1301 Jankowski Court
South Plainfield, NJ07080
Tel (908) 757-8867
amichalski@comcast.net

January 31, 2017

Joseph M. Dlugolenski
NYSDEC Region 7 Cortland Sub-Office
1285 Fisher Ave
Cortland, NY 13045
DEP.R7@dec.ny.gov

Re: DEC Application ID#0-9999-00075/00001 (Cargill Mine Shaft #4)
Comments on Groundwater Issues Related to Shaft #4

Dear Mr. Dlugolenski:

Comments on Corehole #18 Stratigraphic Test Hole Report

There is strong isotopic evidence that a groundwater inflow encountered in the stratigraphic test hole at a depth of 1,490 ft (below the base of the Onondaga Limestone) contained a significant portion of relatively recent meteoric water. The detection of tritium in water samples from the inflow collected during a pumping test indicates the presence of post-1960 water in the inflow.

Table 3-2. Water Sample Analytical Results

	Sample I.D.		
	#18-1490	CH#18-PT-002	CH#18-drillingbrine
Date	5/22/13	6/24/13	7/16/13
Alkalinity (milligrams per liter [mg/L])	1,310	92	40
Chloride (mg/L)	95,900	130,000	220,000
Density (grams per milliliter [g/mL])	1.16	1.14	1.2
Calcium (mg/L)	12,200	7,040	2,870
Magnesium (mg/L)	2,000	1,880	508
Potassium (mg/L)	1,840	720	393
Sodium (mg/L)	12,300	39,200	102,000
Total Dissolved Solids (mg/L)	178,000	190,000	280,000
Sulfate (mg/L)	282	1,600	5,000
$\delta D\ H_2O$ (%)	−74.1	−74.9	−40.1
$\delta^{18}O\ H_2O$ (%)	−9.99	−10.26	−7.53
Tritum (TU)	0.84	1.94	15.5
Standard Deviation	0.15	0.17	0.3

Note: Major ion analyses by Paradigm Environment Services and stable isotope and tritium analyses by Isotech Laboratories.

In addition, isotopic oxygen signatures of these water samples point to modern meteoric recharge as the source of this water, and not to cooler Pleistocene recharge or the drilling/coring fluid; see Figure 3.12 below.

Based on this tritium and oxygen isotopic evidence and my understanding of groundwater flow in sedimentary sequences (specifically the role of bedding fractures as preferential flow pathways), it is concluded that the meteoric water that migrated to CH#18 likely originated from a recharge at topographically elevated outcrop areas of the Onondaga and Oriskany formations located to the northeast of the Site. This recharge followed a crescent-like flow pathway that started down-dip (southward) along bedding plane separations (likely enlarged by karstification) in the lower Onondaga Formation and then turned westward toward a discharge area at the base of glacially-scoured valley beneath the Cayuga Lake where the lower Onondaga and the Oriskany intersect the valley. This concept can be illustrated by a dip section below along the Onondaga Trough east of the Cayuga Valley (Kappel and Miller, 2005). It is provided here as an analog for the Cayuga Lake setting.

Note that the proposed conceptual model of bedding-parallel groundwater flow in the bedrock in the Site vicinity differs from that proposed by Cargill's consultants (Plate 3.19). The latter implies a uniform downward flow in the bedrock across the bedding and ignores bedding-parallel discrete flow along few transmissive bedding fractures.

RESPEC suspected that the isotope results for water samples in CH-18 could be the result of fluid losses during decades of solution mining at Ludlowville (p. 42). As RESPEC states that the abandoned solution mining operation is located 3 miles to the south of the CH-18 site, the RESPEC-suspected origin of the C-18 water would imply the presence of a 3-mile long hydraulic connection between CH-18 and the solution mining area, not only laterally but also vertically, as the Syracuse Formation targeted for solution mining is positioned below the Onondaga/Oriskany contact. (At CH-18, the stratigraphic separation between the water inflow and the top of Salt #1 is 392 ft.) Whereas the presence of such hydraulic connection is possible, the chemistry data comparison does not support the RESPEC-suspected origin. As shown in Table 3.2, the calcium and magnesium concentrations in the CH-18 inflow sample are several times higher, while the sodium content is 8 times lower, than in the CH-18 drilling brine. The chemistry of the latter provides a reasonable substitute for the brine in old solution mining operations.

