

## APPENDIX A

### REFERENCES INSERTED INTO THE RECORD AT PUBLIC COMMENT ON WEST BAY #22 AT COLOMBIA ELEMENTARY SCHOOL ON NOVEMBER 20, 2014

Reference #1: Bell; Cripps; Culshaw, *Groundwater in Engineering Geology*, London (1986) A REVIEW OF THE ENGINEERING BEHAVIOR OF SOILS AND ROCKS WITH RESPECT TO GROUNDWATER - shows that the reliance of Region 5 on the Hydrogeologic Atlas of Michigan is misplaced since permeability estimates cannot be applied to rocks like anhydrite and salt which are susceptible to solution. It also shows that massive anhydrite, which the EPA claims to be impermeable "can be dissolved to produce uncontrollable runaway situations in which seepage flow rates increase in a rapidly accelerating manner." The study claims "the solution rate of gypsum or anhydrite is principally controlled by the area of their surface in contact with water and the flow velocity associated with a unit area of the material." The study also notes that "salt is even more soluble than gypsum..."

Reference # 2: Conley; Bundy, *Geochimica et Cosmochimica Acta*, v. 15 (1958) – MECHANISM OF GYPSIFICATION – shows that the hydration process of anhydrite to gypsum is accelerated in the presence of certain salts, like those contained in the brine that West Bay will be injecting in the Salina formation.

Reference #3: EPA draft investigation on groundwater contamination near Pavillion, Wyoming (EPA 600/R-00/000 December 2011) which concludes "that constituents associated with hydraulic fracturing have been released into the Wind River drinking water aquifer at depths above the current production zone." This proves that the EPA knows injected fluids can migrate upwards and that they have previously made mistakes with regard to impermeability of rock formations when issuing permits.

Reference #4: EPA draft report document on Pavillion which reiterates the draft investigation findings that "the explanation best fitting the data for the deep monitoring wells is that constituents associated with hydraulic fracturing have been released into the Wind River drinking water aquifer at depths above the current production zone."

Reference #5: EPA Permit # MI-163-3G-A002 for the Sunoco Inkster Facility, issued on June 14, 2006. This permit authorized the dissolution of the B-Salt, F-salt, and Anhydrite layers of the Salina Group for the purpose of creating a gas storage cavern. The EPA knows that the Salina Group will dissolve in solution.

Reference #6: Hardie, *The American Mineralogist*, Vol. 52, (January-February 1967) – THE GYPSUM-ANHYDRITE EQUILIBRIUM AT ONE ATMOSPHERE PRESSURE references that gypsum has replaced anhydrite at a depth as great as 3500 feet and gives formula for the chemical reactions.

Reference #7: James; Edworthy, *Hydrological Sciences, Journal*, 30, 3, (September 1985) – THE EFFECTS OF WATER INTERACTIONS ON ENGINEERING STRUCTURES gives formula for the dissolution of soluble rocks.

Reference #8: Jaworski, *InTech: Advances in Crystallization Processes*, (April 2012), - CRYSTALLIZATION, ALTERATION AND RECRYSTALLIZATION OF SULPHATES states that the hydration of buried anhydrite can occur very quickly, within a few years or even within one year and describes the hydration process in some detail.

Reference #9: Klimchouk, *International Journal of Speleology*, 25, (1996) - THE DISSOLUTION AND CONVERSION OF GYPSUM AND ANHYDRITE. Shows that the solubility of anhydrite increases sharply with pressure: each 0.01 Pa increase in pressure results in a 3 to 5 times increase in solubility.

Reference #10: Kreitler, *Journal of Hydrology*, 106 (1989) – HYDROGEOLOGY OF SEDIMENTARY BASINS. This study deals specifically with sedimentary basins in Texas but draws some significant conclusions about hydraulic properties of sedimentary basins and suggests that cross-formational flow or flow through low permeability rocks must be considered an essential element in describing fluid flow in sedimentary basins.

Reference #11: Middleton; WHAT LIES BENEATH: THE THREAT FROM OILFIELD WASTE INJECTION WELLS, published May 18, 2006. Details the complaints to the Texas Railroad Commission of groundwater contamination in Texas because of oil waste injection wells.

