

THE VILLAGE OF WOLVERINE LAKE

MASTER PLAN



Adopted: April 13, 2022

VILLAGE OF WOLVERINE LAKE, MICHIGAN

Memorandum of a Resolution adopted at a regular meeting of the Planning Commission of the Village of Wolverine Lake, Michigan held on March 24, 2022.

PRESENT: Tom Hite, Brian Linman, Paul Snyder, Brian Nedrow, James Clark, Scott Fredericks, Cathy Moretto, and George Weber

ABSENT: Brandon Thorn

The following resolution was offered by Commissioner Linman, and supported by Commissioner Snyder.

WHEREAS the Village of Wolverine Lake Planning Commission recognizes the need to formulate and adopt a Village Master Plan including establishment and support of a Land Use Plan as described in this document and in accordance with the Michigan Planning Enabling Act, PA 33 of 2008, as amended.

WHEREAS the Planning Commission identified the need to amend the Village Master Plan to update the demographics information, existing land use information, future land use goals, and Zoning Plan.

WHEREAS the Planning Commission requested input from the Village of Wolverine Lake residents, Village businesses, property owners, and visitors via an on-line/paper survey to help guide development of the Master Plan update. The Planning Commission also held a Public Hearing to obtain input on the document.

WHEREAS, the Planning Commission used the input obtained from survey, and from those providing comments via the Public Hearing and other methods, to revise the Village Master Plan.

WHEREAS the staff at the Oakland County Economic Development and Community Affairs Department reviewed the amendment and found that the amendment was not inconsistent with the plan of any surrounding communities that received notice of the draft plan.

WHEREAS a copy of this Master Plan amendment has been forwarded to the City Council for adoption.

NOW, THEREFORE, BE IT RESOLVED that:

- 1) The Village of Wolverine Lake Planning Commission hereby recommends adoption by resolution of the Master Plan Update, dated February 28, 2022 including the Future Land Use map.
- 2) A certified copy of the Future Land Use Plan portion of the Plan will be forwarded to Oakland County and Wayne County for filing.
- 3) All resolutions and parts of resolutions insofar as they conflict with the provisions of this resolution be and the same hereby are rescinded.

AYES: Hite, Linman, Snyder, Nedrow, Clark, Fredericks, Moretto, and Weber.

NAYS: 0

RESOLUTION DECLARED ADOPTED



Tom Hite, Chair
Planning Commission



Brian Linman, Vice Chair
Planning Commission

THE VILLAGE OF WOLVERINE LAKE MASTER PLAN

ACKNOWLEDGEMENTS

PLANNING COMMISSION

Tom Hite, Chairperson
Brian Linman, Vice Chairperson
Paul Snyder, Secretary
Brian Nedrow, Council Liaison
James Clark
Scott Fredericks
Cathy Moretto
Brandon Thorn
George Weber

VILLAGE COUNCIL

Brian Nedrow, President
Mark Duff, President Pro Tem
David Dumont
Mark Giromini
Bob Malek
Mike McNutt
Bill O'Brien

VILLAGE STAFF

David Gillam, Administrator & Clerk
Michael Kondek, Village Treasurer
John Ellsworth, Chief of Police
Tim Brandt, Building Inspector

CONSULTANTS

Attorney: Baker & Elowsky, PLLC
Planning: Carlisle/Wortman Associates, Inc.
Engineering: Powell Engineering and Associates, LLC
Photo Credit: Tom Hite and Scott Fredericks (pg. 24)

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INTRODUCTION



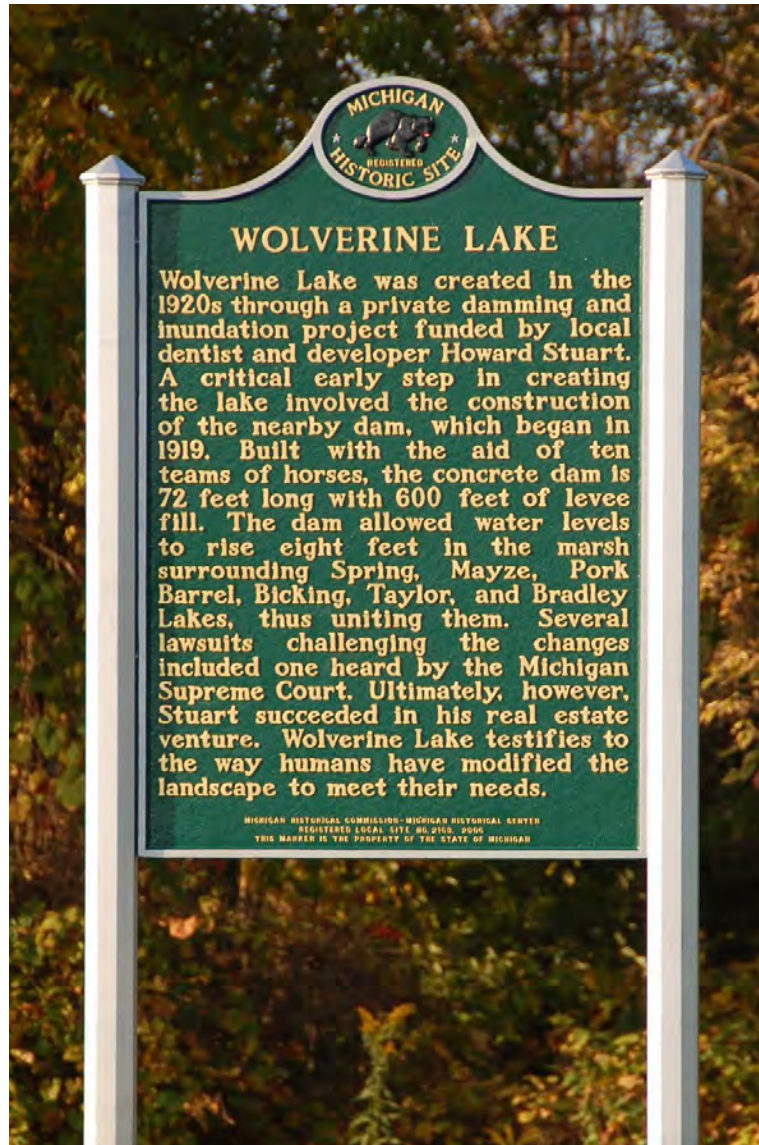
INTRODUCTION

The first Land Use Plan for the Village of Wolverine Lake was prepared by Robert K. Swarthout, Inc. with the participation of the Village of Wolverine Lake Planning Commission. Work was completed during the fall of 1983 and the winter of 1983-4. This Land Use Plan was adopted by the Village Council on January 8, 1986.

The 1986 Plan was used as the basis for the more comprehensive Master Plan in 2008, which included “Goals and Objectives” as established by the Village Council, current land use maps, updated information from SEMCOG based on the 2000 census, plus comparison data of land use in Oakland County from Oakland County Planning and Economic Development. The Planning Commissioners were guided by the Village Planning Consultant, Carlisle/Wortman Associates, Inc., and also included input obtained through surveys and public forums.

Current law requires that communities update master plans every five years. This 2021 Plan was completed by the Planning Commission with the assistance of Carlisle/Wortman Associates, Inc. It represents an update to the previous Master Plan, including information consistent with changes that have occurred over the past five years.

HISTORY AND CHARACTER



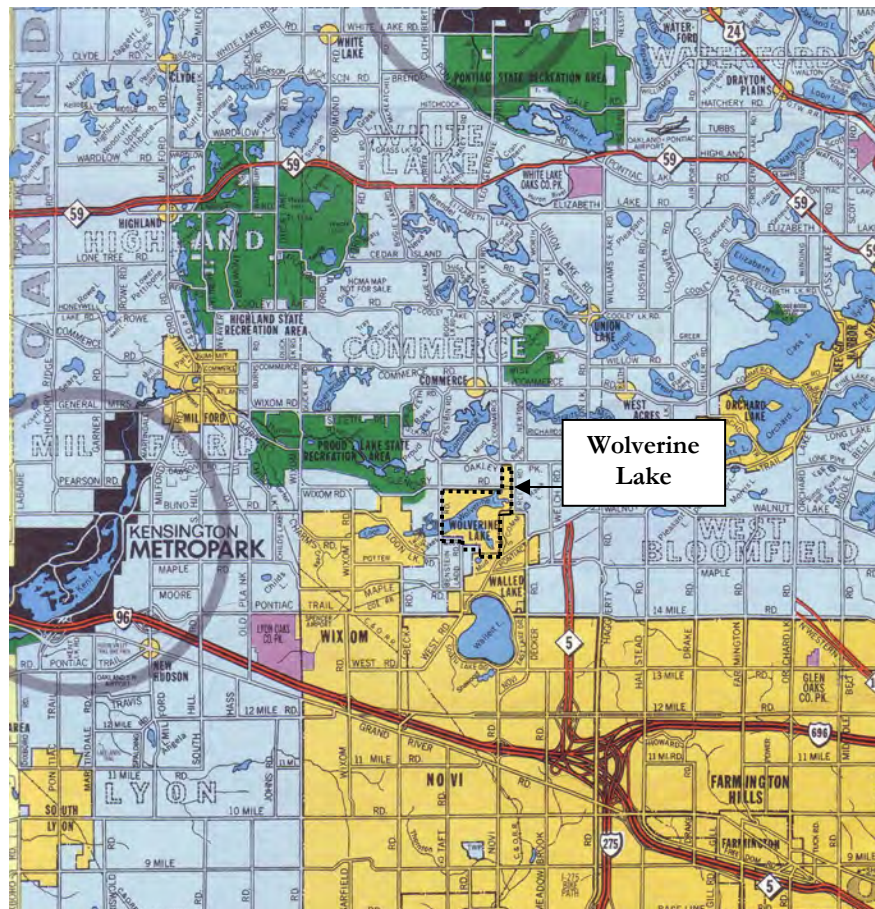
HISTORY AND CHARACTER

Wolverine Lake was created from six small lakes in 1923. Dr. Howard Stuart, known as the Founding Father of Wolverine Lake, was responsible for the building of a dam which raised the water level and connected the six lakes. It took him three years to convince the property owners to sign an agreement to overflow the necessary land. Construction of the dam was finally completed in March of 1923, after many setbacks and two lawsuits.

Wolverine Lake became incorporated as a home rule Village on April 5, 1954. Since then, it has developed into one of the most desirable communities in Oakland County. Today, over 4,000 residents enjoy the lake year round. The Village is mostly residential, including seven miles of shoreline, with very little commercial and no industrial uses.

WOLVERINE LAKE TODAY

The Village of Wolverine Lake is a residential community built around a 289-acre, all-sports lake. The 1.69 square mile village is located 29 miles from Detroit, 25 miles from Detroit Metro airport, and only eight miles from the Oakland International Airport. The Village is part of Commerce Township and surrounded by fully developed communities, including Walled Lake to the south, Wixom to the west, and Commerce Township on the north and east sides.



Wolverine Lake Village is serviced by the Walled Lake school system and Commerce Township Fire Department. The Village maintains its own police department. For the 2020-2021 school year, the Walled Lake School system had a full-time enrollment of 12,495 students with a graduation rate across the school district in 2019-2020 of 92%.

There are a few local retail services in the Village, but residents have convenient access to many retail and commercial services in adjoining communities, including full-service shopping malls and large specialty stores and theaters. Huron Valley Hospital and Henry Ford Medical Center are very close by for full-service and emergency medical treatment. The Village has three churches and there are several in nearby communities. The Village is served by the Walled Lake post office. Village residents can use the Commerce Township library.

THE LAKE

The lake is the nucleus and heart of the community. The citizens are dedicated to preserving and protecting the quality of the lake which they consider as their "main street." Wolverine Lake provides both scenic beauty and recreational space for the entire area. Residents take particular pride in its aesthetic and economic value. It is the focus of neighborhood activities. Residents have access to the lake through subdivision outlots that dot the shoreline. Some of the subdivision parks have swimming beaches and boat launch facilities so residents can fully enjoy the lake. There is also a Department of Natural Resources (DNR) public access site located off Glengary Road.



CIRCULATION AND INFRASTRUCTURE

The Village is approximately five miles north of I-96 and 13 miles east of US-23. A little over one mile east of the Village is the northern terminus of the M-5 project, a relatively new major north-south road that provides a more direct connection to area expressways through the I-96/I-696/I-275/M-5 interchange. The M-5, also known as the Haggerty Road Connector, starts at 13-Mile and ends at Pontiac Trail, where it becomes Martin Parkway. The Parkway extends to a round-about at Richardson Road. These road facilities make the Village easily accessible to major markets and other residential areas.



Many of the area roads are under the jurisdiction of the Road Commission for Oakland County. They include South Commerce, McCoy and Benstein. These roads also function as the boundary lines for the Village, along with Glengary Road.

The nearest major airport is Detroit Metropolitan Airport located approximately 25 miles southeast of the Village, providing both national and international service. The Oakland County International Airport is located approximately eight miles northeast of the Village and is a corporate and general aviation airport that is intended to serve private, rather than commercial passenger, aircraft. Bishop Airport in Flint is an alternative to Detroit Metropolitan Airport and is approximately the same distance north of the Village as Detroit Metropolitan Airport is south. Major airlines serve this airport but are not on the same direct links to major cities as Detroit Metro Airport.

There is no regular bus service provided to the Village. In coordination with Commerce Township, the Village provides transportation services to seniors and people with disabilities.

The Village of Wolverine Lake has been working over the past decade to install a system of non-motorized pathways for pedestrian and bicycle access throughout the community. This system, known as the United Neighborhoods Pathway Plan, now allows a portion of residents on the south side of the lake to access important Village destinations, such as Clara Miller Park, commercial establishments along Benstein and Glengary roads, and the Vita Trail. The map on page 35 in the *Future Land Use Plan* chapter shows the existing pathways, as well as pathways currently under construction, and those planned for the future. The trail system will also connect Wolverine Lake to other communities, such as Commerce Township and the City of Wixom, as well as regional trails and recreation facilities.

Table 1 Village of Wolverine Lake Existing Non-Motorized Pathway Segments		
Existing Segment	Between	Length (Approx.)
S. Commerce Rd.	Oakley Park Rd. and Glengary Rd.	2,500 feet
Oakley Park Rd.	S. Commerce Rd. and Lakes Community Trail in Hickory Glen Park (Commerce Twp.)	5,100 feet
Glengary Rd.	S. Commerce Rd. to Vita Trail Park	4,300 feet
Vita Trail Park/ Wakito/Clara Miller Park	Glengary Rd. and Benstein Rd.	4,050 feet
Benstein Rd.	Clara Miller Park and Connecticut	225 feet
Connecticut	Benstein Rd. and Darnell St.	225 feet
Darnell St.	Connecticut and Delmonte	1,725 feet
Delmonte St.	Darnell St. and Benstein Boardwalk	225 feet
Benstein Boardwalk	Delmonte St. and McCoy Rd.	1,575 feet
McCoy Rd.	Benstein Boardwalk and Lakeview Dr.	400 feet
Lakeview Dr.	McCoy Rd. and Ladd Rd.	2,550 feet
Wolverine Dr.	Adelaide Dr. and Penny Lake Rd.	2,775 feet
Wolverine Dr.	Penny Lake Rd. and S. Commerce Rd.	1,200 feet
S. Commerce Rd.	Wolverine Dr. and Shankin Dr.	825 feet
Benstein Path	Clara Miller Park to Dairy Twist Driveway	1,000 feet
APPROX. TOTAL EXISTING SEGMENTS (in Village)		20,650 feet (3.91 miles)

(Source: Village of Wolverine Lake United Neighborhoods Pathway Plan, 08-18-15)

VILLAGE HALL

Village business was conducted from a leased building on Glengary Road at the corner of Oakview when the Village was incorporated as a home-rule community and adopted its Charter on June 7, 1954. In 1956 the Village purchased property from the State on the north end of the property owned by the DNR and used as a boat launching site. The purchase price was \$1.00 with the agreement that the Village was to maintain the access site and provide restroom facilities. The first portion of the present Village Hall was built in 1962 for an estimated amount of \$8,500, consisting of a garage, police department, administrator's and clerk's offices and Council chambers. The next stage came in 1970 with the addition of a downstairs council chamber, restrooms, furnace room and shower/locker room for the police department and DPW. The upstairs of the new addition held the Village offices for the Administrator, Clerk and Treasurer, and a conference room in one part and the police department in the other part. This addition was designed and built by Village Administrator Clifford Cottrell at a low cost of \$40,000 to the taxpayers.

The building was then remodeled in 1990, including the addition of three new offices to the front of the building, enlarged police department and council chambers, and additional storage area on the lower level. Bonds were sold in the amount of \$325,000 to cover the cost of the renovation.

The most recent renovation was completed in 2015 to modernize the exterior appearance of the building, resurface the parking lot, and add a conference room on the main floor and a storage area on the lower level.

RELATIONSHIP TO COMMERCE TOWNSHIP

Even though the Village of Wolverine Lake is part of Commerce Township in Oakland County, the home-rule charter allows for separate administration and ordinance adoption. The Village has an administrative staff, a building inspector, a public works department, and a police department. The Village residents pay Commerce Township taxes for other services, such as fire protection. Residents pay separate Village and Township property taxes. A State law guarantees the Village boundaries and prohibits annexation of Village property by other communities.

BOARDS AND COMMISSIONS

Village Council is the lead governing body for the Village. The Council is made up of seven members and led by a President and President Pro Tem. Members are elected on a rotating two- and four-year term basis. The Council is responsible for the adoption and enforcement of ordinances and codes for the health and welfare of Village residents. Areas of jurisdiction include, among others, public roads, waterways, public areas, parks, easements and drainage facilities.

The Planning Commission is responsible for working with residents and the Village Council to establish a vision for the Village's future physical development, as reflected in this Master Plan document. It is also responsible for site plan and special use review and approvals, and other planning activities. The Planning Commission reviews existing zoning regulations, holds public hearings on new zoning regulations, and recommends any zoning ordinance text or map amendments to the Village Council. It has nine members appointed by Council and provides liaison members to the Zoning Board of Appeals, Water Management Board, and Parks and Recreation Board.

The Zoning Board of Appeals is responsible to hear and decide on variances to zoning ordinance issues. It is the one Board in which decisions can be overturned only by judicial review. This Board has seven members and two alternates appointed by Council including liaisons from the Planning Commission and Village Council.

The Water Management Board was first formed by an independent group of concerned citizens who were working for the betterment of the lake quality. In 1973, they formed the Water Team, and in February 1992 the Water Team became an official board of the Village and was renamed the Water Management Board. The Water Management Board is a recommending body which is responsible for monitoring and investigating lake issues, including water quality, weed treatment, fish stocking, and boat counts among others. This board has nine members appointed by Council, including liaisons from the Planning Commission and Village Council.

The Park and Recreation Board has nine members appointed by Council including liaisons from the Planning Commission and Council. It is a recommending board to the Village Council. The Park and Recreation Board has planned annual events for residents, including a Fishing Contest, Tiki Candle Night on July 3, Easter Bunny and Santa Claus Brunches for kids, a Village Festival for families, and bus trips to civic, cultural and entertainment events and Michigan tourist destinations. These events have added to the value of community life in the Village.

The Historical Committee was formed in 2004 by the Village Council. Currently, it is in an inactive status due to lack of membership, but can be reinstated if interest is revived. It is known as the Historical Team and their mission is to "develop a complete history of our Village and its people and events; maintain and update records and documents that are part of our history; and develop and implement a format for sharing information with our residents and interested parties." When active, there are eight members who meet monthly to plan and archive records and documents. Their archives are available to residents.

PARK SERVICES

A Park and Recreation Board was first set up in June 1966 with Clara Miller as the first Chairman. An ordinance was adopted in 1977 officially making the Park and Recreation Board an official board of the Village. The park area located between Benstein and Brisbane, and Connecticut and Apple Orchard Lane was used informally for recreation prior to 1983, where only ball diamonds and a field existed for many years. After 1983, Clara Miller Park was master planned and developed. It is now used for informal and organized active recreation and events. The Village adopted an updated 2021-2025 Park and Recreation Master Plan in December 2020. This Plan lays out the goals, policies, and specific actions the Village will work toward to improve its parks system. The Plan also allows the Village to apply for recreation grants from the Michigan Department of Natural Resources.

Clara Miller Park includes playground equipment, basketball courts, in-line hockey rink, ball fields, a soccer field, tennis courts, picnic pavilion, and restrooms on approximately 13 acres of land. Bathrooms were recently updated, and a new storage addition built onto this building. Vehicular access to Clara Miller Park is from Benstein Road about 800 feet south of Glengary. Pedestrian access is from the existing Village trail system, and the regional Lakes Community Trail. The Village adopted a Clara Miller Park Master Plan in 2018 that identifies and prioritizes improvements to this park over the next 20 years. Since adoption of the Plan, the community has come together to build a new Veterans Memorial in Clara Miller Park, and it is currently developing a grant application to replace play equipment with a new playscape, plant trees, and install benches and poured-in-place safety surfacing, as well as a new accessible pathway through the play area. Also, as a component of the United

Neighborhood Pathway system, the Benstein pathway pedestrian connection from Clara Miller Park north to the Dairy Twist driveway along Benstein Road has been recently completed.



AREA GROWTH

The Village is built-out, with very few vacant parcels left. However, the surrounding communities have experienced extensive growth because of I-275, a major north-south thoroughfare, the extension of M-5, and the development of Martin Parkway. These communities include West Bloomfield, Novi, Walled Lake, Wixom, and Commerce Township. Along with residential development, many strip and open-area shopping malls, large freestanding retailers (big-box), and office and industrial parks have been built to support the new residential development.

DEMOGRAPHIC ANALYSIS



DEMOGRAPHIC ANALYSIS

While the Village saw substantial growth in the 1970's, the population has declined slightly and increased slightly over the past 30 years (2000 - 2020). According to the Southeast Michigan Council of Governments (SEMCOG), the Village's population is projected to stabilize through 2045. The demographics analysis below include data from the 2020 U.S. Census, the American Community Survey (also part of the US Census), and SEMCOG estimates and forecasts.

The Village's population increased over the last 10 years (Table 2 and 3). Compared to other lake communities, the Village grew, whereas the other populations lost residents. However, most other larger cities, townships, and the County grew at a similar rate -- and some at a much higher rate -- than the Village. This is likely due to the fact that Wolverine Lake is built out, with little vacant land that is appropriate for development. In contrast, the larger cities and townships still have developable properties. This same fact is also most likely behind SEMCOG's forecast that the Village's population will decrease by 2045.

