Prepared in cooperation with the U.S. Fish and Wildlife Service

Assessment of Water Resources in Areas that Affect the Habitat of the Endangered Hine's Emerald Dragonfly in the Lower Des Plaines River Valley, Illinois

Scientific Investigations Report 2018–5074

U.S. Department of the Interior
U.S. Geological Survey

Cover. View of Lockport Prairie Nature Preserve from Division Street at the Des Plaines River, Illinois, looking northwest. Photograph by Robert T. Kay, U.S. Geological Survey.

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U.S. Geological Survey
James F. Reilly II, Director

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	Hectare (ha)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic feet per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per day (gal/d)	264.2	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
inch per year (in/yr)	2.54	centimeter per year (cm/yr)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F= (1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C= (°F-32)/1.8

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Constituent concentrations are given in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Fecal coliform populations are presented in colonies per 100 milliliter (colonies/100mL).

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations

$CaCO_3$	calcium carbonate
CSSC	Chicago Sanitary and Ship Canal
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
HED	Hine’s emerald dragonfly
ISGS	Illinois State Geological Survey
MCL	maximum contaminant level
NWIS	National Water Information System
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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Abstract

Review of previous investigations indicates that potential decreases in groundwater recharge and increased groundwater extraction in the vicinity of the Lower Des Plaines River Valley in Will County, Illinois, may reduce the amount of groundwater flow in the Silurian aquifer in this area. Groundwater discharge from the Silurian aquifer to wetlands in the Lower Des Plaines River Valley plays an important role in sustaining the habitat of the endangered Hine's emerald dragonfly (*Somatochlora hineana*). Groundwater modeling performed by previous investigators indicates that increasing the amount of water pumped from the aquifer in support of expanded quarry operations near the Lockport Prairie Nature Preserve has the potential to reduce groundwater discharge to the most productive Hine's emerald dragonfly habitats in Illinois, potentially degrading the habitat. Model simulations indicate that mitigation procedures designed to artificially enhance groundwater recharge in the vicinity of dragonfly habitats near the Lockport Prairie Nature Preserve are likely to offset the effects of increased pumping. Several areas with smaller, often intermittent populations of Hine's emerald dragonflies have been identified in other parts of the Lower Des Plaines River Valley and elsewhere in Illinois. Human activities have the potential to produce changes in hydrology and water quality that can threaten all of these habitats.

Introduction

High-capacity pumping for public-water supply and quarry dewatering, and construction of impervious surfaces associated with urbanization, have altered the dynamics of groundwater discharge to a number of wetlands in the Lower Des Plaines River Valley in northeastern Illinois (fig. 1). These wetlands include the Lockport Prairie Nature Preserve and the River South Parcel, near Lockport, Illinois, which are home to the largest populations of Hine's emerald dragonfly (*Somatochlora hineana*) in Illinois (fig. 2). The Hine's emerald dragonfly (HED) was listed by the Illinois Department of Natural Resources as an endangered species in 1991 and was placed on the Federal List of Endangered Species by the U.S. Fish and Wildlife Service in 1995 (U.S. Fish and Wildlife, 1995). A reduction in the volume of discharge from groundwater to these wetlands, as well as alteration of surface-water flow pathways within the wetlands, has the potential to substantially affect much of the best HED habitat remaining in Illinois. Changes to surface-water and groundwater quality associated with anthropogenic activities may also affect the quality of the habitat.

For the purposes of this report the Lower Des Plaines River Valley consists of the area surrounding the Des Plaines River from Route 83 (fig. 3) to the confluence of the Des Plaines River and the Chicago Sanitary and Ship Canal south of the Lockport Lock and Dam (fig. 1). For the purposes of this report the Lower Des Plaines River Valley also includes the area near the Calumet Sag Channel west of Route 45 (fig. 3).

The U.S. Fish and Wildlife Service (USFWS) is overseeing efforts to protect and restore the HED habitat in the Lower Des Plaines River Valley and the hydrology that supports it. The U.S. Geological Survey (USGS) has provided technical assistance in this effort. The primary objective of this assistance is to determine the effect of additional pumping associated with proposed mining from the West Quarry and Middle Parcel Expansion Areas (fig. 1) on HED habitat at the Lockport Prairie Nature Preserve and the River South, Com Ed, and Long Run Parcels. A secondary objective of this assistance is to identify the factors that affect the hydrogeology and water quality at several additional HED habitats within the Lower Des Plaines River Valley and other parts of Illinois. The USGS compiled and analyzed data collected by previous investigators, but also collected and analyzed field data from the habitat area.

The primary study area for this investigation encompasses the vicinity of the Des Plaines River Valley from the northern part of the Romeoville Prairie Nature Preserve to about 1 mile (mi) south of the Lockport Lock and Dam (fig. 1). This area includes parts of the cities of Lockport, Romeoville, and Crest Hill and is referred to as the "Lockport area" in this report. The Lockport area is most likely to

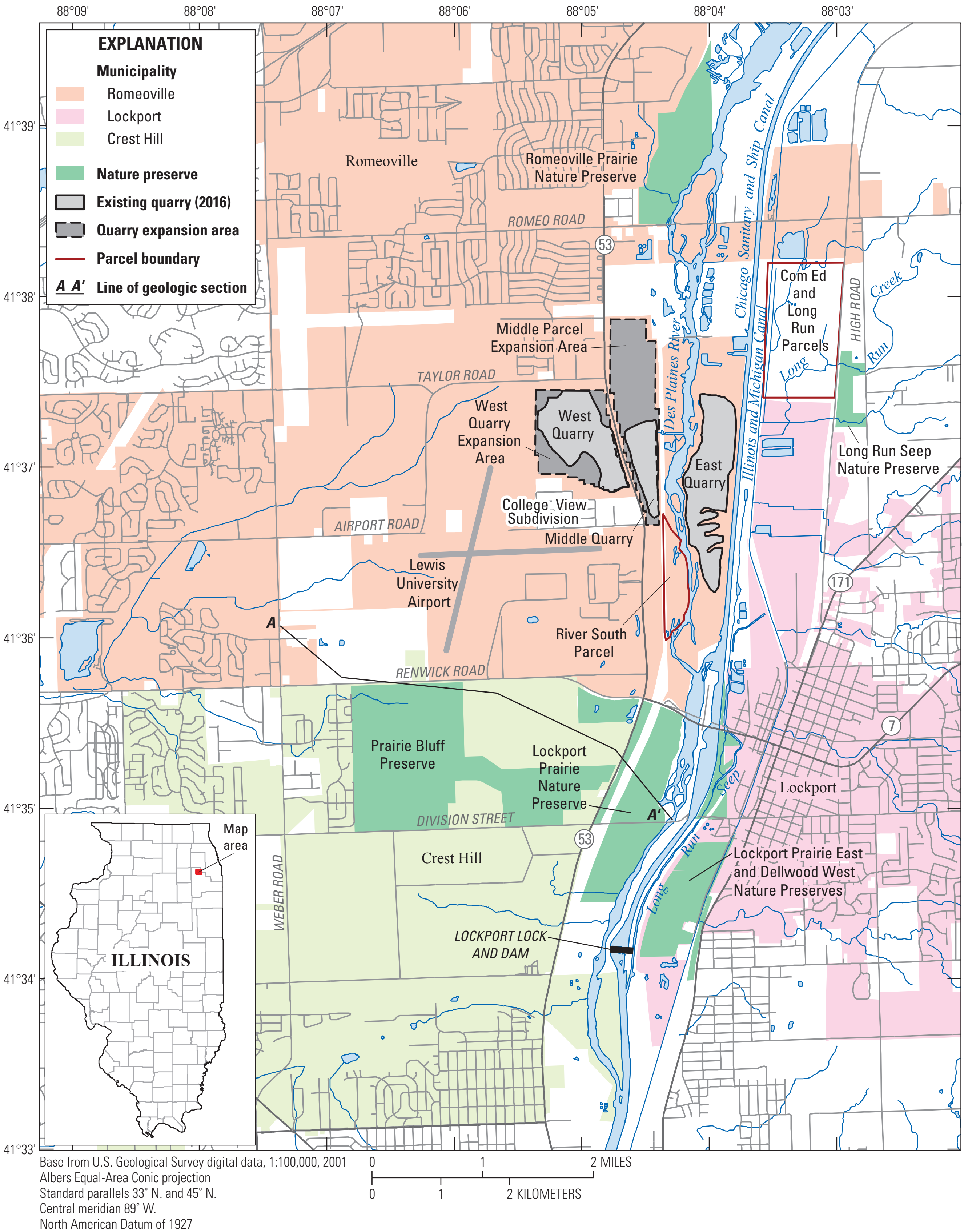


Figure 1. Location of selected features in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois.

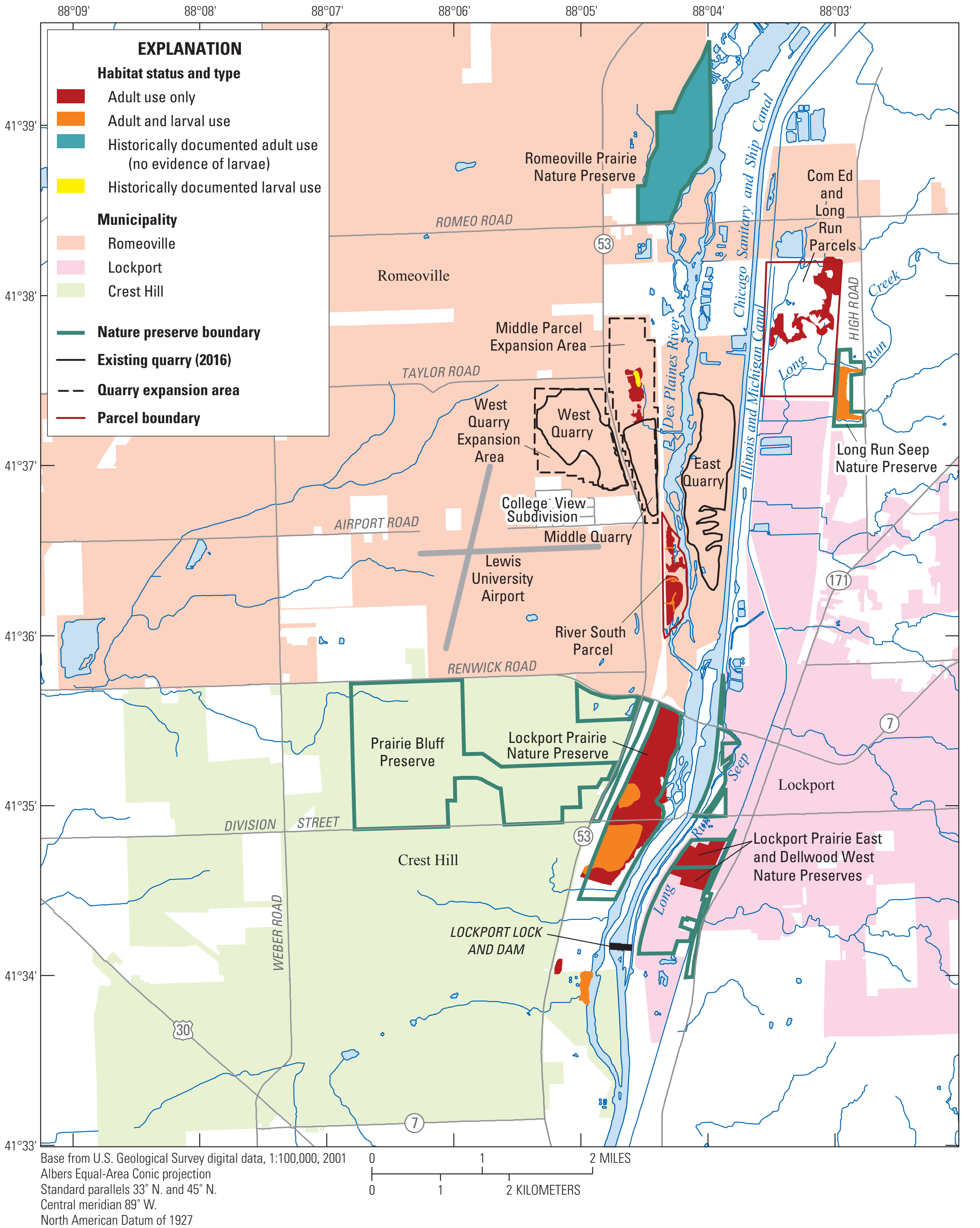


Figure 2. Location of Hine's emerald dragonfly habitat in 2009 in the Lower Des Plaines River Valley near Lockport, Will County, Illinois (from Applied Ecological Services, Inc., 2009).

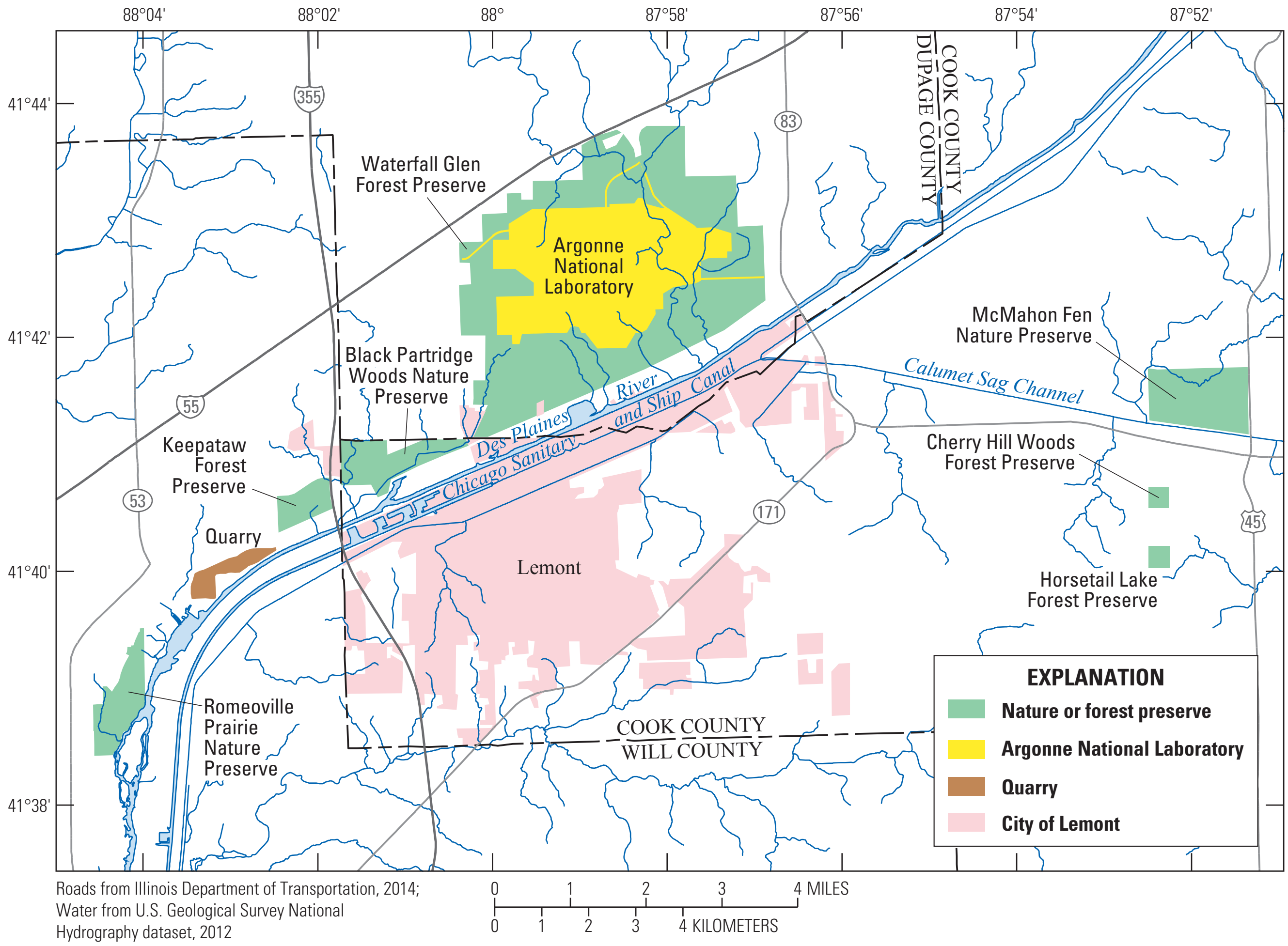


Figure 3. Location of selected features in the vicinity of the Lower Des Plaines River Valley, Will, DuPage, and Cook Counties, Illinois.

be affected by additional pumping at the quarry in the vicinity of Taylor Road and Route 53 and has been intensively investigated. It also is the area containing the most productive HED habitats with the largest HED populations in Illinois (U.S. Fish and Wildlife Service, 2013b). The secondary area of investigation encompasses the vicinity of the Des Plaines River Valley from the northern part of the Romeoville Prairie Nature Preserve to the northern part of the Argonne National Laboratory and east of the McMahon Fen Nature Preserve in the general vicinity of Lemont, Ill. (fig. 3), and is referred to as the "Lemont area" in this report. This area has been less intensively investigated but contains several areas where small HED populations have been identified or HED use is suspected on an intermittent basis.

With the exception of approximately half of the manual water-level measurements taken in July and November 2012 and continuous (reading every 15 minutes using a sensor and datalogger) monitoring of water levels, temperature, and specific conductance at three locations at the Lockport Prairie Nature Preserve and McMahon Fen Nature Preserve between 2011 and 2014, the data presented in this report were collected by entities other than the USGS. Water-level and water-quality data collected by the USGS was done in accordance with standard procedures (Wagner and others, 2006; Cunningham and Schalk, 2011) and are stored in the USGS National Water Information System (NWIS) database for Illinois (U.S. Geological Survey, 2017). The potentiometric surface maps based on the July and November 2012 data were developed by the authors. The USGS is unable to verify the quality of data collected by other entities.

Purpose and Scope

This report provides an assessment of the water resources in areas that affect the habitat of the HED and contains information related to the geologic, hydrologic, and water-quality requirements of the HED, an endangered dragonfly whose largest populations in Illinois are in the wetlands in the Des Plaines River Valley near Lockport. The report provides a general overview of the life cycle of the HED and description of the geology, hydrology, and water quality within the Lower Des Plaines River Valley as a whole, as well as at several individual habitats. This overview is based on data collected by previous investigators at several habitats as well as a regional study of the shallow groundwater resources. Groundwater models developed by consulting firms in the vicinity of the Lockport Prairie Nature Preserve are summarized to assess the effect of increased high-capacity pumping on nearby HED habitats and the effectiveness of groundwater mitigation features to offset the effects of this pumping. The results of synoptic water-level measurements taken by USGS and other parties, along with interpretation of potentiometric surface maps developed by the authors for the Lockport area, are presented. The report identifies gaps in the understanding of hydrologic and water-quality conditions in the area. The data and analysis contained in this report will be used by Federal, State, and local authorities to help guide decisions on how to best protect the HED habitat and identify new potential habitats in Illinois.

Life Cycle of the Hine's Emerald Dragonfly

The life cycle of the HED begins when impregnated females deposit about 1,000 fertilized eggs into shallow water (rivulets, small streams, or small ponds) or wet mud alongside wetland vegetation (Illinois State Museum, 2012; U.S. Fish and Wildlife Service, 2013a). The HED will not lay eggs on dry ground. Egg laying takes place from about late June to late August in Illinois (Vogt and Cashatt, 1997). The eggs remain in the detritus of these shallow water bodies and typically overwinter before hatching into larvae the next spring when water temperatures increase (U.S. Fish and Wildlife Service, 2013a). The HED larvae undergo a 3–5-year period of maturation, inhabiting rivulets typically less than 6 inches (in.) deep at the edges of deeper channels (Nuzzo, 1995) as well as nearby crayfish (*Cambarus diogenes*) burrows to survive predation, drought, and winter conditions (Pintor and Soluk, 2006; Soluk, 2006). After adults emerge from the larval stage during the summer months, there is a 5–6-week flight period during which they mate and the females lay their eggs. It is estimated that the survival rate of HED from eggs to mature larvae is less than 1 percent to 5.5 percent (U.S. Fish and Wildlife Service, 2013b).

Although HED survival requires water in the wetlands, the timing, duration, and severity of the summer dry periods also are important to HED survival and reproduction (Soluk and others, 2004). Droughts, such as those that occurred in northern Illinois in 2005 and 2012, can cause a substantial decrease in the HED population (Soluk and others, 1999; Mierzwa, 2007). However, HEDs tend to be displaced by other dragonfly species in permanent wetlands, indicating that a short summer dry period may give the HED a competitive edge for survival over other dragonfly species (Soluk and others, 1999; Soluk and others, 2015).

The HEDs inhabit wetlands with organic soils overlying calcareous substrate. The presence of open, vegetated areas for forage and nearby forest edge for perching and roosting are important components of HED habitat (Zercher, 2001). The optimal larval habitat is shallow, small rivulets containing slow moving, alkaline (pH greater than 7) water with a short dry period during the summer (Soluk and others, 2004; Illinois State Museum, 2012). The HED can survive in the larval stage at water temperatures between about 2 and 27 degrees Celsius (°C) (Missouri Department of Conservation, [n.d.]) but larvae may have elevated mortality above about 30 °C (D. Soluk, University of South Dakota, written commun., 2016). These habitat requirements are present at groundwater- and spring-fed marshes and sedge meadows underlain by dolomite in the Lower Des Plaines River Valley, which is the location of most of the HED population in Illinois (U.S. Fish and Wildlife Service, 2013b).

The groundwater source for much of the water in these wetlands results in a number of benefits to the HED. Much of the HED wetland habitat has a dry period during the summer; however, because discharging groundwater is a more continuous source of water to the habitat than surface-water runoff, more of the wetlands tend to have water for a longer period of time (longer hydroperiod). The short adult lifespan of the HED must overlap the presence of water in the habitat for egg deposition to be successful, so the comparatively long hydroperiod enables more HEDs to deposit eggs over a larger area for a longer period of time. These factors increase the number of eggs deposited and lessen the chances for predation and egg desiccation. The typically slow movement of water maximizes egg settling through the water column when deposited and the shallow geometry of the rivulets minimizes erosion of the sediment and detritus holding the HED eggs during surface-water runoff events.

The comparatively constant temperature of the groundwater discharging to the rivulets helps to minimize the presence of ice during the winter, minimizing destruction of HED eggs. Discharge of cool groundwater also helps to lower the water temperature in the rivulets during the summer months, potentially reducing larvae mortality.

Although the prevalence of groundwater as a water source provides a number of benefits to the HED habitat, it also poses risks. Small decreases in groundwater level in the vicinity of the wetlands can substantially reduce the amount of groundwater discharged to the wetlands (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). If the reduction in groundwater discharged to the wetlands is large enough to reduce water levels in the wetlands by as little as 1–2 feet (ft) below the mean water level, which is typical of drought conditions but also may be associated with nearby pumping or increased overland runoff of precipitation, there may be insufficient wet sediment for egg laying. Eggs may become desiccated in the dry sediment and the habitat may not support the prey base for the HED adults (Mierzwa, 2007; Graef, Anhalt, Schloemer, and Associates, Inc., 2008).

Hydraulic and water-quality conditions in the Lower Des Plaines River Valley are such that permanent populations of adult and larval HED are present at the Lockport Prairie Nature Preserve, River South Parcel, Long Run Seep Nature Preserve (fig. 2), and the Waterfall Glen Forest Preserve (fig. 3). Adult and larval HED have been identified at the Com Ed and Long Run Parcels, Romeoville Prairie Nature Preserve, Keepataw Forest Preserve, Black Partridge Woods Forest Preserve, Argonne National Laboratory, McMahon Fen Nature Preserve, and southwest of the Lockport Lock and Dam during at least one survey (Soluk and Moss, 2003; Soluk and others, 2004; Mierzwa, 2008, 2013b; Soluk and others, 2012; Mierzwa and Webb, 2012a,b; Hanson Material Service Corporation, 2016). Larvae were historically present at the Middle Parcel Expansion Area but appear to have been extirpated from the site before 1997 (Mierzwa, 2013a). Adult HED have been identified at the Lockport Prairie East and Dellwood West Nature Preserves (fig. 2). In addition to the presence of HED in the vicinity of the Lower Des Plaines River Valley, a sustainable population of HED has been identified in northwest Cook County at the Spring Lake Forest Preserve (Soluk and others, 2016), which is located about 30 mi northwest of the Lower Des Plaines River Valley.

Soluk and Mierzwa (2012) estimated that the Illinois HED population generates 86–313 adults per year and has been declining since at least the 1990s. The HED population in Illinois is especially vulnerable because approximately 55 percent of the population is located within the Lockport Prairie Nature Preserve and approximately 30 percent is located within the River South Parcel (Soluk and Mierzwa 2012). The proximity of these sites exposes the HED population to extirpation by demographic stochasticity (random changes in characteristics of a small population), and the loss of either site would represent at least a 30-percent decrease in the population.

Assessment of Conditions that Affect the Water Resources in the Lockport Area

Because the HED requires well-constrained conditions to survive, it is essential to understand the phenomena that affect the hydrology and water quality of the habitat, including its surface topography, geology, and hydrology. This report discusses these features within the Des Plaines River Valley in the Lockport area where there is a substantial amount of data available. This report also contains a less extensive discussion of conditions at HED habitats near the Des Plaines River Valley in the Lemont area and other parts of northeast Illinois.

Surface Topography

The Lockport area contains topographic uplands that slope toward the Des Plaines River or smaller surface-water drainages at elevations of about 675 to 625 ft above the North American Vertical Datum of 1988 (NAVD 88) (fig. 4). Surface topography slopes sharply toward the Des Plaines River along bluffs located near Illinois Route 53 on the west side of the Des Plaines River Valley, and near High Road and Illinois Route 171 on the east side of the valley. Surface elevation along the bluffs decreases from approximately 625 to 575 ft near the Lockport Prairie Nature Preserve, with similarly large changes in elevation throughout most of the Lockport area.

Surface topography in the valley of the Des Plaines River is somewhat flat, ranging from about 550 to 590 ft in the Lockport area, decreasing from north to south. Surface topography within the river valley slopes toward the Des Plaines River. Superimposed on this flat slope are a series of hummocks and swales that trend roughly parallel to the river. These features have about 1–5 ft of relief. Swales are the locations of the ponds and rivulets constituting part of the HED larval habitat and where the HED lay their eggs. Hummocks are drier, slightly topographically elevated areas that can contain vegetation suitable for perching, which is a necessary process for HED larvae to emerge as adults.

The levees that define the Chicago Sanitary and Ship Canal (CSSC) are more than 30 ft above the surrounding land surface near the Lockport Lock and Dam. The height of the levees above land surface decreases to the north where the elevation of the surrounding land surface increases, converging to more uniform topography. Although the pre-excavation topography is shown in figure 4, the West, East, and Middle Quarries (hereafter referred to collectively as "the Quarry") have been excavated to an elevation of about 470 ft NAVD 88. The surface topography is the result of deposition of glacial drift on top of dolomite bedrock in northeast Illinois and the subsequent erosion of the drift deposits within the Lower Des Plaines River Valley.

Geology

The geologic deposits of concern to this investigation are Silurian dolomite bedrock (chemical formula $CaMg(CO_3)_2$) belonging to the Alexandrian and Niagaran Series. The bedrock deposits are overlain by unconsolidated deposits of glacial and post-glacial origin and are shown along geologic section A–A', which covers most of the groundwater recharge area for the Lockport Prairie Nature Preserve (figs. 1, 5). The stratigraphic nomenclature used in this report is that of the Illinois State Geological Survey (Willman and others, 1975) and does not necessarily follow the usage of the USGS.

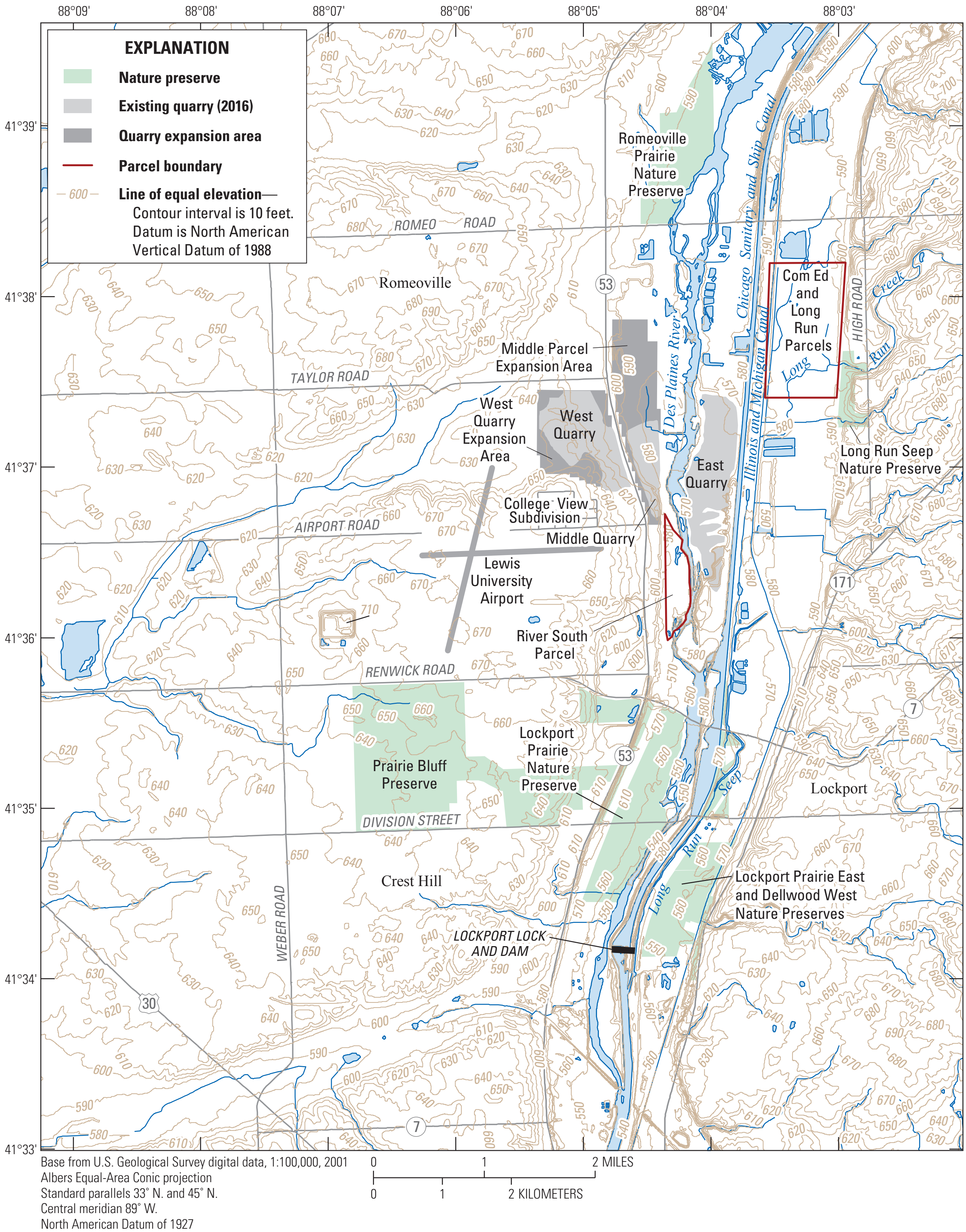
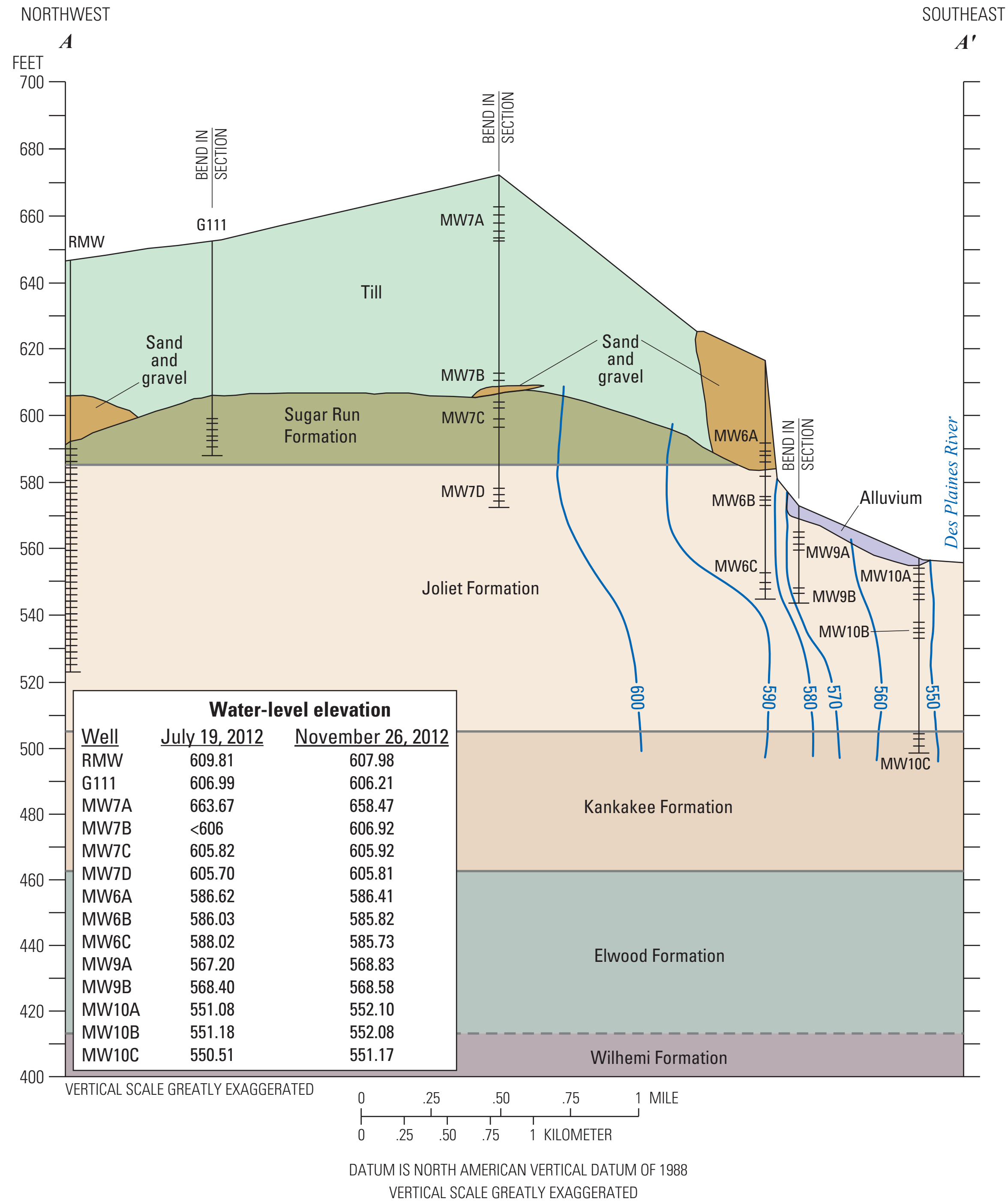


Figure 4. Surface topography in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois.



Water-level elevation

Well	July 19, 2012	November 26, 2012
RMW	609.81	607.98
G111	606.99	606.21
MW7A	663.67	658.47
MW7B	<606	606.92
MW7C	605.82	605.92
MW7D	605.70	605.81
MW6A	586.62	586.41
MW6B	586.03	585.82
MW6C	588.02	585.73
MW9A	567.20	568.83
MW9B	568.40	568.58
MW10A	551.08	552.10
MW10B	551.18	552.08
MW10C	550.51	551.17

EXPLANATION

G111 **Well location and name**—Well log provides basis for lithologic interpretation

Open interval of well

—600— **Line of equal water-level elevation, in feet**

Figure 5. Geologic section *A–A′*, Lockport area, Will County, Illinois.

Silurian Deposits

The stratigraphy, lithology, and other aspects of the Silurian deposits are presented in figure 6. These deposits typically are between 150 and 300 ft thick in the Lockport area (Roadcap and others, 1993). The elevation of the top of the dolomite deposits in the Lockport area can exceed 625 ft NAVD 88 in the topographic uplands to the east and west of the Des Plaines River Valley, and is typically less than 575 ft within the valley (figs. 5, 7). The elevation of the top of the Silurian deposits decreases from north to south within the river valley. Dolomite deposits are exposed at the base of the bluffs at a number of locations on the west side of the Des Plaines River Valley.

The dolomite contains a network of secondary-permeability features consisting of high-angle (near vertical) and subhorizontal fractures and joints (break in the rock without measureable displacement), vugs (small cavities in the rock), and solution openings (void in the rock formed by its chemical dissolution). Secondary-permeability features are especially well developed in the top approximately 8–40 ft of the dolomite where weathering has been most extensive (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a; STS/AECOM, 2009; AECOM, 2013a,b).

Investigators at sites along the Des Plaines River near the Calumet Sag Channel (fig. 3) have identified “sub-regional to regional” subhorizontal fractures in the dolomite at elevations of about 415, 440, 460, 525, 550, 561, 570, and 575 ft (Nicholas and Healy, 1988; KPRG and Associates Inc., 2004). These fractures are located along bedding planes and may be continuous for more than a quarter of a mile. Lithologic logs described potential solution openings in the dolomite at 460 to 640 ft NAVD 88 at a well in Romeoville; fractures at 438, 565, 593, and 603 ft at a well in Lockport; fractures at 442 and 466 ft at a well in Crest Hill; and fractures at 529–539 ft at the College View Subdivision (fig. 1). Fractures along bedding planes in the lower part of the Kankakee Formation and the upper part of the Elwood Formation (about 460 ft at the Quarry) also are postulated (AECOM, 2012).

High-angle fractures, many infilled with clay, were identified from near the bedrock surface to depths of at least 100 ft below ground surface in cores from wells drilled at the Lockport Prairie Nature Preserve and at the Quarry (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a; STS/AECOM, 2009; AECOM, 2013b). High-angle joints and fractures have a mean orientation of about N 35° E with a subsidiary orientation of N 65° W in the greater Romeoville area (Foote, 1982).

Unconsolidated Deposits

In most of the Lockport area the dolomite bedrock is overlain by unconsolidated deposits composed predominately of glacial till (an unsorted mixture of clay, silt, sand, and gravel; fig. 5) belonging to the Wedron Formation (Willman and Lineback, 1970; fig. 8). Small, discontinuous, sand and gravel deposits are interspersed within the Wedron Formation. Till deposits are present in the topographic uplands away from the Des Plaines River Valley and are as much as about 70 ft thick.

Sand and gravel deposits of the Henry Formation are present along the bluffs on the western edge of the Des Plaines River Valley and at low points in the surface topography west of the Romeoville Prairie Nature Preserve, west of the Quarry, southwest of the Lockport Lock and Dam, and near Long Run Creek (Willman and Lineback, 1970; figs. 5, 8). These spatially extensive sand and gravel deposits directly overlie the Silurian bedrock, are as much as 30 ft thick along the bluffs of the Des Plaines River, and typically extend about 1,500 ft west of the bluff (fig. 8; Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). The sand and gravel was deposited by rivers fed by melting glaciers prior to erosion of the Lower Des Plaines River Valley.

Post-glacial alluvial deposits consisting of sand, silt, and clay are present within the Lower Des Plaines River Valley (fig. 5). These deposits typically are 1–4 ft thick and constitute the alluvial aquifer where saturated. Where these deposits are thin or the bedrock surface is low, wetland swales tend to be present. Hummocks may be present where the deposits are thicker or the bedrock surface is slightly higher.

Hydrology

Much of the water in the wetlands that constitute the HED habitat originates as recharge from groundwater. The source area, quantity, and chemistry of the groundwater recharge are affected by the composition of the geologic deposits through which the water moves.

The till deposits of the Wedron Formation (fig. 8) function as a semiconfining unit. Isolated sand and gravel deposits within the till deposits are considered to be part of the semiconfining unit unless they are in direct contact with the underlying dolomite.

The sand and gravel deposits of the Henry Formation along the bluffs of the Lower Des Plaines River Valley (fig. 8) function as an aquifer (referred to in this report as “the glacial drift aquifer”). Sand and gravel deposits can be associated with seeps where they intercept land surface along a bluff face. Where saturated, the alluvial deposits in the valley of the Des Plaines River are considered to be the alluvial aquifer in this report.

The Silurian dolomite deposits constitute the Silurian aquifer. Groundwater flow through the Silurian aquifer is primarily through the network of high-angle and subhorizontal secondary-permeability features in the dolomite, with smaller amounts of flow through the dolomite matrix. Because most of the groundwater flow in the aquifer is through secondary-permeability features, wetlands associated with numerous large, interconnected secondary-permeability features can be expected to receive more water than wetlands with a few small, isolated, clay-filled, secondary-permeability features. Secondary-permeability features tend to be concentrated in

System	Series	Formation	Member	Lithology	Secondary Permeability Features
Silurian	Niagaran	Racine (basal)		Inter-reef strata, highly cherty, argillaceous dolomite, overlain by massive, porous, crystalline, pure dolomite. These lithologies recur in higher strata. Other lithologies include bedded, porous, crystalline, pure dolomite; non-cherty argillaceous dolomite; thin dolomitic shales; and nodular dolomite. May become more argillaceous in upper strata, generally east of the study area. Typically about 80 feet thick in northern part of area of interest; thins to fully eroded in southern part. Generally under-represented by fossils; dominated by annelid worms.	Prone to dissolution along bedding planes, particularly above clay-rich beds and less porous, well-bedded Sugar Run Formation. North of Kingery Highway, permeable "regional" bedding-plane fractures at elevations of about 5 to 17 feet below the bed of the Des Plaines River. Karstic features identified (Nicholas and Healy, 1988).
		Sugar Run		Well-bedded, even-textured, dense, nonporous, argillaceous, gray dolomite, 10 to 30 feet thick. Strata generally flat lying. Prominent, thin, greenish-gray argillaceous partings cause the well-bedded appearance.	Generally not prone to dissolution along bedding planes. Common near-vertical joints generally sealed.
				Fossils can be common and diverse. Thin, sinuous trails, up to 1 foot long often found on bedding surfaces, commonly filled with greenish-gray argillaceous material. Trilobite S. celebra characteristic of the unit; common to lower strata. Other trilobites, crinoids, brachiopods debris common, as is pelmatozoan debris. Orthoconic nautiloids up to 3 feet in length distributed throughout much of the formation. Sporadic occurrence of large, dendritic root systems.	
				Upper contact at the first appearance of rough-textured, abundantly cherty, brown dolomite.	
		Joliet	Romeo	Thick-bedded to massive, pure, porous to vuggy dolomite, 18 to 34 feet thick. Nodular chert near mid-unit; stylolites common throughout.	Not prone to substantial dissolution along near-vertical joints or bedding planes. Local paleokarstic sinkholes infilled with younger clastics, may be eroded resulting as reentrants up to 10 feet deep along Canal walls west of I-355. Common near-vertical joints generally sealed.
				In places a grainstone primarily consisting of pelmatozoan debris; locally very fossiliferous, containing cystoids, various crinoids, trilobites, gastropods, rugose corals, orthoconic nautiloids, and diverse brachiopods.	
				Upper contact gradational transition to the more argillaceous dolomite of the Sugar Run.	
			Markgraf	Medium-bedded dolomite, light gray, approximately 20 feet thick. Basal unit silty. Middle unit moderately argillaceous and silty with bands of chert. Upper unit slightly argillaceous with chert bands.	Potentially prone to dissolution along clay-rich bedding planes.
			Brandon Bridge	Lower part red crinoidal dolomite with interbedded argillaceous red to grey dolomite becoming less argillaceous, grey with red mottles in upper part. Top of unit is uppermost strong shaley parting. Approximately 30 feet thick.	
	Alexandrian	Kankakee		White, pink, or grey fine-to-medium grained dolomite with variable amounts of clay and chert.	About 45 feet thick. Elevation of top of formation 505 feet, North American Datum of 1988 at West Quarry.
		Elwood		Brown to grey thinly bedded dolomite with numerous shale partings and large chert nodules.	About 48 feet thick. Elevation of top of Formation 462 feet, North American Datum of 1988 at West Quarry. Only upper 5 feet mined.
		Wilhelmi		Grey highly argillaceous dolomite and dolomitic shale grading upward to argillaceous dolomite.	Overlies Maquoketa Group. About 5 to 75 feet thick in Lockport area. Elevation of base between about 390 and 450 feet, North American Datum of 1988, top is about 413 feet near the West Quarry. Not mined at Quarry. Penetrated by high-capacity wells.

Figure 6. Stratigraphy and lithology of Silurian deposits near Lockport, Will County, Illinois (from Willman and others, 1975).

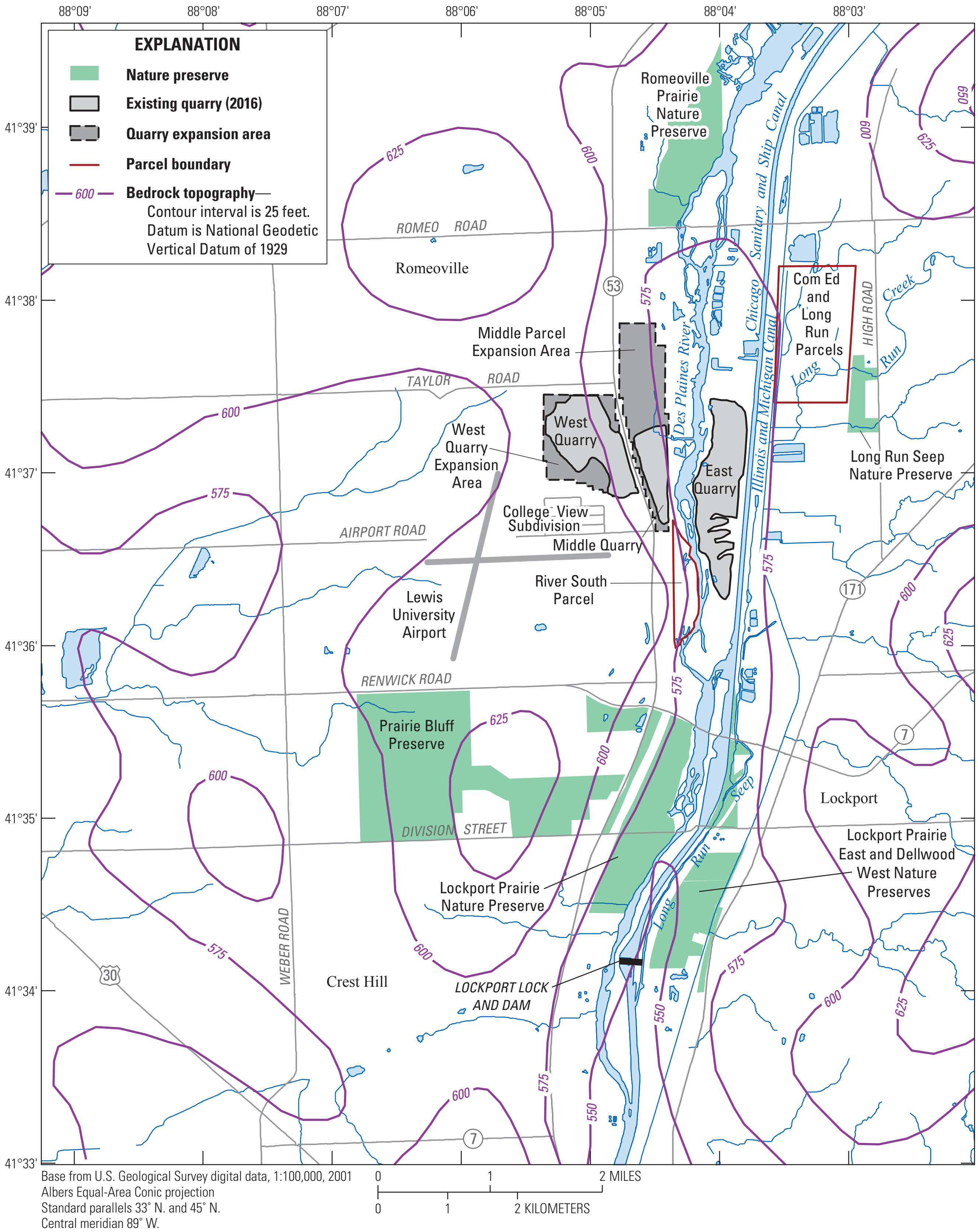


Figure 7. Topography of bedrock surface in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois (modified from Roadcap and others, 1993).

