Report on Groundwater Flow and Contamination at Chemical Waste Management, LLC, Model City, New York, and Proposed RMU-2 Permitting and Siting Issues

Prepared for Niagara County, the Town of Lewiston and
the Villages of Lewiston and Youngstown, New York

November, 2014

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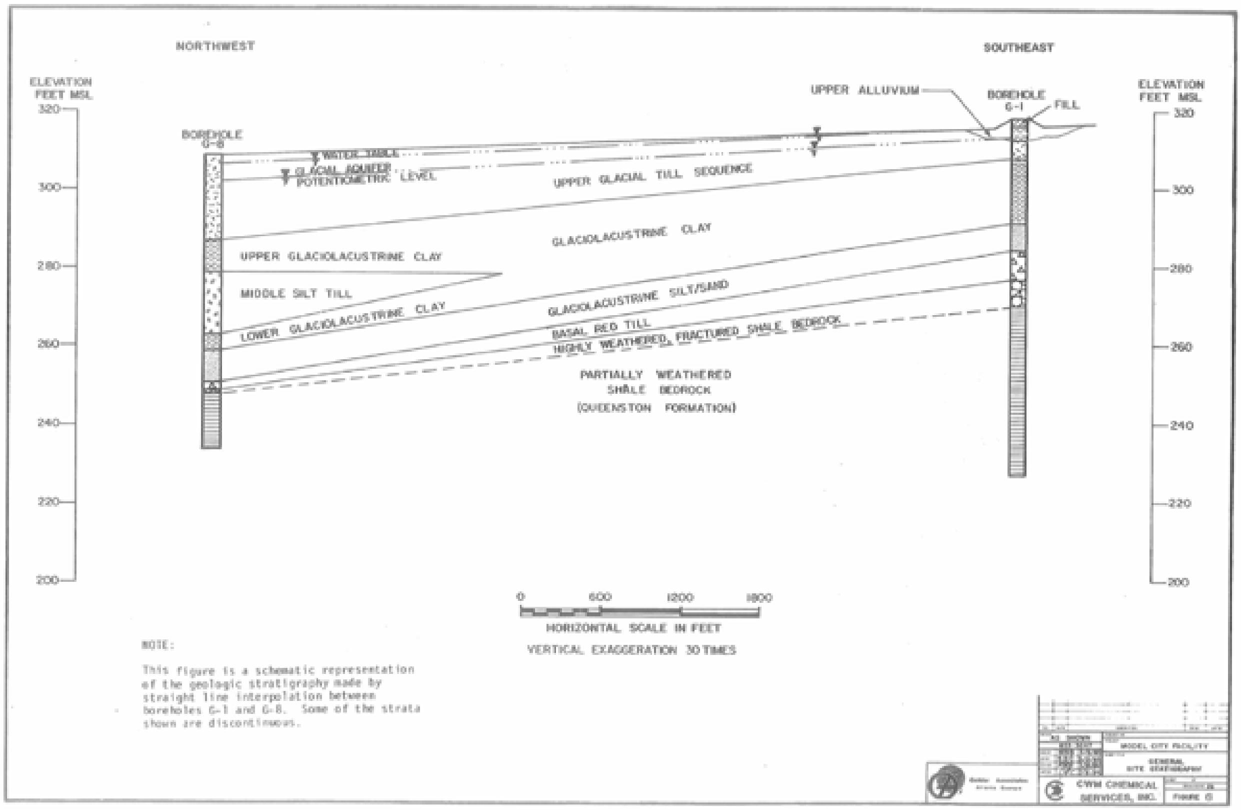
TABLE OF CONTENTS

LIST OF FIGURES

LIST OF EXHIBITS

EXECUTIVE SUMMARY

The conceptual hydrostratigraphic model of the CWM site used by the Applicant posits that a "lower aquifer" and an "upper aquifer" underlie the site, separated by an effective aquitard. *See* Figure 1, below (from Golder (1993), vol. 1, Fig. 6; *reproduced unchanged at* Golder (2014b), Fig. 3; *and below*, Figure 1. These two hydrogeological units are separated by a Glaciolacustrine (lake bottom) Clay unit, the posited low permeability aquitard. Over the northwestern portion of the facility, including the RMU-2 footprint, this unit is separated into an upper and lower member by a silt till (Middle Silt Till) apparently deposited during a local glacial ice advance. Golder Assoc. (2009a), 5. However, according to the Applicant, elsewhere at the site the clay unit is continuous and generally thick.



NOTE:
This figure is a schematic representation of the geologic stratigraphy made by straight line interpolation between boreholes G-1 and G-8. Some of the strata shown are discontinuous.

Figure 1: CWM Hydrostratigraphic Model

The Glaciolacustrine Silt/Sand (GSS) unit beneath the aquitard is the most permeable unit of the lower aquifer. Beneath this unit is a discontinuous lodgment till (Basal Red Till) above shale bedrock. On the adjacent Modern Landfill site and the adjacent Niagara Falls Storage Site (NFSS), the GSS unit and shallow bedrock are hydraulically connected members of the lower aquifer. There are no bedrock monitoring wells at the CWM site, so the lower aquifer is represented there by the GSS unit.

The Applicant's hydrostratigraphic model, originally proposed by Golder (1985), was slightly modified by Golder (1993), and has been incorporated unchanged into the Application. *See* DEIS, 55-59; CWM (2013b) (Groundwater Sampling and Analysis Plan); Golder (2014) (Hydrogeologic Update). However, results of previous hydrogeologic investigations of the site, and those undertaken at the adjacent Modern Landfill and NFSS facilities are not consistent with the model. The latter investigation is recent and the most comprehensive, encompassing all three properties. *See* USACE (2007). In addition, much of the raw data generated by the Applicant's investigations are not consistent with its model. Specifically, the Applicant has disregarded the very large permeability variations within the lower aquifer unit, and has misinterpreted potentiometric surface maps of this unit, groundwater flow direction, and both horizontal and vertical contaminant migration rates within the geologic units.

When the raw data generated by soil borings, monitoring wells and piezometers is examined, together with independent investigations of the regional and site hydrogeology, it is apparent that a buried alluvial valley underlies much of the RMU-2 footprint. This valley contains a distinct alluvial sand and gravel unit that is the most permeable or transmissive unit beneath the site. The Applicant has failed to recognize the alluvial sand and gravel as a distinct important hydrostratigraphic unit by combining it with the overlying glaciolacustrine silt/sand unit. As a result, apparent groundwater flow direction in the lower aquifer is to the north-northwest, whereas the actual flow is towards the western boundary of the site, along the buried alluvial channel.

The Applicant also ignores the fact that historic dewatering operations at borrow pits located west of the CWM site enhanced the west-southwesterly groundwater flow and accelerated potential contaminant migration rates.

Importantly, no array (three or more) of detection monitoring wells has been installed in the alluvial sand and gravel unit west of the RMU-2 footprint.[1] Such wells are installed to the north, east and south, but because of the hydrogeological setting these wells are unable to detect the migration of contaminants released from the proposed new landfill.

The significance of these conclusions is heightened by the presence of areas with missing or thin Glaciolacustrine Clay deposits (permeability windows) and fracturing within the clay deposits overlying the lower aquifer, which are acknowledged in the Applicant's soil boring logs but are ignored in the text of the Applicant's groundwater investigations. Permeability windows and fracturing in the purported aquitard creates preferential vertical contaminant migration pathways and much faster rates of migration into the lower aquifer than the Applicant's model

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[1] Two wells (R201DR, R216D) were installed west of the RMU-2 footprint. *See* Exhibit 7, provided herewith.

admits. Consequently, no effective aquitard protects the lower aquifer.

Groundwater monitoring and corrective action programs have been required at the CWM site, in order to protect the lower aquifer from migration of contaminants that have been found in the shallow aquifer or were previously released to the surface. Contamination of the lower aquifer unit by various chlorinated solvents, including dense non-aqueous liquids (DNAPLs) has already occurred at several locations within the site but resulting contaminant plumes have not been delineated, and no delineation effort has been proposed by the Applicant. Installation of additional detection/delineation wells and supplementary hydrogeologic characterization should be required before RMU-2 is permitted. This additional information is required before it can be determined whether the site is monitorable, a basic requirement for siting a new hazardous waste land disposal facility under the regulations.

1. The Hydrogeological Setting at Model City

A. *The uppermost aquifer*

Both the Applicant (Golder (1993, 2014)) and U.S. Army Corps of Engineers (USACE (2007a)) conclude that generally, the deepest portion of the uppermost aquifer[2] beneath the Model City site is the most permeable unit within the aquifer.

The deepest portion of the aquifer is a glaciolacustrine silt/sand unit according to Golder, but USACE considers portions of this unit to be an alluvial sand and gravel unit. According to USACE, the deposits in this portion of the buried valley are predominantly alluvial and glaciofluvial rather than glaciolacustrine. USACE's conclusion is consistent with Wehran (1977), which investigated the site hydrogeology for CWM's predecessor SCA Chem-Trol. Wehran's and USACE's findings have important implications for understanding the direction and rate of flow of groundwater and contaminants beneath the site.

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[2] For regulatory purposes, in order to demonstrate that groundwater quality would be protected, the applicant must identify "the uppermost aquifers and aquifers hydraulically interconnected beneath the facility property, including ground water flow direction and rate, and the basis for such identification (*i.e.*, the information obtained from hydrogeologic investigations of the facility area)." 6 NYCRR § 373-1.5(a)(3)(ii). "Uppermost aquifer" "means the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary." 6 NYCRR § 370.2(b)(210). As discussed in the text, the "glaciolacustrine silt/sand unit" (Golder) or "alluvial sand and gravel unit" (USACE) is the lower aquifer that is hydraulically interconnected with the uppermost aquifer beneath Model City. In other words, this is the lowest hydrogeological unit of the uppermost aquifer.