Similarly, the number of households increased, but this data also reflects the national trend that fewer people are living in each household than in the past (Table 4).

According to the 2015-2019 American Community Survey 5-Year Estimate, the median age for the Village is slightly higher than that of Oakland County and the State of Michigan (Table 5). Table 6 shows decreases in five age groups (5 to 9 years old, 10 to 14 years old, 15 to 19 years, 40 to 44 years, and 45 to 49 years). The increases for 65 to 84 are consistent with aging trends of the baby boom generation across the nation (Table 7).

The median family income is more than both the County and the State of Michigan (Table 8). Approximately 14% of families in the Village report incomes under the poverty threshold in Michigan (\$16,000 individual/\$33,000 family of four); however, 40% of families have a median income of \$100,000 or more (Table 9).

Table 2			
Village of Wolverine Lake			
Population Change 2000-2020			
Year	Population	# Change	% Change
2000	4,415		
2010	4,312	-103	-2.3%
2020	4,544	+232	+5.2%
Total change 2000-2020		+129	+2.9%

(Source: U.S. Census Bureau)

Table 3 Village of Wolverine Lake and Surrounding Communities Population Growth 2010 – 2020 and 2020 – 2045 Forecast					
	2010	2020	# / % Change (2010-2020)	Forecasted *2045	# / % Forecasted Change (2020 – 2045)
Village of Wolverine Lake	4,312	4,544	232/5.3%	4,431	-113 / -2.5%
City of Orchard Lake Village	2,375	2,238	-137 / -5.8%	2,263	25 / 1.1%
City of Keego Harbor	2,970	2,764	-206 / -6.9%	3,148	384 / 13.9%
City of Sylvan Lake	1,720	1,723	3 / 0.2%	1,865	142 / 8.2%
Commerce Township	35,874	38,514	2,640 / 7.4%	42,023	3,509 / 9.1%
West Bloomfield Twp.	64,690	65,888	1,198 / 1.9%	69,854	3,966 / 6%
White Lake Township	30,019	30,950	931 / 3.1%	32,194	1,244 / 4%
Milford Township	9,561	10,570	1,009 / 10.6%	11,034	464 / 4.4%
City of Novi	55,374	66,243	11,019 / 20%	67,417	994 / 1.5%
City of Wixom	13,498	17,193	3,695 / 27.4%	17,066	-127 / 0.7%
City of Walled Lake	6,999	7,250	251 / 3.6%	7,860	610 / 8.4%
Oakland County	1,202,362	1,274,395	72,033 / 6%	1,319,089	44,694 / 3.5%

(Source: U.S. Census Bureau, *SEMCOG 2045 Regional Development Forecast)

Table 4 Village of Wolverine Lake Household Change		
	2010	*2019
Total Households	1,733	1,967
2+ with Children	545	545
2+ without children	770	851
With Seniors (65+)	363	609
Without Seniors	1,370	1,358
Live Alone, 65+	98	281
Live Alone, under 65	320	290
Average household size	2.49	2.34**

(Source: U.S. Census Bureau, *2015-2019 American Community Survey 5-Year Estimates,
**2020 U.S. Census)

Table 5 Median Age Comparison		
	2010	*2019
Village of Wolverine Lake	42.7	43.6
Oakland County	40.2	40.9
State of Michigan	38.9	39.7

(Source: U.S. Census Bureau, *2015-2019 American Community Survey 5-Year Estimates)

Table 6 Village of Wolverine Lake Population by Gender and Age			
	2010	*2019	# Change
Male	2,226	Not available	
Female	2,086	Not available	
Under 5 years	207	292	85
5 to 9 years	241	222	-19
10 to 14 years	281	220	-61
15 to 19 years	316	254	-62
20 to 24 years	201	219	18
25 to 29 years	260	273	13
30 to 34 years	227	342	115
35 to 39 years	251	304	53
40 to 44 years	350	258	-92
45 to 49 years	452	253	-199
50 to 54 years	401	405	4
55 to 59 years	323	437	114
60 to 64 years	302	390	88
65 to 69 years	212	241	29
70 to 74 years	118	203	85
75 to 79 years	70	153	83
80 to 84 years	47	134	87
85 years plus	53	48	-5

(Source: U.S. Census Bureau, *2015-2019 American Community Survey 5-Year Estimates)

Table 7 Village of Wolverine Lake Projected Population Change by Age Group				
Age Group	2010	Projected *2045	# Change	% Change
Under 5 years	207	207	-0-	0%
5 – 17 years	723	586	-137	-19.0%
18 – 24 years	316	270	-46	-14.5%
25 – 54 years	1,941	1,565	-376	-19.3%
55 – 64 years	625	505	-120	-19.2%
65 – 84 years	447	1,041	594	133%
85 years plus	53	257	204	385%

(Source: U.S. Census Bureau, *SEMCOG 2045 Regional Development Forecast)

Table 8 Median Family Income		
	*2010	**2019
Village of Wolverine Lake	\$82,975	\$85,019
Oakland County	\$77,838	\$79,698
State of Michigan	\$56,597	\$57,144

(Source: *2006-2010 American Community Survey 5-Year Estimate, **2015-2019 American Community Survey 5-Year Estimate)

Table 9
Village of Wolverine Lake
Distribution of Families by Family Income

	2010		*2019	
Income Category	# of Families	% of Total	# of Families	% of Total
Less than \$10,000	23	1.4	30	1.5
\$10,000 to \$14,999	42	2.5	41	2.1
\$15,000 to \$19,999	61	3.6	87	4.4
\$20,000 to \$24,999	56	3.3	77	3.9
\$25,000 to \$29,999	30	1.8	35	1.8
\$30,000 to \$34,999	66	3.9	25	1.3
\$35,000 to \$39,999	82	4.9	94	4.8
\$40,000 to \$44,999	100	6.0	51	2.6
\$45,000 to \$49,999	54	3.2	141	7.2
\$50,000 to \$59,999	169	10.1	169	8.6
\$60,000 to \$74,999	197	11.8	174	8.8
\$75,000 to \$99,999	280	16.8	261	13.3
\$100,000 to \$124,999	234	14.0	323	16.4
\$125,000 to \$149,999	93	5.5	147	7.4
\$150,000 to \$199,999	109	6.5	122	6.2
\$200,000 or more	69	4.1	190	9.7
Total	1,665		1,967	

(Source: U.S. Census Bureau, *2015-2019 American Community Survey 5-Year Estimate)

EXISTING LAND USE



EXISTING LAND USE

The Village of Wolverine Lake is predominately a residential community with *over* 49% of its land use area in residential uses. The next largest land uses are water, at *approximately* 27%, and road right-of-way at 13.2%. Slightly less than three percent of the land is vacant and the remaining 7% is used for commercial/office, public/institutional, and recreation/conservation.

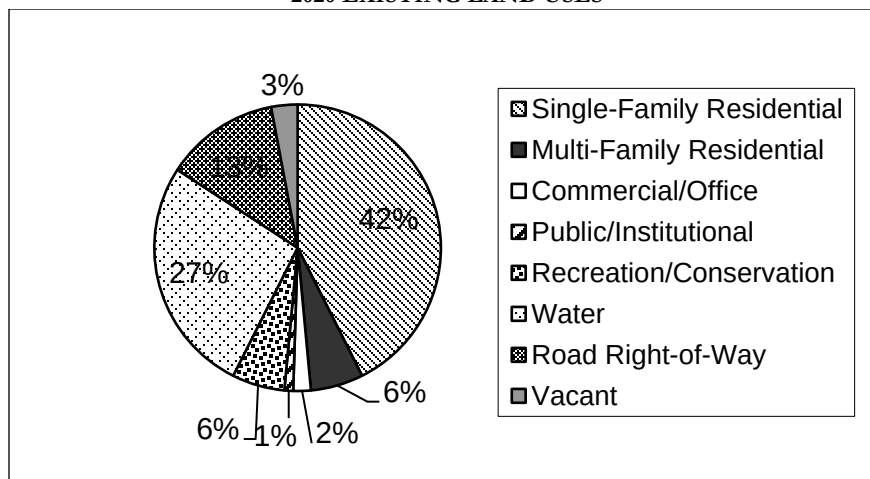
Table 10
Village of Wolverine Lake
Land Use Change 2013-2020

	2013 (acres)	2013 % of Total (acres)	2020 (acres)	2020 % of Total (acres)	% Change 2013-2020
Single-Family Residential	462.3	42.8	466.7	43.4	4.4
Multi-Family Residential	63.5	5.9	63.5	5.9	--
Commercial/Office	15.7	1.5	15.1	1.4	-3.8
Public/Institutional	10.1	0.9	9.9	0.9	-2.0
Recreation/Conservation	60.1	5.6	60.6	5.6	1.0
Water	290.7	26.9	289.6	26.9	--
Road right-of-way	143.5	13.3	141.8	13.2	-1.0
Vacant	33.4	3.1	29.1	2.7	-12.8
Total	1,079.4		1,076.2		

(Source: Oakland County Planning and Economic Development)

The figure below shows the percentage of land occupied by each land use category in the Village.

FIGURE 1
VILLAGE OF WOLVERINE LAKE
2020 EXISTING LAND USES



In contrast to the previous data that measured land use by acreage, the following table shows how many parcels are dedicated to each land use category in the Village, and compares this information with the County.

Table 11 Village of Wolverine Lake and Oakland County Comparison of Number of Parcels and Associated Land Use				
	Village of Wolverine Lake		Oakland County	
Land Use	# of Parcels	% of Parcels	# of Parcels	% of Parcels
Single Family: 10 acres or greater			1,752	0.4%
Single Family: 5 to 9.9 acres			3,983	0.9%
Single Family: 2.5 to 4.9 acres			8,183	1.9%
Single Family: 1.0 to 2.4 acres	8	.5%	24,228	5.6%
Single Family: 14,000 – 43,559 s.f.	406	22.5%	116,020	26.8%
Single Family: 8,000 – 13,999 s.f.	920	51.1%	113,284	26.2%
Single Family: Less than 8,000 s.f.	293	16.3%	102,669	23.7%
More than one unit per parcel			181	0.0%
Total Single Family	1,627	90.4%	370,300	85.5%
Multi-Family	18	1.0%	2,839	0.6%
Commercial/Office	15	.8%	12,839	3.0%
Public/Institutional	5	.3%	3,123	0.7%
Recreation/Conservation	50	2.8%	7,010	1.6%
Vacant	84	4.7%	28,432	6.6%
Agricultural, Industrial, Extractive, RR, Utilities, and Mobile Home Parks			8,149	2.0%
Total	1,799	100.0%	432,692	100.0%

(Source: Oakland County Planning and Economic Development)

An existing land use map on the next page shows the location of each parcel and its current land use designation.

RESIDENTIAL

Much of the original residential development in the Village was in the form of lakefront cottages. For the past 30 years the desirability of lake property has stimulated higher-quality, new residential development and the modernization of existing homes. The trend toward improvement in lake property has had a spin-off effect which has benefited off-lake property owners as well.

The Village is predominantly a single-family residential community. Land use data compiled by the Oakland County Planning Department indicate that the Village contains approximately 463 acres of single-family residential development, representing about 43% of the entire land area of the Village. Most of the single-family development is of the single-family detached type; however, the Village does have a limited amount of single-family attached housing. This provides housing opportunities for people who do not wish to live in single-family detached homes, but also do not want the higher densities associated with multiple-family housing.

The Existing Land Use map shows both single-family and multiple-family residential development. The single-family category describes improved land parcels having three or less units per building in predominantly residential use. The multiple-family category describes improved land parcels having four or more units per building in predominantly residential use, including apartments, condominiums, row houses, and terraces plus any streets, service drives, and community areas such as yards, clubhouses, and pools. Hotels, motels, campgrounds, and mobile home parks are excluded from this category.



Residential developments in the Village have their own distinct physical character based on lot size, home styles and vegetation. Cottage-style homes were located along much of the lake shore. Gradual development of large-footprint homes has replaced cottages. In the southern half of the Village away from the lake, frame bungalow homes predominate. There are also many frame bungalows on the south side of the lake. Many of the lots in these areas are heavily treed. Frame and brick bi-level homes predominate in the area between Pinecrest and Penny Lake Road in the southeast part of the Village, and frame and brick ranch-style homes are concentrated between the east shore of the lake and South Commerce Road in the vicinity of Shankin, Paulette, and Newport Court.

Although many Wolverine Lake homes are several decades old, the overall residential appearance of the Village is very good. Almost all the homes in the Village are well maintained. Newer homes, although limited in number, have a very positive impact because they are generally larger and of higher quality materials than are many of the older homes. Newer subdivisions include Wolverine Acres and Wolverine Commons in the northwest part of the Village near the intersection of Glengary and Benstein Roads, and Lake Ridge in the east-central part of the Village between South Commerce Road and the lake. The many modernization and expansion improvements which have been made to older homes in recent years also contribute to the positive image of Wolverine Lake neighborhoods. Modernizations and expansions are particularly prevalent on the lake.



It is evident that the lake is a valuable asset which attracts residents, enhances property values and encourages home owners to improve their properties. The beneficial effects which the lake has on lake-front property appear to have "spin-off" impact on non-lake-front property. Residents with lake-front lots or easement access to the lake take special pride in its natural beauty. There is a strong community desire to protect the appearance of the lake shore for the enjoyment of both lake shore residents and boaters.

The Village contains a limited amount of multi-family residential development, mostly in the form of one- and two-story garden apartments. The most recent development of single-story apartment units (Redwood) was constructed along South Commerce Road between Glengary and Oakley Park roads. The area devoted to multi-family uses amounts to 64 acres or approximately six percent of the Village's acreage. All the multiple-family development in the Village is located on major thoroughfares.



COMMERCIAL AND OFFICE DEVELOPMENT

The Village of Wolverine Lake contains a very limited amount of commercial and office development. All together there were 12 commercial and office establishments in the Village in 2020. These included two restaurant/taverns, one professional medical office, one financial institution, one auto wash, one ice cream store, two party stores, three specialty businesses, and a general office building. These businesses occupy 15 acres or 0.8 percent of the land area of the Village. By comparison, commercial and office establishments occupy approximately 3 percent of the land area of Oakland County as a whole.

The Commercial/Office category on the Existing Land Use map shows improved land parcels for wholesale, retail, office, entertainment, or services, including those uses predominantly at street level on multi-functional structures, plus related contiguous necessary uses such as parking areas and service drives.



Commercial and office establishments in Wolverine Lake are located in the following seven areas:

1. **At the intersection of South Commerce Road and Oakley Park Road.** This area contains a credit union, office, two to three-tenant plaza, a party store, and an auto wash. There is a small apartment complex in this area.
2. **Along Glengary Road just east of Oakview.** This area contains a party store. There is no potential for additional commercial development in this area because of the lake and existing residential development.
3. **Along Glengary Road between Roselawn and Benstein.** This area contains a soft ice cream establishment at the corner of Glengary and Benstein, and then east along Glengary a hair salon, two vacant establishments, and an Eagles Lodge. On the southeast corner of Glengary and Woodlawn is an established restaurant/tavern that has occupied this location for many years, and has amicably co-existed with the near-by single-family residential uses in the area.
54. **On South Commerce Road east of Ethel Drive.** This area contains a medical office at the corner of South Commerce Road and Ethel Drive and a vacant parcel at the corner where South Commerce Road turns from an east/west alignment to a north/south alignment.
5. **On South Commerce Road South of Wolverine Drive.** This area contains a restaurant/tavern. There is no room for additional commercial development in this area.
6. **On Benstein Road South of Glengary.** This commercial building contains a bait shop and pet salon, a religious organization, and a vacant unit.

INDUSTRIAL DEVELOPMENT

There are no existing industrial land uses in the Village of Wolverine Lake. The Village is very remote and relatively inaccessible. There are no major transportation corridors through or near the Village. These are the main reasons why industrial activities have not located in the Village. The nearest existing industrial land uses are located in Walled Lake. More extensive industrial development is also located in the City of Novi, south of Walled Lake. This development has good access to the 1-96 freeway. There is also some existing industrial development in Commerce Township near Haggerty Road.

PUBLIC/INSTITUTIONAL

As described under the *History and Character* chapter of this Master Plan, the Existing Land Use map under this category includes improved land parcels and facilities that are held in the public interest and are usually exempt from real property taxation plus any service drives or roads inside the actual parcel. Examples of this category are churches, educational facilities, governmental offices, hospitals, municipal parking facilities, and cemeteries.



RECREATION/CONSERVATION

Land parcels for which the primary purpose is for outdoor recreation or natural area conservation fall within this category on the Existing Land Use map. This may include public or privately-owned parks, outdoor sporting clubs, golf courses, marinas, campgrounds, or areas for which the primary purpose is preservation and conservation of undeveloped natural areas.



VACANT

The vacant land use category includes all parcels not included in one of the above definitions. These are unimproved areas, some of which are accessory to an adjacent parcel or are subdivision outlots, or other lots providing access to the lake.

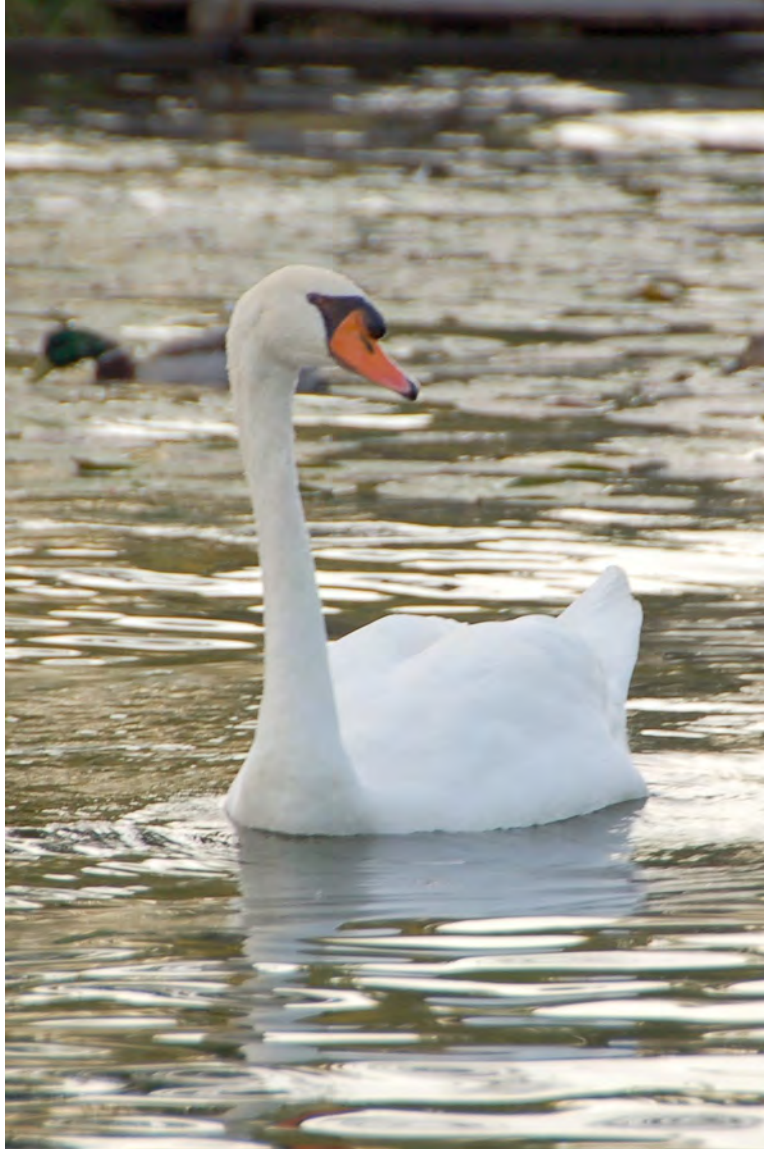
WATER

This category in the Existing Land Use map includes areas that are predominantly and ordinarily covered by water.

ROAD RIGHT-OF-WAY

This land use category includes areas that are predominantly used for vehicular transportation. These areas also contain walkways, utility easements, and/or on-street parking areas.

NATURAL RESOURCES



NATURAL RESOURCES

Regional Geographic Profile

The distribution of the region's natural features corresponds to distinct geological zones. The Southeastern Michigan Region is generally characterized as a gently rolling plain, bounded on the east by a system of water bodies which connect Lake Erie and Lake Huron. The western boundary is composed of a chain of moraines (hills) which divide the flow of rivers between Lake Michigan and Lake Erie. In between these two natural boundaries are three major river systems, the Huron, the Clinton, and the Rouge, which rise from a gravel plain. The Flint and Shiawassee rivers, which are located in the northern fringe of the region, drain to the north and west.

County Physiography

Oakland County covers an area of over nine hundred square miles, encompasses over four hundred lakes, fifty thousand acres of recreational land and approximately eight hundred miles of inland lake shoreline.

As a result of glacial formation, the primary features which characterize the Oakland County landscape are two moraine (or hill) belts (the Saginaw and Huron-Erie systems) which cross the county in a northeast-southwest direction and three outwash plains (Commerce, Drayton and Oxford Plains). The northern portions of the two hill chains are the location of some of the highest points of elevation in the county; elevations between 1,000 and 1,200 feet above sea level. The southern belt of hills has typical elevations between 800 and 1,000 feet above sea level. The average elevation of the Village of Wolverine Lake is 932 feet above sea level, and the summer elevation of the lake is kept at 918.25.

Scattered throughout the hilly belts and outwash plains are hundreds of depressions, many occupied by inland lakes which range in size from small ponds less than one acre in size to lakes covering one and one-half square miles. The approximately four hundred lakes are an outstanding feature of the county. However, the distribution of the lakes is not equal across the landscape; the southern portion is not as well-endowed as other portions. The largest lakes, which occupy 20,000 acres, are Cass and Orchard lakes.

Soils

County soils were deposited by receding glaciers. Soil types range from sand and gravel to clay and peat, representing approximately thirty-nine different kinds of soil throughout the County. The majority of the Village's soils are described as "urban land," which means that they have been sufficiently disturbed by development that their natural characteristics have been permanently altered. The areas not covered by homes, streets, driveways and other amenities are identified as Spinks soils, which are suited to building site development and septic tank absorption fields. Due to the built-out nature of the Village, these soils are generally used for lawns, gardens, and other plantings.

County Hydrology

Five river systems have their origin in the moraine belts and outwash plains in Oakland County. The land area that lies northwest of the upland hills is drained by the Flint and Shiawassee River systems. The area to the southeast of the upland hills is drained by the Clinton, Huron and Rouge River. The Village of Wolverine Lake is located on the very eastern edge of the Huron River watershed.

