HYDROGEOLOGIC INFORMATION IN THE GREAT LAKES BASIN, UNITED STATES, AND APPLICATION OF A GEOGRAPHIC INFORMATION SYSTEM TO PUBLIC-SUPPLY WELLS AND HAZARDOUS-WASTE SITES

by Kelly L. Warner, John D. Earle, and Marvin G. Sherrill

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U.S. Geological Survey
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ABSTRACT

A computerized data base has been established to facilitate analysis and interpretation of potential for ground-water contamination in the Great Lakes basin. The computerized data base is being used in conjunction with a geographic information system (GIS). Locations of public-supply wells were obtained from Federal and State agencies and stored in the system. Well locations are displayed using the Albers equal-area projection. A GIS was used to create a map of public-supply wells and a map of combined waste sites and public-supply wells.

A comprehensive bibliography of 1,114 references, published during the period 1960-86, pertaining to hydrogeologic studies in the Great Lakes basin and geographic information systems, has been compiled using a relational data-base program. Where possible, references are indexed by State and county to assist in determining areas where additional study is necessary.

INTRODUCTION

In 1978, the U.S. and Canada signed a renewed Great Lakes Water Quality Agreement that calls for identifying emerging water-quality problems in the Great Lakes basin. The agreement does not specify monitoring the chemical quality of the ground water, but, in 1982, the Science Advisory Board of the International Joint Commission recommended that "ground-water resources of the Great Lakes System be studied to determine potential contamination routes via this source and to establish mitigative measures" (Swain, 1985). Subsequent reports written for the Commission by Swain (1985) for the U.S., and by Gillham (1985) for Canada, document conditions and locations throughout the Great Lakes basin where ground water is susceptible to contamination.

Swain (1985) found conditions favorable in the U.S. for the transport of contaminants to the Great Lakes by the discharge of ground water to the lakes. Permeable glacial deposits and fractured bedrock in the Great Lakes basin allow rapid infiltration and movement of water and contaminants to the water table, into deeper aquifers, and eventually to streams and lakes. Swain (1985, p. 18) states that "the greatest concentration of hazardous-waste sites are in areas adjacent to the lakes near Chicago, Cleveland, and the Niagara River area."

In 1984, the Groundwater Contamination Task Force was established by the Science Advisory Board to construct a proposal outlining the strategy needed to determine the extent and potential effects of ground-water contamination on the Great Lakes. That proposal recommends that all existing reports, data, and maps for the basin be compiled. The maps would consist of, but not be limited to, the following: composition of surficial materials and depth to bedrock, bedrock geology, permeability of surficial materials, ground-water-flow characteristics, aquifer use, land use, and locations of point sources of ground-water and surface-water contamination.

In 1987, the U.S. Geological Survey (USGS) initiated a project to achieve two of the goals stated above. The work effort involved the listing of existing reports, theses, dissertations, and ongoing activities; and the development of maps locating the potential point sources of ground-water contamination in the eight States adjacent to the Great Lakes.

Purpose and Scope

This report describes the development of a bibliographic listing and the potential sources of ground-water contamination in the Great Lakes basin, gathered from academic researchers and State and Federal agencies in the eight States adjacent to the Great Lakes. Basinwide maps were developed showing the location of public-supply wells and waste sites. The sites include all known contaminated sites as of 1986.

Description of Study Area

The Great Lakes basin, which contains the largest volume of freshwater in the world, has one of the largest concentrations of population and industry in the U.S. Nearly half of the basin's land area is underlain by aquifers that have the potential to yield more than 250,000 $(gal/d)/mi^2$ (Great Lakes Basin Commission, 1975c, p. 7). Throughout most of the Great Lakes basin, shallow ground-water divides coincide with surface-water divides; therefore, in this report, the perimeter of the Great Lakes basin in the U.S., the study area, is defined by the surface-water drainage divides.

The Great Lakes basin consists of the drainage basins of the five Great Lakes--Erie, Huron, Michigan, Ontario and Superior--and has a combined land and water area of 298,800 mi^2. In the U.S., these drainage basins contain all or part of 8 States--Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin--and all or part of 207 counties in these States (fig. 1). The combined land and water area of the Great Lakes basin in the U.S. is 178,400 mi^2, or 59.7 percent of the total basin.

