Public Health Service
DEPARTMENT OF HEALTH & HUMAN SERVICES
Centers for Disease Control and Prevention (CDC)

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From: National Center for Environmental Health, Division of Emergency and Environmental Health Services, Environmental Health Services Branch, Technical Assistance Team

Subject: Environmental Health Assessment for Epi-Aid 2004-076: Outbreak of gastroenteritis with multiple etiologies among resort island visitors and residents—Ohio, 2004.

Background

On August 27, 2004, the Ohio Department of Health (ODH) contacted the National Center of Environmental Health (NCEH) at the Centers for Disease Control and Prevention (CDC) for technical assistance in conducting an environmental health assessment. ODH wanted to identify potential sources of water contamination on South Bass Island, in Lake Erie. On August 29, 2004, four environmental health scientists from NCEH arrived in Port Clinton, Ohio, to assist in the ongoing water-related gastroenteritis outbreak investigation. A team of epidemiologists from CDC's National Center for Infectious Diseases (NCID) had been in Ohio working with the multiagency outbreak response team since August 19, 2004. The Ottawa County Commissioner of Health led the investigation, with critical support from the ODH, the Ohio Environmental Protection Agency (OEPA), and the Ohio Department of Agriculture (ODA).

On August 29, 2004, the ODH/NCID epidemiological report identified 1,031 ill individuals ages 7 months to 83 years. The ill persons reported a sudden onset of symptoms that included diarrhea, cramps, nausea, and vomiting. The median duration of illness was 4 days. The index case became ill on May 30, 2004. All of the ill individuals were visitors or residents of Lake Erie's South Bass Island (see Attachment 1). Pathogenic agents isolated from 19 stool samples submitted by ill persons included: *Campylobacter* (14); norovirus (3); *Salmonella* Group B (1); and Giardia (1). The fecal–oral route is the usual means of transmission for these enteric pathogens. Epidemiological evidence collected by the multiagency outbreak response team implicated drinking water consumed on South Bass Island as the vehicle of this outbreak. Before the NCEH team arrived, the local outbreak response team began to collect information on the various South Bass Island water sources and systems and sewage management practices and procedures.

South Bass Island (Longitude: –82.84970; Latitude: 41.6021), in Ottawa County, Ohio, is located in Western Lake Erie, approximately 50 miles east of Toledo and 72 miles west of Cleveland, Ohio. South Bass Island, Middle Bass Island, and North Bass Island are collectively referred to as the Bass Islands of Ohio. According to the 2000 U.S. Census, the population of South Bass Island is 763 people.

South Bass Island, a popular vacation destination from April through October, attracts visitors from Ohio, neighboring states, and Canada. Island activities include fishing, boating, swimming, golfing, camping, bird watching, and exploring caves and the unique geology of South Bass Island. Vineyards and a winery are located on South Bass Island. These and the many other South Bass Island activities and special events bring an estimated 15,000 visitors to the island each week of the tourist season. South Bass Island visitor's information identifies 21 tourist and recreational attractions, 25 restaurants and taverns, 14 shopping venues, 11 providers of transportation services, 11 bed-and-breakfast operations, 15 short-term rental homes, 11 hotels, and 2 campgrounds (PIB Chamber of Commerce 2005).

South Bass Island has 1,264 single-family dwellings (U.S. Census Bureau, 2000). Services on the island include a bank, six boat docking and marina facilities, two churches, a fuel distributor, two grocery stores, a hardware store, laundry, police, fire, and emergency medical services, post office, library, and a school.

Public service infrastructure includes the Put-in-Bay public water system and wastewater treatment facility operated and managed by the municipality. Portions of the island not served by public water and sewer utilize groundwater wells and onsite wastewater treatment and disposal systems (Graham et al. 1998). Additional information on South Bass Island is available in Attachment 2 of this report.

Purpose of Environmental Health Assessment

NCEH conducted this outbreak-related environmental health assessment to

1) identify the source(s) of the suspected etiologic agent(s);
2) determine how the suspected etiologic agent(s) entered the water source and/or water distribution system;
3) determine why the suspected etiologic agent(s) were able to survive in the potable water system, and;
4) isolate the suspected etiologic agent(s) from drinking water.

The environmental health assessment conducted by NCEH and partners was completed in two phases.

Phase 1—A *rapid field assessment* (RFA) determined water quality and evaluated water supply systems and sewage disposal methods. The RFA was conducted on South Bass Island from August 29–September 2, 2004, with follow-up work, data organization, and analysis completed in Atlanta, Georgia.

Phase 2—A *groundwater quality assessment* (GWQA) was conducted September 7–10, 2004. This assessment included the collection, organization, and analyses of historical and recent outbreak groundwater quality data, precipitation trends, and hydrogeologic information.

Phase 1—Rapid Field Assessment: Determination of Water Quality

Methods

Between August 30 and September 2, 2004, the NCEH field team collected 1 wastewater sample and 11 water samples on South Bass Island. The number of samples collected was limited to 12 because of field time needed to process each sample. An aerial photograph showing the 11 sample locations is found in Attachment 3 of this report. Collected samples included a 250-mL container of raw sewage from the Put-in-Bay wastewater treatment facility. This sample was collected to determine if wastewater generated and treated on the island would give an indication of pathogens circulating in the human population working, residing on, and visiting South Bass Island. The 11 water samples included:

- one from the raw water intake of the Put-in-Bay water treatment plant (Sample 1),
- one treated water sample from the water distribution system (Sample 2),
- five groundwater samples from transient, noncommunity (TNC) public water supplies (Samples 3–7), located near to the Septage disposal site and
- four private wells (Samples 8–11), also located near the Septage disposal site.

The ultrafiltration method was used to collect the drinking water samples. The ultrafiltration technique allows analysis for several potential microbial contaminants (viruses, bacteria, and parasites) from a single sample by processing a high volume of water and concentrating it down to a 200–250 mL sample. Attachment 4 explains this process in greater detail and provides additional information on the results summarized here. Site-specific environmental data were recorded before each water sample was collected. The visual environmental health assessment for each sample location documented the location of house, well, septic tank and drainfield, driveway, roads, outbuilding, and other features. Distances between septic tanks/drainfields and wells also were measured. Attachment 5 is the form used to record sampling data.

CDC laboratories analyzed collected water samples for total coliforms, *Escherichia coli*, *Campylobacter* (by culture, genus, and species DNA), fecal coliforms, somatic coliphages, F-specific coliphages. *Clostridium perfringens, Salmonella* DNA, *Salmonella* culture, *Cryptosporidium* DNA, *Cryptosporidium*, *Cryptosporidium* oocysts, *Giardia* cysts, GI norovirus, GII norovirus, norovirus DNA, adenovirus DNA, enterovirus DNA, and enterococci.

Results

- Analyses of the wastewater sample found concentrations of microbial indicators typical of untreated domestic wastewater.

- Water collected at the raw water intake at the Put-in-Bay water treatment facility was positive for four microbial indicators and *Cryptosporidium* spp. (by polymerase chain reaction [PCR] and microscopy).

- *Cryptosporidium* DNA was detected in finished water collected from the Put-in-Bay distribution system. We do not know whether this detection reflects the presence of viable or infectious *Cryptosporidium*. PCR results are a very conservative indicator of fecal contamination and health risks, as the PCR test can detect DNA that is not associated with viable or infectious pathogens.

- Of the five TNC system wells sampled, three were found to contain fecal coliforms and *E. coli.* Two of these wells (Samples 5 and 7) contained relatively high concentrations of *E. coli*. In addition, three of the five wells contained either somatic coliphages or F-specific coliphages, which are enteric viruses that infect coliform bacteria and are considered an indicator of fecal contamination. One of the wells contained *Clostridium perfringens* (a spore forming enteric bacterium). *C. perfringens* spores, somatic coliphages, and F-specific coliphages represent indicator microbes. They are generally more environmentally persistent than are standard indicators such as fecal coliform and *E. coli,* and may represent contamination that occurred weeks (or longer) before sampling.

- Sample 3 did not contain a culturable microbial indicator of fecal contamination. However, Sample 3 and three other TNC system well samples (2, 6, and 7) were found to be positive for *Salmonella* by PCR (using two different PCR assays). The CDC laboratory was not able to culture *Salmonella* from any of these samples. This is not necessarily surprising, as the PCR technique can detect nonviable and viable, but not culturable (VBNC) microbes.

- Three other pathogens were detected in the five TNC system wells using PCR: *Cryptosporidium* (in three of five wells), adenovirus (in one of five wells), and enterovirus (in one of five wells). However, when more specific PCR assays, immunomagnetic separation (IMS) and an immunofluorescent antibody (IFA) were conducted, samples from the wells were negative for *Cryptosporidium.*

- A single *Giardia* cyst in Sample 5 was detected by IMS and IFA. This sample was also found positive by genotyping nested PCR for *Cryptosporidium hominis*.

- A single *Cryptosporidium* cyst was detected by IMS and IFA in Sample 1 (water treatment plant surface water influent from Lake Erie).

- Samples from the four private wells (Samples 8–11) were received at CDC on Friday, September 3, 2004. They were stored in a refrigerator until Tuesday, September 7 before further processing and analysis. While significant microbial die-off likely occurred during this holding period over a holiday weekend, two of the four samples were still found to be positive for *E. coli*. Beyond fecal coliforms and *E. coli*, none of the private well samples were positive for any other indicator organisms.

- When cultured, none of the NCEH-collected water samples were found to contain *Campylobacter* species. A strain of *Arcobacter butzleri* was confirmed biochemically and by 16S sequencing in groundwater Sample 5.

- Five of the water samples collected (Samples 3, 4, 9, 10, and 11) from TNC public and private water systems, when tested for chlorine before sampling, had a detectable available chlorine residual of 0.01–0.04 mg/L. The TNC public water system at sample location 3 had a chlorinator installed. The chlorinator was turned-off before sampling. The water system was flushed for at least 1 hour before the sample was collected. Prior to sample collection, the water was tested frequently for chlorine residual. A chlorine residual of 0.04 PPM was consistently measured. The other TNC public water supply system, sample location 4, pumped water from a cave. The cave is 52 feet below the ground surface, and 208 feet long by 165 feet wide. The water level in the cave fluctuates according to the water level of Lake Erie, indicating a subterranean connection between Lake Erie and the cave system. This TNC public water supply system was not chlorinated. Although the water system was flushed for more than 40 minutes, chlorine residual was continually detected and measured at 0.02 PPM. Three of the four private residences (Samples 9, 10 and 11) had a chlorine residual of 0.01–0.02 PPM. Owners of these systems report their well water was not recently treated or disinfected.

- Several of the groundwater samples were collected from wells located near an island septic tank sludge (septage) disposal site. Septage pumped from business and privately owned septic tanks by a local service was disposed of in a sink hole/low depression located between Catawba Road and Put-in-Bay Road, near the middle of the island. This disposal site was reported to be in use for several years. NCEH was unable to obtain septage dumping records for the site. More than half of the TNC public and private well water samples (Samples 5 and 7–11) were collected from locations adjacent and relatively near the septage disposal property.

Discussion

The *Giardia* cyst identified in Sample 5 is a significant finding. The presence of this parasite (which is fairly large, with a diameter of 12 μm) indicates that enteric parasites and smaller pathogens (i.e., bacteria and viruses) can enter and be transported through the subsurface aquifer of South Bass Island (Gerba et al. 1984; Moe 1997).

Chlorine was detected in several wells, even those wells that were not chlorinated. This finding strongly supports the hypothesis that chlorine used to treat other wells on the island found its way to the aquifer, so that it was being detected in wells not recently disinfected with a chlorine product. Similarly, pathogens present in on-site wastewater system effluent may find their way into the aquifer and ultimately into drinking water supplies.

Local reports indicate that during the summer months approximately 15,000 tourists visit the island each week. Most visitors arrive Friday evening and depart on Sunday. The weekend visitation peak places an extraordinary demand on the island's groundwater aquifers. The increased demand for water from TNC public and private water systems will draw the aquifer down over time. When this occurs a cone of depression extends around a well, resulting in water being "pulled in" from other sources, such as the lake. That could also pull in effluent from on-site wastewater systems (Fetter 1980; Freeze et al. 1979). Due to the high seasonal demand on the aquifer, the thin-to-absent soils, severe limitations for septic tank absorption fields, and known karst geology (interconnected fractures, channels, and caves), pathogens could reach and contaminate drinking water supplies (Malard et al. 1994). The limited number of groundwater samples collected by NCEH found multiple indicators of a sewage contaminated aquifer.

Raw, untreated surface water from Lake Erie collected at the Put-in Bay community water treatment plant is positive for *Cryptosporidium*. Raw water was also positive for *E. coli*, fecal coliform, somatic coliphages, and *C. perfringens*. The presence of these organisms in surface water is not uncommon. Proper operation of the water treatment plant process effectively removes these organisms.

The water source for the public water system is Lake Erie. Finished water samples collected from the water distribution system are negative for all organisms tested, with one exception. *Cryptosporidium* DNA was found in the finished water sample collected by NCEH on August 30, 2004. *Cryptosporidium* oocysts, often present in surface water, are broken and inactivated by water treatment processes. The analysis process used by CDC may detect DNA on nonviable oocyst particles and fragments present in treated water. The detection of *Cryptosporidium* DNA does not differentiate live from dead oocysts. Finished water from the Put-in-Bay community water system was analyzed by two additional methods for *Cryptosporidium*. Michigan State University also analyzed finished water for

Cryptosporidium. These follow-up tests found no evidence of viable *Cryptosporidium* oocysts in the public water system.

Phase 1—Rapid Field Assessment: Assessment of Water Sources and Supplies

Methods

Put-in-Bay's water treatment plant operation records from May to August 2004 were reviewed to determine if plant or distribution system operation could have contributed to the gastrointestinal disease outbreak. All aspects of the records were reviewed, including operator logs, loading rates, filter operations, chlorination, bacteriological tests, and OEPA inspection reports.

The Village of Put-in-Bay water treatment facility processes water at a rate of 0.216 million gallons per day (MGD). The facility, originally constructed in 1977, was upgraded in 2000 with the installation of a Culligan Multi-Tech treatment system. Water treated at the facility is drawn from lake and groundwater sources. Lake Erie surface water is the primary water source. A groundwater well was developed as an emergency back-up source. Raw (untreated) water pumped from Lake Erie passes through five Culligan Multi-Tech treatment trains. This treatment system consists of clarification, rapid sand filtration, and granular activated carbon filtration. Water is then chlorinated and pumped to a 200,000-gallon elevated storage tank for gravity flow through the Put-in-Bay water distribution system. The distribution system is connected to 104 commercial meters and 95 residential water meters.

Results

- The August 2004 OEPA inspection of the facility discovered that the raw water (low service) pumping system was not installed according to proposed plans. The 2000 upgrade plan called for the installation of a 200-gallon per minute (gpm) pump. However, when construction took place, a 150-gpm pump was installed, thus limiting production to 0.216 MGD (150 gpm). Although this does not to affect the quality of the water produced, it did lower the production rate of the overall plant from 0.288 MGD (200 gpm) to 0.216 MGD (150 gpm).

- Records indicate the water from the emergency groundwater supply well is highly corrosive. Corrosive water, if used for long periods, can leach lead and copper from water distribution lines and building service pipes. Records indicate the groundwater well was used on occasion to meet the demand for water. Because of the corrosiveness of the water and the related lead and copper issues, OEPA ordered this well not be used on a routine basis.

- Michigan State University collected samples from the back-up groundwater well at the Put-in-Bay community water facility. These water samples were negative for all tested biological parameters.

- OEPA records report all bacteriological analysis results of treated water leaving the facility as negative. The review of plant operation logs and records indicated compliance with OEPA standards and reporting requirements.

Discussion

Although some operational issues were identified, they did not affect the ability of the facility to provide adequate quantities of treated water. All routine water tests indicate compliance with OEPA water treatment and quality standards. The pump capacity issue did limit total water production but there is no evidence of inability to meet water demand (i.e. lack of water, low flow, loss of pressure in distribution system). There is no evidence in material reviewed and from discussions with the facility operator of pumping rates exceeding the design capacity of the treatment facility.

If the water treatment facility is operating as designed, the mixing of groundwater from the emergency backup well with surface water at the facility does not present a pathogen exposure risk because the groundwater enters the treatment system at the beginning of the process and receives full treatment including chlorination. It was because of its high corrosivity that the use of water from the emergency well was discontinued. Analyses of groundwater collected from the emergency well by Michigan State University showed no indicators of microbial contamination.

Phase 1—Rapid Field Assessment: Assessment of Community Water Distribution System and Auxiliary Wells

Methods

NCEH reviewed Put-in-Bay community water distribution system operation and maintenance records and water quality data. NCEH also reviewed available information on auxiliary wells developed and utilized by several commercial establishments.

Results

- The review of available information found no indications of water line breaks, leaks or significant loss of pressure in the water distribution system.

- Water quality data maintained on the Put-in-Bay community water distribution system from 2000 to August 2004 report 2 of 196 (1%) samples as total coliform positive. No total coliform bacteria positive sample results were reported for the community water distribution system during the first 8 months of 2004.

- The auxiliary wells provided groundwater for cooling, watering grass, flushing toilets, and other activities. Four of the auxiliary wells were cross-connected to the Put-in-Bay community water distribution system.

- Three of the four cross-connected auxiliary wells were sampled by OEPA. One auxiliary well is positive for total coliforms and *E. coli*, and another is positive for *Campylobacter jejuni*. OEPA ordered these businesses to disconnect all identified cross-connected plumbing.

- Backflow prevention devices were installed on the four cross-connected auxiliary wells. Each was fitted with either a reduced pressure zone (RPZ) valve or a check valve assembly. Properly installed and functioning backflow prevention devices allow water to move in one direction. These devices are installed to prevent water from building supply lines to flow back into the distribution system.

- OEPA examined one of the RPZ valves after it was removed and determined that it was malfunctioning. The condition of the other valves is unknown. Building owners did not maintain valve operation, maintenance, and test records.

Discussion

The results of routine water samples collected from the Put-in-Bay water distribution system found no recent indicators of bacterial contamination.

There is no direct evidence of loss of pressure in the water distribution system to the extent necessary to cause backflow. However, the cross-connections between groundwater supply lines and community water system service lines, the finding of a malfunctioning PRZ valve, and the presence of fecal indicators and *C. jejuni* in samples collect from auxiliary wells are factors that may have contributed to this outbreak.

