Proposal to Hamilton County Park District to Site a Great Miami Ground-Water Observatory (GMGWO) at Miami-Whitewater Forest

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Objective

To provide timely quantitative information on the dynamic flow of ground-water between the Great Miami River and its adjoining alluvial aquifer in order to monitor the health, and promote the sound stewardship of the Great Miami River – Aquifer System.

The proposed Great Miami Ground-Water Observatory (***GMGWO***)[1] would consist of an array of observation wells (*piezometers*) in the Great Miami River Aquifer (***GMRA***) immediately adjacent to Great Miami River. Each piezometer would be instrumented to continuously monitor water level, temperature, oxygen level, specific conductivity, *pH* and selected chemical or biological constituents of interest. These data would be freely and publicly distributed in near-real-time for use by all concerned with the continued safety and availability of our local ground-water system including those in education, public health, natural resource preservation, and public water suppliers pumping from the GMRA. The observatory would be used to provide learning materials and projects for helping primary and secondary school students understand the dynamics of ground-water circulation and the interaction between surface-water and ground-water systems. GMGWO would provide both research and instructional opportunities for students and researchers at area colleges and universities for the study of ground-water quality and dynamics. In addition GMGWO would help inform the public on the sound management of the GMRA through displays at Hamilton County Park's Miami Whitewater-Forest. The observatory would provide the infrastructure for education and research projects that could include:

- Real-time hydrologic data for experiential learning and teaching hydrologic concepts and sound stewardship of natural resources.
- Continuous, long-term monitoring of river bed conductivity of Great Miami River which directly affects the rate, quality and quantity of water exchanged between the GMRA and Great Miami River.
- Interaction of solute with the aquifer material.
- Calibration and validation of flow models (*e.g.*, MODULAR) and solute transport models (*e.g.*, SUTRA) for assessing the movement of water within the aquifer in order to optimize water quality sampling by public water supplies from the GMRA.
- Assessment of the effectiveness of the river-aquifer system in reducing river-borne contamination.

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[1] A PDF version of this document is available at http://homepages.uc.edu/~nashdb/GMGWO/GMGWO.pdf. Blue underlined hyperlinks in online version may be cntrl-clicked to visit link.

Serving the Missions of Both Hamilton County Park District and UC

The proposed Great Miami Ground-Water Observatory (GMGWO) would enhance the Hamilton County Park District's mission: *To preserve and protect natural resources and to provide outdoor recreation and education in order to enhance the quality of life for present and future generations*. Clean water is one of the most important natural resources of our region and is essential to its health and future. By providing the site for GMGWO, the park district would be making a major contribution to our understanding and stewardship of this vital resource.

One of the advantages our area enjoys over most of the rest of the country is the availability of an abundant supply of clean ground water. As more water is withdrawn from the GMRA, recharge by infiltration of river water to the aquifer increases. Such infiltration increases the risk of either organic or inorganic contaminants degrading the quality of water in the aquifer. Increased infiltration of river water also reduces the aquifer system's ability to buffer the river from human-introduced contamination. To assess these risks to the ground-water system, it is essential that the quality, flow path and velocity of water entering the aquifer from the river be thoroughly understood and carefully monitored.

GMGWO would promote the University of Cincinnati's mission to serve, educate, and inform the people of Ohio. GMGWO would provide a "hands-on" facility for UC and local colleges and universities to educate and train hydrologists and others interested in ground water (*e.g.*, naturalists, geologists, geographers, civil and environmental engineers, and land use planners). GMGWO would provide the infrastructure for researchers from governmental agencies and public water suppliers to develop new instrumentation and to formulate and evaluate ground-water management practices that minimize the risk of contamination from infiltrating river water.

GMGWO would provide invaluable educational data and learning projects for primary and secondary schools by coordinating with Project WET (**W**ater **E**ducation for **T**eachers). Project WET is an international organization that provides teaching materials, curriculum guides, lesson plans, and workbooks to primary and secondary school educators and students. Project WET is active in all fifty states and the District of Columbia. In Ohio, Project WET is coordinated through the Division of Water, Ohio Department of Natural Resources. There are four Ohio Project WET Workshop Facilitators in Hamilton County alone! Currently there is one ground-water project in *Healthy Water, Healthy People: Water Quality Educators Guide* (Project WET International, 2003). The data provided by GMGWO would build on Project WET's treatment of ground-water and on the interaction of ground water and surface water.

An online website to distribute data collected by GMGWO would provide near real-time and engaging data for use in Project WET educational projects in local, regional, and national elementary and secondary schools. The website would further promote the park district's and UC's service to our region. Displays explaining the dynamics and importance of the Great Miami River Aquifer would be designed by GMGWO for use in the visitor's center at Miami-Whitewater Forest or elsewhere in Hamilton County Park District.

Background

The vast majority of Ohio's public water suppliers (***PWS***) relying on ground water are situated in alluvial aquifers immediately adjacent to major rivers (fig. 1) where they pump from highly conductive sand and gravel aquifers recharged by infiltration from reliable river discharge. Most PWS wells in southwest Ohio are literally within a stone's throw of a river. The Great Miami River Aquifer (GMRA) is the *sole source aquifer*[2] for most of the PWS in southwest Ohio (fig. 2). In addition to supplying our region with clean drinking water, the aquifer system acts as a natural filter, reducing human-introduced contamination in Great Miami River.

The continued health and reliability of the GMRA is vital to our region's future. Most of what is known about the aquifer comes from a series of studies (Spieker 1968a, b, c) done by the U.S. Geological Survey in the late-1960's when rapid population and industrial growth in southwest Ohio raised concerns about the capacity of the GMRA to meet future demand and about the effect increasing pollution of Great Miami River would have on the quality of water from the aquifer. At the time of the study, the Charles M. Bolton Water Treatment Plant (fig. 3) was being planned, heightening the issue of the long-term reliability of the aquifer. Today, this plant supplies approximately 12% of the daily usage to the Cincinnati Metropolitan Area, primarily to the west side of Cincinnati.

