BEFORE
THE OHIO POWER SITING BOARD

In the Matter of the Application of Firelands Wind, LLC for a Certificate of Environmental Compatibility and Public Need to Construct a Wind-Powered Electric Generation Facility in Huron and Erie Counties, Ohio	)))))	Case No. 18-1607-EL-BGN

DIRECT TESTIMONY OF IRA SASOWSKY ON BEHALF OF THE LOCAL RESIDENT INTERVENORS

Q.1. Please state your name and work address.

A.1. Ira Daniel Sasowsky. 379 Bittersweet Rd., Akron, OH 44333

Q.2. What is your educational background?

A.2. I have a Bachelor of Science (BS) degree in geology from the University of Delaware. I hold masters (M.S.) and doctoral (Ph.D.) degrees in geology from The Pennsylvania State University. Beyond that I have attended many continuing education functions such as general or specialty conferences in my professional field.

Q.3. What is your occupation?

A.3. I am a geoscientist, and a principal in Sasowsky Earth Science Consultants, Ltd., also referred to as SESC, a professional services company providing geologic, hydrologic, and soils consulting. I serve also as Professor of Geosciences at the University of Akron (Ohio).

Q.4. Please provide an overview of your occupational experience.

A.4. A full curriculum vita is given in Exhibit A. I am a registered Professional Geologist in Pennsylvania and Tennessee; Ohio does not offer registration for geologists. My dissertation and thesis research topics were both focused on karst areas in the eastern United States.

I have provided advice to clients including Fortune 100 companies, utilities, homeowners, citizens groups, insurance firms, and legal firms. Much of that work has been in areas underlain by carbonate rocks. Representative projects in carbonate rock settings include: evaluation of quarry water inflows, causes of sinkhole flooding, delineation of groundwater protection areas, hydrology and geochemistry of groundwater contamination in carbonate aquifers, and causes of ground subsidence. I have also received funding through Ohio EPA and U.S. Dept. of Agriculture in support of research to advance understanding of karst areas.

Q.5. What professional honors have you received?

A.5. Professional organizations have recognized my work with the following honors: Fellow and Hydrogeology Division Distinguished Service Award of the Geological Society of America; Fellow, Science Award, Certificate of Merit, and Ralph Stone Research Award of the National Speleological Society; Jeff Jefferson Research Award of the British Cave Research Association; and the Distinguished Service Award of the Association of Ohio Pedologists. Pedology is the study of soil science.

Q.6. On whose behalf are you offering testimony in this case?

A.6. I am offering testimony on behalf of Local Resident Intervenors Patricia Didion, Jane Fox, Marvin Hay, Theresa Hay, Patricia Olsen, Sheila Poffenbaugh, Walt Poffenbaugh, Christina Popa, John Popa, Lori Riedy, Charles Rogers, Kenn Rospert, Dennis Schreiner, Sharon Schreiner, Donna Seaman, William Seaman, Deborah Weisenauer, Kenneth Weisenauer, and Gerard Wensink (together, the "Local Residents").

Q.7. What is the purpose of your testimony?

A.7. The purpose of my testimony is to inform the Ohio Power Siting Board about the geological and hydrogeological risks that are associated with the installation of the Emerson Creek Wind project for which Firelands Wind, LLC is requesting a certificate from the Board. My testimony also identifies the deficiencies in geological and hydrogeological information contained in Firelands Wind's Application for the certificate.

Q.8. What documents did you consult in preparing for your testimony?

A.8. I examined all materials posted on the case page of the OPSB website, including the Staff Report. I made a more detailed examination of those documents that specifically pertained to geology, hydrology, and karst, for example the Groundwater Hydrogeological and Geotechnical Desktop Document Review Summary Report for the Proposed Emerson Creek Wind Project Located in Erie, Huron, and Seneca Counties; ACX006.0002 (Hull, January 17, 2019) and the Geotechnical Report (April 29, 2020) by RRC Power & Energy, LLC (RRC). I also reviewed several other pertinent documents regarding windfarms and karst, which I will discuss later in my testimony.

Q.9. What is karst?

A.9. The definition of karst from the American Geological Institute Glossary is: "A type of topography that is formed on limestone, gypsum, and other rocks, primarily by dissolution, and that is characterized by sinkholes, caves, and underground drainage." Simply put, karst regions are those, usually underlain by limestone or dolostone, types of carbonate rich bedrock, where dissolution of the rocks has produced a characteristic set of features and behaviors. For an illustration, see Exhibit B. Karst forms on, and in, these particular rocks because they are easier to dissolve than many other rocks such as sandstones, shale, and granite. The primary features of karst regions are sinkholes and caves, along with disappearing streams. These features originate by the movement of naturally acidic water through the bedrock, which wears away (dissolves) the rock. This can create relatively large, and laterally extensive, routes for water to move through the rock. When these pathways are large enough for humans to traverse, we call them caves. Some of these can reach extreme size and length. Mammoth Cave, Kentucky, for example is 405 miles long; the longest cave in the world. There are many examples of cave rooms having volume greater than 1 million cubic yards. However, there also exist many smaller and shorter pathways which are not humanly traversable, but which do allow for the very rapid and focused movement of water. This leads to significant challenges for the safe development of any infrastructure in these settings, even in the absence of large sized openings.

To understand the basic process by which karst features form, it is useful to consider them in the context of the water cycle. Water on Earth follows a complex trajectory through what we call the hydrosphere. Briefly stated, water that evaporates from ocean basins and other areas is carried across the continents where it may fall from the atmosphere as precipitation (rain, snow, etc.). When that precipitation lands on the earth it may run off directly across the surface into streams, fairly quickly making its way to larger rivers, and then back to the ocean. An alternative pathway is for the rainwater to infiltrate, or soak into, the soil. When this occurs, the water can make its way downward to join with the groundwater flow system. This is called groundwater recharge. Along this pathway, which is typically quite slow, water is driven by hydraulic gradients in downward, lateral, or even upward directions. It eventually makes its way back to the surface, emerging as springs or seeps, or as base flow in streams. This process is illustrated in Exhibit C. In most non-carbonate rock settings, such as sandstones and shales, the pathway is as shown in the upper cross section. But, in those cases where the bedrock is a carbonate material, such as limestone or dolomite, the water traveling along the path can act to dissolve away the rock creating larger pathways (lower part of Exhibit C). This process is known as karstification. It is an ongoing process that has many phases. Although the process is slow on the human timeframe, the longer periods associated with geologic history allow for the development of extensive pathways and large features. In some cases, the openings within the bedrock can become in filled with loose geological materials, which may be called soil, or regolith. This material may partially or fully block water movement through the bedrock openings, at least temporarily.

Q.10. What experience do you have with hydrogeology and karst?

A.10. Over my career I have specialized in research on karst (cave and sinkhole) development. I have been examining and working in karst terrains for about 40 years. This work has included academic research, as well as consulting for technical concerns. The technical subfields within which I have worked in karst settings include geomorphology, hydrogeology, geochemistry, and environmental chemistry.

This has included field experience in karst areas of 25+ U.S. states, South America, the Caribbean, and Europe. I have observed karst features in natural settings, in quarries, in road cuts, etc. I have entered and examined over 500 caves throughout the world. In the state of Ohio, I have directed several hydrogeologic research projects in various karst and other areas. I have edited 11 scientific books on karst, been an author of numerous technical reports, and published over 50 scientific articles which have appeared in journals such as: Earth & Planetary Science Letters, Environmental Geology, Geology, Geomorphology, Journal of Cave & Karst Studies, Journal of Hydrology, Quaternary Research, Science, Water Research, and Water Resources Research. I have presented the results of scientific work and published more than 100 abstracts at national and international meetings, as well as giving invited lectures at universities in North America and Europe. My knowledge has been shared with thousands of students, colleagues, professionals, and the public through classes, field trips, sessions, and conferences. During my 15-year tenure as the earth sciences editor of the Journal of Cave and Karst Studies, I oversaw the publication of cutting-edge research in this discipline.

Q.11. Have you conducted any karst studies on behalf of any government agencies?

A.11. Yes. I have, along with collaborators, conducted two major projects examining the conditions, processes, and features of karst areas. The first was a two-year project, funded by the US EPA through the Ohio EPA 319 grant program. The general purpose of this project was to improve water quality in an area of Ohio by evaluating the utility of a unified source water protection plan for the Bellevue– Castalia Karst Plain. The second project was funded by the US Department of Agriculture, and in that work we examined methods for the handling of storm water in karst terrains, and made recommendations about best practices. Both of these projects resulted in technical reports.

Q.12. What experience do you have with karst and water issues within or near the Project Area?

A.12. I made my first visits to this area about 20 years ago with colleagues from the geology department at Oberlin College. Since that time, I have made many other visits to examine the karst features, and conduct research. The first government agency project mentioned in the question above was located in and around the Bellevue-Castalia Karst Plain, a physiographic sub-province in Ohio, which significantly overlaps the proposed Emerson Creek Wind project area. I directed that project, with a number of collaborators assisting in the work. The undertaking involved an extensive desktop study which developed a lengthy annotated bibliography for the area. Following that, our investigations included field mapping, dye tracing, well video, statistical analysis of drilling records, geophysical investigations, and geochemical modeling. These are explained in our report, (Sasowsky, I. D., and others, 2005, Results of Investigation: Bellevue-Castalia Karst Plain Groundwater Planning Project, 516 p.) One important conclusion of that study was the recognition that certain areas that did not appear to be karst, because they did not have known sinkholes or caves, actually had karst behavior present in the subsurface.

I have an ongoing project looking at the characteristics of springs in the area, in collaboration with a colleague from Bowling Green State University. For that project we have installed data loggers to monitor groundwater discharge conditions at high frequency.

Q.13. How prevalent is karst in the vicinity of the Project Area?

A.13. Karst is demonstrably present in the northwest part of the project area as evidenced by surficial features such as sinkholes. Karst may also be present in other sections which do not have obvious expression. The project area partially overlaps the Bellevue-Castalia Karst Plain, one of the four main karst districts in Ohio. See Exhibit D. In addition, a

PDF map prepared by the Division of Geological Survey indicates that the project area overlaps the eastern edge of a very broad region which is potentially karst, and also has many identified karst features. Detailed publications prepared by the Division of Geological Survey, authored by Douglas Aden and others, have field verified and precisely mapped these features. Some of these reports are referenced or reproduced in the application by Firelands Wind. Additionally, Application Exhibit E is a consulting report titled Groundwater Hydrogeological and Geotechnical Desktop Document Review Summary Report for the Proposed Emerson Creek Wind Project Located in Erie, Huron, and Seneca Counties; ACX006.0002 (Hull, dated January 17, 2019). Figure 4 in that report, which I include here as my Exhibit E, shows an outline of the Emerson Creek Wind project area (since modified slightly), along with "known karst" points, and hachured areas which are labelled "probable karst". The method in which "probable karst" was delineated is not explained in the report but appears to be from the ODNR recent definition which is: "….areas that: (1) lie within a half mile of a known or indicated karst location, and (2) are underlain by carbonate or gypsiferous bedrock with an overburden of less than 20 feet of non-carbonate bedrock and/or unconsolidated material as shown by comparison of 7.5-minute bedrock-topography and bedrock-topography maps to surface topography". This is a very restrictive use of the word "probable" and does not comport with my understanding of the word as typically used; all areas underlain by carbonate in this region should be considered likely as karst unless otherwise indicated.

When this figure is compared to the karst interactive map viewer available online at the ODNR Division of Geological Survey website, it appears that the karst points on figure 4 (my Exhibit E) match what are called “Karst Points Field Verified” from that database. What is absent from figure 4 are other points which are classified as “Karst Suspect - Field Visited” and “Karst Suspect - Not Visited”. Some of these lie within the footprint of the project. A significant portion of the Emerson Creek Wind Project area bedrock is Silurian and Devonian age carbonate rock overlain by more or less than 20 feet of glacial drift and/or alluvium. This is shown by activating the layer titled “Karst Geology of Ohio” on the ODNR karst interactive map. From this map it is apparent that the region has a substantial additional number of karst features found eastward (outside of) of the boundary as delineated by the bedrock geology, thereby expanding the likely karst area. Consequently, it is clearly not sufficient to ignore the possibility of karst in the vicinity of the lithologic boundary (i.e. within the mapped shale areas). Even in those areas mapped as shale, karst may be present at rather shallow depths at distances miles from the mapped boundary of the limestone (in underlying carbonate layers).

In summary, karst is clearly a concern within all of the mapped limestone area and may be of concern outside of it. It is therefore imperative that steps be taken to characterize the conditions, in order to avoid environmental impacts.

Q.14. Can the underground presence of karst always be detected by examining geological features that are visible on the land surface?

A.14. No. Such a determination cannot be definitively made in many cases, and we showed this is true in the Bellevue-Castalia Karst Plain with the research project that I mentioned above. Throughout this region the bedrock is covered by varying thicknesses of loose sedimentary material; sand, silt, and so forth. Most of these materials were deposited during and at the end of the last ice age, and are collectively called ”glacial drift”. In places where the drift is thick, sinkholes and other superficial karst features may be obscured, or hidden, since they are buried. Several researchers have noted a correlation between thin layers of drift and the presence of visible karst surface features. However, even in places where the bedrock cover is thin, the absence of superficial karst features does not mean that karst is not present. There can be, and frequently are, caves and smaller groundwater conduits present in carbonate bedrock with very little surface expression of dissolution features. Consequently, the old saying "the absence of evidence is not the evidence of absence" holds particularly true. Generally, to be sufficiently protective, when there is carbonate bedrock present below, or adjacent, one should assume that it is karstified unless it can be demonstrated otherwise.

Even areas that seem stable can develop problems. Sometimes these have terrible consequences. For example, in March 2013 in Seffner, Florida a collapse sinkhole developed underneath the bedroom of a house and killed a man. The home is believed to have been built in the mid 1970s and so had remained stable 40 or more years before this unexpected collapse occurred.

Exhibit F shows 2 mechanisms by which sinkholes form, and how they can make a connection between the land surface and the subsurface.

Q.15. How do cavities, conduits and openings form in karst?

A.15. As mentioned above, the general process is that water circulates through carbonate bedrock such as limestone or dolomite, and along its pathway it dissolves the bedrock away creating openings. The dissolving power of the water comes primarily from small amounts of carbon dioxide that are in it. This creates a weak acid, carbonic acid, which greatly accelerates the dissolution of bedrock. The general equations describing this process are H_2O (l) + CO_2 (g) >> H_2CO_3 (aq); H_2CO_3 (aq) >> HCO_3^- (aq) + H^+ (aq); H^+ (aq) + $CaCO_3$ (s) >> Ca2+ (aq)+ HCO_3^- (aq); where $CaCO_3$ is calcite, the mineral comprising limestone. The annotations "l", "g", "aq", and "s" indicate liquid, gas, aqueous, and solid phases, respectively.

Sometimes these rock openings later become filled in, or partially filled in, with loose geological material. This can give the impression of stability, but these materials can be mobilized by infiltrating water, particularly with changes in drainage, and create damaging collapses such as the one mentioned from Florida.

Q.16. Has this dissolution of rock finished, or is it an ongoing process?

A.16. The dissolution of rock is an ongoing natural process. As long as water is moving through the bedrock, some dissolution will likely continue to occur.

Q.17. What information have you learned about karst in the Project Area that is useful for determining whether wind turbines can be constructed there without harming the public and the environment?

A.17. From our previous studies, we have developed a broad understanding of the processes that are at work in this region. This serves as a framework for developing a more nuanced understanding of the potential specific effects of the proposed Emerson Creek Wind project. It does not, however, remove the need for site-specific studies.

Some of the pertinent factors are these. Karstification in this area is actually occurring via two processes. There is evidence of the typical top-down (epigene) karstification that occurs when water moves down into the ground. This is seen, for example in sinkholes and swallets (sinking stream points) in much of the region. However, there is a another very significant process at work. Relatively deep ground water circulation, moving in a generally north direction, is dissolving certain beds in the underlying Salina Group. This is causing upwards collapses which in some cases reach the land surface, creating very large sinkholes in the overlying carbonate rocks. Evidence for this process is found through examining the morphology of the sinkholes, their position in the landscape, and also through geochemical modeling of spring water discharges at regional springs to the north of the Emerson Creek Wind project area. This situation is discussed in detail in the report from our Ohio EPA project mentioned earlier, as well as in a conference paper that we published in 2003 (Sasowsky, I. D., Dinsmore, M. A., Salvati, R., Bixby, R., Raymond, H., and Mazzeo, P., 2003, Subtle but significant karst on the glaciated Bellevue-Castalia Karst Plain, Ohio, USA, in Beck, B. F., ed., Sinkholes and the engineering and environmental impacts of karst (Geotechnical Publication No. 122): Reston, Virginia, American Society of Civil Engineers, p. 95-109.)

