Tables 22 and 23 list the chronic values for the state ammonia nitrogen standards. Tables 24 and 25 list the 1999 revised EPA acute and chronic criteria for ammonia nitrogen. Violations of state standards and/or EPA criteria during this contract period are listed in Table 26.

8.3. Iowa Water Quality

8.3.1. Iowa’s Ambient Water Monitoring Program

The 1999 Water Quality Initiative was the most aggressive step in improving water quality in Iowa since the 1987 Groundwater Protection Act. The initiative provided funds

- to renovate septic systems
- to install farm conservation practices
- to enhance Conservation Reserve Program lands to establish buffer zones
- to conduct long-term water quality monitoring
- to improve water quality planning, standards, and assessment
- to restore or construct wetlands through the Conservation Reserve Enhancement Program
Table 19. Iowa’s 2004 final impaired waters in DMRWQN project areas where TMDL are required, EPA approved.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Waterbody Name</th>
<th>Location</th>
<th>Cause of Impairment</th>
<th>Beneficial Use Impaired</th>
<th>Rationale for 303(d) listing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Moines R. IA 04-UDM-0010_2</td>
<td>Center St. dam in DM to Interstate 80 bridge, Polk Co.</td>
<td>Nitrate</td>
<td>Drinking water</td>
<td>&gt;10% of sample exceed MCL</td>
</tr>
<tr>
<td>Des Moines R. IA 04-LDM-0040_3</td>
<td>From North R. to confluence w/Raccoon R., Polk Co.</td>
<td>Indicator bacteria</td>
<td>Primary contact recreation</td>
<td>Geometric means of indicator bacteria &gt; state water quality standards</td>
</tr>
<tr>
<td>Des Moines R. IA 04-LDM-0040_2</td>
<td>From South R. to confluence w/North R., Polk Co.</td>
<td>Indicator bacteria</td>
<td>Primary contact recreation</td>
<td>Geometric means of indicator bacteria &gt; state water quality standards</td>
</tr>
<tr>
<td>Des Moines R. IA 04-LDM-0040_1</td>
<td>Upper end Red Rock Res. to South R., Warren Co.</td>
<td>Indicator bacteria</td>
<td>Primary contact recreation</td>
<td>Geometric means of indicator bacteria &gt; state water quality standards</td>
</tr>
<tr>
<td>Raccoon R. IA 04-RAC-0010_1</td>
<td>Mouth to Polk/Dallas Co. line</td>
<td>Indicator bacteria</td>
<td>Primary contact</td>
<td>&gt;10% of samples &gt;400 org/100ml</td>
</tr>
<tr>
<td>Raccoon R. IA 04-RAC-0010_2</td>
<td>Polk/Dallas Co. line to confluence of North and South Raccoon R., Dallas Co.</td>
<td>Indicator bacteria</td>
<td>Primary contact</td>
<td>&gt;25% of samples exceed MCL</td>
</tr>
</tbody>
</table>


Note: All Sites listed as Integrated Report category 5a, impaired waters requiring TMDL.
Table 20. Iowa’s 2004 final impaired waters adjacent to DMRWQN project areas where TMDL are required, EPA approved.\(^a\)

<table>
<thead>
<tr>
<th>Waterbody Name</th>
<th>Location</th>
<th>Cause of Impairment</th>
<th>Beneficial Use Impaired</th>
<th>Rationale for 303 (d) listing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yeader Cr. IA 04-LDM-0340_0</td>
<td>Upper end Easter L to headwaters</td>
<td>Priority pollutants, deicing compounds</td>
<td>General uses</td>
<td>Aquatic community in poor condition</td>
</tr>
<tr>
<td>North Raccoon River IA 04-RAC-0040_1</td>
<td>From Buttrick Creek to Short Creek</td>
<td>Indicator bacteria</td>
<td>Primary contact</td>
<td>&gt;10% of samples &gt;400 org/100ml</td>
</tr>
<tr>
<td>North Raccoon River IA 04-RAC-0040_5</td>
<td>From camp Creek to Indian Creek</td>
<td>Indicator bacteria</td>
<td>Primary contact</td>
<td>Geometric means of indicator bacteria &gt; state water quality standards</td>
</tr>
<tr>
<td>North Raccoon River IA 04-RAC-0040_6</td>
<td>From Indian Creek to Cedar Creek</td>
<td>Indicator bacteria</td>
<td>Primary contact</td>
<td>Geometric means of indicator bacteria &gt; state water quality standards</td>
</tr>
<tr>
<td>Middle Raccoon River IA04-RAC-0200-3</td>
<td>From Panora drinking water intake to Lake. Panorama dam Guthrie Co.</td>
<td>Nitrate</td>
<td>Drinking water</td>
<td>Four notices of MCL violations issued by Panora ws (2000-02)</td>
</tr>
<tr>
<td>Roberts Creek Lake IA 04-LDM-00380-L_0</td>
<td>Entire Lake</td>
<td>Turbidity</td>
<td>Primary contact</td>
<td>Aesthetically objectionable conditions</td>
</tr>
<tr>
<td>Whitebreast Creek IA 04-LDM-0200_0</td>
<td>From mouth to Little Whitebreast Creek</td>
<td>Organic enrichment/ Low DO</td>
<td>Aquatic Life</td>
<td>Adverse trend in DO levels</td>
</tr>
<tr>
<td>Des Moines River IA 04-LDM-0020_1</td>
<td>From Soap Creek to Ottumwa dam</td>
<td>Indicator Bacteria</td>
<td>Primary contact</td>
<td>&gt;10% of samples &gt;400 org/100ml</td>
</tr>
</tbody>
</table>


Note: All Sites listed as Integrated Report category 5a, impaired waters requiring TMDL.
## Table 21. Applicable state standards, EPA water quality criteria, FDA action levels, and EPA screening values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard, Criteria, Action Level, or Screening Value(^a)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temperature (Added heat)</td>
<td>State standard class B (WW) No increase &gt;3°C Increase &lt;1°C/hr No increase above 32°C</td>
<td>IAC, p. 12, sec. 61.3(3)b(5)</td>
</tr>
<tr>
<td>pH</td>
<td>State standard classes A, B, and C 6.5–9.0</td>
<td>IAC, pp. 11,13; sec. 61.3(3)a(2); sec. 61.3(3)b(2); and sec. 61.3(3)c(3)</td>
</tr>
<tr>
<td></td>
<td>EPA CCC criteria, freshwater(^b)</td>
<td>“Red Book,” “Gold Book”</td>
</tr>
<tr>
<td></td>
<td>EPA criteria, domestic water supply 6.5–9 5–9</td>
<td>“Gold Book”</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>State standard classes B (WW-1) &gt;5.0 mg/l</td>
<td>IAC, p. 21, Table 2</td>
</tr>
<tr>
<td></td>
<td>EPA criterion, freshwater aquatic life(^c) &gt;5.00 mg/l</td>
<td>“Gold Book,” EPA 1986</td>
</tr>
<tr>
<td>Gases, total saturation</td>
<td>EPA criterion, freshwater aquatic life 110%</td>
<td>“Red Book,” “Gold Book”</td>
</tr>
</tbody>
</table>

\(^a\)Level not to be exceeded, except where noted.

\(^b\)CCC, criteria continuous concentration, highest instream concentration to which organisms can be exposed indefinitely without causing unacceptable effect.

\(^c\)One-day minimum warm water criteria for early life stages.

References:


Table 21. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard, Criteria, Action Level, or Screening Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (as N)</td>
<td>State standard classes B (WW)&lt;sup&gt;d&lt;/sup&gt; EPA criteria, freshwater aquatic life</td>
<td>see Tables 22, 23</td>
</tr>
<tr>
<td>NO₂ (as N)</td>
<td>EPA criterion, domestic water supply</td>
<td>1 mg/l</td>
</tr>
<tr>
<td>NO₂ + NO₃ (as N)</td>
<td>State standard class C EPA criterion, domestic water supply</td>
<td>10.0 mg/l</td>
</tr>
<tr>
<td>Total nitrogen (as N)</td>
<td>EPA Ecoregion VI, subregion WCBP&lt;sup&gt;e&lt;/sup&gt; nutrient criteria lakes and reservoirs</td>
<td>0.963 mg/l</td>
</tr>
<tr>
<td></td>
<td>rivers and streams</td>
<td>2.62 mg/l</td>
</tr>
<tr>
<td>Total phosphorus (as P)</td>
<td>EPA Ecoregion VI, subregion WCBP nutrient criteria lakes and reservoirs</td>
<td>0.06 mg/l</td>
</tr>
<tr>
<td></td>
<td>rivers and streams</td>
<td>0.12 mg/l</td>
</tr>
<tr>
<td>Corrected chlorophyll a</td>
<td>EPA Ecoregion VI, subregion WCBP nutrient criteria lakes and reservoirs</td>
<td>14.6 mg/m³ (µg/l)</td>
</tr>
<tr>
<td></td>
<td>rivers and streams</td>
<td>7.85 mg/m³ (µg/l)</td>
</tr>
<tr>
<td>Turbidity</td>
<td>EPA Ecoregion VI, subregion WCBP nutrient criteria rivers and streams</td>
<td>15 NTU</td>
</tr>
<tr>
<td>Secchi depth</td>
<td>EPA Ecoregion VI, subregion WCBP nutrient criteria lakes and reservoirs</td>
<td>1.23 m</td>
</tr>
</tbody>
</table>

<sup>d</sup>Chronic criteria to be met at all times the flow exceeds low flow (7-day, 10-year).

<sup>e</sup>WCBP—Western Corn Belt Plains.


EPA: December 2000. EPA-822-B-00-008. Ambient Water Quality Criteria Recommendations: Lakes and Reservoirs in Nutrient Ecoregion VI.
### Table 21. Continued.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard, Criteria, Action Level, or Screening Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cadmium</strong></td>
<td>State standard class B (WW-1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>15 µg/l</td>
</tr>
<tr>
<td></td>
<td>State standard class C</td>
<td>5 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA criterion, domestic water supply</td>
<td>5 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA continuous criterion, freshwater&lt;sup&gt;b,f&lt;/sup&gt;</td>
<td>0.48 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA maximum criterion, freshwater&lt;sup&gt;f,g&lt;/sup&gt;</td>
<td>4.9 µg/l</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td>State standard class B (WW-1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>35 µg/l</td>
</tr>
<tr>
<td></td>
<td>State standard class C</td>
<td>1,000 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA CCC criterion, freshwater&lt;sup&gt;b,f&lt;/sup&gt;</td>
<td>19.6 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA CMC criterion, freshwater&lt;sup&gt;f,g&lt;/sup&gt;</td>
<td>31.9 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA criterion, domestic water supply&lt;sup&gt;h&lt;/sup&gt;</td>
<td>1,300 µg/l</td>
</tr>
<tr>
<td><strong>Lead</strong></td>
<td>State standard class B (WW-1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>30 µg/l</td>
</tr>
<tr>
<td></td>
<td>State standard class C</td>
<td>50 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA CCC criterion, freshwater&lt;sup&gt;b,f&lt;/sup&gt;</td>
<td>6.7 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA CMC criterion, freshwater&lt;sup&gt;f,g&lt;/sup&gt;</td>
<td>172 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA criterion, domestic water supply&lt;sup&gt;h&lt;/sup&gt;</td>
<td>15 µg/l</td>
</tr>
</tbody>
</table>

<sup>1</sup>Criteria concentration calculated for waters with hardness of 250 mg/l as CaCO₃; hardness concentrations between 250 and 400 mg/l as CaCO₃ may be used to adjust criteria, as appropriate.

<sup>2</sup>CMC, criteria maximum concentration, highest instream concentration to which organisms can be exposed for a brief period of time without causing an acute effect.

<sup>h</sup>In distribution system.


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard, Criteria, Action Level, or Screening Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury (II)</td>
<td>State chronic standard class B (WW-1)d</td>
<td>2.1 µg/l</td>
</tr>
<tr>
<td></td>
<td>State human health + F (for fish consumption by humans)</td>
<td>0.15 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA CCC criterion, freshwaterb,f</td>
<td>0.77 µg/l</td>
</tr>
<tr>
<td></td>
<td>EPA CMC criterion, freshwaterf,g</td>
<td>1.4 µg/l</td>
</tr>
<tr>
<td>Escherichia coli bacteria</td>
<td>State standard class A</td>
<td>Table 18 126/100 mli</td>
</tr>
<tr>
<td></td>
<td>EPA criterion, recreational bathing</td>
<td></td>
</tr>
<tr>
<td>Mercury in fish flesh</td>
<td>FDA action level for food fish</td>
<td>1.0 ppm as methyl mercury</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.40 ppm/0.049 ppmk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5 ppm</td>
</tr>
<tr>
<td>Dieldrin in fish flesh</td>
<td>FDA action level for food fish</td>
<td>300 ppb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5 ppb/0.31 ppbk</td>
</tr>
<tr>
<td>Heptachlor epoxide in fish flesh</td>
<td>FDA action level for food fish</td>
<td>300 ppb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.39 ppb/0.54 ppbk</td>
</tr>
<tr>
<td>Chlordane in fish flesh</td>
<td>FDA action level for food fish</td>
<td>300 ppb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>114 ppb/14 ppbk</td>
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</tbody>
</table>

iBased on geometric mean of at least five samples over thirty days.

jScreening value for recreational fishers.

kScreening value for subsistence fishers.


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard, Criteria, Action Level, or Screening Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos in fish flesh</td>
<td>EPA screening value (1 in $10^{-5}$ risk)</td>
<td>U.S. EPA 2000, p. 5-11</td>
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1 Applies to total residues of aldrin, BHC, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene, either singly or in combination.


Table 22. Chronic criterion for ammonia in Iowa streams, early life stages present.

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*Note: At 15°C and above, the criterion for fish early life stage (ELS) absent is the same as the criterion for fish ELS present.
Table 24. Temperature and pH-dependent values of the revised EPA (chronic criteria) for ammonia where fish early-life stages are present.a

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bThirty-day average not to be exceeded more than once every three years.
Table 25. Temperature and pH-dependent values of the revised EPA (chronic criteria) for ammonia where fish early-life stages are absent.\textsuperscript{a}

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*Note: At 15°C and above, the criterion for fish ELS absent is the same as the criterion for fish ELS present.


\[\text{bThirty-day average not to be exceeded more than once every three years.}\]
Table 26. Violations of state water quality standards and/or EPA water quality criteria.

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Note: See Table 16 for information on criteria and standards.

\textsuperscript{a}S: surface sample; M: mid-depth sample; B: bottom sample.

\textsuperscript{b}Indicates no sample was taken.

\textsuperscript{c}None of the sampling locations are classified as in class C waters; these data are included for reference only.
| Date       | 1  | 4S\textsuperscript{a} | 4M\textsuperscript{a} | 4B\textsuperscript{a} | 5  | 10 | 6  | 7  | 8S | 8M | 8B | 9  |
|------------|----|-----------------------|------------------------|------------------------|----|----|----|----|----|----|----|----|----|
| 10 Jan 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 121.0 |
| 14 Feb 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 123.3 |
| 07 Mar 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 119.2 |
| 28 Mar 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 120.2 |
| 11 Apr 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 114.7 |
| 25 Apr 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 131.1 |
| 15 May 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 114.5 |
| 22 May 06  |    |                       |                        |                        |    |    |    |    |    |    | 110.6 |    |    | 124.8 |
| 05 Jun 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 124.5 |
| 12 Jun 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 123.4 |
| 26 Jun 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    | 126.9 |
| 10 Jul 06  |    |                       |                        |                        |    |    |    |    |    |    |    | 112.6 |    |    | 122.6 |
| 17 Jul 06  |    |                       |                        |                        |    |    |    |    |    |    |    | 114.5 |    |    | 128.5 |
| 24 Jul 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 125.9 |
| 07 Aug 06  |    |                       |                        |                        |    |    |    |    |    |    | 112.0 |    |    |    |
| 14 Aug 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 124.4 |
| 22 Aug 06  |    |                       |                        |                        |    |    |    |    |    |    | 112.1 |    |    | 124.4 |
| 05 Sep 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 129.9 |
| 19 Sep 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 120.2 |
| 10 Oct 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 127.4 |
| 07 Nov 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 125.1 |
| 05 Dec 06  |    |                       |                        |                        |    |    |    |    |    |    |    |    |    |    | 124.8 |

\textsuperscript{d}Data only collected at Stations 5, 8S, and 9.
Table 26. Continued.

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<td></td>
<td></td>
<td></td>
<td></td>
<td>3,100</td>
<td>2,400</td>
<td>3,700</td>
<td></td>
</tr>
</tbody>
</table>

\(^c\)Stations 1 and 5 are classified as class A2 waters; all other sites are class A1 waters.
• to develop an efficient TMDL program
• to develop floodplain education materials
• to review and issue National Pollution Discharge Elimination System permits
• to improve agricultural input management through education and demonstration programs
• to fund volunteer programs, such as Keepers of the Land, IOWATER, and Adopt-A-Stream
• to update geographic information system data for local watershed use
• to coordinate integrated watershed protection programs

The water monitoring section of the Iowa Department of Natural Resources—Iowa Geological Survey Bureau (IDNR-IGS) is responsible for the design, implementation, and management of the state’s ambient water quality monitoring program. The IDNR-IGS maintains a Web site on Iowa’s water monitoring program (http://wqm.igsb.uiowa.edu/). Data collection was initiated in 2000 at 60 fixed stream locations, 132 recreational lakes, 35 swimming beaches, 10 urban sites, and 175 groundwater wells. In addition, since 1994, the IDNR has used fish and macro invertebrates to assess the biological health of Iowa’s streams and rivers. To date there has not been any biological monitoring conducted on the Des Moines or Raccoon rivers. In 2004 the IDNR added a wetland monitoring component, which included physical, chemical, and biological monitoring. As of 2005, there were 85 ambient stream sites, including monitoring upstream and downstream of 13 cities. Parameters include common water quality parameters and pesticides, which are analyzed monthly, with primary pollutants analyzed three to four times a year. In 2005, 37 state-owned beaches and 29 county/city-owned beaches were monitored for bacteria. A total of 150 municipal wells were monitored for groundwater quality. The groundwater level network was suspended in 2005 due to funding.

The Iowa Lakes Survey of Iowa’s 132 publicly owned lakes is administered by Dr. John Downing and Iowa State University’s Limnology Laboratory. This represented the seventh consecutive year that these sites have been monitored. The Iowa Lake Information System (http://limnology.eeob.iastate.edu/lakereport) lists chemical and physical data, phytoplankton and zooplankton communities, particle size distribution, bathymetric maps, and carbon balance tables. In addition, lakes are classified by morphometry, water quality characteristics, public perception, and economic factors, among others. Also, there are links to relevant studies and research reports.

During 2005 the IDNR and USGS embarked on a pilot program to deploy five real-time water quality probes at USGS gaging sites on Iowa’s streams. In 2004 and 2005 officials from municipalities were trained to collect samples during low flow for a study of statewide total
dissolved solids and chloride concentrations. The data will help shed light on ambient conditions and the potential economic impact of proposed TDS and chloride water quality standards. Also in 2005, the state expanded the algal toxin monitoring to include the 132 publicly-owned lakes, including Corps reservoirs. In 2006, weekly monitoring of cyanobacteria at state-owned beaches was initiated. In 2006, 23 samples exceeded the WHO-recommended guidelines for swimming beaches, and advisories resulted at seven beaches. Beach algae results are reported on the Beach Monitoring Web site (http://wqm.igsb.uiowa.edu/activities/beach/beach.htm).

Beginning in 2000, groundwater monitoring in Iowa was enhanced. In addition to ambient municipal well monitoring, the major aquifers are monitored in a random-selection design. In addition, IDNR is currently cooperating in a five-year study of rural wells. Data from this study will be compared to the statewide Rural Well-Water Survey (SWRL) of the 1980s (IDNR Water Fact Sheet 2007-9).

Also in 2006, IDNR conducted a pilot beach study at three beaches on Coralville Reservoir and Lake McBride to gauge the relative health risks associated with beaches in Iowa. Significant relationships were found in enterococci bacteria level and diarrhea in swimmers at West Overlook Beach at Coralville Reservoir; in enterococci level and skin irritation/rash symptoms in swimmers at Lake McBride Beach; and microcystin toxin level and skin irritation/rash at West Overlook Beach. The enterococci geometric mean levels at West Overlook Beach exceeded the EPA standard (33 organisms/100 ml) 29 times in 17 days, while the Lake McBride Beach exceeded the standard 24 times. Microcystin levels were low (< 1 µg/l), and no visible algal blooms were identified (IDNR Water Fact Sheet 2007-4).

Iowa’s REMAP (Regional Environmental Monitoring Assistance Program) project completed its five-year survey of the ecological status of Iowa’s rivers and streams in 2006. The REMAP project is probabilistically designed to allow conclusions about stream health on a statewide/regional level. Several preliminary highlights follow. The dissolved oxygen and temperature component has helped to understand nutrient enrichment issues in Iowa’s streams. Sampling results have documented a wide range of photosynthetic responses across varying nutrient concentrations. The data suggest that factors such as channel slope, shade, and stream flow greatly influence the degree to which nutrients contribute to excessive algae or plant growth. Also, statewide sampling of stream sediments indicates an inverse relationship between biotic index scores and levels of the metals arsenic, copper, chromium, and lead. Overall, the median index for the biotic integrity of macroinvertebrates from randomized stream sampling in 2003–2004 was 47, a fair rating (IDNR Water Fact Sheet 2007-5).
To handle this complex data set, the IDNR is using the EPA database called STORET (STOrage and RETrieval). Iowa’s STORET database runs on an Oracle™ database platform and is managed by the water monitoring section of the IGS. Data can be retrieved from the Web at http://wqm.igsb.uiowa.edu/iastoret/. Historical data from these Corps water quality studies are now available on STORET.

There are several sites on the fixed stream stations that are of interest to this study. The IDNR-IGS monitored the Des Moines River upstream and downstream from the city of Des Moines and the Raccoon River above the city of Des Moines. These sites correspond to this program’s sampling Stations 5, 6, and 10. A review of the state’s data on STORET showed that the state collected samples within 48–72 hours of when we did during a time without any significant rainfall, which allowed for a rough data comparison (see Table 27). From this table, it is evident that the data is generally comparable. Lake monitoring was also conducted by Iowa State’s Limnology Laboratory as part of the Iowa Lakes Survey, which included monitoring events at Saylorville and Red Rock reservoirs. Data are compared in Tables 28 and 29. It must be noted that the Limnology Laboratory collects integrated samples from the upper mixed zone, while this study collects samples at depths 0.25 m from the surface, mid-depth, and 0.5 m from the bottom. Significant differences were noted in Secchi depth, suspended solids, and chlorophyll concentrations.

8.3.2. Recent Assessments

The EPA requires, by the Clean Water Act Section 305(b), biennial reports of water quality from states. The 305(b) reports are meant to assess the degree to which state waters support intended uses. Recently, these assessments have been included with impaired waters assessments, 303(d) requirements, in an integrated report. The state water quality assessments can be accessed at http://wqm.igsb.uiowa.edu/publications/TOCwaterQualityAssessment.htm. The following assessments of water quality at Saylorville and Red Rock reservoirs are draft comments from IDNR for the next reporting cycle. Table 30 summarizes IDNR’s latest two assessments of water quality along the Des Moines River Water Quality Network.
Table 27. Comparison of data from the DMRWQN and Iowa’s ambient water monitoring programs from the Des Moines and Raccoon rivers on June 5 and June 8, 2006.

<table>
<thead>
<tr>
<th></th>
<th>DMRWQN Station 5</th>
<th>IAWMP&lt;sup&gt;a&lt;/sup&gt; 10770002</th>
<th>DMRWQN Station 6</th>
<th>IAWMP&lt;sup&gt;a&lt;/sup&gt; 10770003</th>
<th>DMRWQN Station 10</th>
<th>IAWMP&lt;sup&gt;a&lt;/sup&gt; 10250002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05Jun06</td>
<td>08Jun06</td>
<td>05Jun06</td>
<td>08Jun06</td>
<td>05Jun06</td>
<td>08Jun06</td>
</tr>
<tr>
<td>Precipitation&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Trace</td>
<td>0.00</td>
<td>Trace</td>
<td>0.00</td>
<td>Trace</td>
<td>0.00</td>
</tr>
<tr>
<td>Sunshine possible&lt;sup&gt;b&lt;/sup&gt;</td>
<td>69%</td>
<td>82%</td>
<td>69%</td>
<td>82%</td>
<td>69%</td>
<td>82%</td>
</tr>
<tr>
<td>Time (CST/CDT)</td>
<td>1125</td>
<td>1040</td>
<td>1445</td>
<td>930</td>
<td>1310</td>
<td>1230</td>
</tr>
<tr>
<td>Flow (ft&lt;sup&gt;3&lt;/sup&gt;/s)</td>
<td>3,830</td>
<td>3,150</td>
<td>5,770</td>
<td>5,400</td>
<td>980</td>
<td>930</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>24.1</td>
<td>24.5</td>
<td>24.3</td>
<td>24.5</td>
<td>24.2</td>
<td>25.5</td>
</tr>
<tr>
<td>pH</td>
<td>7.95</td>
<td>8.30</td>
<td>8.14</td>
<td>8.30</td>
<td>8.42</td>
<td>8.60</td>
</tr>
<tr>
<td>Suspended solids (mg/l)</td>
<td>16</td>
<td>16</td>
<td>45</td>
<td>54</td>
<td>72</td>
<td>76</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>14</td>
<td>10</td>
<td>21</td>
<td>19</td>
<td>27</td>
<td>25</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/l)</td>
<td>9.09</td>
<td>8.4</td>
<td>12.31</td>
<td>7.6</td>
<td>10.04</td>
<td>11.4</td>
</tr>
<tr>
<td>BOD (mg/l)</td>
<td>2.4</td>
<td>ND</td>
<td>5.2</td>
<td>2</td>
<td>3.0</td>
<td>4</td>
</tr>
<tr>
<td>Total hardness (mg/l as CaCO&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>331</td>
<td>350</td>
<td>315</td>
<td>330</td>
<td>271</td>
<td>280</td>
</tr>
<tr>
<td>Ammonia N (mg/l)</td>
<td>0.17</td>
<td>0.14</td>
<td>0.06</td>
<td>ND</td>
<td>0.02</td>
<td>ND</td>
</tr>
<tr>
<td>Kjeldahl nitrogen (mg/l)</td>
<td>1.19</td>
<td>1</td>
<td>1.31</td>
<td>0.9</td>
<td>1.68</td>
<td>1</td>
</tr>
<tr>
<td>Nitrite plus nitrate N (mg/l)</td>
<td>9.36</td>
<td>8.7</td>
<td>10.3</td>
<td>9.6</td>
<td>12.8</td>
<td>13</td>
</tr>
<tr>
<td>Ortho-phosphorus (mg/l)</td>
<td>0.01</td>
<td>0.04</td>
<td>0.04</td>
<td>0.08</td>
<td>&lt;0.01</td>
<td>ND</td>
</tr>
<tr>
<td>Total phosphorus (mg/l)</td>
<td>0.06</td>
<td>0.09</td>
<td>0.19</td>
<td>0.24</td>
<td>0.13</td>
<td>0.14</td>
</tr>
</tbody>
</table>

<sup>a</sup>Iowa’s Ambient Water Monitoring Program data from STORET accessed at [http://wqm.igsb.uiowa.edu/storet/](http://wqm.igsb.uiowa.edu/storet/).

<sup>b</sup>National Weather Service station at Des Moines, Iowa.

ND—Not detected.
<table>
<thead>
<tr>
<th></th>
<th>DMRWQN Station 5</th>
<th>IAWMP Station 10770002</th>
<th>DMRWQN Station 6</th>
<th>IAWMP Station 10770003</th>
<th>DMRWQN Station 10</th>
<th>IAWMP Station 10250002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05Jun06</td>
<td>08Jun06</td>
<td>05Jun06</td>
<td>08Jun06</td>
<td>05Jun06</td>
<td>08Jun06</td>
</tr>
<tr>
<td>Silica (mg/l as SiO$_2$)</td>
<td>11.7</td>
<td>13</td>
<td>12.4</td>
<td>13</td>
<td>14.2</td>
<td>15</td>
</tr>
<tr>
<td>TOC</td>
<td>5</td>
<td>5.2</td>
<td>8</td>
<td>5.6</td>
<td>5</td>
<td>8.1</td>
</tr>
<tr>
<td>Corr chl a (mg/m3)</td>
<td>17</td>
<td>13</td>
<td>61</td>
<td>58</td>
<td>131</td>
<td>76</td>
</tr>
<tr>
<td>E. coli (#/100 ml)</td>
<td>4</td>
<td>10</td>
<td>38</td>
<td>30</td>
<td>44</td>
<td>50</td>
</tr>
</tbody>
</table>
Table 28. Comparison of data from the DMRWQN and Iowa Lakes Survey programs at Saylorville Reservoir for the closest comparative dates in 2006.

<table>
<thead>
<tr>
<th></th>
<th>DMRWQN Station 4S</th>
<th>Iowa Lakes Survey</th>
<th>DMRWQN Station 4S</th>
<th>Iowa Lakes Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date</strong></td>
<td>05Jun06</td>
<td>07Jun06</td>
<td>07Aug06</td>
<td>10Aug06</td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
<td>Trace</td>
<td>0.00</td>
<td>Trace</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Sunshine possible</strong></td>
<td>69%</td>
<td>84%</td>
<td>20%</td>
<td>69%</td>
</tr>
<tr>
<td><strong>Secchi (m)</strong></td>
<td>0.68</td>
<td>0.8</td>
<td>0.83</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Corr. Chlorophyll a</strong> (mg/m³)</td>
<td>18</td>
<td>16.3</td>
<td>27</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Ammonia N</strong> (mg/l as N)</td>
<td>0.10</td>
<td>0.16</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Un-ionized ammonia N</strong> (mg/l as N)</td>
<td>0.006</td>
<td>0.012</td>
<td>0.009</td>
<td>0.091</td>
</tr>
<tr>
<td><strong>Nitrite plus nitrate N</strong> (mg/l as N)</td>
<td>9.53</td>
<td>9.50</td>
<td>2.17</td>
<td>2.19</td>
</tr>
<tr>
<td><strong>Total nitrogen</strong> (mg/l as N)</td>
<td>10.55</td>
<td>10.35</td>
<td>2.93</td>
<td>2.95</td>
</tr>
<tr>
<td><strong>Total phosphorus</strong> (mg/l as P)</td>
<td>0.03</td>
<td>–</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Orthophosphorus</strong> (mg/l as P)</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>0.04</td>
<td>0.068</td>
</tr>
<tr>
<td><strong>Silica</strong> (mg/l as SiO₂)</td>
<td>11.15</td>
<td>–</td>
<td>17.33</td>
<td>–</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>8.08</td>
<td>8.20</td>
<td>8.20</td>
<td>8.10</td>
</tr>
<tr>
<td><strong>Total alkalinity</strong> (mg/l as CaCO₃)</td>
<td>211</td>
<td>213</td>
<td>160</td>
<td>166</td>
</tr>
<tr>
<td><strong>Suspended solids</strong> (mg/l)</td>
<td>6.8</td>
<td>6</td>
<td>45</td>
<td>10</td>
</tr>
</tbody>
</table>


*b* An integrated sample was taken from the upper mixed zone of the lake, at the lake’s maximum depth.

*c* National Weather Service station at Des Moines, Iowa.
Table 28. Continued.

<table>
<thead>
<tr>
<th>Date</th>
<th>DMRWQN Station 4S</th>
<th>ILS\textsuperscript{a,b} Saylorville</th>
<th>DMRWQN Station 4S</th>
<th>ILS\textsuperscript{a,b} Saylorville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05Jun06</td>
<td>07Jun06</td>
<td>07Aug06</td>
<td>10Aug06</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/l)</td>
<td>8.59 (1.2)\textsuperscript{e}</td>
<td>7.1 (~3.0)\textsuperscript{d, e}</td>
<td>6.97 (3.59)\textsuperscript{e}</td>
<td>4.66 (~4.5)\textsuperscript{d, e}</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>24.0 (21.1)\textsuperscript{e}</td>
<td>24.5 (~21.0)\textsuperscript{d, e}</td>
<td>28.3 (27.6)\textsuperscript{e}</td>
<td>26.5 (~27.0)\textsuperscript{d, e}</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>6</td>
<td>19.1</td>
<td>7</td>
<td>20.1</td>
</tr>
</tbody>
</table>

\textsuperscript{d}From YSI meter depth profiles.

\textsuperscript{e}From the bottom depth sample.
Table 29. Comparison of data from the DMRWQN and Iowa Lakes Survey programs at Red Rock Reservoir for the closest comparative dates in 2006.

<table>
<thead>
<tr>
<th></th>
<th>DMRWQN Station 8S</th>
<th>ILSa,b Red Rock</th>
<th>DMRWQN Station 8S</th>
<th>ILSa,b Red Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05Jun06</td>
<td>07Jun06</td>
<td>7Aug06</td>
<td>09Aug06</td>
</tr>
<tr>
<td>Precipitationc</td>
<td>Trace</td>
<td>0.00</td>
<td>Trace</td>
<td>0.05</td>
</tr>
<tr>
<td>Sunshine possiblec</td>
<td>69%</td>
<td>84%</td>
<td>20%</td>
<td>69%</td>
</tr>
<tr>
<td>Secchi (m)</td>
<td>1.06</td>
<td>0.4</td>
<td>1.45</td>
<td>0.8</td>
</tr>
<tr>
<td>Corr. Chlorophyll $a$((mg/m^3))</td>
<td>21</td>
<td>75.1</td>
<td>47</td>
<td>2.6</td>
</tr>
<tr>
<td>Ammonia N (mg/l as N)</td>
<td>0.08</td>
<td>0.03</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Un-ionized ammonia N (mg/l as N)</td>
<td>0.010</td>
<td>0.005</td>
<td>0.011</td>
<td>0.001</td>
</tr>
<tr>
<td>Nitrite plus nitrate N (mg/l as N)</td>
<td>9.16</td>
<td>6.75</td>
<td>2.22</td>
<td>0.11</td>
</tr>
<tr>
<td>Total nitrogen (mg/l as N)</td>
<td>10.29</td>
<td>7.95</td>
<td>3.40</td>
<td>3.31</td>
</tr>
<tr>
<td>Total phosphorus (mg/l as P)</td>
<td>0.08</td>
<td>–</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>Orthophosphorus (mg/l as P)</td>
<td>0.02</td>
<td>0.01</td>
<td>0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>Silica (mg/l as SiO$_2$)</td>
<td>8.59</td>
<td>–</td>
<td>11.66</td>
<td>–</td>
</tr>
<tr>
<td>pH</td>
<td>8.38</td>
<td>8.5</td>
<td>8.73</td>
<td>8.1</td>
</tr>
<tr>
<td>Total alkalinity (mg/l as CaCO$_3$)</td>
<td>193</td>
<td>186</td>
<td>153</td>
<td>162</td>
</tr>
<tr>
<td>Suspended solids (mg/l)</td>
<td>7</td>
<td>23</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>


bAn integrated sample was taken from the upper mixed zone of the lake, at the lake’s maximum depth.

cNational Weather Service station at Des Moines, Iowa.
Table 29. Continued.

<table>
<thead>
<tr>
<th></th>
<th>DMRWQN Station 8S</th>
<th>ILS\textsuperscript{a,b} Red Rock</th>
<th>DMRWQN Station 8S</th>
<th>ILS\textsuperscript{a,b} Red Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05Jun06</td>
<td>07Jun06</td>
<td>07Aug06</td>
<td>09Aug06</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/l)</td>
<td>10.14 (1.10)\textsuperscript{e}</td>
<td>11.3 (~11.0)\textsuperscript{d, e}</td>
<td>12.75 (0.40)\textsuperscript{e}</td>
<td>2.9 (~2.5)\textsuperscript{d, e}</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>24.8 (21.5)\textsuperscript{e}</td>
<td>25.4 (~25.5)\textsuperscript{d, e}</td>
<td>27.7 (25.7)\textsuperscript{e}</td>
<td>26.6 (~27)\textsuperscript{d, e}</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>5</td>
<td>24.5</td>
<td>9</td>
<td>12.1</td>
</tr>
</tbody>
</table>

\textsuperscript{d}From YSI meter depth profiles.

\textsuperscript{e}From the bottom depth sample.
Table 30. Summary of the 2006 (based on data from 2002–2004) and 2004 (based on data from 2000–2002) assessments of water quality along the Des Moines River Water Quality Network by the IDNR for Iowa’s Integrated Report to EPA [Clean Water Act Section 305(b)/303(d) requirement].

<table>
<thead>
<tr>
<th>Location</th>
<th>Class A Primary Contact</th>
<th>Class B (WW) Aquatic Life</th>
<th>Fish Consumption</th>
<th>Class C Drinking Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Moines River—Sayl R to Frazier Dam (St 0, 1)</td>
<td>–</td>
<td>–</td>
<td>FS</td>
<td>FS/T (mercury)</td>
</tr>
<tr>
<td>Saylorville Reservoir—(St 4S)</td>
<td>NS (indicator bacteria)</td>
<td>FS/T (turbidity/algae blooms)</td>
<td>FS</td>
<td>FS/T (DO)</td>
</tr>
<tr>
<td>Des Moines River—I-80/35 to Sayl Dam (St 5)</td>
<td>–</td>
<td>–</td>
<td>FS</td>
<td>FS/T (mercury)</td>
</tr>
<tr>
<td>Des Moines River—Center St to I-80/35</td>
<td>NS (indicator bacteria)</td>
<td>FS</td>
<td>FS</td>
<td>FS/T (mercury)</td>
</tr>
<tr>
<td>Des Moines River—Confluence w/ Raccoon to Center St</td>
<td>–</td>
<td>–</td>
<td>FS</td>
<td>FS/T (mercury)</td>
</tr>
</tbody>
</table>

FS—fully supporting water use (not impaired)
FS/T—fully supporting/threatened water use (minor impacts, not impaired)
PS—partially supporting water use (moderate impacts, impaired)
NS—not supporting water use (severe impacts, impaired)
NA—not assessed

aNot designated for this use during assessment period.
Table 30. Continued.

<table>
<thead>
<tr>
<th>Class A Primary Contact</th>
<th>Class B (WW) Aquatic Life</th>
<th>Fish Consumption</th>
<th>Class C Drinking Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Class B (WW) Aquatic Life</td>
<td>Fish Consumption</td>
<td>Class C Drinking Water</td>
</tr>
<tr>
<td>2006</td>
<td>2004</td>
<td>2006</td>
<td>2004</td>
</tr>
</tbody>
</table>

Raccoon River—Mouth to Polk/Dallas County line (St 10) |
| NS (indicator bacteria) | PS (indicator bacteria) | FS | PS (copper) | FS | FS | NS (Nitrate) | NS (Nitrate) |

Des Moines River—Conf w/ North R to conf w/ Raccoon R (St 6) |
| NS (indicator bacteria) | NS (indicator bacteria) | FS | FS/T (mercury) | FS | FS | – | – |

Des Moines River—Conf w/ South R to conf w/ North R |
| NS (indicator bacteria) | NS (indicator bacteria) | FS | FS/T (ammonia) | NA | NA | – | – |

Des Moines River—Upper Red Rock to conf w/ South R (St 7) |
| NS (indicator bacteria) | NS (indicator bacteria) | FS | FS/T (ammonia) | NA | NA | – | – |

Red Rock Reservoir (St 8S) |
| FS | FS/T (algae blooms) | FS | FS | FS | FS/T (dieldrin) | – | – |

Des Moines River—Conf w/ Cedar R to Red Rock Dam (St 9) |
| FS | FS | NS (fish kills) | NS (fish kills) | FS | FS | – | – |
2006 SUMMARY: Class A (primary contact recreation) uses of the Saylorville Reservoir were assessed (monitored) as “not supported” due to high levels of indicator bacteria at one of the reservoir’s two beaches. The Class B(WW) aquatic life uses are assessed (monitored) as “fully supported” although low levels of dissolved oxygen are a concern. Fish consumption uses were assessed (monitored) as “fully supported” based on ACOE-sponsored annual fish contaminant monitoring from 2002–04. The sources of data for these assessments include (1) the results of water quality monitoring (including fish contaminant monitoring) conducted from 2002 through 2004 at Saylorville Reservoir by Iowa State University under contract with the U.S. Army Corps of Engineers as part of the Des Moines River Water Quality Study, (2) results of the statewide survey of Iowa lakes conducted from 2000 through 2004 by Iowa State University (ISU), (3) information from the IDNR Fisheries Bureau, and (4) information on plankton communities collected from 2000 through 2005 for the ISU lakes survey.

EXPLANATION: Results of water quality monitoring at the ISU/ACOE long-term station on the main reservoir near the dam suggest that the Class A uses should be assessed as “fully supporting.” The geometric mean level of indicator bacteria (E. coli) in the 26 samples collected at this station during the recreational seasons of 2002 through 2004 (4 orgs/100 ml) is well below the Iowa Class A water quality criterion of 126 orgs/100 ml. None of the 26 samples exceeded Iowa’s single-sample maximum value of 235 orgs/100 ml (maximum sample value = 48 orgs/100 ml). Due to recent changes in Iowa’s Water Quality Standards, Iowa’s 2006 assessment methodology for indicator bacteria has changed. Prior to 2003, the Iowa WQ Standards contained a high-flow exemption for the Class A criterion for indicator bacteria (fecal coliforms) designed to protect primary contact recreation uses: the water quality criterion for fecal coliform bacteria (200 orgs/100 ml) did not apply “when the waters [were] materially affected by surface runoff.” Due to a change in the Standards in July 2003, E. coli is now the indicator bacterium, and the high flow exemption was eliminated and replaced with language stating that the Class A criteria for E. coli apply when Class A1, A2, or A3 uses “can reasonably be expected to occur.” Because the IDNR Technical Advisory Committee on WQ Standards could not agree on what flow conditions would define periods when uses would not be reasonably expected to occur, all monitoring data generated for E. coli during the assessment period, regardless of flow or lake level
conditions during sample collection, will be considered for determining support of Class A uses for purposes of the 2006 Section 305(b) assessments and Section 303(d) listings. Results of ACOE beach monitoring from 2002 through 2004, however, suggest an impairment at one of this reservoir’s two beaches. Levels of indicator bacteria at Oak Grove and Sandpiper beaches were monitored approximately three times per month during the primary contact recreation seasons (May through September) of 2002 and 2003 as part of the ACOE/Iowa State University “Des Moines River Water Quality Studies.” This monitoring program began weekly monitoring at the Saylorville beaches in summer 2004. According to IDNR’s assessment methodology, two conditions need to be met for results of beach monitoring to indicate “full support” of the Class A (primary contact recreation) uses: (1) all five-sample, thirty-day geometric means for the three-year assessment period are less than the state’s geometric mean criterion of 126 \( E. coli \) orgs/100 ml and (2) not more than 10% of the samples during any one recreation season exceeds the state’s single-sample maximum value of 235 \( E. coli \) orgs/100 ml. If a 5-sample, 30-day geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A uses should be assessed as “not supported.” Also, if more than 10% of the samples in any one of the three recreation seasons exceed Iowa’s single-sample maximum value of 235 \( E. coli \) orgs/100 ml, the Class A uses should be assessed as “partially supported.” This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

At Oak Grove Beach, the geometric means of all 11 thirty-day periods during the summer recreation seasons of 2002 (3 geometric means), 2003 (4 geometric means), and 2004 (4 geometric means) were below the Iowa water quality standard of 126 orgs/100 ml. Also, none of the 23 samples collected over the three recreation seasons exceeded Iowa’s single-sample maximum criterion of 235 \( E. coli \) orgs/100 ml. According to U.S. EPA guidelines and IDNR’s assessment methodology, these results suggest “full support” of the Class A (primary contact recreation) uses.

At Sandpiper Beach, however, the geometric means for 2 of the 9 thirty-day periods during the summer recreation seasons of 2004 exceeded the Iowa water quality standard of 126 \( E. coli \) orgs/100 ml. None of the geometric means exceeded this standard during the recreational seasons of 2002 (3 geometric means) [or] 2004 (4 geometric means). According to IDNR’s assessment methodology and U.S. EPA guidelines, the occurrence of geometric mean values above Iowa’s Class A criterion suggests impairment (nonsupport) of the Class A (primary contact recreation) uses.
Results from the ISU statewide survey of Iowa lakes from 2000–04 suggest full support of the Class A uses of Saylorville Reservoir. Using the median values from this survey from 2000 through 2004 (approximately 15 samples), Carlson’s (1977) Trophic State Indices for total phosphorus, chlorophyll-a, and Secchi depth are 75, 52, and 62, respectively. According to Carlson (1977), the index value for total phosphorus places this reservoir in the range of hyper-eutrophic lakes; the index value for chlorophyll-a, however, is in the lower range of eutrophic lakes, and the value for Secchi depth is in the lower range between eutrophic and hyper-eutrophic lakes. These index values suggest (1) very high levels of phosphorus in the water column, (2) very low (and much lower than expected) levels of chlorophyll-a, and production of suspended algae, and (3) relatively good water transparency.

According to Carlson (1991), the occurrence of a low chlorophyll-a TSI value relative to those for total phosphorus and Secchi depth indicate non-algal particles or color dominate light attenuation. The ISU lake data suggest that non-algal particles do likely limit algal production at Saylorville Reservoir. The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey from 2000 through 2004 was 5.2 mg/l. Of 131 lakes sampled, Saylorville Reservoir has the 46th highest median level of inorganic suspended solids (6.7 mg/l), thus suggesting that non-algal turbidity likely limits the production of algae as well as contributes to in-lake turbidity. The median level of chlorophyll-a at Saylorville Reservoir is very low (20th lowest of the 131 lakes sampled) and does not suggest either threats or impairments to support of designated uses at this lake. Based on median values from ISU sampling from 2000–04, the ratio of total nitrogen to total phosphorus for this lake is 75; this ratio suggests that algal production at this lake is limited by the availability of phosphorus as opposed to nitrogen availability. The 2000–04 median concentration of total nitrogen at this reservoir (10.4 mg/l) was the seventh highest of the 131 lakes sampled.

