LEVEL II HYDROGEOLOGIC REPORT

PRAIRIE PARKWAY
FOX RIVER BRIDGE CROSSING
SOUTHEAST OF PLANO, ILLINOIS
Job #P-93-007-03 (BDE Seq. #12643)

ISGS Open-File Report 2006-2

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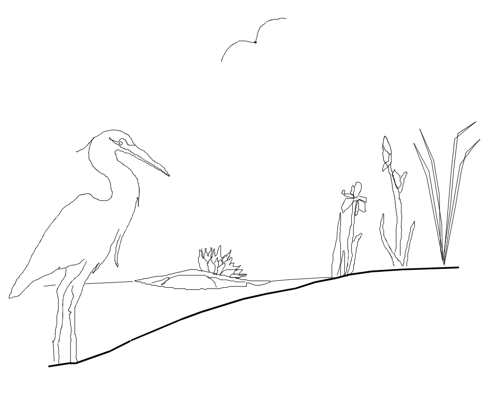

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EXECUTIVE SUMMARY

The Illinois State Geological Survey was tasked by the Illinois Department of Transportation to identify the hydrogeologic conditions that support fen and seep wetlands along the south bank of the Fox River in the Prairie Parkway study corridor. Geologic borings and water-level data suggest that ground water is supplied to the fens by a large, buried body of sand and gravel that extends approximately 1,400-1,700 m (4,600-5,600 ft.) south of the Fox River to the north slope of the Marseilles Morainic System. Ground water in this body flows to the northwest, such that the proposed Prairie Parkway will not cross ground-water flow lines that discharge into the fens of interest until north of Fox Road. South of Fox Road, ground-water flow lines crossed by the alignment will discharge west of the study corridor, where additional fens have been identified but they are beyond the scope of this report. Previously suggested potential impacts to the quality or quantity of ground water supplied to the fens include discharge reductions caused by infiltration losses from increased impervious surfaces, and increases in dissolved constituents such as chloride due to operational activities. This study has determined that the loss of discharge due to increased impervious surfaces is calculated to be a maximum of 0.1% to 3.6% of the current total discharge to the fens. In addition, these minor reductions in discharge are expected have little impact because a fine-grained geologic deposit underlies the fens and maintains the elevations of discharge, thus preventing significant losses in fen acreage. Alterations to ground-water quality due to operational impacts are of concern, especially chloride applied during deicing operations. Accordingly, design changes have been proposed by the Illinois Department of Transportation to prevent infiltration of runoff from the roadway right-of way by collecting and transferring runoff via lined channels to discharge locations that are not within the fens or their ground-water contribution areas. These activities are expected to reduce or eliminate increases in chloride or other unwanted constituents in the ground water.

Prairie Parkway, Fox River Bridge Crossing, Southeast of Plano, Illinois

INTRODUCTION

This report was prepared by the Illinois State Geological Survey (ISGS) to provide the Illinois Department of Transportation (IDOT) with information regarding the hydrogeology of seeps and fens found along the south bluff of the Fox River in the vicinity of the proposed Prairie Parkway, southeast of Plano, Illinois (Figure 1).

The purpose of this report is to provide IDOT with information that can be used in the design of the roadway to minimize potential impacts to the seeps and fens. The primary issue to be addressed in this report is the potential impact of roadway construction and operations on ground-water quantity and quality that currently support the wetlands.

As part of planning studies in 2005, the Illinois Natural History Survey (IHNS) identified a number of wetlands (Figure 2) along the south bluff of the Fox River within the designated Prairie Parkway study corridor (shown as "ESR Study Area Limit" on Figure 2) (Edwards et al. 2006). The wetlands contained calcareous seep and fen communities, hereafter called fens. High-quality plant communities are found in the fens, including uncommon plant species such as the state endangered *Veronica americana* (Edwards et al. 2006).

In December 2005, the ISGS was tasked by IDOT to examine the hydrogeology of the south bluff of the Fox River to assist with roadway planning efforts. ISGS was to identify the geologic units that were supplying ground water to the fens, identify water levels and ground-water flow directions in those units, and estimate any potential impact from roadway construction and operations. ISGS was tasked to focus on the McCarthy parcel (hereafter called the study area or site) in the eastern portion of the study corridor, where preliminary planning efforts had placed the Fox River bridge crossing, and where individuals of *Veronica americana* had been identified (locations shown as "T&E Site" on Figure 2). Wetlands outside of the study corridor are not considered in this report.

METHODS

In January 2006, ISGS and IDOT drilled 7 borings in the study area (Figure 2) directly south of the fens in order to identify the geologic units that provide ground-water discharge to the fens, and to describe the hydrogeologic conditions that support the fen conditions. Monitoring wells were installed in each boring to identify water levels in all identified aquifers (significant water-bearing units), to estimate ground-water flow gradients and directions in each aquifer, and to identify the ground-water contribution area for the fens.

The borings were drilled with an IDOT CME-75 truck-mounted drilling rig using 8.25-cm (3.25-in.) diameter hollow-stem augers, and were sampled using a 0.61 m (2.0 ft.) split-spoon sampler. Samples were collected every 0.75 to 1.5 m (2.5 to 5 ft.) depending on depth and recovery. Samples were described in the field for texture, Munsell color (Munsell Color 2000), sedimentary structures, mineralogy, saturation state, and other features. Descriptive logs for each boring are shown in Appendix A. Geologic samples were grouped into units for description and classification purposes, and were compared with previous geologic mapping in the area to assist in classification of the units and identification of the geologic history of the area.

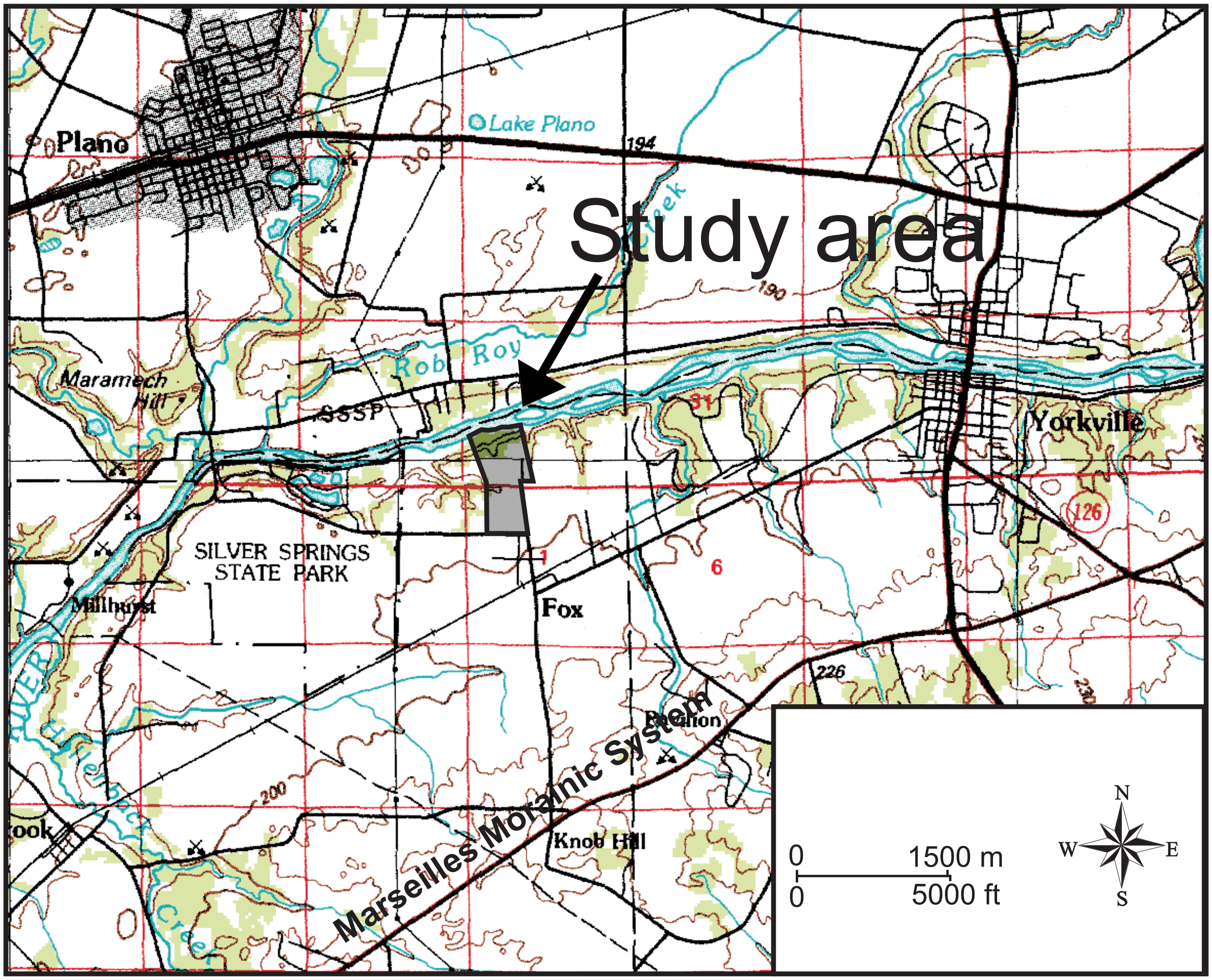

Figure 1. Location of study area (ISGS 2006)

