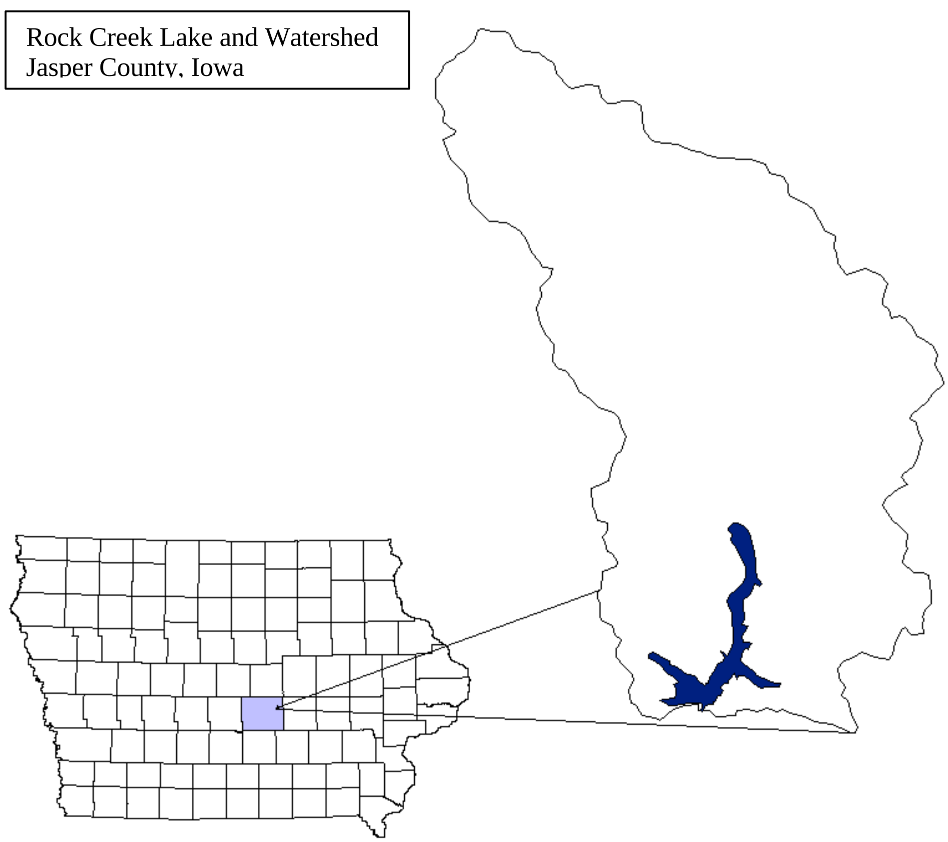
Total Maximum Daily Load
For Siltation and Nutrients
Rock Creek Lake
Jasper County, Iowa

December 13, 2001

Iowa Department of Natural Resources
Water Resources Section

TMDL for Siltation and Nutrients
Rock Creek Lake
Jasper County, Iowa

Waterbody Name:	Rock Creek Lake
IDNR Waterbody ID:	IA 03-NSK-00340-L
Hydrologic Unit Code:	HUC11 10280102050
Location:	Sec. 18, T67N, R25W
Latitude:	41 Deg. 45 Min. N
Longitude:	92 Deg. 50 Min W
Use Designation Class:	A (primary contact recreation) B(LW) (aquatic life) C (potable water source)
Watershed Area:	26,719 acres
Lake Area:	491 acres
Major River Basin:	North Skunk
Tributaries:	Rock Creek
Receiving Water Body:	Rock Creek - North Skunk River
Pollutant:	Siltation and Nutrients
Pollutant Sources:	Agricultural Runoff
Impaired Use	Aquatic Life
1998 303d Priority:	High



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1. Introduction

The Federal Clean Water Act requires the Iowa Department of Natural Resources (DNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. The purpose of these sediment and nutrient TMDLs for Rock Creek Lake is to calculate the maximum amount of sediment and nutrients that the lake can receive and still meet water quality standards, and then develop an allocation of that amount of sediment and nutrients to the sources in the watershed.

Specifically these sediment and nutrient TMDLs for Rock Creek Lake will:

- Identify the adverse impact that sediment and nutrients are having on the designated use of the lake and how the excess load of sediment and nutrients are violating the water quality standards,
- Identify a target by which the waterbody can be assured to achieve its designated uses,
- Calculate acceptable sediment and nutrient loads, including a margin of safety, and allocate to the sources, and
- Present a brief implementation plan to offer guidance to Department staff, DNR partners, and watershed stakeholders in an effort to achieve the goals of the TMDL and restore the lake to its intended use.

Iowa DNR believes that sufficient evidence and information is available to begin the process of restoring Rock Creek Lake. The Department acknowledges, however, that to fully restore Rock Creek Lake additional information will likely be necessary. Therefore, in order to accomplish the goals of this TMDL, a phased approach will be used. By approaching the restoration process in phases, feedback from future assessment can be incorporated into the plan.

Phase I of the sediment and nutrient TMDLs for Rock Creek Lake will address the first target associated with achieving a reduction in the sediment and nutrient loads associated with the aquatic life impairment. Phase II will evaluate the effect that the sediment and nutrient load targets have on the intended results. Included in Phase II will be monitoring for results, reevaluating the extent of the sediment and nutrient impairment, and evaluating if the specific aquatic life impairment originally identified in the TMDL has been remedied. Ultimately, the intent of this TMDL is not to set in stone arbitrary targets, but restore the aquatic life uses that have been impaired. The phased approach allows DNR to utilize a feedback loop to determine if the initial sediment and nutrient load targets have been effective.

2. Waterbody and Watershed

2.1 General Information

Rock Creek Lake was built in 1952 by the Iowa Conservation Commission as an impoundment
Creek which discharges into the North Skunk River below Kellogg, Iowa. The lake is

The surface area of the lake is 491 acres and the volume is 3,704 acre-feet when the water

7.5 feet and a maximum depth of 19.8 feet. The estimated hydraulic residence time is 64.5

Creek.