In terms of all Iowa lakes sampled, data from the ISU survey show only moderately large populations of zooplankton species at this lake that graze on algae. Although sampling from 2000 through 2005 showed that Cladoceran taxa (e.g., Daphnia) comprised about 80% of the dry mass of the zooplankton community of this lake (the highest percentage composition of any of the 131 lakes sampled), the average per summer sample mass of Cladoceran taxa over the 2000–2005 period (95 mg/l) was only the 63rd highest of the 131 lakes sampled. These results suggest little if any non-phosphorus limitation due to zooplankton grazing at Saylorville Reservoir.
The moderately high level of inorganic suspended solids at this lake remains the most likely non-phosphorus limitation to algal production. The levels of nuisance (=noxious) algal species (i.e., bluegreen algae) at this lake do not suggest an impairment of Class A uses. While data from the ISU survey from 2000 through 2004 suggest that bluegreen algae (Cyanophyta) comprise a significant portion (approximately 60%) of this lake’s summertime phytoplankton community, sampling from 2000 through 2004 showed that the median per summer sample mass of bluegreen algae at Saylorville Lake (2.8 mg/l) was the 16th lowest of the 131 lakes sampled. This level is in the lowest 10% of the 131 Iowa lakes sampled. The presence of a relatively small population of bluegreen algae at this lake does not suggest a potential violation of Iowa’s narrative water quality standard protecting against occurrence of nuisance aquatic life. This assessment, however, is based strictly on a distribution of the lake-specific median bluegreen algae values for the 2000–2004 monitoring period. Median levels less than the 75th percentile of this distribution (~29 mg/l) were arbitrarily considered by IDNR staff to not represent an impairment of the Class A uses of Iowa lakes. No criteria exist upon which to base a more accurate identification of impairments due to bluegreen algae. Thus, while the ability to characterize the levels of bluegreen algae at this lake has improved over that of the previous (2004) assessment due to collection of additional data, the assessment category for assessments based on level of bluegreen algae nonetheless remains, of necessity, “evaluated” (indicating an assessment with relatively lower confidence) as opposed to “monitored” (indicating an assessment with relatively higher confidence). Results of ISU/ACOE monitoring, however, do suggest that blooms of bluegreen algae occasionally occur at Saylorville Reservoir. According to the ISU/ACOE annual monitoring reports (e.g., Lutz and Esser 2002, Lutz and Cummings 2003, Lutz 2004, and Lutz et al. 2005), blooms of bluegreen algae typically occur during July and August, especially under elevated pool conditions. These reports contain a summary of when these blooms have occurred at Saylorville Lake since 1990. The occurrence of bluegreen blooms from June to September 2001, in July 2002, and in June 2004 suggests a concern regarding the full support of Class A uses at this reservoir (no algal blooms were observed in 2003).

The Class B(WW) aquatic life uses of the reservoir were assessed as “fully supported.” None of the 52 samples collected during the 2002–2004 period as part of ISU/ACOE monitoring violated Class B(WW) criteria for pH or ammonia-nitrogen. Seven of the 52 samples (14%) violated the Class B(WW) criterion for dissolved oxygen: all these
violations occurred in late summer and all were relatively minor (all were greater than 4 mg/l). Based on IDNR’s assessment methodology, however, these results do not suggest that significantly more than 10 percent of the samples exceed Iowa’s dissolved oxygen criteria and thus do not suggest an impairment of the Class B(LW) uses of Saylorville Lake.

Similarly, the ISU lake survey data for chemical water quality of Saylorville Reservoir suggest “full support” of the Class B(WW) uses. While none of the approximately 14 samples violated Class B(WW) criteria for pH or ammonia, three of 15 samples (21%) collected from 2000–2004 did violate the Class B(WW) criteria for dissolved oxygen. These violations ranged from 3.8 to 4.7 mg/l; all violations occurred in the period from late July through August. Based on IDNR’s assessment methodology, however, these results do not suggest that significantly more than 10 percent of the samples exceed Iowa’s dissolved oxygen criteria and thus do not suggest an impairment of the Class B(LW) uses of Saylorville Lake.

Fish consumption uses were assessed (monitored) as “fully supported” based on results of ACOE/ISU fish contaminant monitoring at Saylorville Reservoir in 2002, 2003, and 2004. The composite samples of whole-fish common carp had low levels of contaminants (the ACOE/ISU samples are not analyzed for mercury or PCBs). Levels of total chlordane in the composite samples were as follows: 2002: 29.8 ppb; 2003: 4.4 ppb; 2004: 2.4 ppb. None of these levels approach the new (2006) advisory trigger level of 600 ppb for chlordane. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of the degree to which Iowa’s lakes and rivers support their fish consumption uses. Prior to 2006, IDNR used action levels published by the U.S Food and Drug Administration to determine whether consumption advisories should be issued for fish caught as part of recreational fishing in Iowa. In an effort to make Iowa’s consumption more compatible with the various protocols used by adjacent states, the Iowa Department of Public Health, in cooperation with Iowa DNR, developed a risk-based advisory protocol. This protocol went into effect in January 2006 (see http://www.iowadnr.gov/fish/news/consump.html for more information on Iowa’s revised fish consumption advisory protocol). Because the revised (2006) protocol is more restrictive than the previous protocol based on FDA action levels, fish contaminant data that previously suggested “full support” may now suggest either a threat to, or impairment of, fish consumption uses. This scenario, however, does not apply to the fish contaminant data generated from the ACOE/ISU fish contaminant sampling conducted at
Saylorville Reservoir: the levels of contaminants do not exceed any of the new (2006) advisory trigger levels, thus indicating no justification for issuance of a consumption advisory for this waterbody.

2004 SUMMARY: Class A (primary contact recreation) uses of Saylorville Reservoir were assessed (monitored) as “fully supported/threatened” due to slight reductions in water transparency caused by moderately high levels of inorganic turbidity and due to presence of blooms of bluegreen algae (noxious aquatic plants) in summers of 2001 and 2002. The primary contact recreation uses at the reservoir’s two beaches, as measured by levels of indicator bacteria, however, remain assessed (monitored) as “fully supported.” The overall assessment of Class A uses for the reservoir is thus “fully supported/threatened.” The Class B(WW) aquatic life uses are assessed (monitored) as “fully supported/threatened” due to (1) slight reductions in water transparency and (2) the occurrence of several violations of the Iowa water quality standard for dissolved oxygen. Fish consumption uses remain assessed (monitored) as “fully supported” based on ACOE-sponsored fish contaminant monitoring from 2000–02. The sources of data for these assessments include (1) the results of water quality monitoring conducted from 2000 through 2002 at Saylorville Reservoir by Iowa State University under contract with the U.S. Army Corps of Engineers as part of the Des Moines River Water Quality Study, (2) results of the statewide survey of Iowa lakes conducted from 2000 through 2002 by Iowa State University (ISU/Limnology), (3) information from the IDNR Fisheries Bureau, and (4) information on plankton communities at Iowa lakes in 2000 from Downing et al. (2002).

Red Rock Reservoir

2006 SUMMARY: Class A (primary contact recreation) uses of the Red Rock Reservoir were assessed (evaluated) as “fully supported” although occasional blooms of algae during summer months remains a concern. The primary contact recreation uses at the reservoir’s two beaches remain assessed (monitored) as fully supported. The overall assessment of Class A uses for the reservoir is thus “fully supported.” The Class B(WW) aquatic life uses are assessed (monitored) as “fully supported.” Fish consumption uses were assessed (monitored) as “fully supported” based on ACOE-sponsored annual fish contaminant monitoring from 2002–04. The sources of data for these assessments include (1) the results of water quality monitoring (including fish contaminant monitoring) conducted from 2002 through 2004 at Red Rock Reservoir by Iowa State University under contract with the U.S. Army Corps of Engineers as part of the Des Moines River
Water Quality Study, (2) results of the statewide survey of Iowa lakes conducted from 2000 through 2004 by Iowa State University (ISU), (3) information from the IDNR Fisheries Bureau, and (4) information on plankton communities collected from 2000 through 2005 for the ISU lakes survey.

EXPLANATION: Results of water quality monitoring at the ISU/ACOE long-term station on the main reservoir near the dam suggest that the Class A uses should be assessed (monitored) as “fully supporting.” The geometric mean level of indicator bacteria (*E. coli*) in the 25 samples collected at this station during the recreational seasons of 2002 through 2004 (5 orgs/100 ml) is well below the Iowa Class A water quality criterion of 126 orgs/100 ml. None of the 25 samples exceeded Iowa’s single-sample maximum value of 235 orgs/100 ml (maximum sample value = 43 orgs/100 ml). Due to recent changes in Iowa’s Water Quality Standards, Iowa’s 2006 assessment methodology for indicator bacteria has changed. Prior to 2003, the Iowa WQ Standards contained a high-flow exemption for the Class A criterion for indicator bacteria (fecal coliforms) designed to protect primary contact recreation uses: the water quality criterion for fecal coliform bacteria (200 orgs/100 ml) did not apply “when the waters [were] materially affected by surface runoff.” Due to a change in the Standards in July 2003, *E. coli* is now the indicator bacterium, and the high flow exemption was eliminated and replaced with language stating that the Class A criteria for *E. coli* apply when Class A1, A2, or A3 uses “can reasonably be expected to occur.” Because the IDNR Technical Advisory Committee on WQ Standards could not agree on what flow conditions would define periods when uses would not be reasonably expected to occur, all monitoring data generated for *E. coli* during the assessment period, regardless of flow or lake level conditions during sample collection, will be considered for determining support of Class A uses for purposes of the 2006 Section 305(b) assessments and Section 303(d) listings. Similarly, results of ACOE beach monitoring from 2002 through 2004 at North Overlook and White Breast beaches also suggest that the Class A uses are “fully supported.” Levels of indicator bacteria at North Overlook and White Breast beaches were monitored approximately three times per month during the primary contact recreation seasons (May through September) of 2002 and 2003 as part of the ACOE/Iowa State University “Des Moines River Water Quality Studies.” This monitoring program began weekly monitoring at the Red Rock beaches in summer 2004. According to IDNR’s assessment methodology, two conditions need to be met for results of beach monitoring to indicate “full support” of the Class A (primary contact recreation) uses: (1) all five-sample, thirty-
day geometric means for the three-year assessment period are less than the state’s geometric mean criterion of 126 \( E. \ coli \) orgs/100 ml and (2) not more than 10% of the samples during any one recreation season exceeds the state’s single-sample maximum value of 235 \( E. \ coli \) orgs/100 ml. This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

At North Overlook Beach, the geometric means of all 23 thirty-day periods during the summer recreation seasons of 2002 (3 geometric means), 2003 (4 geometric means), and 2004 (16 geometric means) were below the Iowa water quality standard of 126 orgs/100 ml. Also, the percentage of samples exceeding Iowa’s single-sample maximum criterion did not exceed 10% in any of the three recreation seasons (2002: 0%; 2003: 0%; 2004: 10%). According to U.S. EPA guidelines and IDNR’s assessment methodology, these results suggest “full support” of the Class A (primary contact recreation) uses.

Similarly, at White Breast Beach, the geometric means of all 23 thirty-day periods during the summer recreation seasons of 2002 (3 geometric means), 2003 (4 geometric means), and 2004 (16 geometric means) were below the Iowa water quality standard of 126 orgs/100 ml. Also, the percentage of samples exceeding Iowa’s single-sample maximum criterion did not exceed 10% in any of the three recreation seasons (2002: 0%; 2003: 0%; 2004: 5%). According to U.S. EPA guidelines and IDNR’s assessment methodology, these results suggest “full support” of the Class A (primary contact recreation) uses.

Results from the ISU statewide survey of Iowa lakes from 2000–04 also suggest full support of the Class A uses of Red Rock Reservoir. Using the median values from this survey from 2000 through 2004 (approximately 15 samples), Carlson’s (1977) Trophic State Indices for total phosphorus, chlorophyll-a, and Secchi depth are 79, 42, and 61, respectively. According to Carlson (1977), the index value for total phosphorus places this reservoir in the range of hyper-eutrophic lakes; the index value for chlorophyll-a, however, is in the lower range of mesotrophic lakes, and the value for Secchi depth is in the lower range between eutrophic and hyper-eutrophic lakes. These index values suggest (1) extremely high levels of phosphorus in the water column, (2) extremely low (and much lower than expected) levels of chlorophyll-a, and production of suspended algae, and (3) relatively good water transparency.

According to Carlson (1991), the occurrence of a low chlorophyll-a TSI value relative to those for total phosphorus and Secchi depth indicate non-algal particles or color dominate
light attenuation. The ISU lake data suggest that non-algal particles do likely limit algal production at Red Rock Reservoir. The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey from 2000 through 2004 was 5.2 mg/l. Of 131 lakes sampled, Red Rock Reservoir has the 43rd highest median level of inorganic suspended solids (7.2 mg/l), thus suggesting that non-algal turbidity likely limits the production of algae as well as contributes to in-lake turbidity. The median level of chlorophyll-a at Red Rock Reservoir is extremely low (3rd lowest of the 131 lakes sampled) and does not suggest either threats or impairments to support of designated uses at this lake. Based on median values from ISU sampling from 2000–04, the ratio of total nitrogen to total phosphorus for this lake is 51; this ratio suggests that algal production at this lake is limited by the availability of phosphorus as opposed to nitrogen availability. The 2000–04 median concentration of total nitrogen at this reservoir (9.2 mg/l) was the eighth highest of the 131 lakes sampled.

In terms of all Iowa lakes sampled, data from the ISU survey show very small populations of zooplankton species at this lake that graze on algae. Although sampling from 2000 through 2005 showed that Cladoceran taxa (e.g., Daphnia) comprised about 45% of the dry mass of the zooplankton community of this lake, the average per summer sample mass of Cladoceran taxa over the 2000–2005 period (37 mg/l) was the 16th lowest of the 131 lakes sampled. These results suggest little if any non-phosphorus limitation due to zooplankton grazing at Red Rock Lake.

The moderately high level of inorganic suspended solids at this lake, however, remains the primary non-phosphorus limitation to algal production at this lake. The levels of nuisance (=noxious) algal species (i.e., bluegreen algae) at this lake do not suggest an impairment of Class A uses. While data from the ISU survey from 2000 through 2004 suggest that bluegreen algae (Cyanophyta) comprise a significant portion (approximately 60%) of this lake’s summertime phytoplankton community, sampling from 2000 through 2004 showed that the median per summer sample mass of bluegreen algae at Red Rock Lake (1.3 mg/l) was the 8th lowest of the 131 lakes sampled. This level is in the lowest 10% of the 131 Iowa lakes sampled. The presence of a relatively small population of bluegreen algae at this lake does not suggest a potential violation of Iowa’s narrative water quality standard protecting against occurrence of nuisance aquatic life. This assessment, however, is based strictly on a distribution of the lake-specific median bluegreen algae values for the 2000–2004 monitoring period. Median levels less than the 75th percentile of this distribution (~29 mg/l) were arbitrarily considered by
IDNR staff to not represent an impairment of the Class A uses of Iowa lakes. No criteria exist upon which to base a more accurate identification of impairments due to bluegreen algae. Thus, while the ability to characterize the levels of bluegreen algae at this lake has improved over that of the previous (2004) assessment due to collection of additional data, the assessment category for assessments based on level of bluegreen algae nonetheless remains, of necessity, “evaluated” (indicating an assessment with relatively lower confidence) as opposed to “monitored” (indicating an assessment with relatively higher confidence). Results of ISU/ACOE monitoring, however, do suggest that blooms of bluegreen algae occasionally occur at Red Rock Lake. According to the ISU/ACOE annual monitoring reports (e.g., Lutz and Esser 2002, Lutz and Cummings 2003, Lutz 2004, and Lutz et al. 2005), blooms of bluegreen algae typically occur during July and August, especially under elevated pool conditions. These reports contain a summary of when these blooms have occurred at Red Rock Lake since 1990. The occurrence of bluegreen blooms from June to September 2001, July 2002, June 29, 2004, and July 6, 2004, suggests a threat to the full support of Class A uses at this reservoir (no algal blooms were observed at this reservoir in 2003).

The Class B(WW) aquatic life uses of the reservoir were assessed as “fully supported.” None of the 51 samples collected during the 2002–2004 period as part of ISU/ACOE monitoring violated Class B(WW) criteria for pH or ammonia-nitrogen. Three of 51 samples (6%), however, violated the Class B(WW) criterion for dissolved oxygen: all these violations occurred in late summer and all were relatively minor (range from 4.4 to 4.9 mg/l). According to U.S. EPA guidelines for Section 305(b) reporting (U.S. EPA 1997b: page 3-17), however, a violation frequency for conventional parameters (including dissolved oxygen) of 10% or less does not suggest an impairment of aquatic life uses.

The ISU lake survey data also show good chemical water quality at this lake. Results of this monitoring show no violations of the Class A,B(LW) criteria for pH in the 14 samples collected during summers of 2000 through 2004 (maximum = 8.7; minimum = 8.0 pH units). Two of 14 samples exceeded the Class B(LW) criterion for dissolved oxygen. Based on IDNR’s assessment methodology, however, these results do not suggest that significantly more than 10 percent of the samples exceed Iowa’s dissolved oxygen criteria and thus do not suggest an impairment of the Class B(LW) uses of Red Rock Lake.
Fish consumption uses were assessed (monitored) as “fully supported” based on results of ACOE/ISU fish contaminant monitoring at Red Rock Lake in 2002, 2003, and 2004. The composite samples of whole-fish common carp and the sample of catfish fillets had low levels of contaminants (the ACOE/ISU samples are not analyzed for mercury or PCBs). Levels of total chlordane in the composite samples were as follows: 2002: 23.9 ppb; 2003: 4.4 ppb; 2004: 4.6 ppb. The level of total chlordane in the sample of channel catfish fillets was 32.3 ppb. None of these levels approach the new (2006) advisory trigger level of 600 ppb for chlordane. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of the degree to which Iowa’s lakes and rivers support their fish consumption uses. Prior to 2006, IDNR used action levels published by the U.S Food and Drug Administration to determine whether consumption advisories should be issued for fish caught as part of recreational fishing in Iowa. In an effort to make Iowa’s consumption more compatible with the various protocols used by adjacent states, the Iowa Department of Public Health, in cooperation with Iowa DNR, developed a risk-based advisory protocol. This protocol went into effect in January 2006 (see http://www.iowadnr.gov/fish/news/consump.html for more information on Iowa’s revised fish consumption advisory protocol). Because the revised (2006) protocol is more restrictive than the previous protocol based on FDA action levels, fish contaminant data that previously suggested “full support” may now suggest either a threat to, or impairment of, fish consumption uses. This scenario, however, does not apply to the fish contaminant data generated from the ACOE/ISU fish contaminant sampling conducted at Red Rock Lake: the levels of contaminants do not exceed any of the new (2006) advisory trigger levels, thus indicating no justification for issuance of a consumption advisory for this waterbody.

2004 SUMMARY: Class A (primary contact recreation) uses of the Red Rock Reservoir were assessed (evaluated) as “fully supported/threatened” due to periodic occurrence of blooms of bluegreen algae during the 2000–02 period. The primary contact recreation uses at the reservoir’s two beaches remain assessed (monitored) as fully supported. The overall assessment of Class A uses for the reservoir is thus “fully supported/threatened.” The Class B(WW) aquatic life uses remain assessed (monitored) as “fully supported” based on results of chemical/physical monitoring conducted from 2000–02. Fish consumption uses were assessed (monitored) as “fully supported/threatened” based on ACOE sponsored annual fish contaminant monitoring from 2000–02. The sources of data for these assessments include (1) the results of water quality monitoring (including fish contaminant monitoring) conducted from 2000 through 2002 at Red
Rock Reservoir by Iowa State University under contract with the U.S. Army Corps of Engineers as part of the Des Moines River Water Quality Study, (2) results of the statewide survey of Iowa lakes conducted from 2000 through 2002 by Iowa State University (ISU), (3) information from the IDNR Fisheries Bureau, and (4) information on plankton communities at Iowa lakes in 2000 from Downing et al. (2002).

8.4. Weather Conditions

Weather conditions during the contract period were generally warmer and drier than normal, with record temperatures in January 2006 and drought conditions during the late spring and early summer. For the 2006 water year, the total precipitation at the National Weather Service station at the Des Moines International Airport was 29.96 inches, which was 86% of the long-term normal (34.72 inches). Five months exhibited above-normal precipitation (see Table 31 and Fig. 3). At Des Moines, the most precipitation was seen in August 2006 (5.82 inches, 129% of the long-term normal). The greatest percentage above-normal precipitation (186%) was noted in March 2006, making it the 14th wettest March in 134 years. The least precipitation was seen in February (0.22 inches), which was only 18% of normal. Statewide, February 2006 ranked as the 12th driest February among 134 years of state records. June 2006 ranked as the 10th driest June. The period May–July 2006 ranked as the 8th driest among 134 years of record for this time period, with only 1988 being drier in the most recent 70 years. Long-term climatology data are presented in Table 32.

At the National Weather Service office in Des Moines, significant storm events, in which 0.5 inch or more of rain fell within 24 hours, occurred on 25 occasions during the 2006 water year (see Table 33), compared to 19 occasions, 20 occasions, 19 occasions, 15 occasions, and 18 occasions during the previous five water years. Major storm events, in which more than 1.0 inch of precipitation fell within 24 hours, occurred on 7 occasions, compared with 5 occasions, 9 occasions, 5 occasions, 6 occasions, and 5 occasions during the previous five water years. The most daily rainfall at the Des Moines station was 1.40 inches on June 24, 2006. Storm events periodically affected water quality along the Des Moines and Raccoon rivers. This was most apparent during samplings on April 11, July 17, August 14, and September 19, 2006.

Air temperatures, as recorded at the City of Des Moines, were significantly above normal. During the 2006 water year, only two months saw below-normal temperatures (December 2005 and September 2006). Overall, temperatures during the 2006 water year were 2.8°F above the long-term average. The greatest departures were seen in January and April 2006,
Table 31. Monthly precipitation versus 30-year normal, 2006 water year.

<table>
<thead>
<tr>
<th>Month</th>
<th>Monthly Precipitation$^a$ (inches)</th>
<th>Monthly Normal$^b$ (inches)</th>
<th>Percentage of Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>0.92</td>
<td>2.62</td>
<td>35</td>
</tr>
<tr>
<td>November</td>
<td>1.33</td>
<td>2.10</td>
<td>63</td>
</tr>
<tr>
<td>December</td>
<td>0.95</td>
<td>1.33</td>
<td>71</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>0.75</td>
<td>1.03</td>
<td>73</td>
</tr>
<tr>
<td>February</td>
<td>0.22</td>
<td>1.19</td>
<td>18</td>
</tr>
<tr>
<td>March</td>
<td>4.10</td>
<td>2.21</td>
<td>186</td>
</tr>
<tr>
<td>April</td>
<td>4.30</td>
<td>3.58</td>
<td>120</td>
</tr>
<tr>
<td>May</td>
<td>1.41</td>
<td>4.25</td>
<td>33</td>
</tr>
<tr>
<td>June</td>
<td>1.83</td>
<td>4.57</td>
<td>40</td>
</tr>
<tr>
<td>July</td>
<td>4.35</td>
<td>4.18</td>
<td>104</td>
</tr>
<tr>
<td>August</td>
<td>5.82</td>
<td>4.51</td>
<td>129</td>
</tr>
<tr>
<td>September</td>
<td>3.98</td>
<td>3.15</td>
<td>126</td>
</tr>
<tr>
<td>SUM</td>
<td>29.96</td>
<td>34.72</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>86</td>
</tr>
</tbody>
</table>

$^a$Monthly precipitation, from National Weather Service.

Table 32. Long-term climatology at Des Moines, Iowa.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Precipitation\textsuperscript{a} (in.)</th>
<th>Mean Temperature\textsuperscript{a} (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967–68</td>
<td>26.4</td>
<td>49.7</td>
</tr>
<tr>
<td>1968–69</td>
<td>33.6</td>
<td>47.5</td>
</tr>
<tr>
<td>1969–70</td>
<td>30.1</td>
<td>49.3</td>
</tr>
<tr>
<td>1970–71</td>
<td>27.9</td>
<td>49.8</td>
</tr>
<tr>
<td>1971–72</td>
<td>37.2</td>
<td>49.5</td>
</tr>
<tr>
<td>1972–73</td>
<td>44.5</td>
<td>49.8</td>
</tr>
<tr>
<td>1973–74</td>
<td>36.1</td>
<td>50.4</td>
</tr>
<tr>
<td>1974–75</td>
<td>35.3</td>
<td>50.0</td>
</tr>
<tr>
<td>1975–76</td>
<td>32.0</td>
<td>52.7</td>
</tr>
<tr>
<td>1976–77</td>
<td>30.9</td>
<td>50.8</td>
</tr>
<tr>
<td>1977–78</td>
<td>33.3</td>
<td>48.2</td>
</tr>
<tr>
<td>1978–79</td>
<td>32.7</td>
<td>47.1</td>
</tr>
<tr>
<td>1979–80</td>
<td>26.6</td>
<td>51.1</td>
</tr>
<tr>
<td>1980–81</td>
<td>28.8</td>
<td>51.8</td>
</tr>
<tr>
<td>1981–82</td>
<td>41.1</td>
<td>48.5</td>
</tr>
<tr>
<td>1982–83</td>
<td>37.0</td>
<td>52.7</td>
</tr>
<tr>
<td>1983–84</td>
<td>45.6</td>
<td>48.8</td>
</tr>
<tr>
<td>1984–85</td>
<td>31.6</td>
<td>50.2</td>
</tr>
<tr>
<td>1985–86</td>
<td>43.4</td>
<td>49.2</td>
</tr>
<tr>
<td>1986–87</td>
<td>35.9</td>
<td>52.6</td>
</tr>
<tr>
<td>1987–88</td>
<td>24.2</td>
<td>51.8</td>
</tr>
<tr>
<td>1988–89</td>
<td>30.9</td>
<td>49.7</td>
</tr>
<tr>
<td>1989–90</td>
<td>40.5</td>
<td>50.6</td>
</tr>
<tr>
<td>1990–91</td>
<td>35.5</td>
<td>51.8</td>
</tr>
<tr>
<td>1991–92</td>
<td>36.6</td>
<td>50.9</td>
</tr>
<tr>
<td>1992–93</td>
<td>60.0</td>
<td>48.0</td>
</tr>
<tr>
<td>1993–94</td>
<td>26.7</td>
<td>48.9</td>
</tr>
<tr>
<td>1994–95</td>
<td>33.3</td>
<td>51.1</td>
</tr>
</tbody>
</table>

\(\textsuperscript{a}\)From NOAA Annual Climatological Summary: Des Moines International Airport Station #132203/14933.

http://hurricane.ncdc.noaa.gov/ancsum/ACS?state=IA
Table 32. Continued.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Precipitation(^{a}) (in.)</th>
<th>Mean Temperature(^{a}) (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995–96</td>
<td>36.4</td>
<td>47.6</td>
</tr>
<tr>
<td>1996–97</td>
<td>27.8</td>
<td>48.4</td>
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<tr>
<td>1997–98</td>
<td>38.7</td>
<td>51.6</td>
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<td>1998–99</td>
<td>30.7</td>
<td>51.6</td>
</tr>
<tr>
<td>1999–2000</td>
<td>24.9</td>
<td>53.4</td>
</tr>
<tr>
<td>2000–01</td>
<td>28.0</td>
<td>48.7</td>
</tr>
<tr>
<td>2001–02</td>
<td>24.9</td>
<td>53.0</td>
</tr>
<tr>
<td>2002–03</td>
<td>28.6</td>
<td>49.8</td>
</tr>
<tr>
<td>2003–04</td>
<td>40.6</td>
<td>50.6</td>
</tr>
<tr>
<td>2004–05</td>
<td>29.6</td>
<td>52.8</td>
</tr>
<tr>
<td>2005–06</td>
<td>30.0</td>
<td>52.8</td>
</tr>
</tbody>
</table>

Note: 1971–2000 30-year normal precipitation 34.72 in.\(^{b}\)
1971–2000 30-year normal mean temperature 50.0°F.\(^{b}\)

\(^{b}\)From NOAA, Climatography of the United States No. 81.
http://lwf.ncdc.noaa.gov/oa/climate/normals/usnormals.html
Table 33. Occurrence of significant storm events (≥ 0.5 inch) at Des Moines, Iowa, 2006 water year.

<table>
<thead>
<tr>
<th>Date</th>
<th>Precipitation Amount (in.)</th>
<th>Major Storm Events (&gt; 1.0 in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15Nov05</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>08Mar06</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>27Mar06</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>30Mar06</td>
<td>1.32</td>
<td>*</td>
</tr>
<tr>
<td>02Apr06</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>25Apr06</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>29Apr06</td>
<td>1.17</td>
<td>*</td>
</tr>
<tr>
<td>30Apr06</td>
<td>1.02</td>
<td>*</td>
</tr>
<tr>
<td>24May06</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>24Jun06</td>
<td>1.40</td>
<td>*</td>
</tr>
<tr>
<td>10Jul06</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>13Jul06</td>
<td>1.12</td>
<td>*</td>
</tr>
<tr>
<td>21Jul06</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>25Jul06</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>26Jul06</td>
<td>1.06</td>
<td>*</td>
</tr>
<tr>
<td>01Aug06</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>10Aug06</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>13Aug06</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>17Aug06</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>18Aug06</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>28Aug06</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>03Sep06</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>10Sep06</td>
<td>1.61</td>
<td>*</td>
</tr>
<tr>
<td>17Sep06</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>21Sep06</td>
<td>0.61</td>
<td></td>
</tr>
</tbody>
</table>
when average temperatures were 35.6°F and 56.6°F, respectively, which were 15.2°F above and 6.0°F below long-term normals. Statewide, January 2006 tied with January 1933 as the warmest January in 134 years. April 2006 ranked as the 14th warmest in 134 years. Ice formation was evident on December 6, 2005, when the reservoirs were completely ice covered. The reservoir sites were still partially ice-covered on the March 7 sampling but were ice free by the March 28 sampling event. Monthly average air temperatures for the 2006 water year are listed in Table 34, and long-term temperatures are listed in Table 32.

8.5. River Discharge

Water in a river channel originates from direct precipitation, overland run-off, or subsurface flow. Overland run-off occurs when water is added to already saturated soils or is added more quickly than the soils can absorb it. Overland run-off is the main factor in peak flows and floods. Subsurface flow, or groundwater, provides the generally stable base flow characteristic of streams and rivers.

The amount of water flowing in a river is probably the most important factor influencing water quality. River discharge can affect water quality in two ways. First, conservative parameters (with a nearly constant input), such as alkalinity and hardness, will decrease in concentration as river flows increase. Also, concentrations of pollutants from point sources are similarly affected; they are more diluted when flows are the greatest. Second, concentrations of several parameters, such as suspended solids, increase as a result of the scouring effect of run-off. Thus, the concentrations of these parameters increase as river flow increases.

Information regarding river flow in the Des Moines and Raccoon rivers and the water surface elevations of Saylorville and Red Rock reservoirs was compiled for each sampling day. Discharge data for Stations 1 and 5 on the Des Moines River, which roughly correspond to the inflow to and outflow from Saylorville Reservoir, and Stations 7 and 9 on the Des Moines River, which similarly correspond to the inflow to and outflow from Red Rock Reservoir, were provided by the U.S. Geological Survey (USGS) and correspond to USGS gaging stations 05481300 (near Stratford), 05481650 (near Saylorville), 05487500 (near Runnells), and 05488500 (near Tracy). River flows at Station 6 on the Des Moines River and at Station 10 on the Raccoon River also were furnished by the USGS and correspond to USGS gaging stations 05485500 (below the Raccoon at Des Moines) and 05484500 (Raccoon River at Van Meter). The USGS document *Water Resources, Iowa, Water Year 2005* is available at [http://pubs.usgs.gov/wdr/2005/wdr-ia-05-1/](http://pubs.usgs.gov/wdr/2005/wdr-ia-05-1/). Discharge data were reported in units of cubic feet per second (ft³/s). Water surface
Table 34. Climatological data for Des Moines, Iowa. Monthly average air temperatures and departures from normal, 2006 water year.\(^a\)

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Temperature (°F)</th>
<th>Monthly Normal(^b) (°F)</th>
<th>Departure from Normal (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct.</td>
<td>54.7</td>
<td>52.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Nov.</td>
<td>42.1</td>
<td>37.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Dec.</td>
<td>23.5</td>
<td>24.9</td>
<td>-1.4</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan.</td>
<td>35.6</td>
<td>20.4</td>
<td>15.2</td>
</tr>
<tr>
<td>Feb.</td>
<td>27.7</td>
<td>26.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Mar.</td>
<td>39.4</td>
<td>38.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Apr.</td>
<td>56.6</td>
<td>50.6</td>
<td>6.0</td>
</tr>
<tr>
<td>May</td>
<td>63.4</td>
<td>61.9</td>
<td>1.5</td>
</tr>
<tr>
<td>June</td>
<td>73.5</td>
<td>71.4</td>
<td>2.1</td>
</tr>
<tr>
<td>July</td>
<td>79.1</td>
<td>76.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Aug.</td>
<td>74.6</td>
<td>73.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Sep.</td>
<td>62.8</td>
<td>65.1</td>
<td>-2.3</td>
</tr>
<tr>
<td>Average</td>
<td>52.8</td>
<td>50.0</td>
<td>3.4(^c)</td>
</tr>
</tbody>
</table>

\(^a\)From the National Weather Service, NOAA.


\(^c\)Absolute average departure.
elevations at both reservoirs were supplied by the Army Corps of Engineers at http://www2.mvr.usace.army.mil/WaterControl/.

The time of travel for water from the headwaters of the Des Moines River to Saylorville Dam is about nine days, from Saylorville Dam to Red Rock Dam is about two days, and from Red Rock Dam to the Mississippi River is about three days (see March 1994 annual report). The time of travel is important when evaluating pollutant loading and stream hydrographs and when predicting river flows and subsequent flooding.

The average annual daily discharges at all stations are listed in Table 35. A comparison is made between annual averages calculated by using USGS data from each day and averages calculated by using only data from the sampling days. This comparison illustrates the issue of sampling frequency. For most years, the two averages are similar. During the 2006 water year, the average sampling-day flows at stations on the Des Moines River overestimated the average daily flows by only 2%. The average sampling-day flow on the Raccoon River was underestimated by 6%. Thus, discharge conditions during the sampling events were representative of the flow conditions of the Des Moines and Raccoon rivers. During some years there has been less agreement due to the fact that the Scope of Work concentrates more effort during the recreational season when river flows are higher, with limited sampling frequency during several months.

These differences were also analyzed on a monthly average basis (see Table 36). Monthly average flows based on sampling-day data are generally more representative of actual averages. The greatest discrepancies were observed in October 2005 and May 2006. Interpreted in this manner, the flow of the Des Moines River was overestimated by only 3%. The results of these flow analyses are important when evaluating data from other physical, chemical, and biological parameters. The discrepancy between the analyses of annual averages and monthly averages is due to the disproportionate number of samplings per month. As directed by the Scope of Work, more samplings occurred during the summer months when river flow was greater, thus the value for the average annual flow determined by individual flows from the sampling days was skewed greater than the actual average annual flow. Therefore, it is important to note that data calculated from monthly averages are more representative of actual annual trends than data averaged from individual observations.

The average annual daily discharges of the Des Moines River at Stations 1 and 6 for the 2006 water year (Table 34) were 112% and 77% of the comparative long-term averages (1968–2006). Last year flows at these sites were 104% and 82% of the long-term flow. The 2006 water year average daily discharge of the Raccoon River at Van Meter (Station 10) was only 39% of its
Table 35. Annual average daily discharge for each water year during the study period and mean discharge for the period of record, recorded in cubic feet per second (ft³/s).

<table>
<thead>
<tr>
<th>Water Year (1 October–30 September)</th>
<th>Stations</th>
<th>1 (2,270 (85 years))</th>
<th>5 (3,191 (44 years))</th>
<th>10 (1,552 (89 years))</th>
<th>6 (4,999 (65 years))</th>
<th>7 (7,339 (19 years))</th>
<th>9 (5,650 (85 years))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean to 2005</td>
<td></td>
<td>411&lt;sup&gt;a&lt;/sup&gt; 499&lt;sup&gt;b&lt;/sup&gt;</td>
<td>466&lt;sup&gt;a&lt;/sup&gt; 478&lt;sup&gt;b&lt;/sup&gt;</td>
<td><em>a</em> <em>b</em></td>
<td><em>a</em> <em>b</em></td>
<td><em>a</em> <em>b</em></td>
<td><em>a</em> <em>b</em></td>
</tr>
<tr>
<td>1968</td>
<td>4,962 5,004</td>
<td>5,175 5,232</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
</tr>
<tr>
<td>1969</td>
<td>1,217 1,313</td>
<td>1,362 1,355</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
</tr>
<tr>
<td>1970</td>
<td>2,321 2,476</td>
<td>2,546 2,595</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
<td>– –</td>
</tr>
<tr>
<td>1971</td>
<td>1,821 1,971</td>
<td>1,950 2,166</td>
<td>– –</td>
<td>3,252 3,415</td>
<td>– –</td>
<td>4,367 4,105</td>
<td>– –</td>
</tr>
<tr>
<td>1972</td>
<td>4,433 4,701</td>
<td>4,995 5,167</td>
<td>4,840 5,171</td>
<td>11,000 11,867</td>
<td>– –</td>
<td>14,420 13,821</td>
<td>– –</td>
</tr>
<tr>
<td>1974</td>
<td>2,150 2,151</td>
<td>2,413 2,216</td>
<td>1,610 1,592</td>
<td>4,660 4,412</td>
<td>– –</td>
<td>5,704 5,682</td>
<td>– –</td>
</tr>
<tr>
<td>1975</td>
<td>700 730</td>
<td>843 898</td>
<td>996 1,008</td>
<td>2,195 2,223</td>
<td>– –</td>
<td>3,576 3,803</td>
<td>– –</td>
</tr>
<tr>
<td>1976</td>
<td>254 312</td>
<td>172 178</td>
<td>271 202</td>
<td>465 401</td>
<td>– –</td>
<td>898 942</td>
<td>– –</td>
</tr>
<tr>
<td>1977</td>
<td>1,577 1,618</td>
<td>1,756 1,863</td>
<td>1,552 1,799</td>
<td>3,767 4,213</td>
<td>– –</td>
<td>5,747 5,661</td>
<td>– –</td>
</tr>
<tr>
<td>1978</td>
<td>4,256 4,264</td>
<td>4,658 4,535</td>
<td>2,691 2,802</td>
<td>8,068 7,822</td>
<td>– –</td>
<td>9,762 9,573</td>
<td>– –</td>
</tr>
<tr>
<td>1979</td>
<td>2,464 2,595</td>
<td>2,688 2,608</td>
<td>1,031 1,019</td>
<td>3,802 3,719</td>
<td>– –</td>
<td>4,328 4,365</td>
<td>– –</td>
</tr>
<tr>
<td>1980</td>
<td>1,423 1,452</td>
<td>1,475 1,512</td>
<td>374 374</td>
<td>1,883 1,894</td>
<td>– –</td>
<td>2,499 2,442</td>
<td>– –</td>
</tr>
<tr>
<td>1981</td>
<td>3,940 3,633</td>
<td>3,394 4,033</td>
<td>2,198 2,681</td>
<td>5,790 6,909</td>
<td>– –</td>
<td>8,937 9,996</td>
<td>– –</td>
</tr>
</tbody>
</table>

<sup>a</sup>USGS average flows for water year beginning October 1 through September 30.

<sup>b</sup>USGS average flows for the sampling days summed and divided by the number of sampling days, which varied from 52 events to 22 events per year.
<table>
<thead>
<tr>
<th>Water Year (1 October–30 September)</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean to 2005</td>
</tr>
<tr>
<td>2005 (85 years)</td>
<td>2,270</td>
</tr>
<tr>
<td></td>
<td>3,191</td>
</tr>
<tr>
<td></td>
<td>1,552</td>
</tr>
<tr>
<td></td>
<td>4,999</td>
</tr>
<tr>
<td></td>
<td>(85 years)</td>
</tr>
<tr>
<td></td>
<td>(44 years)</td>
</tr>
<tr>
<td></td>
<td>(89 years)</td>
</tr>
<tr>
<td></td>
<td>(65 years)</td>
</tr>
<tr>
<td>1984&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2,043</td>
</tr>
<tr>
<td></td>
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<sup>c</sup>No monitoring was conducted in September 1984, thus the USGS daily mean for September was used to calculate both columns.

<sup>d</sup>No monitoring was conducted in October or November 1990, thus the USGS daily mean for October and November was used to calculate both columns.

<sup>e</sup>No monitoring was conducted in November or December 1991, thus the USGS daily mean for November or December was used to calculate both columns.
Table 35. Continued.

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<tr>
<td>Mean since 1968</td>
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fMean postimpoundment flow at Station 1, water years 1978–2006, was 3,352 ft³/s (3,878 ft³/s from sampling days only).

gMean postimpoundment flow at Station 5, water years 1978–2006, was 3,611 ft³/s (4,194 ft³/s from sampling days only).

hMean postimpoundment flow at Station 9, water years 1972–2006, was 7,543 ft³/s (8,469 ft³/s from sampling days only).
Table 36. Monthly average sampling-day flows versus USGS monthly average daily flows for the 2006 water year.

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<td>6,770(^b)</td>
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<td>213</td>
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<td>3,394</td>
<td>3,456</td>
<td>3,631</td>
<td>820</td>
<td>695</td>
<td>4,637</td>
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</table>

\(^a\)USGS average flows.

\(^b\)USGS average flow using only sampling-day data (\(\sum\) sampling-day flow/number of samplings).
post-1968 average, as compared to 65% last year. The 2006 USGS water year annual average daily discharges at Stations 1, 5, 6, 7, and 9 on the Des Moines River were 3,413 ft³/s, 3,456 ft³/s, 4,637 ft³/s, 5,096 ft³/s, and 4,998 ft³/s, respectively. The 2006 USGS water year annual average daily discharge at Station 10 on the Raccoon River was 820 ft³/s.

Comparatively, this period saw lesser extremes in flow. During sampling of the Des Moines River, the flow at Station 1 ranged from 386 ft³/s to 12,400 ft³/s, and the outflow from Saylorville Reservoir, as measured at Station 5, ranged from 289 ft³/s to 12,700 ft³/s. On the Raccoon River at Station 10, the sampling-day flow ranged from 179 ft³/s to 3,980 ft³/s. Sampling-day flows at Stations 6 and 7 above Red Rock Reservoir ranged from 1,020 ft³/s to 16,000 ft³/s and from 1,300 ft³/s to 16,600 ft³/s, respectively. Downstream from Red Rock Reservoir at Station 9, the outflow ranged from 1,130 ft³/s to 16,300 ft³/s. Generally, the highest river flows were seen during April and May 2006, while the lowest river flows were noted in August and September 2006. Analysis of long-term data for river flow during sampling events, as shown in Appendix B, indicates that no new period-of-record monthly or annual means were set.

8.6. Reservoir Elevation

During this contract period, the operational conservation pool at Saylorville Reservoir was 836 feet NGVD. Normally, there is a two-foot seasonal rise in elevation from September through December to improve conditions for migrating waterfowl. Since the completion of Saylorville Reservoir in 1977, the conservation pool level has been raised once. In 1983 the conservation pool was raised from 833 feet NGVD to the current pool level in order to set aside water for municipal and industrial water supply to Des Moines, if needed. At the conservation pool of 836 feet NGVD, the reservoir area is 5,950 acres and storage capacity is 90,000 acre-feet. At the flood pool of 890 NGVD, the reservoir area is 16,700 acres and the storage capacity is 586,000 acre-feet.

The operational conservation pool at Red Rock Reservoir during this contract period was 742 feet NGVD. There is a normal two-foot seasonal rise in elevation from September to December to improve conditions for migrating waterfowl, which was also delayed due to low flow conditions in the fall. Since the completion of Red Rock Reservoir in 1969, the conservation pool has been adjusted three times to offset storage capacity losses to sedimentation. The initial conservation pool of 725 feet NGVD was raised to 728 feet NGVD in 1979. More recently, in December 1988 the conservation pool was raised 6 feet to 734 feet NGVD, and in April 1992 the conservation pool was raised 8 feet to 742 feet NGVD. The Corps has estimated that 43% of the
original conservation pool (725 feet NGVD) filled with sediment during the first 16 years of reservoir operation. In terms of surface area, Lake Red Rock is now the largest water body in Iowa.

Saylorville Reservoir’s level was only slightly elevated in May 2006. Usually, increases in elevation are needed to mitigate spring flooding downstream. The maximum lake level during sampling was 838.97 feet NGVD on May 22, 2006, which was only 2.97 feet above the conservation pool level of 836 feet NGVD. The greatest rise in Saylorville Lake elevation between monitoring events occurred between April 25 and May 15, 2006, when the elevation increased 2.53 feet. The greatest drop in Saylorville Lake elevation between monitoring events occurred between May 22 and June 5, 2006, when the lake level decreased 2.31 feet (see Table 37).

The elevation at Red Rock Reservoir was stable. The greatest increase in lake elevation was during the fall for a planned seasonal increase. The maximum pool recorded during monitoring events was on October 10, 2006, at 744.61 feet NGVD, which was less than one foot above the seasonal conservation pool level of 744 feet NGVD. Last year lake levels at both reservoirs were more variable, with maximum elevations being about 12 feet above conservation pool levels.

8.7. Sampling Depth

Whenever depth samples were collected from the reservoirs, the actual depth in meters was recorded for the locations referred to as surface, mid-depth, and bottom. These depths are listed in Appendix A. By convention, the surface samples (i.e., 4S, 8S) were collected 0.25 meter below the actual water surface in order to avoid sampling material trapped on the air-water interface. The bottom sample was collected 0.5 meter from the actual bottom to avoid disturbing sediments while collecting water samples. The mid-depth samples were collected at a depth equal to one-half the distance to the actual bottom depth. All depth samples were collected using a Van Dorn water sampler, as discussed in Section 6.2. At the conservation pool levels of 836 feet NGVD at Saylorville Reservoir and 742 feet NGVD at Red Rock Reservoir, the approximate depths at Stations 4B and 8B are 9.5 meters and 12.5 meters, respectively.

