PART EIGHT

WATER QUALITY, EROSION, AND SEDIMENT

WATER QUALITY EFFECTS OF POWER BOATING ON THE FOX CHAIN O'LAKES

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Introduction

Motorboat propellers can stir up stable bottom sediments and dislodge aquatic plants with repeated passes, as well as affect benthic communities; and it is possible for motorboats to effectively remove all vegetation at a water depth of three feet (Yousef, 1974; Wagner, 1990). As water clarity is reduced, aesthetic and habitat values can be adversely affected. In turbid water, rooted aquatic vegetation growth is prohibited because insufficient light penetrates to the lake bottom.

Rooted aquatic vegetation is an important component in aquatic ecosystems for several reasons. The leaves and stems of rooted vegetation produce oxygen and serve as forage and habitat for fish, wildlife, and insects. Plants provide attachment surfaces for case building insects. Beds of aquatic vegetation can diminish wave action and help hold sediment in place which, in turn, improves or maintains water clarity (Jackson and Starrett, 1959). Without sufficient water clarity neither the aquatic vegetation nor the associated aquatic community can become established.

Methods

In addition to other water quality parameters, total suspended solids concentration, boat traffic, and wind speed were monitored monthly between May and October and on a 24-hour basis on four pairs of Saturdays and Wednesdays in June and July. Mid-depth water samples were taken once per day or at three-hour intervals during 24-hour sampling. Boat passes were counted for a 10-minute interval at the sampling site.

Results and Discussion

Data analysis indicated that power boating significantly ($P<0.05$) affected the concentration of total suspended solids, a measure of water clarity. The 24-hour monitoring indicated boat traffic influences the concentration of suspended solids in water three ($r^2=0.458$) and six ($r^2=0.25$) feet deep over

