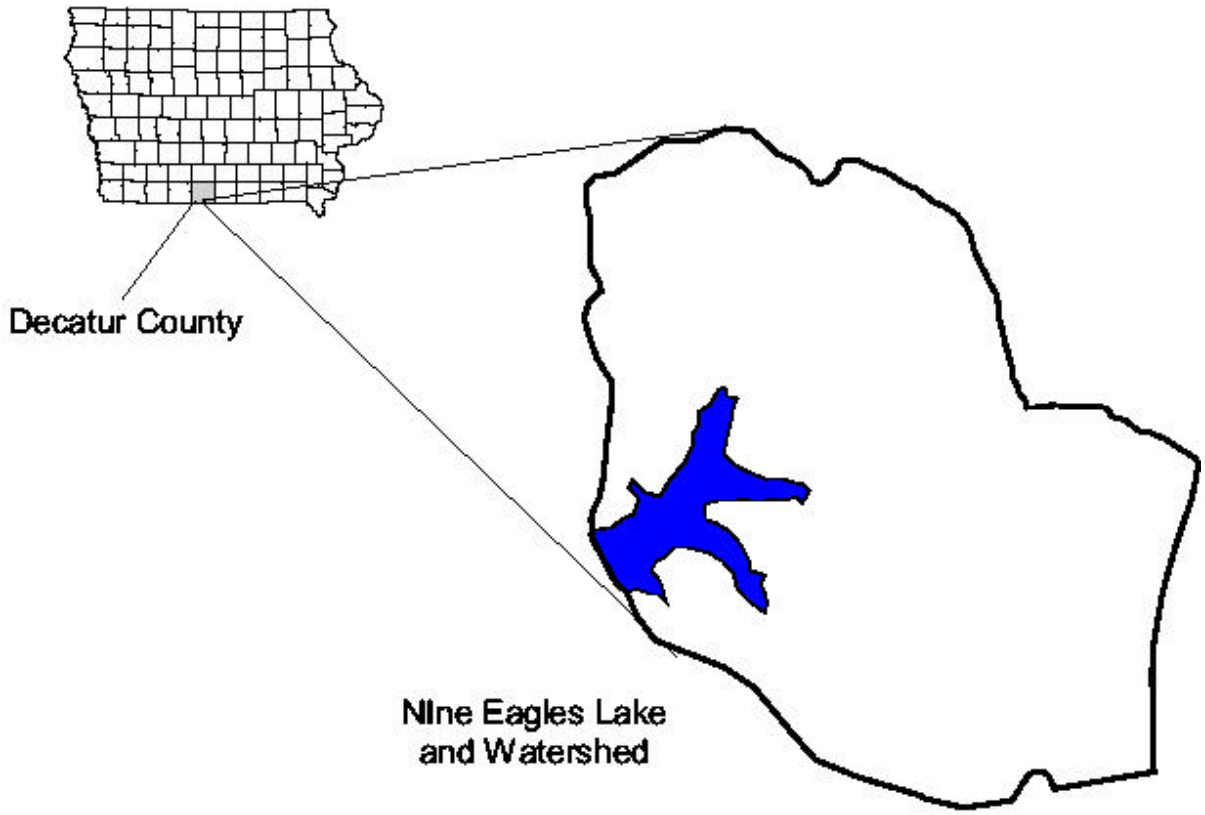
Total Maximum Daily Load
For Turbidity
Nine Eagles Lake
Decatur County, Iowa

December 2000

Iowa Department of Natural Resources
Water Resources Section

TMDL for Turbidity
Nine Eagles Lake
Decatur County, Iowa

Waterbody Name:	Nine Eagles Lake
IDNR Waterbody ID:	IA 05-GRA-01010-L (incorrectly listed as IA 05-THO-00110-L on the 1998 303(d) list)
Hydrologic Unit Code:	HUC11 10280102050
Location:	Sec. 18, T67N, R25W
Latitude:	40 Deg. 36 Min. N
Longitude:	93 Deg. 46 Min W
Use Designation Class:	A (primary contact recreation) B(LW) (aquatic life) C (potable water source)
Watershed Area:	1,185 acres
Lake Area:	Approx. 60 acres
Major River Basin:	Southern Iowa River Basin
Tributaries:	Unnamed intermittent streams
Receiving Water Body:	Thompson River
Pollutant:	Turbidity
Pollutant Sources:	Gully and Streambank Erosion
1998 303d Priority:	High