Spieker (1968a) examined the chemistry of water from Great Miami River and the GMRA, river discharge, current and projected pumpage from the aquifer, the hydraulic characteristics of the aquifer, and the pattern of flow within the aquifer. He concluded that the GMRA could support projected population and industrial growth of the region for at least the next twenty years and probably much longer *if treated water were returned to the river upstream from water supply wells*.

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2 Defined by the US EPA as "An aquifer which is needed to supply 50 percent or more of the drinking water for a given aquifer service area and for which there are no reasonably available alternative sources should the aquifer become contaminated."

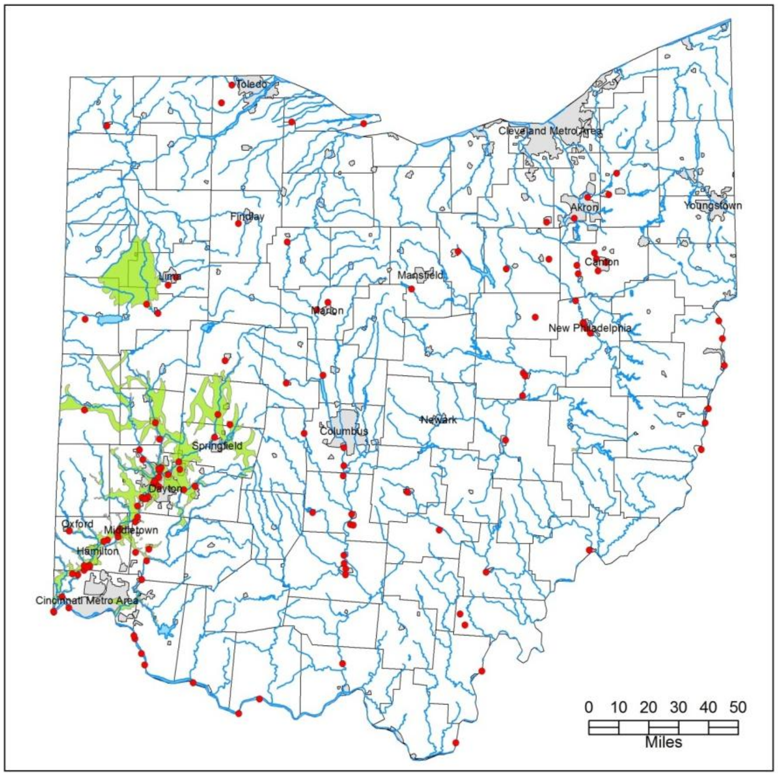

Figure 1. The vast majority of the major Ohio public water suppliers (red dots - withdrawing more than 500 million gallons annually) pump from alluvial aquifers (light green) located immediately adjacent to major streams.

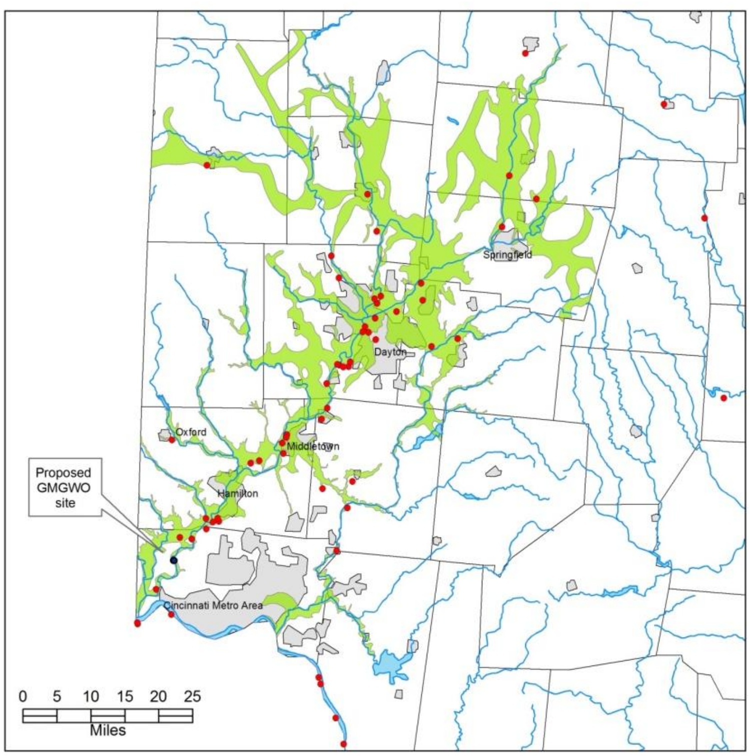

Figure 2. The public water supply for most municipalities in southwest Ohio is derived from the Great Miami Aquifer System (green), a sole source aquifer (red dots correspond to pumpers withdrawing more than 500 million gallons annually).