Phase 1—Rapid Field Assessment: Assessment of Water Sources and Supplies—Development of Groundwater Wells

Methods

To characterize groundwater well development on South Bass Island, NCEH reviewed 503 groundwater well drilling reports provided by the Ohio Department of Health. The most recent information from the 1990 US Census indicates a total of 679 drilled wells and 27 dug wells in Put-in-Bay Township. Characteristics of interest included well and casing depth, grouting, and remarks from well formation logs. Remarks from well formation logs were reviewed for evidence of subsurface openings, crevices, voids, caves, and other geological conditions that may influence the collection, movement, and mixing of groundwater with recharge waters. The reviewed logs dated from 1948 to 2003.

Among those reports, the detailed and clear records developed by the Island Well

Drilling Company provide an excellent source of information on well construction practices and geologic formations of South Bass Island. Island Well Drilling Company records were examined to collect information not consistently recorded by other well drillers. The Island Well Drilling Company developed 82 wells on South Bass Island from 1961 to 1971.

Results

- The review of the Island Well Drilling Company well logs found 56% (20/36) of the wells had openings, crevices, or caves below the protective casing depth (Attachment 6).

- A review of all 503 well log and drilling reports found 172 (34%) wells with a recorded grout seal. A proper grouting seal can prevent contaminants from entering groundwater.

- Of the well logs reporting grouting, 64% did not record type of grout used.

- Well logs report the use of the following grouting materials: 22% well cuttings; 34% cement; 34% bentonite clay; and 10% bentonite mixed with well cuttings.

- The detailed well logs maintained by the Island Drilling Company do not record the use of grout or the grouting of drilled wells. The older well log and drilling report form used by Island Drilling Company did not require the reporting of well grouting, so it is unknown if grouting was used.

Discussion

Island Drilling Company records indicate 56% of the developed wells have openings, crevices, or caves below the protective casing depth. This may allow surface water to quickly reach and enter the drill hole (Attachment 7). Contaminants seeping into the ground from septic tanks or others sources could mix with water in the drill hole (Keswick 1984; U.S. Department of the Interior 1985).

Additionally, the lack of a proper grouting seal could allow contaminants to enter the well. A gap often exists between the well casing and the soil and layers of rock in the well hole. It is common practice to place a grout (cement, clay, well cuttings) seal around the upper portion of well casing to help prevent contaminated surface water from entering the well. Grout also helps to seal crevices or openings in formations to prevent water or other contaminants from entering the well along the casing. The absence of grouting could lead to well contamination. In that case, the casing acts as a funnel, allowing contaminants to flow along the casing sides into the well (Salvato 1992; U.S. Department of the Interior 1985).

Environmental laws well now prohibit cuttings (material removed in the process of drilling) from being used as a grouting material in Ohio. Well cuttings were found to be less effective in providing a proper seal. Only 34% of wells recorded a grout seal. The lack of grouting and the use of ineffective grouting materials, such as well cuttings, could allow contaminants to enter the well.

Phase 1—Rapid Field Assessment: Sewage Disposal Methods

Methods

Information on South Bass Island wastewater treatment and disposal methods and septage management practices was obtained from OEPA, the Ottawa County Health Department, and from operators during site visits to sewage disposal facilities. Soils information for South Bass Island was obtained from the *1985 Soil Survey of Ottawa County, Ohio,* conducted by the U.S. Department of Agriculture, Soil Conservation Service (now the Natural Resources Conservation Service) (Musgrave et al. 1985). This information was organized and reviewed to determine if sewage management on the island may have contributed to the outbreak.

Village of Put-in-Bay Community Wastewater Treatment Facility

Results

- The Village of Put-in-Bay's wastewater treatment facility is the largest sewage system on the island. It has a design capacity of 0.25 MGD. The facility uses a sequencing batch reactor (SBR) activated sludge treatment process followed by chlorination of the final effluent. The effluent is discharged into Lake Erie at the Put-in-Bay Harbor. Design is underway for an expansion of the wastewater treatment facility by converting a portion of the aerobic sludge process into a membrane-type system. This will increase the design capacity of the facility by an additional 0.200–0.250 MGD, for a total capacity of 0.450–0.500 MGD. The project is scheduled for completion by the end of 2006. The membrane system will be evaluated for performance; the community may then opt to convert one or two of the SBR tanks into a membrane system. If both SBR tanks are converted, the facility could have a design capacity of up to 2.0 MGD.

- No discharge violations were reported in recent years or during the time of the outbreak. The facility appeared to be well operated and maintained.

Discussion

The effluent discharged from the treatment plant met discharge standards and records indicate the facility was operating properly at the time of this outbreak. There is no evidence to support a connection between the village wastewater treatment facility and the outbreak.

On-site Wastewater Systems for Residences and Businesses

Results

- Individual on-site septic tank systems are the most common type of wastewater disposal method on South Bass Island. Ottawa County Health Department records indicate there are 476 on-site septic tank systems used at individual homes on South Bass Island.

- On-site septic tank systems are also the most common method of wastewater disposal for businesses on South Bass Island. Several different types of on-site disposal systems have been installed and are in use at business establishments.

- Information provided by OEPA on sewage disposal methods used by 32 businesses on South Bass Island finds 25 of 32 (78%) discharge their wastewater into the subsurface.

- The following information shows the distribution of wastewater disposal methods for businesses—lodging, food service, convenience stores—on South Bass Island:

Type of System	Total Number
Aerator system (surface water discharge)	2
Leach beds (soil absorption)	9
Leach fields (soil absorption)	9
Mound systems (soil absorption)	4
Subsurface sand filter (soil absorption)	3
Subsurface sand filter (surface water discharge)	2
Rock filter (surface water discharge)	1
Holding tanks	2
Unknown type	16
Package treatment plants (surface water discharge)	10

- OEPA ordered two businesses to install holding tanks and discontinue discharging wastewater to existing systems due to high potential for groundwater contamination. One of these systems discharged wastewater directly to a dry well that provided a direct conduit to the groundwater aquifer.

- Five business operations discharge effluent to surface water (Lake Erie).

- Ten of the 32 systems are permitted by OEPA. The wastewater disposal method used by 16 businesses is unknown.

- According to OEPA, 10 businesses use package wastewater treatment plants that discharge effluent to Lake Erie. These systems range in their designed flow capacity from 1500 gpd to 29,000 gpd. The total design capacity of these 10 package plants is 88,600 gpd. All of these systems were inspected between August 10 and August 27. Minor to serious problems were identified at each plant. Some of the more severe problems identified included aeration tank contents being black and septic, blowers malfunctioning, tanks leaking, and disinfection not being applied. Four of the 10 package treatment plants were operating under OEPA permits. The Federal Clean Water Act requires all owners of wastewater systems that discharge to surface waters to obtain a permit under the National Pollutant Discharge Elimination System (NPDES). OEPA ordered all owners of package plants who did not have an NPDES permit to make application. At the time of this assessment, 9 of the 10 package systems are either operating under an NPDES permit or have applied for a permit. One system has not applied and is reported to have repeated operational problems.

- Eleven bed-and-breakfast operations and 15 short-term rentals exist on the island. Due to small lot sizes, adequate room for on-site wastewater systems may not available. Therefore, many of these systems use leach beds instead of leach line systems. This practice concentrates the amount of effluent over a much smaller area. It can result in higher rates of failure, even in suitable soil and geologic environments, due to a great reduction in the soil sidewall area of the disposal system (Salvato 1992; Yates 1987). The use of leach beds is even more problematic on South Bass Island because of severe soil and geologic limitations.

Discussion

A high number of homes and businesses discharge wastewater into the thin soils of the island through conventional on-site wastewater systems. The 476 on-site wastewater systems and the island's karst geology provide a means for wastewater to enter the South Bass Island groundwater aquifer (Gunn et al. 1997; Keswick 1984; Lance 1984; Tranter 1997).

Operational problems were noted with package plants that discharge into Lake Erie. These operational issues could affect the quality of wastewater treatment and allow insufficiently treated sewage to enter the lake, creating a potential health hazard (Hunter et al. 2003).

Soil Limitations for Onsite Wastewater Disposal

Results

- The most recent Soil Survey of Ottawa County, Ohio, was conducted by the U.S. Department of Agriculture, Soil Conservation Service, in 1985. The survey shows that five series of soils—Castalia, Dunbridge, Milton, Nappanee, and Rawson—are native to South Bass Island.

- All five soil types identified on South Bass Island have “severe” limitations for septic tank system use, according to the Soil Survey (Attachment 8). Attachment 9 provides a complete description and primary limitations for each of the soils types found on South Bass Island.

- Chapter 3701 of the Ohio Administrative Code, Section 29-10; “Installation requirements for soil absorption and percolation” (effective 7/1/1977), establishes the following restrictions for the use of onsite wastewater systems:

  > (A) Leaching systems utilizing soil absorption or percolation shall not be permitted where the depth to normal groundwater table or rock strata is less than four feet below the bottom of the proposed system.
  >
  > (B) Leaching systems utilizing soil absorption or percolation shall not be installed where the texture, structure, or permeability of the soil is not suitable to provide internal drainage. The health commissioner may require the owner at the owner’s expense to provide a written site evaluation by a qualified person before a final decision is made in issuing a permit. The criteria of the national cooperative soil survey shall be used as a guideline by the health commissioner to determine the suitability of the soils in lieu of a more detailed guideline relating to the code requirements and soil characteristics.

Discussion

According to the most recent soil survey of Ottawa County and the Ohio Administrative Code, all soils located on South Bass Island are unsuitable for conventional onsite wastewater disposal systems (Musgrave et al. 1985).

In addition to severe limitations for on-site wastewater posed by the native soils of South Bass Island, an additional limitation and threat to groundwater is the karst topography and geology of the area (Myers et al. 2000). Karst is a distinctive topography in which the landscape is largely shaped by the dissolving action of water on carbonate bedrock (usually limestone, dolomite, or marble). This geologic process, occurring over many thousands of years, results in unusual surface and subsurface features. Those range from sinkholes, vertical shafts, disappearing streams, and springs to complex underground drainage systems and caves (Jack 1999; Maire 1994; Malard 1994).

The combination of karst geology and thin soil depths, make the island unsuitable for conventional onsite septic systems (Musgrave et al. 1985; Myers et al. 2000).

Septage Disposal

Results

- Septage was pumped from business and privately owned septic tanks by a local septic tank pumping service and discharged on land into a sink hole/low depression located between Catawba Road and Put-in-Bay Road. This disposal site was reported to be in use for several years. NCEH was unable to obtain septage dumping records for the site. More than half of the water samples (Samples 5 and 7–11) were collected from TNC public water supplies and private wells that were located adjacent to and within 1 mile of the property where septage was discharged.

- None of the private well water samples (8–11) taken from properties adjacent to the septage disposal site were positive for bacterial or viral contamination.

- The TNC public water supplies sampled near the septage disposal site showed significant levels of contamination (Samples 5 and 7).

Discussion

OEPA reports that septage disposal at this site is not allowed under Title 40 of CFR, Part 503 and has stopped. It is unknown if the septage disposal site contributed to the contamination of the TNC public water supplies. Given the karst geology of the island, including large pores, channels, and caves through which surface water and contaminants can travel, it is possible that the septage disposal site may have contributed to contamination of the groundwater aquifer (Keswick 1984; Kowel 1982; Lance 1984).

Phase 2—Groundwater Quality Assessment: ODH/NCEH Assessment

Methods

The ODH/NCEH groundwater quality assessment included only private residential wells. The assessment conducted water source sanitary surveys and collected groundwater samples (U.S. Environmental Protection Agency 1999). The island was divided into 22 sections and a total of 77 water samples were collected. Attachment 10 provides a description of the sampling protocol.

Samples were analyzed for total coliforms, *E. coli*, *Campylobacter*, *Salmonella*, chloride, and nitrate. The primary purpose of collecting a water sample was to support the finding of a sanitary survey. The South Bass Island water quality assessment was designed to collect information on selected well characteristics and conditions that could affect water quality. CDC’s water quality assessment of Midwestern private wells, which yielded valuable information on private well use in the United States, focused on well characteristics such as pitless adapters, backflow devices, sanitary seal, cracked casing, proximity to potential contamination sources, and other data. This protocol was used as a model in the design of the South Bass Island assessment (Centers for Disease Control and

Prevention 1998). However, limited resources and time prevented the collection of accurate and complete sanitary survey data on South Bass Island.

The results of this groundwater sample collection activity are compared to South Bass Island outbreak and existing historical groundwater quality data.

Results

- Of the groundwater samples collected by the ODH/NCEH assessment, 31% were *E. coli* positive (Attachment 11).

- Historical data for South Bass Island reports 9% of private wells as *E. coli* positive.

- Outbreak response water quality data, from August and September 2004 report 30% of private wells *E. coli* positive and 35% of the TNC public water systems as *E. coli* positive

- Of the groundwater samples collected by the ODH/NCEH assessment, 78% were total coliform positive (Attachment 12). Historical data reports 51% total coliform positive for private wells.

- Outbreak response water quality data from August and September 2004 reports 42% of private wells to be total coliform positive and 48% of the TNC public water systems tested positive.

- A statistically significant relationship exists between wells that **are less than 52 feet deep** and positive results for *E. coli* (OR = 7.7 (95% CI; 2.24–27.06); *P* value = 0.0002). Wells constructed with depths less than 52 feet are almost 8 times more likely to be contaminated with *E. coli* than wells with depths of 52 feet or greater (Attachment 13).

- A statistically significant relationship also exists between wells developed in the aquifer **above lake bottom** and *E. coli* positive results (OR = 3.21 (95% CI; 1.13–9.09; *P* value = 0.039). Groundwater wells developed in the aquifer above the lake level are 3.21 times more likely to be contaminated with *E.coli* than wells drilled below the lake bottom.

Discussion

The bacteriological results of the private well groundwater assessment are similar to those obtained in groundwater collection activities implemented in response to the outbreak, but higher than the historical data on private wells.

The results obtained in the ODH/NCEH groundwater quality assessment of 31% *E. coli* and 78% total coliform positive exceed those obtained in the CDC Midwestern states well study of 11% *E. coli* and 41% total coliform positive (Centers for Disease Control and Prevention 1998).

Wells less than 52 feet were more likely to be contaminated with *E. coli*. Deeper wells may provide some protection against contamination.

A comparison of location of well in relation to shoreline and *E. coli* positive results found no association (Attachment 14.). Although no association was found with this analysis, a mixing of ground and lake water in the aquifers under South Bass Island occurs through interconnected caves and fractures in the geology. Historical studies of the island show increased water levels in caves rise as lake levels rise. This shows evidence of interconnectivity of lake water and groundwater on the island (Newell 1999; Verber et al. 1953).

Phase 2—Groundwater Quality Assessment: Collection, Organization, and Analysis of Available Water Quality Data

Methods

Available historical and recent outbreak response groundwater quality records for South Bass Island provided by the Ottawa County Health Department, Ohio Department of Health, Ohio Environmental Protection Agency, and the Ohio Department of Agriculture were combined, organized, and reviewed. The number and percent of total coliform and *E. Coli* positive water samples in the historical database were compared to outbreak sample results to determine if groundwater quality had recently deteriorated.

Review of Existing Historical Private Groundwater Well Sampling Results

Results

Total coliform

- Of the groundwater samples collected from private wells on South Bass Island during 2001, 2002, and 2003, 51% (41/80) are total coliform positive (Attachment 15).
- Of the groundwater samples collected from private wells on South Bass Island during the first 8 months of 2004, 69% (46/67) are total coliform positive.
- Private groundwater well total coliform positive results increased from 50% in 2003 to 77% during the first 7 months (January–July) of 2004 and remained

elevated at 67% during August 2004.

E. coli

- Of the groundwater samples collected from private wells on South Bass Island during 2001, 2002, and 2003, 9% (7/80) are *E. coli* positive (Attachment 15).

- Of the groundwater samples collected from private wells on South Bass Island during the first 8 months of 2004, 24% (16/67) are *E. coli* positive.

- Of the 64 water samples collected by the Ottawa County Health Department at the end of August and the beginning of September 2004, 30% (19/64) were *E. coli* positive.

- The Ottawa County Health Department collected 55 water samples in 2000 from private water wells on South Bass Island. Sample results are reported as *safe* or *unsafe*. Of the samples collected, 56% (31/55) were recorded as *unsafe*.

Discussion

A comparison of recent to historical groundwater quality data found an increase in the number of both total coliform and *E. coli* positive results for samples collected from private groundwater wells during the first 8 months of 2004. Total coliform positive results increased from 51% (2001–2003) to 69% for the first 8 months of 2004. *E. coli*, which is a stronger indicator of fecal contamination, increased from 9% in 2001–2003 to 24% from January through August 2004.

In a 1994 CDC private well study conducted in nine Midwestern states, 41.3% of the wells (N = 5,520) were positive for total coliforms and 11.1% were positive for *E. coli*. Although other studies have been conducted in the United States, this study is most comparable because it was conducted in the same region. Using this study as a comparison, rates were higher for South Bass Island in all categories except *E. coli* in 2001–2003. The percent of total coliform and *E. coli* positive test were higher than the Midwestern states study. A nationwide study conducted by EPA in 1984 showed rural wells with 78% total coliform and 12% *E. coli* positive results. This nation-wide study had higher total coliform rates than South Bass Island, but *E. coli* rates were higher for the island from January through August, 2004 (U.S. Environmental Protection Agency 1984).

Historical Review of Transient and Noncommunity Public Water Sample Results

Results

- Of the groundwater samples collected from 11 TNC public water systems (2000–2003), 7% (19/284) were total coliform positive. In comparison, 51% of the private well samples collected during this same period were total coliform positive.

- Of the groundwater samples collected from 11 TNC public water systems during the first 8 months of 2004, 21% (7/35) are total coliform positive. Of the private well samples collected during this same period, 69% are total coliform positive.

Discussion

The much higher percent of total coliform positive groundwater samples in the private wells compared to the TNC public water systems (51% vs. 7%) for the years 2000–2003 is difficult to explain. Further investigation is needed. One explanation might be that TNC water systems typically have to provide more water than private wells. Consequently, they may be drilled to greater depths, drawing from deeper aquifers, which are generally more protected than shallow aquifers (Gerba et al. 1984; U.S. Department of the Interior 1985).

Association between Precipitation and Water Quality

Methods

Precipitation data were examined for South Bass Island to determine if rainfall trends may have contributed to this outbreak. The karst geology of the island, containing caves, cracks, and fractures, along with a thin soil layer increase the risk of groundwater contamination. Large amounts of rainfall or melting snow may flush contaminants such as septic tank discharge from the upper soils into groundwater wells. Ohio Department of Natural Resources monthly regional precipitation reports for the years 1951–2000 and 2004 were reviewed. This regional data provides an average of precipitation for several sample points in north central Ohio. South Bass Island rainfall data collected at Perry's Monument from 1977 through 1997 were also reviewed. Island-specific data were compared to the regional precipitation data to identify major differences and existing trends.

