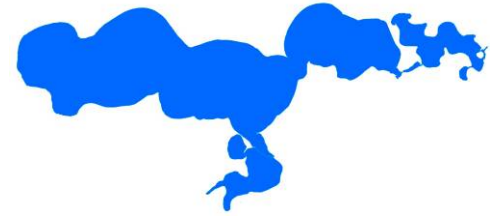


# Chapter 2. Watershed Characteristics

The Pelican Lakes are glacial lakes formed during the last retreat of the Red River Lobe starting about 13,000 years ago. The soils deposited by the glacier are primarily sands and loamy sands.



The Pelican Lakes' watershed is approximately 162,000 acres (includes lake acres) and the watershed to lake ratio of the Pelican Lake is about 40 to 1. The watershed has the potential to have a huge impact on Pelican Lake; however, much of the watershed area drains through large lakes first before the water reaches the Pelican Lakes. The upstream lakes act as "treatment" ponds and help improve water quality of the Pelican River and Spring Creek, two of the major tributaries to the Pelican Lakes. Land use is primarily agriculture comprising 23% of the overall watershed, with forest accounting for about 22% of the total watershed area. Much of the watershed drains to the Pelican River and the Pelican River flows into Little Pelican Lake. The watershed is shown in Figures 2.2-2.3. To ensure good water quality for years to come conservation measures in the watershed and on the lakeshore of the Pelican Lakes are essential.

## Lakesheds

Understanding a lakeshed requires the understanding of basic hydrology. A watershed is the area of land that drains into a surface water body such as a stream, river, or lake and contributes to the recharge of groundwater. There are three categories of watersheds: 1) basins, 2) major watersheds, and 3) minor watersheds.

Little Pelican, Pelican, Bass and Fish Lakes are located within the Red River of the North Basin, which includes the Otter Tail River Major Watershed as one of its twenty five major watersheds (Figure 2.1). The basin covers 45,000 square miles, while the Otter Tail River Watershed covers 1,982 square miles (approximately 1,268,480 acres).

The terrain of the Red River Basin in Minnesota is very diverse; from the flat, intensively farmed plain just east of the length of the Red River, to the rolling uplands full of trees and lakes in the east-central portion of the basin, to the extensive wetlands in the northeast.

Within this watershed hierarchy, lakesheds also exist. A lakeshed is defined simply as the land area that drains to a lake. While some lakes may have only one or two minor watersheds draining into them, others may be connected to a large number of minor watersheds, reflecting a larger drainage area via stream or river networks. Little Pelican Lake falls within the Pelican Lake – Pelican River (5600702) lakeshed, covering 1,899 acres (includes lake area) (Figure 2.2). Pelican, Bass and Fish Lakes Lake fall within the Pelican Lake – Pelican River (5600703) lakeshed, covering 15,783 acres (Figure 2.3).

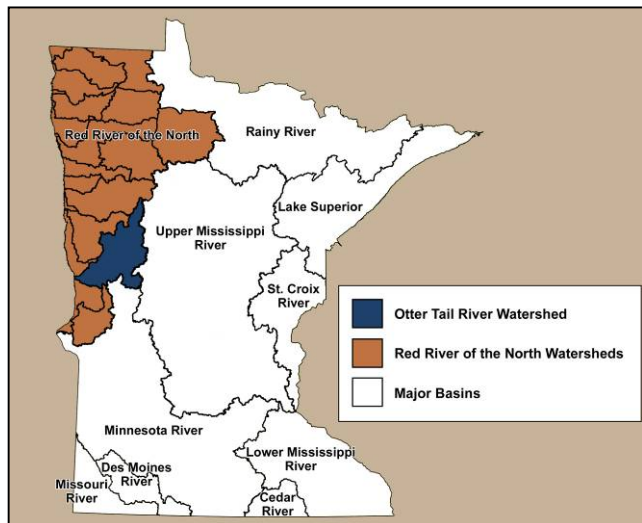


Figure 2.1. Red River of the North Basin and the Otter Tail River Watershed.

Little Pelican, Pelican, Bass and Fish Lakes fall within minor watershed 56007, one of the 108 minor watersheds that comprise the Otter Tail River Major Watershed (Figures 2.2-2.3).

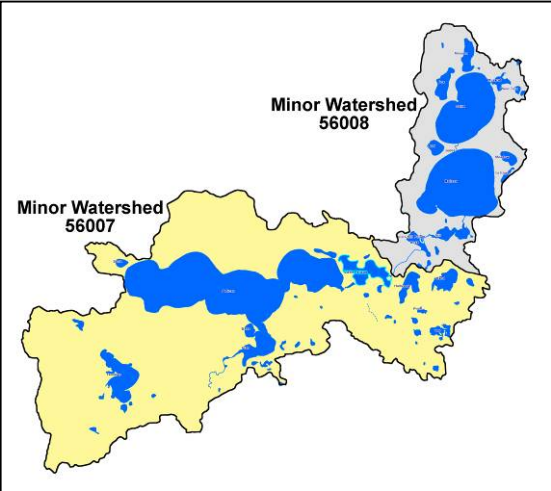


Figure 2.2. Minor Watersheds 56007 & 56008 contribute water directly to Little Pelican Lake.

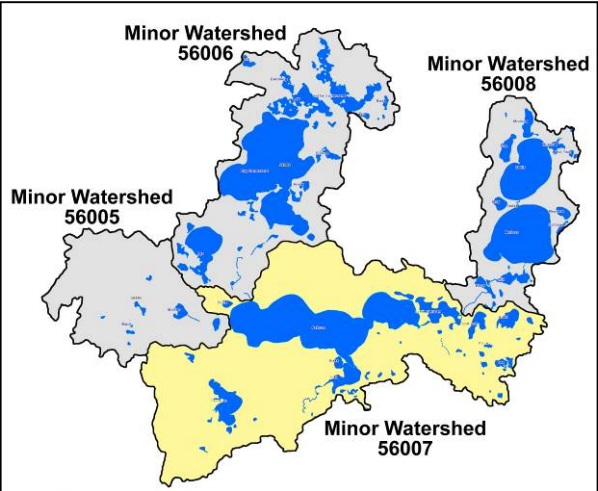


Figure 2.3. Minor Watersheds 56007, 56005, 56006, & 56008 contribute water directly to Pelican, Bass and Fish Lakes.

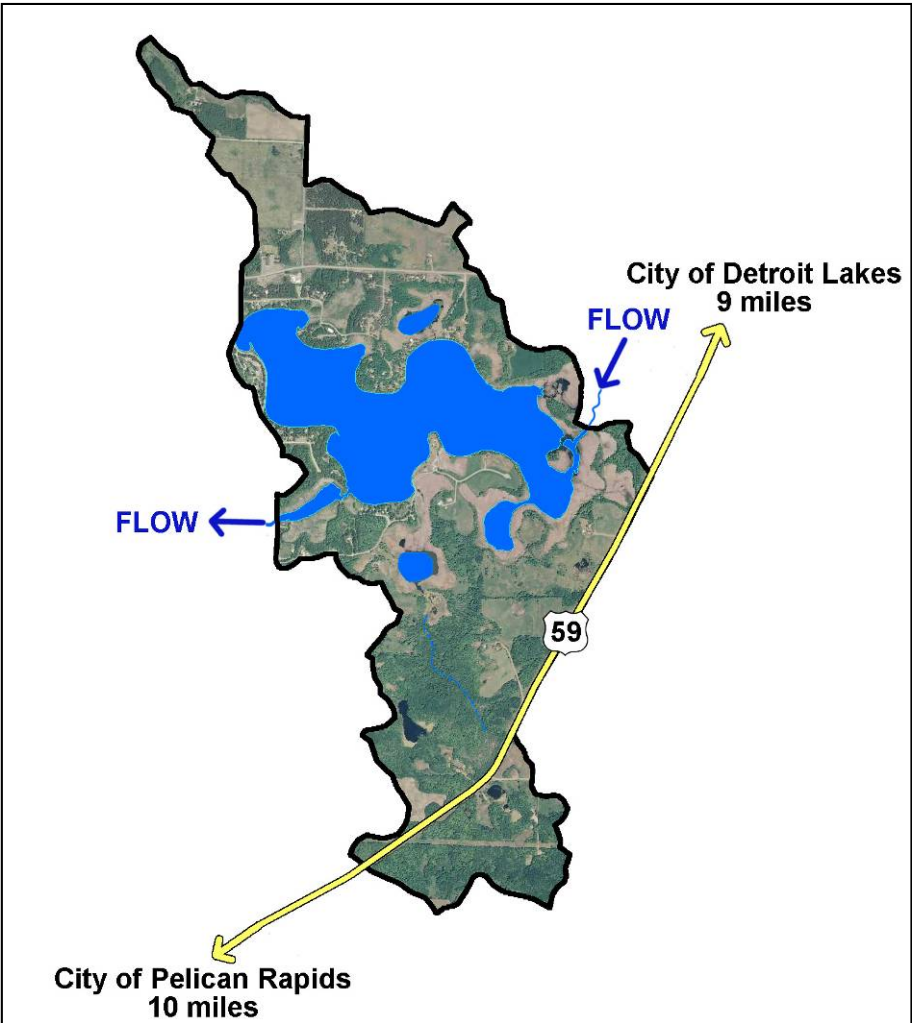


Figure 2.4. The Pelican Lake – Pelican River (5600702) lakeshed (Aerial imagery 2008).