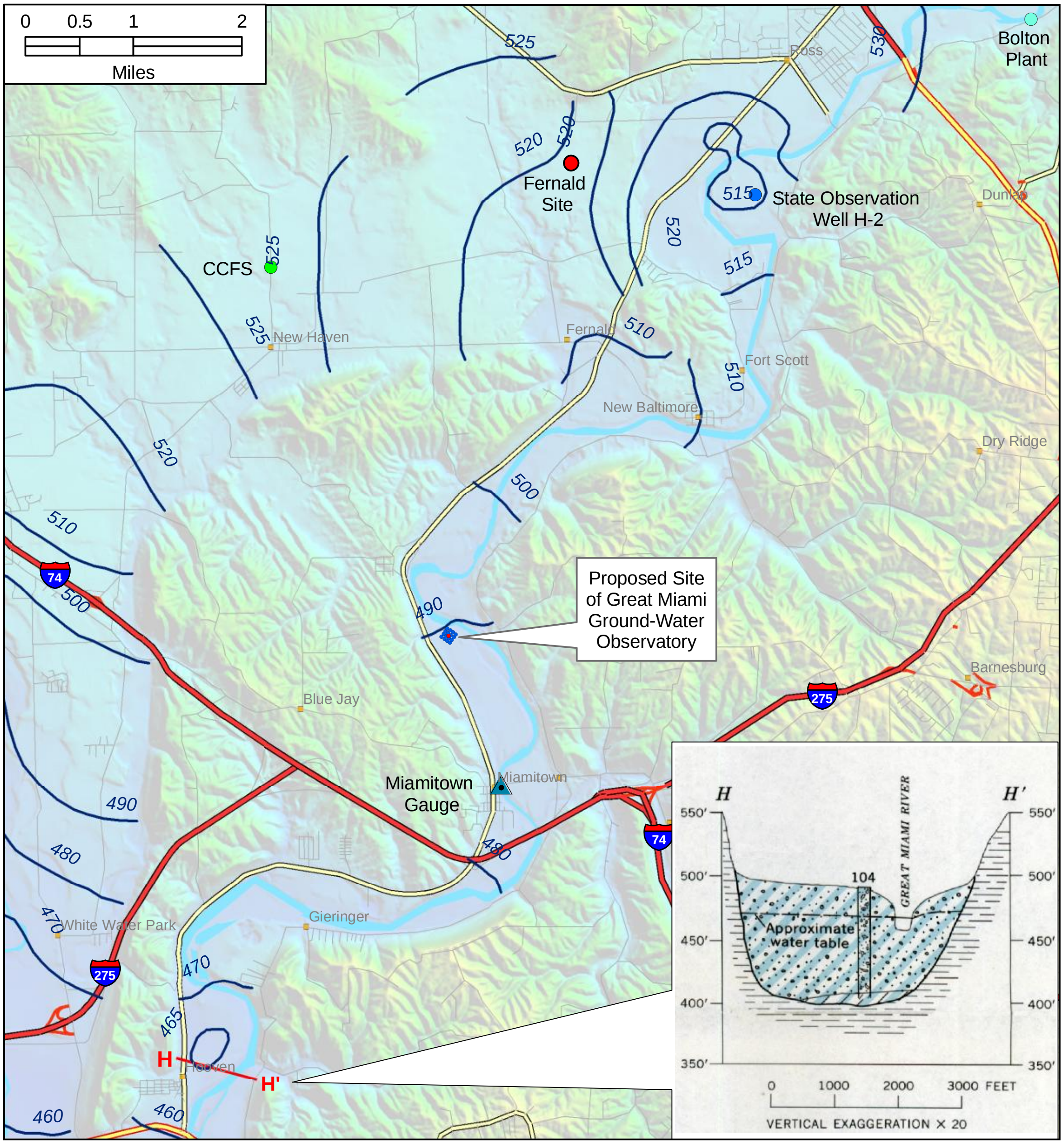

Figure 3. Numbers in dark blue isopotential lines are elevation (feet) of the ground-water table (mapped by Spieker, 1968a)

Spieker's (1968a) map of the steady-state elevation of the ground-water (*piezometric* surface) of the GMRA is widely cited (fig. 3). It is used by Larkin and Sharp (1992) as a type example of an *underflow* alluvial aquifer system, where flow in the aquifer parallels the river as opposed to a *base-flow* system where water flows directly between the aquifer and river. In an underflow system, *isopiezometric lines* (lines of equal ground-water elevation) make nearly perpendicular intersections with the river and show little or no curvature in the vicinity of the river. In an underflow system, water in the aquifer has a long flow path through the aquifer. This long flow path suggests that water taken from the aquifer has had a long resident time in the aquifer. This however, cannot *always* be the case.

Figure 4. Views of Great Miami River looking upstream from the Miamitown bridge (fig. 3).

a. high normal discharge July 1, 2008

b. Flood discharge March 20, 2008.

A continuously recording station with a discharge gauge, a webcam, and chemical sensors would be constructed on one of the bridge piers. This station would be connected to the Internet.

