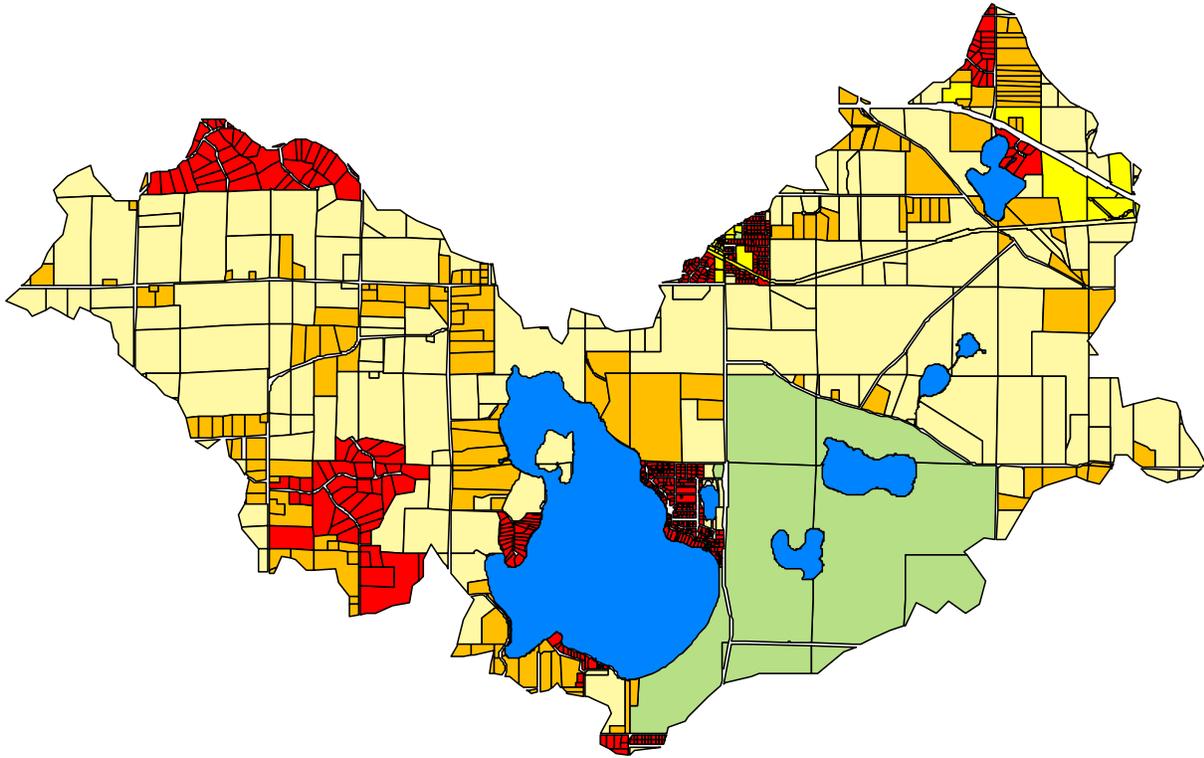


Lake Independence Phosphorus TMDL



January 2007

Prepared by
Pioneer-Sarah Creek Watershed Commission
Three Rivers Park District

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Lake Independence Phosphorus TMDL

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EXECUTIVE SUMMARY

In 2002, the Minnesota Pollution Control Agency listed Lake Independence as impaired for aquatic recreation under Section 303(d) of the Clean Waters Act. The main cause of the impairment is excessive nutrients in the lake. This TMDL document assesses the nutrient load reductions needed for Lake Independence to comply with Minnesota water quality standards. The specific sources of nutrients, target reductions from each source, and strategies to achieve the reductions are discussed in the document.

Lake Independence (MNDNR Lake ID# 27-0176-00) is an 851-acre lake located in the Pioneer-Sarah Creek Watershed approximately 15 miles west of Minneapolis, Minnesota. The lake is used extensively for boating, fishing, swimming and aesthetic viewing by local residents as well as the entire Twin Cities regional area. The south shoreline of the lake is within Baker Park Reserve and contains two public swimming beaches, a campground, an ADA accessible fishing pier, numerous picnic areas and a boat launch.

The lake receives runoff from a 7,631-acre predominantly agricultural watershed which contains portions of three municipalities, Medina, Independence and Loretto. The watershed is undergoing rapid urbanization, although the majority of new residential lots are large, between 2.5 and 5-acres in size. The large lot sizes allow numerous homeowners to maintain small hobby farms. The lake watershed, therefore, contains approximately 298 animal units, mainly horses.

Over the past 15 years, the water quality of the lake has declined and algal blooms now occur throughout much of the summer season, negatively impacting recreational use. Data from 1990 to 2003 show that the lake total phosphorus concentration averages 47-ug/L, exceeding the 40-ug/L water quality standard for Class 2 recreational waters. Monitoring data generated from three stream inflow sites over a three year period showed that the watershed contributes 1,475-pounds of phosphorus and 7,301 pounds of nitrogen annually to Lake Independence. Analysis of the specific sources within each sub-watershed showed that the majority of inflowing nutrients are derived from feedlots (34 percent) and agricultural cropland (24 percent) in the watershed. Other significant sources include urban developments, especially those directly adjacent to the lake (23 percent), rural developments (3 percent) and the Loretto Wastewater Treatment Plant discharge (2.5 percent). Remaining sources including shoreline erosion, geese, failing septic systems, a golf course, and parkland contribute less than four percent of the total load to the lake. Direct precipitation and internal recycling processes add an additional 906 pounds of phosphorus annually to the lake.

To address these issues, a community stakeholders committee was appointed by the Pioneer-Sarah Creek Watershed Management Commission. This group established a water quality goal of 36 ug/L for the mean growing season total phosphorus concentration for Lake Independence. Since the Minnesota water quality standards require that the mean phosphorus concentration not exceed 40 ug/L, achieving this goal would satisfy the Margin of Safety requirement of the TMDL process. The numerical TMDL for Lake Independence necessary to achieve the desired goal was calculated as follows:

$$\frac{\text{TMDL}}{1,335 \text{ lbs/year}} = \frac{\text{WLA}}{603 \text{ lbs/year}} + \frac{\text{LA}}{697 \text{ lbs/year}} + \frac{\text{MOS}}{35 \text{ lbs/year}}$$

The existing phosphorus load to Lake Independence was determined to be 2,381 pounds annually. Achieving the TMDL would require a loading reduction of 1,046 pounds/year, (2,381lbs/yr -1,335lbs/yr), and reduce the in-lake phosphorus concentration to 40 ug/L. However, achieving the desired water quality goal of 36 ug/L will require a phosphorus loading reduction of 1,081 pounds/year, or 45 percent of the current load. The stakeholder committee determined that the required phosphorus loading reductions would come from the following sources:

Agricultural cropland	284 lbs/year	(32 percent)
Livestock manure management	370 lbs/year	(29 percent)
Urban Development	146 lbs/year	(14 percent)
Internal loading reduction	209 lbs/year	(18 percent)
Loretto Sewage Treatment Facility	53 lbs/year	(5 percent)
Shoreline and goose management	11 lbs/year	(2 percent)
Failing Septic Systems	8 lbs/year	(< 2 percent)

The stakeholder committee also recommended that the phosphorus load reductions from each municipality be reduced proportionately relative to the existing export to Lake Independence. Therefore, the City of Independence will need to achieve a larger reduction of phosphorus loading from manure than Medina, because more livestock units are present in Independence. The municipalities agreed with the committee recommendations and will implement measures to obtain the following reductions:

Independence	535 pounds
Medina	284 pounds
Loretto	53 pounds

The communities agreed to jointly work to reduce the internal loading of phosphorus by 209 lbs/year. Because all three communities are classified as MS4 municipalities, the nutrient reduction strategies will be incorporated into the appropriate SWPPP.

1.0 INTRODUCTION

1.1 Purpose

The goal of this Total Maximum Daily Load analysis is to quantify the phosphorus reduction that will be required to meet the water quality standards established for Lake Independence and identify phosphorus reduction strategies for source areas in accordance with section 303(d) of the Clean Water Act.

Lake Independence was identified as a priority resource in the *Pioneer-Sarah Creek Watershed Commission 2nd Generation Plan*. As a part of this plan, a diagnostic feasibility study was completed in 2004 to identify a list of potential management actions to improve the water quality. This list included estimates of associated cost, expected effectiveness, predicted longevity, and technical feasibility for each proposed management alternative. Selection of actions for implementation required public discussion and cooperation between many concerned parties to evaluate and select the most acceptable management alternatives from this list. Through cooperative efforts between Three Rivers Park District, local municipalities, and the Minnesota Pollution Control Agency, this diagnostic feasibility evolved into the Lake Independence Phosphorus TMDL.

1.2 Problem Statement

Lake Independence (MnDNR Lake ID# 27-0176-00) is an 851-acre lake located in the Pioneer-Sarah Creek watershed approximately 15 miles west of downtown Minneapolis, Minnesota (figure 1). Lake Independence and its surrounding drainage area contains portions of three municipalities; Independence, Medina, and Loretto, all within Hennepin County. As with many lakes in the Twin Cities metropolitan area, Lake Independence is used heavily for recreation and is prized for its aesthetic value by homeowners. The *2030 Metropolitan Council Regional Parks Policy Plan* identified Baker Park Reserve and Lake Independence as regionally important natural resources. Over the past several decades, the lake has experienced degraded water quality that has reduced the lake's recreational and aesthetic value. In 2002, the lake was added to the Minnesota 303(d) impaired waters list for impaired aquatic recreation as a result of mean summer phosphorus values that exceeded the 40 ppb phosphorus standard for Class 2 recreational waters.

Three Rivers Park District initiated a comprehensive monitoring plan in 1990 to identify and quantify the factors that affect the water quality of Lake Independence. This included biweekly monitoring of in-lake conditions during ice-free periods from 1990 to 2003, daily tracking of internal mixing in 1999 and 2000, and intensive stream monitoring in 1996, 1997 and 2001 at a majority of the sites where water flowed into the lake. The data showed that the mean summer total phosphorus concentration exceeded the 40 ug/L standard in 11 of the 12 monitored years from 1990 to 2003 (no monitoring was conducted in 1992).

1.3 Description of Lake Independence and the Surrounding Watershed

1.3.1 History of Watershed

The watershed surrounding Lake Independence was predominantly forest and wetland until the mid 1800's. Prior to 1850, Lake Independence was used by Native Americans but was unknown to European settlers. On July 4, 1854, settlers from the Lake Minnetonka area encountered what is now Lake Independence, and named it in honor of the date, Independence Day. Between 1850 and 1870, the lake was the site of a large Native American settlement and the first European settlers began to build homes along the shore. In the 1860's, the village of Perkinsville was platted near the south end of the lake. Perkinsville soon became an active community that catered to vacationers from Minneapolis.

During this same period, the area surrounding the lake was steadily being converted from forest to agricultural use. Conversion to agricultural use included construction of numerous drainage channels to drain wetlands, significantly increasing the hydrologic and nutrient flux to the lake. All of the major tributaries to the lake show evidence of significant channelization. Extensive tile drainage systems were also installed in the watershed to drain cropland, further changing the hydrologic system. Mechanized agriculture in the post World War II period, and increased use of commercial fertilizer also increased the nutrient loading to the lake.

