levels. There also is no systematic increase in ground-water ages along the dominant regional trends of the potentiometric surfaces. An exception to this apparent absence of systematic increase in ground-water ages was identified along a geochemical section that terminates near Lake Erie.

Ground water at the downgradient end of the flow paths that terminate at Lake Erie is some of the oldest in the aquifer system (approximately 13,000 years). The very oldest ground water (approximately 38,000-45,000 years) was identified further west, beneath the Maumee River Basin. The $\Delta^{34}S$ values (69.1 per mil, 68.4 per mil) for ground water sampled near Lake Erie and the Maumee River also indicate relatively long residence times in these parts of the aquifer system. Because the very oldest ground water, which is present beneath the Maumee River Basin, is associated with short (typically less than 10 mi) regional ground-water flow paths as compared to the flow paths that terminate at Lake Erie, it is likely that this part of the aquifer system is fairly stagnant. The old ground water near Lake Erie, however, is more likely to be associated with position along regional flow paths rather than with a stagnation point in the aquifer system. Results of the regional ground-water flow model indicate that flow in the aquifer system near Lake Erie at the end of relatively long flow paths may be predominantly vertical and may be associated with discharge from the deep parts of the aquifer system. Ground-water ages from ^{14}C data for selected wells near Lake Erie increase slightly with decreasing depth, a pattern that is consistent with the modeled upward flow of ground water in this area.

No effects of future pumping on the aquifer system were investigated as part of the Midwestern Basins and Arches Regional Aquifer-System Analysis project. Nearly 433 Mgal/d of ground water was reported to have been withdrawn from the aquifer system by users capable of pumping 100,000 gal/d or greater during the 1990 calendar year. Only 15 percent of this water was reported to have been withdrawn from the carbonate-rock aquifer. Of the remaining 85 percent, most of the water was reported to have been withdrawn from outwash deposits that underlie principal streams. Estimates of mean ground-water discharge to streams for long-term steady-state conditions in the aquifer system indicate that more than 13,000 Mgal/d of water discharges from the aquifer system to streams within the study area. Current pumpage, therefore, is only a small percentage of the total amount of water that moves through the aquifer system. No regional-scale cones of depression are present within the aquifer system; the aquifer system is not heavily stressed at the regional scale, and much more of the water in the Midwestern Basins and Arches aquifer system could be used.

REFERENCES CITED

Anderson, M.P., and Woessner, W.W., 1992, Applied groundwater modeling—Simulation of flow and advective transport: London, Academic Press, p. 20, 152.

Arihood, L.D., 1994, Hydrogeology and paths of flow in the carbonate bedrock aquifer, northeastern Indiana: Water Resources Bulletin, v. 30, no. 2, p. 205-218.

Back, William, 1960, Origin of hydrochemical facies of ground water in the Atlantic Coastal Plain, *in* Back, William, and Freeze, R.A. eds., Chemical hydrogeology: Stroudsville, Pa., Hutchinson Ross Publishing Co., Benchmark Papers in Geology, v. 73, p. 79-87.

_____1966, Hydrochemical facies and ground water flow patterns in northern part of Atlantic Coastal Plain: U.S. Geological Survey Professional Paper 498-A, 42 p.

Back, William, Hanshaw, B.B., Plummer, L.N., Rahn, P.H., Rightmire, C.T., and Rubin, Meyer, 1983, Process and rate of dedolomitization-mass transfer and ^{14}C dating in a regional carbonate aquifer: Geological Society of America Bulletin, v. 94, p. 1415-1429.

Barry, R.G., 1983, Late-Pleistocene climatology, *in* Wright, H.E., Jr., ed., Late-Quaternary environments of the United States, v. 1, The Late Pleistocene: Minneapolis, University of Minnesota Press, p. 390-407.

Beary, E.A., 1993, Ground-water withdrawal in 1990—Midwestern Basins and Arches regional aquifer systems study area: U.S. Geological Survey Open-File Report 93-119 [Water Fact Sheet].

Bennison, A.P., comp., 1978, Geological highway map of the Great Lakes Region: American Association of Petroleum Geologists, United States Geological Highway Map Series, Map 11.

Bloyd, R.M., Jr., 1974, Summary appraisals of the Nation's ground-water resources—Ohio region: U.S. Geological Survey Professional Paper 813-A, 41 p.

Botoman, George, and Faure, Gunter, 1976, Sulfur isotope composition of some sulfide and sulfate minerals in Ohio: Ohio Journal of Science, v. 76, no. 2, p. 66-71.

Botoman, George, and Stieglitz, R.D., 1978, The occurrence of sulfide and associated minerals in Ohio: Ohio Department of Natural Resources, Division of Geological Survey Report of Investigations 104, 11 p.

Bownocker, J.A., comp., 1920, Geologic map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, reprint 1981, scale 1:500,000.

Breen, K.J., 1989, Potentiometric-surface map of the carbonate aquifer in Silurian and Devonian rocks, Lucas, Sandusky, and Wood counties, northwestern Ohio, July 1986: U.S. Geological Survey Water-Resources Investigations Report 88-4144, scale 1:126,720.

