Moment Analysis of the Bromide Data

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Introduction

A potassium bromide tracer was injected in the third pulse. The target concentration was 1000 mg/l and a total of 4 kg of tracer was used. The bromide is used as a tracer for water and it can be compared to the deuterium that was injected at the same time.

Two boreholes, S2 and S3, were drilled, and the core samples were analyzed for bromide. S2 was drilled 21 days after the bromide injection and S3 was drilled 25 days after the injection. Additional pulses of water were added to the site after the bromide injection. The process involved leaching the samples with deionized water and measuring the solution for bromide using an ion specific probe. The concentrations along the two boreholes represent a point in the experimental site for two different sampling times following the tracer injection.

One approach to analyze the data is to use the method of moments techniques to provide some basic information about the movement of the tracer. This report presents the results of the moments analysis for the bromide concentrations from S2 and S3.

Moment analysis

The data as collected were two snapshots in time, so only the spatial moments were analyzed. The approach was taken from Freyberg (1986).

The moment of a concentration distribution is defined as

$$M_{ijk}(t) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \theta(x,y,z,t)C(x,y,z,t)x^i y^j z^k \, dxdydz \qquad (1)$$

where θ(x,y,z,t) is the volumetric water content and C (x,y,z,t) is the concentration of the tracer. The two boreholes and sampling in the vertical or z direction meant that the only moments that were derived were M_{000}, M_{001}, and M_{002}. The zero moment M_{000} is the mass of tracer at the location. Bromide is a conservative tracer so the mass in the plume will remain constant over time, but the sampling in this experiment did not sample the entire plume. The first moment, M_{001} normalized by the mass defines the coordinate for the center of mass in the z direction. The spread of the tracer in the vertical direction is obtained by the following equation

$$\sigma_{zz} = \frac{M_{002}}{M_{000}} - z_c^2 \qquad (2)$$

where σ_{zz} is the spread of tracer in the z direction and z_c is the center of mass in the z direction.

The moments were estimated for each borehole using a simple trapezoidal integration.

Gravimetric water contents were provided for some of the samples. A bulk density of 1.7 g/cm^3 was used to estimate the volumetric water content for those samples. For samples where no water content was available, linear interpolation was used to estimate the volumetric water content for the sample.

The diameter of the core was 15 cm so the volume represented by each sample was a cylinder whose area was defined by a circle with a diameter of 15 cm and length by the sampling interval of the core.

Results

Bromide concentrations for S2 and S3 are presented in Figures 1 and 2, respectively. The concentrations in S3 are higher than S2 (Figure 2). Also, some stratigraphy is included on both figures to relate concentrations with locations of finer alluvial material.

The z_c and σ_{zz} are for both holes are given in Table 1. Note that values appear to be consistent for both holes. The center of mass (z_c) appears to be located above a fine textured layer and it has not been determined if the difference in z_c between S2 and S3 is due to vertical movement of the tracer or the dip in the fine textured layer. The spread about the z_c between the boreholes is consistent.

Table 1. Center of mass and spread for bromide from boreholes S2 and S3 from the FY00 Vadose Zone Field Test at Hanford.

Borehole	z_c	σ_{zz}
	(m)	(m^2)
S2	10.2	2.7
S3	10.5	2.1

Using the z_c values and the sampling time, an estimate of the vertical velocity can be made. These estimated velocities reflect a one-dimensional vertical flow, which is all that can be done for the available data. The value for z_c is corrected for the injection depth, which was 5 m. The vertical velocity for S2 is 0.25 m/d and for S3 the estimated velocity is 0.22 m/d.