While Oakland County has more natural lakes than any other county in the state, Wolverine Lake was created by installing a dam on a stream during the early part of the 20th Century. The water flows from Wolverine Lake into North Commerce Lake, then Proud Lake State Recreation Area, and ultimately into the Huron River. Wolverine Lake is part of the Norton Creek section of the Kent Lake Subwatershed. Kent Lake is an impoundment in the Huron, just south of where Norton Creek flows into the Huron River.

Wolverine Lake Water Quality

The lake is the nucleus and heart of the Village. Wolverine Lake provides both scenic beauty and recreational space for the entire community. The citizens are dedicated to preserving and protecting the quality of the lake which they consider to be their "main street."

Like many county lakes, Wolverine Lake is surrounded by residences. These historic land uses have caused pollution from septic fields and fertilizers, which results in excessive weed growth or eutrophication. To address lake quality, the Village conducts studies each year. Results of the most recent studies are described in three documents: *Wolverine Lake 2020 Water Quality Report*, *Wolverine Lake Aquatic Plant Control Program 2020 Activity Summary*, and *Wolverine Lake Canal Improvement Alternatives Evaluation*. These documents report the results of water quality tests performed in the summer and fall of 2020, aquatic weed control efforts, and a description of options to address issues in the Wolverine Lake canal, as follows (the full studies are included in the Appendix):

- The Water Quality Report indicates that Wolverine Lake is “mesotrophic” which is a lake with mid-level clarity and that supports a moderate amount of plant growth. Because the lake has relatively deep pools, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, it can only support warm water fish such as bass and pike. Key parameters used to evaluate the lake’s productivity or trophic state include total phosphorus, chlorophyll-*a*, and Secchi transparency. The Water Quality Report evaluated sample readings taken in 2020, and averaged them with the readings taken since 2013. The results of this analysis confirm that the overall water quality of the lake is mesotrophic.
- The Aquatic Plant Control Program surveys the lake for both problematic aquatic species, as well as all plant species. In 2020, GPS-guided surveys were conducted by a biologist every month from May through September to locate nuisance species, and apply targeted herbicides. Targeted species in 2020 included starry stonewort and Eurasian milfoil, both invasive, non-native plant species. The Village also operates a mechanical harvester 2 - 3 days per week between approximately June 1 and Labor Day to help control these invasive plants. The all-plant survey was conducted in August, and identified 27 plant species in the lake. Many were species native to Michigan, but some invasive, non-native species were identified such as purple loosestrife and phragmites.
- A lake canal alternative improvements evaluation was conducted in September of 2020 to assess various alternatives that could improve conditions in the canal system, located at the southeast portion of Wolverine Lake. Currently, during spring and summer, frequent herbicide and algacide treatments are required to control excessive plant and algae growth in the canal. This study was conducted to evaluate the feasibility and probable costs of other alternatives that may help improve conditions in the canal. The report concludes that repair of the Helmsford augmentation pump, which could be used to add water to the canal, and application of an algacide would be the most cost-effective solutions.

As an advisory body, the Water Management Board assists the Village in this effort by investigating and making recommendations to the Village Council on water management issues affecting the safety, health, and recreational opportunities of Village residents and visitors. The Village has also developed

the *Mute Swan Management Plan* to successfully address issues in wildlife management. Mechanical weed harvesting and professional herbicide treatments, regular water quality testing, fish stocking, purple loosestrife beetle program, and passage and enforcement of a fertilizer ordinance are other initiatives implemented by the Village.

Stormwater Management Initiatives

The Village of Wolverine Lake is required to obtain a stormwater permit from the State to enable it to discharge stormwater from the Village-owned and operated stormwater utility system. While the Village has conducted many events and programs to protect the water quality in the lake, the stormwater permit enhances these existing programs.

One effort to improve water quality in the Norton Creek area is development and implementation of the *Kent Lake Subwatershed Management Plan*, which was finalized in 2002. This plan was created to address phosphorus loading into the Huron River (and the Kent Lake impoundment) from stormwater runoff into local lakes and streams. Because Wolverine Lake contributes to the Kent Lake watershed system, the Village participated in development and implementation of the Watershed Management Plan. The Village's success in minimizing phosphorus loading will also help the watershed overall. The target phosphorus level for Kent Lake, as reported in the plan, is .030 mg/L.

In 2011, the Village Council adopted a new stormwater management ordinance, the purpose of which is to minimize flooding and stormwater runoff, encourage stormwater infiltration, and to preserve and protect water supplies and water resources. The ordinance establishes minimum standards to protect water bodies from degradation resulting from changing land use. It requires submission and approval of a stormwater management plan for any project involving earth changes, site plan review or subdivision review.

The Village is also a member of the Huron River Watershed Council, which assists communities with watershed and environmental issues shared throughout the watershed as well as through the state-wide Phase II stormwater management permit requirements.

Vegetation

Oakland County lies in a deciduous forest zone. Typical vegetation groups in the county include swamps (or wooded wetlands) and marshes (emergent wetlands), bogs (acidic wetlands), lakeshores, stream sides, meadows, abandoned fields and forests. Five major forest types are found in the county: floodplain forests, mixed hardwoods, oak- hickory, beech-maple, and pine-hardwoods. Early records indicate that conifers constituted an important element in Michigan's original forests; however, pure evergreen forests are characteristic only of the northern and western parts of the Upper Peninsula.

The remaining natural vegetation in the Village is comprised of approximately six acres of deciduous forests and approximately 28 acres of wetlands (7 acres of forested wetlands; 10 acres of scrub-shrub wetlands, and 11 acres of emergent wetlands). The remaining vegetation is planted in lawns and other ornamental landscape material.

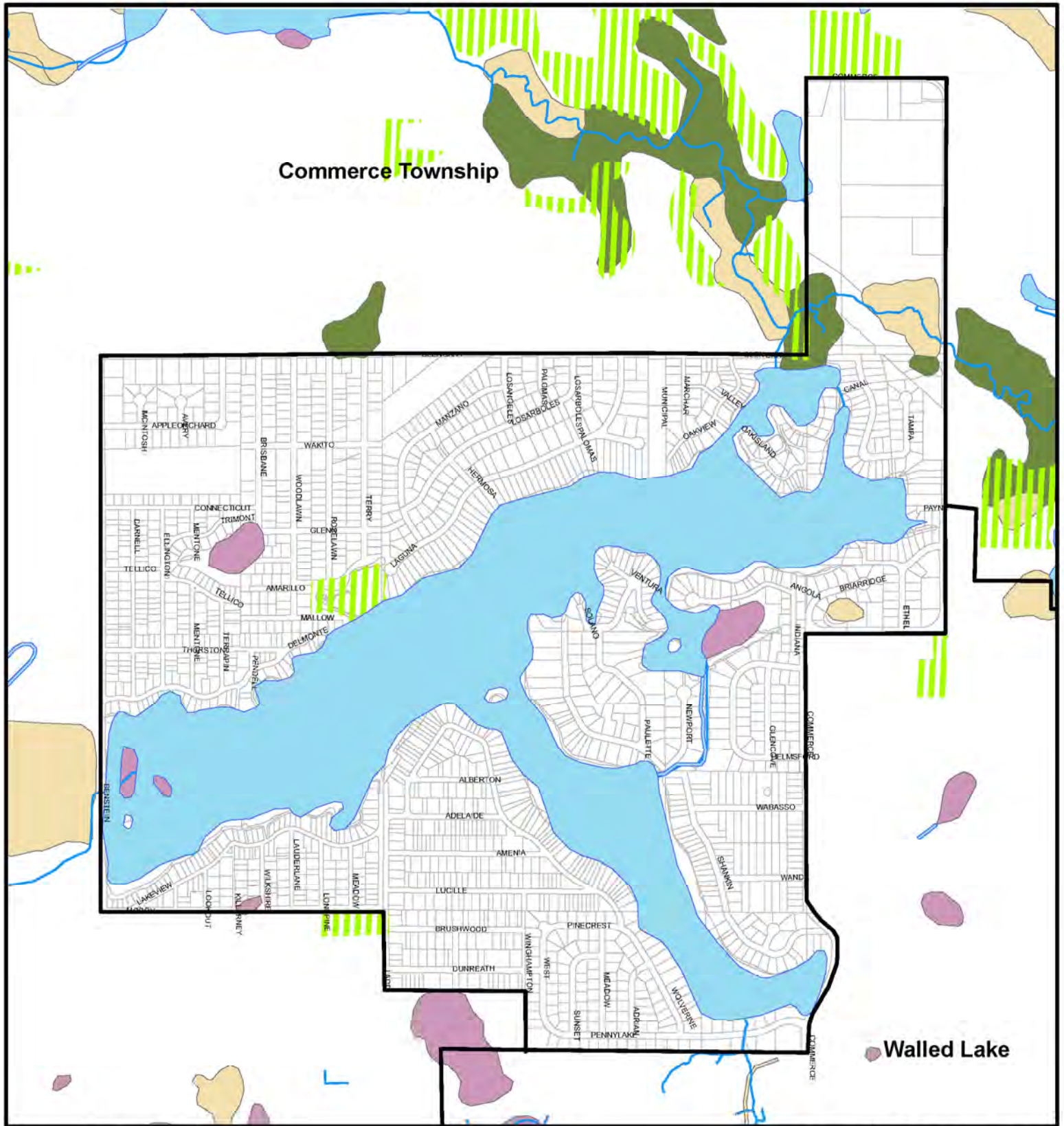
Wildlife

Wolverine Lake supports extensive fish and marine species, waterfowl, and marine plant life. The lake is stocked annually and the more common species of fish include large-mouth bass, northern pike, walleye, crappie, and various pan fish. The lake has been the location for Bass Master Tournaments several times, and is deemed a very good sportsman's lake.

Resident waterfowl includes Canada geese, and many species of ducks that are common to Southeast Michigan. Besides the more commonly found species, the pintail duck occupies the lake during the fall migration, and the mute swan also occupies the lake at certain times of the year. Other marine species, such as the snapping turtle and freshwater clams can also be found. The Michigan Department of Natural Resources along with the Audubon Society educates and issues permits for Canada goose egg replacement to help control over population. An annual round up of Canada geese also takes place.

The Village's Water Management Board supports the education of and access to local water resources. The Benstein Road boardwalk allows residents close interaction with wetlands and waterways, and assists neighboring communities in encouraging wetland and water body education.





Legend

Woodlands

 Deciduous

Wetlands

 Emergent

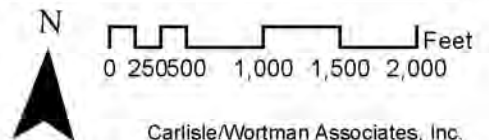
 Forested

 Scrub-Shrub

 Open Water

WOLVERINE LAKE

Natural Features



Carlisle/Wortman Associates, Inc.
Community Planners & Landscape Architects
6-27-14

FUTURE LAND USE PLAN



MASTER PLAN GOALS

Goals formulated by the community establish the framework for public and private decision-making. Goals reflect the broadest of human needs and establish the desired outcomes or end results of the planning process. After consideration of the information gathered, the following goals were created to guide the Village's future land development decisions:

- Goal 1.** Provide the infrastructure to meet the utility and circulation needs of the residents, including facilities for vehicles, bicycles, and pedestrians.
- Goal 2.** Provide financial stability without reducing services or quality of life for the residents.
- Goal 3.** Provide a safe and healthy community comparable with the surrounding communities.
- Goal 4.** Provide the highest quality of service to all residents.
- Goal 5.** Improve inter- and intra-governmental relations through open lines of communication between residents, Village officials, and neighboring communities.
- Goal 6.** Improve the lake quality to satisfy the recreational expectations of residents.
- Goal 7.** Provide recreational uses and enhance and maintain the usefulness of the existing recreational facilities in the Village, as well as identify potential future parkland acquisitions.

NOTE: These goals are generalized goals prepared by the Planning Commission, based on priorities established by the Village Council in 2014 and refined in 2021.

FUTURE LAND USE CATEGORY DESCRIPTIONS

The following describe each land use category shown on the Future Land Use map:

- **Single Family Residential** – The intent of this category is to maintain the well-established character, scale and density of the single-family neighborhoods that are characteristic of the Village of Wolverine Lake. These neighborhoods consist of detached single-family homes, and is the predominant land use pattern in the Village. The recommended density in these areas is three (3) to four (4) dwelling units per acre. These predominant characteristics should be maintained by encouraging programs and techniques to improve neighborhoods and housing conditions. In addition, development on vacant lots within this residential classification should only occur if the character, scale, and development pattern of the new development is consistent and compatible with the older, existing structures, and development patterns of these residential neighborhoods.

- **Lake-Front Residential** – The intent of this category is to preserve the historic pattern of land use around the shores of Wolverine Lake. This designation is historically higher density than other single-family residential designations, at five (5) to six (6) dwelling units per acre. As in the single-family district, development techniques should be used to maintain and preserve the character, scale, and development patterns of the existing residential development along the lake.
- **Multi-Family Residential** – The intent of this category is to provide for the development of multi-family housing in suitable areas. Such areas should be of adequate size to enable establishment of a substantial multiple family environment that are located in close proximity to amenities such as public park and open space areas or established shopping areas which can conveniently serve the concentrations of residents who live in multi-family areas. This designation is intended to accommodate multi-family development up to a maximum of eight (8) units per acre.
- **Office** – The intent of this category is to provide for both low-intensity and higher-intensity office uses. It is located on parcels that are on main thoroughfares. The intensity of the use is based on whether the parcel has sufficient size to create a business environment which can function and be perceived as separate and apart from nearby residential areas. On smaller parcels in this district, office use is limited to protect nearby residential uses.
- **Neighborhood Commercial** – The intent of this category is to provide for a limited range of commercial uses that are compatible with adjoining neighborhoods. Properties in this category are on shallow sites that back up to residential areas.
- **Shopping Center Commercial** – The intent of this category is to provide for a broad range of business uses, including comparison commercial uses. This designation is used on the few wide and deep sites of sufficient size that are located adjacent to major thoroughfares in the Village.
- **General Commercial** – The intent of this category is to provide for a limited range of fringe commercial uses which may be appropriate in certain limited locations in the Village. This designation is provided at the very northern boundary of the Village.
- **Mixed Use** – The Mixed Use future land use designation is specific to areas that currently have a mix of uses, and it is desirable to maintain this mix. The Mixed Use category includes low-impact commercial uses (as listed in the C-1 Local Business District), and low-impact office uses (as listed in the O-1 Office Business District) adjacent to single-family residential areas (as listed in the R-1A Single-Family Residential District). This land use allows for single-family residential uses to continue and to be established, while also allowing low-intensity commercial and office uses to continue that can serve the residential areas. The Mixed Use land use designation is occupied by detached buildings with a character that is compatible with a single-family residential area. Parking in this land use category should be located at the side or rear of the property.
- **Recreation & Conservation** – The intent of this category is to reflect the belief that the quality of the environment is contingent upon the preservation of park space within the Village for the benefit for the citizenry as a whole. These lands may have unique topographic features or natural amenities such as forests, lakes, or natural waterways, which are conducive to recreational use. They also may have man-made amenities which can accommodate publicly-owned civic, cultural, or governmental uses.

IMPLEMENTATION OF THE MASTER PLAN

The following table outlines how the goals of this Master Plan could be implemented through specific action items. These action items (related to land use planning) were established by the Village Council in 2021, with additions by the Planning Commission.

Table 12 Village of Wolverine Lake Master Plan Implementation Strategies		
Action	Responsibility	Priority
Goal 1. Provide the infrastructure to meet the utility and circulation needs of the residents, including facilities for vehicles, bicycles, and pedestrians.		
Establish a percentage goal for residents to connect to sewer.	Staff/Village Council	Five-Year Action Item
Replace street lights with LED bulbs	Staff/Village Council	Five-Year Action Item
Pave remaining dirt roads	Staff/Village Council	Five-Year Action Item
Investigate long-term road funding projects	Staff/Village Council	Five-Year Action Item
Make Benstein boardwalk repairs	Staff/Village Council	Five-Year Action Item
Look into alternative non-motorized route along South Commerce Road	Staff/Village Council	Five-Year Action Item
Reorganize and incorporate Master Plan topics of stormwater, sewer, and water connections in the existing section of the Master Plan dedicated to infrastructure. (Recommended by OCED)	Planning Commission/ Village Council	As part of five-year update to Master Plan.
In Master Plan, identify authority that maintains control of the dam, and identify strategies or best practices that can secure dam's function and safety. (Recommended by OCED)	Planning Commission/ Village Council	As part of five-year update to Master Plan.
Incorporate elements of a hazard mitigation plan into Master Plan. Elements include those related to infrastructure, utilities, natural features, major assets, and historic structures. Coordinate with Village's Capital Improvement Program. (Recommended by OCED)	Planning Commission/ Village Council	As part of five-year update to Master Plan.
Goal 6. Improve the lake quality to satisfy the recreational expectations of residents.		
Include Michigan Natural Features Inventory (MNFI) information in the Master Plan. (Recommended by OCED)	Planning Commission/ Village Council	As part of five-year update to Master Plan.
Include best practices from Oakland County Cooperative Species Management Areas (CISMA) and the Huron River Watershed Council (HRWC) into Master Plan to assist in Wolverine Lake's aquatic plant control program. (Recommended by OCED)	Planning Commission/ Village Council	As part of five-year update to Master Plan.

Goal 7. Provide recreational uses and enhance and maintain the usefulness of the existing recreational facilities in the Village, as well as identify potential future parkland acquisitions.		
Acquire new playground equipment for Clara Miller Park	Staff/Village Council	Five-Year Action Item
Make improvements in pocket parks	Staff/Village Council	Five-Year Action Item
Goal 8. Establish Mixed Use Zoning District.		
Create new Mixed Use Zoning District. (Refer to Zoning Plan in Appendices) Rezone properties identified as Mixed Use on the Master Plan's Future Land Use Map to Mixed Use	Planning Commission/Staff/ Village Council	2022

COMPLETE STREETS

On August 1, 2010, the State of Michigan legislature signed into law the Complete Streets amendments to the State Trunkline Highway System Act (Act 51 of 1951), and the Planning Enabling Act (Act 33 of 2008). The law provides an approach to transportation planning and design that considers all street users – vehicles, pedestrians and bicyclists of all ages and abilities – during the various planning and design stages of a transportation project. It also requires that the Michigan Department of Transportation (MDOT) and local road commissions consider the community’s goals and desires for road projects within their boundaries. These amendments are known as the “Complete Streets” provisions.

Complete streets provide facilities that allow all users, irrespective of their age or abilities, to use the street as a mode of transportation. A Complete Street allows pedestrians, bicyclists, transit users and those with disabilities to easily and safely use roads in their community. Communities with Complete Streets Policies help to ensure that engineers and planners design roadways to accommodate all users, not just motorists.

Facilities that make a street “complete” depend on the existing conditions and the intended users. It’s never a “one-size-fits-all” scenario. Examples include smooth sidewalks and bike lanes that are free of obstacles, curb ramps, audible or tactile signals for blind pedestrians, longer crossing times, and transit stops that can be easily boarded.

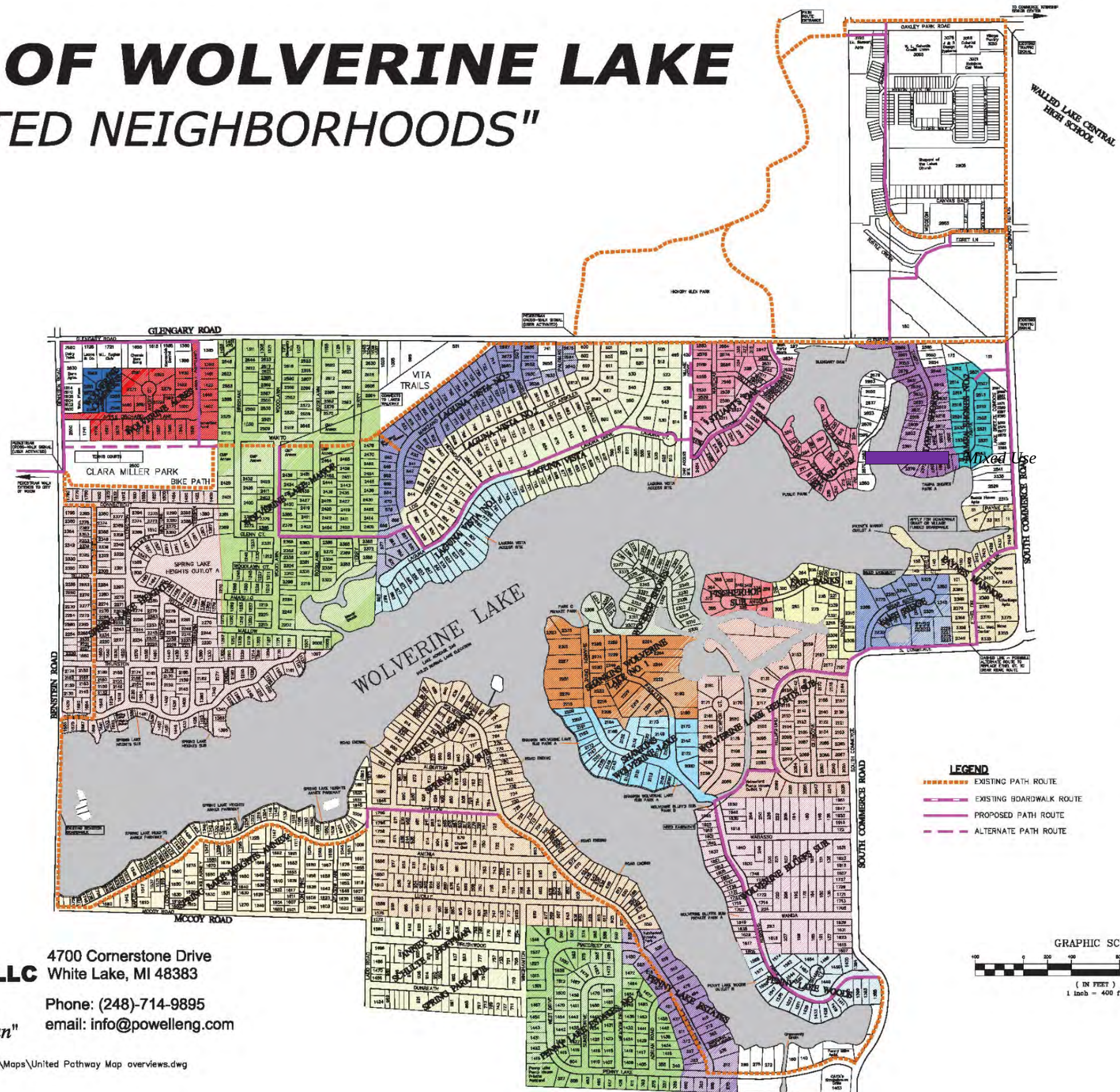
Complete streets provide numerous benefits, including:

- Improved safety for all users, including pedestrians, bicyclists, transit riders and drivers.
- Improved human health by encouraging walking and bicycling.
- Decreased car traffic, reducing dependence on gasoline and petroleum products, and improved air quality.
- More transportation options.
- Fosters more livable communities.