Population density in the Great Lakes basin is four times that of the national average, making the basin the most densely inhabited inland region in the U.S. (Great Lakes Basin Commission, 1976a, p. 18). Approximately 31 million people live in the U.S. part of the Great Lakes basin. This population has

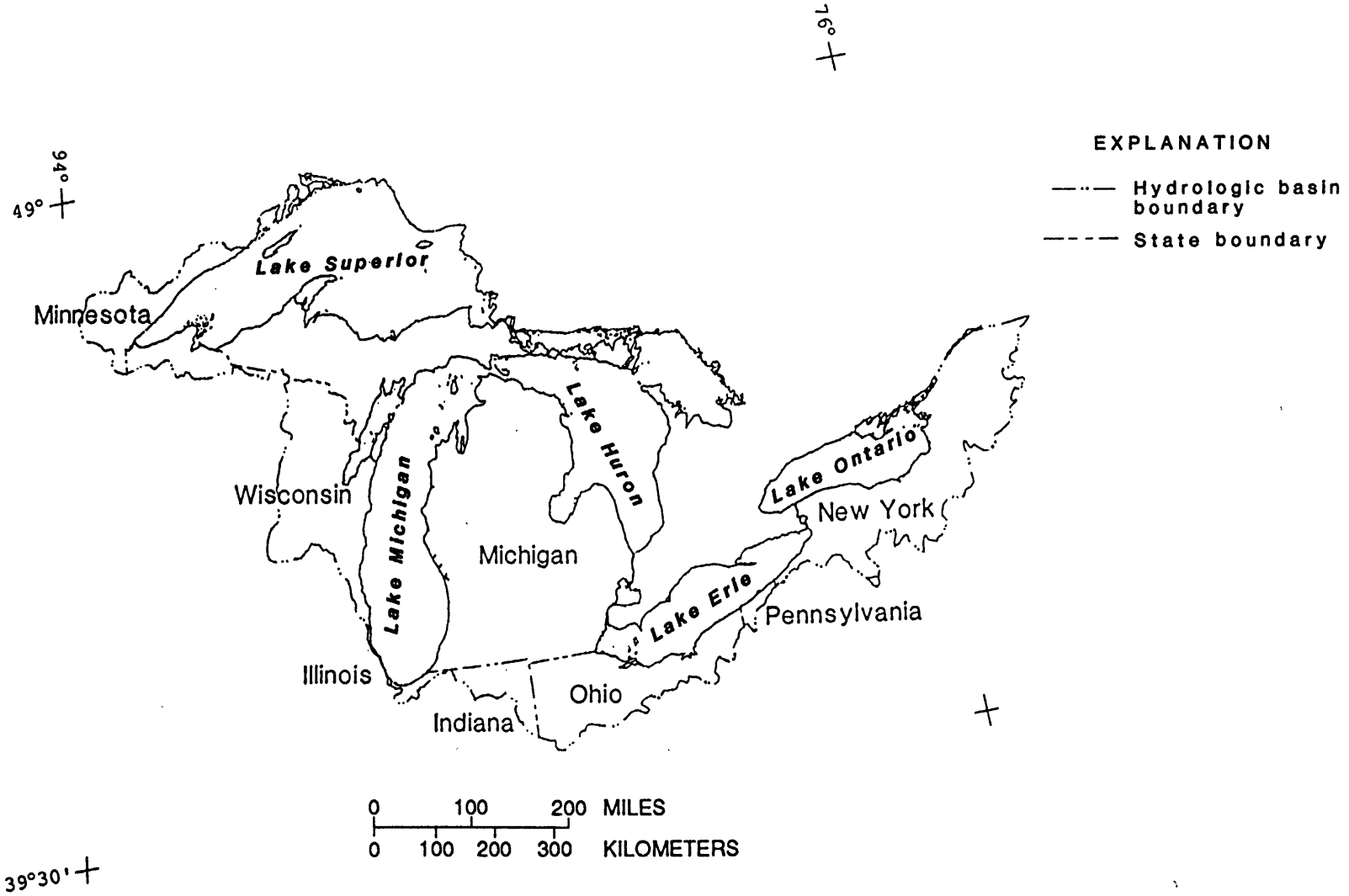

Figure 1.--Location of the Great Lakes basin in the United States.

stayed more or less constant since 1980 (U.S. Department of Commerce, 1986). Illinois and Wisconsin are the only States whose population increased since 1980. Twenty of the 207 counties in the basin contain 50 percent of the population. Two counties--Cook County, Illinois, and Cuyahoga County, Ohio--have more than 1 million inhabitants. The basin also contains 20 percent of the manufacturing value in the U.S. (Great Lakes Basin Commission, 1975a, p. 6).

