PRELIMINARY ASSESSMENT OF THE POTENTIAL FOR MOVEMENT OF EGGS AND (OR) FRY OF ASIAN CARP INTO THE CHICAGO SANITARY AND SHIP CANAL FROM ADJACENT WATERWAYS THROUGH GROUNDWATER PATHWAYS ABOVE THE ELECTRIC FISH BARRIER NEAR ROMEOVILLE, ILLINOIS

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INTRODUCTION

During January-May 2010, various measures were undertaken as part of a preliminary assessment of the potential for fracture openings in the area's Silurian-age dolomite bedrock to act as conduits for the movement of eggs and (or) fry of Asian carp into the Chicago Sanitary and Ship Canal (CSSC) from adjacent waterways. The assessment specifically focused on the reach of the CSSC upstream of the electric fish barrier near Romeoville, Ill., where the CSSC is closely bounded by the Des Plaines River (DPR) and the Illinois and Michigan Canal (IMC). The nearly 17-mile (mi) study reach generally extended from Romeoville Rd (W. 135th St) in Romeoville, northward (upstream) to Archer Ave in Summit, Ill. Additional field inspections of the IMC were made as far as about 3 mi south (downstream) of Romeoville Rd, near Lockport, Ill. Review of hydrogeologic studies by other investigators was done for sites within the DPR valley from about Lockport to Summit, and several hundred yards on either side of the DPR and IMC.

The preliminary assessment included review of relevant information and hydrogeologic data from engineering and investigative reports; these included details of construction of the CSSC, regional and local geology, fracture characteristics, bedrock hydraulic properties, and groundwater levels and flow. Review also included inspection of USGS topographic quadrangle maps of the area and satellite imagery available from Google Earth. Field inspections consisted of boat and foot trips along the DPR, CSSC, and IMC, and included the Heritage Quarries located north of Lemont, Ill., along the IMC and the Calumet Sag Channel (CSC). As part of these inspections, the area's hydrology, geology and stratigraphy were evaluated and mapped; bathymetry and bed composition (bedrock or alluvium) of the DPR and IMC were determined; and bedrock-fracture patterns characterized, including measurements of their orientation, aperture, and

spacing. Relevant hydrogeologic features evident at land surface and along the banks and walls of the waterways and quarries were extensively photo-documented.

From the compilation and integration of the hydrogeologic information, locations for further study are to be selected. These are locations where fractures of sufficient aperture and flow to allow their serving as conduits for inter-waterway movement of Asian carp eggs and (or) fry into the CSSC might reasonably be present. Additional assessment of these locations will incorporate surface-geophysical methods to help identify such subsurface fractures, should they be present. On the basis of the geophysical assessments, specific study sites will be subjected to detailed study, incorporating the installation of observation wells; borehole geophysical surveys; surface-and groundwater level and flow monitoring; and dye- and particle-based tracer tests. These efforts are intended to best determine and describe the potential for, and possible mechanisms of, bedrock-conduit flow and its relation to the continued upstream migration of Asian carp to Lake Michigan and other Great Lakes region waterways.

DOCUMENT REVIEW

For the background review, investigative reports from six study sites were evaluated. Several reports were reviewed that were generally regional in scope, but included investigative results from a few locations within the study area, as were two related reports that considered the near-present-day (1990-94) construction characteristics and hydraulics of the IMC. Also reviewed was an engineering report detailing construction of the CSSC, which included modifications to the DPR channel. All reviewed documents are presented in the "General References listing". Additionally, discussions were held with Illinois State Geological Survey (ISWS) geologist, Dr. Donald Mikulic, regarding characteristics of the Silurian dolomite within the study area. Dr. Mikulic specializes in study of these deposits, authoring many related publications. As part of these discussions, Dr. Mikulic attended a day-long field trip that included boat trips along the DPR and the CSSC, generally from Romeoville Rd to Kingery Hwy (Route 83) (about midway between Romeoville Rd and Summit). The terminal location, just north of the CSC, is about one-half mile south of Red Gate Woods in the Cook County Palos Forest Preserve.

Review of the available documents and discussions with Dr. Mikulic resulted in focusing attention of the preliminary assessment, as well as the boat trips, to reaches of the DPR and CSSC downstream of about Red Gate Woods and Kingery Hwy. Upstream of this area, towards Summit and the Metropolitan Water Reclamation District of Greater Chicago's (MWRDGC) McCook facility (referred to here as the planned McCook

Reservoir), the bed of the DPR is reported to consist of fine-grained glacial and alluvial deposits of Quaternary age that overlay the uppermost Silurian bedrock and the bed of the CSSC to consist extensively of glacial deposits, particularly upstream of Gilbert Ave/Willow Springs Rd near Summit (Hill, 1896). In the vicinity of the McCook Reservoir, the glacial till thickness generally exceeds 25 ft (US Army Corps of Engineers, 1999). Thus, in the upper reaches of the study area, it was presumed there is little to no potential for movement of Asian carp eggs and (or) fry that might be present in the DPR into underlying fractures (flow conduits) that might be present in the sediment-covered dolomite bedrock. However, future assessment might be considered to verify and more accurately describe and map the river-bed composition in the upper reaches of the study area.

Area Geology and Stratigraphy

Surficial unconsolidated deposits, where located between the CSSC and the bordering DPR and IMC, typically consist of buried native topsoil, fill material, and immature topsoil developed from the fill and native soils (V3 Companies, Ltd., 2008; STS Consultants, Ltd., 2002). The distribution of these deposits varies widely throughout the study area, with fill and reworked native materials predominating. Historic and periodic recent deposition of alluvial sediments likely are a contributing source of generally finer-grained unconsolidated deposits. Fill and reworked native materials, consisting of silty clay to sand-to-boulder sized debris (as much as 3 feet (ft) in diameter), generally result from past excavation of the CSSC and IMC and quarrying operations adjacent to the waterways. Generally south of Kingery Hwy, the thickness of these unconsolidated deposits across the study area typically ranges from a few inches to about 10 ft (where canal- excavation spoils were deposited in mounds or ridges). Locally, shallow marshes and wetlands dominated by cattails and phragmites have been established, as have wooded areas. The vegetated areas are present principally north of Romeoville Rd to I-355 (west of the CSSC) and north of the Lemont-area barge slips to Gilbert Ave/Willow Spring Rd.