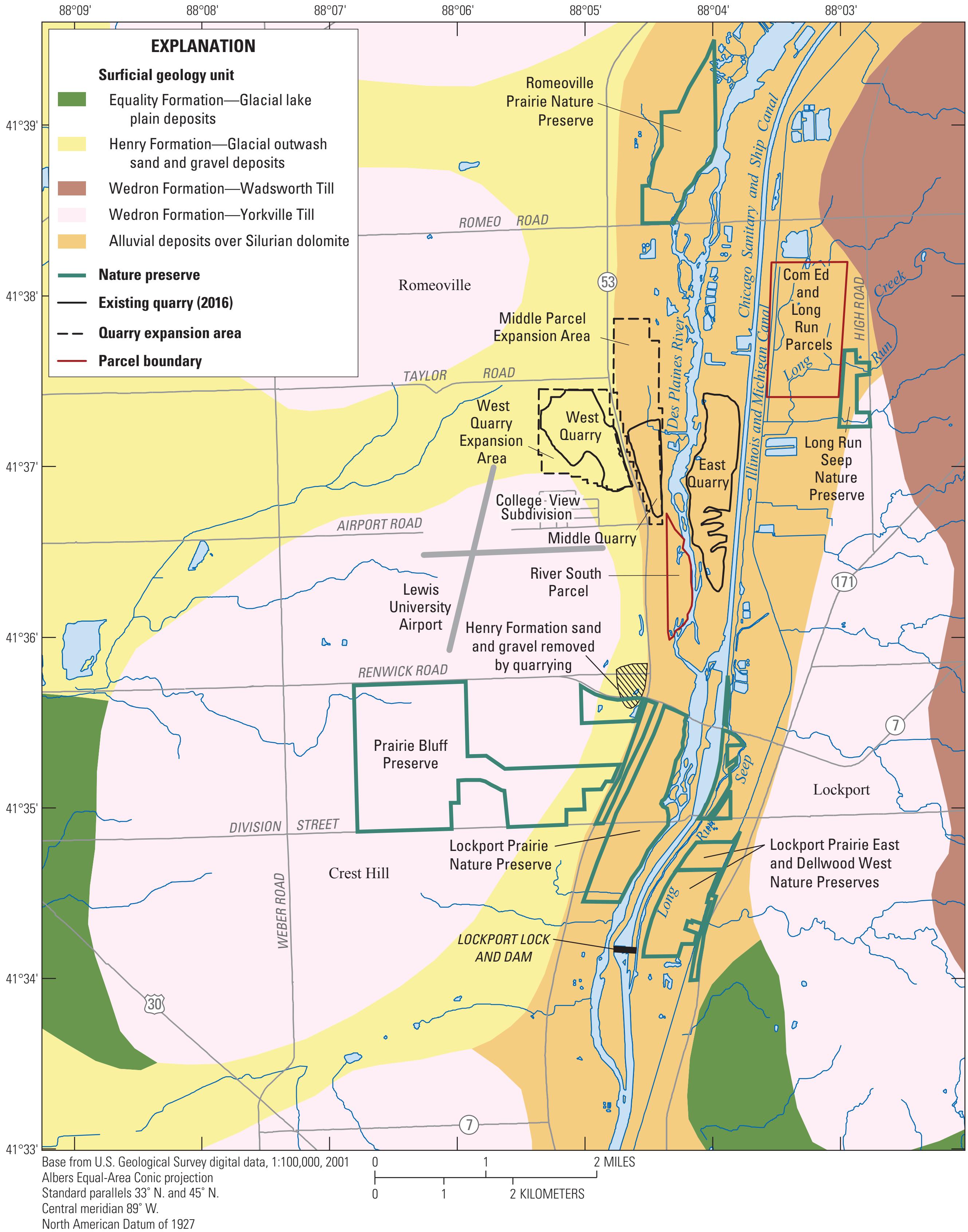


Figure 8. Surficial geology in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois (modified from Roadcap and others, 1993).

the weathered, uppermost part of the aquifer but are present throughout the Silurian aquifer.

Precipitation entering the groundwater system in that part of the Lockport area where the glacial drift aquifer is present, particularly near the bluffs of the Des Plaines River Valley, moves quickly downward through the glacial drift aquifer, recharging the Silurian aquifer. Groundwater in the glacial drift aquifer also flows laterally, discharging from seeps along the bluffs (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). Water levels (and flow) in the glacial drift aquifer are affected by the amount of precipitation, often rising several feet after a precipitation event and becoming unsaturated when precipitation is absent for an extended period of time (AECOM, 2013a,b).

Precipitation entering the groundwater system in that part of the Lockport area where the semiconfining unit (till) is present moves downward slowly, recharging the Silurian aquifer (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). During extended periods of below average amounts of precipitation, the base of the semiconfining unit and the top of the Silurian aquifer can become unsaturated in some areas, reducing the amount of recharge to the Silurian aquifer; however, flow through the semiconfining unit is affected less by individual precipitation events than flow through the glacial drift aquifer, making the semiconfining unit a more stable, continuous source of recharge to the Silurian aquifer than the glacial drift aquifer in areas where the aquifer is comparatively thin. As a consequence, wetlands whose groundwater recharge area includes a substantial portion of the semiconfining unit are likely to receive groundwater discharge for a longer period of time than wetlands that receive water primarily from the more hydrologically variable glacial drift aquifer. This process appears to be especially important to the hydrology in the vicinity of the River South Parcel and the Lockport Prairie Nature Preserve in the southwestern part of the Lower Des Plaines River Valley where the glacial drift aquifer can be comparatively thin. By the same token, the glacial drift aquifer is thick and capable of supporting flow for extended periods of time at the Long Run Seep Nature Preserve and several other parcels in the vicinity of the Lower Des Plaines River Valley.

Groundwater in the Silurian aquifer discharges to either the Des Plaines River, the wetlands in the valley of the Des Plaines River, or from seeps at the base of the bluffs along the Des Plaines River Valley (fig. 5; Roadcap and others, 1993; Graef, Anhalt, Schloemer, and Associates, Inc., 2004a; AECOM, 2013a,b). The Silurian aquifer is hydraulically isolated from surface-water bodies in the topographic uplands by the semiconfining unit. Groundwater that has discharged to the seeps, as well as groundwater that is discharged directly from the Silurian aquifer to the wetlands in the river valley, flows as surface water through the wetlands to the Des Plaines River.

Water-Level Measurements

It is critical to assess the potential effect of increased groundwater withdrawals and decreased recharge to the Silurian aquifer on water levels and groundwater discharge to the HED habitats. The first step in assessing the water resources in the Lockport area was the synoptic measurement of surface-water and groundwater levels on July 19, 2012 (tables 1, 2; fig. 9). A second synoptic measurement was done on November 26, 2012 (fig. 10). These measurements were performed by the USGS in cooperation with a variety of other public and private entities and were compiled and contoured by the authors to

- define the potentiometric surface of the Silurian aquifer in the Lockport area,
- identify directions of groundwater flow in three dimensions,
- identify the nature of the interaction between surface water and groundwater,
- identify the groundwater recharge areas in the Silurian aquifer for selected HED habitats, and
- identify the effects of pumping from high-capacity wells.

In this report, “high-capacity wells” are pumped at greater than 75 gallons per minute (gal/min) and typically yield thousands of gallons on a daily basis, whereas “water-supply wells” are pumped at less than 20 gal/min and typically yield less than 500 gallons on a daily basis.

Much of Illinois was experiencing a drought during July 2012 and was still in a water deficit during November 2012, so these water levels are lower than usual (Illinois Department of Natural Resources, 2013). Additional synoptic measurements during more typical hydraulic conditions and over a larger portion of the Lower Des Plaines River Valley would improve the assessment of the area hydrology.

Water levels in the Silurian aquifer are highest beneath the topographic uplands and decrease overall toward the Des Plaines River Valley. These data indicate the regional direction of groundwater flow in the Silurian aquifer is from the topographic uplands east and west of the Des Plaines River Valley toward the river. Within this regional flow pattern there are a few local variations.

The water level of the CSSC is maintained at an elevation of about 576.7 ft NAVD 88 by the operation of the Lockport Lock and Dam to facilitate navigation (Jackson and others, 2012). The stage of the CSSC is substantially higher than nearby land surface and groundwater levels in most of the Lockport area, creating the potential for flow from the CSSC into the Silurian aquifer from the Lockport Lock and Dam to approximately the southern edge of the East Quarry (figs. 9, 10).

Table 1. Well construction and groundwater-level data in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, July 19 and November 26, 2012.

[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988; F, fill; D, Dolomite; USGS, U.S. Geological Survey; --, no data; C, consultant; GD, Glacial drift; ?, unknown; <, less than]

Well name (location shown in fig. 9)	USGS well name	Latitude, in degrees (NAD 83)	Longitude, in degrees (NAD 83)	Land surface elevation, in feet above NAVD 88	Measuring point elevation, in feet above NAVD 88	Elevation of well screen, in feet above NAVD 88	Unit monitored	Water-level elevation on 7/19/2012, in feet above NAVD 88	Water-level elevation on 11/26/2012, in feet above NAVD 88	Measured by
LP-09-03	413446088042101	41.579483	−88.072350	585.4	586.61	546–551	F/D	570.89	572.71	USGS
LP-09-04	413446088042301	41.579525	−88.073030	585.4	586.47	547–552	F/D	552.20	552.08	USGS
LP-09-01	413453088041301	41.581478	88.070301	585.4	586.72	549–554	F/D	--	560.50	USGS
LP-09-05	413441088042501	41.578054	−88.073829	585.2	586.51	544–549	F/D	--	555.94	USGS
MW-1R	--	41.561666	−88.090028	600.5	600.48	564–584	D	577.06	574.91	C
ERM-5	--	41.563344	−88.090461	582.4	584.65	560–575	D	573.60	574.14	C
MW-18	--	41.560903	−88.088664	590.8	593.11	550–560	D	567.78	568.31	C
MW-3	--	41.655139	−88.077403	611.6	611.05	596–606	GD/D	604.49	--	C
MW-3D	--	41.655139	−88.077403	611.5	611.03	547–557	D	601.97	--	C
MW-14	--	41.653853	−88.071281	601.7	601.41	586–596	GD/D	594.30	--	C
MW-14D	--	41.653853	−88.071281	601.7	601.32	546–556	D	593.10	--	C
MW-21	--	41.654339	−88.068017	586.8	589.88	575–582	D	585.36	--	C
MW-24	--	41.640417	−88.075917	592.4	595.23	581–588	D	585.80	--	C
MW-25	--	41.659772	−88.075475	591.0	594.04	579–587	D	585.58	--	C
B-11	--	41.650439	−88.030896	718.6	721.09	591–596	D	622.99	--	C
GMZ-1	--	41.652740	−88.050886	589.8	593.25	574–584	D	581.50	--	C
GMZ-5	--	41.645968	−88.053050	591.2	593.19	577–587	D	587.34	--	C
SWB-4	--	41.650371	−88.056222	587.9	589.73	538–543	D	578.43	--	C
SWB-5	--	41.650300	−88.056275	587.8	589.97	570–580	D	578.35	--	C
MW-102	--	41.655991	−88.037582	690.7	693.77	570–575	D	605.57	--	C
MW-103	--	41.652168	−88.042304	644.8	648.53	571–575	D	608.55	--	C
MW-105A (N)	--	41.642780	−88.057477	587.9	591.38	580–585	D	580.10	--	C
MW-105A (S)	--	41.642768	−88.057480	587.9	591.26	555–560	D	580.21	--	C
MW-109A	--	41.661599	−88.042548	587.9	590.83	580–585	D	579.83	--	C
MW–109B	--	41.661611	−88.042540	587.9	590.84	555–560	D	579.79	--	C
MW-122	--	41.650120	−88.048535	595.6	597.78	575–585	D	591.18	--	C
PZ-15	--	41.641150	−88.051860	591.2	591.23	574–584	D	586.98	--	C
RP-1S	--	41.608973	−88.073430	600.9	603.98	572–587	D	581.53	581.30	C

Table 1. Well construction and groundwater-level data in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, July 19 and November 26, 2012.—Continued

[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988; F, fill; D, Dolomite; USGS, U.S. Geological Survey; --, no data; C, consultant; GD, Glacial drift; ?, unknown; <, less than]

Well name (location shown in fig. 9)	USGS well name	Latitude, in degrees (NAD 83)	Longitude, in degrees (NAD 83)	Land surface elevation, in feet above NAVD 88	Measuring point elevation, in feet above NAVD 88	Elevation of well screen, in feet above NAVD 88	Unit monitored	Water-level elevation on 7/19/2012, in feet above NAVD 88	Water-level elevation on 11/26/2012, in feet above NAVD 88	Measured by
RP-1D	--	41.608997	−88.073433	601.2	603.19	483–492	D	581.06	580.59	C
RP-2S	--	41.606174	−88.072000	579.3	582.27	565–575	D	574.92	576.42	C
RP-2D	--	41.606160	−88.071973	579.2	581.88	533–538	D	575.27	576.50	C
MP-1S	--	41.625470	−88.074743	582.1	585.10	558–572	D	576.55	578.86	C
MP-1D	--	41.625470	−88.074743	582.8	584.92	475–485	D	577.59	579.40	C
MP-2S	--	41.622616	−88.074771	581.9	585.18	558–573	D	569.89	574.13	C
MP-2D	--	41.622591	−88.074780	582.3	583.46	474–484	D	571.90	575.01	C
MP-3D	--	41.621750	−88.074780	581.7	584.33	434–?	D	561.51	553.28	C
CEP-1S	--	41.636895	−88.052703	586.7	586.96	573–583	D	584.58	586.16	C
CEP-1D	--	41.636921	−88.052715	586.6	589.73	538–545	D	584.58	586.43	C
CEP-2S	--	41.630933	−88.050334	587.2	590.29	568–583	D	584.76	585.49	C
CEP-2D	--	41.630912	−88.050347	587.5	590.32	535–540	D	584.63	585.54	C
CEP-3S	--	41.636837	−88.049806	592.0	595.05	575–590	D	589.49	590.46	C
CEP-3D	--	41.636811	−88.049805	592.0	595.07	543–548	D	590.07	590.80	C
CEP-4S	--	41.629947	−88.056663	584.5	587.40	565–580	D	579.07	582.05	C
CEP-4D	--	41.636837	−88.049806	584.4	587.73	534–538	D	578.99	582.01	C
CEP-5S	--	41.635159	−88.057559	585.3	588.29	566–580	D	578.49	580.17	C
CEP-6S	--	41.635973	−88.053035	586.5	589.02	573–583	D	584.89	586.01	C
CEP-7S	--	41.636390	−88.052241	587.1	589.80	575–585	D	585.65	586.66	C
CEP-8WT	--	41.635755	−88.052384	587.2	589.91	583–585	D	586.09	586.82	C
CEP-9WT	--	41.636929	−88.052216	587.3	590.76	583–586	D	585.66	586.59	C
CEP-10S	--	41.631606	−88.054939	584.7	587.73	566–571	D	580.78	584.56	C
CEP-11S	--	41.632562	−88.054200	585.0	587.90	571–575	D	580.45	584.15	C
CEP-11D	--	41.632554	−88.054202	584.9	587.48	535–539	D	580.43	584.00	C
CEP-12S	--	41.631748	−88.052382	587.3	590.76	571–576	D	584.28	587.51	C
MW-3A	413444088045901	41.579000	−88.083111	611.5	611.22	575–585	D	578.87	578.22	USGS
MW-3B	413444088045902	41.579000	−88.083111	611.5	611.07	545–550	D	560.68	563.07	USGS
MW-6A	413520088043901	41.589056	−88.077583	616.5	619.15	583–593	GD	586.62	586.41	USGS

Table 1. Well construction and groundwater-level data in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, July 19 and November 26, 2012.—Continued

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MW-6B	413520088043902	41.589056	−88.077583	616.3	619.21	571–576	D	586.03	585.82	USGS
MW-6C	413520088043903	41.589056	−88.077583	616.3	619.11	546–551	D	589.91	585.62	USGS
MW-6N	413523088044401	41.589639	−88.078778	622.5	624.75	584–?	D?	588.43	--	USGS
MW-6S	413515088044201	41.587500	−88.078306	615.9	618.65	578–?	D?	586.41	586.21	USGS
MW-7A	413543088053701	41.595333	−88.093556	672.1	674.83	652–662	GD	663.67	658.47	USGS
MW-7B	413543088053702	41.595333	−88.093556	672.1	674.96	606–611	GD/D	<606	606.92	USGS
MW-7C	413543088053703	41.595333	−88.093556	672.1	674.75	597–607	D	605.82	605.95	USGS
MW-7D	413543088053704	41.595333	−88.093556	672.1	674.81	572–577	D	605.70	605.81	USGS
MW-8A	413454088044601	41.581778	−88.079611	566.5	569.33	557–562	GD/D	561.51	563.74	USGS
MW-8B	413454088044602	41.581778	−88.079611	566.5	569.33	539–544	D	561.09	563.82	USGS
MW-9A	413516088043401	41.587861	−88.076139	571.7	574.64	559–564	D	567.20	568.83	USGS
MW-9B	413516088043402	41.587861	−88.076139	571.7	574.39	542–547	D	568.40	568.58	USGS
MW-10A	413454088042201	41.581778	−88.072917	556.3	560.69	543–553?	D	551.06	552.08	USGS
MW-10B	413454088042202	41.581778	−88.072917	556.6	560.40	532–537?	D	551.18	552.08	USGS
MW-10C	413454088042203	41.581778	−88.072917	556.4	560.10	499–504?	D	550.51	551.17	USGS
MW-11A	413533088041401	41.592389	−88.070500	562.6	567.37	555–565?	D	560.74	561.90	USGS
MW-11B	413533088041402	41.592389	−88.070500	562.5	567.40	539–544?	D	561.15	562.05	USGS
MW-11C	413533088041403	41.592389	−88.070500	562.5	567.46	503–508?	D	560.83	562.07	USGS
MW-12A	413519088062501	41.588556	−88.106889	642.0	644.99	622–632?	GD	636.71	636.87	USGS
MW-12B	413519088062502	41.588556	−88.106889	642.1	644.61	581–586?	D	603.16	602.60	USGS
MW-12C	413519088062503	41.588556	−88.106889	642.1	644.69	548–553?	D	602.94	--	USGS
G105	413545088043701	41.595861	−88.076861	595.4	597.91	581–591	D	593.16	593.90	USGS
G106	413543088043401	41.595361	−88.076028	595.0	598.43	576–586	D	591.19	592.18	USGS
G107	413543088043601	41.595444	−88.076639	596.0	599.54	582–592	D	591.54	592.74	USGS
LRS1	413722088025601	41.622639	−88.049056	599.4	603	598–?	GD	598.20	--	USGS
LRS3	413721088025901	41.622389	−88.049778	593.4	597	590–?	GD	593.69	--	USGS
LRS4	413721088025601	41.622472	−88.049056	589.9	595.4	587–?	GD	590.00	--	USGS
RP1	413919088041001	41.655167	−88.069556	592.8	595.78	591–592?	GD	591.01	591.59	USGS

Table 1. Well construction and groundwater-level data in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, July 19 and November 26, 2012.—Continued

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RP2	413918088040801	41.655083	−88.069028	595.5	595.78	542–547?	D	589.77	590.01	USGS
RP3	413920088041001	41.655694	−88.069528	592.0	596.32	589–590?	GD	589.38	--	USGS
RP5	413915088040501	41.654333	−88.068056	589.2	589.87	578–588?	GD	586.27	--	USGS
RP6	413905088040901	41.654083	−88.069333	593.3	594.10	587–590?	GD	589.42	--	USGS
RPPW4	413919088041001	41.655333	-88.069500	593.6	596.42	542–547	D	590.42	590.65	C
SV1	413422088051101	41.572694	−88.086556	595.4	597.82	580–?	GD	581.41	<580.07?	USGS
SV2	413422088051102	41.572694	−88.086556	595.1	597.49	561–571?	D	581.23	572.45	USGS
CH3A	413451088061501	41.580972	−88.104167	641.2	643.74	587–597	GD	590.09	588.27	USGS
CH3B	413452088061501	41.580972	−88.104167	641.2	643.31	565–575	D	588.17	589.33	USGS
CH2A	413400088061001	41.566611	−88.102833	628.7	631.29	579–?	GD	584.61	583.62	USGS
CH2B	413400088061002	41.566611	−88.102833	628.4	630.88	565–575	D	583.92	583.32	USGS
CH2C	413400088061003	41.566611	−88.102833	628.1	630.78	322–482	D	543.17	540.54	USGS
G109	413601088064701	41.600361	−88.113083	660.4	662.45	585–595	D	607.37	606.55	USGS
G110	413557088064701	41.599278	−88.113139	661.6	663.84	584–594	D	606.94	606.23	USGS
G111	413550088064701	41.597250	-88.112972	653.3	655.47	590–600	D	606.99	606.21	USGS
G112	413549088064901	41.597028	−88.113611	652.1	654.52	586–596	D	606.62	605.98	USGS
G113	413549088065701	41.596944	−88.115917	652.8	654.69	582–592	D	606.42	605.81	USGS
CH7	--	--	--	618	618	322–?	D	519	--	C
CH8	--	--	--	584	584	249–?	D	484	--	C
CH9	--	--	--	641	641	340–?	D	564	--	C
CH10	--	--	--	600	600	275–?	D	492	--	C
CH11	--	--	--	641	641	340–?	D	527	--	C
R#1	413911088051601	--	--	640	640	482–599	D	--	610	C
R#3	413848088055401	--	--	621	621	461–581	D	603	601	C
R#5	414020088041301	--	--	707	707	457–646	D	519	518	C
R#7	--	--	--	653	653	353–595	D	609	607	C
R#8	--	--	--	653	653	453–603	D	615	613	C
R#9	--	--	--	650	650	401–595	D	568	570	C

Table 1. Well construction and groundwater-level data in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, July 19 and November 26, 2012.—Continued

[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988; F, fill; D, Dolomite; USGS, U.S. Geological Survey; --, no data; C, consultant; GD, Glacial drift; ?, unknown; <, less than]

Well name (location shown in fig. 9)	USGS well name	Latitude, in degrees (NAD 83)	Longitude, in degrees (NAD 83)	Land surface elevation, in feet above NAVD 88	Measuring point elevation, in feet above NAVD 88	Elevation of well screen, in feet above NAVD 88	Unit monitored	Water-level elevation on 7/19/2012, in feet above NAVD 88	Water-level elevation on 11/26/2012, in feet above NAVD 88	Measured by
R#12	--	--	--	623	623	378–57	D	604	603	C
CV#1	--	--	--	675	675	333–628	D	540	--	C
CV#2	--	--	--	682	682	386–635	D	530	--	C
CV#3	--	--	--	680	680	353–638	D	532	--	C
CO	413645088044301	--	--	628.2	629.00	449–?	D	518?	--	USGS
CG	413647088044401	--	--	625.4	626.83	320–?	D	469.22	470.12	USGS
AL	413648088043601	--	--	620.2	620.59	320–?	D	471.29	472.54	USGS
RMW	413608088072001	--	--	647.3	648.20	523–592	D	609.81	607.98	USGS
RME	413609088071101	--	--	650.5	652.22	523–595	D	610.17	608.03	USGS
AR	413635088063301	--	--	663.8	664.88	?–?	D	620.87	624.98	USGS
CBW	413807088024901	--	--	679.7	681.17	?–?	D	613.93	--	USGS
LGC	413648088025801	--	--	648.1	650.38	450–507	D	596.78	--	USGS
RRR	413548088050601	--	--	655.1	656.97	?–?	D	599.22	599.15	USGS
LUFH	413600088042901	--	--	612.1	613.17	?–?	D	--	575.63	USGS
TR	413732088051401	--	--	636.1	635.67	410–?	D	--	572?	USGS
WC	413642088044401	--	--	632.0	633.13	330–?	D		540.10	USGS

Table 2. Streamgage information and water-level data in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, July 19 and November 26, 2012.

[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988; USGS, U.S. Geological Survey; --, no data]

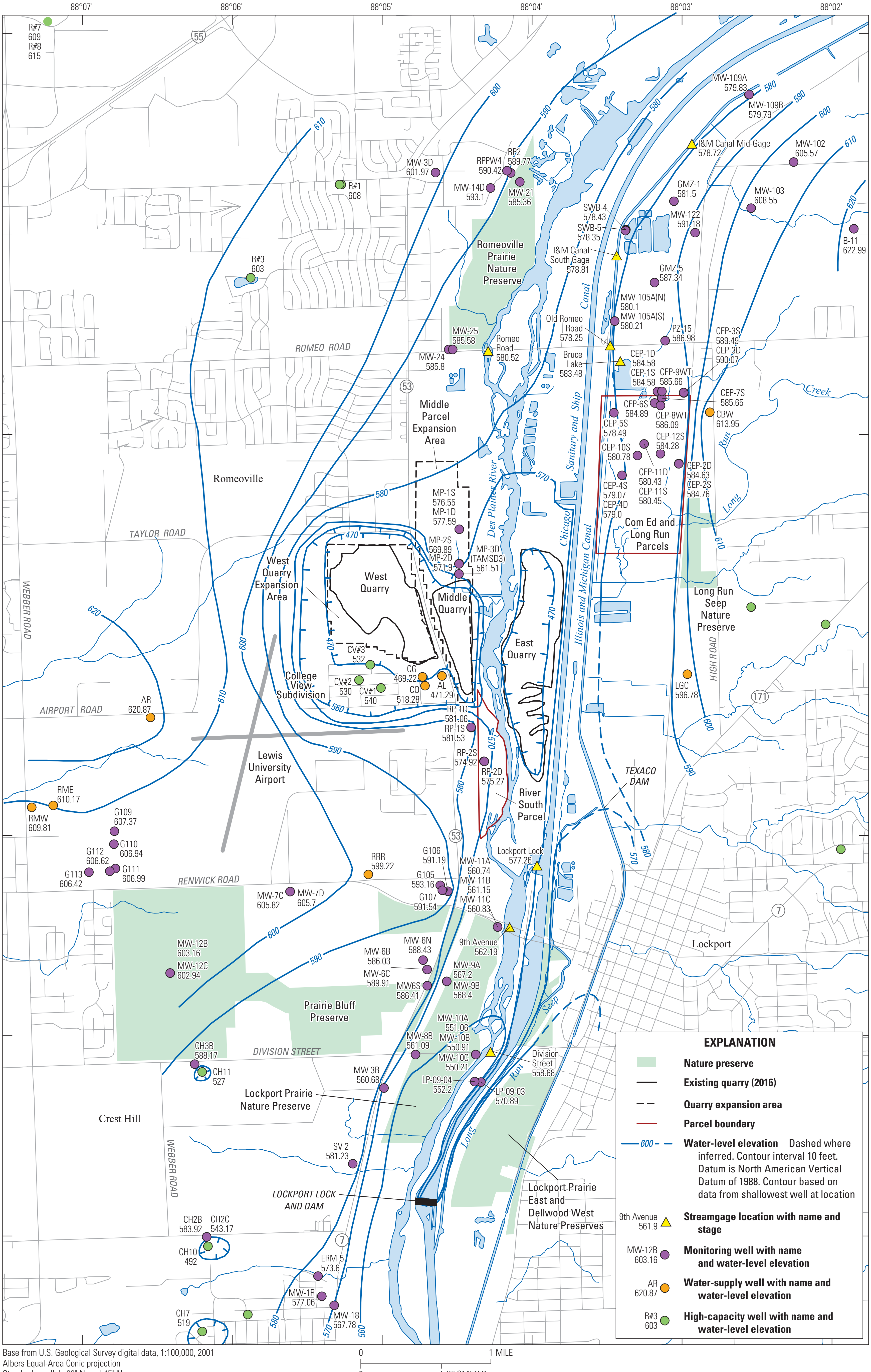
Location (shown in fig. 9)	USGS streamgage name	Latitude, in degrees (NAD 83)	Longitude, in degrees (NAD 83)	Measuring point elevation, in feet above NAVD 88	Water-level elevation on 7/19/2012, in feet above NAVD 88	Water-level elevation on 11/26/2012, in feet above NAVD 88	Measured by
Illinois and Michigan Canal							
Old Romeo Road	--	41.640661	-88.058009	593.05	578.30	578.40	USGS
Middle Gage	--	41.657507	-88.048899	593.27	578.72	--	Consultant
South Gage	--	41.648228	-88.057267	577.31	578.81	--	Consultant
Des Plaines River							
Romeo Road	05534000	41.640279	-88.058009	571.47	580.52	584.55	USGS
9th Avenue	--	41.592550	-88.069550	579.77	562.19	562.08	USGS
Division Street	05534100	41.581993	-88.072030	579.77	558.68	558.41	USGS
Material Service Road	05534050	41.596377	-88.068517	579.77	563.88	--	USGS
Chicago Sanitary and Ship Canal							
Lockport Lock Control Works	05537000	41.597500	-88.066111	579.78	577.26	576.84	USGS
Bruce Lake							
Bruce Lake (shown in fig. 22)	--	41.639441	-88.056858	591.88	583.48	--	Consultant

A cone of depression surrounds the Quarry due to high-capacity pumping to dewater the dolomite and to support Quarry operations. The cone of depression appears to extend to HED habitats at the Middle Parcel Expansion Area and the River South Parcel. Additional groundwater withdrawals from the Silurian aquifer associated with the proposed expansion of quarry operations in the West Quarry and Middle Parcel Expansion Areas (fig. 1) would increase the size of the cone of depression in the vicinity of the Quarry. Note the process affecting flow from the CSSC to the Silurian aquifer near the East Quarry (pumping from the East Quarry) differs from the process affecting flow to the aquifer (approximately) south of the quarry (elevated water levels in the canal) discussed in the previous paragraph.

Lower water levels also were observed at high-capacity wells CH7, CH10, and CH11 in the southern part of the Lockport area (fig. 9). All of the high-capacity wells in this area are open to most or all of the Silurian aquifer. Static water levels are lower in the deeper part of the Silurian aquifer than in the shallow part in the vicinity of some of these wells; for example, high-capacity well CH10 is about 325 ft deep and had a water-level elevation of about 492 ft during July 2012 (table 1). Nearby monitoring wells CH2C (depth about 300 ft) and CH2B (depth about 65 ft) had static water-level elevations of about 543 and 584 ft, respectively, during July 2012. These data indicate that fractures located in the deeper part of the Silurian aquifer can provide substantial amounts of groundwater to the high-capacity wells and that the vertical interconnectedness of the fracture network within the Silurian aquifer is somewhat limited in this area and potentially in the Silurian aquifer as a whole. It is unclear if the extraction of groundwater from secondary-permeability features in the deeper part of the Silurian aquifer diverts substantial amounts of water from the shallower parts of the aquifer and the wetlands.

The potentiometric surface depicted in figures 9 and 10 and from previous investigations (Roadcap and others, 1993) indicates that the groundwater recharge area (the land area where water infiltrates into the ground and contributes to the groundwater that flows to or through a given feature) for the Silurian aquifer to the River South Parcel and the Lockport Prairie Nature Preserve extends west to the vicinity of the intersection of Airport and Weber Roads (fig. 11). The recharge areas are separated by a groundwater divide that extends from the vicinity of the AR well to well RRR and wells G105 through G107 north of the Lockport Prairie Nature Preserve (fig. 9). The groundwater recharge zones show some overlap with the capture zones (the area around a pumping center contributing groundwater to the pumped wells) for the Quarry.

To account for uncertainties in the flow direction, a 0.5-mi wide "buffer area" is drawn around the groundwater recharge area to identify the area that could be affecting the hydrology of the River South Parcel and the Lockport Prairie Nature Preserve. An additional 2-mi buffer was added to account for the area where drawdown or capture from high-capacity pumping wells might affect flow in the recharge areas. The hydrology within a groundwater recharge area and changes to the hydrology within the recharge area have the potential to affect the HED habitat.



Base from U.S. Geological Survey digital data, 1:100,000, 2001
Albers Equal-Area Conic projection
Standard parallels 33° N. and 45° N.
Central meridian 89° W.
North American Datum of 1927

Figure 9. Potentiometric surface of the Silurian aquifer in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois, July 19, 2012.

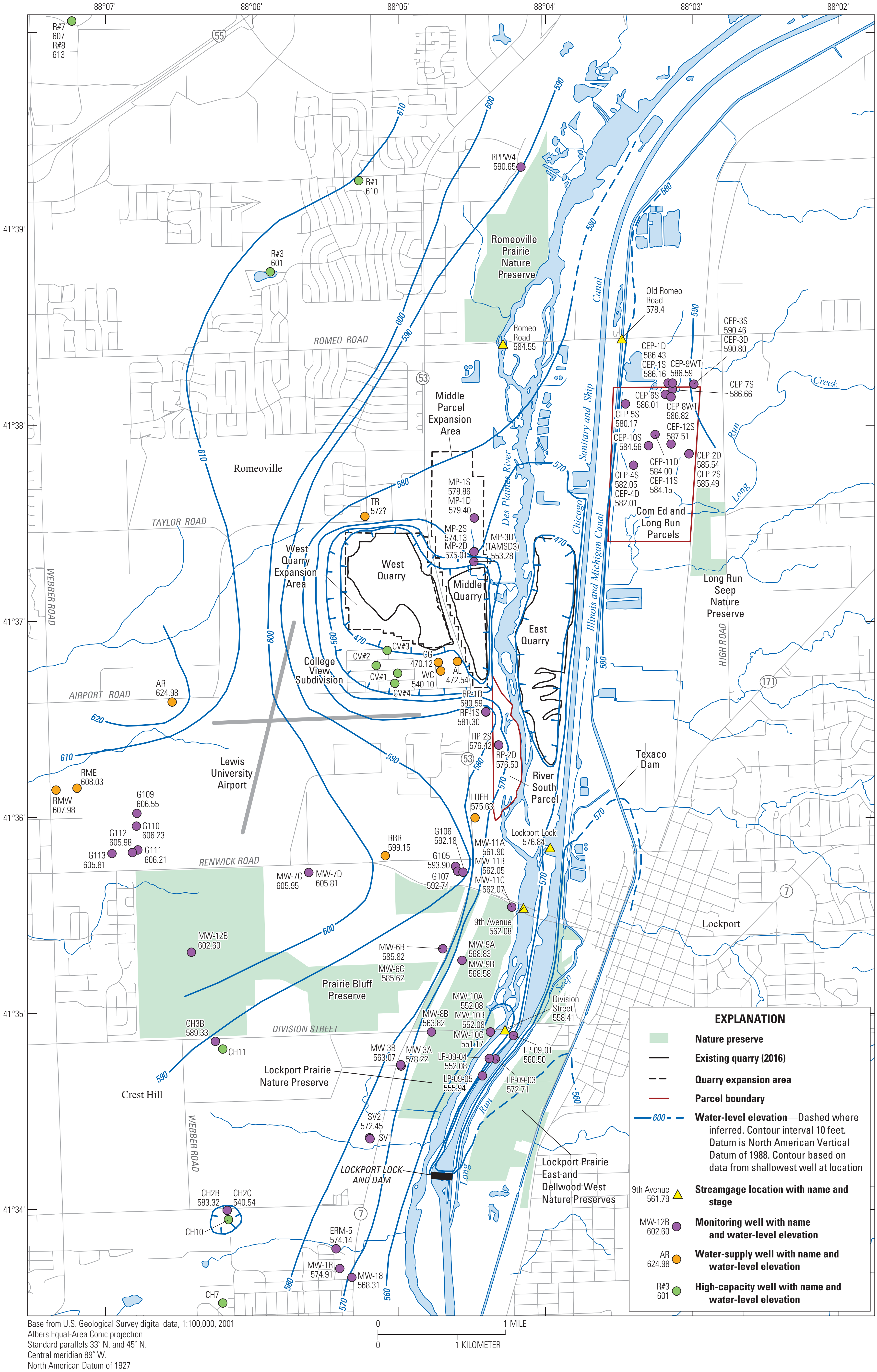


Figure 10. Potentiometric surface of the Silurian aquifer in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois, November 26, 2012.

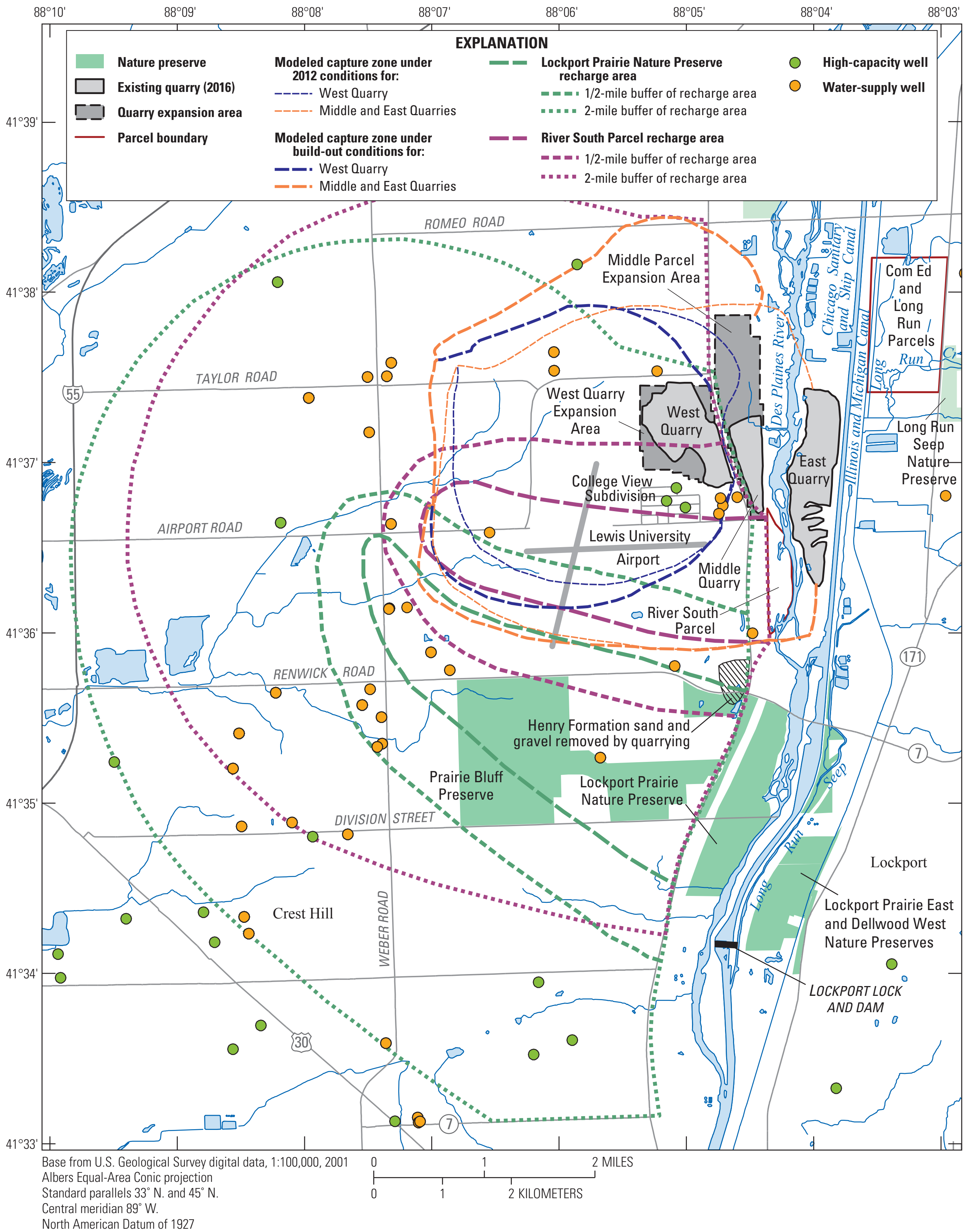


Figure 11. Location of modeled capture zones and groundwater recharge areas in the Silurian aquifer for selected focus areas in the vicinity of the Lower Des Plaines River Valley near Lockport, Will County, Illinois (modified from Graef, Anhalt, Schloemer, and Associates, Inc., 2008).

Assessment of Conditions that Affect the Water Resources at Selected Hine's Emerald Dragonfly Habitats in the Lower Des Plaines River Valley

This assessment focuses on the Quarry, the River South Parcel, the Lockport Prairie Nature Preserve, and the Com Ed/ Long Run Parcels. These parcels have been most intensively characterized; are most likely to be affected by increased pumping at the Quarry; and in the case of River South and the Lockport Prairie Nature Preserve, have the best HED habitat (highest populations). Other habitats (Long Run Seep Nature Preserve, Romeoville Prairie Nature Preserve, Keepataw Forest Preserve, Black Partridge Woods Forest Preserve, Waterfall Glen Forest Preserve, and McMahon Fen Nature Preserve) will be discussed in lesser detail because they (1) are outside of the areas likely to be affected by pumping at the Quarry, (2) have been subjected to less investigation and have less data, and (3) contain smaller HED populations.

Assessment of Water Resources in the Quarry Area

The Quarry is located on Route 53 near Romeoville, Ill. (fig. 1) and consists of several parcels. The West Quarry and the West Quarry Expansion Area are located west of Illinois Route 53 and total about 269 acres. The Middle Quarry is located on the southern part of the property between Route 53 and the Des Plaines River and is about 80 acres in size. The East Quarry is located between the CSSC and the Des Plaines River and is about 219 acres. The Middle Parcel Expansion Area is 125 acres and is located north of the Middle Quarry. The River South Parcel is 66 acres and is located between the Des Plaines River and a north-south trending railroad line that is present east of the bluffs defining the western edge of the Des Plaines River Valley.

Mining began in 1973 at the East Quarry, in 1993 at the Middle Quarry, and in 1994 at the West Quarry. Silurian dolomite has been mined to an elevation of approximately 475 ft NAVD 88 at the West Quarry; 475 ft (northern two-thirds) to 525 ft (southern one-third) at the Middle Quarry; and 475 ft (northern), 497 ft (south-central) and 505 ft (southern) at the East Quarry as of 2016 (STS/AECOM, 2008a, 2009). The draft mining plan that is expected to govern future operations calls for mining the West Quarry Expansion Area, followed by parts of the Middle Quarry and the Middle Parcel Expansion Area once mining in the West Quarry Expansion Area has been completed. The parcels will be mined to an elevation of about 475 ft to the boundaries shown in figure 1. Once mining of the West Quarry is completed, a culvert connecting the West Quarry to the Middle Quarry will be blocked, dewatering at the West Quarry will stop, and the West Quarry will fill with water.

Topography

The Middle Parcel Expansion Area is located between topographic uplands near Route 53 to the west and the Des Plaines River to the east (figs. 4, 12). A narrow berm is present in the western part of the property. The elevation of the land surface in most of the Middle Parcel Expansion Area is between about 580 and 590 ft, increasing to more than 600 ft along the berm and bluffs to the west.

Biology

The HED has historically documented larval use at the Middle Parcel Expansion Area (fig. 2; Cashatt and others, 1993). Larval use has not been documented since 1996 (Mierzwa, 2013a,b) and successful recruitment of larvae to breeding adults is considered unlikely since at least the 2005 drought due to a lack of sustained wet conditions. This lack of sustained wet conditions is related to the effects of quarry operations on the hydrology at the Middle Parcel Expansion Area, particularly during the summer months when surface water is needed for egg deposition and hydration.

Ongoing use of the property by HED adults has been documented for foraging and transit (Mierzwa, 2009, 2013a,b; Mierzwa and Webb, 2012b). The total HED population at the Middle Parcel Expansion Area typically was estimated to be less than 5 individuals for most of 1994–2013. Peak populations of 51 and 36 individuals were observed in 1999 and 2000, respectively. The current (2018) adult and former larval HED habitat at the Middle Parcel Expansion Area is in a topographically flat, wetland area east of the bluff and adjacent to a drainage system that traverses the parcel (fig. 12).

Hydrogeology

The geologic deposits at the Quarry that are of concern to this investigation consist of the Silurian dolomite and the overlying glacial and alluvial deposits. The Silurian dolomite deposits constitute the Silurian aquifer. Sand and gravel deposits of the Henry Formation overlie the bedrock in most of the Quarry area west of Route 53 (fig. 8). Alluvial deposits are present east of Route 53 at the Middle Parcel Expansion Area and in the river valley and constitute the alluvial aquifer.

Alluvial Aquifer

The thickness of the unconsolidated deposits at the Quarry generally increases from east to west. Unconsolidated deposits typically are 1–2 ft thick near the Des Plaines River, 2–5 ft thick in the eastern part of the Middle Parcel Expansion Area, 8–12 ft thick in the eastern part of the West Quarry, and 15–23 ft thick in the western part of the West Quarry. Hydric soils, but not histosols (organic-rich soil), are present in much of the Middle Parcel Expansion Area (Hanson Material Service Corporation, 2016). Hydric soils are permanently or seasonally saturated by water, resulting in anaerobic (low

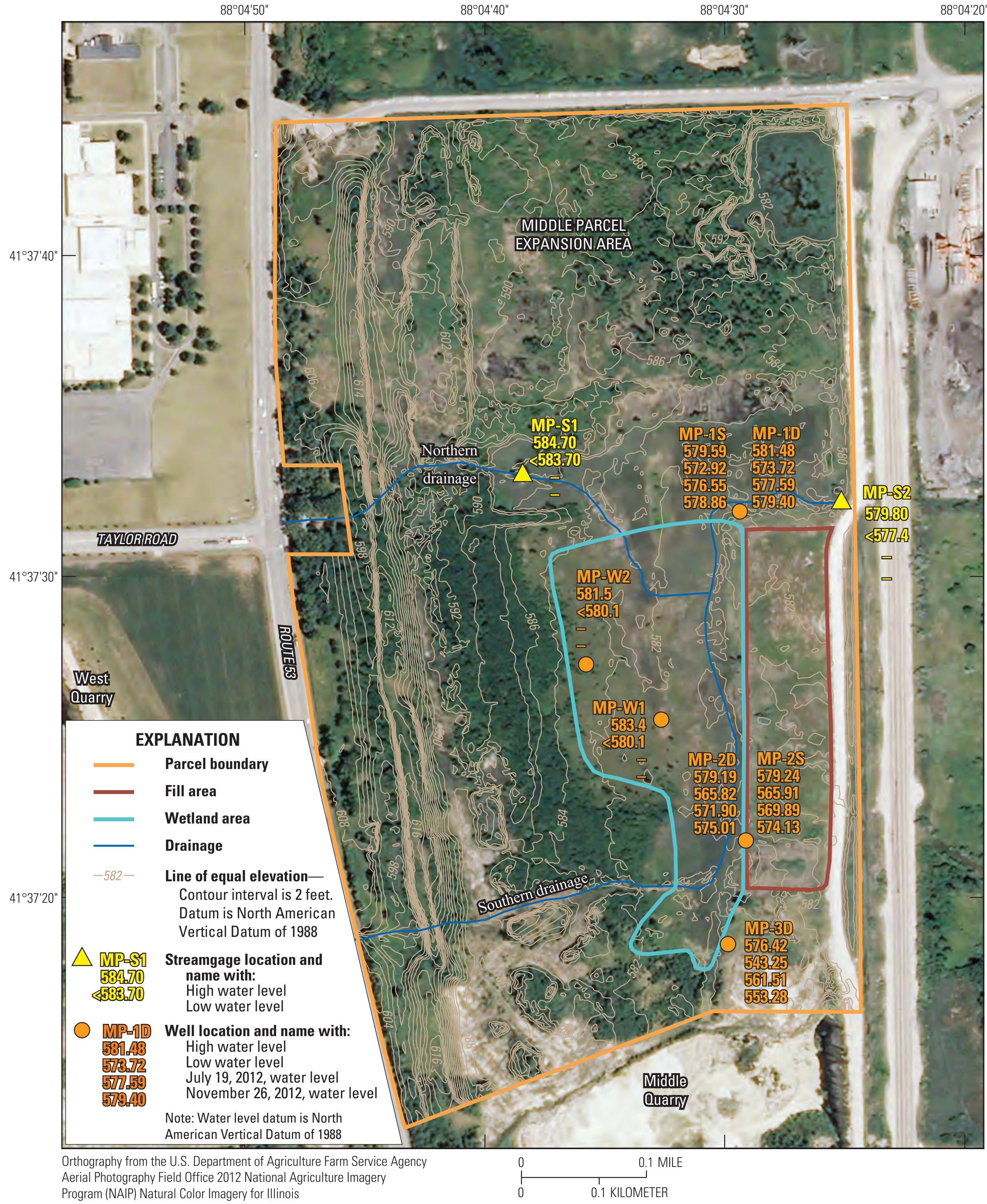


Figure 12. Location of selected features and water-level data at the Middle Parcel Expansion Area, Will County, Illinois.

oxygen) conditions, as found in wetlands. Horizontal hydraulic conductivity values for the alluvial aquifer at the Quarry range from about 0.9 to 100 feet per day (ft/d; STS/AECOM, 2009).