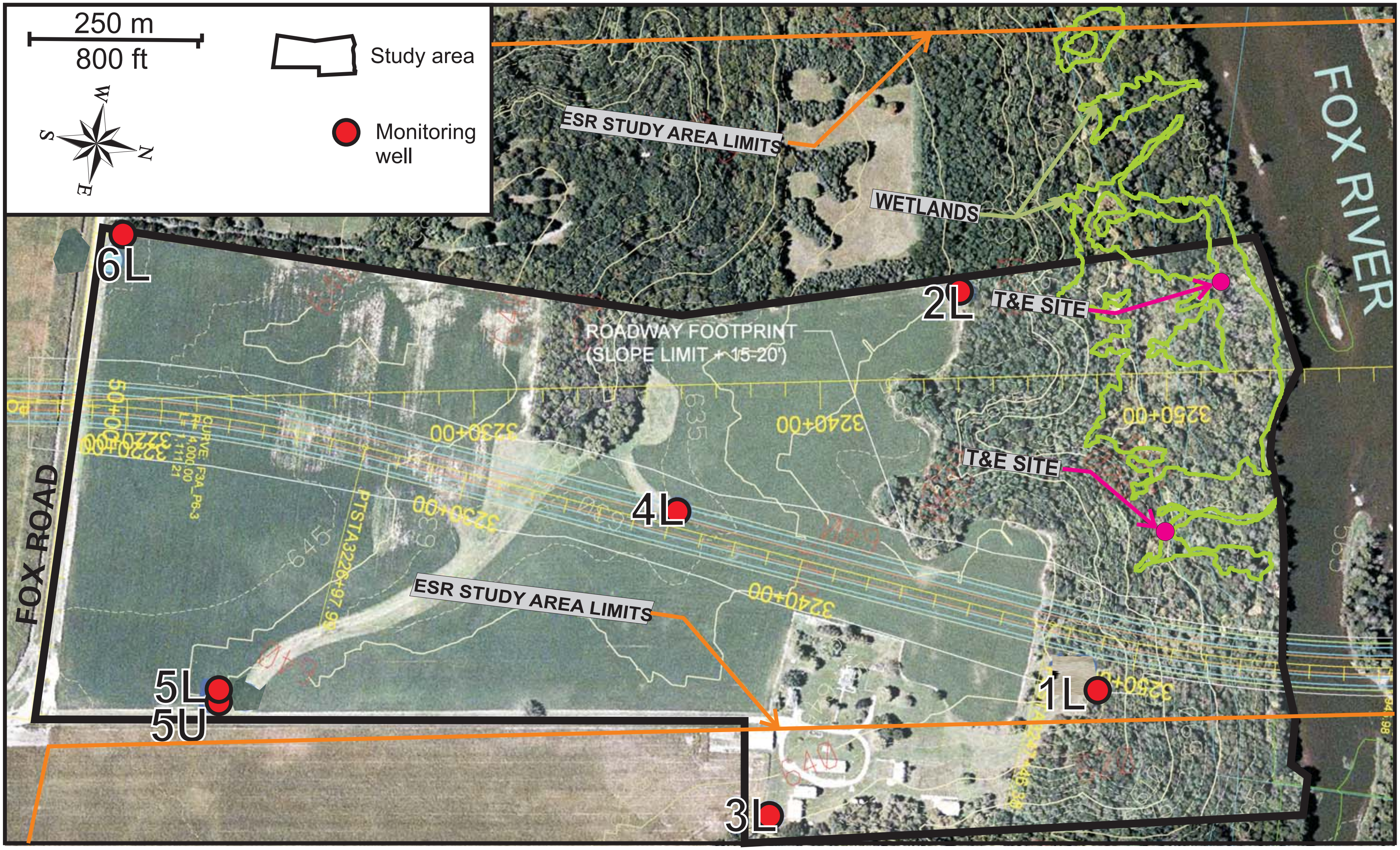

Figure 2. Study area, including ISGS wells, identified fens, locations of threatened and endangered species, study corridor limits, and roadway alignment (map source: Parsons Brinkerhoff)

Prairie Parkway, Fox River Bridge Crossing, Southeast of Plano, Illinois

Monitoring wells were installed in each identified aquifer. Wells were constructed of 2.5-cm or 5.0-cm (1-in. or 2-in.) diameter Schedule 40 PVC with threaded fittings. Well screens were made of the same material, with manufactured slots 0.25-mm (0.01-in.) wide, and were fitted with slip-on caps at the base that were perforated with a hole to allow drainage. Screen lengths varied according to thickness of the aquifer. If more than one aquifer was encountered in a boring, additional borings were made to install nested wells in all aquifers encountered. Appendix B lists construction information for each monitoring well installed.

Water levels were measured in each of the monitoring wells at intervals using a Solinst electronic water-level tape. Depths to water measured below the top of the well casing were converted into water-level elevations and depths below land surface using elevations of the tops of the well casings and elevations of land surface at each well, which were provided by IDOT. Data are shown in Appendix C.

RESULTS

SITE TOPOGRAPHY AND GEOMORPHOLOGY

The site is located between Fox Road on the south and the Fox River on the north (Figure 2), and extends approximately 1,100 m (3,600 ft.) northward from Fox Road. At the southwestern corner of the site, land surface is approximately 199.0 m (653 ft.), and it slopes gently northward to the top of the Fox River bluff at an elevation of about 194.0 m (636.3 ft.) on the northeast corner of the site, where it drops steeply to the Fox River at approximately 172.2 m (565 ft.). Local drainageways traverse the site and flow to the northwest, northeast, and north, providing local relief up to 6 m (20 ft.).

The site lies just north of the Marseilles Morainic System (Willman and Frye 1970), which is an arcuate morainal ridge composed dominantly of glacial till deposited during stillstands of the Wisconsin glacier. South of Fox Road, land surface rises rapidly to the top of the moraine at approximately 238 m (780 ft.) in less than 2.4 km (1.5 mi). When the glacier was depositing the Marseilles Morainic System, the ice was located south of the moraine, and the site was free of ice at that time. Previous glacial advances in the Wisconsin also advanced over the site.

GEOLOGY

Bedrock

Geologic maps of the area (Willman and Lineback 1970) suggest that bedrock is present at land surface at or near the level of the Fox River, which is approximately 172.2 m (565 ft.) in elevation. Bedrock in the area is mapped as shale and dolomite of the Maquoketa Formation, deposited during the Ordovician Period. Bedrock was not encountered during the drilling for this study, although additional alignment borings made by Wang Engineering encountered bedrock at approximately 172.8 m (567 ft.) near the Fox River.

Sediments

Bedrock in the study area is mapped as being overlain by approximately 22.8-30.5 m (75-100 ft.) of unlithified sediments (Piskin and Bergstrom 1975). The thickest sediments encountered in drilling for this study were 24.7 m (81 ft.) thick, although as much as 26.2 m

(86 ft.) thick or more may be present based on bedrock elevations discussed above. The sediments were grouped into 3 units for classification and descriptive purposes.

Unit #1, found at land surface, consists of unsorted or poorly sorted till and diamicton (deposits similar to glacial till where the origin has not been determined), and sorted deposits of silt and sand. This unit ranges in thickness from about 2.7 m (9 ft.) to as much as 11.0 m (36 ft.). Previous ISGS mapping (Willman and Lineback 1970) suggests that the sediments at this site consist primarily of glacial till of the Yorkville Member of the Lemont Formation, which was present at land surface only in boring #6 in the southwestern portion of the site, although till-like diamicton units were present in the other borings, alternating with sand and silt deposits. While Unit #1 commonly was described as a silty sand during drilling, significant amounts of clay and gravel are generally present, suggestive of glacial till deposits that have been remobilized as debris flows, with varying amounts of sorting that altered the original texture.

Unit #2 consists mainly of thick sand and gravel found throughout the site beneath Unit #1 at depths of 2.7-11.0 m (9-36 ft.). These deposits are between 3.0-14.5 m (10-47.5 ft.) thick, and the beds generally vary in texture between silty sand to coarse gravel, although they include beds of diamicton, especially in the northeastern parts of the site. Unit #2 is much thicker in the western and southern parts of the study area.

Unit #3 consists of diamicton encountered beneath Unit #2, but it also includes fine-grained lacustrine sediments found at the base of boring 2L. Unit #3 was found at depths of 6.7-18.1 m (22-59.5 ft.). The beds of lacustrine sediment included in this unit were likely deposited in proglacial lakes.

Geologic cross-sections of the site are shown in Figures 3 and 4. Figure 3 shows a north-south geologic cross-section of the site located along the eastern site boundary. Figure 4 shows an east-west trending cross-section along the edge of the bluff. Both cross-sections show that Unit #2 greatly thickens in the western and southern parts of the site, and thins toward the northeast. The largest discharge and greatest acreage of wetlands along the bluff face also occurs in the western part of the study area where Unit #2 is thick, but discharge is not present along the bluff in the northeastern part of the study area where Unit #2 is thinner and higher in elevation.

GEOLOGIC HISTORY

Given the purpose of this report, the geologic history of the area is only addressed in sufficient detail to describe how the occurrence and continuity of the geologic deposits affect the hydrogeology. The origin of the sediments will be discussed starting with the lowest unit encountered. Bedrock will not be discussed in more detail than already presented.

First, the diamicton of Unit #3 has the characteristics of a glacial till, possibly of the Yorkville Member of the Lemont Formation, although it may belong to a previous glacial advance such the Glasford Formation, which is also found in drilling records from the area (B. Curry, pers. comm.); specific identification of this unit is not part of this report. After