The 492-acre lake and 1,697-acre park are managed by the IDNR, and 100% of the lake's 9 mile shoreline is in public ownership. Lake planning began in 1947, with land acquisition starting in 1950 and continuing through 1970. The park was dedicated in 1952, and the lake was stocked with game fish in 1952 and 1953.

The park contains approximately 7 miles of blacktopped perimeter road providing excellent access to the lake at several points. The park also contains a swimming beach, 9 picnic areas, 198 camping sites, 5 boat ramps, concessions and boat rental.

There are a number of lakes available for recreation in this part of Iowa, yet Rock Creek is used extensively for water-based outdoor recreation. Estimates of lake use were reported by Bachmann et al. (1994) in A Classification of Iowa's Lakes for Restoration. These estimates were made by IDNR district fisheries biologists, and are based on a combination of existing reports and professional judgment. From these data, it is apparent that Rock Creek State Park is used extensively for camping and picnicking forms of recreation. Camping and picnicking account for over 50% of the use of Rock Creek State Park, while multiple types of fishing account for another 30%.

Table 1. Itemized summary of 1991-1992 recreational activities at Rock Creek State Park, from Bachmann et al. (1994). Data reflect estimates made by IDNR district fisheries biologists, and were based on a combination of existing reports and professional judgment.

Activity	**Total Visits**	**Use/Acre**	**% of Total Use**
Fishing- boats	19,776	32.8	9
Fishing- Shore or ice	49,782	82.7	22
Swimming	21,341	35.4	10
Pleasure boating	9,625	16.0	4
Hunting	5,585	9.3	3
Picnicking, camping other activities prompted by the lake's presence	115,558	192.0	52
Snowmobiling	694	1.2	<1
Ice-skating and cross-country skiing	191	0.3	<1
Total	222,552	369.7	100

Table 2. Total visits, camping activities, and intensity of recreational activities at Rock Creek State Park, 1993-1998 (ISU, 2000).

Year	**Total Visits**	**Visits/Acre**
1993	365,000	215.1
1994	391,000	230.4
1995	436,000	256.9
1996	534,000	314.7
1997	552,000	325.3
1998	520,000	306.4

The Rock Creek Lake watershed has an area of 26,719 acres and a watershed to lake ratio of 54:1. The watershed is drained by Rock Creek and its many tributaries. The landuses of the Rock Creek Lake watershed are shown in Table 3. The majority (>87%) of the watershed is used for agricultural purposes with greater than 58% of the watershed in row crop agricultural production.

Table 3. 1998 Landuse in the Rock Creek Lake Watershed (Downing, 2000).

Land Use	**Total Acres**	**Percent of Watershed Area**
Corn	9,695	36
Pasture	6,303	23
Soybeans	6,006	22
Park	1,697	6
Hay	1,097	4
Forest	781	3
Lake	491	2
Grass & Grass Waterways	458	2
Roads (Paved, Gravel, Dirt)	383	1
Farmsteads	380	1
Residential Areas	121	1
Ponds	95	>1
Oats	19	>1
Cemetery	3	>1

Records from NRCS offices, aerial photography and field surveys were used to determine the landuse within the drainage basin of Rock Creek Lake. The majority of the watershed is in row crops (corn and soybeans), with over 58% of the area in this landuse. Nearly 30% of the basin is in permanent herbaceous vegetation (pasture, grass, grassed waterways, hay), while 3% is in timber. The remainder of the watershed is in other uses such as farmsteads, ponds, residential areas, and roads.

The topography of the watershed ranges from nearly level to steeply sloping with slopes from 0 to 25 percent. Prairie-derived soils and forest-derived soils in this area were developed from loess or pre-Wisconsin till. Over 55 percent of the soils in the watershed are loess-based, while 25 percent were derived from glacial till. The major soil associations in the watershed are Tama-Killduff-Muscatine and Downs-Tama-Shelby. The most common soil series in the watershed are Tama (28 %), Shelby (15 %) and Ackmore (13 %).

The soils in the watershed generally have a moderate infiltration rate when thoroughly wet. These soils consist chiefly of moderately deep or deep, moderately well drained or well-drained soils that have moderately fine texture to moderately coarse texture. They have a moderate rate of water transmission.

2.2 Current Watershed Conditions

The Rock Creek Lake Watershed Project was initiated in 1998 due to elevated public concern about the water quality of Rock Creek Lake. The project is funded by grant funds from the Iowa Department of Land Stewardship, Division of Soil Conservation, Water Protection Funds and

EPA Section 319 grant funds from the Iowa DNR. Long-term project goals stress decreasing sediment and phosphorous delivery to Rock Creek Lake.

Since 1998, The Rock Creek Lake Watershed Project has facilitated the installment of best management practices in the watershed. These practices include terraces, grassed waterways, livestock exclusion, grade stabilization structures and water and sediment control basins. Other best management practices in place in the watershed include contour farming and strip cropping. In addition, approximately 3,343 acres are enrolled in the Conservation Reserve Program (CRP), and 115 acres enrolled in continuous CRP.

Current sediment and nutrient delivery to Rock Creek Lake based on 1998-99 monitoring data is 34.6 tons of phosphorous and 25,155 tons of sediment (Table 30, Downing, 2000).

2.3 Watershed Modeling

The Agricultural Non-Point-Source Pollution Model (AGNPS), which estimates runoff, sediment and nutrient transport from agricultural watersheds for specified rainfall events, was run on the Rock Creek Lake watershed as part of the diagnostic/feasibility study (Downing, 2000).

The AGNPS model was applied to Rock Creek Lake watershed using present landuse and management practices. Two storm events to simulate the typical rain event-driven loading seen in Iowa watersheds were modeled using AGNPS. One event was a 2-inch, 24-hour storm, which climatic records show to occur at least once annually. The other event was a 4-inch, 24-hour storm, which should have a 20-year return period for this area.