In the early 1900's, Lake Independence became a popular resort lake. At one point, four resorts were in existence along its shores. By the 1950's, the resorts were no longer popular and by 1990, all of these sites had been demolished and the land was sold for other uses. Beginning in the 1920's the lake shoreline was subdivided for individual lake homes. Initially these were seasonal lakeshore cabins. Over the past 20 years, the seasonal cabins were converted to year round homes, and virtually all of the available shoreline property was developed by the 1980's. Prior to 1990, these homes were served by individual sewage treatment systems (ISTS's).

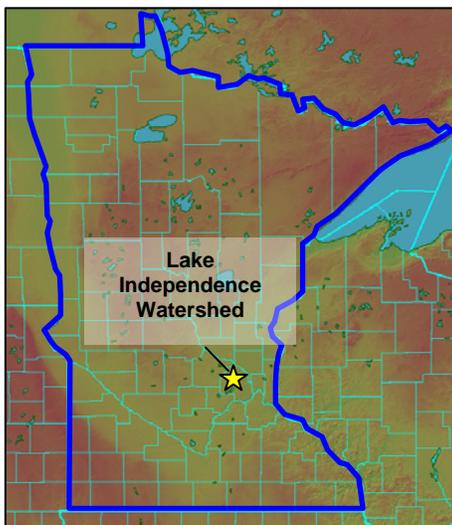


Figure 1. Map of Minnesota showing location of the Lake Independence Watershed.

In the late 1950's, a large portion of the watershed east of Lake Independence, including about one sixth of the lake shoreline, was converted into a park reserve and recreation area named for the Baker family that had owned much of the land. The majority of this area is maintained as forest, prairie, and wetland, but the park does include a golf course, campgrounds, public beach, and picnic areas.

During the past ten years, significant portions of the agricultural lands in the watershed have been converted to residential property. In general, the conversion has occurred from east to west. The majority of residential lots are large, between 5 and 10 acres. Many of these property owners keep horses or other livestock on the property.

1.3.2 Soils and Geology

Lake Independence is located in an area where the soil association has been determined to be Erin-Kilkenny-Peaty muck. This soil association is characterized by gentle undulating terrain with some larger hills, medium to moderately-fine textured soils of glacial origin, and areas of level organic soils (USDA, SCS 1974). This soil association is noted as having severe limitations for the use of onsite sewage disposal systems (septic tanks) due to low percolation rates, a high shrink-swell potential, and generally high water table conditions. The soils within the Lake Independence watershed are predominantly Erin and Hayden loams with some clay loams. In addition, large areas of marsh and peaty muck exist in low areas immediately east and west of Lake Independence. The near-shore areas immediately adjacent to Lake Independence are predominantly Erin loam with some organic marsh soils along the western shoreline.

The topographic elevations in the area range from 955 ft to 1080 feet above mean sea level with the highest elevations in the eastern areas of the watershed within Baker Park Reserve, and the lowest areas predominantly located in the area immediately west of Lake Independence.

1.3.3 Demographic Information

The three municipalities in the Lake Independence watershed are rural communities with a combined population of 7,811. All three communities are growing rapidly and have experienced population increases in excess of 15% over the past five years. Growth rates in the communities are expected to remain high for the next decade.

Municipality	1990 Population	2000 population	% increase	projected 2005	Median age	# house holds	Median income	Median home value
Medina	3,096	4,004	29	4,770	38	1,309	\$96,909	\$237,100
Independence	2,822	3,326	15		39	1,115	\$82,143	\$256,900
Loretto	404	570	41	637	35	225	\$71,944	\$150,000

1.3.3 Climatological Summary

Lake Independence and its surrounding watershed are located within the Northern Central Hardwood Forest (NCHF) ecoregion. Average annual precipitation for the Lake Independence area is 29 inches (74 cm), and the average growing season is 152 days in length. On average, Lake Independence experiences 132 days of ice cover a year, with the average freeze and thaw dates being November 28 and April 7 respectively. Additional climatological data are summarized in Table 1 and Figure 2 below.

Month	Avg (°F)	Precip (in.)	Snowfall (in.)
Jan	11.8	0.83	9.8
Feb	17.9	0.85	8.4
Mar	31.0	1.6	11.7
Apr	46.4	2.17	2.8
May	58.5	3.38	0.1
Jun	68.2	4.17	0
Jul	73.6	3.55	0
Aug	70.5	3.40	0
Sept	60.5	2.89	0
Oct	48.8	2.01	0.5
Nov	33.2	1.45	7.9
Dec	17.9	0.94	9.3
Annual	44.9	27.24	50.5

Table 1. Average monthly temperature (°F), precipitation (inches), and snowfall (inches) for Minneapolis Metropolitan Area

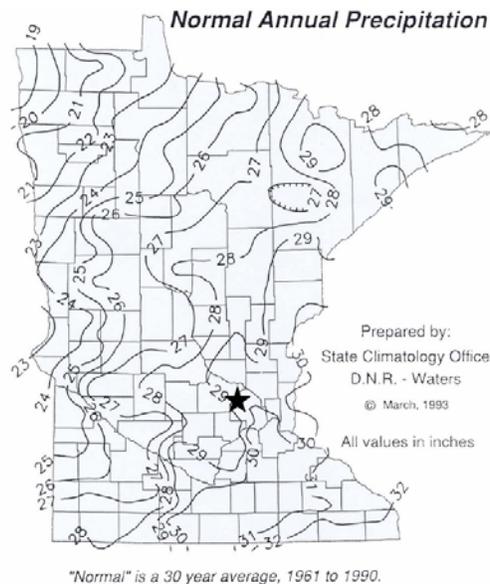


Figure 2. Map showing normal annual precipitation for Minnesota. (Minnesota State Climatology Office).

1.3.4 Watershed Characteristics

The 7631-acre watershed surrounding Lake Independence is predominantly used for crop and livestock agriculture, but also includes residential developments, commercial areas, industrial plots, wetlands, and parkland (Figure 3). However, land-use patterns have shifted dramatically over the past ten to fifteen years as new residential and commercial developments displaced the predominant agricultural areas. The watershed experienced a doubling of impervious surface area from 1986 to 2002, from 942.2-acres to 1,759-acres. These land uses changes are expected to continue as new residential developments are constructed in the area. The Lake Independence drainage area contains portions of three rapidly growing municipalities, Independence, Medina, and Loretto, all within Hennepin County. Nevertheless, the watershed currently contains only 4.5% impervious surface area. The lake discharges into Pioneer Creek (Pioneer-Sarah Creek watershed) which flows southwest to the Crow River.

The shore of Lake Independence is fairly developed but large stretches of natural shoreline still exist. There are approximately 200 permanent and seasonal homes along the shoreline. Most of the current residential developments along the southern and eastern shores of Lake Independence are connected to public sewer systems associated with the cities of Maple Plain or Loretto. Sanitary sewers from these residential areas flow to treatment facilities, but street runoff from these areas drains into Lake Independence or associated ponds untreated. Other residential areas within the watershed generally use individual sewage treatment systems (ISTS's).

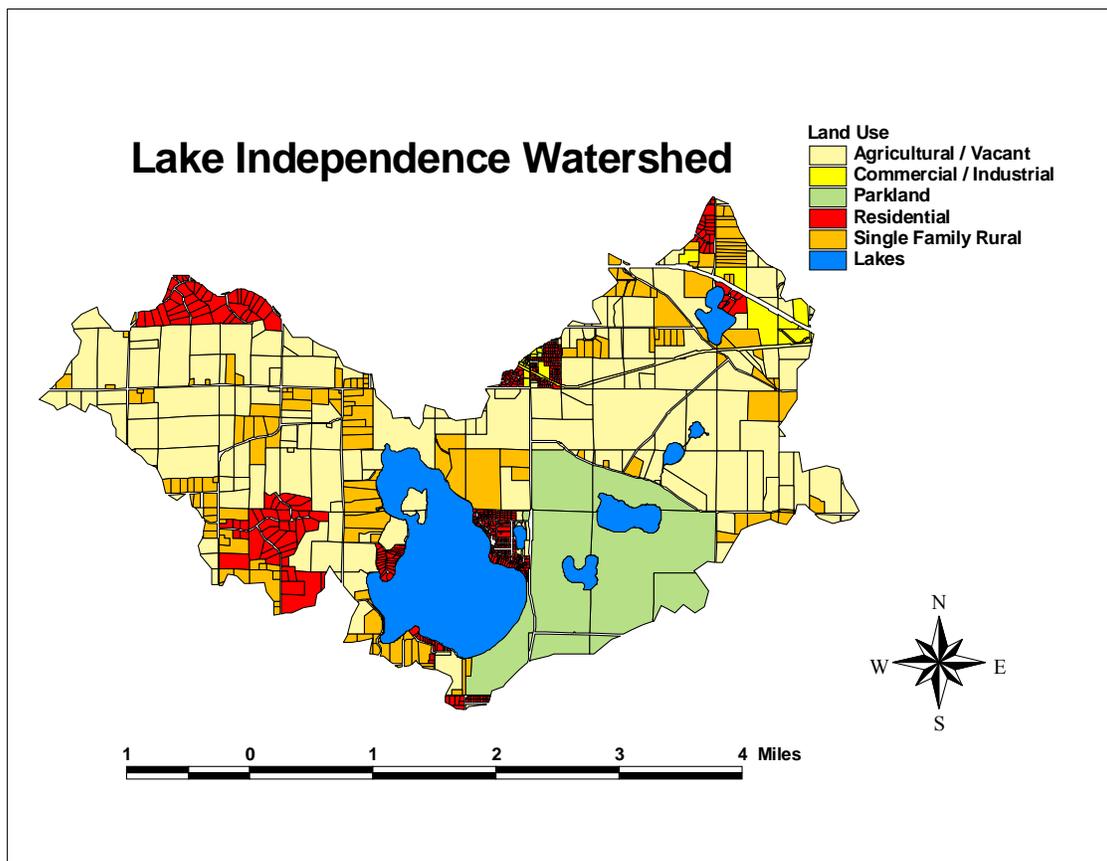


Figure 3. Map detailing the land-use within the Lake Independence watershed in 1999.
Lake Independence Phosphorus TMDL
January 2007

1.3.5 Lake Morphometry and Hydrology

Lake Independence is a relatively deep, 851-acre lake of glacial origin. Table 2 summarizes the lake morphometry and Figure 4 shows the basic bathymetry of Lake Independence. Some groundwater likely enters the lake, but the majority of the water inflow is the result of precipitation runoff from the surrounding watershed that enters at the 5 major inflow points indicated in Figure 5 and Table 3.

Area	851 acres
Shoreline Length	7.08 miles
Volume	15100 acre-feet
Max Depth	58 feet
Mean Depth	17.8 feet
Residence Time	6.4 years

Table 2. Lake Independence morphometry.



Figure 4. Map of Lake Independence showing depth contours in feet.