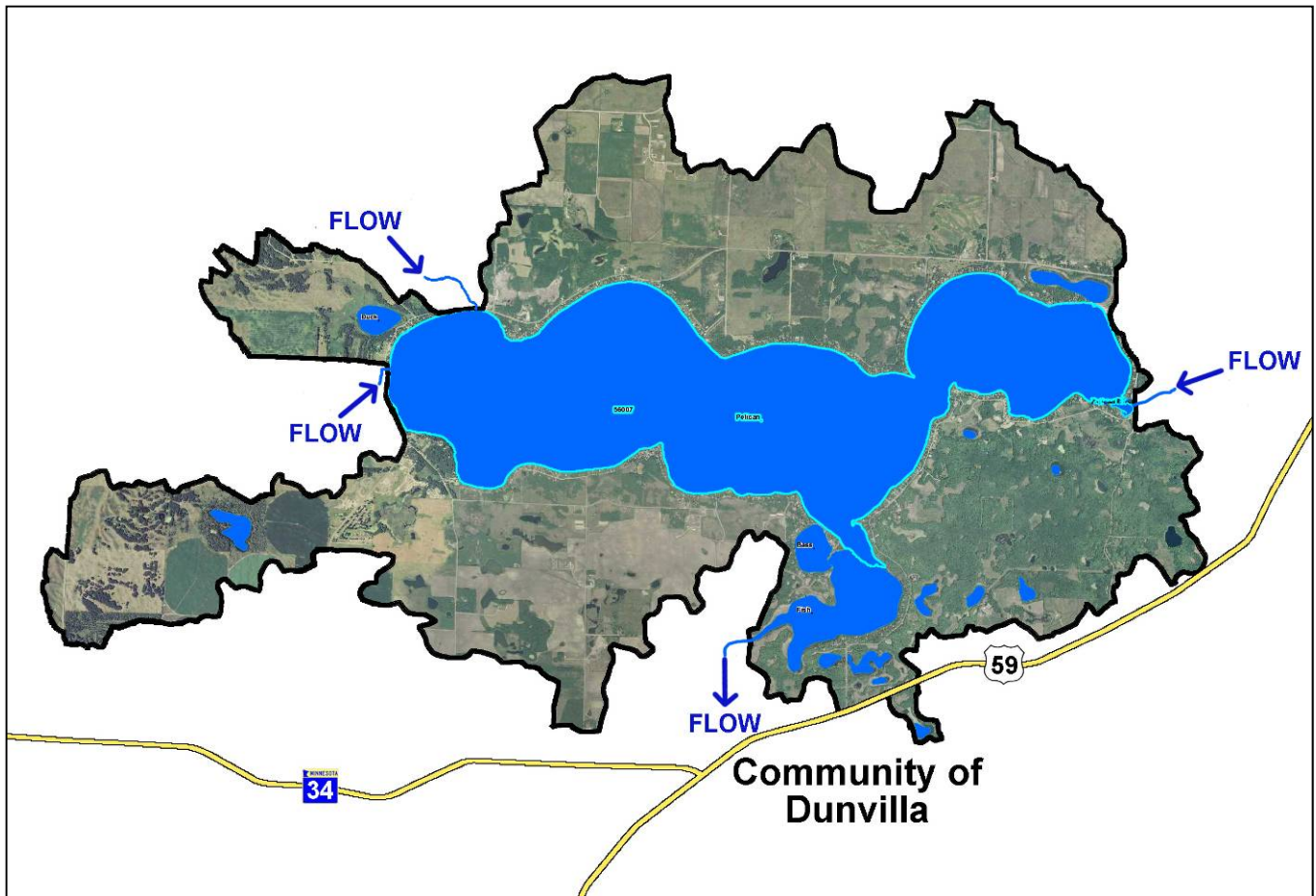


Figure 2.5. The Pelican Lake – Pelican River (5600703) lakedshed (Aerial imagery 2008).

## Land Cover / Land Use

The activities that occur on the land within the lakedshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed. The basic purpose of land use planning is to ensure that each area of land will be used in a manner that provides maximum social benefits without degradation of the land resource.

Changes in land use, and ultimately land cover, impact the hydrology of a lakedshed. Land cover is also directly related to the lands ability to absorb and store water rather than cause it to flow overland (gathering nutrients and sediment as it moves) towards the lowest point, typically the lake. Impervious intensity describes the lands inability to absorb water, the higher the % impervious intensity the more area that water cannot penetrate in to the soils. Monitoring the changes in land use can assist in future planning procedures to address the needs of future generations.

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed.

Table 2.1 describes Little Pelican Lake's lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture, grass/shrub/wetland, and water acreages to forest and urban acreages (Figure 2.6). The largest change in percentage is the increase in urban land cover (61.3%); however, in acreage, forest cover has increased the most (96 acres). In addition, the impervious intensity has increased, which has implications for storm water runoff into the lake. The increase in impervious intensity is consistent with the increase in urban acreage.

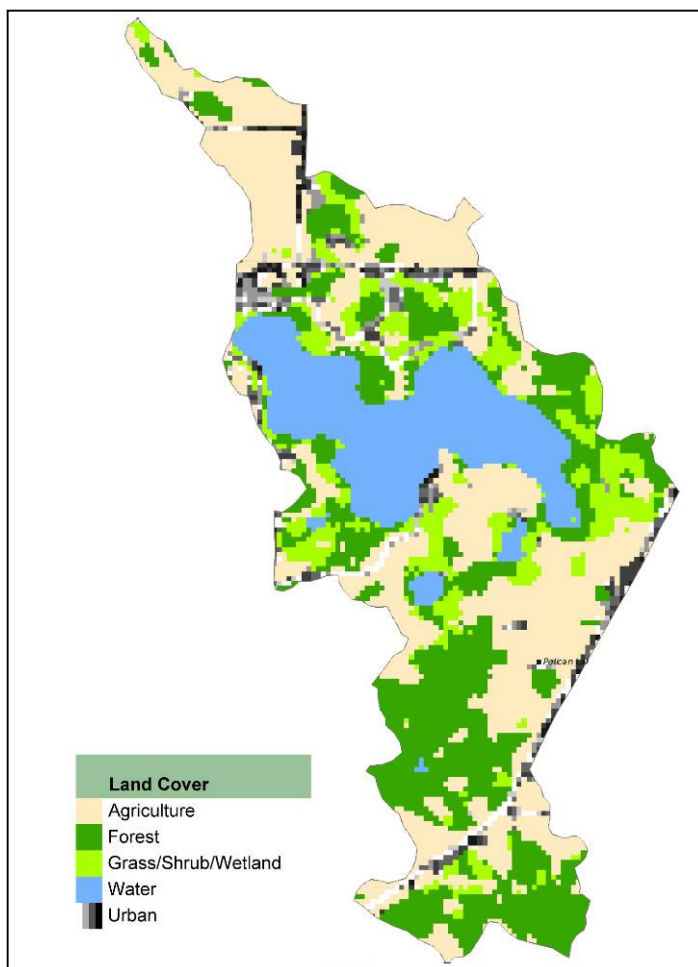


Figure 2.6. Little Pelican Lake Lakeshed showing land cover from 2000 (<http://land.umn.edu>)

Table 2.1. Little Pelican Lake's lakeshed land cover statistics and % change from 1990 to 2000 (<http://land.umn.edu>).

Land Cover	1990		2000		% Change 1990 to 2000
	Acres	Percent	Acres	Percent	
Agriculture	699	36.81	654	34.44	6.4% Decrease
Forest	420	22.12	516	27.17	22.9% Increase
Grass/Shrub/Wetland	302	15.9	225	11.85	25.5% Decrease
Water	367	19.33	325	17.11	11.4% Decrease
Urban	111	5.85	179	9.43	61.3% Increase
<b>Impervious Intensity %</b>					
0	1,801	94.84	1,760	92.68	2.3% Decrease
1-10	15	0.79	16	0.84	6.7% Increase
11-25	23	1.21	34	1.79	47.8% Increase
26-40	22	1.16	31	1.63	40.9% Increase
41-60	29	1.53	38	2	31.0% Increase
61-80	9	0.47	15	0.79	66.7% Increase
81-100	0	0	4	0.21	400% Increase
<b>Total Area</b>	1,899		1,899		
<b>Total Impervious Area</b>	32	2.09	50	3.18	56.3% Increase
(Percent Impervious Area Excludes Water Area)					

