MnROAD High Carbon Fly Ash Research Project

Annual Report Submitted to Minnesota Pollution Control Agency

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I. Project Goal & Scope

The goal of this research project is to study a road base at the Minnesota Road Research Facility (MnROAD) constructed with high carbon fly ash for long term monitoring of engineering and environmental characteristics. This study will provide a controlled long term evaluation of pavement base materials stabilized with High Carbon Fly Ash (HCFA). Engineering laboratory testing has shown HCFA to be a viable stabilizing material. Field construction of road test segments is necessary to validate the structural and environmental performance of high carbon fly ash stabilized bases.

This report concerns the results of ongoing environmental chemical analysis of leachate collected from test cells using off-classification HCFA as a stabilizer of road base materials under an asphalt wearing course. This research opportunity is a portion of Phase II of a fly ash stabilization project performed by Bloom Consultants, LLC and is sponsored by the Department of Energy (DOE). The University of Wisconsin-Madison (UW) is a subcontractor of Bloom Consultants and is conducting ongoing evaluations as the project proceeds. Phase II is titled *Use of High Carbon Fly Ash to Stabilize Recycled Pavement as Base Course*, has a two-year time requirement, and will involve the proposed MnROAD test sections to be constructed in 2007.

II. Physical Description of MnROAD Facility

The MnROAD facility is located in east-central Minnesota adjacent to Interstate 94 between Albertville and Monticello, Minnesota; northwest of the Minneapolis/St. Paul metropolitan area. MnROAD is a cold-region testing laboratory unique in concept, design, and function. MnROAD is located approximately 2.5 miles south of the Mississippi River.

III. Characterization of High Carbon Fly Ash Used for MnROAD Construction

The fly ash used for construction was produced by the combustion of coal at the Riverside #8 electric power plant. Riverside is the oldest coal-fired power plant in the

Xcel Energy power generation system. Fly ash from the Riverside 8 plant is high calcium high carbon cementitious ash. Results of a 2006 characterization of the ash are included as Table 1.

Table 1: 2006 Elemental analysis of Riverside 8 fly ash

DESCRIPTION	METHOD	2006 MEAN	2006 STDEV	2006 COV, %	MPCA PROPOSED MDL
Moisture, AR	FL-03	0.4 %	0.1 %	21.7	
LOI, Dry Basis	ASTM 4638-86	14.6 % LOI	4.8 % LOI	32.8	
Aluminum	EPA 200.7	66113 mg/kg	3755 mg/kg	5.7	1000 mg/kg
Antimony	EPA 200.8	3.3	0.4	11.6	0.1
Arsenic	EPA 200.8	23.5	2.6	11.3	1
Barium	EPA 200.7	2644	651.4	24.6	1
Beryllium	EPA 200.7	5.3	0.5	9.5	0.1
Boron	EPA 200.7	780.5	69.0	8.8	1
Cadmium	EPA 200.8	5.4	0.6	11.0	0.1
Calcium	EPA 200.7	123931	73677	59.4	1
Chromium	EPA 200.7	70.8	7.6	10.8	1
Cobalt	EPA 200.7	28.0	3.9	14.0	1
Copper	EPA 200.7	228	20.4	9.0	1
Iron	EPA 200.7	36460	2398	6.6	1000
Lead	EPA 200.8	62.5	5.3	8.4	1
Magnesium	EPA 200.7	28718	1798	6.3	1
Manganese	EPA 200.7	123	3.2	2.6	1
Mercury	EPA 7473	0.8	0.2	25.4	0.1
Molybdenum	EPA 200.8	136	20.6	15.2	1
Nickel	EPA 200.8	621	93.2	15.0	1
Phosphorus	EPA 200.7	4849	783	16.2	-
Potassium	EPA 200.7	2589	163.3	6.3	100
Selenium	EPA 200.8	16.1	1.4	8.4	1
Silicon	EPA 200.7	6732	258.3	3.8	-
Silver	EPA 200.8	0.4	0.3	78.5	0.1
Sodium	EPA 200.7	14941	2929	19.6	1000
Strontium	EPA 200.7	-	-	-	100
Sulfate		-	-	-	1
Sulfur	EPA 200.7	41128	5099	12.4	1000
Thallium	EPA 200.8	1.1	0.5	45.2	0.01
Tin	EPA 200.7	-	-	-	0.1
Titanium	EPA 200.7	-	-	-	100
Vanadium	EPA 200.7	1397	178.4	12.8	1
Zinc	EPA 200.7	130	25.5	19.6	1
Soil pH	9045	10.8	0.2	1.9	

VI. Test Cell Construction

Three test cells were constructed at the MnROAD facility. One HCFA test cell was constructed with a base course composed of cold in-place recycled paving and base material (RPM) mixed with 14% (by mass) HCFA using a CAT Pavement Reclaiming Machine. This material will hereby be referred to as RPM/FA. RPM is produced by crushing and mixing road asphalt layer and several inches of the underlying base course for use as a new base course or sub-base material. The RPM used in this project contains asphalt and crushed granite sand/gravel, and was reclaimed from the MnROAD facility. Additionally, two control cells were constructed; one with a base course of RPM with no HCFA, and the second with a base course of MNDOT Class 6 crushed stone aggregate (CA).

The base courses of the three test cells were graded and compacted beginning August 7, 2007. The base course of the RPM/FA was covered and allowed to harden for one week. Paving was to commence in early September 2007, however due to heavy rains in late August, only the RPM/FA cell was firm enough to be paved. The RPM base course and the CA base course failed under the weight of paving equipment. MnROAD officials decided to let the subgrade and base dry *in situ,* but after about ten days there was no significant improvement in the stability of the RPM and CA cells. In late September MnROAD removed the base course material from the CA and RPM cells, which was then spread to dry. The subgrade clay was recompacted, and in early October the CA and RPM base courses were recompacted, and paved with an asphalt wearing course

During construction of the three test cells, lysimeters were installed immediately underneath the study sections of base course. Each lysimeter consists of a 1.5-mm-thick low-density polyethylene (LDPE) geomembrane sheet formed into a drainage basin with dimensions of approximately 13 ft. by 13 ft. Each basin drains to the center of the lysimeter, where it is connected via sealed pipes to buried high-density polyethylene (HDPE) collection tanks located adjacent to the roadway. The lysimeter basins were overlain by a geocomposite drainage layer (geonet sandwiched between two non-woven geotextiles), and the base courses were constructed directly on top of this drainage layer. Each lysimeter collects the leachate that drains through the road surface (hot mix asphalt, HMA), and through the base course. A profile drawing of the cell design is included as Figure 1. The installation of lysimeters and fly ash placement are shown in Figures 2 and

3. The asphalt layers on the fly ash section was placed on September 11, 2008 and asphalt layers on RPM and Crushed Aggregates sections were finished on Oct 25, 2008.

