WATER-TABLE CHARACTERISTICS IN THE LAKE WAWASEE BASIN AND VICINITY

Companion Guide to the Water Table Map of the Lake Wawasee Basin

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Introduction

Lake Wawasee is the largest natural lake in Indiana. The lake is late Wisconsin age and occupies a massive ice-block depression in the classic interlobate area that lay between the Saginaw and Erie Lobes. The lake is located in northeastern Kosciusko County, but a large part of the watershed is located in southwestern Noble County. The major tributary is Turkey Creek, which flows into the southeastern corner of the lake. Upstream of the lake, Turkey Creek connects a chain of ten much smaller lakes. Lake Wawasee is hydraulically connected to and at the same elevation as Syracuse Lake, which lies just to the west in the same basin; the two lakes and their associated wetlands cover almost 8 square miles. Turkey Creek discharges from the west end of Syracuse Lake, and thus also acts as the principal outlet for the system. The outlet is regulated by the Indiana Department of Natural Resources to maintain lake levels at slightly less than 859 feet above mean sea level (858.66 ft).

Turkey Creek is the primary source of surface water that drains into Lake Wawasee. Dillon Creek is the other main tributary, and empties into the east end of the lake. The outlet of this drainage is severely disturbed by development and no longer follows its original course. Several other smaller, mostly intermittent ravines that emanate from the uplands to the south and north also discharge surface water into both Lake Wawasee and Syracuse Lake. Collectively, the surface streams provide a significant, though probably not the major, proportion of the water budget of the lake. The lake basin is surrounded by extensive glacial uplands whose summits are commonly greater than 950 feet, and locally exceed 1,000 feet in elevation. These uplands are the source of a large amount of ground water that discharges into the lake. Ground-water discharge also supports the base flows of the two major tributaries. Indeed, it is no coincidence that both tributaries are located on the east side of the lake. Extensive deposits of saturated gravel and sand in that area provide abundant ground-water discharge into both streams on a year-round basis. Similarly, much of the water that leaves the Wawasee basin is also in the form of ground water. Even a cursory review of basin geology and geography makes it clear that the interaction of ground water with the lakes is a key process in the overall water budget and water quality picture.

Saturated sand and gravel aquifers of widely-ranging sizes occur at various depths under and around the basin, and most of these are capable of contributing at least some ground water to the lake. The ground water closest to the land surface is typically recharged at a much greater rate than ground water in aquifers buried beneath clay layers, and such near-surface ground water is generally characterized by faster flow rates. Because of these qualities, the shallow ground water likely contributes the majority of ground water that discharges into the lake. Also, by virtue of its proximity to the land surface, the shallow ground water is considerably more susceptible to contamination from a variety of anthropogenic sources. This discussion is intended to supplement the “Water Table Map of the Lake Wawasee Basin”, and highlights the key characteristics of the shallow ground water of the basin, as revealed by the water table map.

Definition of the Water Table and Related Features

Ground water is defined as all water below the surface of the earth. Ground water occupies the natural openings that occur in rocks and sediments. In the Lake Wawasee basin, the bedrock is between 200 and 400 feet deep, and is overlain by glacially-derived sediment that contains all of the economically and environmentally significant ground water. In this setting, ground water is found in the spaces between the individual mineral grains that comprise the sediment. These openings are referred to as “pores”, and the total volume of pores in the sediment is expressed as a percentage called “porosity”. At any given location, the water table represents the depth below the surface where all of the pores are completely filled with ground water. It also represents the point at which the water pressure in the pores is exactly equal to atmospheric pressure.