Breen, K.J., and Dumouchelle, D.H., 1991, Geohydrology and quality of water in aquifers in Lucas, Sandusky, and Wood Counties, Northwestern Ohio: U. S. Geological Survey Water-Resources Investigations Report 91-4024, 234 p.

Bugliosi, E.F., 1990, Plan of study for the Ohio-Indiana carbonate-bedrock and glacial-aquifer system: U.S. Geological Survey Open-File Report 90-151, 26 p.

Bunner, D.W., 1993, Bedrock-surface altitude in the Midwestern Basins and Arches Region of Indiana, Ohio, Michigan, and Illinois: U. S. Geological Survey Water-Resources Investigations Report 93-4050, scale 1:750,000,

Burger, A.M., Forsyth, J.L., Nicoll, R.S., and Wayne, W.J., 1971, Geologic map of the 1° x 2° Muncie quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map 5, Muncie Sheet, Part A, scale 1:250,000.

Busby, J.F., Plummer, L.N., Lee, R.W., and Hanshaw, B.B., 1991, Geochemical evolution of water in the Madison aquifer in parts of Montana, South Dakota, and Wyoming: U.S. Geological Survey Professional Paper 1273-F, 89 p.

Buxton, H.T., and Modica, Edward, 1992, Patterns and rates of ground-water flow on Long Island, New York: Ground Water, v. 30, no. 6, p. 857-866.

Carlson, E.H., 1991, Minerals of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Bulletin 69, 155 p.

Cartwright, Keros, 1970, Groundwater discharge in the Illinois Basin as suggested by temperature anomalies: Water Resources Research, v. 6, no. 3, p. 912-918.

Casey, G.D., 1992, Hydrogeology of the basal confining unit of the carbonate-rock aquifer system in the Midwestern Basins and Arches Region of Indiana, Ohio, Michigan, and Illinois: U.S. Geological Survey Open-File Report 92-489, 2 sheets, scale 1:1,000,000.

_____1994, Hydrogeology of the Silurian and Devonian carbonate-rock aquifer system in the Midwestern Basins and Arches Region of Indiana, Ohio, Michigan, and Illinois: U.S. Geological Survey Open-File Report 93-663, 14 p., 2 sheets, scale 1:1,000,000.

Chapelle, F.H., and Knobel, L.L., 1983, Aqueous geochemistry and the exchangeable cation composition of glauconite in the Aquia aquifer, Maryland: Ground Water, v. 21, no. 3, p. 343-352.

Chebotarev, I.I., 1955, Metamorphism of natural waters in the crust of weathering: Geochimica et Cosmochimica Acta, v. 8, p. 22-48.

Clark, G.D., ed., 1980, The Indiana water resource—Availability, uses, and needs: Indianapolis, Governor's Water Resources Study Commission, Indiana Department of Natural Resources, 508 p.

Clayton, R.N., Friedman, I., Graf, D.L., Meyeda, T.K., Meents, W.F., and Shimp, N.F., 1966, The origin of saline formation waters: Journal of Geophysical Research, v. 71, no. 16, p. 3869-3882.

Cooley, R.L., and Naff, R.L., 1990, Regression modeling of ground-water flow: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. B4, 232 p.

Craig, Harmon, 1961, Isotopic variations in meteoric waters: Science, v. 133, p. 1702-1703.

Cravens, S.J., Wilson, S.D., and Barry, R.C., 1990, Regional assessment of the ground-water resources in eastern Kankakee and northern Iroquois Counties: Illinois State Water Survey Report of Investigation 111, p. 22, 23.

Cross, W.P., 1949, The relation of geology to dry-weather stream flow in Ohio: Transactions of the American Geophysical Union, v. 30, no. 4, p. 563-566.

Cunningham, W.L., 1992, Hydrogeology and simulation of transient groundwater flow at the South Well Field, Columbus, Ohio: Columbus, Ohio, Ohio State University, unpublished Master's thesis, 154 p.

Daniels, D.P., Fritz, S.J., and Leap, D.I., 1991, Estimating recharge rates through unsaturated glacial till by tritium tracing: Ground Water, v. 29, no. 1, p. 26-34.

Dansgaard, W., 1964, Stable isotopes in precipitation: Tellus, v. 16, p. 436-468.

Deering, M.F., Mohr, E.T., Sypniewski, B.F., and Carlson, E.H., 1983, Regional hydrogeochemical patterns in ground water of northwestern Ohio and their relation to Mississippi Valley-type mineral occurrences: Journal of Geochemical Exploration, v. 19, p. 225-241.

deRoche, J.T., and Breen, K.J., 1989, Hydrogeology and water quality near a solid- and hazardous-waste landfill, Northwood, Ohio: U.S. Geological Survey Water-Resources Investigation Report 88-4093, 76 p.