The depositional environment of the sand and gravel unit was largely controlled by the configuration of the top of Queenston Formation bedrock surface in the study area. As shown on the bedrock surface elevation maps for the CWM site, (Exhibit 1, *from* Golder Assoc., 1993), and for a larger area that includes the NFSS and the Modern Landfill sites, (Exhibit 2, *from* USACE, 2007), a buried sand and gravel valley is present beneath the CWM site. An approximate axis of this valley is shown in red color on Exhibit 1. The axis runs parallel with the ENE-WSW strike of the bedrock, and the valley was likely carved within a weaker member of the Queenston Formation. The valley plunges westward, reaching its lowest elevation of approximately 265 ft msl measured at the western boundary of the CWM site. This buried valley is bounded by two small ridges. The southern ridge rises to an elevation of 300 ft msl (Exhibit 2), whereas the northern ridge tops at an elevation of 280 ft msl (Exhibit 1). Just north of this ridge, another buried east-west valley has been mapped past the northern boundary of the CWM site.

Alluvial and glaciofluvial deposits consist of sands, gravels and silts deposited in channels or floodplains by rivers or streams, in this case by melt-water channels fed by a receding glacier. Glaciolacustrine deposits include fine clay, sand and silt deposited later in proglacial lakes. Thus alluvial and glaciofluvial deposits were formed in buried channels, while glaciolacustrine deposits filled proglacial lake bottoms, generally atop of the alluvial sand and gravel. Alluvial and glaciofluvial deposits are much more permeable than glaciolacustrine deposits, and therefore groundwater moves much faster in the alluvial sand and gravel and in a preferential manner determined by the course of the buried channel.

Throughout this report, the most permeable portions of the aquifer, located the deepest, are called alluvial channel deposits, following USACE (2007) and Wehran (1977).

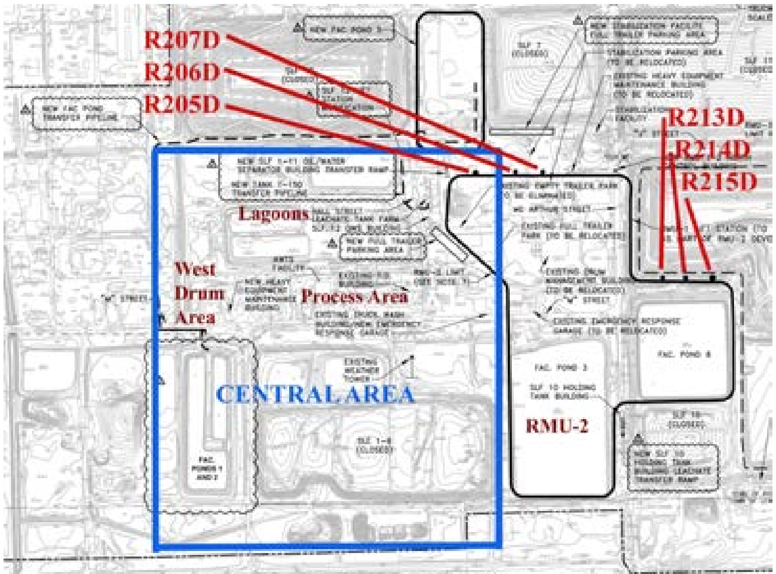

Figure 2 *(modified from* 6 NYCRR Part 361Permit Application (rev. November 2013), Fig. 3))

B. *Lateral permeability variation within Applicant's GSS unit*

The central portion of the CWM site includes the Process Area, Lagoons and West Drum Area. Surface and groundwater contamination has been found in so many areas in and around the Process Area that the Department expanded the designated Area of Contamination, now known as the Central Area. *See* Figure 2.

The Applicant has found that the permeability or hydraulic conductivity of the Glaciolacustrine silt/sand (GSS) unit of the aquifer is at least two orders of magnitude greater beneath the Central Area than beneath the northern portion of the site generally, including the northern edge of RMU-2. Hydraulic conductivity values greater than 1x10^{-3} cm/s have been measured in deep monitoring wells R205D, R206D, and R207D (located along the northern border of RMU-2), and R213D, R214D and R215D (located along the buried alluvial valley. *See* Golder (2010), Table 3; included herein as Exhibit 10.[3]

Low permeability values have been found in deep monitoring wells in the northern portion of the Central Area, aligned in an ENE-WSW pattern. *See* Golder (2014), Table 5 (results for wells TW30D, LMS02D, F5801D and WDA01D). Exhibit 5, a map of hydraulic conductivity of the alluvial sand and gravel unit taken from USACE (2007), shows hydraulic conductivity is consistently very low in the northern portion of the CWM property, in an ENE-SSW pattern that extends off site to the west.

Exhibit 5 also shows that hydraulic conductivity values in the central buried valley (10^{-3} to 10^{-2} cm/sec.) are at least two orders of magnitude greater than the values found on the northern side of the valley and at the top of the northern ridge. This indicates that deposits atop the northern bedrock ridge behave as an aquitard, blocking the groundwater flow to the north. A number of well clusters located at the northern and northwestern portion of RMU-2 (thus away from the axis of the buried valley), show hydraulic conductivity values in the D (deep) wells (nominally GSS wells) that are not only low in absolute terms (10^{-6} to 10^{-5} cm/s) but even lower than the hydraulic conductivity values for the upper till (S wells).[4]

These results, considered together with the high permeability values for the lower aquifer unit beneath the southern portion of the Process Area, are consistent with an ENE-WSW buried alluvial valley bounded by bedrock and glacial till ridges to the north and south. *Cf.* Wehran (2007), Fig. 4. These ENE-WSW aligned ridges were visible in the early 1900s but subsequent grading of the area has removed their appearance at the surface. USACE (2007), 2-5. However, these ridges are apparent in a 1913 topographic map of the site region, reproduced here as Figures 3a and 3b, *from* Plate 2 in Kindle and Taylor (1913), who describe the ridges as “composed mainly of stony till generally overlying ridges of shale.” These low-permeability ridges would block regional groundwater flow to the north and direct the flow westward along the high-permeability alluvial sand and gravel unit at the bottom of the buried valley–the

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[3] Part 373-2.14(b)(1) requires that the soil beneath the facility have a hydraulic conductivity of no more than 1 x 10^{-5} centimeters per second, as determined by in-situ hydraulic conductivity test methods. This standard is generally met by silty sands and clay soil. By contrast, sandy and gravely soils characteristic of glacial outwash generally have a much higher hydraulic conductivity in the range of 1 x 10^{-3} to 1 x 10^{-2}.

[4] *See* hydraulic conductivity values reported by Golder (2010) for wells R202S/D, R203S/D, R210S/D and R211D/S, *reproduced here as* Exhibit 10.

preferential flow and contaminant migration pathway at the CWM site.

The outlines of low-permeability bedrock and glacial till ridges bounding the buried valley, and the two major types of deposits (alluvial channels vs. lake deposits) within the valley are visible on a LiDAR (Light Detection and Ranging) remote sensing imagery of the study area recently downloaded from the NOAA. *See* Figure 4. Owing to its ability to penetrate through surface features like forest and vegetation, LiDAR imagery provides high-resolution topographic mapping and reveals fine geomorphologic features that otherwise are not easily visible.

On a “slope shader” selection of the LiDAR imagery shown on Figure 4, several west-southwest trending lines are visible. These lineaments run parallel to the bedrock strike across the CWM site towards the Niagara River. The northern and southern boundaries of the buried alluvial valley coincide with the lineaments observed north and south of the highway interchange with Pletcher Road. A lighter tone seen just north of the interchange matches the location of the channel deposits that extend from the river eastward beyond the CWM site. Lower aquifer groundwater in this area thus flows west beneath the Lewiston-Porter Central School site and onward toward the Niagara River.

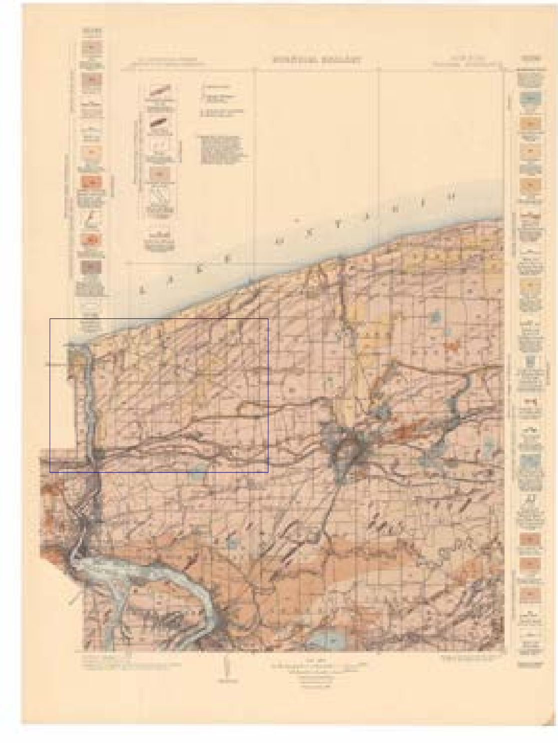

Figure 3a

Figure 3b

Figure 4: LiDAR imagery, site vicinity to Niagara River

C. *The lower aquifer unit*

Exhibit 3, taken from Golder (1993), shows that the glaciolacustrine silt/sand unit (which also includes the alluvial sand and gravel unit) is about five to fifteen feet thick beneath the Process Area, with some areas exceeding 20 feet in thickness. In the southern portion of the CWM site this hydrogeologic unit is consistently about five feet thick along the 300 ft msl bedrock ridge, and off site to the south. The northern ridge is missing the glaciolacustrine silt/sand deposits altogether in some areas. In those areas the sand and gravel is replaced by low-permeability silt and till.