Thus, the isotopic and geochemical evidence leaves no doubt about modern meteoric recharge being the source of water in the CH-18 inflow at the Onondaga/Oriskany contact that is also known as a regional unconformity. The very existence of this meteoric water there necessitates, by hydrogeologic reasoning, the occurrence of ongoing groundwater flow along this contact/unconformity, and water discharge into an aquifer at the base of the valley fill. Because of this hydraulic connection of the Onondaga/Oriskany aquifer to a huge water reservoir in the valley fill aquifers and the Lake, the meteoric (halite under-saturated) water that migrates along the Onondaga/Oriskany contact presents a serious risk of flooding of the proposed Shaft No.4.

The risk of mine flooding from this water source becomes greater as mining progresses northwards in the up-dip direction beneath the Cayuga Lake. It's relevant to note that the same unconformity at the bottom of the Onondaga was a major source of bedrock water that flooded the Retsof Mine ; see Figure 2 from Open-File Report 2001-1286 http://pubs.usgs.gov/of/2011/1286/ attached at the end of this letter.

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RSI-2086-13-021

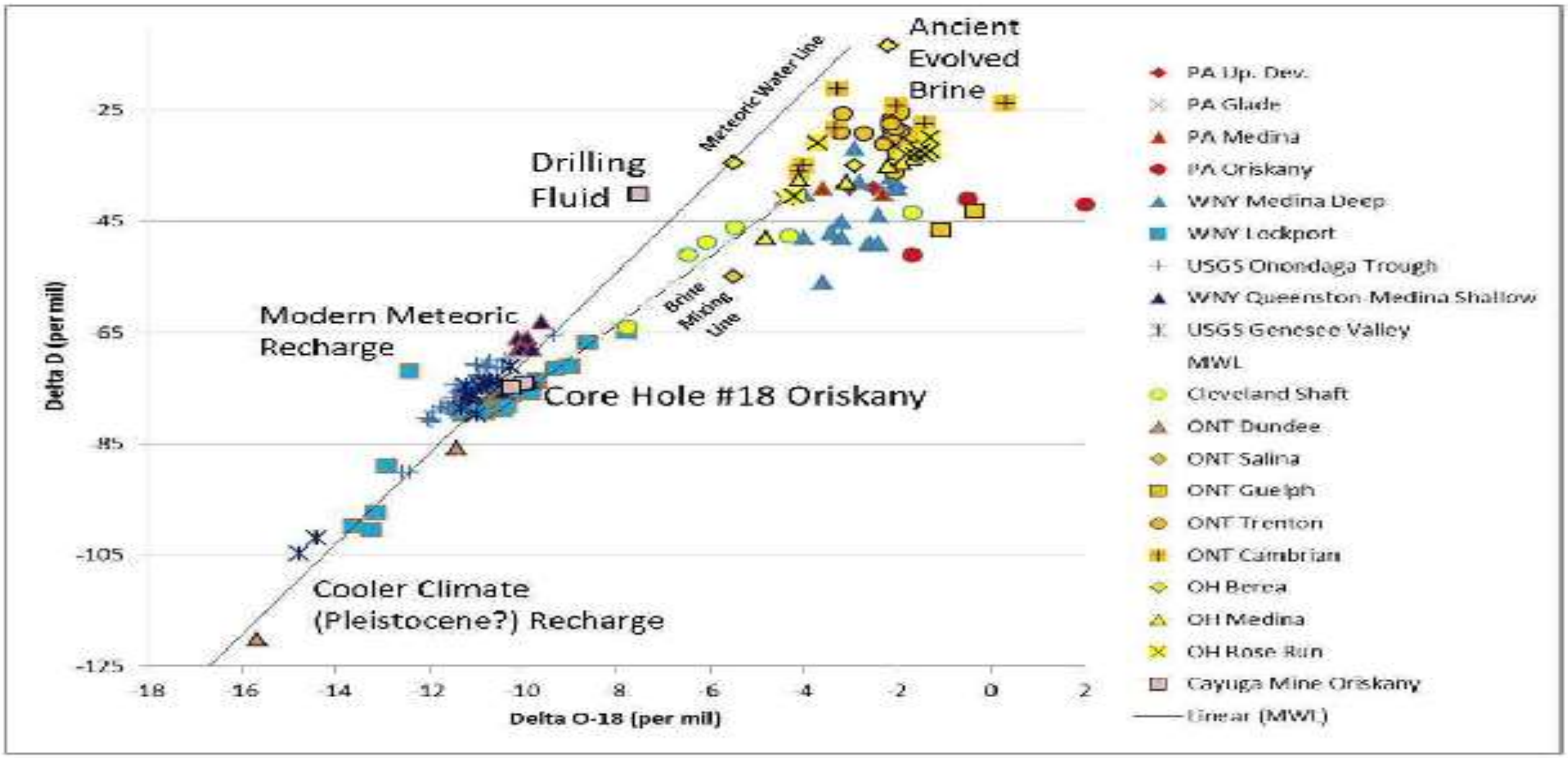

Figure 3-12. Comparison of Corehole #18 Isotope Samples With Regional Isotope Data Points.