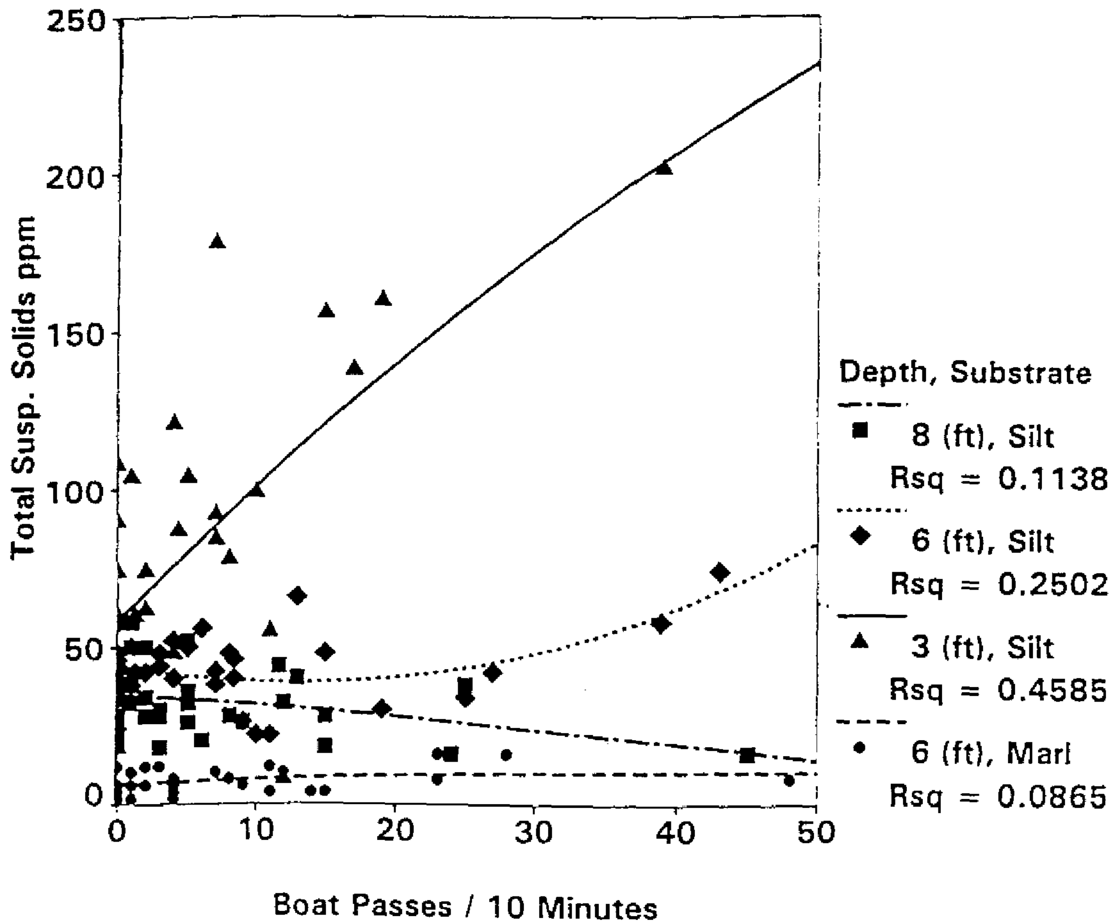

Figure 1. Relationship of boat pass frequency and concentration of suspended solids at four sampling sites during the 24-hour sampling regime.

silty sediments (Figure 1). The strength of the relationship between boating and suspended solids concentration decreased with increasing water depth and when bottom sediments were more cohesive (muck) or settled faster (sand, marl). Wind significantly ($r^2=0.293$) influenced the concentration of suspended solids in water eight feet deep over silt (Figure 2).

Water clarity was better on Wednesday than on Saturday and varied during the day. The concentration of suspended solids was lowest (water clarity was best) during the early morning or late night when boats were not present. Soon after boats appear on the lake, suspended solids concentrations rise, water clarity is reduced, and the water remains turbid during the day. The water clears sufficiently for growth of rooted vegetation three to six hours after the cessation of boating activity, but this occurs primarily at night when sunlight is absent.