Reference #12: Murray, *Journal of Sedimentary Petrology*, Vol. 34, No. 3 (September 1964) – ORIGIN AND DIAGENESIS OF GYPSUM AND ANHYDRITE. Notes that while the conversion of anhydrite usually takes place near the surface, it has been observed as deep as 3500 feet in the Permian San Andrea formation.

Reference #13: Myers, *Ground Water*, (April 2012) POTENTIAL CONTAMINANT PATHWAYS FROM HYDRAULICALLY FRACTURED SHALE TO AQUIFERS. Shows that brines existing more than a 1000 meters above their source is evidence of upward movement from depth to surface and shows that the injection at pressure can cause contaminants to reach overlying formations by simple displacement of fluids from shale into the overburden and claims that advective transport (considered as simple particle velocity) will manifest if there is a significant vertical component to the regional hydraulic gradient.

Reference #14: Rauh; Thuro, *Engineering Geology*, Technische Universitat Munchen, Germany (2006), INVESTIGATIONS ON THE SWELLING BEHAVIOR OF PURE ANHYDRITES. Gives rates of dissolution for different anhydrites.

Reference #15: Sass; Burbaum, *ACTA Carsologica* 39/2 Postonjna (2010) – DAMAGE TO THE HISTORIC TOWN OF STAUFEN (GERMANY) CAUSED BY GEOTHERMAL FRILLINGS THROUGH ANHYDRITE-BEARING FORMATIONS) shows that the introduction of water to an anhydrite formation for a borehole heat exchange installation caused surface upheaval from the resultant swelling. The depth of the anhydrite was less than 200 meters.

Reference #16: Singh, *Amer. Ceram. Soc. Vol. 88* (January 2005) - EFFECT OF ACTIVATOR K<sub>2</sub>SO<sub>4</sub> ON THE HYDRATION OF ANHYDRITE OF GYPSUM (CASO<sub>4</sub>.II) documents the effect of K<sub>2</sub>SO<sub>4</sub> on the hydration of anhydrite.

Reference #17: Steiner, *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*, 30, 4, (1993) – SWELLING ROCK IN TUNNELS – Concludes that *in situ* swelling pressures in anhydrite or anhydritic shale's indicate maximum values of 2.5 MPa and mean values between 1.6 and 2.0 MPa.

Reference #18: Suthersan, CRC Press LLC, (1999) HYDRAULIC AND PNEUMATIC FRACTURING Describes the effect of injected pressure on rocks and notes that fracturing can begin at pressures less than 100psi.

Reference #19: Warner; Jackson; Darrah; Osborn; Down; Zhao; White; Vengosh. *Proceedings of the National Academy of Sciences*, (May 2012) GEOCHEMICAL EVIDENCE FOR POSSIBLE NATURAL MIGRATION OF MARCELLUS FORMATION BRINE TO SHALLOW AQUIFERS IN PENNSYLVANIA. Describes the evidence for upward cross formational flow of Marcellus formation brine into shallow aquifers.

Reference #20: Weaver; Frape; Cherry, *Geol. Soc. Am. Bull.* 107 (1995) – RECENT CROSS-FORMATIONAL FLUID FLOW AND MIXING IN THE SHALLOW MICHIGAN BASIN – This study documents upward migration of saline fluid into the overlying glacial sediments during the historic period since petroleum production began. The fracture intensification and increased permeability of the near surface layers above 1000 feet has been interpreted to reflect isostatic rebound following the retreat of the glaciers. The study area was on the edge of the Michigan basin in Ontario but the authors note a correlation with the Detroit River Group in central Michigan.

Reference #21: Wikipedia: Anhydrite. States the accepted scientific conclusion taught in geology classes. Anhydrite converts to gypsum upon absorption of water.

Reference #22: Wikipedia: Benzene, Ethylbenzene, Toluene, Xylene, Naphthalene, & Polycyclic Aromatic Hydrocarbons. I took the list of oilfield brine chemical constituents from the EPA website and looked up the health effects of each one on Wikipedia.

Reference #23: Zen, *Journal of Petrology*, Vol. 6, Part 1, (1965) – SOLUBILITY MEASUREMENTS IN THE SYSTEM  $\text{CaSO}_4\text{-NaCl-H}_2\text{O}$  at 35, 50, & 70 degrees C and ONE ATMOSPHERE PRESSURE. Gives formula for the conversion of anhydrite to gypsum and notes that anhydrite converts under conditions where it was presumed to be stable.