Water levels at wells MP-W1 (fig. 13) and MP-W2, which are open to the alluvial aquifer at the wetland, indicated seasonal variations that are likely in response to seasonal variations in precipitation and evapotranspiration (Applied Ecological Services, 2012, 2013). The alluvial aquifer at these wells (and the nearby wetland) appears to have been unsaturated during the late spring through fall (June–September 2006, June–December 2007, July–December 2008, June–October 2009, June–December 2010, and June to at least October 2011) and at least partly saturated during late fall through early spring. Water levels increased, typically by less than 1 ft, in response to precipitation events. Response to precipitation events typically was observed during the fall and spring when baseline water levels were higher but was only occasionally detected during the summer when water levels typically were below the sensor.

Silurian Aquifer

The Silurian deposits in the vicinity of the Quarry consist of dolomites of the Wilhelmi, Elwood, Kankakee, Joliet, Sugar Run, and Racine Formations (fig. 5, 6). The Racine, Sugar Run, Joliet, Kankakee, and upper part of the Elwood Formations are mined at the Quarry, but not the more argillaceous deposits of the lower Elwood and Wilhelmi Formations (AECOM, 2012). Secondary-permeability features are most prevalent in the weathered, upper 40 ft of the bedrock. These features become less prevalent with depth, but they were present at depths of at least 135 ft (elevation about 450 ft NAVD 88) in cores drilled at the Quarry.

The Silurian dolomite constitutes the Silurian aquifer. Horizontal hydraulic conductivity values for the aquifer at the Quarry range from 1.7×10^{-4} to 2.8×10^{-1} ft/d (STS/AECOM, 2009; AECOM, 2013a) and tend to decrease with depth (AECOM, 2012), indicating the uppermost part of the aquifer tends to transmit more water than the lower part. Two separate long-term, constant-discharge aquifer tests performed at the West Quarry yielded calculated transmissivities of 55 and 1.2×10^{-2} feet squared per day (ft^2/d) and a storage coefficient of about 4.0×10^{-5} (STS/AECOM, 2009; AECOM, 2013a). These tests indicate low permeability for the Silurian aquifer in the vicinity of the West Quarry and few substantial, interconnected secondary-permeability features in the aquifer within the tested area (above 475 ft NAVD 88). The presence of high-capacity wells CV#1, CV#2, CV#3, and CV#4 south of the Quarry (all of these wells are shown in figure 10 but water level was not measured in well CV#4), which are open to the Silurian aquifer below 475 ft, indicates that highly conductive secondary-permeability features may be present in the aquifer below 475 ft.

Water levels in the Silurian aquifer at the West Quarry were approximately 610 ft NAVD 88 prior to mining (STS/AECOM, 2009) and were likely about 575 ft near the East Quarry prior to mining. Because the bottoms of these quarries are dry at a minimum elevation of about 475 ft, pumping associated with quarry dewatering has reduced the water level in the Silurian aquifer by about 135 ft near the West Quarry and by about 100 ft near the East Quarry.

Periodic measurements (taken at no set interval and typically taken manually) of water levels in wells open to the Silurian aquifer at the Middle Parcel Expansion Area (MP-1S,D; MP-2S,D; MP-3D) from September 2005 through August 2008 and in July and November 2012 indicated a decrease in water levels from north to south, toward a cone of depression associated with dewatering of the Quarry (figs. 9, 10; STS/AECOM, 2008b, 2009). Note that use of the convention MP-1S,D or similar designations (MW-7A, B, C, D) in this report refers to clustered wells MP-1S and MP-1D, with "S" or "A" designating the shallowest well in the cluster and "D" designating the deepest. The direction of groundwater flow in the Silurian aquifer in the vicinity of the Quarry is toward the quarries and represents a diversion of the natural flow in the Silurian aquifer, which was to the wetlands and the Des Plaines River. The cone of depression appears to extend at least 1,000 ft into the southern part of the Middle Parcel Expansion Area and to the south of the West Quarry.

Water levels within the Silurian aquifer at the Middle Parcel Expansion Area are increasingly variable from north to south, with the difference between the measured high and low value ranging from about 7 ft at the MP-1S,D well cluster to more than 30 ft at well MP-3D (fig. 12; STS/AECOM, 2008b, 2009). This variation in water levels is attributed primarily to proximity to dewatering at the Middle Quarry and West Quarry. Comparison of water levels in the wells open to the Silurian aquifer at the Middle Parcel Expansion Area (fig. 12) with the elevation of the top of the dolomite at wells MP-1S,D (top of dolomite about 581 ft), wells MP-2S,D (top of dolomite 575 ft), and MP-3D (top of dolomite about 575 ft) indicates that water levels are occasionally to typically below the top of the Silurian aquifer. These data, and especially the low water level at well MP-3D, indicate that the Silurian aquifer does not discharge to the glacial drift aquifer or surface water during dry conditions. In addition, surface water and water in the glacial drift aquifer typically drains to the Silurian aquifer in at least part of the Middle Parcel Expansion Area, drying out the property.

Water levels in wells open to the Elwood Formation (elevation about 433–462 ft) at the southwest part of the West Quarry during July 2013 were less than 535 ft NAVD 88, whereas water levels in shallower wells tended to be above 550 ft (AECOM, 2013b). Low water levels in the Elwood Formation may indicate the deeper Silurian deposits function as part of the underlying confining unit (STS/AECOM, 2008a) and are diverting water in the deeper part of the Silurian aquifer to the underlying deposits. Alternatively, these deposits may be experiencing drawdown from pumping in wells CV#1, CV#2, CV#3, and CV#4 that is being transmitted through a deep fracture that is hypothesized to be below the base of the

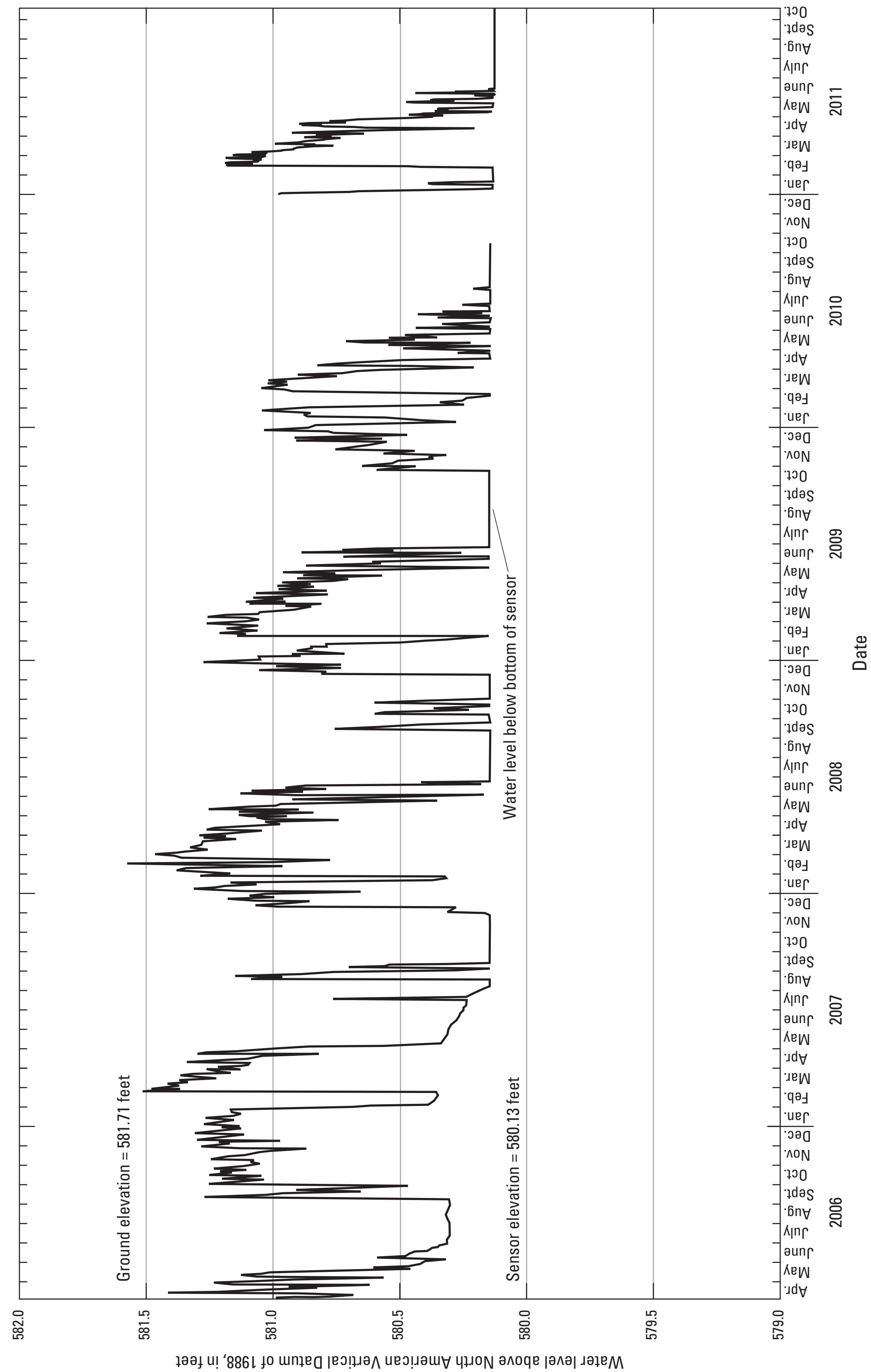


Figure 13. Hydrograph for well MP-W1, Middle Parcel Expansion Area, Will County, Illinois, April 2006 through October 2011 (modified from Applied Ecological Services, Inc., 2013).

West Quarry (AECOM, 2013b), indicating limited vertical hydraulic connection within the Silurian aquifer in this area.

Water levels measured in wells open to the shallow part of the Silurian aquifer north of the Middle Parcel Expansion Area and east of Route 53 in September 2013 decreased from about 592 ft in the western part of the parcel to about 580 ft in the east (AECOM, 2013b). This pattern is generally consistent with the potentiometric surface for the Silurian aquifer shown in figures 9 and 10 and likely indicates the effects of the large change in surface topography along the bluffs on groundwater levels.

Surface Water

The surface-water drainage system in the Middle Parcel Expansion Area consists of a northern and southern drainage (fig. 12). The northern drainage receives water from the Route 53 right-of-way and perhaps west of Route 53. The southern drainage appears to have historically received water from a watershed located west of Route 53, which is now largely occupied by the West Quarry. Currently (2018), the southern drainage receives runoff from the Route 53 right-of-way. Both drainages flow down the bluff before diverting toward the wetland in the center of the Middle Parcel Expansion Area. The drainages converge on the southeast side of the Middle Parcel Expansion Area and exit the parcel at streamgage MP-S2 (fig. 12).

Most of the Middle Parcel Expansion Area, including all portions with potential HED habitat, was described as being completely dry during HED surveys in the summer of 2009, even immediately after heavy rainfall (Mierzwa, 2009). Dryness throughout the Middle Parcel Expansion Area also was observed in the latter part of the summer of 2011 (Mierzwa and Webb, 2012c).

These observations were supported by continuous measurements of surface-water levels at streamgage MP-S1 from April 2006 through April 2009 and at streamgage MP-S2 from April 2006 through October 2011 (fig. 12; Applied Ecological Services, Inc., 2012, 2013). Streamgage MP-S1 monitors the northern surface-water drainage upstream of the wetland. Streamgage MP-S2 monitors the surface-water drainage as it exits the Middle Parcel Expansion Area.

Water was measured at streamgage MP-S1 from September 2006 through April 2007, January through May 2008, and February through March 2009, but typically was below the sensor for the rest of the monitoring period. Increases in water level of typically less than 1 ft were observed for several days following precipitation events before returning to “baseline” levels. These data indicate that surface-water inputs to the upgradient part of the Middle Parcel Expansion Area (primarily surface-water runoff and precipitation) typically are exceeded by losses (primarily evapotranspiration and discharge to groundwater) during the summer and fall, with inputs exceeding losses during the winter and spring.

Water was present at streamgage MP-S2 for most of the 2006–11 monitoring period, with the exception of August 2008, July–September 2009, and most of July–October 2010 and 2011. Baseline water levels were consistently lowest during the summer and highest during the winter and spring in response to annual cycles in snowmelt, precipitation, and evapotranspiration. Superimposed on these broad baseline trends were 1–3-ft increases in water level lasting several days that were associated with individual precipitation events. These data indicate the potential for surface-water flow from the Middle Parcel Expansion Area during most of the year, with dry conditions in the mid-summer through mid-fall.

Water Use

The Silurian aquifer is dewatered to keep water levels in the Quarry below the elevation of the excavations. Water is pumped from West and East Quarries to the Middle Quarry. Water from the Middle Quarry then goes to the processing plant, where it is used to support Quarry operations. Water from the processing plant is partly recirculated back to the Middle Quarry, with excess water being discharged to the Des Plaines River (AECOM, 2010).

An estimated 3,180 gal/min of water derived from groundwater (precipitation being the other major source of water in the discharge following a precipitation event) is pumped from the Quarry (AECOM, 2010). This pumping rate comes out to a total of about 4.6 million gallons per day (Mgal/d). About 1,200 gal/min of this groundwater is ultimately discharged to the Des Plaines River. Of the 3,180 gal/min taken from groundwater, about 500 gal/min is pumped from the West Quarry, about 2,080 gal/min is pumped from the East Quarry, and about 600 gal/min is pumped from the Middle Quarry. The high groundwater input to the East Quarry is attributed to the need to remove large amounts of recharge from the Des Plaines River and CSSC to the Silurian aquifer at the East Quarry.

High-capacity pumping from the Silurian aquifer takes place south of the West Quarry at wells CV#1, CV#2, CV#3, and CV#4. The pumping rate and volume of discharge from these wells is not known. These wells supply 188 homes. Assuming per capita water use of about 80 gallons per day (gal/d; U.S. Geological Survey, 2016b) and an average household population of 2.8 for Lockport (U.S. Census Bureau, 2017), these wells combine to pump about 42,100 gal/d. Although not inconsequential, withdrawals from these high-capacity wells are less than 1 percent of the withdrawals from the Quarry.

Effects of Quarry Dewatering and Pumping Mitigation

A groundwater flow model was developed by STS/AECOM in 2009 and used to assess the effects of groundwater withdrawals from the Silurian aquifer associated with the expansion of quarry operations at the West and Middle Quarries as well as assessing the effects of mitigation features designed to offset the effects of these withdrawals. The 2009 groundwater flow model was substantially refined in response to peer-review comments (Daniel Feinstein and Douglas Yeskis, U.S. Geological Survey, written commun., 2011) and the collection of additional data; therefore, this discussion focuses exclusively on simulations done with the 2012 and 2013 revisions of the model (AECOM, 2012, 2013a). The model uses MODFLOW (McDonald and Harbaugh, 1984; Harbaugh and McDonald, 1996a,b; Harbaugh and others, 2000) to run flow simulations and MODPATH (Pollock, 1998) to identify capture zones associated with pumping from the quarries and the groundwater recharge area for the Silurian aquifer to the Quarry, River South Parcel, and the Lockport Prairie Nature Preserve. The model grid has 261 rows, 277 columns, and 14 layers to encompass an area of 191 square miles (mi^2). Cell dimensions range from 100 to 1,200 square feet (ft^2). The model was calibrated to groundwater levels collected in the vicinity of the Quarry from 2004 through 2006 and to the rate of flow to the Quarry and the Des Plaines River. In the model the Silurian aquifer is assumed to function as an equivalent porous medium. Sensitivity, the evaluation of the degree to which changes in input parameters affect output values in the model, was analyzed.

A review of the 2009 groundwater flow model (Daniel Feinstein and Douglas Yeskis, U.S. Geological Survey, written commun., 2011) and review and verification of the 2012 and 2013 versions of the model was performed by the USGS and provided to USFWS (Daniel Feinstein and Andrew Leaf, U.S. Geological Survey, written commun., 2013, 2014). These reviews concluded that the 2013 version of the model was likely to adequately simulate large-scale aspects of the flow system, such as volumes of groundwater discharge to the wetlands; however, the review suggested that the model scale was too large to optimally simulate the local conditions in the Silurian aquifer that could potentially affect the performance of the mitigation features installed to offset the effects of the additional pumping in the West Quarry Expansion Area, particularly when accounting for seasonal changes in conditions. Pilot-scale testing of the mitigation features and intensive groundwater monitoring were recommended to more accurately identify potential issues and to assess the effectiveness of the mitigation features. Modeling results as they pertain to the River South Parcel and the Lockport Prairie Nature Preserve will be discussed in the sections assessing conditions at those sites.

Groundwater modeling performed by AECOM (2012, 2013a) indicates that dewatering associated with the 2012 operations at the West Quarry produces a capture zone in the Silurian aquifer that encompasses most of the natural groundwater recharge area for the River South Parcel and is within about a quarter of a mile of the groundwater recharge area for the Lockport Prairie Nature Preserve (fig. 11). The overlap of the capture zone for the Quarry with the groundwater recharge area of the Silurian aquifer to the River South Parcel indicates that some of the groundwater that would flow to the River South Parcel under natural conditions is being diverted to the West Quarry.

Model simulations indicate increased groundwater withdrawals from the Silurian aquifer associated with mining the West Quarry Expansion Area will expand the capture zone to the south and west of its 2012 location, further into the recharge area for the River South Parcel (fig. 11) and will induce about 1 ft of drawdown within the recharge area for the Lockport Prairie Nature Preserve. The effects of mining in the West Quarry will dissipate after mining operations cease and the West Quarry fills with water, which is projected to be complete approximately 14 years after mining of the West Quarry Expansion Area begins (AECOM, 2013a). Simulations of increased dewatering in support of mining the Middle Parcel Expansion Area and remnant areas of the East Quarry (most of this mining will be done after the West Quarry has filled with water) indicate the capture zone for the Middle and East Quarries will expand to the north and slightly to the west but will have no additional effect on hydraulic conditions at the River South Parcel or at the Romeoville Prairie Nature Preserve north of the quarry (fig. 10; AECOM, 2013a). The eastern extent of the capture zone for the quarries is modeled as corresponding to the East Quarry because of the presumed hydraulic effects of the groundwater divide in the Silurian aquifer beneath the CSSC (fig. 9).

Infiltration galleries will be installed prior to expansion of Quarry operations immediately west of the River South Parcel and an infiltration pond will be installed southwest of the intersection of Renwick Road and Route 53 north of the Lockport Prairie Nature Preserve (fig. 1). These features are expected to add sufficient water to the Silurian aquifer to offset the volume of water diverted from the River South Parcel and the Lockport Prairie Nature Preserve due to increased pumping from the West Quarry Expansion Area (AECOM, 2013a). Mitigation efforts should be able to effectively replicate seasonal variations in groundwater discharge into the River South Parcel and Lockport Prairie Nature Preserve. Failure to do so may alter their suitability as HED habitat. As part of the effort to ensure mitigation is effective, and to verify the absence of impacts from operations at the West Quarry Expansion Area, surface-water and groundwater levels will be measured by the Quarry operators on an ongoing basis as described by Hanson Material Service Corporation (2016). These measurements will be analyzed to verify that water levels, adjusted for seasonal variation and background trends, are within historical ranges. Adult and larvae HED populations also will be monitored on an ongoing basis. If water levels become too low or too high, the flow to the infiltration galleries or the level of the infiltration pond will be adjusted to optimize the HED habitat (Hanson Material Service Corporation, 2016). If declining water levels are identified in the Silurian aquifer at the Romeoville Prairie Nature Preserve, an infiltration pond will be installed north of the Middle Quarry to offset the drop in water level. Additional adaptive management strategies to offset pumping effects will be developed by the Quarry operators, if necessary.

Water Quality

The U.S. Environmental Protection Agency (EPA) has established standards for the maximum concentration of a constituent in drinking water supplied by a public-water system as well as for aquatic life (U.S. Environmental Protection Agency, 2015, 2016a,b). These standards are provided in table 3 as a means of assessing whether water samples collected from the HED habitats pose a threat to human health or aquatic life. The EPA criteria for total phosphorus in flowing water is 0.1 milligram per liter (mg/L) and is considered an applicable criteria for the surface water analyzed for this report.

In this report, concentrations reported as less than (<) a value indicate the analyte was not detected at the detection limit of the analysis. For example, arsenic (<0.01 mg/L) means that arsenic was not detected in the sample at a detection limit of 0.01 mg/L.

Surface-water samples were collected from the northern drainage in the wetland of the Middle Parcel Expansion Area during August 30, September 29, and November 20, 1995 (TAMS Consultants, Inc., 1995a) and analyzed for a variety of major ions, metals, and organic compounds. Alkalinity values ranged from 284 to 484 mg/L as calcium carbonate ($CaCO_3$). Concentrations of iron (0.2–15 mg/L), phosphorus (<0.05–0.5 mg/L) and manganese (0.02–0.99 mg/L) exceeded regulatory criteria in at least one sample (table 3). Concentrations of the remaining analytes, including several metals, mercury, nitrogen compounds, and pesticides were either not detected (often at a detection limit above regulatory criteria) or were detected at concentrations below regulatory criteria.

Groundwater samples collected in 1996 from six private wells assumed to be open to the Silurian aquifer along the perimeter of the West Quarry were analyzed (STS/AECOM, 2009). Calcium (68–120 mg/L) and magnesium (44–67 mg/L) were the cations present at highest concentrations. Alkalinity was measured at concentrations of 285–355 mg/L as $CaCO_3$. At the near-neutral pH of these waters, alkalinity is likely to consist mostly of bicarbonate (HCO_3^-), indicating that bicarbonate was the anion present at highest concentration in the samples. Chloride concentrations ranged from 21 to 113 mg/L, which exceeds the probable concentration of chloride derived from natural sources (<20 mg/L) in near-surface deposits in the Chicago area (Kelly and Wilson, 2008). Nitrate concentrations exceeded the maximum contaminant level (MCL) of 10 mg/L as nitrogen in one well (10.1 mg/L) northwest of the West Quarry. Analyses for pesticides, herbicides, volatile organic compounds, and polycyclic aromatic hydrocarbons detected only toluene (a component of gasoline) in two wells at concentrations of 16 and 24 micrograms per liter (µg/L), which is below the most stringent regulatory criteria (table 3).

Surface-water samples were collected from streamgages MP-S1 and MP-S2 and groundwater samples were collected from the alluvial aquifer at wells MP-W1 and MP-W2 during April, July, and October 2006 and 2007 at the Middle Parcel Expansion Area (fig. 12; Applied Ecological Services, Inc., 2012). Calcium typically was the dominant cation in all water. Sulfate was the dominant anion in surface water (table 4). Bicarbonate was the dominant anion in groundwater based on the alkalinity values. Chloride concentrations were highest during the April 2006 sampling event at each site, likely reflecting the presence of runoff affected by road salt.

Water quality in the Quarry area (excepting the 2006 and 2007 samples from streamgages MP-S1 and MP-S2) is dominated by calcium, magnesium, and bicarbonate, which reflects the interaction with dolomite for much of this water. Concentrations of major ions (calcium, magnesium, sodium, chloride, sulfate, and bicarbonate) in surface water at streamgages MP-S1 and MP-S2 typically were higher than in groundwater from the alluvial aquifer during 2006 and 2007, indicating some hydraulic separation between these water bodies. At least one sample of surface water or groundwater exceeded regulatory criteria for chloride, iron, phosphorus, and ammonia (assuming all of the total Kjeldahl nitrogen is ammonia). The data also indicate that leaking septic systems may yield elevated concentrations of nitrate; leaking gasoline storage tanks may yield detectable concentrations of toluene; and the application of road salts produces elevated concentrations of chloride, especially during spring.

Assessment of Water Resources at the River South Parcel

The River South Parcel is located south of the Quarry, west of the Des Plaines River, east of Route 53, north of Route 7, and south of about Airport Road in Romeoville, Ill. (figs. 1, 14). The 110.1-acre parcel is about 1 mi long; a maximum of 1,000 ft wide; and includes extensive sedge meadow, marsh, and scattered flood-plain forest communities. Smaller areas of dolomite prairie, pond, successional field, and shrub thicket also are present. There is no water use by humans at the River South Parcel.

Topography

Surface topography at the River South Parcel ranges from about 577 ft NAVD 88 in the northern part of the parcel to about 570 ft in the southern edge and increases from about 574 ft NAVD 88 near the Des Plaines River to about 578–584 ft at the base of the bluff in the western part of the parcel (figs. 4, 14). The berm for the railroad track near the western edge of the River South Parcel and the road bank in the center of the parcel are approximately 1–3 ft above the surrounding land surface. Land-surface elevation at the top of the bluff (west of the area showing topography in fig. 14) is about 605 ft at the RP-1 well cluster.

Biology

There is documented larval use of HED along several rivulets in the River South Parcel, with the greatest

Table 3. Selected water-quality criteria (U.S. Environmental Protection Agency, 2015, 2016a,b).

[EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; mg/L, milligram per liter; µg/L, microgram per liter]

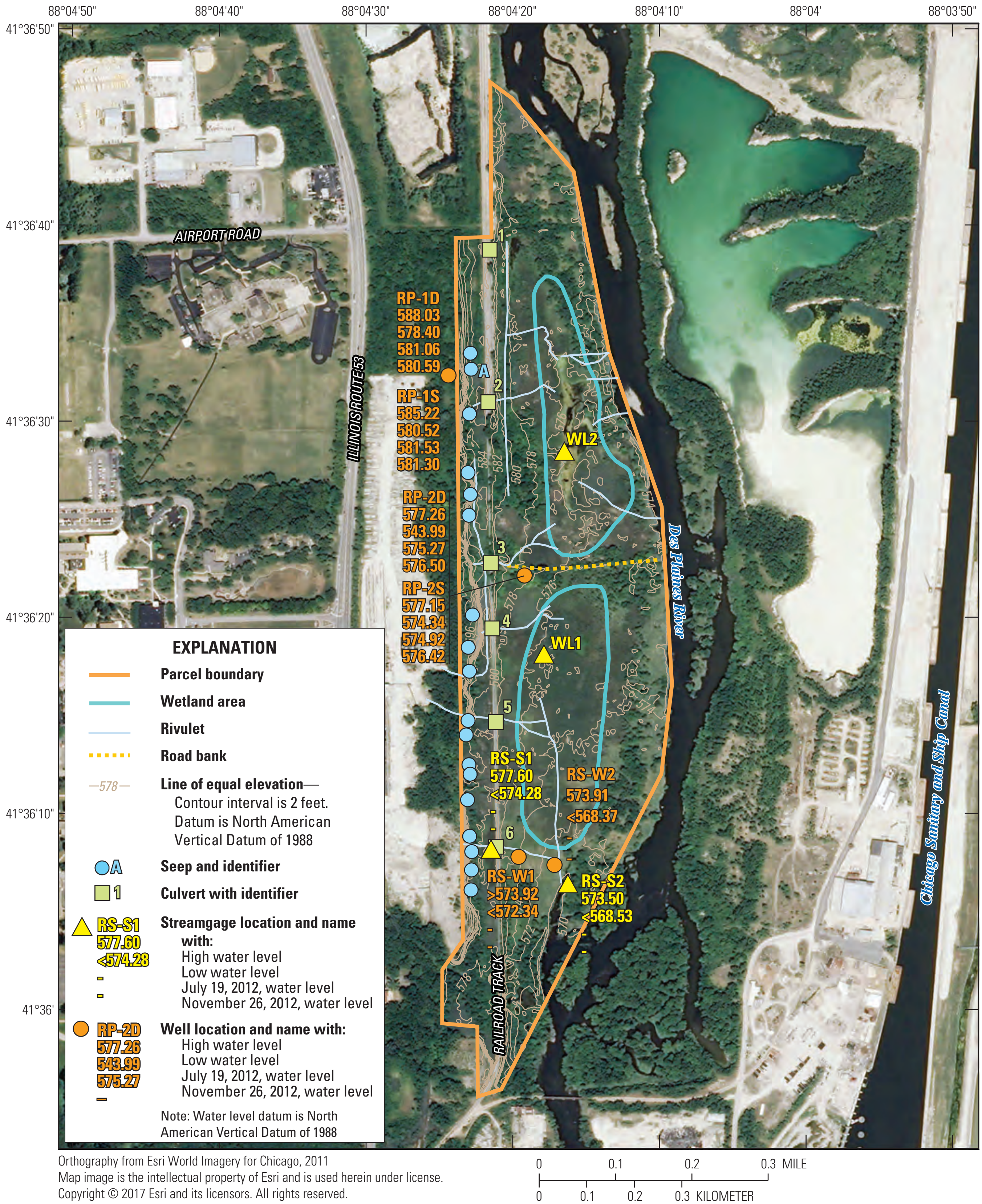
Constituent and units	EPA MCL	EPA aquatic life acute threshold	EPA aquatic life chronic threshold
Aluminum (µg/L)	None	750	87
Ammonia as nitrogen (mg/L)	None	17[a]	1.9[a]
Arsenic (µg/L)	10	340	150
Barium (µg/L)	2,000	2,000	220
Boron (µg/L)	None	34,000	7,200
Cadmium (µg/L)	5	1.8	0.72
Chloride (mg/L)	None	860	230
Chromium (total) (µg/L)	100	570	74
Cobalt (µg/L)	None	None	None.
Copper (µg/L)	1,300	13	9
Dissolved oxygen (mg/L)	None	3.0	None.
Fecal coliform (colonies per 100 milliliters)	0 (goal)	None	None.
Fluoride (mg/L)	4	1,400	None.
Iron (mg/L)	None	None	1
Lead (µg/L)	0 goal	65	2.5
Lithium (µg/L)	None	910	440
Manganese (µg/L)	None	1,680	93
Mercury (µg/L)	2	1.4	0.77
Nickel (µg/L)	None	470	52
Nitrate and nitrite, as nitrogen (mg/L)	10	None	None.
Phosphorus (mg/L)	None	None	1 (elemental)
Potassium (mg/L)	None	None	53
Strontium (µg/L)	None	48,000	5,300
Suspended solids (mg/L)	None	Calculated	Calculated.
Zinc (µg/L)	None	120	120
Alachlor (µg/L)	2	None	None.
Atrazine (µg/L)	3	330	12
Cyanazine (µg/L)	None	2,420	270
Metolachlor (µg/L)	None	110	15
Simazine (µg/L)	4	80	9
Toluene (µg/L)	1,000	560	62
Benzene (µg/L)	5	700	160

[a]Assumed pH is 7.0 and temperature is 20 degrees Celsius.

Table 4. Concentration of major ions, nutrients, and metals in surface water and groundwater at the Quarry Middle Parcel, Will County, Illinois, April 2006 through October 2007 (from Applied Ecological Services, Inc., 2012).

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Total Kjeldahl nitrogen, in mg/L
Streamgage MP-S1 (location shown in fig. 12)										
04/18/06	232	<5	**420**	242	68	178	<0.011	2	<0.02	1.09
07/19/06	226	830	160	279	79	72	0.62	<0.05	0.024	0.40
10/19/06	256	470	180	201	66	148	<0.11	0.55	<0.02	<0.12
04/30/07	146	380	**280**	181	64	160	0.015	0.73	<0.02	0.73
07/25/07	--	--	--	--	--	--	--	--	--	--
10/24/07	--	--	--	--	--	--	--	--	--	--
Streamgage MP-S2 (location shown in fig. 12)										
04/18/06	203	<5	**280**	357	85	80	0.06	0.23	<0.02	0.78
07/19/06	--	--	--	--	--	--	--	--	--	--
10/19/06	236	410	97	186	57	62	0.34	0.13	<0.02	<0.12
04/30/07	128	460	99	280	56	61	0.19	0.15	<0.02	**2.8**
07/25/07	303	240	160	157	60	51	**1.6**	0.78	0.02	1.4
10/24/07	356	370	220	321	80	80	0.61	0.53	<0.02	<0.02
Well MP-W1 (location shown in fig. 12)										
04/18/06	221	130	67	159	67	37	**3.33**	3.5	**0.15**	--
07/19/06	--	--	--	--	--	--	--	--	--	--
10/19/06	254	100	30	148	60	29	0.61	<0.05	<0.02	<0.12
04/30/07	129	100	36	86	32	22	0.24	0.16	<0.02	1.4
07/25/07	--	--	--	--	--	--	--	--	--	--
10/24/07	--	--	--	--	--	--	--	--	--	--
Well MP-W2 (location shown in fig. 12)										
04/18/06	244	113	85	77	29	37	0.44	0.12	0.05	--
07/19/06	--	--	--	--	--	--	--	--	--	--
10/19/06	236	82	24	83	31	24	**1.1**	<0.05	<0.02	<0.02
04/30/07	167	31	19	77	25	22	**1.0**	0.24	**0.41**	**2.6**
07/25/07	--	--	--	--	--	--	--	--	--	--
10/24/07	--	--	--	--	--	--	--	--	--	--



Orthography from Esri World Imagery for Chicago, 2011
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Figure 14. Location of selected features and water-level data at the River South Parcel, Will County, Illinois.

populations at the rivulets south of the road (figs. 2, 14; Soluk, 2006). Larvae were absent at the rivulet near wells RS-W1 and RS-W2. Adult HED use has been documented near the rivulets peripheral to the wetland south of the road and near culvert 1 at the northern edge of the River South Parcel (Mierzwa, 2007, 2009; Mierzwa and Webb, 2012a,c). Adult HED activities at the River South Parcel consist of perching, feeding, territorial patrols, and breeding (Cashatt and Vogt, 1996). The total number of adult HED at the River South Parcel typically was estimated to be in the 100–310 range from 1995 to 2002 but has been less than 75 since 2002 and was 36, 13, 71, and 71 in 2009, 2010, 2011, and 2012, respectively (Mierzwa, 2009; Mierzwa and Webb, 2012a,c). The reduction in population appears to be at least partly due to the effects of the 2005 drought. The River South Parcel contains the second most productive breeding habitat in Illinois, housing approximately 40 percent of the larval HED population and 34 percent of the adult HED population in the Lower Des Plaines River Valley (Soluk and Mierzwa 2012).

Hydrogeology

The geologic deposits of concern at the River South Parcel consist of the Silurian dolomite and the overlying unconsolidated deposits. The Silurian dolomite deposits constitute the Silurian aquifer. Alluvial deposits in the river valley constitute the alluvial aquifer where saturated.

Alluvial Aquifer

Alluvial deposits consist mostly of sand and silt, are less than 4 ft thick at the River South Parcel, and are capped by hydric soils in wetland areas. Continuous measurements of groundwater levels at wells RS-W1 and RS-W2 were collected from April 2006 through December 2012 and from April 2006 through October 2009, respectively (Applied Ecological Services, Inc., 2012, 2013). These wells are located in the southern part of the wetland south of the road bank (fig. 14) and are open to the alluvial aquifer. Water levels in well RS-W1 indicated seasonal trends that were typically within about 0.5 ft of land surface (land-surface elevation 573.9 ft) during the winter and spring and below the sensor (elevation less than 572.3 ft) during parts of the summer and early fall, with the longest dry period occurring during the drought of 2012. Water levels in well RS-W1 frequently rose and fell by as much as 2.5 ft following precipitation (and Des Plaines River flood) events, occasionally exceeding the elevation of the land surface. Water levels in well RS-W2 typically were within 1 ft of land surface (land-surface elevation 570.9 ft) from April 2006 through September 2007. Water levels in the well typically were below the sensor (568.4 ft) during a period of low precipitation from October 2007 through September 2008, rose to land surface by April 2009, and were above land surface for most of April through October 2009. Water levels frequently rose and fell by as much as 4 ft for several days following precipitation events, often exceeding land surface. Water-level increases of this magnitude and water levels above land surface likely are related to flooding of the Des Plaines River. The 2012 drought lowered water levels in the alluvial aquifer by about 1.7 ft, further indicating that extreme events can result in small, but important, changes in the hydrology of the River South Parcel.

Water levels in the alluvial aquifer in the southern part of the River South Parcel varied seasonally in response to precipitation, recharge, and evapotranspiration. Longer-term trends in response to drought also were observed. Large, short-term increases in water level indicate hydraulic interaction with the Des Plaines River during flooding in the southern part of the River South Parcel, which may explain the absence of HED larvae in this area.

Silurian Aquifer

The Silurian aquifer at the River South Parcel has a horizontal hydraulic conductivity ranging from 1.1×10^{-2} to 4.2×10^{1} ft/d, with the geometric mean for the shallow part of the aquifer (elevation greater than 560 ft NAVD 88) being 9.8×10^{-1} ft/d and the value for the deep part (elevation about 480–530 ft) being 6.8×10^{-2} ft/d (STS/AECOM, 2009; AECOM, 2013b). These values indicate the shallow, more weathered part of the Silurian aquifer has moderate aquifer permeability and will transmit more water than the deeper, less permeable part of the aquifer. About 5 ft of dolomite deposits are exposed along the bluff in the western part of the River South Parcel (AECOM, 2015a).

Measurements of groundwater levels in the Silurian aquifer from September 2005 through June 2015 indicate groundwater flow in the River South Parcel is from west to east, toward the Des Plaines River, possibly with intermittent components of flow north toward the Middle Quarry (STS/AECOM, 2009; AECOM, 2013b). Water levels in the Silurian aquifer in the upland area west of the bluff varied from about 580 to 592 ft NAVD 88 at well RP-1S and about 578 to 592 ft at well RP-1D (figs. 14, 15). Water levels in these wells show changes of about 10 ft in response to precipitation events (AECOM, 2013a, 2015a). Water levels showed substantially less variation at the RP-2S,D well cluster in the Des Plaines River Valley, with water levels typically about 575–577 ft. Water levels at wells RP-2S and RP-2D showed less variation than water levels in the alluvial aquifer and the Des Plaines River. These data, combined with upward hydraulic gradients at the well cluster, indicate stable discharge from the Silurian aquifer to the wetlands.

Water levels at the RP-2S,D well cluster typically were above the elevation of the top of the Silurian dolomite (about 575.2 ft), indicating the potential for the Silurian aquifer to discharge to the overlying alluvial aquifer and at least some of the wetlands in the valley. Water levels in wells RP-2S and RP-2D were about 2–3 ft lower than typical during the droughts of 2005 and 2012 and showed 1–2-ft drops during the summers of 2008, 2009, and 2013. Water levels were at or below the top of the Silurian aquifer during the droughts

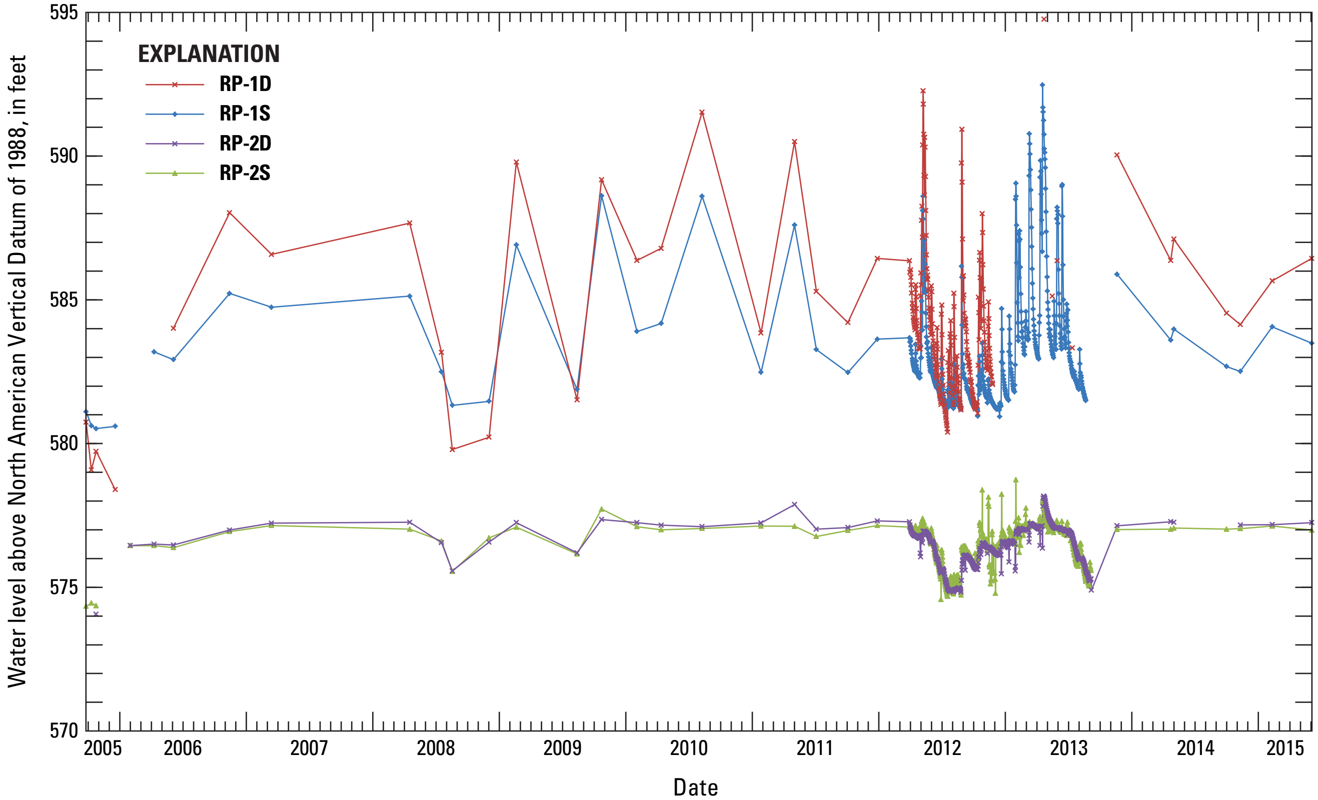


Figure 15. Water levels in wells RP-1S,D and RP-2S,D at the River South Parcel, Will County, Illinois, 2005 through 2015.

of 2005 and 2012 and the summer of 2013, indicating the absence of discharge from the Silurian aquifer to the alluvial aquifer and wetlands in at least part of the valley at the River South Parcel during these times.

Water levels at the RP-1S,D well cluster indicate that flow within the Silurian aquifer at the bluffs is upward toward the seeps during typical conditions (fig. 15). Water levels indicate the potential for flow in the Silurian aquifer from the bluffs to the wetlands in the river valley during drier conditions when seep flow is minimal (AECOM, 2013a).

Water-level data indicate that precipitation rapidly recharges the Silurian aquifer and discharges to the seeps in the bluff area. Flow conditions in the aquifer in the valley area are more stable, but small reductions in water level in the valley are associated with drought conditions that are harmful to the HED.

Surface Water

Surface-water flow at the River South Parcel begins as discharge (average of about 7,700 cubic feet per day [ft^3/d]) from several seeps emanating from the dolomite deposits exposed along the bluffs in the western part of the River South Parcel (fig. 14; Christopher B. Burke Engineering, Ltd., 1997; AECOM, 2013a, 2015a). There are too few measurements to establish a stage-discharge relationship and the discharge rate at the individual seeps has not been quantified; however, the discharge rate from the seeps increases as groundwater levels at the bluff increase (AECOM, 2015a). Water from the seeps pools west of the railroad bed and enters the eastern part of the River South Parcel by way of culverts, at least three of which discharge directly to rivulets that flow to the wetlands north and south of the road bank (fig. 14). Measurements of discharge in the rivulet emanating from culvert 5 during August, September, and November 1995 were 4,750; 4,320; and 6,912 ft^3/d, respectively (TAMS Consultants, Inc., 1995b). Discharge was not detected in the rivulet emanating from culvert 4 during the September measurement. Pooling water behind the berms and diversion of water to the culverts represent a disruption from the natural surface-water hydrology of this area, adding water to some areas and diverting it from others. The effect of this diversion on the HED is unknown but may have detrimental effects not only in areas where water loss has dried the habitat, but also in areas (such as downstream of culverts) where the concentration of surface flow has increased water inputs, stream velocity, and erosion.

The wetland north of the road bank contains a small area of open water that has a maximum depth of 1–2 ft (STS/AECOM, 2009). The wetland south of the road bank has no open water and typically has a depth of less than 1 ft. These areas are surrounded by shallower, more discontinuous wetlands. Water flows through rivulets from the wetlands to the Des Plaines River.

Water levels in the deepest part of the wetland north of the road bank were continuously monitored at streamgage WL2 (fig. 14) from October 2005 through March 2007 and from December 2007 through July 2008 (STS/AECOM, 2009). Water levels rose from about 573.2 ft NAVD 88 during late October 2005 to about 575.8 ft by March 2006 and remained at that approximate level for the remainder of the monitoring period. This trend in water levels is attributed to the effects of increased precipitation following the end of the 2005 drought.

Water levels at the wetland south of the road bank were continuously monitored at streamgage WL1 from March 2006 through February 2007 (STS/AECOM, 2009). The stage at streamgage WL1 was consistently about 574.5 ft NAVD 88 with only minor deviations. Water levels typically showed less than 1 ft increases associated with individual precipitation events but may have begun to increase by several inches near the end of the monitoring period in response to precipitation or snowmelt events.