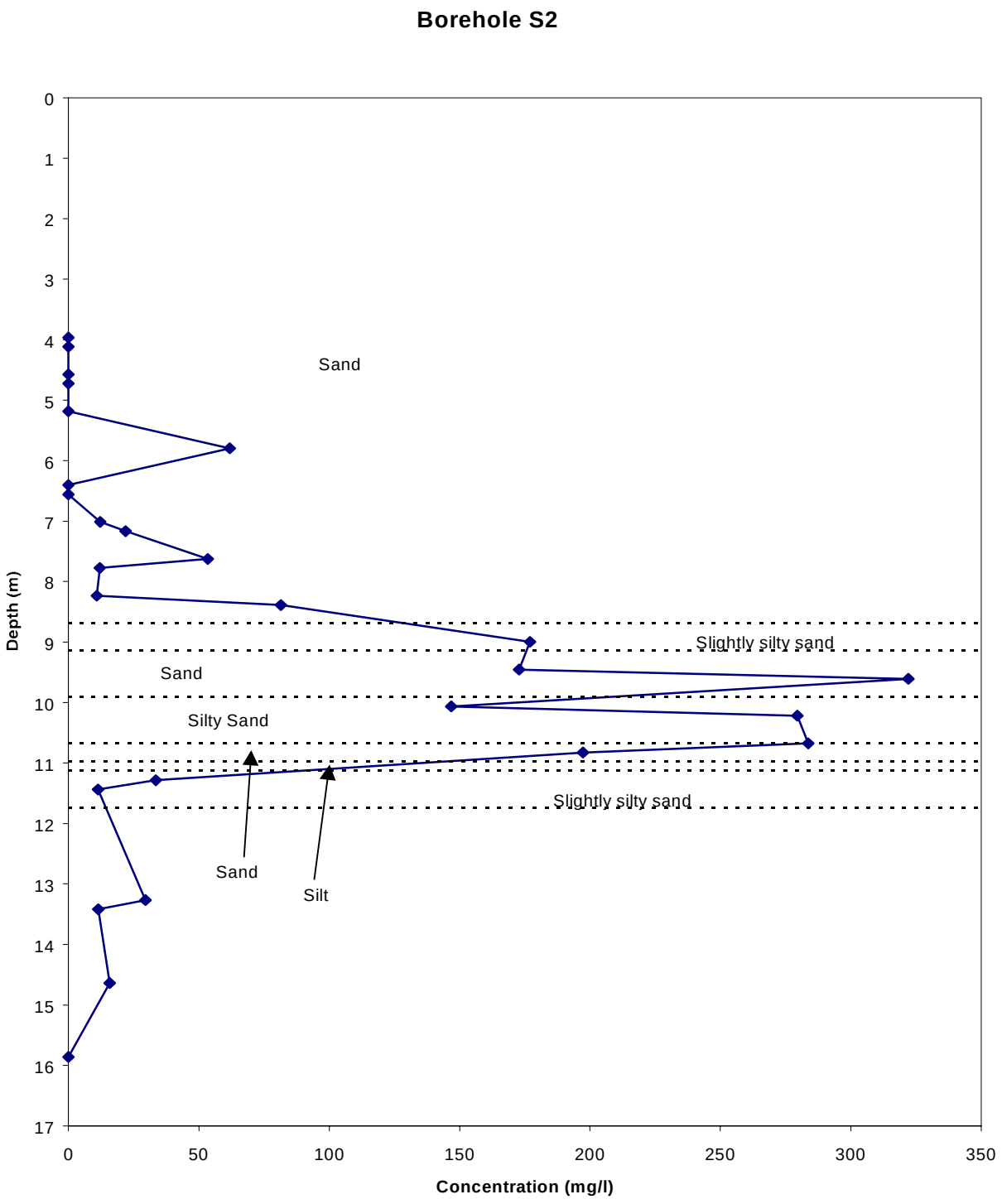

Figure 1. Bromide depth profile for Borehole S2. The bromide profile appears to affected by changes in texture.