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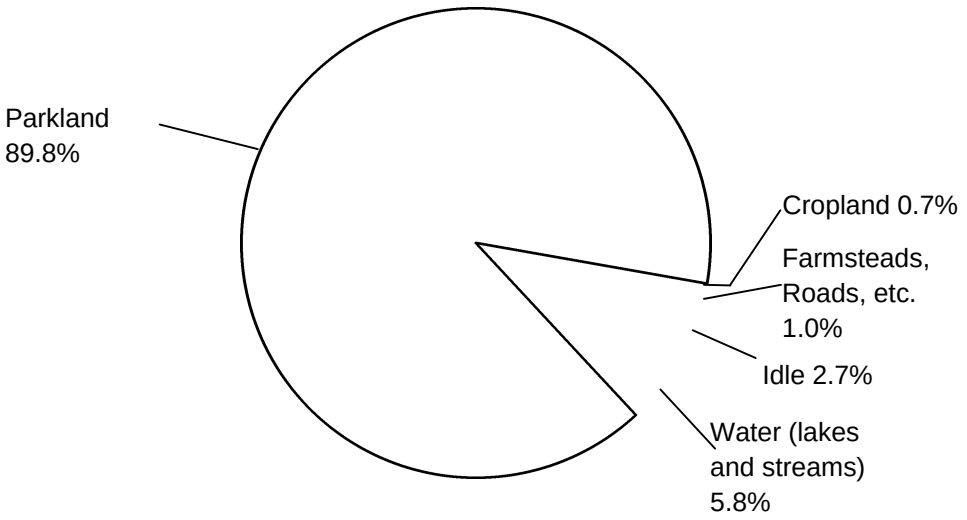
1. Description of Waterbody and Watershed

Nine Eagles Lake was built in 1952 and is located in south central Iowa about 3.5 miles southeast of Davis City, Iowa. In 1973, the lake had a surface area of 67 acres, a mean depth of 13 feet, a maximum depth of 34 feet, a storage volume of 888 acre-feet, and a shoreline of 2.64 miles. The lake was studied again in 1986 by the University of Iowa Hygienic Laboratory (Kennedy and Miller, 1987) and had a surface area of 55 acres, a maximum depth of 32 feet, and a storage volume of 850 acre-feet. The report cautions that the lake mapping methodology used did not provide the level of detail needed to accurately determine changes in the physical characteristics of the lake. The Iowa DNR estimates the current surface area of the lake to be approximately 60 acres.

Nine Eagles State Park provides facilities for boating, swimming, fishing, camping, picnicking, hiking, horseback riding, and snowmobiling. Park use is approximately 77,000 visits per year.

The Nine Eagles Lake watershed has an area of approximately 1,185 acres and has a watershed to lake ratio of 19:1. The State Park comprises 1,119 acres of this watershed. The park consists primarily of woodland. Land use data was collected in 1990 by the Division of Soil Conservation (DSC-DNR, 1991) for the Nine Eagles Lake watershed. The land uses and associated areas for the watershed are shown in Figure 1.

Figure 1. Land use in the 1,185 acre Nine Eagles Lake watershed.



About 32.0 acres of the watershed are identified as idle land, which includes irregularly shaped tracts of land and parts of cropland fields that are not farmable and are not improved for pasture or other uses. Only 8.3 acres of land are identified as cropland. In 1990, this cropland was in meadow. The idle land and cropland were re-evaluated in

spring 2000 by the Natural Resource Conservation Service (NRCS) and were again found to be seeded and not used for row crop production.

Topography of the watershed varies from gently sloping to steep (2-40%). Soils of the watershed are primarily forest-derived developed from pre-Wisconsin till or loess and include Lindley, Keswick, Kniffin, and Bucknell (DSC-DNR, 1991). These soils are generally composed of 27-60% clay. Permeability of these soils is slow to moderately slow and runoff is very rapid. These types of soils present severe erosion hazards and are typically low to very low in available phosphorous (UDSA-SCS, 1990). The physical characteristics of these high clay content soils lead to extended suspension of the clay colloids once they become eroded and are delivered to a waterbody.