During this contract period, the depth to the bottom collection site ranged from 8.00 meters to 9.25 meters at Saylorville Reservoir and from 11.50 meters to 13.00 meters at Red Rock Reservoir.
Table 37. Change in water surface elevation at Saylorville and Red Rock reservoirs between sampling events.

<table>
<thead>
<tr>
<th>Date</th>
<th>Saylorville Elevation Change (ft NGVD)</th>
<th>Feet Above () or Below (-) Conservation Pool Level&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Red Rock Elevation Change (ft NGVD)</th>
<th>Feet Above () or Below (-) Conservation Pool Level&lt;sup&gt;b&lt;/sup&gt;</th>
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<td>-0.96</td>
<td>-0.71</td>
<td>-0.21</td>
<td>0.24</td>
</tr>
<tr>
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<td>0.74</td>
<td>0.03</td>
<td>0.11</td>
<td>0.35</td>
</tr>
<tr>
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<td>0.03</td>
<td>-0.07</td>
<td>0.28</td>
</tr>
<tr>
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<td>0.06</td>
<td>0.09</td>
<td>0.12</td>
<td>0.40</td>
</tr>
<tr>
<td>07Aug06</td>
<td>0.01</td>
<td>0.10</td>
<td>-0.05</td>
<td>0.35</td>
</tr>
<tr>
<td>14Aug06</td>
<td>-0.01</td>
<td>0.09</td>
<td>0.19</td>
<td>0.54</td>
</tr>
<tr>
<td>22Aug06</td>
<td>-0.02</td>
<td>0.07</td>
<td>-0.22</td>
<td>0.32</td>
</tr>
<tr>
<td>05Sep06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.07</td>
<td>-1.86</td>
<td>-0.05</td>
<td>-1.73</td>
</tr>
<tr>
<td>19Sep06</td>
<td>0.12</td>
<td>-1.74</td>
<td>0.06</td>
<td>-0.67</td>
</tr>
<tr>
<td>10Oct06</td>
<td>0.82</td>
<td>-0.92</td>
<td>1.28</td>
<td>0.61</td>
</tr>
<tr>
<td>07Nov06</td>
<td>0.98</td>
<td>0.06</td>
<td>-0.03</td>
<td>0.58</td>
</tr>
<tr>
<td>05Dec06</td>
<td>-0.18</td>
<td>-0.12</td>
<td>-0.20</td>
<td>0.38</td>
</tr>
</tbody>
</table>

<sup>a</sup>The normal conservation pool at Saylorville Reservoir is 836 ft NGVD.

<sup>b</sup>The normal conservation pool at Red Rock Reservoir is 742 ft NGVD.

<sup>c</sup>Water levels are normally raised two feet in September to accommodate migrating waterfowl and are scheduled to return to normal at the end of December; however, this was delayed this year due to drought conditions.
8.8. Water Temperature

By far the greatest source of heat in water is direct absorption of solar radiation. The transfer of heat from air and sediments does occur, but it is a minor source of heat in lakes, although a significant source in streams. Temperature is a measure of the intensity of this heat, not the heat content. Temperature changes occur slowly in water as a result of its large specific heat.

The effects of water temperature in regulating biological, physical, and chemical water quality processes are numerous. Metabolisms of bacteria, plankton, benthic invertebrates, and fish all are dependent upon water temperature. The rate of chemical reactions also is temperature regulated. In addition, the solubility of gases (in particular, oxygen) is related to water temperature. When the water temperature approaches 0.0°C (32.0°F), ice forms, floating on the surface of the denser, warmer water. This ice cover forms a barrier that separates the liquid water from the atmosphere and thus restricts atmospheric exchange of gases. This can lead to the possibility of supersaturated dissolved oxygen concentrations under clear-ice conditions and oxygen-deficient situations under snow-covered ice. Finally, thermal stratification of impounded waters may produce water quality differences at various depths.

Reservoir water temperatures during the 2006 contract period ranged from a high of 30.2°C (86.4°F), recorded at the surface of Red Rock Reservoir on July 17, 2006, to a low of 4.6°C (40.3°F), recorded at both reservoirs on March 28, 2006. Reservoir samples were not collected during winter months under ice conditions. The maximum water temperature at the riverine locations was 32.5°C (90.5°F) at Station 10 on the Raccoon River on July 17, 2006, as compared to maximum temperatures from the previous two years of 30.4°C (86.7°F) and 26.1°C (79.9°F), respectively. The minimum water temperature at the riverine locations was -0.1°C (31.8°F) at Station 1 on December 5, 2006. New period-of-record monthly maximum water temperatures were set in October 2005 at most locations. There was one water temperature above the state standard of 32.0°C for class B (WW) waters during this contract period. Historically, there have only been 25 of 8,814 individual temperatures at surface reservoir and riverine locations above 32°C, many of which occurred in the summer of 1980.

Thermal and chemical stratification events, as a result of temperature differences between the surface and bottom waters of the reservoirs, were evident June through September. Stratification was more intense during the summer months because the change in the density of water per degree centigrade change in temperature is greater at higher temperatures and because elevated lake levels lengthened residence time, allowing stratification to strengthen. When
thermal stratification continues for extended periods of time, the dissolved oxygen in the hypolimnion of a reservoir diminishes, primarily as a result of the oxygen demand of sediments.

Dissolved oxygen concentrations less than 4.00 mg/l occurred in bottom samples from Station 4, in the main basin of Saylorville Reservoir, on six occasions, as compared to ten occasions the previous year. At Station 8, in the main basin of Red Rock Reservoir, there were five occasions when the dissolved oxygen content of the bottom sample contained 4.0 mg/l or less, as compared to seven occasions the previous year. Table 38 lists the surface-to-bottom temperature differences, with stratification periods indicated in parentheses.

Temperature differences between sampling stations are normally caused by diurnal warming of the lower portions of the river sampling route, by the release of warmer or cooler surface waters from the two reservoirs, or by the cooling effects of large amounts of precipitation. The greatest difference in water temperature between river sampling stations occurred on June 12, 2006, when there was a 5.8°C (8.6°F) increase between Stations 1 and 9. The greatest difference in water temperature of the river above and below Saylorville Reservoir at Stations 1 and 5 was 3.9°C (7.0°F), which also occurred on June 12, 2006, when the discharge water was warmer. The greatest difference in water temperature of the river above and below Red Rock Reservoir at Stations 7 and 9 was 2.4°C (4.3°F) on March 25, 2006, when the downstream water temperature was warmer. The greatest difference in temperature from the surface to the bottom of Saylorville Reservoir was 2.9°C (5.2°F) on June 5, 2006. The greatest difference in temperature from the surface to the bottom of Red Rock Reservoir was 3.4°C (6.1°F) on August 22, 2006.

8.9. Suspended Solids

Solid matter can either be suspended or dissolved in water. Measurement of total solids consists of both filterable (dissolved) and nonfilterable (suspended) material. Suspended solids are provided primarily by surface run-off of clays, sands, silts, and organic matter, whereas the predominant source of dissolved solids is groundwater, which normally has a high mineral content. During this contract period, only concentrations of suspended solids were determined.

When water is impounded, its velocity decreases and allows suspended particles to settle more efficiently. Sedimentation, which creates deltas in the headwaters area and decreases the storage capacity of an impoundment, improves the quality of the water downstream. Both Saylorville and Red Rock reservoirs are effective sediment traps, often capturing 80% to 99% of the suspended solids load. It is interesting to note that because of the extreme flood of 1993, Red Rock Reservoir reduced the suspended solids load by only 18% during the 1993 water year. The
Table 38. Surface-to-bottom sample temperature differences (in °C), indicating the degree of thermal stratification; instances in which depth samples contained less than 4.0 mg/l dissolved oxygen are listed to illustrate periods of chemical stratification.

<table>
<thead>
<tr>
<th>Date</th>
<th>Saylorville Lake Surface-to-Bottom Temperature Difference (°C) Station 4</th>
<th>Lake Red Rock Surface-to-Bottom Temperature Difference (°C) Station 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>28Mar06</td>
<td>0.0</td>
<td>-0.4</td>
</tr>
<tr>
<td>11Apr06</td>
<td>-0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>25Apr06</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>15May06</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>22May06</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>05Jun06</td>
<td>2.9 (M, B)&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>3.3 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>12Jun06</td>
<td>1.1</td>
<td>2.7</td>
</tr>
<tr>
<td>26Jun06</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>10Jul06</td>
<td>1.7 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.7 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>17Jul06</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>24Jul06</td>
<td>0.5 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.6 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>07Aug06</td>
<td>0.7 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.0 (M, B)&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>14Aug06</td>
<td>0.4 (S,M,B)&lt;sup&gt;c,a,b&lt;/sup&gt;</td>
<td>0.6 (S,M,B)&lt;sup&gt;c,a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>22Aug06</td>
<td>2.2 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.4 (B)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>05Sep06</td>
<td>1.0</td>
<td>1.4</td>
</tr>
<tr>
<td>19Sep06</td>
<td>0.4</td>
<td>0.3</td>
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<tr>
<td>10Oct06</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>07Nov06</td>
<td>0.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

<sup>a</sup>M: middle sample < 4.0 mg/l dissolved oxygen.

<sup>b</sup>B: bottom sample < 4.0 mg/l dissolved oxygen.

<sup>c</sup>S: surface sample < 4.0 mg/l dissolved oxygen.
area that contributes sediment to Saylorville Reservoir is only 5,797 square miles because of Big Creek Lake. Sediment surveys have been made by the Corps in 1976, 1984, 1994, 1999, and 2000. Between 1976 and 1999, the average sedimentation rate within the reservoir was 1,100 acre feet per year (the design estimate was 800 square feet per year) (U.S. COE 2001). At Red Rock the most recent sedimentation study (based on 1999–2001 data) indicates a 43% filling below the conservation pool during the period 1969–2001. The average sedimentation rate for the conservation pool is 4,470 acre feet per year; for the flood pool it is 1,910 acre feet per year. A vast majority (96%) of the original flood control volume remains (U.S. COE 2003).

Suspended solids concentrations ranged from a minimum of 3 mg/l at Station 9 on December 5, 2006, to a maximum of 1,808 mg/l at Station 7 on August 14, 2006. Normally, the lowest suspended solids concentrations are reported during the winter months, when the lowest river flows predominate and surface run-off is at a minimum; however, minimum suspended solids can sometimes be observed in the reservoirs under high pool levels. This year the maximum suspended solids concentration was observed in August in response to a storm event.

Greater suspended solids concentrations were a result of run-off associated with storm events. Suspended solids concentrations were somewhat less variable this contract period (see Table 39), with maximum concentrations of 216 mg/l at Station 10 on the Raccoon River and 1,808 mg/l at Station 7 on the Des Moines River. Increases in suspended solids load as a result of storm run-off were most apparent on April 11, July 17, August 14, and September 19, 2006. For example, increases in suspended solids concentration on August 14, 2006, were the result of a storm event on August 13, when 0.88 inch of rain fell in Des Moines. In addition, many moderate suspended solids concentrations were linked to algal communities. (Algal pigment concentrations are only determined from May through September.)

Impounding water behind a dam decreases the velocity of the water and allows suspended material to settle. Both Saylorville and Red Rock reservoirs serve as very efficient sediment traps by decreasing flow and thus allowing suspended materials to settle out. During the 2005–2006 water year, an average reduction in suspended solids concentration of 75% occurred between Stations 1 and 5, which are located above and below Saylorville Reservoir, respectively. This is slightly less than the average reduction of 79% over the previous 29 water years. An average reduction in suspended solids concentration of 91% was realized between Stations 7 and 9, located above and below Red Rock Reservoir, respectively, which exceeded the average reduction of 83% over the previous 28 water years. (The reduction averaged only 70% this contract period when Station 6 was used as the upstream location.) Reductions in suspended solids concentrations of 74% and 90% were reported for Saylorville and Red Rock reservoirs,
Table 39. Maximum suspended solids concentration per contract period.

<table>
<thead>
<tr>
<th>Contract Period</th>
<th>Dates</th>
<th>Station</th>
<th>Suspended Solids (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>14Aug06</td>
<td>7</td>
<td>1,808</td>
</tr>
<tr>
<td>37</td>
<td>12Apr05</td>
<td>7</td>
<td>2,440</td>
</tr>
<tr>
<td>36</td>
<td>25May04</td>
<td>10</td>
<td>3,573</td>
</tr>
<tr>
<td>35</td>
<td>05Nov03</td>
<td>7</td>
<td>520</td>
</tr>
<tr>
<td>34</td>
<td>11Jun02</td>
<td>7</td>
<td>884</td>
</tr>
<tr>
<td>33</td>
<td>27Mar01</td>
<td>10</td>
<td>394</td>
</tr>
<tr>
<td>32</td>
<td>27Jun00</td>
<td>7</td>
<td>451</td>
</tr>
<tr>
<td>31</td>
<td>06Jul99</td>
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<td>3,500</td>
</tr>
<tr>
<td>30</td>
<td>09Jun98</td>
<td>10</td>
<td>6,080</td>
</tr>
<tr>
<td>29</td>
<td>07Apr97</td>
<td>10</td>
<td>1,444</td>
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<tr>
<td>28</td>
<td>25Jun96</td>
<td>10</td>
<td>1,164</td>
</tr>
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<td>27Jun95</td>
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<td>1,043</td>
</tr>
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<td>26</td>
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<td>1</td>
<td>564</td>
</tr>
<tr>
<td>25</td>
<td>13Jul93</td>
<td>10</td>
<td>836</td>
</tr>
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<td>24</td>
<td>15Sep92</td>
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<td>5,090</td>
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<tr>
<td>23</td>
<td>14Apr91</td>
<td>7</td>
<td>2,000</td>
</tr>
<tr>
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<tr>
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<td>30May89</td>
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<td>12,490</td>
</tr>
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<td>20</td>
<td>19Jul88</td>
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<td>878</td>
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<tr>
<td>19</td>
<td>07Jul87</td>
<td>7</td>
<td>4,560</td>
</tr>
<tr>
<td>18</td>
<td>18Mar86</td>
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<td>1,570</td>
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<td>13</td>
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<td>6,610</td>
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<td>31Mar76</td>
<td>6</td>
<td>2,230</td>
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<td>2,278</td>
</tr>
<tr>
<td>7</td>
<td>27Sep74</td>
<td>10</td>
<td>2,622</td>
</tr>
</tbody>
</table>
Note: This parameter was not analyzed before contract period 7.
respectively, for the previous water year. Suspended solids are also discussed in Section 8.25 in terms of loading in the river system.

An examination of historical records revealed that new period-of-record minimum monthly concentrations were set at Station 5 in August 2006 and at Stations 10 and 6 in June 2006. A new minimum annual mean concentration was set at Station 6. From monthly mean data, the average suspended solids concentration at the Des Moines River stations (Stations 1, 5, 6, 7, and 9) for the 2006 water year was 52 mg/l (compared to 72 mg/l last period). This concentration was 56% of the long-term average of 93 mg/l from these sites. From the Raccoon River site, Station 10, the 2006 water year average was 60 mg/l, or 26% of the long-term average of 228 mg/l.

An analysis of field-duplicate results for suspended solids concentrations collected during this contract period yielded good results. From 22 samples with an average value of 43 mg/l, an average absolute difference of 2.0 mg/l was calculated. The average absolute percent difference was 4.8%, which is below the long-term (since 1982) average absolute percent difference of 7.2%. See Table 12 for further details on duplicate analysis of samples collected during this period.

8.10. Turbidity

Turbidity in water is a measure of water clarity, or, more correctly, the lack of clarity resulting from suspended materials such as clay, sand, silt, plankton, and other inorganic and organic matter; as such, it is related to both run-off and phytoplankton productivity. This suspended material causes light to be scattered instead of being transmitted directly. Attempts to correlate turbidity with the weight concentration of suspended solids are not practical because it is the material’s optical properties (particle size and shape) that prove to be more important than the concentration. Increases in turbidity have the effect of decreasing the percentage of light transmitted, which results in a decrease in photosynthesis. The EPA recommends that the depth of light penetration in a water body not be reduced by more than 10% as a result of turbidity and suspended solids. Turbidity is generally less in an impoundment, because much of the suspended matter settles out in the headwaters region.

A new Hach model 2100N laboratory turbidimeter was put in use May 2006. The meter has a ratio mode that allows excellent linearity, calibration stability, and the ability to measure turbidity in the presence of color. Sample dilutions were not necessary using this meter.
Previously, samples were diluted if the initial turbidity was greater than 40 nephelometric turbidity units (NTU).

A minimum turbidity of 1 NTU was recorded at several locations in January 2006. The lowest values historically are present during the winter months, when surface run-off is at a minimum, and at the reservoirs under elevated pool levels, when retention times are the greatest. Turbidities of less than 10 NTU were reported for 11 out of 18 values (61%) at the surface of Saylorville Reservoir (as compared to 55%, 32%, 31%, 65%, and 40% for the last five periods) and for 12 out of 18 values (67%) at the surface of Red Rock Reservoir (as compared to 67%, 26%, 21%, 44%, and 38% for the last five periods). Turbidities of less than 10 NTU were reported for 16 of 88 samples (18%) collected from the uncontrolled river Stations 1, 10, 6, and 7, as compared to frequencies of 20%, 14%, 22%, 22%, and 17% during the last five contract periods. Turbidities greater than 100 NTU were reported from 6 out of 88 (7%) of the samples at these stations, compared with 10%, 17%, 12%, 10%, and 9% from the last five contract periods. The overall maximum turbidity reported for this contract period was 1,020 NTU at Station 7 on August 14, 2006; the amount of precipitation in the previous 48 hours was 0.88 inch. Normally no turbidities in excess of 100 NTU are reported at Stations 5 and 9, downstream from Saylorville and Red Rock reservoirs, respectively, because of the sedimentation occurring in the reservoirs. The greatest turbidity below Saylorville Dam at Station 5 was 33 NTU; below Red Rock Dam at Station 9, 31 NTU. The maximum suspended solids below Saylorville Dam occurred in April, while the maximum below Red Rock Dam occurred in September, although both were associated with storm events. During the last contract period, the maximum turbidity below Saylorville and Red Rock reservoirs was similar. An analysis of field-duplicate results for turbidity collected during this contract period yielded good results. From 22 samples with an average value of 21 NTU, the average absolute difference was 1 NTU (5.5% difference).

A new maximum monthly turbidity was set at Station 1 in October 2005. Many new monthly minimum turbidity values were set. A new monthly minimum turbidity was set at Station 1 in July 2006 and at Station 5 in March 2006. On the Raccoon River at Station 10 new minimums were set in January and June 2006. At Station 6 new minimums were established in November and December 2005 and in March and June 2006, while at Station 9 new minimum turbidity values were seen in January and March 2006. Also, new minimum annual averages were set at Stations 1 and 10. From monthly mean data, the average turbidity at the Des Moines River sites was 29 NTU for the 2006 water year, which was 67% of the long-term average of 43 NTU at these sites. The 2006 water year average from the Raccoon River site was 26 NTU, which was
32% of its long-term average turbidity of 81 NTU. Mean turbidity for the previous water year from the Des Moines River and Raccoon River sites was 48 NTU and 83 NTU, respectively.

In 2000, the EPA proposed nutrient criteria based on ecoregions. The criteria are intended to address the effects of excess nutrient inputs. The criteria represent “reference” conditions of surface waters minimally impacted by human activities and protective of aquatic life and recreational uses. The EPA subecoregion Western Corn Belt Plains (WCBP) criterion for turbidity in rivers and streams is 15 NTU. Turbidity in the Des Moines and Raccoon rivers was greater than this value for 56% and 68% of the measurements for the 2006 water year, as compared to frequencies of 62% and 82% for the entire period of record (see Table 40).

8.11. Secchi Disk and Transparency Tube Depths

Light, essential for growth of plants, travels further in clear water than in turbid water that contains suspended solids or in colored water. Two methods that are commonly used to measure the transparency, or degree to which light penetrates, are the Secchi disk and transparency tube. When light strikes the surface of water, some light is reflected and backscattered; the rest is quickly attenuated through absorption and scattering by the water molecules and the dissolved and suspended material present in the water. The depth at which a Secchi disk disappears is related to the percentage of light transmission and is a good indicator of transparency changes occurring seasonally and over longer periods of time. As a rule of thumb, the zone where photosynthesis takes place is considered to be approximately three times the Secchi disk depth.

A Secchi disk is a disk painted in black and white quadrants that is lowered with a rope into lake water to the depth at which it disappears from sight. The distance to vanishing is recorded as the Secchi disk depth. Secchi disks have limited use in river water because the river current sways the line and also because the river bottom may be visible; therefore, there is not enough depth to have the disk disappear. During this contract period, a transparency tube was used to measure clarity at the riverine stations. The transparency tube is a clear, narrow plastic tube 120 cm in length that is marked in graduated units with a Secchi pattern on the bottom. To use, the tube is filled with river water that is drained off using a drain tube until the reference pattern appears. The resultant depth is the transparency tube depth.

Secchi disk depths were less variable than last period. Secchi disk depths at Station 4, in the main basin area of Saylorville Reservoir, averaged 0.72 m and ranged between 0.27 m and 1.02 m during this contract period. At Station 8, in the main basin area of Red Rock Reservoir,
Table 40. EPA nutrient criteria for rivers and streams compared to DMRWQN data for the 2006 water year.

<table>
<thead>
<tr>
<th></th>
<th>EPA Criteria Nutrient Ecoregion VI&lt;sup&gt;a&lt;/sup&gt;</th>
<th>EPA Criteria Sub-ecoregion Western Corn Belt Plains (WCBP)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Proposed Region VII RTAG Benchmark Values&lt;sup&gt;b&lt;/sup&gt;</th>
<th>DMRWQN Data from the Des Moines River&lt;sup&gt;c&lt;/sup&gt;</th>
<th>DMRWQN Data from the Raccoon River (St. 10)</th>
<th>Values &gt; EPA WCBP Sub-ecoregion Criteria at the Des Moines River</th>
<th>Values &gt; EPA WCBP Sub-ecoregion Criteria at the Raccoon River (St. 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphorus</td>
<td>0.076</td>
<td>0.118</td>
<td>0.075</td>
<td>0.20&lt;sup&gt;d&lt;/sup&gt; (0.03–1.36)</td>
<td>0.20&lt;sup&gt;d&lt;/sup&gt; (0.09–0.47)</td>
<td>73% (80 of 110)</td>
<td>73% (16 of 22)</td>
</tr>
<tr>
<td>(mg/l as P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>2.18</td>
<td>2.62</td>
<td>0.90</td>
<td>8.26 (1.47–14.3)</td>
<td>7.91 (1.20–16.8)</td>
<td>95% (105 of 110)</td>
<td>77% (17 of 22)</td>
</tr>
<tr>
<td>(mg/l as N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected chlorophyll a</td>
<td>7.33</td>
<td>7.85</td>
<td>8&lt;sup&gt;f&lt;/sup&gt;</td>
<td>57 (3–256)</td>
<td>80 (17–131)</td>
<td>88% (57 of 65)</td>
<td>100% (13 of 13)</td>
</tr>
<tr>
<td>(mg/m&lt;sup&gt;3&lt;/sup&gt; or µg/l)&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>9.89</td>
<td>15</td>
<td>—</td>
<td>35 (1–1,020)</td>
<td>30 (1–120)</td>
<td>56% (62 of 110)</td>
<td>68% (15 of 22)</td>
</tr>
</tbody>
</table>


<sup>c</sup>DMRWQN data for Des Moines River is from Stations 1, 5, 6, 7, and 9.

<sup>d</sup>Average value (range of values).

<sup>e</sup>Data only available May–September.

<sup>f</sup>Sestonic.
the average Secchi disk depth was 0.96 m and ranged between 0.39 m and 1.45 m. In order to examine the Secchi disk data record, which has varying sampling frequencies, data from only May through September were averaged. This allows comparison of recreational season Secchi disk depths over time. At Saylorville and Red Rock reservoirs, the average May–September 2006 Secchi disk depths were 0.78 m and 1.02 m, respectively, as compared to the long-term averages of 0.91 m and 0.85 m, respectively. During the previous period, May–September 2005, the average Secchi disk depths were 0.69 m and 0.74 m at Saylorville and Red Rock reservoirs, respectively. No new period-of-record monthly or annual records were established during the 2006 water year.

Transparency tube readings began to be measured at the riverine stations in July 2001. During this contract period, transparency tube depths ranged from as little as 3.7 cm at Station 7 on August 14, 2006, to >120 cm at Station 10 on November 7, 2006. This minimum represents the ninth-lowest transparency tube depth measured in the five years since readings began (880 readings).

In 2000, the EPA proposed nutrient criteria based on ecoregions. The criteria are intended to address the effects of excess nutrient inputs. The criteria represent “reference” conditions of surface waters minimally impacted by human activities and protective of aquatic life and recreational uses. The EPA subecoregion WCBP criterion for Secchi disc depth is 1.23 m. The Secchi depths at both Saylorville and Red Rock reservoirs were shallower than this value during all of the 18 readings and 13 of the 18 readings (72%), respectively, taken at each site over the contract period, as compared to frequencies of 88% (444 of 503) and 88% (429 of 488) for the entire period of record (see Table 41).

8.12. Dissolved Oxygen

Dissolved oxygen (DO) concentrations in streams and reservoirs are influenced by several factors. Among these are

- water temperature that affects the solubility of oxygen
- oxygen production via photosynthetic activity (primarily by algae)
- oxygen depletion via respiration
- the time of day the sample is collected
- reaction rates (affected by turbulence, temperature, ice cover, exposed water surface area, and stratification)
Table 41. EPA nutrient criteria for lakes and reservoirs compared to DMRWQN data for the 2006 water year.

<table>
<thead>
<tr>
<th></th>
<th>EPA Criteria Nutrient Ecoregion VIa</th>
<th>EPA Criteria Sub-ecoregion Western Corn Belt Plains (WCBP)a</th>
<th>Proposed Region VII RTAG Benchmark Valuesb</th>
<th>DMRWQN Data from Saylorville Reservoir (St. 4S)c</th>
<th>DMRWQN Data from Red Rock Reservoir (St. 8S)c</th>
<th>Values &gt; EPA WCBP Sub-ecoregion Criteria at Saylorville Reservoir</th>
<th>Values &gt; EPA WCBP Sub-ecoregion Criteria at Red Rock Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphorus (mg/l as P)</td>
<td>0.038</td>
<td>0.055</td>
<td>0.035</td>
<td>0.10d (0.01–0.19)</td>
<td>0.14d (0.07–0.28)</td>
<td>89% (16 of 18)</td>
<td>100% (18 of 18)</td>
</tr>
<tr>
<td>Total nitrogen (mg/l as N)</td>
<td>0.781</td>
<td>0.963</td>
<td>0.700</td>
<td>7.46d (2.55–13.5)</td>
<td>6.98d (2.30–13.6)</td>
<td>100% (18 of 18)</td>
<td>100% (18 of 18)</td>
</tr>
<tr>
<td>Corrected chlorophyll a (mg/m³ or µg/l)e</td>
<td>8.6</td>
<td>14.6</td>
<td>8</td>
<td>33d (7–63)</td>
<td>48d (2–167)</td>
<td>85% (11 of 13)</td>
<td>77% (10 of 13)</td>
</tr>
<tr>
<td>Secchi depth (m)</td>
<td>1.36</td>
<td>1.23</td>
<td>–</td>
<td>0.72d (0.27–1.02)</td>
<td>0.94d (0.39–1.45)</td>
<td>100% (18 of 18)</td>
<td>72% (13 of 18)</td>
</tr>
</tbody>
</table>

cReservoir sites are not sampled when there is ice cover.
dAverage value (range of values).
eData only available May–September.
Because each of these factors is important in determining dissolved oxygen concentrations, this important parameter is particularly difficult to interpret. But of more importance than the concentration of dissolved oxygen is the percentage of saturation. It seems that most fish can tolerate low dissolved oxygen concentrations, at least for a time, although almost any reduction in dissolved oxygen below saturation has adverse effects on growth, reproduction, or fish activity.

Dissolved oxygen concentrations ranged from 19.38 mg/l (253% of saturation) at Station 8S on July 10, 2006, to 0.25 mg/l (3% of saturation, when compared to surface) at Station 8B on July 24, 2006. The higher dissolved oxygen concentrations generally occurred in the winter due to the greater solubility of oxygen at lower temperatures. Increases in dissolved oxygen saturation at most stations, except Stations 5 and 9, were a result of algal production as indicated by elevated chlorophyll pigment concentrations. However, below Saylorville and Red Rock dams, increases in dissolved oxygen saturation were not always linked to primary productivity but usually instead to the structures themselves. The average dissolved oxygen saturation levels at Stations 1 and 5, above and below Saylorville Reservoir, were 94% of saturation and 104% of saturation, respectively. At Station 5, downstream from Saylorville Reservoir, the river water was supersaturated with dissolved oxygen in 68% of the samples, which compares to the last five contract periods when 73%, 50%, 41%, 54%, and 45% of the samples from Station 5 were supersaturated with dissolved oxygen. The averages in dissolved oxygen saturation level at Stations 7 and 9, above and below Red Rock Reservoir, were 106% and 114% of saturation, respectively. At Station 9, downstream from Red Rock Reservoir, the river was supersaturated with dissolved oxygen in 86% of the samples, compared with 91%, 59%, 91%, 82%, and 64% of the samples over the last five contract periods. Historical data indicate that chronic gas supersaturation exists below both dams (see Section 8.34).

At the uncontrolled riverine stations (Stations 1, 10, 6, and 7), dissolved oxygen saturation levels generally range from 70% to 120%. This year the range in dissolved oxygen saturation at the uncontrolled riverine stations was from 62% to 151%. The greatest variations in dissolved oxygen saturation at the river locations were linked to high chlorophyll pigment concentrations, indicating algal production of oxygen. For example, at Station 7 on July 24, 2006, the DO saturation was 147% and the viable chlorophyll a concentration was 179 mg/m³. The average DO saturation levels at the uncontrolled riverine Stations 1, 10, 6, and 7 were 94%, 117%, 110%, and 106%, respectively. Lower levels were seen at Station 1 because of diurnal variations in dissolved oxygen levels. Water samples were normally collected at Station 1 around
9:00 a.m., while samples from Stations 10, 6, and 7 were normally collected at 11:45 a.m., 1:30 p.m., and 2:00 p.m., respectively.

The state of Iowa water quality standard for class B waters is a minimum of 5.0 mg/l dissolved oxygen at any one time, but this standard only applies to the surface waters in a reservoir or lake. To maintain stable fish populations, the EPA has established a criterion for dissolved oxygen at a minimum of 5.0 mg/l during early life stages. During this contract period, the dissolved oxygen fell below the 5.0 mg/l standard on one occasion at the surface of both Saylorville and Red Rock reservoirs (3.87 mg/l and 4.61 mg/l, respectively, on August 14, 2006). These lower dissolved oxygen concentrations were in response to turnover of stratified lake water. There was one instance at the riverine locations where the dissolved oxygen concentration fell below 5.0 mg/l; this was at Station 7 on the Des Moines River above Red Rock Reservoir on August 14, 2006 (4.96 mg/l).

As expected, the lowest dissolved oxygen concentrations were found near the bottom of the reservoirs as a result of stratification. When thermal stratification exists, the dissolved oxygen in the hypolimnion (bottom) of a reservoir diminishes, primarily as a result of the bacterial oxygen demand of the sediments. Events of stratification occur most often in the summer months, because the change in the density of water per degree centigrade change in temperature is greater at higher temperatures. During the sampling period, 11 reservoir bottom samples out of 34 (32%) had dissolved oxygen concentrations less than 4.0 mg/l; this compares with 47%, 34%, 40%, 27%, and 50% of the samples for the previous five contract periods. From data collected during stratification events with a YSI meter, the portion of the water column with concentrations less than 4.0 mg/l ranged from 5% to 100% (averaging 41%) at Saylorville Reservoir, with the greatest occurring on August 14, 2006. At Red Rock Reservoir, the portion of the water column where dissolved oxygen concentrations were less than 4.0 mg/l ranged from 20% to 38% (averaging 31%), with the greatest occurring on August 7, 2006. Stratification events, in which the dissolved oxygen content near the reservoir bottom continued to be less than 4.0 mg/l, occurred this contract period as a result of elevated lake levels and water temperatures. Table 37 is a record of the surface-to-bottom temperature differences at the reservoirs. It also indicates periods of chemical stratification as indicated by dissolved oxygen content.

New period-of-record maximum monthly means were set for dissolved oxygen at Stations 6 and 8S in May 2006 and at Stations 10 and 6 in June 2006. The overall average dissolved oxygen concentration at the Des Moines River sites for the 2006 water year was 11.03 mg/l, which was only slightly higher than the long-term average of 10.93 mg/l. The 2006
water average from the Raccoon River at Station 10 was 11.96 mg/l, which was 111% of the long-term average of 10.75 mg/l at this site. See Appendix B for long-term data.

8.13. Biochemical Oxygen Demand (Carbonaceous)

Biochemical oxygen demand (BOD) determinations measure the amount of oxygen that decomposing organisms require to utilize carbonaceous compounds under aerobic conditions. The BOD test is basically a bioassay that measures the oxygen consumed by bacteria while utilizing the organic matter present in the sample. A quantifiable relationship exists between the amount of oxygen required to convert the organic matter to the end products of carbon dioxide, water, and ammonia. In the determination of BOD, nitrification was suppressed; therefore, nitrogenous demand was not included, and samples were incubated for five days. Water samples were kept on ice during transport and incubated within 24 hours to reduce the change in BOD that occurs between sampling and testing.

Biochemical oxygen demand analyses were conducted on samples routinely collected at Stations 1, 5, 10, 6, 7, and 9. Iowa State supported additional BOD analyses at Stations 4S and 8S so that water quality indices could be calculated at these sites. Results from these analyses were normally low; the maximum BOD measured was 10.1 mg/l at Station 8S on July 10, 2006, corresponding with algal growth. The highest BOD concentrations corresponded with elevated chlorophyll pigment concentrations, as was normally the case. This year, from the riverine stations, there were no values of BOD in excess of 10 mg/l. The average BOD concentrations at Stations 1 and 5 (upstream and downstream from Saylorville Reservoir) were 4.3 mg/l and 2.3 mg/l, respectively, while the average BOD concentrations at Stations 7 and 9 (upstream and downstream from Red Rock Reservoir) were 3.1 mg/l and 2.6 mg/l, respectively. From reviewing long-term data presented in Appendix B, it was noted that a new period-of-record maximum monthly mean was set at Station 10 in November 2005. New minimum monthly mean BOD concentrations were established in March 2006 at Station 1 and in February and May 2006 at Station 6. No new annual records were set. The overall average BOD concentration from the Des Moines River sites for the 2006 water year was 2.8 mg/l, which was slightly lower than the long-term average of 4.0 mg/l at these sites. The 2006 water year average BOD concentration on the Raccoon River at Station 10 was 3.7 mg/l, which nearly equaled the long-term average of 3.6 mg/l.

Analysis of 22 field-duplicate sets for BOD with an average concentration of 3.4 mg/l yielded an average absolute difference of 0.4 mg/l (or 12%), as compared to the long-term (since
1984) average absolute difference of 0.3 mg/l (or 10%). These results are good. For more information, see Table 12.

8.14. Carbon Dioxide and pH

Carbon dioxide and pH are conversely related: the higher the concentration of carbon dioxide, the lower the pH. One of the main factors affecting the carbon dioxide concentration in water is algal activity. Because of the utilization of carbon dioxide by algae, the concentration of carbon dioxide tends to decrease during active photosynthesis; thus, the pH increases. Although photosynthesis reduces carbon dioxide, bacterial and algal respiration and degradation of carbonaceous compounds provide a source of carbon dioxide. Low concentrations of carbon dioxide do not usually limit photosynthesis; however, low carbon dioxide concentrations often are indicative of active photosynthesis. Of importance is the fact that water quality is greatly affected by pH because pH often determines which ionic species will be present, and the toxicity of many compounds is pH dependent. An important example is ammonia; as the pH increases, total ammonia becomes increasingly toxic to fish because of the conversion of ionized ammonia to the gaseous un-ionized form.

Carbon dioxide concentrations ranged from 0.0 mg/l to 21.4 mg/l. The maximum carbon dioxide concentration occurred at Station 5 on June 26, 2006, and corresponded to a pH value of 8.15. The greatest carbon dioxide concentrations were generally reported at Stations 5 and 7 and at the bottom of Saylorville and Red Rock reservoirs. Elevated carbon dioxide concentrations at riverine stations were primarily a result of diurnal fluctuations in algal activity. Greater carbon dioxide concentrations near the bottom of the reservoirs indicated bacterial degradation of organic matter (detritus). However, sometimes elevated carbon dioxide concentrations were a result of storm events or cloud cover inhibiting primary production. Algal photosynthesis ceases at night and is reduced under cloudy conditions, and continual algal respiration produces carbon dioxide and utilizes oxygen. Thus, carbon dioxide concentrations are often greater in the morning and under cloudy conditions.

The range in pH values was moderate this contract period, with wider variations in pH occurring during intense periods of primary productivity. Values of pH ranged from 7.13 to 8.91. The maximum value occurred at Station 10 on August 5, 2006, which happened during a period of low flow and peak algal production. Of surface reservoir and riverine samples, 80 of 168 (or 48%) exhibited pH values in excess of 8.3, which was dissimilar to last contract period when only
12% of the pH values exceeded 8.30. Moderate variations in pH were seen at several stations from week to week.

Historically, from the Paradox database, individual pH values ranged from 6.00 at the preimpoundment Station 2 to 9.90 at Station 1 on December 11, 1969. Of 11,898 individual pH values from regular sampling sites, 80 values (<1%) exceeded 9.00 and 2,548 (22%) were greater than 8.30. No pH values were lower than 6.00.

Long-term data, summarized in Appendix B, show new maximum monthly pH values were set at Stations 6, 7, and 9 in February 2006, at Station 6 in May 2006, and at Station 10 in November 2006. The overall average pH from the Des Moines River sites for the 2006 water year was 8.21, as compared to the long-term average of 8.06. On the Raccoon River the average pH for the 2006 water year was 8.38, which equaled the long-term average.

8.15. Alkalinity

Alkalinity measures the buffering capacity of water, that is, the capacity to accept protons without significantly affecting the pH. The major buffering system in natural waters is the carbonate-bicarbonate system, so alkalinity is closely related to pH and the processes affecting pH, such as photosynthesis and respiration. Both phenolphthalein and total alkalinity were measured. Phenolphthalein alkalinity is present when the pH exceeds 8.3 and is potentiometrically determined by titrating with standard acid to a pH of 8.3. The phenolphthalein alkalinity includes carbonates and bicarbonates and is part of the total alkalinity. Continuing to titrate to a pH of 4.5 measures the remaining bicarbonates and determines the total alkalinity. Both parameters are recorded in milligrams per liter as calcium carbonate (CaCO₃).

There were 67 occasions at the surface reservoir or riverine locations where phenolphthalein alkalinity was evident, which was similar to the past three years but more frequent than usual. The maximum phenolphthalein alkalinity concentration this period occurred on March 28, 2006, at Station 4S when a concentration of 14 mg/l as CaCO₃ was reported. This corresponded with a pH value of 8.76.

The greatest concentrations of total alkalinity are usually reported during the winter months when groundwater influences to river flows are at a maximum. The greatest total alkalinity concentration during this contract period occurred at Station 10 on December 5, 2006, when a total alkalinity concentration of 316 mg/l as CaCO₃ was reported. The average total alkalinity concentrations at the representative riverine Stations 1, 10, and 7 were 225 mg/l as
CaCO₃, 213 mg/l as CaCO₃, and 214 mg/l as CaCO₃, respectively. These alkalinites were slightly higher than those seen last period.

The minimum total alkalinity concentration of 137 mg/l as CaCO₃ was reported at Station 1 on July 17, 2006, and was associated with a large storm event. Normally, instances of lower total alkalinity during the spring were associated with ice melt and storm events, while lower values during the late summer and early fall were associated with algae. Large amounts of algae and intense primary production can lower alkalinity because calcium carbonate precipitates at higher pH. Algae utilize carbon dioxide, driving up pH.

This year there were new period-of-record monthly minimums set at Station 10 in October 2005 and at Station 7 in August 2006. A new period-of-record monthly maximum was set at Station 9 in May 2006. The overall total alkalinity from the Des Moines River sites for the 2006 water year was 231 mg/l as CaCO₃, as compared to the long-term average of 224 mg/l as CaCO₃. On the Raccoon River at Station 10, the 2006 water year average was 212 mg/l as CaCO₃, as compared to the long-term average of 234 mg/l as CaCO₃ at this location.

8.16. Hardness

Water hardness measures the amount of divalent cations present in water and the capacity of their salts to precipitate soap. Geographical characteristics of an area determine which ions will be present. Calcium and magnesium are the primary cations in fresh water because of their predominance in sedimentary rocks; calcium is the cation present in the greatest concentrations in Iowa waters, so it is measured separately. Total hardness also is measured, and the difference between total hardness and calcium hardness is termed non-calcium hardness. Most of the non-calcium hardness is contributed by magnesium, but salts of aluminum, iron, strontium, manganese, and zinc also are included. In Iowa, since calcium and magnesium are the major cations affecting hardness and calcium carbonate plays a major role in the carbonate-bicarbonate system dominating alkalinity, the greater hardness concentrations are usually recorded under winter low-flow conditions because of larger groundwater contributions to the total flow. Because calcium carbonate precipitates at elevated pH values, algae may have a major effect on water hardness by utilizing carbon dioxide, raising the pH, and, thus, precipitating calcium carbonate. In addition, hardness can increase as ice cover forms and the majority of ions are frozen out so that the ice is relatively pure, while the ions are added to the remaining water. When the ice then thaws, a dilution effect may be noticed with a decrease in hardness. Dilution effects of rainwater and subsequent run-off often significantly lower hardness concentrations, especially in rivers.
Hardness may also increase in the hypolimnion of lakes under the right conditions, as carbonates are released from the sediments and resolubilized. Hardness is an important parameter because it modifies the toxicity of many metals to freshwater organisms. The toxicity of many metals (such as cadmium, chromium, lead, and zinc) has been shown to decrease as the water hardness increases.

The greatest calcium and total hardness concentrations observed this contract period were during the winter months for reasons discussed above. Total hardness concentrations ranged from 184 mg/l as CaCO₃ at Station 10 on August 14, 2006, to 485 mg/l as CaCO₃ at Station 7 on January 10, 2006. Calcium hardness concentrations ranged from 83 mg/l as CaCO₃ at Station 10 on August 14, 2006, to 293 mg/l as CaCO₃ at Station 1 on February 14, 2006. Significant decreases in total and calcium hardness were often linked to algal utilization of carbon dioxide and increased pH. Overall, the average total hardness concentrations at representative riverine Stations 1, 10, and 7 were 339 mg/l as CaCO₃, 286 mg/l as CaCO₃, and 316 mg/l as CaCO₃, respectively, as compared to respective averages of 323 mg/l as CaCO₃, 283 mg/l as CaCO₃, and 316 mg/l as CaCO₃ from last period.

New period-of-record maximum monthly means were set in total hardness at Stations 7 and 9 in March 2006. New period-of-record minimum monthly means were set in calcium hardness in October 2005 at Station 10 and in July and August 2006 at Station 9.

The overall average total and calcium hardness concentrations on the Des Moines River for the 2006 water year were 343 mg/l as CaCO₃ and 203 mg/l as CaCO₃, respectively, which compares to respective long-term averages of 336 mg/l as CaCO₃ and 200 mg/l as CaCO₃. The overall average total and calcium hardness concentrations on the Raccoon River for the 2006 water year were 287 mg/l as CaCO₃ and 166 mg/l as CaCO₃, respectively, which compares to respective long-term averages of 310 mg/l as CaCO₃ and 193 mg/l as CaCO₃.

8.17. Total Organic Carbon

In natural water systems, carbon occurs in two basic forms, inorganic and organic. By far, most of the carbon is in the inorganic form, found as free carbon dioxide, carbonic acid, carbonates, and bicarbonates, all of which are related by a series of chemical reactions. A smaller amount of carbon occurs in various organic forms, the most important of which are dissolved organic carbon and particulate organic carbon, although a relatively small amount may exist as living plant material. The conversion of carbon from one form to another via metabolic processes (photosynthesis and respiration), the temporary loss of carbon from the system due to pH changes
(precipitation of CaCO₃), and the loss of carbon dioxide to the atmosphere are all possible and must be kept in mind while evaluating carbon parameters.

The presence of organic matter, including naturally occurring substances and contamination by agricultural chemicals and wastewater effluents, is usually measured as total organic carbon (TOC) and dissolved organic carbon. It is important to know the carbon content of a waterway as it is an indicator of its organic character. The more carbon or organic content, the greater oxygen demand. A high organic content means an increase in the growth of microorganisms, which deplete oxygen supplies.

TOC is measured using an infrared detection system that oxidizes organic carbon to carbon dioxide. The TOC method provides a better measurement of organic quality than either BOD or chemical oxygen demand tests because TOC is independent of the oxidation state of the organically bound elements, such as nitrogen and hydrogen, and inorganics that can contribute to the oxygen demand measured by these other tests. The TOC method measures the organic carbon content after initial purging.

The measurement of TOC was reinstated in 2000 and continues with the support from the Iowa DNR Water Quality Initiative. Previously, TOC had been analyzed from the project’s inception in July 1967 until October 1981, when it was discontinued in order to alleviate budget constraints.

This year, the range in TOC concentrations was less than last period, ranging from 3 mg/l to 14 mg/l. The overall average TOC at most stations was similar, at about 6 mg/l. TOC concentrations observed this period were generally lower than concentrations recorded when TOC was performed earlier in the period of record (1967–1981).