This relationship can be illustrated by considering an imaginary, clear plastic box filled with sand, on one side of which a notch has been cut to simulate a stream outlet. The surface of the sand in the box is arranged to resemble a stream valley draining toward the notch. To simulate rainfall, a fine mist of water is sprayed on the surface of the sand at a rate sufficiently low to preclude any surface runoff. The water seeps down through the sand to the bottom, eventually forming a zone of saturation as all of the pores near the bottom of the box become filled. This zone will have a level surface as long as it remains below the surface of the simulated valley. Continuing addition of water will eventually cause the zone of saturation to rise above the surface of the valley in the box. Once that happens, the water will begin flowing through the notch in the box, and a surface stream will develop in the valley. Away from the valley, the zone of saturation will rise above the level of the notch and valley, because sand is not perfectly permeable, and ground water will begin to flow laterally through the zone of saturation towards the lowest point in the simulated landscape, where it will discharge into the valley. Along the top of the zone of saturation (the water table), the pressure of the water in the sand is exactly the same as the atmospheric pressure of the air in the box. With increasing depth below the water table, however, the water pressure in the pores becomes progressively greater than atmospheric pressure, due to the weight of the overlying water. These pressure differences are one component of “hydraulic head”, which is a measure of the potential energy present at any point in the ground-water flow system. The other component is elevation—with greater elevation, water has more potential energy. These basic forces drive the flow of ground water, and explain why the water table commonly has a similar, though somewhat more subdued, shape as the overlying land surface.

The imaginary exercise described above illustrates several other key principles: 1) in the absence of ground water flow, the water table is flat; 2) a sloping water table means that the ground water is flowing. The slope of the water table is expressed as a gradient (e.g., feet per mile). Ground water flow is always down the slope of the water table; 3) ground water discharge typically occurs in low places in the landscape; 4) shallow ground water generally flows away from topographically high landforms, where it recharges, toward topographic lows, where it discharges.

The zone between the land surface and the water table is referred to as the “unsaturated zone”. In this zone, the pores are only partly filled with water, and the tension created by capillary forces causes fluid pressure to be negative. Water-table depth ranges widely across the landscape, generally being greatest below topographic highs, and least below topographic low spots. The unsaturated zone is probably more than 50 feet thick below some of the highest uplands in the Wawasee basin, especially in those places underlain by thick sand and gravel. On the other hand, the thickness of the unsaturated zone is zero in the vicinities of most lakes and wetlands. By virtue of the presence of gasses such as oxygen, and abundant friendly aerobic microbes, the unsaturated zone has the ability to remove many types of impurities from water that moves downward as recharge. On the other hand, once water hits the saturated zone, there are few or none of these cleansing gasses and microbes available to remove or transform contaminants into more benign substances. At that point, the contaminant will enter the ground-water flow system, by either floating on the water table if the contaminant is lighter than water (e.g., gasoline), sinking to the bottom of the aquifer (heavy liquids like volatile organic solvents), or mixing with and moving at the same or similar rate as the ground water itself (e.g., nitrate, bacteria, many heavy metals, and other miscible solutes).

One other key concept is “permeability”, more correctly referred to as “hydraulic conductivity”. This term refers to the intrinsic ability of a particular mass of sediment to transmit water under a uniform hydraulic gradient. Hydraulic conductivity is chiefly a function of the size and interconnectedness of the pores in the sediment. A clean, well-sorted sand has rounded grains about a millimeter in diameter that touch one another at just a few points, resulting in a significant volume of large pores that are well connected, and hence transmit water readily, on the order of several feet or more per day. In contrast, clay consists of plate-like, electrically-charged particles as little as one-millionth the size of a sand grain, resulting in pore sizes that are measured at the molecular level. Water transmission is exceedingly slow, often measured in inches per year. A good analogy for visualizing these differences would be to take a large room and fill one side to the ceiling with bowling balls, and the other side with newspaper stacked flat. If a million gallons of water was introduced at the ceiling, it is clear that almost all of it would flow through the bowling balls before most of the newspaper ever got wet. Although well-sorted sands and pure clays do exist in nature (and in the basin), the great majority of sediments have properties somewhere between these two end members. For example, a common kind of deposit in the basin is sandy gravel, in which the pores between the gravel are filled with sand. In this case, permeability is mainly a function of the sand size. At the other end of the spectrum, glacial till is an unsorted or poorly sorted mix of particles ranging from large boulders to clay; it typically appears as gravel and stones embedded in a matrix of stiff mud. Primary permeability in till is controlled by the predominant grain size of the matrix, and is generally quite slow. It is important to note that till and other fine-grained deposits can have a well-developed secondary hydraulic conductivity, arising from a combination of fractures and thin, interbedded seams of better-sorted materials, such as silty sands and muddy gravels. Such features can collectively result in a “bulk” hydraulic conductivity orders of magnitude greater than the primary conductivity, though typically far less than that of sand and gravel. Loam- and clay-loam-textured tills of low-to-moderate hydraulic conductivity are common throughout the basin, and are the dominant surface deposit on many uplands.