This is consistent with Wehran's 1977 finding that a buried valley scoured into the bedrock beneath the central portion of the CWM site became filled with alluvial sand and gravel during earlier oscillations of the Wisconsin glacier, creating a distinct and separate water-bearing unit that "would be considered the most vulnerable to any landfill-derived contamination should it occur." Wehran (1977), 43. Wehran estimated groundwater velocity in the buried alluvial valley beneath the central portion of the CWM site in the range of 88 to 624 feet per year. A full discussion of these glacial oscillations and their role in creating the various hydrostratigraphic units in the local area is provided at USACE (2007), Section 2.

Wehran (1977) recommended that a new deep monitoring well be installed at the axis of the buried valley, at the western boundary of the CWM site, but Wehran's recommendation was never implemented. *See id.*, Map 1. Instead, well F102D, installed midway along the western side of Fac Ponds 1&2, shows hydraulic conductivity values in the 10^{-5} cm/s range, indicating it was not installed in the buried sand and gravel aquifer. This well is only 40.7 ft deep. The bottom of this well is at an approximate elevation of 280 ft. msl, or 40 feet below grade. Although the configuration of the buried alluvial valley at the western boundary of the site is poorly defined (because too few deep borings have been made there), Exhibit 1 shows that the bottom of the valley is at an approximate elevation of 265 ft. msl, or over 60 feet below grade. It must therefore be concluded well F102D is installed on the side of the buried valley, not at the bottom where the most permeable deposits are expected. The same conclusion applies to other wells in the western area, specifically F580D and TW3D that also exhibit low hydraulic conductivity values of 10^{-6} cm/s (Table 5 *in* Golder, 2014). Exhibit 4, taken from USACE (2007), shows the ridge *versus* valley thickness contrast is even greater.

Additional data on hydraulic conductivity of GSS deposits in the vicinity of RMU-2 have been obtained from monitoring wells (R200D series) installed along the perimeter of the proposed landfill. Table 5 in Golder (2014) lists hydraulic conductivity values for these wells and for other GSS wells installed at the site. The listed values range over seven (7) orders of magnitude: from 3×10^{-1} cm/s in B-38 to 1.8×10^{-8} cm/s in well WDA01D. It is improper to assign to the same GSS unit wells that show hydraulic conductivity values differing by a factor of 10,000,000.

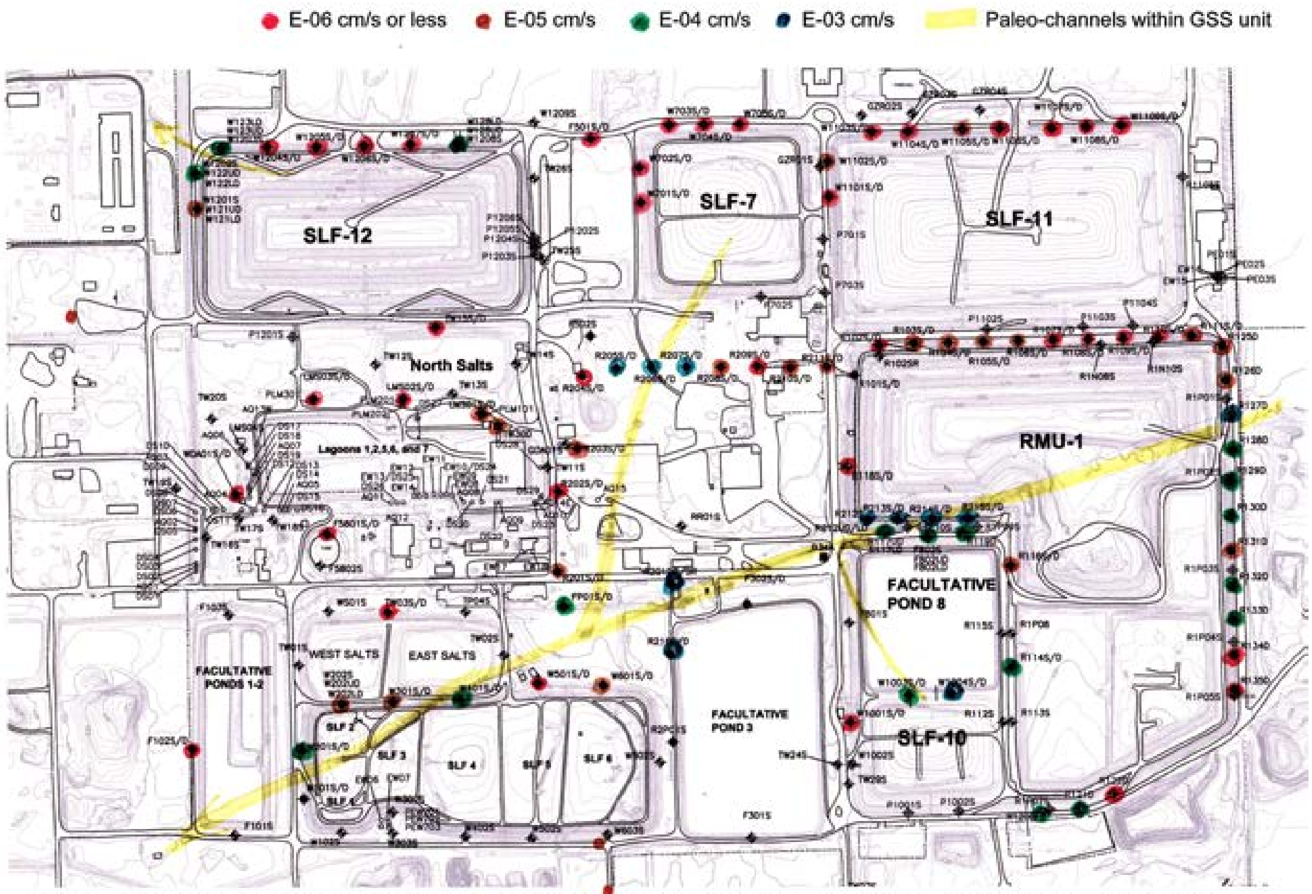

FIGURE 5: Hydraulic conductivity distribution in GSS unit (RMU-2 landfill vicinity)

Using the hydraulic conductivity (k) data from all wells completed in the GSS unit from Table 5 in Golder (2014), we prepared a map showing distribution of this hydraulic parameter within the CWM site (Figure 5). Whereas the GSS unit is represented by low-permeability deposits over most of the site, there is a well-defined pattern of high permeability areas ($k>10^{-4}$ or E-04 cm/s) along the buried valley filled with sand and gravel deposits. In addition to the main trunk of the buried valley (running from ENE to WSW), a tributary valley filled with high permeability deposits is interpreted to run from SLF-7 toward SLF-5 (Figure 5). This interpretation is corroborated by the configuration of the top of basal till surface (Figure 6). The depressions in this surface represent paleo-channels that coincide with the channels shown on Figure 5 and interpreted based on the hydraulic conductivity distribution within the GSS unit.

Given the pattern of hydraulic conductivity distribution depicted on Figure 5 and the presence of buried alluvial channels interpreted in Figure 6, it is apparent that the Applicant’s concept of GSS unit/aquifer is misleading and improper. The only true aquifer in the vicinity of the proposed RMU-2 landfill is represented by alluvial/glaciofluvial sand and gravel bodies deposited in the buried channels. These sand and gravel channels should be considered to be a separate unit. Because these elongated bodies provide preferential flow and contaminant migration pathways, they should become principal targets for groundwater monitoring. Both the main trunk of the alluvial body and its northern tributary run beneath the proposed RMU-2 landfill footprint. The tributary is likely to induce groundwater flow and contaminant migration from the contaminated Process Area toward the landfill. The proposed groundwater monitoring for RMU-2 would be ineffective as it does not account for preferential flow within the buried valleys.

