Well Flow Dynamics and the Application of Passive Sampling Techniques

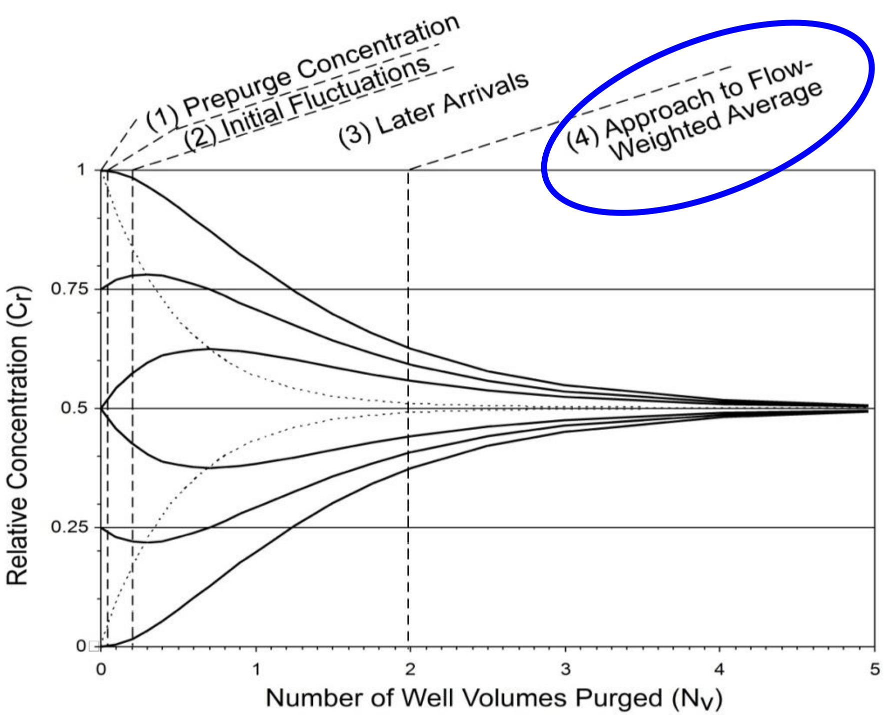
Sanford (Sandy) Britt, PG, CHG
QED Environmental Systems, Inc.
SBritt@QEDenv.com

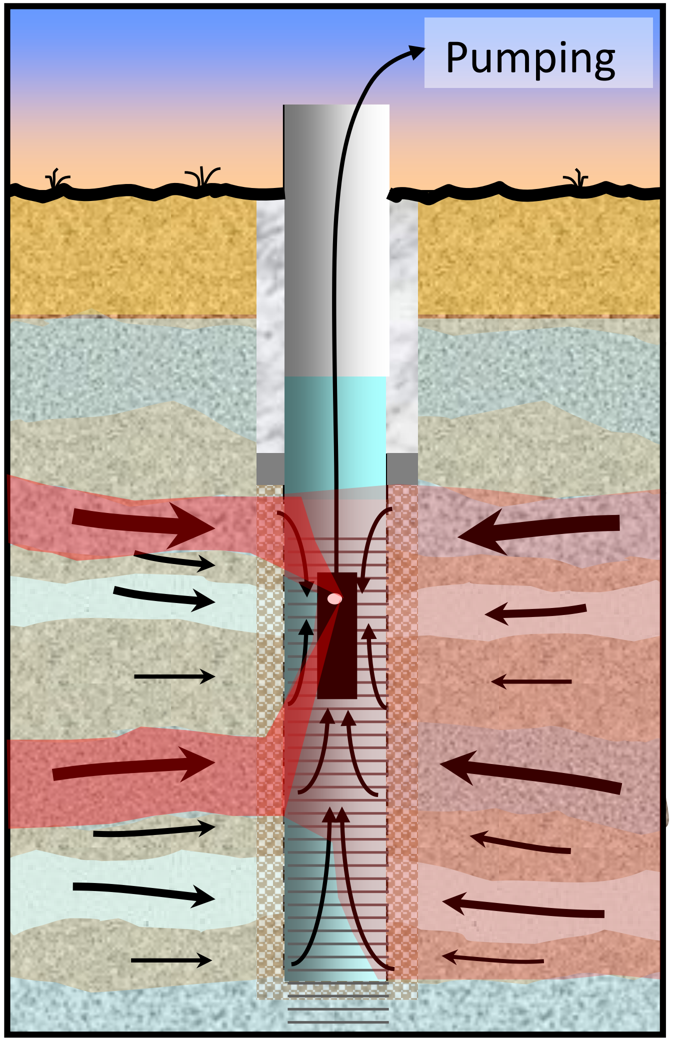
EnviroTech, Calgary, 25 April 2019

Purging a well…

What controls flow-weighting *during pumping*?