Desaulniers, D.E., Cherry, J.A., and Fritz, Peter, 1981, Origin, age and movement of pore water in argillaceous quaternary deposits at four sites in southwestern Ontario: Journal of Hydrology, v. 50, p. 231-257.

Doheny, E.J., Droste, J.B., and Shaver, R.H., 1975, Stratigraphy of the Detroit River Formation (Middle Devonian) of Northern Indiana: Indiana Department of Natural Resources, Division of Geological Survey Bulletin 53, 86 p.

Draper, N.R., and Smith, Harry, 1981, Applied regression analysis: New York, John Wiley & Sons, 709 p.

Droste, J.B., and Vitaliano, C.J., 1976, Geologic report of the Maquoketa Shale, New Albany Shale, and Borden Group rocks in the Illinois Basin as potential solid waste repository sites: U.S. Energy Research and Development Administration, Y/OWI/SUB-7062/1, 25 p.

Dumouchelle, D.H., 1992, Report of slug-test analyses of wells at Wright Patterson Air Force Base: Unpublished data on file in Columbus office of the U.S. Geological Survey.

Dumouchelle, D.H., Schalk, C.W., Rowe, G.L., and de Roche, J.T., 1993, Hydrogeology, simulated ground-water flow, and ground-water quality, Wright-Patterson Air Force Base, Ohio: U.S. Geological Survey Water-Resources Investigations Report 93-4047, 152 p.

Eberts, S.M., 1999, Water levels and ground-water discharge, regional aquifer system of the Midwestern Basins and Arches Region, in parts of Indiana, Ohio, Illinois, and Michigan: U.S. Geological Survey Hydrologic Investigations Atlas 725, scale 1:2,000,000, 3 sheets.

Eberts, S.M., Bair, E.S., and de Roche, J.T., 1990, Geohydrology, groundwater quality, and simulated ground-water flow, Geauga County, Ohio: U. S. Geological Survey Water-Resources Investigations Report 90-4026, 117 p.

Fenelon, J.M., Bobay, K.E., and others, 1994, Hydrogeologic atlas of aquifers in Indiana: U.S. Geological Survey Water-Resources Investigations Report 92-4142, 197 p.

Filley, T.H., 1985, The hydrogeological response to continental glaciation: University Park, Pennsylvania, Pennsylvania State University, unpublished M.S. thesis, 210 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 709 p.

Fleck, W.B., 1980, Geology and hydrology for environmental planning, Washtenaw County, Michigan: U. S. Geological Survey Open-File Report (unnumbered), 23 p.

Fleming, A.H., 1989, Description and results of the pumping test at the Julietta Landfill, Marion County, Indiana: Unpublished memorandum report on file in Bloomington office of the Indiana Geological Survey, 11 p.

Flint, R.F., committee chairman, 1959, Glacial map of the United States east of the Rocky Mountains: Boulder, Colo., Geological Society of America, scale 1:1,750,000.

Foster, M.D., 1950, The origin of high sodium bicarbonate waters in the Atlantic and Gulf Coastal Plains: Geochimica et Cosmochimica Acta, v. 1, p. 33-48.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.

French, R.R., and Rooney, L.F., 1969, Gypsum resources of Indiana: Indiana Geological Survey Bulletin 42-A, 34 p.

Fritz, P., Anderson, T.W., and Lewis, C.F.M., 1975, Late-Quaternary climatic trends and history of Lake Erie from stable isotope studies: Science, v. 190, 267-269.

Fritz, P., and Fontes, J. Ch., 1980, Handbook of environmental isotope geochemistry, volume 1, The terrestrial environment, A: New York, Elsevier Scientific Publishing Company, 545 p.

Garrels, R.M., and Christ, C.L., 1990, Solutions, minerals, and equilibria: Boston, Jones and Bartlett Publishers, 450 p.

Geosciences Research Associates, Inc. and Purdue University, Water Resources Research Center, 1980, An inventory of groundwater data and aquifer assessment for Indiana: Bloomington, Indiana, Part III, Appendixes [no pagination].

_____1982, Hydrogeologic atlas of Indiana: Bloomington, Ind., 31 pl.

Glatfelter, D.R.; Newman, J.E.; Mann, Martin; and Beik, Siavash, 1991, Indiana, floods and droughts, *in* Paulson, R.W., and others, comps., National water summary 1988-89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 271-278.

Goldthwait, R.P., Dreimanis, Aleksis, Forsyth, J.L., Karrow, P.F., and White, G.W., 1965, Pleistocene deposits of the Erie lobe, *in* Wright, H.E., Jr.,

and Frey, D.G., eds.,The Quaternary of the United States: Princeton, N.J., Princeton University Press, p. 85-97.

Gray, H.H., 1972, Lithostratigraphy of the Maquoketa Group (Ordovician) in Indiana: Indiana Geological Survey Special Report 7, 31.

_____1983, Map of Indiana showing thickness of unconsolidated deposits: Indiana Geological Survey Miscellaneous Map 37, scale 1:500,000.