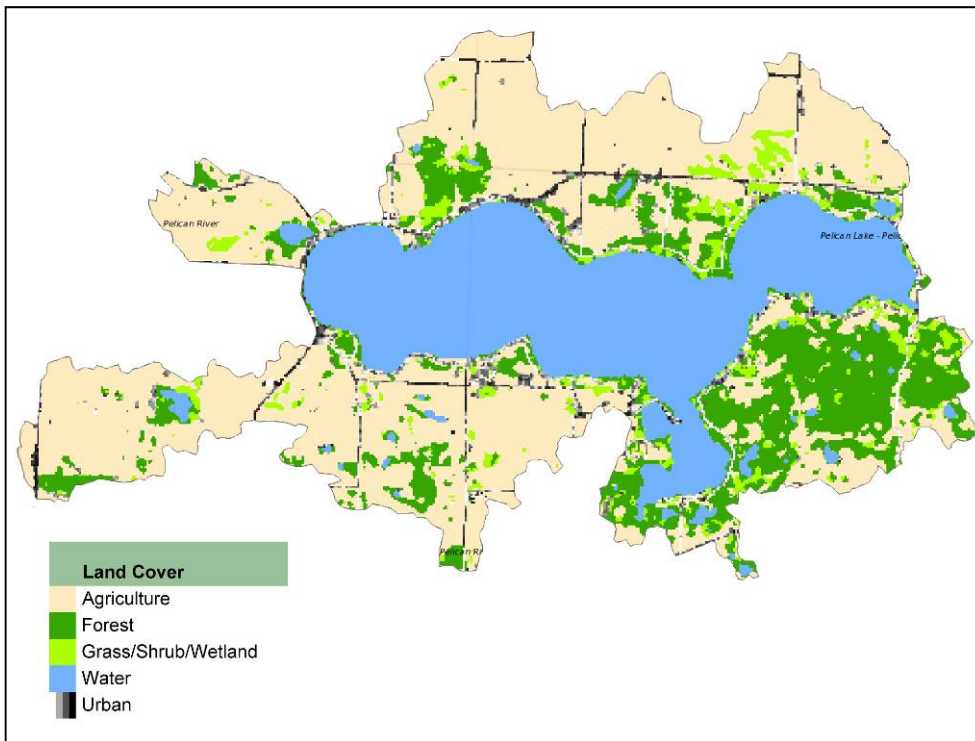


Figure 2.7. Pelican, Bass and Fish Lakes Lakeshed showing land cover from 2000 (<http://land.umn.edu>)

Table 2.2 describes Pelican Lake’s lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture, grass/shrub/wetland, and water acreages to forest and urban acreages (Figure 2.7). The largest change in percentage is the increase in urban land cover (56.9%); however, in acreage, forest cover has increased the most (417 acres). In addition, the impervious intensity has increased, which has implications for storm water runoff into the lake. The increase in impervious intensity is consistent with the increase in urban acreage.

Table 2.2. Pelican Lake’s lakeshed land cover statistics and % change from 1990 to 2000 (<http://land.umn.edu>).

Land Cover	1990		2000		% Change 1990 to 2000
	Acres	Percent	Acres	Percent	
<b>Agriculture</b>	7,507	47.56	7,094	44.95	5.5% Decrease
<b>Forest</b>	2,174	13.77	2,591	16.42	19.2% Increase
<b>Grass/Shrub/Wetland</b>	1,031	6.53	706	4.47	31.5% Decrease
<b>Water</b>	4,481	28.39	4,466	28.3	0.3% Decrease
<b>Urban</b>	592	3.75	929	5.89	56.9% Increase
<b>Impervious Intensity %</b>					
<b>0</b>	15,308	96.98	15,077	95.51	1.5% Decrease
<b>1-10</b>	106	0.67	108	0.68	1.9% Increase
<b>11-25</b>	128	0.81	175	1.11	36.7% Increase
<b>26-40</b>	106	0.67	160	1.01	50.9% Increase
<b>41-60</b>	100	0.63	161	1.02	61% Increase
<b>61-80</b>	33	0.21	82	0.52	148.5% Increase
<b>81-100</b>	4	0.03	22	0.14	450% Increase
<b>Total Area</b>	15,783		15,783		
<b>Total Impervious Area (Percent Impervious Area Excludes Water Area)</b>	136	1.2	246	2.17	80.9% Increase

Figure 2.8 and Table 2.3 show more specifically the types of agriculture occurring in the PGOLID lakesheds. Much of the agricultural land to the north is pasture, which has a phosphorus runoff coefficient similar to grass land and prairie. The row crops are of greatest concern for runoff, and they mainly occur to the southwest of Pelican Lake. Since they are in the lakeshed, they do drain towards the lake.

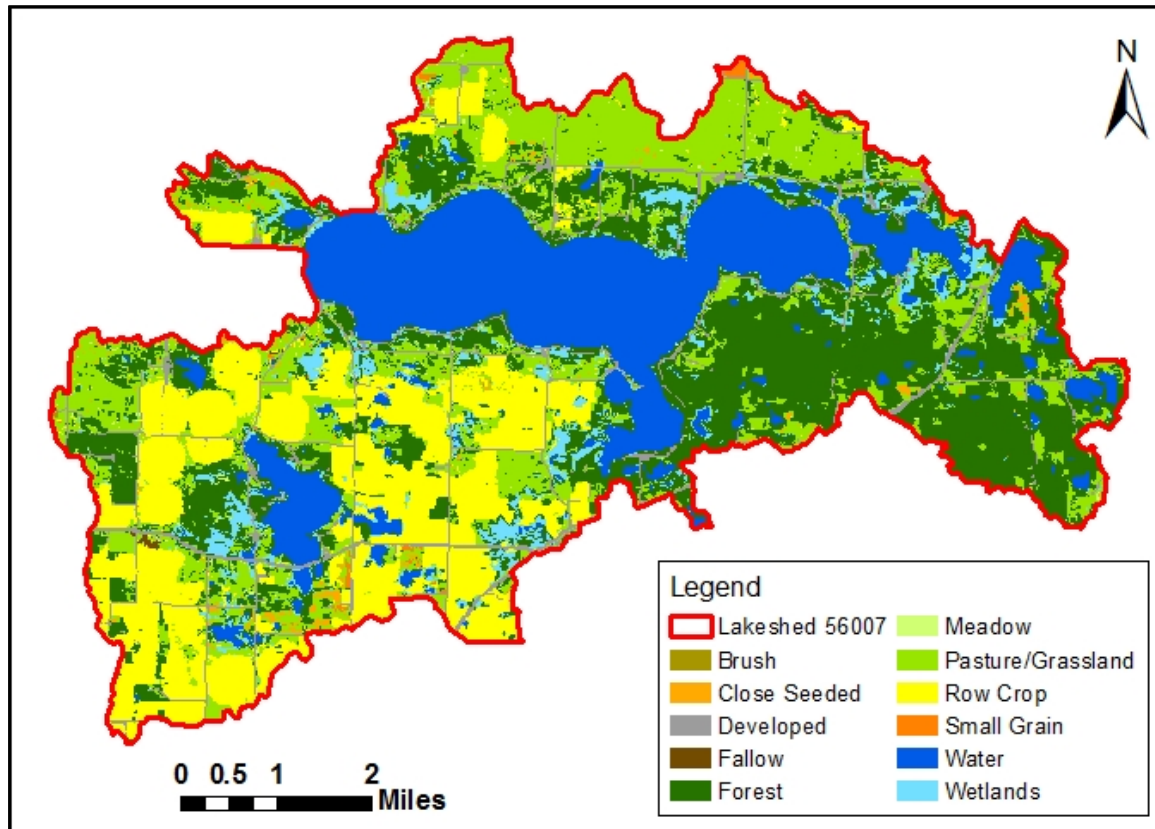


Figure 2.8. Land cover including crop types in the Pelican, Bass, Fish and Little Pelican lakesheds.

Table 2.3. Land cover acreage and percentage in the Pelican, Bass, Fish and Little Pelican lakesheds.

Landcover	Acres	Percent
Water	5,841	21.4%
Wetlands	1,236	4.5%
Forest	7,589	27.8%
Developed	1,248	4.6%
Brush	5	0.0%
Fallow	18	0.1%
Row Crop	5,239	19.2%
Small Grain	78	0.3%
Close Seeded	195	0.7%
Pasture/Grassland	5,635	20.6%
Meadow	216	0
<b>Total</b>	<b>27,300</b>	<b>100%</b>

## Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection. For recommendations, see the next page.

### Little Pelican Lake

	Private (76%)					24%	Public (0%)		
	Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal
<b>Land Use (%)</b>	10%	19%	32%	10%	5%	24%	0%	0%	0%
<b>Runoff Coefficient</b> Lbs of phosphorus/ acre/year	0.45 - 1.5	0.26 - 0.9	0.09		0.09		0.09	0.09	0.09
<b>Description</b>	Focused on Shoreland	Cropland	Focus of development and protection efforts	Open, pasture, grassland, shrubland	Protected				
<b>Potential Phase 3 Discussion Items</b>	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3 <sup>rd</sup> party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

### Pelican, Bass and Fish Lakes

	Private (71%)					28%	Public (1%)		
	Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal
<b>Land Use (%)</b>	6%	33%	21%	8%	3%	28%	0%	0%	1%
<b>Runoff Coefficient</b> Lbs of phosphorus/ acre/year	0.45 - 1.5	0.26 - 0.9	0.09		0.09		0.09	0.09	0.09
<b>Description</b>	Focused on Shoreland	Cropland	Focus of development and protection efforts	Open, pasture, grassland, shrubland	Protected				
<b>Potential Phase 3 Discussion Items</b>	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3 <sup>rd</sup> party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

## **Recommendations**

### **Conservation Easements**

The charts on the previous page show that the lakesheds of Little Pelican, Pelican, Bass and Fish lakes are mostly made up of private land. This means this land is not protected from future development. Any undeveloped lots with lakeshore and those considered "second ring" development should be considered for conservation easements. With conservation easements, these lands would be protected from future development.

### **Forestry**

Property owners who own large forested lots should consider forest stewardship planning. This planning will allow proper protection and management of the forested land. The DNR forestry program is available for private forest landowners including corporations whose stocks are not publicly traded and own between 20 - 1,000 acres of land. At least 20 acres of the land must have or will have trees. For more information, visit:

<http://www.dnr.state.mn.us/grants/forestmgmt/stewardship.html>.