The Village of Wolverine Lake has developed a non-motorized plan called the “United Neighborhoods” plan. This is a system of non-motorized paths that will ultimately enable residents to reach all parts of the Village on foot or bicycle, as well as connect to pathways in other communities. The system is a combination of on-road lanes, off-road paths and boardwalks. The map on the following page shows the segments that have already been constructed, those under construction in 2014, and those proposed for future construction.

VILLAGE OF WOLVERINE LAKE

"UNITED NEIGHBORHOODS"



Powell Engineering & Associates, LLC

Consulting Civil Engineers
"Engineering A Better Michigan"

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email: info@powelleng.com

REVISED: 08/18/15

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COMPLETE STREETS IMPLEMENTATION

The United Neighborhoods non-motorized plan has been implemented using general funds, and constructed as part of Village road resurfacing and repair projects. The Benstein boardwalk was funded, in part, as a special project through a Michigan Department of Transportation enhancement grant.

As shown on the United Neighborhoods map, two significant segments of the pathway system are adjacent to S. Commerce Rd., which is under the jurisdiction of the Road Commission of Oakland County (RCOC). To implement these trail segments, the Village will need to work with the RCOC as it has with other pathway projects. The RCOC has developed Complete Streets Guidelines for use when designing future road improvements to consider needs of all legal users. The Guidelines state that safety is the RCOC's top priority, and that every road has a unique context in terms of user needs, safety concerns, local community values, funding challenges, and environmental constraints, among others. It also states that early communication between the RCOC and the local community is of high value regarding desired non-motorized facilities along RCOC roadways. Since road projects are planned many years in advance, the RCOC needs to know the community's desires for pathways or paved shoulders early in the planning process.

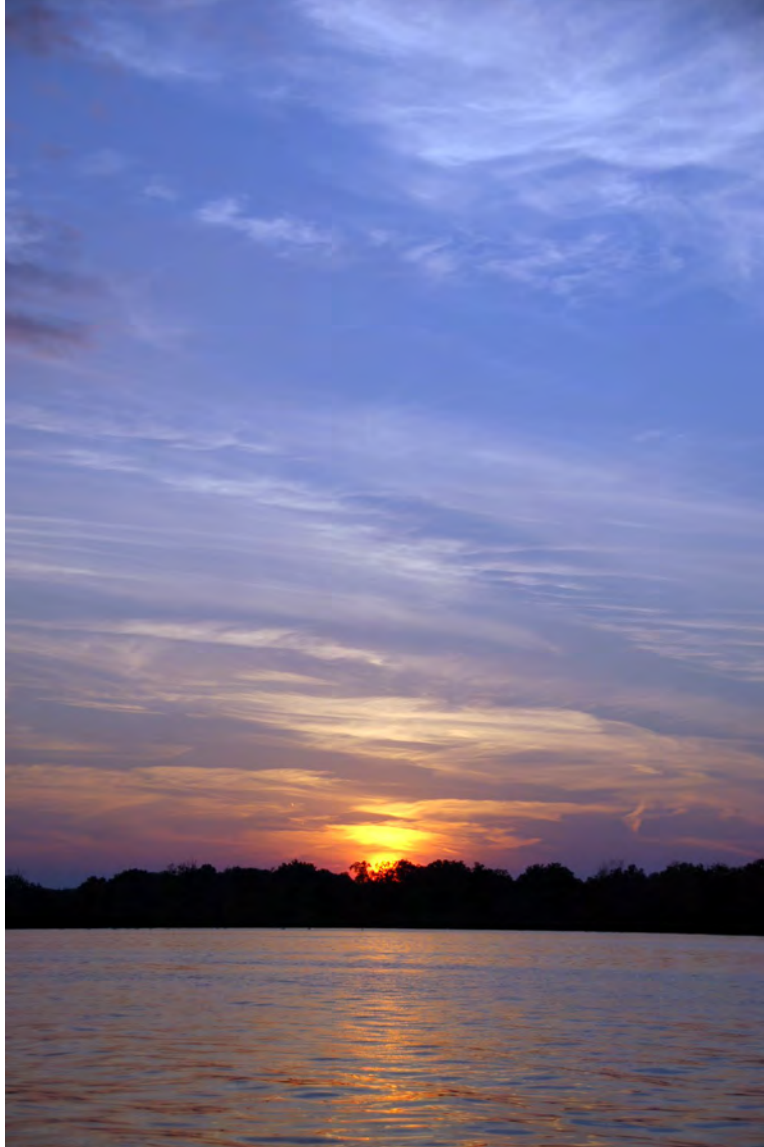
The RCOC hosts strategic planning meetings biennially, and publishes the results of these meetings in a summary document. In May, 2021, the report for Wolverine Lake included discussion regarding non-motorized facilities and particularly a pathway along S. Commerce Road. Sharing the United Neighborhood's plan with the RCOC will continue to be a priority during future strategic meetings.

Regarding funding of non-motorized facilities, Act 51 requires the RCOC to use a minimum of 1% of the funds allocated to it for non-motorized improvements. This money can also be used as a match for federal funds. Other options for non-motorized funding include the following sources:

- MAP-21 Transportation Enhancement & Safe Routes to School funds (MDOT)
- Recreational Trails Program (through Department of Natural Resources (MDNR))
- Michigan Natural Resources Trust Fund (through MDNR)*
- Land and Water Conservation Fund (through MDNR)*

*Requires DNR-approved Five-Year Recreation Plan to be eligible.

APPENDICES



ZONING PLAN

The Master Plan is the statement of planning policy (or “vision”) for decision-making on land use proposals within the Village. This vision provides the foundation of a municipality’s Zoning Ordinance. The Zoning Ordinance provides the “rules” under which land use and development are implemented. Because of this relationship between the Master Plan and the Zoning Ordinance, Michigan state law requires local governments to include a Zoning Plan as a part of their Master Plan. Specifically, the Michigan Planning Enabling Act (PA 33 of 2008) states:

“A master Plan shall also include those of the following subjects that reasonably can be considered as pertinent to the future development of the planning jurisdiction:...For a local unit of government that has adopted a zoning ordinance, a zoning plan for various zoning districts controlling the height, area, bulk, location, and use of buildings and premises. The zoning plan shall include an explanation of how the land use categories on the future land use map relate to the districts on the zoning map.”

The table below relates the future land use categories identified in the Master Plan and the associated zoning district in the Zoning Ordinance.

Table 13 Village of Wolverine Lake Relationship Between Future Land Use Category and Zoning District	
Future Land Use Category (Master Plan)	Zoning District (Zoning Ordinance)
Single-Family Residential	R-1A and R-1B Single-Family Residential
Lake-Front Residential	R-1LF Lake-Front Residential
Multi-Family Residential	RM-1 Multifamily Residential
Office	O-1 Office Business District
Neighborhood Commercial	C-1 Local Business District
Shopping Center Commercial	C-2 Community Shopping Center District
Mixed Use	<i>New Zoning District to be Adopted</i>
General Commercial	C-3 General Business District
Recreation & Conservation	PL Park Land District
	P-1 Parking District

ZONING DISTRICT DESCRIPTIONS

A “Zoning Plan” must contain a general description of the existing and proposed zoning districts, including the purpose of the district, uses allowed in that district, and the locations of each. It also requires a general description of the bulk regulations for each district such as the minimum lot size, height, and setbacks. The following provides this information under the following categories:

1. Residential Districts
2. Park Land Districts
3. Parking District
4. Office and Commercial Districts

1. **Residential Districts**

The Zoning Ordinance contains four residential districts:

- a. R1-A Single-Family Residential District
- b. R1-B Single-Family Residential District
- c. R1-LF Lake Front Single-Family Residential District
- d. RM-1 Multifamily Residential District

R1-A and R1-B Single Family Residential Districts & R1-LF Lake Front Single-Family Residential District.

Purpose: The purpose of these districts is to provide for development of already platted areas with new housing which is compatible with existing residential development densities. Use restrictions for the Single-Family Residential Districts are intended to protect such areas from the encroachment of incompatible uses and to preserve existing neighborhood character.

Uses: The uses in these districts are generally restricted to single-family residential dwellings, and uses that are typically found within close proximity of residential neighborhoods, such as parks and playgrounds, schools, houses of worship, public services, and similar uses.

Bulk Requirements: The R1-A district requires larger minimum lots (min. 12,000 s.f. area; lot width 80 feet) than R1-B district (min. 9,000 s.f. area; lot width 75 feet), while the R1-LF district requires the smallest lot size (min. 7,200 s.f. area; lot width 50 feet) to accommodate the historic lake-side cottage patterns. Minimum setback requirements for R1-A and R1-B include a 25-foot front yard setback, a 10-foot side yard setback, and a 35-foot rear yard setback. R1-LF requires smaller side yard setbacks that relate to the smaller lots (25-foot front; 5-foot side-35-foot rear). Maximum building height is 2.5 stories/30 feet for principal buildings. Non-residential buildings in general have larger setback requirements.

Location: Development in the Village is centered around the lake itself. All R1-LF lots have direct lake frontage. The larger lots in the Village (R1-A) are located on both the north and south sides of the lake, and occupy approximately two-thirds of the residential lots in the Village. The smaller lots (R1-B) are also on the north and south sides of the lake, but they have a smaller footprint, and occupy approximately one-third of the residential lots in the Village.

RM-1 Multifamily Residential District.

Purpose: The purpose of the RM-1 Multifamily Residential District is to provide for the development of multifamily housing in suitable areas. Such areas should be of adequate size to enable establishment of a substantial multiple-family environment. In general, the RM-1 District is intended for mapping on individual parcels of at least 15,000 square feet. Preferable, the RM-1 District should be mapped on parcels which alone or together with other contiguous multifamily parcels, occupy an entire block face or larger area. The RM-1 District is also intended for mapping on individual parcels which are located in close proximity to amenities such as public park and open-space areas or established shopping areas which can conveniently serve the concentrations of residents which live in multiple-family areas.

Uses: This district permits single-family attached and detached dwelling units, as well as traditional multiple-family dwellings. Other traditional uses associated with residential neighborhoods, such as parks, playgrounds, houses of worship, and specialty types of residential uses (including senior housing, nursing care, and adult foster care) are also accounted for in this district. Since there is limited area available for mapping the RM-1 District; the RM-1 District does not provide for as wide a range of nonresidential conditional uses as in the other residential districts.

Bulk Requirements: As mentioned in the purpose statement, the minimum lot area for multi-family dwellings (and attached single-family dwellings) is 15,000 square feet, with a “per unit” minimum of 5,000 square feet. Lots must be a minimum of 100 feet wide. Single-family lots in this district must be a minimum of 9,000 square feet in area, and 75-feet wide. Larger dimensions apply to non-residential uses. Setbacks for single-family and multi-family developments share the same front-yard setback (25-feet) and rear-yard setback (35-feet), but the side yard setback for single-family dwellings is 12.5-feet, while this requirement is 25-feet for multi-family buildings. Similarly, setbacks for non-residential uses are larger. Height requirements for all residential uses in the district is 2.5 stories/30 feet.

Location: Multifamily districts are located in the north-east portion of the Village on S. Commerce Road. Additional multifamily lots are located further south, also on S. Commerce Road.

2. Park Districts

The Zoning Ordinance contains one park district, called the Park Land District.

PL Park Land District

Purpose: The Park Land (PL) District is designed to reflect the belief that the quality of the environment is contingent upon the preservation of park space within the Village for the benefit of the citizenry as a whole. In some cases, these areas may have unique topographic features or natural amenities such as forests, lakes, or natural waterways, which are conducive to recreational uses. In other cases, these amenities are man-made and accommodate publicly owned civic, cultural, or governmental uses.

Uses: This district accommodates outdoor recreational uses such as parks, playgrounds, playfields, golf courses, boating areas, fishing sites, and camping sites. Open space with natural features, including wildlife sanctuaries, forest preserves, and developed open space such as arboreta are also allowed. Schools and cultural services, such as museums and art galleries are also permitted.

Bulk Requirements: There are no bulk requirements in the Park Land District.

Location: Property zoned Park Land District is scattered throughout the Village, encompassing the public parks of Clara Miller Park and Vita Trails, Amenia Park, and Oak Island Park, a conserved wetlands area, the DNR Boat Launch, and various subdivision outlots and private parks.

3. Parking Districts

The Zoning Ordinance contains one Parking District (P-1).

P-1 Parking District

Purpose: The purpose of the P-1 Parking District is to permit establishment of office and commercial use parking facilities on sites which are suitable for such parking, but which are not suitable for office and commercial uses. The P-1 District is intended for mapping on sites which are immediately adjacent to land zoned for office or commercial use.

Uses: Off-street parking, including private and community parking structures are the principal permitted uses in this district.

Bulk Requirements: Property zoned P-1 must be accessory to, and for use in connection with, one or more business establishments on property zoned Office (O-1), or one of the Commercial Districts (C-1, C-2, or C-3). This District requires a minimum front yard setback consistent with the adjacent residential properties (if any), or a minimum of 25-feet. It also requires a screen wall if the side or rear yard is contiguous with residential sites.

Location: This Zoning District is located adjacent to a restaurant (zoned C-1) on the southern boundary of the Village.

4. Office and Commercial Districts

The Zoning Ordinance contains four business districts:

- a. O-1 Office District
- b. C-1 Neighborhood Commercial District
- c. C-2 Shopping Center Commercial District
- d. C-3 General Commercial District

Business Zoning District Purpose: *(Note: The following "Purpose Statement" in the Zoning Ordinance relates to all four business districts, described below).* This chapter sets forth four business districts: the O-1 Office Business District, the C-1 Local Business District, the C-2 Community Shopping Center District, and the C-3 General Business District. The purpose of these four districts is to provide for as wide a range of office and commercial uses as possible while still protecting the quality of the existing residential environment of the Village. It is the determination of the Wolverine Lake Village Council that the Village residential environment can best be protected by limiting business uses to sites which are sufficiently wide and deep to create a business environment which can function and be perceived as separate and apart from nearby residential areas. Where sites exist which are not sufficiently wide the deep, the Council has determined that the residential environment can best be protected by limiting permitted business uses to those which serve primarily residents of adjoining neighborhoods, or which will have the least external impact on adjacent residences.

O-1 Office District

Purpose: The O-1 Office Business District provides for both low-intensity and higher-intensity office uses, and is intended for mapping in certain locations adjacent to residential neighborhoods. (See above for a further description of the intent of this district.)

Uses: A variety of office uses, including offices of professionals (accountant, architect, attorney, etc.), businesses (insurance agents, real estate agents, brokerages, etc.), government, and service establishments serving these uses (duplicating services, mailing services, and others), are the primary permitted uses in this district. Medical offices, and public utilities are also included in this district.

Bulk Requirements: Property zoned O-1 must be located on a site at least 10,000 square feet in area, and 80-feet wide. Setbacks include front-yard setback of 25-feet, side-yard setback of 20 feet, and rear-yard setback of 30 feet. Office buildings may be up to 2 stories/30 feet tall, with a maximum building length of 180 feet, and maximum lot coverage of 30 percent.

Location: Sites zoned O-1 are located at the intersection of S. Commerce Road and Decker. The Village Office is zoned O-1, and located on Glengary Road, just west of Marchar Dr. Another cluster of six O-1 zoned properties exist further west along Glengary Road, between Terry and Apple Orchard Lane.

C-1 Local Business District

Purpose: The C-1 Local Business District provides for the most limited range of commercial uses. The C-1 District is mapped on shallow sites, which back up to residences. In determining uses for inclusion in the C-1 District, the Council has considered trip generating characteristics, trade, and service area characteristics, typical hours of operation and other determinants of neighborhood compatibility. Many uses which would not otherwise be appropriate have been provided for in limited numbers or through establishment of special conditions and design standards. (See above for a further description of the intent of this district.)

Uses: This district accommodates retail establishments that primarily serve the local neighborhood, including drug, dry good, grocery, hardware, and variety stores. Personal service establishments (salons, dry cleaning/laundry, shoe repair, tailors, etc.), libraries, repair shops, and some types of food service (snack bars, limited numbers of restaurants of various types) are also allowed. This district also includes permitted uses in the O-1, Office District.

Bulk Requirements: Property zoned C-1 must be located on a site at least 10,000 square feet in area, and 80-feet wide. Setbacks include front-yard setback of 25-feet, side-yard setback of 20 feet, and rear-yard setback of 30 feet. Buildings may be up to 2 stories/30 feet tall, with a maximum building length of 180 feet, and maximum lot coverage of 30 percent.

Location: Sites zoned C-1 are located at strategic intersections that abut adjacent communities. One cluster of C-1 properties are located at the intersection of Glengary and Benstein. Another site is located on S. Commerce Road at the boundary with Walled Lake.

C-2 Community Shopping Center District

Purpose: The C-2 Community Shopping Center District provides for a broad range of business uses, including comparison commercial uses. (See above for a further description of the intent of this district.)

Uses: This district accommodates larger retail establishments that sell goods to a broader customer base. Examples include household appliance stores, carpet and rug stores, clothing, department stores, furniture stores, garden supply jewelry stores, musical instruments, toy stores, and the like. Food stores of various types, and museums are also allowed. This district also includes permitted uses in the C-1 district. Lastly, a number of higher-intensity non-comparison type businesses (such as auto service stations, drive-in facilities, hotels, theaters, and restaurants) are listed as special land uses.

Bulk Requirements: Property zoned C-2 must be located on a site at least 20,000 square feet in area, and 120-feet wide. Setbacks include front-yard setback of 35-feet, side-yard setback of 25 feet, and rear-yard setback of 40 feet. Buildings may be up to 2 stories/30 feet tall, with a maximum lot coverage of 30 percent.

Location: There are currently no sites zoned C-2 in the Village. Its very likely that there are not sites large enough to accommodate the listed uses in this district.

C-3 General Business District

Purpose: The C-3 General Business District is designed to provide for a limited range of fringe commercial uses which may be appropriate in certain limited location in the Village. (See above for a further description of the intent of this district.)

Uses: The C-3, General Business District, includes permitted uses in the C-1 and C-2 districts. The special land uses in this district include automobile sales, service and washing, clubs and lodges, businesses with drive-through lanes, funeral homes, veterinarians, warehouses, and other uses.

Bulk Requirements: Property zoned C-2 must be located on a site at least 10,000 square feet in area, and 80-feet wide. Setbacks include front-yard setback of 25-feet, side-yard setback of 20 feet, and rear-yard setback of 30 feet. Buildings may be up to 2 stories/30 feet tall, with a maximum building length of 180 feet and maximum lot coverage of 30 percent.

Location: Properties located at the corner of S. Commerce Rd. and Oakley Park Road, and west along Oakley Park Road, is zoned C-3.

MU Mixed Use District (Proposed)

Purpose: The intent of the MU Mixed Use District is to allow a mix of existing residential, office, and commercial uses to continue on sites zoned MU so that they are conforming uses in the district.

Uses: The proposed uses in the MU Mixed Use District include single-family residential, and low-intensity office and commercial uses that serve the nearby neighborhoods.

Bulk Requirements: These requirements will be determined once the new Zoning District is created.

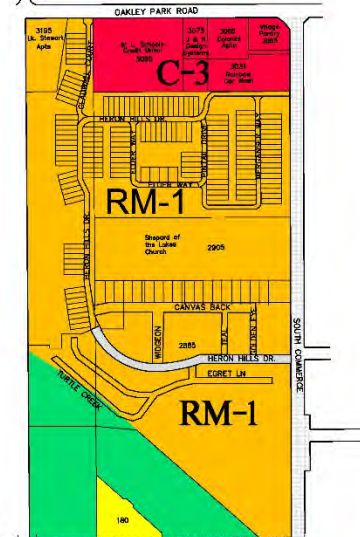
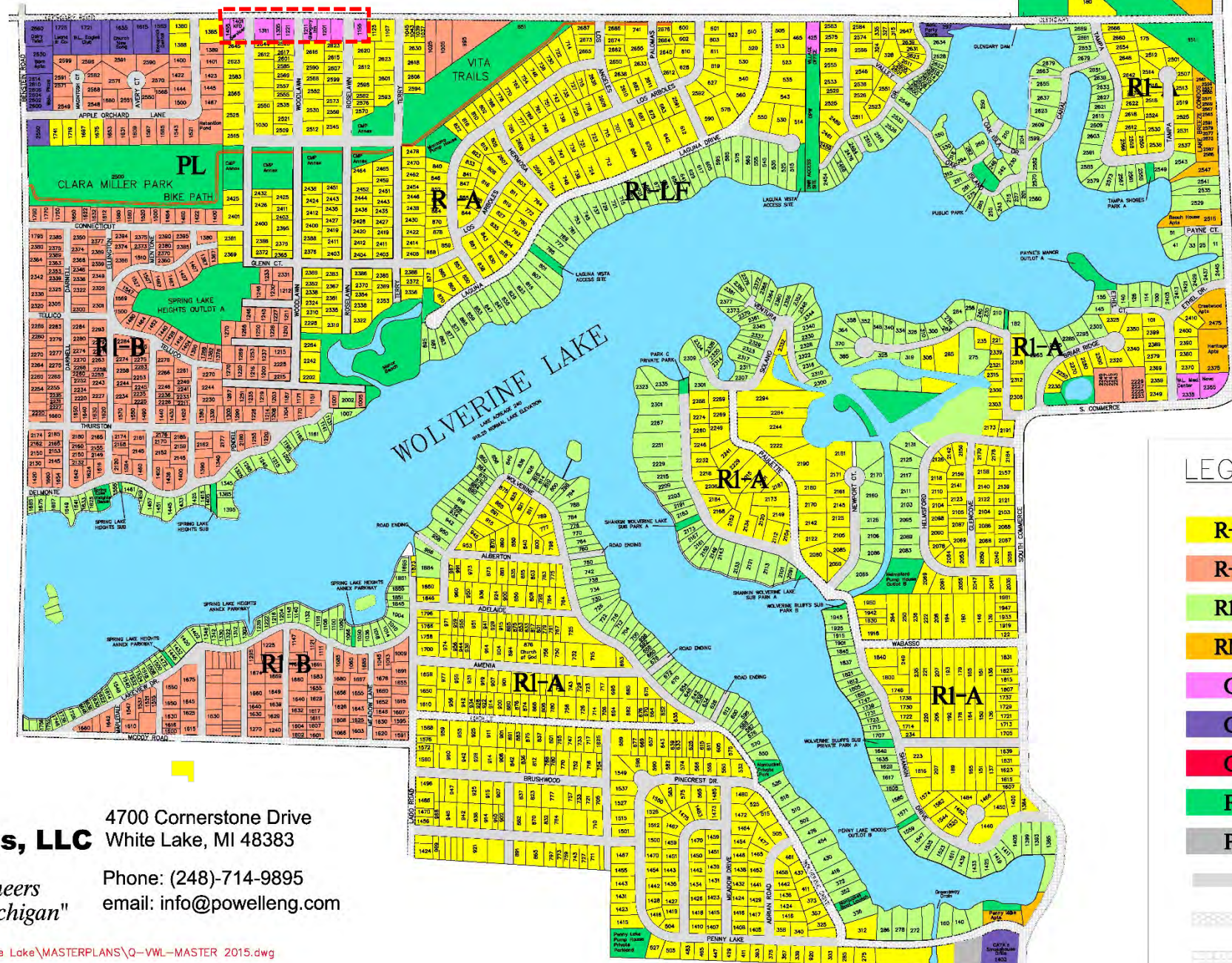
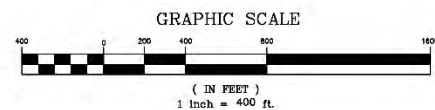
Location: Six properties on Glengary identified as “Mixed Use” on the Future Land Use Map .