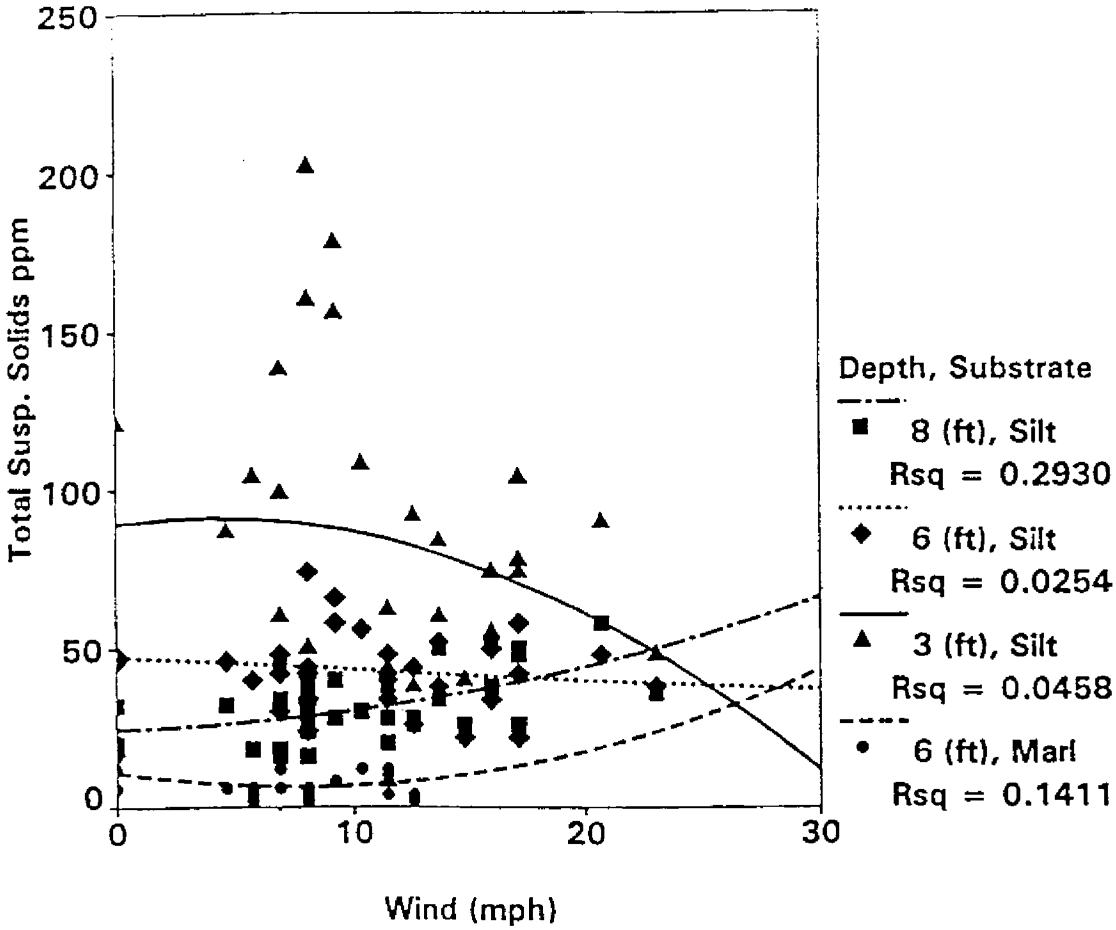

Figure 2. Relationship between wind speed and concentration of suspended solids at four sampling sites. Sites which exhibit a negative relationship with increasing wind velocity were more affected by boat traffic. Boats pass more frequently at low wind velocities. Wind affects water clarity at deeper sites.

Monthly sampling indicated mean boat passes/foot depth accounted for 84% of the variance in suspended solids concentration (r^2=0.3122, P>0.05) over all sampling sites. Mean wind speed/foot depth was not significantly related to suspended solids concentration over all sites (r^2=0.96, P<0.05), but accounted for 96% of the variance in suspended solids at the open lake sites (r^2=0.96, P<0.05). Water clarity was not related to site depth (r^2=0.003, P>0.05).

The passage of boats through areas three feet deep, at frequencies of 30 passes per hour, generated as much or more suspended sediment as a 20 mph wind in the same area. During 235 hours of water quality sampling, boat pass frequency exceeded 30 per hour about 20% of the time. During the same time frame, winds exceeded 20 mph during only 3% of the time. The Fox Chain O'Lakes is highly susceptible to boating impacts because 65% of the lake acreage is less than six feet deep with silt sediments.

By maintaining turbid conditions daily and seasonally, boat traffic is preventing the establishment of rooted vegetation and the associated habitat. Restoration and maintenance of the existing aquatic habitat of the system will not occur without reducing the impact of boats. The environmental effects of boats can be reduced by slowing boats to no-wake speeds in shallow areas and restricting boating activities to areas where the water is more than six feet deep.

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MISSISSIPPI TRAGEDY: IT DIDN'T HAVE TO HAPPEN

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The announcement for this year's conference stressed the need to look at floodplains, stormwater runoff, wetlands and water quality issues holistically. In addition, as the ghost of Peter Palchinsky would remind us, it will be beneficial to view floodplain management plans within their political, social, and economic contents (Graham, 1993). Palchinsky wanted planners and engineers to be hard-headed realists who evaluate problems in all their aspects, particularly the economic ones.

There is a growing awareness that floods cannot be controlled. One can always look forward to a bigger flood in the future. Stephen M. Wolf, chairperson of United Airlines, wrote, "Perhaps it is human nature to lapse into a sense of false confidence, a feeling of being superior to animals and even nature itself. We believe we are in command of the elements; we control our own destinies. Or so we think. Recent events—from earthquakes, floods, and fires to hurricanes and ice storms—demonstrate that, no matter our level of knowledge and technological sophistication, we remain at nature's mercy. . . . As brutal and terrifying as natural disasters can be, however, they also give us glimpses of something good. They remind us that we cannot rely upon the structures and warning systems we construct for protection from the elements, but we can rely upon each other for survival" (1993).

As the threat of new flooding becomes evident in 1994, it is being reported that occupants of the floodplain are "thinking of quitting altogether. We're just too tired" (*Tribune*, 1994). Control structures such as levees, which offer a degree of protection for the small and moderate floods, offer little hope against the large floods. The 1993 flood has shaken the confidence of some residents in levees.

Much has been written about the Great Flood of 1993. The potential mitigating effects of wetlands, the effect of levees on flood stages, the need for nonstructural alternatives, and the adequacy of the 100-year flood standard are topics that are being debated both in the scientific world and the popular press.

The White House has established a Floodplain Management Review Committee to re-evaluate national policy in light of the 1993 flood. The committee will need to identify rational or wise uses of a natural resource (the floodplain). Can a national program be formulated that will be general enough to allow local variations and individual initiatives? If such flexibility is achieved, it will allow plans to be developed that reflect the local political, social, and economic conditions. This will be a first step in achieving the elusive goal of wise use of floodplains.