Lake Independence Surface Hydrology

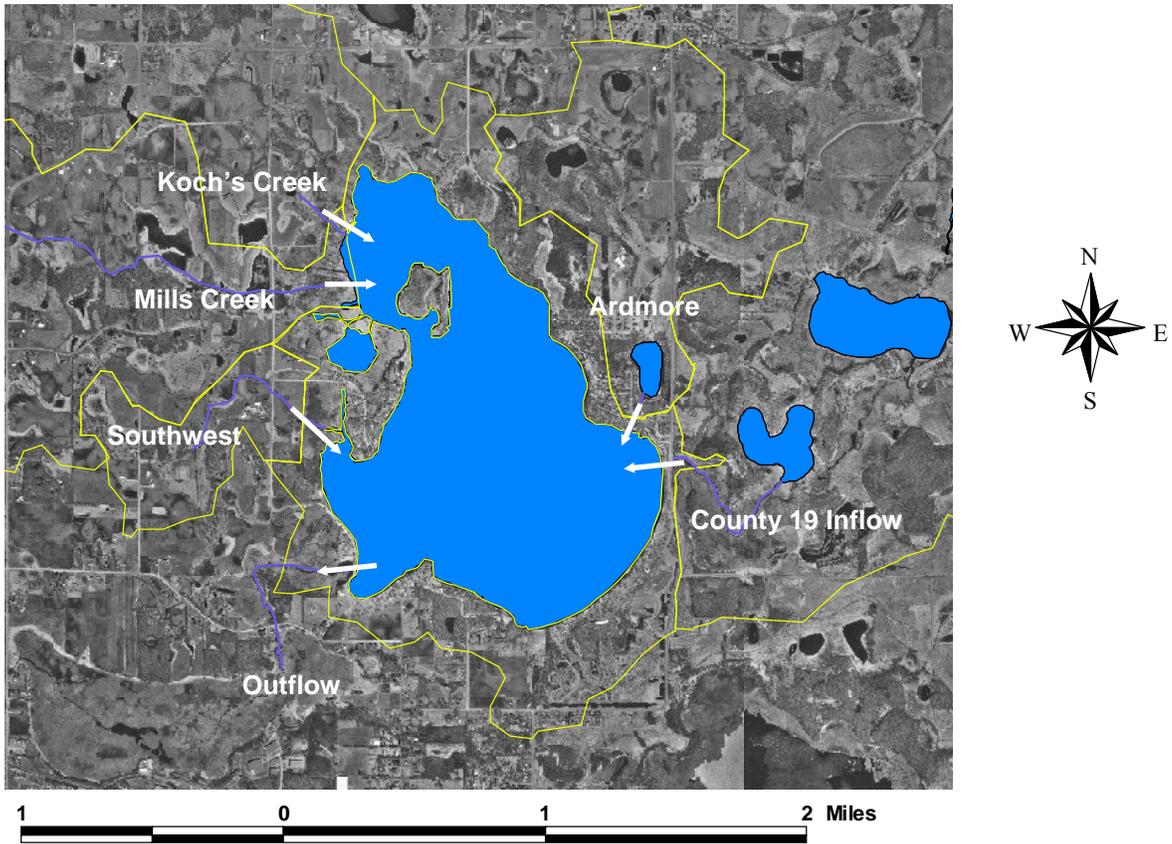


Figure 5. Map detailing the flow of surface water in and out of Lake Independence.

Subwatershed	Area (acres)
Ardmore	523
County 19 Inflow	3660
Koch's Creek	1342
Mill's Creek	1174
Southwest Inflow	215
Direct Runoff	717
Total	7631

Table 3. Summary of subwatershed areas listed by inflow site.

1.3.6 Water Quality

Lake Independence has been monitored biweekly by the Three Rivers Park District since 1990 with the exception of 1992 when no monitoring occurred. Figure 6 shows the typical within-year variations in water quality that Lake Independence experiences. This within-year variation has the potential to obscure between-year trends, but with a sufficiently long monitoring period, water quality trends are more easily detected. The 14 years of water quality data for Lake Independence were collected to enable the detection of between-year changes. The phosphorus and chlorophyll data show no significant trends of improving or declining water quality since 1990. However, the Secchi disk data show a reduction of approximately 3-feet in water clarity since 1990. When compared to computer model predictions based upon reference lakes in the same ecoregion, Lake Independence has consistently exhibited water quality that is sufficiently impaired to warrant remediation. Figure 7 shows the annual summer means for total phosphorus, chlorophyll-a, and water clarity from each monitored year during the period from 1990 to 2002.

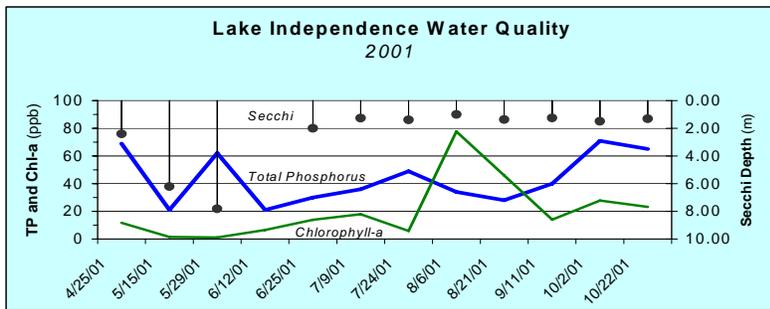


Figure 6. Graph showing typical variation in total phosphorus, chlorophyll-a, and secchi transparency during the 2001 monitoring season.

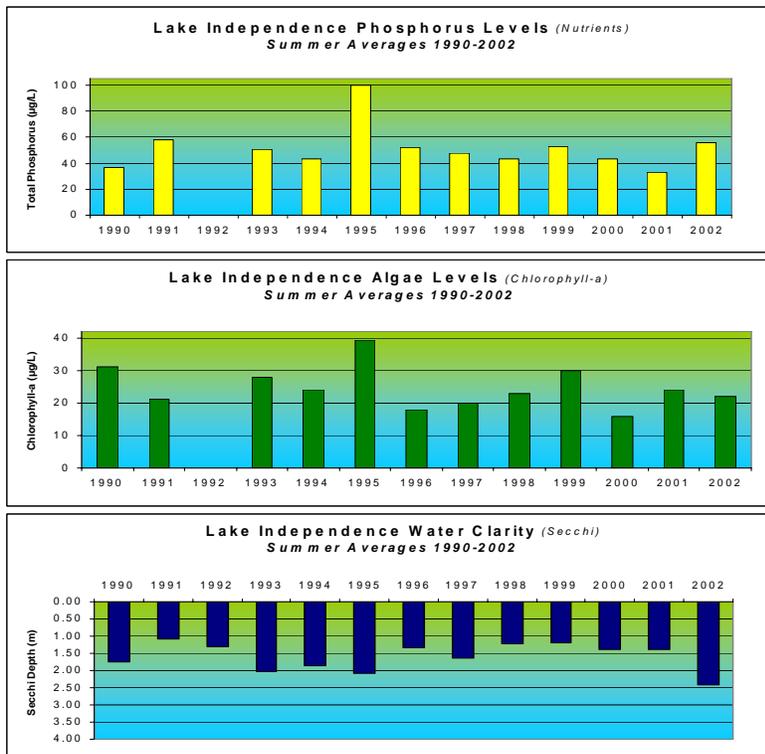


Figure 7. Graphs showing the average annual summer phosphorus (0-2 meter total phosphorus), algae level (0-2 meter chlorophyll-a), and water clarity (secchi depth) for Lake Independence; 1990 to 2002.

1.3.7 Historical Water Quality and Evidence of Impacts from Development

Historical (pre-development) water quality data are not available for Lake Independence, but a review of sediment core data from several nearby lakes may serve as a good indicator of the impacts that development has had upon Lake Independence. Sediment cores from four lakes in Minneapolis and Golden Valley (Lake Calhoun, Lake Harriet, Sweeney Lake, and Twin Lake) were analyzed by the Minnesota Pollution Control Agency to determine the diatom species present within different sections of the core. Historical water quality conditions were estimated by dating the analyzed core sections and applying knowledge of the environmental conditions that favor the different diatom species found within each layer of sediment. Sediment core analysis from all four lakes indicated a large increase (double to triple) of the phosphorus levels in the lake during the last half of the 1800's. This time period coincided with the beginning of significant development within the watersheds of these lakes. It is likely watershed development had very similar effects on the water quality of Lake Independence around the turn of the 20th century.

1.3.8 Fisheries Status

Lake Independence supports a good assemblage of fish and is stocked with walleye and muskellunge in alternating years by the Minnesota Department of Natural Resources. The lake also supports perch, bluegill, largemouth bass, bowfin, carp, pumpkinseed sunfish, hybrid sunfish, and yellow bullhead. Based upon fish surveys conducted in 2001, the DNR lists the lake as having an excellent fishery for black crappie and northern pike. Maintaining a high quality fishery should remain a high priority since the lake is heavily used by anglers.

1.3.9 Aquatic Vegetation

Lake Independence supports an aquatic plant community that includes coontail, bladderwort, bullrush, flat-stem pondweed, sago pondweed, white water lily, bushy pondweed, northern watermilfoil, elodea, and two exotic nuisance species; curlyleaf pondweed and Eurasian watermilfoil. Curlyleaf pondweed has likely been present in the lake since the 1950's and infests most shallow areas of the lake, but Eurasian watermilfoil was not reported in Lake Independence until 1989. In the past 15 years, the exotic milfoil has spread substantially and now infests most of the shallower areas of the lake.

Curlyleaf pondweed presents a slightly different problem than milfoil in that it also has the potential to degrade water quality. This invasive plant grows under the ice and usually forms dense growth by late spring, but then naturally dies off by mid July. This die-off releases a substantial amount of nutrients into the water that can fuel algae blooms and may lead to an overall decline in water clarity. Milfoil generally begins to form dense surface growth by mid-summer, but does not experience the same level of summer die-off as curlyleaf pondweed. Both of these nonnative plant species can lead to impaired usability for motorboats due to very dense growth at the surface of the lake and both have the ability to displace native plant species through shading effects, thus decreasing the quality of available fish habitat and food sources for wildlife.

In order to better track the effects of the curlyleaf and milfoil infestations, the Three Rivers Park District surveyed the aquatic plant community of Lake Independence in 1993, 1995, and 2003 (Table 4). These surveys indicated that curlyleaf pondweed and Eurasian watermilfoil consistently ranked in the top three most common plants in Lake Independence. These surveys were conducted in the late summer of each year after the curly-leaf pondweed had begun to die off. Additional spring plant surveys were conducted in 1998 and 1999 to document the curly-leaf growth. These surveys showed that plants were generally only present in water shallower than 8.0 feet (Figure 8). Under conditions of high water quality, plants would be expected to grow out to areas that were up to 16 feet deep. The lack of plant growth in areas deeper than 8.0 feet is most likely the result of shading that has occurred from the poor summer water clarity in recent years. When water clarity is poor, deeper areas do not receive enough light to support vigorous plant growth. If water clarity in Lake Independence improves, aquatic plants would likely colonize deeper areas of the lake. This may translate into expanding areas of curlyleaf pondweed and Eurasian watermilfoil growth.