Silurian dolomite bedrock geologic units of interest in the study area include from southwestward to northeastward and generally moving up-dip, the Joliet Formation (Fm), Romeo member (mbr); Sugar Run Fm; and Racine Fm. Detailed stratigraphic and lithologic descriptions of these units are given in the included tables. These units have been incised and exposed by construction of the CSSC, the IMC, and past quarrying operations, as well as exposed by natural erosion in the area, including by flow of the DPR. For the most part, construction and quarrying operations have destroyed the natural bedrock surface between and adjacent to the CSSC, DPR, and IMC waterways. The bedrock surface across much of the DPR valley has been planed off, quarried, and

buried with rock debris. Natural surfaces of the bedrock that were exposed between periods of paleo-deposition locally were irregular, with furrows, ridges, and potholes (Leverett, 1899). Few, if any, of these natural surfaces remain following construction operations in the area.

In the southern part of the study area, downstream (southwest) of about I-355, the CSSC has been excavated principally in the Joliet Fm, Romeo mbr. In the upper half of the reach between Romeoville Rd and I-355 this unit typically is overlain by the Sugar Run Fm, as it is reported exposed at the Vulcan Materials Quarry on the west bank of the DPR, downstream of I-355 (Joseph Crawford, Vulcan Construction Materials, oral commun., 2010), and at the former Castle Flagstone Quarry, located south of the CSSC and upstream of I-355 near Lemont (Donald Mikulic, Illinois State Geological Survey, oral commun., 2010). With the land surface on the west bank of the DPR topographically a few feet higher than that adjacent to the CSSC, the Sugar Run Fm tends to overlie the Joliet Fm farther downstream in the western part of the study area than in the eastern part.

The purity of the carbonate deposits and thick-bedded to massive character of the Joliet Fm, Romeo mbr results in limited development of solutionaly enlarged fractures, particularly bedding-plane partings, that might be of an aperture and areal extent to allow the movement of sizable rates and quantities of water within the fractures. A chert horizon that occurs in the mid part of the Romeo mbr can affect solution of the adjacent bed deposits. Pre-Pennsylvanian solution cavities, that include apparent sink holes, are reported in the area, but do not seem numerous. Near-vertical fractures may locally control the development of the solution cavities. Where identified, Pennsylvanian clastics have tended to infill the cavities (Donald Mikulic, Illinois State Geological Survey, oral commun., 2010).

In the mid-part of the study area, upstream (northeastward) of about Lemont Rd, the CSSC has been excavated principally in the Sugar Run Fm, with the Racine Fm increasingly present as an overlying unit as the CSC is approached to the north. South of Lemont to about I-355, the CSSC seems to have been excavated within both the mid-to-upper part of the Joliet Fm, Romeo mbr and the lower part of the Sugar Run Fm. In this reach, the Sugar Run Fm generally is of limited thickness and might be locally absent.

North of Lemont, the Sugar Run Fm thickens and is increasingly exposed along the walls of the CSSC. However, in the vicinity of the Heritage Quarries there is an abrupt change in the thickness of this unit and the overlying Racine Fm (Donald Mikulic, Illinois State Geological Survey, oral commun., 2010). Over a relatively short distance of about

0.5-1.0 mi the Sugar Run Fm reportedly is transposed from its presence as the uppermost 10 ft or so of the downstream Consumers Quarry to its thicker presence at the base of the upstream Great Lakes Quarries, underlying 100 ft or so of Racine Fm deposits. Faulting has been considered one plausible explanation for this anomalous change in unit thickness. There was no direct evidence of a fault reported during quarrying operations and construction of the CSSC in the latter half of the 1800's and presently few bedrock exposures remain that might be useful in documenting the presence of such a fracture. Much of the bedrock in this area is covered by retaining cut stone blocks forming the walls of the CSSC and submerged under waters of the quarries and the CSSC.

The Sugar Run Fm, with its well-bedded, even texture, and dense character also is not strongly conducive to the development of secondary solution features. However, the dolomite deposits have a somewhat more argillaceous content than those of the underlying Joliet Fm. Its argillaceous content, characterized by thin but prominent partings, might contribute to limited-to-moderate secondary solution, particularly expressed as enlargement of the partings. Such bedding-plane solution has been identified in other localities (Donald Mikulic, Illinois State Geological Survey, oral commun., 2010).

In the northern part of the study area, generally upstream of the Lemont-area Heritage Quarries to the CSC and beyond, the CSSC has been excavated principally to fully in the Racine Fm at locations where bedrock was encountered. The highly argillaceous composition of the inter-reef deposits that partly compose this unit and are present along the corridor of the CSSC and DPR in the study area contribute to their high susceptibility to secondary solution. The impedance to vertical flow affected by argillaceous partings and thin dolomitic shales in the unit likely contribute to the strongly enhanced and widely extensive (at least 1,600 ft) solution along bedding planes identified in the area (Nicholas and Healy, 1988). Additionally, a cherty horizon that occurs near the base of the unit can affect solution of the adjacent bed deposits, as this horizon can be rubbly, and thus, relatively permeable.

Fracture Characteristics

The study area is located on the crest of the Kankakee arch (Willman, 1971). Silurian strata dip slightly to the east and southeast (12 to15 ft/mi) because of the eastward plunge of the arch. Tensile stress from subsidence of the Michigan and Illinois basins and uplift of the Wisconsin and Kankakee arches resulted in jointing in the brittle dolomite (Foote, 1982). Joints, referred to here as fractures, occur in the dolomite in three principal and mutually orthogonal sets. Two of the sets are near-vertical (about

20° or less of vertical) and are the result of structural deformation. The third set is near-horizontal and results from solution along bedding planes.