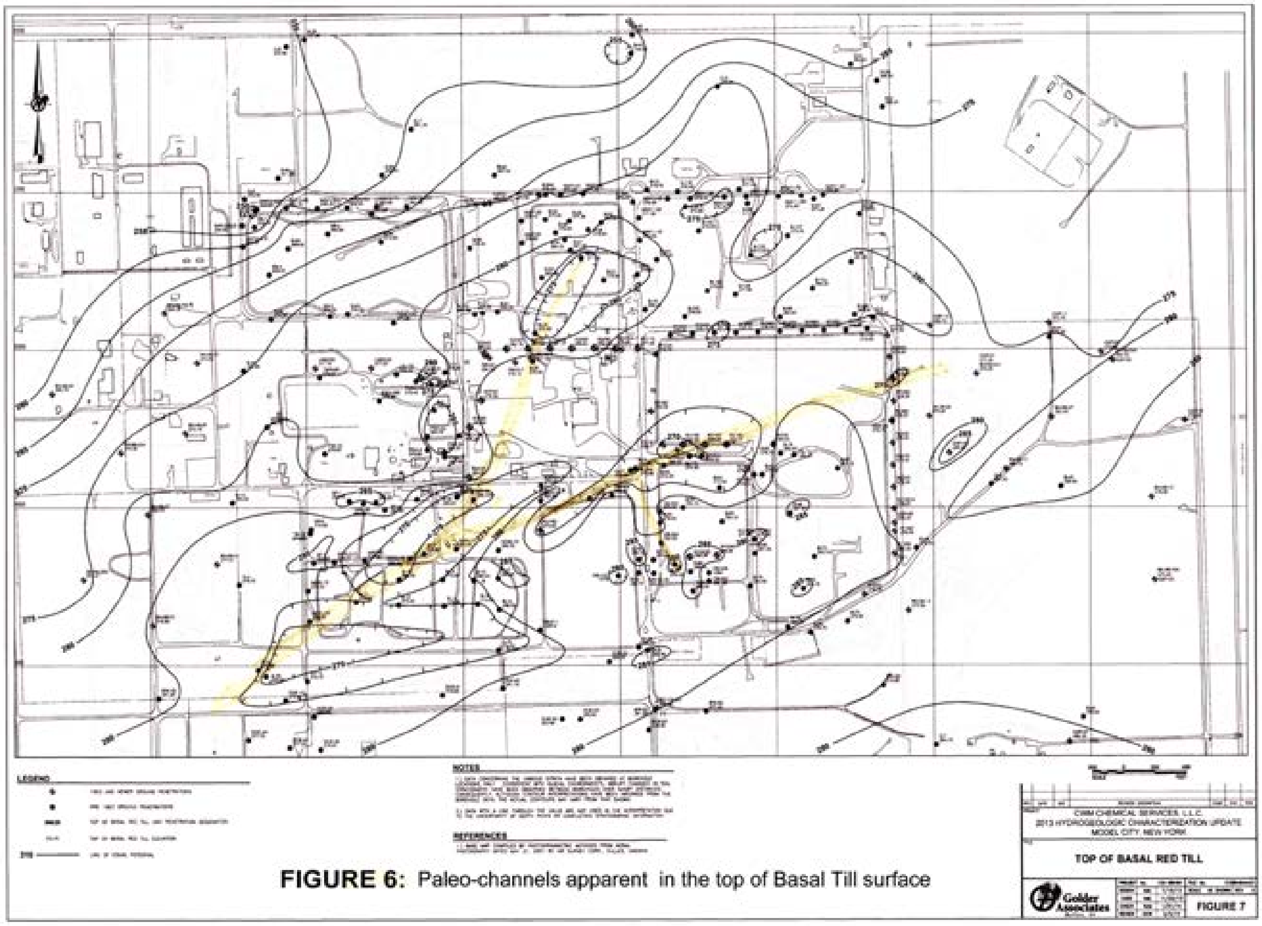

FIGURE 6: Paleo-channels apparent in the top of Basal Till surface

D. *Potentiometric maps and groundwater flow direction*

Exhibit 6, taken from Golder (2012), together with Exhibits 7 and 7A, taken from Golder (2010), (2013), respectively, clearly show the low westerly hydraulic gradient beneath the Process Area in the glaciolacustrine silt/sand unit (which includes the alluvial sand and gravel unit deposited in the lower portion of the buried valley). These potentiometric maps also show a steep northerly hydraulic gradient across the northern ridge area. These features reflect the presence of a buried east-west valley of highly permeable alluvial deposits, bounded on the north and south by bedrock ridges overlain with relatively impermeable deposits, as shown in Exhibit 1. *See also above,* Figure 3. The alluvial sand and gravel of the buried valley is a singular feature

of the site providing preferential groundwater flow and contaminant migration pathway.
A close spacing of the potentiometric contours in the northern portion of the study area in Exhibits. 6, 7 and 7A is in a stark contrast to the wide spacing of the contours in the central area. The Applicant incorrectly states that the wide spacing of the contours is "because of the near-horizontal configuration of the top of rock and the ground surface between the Niagara Escarpment and Lake Ontario." Golder (2014b), 2. Exhibits 1 and 2 show that the actual bedrock configuration in the vicinity of the site is quite variable and not "near-horizontal". In previous studies the Applicant characterized this phenomenon as a "localized condition caused by a combination of low surface rock and thick aquifer in this area." Golder (1985).

The real reason for the wide spacing of potentiometric contours within the central portion of the site is a much greater permeability and transmissivity of the channel deposits within the buried valley relative to the low permeability and transmissivity of the northern bedrock ridge and its cover. This ridge restricts the northerly groundwater flow, and a steep hydraulic gradient in that direction reflects that flow constraint, while the low westerly gradient reflects the ease of groundwater flow to the west. Flow through a drainage pipe or a soaker hose can be invoked as an analog here: The steepest gradient is across the walls of the drain/hose analog, but the bulk of the flow is along the pipe/hose.

A simple comparison of groundwater velocities and flow rates in the northerly and westerly directions can be obtained by applying Darcy's formula to the hydraulic parameters for the buried channel and the ridge portions of the flow domain. Based on the two orders of magnitude contrast in hydraulic conductivity values between these areas, and a one order of magnitude difference in hydraulic gradient values, one estimates that the westerly groundwater velocity within the buried channel is approximately ten times faster than on the northern ridge. The Applicant's groundwater monitoring network in the glaciolacustrine silt/sand unit (the lower aquifer) is based on an interpreted apparent regional groundwater flow direction to the north/northwest, rather than a prevailing westerly direction of actual groundwater flow over much of the CWM site. This fatal deficiency of the monitoring network stems from not recognizing the alluvial sand and gravel as a distinct unit controlling groundwater flow and contaminant migration pathway.

The Applicant acknowledges the presence of a westerly groundwater flow in the lower aquifer unit, but considers such flow a localized feature relative to the apparent regional flow to the north/northwest, essentially inconsequential for groundwater monitoring. However, it is clear from the most recent potentiometric map that groundwater flow beneath a significant portion of the Process Area converges toward the buried valley axis.

E. *Vertical permeability of the upper aquitard*

The upper aquifer unit is composed of Upper Tills overlying the Glaciolacustrine Clay. In the northwestern portion of the site, including portions of the RMU-2 footprint, the Glaciolacustrine Clay aquitard unit includes a relatively low permeability silt till (termed by Golder the

"Middle Silt Till"). The Middle Silt Till was apparently deposited during a local glacial ice advance. Golder (2009a), 5.

There are at least four locations within the Process Area where Glaciolacustrine Clay fails to act as an effective aquitard. This is because the clay is so thin or missing at those locations that *vertical* groundwater flow to the lower unit is much faster than acknowledged by the Applicant. These four locations are marked A through D (in red) on Exhibit 8, taken from Golder (1993), Figure 11. Two of these permeability windows are located adjacent to (A), or beneath (D) the RMU-2 footprint. All four permeability windows provide preferential, relatively fast vertical flow and contaminant migration pathways into the GSS. As a result, it cannot be said, as asserted in the Application, that the glaciolacustrine silt/sand (GSS) unit is a confined aquifer. *Cf.* DEIS, 62.

Vertical head differences measured in well clusters located within or near such windows are expected to be lower than in areas away from the windows. CWM has made few vertical gradient measurements near these permeability window areas. In well cluster R201S/R201D located near, and just upgradient of, Area B on Exhibit 8, a vertical gradient of 0.06 was measured in October of 1992 while the average side-wide vertical gradient was 0.23. *See* Golder (1993), Table 14. The lower vertical gradient in the window areas reflects an enhanced vertical permeability and vertical cross-flow within such areas.

F. *Vertical and horizontal migration rates*

The Applicant's *Groundwater Sampling and Analysis Plan*, (Golder (2009a)), provides a 1987 calculation of vertical groundwater velocity on the northwest side of the "facility" of 0.04 ft/yr. *Id.*, Figure 4. This calculation assumes that groundwater flows through 16 ft. of upper tills at 0.1 ft/yr, then flows through 7 ft. of "upper glaciolacustrine clay" at 0.04 ft/yr, then flows through 17 ft. of Middle Silt Till at 0.07 ft/yr, then flows through 3 ft. of "lower glaciolacustrine clay" at 0.04 ft/yr before reaching the "glaciolacustrine aquifer." Another calculation is provided for the southeast side of facility, where there is no Middle Silt Till. Groundwater is then assumed to flow through 15 ft. upper tills at 0.1 ft/yr, then flows through 20 ft. of glaciolacustrine clay at 0.04 ft/yr. The calculation results in groundwater reaching the lower aquifer in the southeast at a velocity of 1 ft/yr.

These assumptions ignore the large variation in thickness of the glaciolacustrine clay on the site and the presence of the permeability windows (Exhibit 8). By assuming uniformity where none exists, they portray the lower aquifer as confined by relatively a impermeable geologic unit. The variation in thickness of the clay unit can be attributed to the varying depth of abrasive erosion of the soft lacustrine clay by an advancing glacier and/or the displacement of soft clay by till deposits. The regulatory uppermost aquifer identified by the Applicant (the GSS unit)[5] is not,

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[5] *Cf. above*, footnote 1.

therefore, properly considered a confined aquifer.

Importantly, actual field data are available showing the vertical contaminant migration rate is at least 35-50 times greater than what is calculated in the *Groundwater Sampling and Analysis Plan*, Figure 4.

In October 1990, 18 years after the start of disposal operations at Model City, a soil sample was obtained from the bottom of the GSS unit within a depth interval of 38 to 38.9 ft (boring PRO-21). Golder (1993a), Figure 5.24-4. *Reproduced here as* Exhibit 11. Assuming conservatively that VOCs were discharged at the start of the disposal operations, the presence of VOCs detected in PRO-21 indicates an average vertical migration rate of at least 2.1 ft/year. This vertical migration rate value may be further underestimated because it includes an unknown lateral/horizontal migration distance atop the basal till, in addition to the vertical migration across the till, glaciolacustrine clay, and GSS units.[6] Nevertheless, this estimated vertical contaminant migration velocity of 2.1 ft/year, derived from actual field data, is more than 50 times faster than the vertical groundwater velocity of 0.04 ft/year claimed by the Applicant. The actual vertical groundwater velocity is undoubtedly higher than 2.1 ft/year because contaminants move more slowly than groundwater due to sorption and matrix diffusion effects.