### **Developed Land**

In the developed land around the lake, the most impact to the lake comes from runoff from grass lawns and impervious surface. To minimize this runoff, trees, shrubs and native vegetation should be planted along the shoreline. A secondary impact from developed land comes from improperly working septic systems. All septic systems should be properly maintained to protect the lake from excess nutrients.

### **Agriculture**

Agricultural areas tend to have a high concentration of nutrients (fertilizers). Proper agricultural practices near lakes should minimize their impact to lakes. Conservation practices could include Conservation Reserve Program land and wetland restoration. The local Soil and Water Conservation District can help with both of these practices.

## **Lakeshed Vitals Table**

In the table on the next page, potential impacts to the lakes are listed with descriptions of their impacts to the lakes. Pelican, Bass and Fish are combined because they are one large water system with one combined lakeshed.

<b>Lakeshed Vitals</b>	<b>Pelican, Bass, Fish</b>	<b>Little Pelican</b>	<b>Comments</b>
<b>Miles of Shoreline</b>	22.9	7.2	Miles of shoreline describes the distance around the lake shore. Lakes with more miles of shoreline have more area for potential shoreline impacts to occur.
<b>Miles of Stream</b>	0.4	1.0	Streams provide valuable habitat for aquatic and riparian organisms including fish, aquatic invertebrates (insects, crayfish, mussels), waterfowl, muskrats, and otters. Small streams are also highly productive systems, owing to their relationships with adjacent upland habitats. On the other hand, streams are also major sources of nutrients and suspended solids to lakes. It is important that lake residents keep riparian areas natural with vegetated buffers in order to protect the lake and the stream.
<b>Miles of Road</b>	39.3	7.0	Roads are considered impervious surface; they fragment the landscape for wildlife habitat and lead to increased development.
<b>Water Residence Time</b>	1.4 years	<1 year	For lakes having longer residence times (a year or more), long-term average pollutant loadings become more important to overall lake water quality. Lakes that have a residence time of more than 5 years have a capacity of retaining about 60% of the phosphorus loading that occurs and is not lost via outflow. This characteristic requires that the longer the water residence time, the longer the time frame needed for in-lake observations to detect any response to loading reduction.
<b>Municipalities</b>	None	None	Municipalities adjacent to a lake are areas of dense population and impervious surface. Stormwater runoff from streets, parking lots, roofs and storm gutters can contribute nutrient and pollutant loading to a lake. In addition, road salt used in the winter can increase the salinity and conductivity in a lake.
<b>Sewage Management</b>	Individual waste treatment systems (septic systems and holding tanks). County does lakewide inspections every 15-20 years		Properly maintained septic systems and holding tanks are effective in treating human waste. Education of property owners is the best way to get this message across in a positive fashion.
<b>Public Drainage Ditches</b>	None	None	Public drainage ditches can contribute nutrient enriched runoff to lakes during heavy rain events and spring thaw. Channelized streams or constructed ditches effectively increase the slope of the watershed and reduce the time it takes water to reach the lake.
<b>Forestry Practices</b>	None	None	Properly planned and managed forestry will have little impact on lake water quality; however, clear-cutting along a tributary or in the lakeshed can accelerate erosion and runoff.
<b>Development Classification</b>	General Development	Recreational Development	Recreational Development Lakes usually have between 60 and 225 acres of water per mile of shoreline, between 3 and 25 dwellings per mile of shoreline, and are more than 15 feet deep. General Development Lakes usually have more than 225 acres of water per mile of shoreline and 25 dwellings per mile of shoreline, and are more than 15 feet deep. These different classifications have different setback requirements.

<b>Lakeshed Vitals</b>	<b>Pelican, Bass, Fish</b>	<b>Little Pelican</b>	<b>Comments</b>
<b>Shoreline Development Index</b>	2.5	2.7	The shoreline development index is the ratio of the length of shoreline to the circumference of a circle with an area equal to the lake area. As the index value increases from 1, it indicates a more irregularly shaped shoreline. An index value of 1 is the smallest possible value and indicates a lake that is perfectly circular. Lakes with an index value of approximately 2 are more elliptical in form, while elongated or dendritic-shaped lakes can have values greater than 4. The shoreline development index is an important morphological parameter to consider because it can give an idea of a lake's susceptibility to the impacts of shoreline development. Lakes with high index values are more susceptible to the impacts of development because there is more shoreline to be developed compared to a more regularly shaped (round) lake with a similar surface area. (Wetzel 2001)
<b>Total Lakeshed to Lake Area Ratio</b> (total lakeshed includes lake area)	3.7:1	5.2:1	The lakeshed to lake area ratio shows how much land area drains into the lake compared to the size of the lake. If this ratio is greater than 2, the land has more potential impact on the lake.
<b>Public Land : Private Land</b>	0.01:1	0:1	Public land is protected, and therefore additional development cannot occur in those areas. Private land that is undeveloped has the potential to be developed unless there are wetlands present that are protected by the Wetland Conservation Act.
<b>Wetland Coverage</b>	3%	5%	Wetland protection is a critical component for the long-term protection of water quality and recharge of groundwater. Historically, wetlands were drained for various land-use practices. Today, environmental awareness and increased stewardship has lead practices to restoration. All wetlands in the National Wetlands Inventory are protected by the Wetland Conservation Act and cannot be developed. The more land tied up in protected wetlands around a lake, the less development and impact there will be on the lake water quality. Wetlands in agricultural areas around the lake could be restored for better water storage in periods of high precipitation.
<b>Exotic Species</b>	Zebra mussels, Curly-leaf pondweed	Curly-leaf pondweed	Curly-leaf pondweed is under control in the Pelican Group of Lakes by chemical herbicide application. Zebra mussels are a problem with no solution for removal.

## Demographics

Little Pelican Lake is classified as a recreational development lake. Recreational development lakes usually have between 60 and 225 acres of water per mile of shoreline, between 3 and 25 dwellings per mile of shoreline, and are more than 15 feet deep.

Pelican Lake is classified as a general development lake. General development lakes usually have more than 225 acres of water per mile of shoreline and 25 dwellings per mile of shoreline, and are more than 15 feet deep.

The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. These projections are shown in Figure 2.10 below.

Compared to Otter

Tail County as a whole, Dunn Township population growth has higher extrapolated growth projections, while Scambler Township has lower extrapolated growth projections.

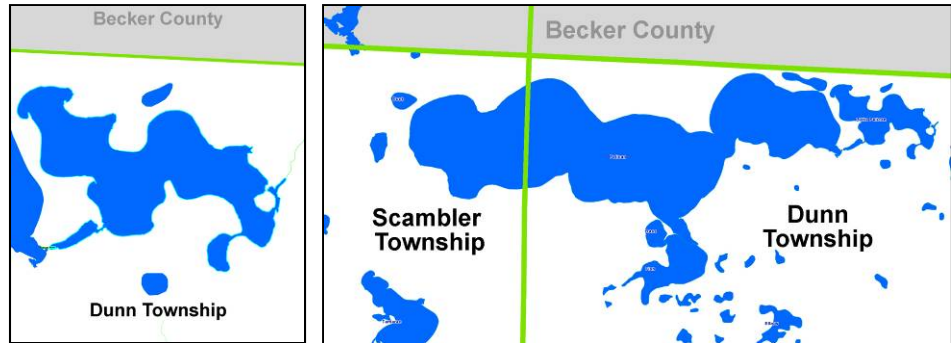


Figure 2.9. Little Pelican Lake showing Dunn Township and Pelican, Bass and Fish Lakes showing Dunn and Scambler Townships.

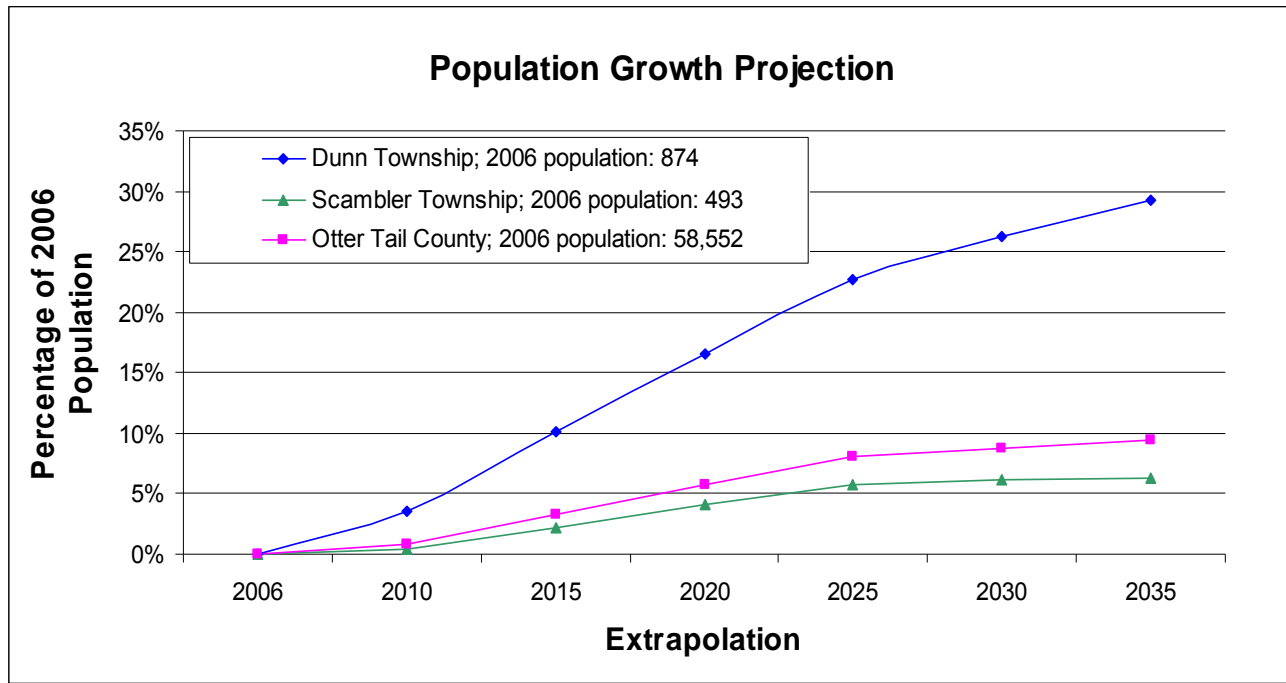


Figure 2.10. Population growth projection for Otter Tail County and the townships around the PGOLID Lakes (source: <http://www.demography.state.mn.us/resource.html?id=19332>).