The results from modeling nutrient and sediment loss under current conditions seem to accurately reflect field observations. Model calibration was made possible by comparing the results of the simulated 2-inch rain event with data collected from an autosampler and flow-meter placed in the watershed. The model predicted that under present watershed conditions, for example, that a 2-inch rain event would yield 6.4 tons of soluble nitrogen, 6.1 tons of total phosphorus, 3,547 tons of sediment, and 18.6 million ft^3 of water passing through sampling site 14. A 2-inch storm event occurred in the watershed on June 18 and 19, 1998. Samples collected by the autosampler and flowmeter indicate that during this event 6.5 tons of soluble nitrogen, 3.1 tons of total phosphorus, 1,888 tons of suspended solids, and 23.7 million ft^3 of water passed through this point. These results indicate that AGNPS model output comes close to accurately predicting soluble nutrient transport and water movement in the watershed. Sediment transport and total suspended solids loading are somewhat similar to each other, and field observations indicate that massive sediment deposition is occurring in stream channels. The model may have difficulty estimating temporary sediment deposition in stream channels, which could explain why these two estimates of sediment loading are dissimilar. Additionally, 89% of phosphorus transported in the model is attached to sediment particles. Thus, stream channel deposition may also explain the difference in total phosphorus loading estimates. In spite of some discrepancy between the model and measurements, the model can be used as an index of the types of changes we might expect from landuse manipulation as well as a means of identifying parts of the watershed particularly prone to release of nutrients and sediments.

3. Applicable Water Quality Standards

The Iowa Water Quality Standards (Iowa, 1996) list the designated uses for Rock Creek Lake as Primary Contact Recreation (Class A), Aquatic Life (Class B(LW)) and Class C (potable water source). Rock Creek Lake also has general uses of secondary contact recreation, agricultural uses, domestic uses, and livestock watering. The Class A use was erroneously assessed in the 1998 305(b) report as not supporting swimmable uses. There is no data to support this assessment. In addition, the Class A and C designated uses were listed in the 2000 305(b) report as not assessed, based on a lack of monitoring data for indicator bacteria and other water quality parameters. The Class B designated uses are assessed as "partially supporting" due to siltation and nutrients primarily from agricultural nonpoint sources in both the 1998 and 2000 305(b) reports.

The State of Iowa does not have numeric water quality criteria for siltation or nutrients that apply to Rock Creek Lake. Rock Creek Lake was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. The 1998 and 2000 Iowa 305(b) reports assess the Class B(LW) uses of Rock Creek Lake as "partially supporting" due to siltation and nutrients primarily from agricultural nonpoint sources. The impacts of excess sediments and nutrients are impairing the Class B(LW) designated use by altering the physical and chemical characteristics of the lake so that a balanced community normally associated with lake-like conditions is not maintained (IAC 567-61.3(1)b(7)). The altering of the physical and chemical characteristics are causing impairments to the aquatic habitat necessary for successful spawning and reproduction. Rock Creek Lake has lost 102 surface acres since 1973 as a result of excess sediment delivered to the lake and settling out in the upper areas of the lake.

A large carp population is partly responsible for the decline of the fishery at Rock Creek Lake. The carp population thrives in the shallow water areas created by the delivery of excess sediment to the lake, and are at least partly responsible for destruction of largemouth bass and bluegill nests, and consequently the survival of these species.

In addition to problems with the fishery of Rock Creek Lake, a summerkill of mussels occurred in July 1998, and again in July and August 1999. An excess of nutrients is suspected to contribute to algae blooms in Rock Creek Lake. When the algae blooms die-off, dissolved oxygen levels in the deeper parts of the lake crash to less than 1 mg/L, resulting in a hypoxic condition. Fish probably selectively avoid these areas of low dissolved oxygen, but mussel populations evidently cannot escape these areas of low dissolved oxygen, and therefore succumb to hypoxia. Local park officials and residents indicate that this is an annual event.

4. Water Quality Conditions

4.1 Water Quality Studies

Water quality studies have been completed on Rock Creek Lake by the U.S. EPA for the National Eutrophication Survey (1974-75), by Iowa State University (ISU) for the lake classification survey (Bachmann, et al., 1980, Bachmann et al., 1994), by ISU for the Rock Creek Lake Diagnostic / Feasability study (Downing, 2000), and by ISU for the 2000 lakes survey (Downing and Ramstack, 2001).

Rock Creek Lake was one of fifteen Iowa lakes and reservoirs studied in the National Eutrophication Survey performed by U.S. EPA in 1974-1975. This survey indicated that Rock Creek Lake was eutrophic, based on a combination of the following parameters: total phosphorus, dissolved ortho-phosphorus, inorganic nitrogen, Secchi disk measured water clarity, chlorophyll a, and dissolved oxygen. A summary of this data is shown in Table 4. This survey ranked Rock Creek Lake eighth out of fifteen lakes on a least to most eutrophic gradient according to measured in-lake parameters. Nutrient loading to Rock Creek Lake by Rock Creek, minor tributaries, and direct precipitation was estimated to be 9 tons phosphorous per year and 101 tons nitrogen per year. Nutrient retention was 7.4 tons of phosphorous and 24.3 tons of nitrogen.

From data collected in Iowa's 1979 lake classification survey (Bachmann et al., 1980), Rock Creek Lake was classified as a eutrophic lake. A summary of this data is in Table 4. Winter and summer fishkills were estimated to be rare. A water quality index was calculated for the 106 Iowa lakes sampled in the 1979 lake classification study based upon Secchi disk depth, total phosphorus concentration, algal chlorophyll concentration, total suspended solids, and winter fishkill frequency. The index for Rock Creek Lake ranked it as the sixth poorest water quality index in all lakes in the survey. Rock Creek Lake's major problem was deemed to be nonpoint source pollution from soil erosion and agricultural chemicals. This was suggested to be due to high soil erosion rates for soils in the watershed, 75.2% of the watershed under row crop production, and a low percentage of the watershed in approved soil conservation practices.

From data collected for Iowa's 1994 lake classification survey (Bachmann et al., 1994), Rock Creek Lake was classified as a eutrophic lake. A summary of this data is provided in Table 4. Winter and summer fishkills were estimated to be rare.

A diagnostic/feasibility study was conducted at Rock Creek Lake March 1998 to June 1999 (Downing, 2000). Monitoring was conducted at one station in the deepest point in Rock Creek Lake, at the highway F27 bridge where the marsh flows into Rock Creek Lake, and at 13 locations along tributaries in the watershed. This data showed an average in lake phosphorous concentration of 163 µg/L and average tributary concentrations of 300 µg/L in Rock Creek, 400 µg/L in the West tributary, and µg/L in the East tributary.