Water levels were continuously monitored at streamgage RS-S1 for most of the period from April 2006 through November 2012 (Applied Ecological Services, Inc., 2012, 2013). Streamgage RS-S1 is located at a culvert and monitors a ponded area between the bluffs and the railroad tracks in the southern part of the River South Parcel (fig. 14). This area received water from seeps, producing baseline water levels of about 576 ft NAVD 88 that typically varied seasonally by less than about 0.5 ft. Superimposed on these baseline levels were short-term (few days) increases of as much as 1.5 ft associated with overland runoff of precipitation from the watershed west of the River South Parcel (STS/AECOM, 2009). Water levels at the streamgage typically were above the elevation of the base of the culvert, indicating that there was flow to the wetlands. Water levels decreased by about 1.7 ft (elevation about 574.3 ft NAVD 88) and the culvert was dry during drought conditions in July and August 2012.

Water levels were continuously monitored at streamgage RS-S2 for most of the period from April 2006 through November 2012 (Applied Ecological Services, Inc., 2012, 2013). Streamgage RS-S2 monitors a wetland area in the southern part of the River South Parcel adjacent to the Des Plaines River (fig. 14). Water was present at a base elevation of about 569 ft NAVD 88 for almost the entire monitoring period, indicating consistent discharge from the wetland south of the road bank to the river. Water level dropped below the elevation of the sensor (568.5 ft) in response to the 2012 drought. Water levels at this streamgage frequently showed as much as 4 ft increases associated with precipitation events followed by a gradual (several days) decline to base level, indicating intermittent flow of water from the Des Plaines River to the wetland when the river stage is high.

Surface-water levels tended to show minimal variation in those parts of the River South Parcel not near the Des Plaines River except during drought periods and following precipitation events. These data indicate the monitored surface-water features at the River South Parcel have consistent amounts of inflow and outflow except during drought. Changes in water level during droughts were small on an absolute scale, less than 3 ft, but appear to have resulted in substantial drying of the HED habitat at the River South Parcel. The effects of at least some of the droughts appear to have resulted in a substantial reduction in the HED population (Soluk and Mierzwa, 2012).

Effects of Quarry Dewatering and Pumping Mitigation

The 2012 and 2013 versions of the groundwater flow model developed on behalf of the Quarry operators (AECOM, 2012, 2013b) were used to assess (1) the effects of the 2012 withdrawals from the Silurian aquifer associated with operation of the West Quarry and the combined East and Middle Quarries, (2) the effects of future withdrawals associated with dewatering of the West Quarry and Middle Parcel Expansion Areas on the aquifer, and (3) the effects of the proposed infiltration galleries at the River South Parcel.

The natural groundwater recharge area for the Silurian aquifer to the River South Parcel appears to have extended about 2 mi to the west-northwest of the parcel (fig. 11) based on water-level measurements collected by Roadcap and others (1993). Much of the natural groundwater recharge area is within the modeled 2012 capture zone for the pumping at the West Quarry and much of the River South Parcel itself is within the capture zone for the Middle and East Quarries.

Groundwater modeling indicates that additional pumping from the Silurian aquifer associated with dewatering of the West Quarry Expansion area will induce more than 1 ft of water-level decrease (drawdown) in the aquifer beneath the River South Parcel as well as in the River South Parcel groundwater recharge area (AECOM, 2013a). One foot of drawdown is at the lower range of decrease in water levels measured during the drought of 2005, which adversely affected the HED population. Additional pumping at the West Quarry Expansion Area will reduce the saturated thickness of the Silurian aquifer at the River South Parcel seeps and reduce the differential hydraulic pressure driving groundwater discharge from the aquifer to the wetlands in the Des Plaines River Valley.

Model simulations indicate that increased pumping associated with mining the West Quarry Expansion Area will expand the capture zone of the West Quarry to the southwest, diverting water that would have gone to the River South Parcel under 2012 conditions to the West Quarry (compare recharge area for River South Parcel with captures zones for West Quarry in figs. 11 and 16). Increased pumping will reduce the volume of groundwater discharge from the Silurian aquifer to the River South Parcel from about 4,200 ft^3/d at the start of mining to about 3,000 ft^3/d when mining is completed (AECOM, 2013b), a reduction of about 30 percent. The

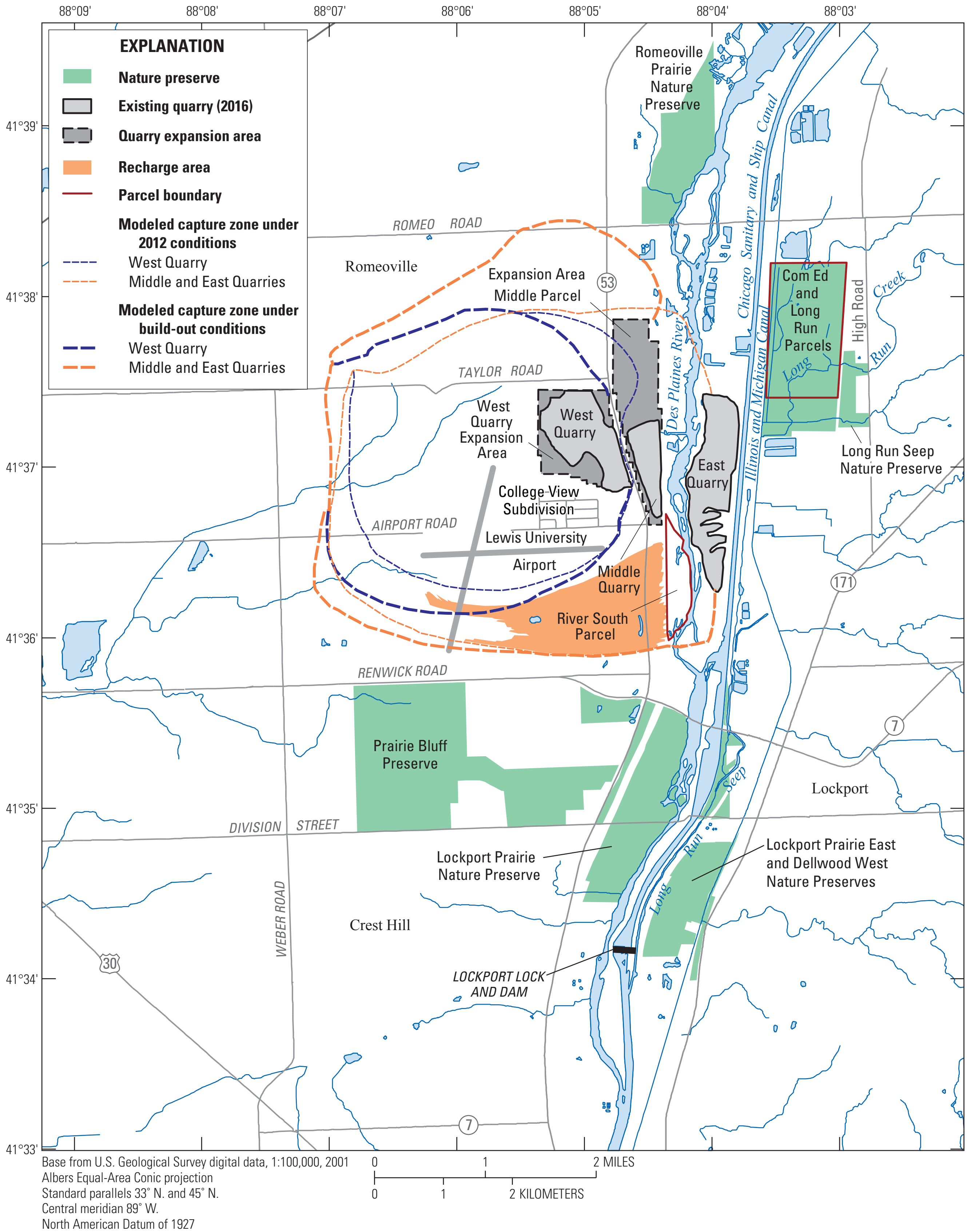


Figure 16. Groundwater capture zones under 2012 and full build-out conditions (excluding mitigation features) at the West, East, and Middle Quarries and groundwater recharge area for the Silurian aquifer to the River South Parcel, Will County, Illinois.

reduction in discharge within the River South Parcel is not apportioned between the northern and southern parts of the River South Parcel but is expected to be higher in the northern part of the parcel than in the southern (AECOM, 2012) due to proximity to the Quarry. These effects will dissipate after the West Quarry Expansion Area has been fully mined and fills with water.

To offset the loss of flow from the Silurian aquifer to the River South Parcel due to increased pumping at the West Quarry Expansion Area, a series of infiltration galleries will be installed on top of the bluffs immediately west of the parcel (AECOM, 2013a; Hanson Material Service Corporation, 2016). The infiltration galleries will use water from the Quarry to recharge the Silurian aquifer, thereby increasing flow to the seeps and the River South Parcel. The infiltration galleries will be operated until the West Quarry refills with water. Model simulations and pilot testing of the infiltration galleries (AECOM, 2015b) indicate the infiltration galleries will be capable of providing more than 6,400 ft^3/d of recharge to the Silurian aquifer. This volume of water is expected to be sufficient to offset the reduction in groundwater discharge to the River South Parcel caused by dewatering of the West Quarry Expansion Area. Surface- and groundwater-level monitoring will be performed by the Quarry operators at a variety of locations and at a variety of time scales (20 minutes to quarterly) to ensure that seasonally adjusted water levels in the vicinity of the River South Parcel remain within historical values. If water levels decline below trigger levels, operation of the infiltration galleries will be adjusted to offset pumping effects.

Water Quality

Several surface-water and groundwater sampling efforts have been performed at the River South Parcel from 1994 through 2014 (TAMS Consultants Inc., 1995a,b; Christopher B. Burke Engineering, Ltd., 1997; STS/AECOM, 2009; Applied Ecological Services, Inc., 2012; AECOM, 2015b). These data indicate that calcium typically was the dominant cation and bicarbonate (measured as alkalinity) was the dominant anion in surface water and groundwater at the River South Parcel (table 5). Chloride concentrations typically were high enough to indicate the presence of effects from road salt application, particularly in surface water and particularly during the spring. The reduction in sulfate concentrations at well RS-W2 during the summer of 2006 and during 2007 may reflect the presence of sulfate-reducing conditions in the alluvial aquifer during that time.

The surface-water temperature was below air temperature at the time of sampling (table 5), indicating that surface-water temperature may have been affected by the temperature of the groundwater source of this water. The pH ranged from 6.9 to 7.8. Nitrate concentrations in surface water in the southern part of the River South Parcel near culverts 5 and 6 often exceeded 3 mg/L. Concentrations of nitrate derived from natural sources are generally considered to be below 3 mg/L (Madison and Brunett, 1985) or less (Nolan and Hitt, 2003; Mueller and Helsel, 1996), indicating the potential effects of fertilizer application within the recharge area of the River South Parcel.

Concentrations of phosphorus, chloride, ammonia (as total Kjehldahl nitrogen), and iron exceeded regulatory criteria in at least one sample (table 5). Concentrations of several dissolved metals, polycyclic aromatic hydrocarbons, and pesticides were either not detected, or detected at concentrations below regulatory criteria.

Water samples also were collected from wells RP-8S-West, RP-10S, RP-8S-East, and RP-9S-South; the seep near culvert 2; and from the Middle Quarry during pilot testing of one of the proposed infiltration galleries on November 10 and 14, 2014 (table 5). The wells are not shown on a map but are open to the Silurian aquifer at the bluffs west of the seep near culvert 2 (fig. 14; AECOM, 2015b). Major-ion chemistry of the quarry sample was similar to that of the Silurian aquifer at the wells. Because water from the quarry is likely to be the source of the water in the infiltration galleries, these data indicate that the water from the infiltration galleries will not substantially alter the chemistry of the water in the Silurian aquifer or the wetlands. To further assess the effects of the infiltration water on aquifer chemistry during the pilot testing, the water in the infiltration gallery was heated to about 30 °C. Continuous monitoring of water temperature in the Silurian aquifer at a well and a seep downgradient of the infiltration gallery were 13.1 and 12.5–13.7 °C, respectively (AECOM, 2015b). Temperatures showed no change that could be attributed to the presence of the heated water, indicating that ambient conditions in the aquifer will rapidly modify the temperature of the infiltration water to near that of the aquifer.

Assessment of Water Resources at the Lockport Prairie Nature Preserve

The Lockport Prairie Nature Preserve is a 222-acre tract located west of the Des Plaines River in Will County, Ill. (figs. 1, 17). The Lockport Prairie East Nature Preserve, located east of the CSSC, is not included in this discussion. The Lockport Prairie Nature Preserve is owned by the Forest Preserve District of Will County, as is the adjacent Prairie Bluff Preserve. The Prairie Bluff Preserve is used to help maintain the natural hydrology of the Lockport Prairie Nature Preserve.

Because of the important role groundwater plays on the ecology of the Lockport Prairie Nature Preserve, there has been concern over the effects of urbanization and groundwater withdrawals in the vicinity of the Lockport Prairie Nature Preserve on its hydrology. Increased groundwater withdrawals within and near the groundwater recharge area for the Lockport Prairie Nature Preserve may reduce the volume of groundwater discharge to the preserve by removing water from the Silurian aquifer that would otherwise flow to the preserve. Increased urbanization within the recharge area has

Table 5. Concentration of selected constituents in surface water and groundwater at the River South Parcel, Will County, Illinois, September 1994 through November 2014.

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Temperature air, in degrees Celsius	Temperature water, in degrees Celsius	Calcium hardness, in mg/L as $CaCO_3$	Magnesium hardness, in mg/L as $CaCO_3$	Dissolved oxygen, in mg/L	pH, in standard units	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Ammonia nitrogen, in mg/L
Rivulet downstream from culvert 5 (location shown in fig. 14; data from TAMS Consultants, Inc., 1995 a,b)										
9/26/94	368	19	14	216	158	8.5	7.8	3.1	0.03	0.70
8/30/95	364	34	14	256	200	8.8	7.4	4.1	<0.05	0.50
9/29/95	356	27	13	252	204	9.2	7.5	4.8	<0.02	0.17
11/20/95	362	11	9	300	192	10.6	7.0	3.3	0.51	<0.05
Rivulet downstream from culvert 6 (location shown in fig. 14; data from TAMS Consultants, Inc., 1995a)										
9/26/94	382	20	14	162	156	8.7	7.7	8.6	0.025	0.70
Rivulet downstream from culvert 4 (location shown in fig. 14; data from TAMS Consultants, Inc., 1995b)										
8/30/95	488	33	26	412	324	0.4	7.1	0.63	<0.05	0.73
11/20/95	382	12	5	288	224	10.1	6.9	1.7	0.37	<0.05

Table 5. Concentration of selected constituents in surface water and groundwater at the River South Parcel, Will County, Illinois, September 1994 through November 2014.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Total Kjeldahl nitrogen, in mg/L
Surface water at streamgage RS-S1 (location shown in fig. 14; data from Applied Ecological Services, Inc., 2012)										
4/19/06	279	97	210	87	40	75	0.09	1.7	<0.02	1.6
7/19/06	233	76	110	90	41	64	0.07	1.3	0.02	2.1
10/19/06	249	59	68	75	32	45	0.16	0.78	0.09	<0.60
5/02/07	105	38	93	56	24	57	0.09	0.94	<0.02	3.0
7/25/07	337	38	91	57	33	44	0.39	2.0	0.04	2.0
10/24/07	422	19	100	108	48	54	**3.4**	0.64	0.03	<0.60
Surface water at streamgage RS-S2 (location shown in fig. 14; data from Applied Ecological Services, Inc., 2012)										
4/18/06	274	130	**250**	94	45	92	0.29	0.91	<0.02	**20**
7/19/06	233	86	110	95	47	58	0.14	2.0	**0.13**	**7.8**
10/19/06	257	51	98	88	41	67	0.23	0.57	<0.02	<0.60
5/02/07	129	68	160	78	37	89	0.15	0.69	0.04	**2.6**
7/25/07	351	49	97	64	40	43	0.20	2.0	<0.02	0.96
10/24/07	452	24	140	122	57	62	0.29	0.50	<0.02	<0.60
Surface water at seep A (location shown in fig. 14; data from AECOM, 2015b)										
11/10/14	327	53	179	101	50	84	--	--	--	--
11/14/14	353	56	171	96	48	76	--	--	--	--
11/10/14	251	109	121	72	54	58	<0.34	--	--	--
Alluvial deposits at well RS-W2 (location shown in fig. 14; data from Applied Ecological Services, Inc., 2012										
4/18/06	289	130	210	111	42	65	0.73	0.08	**0.11**	--
7/19/06	234	37	120	127	48	74	**2.8**	0.24	**0.74**	1.5
10/19/06	264	340	100	123	50	75	0.98	<0.01	**0.18**	0.74
4/30/07	151	35	110	89	37	63	0.84	0.16	0.08	**3.6**
7/25/07	436	9	150	77	40	54	0.05	0.50	<0.06	1.1
10/24/07	493	<1	110	103	43	87	0.15	0.77	**0.16**	0.81

Table 5. Concentration of selected constituents in surface water and groundwater at the River South Parcel, Will County, Illinois, September 1994 through November 2014.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Total Kjeldahl nitrogen, in mg/L
Silurian aquifer at well RP-1S (location shown in fig. 14; data from STS/AECOM, 2009)										
10/28/05	420	71	92	91	58	31	<0.01	--	--	--
6/06/06	310	42	58	66	34	27	--	--	--	--
Silurian aquifer at well RP-1D (location shown in fig. 14; data from STS/AECOM, 2009)										
10/28/05	410	86	19	85	48	20	<0.01	--	--	--
6/06/06	370	85	16	83	47	8.9	--	--	--	--
Silurian aquifer at well RP-2S (location shown in fig. 14; data from STS/AECOM, 2009)										
11/01/05	470	77	76	123	63	28	<0.01	--	--	--
6/06/06	380	80	84	99	46	31	--	--	--	--
Silurian aquifer at well RP-2D (location shown in fig. 14; data from STS/AECOM, 2009)										
11/01/05	450	172	112	83	84	96	<0.01	--	--	--
6/05/06	410	189	110	69	74	96	--	--	--	--
Silurian aquifer at well RP-8S-West (location not shown; data from AECOM, 2015b)										
11/10/14	329	51	175	97	48	74	<0.34	--	--	-
Silurian aquifer at well RP-10S-South (location not shown; data from AECOM, 2015b)										
11/10/14	282	28	55	78	39	26	--	--	--	--
Silurian aquifer at well RP-8S-East (location not shown; data from AECOM, 2015b)										
11/14/14	333	53	173	121	60	120	--	--	--	--
Silurian aquifer at well RP-9S-South (location not shown; data from AECOM, 2015b)										
11/14/14	382	69	141	102	59	62	--	--	--	--

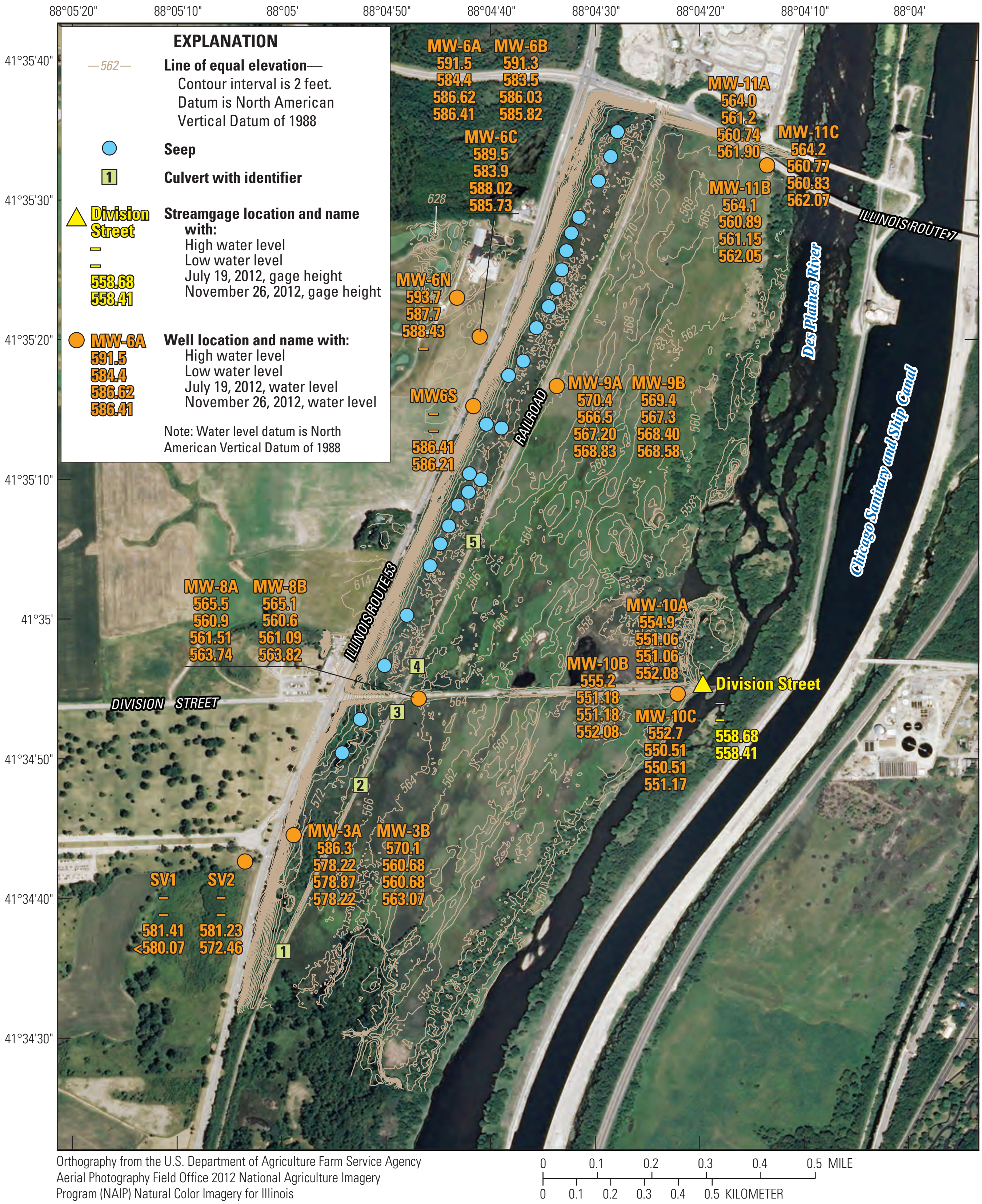


Figure 17. Location of selected features and water-level data at the Lockport Prairie Nature Preserve, Will County, Illinois.

the potential to alter the quality and quantity of groundwater discharged to the preserve because urban landscapes typically contain larger areas of impermeable surfaces that reduce recharge to groundwater and increase overland runoff of precipitation to streams or wetlands. Urban landscapes also tend to have elevated levels of sediment, fertilizers, and road salts in the water (U.S. Geological Survey, 2016c) that could degrade the habitat at the Lockport Prairie Nature Preserve.

Topography

Surface topography at the Lockport Prairie Nature Preserve ranges from about 550 ft NAVD 88 near the Des Plaines River to about 575 ft at the base of the bluff in the western part of the preserve (figs. 4, 17). The berm for the railroad track near the western edge of the Lockport Prairie Nature Preserve and for Division Street in the center of the preserve are approximately 1–3 and 1–8 ft, respectively, above the surrounding land surface. The elevation of the top of the bluffs in the western part of the preserve is about 610–620 ft near Route 53. Surface topography west of the Lockport Prairie Nature Preserve increases to as much as 650 ft.

Biology

Adult HED use has been documented in virtually all of the Lockport Prairie Nature Preserve (fig. 2). Adult HED activities include feeding, territorial patrol (Cashatt and Vogt, 1996), breeding, and egg laying (Cashatt and Vogt, 1992) with five verified breeding areas. The rivulet emanating from culvert 5 (fig. 18) is the most productive larval HED habitat at the Lockport Prairie Nature Preserve (Soluk and Mierzwa, 2012). Rivulets emanating from culvert 2, culvert 4, and the French drains also contain larval habitat. Egg laying was observed at rivulet 2 (Cashatt and Vogt, 1992) and near the seeps at the base of the bluffs (Cashatt and others, 1993).

The mean total adult HED population at the Lockport Prairie Nature Preserve in 2003 was estimated to be 134 individuals, which was 66 percent of the estimated adult population in the Lower Des Plaines River Valley. Population estimates from 1996 to 2008 indicate between 3 and 563 larvae at the Lockport Prairie Nature Preserve (Soluk and Mierzwa, 2012). The mean total larval HED population at the Lockport Prairie Nature Preserve in 2003 was estimated to be 988 individuals, which was nearly 48 percent of the estimated larvae population in the Lower Des Plaines River Valley. The HED population at the Lockport Prairie Nature Preserve has been on a decreasing trend since the 1990s, with an estimated adult population of 66 in 2011 (U.S. Fish and Wildlife Service, 2013b). The downward trend has been exacerbated by the 2002–03 and 2005 droughts.

Hydrogeology

Groundwater in the vicinity of the Lockport Prairie Nature Preserve is contained in the till deposits (the semiconfining unit) in the topographic uplands, the sand and gravel deposits (the glacial drift aquifer) along the bluffs, the alluvial deposits located in the valley of the Des Plaines River (the alluvial aquifer), and the Silurian aquifer. The spatial relation of these units is shown in figures 5 and 8. Each of these units affects the hydrology of the Lockport Prairie Nature Preserve.

Alluvial Aquifer

The alluvial aquifer has a saturated thickness of about 1–5 ft and consists predominately of sand with substantial amounts of silt and clay (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). This unit exchanges water with the surface-water bodies in the Lockport Prairie Nature Preserve. Hydric soils can be present in association with the alluvial aquifer in wetland areas.

Periodic measurements of groundwater levels were taken from August 2001 through September 2008 in 18 well points open to the alluvial aquifer in the Lockport Prairie Nature Preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a, 2009a). Water levels typically showed seasonal variations of less than about 1 ft, with the lowest water levels being present during the summer months. Water levels in the alluvial aquifer varied by a total of less than about 2 ft during most of the monitoring period but decreased by as much as 4 ft during the drought of 2005. These data indicate the alluvial deposit generally has consistent amounts of water except during droughts but that small (2–4 ft) changes in water level may result in substantial detriment to the HED habitat.

Glacial Drift Aquifer

The glacial drift aquifer near the Lockport Prairie Nature Preserve consists of the sand-and-gravel deposits located within about 1,500 ft of the bluffs west of the valley of the Des Plaines River (figs. 5, 8). The glacial drift aquifer has a horizontal hydraulic conductivity ranging from 5.4 to 62 ft/d and can transmit water readily (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). Vertical flow in the glacial drift aquifer is directed downward to the Silurian aquifer at a rate of about 25 inches per year (in/yr) so that 47,800 ft^3/d of water flows from the glacial drift aquifer into the Silurian aquifer within the groundwater recharge area for the Lockport Prairie Nature Preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a).

Horizontal flow in the glacial drift aquifer is directed toward the seeps along the bluff of the Des Plaines River Valley. Discharge to the seeps from the aquifer was measured to range from 140 to 1,300 ft^3/d and is affected by the groundwater elevation (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a).

Groundwater levels in the glacial drift aquifer were measured in wells MW-6A and SV1 (fig. 17) by previous

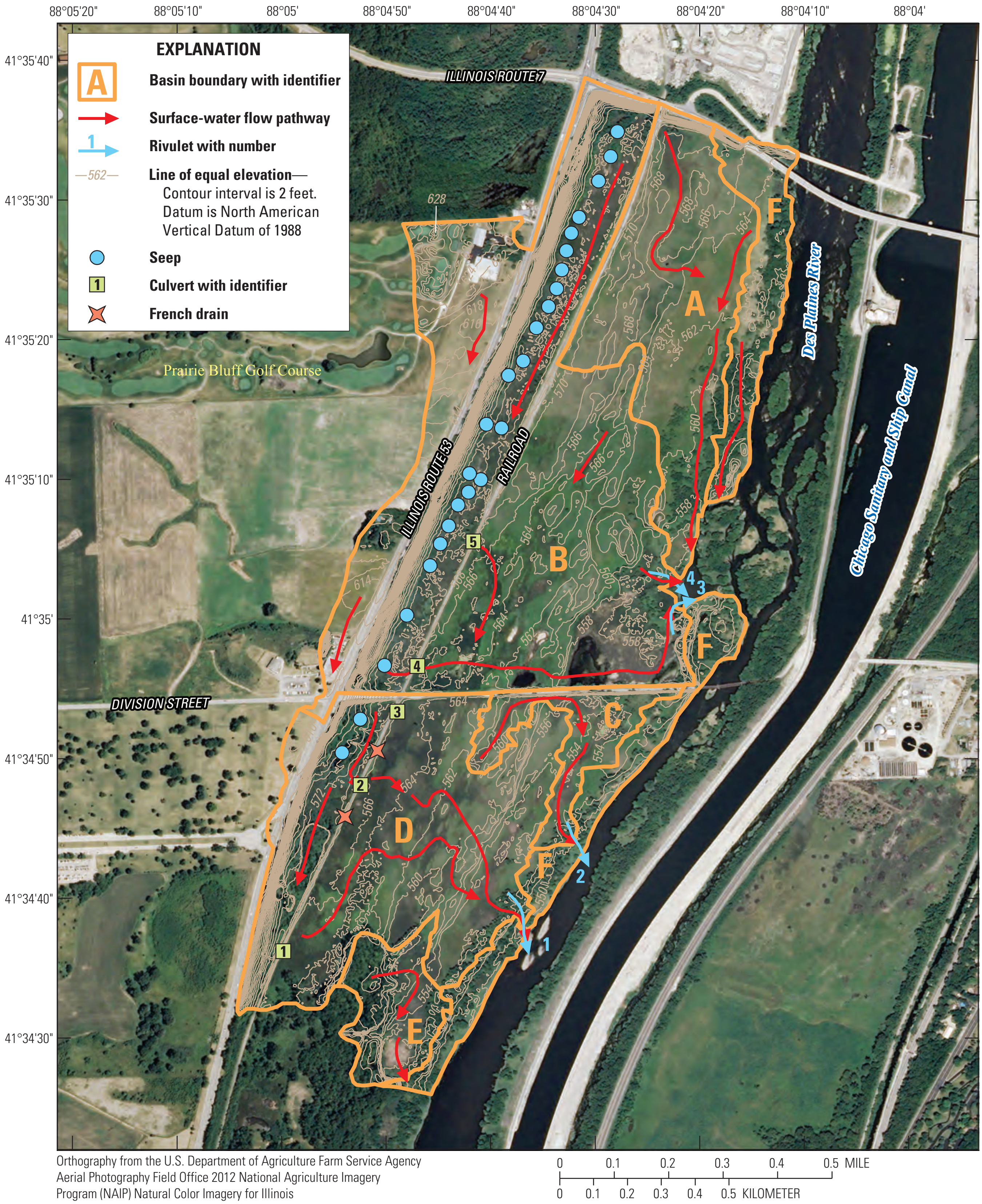


Figure 18. Location of selected surface-water flow pathways at the Lockport Prairie Nature Preserve, Will County, Illinois.

investigators (Graef, Anhalt, Schloemer, and Associates, Inc., 2008, 2009a) and the USGS (U.S. Geological Survey, 2016a; tables 1, 6). Groundwater levels within the glacial drift aquifer rise and fall by as much as 6 ft in response to recharge from individual precipitation events, seasonal variations in recharge, and drought. This fluctuation in water levels affects the location, frequency, and volume of groundwater flow to the Lockport Prairie Nature Preserve. When water levels are high, the volume of discharge from the glacial drift aquifer to the seeps and to the underlying Silurian aquifer is high. When water levels are low, the volume of discharge from the glacial drift aquifer to the seeps and to the underlying Silurian aquifer is low (or absent when the glacial drift aquifer is unsaturated). During low-flow conditions, a higher percentage of the water in the Lockport Prairie Nature Preserve originates as flow through the semiconfining unit.

Semiconfining Unit

The semiconfining unit consists of glacial till deposits, which are predominately of silt and clay with small amounts of interspersed sand and gravel (figs. 5, 8). The till deposits are between 30 and 65 ft thick and are present in the topographic uplands west of the glacial drift aquifer near the Lockport Prairie Nature Preserve. The semiconfining unit is present throughout most of the groundwater recharge area for the Lockport Prairie Nature Preserve (figs. 8, 11) and has an average vertical hydraulic conductivity of 2.3×10^{-4} ft/d (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). Vertical flow in the semiconfining unit is directed downward at a rate of 1–2 in/yr, so that about 14,700–20,000 ft^3/d of groundwater flows from the semiconfining unit into the underlying Silurian aquifer within the groundwater recharge area for the Lockport Prairie Nature Preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a).

Groundwater levels were measured in wells MW-7A and MW-12A by previous investigators (Graef, Anhalt, Schloemer, and Associates, Inc., 2008, 2009a) and the USGS (U.S. Geological Survey, 2016a; tables 1, 6). These wells are open to the shallow part of the semiconfining unit west of the Lockport Prairie Nature Preserve (location of the deep wells in the clusters are shown in fig. 9; MW-7C and MW-7D, MW-12B and MW-12D, respectively). Water levels in well MW-7A showed more than 10 ft of variation during the measurement period, with numerous changes of 2–3 ft in response to individual precipitation events. Declines of about 4–11 ft were observed in well MW-7A during drought periods from about May 2002 through May 2003, from about May through November 2005, and during July and November 2012. Well MW-12A, which has a shorter period of record and less frequent measurements, had about 2.5 ft of water level change and had lower water levels during the 2012 drought.

Periodic measurements of water levels were taken from well MW-7B, which is clustered with shallower well MW-7A (Graef, Anhalt, Schloemer, and Associates, Inc., 2009a). Well MW-7B monitors the bottom of the semiconfining unit, a sand deposit between the base of the semiconfining unit and the top of the Silurian aquifer, and the uppermost 1–2 ft of the Silurian aquifer (table 1). Water levels in well MW-7B were below the bottom of the well screen for about 5 months following well construction, possibly because of pumping from a nearby irrigation well. Water levels also were below the bottom of the well screen during the drought in July 2012 and perhaps during the latter part of the drought in 2005. In addition, the water level in the well was below the elevation of the bottom of the semiconfining unit during most of the period of monitoring. These data indicate that at least parts of the base of the semiconfining unit may become unsaturated during prolonged dry periods or in response to pumping, reducing recharge to the Silurian aquifer.

Periodic measurements were taken from wells CH2A and CH3A, which also monitor the bottom of the semiconfining unit (Graef, Anhalt, Schloemer, and Associates, Inc., 2009a; table 6). Well CH2A is about 330 ft north of high-capacity well CH10 and is clustered with well CH2B and CH2C (shown in fig. 9). Well CH3A is about 140 ft northwest of high-capacity well CH11 and is clustered with well CH3B (fig. 9). Water levels in wells CH2A and CH3A declined by 6–8 ft after the initiation of pumping in wells CH10 and CH11, and have remained several feet lower than pre-pumping water levels. These declines indicate that the deep part of the semiconfining unit is exhibiting drawdown in response to high-capacity withdrawals from the underlying Silurian aquifer within at least a few hundred feet of the pumped wells, diverting water from the deepest part of the semiconfining unit to the Silurian aquifer in these areas.

Water levels in the shallow part of the semiconfining unit show fairly large changes in response to individual precipitation events as well as seasonal changes in precipitation and droughts. Water levels in the deeper part of the semiconfining unit typically show no response to individual precipitation events but respond to longer term changes in precipitation and to high-capacity pumping in localized areas.

Silurian Aquifer

The Silurian aquifer is approximately 200 ft thick near the Lockport Prairie Nature Preserve (Roadcap and others, 1993). The dolomite is present at or near the land surface in the valley of the Des Plaines River and has about 10–15 ft of outcrop along the base of the bluffs (fig. 5). The dolomite contains a variety of secondary-permeability features, particularly in the uppermost 15–40 ft where the dolomite is most weathered.

Water in the Silurian aquifer flows from west to east in the vicinity of the Lockport Prairie Nature Preserve (figs. 9, 10). Water from the weathered, upper part of the aquifer discharges to the seeps at the base of the bluff in the western edge of the preserve. A smaller amount of water discharges to the alluvial aquifer in the Lockport Prairie Nature Preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). The horizontal hydraulic conductivity of the Silurian aquifer is moderately

Table 6. Summary of groundwater-level data for the Lockport Prairie Nature Preserve, Will County, Illinois, 2001 through 2014.

[MM, month; YY, year; NAVD 88; North American Datum of 1988; C, continuous measurement; P, periodic measurement; <, less than; ~, approximate]

Well name	Date of measurement (MM/YY–MM/YY)	Range of water levels, in feet above NAVD 88	Factors affecting water level
Glacial drift aquifer			
MW-6A	06/01–09/05 C 09/11–08/14 C 07/01–11/12 P	584.4–591.5	Precipitation events, seasonal variation, drought.
SV1	03/03–11/12 P	<580.1—~588	Precipitation events, seasonal variation, drought.
Shallow part of semiconfining unit			
MW-7A	07/01–04/04 C 07/01–11/12 P	657.2–668.0	Precipitation events, seasonal variation, drought.
MW-12A	08/07–11/12 P	636.4–639.9	Seasonal variation, drought, possibly precipitation events.
Deep part of semiconfining unit			
MW-7B	07/01–11/12 P	<606–608.2	Drought, possibly pumping, possibly seasonal variation.
CH2A	03/03–11/12 P	583.6–594.5	Pumping, precipitation, seasonal variation, drought.
CH3A	03/03–11/12 P	584.3–597.7	Pumping, precipitation, seasonal variation, drought.
Silurian aquifer overlain by semiconfining unit			
MW-7C	07/01–10/05 C 07/01–11/12 P	604.1–609.2	Pumping, drought, possibly seasonal variation.
MW-7D	10/11–05/13 C 07/01–11/12 P	603.7–609.2	Pumping, drought, possibly seasonal variation.
MW-12B	08/07/11/12 P	602.5–603.1	Pumping, drought, possibly seasonal variation.
MW-12C	08/07/11/12 P	602.2–602.9	Drought, possibly seasonal variation.
CH2B	03/03–11/12 P	583.9–592.1	Pumping, drought, possibly seasonal variation.
CH2C	03/03–11/12 P	540.5–579.7	Pumping, drought, possibly seasonal variation.
CH3B	03/03–11/12 P	585.6–599.3	Pumping, drought, possibly seasonal variation.
Silurian aquifer overlain by glacial drift aquifer			
MW-3A	04/01–07/04 C 07/01–11/12 P	578.2–584.8	Precipitation, drought, possibly seasonal variation.
MW-3B	05/13–09/13 C 07/01–11/12 P	561.6–570.0	Seasonal variation, drought, possibly precipitation events.
MW-6B	07/01–04/01 C 08/12–09/13 C 07/01–11/12 P	583.5–589.8	Precipitation, seasonal variation, drought.
MW-6C	07/01–11/12 P	583.9–589.9	Drought, possibly seasonal variation.
SV2	03/03–11/12 P	572.4–588.2	Seasonal variation, drought.
Silurian aquifer in Des Plaines River Valley			
MW-8B	07/01–12/04 C 07/01–11/12 P	560.7–564.4	Precipitation, seasonal variation, drought.
MW-9A	11/01–11/05 C 07/01–11/12 P	566.5–570.4	Precipitation, seasonal variation, drought.
MW-9B	04/02–06/05 C 03/12–02/14 C 07/01–11/12 P	567.2–569.4	Drought, possibly seasonal variation.
MW-10A	10/06–11/12 P	551.1–555.0	Drought, possibly seasonal variation.
MW-10B	10/06–11/12 P	551.2–555.2	Seasonal variation, drought.
MW-10C	10/06–11/12 P	550.5–552.7	Seasonal variation, drought.

Table 6. Summary of groundwater-level data for the Lockport Prairie Nature Preserve, Will County, Illinois, 2001 through 2014.—Continued

[MM, month; YY, year; NAVD 88; North American Datum of 1988; C, continuous measurement; P, periodic measurement; <, less than; ~, approximate]

Well name	Date of measurement (MM/YY–MM/YY)	Range of water levels, in feet above NAVD 88	Factors affecting water level
Silurian aquifer in Des Plaines River Valley—Continued			
MW-11A	10/06–11/12 P	560.7–563.6	Seasonal variation, drought.
MW-11B	10/06–11/12 P	561.2–564.2	Seasonal variation, drought.
MW-11C	10/06–11/12 P	560.8–564.2	Seasonal variation, drought.

low at the Lockport Prairie Nature Preserve, ranging from 1.8×10^{-1} to 6.8×10^{-1} ft/d (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a).

Continuous and periodic measurements of groundwater levels were taken in wells open to the Silurian aquifer in the vicinity of the Lockport Prairie Nature Preserve at various times from 2001 through 2013 (table 6). The wells monitored the Silurian aquifer where the semiconfining unit was present, where the glacial drift aquifer was present, and in the Des Plaines River Valley. Measurements were taken by previous investigators (Graef, Anhalt, Schloemer, and Associates, Inc., 2008, 2009a) and by the USGS as part of this investigation (U.S. Geological Survey, 2016a).

Groundwater levels were measured in wells MW-7C,D; MW-12B,C; CH2B,C; and CH3B (Graef, Anhalt, Schloemer, and Associates, Inc., 2009a; table 6). These wells are open to various depths of the Silurian aquifer where the aquifer is overlain by the semiconfining unit west of the Lockport Prairie Nature Preserve (table 1; fig. 9). Water levels in wells MW-7C,D appear to have been periodically lowered (see 2001 and 2008 data for well MW-7C in fig. 19) by pumping from a nearby irrigation well that is no longer in operation and varied by a total of about 5 ft. Low water levels were present during the 2012 drought but not the 2005 drought (Graef, Anhalt, Schloemer, and Associates, Inc., 2009a), potentially reflecting the effects of nearby pumping in 2012. Water levels in wells MW-12B,C varied by less than 1 ft, which is a reflection of the stability in the flow system and its isolation from surface influences as well as the shorter monitoring period.

Water levels in well CH3B, open to the shallow part of the Silurian aquifer about 140 ft from high-capacity well CH11, showed an overall decline of about 14 ft during the period of monitoring (table 6; Graef, Anhalt, Schloemer, and Associates, Inc., 2009a). This decline reflects drawdown caused by the diversion of water from the aquifer as a result of pumping from well CH11. Water levels also have responded to the droughts in 2005 and 2012.

Water levels in well CH2B, open to the shallow part of the Silurian aquifer (table 1) declined overall by about 8 ft during the period of monitoring (table 6; Graef, Anhalt, Schloemer, and Associates, Inc., 2009a). Water levels in well CH2C, open to the deep part of the Silurian aquifer (table 1), declined by nearly 40 ft during the same period. These wells are located about 330 ft from high-capacity well CH10 (fig. 9), which began pumping in August 2003. Pumping from high-capacity well CH10 is the cause of the large water-level decreases at the CH2B,C well cluster. Drawdown is substantially greater in the deeper part of the aquifer than in the shallow part, which indicates that the secondary-permeability feature(s) supplying most of the water to well CH10 are located in the deeper part of the Silurian aquifer. These deep features have good hydraulic connection with (deep) well CH2C but have somewhat limited vertical interconnection in this area and perhaps the aquifer as a whole.

Water levels in some of the Silurian-aquifer wells screened beneath the semiconfining unit were below the top of the Silurian dolomite during drought periods, indicating that horizontal flow through the Silurian aquifer exceeded recharge from the semiconfining unit during these times. Water levels in these wells showed (1) minimal variation where not affected by nearby pumping, (2) no response to individual precipitation events, (3) no clear response to seasonal changes in precipitation, and (4) muted response to droughts. The muted response to precipitation likely is due to the slow movement of recharge water through the overlying semiconfining unit.

Groundwater levels were measured in wells MW-3A,B; MW-6B,C; and well SV2 (Graef, Anhalt, Schloemer, and Associates, Inc., 2008, 2009a; U.S. Geological Survey, 2016a). These wells are open to the Silurian aquifer where it is overlain by the glacial drift aquifer on the bluff west of the Lockport Prairie Nature Preserve. Water levels in these wells typically varied by 6–8 ft during the period of record (see data for well MW-3A in fig. 19; table 6). Water levels varied in response to individual precipitation events and typically were near the bottom of the range during drought events in 2002–03, 2005, and 2012. The large (nearly 16 ft) range in water levels at well SV2 is due to the abnormally low (about 11 ft below typical) water levels measured during the droughts of 2005 and 2012. These low water levels may reflect dewatering of fractures in the upper part of the Silurian aquifer near well SV2 in the absence of recharge from the overlying glacial drift aquifer during the droughts. The large difference in water levels at the MW-3A,B well cluster also indicates periodic unsaturated conditions (likely affected by flow through a complex secondary-permeability network in the upper part of the aquifer in this area) within the Silurian aquifer between the open

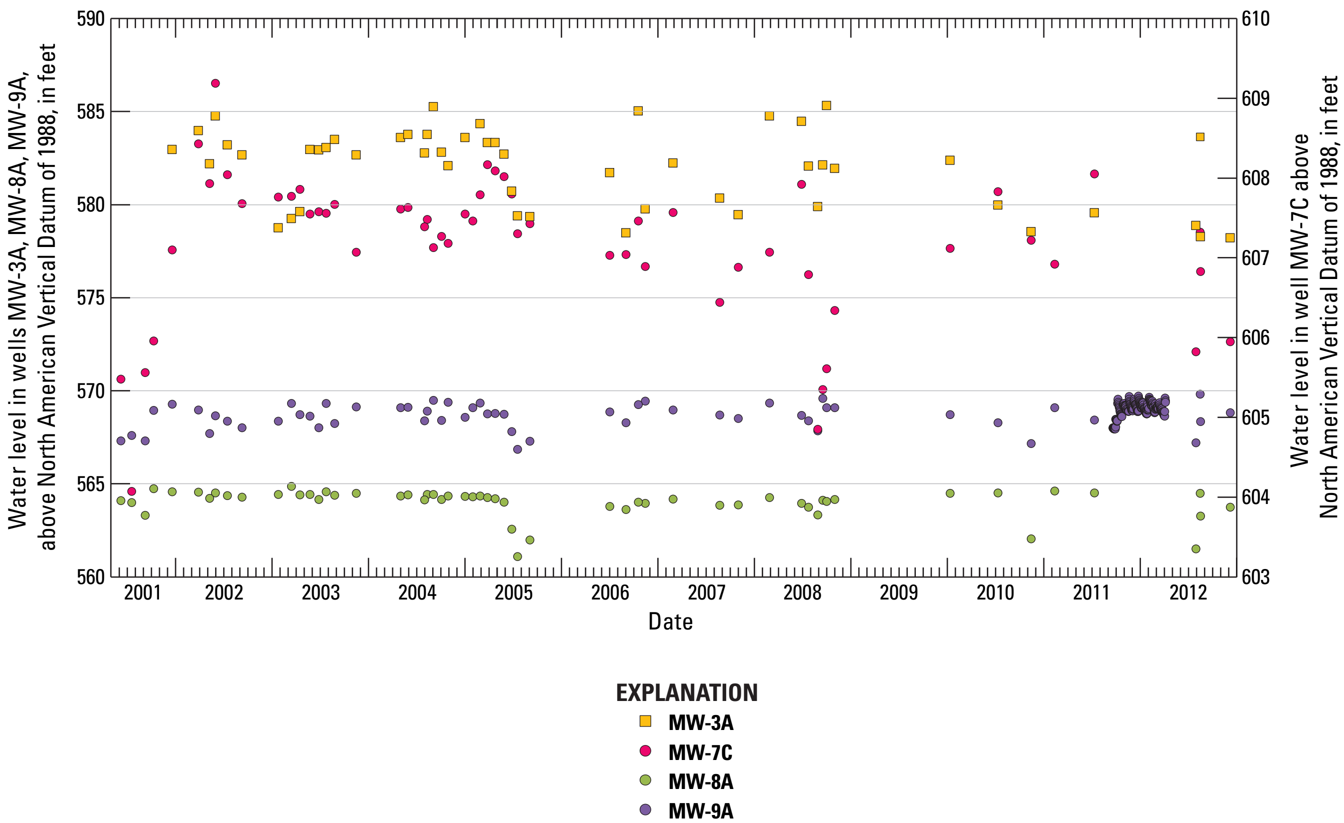


Figure 19. Water levels in wells MW-3A, MW-7C, MW-8A, and MW-9A in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois, 2001 through 2012.

interval at these wells (about 550–575 ft). Unsaturated conditions in the upper part of the Silurian aquifer in the vicinity of well SV2 may explain the lack of seeps in this area (fig. 17).