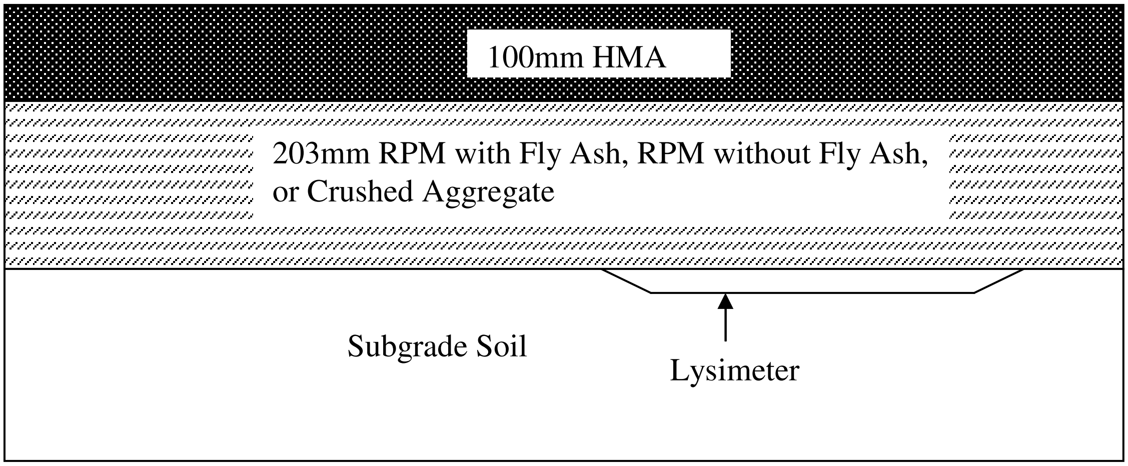

Figure 1: Profile of Test Cell, As Designed

Figure 2. Installation of Lysimeter

Figure 3. Placement and Mixing of Fly Ash

V. Leachate Collection and Sampling

Leachate has been regularly pumped by submersible pump from the lysimeter tanks, and the volumes emptied have been recorded. Periodic sampling of leachate for chemical analysis has also been conducted. Leachate samples were collected by UW students and MnROAD staff using a submersible pump, which was decontaminated by pumping approximately four gallons of tap water through the apparatus before and after each individual sample. Samples were collected in HDPE bottles, and preserved with nitric acid when necessary.

Some samples were analyzed by the UW Soil & Plant Laboratory (SPL). These were analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for twenty-nine (29) elements including nutrient cations and minerals, as well as heavy metals. Also SPL analyzed these samples for six anions using Ion Chromatography. Samples for these elements were collected four times beginning September 11, 2007, and last sampled March 19, 2008. Additional sampling is scheduled to occur quarterly, at least through 2008, with the next sampling event scheduled for July 2008. It should be noted that the first two sampling events occurred prior to the final paving of the two control sections (RPM and CA base courses). The first event occurred after the RPM and CA base courses were originally compacted, and the second occurred after the base courses were excavated, dried, and re-compacted in early October 2008.

Samples were also collected twice for mercury (Hg) analysis in March and April 2008. Regulatory limits are very low for Hg, and background levels are high enough to make contamination likely and significant using traditional water sampling methods. A more stringent method (US EPA Method 1631, Revision E) for Hg was used to minimize the likelihood of contamination of samples. All sampling equipment that contacted the liquid samples was acid cleaned, dried, and double bagged by the Wisconsin State Laboratory of Hygiene (WSLH). Samples were collected by two persons using a "clean-hands, dirty hands" method (adapted from EPA 1669), where one person, "clean-hands", only touches the sample bottles. All other handling of equipment was conducted by the "dirty-hands" person. These samples were collected on March 19 and April 16 2008. Chemical analysis was conducted by WSLH according to US EPA Method 1631.

VI. Analytical Results

Pore Volumes of flow through base course layers were calculated from volumes of leachate collected and by calculating approximate pore volume of the layer using material properties, and construction compaction data. Analytical results of chemical concentration vs. pore volume of flow for the thirty-six (36) elements or compounds that were tested are presented as Figures 4.1 through 4.36, with method detection limit and the Minnesota Department of Health (MDH) Drinking Water Maximum Contaminant Level (MCL) or Health Risk Limit (HRL), if one exists and whichever is lowest. Concentration levels that are below method detection limits are graphed as being at the detection limit.

