Mass Flux and Mass Discharge

Contents

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Remaining Simulcast Questions and Answers from June 10, 2014

Question 1: is the reference for the Reese AFB site (slide 73) in the ITRC doc as the Payne 2008 ref?

- *Trainer name:* (add response here)

Remaining Simulcast Questions and Answers from January 9, 2014

Question 1: What type of condition (data) should I consider to choose appropriate measurement methods? - Participant from EPA; Oklahoma

- *Trainer name:* (add response here)

Question 2: Years ago Murry Einerson emphasized high resolution short screen or multi-port vertical profiling. You said the long screens may be appropriate for an average. Is this a new development? - Environmental Consultant; Irvine, CA

- *Trainer name:* (add response here)

Question 3: Pumping method. Provides valuable source characterization data when combined with time (ideally many years): how mass flux changes with time. especially with mixed solvent sources - Environmental Consultant; Toms River, NJ

- *Trainer name:* (add response here)

Remaining Simulcast Questions and Answers from February 16, 2012

Question 1: Regarding integration of the subject technology into more frequent regulatory use, how will the use of mass flux and discharge be handled statistically and geostatiscally in the new RCRA guidance (EPA, 2008) being developed and the new document from the ITRC Groundwater Statistics and Monitoring Compliance team? What are the state and federal regulators plans to use these data in conventional gw data bases used for compliance demonstration? - Participant from Department of Energy Environmental Management; Washington, DC, United States

- *Trainer name:* (add response here)

Question 2: In Florida we are finding that State Environmental Agencies (GW Cleanup) are wary of different aspects of the program (Passive Flux meters). What are any concerns from EPA? - Participant from Army National Guard; Starke, FL, United States

- *Trainer name:* (add response here)

Question 3: Are there any examples of Mass Flux or Mass Discharge estimates in fractured bedrock? - State Regulator; Augusta, ME, United States

- *Trainer name:* (add response here)

Remaining Simulcast Questions and Answers from January 13, 2011

Question 1: Please comment on geometric or logrithymic interplolation between data points... what methods? - Environmental Consultant; Columbus, OH, United States

- *Chuck Newell:* There are a variety of methods than can be used to interpolate between data points. If you feel your data are log-normally distributed (a generally a good guess for VOC data spanning several orders of magnitude), then using a logarithmic interpolation (where you convert the data to common or natural logs, then do the interpolation, then transform back) is a good approach. The Mass Flux Toolkit has the following built-in methods to interpolate between data points: 1) nearest neighbor; 2) linear interpolation; 3) log interpolation. It will also allow you to import spreadsheets with some other type of interpolation (such as kriging or some type of geometric (polynomial) interpolation.

Question 2: Will the Mass Flux Toolkit be updated for Windows 7 (64-bit) and Excel 2007/2010? - Participant; Tucson, AZ, United States

- *Chuck Newell:* No plans to update this to Windows 7 at this time. The toolkit should run on Windows 7 (64-bit) and Excel 2007/2010, but some of the interface screens may look different and improperly formatted. The functionality of the Toolkit should be unchanged, however. If you have any questions, feel free to email Dr. Shahla Farhat at GSI (skfarhat@gsi-net.com).

Question 3: With respect to building transects (slide 31), will the vertical plume size be measured using, for example, a cluster well (for example, 3 1-inch wells of 15, 20 and 25 feet below surface)? - Environmental Consultant; Tallahassee, FL, United States

- *Grant Carey:* There are a number of options available for resolving the vertical profile of a plume. As an example, nested monitoring wells or multilevel samplers can be used to collect groundwater samples for interval-specific mass flux estimates. Another example may involve the use of passive flux meters to provide vertical profiles of specific discharge (K x i) and chemical flux in different vertical intervals within a single monitoring well screen. Qualititative screening of vertical concentration profiles can be conducted using tools such as CPT-MIP, an analysis of boring PID readings versus depth from core samples, or by evaluating the vertical distribution of soil samples. This type of screening can be done to better define where groundwater monitoring should be be focused on a transect. In some cases it may be appropriate to use different horizontal and vertical spacing for wells on a transect, so that smaller spacing can be used where mass flux is anticipated to be higher to facilitate higher resolution monitoring, and a larger well spacing may be reasonable where mass flux is anticipated to be low. So to summarize, there are multiple options for vertical profiling of mass flux in a plume, and the approach will depend on cost, as well as site-specific characteristics such as the mass distribution in the source, geology at the site, etc.

