SOLE SOURCE AQUIFER PETITION

MICHINDOH GLACIAL AQUIFER

Prepared and Submitted for:

City of Bryan, Ohio

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1.0 INTRODUCTION

The purpose of a sole source aquifer designation is the protection and management of a vulnerable aquifer system that represents the sole source of drinking water within the designated area. The goal of this petition is to present the factual, defendable information necessary to justify a sole source aquifer designation for a portion of the MICHINDOH Glacial Aquifer system. The study area for this petition includes portions of nine counties which are contained within three states (Figure 1).

The MICHINDOH aquifer system is comprised of variably confined, hydraulically-connected, discontinuous sand and gravel intervals distributed vertically within unconsolidated glacial sediments. The research conducted as part of this petition includes:

1. a physical description of the aquifer and the local boundaries;
2. identification of alternative drinking water sources;
3. population, income, and water demand statistics within the designated area;
4. feasibility analyses of alternative source implementation design and costs.

1.1 PETITIONER INFORMATION

The Bryan Municipal Utilities, with the approval of the Bryan Board of Public Affairs, on behalf of the City of Bryan, Ohio, has elected to petition the U.S. Environmental Protection Agency (U.S. EPA) for a Sole Source Aquifer designation for a portion of the MICHINDOH Glacial Aquifer. The City of Bryan is located 15 miles south of the Michigan state border and 12 miles east of the Indiana state border in Pulaski Township, Williams County, Ohio. The aquifer system is present across nearly all the nine-county, tri-state area presented in Figure 1.

The petition has been prepared in accordance with Section 1424(e) of the Safe Drinking Water Act of 1974 (Public Law 93-523, 42 U.S.C. 300 et. Seq.), and following the EPA Sole Source Aquifer Designation Petitioner Guidance document (Document 440/6-87-003). Table 1 contains the Petitioner Identification Information suggested in Exhibit 3-6 of the guidance document.

Table 1. Petitioner Identification Information

Aquifer	Name	MICHINDOH Glacial Aquifer
	Location	Northeast Indiana, Southeast Michigan, Northwest Ohio
Petitioner	Name	Bryan Municipal Utilities
	Address	841 East Edgerton Street
	City, State, Zip	Bryan, Ohio 43506-1413
	Phone Number	(419) 633-6100
Responsible Person	Name	Stephen Casebere (Director of Utilities)
	Phone Number	(419) 633-6101
Contact	Name	Norm Echler (Water Superintendent)
	Name	Lou Pendleton (Director of Public Relations)

1.2 NARRATIVE

The MICHINDOH aquifer system is an extensive sand and gravel aquifer system that covers nearly all the nine-county, three-state study area for this petition. The aquifer system is comprised of hydraulically-connected sand and gravel intervals distributed laterally and vertically through the nearly 200-foot thick Quaternary sediments that blanket the study area. The aquifer system likely extends further west and north than this study area, but the relevant groundwater basin identified within this aquifer system is contained within this nine-county area.

The MICHINDOH aquifer system groundwater quality is generally good. The groundwater contains elevated levels of hardness and iron across the area, similar to the groundwater resources within the Quaternary deposits across the Midwest. Scattered areas also exhibit high concentrations of sulfur and brine, but such areas are not typical in the region.

The existing municipalities, residents, and businesses within the nine-county area rely primarily on two water resources to meet the drinking water demands. All of the communities utilize the MICHINDOH aquifer system where it is present. The secondary water sources are the three major river systems in the area. The Maumee River is the largest of the three. The St. Joseph River and the Tiffin River represent the other two major river systems, and both are tributaries of the Maumee.

Other notable public water supplies that are present adjacent to the proposed SSA area include the municipalities of Angola, Auburn, Fort Wayne, and Garrett in Indiana; Hillsdale and Reading in Michigan; and Archbold, Defiance, and Wauseon in Ohio. The three Ohio communities all rely on surface water resources. The Indiana and Michigan communities rely on groundwater resources.

Bryan Municipal Utilities serves one of the most populated areas in the region and meets one of the largest public water supply demands. The Utility relies exclusively on the MICHINDOH aquifer system as the source for its drinking water. Williams County, Ohio, and the City of Bryan are located in a unique geologic area and are geographically isolated from the other significant adjacent municipal supplies in the region. The Board of Public Affairs recognizes the importance and value of their unique drinking water resource. They have elected to be proactive in the protection of the MICHINDOH aquifer system out of concern for their drinking water customers and their companion communities which also rely on this unique aquifer system. They have worked for the past three years researching the elements of the petition and debating the regional and local implications of a Sole Source Aquifer designation.

The primary reasons for conducting the research, assembling the information, performing the required analyses, and filing the petition for a Sole Source Aquifer designation for the MICHINDOH aquifer system include:

1. *Assisting* the development of local initiatives for managing hazardous materials within the petitioned area.
2. *Integrating* surface water drainage basins and aquifer recharge areas with the existing delineated Wellhead Protection Areas (WHPA). The extent of the WHPAs is limited to the five-year time of travel for ground water particles and does not address contamination that may affect the wellfields via upgradient recharge areas and/or surface water drainage.
3. *Providing* local governments with the knowledge and demonstrable, defendable proof to delineate critical areas within the MICHINDOH aquifer system that are sensitive to potential contamination. The thrust of the petition is to encourage commercial, industrial, and residential growth in a responsible manner that recognizes and protects the region's vital ground water resources.
4. *Designating* critical areas for protection near communities where wellhead protection delineations and programs have not been implemented.
5. *Educating* the urban and rural residents and business owners within the sole source aquifer area regarding the financial value of the aquifer, their dependence on this unique resource, the vulnerability of the aquifer system, the types of potential contamination, the critical portions of the aquifer, and straightforward methods of protecting this resource.
6. *Enlisting* federal funding assistance in encouraging growth of new industry in a responsible manner.

The petition combines extensive information databases from the States of Indiana, Michigan, and Ohio within a common platform and enables hydrogeologic interpretation across state borders. The research has been compiled in a GIS-based format, which provides an expandable, editable, powerful planning and education tool. The research and the petition have the potential to benefit the residents, businesses, communities, and state, federal, and local government agencies represented across the region.

2.0 REGIONAL GEOLOGY

The study area for this petition is located across portions of nine counties at the intersection of the Indiana, Michigan, and Ohio state borders (Figure 1). The description of the geology is based mainly on the available printed and online resources from the Indiana Department of Environmental Management (IDEM), the Michigan Department of Environmental Quality (MDEQ), the Ohio Environmental Protection Agency (OEPA), and the United States Geological Survey (USGS).

Suturing of the data along the state lines is limited in some respects due to the different points of emphasis and mapping methods associated with the different governmental agencies. The maps presented as part of this petition provide a powerful, regional planning tool with numerous data sources compiled on a common reference system within a geographic information system (GIS) database. The information provided is sufficient to verify the defined boundaries of the sole source aquifer petition and to provide the reviewers and subsequent users with a thorough understanding of the areal hydrogeology.

The topography of the study area is relatively flat. The most variable topography is present in the northern portions of the area where the glacial landforms include intermingled areas of end moraine, ground moraine, glacial outwash, and kame features.

The climate in the study area is considered temperate. The average annual temperature across the study area is approximately 50 degrees Fahrenheit with average rainfall between 33 and 36 inches per year (USGS, 1992; Harstine, 1991; King, 1977; WMU, 1981).

2.1 BEDROCK GEOLOGY

2.1.1 Regional Structures

The regional bedrock structure in the three-state area (Indiana, Michigan, and Ohio) is comprised of three basins which flank a saddle-type structure composed of three arches (Figure 2 in RASA Study - Eberts and George, 2000). The bedrock surface dips from the saddle into the basins at a rate of 10 to 30 feet per mile. Minor anticline and folds are present throughout the region along with numerous buried river valleys eroded into the bedrock surface.

The Michigan Basin is present across the northern regions, the Illinois Basin is present across the southwestern regions, and the Appalachian Basin is present across the southeastern regions. The Kankakee Arch separates the Michigan Basin from the Illinois Basin, the Findlay Arch separates the Michigan Basin from the Appalachian Basin, and the Cincinnati Arch separates the Appalachian Basin from the Illinois Basin.

The study area is located on the southeastern margin of the Michigan Basin and the northern limb of the Findlay Arch. The bedrock surface beneath the study area slopes to the northwest at approximately 20 feet per mile (Coen, 1986). In map view, the subcrop pattern of the bedrock formations beneath the Quaternary deposits is a series of concentric arcs (Figure 2). The oldest bedrock formations are present to the southeast, and the formations are progressively younger with distance to the northwest.

2.1.2 Stratigraphy

The description of the uppermost bedrock formations present within the study area relies heavily on the geologic summary presented by Richard Lilienthal (1978) in a report compiling geologic cross sections through the State of Michigan. Additional sources included a series of professional papers published by the United States Geological Survey related to the Regional Aquifer System Analysis (RASA) for the Midwestern Basin and Arches, a USGS water resources investigation report on the groundwater resources of Williams County (Coen, 1989), and the Hydrogeologic Atlas of Aquifers in Indiana (USGS, 1992).

The uppermost bedrock formations represent Mississippian-Age and Devonian-Age deposits (Figure 3 – bedrock column). The youngest rocks are located in Michigan and are represented by the Marshall Formation. The oldest rocks are a Devonian-Age carbonate sequence represented by the Detroit River Group (Michigan and Ohio), also known as the Muscatatuck Group (Indiana).

The potential bedrock aquifers capable of supporting municipal groundwater supplies include the Marshall Formation and the Dundee Limestone. The formations present between the Mississippian-age Marshall Formation and the Devonian-age Dundee Limestone are composed primarily of shale and are commonly interpreted as confining units.

The quantity of groundwater available from the confining rock units is only capable of supporting low-demand residential wells. Additionally, the groundwater extracted from the confining units typically exhibits poor quality with excessive iron and sulfide concentrations. Although greater quantities of groundwater can be derived from the carbonate sequences beneath the Dundee Limestone, the groundwater quality is poor and contains elevated concentrations of bromine, chloride, iodine, sodium, and sulfide.

Marshall Formation

Within the study area the Mississippian-age Marshall Formation is only present in Hillsdale County, Michigan, where the formation is typically less than 75 feet thick. The formation is comprised mainly of sandstone and siltstone with occasional interbedded shale and limestone. The subcrop areas of the formation tend to be highly fractured and highly transmissive. Drilling records reveal a gradational boundary between the Marshall Formation and the underlying Coldwater Shale in southeastern Michigan where the amount of shale interbedded with the sandstones and siltstone increases. The formation is completely eroded away in some areas exposing the underlying Coldwater Shale.

Coldwater Shale (Cuyahoga Shale, Ohio)

The Mississippian-age Coldwater Shale is nearly 500 feet thick at the Michigan-Ohio border. The formation is composed primarily of gray to blue-gray shale with occasional interbedded sandstone and limestone. The basal sandstone and limestone intervals have yielded some gas and oil shows. The sandstone and siltstone intervals within the upper portions of the Coldwater Shale in southeastern Michigan make it difficult to distinguish between this formation and the Marshall Formation. The Coldwater "red rock" unit represents the base of the formation in southeastern Michigan and northern Ohio.

Undivided Sequence

The undivided sequence of the Mississippian-age Sunbury Shale, Berea Sandstone, Bedford Shale, and the Devonian-age Ellsworth Shale (Cuyahoga Shale, Ohio) consists mainly of shale with minor amounts of interbedded sandstone, limestone, and dolomite. The entire sequence is less than 75 feet thick across the study area.

The Sunbury Shale consists mainly of shale with characteristics similar to the Antrim Shale. The Berean Sandstone is a minor sandstone interval that grades into the underlying Bedford Shale and is only present in southeastern Michigan. The Bedford Shale is a gray, silty-to-sandy shale that grades into the underlying Ellsworth Shale and Antrim Shale formations. The Ellsworth Shale is predominantly green shale with a high radioactive signature.

Antrim Shale (Ohio Shale, Ohio)

The Antrim Shale is a dark gray to black carbonaceous shale which contains a large amount of fossilized organic matter. The formation is approximately 200 feet thick across the study area. The top and bottom portions of this formation are gradational with the overlying Undivided Sequence and the underlying Traverse Group. The base of the Antrim Shale has been described as the last highly radioactive zone before a transition into the less radioactive shale at the top of the Traverse Group.

Traverse Group

The Traverse Group, where present within the study area, has been separated into two correlatable units: the Ten Mile Creek Limestone (or Traverse Limestone) and the Silica Formation (or Bell Shale). The Ten Mile Creek Limestone is composed of siliceous shale and limestone with chert. The Silica Formation consists primarily of shale and is considered gradational with the overlying Traverse Limestone. The Traverse Group ranges in thickness from more than 150 feet in the northern portions of the study area to less than 100 feet thick in the southern portions.

DUNDEE LIMESTONE

The Dundee Limestone is the uppermost carbonate interval capable of supporting municipal groundwater withdrawals. The formation consists of a buff-to-brown, fine-to-coarse crystalline limestone that is approximately 45 feet thick across the study area. The base of the formation is represented in some locales by a dolomite sequence.

DETROIT RIVER GROUP

The Detroit River Group consists of the Anderdon Formation, the Lucas Formation, the Amherstburg Formation, and the Sylvania Formation. The Anderton and Lucas formations are often indistinguishable and grouped together. The top of the Detroit River Group is typically identified by the presence of an anhydrite bed at the top of the Lucas Formation.

The Lucas Formation consists of dolomite, anhydrite, salt, limestone, and sandstone. The anhydrite and salt combine with the porous nature of the predominantly carbonate sequence to produce a "sour zone" of brine and groundwater with elevated concentrations of bromine, chlorides, iodine, sodium, and sulfides.

The Amherstburg Formation consists of a dark brown-to-black, fossiliferous limestone with minor amounts of dolomite. The formation is commonly referred to as the "Black Lime".

The Sylvania Formation is the basal unit of the Detroit River Group and consists of well-rounded, well-sorted, fine-to-medium-grained sandstone. Minor amounts of silt, chert, and carbonate are also present within the formation.