Water levels in some of the Silurian-aquifer wells screened beneath the glacial drift aquifer showed substantial variation in response to individual precipitation events, seasonal variations, and drought. These responses are due to the rapid movement of recharge water through both aquifers to the seeps. The low water level at well SV2 during drought indicates the potential for a substantial reduction in flow from the Silurian aquifer in this area during drought conditions.

Groundwater levels were measured in wells MW-8B; MW-9A (fig. 19),MW-9B (fig. 20); MW-10A,B,C; and MW-11A,B,C (Graef, Anhalt, Schloemer, and Associates, Inc., 2009a; U.S. Geological Survey, 2016a; table 6). These wells monitor the Silurian aquifer at the Lockport Prairie Nature Preserve in the valley of the Des Plaines River (fig. 17). Water levels in these wells typically varied by about 4 ft or less, showed less than 1 ft response to individual precipitation events, and were at the low end of the range during the droughts of 2005 and 2012. Water levels in these wells were above the top of the Silurian aquifer, excepting the MW-10 cluster. Water levels in the MW-10 cluster are affected by hydraulic interaction with the Des Plaines River. During the 2012 drought measurements, water levels were typically less than 1 ft above the top of the dolomite. These data indicate that flow from the Silurian aquifer directly to the wetlands in the river valley is a stable source of the water sustaining the wetlands at most of the Lockport Prairie Nature Preserve but that small changes in water level associated with extreme hydrologic events can dry out the HED habitat.

Comparison of water-level data from wells open to different elevations in the Silurian aquifer in the vicinity of the Lockport Prairie Nature Preserve indicates variable vertical flow within the aquifer (fig. 17, table 1). For example, the July 2012 measurements indicate upward flow within the aquifer at the MW-9 well cluster (higher water levels in the deep well [MW-9B]) but downward flow during November 2012 (fig. 17). These data indicate that the volume of groundwater discharge from the Silurian aquifer to the wetlands at the Lockport Prairie Nature Preserve may be affected by drought or other factors.

The groundwater recharge area for the Silurian aquifer to the Lockport Prairie Nature Preserve (fig. 21) was determined by Graef, Anhalt, Schloemer, and Associates, Inc. (2004a). The area of groundwater recharge to that part of the Silurian aquifer that flows to Lockport Prairie Nature Preserve is about 2.6 mi^2. In about 2.3 mi^2 of this area the Silurian aquifer is overlain by the semiconfining unit. In the remainder of this area the Silurian aquifer is overlain by the glacial drift aquifer.

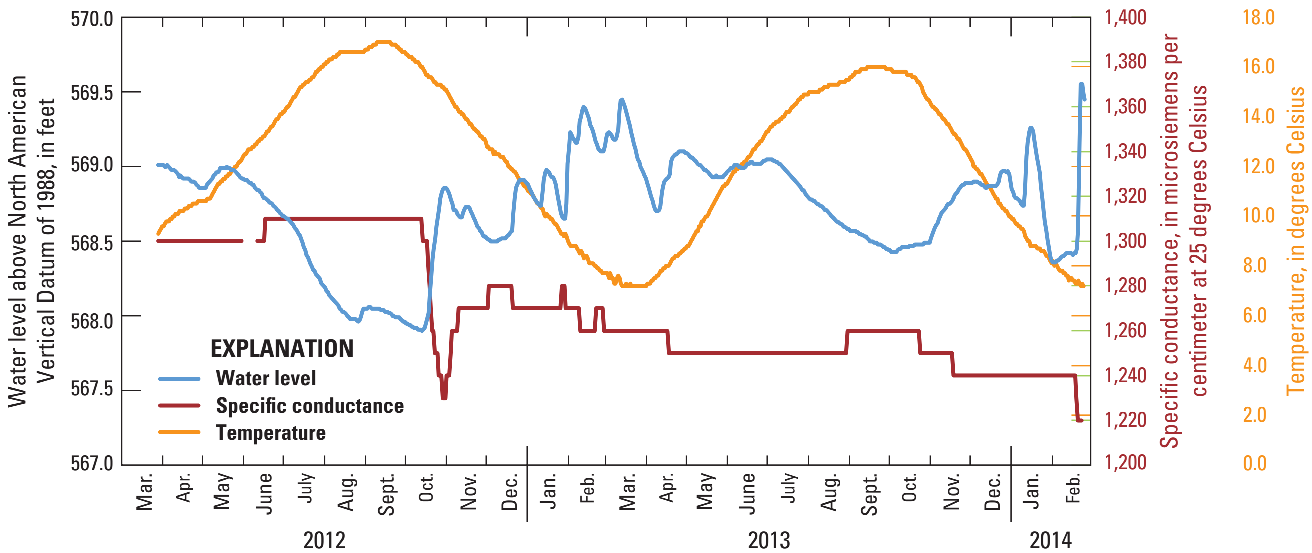


Figure 20. Continuous readings of water level, temperature, and specific conductance for well MW-9B, Lockport Prairie Nature Preserve, Will County, Illinois, March 28, 2012, through February 24, 2014.

The total recharge from precipitation within the groundwater recharge area to the Lockport Prairie Nature Preserve is about 66,000 ft^3/d, of which about 37,000 ft^3/d enters the Silurian aquifer and 29,000 ft^3/d enters the glacial drift aquifer (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a).

Surface Water

Surface-water flow at the Lockport Prairie Nature Preserve begins as discharge from seeps along the bluffs in the western part of the preserve at an elevation of about 578–585 ft NAVD 88 (fig. 18; Christopher B. Burke Engineering, Ltd, 1996; Graef, Anhalt, Schloemer, and Associates, Inc., 2004a,b). Depending on groundwater levels, these seeps emanate from the glacial drift and Silurian aquifers, or from only the Silurian aquifer. Field reconnaissance done in March 1996 identified 25 seeps between the bluff and the railroad tracks (Christopher B. Burke Engineering, Ltd, 1996). All but one of these seeps were north of Division Street, with the most active seeps being approximately halfway between Route 7 and Division Street. Field reconnaissance done in 2000 identified 40 distinct seeps, with additional diffuse areas where seeps were present (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). All but two of these seeps were located north of Division Street. The location of the seeps indicates that saturated, permeable, geologic material intersecting the bluff face is more common north of Division Street than south. This interpretation is consistent with the decrease in groundwater-level elevations from north to south along the bluffs at the Lockport Prairie Nature Preserve (figs. 9, 10).

On an unspecified date during the winter of 2002, described as a period of low groundwater levels, an estimated 14,000 ft^3/d of water was discharged from the seeps (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). On March 28, 2002, an estimated 36,200 ft^3/d was discharged from the seeps (Graef, Anhalt, Schloemer, and Associates, Inc., 2008). During May 2002, described as a period of high groundwater levels, an estimated 21,500 ft^3/d of water was discharged from the seeps (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). If normal seasonal trends in water level were present during the winter and spring of 2002, these data indicate that the volume of discharge from the seeps increases with increased groundwater levels.

Water from the seeps collects in pools located west of the railroad tracks and enters the eastern part of the Lockport Prairie Nature Preserve as flow through culverts and French drains beneath the railroad bed (fig. 18). Water discharging through the culverts and French drains flows in rivulets through the wetlands within the Lockport Prairie Nature Preserve and out to the Des Plaines River. The wetlands also are discharge points for groundwater from the Silurian aquifer, receiving an estimated 850–1,000 ft^3/d of groundwater discharge (Graef, Anhalt, Schloemer, and Associates, Inc., 2004a). The volume of direct discharge from the Silurian aquifer to the wetland is substantially less than the volume of discharge measured from the seeps in 2002.

There are six surface-water basins (A through F) within the wetlands of the Lockport Prairie Nature Preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2004b; fig. 18). Major basin boundaries are associated with the topographic highs at the railroad tracks and Division Street, which along with the culverts represents an alteration from the natural surface-water hydrology at the Lockport Prairie Nature Preserve. Smaller topographic high points (hummocks) control

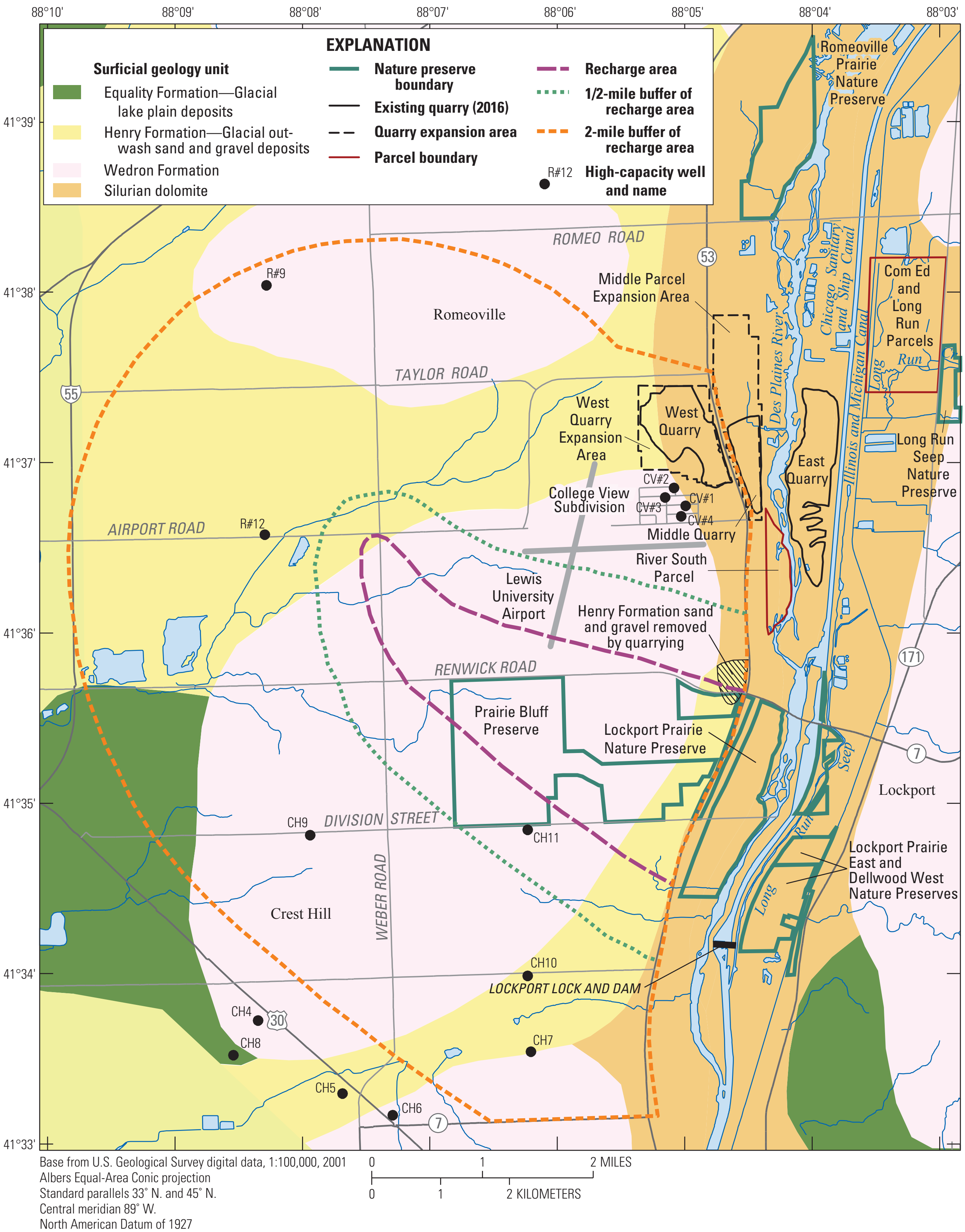


Figure 21. Groundwater recharge area for the Silurian aquifer, with buffers, and location of selected features in the vicinity of the Lockport Prairie Nature Preserve, Will County, Illinois (modified from Graef, Anhalt, Schloemer, and Associates, Inc., 2004a).

surface-water flow within the basins in the Des Plaines River Valley. Larval HED use appears to be focused in basins B and D.

Basin A receives water directly from precipitation, direct groundwater discharge to the basin (in contrast to flow from the seeps), and overland runoff of precipitation from topographic highs at Route 7 (Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). Due to the absence of a culvert, Basin A, which likely received some overland runoff under natural conditions, does not receive surface-water flow from west of the railroad tracks. Basin A does not have a defined outflow channel, but flow is to the Des Plaines River at the southern part of the basin. Installation of a culvert beneath the railroad tracks at Basin A would increase the volume of flow into Basin A and would decrease flow to Basin B, partly restoring the natural hydrology of the northern part of the Lockport Prairie Nature Preserve.

Basin B receives water directly from precipitation, direct groundwater discharge to the basin, overland runoff of precipitation near Route 53, and from numerous seeps along the bluff (Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). Water is ponded west of the berm associated with the railroad tracks and north of Division Street. Surface water flows through culverts 4 and 5 in the berm to rivulets and ponds within the basin, then discharges to the Des Plaines River at rivulets 3 and 4 (fig. 18). Inflow at the culverts produces a concentration of flow that likely was not present under natural conditions and may result in greater erosion near the culverts.

Discharge through weirs installed at the culverts beneath the railroad tracks on the west side of the Lockport Prairie Nature Preserve and through weirs at rivulets near the Des Plaines River was measured during monitoring events in 1995, fall 2001, and spring through winter 2002 to provide insight into the water budget for Basin B (Christopher B. Burke Engineering, Ltd, 1996; Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). The typical and maximum discharge into Basin B by way of culverts 4 and 5 was low in absolute terms but substantially higher at culvert 4 than at culvert 5 (table 7). This difference likely is affected by the position of culvert 4 in the lower part of the basin (fig. 18) where water collects near Division Street and the railroad tracks. Note that culvert 5 flows to the most productive HED habitat, possibly reflecting the effects of the lower discharge rate on the habitat. Discharge into basin B at culverts 4 and 5 typically exceeded discharge out to the Des Plaines River at rivulets 3 and 4, except during some of the precipitation events. Discharge patterns in Basin B likely reflect the comparatively high volume of surface-water inflow from the numerous seeps north of Division Street. Discharge patterns also indicate that evapotranspiration removes a substantial amount of water from Basin B during the summer months. Discharge into and out of Basin B varied seasonally, with both typical and maximum discharge being highest in spring and fall. Inflow and outflow typically were absent during the summer except for infrequent flow during sustained periods of elevated precipitation.

Basin C receives water directly from precipitation, direct groundwater discharge to the basin, and perhaps groundwater discharge from basin B through the berm at Division Street (Christopher B. Burke Engineering, Ltd, 1996; Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). Because Division Street blocks the natural surface-water flow from Basin B to Basin C, Basin C is likely drier under current (2018) conditions than under natural conditions. Surface water flows through rivulets and sheet flow in the wetlands and discharges to the Des Plaines River at rivulet 2. Outflow from Basin C to the Des Plaines River at rivulet 2 varied seasonally, being highest in spring and fall (2001 but not 2002) and typically absent during the summer (table 7). Flow at rivulet 2 during the summer is frequent during precipitation events, possibly due to backflow from the river.

Basin D receives water directly from precipitation, direct groundwater discharge to the basin, overland runoff of precipitation near Route 53, and from seeps along the bluff (Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). Water is ponded west of the berm associated with the railroad tracks. Surface water flows through culverts 1, 2, and (to a small extent) 3 in the berm and (after 1997) three French drains to rivulets within the basin, then discharges to the Des Plaines River at rivulet 1 (fig. 18). As was the case with the other basins, current (2018) flow in Basin D differs from natural conditions.

The typical inflow to Basin D was substantially higher at culvert 2 than at culvert 1 (table 7). Based on a single measurement during spring of 1996, inflow at culvert 3 exceeds that at culverts 1 and 2 (Christopher B. Burke Engineering, Ltd., 1996; Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). If these measurements are representative, these differences indicate increased inflow from south to north (fig. 18) toward Division Street prior to construction of the French drains in 1997. After construction of the French drains, culvert 3 was blocked with sediment and did not transmit water. Flow readings at the culverts and French drains during 2001 and 2002 (table 7) indicate minimal surface-water flow into Basin B, with most of the flow being through culvert 2, which drains to the second most productive HED habitat at the Lockport Prairie Nature Preserve. Outflow from Basin D to the Des Plaines River by way of rivulet 1 was typically less than 0.1 cubic feet per second (ft^3/s), indicating that evapotranspiration removes a substantial amount of water from the basin during the summer months. Discharge into Basin D at culverts 1, 2, and 3 and out of the basin at rivulet 1 showed no clear differences in the 2002 data. It is noted, however, that the typical outflow at rivulet 1 during the latter part of the 2001 (about 0.5 ft^3/s) exceeded the total inflow (about 0.1 ft^3/s). To make up the deficit in the volume of water exiting the basin, there must be an additional source of water entering Basin D between the culverts and the rivulets. Discharge patterns in basin D likely reflect the low volume of inflow from the two seeps south of Division Street and a high volume of groundwater recharge in comparison to surface-water inflow. Flow into and out of Basin D varied seasonally, being highest in spring and fall and absent during the summer except

Table 7. Summary of surface-water discharge data for the Lockport Prairie Nature Preserve, Will County, Illinois.

[MM, month; YY, year; <, less than; Dec., December; Apr., April; Oct., October; ~, approximate]

Well name	Type of flow	Date of measurement (MM/YY–MM/YY)	Typical flow, in cubic feet per second	Range of flow, in cubic feet per second
Basin B (all locations shown in fig. 18)				
Culvert 4	Inflow	03/96	0.7	Single measurement.
		10/01–12/01	1.0–2.0	1.0–12.0 decrease with time.
		04/02–12/02	<0.1–1.0	<0.1–3.0 decrease with time.
Culvert 5	Inflow	03/96	0.1	Single measurement.
		10/01–12/01	<0.1	<0.1–0.11 precipitation dependent.
		04/02–12/02	<0.1	<0.1–2.7 no flow late July–Dec.
Rivulet 3	Outflow	09/01–12/01	<0.1	<0.1–10 precipitation dependent.
		04/02–12/02	<0.1	<0.1–3.0 almost no flow June–Dec. except during substantial precipitation.
Rivulet 4	Outflow	09/01–12/01	0.4	<0.1–2.0 base flow higher Oct.–Dec.
		04/02–12/02	>0.4 (Apr.–June) <0.1 (June–Dec.)	<0.1–1.8 minimal flow July–Dec.
Basin C (all locations shown in fig. 18)				
Rivulet 2	Outflow	08/01–12/01	0.25	<0.1–0.70 flashy, base flow higher in Oct.–Dec.
		04/02–12/02	~0.2 (Apr.–June) <0.1 (June–Dec.)	<0.1–1.1 decreases after mid-June, fairly frequent summer flow during precipitation.
Basin D (all locations shown in fig. 18)				
Culvert 1	Inflow	10/01–12/01	<0.1	<0.1–0.3 flow requires substantial precipitation.
		04/02–12/02	<0.1	<0.1–3.0 decreases after mid-June.
Culvert 2	Inflow	03/96	0.1	Single measurement.
		10/01–12/01	0.1	<0.1–1.7 consistent base flow.
		04/02–12/02	<0.1	<0.1–2.1 minimal flow after May.
Culvert 3	Inflow	03/96	0.5	Single measurement.
		04/02–12/02	<0.1	Blocked with sediment, 2002 flow reduced by 1997 construction of French drains.
North French drain	Inflow	04/02–12/02	<0.1	<0.1–1.8 minimal flow.
South French drain	Inflow	04/02–12/02	<0.1	<0.1–0.1 minimal flow.
Rivulet 1	Outflow	08/01–12/01	<0.1–0.5	<0.1–6.0 base flow higher in Oct.–Dec.
		04/02–12/02	<0.1	<0.1–3.0 little flow after mid-June.

for infrequent flow during sustained periods of elevated precipitation.

Basins E and F were not well characterized but receive water directly from precipitation, direct groundwater discharge to the basin, and perhaps surface-water inflow from adjacent basins during high water events (Graef, Anhalt, Schloemer, and Associates, Inc., 2004b). Basin F also may receive water from flooding of the Des Plaines River. Surface water in these basins flows through rivulets (basin E) or indistinct channels (basin F) whose discharge point is not identified.

Water Use

There are no high-capacity pumping wells within the groundwater recharge area for the Silurian aquifer to the Lockport Prairie Nature Preserve, but there is one high-capacity well open to the Silurian aquifer within the 0.5 mi buffer of the recharge area (fig. 21). An additional nine high-capacity wells in the Silurian aquifer are within the 2-mi buffer of the Lockport Prairie Nature Preserve recharge area, as is the Quarry. Combined withdrawals from high-capacity wells R#9 and R#12 within the 2-mi buffer increased from about 0.37 Mgal/d in 2000 to more than 0.9 Mgal/d in 2011 (Village of Romeoville, written commun., 2012). Withdrawals from high-capacity wells (CH7, CH9, CH10, CH11) within the 2-mi buffer had an average combined discharge of 1.0 Mgal/d during 2011 and 2012 (City of Crest Hill, written commun., 2012).

Nonpumping water levels collected from well R#9 located west of Weber Road and south of Romeo Road during July and November 2012 appear to have been anomalously low (about 568 ft NAVD 88), indicating this well was pumping more water from the Silurian aquifer than was being readily replenished at the time of measurement. The water level collected from well R#12 located at Airport Road west of Weber Road during July and November 2012 (about 604 ft) also was somewhat low in comparison to the nearby AR well (fig. 9).

Water levels in high-capacity wells CH7, CH10, and CH11 taken on July 19, 2012, were substantially lower than the stage of the Des Plaines River at the Lockport Prairie Nature Preserve (tables 1, 2) and nearby shallow monitoring wells (fig. 9). The three-dimensional extent of the pumping effects from these wells within the Silurian aquifer is not known, but the presence of drawdown in nearby monitoring wells CH3A,B and CH2A,B,C indicates pumping effects are present within a few hundred feet of the pumped well, especially in the deeper part of the aquifer. Water-level measurements collected from monitoring wells within the groundwater recharge area for the Silurian aquifer to the Lockport Prairie Nature Preserve show no obvious effects from pumping in high-capacity wells. These data do not indicate that pumping from these wells is diverting water from the Lockport Prairie Nature Preserve; however, a detailed assessment of the flow pathways and the location and magnitude of drawdown within the Silurian aquifer associated with pumping from the high-capacity wells would help to clarify the potential effects of pumping on the habitat.

Results of Groundwater Modeling

Two numerical groundwater-flow models have been developed to simulate the groundwater system in the vicinity of the Lockport Prairie Nature Preserve. The first model was developed by Graef, Anhalt, Schloemer, and Associates, Inc. (2008) to assess the hydrology in the vicinity of the Lockport Prairie Nature Preserve and the effects of urbanization on flow to the Lockport Prairie Nature Preserve. The second model was developed by AECOM (2012, 2013a) and used to assess the effects of proposed future quarry operations on the hydrology in the vicinity of the Quarry as well as the effectiveness of groundwater mitigation structures. Those aspects of the AECOM model that are pertinent to conditions at the Lockport Prairie Nature Preserve are discussed in this section.

Model Focusing on the Water Resources at the Lockport Prairie Nature Preserve

The discussion in this section is restricted to groundwater modeling performed by Graef, Anhalt, Schloemer, and Associates, Inc. (2008). This model used MODFLOW (McDonald and Harbaugh, 1984; Harbaugh and McDonald, 1996a,b; Harbaugh and others, 2000) to run flow simulations and MODPATH (Pollock, 1998) to delineate groundwater recharge areas. The model grid has 162 rows with a width of 100 to 500 ft and 124 columns with a width ranging from 25 to 530 ft. The model used 16 layers to simulate various units in the unconsolidated and Silurian deposits. The model encompassed the Crest Hill area west of the CSSC. The model was calibrated to groundwater levels collected in the vicinity of the Lockport Prairie Nature Preserve from 2004 through 2006 and to the rate of flow to the Des Plaines River and other surface-water bodies. Sensitivity analysis was performed. The Silurian aquifer is assumed to function as an equivalent porous medium. A review of this model was performed by the USGS and provided to USFWS (Daniel Feinstein and Douglas Yeskis, U.S. Geological Survey, written commun., 2011). The review concluded this model was professionally constructed with appropriate quality assurance and quality control measures (calibration, verification, scenario testing). The review also concluded that the model does yield output relevant to issues related to representing the groundwater flow system and recharge area and evaluating the effects of a variety of potential stresses to the system. Limitations to the model as applied to this investigation include an inability to provide a detailed simulation of the effects of quarry operations on the hydrology of the Lockport Prairie Nature Preserve. The absence of accurate field measurements of the volume of discharge from the seeps along the bluffs also limits the ability of the model to simulate this discharge.

Groundwater modeling indicates that during periods of normal or above average precipitation about 36,000 ft^3/d of groundwater discharges from the Silurian aquifer to seeps at the bluffs near the Lockport Prairie Nature Preserve, whereas about 11,000 ft^3/d of groundwater discharges from the aquifer directly to the wetlands within the Lockport Prairie Nature Preserve. During periods of normal or above average precipitation most of the water entering the Lockport Prairie Nature Preserve (at the seeps and in the valley) is recharged to the Silurian aquifer from the glacial drift aquifer near the bluffs west of the Lockport Prairie Nature Preserve. As the amount of recharge from the glacial drift aquifer to the Silurian aquifer decreases, a greater percentage of the groundwater discharge to the Lockport Prairie Nature Preserve originates as recharge to the Silurian aquifer from the semiconfining unit in the western part of the groundwater recharge area and discharges directly to the wetlands. A 50-percent reduction in the rate of recharge to the Silurian aquifer from the glacial drift aquifer, either as a seasonal or drought-related decrease in the amount of precipitation or due to increased runoff of precipitation, results in a simulated decrease in discharge to the seeps and direct discharge to the wetlands of 58 and 24 percent, respectively. These simulations are consistent with the water-level monitoring in the Silurian aquifer that indicates flow in the river valley is lower, but more stable, than at the bluffs. These simulations indicate that maintaining recharge to the glacial drift aquifer along the bluffs near the Lockport Prairie Nature Preserve, and likely other habitats in the Lower Des Plaines River Valley, is crucial to ensuring sufficient water supply to the HED habitat, but that maintaining flow in the rest of the groundwater recharge area also is important as a buffer against drought and other sources of decreased recharge.

Model simulations indicate that pumping at the Quarry and other high-capacity wells in the Silurian aquifer based on 2005 pumping volumes reduced flows to the seeps at Lockport Prairie Nature Preserve by 13–26 percent and to the wetlands in the river valley by 9–14 percent relative to conditions in which there was no pumping. The lower end of the range in the reduction of flow assumes typical recharge, whereas the upper end assumes a 50-percent reduction in recharge. Model simulations of discharge to the Lockport Prairie Nature Preserve assuming pumping volumes from the Quarry and nearby high-capacity wells based on 2030 population estimates indicate a decrease in flow to the seeps of 4–9 percent and in direct discharge to the wetlands of 3–4 percent in comparison to 2005 conditions. The effects of this reduction on the HED habitat are outside the scope of the model.

Model Focusing on the Effects of Quarry Operations on the Water Resources at the Lockport Prairie Nature Preserve

The discussion in this section is restricted to the modeling performed by AECOM (2012, 2013a). Simulations performed using this model indicate that the groundwater recharge area for the Lockport Prairie Nature Preserve is just outside of the groundwater capture zone in the Silurian aquifer associated with the maximum impacts of the dewatering of the Quarry at build-out conditions (fig. 11); however, model simulations indicate increased pumping in support of mining the West Quarry Expansion Area will induce as much as 1 ft of drawdown within the groundwater recharge area for the Lockport Prairie Nature Preserve west of Route 53. Groundwater modeling also indicates that increased pumping from the Silurian aquifer associated with the expansion of dewatering operations at the West Quarry will induce an estimated maximum of 0.20 ft of drawdown in the Silurian aquifer at the MW-9 well cluster in the north-central part of the Lockport Prairie Nature Preserve (AECOM, 2013a). The total difference in water levels in the Silurian aquifer within the groundwater recharge area for the Lockport Prairie Nature Preserve exceeds 30 ft based on the July 2012 measurements (fig. 9), so this drawdown will only slightly reduce the hydraulic gradient within that part of the Silurian aquifer flowing to the Lockport Prairie Nature Preserve. Modeling indicates the amount of discharge from the Silurian aquifer to the Lockport Prairie Nature Preserve will decrease from about 16,400 ft^3/d at the start of the expansion process to about 16,000 ft^3/d when mining is completed (AECOM, 2013b). These effects will dissipate once mining in the West Quarry ceases and the West Quarry fills with water.

To offset the effects of increased pumping from the West Quarry Expansion Area on the Lockport Prairie Nature Preserve, a stormwater retention and infiltration pond has been proposed for construction in part of a former sand and gravel quarry near the northern boundary of the Lockport Prairie Nature Preserve south of Renwick Road and west of Route 53 (fig. 8). This pond will collect runoff from a 186-acre watershed west of Route 53, enhancing the amount of recharge to the Silurian aquifer along the bluff northwest of the Lockport Prairie Nature Preserve. Simulations indicate that the pond will recharge about 5,660 ft^3/d to the Silurian aquifer, exceeding the modeled decrease in flow from the aquifer to the Lockport Prairie Nature Preserve associated with increased pumping at the West Quarry Expansion Area (AECOM, 2013a).

Water Quality

There were numerous surface-water sampling efforts during 1991–2001 at the Lockport Prairie Nature Preserve (table 8). Surface-water samples were collected from four locations at the Lockport Prairie Nature Preserve during 1991 (Cashatt and Vogt, 1992). The sample location(s) and precise date of sampling are not described. Measurements of surface-water temperature, specific conductance, hardness, pH, and dissolved oxygen (DO) were taken approximately weekly at three locations (upstream, midstream, downstream) in each of three rivulets from May 26 through July 29, 1993 (Lin and others, 1993). The locations of the measurement sites are not precisely known, but the rivulets are described as being close to the river and on the north (near culvert 4) and south (near culvert 5) sides of the road next to the railroad tracks (fig. 17). Surface-water samples were collected approximately monthly from August 1997 through November 1998 and from April through December 2001 at culverts 2 and 5 (fig. 17) and at an unspecified seep described as being near Route 53 (Soluk and others, 1999; Soluk and Moss, 2002). These samples were analyzed for a variety of metals, field parameters, nutrients, major ions, and general water-quality indicators.

Calcium was the cation present at the highest concentrations at every site. Bicarbonate, as indicated by the high alkalinity values, was the dominant anion. Alkalinity values showed an overall increase from April through December at the seep near Route 53 and at culverts 2 and 5 (table 8). Seasonal changes in concentrations of sulfate, sodium, and magnesium also were observed, particularly in the 1997 and 1998 sampling at the seep and culvert 5. The timing of these seasonal changes was not uniform between constituents or locations. Seasonal changes in geochemically sensitive constituents, such as sulfate, where present, may reflect variations in the intensity of microbiologic activity and sources of water.

Chloride concentrations next to the road at culvert 2 (geometric mean 128 mg/L) were higher than at culvert 5 (geometric mean 66 mg/L) and the seep (geometric mean 42 mg/L). The presence of elevated chloride at culvert 2, which is near Division Street, likely indicates the increased presence of overland runoff of precipitation and snowmelt affected by the application of road salt at culvert 2 relative to culvert 5. Much of the water at culvert 5 likely is derived from the groundwater

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	pH, in standard units	Manganese, in mg/L
Site 1, precise location and sampling date unknown (data from Cashatt and Vogt, 1992)										
1991	272	67	65	93	41	31	0.29	**31**	8.0	0.013
Site 2, precise location and sampling date unknown (data from Cashatt and Vogt, 1992)										
1991	263	68	72	104	40	31	0.12	**38**	8.0	<0.004
Site 3, precise location and sampling date unknown (data from Cashatt and Vogt, 1992)										
1991	290	86	65	97	43	26	0.20	**22**	8.2	0.020
Site 4, precise location and sampling date unknown (data from Cashatt and Vogt, 1992)										
1991	421	2	49	94	47	15	**10**	<0.1	7.8	**0.43**

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Station number	Water temperature, in degrees Celsius	pH, in standard units	Flow velocity, in feet per second	Hardness, in mg/L as $CaCO_3$	Dissolved oxygen, in mg/L
Culvert 4 (location shown in fig. 17; data from Lin and others, 1993)						
5/26/93	Upstream	11	7.3	0.62	--	8.7
	Midstream	15	7.3	<0.07	300	7.0
	Downstream	16	7.4	0.52	--	7.4
6/02/93	Upstream	10	7.1	0.39	--	8.2
	Midstream	14	7.1	<0.07	308	7.7
	Downstream	15	7.3	0.92	--	7.1
6/10/93	Upstream	11	7.4	0.59	--	8.3
	Midstream	19	7.3	<0.07	236	7.1
	Downstream	19	7.3	1.6	--	5.8
6/16/93	Upstream	10	7.2	0.95	--	8.4
	Midstream	17	7.2	<0.07	300	5.9
	Downstream	17	7.3	0.36	--	6.3
6/23/93	Upstream	12	7.3	0.66	--	8.9
	Midstream	22	7.3	<0.07	305	7.8
	Downstream	20	7.4	0.69	--	5.8
07/01/93	Upstream	12	7.2	0.56	--	8.7
	Midstream	23	7.3	<0.07	310	8.6
	Downstream	20	7.2	0.62	-	5.9
7/07/93	Upstream	13	7.1	0.49	--	8.7
	Midstream	24	7.3	<0.07	312	8.1
	Downstream	21	7.1	0.66	--	5.8
7/14/93	Upstream	12	7.3	0.69	--	8.9
	Midstream	18	7.4	<0.07	323	7.9
	Downstream	20	7.5	0.56	--	5.9
7/21/93	Upstream	13	7.3	<0.07	--	3.0
	Midstream	20	7.3	0.30	345	5.4
	Downstream	21	7.4	0.92	--	7.1
7/28/93	Upstream	12	7.2	0.69	--	8.1
	Midstream	19	7.3	<0.07	320	8.2
	Downstream	21	7.3	0.56	--	6.7

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Station number	Water temperature, in degrees Celsius	pH, in standard units	Flow velocity, in feet per second	Hardness, in mg/L as $CaCO_3$	Dissolved oxygen, in mg/L
Culvert 3 (location shown in fig. 17; data from Lin and others, 1993)						
5/26/93	Upstream	12	7.6	0.72	--	7.4
	Midstream	14	7.6	0.56	328	8.1
	Downstream	14	7.6	0.23	--	8.8
6/02/93	Upstream	12	7.2	0.49	--	8.6
	Midstream	12	7.3	0.33	330	7.1
	Downstream	12	7.4	0.33	--	7.9
6/10/93	Upstream	13	7.6	0.92	--	8.2
	Midstream	14	7.8	0.75	352	8.5
	Downstream	15	7.7	0.20	--	8.3
6/16/93	Upstream	13	7.5	0.66	--	7.5
	Midstream	15	7.6	0.95	380	7.1
	Downstream	16	7.6	0.56	--	7.5
6/23/93	Upstream	15	7.5	0.62	--	7.3
	Midstream	17	7.6	0.92	345	7.7
	Downstream	18	7.6	0.49	--	7.4
7/01/93	Upstream	16	7.4	0.69	--	7.1
	Midstream	17	7.5	0.85	362	7.7
	Downstream	17	7.6	0.59	--	7.4
7/07/93	Upstream	15	7.4	0.79	--	7.1
	Midstream	17	7.8	1.0	362	7.8
	Downstream	17	7.5	0.69	--	7.5
7/14/93	Upstream	15	7.3	0.69	--	7.3
	Midstream	18	7.7	0.85	335	7.7
	Downstream	19	7.8	0.59	--	7.8
7/21/93	Upstream	19	7.3	0.75	--	6.9
	Midstream	21	7.6	0.98	332	7.5
	Downstream	20	7.4	0.43	--	7.7
7/28/93	Upstream	16	7.2	0.62	--	7.0
	Midstream	17	7.4	0.85	328	7.9
	Downstream	18	7.6	0.59	--	7.4

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Station number	Water temperature, in degrees Celsius	pH, in standard units	Flow velocity, in feet per second	Hardness, in mg/L as $CaCO_3$	Dissolved oxygen, in mg/L
Surface water close to Des Plaines River (precise location unknown; data from Lin and others, 1993)						
5/26/93	Upstream	17	7.5	<0.07	--	4.4
	Midstream	13	7.5	0.43	356	6.8
	Downstream	12	7.2	0.95	--	7.5
6/02/93	Upstream	17	7.0	<0.07	--	3.0
	Midstream	14	7.3	0.59	360	6.7
	Downstream	14	7.4	0.75	--	7.6
6/10/93	Upstream	18	7.2	<0.07	--	3.5
	Midstream	17	7.5	0.46	320	7.4
	Downstream	16	7.5	1.5	--	6.9
6/16/93	Upstream	20	7.2	<0.07	--	3.1
	Midstream	19	7.4	0.56	340	7.8
	Downstream	19	7.3	0.98	--	7.5
6/23/93	Upstream	23	7.1	<0.07	--	2.2
	Midstream	19	7.6	0.72	350	6.7
	Downstream	19	7.4	1.1	--	7.0
7/01/93	Upstream	17	7.2	<0.07	--	3.5
	Midstream	16	7.3	0.43	356	7.0
	Downstream	16	7.3	1.1	--	6.9
7/07/93	Upstream	23	7.0	<0.07	--	2.8
	Midstream	22	7.2	0.39	354	5.8
	Downstream	21	7.5	1.0	--	6.9
7/14/93	Upstream	18	7.1	<0.07	--	2.8
	Midstream	17	7.2	0.33	332	5.7
	Downstream	16	7.4	0.85	--	7.0
7/21/93	Upstream	19	7.0	<0.07	--	3.0
	Midstream	17	7.3	0.29	345	5.4
	Downstream	16	7.4	0.92	--	7.1
7/28/93	Upstream	21	7.1	<0.07	--	2.8
	Midstream	20	7.1	0.26	368	5.3
	Downstream	20	7.5	1.1	--	7.4

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Dissolved oxygen, in mg/L	Manganese, in mg/L
Culvert 5 (location shown in fig. 17; data from Soluk and others, 1999; Soluk and Moss, 2002)										
8/21/97	328	80	49	109	52	24	0.34	0.09	2.5	**0.25**
9/24/97	328	17	57	83	43	21	0.14	0.13	2.7	0.01
10/30/97	309	27	56	79	40	19	0.12	0.20	3.3	<0.01
11/19/97	344	24	57	92	48	24	0.27	0.07	6.3	0.04
12/17/97	308	47	58	95	47	25	0.17	0.84	--	0.07
1/30/98	250	59	75	89	47	36	<0.04	3.1	9.7	<0.01
3/26/98	233	56	121	91	45	53	0.04	1.6	6.1	<0.01
4/29/98	244	35	77	76	37	37	<0.04	1.0	7.7	<0.01
5/21/98	264	25	78	72	37	39	0.04	0.50	4.2	0.03
6/19/98	289	10	53	77	37	28	0.15	0.30	3.0	**0.13**
7/23/98	352	10	45	153	43	25	0.11	<0.01	3.5	**0.26**
8/25/98	422	7	48	107	52	45	0.37	<0.01	4.3	**0.50**
9/15/98	410	3	50	103	51	28	0.20	0.01	4.7	**0.37**
10/30/98	347	10	56	94	47	28	0.23	0.08	2.3	**0.13**
11/19/98	341	16	56	92	46	28	0.02	0.32	6.6	**0.14**
4/23/01	148	39	89	56	37	38	0.07	0.65	6.7	0.01
5/11/01	306	33	70	92	47	42	<0.01	0.77	9.3	<0.004
6/16/01	319	26	75	94	45	38	<0.01	0.49	3.1	0.004
7/26/01	363	27	53	101	49	31	0.04	0.06	1.3	<0.002
08/29/01	--	--	--	--	--	--	<0.01	--	--	--
09/28/01	424	44	73	127	60	35	<0.01	0.01	1.7	**0.23**
10/29/01	260	88	151	--	--	--	<0.01	0.52	6.4	--
12/20/01	548	65	88	--	--	--	<0.01	0.58	8.7	--

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Dissolved oxygen, in mg/L	Manganese, in mg/L
Culvert 2 (location shown in fig. 17; data from Soluk and others, 1999; Soluk and Moss, 2002)										
8/21/97	357	155	109	144	61	64	0.04	0.51	7.9	0.04
9/24/97	362	143	116	131	54	58	0.05	0.43	7.8	0.03
10/30/97	371	146	103	124	50	46	<0.01	0.42	8.3	0.02
11/19/97	368	143	100	127	55	56	<0.01	0.41	8.8	0.02
12/17/97	357	129	100	130	56	53	0.03	0.39	--	0.03
1/30/98	335	133	92	129	57	60	<0.01	0.60	10.	<0.01
3/26/98	307	110	102	130	54	76	0.05	1.6	7.5	<0.01
4/29/98	312	99	155	115	49	67	<0.01	1.0	8.1	<0.01
5/21/98	345	85	147	112	48	69	0.03	1.0	5.9	0.03
6/19/98	359	73	151	117	50	67	0.03	1.1	6.5	0.05
7/23/98	383	82	123	180	53	65	0.02	2.0	7.1	**0.14**
8/25/98	372	93	128	133	55	65	0.05	1.3	6.9	**0.10**
9/15/98	386	95	126	131	57	66	<0.01	1.1	7.2	0.05
10/30/98	374	117	125	135	59	70	0.07	0.8	6.2	0.04
11/19/98	362	117	138	128	56	65	0.05	0.8	10.2	0.04
4/23/01	165	73	132	64	44	50	0.01	4.0	8.5	0.003
5/11/01	300	86	134	110	55	71	<0.01	3.7	8.9	<0.002
6/16/01	345	85	159	144	57	78	<0.01	0.67	6.0	0.009
7/26/01	361	205	160	136	59	81	<0.01	0.64	6.4	0.004
8/29/01	352	111	158	146	60	74	<0.01	0.55	6.1	0.050
9/28/01	376	112	156	146	61	81	<0.01	0.44	7.3	0.058
10/29/01	289	113	158	--	--	--	<0.01	0.33	5.1	--
12/20/01	732	106	120	--	--	--	<0.01	0.57	6.9	--

Table 8. Concentration of selected constituents in surface water at the Lockport Prairie Nature Preserve, Will County, Illinois, 1991 through 2001.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data; bold denotes exceedance of criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Dissolved oxygen, in mg/L	Manganese, in mg/L
Seep near Route 53 (precise location unknown; data from Soluk and others, 1999; Soluk and Moss, 2002)										
8/21/97	234	60	69	89	46	31	0.03	9.8	10.6	--
9/24/97	229	52	28	74	37	11	<0.02	9.7	9.8	--
10/30/97	228	44	39	69	34	16	<0.02	6.5	9.2	--
11/19/97	224	39	27	71	36	22	<0.02	5.4	9.2	--
12/17/97	235	36	38	72	36	17	<0.02	5.1	-	--
1/30/98	224	35	35	80	40	23	<0.02	**12.0**	10.1	--
3/26/98	205	37	112	79	38	59	<0.02	**10.0**	10.8	--
4/29/98	187	37	41	65	32	20	<0.02	8.0	11.2	--
5/21/98	197	36	49	59	30	38	<0.02	7.9	7.5	--
6/19/98	186	36	24	60	31	12	<0.02	7.2	13.7	--
7/23/98	196	37	19	149	32	10	<0.02	7.0	10.4	--
8/25/98	202	37	18	60	34	9	<0.02	6.0	10.6	--
9/15/98	210	35	20	62	32	12	<0.02	5.0	8.6	--
10/30/98	235	35	28	68	35	21	<0.02	4.3	10.1	--
11/19/98	241	34	19	67	35	16	<0.02	4.1	11.2	--
4/23/01	124	36	124	41	33	51	0.04	3.8	9.4	<0.02
5/11/01	209	46	82	83	39	44	<0.01	4.3	8.8	0.007
6/16/01	214	46	91	76	38	47	<0.01	4.3	9.3	<0.002
7/26/01	214	48	38	70	37	22	<0.01	4.7	9.5	<0.002
8/29/01	221	49	69	75	39	37	<0.01	5.0	9.3	<0.004
9/28/01	233	49	70	76	38	43	<0.01	4.1	9.3	<0.004
10/29/01	186	41	117	--	--	--	<0.01	7.3	9.4	--
12/20/01	388	48	25	--	--	--	<0.01	3.9	7.6	--

that has discharged to the seeps, with a small amount of water derived from overland runoff. Chloride concentrations showed no clear temporal trends; however, the high chloride concentrations likely indicate the presence of effects from road salts.

Nitrate concentrations substantially exceeded the MCL of 10 mg/L in three of the samples collected during 1991 (Cashatt and Vogt, 1992) and in several samples collected from the seep near Route 53 during 1998 (Soluk and others, 1999). The elevated concentration of nitrate at the seep likely indicates fertilizer application in the recharge area for the seep (likely over the glacial drift aquifer) is affecting water quality. Nitrate concentrations in 1997–2001 at the culverts typically were higher during the spring than the rest of the monitoring period and (as was the case with chloride concentrations) were higher at culvert 2 than at culvert 5. Nitrate concentrations in many of these samples are high enough to indicate the effects of fertilizers on surface water and shallow groundwater in the vicinity of the Lockport Prairie Nature Preserve. Seasonal trends in nitrate concentrations at the culverts may reflect the presence of increased amounts of fertilizer-affected runoff during the spring. Ammonia typically was not detected (detection limit of 0.01 mg/L) during the sampling, except during April 2001, when it was detected at all three sampling sites at concentrations ranging from 0.01 to 0.07 mg/L, potentially reflecting the presence of fertilize-affected runoff.

Water-quality data from the culverts and seep likely indicate seasonal differences in the water sources to the Lockport Prairie Nature Preserve. During a typical year, water quality at the seep would be most affected by the chemistry of the water recharging the glacial drift aquifer during the winter and spring and increasingly by the water quality of the semiconfining unit during the summer and fall. Water quality at culvert 2 may have contained a higher percentage of water derived from overland runoff of precipitation during the winter months in comparison to the seep and culvert 5. These sources could have resulted in increased chloride and decreased alkalinity during the winter and spring in comparison to the rest of the year. The variations in the amount of water from different sources (overland runoff of precipitation and groundwater) may affect the quality of the water in the wetland and thereby the HED habitat.

Water temperatures tended to be lower at the upstream parts of the rivulets in the western part of the Lockport Prairie Nature Preserve than in the downstream areas and near the Des Plaines River (table 8). Cooler water may be associated with proximity to the seeps and other areas of groundwater discharge.