Furthermore, we verified that the apparent absence, or limited occurrence, of surficial karst features such as sinkholes, does not indicate that karst is absent. For example, in Bloom Township, Seneca County (the county which forms the western boundary of the Emerson Creek Wind project area), we found three indications of substantial karst groundwater flow even though there are few sinkholes in the area. The first piece of evidence was an apparently natural collapse that occurred on one of the local streams, Honey Creek, that diverted streamflow into the subsurface for substantial period of time. The second piece of evidence was a sinkhole just south of the Hanson Aggregates Bloomville Quarry, which was reported to take in copious amounts of storm water runoff without ever backflooding. The third line of evidence was a dye trace that we conducted into a small opening in a farmer's field, between the quarry and Honey

Creek. 15 pounds of fluorescein dye powder followed with 145,000 gallons of water was used, yet no dye was recovered at any of the detection points. This confirms deep rapid karst flow behavior, even in portions of this region that are not traditionally considered to be karst.

Q.18. Based on your review of the pertinent records, do you have any concerns with the wind project for which Firelands Wind has requested a certificate?

A.18. Yes.

Q.19. Please provide the Board with a short overview of your concerns.

A.19. A significant portion of the project area is in karst terrain. Experience at many locales has shown that human activities in these sorts of areas require special attention in order to avoid or minimize the following three issues: 1) land failure or subsidence (sinkholes, collapses), 2) disruption of water supplies, and 3) contamination of water supplies. These may occur during the construction or operations phases. The application gives only cursory attention to these potential concerns. In addition, there is scant attention given for water resources even in areas where karst is not likely.

Q.20. What are the risks of land failure or subsidence (sinkholes, collapses) if wind turbines are constructed in karst areas?

A.20. There are number of issues with either slow land subsidence, or rapid collapse. Each instance represents the lowering of the Earth's land surface downward. This occurs either because there was an existing opening in the underlying material, or a new opening has been formed. Subsidence and collapses can be brought about in several ways. The first way is by excessive loading. This occurs when additional weight is put on the land surface, and the underlying material is either compressed, in the case of sediments, or fails. The latter can be the case with sediments or within bedrock containing cavities. In order to avoid this problem, the subsurface must be thoroughly characterized by boring or other methods. A second way that subsidence or collapse can occur is by the generation of new voids in the subsurface. This typically occurs by the erosion of sedimentary fill from existing karst cavities. As mentioned earlier in this testimony, it is very common for bedrock in karst areas to be filled or partially filled in with loose sediments on top of it. If surface drainage is changed, this can direct water down into some of these conduits which has the effect of eroding, or flushing away, the sediments that are present. Once that occurs, increased and rapid water flow maybe induced, and failure of the surface can occur due to removal of the material. The time frame for collapse such as this to be induced may vary from days to decades. You can see in Exhibit G that parts of this area are lacking in surface streams. This means it can be very challenging to safely deal with stormwater, since it is not apparent where it may go.

Q.21. What are the risks of groundwater contamination if wind turbines are constructed in the Project Area?

A.21. Groundwater contamination can happen anywhere, but it is particularly of concern in karst areas because there may be open, and quick, pathways that connect surface water to the groundwater. This is different than in non-karst areas, where slow movement of water through tiny openings usually filters and cleans surface water before it can reach the groundwater. Risks of groundwater contamination primarily come from making changes to the surface that would facilitate rapid movement of surface water into the ground.

This is a well-known problem in the Bellevue Castalia Karst Plain area. For example, there was severe and widespread damage to drinking water supplies in the Bellevue area (directly west of the Emerson Wind project) from the early 1900s through the early 1960s. This occurred due to contaminated water making its way in to wells and sinkholes; a report titled "Contamination of underground water in the Bellevue area" was prepared for the Ohio Water Commission by the Groundwater Geology Section of the Ohio Division of Water in June 1961. A copy of that report is attached as Exhibit H. Changes in waste disposal practices relieved some of these problems for Bellevue.

When changes are made to the land surface from activities like constructing turbines, water from fields, ditches, and constructed areas which may be contaminated may be directed into sinkholes or other openings which provide a direct connection to the aquifer. This water is generally of lesser quality than existing groundwater, and can be unhealthy for human consumption. This is why it is important to have a specific understanding of the movement of water at each site. This can be accomplished in a number of ways, but almost always requires more than simple visual inspection. Dye tracing is a common approach to identifying flow directions and recharge zones. This has been carried out in some parts of Ohio by ODNR and other entities. A report was published in March 1994 titled "Impact of best management practices on surface run off and groundwater quality in a solution limestone area, Thompson Township, Seneca County, Ohio". It was prepared by number of researchers from the ODNR Division of Water, the Seneca County Soil and Water Conservation District, and the University of Toledo. Because this area is adjacent to the Emerson Creek Wind project area, this study could provide insight to more safely construct the wind project. It does not appear that this document was used in preparing the Application.

It is acknowledged in Exhibit E of the Application, the Hull report, that there are several source water protection areas overlapped by the Emerson Creek Wind project. The associated map (their Figure 7) is presented here as Exhibit I. One of these areas is a groundwater source water protection area for Capital Aluminum and Glass. The area is listed as high vulnerability. There are also several surface water protection areas. According to the Hull report, 49 total proposed turbines fell within protection areas.

In these areas, as well as any place where a domestic or agricultural well might be impacted, a high level of care should be taken to protect the resource.

Q.22. What are the risks to the availability of water supplies if wind turbines are constructed in the Project Area?

A.22. This is an important consideration, as the viability of a water supply includes not only its quality, as mentioned above, but also its quantity. The availability of suitable water for drinking, agricultural, and other purposes, is critical in a rural area such as this. The majority of residences are supplied by individual private wells, which make use of groundwater from underneath their property. If such supply were to be lost, it would be devastating for the residents.

For this reason, it is necessary to understand for each well where the water comes from. This includes identifying the aquifer, as well as the recharge zone for the well which is extracting the water. This could then guide design and construction to avoid disruption of recharge to the well. Paving, the installation of concrete bases, and grouting, for example, are all practices which can tend to limit recharge to an underlying aquifer, and need to be avoided or managed. Without this, the proposed project could disrupt residential or other water supplies.

Q.23. Did Firelands Wind conduct an adequate investigation to evaluate the risks you have described?

A.23. Not from the materials that I have reviewed. Based on my examintion, the full possible impact of the project has not been shown in the Application or evaluated in the Geotechnical Report (April 29, 2020) by RRC Power & Energy, LLC, nor is the project designed to have the minimum adverse environmental impact. The overarching concern is that scant attention has been paid to the protection of water resources, or the special concerns of infrastructure development on karst.

In the Application Narrative, page 51-54, it is opined that impacts are expected to be minor, based upon the relatively small footprint compared to total area. For example it is stated: "…will have a negligible effect on surface water runoff and groundwater recharge." and "…measurable impacts on the quality of surrounding water resources are not anticipated." However, this is not supported with presented data, or methods to collect such data. Such predictions do not preclude significant impacts for a given landowner, and nowhere does there seem to be a plan to, for example, identify aquifers being used, and their recharge areas. This should be done both for participating and non-participating landowners, in order to proactively protect these users. The Application is a 269-page document, with numerous appendices. The word karst is used only 13 times within the body of the Application, which is surprising because this landscape characteristic is known to present challenges for construction practices and environmental protections.

Appendix E of the Application is the Hull report, titled Groundwater Hydrogeological and Geotechnical Desktop Document Review Summary Report for the Proposed Emerson Creek Wind Project Located in Erie, Huron, and Seneca Counties; ACX006.0002 (Hull, dated January 17, 2019). In this report there is a brief discussion of karst, and the map which I previously mentioned, my Exhibit E. The emphasis of this report is really construction stability for the turbines. For example, in the summary it is stated "…it does not appear that the construction of the proposed wind turbines will have a significant impact on the local geology and/or hydrogeology of the Project Boundary." But scant consideration is given to karst issues, or even to the aquifers and sources for water in resident wells. Appendix E of that document is a generalized geotechnical exploration workplan. But, again, this really just addresses stability of the construction, not impacts to the environment.

The report by RRC presents results of the work that was proposed in the Hull report, such as boring and geophysical investigations. Karst is addressed, however, really only as a construction problem, rather than an environmental (water) concern. A Site Vicinity Karst Map is included (their Figure 9), and there is some discussion of expected concerns. Some points of note:

a) Seven sites are recommended for void assessment and mitigation (Table A1)

b) Only 8 landowner wells out of 35 are in rock that is not limestone. (Table A3)

c) Twenty-two of 80 borings completed show limestone (Appendix A, logs)

It is mentioned on page 10 of the report that "If a detailed groundwater study is desired, a groundwater hydrologist should be retained to provide these services." Risks discussed all seem to pertain to foundation stability; karst is viewed as a problem to solve for construction purposes, rather than a condition related to an essential resource, water. It seems that detailed groundwater studies would be essential for environmental protection.

Q.24. Exhibit E, Page 9 of Firelands Wind's Application contains the following statement: "It is Hull's understanding that there is a minimum setback distance which will be established from each turbine to the nearest residential structure. Although the exact location of each potable use well cannot be determined with the information obtained to date, it is assumed that the potable wells are located in close proximity to each property owners' residence. Therefore, based on the information presented herein and the associated analysis, construction of the wind turbines, or other project components, are not anticipated to result in any significant negative impact to the property owners' wells. Do you agree with this statement, and if not, why do you disagree with this statement?

A.24. I do not agree with this. Although it is correct that setbacks, in general, afford protection to water supplies, without knowing the specifics of each location there cannot be a high degree of comfort regarding the potential level of impact. This is especially true if karst is present. This has been amply demonstrated around the city of Bellevue which is directly adjacent to the project area. In that city, groundwater contamination originating in the city caused contamination up to 30 miles north and several miles east. See Page 10 of Exhibit H.

Q.25. What additional investigation is necessary to determine whether wind turbines can be constructed in the Project Area without harming the public or the environment?

A.25. The entire area needs to be better understood with regard to understanding the movement of water and the features that are present. Beyond that, each proposed site should be characterized with regard to the movement of surface water and groundwater. This information should then be used to answer the following questions: What impact to aquifer recharge will occur due to the proposed construction? What impact to groundwater quality will occur due to the proposed construction? What changes to surface and subsurface water drainage will occur, and could these promote land subsidence or collapse due to accelerated movement of loose material within the karstified bedrock? The plan for the investigation should be made with the input of a qualified professional who has experience in karst terrains. Likewise, the work on the ground should make use of personnel with experience in karst settings.

Q.26. Does Firelands Wind's application provide sufficient information to determine whether the turbines will cause karst collapse, groundwater contamination, or disruption of groundwater supply?

A.26. Not in my estimation. In order for any construction to be carried out with minimal environmental impact in a karst area, a detailed background study should be conducted, in which potential impacts to water quantity, water quality, and subsidence risks are thoroughly evaluated. This can only be accomplished with an understanding of such basic questions as: What aquifers are present? What are the groundwater flow directions? What are the recharge and discharge areas? Who are the water users? What is the capture zone for their extraction? If these things are not understood, it is difficult, if not impossible, to predict what environmental impacts may occur due to construction. Furthermore, baseline data (pre-construction) should be obtained for water supplies, so that any impacts can be evaluated.

The Application does not demonstrate minimal adverse environmental impact. A full understanding of the nature of the karst environment is not presented or planned. Since the Application does not supply sufficient information to describe the nature of environment, it is impossible to clearly evaluate impact. This is especially true with regard to groundwater impacts.

Q.27. What additional information must be collected before deciding whether a turbine should be constructed at a site?

A.27. If the construction cannot be accomplished without presenting risk to water quality, water quantity, land subsidence, or land collapse, then it should not move forward. In order to evaluate that risk, each location should be characterized at a minimum using appropriate investigative techniques for the following: 1) Aquifers present, and the flow directions within them, 2) cataloging of individual karst features such as caves or sinkholes, 3) ground support characteristics, 4) storm water flow and recharge pathways and amounts, and 5) capture zones for any water extraction points such as residential wells.

Q.28. Based on the findings of this additional investigation, what conditions should preclude the construction of a wind turbine at a specific site?

A.28. It is not possible to make a comprehensive list of conditions that would preclude such construction. It seems to make sense that the Applicant, instead, should demonstrate with the support of data that the work they are proposing will not be damaging to the environment.

Q.29. Is it possible to just refrain from building directly on sinkholes, in order to avoid any problems?

A.29. No. Unfortunately, that is not the case. It is not possible to avoid karst related problems by simply avoiding construction on known karst features (though that practice certainly is advisable). Karst does not occur as isolated features, but rather pervades the entire landscape where underlain by soluble rocks. Avoiding construction on a specific karst landform such as a sinkhole is good, but this does not remove concerns for environmental impacts. Recall that karst is a characteristic of this region. When rainwater falls on the surface, or when snow melts, the water needs to go somewhere. This usually means that it is going to go down into the ground, through one pathway or another. Karst risks exists even where sinkholes are not found. A significant portion of the proposed Emerson Creek Windfarm lies on a known karst area. Even in those locations having no surface expression of karst character, it may be present in the subsurface.

Q.30. How does the application address the concerns of karst?

A.30. It doesn't really address them, except to say that no significant impacts are expected, and that geotechnical investigation will be used to ensure foundation stability.

Q.31. Does the Geotechnical Report presented as Attachment AW-2 to Alfred Williams' direct testimony address the concerns you have discussed in your testimony about karst?

A.31. No, not really. One boring per turbine site is not an adequate characterization of the geology for purposes of groundwater protection in the carbonate rock areas. Even several borings might still miss important features. A comprehensive approach is really warranted. There is no indication that meaningful evaluation would be undertaken before or during installation. Also, it appears that no borings at all were drilled at some turbine sites.

Q.32. Will grouting cavities under a turbine foundation cause risks to the environment?

A.32. There are several concerns with this. From an engineering and stability foundation standpoint, it may seem desirable to grout open cavities that are found. But is important to remember that these cavities may actually be an important part of the natural environmental system. They can provide pathways for recharge to the aquifer. If they are grouted there are three concerns that come about. First, they may block natural recharge to the aquifer. Second, by blocking natural drainage they may reroute water flow, which has to go somewhere, and therefore encourage erosion and movement of sediments in the subsurface in other areas, leading to induced collapses. Third, if new pathways for the movement of surface water into the groundwater system are opened, water quality may suffer.

Q.33. Do you have any concerns with blasting, as mentioned on Page 16 of the Geotechnical Report attached as Attachment AW-2 to Alfred Williams' direct testimony, affecting water quantity or quality in wells?

A.33. Yes. Blasting can generate problems with water supplies, and this should be considered. In all areas there may be problems with disruption of water supplies due to collapse of uncased portions of wells in the case of substantial shaking. And particularly in limestone areas the shaking caused by blasting might cause movement of loose sediments that can be present in voids, potentially increasing well turbidity (murky water), or disrupting recharge pathways to the aquifer.

Q.34. The Geotechnical Report presents the results of water levels from temporary piezometers installed at borings. Is this sufficient to understand groundwater flow at each turbine location?

A.34. No. These results are given in Table A-1 of that report, titled "Summary of foundation design net allowable bearing pressure and design groundwater recommendations". Water levels in temporary piezometers at four different times are reported for most borings. These data appear to be suitable for determining construction techniques and limitations, but they do not provide significant insight about groundwater conditions that could lead to negative outcomes to water resources during or after installation.

Q.35. Do you hold the opinions expressed in this testimony to a reasonable degree of scientific certainty?

A.35. Yes.

Q.36. Does this conclude your direct testimony?

A.36. Yes.

LIST OF EXHIBITS

A. Resume of Dr. Ira D. Sasowsky

B. Block diagram showing typical karst features and drainage.

C. Schematic cross-sections of groundwater movement in (top) non-carbonate rocks, (bottom) carbonate rocks.

D. Map showing pertinent features in proposed Emerson Creek Wind project area.

E Map indicating some karst features and the Emerson Creek Wind project area. Figure 4 from Application Exhibit E, which is a report "Groundwater Hydrogeological and Geotechnical Desktop Document Review Summary Report for the Proposed Emerson Creek Wind Project Located in Erie, Huron, and Seneca Counties; ACX006.0002 (Hull, dated January 17, 2019)".