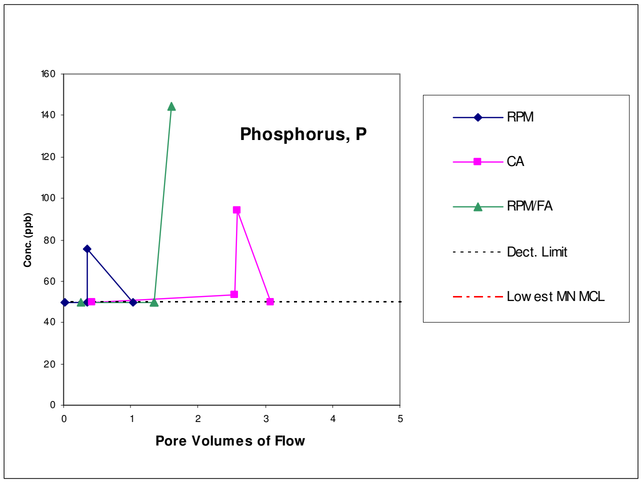

Figure 4.1 – P Concentration vs Pore Volume of Flow

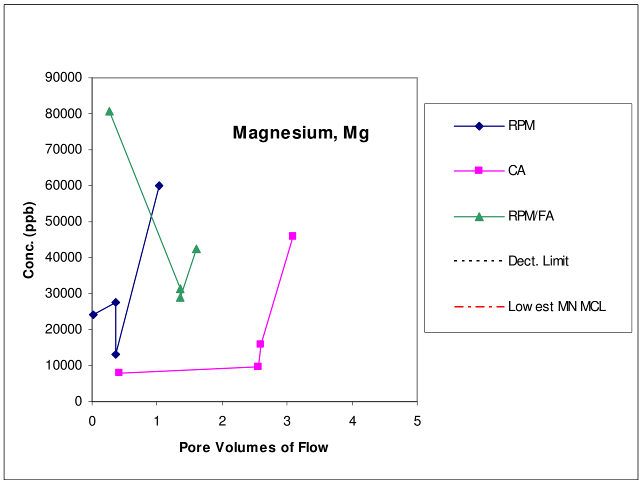

Figure 4.2 – Mg Concentration vs Pore Volume of Flow

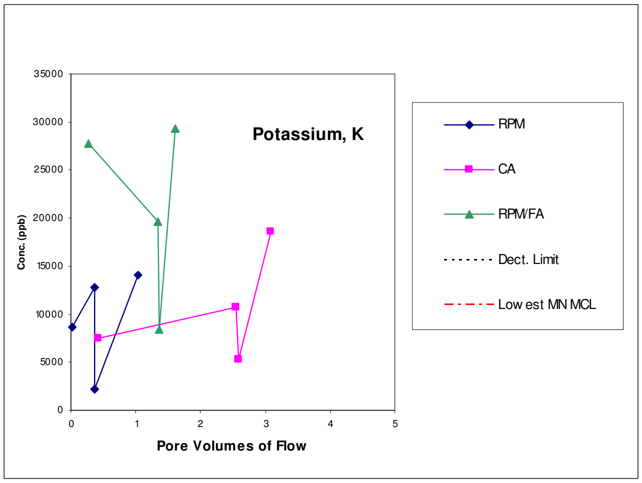

Figure 4.3 – K Concentration vs Pore Volume of Flow

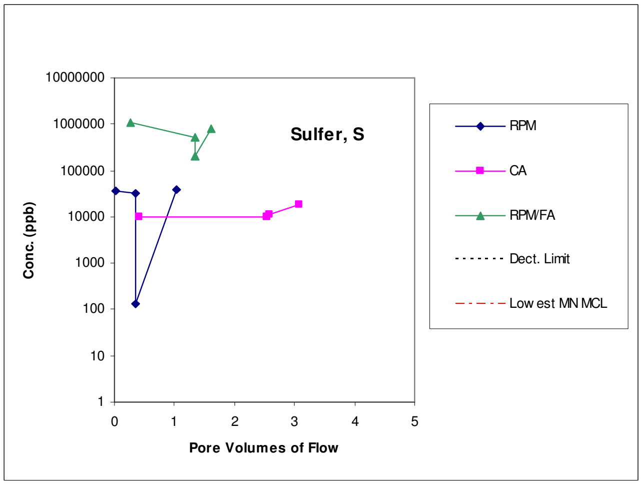

Figure 4.4 – S Concentration vs Pore Volume of Flow

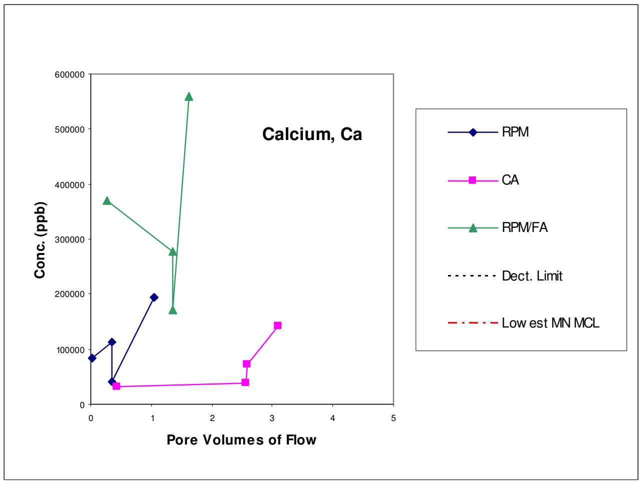

Figure 4.5– Ca Concentration vs Pore Volume of Flow

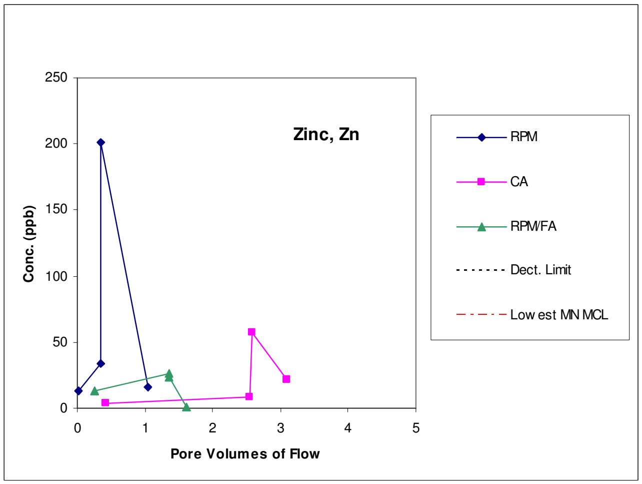

Figure 4.6 – Zn Concentration vs Pore Volume of Flow

Figures 4.1 - 4.6: Dissolved Minerals and Metals