Field data is also available for soil boring MW10-2S-1E, completed in December 1987 between SLF10 and Facultative Pond 3. *See* Golder (1993a), Table 5.6-1. VOCs were detected in this soil sample at a depth of 26 to 28 ft. Assuming conservatively that the discharge of the VOCs occurred at the start of the disposal operations, 15 years prior to the sampling event, the vertical migration rate for the VOCs across the upper till unit and the Glaciolacustrine Clay at that location is calculated to be 1.8 ft/year. This velocity of contaminant migration is 45 times faster than the vertical groundwater velocity of 0.04 ft/year calculated by the Applicant.

In the Lagoons area, the June 1988 sampling of lower aquifer well TMW-10D found tetrachloroethene (PCE) at a concentration of 69 µg/l (Golder, 1988). This well was completed to 50 ft, with the top of screen placed at 37 ft below the top of berm that was 14 ft above the original grade. Assuming again conservatively that the PCE was discharged at the start of disposal operation, 16 years prior to the sampling event, the vertical migration rate for PCE into the lower aquifer in the TMW-10D[7] area is calculated to be at least 1.4 ft/yeat (23 ft/16years),

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[6] No major soil contamination was detected in several soil samples collected from the boring PRO-21 above the basal till sample up to a depth of 28 ft, so some lateral contaminant migration atop the Basal Red Till must have occurred. *See discussion below*, p. 20.

[7] An unconvincing claim was made that the detected contamination possibly resulted from "dragdown during well installation," so this well was abandoned/sealed. Additional borings were proposed to be installed to the northwest of TMW-10D, in the apparent direction of groundwater flow rather than to the southwest, the true groundwater flow direction in that area.

which is 36 times faster than Applicant's calculated groundwater velocity of 0.04 ft/year.

The sampling results from these three boring/wells discussed above document that the lower aquifer (the detection zone) had already been impacted by site-related contaminants in at least three different areas prior to year 1990.

Field data from well sampling conducted in 2008 detected acetone in four lower aquifer wells: R201D (at 790 ug/L), R202D (650 ug/L), R209D (820 ug/L) and R210D (55 ug/L). Golder (2010), Table 7. These deep wells are marked with red circles here on Exhibit 12, taken from *id.*, Figure 5. Acetone was not detected in any adjacent shallow wells of these four well clusters, indicating that the origin of the acetone contamination is a substantial distance from these wells. As a result of the 2008 sampling, acetone was also detected in two shallow wells: R208S (42 ug/L) and R213S (150 ug/L), marked with an "X" on Exhibit 12. The latter well is located near the northwestern corner of Facultative Pond No. 8 where acetone was also detected during pond closure sampling conducted in 2005, in soil/sediment sample F8-G1. Golder (2009). This general area appears to be a source area of acetone that migrated through the glaciolacustrine clay and then within the lower aquifer for a distance of some 1,500 ft. *See* Exhibit 12. This extensive westward migration of acetone occurred within a time span of less than 35 years, indicating a migration velocity of at least 40 ft/yr.

This velocity is consistent with a calculation of groundwater velocity in the lower aquifer, based on field data and Darcy's formula. A subset of six lower aquifer wells completed within the alluvial channel deposits shows hydraulic conductivity values ranging from 1.05×10^{-3} cm/s to 2.5×10^{-3} cm/s, with an arithmetic mean of 1.68×10^{-3} cm/s. *See* Exhibit 10. Using the latter value, and applying the lowest hydraulic gradient value of 0.006 reported for the GSS unit (DEIS, p. 60), and assuming an effective porosity of 0.3, the calculated average horizontal groundwater velocity is at least 35 ft/yr in the channel deposits of the lower aquifer. Even higher groundwater velocity values, ranging from 86 ft/yr to 624 ft/yr were calculated by Wehran (1977) for the alluvial lower aquifer at this site.

It should be noted that a much higher hydraulic conductivity value, on the order of 10^{-2} cm/s, is indicated by results of a pumping test conducted by USACE a short distance to the northeast of RMU-1 and completed in gravel at the top of bedrock. This well was reportedly pumped at 10 gpm with a drawdown of 22 ft. *See* Table 7 in Johnston (1964).

Accordingly, the Applicant-calculated travel time for contaminants spilled as a result of a leachate pipeline rupture is grossly unrealistic: "In the modeled worst-case scenario, the leachate was assumed to move with the same velocity as the groundwater. . . . It was estimated it would take approximately 55,555 and 223 years, respectively, for leachate confined to the water table in the upper till units, and leak transported instantaneously to the Glaciolacustrine Silt/Sand unit to migrate off-site from the area of RMU-2." DEIS, 117-118. No supporting data for these calculated travel times were provided, but the Applicant likely used hydraulic conductivity values that not only were inappropriately averaged but also did not account for the scale effects due to the presence of sand lenses and fracturing. The calculated values are contradicted by the actual migration velocity and travel times indicated by onsite contaminants, presented above.

The difference between the actual and Applicant-calculated migration velocities is largely accounted for by the selection of hydraulic conductivity values used in the Applicant's groundwater velocity calculations. *See Engineering Report*, 9; DEIS, 60-61. All of the reported vertical hydraulic conductivity values were obtained from laboratory permeability tests conducted on small samples of soil matrix which do not include effects of secondary large-scale features like fractures, sand lenses, and weathering. These secondary features are known to increase hydraulic conductivity values by two to three orders of magnitude relative to the hydraulic conductivity of laboratory samples. Stephenson (1988).

In addition, the Applicant uses geometric means as representative hydraulic conductivity values for the various hydrogeologic units. However, the use of a geometric mean is not appropriate when, as is the case at this site, the mean hydraulic gradient is non-uniform and the mean hydraulic conductivity varies in space. Smith and Freeze (1979); Anderson (1989).
In addition, in calculating the geometric mean conductivity in the lower aquifer, the Applicant incorrectly includes wells completed in the low-permeability lacustrine silt sediments, instead of a set of wells completed within the sand and gravel channel deposits that comprise the true lower aquifer.[8]

G. *Impacts of offsite dewatering operations*

In the Application and supporting materials the Applicant mentions offsite pumping impacts only once. *See* DEIS, 62. According to the Applicant, previous dewatering of the lower aquifer (Glaciolacustrine Silt/Sand unit) at the neighboring Modern Landfill, concluded in March 1999, caused a temporary alteration in groundwater flow towards the south in a portion of the CWM site. *Id.* The DEIS states that if Modern Landfill resumes its dewatering operation, southerly flow would be re-established and the RMU-2 monitoring network would then be evaluated. *Id.*

A memorandum by Carey (2005) provides graphs and a discussion of dewatering impacts at the Modern Landfill on wells and piezometers on the Modern Landfill and the DOE/NFSS sites. (No CWM wells were included in Carey's evaluation.) The dewatering pumping rate ranged from approximately 12,000 gpd (8.3 gpm) to 6,000 gpd (4.2 gpm), as detailed on graphs extracted from Carey (2005) and provided herewith as Exhibit 15. These graphs provide

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[8] In a layered system, the effective horizontal hydraulic conductivity is represented by a weighted arithmetic mean, with layer thicknesses being the weighting factor. Freeze and Cherry (1979). However, the fastest contaminant migration pathway is not controlled by this weighted arithmetic mean but by the layer with the highest hydraulic conductivity values that serves as a preferential flow pathway.

potentiometric levels during the 1990-2005 period for wells located more than 2,000 ft away from the pumping centers at the landfill and completed in the Sand and Silt Unit (SSOW wells) and the Queenston Formation bedrock (QFM wells). These distant wells show potentiometric head decline of as much as five feet in response to the dewatering at the Modern Landfill.

More importantly, the graphs in Exhibit 15 indicate that an offsite event other that the Modern Landfill dewatering occurred from spring of 1998 through the winter of 1999 and resulted in lowering of potentiometric levels as much as 10 to 15 below their normal values in both the SSOW and QFM wells. This lowering was two to three times greater than attributed to the Modern Landfill dewatering operations. Since this lowering occurred during a period of reduced pumping at the Modern Landfill, and during normal precipitation, and was more pronounced going westward, Carey (2005) attributed this lowering to contemporaneous clay mining and dewatering operations at the Pletcher Road borrow pit located approximately 1,500 ft to the WSW (and downgradient) of the CWM site.[9]

The same magnitude of offsite lowering of groundwater levels is evident in the Modern Landfill and the NFSS wells again in late 2002 (Exhibit 15), three years after cessation of dewatering at the Modern Landfill. Aerial photographs indicate that the Pletcher Road borrow pit was expanded eastward in 2002, and another borrow pit was created between the Pletcher Road pit and the John Long borrow pit. Available yearly water level measurements for the month of October during the 1993 to 2013 period (Table 9 in Golder, 2014) show that the lowest historic water levels occurred in October 1998, 1999 and 2002, the times coinciding with the borrow pit operations.

A potentiometric map for October 1998, the time of waning pumping operation at the Modern Landfill but continued mining at the Pletcher Mine, shows a southwesterly groundwater flow in the GSS unit (i.e. towards the mine) within the western portion of the CWM site (Golder 1999; Figure 5). This flow pattern is different from the pattern revealed by a number of monthly potentiometric maps prepared by Rust Environmental and submitted monthly by Rust during the 1994-1995 period. The latter maps show southerly to southeasterly flow (toward the Modern Landfill) over the southern portion of the CWM site. This indicates that the Pletcher borrow pit dewatering impacts extended into the CWM site, and that the impacts of Pletcher activities on water level in the lower aquifer were greater than those caused by the Modern Landfill dewatering.