Table 4. Total Phosphorous, Total Nitrogen and Secchi disk Depth values for Rock Creek Lake.

Year	Total Phosphorus (µg/L)			Total Nitrogen (mg/L)			Secchi Depth (m)		
	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
1974	62	60	63	1.3	0.3	2.3	0.6	0.3	0.9
1979	119			1.0 *	1.0	1.0	0.5	0.5	0.6
1990	167	98	227	7.5	7.4	7.7	0.5	0.4	0.5
1998	210	42	410	4.9	1.3	9.7	0.9	0.3	1.6
2000	74	31	120	2.2	1.5	2.8	1.2	0.8	2.1

* total Kjeldahl nitrogen

Table 5. Data from the Rock Creek Lake Diagnostic/Feasibility Study, collected in 1998-99 (Downing, 2000).

	Phosphorous Concentration (µg/L)	Total Suspended Solids (mg/L)
Rock Creek Lake	163	130
Rock Creek (north tributary)	300	90
West tributary	400	130
East tributary	500	200

Current sediment and nutrient delivery to Rock Creek Lake based on 1998-99 monitoring data is 34.6 tons of phosphorous, 110.5 tons of nitrogen, and 25,155 tons of sediment (Table 30, Downing, 2000).

The Iowa Lakes Survey 2000 collected data three times during the summer of 2000 (Downing and Ramstack, 2001). The average total phosphorous, total nitrogen, and Secchi depth are shown in Table 4.

Rock Creek Lake is a typical corn-belt reservoir, being dominated by watershed processes due to the very high ratio of watershed to lake area (54:1). Each cubic meter of the lake is fed by a watershed area of 20 m2. This leads to high silt and nutrient loads, and the dynamics of the watershed mean that the lake structure and limnology change rapidly over the course of the season.

4.2 Bathymetric Surveys

Bathymetric surveys (mapping of lake bottom) of Rock Creek Lake were conducted in November 1998 (Downing, 2000), and also in 1959-1960 and 1973. Sediment deposition in the main body of Rock Creek Lake from 1959 to 1998 can be determined by subtracting the 1998 depth map from the 1959 depth map. The change in depth between the two years is the result of sediment deposition. Between 1959 and 1998, 1,680 ac-ft of lake volume was filled with sediment, while 1,280 ac-ft was lost between 1973 and 1998. This indicates an annual sediment deposition of 50 ac-ft into Rock Creek Lake between 1973 and 1998. Assuming this average is accurate and the trajectory of sediment deposition into the lake has been linear over the life of the lake, then 2,460 ac-ft of sediment has been deposited in Rock Creek Lake. Thus, the lake's original volume would have been 6,170ac-ft and the present volume represents a 40% reduction of the original lake volume. It is expected that sediment deposition rates will decrease with time, as trap efficiency of the reservoir declines. However, assuming constant rates of sediment delivery and deposition in the future, Rock Creek Lake would completely fill with sediment in 72 years, but would become unusable as a lake in a much shorter time-period.

Sediment deposition has resulted in the loss of 102 acres of lake surface area since 1973. 82 acres of these 102 were from the part of the lake north of the Highway F27 bridge. Considering that annual sediment deposition has been 50 ac-ft/yr, and the surface area of the lake is 492 ac, the lake has been losing 1.25 in/yr of depth if this sediment were evenly distributed. This sediment has a density of 1440 kg/m3, which when multiplied by annual sediment deposition rate gives a result of 100,000 tons/yr of sediment added to the lake. Thus, the Rock Creek watershed has lost 4 tons/acre/yr of sediment on average. During the course of the diagnostic/feasibility study, tributary monitoring showed the sediment transport to the lake to be somewhat more than 25,000 tons/yr, which equates to 1 ton/acre/yr. Because these sediment loss flux rates are less than the overall average sediment accumulation rate, it seems that the rates measured during 1998-1999 are lower than those over the lifetime of the lake. The decrease in watershed sediment loss rates may result from climatic variability and improved agricultural conservation practices implemented throughout the watershed.

4.3 Angling

The fishery of Rock Creek Lake provided some good fishing opportunities during the 1950's and 1960's, but began to show declines in both the quantity and quality of the fishery during the 1970's. Several factors were believed to contribute to the decline. A large carp population had become established in the lake, and was at least partly responsible for destruction of largemouth bass and bluegill nests, and consequently survival of these species. The carp population thrives in the shallow water areas created by the delivery of excess sediment to the lake. In 1979, Bachmann, et al. (1980) ranked Rock Creek Lake third worst of 91 lakes surveyed in non-point pollution problems. The high siltation rates in the watershed, estimated at 16–28 tons/ac/year, impacted the water quality and fishery in the lake.

By the early 1980's, the fishery had deteriorated to a point where total renovation was considered the best option for the fishery. However, benefits from the total renovation were considered to be relatively short-term (10-12 years) due to on-going watershed problems. Population densities, age-growth parameters and general well-being of the fish indicated the overall fishery in Rock Creek Lake during 1999 was in good condition, although carp populations are still strong.

4.4 Lake Modeling

As part of the diagnostic/feasibility study, a mass balance lake loading model (Reckhow's EUTROMOD) was used to determine necessary reductions in sediment and nutrient loading to the lake (Appendix). The diagnostic study determined that the average phosphorous concentration in tributaries to Rock Creek Lake (exclusive of very large, sediment laden storm events) is about 410 µg/L, the hydraulic residence time of the lake is 0.18 years, and the mean depth is 2.3 m. This yields a predicted current phosphorous concentration in the water column of 280 µg/L, which is within the range of open-water concentrations actually observed.

5. Desired Target

The listing of Rock Creek Lake is based on narrative criteria. There are no numeric criteria for siltation or nutrients applicable to Rock Creek Lake or its sources in Chapter 61 of the Iowa Water Quality Standards (Iowa, 1996). The Environmental Protection Agency is requiring all states to adopt or show significant progress towards adopting nutrient criteria by 2004. This will include water quality standards for nitrogen, phosphorous, and chlorophyll-a. Since numeric criteria for these parameters do not currently exist, appropriate targets need to be determined. The targets need to address both sediment and nutrient loads to the lake as well as a measurement of the aquatic life within the lake. This is a phased TMDL and each phase will incorporate a separate target. Phase I targets are for sediment and nutrient delivery to the lake, and the Phase II target will address the fishery of the lake.