PROPOSED CHANGES TO THE ZONING ORDINANCE

This Master Plan is adding a new future land use description called “Mixed Use.” The intent of this change is to provide a consistent zoning designation along six properties on Glengary Road that are currently a mixture of compliant residential and office uses, as well as some non-compliant commercial uses. The Zoning Ordinance will need to add this new zoning district, and the properties identified on the Future Land Use Map as Mixed-Use will need to be rezoned to this new district. See the proposed Zoning Map on the following page, which identifies the planned location for this new district.

VILLAGE OF WOLVERINE LAKE

"ZONING"



LEGEND

- R-1A** SINGLE FAMILY RESIDENCE DISTRICT
- R-1B** SINGLE FAMILY RESIDENCE DISTRICT
- R1-LF** LAKE-FRONT RESIDENTIAL DISTRICT
- RM-1** MULTI-FAMILY RESIDENTIAL DISTRICT
- O-1** OFFICE BUSINESS DISTRICT
- C-1** LOCAL BUSINESS DISTRICT
- C-3** GENERAL BUSINESS DISTRICT
- PL** PARK LAND DISTRICT
- P-1** PARKING DISTRICT
- MINOR ROADS
- MAJOR ROADS
- COUNTY ROADS

 Proposed Mixed Use Zoning



Powell Engineering & Associates, LLC

Consulting Civil Engineers
"Engineering A Better Michigan"

4700 Cornerstone Drive
White Lake, MI 48383

Phone: (248)-714-9895
email: info@powelleng.com

REVISED: 08/18/15

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CRITERIA TO CONSIDER FOR A REZONING REQUEST

Specific requests for development and/or use of vacant land will be considered at the time of request and will be reviewed with the following considerations:

- Current analysis of need. Is the proposed change consistent with the needs of the community?
- Residents' desire to maintain character and/or more current feedback.
- Proper fit of the proposal with the existing land use at the time and compliance with the Village's Zoning Ordinance.
- Are there substantial reasons why the property cannot be reasonably used as currently zoned?
- Is the proposed change consistent with the Master Plan?
- Is the proposed boundary appropriate?
- Would the change severely impact or create an unreasonable burden on traffic conditions, public facilities and services, and the natural characteristics of the area, or significantly change the population?
- Would the rezoning constitute a "spot zone" granting a special privilege to one landowner and not another?
- Is the change contrary to the existing land use patterns? Will it adversely affect property values?
- Has there been a change of conditions in the area supporting the proposed rezoning?
- Is the proposed change precedent setting? If the change is approved, what will be the probable effect on stimulating similar zoning requests in the vicinity?



Wolverine Lake 2020 Water Quality Report

A publication of the Village of Wolverine Lake

Wolverine Lake Improvement Board
425 Glengary
Wolverine Lake, MI 48390-1404

Michael Hurst
Water Management Board Chair

Kathy Duff
Water Management Board Vice-Chair

Bob Malek
*Water Management Board/Village Council
Liaison*

Paul Snyder
Water Management Board/Planning Liaison

Ryan Martini
Water Management Board Member

Doug Nye
Water Management Board Member

David Gillam
Village Administrator/Clerk

Water quality monitoring on Wolverine Lake has been ongoing since 2013. This report provides background information on lake water quality and a discussion of sampling results.

Lakes can be classified into three broad categories based on their productivity or ability to support plant and animal life. The three basic lake classifications are oligotrophic, mesotrophic, and eutrophic.

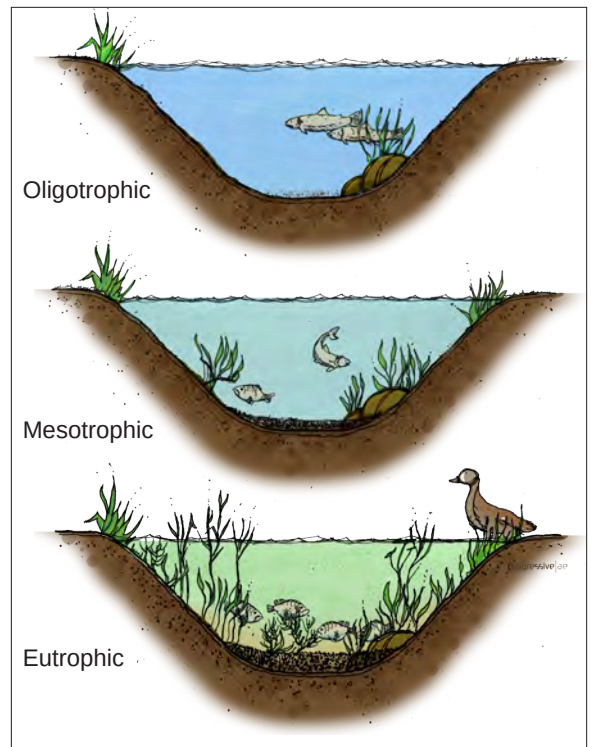
Oligotrophic lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient dissolved oxygen in the cool, deep bottom waters during late summer to support cold water fish such as trout and whitefish.

Eutrophic lakes have poor clarity, and support abundant aquatic plant growth. In deep eutrophic lakes, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, these lakes can only support warm water fish such as bass and pike.

Lakes that fall between the two extremes of oligotrophic and eutrophic are called *mesotrophic* lakes.

Under natural conditions, most lakes will ultimately evolve to a eutrophic state as they gradually fill with sediment and organic

matter transported to the lake from the surrounding watershed. As the lake becomes shallower, the process accelerates. When aquatic plants become abundant, the lake slowly begins to fill in as sediment and decaying plant matter accumulate on the lake bottom. Eventually, terrestrial plants become established and the lake is transformed to a marshland. The natural lake aging process can be greatly accelerated if excessive amounts of sediment and nutrients (which stimulate aquatic plant growth) enter the lake from the surrounding watershed. Because these added inputs are usually associated with human activity, this accelerated lake aging process is often referred to as *cultural eutrophication*.



Lake trophic states.

Key parameters used to evaluate a lake's productivity or trophic state include total phosphorus, chlorophyll-a, and Secchi transparency.

Phosphorus is the nutrient that most often stimulates excessive growth of aquatic plants and causes premature lake aging. By measuring phosphorus levels, it is possible to gauge the overall health of a lake.

Chlorophyll-a is a pigment that imparts the green color to plants and algae. A rough estimate of the quantity of algae present in the water column can be made by measuring the amount of chlorophyll-a in the water column.

A *Secchi disk* is a round, black and white, 8-inch disk that is used to estimate water clarity. Generally, it has been found that plants can grow to a depth of about twice the Secchi disk transparency.

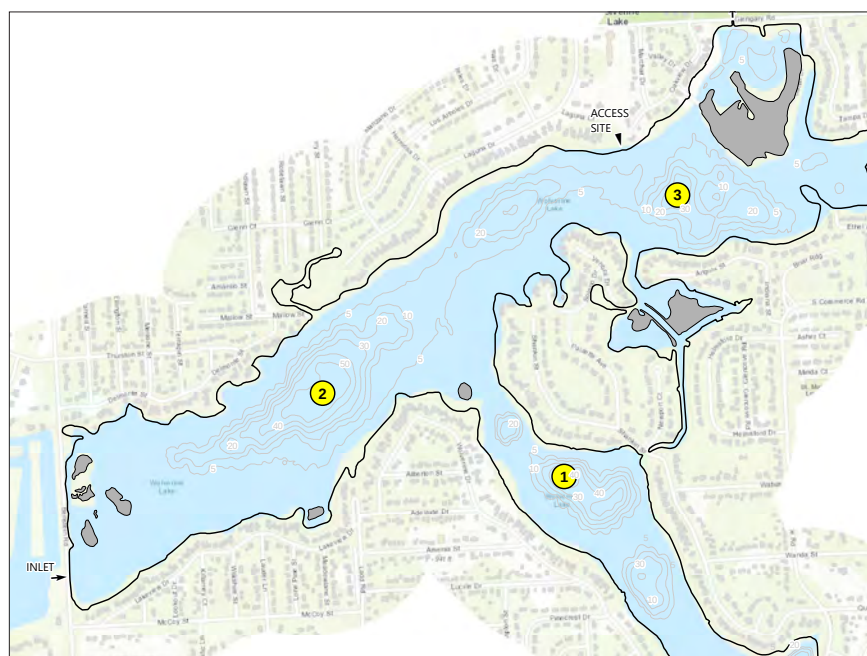
Generally, as phosphorus inputs to a lake increase, algae growth and chlorophyll-a increase and Secchi transparency decreases.



A Secchi disk measures water clarity.

TROPHIC CLASSIFICATION CRITERIA

Lake Classification	Total Phosphorus (µg/L) ¹	Chlorophyll-a (µg/L) ¹	Secchi Transparency (feet)
Oligotrophic	Less than 10	Less than 2.2	Greater than 15.0
Mesotrophic	10 to 20	2.2 to 6.0	7.5 to 15.0
Eutrophic	Greater than 20	Greater than 6.0	Less than 7.5



In 2020, samples were collected during summer and fall at the surface, mid-depth and bottom from three locations in Wolverine Lake.

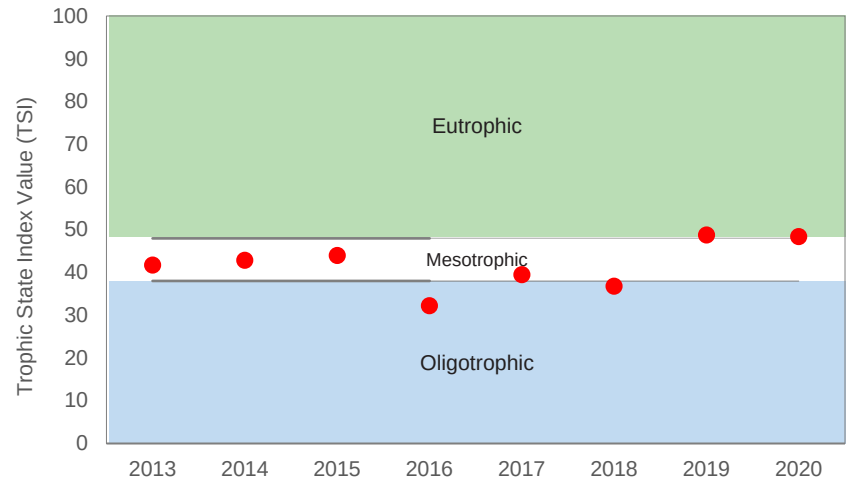
¹ µg/L = micrograms per liter = parts per billion.

Carlson's Trophic State Index (TSI) was developed from mathematical relationships that allowed phosphorus, chlorophyll-a, and Secchi transparency readings to be converted to a numerical scale from 0 to 100, with increasing numbers indicating more productive lakes. The TSI can be used to rate the trophic state of Michigan lakes as follows:

TSI INDEX FOR MICHIGAN	
Trophic State	TSI Value
Oligotrophic	Less than 38
Mesotrophic	38 to 48
Eutrophic	Greater than 48

The average TSI values for Wolverine Lake based on spring phosphorus and summer chlorophyll-a and Secchi transparency data collected between 2013 and 2020 are shown below.

Wolverine Lake average Trophic State Index (TSI) values.



Based upon water quality sampling conducted since 2013, Wolverine Lake is mesotrophic. TSI values of the composite data collected and averaged for the three basins of Wolverine Lake have varied over the past eight years, but overall, water quality appears to be mesotrophic.

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen strongly influence lake water quality and are very important to a lake's fishery.

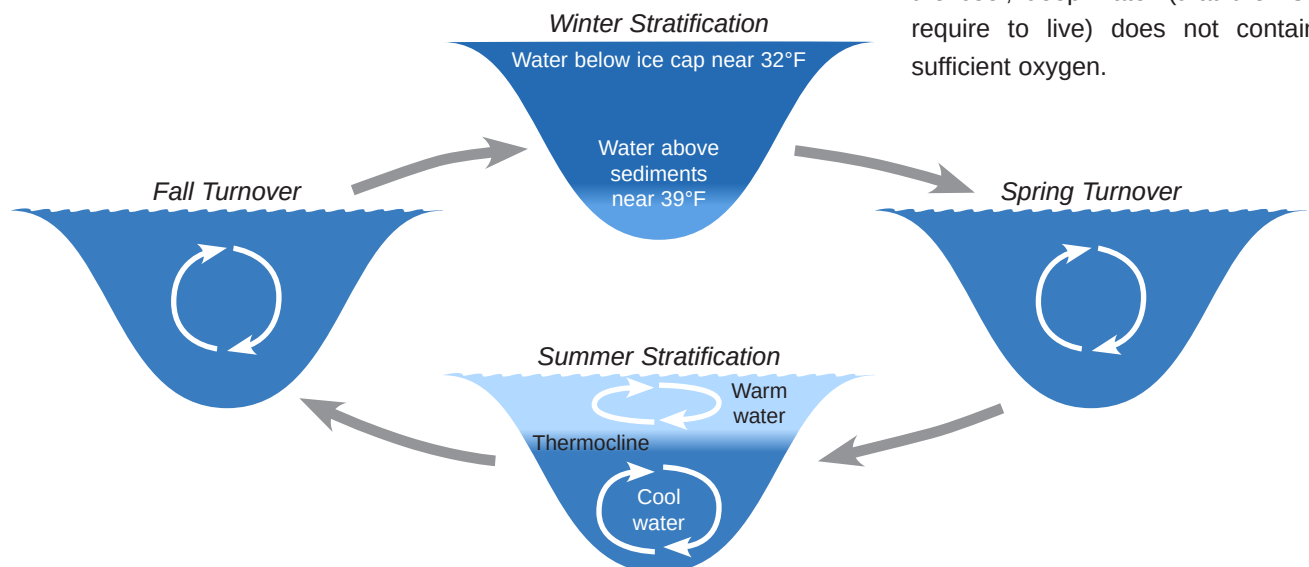
For more information, visit:
michiganlakeinfo.com/turnover-and-stratification

Temperature

4 *Temperature* is important in determining the type of organisms that may live in a lake. For example, trout prefer temperatures below 68°F. Temperature also determines how water mixes in a lake. As the ice cover breaks up on a lake in the spring, the water temperature becomes uniform from the surface to the bottom. This period is referred to as *spring turnover* because water mixes throughout the entire water column. As the surface waters warm, they are underlain by a colder, more dense layer of water. This process is called thermal stratification. In deeper lakes during summer there are three distinct layers. This is referred to as *summer stratification*. Once thermal stratification occurs, there is little mixing of the warm surface waters with the cooler bottom waters. The transition layer that separates these layers is referred to as the *thermocline*. The thermocline is characterized as the zone where temperature drops rapidly with depth. As fall approaches, the warm surface waters begin to cool and become more dense. Eventually, the surface temperature drops to a point that allows the lake to undergo complete mixing. This period is referred to as *fall turnover*. As the season progresses and ice begins to form on the lake, the lake may stratify again. However, during *winter stratification*, the surface waters (at or near 32°F) are underlain by slightly warmer water (about 39°F). This is sometimes referred to as *inverse stratification* and occurs because water is most dense at a temperature of about 39°F. As the lake ice melts in the spring, these stratification cycles are repeated. These stratification cycles occur in deep lakes but not in shallow lakes or ponds. Lakes that are about 15 to 30 feet deep may stratify and destratify with storm events several times during the year. The three deep basins on Wolverine Lake are deep enough to stratify for the entire season. The thermocline typically occurs around a depth of about 20 feet by late summer.

Dissolved Oxygen

An important factor influencing lake water quality is the quantity of *dissolved oxygen* in the water column. The major inputs of dissolved oxygen to lakes are the atmosphere and photosynthetic activity by aquatic plants. An oxygen level of about 5 mg/L (milligrams per liter, or parts per million) is required to support warm-water fish. In lakes deep enough to exhibit thermal stratification, oxygen levels are often reduced or depleted below the thermocline once the lake has stratified. This is because deep water is cut off from plant photosynthesis and the atmosphere, and oxygen is consumed by bacteria that use oxygen as they decompose organic matter (plant and animal remains) at the bottom of the lake. Bottom-water oxygen depletion is a common occurrence in eutrophic and some mesotrophic lakes. Thus, eutrophic and most mesotrophic lakes cannot support cold-water fish because the cool, deep water (that the fish require to live) does not contain sufficient oxygen.



Seasonal thermal stratification. Stratification cycles occur in deep lakes but not in shallow lakes or ponds.

Wolverine Lake Aquatic Plant Control Program 2020 Activity Summary

A publication of the Village of Wolverine Lake

Village of Wolverine Lake

425 Glengary
Wolverine Lake, MI 48390-1404

Michael Hurst
Water Board Chair

Kathryn Duff
Water Board Vice-Chair

John Scott
Water Board/Village Council Liaison

Mike Sergeant
Water Board Member

Ryan Martini
Water Board Member

Paul Snyder
Water Board Member

Doug Nye
Water Board Member

Mike Kondek
Acting Village Administrator

Environmental Consultant
Progressive AE

Herbicide Applicator
Aqua-Weed Control, Inc.

For many years, a nuisance plant control program has been ongoing on Wolverine Lake. The primary objective of the program is to prevent the spread of invasive aquatic plants while preserving beneficial plant species. This report contains an overview of plant control activities conducted on Wolverine Lake in 2020.

Aquatic plants are an important component of lakes. They produce oxygen during photosynthesis, provide food, habitat and cover for fish, and help stabilize shoreline and bottom sediments.

Insects and other invertebrates live on or near aquatic plants, and become food for fish, birds, amphibians, and other wildlife.

Plants and algae are the base of the food chain. Lakes with a healthy fishery have a moderate density of aquatic plants.

Aquatic plants provide habitat for fish and other aquatic life.

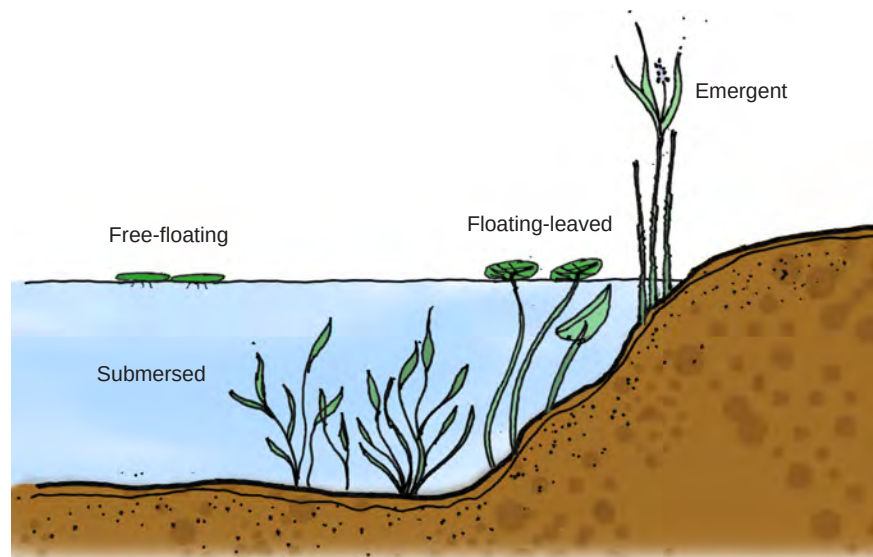
Aquatic plants help to hold sediments in place and improve water clarity.

Trees and shrubs prevent erosion and provide habitat.

Roots and stones absorb wave energy and reduce scouring of the lake bottom.