Exhibit 14 contains hydrographs (water level histories) for some onsite wells going back to the late 1970s, taken from Golder (1985). The hydrographs show that during the 1979-1981

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[9] At the proposed nearby Pletcher Clay Mine, portable pumps with a maximum operating capacity of 800 to 900 gpm were to be used to drain the excavation area. This pumping capacity is more than 100 times greater than the pumping rates used at the Modern Landfill. Glynn (1994), 57 (DEIS for Pletcher Clay Mine).

period water levels in GSS wells declined by as much as 35 ft.[10] The greatest decline of 35 ft was in well B-36 located at the NW corner of the site.[11] This was followed by a 33 ft decline in B-38 located along the axis of the buried valley north of the Fire Pond (NE of East Salt), a 25 ft decline in B-34 located farther to the east, and a 22 ft decline in well B-44 located east of RMU-1. The potentiometric levels in the buried valley for that period thus indicate a strong hydraulic gradient to the west, the direction of greatest decline. Only a small decline was observed in wells located at the northern ridge (e.g., well W-3 in Exhibit 15) and adjacent to the Modern Landfill. This pattern indicates that the Modern landfill was not the cause of the observed decline. These declines in groundwater levels were instead the result of mining/dewatering operations at the John Long mine, located approximately 4,000 ft west-southwest of the West Drum area.

These substantial impacts of dewatering operations at the two borrow pits on potentiometric levels at the CWM site have significant implications. First, the large decline of potentiometric levels enhanced the west-southwesterly groundwater flow during the pits' operations. The clay mining activities during this period also accelerated groundwater and contaminant migration rates across the Glaciolacustrine Clay and within the Lower Aquifer, propelled by the large increases in vertical and horizontal hydraulic gradient values. Groundwater velocity and contaminant migration rates very likely increased by orders of magnitude beneath the most contaminated portions of CWM's Process Area and the West Drum Area. This is the equivalent of several decades of migration under normal conditions, assuming the groundwater velocity and migration rates discussed earlier.

Second, the large extent of the pit dewatering-impacted area, stretching for a distance of at least 10,000 ft from the John Long pond in the west to beyond the eastern boundary of the CWM site, attests to hydraulic continuity and a significant transmissivity of the sand and gravel unit within the buried valley. Furthermore, the lack of any significant responses in CWM wells located at the northern east-west till ridge to the hydraulic stresses from dewatering operations at Modern Landfill, and the Pletcher Road and John Long borrow pits provides a hydraulic verification of the role of this ridge as a flow barrier that imposes the west-southwesterly flow direction along the axis of the buried valley.[12]

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[10] Golder (1985) does not provide a reason for such a large decline but instead questions (unconvincingly) the accuracy of the water level measurements.

[11] This well (B-36) is located in the other (northern) buried valley. The observed decline of water levels in this well and wells in the buried valley beneath the CWM site indicates a likely confluence of both valleys in the John Long pit/pond area.

[12] A potentiometric map for May 1995 tracking the Modern Landfill dewatering impacts shows a south-southwesterly groundwater flow direction over a portion of the CWM site located south of the northern ridge. This provides additional evidence that the northern ridge acts as a flow barrier and a groundwater divide. *See* CWM (1995).

Third, the former John Long clay mine became a Wilderness Preserve with Walleye Rearing Ponds operated by Niagara River Angler Association. Since it is located hydraulically downgradient of the CWM site, the preserve is a sensitive environmental receptor ignored in the Application and supporting materials. No contaminant detection wells exist or are proposed to monitor likely impacts on that receptor.

2. RMU-2 Does Not Meet the Siting Requirement for Hydraulic Conductivity

Part 373 establishes minimum standards for permeability, or hydraulic conductivity at a proposed hazardous waste facility site. Part 373-2.14(b)(1) requires that the soil beneath the facility have a hydraulic conductivity of 10^{-5} centimeters per second or less, as determined by in-situ hydraulic conductivity test methods. Contrary to the statement made on page 23 of the DEIS, the proposed location of RMU-2 does not meet this standard. A geometric mean of $3x10^{-6}$ cm/s for the upper till unit relied on by the Applicant, (DEIS, 61; Groundwater Sampling and Analysis Plan, Table 1; Engineering Report, 2-4), is misleading because this value is not based on field data obtained within the RWM-2 footprint.

Results of field hydraulic conductivity measurements conducted within the proposed RMU-2 footprint are provided in Table 3 of Golder (2010), reproduced here as Exhibit 10. Out of a total of 13 shallow or "S" (Upper Tills) wells tested within the RMU-2 footprint, ten wells show hydraulic conductivity values greater than $1x10^{-5}$ cm/s. Exhibit 10. Only three wells tested meet the minimum hydraulic conductivity standard. These three wells are located at the northern perimeter of the proposed RMU-2 footprint. The 13 shallow wells tested within the RMU-2 footprint have a geometric mean hydraulic conductivity value of $6.9x10^{-5}$ cm/s, more than 23 times greater than the geometric mean of $3x10^{-6}$ cm/s claimed by the Applicant for the upper tills.

In addition, vertical hydraulic conductivity of tills can be even greater than horizontal conductivity due to the presence of vertical fractures.[13] It is well-documented in technical literature that such fractures provide preferential flow and contaminant migration pathways across tills (*e.g.*, O'Hara (2000); Ruland (1991)), and tills and glaciolacustrine deposits in the region contain vertical fractures. *Cf.*, *e.g.*, McIelwain (1989); O'Neill (2000). Wehran (1977) documented the presence of vertical joints in numerous logs of test pits and borings at the CWM site. Unrecognized vertical fractures in a thick glaciolacustrine clay overburden were found to provide vertical migration pathways for DNAPL migration into bedrock at a site in Smithville, Ontario, exposing the fallacy originally believed that the clay would provide a tight barrier against downward contaminant migration. McIelwain (1989).

Finally, and most importantly, the highest hydraulic conductivity values in the upper tills have been measured in shallow/upper till wells R214S, R2015S, W1003S and W1004S located

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[13] Slug tests, the 13 results of which are discussed above, generally measure horizontal rather than vertical hydraulic conductivity.

within the RMU-2 footprint, directly above the buried valley. *See* Exhibit 10. The high hydraulic conductivity data obtained from these wells show that there is a substantially faster downward flow than acknowledged by the Applicant–and a potential contaminant migration pathway into the lower aquifer ignored by the Applicant–near the vertical permeability window labeled with letter D on Exhibit 8.[14]

3. The Lower Aquifer is Heavily Contaminated Beneath the Central Area

The most contaminated areas of the CWM site are located above the buried valley at, or adjacent to, some of the vertical permeability windows mapped on Exhibit 8. Specific sampling points that support this conclusion are discussed below, and shown on Exhibits 9 and 11, taken from Golder (2009c) and an investigation of the Process Area, Golder (1993a), Table 5.24-4, respectively. The impacted Central Area is located directly downgradient (west) of monitoring wells R213D, R214D and R215D completed within the ENE-WSW aligned alluvial sand and gravel of the buried valley. See Exhibit 7A for location of these wells. Hydraulic conductivity values greater than $1x10^{-3}$ cm/s have been measured in these wells. *See* Golder (2010), Table 3, included here as Exhibit 10.

Specifically, the Area B permeability window shown in Exhibit 8 includes a portion of the Process Area and sampling points PRO-9, PRO-10A, B and C, and PRO-31B. *See* Exhibits 9 and 11. Area B is also a short distance downgradient of sampling locations 61-W1 and 61R through 61- S4. *See* Exhibit 9. All these sampling locations have shown very high concentrations of various chlorinated and non-chlorinated solvents and PCBs in soil and/or groundwater, indicative of the likely presence of DNAPL. For example, a PCB-1260 concentration of 35,000 µg/l was detected in groundwater obtained from PRO-9. This concentration is three orders of magnitude higher than the reported aqueous solubility of PCB-1260 (Pankow and Cherry (1996)), indicating the presence of PCB DNAPL (waste PCB product mixed with other solvents) in groundwater at the sampling location.

The highest VOC concentrations have been found in the GSS unit at 30 ft to 32 ft below grade. A groundwater sample collected from boring PRO-10B, (*see* Exhibit 11), shows a total concentration of several solvents as high as 174,803 µg/l. Exhibit 12.

In boring PRO-10C, high solvent concentrations were detected in a soil sample collected from the 30 to 30.5 ft interval. *Id.*

In boring PRO-21, located half way and approximately 100 ft to the west between borings PRO-9 and PRO-10 (*see* Exhibits 9 and 11), high solvent concentrations were detected in a soil

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[14] Extraction wells and trenches subsequently installed in the Process Area, including recently proposed wells EW17 and EW18, are too shallow to affect the DNAPLs that have already entered the lower aquifer.

sample collected at 38 to 38.9 ft. Exhibit 12. According to the log of boring PRO-21, (Exhibit 13, *from* Golder (1993)), this depth interval corresponds to the contact between the bottom of the GSS unit and the top of Basal Red Till. It is noted that no major soil contamination was detected in several soil samples collected from this boring above the Basal Red Till sample up to a depth of 28 ft. *See* Exhibit 12, indicating that DNAPL has migrated laterally along the bottom of the GSS unit, atop the basal till. This also indicates that the underlying bedrock may be impacted.