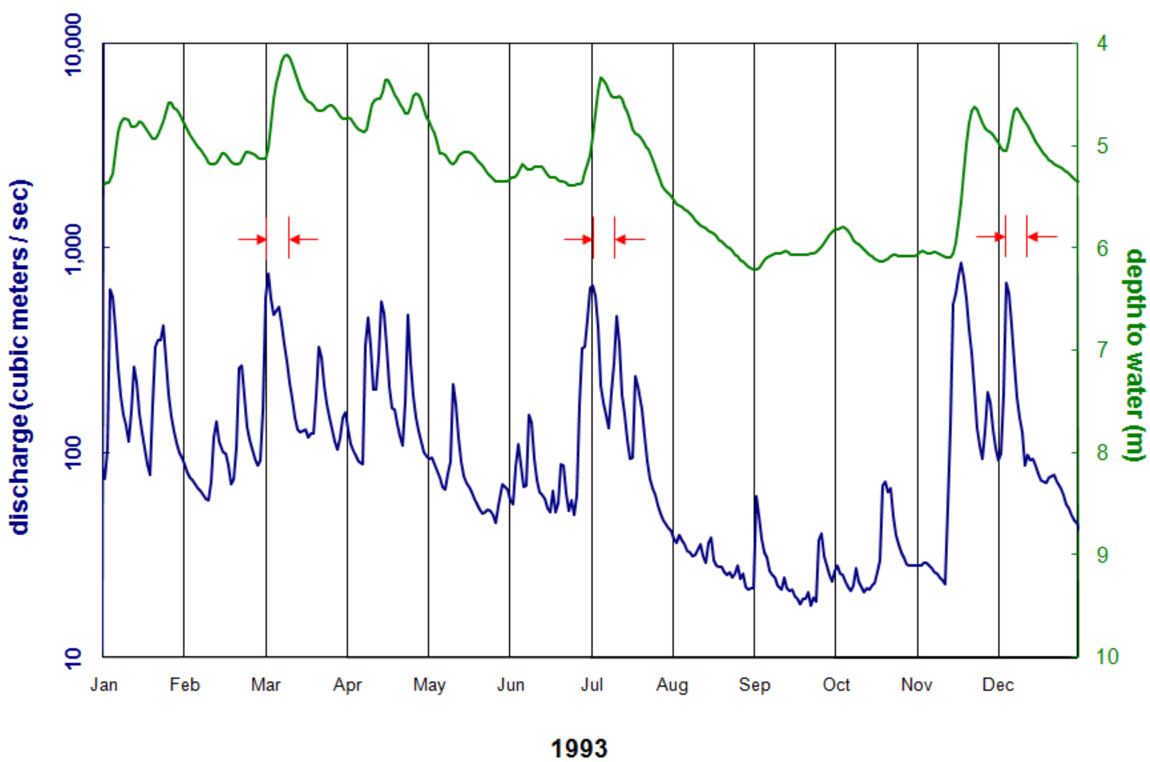

Figure 5. Ground-water elevation at State Observation Well H-2 (fig. 3) lags Great Miami River discharge measured at nearby Hamilton, Ohio by more than a week.

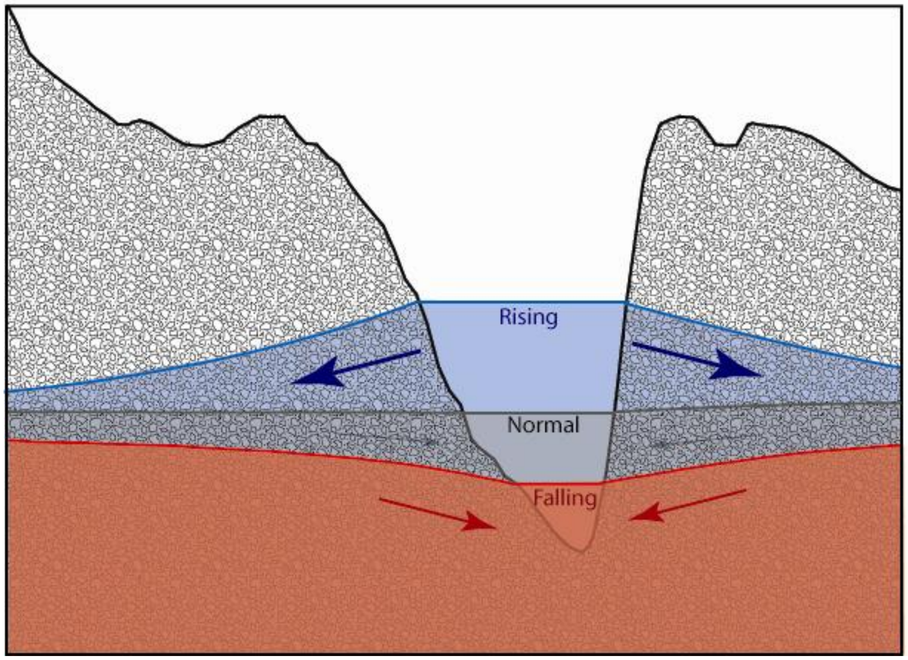

Figure 6. Ground-water elevation at State Observation Well H-2 (fig. 3) lags Great Miami River discharge measured at nearby Hamilton, Ohio by more than a week (simplified geology).

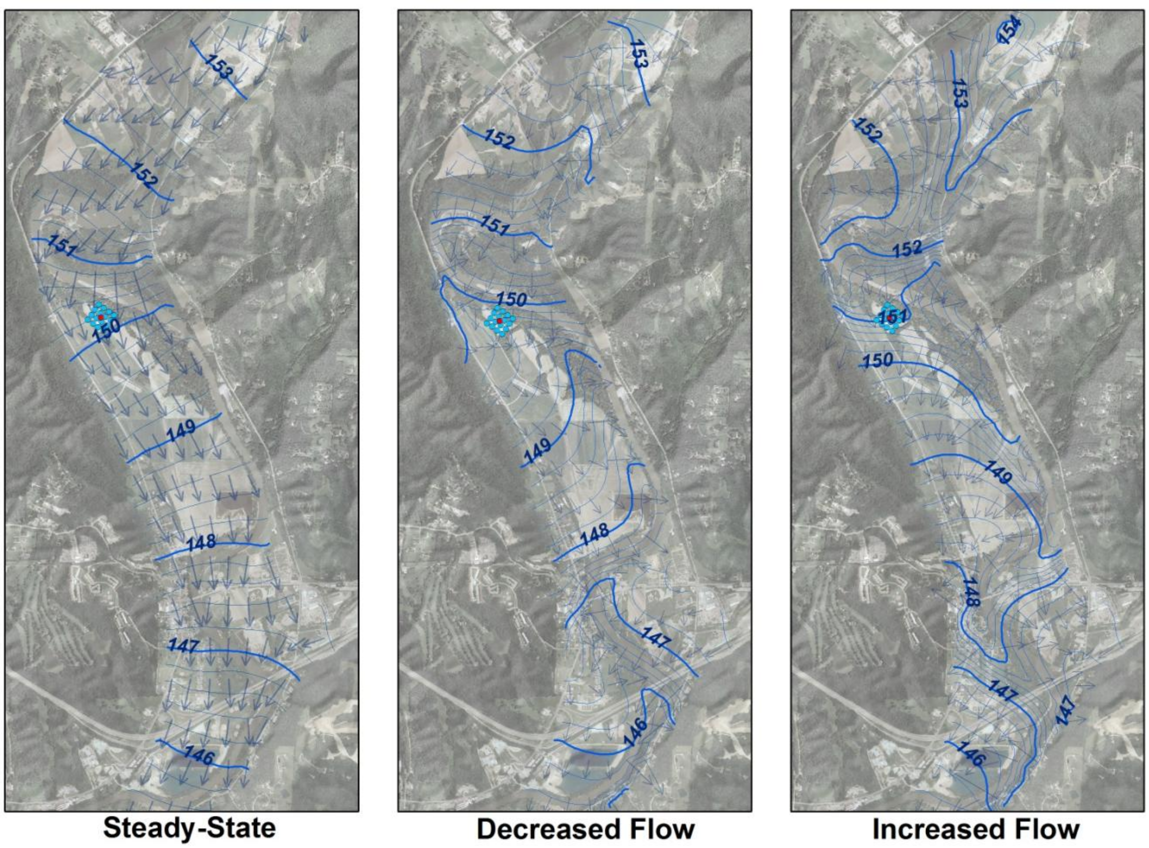

Figure 7. Simulated piezometric surface within the GMRA for steady-state flow and transient flow resulting from a rapid decrease and increase of discharge of Great Miami River using hydraulic characteristics reported in Spieker (1968a) and discharge measured at Hamilton, Ohio.

