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TECHNICAL MEMORANDUM CH2MHILL

Water Quality
Water Treatment Facilities and Water Resources Master Plan

TO: City of Ann Arbor

FROM: CH2M HILL

DATE: May 2006

1 Executive Summary

The water quality task looked at water quality and monitoring practices in the Huron River and groundwater. The objectives of the water quality task are to:

- Make recommendations for dealing with sulfate and 1,4-dioxane in groundwater
- Make recommendations for monitoring and improving water quality in Barton Pond and groundwater

1.1 1,4-Dioxane

1,4-Dioxane is a potential human carcinogen and has been found in some Ann Arbor groundwater aquifers in the City of Ann Arbor. One of the aquifers where 1,4-dioxane has been detected contains one of the City's drinking water supply wells. 1,4-Dioxane has been measured at low levels in the City's well. Subsequent to detection, this well has been taken out of service.

A review of treatment technologies for removal of 1,4-dioxane from water indicated that a combination of ultraviolet (UV) light and hydrogen peroxide may be effective. Removal of 1,4-dioxane at the water plant with existing treatment processes was also reviewed. Based on published literature, it was not anticipated that the existing treatment processes would achieve a high degree of 1,4-dioxane removal. Bench scale tests using Ann Arbor raw water spiked with 1,4-dioxane indicated that only moderate removal (about 40 to 70 percent) could be achieved through all the current water treatment processes. To achieve a high degree of removal (90 to 99 percent), additional processes, such as UV light and hydrogen peroxide, would be needed. Adding these processes to the water treatment plan would be costly (order of magnitude construction cost estimates around $30 million).

This study demonstrates that it would be more cost effective to obtain drinking water sources that do not require 1,4-dioxane treatment, and prevent 1,4-dioxane from entering drinking water sources—as opposed to treating for its removal.

1.2 Sulfate

Elevated concentrations of sulfate and hardness occur in one of Ann Arbor's water supply wells. Sulfate is not regulated as a primary contaminant (human health concern), but can have a laxative effect when ingested. This study evaluated the following four alternatives to address high sulfate concentrations found in the one supply well:

- Dilution with other groundwater and river water
- Treatment at the well to remove sulfate
- Modification of the existing well construction to reduce sulfate levels
- Installation of a new well in a lower sulfate area

Installing a new well in a lower sulfate area is the lowest cost alternative and has the best chance of success. The existing high sulfate well should be abandoned. An investigation of aquifer characteristics and sources of sulfate is also recommended.

1.3 Source Water Quality

1.3.1 Barton Pond

Ann Arbor obtains about 80–90 percent of its water supply from the Huron River at Barton Pond. The following recommendations are made to protect water quality in Barton Pond:

- The City of Ann Arbor should take an active role in watershed management. Areas of the Huron River watershed tributary to Barton Pond will face increased development pressure over the next 25 years. To counteract the influence development will have on the watershed, especially as it relates to water quality, properly designed, constructed, and maintained Best Management Practices (BMPs) will be needed during and after construction activities. It is recommended that the City of Ann Arbor take an active role in watershed management through the Huron River Watershed Council and be an advocate for stormwater inspection and maintenance enforcement throughout the watershed, particularly within Washtenaw County.

- The City of Ann Arbor should advocate phosphorus management practices to protect Barton Pond from developing nuisance algal conditions. Methods of control may include a stormwater ordinance that limits the amount of phosphorus discharged from new development, redevelopment, and agricultural land; a public education program to provide additional benefits that may not be provided in a stormwater ordinance; inspection and maintenance of existing stormwater quality BMPs; and research of methods to prevent the development of anaerobic conditions at the bottom of Barton Pond.

- The City of Ann Arbor should investigate invasive species control techniques further for the management of Eurasian water milfoil (EWM). The two most practical applications in Barton Pond are reservoir management alternatives to kill EWM and biological control with milfoil weevils that eat EWM. These two alternatives may provide significant reduction of EWM without sacrificing raw water quality and help in the long-term management of Barton Pond infrastructure. Continue to track invasive species sampling and reporting programs conducted by MDNR, and re-evaluate monitoring efforts for Barton Pond if the invasive species distribution changes from the current zebra mussel and EWM populations.

- The City of Ann Arbor should continue zebra mussel control. Zebra mussels are present in Barton Pond. The mussels filter out small particles in the water column making the pond clearer and enabling growth of aquatic plants at deeper water depths, including the invasive Eurasian water milfoil. Zebra mussel control at the intake pipeline is currently through polymer addition. It is recommended that this practice be continued.

- The City of Ann Arbor should continue monitoring water quality both in Barton Pond and upstream. An emergency response plan should be developed to address specific water quality issues. Strengthening a spill response notification program to protect the Barton Pond intake should be utilized as a proactive measure to provide timely information from first responders and upstream wastewater treatment plants on source water quality. Additional information and suggestions on spill communication and response is in the Watershed Management memorandum.

- The City of Ann Arbor should monitor additional parameters at Barton Pond. The recommended parameters include:

  - Add an early warning monitor for detecting organics, petroleum products, and other hydrocarbons in the Huron River upstream of Barton Pond. This subject is discussed further in the Source Water Online Monitoring Technology Evaluation Technical Memorandum.

  - Track nitrogen: phosphorus ratios and phycocyanin to indicate algal bloom potential.

  - Install a multi-parameter probe continuous monitor near the Barton Pond intake and connect to the SCADA system. The monitor may be located in Barton Pond or in the intake pump station.

  - Increase Barton Pond grab sample monitoring frequency during conditions consistent with high algae bloom potential.

  - Complete a bathymetric survey every 10 to 15 years to provide information on siltation trends in Barton Pond.

  - Build upon existing information. With respect to pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs), Ann Arbor should build upon the information already obtained during the 2004 monitoring study, track regulatory developments, and plan for future appropriate water treatment responses, if necessary.

1.3.2 Groundwater

Groundwater will be an increasingly important water source. Monitoring recommendations include the following:

- Continue to monitor groundwater quality and increase the frequency of monitoring for volatile organic compounds (VOCs), 1,4-dioxane, radium, and arsenic

- Install monitoring wells around current and new wellfields

1.4 Conclusions

Major conclusions from the water quality task include:

- Avoid 1,4-dioxane contaminated areas for groundwater supply
- Abandon the sulfate contaminated well and install a new well in a lower sulfate area
- Provide additional monitoring at Barton Pond and the wellfields

2 Objectives

The objectives of the water quality task were to:

- Evaluate water quality conditions in Huron River and groundwater
- Make recommendations for dealing with sulfate and 1,4-dioxane in groundwater
- Make recommendations for monitoring and improving water quality in Barton Pond

3 Background

3.1 Water Supply

Ann Arbor gets its water supply from both Huron River and groundwater. Huron River is the major source of water (about 80 to 90 percent), so protection of this resource is very important. Huron River water is relatively hard, so softening is practiced at the water plant, along with disinfection and filtration. Changes in the watershed can impact water quality in the river and thus impact treatment requirements.

Groundwater is harder than river water and requires more softening chemicals. However, groundwater's higher temperature improves the softening and sludge dewatering processes. Higher temperature water may potentially reduce water main breaks in the distribution system. Groundwater will be a critical component of Ann Arbor's water supply, since the Huron River capacity is limited, especially during droughts. Obtaining high quality groundwater is essential. Two groundwater-quality issues include the presence of 1,4-dioxane in a portion of the aquifer, and elevated sulfate concentrations in one well. Also, jet fuel, fuel oil and ethylene glycol are stored and used at the municipal airport immediately to the north of the Steere Farm wellfield. There has been a past spill of jet fuel at the airport. As a result, a cleanup and monitoring program was established. These stored compounds represent potential sources of contamination.

3.2 Cost Estimates

All cost estimates in this memorandum are preliminary (order-of-magnitude) and have been prepared for guidance in project evaluation from the limited information that is available at this time. These cost estimates will vary from final costs depending on actual labor and material costs, site conditions, final project design, design parameters, implementation schedule, competitive market conditions, and other variable factors that are unknown at this time. As a result, final construction and operation and maintenance costs will vary from the preliminary cost estimates shown.

4 Groundwater

4.1 Sulfate

4.1.1 Background

Elevated levels of sulfates in drinking water have been known to increase incidences of diarrhea. Higher sulfate levels are undesirable due to aesthetic and corrosion issues. There is no primary drinking water regulation for sulfates; however, a secondary standard (nonenforceable, based on aesthetics) has been set at 250 milligrams/liter (mg/L) by the United States Environmental Protection Agency (USEPA).

Whereas, Huron River has sulfate levels ranging from 45 to 90 mg/L, the three operating Steere Farm wells have sulfate levels ranging from 120 to 200 mg/L. The fourth Steere Farm well (SF 742) has sulfate levels up to 900 mg/L and has not been used since its construction in 1974. SF 742 also has relatively high noncarbonate hardness (a value of 290 parts per million was measured in July 2001). The cause or source of the elevated sulfate in SF 742 has not been definitively determined. The drift aquifer at Steere Farm is comprised of three permeable sand and gravel layers separated by clay layers and underlain by Coldwater Shale (ALMN 1973). Due to the heterogeneity of glacial drift, it is possible that gypsum and more mineralized water are present in the sand and gravel layer producing water to SF 742. It is also possible that there is an anthropogenic source of sulfate in the vicinity of SF 742.

Increasing the capacity of the Steere Farm wellfield is desired. Reducing the sulfate level in SF 742 would increase the useable capacity of the wellfield. Alternatives to reducing sulfate levels, including modifying the existing well, drilling a new well, or treatment at the wellhead, are discussed in the following sections.

4.1.2 Well Modifications

Because of the construction problems reported for SF 742, it is unlikely that any well modifications could be completed that would reduce the level of sulfate in SF 742. The source and cause of the elevated sulfate needs to be investigated. The sulfate plume may eventually impact the other Steere Farm wells and the exact location, cause and extent of the more mineralized groundwater needs to be accurately determined. Test drilling and water sampling need to be performed to map the lateral and vertical extent of elevated sulfate in the vicinity of SF 742. If the source is due to man-made contamination, it could perhaps be remediated to reduce or eliminate the impact on the existing and future Steere Farm wells. Likely sources of sulfate could include use, storage, or manufacture of agricultural gypsum or ammonium sulfate fertilizer; drainage improvement from gypsum application; oilfield reserve pits or landfills receiving oilfield lignosulfates, pulp waste streams containing lignosulfate. However, none of these are known to exist near the Steere Farm wellfield. If elevated sulfate water is confined to one of the sand and gravel lenses, then future wells can be located and designed to avoid this water. One suggested theory is that there is a leak between the inner and outer casing in the SF 742 well that is allowing more mineralized water to seep into the well from the upper sand and gravel layer. However, other wells in the upper sand and gravel layer do not typically have sulfate levels as high as those observed at SF 742. The USGS has also suggested the source could be the Coldwater Shale.

However, due to distance and an intervening clay layer, it is difficult to show that water from the Coldwater Shale would reach SF 742.

4.1.3 New Well

A replacement well could be constructed in the Steere Farm wellfield area—away from the area of elevated sulfate—to increase the capacity of the wellfield. We have assumed that the source of the sulfate is limited to the shallow portions of the aquifer and constructing a deeper well, similar to SF 21 and SF 25, would produce water with lower sulfate levels.

4.1.4 Sulfate Reduction

Dilution. Diluting SF 742 water with Huron River water and other Steere Farm wells could reduce sulfate levels. Three scenarios were evaluated:

- At lower water demands (10 million gallons per day [mgd]), if 7 mgd come from the river and 3 mgd from SF 742 (assuming conveyance upgrades), the sulfate levels in the finished water would be about 300 mg/L. Very little sulfate is expected to be removed in the treatment processes.
- At average water demands (20 mgd), if 14 mgd come from the river, 3 mgd from SF 742 and 3 mgd from another Steere Farm well (assuming conveyance upgrades), the sulfate level in the finished water would be about 200 mg/L.
- At higher water demands (40 mgd), if 31 mgd come from the river, 3 mgd from SF 742 and 6 mgd from other Steere Farm wells (assumes conveyance upgrades), the sulfate level in the finished water would be about 140 mg/L.

These scenarios result in drinking water sulfate levels at two to four times the current levels. At lower flows, the secondary standard for sulfate would be exceeded. In addition, higher sulfate levels increase the potential for internal pipe corrosion in the distribution system. Therefore, dilution is not recommended as an alternative.

Treatment. Sulfate can be removed from SF 742 through treatment at the wellhead. About 80 percent sulfate removal would be required to reduce SF 742 sulfate concentrations from about 900 mg/L to about 150 mg/L to match the other Steere Farm wells.

Sulfate can be removed from water by a number of treatment processes. For drinking water applications, the most applicable methods are ion exchange and membranes (reverse osmosis, nanofiltration, or electrodialysis reversal).

Ion exchange would involve passing the water through a bed of strong base anion exchange resin, where sulfate would be exchanged for chloride. A portion of the well water could be bypassed around the ion exchange vessel to meet target sulfate concentrations. When the resin is exhausted for sulfate removal, a sodium chloride solution would be passed through the resin bed to remove the sulfate and regenerate the resin for further sulfate removal. The waste brine would be disposed of. Roughly 3 to 5 percent of the well water would be a waste stream. A disadvantage of this process is that chlorides would increase in the water. Hydroxide could be used instead of chloride to exchange for sulfate (regenerate with sodium hydroxide), but a pH increase would cause scaling issues.

Membrane processes involve passing the water through a semipermeable membrane under high pressure. Water and some salts pass through the membrane, while other salts are rejected into a waste stream. The waste stream could be 10 to 20 percent of the treated well water flow. This large volume of waste would require additional well capacity to make up for lost water. Larger molecules such as sulfate, calcium, and magnesium are rejected. These processes not only remove sulfate, but soften the water as well. Chloride would not be significantly removed, but would not increase like strong base anion exchange processes. A portion of the water could be bypassed around the membrane process to meet target sulfate concentrations

Ion exchange is more economical for removing sulfate from SF 742 water than membranes. Ion exchange produces fewer waste products, and requires less pretreatment. It is more easily automated and requires less operator attention. The capital and operating cost of ion exchange is several times less than membrane processes, even without considering the additional waste volume lost with membrane softening.

An order-of-magnitude construction cost estimate for installing ion exchange treatment for the SF 742 well is $2 million to $3 million. Equipment costs are based on treating a maximum flow of 3 mgd (about 0.5 mgd bypass) and reducing sulfate from about 900 mg/L to about 150 mg/L.

Operating and maintenance costs are estimated at $100,000 to $150,000 per year based on 8 months per year operation. These costs do not include waste disposal. Depending on the location of sewers, this could increase both capital and operating costs. The presence of iron could foul both ion exchange and membrane processes, creating the potential for iron removal or sequestration before either process. This would increase costs further. Pilot testing would be required to determine the need for iron removal.

4.1.5 Recommendations

It is recommended that SF 742 be plugged and abandoned, and a replacement well sited within the existing wellfield. Prior to siting the well, the source and extent of the elevated sulfate water present at SF 742 should be investigated. The investigation should include water quality sampling from SF 742 to assess the geochemical balance of the water in that well. Three borings should be drilled to bedrock in a triangular pattern around SF 742. The borings should be located roughly 300 to 500 feet away from SF 742. Rotosonic drilling methods should be used to collect continuous soil core samples that will allow an assessment of the mineralogy of the glacial drift. Water samples should be collected from each sand and gravel layer encountered as the boring progresses. Rotosonic drilling techniques allow for the installation of temporary well screens within the drill casing to allow for pumping and collection of water samples as the boring is drilled. Evaluation of the mineralogy and water quality samples should indicate the lateral and vertical extent of the water with elevated sulfate levels. Additional borings at greater and greater distances from SF 742 may be necessary to reach the limits of the sulfate plume. It may also be prudent to complete the borings as observation wells that can be used to collect water level and water chemistry data as SF 742 or other wells within the wellfield are pumped. Once the source and extent of the sulfate has been determined, a new well site can be identified that should produce water with typical sulfate levels. A rotosonic boring should be drilled with water samples collected as described above, to confirm acceptable water quality before constructing the production well. Assuming a 100-foot total depth and one 10-inch override casing, rotosonic test borings would cost around $6,500 each.

Three to five monitoring wells around the Steere Farm wellfield are recommended for use as sentry wells for early detection of sulfate or other undesirable constituents in groundwater, and for long-term monitoring of aquifer water levels since this may relate to long-term well performance. Monitoring wells could be installed by rotosonic means in conjunction with the sulfate extent testing described above. Additional costs to convert a rotosonic boring to a monitoring well (on top of borehole construction costs noted above) would be around $1,500 each.