Average rainfall in the area is 35 inches/year, with the greatest monthly amount (5.5 inches) occurring in June.

2. Applicable Water Quality Standards

The Iowa Water Quality Standards (Iowa, 1996) list the designated uses for Nine Eagles Lake as Primary Contact Recreation (Class A), Aquatic Life (Class B(LW)), and Potable Water Source (Class C). Nine Eagles Lake also has general uses of secondary contact recreation, agricultural uses, domestic uses, and livestock watering.

Nine Eagles Lake was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. This lake has high turbidity following high rainfall events. The State of Iowa does not have numeric water quality criteria for turbidity or siltation that apply to Nine Eagles Lake. However, the Iowa Water Quality Standards do contain general water quality criteria that apply. Nine Eagles Lake did not meet the narrative water quality standard that states, “waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions” (IAC 567-61.3(1)). It is believed high turbidity is an objectionable aesthetic condition.

3. Water Quality Conditions

Water quality studies have been completed on Nine Eagles Lake by the University of Iowa Hygienic Laboratory (1986) and by Iowa State University (ISU) for the Clean Lakes Classification Study (1979, 1990). In addition, Nine Eagles Lake has been included in an algal toxin project by The University of Missouri (1999).

Data collected on Nine Eagles Lake by the University of Iowa Hygienic Laboratory during 1986 (Kennedy and Miller, 1987) is presented in Table 1.

Table 1. Data for Nine Eagles Lake collected in 1986 by the University of Iowa Hygienic Laboratory (Kennedy and Miller, 1987).

Date Collected	6/25/86			7/22/86			9/3/86		
Depth (feet)	0	14	28	0	10	30	0	16	30
Secchi (meters)	1.7			0.9			0.76		
Total Phosphorus (mg/L)	0.06	0.07	0.11	0.04	0.02	0.07	0.05	0.08	0.20
Suspended Solids (mg/L)	8	13	21	24	14	40	16	14	32

Suspended solids in 1986 ranged from 8 to 40 mg/L with the higher values being found in the bottom samples. The higher solids values may be attributed to the settling of material from the upper water layers that include 1) sediment and organic matter from tributary streams, 2) soil from streambank and lake shoreline erosion, and 3) dead plankton and other allochthonous and autochthonous matter. During a 1979 Clean Lakes Classification Study (Bachmann, et al., 1980), suspended solids ranged from 17 to 107 mg/L and also generally increased with depth. A comparison of suspended solids results are shown in Table 2 for three years of monitoring.

Table 2. Comparison of Secchi Disk Depth and Suspended Solids minimum and maximum results from three studies completed in 1979, 1986, and 1990.

Year	1979		1986		1990	
	Min	Max	Min	Max	Min	Max
Secchi (meters)	1.5	2.6	.76	1.7	0.9	1.9
Suspended Solids (mg/L)	17	107	8	40	11	18

Secchi disk depth is a measurement of the depth of visibility or transparency of a water body. In 1979, Secchi readings measured by ISU ranged from 1.5 to 2.6 meters with an average (N=3) of 2.0 meters (Bachmann, et al., 1980). Readings for the three 1986 sampling events conducted by UHL ranged from .76 to 1.7 meters with a mean (N=3) of approximately 1.1 meters (Kennedy and Miller, 1987). In 1990, a study of Iowa's lakes by ISU (Bachmann, et al., 1994) indicated a Secchi depth range of 0.9 to 1.9 meters with a mean (N=3) of 1.3 meters. Data collected in 1999 by the University of Missouri is also within this range (Table 4)

Table 3. Data collected in 1990 by Iowa State University (Bachmann, et al., 1994).

Date Collected	6/6/90	7/6/90	8/4/90
Secchi (meters)	1.9	1.1	0.9
Total Phosphorus (mg/L) *	0.045	0.049	0.052
Suspended Solids (mg/L) *	15.1	13.3	15.3

* Average of three composite samples taken at different locations.

Table 4. Data collected by the University of Missouri in 1999 (Johnson, 3/2000).

