APPENDIX G: 2004 SOURCE WATER ASSESSMENT

The 2004 Source Water Assessment Report for the City of Muskegon was prepared as a joint effort by the U.S. Geological Survey, Water Resources Division, Michigan District and the Michigan Department of Environmental Quality, Water Division (MDEQ). As of April 2019, MDEQ was reorganized and renamed the Michigan Department of Environment, Great Lakes, and Energy (EGLE).

This report details the climate, geology, and soils in an effort to determine all systems' sensitivity and susceptibility to known potential contaminates. It provides an initial delineation of the source water protection area, a susceptibility determination, and formed the foundation for this SWIPP.

The SWIPP Team has expanded source water protection area delineations based on water plant personnel observations of plumes extending over the intake during precipitation events from Muskegon Lake and the Grand River.

Source Water Assessment Report for the City of Muskegon Water Supply June 2004

The City of Muskegon Water Filtration Plant
Muskegon, Michigan

Prepared for:

City of Muskegon Water Supply; WSSN 4570

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Executive Summary

The purpose of the Source Water Assessment is to analyze the sensitivity and determine the susceptibility of a community's source of drinking water to potential sources of contamination.

Sensitivity is determined from the natural setting of the source water (raw water to the water treatment plant), and indicates natural protection afforded the source water. Using procedures established in the Great Lakes Protocol, Michigan Source Water Assessment Program, the offshore intakes for the Muskegon Water Filtration Plant have a moderate degree of sensitivity to potential contaminants. When the effects of winds, lake currents, and the influence of the Muskegon and Grand Rivers are considered, the Muskegon intakes are categorized as moderately sensitive.

Susceptibility identifies factors within the community's source water area that may pose a risk to the water supply. The susceptibility determination provides information with respect to listed facilities and land areas within the source water area that should be given greater priority and oversight in implementing a source water protection program. The source water area for the Muskegon intakes includes 1,786 potential contaminant sources, at least 3 of which discharge directly to Lake Michigan, plus urban and agricultural runoff from the Muskegon and Grand River watersheds into the Muskegon and Grand Rivers. The potential contaminant sources, in combination with the moderately sensitive intake, indicate that the Muskegon source water has moderately high susceptibility to potential contamination.

The Muskegon source water is categorized with moderately high susceptibility, given land uses and potential contaminant sources within the source water area. However, it is noted that historically, the City of Muskegon Water Filtration Plant has effectively treated this source water to meet drinking water standards. The City of Muskegon has instituted pollution prevention programs, but should be cognizant of additional potential threats to its source of drinking water that are identified in this report. This report explains the background and basis for these determinations.

Using this Assessment

Clean, safe drinking water is fundamental to the viability of any community. Protecting the drinking water **source** is a wise and relatively inexpensive investment in your community's future. The overall intent of this assessment is to provide background information for your community to use in developing a local source water protection program. The assessment benefits your community by providing the following:

- ***A basis for focusing limited resources within the community to protect the drinking water source(s).*** The assessment provides your community with information regarding activities within the **source water area** (**SWA**) that directly affect your water supply. It is within this SWA that a spill or improper use of **potential contaminants** may cause these contaminants to migrate toward the water **intake**. By examining where the source waters are most susceptible to contaminants, and where potential contaminants are located, the assessment clearly illustrates the potential risks that should be addressed.
- ***A basis for informed decision-making regarding land use within the community.***
  The assessment provides your community with a significant amount of information regarding where your drinking water comes from (the source) and what the risks are to the quality of that source. Knowing where the resource is allows your community planning authorities to make informed decisions regarding proposed land uses within the SWA that are compatible with both your drinking water resource and the vision of growth embraced by your community.
- ***A basis for dealing with future regulations.***
  The assessment has been designed to functionally meet proposed requirements for surface-water supplies. Information needed to address regulatory needs and requirements has been collected and made available to your community through this report.

This source water assessment also provides the basis for a locally developed, voluntary source water protection program. Communities interested in voluntarily developing source water protection programs should contact the Michigan Department of Environmental Quality (MDEQ) or visit the Department web page at http://www.michigan.gov/deq.

Introduction

In 1996, Congress amended the **Safe Drinking Water Act** and provided resources for state agencies to conduct source water assessments by identifying SWAs, analyzing the **sensitivity** of the source to natural conditions, conducting contaminant source inventories, and determining the **susceptibility** of the source to potential contamination. Delineations, sensitivity analyses, contaminant inventories, and susceptibility determinations comprise a "source water assessment." Assessments will be completed for every public water supply source in Michigan. To support this effort, the MDEQ Water Division established a partnership with the U.S. Geological Survey (USGS) to develop a method for conducting source water assessments for surface water supplies (Sweat and others, 2000; Sweat and others, *in press*)**.**

The requirements for public water supplies in Michigan to meet United States Environmental Protection Agency (USEPA) **maximum contaminant levels (MCLs)** provide some degree of assurance of safe drinking water; however, all systems are vulnerable to potential contamination. One of the best ways to ensure safe drinking water is to develop a local program designed to protect the source of drinking water against potential contamination. Not only does this add a margin of safety, but it also raises the awareness of consumers and/or the community of the risks of drinking water contamination. It is expected that source water assessment results will provide a basis for developing a source water protection program.

Background

The City of Muskegon is located in Muskegon County, on the eastern shore of Lake Michigan, 40 miles northwest of Grand Rapids (fig. 1). Besides serving city residents, the water supply also serves Muskegon Township, North Muskegon, Roosevelt Park and the County Northside System (City of Muskegon, 2001). The Muskegon water filtration plant (WFP) was originally constructed in 1874. The present intake riser, constructed in 1965, is a 60-inch (in) diameter steel pipe extending 5,400 feet (ft) offshore in 33 ft of water (1927 datum) (City of Muskegon, 2001; Brogren and Cook, 1989). There is one, 60-in diameter emergency intake, located 1,500 ft shoreward from the primary intake, teeing off the primary intake pipe at an estimated depth of 30 feet (1929 datum) (USGS, 1980). Subsequent emergency measures call for reliance on interconnections with other supplies, such as the cities of Muskegon Heights and Norton Shores. The intake draws water from Lake Michigan through a timber intake crib that is supported by riprap. Seven low service pumps deliver raw water from a shore-side well to the filtration plant. Total low service pumping capacity is rated at 54 million gallons per day (MGD), with a firm capacity of 44 MGD (Brogren and Cook, 1989). The City's WFP uses chlorine at the outer crib to control zebra mussels. Treatment at the plant includes coagulation, flocculation, clarification, filtration, and chlorination. Chemicals added to the water include alum (clarification), chlorine (disinfection), and fluoride (dental health), in addition to carbon and potassium permanganate to control taste and odor problems. The WFP is rated at 28 MGD and has two reservoirs on site with a total capacity of 6.2 million gallons (gal). Additionally, there is a 5 million gal reservoir off site at the Harvey Street Station and three 1 million gal elevated city storage facilities located at the corners of Nims and Forest streets, Marshall and Adams streets, and Roberts and Lawrence streets. The Muskegon WFP serves approximately 61,000 people (Robert Veneklasen, verbal commun., June 2004).