4.2 1,4-Dioxane

4.2.1 Background

Groundwater contamination consisting of 1,4-dioxane has been identified emanating from the Pall Life Sciences (PLS; formerly Gelman Sciences Inc.) site. The PLS site includes the PLS plant property located on Wagner Road just south of Jackson Road in Scio Township, and extends eastward and north-eastward into the City of Ann Arbor, and westward and north-westward in Scio Township. There are four areas of groundwater contamination extending off the property. These have been designated as Unit C3 (includes the “Core Area” on the PLS site), Unit D0 (includes the Western System located west of the PLS site), Unit D2 (includes the Evergreen System located northeast of the PLS site), and in May of 2001 the fourth, deeper aquifer called Unit E was discovered to be contaminated.

The Unit E aquifer is contaminated with 1,4-dioxane above the Michigan Department of Environmental Quality (MDEQ) residential criterion (based on drinking water) in an area extending from Parkland Plaza to Worden Street, east of Veterans Park. The Unit E aquifer is the deepest of the glacial aquifers, and lies just above the bedrock, over 200 feet below the ground surface in some areas. In the spring of 2001, it was discovered that there is no clay layer separating the Unit D2 aquifer from the Unit E aquifer in an area west of the PLS property. The exact location(s) of the connection(s) that has allowed 1,4-dioxane contamination to migrate into the Unit E aquifer has not been determined. To date, the investigation appears to have focused on defining the extent of contamination. The Unit E contamination extends into the Wellhead Protection Area of the Montgomery Well. The plume is about 1 mile wide at its widest point and has migrated about 2 miles to the east of the PLS site where low concentrations of 1,4-dioxane have been detected in the Montgomery well. The maximum 1,4-dioxane concentrations known in the Unit E plume are 3,250 parts per billion (ppb) in 2001 and 7,800 ppb in 2004 (MDEQ 2004c).

On December 17, 2004, the Circuit Court for Washtenaw County issued an Opinion and Order Regarding Remediation of the Contamination of the Unit E Aquifer. Among the more significant requirements of this Opinion and Order are (1) Pall perform the investigation described in the August 1, 2004, Work Plan for Test Boring / Well Installation and Aquifer Testing in the Wagner Road Area; (2) the Unit E groundwater remediation and reinjection plan proposed by Pall should be implemented and a sufficient amount of groundwater be withdrawn by that method so that any groundwater escaping the capture zone will not contain 1,4-dioxane above 2,800 ppb; and (3) a map that identifies an area (including buffer zone) for prohibition, by judicial institutional control, against the installation of new water supply wells be submitted to the Court.

4.2.2 Treatment

Objectives. The purpose of this memorandum is to summarize treatment technologies for 1,4-dioxane and their applicability to the Montgomery Well and City of Ann Arbor WTP. The following issues are addressed:

- Determine a feasible treatment technology to remove 1,4-dioxane from the Montgomery Well and WTP to levels below 1 ppb
- Assess the existing water plant processes for its ability to reduce 1,4-dioxane to levels below 1 ppb
- Estimate capital and annual operations and maintenance costs for the 1,4-dioxane treatment options

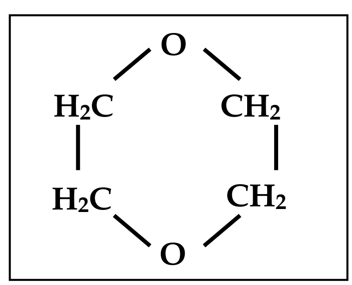
1,4-Dioxane. The compound 1,4-dioxane is both a solvent and a stabilizer for other solvents, and present in products such as paints, varnishes, lacquers, paint and varnish removers, cosmetics, and toiletries. It is used as a degreasing agent; in the manufacture of fats, oils, waxes, and resins; in the pulping of wood; as a stabilizer for chlorinated solvents such as 1,1,1-trichloroethane (TCA); and in the production of cellular acetate membrane filters (MDEQ 2004c).

Drinking Water Regulations. USEPA has classified 1,4-dioxane as a Probable Human Carcinogen. Studies have shown that chronic drinking water exposure of 1,4-dioxane in animals has caused increased mortality rates and kidney and liver damage (USEPA 1995a, 1995b).

Currently, there is no federal drinking water standard for 1,4-dioxane under the Safe Drinking Water Act, although several states have set guidelines for levels of 1,4-dioxane in drinking water. Michigan has a heath advisory level of 85 ppb, while California has an action level at 3 ppb, which is based on a 1 in 1 million (or 10^{-6}) cancer risk factor.

In its proposed amendments to the administrative rules promulgated under the Michigan Safe Drinking Water Act (Act 399, P.A. 1976, as amended), the MDEQ had proposed a maximum contaminant level (MCL) of 1,4-dioxane at 35 ppb. There was stakeholder opposition to this MCL. USEPA has reopened its Integrated Risk Information System database for comment, which may alter its risk assessment for 1,4-dioxane. MDEQ has since decided to withdraw the proposed MCL from this rule package.

FIGURE 1
Chemical Structure of 1,4-Dioxane



Chemical Properties and Fate of Transport. The compound 1,4-dioxane is a colorless, six-member, heterocyclic ether (Figure 1) that mixes well with water and does not bind readily with soil. These factors allow it to move through the ground and into the groundwater. If exposed to sunlight, it will break down into other chemicals but remains relatively stable in groundwater. Table 1 summarizes some physical and chemical properties of 1,4-dioxane.

Treatment Technologies. *Physical and Chemical Processes.* The removal of 1,4-dioxane from water is difficult due to its physical and chemical properties. This compound is very stable under various reaction conditions and does not absorb substantial energy in the visible or UV spectrum, limiting the effectiveness of photolysis as a removal mechanism (Scanlan 1993).

It is also not expected to hydrolyze significantly. The low estimated Henry's Law constant (3×10^{-6} atm-m^3 / mol) suggests that transfer of 1,4-dioxane from water to air is negligible. McGuire (1978) aerated water for 2.4 hours at an air:water ratio of 80:1 and found only 3 percent 1,4-dioxane removal. An air stripper designed to remove chlorinated solvents reduced an initial 610 ppb concentration of 1,4-dioxane by only 30 percent (Bowman 2001).

TABLE 1
1,4-Dioxane Properties

Property	Value
Molecular Weight	88.10
Molecular Formula	$C_4H_8O_2$
Solubility	Miscible
Boiling Point	101.1°C
Henry's Law Constant (H)	3×10^{-6} atm-m^3/mole
Vapor Pressure	37 mm Hg at 25°C
Log K_{OW}[a]	0.43
Log K_{OC}[b]	0.54
Specific Gravity	1.03 at 20°C

[a] K_{OW}, n-Octanol/water partition coefficient, is the ratio of the molar concentrations of a chemical in n-octanol and water, in dilute solution, at 25 degrees Celsius. It measures hydrophobility of a chemical.
[b] K_{OC}, Sorption Coefficient, is used to compare the relative sorption of a chemical. Koc is the distribution coefficient (k_d) divided by the amount of organic carbon in the soil.

With an estimated K_{OC} of 0.54, 1,4-dioxane is not expected to significantly adsorb on suspended sediments or granular activated carbon (GAC) (Mohr 2001). At a groundwater treatment facility in El Monte, California, a GAC system consisting of two 20,000-lb carbon vessels and treating 500 gpm of solvent-contaminated groundwater was ineffective at reducing influent 1,4-dioxane concentrations of 14 ppb to the treatment target of 3 ppb (Mohr 2001). Other studies showed only moderate 1,4-dioxane removals by GAC of 50 percent (Johns 1998) and 67 percent (McGuire 1978).

Conventional water treatment processes such as ferric chloride coagulation, powered activated carbon, potassium permanganate oxidation and chlorine did not detectably remove 1,4-dioxane (McGuire 1978).

Biological Processes. Like most ethers, 1,4-dioxane has been shown to be nonbiodegradable in 10-day biological oxygen demand (BOD) tests (Scanlan 1993). It exhibited a negligible biological oxygen demand in two activated sludge experiments and was classified as relatively nonbiodegradable. Biological treatment, including conventional mixed culture activated sludge and anaerobic biodegradation at wastewater treatment plants (WWTPs), have proven to be ineffective at removing 1,4-dioxane. A study of 3 large wastewater plants in Japan showed 1,4-dioxane removal ranging from 0 to 31 percent (Abe 1999).

There are research studies showing promising treatment technologies with cultured organisms under well-controlled conditions (Mohr 2001, Roy 1994); however, they are not proven for drinking water treatment applications.

There is limited information on attached growth reactors for 1,4-dioxane removal. A mixed culture fluidized bed reactor enriched with organisms that degrade 1,4-dioxane showed 99 percent 1,4-dioxane removal. However, the process required high temperatures (35 Celsius), long residence times, and high initial 1,4-dioxane levels to achieve significant removal (Sock 1993, CH2M HILL 1994). Studies of lab scale trickling filters using tetrahydrofuran as a co-substrate showed 95 to 98 percent removal of 1,4-dioxane with influent concentrations of 2,000 to 25,000 ppb (Zenker 2003). However, this process may not be applicable to drinking water treatment.

Advanced Oxidation Processes. Advanced oxidation processes (AOP) processes include UV/ozone, ozone/hydrogen peroxide (H_2O_2) and UV/H_2O_2. AOP processes produce hydroxyl radicals which oxidize 1,4-dioxane. The goal is to mineralize 1,4-dioxane to water and carbon dioxide. Depending on treatment conditions, intermediate byproducts from oxidation of 1,4-dioxane may include aldehydes (formaldehydes, acetaldehyde, and glyoxal), organic acids (formic, methoxyacetic, acetic, glycolic, glyoxylic, and oxalic acids), and the mono– and diformate esters of 1,2-ethanediol (ethylene glycol) (Mohr 2001, Stefan and Bolton 1998).

UV/Ozone Process. In this process, ozone is added to water containing 1,4-dioxane and then passed through UV reactors. The UV/ozone process has shown up to 99 percent removal of 1,4-dioxane in bench scale tests (Scanlan 1993).

Ozone/H_2O_2 Process. In this process, ozone and H_2O_2 are added to water containing 1,4-dioxane. The optimum H_2O_2 to ozone molar ratio is between 0.5:1 and 1.0:1 (Scanlan 1993). The South El Monte facility in the San Gabriel basin of California uses ozone and H_2O_2 for oxidation of 1,4-dioxane (Mohr 2001). The plant treats contaminated groundwater containing 5 to 8 ppb 1,4-dioxane to levels below detection.

Ozone alone is much less effective in removing 1,4-dioxane. For 99 percent removal of 1,4-dioxane (19,382 ppb 1,4-dioxane initial) with ozone alone, an ozone dose of about 142 parts per million (ppm) was required in bench scale tests (Scanlan 1993).

UV/H_2O_2 Process. In this process, H_2O_2 is added to water containing 1,4-dioxane and then passed through UV reactors where UV light forms hydroxyl radicals. The La Puente Valley facility in the San Gabriel basin of California uses UV/H_2O_2 for oxidation of 1,4-dioxane and n-nitrosodimethylamine (NDMA). It removes 1,4-dioxane from contaminated groundwater containing 5 to 8 ppb to below detection levels (Mohr 2001).

The UV/H_2O_2 process is much more effective than UV alone for 1,4-dioxane removal. Using a total of 5 kW-sec/cm^2 of UV radiation and 360 minutes of reaction time, UV alone has only shown up to 59 percent removal of 1,4-dioxane.

Other Processes. Some textile manufacturers remove 1,4-dioxane from process wastes through distillation, which, due to the small difference in the boiling points of 1,4-dioxane (101°C) and water, requires several distillation cycles at significant expense (Scanlan 1993).

Fenton's reagent (H_2O_2 and ferrous ions) was shown to be neither effective nor economical for treating 1,4-dioxane (Mohr 2001). One study showed 97 percent 1,4-dioxane removal with Fenton's reagent, but this was after 10 hours incubation with a 12:1 ratio of hydrogen peroxide to 1,4-dioxane (Klecka and Gonsior 1986). These conditions are neither practical nor economical for drinking water treatment.

Reverse osmosis membrane processes operated at 50 to 70 percent recovery and showed limited 1,4-dioxane removal capabilities.

Summary. Alternative treatment technologies and their effectiveness in removing 1,4-dioxane are summarized in Table 2.

Based on available information, AOP processes are the most applicable for treatment of 1,4-dioxane in drinking water. Byproducts such as bromate would be lower with the UV / H_2O_2 process as opposed to the UV / Ozone or Ozone / H_2O_2 processes. Ann Arbor has bromide in the source water, and current ozone oxidation can create bromate levels approaching the MCL of 10 ppb. Further ozone oxidation with UV / Ozone processes may cause exceedance of the bromate MCL. Therefore, the UV / H_2O_2 process will be evaluated further.

TABLE 2
Assessment of Alternative 1,4-Dioxane Treatment Technologies

Probably Feasible	Probably Infeasible
UV/Peroxide	Ambient Air Stripping
Ozone/Peroxide	GAC
UV/Ozone	Fenton's Reagent
Multi-cycle Distillation*	Anaerobic Degradation[a]
Biofilm Aerobic Cometabolysis (with THF, butane)*	Reverse Osmosis

[a] Indicates technologies only suitable for nondrinking water applications

AOP Equipment Manufacturers. Table 3 summarizes manufacturers whose systems were either pilot or full-scale tested for 1,4-dioxane removal.

TABLE 3
Tested Systems

Equipment Manufacturer	Product/ Technology	Comments	Operation
Applied Process Technology, Inc., Walnut Creek, CA	HiPOx™ O_3 + H_2O_2		Automated with remote monitoring available.
Calgon Carbon Corporation, Pittsburg, PA	Rayox® Medium Pressure UV + H_2O_2	Full-scale installations	Automated with remote monitoring available.
Hydrogeochem, Tucson, AZ	Low Pressure UV + H_2O_2	Full-scale installation	
Trojan Technologies, Inc., London, Ontario	Low Pressure UV + H_2O_2	Full-scale installations	May require input from operator depending on program design.

Applied Process Technologies Inc. (APT) has installed a HiPOX™ system for remediation of 1,4-dioxane contaminated groundwater.

Calgon Carbon Corporation is a major player in the UV / H_2O_2 process business. Calgon Carbon's Rayox® system uses medium pressure (MP) UV lamps with H_2O_2. Calgon is located in Pittsburgh, but the Rayox® system is from its acquired operation in Canada (formerly Solarchem).

Hydrogeochem of Tucson, Arizona, has a low-pressure (LP) UV system with H_2O_2 for 1,4-dioxane treatment.

Trojan UV is a major UV supplier for the wastewater and drinking water disinfection markets, as well as the oxidation market. Trojan has a LP UV/H_2O_2 system for 1,4-dioxane removal.

1,4-Dioxane Treatment at Montgomery Well. The 1,4-dioxane could be removed from water in the Montgomery well using the UV/H_2O_2 process equipment described above. To operate the equipment properly, a building and associated utilities, site work, piping, and controls would also be required.

The treatment conditions for estimating costs include a maximum flow rate of 2 mgd, an influent 1,4-dioxane concentration of 20 ppb, groundwater UV transmittance of 95 percent and 8 months per year operation. Costs for both 90 and 99 percent removal of 1,4-dioxane were estimated.

An order-of-magnitude construction cost estimate for installing UV/H_2O_2 treatment for the Montgomery well is $1.5 million to $2 million for 90 percent removal and $2.5 million to $3 million for 99 percent removal. Available land is limited at the Montgomery well site, so additional costs might be involved if land acquisition is required.

Operating and maintenance costs for 90 percent 1,4-dioxane removal are estimated at $150,000 to $200,000 per year based on an 8-month-per-year operation. For 99 percent 1,4-dioxane removal, the estimated annual operating and maintenance costs are $200,000 to $250,000. These costs include about 480 person-hours labor per year for operations and maintenance.

Iron in the groundwater might cause additional capital, and operating and maintenance costs. Lower groundwater UV transmittance will also increase capital and operating costs. These costs could be significant and pilot tests are required to quantify them.

1,4-Dioxane Treatment at the Water Plant. The City of Ann Arbor water plant has a number of treatment processes available that include lime softening, ozone, biological GAC filtration, and chlorine/ammonia disinfection. Literature on the removal of 1,4-dioxane using these processes is limited or not available. Therefore, bench tests of these treatment processes were conducted to better quantify the removal levels of 1,4-dioxane.

The information presented is based on laboratory experiments conducted at CH2M HILL's Applied Sciences Laboratory in 2005 in which raw Huron river water blended with Ann Arbor groundwater (15 percent by volume) was spiked with 1,4-dioxane. The water was treated by lime softening, recarbonation, ozone, biological GAC filtration and chloramines. 1,4-dioxane was measured after each treatment process. A detailed test procedure is in Attachment 1. The results are summarized below.