Historically, TOC concentrations ranged from <1 mg/l at several locations to 341 mg/l at Station 10 on June 2, 1980. The highest concentrations were seen upstream from the reservoirs and at Station 10 on the Raccoon River. The 1972–1981 water year average (from monthly averages, see Appendix B) was 12 mg/l, 10 mg/l, 13 mg/l, and 8 mg/l at Stations 1, 5, 6, and 9 on the Des Moines River as compared to the recent 2000–2006 water year average of 7 mg/l, 6 mg/l, 6 mg/l, and 6 mg/l, respectively. The 1972–1981 water year average at Station 10 on the Raccoon River was 14 mg/l, whereas the 2000–2006 water year average was 6 mg/l.

Analysis of 22 field-duplicate sets for TOC with an average concentration of 3.4 mg/l yielded an average absolute difference of 0.4 mg/l (or 13% difference). Analysis of a check sample averaged recoveries of 101%.
8.18. Ammonia Nitrogen

Ammonia nitrogen results from the biological degradation of organic matter and also is the primary excretory product of aquatic organisms. Ammonia also may enter surface water via point source discharges or in run-off from agricultural sources. This compound is important from two perspectives. First, the oxidation of ammonia to nitrite (NO₂) and nitrate (NO₃) exerts an oxygen demand and thereby decreases dissolved oxygen concentrations. Second, at greater concentrations, ammonia can be toxic to aquatic life when enough exists in the un-ionized form (NH₃).

The quantity of water in the Des Moines and Raccoon rivers can have a significant effect on ammonia concentrations. Higher river flows generally reduce ammonia nitrogen concentrations through a dilution effect. In addition, reservoir stratification can lead to increases in ammonia concentration in the hypolimnion, which sometimes lead to small increases in ammonia concentrations downstream from the reservoirs.

Along the Des Moines River monitoring network, low river flow generally affects ammonia concentrations in two ways. First, as a result of less dilution of effluent from the Des Moines Integrated Community Area (ICA) Regional Wastewater Treatment Plant, ammonia concentrations have become significantly greater at Stations 6 and 7 during the fall and winter seasons, although this effect is much less significant after improvements at the wastewater treatment facility in 1987–1990. Second, low flows encourage algal growth, resulting in utilization of ammonia as a nitrogen source. Thus, during periods of high productivity, especially at Stations 1, 7, and 10, ammonia concentrations can be reduced.

In October 2000, the state of Iowa revised the class B water quality standards for ammonia to include acute and chronic values based not only on pH and temperature, but also life stage. The chronic criteria are listed in Tables 22 and 23. The state chronic criteria for warm-water streams range from a low of 0.18 mg/l at a pH of 9.0 and 30°C with early life stages present to 10.8 mg/l at a pH of 6.5 and 0 to 7°C with early life stages absent. Before 1999, the state had a split standard for ammonia in class B waters of 2.0 mg/l from April to October and 5.0 mg/l from November to March. During this contract period, there were no violations of the state standards. There have been no violations of applicable state standards at the surface reservoir or riverine locations during the previous fourteen contract periods.

The EPA criteria for ammonia were revised in December 1999. These criteria are based on total ammonia as mg/l N and vary with pH. Only chronic criteria vary with temperature. Previous to 1998, criteria were also based on un-ionized ammonia. The 1999 criteria are generally
more relaxed than previous criteria, especially at higher and lower ranges of pH. These newer EPA chronic criteria (see Tables 24 and 25) were not exceeded this period. There have been few violations of the applicable EPA ammonia criteria since the 1989–1990 contract period. The EPA plans to review ammonia criteria in light of recent studies that suggest freshwater mussels are more sensitive than species used to derive current criteria (EPA 2006).

Ammonia nitrogen concentrations ranged from <0.01 mg/l at several locations in June and July 2006 to 0.53 mg/l at Station 8B on June 5, 2006. This year, as was the case last year, none of the samples collected at the surface reservoir and riverine stations contained more than 0.5 mg/l. In the first 23 years of the project, greater ammonia concentrations tended to occur at Stations 6 and 7 downstream from the Des Moines Wastewater Treatment Plant; however, plant improvements have mitigated these effects, especially since 1990.

The average ammonia nitrogen concentrations for the 2006 water year (based on monthly means) at Stations 1, 5, 10, 6, 7, and 9 were 0.05 mg/l, 0.12 mg/l, 0.06 mg/l, 0.07 mg/l, 0.07 mg/l, and 0.08 mg/l, respectively. These concentrations can be compared with period-of-record annual averages at these respective stations of 0.25 mg/l, 0.24 mg/l, 0.17 mg/l, 0.53 mg/l, 0.26 mg/l, and 0.24 mg/l, respectively. Overall annual mean ammonia concentrations at the Des Moines River stations for the 2006 water year averaged 0.08 mg/l, or 26% of long-term means. Overall annual mean ammonia concentrations at the Raccoon River station for the 2006 water year averaged 0.06 mg/l, or 35% of its long-term mean. New period-of-record minimum monthly means were set for ammonia nitrogen at Station 6 in February 2006 and Stations 5 and 6 in May 2006. No new annual records were set. Monthly and annual summary statistics for the period of record are listed in Appendix B.

Analyses of the 22 field-duplicate samples for ammonia nitrogen with an average value of 0.06 mg/l yielded an average absolute difference of 0.01 mg/l, as compared to the long-term (since 1982) average absolute difference of 0.02 mg/l. Duplicate analysis began in 1974, but no tabular data were compiled until 1982. These results are very good (see Table 12 for more information). Spike recoveries averaged 104% (see Table 13), as compared to a long-term (since 1983) average recovery of 103%.

8.19. Un-ionized Ammonia Nitrogen

When ammonia dissolves in water, equilibrium between un-ionized ammonia (NH₃), ammonium (NH₄⁺), and hydroxide ions (OH⁻) is established. The toxicity of ammonia to fish and other aquatic organisms has been attributed to the un-ionized form of ammonia (NH₃). This
toxicity has been shown to vary according to species, size, and age of the fish, as well as the length of exposure. Direct measurement of un-ionized ammonia is not yet reliable, but because the concentration is primarily dependent on pH, temperature, and total ammonia concentration, it can be determined by using these factors. An increase in any of these factors increases the un-ionized ammonia concentration.

In 1976, the EPA published an ammonia criterion of 0.02 mg/l as NH₃ (or 0.016 mg/l as N) to protect freshwater aquatic life. In July 1985, the EPA published revised criteria for ammonia in the Federal Register (50FR145) and later in the 1986 edition of Quality Criteria for Water. These criteria were outlined in tabular form for the maximum allowable one-hour average concentrations (to protect against acute toxicity) and the maximum allowable four-day average concentrations (to protect against chronic toxicity). These tables were then divided into values for salmonids and other sensitive species and for more tolerant warm-water species. By using the most appropriate table (allowable four-day average for more tolerant species), it was apparent that the revised criteria were less protective than the original criterion.

In August 1999, EPA announced revised criteria based on total ammonia only. Therefore there are no current EPA criteria for un-ionized ammonia. (See the previous section for information on the most recent revised ammonia criteria.) For purposes of comparison, a benchmark concentration of 0.016 mg/l as N is used in this study.

Un-ionized ammonia nitrogen concentrations during this contract period were low, ranging from less than 0.001 mg/l to 0.032 mg/l. The greatest concentrations were observed in June 2006. Overall, nine values exceeded the 0.016-mg/l benchmark value. Of the last five contract periods, three values, four values, six values, eleven values, and thirty-one values, respectively, exceeded this benchmark value. Un-ionized ammonia concentrations at Stations 6 and 7 were significantly lower when compared with historical data. This continues a trend that is a result of improvements to the Des Moines ICA Regional Wastewater Treatment Plant in 1987–1990. During this contract period, un-ionized ammonia at Stations 6 and 7 averaged only 0.004 mg/l and 0.003 mg/l, respectively.

Monthly and annual summary statistics for the period of record are listed in Appendix B. Overall, the annual means from the Des Moines River stations for the 2006 water year (0.004 mg/l) averaged 41% of long-term means. Overall, the annual mean from the Raccoon River station for the 2006 water year (0.004 mg/l) was 80% of its long-term mean.
8.20. Nitrite Plus Nitrate Nitrogen

Nitrite is the intermediate product in the oxidation of ammonia to nitrate, and these two oxidation steps are mediated by the bacteria *Nitrosomonas* and *Nitrobacter*. When sufficient oxygen is available, practically all the nitrite will be oxidized to nitrate nitrogen, and nitrite concentrations will be extremely low. The major sources of nitrites and nitrates include agricultural run-off of nitrogen fertilizers, biological oxidation of organic nitrogen, fixation of molecular nitrogen, rainfall and dust precipitation, and sewage treatment effluents. Recent studies have suggested precipitation may be a significant source of nitrates. From 1991 to 1994 the mean nitrate nitrogen concentration from rainfall at a central Iowa site was 1.5 mg/l (Hatfield et al. 1996). Losses of nitrate from a system include leaching from the soil, assimilation by living organisms, and conversion to other nitrogen forms. Nitrate nitrogen is water soluble and easily leaches from soils into ground or surface waters. Algae prefer ammonia to nitrate as a nitrogen source because the presence of ammonia inhibits nitrate-reducing enzymes. Under anaerobic conditions, losses can be caused by bacterial (*Pseudomonas*) denitrification when nitrogen is lost as the gas N2. It may be possible for denitrification to occur even under aerobic conditions if the water contains a lot of suspended materials that can cause a micro-anaerobic zone to form around the particles.

A primary drinking water standard of 10 mg/l nitrate nitrogen was established by the Environmental Protection Agency because nitrates can cause methemoglobinemia in infants less than three months of age. In the intestinal tract of some infants, nitrates can be reduced to nitrites that impair the oxygen-carrying capacity of hemoglobin and could possibly lead to death. Later, EPA adopted a maximum contaminant level for nitrite nitrogen of 1 mg/l in drinking water. Some research indicates that the consumption of water containing large amounts of nitrate may be a contributing factor to stomach cancer, insulin dependent diabetes, birth defects, and spontaneous abortions (Yang-Chun-Yuh et al. 1998, Kostraba 1992, Dorsch et al. 1984, Hill et al. 1973, Fraser and Chilvers 1980, Mirvish 1977, Shuval and Gruener 1977, MMWR 1996). A study released in 2001 reported an increased risk for bladder and ovarian cancer in elderly Iowa women who consumed drinking water with nitrate concentrations >2.3 mg/l for over ten years (Weyer et al. 2001).

Concern over excessive use of nitrogen fertilizers from environmental quality and economic standpoints has pressured farmers in Iowa to apply less nitrogen fertilizers to their crops. The series of graphs (Fig. 4) illustrates the history of nitrogen fertilizer use on corn, corn acres planted, and corn yield since 1976. In 2005 the rate of nitrogen fertilizer use was 141
pounds per acre on 12,800 acres of corn. This data was provided by Iowa State Department of Agronomy and the National Agriculture Statistics Service. Generally, when compared with the rest of the corn-belt region, Iowa uses a lower rate of nitrogen fertilizer application while maintaining a higher yield.

A statistical analysis (Seasonal Kendall Tau) of flow-adjusted monthly mean nitrate data from Station 1 on the Des Moines River showed an increasing trend of 0.23 mg/yr (p=0.05) for the period 1967–1982. Data from Station 10 on the Raccoon River showed an even larger increasing trend, 0.36 mg/yr for the period 1967–1982. For both locations, there is no discernable trend if the whole data set is used (1967–2003) or if only the post 1982 data were used. The increasing trend in nitrate concentration in the 1970s reflects the increasing use of nitrogen fertilizer during that time. However, during the period June 1985–June 1993 (pre-1993 flood) when nitrogen application rates plummeted from 145 lb/ac to 114 lb/ac, there was no decreasing trend in nitrate concentration seen at these locations on the Des Moines and Raccoon rivers. Excess use of nitrogen fertilizer continues to be of great concern, especially since nitrate loading from the Mississippi River to the Gulf of Mexico may accentuate oxygen depletion in the offshore waters of Louisiana (see Section 8.25).

Because low concentrations of nitrite were observed in the past, only nitrite plus nitrate concentrations were measured. Nitrite nitrogen was measured separately for 10 years, beginning in 1967, with a maximum concentration of 0.62 mg/l being observed. Most (more than 90%) of the nitrite-nitrogen concentrations were less than 0.10 mg/l.

Nitrite plus nitrate nitrogen concentrations were highly variable during this contract period, with concentrations ranging from less than 0.01 mg/l at Station 1 on July 24 and September 5, 2006, to 16.0 mg/l at Station 10 on May 15, 2006. For the 2006 water year, the average nitrite plus nitrate nitrogen concentrations at Stations 1, 5, 10, 6, 7, and 9 were 8.05 mg/l, 7.43 mg/l, 6.38 mg/l, 7.67 mg/l, 7.51 mg/l, and 6.00 mg/l, respectively, based on monthly averages (see Appendix B). New period-of-record maximum monthly means were set at Stations 1, 5, and 6 in February 2006, at Station 5 in March 2006, and at Stations 10 and 9 in April 2006. Only one new minimum monthly mean was established (Station 10 in October 2005). For the 2006 water year, the monthly nitrite plus nitrate nitrogen concentrations at the riverine stations were higher than last year, being 123% of the long-term averages at these stations (versus 116% last year). Table 42 summarizes the long-term data. During this contract period, the 10-mg/l state drinking water standard was exceeded in 50 of 202 samples (25%), which was similar to the last contract period when 54 of 204 samples (26%) exceeded this value. Although none of the sampling stations are located on a stream segment designated for class C (drinking water), this
standard is used as a benchmark. This value is important because the city of Des Moines obtains some of its drinking water from the Raccoon and/or Des Moines rivers. When it is determined that nitrate concentrations are great in the river water, the Des Moines Water Works dilutes it to safe levels with groundwater or treats it using ion exchange technology to lower nitrate levels. In the past, the city of Des Moines has had to issue health advisories about high nitrate content in its drinking water. In 1992, the city of Des Moines began using ion exchange technology to treat its drinking water when necessary. No advisories have been issued since the nitrate-removal facility became operational. To increase available water, the Des Moines Water Works acquired rights to Maffit Reservoir in 2000. Earlier the frequency of use of the nitrate-removal facility was largely determined by nitrate levels; however, over time water demand has increased, making it another factor in its use. In 2005 the nitrate-removal facility was operational for 50 days, as compared to 44 days, 5 days, 66 days, 57 days, and 58 days for the previous five years.

Analyses of field-duplicate samples for nitrite plus nitrate nitrogen yielded an average value of 6.74 mg/l and an average absolute difference of 0.05 mg/l (or 0.8%), which compares to a long-term (since 1982) absolute average difference of 0.13 mg/l (or 1.9%). These are excellent results (see Table 12 for more information). Spike recoveries averaged 99.5%, as compared to a long-term (since 1983) average recovery of 98.9%.

Data from five riverine stations are available since the 1973 water year. When the comparable periods of water years (1973–2006) were examined, the ranked average annual nitrite plus nitrate nitrogen concentrations were as follows. Station 10 exhibited the greatest average concentration of 7.00 mg/l; next came Station 6 with an average of 6.53 mg/l, then Station 1 with an average of 6.12 mg/l, Station 5 with an average of 6.02 mg/l, and the lowest average concentration of 5.42 mg/l at Station 9.

Out of the total number of samples collected for the complete period of record at Station 10 on the Raccoon River (n = 1,116), 27% exceeded 10 mg/l, whereas 13% of the total samples (n = 5,887) taken at the Des Moines River stations exceeded this amount. At individual stations along the Des Moines River, the percentage of results in excess of 10 mg/l ranged from 16% at Stations 1 and 6 to 6% at Station 9. The complete nitrite plus nitrate nitrogen data set is summarized in Table 42 and Appendix B. Note that the period of record varies for each sampling station.
Table 42. Summary of the nitrite plus nitrate nitrogen data for the period of record.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Station</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total number of individual</td>
<td>1,376</td>
</tr>
<tr>
<td>records\textsuperscript{a}</td>
<td></td>
</tr>
<tr>
<td>Number of water years</td>
<td>39</td>
</tr>
<tr>
<td>Monthly maximum (mg/l)\textsuperscript{b}</td>
<td>15.4</td>
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<tr>
<td>Monthly minimum (mg/l)\textsuperscript{b}</td>
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</tr>
<tr>
<td>Overall mean (mg/l)\textsuperscript{b}</td>
<td>5.83</td>
</tr>
<tr>
<td>Number of individual records (\geq 10.0) mg/l\textsuperscript{a}</td>
<td>226</td>
</tr>
<tr>
<td>Percentage of samples (\geq 10.0) mg/l</td>
<td>16</td>
</tr>
</tbody>
</table>

\textsuperscript{a}From Paradox database query.

\textsuperscript{b}See Appendix B for monthly mean data record.
8.21. Organic Nitrogen

Organic nitrogen is found in both soluble and particulate matter. Dissolved organic nitrogen may consist of various amino acids, peptides, and other products from biological processes. Particulate organic nitrogen is composed primarily of materials containing proteins, such as biological cells. Thus, high organic nitrogen values are indicative of heavy run-off, partially treated wastewater, and/or high rates of algal activity. Typical organic nitrogen concentrations can range from less than 0.01 mg/l in some lakes to over 20 mg/l in raw sewage.

Analytically, organic nitrogen and ammonia can be determined together and have been referred to as “Kjeldahl nitrogen,” a term from the method. Therefore organic nitrogen is calculated by subtracting the concentration of ammonia nitrogen from the Kjeldahl nitrogen concentration.

This year, organic nitrogen was analyzed in samples collected at the surface reservoir and riverine stations. The measurement of organic nitrogen, and therefore total nitrogen, was reinstated in May 2000 with support from the Iowa DNR. Previously, organic nitrogen had been analyzed from the project’s inception in July 1967 until October 1981, when it was discontinued in order to address budget constraints.

During this contract period, organic nitrogen concentrations ranged from 0.28 mg/l at Station 5 on August 14, 2006, to 2.95 mg/l at Station 7 on this same date. This maximum concentration was a result of storm-associated runoff.

Analyses of 22 field-duplicate samples for Kjeldahl nitrogen yielded an average value of 1.12 mg/l and an average absolute difference of 0.09 mg/l (or 7.8% difference). Spike recoveries averaged 100%.

Historically, individual organic nitrogen results ranged from <0.01 mg/l on several occasions to 13 mg/l at the preimpoundment Station 4 on September 12, 1968. To get comparable means, the 1973–1981 water year average (from monthly means) was calculated and yielded 1.16 mg/l, 0.94 mg/l, 1.19 mg/l, and 0.79 mg/l at Stations 1, 5, 6, and 9 on the Des Moines River. The 1972–1981 water year average at Station 10 on the Raccoon River was 0.93 mg/l. These historical means can be used to evaluate recent data.

Long-term data are summarized in Appendix B. New period-of-record maximum monthly organic nitrogen concentrations were set at Stations 1 and 10 in October 2005 and at Station 9 in November 2006. The overall annual mean concentrations for the 2006 water year at the riverine sites were similar to last year and higher than period-of-record means. The 2006 water year average means from Stations 1, 5, 6, and 9 on the Des Moines River were 1.31 mg/l,
0.94 mg/l, 1.08 mg/l, and 0.93 mg/l, respectively, and 1.19 mg/l at Station 10 on the Raccoon River.

8.22. Total Nitrogen

Total nitrogen represents the summation of ammonia nitrogen, nitrite plus nitrate nitrogen, and organic nitrogen. The conversion of nitrogen from one form to another does not alter the total nitrogen concentration; however, loss of nitrogen may occur via sedimentation of particulate matter, uptake of inorganic nitrogen by algae, loss of un-ionized ammonia to the atmosphere, and the reduction of nitrite plus nitrate nitrogen to gaseous nitrogen.

The reinstatement of organic nitrogen to the project’s scope in May 2000 allowed total nitrogen concentrations to be calculated for the first time since 1981. Historically, individual total nitrogen concentrations ranged from 0.22 mg/l at Station 9 on October 17, 1974, to 27.9 mg/l at Station 6 on February 8, 1977. The highest concentrations were seen at Station 6 downstream from the city of Des Moines during a period in 1977 of sewage bypass to the river during low flow. The 1973–1981 water year average (from monthly means) was 7.31 mg/l, 6.64 mg/l, 8.08 mg/l, and 6.06 mg/l at Stations 1, 5, 6, and 9 on the Des Moines River. The 1973–1981 water year average at Station 10 on the Raccoon River was 7.35 mg/l.

Total nitrogen concentrations during this contract period ranged from 1.20 mg/l at Station 10 on August 7, 2006, to 16.9 mg/l at Station 10 on May 15, 2006. Interestingly, the highest concentrations were observed in the winter and spring, which is earlier than usual. Nitrite plus nitrate nitrogen comprised the vast majority of the total nitrogen. Higher total nitrogen concentrations paralleled storm events and associated run-off. The lowest total nitrogen concentrations were seen during the late summer under low flow conditions. Total nitrogen concentrations were somewhat lower below Saylorville and Red Rock reservoirs as there was a 7% and 18% reduction in total nitrogen below Saylorville and Red Rock dams. For the 2006 water year, the average total nitrogen concentrations were 9.37 mg/l, 8.48 mg/l, 8.81 mg/l, 8.87 mg/l, and 7.00 mg/l, at Stations 1, 5, 6, 7, and 9 on the Des Moines River. Total nitrogen concentrations averaged 7.63 mg/l at Station 10 on the Raccoon River. The overall average total nitrogen concentration at the Des Moines River sites was 8.51 mg/l, with ammonia nitrogen comprising about 1% (0.08 mg/l), nitrite plus nitrate nitrogen comprising 86% (7.33 mg/l), and organic nitrogen comprising 13% (1.11 mg/l) of this total.

In 2000, the EPA proposed nutrient criteria based on ecoregions. The criteria are intended to address the effects of excess nutrient inputs. The criteria represent “reference” conditions of
surface waters minimally impacted by human activities and protective of aquatic life and recreational uses. Also, an EPA Region VII nutrient regional technical assistance group (RTAG) has proposed benchmark values. Table 41 lists these criteria and benchmark values for lakes and reservoirs, and Table 40 lists these criteria and benchmark values for rivers and streams. The EPA subecoregion WCBP criterion for total nitrogen in lakes and reservoirs is 0.96 mg/l, which was exceeded in all samples collected from Saylorville and Red Rock reservoirs, as total nitrogen concentrations averaged 7.22 mg/l and 7.15 mg/l, respectively. The EPA subecoregion WCBP criterion for total nitrogen in rivers and streams is 2.62 mg/l, which was exceeded at the Des Moines River sites in 105 of 110 samples (95%) and at the Raccoon River site in 19 of 22 samples (86%), as total nitrogen averaged 8.20 mg/l and 8.89 mg/l in these respective rivers during the contract period. The RTAG group’s proposed benchmark values for total nitrogen in lakes and reservoirs are 0.7 mg/l and 0.9 mg/l in rivers and streams.

The long-term data record is summarized in Appendix B. Total nitrogen could only be calculated until 1981 when the Corps dropped organic nitrogen from the Scope of Work. Therefore, the data record is split with data from 1967 through 1981 and 2000 through 2005. Many period-of-record maximum monthly mean concentrations were set during the spring of 2006. In February 2006, new maximum monthly means were set at Stations 1 and 5; and in March 2006, new maximum monthly means were set at Stations 1, 5, 6, and 9. Also, new maximum monthly means were also measured in April at Stations 5, 10, 6, and 9 and in May at Station 9. A new minimum monthly mean was established in August at Station 10. A new period-of-record maximum annual mean was established at Station 1.

8.23. Total Phosphate and Orthophosphate

Phosphorus usually occurs as phosphate, either organically bound as polyphosphates or as soluble orthophosphate, the latter being most readily available as a plant nutrient. Sources of phosphorus include nonpoint sources, such as overland run-off of agricultural fertilizers, which are often associated with sediment, as well as point sources such as sewage treatment plant effluent and various food processing plant discharges. Because phosphorus is an essential nutrient for plant growth, aquatic plants may be stimulated to increase to nuisance levels when sufficient phosphorus is present. Algal production is related to levels of phosphorus and nitrogen in water. Above a 16:1 (N:P) ratio, the system may experience an algal bloom with the addition of phosphorus. Increases in phosphate at the bottom (hypolimnion) of a lake are due to decomposition, and under reducing conditions phosphate can be released from the sediment.
In recent years, there has been a change to more intensive agricultural production, especially animal production. This change has resulted in a buildup of soil phosphorus to levels rarely encountered in the past. As a result, there is increased potential for phosphorus losses to surface water (Rodecap 2000). A recent University of Illinois study showed that soil test levels as low as 20 mg/l as P with any commonly used tillage system will result in run-off water that is two times greater than the benchmark limit of 0.035 mg/l as P.

Routine analysis of total phosphate was reinstated at the riverine stations in 1999. Additional support in 2000 from the Iowa DNR has allowed more extensive monitoring of this very important parameter, including the reinstatement of orthophosphate analyses. Total phosphate had been routinely monitored during contract periods 4 through 18 (1970–1986), when total phosphate was reduced to a quarterly frequency and orthophosphate was dropped. The reinstatement of these parameters is an important step in monitoring nutrients from run-off and their effect on eutrophication.

Traditionally, these parameters have been reported as mg/l as PO$_4$, which may be converted to mg/l as P by multiplying the concentration by 0.3262, and inversely concentrations in mg/l as P can be converted to phosphate by multiplying by 3.066. Data are listed as both phosphorous and phosphate in Appendix A; however, the data discussed below are presented as phosphate. The detection limit for total phosphate is 0.01 mg/l (or 0.003 mg/l as phosphorus).

Overall, average total phosphate concentrations were similar to last period. The greatest average total phosphate concentration was seen at Station 7 on the Des Moines River, located below the city of Des Moines, and the confluences of the North, Middle, and South rivers. The average total phosphate concentration for the contract period at the Des Moines River sites was 0.60 mg/l, while the average total phosphate concentration of the Raccoon River was 0.56 mg/l. From the 168 riverine and surface reservoir samples, 12 samples (7%) were greater than 1.0 mg/l, and 4 samples (2%) were greater than 2.0 mg/l. During the last five contract periods, 43 of 170 (25%), 42 of 168 (25%), 52 of 166 (31%), and 50 of 160 (31%), were greater than 1.0 mg/l. The maximum concentration seen this period (4.17 mg/l at Station 7 on August 14, 2006) was associated with a storm event. Analyses of field-duplicate samples for total phosphate yielded an average value of 0.43 mg/l (0.14 mg/l as P) and an average absolute difference of 0.09 mg/l (0.03 mg/l as P, or 21% difference). Spike recoveries averaged 101%.

Ratios of nitrogen to phosphorus were calculated. For the 2006 water year, the average N:P ratios on the Des Moines River at Stations 1, 5, 6, 7, and 9 were 56:1, 78:1, 35:1, 27:1, and 36:1, respectively. At Station 10 on the Raccoon River, the average N:P ratio was 37:1. At Stations 4S and 8S on Saylorville and Red Rock reservoirs, the average N:P ratios were 75:1 and
47:1, respectively. These ratios indicate nitrogen is in great excess, and therefore phosphorus is the nutrient limiting algal production.

Historically, individual total phosphate results ranged from <0.1 mg/l at many sites to 17.3 mg/l at Station 6 on February 8, 1977. This maximum coincided with period-of-record maximums for orthophosphate and total nitrogen and occurred during an episode in 1977 of sewage bypass to the Des Moines River during low flow. New period-of-record minimum annual means for total phosphate were set for the 2006 water year at Stations 5, 6, and 9. At Station 1 a new record maximum monthly mean total phosphate was set in October 2005. Many new minimum monthly means were established, especially at Station 6 where new minimums were seen for the period January through May and July 2006.

The EPA WCBP subecoregion total phosphorus criteria for lakes and reservoirs (Table 41) is 0.06 mg/l (0.18 mg/l as PO₄), which was exceeded in 13 of 18 samples (72%) collected at Saylorville Reservoir and in all samples collected at Red Rock Reservoir. Total phosphorus concentrations averaged 0.08 mg/l (0.25 mg/l as PO₄) and 0.14 mg/l (0.43 mg/l as PO₄) at the surface of Saylorville and Red Rock reservoirs, respectively. The EPA WCBP subecoregion criteria for rivers and streams (Table 40) is 0.12 mg/l (0.37 mg/l as PO₄), which was exceeded in 68 of 110 samples (62%) at the Des Moines River sites and in 14 of 22 samples (64%) at the Raccoon River location. Total phosphorus from the five locations on the Des Moines River averaged 0.20 mg/l (0.60 mg/l as PO₄), while concentrations from the Raccoon River site averaged 0.18 mg/l (0.56 mg/l as PO₄). These averages are much lower than last period, when total phosphorus averaged 0.33 mg/l (1.01 mg/l as PO₄) at the Des Moines River sites and 0.18 mg/l (0.89 mg/l) at the Raccoon River site. A regional technical assistance group from EPA Region VII proposed benchmark values for total phosphorus in lakes and reservoirs (0.035 mg/l) and rivers and streams (0.075 mg/l).

During this contract period, concentrations of orthophosphate ranged from less than 0.01 mg/l on many occasions to 2.82 mg/l at Station 6 on September 5, 2006. Concentrations of orthophosphate were more than two times higher at Stations 6 and 7 when compared with riverine locations upstream. The lowest concentrations were observed at Stations 1, 5, and 10, where the primary productivity was greatest. There were several instances where orthophosphate concentrations were reported as slightly greater than total phosphate concentrations (n = 23, 0.08 mg/l average difference). This appears to be an artifact from diluting higher orthophosphate samples, especially when all the phosphate is present as orthophosphate. Analyses of field-duplicate samples for orthophosphate yielded an average value of 0.18 mg/l (0.06 mg/l as P) and
an average absolute difference of <0.003 mg/l (<0.01 mg/l as P). Spike recoveries averaged 104%. These results are good.

Historically, individual orthophosphate concentrations ranged from <0.01 mg/l on several occasions to 14.7 mg/l at Station 6 on February 8, 1977. This maximum corresponded with the maximum total phosphate concentration. Tables in Appendix B summarize the data record. During the 2006 water year, new period-of-record minimum monthly means were set at Station 1 in July 2006, at Station 10 in June and July 2006, and at Station 6 for the period February–April and June–July 2006.

8.24. Dissolved Silica

In fresh waters, silica may occur in the forms of dissolved silica acid or as particulate silica. Particulate silica, in turn, may be in the form of biological material, adsorbed to inorganic particles or organically complexed. In comparison to many other major inorganic constituents of natural waters, silica tends to be relatively consistent and varies little in response to flow. However, in eutrophic waters silica concentration may be greatly affected by the assimilation of silica by diatoms and the subsequent sedimentation of diatoms at a rate that exceeds the replenishment of silica, primarily from groundwater. Therefore, a seasonal silica cycle can exist that results in silica varying negatively with diatom populations.

With support from the Iowa DNR, analysis of dissolved silica was reinstated in 2000. Results are reported in mg/l as silica, SiO₂.

Dissolved silica concentrations during this contract period ranged from 4.70 mg/l at Station 8S on July 10, 2006, to 24.4 mg/l at Station 1 on August 7, 2006. Normally the lowest concentrations of silica were observed in the winter months; however, this year the lowest concentrations were seen in the summer. The maximum silica concentration corresponded to an increase in flow—between the July 24 and August 7, 2006, samplings, the flow increased from 630 ft³/s to 1,720 ft³/s while the silica concentration rose from 17.5 mg/l to 24.4 mg/l. The 2006 water year averages for Stations 1, 5, 6, 7, and 9 on the Des Moines River were 21.0 mg/l, 19.5 mg/l, 18.8 mg/l, 18.3 mg/l, and 15.8 mg/l, respectively, while at Station 10 on the Raccoon River the average concentration was 11.7 mg/l.

Analyses of field-duplicate samples for dissolved silica yielded an average value of 16.4 mg/l and an average absolute difference of 0.14 mg/l (or 1% difference). Spike recoveries averaged 100%. These results are excellent.
Historically, individual dissolved silica concentrations ranged from <0.01 mg/l to 59.6 mg/l at Station 9 on August 23, 1972. The 1973–1981 water year average (from monthly means) was 14.6 mg/l, 13.6 mg/l, 14.4 mg/l, and 12.5 mg/l at Stations 1, 5, 6, and 9 on the Des Moines River and 14.8 mg/l at Station 10 on the Raccoon River.

8.25. Loading

Most state and federal regulations require that concentrations of certain pollutants not be exceeded, so water quality data are usually recorded in units of concentration, such as milligrams per liter. Thus, the expression of water quality data in concentration units is the most convenient way to record such data. When evaluating the effects of impoundments, however, it is necessary to evaluate pollutant concentration in terms of flow, that is, the total transport of a pollutant past a given point in weight units per day. To represent this accurately, we calculated daily loadings by multiplying the concentration, in mg/l, by the river flow, in ft$^3$/s, and converting the mass loading into units of kg/day. The average daily loading for each station was found by simply averaging the respective daily loadings.

Recently, the magnitude of nitrate loading of the Mississippi River has been a topic of concern. Nitrate loading from the Mississippi River to the Gulf of Mexico has accentuated the cycle of fertilization, decay, and oxygen depletion in the offshore waters of Louisiana (USGS 1995). On the Gulf of Mexico’s Texas-Louisiana Shelf, an area of hypoxia (low dissolved oxygen levels) forms during the summer months covering 6,000 to 7,000 square miles, an area that has doubled in size since 1993. This condition is believed to be caused by a complicated interaction of excessive nutrients transported to the Gulf of Mexico by the Mississippi River, physical changes to the river, and the interaction of freshwater from the river with the saltwater of the Gulf. The USGS has estimated the annual nitrate nitrogen loading for the decade 1987–1996 from the Mississippi River to the Gulf of Mexico to be about one million tons. In 2000, the EPA released a draft action plan to mitigate hypoxia in the Gulf of Mexico (EPA). The final action plan (EPA 2001) calls for the reduction of nitrogen inputs by 30%. Data from Iowa streams suggest the state may be contributing, on average, about 1/4 of this total (Libra 1998). For more information, see Mississippi River basin and the Gulf of Mexico hypoxia Web site at http://www.epa.gov/msbasin.

The Natural Resources Conservation Service (NRCS) is proposing the adoption of a nutrient management standard that would require use of the Iowa Phosphorus Index (P index) to assess phosphorus transport in Iowa 303(d) waters (IDNR 2000). The P index is an integrated
approach to estimating the risk of phosphorus delivered to surface water from agricultural fields. This tool was developed to assess the potential for phosphorus moving from individual fields based on selected soil and field characteristics and on management practices. The P index provides a relative rating as to the risk of phosphorus moving from individual fields, which can be used to prioritize fields for nutrient and soil management practices (NCRS 2001).

Loading rates were calculated for suspended solids, ammonia nitrogen, nitrite plus nitrate nitrogen, organic nitrogen, total nitrogen, and total phosphate at Stations 1, 5, 10, 6, 7, and 9 during each sampling trip. The daily loadings of these parameters for each sampling event are recorded in Appendix A. To convert loadings to metric tons, divide by 1,000; to convert to pounds, multiply by 2.2.

Peak suspended solids loadings were lower than loadings last period. Suspended solids loadings during this contract period ranged from a minimum of 3,000 kg/day at Station 5 on December 5, 2006, to a maximum loading of 15,213,000 kg/day at Station 7 on August 14, 2006. This maximum occurred during a storm event and resulted from a river flow of 3,440 ft³/s and a suspended solids concentration of 1,808 mg/l. For this contract period, the average suspended solids loadings above and below Saylorville Reservoir at Stations 1 and 5 were 536,000 kg/day and 177,000 kg/day, respectively, representing an average reduction in loading of 67% as a result of Saylorville Reservoir. Comparatively, the average suspended solids loadings above and below Red Rock Reservoir at Stations 7 and 9 were 1,903,000 kg/day and 191,000 kg/day, respectively, which represented a 90% reduction in loading as a result of Red Rock Reservoir. If corresponding data are evaluated at Station 6, below the city of Des Moines, and Station 9, below Red Rock Dam, the reduction would average 73%. Station 6 is located above the North, Middle, and South rivers.

Normally, going downstream, ammonia nitrogen loadings increase as river flow increases. This contract period, the average ammonia nitrogen loadings at Stations 1, 5, 6, 7, and 9 were less than half of those seen last period at 254 kg/day, 738 kg/day, 579 kg/day, 2,656 kg/day, and 1,042 kg/day, respectively. A maximum ammonia nitrogen loading of 4,386 kg/day was reported at Station 9 on April 11, 2006, when the ammonia concentration was 0.11 mg/l and the river flow was 16,300 ft³/s. Ammonia nitrogen loading increased below Saylorville Reservoir by 190% as a result of degradation and ammonia production in the hypolimnion. Below Red Rock Dam, ammonia nitrogen loading was increased by 58%. However, the average ammonia nitrogen load entering Red Rock Reservoir was more than twice the average load entering Saylorville Reservoir.
The maximum nitrite plus nitrate nitrogen loadings were much higher than last period. The range in nitrite plus nitrate nitrogen loading during this contract period was from a minimum of <1,000 kg/day on several occasions at Stations 1 and 10 to a maximum of 532,000 kg/day at Station 7 on April 11, 2006. The minimum values occurred during low flow when precipitation and run-off was limited and nutrients were depleted by algae. The reservoirs had a lesser effect on nitrite plus nitrate nitrogen loadings, as this is a soluble parameter. During this contract period, the average loading below Saylorville Reservoir actually increased by 2%, although below Red Rock Reservoir loadings averaged 10% less.

The reinstatement of organic nitrogen in 2000 has allowed calculation of organic nitrogen and total nitrogen loadings for the fourth year since 1981. Organic nitrogen loadings were highest at Stations 6 and 7. The range in organic nitrogen loadings during this contract period was narrower, ranging from 452 kg/day at Station 5 on December 5, 2006, to 48,349 kg/day at Station 7 on September 19, 2006. Organic nitrogen loadings decreased by 14% and 35% below Saylorville and Red Rock reservoirs, respectively.

Peaks in total nitrogen loadings closely followed peaks in river flow, organic nitrogen, and nitrite plus nitrate nitrogen. Total nitrogen loadings ranged from 525 kg/day at Station 10 on August 7, 2006, to 576,571 kg/day at Station 7 on April 11, 2006. This maximum resulted from a flow of 16,600 ft³/s and a total nitrogen concentration of 14.2 mg/l. (The associated ammonia nitrogen, nitrite plus nitrate nitrogen, and organic nitrogen concentrations were 0.06 mg/l, 13.1 mg/l, and 0.98 mg/l, respectively.)

Reinstatement of total phosphate in 1999 allowed total phosphate loadings to be calculated and water year averages to be obtained for the last six years. Previous data ended with the 1986 water year. Total phosphate loadings this contract period ranged from 21 kg/day at Station 5 on December 5, 2006, to 47,214 kg/day at Station 7 on September 19, 2006. This maximum resulted from a flow of 9,280 ft³/s and a total phosphate concentration of 2.08 mg/l. Total phosphate loadings corresponded to suspended solids loadings and river flow, as would be expected given their particulate nature. Thus, total phosphate loadings were reduced through sedimentation in the reservoirs. Total phosphate loadings were reduced by 34% and 44%, respectively, below Saylorville and Red Rock reservoirs. Reductions were lower this period as peak loadings were much lower.

Average daily loadings for suspended solids, ammonia, nitrite plus nitrate, and total phosphate for the 2006 water year are listed in Table 43. Averages of the 1974 through 2006 water year loadings of suspended solids, ammonia nitrogen, nitrite plus nitrate nitrogen, organic nitrogen, total nitrogen, and total phosphate are listed in Table 44. It should be remembered that
data from 1993 contained measurements from the extreme flood of July 1993, which made it a very unusual year. The ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphate loadings, along with river flow data, are compiled in Tables 45–48, which detail annual loadings over the period of record by water year. The historical record, as monthly means, for all the loading parameters is given in Appendix B. From looking at these data summaries, it is noted that new period-of-record minimum monthly means were established at Station 10 for ammonia loading in July 2006 and for nitrite plus nitrate loading in October 2005 and November 2006. New minimum monthly means were set for total phosphate loading at Station 10 in November 2005 and at Station 6 in March and July 2006.

The data for suspended solids loading is further discussed. Analysis of suspended solids concentrations was initiated at all stations in 1974, but Station 7 was not sampled until 1982. Thus, apparent reductions in suspended solids loadings downstream from Red Rock Reservoir were usually underestimated when Station 6 was used as the upstream station, because the loading of suspended solids is normally greater at Station 7. Greater loadings were often seen at Station 7 because of the input of suspended sediment from the North, Middle, and South rivers between Stations 6 and 7.

The greatest yearly averages of suspended solids loadings were mostly seen during the high flow (flood) years of 1979, 1983, 1984, 1991, 1993, 1998, and 2004. However, the overall-maximum yearly average suspended solids loading was 21,069,000 kg/day at Station 6 for the 1978 water year. Minimum average suspended solids loadings were seen during the low flow (drought) years of 1977, 1981, 1988, 1989, 2000, and 2006. Suspended solids loadings from the 2006 water year were much lower than period-of-record averages. At the uncontrolled Des Moines River sites (Stations 1 and 7), the suspended solids transport for the 2006 water year averaged 37% of the period-of-record averages, and the average at the Raccoon River site (Station 10) was only 6% of its period-of-record average.

Suspended solids loading data are available for the 30 years since Saylorville Reservoir has been in existence. From Table 46, the after-closure period-of-record averages of suspended solids loadings upstream and downstream of Saylorville Reservoir at Stations 1 and 5 are listed as 1,630,000 kg/day and 245,000 kg/day, respectively. These values denote an average reduction of suspended solids loading of 85% as a result of Saylorville Reservoir. The greatest reductions in suspended solids loading were seen during years when loading was the greatest. Reductions in excess of 90% were observed during the 1977, 1979, 1982, 1991, 1996, 1998, and 2002 water years.
For Red Rock Reservoir, there are 33 years of suspended solids loading data from Stations 6 and 9 and 26 years of data from Station 7. Using Station 6 as the upstream station, there was an average reduction of 85% in suspended solids loading from 1974 to 2006 as a result of Red Rock Reservoir. Since 1981, there are data from Stations 6, 7, and 9. For these 26 years, if Station 6 is used as the upstream station, the reduction in suspended solids loading would be 82%; if Station 7 is used for the upstream station during the same time period, the average reduction in suspended solids loading would be 89%. Station 7 is located on the Des Moines River below the North, Middle, and South rivers, while Station 6 is located above their confluences.

No matter which periods are examined, both Saylorville and Red Rock reservoirs act as efficient “sediment traps” and thus improve water quality downstream. But the capacity of these reservoirs to accumulate sediment is not unlimited. The average yearly suspended solids loading rate at Station 7 is approximately three times the average yearly suspended solids loading rate at Station 1, so the impact of suspended solids clearly is much greater at Red Rock Reservoir than at Saylorville Reservoir. Increases in the conservation pool of Red Rock Reservoir have been necessary to offset losses to sedimentation. The conservation pool has risen a total of 17 feet since 1968.

It’s known that sediment from small tributaries accounts for a majority of the sediment delivered to Red Rock Reservoir. The Middle and South rivers and Whitebreast Creek (which enters Red Rock Reservoir from the southwest through Whitebreast Bay) account for 55% of the sediment delivered to Red Rock Reservoir despite the fact that they account for only 24% of the uncontrolled drainage. The average rate of soil erosion on steeper cropland in the area is about three times the average rate for cropland in Iowa (U.S. Department of Agriculture 2000).

8.26. Heavy Metals

Heavy metals are important when evaluating water quality because of their toxicity at extremely low concentrations and their ability to accumulate in the food chain. Trace metals are also important nutrients and can affect the cycling of other elements. The presence of heavy metals is important when considering a source for drinking water because soluble metals are difficult to remove in the treatment of water.

Analyses of soluble cadmium, copper, lead, and mercury were conducted on samples collected quarterly at Stations 1, 5, 10, 6, and 9. Thus, water samples were collected for metals analyses on only four occasions this contract period, reflecting a reduction in scope that began in
Table 43. Average daily loadings (kg/day) for selected parameters for the 2006 water year, from monthly means in Appendix B.

<table>
<thead>
<tr>
<th></th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Discharge (ft³/s)</td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>3,196</td>
</tr>
<tr>
<td>minimum</td>
<td>577</td>
</tr>
<tr>
<td>maximum</td>
<td>10,620</td>
</tr>
<tr>
<td>Suspended solids</td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>670,000</td>
</tr>
<tr>
<td>minimum</td>
<td>32,000</td>
</tr>
<tr>
<td>maximum</td>
<td>2,516,000</td>
</tr>
<tr>
<td>Ammonia nitrogen</td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>348</td>
</tr>
<tr>
<td>minimum</td>
<td>40</td>
</tr>
<tr>
<td>maximum</td>
<td>823</td>
</tr>
<tr>
<td>NO₂+NO₃ (as N)</td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>84,000</td>
</tr>
<tr>
<td>minimum</td>
<td>5,000</td>
</tr>
<tr>
<td>maximum</td>
<td>280,000</td>
</tr>
<tr>
<td>Organic nitrogen (as N)</td>
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</tr>
<tr>
<td>average</td>
<td>11,128</td>
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<tr>
<td>minimum</td>
<td>2,122</td>
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<tr>
<td>maximum</td>
<td>34,792</td>
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<tr>
<td>Stations</td>
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<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total nitrogen (as N)</td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>94,875</td>
</tr>
<tr>
<td>minimum</td>
<td>7,631</td>
</tr>
<tr>
<td>maximum</td>
<td>312,393</td>
</tr>
<tr>
<td>Total phosphate</td>
<td></td>
</tr>
<tr>
<td>average</td>
<td>5,011</td>
</tr>
<tr>
<td>minimum</td>
<td>795</td>
</tr>
<tr>
<td>maximum</td>
<td>20,968</td>
</tr>
</tbody>
</table>
Table 44. Averages of available comparative water year loadings from 1974 through 2006 of suspended solids, ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphate, as well as the minimum and maximum monthly and yearly means, observed in kg/day.