Influence of Basin Geology on Water Table Characteristics

If the basin was everywhere underlain by uniform sand, such that permeability was the same in all directions, the water table would resemble an extremely subdued version of the surface topography, with broad highs and lows, evenly-spaced contours, and gently sloping water-table topography throughout. In reality, the water table is developed in a diverse group of sediments of contrasting permeability that overlie and interfinger with one another in complex patterns. This juxtaposition of different sediment types across the basin results in the varied and locally irregular water table pattern evident in the map. These sediments are broadly grouped into 3 contrasting categories, whose distributions are depicted at a coarse scale in figure 1 of the Water Table map. Extensive areas of surficial sand and gravel occur mainly to the north of the basin, as well as along a northwest-trending axis defined by Turkey Creek and the City of Syracuse. The water table contours in these areas do exhibit the kind of gentle, low-relief pattern described above. Large depressional areas underlain by muck and peat, either atop sand and gravel or other kinds of sediment, also exhibit a gently-sloping water table. Good examples of this sort of water-table pattern are visible in the broad lowland occupied by Solomon Creek, and in the outwash fan bordering the east shore of the lake north of Turkey Creek. In contrast, the water table below uplands underlain by thick sequences of till has a strongly mounded appearance, with tightlyspaced contours that rise sharply from adjacent lowlands, parallel to surface topography. The tightly-packed water-table contours along the north side of Turkey Creek between Indian Village and Knapp Lake, and along the east side of Tri-County State Preserve, are both examples of places where the water table descends steeply off till-cored uplands into adjacent lowlands underlain by more permeable materials. The flatter parts of these till-cored uplands may well have what is termed a "perched" water table, wherein the slowly permeable till holds up the downward movement of soil water, creating a secondary zone of saturation that is "perched" above the real (perennial) water table, which may lie tens of feet below this. This condition is most common where a more permeable layer (e.g., sand and gravel) occurs at some depth below the surface. The amount of recharge coming through the overlying till is too slow to keep up with the ability of sand to transmit the water away laterally, and results in another unsaturated zone in the top of the sand and lower part of the overlying till. In some parts of the basin, the landscape appears to be underlain by a sometimes-chaotic and unpredictable mix of coarse- and fine-grained sediments, whose distributions are too complex to characterize or depict at the current map scale, at least without the benefit of a detailed subsurface analysis. The largest example in the map area is the intensely collapsed landscape running between Webster and Papakeechie Lakes that corresponds broadly to the Tri County State Preserve. Here, the surface sediment ranges from gravelly to clayey over short distances, and a review of well logs in the area suggests that several large sand and gravel bodies emerge from beneath their till cover along the sides and at the bottoms of the numerous deep ravines and depressions that pock the area. Numerous lakes and wetlands of various types and sizes occur at widely ranging elevations, suggesting that there may be multiple perched water tables in this landscape. The water-table contours in this and other areas shown as "mixed sediment" on figure 1 most likely represent a composite of one or more perched water tables and the actual (perennial) water table marking the top of the continuous zone of saturation. In general, the lower in the landscape, the more likely the contours are to represent the top of the actual, permanent zone of saturation.

Whereas the contours can reasonably be expected to accurately represent the local flow patterns of very shallow ground water, the potential for perched water tables in landforms with a significant component of fine-grained sediment may result in exaggerated water-table mounds in these areas, whose configurations do not reflect the flow direction of ground water at somewhat greater depth. In general, the deeper the ground water, the less affected it is by local variations in the overlying surface topography. Hence, the water table contours on the map should be interpreted as reflecting flow conditions in only the most near-surface part of the saturated zone.