There were three general levels of initial 1,4-dioxane concentrations, selected for the following reasons:

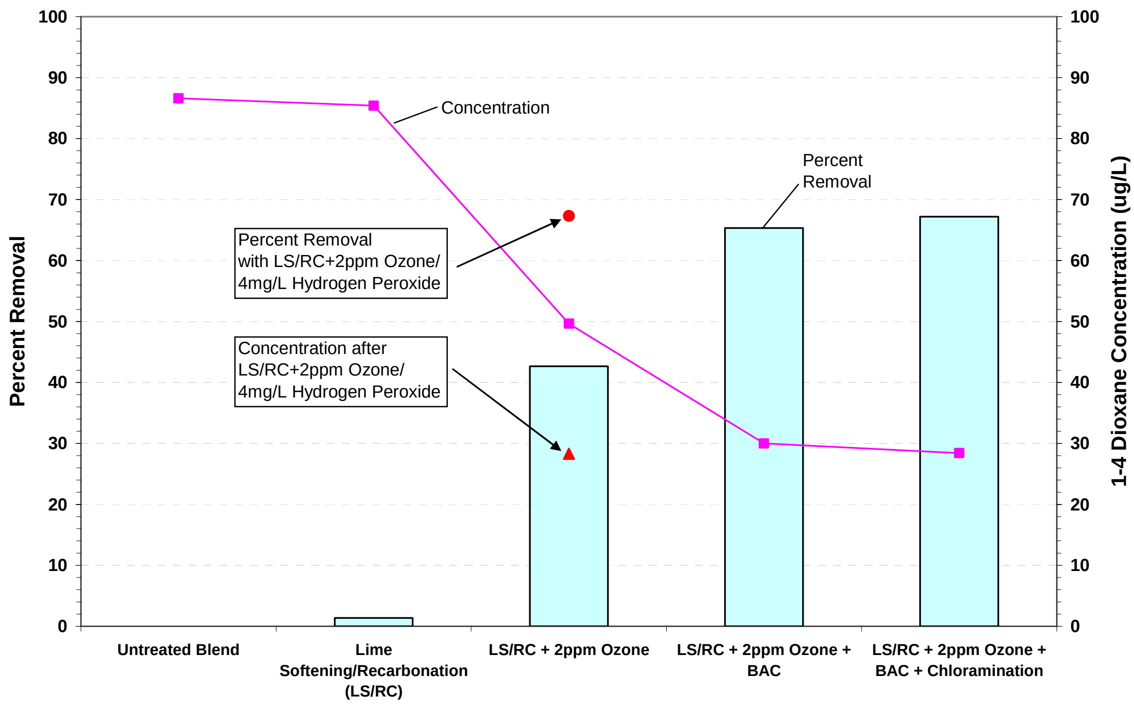
- Low levels (less than 10 μg/L) to represent low levels that might be detected in source waters.
- Medium levels (30–90 μg/L) to represent current discharge limits to Honey Creek.

- High levels (~3,000 μg/L) to represent concentrations allowed in the contaminated groundwater.

Figure 2 shows the cumulative percent removal (and concentration in μg/L) of 1,4-dioxane through simulated bench scale treatment processes currently used by the City's water treatment plant, which include lime softening, recarbonation, ozonation at 2 ppm, biologically active carbon (BAC) filtration, and chloramination.

As Figure 2 shows, a 67 percent reduction of 1,4-dioxane was achieved by the treatment processes and the final concentration of 1,4-dioxane was about 28 μg/L. Most reduction (43 percent) was achieved using ozonation at a dose of 2 ppm. An additional 22 percent reduction was achieved using BAC. Less than 2 percent reduction was achieved with lime softening, recarbonation, and chloramination. 1,4-dioxane removal increased from 43 percent with ozonation at 2 ppm to 67 percent with ozonation at 2 ppm simultaneously with 4 mg/L of hydrogen peroxide. These results are consistent with previous findings which reported very little removal of 1,4-dioxane through conventional coagulation and settling processes, moderate removal using ozone, and good removal (90 to >99 percent) using higher doses in advanced oxidation processes like ozonation plus hydrogen peroxide, and ultraviolet light plus hydrogen peroxide (Zenker, et al. 2003).

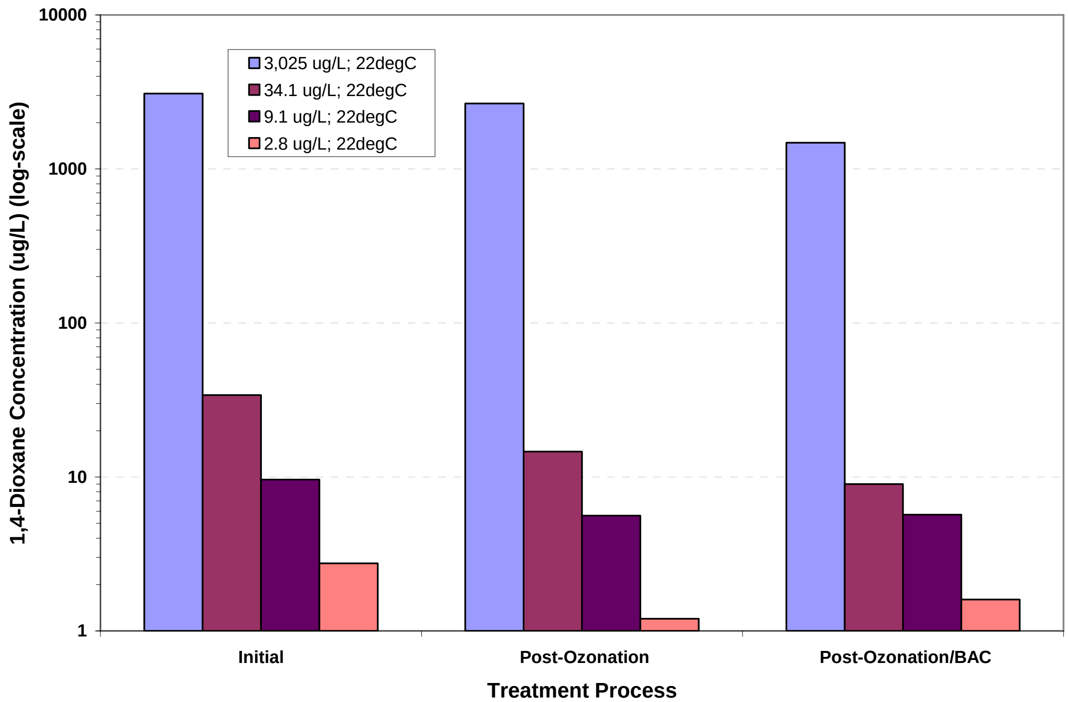
FIGURE 2
Removal of 1,4-Dioxane Through Water Treatment Processes



Additional tests were conducted with different initial concentrations of 1,4-dioxane. These tests focused on the ozone and BAC processes, since they indicated the most removal. Softened water from the Ann Arbor water plant was shipped to the CH2M HILL lab, recarbonated to pH 8, and spiked with 1,4-dioxane. A detailed test procedure is in Attachment 1. The results are summarized below.

Figure 3 shows the concentration (µg/L) of 1,4-dioxane after ozonation at 2 ppm and biologically active carbon (BAC) treatment post-ozonation. Softened water was spiked with 1,4-dioxane to concentrations of 2.8 µg/L, 9.1 µg/L, 34.1 µg/L, and 3,025 µg/L. The temperature for these tests was 22°C and pH was 8.

FIGURE 3
Removal of 1,4-Dioxane after Ozonation and BAC at Various Initial Concentrations



Two tests were conducted with average initial 1,4-dioxane concentrations less than 10 µg/L. In those tests, the majority of 1,4-dioxane removal occurred through ozonation. The total percent removal after ozonation and BAC treatment was around 40 percent for both tests. BAC did not remove 1,4-dioxane at the low initial concentrations.

Another test was conducted with an average initial 1,4-dioxane concentration of 3,025 µg/L. The majority of 1,4-dioxane removal occurred through BAC. The total percent removal after ozonation and BAC treatment was around 50 percent, somewhat greater than observed in tests with initial concentrations less than 10 µg/L.

A fourth test was conducted with an average initial concentration of 34.0 µg/L. The majority of 1,4-dioxane removal occurred through ozonation. The total percent removal after ozonation and BAC treatment was around 70 percent.

In general, ozonation removed more 1,4-dioxane than BAC at low and moderate initial concentrations. The reverse was true at high 1,4-dioxane concentrations.

Additional tests were conducted in both warm and cold water to determine any treatment differences. Figure 4 shows the concentration (µg/L) of 1,4-dioxane after ozonation at 2 ppm and biologically active carbon (BAC) treatment at both 22 degrees Celsius and 5 degrees Celsius. Figure 5 summarizes the percent removal of 1,4-dioxane for these tests.

FIGURE 4
Concentration of 1,4-Dioxane after Ozonation and BAC in Warm and Cold Waters

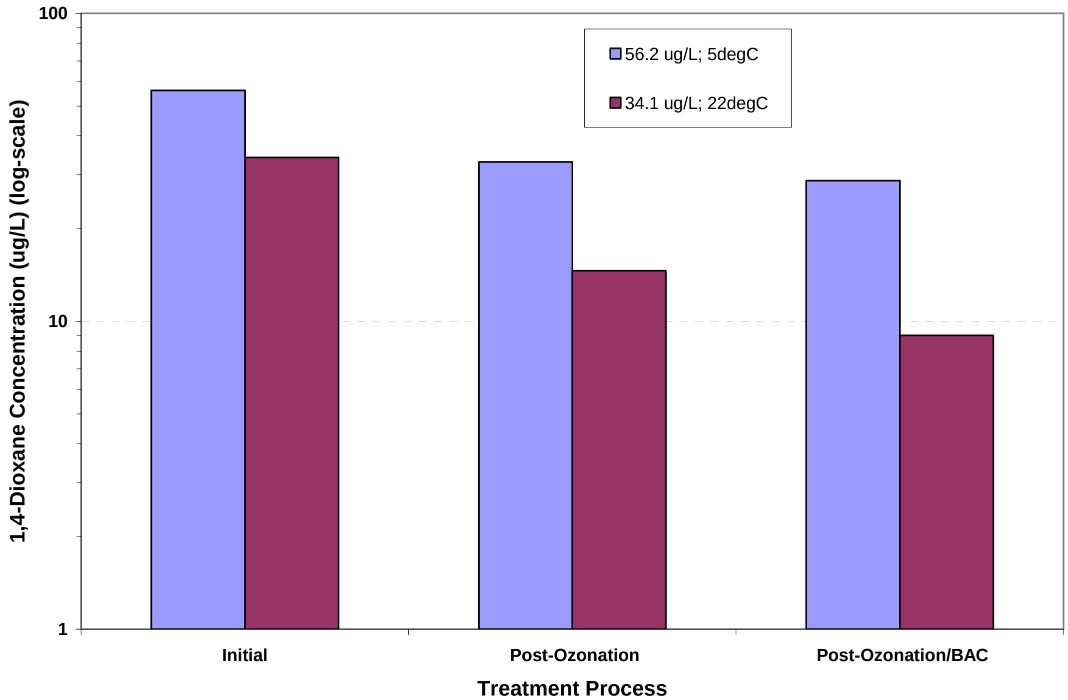
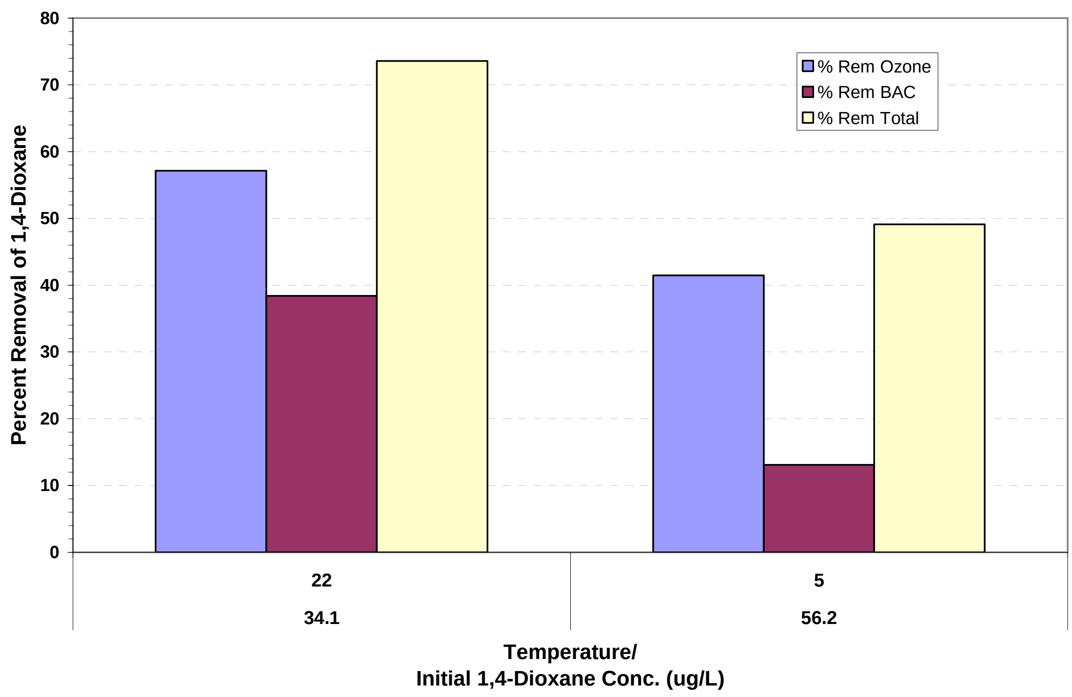


FIGURE 5
Percent Removal of 1,4-Dioxane after Ozonation and BAC in Warm and Cold Waters



As Figures 4 and 5 show, the total percent removal of 1,4-dioxane in warm water test was around 74 percent, compared to only 49 percent in the cold water test. In addition, more removal of 1,4-dioxane was achieved through each individual treatment process in the warm water test. Ozonation achieved 57 percent removal of 1,4-dioxane in the warm water test, but only 42 percent in the cold water test. BAC achieved 38 percent removal of 1,4-dioxane in the warm water test, but only 13 percent in the cold water test. The final concentrations of 1,4-dioxane after ozonation and BAC were 9 and 29 µg/L in the warm and cold water tests, respectively.

These tests indicate only moderate removal of 1,4-dioxane with existing water plant processes. 1,4-Dioxane removal mechanisms are dependant on a number of factors, and water plant performance will vary under different conditions. If a consistently high degree of 1,4-dioxane removal was desired at the plant to protect drinking water, two potential methods include the following:

- Increase the ozone dose capability and contact time, while adding hydrogen peroxide facilities. This would require the expansion of the existing ozone generation and contact facility and addition of a new hydrogen peroxide facility. Currently, there is insufficient space to expand the ozone facilities. Purchasing nearby residential properties or installing more compact lime-softening processes that free up plant space would be required. This alternative raises concerns for byproducts. The Huron River has natural bromide. Upon oxidation under such conditions, bromate may be formed at levels exceeding the regulatory limit of 10 ppb.
- Install a UV/H_2O_2 facility similar to the facility described to treat water at the Montgomery well, but much larger. The water plant can treat a maximum of 50 mgd while the Montgomery well capacity is about 2 mgd. Currently, there is insufficient space to add UV/H_2O_2 facilities. Purchasing nearby residential properties or installing more compact lime softening–process equipment would be required.

Both alternatives to remove 1,4-dioxane at the water plant would be major projects. It is difficult to estimate the costs of such major facilities at this preliminary stage. Preliminary order of magnitude construction cost estimates for a UV/hydrogen peroxide treatment system for 90 percent 1,4-dioxane removal are about $25 million to $30 million and annual operating and maintenance costs of about $1.5 million to $2 million (based on 15 mgd average day water demand). These costs do not include additional land acquisition or installation of new compact lime-softening processes to free up space on the plant site.

Treatment of 1,4-dioxane at the water plant would require significant new facilities, and operation and maintenance costs. Obtaining source water that does not require 1,4-dioxane treatment is preferable.

4.2.3 Recommendations

For many treatment processes, it is difficult to remove the compound 1,4-dioxane from water. For Ann Arbor’s drinking water, UV/H_2O_2 is the most applicable treatment technology for a high degree of removal. Capital and operating costs for 1,4-dioxane treatment are high. It is preferable to obtain drinking water sources that do not require 1,4-dioxane treatment, and prevent 1,4-dioxane from entering drinking water sources, as opposed to treating for the removal of 1,4-dioxane. Evaluation of new groundwater supplies is discussed in the Water Supply Capacity Technical Memorandum.

5 Barton Pond

5.1 Background

Water quality conditions in Barton Pond and potential pollutants in the watershed as documented in the Source Water Assessment Report (USGS and MDEQ 2004) were reviewed. The factors influencing Barton Pond water quality include the following elements:

- Increasing urbanization impacts
- Pond recreational usage
- Eutrophication
- Invasive species
- Additional contaminants identified by Source Water Assessment Plan (SWAP)
- Emerging issues

Each of these areas was reviewed with a focus on current conditions as well as future development trends. Based upon this information, monitoring recommendations have been made. A summary of the findings is included below.