Results

- Average monthly precipitation on South Bass Island is 0.20–0.58 inches less than north central Ohio precipitation for all months except August, September, and October. During these months, the rainfall on South Bass Island is greater (Attachment 16).

- The average yearly precipitation for the north central Ohio region is 35.09 inches compared to the South Bass Island yearly average of 31.77 inches.

- In 2004, north central Ohio precipitation exceeded the historical average for the region by 4.58 inches in May, 1.23 inches in June, 0.34 inches in July and 0.40

inches in August.

Discussion

Regional precipitation for the months of March, May, June, July, and August 2004, is higher than historical measures and may have contributed to contamination of groundwater wells on South Bass Island. Periods of high precipitation can cause contaminants from sewage treatment facilities to be flushed into the groundwater aquifer. Periods of high snow melt may have the same effect on groundwater quality. Although higher then normal precipitation may exacerbate the problem of groundwater contamination on the island, it should not be considered the single contributing factor to this outbreak. Continued use of on-site systems in this type of soil and geologic environment will result in continued contamination of the groundwater regardless of variations in precipitation (National Research Council 2001; Rose et al. 2001).

Conclusions

Conclusion 1. Suspected Source of Etiological Agent

Sewage has contaminated the groundwater aquifers that provide drinking water to South Bass Island. Inadequate soil depth to bedrock, which is fractured and contains numerous solution channels, contributes to the problem. This increases the likelihood that on-site subsurface sewage disposal systems at homes and businesses are introducing sewage directly into groundwater supplies. The karst formation of the island facilitates the movement of sewage into the aquifer and the movement of contaminated groundwater within the aquifer (Gunn et al. 1997; Jack 1999; Malard et al. 1994; Yates 1987).

The subsurface disposal of sewage is not the only contributor to the contamination of the aquifer. Another source could be poorly maintained, malfunctioning, and possibly undersized package wastewater treatment plants. In addition, on-site wastewater disposal systems designed to discharge to surface water could be introducing untreated or poorly treated wastewater to the shoreline of the island. Depending on the location, duration, and volume of discharge, this situation may expose swimmers and recreational water enthusiasts to contaminated water. Considering the apparent influence of surface water on South Bass Island groundwater supplies, contaminated surface water could be mixing with groundwater.

Because of the thin layer of soils on the island, water runoff may move contaminants from the ground surface into the aquifer through openings and cracks near the ground surface (Centers for Disease Control 1999; Michaud et al. 2004). The possible connection between the septage disposal site and contamination of the aquifer has not been adequately investigated (Keswick 1984; Kowel 1982).

Conclusion 2. Suspected Mode of Contamination of Water Supply

A review of operational records and bacteriological results for water leaving the water treatment plant does not support a link between drinking water from this source and illness. Cross connections were found between auxiliary wells and the village water distribution system. These cross connections could have allowed contaminated groundwater to enter the public water distribution system. However, a review of routine bacteriological results maintained on the distribution system did not find evidence of wide-spread contamination in the distribution system. All water samples collected from the distribution system before and during the outbreak are negative for standard indicator organisms. In addition, water from the public water systems was not implicated in the outbreak by the epidemiologic investigation.

Backflow prevention devices were installed at cross-connected auxiliary wells. A properly functioning backflow prevention device prevents water from flowing back into the water service line that connects the building to the distribution main. After removing the cross connections, one reduced pressure zone (RPZ) valve was examined. At the time of inspection the valve was found to not be working properly. Reports did not indicate that other backflow prevention devices were tested. If backflow prevention devices were not operating properly contaminated groundwater could have entered the building's water service line and the public water distribution system.

Two auxiliary wells that were discovered to be cross-connected at the time of the outbreak were sampled. One of these auxiliary wells was positive for total coliform and E. coli. The second well was positive for *C. jejuni*. The cross connected wells may have provided contaminated groundwater a mode of entry into the public water distribution system.

Drinking water from a groundwater well on South Bass Island is identified in the epidemiological investigation as the likely source of exposure for those individuals reporting illness. The environmental investigation supports this conclusion. Groundwater samples collected in response to this outbreak found strong indicators of fecal contamination (Haas et al. 1999; National Research Council 2004). *E. coli*. was positive in 30% to 40% of collected groundwater samples. The geographical distribution of these sample locations indicates widespread contamination of the groundwater aquifer. On-site wastewater systems are installed in soils identified as having severe limitations for septic tank absorption fields (Musgrave et al. 1985). The karst geology of the island provides a direct connection between on-site wastewater system effluent and the drinking water aquifer. Well logs report numerous subsurface voids, openings, crevices, and caves, many below the protective casing depth. This facilitates the mixing of sewage with groundwater in well holes and the movement of lake water into the aquifer (Gunn et al. 1997; Maire 1994; Malard 1994; Tranter 1997).

Conclusion 3. Possible Reasons the Etiological Agents Survived in the Water Supply

The demand on island sewage and water systems during peak visitation periods, especially summer weekends, increases when an average of 15,000 tourists visit the island. In a short period (2-day weekends), large volumes of ground and surface water are used and returned to the subsurface of the island or to the lake as wastewater. This surge of wastewater into the island's many small, on-site wastewater treatment and disposal systems may result in the discharge of inadequately treated sewage into the subsurface of the island and the lake. The thin soil layer and the fractured karst geology allow sewage discharged to the subsurface to move quickly (days to weeks) into the drinking water aquifer. Sewage contaminated lake water may also move under the island and mix with groundwater used for drinking.

This weekly surge of sewage into the island's subsurface and surrounding lake water may contain a heavy concentration of pathogens. Hardy pathogens, including *Cryptosporidium*, *Giardia*, *Campylobacter*, and *Salmonella*, were detected in South Bass Island groundwater samples. *Cryptosporidium* and *Giardia* were also detected in the untreated wastewater sample collected from the municipal wastewater treatment facility.

The protozoa *Cryptosporidium* and *Giardia* do not easily move through soils. Their detection in groundwater is an indication that other organisms may also be moving through the subsurface unimpeded. Consuming as few as 10–25 *Giardia* cysts can cause infection. *Giardia* cysts maintain viability for up to 3 months in cold water. Studies conducted on *Cryptosporidium* found oocysts surviving in soils for 60–180 days and in surface water and groundwater for 176 days (Salvato 1992; Percival et al. 2004). As few as 30 oocysts can cause infection in healthy individuals (Moe 1997; Percival et al. 2004; Salvato 1992).

The infectious dose of *Campylobacter* is a few hundred organisms. Studies have isolated *Campylobacter* from surface water and this bacterium is commonly found in high numbers in domestic sewage. The survival of *Campylobacter* in the environment is dependent upon temperature and other factors, with the range being a few days to weeks (Fricker 1999; Moe 1997; Percival et al. 2004).

Salmonella can survive in soils for 1–120 days, in surface water from days to 2 months, and in groundwater for 70 days. In addition to being able to survive in water for prolonged periods *Salmonella* is also able to grow in warm polluted waters. Studies have identified large numbers of *Salmonella* in the effluent of wastewater treatment plants. The infective dose of *Salmonella* can be as few as 1,000 organisms (Gerba et al. 1984; Percival et al. 2004; Salvato 1992).

The geology of South Bass Island provides an avenue of connection between surface water runoff, sewage, lake water, and the groundwater aquifer (Graham et al. 1998; Musgrave et al. 1985; Myers et al. 2000). The influx of visitors on weekends to the island creates a demand for water that draws available recharge water to groundwater wells. This demand for water may facilitate contamination of groundwater from on-site systems and increase the mixing of lake water with groundwater. These periods of high water use also generate a high volume of sewage that existing systems may be unable to adequately treat. This cycle of water demand and sewage discharge in the unique geology of South Bass Island creates a system that may allow a heavy concentration of viable pathogens to move quickly from host to susceptible persons.

The lack of a treatment barrier also influences the survival of pathogens in water. The number of households and business establishments using point-of-use water treatment equipment is unknown. Groundwater may not be filtered or disinfected before consumption.

Conclusion 4. Isolation of Suspected Etiological Agent From Water Supply

Indicators of fecal contamination were found in groundwater samples collected from South Bass Island. Total coliforms, *E.coli*, fecal coliforms, somatic coliphages, F-specific coliphages. *Clostridium perfringens*, *Salmonella* DNA, *Cryptosporidium* DNA, *Giardia*, adenovirus DNA, enterovirus DNA, enterococci, and *Campylobacter* (by culture, genus and species DNA) were detected in water samples. *Campylobacter jejuni*, *Arcobacter butzleri, Campylobacter upsaliensis* and *Acinetobacter* were also detected in South Bass Island water samples.

Campylobacter, *Salmonella* Group B, norovirus, and *Giardia* were isolated from ill persons. Molecular sub-typing of *C. jejuni* found the pattern of clinical isolates to differ from the pattern of *C. jejuni* isolated from water. This investigation was unable to genetically match a pathogen isolated from an environmental sample with a clinical isolate collected from an ill individual. Considering the number and variety of pathogens and indicators of fecal contamination identified in South Bass Island water samples, this lack of a genetic match should not be taken as evidence that groundwater is not linked to the illnesses (Baumann 1968; Hunter et al 2003; National Research Council 2004; Percival et al. 2004).

Recommendations

Recommendation 1. All housing units and commercial establishments on the island should be served by a public sewage collection and disposal systems and a public water supply system. Extending public water supply lines without provision of public sewer system could result in higher water use and an increase in the volume of wastewater generated per household and business. Extending water supply lines to most of the island could result in additional residential and commercial development. This growth may increase water use and wastewater production on the island. If such development took place without adequate sewage disposal system expansion, contamination of the aquifer could actually increase. In addition, increased water use would require expansion of the existing public water treatment facility.

Recommendation 2. The septage disposal site should be closed and septage be disposed of at the sewage treatment facility or off the island at a site and methods approved of by local and state health and environmental authorities. An assessment should be made to determine if the septage disposal site is contributing to the contamination of the aquifer. If pathogens are present on the ground surface, in the soil, or in the subsurface at this location, action should be implemented to remove this contamination source.

Recommendation 3. Residents should not consume groundwater unless the source has a demonstrated history of negative bacteriological results. All Island groundwater should be treated before consumption. The Pennsylvania Department of Environmental Protection document listed in the reference section of this report provides treatment guidelines (Pennsylvania Department of Environmental Protection 2003).

Recommendation 4. For all groundwater supplies on South Bass Island, local and state environmental and health authorities should determine the influence of surface water on groundwater. Inform those that plan to use groundwater that may be under the influence of surface water of precautions and actions needed to ensure safe drinking water. Surface water treatment methods and procedures may need to be implemented when regulated systems use groundwater under the influence of surface water.

Recommendation 5. Local and state environmental and health authorities should develop a sewage management plan for South Bass Island. The severe soil and geologic limitations for conventional soil-based on-site wastewater disposal systems on South Bass Island may preclude the continued use of these types of systems (Ohio Department of Health 2005). Continued use of existing on-site wastewater disposal systems will likely result in persistent contamination of groundwater supplies and present a serious risk to public health. A moratorium on the construction of new on-site wastewater treatment and disposal systems should be imposed until a sewage management plan is developed and implemented.

Recommendation 6. Repair and alteration of existing on-site systems or the permitting of any new construction on the island would require extensively engineered alternative systems to overcome soil depth and permeability issues. These systems would likely need to be elevated, pressure-dosed alternative wastewater systems such as mounds. However, mound-type systems are often costly and require much more maintenance than conventional systems. They also have a high probability of failure when used in high water use or "shock-loading" situations such as those that typically occur in the summer months for business establishments located on South Bass Island. Increased monitoring of existing package treatment plants during high use periods should be part of the sewage management plan.

Recommendation 7. Another possible alternative to on-site wastewater disposal would be the development of one or more centralized wastewater treatment system (package plant) with surface water discharge. Given the extreme fluctuation in island population during the summer months, treatment facilities would need to be designed to accommodate maximum wastewater loading during peak wastewater discharge periods. These systems are often costly and must comply with the NPDES provisions of the Clean Water Act. Extensive maintenance and monitoring would be required, along with the hiring of certified operators to manage and maintain the systems. The greatest advantage to using surface water discharge as the primary method of wastewater disposal is that it reduces the threat of further groundwater contamination from on-site wastewater disposal. This threat is not entirely eliminated, however, because of the characteristics of karst environments. Any discharge that reaches *losing* or *disappearing* streams *(a* stream reach in which the water table adjacent to the stream is lower than the water surface in the stream, causing infiltration from the stream channel, recharging the groundwater aquifer and decreasing the stream flow) that feed groundwater could then contaminate the aquifer.

Recommendation 8. Local and state environmental and health authorities should develop and implement a public information effort to inform business owners and residents using groundwater wells of the potential exposure and health risks. Provide information on protective measures and options available to reduce exposure to contaminated drinking water.

Recommendation 9. Local and state environmental and health authorities should identify all private and business auxiliary wells to ensure that no additional cross connections exist within the distribution system.

Recommendation 10. To ensure that all cross connections have been removed, a tracer test using an inert substance should be considered. The inert tracer would be added to the auxiliary well. Drinking water within the home or business would then be analyzed for presence of the tracer.

Recommendation 11. Local and state environmental and health authorities should identify and properly close abandoned wells and all improperly developed dug wells. Place a moratorium on new well installation until appropriate well development guidelines can be written for South Bass Island.

Recommendation 12. Local and state environmental and health authorities should assess water supplies and wastewater treatment facilities located on other islands with karst geology to determine if similar groundwater contamination issues exist.

This Trip Report summarizes the field component of our EIP-AID investigation. Because of the preliminary nature of this investigation, future correspondence, MMWR articles, or other published reports might present results interpretation, and recommendations that are different from those contained in this document.

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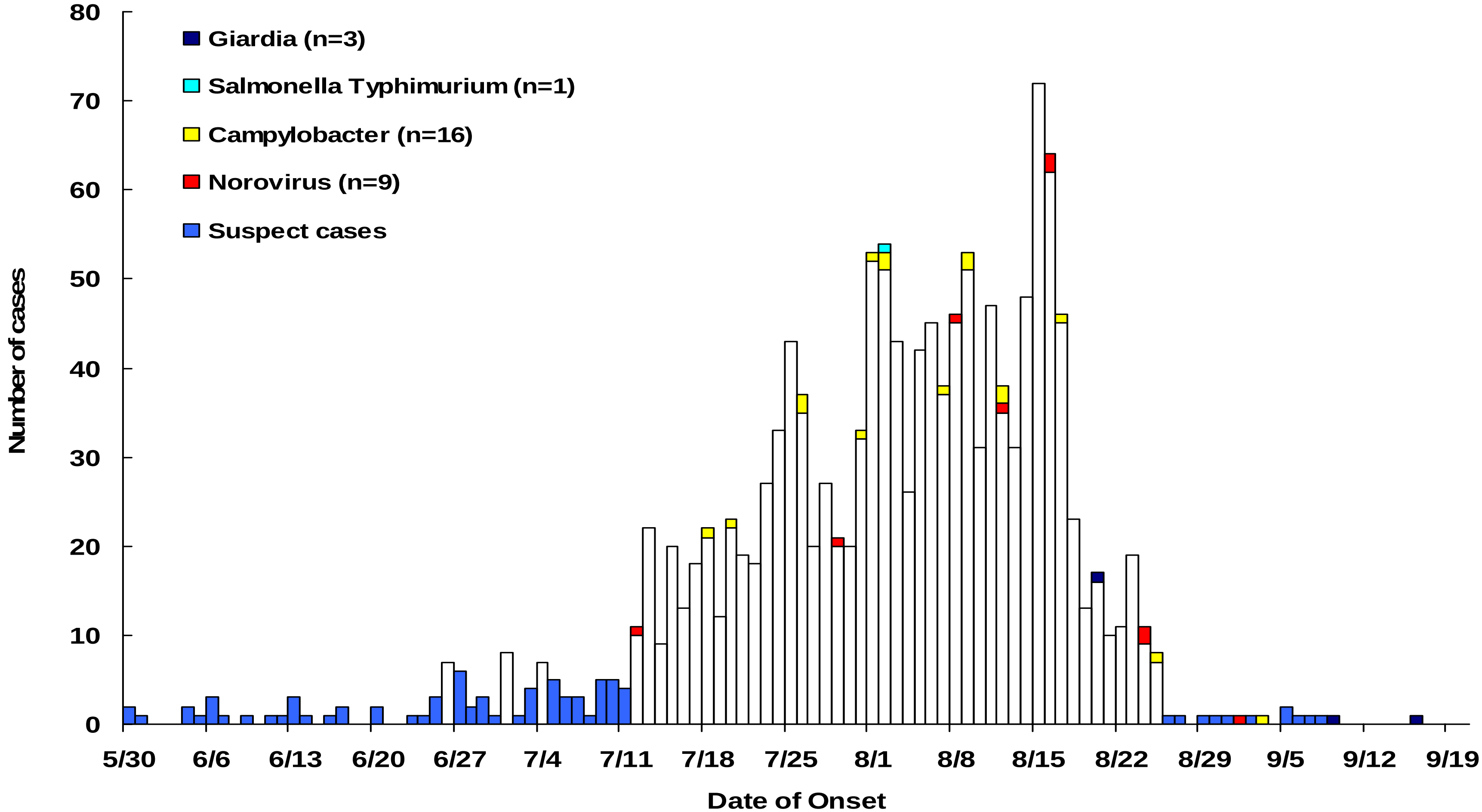
ATTACHMENTS

Environmental Health Assessment for Epi-Aid 2004-076: Outbreak of Gastroenteritis with Multiple Etiologies among Resort Visitors and Residents—Ohio, 2004



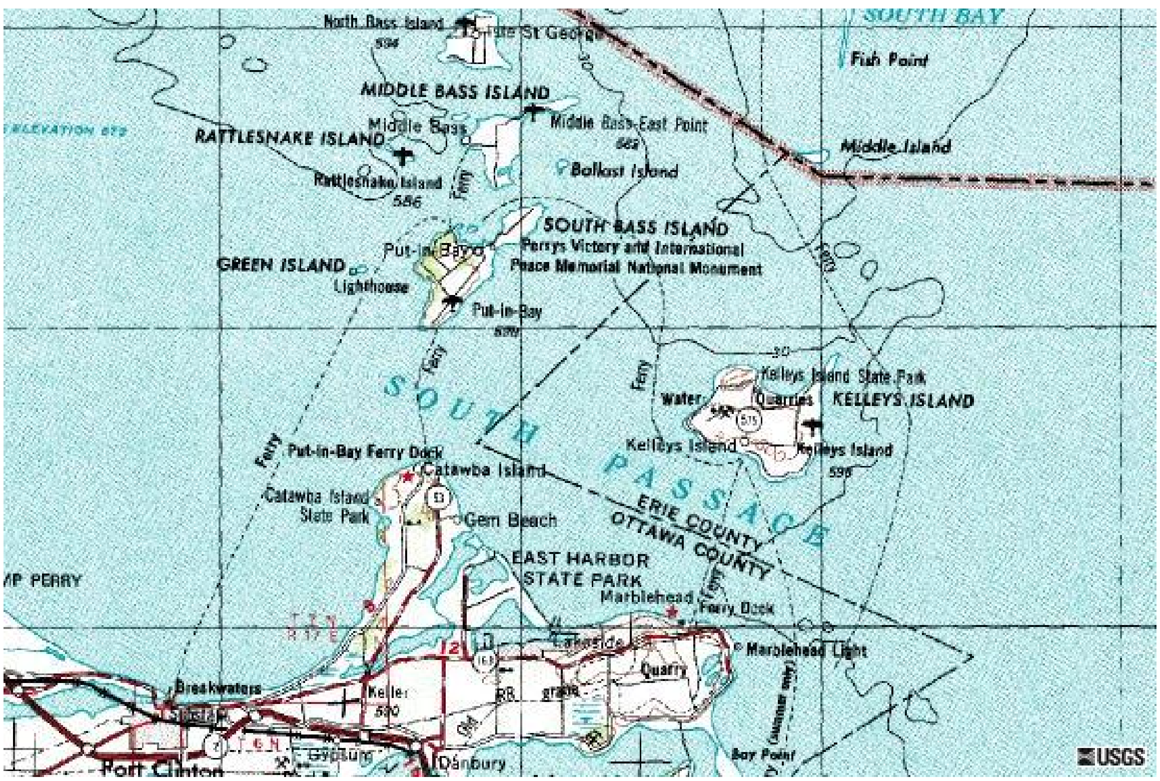
ATTACHMENT 1. Cases of gastroenteritis by date of onset and etiology, South Bass Island, Ohio, May 30–September 12, 2004 (N = 1,450)

ATTACHMENT 2. INFORMATION ON SOUTH BASS ISLAND, OHIO

South Bass Island (Longitude: –82.84970; Latitude: 41.6021), in Ottawa County, Ohio, is located approximately 50 miles east of Toledo and 72 miles west of Cleveland, Ohio. South Bass Island, Middle Bass Island, and North Bass Island are collectively referred to as the Bass Islands of Ohio. South Bass Island is the most developed of the three islands. The village of Put-in-Bay is located on South Bass Island. Middle Bass Island is situated between South and North Bass Islands. North Bass Island is the farthest island from the Ohio mainland and the closest to the Canadian boarder (Figure 1).