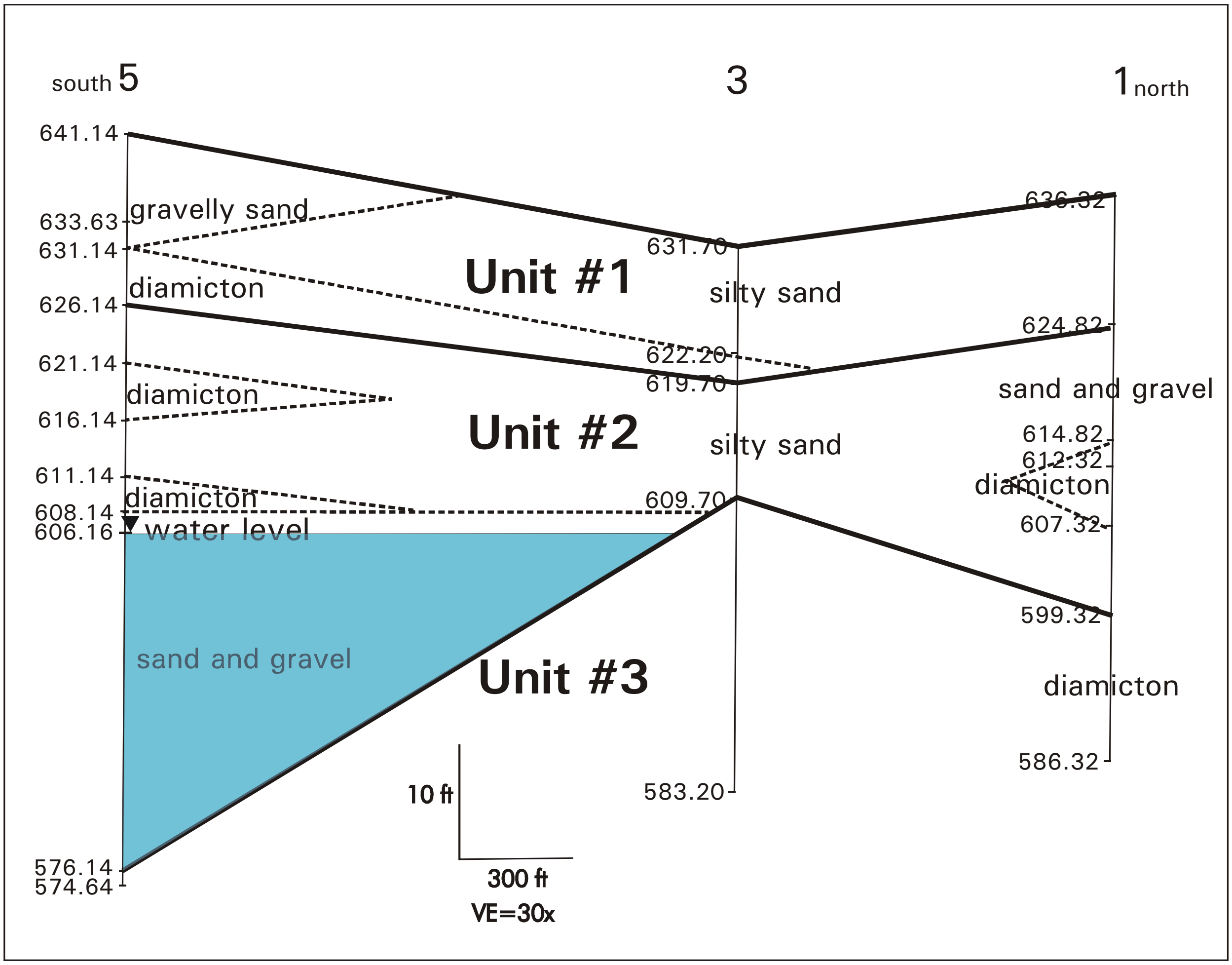

Figure 3. Geologic cross-section from borings 5 to 1, including lithology and elevation of beds and water levels (in feet) noted in monitoring wells on January 19, 2006. Saturated portion of aquifer shown in blue.

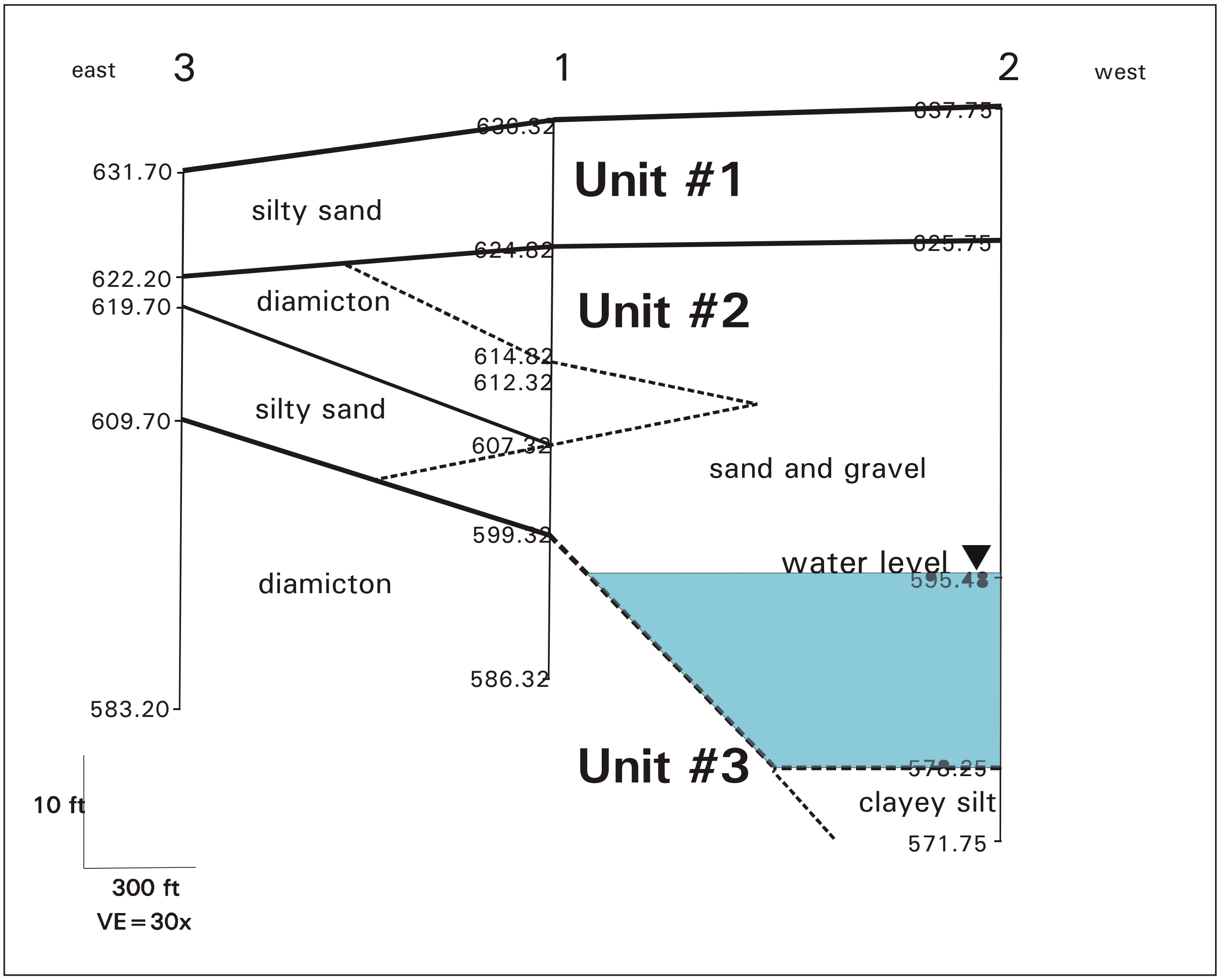

Figure 4. Geologic cross-section from borings 3 to 2, including lithology and elevation of beds and water levels (in feet) noted in monitoring wells on January 19, 2006.

depositing the till, the glacier retreated, leaving the study area free of ice. Unit #3 is present throughout the study area.

The sand and gravel of Unit #2 was deposited by glacial meltwaters, and the fine-grained diamicton deposits in the unit likely were deposited as glacial till or were debris flows that remobilized till deposits. Because the origin is not certain, it is not clear if the unit consists of deposits from a single glacial advance/retreat cycle or from multiple advances and retreats over longer periods to time. A more detailed study would help resolve that question, although it is not germane to the goals of the study at hand, for which the current grouping of sediments is adequate. Because the diamicton units are not present in the southern and western portions of the site, erosion likely removed them prior to deposition of the thick sand and gravel that is found there in Unit #2. Alternatively, if the fine-grained units were debris flows, they may have been local and discontinuous in nature and were never deposited in those areas. The meltwaters may have originated from the Marseilles Morainic System, or may have flowed down the ancestral Fox River from other documented flood events. Unit #2 would likely be classified as Henry Formation sand and gravel of the Mason Group. The origin and classification of the fine-grained units is not addressed here.

Unit #1, present at land surface throughout the site, was deposited when the glacier was at the Marseilles Morainic System, when the site was free of ice. The sediments were deposited by a combination of processes that likely included debris flows, meltwater streams, and glacial ice. Debris flows carried sediment across the site from the Marseilles Morainic System, depositing slightly sorted diamicton. In addition, small meltwater streams flowed across the site, depositing beds of sorted silt and sand. In the southwestern corner of the site, which is topographically highest, the glacier may have readvanced briefly to that position from the south, depositing compacted and unsorted Yorkville till at land surface in that location. Unit #1 would likely be classified as Yorkville till despite containing other ice-proximal deposits. The debris flows are likely to be remobilized glacial till, which is commonly grouped within units mapped as glacial till in areas proximal to a moraine due to common origins and difficulty distinguishing the two types of deposits. The stream-deposited sediments within the unit would be classified as Henry Formation deposits, although the limited thickness and distribution of the sorted sediments prevents them from being mapped individually.

HYDROLOGY

Ground-Water Levels

The hydrology of the site was determined by installing 7 monitoring wells at the 6 boring locations discussed earlier. Unit #2 is the thickest and most extensive aquifer identified during the drilling, and a monitoring well was placed near the base of Unit #2 at all boring locations.

Water levels in Unit #2 were measured in order to determine ground-water gradients and flow directions within the aquifer. Appendix C shows water levels measured in all wells during the monitoring period. Water levels measured on 1/19/06 suggest that ground-water flow was to the northwest on that date (Figure 5), and water levels measured on other dates were similar. Unit #2 generally is not saturated in the northeastern parts of the site in the vicinity of wells 1L and 3L, where the sand and gravel is less coarse, higher in elevation, and contains fine-grained deposits. Water was detected only once in well 3L in July, 2006, and well 1L was dry throughout the monitoring period.

In addition, a sand bed in Unit #1 was thick enough to warrant installation of a monitoring well (5U) at boring #5 in the southeastern part of the site. However, no saturated sediments were observed elsewhere in Unit #1 during the drilling program, and no additional wells were installed in that unit. Therefore, no ground-water flow directions can be determined for Unit #1 because only one data point is available.