GENERALIZED BEDROCK GEOLOGIC SECTION -
TULLY MORAINE TO ONONDAGA LAKE NEAR SYRACUSE

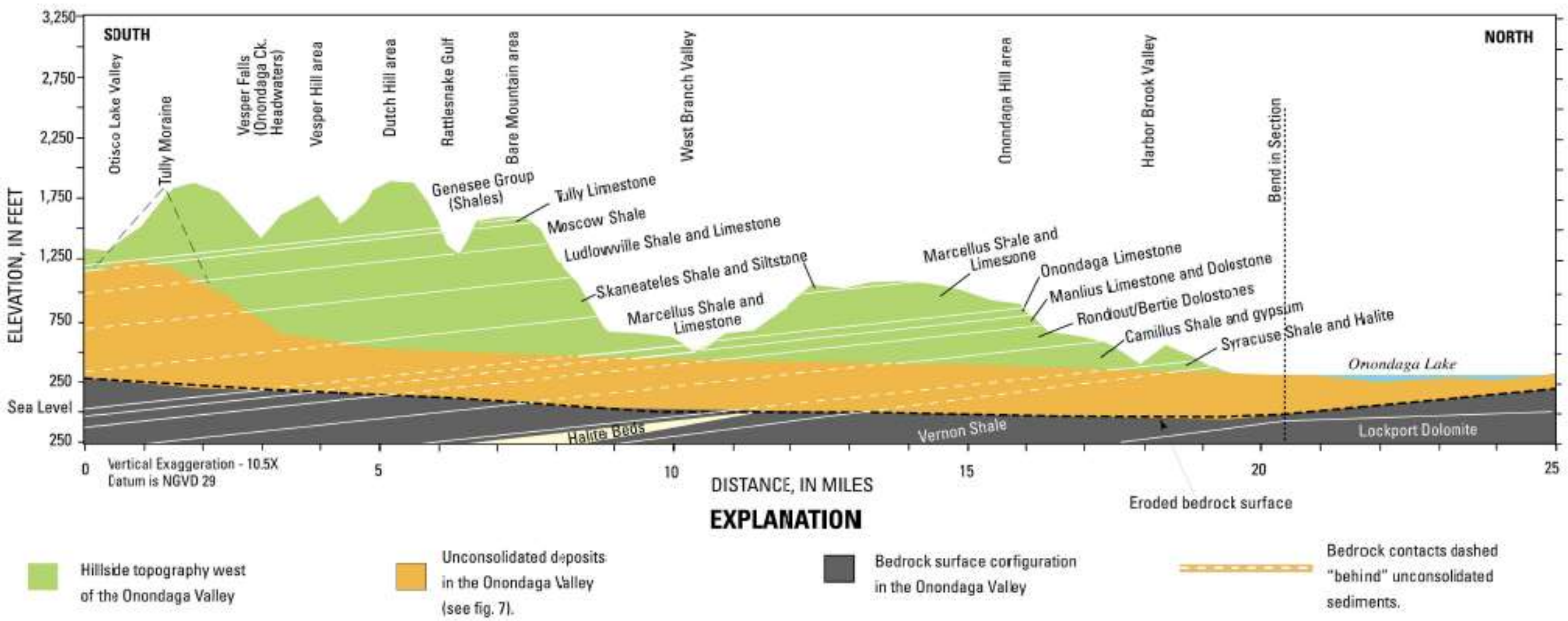

Figure 5. Geologic section along the thalweg of the Onondaga trough valley from the Tully Moraine to the Onondaga Lake outlet showing the generalized bedrock stratigraphic sequence.

An initial ("stabilized") water level reported for this inflow in CH#18 was 502 ft below grade (page 38 of the CH#18 report), which corresponds to an elevation of 282 ft msl based on the top of test hole elevation of 784ft msl. This measured water level elevation is approximately 100 ft lower than the elevation of the Cayuga Lake, the regional discharge level. The much lower elevation of the Onondaga/Oriskany water can be explained either by an inaccurate water level measurement (conducted under shut-in condition), or, if the measurement was accurate, the leakage of this water along some flow pathway to the mine, the only potential sink lower than the Lake. Cargill should explain this discrepancy, given its serious implications.

I believe that RESPEC underestimated an anticipated rate of water inflow from the Onondaga/Oriskany contact to the proposed shaft. Their estimate of 4 to 6 gpm after 100 days was based on a "stabilized" inflow rate to CH-18 of 3 gpm during a pumping test, with correction for a greater drawdown in a larger-diameter Shaft. An observed reduction of inflow rate in CH-18 from 10-15 gpm noted during drilling to 3 gpm at the end of the pumping test was likely due to 1) a partial fracture closure during the pumping test when a large generated drawdown increased the effective vertical stress across the fracture(s) resulting in partial fracture closure, and 2) co-production of gas. These factors are not likely to be be significant in the 18 ft diameter shaft, as the geologic heterogeneities and channelized flow in bedding fractures become more prominent and effective in such large diameter hole relative to the less-then-4"-diameter stratigraphic hole. I believe an inflow to the Shaft would be on the order of 30+ gpm. This would result in much greater inflows than estimated by Spectra on page 6 in their January 26, 2016 letter to the NYSDEC.