Question 4: It was mentioned that mass flux is based upon horizontal movement of the groundwater. Would this method be limited with DNAPL chemicals like tetrachloroethene? Also, has there been studies utilizing mass flux measurements with hexavalent chromium? - State Regulator; Indianapolis, IN, United States

- *Grant Carey:* Mass flux and mass discharge can be estimated for any chemicals that are dissolved in groundwater, so yes, mass flux and mass discharge can be estimated for chemicals such as tetrachloroethene (PCE). Mass flux and mass discharge have also been used often in the past with inorganic chemicals (e.g. nitrate loading to surface water bodies) as well as metals, although I don't know off-hand of specific examples involving hexavalent chromium. Measurement methods involving collection of groundwater samples can be used for any chemicals that are dissolved in groundwater including hexavalent chromium. The passive flux meter uses a sorbent that tends to be specific to certain groups of chemicals, so you could check with the vendor (www.enviroflux.com) to confirm if there are passive flux meters available for specific chemicals.

Remaining Simulcast Questions and Answers from November 18, 2010

Question 1: If using wells for your transects, the well concentration is a vertical average over the screen length. Using this to average a concentration across a horizontal distance is essentially averaging averages. How many orders of magnitude would be considered a fairly accurate measurement. - Local Government Participant; Madison, WI, United States

- *Grant Carey/Chuck Newell:* The multiple vertical samples would give the same theoretical result as the long screen well average if there are enough vertical samples that (when averaged) approach the average concentration from a long screened well. We think the main point is that with longer screened wells you can't see the structure of the plume (the mass flux distribution). However, if the main objective is simply to measure mass discharge across a transect, than using vertically-averaged concentrations from longer well screens is a reasonable approach if the vertical well does provide a good vertical average (some new SERDP research is suggesting that may not be the case for some wells due to inadequate mixing in the well). Regarding the question of how many OoMs are accurate, it depends on the measurement technique, the number of samples, and the objectives for the measurements. Based on our experience with the variability in hydraulic conductivity and concentrations in groundwater monitoring wells, the accuracy of mass discharge measurements is likely not less than a factor of two (note this just a personal opinion, and that result is not presented in the ITRC document), but that is most cases this still provides useful information. Some Md measurements that are only accurate to a factor of 10 can still provide useful information for some questions.

Question 2: Most of the demonstrations seem to assume direction and magnitude of ground water flow is relatively constant across site. What if there is significant variation in the direction and magnitude of the hydraulic gradient across the site. Are their ways of accommodating this in the methods presented? State Government Participant; Wilkes-Barre, PA, United States

- *Alec Naugle:* (Others may have a different response, but as a regualtor I would always insist upon the use of the gradeint (direction and magnitude) as measured at the same time the concentration data are measured (i.e., when the wells are sampled) if the gradient is not known to be fairly uniform. At least then you are using data sets (i.e., gradient + concentration) from the same time period to estimate teh mass flux/discharege. So this means you still need to be monitoring the gradient across your site while you're focusing on building and sampling your transect. If the direction of the gradient fluctuates such that the direction of groundwater flow is not perpendicular to the transect, then you could have problems because you may not be fully capturing the mass discharge. But assuming your transect is still capturing the portion of the mass discharge you're interested int, but at some oblique angle, then I think a simple trigonometry prolem would give you the component of flow that's being captured by the transect.)