2.2 QUATERNARY GEOLOGY

2.2.1 Modern Alluvial Sediments

Modern sediments include post-glacial deposits of silt, sand, and gravel. The most common origins of these sediments are the modern rivers, streams, and lakes, but these deposits are not restricted to the current drainageways. Rivers and streams that flow across relatively flat topography tend to meander across the landscape continually eroding, winnowing, and re-depositing the surficial sediments. Thus, the re-worked sands and gravel tend to be ribbon-shaped and span the flood-plain areas of the rivers and streams.

The largest modern alluvial deposits within the study area are associated with the Maumee River, the St. Joseph River, and the Tiffin River. These deposits tend to be composed of well-sorted, stratified sand and gravel. The deposits typically exhibit a thickness close to the current river depth and have a limited lateral component associated with the historical river course changes.

2.2.2 Glacial Sediments

Till is a generic term used to describe the sediments deposited within a glacial environment and is commonly interchangeable with the term drift. Generally, glacial till deposits are poorly sorted, compact, and exhibit a massive structure without lamination or gradational bedding planes. The coarser grain sizes within the till are typically angular and are composed of a large variety of rocks and minerals.

The till deposits in the study area range from less than 100 feet thick in portions of Ohio and Indiana to more than 200 feet thick in portions of Hillsdale County, Michigan. For the purpose of this study, five categories of glacial deposits have been identified on the basis of grain size, texture, and the associated geomorphology (Figure 4).

Undifferentiated Glacial Outwash deposits are typically found adjacent to end moraines and represent sand and gravel deposits laid down by the braided stream outwash tributaries at the downstream margin of glaciers. These deposits vary from well-sorted to poorly-sorted and are composed of a fine-to-coarse sand matrix interbedded with gravel and cobble lenses. The geomorphology of the outwash deposits include fans, sheets, deltas, and less frequently, fluvial terraces along modern streams.

Buried Lake, River, or Beach Ridge deposits represent former beach and near-shore littoral environments associated with the glacial Great Lakes. The deposits are often interbedded with lacustrine silts and clays and may include small, discontinuous dune areas and large areas of organic soil.

Lacustrine deposits are associated with the glacial Great Lakes. The geomorphology of these areas is extensive, flat, low-lying regions. These deposits contain negligible amounts of sand and gravel and represent confining intervals in hydrogeologic settings. In some areas varves are present, but these bedding planes representing annual variations in the lake chemistry do not provide significant hydraulic pathways. The mapped areas may also contain smaller lake basins and clay-rich tills.

Ground moraines are deposited beneath glaciers and are composed of fine-to-medium textured till. The geomorphology of these features is a broad, relatively flat land surface with subtle undulation. The matrix of ground moraine till is primarily clay, silt, and loam. Variable amounts of sand, gravel, and cobbles are often present within the matrix. The deposits typically exhibit low permeability and often function as confining units in a hydrogeologic setting. The mapped ground moraine areas may also contain small areas of outwash deposits and complex till deposits of undifferentiated ground and end moraine deposits.

End moraines are deposited at the margins of glaciers, often represent “stillstands” of the ice sheet at the regional scale and are composed of medium-to-coarse textured till. The geomorphology of these glacial features is linear belts of “hummocky”, “knob and kettle,” or “swell and swale” topography. The matrix of end moraine till is primarily silt and loam. Hydraulically connected intervals of sand and gravel are commonly present and represent potential aquifers that can be developed as groundwater resources. The mapped end moraine areas contain small areas of outwash deposits and complex till deposits of undifferentiated ground and end moraine deposits.

2.3 SOILS

The description and mapping of the soils present across the study area were derived from the STATSGO database and the digital general soil association maps for Indiana, Michigan, and Ohio as developed by the National Cooperative Soil Survey and distributed by the Natural Resources Conservation Service (formerly Soil Conservation Service) of the U.S. Department of Agriculture. The database consists of a generalized inventory of soils that occur in repeatable patterns that can be mapped at regional scales (Figure 5, Appendix A).

The STATSGO soil maps are generalized from detailed soil survey maps, geologic data, topographic information, vegetation distribution, climatic data, and Land Remote Sensing Satellite (LANDSAT) images. Areas of similar characteristics are studied, and probable classifications and extents of the soils are determined. The specific map units are derived by transecting areas on more detailed maps and expanding the supporting data statistically to characterize map units as a whole.

The STATSGO data consists of geo-referenced digital map data and tabulated attribute data. The data are presented in 1-degree by 2-degree topographic quadrangle units, which are then combined into statewide coverage. The map units are linked to the Map Unit Interpretations Record data base, which gives the proportionate extent of the soils and the soil group properties. Separate data sets have been prepared for each state. The data is presented in ESRI GIS format.

STATSGO was designed primarily for regional, multi-county, river basin, state, and multi-state resource planning, management, and monitoring. The data is not detailed enough to make interpretations at a site-specific level. The presented soil boundaries, interpretations, and analyses do not eliminate the need for site-specific sampling, testing, and detailed study for specific sites.

High-detail level soil data has been included for Fulton, Henry, and Williams counties in Ohio to assist in local planning efforts for those areas. The data was taken from the available Pollution Potential Reports but is not reviewed or discussed as part of this petition.

3.0 MICHINDOH GLACIAL AQUIFER SYSTEM

3.1 Physical Description

The Quaternary deposits consist primarily of unconsolidated glacial till deposits that range between 75 and 250 feet thick across the study area. The till is composed mainly of confining clay layers. These layers contain variable amounts of silt, sand, and gravel within the clay matrix.

Potential sand and gravel aquifers are interbedded with the clay layers. The sand and gravel intervals are not laterally continuous across the area; that is, the layers are not evident as a "sheet" of sediment that blankets the study area. In map view, there are "holes" in the aquifer. In addition, geologic cross sections indicate that there is typically only one significant potential sand and gravel aquifer present in the vertical sequence of the glacial till at any given location.

Based on past and present groundwater mapping efforts, all of the sand and gravel intervals within the Quaternary deposits are physically and hydraulically connected and represent one aquifer system, the MICHINDOH Glacial Aquifer. Similar interpretations of the glacial till package in this region as a complex aquifer system with hydraulically-connected, discontinuous sand and gravel intervals are drawn by Thomas (2000) and Strobel (1994).

3.1.1 Aquifer Boundaries

The MICHINDOH aquifer system is laterally extensive. Three physical boundaries within the system were delineated as part of this study. The boundaries were delineated based on nearly 54,000 well logs and 3,500 measured groundwater elevations across the nine-county study area. Four cross sections were constructed to interpret the vertical distribution and lateral continuity of the sand and gravel comprising the aquifer system (Figures 6, 7, 8, 9, 10).

Cross section D-D' trends from the northeast to the southwest, roughly follows the Fort Wayne Moraine and is perpendicular to the regional groundwater flow. The remaining three cross sections trend from the northwest to the southeast and are parallel to the regional groundwater flow. The cross sections demonstrate that the significant sand and gravel deposits are present at various depths but are overlain across most of the region by clay intervals. The clay intervals often confine the aquifers and provide a measure of protection from vertical migration of contamination (OEPA, 2004, 2003, 2002, 2001).

A lateral physical extent boundary is present at the demarcation line where significant sand and gravel deposits are no longer present in the glacial deposits. This boundary was delineated using the geologic cross sections and the change from groundwater-based municipal supplies to surface water-based municipal supplies in Defiance, Fulton, Henry, and Paulding Counties in Ohio (Figure 11). The physical boundary can also be generally correlated with the transition from ground and end moraine deposits to the glacial lacustrine deposits in the southeastern portions of the study area.

This physical boundary begins in Indiana near Spencerville and extends along the county line between Defiance and Paulding Counties in Ohio. The boundary trends to the northeast nearly halfway across Defiance County and extends up into Michigan between Morenci (MI) and Oakshade (OH). The location of the physical boundary is supported within the groundwater literature reviewed as part of this study.

Two groundwater basin divides identified within the study area represent additional physical boundaries within the MICHINDOH aquifer system. The divides are evident in the groundwater contour map generated for the area (Figure 12). The divides were delineated using groundwater contouring and groundwater flow path construction based on nearly 3,500 measured water levels. The first groundwater divide begins near Stroh, Indiana, and extends to the northeast beneath Angola, Indiana, and Hillsdale, Michigan. The groundwater north of this boundary flows to the northwest and the groundwater to the south flows to the southeast.

The second groundwater divide is located in the northeastern portion of the study area (Figure 12). The divide begins near North Adams, Michigan, and extends to the southeast near Clayton, Weston, and Jasper, Michigan. Groundwater north of this divide is influenced by the River Raisin in Michigan and flows to the east. The groundwater south of the divide is influenced by the Maumee River in Ohio and flows to the south.

The MICHINDOH aquifer system extends beyond the western limits of the study area and continues into Indiana. No physical extent boundary was identified in Indiana, but a hydraulic boundary was identified in the northern portions of Steuben County. An economic boundary within the remainder of Steuben and DeKalb counties is delineated and explained in Section 5 of this petition document.

3.1.2 Hydraulic Characteristics

The hydraulic characteristics of the MICHINDOH aquifer system vary across the study area. Values for the aquifer transmissivity, hydraulic conductivity, storage coefficient, and potential production well yields were compiled from a variety of sources including:

1. USGS reports,
2. University of Toledo Ohio student projects,
3. Groundwater modeling for Bryan, Ohio (Bennet & Williams, 2002),
4. Michigan groundwater mapping project (MDEQ),
5. Hydrogeologic Atlases for Indiana and Michigan.

Michigan's groundwater mapping project provides a breakdown by land survey section of the transmissivity and potential well yield for the glacial aquifers within the study area. The summary is based on aquifer performance tests submitted by various municipalities, pumping test information recorded on well logs, and previous mapping efforts.

The aquifer transmissivity across Branch, Hillsdale, and Lenawee Counties is typically between 1,300 and 1,800 ft^2/day. Transmissivities greater than 4,000 ft^2/day are present in northern Hillsdale County. Transmissivities less than 500 ft^2/day are present in sporadic areas of limited extent across all three counties. The reported aquifer yields are typically between 200 and 500 gallons per minute (gpm). In areas where the glacial aquifers are limited, lower potential yields of between 70 and 200 gpm are evident.

Description of the MICHINDOH aquifer system hydraulic characteristics across the Indiana counties is derived from the Hydrogeologic Atlas for Indiana and the USGS Regional Aquifer System Analysis (RASA) for the Midwestern Basin and Arches Aquifer System (of which the MICHINDOH aquifer system is a part). The hydrogeologic atlas describes the buried sand and gravel aquifers within the Quaternary deposits near DeKalb County with an average thickness of 25 feet. The median yield of production wells at least 10 inches in diameter is 250 gpm with a range of 20 to 500 gpm. There are two areas north of the St. Joseph River in DeKalb County where more than 1,000 gpm is available from the sand and gravel aquifers. The report states that equally large well yields are probably available throughout the area, and that large yields have been described wherever groundwater production wellfields have been developed.

The RASA study summarizes seven aquifer performance tests conducted in Steuben County, Indiana. The tests indicated aquifer transmissivities of between 1,000 and 10,000 ft^2/day with storage coefficients between 0.38 and 0.00002 ft/ft.

Coen (USGS, 1989) and Bennet & Williams, Inc. have compiled aquifer performance test results within Williams County, Ohio. The range of transmissivity is between 2,800 and 64,300 ft^2/day with a median of nearly 14,000 ft^2/day. The associated storage coefficients range from 0.0001 to 0.0038 ft/ft with a median of 0.0002 ft/ft. The Source Water Assessment Program in Ohio has performed wellhead protection modeling for the communities of Edon, Pioneer, Sherwood, and Stryker. The modeled aquifer thickness ranged from 13 to 25 feet, with a hydraulic conductivity of 100 to 300 ft/day and transmissivities of 1,600 to 5,000 ft^2/day.

In the Ohio counties, the horizontal hydraulic conductivities measured in the deeper sand and gravel intervals using aquifer performance tests, and used in Coen's model, typically range from 100 to 300 feet per day (Jones and Henry, 1968; ODNR, 1969; Basic Design Associates, 1975; King, 1977; Baggett, 1987; MDEQ – GMIS, current). The Ohio EPA uses the same range of horizontal hydraulic conductivities to conduct source water assessments for the various municipalities in the region. The Bennett & Williams model for Williams County, Ohio, incorporated a horizontal hydraulic conductivity range of 100 to 140 feet per day for the aquifers within the glacial drift.

A contour map of the potentiometric surface was produced using nearly 3,500 well logs with recorded depth to water and ground surface elevation (Figure 12). The Michigan Department of Environmental Quality and the Indiana Department of Environmental Management maintain extensive digital well log databases that can be accessed either as Adobe Acrobat .pdf files or as data files. The information includes a number of well descriptors including well identification numbers, lithology descriptions (depth, thickness, composition, classification), well construction details, location by section breakdowns, physical addresses, GPS coordinates, pump and pumping information, water level data, etc. These data can be easily imported electronically into GIS-based environments.

The Ohio Department of Natural Resources also maintains a database, but the well logs are available as individual documents of .GIF image files. The available digital data cannot be easily tied to a GIS-based environment and contains limited information related to the submitted well logs. The data include well identification numbers, physical addresses, casing lengths, well depths, groundwater levels, and aquifer types. Limited data for pumping test rates are provided, but no drawdown data is recorded. The well latitude and longitude descriptors are extremely limited, and the lithology information is not provided in a tabulated digital format. The .GIF files were used to locate the wells and manually input the needed lithology and ground surface elevation data.

The set of well logs selected from the available databases for use in the groundwater contouring effort included 2,100 wells across Branch, Hillsdale, and Lenawee Counties in Michigan; 1,050 wells in DeKalb and Steuben Counties in Indiana; and 330 wells across Defiance, Williams, and portions of Fulton and Henry Counties in Ohio. The total number of groundwater levels used was nearly 3,500. These represent sand and gravel aquifers from various depths within the MICHINDOH aquifer system.

The contouring was performed using the software Surfer (Golden Software, version 8.05, 2004). The data was sorted by depth and contour maps were generated for shallow, intermediate, and deep sand and gravel intervals. A fourth map was generated using all of the water levels regardless of the well depth (Figure 12). The four maps are nearly identical and indicate that the significant sand and gravel deposits across the study area are hydraulically connected regardless of depth.