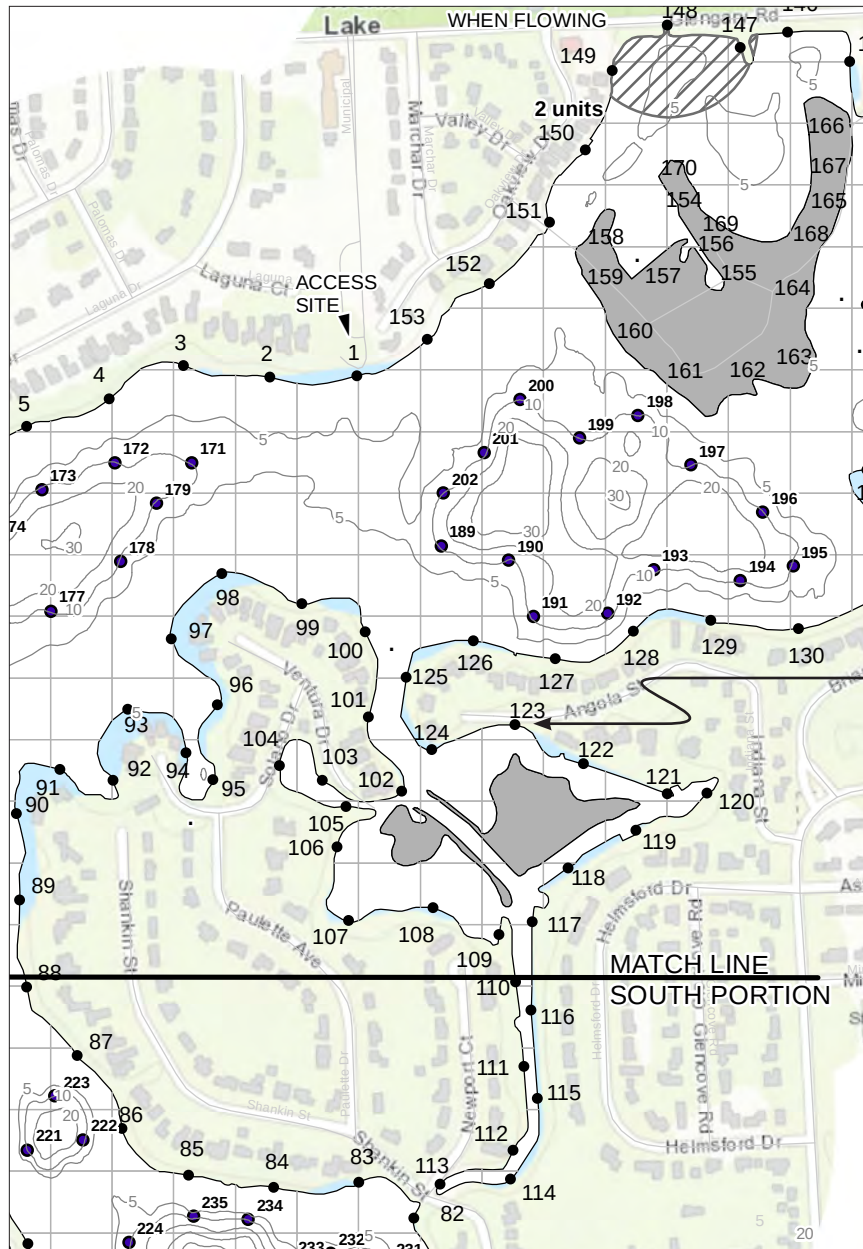
Predator-fish such as pike hide among plants, rocks, and tree roots to sneak up on their prey. Prey-fish such as minnows and small sunfish use aquatic plants to hide from predators.

There are four main aquatic plant groups: submersed, floating-leaved, free-floating, and emergent. Each plant group provides important ecological functions. Maintaining a diversity of aquatic plants is important to sustaining a healthy fishery and a healthy lake.



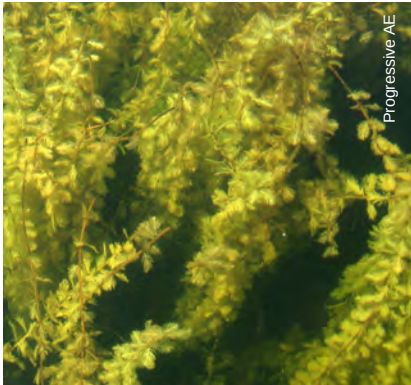
Plant control activities are coordinated under the direction of an environmental consultant, Progressive AE. Biologists from Progressive conduct GPS-guided surveys of the lake to identify problem areas, and georeferenced plant control maps are provided to the plant control contractor.

2



GPS reference points established along the shoreline and off-shore drop-off areas of Wolverine Lake are used to guide plant surveys and to accurately identify the location of nuisance plant growth areas.

Plant control in Wolverine Lake involves the select use of herbicides and mechanical harvesting to control invasive plant growth. Primary plants targeted for control in Wolverine Lake include Eurasian milfoil and starry stonewort. Both of these plants are non-native (exotic) species that tend to be highly invasive and have the potential to spread quickly if left unchecked.



Eurasian milfoil (*Myriophyllum spicatum*)



Starry stonewort (*Nitellopsis obtusa*)

Plant control activities conducted on Wolverine Lake in 2020 are summarized in the table below. In addition to aquatic herbicide treatments, the Village of Wolverine Lake operates a mechanical harvester 2 - 3 days per week between approximately June 1 and Labor Day.

WOLVERINE LAKE
2020 NUISANCE AQUATIC PLANT CONTROL SUMMARY

Work Type	Date	Plants Targeted	Acres
Survey	May 6		
Herbicide	May 13	Eurasian milfoil, curly-leaf pondweed	21
Survey	May 26		
Herbicide	June 1	Eurasian milfoil, starry stonewort	20
Survey	June 18		
Herbicide	June 24	E. milfoil, curly-leaf pondweed, starry stonewort	40
Survey	July 9		
Herbicide	July 14	E. milfoil, starry stonewort, wild celery	41
Survey	July 23		
Herbicide	July 29	E. milfoil, starry stonewort, wild celery	31
Survey	August 6		
Herbicide	August 13	Eurasian milfoil, starry stonewort	30
Survey	August 20		
Herbicide	August 27	E. milfoil, starry stonewort, wild celery	14
Survey	September 15		
Total			197

End-of-year Aquatic Plant Survey

4

In addition to the surveys of the lake to identify invasive plant locations, a vegetation survey of Wolverine Lake was conducted on August 20 to evaluate the type and abundance of all plants in the lake. The table below lists each plant species observed during the survey and the relative abundance of each. At the time of the survey, 17 submersed species, two free-floating species, two floating-leaved species, and six emergent species were found in the lake. Wolverine Lake maintains a very good diversity of beneficial, native plant species.

WOLVERINE LAKE AQUATIC PLANTS

August 20, 2020

Common Name	Scientific Name	Group	Percent of Sites Where Present
Illinois pondweed	<i>Potamogeton illinoensis</i>	Submersed	61
Wild celery	<i>Vallisneria americana</i>	Submersed	59
Slender naiad	<i>Najas flexilis</i>	Submersed	49
Variable pondweed	<i>Potamogeton gramineus</i>	Submersed	44
Chara	<i>Chara</i> sp.	Submersed	39
Starry stonewort	<i>Nitellopsis obtusa</i>	Submersed	37
Flat-stem pondweed	<i>Potamogeton zosteriformis</i>	Submersed	18
Thin-leaf pondweed	<i>Potamogeton</i> sp.	Submersed	13
Large-leaf pondweed	<i>Potamogeton amplifolius</i>	Submersed	10
Water stargrass	<i>Heteranthera dubia</i>	Submersed	9
Eurasian milfoil	<i>Myriophyllum spicatum</i>	Submersed	5
Underwater arrowhead	<i>Sagittaria</i> sp.	Submersed	1
Green milfoil	<i>Myriophyllum verticillatum</i>	Submersed	1
Elodea	<i>Elodea canadensis</i>	Submersed	1
Bladderwort	<i>Utricularia vulgaris</i>	Submersed	1
American pondweed	<i>Potamogeton nodosus</i>	Submersed	1
Southern naiad	<i>Najas guadalupensis</i>	Submersed	1
Watermeal	<i>Wolffia punctata</i>	Free-floating	2
Duckweed	<i>Lemna minor</i>	Free-floating	1
White waterlily	<i>Nymphaea odorata</i>	Floating-leaved	55
Yellow waterlily	<i>Nuphar</i> sp.	Floating-leaved	6
Cattail	<i>Typha</i> sp.	Emergent	16
Purple loosestrife	<i>Lythrum salicaria</i>	Emergent	5
Iris	<i>Iris</i> sp.	Emergent	4
Swamp loosestrife	<i>Decodon verticillatus</i>	Emergent	4
Phragmites	<i>Phragmites australis</i>	Emergent	2
Bulrush	<i>Schoenoplectus</i> sp.	Emergent	1



Wolverine Lake Canal Improvement Alternatives Evaluation

Prepared for:

Village of Wolverine Lake
425 Glengary
Wolverine Lake, MI 48390

Prepared by:

Progressive AE
1811 4 Mile Road, NE
Grand Rapids, MI 49525-2442
616/361-2664

January 2021

Project No: 71940001

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Introduction

In September of 2020, Progressive AE was retained by the Village of Wolverine Lake to conduct a preliminary evaluation of alternatives to improve conditions in the canal system at the southeast portion of Wolverine Lake (Figure 1). Currently, during spring and summer, frequent herbicide and algacide treatments are required to control excessive plant and algae growth in the canal. This study was conducted to evaluate the feasibility and probable costs of other alternatives that may help improve conditions in the canal.

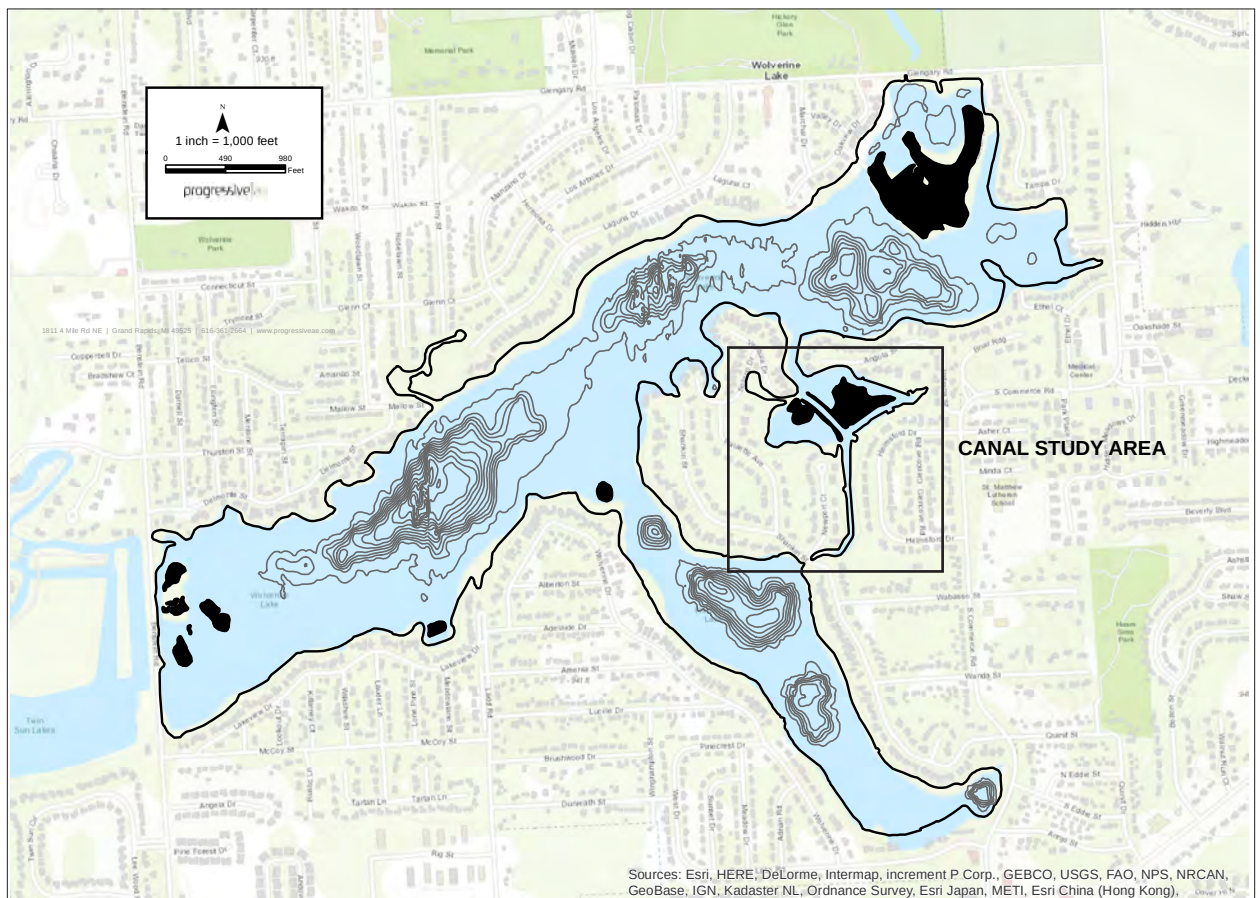


Figure 1. Wolverine Lake Canal project location map.

INTRODUCTION

Historical mapping of the Wolverine Lake area indicates that the canal system was formerly a wetland area (Figure 2). The current shoreline (in red) is overlain on the 1907 United States Geological Survey (USGS) topographical map of the Wolverine Lake area. As urbanization occurred, this wetland area was channelized to accommodate development and today several homes border the canal. The pre-existing conditions in the area coupled with the lack of water circulation in the canal create ideal conditions for aquatic plant growth, both rooted plants and algae.



Figure 2. Wolverine Lake historical conditions map (1907 U.S. Geological Survey).

Existing Conditions

Currently, the canal system has approximately 7,500 feet of shoreline and about 10.5 acres of open water (Figure 3). On October 29, 2020, a field survey was conducted to measure water and sediment depths within the canal. A calibrated range pole was used to measure water depth and the pole was pushed into the sediment until a relatively firm bottom was encountered. The difference between the water depth and the firm bottom was the estimated sediment thickness. GPS reference points established along the shoreline of the canal were used to geographically reference measurement locations. In total, 20 discrete measurements were made. Water depth within the canal system ranged from 2.1 feet to 5.3 feet with an average depth of 3.5 feet. Sediment thickness ranged from less than a foot to 7.4 feet with an average thickness of 3.7 feet (Figure 4). Note that, during the survey, the lake level was drawn down approximately 9 inches below the normal lake level of 918.25 feet USGS and the water depths reported herein were adjusted to the normal lake level.

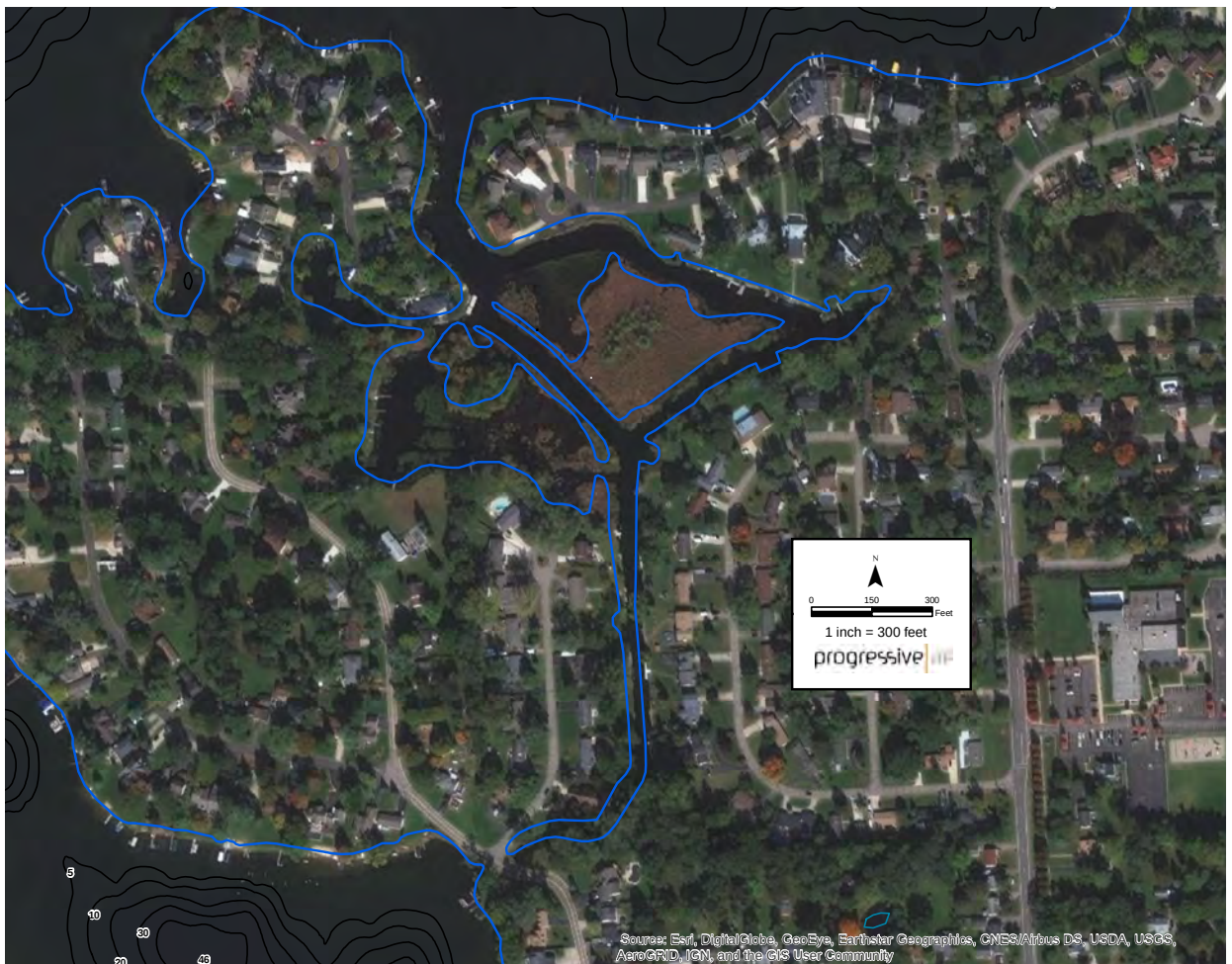


Figure 3. Wolverine Lake existing conditions map.

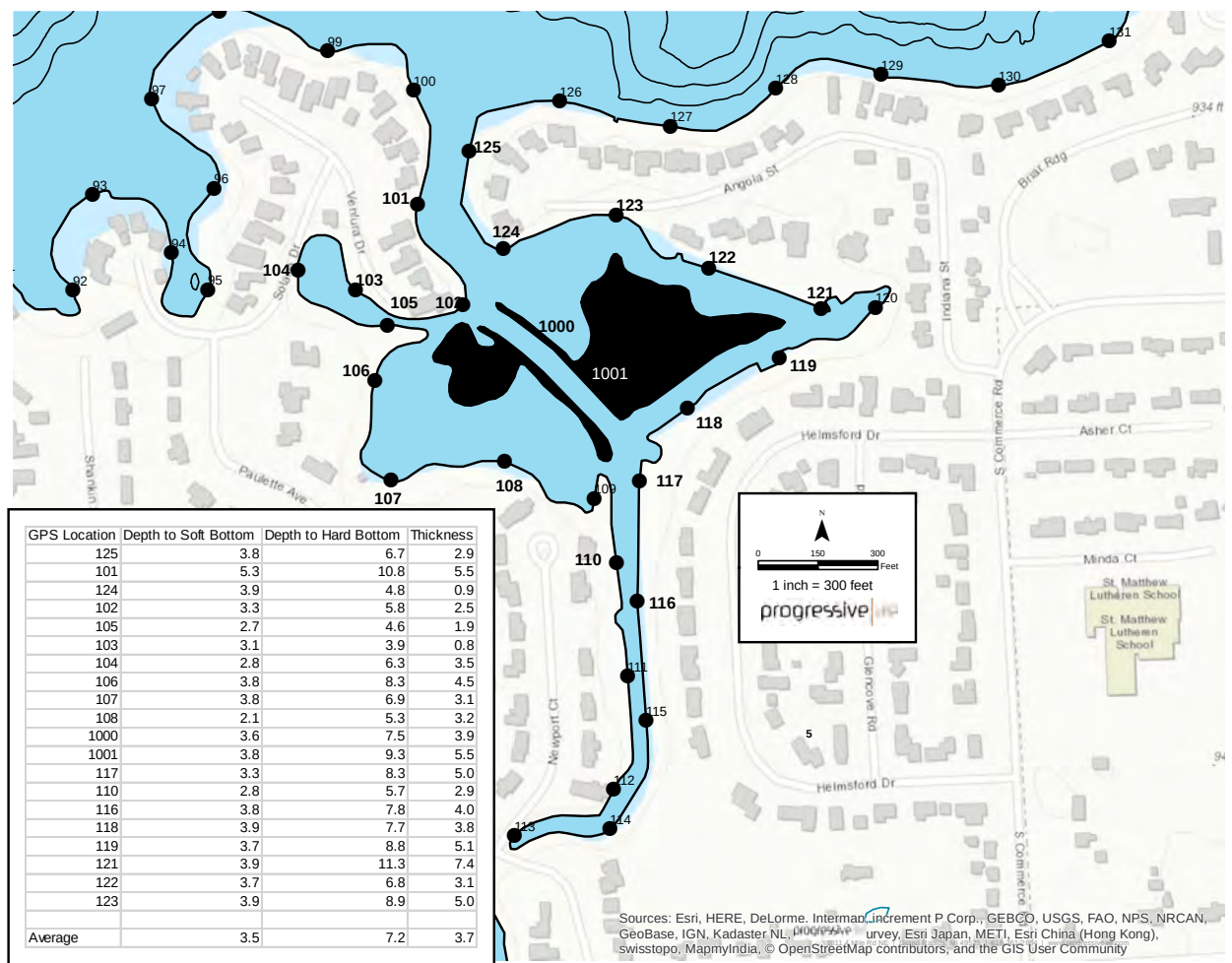


Figure 4. Wolverine Lake sediment thickness map.

Improvement Alternatives

The following improvement alternatives were evaluated to improve conditions within the canal study area.

Dredging

There are two basic dredging methods: mechanical and hydraulic. While both methods involve removing sediment from the water, the operations are quite different. Mechanical dredging involves removing lake sediments with an excavator operating from shore or from a floating barge. Dredged material is disposed on shore or contained on the barge and off-loaded for final disposal. By contrast, material excavated with a hydraulic dredge is pumped in a slurry through a floating pipeline to the point of disposal. In some cases, an interim disposal site is constructed to allow time for dredged sediment to dewater before being hauled to a final disposal site (Figure 5). Given the constrained working conditions in the canal and the amount of shoreline development, dredging of the canal would likely require a small hydraulic dredge.

While dredging to remove soft bottom sediments in the canal would help to reduce rooted plant growth, it would do little to control algae growth. Further, dredging in the canal could de-stabilize adjacent shoreline areas and cause sloughing and shoreline damage. Another primary consideration with dredging is cost. To remove one foot of sediment on average from the canal would require the dredging and disposal of approximately 17,000 cubic yards of sediment. Assuming a cost of \$50 to \$60 per cubic yard to dredge and dispose of sediment, dredging costs could be in the range of \$850,000 to 1 million dollars. Dredging does not appear to be a viable or cost-effective alternative to improve conditions in the canal.



Figure 5. Geotextile bag used for temporary disposal sites with hydraulic dredging.