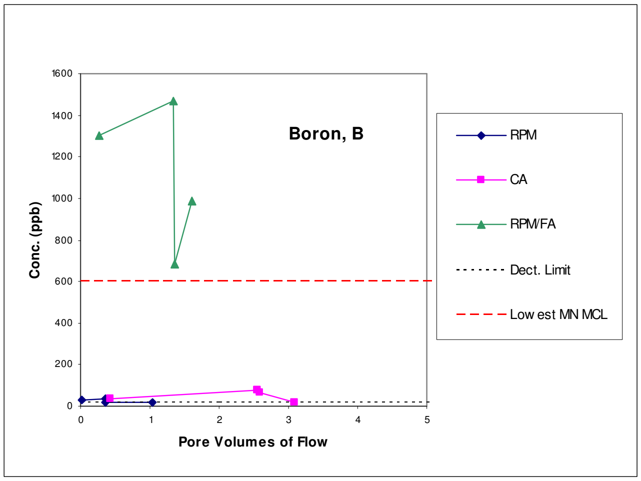

Figure 4.7 – B Concentration vs Pore Volume of Flow

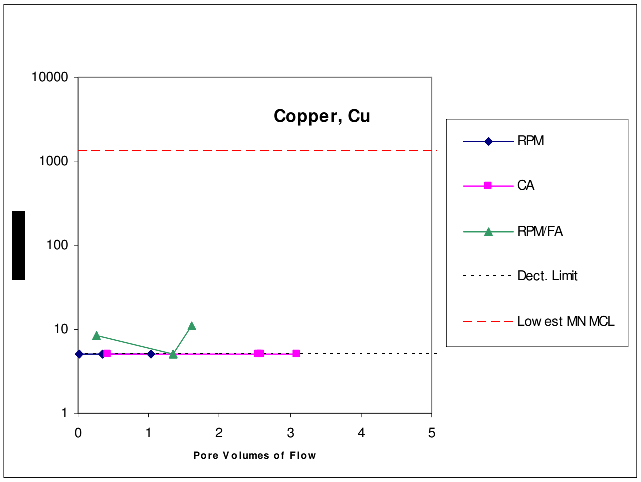

Figure 4.8 – Cu Concentration vs Pore Volume of Flow

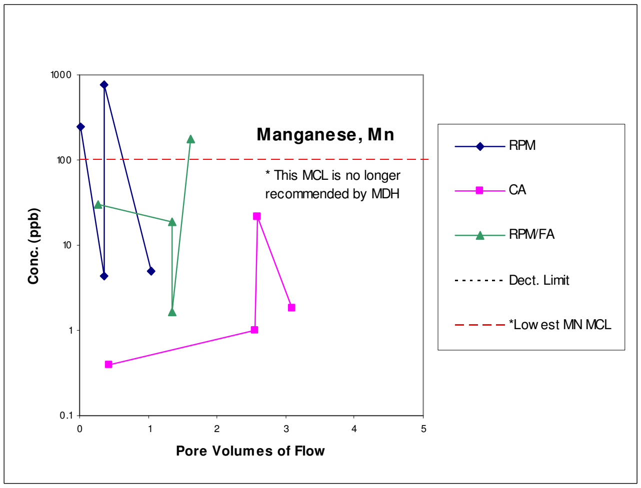

Figure 4.9 – Mn Concentration vs Pore Volume of Flow

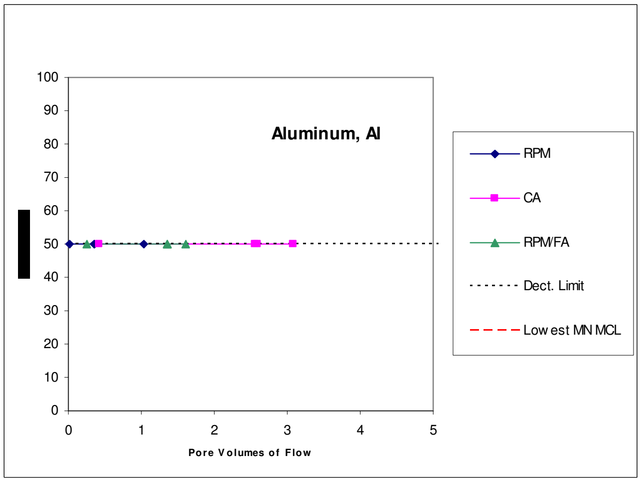

Figure 4.10 – Al Concentration vs Pore Volume of Flow

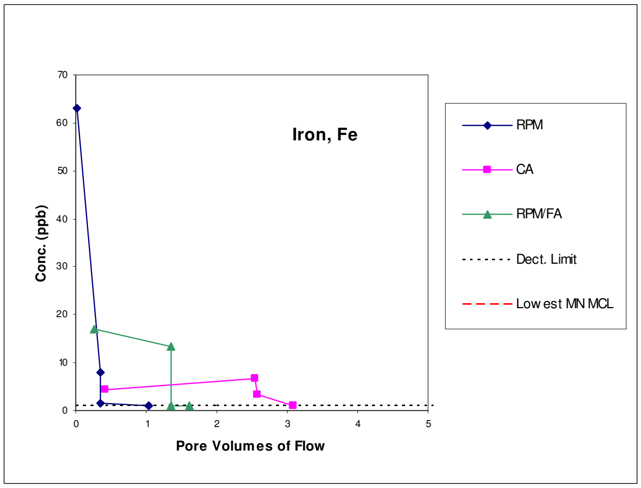

Figure 4.11 – Fe Concentration vs Pore Volume of Flow

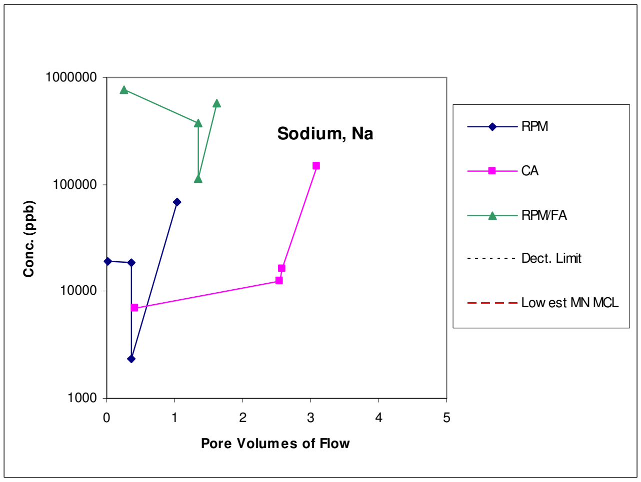

Figure 4.12 – Na Concentration vs Pore Volume of Flow

Figures 4.7 - 4.12: Dissolved Minerals and Metals