This paper focuses on the issue of water quality. Water quality is of concern not only during periods of flooding, but also when the river is within its banks. Pollutants are discharged into our waterways every day. During nonflood periods, they are in the form of partially treated sewage effluent. When floods occur, the discharges often are exacerbated when hydraulically overloaded or inundated treatment plants spew raw sewage into the waterways.

Efforts to improve water quality can have an important influence in floodplain management efforts. The need for clean water can stimulate efforts to implement greenways. The establishment of greenways often involves changes in land use, which in turn produces a reduction in the flood hazard. Fishing, boating, biking, hiking, and bird watching activities that are enhanced by greenways and clean water improve the quality of life.

Former Superintendent of the Forest Preserve District of Cook County, "Cap" Sauers, once referred to the Des Plaines River greenway as a shining red apple with a worm in the middle. The worm to which he referred was the polluted Des Plaines River.

A comprehensive floodplain management program will generate linkages between people and waterways. Such linkages can be symbiotic. Just as clean water helps to trigger and sustain efforts to establish greenways, the establishment of greenways removes floodprone development from the floodplain.

Traditional sewage treatment plants are located downstream of the communities they serve, generally at the lowest elevation to maximize the use of gravity sewers. This places them on the floodplains. According to published reports, the Environmental Protection Agency said about 425 sewage treatment plants were damaged during last summer's flooding. The treatment plants were "in harm's way" to facilitate the discharge of partially treated effluent into the rivers. Two negatives are at work by this practice. First, severe flood damage occurs to the treatment plants. Second, the essentially untreated discharges deteriorate the water quality.

Nitrogen, a primary plant nutrient in fertilizer, can be used to illustrate the adverse effects partially treated effluent can have on water quality. Untreated municipal wastewater will contain 35 mg/l nitrogen. After secondary treatment it will contain 25 mg/l nitrogen. A community with a population equivalent (PE) of 500,000 will discharge 10,425 pounds of nitrogen each day (50.0 mgd x 25 x 8.34). On an annual basis, this amounts to 3,805,125 pounds of nitrogen. This is the quantity of nitrogen that would be found in 761,025 50-pound bags of 10-10-10 commercial fertilizer. Obviously, three quarters of a million bags of commercial fertilizer, when dumped into a river, will affect water quality.

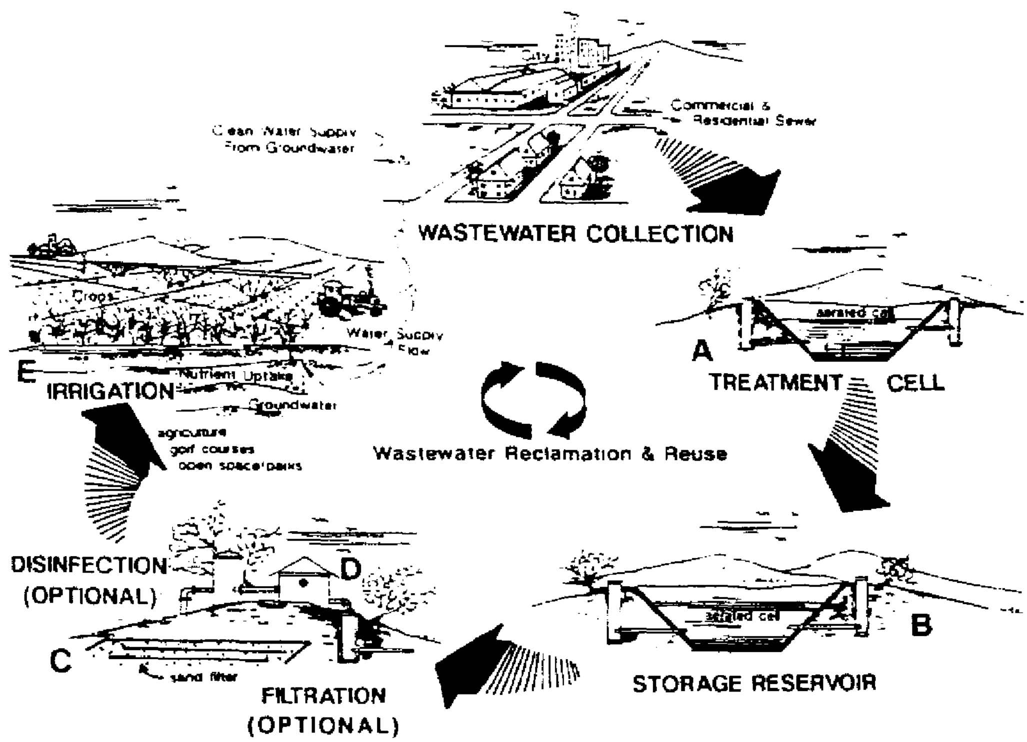
Linkages between pollutant recycling and floodplain management are presented in the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) and in Section 73(a) of the Water Resources Development Act of 1974. The 1972 Amendments state: "The Administrator shall encourage waste treatment management which combines 'open' space and recreational considerations with such management" (Sec. 201 (f)).