- *Grant Carey/Chuck Newell:* Here is some more thoughts to complement Alec's response. For variation in the magnitude of the hydraulic gradient, temporally-varying hydraulic gradients can be monitored in the field and used as one of the inputs for estimating temporal variations in mass discharge across a transect. For variation in groundwater flow direction, Some practitioners use flow vectors to adjust the Darcy velocity through the transect. For example, if flow through the transect were 30 degrees off perpendicular from the transect, the Darcy velocity that can be used for estimating mass discharge across the transect (which in this case would have a shorter length perpendicular to groundwater flow) would be 87% of the Darcy Velocity in the direction of groundwater flow. In other words, the mass discharge across the fixed transect may vary to some degree with changes in flow direction. However, the sensitivity of mass discharge to a change in angle up to 30 degrees is small relative to the degree of uncertainty associated with estimating hydraulic conductivity at most sites so fixed transects still provide a reliable approach for estimating mass discharge for sites with relatively small variability in the angle of flow direction.

Question 3: When using multi-level screened wells, can I use USGS passive diffusion bags to get contam concs in gw? For example, if I have ten screened intervals separated by 10 feet of unscreened casing, can I hang 10 USGS PDBs on ropes 10 feet long? - State Government Participant; Salt Lake City, UT, United States

- *Grant Carey/Chuck Newell:* This method would work if there is not flow in the well bore or sand pack around the well. Unfortunately there is likely to be some vertical flow in many wells. You can control the vertical flow inside the well bore with packers, and so the system you describe would work if you had a packer, PDB, packer, PDB, etc. However, there still might be some vertical flow in the sand pack that can affect the results.

Question 4: It seems that unless the screen filter pack is customized to the formation grain size distribution for each discrete monitoring point, the convergence of groundwater streamlines through the well screen will occur to a much lower degree in a gravel formation compared to sand or silt. Hence, the passive mass flux meter will underestimate mass flux in the gravel zone (i.e. the difference in flux between gravel and silt will be lower than the true value). What approaches have been used to mitigate this bias, if any? - Environmental Consultant;

Columbia, MD, United States

- *Grant Carey/Chuck Newell:* The convergence calculation is shown in Hatfield et al., 2004 (J. Cont. Hydrogeology) and is based on the K contrast between the well screen, the meter, and formation, so when using the PFM the K of the formation is considered (e.g., gravel vs. silt). Overall these differences are usually large enough that in most cases the k difference between the formation and filter pack, while a factor, doesn't introduce significant error (defined as less than 15% in the field trials). At the Borden site, the following small differences were observed between wells with and without filter packs (ESTCP Cost and Performance Report, 2007): "For screened wells with filter pack, the maximum error was 7.7% at the well level; for the gate cross section, the error in the integrated estimate was 0.7%. For screened wells the maximum error was -11.2% at the well level; for the gate cross section, the error in the integrated estimate was -2.3%." Dr. Mike Annable also noted that this paper also provides information about the convergence calculation: Klammler, H., K. Hatfield, M. D. Annable, E Agyei, B. L. Parker, J. A. Cherry, and P. S. C. Rao (2007), , Water Resour. Res., 43, W04407

Question 5: In the Tech Overview document, figures 4-2 & 4-3 show very close vertical screened intervals. Do you install bentonite annular seals between the screened intervals? - State Government Participant; Salt Lake City, UT, United States

- *Grant Carey/Chuck Newell:* I think these Figure 4-3 were intended to represent any type of high-resolution vertical data, either with a geoprobe or some type of multi-level sampler. Figure 4-2 represents something like a Waterloo multilevel sampler with one well and multiple ports separated by some type of seal in the well bore. But the figures were intended to be illustrative rather than specific of some type of actual sampling method.