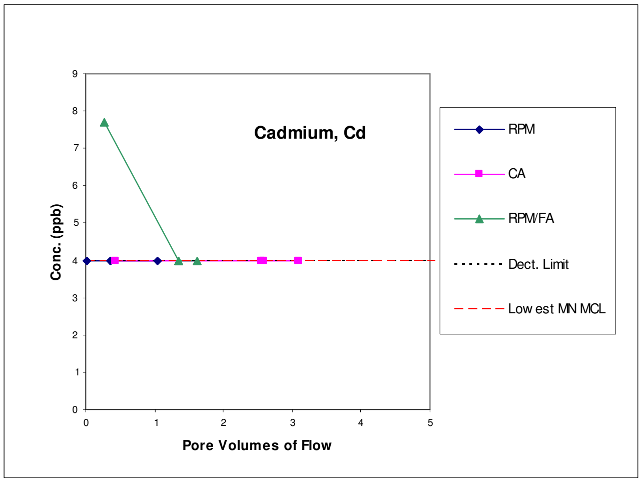

Figure 4.13 – Cd Concentration vs Pore Volume of Flow

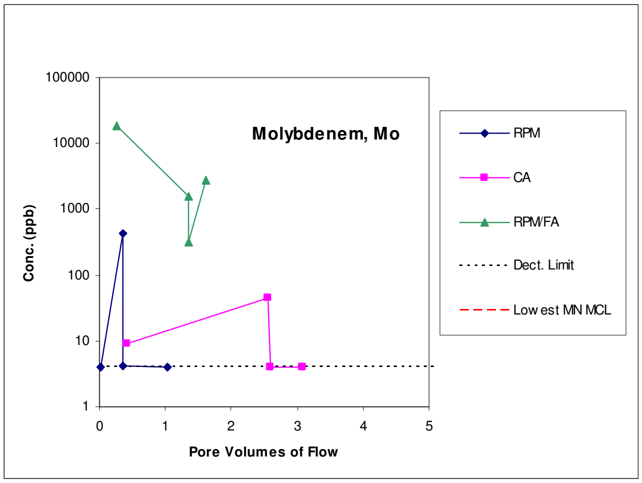

Figure 4.14 – Mo Concentration vs Pore Volume of

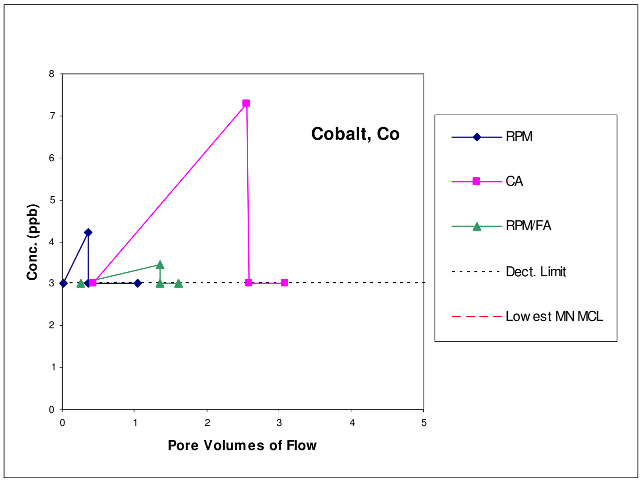

Figure 4.15 – Co Concentration vs Pore Volume of Flow

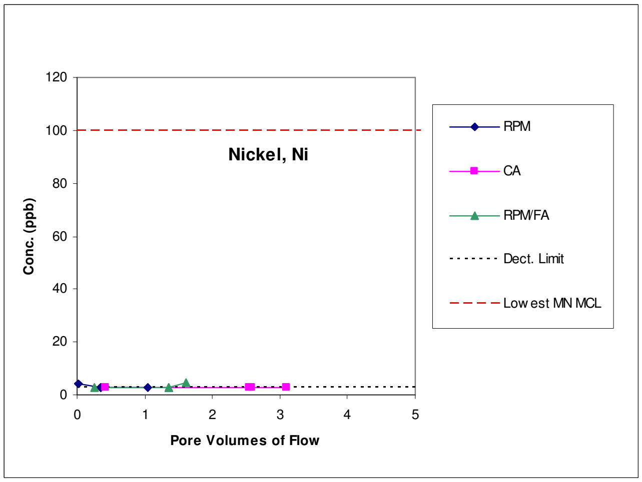

Figure 4.16 – Ni Concentration vs Pore Volume of Flow

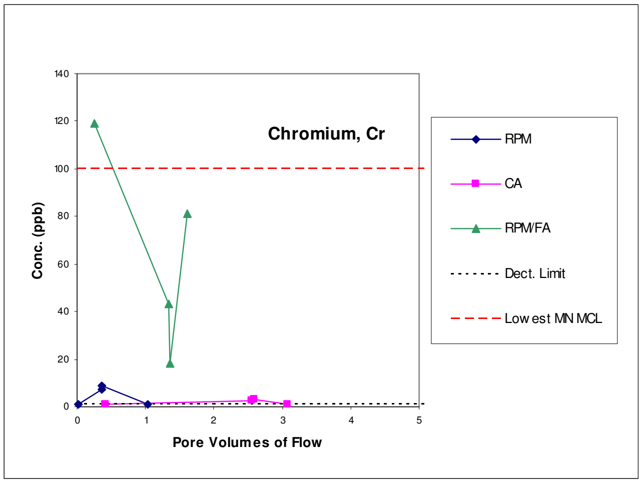

Figure 4.17 – Cr Concentration vs Pore Volume of Flow

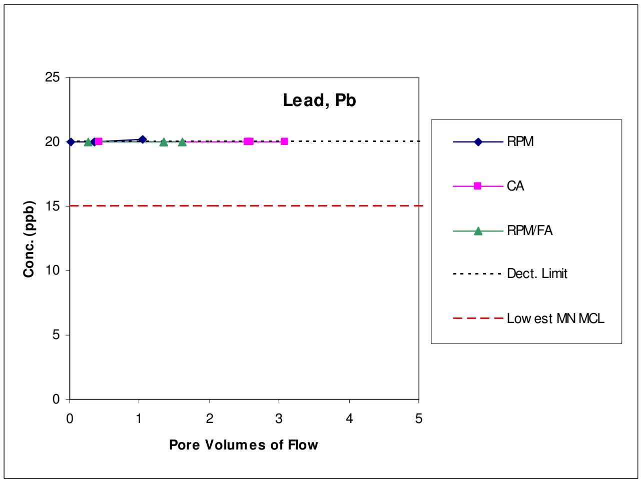

Figure 4.18 – Pb Concentration vs Pore Volume of Flow

Figures 4.13 - 4.18: Dissolved Heavy Metals