The city of Port Clinton (population 11,000), the capitol of Ottawa County, Ohio, is the nearest mainland city to South Bass Island. South Bass Island is accessible by watercraft and air transportation. Two ferry lines serve South Bass Island, one carries only passengers and operates between Port Clinton and Put-in-Bay (12 mile trip), the other carries passengers and vehicles and operates between Catawba Island and the southern point of South Bass Island (3 mile trip). Ferry service is not available during the winter months, though air service is available year-round. When Lake Erie freezes, local residents also travel over the ice to get to and from South Bass Island and the mainland.

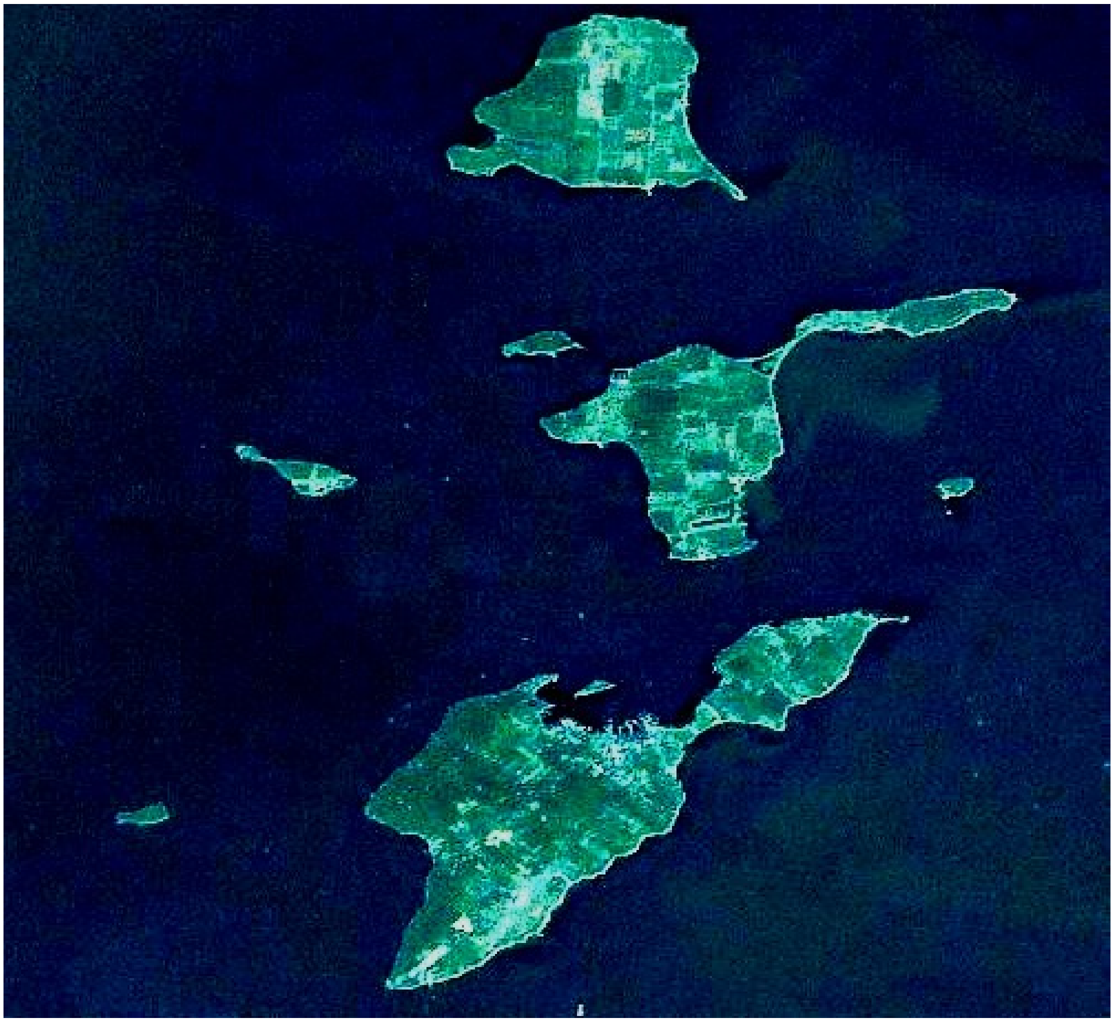
Figure 1. Bass Islands, Lake Erie, Ohio



Source: United States Geological Survey; Put-in-Bay Topographic Map; http://www.terraserver.com

South Bass Island is 570.5 feet above sea level and covers an area of 1,382 acres. The island is 3.5 miles long by 1.5 miles wide; it is 5 miles from the international border with Canada (Figures 2 & 3). The island has an average annual temperature of 50.6°F with the annual average precipitation being among the lowest in the state at 29.05 inches.

Figure 2. Aerial Photograph, Bass Islands, Lake Erie, Ohio



Source: http://www.terraserver.com

South Bass Island, a popular vacation destination from April through October, attracts visitors from Ohio, neighboring states, and Canada. Island activities include fishing, boating, swimming, golfing, camping, bird watching, and exploring caves and the unique geology of South Bass Island. Vineyards and a winery are located on South Bass Island. These and the many other South Bass Island activities and special events bring an estimated 15,000 visitors to the island each week of the tourist season. Visitor information for South Bass Island lists 21 tourist and recreational attractions, 25 restaurants and taverns, 14 shopping venues, 11 providers of transportation services, 11 bed and breakfasts, 15 short-term rental homes, 11 hotels, and 2 campgrounds.

Services on South Bass Island include a bank, six boat docking and marina facilities, two churches, a fuel distributor, two grocery stores, a hardware store, laundry, police, fire, and emergency medical services, post office, library, and a school.

The island's public service infrastructure includes the Put-in-Bay public water system and wastewater treatment facility operated and managed by the municipality. Portions of the island not served by public water and sewer use groundwater wells and on-site wastewater treatment and disposal systems.

The 1990 U.S. Census reports 679 drilled wells and 27 dug wells in use in Put-in Bay Township and 191 connections to the public water system. The census reports 114 connections to the public sewer system and 749 septic tanks or cesspools in the township. The 1990 U.S. Census for the Village of Put-in-Bay reports 110 connections to the public water system and 82 housing units served by a drilled well. The census reports 61 connections to the public sewer system and 127 septic tanks or cesspools in use in the village.

The 1990 census figures are used here because well and septic system data were not collected in the more recent 2000 census.

Septage from island septic tanks is land-applied near the center of the island. Solid waste generated on the island is collected for disposal on the mainland.

The Put-in-Bay Township/South Bass Island 2000 U.S. Census reports the following:

- Population: 763
- Median age of residents: 45.1 years
- Total housing units: 1,264
- Occupied housing units: 355 (28%)
- Vacant housing units: 909 (72%)
  (851 [67%] of the vacant housing units are seasonal, recreational, occasional use units)
- Homeowner vacancy rate: 3%
- Rental vacancy rate: 29%
- Average household size of owner-occupied units: 2.25
- Average household size of renter-occupied units: 1.76

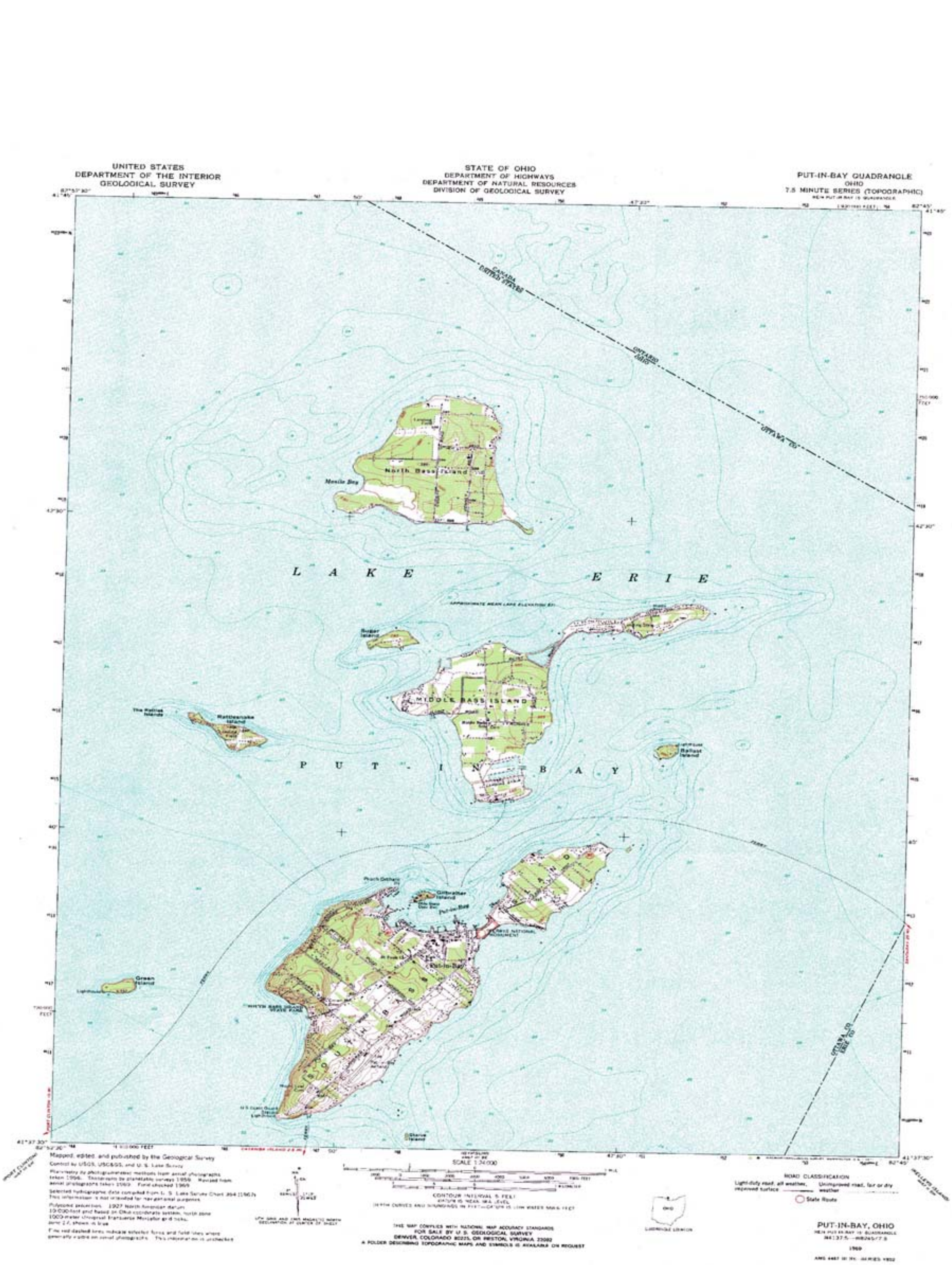


Figure 3. Topographic Map of Bass Islands, Lake Erie, Ohio

Source: United States Geological Survey, Put-in-Bay Topographic Map at: http://www.terraserver.com

ATTACHMENT 3.

Aerial photograph identifying 11 NCEH water sample collection locations, South Bass Island, Ohio, August 30–September 2, 2004.

Photograph Source: National Oceanic and Atmospheric Administration at: http://mfproducts.nos.noaa.gov/images/photos/5wn21675.gif

Information Source: NCEH Ultrafiltration Sampling Records, South Bass Island, August 30–September 2, 2004.

Sample Locations

- Sample #01 – August 30, 2004—Village of Put-in-Bay Water Treatment Plant
- Sample #02 – August 30, 2004—Perry's Monument, National Park Service, Maintenance Building at 17 Park Avenue
- Sample #03 – August 30, 2004—Saunders Cottages, North Well at 1495 Catawba
- Sample #04 – August 31, 2004—Perry's Cave, 979 Catawba
- Sample #05 – August 31, 2004—Joe's Bar and Grill (Press House), 1400 Catawba
- Sample #06 – August 31, 2004—Irving's Put-in-Bay Deli, 2110 Langram
- Sample #07 – September 1, 2004—Heineman's Winery, 978 Catawba
- Sample #08 – September 1, 2004—1282 Catawba
- Sample #09 – September 1, 2004—1210 Catawba
- Sample #10 – September 2, 2004—1391 Put-in-Bay Road
- Sample #11 – September 2, 2004—1030 Put-in-Bay Road

Ultrafiltration Sample Collection Field Notes
South Bass Island, Ohio, August 30–September 2, 2004

Sample #01 – August 30, 2004—Village of Put-in-Bay Water Treatment Plant: Centrally located on the eastern shore of South Bass Island, the water treatment plant is designed for daily operation at 0.216 million gallons per day (MGD) and a maximum production of 0.288 (MGD). Water for the plant is drawn from Lake Erie. The plant has five treatment chambers, each with a maximum loading capacity of 50 gallons per minute (gpm). Treated water is chlorinated and pumped to a 200,000 gallon elevated storage tank. The water then flows into the distribution system serving the Village of Put-in-Bay on the north side of the island. The distribution system connects to 104 commercial meters and 95 residential water meters.

Sample #02 – August 30, 2004—Perry's Monument, National Park Service, Maintenance Building at 17 Park Avenue: The National Park Service site is one of the most distant locations of the community water distribution system. The sample was taken at the maintenance building breakroom sink. Because the National Park Service site was connected to the Put-in-Bay Village water distribution system, no property environment assessment was needed. A free chlorine residual was measured at 0.41 parts per million (ppm).

Sample #03 – August 30, 2004—Saunders Cottages, North Well at 1495 Catawba: The Saunders Cottages are small cottages located on the west side of the island near the shore line. The north well supplies water to approximately six cottages in this area. No septic tanks were used. Wastewater is treated by a small aeration package plant located north of the cottages. A chlorinator was installed on the north well but, was turned off several hours before sampling. The sample was collected from a tap upstream from the chlorinator. The free chlorine residual was measured at 0.04 ppm.

Sample #04 – August 31, 2004—Perry's Cave, 979 Catawba: Perry's Cave is a tourist attraction for an underground cavern. It is located inland, across the road from the Heineman Winery. The property has a miniature golf course, gift shop, a gold panning sluice, and a butterfly house. The water supply for the business is obtained from underground creek in the cave, located directly under the gift shop. The property was equipped with a septic tank located northwest of the gift shop and cavern. The water system was flushed for approximately 40 minutes before sampling. Free chlorine testing of the water supply was frequently made while the system was being flushed. The free chlorine residual was measured at 0.02 ppm. The water was not chlorinated.

Sample #05 – August 31, 2004—Joe's Bar and Grill (Press House), 1400 Catawba: Joe's Bar & Grill is a restaurant and bar located at the corner of Catawba and Meechen Roads, opposite a cemetery. The property also had two dormitory type housing units. The well was located at the southeast corner of the metal building, located behind or south of the bar. An old stone-lined septic leach tank was recently replaced with three 1,500 gallon sewage holding tanks. The septic leach tank that was removed measured 20 feet long, 6 feet wide, and 6 feet deep. It was a stone-lined "tank" with no lateral lines. The owner was ordered to abandon this system and replace it with the storage tanks. The well was run approximately 2 hours before sampling. The well was equipped with a chlorinator, but it was not working during our visit. No chlorine residual was detected.

Sample #06 – August 31, 2004—Irving's Put-in-Bay Deli, 2110 Langram: The deli and convenience store was located on the south end of the island near the shore and next to the ferry dock. An employee dormitory was located on the property, but was supplied by another well. The well for the deli was located on the northeast side of the property near the driveway to the ferry loading area. The sewage was pumped from the property through a lift station to a small package treatment plant on the north side of Langram Road. The well was run approximately 4 hours before sampling. It had reportedly been chlorinated several days prior. The chlorine residual was detected at 0.01 ppm.

Sample #07 – September 1, 2004—Heineman's Winery, 978 Catawba: The property is a local winery with a gift shop and restaurant and bar. Located north of the winery was a single-story house. The well casing was located in a pit, under a metal plate of the sidewalk leading to the restaurant and bar. Because the casing is located below the ground surface, it is also prone to being flooded and had reportedly flooded as recently as August 16, 2004. Two septic tanks served the house, a 250-gallon tank and a 1,000-gallon tank. The septic tanks were located on the west side of the house and were being pumped during our visit of September 1, 2004. The drainfield pipes had been capped August 19, 2004, and tanks were being pumped on an as-needed basis. Two 1,000-gallon tanks serving the restaurant and bar, located on the southwest side of the winery, were also capped on August 17, 2004, and are also pumped on an as-needed basis. The well was equipped with a chlorinator and was turned off several hours before sampling. Water was taken from a tap upstream from the chlorinator. The well ran a minimum of 4 hours before sample collection. No chlorine residual was detected.