# Lake Water Level Report

DNR: <http://www.dnr.state.mn.us/lakefind/showlevel.html?id=56078600>

## Water Level Data

Period of record: 03/24/1938 to 12/02/2009

# of readings: 1448

Highest recorded: 1319.72 ft (08/25/1993)

Highest known: 1319.72 ft (08/25/93)

Lowest recorded: 1314.78 ft (03/24/1938)

Recorded range: 4.94 ft

Last reading: 1317.84 ft (12/02/2009)

Ordinary High Water Level (OHW) elevation: 1318 ft

Datum: MSL 1912 (ft)

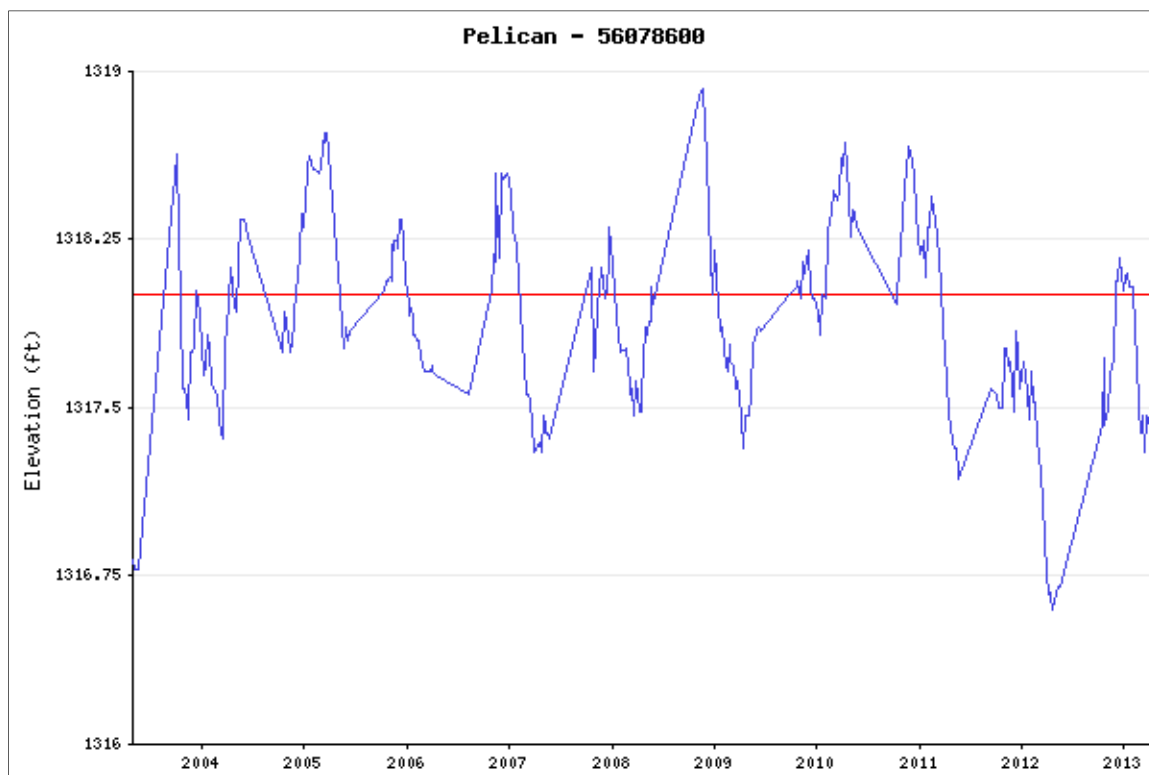


Figure 2.11. Water levels in Pelican Lake 2000-2009. Source: MN DNR

## Benchmarks

Elevation: 1322.25 ft Datum: MSL 1912 (ft)	Date Set: 07/28/1978	<b>Benchmark Location</b> Township: 137 Range: 42 Section: 20
Description: Bent 60d spk in notched NW root of a 12" maple, 95' SE of Pelican Lk dam.		
Elevation: 1327.76 ft Datum: MSL 1912 (ft)	Date Set: 03/24/1976	<b>Benchmark Location</b> Township: 137 Range: 42 Section: 2
Description: MHD disk in S end of E conc wheelguard of bridge for CSAH 31 crossing on narrows between Little Pelican and Pelican Lakes.		

## Wetlands

"Wetlands" is the collective term for marshes, swamps, bogs, and similar areas. Wetlands are found in flat vegetated areas, in depressions on the landscape, and between water and dry land along the edges of streams, rivers, lakes, and coastlines.

Wetlands prevent flooding by holding water much like a sponge. By doing so, wetlands help keep river levels normal and filter and purify the surface water. Wetlands accept water during storms and whenever water levels are high. When water levels are low, wetlands slowly release water. Wetlands encompass many different habitats including ponds, marshes, swamps, and peatlands. They are areas where land and water meet and are wet for an ecologically significant part of the year. Wetlands may be temporarily flooded by rain, or be filled seasonally with water from melting snow.

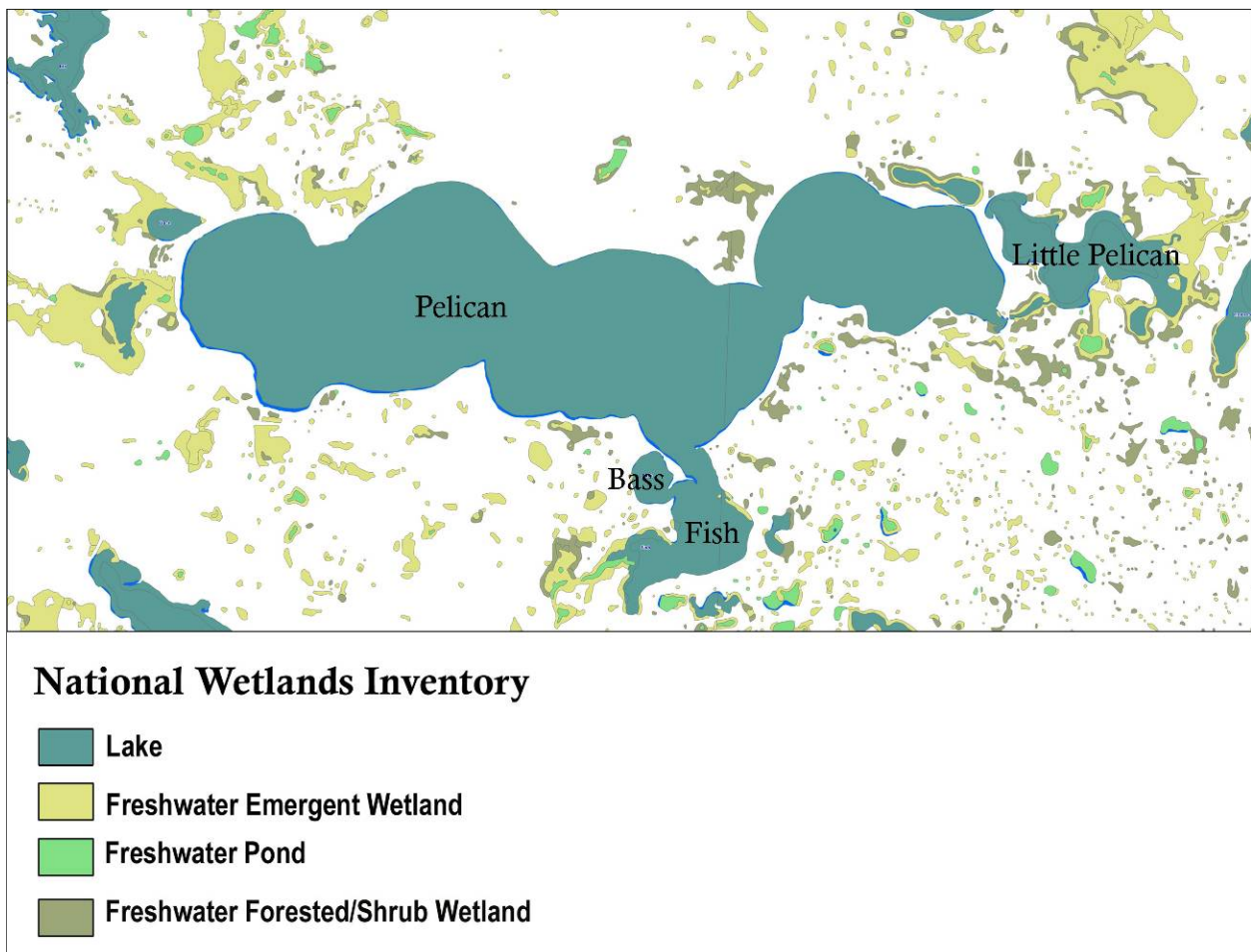


Figure 2.12. National Wetlands Inventory in the area around Little Pelican, Pelican, Bass and Fish Lakes.