Concentrations of DO typically were above 2.0 mg/L, making these waters slightly oxic. Concentrations of DO showed no consistent spatial pattern or temporal trends.

Additional analyses for phosphorous, mercury, and trace metals was done (Cashatt and Vogt, 1992; Soluk and others, 1999; Soluk and Moss, 2002). With the exception of manganese (<0.02–0.37 mg/L) and phosphorus (<0.01–0.11 mg/L), these compounds either were not detected, or were detected at concentrations below regulatory criteria.

Concentrations of manganese exceeded the aquatic life chronic threshold (table 3) in several samples from culverts 2 and 5 and in one of the samples collected during 1991. The MCL for nitrate was exceeded in most of the samples collected during 1991 and in some of the seep samples. Phosphorous concentrations (not shown in table 8) exceeded the EPA criteria for flowing water in one sample from culvert 5.

Continuous Monitoring of Groundwater

Continuous measurements of groundwater temperature and specific conductance were collected from March 28, 2012, through February 24, 2014, in well MW-9B (fig. 20). Groundwater temperatures showed seasonal variation, increasing from about 7 °C in February or March to about 16 °C in September. This trend likely is an effect of the conductive transfer of heat from the atmosphere and soil (Taylor and Stefan, 2009). Specific conductance values in well MW-9B showed a small overall decrease but were generally stable at 1,220 to 1,300 microsiemens per centimeter at 25 degrees Celsius (µS/cm). Specific conductance values often showed small decreases during periods of increased water levels, reflecting the presence of low-conductivity precipitation in the groundwater.

Future Monitoring

Land use in the drainage area for the proposed infiltration pond north of the Lockport Prairie Nature Preserve indicates that water in the pond could be affected by runoff from roadways and a golf course south of Renwick Road and west of Route 53. The effect of these land uses on the quality of the water in the pond, and the effect of recharge of this water on the quality of the groundwater (including temperature) entering the Lockport Prairie Nature Preserve, is not known. Pond water and downgradient groundwater will be sampled periodically by the Quarry operators to evaluate the effect of water from the infiltration pond on the HED habitat (Hanson Material Service Corporation, 2016).

Assessment of Water Resources at the Com Ed and Long Run Parcels

The Com Ed and adjacent Long Run Parcels occupy about 300 acres east of the Illinois and Michigan Canal, approximately 0.5 mi south of Romeo Road, and west of New Avenue (figs. 1, 22). A railroad is located along the eastern edge of the parcels. Buried oil pipelines are present along the railroad tracks and at the boundary between the parcels.

A subterranean pipeline break occurred on December 14, 2010, just north of the boundary between the parcels (fig. 22; Groundwater and Environmental Services, Inc., 2017). Crude oil from this break drained to a ditch along New Avenue, through a culvert that drains to a depression along the boundary between the parcels, to a marsh in the northeast part of the Long Run Parcel that currently (2018) is a pond created by the excavation of sediment down into bedrock. Oil from this leak

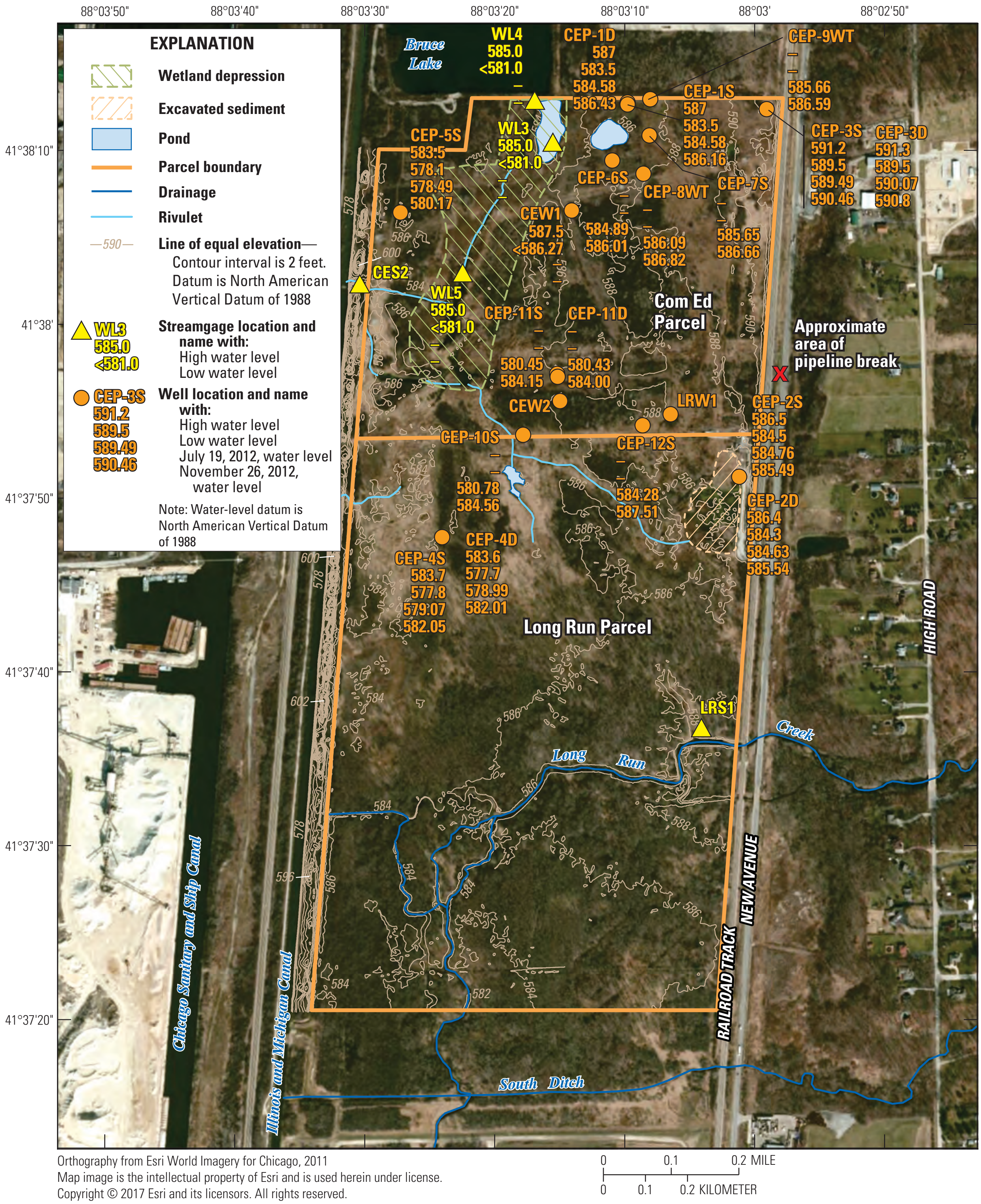


Figure 22. Location of selected features and water-level data at the Com Ed and Long Run Parcels, Will County, Illinois.

entered surface water, sediments, and groundwater, mostly near the boundary between the parcels. The leak is being remediated, partly by excavation of contaminated sediment, but some residual oil remains.

Topography

The area east of the Com Ed and Long Run Parcels (fig. 22) is bluff rising in elevation from about 590 ft NAVD 88 near New Avenue to more than 650 ft near High Road (fig. 4). The parcel itself consists of flat land surface with an elevation between about 591 ft in the northeastern edge of the parcel to 584 ft near the Illinois and Michigan Canal. The elevation of most of the parcel is between about 587 and 584 ft. The Illinois and Michigan Canal is a vertical drop of 5–7 ft from the western edge of the Com Ed and Long Run Parcels. Excavation to remove contaminated sediment in the northeast part of the Long Run Parcel has lowered the land surface in this area from natural, pre-spill conditions, potentially altering the hydrology.

Biology

Larval HED use was documented during August 2011 at crayfish burrows near the pond south of well CEP-10S (Brown and Soluk, 2012; Soluk and Mierzwa, 2012; fig. 22). Adult HED use has been documented in the vicinity of rivulets in the eastern part of the Com Ed Parcel and the northern part of the Long Run Parcel (fig. 2). Adult use includes perching, transit, territorial patrol, and breeding (Mierzwa and Webb, 2010; Soluk and Mierzwa, 2012). Some of these areas were affected by the oil spill. The leafy prairie clover (*Dalea foliosa*) inhabits the site but is mainly present in the drier portion of the Com Ed Parcel. The Blanding's turtle (*Emys blandingii*) also inhabits the Com Ed and Long Run Parcel but little is known regarding the species use of the site.

Hydrogeology

Groundwater is present in parts of the alluvial deposits that constitute the alluvial aquifer and the underlying Silurian aquifer within the Com Ed and Long Run Parcels. These units are hydraulically connected to each other and to the surface-water bodies.

Alluvial Aquifer

The alluvial deposits at the Com Ed and Long Run Parcels consist of 1–2 ft of sand. Alluvial sands were excavated prior to the oil spill in areas within the north-central part of the Com Ed Parcel and after the oil spill in the northeast part of the Long Run Parcel (AECOM, 2011, 2013b). Hydric soils are present in wetland areas where the alluvial deposits have not been excavated (Hanson Material Service Corporation, 2016).

Continuous measurements of groundwater levels were taken from April 2006 through December 2012 in wells CEW1 and LRW1, which are open to the alluvial aquifer (Applied Ecological Services, Inc., 2012, 2013). Water levels in well CEW1 typically were below the sensor, indicating that the alluvial deposits typically were unsaturated in the north-central part of the Com Ed Parcel. Water levels occasionally rose to within about 0.3 ft of land surface for short periods following precipitation events in the fall through spring. Summer precipitation events typically did not produce an increase in water levels sufficient to raise the water level to the level of the sensor. Water levels in well LRW1 typically were within 1.5 ft of land surface during the fall through spring, occasionally increasing to above land surface for short periods following precipitation events during the fall through spring. Water levels typically were below the sensor (more than 2 ft below land surface) during the summer months, even following precipitation events.

Silurian Aquifer

At the Com Ed and Long Run Parcels, the top of the Silurian dolomite is present at about 583–591 ft NAVD 88, generally decreasing from east to west. The Silurian aquifer at the Com Ed and Long Run Parcels has a horizontal hydraulic conductivity ranging from 2.1×10^{-1} to 1.0×10^{1} ft/d (STS/AECOM, 2009). The geometric mean horizontal hydraulic conductivity value for the upper 25 ft of the aquifer was 2.1×10^{0} ft/d and was 1.0×10^{-1} ft/d for the deeper part. These values are indicative of moderately low to moderately high aquifer permeability, with the shallow part of the Silurian aquifer being more permeable than the deep part.

Periodic measurements of groundwater levels in wells open to the Silurian aquifer from October 2005 through November 2013 indicate that the overall direction of groundwater flow in this area is from east to west, approximately perpendicular to the Illinois and Michigan Canal (figs. 9, 10; STS Consultants, 2007; STS/AECOM, 2009; AECOM, 2013a). These data, combined with continuous monitoring data from May 2011 through April 2012 (AECOM, 2013a), indicate that water levels in the Silurian aquifer (1) were lowest during the summer and highest during winter and spring, (2) often exceeded the elevation of land surface during the spring and fall, and (3) indicate periodic discharge from the Silurian aquifer to the wetlands. The lowest water levels were observed during drought conditions in October through December 2005 and were less than about 3.5 ft below their highest recorded level at the CEP-1 and CEP-2 well clusters. Groundwater levels in the Silurian aquifer also tended to show progressively more variation from the eastern part of the parcel (about 2.5 ft) to the western part (about 6 ft) (AECOM, 2013a), reflecting the effects of increased drainage from the aquifer to the Illinois and Michigan Canal with proximity to the canal.

Water levels in Silurian-aquifer wells CEP-1S,D often exceeded the stage of nearby streamgages WL3, 4, and 5, indicating that groundwater from the Silurian aquifer discharges to surface water in the northern part of the Com Ed Parcel. Groundwater levels in other well clusters indicate variable vertical hydraulic gradients at the site. Water levels at the CEP-1S,D; CEP-3S,D; and CEP-4S,D well clusters frequently or typically have upward hydraulic gradients (AECOM, 2013a), whereas the CEP-2S,D and CEP-11S,D clusters typically have downward gradients. These variations of vertical gradients indicate groundwater discharge to surface water at Com Ed and Long Run Parcels is affected by localized changes in the flow regime, similar to those at Lockport Prairie Nature Preserve.

Surface Water

Long Run Creek enters the center of the Long Run Parcel then bifurcates, with one branch flowing west to the Illinois and Michigan Canal and a second branch flowing south beyond the parcel boundary (fig. 22). The watershed for Long Run Creek is about 16,800 acres and extends about 8 mi east of the Long Run Parcel (Integrated Lakes Management, Inc., 2008). Discharge of Long Run Creek was measured monthly at the approximate middle of the bluff between High Road and New Avenue from March through September 2008 and ranged from 5.2 to 28.5 ft^3/s (Integrated Lakes Management, Inc., 2008).

The “south ditch” is present a few hundred feet south of the Long Run Parcel (fig. 22). This ditch flows from the bluff east of the parcel to the Illinois and Michigan Canal. South ditch intercepts Long Run Creek south of the Long Run Parcel, potentially diverting some of the creek flow.

Continuous measurements of surface-water levels were taken at streamgage LRS1 from June 2009 through December 2012 (Applied Ecological Services, Inc., 2012, 2013). This streamgage monitors Long Run Creek near its entrance to the Long Run Parcel (fig. 22). Water was present at the streamgage for most of the monitoring period, indicating inflow from the creek is a potentially substantial source of water to the wetlands in the southern part of the Long Run Parcel. Baseline water levels varied by less than 2 ft for most of the monitoring period and were lowest during the summer and highest during the winter and spring in response to annual cycles in snowmelt, precipitation, and evapotranspiration. Increases of as much as 4 ft were superimposed on these baseline water levels during precipitation events. Water levels were below the sensor during parts of September and October 2010 and from April through December 2012. The low water levels during 2012 were a response to drought.

There are a number of ponds, ditches, and rivulets in the Com Ed Parcel and the northern part of the Long Run Parcel that are hydraulically connected to Bruce Lake northwest of the Com Ed Parcel (fig. 22). Hourly measurements of surface-water levels were taken at streamgages WL3 and WL4, located at the pond at the northern edge of the Com Ed Parcel, and streamgage WL5, located at a rivulet in the west-central part of the parcel, from October 2005 through August 2008 (STS Consultants, 2007; STS/AECOM, 2008b, 2009). These streamgages were dry in response to drought prior to about December 2005 but had about 2 ft of water for the rest of the monitoring period. The average water level at all three streamgages was approximately 584.2 ft NAVD 88, with water levels at streamgage WL5 often being somewhat lower, particularly during the summer months. These data indicate that once the stage of the pond at streamgage WL4 exceeds about 582.5 ft NAVD 88, surface water can flow from Bruce Lake through the rivulets and ditches in the northeast part of the Com Ed Parcel into the Illinois and Michigan Canal near streamgage CES2 (STS Consultants, 2007; STS/AECOM, 2008b, 2009). Water from Bruce Lake is potentially a substantial source of water in the wetlands in the northwestern part of the Com Ed Parcel.

Surface water enters the northeast part of the Long Run Parcel through a culvert transmitting water from the upland area east of the Long Run Parcel, including the area of the oil spill. Water from the upland area is partly derived from seep flow. This water flowed to a former marsh area that is the current (2018) site of a pond associated with the excavated sediment in the northeast part of the Long Run Parcel. The marsh (pond) also receives discharge from upwelling groundwater and seeps. Surface water in the northern part of the Long Run Parcel flows from the pond through rivulets for about 1,000 ft to the west-northwest (fig. 22; STS Consultants, 2007; STS/AECOM, 2008b, 2009; AECOM, 2011). The drainage then intersects a rivulet draining from a small pond in the north-central part of the Long Run Parcel, which appears to be partly fed by rivulets draining wetlands to the south. The rivulets flow to the north, entering a wetland area that discharges to the Illinois and Michigan Canal near streamgage CES2 (STS/AECOM, 2009; AECOM, 2011). Discharge rates and surface-water levels in this area, which includes the HED larval habitat, have not been measured.

Continuous measurements of surface-water levels were taken from April 2006 through December 2012 at streamgage CES2 (Applied Ecological Services, Inc., 2012, 2013). This streamgage monitors water levels in soil adjacent to a rivulet that drains most of the Com Ed Parcel and the northern part of the Long Run Parcel at the point of discharge to the Illinois and Michigan Canal. Measurements at this streamgage are assumed to be representative of water levels in the rivulet. Water was present at the streamgage for most of the period of monitoring but was typically below ground surface (fig. 23), indicating only periodic flow of surface water from the Com Ed and Long Run Parcels. Baseline water levels typically varied by less than 1 ft and were consistently lowest during the summer and highest during the winter and spring in response to annual cycles in snowmelt, precipitation, and evapotranspiration. Water-level increases of as much as 4 ft were occasionally superimposed on these broad trends. These increases lasted 7–10 days and were associated with precipitation events resulting in surface-water discharge to the canal. There is nothing clearly anomalous in the 2011 water-level data at streamgage CES2 that could be attributed to the effects of post-December 2010 oil-spill remediation activities. Low

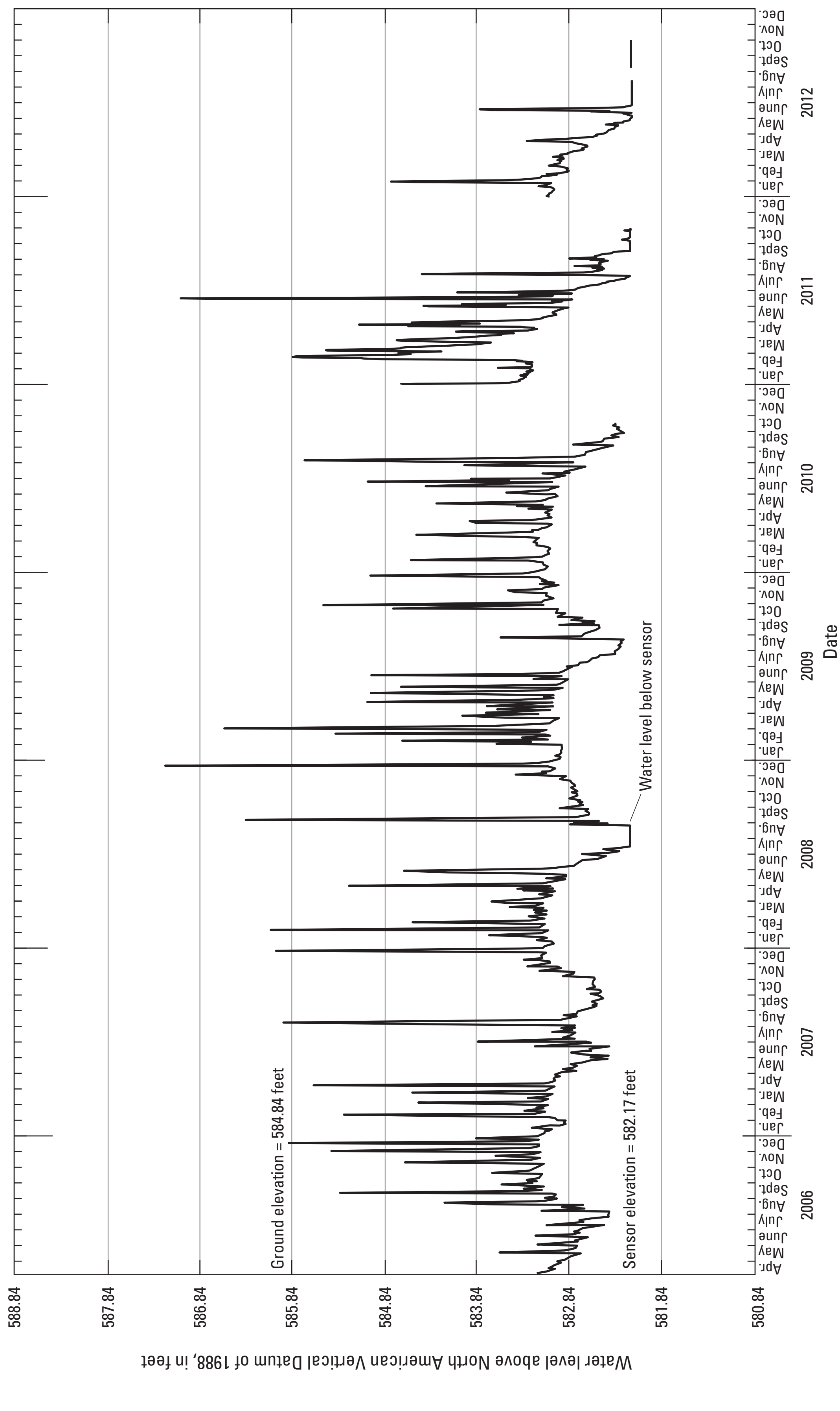


Figure 23. Water levels at streamgage CES2, Com Ed Parcel, Will County, Illinois, April 2006 through October 2012 (from Applied Ecological Services, Inc., 2012, 2013).

water levels observed after September 2011, although present for a somewhat longer than typical period of time, appear to be part of normal seasonal variations resulting from a lack of precipitation and elevated evapotranspiration in the wetlands. The low water levels observed during much of 2012 are likely a response to drought conditions.

Water Use

The groundwater recharge area for the Silurian aquifer at the Com Ed and Long Run Parcels (fig. 24) encompasses about 14,500 acres extending approximately 11 mi to the southeast of the parcels based on AECOM (2011) flow-net analysis of the potentiometric surface of the Silurian aquifer provided by Roadcap and others (1993). Several homes at the bluffs east of the Com Ed and Long Run Parcels draw water for domestic use from the Silurian aquifer. In addition, at least five high-capacity wells that draw water from the Silurian aquifer are located within the groundwater recharge area for the Com Ed and Long Run Parcels, with additional wells being contemplated. The volume of water discharged from the high-capacity wells on an annual basis is unknown but is likely to exceed 2.0 Mgal/d based on 2016 population estimates for Lockport (U.S. Census Bureau, 2017) and an 80-gal/d per capita water use. The effect of pumping from these wells on water levels and flow at the Com Ed and Long Run Parcels has not been investigated.

It is assumed that the CSSC is a hydraulic boundary to groundwater flow that prevents drawdown due to pumping at the East Quarry from migrating to the east beneath the CSSC in the deeper part of the Silurian aquifer (figs. 9, 10); therefore, increased pumping in support of quarry expansion at the West or Middle Quarries is expected to have no effect on the hydrology of the Com Ed and Long Run Parcels (AECOM, 2013a). The validity of this assumption will be checked by ongoing water-level monitoring at the parcels by the Quarry operators (Hanson Material Service Corporation, 2016).

Water Quality

Groundwater samples were collected from 2005 through 2007 from several wells open to the alluvial aquifer and the Silurian aquifer at the Com Ed and Long Run Parcels (STS/AECOM, 2009; Applied Ecological Services, Inc., 2012; AECOM, 2013a,b). Surface-water samples were collected during 2006 and 2007 from the two ponds in the northwest part of the Com Ed Parcel (Applied Ecological Services, Inc., 2012). This sampling was done in support of investigations into the HED habitat (table 9).

Calcium and bicarbonate (measured as alkalinity) were the dominant cation and anion in these samples (table 9). Chloride concentrations typically were high enough to indicate the presence of road salts and were higher in the shallow wells at each well cluster. Sulfate concentrations were higher in the deep well, indicating a natural source. Phosphorous concentrations in surface water were often above regulatory criteria for flowing water (0.1 mg/L), especially at streamgage CES2. Total Kjeldahl nitrogen concentrations (if present as ammonia) also exceeded regulatory criteria in some of the surface-water samples. Nitrate as nitrogen concentrations were less than 1.5 mg/L, which is below levels indicative of the presence of anthropogenic contamination. The pH values were slightly alkaline at 7.5–7.8.

Surface-water samples were collected during December 2010 and January 2011 to assess the effects of the pipeline break in the east-central part of the Com Ed and Long Run Parcels. Benzene was detected in the rivulet flowing from the excavated area to the outfall to the Illinois and Michigan Canal at S12 (fig. 25). Concentrations were above acute screening levels (table 3) near the pond excavation. Post-remediation sampling performed during September 2016 did not detect benzene in surface water at the locations where samples were collected.

Groundwater samples also were collected during 2013 from 13 wells open to the Silurian aquifer to assess the effects of the pipeline break (fig. 25). Benzene was detected at the northeast part of the boundary between the parcels at concentrations as high as 3,780 µg/L; however, concentrations were below 1 µg/L within about 1,000 ft of the pipeline break. Post-remediation sampling from these wells performed in September 2016 detected benzene concentrations in groundwater that were substantially lower than during April 2012, with detections only in the vicinity of the railroad. Benzene concentrations remain above the MCL (table 3) near the location of the pipeline break. Residual contamination in the form of oil sheen and seeps was observed near the railroad tracks (Groundwater and Environmental Services, Inc., 2017).

Surface water and groundwater in the Com Ed and Long Run Parcel is alkaline with a neutral to alkaline pH. Ranges in constituent concentrations typically were similar for surface water and groundwater and indicate the Silurian aquifer is the primary source of surface water. The EPA flowing water criteria for phosphorus are exceeded in some samples. The chemistry of this water, particularly the surface water, is affected by anthropogenic processes such as the application of road salts. The presence of oil associated with a historical pipeline break affected surface-water quality along the flow pathways in much of the center of the parcel and groundwater quality in the eastern part of property along the boundary between the parcels.

Assessment of Water Resources at the Long Run Seep Nature Preserve

The Long Run Seep Nature Preserve is an 80-acre parcel located east of the Com Ed and Long Run Parcels (fig. 1). The portion of the parcel of concern for the HED is the hillside between New Avenue, High Road, South Ditch, and Long Run Creek where a number of groundwater seep-fed rivulets are located (fig. 26).

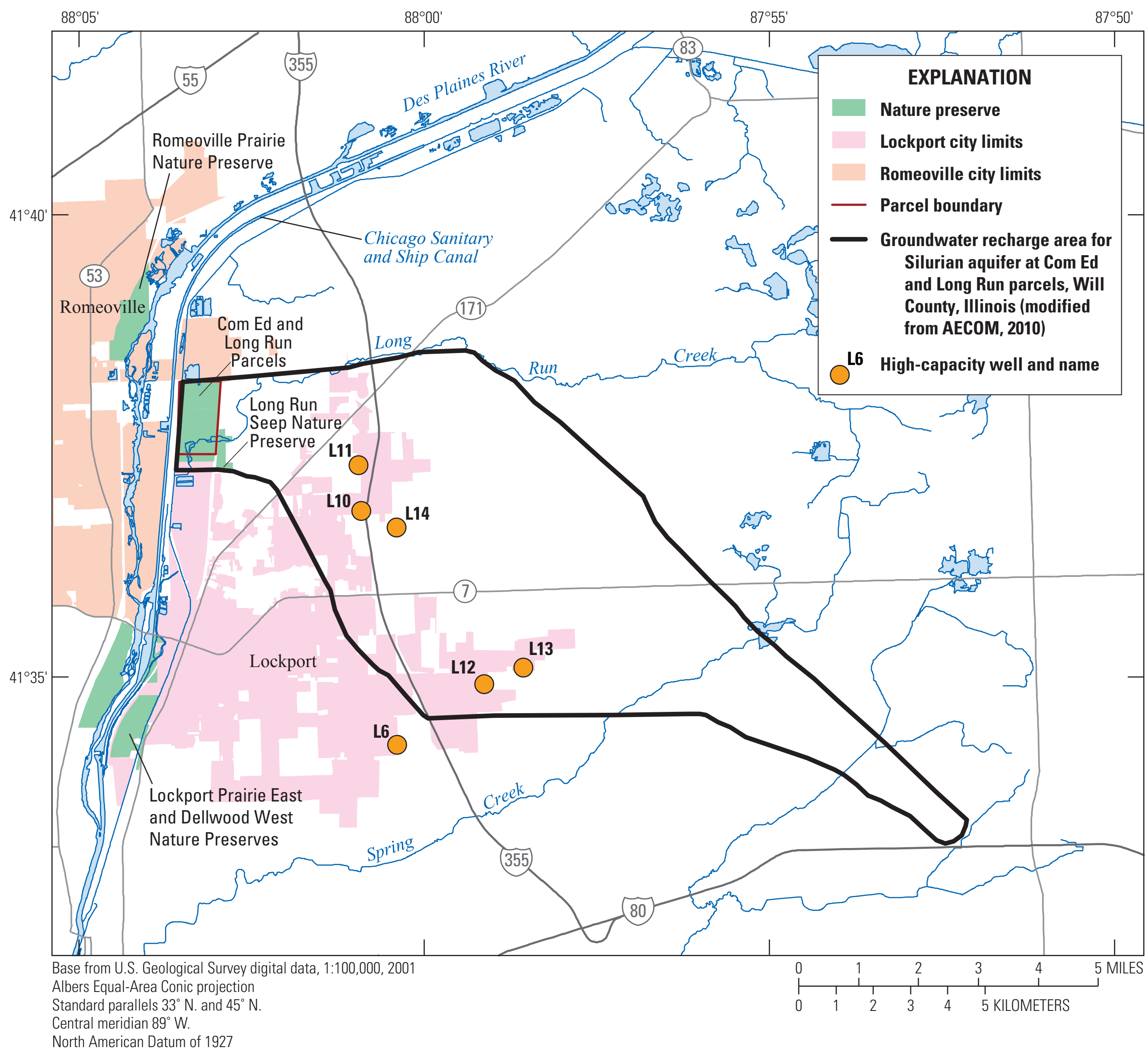


Figure 24. Groundwater recharge area for the Com Ed and Long Run Parcels, and location of high-capacity pumping wells, Will County, Illinois (modified from AECOM, 2011).

Table 9. Concentration of selected constituents in surface water and groundwater at the Com Ed and Long Run Parcels, Will County, Illinois, 2005 through 2007.

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Total Kjeldahl nitrogen, in mg/L
Silurian aquifer well CEP-5S (location shown in fig. 22, data from STS/AECOM, 2009)										
10/27/05	360	82	15	102	46	13	<0.01	--	--	--
6/05/06	310	73	16	80	35	9.8	--	--	--	--
Silurian aquifer well CEP-1S (location shown in fig. 22, data from STS/AECOM, 2009)										
10/25/05	280	184	109	104	53	48	<0.01	--	--	--
6/05/06	310	172	96	88	46	44	--	--	--	--
Silurian aquifer well CEP-1D (location shown in fig. 22, data from STS/AECOM, 2009)										
10/27/05	450	188	69	148	70	27	<0.01	--	--	--
6/05/06	430	220	48	135	61	20	--	--	--	--
Silurian aquifer well CEP-3S (location shown in fig. 22, data from STS/AECOM, 2009; AECOM, 2013a)										
10/27/05	490	126	120	132	60	48	<0.01	--	--	--
6/02/06	380	148	128	121	54	45	--	--	--	--
5/20/11	280	130	140	160	85	80	--	--	--	--
10/13/11	380	110	160	160	80	68	--	--	--	--
Silurian aquifer well CEP-3D (location shown in fig. 22, data from STS/AECOM, 2009; AECOM, 2013a)										
10/27/05	460	125	128	131	612	49	<0.01	--	--	--
6/02/06	410	160	110	117	54	39	--	--	--	--
5/20/11	310	150	100	150	79	51	--	--	--	--
10/13/11	390	150	110	130	67	42	--	--	--	--
Silurian aquifer well CEP-2S (location shown in fig. 22, data from STS/AECOM, 2009; AECOM, 2013a)										
10/27/05	430	173	108	133	60	76	<0.01	--	--	--
6/02/06	380	189	118	124	54	46	--	--	--	--
5/20/11	220	130	130	130	57	72	--	--	---	--
10/13/11	360	180	39	110	57	30	--	--	--	--

Table 9. Concentration of selected constituents in surface water and groundwater at the Com Ed and Long Run Parcels, Will County, Illinois, 2005 through 2007.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; -, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Total Kjeldahl nitrogen, in mg/L
Silurian aquifer well CEP-2D (location shown in fig. 22, data from STS/AECOM, 2009; AECOM, 2013a)										
10/25/05	450	178	62	116	59	42	<0.01	--	--	--
6/02/06	410	208	46	47	51	100	--	--	--	--
5/20/11	260	180	38	110	58	31	--	--	--	--
10/13/11	370	130	130	120	56	63	--	--	--	--
Silurian aquifer well CEP-4S (location shown in fig. 22, data from STS/AECOM, 2009)										
10/25/05	470	169	140	131	64	80	<0.01	--	--	-
6/05/06	230	203	130	112	49	94	--	--	--	-
10/13/11	360	160	180	120	56	94	--	--	--	-
Silurian aquifer well CEP-4D (location shown in fig. 22, data from STS/AECOM, 2009)										
10/25/05	410	263	94	161	78	36	<0.01	--	--	--
6/05/06	430	267	88	153	72	33	--	--	--	--
Alluvial deposit well CE-W1 (location not shown, data from Applied Ecological Services, Inc., 2012)										
04/19/06	280	30	4.2	68	29	8.9	0.50	1.4	<0.02	--
10/19/06	255	40	1.0	83	37	13	0.35	0.09	<0.02	<0.60
Surface water at streamgage WL4 (location shown in fig. 22, data from Applied Ecological Services, Inc., 2012)										
4/18/06	314	14	130	116	51	40	0.13	1.3	<0.02	1.0
7/19/06	148	68	98	20	36	48	0.16	<0.05	0.04	3.0
10/19/06	255	62	90	86	45	49	0.04	<0.01	<0.02	<0.60
4/30/07	126	73	77	63	40	43	0.53	0.15	<0.02	0.93
7/25/07	308	47	91	48	40	34	0.61	0.17	<0.02	<0.60
10/24/07	299	50	150	68	63	38	0.19	0.09	0.35	<0.60

Table 9. Concentration of selected constituents in surface water and groundwater at the Com Ed and Long Run Parcels, Will County, Illinois, 2005 through 2007.—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; -, no sample; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Iron, in mg/L	Nitrate as nitrogen, in mg/L	Phosphorous, in mg/L	Total Kjeldahl nitrogen, in mg/L
Surface water at streamgage CES2 (location shown in fig. 22, data from Applied Ecological Services, Inc., 2012)										
4/18/06	184	130	180	63	29	56	0.73	1.4	0.19	1.0
7/19/06	232	31	81	92	44	44	0.09	<0.05	0.26	2.7
10/19/06	226	70	66	68	31	41	0.65	0.14	0.22	<0.60
4/30/07	102	65	76	61	32	43	0.28	0.17	0.09	0.73
7/25/07	318	150	63	75	44	28	0.36	0.18	0.06	<0.60
10/24/07	472	94	83	150	63	38	0.86	0.58	0.10	<0.60
Silurian aquifer well CEP-10S (location shown in fig. 22, data from AECOM, 2013a)										
5/27/11	280	110	95	98	47	55	--	--	--	--
10/13/11	430	45	150	120	53	55	--	--	--	--
Silurian aquifer well CEP-11S (location shown in fig. 22, data from AECOM, 2013a)										
5/20/11	200	77	13	79	50	12	--	--	--	--
10/13/11	300	89	18	77	43	8.6	--	--	--	--
Silurian aquifer well CEP-11D (location shown in fig. 22, data from AECOM, 2013a)										
5/20/11	280	190	7.5	91	66	48	--	--	--	--
10/13/11	340	210	3.7	110	62	23	--	--	--	--
Silurian aquifer well CEP-12S (location shown in fig. 22, data from AECOM, 2013a)										
5/20/11	270	230	77	110	64	55	--	--	--	--
10/13/11	360	190	69	110	56	74	--	--	--	--

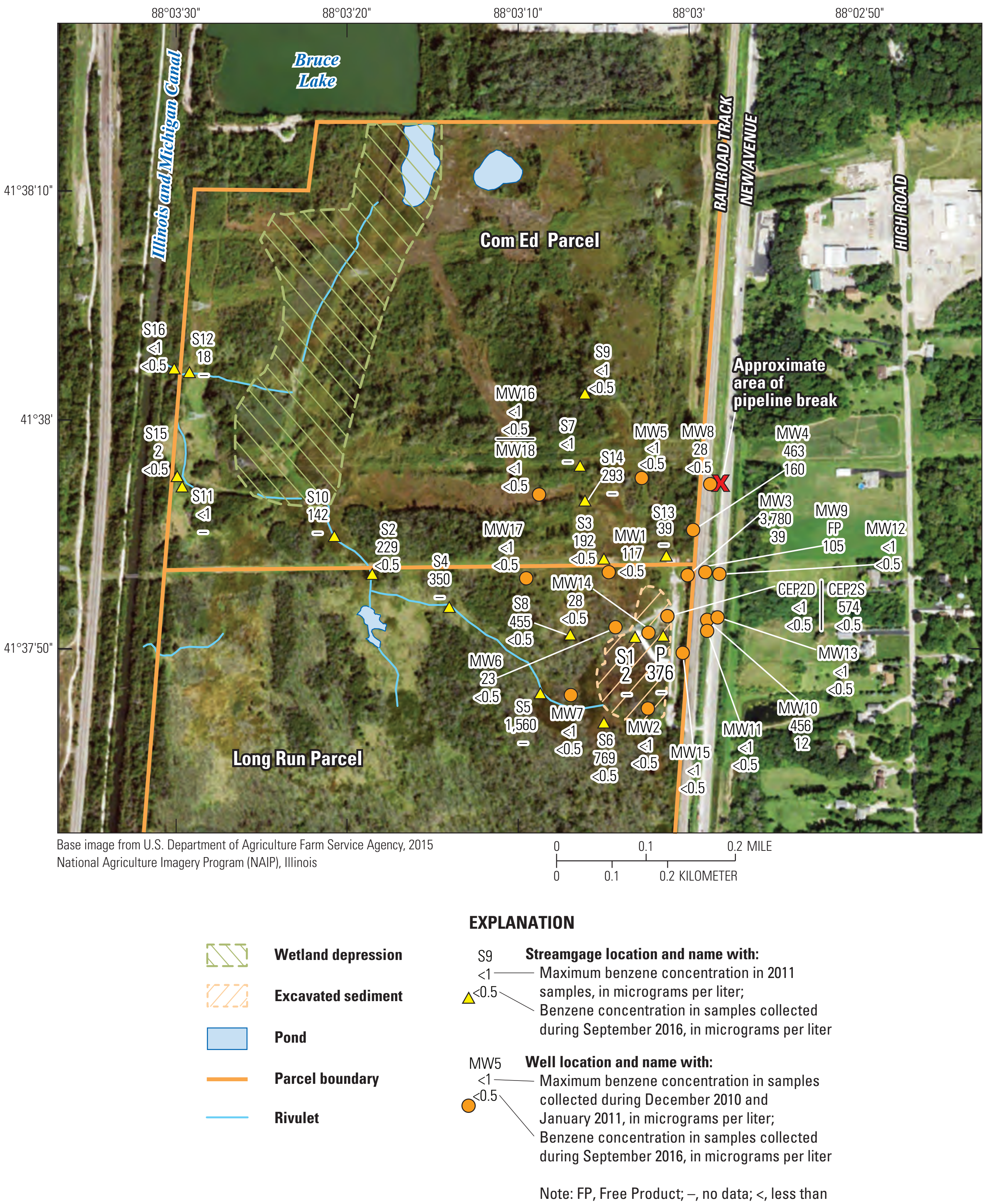
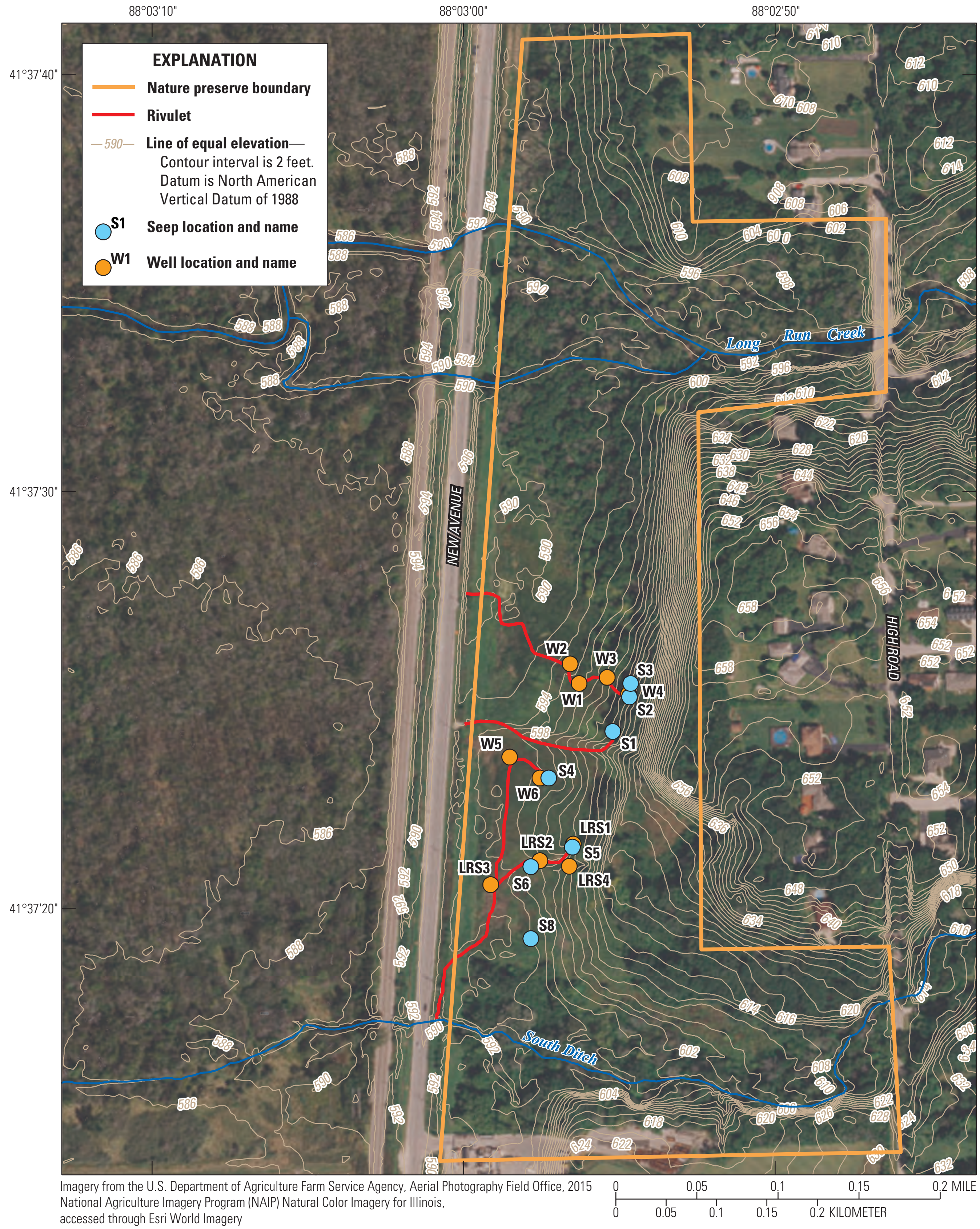


Figure 25. Concentration of benzene in surface water and groundwater after oil spill, Com Ed and Long Run Parcels, Will County, Illinois (modified from Antea Group, 2012).



Imagery from the U.S. Department of Agriculture Farm Service Agency, Aerial Photography Field Office, 2015
National Agriculture Imagery Program (NAIP) Natural Color Imagery for Illinois,
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Figure 26. Location of selected features at the Long Run Seep Nature Preserve, Will County, Illinois.

Topography

The Long Run Seep Nature Preserve occupies the hillside near the bluff along the eastern part of the Des Plaines River Valley (fig. 26). The parcel slopes toward the river from an elevation of about 650 ft NAVD 88 near the top of the bluff in the eastern part of the parcel near High Road to about 590 ft at the base of the bluff at New Avenue (figs. 4, 26).

Biology

The HED has documented larval and adult use at the Long Run Seep Nature Preserve (fig. 2). Larval habitat is present along the rivulet emanating from seep S4 (fig. 26; Hanson Material Service Corporation, 2016). Larval populations were estimated to average 46 individuals during surveys from 1995 through 2011, making the Long Run Seep Nature Preserve at least periodically the third most productive larval habitat in Illinois (Soluk and Mierzwa, 2012). Adult use at the site includes egg laying, feeding, foraging, and territorial patrols (Cashatt and Vogt, 1996). Adult populations were estimated to be between 2 and 9 individuals (Mierzwa and Webb, 2010; U.S. Fish and Wildlife Service, 2013b).

Hydrogeology

Construction logs for residential wells in the vicinity of the Long Run Seep Nature Preserve obtained from the Illinois State Geological Survey (ISGS) from their well log database (Illinois State Geological Survey, [n.d.]) indicate that the Silurian aquifer is present below an elevation of about 590 ft, the approximate elevation of the land surface at New Avenue (fig. 4, 26). The Silurian aquifer is overlain by 2–50 ft of sand and gravel constituting the glacial drift aquifer, which intersects the lower part of the hillside at the Long Run Seep Nature Preserve. The glacial drift aquifer is overlain by 15–30 ft of silt and clay deposits forming a semiconfining unit, which intersects the topographic upland.

Periodic measurements of groundwater levels taken from September 20, 2006, through December 4, 2008, in wells open to the upper 5 ft of the glacial drift aquifer (fig. 26) indicate the depth to water was less than 1.5 ft below land surface in every well except LRS1; was periodically less than 0.5 ft above land surface at wells W5, W6, and LRS3 on the lower part of the bluff; and varied by less than 1 ft in any well (Integrated Lakes Management, Inc., 2008). Water levels collected by the USGS during July 2012 varied from less than 1.5 ft below land surface at wells LRS1 and LRS2 to less than 0.5 ft above land surface at wells LRS3 and LRS4 (table 1). These data indicate that recharge to the glacial drift aquifer through the overlying semiconfining unit is likely to sustain at least some of the seeps in this area, even during drought conditions. These data are consistent with the seeps being derived from groundwater emanating from the glacial drift aquifer.

Surface Water

Long Run Creek is present in the northern part of the Long Run Seep Nature Preserve and South Ditch approximates the southern boundary. The Long Run Creek watershed (which includes South Ditch) occupies an area of 26.3 mi^2 and extends about 5 mi east of the preserve (Integrated Lakes Management, Inc., 2008). Because conditions at Long Run Creek and South Ditch do not affect the HED habitat, they are not discussed in this report.

Seep-fed rivulets are located along the hillside between Long Run Creek and South Ditch at elevations below about 610 ft (fig. 26; Integrated Lakes Management, Inc., 2008). These seeps emanate from the unconsolidated deposits. Water from these rivulets is blocked by ditches along New Avenue and diverts to the South Ditch. Seeps also have been identified along the hillslope in the southeast part of the Long Run Seep Nature Preserve north of South Ditch (TAMS Consultants, Inc., 1995b).

Water Quality

Surface water was collected at the Long Run Seep Nature Preserve on four occasions during 1991 (Cashatt and Vogt, 1992). The samples were analyzed for major ions, several metals, and nutrients. The water body, location, and dates of sampling are not described. Concentrations of major ions showed minimal variation. Calcium was the dominant cation (112–132 mg/L) with substantial concentrations of magnesium (about 59 mg/L) and sodium (about 35 mg/L). Alkalinity ranged from 358 to 375 mg/L as $CaCO_3$, with substantial concentrations of chloride (70–75 mg/L) and sulfate (114–131 mg/L). The pH values were alkaline at 7.9–8.2. Nitrate concentrations ranged from 2.1 to 7.6 mg/L, indicating an anthropogenic component to at least some of the samples. Concentrations of all constituents, including serval trace metals and nutrients, were below regulatory criteria.