Although the average, long-term, steady-state ground-water flow in the GMRA may parallel the river, river discharge is highly variable (figs. 4), changing rapidly by more than an order of magnitude (fig. 5). The response of the piezometric surface lags the change in river discharge by up to a week. During this lag period, the river level will be substantially above the adjoining aquifer and river water rapidly infiltrates to the aquifer (fig. 6). The precise (or even approximate) amount of river discharge entering the aquifer is difficult to estimate without specific data. Infiltration is a function of the magnitude and duration of the elevation difference between the water levels in the river and the aquifer and the hydraulic conductivity of the river channel sediments.

Approximate flow models can be constructed of the GMRA during flooding events (fig. 7) using the hydraulic properties (*i.e.*, thickness, transmissivity, and specific yield) of the aquifer reported by Spieker (1968a), but other parameters, particularly channel sediment conductivity, can only be approximated.

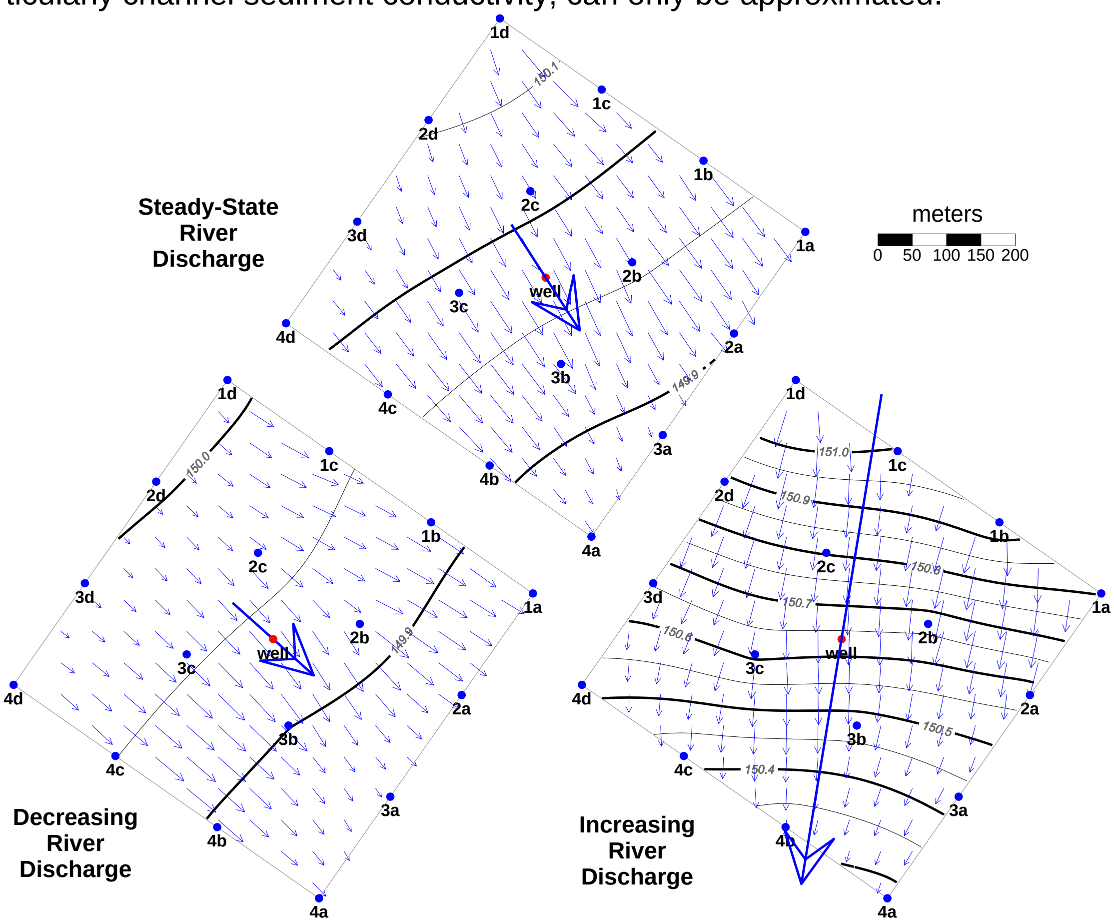

Figure 8. The Great Miami Ground-Water Observatory would post maps showing the current piezometric surface at the observatory and the direction and rate of ground-water flow. The examples shown here are generated from model data (fig. 7). The lengths of the large arrows are proportional to discharge velocity and show average direction of flow. Contour lines and flow vectors generated for simulated heads measured in GMGWO piezometers (0.5m contour interval).