Gray, H.H., Forsyth, J.L., Schneider, A.F., and Gooding, A.M., 1972, Geologic map of the Cincinnati quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map 7, Cincinnati Sheet, Part A, scale 1:250,000.

Gray, H.H., Droste, J.B., Patton, J.B., Rexroad, C.B., and Shaver, R.H., 1985, Correlation chart showing Paleozoic stratigraphic units of Indiana: Indiana Department of Natural Resources, Geological Survey Supplement to Miscellaneous Map 48, 1 sheet.

Gray, H.H., Ault, C.H., and Keller, S.J., 1987, Bedrock geologic map of Indiana: Indiana Geological Survey Miscellaneous Map 48, scale 1:500,000.

Gupta, Neeraj, 1993, Geologic and fluid-density controls on the hydrodynamics of the Mt. Simon Sandstone and overlying geologic units in Ohio and surrounding states: Columbus, Ohio, Ohio State University, Ph.D. dissertation, 266 p.

Hach Chemical Company, 1989, Water analysis handbook: Ames, Iowa, 690 p.

Hanover, R.H., 1994, Analysis of ground-water flow along a regional flow path of the Midwestern Basins and Arches Aquifer System in Ohio: U.S. Geological Survey Water-Resources Investigations Report 94-4105, 29 p.

Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 90-392, 23 p.

Harrison, P.W., 1960, Original bedrock composition of Wisconsin till in central Indiana: Journal of Sedimentary Petrology, v. 30, p. 432-446.

Hendry, M.J., Cherry, J.A., and Wallick, E.I., 1986, Origin and distribution of sulfate in a fractured till in southern Alberta, Canada: Water Resources Research, v. 22, no. 1, p. 45-61.

Hill, M.C., 1992, A computer program (MODFLOWP) for estimating parameters of a transient, three-dimensional, ground-water flow model using nonlinear regression: U.S. Geological Survey Open-File Report 91-484, 358 p.

_____1994, Five computer programs for testing weighted residuals and calculating confidence and prediction intervals on results from the ground-water parameter-estimation computer program MODFLOWP: U.S. Geological Survey Open-File Report 93-481, 81 p.

Holser, W.T., and Kaplan, I.R., 1966, Isotope geochemistry of sedimentary sulfates: Chemical Geology, v. 1, p. 93-135.

Hull, D.N., 1990, Generalized column of bedrock units in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, 1 p.

Indelman, P., and Dagan, F., 1993, Upscaling of permeability of anisotropic heterogeneous formations—1. The general framework: Water Resources Research, v. 29, no. 4, p. 917-923.

Indiana Department of Natural Resources, 1988, Water resource availability in the Whitewater River basin, Indiana: Water Resource Assessment 88-2, 126 p., 3 pls. in pocket.

_____1990, Water resource availability in the Kankakee River basin, Indiana: Water Resource Assessment 90-3, 247 p.

Janssens, Adriaan, 1977, Silurian rocks in the subsurface of northwestern Ohio: Ohio Department of Natural Resources, Division of Geological Survey Report of Investigations 100, 96 p.

Johnson, G.H., and Keller, S.J., 1972, Geologic map of the 1° x 2° Fort Wayne quadrangle, Indiana, Michigan, and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map 8, Fort Wayne Sheet, Part A, scale 1:500,000.

Jorgensen, D.G., Signor, D.C., and Imes, J.L., 1989a, Accounting for intracell flow in models with emphasis on water table recharge and stream-aquifer interaction—1. Problems and concepts: Water Resources Research, v. 25, no. 4, p. 669-676.

_____1989b, Accounting for intracell flow in models with emphasis on water table recharge and stream-aquifer interaction—2. A procedure: Water Resources Research, v. 25, no. 4, p. 677-684.

Joseph, R.L., and Eberts, S.M., 1994, Selected data on characteristics of glacial-deposit and carbonate-rock aquifers, Midwestern Basins and Arches Region: U.S. Geological Survey Open-File Report 93-627, 43 p.

Kaatz, M.R., 1955, The Black Swamp, a study in historical geography: Annals of the Association of American Geographers, v. 45, no. 1, 34 p.

Keller, C.K., and Van Der Kamp, G., 1988, Hydrogeology of two Saskatchewan tills, II. Occurrence of sulfate and implications for soil salinity: Journal of Hydrology, v. 101, p. 123-144.

Keller, S.J., 1983, Analyses of sub-surface brines of Indiana: Indiana Department of Natural Resources, Division of Geological Survey Occasional Paper 41, 30 p.

Krouse, H.R., 1980, Sulphur isotopes in our environment, *in* Fritz, P., and Fontes, J.Ch., eds., Handbook of environmental isotope geochemistry, Volume 1: The terrestrial environment, A: New York, Elsevier Scientific Publishing Company, p. 435-471.

Lamborn, R.E., 1952, Additional analyses of brines from Ohio: Ohio Department of Natural Resources, Division of Geological Survey Report of Investigations 11, 56 p.