According to the diagnostic/feasibility study, reductions in phosphorous and sediment loading can be calculated that would bring the lake close to a reasonable level of 100 µg/L of phosphorus (Downing, 2000). EUTROMOD was used to determine necessary reductions in sediment and nutrient loading to the lake (Appendix). Using these data, reductions in phosphorous and sediment loading can be calculated that would bring the lake close to a reasonable level of 100 µg/L of phosphorus. Such an improvement would require a reduction in phosphorous and sediment loads of about 70% from current rates to 10.4 tons of phosphorous per year, and 7,547 tons of sediment per year (reduced average tributary concentration of phosphorous from 410 µg/L to 123 µg/L). This should extend the life expectancy of the lake by a factor of about 3-fold. Current sediment and nutrient delivery to Rock Creek Lake based on 1998-99 monitoring data is 34.6 tons of phosphorous and 25,155 tons of sediment (Table 30, Downing, 2000).

The Phase I nutrient target for Rock Creek Lake as represented in the diagnostic/feasibility study (Downing, 2000) is an in-lake phosphorous concentration of 100 µg/L. The sediment target for Rock Creek Lake is sediment delivery rate of 7,547 tons/year. This is a reasonable first estimate to accomplish a reduction in sediment and nutrients to slow the degradation of the lake and restore aquatic life. In addition, a reduction in total phosphorous from 210 µg/L in 1998 to 100 µg/L would indicate a shift from hypereutrophy to eutrophy.

The Phase II target for this TMDL will be achieved when the fishery of Rock Creek Lake is determined to be fully supporting the Class B aquatic life uses. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This protocol is currently being used to develop benchmarks for the fishery of Iowa's lakes. The results from the Rock Creek Lake assessment will be compared with the benchmarks being developed. These assessments will include age, growth, size structure, body condition, relative abundance, and species.

Rock Creek Lake will not be considered restored until the Phase II target is achieved. If the aquatic life target is achieved prior to the sediment and nutrient delivery target, then the level of land practices may be maintained at a level at or above those in place at the time of the assessment. If however, after a reasonable time following the completion of the sediment and nutrient delivery practices the aquatic life has not been restored, then further study and practices may be necessary.

6. Loading Capacity

The State of Iowa does not have numeric water quality criteria for siltation and nutrients that apply to Rock Creek Lake. Rock Creek Lake was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. Excess sediment is impairing the Class B(LW) designated use by altering the physical and chemical characteristics of the lake so that a balanced community normally associated with lake-like conditions is not maintained (IAC 567-61.3(1)b(7)). A general reduction in sediment and nutrient delivery to the lake is needed to restore the aquatic life uses.

According to the diagnostic/feasibility study, reductions in phosphorous and sediment loading can be calculated that would bring the lake close to a reasonable level of 100 µg/L of phosphorus (Downing, 2000). A mass balance lake loading model (Reckhow's EUTROMOD) was used to determine necessary reductions in sediment and nutrient loading to the lake that would bring the lake close to a reasonable level of 100 µg/L of phosphorus. Such an improvement would require a reduction in phosphorous and sediment loads of about 70% from current rates, and result in a loading capacity of 10.4 tons of phosphorous per year, and 7,547 tons of sediment per year.

7. Pollution Sources

There are no permitted point source discharges in the Rock Creek Lake watershed. In addition, there are presently no permitted livestock facilities in the watershed. Water quality in Rock Creek Lake is influenced only by nonpoint sources.

There are residential areas in the watershed and sewage treatment lagoons at the state park that could be sources of nutrients to the lake. The Jasper County Sanitarian indicates that plans are in place for a rural sanitary sewer that would provide service to all residential areas around the lake, as well as the state park. This service, if participated in by local residents, could reduce potential nitrogen and phosphorus loading to the lake.

AGNPS modeling was completed on Rock Creek Lake using present landuse and management practices as part of the diagnostic study (Downing, 2000). This modeling of the Rock Creek Lake watershed was able to locate areas of the watershed with higher delivery rates of sediment and nutrients. These results showed high levels of phosphorous coming from subwatersheds dominated by pasture, and streambank and streambed erosion significantly contributing phosphorous and sediment.

Shoreline stabilization is necessary around many parts of Rock Creek Lake. During surveys of the lake, ISU Limnology Laboratory personnel noted many areas of active erosion along the lakeshore. Iowa Department of Natural Resources (IDNR) personnel measured lengths of shoreline where active erosion is taking place, and found that over 20,500 ft of shoreline were in need of stabilization. Of this 20,500 ft, nearly 200 ft are in need of immediate restoration, due to the high rates of shoreline erosion in this area.

8. Pollutant Allocation

8.1 Point Sources: There are no point discharges within the Rock Creek Lake watershed. Therefore, the Wasteload Allocation established under this TMDL is zero.

8.2 Non-Point Sources: The non-point source discharges are originating from sheet and rill, gully and streambank, and shoreline erosion. The majority of the watershed is used for agriculture production, either row crop, hay, or pasture. According to the Rock Creek Lake diagnostic/feasibility study, the majority of the erosion is originating from sheet and rill and streambank erosion. The Load Allocation set by this TMDL is 10.4 tons of phosphorous and 7,547 tons of sediment delivered to the lake each year.

8.3 Margin of Safety:

The margin of safety for this TMDL is implicit. The separate endpoints for sediment, nutrients and aquatic life for this TMDL assures that that the aquatic life uses will be restored regardless of the accuracy of the sediment delivery or nutrient endpoints. Failure to restore the designated aquatic life use will result in review of the TMDL, allocations, and/or sediment management approaches and probable revision.