The RESPEC inflow estimate does not include any water inflows from the upper 590 ft of the hole that was completed using air-rotary drilling and then cased-off. A set of geophysical logs for this interval attached below does not include continuous logs of fluid temperature, conductivity/resistivity and vertical flow (flowmeter). These logs are groundwater industry standards for identification of water bearing/aquifer unit.

Nevertheless, available data from nearby supply wells provide strong indirect evidence for the presence of at least two water-bearing units within this interval. A yield of 60 gpm is reported for the Koplinka-Loehr bedrock supply well located approximately 1,700 ft to the west-southwest of the proposed Shaft #4 location. This 200 ft deep well terminates at an approximate elevation of 500 ft. The open interval of this well includes likely limestone beds identifiable within the 220'-235' interval on the geophysical logs for CH-18 provided below. This interval corresponds to the lowest portion of the Hubbard Quarry Member (Table 3-1 of the CH-18 report).

The reported yield of 60 gpm indicates a relatively high transmissivity of the water-bearing zone intersected by this well. It's a well-established fact that in this type of sedimentary sequences principal flow pathways are provided by bedding plane separation ("fractures"). The entire system exhibits a strong anisotropy of hydraulic conductivity and transmissivity, with the largest value coinciding with the bedding. Given the continuity of the bedding fractures (or the unconformity at the Onondaga/Oriskany contact) between this well and the proposed Shaft #4, there is no doubt that a significant drawdown, accompanying by a loss of well yield, will develop in this well during construction of the Shaft #4. Note that as much as approximately 200 ft of drawdown will be created at the Shaft in the common water-bearing unit. The same water-bearing unit is intercepted by the 187 ft deep Ross Road bedrock well. Cargill should be required to install pressure transducers in these two wells and in the Cargill supply well that is nearest to the Shaft, in order to monitor drawdown impacts during drilling of the pilot hole and during and after the period of upward reaming of the Shaft.