F. Diagrams showing mechanisms of cover subsidence (top) and cover collapse (bottom) sinkholes.

G. Drainage network map, showing lack of surface streams within portions of the 4 County area. From: Sasowsky, I.D., Dinsmore, M.A., Salvati, R., Bixby, R., Raymond, H., and Mazzeo, P., 2003, Subtle but significant karst on the glaciated Bellevue-Castalia Karst Plain, Ohio, USA, in: Beck, B.F. (ed.), Sinkholes and the Engineering and Environmental Impacts of Karst (Proceedings of the Ninth Multidisciplinary Conference), American Society of Civil Engineers Geotechnical Special Publication No, 122, p. 95-109.

H Report investigating the extent of groundwater contamination in the Bellevue area in the 1960's: Ground-Water Geology Section, Ohio Division of Water, 1961, Contamination of underground water in the Bellevue area, Columbus, Ohio, 30 p.

I Map indicating groundwater and the Emerson Creek Wind project area. Figure 7 from Application Exhibit E, which is a report "Groundwater Hydrogeological and Geotechnical Desktop Document Review Summary Report for the Proposed Emerson Creek Wind Project Located in Erie, Huron, and Seneca Counties; ACX006.0002; ACX006.0002" (Hull, dated January 17, 2019).

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CERTIFICATE OF SERVICE

On September 21, 2020, I served a copy of this filing by electronic mail on the following persons:

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EXHIBIT A

DR. IRA D. SASOWSKY
Professional Resume

Geologist & Principal
Sasowsky Earth Science Consultants, Ltd.

Professional Expertise

Groundwater and surface water supply and quality
Communication of science to the public
Land subsidence & sinkholes
Expert review and testimony
Groundwater supply
Groundwater hydrology
Mine hydrology & flooding analysis
Petroleum geology
Natural water geochemistry
Groundwater sampling
Acid mine drainage
Karst hydrogeology & geomorphology
35 years field experience in 30 states, Caribbean, Brazil, and Europe

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Education

Ph.D., Geology, The Pennsylvania State University, 1992
M.S., Geology, The Pennsylvania State University, 1988
B.S., Geology, University of Delaware, 1983

Certifications

Professional Geologist, PG-000417G, Pennsylvania
Professional Geologist, PG-5504, Tennessee
OSHA 40 Hour Hazardous Waste Site Operations
OSHA 8 Hour Hazardous Waste Site Supervisor
Innov-X Portable XRF Analyzer Safety Certificate

Professional Experience & Responsibilities

2000 - Present
Geologist & Principal
Sasowsky Earth Science Consultants, Ltd., Akron, Ohio
Technical consultation to individuals, corporations, and legal firms on geologic and hydrogeologic concerns. Representative projects include groundwater availability & quality for developers, evaluating causes of land subsidence and foundation failure, resolving excess water problems, and characterizing petroleum reservoir properties. Work includes technical review, development of reports and exhibits, and provision of expert opinion.

1995 - Present
Dept. of Geosciences and
Center for Environmental Studies
University of Akron
Akron, Ohio
Professor of Geosciences, 2007- present
Associate Professor of Geology, 2001 - 2007
Assistant Professor of Geology, 1995-2001
Director, Center for Environmental Studies, August 2000 - present

Teaching duties include Environmental Geology, Petroleum Geology, Groundwater Hydrology, Advanced Groundwater Hydrology, and various seminars and field trips. Other activities include development and execution of research programs, grant writing, guidance of graduate students in their thesis work, presentation of research at professional meetings, publishing scholarly articles, and public service.

November 1991 - August 1995
Hydrogeologist, Nittany Geoscience, Inc.
State College, Penna.
Hydrogeologic consultation to municipalities, private citizens, and corporations on environmental geology, and groundwater supply, contamination, and cleanup problems. Involved in all phases of work including: preparation of proposals, authoring of technical workplans, interpretation of regulations, supervision of field and office activities of both technical and non-technical staff, development of unique solutions to technical problems, interpretation of data (geochemical, hydrologic, and geologic), and authoring and review of reports.

1983 - 1989
Research Assistant, Materials Research Lab,
The Pennsylvania State University, University Park, Penna.
Designed and conducted experiments to develop infrared window materials. Effected computer analysis of nuclear waste isolation materials. Maintained laboratory equipment including high-temperature ovens with hydrogen sulfide atmospheric systems. Presented results to contract sponsors and at national professional meetings.

1983 - 1988
Teaching Assistant, Department of Geosciences, The Pennsylvania State University, University Park, Penna.
Formally appointed as a teaching assistant for 1 semester for an introductory geology course. In addition, frequently prepared, delivered, and graded laboratory exercises for hydrogeology and aqueous geochemistry courses.

June 1984 - August 1984
Petroleum Geologist (exploration), Exxon Company, USA,
Denver, Colorado
Investigated hydrocarbon potential of areas in the Rocky Mountain Overthrust Belt, Wyoming. Constructed geologic maps, cross sections, analyzed well data. Presented recommendations and evaluation of geologic setting to management.

June 1983 - August 1983
Petroleum Geologist (production), Exxon Company, USA,
Andrews, Texas
Conducted regional stratigraphic study of channel sands in Lea County, New Mexico. Constructed regional geologic maps (isopach and structure). Carried out stratigraphic analysis of basin. Presented recommendations to management for acquisition of mineral rights to expand production areas .

1982 - 1983
Research Assistant, Delaware Geological Survey, Newark, Delaware
Maintained offshore seismic data library (electronic and hardcopy) and processed seismic data. Developed documentation for FORTRAN-based seismic processing software in use by the Survey.

1980 - 1981
Mudlogger, Tooke Engineering, Williston, North Dakota
Conducted real-time logging of well cuttings and chromatograph gas levels, and prepared detailed geologic columns for numerous hydrocarbon exploration wells in North Dakota, Montana, and South Dakota. Advised company representatives of potential pay zones. Supervised two-man logging unit.

Awards

Edwards Aquifer Authority Distinguished Lecturer, 2014
Distinguished Service Award, GSA Hydrogeology Division, 2009
Karst Waters Institute Service Recognition Award (Droplet), 2009
Certificate of Appreciation (GSA Committee on Accreditation), 2008
Presidential Citation, Association of Environmental and Engineering Geologists, 2007, 2008, 2010
Science Award, National Speleological Society, 2006
Elected Fellow, Geological Society of America, 2003
Distinguished Service Award, Association of Ohio Pedologists, 2002
Citation for excellence in service to the GSA Hydrogeology Division, 2001
The Chairs Citation, Notable Achievement - Professional Service Award, University of Akron, 1999
Certificate of Merit, National Speleological Society, 1998
Graduate Fellowship, Cave Research Foundation, 1990
RASS Graduate Research Fellowship, 1989
Elected Fellow, National Speleological Society, 1989
Jeff Jefferson Research Award, British Cave Research Association, 1989
Ralph Stone Research Award, National Speleological Society, 1988
P.D. Krynine Fund, The Pennsylvania State University, 1984, 1985, 1988, 1989, 1990, 1991

Professional Affiliations & Responsibilities

Geological Society of America
(Editor of *Hydrogeologist* newsletter, 1997-2001)
(Chairman Historical Comm., Hydrogeo. Div., 1997)
(Nominating Comm., Hydrogeo. Div., 2003)
(Long Range Planning-Publicat. Comm., 1998-2002)
(Technical Prog. co-chair, North-Central Mtg., 2006)
(Co-editor, *Environmental & Engineering Geoscience*, 6/06-1/15)
(Ad Hoc Committee on Accreditation, 2007 - 2008)
(50th Anniversary Planning Comm., Hydrogeo. Div., 2007-2009)
(Hydro. Div. Dist. Serv. Award Comm., 2010-2012)
(Publications Ethics Advisory Committee, 1 July 2015 to 30 June 2018)

Editorial Board for journal *Environmental & Engineering Geoscience* (representing GSA's EEG Division, 11/17-11/20)
American Geophysical Union (1983-2012)
Association of Environmental & Engineering Geologists (AEG)
(Manager of Groundwater/Karst Technical Working Group, 2007-2010)
National Ground Water Association
(Reviewer for the journal *Ground Water*, 1992-1997)
(Associate Editor for journal *Ground Water*, 1997-2002)
American Association of Petroleum Geologists
(House of Delegates, 1996-2014)
(Academic Liaison Committee, 1997-2000)
(Faculty Sponsor, Akron Student Chapter, 1998-present)
(Matson Award Judge, 1998)
(Univ. Rep., East. Sect. Membership Comm., 1998-2001)
(HOD Nominations Committee, 8/00)
Cave Conservancy of the Virginias, Board Member (2005-2017)
National Speleological Society
(Earth Sci. Editor for *Journal of Cave & Karst Studies,* 1994-2009)
Theoretical & Applied Karstology (Associate Editor, 5/01-present)
Karst Waters Institute
(Board of Directors 1994-present)
(Vice-President for Communications, 1994-2009)
(Vice Chairman of Board, 2009-2010)
(Secretary, 2010-present)
(Awards Committee, 2010)
British Cave Research Association
National Association of Geoscience Teachers
Sigma Xi, The Scientific Research Society (1997-present)
Northern Ohio Geological Society
(Delegate to AAPG, 1996-2014)
(Member-at-large, 1998-1999, 2006)
American Library Association, Consultant-reviewer for *Choice* magazine
U.S. Environmental Protection Agency, Grant panel peer reviewer
USDA- expert committee for the development of a “Soil rating tool for soil-based stormwater management practices in West Virginia”, 2009.
Ohio Oil and Gas Energy Education Program, Geology Education Committee (2015-2016)
American Association of University Professors, Akron Chapter,
(Interim Treasurer, Fall 2013 - Spring 2014)
(Treasurer, Summer 2014 -Spring 2018; June 2020-xxxx)
(Geosciences Dept. Liaison, 2003-2009; Fall 2018-xxxx)
(Liaison repr. to Executive Committee, Fall 2019-June 2020)

Selected Publications

Edited Books

Sasowsky, I.D., Byle, M.J, and Land, L., (eds.), 2018, Proceedings of the 15th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst and the 3rd Appalachian Karst Symposium, April 2-6, Shepherdstown, West Virginia: NCKRI Symposium 7. Carlsbad, New Mexico: National Cave and Karst Research Institute, 425 p.

Klimchouk, A., Sasowsky, I.D., Mylroie, J.E., Engel, S.A, & Engel, A.S. (eds.), 2014, Hypogene Cave Morphologies: Special Publication 18, Karst Waters Institute, Leesburg, Va., 103 p.

Sasowsky, I.D., Feazel, C.T, Mylroie, J.E., Palmer, A.N., and Palmer, M.V. (eds.), 2008, Karst from recent to reservoirs: Special Publication 14, Karst Waters Institute, Leesburg, Va., 219 p.

Kranjc, A., Gabrovsek, F., Culver, D.C., and Sasowsky, I.D. (eds.), 2007, Time in Karst: Special Publication 12, Karst Waters Institute, Leesburg, Va., 243 p.

Sasowsky, I.D. and Mylroie, J. (eds.), 2004, Studies of Cave Sediments: Physical and Chemical Records of Paleoclimat*e*: Kluwer Academic/Plenum Publishers, New York, 329 p.

Martin, J.B., Wicks, C.M., and Sasowsky, I.D. (eds), 2002, Hydrogeology and biology of post-Paleozoic carbonate aquifers: Special Publication 7, Karst Waters Institute, Charles Town, West Va., 211 p.

Culver, D.C., Deharveng, L., Gibert, J., and Sasowsky, I.D. (eds.), 2001, Mapping subterranean biodiversity: Proceedings of an international workshop held March 18 through 20, 2001, Moulis, France, The Karst Waters Institute, Charles Town, West Va., 82 p.

Sasowsky, I.D. and Wicks, C.M. (eds.), 2000, Groundwater flow and contaminant transport in carbonate aquifers: A.A. Balkema, Rotterdam, 193 p.

Palmer, A.N., Palmer, M.V., and Sasowsky, I.D. (eds.), 1999, Karst Modeling: Proceedings of the symposium held February 24 through 27, 1999, Charlottesville, Virginia, The Karst Waters Institute, Charles Town, West Va., 118 p.

Sasowsky, I.D. Fong, D.W., and White, E.L. (eds.), 1997, Conservation and protection of the biota of karst: The Karst Waters Institute, Charles Town, West Va., 118 p.

Sasowsky, I.D. and Palmer, M.V. (eds.), 1994, Breakthroughs in karst geomicrobiology and redox geochemistry: The Karst Waters Institute, Charles Town, West Va., 111 p.

Papers

Kambesis, P., Sasowsky, I.D., and Moore, B.P., 2020, Sinkholes and karst in Puerto Rico; picturesque and problematic, in: Land, L., Kromhout, C., and Byle, M. (eds.), Proceedings of the 16th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, San Juan, Puerto Rico: NCKRI Symposium 8. Carlsbad, New Mexico: National Cave and Karst Research Institute, p. 278-286.

Sasowsky, I.D., and Alexander, E.C. Jr., 2020, Sinkholes developed in sandstone, in: Land, L., Kromhout, C., and Byle, M. (eds.), Proceedings of the 16th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, San Juan, Puerto Rico: NCKRI Symposium 8. Carlsbad, New Mexico: National Cave and Karst Research Institute, p. 307-314.

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Kosič Ficco, K., and Sasowsky, I. D., 2018, An interdisciplinary framework for the protection of karst aquifers *Environmental Science and Policy,* v. 89, p. 41-48.

Shank, D.A., Fucci, M.C., and Sasowsky, I. D., 2018, Windy Mouth Cave. In: White, W.B. (ed.), *Caves and Karst of the Greenbrier Valley in West Virginia,* Springer, Berlin, p. 313-337,

Lane, S., Bishop, M.R., Dore, M.J., and Sasowsky, I. D., 2018, Scott Hollow Cave. In: White, W.B. (ed.), *Caves and Karst of the Greenbrier Valley in West Virginia*, Springer, Berlin, p. 339-357,

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Watts, A. M. and Sasowsky, I. D., 2016, Apparent glacially induced structural controls on limestone conduit development in Ohio Caverns, United States: *International Journal of Speleology,* v. 45, no. 1, p. 59-69.
Schmidt, V.A., Sasowsky, I.D., and Storrick, G.D., 2015, Paleomagnetism of clastic sediments from Breathing Cave, Virginia, USA, in: White, W.B. (ed.), *The caves of Burnsville Cove, Virginia: Fifty years of exploration and science*: Springer, p. 360-364.

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Carbonel, D., Rodriguez, V., Gutierrez, F., McCalpin, J.P., Linares, R., Roque, C., Zarroca, M., Guerrero, J., Sasowsky, I.D., 2014, Evaluation of trenching, ground penetrating radar (GPR) and electrical resistivity tomography (ERT) for sinkhole characterization: Earth Surface Processes and Landforms, v. 39, no. 2, p. 214-227.

Sasowsky, I.D., 2012, Paleomagnetic Records in Cave Sediments, in: White, W.B. and Culver, D.C (eds.), *Encyclopedia of Caves*, 2nd ed., Elsevier-Academic Press, Chennai, India, p. 585-590.
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Bosak, P., Knez, M., Pruner, P., Sasowsky, I.D., Slabe, T, and Sebela, S.2007, Paleomagnetic research of unroofed caves opened during the highway construction at Kozina, SW Slovenia: Annals for Istrian and Mediterranean Studies, v. 17, no. 2, p. 249-260.

Sebela, S. and Sasowsky, I.D., 2007, Starost jamskih sedimentov Brezstropih Jam odprtih pri Gradnji avtoceste pr Kozini (Jugozahodna Slovenija), dolocena s paleomegnetimi analizami [The age of cave sediments from unroofed caves opened during highway construction near Kozina (SW Slovenia), determined with paleomagnetic analyses], in: Knez, M. and Slabe, T. (eds.), Kraski pojavi, razkriti med gradnjo Slovenskih avtocest [Karst features uncovered during construction of Slovene Highways]: Carsologica 7, Institut rasiskovanje krasa ZRC SAZU, Ljubljana, Slovenija, p. 195-200.