The contour lines indicate that the regional groundwater flow is generally from the northwest to the southeast. The gradient of the potentiometric surface is approximately 0.0015 to 0.0031 feet per feet across the region. The steepest gradient is located near the high recharge areas in southern Michigan at the headwaters of the Tiffin and St. Joseph (east) Rivers.

A distinct flattening of the gradient is present near the transition from the ground and end moraines in southeastern Williams County to the glacial lake plain deposits to the southeast. The regional groundwater gradient decreases to about 0.0005 feet per feet in this area, and the groundwater flow direction trends more to the east.

3.1.3 Groundwater Discharge and Withdrawal

The water demand statistics for the study area were derived from the 2000 U.S. Census data. The study area is comprised of nine counties in Indiana, Michigan, and Ohio. The statistics represent water withdrawn and used for drinking water, industrial purposes, and irrigation needs. The data are summarized in Table 2 under the headings of gross water withdrawal, end user, and source water.

The total water demand was 81.46 million gallons per day (MGD). Thirty-nine percent of this demand was met through public water supply systems, 29 percent through residential wells, and 32 percent through commercial or agricultural systems.

Table 2. Population, Water Demands, and Source Waters

State/County		Total population served	Public Water Supply Systems				Domestic Water Self-Supply System			
			Population served	Total withdrawals (MGD)	Groundwater (MGD)	Surface water (MGD)	Population served	Total withdrawals (MGD)	Groundwater (MGD)	Surface water (MGD)
De Kalb	IN	40,280	23,920	4.37	4.37	0.00	16,360	1.24	1.24	0.00
Steuben	IN	33,210	10,090	1.46	1.46	0.00	23,120	1.76	1.76	0.00
Branch	MI	45,790	20,780	3.23	3.23	0.00	25,010	2.16	2.16	0.00
Hillsdale	MI	46,530	15,030	2.11	2.11	0.00	31,500	2.72	2.72	0.00
Lenawee	MI	98,890	49,580	6.45	3.47	2.98	49,310	4.26	4.26	0.00
Defiance	OH	39,500	24,490	5.17	0.59	4.58	15,010	1.08	1.06	0.02
Fulton	OH	42,080	21,882	4.02	0.15	3.87	20,198	1.46	1.43	0.03
Henry	OH	39,190	15,500	1.75	0.31	1.44	14,310	0.99	0.97	0.02
Williams	OH	39,190	22,730	3.03	3.03	0.00	16,460	1.28	1.25	0.03

State/County		Total withdrawals (MGD)	Other Water Uses		Public Water Supply Systems			Domestic Water Self-Supply System		
			Groundwater (MGD)	Surface water (MGD)	Total withdrawals (MGD)	Groundwater (MGD)	Surface water (MGD)	Total withdrawals (MGD)	Groundwater (MGD)	Surface water (MGD)
De Kalb	IN	11.58	4.71	0.31	4.37	4.37	0.00	1.24	1.24	0.00
Steuben	IN	4.79	0.58	0.24	1.46	1.46	0.00	1.76	1.76	0.00
Branch	MI	17.97	7.14	5.16	3.23	3.23	0.00	2.16	2.16	0.00
Hillsdale	MI	8.39	2.02	1.22	2.11	2.11	0.00	2.72	2.72	0.00
Lenawee	MI	12.28	0.48	0.81	6.45	3.47	2.98	4.26	4.26	0.00
Defiance	OH	6.47	0.00	0.07	5.17	0.59	4.58	1.08	1.06	0.02
Fulton	OH	5.93	0.00	0.06	4.02	0.15	3.87	1.46	1.43	0.03
Henry	OH	9.07	0.00	6.20	1.75	0.31	1.44	0.99	0.97	0.02
Williams	OH	4.98	0.36	0.09	3.03	3.03	0.00	1.28	1.25	0.03

The water demand was met with withdrawals from groundwater and surface water resources. Ninety-nine percent of the private residential users withdrew water from groundwater resources while less than 1 percent utilized surface waters. Fifty-nine percent of the water used by public water supply systems was derived from groundwater resources and 41 percent was derived from surface waters. Fifty-two percent of the water used by industrial and agricultural consumers was derived from groundwater resources and 48 percent was derived from surface waters.

The statistics above represent the study area, but not the proposed petition area. None of the nine counties in the study area are contained wholly within the petition area. Furthermore, the entirety of Henry County (Ohio) lies outside the petition area (Figure 16). Based on the water sources reported in the 2000 U.S Census data, the water demands of the private and public water consumers within the proposed petition area are met solely with groundwater resources.

No groundwater discharge wells have been identified in the study area. A few municipal waste water treatment plants do discharge polished water into the local drainage systems and streams. However, the amount of discharge is not a significant source of stream discharge and has a negligible effect on the groundwater system.

3.2 Recharge Areas

The recharge estimates for the study area are drawn from three primary sources. First, the OEPA estimated recharge as part of its DRASTIC studies for Fulton, Henry, and Williams counties. Second, the Michigan Groundwater Mapping Project assigned recharge values to every land survey section within the state's primary watersheds. Third, the results of a regional recharge rate study (USGS, 2005) were used to provide estimates for the portions of the study area not addressed in either of the two previously cited sources.

Each of these three sources comprises a regional level, recharge representation based on different methods applied to different sets of factors. No attempt was made to reanalyze the tremendous amount of background data from the three sources using a common method applied across the entire area. Rather, the results of the three studies are presented individually, and the methodology employed within each study to determine the regional recharge rates is described below (Figure 13).

The applicability of the regional-level data is summarized in the USGS report (2005):

> "No one approach is ideal for making detailed estimates on a large spatial scale; each approach is better suited to examine recharge at particular spatial and temporal scales and particular hydrogeologic settings, and some approaches may not be applicable in the Great Lakes Basin. In general, the approaches that provide estimates at fine spatial and temporal scales are limited in the areal extent to which they can be applied. Consequently, using a combination of approaches may prove to be the best method for estimating shallow ground-water recharge in the Great Lakes Basin."

The regional recharge estimates are useful for determining the portions of the study area critical to the area's groundwater resources. However, additional studies should be prepared for site-specific projects.

3.2.1 Recharge Delineation Methods and Results

The OEPA calculated recharge rate values within the DRASTIC studies based on numerous factors including depth to groundwater, topography, soil type, surface drainage, vadose zone material, aquifer type, and annual precipitation. The calculated recharge rates were then associated with glacial landforms and areas where the glacial aquifer system is confined, leaky confined, or unconfined. The results include:

1. 0 to 2 inches per year where glacial lake deposits confine glacial outwash aquifers;
2. 2 to 4 inches per year where low-permeable soils provide leaky-confined aquifer conditions in areas of ground moraine and lake plain deposits;
3. 4 to 7 inches per year where moderately permeable soils overlie end moraines, stream deposits, outwash deposits, and buried beach ridges;
4. 7 to 10 inches per year where coarse-grained deposits are present in buried valley settings.

The Michigan Groundwater Mapping Project assigned recharge values using base-flow separation techniques applied to USGS stream flow gauge data. Additional consideration was given to watershed characteristics which describe the geology, land cover, and general climate. These data were analyzed with a forward stepwise regression procedure. Within the eastern Lower Peninsula, the significant predictive variables, in addition to area, included agricultural land use, urban land use, annual growing degree days, annual precipitation, and percent of the watershed underlain by lacustrine deposits. The accuracy of the recharge estimates are considered to be within 1.1 inches per year in the southeastern Lower Peninsula.

The mapping project results are presented in Figure 13. The recharge estimates range from 4 to 6 inches per year across much of Lenawee County to between 7 and 10 inches per year across much of Branch and Hillsdale Counties. The highest recharge values of 12 to 15 inches per year are present near the City of Hillsdale.

The USGS RASA project focus was a regional determination of recharge associated with large river basins. The general technique was to correlate river base flow with areal recharge. To accomplish this, six steps were taken. First, the local base flow index (BFI) was defined from streamflow data using a hydrograph separation program (PART). Second, the BFI was related to the surficial geologic materials using a regression model. Third, the regression model was used to interpret the BFI for each un-gauged watershed assigned a Hydrologic Unit Code (HUC). Fourth, the total streamflow was estimated for each HUC by interpolating the ratio of the long-term average streamflow per unit area. Fifth, the long-term average run-off was multiplied by the long-term average BFI to estimate the long-term average base flow. Sixth, the long-term average base flow was converted to recharge by summing the base flow quantity for the HUC and dividing this value by the drainage basin area. The end result is a depth of recharge per year for each drainage basin.

Additional independent projects that estimate recharge values within Williams County, Ohio, include modeling performed by Coen (1989), and Bennett & Williams (2002). Coen relied on the recharge estimates of Pettyjohn and Hemming (1977) to apply a range of 2 to 8 inches per year within his groundwater flow model.

Generally, he correlated low, moderate, and high recharge areas with soil infiltration rates determined from the U.S Soil Conservation Service. The Wabash Moraine area had high recharge rates, the Fort Wayne Moraine had moderate rates, and the lacustrine deposits had low recharge rates assigned. The more recent MODFLOW model constructed by Bennett & Williams utilizes recharge rates of 1, 3, and 4 inches per year for lacustrine, ground moraine, and end moraine deposits, respectively.

3.2.2 Recharge Source Description

The groundwater that flows through the sole source aquifer area comes from two main sources. First, recharge occurs from infiltration of precipitation across the area. The amount of recharge due to infiltration is highly variable. Some of the factors that affect the recharge include vegetation cover, soil moisture, land use, air temperature, precipitation variables, soil types, and presence of clay layers (King, 1977). Stream gauge records are typically used to quantify the recharge from infiltration.

The second source of recharge is the lateral movement, or inflow, of groundwater from areas which are further up-gradient within the groundwater basin. King (1977) states in his thesis that the main source of recharge in Williams County, Ohio, is groundwater inflow from the northwest through the deeper sand and gravel deposits. Coen's (1989) groundwater model for Williams County suggests that about half of the total areal recharge into the county comes from local infiltration of precipitation and the other half from groundwater flowing into the county from the northwest. The Bennett & Williams (2002) model for the county attributes a higher percentage of recharge to the inflow from the northwest than does the Coen model, due to lower estimated areal recharge estimates. Although the various researchers apply different recharge rates, there is a consensus in the more recent studies that more than 50 percent of the recharge across the area is due to infiltration.

A few municipal wastewater treatment plants discharge polished water to the surface water drainage systems. Some of this treated water does contribute to the areal recharge in losing stream segments.

There are no surface impoundments located within the proposed SSA area that could represent an additional recharge source from bed leakance. Additionally, there are no groundwater injection wells or other man-induced direct groundwater recharge activities present across the area.

3.3 VULNERABILITY ASSESSMENT

Potential pollution threats to the MICHINDOH aquifer system are related to two types of recharge. First, groundwater flows from the groundwater basin divide in Hillsdale County, Michigan, to the southeast through the aquifer system. Thus, contamination in the northern portions of the proposed sole source aquifer area could migrate laterally to the southeast through the sand and gravel aquifers. Second, precipitation across the area could migrate vertically through the unconsolidated glacial sediments and into the aquifer system. This vertical migration can be attributed to at least three factors including near surface sand and gravel intervals, fractures or weathering in clay intervals that overly the significant aquifers, and exiting water wells.

Lateral contaminant migration from the northwest groundwater divide presupposes contamination is already present within the aquifer system at or near the divide. Such contamination would be related to vertical infiltration of contaminants from the ground surface into the underlying aquifer system. The potential for such infiltration is present near the groundwater divide in Hillsdale County, Michigan, where high estimated recharge values (12 to 15 inches per year) coexist with permeable, coarse-grained soils and sand and gravel aquifers at or near the ground surface.

Vertical contaminant migration threats are also present within the modern and historical river valleys of the Tiffin and St. Joseph (east) Rivers (Angel, 2003; Miller, 2002; Plymale, 2002) which are described with high recharge values. The reported recharge in these basins reaches 8 inches per year, which is 25 to 50 percent greater than the surrounding areas of ground and end moraine deposits (2 to 4 inches per year).

Geologic cross sections through these river valleys presented within Coen's study (1989), Baggett's thesis (1987), the City of Bryan's new wellfield study (Tritium, Inc., 2006), and the regional cross sections constructed for this petition all indicate that in places the near surface sand and gravel intervals associated with these rivers extend to depths of more than 100 feet and are in direct contact with the sand and gravel aquifers within the MICHINDOH aquifer system. These physical connections provide direct routes for precipitation and potential contamination to migrate vertically through the river beds and into the underlying aquifer systems.

Vertical contaminant migration may also occur even in areas with low estimated recharge values and in areas where the geologic cross sections indicate that the significant potential aquifers are confined beneath clay layers greater than 50 feet thick. Historical research indicates that vertical groundwater and contaminant migration through significant, deep clay layers is limited, but more recent research indicates that such vertical migration may be more significant.

Historical research was based on constant head permeability tests performed on clay sediment cores taken from the glacial drift deposits from locales across Indiana, Illinois, Michigan, and Ohio. The tests measured the vertical hydraulic conductivities of the clay sediments. The measured conductivities ranged from 0.3 feet per day in near surface sandy clay to less than 3.0×10^{-8} feet per day in deep clay (Norris, 1962; Das, 1985).

A recent USGS paper (Thomas, 2000) evaluated aquifer vulnerability beneath confining clay layers. The research is based on water quality analyses of groundwater samples collected from 45 wells across eight counties in northwest Ohio and southeast Michigan. The study concluded that a dynamic local flow system is present to depths of up to 35 feet below grade. The study also found anthropogenic constituents in wells screened at intervals between 60 and 120 feet below grade in areas where the glacial till is coarse-grained. Finally, the paper states that surficial glacial till is heterogeneous and not likely to offer uniform protection to the underlying aquifers due to potential pathways of near-vertical fractures and sand-and-gravel stringers present in clay layers.