Draining of this water bearing unit by the Shaft may also adversely impact springs located on the hillside west of the Shaft, along an interpreted southward-dipping outcrop of the Hubbard Quarry Member (at approximately 500 ft directly west of the Shaft).

The presence of another, deeper water-bearing unit associated with bedding is indicated by data for the Oursler bedrock supply well located near the Lake. This 225 ft well terminates at an approximate elevation of 200 ft msl. A thin interval (limestone?) found just below the 500 ft depth mark on the geophysical logs below is a likely host of the water bearing zone.

No data have been provided to assess permeability variations within a nearly 1,000 ft cored section in CH-18 below the Onondaga/Oriskany inflow at 1,490 ft. The only reference found about this interval is this one-sentence somewhat ambiguous statement: "Boart did not report to RESPEC any evidence of water-bearing zones in the cored interval "(p. 13). However, Retsof's *post mortem* investigation revealed inflows from another significant deep regional aquifer unit at the Bertie-Camillus contact; see attached below Figure 2 from Open-File Report 2001-1286 http://pubs.usgs.gov/of/2011/1286/.

Based on the above assessment, it is concluded that an estimate of inflows to the Shaft provided by Spectra significantly underestimates the likely inflows. Consequently, a greater-then-estimated underground storage capacity is needed to accommodate the halite-unsaturated inflows and shaft drilling fluids. Cargill should be required to re-assess the inflows based on inflows measured in the pilot hole. The impact of increased inflows on the mine storage area needs and the stability of the storage area should then be re-evaluated.

NOIA Response on Groundwater Impacts

Spectra's response to NYSDEC's comment on groundwater impacts is inaccurate, simplistic and elusive. It shows the lack of understanding of regional bedrock hydrogeology and the role of bedding-parallel flow of groundwater.

Spectra's statement that the record of CH#18 is "the only reliable source" of hydrogeologic information is misleading. As I stated earlier, relevant hydrogeologic data for the upper 590 ft of CH#18 was either not collected or suppressed.

The two "ravines" that are supposed to control groundwater flow are shallow features (~20 ft deep based on topo map) that have practically no impact on groundwater flow in the bedrock that features a multi-unit aquifer/aquitard system, with thin aquifer units. A suggestion that the "ravines" act as discharge boundaries that limit the area impacted by Shaft construction is preposterous. Likewise, a notion that drawdown in even transmissive units is limited to "a few hundred feet" underestimates actual distance of drawdown impacts along the bedding by an order of magnitude.

Points of Concern on Global Mine Stability

I'm concerned that Cargill may not considered all risks associated with mining under the Cayuga Lake valley fill, particularly as mining progresses northward in the up-dip direction. The thickness of bedrock strata separating the mined salt bed from the valley fill deposits decreases in that direction. Beyond that, the carbonates, which make the stiffest units within the separation, have been thinned by erosion there, while tectonic features become more pronounces on seismic sections. Cargill's conceptualization of global mine stability may not consider the most likely mine failure scenario outlined below based on the Retsof mine collapse experience and conditions encountered in CH#18 at the Cayuga Mine.

Cargill's consultants argue that mining under the Cayuga Lake makes mine ground control easier, as the dead weight of the overlying rock and water (or the vertical stress) is lower than in mined portions under the hillside. It is known, however, that in this region south of Lake Ontario, including the Cayuga and Retsof mines, the horizontal stress is much greater than the vertical stress, typically by a factor of 2.

The difference between the major (horizontal) stress and the minor (vertical) stress is thus much greater in the bedrock separation units under the Lake than in the same units under the hillside. As shearing stress is proportional to this stress difference, it follows that the bedrock separation units were already under severe stress in their *in situ* state. Add to this mining-induced stresses, both from current Cargill operations and old solution mining cavities on the eastern side of the valley. The reported occurrence of micro-seismic events in the Onondaga Formation is likely the reflection of an over-stressed nature of the Onondaga, the stiffest unit in the bedrock separation carrying much of the load.

