VECTOR ENGINEERS, INC
GEOTECHNICAL • MATERIALS • GEOSCIENCES

March 10, 2019

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Re; Preliminary Summary
Louisville Zoo Ground Subsidence
Louisville, Kentucky
Vector Project Number 19-3623

A site visit was made on March 10, 2019 to observe the subsidence located along the southern portion of the Louisville Zoo property just north of the Mega Cavern entrance (Figure 1). This portion of the Louisville Zoo property is underlain by a section of the former Louisville Crushed Stone underground aggregate mine currently called the Louisville MegaCavern.

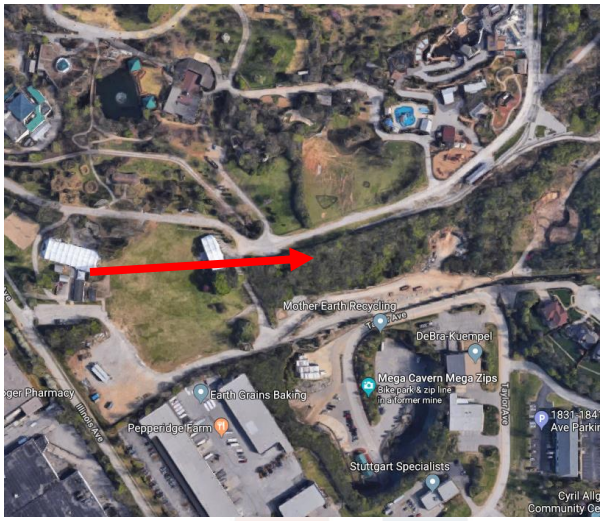

Figure 1: General area of subsidence indicated by the red arrow.

The area of subsidence is located in an unmanaged area of heavy tree growth and underbrush. A large drainage area converges on the area where the subsidence occurred. A drainage swale was observed beyond where the subsidence occurred generally traversing the center of the subsidence area. Visually, there is a substantial drainage area that converges on the area that subsided.

What caused the subsidence?

The ground subsidence appears to have been the result of a combination of pre-existing vertical joints within the Louisville Limestone upper strata over the undeveloped and unoccupied area of the Louisville Mega Cavern and the impact of

excessive surface water flow over the area. Based on our observations during our site visit, a large drainage area upgradient from the subsided area directs water to a 24-inch diameter concrete pipe that focused the water flow to a shallow ditch at the west end of the subsided area and traversed eastward over the area where it continued west of the subsided area (Figure 2).

Figure 2: Location of the 24-inch pipe indicated by the black arrow (Photograph from WAVE News).

The ground subsidence event is most likely due to oversaturation of the overburden soils and from saturation of the pre-existing vertical joints within limestone unit over many years. This saturation of the joint(s) resulting in loss of strength between either side of the joint resulting in the subsided Louisville Limestone upper strata dropping into the undeveloped and unoccupied section of the cavern. As one section of the strata sheared, other sections may have been "pulled" causing a larger subsidence area. This is evident by the near vertical, clean face of the exposed bedrock (Figure 3). The subsidence was not what would be referred to as a sinkhole. A sinkhole is typically due to soil raveling into a void or conduit within a limestone or dolomite bedrock over a period of time. Bedrock collapse sinkholes are rare in Kentucky.

Figure 2: View of Shear Face standing on subsided material looking back to the south toward the access road.

For perspective, this subsidence collapse is similar to the collapse at the National Corvette Museum in Bowling Green Kentucky a few years ago. The NCM subsidence was determined to be the result of shearing of the roof rock of a previously unknown cave under the building. The shearing of the bedrock was due to water saturation of the overburden soil under the museum showroom from water runoff from the roof over a 20+ year period.

Is the remainder of the quarry stable?

Observations of areas of the quarry generally extending from pillars 90, 91, and 92 northeast toward the exposed wall at the end of the mine. The observations were conducted visually, and no testing was conducted. This area was reported by the Mega Cavern staff to be under the Louisville Zoo property.

Based on our cursory observations, there appeared to be no obvious detrimental impact to the remainder of the mine from the subsidence collapse.

Preliminary Surface Drainage Recommendations

To reduce the risk of future subsidence, the surface drainage should be directed away from the area. The Louisville Zoo expediently installed a temporary berm and 24-inch pipe to direct water away from the subsidence area. This assisted greatly in preventing a large rain event on Saturday, March 9, 2019 from impacting the already subsided area. We recommend that the entire drainage area for this area be evaluated for future permanent improvements to reduce the amount of water over this portion of the mine. We believe additional smaller sections of the area may subside due to the location of observed joints and the saturated overburden. The subsidence may enlarge as perimeter sections of the already subsided areas reach a natural breaking point.

Once additional research of past reports and exploration and testing are completed, a full report will be issued. This letter is for the exclusive use by the Louisville Underground, LLC and the Louisville Mega Cavern, LLC Only. It may not be relied upon by any other party.

Sincerely,

VECTOR ENGINEERS, INC.

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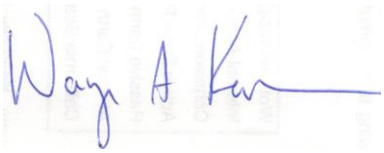

Wayne A. Karem, PhD, PE, PG, D.GE
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KY Licensed Engineer 15058
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Qualifications of Dr. Wayne A. Karem

Dr. Karem has over 35 years' experience in geotechnical engineer. He has worked with a large International Engineering Consulting Firm, a large regional firm where he served as executive vice president and is now the President of Vector Engineers, Inc.

In addition to his consulting experience, he also has served as a part time professor of Geotechnical Engineering at the University of Kentucky where he conducted research on development of old mine spoil fill sites. He has extensive experience in Karst geology, having served as the geotechnical consultant on multiple site characterizations of industrial parks and industrial developments in highly Karstic areas. He was a geotechnical consultant on the National Corvette Museum subsidence working with the NCM insurance company and the site remediation contractor.

He has published two papers on building in sinkhole prone areas. Dr. Karem, while at the Universtiy of Louisville in the early 1980's was a part of the team lead by Dr. Bob Ullrich, that evaluated the quarry for use by the City of Louisville. He is a licensed professional engineer and a licensed professional geologist. In addition, he has achieved the prestigious designation as a Diplomate of Geotechnial Engineering by the American Society of Civil Engineers.