The few studies that have addressed the presence of fractures in the Silurian dolomite in the study area focused on two areas--near the McCook Reservoir near Summit, and near Kingery Hwy and the confluence of the CSC with the CSSC, which includes the Palos Forest Preserve. These reports include US Army Corps of Engineers (USACE) (1999); Nicholas and Healy (1988); and Environmental Resources Management-North Central, Inc. (1992b) (as well various related reports—see General References listing). A more regional report by Foote (1982) included fracture data from a quarry (Castle Flagstone) west of Lemont, near I-355.

The USACE (1999) described the Silurian dolomite deposits and fracture characteristics in the nearby Vulcan Materials McCook Quarry. Subsequent related reports further described the Silurian geology on the basis of numerous rock cores. An orthogonal set of the near-vertical fractures was indicated, with orientations of 48° (N48E) and 134° (N46W). A third fracture set oriented about 165° (N15W) with a dip of about 75° SW also was indicated. Fracture spacings of the first set are 1 per 2 ft to 10 ft; spacings for the second set about 1 per 10 ft to 1 per 50 ft. The spacings of both sets were indicated to be highly variable, with gaps up to 500 ft. The northeastward trending fractures were described as normally tight, but more likely to contain water. The northwestward trending fractures were described as normally dry and often filled with clay, particularly near land surface. Other assessments of fracture orientations in the vicinity of the quarry and nearby McCook Reservoir indicate two predominant near-vertical (about 85° fracture sets, oriented at 26° to 65° (N26E to N65E) and 118° to 145° (N62W to N35W) (STS Consultants, Ltd., 2002).

Nicholas and Healy (1988) cited evidence from other area investigations of substantial bedding-plane fractures in the dolomite bedrock. Among the citations, Zeizel and others (1962) reported extensive solution cavities “tens of feet in dimension” at a location near the DPR in southwest DuPage County. Marge Bynoe (Argonne National Laboratory, written commun., 1982) described the drainage of hundreds of thousands of gallons of water from excavated, water-filled glacial sediments with the loss attributed to drainage to a solution cavity in the underlying dolomite unit at Argonne National Laboratory. Rock cores collected by the USACE during construction of the CSC indicate the presence of bedding-plane fractures with apertures as large as 2 ft. Additionally, Nicholas and Healy (1988) report that in many cases these horizontal fractures, as well as those identified in wells drilled by the USGS, are filled with clay- to sand-sized sediment of glacial origin.

Nicholas and Healy (1988) measured orientations of 156 near-vertical fractures in the exposed dolomite at two local quarries near the Palos Forest Preserve (Sag Quarry; unidentified quarry). Additionally, lineaments were mapped on aerial photographs over a 25 square mile area centered on their study site. As analyzed by rose diagram, an orthogonal set of the near-vertical fractures was indicated, with a primary orientation of about 40° (N40E) and a secondary orientation of about 130° (N50W). The 106 lineaments that were mapped indicated a similarly oriented orthogonal set, as well as an additional fracture set oriented at about 20° (N20E). Foote (1982) and others investigating regional fracturing patterns have indicated that the frequency and aperture of near-vertical fractures in the area's Silurian bedrock deposits decrease with depth below the bedrock surface. Nicholas and Healy (1988) note that the presence of sinkholes at some locations in the region suggests some closely spaced groups of deeper vertical fractures may be present in the study area.

Nicholas and Healy (1988) identified several prominent horizontal fractures developed along bedding planes and opened by subsequent solution in the Racine Fm deposits at the Red Gate Woods site. The fractures extend up to hundreds of feet in outcrops along the northern side of the DPR, and, as identified in the borehole geophysical logs of study area wells, may be continuous for greater than a quarter mile. These "sub-regional to regional" subsurface fractures were mapped at elevations of about 577, 565, 550 ft (NGVD29), as well as a much greater depths. The horizontal fractures at about 577 and 565 ft were indicated to intersect the CSSC (Nicholas and Healy, 1988, fig. 6). Bedrock surface in that study was indicated as about 580 ft. On the basis of water-level data available from the Lenz Oil industrial site (Environmental Resources Management-North Central, Inc., 1992a), about 1 mi southwest of Red Gate Woods, and from water-level and river-depth information collected during a boat trip for the present study, a similar bedrock-surface elevation (about 582 ft) was estimated. As such, none of the bedding-plane fractures reported by Nicholas and Healy (1988) are expected to intersect the DPR. Additionally, these investigators mapped the bed of the IMC a few feet above the bedrock surface and within the surficial glacial drift deposits that generally blanket the region.

Foote (1982) summarized fracture orientations from multiple measurements at a former quarry, Castle Flagstone, located west of Lemont along the bank of the IMC. The reported primary orientation of orthogonal sets of near-vertical fractures was 37° (N37E) and the secondary orientation was 115° (N65W). Uppermost bedrock in the quarry (and generally to tens of feet below the base of the CSSC) is the Joliet Fm, Romeo mbr. Fracture spacings are reported as about 1 fracture every 10 ft for the primary fracture set and about 1 every 20 feet for the secondary set.

Stratigraphic evidence suggests the possibility of the presence of a fracture with notable vertical offset in the vicinity of the Heritage Quarries north of Lemont (Donald Mikulic, Illinois State Geological Survey, oral commun., 2010). If present, the fracture could possibly be laterally extensive and occur as a zone of rubble. Such fractures often can be quite permeable, and thus, could possibly act as a conduit for inter-waterway movement of Asian carp eggs and (or) fry into the CSSC.