Larsen, G.E., 1991, Development of Silurian and Devonian lithostratigraphic nomenclature, central-western and northwestern Ohio: Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 91-1, 1 pl.

Leahy, P.P., and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain aquifer system: U.S. Geological Survey Professional Paper 1404-K, 81 p.

Lesney, L.L, 1992, Geochemistry of ground water in glacial aquifers in the Cuyahoga River Basin, northeastern Ohio: Kent, Ohio, Kent State University, unpublished Master's thesis, 177 p.

Long, D.L., Wilson, T.P., Takacs, M.J., and Rezabek, D.H., 1988, Stable-isotope geochemistry of saline near-surface ground water – East-central Michigan Basin: Geological Society of America Bulletin, v. 100, p. 1568-1577.

Lowry, R.M., Faure, Gunter, Mullet, D.I., and Jones, L.M., 1988, Interpretation of chemical and isotopic compositions of brines based on mixing and dilution, "Clinton" sandstones, eastern Ohio, U.S.A.: Applied Geochemistry, v. 3, p. 177-184.

Lumb, A.M., Kittle, J.L., and Flynn, K.M., 1990, Users manual for ANNIE, a computer program for interactive hydrologic analysis and data management: U.S. Geological Survey Water-Resources Investigations Report 89-4080, 236 p.

Mazor, E., Drever, J.I., Finley, J., Huntoon, P.W., and Lundy, D.A., 1993, Hydrochemical implications of groundwater mixing – An example from the southern Laramie Basin, Wyoming: Water Resources Research, v. 29, no. 1, p. 193-205.

McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A1 [variously paginated].

Melhorn, W.N., and Kempton, J.P., eds., 1991, Geology and hydrogeology of the Teays-Mahomet bedrock valley systems: Geological Society of America Special Paper 258, 128 p.

Meyer, William, 1978, Hydraulic characteristics of the White River streambed and glacial-outwash deposits at a site near Indianapolis, Indiana: U.S. Geological Survey Journal of Research, v. 6, no. 2, p. 273-283.

Michel, R.L., 1989, Tritium deposition in the Continental United States, 1953-83: U.S. Geological Survey Water-Resources Investigation Report 89-4072, 46 p.

Mickelson, D.M.; Clayton, Lee; Fullerton, D.S.; and Borns, H.W., Jr., 1983, The late Wisconsin glacial record of the Laurentide ice sheet in the United States, *in* Wright, H.E., Jr., ed., Late-Quaternary environments of the United States, v. 1, The Late Pleistocene: Minneapolis, University of Minnesota Press, p. 3-37.

Mook, W.G., 1980, Carbon-14 in hydrogeological studies, *in* Fritz, P., and Fontes, J.Ch., eds., Handbook of environmental isotope geochemistry, volume 1: The terrestrial environment, A: New York, Elsevier Scientific Publishing Company, p. 49-74.

Mozola, A.J., 1969, Geology for land and ground-water development in Wayne County, Michigan: Michigan Department of Natural Resources, Geological Survey Report of Investigations 3, 25 p., 5 pl.

_____1970, Geology for environmental planning in Monroe County, Michigan: Michigan Department of Natural Resources, Geological Survey Report of Investigations 13, 34 p., 6 pl.

Nicholas, J.R., Rowe, G.L., Brannen, J.R., and Gillespie, J.L., 1996, Hydrology, water quality, and effects of drought in Monroe County, Michigan: U.S. Geological Survey Water-Resources Investigations Report 94-4161.

Nordstrom, D.K., Jenne, E.A., and Ball, J.W., 1979, Redox equilibria of iron in acid mine waters, *in* Jenne, E.A., ed., Chemical modeling of aqueous systems—Speciation, sorption, solubility, and kinetics: Washington, D.C., American Chemical Society Symposium Series 93, p. 51-79.

Nordstrom, D.K., and Ball, J.W., 1989, Mineral saturation states in natural waters and their sensitivity to thermodynamic and analytic errors: Scientific Geology Bulletin, v. 42, no. 4, p. 269-280.

Norris, S.E., 1959, Vertical leakage through till as a source of recharge to a buried-valley aquifer at Dayton, Ohio: Ohio Department of Natural Resources, Division of Water Technical Report 2, 16 p.

_____1974, Regional flow system and ground-water quality in western Ohio: U.S. Geological Survey Journal of Research, v. 2, no., 5, p. 527-531.

_____1979, Hydraulic properties of a limestone-dolomite aquifer near Marion, north-central Ohio: Ohio Department of Natural Resources, Division of Geological Survey Report of Investigations 110, 23 p.

_____1986, Draft report on the hydrogeology of the Scioto River valley between Columbus and Shadeville: Unpublished report on file in the library of the Columbus, Ohio office of the U.S. Geological Survey [variously paginated].

Norris, S.E., Cross, W.P., and Goldthwait, R.P., 1950, The water resources of Greene County, Ohio: Ohio Department of Natural Resources, Division of Water Bulletin 19, p. 23.