	19 93		19 95		20 03	
	Max Depth (m)	Abundance	Max Depth (ft)	Abundance	Max Depth (ft)	Abundance
Eurasian watermilfoil	2.3	Abundant	2.6	Abundant	2.3	Common
Curly-leaf Pondweed	2.1	Abundant	2.1	Common	-	-
Coontail	2.0	Abundant	2.3	Abundant	2.7	Abundant
Flat-stem Pondweed	2.0	Rare	1.8	Common	2.7	Rare
Sago Pondweed	2.0	Rare	-	-	-	-
Elodea	1.2	Rare	1.8	Common	-	-
Bushy Pondweed	2.3	Rare	-	-	-	-
Leafy Pondweed	-	-	1.5	Rare	1.5	Rare
White Lily	1.2	Rare	0.9	Rare	1.0	Rare
Yellow Lily	-	-	-	-	0.9	Rare
Northern Watermilfoil	1.2	Rare	2.6	Rare	-	-
Bur-reed	-	-	0.9	Rare	0.5	Rare
Chara	1.8	Rare	2.0	Rare	-	-

Table 4. Summary of Lake Independence aquatic plant surveys for 1993, 1995, and 2003. (Rare= 0-20% occurrence, Common = 20-50%, Abundant= 50-100%)

Lake Independence

Aquatic Vegetation Survey



Figure 8. Map showing areas of Lake Independence where aquatic plants were encountered in 1993, 1995, and 2003. Encountered species are listed in order of decreasing abundance.

1.3.10 Water Level

The average water level elevation for Lake Independence over the past ten years has been 957.32 feet above sea level. The ordinary high water elevation (OHW) as listed on the Minnesota Department of Natural Resources web site is 956.8 feet. In the past three years, Lake Independence has experienced elevated water levels due to abnormally high amounts of rainfall (Figure 9). 2002 was extremely wet, and consequently the water level of Lake Independence remained high for a majority of the summer. Elevated water levels may be responsible for increased shoreline erosion, especially in areas exposed to severe wave action from wind or motorboat wake. The water level in the lake is controlled by a concrete spillway located under the bridge on Independence Road at the extreme southwest corner of the lake. The spillway is set to maintain a water surface elevation of 956.5 feet.

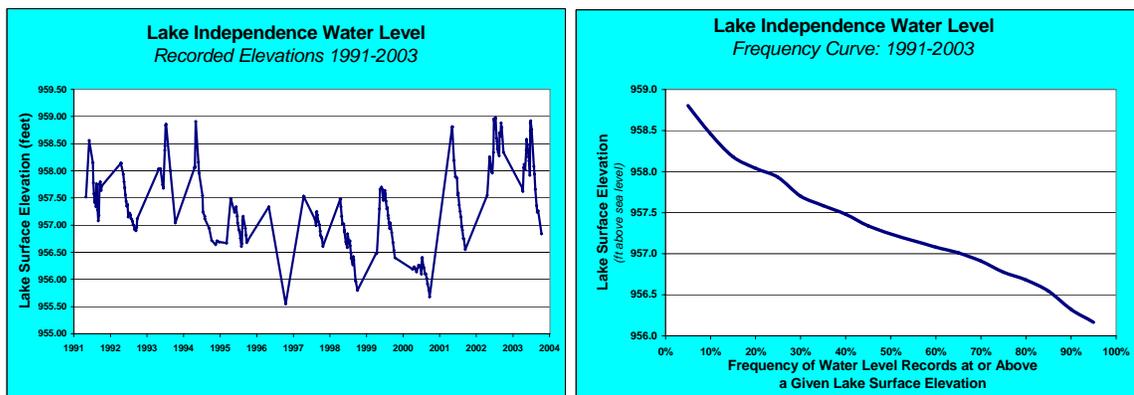


Figure 9. Graphs showing the recorded water level of Lake Independence during the period from 1991 to 2003 and the frequency of occurrence for water levels during that same period.

1.4 303(d) Listing

In 2002, the lake was added to the Minnesota 303(d) impaired waters list as a result of mean summer phosphorus values that exceeded the 40 ppb phosphorus standard for Class 2 recreational waters. Lake Independence was listed as having impaired water recreation.

2.0 WATER QUALITY STANDARDS AND NUMERIC TARGETS

2.1 Water Quality Standards for Designated Uses

Lake Independence has generally experienced moderate to heavy recreational use in the last twenty years. In addition to use by shoreline homeowners, the lake is regularly visited by many people from the surrounding metropolitan and rural areas. The majority of these visitors access Lake Independence via the Baker Regional Park Reserve located along a one-mile stretch of shoreline at the southeastern corner of the lake. The park includes two swimming beaches, a public boat launch, a fishing pier, canoe rental facility, picnic area, playground, and campground. In 2003, Baker Park accommodated over 300,000 visitors, of which 51% reported using Lake Independence for swimming, 34% for boating, and 25% for fishing. The lake is also used heavily for ice fishing during the winter months.

The Three Rivers Park District master plan for Baker Park incorporates swimming, boating, and fishing as primary designated uses for the park and contiguous portion of Lake Independence. This master plan was reviewed and approved by the Metropolitan Council. In order to maintain water quality conditions that warrant full support of these primary designated uses, the Three Rivers Park District has adopted a phosphorus standard of 36 ppb for Lake Independence.

Lake Independence is designated as a class 2B water. The lake is located in the North Central Hardwood Forest (NCHF) ecoregion. The lake is considered a deep lake. Currently, MPCA is undergoing revisions to some of the water quality standards presented in Minn. R. Chap. 7050 to include numeric targets for lakes. The proposed numeric phosphorus standard for the Class 2B deep lakes in the NCHF ecoregion is (40 µg/L).

Minnesota's standards include narrative criteria for nutrients which limits the quantity of nutrients which may enter the waters. Minnesota's standards (Minn. R. Chap. 7050. Subp. 3 & Subp. 5) state that all Class 2 waters of the state shall be free from any material increase in undesirable slime growths or aquatic plants including algae. Since MPCA currently doesn't have statewide numeric criteria for nutrients, the MPCA's proposed phosphorus standard for the Class 2B deep lakes in the NCHF ecoregion (40 µg/L) is being used as the basis for the proposed nutrient TMDL numeric target in the Lake Independence TMDL. MPCA proposed numeric standards for phosphorus, even though not yet approved, are designed to meet the current applicable narrative water quality standards and designated uses. Since the numeric target for the Lake Independence TMDL (36 µg/L of phosphorus) is 10% lower than the MPCA proposed phosphorus standard (40 µg/L), the TMDL target will also meet the applicable water quality standard for nutrients.

2.2 Analysis of Impairment

During the period 1990 to 2003, the summer mean total phosphorus concentration exceeded 40 ug/L in ten out of twelve years. Mean total phosphorus concentrations were calculated from a minimum of nine samples in each year. The data showed that Lake Independence had a nutrient concentration that did not meet standards for full support of its designated recreational uses. Consequently, the lake was placed on the 303(d) list as an impaired waterbody.

2.2.1 Critical Conditions

The critical environmental conditions for the phosphorus impairments in Lake Independence correspond to the summer months' period, when observed phosphorus concentrations in the lake are highest. Surface runoff contains nutrients which are transported into the lake during summer rain events. Nutrients can also be internally loaded to the lake, resulting from aquatic plant senescence or entrainment of phosphorus-rich hypolimnetic water during summer mixing events.

2.3 Decision Process and Basis for the Adopted Numeric Phosphorus Target

To better define a threshold level of acceptable impairment, the Minnesota Pollution Control Agency (MPCA), Metropolitan Council, and Three Rivers Park District conducted lake user surveys to correlate public impressions of lake usability with more objective water quality measurements. The results of these surveys indicated that 75% of those surveyed felt comfortable swimming in metro-area lakes that had mean summer total phosphorus levels at or below 36 ppb. While there is no inherent health risk at higher phosphorus levels, the 36 ppb threshold was used to define the level where phosphorus begins to impair recreational usability of a lake, specifically for water contact recreation. For this reason, a target phosphorus concentration of 36 ppb was adopted for Lake Independence by the Three Rivers Park District Board. This target is 11 ppb lower than the average summer concentration observed during the monitored period (1990 to 2004), and would represent a 23% reduction in the mean summer phosphorus level of Lake Independence when compared to current conditions.

The MINLEAP computer model was used to predict the expected water quality of Lake Independence if it had experienced "typical" nutrient inflows similar to those measured for unimpaired lakes in east central Minnesota. The model predicted markedly better water quality than what had been observed in Lake Independence during the fourteen-year monitoring period from 1990 to 2004 (Table 5).

	OBSERVED	PREDICTED (MINLEAP)
Water Clarity (secchi)	1.6 meters (5.25 feet)	2.0 meters (6.6 feet)
Chlorophyll-a	25.0 ppb	9.7 ppb
Total Phosphorus	47 ppb	31 ppb
Total Nitrogen	1324 ppb	NA
Trophic State Index	58.4	52.3

Table 5. Summary of observed average summer water quality from 1990 to 2004 and predicted water quality values (MINLEAP) for Lake Independence.

The model prediction of 31 ppb for mean summer phosphorus concentration is relatively close to the recommended target concentration of 36 ppb. This means that the target concentration is likely attainable based upon local climate, soils, and lake morphometry. The potential for such improvement is further supported by the pre-development historical water quality estimates obtained from sediment core analysis (see 1.3.7).

3.0 PHOSPHORUS SOURCE ASSESSMENT

3.1 Phosphorus Source Inventory

The computer model simulations that incorporated the monitored inflow results and lake water quality data indicated that storm water runoff was the primary source of nutrients leading to the impaired water quality of Lake Independence. The models also showed that the majority of the external nutrient load could be attributed to non-point sources associated with crop agriculture, livestock rearing, and urban and residential runoff (Table 6). Additionally, models showed that there is likely a substantial amount of internal phosphorus loading from curlyleaf pondweed senescence and periodic entrainment of nutrient-rich hypolimnetic water into the epilimnion during thunderstorms and windy days. The relative importance of the urban and residential runoff may increase markedly in the future as vacant and agricultural lands are developed.

Identified Phosphorus Sources
Livestock
Vacant & Crop Ag
Urban Developed
Direct Aerial Load
Rural Developed
Loretto Sewage Treatment
Shoreline Erosion
Park
Geese
Failing Septic Systems
Deer
Golf Course
Internal Phosphorus Load

Table 6. Summary of identified sources contributing phosphorus to Lake Independence.

3.2 Assessment and Analysis of Phosphorus Contribution from Identified Sources

The subwatersheds within the Lake Independence watershed exhibited different land use patterns; the western areas were generally more agricultural while the eastern subwatersheds contained substantially more urban, residential, and parkland areas. Initial assessments and analyses of phosphorus transport within the Lake Independence watershed were focused on a subwatershed scale. Modeling the entire watershed as a collection of subwatersheds allowed for better estimation of nutrient contributions associated with each land use type and better calibration of computer models based upon field data collected at the inflow points from each subwatershed. This allowed for more accurate division of the total watershed load when assigning individual load and wasteload allocations based upon the area and geographic location of individual land uses within each municipality.