5.2 Impact of Increasing Urbanization

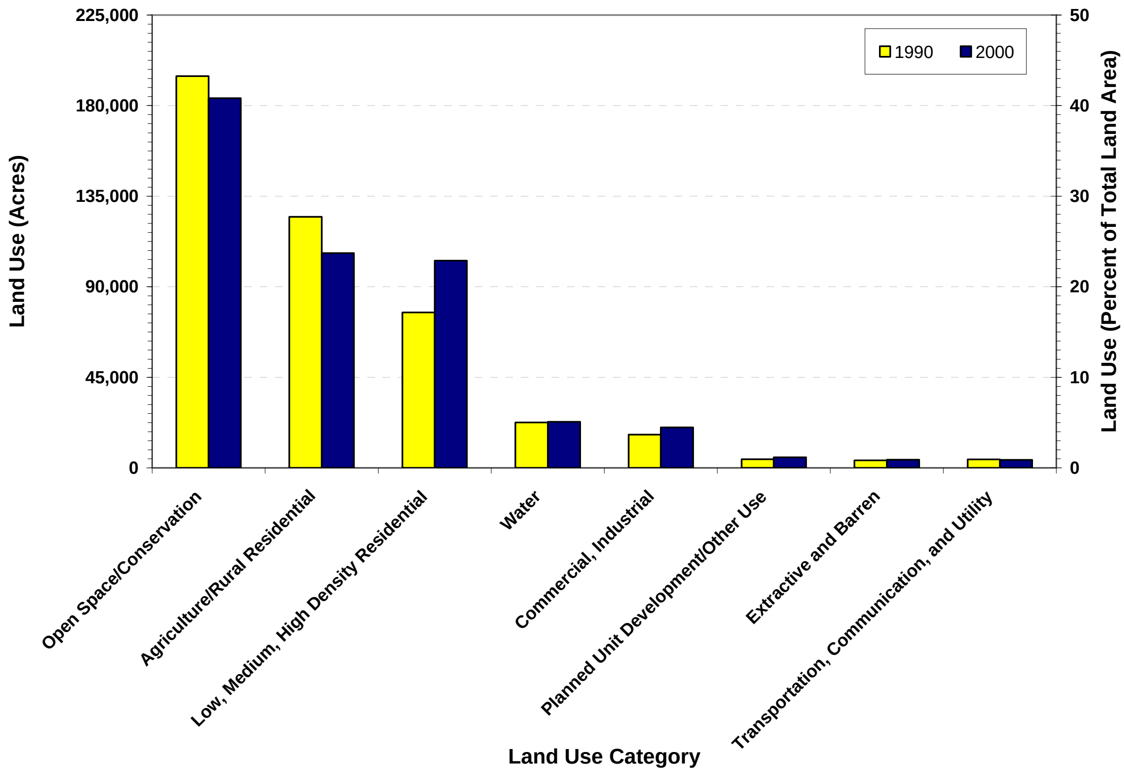
Increasing urbanization results in less infiltration and more surface water runoff. Increases in impervious surfaces prohibit water from infiltrating into the ground to recharge groundwater aquifers. This in turn increases the amount and magnitude of stormwater runoff. In addition to changes in runoff magnitude, water quality changes when urbanization of rural and agricultural land occurs (USEPA 2005a).

Runoff from streets and lawns carries fertilizers, oil, chemicals, grass clippings, litter, pet waste, and sediment into surface waters (SEMCOG 2005). Runoff from rural areas also carries pollutants, depending upon the land-use type, including sediment, fertilizers, animal waste, and other materials contained on the land surface. In addition, construction sites in the urbanizing area have the potential to contribute sediment loads to the watershed during land disturbing activities. Whatever is on the land surface has the potential of ending up in Barton Pond.

Historical changes within the watershed are shown in Figure 6. They show how urbanization has occurred. The development trends show that five percent of the watershed land use changed from agricultural and open space to residential over the 10-year period spanning 1990 to 2000. Between 1990 and 2000 there were reductions of 17,994 acres in agriculture/rural residential land use and 10,999 acres of open space/conservation with nearly corresponding increases of 25,701 acres of residential and 3,618 acres of commercial/industrial land use.

Population projections developed by the Southeast Michigan Council of Governments (SEMCOG) predict a large population increase in the Huron River Watershed. This trend is consistent with the past history of land use changes in the watershed, where agricultural,

FIGURE 6
Huron River Land Use Change Comparison 1990–2000



rural, and open space have given way to increased commercial, industrial, and residential land use. In the 2000 Census, population estimates for the Huron River Watershed totaled 540,000. Population projections completed by SEMCOG estimated a 2030 population of 768,000, representing a 42 percent increase between 2000 and 2030 (SEMCOG 2002). Population projections for the Huron River Watershed are summarized in Table 6.

As population increases and urbanization within the Huron River watershed continues, the effects on Barton Pond without proper controls would include increased peak flows and water quality changes. Properly designed stormwater BMPs can reduce erosion and sediment loads, decrease peak flows, protect water quality, and provide additional infiltration to offset the effects of increased impervious area. Examples of BMPs include silt fences and hay bales during construction and stormwater detention ponds, grass swales, and stormwater infiltration devices after construction.

TABLE 6
2030 Population Estimates for Huron River Watershed

	Population
2000	540,000
2030	768,000
Change	228,000
Percent	42

In the Huron River watershed, stormwater management falls under many jurisdictions, including the Washtenaw County Drain Commission, Ann Arbor, and other municipalities. The Huron River also includes parts of Oakland, Livingston, Ingham, and Jackson Counties.

A review of the Washtenaw County Drain Commission stormwater management requirements showed that the design requirements for new development include peak flow control as well as water quality design components. Consequently, properly designed BMPs would be expected to reduce the impact of urbanization upon the watershed. However, enforcing maintenance requirements of the BMPs appears to be an area which can be improved. Typical maintenance requirements would include inspection for bank stability, removal of sediment build-up, and vegetation management.

The Drain Commission requires that new BMPs submit a maintenance plan, but they lack the resources to inspect and enforce BMP maintenance requirements. In addition, older BMPs did not have a maintenance requirement written into the management plan when they were originally designed. Improperly maintained BMPs will eventually not provide the water quality and quantity benefits that were originally intended. Consequently, while new development BMPs are required in Washtenaw County, without proper maintenance, the beneficial effects will dwindle over time and water quality will degrade in the watershed.

5.3 Agricultural Best Management Practices

While the percentage of the watershed classified as agricultural land use is decreasing (28 percent 1990 to 24 percent 2000), agricultural BMPs can still play an important role in Barton Pond water quality. Mill Creek is a major tributary to the Huron River. The Mill Creek Watershed Plan was developed to primarily address agricultural BMP implementation. The Mill Creek Plan is designed to reduce total suspended solids (TSS) and phosphorus loadings in Mill Creek and the downstream Huron River through the use of filter strips, conservation cover, waste storage facilities, and other agricultural BMP practices. Development pressures in the watershed will reduce the percentage of farmland over time. However, continued application and maintenance of agricultural BMPs can help protect Baton Pond water quality.

Agricultural BMP practices are currently supported through the Washtenaw County Conservation District which draws upon national programs for implementing and funding the practices such as the Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentives Program (WHIP), and Grassland Reserve Program (GRP).

5.4 Recreation Usage

Barton Pond is a multiuse recreation area . The pond is used for recreation activities such as fishing and boating, although access is limited. Recreational goals can compete with Ann Arbor water supply goals. Ann Arbor has a vested interest in working with all Barton Pond users to balance the recreational needs of the area with Ann Arbor's goal of providing high quality drinking water to area residents.

Barton Pond has public access through Barton Park on Huron River Drive, however access for boating is through primarily private property or the Barton Boat Club (BBC). The pond is bordered on the south by a railroad track and bordered on the north by private residences and property owned by Ann Arbor and Barton Village. The limited access to Barton Pond may significantly reduce the amount of recreation that could be possible on the pond. The limited access to Barton Pond serves as a protective measure for source water protection.

The BBC is a public sailing club located on the north shore of Barton Pond. It is an independent boating club that leases property from Barton Village for boating access to Barton Pond. The BBC has hosted several regattas between May and October for about

30 years. However, boating activities have been significantly hampered since EWM invaded Barton Pond several years ago. EWM is a non-native aquatic plant species which can have adverse affects on beneficial uses of Barton Pond because the plant forms dense mats which block out other native aquatic plants and can even prevent boats from moving. EWM is discussed in detail in the Invasive Species section.

Methods to control EWM by chemical or mechanical means raise concerns over introducing chemicals into a water supply source and potentially clogging the water intakes with aquatic plant fragments. Additional information on EWM and potential management techniques are discussed in detail in the Invasive Species section.

5.5 Eutrophication

Eutrophication has long been a concern for portions of the Huron River, especially in Ford and Belleville Lakes downstream of Barton Pond and Ann Arbor. In 1975, USEPA estimated that phosphorus loading into Ford Lake was seven times higher than that necessary to produce eutrophic conditions (USEPA 1975).

In 1987, the Water Resources Commission of the State of Michigan set a goal of 30 micrograms per liter of total phosphorus for Belleville Lake in an effort to achieve the designated use of the lake for sport and recreation. Nuisance algal blooms each summer had become regular and severe. The nuisance blooms consisted of blue green algae belonging to species known to produce toxins. In direct response to the conspicuous problems, MDEQ proposed in 1996 a Total Maximum Daily Load (TMDL) for phosphorus in both Ford and Belleville Lakes. Nuisance algal blooms have not been a documented problem in Barton Pond, however filamentous algae and diatoms have been observed.

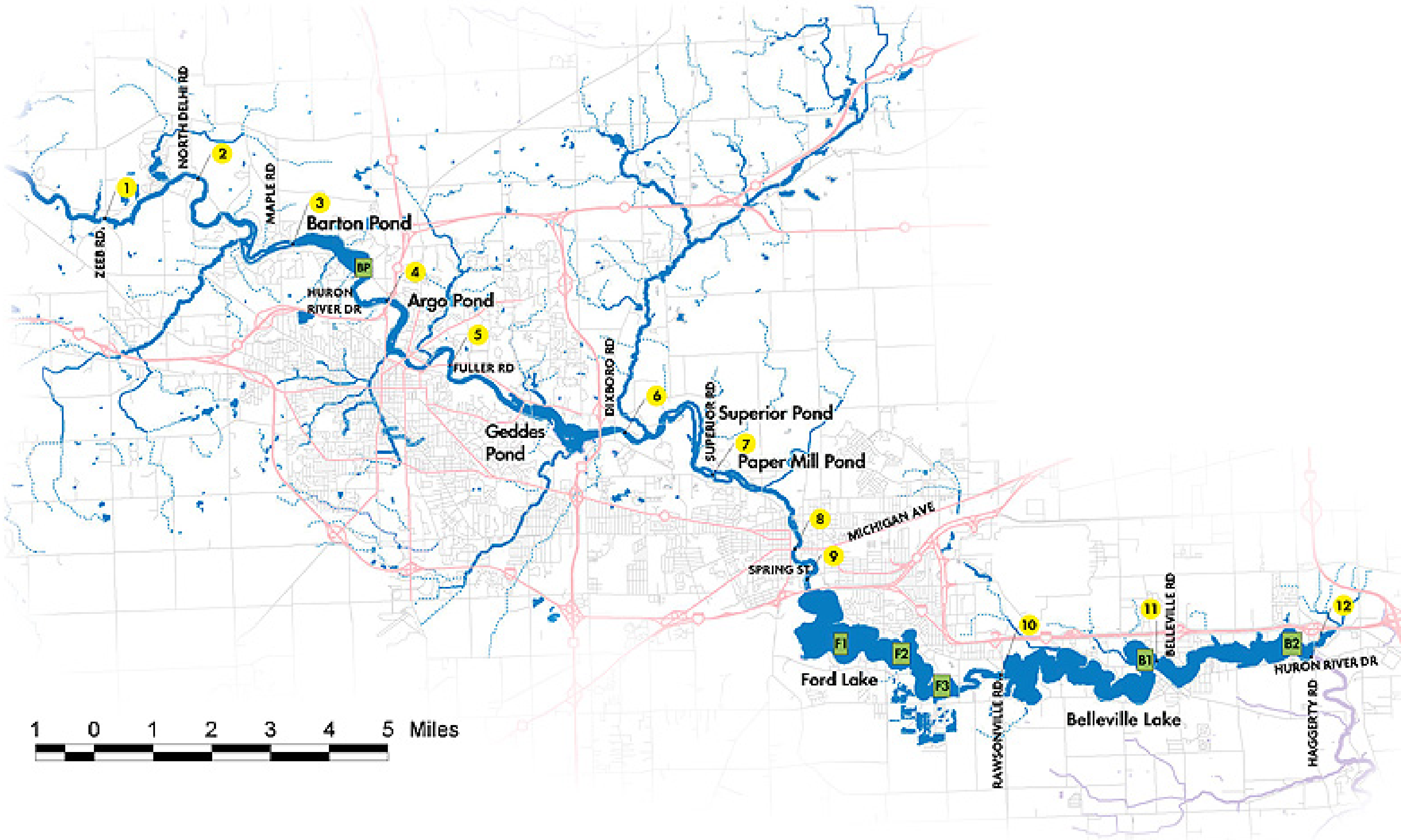
In response to urging by MDEQ, 21 communities along the middle Huron River joined in a voluntary pollution control effort called the Middle Huron Initiative (MHI). The MHI built upon phosphorus loading estimates assembled by MDEQ personnel and set about to find ways to reduce phosphorus loading to 50 percent of 1995 levels within the middle Huron River (Mill Creek 2003).

These goals have been established to return Ford and Belleville Lakes to their designated uses. Reducing the phosphorus load within the middle portion of the Huron River is expected to improve the water quality conditions in Barton Pond in addition to the conditions downstream in Ford and Belleville lakes.

5.5.1 Ongoing Research and Findings

Ongoing water quality monitoring has been occurring on the Huron River, stretching from upstream of Barton Pond to downstream of Ford and Belleville Lakes, as part of a research project at the University of Michigan (led by Dr. John Lehman). Dr. Lehman's research has included gathering water quality information, determining nutrient thresholds at which nuisance algal populations start to thrive, and studying potential management actions to restore the lakes. As part of these efforts, water quality data has been gathered at the locations shown in Figure 7. Data collection at Barton Pond was intended to provide control or reference water quality information for comparison with the conditions downstream in Ford and Belleville Lakes.

FIGURE 7
Water Quality Data Locations



Data collection has included the following parameters: ammonium, nitrate, dissolved nitrogen, particulate nitrogen, total nitrogen, soluble molybdate reactive phosphorus, dissolved phosphorus, total phosphorus, color, specific conductance, pH, and flow at the USGS Wall Street gage in Ann Arbor. In Barton Pond, as well as in Ford and Belleville Lakes, measurements have also included chlorophyll *a*, a pigment common to all algae, and phycocyanin, a pigment specific to blue greens.

Research has indicated that nuisance blue green algae can dominate other algae species when the ratio of nitrogen to phosphorus mass (N:P) drops below roughly 30. Nuisance algal species primarily occur during low flow conditions in the hot summer or early fall months. Figures 8 and 9 show the N:P ratio at Ford Lake and Barton Pond, respectively.

When the Huron River flow is low, it takes longer for the water to travel through the Barton Pond impoundment. The warmer conditions also correspond to higher decay rates for detritus in the impoundments, which exert an oxygen demand and reduce the oxygen levels. When conditions become anaerobic at the bottom of the impoundments, phosphorus normally bound to iron within the sediments becomes mobile and can tip the N:P ratio to a condition where nuisance algae becomes dominant.

From observation, atmospheric conditions also play a role in nuisance algal blooms. Windy weather or a storm front can produce mixing within the impoundment. After anaerobic conditions cause phosphorus release from the sediments, the mixing caused by the storm front can spread the phosphorus throughout the water column and into the surface water where sunlight is also available. Once the right nutrient conditions are available for the nuisance algae, an algal bloom and nuisance conditions can occur.

Another factor which influences algae production is invasive species. The zebra mussel is a documented invasive specie in Barton Pond. Zebra mussels strain small particles from the water column which results in clearer water. The clearer water in turn allows deeper sunlight penetration which provides more area for rooted aquatic plants and algae to grow. Increased plant production may result in more detritus from plant decay, which in turn can create organic-rich sediments with high oxygen demand furthering development of anaerobic conditions during hot low flow periods. Additional discussion can be found in the Invasive Species section.