Date Collected	7/26/99	8/16/99
Secchi (meters)	1.0	1.0
Total Phosphorus (mg/L)	0.035	0.025
Suspended Solids (mg/L)	10.6	5.0

Secchi disk depths for lakes in general are expected to be the lowest during July and August due to both sediment and algae growth. The readings at Nine Eagles Lake were taken during those seasons and therefore are likely to represent the most critical seasonal conditions. Over the long term, summer Secchi depths have remained relatively constant for the last 14 years. However, anecdotal evidence suggests that high turbidity results after precipitation events. The presence of highly erodable and high clay content soils in the watershed is consistent with that anecdotal data. The fine-grained clay sediment can remain suspended in the water for extended periods. This

soil erosion, and subsequent suspension of clay particles, is believed to be the principal cause of low Secchi disk readings.

Phosphorous levels were studied in Nine Eagles Lake in 1986 by the University of Iowa Hygienic Laboratory (Kennedy and Miller, 1987) and in 1990 by Iowa State University (Bachmann et al., 1994). Nine Eagles Lake had the 9th lowest phosphorous result of the 115 publicly owned lakes studied in 1990 and 1992 (Bachmann et al., 1994). These results indicate that the lake is eutrophic. However, excess phosphorus loading and algae growth are not believed to be the principal cause for low turbidity at Nine Eagles Lake. The phosphorus results collected in 1986 and 1990 are shown in Tables 1 and 3.

Despite problems with turbidity, the fishery at Nine Eagles Lake appears to be strong. Fish population estimates are available from a 1984-86 mark and recapture study (DSC-DNR, 1991). The biomass and population estimates for the major game species are shown in Table 5. An Iowa DNR Fisheries Biologist indicates that these numbers are representative of the current fishery at Nine Eagles Lake. The lake is currently dominated by 10-14 inch largemouth bass (McGhee, 4/2000).

Table 5. Major Species, Biomass and Population Estimates with Confidence Intervals for Nine Eagles Lake, 1986

Species	Pounds/Acre			Total Number		
Bluegill	138	+/-	33	83,300	+/-	19,100
Redear Sunfish	48	+/-	10	7,800	+/-	2,100
Black Crappie	24	+/-	6	5,700	+/-	1,720
Largemouth Bass	38	+/-	4	4,860	+/-	694
Channel Catfish	14	+/-	1	1,006	+/-	165

4. Desired Endpoint

The listing of Nine Eagles Lake is based on narrative criteria. There are no numeric criteria for turbidity applicable to Nine Eagles Lake or its sources in Chapter 61 of the Iowa Water Quality Standards (Iowa, 1996). Therefore, an appropriate endpoint for turbidity needs to be determined. Secchi disk depth was chosen as the best indicator for this impairment for two reasons. First, it is an accepted form of measurement for the depth of visibility or transparency of lake water. Secondly, there is a small body of information that exists with respect to historical Secchi disk depth at Nine Eagles Lake.

To determine an appropriate Secchi disk depth endpoint, two pieces of information were reviewed. First, a Clean Lake Restoration Project recently completed by the IDNR Fisheries Bureau (Bonneau, 1999) was reviewed. The report concludes that as a partial result of the lake restoration and improved water quality, park usage tripled after the restoration was complete. Second, the available data on Nine Eagles lake suggest an acceptable Secchi disk depth of 1.25 meters.

Thus, the endpoint for the TMDL for Nine Eagles Lake will be set at a mean Secchi disk depth of 1.25 meters. Secchi disk readings will be taken weekly at the deepest area of the lake and averaged for the year to determine if the lake has met its desired endpoint.

The endpoint will be achieved by reducing sediment load delivery to the lake by 50%. The main source of sediment to Nine Eagles Lake is naturally occurring gully and

streambank erosion within the forested areas of the watershed. Minimizing these sources will result in at least a 50% reduction in the overall watershed sediment delivery rate.

5. Loading Capacity

The Iowa DNR has restored several lakes as part of the Clean Lakes program. These prior restorations have shown that reducing sediment delivery by 50% will allow the lakes to achieve the necessary water quality needed to fully support their designated uses (Bonneau, 1999). These restorations have also shown that an increase in water clarity will increase the visitor use of the lake. Though other factors influence turbidity and Secchi disk depth, a reduction in sediment delivery usually results in an increased Secchi disk depth. The Iowa DNR has determined, based on Bonneau's report (1999), that by reducing sediment delivery to Nine Eagles Lake to 3,633 tons/year (3 ton/acre/year average), Secchi disk depth can be improved to the desired endpoint, thus restoring the lake to water quality standards. A sediment delivery rate of 3 t/a/y also correlates with an erosion factor T of 4.32 t/a/y. "T is an estimate of the maximum average annual rate of erosion by wind or water that can occur without affecting crop productivity over a sustained period" (USDA-SCS, 1990). An average delivery rate of 70% (Appendix I) would then yield 3.0 t/a/y of sediment delivered to the lake at T.