Determination of direct- and indirect-ground-water flow in the basin is essential to understanding the total ground-water inputs to the Great Lakes. Nearly half of the basin's land area is underlain by aquifers that have the potential to yield more than 250,000 $(gal/d)/mi^2$ (Great Lakes Basin Commission, 1975c, p. 7). The direct-ground-water flow to the Great Lakes is commonly assumed to be the amount of water input that is not accounted for by surface-water flow and precipitation. Direct-ground-water flow to the Lakes has not been measured for the basin. Indirect flow is the ground water that flows to streams that discharge to the Lakes. Thus, the effect of ground water on the water budget, and ultimately the water quality of the Great Lakes, is not fully understood.

Although productive aquifers are found throughout the basin, ground water is often ignored in studies of the water budget of the Great Lakes. Taylor and Cherkauer (1984) estimated that ground-water contributions to the Lake Michigan water budget can be as high as 5 to 10 percent. This can have a noticeable effect on the Lake's chemistry, because ground water generally carries much higher concentrations of dissolved constituents than does rain water or surface water.

Acknowledgments

This project was made possible through the support of the International Joint Commission, and funding by the U.S. State Department and U.S. Geological Survey, Office of Water Data Coordination. Thanks are given to the various State agencies that provided public-supply-well locations. Articles and references from universities, research institutes, and laboratories in the Great Lakes basin are greatly appreciated.

HYDROGEOLOGIC INFORMATION

A bibliography of 1,114 references pertaining to the hydrogeology of the Great Lakes basin in the U.S. was compiled in a relational data-base system. The references were collected from many sources. Computerized bibliographic searches were completed on several subjects, including ground water, water quality, contamination sources, geology, and land use. An earth-science data base, GeoRef (Geological References), produced by the American Geological Institute, was the primary data base searched. Letters were sent to various research institutions in the Great Lakes basin requesting lists of their publications, on-going research, and reprints. The USGS water-use specialists in each of the Great Lakes States provided supplementary information for the bibliography. The criteria used for selecting documents was their relevance to the above list of subjects.

The bibliographic data base was arranged alphabetically by author, and each reference was given a unique number. The unique numbers are used to index the references to various subjects. The subject terms used to index each reference were taken from "GEOREF Thesaurus and Guide to Indexing" (Riley, 1981) and "Water Resources Thesaurus" (U.S. Department of the Interior, 1980). Each reference was coded by State and county if the information was readily accessible. The data base can be searched by author, subject, State, county, and year. The bibliography is in a relational data base that may be accessed from a geographic information system (GIS).

APPLICATION OF A GEOGRAPHIC INFORMATION SYSTEM

A GIS was used to generate digital maps of public-supply wells and hazardous-waste sites. The GIS is used to manage digital data related to each public-supply well or hazardous-waste site. The data was collected from various sources.

Public-Supply Wells

Site-specific data for public-supply wells (henceforth referred to as wells) were retrieved from the USGS State Water-Use Data System (SWUDS), the Ground-Water Site Inventory (GWSI), and (or) from State agencies in 1987. The SWUDS and GWSI are USGS-maintained data-storage and retrieval systems that contain ground-water information from local, State, Federal, and private organizations. The SWUDS contains water-use data, and the GWSI contains aquifer characteristics and well data. Locations of 4,236 wells in 8 States are shown on plate 1--Illinois (13), Indiana (316), Michigan (2,939), Minnesota (46), New York (245), Ohio (322), Pennsylvania (36), and Wisconsin (319).

Obtaining well locations was the primary goal for compiling the public-supply-well map, but additional information was requested, including well owner, well identification number, State, county, latitude and longitude, hydrologic unit, aquifer; township, range, and section (TRS); and remarks. Remarks include total withdrawals for 1986 and comments regarding the status or accuracy of the well location. Data on aquifer characteristics were not available for most older wells.

There are no consistent guidelines for collecting and storing well information among the States in the Great Lakes basin. Discrepancies concerning definition of what constitutes a public-supply well and inconsistencies among data-collection programs cause disparities in the regional data base. For example, the large concentration of wells in the eastern part of the Upper Peninsula of Michigan results from the designation of fire department wells as public-supply wells. Snavely (1986) summarizes the water-use programs, including well data for the Great Lakes basin.