City of Muskegon Water Filtration Plant

Water treatment plants are periodically inspected to identify construction, maintenance, operational, or source defects that could make them vulnerable to contamination, particularly from contaminants that are microbial in nature, such as fecal coliforms. Water suppliers are provided a sanitary survey report that notes any deficiencies in the system, and the State may direct the system to make necessary corrections. The sanitary survey is an important part of a safe drinking water program. The most recent sanitary survey of the Muskegon WFP was completed in 1989.

Climate

The Muskegon water supply is located in the West-Central Lower Peninsula hydrologic province (Rheaume, 1991). The region experiences temperate summers with moderate winters. The Muskegon County Airport weather station reports that the long-term average annual precipitation for the period of record (1894-1999) was 32.56 inches, with about 31 percent of that as snowfall between November and March. Average annual precipitation from 1995-1999 was 28.08 inches (NOAA, 1999). Annual average runoff for the Muskegon SWA, extrapolated from Miller and Twenter (1986, fig. 1), is 12 inches to 15 inches, with higher runoff values closest to Lake Michigan.

Source Water Area Geology and Hydrology

The study area for evaluating the extent of the Muskegon WFP SWA includes portions of the Muskegon and Lower Grand River watersheds, in addition to Lake Michigan (fig. 1). The SWA consists of lakebed and outwash deposits in the northern and eastern portions of the SWA, and moraines and ground moraines in the western and southern portions of the SWA. These landforms are underlain by Coldwater Shale, Marshall Sandstone, Bayport Limestone, the Michigan and Saginaw Formations, and a few small areas of Red Beds (Martin, 1955; Milstein, 1987). Soils in the Muskegon SWA are primarily from the Owosso, Grattan, and Water complexes. They include fine sandy loams, loams, loamy sandy, sands, silty clays, muck, and combinations (U.S. Department of Agriculture, 1968,1986; BASINS, 1998).

Lake Michigan – Muskegon Source Water

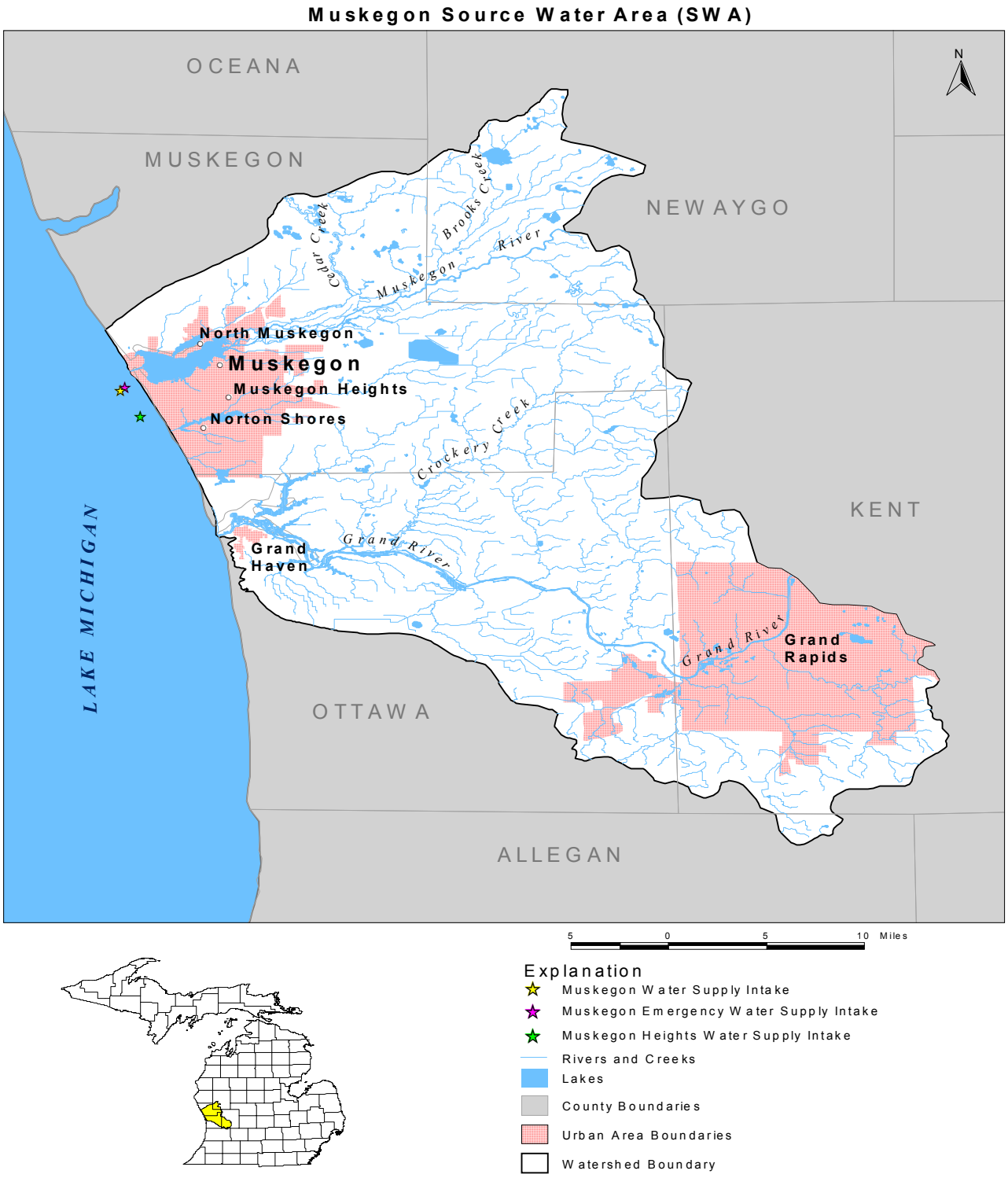


Figure 1. Source water assessment area for the Muskegon Water Filtration Plant, Muskegon, Michigan

Soil permeability is based on the calculated time of travel, in inches per hour (in/hr), for water to move vertically through a saturated soil zone. Soil thickness and permeability values are available in soil survey reports published by the National Cooperative Soil Survey and U.S. Department of Agriculture (1968, 1986). Permeability ranges from less than 0.06 in/hr, rated as very slow, to more than 20 in/hr, rated as very rapid.

Very slowly permeable soils significantly reduce the movement of water through the soil zone and, as a result, allow greater time for natural degradation of contaminants. However, such soils also provide for rapid overland transport of contaminants directly to receiving waters, which in turn may affect the water supply intake. In contrast, very rapidly permeable soils allow for rapid infiltration and passage through the soil zone from the surface. Such soils potentially allow rapid transport of contaminants with minimal contact-time available for contaminant breakdown. Erosion and transport of soils by surface waters can cause an increase in turbidity.