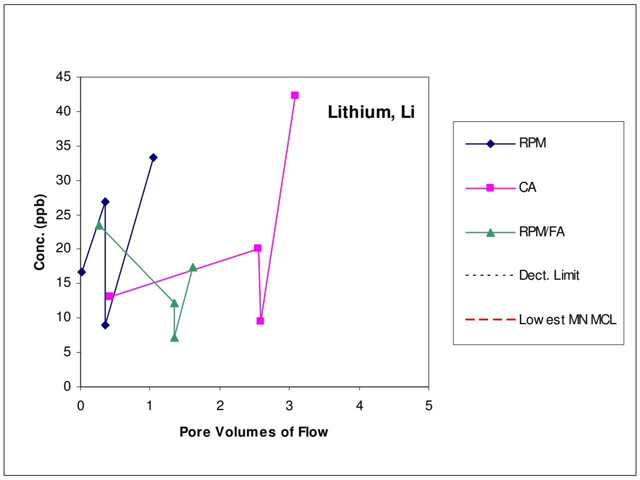

Figure 4.19 – Li Concentration vs Pore Volume of Flow

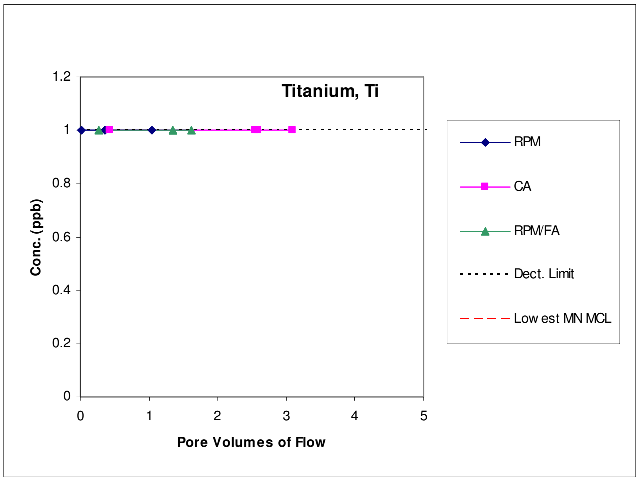

Figure 4.20 – Ti Concentration vs Pore Volume of Flow

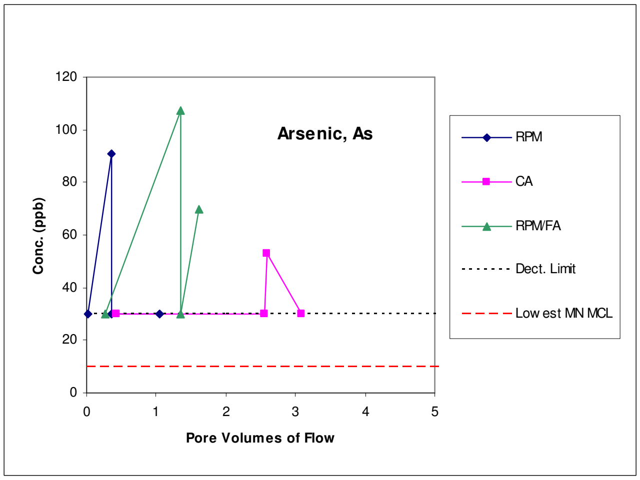

Figure 4.21 – As Concentration vs Pore Volume of Flow

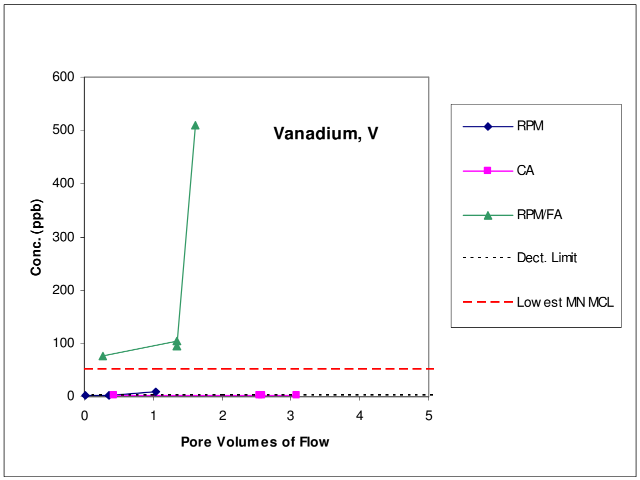

Figure 4.22 – V Concentration vs Pore Volume of Flow

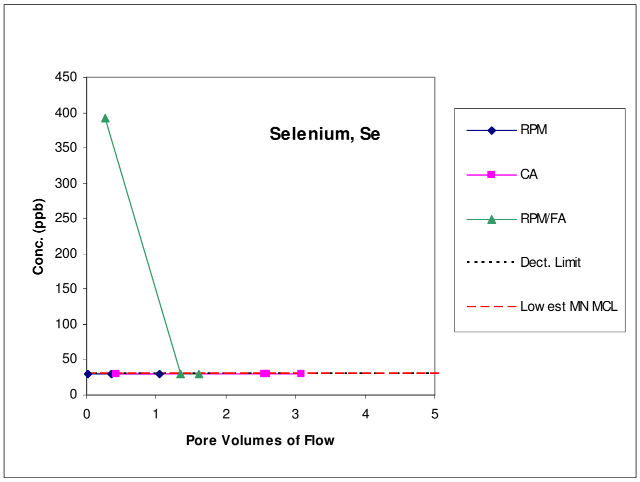

Figure 4.23 – Se Concentration vs Pore Volume of Flow

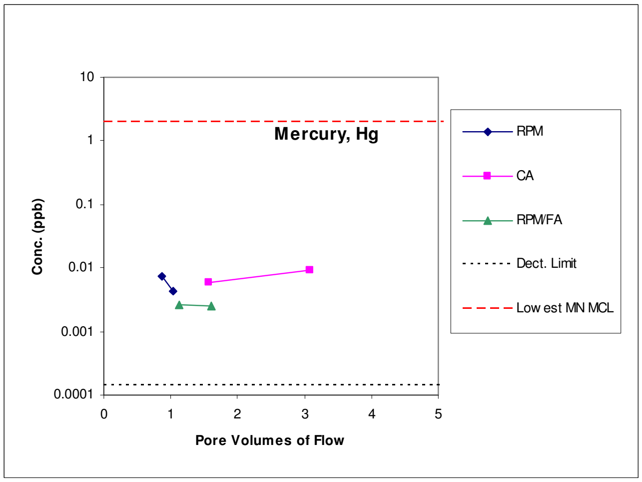

Figure 4.24 – Hg Concentration vs Pore Volume of Flow

Figures 4.19 - 4.24: Dissolved Heavy Metals