The only significant and widespread aquifer noted during drilling was Unit #2. Given that most of the wetlands and seepage observed on the face of the bluff are at approximately 181.4 m (595 ft.), which is similar to the water levels observed in Unit #2 at boring 2L located directly uphill of the seeps, it is apparent that Unit #2 is the source of water for the wetlands. While small seepages are also noted at higher levels along the bluff face and are likely supported by discharge from sorted sediments within Unit #1, these seepages were not mapped as wetlands by INHS and are likely insignificant to this project, so any impacts to these discharges will not be addressed in this report. Further evidence that Unit #2 is the source of water for the fens is that discharge is generally absent east of well 1L, where Unit #2 is not saturated. This is shown on Figure 4, where the saturated portion of Unit #2 pinches out an estimated 30 m (100 ft.) or more west of well 1L.

Ground-Water Contribution Areas

Because Unit #2 is the origin of discharge to the fens, the sources of water carried by Unit #2 must be identified to determine whether roadway construction or operation may have an impact on water quality or quantity transmitted to the fens. For the purposes of this analysis, there are two sources of ground water supplied to Unit #2: off-site sources flowing through the aquifer from upgradient areas, and on-site infiltration that causes recharge to Unit #2 through Unit #1. While these two sources are similar in origin, they are addressed separately due to their differing susceptibility to alteration from the roadway.

Off-site ground-water sources

While the extent of Unit #2 was not comprehensively determined beyond the study area, the origin of the deposit suggests that the unit extends south to the Marseilles Morainic System. Records of water wells on file at ISGS show that significant sand and gravel deposits extend 300-600 m (1,000-2,000 ft.) south of Fox Road to the flank of the Marseilles Morainic System.

Unit #2 transmits ground water northwest toward the Fox River. This ground water ultimately derives from infiltration through Unit #1 at land surface over the large area where Unit #2 is present. As shown in Figure 5, ground water entering the site from the south and east does not cross beneath the proposed roadway prior to entering the site, so ground-water from upgradient areas is not expected to be impacted by construction or operations. Ground-water flow paths that are crossed by the roadway south of the site will discharge west of the study corridor, and the existence of, and impacts to, wetlands in those areas

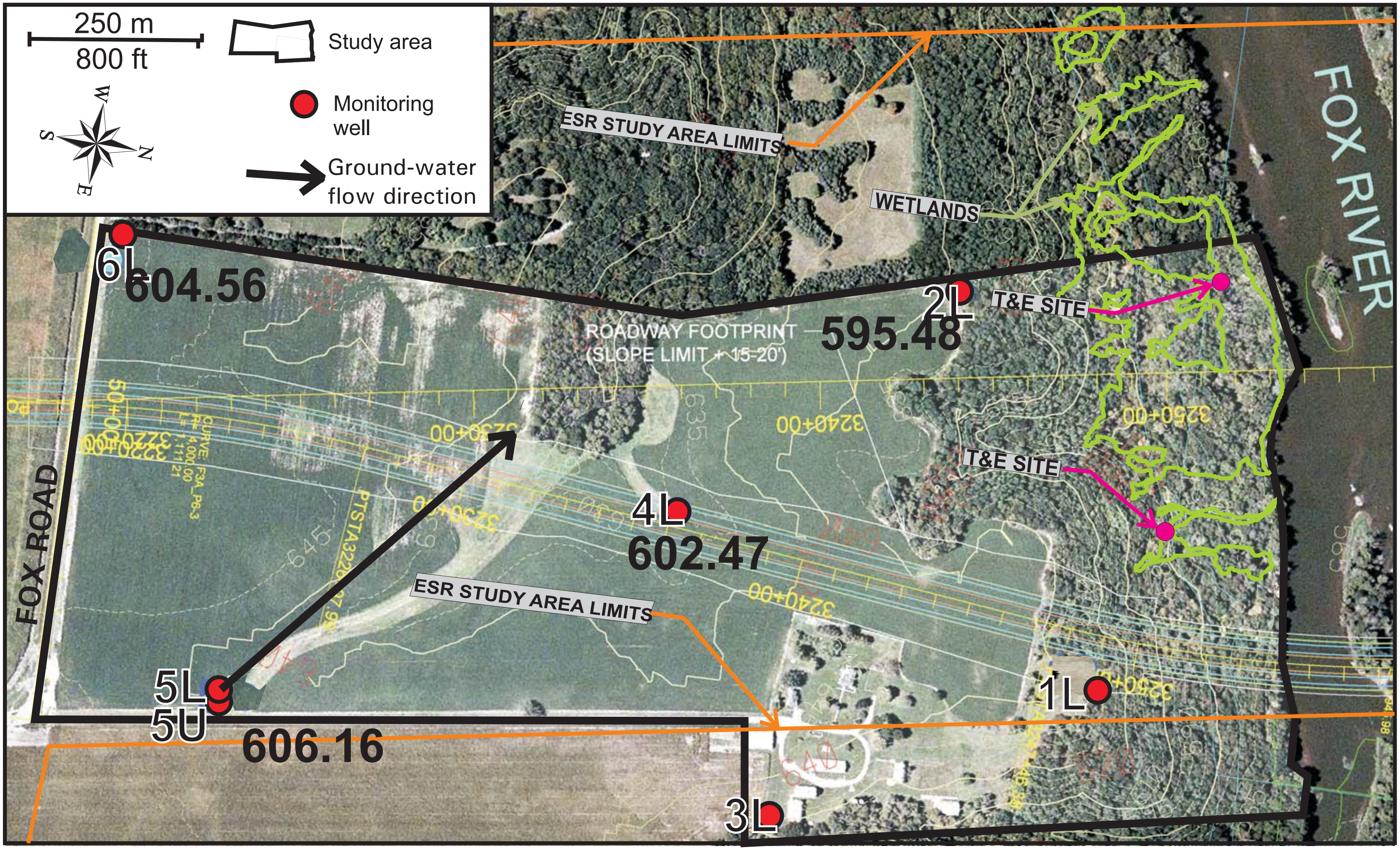

Figure 5. Water levels and ground-water flow directions in Unit #2 measured on January 19, 2006.

are not part of this report. It should be noted that Silver Springs State Park is present in that area, and fens are found within the park, so additional analysis in that area may be warranted.

On-site ground-water sources
Ground water generated on site derives from infiltration of precipitation through Unit #1. While this is the same process that provides ground water to Unit #2 in the offsite areas as described above, it is listed separately because in this area the roadway crosses ground-water flow lines that discharge in the study corridor and may impact the quantity or quality of ground water supplying the fens in the area of concern. Additionally, the short flow path to the fens from on-site infiltration will reduce natural attenuation, so this area deserves additional scrutiny. No other sources of ground water were identified on site that could recharge Unit #2.

Although no ground-water flow directions can be determined in Unit #1 due to the lack of saturated deposits in which to install monitoring wells, shallow ground-water flow in Unit #1 is likely to mimic topography, where ground water in the higher portions of the site flows toward the nearest low area, such as a ravine or the Fox River. As noted previously, the ravines that traverse the study area are incised as much as 6 m (20 ft.) below land surface. Therefore, it is likely that a significant portion of the infiltration through Unit #1 makes its way to the nearest ravine and discharges to land surface, where it flows toward the Fox River in surface channels. This is evidenced by observations of small discharges of ground water in the ravines and erosive marks showing regular flows.

While some of the infiltration discharges to on-site ravines, it is expected that a portion of the infiltration flows downward into Unit #2. Water-level data collected on 1/19/06 show that there is a strong downward hydraulic gradient between Unit #1 and Unit #2, suggesting downward ground-water flow and recharge to Unit #2. While the amount of ground water transferred to Unit #2 is not reliably quantifiable due to a lack of information about the hydraulic properties of the fine-grained deposits within Unit #1, recharge to Unit #2 would be smaller than total infiltration considering that some ground water discharges to land surface rather than recharges Unit #2. The fine-grained deposits within Unit #1 likely limit recharge to Unit #2 by slowing downward ground-water flow.

LIKELY EFFECTS FROM ROADWAY CONSTRUCTION
Concerns have been raised about potential impacts to identified fens. Possible scenarios include the loss of infiltration on site due to the increase in impervious surfaces, which may cause reductions in discharge and consequent reductions in fen acreage or alterations in hydropatterns and plant communities. Changes to ground-water quality due to roadway operations are also possible, causing increases in chloride, silt, heavy metals, and oils and greases, some of which have been identified as detrimental to native plant communities.

Reductions in Discharge
A ground-water model would be needed to quantitatively assess the magnitude of discharge loss and reductions in water levels in the fens. However, the large effort needed to create a ground-water model for this site was determined by IDOT to be unnecessary if semi-quantitative analyses could assist with decision-making. Therefore, ISGS prepared a water

budget to assess the magnitude of potential alterations relative to the total discharge as an alternative to a labor-intensive modeling process.

In order to compare the loss of infiltration to the total volume of discharge, each source of ground water being discharged in the fen was calculated in its current condition and compared to a post-construction calculation. Appendix D shows the calculations made for each source of ground water. Ground water being received from upgradient areas was calculated for a representative flow tube (cross section of saturated aquifer along the flow path) 0.3 m (1 ft.) wide. The amount of infiltration that is expected to occur on land surface above the flow tube on site was also calculated, as well as the loss of infiltration from proposed impervious surfaces on the flow tube. In order to calculate the maximum potential impact, it is assumed that all infiltration into Unit #1 on site flows downward and recharges Unit #2 because no scientific basis exists for calculating how much is discharged to land surface in the on-site ravines.

Ground-water recharge provided by upgradient areas off site is calculated to range between 74 and 300 m^3 (2,600 and 10,600 ft^3) per year in the flow tube (Appendix D). A range of hydraulic conductivity values was used in the calculation as determined from on-site slug testing, with results evaluated using the AQTESOLV Pro computer program (version 3.5). Results from two tests at well 2L are shown in Appendix E. Attempts to measure hydraulic conductivity were not highly reliable due to limitations imposed on measuring equipment due to the small well diameters; initial displacements were less than optimum due to the nonstandard equipment required. Extremely rapid recovery and possible inertia effects were observed. Additional analysis of this parameter is recommended, although values returned by the testing are well within the range of expected values for coarse deposits like Unit #2 (Freeze and Cherry 1979, p. 29).