Sample #08 – September 1, 2004—1282 Catawba: The residence was a single-family home located adjacent, north and west of a septage disposal site. The residence well was located at the southwest corner of the property and was located approximately 72 feet from the septic tank and 50 feet from the drainfield. The well was not equipped with a chlorinator. Water was run at three sinks in the home for 1.5 hours while water the sample was being taken. No chlorine residual was detected.

Sample #09 – September 1, 2004—1210 Catawba: The residence was a single-family home surrounded on all but the west side of the septage disposal site. The well was located in the back yard, approximately 54 ft from the septic tank. Water was run for approximately 2.5 hours before sampling. The free chlorine residual was detected at 0.02 ppm.

Sample #10 – September 2, 2004—1391 Put-in-Bay Road: The residence was a single-family home with a museum located approximately 100 feet northwest of the home. The museum belonged to the homeowner. The property was located west of septage disposal site. The well was located on the northwest side of the home. A septic tank was located behind the home and a gray water disposal area was located between the home and the museum. The well was not chlorinated and had not been disinfected recently. Water was run for approximately 30 minutes before sampling. Chlorine residual was detected at 0.02 ppm.

Sample #11 – September 2, 2004—1030 Put-in-Bay Road: The residence was a single-family home located northeast of the septage disposal site. The well was located next to the home, on the south side. The septic tank was located behind the home, to the east. The well was not chlorinated and according to the owners had not been disinfected this year. Chlorine residual was detected at 0.01 ppm.

Wastewater Sample – August 30, 2004—Village of Put-in-Bay Wastewater Treatment Plant: A 250-mL sample of raw wastewater was collected from the wastewater treatment plant. The bottle was capped and labeled as “wastewater.” The 250-mL bottle was double-bagged and sealed with tape and immediately stored on ice. The ice-packed wastewater sample was delivered to the Centers for Disease Control and Prevention (Atlanta, Georgia) on August 31, 2004, for testing.

ATTACHMENT 4

Environmental Sampling Conducted in the Investigation of a Suspected Waterborne Outbreak, South Bass Island, Ohio, August–September 2004

Analytical Results from the Water and Environmental Projects Laboratories of the Division of Parasitic Diseases, Centers for Disease Control and Prevention (CDC) National Center for Infectious Diseases

Water and Wastewater Sampling Performed by CDC National Center for Environmental Health (NCEH) Field Team

Between August 30 and September 2, 2004, a field team from CDC/NCEH collected 1 wastewater sample and 11 water samples from South Bass Island, Ohio. The wastewater sample was an approximately 250-mL sample of raw sewage collected at the Put-in-Bay wastewater treatment facility. This sample was collected to determine if wastewater generated and treated on the island would give an indication of what pathogens were circulating in the human population working, residing on and visiting South Bass Island. Of the 11 water samples collected, 1 was from the raw water intake of the Put-in-Bay water treatment plant (Sample 1), 1 was the finished water from the water treatment plant (Sample 2), 5 were groundwater from transient, noncommunity (TNC) public water supplies (Samples 3–7), and 4 were from private wells (Samples 8–11). Table 1 provides information on the sampling sites and conditions.

All water samples were concentrated using an ultrafiltration technique developed at CDC. Briefly, 50 L of water was collected and concentrated in the field using an ultrafilter module having a molecular weight cut-off of ~20,000 daltons, a pore size small enough to enable the ultrafilter to effectively retain all solid particles (including microbes) in the water samples. If a free chlorine residual was detected in water to be sampled, sodium thiosulfate was added to deactivate the disinfecting properties of chlorine. A negatively charged chemical, sodium polyphosphate, was used to pretreat all ultrafilters, and was also added to each water sample. This was done to reduce potential sticking of microbes to the surfaces of the ultrafilter system. All samples were concentrated to 200–250 mL (termed "retentate"). All samples and ultrafilters were stored and shipped refrigerated to CDC for further processing and analysis.

Water and Wastewater Analysis at CDC

At CDC, the ultrafilters were backflushed with a surfactant solution to remove residual microbes from the filter surfaces. This backflush water was added to the corresponding retentate and the combined sample centrifuged to concentrate bacteria and parasites in the samples. The supernatant from the centrifugation process was treated using chemical precipitation to concentrate viral pathogens in the samples. In general, coliphages were assayed directly from retentate, not from the precipitation-concentrated samples.

The “bacteria and parasite pellets” were resuspended and aliquoted for analysis by several different labs at CDC:

- the *Campylobacter* reference laboratory (Collette C. Fitzgerald),
- the water and environmental projects laboratory (Vincent Hill),
- the waterborne parasite laboratory (Michael J. Arrowood), and
- the parasite genotyping laboratory (Lihua X. Xiao).

This report presents the results of the water and environmental projects and waterborne parasite laboratories. The parasite genotype analyses are not yet completed. The results of the *Campylobacter* reference laboratory are summarized in a separate report.

In addition to analyzing the samples for pathogenic microbes, CDC also analyzed samples for microbial indicators of fecal contamination. The microbial indicators studied are enteric microbes that do not tend to multiply in the environment. Thus, their presence in environmental samples can be considered an indication that the sampled water have been contaminated to some degree by fecal matter (which could either be from humans or animals). Fecal coliforms and *Escherichia coli* are well-established bacterial indicators of fecal contamination. *Clostridium perfringens* are spore-forming bacteria that are highly persistent under environmental conditions (especially versus viruses and non-spore-forming bacteria). The presence of *C. perfringens* is a conservative indicator of fecal contamination, as the presence of the spores can reflect historical fecal contamination (months to many years). Somatic and F-specific coliphages are viruses that infect coliform bacteria. Thus, they are normal gastrointestinal microfloras that are fairly specific indicators of fecal contamination. Research has suggested that coliphages are superior to coliform bacteria as indicators for the presence of viral pathogens.

Summary of Results:

The wastewater analyses indicate that the wastewater sampled contained concentrations of microbial indicators that are typical of untreated private wastewater (Table 2). All positive microbial detections for this sample and the water samples are highlighted in Table 2 by shaded cells. *Cryptosporidium* spp. and adenoviruses were also detected in the wastewater sample, using real-time (TaqMan) polymerase chain reaction (PCR). The aliquot of the wastewater sample assayed by immunomagnetic separation (IMS) and an immunofluorescent antibody (IFA) kit (a standard microscopy technique for these parasites) was found to be positive for *Giardia* spp. Fluorescent structures that were considered to possibly be *Cryptosporidium* were also observed in the wastewater sample, but these particles did not have the typical size expected for *Cryptosporidium* and thus are not reported here as being positively identified as *Cryptosporidium*. Additional analysis of the wastewater sample by IMS-IFA microscopy and nested PCR genotyping report negative results for *Cryptosporidium* and positive results for *Giardia*.

We found water collected at the raw water intake at the Put-in-Bay water treatment facility to be positive for four microbial indicators, as well as for *Cryptosporidium* spp. (by both PCR and microscopy). In the finished water collected from the Put-in-Bay distribution system, we did detect the DNA of *Cryptosporidium*. It is not known whether this detection reflects the presence of viable or infectious *Cryptosporidium*. PCR results are a very conservative indicator of fecal contamination and health risks, as the PCR test can detect DNA that is not associated with viable or infectious pathogens. However, this data can be considered as warranting additional investigation of the effectiveness of equipment and procedures used at the Put-in-Bay water treatment facility.

Of the five TNC wells sampled, three were found to contain fecal coliforms and *E. coli.* Two of these wells (Samples 5 and 7) contained relatively high concentrations of *E. coli*. In addition, three of the five wells contained either somatic coliphages or F-specific coliphages. One of the wells contained *C. perfringens*. Only one of the wells (Sample 3) did not contain a culturable microbial indicator of fecal contamination. However, Sample 3, as well as three other samples, was found to be positive for *Salmonella* by PCR (using two different PCR assays). We were not able to culture *Salmonella* from any of these samples. This is not necessarily surprising, as the PCR technique can detect nonviable and viable-but-not-culturable (VBNC) microbes. In addition to *Salmonella*, three other pathogens were detected in the TNC wells using PCR: *Cryptosporidium* (in three of five wells), adenovirus (in one of five wells), and enterovirus (in one of five wells). While the IMS/IFA analyses for *Cryptosporidium* are negative, the analyses did detect a single *Giardia* cyst in Sample 5. This is a significant finding, as the presence of this parasite (which is fairly large, with a diameter of 12 μm) indicates that enteric parasites, as well as smaller pathogens (i.e., bacteria and viruses) can enter and be transported through the subsurface aquifer at South Bass Island. Additional analysis of these samples included genotyping by nested PCR. *Cryptosporidium hominis* was detected in Sample 5 by Nested PCR Genotyping.

Samples from the four private wells (Samples 8–11) were received at CDC on September 3, 2004, and stored in a refrigerator until September 7 before further processing and analysis. While significant microbial die-off likely occurred during this extending holding period, two of the four samples were still found to be positive for *E. coli.* Beyond fecal coliforms and *E. coli* none of the private well samples were found to be positive for any other microbial analyte. All *Salmonella* cultures for the private samples are negative.

Table 1. NCEH Field Team Water Sample Collection Log,
South Bass Island, Ohio, Investigation

Sample Collection Dates: August 30 to September 2, 2004

Sample Number	Location	Chlorine Residual	Date Collected	Date Sent to CDC	Date Received
1	Raw Water: Community Water Treatment Facility	None Detected (ND)	Mon-30 Aug	31 Aug	31Aug
Notes:	Community Water System				
2	Finished Water: Community Water Distribution System	0.41 ppm	Mon-30 Aug	31 Aug	31 Aug
Notes:	Perry's Monument, National Park Service Maintenance Building, 17 Park Ave.				
3	Saunders Cottages: North Well	0.04 ppm	Mon-30 Aug	31 Aug	31 Aug
Notes:	Transient Noncommunity Water Supply System				
4	Perry's Cave	0.02 ppm	Tue-31 Aug	31 Aug	1 Sept
Notes:	Transient Noncommunity Water Supply System				
5	Joe's Bar	ND	Tue-31 Aug	31Aug	1 Sept
Notes:	Transient Noncommunity Water Supply System				
6	Irving's Put-in-Bay Deli	0.01 ppm	Tue-31 Aug	1 Sept	2 Sept
Notes:	Transient Noncommunity Water Supply System				
7	Heineman Winery	ND	Tue-31 Aug	1 Sept	2 Sept
Notes:	Transient Noncommunity Water Supply System				
8	1282 Catawba Residence	ND	Wed-1 Sept	2 Sept	3 Sept
Notes:	Private Goundwater Well				
9	1210 Catawba Residence	0.02 ppm	Wed-1 Sept	2 Sept	3 Sept
Notes:	Private Goundwater Well				
10	1391 Put-in-Bay Residence	0.02 ppm	Thurs-2 Sept	2 Sept	3 Sept
Notes:	Private Goundwater Well				
11	1030 Puti-in-Bay Residence	0.01 ppm	Thurs-2 Sept	2 Sept	3 Sept
Notes:	Private Goundwater Well				

Table 2. Water and Wastewater Analytical Results from CDC/NCID/DPD Water and Environmental Projects Laboratories

Sample ID	Fecal Coliforms	*E. coli*	Somatic Colipahges	F-specific Coliphages	*C. perfringens*	*Salmonella* PCR	*Salmonella* Culture
Wastewater	45,000 cfu/mL	ND	ND	680,000 pfu/mL	130 cfu/mL	Negative	< 0.02 MPN/mL
Sample 1	3 cfu/L	2 cfu/L	0.2 pfu/L	< 0.1 pfu/mL	10 cfu/L	Negative	< 0.1 MPN/L
Sample 2	< 0.4 cfu/L	< 0.4 cfu/L	< 0.1 pfu/L	< 0.1 pfu/mL	< 0.8 cfu/L	Negative	< 0.1 MPN/L
Sample 3	< 0.4 cfu/L	< 0.4 cfu/L	< 0.1 pfu/L	< 0.1 pfu/mL	< 0.8 cfu/L	Positive	< 0.1 MPN/L
Sample 4	< 0.8 cfu/L	< 0.8 cfu/L	7 pfu/L	< 0.9 pfu/mL	< 0.8 cfu/L	Positive	< 0.1 MPN/L
Sample 5	714 cfu/L	420 cfu/L	92 pfu/L	< 0.9 pfu/mL	11 cfu/L	Negative	< 0.1 MPN/L
Sample 6	21 cfu/L	20 cfu/L	< 1 pfu/L	< 0.9 pfu/mL	< 0.8 cfu/L	Positive	< 0.1 MPN/L
Sample 7	135 cfu/L	118 cfu/L	3 pfu/L	8 pfu/mL	< 0.8 cfu/L	Positive	< 0.1 MPN/L
Sample 8	1 cfu/L [a]	1 cfu/L [a]	ND	ND	< 0.8 cfu/L	Negative	< 0.1 MPN/L
Sample 9	2 cfu/L [a]	1 cfu/L [a]	ND	ND	< 0.8 cfu/L	Negative	< 0.1 MPN/L
Sample 10	< 0.6 cfu/L [a]	< 0.6 cfu/L [a]	ND	ND	< 0.8 cfu/L	Negative	< 0.1 MPN/L
Sample 11	< 0.6 cfu/L [a]	< 0.6 cfu/L [a]	ND	ND	< 0.8 cfu/L	Negative	< 0.1 MPN/L

Notes:

(a) Estimated concentration. Samples were held 5 days until culture analysis; "<" = microbe was not detected in sample at detection limit noted; cfu = colony forming units; pfu = plaque forming units; MPN = most probable number (5-tube); ND = not done.

Table 2. CDC/CCID/DPD Analytical Results (Cont.)

Sample ID	*Cryptosporidium* PCR	*Cryptosporidium* IMS-IFA	*Giardia* IMS-IFA	GI Norovirus	GII Norovirus	Adenovirus PCR	Enterovirus PCR
Wastewater	Positive	"Negative" [(b)]	151 cysts/100 mL	Negative	Negative	Positive	Negative
Sample 1	Positive	1.5 oocsysts/10 L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 2	Positive	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 3	Positive	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 4	Negative	< 2 oocysts/10L	< 2 cysts/10 L	Negative	Negative	Negative	Negative
Sample 5	Negative	< 2 oocysts/10L	1.8 cysts/10 L	Negative	Negative	Positive	Positive
Sample 6	Positive	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 7	Positive	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 8	Negative	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 9	Negative	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 10	Negative	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative
Sample 11	Negative	< 1.5 oocysts/10L	< 1.5 cysts/10 L	Negative	Negative	Negative	Negative

(b) Approxmately 10 "crypto-like" structures were observed in a volume equal to 14% of the sample. While these structures fluoresced brightly and were close to the expected appearance, they were slightly too large (6 to 6.5 µm rather than the typical 4.5 to 5 µm oocysts of *C. parvum* and *C. hominis*). These structures may have been artifacts or possibly *C. andersonii* (or equivalent). The assay was not sufficiently clear to confidently identify these structures as being *Cryptosporidium* spp.

Cryptosporidium and *Giardia* analysis results
South Bass Island, Ohio

Sample Location/ID	Real-time PCR*	IMS-IFA Microscopy†	Genotyping Nested PCR‡
Wastewater	*Cryptosporidium* PCR Positive	*Cryptosporidium* Negative *Giardia* Positive (151cysts/100mL)	*Cryptosporidium* Negative *Giardia* Positive
Sample 1. Raw Water CWS	*Cryptosporidium* PCR Positive	*Cryptosporidium* IMS-IFA 1.5 oocsysts/10 L *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 2. Finished Water PWS	*Cryptosporidium* PCR Positive	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 3. Saunders Cottages, North Well	*Cryptosporidium* PCR Positive	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 4. Perry's Cave	*Cryptosporidium* Negative	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 5. Joes Bar	*Cryptosporidium* Negative	*Cryptosporidium* Negative *Giardia* Positive (1.8cysts/10 L)	*Cryptosporidium hominis* Positive *Giardia* Negative
Sample 6. Irivings Put-In-Bay Deli	*Cryptosporidium* PCR Positive	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 7. Heineman Winery	*Cryptosporidium* PCR Positive	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 8. 1282 Catawba	*Cryptosporidium* Negative	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 9. 1210 Catawba	*Cryptosporidium* Negative	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 10. 1391 Put-in-Bay	*Cryptosporidium* Negative	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative
Sample 11. 1030 Put-in-Bay	*Cryptosporidium* Negative	*Cryptosporidium* Negative *Giardia* Negative	*Cryptosporidium* Negative *Giardia* Negative

Reporting sources: Centers for Disease Control, National Center for Infectious Diseases, Parasitic Diseases Laboratory, Atlanta, GA; *water and environmental projects laboratory (Vincent Hill), †waterborne parasite laboratory (Michael J. Arrowood), and ‡parasite genotyping laboratory (Lihua X. Xiao).

Campylobacter results on samples collected by NCEH on South Bass Island August 30–September 2, 2004.

We received 12 samples from Vincent Hill's laboratory at CDC. The sample numbers 1–11 correspond to the sample numbers used in the attachment sent by John Sarisky on 9/27/04 entitled "Released NCID NCEH Environmental Lab Results 09.24.04." The remaining sample was a wastewater sample. The results are summarized in the table below:

Only one sample, "5" was culture positive for a campylobacter-like organism. This has now been confirmed biochemically and by 16S sequencing as an *Arcobacter butzleri* strain . No sample was culture positive for *Campylobacter sp.*

Sample Number	**Culture**	**Lightcycler PCR* Genus / *C. jejuni***	**Seminested PCR***
1	NBG	Neg	Neg
2	NBG	Neg	Neg
3	NBG	Neg	Neg
4	NBG	Neg	Neg
5	*Arcobacter butzleri*	+/+	+
6	NBG	Neg	Neg
7	NBG	Neg	+
8	NBG	Neg	Neg
9	NBG	Neg	Neg
10	NBG	Neg	Neg
11	NBG	Neg	Neg
wastewater sample	NBG	Neg	Neg

NBG – no bacterial growth
Neg – negative
+ - positive
* The PCR procedure described by Waage *et al* 1999 was followed (Waage AS. Vardund T. Lund V. Kapperud G. 1999). Detection of small numbers of *Campylobacter jejuni* and *Campylobacter coli* cells in environmental water, sewage, and food samples by a semi-nested PCR assay. Appl. Environ. Microbiol. 65:1636-43, 1999. This assay is specific for *C. jejuni* and *C. coli* and is based on the intergenic region between two flagelling genes (*fla*A and *fla*B).