Federal agencies are required to evaluate nonstructural alternatives when formulating a flood loss reduction project. The nutrient recycling possibilities inherent in nonstructural floodplain management were well recognized, as the following quotation from Charles R. Ford, former Deputy Assistant Secretary of the Army, shows:

> The authorities in P.L. 92-500 regarding the acquisition of sites for the land treatment process for wastewater, when combined with the authorities in Section 73, offer an outstanding opportunity for multiple uses of flood plains while preserving green space and providing recreational opportunities. Why not use our flood plains in urban areas for crop production, golf courses, forests, and other uses which can capitalize on the nutrients in our wastewater and provide tertiary waste treatment at the same time? Such land-treatment sites can be located on the higher areas of the flood plain, but they can also be designed to store flood water when necessary without permitting the release of the stored water except through the soil filtration process (1975).

The State of Illinois has recognized the potential to use floodplains to improve water quality. The EPA allows the use of floodplains above the 10-year floodplain as irrigation areas for reclaimed water so that the nutrients can be reused or recycled. The national goal was to eliminate the discharge of pollutants into the navigable waters by 1985. We have missed the deadline, but the goal still remains. Technology exists that allows communities to use wastewater as a raw material or resource. Rather than discharging partially treated wastewater into a river, wastewater is reclaimed and used in the production of food and fiber. When this is done, traditional treatment plants can be removed from vulnerable floodplain sites and the elimination of discharge will improve water quality, which in turn will support efforts to establish greenways.

Wastewater reclamation and reuse technology is being implemented in many states and several foreign countries. Figure 1 depicts the technology often referred to as a circular system. The question is, "What investment must be made to use the wastewater beneficially?" rather than "What expenditures must be made to dispose of or relocate wastes?" It is another weapon in the floodplain manager's arsenal. Proper use of technology will assist our national efforts to achieve two elusive goals: clean water and reductions in flood losses.



A. Aerated cells
B. Storage reservoir
C. Sand filters/disinfection (optional)
D. Operations building
E. Irrigation areas

Figure 1: Elements of wastewater reclamation and reuse system.

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DIAGNOSTIC STUDY OF NEWKIRK LAKE THROUGH SECTION 314 OF THE CLEAN WATER ACT

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Introduction

Located on the eastern edge of the Central Great Plains in Kay County Oklahoma, Newkirk Lake was established by the impoundment of a tributary to Wolf Creek in the early 1900s. The Santa Fe railroad used this reservoir as a water supply for their locomotive steam engines. Ownership was transferred to the City of Newkirk in 1953 and the reservoir renamed Newkirk Country Club Lake. The lake was used for boating, swimming, fishing, and picnicking. Present day recreational uses include only picnicking and limited fishing because of the restricted access to boatable and fishable water. To address the impairment of recreational uses, a study ("Clean Lakes") was proposed to the U.S. Environmental Protection Agency through section 314 of the Clean Water Act requesting $107,171 (70% federal, 30% state matching funds). The proposal was funded and a Clean Lakes workplan was developed to evaluate the causes of impaired recreational uses and develop feasible restoration measures.

The Clean Lakes study utilized two separate evaluation techniques, one for the lake and another for the watershed. The lake evaluation was performed by the Water Quality Programs Division of the Oklahoma Water Resources Board through a bathymetric survey and monitoring of tributary and lake water quality. The lake watershed was evaluated at the Environmental Modeling and GIS Laboratory, School of Civil Engineering and Environmental Science, University of Oklahoma under contract with the Oklahoma Water Resources Board. Through the use of a geographic information system (GIS) and a non-point source pollution model (AGNPS), the location and severity of non-point source pollution were identified in the watershed (Vieux et al., 1993).