Although specific river-borne contaminants have changed over time, from *Crenothrix* bacteria, nitrite, ammonia, and anionic alkyl-benezene sulfonate (from detergents of the time) reported by Spieker (1968a), followed more recently by antibiotic-resistant bacteria, insecticides, herbicides, endocrine-disrupting compounds

(Rowe *et al.*, 2004), and arsenic (Thomas, *et al.*, 2005), to the “emerging contaminants” of today (*e.g.*, acetaminophen, caffeine, and various prescription drugs), degradation of water quality in the GMRA remains a serious concern. Recent research has focused on the hydraulic characteristics of the river channel sediments and the rate at which river water passes into the GMRA. Jonathan Levy, Miami University, studies channel infiltration near the Charles M. Bolton Water Treatment Plant (fig. 3) and Denise Dumouchelle, USGS is studying channel infiltration at other sites along the river. Their investigation suggest that the hydraulic conductivity of the channel sediments is not constant, as is frequently assumed, but rather varies with discharge (Jonathan Levy, personal communication). Unfortunately, the direct measurement of channel conductivity with permeameters is virtually impossible during high discharge events (the time of the most rapid infiltration) and is difficult at other times due to the coarse channel sediments of Great Miami River.

Proposal

We propose to construct an observatory for researching the dynamics and health of the GMRA. The Great Miami Ground-Water Observatory (GMGWO) would consist of an array of sixteen piezometers. Each piezometer would be instrumented and connected to a datalogger for continuous monitoring of ground-water level, temperature, specific conductivity, oxygen level, and *pH*. A continuously-recording stream gauge of Great Miami River would be constructed (possibly in cooperation with the USGS, WRD) on a pier of the Miamitown Bridge over Great Miami River (figs. 3 and 4). This gauge would also be connected to a datalogger and equipped with a webcam and chemical sensors. These ground- and surface-water data would be made continuously available in near-real time on a webserver connected to both dataloggers. The website would regularly (probably hourly but dependent on how rapidly conditions changed) produce a contour map showing the morphology of the piezometric surface within the array of GMGWO piezometers (*e.g.*, fig. 8). The electrical harness used to connect instrumentation at each piezometer would be designed to allow the addition of ion-specific probes and other instrumentation. A 8” diameter well would be installed at the center of the array in which a truck-mounted, high-capacity pump capable of a sustained discharge of at least 500 gpm could be temporarily installed for conducting stress tests on the aquifer (necessary for determining its transmissivity, anisotropy, and coefficient of storage, fig. 9).

All the piezometers, sensors, and wiring would be below grade. Access to the piezometers would be through locked manholes. Dataloggers, other electronics, and connection to the internet, and the piezometer vents would be elevated above the 100-year flood elevation by a small fifteen-foot high platform.

The only suitable site for GMGWO is within Miami-Whitewater Forest

GMGWO should be located in a relatively undeveloped area in which there is minimal pumping to interfere with the natural circulation of ground-water. Because the site would be used for research and teaching by both the University of Cincinnati and Miami University, it should be in an area a relatively short distance from both universities. The composition of the aquifer should be reliably known and relatively simple. GMRA is an important source of sand and gravel for the area and a great many quarries are situated in the river's floodplain. These quarries interfere with the natural circulation of ground water so GMGWO should be located as far away from them as possible. In addition, because GMGWO is intended to monitor solute brought into the aquifer by infiltrating river water, areas that may already contain solutes of interest (*e.g.*, former Chevron facility near Cleves and former Fernald Uranium Processing Facility near Fernald) should be avoided.

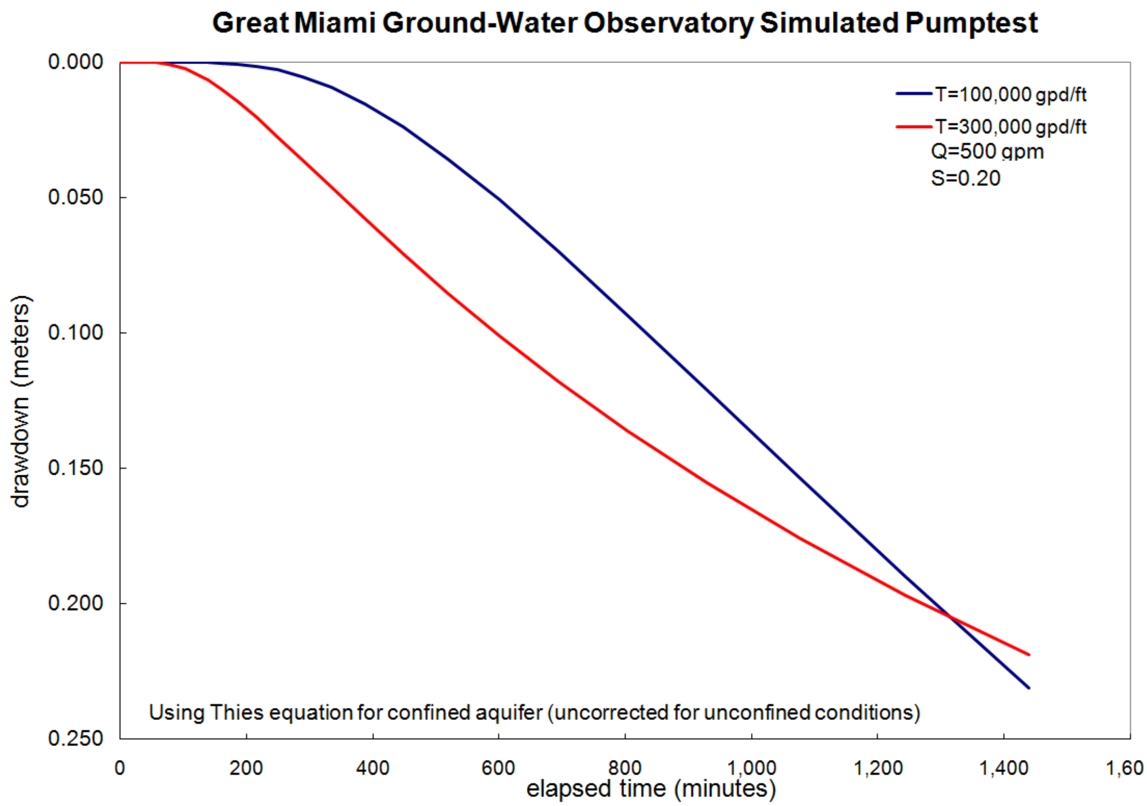

Figure 9. Theoretical drawdown at the piezometer closest to the pumping well predicted to result from an aquifer stress test based on high and low levels of transmissivity reported by Spieker (1968a).