A groundwater sample from PRO-21 shows a total solvent concentration of 280,477 µg/l, with TCA-DCA at 210,000 µg/l and TCE at 51,269 µg/l. *Id.* Such high concentrations of these chemicals indicate the presence of DNAPL product atop the basal till. Pankow and Cherry (1996). It is well established that this type of DNAPL product has a greater mobility, and can travel faster, than groundwater. *Id.* The presence of DNAPL atop of the Basal Till triggers the need for installing bedrock monitoring well southeast down-slope and downgradient (i.e., southwest) of PRO-21 to assess impacts of this DNAPL on bedrock groundwater quality.

Another groundwater sample collected directly from the lower aquifer unit via double-cased boring PRO-35, located approximately 25 ft north of PRO-21, shows a TCE concentration of 1,911 µg/l. Exhibits 11 and 12. Benzene, toluene, 1,1DCE and PERC were also detected in this sample. *Id.*

4. Shallow Permeability Windows are the Likely Route of Lower Aquifer Contaminants

The results of the investigation of the Process Area, (Golder (1993a), provide compelling evidence that the lower aquifer has been impacted by various solvents since at least 1990 and that DNAPL product has likely migrated through a permeability window (Area B in Exhibit 8) and accumulated atop the basal till, possibly even penetrated into the underlying bedrock. DNAPLs provide a long-term source of dissolved contamination in the lower aquifer.

No deep source area wells, or downgradient monitoring wells, have been installed at Area B or west of the Process Area since the impact was revealed by the 1990 investigation. The Applicant does not propose to delineate and monitor the solvent plume in the lower aquifer in the eastern Process Area, notwithstanding the designation of the GSS unit as the regulatory "uppermost aquifer" and the "detection zone." The nearest and the only downgradient monitoring well (F5801D) is located approximately 800 ft from the known impacted area. However, the hydraulic conductivity of deposits screened by this well is only $3.4\text{X}10^{-6}$ cm/s. Golder (2014), Table 5. This indicates that F5801D was installed in the low-permeability deposits on the side of the northern ridge, and not within the buried valley deposits of the lower aquifer. Consequently, this well is not capable of monitoring faster migration pathways associated with sand and gravel channels within the buried valley.

This conclusion is important to stress because the Department believes that remedial measures to contain DNAPL in "the heavily contaminated upper tills" installed in 1992 provide sufficient monitoring, and "[m]onitoring wells screened in the lower zone in the vicinity (R201D, R202D, TW30D, LMS01D, LMS02D) down gradient of the location of these remedial measures have not detected contamination." NYSDEC (2013), 2-3. However, contrary to this statement, the identified monitoring wells are not located truly downgradient of the impacted Process Area. These wells are either upgradient (R201D, R202D) or cross gradient (TW30D, LMS01D, LMS02D), as demonstrated in the discussion above of the hydrogeologic setting. This conclusion is also consistent with the low hydraulic conductivity values measured in these wells, which is characteristic of an aquitard, not an aquifer. *See* Golder (2010), Table 3, included here as Exhibit 10.[15]

As an interim remedial measure, a groundwater interceptor trench with two DNAPL collection sumps, DS22 and DS23, was installed in Process Area I. The trench was supposed to terminate in the Glaciolacustrine Clay (GC) unit. It appears, however, that portions of the eastern segment of this trench (where the GC unit is thin) penetrated into the underlying Glaciolacustrine Silt/Sand (GSS) unit, thus creating an inadvertent DNAPL migration pathway into the GSS unit. This penetration is apparent when one compares the elevation of the trench bottom and DNAPL sump DS23 (289.5 ft) against elevations of the GC/GSS contact reported on logs of adjacent borings. The GC/GSS contact elevation is above the trench bottom in PRO-4 (294.10 ft), PRO-34 (291.70 ft), PRO-35 (292.10 ft), and R202D (290.54). The latter well is part of a proposed monitoring network for RMU-2. The presence of a DNAPL zone in the GSS unit adjacent to, and downgradient of RMU-2, interferes with the ability of the Applicant to monitor RMU-2 contaminant releases.

Other known DNAPL releases are located in portions of the West Drum Area near the vertical permeability window labeled as Area C on Exhibit 8. Some deep soil borings completed in this area show clay thickness is as little as 2 ft (WDA-1, B-42) or 2.3 ft (WDGW33). Contrary to the Department's belief (NYSDEC (2013), 3), the presence of DNAPL in the West Drum Area is not limited to the area adjacent to wells TMW16S and TWW17S. DNAPL is also found near WDGW5, 7 and 17; and TB-20 and 22S. Golder (1993a), Figure 5.3-2. DNAPL was also found nearby in TMW-5S-5W at Lagoon 6. *Id.* Each of these wells have detected DNAPL in the upper tills.

Soil and groundwater sampling results obtained during the remedial investigation of the West Drum Area are very limited. The downward extent of DNAPL migration has not been defined there, but the Applicant implies that the glaciolacustrine clay unit would act as a barrier. However, given the large size of the DNAPL-impacted areas, the small and variable thickness of the clay unit, the fact that the bottoms of existing DNAPL recovery sumps are set into the clay close to the top of the lower aquifer, and based on the experience from the eastern Process Area with a similar hydrogeologic setup, it is very likely that DNAPL has impacted the lower aquifer in the West Drum Area.

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[15] The same hydraulic conductivity values are included in Golder (2014a), Table 5.

The only lower aquifer monitoring well in the West Drum Area (WDA01D) is located in the Lagoon Area hydraulically cross-gradient from the West Drum DNAPL areas. Because the lower aquifer is the regulatory "uppermost aquifer" and the "detection zone,"[16] the absence of any source area and truly downgradient monitoring wells in the already impacted West Drum Area lower aquifer is puzzling, as it is contrary to the goals of groundwater monitoring.

The implied role of the glaciolacustrine clay unit as a barrier to contaminant migration into the lower aquifer should also be questioned based on the lessons learned from the Smithville, Ontario case. The Smithville site is located approximately 35 miles west of the Niagara River in a similar hydrogeologic setting as the CWM site. The thickness of glaciolacustrine clay at the Smithville site ranges from 18 ft to 30 ft (thus more than reported for the CWM site, DEIS, 57). The clay overlies dolomitic bedrock of the Lockport Formation. It was estimated that several thousand gallons of PCB DNAPL migrated from a waste lagoon into the bedrock through unrecognized vertical fractures in the thick glaciolacustrine clay unit that was originally presumed to provide a tight barrier against downward contaminant migration. McIelwain (1989). The Applicant does not mention the Smithville case, or the presence of vertical fracturing in the glaciolacustrine clay with its impact on bulk permeability of this clay unit. Instead, the Applicant relies on hydraulic conductivity values determined on small laboratory samples of the matrix material.

5. Department Conclusions Regarding Groundwater Contaminants and Migration Rates are Erroneous

The Department has stated that due to slow rates of groundwater migration at the site, there are no cases where contamination has traveled more than a short distance from its presumed source. NYSDEC (2013), 3. This conclusion is contradicted by the known extent of at least 240 ft of seriously contaminated groundwater in the lower aquifer, based on the distance between impacted borings PRO-9 and PRO-5 located in the eastern Process Area. The impacted area between those two borings includes PRO-21 and temporary well PRO-35. *See* Golder (1993a), Figure 5.24-1, attached here as Exhibit 11.

This 240 ft long area of contamination in the lower aquifer beneath the Process Area indicates contaminants are migrating horizontally at a velocity of at least 13 ft/year, assuming conservatively that the discharge occurred at the start of the CWM operation, 18 years prior to the 1990 sampling in the Process Area. Because VOC migration is retarded by soil matrix, the horizontal groundwater velocity is likely to be several times faster than 13 ft/year. This conclusion contrasts with the Applicant's view that horizontal groundwater velocity in the lower aquifer averages 6-7 feet per year, a view adopted by the Department.

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[16] *Cf. above,* footnote 1.

6. Site Characteristics May Preclude Effective Groundwater Monitoring

Part 373-2.6(h)(1) requires "a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer that . . . allow for the detection of contamination when hazardous waste or hazardous constituents have migrated from the waste management area to the uppermost aquifer." 6 NYCRR § 373-2.6(h)(1)(iii). *See also* 6 NYCRR § 373-1.1(b)(2) (making 6 NYCRR Part 360 applicable to hazardous waste facilities); 6 NYCRR § 360-2.12(c)(5) ("Lateral expansions adjacent to existing landfills which are already contaminating groundwater may be allowed by the department if [among other things] . . . additional monitoring wells surrounding the entire site [are installed]").

The combination of unusual site-specific factors discussed here may preclude an effective groundwater monitoring program at RMU-2 under these standards. The presence of pre-existing contamination at and adjacent to the proposed RMU-2 landfill, together with complex contaminant migration pathways unrecognized by the Applicant, will make it impossible to distinguish between contamination that might be released from RMU-2 and contamination originating from numerous other sources. Other sources of contamination include VOC contamination within the proposed RMU-2 footprint at sampling locations PRO-B6, W-31, W-32, W-34, W-36, W-37, and others (Exhibit 9, taken from Golder (2009c)); DNAPL-level contamination in soils and groundwater adjacent to the western boundary of the RMU-2 footprint in the area of W-19 and the Process Area, directly downgradient of RMU-2; and significantly more permeable till deposits than is acknowledged by the Applicant are present within the RMU-2 footprint near wells R214S, R2015S, W1003S and W1004S (Exhibit 10).

In addition, because the proposed bottom/secondary liner above the leachate detection system would be positioned below the water table and the potentiometric surface of the GSS unit, (*Engineering Report*, 16), it may not be possible to resolve whether future contamination found in the leak detection system originated from a leaky landfill above or an upward leakage from below the bottom liner.