On-site infiltration into Unit #1 was estimated, and calculations are shown in Appendix D. Because Unit #1 is heterogeneous in texture (ranging from sand to clay), a range of values was used as determined from large-scale studies performed by the Illinois State Water Survey (Walton 1965). This range of values is likely to give a better estimate of the maximum expected impact. The amount of infiltration expected on site along each flow tube is calculated to range between 8 m^3/yr and 51 m^3/yr (300 $ft.^3$/yr and 1800 $ft.^3$/yr). Similarly, the volume of infiltration loss within the right-of-way was also calculated, and is estimated to range between 0.5 and 3.0 $m^{3/}$yr (17.5 and 105 $ft.^3$/yr), assuming all precipitation in the right-of-way is prevented from infiltrating (Appendix D).

Total discharge to the fens along each flow tube is the sum of recharge from offsite plus infiltration on site, or 82 to 351 m^3/year (2,900 and 12,400 $ft.^3$). Given the above values for infiltration, the total loss of recharge to Unit #2 caused by the proposed impervious surfaces in the study area is expected to range between 0.1% and 3.6% of the total discharge in the fens. As previously stated, these are expected to be maximum values for recharge loss, and the actual value is expected to be significantly less because not all infiltration on site currently recharges Unit #2.

Without a ground-water model, it is not possible to translate these values to a lowering of water levels in the fen, or a reduction in fen acreage. However, these losses are a relatively small component of the total volume of flow. In addition, there are two mitigating circumstances that make it likely that effects on the fens will be minimal.

First, as discussed earlier, it is expected that a significant quantity of infiltration through Unit #1 is diverted to ravines on site, where it discharges to land surface. Although this quantity has not been calculated and is difficult to quantify in the absence of a ground-water model, the amount of infiltration discharged to the ravines is expected to be significant. This would greatly reduce the estimate of infiltration volume currently being provided to the fens from the study area, and therefore would reduce the percentage of recharge to Unit #2 lost due to increasing the impervious areas. No scientific basis exists to make those estimates without significant additional study.

Second, the hydrogeologic setting of the fens helps determine how water levels in the fens will be impacted by reduced ground-water discharge. Hensel et al. (1992) described two general types of geologic settings of fens (Figure 6), and how each would react to reduced discharge. Fens where there is an aquitard (fine-grained unit of low permeability) that underlies the discharge point (type A) will be less sensitive to losses in discharge, because the elevation of the ground-water discharge is partially controlled by the elevation of the underlying aquitard, inhibiting large losses of fen acreage. In the second type of fen (type B), no aquitard is present, and the ground-water discharge point is determined by a balance between inputs and outputs rather than by geologic structure, and therefore may have greater fluctuation in response to changes in discharge. The fens in the study area are underlain by aquitard material composed of clay-rich diamicton (Figures 3 and 4), which helps establish and maintain the elevation of discharge, similar to fen type A in Figure 6. Therefore, water levels in these fens are less likely to change due to the minor loss of discharge calculated here.

Water Quality Alterations

In addition to changes in the volume of ground water discharged in the fens, concerns were raised regarding possible changes to ground-water chemistry. Calcareous seeps and fens, such as those identified in the study corridor, require water with high alkalinity and high levels of dissolved minerals, such as calcium and magnesium, to support the specific plant species that inhabit the fens, either directly or by providing a harsh environment that less conservative plant species are unable to colonize successfully (Amon et al. 2002). In addition, increases in chloride have been documented as being detrimental to calcareous fen plant communities (Panno et al. 1999), which might be expected due to deicing operations. Each of these impacts will be discussed below.

It is not expected that alkalinity or dissolved mineral levels would be changed by roadway construction or operations, assuming surface runoff is not directed into the fens. No processes that dilute ground-water chemistry have been identified. The minor reductions in infiltration discussed above will not act to dilute the alkalinity of the discharge. Management of surface runoff from the roadway will be discussed below.

Regarding increases in chloride and other operational impacts to the quality of ground water, deicing operations are of sufficient concern that design changes have been proposed by IDOT and their consultants to address any increase in chloride to the ground

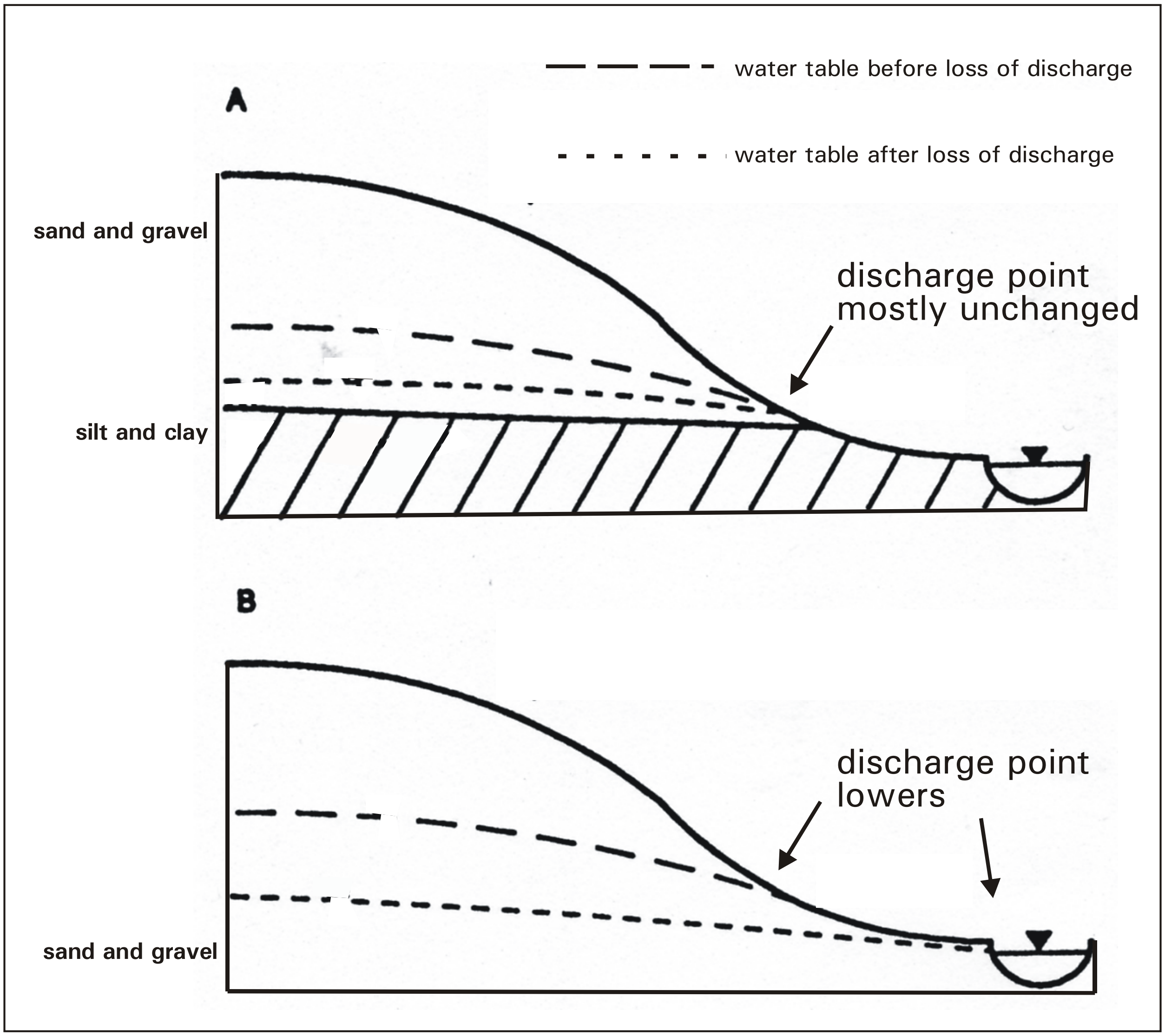

Figure 6. Diagram of fen types, showing: A) fen type less susceptible to water-level changes caused by minor reductions in discharge due to underlying fine-grained sediment that supports the discharge elevation, and B) fen type that is more susceptible to water-level changes caused by discharge reduction due to a lack of geologic control on the discharge elevation (after Hensel et al. [1992]). Fens in the study area are more similar to type A.

water. At the time this report was prepared, roadway features were being designed to contain all roadway runoff in the study area and transport it via lined ditches to discharge points outside the fen boundaries or the ground-water contribution areas for the fens. These features were designed to prevent the infiltration of chloride-laden runoff into the ground-water system. The design of these features is not part of this report. Assuming these features are included in the design and function as expected, no significant increase in chloride in the ground water is expected from operations. This study does not address any increases in chloride due to salt spray that travels beyond the right-of-way.

As discussed above, any runoff that enters the wetlands as surface flow may contribute chloride, or may cause dilution of alkalinity and dissolved mineral levels. Therefore, it is inadvisable to discharge runoff into any ravine that enters the fens or is located in the ground-water contribution area for the fens, where it could infiltrate and flow toward the fens. South of the study area, the roadway crosses ground-water flow lines that are expected to discharge west of the study corridor, where chloride may emerge in any wetlands that may exist in those areas. Any effects caused by roadway operations south of the site are beyond the scope of this study. Other roadway operations may contribute oils, greases, heavy metals, silt, and other constituents to runoff. Although no direct alterations to the fen plant community have been documented for many of these constituents, and some are not significantly mobile in the subsurface, it is not advisable to allow runoff containing these materials to be recharged to the ground-water system or discharged in surface flow into the fens. Given the runoff control discussed for chloride above, these materials are expected to be similarly isolated from the ground-water system.

SUMMARY

This study identifies the hydrogeologic conditions that supply ground water to fen wetlands along the south bluff of the Fox River in the study corridor of the proposed Prairie Parkway. The study also assesses the potential impacts of roadway construction and operation on ground-water quantity and quality, and identifies likely impacts on the fens.