The observations at Ford and Belleville Lakes have direct application to Barton Pond. The same N:P ratio at which nuisance algae become the dominant species in Ford and Belleville Lakes applies to Barton Pond. Lessons learned at these downstream lakes can help predict the conditions that could lead to nuisance algal blooms in Barton Pond; they can also identify management strategies to reduce the impact of nuisance algal potential.

From data assembled by Dr. John Lehman, Barton Pond appears to be on the edge of developing nuisance algal conditions. Figure 9 shows how the N:P ratios vary in Barton Pond over time. The anaerobic conditions which result in additional phosphorus entering the water column from the sediments is at times on the verge of occurring, as shown in Figure 10.

FIGURE 8
Comparison Data from Ford Lake

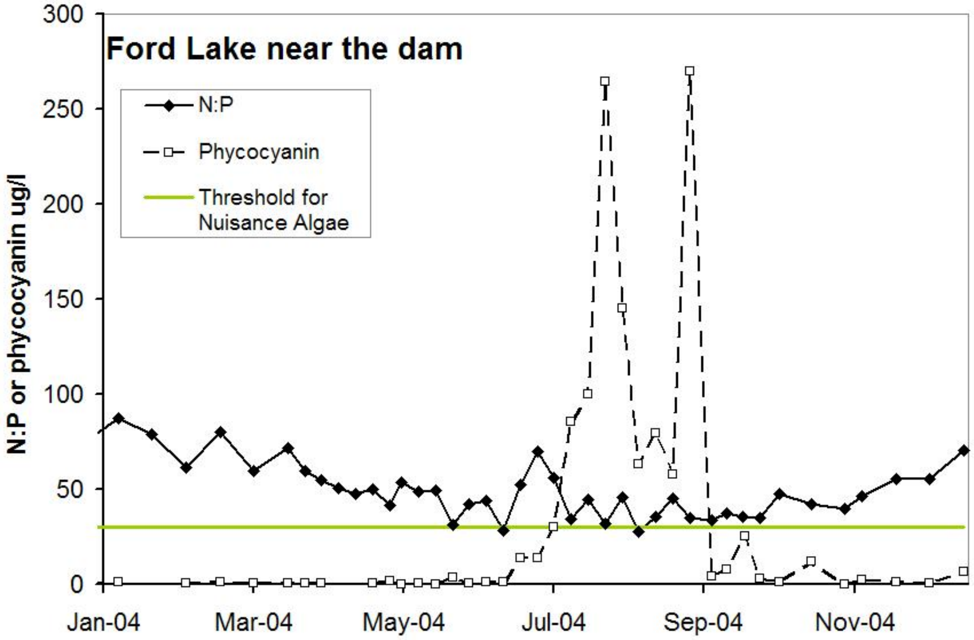


FIGURE 9
Comparison Data from Barton Pond

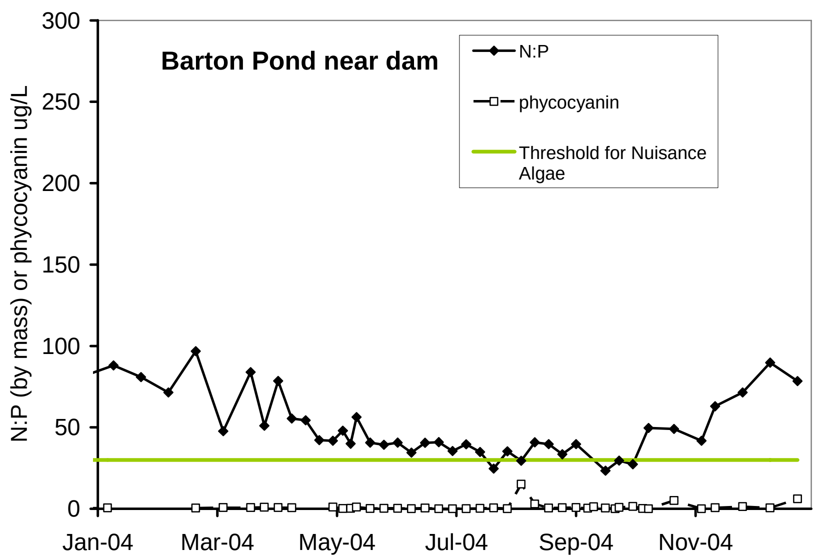
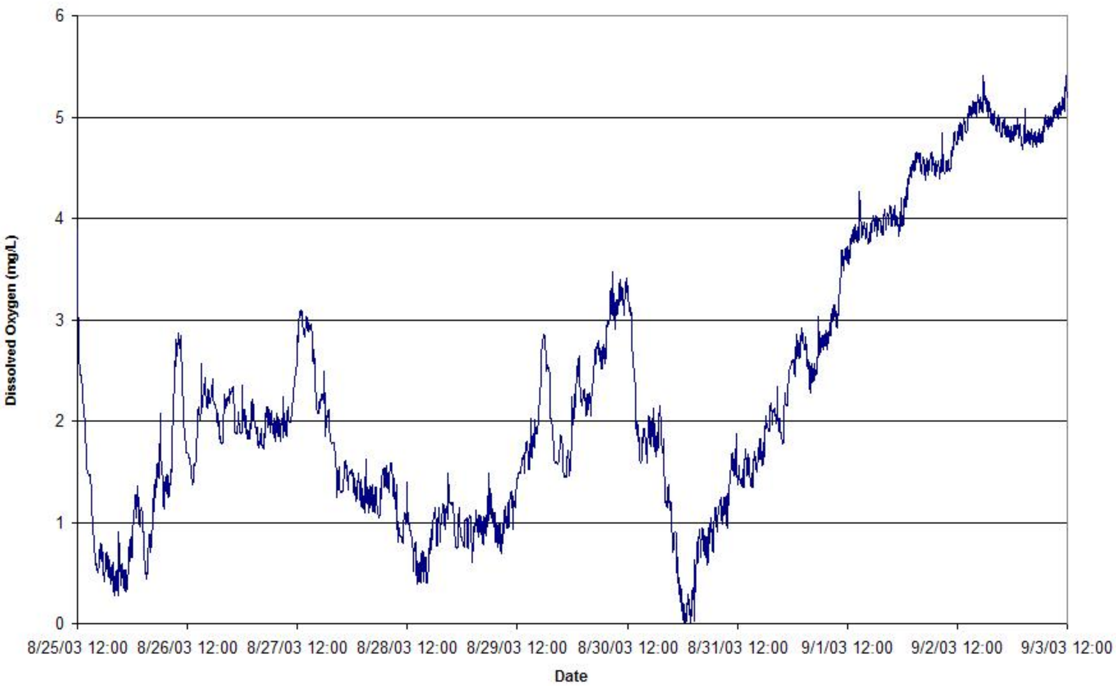


FIGURE 10
Barton Pond Dissolved Oxygen Concentration at Intake—20-foot Depth



5.5.2 Potential Management Strategies

Multiple strategies that have potential application to Barton Pond have emerged to control the nuisance conditions being experienced at Ford and Belleville Lakes. They include both regulatory efforts and management efforts.

Oxygen Control. Several strategies have emerged to reduce the potential of anaerobic conditions that develop in the impoundments. These strategies include modifications to the impoundment outlet to promote mixing and to directly add oxygen into the reservoir. The outlet structure at Ford Lake is controlled during low-flow conditions through an overflow weir. The dam draws water from the lake surface and not from potentially oxygen deficient water at the bottom of the lake. A retrofit of the outlet is being considered as part of the algal management strategy. Options that may be evaluated include baffles or other means to increase the amount of water drawn from lower depths in the lake and consequently discourage anaerobic conditions by rapidly flushing with oxygen-rich waters. The findings of the Ford Lake dam retrofit study could have potential implications for Barton Pond and should be reviewed in the future.

The location of the 36-inch primary intake in Barton Pond might currently benefit oxygen concentrations. Barton Pond has a slight vertical temperature stratification during the summer which reduces mixing of oxygen rich water at the pond surface with oxygen depleted water at the pond bottom. The intake, located towards the bottom of Barton Pond, may actually help flush oxygen-depleted water from the pond and reduce the potential for anaerobic conditions to develop.

Should anaerobic conditions in Barton Pond become more severe, increasing the amount of water drawn from the pond bottom during low flow conditions could prove beneficial. The findings of the Ford Lake dam retrofit study could have potential implications for Barton Pond and should be reviewed in the future. Any changes to the Barton Pond dam, however, may require significant environmental permitting efforts (Federal Energy Regulatory Commission, MDEQ) and should be evaluated for safety, impact on power generation, and public acceptance.

A second management option that has been proposed for research study is utilizing hyperbaric oxygen injection to areas most likely to face oxygen shortages. With this technology, supersaturated oxygen is pumped into the lake strata that face potential oxygen depletion. The process utilizes special laminar flow nozzles to aid oxygen dispersion directly into the water column by preventing oxygen bubbles from forming. This technology has been applied in Canada with some success (OCETA 2005). Dr. John Lehman is currently planning a small scale pilot study of the technology for potential future application on Ford or Belleville Lake. This technology could also be evaluated based upon research findings if oxygen conditions in Barton Pond drop in the future.

TMDL Requirements. TMDL requirements have been set for both point and nonpoint phosphorus sources (MDEQ 2004a). The TMDL has set phosphorus loading reduction requirements for the months of April through September, which is the primary algae season. In order to achieve these goals, nonpoint source reductions of over 50 percent are needed in addition to the point source reductions. The Water Utility can advocate for phosphorus management practices to protect Barton Pond from developing nuisance algal conditions. Methods of control may include a stormwater ordinance that limits the amount of phosphorus discharged from new development, redevelopment, and from agricultural land; a public education program to provide additional benefits that may not be covered in a stormwater ordinance; and inspection and maintenance of existing stormwater quality BMPs.

Monitoring. The monitoring associated with Dr. John Lehman's research has documented current water quality conditions along the middle Huron River as well as the thresholds at which nuisance algal blooms are likely to occur. This information provides a baseline not only for the present condition of Barton Pond, but also for the characteristics of the water flowing into the Pond from points upstream. The results offer insight into management options available for counteracting potential nuisance algal growths. Adapting the findings and methods to Barton Pond water quality monitoring could proactively identify and counteract the effects of nuisance algal blooms.

Monitoring also provides a baseline reference and standard for discovering trends in water quality. As development proceeds upstream of Barton Pond and various changes occur in the watershed over time, having strong water quality trend information could be very helpful in water quality management.

Other Management Strategies. In addition to the strategies outlined above, other options exist if the water quality in Barton Pond degrades to the point where nuisance algal conditions exist. Aeration, using mechanical methods or oxygen diffusers, is an option that could be used if Barton Pond water quality degrades. Alum treatment for binding phosphorus to the sediments has been another management strategy that could be considered if trends show an increase in anoxic conditions in Barton Pond over time. Alum treatment would require environmental precautions for treatment dosages and a strong public involvement process; however, it could prove to be a useful tool.

Watershed protection activities could also provide water quality benefits to Barton Pond by reducing sediment deposition and nutrient loadings. This will be discussed in a separate technical memorandum.

5.6 Invasive Species

Invasive species are known to occur in Barton Pond. These species have caused negative but manageable impacts to Barton Pond as a water supply source. The two main invasive species are the zebra mussel and EWM.

5.6.1 Zebra Mussel

The zebra mussel (*Dreissena polymorpha)* is a small, fingernail-sized mussel native to the Caspian Sea region of Asia. They are believed to have been transported to the Great Lakes through ship ballast water (GLIN 2005). While some ducks and other waterfowl are known to eat zebra mussels, they do not eat them at levels necessary to control them and no other natural predators exist in this area of the world. The mussels tend to biofoul and restrict the flow of water through intake pipes and can disrupt water supply infrastructure. The mussels also attach to boat hulls, docks, locks, breakwaters, and navigation aids, increasing maintenance costs and impeding waterborne transport.

The zebra mussel filters out small particles in the water column to feed. Zebra mussels are filter feeders and can process up to 1 gallon of water per day per mussel. This feeding ability, in combination with high population densities, rapidly clears the water of even the largest lakes. This can lead to poor water quality conditions. For example, since zebra mussels became established in Lake Erie, water clarity has increased from 6 inches to 30 feet in some areas. The increased water clarity allows light to penetrate to and establish aquatic plants and algae at depths deeper than what would normally occur (USGS 2005). This increased plant growth can cause problems for recreational boaters and swimming beaches, increase taste and odor problems in drinking water supplies, and clog water supply intake pipes.

The zebra mussels were first documented in Barton Pond in 1994. Since then, they have dramatically increased in numbers and appropriations have been necessary to prevent them from disrupting Ann Arbor’s raw water supply pipeline.

Control Methods. Control methods for zebra mussels have centered on preventing water intakes from clogging. Ann Arbor controls the growth of zebra mussels for the two water intakes in Barton Pond by adding polymer, which prevents the establishment and growth of zebra mussels in the pipe. Once established in the water body, however, no control method is available today which will selectively remove zebra mussels from the water body.

5.6.2 Eurasian Water Milfoil

EWM (*Myriophyllum spicatum*) is a submerged aquatic plant native to Europe, Asia, and northern Africa. It has slender stems with submerged feathery leaves and small flowers. EWM grows best in fertile, fine-textured, inorganic sediments (MDEQ 2004b). It has a history of becoming dominant in eutrophic, nutrient-rich lakes, although this pattern is not universal. EWM prefers highly disturbed lake beds with high nitrogen and phosphorus levels in the sediments and water column. EWM is most commonly spread by boats, motors, trailers, bilges, live wells, and bait buckets (WDNR 2005). EWM is thought to have been introduced to the U.S. through the aquarium industry.

EWM is an invasive aquatic plant to Barton Pond. Over the past several years, EWM has become a well established nuisance plant in Barton Pond. The combination of the clearer water caused by zebra mussels and the nutrient-rich sediment and water column allows aquatic plants to grow to deeper depths and densities than what would otherwise occur.

The adverse affects of EWM on Barton Pond are typical of experiences elsewhere. Dense stands of EWM inhibit recreational uses like swimming, boating, and fishing. In other locations, EWM stands are dense enough to obstruct industrial and power generation water intakes. Cycling of nutrients from sediments to the water column by EWM may lead to deteriorating water quality and algae blooms of infested lakes (WDNR 2005). Ann Arbor has anecdotal evidence of operational difficulties with EWM in Barton Pond. During a year with heightened EWM management activities in Barton Pond, Ann Arbor had to clean the raw water intake more frequently than under normal conditions (Skadsen 2005).

The Barton Pond boating community has also been negatively impacted by the EWM. For approximately 30 years, the BBC has held annual regattas for two different boat classes in Barton Pond. It attracted as many as 50 boats in the past, but in recent years attendance has diminished to under 20 participants. The BBC has only held a couple of events since 2000 because of the EWM. Regattas are now only held in early spring or fall when the EWM is not as thick. In recent years, sailing has been limited to May and September because of overwhelming weed density in July and August (BBC 2004).

EWM has the potential of reducing the storage volume in Barton Pond through build-up of detritus and sedimentation. EWM provides additional surface area for removing suspended sediment from the water column and the mass of EWM may build up over time in Barton Pond. This could result in shallower water depths in Barton Pond over time. If areas that are currently too deep for EWM establishment become shallower, EWM will colonize over time. If effective and acceptable EWM control methods can be utilized on Barton Pond, it will help in the long-term management of Ann Arbor’s water supply infrastructure.

Control Methods. Multiple control methods exist for EWM, including chemical application, reservoir management techniques, mechanical control, and biological control (WAPMS 2005). Because Barton Pond is a drinking water reservoir, the control methods are limited to ensure that the raw water will not adversely affect the treatment processes and finished water quality.

Chemical applications can include 2,4-dichlorophenoxyacetic acid (2,4-D), diquat, diquat and complexed copper, endothall dipotassium salt, endothall and complexed copper, fluridone (Sonar®), and triclopyr. Although these chemicals have been successfully used to eradicate EWM, they are not selective to just EWM and can threaten native plant species. More importantly, chemical addition can negatively affect the water quality of Barton Pond, treatment processes, and finished drinking water quality after treatment at the City of Ann Arbor WTP. In 2001, the BBC researched applying chemical methods for EWM control. The

BBC filed an application with the MDEQ but the application was denied due to concerns about the effects on the source water for the City of Ann Arbor WTP.

Mechanical control methods can include cutting, harvesting, and underwater rototilling (rotovation). Mechanical controls are typically used only when the extent of the infestation is such that all available niches (habitat) have been filled by EWM. Mechanical controls can enhance the EWM rate of spread because EWM can spread rapidly due to fragmentation. Because of Barton Pond's size and the large extent of EWM, mechanical methods are not practical. In addition, harvesting EWM can cause clogging problems in the raw water intake.