Wetlands around PGOLID include emergent wetlands, which are usually colonized with cattails, ponds and forested/shrub wetlands (Figure 2.12).

If these areas are filled in, the water needs to go somewhere and could cause lake levels to rise. These areas are important for water storage and filtration and should be preserved to maintain water levels in the PGOLID lakes.

## Stream Assessments

Streams and rivers are rated by the Minnesota Pollution Control Agency to have the most potential to impact lakes. After all, a lake can only be as healthy as the water that flows into it.

Pelican Lake has 4 impacting streams. All of which are tested in several places. By breaking up the sampling per stream we can better locate pollution sources. For example; points A, B, and C are sampled for pollutant X. A is upstream from B, and B is upstream from C. Pollutant X is found at C but not B or A. This means that the pollutant source must be in-between B and C. Say that pollutant X is found at B but not C. This means that (usually naturally) the pollutant is being "filtered" between B and C. Perhaps the most important sites are at where they enter the lake body. The rivers and streams that exit the lake are also sampled. This is for comparison purposes. For example the totals of a substance entering the lake can be found and compared with the totals exiting the lake. This is another way to distinguish if other pollutants are entering the lake by other means than streams.

PGOLID monitors 9 sites in 4 watersheds. The sites are numbered below and refer to the map below (Figure 2.13):

1. Highway 20 Culvert, Pelican River
2. Strom's Bridge, Pelican River
3. Pelican River Outlet
4. Bob Creek Inlet
5. Burton Lake Outlet
6. Spring Creek Inlet (Simenson)
7. 15823 Sherbrooke Road , Spring Creek
8. Lake Ida Outlet
9. Cormorant Lake Outlet

Samples are collected monthly year around. The PGOLID Water Resource Coordinator also periodically takes samples after "storm events" or after heavy precipitation (usually >1 inch). Sampling after a storm event can give us a relation as to how the watersheds runoff is impacting the water or the "worst case scenario". Storm event samples are included with other samples in statistics. This evens out to more accurately represent a true average. It also makes up for the other storm events that are not monitored, or recorded in the monthly samples.

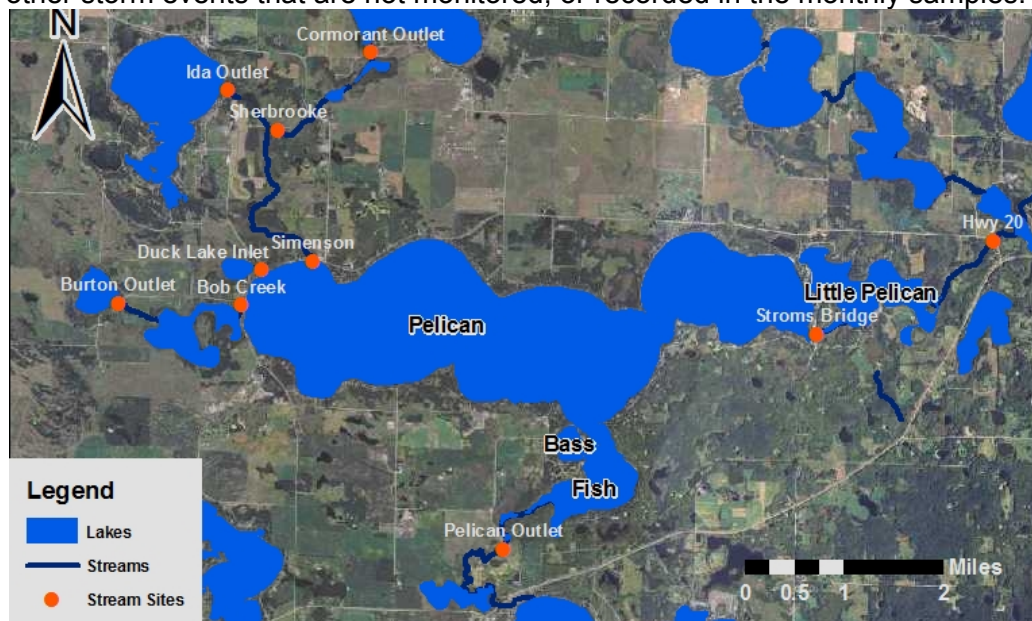


Figure 2.13. PGOLID stream monitoring sites.

*PGOLID Lake Management Plan, 2013*

## Inlets and Outlet Loading Comparisons

Totals are approximated by averaging all the values. Storm events are included.

Average Totals Entering Pelican Lake	
3.03	Chlorophyll a ( lbs / day )
1188	Total Suspended Solids ( lbs / day )
48,615	Fecal Coliform Bacteria ( Fecal Colonies / day )
13.63	Total Phosphorus ( lbs / day )
9.80	Ortho Phosphorus ( lbs / day )
63,644,236	Flow (GPD)

Average Totals Exiting Pelican Lake	
1.99	Chlorophyll a ( lbs / day )
652	Total Suspended Solids ( lbs / day )
50,234	Fecal Coliform Bacteria ( Fecal Colonies / day )
8.81	Total Phosphorus ( lbs / day )
7.91	Ortho Phosphorus ( lbs / day )
66,275,478	Flow (GPD)

### Flow

The combined flow from the inlets mirrors the outlet flow (Figure 2.14). This result is expected, and means that most of the water that is flowing into the PGOLID lakes is flowing back out. The peaks in flow correspond to spring thaw and usually occur in May-June.

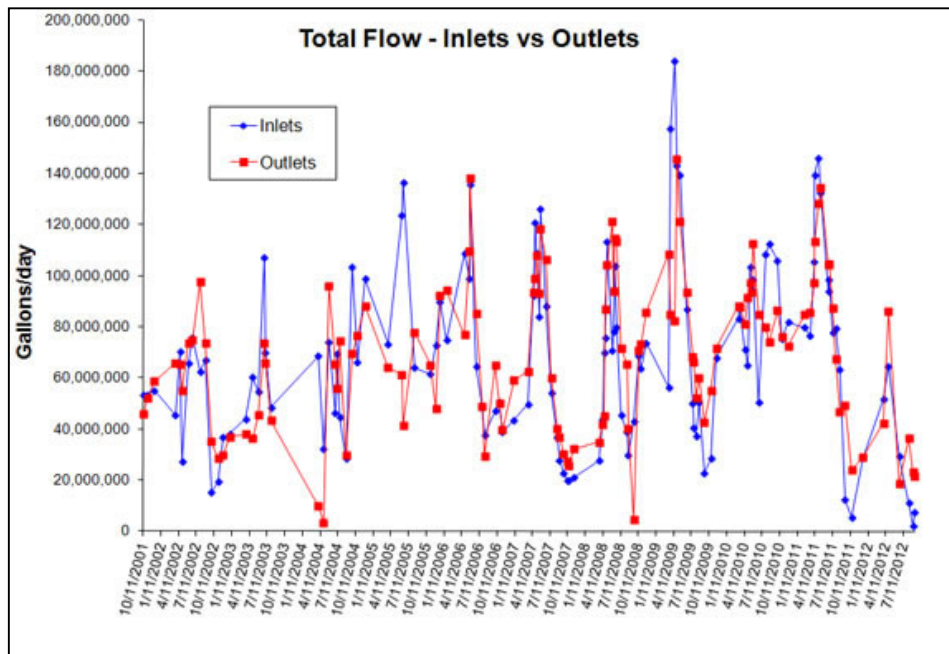


Figure 2.14 Combined inlets flow versus the outlet flow for the PGOLID lakes.

## Total Phosphorus

The total phosphorus loading is calculated by taking into account both the phosphorus concentration in the water and the volume of flow passing through a certain area. In streams, phosphorus loading is a better indicator for water quality than phosphorus concentration. A stream with high phosphorus concentration that is just a trickle of water could be depositing less phosphorus into a lake than a stream with low phosphorus concentration and high flow.

The combined phosphorus loading from the inlets mirrors the phosphorus loading at the outlet. As pulses of phosphorus enter the PGOLID lakes, much of that phosphorus exits back out of the system. A portion of the phosphorus stays in the lake and gets taken up by plants and algae. If all the phosphorus was staying in the lake and not flowing back out, it would be a problem and would contribute to the lake getting greener with more plants and algae.

The peaks in phosphorus loading correspond with the peaks in flow (Figure 2.15). These peaks occur in the spring (April-June) as spring thaw and rains contribute to higher water levels.