Given these preconditions for the siting of GMGWO, there is only one site that meets all of the necessary criteria: Miami-Whitewater Forest. The area immediately north of Miamitown within the park is the ideal location for GMGWO (figs. 2 and 3). The area is relatively undeveloped, and there is no major pumpage in the vicinity. The geology of the area was determined by Spieker (1968a) from local cores and is relatively homogenous sand and gravel (section, fig. 3). Given its land-use history, the site has not been contaminated. The area is readily accessible to researchers and could be easily supplied with power and connection to the internet.

We have worked with John Klein and Bob Mason to find a site that would not interfere with park operations or with farming of plots the park district plans to make available for lease in the future (figs. 10 and 11). Most of the infrastructure for GMGWO would be below grade, enclosed within small manholes to keep disturbance of the site to an absolute minimum.

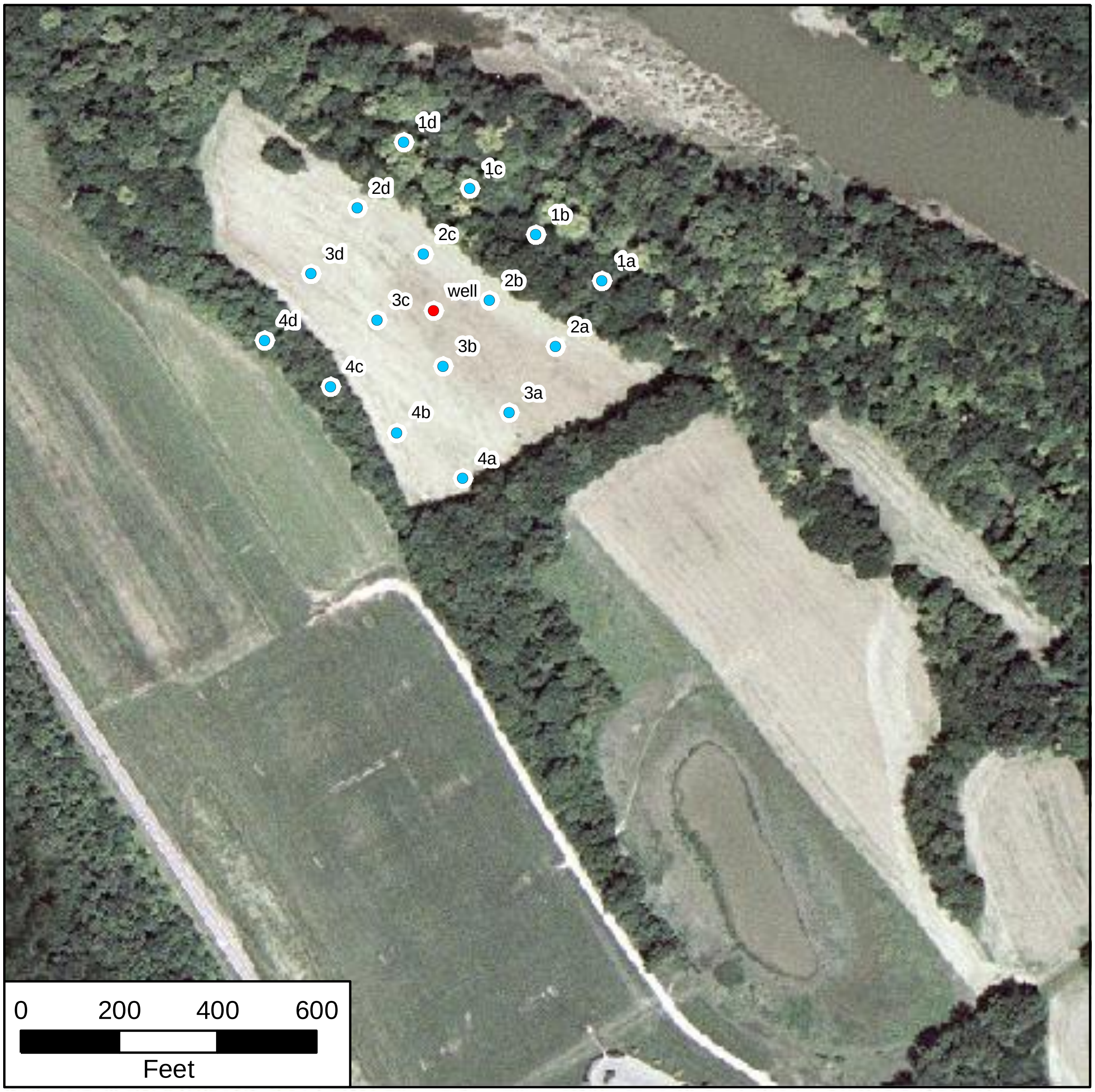

Figure 10. Proposed site of the Great Miami Ground-Water Observatory.

Figure 11. Proposed site of GMGWO viewed from the southeast to the northwest July 1, 2008.

Because the proposed site is (and must be) within the floodplain of Great Miami River, it would be necessary to construct an elevated platform to bring the well-head venting pipes and electronic monitoring equipment above the flood waters. The possibility of this platform also serving as monitored (including webcam) nesting area for raptors was discussed with John Klein. The platform would be elevated above the anticipated height of the 100-year flood, approximately 15 feet above grade at the proposed site of the pumping well (figs. 12 and 13).