Reservoir management techniques can include periodically drawing down the reservoir during cold periods. The success of a drawdown is dependent on several factors such as degree of desiccation, the composition of pond substrate, air temperature, and the presence of snow. Due to the relatively shallow depth of Barton Pond, periodic reservoir drawdown may provide some EWM relief. Prior to drawing down Barton Pond to control EWM, the following aspects should be further evaluated: economic impact of reducing the amount of hydroelectric power generated; effect a drawdown would have on raw water pumping capability; potential of EWM breaking off after the pool level is restored and clogging the intakes; and permitting process with FERC, the Corps of Engineers, and MDEQ for reservoir management and natural resource impacts. If these potential concerns can be effectively managed, reservoir management is a technique that offers good potential for controlling EWM in Barton Pond when compared to the limitations associated with chemical and mechanical EWM removal.

Biological controls can include insects and grass carp. Carp have been used in many applications, however EWM is neither highly palatable to nor preferred by carp. EWM control with grass carp generally requires the total removal of more palatable native aquatic species before the grass carp will consume EWM. In situations where EWM is the only aquatic plant species in the lake, this may be acceptable; however this is not the case in Barton Pond. Generally grass carp are not recommended for EWM control and would likely be opposed by MDEQ due to the potential for introducing an invasive species to the Great Lakes.

Insects are also a form of biological control of EWM. The milfoil weevil (*Eurhychiopsis lecontei)*, an herbivorous weevil native to North America, is a small beetle which eats milfoil in the larval stage. Adult weevils feed on the stems and leaves and females lay their eggs on the EWM. The larvae bore into the stems and cause extensive damage to plant tissue before pupating and emerging from the stem. Three generations of weevils hatch each summer, with females laying up to two eggs per day. Because the weevil prefers EWM, other native aquatic plant species are not at risk from the weevil's introduction (WDNR 2005).

In 2001, the BBC received a permit to apply the weevil process in Barton Pond. In the spring of 2001, the first application of weevils in Barton Pond occurred. The weevils were stocked at a rate of 2,000 to 3,000 per acre of weed bed at four different sites totaling 2 to 3 acres. An additional stocking was conducted in 2002 with monitoring occurring after the first application through 2003. The total cost for the applications was roughly $16,000.

Results of the stocking indicated a significant reduction in EWM in the areas of application (EnviroScience 2004). However, the success in controlling the EWM with weevils did not meet expectations since the weevils did not spread beyond their initial application zones. The BBC application of the weevils was conducted on a small scale that proved to be successful where applied. This form of control would also be favored over chemical and mechanical EWM removal. Applied in combination with reservoir management, weevil application might provide significant benefits to Barton Pond if introduced on a larger scale and is worth exploring further.

5.6.3 Other Invasive Species

Barton Pond is also affected by curly-leaf pondweed. Curly-leaf pondweed (*Potamogeteon crispus*) is distinguished from other aquatic plants by undulating (or "curly") leaf edges. Curly-leaf pondweed has been long established in Michigan and has predated most other well-known invasive aquatic plants, including EWM. It can be found in the Great Lakes as well as many, if not most, inland lakes and rivers, and can form dense mats of vegetation, much like EWM. Curly-leaf pondweed has also contributed to the boating restrictions on Barton Pond (BBC 2004). Chemical control and mechanical harvesting have been used to control this species, but such measures are not without related adverse ecological impacts as discussed above (MDEQ 2004b; TNC 2005).

Other invasive species recorded in Michigan, but not necessarily in Barton Pond, include Eurasian ruffe (*Gymnochephalus cernus*) and round goby (*Neogobus melanostomus*), two bottom dwelling fish; spiny water flea (*Bythotrephes cederstroemi*); and fishhook water flea (*Cercopagis pengoi*) (TNC 2005). Rusty crayfish (*Orconectes rusticus*) have been identified as being sold as bait in the Chelsea area of Washtenaw County, but there are no records of the crayfish populating Barton Pond (MDNR 1995).

There are several other aquatic invasive species in Michigan and in the Great Lakes Basin, however, from our current understanding of the impacts of these invasive species, they do not pose as big of an influence on Barton Pond as the zebra mussel and EWM. Ann Arbor should continue to track invasive species sampling and reporting programs conducted by MDNR, and should re-evaluate monitoring efforts for Barton Pond if the invasive species distribution changes from the current zebra mussel and EWM populations.

5.6.4 Recommended Invasive Species Control Methods

It is recommended that control methods for EWM be further studied. If the potential drawbacks of EWM control can be managed, the most promising control methods for Barton Pond include reservoir management, weevil control, or a combination thereof. The area of Barton Pond that could be potentially controlled through various drawdown depths could be analyzed. Other factors that should be considered include: the impact on hydropower generation for an extended drawdown, raw water pumping capability with the drawdown, intake clogging potential, public outreach to Barton Pond landowners and recreational users, safety precautions, and resulting environmental impacts. Partnerships with BBC and other interested stakeholders should be pursued, if implemented, to identify funding sources and to develop prioritized areas for EWM control.

Zebra mussel control at the intake pipeline is currently through polymer addition. It is recommended that this practice be continued.

5.7 Watershed Items of Concern

A Source Water Assessment Plan (SWAP) was developed for the City of Ann Arbor's water supply system through collaboration between the USGS, MDEQ, and the Ann Arbor Water Utility Department (USGS 2004). The purpose of the SWAP was to determine the sensitivity and susceptibility of Ann Arbor's surface water system to potential sources of contamination. The SWAP completed an analysis that identified potential contaminant sources (PCS) within a susceptible area of Barton Pond and its tributaries. The susceptible area for Barton Pond in the vicinity of Ann Arbor is shown in Figure 11 (USGS 2004) and comprises three areas:

- The critical assessment zone, which is a 3,000-foot arc centered on the raw water intake in Barton Pond (penstock in dam); the critical assessment zone extends radially upstream of the intake to identify an area from the intake structure to the shoreline and inland
- Barton Pond and all tributary surface waters
- A 300-foot buffer extending inland from the shoreline of the tributary surface waters (MDEQ 1999)

The PCSs identified by the SWAP were developed by querying several databases from the USGS, MDEQ, Michigan Department of Transportation, and USEPA. Past, current, and potential future sources of contaminants were inventoried in the SWAP to identify categories of potential sources of contaminants including microorganisms, inorganic and organic compounds, and disinfection byproduct precursors. The PCSs in the susceptible area that were identified in the SWAP are shown in Attachment 2 (USGS 2004). It is important to note that this list represents sources that have the potential to contaminate surface water and it does not suggest that contamination has occurred from these sources.

The PSC sites included WWTPs, automotive refueling and service stations, dry cleaners, automotive and accessory facilities, and medical supply facilities. The facilities were listed in three broad categories including Industrial Facilities Discharge Sites, Permit Compliance System Facilities, and Hazardous or Solid Waste Sites. The PCS list developed in the SWAP (Attachment 2) identified the potential sources of contaminants but did not identify the types of contaminants that could affect the water supply.

The PCS information developed in the SWAP was used to identify the types of potential contaminants (that is, gasoline, diesel fuel, dry cleaning fluid, etc.) in the susceptible area. The MDEQ, USGS, and USEPA were contacted to discuss the available databases that would document contaminant information for the facilities identified in Attachment 2. There is no comprehensive record keeping with the agencies that documents the chemical inventory at the permitted facilities. Instead, the databases record information about the facility name and owner, facility operations, and discharge permit requirements. Consequently, the contaminants listed for facility categories were developed based upon permit monitoring and not where pollutants were definitely present. Determining exact materials present would be an extremely large undertaking, and onsite materials would change over time as the businesses and industries change at the site. Using an approach to identify general pollutant types at PSC locations provides Ann Arbor the ability to focus limited resources on potential contaminants with a higher chance of being present in the raw water supply.

The following databases were queried to help identify potential contaminants in the susceptible area:

- Permit Compliance System
- Toxics Release Inventory (TRI)
- Michigan Waste Data System (WDS)
- North American Industry Classification System (NAICS)

Permit Compliance System. The Permit Compliance System database allows the query of the Envirofacts database for facilities holding National Pollutant Discharge Elimination System (NPDES) permits (USEPA 2005). The database has information about NPDES permitted discharge constituents for some of the facilities identified in Attachment 2. The database does not provide an inventory of contaminants stored onsite.

Toxics Release Inventory. The TRI is a publicly-available USEPA database that contains information on toxic chemical releases and other waste management activities reported annually by certain industry groups and federal facilities. The TRI queries the same Envirofacts database as the Permit Compliance System and therefore contains similar information about potential contaminants at a facility, but it is still useful to consider both sets of information.

Michigan Waste Data System. The Michigan WDS tracks activities at facilities regulated by the Solid Waste, Scrap Tire, Hazardous Waste, and Liquid Industrial Waste programs (MDEQ 2005). The Michigan WDS has facility information about site activities, NAICS codes, size of facility and any violations at the facility. The database does not provide an inventory of contaminants stored onsite.

North American Industry Classification System. Where additional information was needed for each facility that was not included in other databases, the NAICS codes were used to better identify the operations at each facility (NAICS 2005). From the NAICS codes, the facilities were classified by their type of business. Previous experience and knowledge of the facility classifications was used to predict potential contaminants for the facilities (VDH 1999).

Using information from the databases and past project experience in Virginia, the PCS list developed in the SWAP was updated with potential contaminant types. The list was further updated by identifying potential analytes that could detect the presence of the potential contaminant. The updated table with the potential contaminants and analytes for each facility is shown in Attachment 3.

A query of the databases indicated that several of the facilities were out of business or that they no longer generated waste. Although the facility may be out of business or has stopped generating waste, the databases do not indicate if onsite storage of potential contaminants has ceased. The facility may still be a PCS if contaminants are still present in storage tanks, process equipment, etc. The WWTPs in the susceptible area have similar NPDES monitoring requirements and contain similar types of onsite bulk storage. The potential contaminants for the WWTPs are lumped together and apply to each WWTP.

Table 7 lists the most frequent occurrence of potential contaminants. The list was generated by occurrence in the watershed and the amount of area the facility covers in the watershed. There was a high number of automotive refueling and manufacturing facilities in the

TABLE 7
Most Frequent Occurrences of Potential Contaminants

Facility Type	Occurrence in Susceptible Area	Contaminants and Analytes
Automotive Refueling and Repair	High	Solvents, VOCs, SVOCs, TPH, metals
Manufacturing Facilities	High	Solvents, VOCs, SVOCs, metals
WWTP	High	Fecal coliforms
Agriculture	High	Pesticides/herbicides

susceptible area and a large area of agricultural land use. There were also several WWTPs upstream of Barton Pond.

The contaminant type and analytes that would indicate the presence of a contaminant are also summarized in Table 7. These parameters are intended to provide an indication that a contaminant exists in the system. For example, if a water sample was drawn to determine if a WWTP has polluted the water supply, a fecal coliform sample may provide the best indication of water contamination. Other parameters could be used, such as total suspended solids (TSS), chloride, or BOD; however these parameters may not be appropriate or could have fluctuations in the source water from events other than a WWTP problem. TSS and BOD would not be an appropriate parameter because natural fluctuations may vary widely during storm runoff events and high river flow. Chloride would not be an appropriate parameter because high chloride values are seen during winter road salting activities. In addition, TSS, BOD, and chloride do not present a significant risk to the Ann Arbor water treatment processes. BOD would be a surrogate for *E. Coli*, which would in turn be a surrogate for fecal coliform or other potential pathogens. Fecal coliforms occur naturally in the environment and can be removed by the Ann Arbor water treatment processes. However, testing for large fluctuations may provide an indication of significant changes in the watershed, specifically at an upstream WWTP and be indicators of other potential pathogens.

A few additional analytes can be used to detect the presence of other watershed pollution. VOCs can be used as an indicator for contamination from the large number of automotive and manufacturing facilities in the susceptible area. Using VOCs as an analyte would indicate the presence of organic compounds in the water system and could indicate petroleum or solvent products. Although the VOC measurement would not specifically identify the pollutant in the water, it would act as an indicator that a pollutant had entered the system and possible further sampling and chemical analysis should be completed.

The SWAP did not explicitly identify a potential contaminant source for the railroad along the south bank of Barton Pond, however many of the potential contaminants identified elsewhere in the watershed are similar to those of the railroad. The railroad presents a unique hazard because it is directly adjacent to Barton Pond and continues upstream along the Huron River for several miles to Dexter, Michigan. The railroad remains in the watershed for several additional miles as it continues west from Dexter through Chelsea, Michigan. The railroad has the potential to contribute a concentrated and direct discharge into Barton Pond and Huron River were an accident to occur at a point where the railroad runs directly adjacent to the water bodies. Table 8 identifies a list of potential contaminants that are presented by the railroad (CSX 2005; CONRAIL 2005; Norfolk Southern 2005). This list is expected to vary over time based on railroad customers.

5.7.1 Emerging Issues

In addition to the land use and industry contained within a watershed used for a water supply source, there has been an increasing interest in the presence of pharmaceuticals and personal care products (PPCPs) and endocrine disrupters (EDCs) in source water supplies. PPCPs and EDCs enter the environment through:

TABLE 8
Potential Cargo Freight Contamination Posed by Railroad Adjacent to Barton Pond and Huron River

Agricultural fertilizers, herbicides, pesticides
Automobiles
Raw chemicals and chemical wastes
Petroleum Products
Coal
Metals

- Discharge from wastewater treatment processes such as treatment plant or septic systems
- Regulated and unregulated industrial discharges to surface and groundwater
- Leaking or overflowing animal waste storage from confined animal feeding operations
- Land application of treated animal waste from certain animal feeding operations

Currently, other researchers are evaluating the environmental effects of human and aquatic exposure to PPCPs and EDCs.

Ann Arbor conducted monitoring for a 22-compound target list of PPCPs and EDCs at various locations within the City of Ann Arbor's water use cycle (Ann Arbor 2004). Follow-up testing is being conducted in 2005. The monitoring indicated variability in the reduction of compounds through the water and wastewater treatment processes.

As additional research becomes available on the environmental exposure effects and potential control strategies of PPCPs and EDCs, Ann Arbor should evaluate and build upon the information already obtained during the 2004 monitoring study to determine appropriate water treatment responses.

5.8 Monitoring

The source water quality monitoring approach for Ann Arbor was reviewed, with particular attention paid to information contained in the watershed susceptible area, known water quality interactions in Barton Pond, and groundwater sampling efforts. The existing monitoring program was first reviewed and then compared to known activities and trends in the watershed; this information will be used for future monitoring recommendations. Early warning systems related to security issues are addressed separately as part of the Source Water Online Monitoring Technology Evaluation technical memorandum (Attachment 4).

5.8.1 Existing Monitoring Program

The current sampling program for Ann Arbor source water is summarized in Table 9 below. The only online equipment dedicated to monitoring the source water is a turbidimeter on the Barton Pond influent. The remaining samples are grab samples. At least once a month, basic parameters such as nitrate, phosphorus, and total organic carbon are analyzed in both the groundwater wells and Barton Pond. On a less frequent basis, more exotic parameters such as metals, organics, herbicides, and gross alpha and beta from Barton Pond and the well water supplies are sampled.

TABLE 9
Summary of Current Source Water Sampling Program at the Ann Arbor Water Utility

Wells		Barton Pond Influent	
Parameter	**Frequency**	**Parameter**	**Frequency**
Nitrate	2xMonth	Turbidity	Continuous, online
Nitrite	Weekly	Nitrate	2xMonth
Ammonia	Weekly	Nitrite	Weekly
Phosphorus	2xMonth	Ammonia	Weekly
Total Solids	Monthly	Phosphorus	2xMonth
Sulfate	2xMonth	Total Solids	Monthly
Chloride	2xMonth	Sulfate	2xMonth
Sodium	Monthly	Chloride	2xMonth
Conductivity	Monthly	Sodium	Monthly
Iron, Copper	Monthly	Conductivity	Monthly
Lead	Monthly	Iron, Copper	Monthly
TOC	Weekly	Lead	Monthly
UV254	Monthly	TOC	Weekly
Alkalinity	8 hrs	UV254	Monthly
Calcium	8 hrs	*E-coli*, *Enterrococcus*	Weekly
Fluoride	Daily	Chlorophyll, Algae	Weekly
Hardness	8 hrs	*Giardia*, *Cryptosporidium*	Monthly
Magnesium	8 hrs	Alkalinity	8 hrs
pH	8 hrs	Calcium	8 hrs
Coliform	Monthly	Fluoride	Daily
Metals[a]	Annually	Hardness	8 hrs
VOCs	Annually	Magnesium	8 hrs
Pesticides/herbicides	Annually	pH	8 hrs
Select metals, gross alpha and beta, organics, herbicides	Every 3 to 5 Years	Coliform	Monthly
		Metals[a]	Annually
		VOCs	Annually
		Pesticides/herbicides	Annually
		HPC	Daily
		Bromide	Monthly
		Color	Daily
		Odor	Daily
		Select metals, gross alpha and beta, organics, herbicides	Every 3 to 5 Years

[a] Metals comprise the following: aluminum, antimony, beryllium, barium, cadmium, copper, chromium, iron, lead, mercury, manganese, nickel, selenium, silver, thallium, and zinc.