A thick, buried unit of sand and gravel, identified as Unit #2 in this report, supplies ground water to the fens. Unit #2 is likely classified as Henry Formation sand and gravel of the Mason Group. This unit is present throughout the study area, although it thins to the northeast, and it extends south of Fox Road approximately 300-600 m (1,000-2,000 ft.) to the flanks of the Marseilles Morainic System. Ground water in this unit is derived from infiltration of precipitation over a large area through surface deposits of Unit #1 that vary from sandy to clay-rich. Ground water flows through Unit #2 to the northwest, so the roadway only crosses ground-water flow paths discharging to fens in the study corridor north of Fox Road. South of Fox Road, the roadway crosses ground-water flow paths that discharge to the Fox River west of the study corridor in the vicinity of Silver Springs State Park, and possible impacts to wetlands that exist in that area are not addressed in this report.

Potential alterations to the fens caused by roadway construction or operations include changes to the quantity and quality of ground-water discharge. Losses of infiltration and ground-water recharge are expected due to the creation of impervious surfaces. The loss of recharge to Unit #2 is calculated to be 0.1 to 3.6% of total discharge being provided to the

fens, and the actual value is expected to be much less than this calculation, although the actual value is not quantifiable without a ground-water model and additional field work. In addition, the fens are less sensitive to changes in discharge than other types of fens because the fine-grained, less permeable character of Unit #3 beneath the discharge zone helps maintain the elevation of the springs even if discharge is reduced. Therefore, it is not expected that a significant change in water levels or fen acreage will occur, although preparation of a ground-water model would provide quantifiable results.

Changes to major-ion ground-water chemistry, such as alkalinity and calcium levels, are not expected due to the infiltration loss because no dilution processes have been identified, assuming roadway runoff is not routed into the fens or infiltrated at a point location. However, it is likely that roadway operations such as deicing may have undesirable impacts. Increases in chloride have been associated with invasions of nonnative plant species in fens and other wetlands. Roadway design changes have been proposed by IDOT to prevent infiltration of runoff by collecting and discharging it to areas outside of wetlands or the ground-water contribution area for the fens. These changes are expected to significantly reduce or eliminate increases in chloride and any effects to the fen.

ACKNOWLEDGMENTS

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APPENDIX A. DESCRIPTIVE LOGS OF GEOLOGIC BORINGS

Boring 1
Date: 1/3/06, 10 AM
Location: McCarthy Parcel, Prairie Parkway, approx. 3250+100
TRS: T37N, R6E, Section 36, NE, SE, SW
Equipment: IDOT CME 750
ISGS Personnel: Miner

Sample depth (ft./m)		material	% gr/sa/si/cl	color	description
1.5-3	.46-.91	silty sand	tr/50/35/15	yellowish brown (10YR5/6)	dry to moist, moderate to high stiffness, moderate porosity, matrix supported sand with organics, faint lamination, and a significant clay fraction
4-5.5	1.22-1.52	silt	0/tr/90/10	d. yellowish brown (10YR4/4)	dry to moist, high stiffness, moderate porosity, slight lamination, presence of fine organic matter
6.5-8	1.98-2.44	same as above			
9-10.5	2.74-3.20	gravelly silty sand	5/50/35/10	brown (10YR4/3)	dry to moist, moderate porosity, matrix-supported, clasts up to 2 cm diameter of dolomite
11.5-13	3.51-3.96	gravelly sand	5/80/15/tr		dry to moist, very high porosity, low stiffness, clast supported, poorly sorted, angular to rounded clasts of dolomite up to 1 cm diameter
14-15.5	4.26-4.72	same as above		lt. yellowish brown (10YR6/4)	clasts are dolomite, black aphanitic rocks, and sandstone, sand is 75% quartz and 25% rock fragments
16.5-18	5.03-5.49	sand	tr/100/tr/tr	yellowish brown (10YR5/6)	moist, low stiffness, well sorted and rounded, fine to medium sand, matrix supported
19-20.5	5.79-6.25	same as above			fine beds 0.5-1 cm thick of medium to coarse sand present
21.5-23	6.55-7.01	diamicton	1/5/74/20	yellowish brown (10YR5/4)	silty clay loam texture, moist, firm, low stiffness, clasts of dolomite, black aphanitic, light brown fracture traces
24-25.5	7.32-7.77	sand/ diamicton			beds of sand and silt up to 8 cm thick (sand is med., sorted) with some silty clay loam diamicton beds (brown 7.5YR5/4) with clasts
26.5-28	8.07-8.53	sand/ diamicton			grading from sand to diamicton with sandy loam texture and apparent sorting, moist, high to moderate porosity and low stiffness
29-30.5	8.84-9.30	sandy gravel	40/60/tr/tr		dry to moist, high porosity and low stiffness, fine to coarse gravel up to 4 cm diameter, contains dolomite, quartzite, black aphanitic, well rounded
31.5-33	9.60-10.06	same as above			moist to wet
34-35.5	10.36-10.82	same as above			moist to wet, clasts up to 4 cm diameter
36.5-38	11.13-11.58	diamicton	1/20/60/20	gray (10YR5/1)	moist, very high stiffness, low porosity, silty clay loam texture, d. yellowish brown in top 8 cm
39-40.5	11.88-12.34	sand/silt		gray (10YR5/1)	2.5-5 cm interbeds of fine, poorly sorted gray sand (saturated) saturated gray silt, diamicton as above at top of spoon
41.5-43	12.64-13.11	diamicton	1/5/75/20	dark gray (10YR4/1)	dry to moist, low porosity, high stiffness, less than 1% clasts of dolomite less than 0.5 cm diameter

44-45.5	13.4-13.87	same as above			
46.5-48	14.17-14.63	same as above		gray (10YR5/1)	dry to moist, although saturated sandy silt beds occur in lenses less than 5 cm thick
49-50.5	14.94-15.39	same as above			

APPENDIX A. DESCRIPTIVE LOGS OF GEOLOGIC BORINGS (con't.)

Boring 2
Date: 1/9/06, 10 AM
Location: McCarthy Parcel, Prairie Parkway, approx. 3244-400
TRS: T37N, R6E, Section 36, NW, SW, SW
Equipment: IDOT CME 750 rig
Personnel: Miner

Sample depth	ft./m	material	% gr/sa/si/cl	color	description
2.5-4	0.76-1.22	fine silty sand	tr/30/60/10	yellowish brown (10YR5/4)	dry, low to moderate porosity, moderate to high stiffness, structureless, brittle, grades to sandy clayey silt at base, trace gravel
4.5-6	1.37-1.83	silty fine sand	3/60/30/7	same as above	dry, low to moderate porosity, moderate to high stiffness, contains gravel up to 1 cm diameter (2-4 mm diam. Dolomite, aphanitics), slight lamination
7-8.5	2.13-2.53	same as above		brown (10YR5/3)	mottles of 10YR6/8 and 10YR4/1, oxidized fractures, dolomite up to 4 cm diameter
9.5-11	2.90-3.35	sandy silt	5/35/50/10	yellowish brown (10YR5/4)	same as above exc. for texture change, dry to moist
12-13.5	3.66-4.11	fine sand	5/85/10/tr	lt. yellowish brown (10YR6/4)	dry, high porosity, low stiffness, poorly sorted, structureless, clasts of dolomite up to 3 cm diam.
14.5-16	4.42-4.88	gravelly sand	10/90/tr/tr	lt. yellowish brown (10YR6/4)	same as above exc. larger gravel content
17-18.5	5.18-5.64	medium sand	tr/100/tr/tr	brown (10YR5/3)	dry to moist, high porosity, low stiffness, bedded with 3-5 cm beds of very coarse sand and sand with fine gravel. Sand is well sorted, laminated, 50% quartz/50% rock fragments. Gravel is well rounded dolomite, granite, black aphanitics >1 cm diam.
19.5-21	5.95-6.40	same as above			same as above exc. 6 cm layer of brown clayey sand at 10 cm in spoon, dry gravelly sand at base
22-23.5	6.71-7.16	sandy fine gravel	40/60/tr/tr		same as above exc. more gravel, mostly 2-5 mm diameter well-rounded dolomite, with sandstone, red and black aphanitic rocks. Some clasts to 4 cm diameter.
24.5-26	7.47-7.92	same as above			
27-28.5	8.23-8.69	medium sand	tr/100/tr/tr	lt. yellowish brown (10YR6/4)	dry to moist, high porosity, low stiffness, sand is 80% quartz and 20% rock fragments, well sorted, faintly bedded, rare clasts to 1 cm diam.
29.5-31	9.00-9.45	gravelly medium sand	40/60/tr/tr		same as above exc. more clasts to 3 cm diameter
32-33.5	9.76-10.21	same as above			brownish yellow (10YR6/8) layer 1 cm thick midway in spoon
34.5-36	10.52-10.97	same as above			moist to wet
37-38.5	11.28-11.73	same as above			

39.5-41	12.04-12.50	same as above		yellowish brown (10YR5/4)	wet at base
42-43.5	12.81-13.26	same as above	1/5/75/20		
44.5-46	13.57-13.26	same as above		grayish brown (10YR5/2)	saturated
47-48.5	14.33-14.76	sandy gravel	90/10/tr/tr		saturated, very high porosity, low stiffness, gray color, well sorted and rounded gravel 0.5-2 cm in diameter of dolomite, granite, black aphanitics, with some fn to very coarse sand
49.5-51	15.09-15.54	same as above			
52-53.5	15.85-16.31	same as above			some fine sand at base, more rock fragments, poorly sorted
54.5-56	16.62-17.07	same as above	3/97/tr/0	grayish brown (10YR5/2)	high porosity, low stiffness, 5-10 cm beds by grain size (medium to coarse sand), rare clasts to 4 cm diameter
59.5-61	18.14-18.59	clayey silt	0/0/80/10	gray (10YR5/1)	moist, porosity, moderate to high stiffness, rare clay-rich 1 mm laminae of dark gray (10YR4/1)
64.5-66	19.67-20.12	same as above			

Prairie Parkway, Fox River Bridge Crossing, Southeast of Plano, Illinois

APPENDIX A. DESCRIPTIVE LOGS OF GEOLOGIC BORINGS (con't.)