Norris, S.E., and Fidler, R.E., 1973, Availability of water from limestone and dolomite aquifers in southwest Ohio and the relation of water quality to the regional flow system: U.S. Geological Survey Water-Resources Investigations Report 17-73, 42 p.

Ohio Department of Natural Resources, Division of Water, 1970, Ground water for planning in northwest Ohio—A study of the carbonate rock aquifers: Ohio Water Plan Inventory Report 22, 62 p.

Ohmoto, Hiroshi, and Rye, R. O., 1979, Isotopes of sulfur and carbon, *in* Barnes, H. L., ed., Geochemistry of hydrothermal ore deposits: New York, John Wiley & Sons, p. 509-567.

Panno, S.V., and Bourcier, W.L., 1990, Glaciation and saline-freshwater mixing as a possible cause of cave formation in the eastern midcontinent region of the United States—A conceptual model: Geology, v. 18, p. 769-772.

Pearson, F. J., Jr., and Rightmire, C. T., 1980, Sulfur and oxygen isotopes in aqueous sulphur compounds, *in* Fritz, P., and Fontes J. Ch., eds., Handbook of environmental isotope geochemistry, volume 1: The terrestrial environment, A: New York, Elsevier Scientific Publishing Company, p. 227-258.

Pearson, F.J., Jr., and White, D.E., 1967, Carbon 14 ages and flow rates of water in Carrizo Sand, Atascosa County, Texas: Water Resources Research, v. 3, no. 1, p. 251-261.

Pettyjohn, W.A., and Henning, R.J., 1979, Preliminary estimate of groundwater recharge rates, related streamflow and water quality in Ohio: Columbus, Ohio State University, Water Resources Center, Project Completion Report 553, 323 p.

Piper, A.M., 1944, A graphic procedure in the geochemical interpretation of water analyses: American Geophysical Union, v. 25, p. 914-923.

Plummer, L.N., 1977, Defining reactions and mass transfer in part of the Floridan aquifer: Water Resources Research, v. 13, no. 5, p. 801-812.

Plummer, L.N., Jones, B.F., and Truesdell, A.H., 1976, WATEQF—A Fortran IV version of WATEQ, a computer program for calculating chemical equilibria of natural waters: U.S. Geological Survey Water-Resources Investigations Report 76-13, 61 p.

Plummer, L.N., Michel, R.L., Thurman, E.M., and Glynn, P.D., 1993, Environmental tracers for age dating young ground water, *in* Alley, W.M., ed., Regional ground-water quality: New York, Van Nostrand Reinhold, p. 255-294.

Pollock, D.W., 1989, Documentation of computer programs to compute and display pathlines using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 89-381, 188 p.

Richards, R.P., 1990, A study of water quality in private rural wells in the limestone ridge area near Carey, Ohio—Preliminary report of first year results: Tiffin, Ohio, Heidelberg College Water Quality Laboratory, 23 p.

Roadcap, G.S., Cravens, S.J., and Smith, E.C., 1993, Calculating groundwater recharge rates to the Silurian dolomite aquifer in northeastern Illinois [abs.], *in* 38th Annual Midwest Ground Water Conference, Program and Abstracts, p. 53.

Rosenshein, J.S., 1963, Recharge rates of principal aquifers in Lake County, Indiana: Ground Water, v. 1, no. 4, p. 4-20.

Rowland, M.R., and Kunkle, G.R., 1970, Cones of influence developed in the Silurian-Devonian aquifer, Maumee River Basin, Ohio: Ground Water, v. 8, no. 3, p. 37-43.

Rupp, J.A., and Pennington, Dean, 1987, Determination of the 10,000 mg/l TDS surface within the bedrock aquifers of Indiana: Proceedings of the Indiana Academy of Science, v. 97, p. 383-389.

Rye, R.O.; Back, William; Hanshaw, B.B.; Rightmire, C.T.; and Pearson, F.J., Jr., 1981, The origin and isotopic composition of dissolved sulfide in groundwater from carbonate aquifers in Florida and Texas: Geochimica et Cosmochimica Acta, v. 45, p. 1941-1950.

Schmidt, J.J., 1979, Ground-water resources of Delaware County: Ohio Department of Natural Resources, Division of Water, 1 sheet.

Schneider, W.J., 1957, Relation of geology to streamflow in the upper Little Miami Basin: Ohio Journal of Science, v. 57, no. 1, p. 11-14.

Scott, J.C., 1990, A statistical processor for analyzing simulations made using the modular finite-difference ground-water flow model: U.S. Geological Survey Water-Resources Investigations Report 89-4159, 218 p.

Searcy, J.K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542-A, 33 p.

Seber, G.A.F. and Wild, C.J., 1989, Nonlinear regression: New York, John Wiley & Sons, 768 p.

Shaver, R.H., regional coordinator, 1985, Midwestern Basin and Arches Region—Correlation of stratigraphic units of North America (COSUNA) project: American Association of Petroleum Geologists, 1 sheet.