<table>
<thead>
<tr>
<th>Stations</th>
<th>1</th>
<th>5</th>
<th>10</th>
<th>6</th>
<th>7a</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discharge (ft³/s)</strong></td>
<td>3,196</td>
<td>3,398</td>
<td>2,027</td>
<td>5,959</td>
<td>7,402</td>
<td>7,325</td>
</tr>
<tr>
<td><strong>Suspended solids</strong></td>
<td>1,563,000</td>
<td>362,000</td>
<td>3,287,000</td>
<td>3,715,000</td>
<td>4,977,000</td>
<td>577,000</td>
</tr>
<tr>
<td><strong>Ammonia (as N)</strong></td>
<td>1,013</td>
<td>1,447</td>
<td>857</td>
<td>3,022</td>
<td>2,896</td>
<td>3,447</td>
</tr>
<tr>
<td><strong>NO₂ + NO₃ (as N)</strong></td>
<td>64,000</td>
<td>67,000</td>
<td>47,000</td>
<td>126,000</td>
<td>143,000</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total phosphate</strong></td>
<td>5,011</td>
<td>3,367</td>
<td>1,343</td>
<td>7,835</td>
<td>11,405</td>
<td>7,470</td>
</tr>
</tbody>
</table>

**Range in Water Year Means**

<table>
<thead>
<tr>
<th><strong>Discharge (ft³/s)</strong></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>minimum</td>
<td>316</td>
<td>175</td>
<td>198</td>
<td>393</td>
<td>1,087</td>
<td>930</td>
</tr>
<tr>
<td>maximum</td>
<td>10,608</td>
<td>11,739</td>
<td>5,052</td>
<td>19,584</td>
<td>21,871</td>
<td>24,183</td>
</tr>
</tbody>
</table>

| **Suspended solids** | | | | | | |
| minimum | 139,000 | 22,000 | 72,000 | 173,000 | 314,000 | 48,000 |
| maximum | 5,611,000 | 2,909,000 | 16,926,000 | 21,069,000 | 11,477,000 | 2,691,000 |

| **Ammonia (as N)** | | | | | | |
| minimum | 49 | 127 | 25 | 206 | 229 | 166 |
| maximum | 3,139 | 4,103 | 3,914 | 8,986 | 8,192 | 10,172 |

---

*Data from Station 7 do not begin until the 1981 water year.

*bFrom monthly means.

cUnits are kg/day.

Table 44. Continued.

<table>
<thead>
<tr>
<th></th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>NO₂ + NO₃ (as N)</strong></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>2,000</td>
</tr>
<tr>
<td>maximum</td>
<td>161,000</td>
</tr>
<tr>
<td><strong>Total phosphate</strong></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>1,679</td>
</tr>
<tr>
<td>maximum</td>
<td>20,873</td>
</tr>
<tr>
<td><strong>Ranges Monthly Averages</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Discharge (ft³/s)</strong></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>19</td>
</tr>
<tr>
<td>maximum</td>
<td>29,433</td>
</tr>
<tr>
<td><strong>Suspended solids</strong></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>1,000</td>
</tr>
<tr>
<td>maximum</td>
<td>40,391,000</td>
</tr>
<tr>
<td><strong>Ammonia (as N)</strong></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>&lt;1</td>
</tr>
<tr>
<td>maximum</td>
<td>20,820</td>
</tr>
<tr>
<td><strong>NO₂ + NO₃ (as N)</strong></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>1,000</td>
</tr>
<tr>
<td>maximum</td>
<td>619,000</td>
</tr>
</tbody>
</table>
Table 44. Continued.

<table>
<thead>
<tr>
<th>Total phosphate</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>minimum</td>
<td>59</td>
</tr>
<tr>
<td>maximum</td>
<td>191,522</td>
</tr>
</tbody>
</table>
Table 45. Average river discharge (ft³/s) since the 1974 water year, from monthly means.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1974</td>
<td>3,133</td>
</tr>
<tr>
<td>1975</td>
<td>2,110</td>
</tr>
<tr>
<td>1976</td>
<td>713</td>
</tr>
<tr>
<td>1977</td>
<td>316</td>
</tr>
<tr>
<td>1978</td>
<td>1,631</td>
</tr>
<tr>
<td>1979</td>
<td>4,806</td>
</tr>
<tr>
<td>1980</td>
<td>2,469</td>
</tr>
<tr>
<td>1981</td>
<td>1,467</td>
</tr>
<tr>
<td>1982</td>
<td>2,860</td>
</tr>
<tr>
<td>1983</td>
<td>7,160</td>
</tr>
<tr>
<td>1984</td>
<td>6,642</td>
</tr>
<tr>
<td>1985</td>
<td>2,039</td>
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<tr>
<td>1986</td>
<td>4,775</td>
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<tr>
<td>1987</td>
<td>3,093</td>
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<tr>
<td>1988</td>
<td>971</td>
</tr>
<tr>
<td>1989</td>
<td>941</td>
</tr>
<tr>
<td>1990</td>
<td>1,316</td>
</tr>
</tbody>
</table>

<sup>a</sup>Preimpoundment period. Saylorville Reservoir was constructed in three phases from June 1965 through April 1977. The Des Moines River was diverted through outlet works in July 1975. Final construction was completed and the reservoir began to fill in April 1977.
Table 45. Continued.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>1</td>
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<tr>
<td>1991</td>
<td>5,045</td>
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<tr>
<td>1992</td>
<td>3,833</td>
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<tr>
<td>1993</td>
<td>10,608</td>
</tr>
<tr>
<td>1994</td>
<td>3,354</td>
</tr>
<tr>
<td>1995</td>
<td>3,942</td>
</tr>
<tr>
<td>1996</td>
<td>2,555</td>
</tr>
<tr>
<td>1997</td>
<td>3,147</td>
</tr>
<tr>
<td>1998</td>
<td>2,866</td>
</tr>
<tr>
<td>1999</td>
<td>4,401</td>
</tr>
<tr>
<td>2000</td>
<td>746</td>
</tr>
<tr>
<td>2001</td>
<td>4,127</td>
</tr>
<tr>
<td>2002</td>
<td>1,505</td>
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<tr>
<td>2003</td>
<td>2,416</td>
</tr>
<tr>
<td>2004</td>
<td>2,967</td>
</tr>
<tr>
<td>2005</td>
<td>4,008</td>
</tr>
<tr>
<td>2006</td>
<td>3,519</td>
</tr>
<tr>
<td>Period average</td>
<td>3,196</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Average after closure</td>
<td>3,421</td>
</tr>
</tbody>
</table>
Table 46. Average suspended solids loadings (1,000 kg/day) since the 1974 water year, from monthly means.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>1</th>
<th>5</th>
<th>1→ 5%a</th>
<th>10</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>6→ 9%a</th>
<th>7→ 9%a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>1,746</td>
<td>2,909b</td>
<td>–</td>
<td>8,089</td>
<td>8,755</td>
<td>–</td>
<td>1,165</td>
<td>-87</td>
<td>–</td>
</tr>
<tr>
<td>1975</td>
<td>1,615</td>
<td>1,544b</td>
<td>–</td>
<td>2,805</td>
<td>3,345</td>
<td>–</td>
<td>757</td>
<td>-77</td>
<td>–</td>
</tr>
<tr>
<td>1977</td>
<td>577</td>
<td>22b</td>
<td>-96</td>
<td>102</td>
<td>173</td>
<td>–</td>
<td>155</td>
<td>-10</td>
<td>–</td>
</tr>
<tr>
<td>1978</td>
<td>1,427</td>
<td>164b</td>
<td>-89</td>
<td>16,926</td>
<td>21,069</td>
<td>–</td>
<td>908</td>
<td>-96</td>
<td>–</td>
</tr>
<tr>
<td>1979</td>
<td>4,041</td>
<td>269</td>
<td>-93</td>
<td>9,682</td>
<td>8,140</td>
<td>–</td>
<td>855</td>
<td>-89</td>
<td>–</td>
</tr>
<tr>
<td>1980</td>
<td>694</td>
<td>137</td>
<td>-80</td>
<td>574</td>
<td>1,733</td>
<td>–</td>
<td>367</td>
<td>-79</td>
<td>–</td>
</tr>
<tr>
<td>1981</td>
<td>630</td>
<td>106</td>
<td>-83</td>
<td>641</td>
<td>652</td>
<td>3,963</td>
<td>349</td>
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<td>-91</td>
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<tr>
<td>1982</td>
<td>2,718</td>
<td>196</td>
<td>-93</td>
<td>4,189</td>
<td>2,574</td>
<td>11,271</td>
<td>1,008</td>
<td>-61</td>
<td>-91</td>
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<tr>
<td>1983</td>
<td>2,167</td>
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<td>3,464</td>
<td>5,417</td>
<td>6,844</td>
<td>1,027</td>
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<td>-85</td>
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<td>1984</td>
<td>5,611</td>
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<td>4,043</td>
<td>6,528</td>
<td>11,477</td>
<td>854</td>
<td>-87</td>
<td>-92</td>
</tr>
<tr>
<td>1985</td>
<td>838</td>
<td>130</td>
<td>-84</td>
<td>568</td>
<td>1,611</td>
<td>6,358</td>
<td>960</td>
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<td>-85</td>
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<tr>
<td>1986</td>
<td>2,590</td>
<td>344</td>
<td>-87</td>
<td>2,711</td>
<td>4,543</td>
<td>6,009</td>
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<td>1987</td>
<td>855</td>
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<td>1988</td>
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<td>312</td>
<td>595</td>
<td>223</td>
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<td>-63</td>
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<td>1989</td>
<td>139</td>
<td>22</td>
<td>-84</td>
<td>1,733</td>
<td>300</td>
<td>314</td>
<td>48</td>
<td>-84</td>
<td>-85</td>
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<td>1990</td>
<td>655</td>
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<td>-89</td>
<td>2,408</td>
<td>3,110</td>
<td>3,332</td>
<td>359</td>
<td>-88</td>
<td>-89</td>
</tr>
</tbody>
</table>

a A negative change shows a decrease in loading; a positive change shows an increase in loading.

b Preimpoundment period. Saylorville Reservoir was constructed in three phases from June 1965 through April 1977. The Des Moines River was diverted through outlet works in July 1975. Final construction was completed and the reservoir began to fill in April 1977.
### Table 46. Continued.

<table>
<thead>
<tr>
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<th>7</th>
<th>9</th>
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<th>7&gt;9%&lt;sup&gt;a&lt;/sup&gt;</th>
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<td>4,977</td>
<td>532</td>
<td>-82</td>
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<sup>a</sup>No sampling was conducted in October and November 1991 and November and December 1992. Suspended solids transports from these months were calculated from estimated suspended solids concentrations.
Table 47. Average ammonia nitrogen loadings (kg/day) since the 1974 water year, from monthly means.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>1</th>
<th>5</th>
<th>1→ 5%(^a)</th>
<th>10</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>6→ 9%(^b)</th>
<th>7→ 9%(^b)</th>
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<td>69</td>
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<tr>
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<td>2,464</td>
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</tbody>
</table>

\(^a\) A negative change shows a decrease in loading; a positive change shows an increase in loading.

\(^b\) Preimpoundment period. Saylorville Reservoir was constructed in three phases from June 1965 through April 1977. The Des Moines River was diverted through outlet works in July 1975. Final construction was completed and the reservoir began to fill in April 1977. Table 47. Continued.
<table>
<thead>
<tr>
<th>Water Year</th>
<th>1</th>
<th>5</th>
<th>1→ 5%&lt;sup&gt;a&lt;/sup&gt;</th>
<th>10</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>6→ 9%&lt;sup&gt;a&lt;/sup&gt;</th>
<th>7→ 9%&lt;sup&gt;a&lt;/sup&gt;</th>
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<tbody>
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<sup>a</sup>No sampling was conducted in October and November 1991 and November and December 1992. Ammonia nitrogen transports from these months were calculated from estimated ammonia concentrations.
Table 48. Average nitrite plus nitrate nitrogen loadings (1,000 kg/day) since the 1974 water year, from monthly means.

<table>
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<th>Water Year</th>
<th>1</th>
<th>5</th>
<th>1→ 5%&lt;sup&gt;a&lt;/sup&gt;</th>
<th>10</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>6→ 9%&lt;sup&gt;a&lt;/sup&gt;</th>
<th>7→ 9%&lt;sup&gt;a&lt;/sup&gt;</th>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
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<td>–</td>
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<td>-4</td>
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<td>1990</td>
<td>39</td>
<td>43</td>
<td>10</td>
<td>51</td>
<td>99</td>
<td>111</td>
<td>104</td>
<td>5</td>
<td>-6</td>
</tr>
</tbody>
</table>

<sup>a</sup>A negative change shows a decrease in loading; a positive change shows an increase in loading.

<sup>b</sup>Preimpoundment period. Saylorville Reservoir was constructed in three phases from June 1965 through April 1977. The Des Moines River was diverted through outlet works in July 1975. Final construction was completed and the reservoir began to fill in April 1977. Table 48. Continued.
<table>
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<tr>
<th>Water Year</th>
<th>1</th>
<th>5</th>
<th>1→ 5%&lt;sup&gt;a&lt;/sup&gt;</th>
<th>10</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>6→ 9%&lt;sup&gt;a&lt;/sup&gt;</th>
<th>7→ 9%&lt;sup&gt;a&lt;/sup&gt;</th>
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<td>147</td>
<td>1</td>
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<td>267</td>
<td>237</td>
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<td>-11</td>
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<td>299</td>
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<td>1999</td>
<td>120</td>
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<td>3</td>
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<td>142</td>
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<td>148</td>
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<td>-30</td>
<td>33</td>
<td>59</td>
<td>66</td>
<td>46</td>
<td>-22</td>
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<td>55</td>
<td>139</td>
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<td>55</td>
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<td>123</td>
<td>115</td>
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<tr>
<td>2005</td>
<td>95</td>
<td>86</td>
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<td>-5</td>
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<td>105</td>
<td>112</td>
<td>100</td>
<td>-5</td>
<td>-11</td>
</tr>
<tr>
<td>Period average</td>
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<td>–</td>
<td>45</td>
<td>124</td>
<td>143</td>
<td>123</td>
<td>-1</td>
<td>–</td>
</tr>
</tbody>
</table>

Average after closure: 70 70 0

<sup>a</sup>No sampling was conducted in October and November 1991 and November and December 1992. Nitrite plus nitrate nitrogen transports from these months were calculated from estimated nitrite plus nitrate nitrogen concentrations.
1990. Previous to that time, metals analyses were conducted on a monthly basis. As before, only concentrations of soluble metals were determined. Laboratory detection limits for each of the analyses are listed in Table 49. Table 50 lists the percentage recovery of the spike in spiked samples. The numerous standards and criteria for the heavy metals are listed in Table 21 for easy reference and clarification. Violations of primary drinking water standards will be noted in this discussion, despite the fact that none of the sampling stations are designated as class C waters. This was done for reference and comparison purposes. Violations of state standards and EPA criteria are listed in Table 26. In 1993, EPA experts concluded that total recoverable metal concentrations be used for mass balances and permits and dissolved metal concentrations be used for criteria application, as dissolved metal concentrations more closely estimate the bioavailable metal fraction. An important change in the analytical methods for cadmium, chromium, and lead (the use of S-H background correction) were made in 1988 as discussed in the February 1989 annual report. These changes were such that data collected before May 1988 for soluble cadmium and lead should be viewed with care. Thus, period-of-record data for soluble cadmium and lead, as summarized in Table 16, include only data since the May 1988 method change. In addition, graphite furnace methodology was used from March 1990 through October 1999 for the determination of soluble arsenic, cadmium, chromium, and lead, as described in the February 1990 annual report (S-H background correction was made for arsenic, cadmium, and lead). This change in analytical methodology greatly decreased laboratory detection limits for cadmium, chromium, and lead analyses and slightly increased detection limits for arsenic analyses. Analyses for soluble copper content were initiated in 1991 using graphite furnace methodology without background correction, as the samples were not concentrated. A GBC atomic absorption spectrophotometer was in operation in February 2000, with deuterium background correction used for all AA analysis.

During this contract period, none of the 20 samples analyzed for soluble cadmium were above laboratory detection limits, which ranged from 0.3 µg/l to 0.6 µg/l. Therefore, results were less than the state water quality standards for designated use class B (WW) (15 µg/l) and class C (5 µg/l). No results exceeded EPA acute criteria; however, because the new chronic criteria are so low (0.53 µg/l at a hardness of 250 mg/l CaCO₃), it is not known if these criteria were approached. Currently, no reservoir samples are analyzed for metals content. The average percentage recovery of laboratory-prepared spiked samples was 108%. A field blank was used for each metals monitoring event. There was no detectable soluble cadmium in any of the four field blanks (see Table 51).
Table 49. Laboratory detection limits for each of the heavy metal analyses, recorded in µg/l.

<table>
<thead>
<tr>
<th>Date</th>
<th>Soluble Cadmium</th>
<th>Soluble Copper</th>
<th>Soluble Lead</th>
<th>Soluble Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>14Feb06</td>
<td>0.6</td>
<td>4</td>
<td>4</td>
<td>0.06</td>
</tr>
<tr>
<td>22May06</td>
<td>0.3</td>
<td>1</td>
<td>2</td>
<td>0.03</td>
</tr>
<tr>
<td>07Aug06</td>
<td>0.4</td>
<td>5</td>
<td>3</td>
<td>0.01</td>
</tr>
<tr>
<td>07Nov06</td>
<td>0.6</td>
<td>6</td>
<td>6</td>
<td>0.02</td>
</tr>
<tr>
<td>Average</td>
<td>0.5</td>
<td>4</td>
<td>4</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Table 50. Recovery of laboratory-prepared spiked samples for each of the heavy metal analyses, recorded in percentages.

<table>
<thead>
<tr>
<th>Date</th>
<th>Soluble Cadmium</th>
<th>Soluble Copper</th>
<th>Soluble Lead</th>
<th>Soluble Mercury</th>
</tr>
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<tbody>
<tr>
<td>14Feb06</td>
<td>105.6</td>
<td>102.0</td>
<td>100.4</td>
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<tr>
<td>22May06</td>
<td>109.6</td>
<td>103.2</td>
<td>97.2</td>
<td>124</td>
</tr>
<tr>
<td>07Aug06</td>
<td>111.2</td>
<td>101.6</td>
<td>98.4</td>
<td>99.3</td>
</tr>
<tr>
<td>07Nov06</td>
<td>104.0</td>
<td>94.4</td>
<td>105.2</td>
<td>100</td>
</tr>
<tr>
<td>Average</td>
<td>107.6</td>
<td>100.3</td>
<td>100.3</td>
<td>134</td>
</tr>
</tbody>
</table>
Table 51. Results from a field blank for each of the heavy metal analyses, recorded in μg/l.

<table>
<thead>
<tr>
<th>Date</th>
<th>Cd</th>
<th>Cu</th>
<th>Pb</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>14Feb06</td>
<td>&lt;0.6</td>
<td>&lt;4</td>
<td>&lt;4</td>
<td>&lt;0.06</td>
</tr>
<tr>
<td>22May06</td>
<td>&lt;0.3</td>
<td>&lt;1</td>
<td>&lt;2</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>07Aug06</td>
<td>&lt;0.4</td>
<td>&lt;5</td>
<td>&lt;3</td>
<td>0.01</td>
</tr>
<tr>
<td>07Nov06</td>
<td>&lt;0.6</td>
<td>7</td>
<td>&lt;6</td>
<td>&lt;0.06</td>
</tr>
</tbody>
</table>
Soluble copper has been quantified since January 1991. This year 2 of the 20 samples (10%) analyzed contained detectable amounts of soluble copper, ranging from 2 µg/l to 7 µg/l. The EPA continuous criterion, which is based on hardness, was never exceeded. The state water quality standard for class B (WW-1) waters of 35 µg/l was also not exceeded. The human health standard of 1,000 µg/l was never approached. The laboratory detection limit for the analyses of copper, using graphite furnace methodology, ranged from 1 µg/l to 6 µg/l. The average recovery of spiked samples was 100%. A field blank was used for each metals monitoring event. One of four field blanks yielded a detectable concentration (7 µg/l) of soluble copper (see Table 51).

Soluble lead determinations also were conducted. Detection limits obtained this year ranged from 2 µg/l to 6 µg/l. None of the 20 samples had detectable concentrations. The EPA CCC criterion of 8.1 µg/l (at a hardness of 250 mg/l as CaCO₃), the state class B (WW-1) standard of 30 µg/l, and the state class C standard of 50 µg/l were not exceeded. The average recovery of laboratory-prepared spiked samples was 100%. A field blank was used for each metals monitoring event. There was no detectable soluble lead in any of the four field blanks (see Table 51).

Of the soluble mercury determinations, 40% were above detection limits, ranging from 0.01 µg/l to 0.06 µg/l. Soluble mercury concentrations ranged from 0.02 µg/l to 0.08 µg/l with none of the 20 samples exceeding the state human health standard for fish consumption by humans of 0.15 µg/l or the EPA CCC criterion of 0.77 µg/l. The average recovery of laboratory-prepared spiked samples was 134%; however, if one high result is dropped the resultant spike recovery would be 108% for the remaining three analyses. A field blank was used for each metals monitoring event. There was one detectable soluble mercury concentration (0.01 µg/l) from one of four field blanks (see Table 51).

Recent data has shown dangerous mercury levels in rain falling on Midwestern cities in Michigan, Minnesota, and Illinois. In 1996 the National Atmospheric Deposition Program began the Mercury Deposition Network (http://nadp.sws.uiuc.edu/mdn/). Currently 90+ sites nationwide are monitored weekly. The site nearest to the Des Moines River is in southern Minnesota (site MN27—Lamberton, Redwood County, Minnesota). From this site the seven-year (1998–2005) average total mercury concentration was 13.3 ng/l and the average total mercury wet deposition was 8.2 µg/m³ (no data was available for 2002). In 2006, a new NADP initiative was announced to include dry deposition and modeling. The latest information on fish consumption advisories was from 2004 when 44 states issued advisories because of mercury in fish. The number of individual advisories issued had increased from 2,362 in 2003 to 2,436 in 2004. Many advisories specifically identified atmospheric deposition of mercury as the cause of the contamination. In
2004, the EPA and FDA issued advice for women who might become pregnant, nursing mothers, and young children. The intent was to make recommendations to allow consumers to receive the benefits of eating fish while reducing exposure to mercury (EPA-823-F-04-009). Previous studies of mercury in fish flesh along the Des Moines River Water Quality Network, however, found concentrations were far less than the FDA action level. Fish accumulate mercury in their organs (spleen, kidney, liver), and skeletal muscle acts as a reservoir. Ingestion of mercury-laden fish could have human health effects as well as effects on predators. Prompted by the apparent numerous violations of the state standard for soluble mercury in class B waters, a preliminary investigation into the mercury content of several species of fish from the Des Moines River was conducted during 1984. The mean mercury concentrations ranged from 0.18 ppm in a largemouth bass (*Micropterus salmoides*) sample to 0.06 ppm in a crappie (*Pomoxis sp.*) sample. The preliminary study utilized only a few fish of five species. Nine times during the period 1984–1994, a portion of the carp (*Cyprinus carpio*) fillets collected for pesticide analysis were reserved for analysis of mercury content. In addition, mercury content was determined in whole fish annually from 1987 to 1994. All results from both the fillet and whole fish samples were well below the FDA’s action level of 1.0 ppm for food fish, the EPA screening value of 3 ppm, and the NAS/NAE guideline for whole fish of 0.5 ppm, which were applicable at the time of the study. The average mercury concentrations in the carp fillets from Stations 4, 5, 8, and 9 ranged from 0.02 ppm to 0.34 ppm, with the highest concentration occurring in Saylorville Reservoir in the spring of 1990 and 1991. Concentrations of mercury in the whole fish samples were consistently less than in the fillet samples, ranging from 40% to 70% of the average fillet concentration. Historically, higher mercury concentrations have been noted in fillet samples, as muscle tissue acts as a reservoir for mercury. The average mercury concentrations in the whole carp samples from 4, 5, 8, and 9 ranged from 0.02 ppm to 0.11 ppm, with the highest concentrations occurring in the spring of 1989. Analyses of mercury in fish tissue were dropped from the Scope of Work in 1995; it continues to be recommended that it be reinstated in order to provide more information about current concentrations in fish from the study area.

In 2004 the Iowa DNR agreed to support analyses of mercury content in carp and channel catfish (*Ictalurus punctatus*) fillets collected below both reservoirs. The average total mercury concentrations from carp fillets in the Des Moines River below Saylorville and Red Rock reservoirs were 0.06 µg/l and 0.04 µg/l, respectively, and from channel catfish fillets total mercury concentrations were 0.13 µg/l and 0.06 µg/l, respectively. Monitoring of mercury in carp and largemouth bass (*Micropterus salmoides*) were supported by ISU in 2005. The average total mercury concentrations from carp fillets in the Des Moines River below Saylorville and Red
Rock reservoirs were 0.04 µg/l and 0.05 µg/l, respectively, and from largemouth bass fillets the total mercury concentrations were 0.11 µg/l and 0.05 µg/l, respectively.

**8.27. Additional Inorganic Constituents**

In addition to the inorganic parameters already discussed, chloride, sodium, potassium, and sulfate were analyzed four times during the contract period. These analyses permitted the completion of ion balances used to evaluate the precision of tests done in the field.

Sodium and chloride are relatively conservative in nature, meaning that they are very soluble, occur in concentrations that far exceed metabolic requirements, and exhibit only minor fluctuations in concentration. On the other hand, potassium, phosphate, and sulfate concentrations fluctuate widely, because they are very dynamic and are required in the metabolism of most plants and animals.

Secondary aesthetic drinking water standards of 250 mg/l for both chloride and sulfate were not approached during the contract period, nor was the EPA criterion for chloride of 230 mg/l. The maximum chloride and sulfate concentrations were 54.4 mg/l and 105 mg/l, respectively. The state of Iowa is considering adopting aquatic life criteria for chloride. Among the recommendations are an acute criterion of 860 mg/l and a chronic criterion, ranging from 230 mg/l to 564 mg/l, for class B waters, with a 1,500-mg/l limit for general use streams (IDNR, April 2003). To gather baseline data on the ambient conditions for TDS (total dissolved solids) and chloride, the IDNR and the Iowa Water Pollution Control Association collected and tested samples from 123 cities in 2004 and 2005 during low flow conditions (wastewater effluent, tap water, and receiving stream).

**8.28. Ion Balances**

Ion balances were conducted periodically to check the correctness of several analyses, especially those done in the field. Theoretically, the sum of the anions, in milliequivalents per liter, should equal the sum of the cations, in milliequivalents per liter, but the sums are seldom equal because of the unavoidable variations in analysis. This inequality becomes greater with increasing ionic content. Theoretically, two-thirds of the differences between cation and anion concentrations, in milliequivalents, should be within one standard deviation of the theoretical difference (zero), while nearly all of the differences should be within two standard deviations. In fresh waters, the major cations include calcium, magnesium, sodium, and potassium; the major
anions consist of carbonates, bicarbonates, sulfate, and chloride. Nitrite plus nitrate nitrogen can also contribute significantly to the anions.

Ion balances were performed on routine samples collected on March 3, June 12, September 5, and December 5, 2006. The results are listed in Table 52 and are graphically represented in Fig. 5. The average absolute differences for the ion balances were 2.88%, 0.74%, 1.19%, and 1.94%, listed chronologically. The overall absolute difference was 1.69%, as compared to 3.33%, 2.32%, 2.69%, 2.44%, and 1.42% for the last five contract periods.

From the confidence intervals established in *Standard Methods* (American Public Health Association 1998), 20 samples out of 24 (or 83%) were within one standard deviation, 3 samples (12%) were outside one standard deviation but within two standard deviations, and 1 sample (4%) was outside two standard deviations of the theoretical difference. These results are good. This year, anions were found in excess of the cations in eleven (46%) of the ion balances, as compared to 8%, 45%, 75%, 50%, and 62% for the last five contract periods.

### 8.29. Mineral Standard

Commercially prepared mineral standards from Ultra Scientific were analyzed for ion content, pH, and specific conductance on three occasions this period as part of a comprehensive quality assurance program. Normally mineral standards are analyzed quarterly; however, one event was unusable as the standard was frozen due to an equipment malfunction. Analyses of the mineral standards were conducted along with water samples collected June 12, September 5, and December 5, 2006. The results from these three analyses were excellent. Almost all of the results were within the established 95% confidence intervals. Our results for pH were slightly lower than these limits. The results from analyses of the mineral standards are listed in Table 53.

### 8.30. Chlorophyll

All plants contain chlorophylls, the pigments that absorb light for photosynthesis. In Iowa rivers and reservoirs, the plants of primary importance are algae. The algal community of rivers is generally sessile, growing on submerged stones, rocks, and higher plants. Planktonic river algae are usually members of the sessile bottom flora scoured off the rocks by the current. If the river is draining a pond, lake, or reservoir, lake plankton also may enter the river. In both lakes and rivers, algae are the main food source for zooplankton and also are the major oxygenators of the water.
Table 52. Ion balance results.

<table>
<thead>
<tr>
<th>Date</th>
<th>Station</th>
<th>Anions (meq/l)(^b)</th>
<th>Cations (meq/l)</th>
<th>Percent(^a) Difference</th>
</tr>
</thead>
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<td>8.80</td>
<td>5.94</td>
</tr>
<tr>
<td></td>
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<td>9.86</td>
<td>9.57</td>
<td>2.94</td>
</tr>
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<td></td>
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<td>9.06</td>
<td>3.58</td>
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<td>8.07</td>
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<td>7.22</td>
<td>0</td>
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<td>6.21</td>
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<td>7.02</td>
<td>6.97</td>
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<td>7.08</td>
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<td>9</td>
<td>6.76</td>
<td>6.90</td>
<td>-2.08</td>
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<td>05Sep06</td>
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<td>6.89</td>
<td>7.03</td>
<td>-1.97</td>
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<td>5.94</td>
<td>5.97</td>
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</tr>
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<td>8.50</td>
<td>8.45</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>7.37</td>
<td>7.57</td>
<td>-2.79</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>7.03</td>
<td>7.05</td>
<td>-0.30</td>
</tr>
</tbody>
</table>

\(^a\)[(\(\sum\) Anions - \(\sum\) Cations)/ \(\sum\) Anions] x 100.

\(^b\)Milliequivalents per liter.
Table 53. Results from analyses of commercial mineral standards.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Date</th>
<th>Our Result</th>
<th>True Value</th>
<th>95% Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>12Jun06</td>
<td>9.10</td>
<td>9.22</td>
<td>9.02–9.42</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>8.65</td>
<td>9.22</td>
<td>9.02–9.42</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>8.65</td>
<td>9.28</td>
<td>9.08–9.48</td>
</tr>
<tr>
<td>Total alkalinity(^a)</td>
<td>12Jun06</td>
<td>175</td>
<td>192</td>
<td>172–211</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>173</td>
<td>192</td>
<td>172–211</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>224</td>
<td>249</td>
<td>224–274</td>
</tr>
<tr>
<td>Total hardness(^a)</td>
<td>12Jun06</td>
<td>522</td>
<td>531</td>
<td>478–584</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>524</td>
<td>531</td>
<td>478–584</td>
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<td></td>
<td>05Dec06</td>
<td>528</td>
<td>531</td>
<td>478–584</td>
</tr>
<tr>
<td>Calcium(^b), (^c)</td>
<td>12Jun06</td>
<td>136</td>
<td>140</td>
<td>126–154</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>133</td>
<td>140</td>
<td>126–154</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>140</td>
<td>140</td>
<td>126–154</td>
</tr>
<tr>
<td>Magnesium(^c)</td>
<td>12Jun06</td>
<td>44.4</td>
<td>43.8</td>
<td>39.8–48.3</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>46.1</td>
<td>43.8</td>
<td>39.8–48.3</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>43.6</td>
<td>43.8</td>
<td>39.8–48.3</td>
</tr>
<tr>
<td>Sodium(^b)</td>
<td>12Jun06</td>
<td>142</td>
<td>136</td>
<td>122–149</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>134</td>
<td>136</td>
<td>122–149</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>140</td>
<td>136</td>
<td>122–149</td>
</tr>
<tr>
<td>Potassium(^b)</td>
<td>12Jun06</td>
<td>55.0</td>
<td>55.6</td>
<td>49.5–62.6</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>54.8</td>
<td>55.6</td>
<td>49.5–62.6</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>52.1</td>
<td>55.6</td>
<td>49.5–62.6</td>
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<tr>
<td>Chloride(^b)</td>
<td>12Jun06</td>
<td>45.3</td>
<td>47.0</td>
<td>42.3–52.3</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>45.5</td>
<td>47.0</td>
<td>42.3–52.3</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>37.7</td>
<td>36.8</td>
<td>33.0–41.3</td>
</tr>
<tr>
<td>Sulfate(^b)</td>
<td>12Jun06</td>
<td>65.0</td>
<td>69.8</td>
<td>61.3–76.7</td>
</tr>
<tr>
<td></td>
<td>05Sep06</td>
<td>69.7</td>
<td>69.8</td>
<td>61.3–76.7</td>
</tr>
<tr>
<td></td>
<td>05Dec06</td>
<td>76.2</td>
<td>69.8</td>
<td>61.3–76.7</td>
</tr>
</tbody>
</table>

\(^a\)mg/l as CaCO\(_3\).

\(^b\)mg/l.

\(^c\)From total hardness minus calcium hardness.
An estimation of algal productivity and composition can be made from analyzing the quantity and the type of algae present. The three major chlorophylls commonly found in algae are the chlorophylls $a$, $b$, and $c$. Chlorophyll $a$ is present in all plants, making up 1% to 2% of the dry weight of planktonic algae; thus, chlorophyll $a$ is useful as an indicator of phytoplankton biomass. An estimate of algae biomass is given by multiplying the chlorophyll $a$ concentrations by a factor of 67. Chlorophyll $b$ occurs in green algae and higher plants. Chlorophyll $c$ is contained in diatoms. Pheophytin $a$ is a common degradation product of chlorophyll $a$. In dead cells, the loss of magnesium from the chlorophyll molecule results in a shift of the absorption spectra so that the degradation product pheophytin $a$ can be distinguished from chlorophyll $a$. Analytically, chlorophyll $a$ can be degraded to pheophytin through acidification. The ratio of the absorbencies before and after acidification range from 1.00 to 1.7. The ratio of chlorophyll $a$ to pheophytin $a$ indicates the physiological condition of the phytoplankton. A ratio of 1.00 indicates that all of the chlorophyll $a$ has been degraded and is no longer photosynthetically active. A ratio of 1.7 indicates that the sample is in excellent physiological condition and contains no pheophytin. As a result of this procedure, a corrected chlorophyll $a$ concentration, which does not include pheophytin, can be calculated. Concentrations are reported as mg/m$^3$, which equals $\mu$g/l.

Chlorophyll concentrations were determined in samples collected from Stations 1, 4S, 5, 10, 6, 7, 8S, and 9 during May through September. The greatest chlorophyll concentrations were usually observed at Station 1 on the Des Moines River and Station 10 on the Raccoon River. Corrected chlorophyll $a$ concentrations at the riverine stations ranged from 2 mg/m$^3$ at Station 8S on August 14, 2006, to 256 mg/m$^3$ at Station 1 on August 22, 2006. This range was similar to the last contract period. This period, consistently elevated pigments concentrations were noted at Station 1, where the average corrected chlorophyll $a$ concentration was 114 mg/m$^3$, as compared with averages of 121 mg/m$^3$, 88 mg/m$^3$, 77 mg/m$^3$, 102 mg/m$^3$, and 107 mg/m$^3$ during the last five contract periods. Corrected chlorophyll $a$ concentrations at Station 10 on the Raccoon River averaged 75 mg/m$^3$, as compared to 81 mg/m$^3$, 96 mg/m$^3$, 55 mg/m$^3$, 73 mg/m$^3$, and 120 mg/m$^3$ during the last five periods. Above Red Rock Reservoir at Station 7, the average corrected chlorophyll $a$ concentration was 66 mg/m$^3$, as compared to 58 mg/m$^3$, 50 mg/m$^3$, 58 mg/m$^3$, 46 mg/m$^3$, and 86 mg/m$^3$ during the last five periods.

The maximum chlorophyll $a$ concentration observed, 283 mg/m$^3$, corresponded to a corrected chlorophyll $a$ concentration of 256 mg/m$^3$ and a pheophytin $a$ concentration of 29 mg/m$^3$. These peak values were similar to those seen last period (278 mg/m$^3$, 256 mg/m$^3$, and 35 mg/m$^3$, respectively).
Chlorophyll concentrations were reduced at Stations 4 and 8 at the surface of the main basin areas of Saylorville and Red Rock reservoirs as a result of algal die-off and sedimentation. The average corrected chlorophyll $a$ concentrations at Stations 4S and 8S were 32 mg/m$^3$ and 46 mg/m$^3$, respectively, which compares to respective averages of 35 mg/m$^3$ and 23 mg/m$^3$ last period. This year the maximum corrected chlorophyll $a$ concentration in the main basin of Saylorville Reservoir was 63 mg/m$^3$ at Station 4S on July 10, 2006, while the maximum corrected chlorophyll $a$ concentration in the main basin of Red Rock Reservoir was 167 mg/m$^3$ at Station 8S on the same date. Pigment concentrations are sometimes higher in reservoir inlets and bays because populations can flourish in calm, warm, shallow water or be congregated in an area by the wind. Generally, fluctuations in pigment concentration are a result of a flushing of the river systems during storm and run-off events and a resurgence of algal populations. Occasionally, nutrient depletion can cause populations to drop. Nutrient depletion as a result of algal utilization, mainly in ammonia nitrogen and orthophosphate, was most notable at the riverine stations (especially Stations 1 and 10) in late summer and early fall. In addition, from looking at historical corrected chlorophyll $a$ data presented in Appendix B, it is evident that new period-of-record monthly maximum concentrations were set at Station 6 in June 2006, at Station 8S in July 2006, and at Station 5 in September 2006. The May–September 2006 corrected chlorophyll $a$ average at the Des Moines River locations was 53 mg/m$^3$, as compared to the long-term seasonal average at these sites of 46 mg/m$^3$. At Station 10 on the Raccoon River, the May–September 2006 corrected chlorophyll $a$ average was 69 mg/m$^3$, as compared to the long-term seasonal average of 71 mg/m$^3$.

In 2000, the EPA proposed nutrient criteria based on ecoregions. These criteria also included guidance for chlorophyll $a$ concentrations. The criteria are intended to address the effects of excess nutrient inputs. They represent “reference” conditions of surface waters minimally impacted by human activities and protective of aquatic life and recreational uses. The EPA subecoregion WCBP criterion for chlorophyll $a$ in lakes and reservoirs is 14.6 µg/l or mg/m$^3$, which was exceeded in 85% and 77% of samples collected from Saylorville and Red Rock reservoirs, as corrected chlorophyll $a$ concentrations averaged 32 mg/m$^3$ and 46 mg/m$^3$, respectively. The EPA subecoregion WCBP criterion for chlorophyll $a$ in rivers and streams is 7.8 mg/m$^3$, which was exceeded at the Des Moines River sites in 57 of 65 samples (88%) and at the Raccoon River site in all samples. Corrected chlorophyll $a$ from the Des Moines River and Raccoon River sites averaged 53 mg/m$^3$ and 69 mg/m$^3$, respectively, during the 2006 season. Keep in mind that pigment analyses are only performed from May through September. A regional
technical assistance group for EPA Region VII has proposed a benchmark value for chlorophyll \( a \) in lakes and reservoirs and also rivers and streams of 8 mg/m\(^3\) (equivalent to µg/l).

There were few occasions of significant chlorophyll \( b \) concentrations. The maximum chlorophyll \( b \) concentration (20 mg/m\(^3\)) was seen at Station 10 on August 14, 2006, and corresponded with a chlorophyll \( a \) concentration of 113 mg/m\(^3\). This period’s chlorophyll \( b \) maximum was similar to last period’s maximum of 18 mg/m\(^3\). Chlorophyll \( c \) concentrations were typical, indicating moderate planktonic diatomaceous growth. The maximum chlorophyll \( c \) concentration (27 mg/m\(^3\)) was seen at Station 10 on August 14, 2006. The usual occurrence of diatoms in the fall and winter that was documented earlier in the period of record was not observed because analyses of pigments were only performed on samples collected from May through September.

Blooms of cyanobacteria, also referred to as bluegreen algae, were not visually observed at either Saylorville Reservoir (Station 4S) or Red Rock Reservoir (Station 8S) during the 2006 season. Data from the Iowa Lakes Information System (ISU 2006) quantified the cyanobacteria wet mass at Saylorville Reservoir for the summer of 2006 as 83.536 mg/l (maximum value, 179.919 mg/l in June), as compared to 5.958 mg/l, 42.236 mg/l, 20.553 mg/l, and 457.191 mg/l for the previous four summers. The Iowa Lakes Information System quantified the cyanobacteria wet mass at Red Rock Reservoir for the summer of 2006 as 312.738 mg/l (maximum value, 773.812 mg/l in July), as compared to 1.020 mg/l, 70.642 mg/l, 10.174 mg/l, and 20.211 mg/l for the previous four summers. (Both cyanobacteria and bluegreen algae are valid and compatible systematic terms. This group of micro-organisms comprises unicellular to multicellular prokaryotes [without a distinct nucleus] that possess chlorophyll \( a \) and perform photosynthesis.) Cyanobacteria are especially visible because they are buoyant and prevailing winds move them to areas where they accumulate. When dried on the shoreline, they can eerily look like dried paint. Cyanobacteria blooms often develop in nutrient-rich lakes; however, they do not bloom in water with short retention times because of their slow growth rate. Blooms may be associated with unpleasant odors and offensive appearance of water and shorelines. Traditionally it was believed that the occurrence of cyanobacteria could be predicted by N:P ratios. However, Downing et al. (2001) showed that cyanobacteria dominance in temperate zone lakes was more strongly correlated with the variation in total P, total N, or standing algal biomass than the ratio of N:P. These blooms can be a cause for concern because some cyanobacteria strains can contain toxins. Major routes of exposure to cyanotoxins include oral and dermal routes through drinking water and recreational water use. The World Health Organization established a guideline of 1.0 µg/l microcystin-LR in drinking water. In recreational water there are three exposure routes—direct
contact, accidental swallowing, and inhalation of water. Health effects can be divided into
generalized irritative symptoms (eye or ear irritation, skin rash, cold/flu symptoms, mouth ulcers,
and fever) and the greater health risks associated with toxin poisoning. Table 54 lists guidelines
developed for assessing risk in bathing waters. There is a risk of short-term health problems at the
biomass guidance level 1 of 20,000 cyanobacteria cells per ml or 10 mg/m³ chlorophyll \( a \) with a
dominance of cyanobacteria. Increased risk is seen at guidance level 2 of 100,000 cyanobacteria
cells per ml or 50 mg/m³ chlorophyll \( a \) with a dominance of cyanobacteria. At this level, it is
recommended that bathing be restricted. An additional risk level 3 is reached when there is scum
formation in bathing areas. It is recommended that immediate action be taken to prevent contact
with scums, possibly prohibiting swimming. Monitoring strategies for cyanobacteria blooms
include site inspections (transparency, coloration, mat, or scum growth), analysis of total
phosphate concentrations, and monitoring of toxin content when cells are dense or scums are

Historically, cyanobacteria or bluegreen alge concentrations have been noted at the
reservoirs in July and August, especially under elevated pool conditions. A review of monthly
reports since 1990 showed that blooms were noted for July 1996, July and August 1997, June,
July, August, and September 2001, July 2002, and July 2004 at Saylorville Reservoir; and August

Analyses of field-duplicate samples for chlorophyll \( a \) yielded an average value of
77 mg/m³ and an average absolute difference of 2.2 mg/m³ (or 2.9%), as compared to a long-
term (since 1982) average absolute difference of 5.0 mg/m³ (or 8.4%). These results are excellent
(see Table 12).

8.31. Fecal Coliform and *Escherichia coli* Bacteria

8.31.1. Introduction

The fecal coliform group of bacteria, which includes *Escherichia coli* and *Aerobacter aerogenes*,
and the fecal streptococcus group of bacteria, which is primarily composed of
*Streptococcus faecalis*, *S. faecium*, *S. bovis*, *S. equinus*, and *S. avium*, are often used as indicators
of fecal contamination from humans and other warm-blooded animals. These bacteria are native
to the intestinal tract of warm-blooded animals and, thus, are dispersed in fecal material. This
material can enter a water source through storm run-off, flooding, sewage discharge, or through
Table 54. Guidelines for safe practice in managing bathing waters that may contain cyanobacterial cells and/or toxins.a

<table>
<thead>
<tr>
<th>Guidance Level or Situation</th>
<th>How Guidance Level Derived</th>
<th>Health Risks</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanobacterial scum formation in bathing areas</td>
<td>Inference from oral animals lethal poisonings Actual human illness case histories</td>
<td>Potential for acute poisoning Potential for long-term illness with some cyanobacterial species Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness</td>
<td>Immediate action to prevent contact with scums; possible prohibition of swimming and other water-contact activities Public health follow-up investigation Inform relevant authorities</td>
</tr>
<tr>
<td>100,000 cells cyanobacteria per ml or 50 µg chlorophyll a per litre with dominance of cyanobacteria</td>
<td>From provisional drinking water guideline for microcystin-LR and data concerning other cyanotoxins</td>
<td>Potential for long-term illness with some cyanobacterial species Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness</td>
<td>Watch for scums Restrict bathing and further investigate hazard Post on-site risk advisory signs Inform relevant health authorities</td>
</tr>
<tr>
<td>20,000 cells cyanobacteria per ml or 10 µg chlorophyll a per litre with dominance of cyanobacteria</td>
<td>From human bathing epidemiological study</td>
<td>Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness, probably at low frequency</td>
<td>Post on-site risk advisory signs Inform relevant authorities</td>
</tr>
</tbody>
</table>

aFrom Chorus and Bartram, 1999.
discharges of inadequately treated water. As a rule, these bacteria are harmless and even aid in digestion. They are useful indicators because they are always present when there is fecal contamination, they exist in a water source longer than most pathogens, and they disappear rapidly under the same conditions that remove pathogens. These bacteria are considered indicators of the possible presence of pathogenic Enterobacteriaceae (Salmonella, Shigella, etc.), as well as other enteric bacteria and viruses. The presence of fecal coliform and fecal streptococcus bacteria indicates fecal waste contamination. Previously, the ratio of these two indices was thought to be useful in identifying the source of the contamination (human vs. livestock), but later recommendations were that FC/FS ratios were not useful for this purpose because of the variable survival rates of the fecal streptococcus group species. Also, waterfowl are often suspected in contamination of natural waters. Alderisio and DeLuca (1999) found that ring-billed gull feces contain a greater average concentration of fecal coliform bacteria per gram (about 370 million) than do Canada geese feces (about 15,000); however, average fecal sample weights of the geese were more than 15 times greater than those of gulls. They concluded that, considering the average weights and fecal coliform concentrations of the gull and goose feces, they can potentially contribute approximately 180 million and 130,000 fecal coliform per fecal deposit to surface water, respectively.