Boring 3
Date: 1/4/06, 10 AM
Location: McCarthy Parcel, Prairie Parkway, approx. 3241+700
TRS: T37N, R6E, Section 36, SE, SE, SW
Equipment: IDOT CME 750 rig
Personnel: Miner

Depth	ft./m	material	% gr/sa/si/cl	color	description
2-3.5	0.61-1.07	fine silty sand	tr/30/70/10	yellowish brown (10YR5/4)	dry, moderate porosity, moderate stiffness, heterogeneous texture, with dolomite gravel up to 3 cm diameter, with roots and organic matter, very slight mottling
4.5-6	1.37-1.83	same as above			contains 8 cm lens of matrix-supported silty sand and some clay
7-8.5	2.13-2.53	silty sand			moist, contains well rounded gravel up to 1 cm diameter, silt laminae, and brownish yellow (10YR 6/8) mottles
9.5-11	2.90-3.35	diamicton	tr/tr/85/15	dark yellowish brown (10YR4/4)	moist, silt loam texture, low porosity, high stiffness, trace of small 1-2 mm gravel of dolomite and black aphanitic rocks, some manganese skins on fractures
12-13.5	3.66-4.11	fine sand	0/90/10/tr	brownish yellow (10YR6/6)	dry to moist, high porosity, low stiffness, well sorted fine sand with some silt, faint lamination, 50% quartz/50% rock fragments
14.5-16	4.42-4.88	fine sandy silt		yellowish brown (10YR5/6)	moist to saturated, moderate porosity, moderate stiffness, finely laminated by grain size, fining downward to clayey sand with trace gravel, some sorting noted
17-18.5	5.18-5.64	silty fine sand		yellowish brown (10YR5/4)	moist to wet, moderate porosity, low stiffness, variably textured unit from silty sand to sandy silt, laminated, diamicton in last 6 cm with fine gravel
19.5-21	5.95-6.40	silty sand	tr/60/30/10		moist, low to moderate porosity, moderate stiffness, clast supported, laminated, contains lenses of sand/gravelly sand, with 1-2 mm gravel
22-23.5	6.71-7.16	diamicton	5/60/25/10	dark gray (10YR4/1)	moist, low to moderate porosity, moderate stiffness, sandy loam texture, gravel up to 4 cm diameter of dolomite, granite, gray crystalline rocks
24.5-26	7.47-7.92	diamicton	5/50/35/20	grayish brown (10YR5/2)	loam texture, moist, low to moderate porosity, mow to moderate stiffness, softer, more clay rich than above, gravel up to 2 cm diameter of well rounded dolomite, granite, and black aphanitics
27-28.5	8.23-8.69	silt	tr/tr/90/10	gray (10YR5/1)	moist, low porosity, moderate stiffness, laminated by texture, contains lens of sand 2 cm thick at top and is saturated, oxidized at top
29.5-31	9.00-9.45	diamicton	1/5/75/20	gray (10YR5/1)	moist, low porosity, moderate stiffness, silty clay loam texture, contains fine well-rounded gravel of dolomite and granite up to 1 cm diameter
32-33.5	9.76-10.21	same as above			moist, contains 0.5 cm thick layer of gravel in spoon, water in sampler but sample not saturated
34.5-36	10.52-10.97	same as above			
37-38.5	11.28-11.73	same as above			
39.5-41	12.04-12.50	same as above			

42- 43.5	12.81- 13.26	sandy gravel	25/75/tr/tr		saturated, high porosity, low stiffness, up to 4 cm diameter gravel of dolomite, granite, and black aphanitic rocks
44.5- 46	13.57- 13.26	diamicton			same as described above for 39.5-41 ft.
47- 48.5	14.33- 14.76	same as above			slightly sandier

APPENDIX A. DESCRIPTIVE LOGS OF GEOLOGIC BORINGS (con't.)

Boring 4
Date: 1/5/06, 11 AM
Location: McCarthy Parcel, Prairie Parkway, approx. 3236+00
TRS: T37N, R6E, Section 36, SE, SW, SW
Equipment: IDOT CME 750 rig
Personnel: Pociask

Depth	ft./m	material	% gr/sa/si/cl	color	description
2-3.5	0.61-1.07	clayey silt	0/tr/80/20	pale yellow (2.5Y7/3)	dry, low porosity, high stiffness, noncalcareous, some mottling
4.5-6	1.37-1.83	nr			
7-8.5	2.13-2.53	diamicton	2/tr/73/25	brown (10YR4/3)	silt loam texture, moist, low porosity, high stiffness, noncalcareous, some gravel of chert
9.5-11	2.90-3.35	same as above		brown (10YR4/3)	fractures in till with oxidation, less gravel than above
12-13.5	3.66-4.11	same as above			
14.5-16	4.42-4.88	sandy silt		brownish yellow (10YR 5/4)	moist, moderate to high porosity, sandy silt in upper 12 cm, then 30 cm of sand and gravel overlying more sandy silt
17-18.5	5.18-5.64	gravelly silty sand	5/70/25/tr	yellowish brown (10YR5/4)	moist, moderate to high porosity, quartz sand with round, well sorted sand and dolomite fragments
19.5-21	5.95-6.40	gravelly sand	25/75/tr/tr	lt. yellowish brown (10YR6/4)	moist to dry, high porosity, quartz sand with dolomite and granite rock fragments, well rounded gravel
22-23.5	6.71-7.16	same as above		yellowish brown (10YR5/4)	
24.5-26	7.47-7.92	same as above			well sorted medium sand at base
27-28.5	8.23-8.69	same as above			
29.5-31	9.00-9.45	same as above		brownish yellow (10YR6/8)	saturated at base
34.5-36	10.52-10.97	same as above			grades to 10YR5/1 gray at base
39.5-41	12.04-12.50	diamicton	tr/tr/80/20	grayish brown (10YR5/2)	moist, low porosity, soft, silt loam texture, small angular pebbles
44.5-46	13.57-13.26	same as above		grayish brown (10YR5/2)	saturated

APPENDIX A. DESCRIPTIVE LOGS OF GEOLOGIC BORINGS (con't.)

Boring 5
Date: 1/4/06, 1 PM
Location: McCarthy Parcel, Prairie Parkway, approx. 3223+700
TRS: T36N, R6E, Section 1, SW, NE, NW
Equipment: IDOT CME 750 rig
Personnel: Miner

depth	ft./m	material	% gr/sa/si/cl	color	description
2.5-4	0.76-1.22	silty sandy gravel	20/40/30/10	grayish brown (10YR5/2)	moist, moderate porosity, low stiffness, clasts to 7 cm diameter, angular to rounded of dolomite
4.5-6	1.37-1.83	same as above			
7-8.5	2.13-2.53	sand	tr/100/tr/tr	brownish yellow (10YR6/8)	fine to medium sand, saturated, high porosity, low stiffness, orange brown, faintly laminated by color and grain size
9.5-11	2.90-3.35	diamicton	1/1/75/23		moist, silt loam texture, low porosity, high stiffness, dense. 1-2 mm white granules and 1 cm diameter dolomite clasts
12-13.5	3.66-4.11	same as above			
14.5-16	4.42-4.88	sandy silt	tr/40/60/tr	yellowish brown (10YR5/4)	moist, moderate porosity, moderate stiffness, rare gravel fragments <1 cm of mostly dolomite, lens of fine sand at top and bottom of spoon about 2 cm thick, mottles of strong brown (7.5YR5/8)
17-18.5	5.18-5.64	gravelly silty sand	10/60/30/tr	yellowish brown (10YR5/4)	moist, low to moderate porosity, contains well rounded gravel of dolomite, granite, black aphanitics, some sorted silty lenses
19.5-21	5.95-6.40	diamicton	10/40/40/10	brown (10YR5/3)	loam texture, not certain about origin, clasts larger than spoon diameter
22-23.5	6.71-7.16	no sample			
24.5-26	7.47-7.92	fine gravelly sand	10/90/tr/tr	lt. yellowish brown (10YR6/4)	starts at 22.5 ft., dry to moist, high porosity, low stiffness, gravel is >2 cm diameter of dolomite, granite, and black aphanitics, sand is fine to medium, 50% rock fragments and 50% quartz
27-28.5	8.23-8.69	same as above			dry
29.5-31	9.00-9.45	diamicton	1/10/70/19	dark gray (10YR4/1)	loam texture, moist, low porosity, moderate to high stiffness
32-33.5	9.76-10.21	same as above			grades to fine gravelly sand in bottom 13 cm similar to above unit
34.5-36	10.52-10.97	fine gravel	90/10/tr/tr	grayish brown (10YR5/2)	saturated, high porosity, low stiffness, bedded with fine gravelly sand, well rounded and sorted, gravel is dolomite, granite, chert, and black aphanitics
37-38.5	11.28-11.73	fine gravelly sand			same as above
39.5-41	12.04-12.50	same as above			bedded by grain size 60% quartz and 40% rock fragments
42-43.5	12.81-13.26	coarse sand			same as above but lacking gravel, , grades to very fine sand at base
44.5-46	13.57-13.26	fine gravelly sand			same as 39.5-41 ft.
49.5-51	15.09-15.54	no sample			blow in, clasts in sampler
54.5-56	16.62-17.07	same as above			
59.5-61	18.14-18.59	same as above			

Prairie Parkway, Fox River Bridge Crossing, Southeast of Plano, Illinois

64.5-66	19.67-20.12	diamicton	5/50/35/10	gray (10YR5/1)	loam texture, dry to moist, low porosity, very high stiffness, mostly dolomite clasts >3 cm diameter and few black aphanitics

APPENDIX A. DESCRIPTIVE LOGS OF GEOLOGIC BORINGS (con't.)