Sasowsky, I.D., 2007, Clastic sediments in caves - imperfect recorders of processes in karst in: Kranjc, A., Gabrovsek, F., Culver, D.C., and Sasowsky, I.D. (eds.), Time in Karst: Special Publication 12, Karst Waters Institute, Leesburg, Va., p. 143-149.

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Clark, G.M., Kohl, M., Moore, H.L., and Sasowsky, I.D., 2005, The Gray Fossil Site: An spectacular example in Tennessee of ancient regolith occurrences in carbonate terranes, Valley and Ridge subprovince, southern Appalachians, U.S.A., in: Beck, B.F., *Sinkholes and the engineering and environmental impacts of karst - proceedings of the 10th conference*: American Society of Civil Engineers, Reston, Virginia, Geotechnical Special Publication No. 144, p. 82-90.

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de Chambeau, A.L. and Sasowsky, I.D., 2003, Using information literacy standards to improve geoscience courses: *Journal of Geoscience Education,* v. 51, no. 5, p. 490-495.

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Salvati, R. and Sasowsky, I.D., 2002, Development of collapse sinkholes in areas of groundwater discharge: *Journal of Hydrology,* v. 264, p. 1-12.

Sebela, S. and Sasowsky, I.D., 2000, Paleomagnetic dating of sediments in caves opened during highway construction near Kozina, Slovenia: *Acta Carsologica*, v. 29, no. 2, p. 303-312.

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Sasowsky, I.D., Foos, A., and Miller, C.M., 2000, Lithic controls on the removal of iron and remediation of acidic mine drainage: *Water Research*, v. 34, no. 10, p. 2742-2746.

Sasowsky, I.D., 2000, Carbonate aquifers: A review of thoughts and methods, in: Sasowsky, I.D. and Wicks, C.M. (eds.), *Groundwater flow and contaminant transport in carbonate aquifers*, A.A. Balkema, Rotterdam, p. 1-14.

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Sasowsky, I.D., 1999, Structural controls on carbonate aquifers, in: Palmer, A.N., Palmer, M.V., and Sasowsky, I.D. (eds.), *Karst Modeling: Proceedings of the symposium held February 24 through 27, 1999, Charlottesville, Virginia*, Karst Waters Institute Special Publication 5, Charles Town, West Virginia, p. 38-42.

Ramage, J.M., Gardner, T.W., and Sasowsky, I.D., 1998, Early Pleistocene glacial Lake Lesley, West Branch Susquehanna River Valley, Central Pennsylvania: *Geomorphology*, v. 22, no. 1, p. 19-37.

Sasowsky, I.D., 1998, Cave formation: Determining the age of what is not there: *Science*, v. 279, p.1874.

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EXHIBIT B

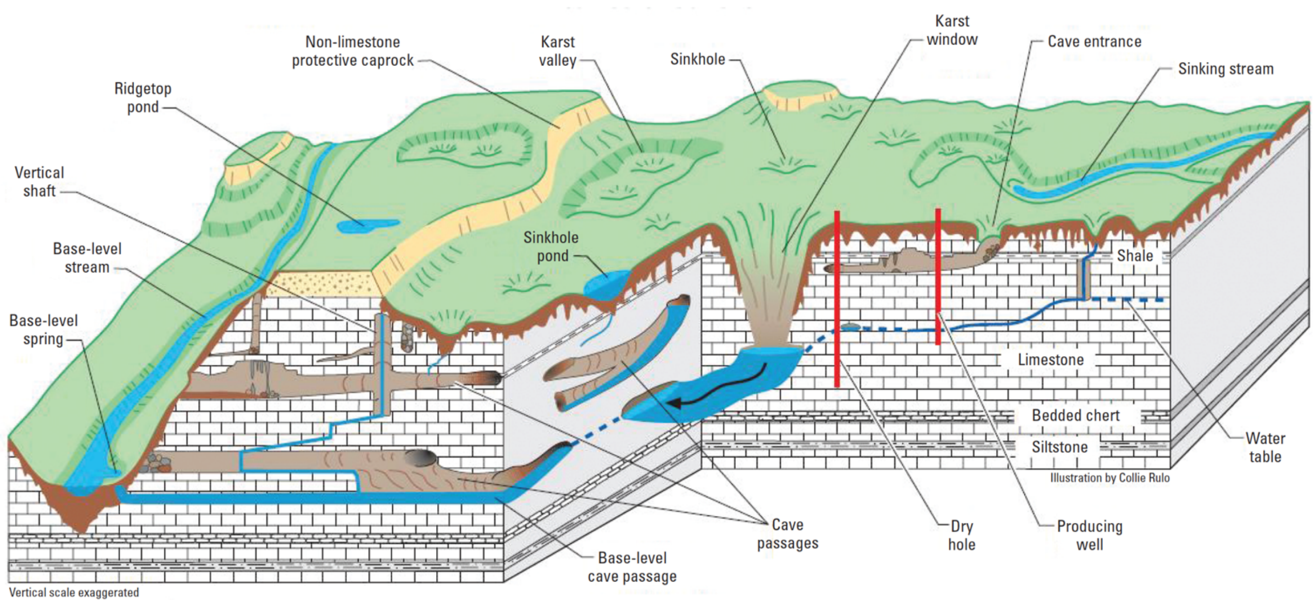
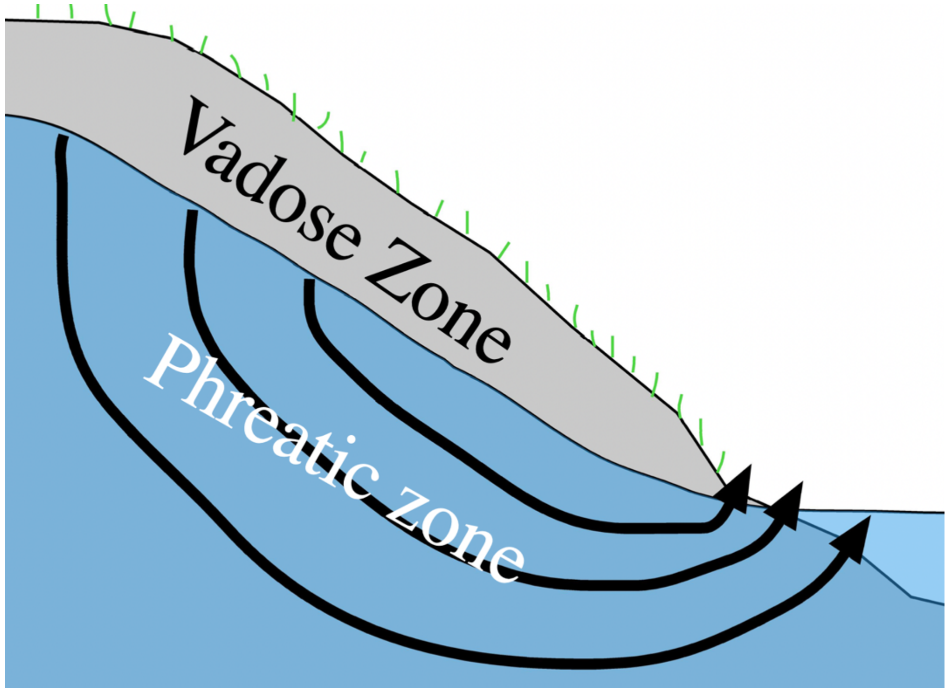


Exhibit B: Block diagram showing typical karst features and drainage. Source: Figure 1 in Taylor, Charles J., and Earl A. Greene. "Hydrogeologic characterization and methods used in the investigation of karst hydrology." US Geological Survey (2008). Chapter 3 of Field Techniques for Estimating Water Fluxes Between Surface Water and Ground Water, Edited by Donald O. Rosenberry and James W. LaBaugh, Techniques and Methods 4–D2

EXHIBIT C



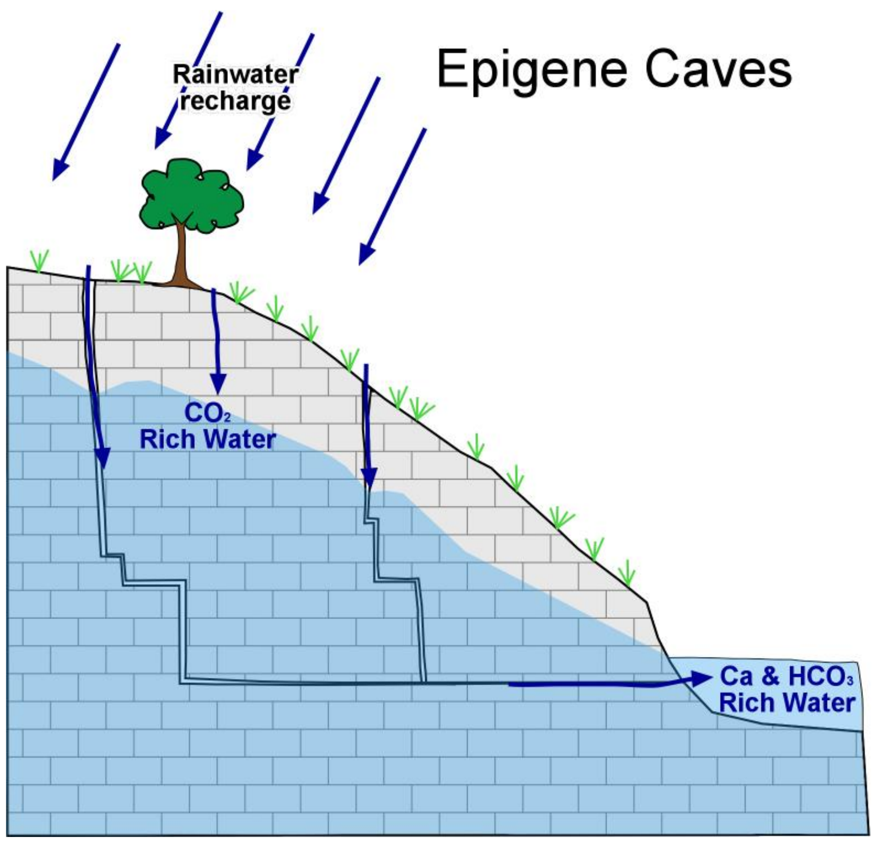


Exhibit C. Schematic cross-sections of groundwater movement underneath a hillside in (top) non-carbonate rocks, (bottom) carbonate rocks.

EXHIBIT D

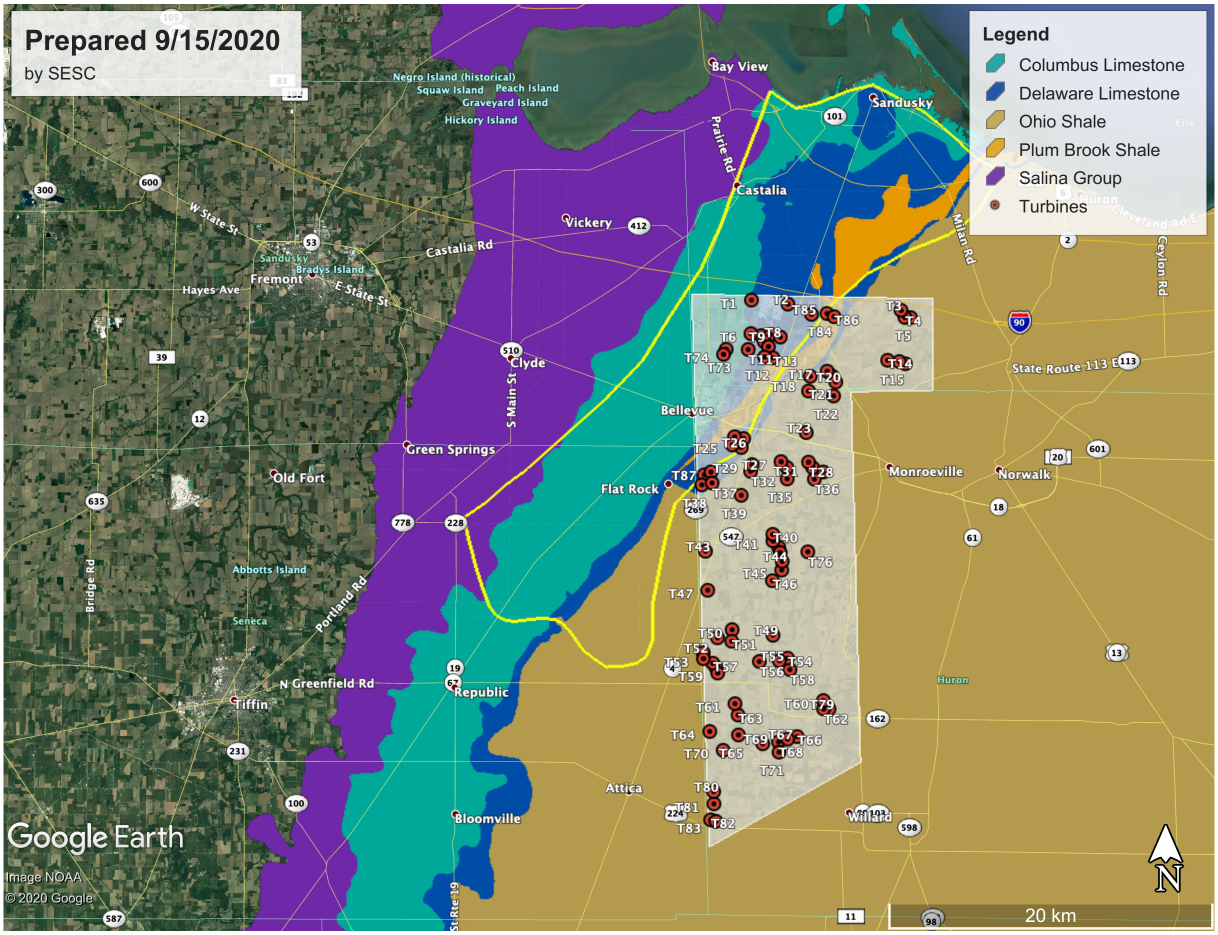
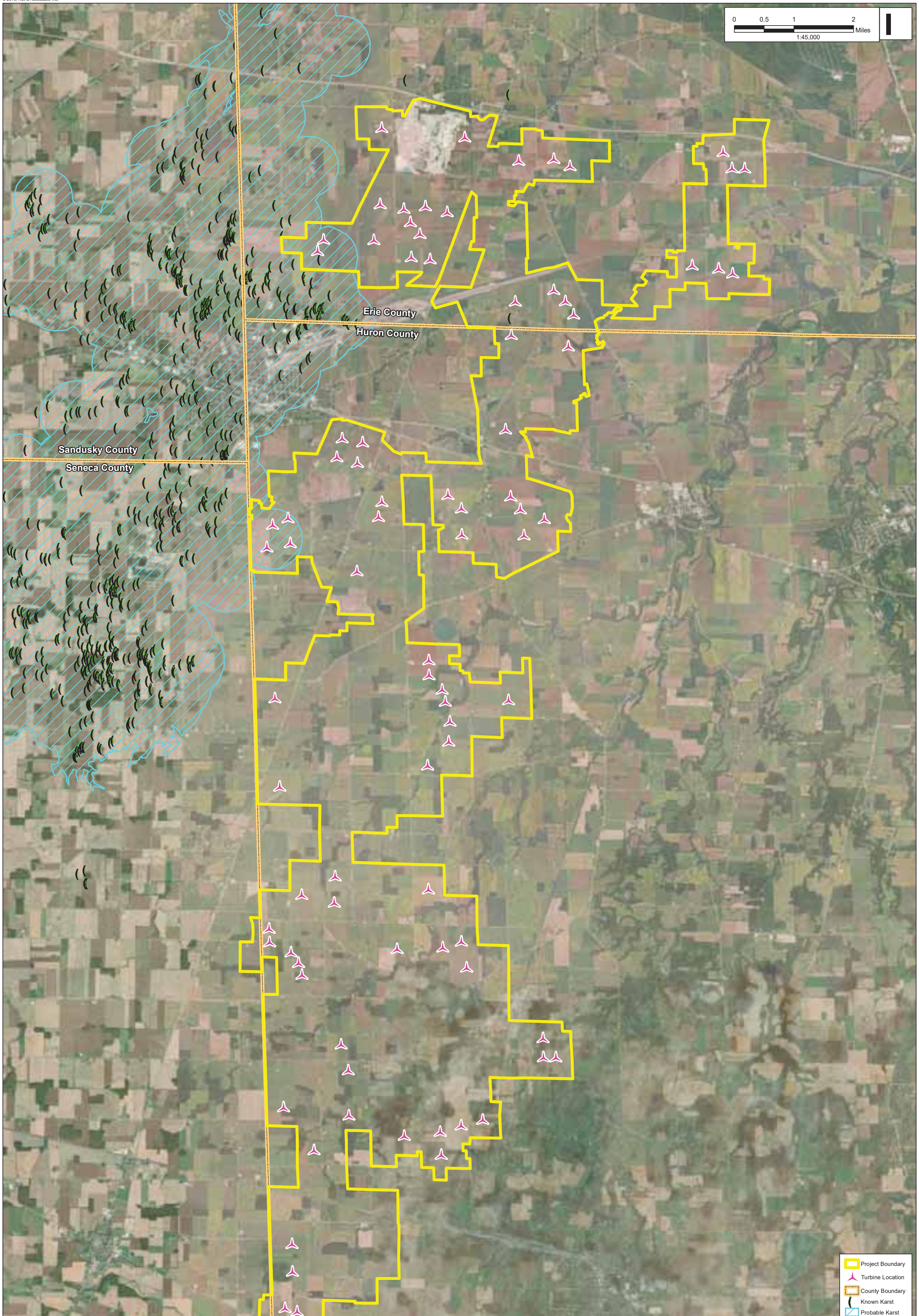


Exhibit D: Map showing pertinent features in proposed Emerson Wind project area. Illustrated are the project area outline (white shaded polygon, source: Fig. 7, RRC Geotechnical Report), proposed locations of Emerson Wind turbines (red circles), traditional boundary of Bellevue-Castalia Karst Plain (yellow line), and bedrock geologic units (colored polygons). Karst Plain boundary is from ODNR map: Physiographic Regions of Ohio - Ohio Geological Survey. Bedrock data from: https://mrdata.usgs.gov/geology/state/state.php?state=OH

EXHIBIT E



Notes:
The aerial photo was acquired through the ESRI Imagery web service. Aerial photography dated 2015.