Sherwood, J.M., Rogers, J.C., and Pickens, J.B., 1991, Ohio, floods and droughts, *in* Paulson, R.W., and others, comps., National water summary 1988-89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 443-450.

Shindel, H.L., Klingler, J.H., Mangus, J.P., and Trimble, L.E., 1991a, Water resources data, Ohio, water year 1990: U.S. Geological Survey Water-Data Report OH-90-1, v. 1, 305 p.

_____1991b, Water resources data, Ohio, water year 1990: U.S. Geological Survey Water-Data Report OH-90-2, v. 2, 281 p.

Siegel, D.I., 1989, Geochemistry of the Cambrian-Ordovician aquifer system in the northern Midwest, United States: U.S. Geological Survey Professional Paper 1405-D, 76 p.

_____1991, Evidence for dilution of deep, confined ground water by vertical recharge of isotopically heavy Pleistocene water: Geology, v. 19, p. 433-436.

Siegel, D.I., and Mandle, R.J., 1984, Isotopic evidence for glacial meltwater recharge to the Cambrian-Ordovician aquifer, north-central United States: Quaternary Research, v. 22, p. 328-335.

Smith, B.S., Hardy, M.A., and Crompton, E.J., 1985, Water resources of Wildcat Creek and Deer Creek basins, Howard and parts of adjacent Counties, Indiana, 1979-82: U.S. Geological Survey Water-Resources Investigations Report 85-4076, 92 p.

Soller, D.R., 1986, Preliminary map showing the thickness of glacial deposits in Ohio: U.S. Geological Survey Miscellaneous Field Studies Map 1862, scale 1:500,000.

Steiger, J.R., and Holowaychuk, Nicholas, 1971, Particle size and carbonate analysis of glacial till and lacustrine deposits in western Ohio *in*, Goldthwait, R. P., ed., Till, a symposium: Ohio State University Press, p. 275-289.

Stith, D.A., 1979, Brine analyses, 1972-1974: Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 79-1 [no page numbers].

Stoertz, M.W., 1989, A new method for mapping groundwater recharge areas and for zoning recharge for an inverse model: Madison, Wis., University of Wisconsin, Ph.D. dissertation, p. 178.

Stoertz, M.W., and Bradbury, K.R., 1989, Mapping recharge areas using a ground-water flow model—A case study: Ground Water, v. 27, no. 2, p. 220-228.

Stout, Wilbur, Lamborn, R.E., and Schaaf, Downs, 1932, Brines of Ohio: Geological Survey of Ohio Bulletin 37, Fourth Series, 123 p.

Strobel, M.L., 1990, Characteristics affecting the vertical flow of ground water through selected glacial deposits in Ohio: Ohio State University, unpublished Master's thesis, 185 p.

_____1993, Hydraulic properties of three types of glacial deposits in Ohio: U.S. Geological Survey Water-Resources Investigations Report 92-4135, 41 p.

Strobel, M.L., and Faure, Gunter, 1987, Transport of indicator clasts by ice sheets and the transport half-distance—A contribution to prospecting for ore deposits: Journal of Geology, v. 95, p. 687-697.

Stueber, A.M., Pushkar, Paul, and Heatherington, E.A., 1987, A strontium isotopic study of formation waters from the Illinois Basin, U.S.A.: Applied Geochemistry, v. 2, p. 477-494.

Stueber, A.M., and Walter, L.M., 1991, Origin and chemical evolution of formation waters from Silurian-Devonian strata in the Illinois Basin, U.S.A.; Geochimica et Cosmochimica Acta, v. 55, p. 309-325.

Stueber, A.M., Walter, L.M., Huston, T.J., and Pushkar, Paul, 1993, Formation waters from Mississippian-Pennsylvanian reservoirs, Illinois Basin, U.S.A.—Chemical and isotopic restraints on evolution and migration: Geochemica et Cosmochimica Acta, v. 57, p. 763-784.

Sun, R.J., and Johnston, R.H., 1994, Regional aquifer-system analysis program of the U.S. Geological Survey, 1978-92: U.S. Geological Survey Circular 1099, 126 p.

Thatcher, L.L., 1962, The distribution of tritium fallout in precipitation over North America: Bulletin of the International Association of Scientific Hydrology, v. 7, no. 2, p. 48-58.

Thorstenson, D.C., Fisher, D.W., and Croft, M.G., 1979, The geochemistry of the Fox Hills-Basal Hell Creek aquifer in southwestern North Dakota and northwestern South Dakota: Water Resources Research, v. 15, no. 6, p. 1479-1498.

Thelin, G.P., and Pike, R.J., 1991, Landforms of the conterminous United States—A digital shaded-relief portrayal, U.S. Geological Survey Miscellaneous Investigations Series Map I 2206, scale 1:3,500,000

Todd, D.K., 1969, Ground water resources of the Upper Great Miami River basin and the feasibility of their use for streamflow augmentation: Dayton, Ohio, Miami Conservancy District, 142 p.