3.2.1 Watershed Modeling

The vast majority of the water that runs off of the watershed enters Lake Independence via several small creeks. These creeks were monitored independently to determine differences in the nutrient loading from different areas of the watershed and offer insight into the relative importance of different land uses in the overall lake nutrient budget. The four major inflows were monitored in 1996, 1997, and 2001 (Figure 5 and Table 3). This monitoring included the collection of continuous flow data and flow-weighted composite samples from a range of flow events.

The collected data were used to develop calibrated FLUX and BATHTUB models that estimated total nutrient inflow from each subwatershed based upon land use characteristics, local climate, and literature values for nutrient export from given land use areas (Table 7 and Figure 10). These models predicted that 1,475 pounds of phosphorus and 7,301 pounds of nitrogen entered Lake Independence annually from the surrounding watershed. The largest loadings occurred at County Road 19, Koch's Creek, and Mill's Creek.

Subwatershed Area	Water Inflow <i>acre-feet/year</i>	Average TP Concentration <i>ppb</i>	Estimated External TP Load <i>lb/year</i>	Average TN Concentration <i>ppb</i>	Estimated External TN Load <i>lb/year</i>
Ardmore	185	181	96	2440	1299
County 19	1119	122	385	1434	4515
Koch's Creek	285	314	228	4709	3386
Mill's Creek	363	482	483	3811	3825
Southwest	199	300	148	4000	1971
Direct Runoff	107	471	134	3874	1100
Totals	2258	-	1475	-	7301

Table 7. Summary of the FLUX and BATHTUB model outputs for Lake Independence based upon current inflow.

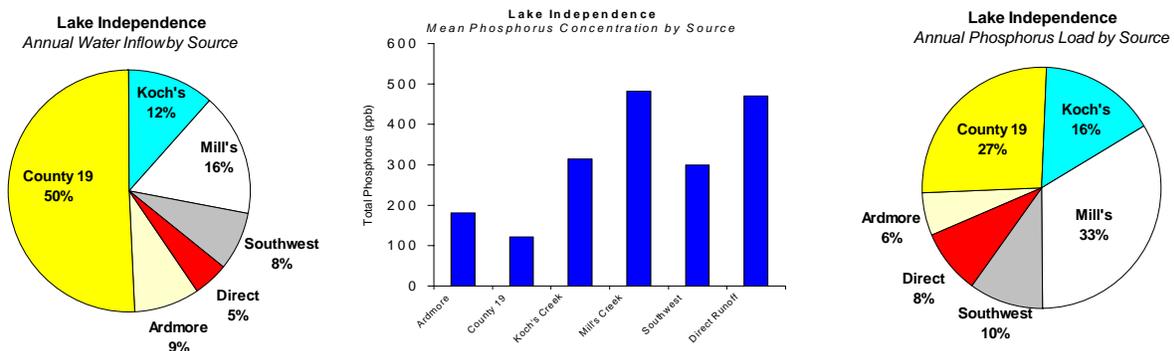


Figure 10. Graphs showing the relative percent of the total annual water volume and phosphorus load entering Lake Independence by subwatershed as well as the annual mean total phosphorus concentration for each monitored inflow site (as determined by FLUX model).

The phosphorus entering Lake Independence in the inflow streams originates from many sources. A sizeable amount of research has been conducted over the last few decades to determine phosphorus runoff rates from different land use types and activities, including the Environmental Protection Agency, numerous universities, state agencies, and others (EPA 1980). Phosphorus export rates reported from these studies were used to estimate the phosphorus export from each subwatershed in the Lake Independence watershed (Table 7 and Figure 10).

3.2.2 GIS Model for Assessment of Phosphorus Contribution from Livestock

The portion of the phosphorus produced by livestock that actually flows into Lake Independence is likely reduced significantly from the initial source export values by intervening management practices, wetlands, infiltration areas, and biological uptake as the phosphorus moves through the watershed on its way to the lake. To estimate the phosphorus contribution from livestock, Three Rivers Park District staff developed a Geographic Information System (GIS) model that identified all parcels within the watershed containing livestock, calculated the area of land actually used for pasture and feedlot, and estimated the potential that each site posed for loading phosphorus to the lake. The model assessed this *loading potential* for each individual site by considering the slope of the land, proximity to creeks, and distance from Lake Independence. Sites on steep slopes, closest to creeks, and closest to the lake would be expected to contribute more phosphorus to the lake and thus received the highest loading potential scores. The estimated loading potential for each livestock site was then used to calculate the percent of the phosphorus flowing directly off of individual sites that would be expected to flow into Lake Independence. Figure 11 and Table 8 summarize the results of this model for livestock areas within the Lake Independence watershed.

Using a combination of GIS assessments and inflow model results, it was estimated that 34% of the phosphorus entering Lake Independence originated from livestock, 24% from vacant and agricultural cropland, and 23% from urban runoff. The remaining 19% was attributed to direct aerial loading, rural development, sewage treatment effluent (public and private), wildlife, erosion, and runoff from park and golf course areas (Figure 12 and Table 10).

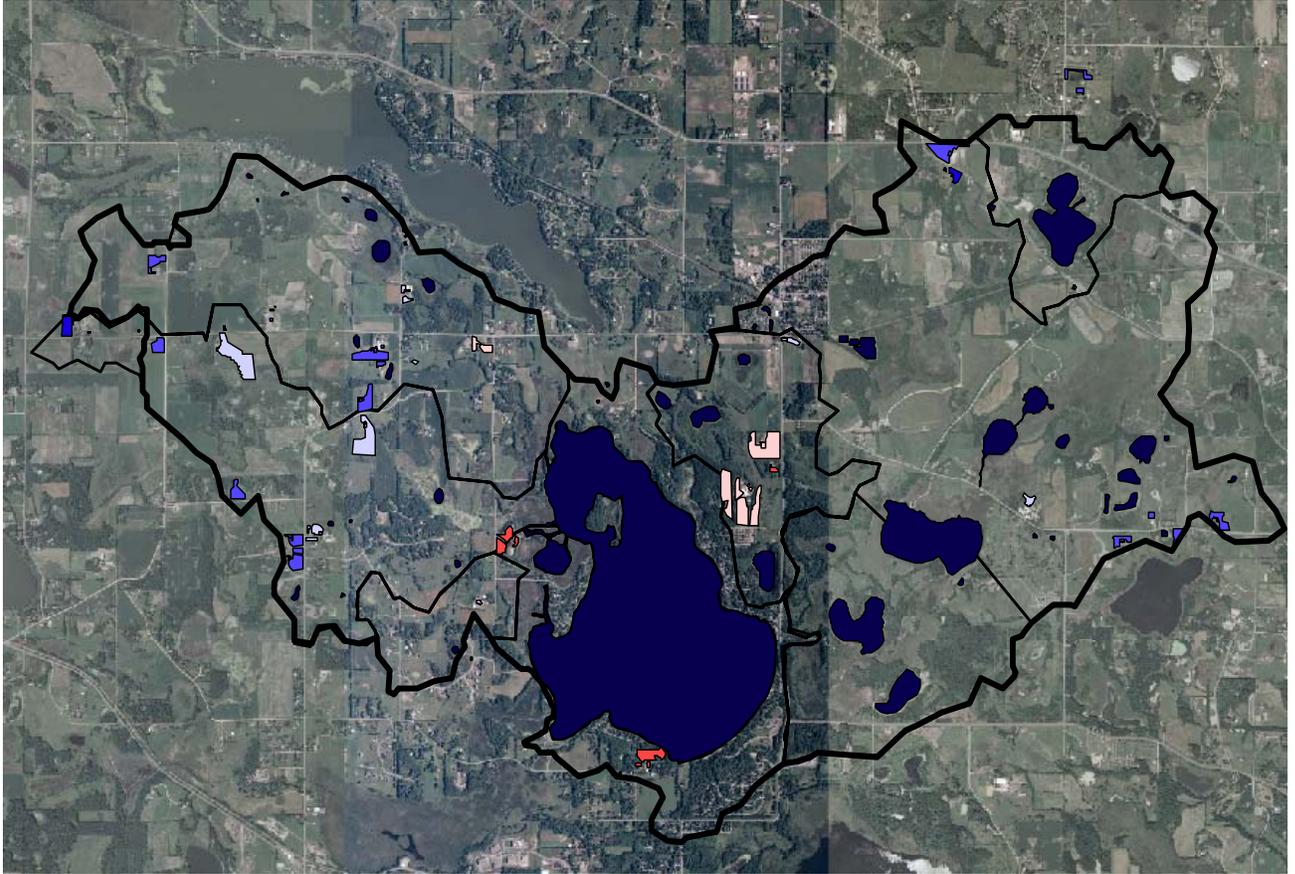


Figure 11. Map showing areas of pasture and feedlot within the Lake Independence watershed color coded to indicate the loading potential for each site (bright blue sites have the lowest potential, red the highest)

Property ID#	Manure P-Content <i>lbs/year</i>	P-Load to Lake Independence <i>lbs/year</i>	P-Load Rank
23	3312	166	1
20	2665	133	2
15	2535	127	3
11	558	79	4
24	1014	51	5
28	1014	51	6
17	316	41	7
9	507	25	8
26	355	18	9
1	316	16	10

Table 8. Summary of calculated manure production and adjusted P-loadings for the top ten livestock source areas based upon GIS watershed modeling.

3.2.3 Loretto Wastewater Treatment Facility Effluent Discharge

The municipal wastewater treatment facility in Loretto, Minnesota is currently permitted to periodically release treated sewage effluent into a wetland complex that flows to Spurzem Lake within the Lake Independence watershed. Spurzem Lake is hydrologically connected to Lake Independence via a small intermediate lake and a series of creeks that flow approximately 2 kilometers to Lake Independence. In recent years, the Loretto treatment facility has been applying alum to their treatment ponds prior to discharge. This measure has drastically reduced the concentration of phosphorus in the effluent. Currently, the treatment facility is permitted to discharge up to 7 lbs of phosphorus per day, at a maximum effluent concentration of 1000 ppb. Actual discharges have been reported annually to the MPCA and are given in Table 6 below.

Discharge Period	Discharged Volume (million gallons)	Phosphorus Concentration (ppb)	Exported Phosphorus (Lbs)
April 2001	2.24	1090	20.4
Sept 2001	1.03	2730	23.5
Nov 2001	7.28	260	15.5
May 2002	9.90	380	31.4
Sept 2002	1.60	1200	16.0
Nov 2002	8.00	490	32.7

Table 9. Reported effluent discharge volumes and concentrations reported by the Loretto Municipal Wastewater Treatment Facility to the MPCA in 2001 and 2002. Also included are the calculated loads of phosphorus for each reported discharge. Note that discharge periods may include multiple days.