The information obtained on wells had to be manipulated for use in an ARC/INFO[1] GIS. Latitude and longitude coordinates or Universal Transverse Mercator (UTM) coordinates of wells were converted to Albers map coordinates in order to be consistent with other USGS GIS data bases. Location descriptions are given for wells in some States by township, range, section, and quarter-section coordinates. Latitude and longitude were obtained for these wells by manually plotting the points on 7-1/2-minute topographic quadrangle maps, then encoding the corresponding latitude and longitude into the system. The well locations were plotted in the center of the closest quarter section.

The source of data in each State determines the accuracy of the location information. Some agencies report site-specific information, but most previously published data were aggregated by county. State agencies use various legal or unique geographic coordinates that must be converted to latitude and longitude, UTM, State plane, or other coordinates that are readily input to ARC/INFO.

Most locations of wells in New York were provided by the New York Department of Public Health in latitude and longitude, but some latitudes and longitudes were determined from well locations plotted and digitized on paper maps. Half of the Minnesota wells were located from a well-tabulation form (Lee Trotta, U.S. Geological Survey, oral commun., 1987), and the latitudes and longitudes for the rest of the wells were derived by manually plotting well locations. In Michigan, 99 percent of the 2,939 wells were located only by street address provided by the Michigan Department of Public Health. The conversion of street address to latitude and longitude was accomplished for approximately 75 percent of the wells in Michigan by locating, and then digitizing, the wells on topographic maps. Wells in the Upper Peninsula had TRS information (1 percent of wells) that was manually plotted on 7-1/2-minute quadrangle maps; latitude and longitude were determined from these maps. The Michigan State University, Center for Remote Sensing, digitized most public-supply-well locations for the purpose of evaluating trends in nitrate contamination of ground water (Kittleson and Kruska, 1986). This information is in unique coordinates that could not be converted to ARC/INFO coordinates at the time of the writing of this report (Mike Badar, University of Michigan, oral commun., 1988).

Information for Illinois, Indiana, Ohio, Pennsylvania, and Wisconsin was readily available and needed only minor revisions to develop a location coverage in ARC/INFO. The Illinois State Water Survey located wells by TRS; each section further subdivided to locate the well within a 10-acre plot. These were manually converted to latitude and longitude. The Indiana Department of Natural Resources provided information in UTM coordinates. The Ohio Department of Natural Resources provided locations in latitude and longitude. The well locations in latitude and longitude for Pennsylvania and Wisconsin were provided by the USGS District offices.

[1]Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Waste Sites

The waste sites include all known contaminated sites as of 1986 listed under the Resource Conservation and Recovery Act (RCRA) of 1976 and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. The basin contained 196 waste sites in 1986 (pl. 2 and fig. 2) (U.S. Geological Survey, 1988b). Six attributes in the GIS are associated with each site.

Several problems were discovered in producing these maps by means of a GIS. The maps that were developed from existing information have several resolution problems. If no latitude and longitude were available for a site, latitude and longitude were computer generated by the centroid of the postal zone improvement program (ZIP) code. The latitude and longitude coordinates generated from the ZIP code correspond to the owners address, which is not always the same as the waste-site ZIP code. This is the only computerized information available. Care should be taken in using this map (pl. 2) for planning purposes because the locations of the waste sites are not field verified.

A second problem concerns the accuracy of determining the number of waste sites in a given area. One point may represent more than one site. This problem is most likely the result of computer-generated latitude and longitude that plot all sites with the same postal ZIP code at the center of the city. Resolution of density on the existing data base could be enhanced by searching for identical latitudes and longitudes and then using a unique symbol to represent site density.

Many institutions in the Great Lakes basin are using ARC/INFO to create and edit digital information. The ARC/INFO data base that the USGS established is based on existing national or regional digital data. There is a need to integrate existing digital data from a variety of sources and to edit all data bases for precision and applicability. By using ARC/INFO, very specific regional information can be accumulated and used in local studies or generalized for regional analysis. Documentation of digitized information and map-scale variability will determine the extent to which this information can be integrated.

There are many sources of digital data. Currently, the National Cartographic Information Center and the Information Systems Division of the USGS have two computerized information directories--the Spatial Digital Data Directory and the Earth Science Data Directory. These directories include references to GIS data bases and sources of information.