Additional recent research in Ohio has focused on vertical groundwater infiltration through clay intervals which were previously considered impermeable to groundwater for practical purposes (Weatherington-Rice, et al, 2006 and 2000; Allred, 2000; and Brockman, 2000). These studies are based on inspection of insitu boring samples, streambed cuts, and test pits typically restricted to the uppermost 30 feet of the unconsolidated deposits. Vertical infiltration and groundwater migration is attributed due to the presence and effect of fractures, macropores, weathering, and horizontal microseams of sand. The studies also suggest that the fractures in the clay may extend to depths of more than 50 feet.

Lastly, vertical contaminant migration could occur through the thousands of private active and abandoned wells scattered across the study area. Each of these wells represents a potential pathway into the aquifer system. Well logs are available for less than half of the wells present within the study area and the well logs that are available indicate a number of different drilling techniques combined with variable construction materials and methods. Different grouting techniques may be especially critical when considering vertical groundwater migration on the outside of the well casings.

In summary, the potential contamination threats for the MICHINDOH aquifer system include the following "windows" into the aquifer system:

1. direct recharge to the aquifers in Hillsdale County, Michigan,
2. groundwater inflow from the northwest to the southeast,
3. direct recharge to the aquifers through extensive sand and gravel deposits associated with the modern and historical Tiffin and St. Joseph Rivers,
4. potential leakage through overlying clay layers,
5. thousands of private water wells.

All of the above indicate that the MICHINDOH aquifer system is vulnerable to potential contamination threats. Highly vulnerable areas would include the high recharge areas found in Hillsdale County, Michigan, and along the Tiffin and St. Joseph River valleys where vertical migration of groundwater and contaminants occurs at more rapid rates. Even areas with low susceptibility ratings with respect to contamination present multiple potential pollution pathways. Such pathways include private water wells that penetrate the confining clay layers and are screened across sand and gravel intervals within the aquifer system. Potentially interconnected fractures, microseams, macropores, and weathered zones also present pathways for vertical migration of groundwater and contaminants, especially within the uppermost 50 feet of coarse-grained glacial tills.

3.4 STREAMFLOW SOURCE AREA

3.4.1 Source Area Delineation

The Maumee River is the largest of the river systems that drain portions of the study area. The headwaters of the river are located near Fort Wayne, Indiana, and the river flows across the southern portions of the study area through Paulding, Defiance, and Henry counties. Notable tributaries to the Maumee River that have an impact on the proposed sole source aquifer area include the St. Joseph River and the Tiffin River. The drainage basin boundaries of the St. Joseph and Tiffin Rivers are presented in Figure 14.

The Maumee River drains an area of 6,354 square miles and discharges an average of 5,297 cfs (3,423 MGD) into Lake Erie. The river stretches over 350 miles with a ground surface elevation change of 750 feet at the headwater to 571 feet above mean sea level (amsl) at the river mouth along the southern shore of Lake Erie (gradient of 0.000097 ft/ft). The daily river discharge is measured at a gauging station located 4 miles downstream of the Auglaize River, 40 feet upstream of the Independence Dam, and 4.5 miles east of Defiance, Ohio (gauge 04192500). A plot of the monthly-mean daily discharge measured at this gauge over the past 10 years is included in Appendix B. The geometric mean of the measured daily discharge at this gauging station from the period 1925 to 2006 is 4,090 cfs (2,643 MGD).

Flow in the Maumee River is affected by hydroelectric plant operation on the Auglaize River seven miles upstream of the stream gauge. Low flow is slightly regulated by the powerplant at Fort Wayne, Indiana, and slight diversions into the Miami and Erie Canals through a 24-inch conduit.

The headwaters of the Tiffin River are located in Hillsdale and Lenawee counties in Michigan. The river flows south through Fulton, Williams, and Defiance counties in Ohio and discharges into the Maumee River near the City of Defiance, Ohio. Prominent tributaries of the Tiffin River include Bean Creek, Brush Creek, Lick Creek, Lime Creek, Lost Creek, Mill Creek, and Mud Creek.

The Tiffin River drainage basin encompasses nearly 805 square miles, and the river highly meanders over a 75 mile course. The land surface elevation ranges from 1,000 feet amsl near the headwaters to 665 feet amsl near the river mouth (gradient of 0.00083 ft/ft).

The river discharge is monitored by a gauging station (04185000) near Stryker, Ohio, a mile and a half downstream from Leatherwood Creek and half a mile upstream from the Penn Central Railroad Bridge. A plot of the monthly-mean daily discharge measured at this gauge over the past 10 years is included in Appendix B. The Tiffin River has discharged a geometric mean of 311 cfs (201 MGD) into the Maumee River for the period 1922 to 2005.

Two rivers in the study area bear the name St. Joseph River. The headwaters of the easternmost St. Joseph River are located in Hillsdale County in Michigan, and impact the MICHINDOH aquifer system. The river flows to the southwest through Williams and Defiance counties in Ohio and through DeKalb and Allen counties in Indiana, and discharges into the Maumee River near Fort Wayne, Indiana. The St.

Joseph River (east) drainage basin encompasses 1,060 square miles and flows from nearly 1,050 feet amsl at the headwaters near Hillsdale, Michigan to 754 feet amsl at the river mouth near Fort Wayne, Indiana. The river flows for nearly 100 miles with a gradient of 0.00056 ft/ft.

A stream gauge (04178000) is located near Newville, Indiana, about 800 feet east of the Indiana-Ohio state line on State Road 249 about 500 feet southeast of Conkle Road (County Road 42). A plot of the monthly-mean daily discharge measured at this gauge over the past 10 years is included in Appendix B. The drainage basin above this stream gauge is 610 square miles. The geometric mean of the measured daily discharge from the period 1948 to 2006 is 508 cfs (328 MGD).

A second stream gauge (04180500) is located at the mouth of the river near Fort Wayne, Indiana, 0.8 mile downstream from Ely Run and 1.3 miles upstream from Mayhew Road. A plot of the monthly-mean daily discharge measured at this gauge over the past 10 years is included in Appendix B. The geometric mean of the measured daily discharge from the period 1984 to 2006 is 1,014 cfs (655 MGD).

Two other river systems are present in the study area, but neither provides surface water to the sole source aquifer area. The headwaters of the River Raisin are located in Lenawee County, Michigan, and Fulton County, Ohio, and are adjacent to the headwaters of the Tiffin River. The River Raisin flows to the east and discharges into Lake Erie. The headwaters of the St. Joseph River (west) are located in Hillsdale County, Michigan, within five miles of the headwater of the St. Joseph River (east). The St. Joseph River (west) flows west through Indiana and Michigan and discharges into Lake Michigan. This river system does not provide surface water to the SSA area.

3.4.2 Gaining/Losing Rivers

The regional geology indicates that the significant sand and gravel intervals of the MICHINDOH aquifer system are present near the ground surface primarily in the northern portions of the study area in Michigan and northern Williams County, Ohio. The depth to these potential aquifer intervals increases with distance to the southeast. In the southern portions of the study area the depth to the significant potential aquifers is between 75 and 100 feet.

A comparison of the potentiometric surface contours and the local river elevations (derived from USGS 7.5-minute quadrangle maps) was used to determine the location of the gaining and losing portions of the two largest river systems. Where the contour elevation exceeded the river elevation, the river segment was considered to gain discharge. Where the river elevation was greater than the contour elevation, the river segment was considered to lose discharge (recharging the sand and gravel intervals beneath the river bed).

Two gaining river segments, each less than three miles long, are evident in the upper reaches of the St. Joseph (east) River and the Tiffin River (Figure 14). These reaches are associated with permeable soil types in high surface recharge areas and located within the headwaters of these two river systems. The third, and largest, gaining river segment is located in the middle reach of the Tiffin River along Bean Creek. The segment begins just downstream of the Village of Morenci, Michigan, and continues nearly eight miles south to the confluence of Bean Creek with the Tiffin River. The area is marked on the Morenci 7.5-minute USGS quadrangle map as an area where flowing wells are present.

The RASA Study for the Midwestern Basin and Arches Aquifer System (of which the MICHINDOH aquifer system is a part) indicates that the St. Joseph and Tiffin River systems contribute a mean sustained recharge of between 21 and 42 cubic feet per second (cfs) to the sediments beneath the stream beds. This equates to approximately 15 to 16 percent of the total stream discharge.

Coen (1989) conducted a more detailed gaining/losing stream study in portions of Williams County as part of his research. Measurements were taken during low-flow season on segments of six different local streams (Bear, Beaver, Eagle, Mill, Nettle, and Prairie Creeks). Each of the streams either gained or maintained discharge over the observed stream segment indicating continual discharge of groundwater into the streams. His research suggests that 10 to 15 percent of the total stream discharge is lost through the stream beds into the underlying glacial sediments.

Groundwater levels within permanent monitoring wells are measured by the ODNR Division of Water at three locations within Williams County, Ohio (Table 3). The historical records from these locations indicate that although there is some variation in the elevation of the groundwater levels, the standard deviations range from 2.21 to 3.74 feet (Appendix C). This elevation change is not enough to affect significant portions of the larger river systems and induce changes from losing to a gaining river segments for considerable periods of time. Plots of the stream gauge data that represent the stream discharge over the past 10 water years for the St. Joseph River (east), Tiffin River, and Maumee River are included in Appendix B.

Table 3. Groundwater Levels within Permanent Monitoring Wells

Well	Depth to Water			Standard
Identifier	Greatest	Least	Average	Deviation
WM-1A	34.89	18.84	27.34	3.74
WM-3	28.8	15.3	20.42	2.21
WM-12	10.75	5.17	8.87	1.06

3.5 AQUIFER SERVICE AREA

The aquifer service area boundaries associated with this petition lie within the other boundary types. That is, the end water users of the proposed sole source aquifer all reside in the areas immediately above the proposed petition area. There are no additional water demand needs that must be satisfied by selling or transmitting groundwater out of the proposed area. Therefore, the aquifer service area does not expand the sole source aquifer boundaries. Additionally, no additional water demands, production expenses, or additional available funding are required to be included in the economic feasibility analysis in Section 5 of this petition document.

3.6 PROJECT REVIEW AREA (DESIGNATED AREA)

The project review area, or the designated area, is presented in Figure 16. The outline of the area is a conservative compilation of four delineated boundaries: the physical extent of the aquifer, the groundwater divides, an economic boundary, and the surface water basin boundaries (divides). The intent of the compiled boundary is to provide the maximum protection for the proposed SSA area and the water users within that area.

3.6.1 Physical Extent Boundary

The MICHINDOH aquifer system physical limits were delineated on the basis of well logs, geologic cross sections, and municipal water supply source changes. The aquifer system extends past the northern, western, and eastern study area limits. However, a physical extent boundary was identified in the southern portions of the study area. This boundary is present in Indiana near Spencerville, and extends along the county line between Defiance and Paulding Counties in Ohio (Figure 15). The boundary trends to the northeast across the eastern portions of Defiance County and extends between Morenci (Michigan) and Oakshade (Ohio).

3.6.2 Groundwater Divide Boundaries

The two groundwater divides displayed in Figures 12 and 15 were derived from the groundwater contour map generated for the area. The groundwater contouring was performed using Surfer (Golden Software, 2004) and kriging techniques performed on nearly 3,000 measured water levels within the study area. The northern divide begins near Stroh, Indiana, and extends to the northeast beneath Angola, Indiana, and Hillsdale, Michigan. Groundwater north of the divide flows to the northwest and groundwater to the south flows to the southeast.

The second divide is located in the northeastern portion of the study area and begins near North Adams, Michigan. The divide extends southeast and passes near Clayton, Weston, and Jasper, Michigan. Groundwater north of this divide flows to the east and is associated with the River Raisin in Michigan. Groundwater south of the divide flows to the south under the influence of the Maumee River.

3.6.3 Economic Boundary

The MICHINDOH aquifer system physically extends beyond the western limits of the study area. Neither a groundwater divide, nor a physical extent limitation was identified based on the available information. However, the economic feasibility analysis present in Section 5 of this petition document can be used to delineate an economic boundary for the Sole Source Aquifer designation (Figure 15).

The economic boundary represents a demarcation line where the MICHINDOH aquifer system no longer is a sole source. This line represents a boundary for the SSA area even though the MICHINDOH aquifer system extends further to the west. The economic feasibility analysis shows that there are alternative water supply sources which can be reasonably developed (in accordance with the EPA guidelines) to completely replace the MICHINDOH aquifer system.

3.6.4 Surface Water Drainage Basins

The two major surface water drainage basins that contribute to groundwater recharge for the designated area are the Tiffin River and the St. Joseph River (east). The boundaries of these two river systems are presented in Figure 14. Both systems have surface boundary expressions that extend beyond the two delineated groundwater divides. Additionally, the headwaters of both rivers are located in high recharge areas in Michigan and northern Ohio where highly permeable soils are present at the ground surface. Thus, the surface water drainage areas that have the potential to transport contaminated surface water across the groundwater divides are included in the proposed SSA area designated area.

4.0 SOLE (PRINCIPAL) SOURCE DETERMINATION

The information presented in this section is sufficient to defend designation of the proposed land surface area as a sole source aquifer. Population statistics, water usage, current water supply resources, alternative resources, and economic feasibility analyses were evaluated for the areas within the boundaries described in the previous sections. The results prove that the MICHINDOH aquifer system is the sole source of drinking water for the designated area.

4.1 POPULATION

The population statistics are based on the 2000 U.S Census data. The next census is due to take place in 2010. Previous census projection analysis indicate that although some of the areas within the study area have shown growth, other areas have shown a decline. Yet, both the growth and decline rates were less than 5 percent of the total recorded population between 1990 and 2000 across the State of Ohio according to the U.S. Census Bureau (Figure 17).

The population data is categorized by state, county, and municipality and is presented in Tables 4 and 5. The county data is the product of the rural population density (person per square mile) and the number of square miles within the SSA area for each county.

4.1.1 Total Population

The State of Ohio represents the greatest land area within the proposed SSA boundaries, as well as, the largest population base with nearly 69,000 residents across 750 square miles. Thirteen municipalities within the state were included in this study with a population range from 8,360 (City of Bryan) to 126 (Village of Blakeslee). The mean municipal population is nearly 1,200 persons.