Augmentation

To maintain water levels in Wolverine Lake during the summer months, water is periodically pumped into the lake via augmentation wells. There are currently two functioning wells: one at the south end of Terry Street (on the north side of the lake), the other on Wolverine Drive at the Nantucket Boat Launch (on the south end of the lake). Each well has a 10" outlet and a pumping capacity of 1,500 gallons per minute. There is a third augmentation well in the Helmsford Pump House, but it is currently not operable. Historically, water was pumped directly into the south end of the canal using the Helmsford augmentation well. Water movement in the canal could be enhanced (and algae growth reduced) if the Helmsford augmentation well was again operational. Based on a cost estimate received by the Village of Wolverine Lake Department of Public Works (DPW), the estimated cost to repair the well is between \$6,000 and \$10,000 depending on the condition of the pump once it is inspected (Appendix A). DPW estimates annual operation and maintenance costs for all three wells would range between \$5,000 and \$8,000 per year.

Aeration

Another alternative to improve conditions in the canal is to use the aeration equipment from the Penny Lake project (Figure 6). This alternative would involve deploying the aeration equipment into the canal to promote water movement and circulation. Village staff have indicated that the aeration pumps have been removed from Penny Lake, but the hoses and tubing are still in place. The estimated cost to reinstall the aeration system in the canal is between \$12,000 and \$20,000 and would not include electrical hook-up fees and annual electrical usage. A more accurate assessment of costs can be made in the spring after snow melt by staff from The Pond Guy. This figure would include removal of the existing airlines currently deployed in Penny Arm (Appendix B). In addition, current Michigan Department of Environment, Great Lakes, and Energy (EGLE) regulations require an installation permit and extensive monitoring of the aeration system (Appendix C). It is anticipated that monitoring and reporting costs over the five-year permitting period would be approximately \$35,000. Therefore, the total estimated cost for aerating the canals over five years would equate to approximately \$60,000 to \$80,000.



Figure 6. Aeration diffuser used in Penny Arm.

Nutrient Inactivation

Another alternative that may help to reduce the severity of algae blooms in the canal would be to apply a product called SeClear. SeClear is an algaecide with a trace of a phosphorus-binding agent called lanthanum. Phosphorus is the nutrient that most often stimulates algae growth. Theoretically, repeated treatments with SeClear would control algae and reduce phosphorus in the water column which, in turn, would help to reduce the potential for future algae blooms. SeClear treatment costs would range from \$170 to \$425 per acre depending on dose. Assuming the developed portion of the canal was treated (about 7 acres), the cost per treatment would range from \$1,200 to \$3,000. SeClear could be applied under the current aquatic nuisance control permit issued annually by EGLE for herbicide treatments in Wolverine Lake.

Another phosphorus inactivation agent that may help improve conditions in the canal is a product called PhosLock. Like SeClear, PhosLock contains lanthanum, but at a much higher concentration than SeClear. PhosLock is not an algaecide but limits algae growth by binding phosphorus and removing it from the water column. The estimated cost to treat the entire canal with PhosLock is \$8,000 per treatment. Assuming three treatments were conducted over the course of a growing season, annual costs for treatment would be about \$24,000. In addition, the use of PhosLock in the canal would require a Rule 97 Certification of Approval from EGLE and periodic monitoring and reporting which would add additional costs.

More information on SeClear and PhosLock can be found at the links below:

<https://www.sepro.com/aquatics/seclear>

<https://www.sepro.com/aquatics/phoslock>

Recommended Course of Action

Based on cost and expected benefits, it appears that repairing the Helmsford augmentation well and periodic applications of SeClear would be the most cost-effective alternatives to improve conditions in the canal. If, after implementation of these alternatives, conditions in the canal did not satisfactorily improve, consideration could be given to redeploying the aeration system and/or the use of the product PhosLock.

Appendix A

Helmsford Pump Repair Cost Estimate



Established 1927



7215 Highland Road (M-59)

Howell, Michigan 48843

(517) 546-0600

FAX (517) 546-3974

January 15, 2021

Wolverine Lake

SENT VIAL EMAIL: dpw@wolverinelake.com

Attn: Andy

Re: Helmsford
Pull and Inspect Pump Estimate

Andy:

Brown Drilling Co., Inc. is pleased to provide the following estimate to pull and inspect the pump in the Helmsford Pump House. We propose to pull the pump, drop pipe and wire from the well and inspect it as it comes out. Based on our findings we will prepare a cost estimate for any pump or well repairs, which may be required. For budgetary purposes, we have included ball park prices for the pump, motor and associate components.

ESTIMATE

<u>Item</u>	<u>Units</u>	<u>Unit Price</u>	<u>Amount</u>
<u>Pull and Inspect Pump</u>			
Labor, 3 men, Crane & Support Truck, Pull & Inspect Pump w/mob.	7 Hr.	285.00	\$ 1,995.00
Steam Clean and Additional Inspection at BDCI Shop	3 Hr.	70.00	210.00
<i>Based on the findings of our inspection we will prepare a cost estimate for any recommended pump and well repairs or replacement and submit it to you for approval. We will not proceed with any additional work without your approval. When the pump is ready, we will reinstall it.</i>			
Labor, 3 men, Crane & Support Truck, to Reinstall Pump, Conduct Short Pumping Test, w/Mob.	9 Hr.	285.00	2,565.00
Mats (If Needed)	1	500.00	
Misc. Material	LS		<u>250.00</u>
Total Estimate (Pull & Inspect Pump)			\$ 5,020.00

Budgetary Costs

F. E. 10 HP, 230V, 3 PH Motor	1	3086.00	\$ 3,086.00
Franklin 10 HP, 200 GPM, 6" Pump End	1	2613.00	2,613.00
8" x 3" Well Seal	1	219.81	219.81
3" Galvanized Drop Pipe	84' (Est.)	24.50	2,050.00
3" Brass Check Valve (Simmons)	1	781.00	781.00
Submersible Wire (8-3w/grd.)	100'	3.50	350.00
Magnetic Starter	1	1038.00	<u>1,038.00</u>
Total (Potential Budgetary Replacement Costs)			\$ 9,918.00 (*)

(*) Plus Labor

This is an estimate only. Billings will be for actual units used. We appreciate the opportunity to provide our services. If you have any questions, please contact us at 517-546-0600.

Thank you,

Brown Drilling Co., Inc.



Gary L. Sunderland

Payment Terms:

30 Day after receipt of invoice.

NOTICE TO PROCEED

To accept this estimate and to authorize us to proceed with the scope of work presented, please sign below, keep a copy for your records, and return a copy to our office:

By: _____

Date: _____

Title: _____

Co: _____

Appendix B

Airline Removal Cost Estimate



QUOTE

The Pond Guy® , Inc.

P.O. Box 38, Romeo, MI 48065

586-336-POND (7663) | Fax: 586-336-9049

www.weknowponds.com

Quote # SERVQTE004298	Customer No. 376483	Sales I.D. RBN	Quote Date 09/10/2020	Page 1/1
Bill To Village Of Wolverine Lake 425 Glengary Rd Walled Lake MI 48390-1404 (248) 624-1710		Ship To Village Of Wolverine Lake 425 Glengary Rd Walled Lake MI 48390-1404 (248) 624-1710		
PO No.	Reference No.	Terms 50% Deposit with remaining balance due upon completion		

Quote pricing is valid for 90 days from quote date indicated above.

Qty	Item #	Description	Unit Price	Discount %	Ext. Price
1	LABOR ONSITE	Onsite Labor 1-2 Days,4 People-Mini Skidsteer-Boat. Customer to supply dumpster near pond to dispose of airline and diffusers. if airline is to be reused it will need to be respooled. This will increase cost by at least 50% due to the extra time to respool this much airline.	\$5895.00		\$5895.00

Merchandise Quotation Total:	\$	5895.00
Sales Tax:	\$	0.00
Quotation Total:	\$	5895.00

X_____

Accepted by: (Signature)

Print Name

Date _____

Appendix C

Baseline Information and Monitoring Requirements for Lake Aeration Projects



Michigan Department of Environmental Quality
Water Resources Division

Guidance for Permit Applicants and Permittees Regarding Baseline Information and Monitoring
Requirements for Lake Aeration Projects

Decisions on inland lake aeration permit applications are based on the Michigan Department of Environmental Quality's (MDEQ) review of the proposed project in light of the criteria in Part 301, Inland Lakes and Streams, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, and associated administrative rules, which generally require that a project will not adversely affect the public trust, riparian rights, or the environment. For the purposes of this guidance, aeration is the process of artificially introducing air to the bottom of a lake to circulate the water to create an aerobic environment. As part of the application review process, MDEQ staff consider existing lake conditions and whether the proposed project is expected to result in unacceptable changes to the natural condition of the lake. Information regarding current conditions must be submitted with the permit application; it is considered to be "baseline" information. Baseline monitoring data submitted with the permit application must include basic parameters that will enable staff to evaluate whether projects may, or do, adversely affect the lake. In addition, there are, or could be, other potential concerns with riparian rights, fish, and other wildlife, impacts to wetlands, or state regulation that must be met. To this end, in addition to meeting the requirements outlined in this document, a project must meet all requirements of other environmental regulations. Monitoring during the project, if permitted, may also be required and would be detailed as a condition of the permit.

In general, installation of aeration systems has focused on one or more of the following objectives: (1) improve water quality; (2) decrease organic substrate (e.g., muck); and (3) reduce the growth of plants and algae. Although the intent of the aeration system is to improve lake conditions, there may be unintentional negative effects that occur as a result of manipulating the natural physical and chemical characteristics of a lake. The following baseline information, monitoring parameters, and protocols are the minimum amount of information necessary for a complete permit application. Quality assurance and control performance requirements are also needed to ensure that the data being collected are high quality. The MDEQ has tried to simplify and streamline these monitoring requirements by focusing only on the critical water quality and biological indicators needed to properly evaluate potential impacts on a lake.

Monitoring Requirements

The following information should be collected for any proposed lake aeration project, regardless of the cited objective(s). One year of pre-aeration monitoring data must be submitted with the permit application to establish baseline water quality conditions in a lake. The permit, if issued, may also require collection of the information during project implementation. Three years of monitoring during project implementation will typically be required as a permit condition, usually in permit years one, two, and five. In rare circumstances, more or fewer years of monitoring may be required as site-specific circumstances warrant. If the applicant does not apply for a permit reissuance, the year five monitoring requirement will be waived. If another permit is sought, the year five monitoring can be conducted with the system still operational (i.e., it does not need to be shut off). If an existing permit does not include a condition for monitoring in year 5 (or the last year the permit is valid), the permittee is advised to conduct monitoring in

year five to serve as the pre-application monitoring for another permit application, should another permit be sought.

When an applicant proposes to destratify a lake, or in cases where MDEQ staff are concerned that destratification may occur even if not intended, additional monitoring will be required to ensure protection of the lake. These requirements are described in a separate section below.

For purposes of this guidance, a year of monitoring consists of consecutive sampling events in the spring after ice-out (April/mid-May), mid-summer (mid-June/July), and late summer (mid-August/September). Such sampling could occur in one calendar year (e.g., spring 2017, mid-summer 2017, late summer 2017), or over two consecutive years (e.g., late summer 2017, spring 2018, and mid-summer 2018). In addition, winter monitoring for temperature, dissolved oxygen, and Secchi depth will be conducted once during ice cover, ideally in February if ice cover is sufficient.

Data should be collected by an entity with established expertise and experience conducting water quality monitoring on inland lakes, following the protocols outlined in this guidance. Sample analysis must be completed by a laboratory with defined standard operating procedures and quality assurance/quality control practices.

Water Chemistry and Physical Parameters

One sample should be collected from every 50 acres of lake surface area, or fraction thereof, undergoing treatment, at the deepest location within each 50-acre plot. One or more locations in an area unaffected by the aeration should also be sampled, if applicable, depending on site-specific conditions.

At the beginning of each sampling event, a vertical profile of depth, temperature, and dissolved oxygen will be made to determine the extent of stratification, and identify the epilimnion, thermocline, and hypolimnion if these strata exist at the time of sampling. Water quality characteristics for specific conductance, water temperature, dissolved oxygen, and pH throughout the water column should be made by measuring these parameters versus depth at every two-foot interval. The nutrients listed in Table 1 (total phosphorus, soluble reactive phosphorus, ammonia, nitrate-nitrite, Kjeldahl nitrogen) and total suspended solids should be collected at three discrete depths using a Van Dorn sampler, or similar collection device. Sampling at three discrete depths consists of collecting samples within three feet of the surface, at mid-depth, and at one-half to one foot from the lake bottom. If the lake is stratified, the mid-depth sample should be collected in the thermocline. In cases where the lake is shallow and the vertical profile is completely mixed and uniform (i.e., no evidence of stratification), then one mid-depth sample for nutrients and total suspended solids will be sufficient. The performance requirements for the analytical methods are provided in Table 1.

Secchi disk measurements determine transparency and define the euphotic zone. The euphotic zone in a lake is the layer of water that receives enough light for photosynthesis to occur, and is considered to be two times the Secchi depth. Therefore, the Secchi depth must be measured and the euphotic zone established, prior to collecting a chlorophyll *a* sample. Samples for chlorophyll *a* will be collected using a depth integrated composite sampler that is lowered through the euphotic zone (i.e., two times Secchi depth) to obtain a composite sample for chlorophyll *a* analysis.

Table 1. Performance Requirements for Water Chemistry and Chlorophyll a Analytical Methods.

Parameter	Units	Analytical Method	Analytical Method Technique	Method Detection Level	Sample Holding Time
Temperature	°F	Data sonde	Measured with Field Instrument	0.01 ¹	N/A
Dissolved Oxygen	mg/l	Data sonde	Measured with Field Instrument	0.01 ¹	N/A
pH	pH units	Data sonde	Measured with Field Instrument	0.01 ¹	N/A
Specific Conductance	mS/cm at 25°C	Data sonde	Measured with Field Instrument	0.1 ¹	N/A
Total Phosphorus	mg/l	EPA 365.4	Block Digester; Auto Colorimetric Ascorbic Acid Reduction	0.01	28 days, cool <4°C, pH<2 ²
Soluble Reactive Phosphorus	mg/l	EPA 365.1	Filter w/ 0.45 µm filter, Auto Colorimetric Ascorbic Acid Reduction	0.01	48 hrs, cool 4°C
Ammonia	mg/l	EPA 350.1	Semi-automated colorimetry	0.01	28 days, cool <4°C, pH<22
Nitrate-Nitrite	mg/l	EPA 353.2	Automated colorimetry	0.01	28 days, cool <4°C, pH<2 ²
Kjeldahl Nitrogen	mg/l	EPA 351.2	Semi-automated colorimetry	0.1	28 days, cool <4°C, pH<2 ²
Total Suspended Solids	mg/l	SM2540D ³ or EPA 160.2	Total suspended solids dried at 103-105°C	1.0	7 days, cool 4°C
Chlorophyll <u>a</u> ⁴	µg/l	EPA 445.0 or 4500-CI-E ³	Chlorophyll filtered; pigment extracted, Fluorometric	1.0	48 hours

¹ Performance Resolution

² Preserve sample to pH <2 using sulfuric acid (10 drops/500 ml)

³ Standard Methods for the Examination of Water and Wastewater, 18th, 19th, or 20th edition

⁴ Preserve sample using magnesium carbonate

Increased productivity and sediment resuspension may lead to increased biological oxygen demand throughout the winter, resulting in potential hypoxia and fish kills. Therefore, in addition to the spring and summer monitoring, a dissolved oxygen and temperature profile should be taken from ice-covered lakes as part of the pre-treatment and treatment phases to assess potential hypoxic conditions. This sampling should occur in late January, February, or early March. A Secchi disk reading should also be taken at this time. This sampling assumes that safe ice conditions exist; if there is not safe ice cover, the sampling is not required.

To protect spawning habitat and aquatic life from the potential spread of fine-grained or organic sediment to areas with high-quality substrate, as well as to prevent potential nuisance conditions for riparian owners, an assessment of substrate types will be conducted. During the late summer pre-aeration sampling, the applicant is responsible for characterizing the bottom substrate in the area(s) where the diffusers will be placed. This can be accomplished using sonar techniques to map bottom sediment hardness, complemented by grab samples to verify the sonar results. Grab samples can be collected using a PONAR sampler, Ekman dredge, core sampler, or similar sampling device. As a general rule, we suggest collecting one sample for every five acres of lake area where the diffusers are located. More or fewer samples may be needed, depending on substrate uniformity/variability. Samples also may be needed in shallow areas that are not adequately mapped by sonar due to accessibility. Samples will be analyzed for percent organic matter using ASTM Method D-2974-87 (Appendix 2) and for particle size using ASTM Method D 422-63 (Appendix 3) at a certified laboratory.

Based on the number and location of diffusers, the pre-aeration substrate data, and lake-specific characteristics such as known fish spawning beds, littoral zone sites will be identified for continued sampling during project implementation. Like the baseline assessment, the post-aeration substrate monitoring should consist of sonar mapping complemented by PONAR grab samples during the late summer sampling event.

Sediment sampling for contaminant analysis may be required if the proposed project area is in an area with known or suspected contamination. The need for sediment contaminant testing is expected to occur only occasionally. Therefore, MDEQ staff will screen proposed projects for any needed sediment testing as part of the application review process and notify the applicant should testing be necessary. If required, the number of sampling locations and the parameters to be measured will be based on site-specific conditions.

Biological Parameters

The various types of phytoplankton (algae) found in a lake serve as good indicators of water quality. The resuspension of nutrient-laden sediments from the bottom waters could cause an increase in water column nutrients at the surface, result in an increase in algal productivity, and decrease water column clarity (i.e., Secchi depth). The type of algae present and their abundance in an aquatic system can reflect a lake's trophic status and may be indicative of nutrient enrichment conditions. Therefore, the percent community assemblage (i.e., taxonomic community) of green, blue-green, and diatom algae will be determined during the late summer sampling event. Phytoplanktonic algae, which are suspended or swim freely in open water, should be the focus of collection. Depth-integrated water samples should be collected from the photic zone at each sampling location. These samples should then be composited into one sample, mixed, and a 500 milliliter sub-sample taken and preserved. Phytoplankton samples should be identified by trained personnel.

A commonly-cited objective of lake aeration projects is to reduce the nuisance growth of both invasive and non-invasive aquatic plants. However, because multiple strategies are often

employed to manage plants in lakes, making it difficult or impossible to identify potential effects on plant communities specifically due to aeration, the MDEQ is **not** requiring the collection of aquatic vegetation information under this guidance. In some circumstances the vendor, monitoring consultants, or lake residents might want to collect such information to help determine whether changes in vegetation type or abundance have occurred. An aquatic vegetation survey can provide a baseline of the aquatic macrophyte community present, and the cumulative cover percentages for each plant species found throughout a lake's littoral zone. A list of the species (both native and non-native) and their distribution in the lake, and density and cumulative cover of both native and non-native plant species are useful components of an aquatic vegetation survey. If such a survey is required or conducted voluntarily, a survey should be conducted by sampling individual sites throughout a lake's littoral zone using the MDEQ Procedure for Aquatic Vegetation Assessment Surveys (AVAS). This procedure can be supplied to applicants upon request.

Requirements in Deep Lakes when Destratification is Proposed or Possible

In circumstances where aeration is proposed that may - intended or not - destratify a lake, additional monitoring will be required and additional review will be done in coordination with the Michigan Department of Natural Resources (MDNR), Fisheries Division, due to the potential for significant impacts. In these cases, zooplankton should be collected for community analysis during the spring and late-summer sampling events at the locations used for water quality and phytoplankton sampling. A plankton net with a straining bucket should be lowered to the top of the hypolimnion if the lake is stratified, or near the bottom (without disturbing it) if the water is mixed at the sampling location. We recommend a zooplankton net mesh size of 63 or 153 micrometers. After pausing for about 30 seconds, the net should be lifted in a smooth motion at a rate of about four feet per second. The net should be raised above the surface until the bucket is just above the surface. Water should be splashed on the outside of the net to dislodge zooplankton from the net into the bucket. Drain the bucket into a 125 milliliter bottle with a CO₂ tablet (e.g., Alka Seltzer) (to anesthetize the zooplankton), then preserve with 70 percent ethyl alcohol. Community analysis should consist of species identification and a summary of the percentage of cladocerans, copepods, and rotifers in the samples.

Aeration systems (i.e., pumping ambient air from the atmosphere as opposed to oxygen from a tank) pump nitrogen gas into the lake. Nitrogen gas pumped into deep water (>30 feet) has the potential to result in nitrogen gas supersaturation and could cause gas bubble disease in fish. Permits for aeration systems at depths >30 feet should require nitrogen gas monitoring using a total gas meter. A nitrogen gas meter is relatively inexpensive and has been successful in monitoring at MDNR fish hatcheries.

The timing of sample collection for each of the parameters described above are summarized in Table 2.

Table 2. Sample timing for each monitoring parameter. Monitoring to be conducted one year prior to aeration (baseline data), and in years 1, 2, and 5 of the permitted aeration.

MONITORING PARAMETER	Spring after ice-out (April/mid-May)	Mid-Summer (late-June/July)	Late summer (mid- August/September)	Winter during ice cover (February)
Temperature	X	X	X	X
Secchi Disk Transparency	X	X	X	X
Dissolved Oxygen	X	X	X	X
pH	X	X	X	
Specific Conductance	X	X	X	
Total Phosphorus	X	X	X	X (destratification only)
Soluble Reactive Phosphorus	X	X	X	X (destratification only)
Ammonia	X	X	X	X (destratification only)
Total Nitrogen	X	X	X	X (destratification only)
Nitrate-Nitrite	X	X	X	X (destratification only)
Kjeldahl Nitrogen	X	X	X	X (destratification only)
Total Suspended Solids	X	X	X	X (destratification only)
Chlorophyll <i>a</i>	X	X	X	
Substrate			X	
Phytoplankton			X	
Nitrogen Gas (destratification only)	X	X	X	
Zooplankton (destratification only)	X		X	

Report Format

Data that are collected for submittal with the application, as well as data collected during the project period, should be reported in the format outlined in Appendix 1.

For information or assistance on this publication, please contact the Water Resources Division, through the DEQ Environmental Assistance Center at 800-662-9278. This publication is available in alternative formats upon request.

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This publication is intended for guidance only and may be impacted by changes in legislation, rules, policies, and procedures adopted after the date of publication. Although this publication makes every effort to teach users how to meet applicable compliance

APPENDIX 1

Report Format Example

Introduction

This section should include:

- a. A summary of aeration operations, with beginning and ending dates of aeration for each year the system is in operation, and any variations in operation intensity. If bacteria or any other chemicals/materials were added to the water during aeration as part of the project, this should be reflected in the introduction. In addition, the Rule 97 Certification that was obtained prior to the project initiation should be attached. This link has information on applying for a Rule 97 Certification to use bacterial products in surface waters. http://www.michigan.gov/deq/0,4561,7-135-3313_46123_46124---,00.html
- b. A brief, but specific summary of intended objective(s) and goals of aeration operations.
- c. A brief summary of lake management activities to date and lake levels (if applicable).