From: Xiao, Lihua X.
Sent: Friday, November 05, 2004 3:23 PM
To: Hill, Vincent; Sarisky, John
Cc: Beach, Michael J.
Subject: Results for Put-in-Bay Investigation--

John and Vince,

Below are Crypto and Giardia genotyping results for water samples from the South Bass outbreak. We also analyzed the samples for microsporidia (Enterocytozoon bieneusi). Quite a few of the samples produced bands of the expected size, several (2 for each sample) of which were sequenced. However, we were unable to read out the sequences due to underlying signals (a sign for mixed genotypes) in the electropherogram.

I apologize for taking so long to get the results back to you, but I am short handed and there were five outbreaks under investigation. It took us quite some efforts to genotype and subtypethe Giardia in the wastewater samples, as we had to cut the PCR products out of gel several times for sequencing because of the presence of other bands.

Lihua

South Bass Ohio (Put-in-Bay) Drinking Water Cryptosporidium Outbreak Sept/04					
Crypto		**Giardia**			
9158	Put-in-Bay Water Outbreak Ohio	Sample No. 1-Surface water	Neg	Negative	
9159	Put-in-Bay Water Outbreak Ohio	Sample No. 2 -Treated water	Neg	Negative	
9160	Put-in-Bay Water Outbreak Ohio	Sample No. 3- Saunders North Well	Neg	Negative	
9161	Put-in-Bay Water Outbreak Ohio	Sample No. 4 water	Neg	Negative	
9162	Put-in-Bay Water Outbreak Ohio	Sample No. 5 water	C. hominis	Negative	
9163	Put-in-Bay Water Outbreak Ohio	wastewater	Neg	Assemblage A	WA1 subtype
9164	Put-in-Bay Water Outbreak Ohio	Sample No. 6 water	Neg	Negative	
9165	Put-in-Bay Water Outbreak Ohio	Sample No.7 water	Neg	Negative	
9166	Put-in-Bay Water Outbreak Ohio	Sample No.8 water	Neg	Negative	
9167	Put-in-Bay Water Outbreak Ohio	Sample No.9 water	Neg	Negative	
9168	Put-in-Bay Water Outbreak Ohio	Sample No.10 water	Neg	Negative	
9169	Put-in-Bay Water Outbreak Ohio	Sample No.11 water	Neg	Negative	

ATTACHMENT 5

Bass Island Sample Form

Sample # ______ Date: ___/____/2004 Chlorinated: YES □ No □

Location: (Include diagram on back, show location of well, septic tank, drainfield, house and other features)____
____

Weather Conditions: ____

Free Chlorine Test: ____PPM Nitrate Test: _____PPM

Home Water Pumping Started:____:____AM □ PM □

Filter Apparatus Setup Start: ____:____ AM □ PM □
Filter Apparatus Setup Complete: ____:____ AM □ PM □

10 ml Sodium Thiosulfate/ 20 L Water YES □ No □ NA □
2 Tubes (15/ml) Sodium Polyphosphate/ 20 L Water YES □ No □
Sample Start Time: ___:___ AM □ PM □
Permeate Rate _____ ml/min

10 ml Sodium Thiosulfate/ 20 L Water YES □ No □ NA □
2 Tubes (15/ml) Sodium Polyphosphate/ 20 L Water YES □ No □
Sample Start Time: ___:___ AM □ PM □
Permeate Rate _____ ml/min

5 ml Sodium Thiosulfate/ 10 L Water YES □ No □ NA □
1 Tubes (15/ml) Sodium Polyphosphate/ 10 L Water YES □ No □
Sample Start Time: ___:___ AM □ PM □
Permeate Rate _____ ml/min

Ultrafilter in Ziplock Bag at ___:___ AM □ PM □ (on ice)
(color connectors/adapters included)

250 ml polycarbonate bottle capped with retenate at ___:___ AM □ PM □ (on ice)
(labeled the same as Ultrafilter)

Filter Apparatus Takedown Start: ____:____ AM □ PM □
Filter Apparatus Takedown Complete: ____:____ AM □ PM □

Iced down and shipped overnight to: CDC c/o Vince Hill, 4770 Buford Highway, MS F-36, Building 109, Room 1318, Atlanta, GA 30341

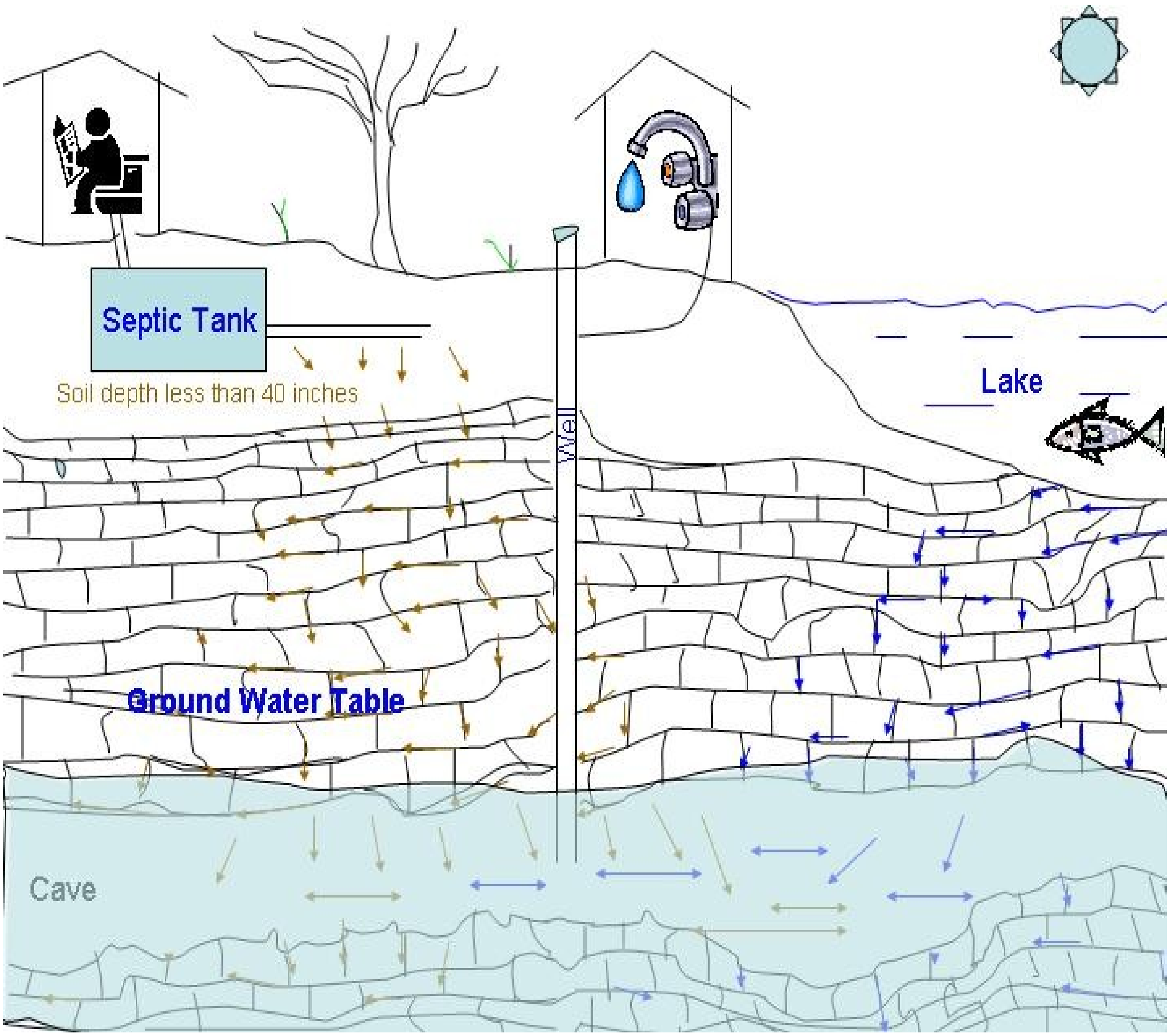
ATTACHMENT 6.
Well Log and Drilling Report – Historical Review 1951–2004
South Bass Island, Ohio

Drilling Company	Total Wells	Wells with Crevices/Caves	Wells with Crevices/Caves below Well Casing	Percent of Wells with Crevices below Casing
Tibboles Well Drilling (1975–1997)	214	6	6	100%
Edgil Collins Well Drilling (1988–1995)	80	0	0	0%
Island Well Drilling (1961–1971)	82	36	20	56%
Oddo & Kimmet Well Drilling (1996–2003)	48	0	0	0%
Water Well Drilling & Supply (1956–1960)	32	1	1	100%
N.O. Manahan (1948–1953)	15	0	0	0%
Robertson’s (1973–1997)	17	0	0	0%
Clear Water Well Drilling (1995)	4	0	0	0%
Dunbar Drilling (1970–1978)	4	0	0	0%
Aicirtap Enterprises Inc… (1979)	3	0	0	0%
L.G. Argutte (1964–1969)	4	2	2	100%
TOTAL	**503**	**45**	**29**	**64%**

Source: South Bass Island well drilling logs, Ohio Department of Natural Resources.

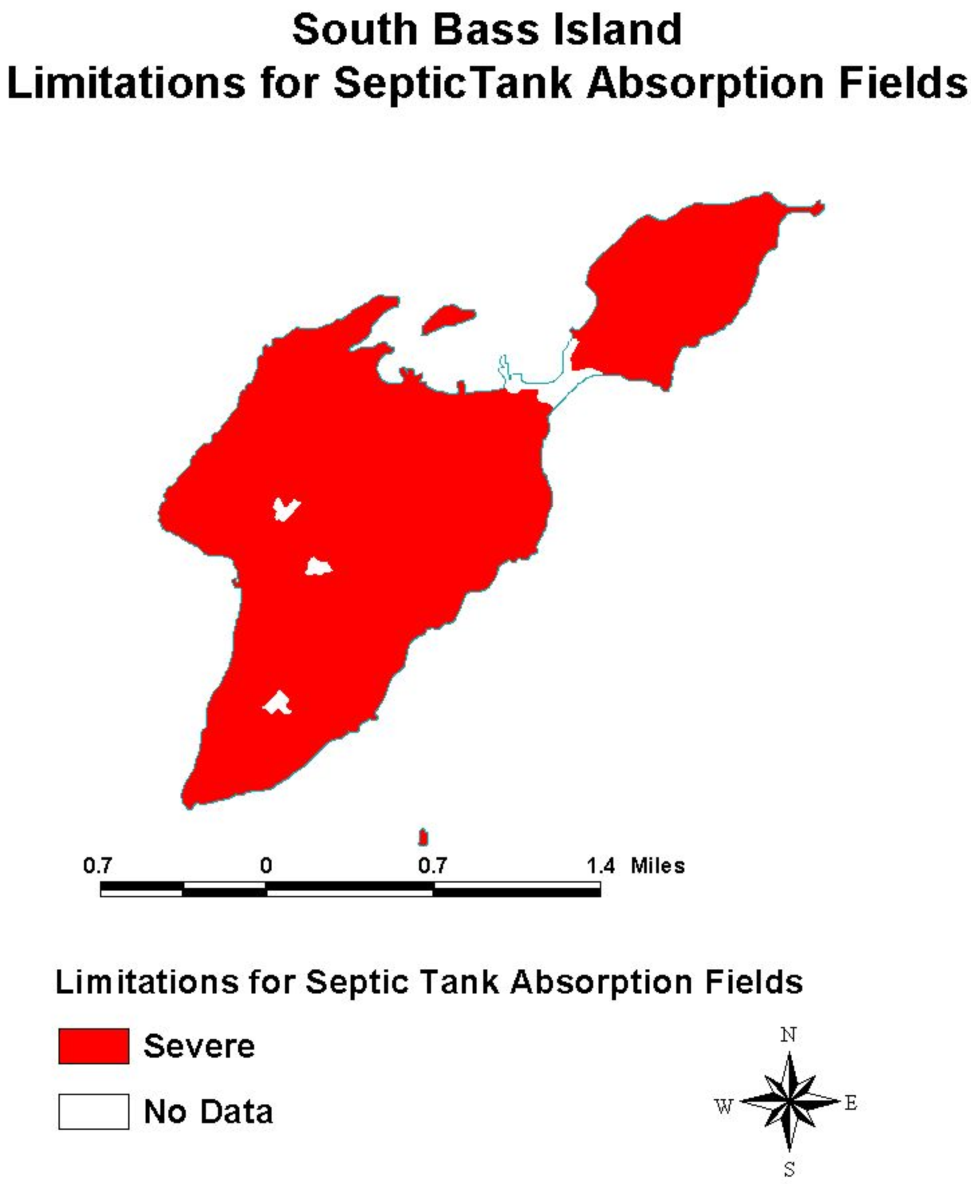
ATTACHMENT 7

Movement of Water in Karst Geology



ATTACHMENT 8

Ottawa County SSURGO Digital Soil Survey
Limitations for Septic Absorption Fields
South Bass Island, Ohio, 1985



Source: Ottawa SSURGO Digital Soil Survey, Division of Soil and Water Conservation, Ohio Department of Natural Resources, Columbus, Ohio, January 2000.

ATTACHMENT 9

Soil Limitations for Wastewater Disposal

All five soil types identified on South Bass Island have limitations for septic tank systems rated as “severe” in the Soil Survey. The following is a list of each soil series located on South Bass Island along with its primary limitations:

Castalia* – This is the predominant soil on South Bass Island. The primary limitations are depth to bedrock and many large stones ranging in size from 10 inches to 4 feet across. Unweathered bedrock (dolomitic limestone) is found at depths from 20 to 40 inches. Vertical fractures in bedrock are 3 to 6 feet apart.

Dunbridge* – The primary limitation is depth to bedrock. Unweathered bedrock is found at depths from 20 to 40 inches in this soil series. Vertical fractures in bedrock are 2 to 4 feet apart.

Milton* – Major limitations include depth to bedrock and slow permeability. Depth to bedrock ranges from 20 to 40 inches.

Nappanee – The primary limitations are slow permeability and soil wetness. The perched seasonal high water table is between depths of 1 to 2 feet in fall, winter, spring, and extended wet periods.

Rawson – Major limitations are soil permeability and wetness. It is also noted that some Rawson soils may have bedrock as shallow as 20 to 40 inches. The perched seasonally high water table is at depths between 30 and 48 inches in winter and spring and other extended wet periods. Soil permeability is rated as slow to very slow in the lower profile of the soil.

Disturbed areas – Areas where soils were not classified include the area around the Perry Monument, which is owned by the National Park Service, and two small areas identified as “pits” where limestone bedrock has been removed for use in construction.

For soils identified with an asterisk (*), the soil survey notes that effluent from sanitary facilities used in these soils may move through fissures in the bedrock and pollute groundwater supplies.

ATTACHMENT 10

ODH/NCEH Groundwater Quality Assessment Procedure

The South Bass Island groundwater assessment included only private residential wells and consisted of a sanitary survey and the collection of a groundwater sample. The island was divided by topographical features into 22 sections. To obtain a statistically valid number of samples, in each of the 22 sections an Ohio Department of Health (ODH) surveyor selected four housing units representing a geographic distribution within the section. If a household resident of a selected unit agreed to participate in the assessment the surveyor collected a water sample and conducted a sanitary survey of the groundwater supply system. Ohio Department of Health surveyors were to visit homes in each of their assigned sections until they enrolled four locations. Collected water samples were stored in insulated containers and returned to the Ottawa County Health Department by 5:00 PM of each of the three sample collection days. Samples were shipped to a certified water quality laboratory for analysis (Benchmark Laboratory and the Ohio Department of Agriculture Laboratory). Samples were analyzed for total coliforms, *E. coli*, *Campylobacter*, *Salmonella*, chloride, and nitrate. Sample collection and sanitary survey information was collected, reviewed, clarified, and corrected when needed, and recorded on the master tracking log.

To facilitate mapping of sampled wells, longitude and latitude coordinates were recorded in the field. The sample collection tracking log and sanitary survey codebook were developed for this activity. A Web-based data entry system and a GIS mapping tool were developed by the ODH and the Centers for Disease Control and Prevention’ s National Center for Environmental Health (NCEH) to assist with analysis of collected data. The NCEH Health Informatics Office developed an additional GIS analysis tool to support data analysis.

The ODH/NCEH groundwater quality assessment collected groundwater samples from 11% (77/679) of the housing units served by a groundwater well on South Bass Island. The protocol called for a sample size of 88 private groundwater wells (4 wells for each of the 22 sections); however, resource and time limitations restricted the number of households visited to 77. Seventy-seven is a valid sample size for this descriptive study.

Data from the sanitary survey and well-logs were entered into a Microsoft Access database. Statistical analysis was performed using SAS version 8.02 and EPI Info version 3.2.2. Geographic information system analysis was performed using Spatial Epidemiology and Emergency Management System (SEEM) version 1.1. Following is the sanitary survey data collection form, water sample collection tracking log and the sanitary survey codebook.

ATTACHMENT 10
Form 1

ODH/NCEH Groundwater Quality Assessment
Sanitary Survey Form
South Bass Island, Ohio
September 2004

South Bass Island - Sanitary Survey

Owner Name____
Address (street number, name)____
GPS Coordinates (NAD 83) ____
Sample collected?_

Water Well Information
Well Currently Used for Drinking Water______

Well Casing (circle one) - Steel PVC Well casing (circle) - Above grade In Pit

Well casing height above grade__________ Well Log Number_____________________

Condition of casing (circle) Good Fair Deteriorated Holes/cracks in casing

Well Cap(circle) - Aluminum 2 Part gasketed Sanitary Seal
Condition of cap____

Type of pump (circle) Jet Deep(2 lines) Jet Shallow Submersible Hand pump

Pitless Adapter______ Well Pit ______(wet or dry) Well House_____________________

Conditions around well (subsidence, slope, rock at surface)____________________________________
____

Comments____
____

HSTS Information

Tank/Risers visible______ Distribution Boxes____ ATU visible______ Discharge ______

Location of Discharge_______________Lake discharge______ Discharge - clear, cloudy, odor (circle)

Elevated leach field or mound______ Chlorinator present and filled?_______
Aeration sytem – motor present?______

Comments on system conditions (surfacing sewage, wet areas, green stripes, etc.