In 2001 and 2002, the treatment facility reported discharging 59 and 80 lbs. of phosphorus respectively, or 70 lbs. as a two-year annual average. Due to some additional removal by small lakes and wetland systems downstream (estimated 25% removal of phosphorus), the loading to Lake Independence from this point source was estimated to be 53 lbs/year. Spurzem Lake, which is directly downstream from the effluent discharge point, has experienced substantially higher nutrient levels and poorer water quality than expected based upon ecoregion and lake morphometry. While the effluent discharge from the treatment facility appears to be leading to nutrient enrichment of downstream waters, the latest measures used by the Loretto treatment facility to reduce the phosphorus concentration in discharged effluent (alum treatment and settling ponds) have effectively reduced the potential impact of such discharges to Lake Independence. Stricter adherence to the 1000 ppb concentration limit would yield even greater reductions.

3.2.4 Agricultural Non-Point Sources

The stream data collected in 1996, 1997, and 2001 indicated that the highest nutrient concentrations occurred in Mill's Creek and Koch's Creek (Table 7). Recent studies conducted by the Three Rivers Park District showed that these two subwatersheds had substantially more area devoted to livestock rearing and crop agriculture than the other subwatersheds. This suggests that these land uses may be major contributors to the nutrient levels in these two creeks. In 1997 Three Rivers Park District staff determined that there were an estimated 572 livestock animals within these subwatersheds that produced 19 million pounds of wet manure, containing 16,755 lbs of phosphorus, and 85,186 lbs of nitrogen. More intensive surveys and analysis in

2005 determined that there was a conservative estimate of 298 animal units within the watershed which annually produced 11.3 million pounds of wet manure, containing 14,060 lbs of phosphorus, and 62,311 lbs of nitrogen. 2005 estimates for manure production and phosphorus content were revised from those used in the 1997 survey to reflect the latest data on manure characteristics from different livestock. The exact amount of this manure that washes into Lake Independence is difficult to determine, but research and computer model simulations of the Lake Independence watershed suggest that most of the livestock production areas within the watershed are potential sources of nutrients that contribute to the water quality degradation of the lake. These agricultural non-point sources would be an attractive management target if cost-effective ways to control nutrient export can be implemented.

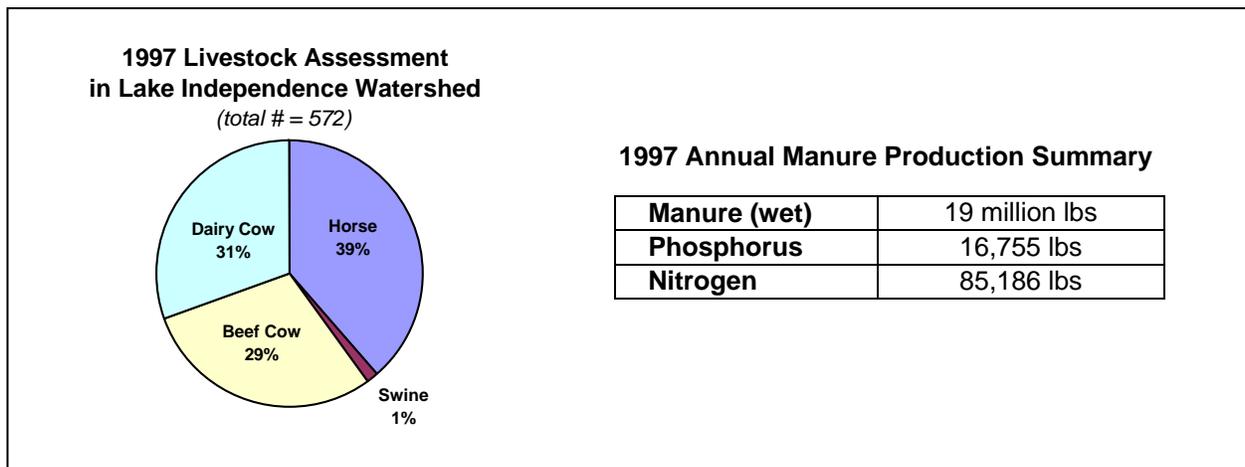


Figure 10. Summary of livestock animals and their associated annual manure production within the Lake Independence Watershed. Based upon a 1997 survey of livestock areas conducted by the Suburban Hennepin Regional Park District and literature values for manure production (MSUE).

3.2.5 Urban and Residential Sources

As of 2004, several residential areas drain to Lake Independence via municipal storm water systems. Some of this runoff is directed into small ponds where some nutrient removal occurs, but much of the area drains directly to the lake in an untreated state. Nutrient loading from these areas was estimated based upon monitored water quality data, literature nutrient export values for residential land use in Minnesota, and computer model estimates (Table 7).

3.2.6 Failing Individual Sewage Treatment Systems (ISTS's)

Though many of the homes near Lake Independence are connected to city sewage disposal infrastructure, many private septic systems still exist. Many of these systems are likely failing to some degree, but without comprehensive inspections, it is difficult to know the amount of phosphorus loading that can be attributed to failing systems. We conservatively estimated that about 0.5% of the current external load could be attributed to failing ISTS's (8 pounds).

3.2.7 Nutrient Recycling within Lake Independence (Internal Phosphorus Load)

Lake Independence regularly experiences stratification that is sufficiently stable to promote the near total loss of oxygen below the thermocline (Figure 13). This typically results in a significant accumulation of phosphorus, released from the sediments, in deeper areas of the lake. Data collected by an automated sampling raft (RUSS unit) in 1999 and 2000 indicated that the lake often experienced significant partial mixing during thunderstorms and windy days. This periodic partial destratification mobilized phosphorus that had accumulated in the deeper waters and mixed it into the surface layer of the lake where it became available to algae and plants. Additional internal loading may occur due to the substantial release of phosphorus when curlyleaf pondweed dies off and begins to break down in early summer.

Internal phosphorus recycling has likely been a major factor in producing the frequent algae blooms that have impaired the water quality of Lake Independence in recent decades. Management alternatives that focus on reducing this internal nutrient recycling would likely result in a drastic nutrient reduction and greatly improved water quality within the lake, but the longevity of such a treatment would likely be shortened substantially if the external loading of phosphorus was not reduced first.

Three Rivers Park District used a calibrated BACHMAN-CANFIELD model to estimate the total annual phosphorus load to Lake Independence. It predicted that the lake would have to receive 2,381 lbs of phosphorus loading per year to explain the observed water quality. By subtracting the estimated external load (1,699 lbs.) from this predicted total load, the internal nutrient recycling was estimated at 682 lbs/year or 29% of the total annual phosphorus load.

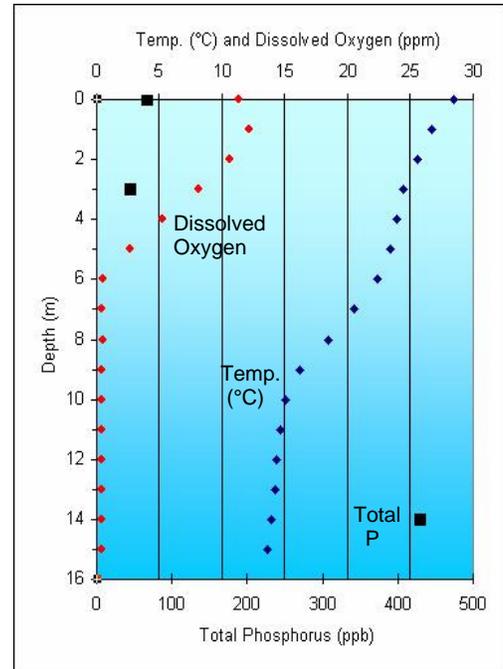


Figure 13. Water column profile of Lake Independence from August of 2000 showing lake stratification

3.2.8 Conclusions

Figure 12 and Table 10 summarize the final estimates of phosphorus loading to Lake Independence from each of the identified sources.

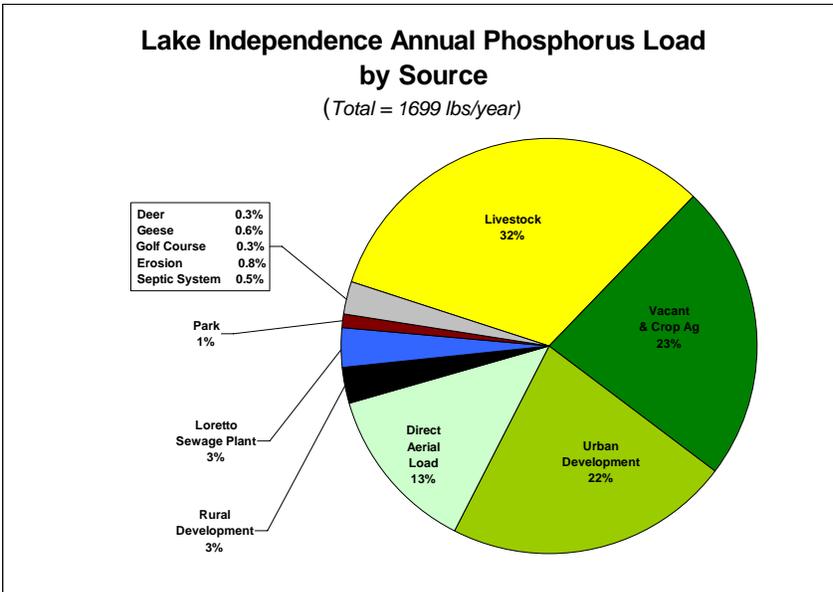


Figure 12. Lake Independence external phosphorus loading by source.

Phosphorus Source	P-Loading to Lake (lbs/year)
Livestock	545
Vacant & Crop Ag	392
Urban Developed	374
Direct Aerial Load	224
Rural Developed	51
Loretto Sewage Treatment	53
Shoreline Erosion	14
Park	17
Geese	10
Failing Septic Systems	8
Deer	5
Golf Course	5
Total External P Load	1699 lbs/year
Internal Phosphorus Load	682 lbs/year
Total P Loading	2381 lbs/year

Table 10. Estimated annual phosphorus load to Lake Independence from identified sources.

4.0 RELATING ADOPTED PHOSPHORUS TARGET TO SOURCE LOADS

4.1 Computer Model Selection and Development

Computer models were used to translate the target in-lake phosphorus concentration of 36 ppb into a target reduction of phosphorus loading from the watershed. Three lake response models were used to determine the final target phosphorus load reduction: MINLEAP, BATHTUB, and Canfield and Bachman 1979.

The MINLEAP model was used to quantify the feasibility of the target goal. MINLEAP estimated the expected water quality of Lake Independence assuming “typical” nutrient inflows based upon basin characteristics, basic water chemistry, and geographic location (based largely upon the ecoregion concept). The model predicted an average summer phosphorus concentration of 31 ppb. This is markedly better water quality than what had been observed in Lake Independence during the fourteen-year monitoring period from 1990 to 2004 (Table 5).

The Canfield and Bachman (1979) model was used to estimate the total annual phosphorus load necessary to achieve the observed in-lake water quality considering annual precipitation, lake morphometry, and lake water residence time. The Canfield and Bachman (1979) model was used to estimate the total phosphorus load needed to explain the observed water quality, as well as the amount of phosphorus load reduction needed to achieve the target in-lake phosphorus concentration of 36 ppb. This was accomplished by calibrating the model with observed field data to estimate the total phosphorus load, followed by sequential reduction of the phosphorus load value until the desired in-lake concentration was achieved. In addition, the final output was used to estimate internal phosphorus loading by subtracting the estimated external load (BATHTUB model output) from the total load calculated by Canfield and Bachman (1979).