Boring 6
Date: 1/6/06, 10 AM
Location: McCarthy Parcel, Prairie Parkway, approx. 3219-400
TRS: T36N, R6E, Section 1, NE, SW, NW
Equipment: IDOT CME 750 rig
Personnel: Pociask

depth	ft./m	material	%gr/sa/si/cl	color	description
2-3.5	0.61-1.07	clayey silt		brown (10YR4/3)	dry, low porosity, very high stiffness, soil zone
4.5-6	1.37-1.83	diamicton	5/tr/75/25	lt. yellowish brown (2.5Y6/4)	silt loam texture, dry, low porosity, very high stiffness, disturbed?
7-8.5	2.13-2.53	same as above			larger gravel, some iron concretions, 2.5Y5/4 light olive brown
9.5-11	2.90-3.35	same as above			silt lenses, more coarse toward bottom of spoon
12-13.5	3.66-4.11	same as above	2/tr/68/30	dark gray (10YR4/1)	slightly fractured, roots and oxidized zones along fractures
14.5-16	4.42-4.88	same as above			moist
17-18.5	5.18-5.64	same as above		dark grayish brown (2.5Y4/2)	moist to wet, moderate porosity, low stiffness, variably textured unit from silty sand to sandy silt, laminated, diamicton in last 6 cm with fine gravel
19.5-21	5.95-6.40	same as above			silty clay loam texture, more plastic, calcareous
22-23.5	6.71-7.16	same as above	3/3/64/30		increased sand and gravel
24.5-26	7.47-7.92	same as above	3/3/74/20	dark gray (10YR4/1)	moist to saturated, small sand and silt lenses near base of spoon
29.5-31	9.00-9.45	same as above	3/3/64/30	gray (10YR5/1)	very moist
34.5-36	10.52-10.97	same as above	2/60/20/10	yellowish brown (10YR5/6)	moist, low porosity, moderate stiffness, sandy loam texture, reddish sand and small amount of gravel, faint platy structure
39.5-41	12.04-12.50	sand	1/90/5/4	yellowish brown (10YR5/6)	moist to saturated, moderate to high porosity, bedded reddish sand with 1-3 lenses of clay, silt, and gravel, sand is 50/50 quartz and rock fragments, well rounded, fine to medium
44.5-46	13.57-13.26	same as above	1/99/tr/tr	pale brown (10YR6/3)	moist, well sorted, uniform medium sand, with horizontal oxidized band
49.5-51	15.09-15.54	gravel	90/10/tr/tr	gray (2.5Y5/1)	saturated, poorly sorted fine gravel, well rounded, 1-2 cm diameter dolomite, granite, aphanitics, jasper
54.5-56	16.61-17.07	sand and gravel	25/75/tr/tr	lt. brownish gray (2.5Y6/2)	similar to above with more sand, contains 10-cm layer of black organic clayey silt with roots
59.5-61	18.14-18.59	same as above	10/90/tr/tr	light gray (2.5Y7/2)	coarse, well sorted subangular sand with rounded gravel, lower 15 cm is fine sand, silt, and gravel
64.5-66	19.66-20.12	gravel	80/20/tr/tr	gray (2.5Y5/1)	less than 4 cm diameter subrounded gravel of dolomite, chert, granite
69.5-71	21.18-21.64	same as above			
74.5-76	22.71-23.16	no sample			
79.5-81	24.23-24.69	diamicton	1/20/69/10	gray (10YR5/1)	silty clay loam texture, moist, soft, low porosity, gravel is few, small, subangular

APPENDIX B. WELL-CONSTRUCTION INFORMATION

Well	1L	2L	3L	4L	5L	5U	6L
Total depth	10.1 m (33.0 ft.)	16.6 m (54.5 ft.)	6.0 m (19.6 ft.)	12.2 m (40.0 ft.)	12.7 m (41.8 ft.)	3.7 m (12.0 ft.)	21.5 m (70.7 ft.)
Screen length	1.4 m (4.5 ft.)	1.5 m (4.8 ft.)	1.4 m (4.5 ft.)	0.7 m (2.2 ft.)	(1.4 m (4.5 ft.)	0.6 m (2.1 ft.)	3.0 m (9.8 ft.)
Sand pack interval	8.4-11.0 m (27.5-36 ft.)	none-natural collapse	3.4-6.0 m (11.0-19.6 ft.)	none-natural collapse	none-natural collapse	1.4-3.7 m (4.5-12.0 ft.)	collapse to 18.3 m (60 ft.), sand from 10.1-18.3 m (33-60 ft.)
Bentonite seal interval	0.6-8.4 m (2-27.5 ft.)	0.6-12.8 m (2-42 ft.)	0.9-3.4 m (3.0-11.0 ft.)	0.9-7.0 m (3-23 ft.)	0.9-10.2 m (3.0-33.5 ft.)	0.8-1.4 m (2.5-4.5 ft.)	0.3-10.1 m (1-33 ft.)
Concrete	0-0.6 m (0-2 ft.)	0-0.6 m (0-2 ft.)	0-0.9 m (0-3.0 ft.)	0-0.9 m (0-3 ft.)	0-0.9 m (0-3 ft.)	0-0.8 m (0-2.5 ft)	0-0.3 m (0-1 ft.)
Land-surface elevation	194.0 m (636.32 ft.)	194.7 m (637.75 ft.)	192.5 m (631.70 ft.)	193.2 m (633.79 ft.)	195.3 m (640.85 ft.)	195.4 m (641.14 ft.)	199.0 m (652.89 ft.)

APPENDIX C. WATER-LEVEL DATA INCLUDING DEPTHS TO WATER AND WATER-LEVEL ELEVATIONS

DTW (ft.)	1/19/2006	2/1/2006	3/1/2006	5/19/2006	7/12/2006
1L	dry	dry	dry	dry	dry
2L	44.65	44.70	44.64	44.02	44.23
3L	dry	dry	dry	dry	20.03
4L	33.40	33.46	33.57	35.11	33.02
5U	11.63	none	9.15	5.66	6.45
5L	36.91	36.66	blocked	blocked	blocked
6L	51.80	51.80	51.85	51.36	51.28

WLE (ft.)	1/19/2006	2/1/2006	3/1/2006	5/19/2006	7/12/2006
1L	dry	dry	dry	dry	dry
2L	595.48	595.43	595.49	596.11	595.90
3L	dry	dry	dry	dry	613.83
4L	602.47	602.41	602.30	600.76	602.85
5U	632.10	none	634.58	638.07	637.28
5L	606.16	606.41	blocked	blocked	blocked
6L	604.56	604.56	604.51	605.00	605.08

DTW (m)	1/19/2006	2/1/2006	3/1/2006	5/19/2006	7/12/2006
1L	dry	dry	dry	dry	dry
2L	13.60	13.62	13.60	13.41	13.48
3L	dry	dry	dry	dry	6.105144
4L	10.18	10.19	10.23	10.70	10.06
5U	3.54	none	2.79	1.73	1.97
5L	11.25	11.17	blocked	blocked	blocked
6L	15.79	15.79	15.80	15.65	15.63

WLE (m)	1/19/2006	2/1/2006	3/1/2006	5/19/2006	7/12/2006
1L	dry	dry	dry	dry	dry
2L	181.50	181.49	181.51	181.69	181.63
3L	dry	dry	dry	dry	187.10
4L	183.63	183.62	183.58	183.11	183.75
5U	192.66	none	193.42	194.48	194.24
5L	184.76	184.83	blocked	blocked	blocked
6L	184.27	184.27	184.25	184.40	184.43

APPENDIX D. GROUND-WATER CALCULATIONS INCLUDING INFLUX FROM OFFSITE AREAS, INFILTRATION ON SITE, TOTAL DISCHARGE, AND INFILTRATION LOSS DUE TO ROADWAYS

INFLUX FROM OFFSITE AREAS: using the formula Q=KIA (discharge=hydraulic conductivity*hydraulic gradient*area)

Given

I. A=2.79 m^2 (30 $ft.^2$), using a flow tube 0.30 m (1 ft.) wide with a saturated thickness of 9.1 m (30 ft.) (well 5L observed during drilling)

II. I=0.0031 (a hydraulic gradient of 0.0031 using a head drop of 1.12 m (3.69 ft.) from well 5L to well 4L and a horizontal distance of 363.3 m (1192 ft.), which is the distance between the wells as measured along the flow path)

III. K=0.027 cm/sec to 0.11 cm/sec (27,955 to 113,889 ft./yr) (see Appendix F)

Then ground-water flow into the site from upgradient areas south of Fox Road is Q=(27,955 ft./yr to 113,888 ft./yr)(30$ft.^2$)(0.0031)=**74 to 300 m^3/yr (2,600 to 10,600 $ft.^3$/yr)** in each flow tube.

INFILTRATION ON SITE AND TOTAL DISCHARGE TO FENS:

Given

I. Infiltration likely ranges between 2.54 and 15.24 cm (1 and 6 in., or 0.083 to 0.50 ft.) per year (Walton 1965) given the variability in sediment texture

II. Distance along flow path from Fox Road to the fens is approximately 1,097 m (3600 ft.), giving a surface area of 334 m^2 (3600 $ft.^2$) when using a 0.30-m (1-ft.) wide flow tube

Then infiltration on site ranges between **8 and 51 m^3/yr** (**300 and 1,800 $ft.^3$/yr)**, making total discharge to the fens (per flow tube) between **82 and 351 m^3/yr (2,900 and 12,400 $ft.^3$/yr)** (adding influx from offsite and on-site infiltration)

INFILTRATION LOSS FROM INCREASED IMPERVIOUS SURFACES:

Given

I. Infiltration likely ranges between 2.54 and 15.24 cm (1 and 6 in., or 0.083 to 0.50 ft.) per year (Walton 1965) given the variability in sediment texture

II. The distance across the roadway from the outer edge of each ditch is approximately 64.0 m (210 ft. (given that the flow path crosses the roadway at an approximately 40 degree angle, using an area of roadway 0.30 m(1 ft.) wide to match flow tube width above)

III. Assuming all recharge falling on roadway area is prevented

Then infiltration loss is estimated to be

Loss=(0.025 to 0.15 m/yr)(64 m^2)= **0.5 to 3.0 m^3/yr (17.5 to 105 $ft.^3$/yr)**

Or **0.1% to 3.6%** of total ground-water discharge in the fens

APPENDIX E. CALCULATION OF HYDRAULIC CONDUCTIVITY (K) FROM SLUG TESTS ON SITE