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Lake Evaluation

Historical records indicate an original maximum depth of 25 feet (7.6 meters), surface area of 41 acres (0.16 km^2), approximate volume of 430 acre-feet, and a watershed of 1,510 acres (6.11 km^2). A bathymetric survey performed in 1990 revealed a maximum lake depth of 6.5 feet (2.0 meters), surface area of 45 acres (0.18 km^2), and approximate volume of 125 acre-feet. Reduction of volume is the primary cause of the loss of recreational use of the lake.

Water quality was monitored from July 1992 through June 1993 to chemically characterize Newkirk Country Club Lake. Mean annual chlorophyll-a concentration measured at the central sampling station was 27.7 mg/m^3. Mean annual total phosphorous concentration measured at the central sampling station was 75 mg/m^3. Mean annual total nitrogen concentration was 1,900 mg/m^3. Approximately one third of the total nitrogen present was in the form of nitrate. An examination of chlorophyll-a concentrations showed a reservoir supporting a highly productive phytoplankton community. The nutrient concentrations present indicate that nitrogen and phosphorous are not the factors limiting phytoplankton growth.

The dominant visual feature of Newkirk Country Club Lake is a standing crop of aquatic macrophytes. The lake margin is dominated by emergent aquatic plants. Cattails (*Typha latifolia*) are found near to shore, while a mix of water willow (*Justicia americana*) and water primrose (*Ludwigia peploides*) are found farther from the lake shore. Free-floating rafts of water willow were observed in the open water areas of the lake. It is presumed that storms occasionally break off and wash stands of this plant into the lake. The rest of the lake is colonized by coon-tail (*Cerataphylum desmersum*). Areal coverage by this species varies from 50% to 95% of the open water area. It is likely that phytoplankton productivity is limited to the top few inches of the lake while the coontail is dominant in the open water area of the lake. Senescence of the standing crop of aquatic macrophytes in the fall is a source of sediment for Newkirk Lake.

Monitoring of dissolved oxygen concentrations showed the water column below the stands of coontail to be anoxic from May through October. From November through April, when plant growth was minimal, lake water was oxic. The implications of anoxia are the solubilization of sediment bound nutrients into the water column.

Water quality samples taken from the lake tributary had settleable solid values below the detection limit (<0.1 mg/L). Mean total phosphorous was 0.151 mg/L. Mean total nitrogen was 8.91 mg/L. Nitrate accounted for just over two-thirds of the total nitrogen. Local residents tell of two springs in the lake's watershed. USGS records show one ephemeral spring. Water quality sampling of the spring showed mean total phosphorous values of 0.050 mg/L, total nitrogen of 13.32 mg/L, and nitrate making up 97% of the total nitrogen. Sampling of stormwater entering Newkirk Lake showed mean total nitrogen in water and sediment as 4.4 mg/L and 2.54 mg/L, respectively. Mean total phosphorous in water and sediment was 0.30 mg/L and <0.1 mg/L, respectively. Mean total solids of the inflowing stormwater was 942 mg/L.

The evaluation of the lake revealed a reservoir with approximately one-third of its original volume. In 1990 Newkirk Lake was shallow enough for coontail to monopolize the open water area. Contributors of sediment and nutrients to Newkirk Lake are both internal and external. The resident aquatic plants and inflowing storm water contribute sediment, while the anoxic lake sediments and inflowing water contribute nutrients. Making the lake depth exceed that which light will penetrate will eliminate the nuisance aquatic macrophyte growth and reduce the internal sources of nutrients. External sources of sediment and nutrients must be addressed to effectively allow for the restoration of recreational uses.

Watershed Evaluation

The Kirkland-Tabler-Bethany soils comprise approximately 50% of the soils in the watershed. These soils are on broad, very gently sloping to rolling uplands. The thin surface layer does not absorb much rainfall in a short duration. For this reason, runoff and erosion are greater than at other places in the watershed. About 80% of this association is cultivated. The Newtonia-Summit-Sogn series comprises 44% of the watershed. These soils consist of generally well-drained soils with depth to limestone greater than four feet. About 60% of this association is cultivated for winter wheat. The remaining 40% is native pasture. Cropland comprises 78% of the entire watershed. Pasture and meadowland make up approximately 22%. Urban development constitutes approximately 8% of the watershed. A marshland lies immediately upstream of Newkirk Lake. Table 1 summarizes land use for the Newkirk Lake watershed.