The State of Michigan represents the second-most land area but is the least populated state within the proposed boundaries with nearly 45,500 residents across almost 600 square miles. Six Michigan municipalities were included in this study with a population range from 2,415 residents in the Village of Hudson to 542 residents in the Village of Camden. The mean municipal population is approximately 2,000 residents.

The State of Indiana represents the least amount of land area and is the second-most populated state within the proposed boundaries with nearly 49,000 residents across almost 269 square miles. The study included six Indiana municipalities with a population range from 7,344 (City of Angola) to 452 (Village of Saint Joe). The mean municipal population is nearly 2,700 residents.

The total land area within the proposed boundaries is just over 1,600 square miles. More than 163,000 residents live within the area with an average municipal population of 1,500 and a mean rural population density of 59 (residents/mi^2).

Table 4. Rural Population by County

County	State	Rural Population Density (persons per sq mi)	Area within Proposed SSA Boundaries (sq mi)	Total Rural Population in proposed SSA area
De Kalb	IN	46.5	158	7,352
Steuben	IN	73.6	111	8,169
Branch	MI	61.8	14	866
Hillsdale	MI	58.9	368	21,680
Lenawee	MI	71.5	200	14,304
Defiance	OH	45.7	230	10,511
Fulton	OH	59.0	100	5,898
Henry	OH	33.9	0	0
Williams	OH	61.9	420	26,007

4.1.2 Total Population Served

The total population served and the breakdown of the water demand are summarized in Table 6. The total served population is just over 385,000 persons, and the total water demand is 72.39 MGD. The population and demand statistics were derived from the 2000 U.S. Census data and are organized according to State and County. Public water supply systems provide nearly 30 MGD of drinking water to 188,500 persons. Private domestic water supply systems provide nearly 16 MGD of drinking water to approximately 197,000 persons. The rest of the water demand is distributed across a variety of end uses, some of which include irrigation, thermo-electric power supply, and industry.

4.2 CURRENT DRINKING WATER SOURCES

The population of Branch, Defiance, DeKalb, Fulton, Hillsdale, Lenawee, Steuben, and Williams counties is more than 385,000 persons. The total water usage is 72.39 MGD with approximately 43 percent of the water use dedicated to public water supply systems and 23 percent of the water use dedicated to private or residential water supply systems. The remaining 34 percent of the water usage is related to irrigation, industry, and other similar needs.

Based on the 2000 U.S. census data the population within the nine counties included in the study area rely on a combination of groundwater and surface water resources to meet their drinking water needs. However, the census data also reveals that the entire population that resides within the petition area relies exclusively on the MICHINDOH aquifer system to meet their drinking water demand.

Table 5. Population by Municipality and State

City	State	Population
Auburn	IN	12,074
Angola	IN	7,344
Garrett	IN	5,349
Butler	IN	2,725
Waterloo	IN	2,200
Hamilton	IN	1,944
Ashley	IN	1,010
Hudson	IN	596
Saint Joe	IN	452
Total Rural	IN	15,521
Total State	*IN*	*49,215*
Hudson	MI	2,415
Morenci	MI	2,352
Manitou Beach	MI	2,080
Addison	MI	611
Waldron	MI	577
Camden	MI	542
Total Rural	MI	36,850
Total State	*MI*	*45,427*
Bryan	OH	8,360
Monpelier	OH	4,135
Hicksville	OH	3,533
Edgerton	OH	2,015
West Unity	OH	1,803
Stryker	OH	1,391
Fayette	OH	1,326
Pioneer	OH	1,248
Edon	OH	863
Sherwood	OH	801
Ney	OH	364
Alvordton	OH	298
Blakeslee	OH	126
Total Rural	OH	42,416
Total State	*OH*	*68,679*
Grant Total		**163,321**

4.2.1 Source Matrix

The current public water supply demands met by withdrawal from the MICHINDOH aquifer system through municipal wellfields are summarized in Table 6. This table does not include smaller public water supply systems such as those that service manufactured housing communities, churches, schools, lake associations, and commercial enterprises.

Table 6. Current Municipal Drinking Water Demands

City	State	Population	Average Daily Water Demand (MGD)*	Design Capacity	Projected 2020 Water Demand (MGD)
Auburn	IN	12,074	2.293	10,338 gpm	na
Angola	IN	7,344	0.608	2,620 gpm	na
Garrett	IN	5,349	0.611	2,900 gpm	na
Butler	IN	2,725	0.256	1,750 gpm	na
Waterloo	IN	2,200	0.160	640 gpm	na
Hamilton	IN	1,944	0.173	900 gpm	na
Ashley	IN	1,010	0.259	900 gpm	na
Hudson	IN	596	*0.119*	na	na
Saint Joe	IN	452	0.041	384 gpm	na
Combined**	IN	19,623	3.064	13,878 gpm	na
Hudson	MI	2,415	*0.205*		na
Morenci	MI	2,352	*0.200*		na
Manitou Beach	MI	2,080	*0.195*		na
Addison	MI	611	*0.122*		na
Waldron	MI	577	*0.115*		na
Camden	MI	542	*0.108*		na
Bryan	OH	8,360	1.610	5.184 MGD	5.00
Monpelier	OH	4,135	0.485	2.000 MGD	0.95
Hicksville	OH	3,533	0.350	0.792 MGD	0.74
Edgerton	OH	2,015	0.188	0.504 MGD	1.20
West Unity	OH	1,803	0.271	0.499 MGD	0.68
Stryker	OH	1,391	0.114	0.36 MGD	0.49
Fayette	OH	1,326	0.149	0.288 MGD	0.61
Pioneer	OH	1,248	0.262	0.648 MGD	0.37
Edon	OH	863	0.129	0.254 MGD	1.28
Sherwood	OH	801	0.105	0.144 MGD	0.28
Ney	OH	364	0.030	0.144 MGD	0.05
Alvordton	OH	298	0.06	na	na
Blakeslee	OH	126	0.06	na	na

**italicized water demands are estimated based on population and adjacent municipal water demands*

***combined water demand for Auburn, Waterloo, and Garrett, Indiana*

4.2.2 Source Narratives

The available information related to public water supply demands and production capacities of municipal wells and wellfields varied across the region. The three states provide varying degrees of access to information regarding the location and production ratings of the public water supply wellfields and wells, municipal water demands, and pumping records.

Quantification of the water demands related to the municipal water supply systems is based on a combination of pumping records, rated wellfield and production well capacities, and population statistics. Pumping records reflecting the public water demands were given the greatest weight. Individual production well or wellfield capacity ratings were used when pumping records were not accessible or available. Where neither pumping information, nor production capacities were available, the population of a given area was multiplied by the average household water use reported for the adjacent municipalities.

4.2.3 Explanation of Variations

The water demands presented in Table 6 are the average daily demand for each of the municipalities. The greatest water demands placed on the municipal systems across the Midwest are commonly associated with the months of June, July, and August. These water demand increases are due in part to an increase in outdoor activities of the residents, lawn irrigation, and pool usage during the summer months.

The seasonal variation of the total amount of groundwater withdrawn from the MICHIDOH Aquifer system is largely dependent on the agricultural land use across the region. Although the water usage for such practices is prolific and typically represents a high volume of pumped water, quantifying the increase is unfeasible. Only limited regulations are in place across all three states related to these irrigation systems, and the available pumping information is extremely limited.

4.2.4 Current Demand and Potential Withdrawal

The MICHINDOH aquifer system groundwater resources have been developed as needed by the municipalities. The standard procedure for development of the existing municipal production wells is to perform aquifer performance testing to determine the hydraulic characteristics of the screened aquifer interval. Subsequently, these localized hydraulic characteristics are used to assign each municipal production well a maximum, safe production rating in accordance with the appropriate state regulations. Each of the municipal wellfields located within the study area has a total production rating that satisfies the current public water supply demand and provides for variable increments of projected future demands.

The full potential of the available groundwater production within the MICHINDOH aquifer system has not been reached. A reasonable estimate of the full potential cannot be determined given the available data from drilling records, pumping tests, regional studies, and modeling efforts.

No surface water resources are currently being utilized to meet the public drinking water supply demands within the proposed SSA area. The potential capacity of the existing surface water resources that could be used as an alternative drinking water source is addressed in Section 4.3.

4.3 ALTERNATIVE DRINKING WATER SOURCES

The alternative drinking water sources for the proposed sole source aquifer area were identified and evaluated based on the geology, hydrogeology, population to be served, geographic location of population centers, water demands, engineering design, implementation cost estimation, and economic descriptions of the study area.

The evaluations are based on the 2000 U.S. Census data, previous mapping efforts and research across the three-state area, well logs, and pumping test information.

Four alternative drinking water resources were identified and each presents varying degrees of expense and difficulty. The alternative sources include:

1. surface water intakes in the local drainageways,
2. new wellfields in adjacent groundwater basins within the MICHINDOH aquifer system,
3. new wellfields within the uppermost carbonate bedrock aquifer,
4. purchased drinking water supplies from adjacent providers.

First, the proposed surface water intakes are limited to the three largest river systems in the area, the Maumee River, St. Joseph (east) River, and the Tiffin River. Surface water intakes have already been developed within each of these river systems for communities inside the study area, but outside the proposed sole source aquifer petition area. At surface water intake locations where the river discharge is not great enough to support direct withdrawals from the rivers without causing ecosystem damage, additional storage in the form of up-ground (off-channel) reservoirs provides a potential solution.

As a second alternative, additional wellfields could be constructed within adjacent groundwater basins to the north (Michigan) and west (Indiana) that are in MICHINDOH aquifer system. Lithology and pumping records from the sand and gravel deposits in the adjacent basins indicate that sufficient quantity of groundwater is present to sustain municipal water demands. The water quality of this resource would also be similar to the current drinking water sources and potentially require only minimal, if any, changes to the existing treatment systems. In Ohio, the potential glacial aquifers are limited to the one groundwater basin within the MICHINDOH aquifer system petition area.

The third alternative is development of the uppermost potential bedrock aquifer. The two formations that represent potential groundwater resources are the Marshall Formation and the Dundee Limestone. The Marshall Formation is only present in northern Hillsdale County, Michigan, and exhibits production rates in excess of 1,500 gpm at some existing wellfields. The groundwater extracted from this formation often exhibits high hardness and iron concentrations.

The first usable aquifer at depth in the bedrock is the Dundee Limestone. This aquifer is present between 400 and 600 feet below the ground surface. The formation is about 40 feet thick and the water quality is poor (Eberts, 2000). Little information is known about the potential aquifer as exploratory drilling and pumping test information is limited.

The uppermost bedrock units across the remainder of the study area are shale (Coldwater Shale, Antrim Shale, Ellsworth Shale, Bell Shale) and are not viable drinking water resources. The shale typically produces limited quantities of poor quality groundwater.

The fourth alternative is to purchase water from adjacent drinking water providers. The current water providers capable of meeting the proposed additional water demands border the northern, western, and southern limits of the proposed area and include the cities of Angola and Fort Wayne in Indiana, Reading and Hillsdale in Michigan, and Defiance in Ohio.

Alternative Source Limitations

The surface water intake alternative is limited by the discharge volume measured in the local river systems. The discharge measurements at stream gauge stations in the St. Joseph and Tiffin Rivers indicate that the discharge volume is not great enough to support direct withdrawal. Up-ground (off-channel) reservoirs would be required to meet the storage requirements. This statement is supported by the existence of multiple intakes in different drainage basins that are required in order to meet the water demands of the City of Archbold, Ohio. The statement is further supported by the presence of up-ground reservoirs adjacent to the surface water intakes for across nearly all of Fulton, Henry, Defiance, and Paulding counties in Ohio.

If new surface water intakes were to be installed, the maximum allowable withdrawal and the required storage reservoir capacity would be determined by the Ohio EPA. The full potential yield would be based on site-specific analyses of stream discharge data. Given the flat topography and the current water demands, the preliminary required storage estimates indicate that the reservoir footprints would be on the order of hundreds of acres.

Currently, the surface water resources have not been further developed due to the presence of the MICHINDOH aquifer system and the economic scale differences between developing groundwater versus surface water resources. Water quality differences, treatment alternatives, additional water supply system infrastructure, and distances to viable surface water sources are also significant factors in the lack of surface water intakes across the proposed SSA area.

The second alternative of additional wellfields constructed within an adjacent groundwater basin is limited by the location of the adjacent groundwater basins. Two adjacent basins are present in the study area: one is in Branch and Hillsdale counties in Michigan, the other is in Steuben County in Indiana. Utilizing either basin can only be feasibly exercised in locations where the distance to the adjacent groundwater basin allows for reasonable construction costs for transmission lines. This would only be the case for the municipalities in Michigan and Indiana. Each of the Ohio municipalities is located too far from the adjacent groundwater basins to construct transmission pipelines at reasonable costs.

The third alternative, additional wellfields in the Dundee Limestone, is limited by the depth to the potential aquifer, the water quality, and lack of knowledge regarding this aquifer. The formation averages approximately 40 feet thick across the study area and is located at depths of more than 400 feet below grade. The groundwater quality within this potential aquifer is poor, exhibiting high hardness, sulfur, salinity, and iron content. Additionally, very little is known about the production capacity of this aquifer due to a lack of exploratory drilling and pumping tests conducted within the aquifer. The drilling and well construction expenses and the necessary water treatment alternatives have previously eliminated this resource as an alternative.

The final alternative resource is purchased drinking water from adjacent suppliers. Two limitations restrict the development of these resources. The geographic separation of the adjacent communities dictates transmission pipelines that are prohibitively expensive. Additionally, the adjacent water providers may have either limited source capacity or treatment capacity. To overcome these limitations additional project costs would be incurred to increase the production capacity of the providers outside the proposed area to the level required to meet the total water proposed water demands.

POLITICAL CONSTRAINTS

Two legal constraints arise from the alternative source development. The proposed sole source aquifer area encompasses portions of eight counties within three states. Each of the three states has different regulations in place regarding the development, maintenance, and operation of public water supplies that would have to be overcome if municipalities were to share a resource or purchase water from another provider. Additionally, much debate has taken place over sustainability of water resources and the removing of groundwater from the source watershed in the Great Lakes area.

The second legal constraint is related to the decision of intake ownership. The debate of whether alternative resource development should be performed by a coalition of communities that share responsibility, or by a single municipality which then assumes full responsibility for the new withdrawal facility and then sells drinking water to the adjacent communities is the issue. Crossing county lines within a particular state may pose fewer problems, but legal debate would still take place.