Question 6: I like this concept, but well installation and sampling would be very expensive. For example, in the Tech Overview document, figures 4-2 and 4-3, you would collect/analyze 210 gw samples from the 3 transects. The analyses alone would cost $21,000. This does not include consultant sampling time. - State Government Participant; Salt Lake City, UT, United States

- *Grant Carey/Chuck Newell:* Here are three different considerations:

- 1) You gain a lot of information with high resolution transect data, as indicated in the bullets on top of page 4 of the ITRC document. Another example: there is a case study where an incorrect conceptual model regarding sources, high concentration zones had been used for over 10 years. After high resolution sampling the actual sources and flow regime became clear. So in that case the expense (> $21K) was really worth it.

- 2) There are other methods that might provide some of the same type of information at less expensive (Methods in Sections 4.4 and 4.5). But these are heavily dependent on the amount of data (number of wells) already at the site.

- 3) There are emerging methods for generating lots of cheap groundwater monitoring data from transects. One technique that may be useful is to equilibrate a groundwater sample with air (in a ziploc bag for instance), use a field vapor analyzer (GC, HAPSITEGC/MS, or maybe a PID) to get the vapor concentration, and then calculate groundwater concentrations with Henry's Law. There is an on-going SERDP project that has shown this method has promise for generating high volume (but lower quality) groundwater data, such as for generating mass flux transect data.

Question 7: are the databases prepared by DOD and Einarson and Mackey freely accessible on line? - Environmental Consultant; Long Beach, CA, United States

- *Alec Naugle:* (The DoD (i.e., SERDP) database that I mentioned in the applications portion of the training is a work in progress and has not yet been published. I understand that it is based on a review of about 280 case studies, looking at the remedial approach and remediation technologies applied and how succesful they were at meeting the site-specific cleanup objectives. I think that study should be ready for publication in the next few months, but Hans Stroo (hstroo@hgl.com) and Carmen Lebron (carmen.lebron@navy.mil) who are ITRC team memebers working on this project are good contacts for specifics.

- I'm not aware that the Einarson and Mackay case studies are available on line however I believe the information was published in 2001 in Envrionmental Science and Technology (ES&T). The specific reference for this publication is found on page 83 of the ITRC Technology Overview document. Table A-1 in the appendix of the Tech Overview document summarizes the Einarson and Mackay case examples as wells as several others)

- *Grant Carey/Chuck Newell:* Remediation performance results from one SERDP project are summarized in McGuire et al. (2006, Ground Water Monitoring and Remediation - email cjnewell@gsi-net.com for a copy) and in a pubic domain software tool (GSI-net.com or http://www.gsi-net.com/en/software/free-software/serdp-source-depletion-decision-support-system.html.

- The purpose of the Md database reference in the ITRC Technology Overview was to let people know that they can make approximate predictions of how much mass discharge reduction they might expect at their sites by referring to the empirical data compiled by others for similar sites. Trying to estimate how much concentrations will change is difficult to do because each well will behave differently. But trying to estimate the change to overall mass discharge (a single metric for a source zone) is easier to do, and the range in empirical observations of mass discharge reduction ?success? is smaller than the range in concentration changes we observe at individual wells.

Question 8: has max flux estimation been successfully used in active ozone sparge remediated sites? - Environmental Consultant; Long Beach, CA, United States

- *Grant Carey/Chuck Newell:* Not that we are aware of.

Question 9: in case of large variety of K and C, what is the optimum size of the cell; what is more important to consider C or K in the decision? - Environmental Consultant; Long Beach, CA, United States

- *Grant Carey/Chuck Newell:* The ITRC IDSS team spent a lot of time trying to come up with some quantitative guidance on the appropriate sampling density for mass flux/mass discharge, but in the end provide the qualitative information in Table 1-1. Regarding "is C or K more important": 1) most transect method applications to date use a constant K for permeable media, but that doesn't necessarily mean C is more important; 2) C might range over 3 to 5 OoMs (orders of magnitude), while K in permeable units might be a little less (2 or 3 orders of magnitude?). So overall it would likely be better to have high resolution C data and some type of average K vs. high resolution K data and an average C.