9. Seasonal Variation

This TMDL accounts for seasonal variation by recognizing that (1) sediment and nutrient loading varies substantially by season and between years, and (2) sediment and nutrient impacts are felt over multi-year timeframes. The loading and transport of sediment and nutrients are predictable only over long timeframes. Moreover, in contrast to pollutants which cause short-term beneficial use impacts and are thus sensitive to seasonal variation and critical conditions, the sediment and nutrient impacts in this watershed occur over much longer time scales. For these reasons, the longer time frames (pounds or tons per year) used in this TMDL is appropriate.

10. Monitoring

Additional monitoring will be completed at Rock Creek Lake as part of the Iowa Lakes Survey 2000. In-lake water monitoring will be completed three times per year for each of the field seasons 2000 – 2004. In addition, the DNR Fisheries Bureau will conduct an assessment of the fishery of Rock Creek Lake in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). At the completion of this assessment, the data will be evaluated to determine the listing status of Rock Creek Lake.

11. Implementation

11.1 General Information

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy to DNR staff, partners, and watershed stakeholders as a guide to improving water quality at Rock Creek Lake.

This TMDL is being designed as a Phased TMDL. In Phase I, the amount of sediment and nutrients delivered to the lake will be reduced so that the TMDL is met. In-lake restoration and an assessment of the fishery will be completed during Phase II.

Phase I of the TMDL will be accomplished by reducing the amount of sediment and nutrients delivered to Rock Creek Lake from the watershed. The Rock Creek Lake Watershed Project was initiated in 1998 due to elevated public concern about the water quality of Rock Creek Lake. The project is funded by grant funds from the Iowa Department of Land Stewardship, Division of Soil Conservation, Water Protection Funds and EPA Section 319 grant funds from the Iowa DNR. Long-term project goals stress decreasing sediment and phosphorous delivery to Rock Creek Lake.

Field observations conducted by ISU Limnology Laboratory staff and the Rock Creek watershed Project Coordinator for the Rock Creek Lake Diagnostic/Feasibility Study (Downing, 2000) indicate that grass waterway maintenance, streambank stabilization, pasture management, and lake shoreline stabilization are major needs in the watershed.

A principle objective of the feasibility study (Downing, 2000) was to provide the greatest protection to the lake at the least cost. A well-known watershed model and GIS (Geographic Information Systems) was applied to identify areas in the watershed that are currently supplying the highest rates of sediment and nutrient delivery. The AGNPS model was used to simulate sediment and nutrient transport following rain events in the Rock Creek Lake watershed and to analyze the affect of changes in the watershed on sediment and nutrient delivery to the lake. The Rock Creek Lake Watershed Project is using the results of this modeling to help prioritize areas within the watershed for best management practices to achieve maximum benefit to water quality of the lake.

11.2 Land Conversion

Through the use of model simulations, it was found that strategically placing 544 acres of cropland with high erosion and delivery potential into permanent vegetation could reduce sediment transport to the lake by 15%. This minor landuse change could also reduce phosphorus transport to the lake by 11%. This would be a significant reduction, while impacting only a small amount of land. The locations of these selected cropland acres are outlined in the diagnostic/feasibility study. In addition, producers in the watershed should be encouraged and assisted in determining the risk of phosphorous movement from their fields by use of the P-Index developed by Iowa State University, the National Soil Tilth Lab, and NRCS, and adopted by NRCS in Technical Notice #25.

GIS and AGNPS also demonstrate large potential reductions in sediment loss and nutrient flux through riparian management. Riparian buffer strips could be installed along stream channels in the watershed. Using the AGNPS model, landuse was changed from present conditions to permanent vegetation along all stream corridors. Installation of 25 m (82 ft.) wide buffers would impact 1,407 acres, but not all of this land is in row crop production. This simulated change, when combined with idling highly erosive cropland, could potentially reduce sediment transport to the lake by 30% and phosphorus transport by 22%. In an Illinois study (Roseboom and White, 1990), 40-60% of the sediment yield from the watershed was the result of channel and streambank erosion. Streambank erosion is an observed problem in the Rock Creek Lake watershed, so riparian buffer zones and streambank stabilization efforts might reduce sediment and phosphorus transport by even more than the modeling efforts predict. Additionally, 20 m (66 ft) wide buffers are commonly installed throughout Iowa, and would provide nearly equivalent protection to the streams. The location of streams targeted for riparian zone buffer installations is shown in the diagnostic/feasibility study.

11.3 Sediment Basins

Small impoundments are well known to immobilize significant amounts of sediments and nutrients in agricultural watersheds. AGNPS and GIS was used to predict the impact of the installation of small nutrient retention ponds in critical areas throughout the watershed. Fifty-eight ideal impoundment sites were located and added to the landscape in areas where they could be easily installed (near stream-road intersections) and where they could intercept high concentrations of sediment and phosphorus (upland row crop areas). By placing a pond in the landscape in the path of moving water, approximately 90% of the sediment and sediment-related nutrients are efficiently removed from channel flow. The results from modeling this change combined with the two alternatives listed earlier produced a 58% reduction in predicted sediment loading to the lake and a 53% reduction in predicted phosphorus loading.

The diagnostic study indicated very high sediment and nutrient loads. Therefore, further sediment delivery and erosion control could be obtained by constructing large detention basins on the three major tributaries to Rock Creek Lake above the points where these tributaries enter the lake. GIS and AGNPS modeling were applied to this scenario combined with the other changes discussed above. The model predicted a 90% reduction in sediment and phosphorus loading to the lake, when compared to modeling of present conditions. The feasibility study proposal would require construction of only two detention basins, one each on the eastern and western tributaries to the lake. If the area north of the F27 highway bridge were dredged, it would function as a detention basin for the main stem of Rock Creek, before it enters the lake.

The eastern tributary to Rock Creek Lake provided approximately 2,300 ac-ft (2.8 million m3) of runoff and 3,300 tons of sediment in a one-year period during the study. Construction of a sediment detention basin on the eastern tributary to Rock Creek with a 65% trap efficiency would require a structure with a holding capacity of at least 60 ac-ft according to Brune's (1953) curve. A structure with an 80% trap efficiency would need to hold at least 150 ac-ft. The larger structure would reduce sediment loading to the lake by 9% and would have a design life of 36 years. The western tributary to Rock Creek Lake provided approximately 3,100 ac-ft (3.8 million m3) of runoff and 7,300 tons of sediment in a one-year period during the study. Construction of a sediment detention basin on the western tributary to Rock Creek Lake with a 65% trap efficiency would require a structure with a holding capacity of 81 ac-ft according to Brune's (1953) curve. A structure with a 76% trap efficiency would need to hold 150 ac-ft. The larger structure would reduce sediment loading to the lake by 19% and would have a design life of about 17 years.