The BATHTUB model was used to estimate nutrient inflows from each of the major subwatersheds within the entire Lake Independence drainage area. By entering the areas for individual land-use categories, as determined by GIS mapping, and literature values for typical nutrient export from each land-use category, we were able to develop a nutrient runoff model for the entire watershed. This model was then calibrated with storm water inflow data collected in 2001 and lake water quality data from 1990 to 2003. The final BATHTUB model allowed us to estimate the relative phosphorus contribution of each land-use category within the watershed.

4.2 Conclusions

The current estimated phosphorus load to Lake Independence based upon field monitoring and computer model results is 2,381 pounds per year (1,699 lbs/year external, and 682 lbs/year internal) assuming normal annual precipitation. This translates to 6.52 lbs/day (4.04 lbs/day external, and 2.48 lbs/day internal). To reach the goal of 36 ppb for in-lake phosphorus concentration, the Canfield and Bachman (1979) model predicted that the annual phosphorus load to Lake Independence would need to be reduced to 1300 lbs/year (3.6 lbs/day). This translated to a total reduction of 1,081 lbs/year (2.84 lbs/day), or a 45% reduction from the current total annual phosphorus load estimate of 2,381 lbs/year.

5.0 PHOSPHORUS TMDL AND LOAD ALLOCATIONS

5.1 Total Maximum Daily Load Calculation

The numerical TMDL for Lake Independence was calculated as the sum of the *Waste Load Allocation* (WLA), the *Load Allocation* (LA) and the *Margin of Safety* (MOS), expressed as phosphorus mass per unit time according to the following formula:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS}$$

5.2 Wasteload Allocations (WLA's)

All three of the municipalities within the Lake Independence watershed have been designated as *Mandatory Municipal Separate Storm Sewer Systems* (MS4's) by the Minnesota Pollution Control Agency. As a result, the allowable discharges associated with each of these municipalities have been designated as *wasteload allocations* (Tables 11). The target phosphorus reductions necessary to comply with the allowed wasteload allocations total 872 lbs/year from the three municipalities. The Loretto wastewater treatment plant discharge to a wetland is included in the Wasteload Allocation shown in Table 11.

The Cities of Independence, Loretto, and Medina and Hennepin County and MnDOT Metro District are covered under the Phase II General NPDES Stormwater Permit – MNR04000. The Unique permit numbers assigned to these cities, Hennepin County and MnDOT Metro District are as follows;

- Independence – MS400095
- Loretto – MS400030
- Medina – MS400105
- Hennepin County – MS400138
- MnDOT Metro District – MS400170

The cities have all been assigned Wasteload allocations for this Lake Independence Excess Nutrient TMDL as shown in Table 11. However, Hennepin County and MnDOT Metro District are considered de minimus in regard to phosphorus and are not assigned a Wasteload allocation in this TMDL.

The City of Loretto owns and operates a WWTP – NPDES number MN0023990, which has been assigned a Wasteload of zero.

5.3 Load Allocations (LA's)

Internal loading of phosphorus, resulting from aquatic plant senescence or entrainment of phosphorus-rich hypolimnetic water during summer mixing events, has been designated as a *load allocation* (table 12). The loading of phosphorus from rainfall directly onto the lake is also included as a load allocation. Internal loading of phosphorus is predicted to decrease by 209 lbs/year as external loads are reduced.

Phosphorus Loading - Wasteload Allocation (WLA)

Assigned Source	Existing Phosphorus Loading		Waste Load Phosphorus Allocation		Load Reduction (lbs)
	(lbs/year)	(lbs/day)	(lbs/year)	(lbs/day)	
Independence	891	2.44	356	0.95	535
Loretto	69	0.19	16	0.07	53
Medina	515	1.41	231	0.63	284
Total (external only)	1475	4.04	603	1.65	872

Table 11. Summary of total phosphorus loading and waste load allocations for individual sources within the Lake Independence watershed.

Phosphorus Loading - Load Allocation (LA)

Assigned Source	Existing Phosphorus Loading		Phosphorus Load Allocation		Load Reduction (lbs)
	(lbs/year)	(lbs/day)	(lbs/year)	(lbs/day)	
Internal Loading	682	1.87	473	1.30	209
Direct Aerial Loading	224	0.61	224	0.61	0
Total	906	2.48	697	1.91	209

Table 12. Summary of total phosphorus load allocations for individual sources within the Lake Independence watershed.

Proposed Annual Loading Reductions by Source for Individual Municipalities

Municipality	Sewage Effluent (lbs/year)	Livestock (lbs/year)	ISTS's (lbs/year)	Vacant & Ag (lbs/year)	Urban & Res. (lbs/year)	Geese (lbs/year)
Independence	0	260	6	187	80	8
Loretto	53	0	0	0	0	0
Medina	0	110	2	97	66	3
Total Reduction	53	370	8	284	146	11

Table 13. Summary proposed annual reductions in phosphorus loading by source for individual municipalities within the Lake Independence watershed.

5.4 Seasonal Variation

Nutrient loads to Lake Independence are strongly influenced by the precipitation pattern which has significant annual variability. Loadings to the lake were estimated for “average year” rainfall volumes, 30-inches for Hennepin County. When precipitation exceeds average conditions, nutrient loading to the lake increases. Tables 14 and 15 summarize the modeled sensitivity of in-lake phosphorus to changes in annual precipitation.

Modeled Sensitivity to Changes in Annual Precipitation (*Based upon Observed Phosphorus Loading*)

Annual Precip. (inches)	Inflow Volume (acre-feet)	External P-Load (lbs/year)	Internal P-Load (lbs/year)	Predicted In-Lake P (ppb)
26	1974	1389	682	45.4
28	2126	1544	682	46.9
30	2278	1699	682	48.4
32	2430	1854	682	49.9
34	2582	2009	682	51.3

Table 14. Summary of effects that deviation from normal annual precipitation would have upon inflow volume (PONDNET), phosphorus loading (PONDNET), and in-lake phosphorus concentrations (LTROPHIC) based upon observed phosphorus loading to Lake Independence.

Modeled Sensitivity to Changes in Annual Precipitation (*Based upon Proposed Phosphorus Load Reductions*)

Annual Precip. (inches)	Inflow Volume (acre-feet)	External P-Load (lbs/year)	MOS (lbs/year)	Internal P-Load (lbs/year)	Predicted In-Lake P (ppb)
26	1974	517	35	473	29.0
28	2126	672	35	473	31.4
30	2728	827	35	473	33.5
32	2430	982	35	473	35.6
34	2582	1137	35	473	37.5

Table 15. Summary of effects that deviation from normal annual precipitation would have upon inflow volume (PONDNET), phosphorus loading (PONDNET), and in-lake phosphorus concentrations (Bachman-Canfield) based upon proposed reductions in annual phosphorus loading to Lake Independence.

5.5 Margin of Safety (MOS)

The Lake Independence TMDL incorporated a margin of safety (MOS) in the pollutant load reduction requirements by setting an aggressive water quality goal that exceeded the mandated standard for defining impaired waters. As previously noted, the nutrient load reductions were established to achieve an in-lake phosphorus concentration of 36 ppb. This target concentration is 10% lower than the TMDL requirement of 40 ppb. An MOS value of 35 lbs/year was incorporated into the TMDL formula to account for effects of rainfall variability. Computer model simulations indicated that for years with near-normal average rainfall (within 13% of normal), the in-lake phosphorus concentration would not be expected to exceed the 40 ppb standard given the external load reductions proposed in this TMDL (Table 11). The calculated TMDL shown below will reduce the in-lake phosphorus concentration to less than 40 ug/L, meeting the Minnesota water quality standard. Achieving the target of 1300 lbs/year, will reduce the in-lake concentration to 36 ug/L. The MOS was therefore calculated as 35 lbs/year.

5.6 Future Changes in the Watershed: Non-degradation Policy

The *Pioneer-Sarah Creek Watershed Commission 2nd Generation Plan* includes a non-degradation policy (section VI, A.21) for future land development that requires any proposed development activities within the watershed to meet strict guidelines to protect water quality and prevent increases in runoff and nutrient loading. In addition, all three municipalities have been

designated as MS4 communities, and nutrient loading from future developments is included in the Wasteload Allocation covered under NPDES Regulations.

5.7 Final Phosphorus TMDL

Inserting the target phosphorus load reductions detailed in this report, the numerical TMDL for Lake Independence was determined to be:

$$\text{(Annual)} \quad \text{TMDL} = \frac{\text{WLA} + \text{LA} + \text{MOS}}{\text{Year}} = \mathbf{1,335 \text{ lbs/year} = 603 \text{ lbs/year} + 697 \text{ lbs/year} + 35 \text{ lbs/year}}$$

$$\text{(Daily)} \quad \text{TMDL} = \mathbf{3.66 \text{ lbs/day} = 1.65 \text{ lbs/day} + 1.91 \text{ lbs/day} + 0.10 \text{ lbs/day}}$$

6.0 PUBLIC PARTICIPATION

Determination of a target goal for Lake Independence, as well as the WLA and LA discussed below, was completed by a large group of stakeholders in the watershed. The following groups were represented on the TMDL stakeholder committee:

- The Lake Independence Citizens Association
- Pioneer Sarah Creek Watershed Management Commission
- The City of Medina
- The City of Independence
- The Independence Horse Owners Association
- The Medina Horse Association
- Hennepin County Environmental Services
- Three Rivers Park District
- At large citizens
- A representative of the agricultural producers in the watershed

Committee members met monthly for approximately two years. The committee was chaired by a representative from the Lake Independence Citizens Association. As discussed below, the committee decided to assess WLA and LA on a source basis as opposed to a municipal or sub-watershed basis. Target load reductions from each source were determined to achieve the desired water quality goal.

The Pioneer-Sarah Creek Watershed Commission hosted two community-wide meetings to discuss the TMDL results. Each of these meetings were attended by approximately 50 citizens in the Lake Independence community. All citizens were encouraged to provide input into the process. In addition, the Watershed Commission organized multiple meetings with the three municipalities in the watershed to discuss the WLA's. These meetings were attended by the mayor and council members from Median and Independence. The final WLA's from each municipality were discussed and agreed upon at these meetings.

This TMDL will go through the formal public noticing process of the Minnesota Pollution Control Agency and the MPCA will respond to all comments received during the Public Notice process.

7.0 IMPLEMENTATION PLAN

7.1 Recommended Phosphorus Management Strategies

This TMDL implementation plan focuses on reducing the movement of phosphorus from the watershed area into Lake Independence. As previously indicated, a reduction of 45% (1081 pounds/year) in the current nutrient loading to the lake is necessary to achieve the adopted water quality goal of 36 ppb. The stakeholder group agreed that the reductions (872 lbs/yr) from each identified phosphorus source summarized in table 15 could be achieved. In addition, internal loading is predicted to decrease by 209 lbs/year as external loading is reduced.