Hydrology

Surface-water levels in the DPR valley waterways range from about 590 ft in DPR to about 580 ft in the CSSC. South of I-355, where the DPR widens as it approaches Romeoville Rd, the level of the DPR drops close to 7 ft; the drop in water level and related increase in water velocity are associated with a notable decline in the bedrock-surface elevation downstream to about Lockport (James Duncker, U.S. Geological Survey, oral commun., 2010). Generally consistent water-levels and flow rates in the CSSC are maintained for navigation purposes by waterway control structures operated by the MWRDGC and the USACE. The levels in the IMC generally are similar to those in the DPR upstream of Romeoville Rd. With the substantially higher surface-water levels in the waterways flanking the CSSC, groundwater-flow gradients within the dolomite bedrock are likely to be large and in the direction of the CSSC. Water levels in the CSSC are largely controlled for maintenance of downstream flow away from Lake Michigan and management of barge traffic in the canal. As such, these levels generally vary little and flow gradients between the adjacent waterways and the canal are similarly expected to vary little. Levels in the DPR generally seem to vary by no more than a few feet, (Environmental Resources Management-North Central, Inc., 1992a) depending on climate conditions, but the historic range in water levels were not determined as part of this groundwater-flow-system assessment. There is evidence that DPR levels can rise high enough periodically to result in bank overflow and allow direct discharge to the CSSC. The discharge can occur as overland flow, principally along topographically low passages, and (or) as subsurface flow through the rubbly fill material overlying the bedrock surface. Assessment of the surficial-flow pathways and their potential for inter-waterway movement of Asian carp eggs and (or) fry is the subject of further study by the USGS and USACE.

Sub-regional groundwater flow in the DPR valley is related principally to the predominant surface-water bodies—the DPR and the CSSC. Flow is from the uplands flanking the valley to the valley floor, where groundwater recharges these surface-water bodies. Vertical groundwater gradients measured at study sites bordering the DPR near Kingery Hwy (Lenz Oil) (Environmental Resources Management-North Central, Inc., 1992a) and near Lockport (Lockport Prairie Nature Preserve) (Graef, Anhalt, Schloemer

& Associates, Inc., 2008) are upward, indicating discharge to the DPR. Similarly, flow from the east side of the DPR valley is reported to discharge to the IMC and CSSC (Nicholas and Healy, 1988). Groundwater discharge to the CSSC, DPR, and IMC principally is limited to flow through the dolomite bedrock deposits, as only a thin veneer of unconsolidated materials overlie bedrock within the study area.

Within the dolomite, groundwater flow is primarily through connected vertical and horizontal fracture networks (Nicholas and Healy, 1988). Horizontal hydraulic conductivities (Kh) ranging from about 2 feet per day (ft/d) to 110 ft/d are reported in the Racine Fm deposits present near the confluence of the CSC and CSSC (Lenz Oil site; Environmental Resources Management-North Central, Inc., 1992a). Evidence from other hydraulic tests and observations suggest that the Kh of certain large fractures in the Kingery Hwy/Palos Forest Preserve area may greatly exceed 110 ft/d. Although no quantitative information was obtained, results of well development led Nicholas and Healy (1988) to conclude that the weathered-bedrock surface also has a large hydraulic conductivity. In the far northern part of the study area (McCook Reservoir near Summit) reported values in the uppermost Racine Fm average 0.03 ft/d (geometric mean), with a maximum of 2.8 ft/d (STS Consultants, Ltd., 2002). Geophysical and borehole-flow testing indicated some flow associated with fractures and bedding-plane partings in this unit and water-level data indicated the unit to be in hydraulic communication with the DPR and CSSC. However, reported observations of the exposed walls of the nearby Vulcan Materials McCook Quarry make no mention of notable quantities flow associated with fractures or partings that may be present in upper parts of the unit.

Downstream of the southern part of study area (Lockport Prairie Nature Preserve, near Lockport), reported values of Kh range from about 0.1 ft/d to 18 ft/d (Joliet Fm, Romeo mbr) (Graef, Anhalt, Schloemer & Associates, Inc., 2008). Observations from the Vulcan Materials Quarry, located between Romeoville Rd and I-355 and open to the Sugar Run and Joliet Fms, lend support to this quantitative indication of a limited contribution of fractures to groundwater flow in these units. Joseph Crawford, Vulcan Construction Materials (oral commun., 2010) reports seepage from the high wall of the quarry, located within 100 to 1,000 ft of the DPR, is minimal and easily managed.

Construction and Hydraulic Characteristics of the Illinois and Michigan Canal

Two reports that describe near-present-day (1990-94) construction and hydraulic characteristics of the IMC near Lockport were reviewed (Demissie and Xia, 1990; Demissie and Akanbi, 1994). Particularly considered were factors that could relate to the possible deterrence of upstream migration of Asian carp from the canal's confluence with the CSSC near Lockport to above the electric fish barrier near Romeoville.

Two water-flow control structures have been present on the IMC about 3 mi downstream of the electric barrier for more than 20 years (Demissie and Xia, 1990). These structures, located near the oil refinery north of Lockport, include a dam (identified as the "Texaco Dam") and a side-overflow weir. The Deep Run Creek weir is located along the west bank of the canal about two-thirds of a mile upstream of the dam. The dam, with a top elevation of 578.35 ft above sea level, was constructed to pond water in the canal for use in firefighting at the adjacent refinery. The eight gates of the dam have remained closed and non-operational since possibly the late 1980's. The weir, consisting of two steel beams placed along a break in the canal bank and with a top elevation of 577.79 ft, was constructed to permit floodwaters transmitted down the canal to overflow into Deep Run Creek; thus, under most storm conditions, reducing the potential for flooding in the area of the refinery and overtopping of the Texaco Dam by flow in the IMC.