Mean, area-weighted, depth-integrated permeabilities for the Muskegon SWA range from 0.43 to as much as 14.59 in/hr. The mean permeability is 4.82 in/hr (Schneider and Erickson, undated, series of 5 maps; BASINS, 1998;). Soils are generally moderately to rapidly permeable throughout the SWA (fig. 2; U.S. Department of Agriculture, 1968,1986; BASINS, 1998), with some small areas of moderately slow permeability in the northern part of the SWA. Soils with rapid permeability are close to the Muskegon and Grand Rivers, and Lake Michigan (Lusch and others, 1992; BASINS, 1998).

The Muskegon SWA contains an area of about 1,066 square miles (mi^2) and is directly connected to Lake Michigan. The most significant tributaries to Lake Michigan from the SWA are the Muskegon and Grand Rivers, with drainage areas of about 2,736 mi^2 and 3,762 mi^2, respectively. Between 1901 and 2000 as many as 6 stream gages were operated in the Muskegon SWA by the USGS (Blumer and others, 2001, p. xii). Currently there are 11 gages operated in the entire Muskegon River watershed. Annual mean discharge at the Croton gaging station was 1,690 cubic feet per second (cfs) between 1996 and 1999, and ranged from 1,550 to 2,288 cfs. In the Grand River Watershed, 10 gages are currently in operation. Annual mean discharge at the Grand Rapids gaging station was 2,580 cfs between 1901 and 1999, and ranged from 1,264 to 6,314 cfs.

Under ambient conditions, currents in Lake Michigan are, typically, from the south-southwest and pass over the Muskegon WFP intakes. Water from the Muskegon River flows north from its mouth, away from the intake. Sustained winds from the northwest through northeast can cause the flow of the Muskegon River to pass over the intake, causing changes in water quality and chemistry at the intake. Moreover, the Grand River empties into Lake Michigan about 11 miles down current from the Muskegon WFP intakes. Water from the Grand River also flows north from its mouth, and due to its location south of the Muskegon WFP intake, the Grand River may influence water quality and chemistry more consistently at the intake than the Muskegon River. Sustained strong winds from the west also affect lake currents, causing increases in near shore turbidity, and possibly coliforms.

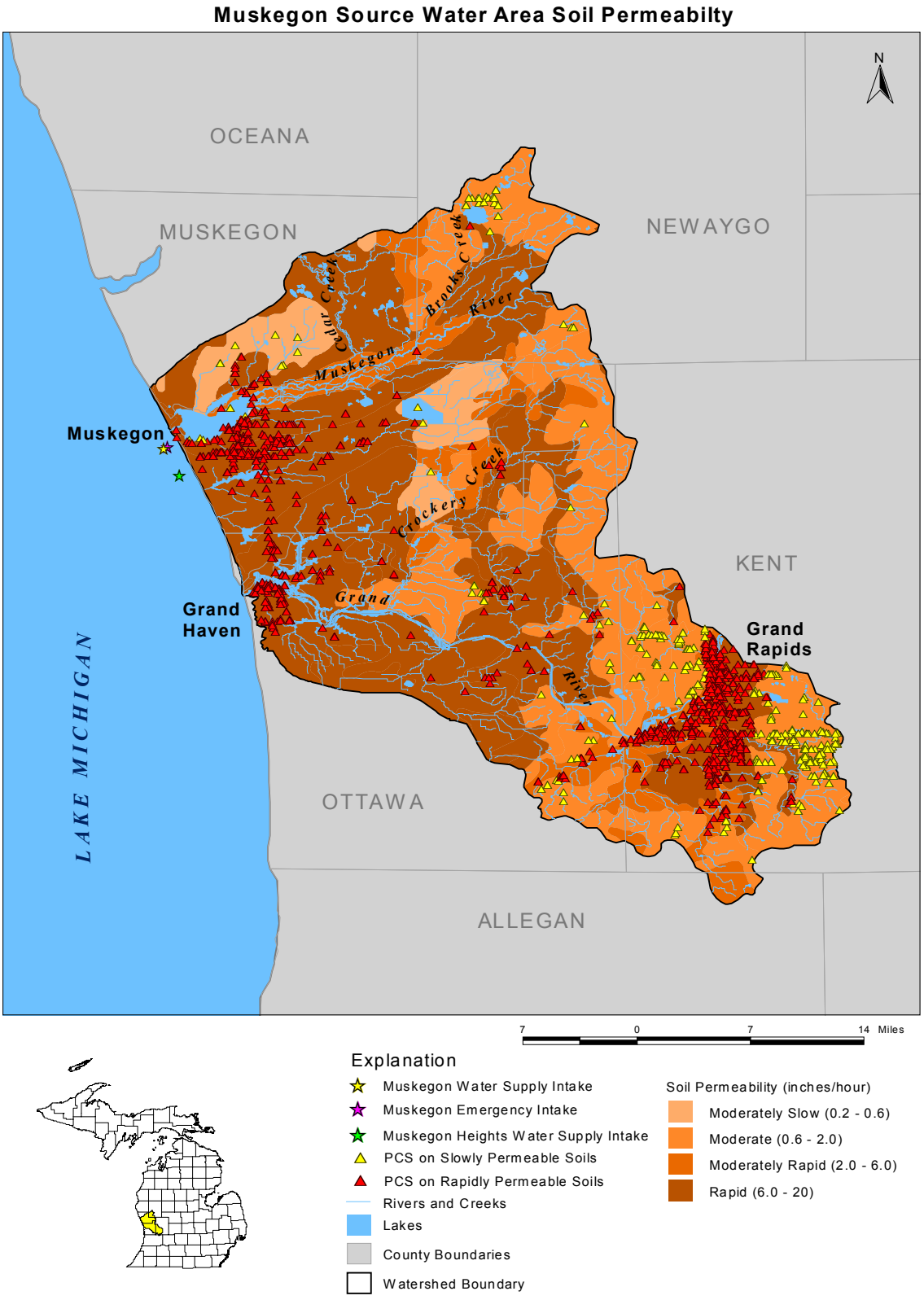


Figure 2. Source water area (SWA) permeability map for the Muskegon water supply, Muskegon, Michigan

History of Raw Water Quality at the Source

Public water supplies are required to routinely monitor raw water quality for selected parameters to optimize treatment, and to monitor treated water quality for a list of contaminants that is determined by MDEQ and the Safe Drinking Water Act. A detection of any contaminant may indicate that a pathway exists for contaminants to reach the intake. It is important to realize that the results from a given sample only provide information regarding the water quality at the time the sample was collected. Water quality can change with time for a number of reasons. The fact that a water sample does not contain contaminants is no guarantee that contamination will not occur in the future. Conversely, the detection of a contaminant in the past does not indicate that it will occur in the future.