Phosphorus Source	Proposed Phosphorus Reduction
Agricultural Cropland	284 pounds
Animal waste	370 pounds
Urban Development	146 pounds
Failing Individual Sewage Treatment Systems	8 pounds
Loretto Sewage Treatment Facility	53 pounds
Geese	11 pounds

Table 16. Summary of proposed phosphorus reductions to be implemented within the Lake Independence watershed by source.

7.1.1 Agricultural Cropland

The committee agreed that establishment of buffer strips along drainage ditches, streams, and wetlands would significantly reduce nutrient runoff from agricultural cropland in the watershed. Priority areas for buffer establishment in the watershed will be determined using the NRCS Universal Soil Loss Equation. Areas with the greatest erosion potential and proximity to sediment and nutrient conveyance systems will be targeted for buffers zone establishment. The Pioneer-Sarah Creek WMO and Three Rivers Park District will undertake the prioritization process. Buffer establishment will be on a voluntary basis. State and federal grant monies will be solicited by the Pioneer-Sarah Creek Watershed Management Commission to cost share buffer establishment. A GIS analysis of streams and wetlands in the watershed indicated that approximately 300 acres of buffer strips can be installed. The projected cost of installing these buffers will range from \$150,000 to \$500,000.

7.1.2 Animal Waste

The committee agreed that improved management of animal waste in the watershed would significantly reduce the phosphorus load to Lake Independence. Reduction of phosphorus runoff from existing feedlots will require improved manure storage, improved land application practices, and better pasture management. In addition, because of high animal density at many sites and existing high soil fertility, land application of manure is not practical. Thus, proper management of feedlots will require removal of manure from the watershed.

Three Rivers Park District staff inventoried the livestock operations in the watershed and developed a priority ranking to determine the feedlots with the greatest potential to affect the lake (Table 8). Optimal implementation of animal waste BMP's will focus on the highest ranking feedlots. Pasture and feedlot management plans will be developed by the Hennepin County Extension Agency in consultation with landowners on a voluntary basis. The Pioneer-Sarah Creek Watershed Commission and the Cities of Independence and Medina will solicit State and Federal Grant monies to assist in the implementation of the waste management plans.

In the event that voluntary implementation of manure management plans does not occur on the majority of feedlot, Medina and Independence will revise existing Conditional Use Permits or Zoning Ordinances to require compliance. In cooperation with the Pioneer-Sarah Creek Watershed Management Commission, Three Rivers Park District, and Hennepin County Environmental Services (HCES), Medina and Independence will develop a manure hauling and disposal service to assist landowners with manure management. Projected costs to develop and implement manure management plans for the 33 feedlots in the Lake Independence watershed will range from \$330,000 to \$825,000.

7.1.3 Urban Development

The stakeholder committee agreed that improved management of urban runoff, particularly from lakeshore properties would reduce nutrient loading to Lake Independence. Urban runoff management will include the following components; installation of rain gardens, street sweeping, removal of leaf litter from streets, installation of shoreline buffers, and stabilization of eroding lake shore.

Rain garden installation will be coordinated by the Lake Independence Citizens Association (LICA). LICA members will contact homeowners to determine interest in rain garden construction. HCES will assist LICA with rain garden design and will apply for grant monies to design and construct demonstration sites for homeowners to view. Construction of 200 rain gardens in the watershed to meet the phosphorus reduction target for this BMP will cost between \$300,000 and \$500,000.

Shoreline stabilization on Lake Independence will be coordinated by LICA with technical assistance from HCES. HCES will coordinate a grant application to solicit funds to assist homeowners with lakeshore stabilization projects. Three Rivers Park District staff inventoried the Lake Independence shoreline to develop a priority ranking to determine where initial stabilization efforts should focus. Over 2000 feet of the lake shoreline is experiencing significant erosion. Stabilization of these areas will cost between \$100.00 and \$300.00/foot, for a total estimated cost between \$200,000 and \$600,000.

Street sweeping in areas immediately adjacent to Lake Independence will be completed by Medina and Independence. Street sweeping will focus on springtime removal of debris accumulated during the winter, and during leaf drop in the fall. At a projected cost of \$80.00/hour, street sweeping will cost approximately \$10,000/year.

Removal of leaf litter from lakeshore lawns and streets adjacent to Lake Independence will be coordinated by LICA. Independence and Medina will assist with transport of leaf litter off site and disposal.

Installation of shoreline buffers will be coordinated by LICA with technical assistance from HCES. Three Rivers Park District inventoried the lake shoreline to determine where lawns currently extend to the waters edge along the lake. These areas will be targeted by LICA. Installation of shoreline buffers is estimated to cost between \$10,000 and \$50,000.

7.1.4 Failing Individual Sewage Treatment Systems (ISTS's)

Reduction of loading from ISTS's will be achieved through increased inspections of septic systems by local city governments, requiring remediation of failing systems, and more frequent pump-out of all septic system tanks. These requirements will conform to Minnesota State standards for ISTS's (R. Ch. 7020). An annual reduction of 8 lbs will be achieved through rigorous enforcement of ISTS rules with the ultimate goal being elimination of all loading from failing ISTS's. The estimated cost to establish an annual inspection program for ISTS's is \$5,000/year. The projected cost to bring all systems into compliance with state standards is approximately \$500,000.

7.1.5 Goose Removal

A reduction in phosphorus loading will be achieved by reducing the resident goose population. Three Rivers Park District, Medina and Independence will develop a cooperative program to capture and remove geese from the lake in late summer when the birds are flightless. LICA will assist in obtaining permission to enter private property to collect geese. Removal will be contracted to Dr. Jim Cooper, the only licensed removal firm. Annual costs to remove the geese are estimated at \$2,500.00.

7.1.6 Loretto Wastewater Treatment Facility

The City of Loretto Municipal WWTP (NPDES # MN0023990) has been estimated to have a current load of 53 lb/yr in this TMDL. This treatment system has two aerated ponds followed by a settling pond with a controlled discharge. Alum is added prior to every discharge to reduce the phosphorus down to <1.0 mg/L. For the City's discharges from May 2002 to May 2006, the average total phosphorus discharge concentration has been 0.68 mg/L. The City's discharge is to a wetland complex which eventually discharges to Lake Independence. The City is complying with its current NPDES permit.

However, since it is the ultimate goal of the City of Loretto to hook-up to the Metropolitan Council Environmental Services (MCES) municipal sewer system and phase out this WWTP, it has been assigned an individual waste load allocation of zero.

If this connection with MCES is delayed for any reason, and the Loretto's NPDES permit must therefore be reissued at its current effluent limit, the overall wasteload allocation for all NPDES

dischargers in the Lake Independence TMDL will remain the same. However, individual NPDES wasteload allocations for the other NPDES permitted dischargers in the watershed will be redistributed to allow for this permit to be renewed with current effluent limits. This adjustment of the TMDL individual wasteload allocations can take place when Loretto's permit is public noticed for reissuance, and all NPDES permit holders, EPA, and the public must be notified at the time the individual wasteload allocations are redistributed.

7.2 Reasonable Assurance for BMP Implementation

Implementation of the BMPs necessary to achieve the total maximum daily load phosphorus targets will be the responsibility of the Cities of Independence, Loretto, and Medina. These municipalities have the constitutional authority to adopt and enforce ordinances requiring compliance with the target phosphorus load reductions discussed in this TMDL report.

The Pioneer-Sarah Creek Watershed Management Commission will coordinate the required phosphorus load reductions with all three of the affected municipalities. The Commission has the legislative authority to assess an *ad valorem* tax to implement capital improvement projects in the watershed to reduce nutrient loading to Lake Independence. Working cooperatively, the two municipalities and the watershed commission have the regulatory authority and funding capacity to ensure achievement of the Lake Independence TMDL.

Additional assurance for BMP implementation will be provided by the *Pioneer-Sarah Creek Watershed Commission 2nd Generation Plan* which includes a non-degradation policy for future land development. This policy requires any proposed development activities within the watershed to meet strict guidelines to protect water quality and prevent increases in runoff and nutrient loading.

In the event that voluntary implementation of manure management plans does not occur on the majority of feedlot, Medina and Independence will revise existing Conditional Use Permits or Zoning Ordinances to require compliance. In cooperation with the Pioneer-Sarah Creek Watershed Management Commission, Three Rivers Park District, and Hennepin County Environmental Services (HCES), Medina and Independence will develop a manure hauling and disposal service to assist landowners with manure management.

7.2.1 Existing Storm Water Management Plans

All three of the municipalities within the Lake Independence watershed, Independence, Loretto, and Medina, have been designated as *Mandatory Municipal Separate Storm Sewer Systems* (MS4's) by the Minnesota Pollution Control Agency. As a result, these municipalities will be responsible for developing and implementing a *Stormwater Pollution Prevention Program* (SWPPP) that will reduce phosphorus and other pollutants to the "maximum extent practicable" as a part of the *Phase II National Pollutant Discharge Elimination System (NPDES)* program. These SWPPP's are required to incorporate six "minimum control measures" intended to ensure adequate storm water management and pollution prevention by designated MS4's. These minimum control measures include:

1	Public Education and Outreach on Storm Water Impacts
2	Public Involvement and Participation
3	Illicit Discharge Detection and Elimination
4	Construction Site Runoff Control
5	Post-Construction Storm Water Management in New Development and Redevelopment
6	Pollution Prevention and Good Housekeeping for Municipal Operations

Table 16 summarizes the incorporation of these six minimum control measures into the recommended phosphorus reduction strategies given in this TMDL. The final SWPPP's for each municipality may incorporate additional pollution control measures.

Phosphorus Source	Phosphorus Reduction Strategies	NPDES Phase II Minimum Control Measures
Agricultural Cropland	Vegetated buffer strips	Public Education Public Participation Good Housekeeping
Animal Waste	Improved manure storage Improved land application practices Improved pasture management Removal of manure	Public Education Public Participation Good Housekeeping
Urban Development	Rain garden installations Shoreline stabilization Increased street sweeping Removal of leaf litter Shoreline buffer installations	Public Education Public Participation Construction Site Measures Good Housekeeping
Failing Individual Sewage Treatment Systems (ISTS's)	Increased inspection of ISTS's Increased enforcement of violations More frequent pump-out	Public Education Public Participation Illicit Discharge Measures Good Housekeeping
Geese	Reduce resident goose flock Promote shoreline buffers	Public Education Public Participation
Loretto Sewage Treatment Facility	Eliminate all discharge of effluent	Illicit Discharge Measures Good Housekeeping

Table 17. Summary of identified phosphorus sources for Lake Independence, proposed phosphorus reductions strategies for each identified source, and NPDES Phase II minimum control measures met by each set of strategies.

7.2.2 Follow-up Monitoring Plan

Current plans are to continue the existing water quality monitoring program for Lake Independence. This includes bi-weekly collection of water column profiles (temperature, dissolved oxygen, pH, conductivity) and discrete water sample collection from the surface, middle, and bottom of the water column with actual sample depths dependent upon stratification conditions at the time of sample collection. Water samples will be analyzed for total phosphorus, soluble reactive phosphorus, total nitrogen, and chlorophyll-a. Additional inflow monitoring will

also be initiated during and after implementation of this TMDL to quantify actual external load reductions.

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