The typical 2 to 3 ft (approximate) difference in stage in the IMC above and below the Texaco Dam, along with the dam structure and its overlying cat walk, seemingly serve as an effective barrier against the upstream movement of Asian carp to and beyond the electric fish barrier under most streamflow/meteorologic conditions. Hydraulic modeling by Demissie and Akanbi (1994) to estimate water levels/stage in the IMC under various precipitation frequency and duration scenarios indicate that water levels in the modeled watershed near Lockport could exceed the height of the Texaco Dam under conditions of a 50-year, 24-hour storm. Under such circumstances, it might be possible for Asian carp to move upstream of the dam and beyond the electric fish barrier. Once upstream of the barrier, there might be some potential for the movement of their eggs and (or) fry to move through bedrock-fracture-flow conduits from the IMC to the CSSC.

To evaluate the possibility of flood-stage waters being high enough to allow the overtopping of the Texaco Dam at any time from 1994 to the present (May 2010), the hydraulic simulation results of Demissie and Akanbi (1994) were further considered. This target period conservatively includes the estimated time of first arrival of Asian carp in the upper Illinois River/CSSC system (about 1997 or thereafter; Kolar and others, 2007, p. 48, table 4.4). The equivalent precipitation depth under the simulated storm condition was 6.46 inches (in.). A review of daily precipitation totals included in various databases for nearby gages in Lockport, Romeoville, or Argonne National Laboratory (near Lemont) indicate that during the target period, the highest recorded precipitation totals never exceeded 6 in., with the greatest recorded totals, 5.55 and 5.35 in., respectively, occurring on July 18 and 19, 1996. Thus, precipitation totals during this period likely never have approached those that could result in overtopping of the dam, and thus, allowed the further upstream movement of Asian carp. However, detailed and

complete hydraulic analysis and survey of local observers would be necessary to verify this conclusion.

Demissie and Xia (1990) did indicate that sediment accumulation in the IMC from tributaries in the watershed was an issue that could increasingly affect the flow dynamics within the IMC. However, as sediment infilling occurs in the ponded canal above the Texaco Dam, excess flow should be diverted into Deep Run Creek, as controlled by the height of the weir. A large-scale sediment-removal operation was undertaken during 2008-09 to resolve or avoid problematic levels of sediment infill in the ponded reach (Chevron, 2010). Inspection of satellite imagery available on Google Earth from April 30, 2008 shows a 1.6 mi reach of the IMC from the Texaco Dam to several hundred yards north of Long Run Creek mostly emptied of water. Flow apparently was diverted by pumping from the IMC, where dammed above Long Creek Run, and then discharged to the IMC, immediately downstream of the Texaco Dam. Earthmoving equipment is shown engaged in removing the canal-filling sediment, with fractured (jointed) bedrock seemingly exposed along a substantial reach of the canal (about 0.7 mi). As a result of the sediment removal there should be increased storage capacity for water in the canal, and thus, less potential for overtopping of the dam during future periods of substantial precipitation.

FIELD INSPECTION

Geology

Field inspection of the dolomite deposits in the area was made to better assess the relation between their lithologic composition and the development and distribution of near-vertical and (or) horizontal fractures. As part of the inspection, the general areas along the CSSC, DPR, and IMC where the various Silurian stratigraphic units are present were identified. As noted, bedrock units of interest in the study area include from southwestward to northeastward and generally moving up-dip, the Joliet Fm, Romeo mbr; Sugar Run Fm; and Racine Fm. In the southern part of the study area, downstream of about I-355, the CSSC has been excavated principally in the Joliet Fm, Romeo mbr. A chert horizon observed within the west wall of the CSSC in the southern third of this reach identifies a mid-Romeo mbr stratigraphic position. There was no evidence of bedding solution associated with this chert horizon. Along the walls of the canal, particularly between the fish barrier at the downstream end and about the upstream location of the Vulcan Materials Quarry, several karst-like solution openings were present. The openings extend as much as 10 ft into the canal wall toward the DPR. Inspection of the openings indicated that the openings likely do not extend much

further inland. Seemingly, their apertures are greatly reduced, and where openings might persist along near-vertical fractures, they likely are infilled with sediments.

Several hundred yards north of the Vulcan Materials Quarry, in quarry spoil along the east bank of the DPR, a 1.5 ft long orthoconic nautiloid indicates near-surface bedrock deposits in this reach to be within the Sugar Run Fm, as does the less-massive, flagstone character of the bedding. The presence of the formation is either not as readily apparent or is not present along the CSSC within the reach between I-355 and Lemont Rd. Upstream of Lemont, along the IMC, the presence of sinuous trails in the bedding surface indicates the uppermost bedrock deposits in this area south of the CSSC are of the Sugar Run Fm.

Beginning generally upstream of the barge slips east of Lemont Rd, cut stone block replaces the exposed bedrock of walls of the CSSC. The canal walls are almost consistently block for several miles upstream of the barge slips. The blocks seem to sit on or near the top of the Sugar Run Fm, near the water line along the canal wall. The blocks hold back unconsolidated deposits present along the banks of the canal as far upstream as at least Kingery Hwy. Field inspection by boat did not extend upstream beyond this point. It is reported that the block walls extend several miles upstream of Kingery Hwy, approaching Gilbert Ave/Willow Springs Rd. In the reach upstream of about Red Gate Woods/Palos Forest Preserve the banks of the CSSC become increasingly more earthen and vegetated. In some locations, the block have eroded or been dislodged and unconsolidated material is eroding into the canal. The blocked-wall reach of the CSSC generally represents the area of the DPR, CSSC, and IMC where dolomite of the Racine Fm replaces that of the Sugar Run Fm and where upstream of Kingery Hwy, fine-grained unconsolidated deposits, generally of glacial origin, increasingly overlie the Racine Fm.