The potentiometric surface of the lower aquifer will be disturbed by the proposed remedial pumping at the Process Area adjacent to the RMU-2 footprint. Note that a likely resumption of remedial pumping at the Modern Landfill will also disturb the lower aquifer. The disturbance will temporarily affect groundwater flow and potential contaminant migration pathways, during the period of pumping operations, interfering with the Applicant's ability to effectively monitor groundwater. In this context, if the proposed slurry cut-off wall around the RMU-2 perimeter works as designed, it would have an unintended effect of directing potential releases into the lower aquifer.

7. Conclusions

Groundwater in the lower aquifer beneath the central portion of the CWM site flows to the west-southwest towards the Niagara River. Highly toxic chlorinated solvents (*e.g.*, TCE, TCA) and other dissolved contamination originating from DNAPLs known to be contaminating the site groundwater might be leaving the site and migrate toward the river along the preferential migration provided by the alluvial sand and gravel of the buried valley. Historic dewatering operations at two borrow pits located west of the CWM site enhanced the west-southwesterly groundwater flow and accelerated contaminant migration rates. The Wilderness Preserve at the former John Long borrow pit is a sensitive receptor likely to be impacted by contaminated groundwater from the CWM site.

An assurance that this will not be the outcome of continued operation of the site cannot be provided based on the proposed system of monitoring wells and the state of knowledge of existing site groundwater contamination. First, the monitoring well system lacks wells that could track the migration of contaminants within the lower aquifer, in which groundwater flows west-southwest. Second, existing DNAPL-related contaminant plumes must be properly delineated prior to designing an effective monitoring system for new releases. Third, it is likely based on what is known about the site that effective groundwater monitoring systems and corrective actions will need to be re-designed based on the new information.

In order to define the architecture of alluvial channel deposits comprising the lower aquifer, including the relation of the lower aquifer to the bedrock and the upper aquifers, and to determine aquifer parameters, the Applicant should be required to install additional lower aquifer and bedrock monitoring wells in the channel deposits west of the Process Area and the West Drum DNAPL areas, and then to conduct a pumping test. Such a pumping test can determine whether the site can be effectively monitored. Conducting such a test is clearly feasible, given the drawdown impacts observed during dewatering operations at the Modern Landfill and the two borrow pits, as well as during a pumping test conducted at the USACE wells located a short distance from RMU-1.

REFERENCES

Anderson, M.P. (1989). Hydrogeologic Facies Models to Delineate Large-Scale Spatial Trends in Glacial and Glaciofluvial Sediments. Geological Society of America Bulletin, v.101, 501-511.

Arcadis (2013). Draft Environmental Impact Statement for Residual Management Unit 2, rev. November 2013.

Carey P.J and Associates (2005). Memorandum to Louise Lindsay, Re: Modern Landfill IV – Evaluation of Offsite Impacts – Past and Proposed Groundwater Removal Activities, dated July 26, 2005.

CWM Chemical Svcs., LLC (2013a). Engineering Report for RWU-2, CWM Chemical Services, Model City, New York, rev. November 2013.

CWM Chemical Svcs. (2013b). Groundwater Sampling and Analysis Plan Dated December 11, 2013.

CWM Chemical Svcs., LLC (2012a). 6 NYCRR Part 373 Sitewide Permit Renewal Application, July 31, 2012, available at <http://modelcity.wm.com/>.

CWM Chemical Svcs., LLC (2012b). Model City TSDR Facility Groundwater Extraction Systems, Operation and Maintenance Manual, rev. May 2012; available at <http://modelcity.wm.com/>.

CWM Chemical Svcs., LLC (2008). Model City TSDR Facility Groundwater Extraction Systems, Operation and Maintenance Manual, revised April 2008; available at <http://modelcity.wm.com/>.

CWM Chemical Svcs. (1995). Letter report from Jill A. Knickerbocker to Paul A. Conterman, NYSDEC, dated June 6, 1995.

Freeze R.A. and J.A Cherry (1979). Groundwater. Prentice-Hall Inc.

Glynn (1994). Glynn Geotechnical Engineering, Draft Environmental Impact Statement for the Proposed Pletcher Pond Project, Town of Lewiston, Niagara Co., NY. Submitted in March 1994.

Golder Assoc. (2014a). 2013 Hydrogeologic Update, Model City TSD Facility, Model City , New York, dated January 31, 2014.

Golder Assoc. (2014b). Groundwater Sampling and Analysis Plan, rev. January 2014 (incorporated by reference into proposed draft Part 373 Permit).

Golder Assoc. (2013). Report on 2012 Groundwater Level Interpretation, Model City TDS Facility, Model City, New York, dated February 28, 2013.

Golder Assoc. (2012). Engineering Report for CWM Chemical Services, LLC Model City Facility, Residual Management Unit 1, revised August 2012; available at <http://modelcity.wm.com/>.

Golder Assoc. (2012a). Design Report for Process Area IV Extraction Wells, CWM Chemical Services, Model City, New York. January 2012, rev. April 2012.

Golder Assoc. (2010). Residuals Management Unit Two, Phase I Groundwater Monitoring Program, CWM Chemical Services, Model City, January 22, 2010.

Golder Assoc. (2009a). Groundwater Sampling and Analysis Plan, revised August 2009, available at <http://modelcity.wm.com/>.

Golder Assoc. (2009b). Report on Facultative Pond Number 8 Closure Certification, CWM, Model City, NY.

Golder Assoc. (2009c). Landfill Footprint Analytical Data Study and Western Boundary Relocation Investigation, Residuals Management Unit Number 2.

Golder Assoc. (2002). CWM Engineering Report, RMU-2, Appendix A (letter report entitled "Geotechnical Investigation for Proposed Residuals Management 2 Western Expansion Area").

Golder Assoc. (1999). Report on 1998 Groundwater Level Interpretation, Model City TSD Facility, Model City, New York. Report dated February 1999.

Golder Assoc. (1993). Final Report on 1993 Hydrogeologic Characterization Update, Model City TSDR Facility, 3 vols., June 1993.

Golder Assoc.(1993a). RCRA Facility Investigation Summary Report, Model City TSDR Facility, Model City, NY, dated January 14, 1993.

Golder Assoc. (1988). Well TMW-10D Investigation Plan, Model City TSD Facility, Model City, New York, September 1988.

Golder Assoc. (1985). Hydrogeologic Characterization, Chemical Waste Management, Inc., Model City, New York Facility, March 1985.

Johnston, R. H. (1964). Ground Water in the Niagara Falls Area, New York. Bulletin GW-53.

Kindle, E. M., and Taylor, F. B. (1913). Description of the Niagara quadrangle: U.S. Geological Survey Geologic Atlas, Folio 190, 26 p.

McIelwain T.A, D.W. Jackman and P. Beukema (1989). Characterization and Remedial Assessment of DNAPL PCB Oil in Fractured Bedrock: A Case Study of the Smithville, Ontario Site. Ontario Site Water Issues,Valhalla Inn, Kitchener, Canada, 303-312.

NYSDEC (2013). Letter from David F. Stever, Esq. to Gary Abraham, Esq. Re: groundwater monitoring at CWM Chemical Services, NYSDEC Site #932045, dated December 11, 2013.

NYSDEC (2001). Statement of Basis Selecting of Final Corrective Measures, CWM Chemical Services L.L.C., USEPA ID No. NYD049836679, Model City, NY 14107.

NYSDEC (2005). 6 NYCRR Part 373 Hazardous Waste Management - Model City Facility Draft Permit, DEC No. 9-2934-00022/00097, EPA ID No. NYD049836679, available at < http://www.dec.ny.gov/chemical/49051.html >.

O'Hara S.K., B.L. Parker, P.R. Jorgensen, and J.A. Cherry (2000). Trichloroethene DNAPL Flow and Mass Distribution in Naturally Fractures Clay: Evidence of Aperture Variability, *in* Water Resources Research, Vol. 36, No. 1, 135-147.

O'Neill, J.E and J. Mayes (2000). *Remediation of Smithville, Canada, PCB Spill Site,* in Wickramanayake et. al, eds., Treating Dense Non-Aqueous Phase Liquids (DNAPLs): Remediation of Chlorinated and Recalcitrant Compounds (Battelle 2000).

Pankow, J.F. and J.A. Cherry)1996). Dense Chlorinated Solvents and Other DNAPLs in Groundwater (Waterloo Press 1996).

Ruland W.W., J.A. Cherry, and Stan Fenstra (1991). The Depth of Fractures and Active Ground-Water Flow in a Clayey Till Plain in Southwestern Ontario.

Smith, N.D. and R.A. Freeze (1979). Stochastic Analysis of Steady State Ground-Water Flow in a Bounded Domain; 2, Two-Dimensional Simulations. Water Resources Research v. 15(6), 1543-1559.

Stephenson, D.A., A.H. Fleming, and D.M. Mickelsos (1988). The Hydrogeology of Glacial Deposits. The Geology of America, vol. O-2 Hydrogeology, Geological Society of America.

USACE (2007). Groundwater Flow and Contaminant Transport Modeling, Niagara Falls Storage Site, Lewiston, New York, *prepared by HGL in* December 2007.

USACE (2007a). Remedial Investigation Report for the Niagara Falls Storage Site, December 2007; available at <http://www.lrb.usace.army.mil/Missions/HTRW/FUSRAP/NiagaraFallsStorageSite.aspx>.

Wehran Engineering Corp. (1977). Hydrogeologic Investigation, ChemTrol Pollution Services, Townships of Porter and Lewiston, Niagara County, New York, October 14, 1977.

EXHIBITS

Dr. Michalski's Exhibits are found in Part 4 of OHMS Document No. 201469232-00112