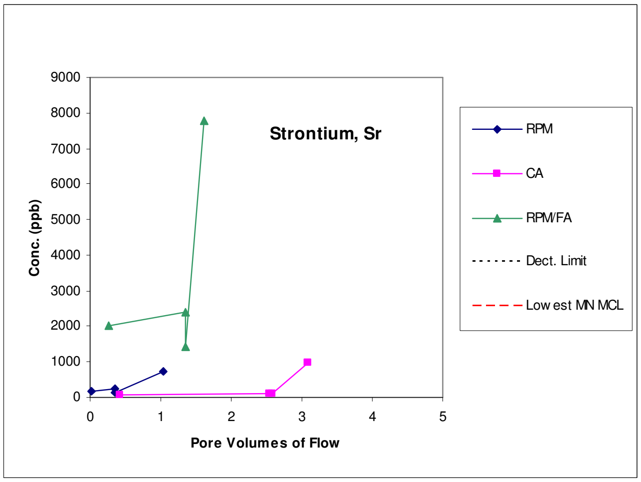

Figure 4.25 – Sr Concentration vs Pore Volume of Flow

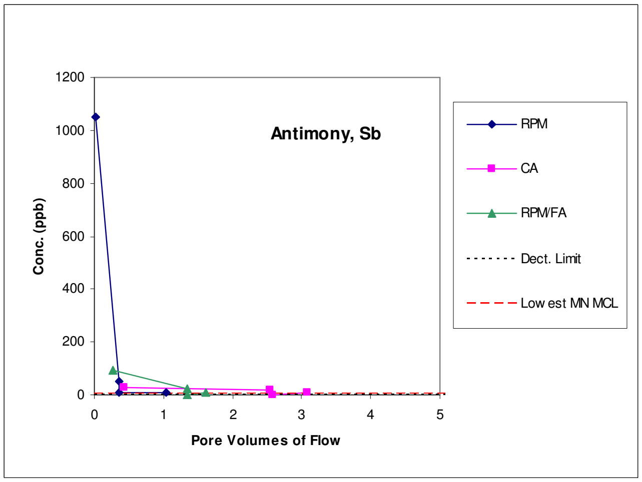

Figure 4.26 – Sb Concentration vs Pore Volume of Flow

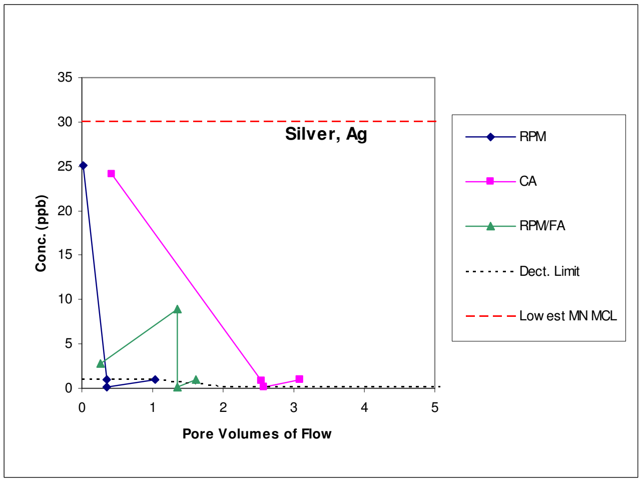

Figure 4.27 – Ag Concentration vs Pore Volume of Flow

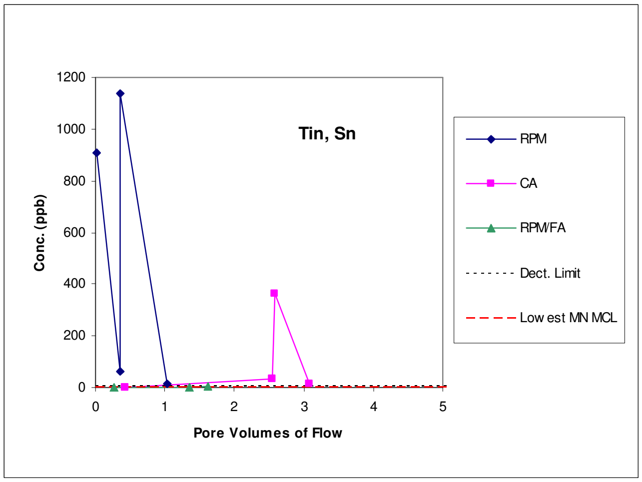

Figure 4.28 – Li Concentration vs Pore Volume of Flow

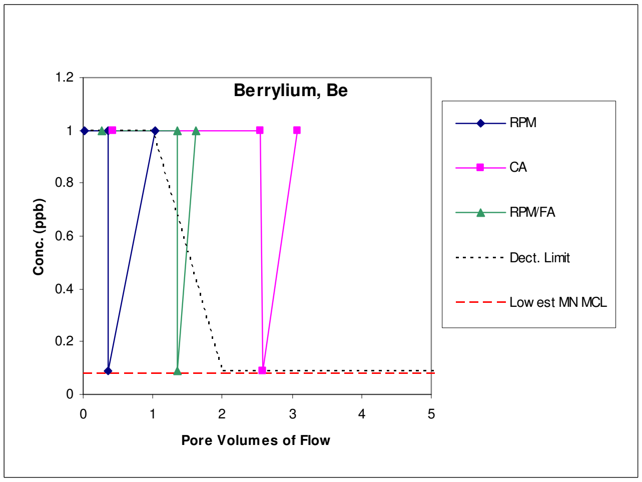

Figure 4.29 – Be Concentration vs Pore Volume of Flow

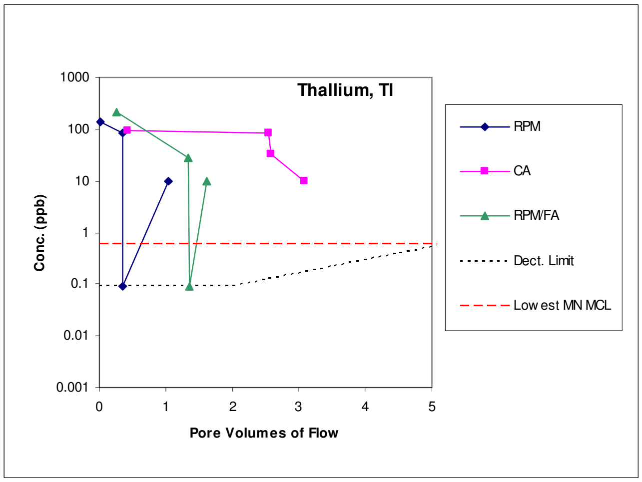

Figure 4.30 – Tl Concentration vs Pore Volume of Flow

Figures 4.25 - 4.30: Dissolved Heavy Metals