The Muskegon WFP records show that annual water use in 1999 ranged from 6.58 to 18.63 MGD, with an average annual use of 3,740 million gallons. Water quality and meteorological conditions have been monitored since about 1894. An analysis of wind direction, water and air temperature, precipitation, discharge from the Muskegon and Grand rivers, and source water chemistry, indicates that there may be an indirect correlation between wind direction and turbidity, and perhaps wind direction and total coliform bacteria. Regression analysis of these data indicated that when the wind is from the north-northwest through north-northeast (330-30°) for more than 24 to 36 hours, there is a quantifiable increase in turbidity of the source water after 3 to 4 days, and possibly an increase in total coliforms after 2 to 3 days. This occurs because these sustained winds alter, and locally may reverse, the circulation pattern in the Lake near the intake, which may cause water from the Muskegon River to pass over the intake. This increase in turbidity and total coliforms requires modifications to the treatment process.

Similarly, data indicate that sustained winds from the southwest (200-225°) can cause in increase in turbidity. These changes are most likely associated with changes to circulation patterns in Lake Michigan, which can cause sediments near the intake to be suspended in the water column due to wave action. While not regulated, esthetic parameters such as taste and odors associated with algae blooms are also a source water concern for the Muskegon WFP. Additionally, southwest winds may also increase the concentration of water from the Grand River that passes over the intake.

Thermal inversions in Lake Michigan can also cause treatment problems for the plant. Thermal inversions are typically associated with heating of the surface of the lake in spring, and cooling of the surface of the lake in the fall or early winter. Both events cause density differences in the lake that cause the water to turnover and mix, often stirring up bottom sediments and detritus. These materials enter the WFP through the intake and may cause treatment difficulties. In addition, rapidly fluctuating lake temperatures can upset the treatment process at the WFP.

The Muskegon WFP periodically tested both raw and treated water for the presence of total coliform bacteria before 1992. In 1992, the WFP began applying chlorine at the intake to control zebra mussels. Treated water continues to be tested for the presence of fecal coliform bacteria, with the results indicating that fecal coliform bacteria are not present in the treated water.

Source Water Assessment Methodology

Technical guidelines for completing source water assessments are contained in the Michigan **Source Water Assessment Program**, Assessment Protocol for Great Lakes Sources (Protocol) (MDEQ, 1999, Appendix L) available at http://www.deq.state.mi.us/dwr. In general, an assessment is a process for evaluating a drinking water supply and the potential for its treated water to exceed an MCL due to raw water contamination. A source water assessment considers the SWA, potential sources of contamination within the SWA, conditions of the water supply intake, and susceptibility to contaminants in order to identify potential risks to drinking water quality. Although the Protocol provides the minimum requirements and instructions on how to conduct an assessment, each water supply is unique with respect to how the process is carried out, due to local conditions and information. Sweat and others (2000, *in press*) have developed and documented the methodology used in the preparation of this assessment.

Delineating Source Water Areas

Delineation of the SWA is accomplished by using **geographic information system** (GIS) software to map the watershed(s) that have the potential to affect source water at the intake. Using information from the water supply, a **critical assessment zone** (CAZ) is defined for the intake (MDEQ, 1999, Appendix L). A buffer is then created along any shoreline intersected by the CAZ, and from the edge of the CAZ to the mouth of any river(s) that might influence the intake. Finally, the buffer is extended along the shoreline of any river(s) that might influence the intake, from the mouth of the river to its headwaters. The area defined by the CAZ, river and shoreline buffers is termed the **susceptible area.** The susceptible area within the SWA defines locations where a water supply should focus its management strategies and resources to benefit the drinking water resources. When the CAZ does not intersect the shoreline, no additional buffer zones are determined and the CAZ becomes the susceptible area.

Using the Great Lakes Protocol and the Muskegon water supply information:

- The CAZ for the Muskegon intake is calculated as:

  5,400 (the distance of the intake from the shore in ft.) x 33 (the depth of the intake in ft.) = 178,200 (unitless)
  This results in rating the intake as moderately sensitive, with a CAZ of 1,000 ft (MDEQ, 1999, Appendix L; fig. 3).
- The CAZ for the emergency intake for the Muskegon intake is calculated as:

  3,900 (the distance of the intake from the shore in ft.) x 30 (the depth of the intake in ft.) =117,000 (unitless)
  This results in rating the emergency intake as moderately sensitive, with a CAZ of 2,000 ft (MDEQ, 1999, Appendix L; fig. 3).
- Since the CAZ does not intersect the shoreline, no other susceptible area is defined.

Contaminant Source Inventory

Past, current, and potential future sources of contaminants are inventoried to identify several categories of potential sources of contaminants including microorganisms (bacteria, oocysts, and viruses), inorganic compounds (nitrates and metals), organic compounds (solvents, petroleum compounds, pesticides), and disinfection by-product precursors (trihalomethanes, haloacetic acids).

It is important to remember that sites and areas identified by this process are only **potential contaminant sources** (PCS) to the drinking water. Environmental contamination is not likely to occur when potential contaminants are used and managed properly. In addition, assumptions were made about particular types of land uses and risks associated with those land uses. Assumptions are discussed further in the results portion of this report.

The process for completing the inventory includes several steps, which are summarized as follows:

1. Reviewed readily available land use maps and historical/current aerial photographs.
2. Plotted relevant information from applicable state and federal regulatory databases including the following lists:
   - MDEQ leaking underground storage tank (LUST) sites;
   - MDEQ registered underground storage tank (UST) sites;
   - MDEQ Environmental Cleanup Site Information System (ECSI) sites;

Muskegon WFP Backwash Drain to Lake Michigan

- MDEQ Source Information System (for water discharge permit sites including National Pollutant Discharge Elimination System (NPDES) permits, Water Pollution Control Facility (WPCF) permits, storm water discharge permits, and on-site sewage (septic) system permits);
- MDEQ Underground Injection Control (UIC) database;
- MDEQ Active Solid Waste Disposal Permits list;
- Michigan Department of Transportation (MDOT) - Hazardous Materials database;
- State Fire Marshall registry of above-ground fuel storage tank sites;
- State Fire Marshall Hazardous Material Handlers and Hazardous Material Incidents (HAZMAT) sites;
  U.S. EPA BASINS software, version 2.01.
- U.S. EPA Envirofacts database;
- U.S. EPA Resource Conservation Recovery Act (RCRA) generators or notifiers list;
- U.S. EPA RCRA Treatment, Storage, and Disposal Facility (TSDF) Permits list;
- U.S. EPA National Priorities List (NPL);
- U.S. EPA Comprehensive Environmental Response, Compensation and Liability Information System (CERCLA) List;
- U.S. EPA RCRA Corrective Action Activity List (CORRACTS);
- U.S. Department of Transportation (DOT) Hazardous Materials Information Reporting System (HMIRS);
- U.S. EPA Oil Pollution Act of 1990 Spill Response Atlas; and
- U.S. EPA Toxic Chemical Release Inventory System (TRIS).