How the Map Was Made

The water-table map was constructed entirely from office-derived information following the method outlined by Blanchard and Bradbury (1987). The lakes, wetlands, and streams in the Wawasee basin are all, to some degree, connected to the water table, and there is a high density of such features throughout the basin. All of the lakes are thought to be water-table lakes, as are most of the wetlands and streams, especially in the lower-lying parts of the landscape. As such, they represent the intersection of the water table with the land surface. The elevations of these surface water features are readily identifiable on the 1:24,000 USGS topographic maps that cover the basin. By using a color-coding scheme to highlight surface water bodies according to their respective elevations, the water-table pattern becomes very apparent and can be contoured using the topographic maps as a base. The relationship between the water table and the many small, isolated wetlands and ephemeral streams on large uplands where till is a major component of the surface sediment is less clear. It is possible that some, or even many of these features are simply indicating places where a perched water table is present, but it is also possible that they may represent the perennial water table, especially in areas underlain by thick till with little interbedded sand and gravel. It is not possible to resolve this question in the absence of field verification (which may require installing observation wells in some cases).

To address this issue in the making of the map, two approaches were utilized. First, figure 1 was added as an inset to the main map in order to broadly identify areas underlain by different kinds of sediment assemblages that may affect the water table in the ways noted previously. Used in conjunction with the water table map, the information on figure 1 can help the user recognize that a given area or landform of interest is not uniform or differs from adjacent areas in its composition, and thus alert the user that the water-table contours should be interpreted carefully. Second, a measured approach was used when contouring uplands known to be partly or wholly underlain by fine-grained soils and sediment. Typically, the highest water-table contours mapped on these uplands do not correspond to the highest wetlands or ephemeral streams shown on the topographic maps, in fact, the highest water-table contour may stop several tens of feet below the highest surface-water feature shown on the topo map. This is due to the aforementioned relationship that this method of making a water table map is most reliable in the lowest parts of the landscape and becomes less so at higher elevations; there is a good chance that these highest wetlands and streams shown on the topo map represent a perched condition. The only way to determine otherwise is to conduct field verification in these areas. In short, the highest water-table elevations represented on most of these uplands are intermediate between the probable elevations of the actual water table (as represented by lakes, large depressional wetlands, and perennial streams), and the elevations of isolated wetlands and ephemeral streams whose affinities (i.e., perched or not) are unclear.

How to Use the Water Table Map

The map is intended to show the general configuration of the water table around the Lake Wawasee basin, and to help identify the parts of the landscape that contribute shallow ground water to the overall water budget of the lake (i.e., the "ground-watershed). The map is accurate only to within the 10-foot contour interval used to depict lines of equal water table elevation. Additional errors may result from: 1) the fact that the water table elevation is interpreted from surface-water features shown on the topographic maps, which are themselves interpretations of aerial photographs used by the USGS to construct the topographic maps; and 2) the potential presence of one or more perched water tables in areas where the surface is underlain by fine-grained materials. Therefore, the map should act as a general guide for determining the water-table elevation at any particular location—and it should not be the sole source of information used to provide a precise elevation. On the other hand, the map is expected to accurately represent the general shape and slope of the water table, and thus can be used with reasonable confidence to predict the direction of shallow ground-water flow in specific areas, which is always perpendicular to the water-level contours. The map pattern also allows the parts of the land surface that function as source areas (i.e., recharge areas) for the shallow ground water that enters the lake to be inferred reasonably reliably. The map also allows the positions in the ground-water flow system of many wetlands to be deduced, enabling them to be broadly classified according to their hydrologic function (i.e., recharge, discharge, flow-through types). This type of classification should be the first step in a more detailed investigation of specific wetlands of interest, insofar as large wetlands (and lakes) are likely to be characterized by different hydrologic functions at different places and in different seasons. Finally, it is important to note that water levels, ground-water flow directions, and recharge-discharge relations associated with deeper (confined) aquifers may be different from those associated with the water-table. The topics presented in the following discussion summarize some key features of the shallow ground-water flow system in the basin, and serve as examples of the kinds of information that can be appropriately gleaned from the map.