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January 2019

Emerson Creek Wind Project

Karst Map

Huron, Erie, and Seneca Counties, Ohio

Figure 4

Produced using ArcGIS 10.5

File Name: ACX006_01_Fig04_Karst.mxd

Edited: 1/4/2019 By: rkaip

EXHIBIT F

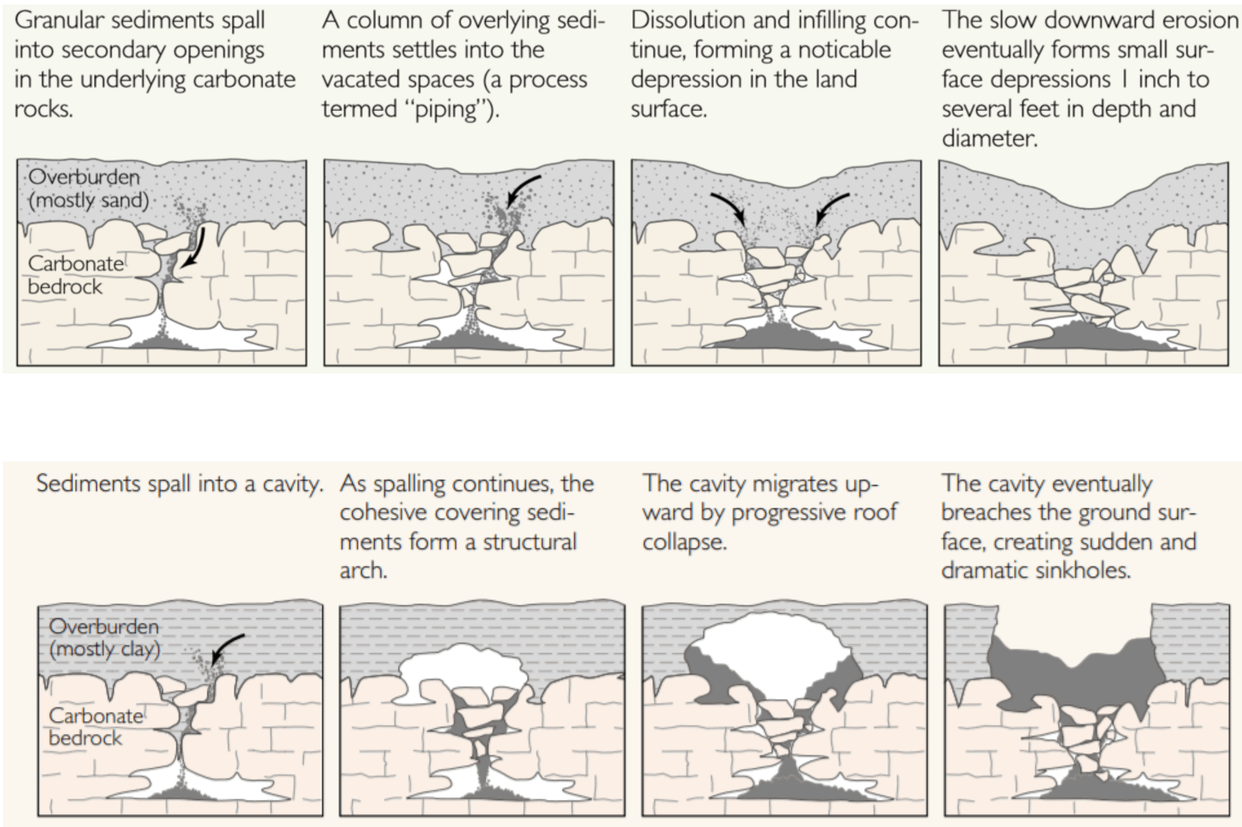


Exhibit F: Diagrams showing mechanisms of cover subsidence (top) and cover collapse (bottom)sinkholes. Source: U.S. Geological Survey, https://www.usgs.gov/special-topic/water-science-school/science/sinkholes

EXHIBIT G

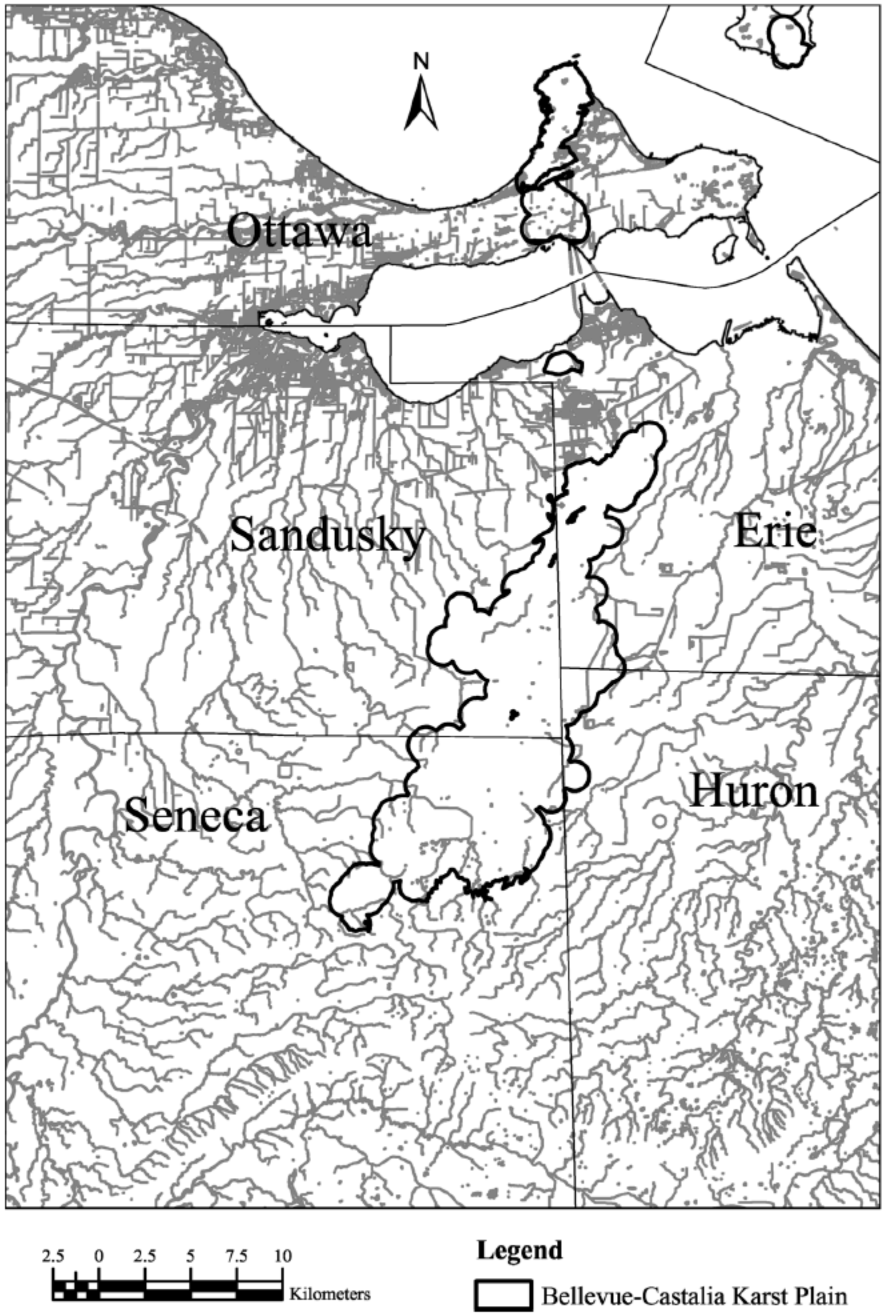


FIG. 5. Drainage network map, showing lack of surface streams within the Bellevue-Castalia Karst Plain.

Exhibit G: Drainage network map, showing lack of surface streams within portions of the 4 County area. From: Sasowsky, I. D., Dinsmore, M. A., Salvati, R., Bixby, R., Raymond, H., and Mazzeo, P., 2003, Subtle but significant karst on the glaciated Bellevue-Castalia Karst Plain, Ohio, USA, in Beck, B. F., ed., Sinkholes and the engineering and environmental impacts of karst (Geotechnical Publication No. 122)

EXHIBIT H

Ira Daniel Sasowsky

CONTAMINATION OF UNDERGROUND WATER in the BELLEVUE AREA

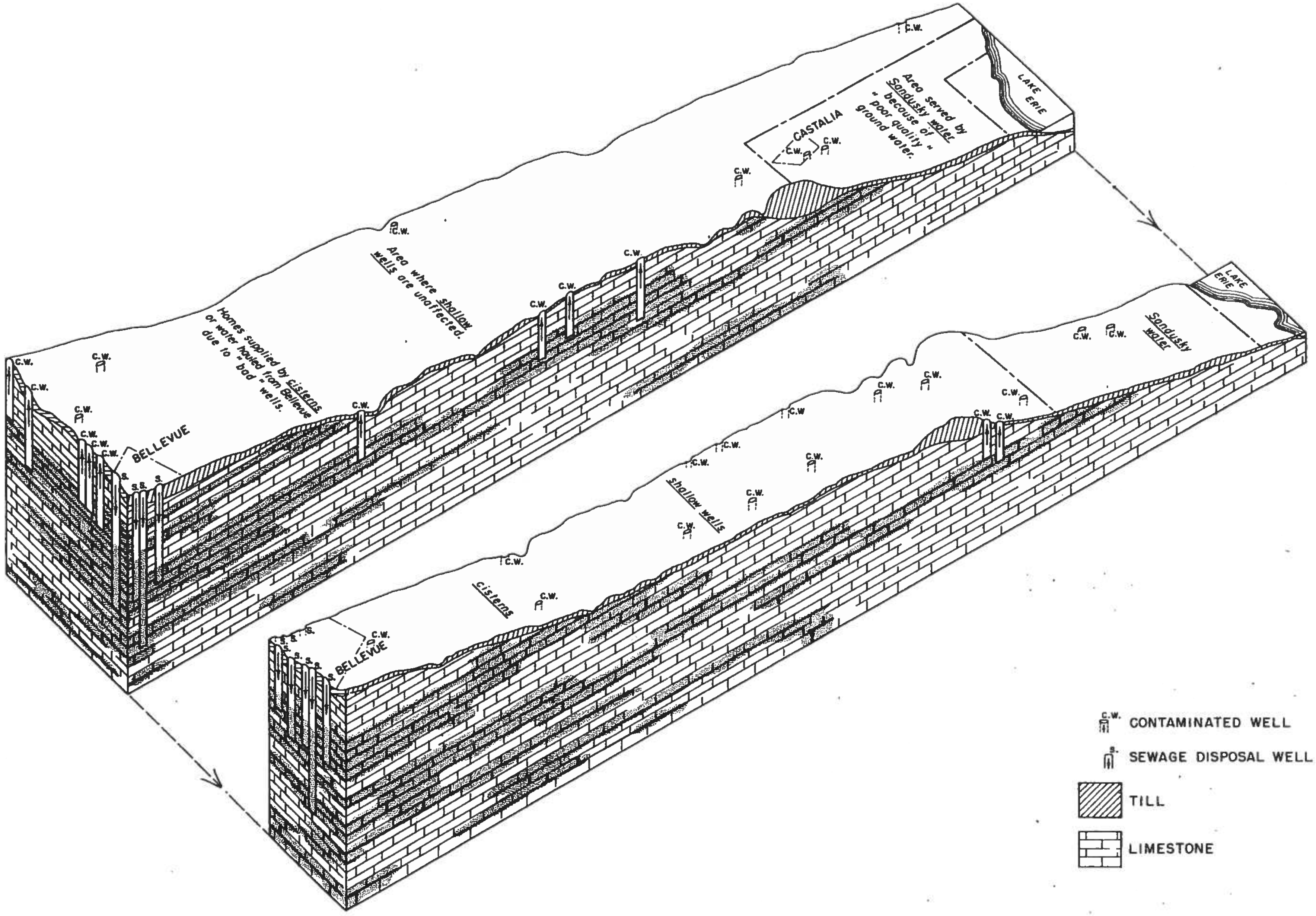
A Report Prepared For The

OHIO WATER COMMISSION

by the

GROUND-WATER GEOLOGY SECTION
OHIO DIVISION OF WATER

Columbus, Ohio
June 1961



BLOCK DIAGRAM, SHOWING GROUND-WATER CONTAMINATION IN THE BELLEVUE AREA.

CONTENTS

TABLES

ILLUSTRATIONS

I. INTRODUCTION

A report, presented to the Ohio Water Commission in October 1960, pointed out that contamination is introduced in the Bellevue area through wells drilled for sewage disposal. Mention was made of 84 sewage disposal wells drilled within the city in the past seven years; contaminated water wells north of Bellevue in Sandusky and Erie Counties; and, the extremely porous nature of the limestone aquifer which permits contamination to spread over wide areas. This was based largely upon logs of disposal wells drilled for individuals and housing developments.

At that time, members of the Water Commission suggested that a more complete investigation be made of the Bellevue area for the purpose of determining the extent of underground-water contamination.

During the first four months of 1961, field investigations were made by Alfred C. Walker, James J. Schmidt, Henry L. Pree, and Russell B. Stein, geologists of the Ohio Division of Water. Donald Day, Assistant Sanitary Engineer, Ohio Department of Health, assisted in collecting water samples for analysis. Chemical analyses of water samples were made by the staff of the U.S. Geological Survey Quality of Water Laboratory, Columbus, and bacteriological analyses by the Ohio Department of Health laboratory. Additional analyses were supplied by personnel in the health offices of Erie and Sandusky Counties.

During the course of this study, all available well logs and water analyses were collected and studied; water well drillers and well owners were interviewed; old records were studied; and, all complaints were investigated. Mrs. Lydia Rickerds, R.N., Bellevue; George A. Hall, Ohio Water Pollution Control Board; Professor George Hanna, Water Resources Center, O.S.U.; Bruce McDill, Ohio Department of Health;

George Whetstone, U.S. Geological Survey, and many others, including residents of the Bellevue area, offered helpful advice.

A more complete study of this problem might take several years and involve test drilling and continuous sampling. However, we feel that the results of this four-month study show that:

(1) A large portion of a potential industrial aquifer has been rendered unuseable.

(2) Contamination of this water source can be directly attributed to underground sewage disposal from Bellevue.

(3) Continued dumping of contaminants will worsen this already deplorable situation.

Disposing of sewage and other wastes underground is much like sweeping dirt under the rug. It's out of sight, but it's still there.