The issues would be addressed on a case by case basis. The legal debate and political implications may very well preclude any project proposing to cross regulatory boundaries or formation of drinking water coalitions.

5.0 ECONOMIC FEASIBILITY

The purpose of this section is to provide preliminary estimates of the capital costs associated with the transfer to alternative drinking water sources. The location of the alternative source intake areas are based on the regional geology, hydrogeology, population to be served, and geographic location of population centers. The economic analyses are based on the water demands, engineering design, cost estimation, and economic descriptions associated with the existing municipalities within the proposed sole source aquifer area. The population and income statistics are taken from the 2000 U.S. Census data and are adjusted for growth and inflation.

The economic feasibility analyses were performed with the following assumptions:

1. The MICHINDOH aquifer system has been rendered un-usable.
2. The alternative source is capable of providing water of comparable quantity and quality to the existing water sources.
3. If municipal areas cannot afford to replace their systems, then rural distribution systems will not be feasible either.
4. Surface water intake infrastructures are evaluated individually. The analyses ignore the effective decrease in the river discharge due to additional upstream intakes and the downstream location of the river gauges.
5. Only basic infrastructure design and development costs are proposed.

The sole source designation is specifically designed to protect against the loss of the existing drinking water source, the MICHINDOH aquifer system. Evaluation of the potential economic impacts of losing this source necessarily must include the assumption that this source is unusable to the current drinking water providers.

The alternative sources can only be reasonably compared to the MICHINDOH aquifer system if the quantity and quality of the source water is treated to meet the EPA drinking water standards. Lesser quantities of source water would necessitate additional intake structure(s). Poorer quality of source water would necessitate additional treatment infrastructure and expense. This assumption is particularly important when considering surface water resources and the Dundee Limestone that both exhibit limited quantities and poorer water qualities compared to the MICHINDOH aquifer system.

The decision to examine only the urban water systems is based on the fact that the population densities and mean annual household incomes across the proposed sole source aquifer area are greater in urban areas than in the rural areas (see Section 5.5.2). Thus, the urban areas represent the greatest potential financial contribution by residents to implement alternative drinking water sources. Likewise, if the areas with the greatest financial potential are unable to feasibly install alternative water supplies, then the residents of the rural areas with significantly fewer resources will also be unable to fund such projects. Personal communications with the Region 5 U.S. EPA office personnel support this assumption. As recommended by that office, a cursory feasibility analysis rather than a detailed analysis was conducted for a rural water distribution system.

A large expense factor in the economic analysis of surface water infrastructure is the storage requirements that must be met using up-ground reservoirs. Generally, the storage requirements greatly increase with a decrease in the available river discharge. The assumed maximum river discharge values based on the existing river gauges provide a conservative estimate of the storage requirements and project costs to implement the proposed surface water intakes.

Similarly, a conservative approach was utilized when estimating the most economical method of transferring to an alternative water supply resource. Each of the current municipal public water supply systems was evaluated to determine the type of alternative water source, the intake site location (wellfield or surface water intake), and the new water system component requirements. Only the minimal cost for each municipality to transfer to an alternative water source is presented. For example, rural area pipeline construction costs were applied to minimized transmission line route distances for all the pipeline estimates. Additionally, multiple municipalities share an alternative resource to minimize costs where practical.

The infrastructure required for withdrawal, transmission, and treatment of the water derived from the alternative resource was determined by the civil engineers of Williams & Works, Inc. (Grand Rapids, Michigan). The cost estimates for the necessary infrastructure were determined using industry-standard pricing techniques and references.

The sections below describe in general what is entailed in implementing the identified alternative sources and the rationale for implementing the selected alternative source for each of the affected municipalities. In addition, specific details related to the infrastructure necessary to withdraw, transmit, and treat the source water are provided as tables in Appendix D.

Alternative supplies were evaluated for each public water supply system within the proposed sole source aquifer boundaries. The municipal water demands used as the design basis were taken from the available data sources and are presented as either the current water demand or the current maximum production capacity.

The projected cost estimates are divided into the following three categories:

1. water withdrawal method using either large-diameter wells (groundwater) or an intake structure (surface water),
2. transmission pipelines for either raw water conducted to treatment facilities or finished water conducted to the existing distribution lines,
3. treatment of the raw water supplies in accordance with the U.S. EPA drinking water quality requirements.

The estimates are conservative in nature. That is, the estimates are completed at a feasibility level and contain a very basic level of component sizing. The cost estimates include only the capital costs associated with materials, labor, and equipment expenses for each project.

Storage components, including water towers and up-ground reservoirs, are not included in the estimates. The up-ground reservoirs in particular can greatly increase the project costs. The recorded low-flow discharge in the Tiffin and St. Joseph (east) Rivers, combined with the relatively flat topography of the area, necessitate off-channel reservoirs with footprints on the order of hundreds of acres.

Other costs not addressed in the estimates include consulting and engineering fees, land and easement acquisition, environmental studies, mitigation and construction interests, operation and maintenance costs, and repayment of borrowed funds.

The cost estimates are standardized and intended to be used for budgetary comparison. The estimates have been prepared using EPA water treatment cost estimating procedures, RS Means Estimating Data, and experienced unit price compilations and are in 2006 U.S. dollars. An ENR Index can be used to cross check the validity of the estimates to similar projects previously completed within the area if necessary. Final construction cost depends on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, and other variable factors.

5.1 PURCHASED WATER

The purchased water cost estimates include only the pumping station and transmission line costs. The underlying assumption is that the proposed provider would sell finished water and currently has necessary intake and treatment facilities in place that can meet the increased water demand.

Pipeline capital costs are dependent upon a variety of factors, including pipe material used, trenching slopes and depths, fill material quality, frequency of valves/fittings, number of obstruction crossings, necessity of pavement removal and replacement, utility interference, traffic control, geologic conditions, and degree of urbanization. Rock excavation and groundwater conditions are two variables that can add cost but are not included with the estimates. Table 7 below shows the unit costs applied for pipe diameters from 12 to 48 inches.

The pipe sizes proposed are minimum recommended diameters. The hydraulic characteristics anticipated for the pump stations are based on the values provided.

The unit costs are based on open cut construction methods, with the exception of special crossings. Special crossings at railroads, highways, and rivers will likely be accomplished by horizontal boring or boring and jacking. The actual number and technique employed will vary dependent on the selected utility alignment and conditions present.

Table 7. Unit Transmission Pipeline Costs

Pipe Diameter (inches)	Rural Construction (2006 dollars per lineal foot)	Urban Construction (2006 dollars per lineal foot)
12	60	90
16	75	130
18	90	145
24	125	210
30	170	280
36	205	340
48	285	475

5.2 New Wellfield

Replacement of the existing MICHINDOH aquifer system groundwater resource with an alternative groundwater resource will involve two components at a minimum. First, a new wellfield must be located and constructed within an adjacent groundwater basin. Second, new transmission lines must be constructed from the new wellfield to the existing water supply distribution system.

Wellfield construction would involve installation of at least two production wells, appropriate pumps, and distribution piping. A new climate-controlled wellhouse would be needed to protect various above-ground elements such as the pump controls, valves and meters, limited treatment options, and limited distribution piping.

The communities where new wellfields are a feasible option have relatively low water demands. Therefore, a 12-inch diameter, steel-cased well with a 12-inch diameter, stainless-steel, wire-wound screen would be sufficient to produce the required groundwater. Two wells would be needed to provide a redundant water supply at the wellfield. A total well depth of 175 feet below grade is an appropriate conservative estimate that can be applied to each of the proposed new wellfields.

Current steel prices, experienced cost estimates, and recent proposals across the three-state area indicate that the wells described above can be constructed and equipped with the appropriate pump and motor for an estimated cost of $100,000 per production well. The wellhouse, pump controls, distribution piping, and limited treatment options can be purchased and installed for approximately $150,000. The total cost of a new wellfield would be at least $350,000. This cost estimate does not include the land/easement purchase(s), consulting fees, or operation and maintenance costs. Additionally, depending on the well spacing, installation of vertical turbine pumps could require an individual wellhouse for each production well.

5.3 Surface Water

The surface water intakes were designed as direct withdrawal intakes without consideration of the low-flow discharge measurements of the St. Joseph (east) and

Tiffin Rivers. This underlying assumption provides a minimal infrastructure design by omitting construction of up-ground (off-channel) reservoirs that would address the storage/stilling needs during the river(s) low-flow discharge periods. This assumption also minimizes the proposed project costs and allows for very conservative economic feasibility analyses.

Daily discharge statistics data indicate a record low-flow value of 21 cubic feet per second for the Tiffin River, and 36 cubic feet per second for the St Joseph River. Furthermore, monthly mean discharge data indicate that low-flow rates occur almost semi-annually and for extended periods of six months or longer. Thus, the storage reservoirs would likely be required to utilize the surface water from these rivers.

Consistent with Ten States Standards, the water intake systems are divided among communities utilizing the same water course and sufficiently sized so that the first community would not degrade stream quality. Regionalization was evaluated where geographic isolation would necessitate redundancy of transmission lines.

5.3.1 Pump Stations

The cost of a pump station depends upon a wide variety of conditions, including pump discharge, pumping head, pump type, site conditions, desired usage, and structural design. In this preliminary cost estimate of a pump station, it is the intent to estimate the cost of a general station capable of pumping the desired discharge at the necessary head conditions. Pump station project cost estimates and construction records were used to adjust published EPA pump station cost curve data.

Pump stations are generally classified as transmission or intake type structures, depending on the source of the water coming into the station. Intake stations normally pump water from a raw water source, such as a river or reservoir, and therefore require an intake structure to insure that proper flow conditions into the station are permitted. Transmission stations normally act as boosters in a plant or pipeline and do not require intake structures since the inlet pipe flow conditions are fairly constant.

The pump stations at the intake structures are likely to be relatively small and costs of pump stations located at intakes are included with the intake structures.

Electrical costs, with the exception of standby power, are included in the pump station construction cost. Standby power, normally either a diesel generator or a dual power feed, is necessary to insure that the pump station can remain operational in the event of a power failure.

5.3.2 Water Treatment Plants

Water treatment plant capital costs are shown separately (Table 8). Many treatment processes are available; primarily they are media filter or membrane. The source water quality normally dictates which type is used. Since river water is anticipated as the water source with off-line storage, the quality is assumed to be less pure than a groundwater source. That is, influent suspended solid concentrations are sufficient to warrant a sedimentation process prior to filtration so that a reasonable backwash cycle on the filtration units can be used.

Table 8. Surface Water Treatment Plant Cost Estimates

Plant Capacity (MGD)	Average Cost (2006 dollars)
0.1	360,000
0.5	1,450,000
1	2,670,000
2	4,910,000
3	7,020,000
4	9,040,000
5	11,000,000
10	20,260,000
20	37,300,000

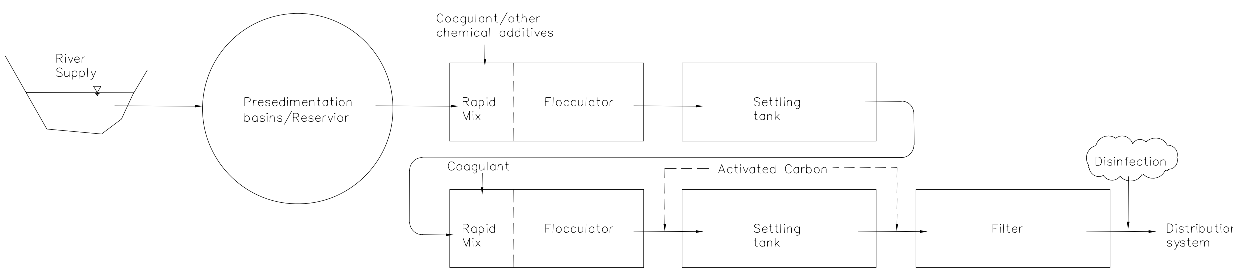

Figure 18. Traditional Surface Water Treatment Process Sequence

CLEARWELLS

Clearwell storage tanks provide disinfectant contact time and normalize plant production during filter cleaning. The volume required depends on several factors. For purposes of this study, we have assumed clearwell volume to be equal to one quarter daily plant capacity. The costs of storage tanks given are based on ground-level pre-stressed concrete construction for a range of capacities (Table 9).

Table 9. Clearwell Cost Estimates

Storage Capacity (MG)	Estimated Cost (2006 dollars)
0.01	50,000.00
0.02	80,000.00
0.03	110,000.00
0.04	130,000.00
0.05	160,000.00
0.1	250,000.00
0.2	400,000.00
0.3	530,000.00
0.4	640,000.00
0.5	750,000.00
1	1,210,000.00

UP-GROUND (OFF-CHANNEL) RESERVOIRS

An off-channel reservoir is a storage basin that receives no natural inflow. The anticipated storage plans involve drawing surface water from a river or creek at a predetermined rate, passing it through a pre-sedimentation basin, and then storing the raw water for treatment as it is needed. The actual volume of the reservoir is a function of the system demand and the record low flow for the supply surface water source.

The cost of reservoirs is highly variable depending on the height of the levees, depth of existing groundwater, and cost of land. The developed estimates assume a rectangular footprint with the maximum excavation depth of 5 feet, HDPE liner, no wave protection rip-rap, and excavated soils that are all suitable for levee construction (Table 10). Levee configuration assumes a 10-foot levee height on the storage side with a 2-foot freeboard when at capacity. It is also assumed that excavation volume equals dike fill volume.

Table 10. Reservoir Cost Estimates

Storage Volume (MG)	Reservoir Cost (2006 dollars)
30	850,000
40	1,150,000
50	1,450,000
60	1,750,000
70	2,050,000
80	2,350,000
90	2,650,000
100	2,950,000

STILLING BASINS

Stilling basins are normally used in surface water treatment systems to decrease the water flow velocity and allow sediment to settle out prior to entering a reservoir. Stilling basin costs are included in the estimate and are based on the maximum daily flow parameter.