Toth, Jozsef, 1963, A theoretical analysis of groundwater flow in small drainage basins: Journal of Geophysical Research, v. 68, no. 16, p. 4795-4812.

Turner, W.S., 1977, A geochemical study of some Silurian dolomites in northwestern Ohio: Toledo, Ohio, University of Toledo, unpublished Master's thesis, 82 p.

U.S. Environmental Protection Agency, 1984, National secondary drinking water regulations: EPA-570/9-76-000, Appendix A [no pagination].

U.S. Geological Survey, 1987, Digital elevation models, data users guide: U.S. Geological Survey National Mapping Program Technical Instructions Data Users Guide 5, 38 p.

_____1989, Digital line graphs from 1:100,000-scale maps: U.S. Geological Survey National Mapping Program Technical Instructions Data Users Guide 2, 88 p.

U.S. Geological Survey, 1970, Hypsography of Indiana: U.S. Geological Survey State Base Map, scale 1:500,000.

U.S. Geological Survey, 1971, Hypsography of Ohio: U.S. Geological Survey State Base Map, scale 1:500,000.

Van Metre, P.C., 1990, Structure and application of an interface program between a geographic-information system and a ground-water flow model: U.S. Geological Survey Open-File Report 90-165, 68 p.

Walker, F.H., 1959, Natural brines of Indiana and adjoining parts of Illinois and Kentucky: Indiana Geological Survey Report of Progress 13, 58 p.

Walter, L.M., Stueber, A.M., and Huston, T.J., 1990, Br-Cl-Na systematics in Illinois basin fluids—Constraints on fluid origin and evolution: Geology, v. 18, p. 315-318.

Walton, W.C., and Scudder, G.D., 1960, Ground-water resources of the valley-train deposits in the Fairborn area, Ohio: Ohio Department of Natural Resources, Division of Water Technical Report 3, 57 p.

Watkins, F.A., Jr., and Rosenshein, J.S., 1963, Ground-water geology and hydrology of the Bunker Hill Air Force Base and vicinity, Peru, Indiana: U.S. Geological Survey Water-Supply Paper 1619-B, 32 p.

Wayne, W.J., and Zumberge, J.H., 1965, Pleistocene geology of Indiana and Michigan, *in* Wright, H.E., Jr., and Frey, D. G., eds., The Quaternary of the United States: Princeton, N.J., Princeton University Press, p.63-83.

Weist, W.G., Jr., 1978, Summary appraisals of the Nation's ground-water resources—Great Lakes Region: U.S. Geological Survey Professional Paper 813-J, 28 p.

Western Michigan University, Department of Geology, 1981, Hydrogeologic atlas of Michigan: Kalamazoo, Mich., plate 14, scale 1:500,000.

Wigley, T.M., 1975, Carbon-14 dating of ground water from closed and open systems: Water Resources Research, v. 11, p. 324-328.

Wilding, L.P., Drees, L.R., Smeck, N.E., and Hall, G.F., 1971, Mineral and elemental composition of Wisconsin-age till deposits in west-central Ohio *in*, Goldthwait, R.P., ed., Till, a symposium: Ohio State University Press p. 290-317.

Williams, T.A., and Williamson, A.K., 1989, Estimating water-table altitudes for regional ground-water flow modeling, U.S. Gulf Coast: Ground Water, v. 27, no. 3, p. 333-340.

Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf Coast aquifer systems, south-central United States—A preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 89-4071, 124 p., 4 pls.

Willman, H.B., and others, comps., 1967, Geologic map of Illinois: Illinois State Geological Survey, scale 1:500,000.

Wilson, T.P., and Long, D.T., 1993a, Geochemistry and isotope chemistry of Michigan Basin brines—Devonian formations: Applied Geochemistry, v. 8, p. 81-100.

_____1993b, Geochemistry and isotope chemistry of Ca-Na-Cl brines in Silurian strata, Michigan Basin, U.S.A.: Applied Geochemistry, v. 8, p. 507-524.

Winter, T.C., 1983, The interaction of lakes with variably saturated porous media: Water Resources Research, v. 19, no. 5, p. 1203-1218.

Wood, W.W., 1976, Guidelines for collection and field analysis of groundwater samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. D2, 24 p.

Yager, R.M., 1993, Simulated three-dimensional ground-water flow in the Lockport Group, a fractured dolomite aquifer near Niagara Falls, New York: U.S. Geological Survey Water-Resources Investigations Report 92-4189, 43 p.

Yapp, C.J., and Epstein, Samuel, 1977, Climatic implications of D/H ratios of meteoric water over North America (9500-22,000 B.P.) as inferred from ancient wood cellulose C-H hydrogen: Earth and Planetary Science Letters, v. 34, p. 333-350.

Young, G.M., Sharpe, D.R., and McKenzie, G.S., 1985, Quaternary and Proterozoic glacial deposits of the central Great Lakes: Columbus, Ohio, Sixth Gondwana Symposium, August, 19-23, 1985, Ohio State University, Field Excursion 7, Guidebook, 119 p.