6. Pollutant Sources

Water quality in Nine Eagles Lake is influenced only by nonpoint sources. There are no point source discharges in the watershed. Field investigations to determine landuses, cropping patterns, fertilizer use, conservation practices, livestock operations, and gully erosion were originally made in October 1990 by the Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation and were repeated in March 2000 by the local NRCS office. In 1990 and 2000, the 8.3 acres of cropland in the watershed were in meadow and not used for row crop production. There are no livestock operations in the watershed.

Nonpoint source pollution is caused by materials transported to the lake with runoff from the watershed. Gully, streambank, and streambed erosion can be a significant contributor to poor water quality and lake degradation. Although all land within a watershed contributes runoff containing sediment, the main source of this pollutant in the Nine Eagles Lake watershed is naturally occurring gully and streambank erosion within the forested areas of the watershed. Almost all soil eroded by these methods ends up in the lake, causing excessive turbidity.

It is clear from observations made that the most significant sediment delivery problem in the Nine Eagles Lake watershed is from gully erosion. Each of the four main watercourses entering the lake has active gully erosion. Four sedimentation basins are located within the watershed and six rock dams have been placed across upper cove areas at watercourse inlets to the lake. However, these existing structures are showing signs of degradation and will require improvements and continued maintenance if they are to remain effective in preventing sediment delivery.

7. Pollutant Allocation

7.1 Point Sources

The state park has a waste treatment lagoon that discharges at a point downstream from the lake. Since there are no point discharges within the Nine Eagles Lake watershed the Wasteload Allocation established under this TMDL is zero.

7.2 Non-Point Sources

The watershed of Nine Eagles Lake is almost entirely timber. Cropland accounts for less than one percent of the land use. However, nonpoint source gully and streambank erosion accounts for almost all sediment entering the lake and the resulting turbidity of the water.

Sediment delivery estimates were determined by using the Iowa Small Structures Design Manual (SCS, 1985). The following equation was used to calculate sediment delivery to Nine Eagles Lake:

Sediment Delivery (t/a/y) = Drainage Area x Gross Erosion Rate x SDR x Gully Factor

Where: Drainage Area is the subwatershed in acres
Gross Erosion is 5 Tons/acre/year
SDR is the Sediment Delivery Rate = 70%
Gully Factor is determined by the activity in the watershed:
When no gullies are present this factor is 1. For active, uncontrolled gullies, these factors are:
(1) moderately active gully = 1.35
(2) active gully = 1.7
(3) Extremely active gully = 2.0.

Calculations were made for each subwatershed using this sediment delivery equation. Each subwatershed was broken into two categories, areas to be protected by structures, and those not protected by structures. Calculations were made for each category within each subwatershed. A trap efficiency of 80% was calculated for those areas of the watershed protected by the structures. The sediment deliveries for each category within a subwatershed were added together to obtain a total sediment delivery for the subwatershed. The total sediment delivery for the entire Nine Eagles Lake watershed was obtained by adding the sediment deliveries for all subwatersheds (see Appendix I).

The current sediment delivery to Nine Eagles Lake is 7,264 tons/year. The Load Capacity established to support the endpoint of this TMDL, is 3,633 tons/year of sediment delivered to Nine Eagles Lake. This represents a 50% annual reduction in the amount of sediment entering the lake. A reduction in total sediment delivered will result in improved Secchi depth readings, which will improve water clarity.

Table 6 shows, by subwatershed, the gross sediment delivery without any structures, a Load Capacity representing a 50% sediment delivery, and an allocation of sediment Load Capacity incorporating a margin of safety.

Table 6. Sediment delivery to Nine Eagles Lake (T/A/Y).