In my opinion, the discrete regional aquifer unit present at the base on the Onondaga in CH#18 and in Retsof Mine (Figure below) has played a key role in triggering the Retsof mine collapse. It would likely do the same in Cayuga Mine. Once mining causes a leak (hydraulic connection) to develop between this aquifer and a mine, the head in the aquifer drops, which produces an increased total and effective stress on the top of the Onondaga still exposed to the head/weight of the overlying water column plus the lake. It is like a punching of already over-stressed rock by hydraulic fracturing. The formation of chimney-like rubble zones above each of the two Retsof collapsed and flooded yards is best explained by this mechanism under a high horizontal stress regime. Once triggered, this mechanism cannot be stopped if a virtually infinite water source is available above the mine.

The Cayuga Mine operators seem to be preoccupied with near-field ground control issues in their yielding pillar design. Closure rate measurements are useful; however, there may be little room for an effective corrective action once high closure rates develop. The majority of salt mines succumb to collapse and flooding. A proactive approach to enhancing global mine stability would be to put reasonable but strict limits on the maximum extraction ratio, given the fact that this ratio would determine the maximum load on the pillars. The two collapsed yards in Retsof Mine shared a common fault of excessive extraction ratios.

I appreciate the opportunity to submit comments on this matter.

Sincerely,

A. Michalski

Andrew Michalski, Ph.D., CGWP, LSRP
Michalski & Associates, Inc.