Sampling Methods

This section should include:

- a. A summary of the types of equipment and sampling devices used; the number of samples and replicates that were collected; the depths at which samples were collected; and a map of the lake with sampling locations and diffuser locations identified using Global Positioning System coordinates.
- b. Sampling dates, and the lake/water chemistry parameters collected on the specific sampling dates.
- c. A brief summary of Standard Methods used for processing and analyzing samples.

Sampling Results

This section should include:

- a. Summary tables and figures developed from raw data collected during preoperation and during operation of the aeration system, and any ambient weather data such as wind speed, wind direction, and ambient air temperature. Raw data should be included as an appendix in the final report.
- b. The summary tables and figures should include profiles of water temperature versus depth; dissolved oxygen versus depth; conductivity versus depth; and pH versus depth. They also should include summary tables and figures for water chemistry (i.e., total phosphorus, orthophosphorus, and total suspended solids), and chlorophyll *a*.
- c. Summary tables and figures for phytoplankton community assemblage data (i.e., percent green, blue-green, and diatom algae), and zooplankton community assemblage if collection is required. Likewise, if the applicant chooses to collect AVAS data (which is

optional per the guidance), the identified macrophyte species as well as distribution, density, and cumulative cover of both native and non-native species within the lake, should be provided.

- d. A description and summary of sediment measurements (% organic matter, particle size) taken at specified locations around the diffusers, and a description of substrate type (i.e., sand, silt, and clay). A comparison of pre- and post-operational sediment conditions should be included in the report.

Conclusions

This section should include:

- a. A narrative summary of trends during the sampling years for water chemistry parameters (i.e., water temperature, conductivity, pH, dissolved oxygen, Secchi depth, nutrients, and suspended solids), lake productivity (documented changes in lake trophic state through chlorophyll *a* analysis), any influence of aeration on algal and aquatic macrophyte species, and sediment measurements.
- b. An analysis of whether herbicide treatments or other management activities (dredging, lake drawdown, mechanical, etc.) occurred and influenced sampling results.

ASTM D 2974-87

Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

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THIS STANDARD is issued under the fixed designation D 2974; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.18 on Peats and Related Materials.

Current edition approved May 29, 1987. Published July 1987. Originally published as D 2974 - 71. Last previous edition D 2974 - 84.

1. Scope

1.1 These test methods cover the measurement of moisture content, ash content, and organic matter in peats and other organic soils, such as organic clays, silts, and mucks.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Methods

2.1 *Method A* — Moisture is determined by drying a peat or organic soil sample at 105°C. The moisture content is expressed either as a percent of the oven dry mass or of the as-received mass.

2.2 *Method B* — This is an alternative moisture method which removes the total moisture in two steps: (1) evaporation of

moisture in air at room temperature (air-drying), and (2) the subsequent oven drying of the air-dried sample at 105°C. This method provides a more stable sample, the air-dried sample, when tests for nitrogen, pH, cation exchange, and the like are to be made.

2.3 *Methods C and D* — Ash content of a peat or organic soil sample is determined by igniting the oven-dried sample from the moisture content determination in a muffle furnace at 440°C (Method C) or 750°C (Method D). The substance remaining after ignition is the ash. The ash content is expressed as a percentage of the mass of the oven-dried sample.

2.4 Organic matter is determined by subtracting percent ash content from 100.

3. Apparatus

3.1 *Oven*, capable of being regulated to a constant temperature of 105 ± 5°C.

NOTE — The temperature of 105°C is quite critical for organic soils. The oven should be checked for "hot spots" to avoid possible ignition of the specimen.

3.2 *Muffle Furnace*, capable of producing constant temperatures of 440°C and 750°C.

3.3 *Evaporating Dishes*, of high silica or porcelain of not less than 100 mL capacity.

3.4 *Blender*, high-speed.

3.5 *Aluminum Foil*, heavy-duty.

3.6 *Porcelain Pan, Spoons*, and equipment of the like.

3.7 *Desiccator*.

4. Preparation of Sample

4.1 Place a representative field sample on a square rubber sheet, oil cloth, or equivalent material. Reduce the sample to the quantity required by quartering and place in a moisture-proof container. Work rapidly to prevent moisture loss or perform the operation in a room with a high humidity.

Moisture Content

5. Method A

5.1 Record to the nearest 0.01 g the mass of a high-silica or porcelain evaporating dish fitted with a heavy-duty aluminum foil cover. The dish shall have a capacity of not less than 100 mL.

5.2 Mix thoroughly the representative sample and place a test specimen of at least 50 g in the container described in 5.1. Crush soft lumps with a spoon or spatula. The thickness of peat in the container should not exceed 3 cm.

5.3 Cover immediately with the aluminum foil cover and record the mass to the nearest 0.01 g.

5.4 Dry uncovered for at least 16 h at 105°C or until there is no change in mass of the sample after further drying periods in excess of 1 h. Remove from the oven, cover tightly, cool in a desiccator, and record the mass.

6. Method A Calculation

6.1 Calculate the moisture content as follows:

$$\text{Moisture Content, \%} = [(A - B) \times 100]/A$$

where:

A = mass of the as-received test specimen, g, and

B = mass of the oven-dried specimen, g.

6.1.1 This calculation is used primarily for agriculture, forestry, energy, and horticultural purposes, and the result should be referred to as the moisture content as a percentage of as-received or total mass.

6.2 An alternative calculation is as follows:

$$\text{Moisture Content, \%} = [(A - B) \times 100]/B$$

where:

A = as-received test specimen, g, and

B = mass of the oven-dried specimen, g.

6.2.1 This calculation is used primarily for geotechnical purposes, and the result should be referred to as the moisture content as a percentage of oven-dried mass.

6.3 Take care to indicate the calculation method used.

7. Method B

7.1 This method should be used if pH, nitrogen content, cation exchange capacity, and the like are to be tested.

7.2 Mix the sample thoroughly and select a 100 to 300 g representative sample. Determine the mass of this sample and spread evenly on a large flat pan. Crush soft lumps with a spoon or spatula and let the sample come to moisture equilibrium with room air. This will require at least 24 h. Stir occasionally to maintain maximum air exposure of the entire sample. When the mass of the sample reaches a constant value, calculate the moisture removed during air drying as a percentage of the as-received mass.

7.3 Grind a representative portion of the air-dried sample for 1 to 2 min in a high-speed blender. Use the ground portion for moisture, ash, nitrogen, cation exchange capacity tests, and the like.

7.4 Thoroughly mix the air-dried, ground sample. Weigh to the nearest 0.01 g the equivalent of 50 g of test specimen on an as-received basis. Determine the amount, in grams, of air-dried sample equivalent to 50 g of as-received sample, as follows:

Equivalent Sample Mass, g = $50.0 \cdot [(50 \times M)/100]$

where:

M = moisture removed in air drying, %.

7.5 Place the sample in a container as described in 5.1 and proceed as in Method A.

8. Method B Calculation

8.1 Calculate the moisture content as follows:

Moisture Content, % = $(50 - B) \times 2$

where:

B = oven-dried sample, g.

8.1.1 This calculation gives moisture content as a percentage of as-received mass.

8.2 An alternative calculation is as follows:

Moisture Content, % = $[(50 - B) \times 100]/B$

8.2.1 This calculation gives moisture content as a percentage of oven-dried mass.

Ash Content

9. Method C

9.1 Determine the mass of a covered high-silica or porcelain dish.



A muffle furnace, used for organic matter analysis.

9.2 Place a part of or all of the oven-dried test specimen from a moisture determination in the dish and determine the mass of the dish and specimen.

9.3 Remove the cover and place the dish in a muffle furnace. Gradually bring the temperature in the furnace to 440°C and hold until the specimen is completely ashed (no change of mass occurs after a further period of heating).

9.4 Cover with the retained aluminum foil cover, cool in a desiccator, and determine the mass.

9.5 This method should be used for all geo-technical and general classification purposes.

10. Method D

10.1 Determine the mass of a covered high-silica or porcelain dish.

10.2 Place a part of or all of the oven-dried test specimen from a moisture determination in the dish and determine the mass of the dish and specimen.

10.3 Remove the cover and place the dish in a muffle furnace. Gradually bring the temperature in the furnace to 750°C and hold until the specimen is completely ashed (no change of mass occurs after a further period of heating).

10.4 Cover with the retained aluminum foil cover, cool in a desiccator, and determine the mass.

10.5 This method should be used when peats are being evaluated for use as a fuel.

11. Calculation for Methods C and D

11.1 Calculate the ash content as follows:

Ash Content, % = $(C \times 100)/B$

where:

C = ash, g, and

B = oven-dried test specimen, g.

Organic Matter

12. Calculation

12.1 Determine the amount of organic matter by difference, as follows:

Organic matter, % = $100.0 - D$

where:

D = ash content, %.

13. Report

13.1 Report the following information:

13.1.1 Results for organic matter and ash content, to the nearest 0.1%.

13.1.2 Furnace temperature used for ash content determinations.

13.1.3 Whether moisture contents are by proportion of as-received mass or oven-dried mass.

13.1.3.1 Express results for moisture content as a percentage of as-received mass to the nearest 0.1%.

13.1.3.2 Express results for moisture content as a percentage of oven-dried mass as follows:

(a) Below 100% to the nearest 1%.

(b) Between 100% and 500% to the nearest 5%.

(c) Between 500% and 1000% to the nearest 10%.

(d) Above 1000% to the nearest 20%.

14. Precision and Bias

14.1 The precision and bias of these test methods have not been determined. Data are being sought for use in developing a precision and bias statement.

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ASTM C-88-90

Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

ASTM C-131-89

Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM procedures C-88-90 and C-131-89 are special situation tests that rarely will be required, and have not been published here. They are available from the American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.



Standard Test Method for Particle-Size Analysis of Soils¹

This standard is issued under the fixed designation D 422; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Note 1 and Note 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-μm), or No. 200 (75-μm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-μm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 μm.

2. Referenced Documents

2.1 ASTM Standards:

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants²

E 11 Specification for Wire-Cloth Sieves for Testing Purposes³

E 100 Specification for ASTM Hydrometers⁴

3. Apparatus

3.1 **Balances**—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 **Stirring Apparatus**—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated

stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup⁵ (Note 3) conforming to the general details shown in Fig. 3 (Note 4 and Note 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft³/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 **Hydrometer**—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 **Sedimentation Cylinder**—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 **Thermometer**—A thermometer accurate to 1°F (0.5°C).

3.6 **Sieves**—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

⁵ Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Order Adjunct No. ADJD0422.

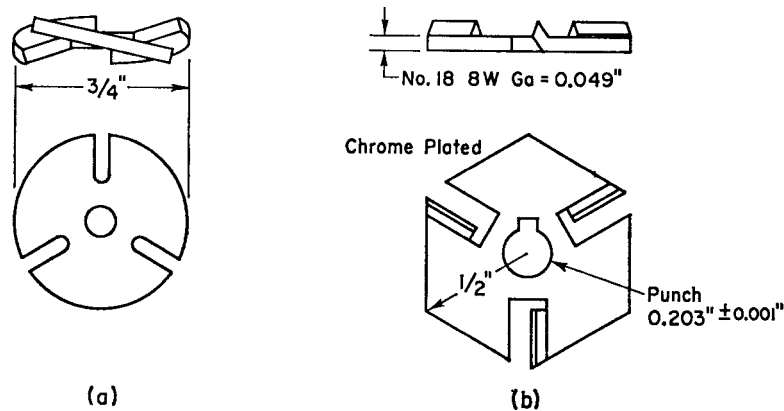
¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved Nov. 21, 1963. Originally published 1935. Replaces D 422 – 62.

² *Annual Book of ASTM Standards*, Vol 04.08.

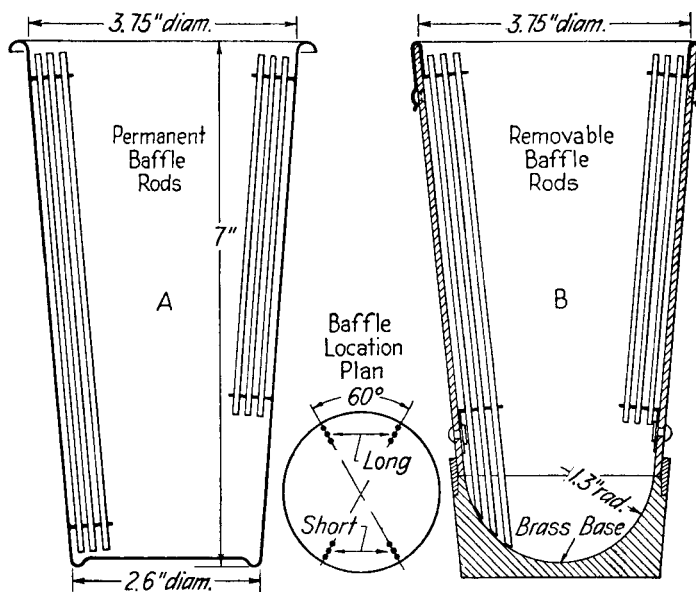
³ *Annual Book of ASTM Standards*, Vol 14.02.

⁴ *Annual Book of ASTM Standards*, Vol 14.03.



Metric Equivalents					
in.	0.001	0.049	0.203	1/2	3/4
mm	0.03	1.24	5.16	12.7	19.0

FIG. 1 Detail of Stirring Paddles



Metric Equivalents			
in.	1.3	2.6	3.75
mm	33	66	95.2

FIG. 2 Dispersion Cups of Apparatus

3-in. (75-mm)	No. 10 (2.00-μm)
2-in. (50-mm)	No. 20 (850-μm)
1½-in. (37.5-mm)	No. 40 (425-μm)
1-in. (25.0-mm)	No. 60 (250-μm)
¾-in. (19.0-mm)	No. 140 (106-μm)
⅝-in. (9.5-mm)	No. 200 (75-μm)
No. 4 (4.75-mm)	

NOTE 6—A set of sieves giving uniform spacing of points for the graph, as required in Section 17, may be used if desired. This set consists of the following sieves:

3-in. (75-mm)	No. 16 (1.18-mm)
1½-in. (37.5-mm)	No. 30 (600-μm)
¾-in. (19.0-mm)	No. 50 (300-μm)
⅝-in. (9.5-mm)	No. 100 (150-μm)
No. 4 (4.75-mm)	No. 200 (75-μm)
No. 8 (2.36-mm)	

3.7 *Water Bath or Constant-Temperature Room*—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

3.8 *Beaker*—A beaker of 250-mL capacity.

3.9 *Timing Device*—A watch or clock with a second hand.

4. Dispersing Agent

4.1 A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

NOTE 7—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

4.2 All water used shall be either distilled or demineralized water. The water for a hydrometer test shall be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure

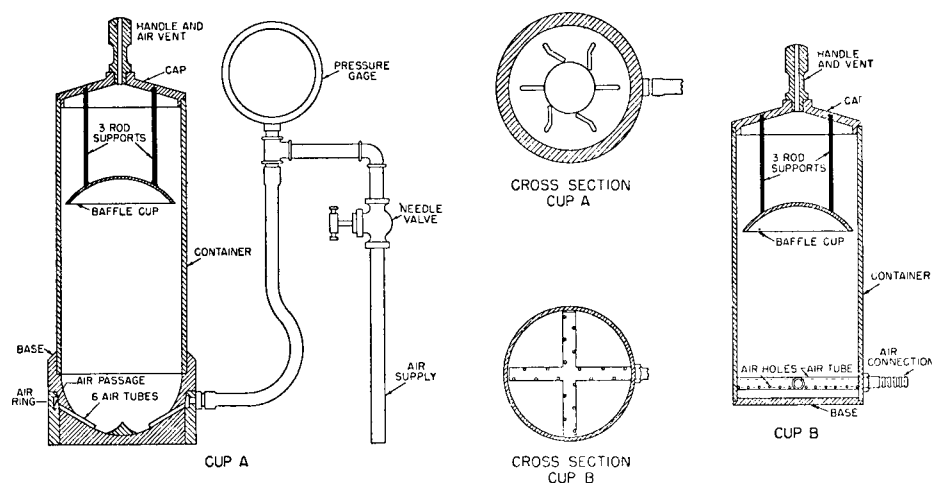
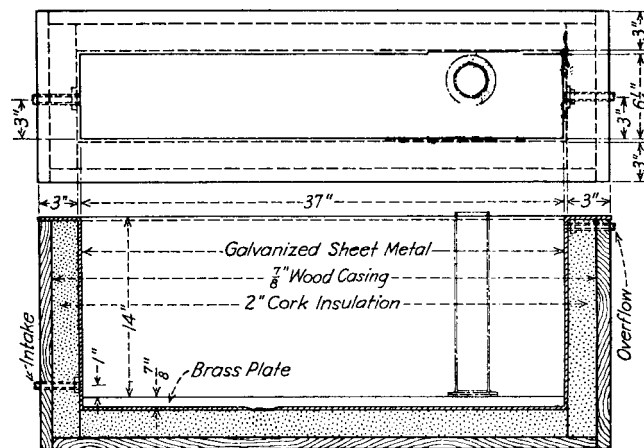


FIG. 3 Air-Jet Dispersion Cups of Apparatus B



Metric Equivalents						
in.	7/8	1	3	6 3/4	14	37
mm	22.2	25.4	76.2	158.2	356	940

FIG. 4 Insulated Water Bath

the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
3/8 (9.5)	500
3/4 (19.0)	1000
1 (25.4)	2000
1 1/2 (38.1)	3000
2 (50.8)	4000
3 (76.2)	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in Section 5 of Practice D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm), 2-in.

(50-mm), 1½-in. (37.5-mm), 1-in. (25.0-mm), ¾-in. (19.0-mm), ⅜-in. (9.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.

HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1° temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cylinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus

formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hydrometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at 230 ± 9°F (110 ± 5°C), and weigh again. Record the masses.

9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/L). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. If stirring apparatus A is used, transfer the soil-water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

NOTE 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil-water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, if necessary, so that the total volume in the cup is 250 mL, but no more.

NOTE 10—The initial air pressure of 1 psi is required to prevent the soil-water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil-water slurry to the sedimentation cylinder.

10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil-water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75- μ m) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at $230 \pm 9^\circ\text{F}$ ($110 \pm 5^\circ\text{C}$) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

CALCULATIONS AND REPORT

12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the $\frac{3}{8}$ -in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the $\frac{3}{8}$ -in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

13. Hygroscopic Moisture Correction Factor

13.1 The hygroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight W in the equation for percentage remaining in suspension.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\ 000/W) [m]P5\ G/(G - G_1)](R - G_1) \quad (1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) [m]P5\ 100 \quad (2)$$

where:

- a = correction factor to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),
- P = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,
- R = hydrometer reading with composite correction applied (Section 7),
- W = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,
- G = specific gravity of the soil particles, and
- G_1 = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for R is based on a value of one for G_1 .

15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at

TABLE 1 Values of Correction Factor, α , for Different Specific Gravities of Soil Particles^A

Specific Gravity	Correction Factor ^A
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

^AFor use in equation for percentage of soil remaining in suspension when using Hydrometer 152H.

which the hydrometer is measuring the density of the suspension. According to Stokes' law: see Table 2

$$D = \sqrt{[30n/980(G - G_1)] [m]P5 L/T} \quad (3)$$

where:

D = diameter of particle, mm,

n = coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),

L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (see Table 2)),

T = interval of time from beginning of sedimentation to the taking of the reading, min,

G = specific gravity of soil particles, and

G_1 = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE 14—Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows: see Table 3

$$D = K\sqrt{L/T} \quad (4)$$

where:

K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 3. The value of K does not change for a series of readings constituting a test, while values of L and T do vary.

15.3 Values of D may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of L is divided by T using the A - and B -scales, the square root being indicated on the D -scale. Without ascertaining the value of the square root it may be multiplied by K , using either the C - or CI -scale.

16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves

TABLE 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes^A

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L , cm	Actual Hydrometer Reading	Effective Depth, L , cm	Actual Hydrometer Reading	Effective Depth, L , cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.8	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

^AValues of effective depth are calculated from the equation:

$$L = L_1 + 1/2 [L_2 - (V_B/A)] \quad (5)$$

where:

L = effective depth, cm,

L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm,

L_2 = overall length of the hydrometer bulb, cm,

V_B = volume of hydrometer bulb, cm³, and

A = cross-sectional area of sedimentation cylinder, cm²

Values used in calculating the values in Table 2 are as follows:

For both hydrometers, 151H and 152H:

L_2 = 14.0 cm

V_B = 67.0 cm³

A = 27.8 cm²

For hydrometer 151H:

L_1 = 10.5 cm for a reading of 1.000

= 2.3 cm for a reading of 1.031

For hydrometer 152H:

L_1 = 10.5 cm for a reading of 0 g/litre

= 2.3 cm for a reading of 50 g/litre

used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10

TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature, ° C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

17. Graph

17.1 When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

(1) Gravel, passing 3-in. and retained on No. 4 sieve	 %
(2) Sand, passing No. 4 sieve and retained on No. 200 sieve	 %
(a) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve	 %
(b) Medium sand, passing No. 10 sieve and retained on No. 40 sieve	 %
(c) Fine sand, passing No. 40 sieve and retained on No. 200 sieve	 %
(3) Silt size, 0.074 to 0.005 mm	 %
(4) Clay size, smaller than 0.005 mm	 %
Colloids, smaller than 0.001 mm	 %

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains material retained on the No. 4 sieve sufficient to require a sieve analysis on that portion, the results may be reported as follows (Note 17):

SIEVE ANALYSIS

Sieve Size	Percentage Passing
3-in.	
2-in.	
1½-in.	
1-in.	
¾-in.	
⅝-in.	
No. 4 (4.75-mm)	
No. 10 (2.00-mm)	
No. 40 (425-µm)	
No. 200 (75-µm)	

HYDROMETER ANALYSIS

0.074 mm	
0.005 mm	
0.001 mm	

NOTE 17—No. 8 (2.36-mm) and No. 50 (300-µm) sieves may be substituted for No. 10 and No. 40 sieves.

19. Keywords

19.1 grain-size; hydrometer analysis; hygroscopic moisture;
particle-size; sieve analysis

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