There is little difference between waste disposal into a ground-water mass and waste disposal into a surface water mass. Although it may be temporarily out of sight, contamination of ground water is far more serious than similar contamination of surface waters. Underground water moves so slowly that years may pass before the contamination is detected. Once it has occurred, it may require many more years before the water is again free from contamination.

II. BACKGROUND

In the city of Bellevue (population 8286), practically every dwelling and industrial plant is provided with a well for the purpose of disposing of sewage.

Wells ranging from 35 feet to 270 feet deep discharge toilet flushings, restaurant and laundry washings, kitchen sink garbage, bath water, mortuary and hospital refuse, etc., into the limestone beneath this area.

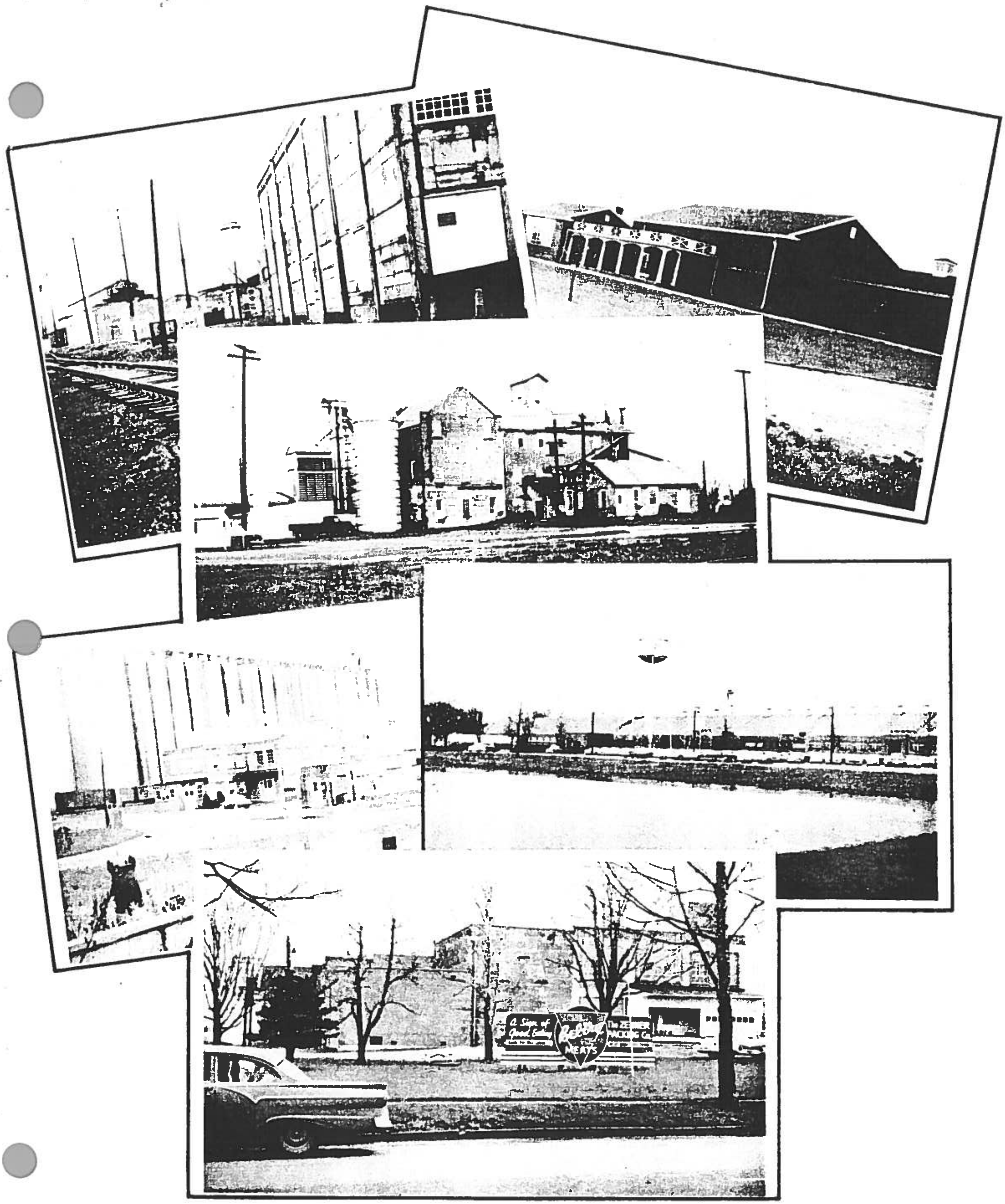
There are more than 1400 privately owned sewage disposal wells, or sinkholes, within the city and more than 200 municipally operated disposal wells, all using the porous limestone bedrock as a sewer. This system comprises what is probably the most concentrated area of underground sewage disposal in the United States.

Contaminated water wells have been reported in the Bellevue area for over 40 years. However, city wells, which were used to supplement the surface water supply, were apparently unaffected until 1944.

A brief resume of the history of Bellevue's water supply is given below.

1872 Water supply system established for the city. Surface source.

1919 A report on proposed improvements of the public water supply states, "The disposal of sewage is effected in a very unusual manner without the use of sewers; by discharging the sewage into so-called sinkholes or drilled wells penetrating the open limestone formations underlying this locality. This method of sewage disposal is quite generally practiced throughout the city and results in rendering drilled wells unsafe sources of water supply."



Industries and public buildings in Bellevue also dispose of sewage underground.

1932 Water well drilled as an auxiliary water source.

1937 Four storage reservoirs are insufficient to serve the city. Wells drilled to supplement them.

Engineer's report states that during the (1937) flood, ".... a large number of sinkholes containing sewage overflowed and the area immediately surrounding, and for miles north, was polluted with sewage. Analyses of well and cistern water in this area showed a large percentage to be contaminated."

1941 Two additional wells drilled to supplement city water supply. These wells were reported to yield a combined supply of 1050 gallons per minute from depths of around 200 feet.

Water from well (125 feet deep) at France quarry was found to be contaminated. This well was located 0.2 mile west of the city limits and produced 300 gpm.

1942 New city well drilled at water works.
Total depth: 137 feet. Yield: 500 gpm. Total hardness: 408 ppm.

1944 City water wells show contamination.

Plans for developing 500,000 gallons per day ground-water supply for soybean processing plant abandoned due to contaminated water obtained at depth of 230 feet.

1945 City plans to abandon wells.

Plans being considered to install adequate sewerage and drainage facilities.

1946 Soybean plant opens using city water and 230-foot sewage disposal well. Additional upground reservoir built by city. City wells abandoned. All industrial wells in the city abandoned.

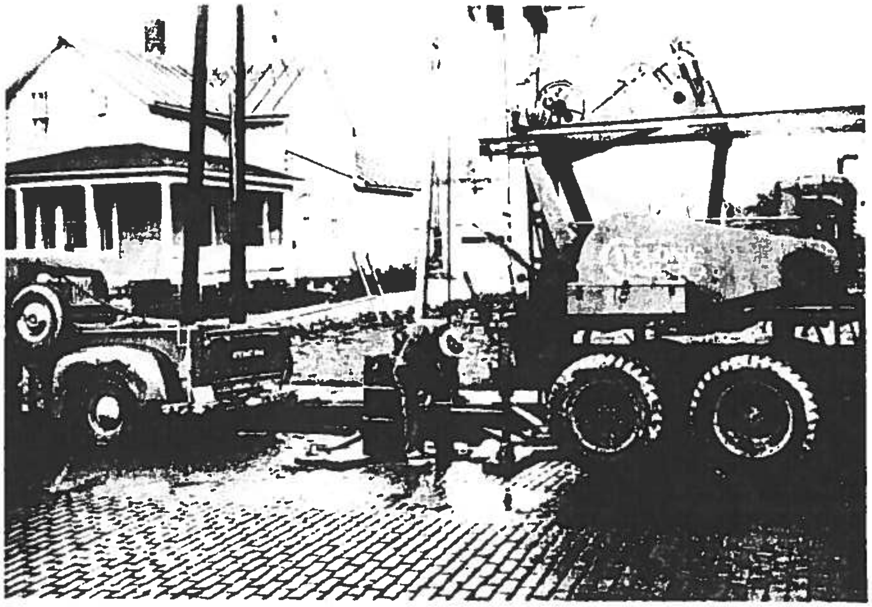
1947 Plans for sewerage abandoned due to excessive cost.

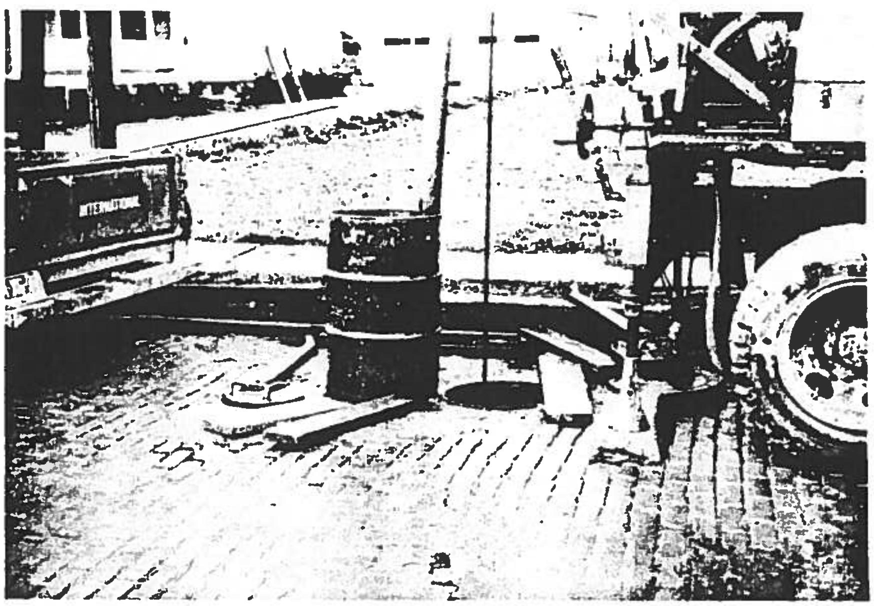
1954 Water supply capacity enlarged to 4 million gallons per day.

Until recent years, all waste in the city was disposed of directly into drilled wells. Local well drillers reported that, in time, those old wells became completely plugged with sewage and it was necessary to redrill them to remove the "sewage plug" so they would again permit free flow into the limestone. With the increased use of detergents for household use, plugging is reportedly no longer a major problem, although it still occurs.

Household sewage has clogged this disposal well. Re-drilling will again permit free flow into the underlying limestone formations.

The "modern" method of sewage disposal consists of a septic tank installation with the effluent from the tank flowing into a disposal well. Although a portion of the suspended matter has settled out, the remaining suspended matter and matter in solution is still present in septic tank effluent. It was not determined what means is used to dispose of the sludge from these septic tanks.





Buckeye Street, Bellevue

A city storm drainage disposal well has become clogged and is being re-drilled.

Although the Bellevue system of sewage disposal is a vestige of the 19th century, it is not unique in the United States. Nearly the entire State of Florida is underlain by limestone, which provides large supplies of ground water. Since the turn of the century, drainage wells have been drilled for waste disposal into limestone aquifers. This has resulted in continual contamination of ground-water supplies in many areas. In 1913, an act was passed by the Florida legislature to prohibit pollution of surface and ground waters. Although this law provided criminal penalties for its violation, it had no provisions for injunctive enforcement. This loophole was remedied by an amendment in 1955 which has proven helpful to the State Board of Health in its work of underground-water pollution control. (See appendix.) Last year the city of Live Oak, one of Florida's worst offenders for 56 years, completed an adequate sewage disposal system and has abandoned the use of disposal wells.

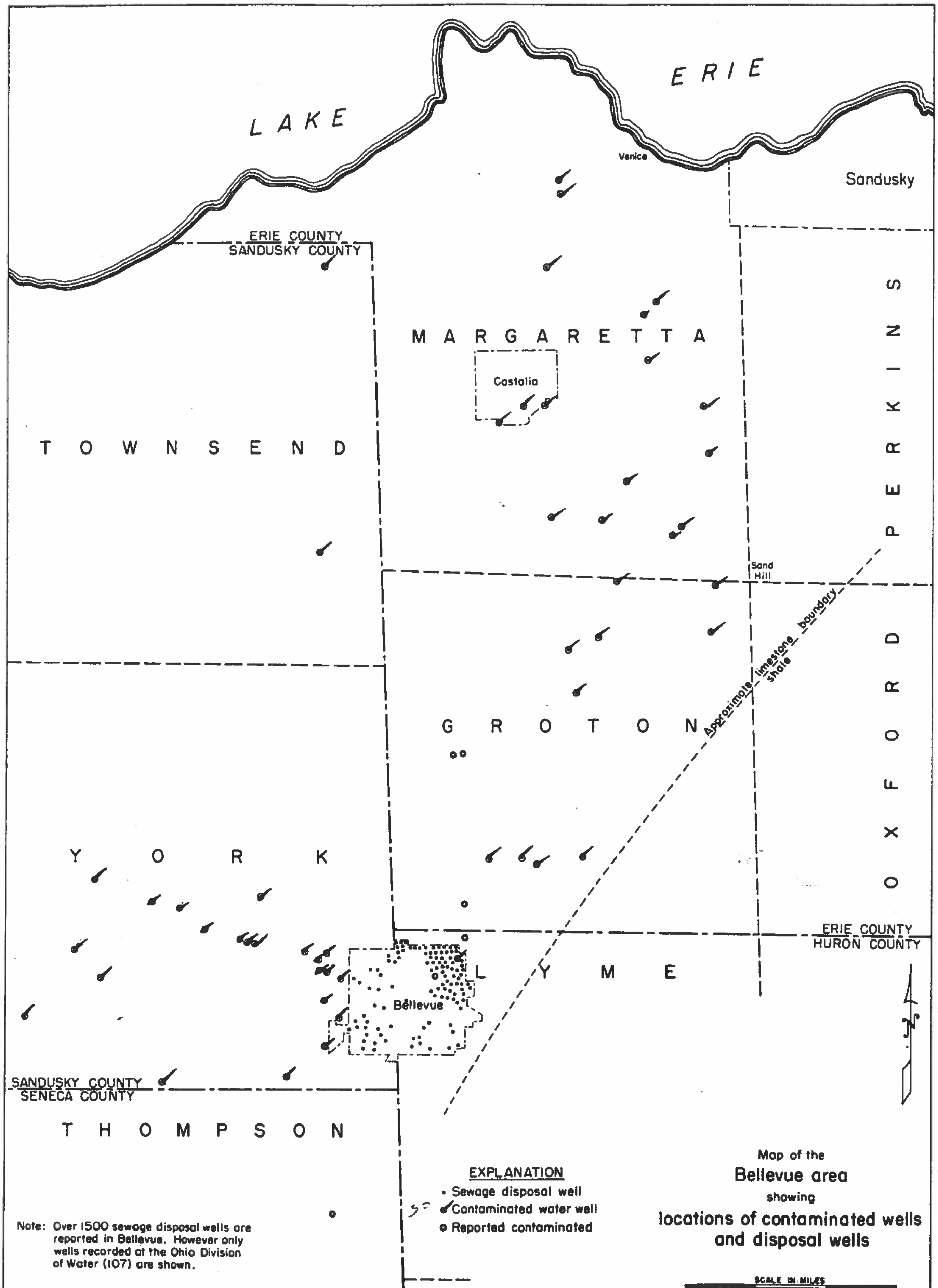
III. PRESENT STUDY

When the investigation was started, it was assumed that contamination introduced through disposal wells in Bellevue was compounded by additional disposal wells beyond the city limits. Field investigations have since shown this to be untrue. Very few disposal wells are in operation outside of the city.

A survey of 52 homes in Groton Township, Erie County, revealed that only one home uses a well, or sinkhole, for sewage disposal. Numerous disposal wells reported in Lyme Township, Huron County, were all found to be located within the city limits. None are known to exist elsewhere in this township. Wells and natural sinkholes were formerly used west of Bellevue in York Township, Sandusky County. In recent years, however, these have been replaced by septic tanks and leaching tile fields under the direction of the Sandusky County health authorities. Thus, with very few exceptions, the only direct underground contamination in the entire area is from Bellevue proper. The locations of disposal wells determined by this survey are shown on page 10.