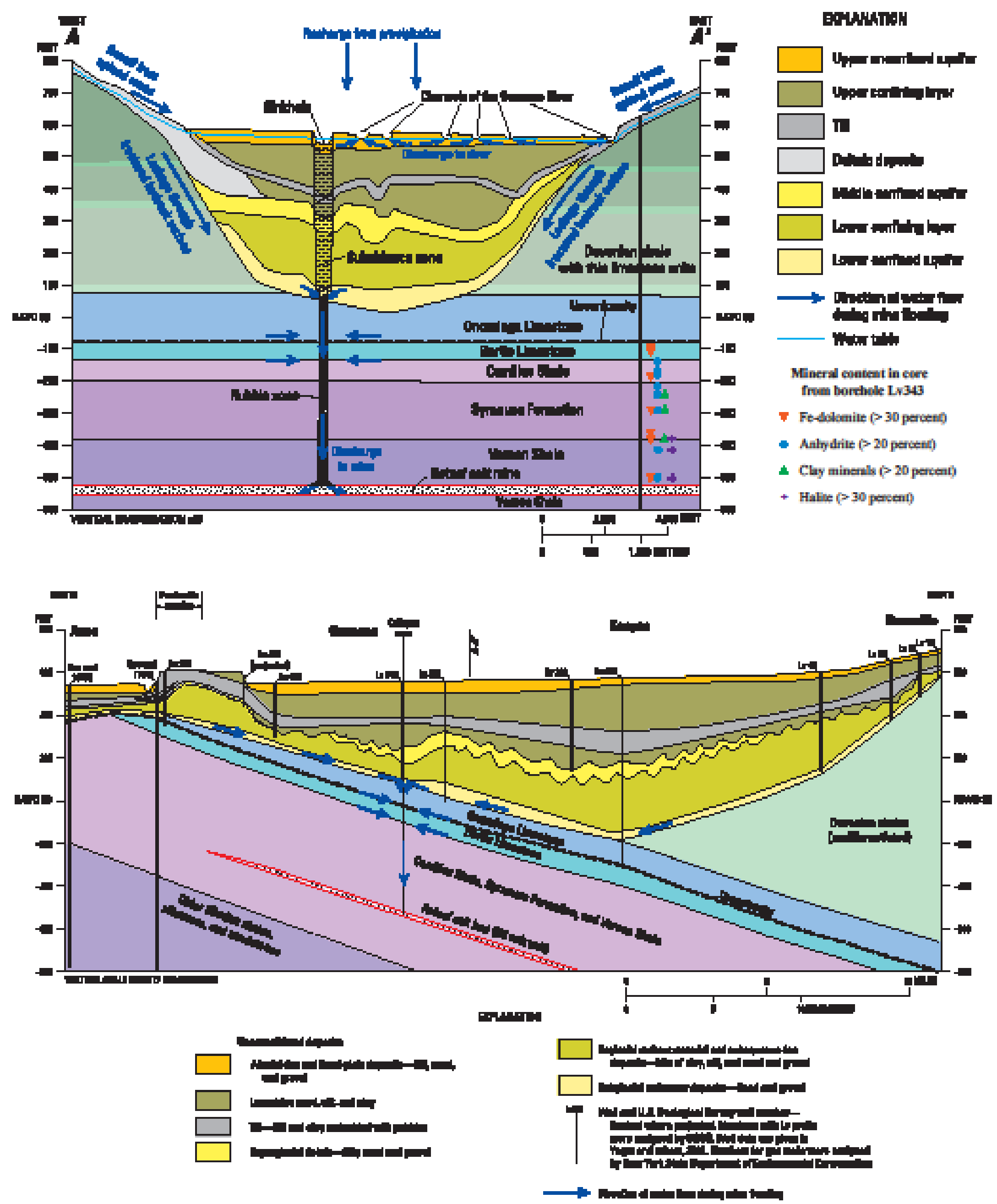

Figure 2. The upper stratigraphic cross-section *A–A'* shows one rubble chimney above the collapsed ceiling and the directions of groundwater flow into the Retsof salt mine, Livingston County, New York. The map view of the location of cross section *A–A'* is shown in figure 1 (from Yager and others, 2009, fig. 2). The lower cross section shows a view from north to south under the valley from Avon to Dansville, New York (see fig. 1), describing the unconsolidated deposits and direction of water flow in the lower confined aquifer during mine flooding.

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Weatherford

Photo Density
Compensated Neutron
Gamma Ray

COMPANY	Cargill Inc.		
WELL	Cargill 18		
FIELD	Lansing		
PROVINCE/COUNTY	Tompkins County		
COUNTRY/STATE	U.S.A. / New York		**FIELD PRINT**
LOCATION			
SEC / TWP / RGE		Other Services	
		Array Inductor	Data Pack
API Number		Compensated Sonic	Caliper
Permit Number 31-109-25509-00		Vector	
Permanent Datum Ground Level, Elevation 887 feet		Elevations	feet
Log Measured From GL		KB	898.00
Drilling Measured From GLL		DF	897.00
		GL	887.00
Date	15 May 2013		
Run Number	One		
Service Order	253140?		
Depth Driller	590.00	feet	
Depth Logger	587.00	feet	
First Reading	587.00	feet	
Last Reading	0.00	feet	
Casing Driller	28.00	feet	
Casing Logger	28.00	feet	
Bit Size	8.875	inches	
Hole Fluid Type	Water Based		
Density / Viscosity	8.50 lb/USg	27.00 sec/qt	
PH / Fluid Loss			
Sample Source	Flow Line		
Rm @ Measured Temp	9.51 @ 68.0	ohm-m	
Rmf @ Measured Temp	7.133 @ 68.0	ohm-m	
Rmc @ Measured Temp	14.265@ 68.0	ohm-m	
Source Rmf / Rmc	Calc.	Calc.	
Rm @ BHT	9.51 @ 68.0	ohm-m	
Time Since Circulation	4 Hrs		
Max Recorded Temp			
Equipment / Base	13041	Muncy	
Recorded By	Nibras Nureldin		
Witnessed By	Patrick mcgrath		

BOREHOLE RECORD

Last Edited: 15 MAY 2013 13:47

Bit Size inches	Depth From feet	Depth To feet
0.750	28.50	587.00

CASING RECORD

Type	Size inches	Depth From feet	Shoe Depth feet	Weight pounds/ft
	10.750	0.00	30.50	/3.00