8.31.2. Criteria and Standards

Prior to 1986, the EPA’s bacteria criterion was based on fecal coliforms and recommended that maximum densities not exceed the geometric mean of 200 organisms/100 ml in recreational waters or single sample concentration of 400 organisms/100 ml. In the 1986 document Ambient Water Quality Criteria for Bacteria, EPA revised this recommendation stating that enterococci and E. coli were better indicators as they are considered to have a higher association with disease outbreaks. Now the criteria is that the geometric mean (not less than 5 samples in 30 days) should not exceed either 126 organisms/100 ml E. coli or 33 organisms/100 ml Enterococci. The EPA has strongly recommended states base water quality standards on E. coli or Enterococci concentrations. The state of Iowa made substantial changes in its bacteria standards in 2003. The state switched to using E. coli, rather than total fecal coliform, as its indicator bacteria and extended the time period when standards are in force to March 15 through November 15. In addition, the state changed the class A use designation into three separate use designations (A1–primary contact recreational use; A2–secondary contact recreational use; and A3–children’s recreational use) with variable allowable E. coli bacteria
limits (see Table 18). The A2 designation includes fishing and boating, and the A3 designation includes wading in small streams. The standard is in effect when these recreational uses can reasonably be expected to occur. The IDNR conducted a pilot beach study at three Iowa beaches in 2006. See Section 8.3.1 for more information.

In this study, quantification of *E. coli* concentrations was initiated in 2001. Quantification of total fecal coliform bacteria has occurred since 1970. This year total fecal coliform and *E. coli* bacteria concentrations were determined at Stations 1, 4S, 5, 10, 6, 7, 8S, and 9, as well as at each of the swimming beaches at both reservoirs, during the major part of the recreational season (mid-May through mid-September). The data collection period was expanded in 2004 to include the period two weeks before Memorial Day to two weeks after Labor Day. Please note that when using a set of data—for example, a time series of concentrations at a certain site—the geometric mean was used. A policy for the calculation and use of arithmetic and geometric means was established for this study, which can be found at [http://te-webserver.cce.iastate.edu/research/lutz/dmrwqn/geomean.htm](http://te-webserver.cce.iastate.edu/research/lutz/dmrwqn/geomean.htm).

**8.3.1.3. Results from Monitoring in 2006**

**Lake and River Samples**

All of the stations that were sampled, Stations 1, 4S, 5, 10, 6, 7, 8S, and 9, as well as the swimming beach locations, are currently designated as class A1 waters (primary recreation). Violations of the class A1 standard are listed in Table 26. Please note that concentrations recorded as less than or greater than a particular value are treated as equal to that value in Tables 55–58 and are treated as missing values in the plots in Appendix A.

On many occasions during this period, the riverine waters appeared to be materially affected by surface run-off, which usually increased bacteria concentrations. This was especially apparent during sampling events on April 11, July 17, August 14, and September 19, 2006. Dates of significant storm events and the corresponding amounts of precipitation received at the city of Des Moines are listed in Table 33.

Even though concentrations were lower than usual, total fecal coliform bacteria concentrations still exceeded 200 organisms/100 ml (previous EPA criteria, used for benchmark value) for many of the sampling occasions at Station 10 on the Raccoon River and Stations 6 and 7 on the Des Moines River. The geometric mean fecal coliform bacteria concentrations at Stations 10, 6, and 7 were 161 organisms/100 ml, 216 organisms/100 ml, and
207 organisms/100 ml, respectively, during this contract period, which compares with respective geometric means of 413 organisms/100 ml, 271 organisms/100 ml, and 176 organisms/100 ml during a comparable period last summer. The geometric mean \textit{E. coli} bacteria concentrations at Stations 10, 6, and 7 were 119 organisms/100 ml, 183 organisms/100 ml, and 180 organisms/100 ml for the period mid-May through mid-September 2006, as compared to respective geometric means last summer of 315 organisms/100 ml, 210 organisms/100 ml, and 113 organisms/100 ml.

As expected, there was a considerable decrease in fecal coliform concentrations in Saylorville and Red Rock reservoirs. These comparative decreases from the river concentrations were a result of bacterial sedimentation and die-off; since enteric bacteria can exist only in a temperature range of 35°C to 37°C, they do not persist long after entering a water source. The state standard for class A1 and the EPA criterion for \textit{E. coli} (single maximum of 235 organisms/100 ml; 30-day geometric mean of 126 organisms/100 ml) were never approached at the main basin reservoir sites. The maximum surface concentrations of \textit{E. coli} bacteria at Stations 4S and 8S at Saylorville and Red Rock reservoirs were 14 organisms/100 ml and 11 organisms/100 ml, respectively, as compared to respective maximum concentrations last period of 62 organisms/100 ml and 140 organisms/100 ml. The 2006 seasonal geometric mean \textit{E. coli} concentrations at Stations 4S and 8S were both only 2 organisms/100 ml, which was similar to the 2005 seasonal geometric means. The maximum surface concentrations of total fecal coliform bacteria at Stations 4S and 8S at Saylorville and Red Rock reservoirs were 14 organisms/100 ml and 18 organisms/100 ml, respectively, as compared to respective maximum concentrations last summer of 210 organisms/100 ml and 140 organisms/100 ml. The 2006 seasonal geometric mean total fecal coliform concentrations at Stations 4S and 8S were both only 2 organisms/100 ml, which were similar to 2005 seasonal geometric means. Bacteria concentrations in the river below both Saylorville and Red Rock dams (Stations 5 and 9) were generally somewhat higher than in-lake concentrations, with respective \textit{E. coli} bacteria geomans of 8 organisms/100 ml and 3 organisms/100 ml.

Long-term total fecal coliform data are presented in Appendix B. From looking at 37 years of seasonal data (June–August) from the riverine stations, it was noted that new period-of-record minimums were set at Stations 10 and 6 in May 2006, Station 10 in July 2006, and Station 5 in July 2006.
Beach Samples

In 2003 Iowa adopted new water quality standards recommended by the EPA using *E. coli* as an indicator organism for Iowa beaches. Recent studies have shown that *E. coli* is more closely related to gastrointestinal illnesses. In 2004 the Rock Island District developed new beach bacteria monitoring protocols that described sampling, reporting, and closure procedures. The new protocol begins bacteria monitoring two weeks prior to Memorial Day and ends on the second week after Labor Day. The monitoring includes two swimming beaches on Saylorville Reservoir (Oak Grove Beach and Sandpiper Beach) and two beaches on Red Rock Reservoir (Whitebreast Beach and North Overlook Beach). The new sampling protocol involves collecting one composite sample from each beach that is made from nine individual subsamples. The nine subsamples are taken at different depths (ankle, knee, and chest) from three transects along each beach. Each subsample is collected in a 250-ml sterilized bottle. To collect a subsample the bottle lid is removed and plunged mouth down into the water to elbow depth, tipped up to allow the water in, and then raised out of the water. The water on top is poured off to allow approximately one inch of head space. The lid is replaced to avoid contamination. When all subsamples were collected, they were inverted to mix before being added to a 1L composite sample bottle. Samples were placed on ice immediately. Ancillary parameters were collected after samples were collected to avoid contamination from person or sediment disturbance. Besides the composite sample collection, the field crew also recorded time, air temperature, cloud cover, water temperature, number of users, number of wildlife, maximum wave height, wind speed, wind direction, transparency tube depth, and 48-hr rainfall.

The composite samples were returned to the lab and tested within 24 hours by an approved EPA method. Resampling occurred if the composite result for *E. coli* was higher than 235 organisms/100 ml. The Corps protocol indicate that an advisory would be posted if the *E. coli* result from resampling was also over 235 organisms/100 ml or if five consecutive values were over a geometric mean of 126 organisms/100 ml. For consistency while calculating 30-day geometric means, the following guidelines were used to select a statistically sufficient number of samples:

- Only use data collected within a 30-day period (strict)
- If data are evenly distributed and geomean can be calculated from 4 samples (but not from 2 or 3 samples)
If more than 5 samples have been collected (usually due to resamplings), use all results within the 30-day period.

In 2006 for the first time advisories were posted at the Corps beaches at Red Rock Reservoir.

From samples collected at Sandpiper Beach on Saylorville Reservoir, there was one of 17 weekly samples whose \textit{E. coli} exceeded the 235 organisms/100 ml single-sample limit (see Table 55). The maximum concentration of \textit{E. coli} bacteria in a routine sample was 860 organisms/100 ml (August 29, 2006), which, when resampled on August 31, 2006, was even greater (2,300 organisms/100 ml). The 30-day geometric mean concentrations ranged from 3 organisms/100 ml in early July to 141 organisms/100 ml in late August. The overall fecal coliform and \textit{E. coli} bacteria seasonal geometric means at Sandpiper Beach were 25 organisms/100 ml and 21 organisms/100 ml, respectively, compared to 2005 geometric means for fecal coliform and \textit{E. coli} bacteria of 29 organisms/100 ml and 21 organisms/100 ml, respectively.

From samples collected at Oak Grove Beach on Saylorville Reservoir, there were two of 17 weekly samples that exceeded the state \textit{E. coli} single sample maximum of 235 organisms/100 ml (Table 56). However, there were never two consecutive samples that exceeded this value and running 30-day geometric means remained low. The 30-day geometric mean concentrations ranged from 1 organism/100 ml in early July to 46 organisms/100 ml at the end of the season. The maximum concentration of \textit{E. coli} bacteria was 300 organisms/100 ml on August 22, 2006, which when resampled on August 24 was much lower (29 organisms/100 ml). The seasonal geometric means for fecal coliform and \textit{E. coli} bacteria at Oak Grove Beach were 13 organisms/100 ml and 11 organisms/100 ml, respectively, compared to 2005 geometric means for fecal coliform and \textit{E. coli} bacteria of 23 organisms/100 ml and 12 organisms/100 ml, respectively.

At Whitebreast Beach on Red Rock Reservoir, the state class A1 single-sample standard of 235 organisms/100 ml was exceeded in four of seventeen weekly samples collected and in two of three resamplings (Table 57). Whitebreast Beach was posted with an advisory after the resampling on August 8, 2006, yielded a second \textit{E. coli} bacteria concentration over 235 organisms/100 ml. The sign posted read “Notice: Swimming not recommended due to high bacteria levels.” The beach was posted for the remainder of the season as bacteria concentrations remained elevated due to waterfowl influences as evidenced by feathers and feces. The 30-day geometric mean concentrations ranged from 5 organisms/100 ml to 465 organisms/100 ml at the end of the season. From mid-August to the end of monitoring on September 5, the 30-day geometric means exceeded the state class A1 standard. The overall fecal coliform and \textit{E. coli} bacteria seasonal geometric means were 23 organisms/100 ml and 21 organisms/100 ml, respectively.
Table 55. Fecal coliform (FC) and *Escherichia coli* (EC) concentrations (#/100 ml) at Sandpiper Recreational Area Beach on Saylorville Reservoir during May–September 2006.

<table>
<thead>
<tr>
<th>Date</th>
<th>FC</th>
<th>EC</th>
<th>Transparency Tube (cm)</th>
<th>Wind Direction</th>
<th>Cloud Cover (%)</th>
<th>Waterfowl Present</th>
<th>48-hr Rainfall (in.)</th>
<th>Solar Radiation (watts/m²)</th>
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aResampling.
bTo calculate means, < and > values were set to that value.
cGeometric mean= \(\sqrt[n]{y_1y_2y_3\cdots y_n}\).
Table 56. Fecal coliform (FC) and *Escherichia coli* (EC) concentrations (#/100 ml) at Oak Grove Recreational Area Beach on Saylorville Reservoir during May–September 2006.

<table>
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<tr>
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<th>Transparency Tube (cm)</th>
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<th>Cloud Cover (%)</th>
<th>Waterfowl Present</th>
<th>48-hr Rainfall (in.)</th>
<th>Solar Radiation (watts/m²)</th>
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<td>Waterfowl Present</td>
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Table 56. Continued.

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<th>Cloud Cover (%)</th>
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<th>Solar Radiation (watts/m²)</th>
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</table>

aResampling.

bTo calculate means, < and > values were set to that value.

cGeometric mean=$\sqrt[n]{y_1y_2y_3\cdots y_n}$.
Table 57. Fecal coliform (FC) and *Escherichia coli* (EC) concentrations (#/100 ml) at Whitebreast Recreational Area Beach on Red Rock Reservoir during May–September 2006.

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<th>Transparency Tube (cm)</th>
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<th>Cloud Cover (%)</th>
<th>Waterfowl Present</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>05Sep06</td>
<td>2200</td>
<td>1900</td>
<td>42.6</td>
<td>NW</td>
<td>40</td>
<td>Y</td>
<td>0.74</td>
<td>369</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>690</td>
</tr>
<tr>
<td>Geometric Meanb,c</td>
<td>65</td>
<td>59</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*aResampling.

bTo calculate means, < and > values were set to that value.

cGeometric mean = \( \sqrt[n]{y_1 y_2 y_3 \cdots y_n} \).
bacteria seasonal geometric means at Whitebreast Beach were 65 organisms/100 ml and 59 organisms/100 ml, respectively, as compared to 2005 geometric means of 40 organisms/100 ml and 34 organisms/100 ml, respectively.

From samples collected at North Overlook Beach on Red Rock Reservoir, there were two of seventeen weekly samples that exceeded the single sample maximum of 235 organisms/100 ml; however, they were not consecutive. The maximum concentration of *E. coli* bacteria in an individual sample was 380 organisms/100 ml (August 29, 2006), which, when resampled on August 31, was somewhat lower at 130 organisms/100 ml. In addition, an *E. coli* concentration of 270 organisms/100 ml on August 22, 2006, prompted a resampling on August 24 with a resultant *E. coli* concentration of 32 organisms/100 ml. The 30-day geometric mean concentrations ranged from 4 organisms/100 ml in early June to 149 organisms/100 ml at the end of the season, which exceeded the state class A1 standard. North Overlook Beach was posted with a swimming advisory in early September 2006. At North Overlook Beach (Table 58), the overall fecal coliform and *E. coli* bacteria seasonal geometric means were 31 organisms/100 ml and 27 organisms/100 ml, respectively. The comparable 2005 geometric means for fecal coliform and *E. coli* bacteria were 26 organisms/100 ml and 21 organisms/100 ml, respectively.

**Quality Control**

Analyses of field-duplicate samples during this contract period for fecal coliform bacteria concentration yielded an average absolute difference of 38 organisms/100 ml and an average concentration of 182 organisms/100 ml. The average percentage difference was 21%. The long-term (since 1982) average absolute difference in fecal coliform concentration between duplicate samples was 684 organisms/100 ml, with an average concentration of 1,700 organisms/100 ml (or 33% difference). Analyses of field-duplicate composite samples from this contract period for *E. coli* bacteria concentration yielded an average absolute difference of 46 organisms/100 ml and an average concentration of 169 organisms/100 ml. The average percentage difference was 27% (see Table 12). Since quantification of *E. coli* bacteria only began in 2001, long-term statistics are not available.
Table 58. Fecal coliform (FC) and *Escherichia coli* (EC) concentrations (#/100 ml) at North Overlook Recreational Area Beach on Red Rock Reservoir during May–September 2006.

<table>
<thead>
<tr>
<th>Date</th>
<th>FC</th>
<th>EC</th>
<th>Transparency Tube (cm)</th>
<th>Wind Direction</th>
<th>Cloud Cover (%)</th>
<th>Waterfowl Present</th>
<th>48-hr Rainfall (in.)</th>
<th>Solar Radiation (watts/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15May06</td>
<td>6</td>
<td>5</td>
<td>21.3</td>
<td>NNW</td>
<td>90</td>
<td>N</td>
<td>0.09</td>
<td>189</td>
</tr>
<tr>
<td>22May06</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>31.7</td>
<td>SE</td>
<td>15</td>
<td>N</td>
<td>Trace</td>
<td>417</td>
</tr>
<tr>
<td>30May06</td>
<td>8</td>
<td>8</td>
<td>60.0</td>
<td>SW</td>
<td>90</td>
<td>N</td>
<td>0.06</td>
<td>118</td>
</tr>
<tr>
<td>05Jun06</td>
<td>13</td>
<td>9</td>
<td>32.1</td>
<td>S</td>
<td>100</td>
<td>N</td>
<td>0.00</td>
<td>410</td>
</tr>
<tr>
<td>12Jun06</td>
<td>46</td>
<td>32</td>
<td>32.0</td>
<td>Calm</td>
<td>40</td>
<td>N</td>
<td>0.00</td>
<td>411</td>
</tr>
<tr>
<td>20Jun06</td>
<td>4</td>
<td>4</td>
<td>55.0</td>
<td>E</td>
<td>85</td>
<td>N</td>
<td>0.07</td>
<td>42</td>
</tr>
<tr>
<td>26Jun06</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>37.9</td>
<td>N</td>
<td>50</td>
<td>N</td>
<td>1.56</td>
<td>274</td>
</tr>
<tr>
<td>05Jul06</td>
<td>3</td>
<td>3</td>
<td>&gt;60</td>
<td>N</td>
<td>10</td>
<td>N</td>
<td>0.18</td>
<td>289</td>
</tr>
<tr>
<td>10Jul06</td>
<td>210</td>
<td>190</td>
<td>27.0</td>
<td>W</td>
<td>100</td>
<td>N</td>
<td>0.00</td>
<td>219</td>
</tr>
<tr>
<td>17Jul06</td>
<td>33</td>
<td>30</td>
<td>11.9</td>
<td>SSW</td>
<td>5</td>
<td>N</td>
<td>0.00</td>
<td>419</td>
</tr>
<tr>
<td>24Jul06</td>
<td>152</td>
<td>140</td>
<td>26.1</td>
<td>WSW</td>
<td>40</td>
<td>N</td>
<td>0.00</td>
<td>199</td>
</tr>
<tr>
<td>31Jul06</td>
<td>11</td>
<td>11</td>
<td>29.2</td>
<td>SW</td>
<td>0</td>
<td>Y</td>
<td>0.00</td>
<td>305</td>
</tr>
<tr>
<td>07Aug06</td>
<td>200</td>
<td>170</td>
<td>19.8</td>
<td>Calm</td>
<td>40</td>
<td>N</td>
<td>0.26</td>
<td>–</td>
</tr>
<tr>
<td>Date</td>
<td>FC</td>
<td>EC</td>
<td>Transparency Tube (cm)</td>
<td>Wind Direction</td>
<td>Cloud Cover (%)</td>
<td>Waterfowl Present</td>
<td>48-hr Rainfall (in.)</td>
<td>Solar Radiation (watts/m²)</td>
</tr>
<tr>
<td>-------------</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14Aug06</td>
<td>100</td>
<td>100</td>
<td>28.0</td>
<td>NNE</td>
<td>5</td>
<td>N</td>
<td>0.88</td>
<td>–</td>
</tr>
<tr>
<td>22Aug06</td>
<td>290</td>
<td>270</td>
<td>29.3</td>
<td>Calm</td>
<td>5</td>
<td>N</td>
<td>0.00</td>
<td>393</td>
</tr>
<tr>
<td>24Aug06</td>
<td>35</td>
<td>32</td>
<td>30.6</td>
<td>WSW</td>
<td>5</td>
<td>N</td>
<td>0.00</td>
<td>342</td>
</tr>
<tr>
<td>29Aug06</td>
<td>460</td>
<td>380</td>
<td>58.9</td>
<td>WNW</td>
<td>100</td>
<td>Y</td>
<td>0.88</td>
<td>86</td>
</tr>
<tr>
<td>31Aug06</td>
<td>130</td>
<td>130</td>
<td>38.8</td>
<td>SE</td>
<td>0</td>
<td>Y</td>
<td>0.29</td>
<td>196</td>
</tr>
<tr>
<td>05Sep06</td>
<td>340</td>
<td>220</td>
<td>35.0</td>
<td>WNW</td>
<td>15</td>
<td>Y</td>
<td>0.74</td>
<td>362</td>
</tr>
<tr>
<td>Geometric Mean(^{a})</td>
<td>31</td>
<td>27</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

\(^{a}\) Resampling.

\(^{b}\) To calculate means, < and > values were set to that value.

\(^{c}\) Geometric mean = \(\sqrt[n]{y_1 y_2 y_3 \cdots y_n}\).
8.32. Pesticides in Fish

8.32.1. Introduction

Analyses of pesticide residues in fish are conducted for two main reasons. First, fish may accumulate pesticides and yield detectable amounts when concentrations in the water are still less than laboratory detection limits, making fish tissue sampling a good monitoring tool. Second, even low concentrations of pesticides can accumulate to toxic levels in fish, making consumption hazardous to humans or predators.

Most pesticide monitoring programs include measuring residue concentrations of older, often discontinued organochlorine pesticides, as well as the newer classes of herbicides. The chemical properties that led to the banning of many organochlorine pesticides (low water solubilities, high bioconcentration factors, and toxicity to nontarget organisms at low levels) result in continued concern about persistent organochlorine residues. Although DDT, aldrin, and heptachlor use was discontinued in the 1970s, detectable concentrations of these parameters and their metabolites (DDD, DDE, dieldrin, and heptachlor epoxide) continue to be measured in fish. The newer classes of pesticides are generally of less concern because they are much more water soluble, have lesser bioconcentration factors, are less persistent, and are not as toxic to non-target organisms. There are several of these pesticides, however, that require careful monitoring and consideration because of their chemical characteristics.

Pesticide Use in Iowa

The greatest increase in pesticide use in Iowa has been in the use of herbicides. In 2005, 96% of corn acres were treated with a herbicide, and 11% of corn acres were also treated with an insecticide. Agricultural chemical use on soybean acres in 2005 was similar, with 96% of soybean acres treated with herbicides and 16% of soybean acres treated with insecticides. The most popular herbicides used in corn production (according to percentage of acres treated) were atrazine (Aatrex, Bicep, Laddock, Lariat), acetochlor (Harness, TopNotch), mesotrione (Callisto, Lumax), S-metalachlor (Bicep, Dual, Lumax), and glyphosate isopropylamine salt. Between 2003 and 2005, usage of atrazine decreased about 10%, as it was used on 61% of corn acres. Also, usage of isoxaflutole (Balance, Epic) became less popular. Mesotrione, which was first reported on the USDA Agricultural Chemical Applications report for 2002, was applied on 32% of the 2005 corn acres (USDA 1999–2005). Herbicide usage statistics in soybeans from 2005 were not
compiled by individual state. In 2004, the most popular herbicides used in Iowa soybean production (according to percentage of acres treated) were glyphosate (Roundup), which was used on 87% of soybean acres, trifluralin (Treflan), pendimethalin (Prowl), sulfentrazone (Command), and chlorimuron-ethyl (Classic). Pendimethalin use on soybeans had significantly decreased. In 2005, cyfluthrin (Aztec, Baythriod), tebupirimphos (Aztec), and tefluthrin were the most popular insecticides used on corn. In the 2004 report, lambda-cyhalothrin (Karate) was the only insecticide used on soybeans listed. Lambda-cyhalothrin, which is highly toxic to fish, aquatic invertebrates, and honeybees, was used on 1% of Iowa soybeans. In 2002, permethrin (Pounce/Ambush) was the only soybean insecticide used.

Table 59 lists several chemical characteristics of the most popular farm pesticides used in Iowa, including water solubility, bioconcentration factor, and acute toxicity. From this table, it is apparent that the insecticides are generally less soluble and more toxic than the herbicides. Of the herbicides, trifluralin and pendimethalin are of interest because of their low solubility and relatively high bioconcentration factor. Both trifluralin and pendimethalin are listed by EPA as reportable PBT—persistent, bioaccumulative, and toxic—chemicals (US EPA 2006). In addition, acetochlor may be a concern because of its high toxicity, and it is labeled as a probable human carcinogen. Also, alachlor (Lasso) and cyanazine (Bladex) are of interest because alachlor is a suspected human carcinogen and cyanazine may pose dangers of birth defects. Of the insecticides, chlorpyrifos, bifenthrin, lambda-cyhalothrin, tefluthrin, and permethrin may be of interest because of their relatively low water solubilities (2 mg/l or less), high bioconcentration factors (320 to 3,000), and acute toxicities to fish at limited concentrations (0.9 to 4.3 µg/l for bluegill). Commonly used restricted-use herbicides are acetochlor, atrazine, glyphosate isopropylamine salt, and S-metolachlor. Commonly used restricted-use insecticides are cyfluthrin, tebupirimphos, chlorpyrifos, bifenthrin, tefluthrin, lambda-cyhalothrin, and permethrin (USDA 2006). Restricted-use pesticides are those that may cause adverse effects to the environment or to the applicator unless applied and used correctly. Restricted-use pesticides also may only be used by certified pesticide applicators.

8.32.2. Selected Pesticide Parameters

The contracts specified that the whole fish samples were to be analyzed for the following pesticide residues: dieldrin, heptachlor epoxide, chlordane, alachlor, trifluralin, and chlorpyrifos. Table 60 lists some of the chemical characteristics of these selected pesticides for comparison.
Table 59. Chemical characteristics of popular farm chemicals used in Iowa.

<table>
<thead>
<tr>
<th>Chemical Name (CAS#)</th>
<th>Common Name</th>
<th>Chemical Class</th>
<th>Water Solubility</th>
<th>BCF</th>
<th>Kow</th>
<th>Koc</th>
<th>Mobility Class</th>
<th>96 hr LC₅₀ (bluegill)</th>
<th>LD₅₀ (rat)</th>
<th>Toxicity Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herbicides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetochlor* 34256–82–1</td>
<td>Harness Surpass</td>
<td>Acetamide</td>
<td>223 mg/l (25°C)</td>
<td>84^b</td>
<td>3.03^a</td>
<td>100^c</td>
<td>Low</td>
<td>1.3 mg/l^a</td>
<td>1,426–2,953 mg/kg^a</td>
<td>I^a</td>
</tr>
<tr>
<td>Alachlor* 15972–60–8</td>
<td>Lasso</td>
<td>Amide</td>
<td>242 mg/l (25°C)</td>
<td>0^e</td>
<td>830^e</td>
<td>190^e</td>
<td>Medium^f</td>
<td>2.8 mg/l^d</td>
<td>930 mg/kg^d</td>
<td>III^g</td>
</tr>
<tr>
<td>Atrazine* 1912–24–9</td>
<td>Aatrex</td>
<td>Triazine</td>
<td>33 mg/l (27°C)</td>
<td>0–11^e</td>
<td>476^e</td>
<td>149^e</td>
<td>High^f</td>
<td>16 mg/l^h</td>
<td>3,090 mg/kg^a</td>
<td>III^g</td>
</tr>
<tr>
<td>Bentazon 25057–89–0</td>
<td>Basagran</td>
<td>Thiaiazinol</td>
<td>500 mg/lg</td>
<td>0^e</td>
<td>220^e</td>
<td>0^e</td>
<td>Very High^f</td>
<td>616 mg/lg^d</td>
<td>2,063 mg/kg^a</td>
<td>III^g</td>
</tr>
<tr>
<td>Bromoxynil 1689–84–5</td>
<td>Buctril</td>
<td>Nitrile</td>
<td>130 mg/l (25°C)</td>
<td>79^j</td>
<td>630^k</td>
<td>190^l</td>
<td>Low^m</td>
<td>0.15 mg/l^a^+</td>
<td>190^h–780 mg/kg^n</td>
<td>II^c</td>
</tr>
<tr>
<td>Carfentrazon ethyl 128639–02–1</td>
<td>Aim</td>
<td>Aryl</td>
<td>22 mg/l^o</td>
<td>–</td>
<td>2,290^k</td>
<td>–</td>
<td>Low^o</td>
<td>2.0 mg/l^o</td>
<td>&gt;5,000 mg/kg^o</td>
<td>IV^o</td>
</tr>
<tr>
<td>Chlorimuron 099283–00–8</td>
<td>Classic</td>
<td>Sulfonylurea</td>
<td>1,200 mg/lg</td>
<td>130^c</td>
<td>320^p</td>
<td>128^l</td>
<td>High^q</td>
<td>&gt;12 mg/lg^+</td>
<td>&gt;4,000 mg/kg^g</td>
<td>III^g</td>
</tr>
<tr>
<td>Clomazone 81777–89–1</td>
<td>Command</td>
<td></td>
<td>1,100 mg/l^a</td>
<td>40^a</td>
<td>2.54^a</td>
<td>300^a</td>
<td>Medium^a</td>
<td>34 mg/l^a</td>
<td>1,369 mg/kg^a</td>
<td>III^a</td>
</tr>
<tr>
<td>Clopyralid 1702–17–6</td>
<td>Stinger</td>
<td>Picolinic acid</td>
<td>7,850 mg/l (20°C)</td>
<td>–</td>
<td>11^k</td>
<td>6^l</td>
<td>Very High^q</td>
<td>125 mg/l^f</td>
<td>&gt;5,000 mg/kg^c</td>
<td>III^F</td>
</tr>
<tr>
<td>Cyanazine* 21725–46–2</td>
<td>Bladex</td>
<td>Triazine</td>
<td>171 mg/l (25°C)</td>
<td>0^e</td>
<td>150^e</td>
<td>200^e</td>
<td>Medium^f</td>
<td>22 mg/l^s</td>
<td>334 mg/kg^d</td>
<td>II^g</td>
</tr>
</tbody>
</table>

BCF: bioconcentration factor.
Kow: octanol-water partition coefficient (indicates ability to bioaccumulate in organisms–higher value, more bioconcentrating).
Koc: soil sorption coefficient (measures comparative leachability in soil–higher value, less mobile).
Mobility class: used to rank and compare chemicals according to leaching potential.
96 hr LC₅₀ (bluegill): median lethal concentration after 96 hours; an acute toxicity test (aquatic).
LD₅₀ (rat): median lethal dose; a mammalian acute toxicity test.
Toxicity class based on human toxicity, with Class I being the most toxic and Class IV the least toxic.
+For rainbow trout; bluegill data not available.
*Federal restricted use, 2003 list (http://entweb.clemson.edu/pesticid/document/FebRUP.htm)
<table>
<thead>
<tr>
<th>Chemical Name (CAS#)</th>
<th>Common Name</th>
<th>Chemical Class</th>
<th>Water Solubility</th>
<th>BCF</th>
<th>Kow</th>
<th>Koc</th>
<th>Mobility Class</th>
<th>96 hr LC$_{50}$ (bluegill)</th>
<th>LD$_{50}$ (rat)</th>
<th>Toxicity Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicamba 1918–00–9</td>
<td>Banvel</td>
<td>Benzoic acid</td>
<td>4,500 mg/l$^d$</td>
<td>0$^e$</td>
<td>162$^k$</td>
<td>0.4$^e$</td>
<td>Very High$^f$</td>
<td>135 mg/l$^g$</td>
<td>757–1,707 mg/kg$^s$</td>
<td>III$^g$</td>
</tr>
<tr>
<td>Diflufenpyr-sodium 109293–97–2</td>
<td>Distinct</td>
<td>Semicarbazone</td>
<td>5,850 mg/l$^o$</td>
<td>–</td>
<td>109$^o$</td>
<td>18–156$^o$</td>
<td>Very High$^o$</td>
<td>Low toxicity$^o$</td>
<td>&gt;5,000 mg/kg$^o$</td>
<td>IV$^o$</td>
</tr>
<tr>
<td>Dimethenamid 87674–68–8</td>
<td>Frontier Guardsman</td>
<td>Amide</td>
<td>1,200 mg/l$^k$ (20°C)</td>
<td>–</td>
<td>141$^k$</td>
<td>–</td>
<td>–</td>
<td>6.4 mg/l$^+$</td>
<td>1,500 mg/kg$^t$</td>
<td>II</td>
</tr>
<tr>
<td>Diuron 330–54–1</td>
<td>Karmex</td>
<td>Substituted urea</td>
<td>42 mg/l (25°C)$^a$</td>
<td>66$^u$</td>
<td>479$u$</td>
<td>431$u$</td>
<td>–</td>
<td>3-60 mg/l$^o$</td>
<td>3,400 mg/kg$a$</td>
<td>III$a$</td>
</tr>
<tr>
<td>EPTC 759–94–4</td>
<td>Eradicane</td>
<td>Thio carbamate</td>
<td>370 mg/l$^g$</td>
<td>37–190$^a$</td>
<td>1,580$^u$</td>
<td>240$^e$</td>
<td>Medium$^f$</td>
<td>27 mg/l$^d$</td>
<td>1,630 mg/kg$^g$</td>
<td>III$^g$</td>
</tr>
<tr>
<td>Flufenacet 14259–58–3</td>
<td>Radius</td>
<td>Aniline</td>
<td>56 mg/l$^o$</td>
<td>71$^v$</td>
<td>1,600$^o$</td>
<td>202$^v$</td>
<td>High</td>
<td>2.4 mg/l$^o$</td>
<td>371 mg/kg$^o$</td>
<td>IV$^o$</td>
</tr>
<tr>
<td>Flumetsulam 98967–40–9</td>
<td>Broad Strike</td>
<td>Triazolo pyrimidine</td>
<td>49 mg/l$^k$</td>
<td>–</td>
<td>1.62$^k$</td>
<td>5–75$^l$</td>
<td>Very High</td>
<td>300 mg/l$^w$</td>
<td>&gt;5,000 mg/kg$^w$</td>
<td>III</td>
</tr>
<tr>
<td>Glufosinate 77182–82–2</td>
<td>Finale</td>
<td>–</td>
<td>1,370,000 l$^l$</td>
<td>1</td>
<td>64,000$^k$</td>
<td>156–352$^l$</td>
<td>High</td>
<td>–</td>
<td>1,620 mg/kg$x$</td>
<td>III$^o$</td>
</tr>
<tr>
<td>Glyphosate 1071–83–6</td>
<td>Roundup</td>
<td>Phosphonoglycine</td>
<td>1,200 mg/l (25°C)$^i$</td>
<td>&lt;1</td>
<td>0.32$^u$</td>
<td>500–2,640$^j$</td>
<td>Low$^m$</td>
<td>120 mg/l$d$</td>
<td>4,900$^m$–5,400 mg/kg$d^d$</td>
<td>II$a$</td>
</tr>
<tr>
<td>Imazamox 114311–32–9</td>
<td>Raptor</td>
<td>–</td>
<td>4,413$^o$</td>
<td>–</td>
<td>5.36$^o$</td>
<td>–</td>
<td>Low$^o$</td>
<td>&gt;119 mg/l$^o$</td>
<td>&gt;5,000 mg/kg$x$</td>
<td>III-IV$^o$</td>
</tr>
<tr>
<td>Imazethapyr 081335–77–5</td>
<td>Pursuit</td>
<td>Imidazolinone</td>
<td>1,415 mg/l$^g$</td>
<td>–</td>
<td>11$^p$</td>
<td>7$^l$</td>
<td>High$^o$</td>
<td>420 mg/l$^p$</td>
<td>&gt;5,000 mg/kg$x$</td>
<td>III$a$</td>
</tr>
<tr>
<td>Isoxaflutole* 14112–29–0</td>
<td>Balance</td>
<td>Isoxazole</td>
<td>0.006 mg/l$^o$</td>
<td>–</td>
<td>219$^o$</td>
<td>–</td>
<td>High$^o$</td>
<td>&gt;4.5 mg/l$^o$</td>
<td>&gt;5,000 mg/kg$^o$</td>
<td>III$^o$</td>
</tr>
<tr>
<td>Mesotrione 104206–82–8</td>
<td>Callisto</td>
<td>Triketone</td>
<td>15,000 mg/l$^x$</td>
<td>Low$^c$</td>
<td>1.3$^c$</td>
<td>16.5–390$^c$</td>
<td>High</td>
<td>non-toxic$^c$</td>
<td>&gt;5,000 mg/kg$x$</td>
<td>-</td>
</tr>
<tr>
<td>Metolachlor* 5128–45–2</td>
<td>Dual</td>
<td>Amide</td>
<td>530 mg/l (20°C)$^d$</td>
<td>140$^s$</td>
<td>2,820$^p$</td>
<td>20$^g$</td>
<td>Medium$^{hn}$</td>
<td>15 mg/l$^c$</td>
<td>2,534 mg/kg$^d$</td>
<td>III$^g$</td>
</tr>
</tbody>
</table>
Table 59. Continued.

<table>
<thead>
<tr>
<th>Chemical Name (CAS #)</th>
<th>Common Name</th>
<th>Chemical Class</th>
<th>Water Solubility</th>
<th>BCF</th>
<th>Kow</th>
<th>Koc</th>
<th>Mobility Class</th>
<th>96 hr LC50 (bluegill)</th>
<th>LD50 (rat)</th>
<th>Toxicity Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metribuzin 21087–64–9</td>
<td>Sencor/ Lexone</td>
<td>Triazine</td>
<td>1,220 mg/l (20°C) (d)</td>
<td>12(u)</td>
<td>40(p)</td>
<td>95(e)</td>
<td>High(f)</td>
<td>80 mg/l(h)</td>
<td>~2,300 mg/kg(h)</td>
<td>III(g)</td>
</tr>
<tr>
<td>Nicosulfuron 111991–09–4</td>
<td>Accent</td>
<td>Sulfonylea</td>
<td>2,200 mg/l (25°C) (j)</td>
<td>–</td>
<td>0.44(i)</td>
<td>22–70</td>
<td>Medium(a)</td>
<td>&gt;1,000 mg/l(l)</td>
<td>&gt;5,000 mg/kg(i)</td>
<td>I(o)</td>
</tr>
<tr>
<td>Pendimethalin 40487–42–1</td>
<td>Prowl</td>
<td>Dinitroaniline</td>
<td>&lt;0.5 mg/l(g)</td>
<td>1,944(y)</td>
<td>152,000(p)</td>
<td>6,500–29,000</td>
<td>Slight(f)</td>
<td>Toxic(g)</td>
<td>1,250 mg/kg(g)</td>
<td>III(g)</td>
</tr>
<tr>
<td>Prometon 1610–18–0</td>
<td>Pramitol</td>
<td>Triazine</td>
<td>620 mg/l(o)</td>
<td>33(u)</td>
<td>199(u)</td>
<td>182(u)</td>
<td>High(z)</td>
<td>40 mg/l(o)</td>
<td>2,980 mg/kg(o)</td>
<td>III</td>
</tr>
<tr>
<td>Pyridate 055512–33–9</td>
<td>Tough</td>
<td>Pyridazine</td>
<td>1.5 mg/l(aa)</td>
<td>–</td>
<td>537,000(k)</td>
<td>–</td>
<td>Low(aa)</td>
<td>–</td>
<td>&gt;2,000 mg/kg(aa)</td>
<td>–</td>
</tr>
<tr>
<td>Rimsulfuron 122931–48–0</td>
<td>Basis</td>
<td>Sulfonylea</td>
<td>7,300 mg/l(l)</td>
<td>–</td>
<td>0.03–1.9(l)</td>
<td>13–76</td>
<td>High</td>
<td>&gt;390 mg/l(bb)</td>
<td>&gt;5,000 mg/kg(bb)</td>
<td>III</td>
</tr>
<tr>
<td>Sulfosate 81591–81–3</td>
<td>Touchdown</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>750 mg/kg(x)</td>
<td>III</td>
</tr>
<tr>
<td>Tebuthiuron 34014–18–1</td>
<td>Spike</td>
<td>Substituted urea</td>
<td>2,500 mg/l (25°C)(a)</td>
<td>0.77(u)</td>
<td>62(l)</td>
<td>80(a)</td>
<td>High</td>
<td>87–112 mg/l(a)</td>
<td>644 mg/kg(a)</td>
<td>III(a)</td>
</tr>
<tr>
<td>Thifensulfuron methyl 79277–27–3</td>
<td>Pinnacle</td>
<td>Sulfonylea</td>
<td>24 mg/l (25°C)(c)</td>
<td>–</td>
<td>3.3(p)</td>
<td>–</td>
<td>–</td>
<td>&gt;100 mg/l(n)</td>
<td>&gt;5,000 mg/kg(n)</td>
<td>III(g)</td>
</tr>
<tr>
<td>Trifluralin 1582–09–8</td>
<td>Treflan</td>
<td>Dinitroaniline</td>
<td>0.3 mg/l (25°C)(d)</td>
<td>926–4,570(o)</td>
<td>220,000(e)</td>
<td>13,700(e)</td>
<td>Slight(f)</td>
<td>58 mg/l(l)</td>
<td>&gt;10,000 mg/kg(h)</td>
<td>III</td>
</tr>
<tr>
<td>Insecticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bifenthrin* 82657-04-3</td>
<td>Capture</td>
<td>Synthetic pyrethroid</td>
<td>0.1 mg/l(a)</td>
<td>6,000(cc)</td>
<td>1.0 x 106(a)</td>
<td>1.3–3.0 x 105(cc)</td>
<td>Slight(a)</td>
<td>0.35 mg/l(a)</td>
<td>54–70 mg/kg(a)</td>
<td>II(F)</td>
</tr>
<tr>
<td>Carbofuran* 1563–66–2</td>
<td>Furadan</td>
<td>Carbamate</td>
<td>700 mg/l (25°C)(h)</td>
<td>0(dd)</td>
<td>40(e)</td>
<td>29(g)</td>
<td>High(m)</td>
<td>240 µg/l(s)</td>
<td>8–14 mg/kg(h)</td>
<td>I,II</td>
</tr>
<tr>
<td>Chlorpyrifos* 2921–88–2</td>
<td>Lorsban</td>
<td>Organophosphate</td>
<td>2 mg/l (25°C)(h)</td>
<td>320(e)</td>
<td>97,000(e)</td>
<td>13,600(e)</td>
<td>Immobile(f)</td>
<td>2.4 µg/l(s)</td>
<td>135–163 mg/kg(h)</td>
<td>II(g)</td>
</tr>
<tr>
<td>Chemical Name (CAS #)</td>
<td>Common Name</td>
<td>Chemical Class</td>
<td>Water Solubility</td>
<td>BCF</td>
<td>Kow</td>
<td>Koc</td>
<td>Mobility Class</td>
<td>96 hr LC50 (bluegill)</td>
<td>LD50 (rat)</td>
<td>Toxicity Class</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------</td>
<td>----------------</td>
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<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>----------------</td>
<td>------------------------</td>
<td>------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Cyfluthrin* 68359–37–5</td>
<td>Banthroid</td>
<td>Synthetic pyrethroid</td>
<td>0.002 mg/l (20°C)c</td>
<td>856c</td>
<td>42,000c</td>
<td>100,000g</td>
<td>Slightc</td>
<td>1.5 µg/lc</td>
<td>291 mg/kgc</td>
<td>IIc</td>
</tr>
<tr>
<td>Fenvalerate* 61630–58–1</td>
<td>Pydrin</td>
<td>Synthetic pyrethroid</td>
<td>&lt;1 mg/l (20°C)h</td>
<td>3,000bb</td>
<td>26,500aa</td>
<td>100,000g</td>
<td>Mediumm</td>
<td>3.6 µg/lh+</td>
<td>451 mg/kgh</td>
<td>IIg</td>
</tr>
<tr>
<td>Lambda-cyhalothrin* 91465–08–6</td>
<td>Excaliber</td>
<td>Synthetic pyrethroid</td>
<td>0.005 mg/l*a</td>
<td>858a</td>
<td>10,000,000a</td>
<td>180,000a</td>
<td>Low</td>
<td>0.21 µg/l*a</td>
<td>56 mg/kg*a</td>
<td>IIa</td>
</tr>
<tr>
<td>Permethrin* 52645–53–1</td>
<td>Pounce/Ambush</td>
<td>Synthetic pyrethroid</td>
<td>0.2 mg/l (30°C)h</td>
<td>3,000ee</td>
<td>3,060y,ff</td>
<td>100,000g</td>
<td>Lowm</td>
<td>0.9 µg/lh</td>
<td>430–4,000 mg/kgh</td>
<td>II,IIIG</td>
</tr>
<tr>
<td>Phorate* 298–02–2</td>
<td>Thimet</td>
<td>Organic phosphate</td>
<td>509 mg/l (25°C)h</td>
<td>12u</td>
<td>8,410p</td>
<td>543p</td>
<td>Slightf</td>
<td>2 µg/ls</td>
<td>1.6–3.7 mg/kg</td>
<td>I</td>
</tr>
<tr>
<td>Tebufurin* 79538-32-2</td>
<td>Force</td>
<td>Synthetic pyrethroid</td>
<td>0.002 (20°C) mg/l</td>
<td>-</td>
<td>3.2 x 106</td>
<td>20,000</td>
<td>Low</td>
<td>4.3 mg/lw</td>
<td>22 mg/kg</td>
<td>Iw</td>
</tr>
<tr>
<td>Terbufos* 13071–79–9</td>
<td>Counter</td>
<td>Organophosphate</td>
<td>15 mg/l (25°C)h</td>
<td>370u</td>
<td>33,000p</td>
<td>580l</td>
<td>Mediumm</td>
<td>4 µg/lh</td>
<td>1.6–5.4 mg/kg</td>
<td>Ig</td>
</tr>
</tbody>
</table>

References:


Table 59. Continued.


zTexas A & M University, Blackland Research Center, Tex*A*Syst, Pesticide Leachability. http://waterhome.brc.tamus.edu/texastx/66025b.html


ddFMC Corporation, Agricultural Chemical Division. 1975. Furadan. Middleport, N.Y.
Table 59. Continued.


http://www.tifton.uga.edu/sewrl/gleams/glm30pst.pdf

Table 60. Water solubility, bioconcentration factor (BCF), and acute toxicity values for selected parameters analyzed during this contract period.