A further detention structure could be supplied by the now-filled basin north of the F27 highway bridge. The area north of the F27 highway bridge, after dredging, could hold approximately 150 acre-ft of water if no other alterations were made (such as raising water levels by construction of a rock weir). During the period of study, the watershed above this detention basin supplied approximately 17,000 ac-ft (20.7 million m3) of runoff and 15,000 tons of sediment in a one-year period. From Brune's (1953) curve, the trap efficiency of this detention basin would be 40%. From these calculations it is estimated that this detention basin would reduce sediment loading to the lake by 21% and would have a design life of 16 years.

The installation of these three retention basins would reduce sediment loading to the lake at the point of entry from these tributaries by 50%. The management practice and landuse changes modeled in the watershed reduced sediment and phosphorus loading from the watershed by

58% and 53%, respectively. Thus, by implementing these changes in the watershed, sediment loading to Rock Creek Lake should be reduced by nearly 80%, and phosphorus loading should be reduced by nearly 70%.

Phase II of this TMDL includes in-lake restoration to Rock Creek Lake. This could include construction of fish habitat, jetty construction for access, and dredging of accumulated sediments from the lake bottom. Resources should not be spent on in-lake restoration until proper management practices are in place in the watershed and the load reductions called for in Phase I are met. These management practices should protect the lake from further excessive loading of sediment and nutrients.

11.4 Sediment Removal

Restoring Rock Creek Lake to its original volume would require the removal of 2,460 ac-ft of sediment. A realistic goal for the lake is to restore the historic channels in the eastern and western arms of the lake to greater depths, and dredge an area north of the highway F27 bridge to serve as a detention basin. Dredging in the main lake would provide important additional volume for the dilution of incoming nutrients and additional depth for improvement of fish habitat. Dredging a detention basin north of the highway would provide an important area for the deposition of sediment and nutrients being carried down the main stem of Rock Creek. The proposed dredging and spoil areas are shown in the diagnostic/feasibility Study (Downing, 2000).

The western arm of Rock Creek Lake requires the removal of 95 ac-ft of sediment to have 8 acres at 13 feet (4 m) of depth and 8 acres with between 7 feet (2 m) and 13 feet (4 m) of depth. This can be accomplished by dredging a strip approximately 2100 feet long (650 m) and 350 feet wide (100 m). The inclusion of 10% side slopes will make the area of the sediment removal zone 21.5 acres. The eastern arm of Rock Creek Lake requires the removal of 108 ac-ft of sediment to have 9 acres at 13 feet (4 m) of depth and 9 acres with between 7 feet (2 m) and 13 feet (4 m) of depth. This can be accomplished by dredging a strip approximately 3300 feet long (1000 m) and 230 feet wide (70 m). The inclusion of 10% side slopes will make the area of the sediment removal zone 25 acres.

The area north of the highway F27 bridge requires the removal of 147 ac-ft of sediment to have 19.5 acres at 7 feet (2 m) of depth. This can be accomplished by dredging an area approximately 1300 feet long (400 m) and 650 feet wide (200 m). The inclusion of 10% side slopes will make the area of the sediment removal zone 22.5 acres. Dredging this volume of sediment will provide holding capacity of approximately 150 ac-ft in the detention basin if no other alterations are made to this area.

Phase II of this TMDL will be achieved when the fishery of Rock Creek Lake is determined to be fully supporting the Class B aquatic life uses. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This protocol is currently being used to develop benchmarks for the fishery of Iowa's lakes. The results from the Rock Creek Lake assessment will be compared with the benchmarks being developed. These assessments will include age, growth, size structure, body condition, relative abundance, and species.

12. Public Participation

A public meeting was held regarding the Rock Creek Lake TMDL in Des Moines and Newton on January 17 and January 18, 2001, respectively. A public meeting was held in Newton on

October 29, 2001 to present the final draft TMDL. Any comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