The bed material of the DPR was surveyed from about Romeoville Rd to about 1 mi upstream of Kingery Hwy. For the survey, 1-in. diameter PVC tubing was used to “feel” the bed of the river and collect a small sediment sample, if possible. Survey points typically were at about one-quarter mile intervals. Survey results are depicted here in cross-sectional and areal formats. The results generally are consistent with the geologic materials (drift and bedrock) mapped during construction of the CSSC (Hill, 1896).

Locally from about Lemont Rd downstream to Romeoville Rd, 1 to 2 ft of bedrock may outcrop along the banks of the river; however, in most locations, the banks of the DPR is fine-grained fill, alluvium, and organic soils, intermixed with dolomite quarry spoils that flank the river along its banks. In the lower half of this reach, from about 1 mi downstream of the CSC to Romeoville Rd, the bed of the DPR is the exposed bedrock

surface. In the vicinity of the confluence of the CSC with the CSSC, the channel of the DPR deepens several feet and the bedrock surface that comprises the riverbed further downstream seemingly is overlain by a foot or more of fine-grained alluvium. The bedrock surface of the river bed is increasingly more exposed downstream of this buried reach, until overlying or intermixed fines are absent.

Upstream of the CSC confluence, particularly in the vicinity of Kingery Hwy to about the Red Gate Woods area, the DPR bed seems to be course-grained aggregate that might be composed of weathered bedrock and (or) alluvial sands and gravels of glacial origin. A facility study conducted immediately upstream of Kingery Hwy (Lenz Oil industrial site) indicated that within the study reach the bed of the DPR is the weathered-bedrock surface (Environmental Resources Management-North Central, Inc., 1992a). A bedrock high depicted a short distance upstream of the Lenz Oil site in the mapped cross-section of the CSSC (Hill, 1896) possibly supports the Lenz Oil observation regarding the DPR bed composition. However, the geology mapped by Hill (1896) also seems to clearly indicate the river bed to be fully within glacial drift upstream of the vicinity of the northernmost barge slip along the CSSC (about 1.5-2 mi downstream of the CSC and CSSC confluence).

Although field inspection of the DPR bed was not conducted further upstream of the vicinity of Kingery Hwy/Red Gate Woods, various sources of information indicate that within the uninspected upstream reach the DPR is fully incised into and underlain by glacial drift—primarily the fine-grained deposits that predominantly blanket the bedrock in this area. Supporting information includes descriptions of the unconsolidated and bedrock geology at the McCook Reservoir near Summit (STS Consultants, Ltd., 2002) and elsewhere along the CSSC and DPR (Hill, 1896) and observations of regional glacial (morainal) and lacustrine (ancestral Lake Michigan) geology. In the immediate vicinity of the McCook facility, the bed sediments of the river (silt/sand alluvium, organic materials, and silty clay) are reported to be 11.5 to 25.5 ft thick. Additionally, the bed sediments of the adjacent CSSC (sand and clay) are reported to be about 4 to 10 ft thick. The presence of dolomite spoil along the banks of the CSSC indicate that the canal was partly excavated into bedrock at this location. Whereas bedrock may have been locally exposed along the bed of the canal following its construction, those exposures seemingly are now thoroughly buried by sediments.

Fracture Characteristics and Hydrology

Field inspections of the fractured-dolomite deposits in the area were made to assess 1) the physical characteristics and hydrologic significance of the near-vertical fractures that are prominently exposed, and 2) the potential for and physical characteristics of any

hydraulically significant bedding-plane fractures that may be exposed along the walls of the CSSC or be present below its water surface or bed. Descriptions of these fractures included representative measurements of fracture orientations, along with approximated dip angles, apertures, and the spacing between fractures. Exposures were inspected along the walls of the CSSC and banks of the DPR, from about the electric fish barrier upstream to about 1 mi north of Kingery Hwy. Exposures also were inspected on the bedrock surface between the DPR and CSCC, and in the Heritage Quarries north of Lemont and the SAG Quarry north of Kingery Hwy, near the confluence of the CSC with the CSSC and Palos Forest Preserve.

Near-vertical fractures were prevalent throughout the study area. Where identified in bedrock surfaces and in the minimally exposed outcrops along the DPR, the fractures were tightly sealed, with no measureable aperture. Where indentified in the walls of the CSSC, the fractures usually were tightly to near-fully sealed. Fracture spacings, where observed at the bedrock surface adjacent to the CSSC and other area waterways, generally were similar to those described by Foote (1982)—about 1 every 10 ft to 20 ft—to as great as about 50 ft or more. There was no evidence of seepage or groundwater flow observed in association with any of the near-vertical fractures.

At about 90 spatially clustered locations, the orientations of 265 near-vertical fractures were measured. The results are summarized in a rose diagram using one unit length per fracture and grouping the fractures in 10° sectors. As indicated, there is a near-orthogonal pattern of fractures in the study area, with a primary orientation of 35° (N35E) and secondary orientation of 115° (N65W). These orientations were almost identical to those previously measured by Foote (1982) in a single quarry (Castle Flagstone) in a central part of the study area near Lemont, and reasonably approximated those measured by Nicholas and Healy (1988) (40°, 130°) in two quarries (Sag Quarry; unnamed quarry) further upstream, near Kingery Hwy/Palos Forest Preserve.

Fractures with measurable apertures were observed periodically along the full reach and within the various stratigraphic units of the canal, from just upstream of the electric fish barrier to the last exposure of bedrock walls, shortly north of Lemont. Spacings of these more prominent fractures were closer to the range of several hundreds of feet. Fractures, or possible paleo-karstic sinkholes, with the largest apertures—up to about 10 ft—occurred in the lower reaches of the canal, where excavated in the Joliet Fm, Romeo mbr. Elsewhere, apertures of the periodic fractures generally ranged from a few inches to about 1 ft. There was no evidence to suggest that the largest open fractures extend more than a short distance inland from the canal walls. Many of these large openings seem to be sinkholes where paleo-sediment infill likely has washed out

following their exposure during and after canal construction (Donald Mikulic, Illinois State Geological Survey, oral commun., 2010). Others of these large openings terminate just above the water surface, where an unaltered bedding surface is exposed at the base of the openings. As such, many of the enlargements seemed to be the result of factors other than post-depositional solution--and thus, not karstic-formed sinkholes. These openings possibly initially developed along local planes of weakness associated with near-vertical fractures in the bedrock and widened as the result of canal construction, which included use of explosives, and subsequent weathering and contact with barges.