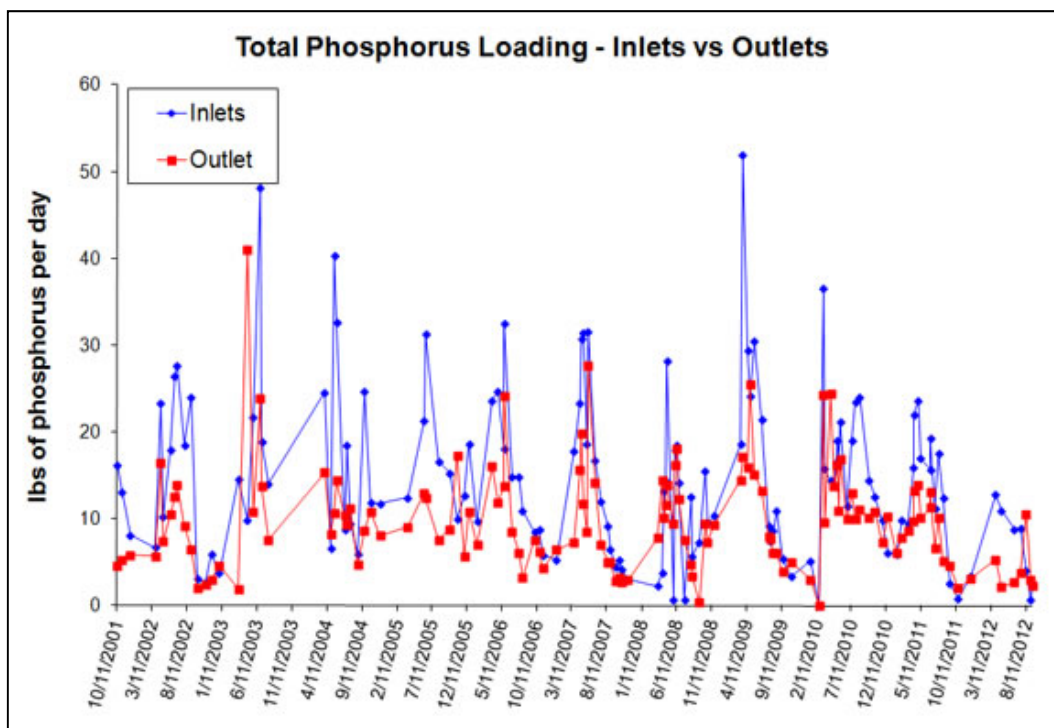


Figure 2.15. Combined inlets phosphorus loading versus the outlet phosphorus loading for the PGOLID lakes.

## Totals and Average Loading by Watershed

Minor watersheds are grouped by the stream that discharges into Pelican Lake. These groups of watersheds are Bob Creek, Spring Creek, and the Pelican River (Figure 2.16).

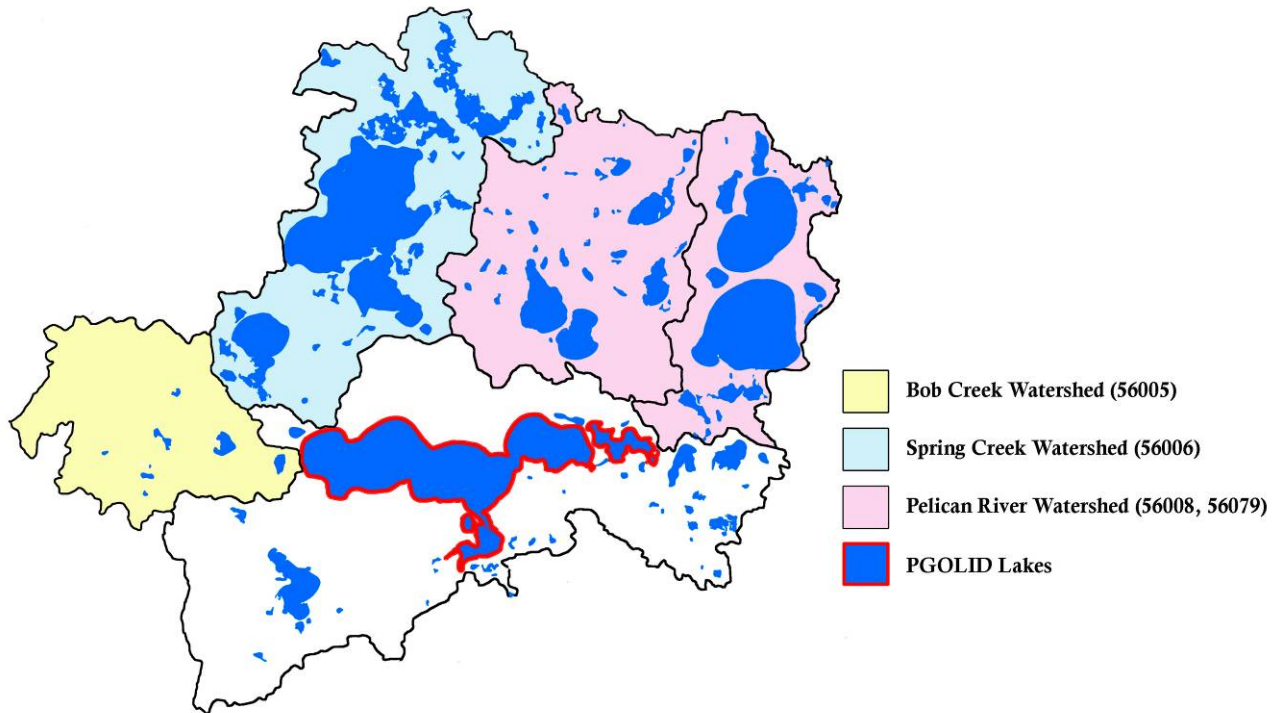


Figure 2.16 Minor watersheds draining directly into PGOLID Lakes.

### Flow

In comparing the flow between the different inlets, the Pelican River accounts for the majority (75%) of the water flowing into the PGOLID lakes (Figure 2.17).

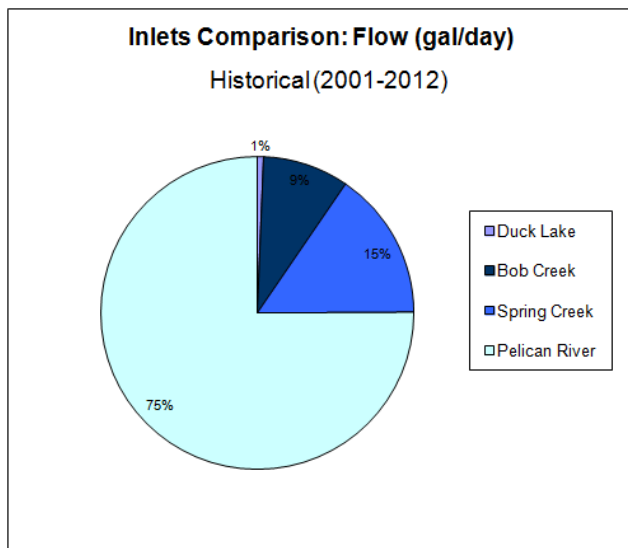


Figure 2.17 Comparison of water flow entering Pelican Lake between the different inlets.

## Total Phosphorus

In comparing the total phosphorus between the different inlets, the Pelican River accounts for over half (63%) of the total phosphorus entering Pelican Lake (Figure 2.18). This would prioritize this stream for source identification; however, the phosphorus concentration in the Pelican River is average compared to the other sites, and is nearly half of other area streams. This would suggest that heavy loading is due to the sheer volume of water (Figure 2.17).

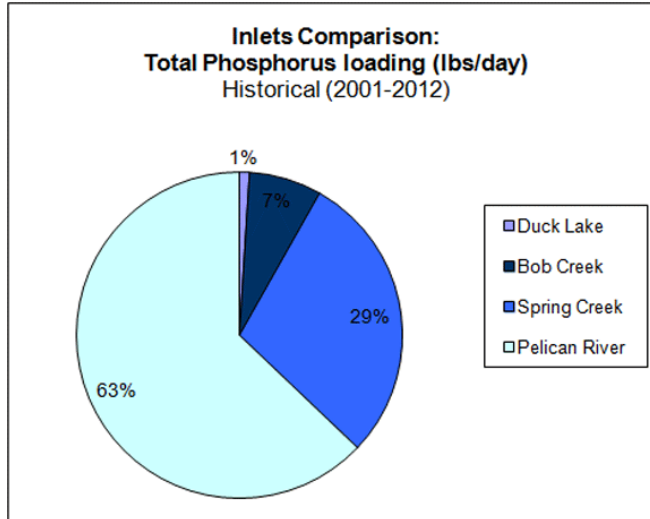


Figure 2.18 Total phosphorus loading proportions from each inlet to Pelican Lake.

Figure 2.19. shows the actual phosphorus loading for each inlet. Duck Lake is a small inlet that trickles in from a wetland on the west side of Pelican Lake. The flow and phosphorus loading from Duck Lake is negligible.