Regional Water-Table Pattern: The regional ground-water flow direction in this part of northeast Indiana is to the northwest (Beaty and Clendenon, 1987). Although the pattern is interrupted to a degree by chains of lakes and other extensive low lying areas, this also is the dominant flow direction shown on the water table map. The dominant southeast-to-northwest trend is manifested by a preponderance of higher contours in the southern and eastern parts of the map area, and progressively lower contours to the northwest. The same trend is apparent from the surface elevations of the lakes in the map area: the highest lake elevations are consistently found in the southeast, with gradually diminishing elevations to the northwest. This pattern is not surprising, since the lakes are themselves a manifestation of the water table elevation.

Ground-Water Inflows and Outflows to Lake Wawasee: The Wawasee Basin is such a large and topographically low feature that it has a pronounced effect on ground-water flow patterns and creates an extensive low area on the regional water table that acts as a “sink” for ground water at greater elevations around it. The map pattern suggests that the basin intercepts a large amount of the ground water that originates on the uplands to the south and east, and a significant amount from the upland north of Syracuse Lake as well. This makes all of these shorelines potential ground-water discharge areas. However, the actual volume of ground-water discharged in any of these places is as much a function of local geology as it is water-table gradient: relatively little ground water will discharge from even the steepest water-table slopes if the underlying sediment is dominantly fine-grained material such as till. Such low-permeability sediment simply does not have the ability to transmit much ground water, regardless of how great the hydraulic gradient might be. In contrast, even a moderate thickness (10-25 feet) of saturated sand and/or gravel can transmit vast quantities of ground water under a relatively slight gradient. From these principles, it stands to reason that the major locations of ground-water discharge in the basin occur where extensive bodies of sand and gravel coincide with relatively steep hydraulic gradients. The section of shoreline (and lakebed) extending southward from Johnson Bay to Papakeechie Lake fits this description, as does the entire valley of Turkey Creek. These areas are underlain by widespread deposits of coarse sand and gravel that almost everywhere have a saturated thickness of more than 10 feet, and in some places more than 50 feet. Turkey Creek occupies a deeply incised channel, around which the surrounding water-table contours are steeply arrayed; the uppermost parts of the stream also originate from broad areas of sandy deposits. Ground-water discharge is interpreted to be taking place virtually everywhere along the valley. In this context, it is worth noting that the volume of *surface* water discharged into Lake Wawasee by Turkey Creek under base flow conditions (i.e., non-stormwater runoff) is substantial, and all of that originates as ground-water discharge in the relatively short valley of this stream. The east side of the lake also appears to be a substantial ground-water discharge area; in this case, the ground water discharges from the toe of a prominent outwash fan that emanates from the large end moraine that forms the basin divide in this area. Some of the discharge is directly into the lake (probably occurring below the lake surface), whereas some of it is clearly into the small streams that drain the outwash fan, especially Dillon Creek and the Turkey Creek tributary south of old SR 8 (200 S). A significant amount of ground water also is probably discharging along the north side of Syracuse Lake. Although most of the surface of this upland is till-capped, well records in this area indicate the presence of a very thick gravel body that comes out from under the till cap and is truncated along the lower part of the hillside at and above lake level. The full extent of the gravel body is unknown, as are water levels where the aquifer is capped by till.

In contrast, relatively less ground-water appears to discharge along the south side of the lake west of Papakeechie Lake. The upland in this area appears to be composed primarily of till and other slowly permeable material, with only a minor amount of interbedded sand and gravel near the lake. Much of the ground water that may originate from this upland probably flows under the low area near the head of Skinner Ditch, and discharges along the south side of Conklin Bay, as shown on the map.