13. References

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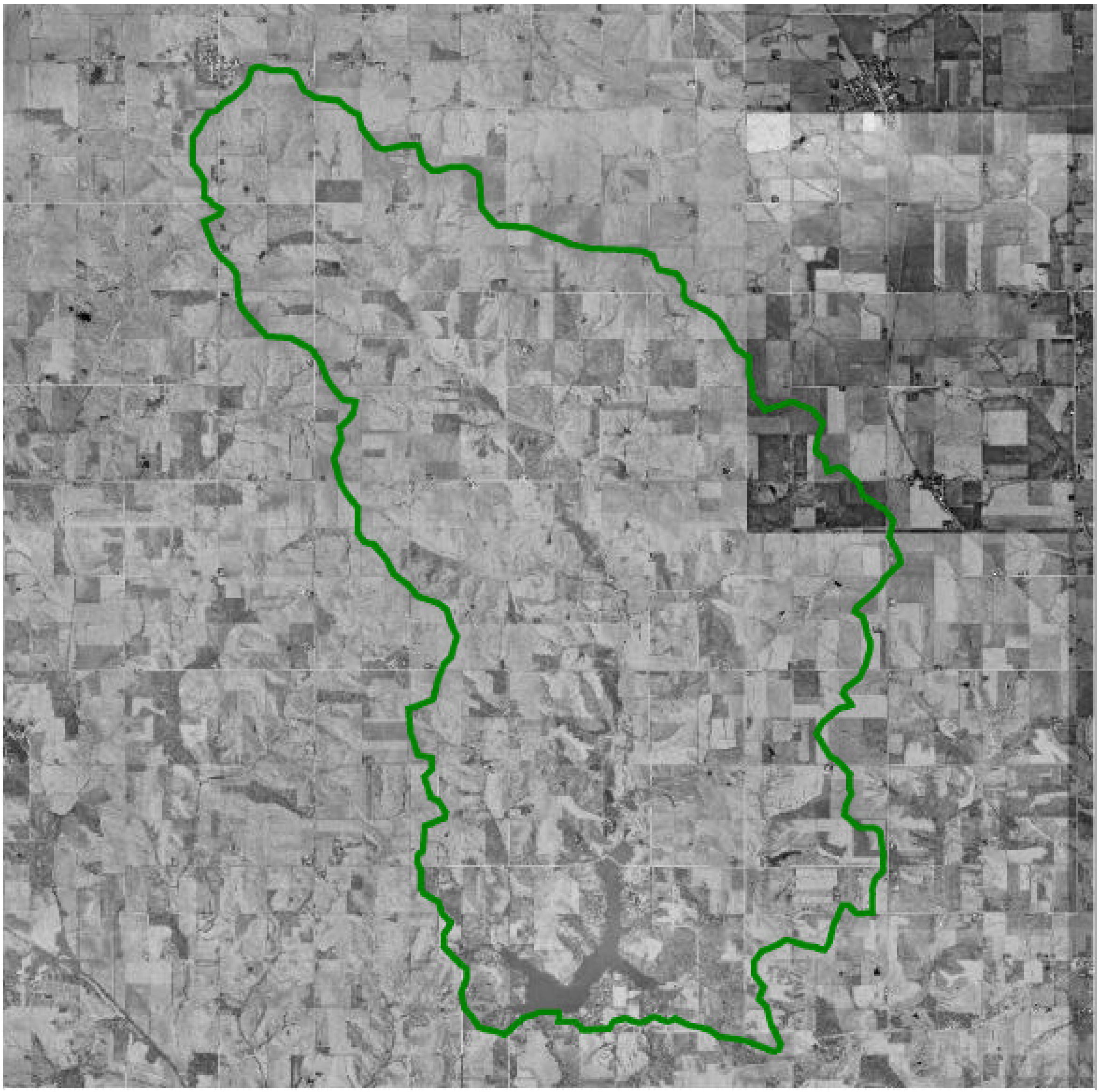
14. Appendix I

Rock Creek Lake and watershed



15. Appendix II - Estimating Phosphorous Loading Using Reckhow's Eutromod Loading Equations for Lakes

Equations utilizing regression analysis have been developed by Kenneth Reckhow for the EUTROMOD Watershed and Lake Model. These equations have been incorporated into the Rock Creek Lake Restoration Diagnostic Feasibilty Study to compare total phosphorous concentration values computed using the model equations and those obtained by direct measurement. Information required to use the model equations includes average total phosphorous influent concentration, 410 µg/l; mean depth,2.3 m; and the hydraulic residence time, 0.18 yr.

Calculation of the predicted total phosphorous load is as follows:

$$k = 10.77\tau^{0.39} z^{0.01} P_{in}^{0.82} = 10.77(0.18^{0.39})(2.3^{0.01})(410^{0.82}) = 2.678$$

$$\log_{10}(P) = \log_{10}\left[\frac{P_{in}}{1 + k\tau}\right] = \log_{10}\left[\frac{410}{1 + (2.678)(0.18)}\right]$$

$$P = 280 \mu g / l$$

These two equations are from the *EUTROMOD Watershed and Lake Modeling Software* documentation and are described below.

EUTROMOD – KA, MO, OK, AK, IA, NE Lake Models

K. H. Reckhow

Duke University, June 10, 1991

MODEL PARAMETER ESTIMATION

The models have been fitted using robust regression (linear, nonlinear, and logistic). The robust weighting scheme usually results in a model that best (in a least squared error sense) represents the pattern in the bulk of the data. Standard errors have been adjusted to account for the robustness criterion.

MODELS

Total Phosphorous (mg/l)

$$\log_{10}(P) = \log_{10}\left[\frac{P_{in}}{1 + k\tau}\right]$$

Where $k = 10.77\tau^{0.39} z^{0.01} P_{in}^{0.82}$ standard error = 0.219

Total Nitrogen (mg/l)

$$\log_{10}(N) = \log_{10}\left[\frac{N_{in}}{1+k\tau}\right]$$

Where $k = 10.77\tau^{0.39} z^{0.01} P_{in}^{0.82}$ standard error = 0.108

Chlorophyll a (μg/l)

$$\log_{10}(Chla) = 1.99 + 0.51\log_{10}(\hat{P}) + 0.23\log_{10}(\tau) - 0.35\log_{10}(z)$$

standard error = 0.226

Secchi Disk Depth (m)

$$\log_{10}(SD) = -1.32 - 0.66\log_{10}(\hat{P}) + 0.47\log_{10}(z)$$

standard error = 0.171

Trophic State Index

The TSI is based on that proposed by R, Carlson (1977) using predicted P, Chla, and SD.
Allowable Phosphorous loading to meet in-lake goal:

$$\log_{10}(P_{in}) = \log_{10}\left[P\left(1+1{,}49\tau^{0.35} z^{-0.97} p^{-0.78}\right)\right]$$

standard error = 0.317

SYMBOLS

P_{in}, N_{in} = average influent concentrations (mg/l)
τ = hydraulic detention time (year)
$\hat{P}$ = predicted in-lake phosphorous concentration (mg/l)
$\hat{N}$ = predicted in-lake nitrogen concentration (mg/l)
Z = lake mean depth (m)
Log_{10} = base 10 logarithm

CONSTRAINTS ON ABOVE MODELS

The following constraints reflect the data set used to fit the models. In some instances (e.g., nutrient retention less than zero) additional constraints were imposed to create homogeneity in the data set or to eliminate suspected errors. Constraints involving phosphorous refer only to models that include phosphorous; constraints involving nitrogen refer only to models involving nitrogen.

Phosphorous Retention (R_P) > zero
0.003 mg/l < P < 0.424 mg/l
0.010 mg/l < P_{in} < 1.334 mg/l
Nitrogen Retention (R_N) > zero
0.090 mg/l < N < 7.185 mg/l
0.268 < N_{in} < 10 mg/l
0.0008 mg/l < Chla < 0.953 mg/l
0.008 year < τ < 285 year
1.2 m < z < 3.6 m