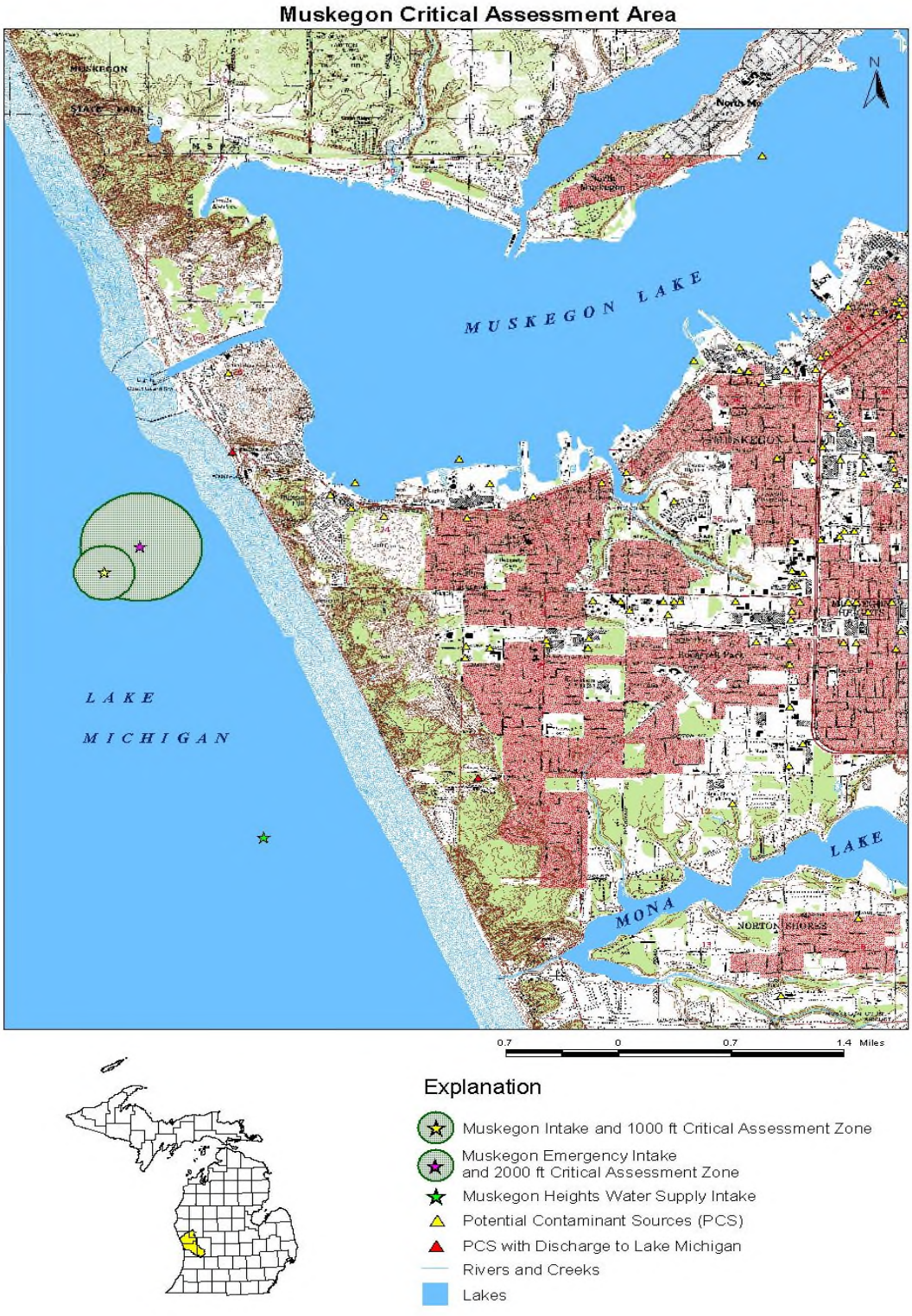


Figure 3. Critical Assessment Zone for the Muskegon water supply, Muskegon, Michigan.

3. Met with public water supply and community officials on May 23, 2001 to identify potential sources not listed elsewhere in databases or on maps and completed a preliminary inventory form to be used in completing the SWA base map. Subsequent contacts by email and telephone on numerous occasions to request additional data, clarify data, and discuss results.
4. Land use and/or ownership (for example, residential/municipal; commercial/industrial; agricultural/forest; and other land uses) was mapped and evaluated in relation to PCS, soil characteristics, and proximity to the intake
5. Conducted an informal field inventory to locate additional PCS.
6. Completed final inventory form of PCS and plotted locations of PCS on the base map.

The purpose of the inventory is three fold: first, to provide information about the location of PCS, especially those within the susceptible area; second, to provide an effective means of educating the public about PCS; and third, to provide a reliable basis for developing a management plan to reduce potential contaminant risks to the Muskegon water supply.

The inventory process attempts to identify potential point-source contaminants within the SWA. It does not include an attempt to identify specific potential contamination problems at specific sites, such as facilities that do not safely store potentially hazardous materials. However, assumptions were made about particular types of land use. For example, it is assumed that rural residences associated with farming operations have specific potential contamination sources such as fuel storage, chemical storage and mixing areas, and machinery repair shops. It should also be noted that although the inventory depicts existing agricultural uses (crops grown), these are likely to undergo continual change due to normal crop rotation practices. What is irrigated farmland now may be non-irrigated farmland next year, or vice versa.

The results of the inventory are analyzed in terms of current, past, and future land uses and their relationship to the susceptible area and the supply intake. In general, land uses and PCS that are closest to the supply intake pose the greatest threat to a safe drinking water supply. Inventory results are summarized in tables 1and 2 and are shown on figure 4.

Table 1. Potential contaminant sources in the source water area

Type of potential contaminant source	Number of potential contaminant sources	Number of potential contaminant sources with permitted discharges to Lake Michigan
Hazardous or Solid Waste Site	1383	0
Industrial Facilities Discharge Site	97	0
National Priority List Sites	18	0
Permit Compliance System	84	3
Toxic Release Inventory	204	0

Table 2. Potential Contaminant Source Inventory results

Site Name	ID Number	Reason for Permit	Reason for Listing as Potential Contaminant Source
MUSKEGON HEIGHTS WFP	MI0005096	Waste Water, Dust, and Process Water	Permit Compliance System
MUSKEGON WFP	MI0005371		
NORTHWEST OTTAWA CO-WTP II	MI0053198		