It is clear from the water-level pattern that the main place ground water leaves the basin is at the west end of both lakes, between Oakwood Park and downtown Syracuse. Most of this area is underlain by permeable, sandy deposits that readily transmit ground water. A significant proportion of the outflow likely follows the lowland now occupied by Skinner Ditch. The amount of ground-water outflow at the west end of the basin must be substantial in order to balance the inflows, so a considerable amount of ground-water recharge is inferred to be taking place along the west shorelines and under the near-shore lakebeds in that area.

<u>Ground-Water Flow Patterns around Johnson Bay and Bonar Lake</u>: The north shore of Lake Wawasee from Johnson Bay westward to Bonar Lake is bounded by a low-lying terrace that, at places, stands only slightly higher than the surface of the lake. There are few perennial surface water features visible on the topographic map in this area, so the presence of the 860-foot water-level contour and the location of the divide shown on the water table map are both speculative. Several factors suggest that this area may function as a ground-water outlet at times: 1) the two branches of Meyer Ditch start in low gaps on either end of the terrace, and flow northward into the Solomon Creek watershed. Typically, shallow ground-water flow is in the same direction as surface drainage; 2) there is strong geomorphic evidence (from aerial photography, the topographic map, and field conditions) that Dillon Creek formerly flowed northward through Johnson Bay and out the low gap now occupied by the east branch of Meyer Ditch—essentially a “river of grass”. It is unclear to what extent the alteration of lower Dillon Creek to suit development needs in the “Enchanted Hills” area has also altered ground-water flow direction in Johnson Bay and points north; 3) regional ground-water flow has a strong northerly component; and 4) the terrace appears to be underlain by a minimum of 10 to 20 feet of permeable gravel and sand; this is less conducive to the formation of a ground-water mound (divide) than if the terrace was underlain by low-permeability till or lake muds, which would form a barrier to ground-water flow and promote a higher water table. Seasonal or longer-term reversals of ground-water flow are one potential scenario for this area: ground water outflow would occur during dry periods when regional water table levels decline relative to lake level, whereas neutral conditions or weak ground-water inflow from the terrace might occur during wet periods when ground-water levels are highest relative to lake level. This is how the area is identified on the map. One other feature whose impact on shallow ground-water flow might reasonable be questioned is the railroad embankment that cuts across the wetlands at Johnson Bay and south of Bonar Lake. Although the details of its construction are unknown, such embankments are typically built up on ballast composed of very coarse rock, which essentially acts like an open-framework gravel with very high permeability. Based on the fact that the ballast material exposed on this embankment is of this type, the embankment is not expected to have a material effect on either the direction or rate of shallow ground-water flow, assuming that no other materials of low permeability exist in the interior of the embankment.

<u>Ground-Water Focusing</u>: Large concave slopes typically create prominent inflections in the water-level contours that parallel the surface topography. This causes shallow ground water to flow into the centers of such concavities, and away from adjacent convex slopes. This process “focuses”

ground-water discharge at the bottoms of concave slopes, which are favored sites for a variety of spring-fed wetlands, especially fens. The water table map suggests numerous places where this process is likely occurring, and these are among the areas highlighted in green as having potentially “significant ground-water discharge”. Prominent examples include the large wetlands near the mouth of Turkey Creek, Dillon Creek at Enchanted Hills, and any number of small arcuate bays along the south and east sides of the lake. Other conspicuous examples can be found along the valley walls of Turkey Creek and in the Tri-State Preserve. These represent prime areas that could be investigated for the presence of high-quality wetlands.