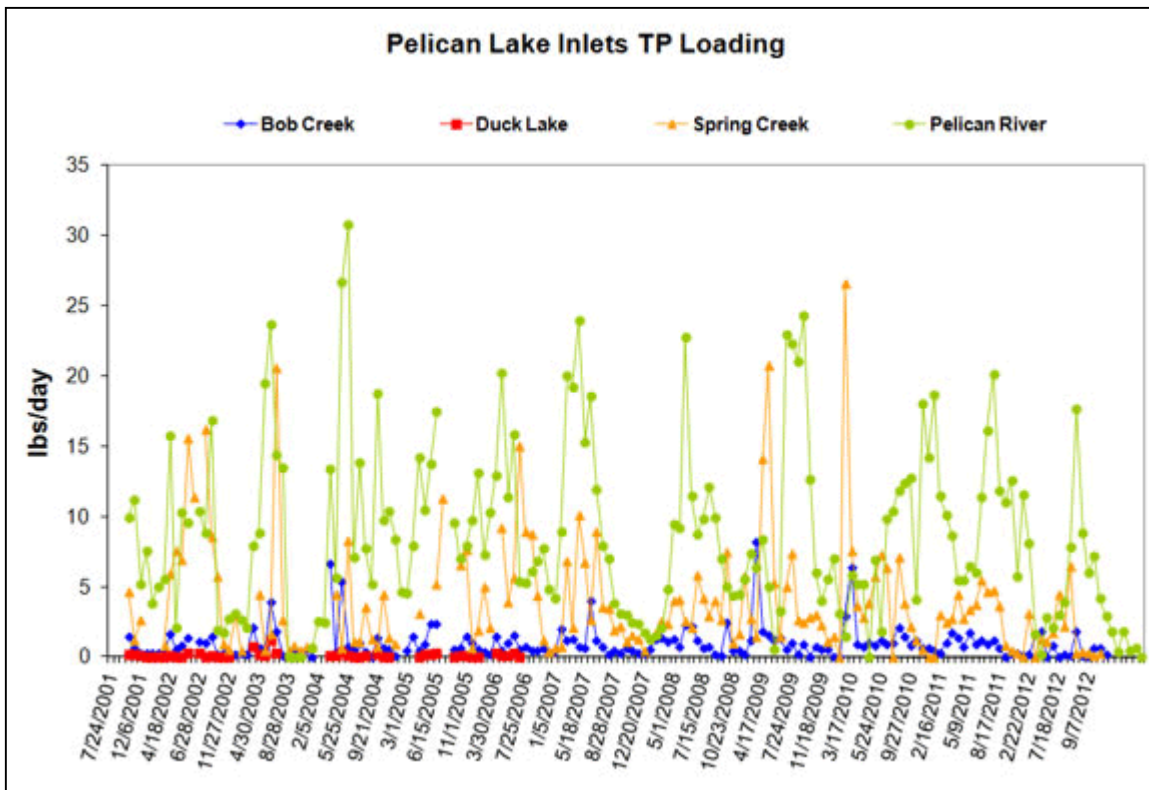


Figure 2.19 Comparison of total phosphorus loading from each inlet to Pelican Lake.

In looking at all the monitoring sites in each watershed, one can better pinpoint potential sources of phosphorus (Figure 2.20). In the Bob Creek watershed, both the Burton Lake Outlet (upstream) and the Bob Creek Inlet to Pelican Lake have similar phosphorus loading. This result means that not much phosphorus is picked up by Bob Creek as it passes through a cattle farm and a large wetland.

In the Spring Creek Watershed, water exits Lake Ida and Big Cormorant Lake with very low phosphorus concentrations. The Sherbrooke Road site has higher phosphorus loading than the source at Big Cormorant Lake. As Spring Creek winds back and forth through the city of Cormorant, it has a rapids-like nature and picks up phosphorus from the stream banks as it flows. Further downstream, the branch from Lake Ida joins Spring Creek and then enters Pelican Lake at the Spring Creek Inlet. The phosphorus loading at the Spring Creek Inlet is slightly higher than at Sherbrooke Road, which could come from the Lake Ida branch or the wetlands.

The Pelican River has the highest phosphorus loading of all the watersheds. The Highway 20 site is just upstream from Little Pelican Lake and the Stroms Bridge site is between Little Pelican and Pelican Lakes. The results show that some phosphorus remains in Little Pelican Lake and most likely gets taken up by plants and algae for food.

The sum of the phosphorus loading from the inlets is higher than from the Pelican River Outlet, but this is common in lakes. The extra phosphorus gets utilized by plants and algae in the lake and also gets deposited at the bottom of the lake into the sediments.

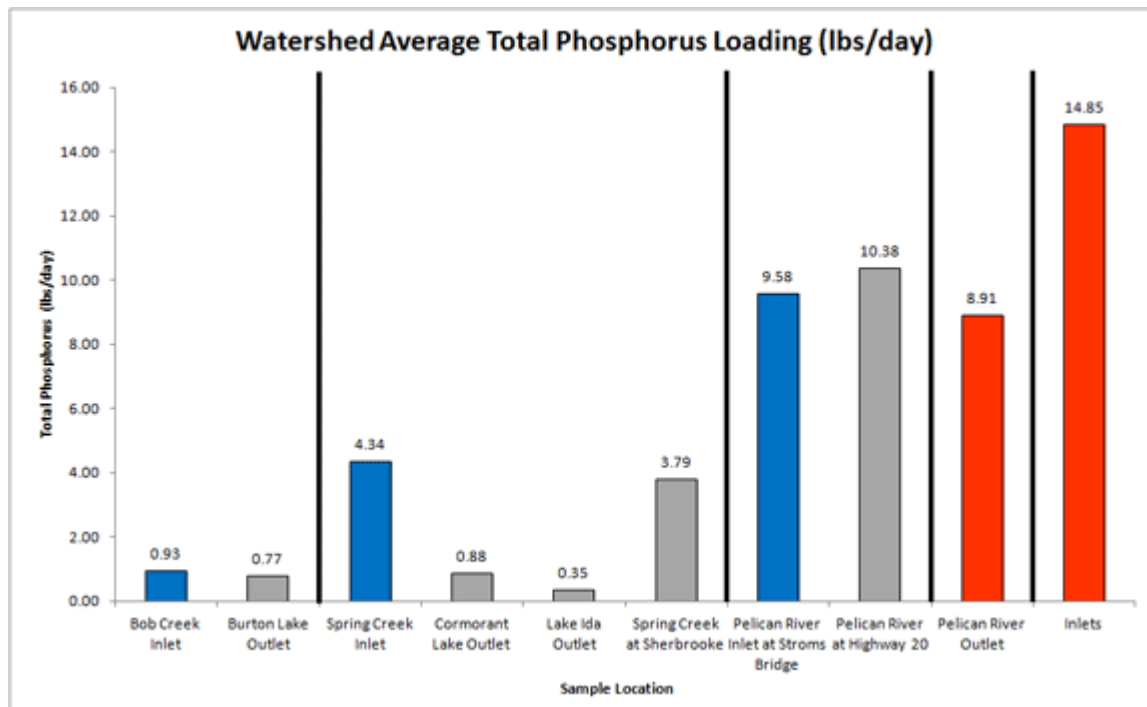


Figure 2.20 Comparison of total phosphorus loading from each watershed. The bars in blue are the actual inlets to Pelican Lake. The grey bars are monitoring sites upstream from the lake. For locations see Figure 2.13.

### Chlorophyll a

The chlorophyll a (algae concentration) loading patterns in Pelican Lake follow the phosphorus loading patterns since phosphorus is food for algae (Figure 2.20-2.21).

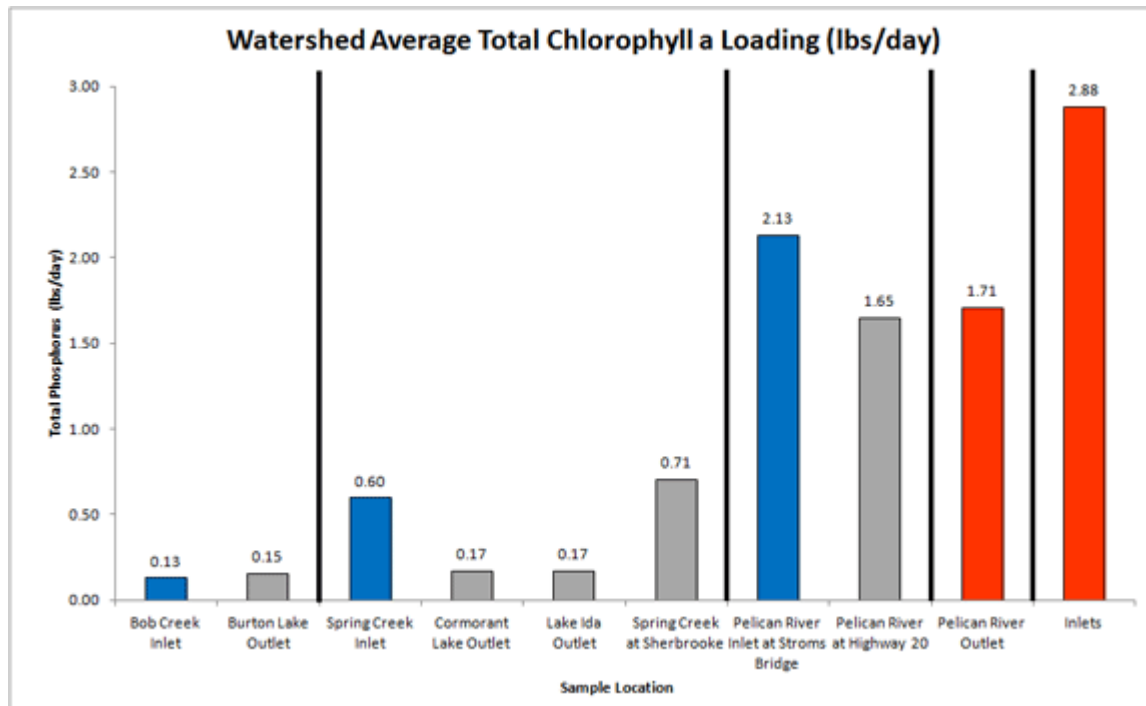


Figure 2.21. Comparison of total phosphorus loading from each watershed. The bars in blue are the actual inlets to Pelican Lake. The grey bars are monitoring sites upstream from the lake. For locations see Figure 2.

### Links to more detailed stream data

For more detailed stream data, analysis and conclusions, please visit the Lake Management Plan on the PGOLID website: <http://www.pgolid.org/LMP/main.htm>.