5.3.3 Other Project Costs

Engineering, financial and legal services and contingencies are estimated as a lump sum. The industry standard is 30 percent of the total construction costs for transmission pipelines and 35 percent of the total construction costs for water treatment plant design.

Land related costs for a project are typically one of two types: land permanently purchased for construction of a facility or easement costs. The amount and cost of land purchased for various types of projects is considered on an individual project basis, taking into consideration similar project experience. Easement costs, on the other hand, can vary considerably in a single project based on the variety of site conditions that a pipeline may encounter along its path. Easements are generally acquired for pipeline projects and can normally be classified as temporary or permanent. Permanent easements are purchased for the land that the pipeline will remain in once it is completed, including a wide enough buffer zone to allow maintenance access and protect the pipeline from other parallel utilities. Temporary easements are "rented" to allow extra room for material and equipment staging, as well as other construction related activities.

Land related costs include legal services, sales commissions, and surveying. Ten percent of the total land and easement cost would be appropriate to account for all legal services, sales commissions, and surveying associated with the land related purchases. Land costs can vary considerably, even throughout a small region, based on degree of urbanization and other economic factors.

Costs for environmental studies, archaeological studies, permitting, and mitigation are estimated on an individual project basis, taking into consideration previous project estimates, the judgment of qualified professionals, and any other available information. In the case of reservoir projects, mitigation costs are generally equal to the land value of the acreage that would be inundated.

5.3.4 Annual Costs

Annual costs are expenses which the owner of the project can expect once the project is completed. Debt service and power costs are examples. Debt service is the total annual payment that is required to repay borrowed funds. Power costs are dependent on pumping conditions and water demand and would need to be calculated independently for each individual water supply system.

Operation and maintenance costs are another large expense and include all labor and materials required to run the facility and keep it operational, including periodic repair and/or replacement of facility equipment. These costs can be estimated as 1 percent of the total estimated construction costs for pipelines, distribution facilities, and tanks, 1.5 percent of the total estimated construction costs for dams and reservoirs, and 2.5 percent of the total estimated construction costs for intake structures and pump stations.

5.3.5 Alternate Source Selection

Multiple potential alternate sources were evaluated for the municipalities within the proposed SSA boundaries. In each case, the most economical source to implement was used in the economic feasibility analysis. The most economical solutions included independent municipal development of an alternative source and development of regional water supply systems to supply multiple municipalities (Figure 20).

Determination of the most economical option was based on a cost balance for transmission pipelines, intake structures, pumping stations, storage considerations, and water treatment. All of the municipalities within the SSA boundaries currently utilize groundwater resources to meet the drinking water demands. Limited drinking water treatment systems suitable for groundwater sources are already in place in every municipality. However, additional treatment facilities may be required at a surface water intake, or upgrades of the existing facilities may be required to meet the additional treatment required for surface water sources.

In other cases, the most feasible approach is to have one community establish an alternative source and sell finished water to the adjacent communities. Such is the case for Edgerton, Fayette, and Montepelier in Ohio where each of these larger municipalities would construct surface water intake structures and the associated treatment facilities. The significantly smaller adjacent municipalities would construct extended transmission pipelines and buy finished water rather than undertake the expense of constructing or upgrading their own surface water intake and treatment facilities.

Five regional water supply systems are recommended. The surface water based regional systems include Edgerton-Edon-Blakeslee, Bryan-Stryker-West Unity, Montpelier-Pioneer-Kunkle, and Fayette-Alvordton. The Morenci-Waldron system is the only groundwater-based regional supply system.

The four municipalities that should develop independent water supply systems include the City of Angola (IN), The City of Hudson (MI), and the Villages of Addison and Manitou Beach (MI). Each of these municipalities would construct new wellfields within adjacent groundwater basins.

The remaining 14 municipalities should construct pipelines to purchase finished drinking water from adjacent municipalities. Three of these municipalities (Auburn, Garrett, and Waterloo) in Indiana would construct and share a single transmission line to Fort Wayne, Indiana.

Table 11 lists the municipalities within the proposed SSA boundaries and the most economical alternative source identified for each. The tables in Appendix D provide detailed summaries of the necessary infrastructure and the associated costs required to transfer the existing municipal drinking water systems to an alternative source. Table 12 provides a summary of the minimum total projects costs.

Table 11. Municipal Water Demands and Alternative Sources

MUNICIPALITY	WATER DEMAND (MGD)	ALTERNATIVE SOURCE
Addison, MI	0.122	new wellfield
Camden, MI	0.108	new wellfield
Hudson, MI	0.119	new wellfield
Manitou Beach, MI	0.195	new wellfield
Morenci, MI	0.200	new wellfield
Alvordton, OH	0.060	purchased
Ashley-Hudson, IN	0.378	purchased
Auburn-Garrett-Waterloo, IN	3.514	purchased
Blakeslee, OH	0.060	purchased
Butler, IN	0.256	purchased
Edon, OH	0.129	purchased
Farmer, OH	na	purchased
Hamilton, IN	na	purchased
Hicksville, OH	0.350	purchased
Kunkle, OH	na	purchased
Ney, OH	0.030	purchased
Pioneer, OH	0.262	purchased
Saint Joe, IN	0.041	purchased
Sherwood, OH	0.105	purchased
Waldron, MI	0.115	purchased
West Unity, OH	0.271	purchased
Bryan, OH	1.610	surface water
Edgerton, OH	0.188	surface water
Fayette, OH	0.149	surface water
Montpelier, OH	0.485	surface water
Stryker, OH	0.114	surface water

Table 12. Estimated Alternative Source Transfer Costs

Municipality	State	Population	Alternative Source Type	Estimated Project Cost (2007 dollars)
Angola	IN	7,344	groundwater	$1,000,000
Butler	IN	2,725	purchased	$4,644,000
Hamilton	IN	1,944	purchased	$4,434,000
Ashley	IN	1,010	purchased	$3,252,000
Hudson	IN	596	purchased	$3,252,000
Saint Joe	IN	452	purchased	$4,476,000
Auburn	IN	12,074	purchased	*combined*
Garrett	IN	5,349	purchased	*combined*
Waterloo	IN	2,200	purchased	*combined*
Auburn/Garrett/Waterloo	IN	452	purchased	$11,358,000
Hudson	MI	2,415	groundwater	$5,420,000
Morenci	MI	2,352	groundwater	$11,072,000
Manitou Beach	MI	2,080	groundwater	$2,804,000
Addison	MI	611	groundwater	$1,916,000
Waldron	MI	577	purchased	$5,796,000
Camden	MI	542	groundwater	$3,120,000
Bryan	OH	8,360	surface water	$35,734,000
Montpelier	OH	4,135	surface water	$30,536,000
Hicksville	OH	3,533	purchased	$9,996,000
Edgerton	OH	2,015	surface water	$12,848,240
West Unity	OH	1,803	purchased	$4,956,000
Stryker	OH	1,391	surface water	$14,319,120
Fayette	OH	1,326	surface water	$11,622,000
Pioneer	OH	1,248	purchased	$4,200,000
Edon	OH	863	purchased	$4,284,000
Sherwood	OH	801	purchased	$9,030,000
Ney	OH	364	purchased	$5,136,000
Alvordton	OH	298	purchased	$3,228,000
Blakeslee	OH	126	purchased	$2,112,000

5.4 AVAILABLE FUNDING

The economic feasibility is evaluated in part based on whether the annual costs to use an alternative water supply source would create an economic burden for the local residents or municipal water customers. As proposed in the petition guidance document, a quantitative analysis of the annual system cost for a typical user was calculated. By definition, if this cost exceeds 0.4 to 0.6 percent of the mean annual household income, use of the alternative source would create a financial hardship for the end users and be considered economically unfeasible.

The available funding associated with each municipality was determined by combining the 2000 U.S Census data statistics for the household mean annual income and the municipal population. The total available funding for each project was compared to the estimated project costs to determine if a transfer to an alternative water supply resource would create a financial hardship for the residents and municipal water customers.

The 2000 U.S. Census population data is reported by municipality. The mean annual income within each municipality is reported by household. To correlate the two data sets, the population values were divided by 2.5. This factor is the industry standard used in water demand calculations and describes the number of persons per household. The maximum available funding for each municipality was calculated as 0.6 percent (maximum allowable percentage) of the product of the number of households and the mean annual household income.

Variable inflation rates had a significant effect on the available funding results. The calculations were adjusted for a total of 19.91 percent inflation between January 2000 and January 2007 based on the Consumer Price Index (205.352).

A second variable that could affect the available funding calculations is population change. The U.S. Census Bureau statistics indicate that the average population change across Ohio between 1990 and 2000 was 4.7 percent. However, some municipalities may experience greater gains or losses of residents than the state average. Given the substantial difference between the available funding (adjusted for inflation) and the project cost estimates, the population changes within the study area from 2000 to 2007 were considered negligible for the purposes of this study.

Table 13 provides a summary of the available funding that each municipality can be expected to contribute toward the cost of a transfer to an alternative drinking water source. The numbers in the table reflect the 19.91 percent inflation adjustment but do not include any adjustment for population changes.

Table 13. Available Funding by Municipality

City	State	Population	Households (Pop/2.5)	Household Mean Annual Income*	0.6% of MAI	Available Funding
Auburn	IN	12,074	4830	$51,276	$308	$1,485,853
Angola	IN	7,344	2938	$41,879	$251	$738,135
Garrett	IN	5,349	2140	$50,059	$300	$642,755
Butler	IN	2,725	1090	$44,666	$268	$292,119
Waterloo	IN	2,200	880	$47,761	$287	$252,180
Hamilton	IN	1,944	778	$50,062	$300	$233,571
Ashley	IN	1,010	404	$43,039	$258	$104,327
Hudson	IN	596	238	$50,747	$304	$72,589
Saint Joe	IN	452	181	$43,668	$262	$47,371
Clear Lake	IN	242	97	$59,056	$354	$34,300
Hillsdale	MI	7,904	3162	$41,603	$250	$789,188
Rollin	MI	3,171	1268	$47,530	$285	$361,722
Hudson	MI	2,415	966	$49,309	$296	$285,797
Morenci	MI	2,352	941	$48,024	$288	$271,086
Manitou Beach	MI	2,080	832	$45,491	$273	$227,093
Medina	MI	1,292	517	$48,380	$290	$150,017
Reading	MI	1,104	442	$40,470	$243	$107,228
Addison	MI	611	244	$42,905	$257	$62,916
Waldron	MI	577	231	$36,473	$219	$50,508
Camden	MI	542	217	$40,803	$245	$53,077
Montgomery	MI	379	152	$50,962	$306	$46,355
Bryan	OH	8,360	3344	$44,340	$266	$889,644
Monpelier	OH	4,135	1654	$37,985	$228	$376,964
Hicksville	OH	3,533	1413	$47,315	$284	$401,196
Edgerton	OH	2,015	806	$46,465	$279	$224,705
West Unity	OH	1,803	721	$42,268	$254	$182,903
Stryker	OH	1,391	556	$47,899	$287	$159,907
Fayette	OH	1,326	530	$38,509	$231	$122,551
Pioneer	OH	1,248	499	$44,550	$267	$133,437
Edon	OH	863	345	$52,161	$313	$108,036
Sherwood	OH	801	320	$46,927	$282	$90,212
Ney	OH	364	146	$44,030	$264	$38,464
Alvordton	OH	298	119	$43,467	$261	$31,088
Blakeslee	OH	126	50	$52,461	$315	$15,864
Holiday City	OH	48	19	$34,849	$209	$4,015

**mean annual income figures adjusted for inflation of 19.91% (2000-2007)*

5.5 Economic Analyses

The water customer bill after a municipality transfers to an alternative drinking water source could be divided into two portions. The first portion would be based on the volume of water used by the customer and would reflect, at a minimum, the costs related to the water supply system operation, treatment, power, and maintenance. Most of these costs can be estimated as a percentage of the construction cost of the supply system infrastructure (see Section 5.4).

The second portion of the water bill would represent the debt service to cover the construction project costs associated with the transfer to the alternative water source. These costs would include at a minimum the land/easement, design, intake(s), pumping station(s), water storage/stilling options, transmission pipelines, treatment facilities, and contingencies (see Section 5.4).

The economic feasibility analysis was conducted using conservative numbers for both the available funding and the anticipated project costs. First, the maximum percentage (0.6 percent) was applied to the mean annual household income to determine the expected municipal contribution. Second, the annual municipal costs are based on only the debt service portion of the water bill. Furthermore, the debt service represents a feasibility level engineering design with a very basic level of component sizing.

In all likelihood, the actual project costs to transfer to an alternative drinking water source would be significantly higher. This would be especially true for municipalities that utilize surface water resources since up-ground (off-channel) reservoirs would almost certainly be required due to the discharge volume of the Tiffin and St. Joseph Rivers during the extended low-flow periods. Such reservoirs are not included in the current proposed project cost estimates.

The required debt service to complete the proposed projects is expressed as a percentage derived by dividing the maximum funding contribution by the minimized project cost. The number of years required to pay off the debt service was estimated with the assumptions of no inflation, no population change, and zero-interest loans. A payment term of greater than 10 years to eradicate the debt was considered to be unreasonable and provide a hardship for the municipality.

5.5.1 Municipal PWSS

Economic feasibility analyses were conducted for 28 municipalities within the proposed sole source aquifer area. The results indicate that only 4 of the 28 municipalities can transfer to an alternative source without creating a financial hardship on the residents. All four of these communities are located within Indiana along Interstate 69.

The City of Angola (Indiana) is located on the northwestern groundwater basin divide that forms the northern boundary of the proposed sole source aquifer area. The most economical alternative source for this municipality is installation of new wellfields in the adjacent groundwater basin to the north near the northern city limits. The proposed project costs are $1,000,000 and the city has $738,000 in available funding. The debt service for the project could potentially be eliminated in less than two years.

A regional system is proposed for the municipalities of Auburn, Garrett, and Waterloo. The proximity of these communities to each other allows for interconnection of their public water supply systems. Additionally, the City of Auburn already has a surface water treatment plant in place to supplement its groundwater resources. The proposed alternative source is purchased water from Fort Wayne, Indiana. The project cost to transfer to this source would be \$11,358,000, and the combined available funding from these municipalities is \$2,380,788. The debt service for this project could potentially be paid off in approximately eight years.