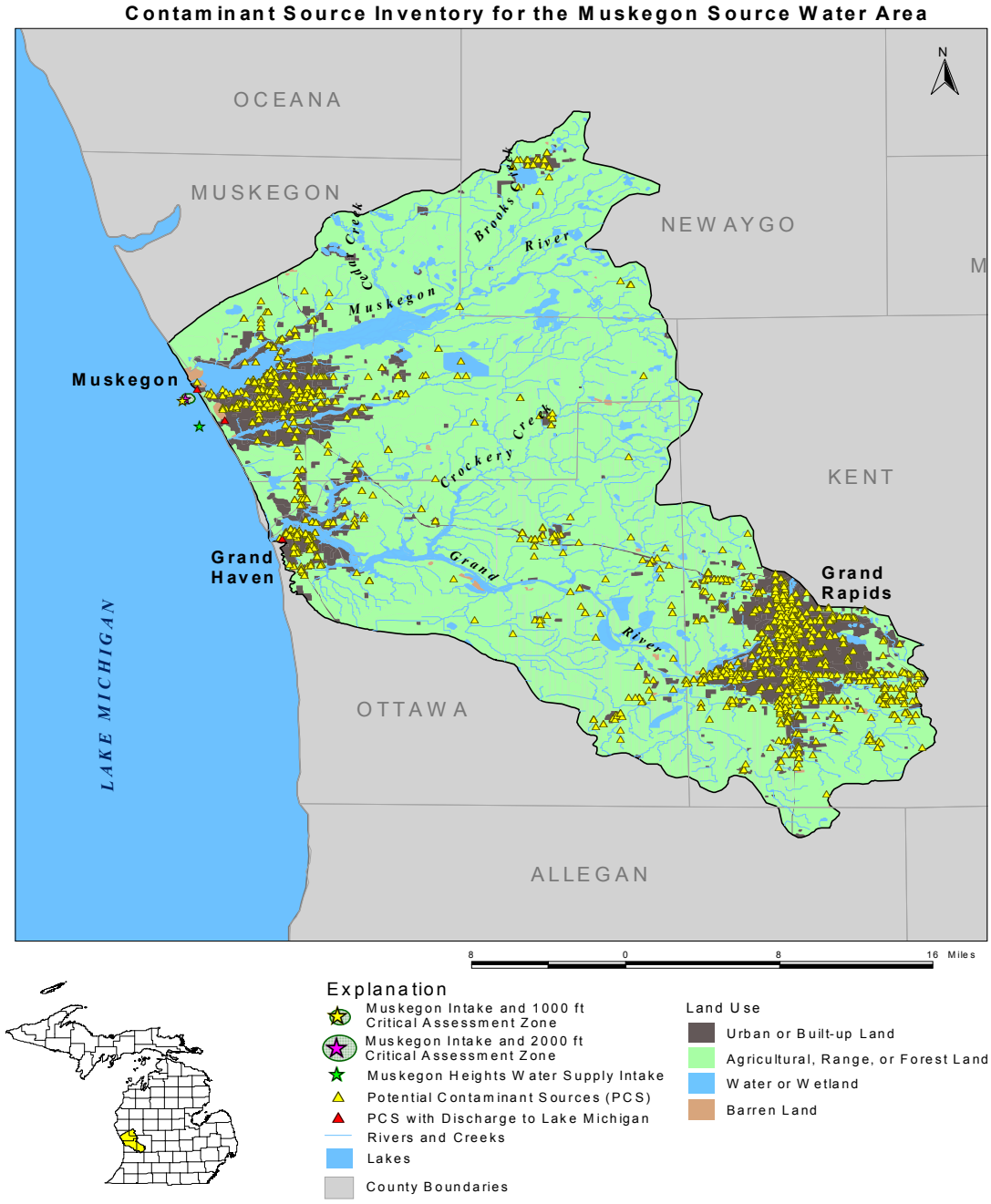


Figure 4. Contaminant Source Inventory and land use for the Muskegon water supply, Muskegon, Michigan

Many PCS are readily identifiable because they have a single discharge point, and often a permit is required for these discharges. Dredging in Muskegon Lake is also a point source concern for the Muskegon SWA. Dredging activities could potentially release contaminated sediments into the water column and could have an adverse affect on water quality. In general, Muskegon Lake acts as a sink for contaminants in water from the Muskegon River. With a residence time of about 28 days (personal commun, R. Veneklasen, May 23, 2001), most suspended contaminants settle out in the lake and only dissolved contaminants are transported to Lake Michigan. Similarly, Spring Lake acts as a sink for contaminants in the Grand River.

Other PCS have diffused, poorly defined discharge locations. These are known as non-point discharges because they occur over large areas and may not be quantifiable by readily accepted methods. These non-point source discharges are difficult to identify and control, and consequently to quantify, yet they are a major source of water pollution (Carpenter and others, 1998). Non-point sources also include atmospheric deposition over water and land, and include urban, rural, and agricultural runoff from areas such as lawns, golf courses, farm fields, pastures, parking lots, and roadways. Runoff from these areas can contain many types of pollutants including sediments, metals, organic and inorganic chemicals, viral and bacterial pathogens, pharmaceuticals, and animal wastes.

Transportation also represents a non-point source of contamination. Trucking, railroads, and shipping all transport potential contaminants through the SWA. An accident causing a spill could lead to potential contaminants entering a storm sewer, or in the case of shipping, directly discharge to Lake Michigan, possibly near the water intake. Non-point sources of concern to the Muskegon water supply are primarily from agriculture and livestock in the Muskegon SWA, and from industrial, commercial, and residential sources in Muskegon and surrounding communities, and from the transport of fuel, coal, salt, and cement on Lake Michigan.

The Michigan Department of Agriculture has identified at least 5 concentrated animal feedlots (greater than 1000 animal units) in the Muskegon and Grand River watersheds. In addition, at least one animal feedlot operation has a documented discharge to the watershed.

The U.S. Environmental Protection Agency (USEPA) has identified 15 **impaired water bodies** in the Muskegon River watershed on its Clean Water Act 303(d) list. The parameters of concern listed for the river and its tributaries are mercury, polychlorinated biphenyl's (PCBs), polycyclic aromatic hydrocarbons (PAH), BIS-2-Chloroethyl ether, tetrachloroethylene, triethylene glycol dichloride, threatened and poor macro-invertebrate communities, nuisance plant growths, nutrient overloading, algae, pathogens and poor rated fish communities. In the Lower Grand River watershed, 22 **impaired water bodies** have been identified. The parameters of concern for the Lower Grand River watershed and its tributaries are mercury, polychlorinated biphenyl's (PCBs), threatened and poor macro-invertebrate communities, nutrient overloading, algae, pathogens, bacterial slimes, and poor rated fish communities (MDEQ, 2001).

In addition, the Muskegon River has been identified as a minor contributor of *trans*-Nonachlor loading to Lake Michigan, while the Grand River is listed as a major contributor of *trans*-Nonachlor (USEPA, 2001). The Grand River is a significant contributor of mercury to Lake Michigan, and the Muskegon River contributes minor amounts of mercury. Both the Muskegon and Grand Rivers were identified as minor contributors of PCBs. Results for atrazine have not yet been released.