There was little to no visible evidence of notable bedding-pane fractures in the study area. Minor partings were observed along bedding planes observed at some locations, but typically these did not appear to actively contribute to the subsurface movement of water. Minor to moderate seeps associated with bedding planes were identified at three locations along the west/north wall of the CSSC. These locations included 1) just upstream of the electric fish barrier, at the "pipe arch" that conveys refined petroleum across the canal; 2) about midway between Romeoville Rd and I-355, generally east of the southern limits of the Vulcan Materials Quarry (located west of the DPR); and 3) about one-quarter mile upstream of the northernmost barge slip, north of Lemont. Seepages at the locations downstream of I-355 occur within the Joliet Fm, Romeo mbr; those north of Lemont occur within the basal part of the Racine Fm.

A moderate rate of seepage with measureable flow was observed along a bedrock horizon beneath the pipe arch. Bedding above the seep appears uncharacteristically disturbed, with the beds notably separated. The disturbance likely is associated with the construction necessary to bury the pipeline along a defined corridor trending westward across the DPR. Surface drainage in the area apparently is to the permeable pathway created above the competent bedrock, undisturbed during excavation and burial of the pipeline beneath soil and rock fill.

Minor, generally unmeasureable seepage, occurs at the two locations upstream of the pipe arch. Seepage at the upstream location in the Joliet Fm, Romeo mbr is associated with overland flow above the bedrock surface, as observed here and elsewhere downstream of I-355. Seepage observed in the argillaceous dolomite deposits of the Racine Fm, seemed to be iron rich, as the underlying rocks were stained orange. The area within a few hundred feet showed signs of past industrial activities, including quarrying. In places, the ground surface was littered with scattered debris and covered with what appeared to be melted rubber.

Illinois and Michigan Canal

The bedrock-outcrop and bed-sediment and morphology characteristics of the IMC were assessed by 1) reviewing satellite imagery available from Google Earth and 2) inspecting the canal, where readily accessible, by way of road/bridge crossings and the adjacent Centennial Bike Trail (south of Romeoville Rd) and I & M Canal Trail (north of Lemont). Satellite imagery was helpful in assessing outcrop, bed-sediment/morphology characteristics where the canal was not readily accessible.

Satellite imagery from April 30, 2008 indicated that over much of the reach between the electric fish barrier to the vicinity of the Heritage Quarries, north of Lemont, the canal banks are outcroppings of Silurian dolomite. The dolomite units in this reach included the Joliet Fm, Romeo mbr; the Sugar Run Fm; and possibly, in small part, the Racine Fm. Where field inspected, the height of the outcrops above the water surface in the canal ranged from about 2 ft to about 5 ft. Near-vertical fractures (joints) were present throughout the reaches of exposed bedrock; where present, the fractures typically appeared effectively sealed with no measureable to very small apertures.

Satellite imagery also indicated that throughout the reach of the IMC between the electric fish barrier and its upstream termination at the CSC, the canal bed possibly was silt laden and numerous reaches were infilled with sediments and (or) vegetation, such as cattails. Field inspection verified the silt-laden condition of the canal bed as well as the substantial infilling of the canal with cattails in several reaches. In particular, dense accumulations of cattails, with little-to-no presence of standing water, infilled reaches at distances from about 1.1 to 1.8 mi and 2.1 to 2.2 mi above the fish barrier (near the Cico Rd bridge crossing the IMC). Additionally, at the upstream limit of the previously described sediment-removal operation, about 1.4 mi downstream of the fish barrier, the rock dam seemingly installed for the operation remained as a barrier to upstream flow in the canal. During the field inspection in March 2010, stage on the upstream side of the dam was about 2 ft higher than on the downstream side. At the Texaco Dam, stage on the upstream side of the dam was about 3 ft higher than on the downstream side.

Subsequent inspection of the canal on July 30, 2010 found the water level in the IMC above the Texaco Dam about 2 ft higher than when inspected in March 2010. Earlier in the week the Chicago area was hit by record rainfalls, including over 7 in. in a 24-hour period in the upper part of the CSSC watershed (near Midway Airport). All previously inspected locations along the canal, including the reach near Cico Rd. were water-filled; the rock dam downstream of the fish barrier was submerged, resulting in riffles as water flowed over the dam and dropped a few inches in level. Additionally, a portion of the flow in the canal was diverted over the side weir, with the weir submerged. Despite the

overall increase in water level in the canal, there remained about a 3 ft difference in water level above and below the Texaco Dam.

FUTURE STUDY LOCATIONS

On the basis of the assessment, six locations were selected for further study. These included reaches where subsurface hydraulically significant fractures might reasonably be present in areas where the streambed of the DPR consists of bedrock or presumably less than about 2 ft of alluvium or glacial drift. The locations include 1) upstream of Kingery Hwy, where notable bedding-plane fractures in the Racine Fm are known to occur; 2) the vicinity of the observed bedrock seeps in the Racine Fm, north of Lemont; 3) the vicinity of the barge slips north and south of Lemont, where the distance between the DPR and CSSC is least and the bedrock deposits and bedding might have been disturbed by use of explosives during their excavation; 4) a downstream reach, where karstic cavities and seeps were observed in the Joliet Fm, Romeo mbr. Selection of the study locations, additionally required consideration of the feasibility of physical and permitted access, and the presence of possible electrical interferences to sensitive geophysical measurements. The “pipe arch” corridor, a seemingly apparent inter-waterway flow conduit, was not selected for future study because of its obvious limitations---potential safety hazards and property-access issues. Also not selected, but possibly of interest for future investigation, is the area of unit thickening and the possible fracture in the vicinity of the Heritage Quarries north of Lemont. Identification of such a fracture could require extensive effort. Two of the locations selected by the USGS for surface geophysics (sites 2 and 3) and screening of the CSSC below the water surface using side-scan sonar and water-quality monitors should provide useful preliminary information in this regard.