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Chemical Class</th>
<th>Water Solubility</th>
<th>BCF</th>
<th>96 hr LC₅₀ (Bluegill)</th>
<th>96 hr LC₅₀ (Daphina pulex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dieldrin</td>
<td>Cyclodiene</td>
<td>22 µg/lᵃ</td>
<td>4,420ᵃ</td>
<td>3.1 µg/lᵇ</td>
<td>190 µg/lᵇ</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>Cyclodiene</td>
<td>30 µg/lᶜ</td>
<td>2,150ᵃ</td>
<td>13 µg/lᵇ</td>
<td>42 µg/lᵇ</td>
</tr>
<tr>
<td>Heptachlor epoxide</td>
<td>Cyclodiene</td>
<td>30 µg/lᶜ</td>
<td>5,000-15,000ᶜ</td>
<td>5.3 µg/lᵇ</td>
<td>—</td>
</tr>
<tr>
<td>Chlordane</td>
<td>Cyclodiene</td>
<td>56 µg/lᵃ</td>
<td>8,260ᵃ</td>
<td>57 µg/lᵇ</td>
<td>24 µg/lᵇ</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Organophosphate</td>
<td>2 mg/lᵈ</td>
<td>320ᵃ</td>
<td>2.4 µg/lᵇ</td>
<td>—</td>
</tr>
<tr>
<td>Herbicides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alachlor</td>
<td>Amide</td>
<td>242 mg/lᵃ</td>
<td>0ᵃ</td>
<td>4 mg/lᵇ</td>
<td>—</td>
</tr>
<tr>
<td>Trifluralin</td>
<td>Dinitroaniline</td>
<td>0.6 mg/lᵃ</td>
<td>926ᵃ</td>
<td>0.06 mg/lᵇ</td>
<td>0.62 mg/lᵇ</td>
</tr>
</tbody>
</table>


The organochlorine insecticides (dieldrin, heptachlor, and chlordane) are relatively insoluble in water and can bioaccumulate in the tissues of organisms. The organochlorines are persistent, mobile, and not readily broken down or metabolized. Dieldrin, heptachlor epoxide, and chlordane are classified as cyclodienes, and their mode of action is by stimulating excessive releases of acetylcholine, which causes prolonged responses to presynaptic stimulation. Aldrin and heptachlor, which in nature are converted to the persistent forms dieldrin and heptachlor epoxide, were used to control soil insects until the U.S. Environmental Protection Agency suspended their production in 1975 and their use soon after. In 1978, the EPA canceled the registration for chlordane and began to phase out products containing chlordane. In 1980, chlordane use was restricted to termite control. In 1987, the EPA moved to ban chlordane use in homes, although allowing for the use of existing inventories. In 1988, court action prompted a ban of the sale of existing stocks of chlordane. Natural waters continue to be contaminated with these organochlorine residues because of their long half-lives (8 to 10 years for dieldrin) and because they are adsorbed onto soil particles that may then be washed into streams and rivers. All of these chemicals are of particular concern because they tend to accumulate in fish and other organisms. Because of their potential for carcinogenic effects, these chemicals are assumed to have a zero threshold toxicity value.

Most organochlorine insecticides were first replaced by organophosphate or carbamate insecticides such as fonofos (Dyfonate) and carbofuran (Furadan). Concentrations of these two chemicals were determined in fish during 1985; no carbofuran residues were found in excess of the detection limit of 11 ppb and no fonofos concentrations were found in excess of the detection limit of 10 ppb. Production of fonofos ended in 1997. Analyses of the triazine herbicides atrazine and cyanazine had been discontinued because results from 1987 and 1988 indicated that there were no residues of these triazines in excess of laboratory detection limits ranging from 0.6 ppb to 3.6 ppb.

Alachlor is a pre-emergent amide herbicide that is used in corn and soybean fields to control annual grasses and broadleaf weeds. Alachlor, once widely used in Iowa, has been largely replaced by acetochlor (Benbrook 2001). Between 1990 and 1995, the amount of acres of corn that were treated with alachlor decreased from 22% to 2.2%, and in 1998 the list of applications to Iowa corn fields no longer included alachlor. Alachlor was reregistered by the EPA in 1998.

Trifluralin is a toluene-derived dinitroaniline herbicide often used in soybean production for grass control. Most all uses of trifluralin were reregistered in 1996. It was the most popular herbicide used in Iowa soybean fields in 1985 and 1990; it is also one of the most persistent and insoluble of the newer herbicides. In 1995, it ranked second to pendimethalin use in Iowa.
soybean production. Between 1990 and 1995, the acres treated with trifluralin decreased from 55% to 30% (Iowa State 1991). In 1999, 2002, and 2004, trifluralin applications were reported on 41%, 18%, and 14% of Iowa soybean fields, respectively. In 2004, it ranked second to glyphosate (87%) (USDA-NASS 2005).

Chlorpyrifos (Lorsban) is an organophosphate insecticide used in Iowa primarily as a soil and foliar insecticide to control corn rootworms, corn cutworms, and corn borers. In 1985 and 1990, chlorpyrifos ranked second only to terbufos (Counter) in agricultural insecticide use. In 1995, it was the most popular insecticide used in Iowa corn production. In 2000, chlorpyrifos was the third most popular corn insecticide. Insecticide use data from 2001 was not available. In 2003, chlorpyrifos ranked second behind cyfluthrin/tebupirimphos in acres applied; however, the total pounds of active ingredient was many times higher. Chlorpyrifos was not listed as applied on corn acres in 2005. Chlorpyrifos acts primarily by contact activity as a stomach poison and is relatively toxic to fish and crustaceans. In June 2000, the EPA released a revised risk assessment and announced an agreement with registrants to phase out/eliminate chlorpyrifos use, especially on apples, tomatoes, and grapes and for home use. In agriculture, chlorpyrifos products must now be classified as new end use products for restricted use and bear revised restricted entry intervals. In 2002, the EPA released a favorable interim reregistration eligibility decision for chlorpyrifos.

Historically, the FDA’s action levels for pesticides in food stuffs had been used by some states, including Iowa, for issuing consumption advisories. Previously in Iowa, concentrations at one-half the FDA level prompt concern. In fact, in December 1989, the Iowa DNR issued a health advisory warning against consumption of catfish and carp in the Des Moines River from Saylorville Dam to Red Rock Dam because of elevated chlordane levels. (Data from this project were in sharp contrast with Iowa DNR results, with outcomes never approaching the FDA action level.) This advisory was rescinded in 1993. The current recommendations of the EPA are to use screening values, which for carcinogens are based on a $10^{-5}$ risk level (U.S. EPA 2000). The screening levels for most pesticides are more restrictive than the FDA action levels, and thus the announcement of fish consumption advisories would become more frequent if they were used by the state to define a level of concern. For example, the EPA screening value for total chlordane is 114 ppb for recreational fishers and 14 ppb for subsistence fishers as compared to the FDA action level of 300 ppb (see Table 21). In January 2006, the state of Iowa revised its fish consumption advisory protocol. Previously, the Iowa advisory protocol was based on FDA action levels (1 ppm methylmercury, 2 ppm PCBs, and 0.3 ppm chlordane in fish tissue).

As of January 1, 2006, the following levels of fish contaminants and the corresponding recommended consumption levels are:
<table>
<thead>
<tr>
<th>Compound</th>
<th>0 to 0.2 ppm</th>
<th>&gt;0.2 to &lt;1.0 ppm</th>
<th>1.0 ppm and over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylmercury:</td>
<td>unrestricted consumption</td>
<td>– one meal per week</td>
<td>– do not eat</td>
</tr>
<tr>
<td>PCBs:</td>
<td>unrestricted consumption</td>
<td>– one meal per week</td>
<td>– do not eat</td>
</tr>
<tr>
<td>Chlordane:</td>
<td>unrestricted consumption</td>
<td>– one meal per week</td>
<td>– do not eat</td>
</tr>
</tbody>
</table>

The methylmercury and PCB levels for no consumption are the same as the previous recommendations, and the new chlordane no consumption level is based on a risk-based calculation, not a health-based study. The reasoning for these new advisory levels is to become more in line with neighboring states without discouraging the consumption of fish or the activity of fishing.

The National Fish Tissue Study ([http://www.epa.gov/waterscience/fishstudy](http://www.epa.gov/waterscience/fishstudy)) is a four-year national screening-level freshwater fish contaminant study. Results from the fish tissue analyses indicate that mercury, PCBs, and dioxins and furans are widely distributed in lakes and reservoirs in the lower 48 states. Mercury and PCBs were detected in all the fish samples collected from the 500 sampling sites. Dioxins and furans were detected in 81% of the predator samples (fillet composites) and 99% of the bottom-dweller samples (whole fish composites). A number of chemicals were not detected in any of the fish samples, including the nine organophosphate pesticides (e.g., chlorpyrifos and diazinon) and 32 of the 40 semi-volatile organic chemicals (e.g., polycyclic aromatic hydrocarbons [PAHs] and chlorobenzenes) (Stahl 2006).

### 8.32.3. Sampling Program

According to the research contracts, fish were collected in and below both Saylorville and Red Rock reservoirs for analysis of pesticide residues in whole fish. This contract period marks the nineteenth time since 1987 that amounts in whole fish were examined. Due to budget constraints, pesticide monitoring in carp fillets was suspended in 1996. This was unfortunate because pesticides in fish fillets had been monitored for about 20 years and a good database had been established. Iowa State has supported the analyses of pesticides in fish fillets at selected sites (1998–1999, 2001–2006) in order to maintain the database until it can be reinstated in the Scope.
of Work. Thus, pesticides in fish fillets have been monitored since 1997 (with no activity in 1983, 1996, 1997, and 2000).

As before, the fish species used to monitor the accumulation of pesticide residues was the common carp, *Cyprinus carpio*. The common carp was selected because it is a bottom-feeding fish and is one of the most prevalent species. The target class was three-year-olds that were 312 mm to 351 mm in length. Occasionally, larger or smaller fish might be used when enough fish in the target class cannot be obtained in a reasonable amount of time.

The fish were collected during the period May 18–June 7, 2006, with two subsamples consisting of five fish each collected at each site. The general procedure was that from each of the four sampling sites, two whole fish subsamples were prepared. Additionally, fillet samples were prepared from fish collected at Station 5. The initial fish preparation, which consisted of measuring the length and weight of the fish, packaging into subsamples, and freezing, was completed within 24 hours of collection. Later, the frozen subsamples were ground and homogenized and aliquots of the subsample mixtures were kept frozen in glass sample jars until extractions and analyses could be performed.

### 8.32.4. Results from Monitoring in 2006

The fish samples, prepared as described earlier, were analyzed for dieldrin, heptachlor epoxide, chlordane, alachlor, trifluralin, and chlorpyrifos by gas chromatography according to procedures listed in Table 14. In summary, these methods involve blending homogeneous fish tissue with petroleum ether to extract the pesticide residues, concentrating the sample, cleaning it up with acetonitrile partitioning and a Florisil cleanup step, reconcentrating, and then analyzing the extract with appropriate standards on a gas chromatograph using an electron capture detector. The results, calculated on a wet-weight basis, were not corrected for recovery.

#### Uniformity of Fish Samples

Generally, fish samples were satisfactorily uniform. The subsamples of whole fish from Stations 4, 5, 8, and 9 ranged from 329 mm to 343 mm in length and from 468.0 g to 577.5 g in weight. The subsamples at Station 4 differed by 1 mm in length (<1%) and by 3.2 g in weight (<1%). The subsamples at Station 5 differed by 2 mm in length (<1%) and differed in weight by 31.8 g (6%). The subsamples at Station 8 differed by 1 mm in length (<1%) and by 44 g in weight (8%). The subsamples at Station 9 differed by 9 mm in length (3%) and 34.7 g in weight (7%).
These data are compiled in Table 61. One subsample of common carp fillets was taken from Station 5. The carp used for this sample was 345 mm in length and 513.5 g in weight (Table 62).

Condition factors, a measure of the physiological condition of the fish, are found by the formula $K$ (condition factor) = $[\text{Weight (g)} \times 10^5]/[\text{Length (mm)}^3]$ and also are listed in Tables 61 and 62. For the same species, differences in condition factors indicate that the fish are not equally plump for their length. Generally, carp found in rivers have a more tubular shape and a lower condition factor than those found in lakes and reservoirs. The average condition factors for the fish used as whole fish were 1.24 at the riverine locations versus 1.38 at the reservoir locations. These condition factors were similar to previous years. The average lipid content of the whole carp samples ranged from 2.9% to 5.2%. The average lipid content of the carp fillet sample was <1%. The greatest whole fish lipid content was seen for fish collected in Saylorville Reservoir at Station 4. The percentage of lipid content (fat) in the subsamples is listed in Tables 63 and 64.

Overall, whole fish subsamples per station were relatively comparable in condition factors, indicating that both are representative of the same population. Condition factors and percentage fat content did vary between stations. Hydrophilic compounds (such as organochlorine pesticides) tend to concentrate in fat and so should be present at somewhat greater concentrations in fattier fish even from the same population exposed to the same conditions. Thus, from only a fat basis, greater organochlorine pesticide concentrations would be expected at Station 4. However, this was only the case for chlorpyrifos, indicating that other site-specific variables can be important.

**Results Compared to Standards and Criteria**

All concentrations of the selected pesticides in the fish samples were low. Dieldrin, heptachlor epoxide, and chlordane concentrations in whole fish samples were below the FDA’s food-fish action limits of 300 ppb for each of these pesticides. This action limit, as with EPA’s screening values, is most applicable to fillet samples and is used here for comparison purposes only. Dieldrin concentrations from whole fish subsamples from both Stations 5 and 9 exceeded the EPA screening value of 2.5 ppb for recreational fishers, while all but one subsample result exceeded the screening value for subsistence fishers of 0.31 ppb. The overall average concentration of dieldrin from Stations 4, 5, 8, and 9 was 3.1 ppb. Average heptachlor epoxide and total chlordane concentrations were well below EPA screening values of 2.2 ppb and 114 ppb for recreational fishers, respectively. The maximum subsample concentrations for heptachlor epoxide and chlordane in the whole fish samples were 0.9 ppb and 14.4 ppb, respectively. The
Table 61. Length and weight of individual fish, condition factors, and subsample averages for whole carp (*Cyprinus carpio*, age class III) collected at four sites in 2006.

<table>
<thead>
<tr>
<th></th>
<th>Subsample 1 (W1)</th>
<th></th>
<th>Subsample 2 (W2)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length(^a) (mm)</td>
<td>Weight (g)</td>
<td>Condition Factor(^b)</td>
<td>Length(^a) (mm)</td>
</tr>
<tr>
<td><strong>Station 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01Jun06</td>
<td>347</td>
<td>557.8</td>
<td>1.34</td>
<td>345</td>
</tr>
<tr>
<td></td>
<td>330</td>
<td>472.8</td>
<td>1.32</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>320</td>
<td>442.0</td>
<td>1.35</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>352</td>
<td>582.6</td>
<td>1.34</td>
<td>322</td>
</tr>
<tr>
<td></td>
<td>324</td>
<td>461.8</td>
<td>1.36</td>
<td>334</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>335</td>
<td>503.4</td>
<td>1.34</td>
<td>336</td>
</tr>
<tr>
<td><strong>Station 5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18May06</td>
<td>332</td>
<td>481.8</td>
<td>1.32</td>
<td>322</td>
</tr>
<tr>
<td></td>
<td>325</td>
<td>439.0</td>
<td>1.28</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>622.5</td>
<td>1.33</td>
<td>364</td>
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<td></td>
<td>358</td>
<td>568.5</td>
<td>1.24</td>
<td>368</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td>397.1</td>
<td>1.26</td>
<td>305</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>338</td>
<td>501.8</td>
<td>1.29</td>
<td>340</td>
</tr>
<tr>
<td><strong>Station 8</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06Jul06</td>
<td>343</td>
<td>530.2</td>
<td>1.31</td>
<td>356</td>
</tr>
<tr>
<td></td>
<td>367</td>
<td>673.9</td>
<td>1.36</td>
<td>343</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>567.7</td>
<td>1.32</td>
<td>365</td>
</tr>
<tr>
<td></td>
<td>343</td>
<td>518.6</td>
<td>1.29</td>
<td>305</td>
</tr>
<tr>
<td></td>
<td>310</td>
<td>377.1</td>
<td>1.27</td>
<td>–</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>343</td>
<td>533.5</td>
<td>1.31</td>
<td>342</td>
</tr>
<tr>
<td><strong>Station 9</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07Jun06</td>
<td>315</td>
<td>399.0</td>
<td>1.28</td>
<td>315</td>
</tr>
<tr>
<td></td>
<td>335</td>
<td>457.8</td>
<td>1.22</td>
<td>328</td>
</tr>
<tr>
<td></td>
<td>320</td>
<td>351.4</td>
<td>1.07</td>
<td>293</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>669.6</td>
<td>1.44</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>358</td>
<td>635.6</td>
<td>1.39</td>
<td>359</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>338</td>
<td>502.7</td>
<td>1.28</td>
<td>329</td>
</tr>
</tbody>
</table>

\(^{a}\) Length from snout to tip of caudal fin (total length).

\(^{b}\) Condition Factor: Weight (g) \(\times 10^5\)/Length (mm)\(^3\).
Table 62. Length and weight of individual fish, condition factors, and subsample averages for carp fillets (*Cyprinus carpio*, age class III) collected in 2006.

<table>
<thead>
<tr>
<th>Subsample 1 (F1)</th>
<th>Length(^a) (mm)</th>
<th>Weight (g)</th>
<th>Condition Factor(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 5 18May06</td>
<td>356</td>
<td>510.3</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>653.1</td>
<td>1.40</td>
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<tr>
<td></td>
<td>310</td>
<td>417.9</td>
<td>1.40</td>
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<tr>
<td></td>
<td>330</td>
<td>438.0</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>368</td>
<td>548.0</td>
<td>1.10</td>
</tr>
<tr>
<td>Average</td>
<td>345</td>
<td>513.5</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Note: This work was supported by Iowa State University in order to maintain a data set of pesticides in fish fillets.

\(^a\) Length from snout to tip of caudal fin (total length).

\(^b\) Condition Factor: Weight (g) \(\times 10^5\)/Length (mm)\(^3\).
Table 63. Concentrations (ppb or µg/kg) of pesticide residues in composite samples of whole carp (*Cyprinus carpio*, age class III).

<table>
<thead>
<tr>
<th>Station and Date</th>
<th>Sample ID</th>
<th>Average Length (mm)</th>
<th>Average Weight (g)</th>
<th>Lipid Content (%)</th>
<th>Dieldrin</th>
<th>Heptachlor Epoxide</th>
<th>Chlordane (Summation of Constituents—see Table 63)</th>
<th>Alachlor (Lasso)</th>
<th>Trifluralin (Treflan)</th>
<th>Chlorpyrifos (Lorsban)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01Jun06 4W1</td>
<td></td>
<td>335</td>
<td>503.4</td>
<td>4.87</td>
<td>1.61</td>
<td>0.17</td>
<td>4.41</td>
<td>ND</td>
<td>1.38</td>
<td>7.56</td>
</tr>
<tr>
<td>4W2</td>
<td></td>
<td>336</td>
<td>506.6</td>
<td>5.25</td>
<td>ND</td>
<td>0.06</td>
<td>1.62</td>
<td>0.33</td>
<td>1.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>336</td>
<td>505.0</td>
<td>5.02</td>
<td>0.80</td>
<td>0.12</td>
<td>3.01</td>
<td>0.17</td>
<td>1.31</td>
<td>3.89</td>
</tr>
<tr>
<td>18May06 5W1</td>
<td></td>
<td>338</td>
<td>501.8</td>
<td>2.88</td>
<td>1.66</td>
<td>0.16</td>
<td>1.56</td>
<td>0.30</td>
<td>0.73</td>
<td>0.06</td>
</tr>
<tr>
<td>5W2</td>
<td></td>
<td>340</td>
<td>470.0</td>
<td>2.93</td>
<td>5.26</td>
<td>0.86</td>
<td>2.02</td>
<td>0.41</td>
<td>1.18</td>
<td>2.24</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>339</td>
<td>485.9</td>
<td>2.91</td>
<td>3.46</td>
<td>0.51</td>
<td>1.79</td>
<td>0.35</td>
<td>0.96</td>
<td>1.15</td>
</tr>
<tr>
<td>06Jul06 8W1</td>
<td></td>
<td>343</td>
<td>533.5</td>
<td>4.69</td>
<td>1.63</td>
<td>0.16</td>
<td>2.05</td>
<td>0.10</td>
<td>0.89</td>
<td>0.85</td>
</tr>
<tr>
<td>8W2</td>
<td></td>
<td>342</td>
<td>577.5</td>
<td>4.01</td>
<td>0.69</td>
<td>0.09</td>
<td>0.99</td>
<td>0.27</td>
<td>0.95</td>
<td>0.92</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>342</td>
<td>555.5</td>
<td>4.35</td>
<td>1.16</td>
<td>0.12</td>
<td>1.52</td>
<td>0.18</td>
<td>0.92</td>
<td>0.89</td>
</tr>
<tr>
<td>07Jun06 9W1</td>
<td></td>
<td>338</td>
<td>502.7</td>
<td>1.76</td>
<td>2.49</td>
<td>0.21</td>
<td>4.59</td>
<td>1.39</td>
<td>0.65</td>
<td>0.30</td>
</tr>
<tr>
<td>9W2</td>
<td></td>
<td>329</td>
<td>468.0</td>
<td>4.39</td>
<td>11.27</td>
<td>0.52</td>
<td>14.43</td>
<td>1.39</td>
<td>2.85</td>
<td>0.60</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>334</td>
<td>485.4</td>
<td>3.08</td>
<td>6.88</td>
<td>0.36</td>
<td>9.51</td>
<td>1.39</td>
<td>1.75</td>
<td>0.45</td>
</tr>
<tr>
<td>Detection limits</td>
<td></td>
<td></td>
<td>0.030</td>
<td>0.001</td>
<td>0.002</td>
<td>0.001–0.01</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.007</td>
</tr>
</tbody>
</table>

ND—Not detected.
Table 64. Concentrations (ppb or µg/kg) of pesticide residues in composite samples of carp fillets (*Cyprinus carpio*, age class III).

<table>
<thead>
<tr>
<th>Station and Date</th>
<th>Sample ID</th>
<th>Average Length (mm)</th>
<th>Average Weight (g)</th>
<th>Lipid Content (%)</th>
<th>Dieldrin</th>
<th>Heptachlor Epoxide</th>
<th>Chlordane (Summation of Constituents—see Table 69)</th>
<th>Alachlor (Lasso)</th>
<th>Trifluralin (Treflan)</th>
<th>Chlorpyrifos (Lorsban)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 5</td>
<td>5F1</td>
<td>345</td>
<td>513.5</td>
<td>0.50</td>
<td>0.19</td>
<td>ND</td>
<td>0.53</td>
<td>ND</td>
<td>0.70</td>
<td>ND</td>
</tr>
<tr>
<td>Detection limits</td>
<td></td>
<td></td>
<td></td>
<td>0.030</td>
<td>0.001</td>
<td>0.002</td>
<td>0.001–0.01</td>
<td>0.003</td>
<td>0.003</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Note: This work was supported by Iowa State University in order to maintain a data set of pesticides in fish fillets.

ND—Not detected.
maximum chlordane concentration was just below Iowa’s advisory limit for unrestricted consumption.

The National Academy of Sciences and the National Academy of Engineering (NAS/NAE) jointly developed guidelines for concentrations of pesticides, DDT, PCBs, and mercury in fish in 1972. These criteria were designed to protect predator species and are tentatively used to evaluate the whole-fish data. The pesticide guideline involves summing the measured concentrations of many pesticides that are recommended to total less than 100 ppb. Under our program, only concentrations of dieldrin, heptachlor epoxide, and chlordane were evaluated; as established by the Regional Ambient Fish Tissue Monitoring Program; however, these are the pesticides normally seen in the greatest concentrations in Iowa fish. When the NAS/NAE criteria were used, but only these three pesticide concentrations were totaled, none of the whole fish sample averages exceeded 100 ppb. Over the previous thirteen years (1992–2004), only six subsamples exceeded the NAS/NAE criteria. However, in 1991 six of eight subsamples exceeded this value. Before that, the NAS/NAE guideline was exceeded in only four other subsamples over the other four years since pesticide analyses in whole fish began in 1987.

**Pesticides in Carp Results**

Most pesticide constituents were lower this year when compared to the previous year. Concentrations of dieldrin from fish collected in 2006 were low at most all locations. Dieldrin concentrations in whole fish samples ranged from 0.80 ppb at Station 4 to 6.88 ppb at Station 9. In the previous 9 years, since analyses of whole fish began in 1987, the maximum dieldrin concentration in whole fish (from averaging two subsamples) ranged from 3 ppb (2005) to 296 ppb (1991). From the historical record (1987–2006), the long-term average dieldrin concentrations from whole carp collected at both reservoirs were similar, being 42.9 ppb at Station 4 and 41.8 ppb at Station 8 (corresponding condition factors were 1.32 and 1.39). However, at the river locations below each dam, the long-term average dieldrin concentrations were less below Red Rock Dam, being 26.9 ppb at Station 5 and 15.3 ppb at Station 9 (corresponding condition factors were 1.26 and 1.29).

Chlordane concentrations, as listed in Tables 63 and 64, were obtained by summing the residues quantified as cis- and trans-chlordane, cis- and trans-nonachlor, and oxychlordane, as recommended by the EPA. Table 65 lists the separate concentrations of all five constituents of chlordane in whole fish, while Table 66 lists these concentrations from fillet samples. Heptachlor, which is also a constituent of technical chlordane, is measured and discussed separately.
Table 65. Concentrations (ppb or µg/kg) of chlordane constituents in composite samples of whole carp (*Cyprinus carpio*, age class III).

<table>
<thead>
<tr>
<th>Station and Date</th>
<th>Sample ID</th>
<th>Trans-Chlordane</th>
<th>Cis-Chlordane</th>
<th>Trans-Nonachlor</th>
<th>Cis-Nonachlor</th>
<th>Oxy-Chlordane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 4</td>
<td>4W1</td>
<td>0.03</td>
<td>ND</td>
<td>0.04</td>
<td>1.01</td>
<td>3.32</td>
</tr>
<tr>
<td></td>
<td>4W2</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>1.39</td>
<td>0.23</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.02</td>
<td>ND</td>
<td>0.02</td>
<td>1.20</td>
<td>1.78</td>
</tr>
<tr>
<td>Station 5</td>
<td>5W1</td>
<td>&lt;0.001</td>
<td>0.31</td>
<td>0.08</td>
<td>0.96</td>
<td>0.20</td>
</tr>
<tr>
<td>18May06</td>
<td>5W2</td>
<td>0.10</td>
<td>0.23</td>
<td>0.21</td>
<td>0.93</td>
<td>0.54</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.05</td>
<td>0.27</td>
<td>0.15</td>
<td>0.95</td>
<td>0.37</td>
</tr>
<tr>
<td>Station 8</td>
<td>8W1</td>
<td>0.22</td>
<td>0.25</td>
<td>0.41</td>
<td>0.87</td>
<td>0.29</td>
</tr>
<tr>
<td>06Jul06</td>
<td>8W2</td>
<td>0.19</td>
<td>0.07</td>
<td>ND</td>
<td>0.58</td>
<td>0.51</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.21</td>
<td>0.16</td>
<td>0.20</td>
<td>0.73</td>
<td>0.40</td>
</tr>
<tr>
<td>Station 9</td>
<td>9W1</td>
<td>0.03</td>
<td>0.30</td>
<td>0.20</td>
<td>3.62</td>
<td>0.44</td>
</tr>
<tr>
<td>07Jun06</td>
<td>9W2</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>13.81</td>
<td>0.62</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.02</td>
<td>0.20</td>
<td>0.10</td>
<td>8.72</td>
<td>0.53</td>
</tr>
<tr>
<td>Detection limit</td>
<td></td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.009</td>
<td>0.01</td>
</tr>
</tbody>
</table>

ND—Not detected.
Table 66. Concentrations (ppb or µg/kg) of chlordane constituents in composite samples of carp fillets (*Cyprinus carpio*, age class III).

<table>
<thead>
<tr>
<th>Station and Date</th>
<th>Sample ID</th>
<th>Trans-Chlordane</th>
<th>Cis-Chlordane</th>
<th>Trans-Nonachlor</th>
<th>Cis-Nonachlor</th>
<th>Oxy-Chlordane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 5</td>
<td>5F1</td>
<td>ND</td>
<td>ND</td>
<td>0.19</td>
<td>0.15</td>
<td>0.19</td>
</tr>
<tr>
<td>Detection limit</td>
<td></td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.009</td>
<td>0.01</td>
</tr>
</tbody>
</table>

ND—Not detected.
Chlordane concentrations in whole fish samples were more widely ranged from 1.5 ppb to 9.5 ppb, as compared to 2.3 ppb to 3.2 ppb last summer. In the previous 19 years, the maximum chlordane concentration in whole fish (averaging from two subsamples) ranged from 2.8 ppb (2001) to 132 ppb (1991). From the historical record (1987–2006), the long-term average total chlordane concentrations from whole fish collected at both reservoirs were 15.2 ppb and 11.7 ppb (corresponding condition factors were 1.32 and 1.39). Below Saylorville Dam at Station 5, the long-term chlordane in whole carp average was 19.9 ppb, which was similar to 19.7 ppb in whole carp below Red Rock Dam at Station 9 (respective average condition factors were 1.26 and 1.29).

Heptachlor epoxide concentrations were low in whole fish from all locations in 2006. Normally, heptachlor epoxide concentrations generally parallel chlordane concentrations, indicating that heptachlor in technical chlordane was probably a significant source of heptachlor epoxide. Heptachlor epoxide concentrations in whole fish samples ranged from 0.1 ppb to 0.5 ppb. In the previous 19 years, since analyses of whole fish began in 1987, the maximum average heptachlor epoxide concentration in whole fish ranged from 0.4 ppb (2001) to 60.2 ppb (1991); last year’s maximum was 2.1 ppb.

Trifluralin (Treflan) residues were detected in all of the fish samples this year. Trifluralin concentrations in whole fish samples ranged from only 0.9 ppb to 1.8 ppb. In the previous 19 years, since analyses of whole fish began in 1987, the maximum average trifluralin concentration in whole fish (from averaging two subsamples) ranged from 0.8 ppb (2001) to 214 ppb (1991); last year’s maximum was 5.7 ppb.

Alachlor (Lasso) concentrations were very low. Alachlor concentrations in whole fish samples ranged from 0.2 ppb to 1.4 ppb. In the previous 19 years, since analyses of whole fish began in 1987, the maximum alachlor concentration in whole fish (from an average of two subsamples) ranged from 4.7 ppb (1994–1995) to 55.8 ppb (1991); last year’s maximum was 12.6 ppb.

Chlorpyrifos (Lorsban) concentrations were low. Chlorpyrifos concentrations in whole fish subsamples ranged from 0.4 ppb to 3.9 ppb. In the previous 17 years, since analyses of chlorpyrifos began in 1989, the average chlorpyrifos concentration in whole fish (from an average of two subsamples) ranged from 0.2 ppb (1995) to 126 ppb (1992); last year’s maximum was only 0.8 ppb.
Comparative Study of Two Age Classes

In 2006, carp from two different age classes, age class III and age class V, were analyzed for pesticide residues (see Tables 67–69). This was done because it has become increasingly more difficult to find fish in age class III, size range 335 mm ± 10%, and it may be necessary to move to another size range. Currently, it often takes the field crew more than one day to collect the appropriate number of age class III common carp. The age/length relationships for carp in the Des Moines River basin were listed in *Diversity and Standing Stocks of Stream Fishes* (Iowa Conservation Commission 1986) and verified with fish scales. From this study, age class V common carp averaged 455 mm in the Des Moines River.

In the comparative study, although the older fish were 36% longer and 126% heavier, their condition factors were similar to the younger fish, averaging 1.36. However, the comparative concentrations of pesticide residues varied greatly. The concentrations of dieldrin and alachlor were much greater in the older fish, being four times and eight times higher, respectively, than in the smaller fish. However, total chlordane was not even doubled and trifluralin concentrations in the older fish were even lower than the younger fish. It is not too surprising that there are considerable differences in the concentrations from these two age ranges, due to the differences in the chemical characteristics of these pesticides; however, it is surprising that alachlor is that much higher, as it doesn’t bioaccumulate. These differences make any comparisons between age groups more complex. Another comparative study may be done in 2007, depending on funding.

Pesticide Scan by EPA

In addition to these analyses, fish extracts are occasionally prepared and submitted to the regional EPA lab for a gas chromatography-mass spectrum scan. Results from EPA help indicate whether there are any other pesticide residues present in significant concentrations. The latest results were from whole carp collected in 2002. The pesticide residues above laboratory detection levels were DDD, dieldrin, and trifluralin. The reported DDD, dieldrin, and trifluralin levels from the whole carp sample from Station 5 were 5 ppb, 7 ppb, and 8 ppb, respectively. From a whole carp sample from Station 9, only dieldrin was detected (11 ppb).

The only detectable pesticide residue found in samples from 2000 was dieldrin (11 ppb from Station 4). From samples collected in 1997, EPA scans found detectable concentrations of heptachlor epoxide, DDE, PCB (1260), and hexachlorobenzene were seen from a whole fish.
Table 67. Comparative data, length and weight of individual fish, condition factors, and subsample averages for whole carp (*Cyprinus carpio*, age class V) collected at Red Rock Reservoir in July 2006.

<table>
<thead>
<tr>
<th>Subsample</th>
<th>Subsample 1 (WC1)</th>
<th>Subsample 2 (WC2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length&lt;sup&gt;a&lt;/sup&gt; (mm)</td>
<td>Weight (g)</td>
</tr>
<tr>
<td>Station 8 06Jul06</td>
<td>438</td>
<td>1,043.2</td>
</tr>
<tr>
<td></td>
<td>455</td>
<td>1,151.0</td>
</tr>
<tr>
<td></td>
<td>492</td>
<td>1,476.1</td>
</tr>
<tr>
<td></td>
<td>463</td>
<td>1,492.9</td>
</tr>
<tr>
<td></td>
<td>477</td>
<td>1,506.3</td>
</tr>
<tr>
<td>Average</td>
<td>465</td>
<td>1,333.9</td>
</tr>
</tbody>
</table>

<sup>a</sup>Length from snout to tip of caudal fin (total length).

<sup>b</sup>Condition Factor: Weight (g) x 10<sup>5</sup>/Length (mm)<sup>3</sup>.
Table 68. Comparative data, concentrations (ppb or µg/kg) of pesticide residue in whole carp (*Cyprinus carpio*, age class V) collected at Red Rock Reservoir in July 2006.

<table>
<thead>
<tr>
<th>Station and Date</th>
<th>Sample ID</th>
<th>Average Length (mm)</th>
<th>Average Weight (g)</th>
<th>Lipid Content (%)</th>
<th>Dieldrin</th>
<th>Heptachlor Epoxide</th>
<th>Chlordane (Summation of Constituents—see Table 66)</th>
<th>Alachlor (Lasso)</th>
<th>Trifluralin (Treflan)</th>
<th>Chlorpyrifos (Lorsban)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 8S 06Jul06</td>
<td>8WC1</td>
<td>465</td>
<td>1333.9</td>
<td>3.13</td>
<td>2.58</td>
<td>0.52</td>
<td>3.64</td>
<td>0.41</td>
<td>0.81</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>8WC2</td>
<td>465</td>
<td>1408.3</td>
<td>5.32</td>
<td>9.10</td>
<td>ND</td>
<td>1.62</td>
<td>2.89</td>
<td>0.17</td>
<td>ND</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8WC1 8WC2</td>
<td>465</td>
<td>465</td>
<td>3.13</td>
<td>2.58</td>
<td>3.64</td>
<td>0.41</td>
<td>0.81</td>
<td>ND</td>
</tr>
<tr>
<td>Detection limits</td>
<td></td>
<td></td>
<td>1333.9</td>
<td>1371.1</td>
<td>3.13</td>
<td>2.58</td>
<td>3.64</td>
<td>0.41</td>
<td>0.81</td>
<td>ND</td>
</tr>
</tbody>
</table>

Notes:
- ND indicates not detected.

Table 66 provides the summation of constituents for Chlordane.
Table 69. Comparative data, concentrations (ppb or µg/kg) of chlordane constituents in composite samples of whole carp (*Cyprinus carpio*, age class V).

<table>
<thead>
<tr>
<th>Station and Date</th>
<th>Sample ID</th>
<th>Trans-Chlordane</th>
<th>Cis-Chlordane</th>
<th>Trans-Nonachlor</th>
<th>Cis-Nonachlor</th>
<th>Oxy-Chlordane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 8S</td>
<td>8WC1</td>
<td>ND</td>
<td>0.70</td>
<td>ND</td>
<td>ND</td>
<td>2.34</td>
</tr>
<tr>
<td>06Jul06</td>
<td>8WC2</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>1.62</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>ND</td>
<td>0.35</td>
<td>ND</td>
<td>1.98</td>
<td>0.30</td>
</tr>
<tr>
<td>Detection limit</td>
<td></td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.009</td>
<td>0.01</td>
</tr>
</tbody>
</table>

ND—Not detected.
subsample from Station 5. Detectable concentrations of dieldrin, DDE, and hexachlorobenzene were seen from a whole fish subsample from Station 9. In 1997, for the first time a catfish fillet sample was submitted to the EPA lab. Detectable concentrations of dieldrin, DDE, technical chlordane, and trans-chlordane were seen in the catfish sample. Previous scans for whole carp in 1988, 1990, and 1992 showed significant levels of dieldrin, DDE, DDD, chlordane, and PCB (1260). Hexachlorobenzene and pentachloroanisole were detected in 1997. Hexachlorobenzene was used as a wood preservative and as a fungicide for treating seeds. Hexachlorobenzene is a carcinogen and was banned from use in the U.S in 1984. Its low water solubility and high BCF indicate a significant potential for bioaccumulation (EXTOXNET). Pentachloroanisole is a degradation product of other chemicals such as pentachlorophenol (PCP) and pentachloronitrobenzene. Pentachlorophenol was used as a biocide and wood preservative. It was one of the most heavily used pesticides in the U.S. Now only certified applicators can apply pentachlorophenol; thus, it no longer appears in household products. It is still used as an industrial wood preservative. Pentachlorophenol is a suspected carcinogen (ASTR 1999).

8.33. Mercury in Fish

8.33.1. Introduction

Fish accumulate mercury in their organs (spleen, kidney, liver) and in their skeletal muscle acts as a reservoir. Ingestion of mercury-laden fish can have health effects in humans as well as predators. Prompted by numerous violations of the previous Class B state standard of 0.05 ug/l mercury in the Des Moines River, a preliminary investigation into the mercury content of several species of fish was conducted in 1984. The mean mercury concentrations ranged from 0.18 ppm in largemouth bass (322 mm) to 0.006 ppm in crappie (184 mm). The preliminary study utilized only one fish from five species (Baumann et al. 1985). This evolved into a monitoring program sponsored by the Corps of Engineers, Rock Island District, in which mercury was quantified in Class III carp (fillets and whole fish) over an eight-year period (1987–1994). Budgetary constraints led the Corps to drop mercury from the constituents measured in fish, which now remain as chlordane, dieldrin, heptachlor epoxide, trifluralin, and chlorpyrifos.

The U.S. Food & Drug Administration and the EPA issued a joint consumer advisory on March 19, 2004, about mercury in fish and shellfish (http://www.epa.gov/waterscience/fishadvice/advice.html). The advice is for women who might become pregnant, women who are pregnant, nursing mothers, and young children. Aside from being issued jointly by two federal
agencies, this advisory is important because it emphasizes the positive benefits of eating fish and gives examples of commonly eaten fish that are low in mercury. In the past, the FDA issued an advisory on consumption of commercially caught fish, while the EPA issued advice on recreationally caught fish. By following these three recommendations for selecting and eating fish or shellfish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury. The advisory also states, “Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but do not consume any other fish during that week.”

Recent data has shown dangerous mercury levels in rain falling on Midwestern cities in Michigan, Minnesota, and Illinois (NWF 1999). In 1996 the National Atmospheric Deposition Program began the Mercury Deposition Network (http://nadp.sws.uiuc.edu/mdn/). Currently 90+ sites nationwide are monitored weekly. The site nearest to the Des Moines River is in southern Minnesota (site MN27—Lamberton, Redwood County, Minnesota). From this site the seven-year (1998–2005) average total mercury concentration was 13.3 ng/l and the average total mercury wet deposition was 8.2 µg/m³ (no data was available for 2002). In 2004, 44 states had issued fish consumption advisories for mercury, and many had specifically identified atmospheric deposition of mercury as the cause of the contamination. In 2004, the EPA and FDA issued advice for women who might become pregnant, nursing mothers, and young children. The intent was to make recommendations to allow consumers to receive the benefits of eating fish while reducing exposure to mercury (EPA-823-F-04-009).


Previous studies of mercury in fish flesh along the Des Moines River Water Quality Network, however, found concentrations were far less than the FDA action level. Fish accumulate mercury in their organs (spleen, kidney, liver), and skeletal muscle acts as a reservoir. Ingestion of mercury-laden fish could have human health effects as well as effects on predators. Prompted by the apparent numerous violations of the state standard for soluble mercury in class B waters, a preliminary investigation into the mercury content of several species of fish from the Des Moines River was conducted during 1984. The mean mercury concentrations ranged from 0.18 ppm in a largemouth bass sample to 0.06 ppm in a crappie sample. The preliminary study utilized only a few fish of five species. Nine times during the period 1984–1994, a portion of the carp fillets
collected for pesticide analysis were reserved for analysis of mercury content. In addition, mercury content was determined in whole fish annually from 1987 to 1994. All results from both the fillet and whole fish samples were well below the FDA’s action level of 1.0 ppm for food fish, the EPA screening value of 3 ppm, and the NAS/NAE guideline for whole fish of 0.5 ppm, which were applicable at the time of the study. The average mercury concentrations in the carp fillets from Stations 4, 5, 8, and 9 ranged from 0.02 ppm to 0.34 ppm, with the highest concentration occurring in Saylorville Reservoir in the spring of 1990 and 1991. Concentrations of mercury in the whole fish samples were consistently less than in the fillet samples, ranging from 40% to 70% of the average fillet concentration. Historically, higher mercury concentrations have been noted in fillet samples, as muscle tissue acts as a reservoir for mercury. The average mercury concentrations in the whole fish samples from 4, 5, 8, and 9 ranged from 0.02 ppm to 0.11 ppm, with the highest concentrations occurring in the spring of 1989.

8.33.3. Recent Data (2004–2005)

Analyses of mercury in fish tissue were dropped from the Scope of Work in 1995; it continues to be recommended that it be reinstated in order to provide more information about current concentrations in fish from the study area. However, in 2004 and 2005 the Iowa DNR agreed to support analyses of mercury content in fish fillets collected below both reservoirs. In 2004, the average total mercury concentrations from fillets of class III common carp in the Des Moines River below Saylorville and Red Rock reservoirs were 0.06 ppm and 0.04 ppm, respectively, and from fillets of class VIII channel catfish (*Ictalurus punctatus*), total mercury concentrations were 0.13 ppm and 0.06 ppm, respectively. In 2005, the average total mercury concentrations from fillets of class III common carp in the Des Moines River below Saylorville and Red Rock reservoirs were 0.04 ppm and 0.05 ppm, respectively, and from fillets of class V largemouth bass (*Micropterus salmoides*), total mercury concentrations were 0.11 ppm below both reservoirs. Data for fish length, weight, condition factors, and percent lipid content of fish collected in 2004 and 2005 are listed in previous annual reports.
8.34. Gas Saturation and Fish Kills

8.34.1. Introduction

In the past, fish kills of varying intensities have occurred at several stations along the sampling route. Generally, most of the reported fish kills occurred at Station 9, downstream from Red Rock Reservoir. Beginning in 1983, the extent of dissolved gas supersaturation and its effect on fish mortality was studied, especially during Tainter gate operation at the dam. Saturometer readings were taken and gas saturations were calculated. Forms for fish-kill reports were developed so that fish-kill events could be better documented. Gas pressure data were calculated as recommended by Colt (1984). These equations are listed in Table 70.

Historical fish-kill data were investigated, divided into events, and listed in the February 1989 annual report. It became obvious that the most extensive fish-kill episode occurred at Station 6 during an extremely low-flow winter (1977) and that the mortalities were due to ammonia toxicity. Despite this rare case, two other kinds of fish kills occurred rather routinely. Kills of only small gizzard shad (*Dorosoma cepedianum*) occurred frequently in the colder months. These fish kills have been reported at all stations except Stations 1 and 10 and were most probably caused by thermal stress. Shad are susceptible to temperature fluctuations in the 4°C to 6°C range and to rapid temperature changes (Chittenden 1972). These thermal stress kills have a rather sudden onset, range in severity from minor to moderate, and may last for several weeks. Other fish kills that occurred only at Station 9 in the late summer or early fall were suspected to be caused by gas-saturation-induced gas bubble trauma. These kills seemed to occur more gradually, were less severe, and were of shorter duration. (Please refer to the March 1985, March 1991, and March 1994 annual reports for a detailed discussion of gas saturation and gas bubble trauma.) Many fish kills observed early in the period of record at Station 9 were probably a result of gas bubble trauma, but because gas saturation measurements were not available and detailed fish-kill records were not kept, the cause of these kills is listed as unknown.