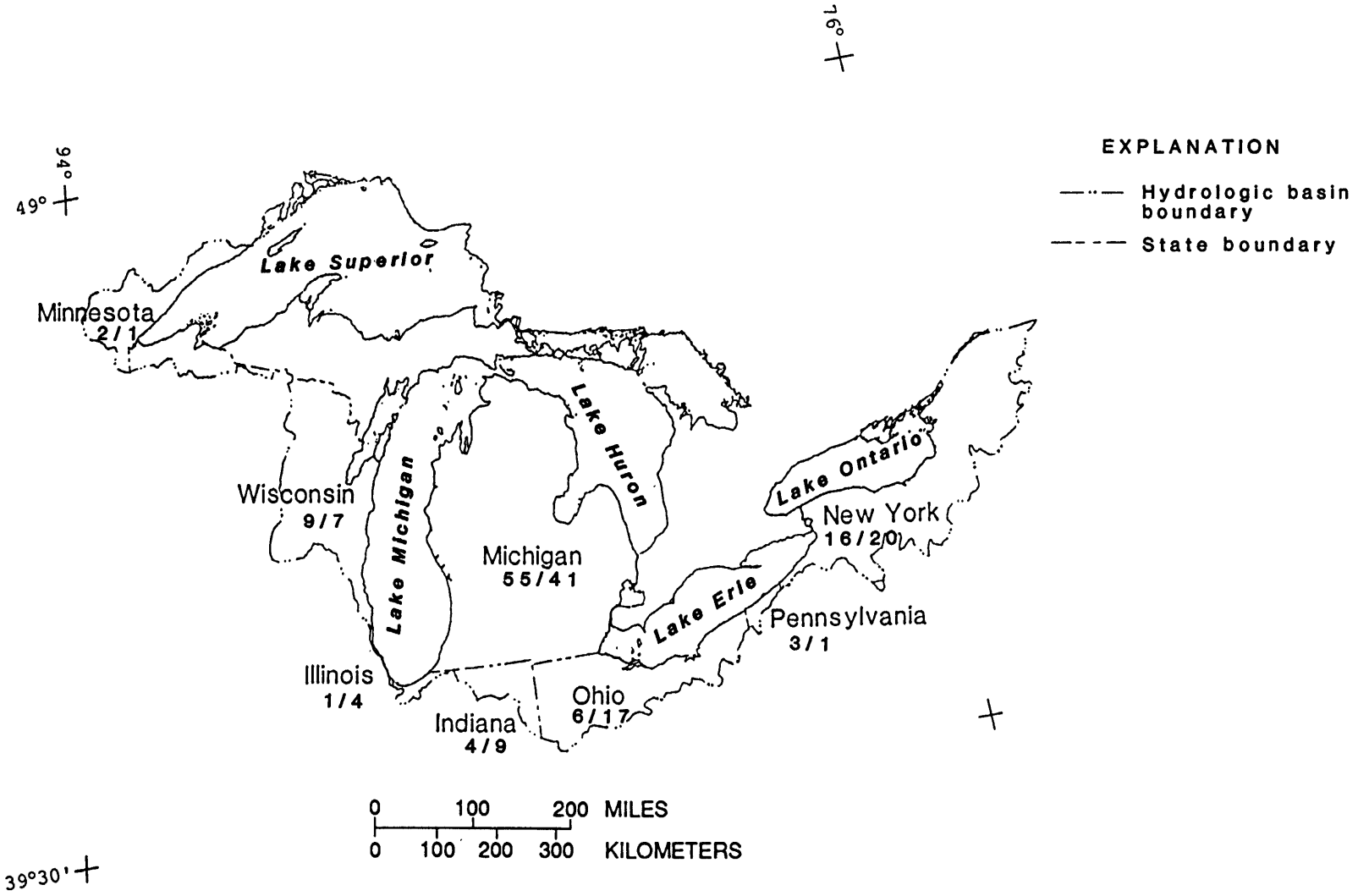

Figure 2.--Number of waste sites by State. (Upper number is CERCLA sites, lower number is RCRA sites.)

SUMMARY

A bibliography of 1,114 references pertaining to the hydrogeology of the Great Lakes basin in the U.S. was compiled in a relational data-base system. These references span the period 1960-86. When information was available, the references were indexed by author, year, subject, State, and county. Regional information on aquifers and water quality is scarce.

A GIS was used for data management and for the display of locations of public-supply wells and waste sites. Public-supply-well information was collected from USGS water-data storage systems or from State agencies.

A map showing the proximity of public-supply wells to waste sites was developed using ARC/INFO. Waste sites include all known contaminated RCRA and CERCLA sites as of 1986. Problems involving accurate site locations of waste sites include location duplication and inaccurate extrapolation of latitude and longitude based on site address and postal ZIP code.