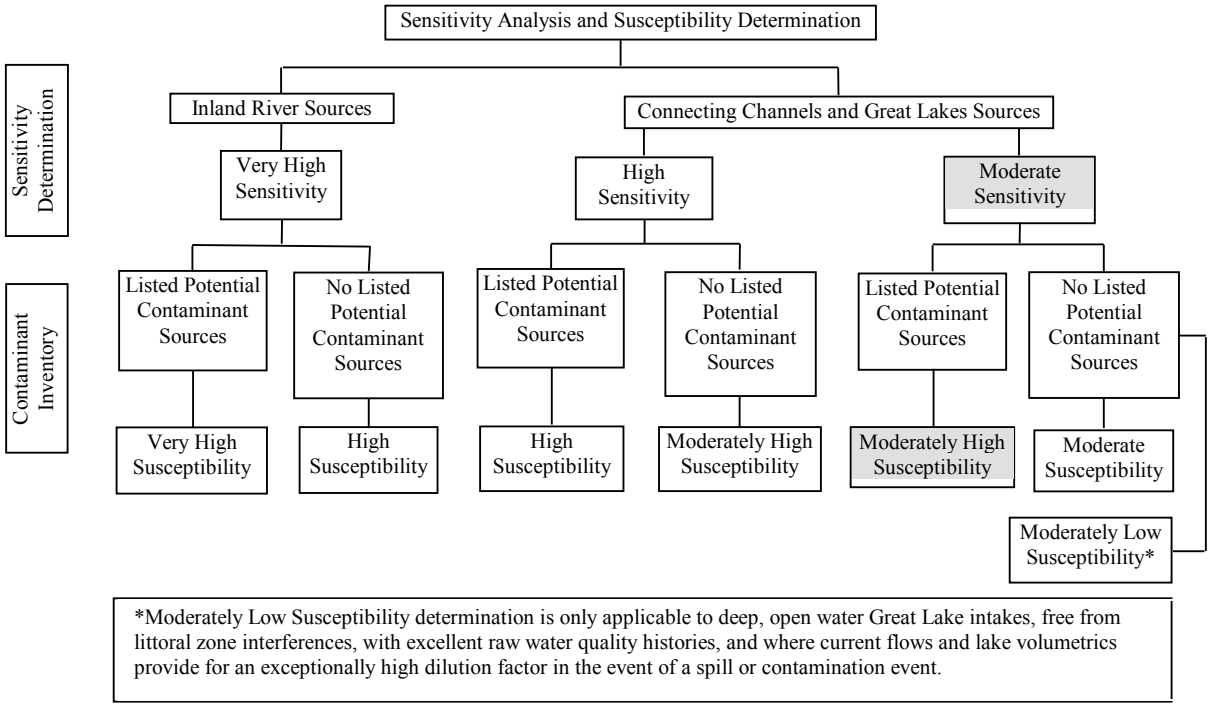
In general, PCS within the susceptible area pose greater risks than those outside the susceptible area. The presence of PCS within the SWA indicates potential sources of chemicals that could, if improperly managed or released, affect the water quality at the intake. A small quantity of these chemicals, in some cases a gallon or less, can significantly affect the supply. Also of concern is the location and distribution of these sources with respect to highly permeable soils. Overlaying the PCS locations and the soil permeability map for the Muskegon SWA indicates that more than 1,350 of the located PCS are located on or very near to areas with moderate to rapidly permeable soils (fig. 2). The SWA consists of primarily agricultural, forested, and urban land (fig. 4). The results of the PCS inventory performed for the Muskegon water supply are shown on figure 4 and are summarized as a function of PCS locations within the SWA relative to land use. Inventory results indicate that there are 1786 PCS within the SWA, at least of 3 of which discharge directly to Lake Michigan (tables 1, 2).

Sensitivity Analysis

Sensitivity is the natural ability of a SWA to provide protection against the contamination of the water supply intake, and includes physical attributes of lakes, rivers, and soils. The sensitivity analysis requires consideration of several different variables related to the natural environment, for example:

- Water quality history of the source.
- Distribution of moderately to highly permeable soils.
- Amount of available water from precipitation or runoff.
- Potential for runoff to affect the intake.
- Nature of the intake, including: depth, distance from shore, age, and materials used.
- Surface water flow patterns in vicinity of intake.

To perform this analysis, USGS, MDEQ, and the operator of the Muskegon WFP collected, researched, and analyzed information from the WTP, monthly operator reports, sanitary surveys, soil maps, published reports, and historical plant operation and raw water quality data. The Michigan SWAP has three categories of sensitivity for surface water sources ranging from moderately sensitive to very highly sensitive. Analysis of this information, using guidelines provided in Brogren and Cook (1999) and Sweat and others (2000, *in press*), indicates that the Muskegon intake is moderately sensitive (fig. 5). This means that the natural environment offers some limited protection against contamination of the water supply intake.



*Moderately Low Susceptibility determination is only applicable to deep, open water Great Lake intakes, free from littoral zone interferences, with excellent raw water quality histories, and where current flows and lake volumetrics provide for an exceptionally high dilution factor in the event of a spill or contamination event.

Susceptibility Determination

Susceptibility is the relative potential for contamination to reach the public water supply intake used for drinking water purposes. Whereas the sensitivity of a water supply is the natural ability of the area to protect the intake against contamination, the susceptibility determination also takes into account other factors that will affect whether a contaminant reaches the intake. Whether or not a particular drinking water source becomes contaminated depends on three factors:

(1) The distribution of PCS;
(2) The source water area; and
(3) The natural protection, or sensitivity, of the source.

In conducting a susceptibility determination, the part of the SWA that yields water to the water supply-system intake is identified by establishment of the susceptible area within the source water area. PCS within the susceptible area are then located. Based on the distribution of PCS within the susceptible area, the type of PCS, and the nature of the chemicals they use or store, PCS are analyzed for the risk they may represent to the water supply intake. Along with the presence and distribution of PCS, the sensitivity analysis is then used to determine the susceptibility of the water supply (fig. 5). This leads to a determination of whether the drinking water source is moderately susceptible, highly susceptible, or very highly susceptible to contamination (Sweat and others, *in press*). It is important to understand that a system can have low sensitivity relative to some conditions (for example, intake construction and location), and high susceptibility because of other conditions (for example, the type of PCS). In Michigan, surface water sources of drinking water range from moderately low to very-high susceptibility.

When a public water supply is determined to have a moderate, high, or very high susceptibility because of a particular condition or set of conditions, there is a significant risk of contamination of the drinking water source because of that condition or set of conditions. Although the susceptibility determination does not predict when or if contamination will actually occur, it does recognize conditions that are highly favorable for contamination of the supply. In the event of a contaminant release to soils or surface water within the susceptible area, it is very likely that contamination at the intake would occur without completion of remedial actions.

If a public water supply's drinking water source is determined to be highly susceptible, it is recommended that the system identify the condition(s) that lead to the high susceptibility. Immediate steps should be taken to

protect the source, and action should be considered to remedy the condition (for example, repairing or replacing faulty intake construction, working directly with facility operators to implement sound management practices, etc.).

All water supplies, regardless of their susceptibility, should consider identified factors that could lead to higher susceptibility in the future, and should prepare a strategy to protect the water supply source. Raising public awareness through signs and other education programs, encouraging proper intake construction and the use of best management practices in existing facilities are good ways of ensuring that a surface water source maintains its moderate susceptibility rating. The Muskegon WFP primary and emergency intakes are located far enough from shore and in deep enough water that their CAZs are 1,000 and 2,000 ft., respectively. Neither CAZ intersects the shoreline, so a susceptible area was not determined for the Muskegon WFP (figs. 3, 4); the Muskegon WFP intake has moderately high susceptibility (fig. 5).