Historical evidence of gas supersaturation and gas bubble trauma has accumulated into basically four areas. First, fish kills from gas bubble trauma did not have a sudden onset and many different species and sizes of fish were affected. Second, visual signs of gas bubble trauma (emphysema [gas blisters] and exophthalmia [pop-eye]) were observed in recently expired fish. Often, these visual indications were not present in dead fish that were discovered after the kill was over, but gas bubbles present in tissues of dead fish or in fish removed from supersaturated conditions do disappear over time.
Equation 1: Total gas pressure (TGP), in percentage of saturation

\[
\text{Total gas pressure (\%)} = \frac{P_{\text{bar}} + P_{\text{sat}}}{P_{\text{bar}}} \times 100
\]

Equation 2: Nitrogen gas pressure (N2P), in percentage of saturation

\[
\text{Nitrogen gas pressure (\%)} = \frac{(P_{\text{bar}} + P_{\text{sat}}) - \left(\frac{[O_2]_m}{\beta} \times 0.532\right) - P_{H_2O}}{(P_{\text{bar}} - P_{H_2O})(0.7902)} \times 100
\]

Equation 3: Oxygen gas pressure (O2P), in percentage of saturation

\[
\text{Oxygen gas pressure (\%)} = \frac{\left(\frac{[O_2]_m}{\beta} \times 0.532\right)}{(P_{\text{bar}} - P_{H_2O})(0.2095)} \times 100
\]

\[\begin{align*}
P_{\text{bar}} & : \text{barometric pressure (mmHg)} \\
P_{\text{H}_2\text{O}} & : \text{water vapor pressure (mmHg)} \\
P_{\text{sat}} & : \text{dissolved gas meter reading (mmHg), equal to } \Delta P \\
[O_2]_m & : \text{dissolved oxygen concentration measured by Winkler method, azide modification (mg/l)} \\
\beta & : \text{Bunsen coefficient of oxygen solubility} \\
0.532 & : \text{a correction factor to change Bunsen coefficient to mg/l} \\
0.7902 & : \text{the fractional composition of nitrogen (plus argon) in air} \\
0.2095 & : \text{the fractional composition of oxygen in air}
\end{align*}\]
Table 70. Continued.

Equation 4a,b,c: Hyperbaric pressure ($\Delta P$) at surface

$$\Delta P('mmHg') = P_{sat}$$

$$\Delta P_{N_2}('mmHg') = (P_{bar} + P_{sat}) - \left( \frac{[O_2]_m}{\beta} \times 0.532 \right) - P_{H_2O} - \left( P_{bar} - P_{H_2O} \right) \times 0.7905$$

$$\Delta P_{O_2}('mmHg') = \left( \frac{[O_2]_m}{\beta} \times 0.532 \right) - \left( P_{bar} - P_{H_2O} \right) \times 0.2095$$

Equation 5a and 5b: Effect of depth (uncompensated data relate pressure and saturation to particular depths, i.e., at the river bottom).

$$\Delta P_{uncmp} = P_{sat} - pgZ$$

$$TGP_{uncmp} = \left( \frac{P_{bar} + P_{sat}}{P_{bar} + pgZ} \right) \times 100$$

where

- $P$ = density of water
- $g$ = acceleration due to gravity, 9.80665 m/s$^2$
- $pg$ is from Table 25 in Colt (1984)
- $Z$ = depth, m
Third, gas saturation values, calculated from regular saturometer readings at Station 9, were taken consistently since May 1984. Of the 562 readings taken over 23 years, only one indicated an undersaturated condition, whereas 401 readings (or 71%) exceeded the EPA criterion of 110%. Overall, the average total gas, nitrogen gas, and oxygen gas pressures were 115%, 117%, and 109% of saturation, respectively, and the uncompensated total gas pressure at the maximum depth averaged 97% of saturation.

Since 1983, 29 fish kills have been attributed to gas bubble trauma at Station 9 below Red Rock Dam. Of these, 28 fish-kill episodes occurred when gas pressure data was collected. The majority occurred when total gas saturation was 120% or greater and river depth was shallow. Seven of the other episodes occurred when the river flow had either been drastically reduced over a short period of time or significantly reduced for dam maintenance work. One fish kill occurred as the N₂:O₂ ratio increased to the maximum 1.4. Another fish kill was prompted by extreme flows and high total gas pressure.

Fourth, data have been evaluated as hyperbaric pressures. Hyperbaric pressure (ΔP) is the difference between the cavitation pressure (sum of the dissolved gas pressures) and the compensation pressure (sum of the barometric and hydrostatic pressures). Theoretically, gas bubble trauma can occur only when the cavitation pressures are greater than the compensation pressures or, in other words, when the hyperbaric pressure is positive. Saturometer readings taken near the surface indicate hyperbaric pressure. Also, uncompensated hyperbaric pressures (ΔP_{uncmp}) were calculated at the maximum depth. Thus, hyperbaric pressures that organisms would be subject to would vary between these levels, depending on the location of the organism. During the 28 fish-kill episodes since 1983 where gas data is available, the uncompensated hyperbaric pressure calculated for the maximum depth averaged 46.5 mmHg and was significantly positive in 21 cases (75%). Often, fish-kill events seemed to be triggered by rapid changes in release flows from the dam rather than from excessive hyperbaric pressures. Most fish-kill events occurred during lower release and shallower river depth, with the most severe kills occurring after rapid decreases in outflow rate (see Lutz 1995). Average hyperbaric pressures ΔP, ΔPN₂, and ΔPO₂ for the period of record were 112 mmHg, 98 mmHg, and 14 mmHg, respectively, and the uncompensated hyperbaric pressure (ΔP_{uncmp}) at the maximum depth averaged -36 mmHg. During the 28 fish-kill events, the average hyperbaric pressures ΔP, ΔPN₂, and ΔPO₂ were 140 mmHg, 118 mmHg, and 22 mmHg, respectively, and the uncompensated hyperbaric pressure (ΔP_{uncmp}) at the maximum depth averaged 46 mmHg.
8.34.2. Gas Pressure Data for the Period of Record

This section summarizes the data records for gas pressure at four locations (Station 1 above Saylorville Reservoir, Station 5 below Saylorville Dam, Station 8S in Red Rock Reservoir, and Station 9 below Red Rock Dam). These data allow comparisons of recent trends in total gas pressure data with historical data (see Table 71).

**Upstream from Saylorville Dam (Station 1)**

Readings were taken on five occasions in 1993 upstream from Saylorville Reservoir at Station 1 (and once at Station 0 when the reservoir reached 870 ft NGVD). This location was selected to represent gas pressure in the Des Moines River without the influence of a major dam. There are low head dams at Fort Dodge and Boone, which may influence gas pressure under low flow conditions. During the five observations at Station 1, the total gas pressure was stable near 100% saturation. There was some minor variation, however, in constituent gas pressures. Nitrogen gas pressure averaged 102% of saturation, ranging from 100% to 106%. Oxygen gas pressure averaged 92% of saturation, ranging from 76% to 101%. The time of these observations was about 9:00 a.m., which would explain the lower dissolved oxygen levels, since dissolved oxygen levels are lowest in the early morning hours because of respiration throughout the night under the lack of photosynthetic production of oxygen.

**Downstream from Saylorville Dam (Station 5)**

Since November 1989, 369 gas pressure readings have been taken at this location. The averages of total gas pressure, nitrogen gas pressure, and oxygen gas pressure were 109% of saturation, 111% of saturation, and 102% of saturation, respectively. The average hyperbaric pressure ($\Delta P$) was 67 mmHg. Forty percent (149 of 369) of total gas pressure readings below Saylorville Reservoir exceeded the EPA criterion of 110%. There have been three minor fish kills that are being attributed to acute gas bubble trauma. These occurred on July 16, 1991, September 15, 1993, and May 25, 1999. Only freshwater drum (*Aplodinotus grunniens*) succumbed during these fish-kill events. There was evidence from deceased fish of external and internal signs of gas bubble trauma. The first fish kill appears to have been prompted by rapidly decreasing river flows, and the second and third fish kills appear to have been prompted by excessive total gas pressure.
Table 71. Summary of gas pressure data at Stations 1, 5, 8S, and 9 for the period of record.

<table>
<thead>
<tr>
<th>Station number</th>
<th>1</th>
<th>5</th>
<th>8S</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of observations</td>
<td>5(^a)</td>
<td>369(^b)</td>
<td>285(^c)</td>
<td>562(^d)</td>
</tr>
<tr>
<td>Approximate time (CST/CDT)</td>
<td>900</td>
<td>1030</td>
<td>1500</td>
<td>1530</td>
</tr>
<tr>
<td>No. of samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGP(^e) ≥110%</td>
<td>0</td>
<td>149</td>
<td>50</td>
<td>401</td>
</tr>
<tr>
<td>TGP ≥115%</td>
<td>0</td>
<td>90</td>
<td>20</td>
<td>290</td>
</tr>
<tr>
<td>TGP ≥120%</td>
<td>0</td>
<td>21</td>
<td>7</td>
<td>149</td>
</tr>
<tr>
<td>TGP(_{\text{uncmp}}) ≥100%</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>219</td>
</tr>
<tr>
<td>O(_2)P ≥125%</td>
<td>0</td>
<td>3</td>
<td>56</td>
<td>86</td>
</tr>
<tr>
<td>N(_2)P ≥125%</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>108</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGP (%)</td>
<td>100</td>
<td>109</td>
<td>104</td>
<td>115</td>
</tr>
<tr>
<td>N(_2)P (%)</td>
<td>118</td>
<td>111</td>
<td>104</td>
<td>117</td>
</tr>
<tr>
<td>O(_2)P (%)</td>
<td>92</td>
<td>102</td>
<td>106</td>
<td>109</td>
</tr>
<tr>
<td>TGP(_{\text{uncmp}}) (%)</td>
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<td>TGP (%)</td>
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<td>98–123</td>
<td>88–132</td>
<td>99–134</td>
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<td>O(_2)P (%)</td>
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<td>57–134</td>
<td>46–382</td>
<td>68–185</td>
</tr>
<tr>
<td>TGP(_{\text{uncmp}}) (%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>73–120</td>
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</tbody>
</table>

\(^a\) In 1993 only.
\(^b\) Since November 1989.
\(^c\) Since April 1988.
\(^d\) Since August 1983.
\(^e\) TGP: total gas pressure, %.
\(^f\) TGP\(_{\text{uncmp}}\): total gas pressure, %, at the river bottom.
\(^g\) O\(_2\)P: oxygen gas pressure, %.
\(^h\) N\(_2\)P: nitrogen gas pressure, %.
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<tr>
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<td>369(^b)</td>
<td>285(^c)</td>
<td>562(^d)</td>
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<td>1530</td>
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<tr>
<td>Hyperbaric Pressure (mm Hg)</td>
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<td></td>
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</tr>
<tr>
<td>(\Delta P)</td>
<td>-2</td>
<td>67</td>
<td>30</td>
<td>112</td>
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<tr>
<td>(\Delta P_{N_2})</td>
<td>13</td>
<td>63</td>
<td>-</td>
<td>98</td>
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<tr>
<td>(\Delta P_{O_2})</td>
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<td>4</td>
<td>-</td>
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</tr>
<tr>
<td>(\Delta P_{uncmp})</td>
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<td>-</td>
<td>-</td>
<td>-36</td>
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<td>-11–171</td>
<td>-88–241</td>
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<td>-6–220</td>
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<td>(pp_{O_2})</td>
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<td>547–964</td>
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<td>(pp_{O_2})</td>
<td>117–151</td>
<td>-</td>
<td>-</td>
<td>102–274</td>
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<tr>
<td>Ratio (N_2:O_2)</td>
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<td>2.2–7.3</td>
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<td>Flow (ft³/s)</td>
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<td>186–42,100</td>
<td>-</td>
<td>298–99,300</td>
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</table>

\(^i\Delta P\): hyperbaric pressure, mmHg.

\(^j\Delta P_{N_2}\): excess nitrogen gas pressure, mmHg.

\(^k\Delta P_{O_2}\): excess oxygen gas pressure, mmHg.

\(^l\Delta P_{uncmp}\): hyperbaric pressure, mmHg, at the river bottom.

\(^m\)Ratio \(N_2:O_2\): ratio of partial pressures of nitrogen to oxygen gas.
Table 71. Continued.

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<tr>
<th>Station number</th>
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<th>8S</th>
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<td>369&lt;sup&gt;b&lt;/sup&gt;</td>
<td>285&lt;sup&gt;c&lt;/sup&gt;</td>
<td>562&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>1500</td>
<td>1530</td>
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<td>River Depth (m)</td>
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<td></td>
<td></td>
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<td>–</td>
<td>–</td>
<td>2.0</td>
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<td>range</td>
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<td>–</td>
<td>–</td>
<td>0.5–5.0</td>
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<tr>
<td>Compensation depth&lt;sup&gt;o&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>mean</td>
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<td></td>
<td></td>
<td>1.5</td>
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<td>range</td>
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<td></td>
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<td>Fish Kills (since September 1983)</td>
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<td>No. observed&lt;sup&gt;p&lt;/sup&gt;</td>
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<td>17</td>
<td>5</td>
<td>41</td>
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<td>thermal stress</td>
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<td>14</td>
<td>1</td>
<td>10</td>
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<tr>
<td>GBT&lt;sup&gt;q&lt;/sup&gt;</td>
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<td>3</td>
<td>0</td>
<td>29</td>
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<tr>
<td>unknown</td>
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<td>0</td>
<td>4</td>
<td>2</td>
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</tbody>
</table>

<sup>n</sup>Maximum depth: maximum depth of river, m.
<sup>o</sup>Compensation depth: depth required to reach a gas pressure equal to air-equilibrated water.
<sup>p</sup>Since August 1983, at all locations.
<sup>q</sup>GBT: gas bubble trauma.

Note: EPA criterion for total gas pressure is 110% saturation or 76 mmHg as ∆P.
Note: Water in equilibrium with air has a nitrogen to oxygen gas partial pressure ratio of 3.77.
At Red Rock Reservoir in the Main Basin (Station 8S)

Gas pressure data collection began at this location in April 1988 in an attempt to verify that elevated gas pressures downstream from the dam were an artifact of the dam itself. From 285 readings at this location, the averages of total gas pressure and nitrogen gas pressure were both 104% of saturation, while oxygen gas pressure was 106% of saturation. The greatest variance was seen in oxygen gas pressure as a result of algal production and utilization of oxygen (ranging from 46% of saturation to 382% of saturation). Interestingly, nitrogen gas pressure was also elevated at times at this location (ranging from 62% of saturation to 127% of saturation). Denitrification of nitrogen compounds to nitrogen gas may account for this excess gas as elevated nitrogen gas pressures were often accompanied by increases in ammonia nitrogen in the hypolimnion.

Below Red Rock Dam (Station 9)

The gas pressure data record for the location below Red Rock Dam was updated to include 562 gas pressure readings. Surveillance of total gas pressure below Red Rock Dam began in August 1983. The occurrence of elevated total gas pressure below Red Rock Dam has been addressed in many other project reports; thus, only a brief summary of the period of record statistics will appear here (see Table 72). The averages of total gas pressure, nitrogen gas pressure, and oxygen gas pressure were 115% of saturation, 117% of saturation, and 109% of saturation, respectively. The maximum total gas pressure (134% of saturation) was seen on August 24, 1993. Seventy-one percent of total gas pressure readings below Red Rock Reservoir (401 of 562) exceeded the EPA criterion of 110%. The average hyperbaric pressure (ΔP) was 112 mmHg. The averages of the uncompensated (at the river bottom) gas pressure (TGPuncmp) and uncompensated hyperbaric pressure (ΔPuncmp) were 97% and -36 mmHg, respectively. The average compensation depth (the calculated depth where the total gas pressure would equal 100% saturation) was 1.5 meters, which would require a flow of about 2,850 ft³/s. The average outflow for the period was 8,575 ft³/s. Of 559 calculated uncompensated total gas pressures during the period, 219 (or 39%) exceeded 100%, meaning that the river water on these occasions was supersaturated down to the river bottom. On 72 occasions (13%) the total gas pressure exceeded 110% at the bottom, and on 23 occasions (4%) the total gas pressure exceeded 115% at the bottom. There have been 41 fish kills documented since 1983 at this location (of minor to major
Table 72. Summary of gas pressure data (as percent saturation) at Station 9 for 1985–2006 water years, calculated according to Colt (1984).

<table>
<thead>
<tr>
<th>Water Year (October-September)</th>
<th>1985</th>
<th>1986</th>
<th>1987</th>
<th>1988</th>
<th>1989</th>
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<td>44</td>
<td>23</td>
<td>26</td>
<td>32</td>
<td>22</td>
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<tr>
<td>TGP ≥ 115%</td>
<td>28</td>
<td>12</td>
<td>19</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td>TGP ≥ 120%</td>
<td>11</td>
<td>1</td>
<td>10</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>O₂P ≥ 125%</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>N₂P ≥ 125%</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGP (%)</td>
<td>116</td>
<td>112</td>
<td>116</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>N₂P (%)</td>
<td>118</td>
<td>116</td>
<td>119</td>
<td>120</td>
<td>121</td>
</tr>
<tr>
<td>O₂P (%)</td>
<td>111</td>
<td>98</td>
<td>106</td>
<td>122</td>
<td>118</td>
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<tr>
<td>Range</td>
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<td></td>
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<tr>
<td>TGP (%)</td>
<td>103–126</td>
<td>99–120</td>
<td>105–126</td>
<td>104–126</td>
<td>112–126</td>
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<tr>
<td>O₂P (%)</td>
<td>82–133</td>
<td>72–117</td>
<td>79–130</td>
<td>83–185</td>
<td>86–141</td>
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<tr>
<td>N₂P/O₂P</td>
<td>0.9–1.3</td>
<td>0.9–1.6</td>
<td>0.8–1.5</td>
<td>0.6–1.3</td>
<td>0.8–1.4</td>
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<td>Ave. flow (ft³/s)</td>
<td>3,898</td>
<td>10,583</td>
<td>7,844</td>
<td>1,995</td>
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<tr>
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<tr>
<td>Thermal stress</td>
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<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>GBTd</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
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</table>

\( ^a \)TGP: total gas pressure, %.  
\( ^b \)O₂P: oxygen gas pressure, %.  
\( ^c \)N₂P: nitrogen gas pressure, %.  
\( ^d \)Gas bubble trauma.
<table>
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<tr>
<th></th>
<th>Water Year (October-September)</th>
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<td>1</td>
<td>8</td>
<td>21</td>
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<td>18</td>
<td>8</td>
<td>0</td>
<td>5</td>
<td>18</td>
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<tr>
<td>TGP ≥ 120%</td>
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<td>0</td>
<td>4</td>
<td>13</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<tr>
<td>N₂P ≥ 125%</td>
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<td>0</td>
<td>4</td>
<td>9</td>
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<td>97</td>
<td>101</td>
<td>100</td>
<td>108</td>
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<td>71–130</td>
<td>74–118</td>
<td>82–114</td>
<td>85–133</td>
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<td>0.8–1.7</td>
<td>0.9–1.3</td>
<td>0.9–1.4</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Cause</td>
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<td>GBT d</td>
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Table 72. Continued.

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<td>68–137</td>
<td>79–146</td>
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<td>0.8–1.7</td>
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<td>Thermal</td>
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<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>GBTd</td>
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<td>3</td>
<td>0</td>
<td>1</td>
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<td>------</td>
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<td>22</td>
<td>22</td>
<td>22</td>
</tr>
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<td>20</td>
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<td>16</td>
<td>15</td>
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<td>0</td>
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<td>3</td>
<td>7</td>
<td>5</td>
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</tr>
<tr>
<td>O2P≥125%</td>
<td>2</td>
<td>10</td>
<td>5</td>
<td>9</td>
</tr>
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<td>3</td>
<td>4</td>
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</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGP (%)</td>
<td>116</td>
<td>118</td>
<td>114</td>
<td>106</td>
</tr>
<tr>
<td>N2P (%)</td>
<td>119</td>
<td>118</td>
<td>116</td>
<td>104</td>
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<tr>
<td>O2P (%)</td>
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<td>117</td>
<td>107</td>
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<td>102–130</td>
<td>104–126</td>
<td>104–108</td>
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<td>98–113</td>
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<td>84–133</td>
<td>83–130</td>
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</tr>
<tr>
<td>N2P/O2P</td>
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<td>0.9–1.4</td>
<td>0.8–1.5</td>
<td>0.7–1.3</td>
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<tr>
<td>Ave. flow (ft³/s)</td>
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</tr>
<tr>
<td>Cause</td>
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<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GBTd</td>
<td>4</td>
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Table 72. Continued.

<table>
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<tr>
<th></th>
<th>Water Year (October-September)</th>
<th>2003</th>
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<th>2006</th>
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<td>TGP ≥ 110%</td>
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<td>18</td>
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<td>TGP ≥ 115%</td>
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<td>12</td>
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<td>5</td>
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<td>N2P ≥ 125%</td>
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<td>0</td>
<td>3</td>
<td>12</td>
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<tr>
<td>Mean</td>
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<td></td>
<td></td>
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<td>TGP (%)</td>
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<td></td>
</tr>
<tr>
<td>TGP (%)</td>
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<td>103–112</td>
<td>108–128</td>
<td>102–131</td>
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<tr>
<td>N2P (%)</td>
<td></td>
<td>96–113</td>
<td>103–114</td>
<td>104–132</td>
<td>104–136</td>
</tr>
<tr>
<td>O2P (%)</td>
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<td>86–138</td>
<td>76–134</td>
<td>100–137</td>
<td>96–132</td>
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<td>0.7–1.3</td>
<td>0.9–1.5</td>
<td>0.8–1.2</td>
<td>0.8–1.3</td>
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<tr>
<td>Ave. flow (ft³/s)</td>
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<td>6,381</td>
<td>7,973</td>
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<td>5,285</td>
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<td>Fish kills</td>
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</tr>
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<td>No. observed</td>
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</tr>
<tr>
<td>GBTd</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
severity and affecting many different species), 29 of which can be attributed to acute gas bubble trauma.

Table 72 summarizes gas saturation data at Station 9 for the 22 water-year periods for which readings have been taken. From this table, during the 2006 water year the total gas saturation at Station 9 exceeded the 110% EPA criterion 20 times. The greatest average total gas pressure (121% of saturation) was seen during the 2006 water year.

8.3.4.3. Recent Gas Pressure Results

During this contract period, saturometer readings were continued at Station 5 below Saylorville Dam, at Station 8S in the main basin of Red Rock Reservoir, and at Station 9 below Red Rock Dam. Saturometer readings were taken with a Common Sensing gas meter at the reservoir location (Station 8S) and with a Weiss saturometer below the reservoirs (Stations 5 and 9). Results from Stations 5, 8S, and 9 for the contract period are listed in Appendix A. A summary of the long-term data as monthly means is in Appendix B.

At Station 5, downstream from Saylorville Reservoir, gas pressure during this contract period was higher, although gas pressure was even higher at Station 9 below Red Rock Reservoir. Average total gas pressures at Stations 5 and 9 were 110% saturation and 123% saturation, respectively. Total gas pressure at Station 5 ranged from 101% to 118% of saturation, while the total gas pressure at Station 9 ranged from 109% to 131% saturation. Nitrogen gas pressure at Station 9 averaged 126% of saturation, ranging from 113% to 136%, and oxygen gas pressure averaged 114% of saturation, ranging from 87% to 134%. At Station 5, the average nitrogen gas pressure was 112% of saturation, ranging from 104% to 121%, and oxygen gas pressure averaged 104% of saturation, ranging from 79% to 123%.

Total gas pressure in the main basin area of Red Rock Reservoir (Station 8S) was slightly higher than last year. During this contract period, 5 of the 18 samples (28%) exceeded 110% total gas saturation, while 3 of 18 samples (17%) exceeded this value last period. The maximum total gas saturation seen this period at Station 8S was 114% on July 17, 2006, which was similar to the maximum seen last period. Overall, 50 of 285 values (17%) at Station 8S have exceeded the EPA criterion of 110% since monitoring began in April 1988. The greater gas pressures due to algal production of oxygen at this location probably have a lesser adverse affect on aquatic organisms because of the temporal nature of this gas production.

A review of historical data presented in Appendix B showed that new monthly maximum total gas saturation values were set at Station 5 in October 2005 and January and February 2006.
At Station 9 below Red Rock Reservoir, a new monthly minimum was set in October 2005 and new monthly maximum values were established in March and September 2006. At Station 5 below Saylorville Reservoir, 4 of 16 annual means for the period 1990–2006 exceeded 110% total gas saturation. At Station 9 below Red Rock Reservoir, 19 of 23 annual means for the period 1984–2006 exceeded 110% total gas saturation.

8.35. Trophic State Indices (TSIs)

Water quality indices are a way of ranking or classifying waters according to a numerical scale used to compare variables with one another or with some reference number. In the last section, a general water quality index was described that ranked overall water quality. This section will discuss Trophic State Indices and their values along the Des Moines River Water Quality Network. The concept of trophic status is based on the fact that changes in nutrient levels (measured by total phosphorus) cause changes in algal biomass (measured by chlorophyll $a$), which in turn causes changes in lake clarity (measured by Secchi disk transparency). A TSI is a convenient way to quantify this relationship (EPA 2007). The index used was developed by Dr. Robert Carlson of Kent State University. Basically, the lower the TSI the less algal biomass and nutrients in the system and the greater the transparency.

Carlson’s index uses a log transformation of Secchi disk values as a measure of algal biomass on a scale from 0 to 110. Each increase of ten units on the scale represents a doubling of algal biomass. Because chlorophyll $a$ and total phosphorus are usually closely correlated to Secchi disk depths, these parameters can also be assigned TSI values. Chlorophyll pigments double every seven units. The Carlson TSI is useful for comparing lakes within a region and for assessing changes in trophic status over time. Be aware, however, that the Carlson TSI was developed for use with lakes that have few rooted aquatic plants and little non-algal turbidity. Ranges of TSI values are often grouped into trophic state classifications. Index values less than 40 are associated with oligotrophy (low productivity); between 40 and 50, mesotrophy (moderate productivity); greater than 50, eutrophy (high productivity); and between 70 and 80, hypereutrophy (extreme productivity). Carlson urges that if data for chlorophyll and phosphorus are available, chlorophyll be used as the primary index for trophic state classification. The deviations of the Secchi depth and total phosphorus indices from the chlorophyll index can be used to infer additional information about the functioning of the lake. These three TSI values should not be averaged. Besides classification of lakes, the interrelationships between TSI values,
as seen in plots of seasonal trends in the three TSI, can be used to identify conditions that limit algal biomass or affect TSI variables (Carlson 2007).

- **TSI(Chl) = TSI(TP) = TSI(SD)**  
  Algae dominate light attenuation; TN/TP ~ 33:1

- **TSI(TP) = TSI(SD) > TSI(CHL)**  
  Non-algal particulates or color dominate light attenuation

- **TSI(Chl) > TSI(SD)**  
  Large particulates, such as *Aphanizomenon* flakes, dominate

- **TSI(SD) = TSI(CHL) > TSI(TP)**  
  Phosphorus limits algal biomass (TN/TP >33:1)

- **TSI(TP) > TSI(CHL) = TSI(SD)**  
  Algae dominate light attenuation but some factor, such as nitrogen limitation, zooplankton grazing, or toxics, limit algal biomass

In Iowa TSIs are calculated for publicly owned lakes and are included in the Iowa Lakes Information System ([http://limnology.eeob.iastate.edu/lakereport/](http://limnology.eeob.iastate.edu/lakereport/)). TSI data have been used in Iowa to set goals for TMDLs to mitigate impaired waters. For example, the nutrient target for the TMDL for Lake Darling is to reduce the trophic state below hypereutrophic, as evidenced by TSI values below 70 (IDNR 2002). Data presented here are meant to be a way to compare Corps reservoirs with lakes in the region. For clarification, DMRWQN TSI use chlorophyll *a*, which has not been corrected for pheophytin, and total phosphorus as P in µg/l. The formulas for calculating the Carlson TSI values for Secchi disk, chlorophyll *a*, and total phosphorus are presented along
with calculated index values for the period of record in Table 73. Included in Appendix A are the individual TSI values for this year and associated plots.

8.35.1. TSI (Chlorophyll)

From summarizing long-term TSI values from main basin sites at Saylorville and Red Rock reservoirs (Stations 4S and 8S), it is apparent that the primary TSI (chlorophyll) values are similar at both reservoirs with a slightly higher median at Saylorville Reservoir but a slightly wider range at Red Rock Reservoir. The long-term median TSI (chlorophyll) values at Stations 4S and 8S were 61 (range 37–85) and 58 (range 31–86), respectively. For the mid-May to mid-September 2006 period, the median TSI (chlorophyll) values at Stations 4S and 8S were 67 (range 52–73) and 67 (range 41–81), respectively. There was one unusually high (greater than the 95% of long-term data of 71) TSI (chlorophyll) value of 73 at Saylorville Reservoir on July 10, 2006. There were three unusually high TSI (chlorophyll) values at Red Rock Reservoir, 75 on June 26, 81 on July 10, and 74 on July 17. There was one unusually low (lesser than the 10% of long-term data of 45) TSI (chlorophyll) value of 41 at Red Rock Reservoir on June 12, 2006. At Station 8S the monthly mean TSI (chlorophyll) value for July 2006 set a new period-of-record maximum, while the September 2006 monthly mean set a new period-of-record minimum (see Appendix B).

8.35.2. TSI (Phosphorus)

Long-term TSI values from main basin sites at Saylorville and Red Rock reservoirs (Stations 4S and 8S) show that the TSI (phosphorus) values are much higher at Red Rock Reservoir, with both the minimum and maximum TSI (phosphorus) values being about 20 points higher. The long-term median TSI (phosphorus) values at Stations 4S and 8S were 73 (range 31–93) and 80 (range 53–114), respectively. For the mid-May to mid-September 2006 period, the median TSI (phosphorus) values at Stations 4S and 8S were 69 (range 47–73) and 73 (range 65–85), respectively. The 2006 median TSI (phosphorus) value at Red Rock Reservoir was significantly lower than the long-term median. At Saylorville and Red Rock reservoirs, respectively, 5 of 18 and 8 of 18 TSI (phosphorus) values calculated in 2006 were unusually low (less than the 10% of long-term data). At Station 4S the monthly mean TSI (phosphorus) values for May and July 2006 set new period-of-record minimums, and at Station 8S the monthly means for March and May 2006 set new period-of-record minimums (see Appendix B).
Table 73. Summary of Trophic State Indices (TSI) at Stations 4S and 8S for the period of record.

<table>
<thead>
<tr>
<th>Station ID</th>
<th>4S Saylorville Reservoir</th>
<th>8S Red Rock Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TSI (Chlorophyll a)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time period</td>
<td>06Nov79–05Dec06</td>
<td>03Oct78–05Dec06</td>
</tr>
<tr>
<td># of observations</td>
<td>445</td>
<td>477</td>
</tr>
<tr>
<td>Mean</td>
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<td>57</td>
</tr>
<tr>
<td>Range</td>
<td>37–85</td>
<td>31–86</td>
</tr>
<tr>
<td>Median</td>
<td>61</td>
<td>58</td>
</tr>
<tr>
<td>25% percentile</td>
<td>57</td>
<td>51</td>
</tr>
<tr>
<td>75% percentile</td>
<td>67</td>
<td>65</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>7.3</td>
<td>10.7</td>
</tr>
</tbody>
</table>

| **TSI (Phosphorus)** | | |
| Time period | 29Jun77–05Dec06 | 01Aug74–05Dec06 |
| # of observations | 347 | 422 |
| Mean | 73 | 80 |
| Range | 31–93 | 53–114 |
| Median | 73 | 80 |
| 25% percentile | 69 | 76 |
| 75% percentile | 79 | 84 |
| Standard deviation | 7.4 | 7.3 |

| **TSI (Secchi)** | | |
| Time period | 04Nov80–05Dec06 | 04Nov80–05Dec06 |
| # of observations | 508 | 493 |
| Mean | 65 | 67 |
| Range | 48–93 | 37–101 |
| Median | 64 | 69 |
| 25% percentile | 61 | 63 |
| 75% percentile | 69 | 74 |
| Standard deviation | 6.4 | 8.8 |

\[ a \text{TSI (Chlorophyll } a) = 9.81 \times \ln(\text{Chlorophyll } a, \mu\text{g/l}) + 30.6 \]
\[ b \text{TSI (Phosphorus)} = 14.42 \times \ln(\text{Total Phosphorus, } \mu\text{g/l}) + 4.15 \]
\[ c \text{TSI (Secchi)} = 60 - 14.41 \times \ln(\text{Secchi, m}) \]
8.35.3. TSI (Secchi)

At Saylorville and Red Rock reservoirs (Stations 4S and 8S), long-term TSI values from main basin sites make it apparent that the TSI (Secchi) values are somewhat greater at Red Rock Reservoir with a much wider range. The long-term median TSI (Secchi) values at Stations 4S and 8S were 64 (range 48–93) and 69 (range 37–101), respectively. However, for the mid-May to mid-September 2006 period the median TSI (Secchi) value at Station 4S (64) was greater than at Station 8S (60). The 2006 median TSI (Secchi) value at Red Rock Reservoir was significantly lower than the long-term median. At Red Rock Reservoir, 5 of 18 TSI (Secchi) values calculated in 2006 were unusually low (less than the 10% of long-term data). The 2006 water year mean TSI (Secchi) value at Red Rock Reservoir set a new period-of-record minimum, although no new monthly mean records were set (see Appendix B).

8.35.4. TSI Deviations

Generally, the three TSIs tracked more closely at Saylorville Reservoir, when compared to Red Rock Reservoir. At Saylorville Reservoir (Station 4S) the greatest difference was in the TSI (phosphorus) value on May 22, which had dropped 24 points in one week and was 20 points below the TSI (chlorophyll) value. Two weeks later a similar drop was seen in TSI (chlorophyll). At Red Rock Reservoir (Station 8S) there were two significant decreases in TSI (chlorophyll) value; a 21-point drop between May 5 and 12, and a 23-point drop between August 7 and August 14, 2006.

8.36. Water Quality Index

A water quality index was derived by Chantill Kahler-Royer as documented in her master’s thesis entitled “A water quality index devised for the Des Moines River in central Iowa” (Kahler-Royer 1999). The Des Moines River Water Quality Index (DMRWQI) was based on the National Sanitation Foundation’s Water Quality Index (NSFWQI). This index is intended to give the general public a better idea of the state of the water quality in the DMRWQN. The DMRWQI examines dissolved oxygen saturation, pH, biochemical oxygen demand, nitrate and nitrite nitrogen, un-ionized ammonia nitrogen, turbidity, and suspended solids for sampling stations along the Des Moines and Raccoon rivers and on Saylorville and Red Rock reservoirs. Rating curves are used to rank parameter values, and these rankings are aggregated into an index score
for each station each day sampling occurred. Index ratings from 91 to 100 indicate excellent water quality; ratings 71 to 90 are good; ratings 51 to 70 are fair; ratings 26 to 50 are bad; and ratings 0 to 25 are considered very bad water quality. The derivation of the index and the rating curves and historical water quality index values are found in Appendix C of the 1999 Annual Report and at http://www.kahler-rover.com/Chan/thesis/.

The state of Iowa used the NSFWQI to calculate indices of stream sites from 2000 to 2005, with 81% of streams having a WQI in the medium category, while the remaining 19% were in the good category (IDNR 2005, Water Quality Index: Iowa, http://wqm.igsb.uiowa.edu/wqi/wqi.asp). A new index for Iowa was developed by Katherine Foreman, University of Iowa graduate student, based on the Oregon WQI using geographically specific parameters (Foreman 2005, IDNR 2006). Foreman’s WQI differs from the NSFWQI and DMRWQI by including dissolved solids and pesticides data. Also, the index uses an unweighted harmonic square mean method for subindex aggregation, which was shown to reduce eclipsing and ambiguity problems in index calculations, whereas the NSFWQI and DMRWQI use weighted means employing significance ratings from professional judgment.

Historically, water quality index values from this project were calculated for each monitoring event at the riverine sites. DMRWQI values were not able to be determined at the reservoir sites, as the analysis of BOD was not supported at these sites. However, since 2000 Iowa State University has supported BOD analyses at the surface reservoir sites. Historically, water quality index values ranged from 45 to 94 at sites along the Des Moines River and from 43 to 92 at Station 10 on the Raccoon River. The lowest water quality indices were normally seen in January, February, and March, while the highest water quality indices were generally seen in the fall. The greatest average index values were seen below the reservoirs, indicating an overall positive effect on water quality.

During this contract period, water quality indices at Stations 1 and 7, above Saylorville and Red Rock reservoirs, averaged 74 and 71, respectively, while the average water quality indices at Stations 5 and 9, below Saylorville and Red Rock dams, averaged 78 and 76, respectively. The average water quality index at Station 10 on the Raccoon River was 71. For the sixth year, water quality indices were able to be calculated for samples collected from the surface at the reservoir sites. This contract period, the average water quality indices at Stations 4S and 8S were 75 and 74, respectively, ranging from 67 to 82 at Saylorville Reservoir and 63 to 84 at Red Rock Reservoir.

Long-term data are compiled in Appendix B. An examination of historical monthly index values indicates that new monthly maximum values were set at Station 9
in December 2005, Station 10 in January and July 2006, and at Stations 5 and 6 in August 2006. At the Des Moines River sites 1, 5, 6, 7, and 9, water quality indices for the 2006 water year averaged 75.4 or 105% of the long-term normal of 71.8. At the Raccoon River site, water quality indices for the 2006 water year averaged 72.5 or 104% of the long-term normal of 69.8.
9. ACKNOWLEDGMENT

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Others who contributed significantly to the success of this work include Mr. David Schoeller and Ms. Kendra Lee, chemists for the laboratory who were responsible for the analyses of the chemical, physical, and microbiological water quality parameters, and the additional members of the lab staff—Ms. Margaret Melcher and Mr. Joshua O’Toole—who helped perform the analyses. Mr. Joshua Klesel is additionally thanked for advice on computer-networking aspects of this project.

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Also, the Iowa Department of Natural Resources Water Quality Bureau (in particular Mr. John Olson) is acknowledged for providing information exchange. In addition, staff of Iowa’s Ambient Water Monitoring Program (especially Dr. Mary Skopec) and Iowa Hygiene Laboratory (in particular Dr. Nancy Hall) are also thanked.

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U.S. EPA Region VII. *Standard Operating Procedure 7221FOO Determination of Organics in Fish.* Kansas City, Kansas.


11. RELATED PUBLICATIONS

The following is a list of publications and theses developed with the support of this study.

**Journal Articles (by Project Personnel)**


**Journal Articles (by Others Using DMRWQN Data)**


http://jeq.scijournals.org/cgi/content/full/32/6/2280
Theses


**Annual Reports**

http://www.cce.iastate.edu/research/lutz/dmrwqn/annual.htm

http://www.cce.iastate.edu/research/lutz/dmrwqn/annual.htm

http://www.cce.iastate.edu/research/lutz/dmrwqn/annual.htm

http://www.cce.iastate.edu/research/lutz/dmrwqn/annual.htm


**Conference Proceedings**


http://www.cce.iastate.edu/research/lutz/dmrwqn/basins/index.htm

http://www.cce.iastate.edu/research/lutz/dmrwqn/update/index.htm


**Undergraduate Student Papers**

Jessick, Ashley. 2005. What goes down must come up: A closer look at phosphorus’ impact on reservoir sediment at Lake Red Rock. (PWSE summer intern)

Woolley, Dana. 2003. Phosphorus in reservoir sediment. (PWSE summer intern)

Rau, Katherine. 2001. Comparison of two water quality indices. (PWSE summer intern)


Fastenow, Dianne. 1996. Long-term nitrate trends in water quality. (PWSE summer intern)

Eckert, Damon. 1995. Changes in total ammonia loading in the Des Moines River from sewage treatment plant effluent due to plant updates.

Opheim, Jen. 1995. The waiting game with chlordane. (PWSE summer intern)


1

12. DISTRIBUTION

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|               | U.S. Army Corps of Engineers |
| 2             | 2. Sherri Richardson-Duey  
|               | Park Manager  
|               | Red Rock Lake |
| 2             | 3. Stephen Fairbanks  
|               | Park Manager  
|               | Saylorville Lake |
| 1             | 4. John Olson  
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|               | Iowa Department of Natural Resources |
| 2             | 5. Parks Library, Acquisitions  
|               | Iowa State University |
| 1             | 6. Library, Acquisitions  
|               | University of Iowa |

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|         | Manager  
|         | Des Moines Water Works |
| 1       | 8. Roger Link  
|         | Natural Resources Conservation Service |
| 1       | 9. Doug Goodrich  
|         | USGS, Iowa City |
| 1       | 10. Department of Civil, Construction and Environmental Engineering  
|         | Iowa State University |
| 1       | 11. Manager  
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APPENDIX A: TABLES AND PLOTS FOR CONTRACT PERIOD

(On the CD version, tables for Appendix A appear separately from text)
APPENDIX A: TABLES AND PLOTS FOR CONTRACT PERIOD

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<td>Chlorophyll $c$</td>
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<td>Fecal Coliform</td>
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<tr>
<td><em>Escherichia coli</em></td>
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<td>Total Gas Saturation</td>
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<td>Nitrogen Gas Saturation</td>
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<tr>
<td>$\Delta P$</td>
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<td>$\Delta$ Oxygen Gas</td>
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<tr>
<td>Barometric Pressure</td>
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<tr>
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</table>
APPENDIX B: LONG-TERM MONTHLY MEAN DATA 1967–2006

(On the CD version, tables appear separately from text)
APPENDIX B: LONG-TERM MONTHLY MEAN DATA 1967–2006

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Total Hardness 478
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<td>Chlorophyll $a$ (corrected)</td>
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<td>TSI (Phosphorus)</td>
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<td>599</td>
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<tr>
<td>Water Quality Index</td>
<td>602</td>
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</tbody>
</table>
B.1. Introduction

In an effort to put current water quality data into an historical perspective, long-term data from the Des Moines River water quality network have been summarized into monthly mean (arithmetic average) data for most parameters. The monthly mean data are compiled in tables in this appendix. The data were also compiled into a separate database. This database is used to perform statistical analyses of the long-term data. Previous attempts at trend analysis have been hampered by the large amounts of raw data and by the fluctuating frequency of samplings per month. These problems are partially alleviated by using monthly mean data.

B.2. Monthly Mean Data

The historical period of record (until September 2006) for selected parameters was statistically summarized into tables using the Water Database Program I (md.exe). Water Database Program II (md2.exe) compiled this data into a database compatible with our regular Paradox database (Isudata.db). The database thus created was named the Monthly Means Database (datamonthly.db). This database allows greater ease of data use in statistical computer packages. Tables that compile the monthly mean data follow in the next section.

Please remember that the data are from monthly averages and that the frequency of samples per month has changed over time. Until 1981 samples were collected weekly; after this time, there was a reduction in the frequency of samples collected in the non-recreational months. Please refer to Table 5 in the main section of the annual report for the frequency of samplings per contract period. In addition, the period of record may vary between stations. Please refer to Table 7 in the main section of the annual report for length of records at particular stations. Occasionally, monthly means were estimated in order to avoid gaps in the database. If only one or two months of data were missing, the missing monthly mean was estimated. Doing this allowed calculation of annual means for years where only a few data were missing. Estimated data are noted with an “e” in the tables.

These monthly mean data tables are most helpful in identifying normal conditions during a particular month. They can also be used to compare conditions at different stations. Exceedences of long-term minimum and maximum monthly means were noted
in the discussion of each parameter in the main document and are presented here in Table B1. Similarly, long-term annual means established are listed in Table B2.

For the 2006 water year, from the 16 parameters listed in Table C1, 38 new monthly minimum concentrations and 33 new monthly maximum concentrations were set. The previous water year, from the same parameters, 17 new monthly minimum concentrations and 9 new monthly maximum concentrations were set, versus the 2004 water year when 20 new monthly minimum concentrations and 9 new monthly maximum concentrations were set. The 2006 water year was characterized by minimum monthly records being set for turbidity, suspended solids, total phosphate, fecal coliform bacteria, and water quality indices; and maximum monthly records being set in water temperature, pH, nitrite plus nitrate nitrogen, chlorophyll, and total gas pressure.

In the 2006 water year, there was one new minimum annual mean set for suspended solids (Station 6), two minimum annual means set for turbidity (Stations 1 and 10), and three minimum annual means set for total phosphate (Stations 5, 6, and 9). In the 2005 water year, two new minimum or maximum annual means were established, in 2004 no new records were established, whereas in the 2003 water year, seven new minimum annual means and three new maximum annual means were established.
Table B1. Minimum and maximum record monthly means established in the long-term database during the 2006 water year.

<table>
<thead>
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<th>Parameter</th>
<th>St. 1</th>
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<td>(1) Min</td>
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<td>(1) Min</td>
<td></td>
<td>(1) Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T. hardness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1) Max</td>
</tr>
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<td>(1) Min</td>
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<td>(2) Min</td>
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<tr>
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<td>(2) Max</td>
<td>(1) Max</td>
<td>(1) Max</td>
<td>(1) Max</td>
</tr>
<tr>
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<td>(2) Min</td>
<td>(2) Min</td>
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<td>(1) Max</td>
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<td>(2) Min</td>
<td>(1) Min</td>
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<td>---</td>
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<td>(2) Max</td>
<td>(1) Max</td>
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<td>(1) Max</td>
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</table>

Numbers in parentheses indicate the number of months that records were set.
Blank cells indicate data was collected, but no record concentrations were set.
<sup>a</sup> May–September only.
<sup>b</sup> June–August only.
Table B2. Minimum and maximum record annual means established in the long-term database during the 2006 water year.

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<td>NO₂ + NO₃ N</td>
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Blank cells indicate data was collected, but no record concentrations were set.