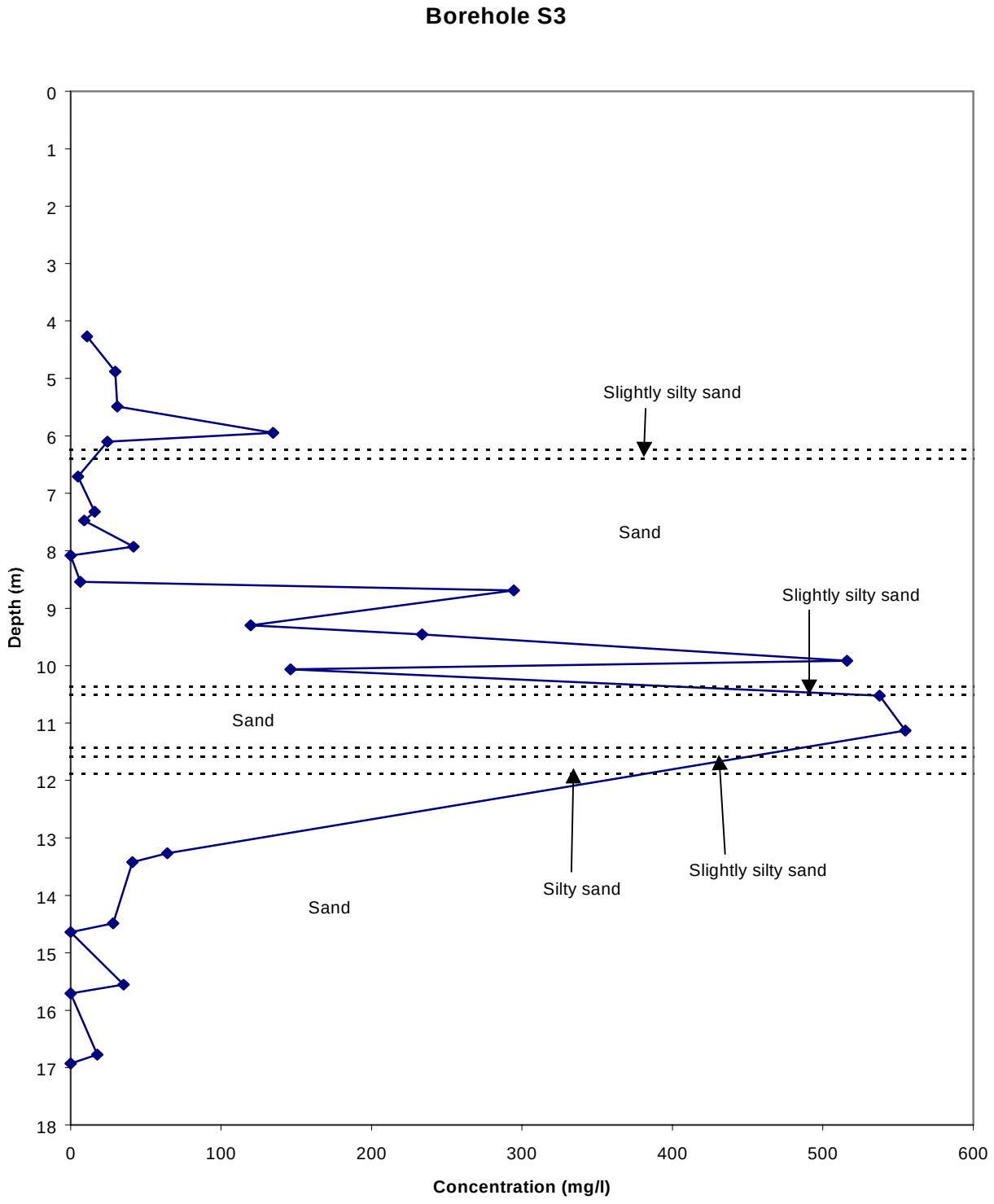

Figure 2. Bromide depth profile for Borehole S3. Like S2, the bromide profile appears to affected by changes in texture, although concentrations are higher in S3.

Conclusions

The method of moments was used to analyze the bromide data from the FY00 vadose zone field test at Hanford. Two boreholes were drilled and core samples collected for bromide analysis. The bromide concentrations appeared to fluctuate in concert with the location of fine textured layers in the alluvium. The first and second moments were consistent between sampling locations.

Future tests need to consider solution samplers to obtain bromide concentrations with time and space. This will allow better definition of key transport parameters such as velocity and dispersion, which will be needed to predict transport of radionuclide and other solutes at Hanford.