Subwatershed	Gross Delivery	Load Capacity	Allocation w/ MOS
I	1,656	828	745
II	1,153	577	519
IIA	1,554	777	699
III	1,285	643	579
IV	1,068	534	481
V	422	211	190
VI	126	63	57
Total	7,264	3,633	3,270

7.3 Load Allocation and Margin of Safety

The margin of safety is explicit. The margin of safety is incorporated into the load allocations by deducting 10% from the loading capacity of each of the seven subwatersheds. This results in a final load allocation, including the margin of safety, of 3,270 tons of sediment delivered to the lake per year (Table 6). This is expected to provide ample reductions in sediment delivery such that the 1.25 meter mean Secchi disk depth endpoint can be achieved.

8. Seasonal Variation

It is expected that the majority of all erosion occurring in the Nine Eagles Lake watershed occurs in the spring and early summer during periods of high rainfall.

9. Implementation

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy as a guide to improve water quality at Nine Eagles Lake.

The watershed of Nine Eagles Lake is primarily woodland and varies from gently sloping to steep. Active gully erosion has been identified as a problem within the watershed. The problem was addressed in 1979 by constructing four sedimentation basins in the watershed and placing rock dams across cove inlets to the lake. These structures are presently reducing the amount of sediment delivered to the lake. Continued maintenance will be required if they are to remain effective in protecting the lake.

The following is an inventory by subwatershed of structures within in the Nine Eagles Lake watershed (see Figure 2 for identification of subwatersheds):

Subwatershed	Structures
I	Nonfunctioning structure near lake needs repair.
II	No structures present.
IIA	Roadside dam before draining to subwatershed II. Functional, but needs minor repair.
III	Functioning water retaining pond within watershed. Needs repair.
IV	Functioning water retaining pond within watershed. Needs repair.
V	No structures present.
VI	No structures present.

The repair of four existing structures and the construction of additional structures within the forested portion of the watershed will reduce the amount of sediment delivered to Nine Eagles Lake (Appendix I).

In addition to gully erosion, there are areas within the park where trail erosion is a problem. The trails at Nine Eagles State Park have very little erosion control practices in place. The Division of Parks, Preserves and Recreation, IDNR, will be consulted with respect to reducing the amount of erosion on the trail system. The Division of Forests and Prairies, IDNR, has begun work on developing a forest management plan for the state owned land surrounding Nine Eagles Lake. Part of this management plan will determine how to establish more ground vegetation within the forest to help slow the rate of gully erosion.

Bathymetric mapping of Nine Eagles Lake will be completed at Nine Eagles Lake by 2002. This mapping will show the original lake bottom and the depth of sediment that has been deposited in the lake. Additional water quality monitoring will be completed at Nine Eagles Lake as part of the Iowa Lakes Survey 2000. In lake water monitoring will be completed three times per year for each of the field seasons 2000 –2005.

The Fisheries Bureau of the Iowa Department of Natural Resources has applied for grants from Clean Water Act Section 319/Division of Soil Conservation Water Protection Funds to construct and repair sediment control structures in the Nine Eagles Lake watershed. If approved, construction will be completed in 2001. Section 319 grants are subject to the provisions of the Endangered Species Act. Any projects within the watershed will consider any endangered species.

10. Public Participation

A public meeting regarding the Nine Eagles Lake TMDL was held on November 15, 2000 in Leon, Iowa. Comments were received until December 15, 2000, and where appropriate, incorporated into the final document.

11. References

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12. Appendix I

Sediment Delivery by subwatershed for each category of the subwatershed. Those areas protected by sedimentation basins, and those not protected.

SubWatershed & Total Acres		Acres	Delivery w/o structures	Delivery with structures	Gully Factor	Percent Reduction
I (268)	Protected	205	1435	287	2.0	70
	Not protected	63	221	221	1.0	
II(184)	Protected	107	749	150	2.0	52
	Not protected	77	404	404	1.5	
IIA (222)	Protected	222	1554	311	2.0	80
III (202)	Protected	165	1155	231	2.0	72
	Not protected	37	130	130	1.0	
IV (156)	Protected	149	1043	209	2.0	78
	Not protected	7	25	25	1.0	
V (68)	Protected	37	259	52	2.0	49
	Not protected	31	163	163	1.5	
VI (25)	Protected	11	77	15	2.0	48
	Not protected	14	49	49	1.0	
Total		1125	7,264	2,247		70

Nine Eagles Lake Watershed