Surface-water samples were collected approximately monthly from August 1997 through November 1998 at an unidentified location at the Long Run Seep Nature Preserve (Soluk and others, 1999). These samples were analyzed for a variety of metals, nutrients, and major ions. Bicarbonate was the dominant anion (as measured from alkalinity values) with approximately equal concentrations of sulfate and chloride (table 10). Concentrations of DO were greater than 7.0 mg/L and typically were higher during 1998 than 1997 sampling events. No constituent was detected above regulatory criteria.

Water samples were collected at the seeps four times from March 9 through April 21, 2006 (Integrated Lakes Management, Inc., 2008). The average temperature ranged from about 7.3–10.5 ^{o}C and typically was substantially higher on April 21 than during the other sampling events, indicating that the readings were influenced by atmospheric temperatures. Concentrations of DO typically ranged from 4 to 10 mg/L and tended to be lowest at seeps 4 and 8. The pH was 7.0–8.2. Alkalinity values were typically between 350 and 450 mg/L

Table 10. Concentration of major ions and nutrients in surface water at the Long Run Seep Nature Preserve, Will County, Illinois, August 1997 through November 1998 (from Soluk and others, 1998).

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; <, less than; --, no data]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Amnonia, in mg/L	Nitrate as nitrogen, in mg/L	Dissolved oxygen, in mg/L	Total phosphorous, in mg/L
8/21/97	375	134	113	129	69	59	0.04	1.4	8.7	0.02
9/24/97	315	144	124	123	64	57	0.04	1.5	7.9	0.02
10/30/97	385	152	129	119	60	46	0.01	1.5	7.7	<0.01
11/19/97	386	141	119	127	67	62	<0.01	1.5	8.3	0.02
12/17/97	382	122	105	132	67	59	0.05	1.4	--	0.02
1/30/98	375	132	106	133	71	65	<0.01	**1.3**	9.0	0.02
3/26/98	367	154	122	141	74	67	0.03	**1.3**	9.5	<0.01
4/29/98	370	184	150	131	69	65	0.02	1.0	10.6	0.03
5/21/98	384	150	127	121	64	61	0.02	1.3	8.8	0.02
6/19/98	360	146	107	124	65	58	0.04	1.2	10.0	0.03
7/23/98	355	147	112	139	67	62	0.02	1.0	9.5	0.06
8/25/98	374	144	111	127	69	62	0.03	1.2	9.4	0.03
9/15/98	368	150	114	129	70	62	<0.01	1.2	8.4	0.04
10/30/98	341	159	133	136	73	67	0.05	1.2	9.5	0.03
11/19/98	326	155	122	131	69	32	0.04	1.2	10.5	0.05

as $CaCO_3$. Average chloride concentrations ranged from 85 to 280 mg/L, with several samples exceeding the EPA chronic threshold for aquatic life of 230 mg/L (table 3).

Samples were collected in April and December 2007 and April, July, and October 2008 from each of the wells (fig. 26; Integrated Lakes Management, Inc., 2008). These wells are open to the glacial drift aquifer. Alkalinity ranged from 257 to 1,000 mg/L as $CaCO_3$ but was typically between 300 and 500 mg/L as $CaCO_3$. Chloride concentrations ranged from 160 to 260 mg/L, exceeding the EPA chronic threshold for aquatic life of 230 mg/L in several samples. Chloride concentrations tended to be highest in April 2008, likely indicating the presence of roadside runoff. Groundwater temperature varied seasonally, being lowest (about 4–9 ^{o}C) during December 2007 and highest (about 15–19 ^{o}C) during July 2008. The pH was neutral to alkaline, ranging from about 6.6 to 8.2. Concentrations of nitrogen as nitrate ranged from <0.01 to 2.2 mg/L and typically were less than 1 mg/L. Concentrations of DO ranged from about 2 to 10 mg/L. Concentrations of total phosphorus as P often were above the EPA criteria for open water of 0.1 mg/L.

Water quality at the Long Run Seep Nature Preserve is affected mainly by the dissolution of dolomite and other carbonate minerals present in the unconsolidated deposits. Application of road salts appears to result in the concentrations of chloride occasionally above regulatory limits in both surface water and groundwater. The presence of somewhat elevated concentrations of nitrate in some of the surface-water samples indicates that fertilizer application or discharge from nearby septic systems may be affecting water quality.

Assessment of Water Resources at the Romeoville Prairie Nature Preserve

The Romeoville Prairie Nature Preserve is located north of the Quarry in Will County (figs. 1, 27). The Romeoville Prairie Nature Preserve is about 155 acres in size and has been the subject of minimal biologic and hydrologic characterization.

Topography

The Romeoville Prairie Nature Preserve occupies the flood plain of the Des Plaines River Valley. Surface topography at the Romeoville Prairie Nature Preserve has minimal relief, with a typical elevation of 585–590 ft NAVD 88 (figs. 4, 27). The bluff that defines the boundary of the Des Plaines River Valley has lower relief than at some of the other sites and is located as much as about 0.5 mi west of the Romeoville Prairie Nature Preserve.

Biology

Adult use for transit has been documented at the site during a small number of surveys. Recent observations of a copulating pair of HED and a teneral adult (an adult that has recently molted) indicate that larval habitat may exist along a rivulet in the center of the Romeoville Prairie Nature Preserve (fig. 27; Soluk and Mierzwa, 2012). This site has less forest vegetation than many of the other HED habitats, potentially reducing its suitability as habitat.

Hydrogeology

The Romeoville Prairie Nature Preserve is underlain by 1–2.5 ft of partly saturated alluvium and clayey topsoil. Continuous measurements of groundwater levels were taken from January through September 2006 at well points 1 through 4 (Graef, Anhalt, Schloemer, and Associates, Inc., 2007a). These well points are open to the alluvial aquifer along a northwest-southeast transect (fig. 27). Baseline water levels decreased from about 585.6 ft in the northwest well 2 to about 584.2 ft in the southeast well 4, indicating flow toward the river under typical conditions. Water levels showed numerous several-day-long increases of about 1 ft in response to precipitation events and possibly high water in the Des Plaines River. Water levels also showed numerous several-day-long decreases of about 0.5 ft during June through August that were likely in response to evapotranspiration.

Continuous measurements of groundwater levels were taken from May 2005 through August 2006 in well RPPW4 and well S (Graef, Anhalt, Schloemer, and Associates, Inc., 2007a). These wells are open to the upper part of the Silurian aquifer in the west-central part of the Romeoville Prairie Nature Preserve. Water levels in well RPPW4 were about 591.5 ft during the summer months in 2005 and 2006 and increased to about 592.7 ft during the intervening winter. Numerous increases of about 1–2 ft associated with precipitation events were superimposed on the baseline, indicating hydraulic interconnection within the upper part of the aquifer. Baseline water levels in well S increased from about 588 ft during the (drought) summer of 2005 to about 590.8 ft after January 2006 as the 2005 drought ended.

Surface Water

A creek is located along the southwestern boundary of the Romeoville Prairie Nature Preserve (fig. 1). Numerous creeks and ponds also are present in the northern part of the Romeoville Prairie Nature Preserve. These water bodies do not appear to affect hydrologic conditions at the HED habitat in the center of the Romeoville Prairie Nature Preserve and are not discussed further.

Several seeps are present along a northeast to southwest trending line in the middle of the preserve at an elevation of about 587 to 589 ft (fig. 27). Unlike many of the other sites where discharging groundwater at the base of the bluffs is the source of water to the seeps, these seeps appear to be recharged by upwelling groundwater. The location of the seeps and identified upwelling groundwater may indicate flow from

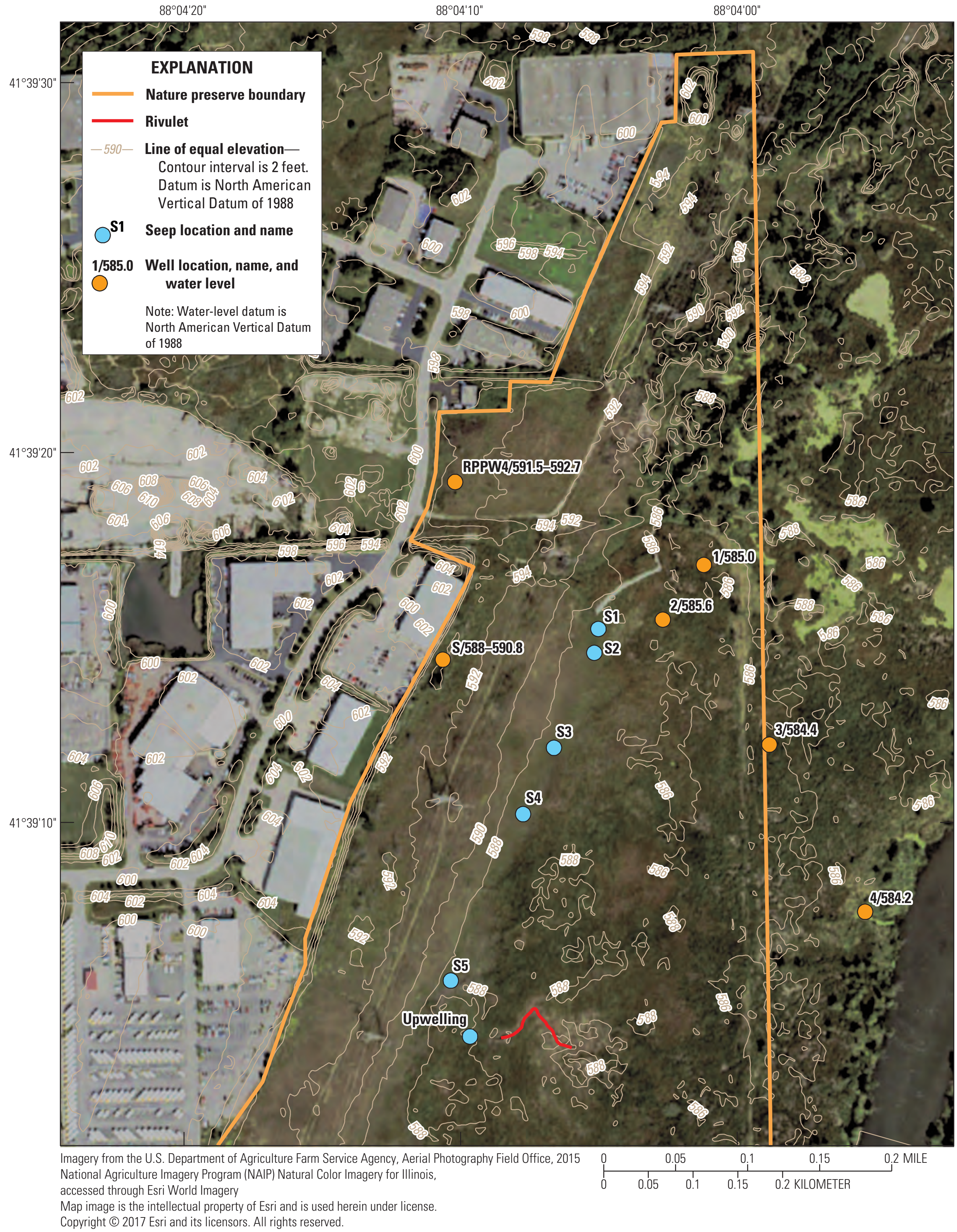


Figure 27. Location of selected features in the central and northern part of the Romeoville Prairie Nature Preserve, Will County, Illinois. Baseline water levels, May 2005–September 2006, from Graef, Anhalt, Schloemer, and Associates, Inc., (2007a).

a permeable feature in the Silurian aquifer to the wetlands. The seeps provide water to a network of rivulets in the center of the Romeoville Prairie Nature Preserve that flow to wetlands in the eastern part of the preserve and then to the Des Plaines River. The only described rivulet is the one with HED shown in figure 27.

Water Use

The groundwater recharge area for the Silurian aquifer to the Romeoville Prairie Nature Preserve extends about 2.3 mi to the northwest, terminating just north of Interstate I-55 (fig. 28; Locke and others, 2005). High-capacity well R#1 withdraws water from the Silurian aquifer within this recharge area. High-capacity wells R#3 and R#5 withdraw water from the Silurian aquifer within 0.5 mi of the recharge area. The volume of water pumped from wells R#1, R#3, and R#5 during 2010 was estimated to be 360,000; 780,000; and 120,000 gal/d, respectively (AECOM, 2012). Available data (Graef, Anhalt, Schloemer, and Associates, Inc., 2007a; figs. 9, 10) do not clearly indicate that pumping affects water levels in the shallow groundwater at the Romeoville Prairie Nature Preserve; however, the effect of this high-capacity pumping on the hydrology of the Preserve needs to be investigated.

A quarry is located along the Des Plaines River about 3,000 ft northeast of the Romeoville Prairie Nature Preserve (fig. 3). The elevation of the base of the quarry excavation is 490 ft according to Google Earth™. The quarry is dry, indicating that pumping at the quarry has dewatered the Silurian aquifer to an elevation of less than 490 ft. The volume of pumping from this quarry, and its effects on the hydrology of the Romeoville Prairie Nature Preserve, are unknown.

Model simulations indicate that the additional groundwater withdrawals associated with dewatering of the West Quarry and Middle Parcel Expansion Areas will not affect the hydrology at the Romeoville Prairie Nature Preserve (AECOM, 2012, 2013a). Water-level measurements will be collected at the Romeoville Prairie Nature Preserve by the Quarry operators to assess the future pumping effects from the Quarry. If future pumping associated with the Quarry expansion is determined to affect groundwater north of the Quarry, mitigation efforts have been proposed (Hanson Material Service Corporation, 2016).

Water Quality

A surface-water sample was collected in 1991 from the Romeoville Prairie Nature Preserve. This sample was analyzed for major ions, several metals, and nutrients (Cashatt and Vogt, 1992). The location and date of sampling are not described. Calcium was the dominant cation (118 mg/L) with substantial concentrations of magnesium (57 mg/L) and sodium (96 mg/L). The alkalinity value was 316 mg/L as $CaCO_3$, with high concentrations of chloride (215 mg/L) and sulfate (113 mg/L). The pH was 7.9. Concentrations of nitrate (15 mg/L) and arsenic (120 µg/L) exceeded their MCLs (table 3). Concentrations of arsenic are anomalously high and warrant further characterization. Concentrations of the remaining analytes were below regulatory criteria. These values indicate that road salt and fertilizer application may have affected the chemistry of the sample.

Assessment of Water Resources at the Keepataw Forest Preserve

The Keepataw Forest Preserve is located north of the Des Plaines River, south of Bluff Road, and west of Interstate I-355 in Will County (figs. 3, 29). The Keepataw Forest Preserve is about 215 acres in size and has been the subject of minimal biologic and hydrologic characterization. Construction of Interstate I-355 began in this area in 2004 (Plankell, 2014). The roadway was opened for use in 2007.

Topography

The Keepataw Forest Preserve occupies the flood plain of the Lower Des Plaines River Valley, typically at an elevation of about 587–600 ft NAVD 88 (fig. 29). Land-surface elevation increases to as much as about 670 ft at the top of the bluff south of Bluff Road. Land-surface elevation increases to more than 700 ft at the topographic uplands north of Bluff Road. There is a shallow "U" shaped depression directly south of the seeps at the bottom of the bluff. The low point of this depression appears to be near seep 6.

Biology

The larvae of HEDs have been identified at the Keepataw Forest Preserve near seeps 1, 3, 4, 6, and 7 (Soluk and Mierzwa, 2012; Soluk and others, 2015). The highest larvae populations were estimated at seeps 3 (average of 55 from 2004 to 2010) and 1 (average of 36 from 2004 to 2010), two of the westernmost seeps, with a total larvae population in seeps 1, 3, and 6 of 80 in 2014 (Soluk and others, 2015). These habitats appear to be located in the topographic depression south of the bluffs. The adult population was estimated to be 10 individuals. Adult use for foraging, travel, and territorial patrol has been observed south of the bluff at the Keepataw Forest Preserve (Soluk and others, 2010). The growth rate for captive HED larvae at man-made rivulets south of the seeps is lower than in natural habitats (Soluk and others, 2015). The lower growth rate is due to an environmental factor other than food availability.

Hydrogeology

Boring logs obtained from the ISGS database (Illinois State Geological Survey, [n.d.]) indicate the elevation of the top of the Silurian dolomite at the Keepataw Forest Preserve is about 584 ft NAVD 88 near Interstate I-355 about 1,500 ft

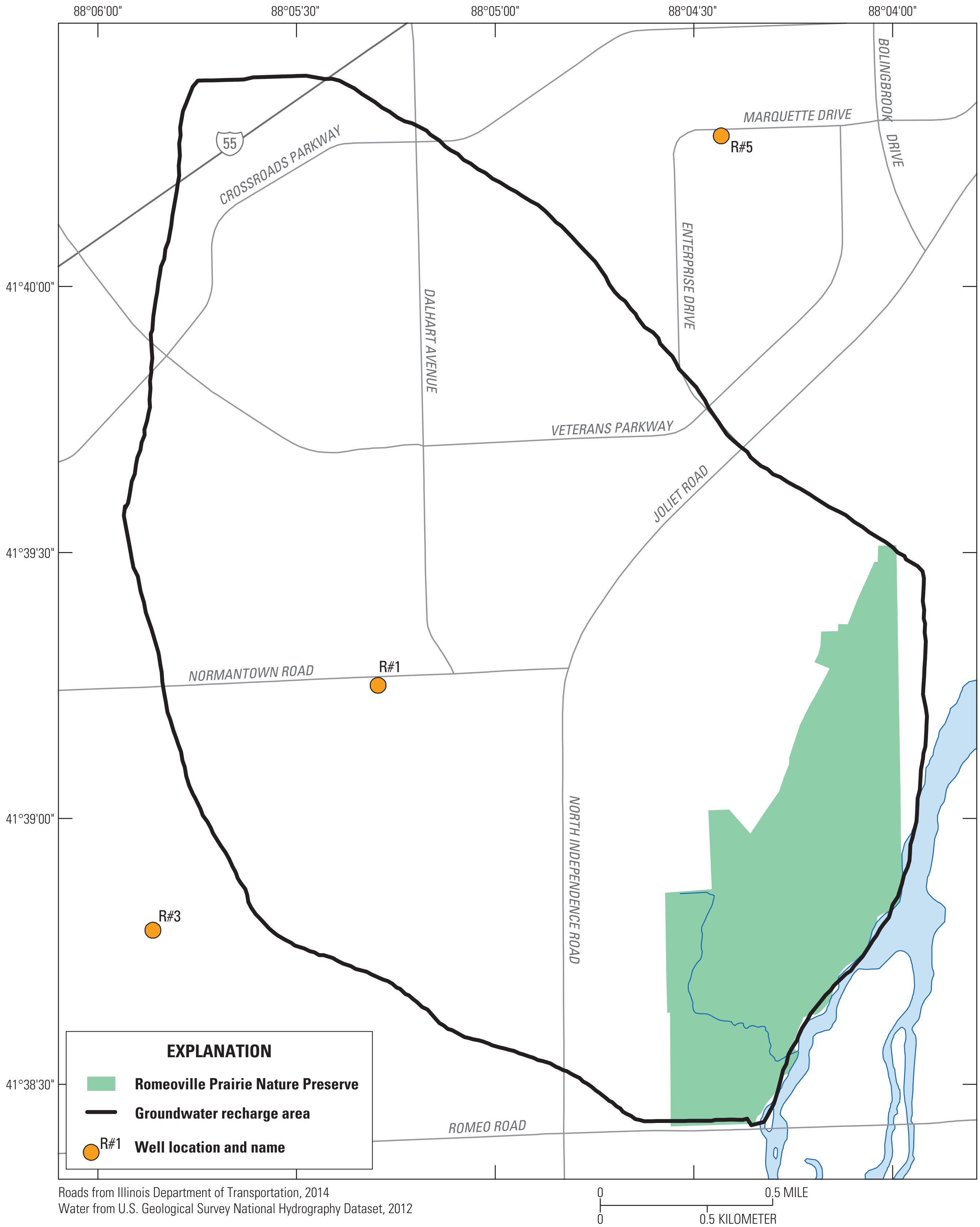


Figure 28. Location of groundwater recharge area for the Silurian aquifer to the Romeoville Prairie Nature Preserve and selected high-capacity wells, Will County, Illinois (modified from Locke and others, 2005).

Figure 29. Location of selected features in the eastern part of the Keepataw Forest Preserve, Will County, Illinois.

north of the Des Plaines River. The overlying unconsolidated deposits consist of a mixture of silt and clay till with sand and gravel lenses. The unconsolidated deposits are likely to be 1–2 ft thick near the Des Plaines River, increasing to about 20 ft south of the bluff, and are more than 90 ft north of Bluff Road. Groundwater is present in the unconsolidated deposits and the underlying Silurian aquifer at the Keepataw Forest Preserve.

Surface Water

Several seeps are present in the Keepataw Forest Preserve along a northeast to southwest trending line on the face of the bluff at an elevation between about 590 and 597 ft NAVD 88 (fig. 29). Based on the bedrock elevation at nearby borings, the seeps are emanating from the unconsolidated deposits. These seeps were documented as having water during the entirety of the droughts of 1988–89 and 2005 (Soluk and Mierzwa, 2012), which indicates stable flow from the lower part of the thick unconsolidated deposits in the topographic uplands north of the Keepataw Forest Preserve.

The shallow topographic depression south of the seeps appears to be part of an intermittent surface-water drainage entering from the northeast part of the Keepataw Forest Preserve. This drainage receives overland runoff from Interstate I-355 east of the preserve and a commercial park north of the preserve. Some portion of this runoff may flow south out of the depression by way of a rivulet in the topographic gap south of seep 6, potentially reducing water velocity and erosion west of seep 6 at the primary HED habitats near seeps 1 and 3. A network of additional rivulets is present at the Keepataw Forest Preserve that transmits surface water to ponds and wetlands in the southern part of the Keepataw Forest Preserve and to the Des Plaines River (Soluk and others, 2010). The elevation of the ponds in the center of the preserve south of the seeps is about 587 to 589 ft NAVD 88 based on figure 29.

Water Use

The elevation of the base of the quarry southwest of the Keepataw Forest Preserve (fig. 3) is about 481 ft according to Google Earth™. The quarry is dry, indicating that pumping at the quarry has dewatered the Silurian aquifer to an elevation of less than 481 ft. The volume of pumping from the Silurian aquifer and its effect on the hydrology of the Keepataw Forest Preserve is unknown.

Water Quality

Surface-water samples were collected approximately monthly from August 1997 through November 1998 from seeps 1, 2, 3, and 4 (fig. 29; Soluk and others, 1999). All of the waters were alkaline (table 11), with substantial concentrations of sulfate and chloride. Calcium was the dominant cation, with substantial concentrations of magnesium and sodium. Excepting the (potentially erroneous) calcium, magnesium, and sodium data from seeps 1 and 2 during March 1998 and perhaps the periodically low chloride at seep 3 (the westernmost seep) during August 1997 and December 1997 through April 1998, concentrations of major ions were generally consistent between sampling events and sites. Nitrate and ammonia concentrations were low at all sites.

Samples from seeps 1, 2, 3, and 4 collected from August 1997 through November 1998 also were analyzed for concentrations of several trace metals and phosphorous. Only manganese (<0.02–0.10 mg/L) was detected at a concentration above regulatory criteria (table 3).

Temperature of water in the rivulets measured at the Keepataw Forest Preserve during June 2011 ranged from about 11 to 13.3 °C, likely reflecting the temperature of the groundwater source of the water in the rivulets (Soluk and others, 2012). Temperatures increased with increasing distance downstream, reflecting the influence of atmospheric temperature.

Assessment of Water Resources at the Black Partridge Woods Nature Preserve

The Black Partridge Woods Nature Preserve is located north of Bluff Road, west of Lemont Road, and east of Interstate I-355 at the western edge of Cook County (fig. 30). The Black Partridge Woods Forest Preserve is located south of Bluff Road. For the purposes of this report, these two entities are combined to constitute the Black Partridge Woods Nature Preserve (figs. 3, 30). The Black Partridge Woods Nature Preserve is about 80 acres in size and has been the subject of some biologic, hydrogeologic, and water-quality characterization.

Topography

Much of the Black Partridge Woods Nature Preserve occupies the flood plain of the Des Plaines River Valley. Land-surface elevation in the valley typically is about 580–585 ft NAVD 88 (fig. 30). In the northern and western parts of the Black Partridge Woods Nature Preserve, the land-surface elevation increases to about 590–625 ft near Bluff Road and exceeds 675 ft north of Bluff Road.

Biology

Adult use for undescribed purposes was documented at the Black Partridge Woods Nature Preserve in 1990 and 1992, primarily near the edge of a seepage marsh in the northeast part of the preserve (Cashatt and Vogt, 1996). Although small numbers of larvae have been identified at the preserve, breeding areas have not been confirmed and HED populations have not been calculated (U.S. Fish and Wildlife Service, 2013b). The area of potential adult HED habitat is estimated to be about 6.4 acres south of Bluff Road that is interspersed within the larger preserve where HED habitat is not present (TAMS Consultants, Inc., 1995a).

Table 11. Concentration of major ions and nitrogen compounds in surface water at the Keepataw Forest Preserve, Will County, Illinois, August 1997 through November 1998 (from Soluk and others, 1998).

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; --, no data; <, less than]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Amnonia, in mg/L	Nitrate, in mg/L	Dissolved oxygen, in mg/L
Seep 1 (location shown in fig. 29)									
8/21/97	376	236	56	132	67	19	0.06	0.09	7.3
9/24/97	336	244	54	134	67	20	0.10	0.05	3.8
10/30/97	396	166	63	122	59	15	0.05	0.08	2.0
11/19/97	395	238	55	133	67	22	0.03	0.03	2.4
12/17/97	403	230	49	127	67	20	0.05	0.04	--
1/30/98	374	126	48	133	67	22	0.06	0.09	3.6
3/26/98	386	140	54	61	39	11	0.06	<0.01	4.7
4/29/98	375	177	54	128	64	20	0.03	<0.01	5.6
5/21/98	387	152	54	126	64	20	0.04	<0.01	5.0
6/19/98	366	149	57	131	64	20	0.07	0.02	4.1
7/23/98	366	151	57	133	66	22	0.02	<0.01	3.5
8/25/98	380	151	59	133	69	22	0.09	0.02	6.9
9/15/98	366	151	57	138	70	22	0.04	0.01	4.6
10/30/98	362	161	66	139	71	24	0.11	0.03	4.6
11/19/98	354	161	63	136	69	23	0.08	<0.01	1.7
Seep 2 (location shown in fig. 29)									
8/21/97	375	141	48	128	66	16	0.10	<0.01	4.8
9/24/97	327	149	46	128	63	14	0.12	<0.01	2.6
10/30/97	385	160	46	131	65	16	0.08	<0.01	2.7
11/19/97	381	145	44	126	65	16	0.07	<0.01	3.6
12/17/97	379	127	41	132	65	15	0.11	<0.01	--
1/30/98	327	137	35	129	67	14	<0.01	0.11	9.5
3/26/98	357	143	42	42	21	5	0.09	<0.01	4.9
4/29/98	370	155	53	127	64	15	0.02	<0.01	6.1
5/21/98	379	153	51	126	65	16	0.08	<0.01	5.3

Table 11. Concentration of major ions and nitrogen compounds in surface water at the Keepataw Forest Preserve, Will County, Illinois, August 1997 through November 1998 (from Soluk and others, 1998).—Continued

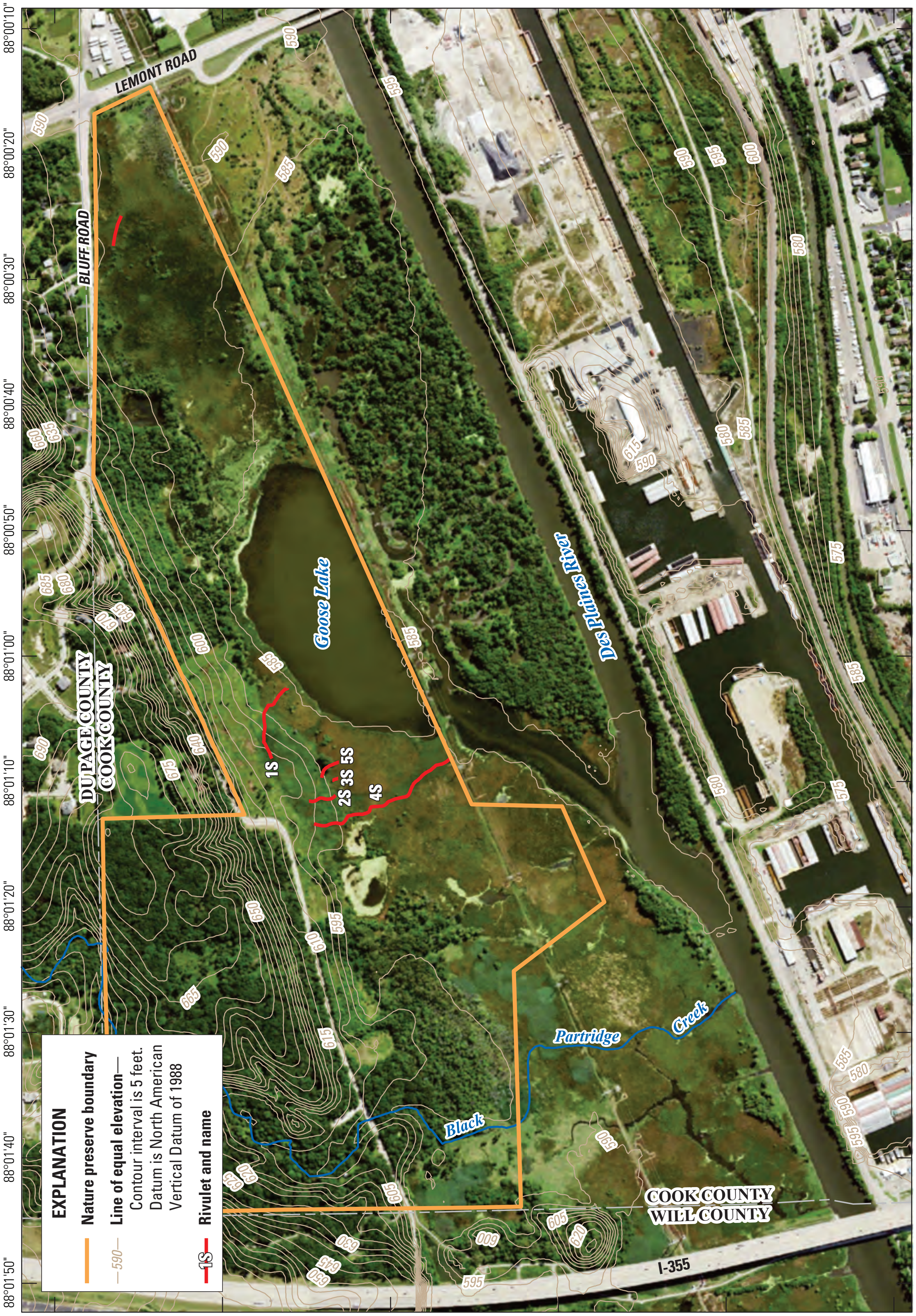
[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; --, no data; <, less than]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Amnonia, in mg/L	Nitrate, in mg/L	Dissolved oxygen, in mg/L
Seep 2 (location shown in fig. 29)—Continued									
6/19/98	361	155	49	130	65	16	0.08	0.02	4.7
7/23/98	357	158	49	138	66	16	0.03	<0.01	3.2
8/25/98	365	154	51	132	69	17	0.10	<0.01	4.6
9/15/98	360	162	51	133	69	17	0.07	<0.01	5.3
10/30/98	352	161	57	136	70	18	0.15	0.02	4.3
11/19/98	344	165	53	134	68	18	0.08	<0.01	5.6
Seep 3 (location shown in fig. 29)									
8/21/97	367	74	21	105	48	11	0.10	0.09	2.8
9/24/97	339	150	43	128	63	13	0.14	<0.01	4.0
10/30/97	394	156	46	129	64	17	0.07	<0.01	2.8
11/19/97	395	145	42	128	64	15	0.04	<0.01	3.9
12/17/97	376	169	24	145	68	10	0.06	0.06	--
1/30/98	336	153	26	124	60	11	0.10	0.14	7.1
3/26/98	340	163	28	126	60	13	0.18	0.01	6.3
4/29/98	346	186	29	123	59	12	0.07	<0.01	7.4
5/21/98	374	166	43	129	65	15	0.10	<0.01	4.8
6/19/98	357	160	43	130	64	15	0.07	0.09	4.6
7/23/98	369	153	44	155	65	15	0.08	<0.01	4.7
8/25/98	366	160	43	130	67	15	0.13	0.02	5.0
9/15/98	370	154	43	131	67	15	0.08	0.02	4.3
10/30/98	349	152	40	128	64	15	0.11	0.04	4.9
11/19/98	333	200	59	130	35	16	0.14	0.01	7.4
Seep 4 (location shown in fig. 29)									
8/21/97	377	131	56	133	68	17	0.04	<0.01	3.3
9/24/97	344	138	59	136	68	16	0.10	<0.01	1.6

Table 11. Concentration of major ions and nitrogen compounds in surface water at the Keepataw Forest Preserve, Will County, Illinois, August 1997 through November 1998 (from Soluk and others, 1998).—Continued

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; --, no data; <, less than]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Amnonia, in mg/L	Nitrate, in mg/L	Dissolved oxygen, in mg/L
Seep 4 (location shown in fig. 29)—Continued									
10/30/97	404	148	56	135	67	17	0.05	<0.01	1.7
11/19/97	398	136	55	134	68	18	<0.01	<0.01	3.8
12/17/97	404	124	53	144	71	17	0.09	<0.01	--
1/30/98	356	134	51	135	69	17	<0.01	<0.01	6.1
3/26/98	377	150	51	143	70	17	0.05	<0.01	3.6
4/29/98	367	147	59	132	66	17	<0.01	<0.01	6.3
5/21/98	388	147	54	131	67	18	0.01	<0.01	6.7
6/19/98	377	144	50	131	66	17	0.07	<0.01	4.9
7/23/98	356	153	50	160	66	17	0.04	<0.01	4.7
8/25/98	380	139	52	132	68	18	0.09	<0.01	3.4
9/15/98	372	142	51	135	70	18	0.06	<0.01	1.5
10/30/98	367	149	56	133	67	18	0.15	<0.01	1.3
11/19/98	342	151	54	134	67	18	0.09	<0.01	3.2



Imagery from the U.S. Department of Agriculture Farm Service Agency, Aerial Photography Field Office, 2015
National Agriculture Imagery Program (NAIP) Natural Color Imagery for Illinois

Figure 30. Location of selected features at the Black Partridge Woods Nature Preserve, Cook County, Illinois.

Hydrogeology

There are no wells in the Black Partridge Woods Nature Preserve, but an investigation performed due south of the preserve between the Des Plaines River and the CSSC indicated that the top of the Silurian dolomite at the Black Partridge Woods Nature Preserve is present at about 582–588 ft (Kay and others, 2016). Observations at outcrops in the southern part of the preserve along the bank of the Des Plaines River indicate the dolomite is overlain by 1 to 2.5 ft of silt and clay alluvium in the river valley. The depth to water beneath the site is not known but is at or near land surface in wells open to the Silurian aquifer south of Black Partridge Woods Nature Preserve across the Des Plaines River and is likely shallow at the wetlands in the Black Partridge Woods Nature Preserve. The horizontal hydraulic conductivity in the upper 70 ft of the Silurian aquifer typically was less than 0.05 ft/d south of the Black Partridge Woods Nature Preserve (Kay and others, 2016). Water collects on top of the dolomite, ponding in areas where the surface of the dolomite forms a basin. If these conditions are representative of the Black Partridge Woods Nature Preserve, groundwater flow to the wetlands would be focused in the alluvial aquifer.

Surface Water

Black Partridge Creek is located near the western part of the Black Partridge Woods Nature Preserve (fig. 30). The creek drains a predominately residential and commercial area north of Bluff Road. Several ponds and wetlands, including Goose Lake, are present in the central and southern parts of the Black Partridge Woods Nature Preserve. Several rivulets are present north and west of Goose Lake.

Water Quality

Samples of surface water were collected twice during 1991 at the Black Partridge Woods Nature Preserve (Cashatt and Vogt, 1992). These samples were analyzed for major ions, several metals, and nutrients (table 12). The location and dates of sampling are not described. Calcium was the dominant cation and alkalinity (as bicarbonate) was the dominant anion. Concentrations of nitrate were less than 3 mg/L, indicating the absence of an anthropogenic component (Mueller and Helsel, 1996). The pH readings were 7.8–8.2, indicating alkaline water. With the exception of iron (1.1–1.4 mg/L) and manganese (0.04–0.18 mg/L), which were detected above the above the EPA chronic threshold for aquatic life in at least one sample (table 3), concentrations of trace metals were below regulatory criteria.

Samples collected monthly during May 2011 through May 2012 from Black Partridge Creek immediately south of Bluff Road also were analyzed for major ions, nutrients, and metals (Plankell, 2014). Sodium typically was the cation present at highest concentrations in these samples and chloride was the cation typically present at highest concentrations (table 12). Concentrations of the major ions showed seasonal variation, being high in May 2011, lower in June through December 2011, and higher in January through May 2012. The high concentrations of chloride and sodium and the seasonality in the values indicate likely effects of road salt application on the water quality of the creek. The pH readings were 7.9–8.2. Nitrate concentrations were below the threshold indicating anthropogenic sources. Trace metals were either not detected in the Creek samples, or were detected at concentrations below regulatory criteria. Concentrations of chloride were above the EPA chronic threshold for aquatic life (230 mg/L) and phosphorus was detected above the EPA criteria for open water of 0.1 mg/L.

Assessment of Water Resources at the Waterfall Glen Forest Preserve

The Waterfall Glen Forest Preserve is located north of the Des Plaines River and east of Bluff Road in DuPage County (fig. 31). The Waterfall Glen Forest Preserve surrounds Argonne National Laboratory (fig. 3) and is nearly 2,500 acres in size. The focus area for this discussion is the southwest part of the preserve at the drainages to Emerald Fen.

Topography

The Emerald Fen part of the Waterfall Glen Forest Preserve is located at the base of the bluff along the northern part of the Des Plaines River Valley (fig. 31). The parcel slopes toward the river from a surface elevation of about 605 ft NAVD 88 in the northern area near the 1U,L well cluster to about 590 ft near the 3U,L well cluster (Plankell and others, 2009). Land surface at the fen typically is between 590 and 595 ft.

Biology

The HED has documented larval and adult use in the vicinity of the natural rivulet draining to the Emerald Fen (Soluk and others, 2008). Larval use in historical habitat at Emerald Fen has not been identified since 2009. Adult use at the site includes traveling, foraging, perching, and territorial patrol (Cashatt and Vogt, 1996; Soluk and others, 2010, 2011). Attempts are being made to create HED habitat at a series of artificial rivulets north of the fen (Plankell and others, 2009).

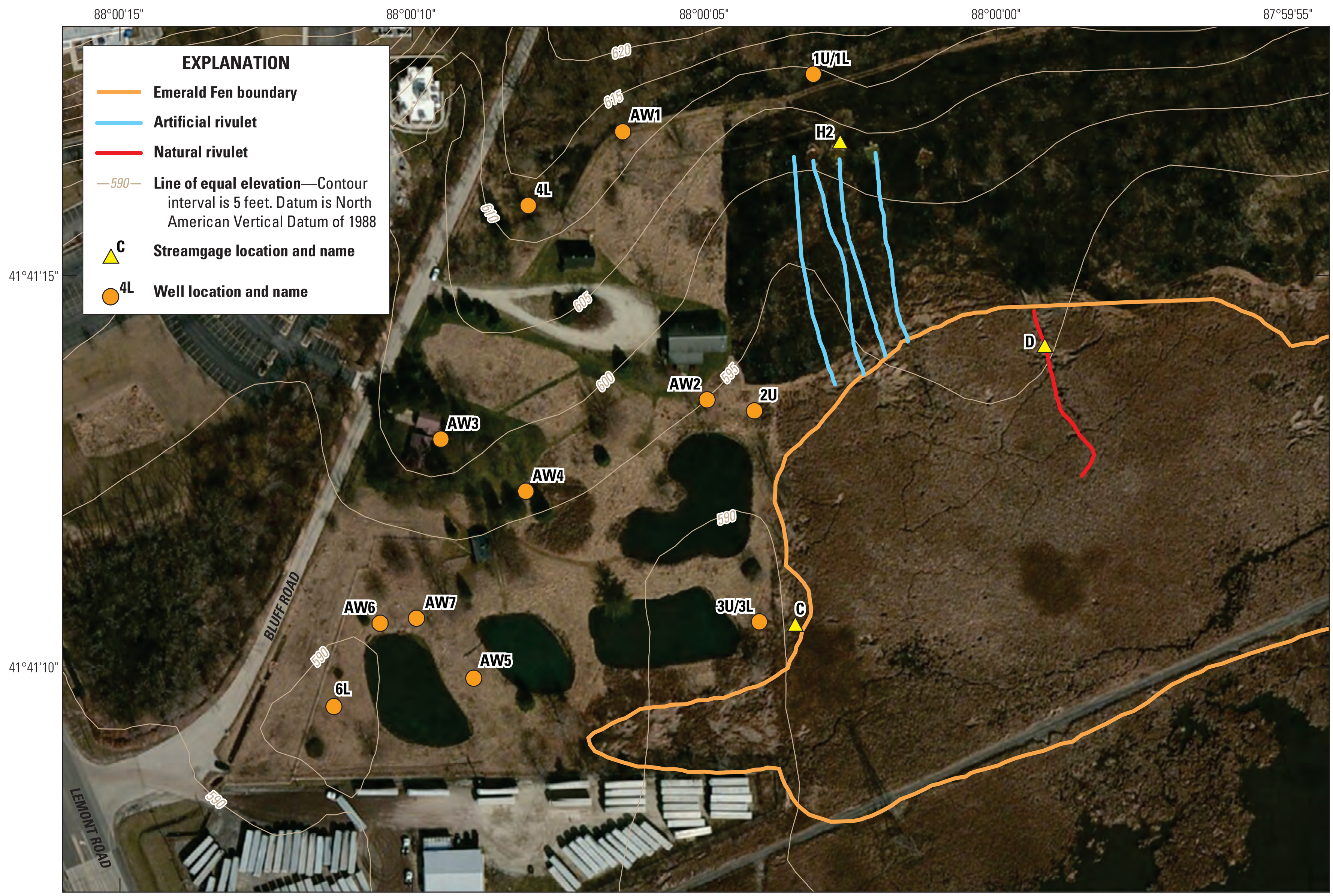
Hydrogeology

Groundwater at the Waterfall Glen Forest Preserve is present in the semiconfining unit, glacial drift aquifer, and the Silurian aquifer (Plankell and others, 2009). The top of the dolomite that constitutes the Silurian aquifer slopes toward the river, ranging in elevation from about 593 ft NAVD 88 near

Table 12. Concentration of major ions, nitrogen compounds, and metals in surface water at the Black Partridge Woods Nature Preserve, Cook County, Illinois, 1991 through 2012.

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; - -, no data; <, less than; bold denotes exceedance of regulatory criteria]

Date	Alkalinity, in mg/L as $CaCO_3$	Sulfate, in mg/L	Chloride, in mg/L	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Amnonia, in mg/L	Nitrate, in mg/L	Iron, in mg/L	Manganese, in mg/L
Surface water (location and dates of sampling unknown; data from Cashatt and Vogt, 1992)										
1991	336	170	53	128	54	22	--	2.1	**1.4**	0.043
1991	356	145	99	128	57	44	--	0.4	**1.1**	**0.182**
Black Partridge Creek directly south of Bluff Road (location shown in fig. 30; data from Plankell, 2014)										
5/18/11	253	76	**346**	94	44	216	0.16	0.33	0.027	0.018
6/20/11	107	23	**233**	33	23	99	<0.03	**0.23**	0.062	0.006
7/27/11	139	38	**264**	46	30	116	<0.03	**0.20**	0.024	<0.002
8/24/11	144	37	**249**	44	19	94	<0.03	0.21	0.037	0.005
92/28/11	141	41	156	48	21	105	<0.03	0.25	0.058	0.007
11/09/11	141	40	152	43	19	98	<0.03	0.30	0.032	0.007
12/07/11	218	67	177	72	29	105	<0.03	0.19	<0.024	0.005
1/11/12	249	83	216	83	37	127	<0.03	0.09	<0.024	0.005
2/27/12	222	82	**496**	95	42	276	<0.03	<0.07	<0.024	0.005
3/27/12	227	78	**470**	92	44	265	<0.03	0.09	<0.024	0.008
5/01/12	180	66	**356**	67	33	216	<0.03	0.19	<0.024	0.006



Imagery from Esri World Imagery for Chicago, 2015
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Figure 31. Location of features in the vicinity of Emerald Fen at the Waterfall Glen Forest Preserve, DuPage County, Illinois.

the 1U,L cluster to about 587 ft near the 3U,L well cluster. The Silurian deposits contain secondary-permeability features, including a prominent subhorizontal fracture at an elevation of about 545 ft NAVD 88. The bedrock is directly overlain by the glacial drift aquifer, which consists of as much as 10 ft of glacial sand and gravel in the northern part of the property. The sand and gravel aquifer pinches out in the southern part of the Waterfall Glen Forest Preserve. The top of the glacial drift aquifer is at about 602 ft NAVD 88 at well 1L, 591 ft at well 2U, and is absent at well 3L. Overlying the glacial drift aquifer in the northern part of the Waterfall Glen Forest Preserve, and directly overlying the bedrock in the southern part, are silt and clay deposits that form a semiconfining unit. These deposits are as much as 10 ft thick.

Groundwater levels were measured periodically from November 2007 through December 2008 in wells open to the glacial drift aquifer (wells 1U, 2U), semiconfining unit (well 3U), and the upper 10 ft of the Silurian aquifer (wells 1L, 3L, 4L, 6L). Water levels ranged from about 600 ft NAVD 88 in the northern part of the Waterfall Glen Forest Preserve to about 593 ft in the southern part, indicating that the overall direction of groundwater flow is toward the Des Plaines River (Plankell and others, 2009). Groundwater levels tended to be lowest during the summer through fall and highest during the spring. This trend was interrupted by high water levels associated with flooding of the Des Plaines River in September 2008. Groundwater levels varied by as much as 4.1 ft in a well during the flood.

There was less than 0.05 ft of difference in water-level elevation between the glacial drift and Silurian aquifers at the 1U,L well cluster, indicating hydraulic connection of the upper part of the groundwater system in this area where they are in direct contact. Water levels in well 3U typically were about 1 ft higher than in well 3L, indicating the semiconfining unit restricts flow into the Silurian aquifer where the units are in contact. Groundwater levels at wells 3U and 3L typically exceeded the stage of the Emerald Fen at streamgage C, indicating groundwater discharge to the fen.

Groundwater levels at well AW1, which is open to the deeper part of the Silurian aquifer, were above land surface (about 603 ft NAVD 88). Natural discharge from this well was measured to be at least 30 gal/min (Plankell and others, 2009).

Surface Water

A natural rivulet is located in the northern part of Emerald Fen (fig. 31). Water from this rivulet is derived from seeps emanating from the unconsolidated material (likely the glacial drift aquifer) north of the fen at an elevation of about 593 ft. Water from this rivulet discharges into the fen.