____
____
____

Water Treatment Information

System type (circle one) – Softener Oxidizing Unit(chlorine/iodine) Continuous chlorination
Ultraviolet Carbon Filter Sediment Filter
Other____

Sampling port or bypass present____

Survey completed by:____
Date:____

LAB:

Attachment 10
Form 2

Water Sample Collection Log
Bass Island, Ohio

Lab:

DATE COLLECTED	TIME	NAME	ADDRESS	WELL LOG #	CLOOECTED BY	SECTION

ATTACHMENT 10
Table 1

ODH/NCEH Groundwater Quality Assessment Codebook
South Bass Island, Ohio, September 2004

Variable Name	Variable Type	Variable size	Variable Description	Values or Explanation	Data Source
Well_log	Number	6	Well log number uniquely describes well		Plunket.mdb; Sanitary survey
Last_name	Character	20	Last name of well owner		Sanitary survey; Tracking database
First_name	Character	20	First name of well owner		Sanitary survey; Tracking database
Street_name	Character	25	Street name where well is located		Plunket.mdb; Sanitary survey
Street_number	Character	5	Street number where well is located		Plunket.mdb; Sanitary survey
Well_depth	Number	4	Depth of the well in feet		Plunket.mdb; Sanitary survey
Latitude	Number	9	Latitude of well position		Plunket.mdb; Sanitary survey
Longitude	Number	9	Longitude of well position		Plunket.mdb; Sanitary survey
Sample_date	Date	10	Date sample was taken		Santary survey; Laboratory results
Sample_number	Character	?	Number assigned to lab results for sample		Laboratory results

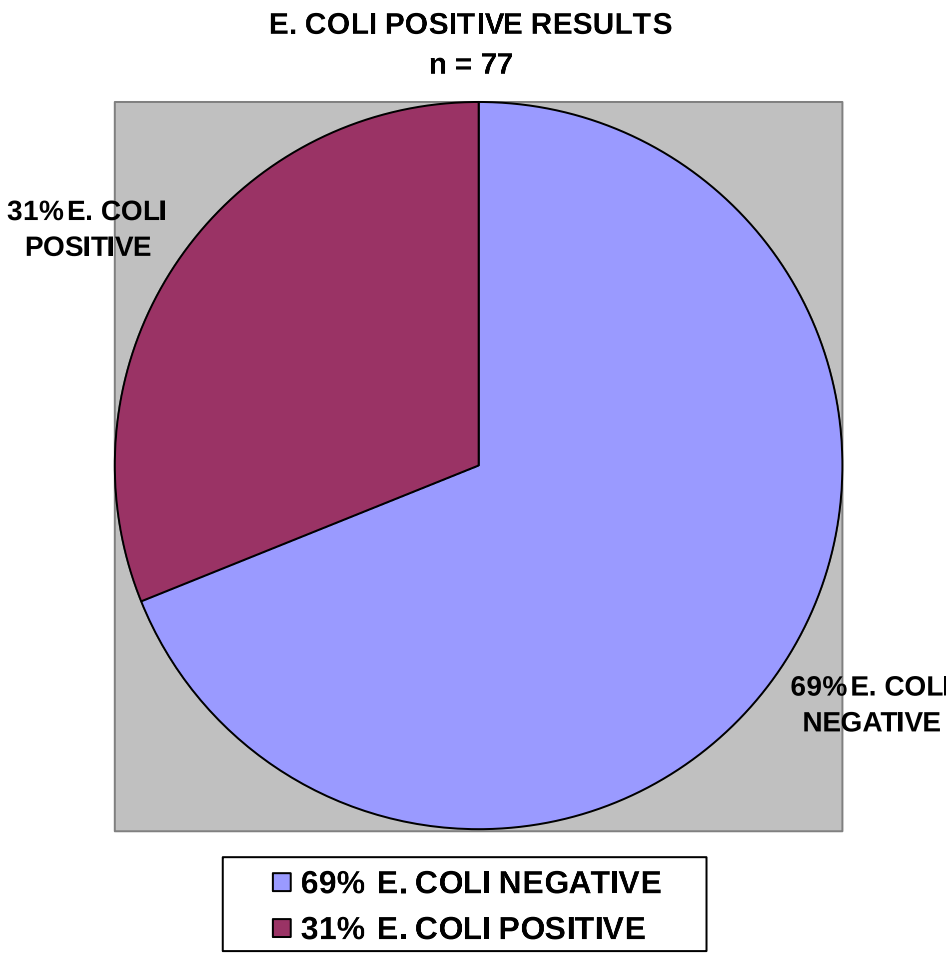
Quadrant	Character	22	Quadrant where sample was drawn	1-22 quadrants	Sanitary survey; Tracking database
Collector	Character	20	Name of Surveyor		Sanitary survey; Tracking database
Lab	Character	30	Name of Laboratory performing analysis	Ohio Department of Agriculture; BenchMark	Tracking database
TC	Number		Laboratory results for Total Coliforms		Laboratory results
EC	Number		Laboratory results for E coli		Laboratory results
Campy	Number		Laboratory results for Camybolacter		Laboratory results
Salmon	Number		Laboratory results for Salmonella		Laboratory results
Nitrate	Number		Laboratory results for Nitrates		Laboratory results
Chloride	Number		Laboratory results for Chlorides		Laboratory results
Casing_mat	Character	8	Material used for well-casing	Steel; PVC; Brick; Concrete	Sanitary survey
Casing_location	Character	16	Location of well-casing	Above grade; In pit; Buried; Cannot determine	Sanitary survey
Casing_height	Number	2	Height of well-casing above grade in inches		Sanitary survey
Casing_cond	YES-no		Does the well-casing havecracks, holes, or gaps		Sanitary survey
Case_diam	Number	4	Diameter of well casing in inches		Well logs

Case_length	Number	5	Length of the well casing in feet		Well logs
Cap	YES-no		Is the well top covered	YES;no	Sanitary survey
Cap_seal	YES-no		Well top provides a sanitary seal	YES;no	Sanitary survey
Pitless	YES-no		Presence of pitless adapter	YES;no	Sanitary survey
Wellhouse	YES-no		Well head in protected wellhouse	YES;no	Sanitary survey
Wellhead	YES-no		Well head located in pit	YES;no	Sanitary survey
wellhead_dry	YES-no		Well head in pit is dry	YES;no	Sanitary survey
Date_comp	Date	10	Date well constuction completed		Well logs
Drawdown	Number	3	Number of feet that water can be drawn down in a well		Well logs
Static_level	Number	3	Depth to water level in feet		Well logs
Well_pres	YES-no		Presence of a properly sealed water well (10ft)	YES;no	Sanitary survey
Slines_pres	YES-no		Presence of sewer lines (10ft)	YES;no	Sanitary survey
Sewage_pres	YES-no		Presence of sewage disposal systems (50ft)	YES;no	Sanitary survey
Water_pres	YES-no		Presence streams, lakes, ponds, and ditches near well source (25ft)	YES;no	Sanitary survey
Manure_pres	YES-no		Presence of manure ponds, piles, or lagoons near well source (50-300ft)	YES;no	Sanitary survey
Landfill_pres	YES-no		Land fills or dump sites present near well source (1000ft)	YES;no	Sanitary survey

Watercoll	YES-no		Surface water collects around well-casing	YES;no	Sanitary survey
Cont_pres	YES-no		Other sources of contamnation present near well source	YES;no	Sanitary survey
Cont_other	Text	250	Explanation of other type of contamination source		Sanitary survey
Sewage_home	YES-no		Home sewage tretment system is designed to discharge effluent to surface	YES;no	Santary survey
Discharge	Character	15	Surface discharge location	Drainage ditch; Storm drain; Lake; Pond; Stream	Sanitary survey
Disch_qual	Character	10	Quality of effluent	Clear; Cloudy; Odor	Sanitary survey
Chlorination	YES-no		Chlorinated effluent	YES;no	Sanitary survey
Oper_chl	YES-no		chlorination system operates as designed	YES;no	Sanitary survey
Aeration	YES-no		Presence of aeration system	YES;no	Sanitary survey
Oper_aer	YES-no		Aeration system functions as designed	YES;no	Sanitary survey
Treat_type	Character	30	Type of water treatment system used	Softener; Oxidizing unit(iodine/chlorine); Carbon Filter; Sediment Filter; Ultraviolet; Continuous chlorination	Sanitary survey
Port	YES-no		Presence of sampling port or bypass	YES;no	Sanitary survey

ATTACHMENT 11
Table 1

***E. coli* Analysis Results**
Groundwater Samples Collected on South Bass Island, Ohio
September 2004



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 11
Table 2

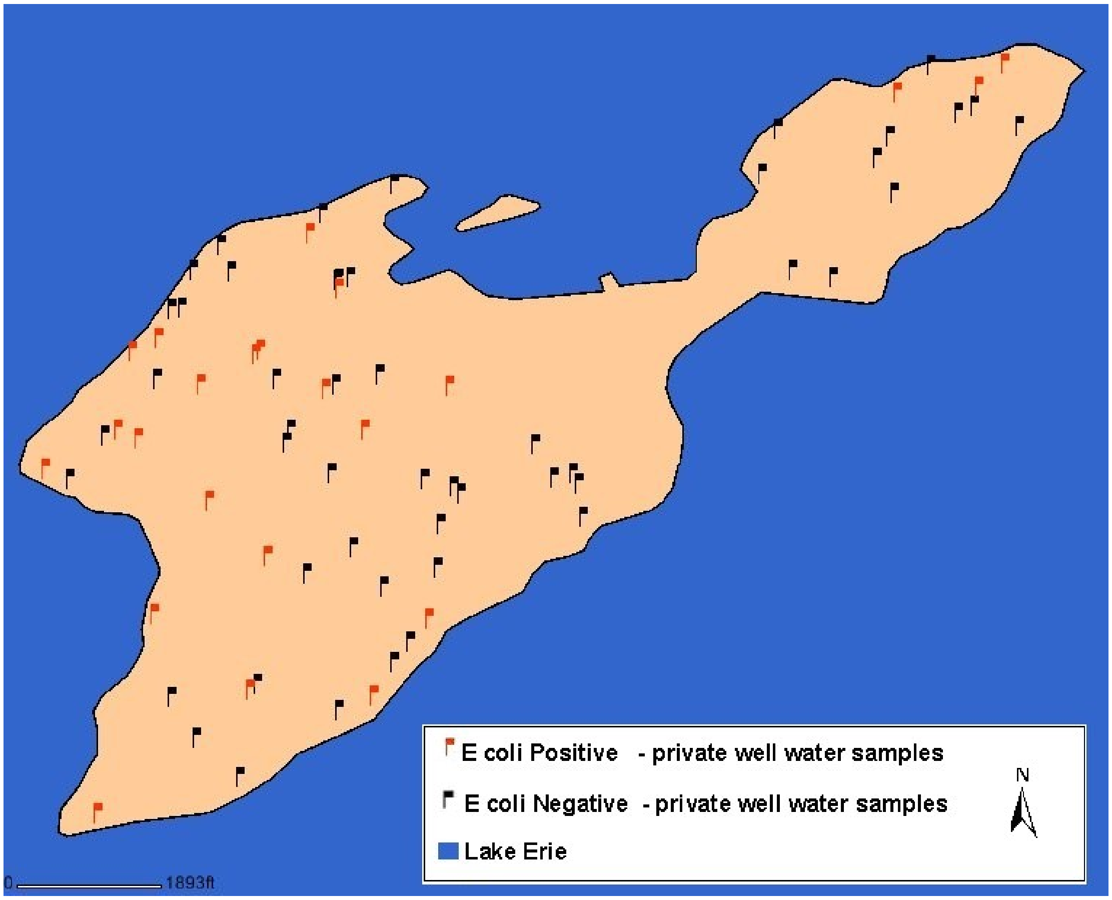
E. coli Analysis Results by Laboratory
Groundwater Samples Collected on South Bass Island, Ohio
September 2004

Lab & Sample Set	Date Collected	Total Samples	Number *E. coli* Positive	Percent Positive
Benchmark 1	Wednesday 09/08/04	16	5	29.4%
ODA 2	Wednesday 09/08/04	6	1	16.7%
Benchmark 3	Thursday 09/09/04	15	6	40.0%
ODA 4	Thursday 09/0904	12	4	30.8%
Benchmark 5	Friday 09/10/04	20	3	15.0%
ODA 6	Friday 09/10/04	8	5	62.5%
Total		77	24	31.2%

Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 11
Table 3

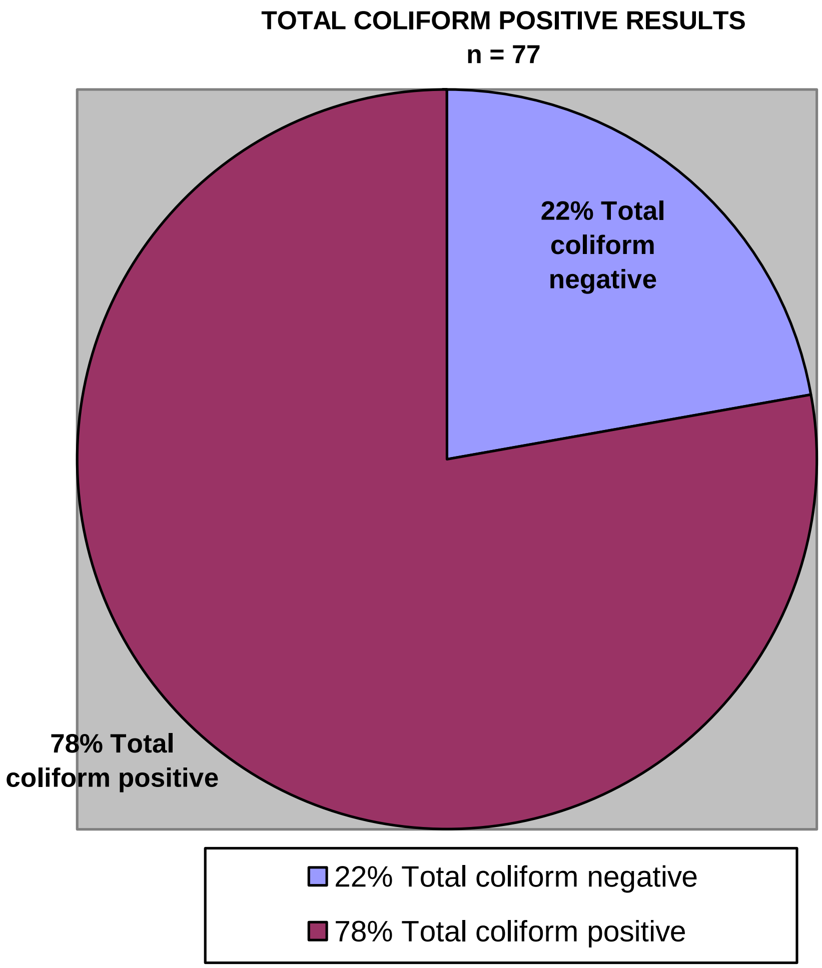
Location of *E. coli* Positive Sample Results
Groundwater Samples Collected on South Bass Island, Ohio
September 2004



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 12
Table 1

Total Coliform Analysis Results
Groundwater Samples Collected on South Bass Island, Ohio
September 2004



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 12
Table 2

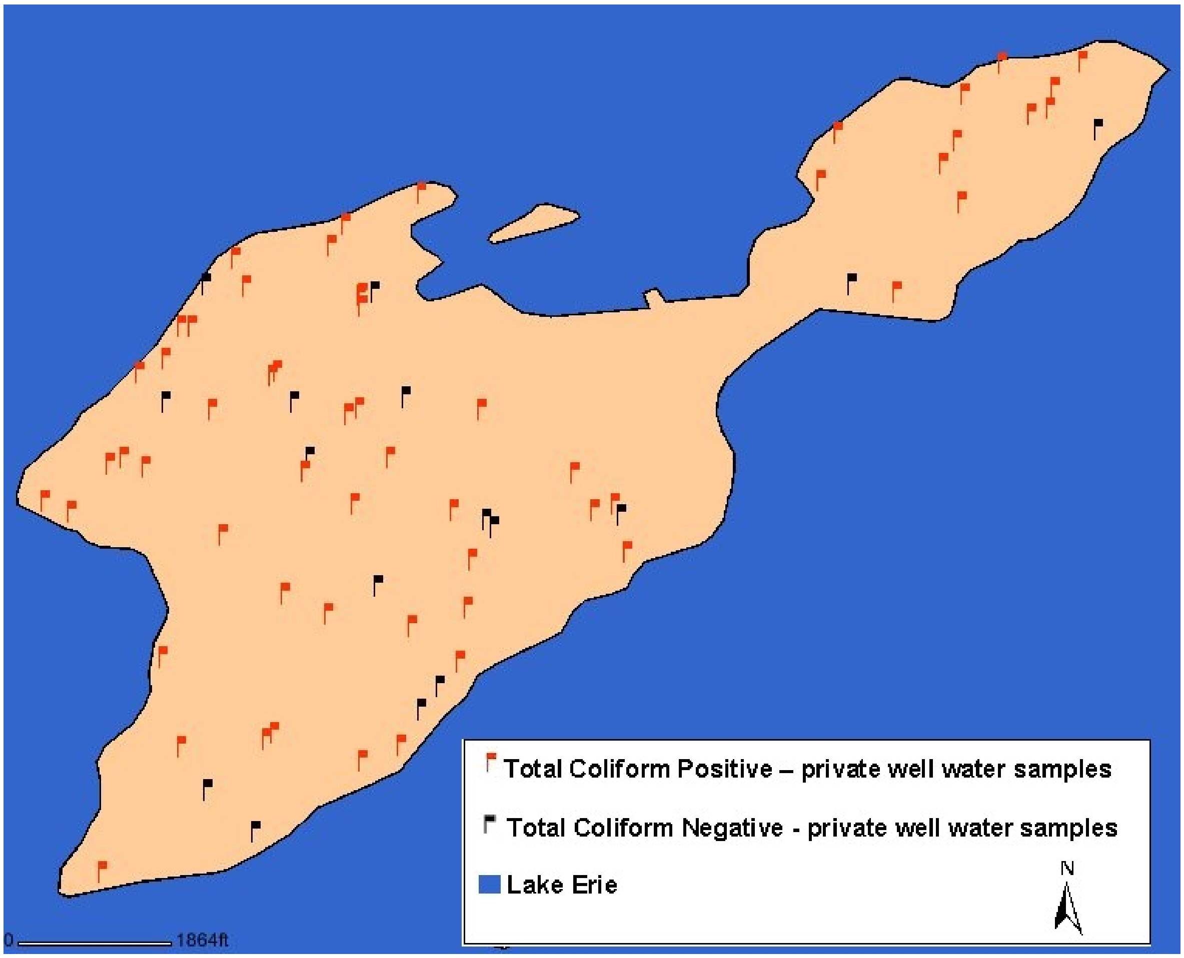
Total Coliform Analysis Results by Laboratory
Groundwater Samples Collected on South Bass Island, Ohio
September 2004