Relations of Wetlands to the Water Table and Surface Topography: The position of any given wetland in the ground-water flow system (i.e., its hydrologic function) is a critical factor in determining the potential impact of the wetland on water quality as well as the kind of natural communities it will support. Coastal wetlands are often complex in this regard, and different hydrologic functions may be dominant in different parts of larger wetland complexes. This is probably true in the Wawasee Basin as well: large, complex wetlands such as above the mouth of Turkey Creek are probably dominated by mineral-based calcareous fens and large ground-water fluxes near the bases of the adjacent slopes, that grade into organic-based acidic or circum-neutral sedge marshes and other flow-through wetlands further offshore. The ground-water discharge provides a constant low-level influx of macro and micro nutrients into these wetlands that promotes a high level of biodiversity. In contrast, the wetlands at the far west end of the basin, where ground-water is leaving the lakes, are expected to mainly be places of ground-water recharge, and perhaps less biologically rich. Nevertheless, recharge wetlands still provide many valuable wetland services, not the least of which are shoreline stabilization, denitrification, and sediment retention. All of these wetland types and functions are likely to be intimately associated in the low-lying series of natural and man-made spits and the adjacent bays that lie between Lake Wawasee and Syracuse Lake. There, westward-flowing ground water is likely recharging through wetlands and shorelines along the east sides of the landforms, discharging along the west sides, and flowing through the marshy bays in between. A similar pattern probably occurs longitudinally along the valley floor of Turkey Creek.

Susceptibility of Shallow Ground-Water to Contamination: There are a plethora of potential contaminants and associated sources that can impact shallow ground water. A few examples include: nitrate and bacteria from septic systems, livestock operations, and agricultural fertilizers; aromatic hydrocarbons derived from leaking underground fuel tanks, spills, and improper disposal of used motor oil; volatile organic compounds (VOC’s) derived from industrial solvents, leaking transformers, and cleaning products; and sodium and chloride from road de-icing salt. Each of these contaminants behaves differently in ground water: aromatic compounds typically float on the water table, VOC’s sink to the bottom of the aquifer, whereas nitrate and salt dissolve in the water. There are also a variety of factors that determine the susceptibility to contamination of ground water below any given location, such as geology, soil type, direction of ground-water flow, and thickness of the unsaturated zone, to name a few. In terms of the most shallow ground water represented by the water table, a key factor is geology: all other factors being equal, it is safe to say that the shallow ground water in areas underlain by sand and gravel is significantly more vulnerable to contamination than that in areas underlain by till or lake clay. The reason is simple: the higher permeability of the granular material allows water and contaminants to reach the water table much faster than in silt and clay. Sand and gravel are commonly composed of quartz, limestone, and other relatively nonreactive minerals, whereas clay possesses a high degree of electro-chemical activity that imparts an ability to attract, react with, and/or adsorb many kinds of contaminants. The position in the flow system is also critical: in discharge areas, where ground water is moving up, the potential for contamination is greatly reduced because only heavier-than-water contaminants can penetrate below the water table; all others will be discharged to the surface. But in places where recharge dominates, such as uplands underlain by sand and/or gravel, the opposite is true. In such places, the thickness of the unsaturated zone (i.e., the depth to the water table), and the degree of soil development (e.g., presence of significant clayey subsoil horizons) are critical. The inset map in figure 1 gives a general idea of the areas where surface sand and gravel is dominant; this can be refined further by examining the county soil surveys, well records, and similar data (see references section below). The water table map can then be used to identify the position in the flow system and to estimate the thickness of the unsaturated zone. Using these principles allows the relative vulnerability of ground water in different areas to be estimated. For example, one of the vulnerable areas appears to be the middle and upper parts of the outwash fan due east of Lake Wawasee in sections 13, 18, 19, and 24. The area underlain by sand and gravel is readily evident from the smooth surface topography and the flatter water table, both marked by smooth, more broadly spaced contours. The relationship between the two types of contour lines suggests that the water table lies relatively close to the surface, but there are few surface water features suggestive of any ground-water discharge in the area. The soil survey shows parts of the area as being underlain by saturated sandy soils with seasonal high water table as close as “0” feet below grade. Based on this information, this area is best interpreted as a water-table recharge area, with a relatively thin unsaturated zone, limited soil development, and thus an elevated vulnerability to contamination. The fact that the ground water in this area appears to flow straight to the lake over a short distance also heightens the sense of vulnerability. A similar analysis can be performed anywhere in the basin using the water table map in conjunction with other readily available data.

References

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