Four north-south trending artificial rivulets located north of the fen also discharge to the fen. Water from the Silurian aquifer flowing under artesian conditions out of well AW1 is channeled to the artificial rivulets (fig. 31). Beginning in 2008, water from well AW1 was discharged to a pond before draining to the artificial rivulets in an effort to improve the HED habitat by moderating water temperature in the rivulets (Soluk and others, 2010). Discharge measurements taken from each of the artificial rivulets on July 21, 2010, ranged from 3.1×10^{-4} to 5.1×10^{-4} ft^3/s (Soluk and others, 2011). Discharge measurements taken from each of the artificial rivulets on August 24, 2011, ranged from 8.1×10^{-5} to 2.1×10^{-4} ft^3/s (Soluk and others, 2012). Discharge measurements taken from each of the artificial rivulets on May 22, 2012, ranged from 4.9×10^{-2} to 8.1×10^{-1} ft^3/s (Soluk and others, 2013). These data demonstrate minimal, but present, flow in the artificial rivulets during the late summers of 2010 and 2011, indicating that the artificial flow regime prevents the rivulets from becoming dry.

Monthly stage measurements were taken of the natural rivulet at streamgage D (fig. 31) from March 2008 through December 2008 (Plankell and others, 2009). Water levels were consistently about 591 ft NAVD 88, with the exception of an increase to about 592.5 ft during September when the Des Plains River was in flood stage. The effects of this flooding on the HED habitat at the rivulet is not known, but erosive forces associated with flood events may be detrimental to the survival of eggs laid in the sediment of the rivulet.

Water Quality

A surface-water sample was collected from the Waterfall Glen Forest Preserve once during 1991 (Cashatt and Vogt, 1992). The location and date of sampling are not described, but the artificial rivulets likely were not in place in 1991. The sample was analyzed for concentrations of major ions, several metals, and nutrients. Calcium was the dominant cation (121 mg/L) with lower concentrations of magnesium (68 mg/L) and sodium (15 mg/L). Bicarbonate was the dominant anion (alkalinity 412 mg/L as $CaCO_3$), with lower concentrations of chloride (35 mg/L) and sulfate (136 mg/L). The pH was 7.7. The concentration of nitrate was 2.9 mg/L. Concentrations of all constituents were below regulatory criteria.

Continuous measurements of water temperature were taken from November 2007 through January 2009 in the natural and artificial rivulets (Plankell and others, 2009). Average daily water temperatures in the natural rivulet at streamgage D showed seasonal variations, decreasing from about 7 °C in November 2007 to about 1 °C in February 2008, increasing to about 18 °C in the summer of 2008, before decreasing to about 5 °C in January 2009. The timing of the trends in water temperature at the natural rivulet were similar to trends in atmospheric temperature, but water temperature was about 5 °C warmer than the atmosphere during the winter and about 5 °C cooler during the summer. Water temperatures in the upstream part of the artificial rivulets near the point of the discharge from the well ranged from about 10 to 12 °C, approximating the water temperature in the Silurian aquifer. Water temperatures were generally modified by interaction with the atmospheric temperature with increased distance downstream (Soluk and others, 2011).

Continuous measurements of the specific conductance of water in the natural and artificial rivulets were taken from November 2007 through January 2009 (Plankell and others, 2009). Specific conductance values in the natural rivulet at streamgage D typically ranged from about 1,000 to 1,300 µS/cm. Large decreases in specific conductance were associated with precipitation events, reflecting the presence of overland runoff from precipitation. Specific conductance values in the natural rivulet were lower during the spring than the rest of the year, indicating dilution of natural rivulet water by overland runoff from snowmelt and precipitation. The lower conductivity during the spring also may reflect the effects of increased amounts of low-conductivity recharge from snowmelt and precipitation to the shallow groundwater that discharges to the natural rivulet. Specific conductance values in the artificial rivulet at streamgage H2 typically were consistently between 1,200 and 1,300 µS/cm but also showed large decreases during precipitation events.

Continuous measurements of the pH of water in the natural and artificial rivulets were taken from January 2008 through December 2008 (Plankell and others, 2009). Values in the natural rivulet showed an overall decrease from about 7.7 in January to about 6.3 in December. Values in the artificial rivulet typically were between 7.0 and 7.5, reflecting the pH of its source water from the Silurian aquifer.

Groundwater samples were collected at least once and as often as quarterly from December 2007 through September 2008 from wells 1U, 1L, 2U, 3L, 4L, 6L and AW2; from an artificial rivulet fed by artesian water from well AW1; and from the natural rivulet at streamgage D (table 13). These samples were analyzed for concentrations of metals, major ions, and nutrients, and organic carbon (Plankell and others, 2009). Water-quality criteria were exceeded in the Silurian aquifer for iron at wells 3L (1.3 mg/L), 6L (11 mg/L), and AW2 (1.1 mg/L); manganese at well 3L (0.92 mg/L) and 6L (1.7 mg/L); and phosphorus at well 6L (0.17 mg/L; table 3). Water quality criteria also were exceeded in some samples from the natural rivulet for manganese (geometric mean 0.12 mg/L). The data indicate calcium was the dominant cation and that the water was alkaline, indicating that dissolution of carbonate minerals in the unconsolidated and bedrock deposits affected water quality at the Waterfall Glen Forest Preserve. Chloride concentrations greater than 75 mg/L in both surface and groundwater indicate the effect of road salts. Constituent concentrations in the artificial rivulet are similar to those in well AW2. This similarity is expected because wells AW1 and AW2 are both open to the deeper part of the Silurian aquifer and well AW1 is the water source for the artificial rivulets. Constituent concentrations in the natural rivulet typically are lower than in the artificial rivulet and are generally consistent with concentrations in well 1U, indicating the water in the natural rivulet is derived from the unconsolidated deposits.

Assessment of Water Resources at the McMahon Fen Nature Preserve

The McMahon Fen Nature Preserve occupies 373 acres approximately 4 mi east of the Des Plaines River in southwest Cook County (fig. 3). The McMahon Fen Nature Preserve is bounded by the Calumet Sag Channel to the south, 107th Street to the north, Willow Springs Road to the west, and Route 45 to the east (figs. 3, 32). The area of concern to this investigation is in the west-central part of the preserve south of Crooked Creek (fig. 32).

Topography

The McMahon Fen Nature Preserve contains a northwest-southeast trending topographic high at an elevation of about 610 ft NAVD 88 (fig. 32). North of this high, land surface slopes toward Crooked Creek at a minimum elevation of about 604 ft near 107th Street. South of the high, land surface slopes down to the Calumet Sag Channel at an elevation of about 587 ft. North of 107th Street, land surface increases to more than 700 ft. Berms are present near the western and southern parts of the preserve.

Biology

Adult HED use of the McMahon Fen Nature Preserve for foraging, territorial patrol, and breeding has been periodically documented (Cashatt and others, 1993; Cashatt and Vogt, 1996; Soluk and others, 2014), often in the vicinity of spring-fed rivulets near the east end of the preserve. HED larvae have been identified at rivulets in the eastern part of the McMahon Fen Nature Preserve (Soluk and others, 2010, 2014).

Hydrogeology

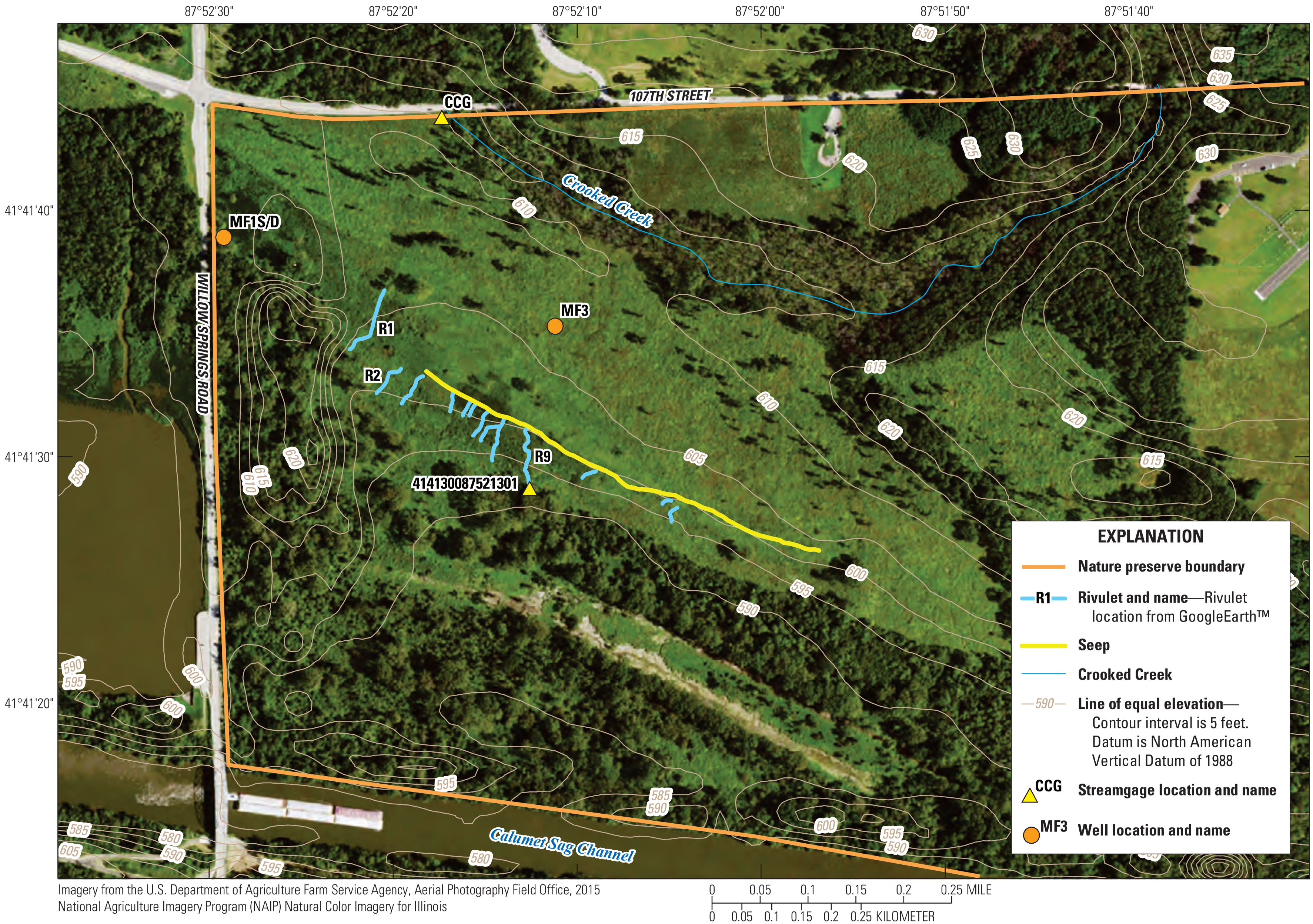
The surficial geology transitions from glacial river bottom sand and gravel in much of the northern part of the preserve to peat and muck in the southern part at the approximate location of the tree line south of the open area in the center of the preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2007b). The berms in the western and southern parts of the preserve consist of fill. Lithologic logs obtained from the ISGS database (Illinois State Geological Survey, [n.d.]) indicate the top of the Silurian dolomite, which constitutes the Silurian aquifer, is present at an elevation of about 575 ft. The unconsolidated deposits are 10–30 ft thick in this area.

Lithologic logs for well MF1D installed by the USGS in the northwest corner of the McMahon Fen Nature Preserve during the spring of 2013 (fig. 32) indicate the presence of at least 12 ft of semiconfining unit consisting of silt and clay till. The log for USGS well MF3 indicates the presence of a sand deposit constituting the glacial drift aquifer at a depth of about 6 ft (elevation of about 600 ft) overlain by silt and clay.

Table 13. Concentration of major ions and nitrogen compounds in surface water and groundwater at the Waterfall Glen Forest Preserve, DuPage County, Illinois, December 2007 through September 2008.

[mg/L, milligram per liter; $CaCO_3$, calcium carbonate; GM, geometric mean value of all samples from location; <, less than]

Sample location (shown in fig. 31)	Sample date	Unit monitored	Calcium, in mg/L	Magnesium, in mg/L	Sodium, in mg/L	Alkalinity, in mg/L as $CaCO_3$	Chloride, in mg/L	Sulfate, in mg/L	Nitrate as nitrogen, in mg/L	Ammonia as nitrogen, in mg/L
1U	12/18/07	Unconsolidated	93 GM	47 GM	77 GM	294 GM	158 GM	73 GM	0.62 GM	All <0.06
	3/11/08									
	6/17/08									
	9/16/08									
1L	12/18/07	Shallow Silurian aquifer	100 GM	48 GM	60 GM	315 GM	213 GM	84 GM	0.44 GM	0.09 GM
	3/11/08									
	6/17/08									
	9/16/08									
2U	12/18/07	Unconsolidated	128	51	52	317	130	143	0.31	<0.06
3L	12/18/07	Shallow Silurian aquifer	121	50	35	388	78	75	<0.07	0.96
4L	12/18/07	Shallow Silurian aquifer	119	54	83	356	188	102	0.34	<0.06
Artificial rivulet flow from well AW1	12/18/07	Surface water derived from deep Silurian aquifer	140 GM	55 GM	56 GM	342 GM	134 GM	148 GM	<0.07	0.57 GM
	3/11/08									
	6/17/08									
	9/16/084									
Natural rivulet	12/18/07	Surface water	87 GM	44 GM	63 GM	273 GM	126 GM	70 GM	0.22 GM	All <0.06
	3/11/08									
	6/17/08									
	9/16/08									
AW2	12/18/07	Deep Silurian aquifer	144	54	54	339	128	154	<0.07	0.60



Imagery from the U.S. Department of Agriculture Farm Service Agency, Aerial Photography Field Office, 2015
National Agriculture Imagery Program (NAIP) Natural Color Imagery for Illinois

Figure 32. Location of selected features at the McMahon Fen Nature Preserve, Cook County, Illinois.

The USGS measured water levels in wells MF1S and MF1D five times from June 10 through November 27, 2013 (U.S. Geological Survey, 2016a). Individual measurements are presented in the USGS NWIS database (U.S. Geological Survey, 2017). Well MF1S is open to the semiconfining unit from 5 to 8 ft below land surface. Well MF1D is open to the semiconfining unit from 9 to 12 ft. Depth to water was 1–4.5 ft below land surface (water elevation 596.5–599.75 ft) at well MF1S and about 1.3 ft above land surface to 1.6 ft below land surface at well MF1D (elevation 600.4–603.3 ft). Water levels showed seasonal variation, being highest in June and November and lowest in September. Water levels in well MW1D were consistently higher than in well MW1S, indicating the potential for upward groundwater flow in this area. This flow may help sustain the surface-water bodies.

The USGS took continuous and periodic water-level measurements at well MF3 from April through November 2013 (fig. 33; U.S. Geological Survey, 2016a). Well MF3 is open to the glacial drift aquifer from 3.6 to 6.6 ft below land surface. Water levels decreased by as much as about 3 ft overall from April to late October, likely in response to a seasonal reduction in the amount of recharge to groundwater, before increasing in November. There were also a number of short-term increases that could exceed 1 ft associated with recharge from precipitation events. Water levels did not drop below the top of the sand layer (about 600 ft), indicating the glacial drift aquifer is connected to a stable source of recharge that may extend north of the McMahon Fen Nature Preserve. Water levels in well MF3 were consistently below the elevation of the land surface (606 ft).

Surface Water

Crooked Creek traverses the northern part of the McMahon Fen Nature Preserve. The elevation of the base of the creek ranges from about 615 ft at 107th St in the northeastern part of the McMahon Fen Nature Preserve to about 605 ft at 107th St in the northwestern part. Surface-water modeling indicates that the stage of Crooked Creek may occasionally flood the center and southern parts of the McMahon Fen Nature Preserve, partly due to constriction of flow by the west culvert beneath 107th Street (Graef, Anhalt, Schloemer, and Associates, Inc., 2009b). A larger culvert in this area would decrease the magnitude of flooding in the McMahon Fen Nature Preserve. If the floodwater extends to HED habitat, it could result in erosion and other effects that are detrimental to HED survival.

A large seep is located near the center of the McMahon Fen Nature Preserve at an elevation of about 600 ft (fig. 32). The location of the seep roughly corresponds to the area where the geology transitions from river bottom deposits to the north to peat and muck deposits to the south (Graef, Anhalt, Schloemer, and Associates, Inc., 2007b). The seep is present where the elevation of land surface is equal to the elevation of the top of the sand deposit identified at well MF3.

Seep-fed rivulets are located in the center of the McMahon Fen Nature Preserve. The rate of base flow is about 0.2 ft^3/s at rivulet R9 and about 0.01 ft^3/s at rivulets R1 and R2. There typically is no flow at the rivulets near rivulet R9, possibly because the groundwater flow that would sustain flow in these rivulets is diverted to rivulet R9. The bed of much of

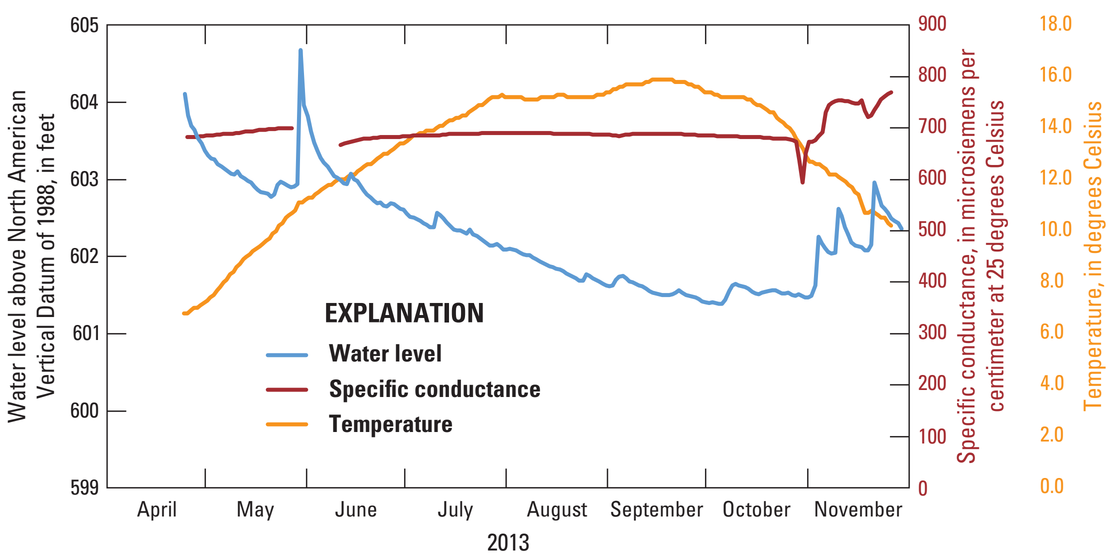


Figure 33. Water level, specific conductance, and temperature of groundwater in well MF3, McMahon Fen Nature Preserve, Cook County, Illinois, April through November, 2013.

rivulet R9 has eroded through the surficial geologic deposits and contains gravel-sized sediment with minimal detritus. Erosion likely is caused by high water velocities associated with the elevated flow and topographic gradient at some segments of rivulet R9. The lack of detritus and high water velocities likely reduce the chance for survival of any HED eggs deposited in rivulet R9.

Continuous water-level measurements taken from March through October 2013 by the USGS at rivulet R9 (U.S. Geological Survey, 2016a) indicate baseline water levels are near land surface with periodic increases of as much as 0.60 ft associated with precipitation events (fig. 34). The spike in water level in April may be associated with flooding of Crooked Creek. Water was present at the rivulet throughout the measurement period, indicating stable discharge from the seep supplying the rivulet.

Water Quality

Continuous measurements of specific conductance and temperature were taken by the USGS at well MF3 (fig. 33) and rivulet R9 (fig. 34) during most of 2013 (U.S. Geological Survey, 2016a). Specific conductance values in groundwater at well MF3 typically were about 650–700 µS/cm but tended to change when water levels increased during recharge events. Specific conductance values in the water at rivulet R9 increased from about 700 to 1,200 µS/cm from March through June and showed a small overall decrease to about 1,100 µS/cm by late October. Numerous short-term decreases in specific conductance were observed during precipitation events. Although specific conductance values are lower at MF3 than at rivulet R9, the baseline specific conductance values at rivulet R9 likely are a reflection of the specific conductance of the groundwater discharging to the rivulets. Increasing conductance values observed in the rivulet during the spring likely reflect the presence of water derived from snowmelt and spring rains being replaced by groundwater derived from longer-term recharge entering the glacial drift aquifer north of the McMahon Fen Nature Preserve. Sharply lower conductance values reflect the presence of precipitation in the rivulet. Water temperatures in well MF3 and rivulet R9 were similar, ranging from about 6 ºC in March to about 15 ºC in September before decreasing to about 10 ºC in late November. These values reflect the effects of groundwater temperature, modified by atmospheric interaction, on water temperature at rivulet R9.

Other Hine's Emerald Dragonfly Habitats in Illinois

In addition to the HED habitats described, HED adults have been documented at the Lockport Prairie East and Dellwood West Nature Preserves (Hanson Material Service Corporation, 2016), which are located across the Des Plaines River from the Lockport Prairie Nature Preserve (fig. 2). These properties appear to be used for foraging by HED from the Lockport Prairie Nature Preserve (Hanson Material Service Corporation, 2016). Biologic, hydrologic, and water-quality conditions at this property have not been investigated. Geologic conditions are likely to be similar to those at the Lockport Prairie Nature Preserve.

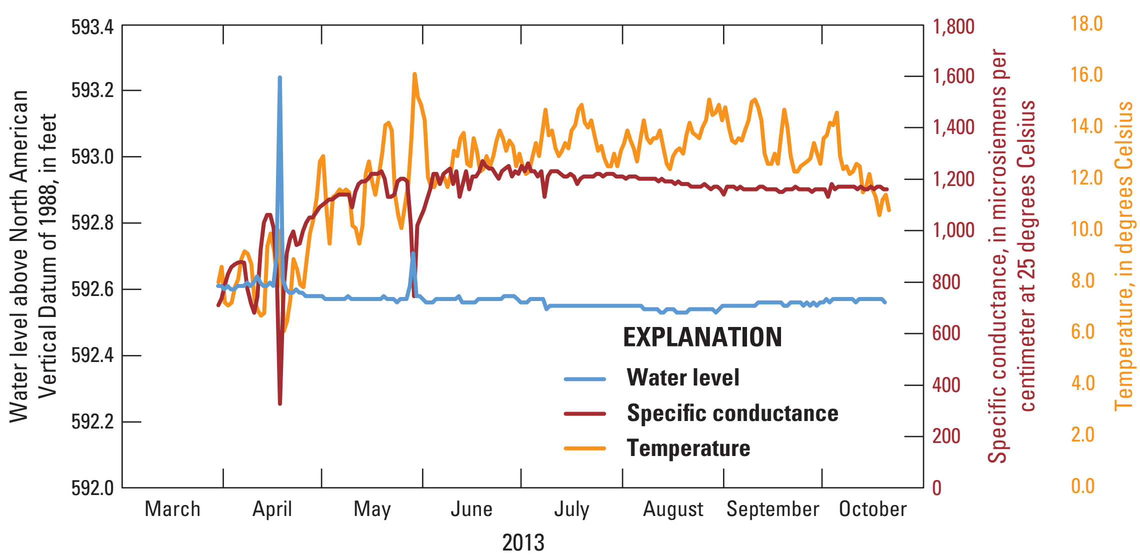


Figure 34. Water level, specific conductance, and temperature of rivulet 9 at streamgage 414130087521301, McMahon Fen Nature Preserve, Cook County, Illinois, March through October, 2013.

HED larval and adult use has been documented southwest of the Lockport Lock and Dam (fig. 2; Hanson Material Service Corporation, 2016). This property is near a wastewater treatment plant, which may affect the hydrology and water quality of the habitat. Biologic, hydrologic, and water-quality conditions at this property have not been investigated. Geologic conditions are likely to be similar to those at the Lockport Prairie Nature Preserve.

Larvae of the HED have been identified in the northwest corner of the Argonne National Laboratory and adult use has been observed in the southeast corner of the Laboratory (fig. 3; Danial Soluk, University of South Dakota, written commun., 2016, 2017). This habitat consists of a small wetland area in the topographic uplands approximately 1.8 mi north of the bluffs of the Des Plaines River Valley. This wetland is associated with seeps located in the upper few feet of the unconsolidated deposits. Depth to the Silurian bedrock in this area is more than 100 ft according to well logs obtained from the ISGS (Illinois State Geological Survey, [n.d.]). The habitat in the southeast corner of the Argonne National Laboratory appears to be associated with a wastewater discharge. Biologic, hydrologic, geologic, and water-quality conditions associated with HED use at the Argonne National Laboratory have not been investigated.

HED adults have been documented at the Cherry Hill Woods and Horsetail Lake Forest Preserves (Cashatt, 2015). These sites are south of McMahon Fen (fig. 3). Territorial patrols have been observed at both sites. Biologic, hydrologic, and water-quality conditions at these properties have not been investigated.

In addition to areas in and near the Lower Des Plaines River Valley, HED larval and adult use has been documented at the Spring Lake Forest Preserve in northwest Cook County. The Spring Lake Forest Preserve is approximately 35 mi northwest of the Lockport Prairie Nature Preserve (Soluk and others, 2016). HED habitat in this area is associated with springs emanating from unconsolidated deposits. Well logs indicate the depth to bedrock in this area exceeds 120 ft (Illinois State Geological Survey, [n.d.]). Biologic, hydrologic, geologic, and water-quality conditions at this property have not been investigated.

Implications for Habitat Preservation and Future Data Collection

A summary of the conditions at selected HED habitats (table 14) demonstrates that HED habitat in Illinois is associated with alkaline seeps emanating from dolomite bedrock or unconsolidated deposits that can be more than 100 ft above bedrock. Because alkaline seeps in unconsolidated deposits are present in much of Illinois and the northern United States, suitable conditions for HED habitat may extend beyond the Lower Des Plaines River Valley; however, the (apparent) requirement for seep flow makes the quality of the HED habitat susceptible to small changes in the groundwater flow system that take place seasonally, over periods of months or years, or that are permanent.

Hydraulic, geologic, and water-quality conditions at many of the HED habitats discussed in this report are inadequately understood. The source of water to seeps (bedrock or unconsolidated deposits), surface-water flow pathways, location of the groundwater recharge area, water use within the groundwater recharge area, discharge rates from seeps, water chemistry, variations in water levels, volume of direct discharge from groundwater to the wetlands, location where there is direct discharge from groundwater to the wetlands, and the relation of these hydraulic and chemical phenomena to the HED populations requires characterization at many habitats.

The water-quality characterization at many of the habitats is limited by a lack of precise information on sample location and date of collection. Many of the analyses, especially pesticides and mercury, have elevated detection limits relative to their regulatory criteria. Re-sampling many of these water bodies using currently available (2018) analytical techniques would improve the understanding of the threat these constituents pose to the HED. Finally, anomalous sample results were observed in some areas, such as arsenic at the Romeoville Prairie Nature Preserve. Confirmation sampling to verify anomalous data should improve understanding of water-quality conditions.

Changes in the hydraulics within areas supplying groundwater to the HED habitats can be caused by altering the timing and amount of recharge to groundwater associated with seasonal cycles in recharge from precipitation, multiyear droughts, as well as long-term climate change. Understanding the effects of changes in precipitation on water levels and flow at, and within, the groundwater recharge areas that support different HED habitats can be useful in assessing the long-term potential for HED survival. For example, the conditions that result in comparatively stable discharge from the Silurian and (to a lesser extent) glacial drift aquifers to the Lockport Prairie Nature Preserve render this site somewhat less susceptible to the effects of variations in precipitation than the shallow unconsolidated deposits at sites such as Romeoville Prairie; however, even small reductions in water levels in the Silurian aquifer at many of the HED habitats could result in a substantial decrease in the quality of the habitat. Ongoing periodic and continuous measurement of water levels at selected locations within the Lower Des Plaines River Valley would help to identify hydraulic stresses on the flow system and the source of the stress.

In addition to the effects of climate on the timing and amount of precipitation, changes in the groundwater flow system can be caused by a reduction in the amount of recharge to groundwater associated with an increase in the amount of overland runoff of precipitation from impervious surfaces within the groundwater recharge area for a particular habitat. Of particular importance for the HED habitat in the Lower Des Plaines River Valley is maximizing the amount of recharge to the glacial drift aquifer along the bluffs at the

Table 14. Summary of conditions at Hine's emerald dragonfly habitats in Illinois (compiled from Cashatt and Vogt, 1992, 1996; Mierzwa and Webb, 2010, 2012a,b)

[A, adult; T, transit; F, feeding/foraging; L, larval; B, breeding; P, perching; TP, territorial patrol; E, egg laying; D, dolomite; U, unconsolidated deposits]

Site names (shown in figs. 1, 2, or 3)	Hine's emerald dragonfly use	Hine's emerald dragonfly behavior	Site of larval habitat	Source of seeps	Potential hydrologic and water-quality threats to habitat
Quarry	A	T, F	Not since at least 2005	No seeps identified	Reduction in flow due to high-capacity pumping and reduction in watershed area due to excavation. Water-quality changes due to application of road salt.
River South Parcel	A,L	B, F, T, P, TP, E	Rivulets in southern part of property	D	Reduction in water due to high-capacity pumping in recharge area; impervious surface in recharge area. Flow disruption from roadbed in habitat. Water-quality changes due to application of road salt, fertilizer, and possibly pesticides.
Lockport Prairie Nature Preserve	A, L	B, TP, E, F, P, T	Rivulets near center of property	U, D	Reduction in water due to high-capacity pumping near recharge area and increased impervious surfaces in recharge area. Flow disruption from culvert and roadbed in habitat. Water-quality changes due to application of road salt, fertilizer, and possibly pesticides.
Com Ed/Long Run Parcels	A,L	F, TP, T, B	Rivulets near open water south of boundary between parcels	D	Reduction in water due to high-capacity pumping in and near recharge area; impervious surface in recharge area. Flow disruption from roadbed in habitat and sediment excavation. Water-quality changes due to oil spill and application of road salt.
Long Run Seep Nature Preserve	A,L	B, TP, F, E	Rivulets in western part of property	U	Reduction in water due to impervious surface in recharge area. Water-quality changes due to application of road salt, fertilizer, and possibly pesticides.
Romeoville Prairie Nature Preserve	A	B, T	Possibly in rivulet in center of site	D	Reduction in water due to high-capacity pumping in and near recharge area; impervious surface in recharge area. Water-quality changes due to application of road salt and fertilizer. Flooding on Des Plaines River.
Keepataw Forest Preserve	A,L	F,T, TP	Seeps area	U	Reduction in water due to high-capacity pumping near recharge area; impervious surface in recharge area. Water-quality changes due to application of road salt. Hydrologic and erosive effects of intermittent drainage in northeast part of property.
Black Partridge Woods Forest Preserve	A,L	Unknown	None identified	U	Insufficient characterization to assess hydrologic threats. Water-quality changes due to application of road salt.
Waterfall Glen Forest Preserve	A,L	T, F, P, TP	Natural rivulet	U	Water-quality changes due to application of road salt. Artificial rivulet water may be too cold. Flow rate may be too high in artificial rivulet. Flooding of Des Plaines River.

Table 14. Summary of conditions at Hine's emerald dragonfly habitats in Illinois (compiled from Cashatt and Vogt, 1992, 1996; Mierzwa and Webb, 2010, 2012a,b)—Continued

[A, adult; T, transit; F, feeding/foraging; L, larval; B, breeding; P, perching; TP, territorial patrol; E, egg laying; D, dolomite; U, unconsolidated deposits]

Site names (shown in figs. 1, 2, or 3)	Hine's emerald dragonfly use	Hine's emerald dragonfly behavior	Site of larval habitat	Source of seeps	Potential hydrologic and water-quality threats to habitat
McMahon Fen Nature Preserve	A,L	B, F, TP	Rivulet in eastern part property	U	Periodic loss of water in seeps due to below average precipitation. Water-quality changes due to application of road salt. Erosion and diversion of flow in some rivulets.
Dellwood West and Lockport Prairie East Nature Presereves	A	T, F	None identified	Unknown	Insufficient characterization to assess threats.
Southwest of Lockport Lock and Dam	A,L	Unknown	Unknown	Unknown	Insufficient characterization to assess threats.
Argonne National Laboratory	L	Unknown	Wetland in northeast part of property	U	Insufficient characterization to assess threats.
Spring Lake Nature Preserve	A,L	Unknown	Springs	U	Insufficient characterization to assess threats.

valley boundaries. Use of best management practices, which has been done in parts of the recharge area for the Lockport Prairie Nature Preserve, has the potential to offset the effects of the reductions in groundwater recharge due to runoff from impervious surfaces. Reducing overland flow of runoff from precipitation has the potential to reduce erosion and sediment deposition in some of the habitats and has the potential to improve some components of water quality.

Changes in the groundwater system can be caused by high-capacity pumping in and near the groundwater recharge areas by removing water from the Silurian aquifer that would otherwise have discharged to HED habitat. The area within which pumping from a high-capacity well open to the Silurian aquifer can divert water from a particular HED habitat and the volume of water diverted are affected by the hydraulic properties of the aquifer, the location and degree of interconnection between the secondary-permeability features at the well and the habitat, and the volume of pumping from the well. None of these factors are well understood within the Lower Des Plaines River Valley as a whole or within the groundwater recharge area for any of the HED habitats. Better understanding of these factors would be gained from monitoring the timing of pumping as well as monthly assessment of the volume of discharge from the high-capacity wells. Detailed characterization of the flow system within the Silurian aquifer by performance of continuous water-level monitoring, geophysical logging, and aquifer testing would enable more accurate identification of how the hydraulic stresses will affect the habitats. This characterization is of particular importance at the Lockport Prairie Nature Preserve, River South Parcel, Com Ed and Long Run Parcels, and the Romeoville Prairie Nature Preserve.

Surface-water flow pathways within many of the wetlands have been substantially altered by the construction of culverts, roads, and railroads. This alteration likely has affected the HED habitat by drying some areas and increasing water levels, streamflow, and erosion in others, particularly near culverts. An important consideration during future construction is to replicate the natural hydrology, particularly with regard to the placement of culverts at locations that result in flow to natural drainages. Accurate assessment of discharge, velocity, sedimentation, and erosion at these features along with ongoing identification of the location of HED populations has the potential to add insight to the hydraulic and chemical effects on the HED habitat so that more effective mitigation can be devised. This characterization is of particular importance at the Lockport Prairie Nature Preserve, the River South Parcel, the Com Edison and Long Run Parcels, and the McMahon Fen site.

Flooding of the Lower Des Plaines River has the potential to result in HED mortality. The extent of floodwater needs to be identified and compared to locations of HED use to better identify and protect potential HED habitat. For example, larval HED use at the Lockport Prairie Nature Preserve and the River South Parcel are near the western parts of the river valley, away from the river. The area inundated by the Des

Plaines River at sites subject to periodic flooding could be evaluated to determine if high water, sediment deposition, and erosion have affected the HED population.

The water balance (volume of water entering a habitat as surface-water flow, groundwater flow, and precipitation as compared to the amount of water exiting the site as surface-water flow and evapotranspiration) is unknown for all of the sites. This information is critical to assessing the stability of the various HED habitats. Collection of the geologic, climate, water use, and hydrologic information outlined in this section should enable an accurate water balance to be developed for at least some of the sites.

The effects of oil spills, as well as the application of road salts and fertilizers at many of the sites, is a potential concern to the HED habitat, particularly with regard to its effects on the flora and fauna that support the HED. Additionally, the alteration of surface-water flow pathways has altered water temperatures at some of the HED habitats. Of particular concern is the effect of damming seep discharge behind the berms of the railroad tracks and diverting flow to the culverts on the temperature of the water entering the wetlands. A reduction in the amount of groundwater discharge to the wetlands also has the potential to alter the temperature and water chemistry in the habitats. Collection of periodic and continuous data on temperature, alkalinity, chloride, nutrients, suspended solids, and pesticides in surface and groundwater would improve the understanding of the sources and types of water-quality stressors in the Lower Des Plaines River Valley. This information could be used to improve HED productivity and mortality.

Understanding how changes in hydrology affect the HED habitats also requires an understanding of how (if at all) current and natural hydraulic conditions differ, with natural conditions presumably being closer to optimal for the HED. The natural hydrology of the Lower Des Plaines River Valley has been altered by construction of canals, modification of the course of the Des Plaines River, urbanization, groundwater pumping, and other processes. Water-level data collected from well 414217087592801 open to the Silurian aquifer at Argonne National Laboratory showed a decrease of about 15 ft from 1948 through 1990 (U.S. Geological Survey, 2016), partly in response to nearby high-capacity pumping that ceased in January 1997. Water levels only recovered about 5 ft when pumping ceased, indicating that long-term processes may have permanently altered hydraulic conditions in the Silurian aquifer—and the wetlands they discharge to—in at least parts of the Lower Des Plaines River Valley. Modeling efforts designed to assess natural groundwater flow conditions have been completed at the Lockport Prairie Nature Preserve (Graef, Anhalt, Schloemer, and Associates, Inc., 2008) but are not available for any of the other focus areas. Application of groundwater-flow modeling to assess natural conditions is particularly important for the River South Parcel.

Summary and Conclusions

The federally endangered Hine's emerald dragonfly (HED) inhabits wetlands in parts of the Lower Des Plaines River Valley and other areas in northeast Illinois that are recharged by cool, slow moving, alkaline groundwater derived from Silurian dolomite or unconsolidated deposits consisting partly of eroded Silurian dolomite. The habitat requirements of the dragonfly are constrained so that small changes in the amount and quality of groundwater being discharged into the wetlands can have a substantial effect on the habitat. Previous investigations of the biology, geology, hydrology, and water quality at the various HED habitats in the Lower Des Plaines River Valley have identified potential threats to the habitats, as well as potential work activities that could improve the quality of the various habitats.

The West, East, and Middle Quarries (hereafter referred to collectively as "the Quarry") contain a flat wetland area in the center of the Middle Parcel Expansion Area that is currently (2018) used by adult HED mainly for foraging and as a flight corridor. The wetland receives water from precipitation and inflow of surface water from small drainages near Route 53 offsite and perhaps some groundwater discharge from the Silurian and glacial drift aquifers during short periods of high water. Water exits the Middle Parcel Expansion Area as evapotranspiration, through surface-water drainage, as drainage to the Silurian aquifer during periods of lower water levels, and as drainage from the Silurian aquifer to the quarries in at least the southern part of the Middle Parcel Expansion Area. Water-quality data indicate a variety of contaminants in surface water and, to a lesser extent, groundwater.

Removal of much of the watershed that fed the southern drainage and diversion of groundwater to quarry dewatering centers has produced a hydrologic regime at the Middle Parcel Expansion Area that is substantially drier than would occur if the Quarry did not exist. These drier conditions have degraded the Middle Parcel Expansion Area as HED habitat. Because HED activities at the Quarry are restricted to transit and foraging, increased pumping to support expanded mining at the East and Middle Quarries is expected to have minimal effect on the HED at the Quarry. Model simulations indicate that increased pumping to support expanded mining at the West Quarry will substantially reduce the amount of groundwater discharged to the River South Parcel and will reduce groundwater discharge to the Lockport Prairie Nature Preserve by a small amount. Model simulations indicate that recharge from groundwater mitigation features will be sufficient to offset this decrease.

The River South Parcel contains wetland areas that are the second most productive HED breeding habitat in Illinois. The wetlands receive water directly from precipitation, surface-water inflow derived from the Silurian aquifer at seeps along the bluffs, groundwater discharge from the Silurian aquifer in the river valley, and periodic inflow from the Des Plaines River in the southern part of the River South Parcel. Water exits the River South Parcel as evapotranspiration and surface-water drainage to the Des Plaines River in the eastern and southern parts of the parcel. Water levels show large variations in the Silurian aquifer near the bluffs in response to changes in precipitation, resulting in substantial variation in the amount of flow to the seeps. Water-level data show fairly small variation in the river valley, indicating stable flow to the wetland from the Silurian aquifer. Small changes in water level at the River South Parcel appear to have potentially large effects on HED habitat. Surface-water and groundwater quality data indicate predominately calcium and alkaline water derived from the Silurian aquifer with some modification by anthropogenic sources of chloride, nitrate, and phosphorus.

The hydrologic regime at the River South Parcel has been altered by pumping at the Quarry. Expansion of quarry operations into the West Quarry Expansion Area is expected to divert additional water from the River South Parcel. Artificial infiltration to shallow groundwater in this area, coupled with intensive monitoring, is anticipated to ameliorate the expected hydrologic effects of quarry expansion.

The Lockport Prairie Nature Preserve contains wetlands that constitute the largest single HED habitat in Illinois. The wetlands receive water directly from precipitation, surface-water inflow derived from seeps fed by the glacial drift aquifer and the upper part of the Silurian aquifer along the bluffs and groundwater discharge from the Silurian aquifer in the river valley. Flow from the seeps appears to constitute a larger portion of the flow into the Lockport Prairie Nature Preserve north of Division Street than south. Discharge from the Silurian aquifer to the wetlands appears to constitute a higher percentage of the total volume of water in the wetland south of Division Street than north. Water exits the Lockport Prairie Nature Preserve as evapotranspiration and surface-water drainage to the Des Plaines River in the eastern part of the preserve. The amount of discharge from the glacial drift and Silurian aquifers to the seeps at the bluff varies in response to changes in the amount of groundwater recharge that takes place at a variety of time scales. Discharge from the Silurian aquifer to the alluvial deposit in the valley of the Des Plaines River is more consistent due to an increased amount of water originating from the semiconfining unit in this part of the flow regime. Water levels in the Silurian aquifer in the river valley consistently indicate the potential for consistent, stable flow to the alluvial aquifer and the wetlands at most of the Lockport Prairie Nature Preserve but show less potential to recharge to these deposits during droughts. The stable flow helps to sustain the wetlands during drier periods when water from other sources is reduced.

Surface water at the Lockport Prairie Nature Preserve is alkaline and calcium rich. Lower surface-water temperatures presumably associated with areas of groundwater discharge have been observed. Temperatures are increasingly affected by atmospheric temperature with increased distance from the point of discharge. Water quality shows inconsistent seasonal trends and appears to be affected by changes in the source water, roadside runoff, and fertilizer application.

Modeling indicates the hydrologic regime at the Lockport Prairie Nature Preserve may have been altered by pumping from nearby high-capacity wells and possibly the Quarry, but this pumping has no obvious effects on water levels measured within the groundwater recharge area for the Silurian aquifer at the Lockport Prairie Nature Preserve. Model results also indicate that small changes in water level in the Silurian aquifer at the Lockport Prairie Nature Preserve may substantially affect the volume of discharge to the wetlands. Model simulations indicate that future pumping associated with dewatering of the West Quarry will reduce the volume of water discharged from the Silurian aquifer to the Lockport Prairie Nature Preserve, but that increased recharge from proposed mitigation features will be sufficient to offset this reduction.

The Com Ed and Long Run Parcels contain substantial wetland areas used by HED larvae and adults. These wetlands receive water from precipitation, inflow of surface water from offsite sources such and Bruce Lake and Long Run Creek, and groundwater discharge from the Silurian aquifer in at least the eastern and central parts of the Com Ed Parcel. Water levels in the parcels are affected by seasonal and longer term variations in recharge from precipitation and groundwater, which periodically results in the wetlands and alluvial aquifer going dry in parts of this area. Water levels at a location typically vary by less than a few feet, even during drought conditions. Surface water drains from the wetlands to the Illinois and Michigan Canal and to the Silurian aquifer in the western part of the parcels. Water-quality data indicate this area contains alkaline water derived primarily from the Silurian aquifer, with the likely presence of road-salt constituents in the shallow water. Expansion of dewatering operations at the Quarry is not expected to affect the hydrology of the Com Ed and Long Run Parcels. The effect of increased high-capacity pumping within the groundwater recharge area for the parcels has not been investigated.

The Long Run Seep Nature Preserve contains larval HED habitat associated with seep-fed rivulets discharging from the glacial drift aquifer. Water chemistry in the rivulets and shallow groundwater likely are affected by dissolution of carbonate minerals in the unconsolidated materials, road salt and fertilizer application, and possibly discharge from nearby septic systems.

The Romeoville Prairie Nature Preserve is used by adult HED in areas of seep-fed rivulets discharging from the thin unconsolidated deposits, potentially from a fracture in the near-surface bedrock. Water levels in the unconsolidated deposits and shallow bedrock are typically stable but are affected by precipitation events. Water levels in the unconsolidated deposits also are affected by evapotranspiration during the summer months. The Silurian aquifer is used for high-capacity groundwater withdrawals within and near the groundwater recharge area for the Romeoville Prairie Nature Preserve. The effects of this pumping on the hydrology of the Romeoville Prairie Nature Preserve have not been assessed. Elevated concentrations of chloride, nitrate, and arsenic indicate that human activities are affecting water quality at an unidentified surface-water feature in the Romeoville Prairie Nature Preserve.

The Keepataw Forest Preserve is used by adult HED in areas of seep-fed rivulets likely discharging from unconsolidated deposits and partly fed by surface-water drainage from the northeast part of the property. The hydrology and geology at the Keepataw Forest Preserve have not been characterized, particularly the effects of seep flow and surface-water runoff on the HED habitat in the topographic depression south of the seeps. The effect of groundwater withdrawals from the Silurian aquifer south of the Keepataw Forest Preserve also has not been characterized. Water quality at the seeps is calcium bicarbonate in type with substantial concentrations of sulfate and chloride. The effects of surface-water runoff from Interstate I-355 on surface-water quality at the HED habitats in the Keepataw Forest Preserve are unknown.

The Black Partridge Woods Forest Preserve is occasionally used by larvae and adult HED near a seepage marsh in the northeast part of the preserve. Biologic, hydrologic, and water-quality conditions at the habitat have not been characterized. Elevated concentrations of chloride indicate that anthropogenic activities are affecting surface-water quality at Black Partridge Creek.

The natural rivulet in the Emerald Fen area of the Waterfall Glen Forest Preserve contains larval and adult HED habitat. The fen receives water from a natural seep-fed rivulet discharging from the unconsolidated deposits as well as four artificial rivulets whose water is derived from artesian flow from a water-supply well open to the Silurian aquifer. The rivulets appear to have flowing water year round. Discharge at the natural rivulet is occasionally affected by flooding of the Des Plaines River. Water temperature, specific conductance, and pH in the natural rivulet display more variation than in the artificial rivulets. In combination with differences in the major ion chemistry, these differences reflect differences in the source of the water in the rivulets and the amount of modification in water temperature due to atmospheric interaction. Water chemistry indicates the dissolution of carbonate minerals in the unconsolidated deposits and the Silurian aquifer affects water chemistry, as does the application of road salts.

Seeps associated with groundwater discharging from the glacial drift aquifer at the McMahon Fen Nature Preserve provide water to a number of rivulets that provide at least periodic adult and larval HED habitat. Discharge to the seeps is likely to be sustained by recharge to the glacial drift aquifer near the seeps, in areas north of the preserve, and perhaps upwelling from the underlying semiconfining unit. Bed erosion along some of the rivulets may reduce the quality of this habitat for the survival of HED eggs and larvae.

In addition to the above mentioned habitats, uncharacterized and recently discovered (2016) HED habitats are present in Illinois. These habitats indicate HED habitat may exist in areas of Illinois beyond the Lower Des Plaines River Valley and in areas not directly overlying dolomite bedrock.

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