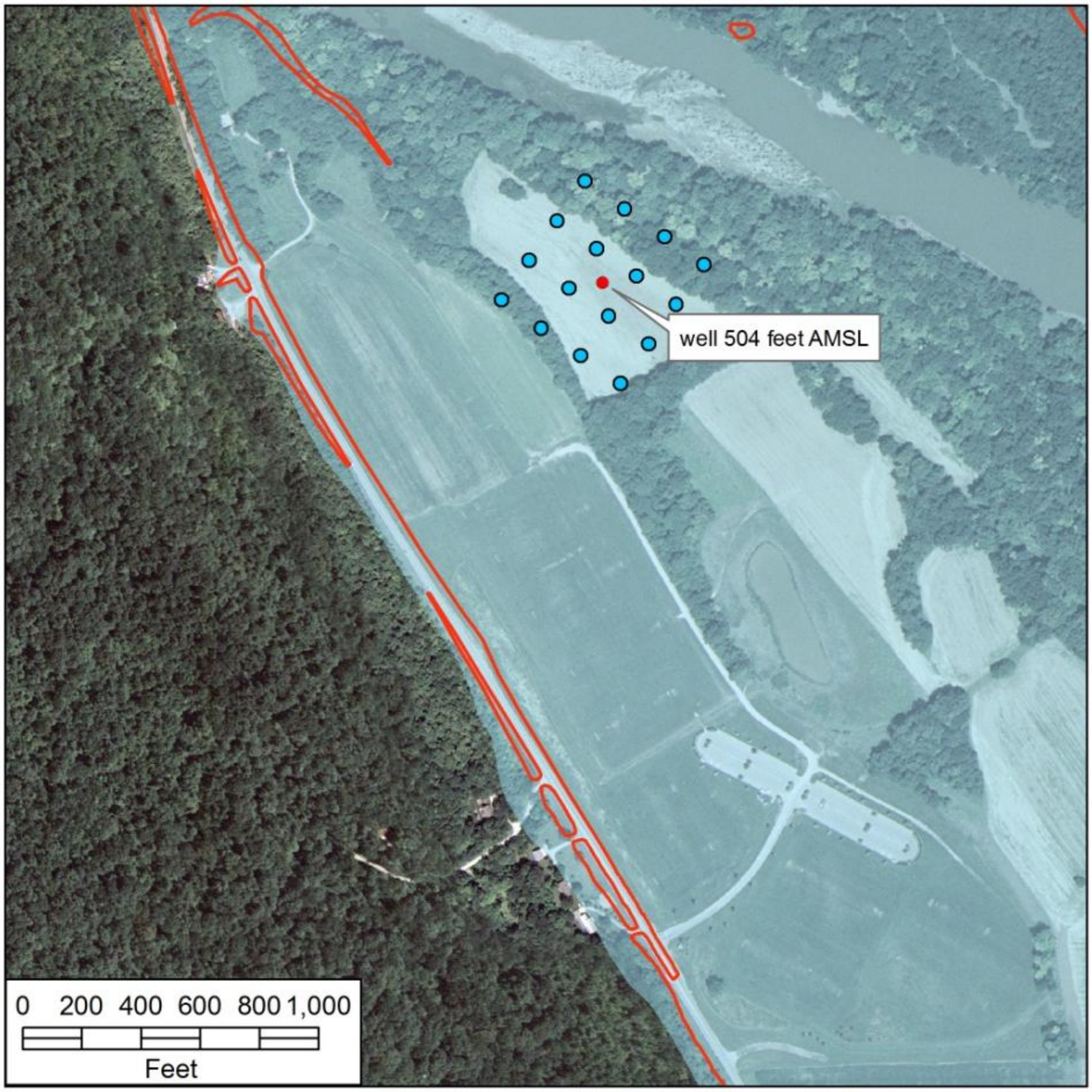

Figure 12. Light blue area corresponds to the extent of the 100-year flood (from ODNR). The 518-foot elevation contour (red line) is the approximate limit of flooding. The ground elevation at the pumping well is c. 504 feet so the elevated platform would be about 15 feet above grade.

We would be delighted to consider revising the design or siting of GMGWO in any way that the Hamilton County Park District wishes. We would also welcome the opportunity to integrate GMGWO into the educational and natural resource preservation mission of the district.

Figure 13. Example of simple platforms of types that could be used to elevate well-head above flood level. The elevated platform for GMWO would be designed in consultation with Hamilton County Park District.

References

Larkin, R. G. and Sharp, J.M., 1992, On the relationship between river-basin geomorphology, aquifer hydraulics, and ground-water flow direction in alluvial aquifer, *Bulletin of the Geological Society of America*, 104:1608-1620.

Rowe, G.L.; Reutter, D.C.; Runkle, D.L.; Hambrook, J.A.; Janosy, S.D.; and Hwang, L.H., 2004, Water quality in the Great and Little Miami River Basins Ohio and Indiana 1999-2001. *USGS Circular 1229*.

Sheets, R. A. and Bossenbroek, K. E., 2005, Ground-Water Flow Directions and Estimation of Aquifer Hydraulic Properties in the Lower Great Miami River Buried Valley Aquifer System, Hamilton Area, Ohio, *USGS Scientific Investigations Report 2005-5013*.

Spieker, A.M., 1968a, Ground-water hydrology and geology of the lower Great Miami River valley, Ohio. *USGS PP 605-A*. 37p.

Spieker, A.M., 1968b, Effect of increased pumping of ground water in the Fairfield-New Baltimore area, Ohio; a prediction by analog-model study, *USGS PP 605-C*, 34p.

Spieker, A.M., 1968c, Future development of the ground-water resources in the lower Great Miami River Valley, Ohio--Problems and alternative solutions. *USGS PP 605-D*, 15p.

Project WET International, 2003, *Healthy Water, Healthy People: Water Quality Educators Guide*, The Watercourse, 226p.

Thomas, M.A.; Schumann, T. L.; and Pletsch, B. A., 2005, Arsenic in ground water in selected parts of Southwestern Ohio, 2002-03, *USGS Scientific Investigations Report 5138*.

Watkins, J.S. and Spieker, A.M., 1971, Seismic refraction survey of Pleistocene drainage channels in the lower Great Miami River Valley, Ohio, *USGS PP 605-B*, 17p.