Summary and Recommendations

The actual susceptibility of the drinking water source of a water supply depends on a number of contributing factors, some of which are only slightly related. Sensitivity is determined from the natural setting of the source and identifies the natural protection afforded to the source water. Susceptibility is determined by identifying those factors within the community's SWA that may pose a risk to the source water. The susceptibility determination provides information with respect to facilities within the SWA or land areas within the SWA that should be given greater priority and oversight in the implementation of a drinking water protection program.

Sensitivity Analysis: Based on criteria adopted in the Great Lakes Protocol of the Michigan Source Water Assessment Program, the offshore intake for the Muskegon Water Filtration Plant has a moderate degree of sensitivity to potential contaminants. When considering off shore winds and the influence of the Muskegon and Grand Rivers, the Muskegon intake is categorized as moderately sensitive.

Susceptibility Determination: The SWA for the Muskegon intake includes 1,786 listed potential contaminant sources, plus agricultural, urban, and industrial runoff from the Muskegon SWA. However, the intakes are far enough from shore that a susceptible area was not determined. The moderately sensitive intake for the Muskegon WFP has source water categorized with moderately high susceptibility (fig. 5).

Effective Treatment: While it has been determined the Muskegon source water has moderately high susceptiblity to potential contamination, it is also noted the City of Muskegon Water Filtration Plant has, historically, effectively treated this source water to meet drinking water standards with minimal complaints from the public. This assessment provides the City with a basis to institute a source water protection program as another tool to assure the continued safety of its water supply.

The results of this assessment and the recommendations based on these results are summarized as follows:

- ***Intake -*** The Muskegon Water Supply was originally constructed in 1874. The current intake was installed in 1965, 5,400 ft from shore, in 33 ft of water, making it a moderately sensitive intake.
- ***Emergency Intake*** –The emergency intake tees off the primary intake pipe at a distance of 3,900 feet offshore, at an estimated depth of 30 ft of water, making the emergency intake moderately sensitive.
- ***Soils*** – Using a mean, area-weighted, depth-integrated permeability estimation, the soil and subsoil material in the SWA range from 0.43 in/hr to as much as 14.59 in/hr. The mean permeability is 4.82 in/hr (Schneider and Erickson, undated, series of 5 maps; BASINS, 1998). Over half of the soils in the Muskegon SWA are highly permeable. More than 1,350 PCS are located on these soils. These factors combine to make the SWA, and thus the intake, moderately sensitive. The community should take steps to evaluate current and future land use in areas of highly permeable soils, particularly those occurring within the susceptible area. Those PCS that have been identified either on or in close proximity to these soils should be informed of the sensitive nature of the area and encouraged to adopt best management practices designed to minimize the risk of a ground release. Residential areas that have been developed on these soils should be targeted for educational programs identifying steps that residents can take to protect the water supply.
- **Historical Contaminant Detections -** There have been no detections of synthetic or volatile organic contaminants in the systems raw water. Inorganic contaminants are typically at lake background levels. Nitrate concentrations are routinely below the detection limit. Positive coliform bacteria detections have occurred often associated with snowmelt, spring runoff, and discharge from the Muskegon and Grand Rivers above median flow. The periodic presence of coliform bacteria is indicative of a relationship between runoff and soil conditions, causing the occasional presence of bacteria at detectable levels in the source water. These factors indicate that the SWA, and thus the intake, is moderately susceptible.
- ***Sanitary Survey -*** The most recent sanitary survey (Brogren and Cook, 1989) revealed only minor defects. Those requiring repair either have been corrected or are scheduled for repair. It is important that the water supply continue to follow good management practices.
- ***Potential Contaminant Sources -*** A review of the PCS inventory and the moderately and highly permeable soil distribution indicates that the Muskegon SWA has more than 1,350 PCS located on highly permeable soils. However, Lake Muskegon provides a significant buffer between the Muskegon River and Lake Michigan, acting as a settling basin for many contaminants transported in the river; Spring Lake likewise provides a buffer between the Grand River and Lake Michigan. It is recommended that the community focus initially on PCS that are located on rapidly permeable soils and nearest any water bodies, as they pose the greatest potential threat to the water supply. These facilities should be made aware of free technical assistance that is available through MDEQ's pollution prevention programs. Through chemical inventory, waste reduction, and by increasing awareness of best management practices, the risk these facilities pose to source waters can be reduced. The PCS inventory indicates that the source has moderately high susceptibility.
- ***Source Water Assessment -*** The Muskegon source water assessment moderately high susceptibility determination is based on these site-specific parameters:
    1. Definition of a Critical Assessment Zone around both primary and emergency intakes for a source with moderate sensitivity;
    2. Definition of a SWA for the Muskegon and Grand river watersheds and the shoreline near the intake;
    3. Wind and current patterns in Lake Michigan near the Muskegon WFP intakes and their effects on source water quality; and
    4. Listed and nonlisted potential contaminant sources.
- ***Source Water Protection*** – The City has initiated source water protection activities with an Industrial Pretreatment Program incorporating management plans, chemical containment, and spill response, spill response training, and quarterly street cleaning. The Muskegon WFP and/or the community should assemble a team to assist in the development and implementation of a source water protection program that uses this assessment to further protect the Muskegon source water area.

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GLOSSARY

Critical Assessment Zone (CAZ) – the area from the intake structure to the shoreline and inland, including a triangular water surface and a land area encompassed by an arc from the endpoint of the shoreline distance on either side of the on shore intake pipe location

Geographic Information System (GIS) – a system to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information

Impaired water bodies - As listed by the State of Michigan and defined by Clean water Act section 303(d).

Intake – the point at which source (raw) water is drawn into a pipe to be delivered to a water treatment plant

Lignins – an amorphous, cellulose-like, organic substance that acts as a binder for the cellulose fibers in wood and adds strength and stiffness to cell walls

Maximum Contaminant Level (MCL) – the maximum permissible level of a contaminant in water that is delivered to any user of a public water system

Potential Contaminant Sources (PCS) – listed and non-listed agricultural sites, businesses, and industries that have the potential to cause contaminants to be introduced into source water

Sensitivity – a measure of the physical attributes of the source area and how readily they protect the intake from contaminants

Source – the water body from which a water supplier gets its water

Source Water Area (SWA) – the land and water area upstream of an intake that has the potential to directly influence the quality of the water at the intake

Source Water Assessment Program (SWAP)– in Michigan, the process defined by the state Department of Environmental Quality to complete assessments of all the state's public water supplies

Susceptibility – the Susceptibility identifies factors that may pose a risk within the community's source water area

Susceptible Area – the area defined by the critical assessment zone and a buffer on either side of any drainages that contribute water to an intake

Synthetic Organic Contaminants (SOC) – Manmade organic chemical compounds such as pesticides, etc.

Tannins – naturally occurring phenolic compounds that precipitate proteins, alkaloids, and glucosides from solution that has a yellowish appearance

Volatile Organic Contaminants (VOC) – Unnatural, volatile organic chemical compounds such as gasoline components, solvents, degreasers, etc.