Lab & Sample Set	Date Collected	Total Samples	Total Coliform Positive	Percent Positive
Benchmark 1	Wednesday 09/08/04	16	14	87.5%
ODA 2	Wednesday 09/08/04	06	03	50.0%
Benchmark 3	Thursday 09/09/04	15	12	80.0%
ODA 4	Thursday 09/0904	12	09	75.0%
Benchmark 5	Friday 09/10/04	20	16	80.0%
ODA 6	Friday 09/10/04	08	06	75.0%
		77	60	77.9%

Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 12
Figure 1

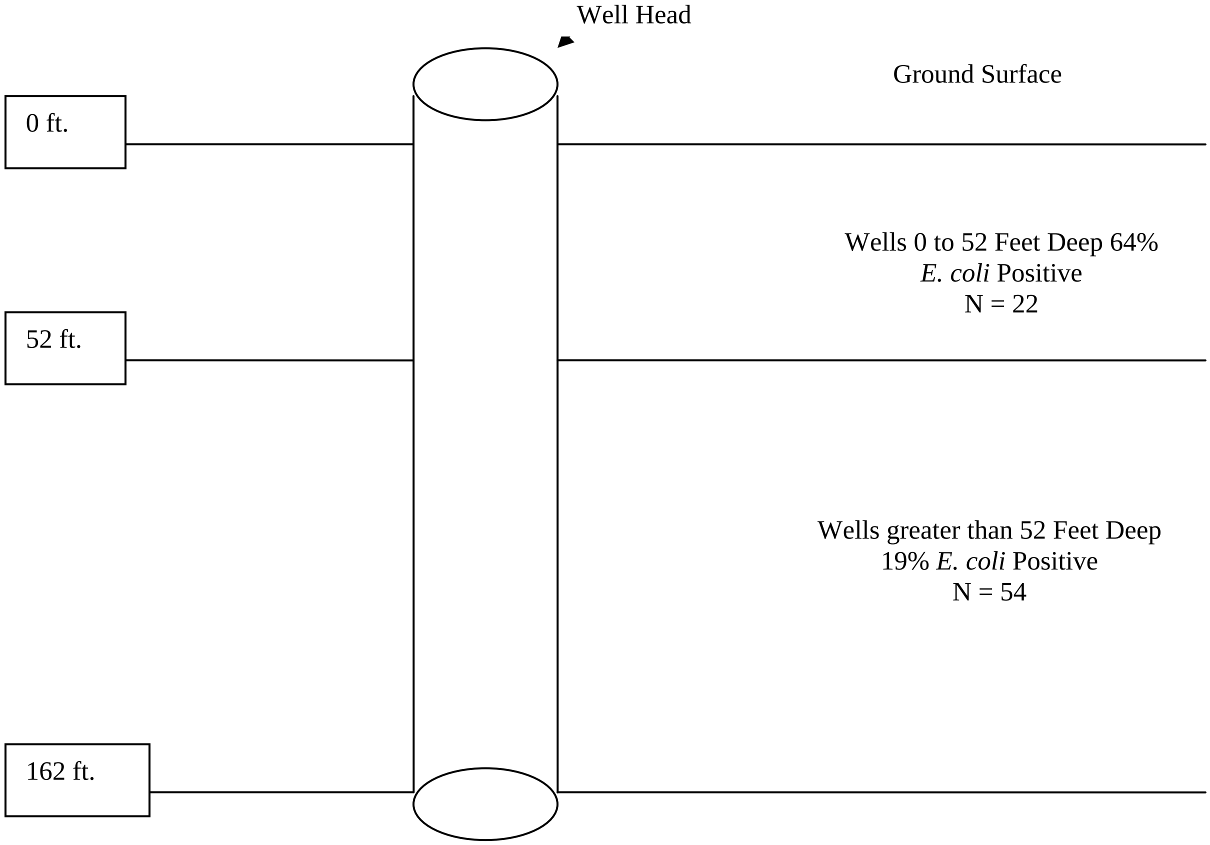
Location of Total Coliform Positive Samples
Groundwater Samples Collected on South Bass Island, Ohio
September 2004



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 13
Figure 1

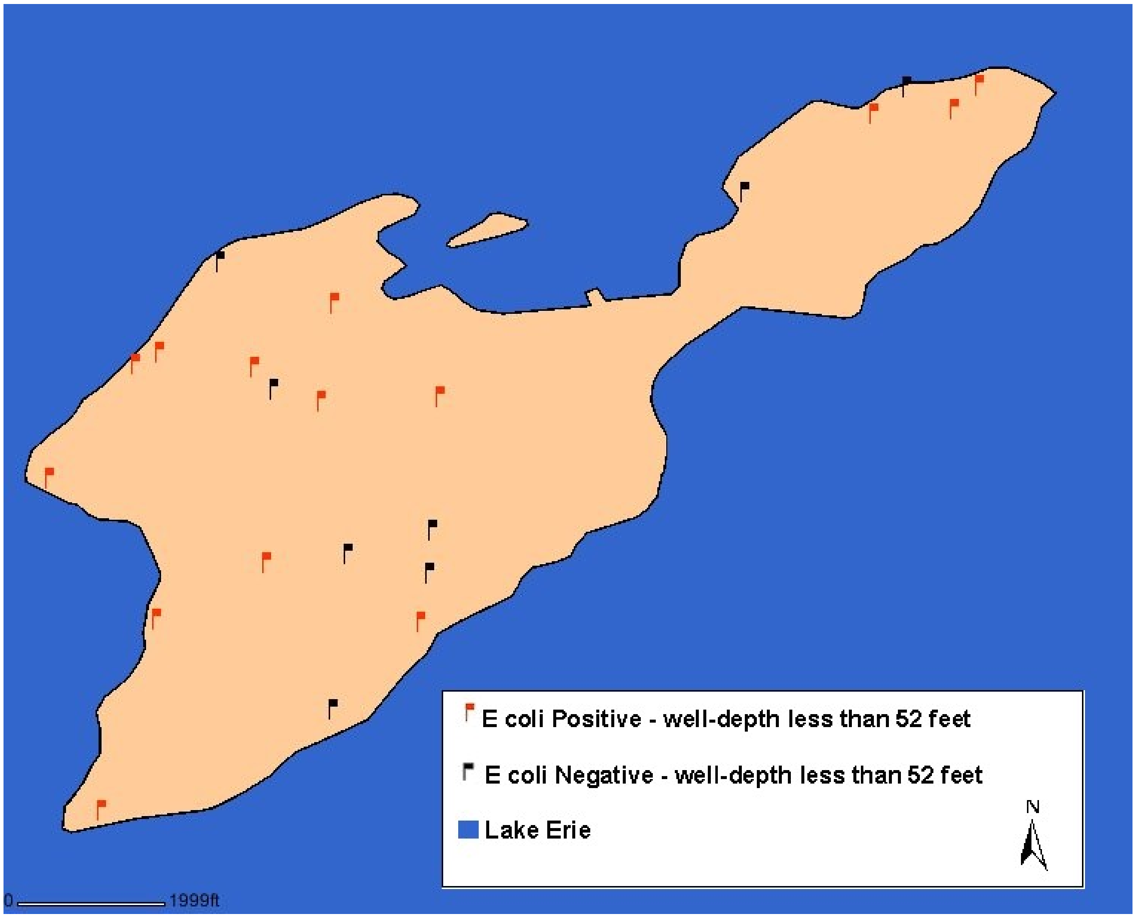
***E. coli* Positive Results by Well Depth**
Groundwater Samples Collected on South Bass Island, Ohio
September 2004



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 13
Figure 2

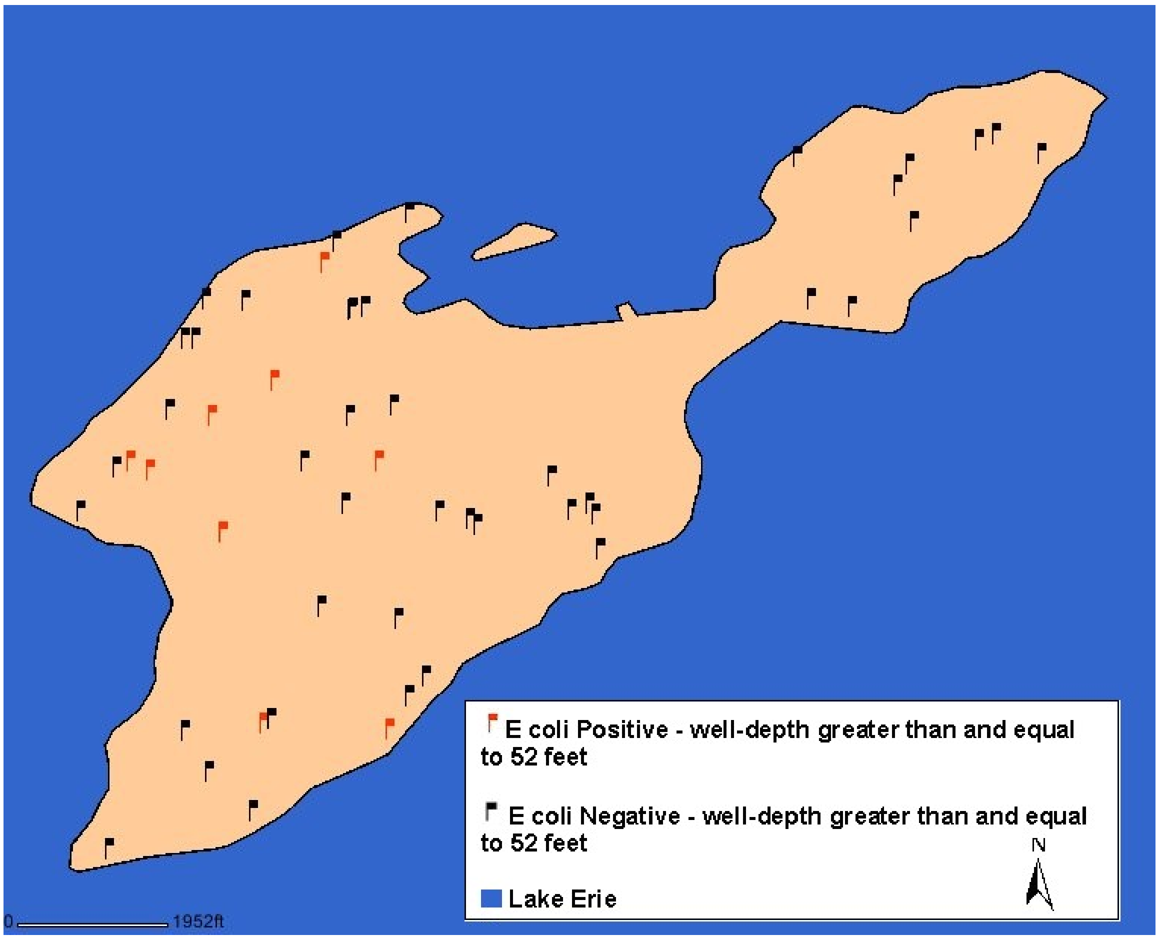
***E. coli* Results Well Depths Less Than 52 Feet**
Groundwater Samples Collected
September 8–10, 2004, South Bass Island, Ohio



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 13
Figure 3

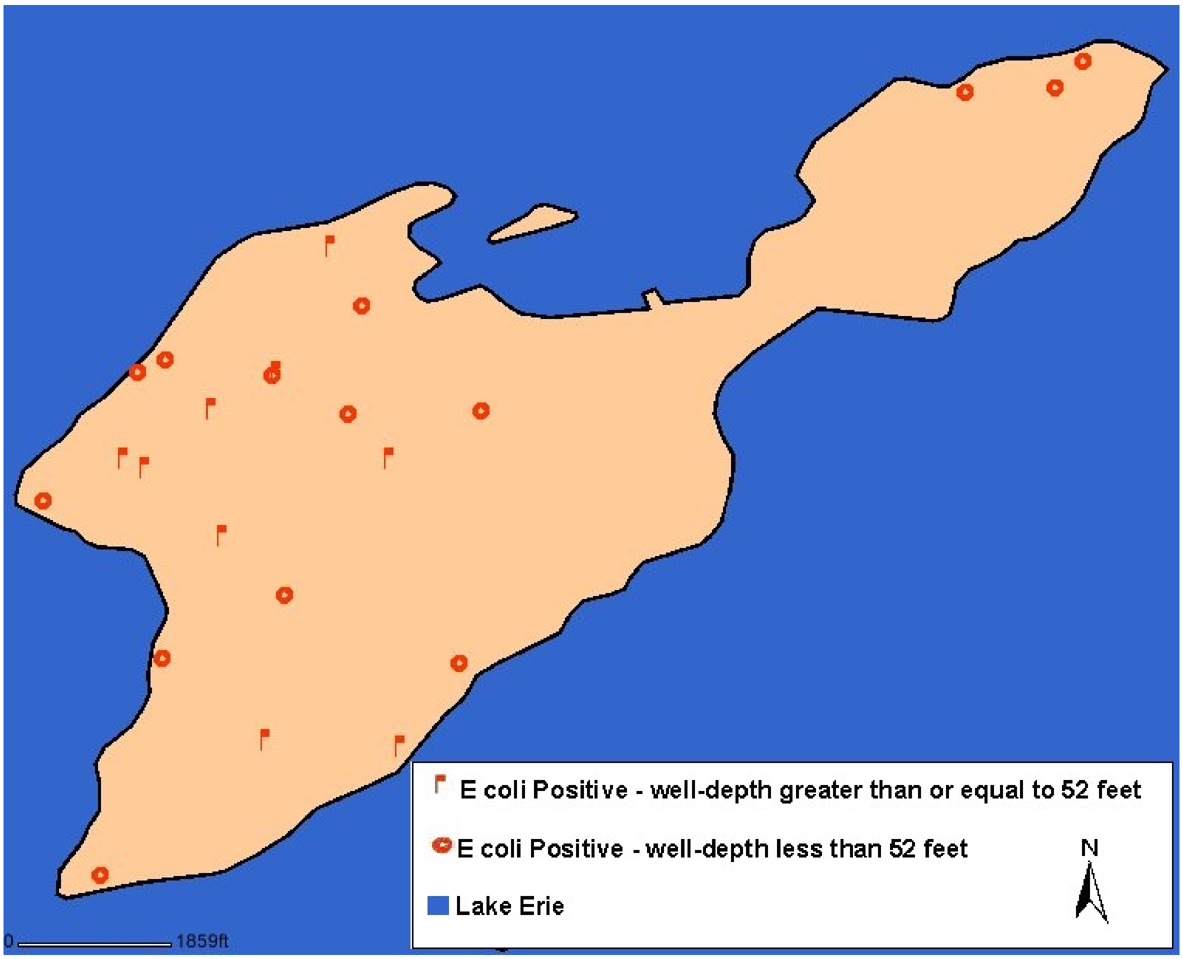
***E. coli* Results Well Depths Greater Than or Equal to 52 Feet**
Groundwater Samples Collected
September 8–10, 2004, South Bass Island, Ohio



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 13
Figure 4

***E. coli* Positive Results by Well Depths**
Groundwater Samples Collected
September 8-10, 2004 South Bass Island, Ohio



Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 14

E. coli Positive Results by Section Location
Groundwater Samples Collected on South Bass Island, Ohio
September 2004

Location	Total Samples	Number *E. coli* Positive	Percent Positive
Shoreline	55	17	30.9%
Interior	22	7	31.8%

Source: Ohio Department of Health (ODH) and Centers for Disease Control and Prevention, National Center for Environmental Health (NCEH), groundwater quality assessment, South Bass Island, Ohio, September 8–10, 2004

ATTACHMENT 15
Table 1

Water Quality Analysis Results
Private Groundwater Wells Sampled by Ottawa County Health Department
South Bass Island, Ohio, August–September 2004

Date Collected	**Number Collected**	**Number & % Total Coliform Positive**	**Number & % *E.coli* Positive**
AUG 23	9	5 (56 %)	2 (22%)
AUG 25	8	4 (50 %)	1 (13%)
AUG 30	23	12 (52 %)	8 (35%)
SEPT 01	6	3 (50 %)	2 (33%)
SEPT 08	18	3 (17%)	6 (40%)
Total (% Pos)	**64**	**27 (42%)**	**19 (30%)**

Source: Ottawa County Health Department, Port Clinton, Ohio, September 10, 2004.

ATTACHMENT 15
Table 2

Water Quality Analysis Results
Total Coliform and *E. coli* Positive Private Groundwater Well Samples
South Bass Island, Ohio, 2001–August 2004

Year	Number of Samples Collected	Number Total Coliform Positive	Percent Total Coliform Positive	Number *E. coli* Positive	Percent *E.coli* Positive
2001	29	18	62%	2	7%
2002	23	9	39%	2	9%
2003	28	14	50%	3	11%
Jan – July 2004	13	10	77%	2	15%
Aug 2004	54	36	67%	14	26%
Total	**147**	**87**	**59%**	**23**	**16%**

Source: Ottawa County Health Department, Port Clinton, Ohio, September 10, 2004.

ATTACHMENT 15
Table 3

Groundwater Quality Analysis Results
All Water Samples Collected, Total Coliform and *E. coli* Results by Agency
South Bass Island, Ohio, August–September 2004

Agency	Total Coliforms				*E. coli*		
	No. Analyzed	No. Positive	Percent +		No. Analyzed	No. Positive	Percent +
OEPA	87	38	44%		48	17	35%
MSU	8	4	50%		8	2	25%
ODA	10	3	33%		10	2	20%
CDC	0	—	—		7	4	57%
ODH	6	4	66.6%		4	2	50%
Total	**111**	**49**	**44%**		**77**	**27**	**35%**

Source: Ottawa County GI Illness—Summer 2004 Sample Results Log, Oct 14, 2004, Ohio Environmental Protection Agency (OEPA), Columbus, Ohio; MSU = Michigan State University, ODA = Ohio Department of Agriculture, CDC = Centers for Disease Control and Prevention, ODH = Ohio Department of Health.

ATTACHMENT 16

South Bass Island and North Central Ohio Precipitation (in inches)

Month	North Central Region 2004	North Central Region 1951–2000	South Bass Island 1977–1997
January	2.25	2.21	1.63
February	0.63	1.91	1.45
March	3.62	2.66	2.28
April	2.36	3.37	2.98
May	8.09	3.51	3.33
June	4.96	3.73	3.49
July	4.06	3.72	3.01
August	3.76	3.36	3.43
September	2.45	2.99	3.03
October	2.33	2.26	2.48
November	3.59	2.83	2.53
December	3.35	2.54	2.13
Total	41.45	35.09	31.77

Sources:
Monthly Water Inventory Report for Ohio, Ohio Department of Natural Resources
Monthly Station Normals, Station 33 Put-In-Bay, National Oceanic and Atmospheric Administration