(p. 11 follows)

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Geophysics	000014	000025	000035	000036	000044	000077	000089
	000099	000150	000199	000232	000238	000336	000342
	000367	000400	000401	000477	000509	000512	000579
	000720	000727	000929	000933	001095		
GIS	000003	000012	000037	000086	000097	000154	000168
	000191	000211	000214	000216	000239	000249	000269
	000270	000296	000297	000341	000379	000431	000433
	000481	000489	000490	000550	000612	000619	000805
	000832	000940	000941	000988	000991	001055	001063
Glacial Aquifer	000005	000009	000010	000041	000046	000078	000091
	000092	000099	000105	000106	000124	000131	000140
	000141	000142	000143	000144	000148	000149	000150
	000151	000170	000171	000181	000185	000193	000194
	000195	000196	000197	000198	000222	000279	000340
	000351	000354	000355	000358	000359	000360	000365
	000374	000434	000442	000449	000450	000460	000462
	000482	000486	000487	000491	000514	000517	000518
	000528	000532	000556	000596	000597	000599	000604
	000606	000616	000617	000618	000666	000667	000668
	000676	000688	000689	000690	000706	000710	000716
	000729	000730	000739	000756	000759	000765	000773
	000774	000775	000778	000779	000782	000785	000788
	000789	000792	000800	000835	000836	000837	000838
	000843	000844	000850	000905	000932	001003	001030
	001031	001035	001036	001042	001078	001097	001108
Glacial Geology	000002	000007	000015	000017	000025	000028	000030
	000041	000047	000057	000059	000080	000093	000094
	000095	000099	000101	000105	000117	000128	000133
	000139	000176	000184	000188	000199	000200	000201
	000229	000230	000231	000232	000233	000237	000266
	000268	000333	000352	000369	000380	000384	000416
	000438	000456	000477	000484	000485	000494	000495
	000507	000511	000512	000531	000534	000553	000555
	000579	000614	000633	000634	000639	000662	000664
	000673	000722	000734	000735	000744	000763	000766
	000788	000789	000794	000795	000806	000812	000824
	000842	000847	000875	000900	000912	000923	000935
	001003	001058	001059	001060	001062	001098	001099
	001100						

Water Level	000004	000005	000007	000124	000125	000133	000134
	000135	000136	000145	000148	000149	000172	000184
	000212	000213	000251	000280	000288	000289	000336
	000364	000526	000538	000552	000611	000632	000672
	000711	000717	000788	000860	000865	000871	000904
	000908	000909	000935	000937	000956	001017	001018
	001019	001020	001033	001040	001068	001088	001091
	001093	001103	001114				
Water Management	000032	000034	000045	000055	000100	000147	000307
	000314	000343	000344	000453	000511	000536	000552
	000562	000740	000804	000827	000828	000880	001020
	001052	001093	001114				
Water Quality	000011	000017	000021	000022	000023	000026	000032
	000033	000062	000067	000068	000078	000082	000086
	000092	000096	000097	000106	000118	000119	000123
	000125	000129	000130	000136	000144	000145	000148
	000151	000153	000155	000156	000169	000171	000184
	000206	000210	000211	000218	000241	000250	000263
	000271	000275	000277	000278	000282	000284	000343
	000344	000346	000349	000350	000351	000357	000362
	000371	000378	000405	000425	000441	000509	000511
	000519	000562	000620	000621	000665	000674	000677
	000683	000691	000720	000721	000725	000755	000757
	000792	000821	000822	000829	000831	000851	000862
	000872	000907	000924	000951	000954	000967	000986
	000987	000995	000997	001017	001018	001052	001081
	001106	001107					
Water Resources	000001	000004	000026	000027	000031	000066	000132
	000134	000135	000136	000137	000140	000143	000148
	000149	000153	000191	000194	000195	000196	000197
	000217	000227	000262	000263	000270	000281	000283
	000288	000292	000294	000307	000311	000347	000348
	000361	000363	000376	000377	000379	000396	000397
	000399	000411	000412	000470	000471	000489	000490
	000515	000550	000556	000568	000572	000573	000574
	000575	000596	000611	000613	000620	000659	000669
	000693	000694	000698	000699	000708	000714	000721
	000737	000738	000787	000804	000810	000811	000813
	000814	000826	000827	000833	000840	000868	000878
	000881	000916	000942	000955	000956	000965	001008
	001009	001011	001020	001034	001038	001045	001048
	001052	001053	001066	001067	001077	001080	001101
	001105	001107					

(p. 155 follows)

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