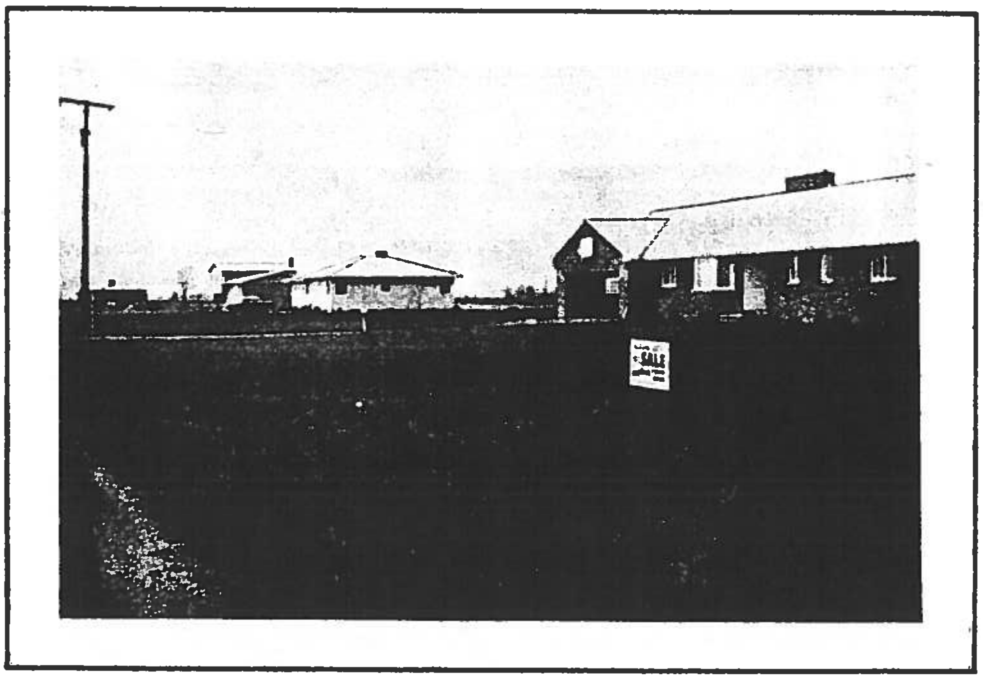
Probably the most serious danger associated with domestic sewage is the possible presence of pathogenic micro-organisms. Recent studies of domestic sewage have shown viruses to be another danger. Professor W. L. Mallman, Michigan State University, has indicated that viruses can travel great distances in ground water and that chlorine is ineffective against them.

This same study shows that in granular materials, such as sandstone, bacteria will travel only a few feet from the point of entry. However, in limestone aquifers, where free movement is not restricted, the


LAKE
ERIE
Venice
Sandusky
ERIE COUNTY
SANDUSKY COUNTY
MARGARETTA
Castalia
TOWNSEND
PERKINS
Sand Hill
Approximate limestone shale boundary
GROTON
OXFORD
YORK
ERIE COUNTY
HURON COUNTY
LYME
Bellevue
SANDUSKY COUNTY
SENECA COUNTY
THOMPSON
EXPLANATION
• Sewage disposal well
Contaminated water well
o Reported contaminated
Note: Over 1500 sewage disposal wells are reported in Bellevue. However only wells recorded at the Ohio Division of Water (107) are shown.
Map of the
Bellevue area
showing
locations of contaminated wells and disposal wells
SCALE IN MILES
0
1
2
3

travel of bacteria is limited only by the extent of the water-bearing joints and solution channels in the rock. In most aquifers, particularly in limestone aquifers, the horizontal permeability is much greater than the vertical permeability.

A major difficulty in this study has been in obtaining samples of water from contaminated, or reportedly contaminated, wells. It is a common practice for well drillers or homeowners to abandon and plug a water well that is found, or suspected, to be unsafe. Thus, in most instances where the local health district has a record of an unsafe water well, our field investigators have been unable to collect additional samples for further analyses. Stories have been relayed to us during this investigation of wells which yielded easily recognizable raw sewage (including toilet tissue) while being drilled. Others have foamed because of high detergent content, and, still others, the contents of which are best left to the reader's imagination! Needless to say, these wells had all been immediately plugged and abandoned, so our investigators have no first-hand information.



These new homes, north of Bellevue, have no water wells because of ground-water contamination. Water is hauled in by tank truck to supplement inadequate cistern supplies.

Because of the poor quality of the ground water available north of Bellevue, many homeowners and builders have made no attempt to develop well supplies. A number of new homes built in southwestern Groton Township, Erie County, use cisterns for their household water supplies. When adequate supplies are not available from rainwater, water is hauled from Bellevue. Although twenty years ago, yields of as much as 500 gallons per minute were obtained from wells in the underlying limestones, today homes must rely upon inadequate cistern supplies. Similar quantities can still be expected, but the quality is too poor for use.

In northern Groton Township, shallow wells are apparently unaffected by contamination and they are commonly used as sources of domestic water supply. Many of the homeowners, however, chlorinate their water supplies before using, "just to be safe." Deep wells (greater than 60 feet) are reported to produce water of poor quality.

The northern part of Margaretta Township, Erie County, is served by water piped from the Sandusky water plant because of "inadequate" well supplies in this area. Records of wells on file at the Division of Water indicate this to be a quality inadequacy, rather than insufficient quantity.

A number of wells in York Township, Sandusky County, have been found unsafe and are now chlorinated before being used, although chlorination as a "cure-all" for sewage-contaminated wells is questionable.

A brief discussion of some chemical constituents, which are possible sewage indicators, follows.

Ammonia

In pure form ammonia is a colorless gas. In ground waters it generally results from the decomposition of nitrogenous organic matter. If present in ground waters in appreciable amounts (0.2 ppm), it provides strong presumptive evidence of the presence of sewage or sewage effluent, especially if there is also a rise in the chloride content. The Royal Commission on Sewage Disposal (Gt. Britain) stated in the 8th annual report that, "the most delicate chemical index of recent sewage pollution in water is the increase in the figure for ammoniacal nitrogen."

An interesting sidelight is the fact that water with traces of ammoniacal nitrogen has a high chlorine demand and requires much longer contact periods for satisfactory sterilization.

No limits have been set by the USPHS Drinking Water Standards for ammonia, but in 1938 Swiss standards for drinking water gave maximum content of free ammonia as 0.02 ppm.

Although free ammonia is often of vegetable or mineral origin and without hygienic significance, its concentration in excess of 0.10 ppm renders the water suspect of recent pollution.

Nitrites

In water, nitrites are generally formed by the action of bacteria upon ammonia and organic nitrogen. Owing to the fact that they are quickly oxidized to nitrates, they are seldom present in water in significant concentrations. In conjunction with ammonia and nitrate, nitrites in water are often indicative of pollution.

No standards have been set for nitrite in drinking water. A generally accepted limit in domestic water supplies is 2.0 ppm.

<u>Nitrate</u>

Nitrates are the end product of aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification. In a few instances, nitrates may be added to underground water by natural weathering processes involving nitrate salts.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in water. Reported as nitrates, concentrations of 20 ppm and 70 ppm have caused serious cyanosis in children.

No drinking water standards were set in the 1946 USPHS standards. However, the recommended standards of 1960 contain the following statement concerning nitrate:

"High nitrate content in private wells has been reported to cause methemoglobinemia in infants, but public supplies have not been involved. Although precise limits have not been established, it is generally agreed that water containing more than 10-20 ppm of nitrate as nitrogen should not be used to feed infants. The committee believes, therefore, that a recommended limit of 10 ppm nitrate nitrogen should be set. If the nitrate content of the water exceeds the recommended limit, the public and the medical profession should be informed."

The process of nitrification is also reversible. When the dissolved oxygen content of a water falls to zero, nitrates may supply the combined oxygen to bacteria and be reduced in the process.

$$NO_3 \longrightarrow NO_2 \longrightarrow NO \longrightarrow N \longrightarrow NH_2 \longrightarrow NH_3$$

This process occurs in ground water when the dissolved oxygen is depleted either by bacterial action or chemical decomposition. Anaerobic bacteria could utilize the combined oxygen in nitrate and initiate the process.

Anionic Detergent

Detergents contain surface-active agents along with wetting, dispensing, and emulsifying agents. They do not form insoluble compounds with calcium and magnesium ions in water and are generally preferred to soap which forms insoluble compounds with these ions. More than 75% of synthetic detergents in household use are the anionic type, alkyl benzene sulfonate (ABS).

Because reports of contamination of water supplies by detergents are becoming more common, standards have been proposed. The recommended limit of 0.5 ppm as ABS was set on the basis that beyond this limit water so contaminated may exhibit foaming. Actually, the presence of any ABS in ground water above 0.1 ppm is indicative of pollution.

Prior to the water quality survey of ground water in the vicinity of Bellevue, nine ground water samples had been collected in Erie, Sandusky, and Huron Counties in connection with other projects. A brief summary of these analyses is given in the following table:

Table 1

Chemical constituents in ppm

	Max.	Min.	Median
Dissolved solids	1,560	38	--
Total hardness	2,500	370	--
Nitrate (NO_3)	7.0	0.0	0.1
Chloride (Cl)	596	6.8	12

Determinations of ammonia nitrogen and nitrite nitrogen were not made in connection with these studies.

During February, March and April 1961, a series of ground water samples were collected in the vicinity of Bellevue, Ohio. Thirty-two samples were collected and the pertinent analytical results are given in table 2.

Table 2

February - April 1961 Survey

Chemical constituents, in ppm

	Max.	Min.	Median
Dissolved solids	1,000	150	430
Ammonia as NH_4	2.7	0.0	0.1
Nitrite (NO_2)	12	0.0	0.5
Nitrate (NO_3)	158	0.5	25
Chloride (Cl)	146	5.0	--
ABS	0.7	0.0	0.1

Of the 32 samples collected in the vicinity of Bellevue, 27 contained ammonia. Nine of the samples contained more than 0.3 ppm of ammonia. Approximately one-half of the samples analyzed contained detectable amounts of nitrite nitrogen.

All samples contained nitrate. The maximum amount in ground water in Bellevue, 158 ppm, was found in the Thomas well. This well contained 0.3 ABS and 0.1 ppm ammonia.

Alkyl benzene sulfonate (ABS) was detected in 22 of the 32 samples collected in the study area. The highest concentration observed was in a sample from the Lyons well, 0.7 ppm. Phosphates are present in all well waters. The highest phosphate concentrations were generally associated with the samples with the highest ABS concentrations. This is to be expected since phosphates are generally used as "builders" in commercial synthetic detergents.

There was no correlation between chlorides and nitrates in the study area. The sample with the highest nitrate (Thomas well) contained 36 ppm of chloride. The highest observed chloride (146 ppm) was associated with a sample (Bunting well) containing one of the highest ammonia (0.6 ppm as NH_4) concentrations. However, this sample contained only 1.3 ppm of nitrate and 0.15 ppm of nitrite.

Samples collected in Bellevue during February 1961 contain nitrate concentrations which range from 0.6 ppm and 38 ppm. The samples were collected during an extended period of below freezing temperatures. During this period the ground water reservoir was at least partially cut off from surface water recharge. During March the range in nitrate was 0.5 ppm to 77 ppm. Although the weather was cold during the time the samples were collected in March, the period between sampling runs was above freezing most of the time. Three of the four low nitrate samples (Weilnau, Close, and Beechler) contained traces of hydrogen sulfide indicating that there was a reducing environment in the ground water at that time and no doubt the low nitrate content of these samples can be attributed to the reduction of the nitrate and subsequent escape of ammonia.

Six samples were collected in April at points where samples had been collected either during March or February.

Table 3 lists the results of chemical analyses of water from wells where samples had been collected on two or more occasions during the survey.

Table 3

		ABS	Ammonia as NH_4	NO_2 (ppm)	NO_3 (ppm)
Weiland	2-6-61	0.1	0.1	0.5	29
	4-18-61	0.1	0.2	0.05	52
Thomas	3-7-61	0.1	0.2	0.00	92
	4-18-61	0.3	0.1	.00	158
Neill	3-7-61	0.1	0.2	1.0	41
	4-18-61	0.1	0.1	.05	38
Andrews	2-6-61	0.1	0.2	1.5	26
	4-18-61	0.2	0.2	.00	36
Adams	3-5-61	0.2	0.1	0.05	77
	4-18-61	0.2	0.3	0.20	91

In every well but one, there was an increase in the nitrate content of the water after the end of the cold weather in February or March. The Neill well did not change appreciably between early March and the middle of April.

In summary, the underground water in the vicinity of Bellevue, Ohio, contains higher concentrations of nitrogen compounds than water from other underground reservoirs in Erie and adjacent counties. A significant number of samples (70%) contained alkyl benzene sulfonate and about 85% contained ammonia nitrogen. Since alkyl benzene sulfonate is not a naturally occurring compound, it is safe to say that there is a significant amount of pollution in the underground water in the Bellevue area.

Table 4

Chemical Analyses of Ground Water in the Bellevue Area

	Ammonia as NH_4	ABS	Nitrite NO_2	Nitrate NO_3	Phosphorus as PO_4
F. C. Adams (Bragg Rd.) #1	0.1	0.2	.05	77.	.20
#2	0.3	0.2	.20	91.	.50
Mr. Adams (Potter Rd.)	0.2	0.0	.00	.7	.24
Walter Andrews (Knauss Rd.) #1	0.2	0.1	1.5	26.	.10
#2	0.2	0.2	.00	36.	1.0
Mr. Beechler (MaGill Rd.)	0.1	0.0	.00	5.3	.15
Wayne Bunting (Billings Rd.) #1	0.1	0.1	1.0	2.7	.10
#2	0.1	0.1	.10	15.	.70
#3	0.6	0.1	.15	1.3	.50
Dale Close (Smith Rd.)	0.0	0.0	.00	.4	.15
D. D. Crouch (Route 99)	0.0	0.0	.00	8.0	.20
L. H. Danklefsen (Billings Rd.)	0.1	0.1	.40	17.	.20
Mrs. DeCaro (Route 269)	0.2	0.0	.10	6.5	.20
H. N. Farmer (Portland Rd.)	0.2	0.0	.00	.6	.20
Wm. Gibbs (MaGill Rd.)	2.7	0.6	12.	38.	1.0
M. Lyons (MaGill Rd.)	0.0	0.7	.05	30.	.10
L. Markle (Potter Rd.)	0.3	0.1	.00	29.	.10

Table 4 (continued)

Chemical Analyses of Ground Water in the Bellevue Area

		Ammonia as NH_4	ABS	Nitrite NO_2	Nitrate NO_3	Phosphorus as PO_4
Earl McKinney (MaGill Rd.)		0.6	0.6	.00	28.	.20
Robert Moore (MaGill Rd.)		0.0	0.4	.90	30.	.50
Donald Moyer (Knauss Rd.)		0.7	0.1	.30	2.9	.10
Swaze Neill (Billings Rd.)	#1	0.2	0.1	1.0	41.	.20
	#2	0.1	0.1	.05	38.	.50
Mrs. Sanders (Maple Rd.)		0.1	0.1	.40	16.	.10
Sand Hill Comm. (Route 4)		0.6	0.0	.00	22.	.20
J. Stickradt (Route 4)		0.1	0.0	.00	3.7	.20
R. W. Thomas (Portland Rd.)	#1	0.2	0.1	.00	92.	.40
	#2	0.1	0.3	.00	158.	1.0
Weiland Bros. (Bragg Rd.)	#1	0.1	0.1	.50	29.	.20
	#2	0.2	0.1	.05	52.	.40
Kenneth Weilnau (Portland Rd.)		1.0	0.0	.45	1.9	.20
Mr. Williams (MaGill Rd.)		0.4	0.1	.00	.5	.20
L. F. Wright (MaGill Rd.)		0.0	0.1	.00	1.0	.20

IV. SUMMARY AND CONCLUSIONS

As was stated in the introduction to this report, more comprehensive studies could be made of this situation to definitely determine the direction and movement of contaminated water through the limestone. However, further investigations of this nature would be of academic interest only and of little value in eliminating the problem of ground-water contamination in this area.

We believe that the present study has shown this area to be widely contaminated. We also believe that the source of this contamination is obvious. It can be stopped by construction of a sewerage system and an adequate sewage treatment plant for Bellevue.

Is there a good reason to stop this contamination? ... and, if so, how can this be accomplished? Many reasons have been proposed for permitting this condition to remain. These will be briefly discussed.

It is said that the quality of the ground water in the Bellevue area has excessively high hardness and total solids which make it unuseable for domestic supplies. Therefore, it should not be considered as an aquifer. Examples were cited where several wells yielded water with total solids in excess of 1500 parts per million (ppm) and total hardness of over 1000 ppm.