In addition to the sampling parameters identified in Table 9, Ann Arbor also conducts sampling at three locations in Barton Pond twice per month from May to October. This additional sampling addresses the health of the lake. Parameters that are monitored include Secchi depth, dissolved oxygen, temperature, nitrate, nitrite, ammonia, phosphorus, algae, chlorophyll, *E-coli*, and *Enterococcus*.

5.8.2 Proposed Sampling

The Utility's existing water quality sampling program is fairly robust and covers a wide range of potential contaminants. Nonetheless, there are a few areas of the program that could be enhanced. Improvement areas may include sampling to monitor for eutrophication of Barton Pond, chemical spills in the Huron River watershed, and contamination of the groundwater wells.

In addition, strengthening a spill response notification program to protect the Barton Pond intake should be utilized as a proactive measure to provide timely information on source water quality. Additional information and suggestions on spill communication and response will be developed as part of the Watershed Characterization task. This will help promote knowledgeable decision making for treatment and operation responses.

Barton Pond. Since Barton Pond is the primary source of water for the City of Ann Arbor, its health is of utmost importance. The sampling review identified two key elements which can be improved. They include eutrophication sampling in Barton Pond and sampling for chemical spills from upstream land-use and activities.

Eutrophication Sampling. Gradual eutrophication of Barton Pond due to increased nutrient loads in the Huron River watershed may increase the frequency of algal blooms and lead to taste and odor issues. Also, during periods of low flow, the water quality of Barton Pond generally becomes degraded. Therefore, monitoring of the water quality in Barton Pond is one area that could be enhanced.

The use of continuous, online multiparameter water quality monitoring device(s) could accomplish several goals. For one, the device would yield base data regarding the water quality of Barton Pond, both on a daily basis and on a yearly basis. This database created by the device could be used to identify conditions that may be favorable for algal bloom formation and year-to-year trends in water quality. The information can also be used to notify the utility of an impending algal bloom, which could prompt management changes such as temporarily shifting to a higher percentage of groundwater supply or increasing the ozone dosage. The data could also be used to track changes in water quality over the period of several years. This may be useful for documenting how land use changes have impacted the water quality of Barton Pond. The online monitoring device could be installed near the intake in Barton Pond (attached to the dam or suspended in the water column) or in the pump station. Installing the device in the pump station may reduce the effort required for routine maintenance. If the device were located in Barton Pond, staff may be required to access the probe by boat or from the dam.

The types of parameters that can be monitored continuously include, but are not limited to: nitrate, ammonia, oxidation reduction potential, chloride, pH, chlorophyll, temperature, conductivity, total dissolved gas, depth, dissolved oxygen, and/or turbidity. Recommended sampling parameters with a continuous monitoring device are included in the

Recommendations section (Table 10) below. For additional Barton Pond water quality information, a second device could be added at a shallower depth if initial monitoring results indicate additional information could be beneficial. If multiple depth monitoring is desired, one of the devices would be required to be installed in Barton Pond, secured to the dam or to a buoy-type device and suspended in the water column.

Whether a single or multiple depth arrangement is chosen, the multi-parameter device(s) should be placed at or near the Barton Pond intake. The probes should also be connected to the WTP SCADA system to allow for remote control and data analysis. The multiparameter device(s) should not take the place of the current and proposed sampling conducted on Barton Pond.

Dissolved oxygen concentration is an important indicator because, if anaerobic conditions develop, additional phosphorus will enter the water column from the sediments, which could tip the nutrient balance to the point where nuisance algal blooms could occur. Phycocyanin is an indicator of the extent of nuisance algal populations, and the ratio of phycocyanin to chlorophyll indicates the proportion of nuisance algae to total algal biomass.

It will remain important to gather samples at various locations in the pond and at various depths. During the summer months, when the presence of cyanobacteria is greatest, manual sampling should be conducted once per week for the factors which most directly influence nuisance algal production (nitrogen, phosphorus, and phycocyanin) and more frequently when other sampling parameters indicated an algal bloom could be imminent. During actual algal blooms, additional tests should include geosmin and methylisoborneol (MIB) tests for the presence of taste- and odor-producing compounds and algal toxin tests (for example, microcystin-LR) for the presence of harmful toxins.

Chemical Spill Sampling. The other concern for Barton Pond is the potential for chemical spills upstream of the intake, especially from transportation accidents, or industrial spills. Based upon the industrial activities in the watershed, the most likely type of contamination is from oil and petroleum products.

Monitoring for oil and petroleum products in the water could be accomplished using an online monitor. These devices have been developed for the petroleum industry for accidental spill monitoring and the same technology could be utilized at the intake or in the Huron River just before it enters Barton Pond.

To protect the raw water quality of Barton Pond, water sampling can be conducted within the pond and upstream in the Huron River. Sampling in Barton Pond will provide information on its water quality and what is being drawn in the raw water intake to the WTP. Sampling at the intake will not provide an early warning system to detect contamination before the reservoir is compromised. To detect contamination before intake water quality is compromised, sampling upstream in the Huron River can detect contaminants before they enter Barton Pond and mix at the raw water intake. An upstream monitoring program can provide an early warning system for the water utility to effectively manage the raw water intake; however, the potential still exists for pollutants to enter Barton Pond directly and not be detected by an upstream monitoring program.

The average annual residence time in Barton Pond is roughly 45 hours (Limno-Tech 2000). If a contaminant is detected upstream of Barton Pond in the Huron River, the City of Ann

Arbor would have time to respond to a contaminant before the WTP would receive the contaminated water. Upon detection and verification of a spill, the city could close its intake and manually gather samples for additional analysis using a GC/MS for exact contaminant identification if the material type is unknown.

Depending on the nature of the contaminant, the intake could either be reopened or the utility could choose to wait until the plume has passed. Adjustments in the treatment operations to account for the contaminant could also be made, such as an evaluation to decrease the Barton Pond supply and increase the raw groundwater supply to the WTP. In such an event, the water utility could take protective measures to protect the WTP processes and finished water supply.

There are challenges in placing the sampler in the Huron River just before it enters Barton Pond, such as determining how to gather a sample from the entire water column and how debris or ice conditions would affect the sampler, and introduction of a contaminant downstream in Barton Pond. Periodic cleaning and maintenance would be needed. However, having a sample location at the entrance to Barton Pond is advantageous since it would provide additional time for Ann Arbor to respond to a spill when it is detected. A potential location could be at the Maple Road bridge.

The groundwater contamination from 1,4-dioxane may eventually discharge to surface waters. In addition, the current 1.4-dioxane groundwater treatment process discharges effluent to a stream tributary to Barton Pond. Consequently, until additional understanding of the 1,4-dioxane plume interaction with surface waters is known, monthly sampling for 1,4-dioxane is recommended.

Upstream Dam Removal or Draw-down. Dams upstream of Barton Pond can pose a water quality threat to Barton Pond. This is specifically the case when upstream impoundments are regulated on an annual or seasonal basis, or if the impoundment is removed. The types of water quality issues generally associated with dams include contaminated sediments (PCBs, metals, etc.) and sediments rich with nutrients. Mill Pond Dam in Dexter, Michigan, is one of several dams on Huron River upstream of Barton Pond. Several studies have been conducted on the feasibility and public acceptance of the removal of Mill Pond Dam, and the environmental benefit it would have on the Huron River Watershed. A cursory sediment quality analysis of the Mill Pond sediments indicated that arsenic may be present at levels that may pose health safety problems (HRWC 2003).

Each dam upstream of Barton Pond will have unique characteristics related to the water quality risks associated with discharge (stage) regulation or dam removal. More frequent monitoring of water quality parameters of concern should be considered when upstream dams are raised or lowered, or if the dams are removed. Specific water quality monitoring parameters of concern should be selected on a dam-by-dam basis, depending on the issues associated with the dam of concern. For example, if an upstream dam presents concerns of arsenic release, additional daily arsenic sampling should occur in Barton Pond for 1 to 2 weeks. At a minimum, nitrogen and phosphorus should be monitored daily for a 1 to 2 week period when discharge from an upstream dam(s) is changed. The duration of the daily water quality monitoring should depend upon the travel time between the dam of concern and Barton Pond and the number of additional impoundments between the dam of concern and Barton Pond. Actual travel time will vary depending upon the flow level in the

Huron River. However, a range in travel times can be determined using a high and low velocity range estimate to bound the time it takes to travel to Barton Pond. The bounds upon this range can then be supplemented with sampling. If there are several impoundments between the dam of concern and Barton Pond, the duration of daily monitoring may require an extended duration (2 weeks or beyond) due to the long travel time to Barton Pond.

Barton Pond Siltation. Ann Arbor completed a bathymetric survey of Barton Pond in 2000. The study recorded a pond volume of 76,500,000 ft^3 (Limno-Tech 2000). Bathymetric surveys are the most comprehensive method for monitoring siltation depths and locations and overall changes in storage volume. The current and proposed monitoring parameters can provide a general insight into siltation, however completing a routine bathymetric survey is recommended. The frequency of completing the surveys will depend on upstream sediment loads, however completing a bathymetric survey every 10 to 15 years can provide information on siltation trends in Barton Pond. If completed on a more frequent basis, bathymetric surveys may provide insight on the effectiveness of watershed protection activities such as stormwater detention ponds, agricultural runoff control, and stream bank stabilization. Completing routine bathymetric surveys will be an important monitoring practice given the projected 2030 population increase in the watershed.

The frequency of the bathymetric surveys should be adjusted based upon observed siltation trends. If the volume of Barton Pond significantly decreases between bathymetric surveys, surveys should be conducted more frequently to track siltation rates and to measure success of actions taken to control the siltation.

Wells. The water quality of the groundwater wells is more consistent than that of Barton Pond. Nonetheless, the groundwater quality can still become degraded over time. The current sampling program monitors for metals, VOCs, and multiple pesticides/herbicides on an annual basis. (This level of sampling should be adequate to identify degradation of the aquifer water quality due to leaking storage tanks, chemical spills, or septic field discharge since aquifer contamination will typically occur slowly over time.)

Besides land-use contaminants entering the groundwater, changes in aquifer water quality can occur as the water table lowers due to pumping. Concentrations of contaminants like arsenic, radium, and total dissolved solids can slowly increase over time. Therefore, the utility should also monitor for radium and arsenic annually.

Other Considerations. Another method to monitor Barton Pond for a large range of potential chemical contaminants is through the use of a biological early warning system (BEWS). An online BEWS, also termed biomonitoring, is a methodology that utilizes several types of organisms such as fish, mussels, macroscopic invertebrates, bacteria, or algae as biosensors. The sophistication of the monitoring ranges from automated fish and *Daphnia* behavior and movement analysis, avoidance patterns, and respiration monitoring, to measuring algae fluorescence and microbial respiration. Biomonitoring devices indicate only that a contaminant is present in the water without the capability to identify what is causing the effect on the organisms.

For Ann Arbor, a biomonitoring device could be installed at the WTP that continuously monitors the influent from Barton Pond. The Online Monitoring Technology Evaluation

Technical Memorandum provides additional discussion regarding the feasibility of using BEWSs.

An emergency response plan is an important component of the water quality sampling plan and source water protection. Action levels and response procedures based on the concentration of the sampled water quality parameters should be integrated into Ann Arbor's emergency response plan.

5.9 Recommendations

The following recommendations are made to protect water quality in Barton Pond:

- Areas of the Huron River watershed tributary to Barton Pond will face increased development pressure over the next 25 years. To counteract the influence the development will have on the watershed, especially as it relates to water quality, properly designed, constructed, and maintained BMPs for construction sites during and after construction will be needed. It is recommended that the City of Ann Arbor take an active role in watershed management through the Huron River Watershed Council and be an advocate for stormwater inspection and maintenance enforcement throughout the watershed, but especially within Washtenaw County.
- Investigate invasive species control techniques further for the management of EWM. The two most practical applications in Barton Pond are reservoir management alternatives to kill EWM and biological control with milfoil weevils that eat EWM. These two alternatives may provide significant reduction of EWM without sacrificing raw water quality and help in the long-term management of Barton Pond infrastructure.
- At the Intake Pump Station install an auto-sampling device and multi-parameter monitor (see Attachment 4).
- In Barton Pond at the Maple Road Bridge install a multi-parameter monitor and auto-sampling device (see Attachment 4).

Table 10 summarizes the proposed changes to the Ann Arbor sampling program.

TABLE 10
Summary of Proposed Changes to Sampling Program at the Ann Arbor Water Utility

Wells		Barton Pond	
Parameters	**Frequency**	**Parameters**	**Frequency**
Radium	Screen on an annual basis	Surrogate water quality parameters like pH, temperature, dissolved oxygen, chlorophyll, depth, and conductivity. TOC, UV 254, nitrate, ammonia, chloride, and phycocyanin are "additional" parameters that should be considered.	Monitor continuously at or near intake with online device. A YSI 6600EDS device is recommended. A YSI 6920 device should be considered to monitor for nitrate, ammonia, and chloride.
		Algae, chlorophyll, phycocyanin, phosphorus, Secchi, DO, temp, *E. Coli*, Enterococcus, nitrite, nitrate, ammonia.	Increase frequency of manual grab sampling at lake locations during summer months to once per week.
		Track total nitrogen to total phosphorus ratio.	
		Nitrogen and phosphorous	Weekly during summer months. More frequently if conditions for algal blooms develop.
			Daily, for 1 to 2 weeks' duration if discharge from upstream dams change
		1,4-Dioxane	Monthly
		MIB, Geosmin, Algal Toxins	Screen for during algal blooms or taste and odor complaints. Compare source water and finished water concentrations.
Other Monitoring Options			
		Oil and petroleum products	Monitor continuously with online probe at upstream end of Barton Pond and/or at intake location. Consider Turner Designs 4100 to monitor for hydrocarbons, including oil and petroleum products. A parameter that could be monitored as a surrogate is TOX to monitor specifically for organic hydrocarbon.
			If detection occurs, obtain manual grab samples and analyze by GC/MS through outside lab to confirm hydrocarbon type and concentration.
		Organic and inorganic chemicals	Method uses bacteria to detect the presence or organic and inorganic chemical pollutants. The test is based on the amount of luminescence lost from a chemical contaminant compared to a control sample.

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Attachment 1

1,4-Dioxane Test Procedure

1,4-Dioxane Jar Test Plan

PREPARED FOR: City of Ann Arbor
PREPARED BY: CH2M HILL
DATE: May 19, 2005

This memorandum summarizes the jar testing plan for evaluating 1,4-dioxane removal with similar processes used at the Ann Arbor water treatment plant.

Treatment Objectives

These jar tests are designed to indicate the ability of the existing Ann Arbor water plant treatment processes to remove 1,4-dioxane.

Testing Approach

Samples of Ann Arbor river water (5 gallons), well water (2 gallons), and GAC (1 gallon container) will be sent to the CH2M HILL treatability lab. Sample containers will be sent to Ann Arbor with prepaid Federal Express return forms. Ann Arbor will fill the containers and coordinate with Federal Express for pickup.

A pint container of quicklime from the Ann Arbor plant will also be sent with the water samples.

Raw Water Characterization

The river and well water samples will be characterized by analyzing for the following parameters:

- pH
- Total alkalinity
- Turbidity
- Calcium, magnesium, and total hardness
- Total organic carbon
- 1,4-Dioxane

Test Protocol

A batch of raw water will consist of 85 percent river water and 15 percent well water. All tests will be conducted with the water at room temperature. The water will be spiked to approximately 85 parts per billion (ppb) 1,4-dioxane. A sample will be collected and analyzed for 1,4-dioxane in duplicate. 1,4-dioxane analytical procedure must have a detection level of 1 to 2 ppb.

The water will be lime softened (see details below). The supernatant will be decanted. A single sample will be analyzed for 1,4-dioxane.

The lime softened supernatant will be recarbonated to pH 8.0. A single sample will be analyzed for 1,4-dioxane.

The recarbonated water will be dosed with ozone at an applied dose of 2 mg/L. The ozone will be allowed to decay for 20 minutes. Record initial and final ozone residual. A sample will be collected and analyzed for 1,4-dioxane in duplicate.

Another sample of recarbonated water will be dosed with ozone at an applied dose of 2 mg/L and hydrogen peroxide at 4 mg/L. A single sample will be collected and analyzed for 1,4-dioxane.

The sample ozonated at 2 mg/L (no hydrogen peroxide) will be passed through a filter column containing 2 feet of GAC from the Ann Arbor water plant. The flow rate will be 2 gpm/ft^2. Filter effluent will be collected and a sample will be analyzed for 1,4-dioxane in duplicate.

Filter effluent will be chloraminated with a chlorine dose of 3 mg/L and an ammonia dose of 0.67 mg/L. After 2 hours contact with chloramine, a single sample will be collected and analyzed for 1,4-dioxane.