REMARKS

Software: WLS 13.05.9583

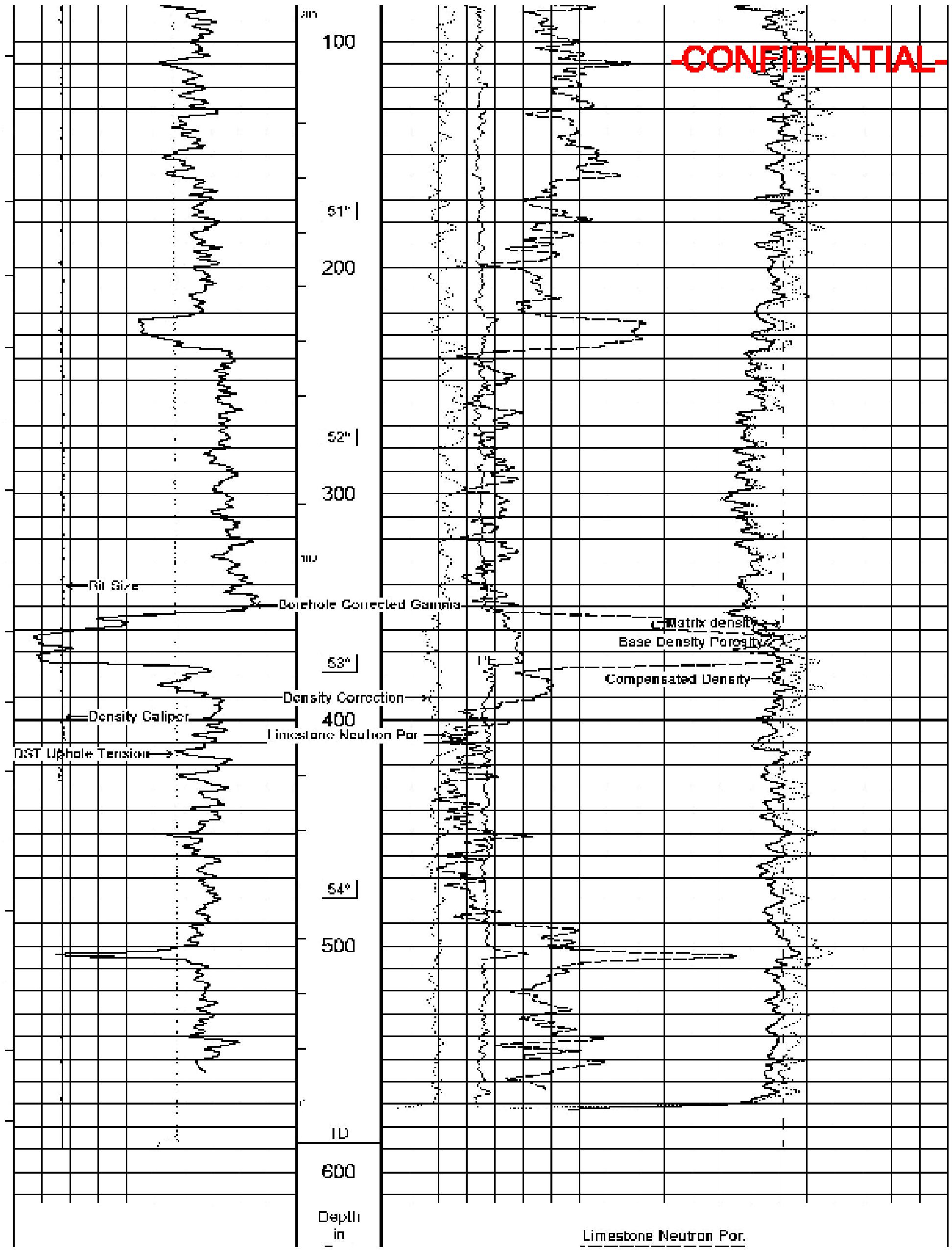
Tools Run: SSIA, MCG, MDN, MPD, MTE, MA

Hardware: MDN - Dual Eccentraliser
MAI - Two-1 Inch Standoffs
MPD - Two Roll over subs

Density Matrix was run on 2.71 gg/cc

Crew: Nibras Nureldin
Bruce Clark

Gamma ray spikes up at the bottom of the borehole because the gamma ray is run below the sources
7 inch casing was used to calculate annular hole volumes
Gamma ray was recorded to ground level



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100
200
300
400
500
600
Depth
in
Bit Size
Borehole Corrected Gamma
Density Caliper
DST Uphole Tension
Density Correction
Limestone Neutron Por
Matrix density
Base Density Porosity
Compensated Density
Limestone Neutron Por.
TD