The project costs for the remaining municipalities range from just under \$2,000,000 (Addison, MI) to almost \$36,000,000 (Bryan, OH) with a mean project cost of nearly \$6,000,000. The construction debt payoff periods range from 19 years (Hamilton, IN and Hudson, MI) to 134 years (Blakeslee and Ney, OH) with a mean payoff period of nearly 48 years. Table 14 contains a summary of the anticipated project cost estimates detailed in Appendix D, expected municipal funding contribution, and number of years estimated for project debt payoff.

Applying the maximum allowable percentage of the mean annual household income against the very conservative project cost estimates clearly indicates that a transfer to an alternative drinking water source from the MICHINDOH aquifer system would create a financial hardship for the municipalities and their drinking water customers (Table 14).

Table 14. Economic Feasibility Analysis Results

City	State	Population	Alternative Source Type	Estimated Project Cost (2007 dollars)	Available Funding (2007 dollars)	Available Percent of Project Cost	Debt Repayment Years
Angola	IN	7,344	GW	$1,000,000	$738,135	74%	1
Butler	IN	2,725	PW	$4,644,000	$292,119	6%	16
Hamilton	IN	1,944	PW	$4,434,000	$233,571	5%	19
Ashley	IN	1,010	PW	$3,252,000	$104,327	3%	31
Hudson	IN	596	PW	$3,252,000	$72,589	2%	45
Saint Joe	IN	452	PW	$4,476,000	$47,371	1%	94
Auburn	IN	12,074	PW	*$11,358,000*	$1,485,853	*13%*	*8*
Garrett	IN	5,349	PW	*$11,358,000*	$642,755	*6%*	*18*
Waterloo	IN	2,200	PW	*$11,358,000*	$252,180	*2%*	*45*
Combined	IN	452	PW	$11,358,000	$2,380,788	21%	5
Hudson	MI	2,415	GW	$5,420,000	$285,797	5%	19
Morenci	MI	2,352	GW	$11,072,000	$271,086	2%	41
Manitou Beach	MI	2,080	GW	$2,804,000	$227,093	8%	12
Addison	MI	611	GW	$1,916,000	$62,916	3%	30
Waldron	MI	577	PW	$5,796,000	$50,508	1%	115
Camden	MI	542	GW	$3,120,000	$53,077	2%	59
Bryan	OH	8,360	SW	$35,734,000	$889,644	2%	40
Monpelier	OH	4,135	SW	$30,536,000	$376,964	1%	81
Hicksville	OH	3,533	PW	$9,996,000	$401,196	4%	25
Edgerton	OH	2,015	SW	$12,848,240	$224,705	2%	57
West Unity	OH	1,803	PW	$4,956,000	$182,903	4%	27
Stryker	OH	1,391	SW	$14,319,120	$159,907	1%	90
Fayette	OH	1,326	SW	$11,622,000	$122,551	1%	95
Pioneer	OH	1,248	PW	$4,200,000	$133,437	3%	31
Edon	OH	863	PW	$4,284,000	$108,036	3%	40
Sherwood	OH	801	PW	$9,030,000	$90,212	1%	100
Ney	OH	364	PW	$5,136,000	$38,464	1%	134
Alvordton	OH	298	PW	$3,228,000	$31,088	1%	104
Blakeslee	OH	126	PW	$2,112,000	$15,864	1%	133

GW=groundwater; PW=purchase water; SW=surface water

5.5.2 Rural Distribution System

A rough analysis of a potential rural water distribution system for the homeowners and businesses serviced by private wells was also performed based on the 2000 U.S. Census statistics. The proposed SSA area encompasses nearly 1,600 square miles across three states and eight counties. The average population density across this area is 59 persons per square mile. This is equivalent to 24 households per square mile (population divided by 2.5). Thus, there are approximately 38,400 rural households within the proposed SSA area.

The cost of a rural water distribution system was estimated with the following assumptions:

1. 8-inch transmission pipelines are sufficient,
2. rural construction cost of 8-inch pipeline is $40 per lineal foot,
3. no road or river crossing is included in the cost estimate,
4. all water sources would be purchased from existing suppliers,
5. existing drinking water sources have sufficient quantity and quality to sustain the rural distribution system.

The lineal feet of pipeline required was estimated from the total proposed SSA area of 1,600 square miles. If roads were present around the perimeter of every square mile within the proposed area the total road length would be nearly 3,200 miles. To account for municipal areas and areas with limited road access, a conservative estimate of 1,600 miles of roadway was used (8,448,000 lineal feet). The total cost of the rural water distribution system pipelines would be nearly $338,000,000.

The mean annual household income across the counties in Indiana, Michigan, and Ohio that are represented within the proposed SSA area is $46,163 ($38,497 adjusted for 19.91 percent inflation from 2000 to 2007). Based on this income level, a total of 38,400 households, and a maximum contribution of 0.6 percent of the mean annual income, the total available funding is nearly $10,650,000.

The rural distribution system calculations are based on a conservative pipeline size, limited pipeline lengths, and no additional infrastructure. Yet, applying an annual contribution from the residents of $10,650,000 against the highly conservative project cost of $338,000,000 results in a project debt repayment schedule of more than 50 years.

6.0 CONCLUSIONS

Bryan Municipal Utilities is dedicated to the protection of the groundwater resource used to meet the city's drinking water demands. Wellhead protection areas for the City of Bryan wellfields have been delineated and a wellhead protection program is in place. Designation of the MICHINDOH Glacial Aquifer as a sole source aquifer by the U.S. EPA would provide additional protection. Such a designation would also benefit all of the communities in the region with groundwater-based drinking water supplies.

A sole source aquifer designation is designed to increase protection of vulnerable water sources that are used to meet more than 50 percent of the drinking water demand for a region. The designation creates a mechanism for U.S. EPA to review federally-funded projects within the delineated sole source area. Additionally, the research included within the petition document provides a powerful management, planning, and educational tool for the local residents, businesses, and governmental offices (local, state, and federal).

The study area for this petition encompasses more than 30 municipalities across portions of nine counties within three states. Williams County, Ohio, is located in the center of the proposed Sole Source Aquifer area and is surrounded by Fulton, Henry, and Defiance counties in Ohio; Branch, Hillsdale, and Lenawee counties in Michigan; and DeKalb and Steuben counties in Indiana.

The review of the geology and hydrogeology of the region includes examination of the unconsolidated Quaternary deposits, the uppermost 600 feet of the bedrock formations, and the surficial drainage basins. The Quaternary deposits are more than 200 feet thick in some areas and can be divided into four general depositional environments: modern alluvium, glacial till (ground and end moraine), glacial outwash, and glacial lacustrine sediments.

The uppermost bedrock formations in the region are composed of more than 400 feet of shale. The exception is the presence of the Marshall Formation, which is a viable aquifer system, comprised of sandstone and shale and found only in northern Hillsdale County, Michigan. The other potential bedrock aquifer is a carbonate sequence located between 400 and 600 feet below the ground surface across the study area. The Dundee Limestone represents the uppermost potential aquifer within the carbonate sequence, but this formation is only about 40 feet thick and contains groundwater of questionable quality.

The potential sand and gravel aquifers within the four Quaternary environments are hydraulically connected to varying degrees and comprise the MICHINDOH aquifer system. The aquifer intervals are typically less than 40 feet thick and are present at depths of 25 to more than 150 feet below the ground surface. Generally, these potential aquifers are the closest to the ground surface in the northern portions of the study area, and the depth to the intervals increases to the southeast. Clay-rich intervals within the Quaternary deposits variably confine the potential aquifers.

Based on contours of the potentiometric surface within the MICHINDOH aquifer system, the groundwater flow direction is from the northwest to the southeast at a gradient of 0.0015 to 0.0031 feet per feet. Measured horizontal hydraulic conductivities are typically between 100 and 300 feet per day. The aquifer transmissivities range from less than 500 ft^2/day to more than 14,000 ft^2/day with storage coefficients of 0.38 to 0.00002 (dimensionless). The areas of highest recharge (nearly 15 inches per year) are located in Hillsdale County, Michigan, in the headwaters of the St. Joseph (east) and Tiffin Rivers. Other significant recharge zones are located along the St. Joseph River valley in Ohio, where the recharge approaches 8 inches per year.

The MICHINDOH Glacial Aquifer is vulnerable to potential contamination threats. Sensitive areas include the high recharge areas in Hillsdale County, Michigan, and along the Tiffin and St. Joseph River valleys. Even areas with low susceptibility ratings, with respect to contamination, contain numerous potential pollution pathways such as thousands of private wells that penetrate the confining clay layers. Additionally, recent research has indicated that hydraulically-active local zones may be present within the overlying clay layers where interconnected fractures, micro-seams, macro-pores, and weathered zones may present pathways for vertical migration of groundwater and contaminants within the uppermost 50 feet of coarse-grained glacial tills.

Four alternative drinking water sources were identified within the study area. First, additional wellfields could be constructed within the adjacent groundwater basins. Second, additional wellfields could be constructed within the uppermost bedrock aquifer. Third, surface water intakes could be installed within the local major river systems. Fourth, drinking water could be purchased from adjacent municipal water providers outside the proposed SSA area.

The alternative sources were limited by a variety of factors. Additional wellfields in adjacent groundwater basins are restricted to the northern portions of the study area by the geographic separation and excessive distribution system infrastructure costs. Additional wellfields constructed within the uppermost bedrock aquifer are restricted by aquifer depths that exceed 600 feet in places and poor groundwater quality within the aquifer. Surface water intakes are limited by the discharge volume present in the local rivers, storage requirements, and water treatment costs. Purchased drinking water supplies are also restricted by geographic separation and excessive distribution system infrastructure costs.

The proposed SSA area was delineated based on four types of boundaries. The first boundary type consists of groundwater divides. Two groundwater divides in the area were identified based on the potentiometric surface contours. The first divide is present from Angola, Indiana, northeast to Hillsdale, Michigan. Groundwater north of the divide flows to the northwest, and groundwater south of the divide flows to the southeast. The second divide is present from near Manitou Beach, Michigan, with a southeast trend to Weston, Michigan. Groundwater north of this divide flows to the east under the influence of the River Raisin. Groundwater south of this divide flows to the southeast under the influence of the Maumee River.

The second boundary type is the physical extent of the MICHINDOH aquifer system. The aquifer appears to extend beyond the study area to the west, north, and limited areas to the east. The southern physical limits of the aquifer were delineated based on the available well logs, geologic cross sections, and the location of surface-water based municipal drinking water supplies. The physical extent boundary trends west to east from near Auburn, Indiana, along the Defiance-Paulding county line almost to the City of Defiance, Ohio. The trend then changes to a northeasterly direction, and the boundary passes between Stryker and Archbold, Ohio, and extends to Weston, Michigan.

The third boundary type is an economic boundary where the MICHINDOH aquifer system ceases to be the sole source for drinking water supplies. An economic feasibility analysis for the communities of Ashley, Auburn, Angola, Garrett, Hudson, and Waterloo, Indiana, indicates that these communities have the potential to meet their water demands with either additional wellfields in adjacent groundwater basins and/or purchased drinking water from adjacent water suppliers.

The fourth boundary type is the river basin divides. These divides were utilized in areas where the surficial drainage posed a potential contamination threat to the MICHINDOH aquifer system via potentially rapid surface transport of contaminants into high recharge areas above the MICHINDOH aquifer system. Such areas are located near the municipalities of Addison, Devils Lake, Hillsdale, Manitou Beach, Osseo and Reading, Michigan; and Auburn and Waterloo, Indiana.

The residents, businesses, and municipal drinking water supplies within the proposed sole source aquifer area rely exclusively on the MICHINDOH Glacial Aquifer to meet their drinking water demands. Additional users include smaller public water supply systems and irrigation supplies for agricultural use. No surface water intakes or purchased drinking water transmission lines are currently in place within the proposed sole source aquifer area. This is due to the ubiquitous presence of the MICHINDOH Glacial Aquifer, the geographic separation of the communities from each other and the surface water resources, and the expense to construct surface water treatment facilities and extensive drinking water transmission lines.

The economic feasibility of transferring to an alternative resource was based on the 2000 U.S. Census data for population and mean household income, civil engineering project design and estimated project costs, and the estimated water demands of the municipalities within the proposed SSA area. The underlying assumption of the feasibility analysis approach taken in this petition is that if the population centers where the greatest financial potential exists cannot feasibly afford to transfer to an alternative supply, the private users of the MICHINDOH aquifer system would not be able to afford a drinking water source transfer either.

The economic feasibility analysis is conservative. First, a civil engineer proposed the economical project designs and project costs for transferring each of the municipalities to an alternative drinking water resource. The project designs and costs were simplified and represent basic construction elements. In all likelihood, the total project requirements and costs would be considerably more than the estimates presented in this petition. Second, the available funding from the area residents is assumed to be the maximum of 0.6 percent of the reported income, as defined by the EPA guidance document. Third, the construction loans were assumed to be granted at zero percent interest.

The income data were adjusted for nearly 19 percent inflation between 2000 and 2007. The population estimates were not adjusted due to historically low changes of less than 5 percent in population across Ohio.

The results of the economic analyses indicate that the costs of implementing an alternative water supply source are not feasible and would create a significant financial hardship for the local residents and businesses. The costs for infrastructure replacements or upgrades ranged from $2,000,000 to nearly $36,000,000. The estimated debt repayment schedules ranged from 1 year to 134 years.

In conclusion, the requested Sole Source Aquifer designation for a portion of the MICHINDOH Glacial Aquifer is supported by a thorough examination of the geology, hydrogeology, and economic feasibility performed as part of the petition research. The proposed boundaries are based on defendable delineations of the groundwater divides, the physical extent of the aquifer, the surface water drainage basins, and the regional economics. The MICHINDOH aquifer system is a well-defined, valuable resource that represents the sole source of drinking water for the region's residents and could not be replaced without imposing significant financial difficulties for the drinking water users.

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FIGURES

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APPENDIX C GROUNDWATER LEVEL DATA

APPENDIX D PROJECT DESIGN AND ESTIMATED PROJECT COSTS

APPENDIX E USGS RASA STUDY - MIDWESTERN BASINS AND ARCHES

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