Digital soils, land use, hydrographic, and topographic base maps were compiled using the geographic resource analysis support system (GRASS) GIS developed by the U.S. Army Corps of Engineers. From GRASS the information was recoded into model parameters that were used to run the agricultural non-point source pollutant (AGNPS) model at 2.5-acre resolution. Grid cell resolution effects were investigated by Nickisch (1993). To quantify the relative effect of management practices in controlling or reducing pollution of Newkirk Lake, four scenarios of various land use/cover were generated. These scenarios

Table 1. *Land use in Newkirk Lake watershed.*

(NHEL=not highly erodible land, HEL=highly erodible land)

Land Use Description	area (acres)	area (% cover)
Smallgrain (Terraced/NHEL/Waterway)	313	21
Pasture (Moderate)	250	17
Smallgrain (Not Terraced/NHEL/No Waterway)	238	16
Smallgrain (Not Terraced/NHEL/Waterway)	192	13
Legume and Rotation Meadow	79	5
Smallgrain (Terraced/NHEL/No Waterway)	75	5
Park/Golfcourse	69	5
Smallgrain (Not Terraced/HEL/Waterway)	61	4
Urban (21-27% impervious)	42	3
Marsh	49	3
Water	42	3
Smallgrain (Terraced/HEL/Waterway)	37	2
Roads	33	2
Farmstead	22	1
Pasture (Good)	4	<1
Woodland	4	<1

were conditions estimated to be (1) present conditions, (2) worst case conditions, (3) management practices applied to worst case conditions, and (4) management practices applied to present conditions. The rainfall series (1959-1991) was simulated to obtain the full range of effects for the four scenarios. The simulations assume that the practices functioned as intended for the full range of precipitation events. Most conservation practices are designed for the 10-year, 24-hour storm. An AGNPS input file was generated for each of the four scenarios. Each scenario input file was then used with the actual storm events to simulate long-term averages of yield to the lake.

Table 2 contains a summary of various model constituents delivery to Newkirk Lake. The modeling results showed soil erosion and sedimentation to be greatest in the cropland areas. Water erosion was also shown to be greatest in areas of highest slope. Phosphorous contributions were predicted to be dominated by sediment transport from the Kirkland-Tabler-Bethany soils found in the western half of the basin. Sediment and erosion control practices applied to cropland in this area were predicted to produce the largest reduction of phosphorous delivery to Newkirk Lake. Further reductions of nutrient contributions to Newkirk Lake can be achieved by nutrient management. By simulating management practices to existing cropland and improving the retention abilities of marsh area, it is predicted that sediment loading to the lake can be reduced 28% from present conditions.

Table 2. Non-point source pollution model predictions of watershed delivery to Newkirk Lake. (average annual values based on storms occurring 1959—1991).

Scenario	Sediment Yield (tons)	Clay Yield (tons)	Soluble Nitrogen (ppm)	Sediment Attached Phosphorous (lbs/acre)
1	61.29	45.09	3.82	0.18
2	67.20	50.64	5.51	0.19
3	63.38	49.16	4.99	0.19
4	44.11	28.50	2.66	0.14

Discussion and Conclusions

Recreational uses of Newkirk Lake have declined over time due to sedimentation. The reduction in volume has allowed aquatic plants to colonize virtually the entire surface area of the lake. Deepening the lake should eliminate the nuisance growth of aquatic macrophytes and one source of nutrients and sediment. Water quality monitoring shows a highly productive phytoplankton community limited by intense aquatic macrophytic growth. Deepening the lake without nutrient controls would allow for excessive phytoplankton growth and result in a lake that is not aesthetically pleasing. Control of the nutrients flowing into Newkirk Lake will be essential for the restoration of recreation uses. Through the use of a GIS and hydrologic model, it has been shown that by the manipulation of land use within the lake watershed, the delivery of sediment and nutrients to the lake can be reduced. Reversing pasture or meadow conversion to cropland would have the greatest impact on reducing the sediment yield to the lake. Addressing the sediment delivery to Newkirk Lake will concomitantly address the greatest identified source of nutrients from the watershed. Enhancing the trapping ability of the marshlands immediately above Newkirk Lake will further reduce sediment and nutrient delivery to Newkirk Lake.

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