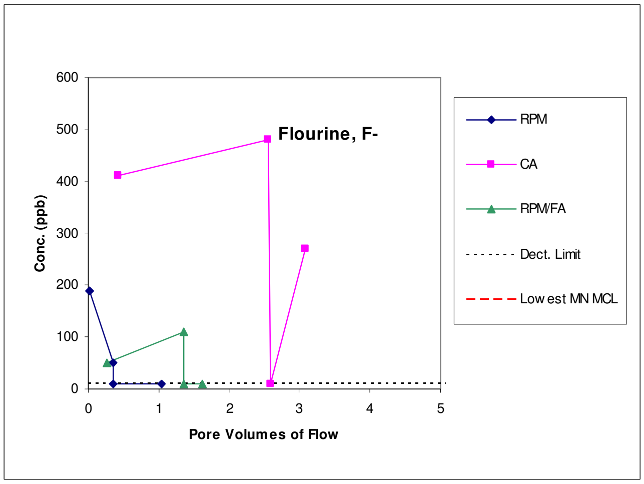

Figure 4.31 – F$^-$ Concentration vs Pore Volume of Flow

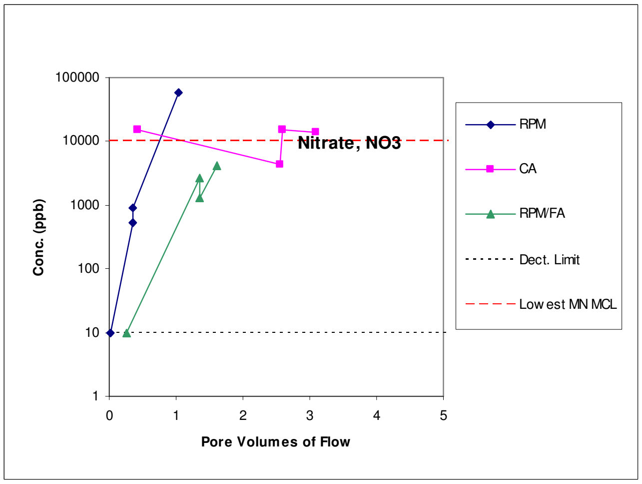

Figure 4.32 – NO$_3^-$ Concentration vs Pore Volume of

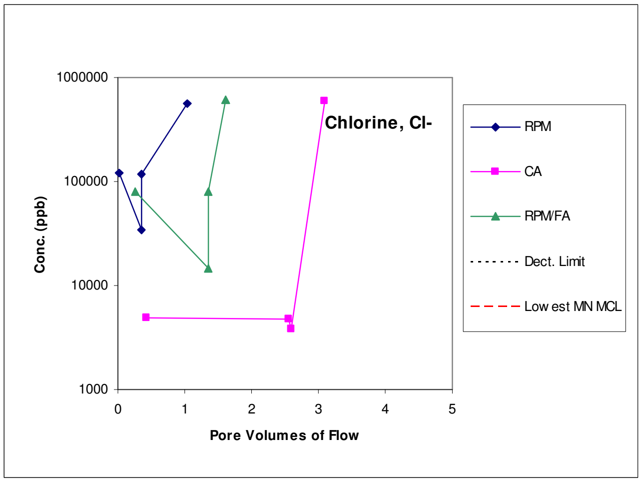

Figure 4.33 – Cl$^-$ Concentration vs Pore Volume of Flow

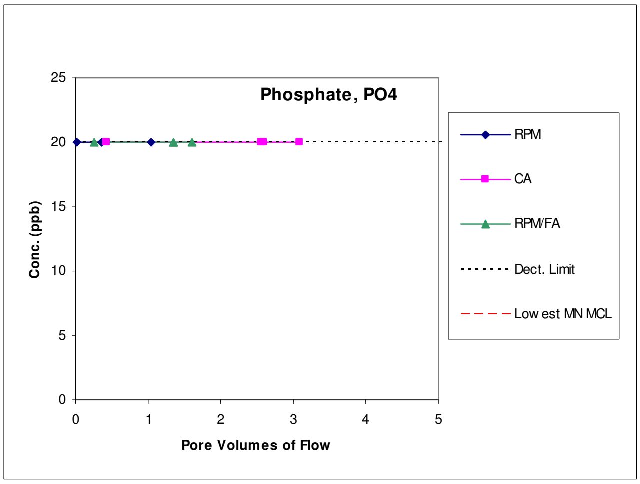

Figure 4.34 – PO$_4^{3-}$ Concentration vs Pore Volume of

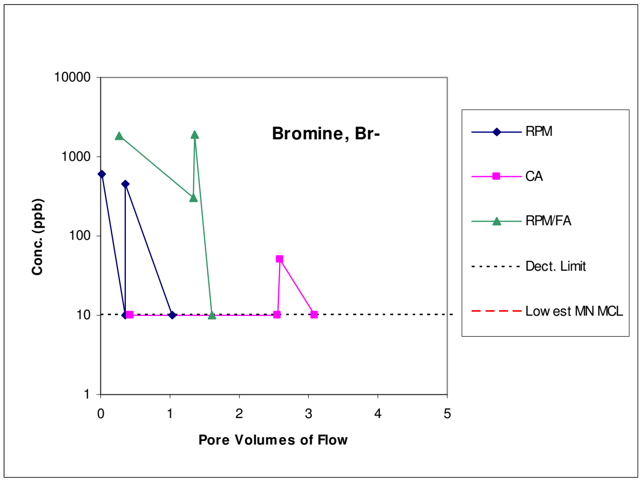

Figure 4.35 – Br$^-$ Concentration vs Pore Volume of Flow

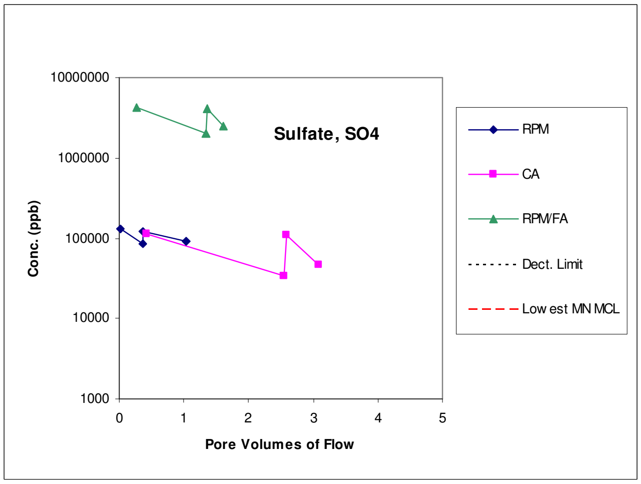

Figure 4.36 – SO$_4^{2-}$ Concentration vs Pore Volume of

Figures 4.25 - 4.30: Dissolved Anions