These examples are probably true. Ground waters from limestone, not only in Bellevue, but throughout the State, are hard and high in total solids. Chemical analyses of the water from 16 wells in limestone in the Bellevue area are on file at the Division of Water. The average of the total hardness is 564 ppm and the average total solids, 782 ppm. Four of these samples show extremely high total solids and hardness; however, the average is chemically suitable for most uses. These constituents are the most objectionable in well water from Riley and Townsend Townships, Sandusky County.

Another argument in favor of keeping the status quo is that there are very few domestic ground-water users in the area and no industrial users. Therefore, very few people are affected.

This is true, but it should be pointed out that the reason for this is contamination, or fear of contamination. Many industrial wells have been developed in and around Bellevue only to be abandoned because they became contaminated. These include individual wells yielding 500 gallons per minute (720,000 gallons per day, or over 252 million gallons per year!). Numerous domestic water users have had similar experiences with their wells. Even the city of Bellevue found it necessary to abandon its unsafe wells in 1946.

We have been advised that natural sinkholes in much of this area will continue to introduce pollution underground from surface drainage, even if Bellevue's contribution is stopped.

This also is true. However, the number of sinkholes, the amount of drainage entering them, and the concentration of pollutants in the water are only a fractional part of the total Bellevue contribution.

The last, and probably the most serious, reason offered to retain the present system of disposal is that the total cost for a municipal sanitary sewerage system and a sewage treatment plant to serve the city of Bellevue would result in a prohibitive cost per capita. Such a project would be impossible to finance in the usual ways provided by law.

This, too, is apparently true. The possibility of State aid in this project might be investigated. It is beyond the scope of this report to suggest means of financing.

We do not feel that this problem can be ignored. It is, in fact, a multiple problem since it is (1) a health problem, (2) a natural resources problem, and, (3) a moral problem.

V. APPENDIX

FLORIDA STATE SANITARY CODE

CHAPTER XXI

Drainage Wells

Reference is made to Chapter 381 and Chapter 387 Florida Statutes.

These statutes place the sanitary control of all waters of the State of Florida under the jurisdiction of the State Board of Health.

Section (1) Drainage well defined. A drainage well referred to in these regulations is any cavity drilled or natural which taps the underground water and into which surface waters, waste waters, industrial wastes, or sewage is placed.

Section (2) Application for approval. Before entering into a contract for the use of a drainage well it shall be the responsibility of the well drilling contractor to make application to the State Board of Health. Drilling shall not be begun until the proposed construction is approved by written permit signed by the Director of the Bureau of Sanitary Engineering of the State Board of Health.

Section (3) Data to be submitted with application. The application shall be accompanied by the following data:

(a) Location, depth, depth of casing of all wells used for water supply within a one mile radius of the proposed well.

(b) Nature of wastes to be placed in the proposed well with analysis if deemed necessary.

(c) Additional data as may be required by the State Board of Health.

Applications shall be signed by:

(1) The well drilling contractor, and
(2) The owner or the duly authorized representative of the owner.

Section (4) Submission of logs. A log showing the various strata pierced by the well shall be forwarded to the State Board of Health within 2 days after completion of the drilling operation. Samples of the various formations pierced in the drilling operation shall be forwarded to the State Geologist when the drilling operation has been completed.

Section (5) Wastes prohibited from disposal to drainage wells. Drainage wells shall not be used for the disposal of human wastes, or any waste deemed by the State Board of Health to be injurious to the public health.

Section (6) Casing. First quality lap-welded pipe only shall be used as a casing material. The use of butt welded pipe is prohibited.

The practice of dynamiting wells which have become clogged shall not be resorted to except with permission of the State Board of Health.

Section (7) Rights of Municipality. No government agency, municipality, county, or organization shall have the right to require the placing of any wastes in a drainage well. This is the function of the State Board of Health only.

The sections of this Chapter were adopted by the State Board of Health in executive session on February 16, 1946, to be effective from that date.

POLLUTION OF WATERS

Chapter 387, Florida Statutes

387.01 Underground Waters of the State" Defined. The term "underground waters of the state," when used in this chapter, shall include all underground streams and springs and underground waters within the borders of the state, whether flowing in underground channels or passing through the pores of the rocks.

387.02 Permit Required for Draining Surface Water or Sewage into Underground Waters of State. No municipal corporation, private corporation, person or persons within the state shall use any cavity, sink, driven or drilled well now in existence, or sink any new well within the corporate limits, or within five miles of the corporate limits, of any incorporated city or town, or within any unincorporated city, town or village, or within five miles thereof, for the purpose of draining any surface water or discharging any sewage into the underground waters of the state, without first obtaining a written permit from the state board of health.

387.03 Permits Revocable and Subject to Change; Notice by Publication; Filed with Clerk. Every permit for the discharge of sewage or surface water, shall be revocable or subject to modification or change by the state board of health, on due notice, after an investigation and hearing, and an opportunity for all interests and persons interested therein to be heard thereon; said notice or notices being served on the person or persons owning, maintaining or using the well, cavity or sink, and by publication for two weeks in a newspaper published in the county in which said well, cavity or sink is located. The length of time after the receipt of the notice within which it shall be discontinued may be stated in the permit. All such permits, before becoming operative, shall be filed in the office of the clerk of the circuit court of the county in which such permit has been granted.

387.04 Sewage Defined. For the purpose of this chapter, sewage shall be defined as any substance that contains any of the waste products, excrement or other discharge from the bodies of human beings or animals.

387.05 Sewage or Surface Drainage into Underground Waters of State to be Discontinued within Ten Days after Order by State Board of Health. Every individual, municipal corporation, private corporation or company shall discontinue the discharge within the corporate limits or within five miles of the corporate limits of any incorporated city or town, or within any unincorporated city, town or village or within five miles thereof, of sewage or surface drainage into any of the underground waters of the state within ten days after having been so ordered by the state board of health.

387.06 Penalty for Violation of Provisions of this Chapter. Any municipal corporation, private corporation, person or persons that shall discharge sewage or surface drainage, or permit the same to flow into the underground waters of the state, contrary to the provisions of this chapter, shall be deemed guilty of a misdemeanor and shall, upon conviction, be punished by a fine of twenty-five dollars for each offense or by imprisonment not exceeding one month. The doing of the prohibited act for each day shall constitute a separate offense.

387.07 Penalty for Interference with Water Supply. Whoever willfully or maliciously defiles, corrupts or makes impure any spring or other source of water reservoir, or destroys or injures any pipe, conductor of water or other property pertaining to an aqueduct, or aids or abets in any such trespass, shall be punished by imprisonment not exceeding one year, or by fine not exceeding one thousand dollars.

387.08 Penalty for Deposit of Deleterious Substance in Lakes, Rivers, Streams, Ditches, etc. Any person, firm, company, corporation, or association in this state, or the managing agent of any person, firm, company, corporation or association in this state, or any duly elected, appointed or lawfully created state officer of this state, or any duly elected, appointed or lawfully created officer of any county, city, town, municipality, or municipal government in this state, who shall deposit or who shall permit or allow any person or persons in their employ or under their control, management or direction to deposit in any of the waters of the lakes, rivers, streams, and ditches in this state, any rubbish, filth or poisonous or deleterious substance, or substances, liable to affect the health of persons, fish, or livestock, or place or deposit any such deleterious substance or substances in any place where the same may be washed or infiltrated into any of the waters herein named, shall be deemed guilty of a misdemeanor, and, upon conviction thereof in any court of competent jurisdiction, shall be fined in a sum not more than five hundred dollars; provided, further, that the carrying into effect of the provisions of this section shall be under the supervision of the state board of health.

387.10 Proceedings for Injunction.

(1) In addition to the remedies provided in this chapter and notwithstanding the existence of any adequate remedy at law, the state health officer or other appropriate officer of the state board of health is authorized to make application for injunction to a circuit judge, and such circuit judge shall have jurisdiction upon a hearing and for cause shown to grant a temporary or permanent injunction or both restraining any person from violating or continuing to violate any of the provisions of this chapter or from failing or refusing to comply with the requirements of this chapter, such injunction to be issued without bond provided, however, no temporary injunction without bond shall be issued except after a hearing of which the respondent or respondents has or have been given not less than seven days prior notice, and no temporary injunction without bond, which shall limit or prevent operations of an industrial, manufacturing or processing plant shall be issued, unless at the hearing it shall be made to appear by clear, certain and convincing evidence that irreparable injury will result to the public from the failure to issue the same.

(2) In event of the issue of a temporary injunction or restraining order hereunder without bond, then the state, in event said injunction or restraining order was improperly, erroneously or improvidently granted, shall be liable in damages and to the same extent as if said injunction or restraining order had been issued upon application of a private litigant instead of a public litigant, and the state hereby waives its sovereign immunity and consents to be sued in any such case.

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TO: S. L. Frost, Secretary, Ohio Water Commission DATE: July 11, 1961

FROM: A. C. Walker, Geologist, Ohio Division of Water

On June 22, a report was presented to the Water Commission, describing our investigation of ground-water contamination in the Bellevue area.

At that time, Mr. A. A. Westrick, City Engineer of Bellevue, stated that there was no "proof" that some 1600 disposal wells in the city had caused widespread contamination. The use of tracer dyes was suggested. He also said that the city has two wells which are used for public drinking water and that numerous private water wells are now in use in Bellevue.

On July 5, samples were collected from the two city wells described by Mr. Westrick. Because of the poor condition of these wells and their locations with respect to disposal wells, Mr. Day, Ohio Department of Health, felt that they were subject to contamination and probably could not be approved as sources of public water supply. In all fairness, it must be pointed our that water from one of these wells (well No. 1) tested "safe" according to the Health Department.

Chemical analyses of water from these wells showed:

	No. 1 Total Depth: 210 Aquifer: Limestone	No. 2 Total Depth: 212 Aquifer: Limestone
Silica (SiO_2)	6.9	7.4
Iron (Fe)	.23	4.7
Manganese (Mn)	.01	.28
Calcium (Ca)	320.	153.
Magnesium (Mg)	27.	28.
Sodium (Na)	6.3	29.
Potassium (K)	2.6	5.0
Ammonia Nitrogen as NH4	.4	6.7*
ABS	0.0	0.8*
Dissolved solids	1180.	687.
Total hardness	910.	497.
Bicarbonate (HCO_3)	285.	360.
Sulfate (SO_4)	662.	244.
Chloride (Cl)	10.	29.
Fluoride (F)	.6	.3
Nitrite (NO_2)	0.00	.05
Nitrate (NO_3)	1.8	.2
Orthophosphate (PO_4)	.07	.70
Phosphorus as PO_4	.15	2.5*
pH	7.1	7.2
Color	2.	7. *
Turbidity	4.	90. *

* Indicative of contamination.

According to Mr. Westrick, both of these wells are used as standby wells for public supply. However, they have not been used since 1946. Mr. Westrick insists that neither of these wells was abandoned bacause of contamination. Use of well No. 1 was discontinued because of high hardness and well No. 2 was discontinued because of "insufficient yield."

It is generally agreed that one of the most effective indicators of sewage-polluted ground waters is the presence of detergents (ABS). I feel that the presence of significant amounts of ABS in 70% of the samples collected is, in itself, "proof" enough. Other chemical constituents, described in the report, strengthen this conclusion.

The sample collected from well No. 2 had approximately one-half inch of foam on the surface. The chemical analysis of this water showed it to contain higher concentrations of ammonia and ABS than any of the 32 wells previously sampled. This was described by the analyzing chemist as "foul."

But, although well No. 2 is badly contaminated, well No. 1 shows no signs of contamination. This variation between two wells of approximately the same depth is surprising, but not without precedent in limestone areas where ground water moves through an intricate series of partially interconnected crevices and solution channels. A well at the Zehner Packing Company, approximately 2500 feet from city well No. 1, was used as a water source until five years ago, when it was closed by local health officials because of contamination.

Mr. Westrick was vague about the locations of the "numerous" other water wells in the city. We were unable to find any.

We were told: "About every ten years someone tries to stir up trouble over Bellevue's disposal system, but the State people won't do anything about it. They never do."

I do not think it is worthwhile for Division of Water personnel to spend any more effort on investigations in this area.

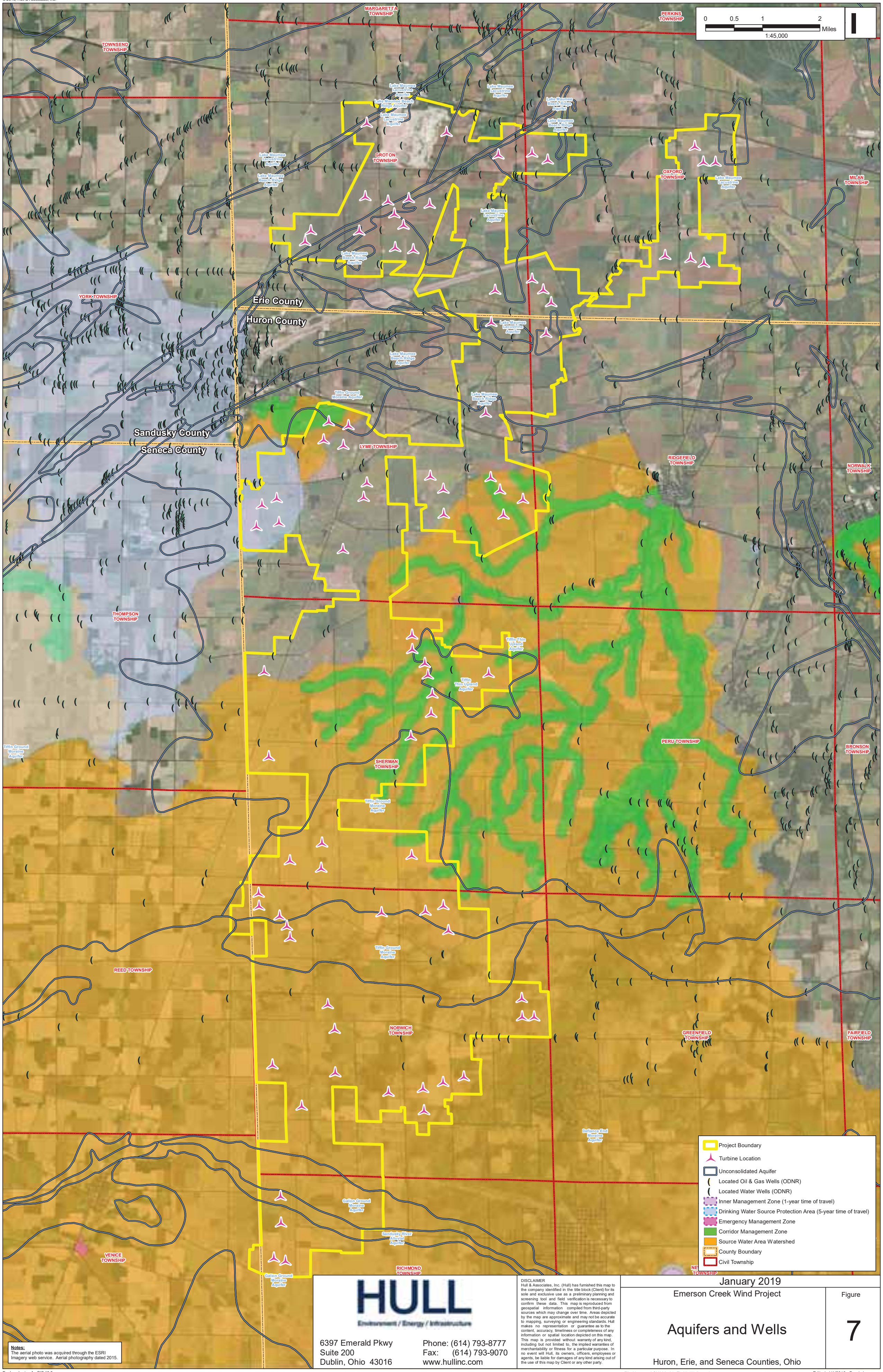
A. C. Walker

A. C. Walker

ACW/fo

cc: C. V. Youngquist

EXHIBIT I



Notes:
The aerial photo was acquired through the ESRI Imagery web service. Aerial photography dated 2015.

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January 2019

Emerson Creek Wind Project

Aquifers and Wells

Huron, Erie, and Seneca Counties, Ohio

Figure 7

Produced using ArcGIS 10.5

File Name: ACX006_01_Fig07_Wells.mxd

Edited: 1/4/2019 By: rkaip