Analyze the finished water for total alkalinity, calcium, magnesium, total hardness, pH, turbidity, and total organic carbon.

Lime Softening Procedure

Approximately 200 mg/L of primary sludge from the water plant will be added before lime addition.

Quick lime from the Ann Arbor plant will be used for the testing. A stock lime slurry of 1 percent (10,000 mg/L) lime (as CaO) will be prepared. The lime must be slaked (mixed with a small amount of water to form a paste) before dilution. Note that this is an exothermic reaction, so use proper precautions.

Add 275 mg/L lime (as CaO) to the raw water and primary sludge mixture. The target pH is 11.0. Add more or less lime until pH 11.0 is reached.

The following lime softening mixing intensities and durations will be used:

- Rapid mix at 120 rpm for 30 seconds
- Flocculation at 70 rpm for 5 minutes
- Flocculation at 50 rpm for 10 minutes
- Flocculation at 30 rpm for 5 minutes
- Settle for about 15 minutes. Draw off all supernatant to sample tap level (20 inches below water surface). Measure turbidity.
- Recarbonate supernatant by bubbling CO_2 in the supernatant to pH 10.
- Rapid mix the recarbonated supernatant with 0.6 mg/L cationic polymer and second stage sludge (100 mg/L), flocculate, and settle for 15 minutes. Draw off sample (20 inches below the water surface).
- Analyze treated water for 1,4-dioxane as indicated above.

Phase 2 Testing

Ann Arbor will ship softened water to the lab.

Test A

1. Recarbonate the water to pH 8.0.
2. Spike the water with 1,4-dioxane to 35 ppb. Measure 1,4-dioxane in duplicate.
3. Ozonate the sample at 2 ppm ozone and let it decay for 20 minutes. Measure 1,4-dioxane.
4. Pass the ozonated water sample through biological GAC (24 inches of BAC at 2 gpm / ft^2). Measure 1,4-dioxane in the effluent.

Test B

Repeat test A, but spike the water to 10 ppb 1,4-dioxane.

Test C

Repeat test A, but spike the water to 3 ppb 1,4-dioxane.

Test D

Repeat test A, but instead of room temperature water, use water at 5 degrees C. The BAC column should be run with cold water for some time before sampling for 1,4-dioxane.

Test E

Repeat test A, but spike the water to 3,000 ppb 1,4-dioxane.

Attachment 2

Potential Contaminant Source Inventory Results for the Ann Arbor Susceptible Area

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor Susceptible Area

Site Name	City	ID Number	Reason for Permit	Reason for Listing
Pinckney STP	—	MI0000259	Process, Treatment, and Waste Water	Industrial Facilities Discharge Site
South Lyon WWTP	South Lyon	MI0020273		
Chelsea WWTP	Chelsea	MI0020737		
Dexter WWTP	Dexter	MI0022829		
Milford Wstwtr Trmt Plt	Milford	MI0023604		
Oakland Co DPW-Sub Knolls WWTP	Pontiac	MI0023728		
Oakland Co DPW-Wixom WWTP	Wixom	MI0024384		
South Commerce Twp WWTP	Walled Lake	MI0025071		
McPherson Oil Co	Pinckney	MI0046353	Waste Water, Dust, and Process Water	Permit Compliance System
Chrys-Chelsea Proving Grounds	Chelsea	MI0046540		
Oakland Co DPW-Sub Knolls WWTP	Highland Twp	MI0023728		
Oakland Co DPW-Wixom WWTP	Wixom	MI0024384		
Mascotech Tubular Prod	Hamburg	MI0043737		
Thetford Corp-Dexter	Dexter	MI0036951		
Milford WWTP	Milford /V/	MI0023604		
Woodbridge Foam	Whitmore Lake	MI0003212		
Gm-Proving Grounds-Milford	Milford /V/	MI0001911		
Quanex Corp-Mich Seamless Tube	South Lyon	MI0001902		
Pittsfield Products-Aco Div	Pinckney	MI0048534		
Sweepster Jenkins Equipment Co	Dexter	MI0045934		
Dexter Automatic Prod-Bishop	Dexter	MI0046655		
Wakeland-Brighton-W Grd River	Brighton	MI0052132		
Hop-In Of Mich-Whitmore Lake	Whitmore Lake	MI0053341		
Farmers Petroleum-Highland	Highland Twp	MI0048381		
Brighton Wtp	Brighton	MI0047074		
Chelsea Wfp	Chelsea	MI0004804		
Commerce Twp WWTP	Walled Lake	MI0025071		
South Lyon Community Schools	Salem	MI0027081		
South Lyon WWTP	South Lyon	MI0020273		
Superamerica-Ann Arbor	Ann Arbor	MI0049956		
Whitmore Lake Schools	Whitmore Lake	MI0045691		
Gelman Sciences Inc	Ann Arbor	MI0048453		
Northfield Twp WWTP	Whitmore Lake	MI0023710		
Loch Alpine Sa-Scio-Web WWTP	Ann Arbor	MI0024066		
Chelsea WWTP	Chelsea	MI0020737		
Dexter WWTP	Dexter	MI0022829		
Dexter Wfp	Dexter	MI0038504		
North Arbor Park Mhp WWTP	Ann Arbor	MI0043575		

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor Susceptible Area

Site Name	City	ID Number	Reason for Permit	Reason for Listing
Dandy Oil Co-Brighton	Brighton	MI0049158	Waste Water, Dust, and Process Water	Permit Compliance System
Barrington Chem Co	Williamston	MI0042480		
GM-Proving Grounds-GWCU	Milford /V/	MI0053554		
Brighton WWTP	Brighton	MI0020877		
Novi Village Mhp WWTP	Novi	MI0054143		
Cpco-Freedom Gas Co	Manchester	MI0002038		
Wixom Sewage Disposal Plant	Wixom	MID000776112	Onsite Storage	Hazardous or Solid Waste Site
Dexter Automatic Products Co. Dapco Ind	Dexter	MID005338611		
Gelman Sciences Inc	Ann Arbor	MID005341813		
Dedoes Industries Inc	Walled Lake	MID006006589		
Williams International	Walled Lake	MID006401970		
Petro Lube Inc	Whitmore Lake	MID018998971		
Kaiser Optical Systems Inc	Ann Arbor	MID037744919		
Kelsey Hayes Milford Plant	Milford	MID053347456		
Abs Body And Frame Shop	Ann Arbor	MID058801408		
Millmet Inc	Brighton	MID074250275		
Oakland Tech Ctr SW Campus	Walled Lake	MID091949743		
Dons Body Shop	Whitmore Lake	MID095401998		
A And M Restorations	Ann Arbor	MID106753965		
Country Fresh Dry Cleaners	Brighton	MID113060958		
Fab-Mart	Walled Lake	MID125817858		

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor Susceptible Area

Site Name	City	ID Number	Reason for Permit	Reason for Listing
Spearhead Development Tech	Walled Lake	MID175211713	Onsite Storage	Hazardous or Solid Waste Site
Stockbridge Auto Supply Inc	Stockbridge	MID981960180		
Sweepster Jenkins Equip Co	Dexter	MID982608473		
American Truck Customizing	Pinckney	MID982623266		
Matpex Inc	Dexter	MID985567247		
Mobil Oil Corp	Ann Arbor	MID985573591		
Chelsea Village Of	Chelsea	MID985575927		
Speedway 2367	Walled Lake	MID985595941		
Milford Standard Svc Inc 5214	Milford	MID985611813		
Hop In Food Stores	Dexter	MID985620657		
Hop In Food Stores	Whitmore	MID985620681		
Corkys Car Clinic	Brighton	MID985625235		
Dept Of Public Works	South Lyon	MID985632371		
Sake Sales Inc	Manchester	MID985635564		
Gt Specialty Fastners	Walled Lake	MID985636554		
Dietrich Shell Inc	Union Lake	MID985649755		
Moeller Mfg Co Inc Wixom Plt	Wixom	MID985650936		
Pohl Walter	White Lake	MID985655927		
Tushis Steve Decorating	Highland Twp	MID985658327		
Kwik Photo 1 Hr	Milford	MID985611813	Onsite Storage	Hazardous or Solid Waste Site
Chrysler Corp Introl Div	Ann Arbor	MID990760100		
Mht Corp	Milford	MI0000018507		
Loch Alpine Sa Scio Web WWTP	Ann Arbor	MI0000052670		
Rays Landscaping And Nursery Inc	Walled Lake	MI0000071845		
Quality Fuels Inc	White Lake	MI0000274571		
Uniflex Inc	Brighton	MIR000001511		
Clark Store #1947	Brighton	MIR000004655		
Mobil Oil Corp White Lake	White Lake	MIR000008003		
Gelman Sciences Inc.	Ann Arbor	MID005341813	Release or Manufacture of Toxic Compounds	Toxics Release Inventory
Kelsey-Hayes Co.	Milford	MID053347456		
Millmet Inc.	Brighton	MID074250275		
Williams Intl	Walled Lake	MID006401970		

Attachment 3

Potential Contaminant Source Inventory Results for the Ann Arbor Susceptible Area and Potential Analytes

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor SWA Susceptible Area

Site Name	Business Type	Potential Analyte Types	Comments
Pinckney STP South Lyon WWTP Chelsea WWTP Dexter WWTP Milford Wstwtr Trmt Plt Oakland Co DPW-Sub Knolls WWTP Oakland Co DPW-Wixom WWTP South Commerce Twp WWTP	Sewerage Systems	**Potential Onsite Storage** Chlorine, Ferric Chloride, Alum(Aluminum Sulfate), Polymers, Sodium Hydroxide, Magnesium Hydroxide, gas, diesel, Sodium Bisulfite, Sodium Thiosulfate, Sodium Hypochlorite, Ferric Sulfates **Effluent Constituents** Dissolved Oxygen pH Total Suspended Solids Ammonia Nitrogen Total Phosphorus Fecal Coliform BOD	
Mcpherson Oil Co	Unclassified	VOCs; TPH	
Chrys-Chelsea Proving Grounds	Commercial Testing Lab	Metals; VOCs; TPH	
Oakland Co DPW-Wixom WWTP	Sewerage System	See Above	
Mascotech Tubular Prod	Motor Vehicles and Accessories	VOCs, Phosphorus; TPH	
Thetford Corp-Dexter	Plastic Products	VOCs, SVOCs	
Woodbridge Foam	—	Unknown	
Gm-Proving Grounds-Milford	—	Metals; VOCs; TPH	
Quanex Corp-Mich Seamless Tube	Steel Pipe & Tubes	Metals (including Bo; Cu; Mg; Zn; Pb); Phosphorus; VOCs	
Pittsfield Products-Aco Div	Unclassified	Unknown	
Sweepster Jenkins Equipment Co	Motor Vehicles and Car Bodies	Phosphorus; Metals; TPH	
Dexter Automatic Prod-Bishop	—	Unknown	
Wakeland-Brighton-W Grd River	—	Unknown	

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor SWA Susceptible Area

Site Name	Business Type	Potential Analyte Types	Comments
Hop-In Of Mich-Whitmore Lake	—	Unknown	
Farmers Petroleum-Highland	—	TPH	
Brighton Wtp	Water Supply	Ferric Chloride; Sodium Hypochlorite; Alum; Chlorine, Gas, Diesel	
Chelsea Wfp	Water Supply	Ferric Chloride; Sodium Hypochlorite; Alum; Chlorine, Gas, Diesel	
South Lyon Community Schools	Elementary & Secondary Schools	Unknown	
Superamerica-Ann Arbor	—	TPH	
Whitmore Lake Schools	—	Unknown	
Gelman Sciences Inc		VOCs; SVOCs; 1,4-Dioxane	
Northfield Twp WWTP	Sewerage System	See Above	
Loch Alpine Sa-Scio-Web WWTP	Sewerage System	See Above	
Dexter Wfp	Water Supply	Ferric Chloride; Sodium Hypochlorite; Alum; Chlorine, Gas, Diesel	
North Arbor Park Mhp WWTP	Sewerage System	See Above	
Dandy Oil Co-Brighton	—	TPH	
Barrington Chem Co	—	Unknown	
Gm-Proving Grounds-Gwcu	—	Metals; VOCs; TPH	
Brighton WWTP	Sewerage System	See Above	
Novi Village Mhp WWTP	Sewerage System	See Above	
Cpco-Freedom Gas Co	Mixed Manufacturing or Liq Gas Prod.	Unknown	
Wixom Sewage Disposal Plant	Government Support (92119)	Unknown	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor SWA Susceptible Area

Site Name	Business Type	Potential Analyte Types	Comments
Dexter Automatic Products Co Dapco Ind	—	Unknown	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Gelman Sciences Inc	Plastic Products and Medical Equipment and Supplies	VOCs; SVOCs	
Dedoes Industries Inc	Metal Manufacturing (332999,333319)	Metals; VOCs	Small Quantity Generator. Liquid Waste Generator.
Williams International	Batteries and Electric Lamps, Missile and Space Propulsion, Aircraft Engine Manuf. (336415, 336412)	Metals; VOCs; TPH	Small Quantity Generator. Liquid Waste Generator.
Petro Lube Inc	—	Metals; VOCs; TPH	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Kaiser Optical Systems Inc	Instruments, Aircraft Parts, Optical Lens Manuf. (334513,336413,333314)	Metals; VOCs	Small Quantity Generator. Liquid Waste Generator.
Kelsey Hayes Milford Plant	—	Unknown	
Abs Body And Frame Shop	—	Metals; VOCs; TPH	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Millmet Inc	Interior Design (54149, 54141)	Unknown	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Oakland Tech Ctr Sw Campus	—	Unknown	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Dons Body Shop	Automotive Body (811121)	Metals; VOCs; TPH	Small Quantity Generator.
A And M Restorations	Automotive Body (811121)	Metals; VOCs; TPH	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Country Fresh Dry Cleaners	Laundry and Drycleaner (81231)	VOCs	Small Quantity Generator.

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor SWA Susceptible Area

Site Name	Business Type	Potential Analyte Types	Comments
Fab-Mart	—	Unknown	
Spearhead Development Tech	Industrial Machine & Equip Wholesale (423830)	VOCs; Metals	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Stockbridge Auto Supply Inc	Auto Repair (811111)	TPH; VOCs	Small Quantity Generator.
Sweepster Jenkins Equip Co	Construction Machine Manu (33312)	VOCs; Metals	Large Quantity Generator
American Truck Customizing	—	Metals; VOCs; TPH	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Matpex Inc	—	Unknown	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Mobil Oil Corp	Gas Station & Convenience (44711)	TPH	Small Quantity Generator.
Chelsea Village Of	Government Support (921190)	Unknown	Small Quantity Generator. Liquid Waste Generator.
Speedway 2367	—	TPH	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Hop In Food Stores	Gas Station (44719)	TPH	Small Quantity Generator.
Hop In Food Stores	Gas Station (44719)	TPH	Small Quantity Generator.
Corkys Car Clinic	Auto Repair (811111)	TPH; VOCs	Small Quantity Generator. Liquid Waste Generator. Used Oil Collection.
Dept Of Public Works	—	TPH; Chloride	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Sake Sales Inc	—	Unknown	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Gt Specialty Fastners	—	Unknown	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Dietrich Shell Inc	Gas Station & Convenience (44711)	TPH	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business

TABLE 1
Potential Contaminant Source Inventory Results for the Ann Arbor SWA Susceptible Area

Site Name	Business Type	Potential Analyte Types	Comments
Moeller Mfg Co Inc Wixom Plt	Machine Shop & Aircraft Engine & Engine Parts (332710, 336412)	Metals; TPH	Small Quantity Generator.
Pohl Walter	—	Unknown	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Tushis Steve Decorating	—	Unknown	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Kwik Photo 1 Hr	—	VOCs	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Chrysler Corp Introl Div	Vehicle Electric Manu (336322)	Metals; VOCs	OUT OF BUSINESS. Generation of Waste Ceased/Site Closed. No Longer Generating.
Mht Corp	Management Consult Services (54161)	Unknown	Hazardous Waste Transporter. Management and Consulting Services.
Loch Alpine Sa Scio Web WWTP	Sewerage System	See Above	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Rays Landscaping And Nursery Inc	—	Pesticides; Herbicides	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Quality Fuels Inc	1-Hour Photo (812922)	TPH; VOCs	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business
Uniflex Inc	Rubber Product Manu (32629)	Unknown	Small Quantity Generator.
Clark Store #1947	Gas Station & Convenience (447110)	TPH	Small Quantity Generator.
Mobil Oil Corp White Lake	—	TPH	Generation of Waste Ceased/Site Closed No Longer Generating/Still in Business

VOC = volatile organic compounds
SVOC = semivolatile organic compounds
TPH = total petroleum hydrocarbons

Attachment 4

Source Water Online Monitoring Technology Evaluation