SUMMARY

Inspections of satellite imagery, field inspections, and review of reported hydraulic-simulation results, and precipitation data strongly indicate that flow-affecting structures in the Illinois and Michigan Canal (IMC), the “Texas Dam” in particular, have prevented any possible movement of Asian carp upstream of the structures and beyond the location of the electric fish barrier in the adjacent Chicago Sanitary and Ship Canal (CSSC). Additionally, substantial siltation of the bed of the IMC, and limited evidence of fracture conduits in the canal banks seemingly further inhibit upstream movement of carp beyond the electric fish barrier and strongly reduce the potential for inter-waterway movement of Asian carp eggs and (or) fry from the IMC to the CSSC.

Based on the collection of indicators, no additional consideration of the speculated IMC pathway for movement of Asian carp into the upper reaches of the CSSC and CSC was deemed warranted within the scope of the present assessment. It might be that during recent years, under possible conditions of a 50-year, 24-hour storm, flow in the IMC periodically has overtopped the Texas Dam, thus potentially allowing the upstream movement of Asian carp. However, the most recent occurrence of notable precipitation was in 1996, which is considered to pre-date the presence of Asian carp in the northern Illinois waterways by several years. Verification of storm response and flooding patterns in this reach of the IMC during the past decade might be considered. Such verification could include inquiries with staff of the dam's operator, the adjacent refinery, and (or) hydraulic modeling based on the history and intensity and duration of storm events during this period.

Review and field inspection of the lithologic and fracture characteristics of the three Silurian dolomite stratigraphic units in which the CSSC and IMC are excavated in the study area, along with supporting field measurements and reported information, indicate limited evidence for the potential for substantial development of near-vertical or horizontal (bedding-plane) fractures in the Joliet (Romeo Member) and Sugar Run Formations. These units are prominent in the canal and Des Plaines River (DPR) reaches downstream of about north Lemont, Ill. Generally, the purity of the dolomite deposits that compose the units limits the potential for development of solutionaly enlarged fractures, particularly bedding-plane fractures. Paleo-karstic cavities resembling sinkholes are reported to be present to a limited extent in the Joliet Formation and there is possible evidence of those cavities in the walls of the CSSC in its lower reaches downstream of I-355. Where observed elsewhere during past quarrying operations, the cavities were infilled with Pennsylvanian clastics. The possible karstic cavities evidenced in the canal walls are not infilled, maybe because of erosion associated with their exposure. Many of these cavity-like features seem likely to have resulted from mechanical enlargement of near-vertical fractures, as associated with canal and industrial construction and barge contact. There is no visible evidence to suggest that the cavities extend inland from the canal walls much further than about 10 feet; additionally, the lowermost vertical extent of most was about the water surface in the canal.

The greatest potential for development of substantial fracture networks that could provide conduits for inter-waterway movement of Asian carp eggs and (or) fry from the DPR to the CSSC is within the Racine Formation. The CSSC generally is excavated within this unit between about the Calumet Sag Channel (CSC) and Summit, Ill. The argillaceous to cherty composition of this unit along with the disparity in composition between this unit and the underlying Sugar Run Formation contributes to its propensity

for development of solution enlargement along bedding planes. Despite this propensity, lithologic controls within the area limit where these solutional enlargements may act as possible inter-waterway conduits for Asian carp. From about 2 miles upstream of Kingery Hwy (Rt 83) to beyond the northern extent of the study area in Summit, the bed of the DPR is generally is within the fine-grained glacial deposits that blanket bedrock. Additionally, CSSC construction records indicate that the bed of the DPR may be within glacial deposits as far downstream as about 1.5-2 miles beyond the confluence of the CSC and CSSC. The texture of these deposits should inhibit the flow of water and any other contained material from the river into the underlying bedrock unit, regardless of the presence of well-developed fractures. Along the approximate 2-mile reach upstream of Kingery Hwy the bed of the DPR possibly consists of weathered bedrock and course-grained alluvium, which should somewhat limit any possible movement of water-transported particulates, such as Asian carp eggs, into connected vertical and horizontal fracture networks that may be present in the underlying bedrock. The shallowest reported sub-regional bedding-plane fracture in this region that might act as an inter-waterway conduit is at least 15 feet beneath the bed of the DPR (a reported shallower sub-regional fracture might represent the weathered-bedrock surface that possibly comprises the bed of the DPR). Regardless of these possible constraints, the greatest likelihood for functional inter-waterway conduits is within this approximate 2-mile reach of the DPR. Additionally, notable seepage occurs along a bedding horizon in the exposed west wall of the CSSC, beneath the “pipe arch”. Seepage flow here likely is constrained to the permeable fill material used to bury the pipe line along a corridor between the CSSC and DPR. This subsurface pathway may be hydraulically sufficient to act as an inter-waterway conduit for Asian carp.

In the present assessment, field inspection and bed-sediment data collection was limited to no more than about a mile north of Kingery Hwy. Additional field study, including bed-sediment sampling or in-stream surface geophysics, might be considered to verify conclusions regarding the bed composition of the DPR in and somewhat upstream of this reach, where a bedrock high previously has been identified. Also, although its presence is only postulated, additional efforts might be considered to confirm the presence or absence of a unit-offsetting fracture in the vicinity of the Heritage Quarries which possibly could act as an inter-waterway conduit for Asian carp. Several of the six sites selected for additional study could provide useful preliminary information in this regard.

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