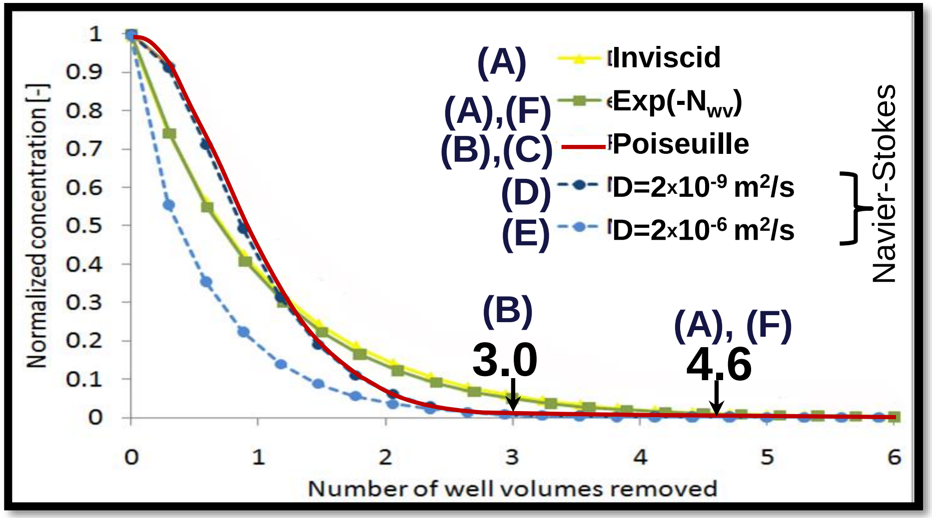
- **Contaminant stratification**
- **Inflow distribution**
- **Pump position relative to stratification**





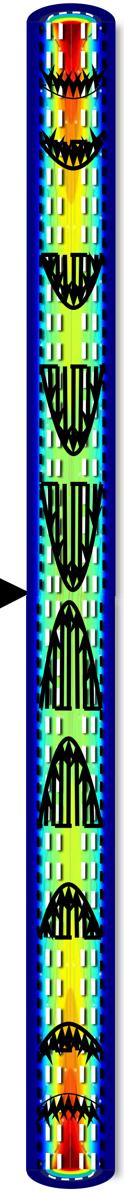
Martin-Hayden, 2000, Sample Concentration Response to Laminar Wellbore Flow: Implications to Ground Water Data Variability. *Ground Water* 38, no. 1: 12-19.

How do we get to a Flow-Weighted Average?



Martin-Hayden, J., M. Plummer and S. Britt (2014) Controls of Wellbore Flow Regimes on Pump Effluent Composition, Ground water, v52, p. 96-104.

Pumping

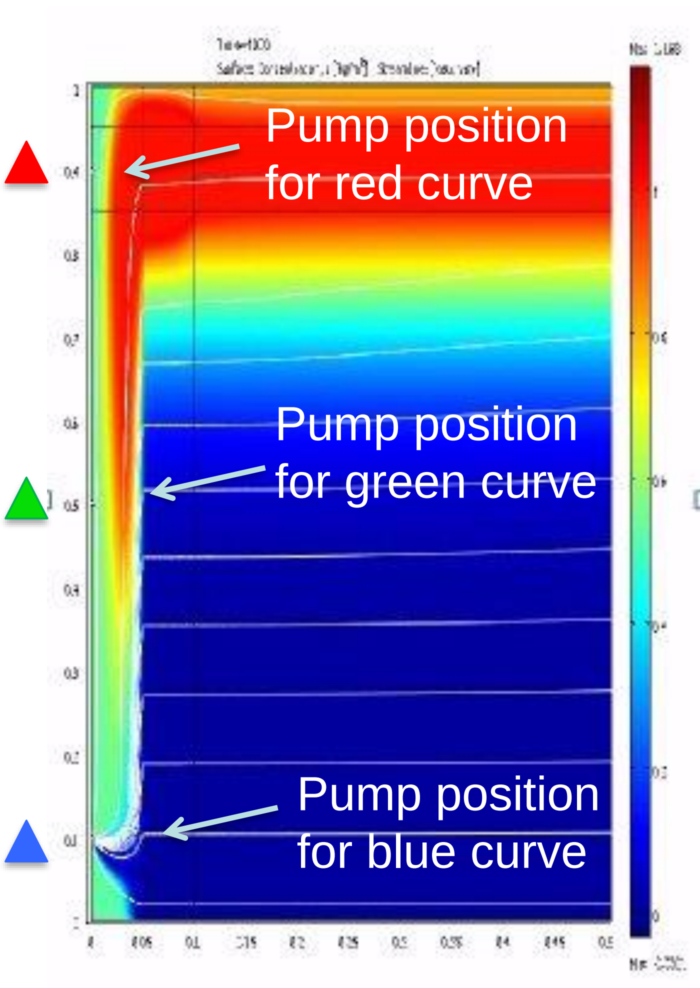


Arrival time and FWA depends on….

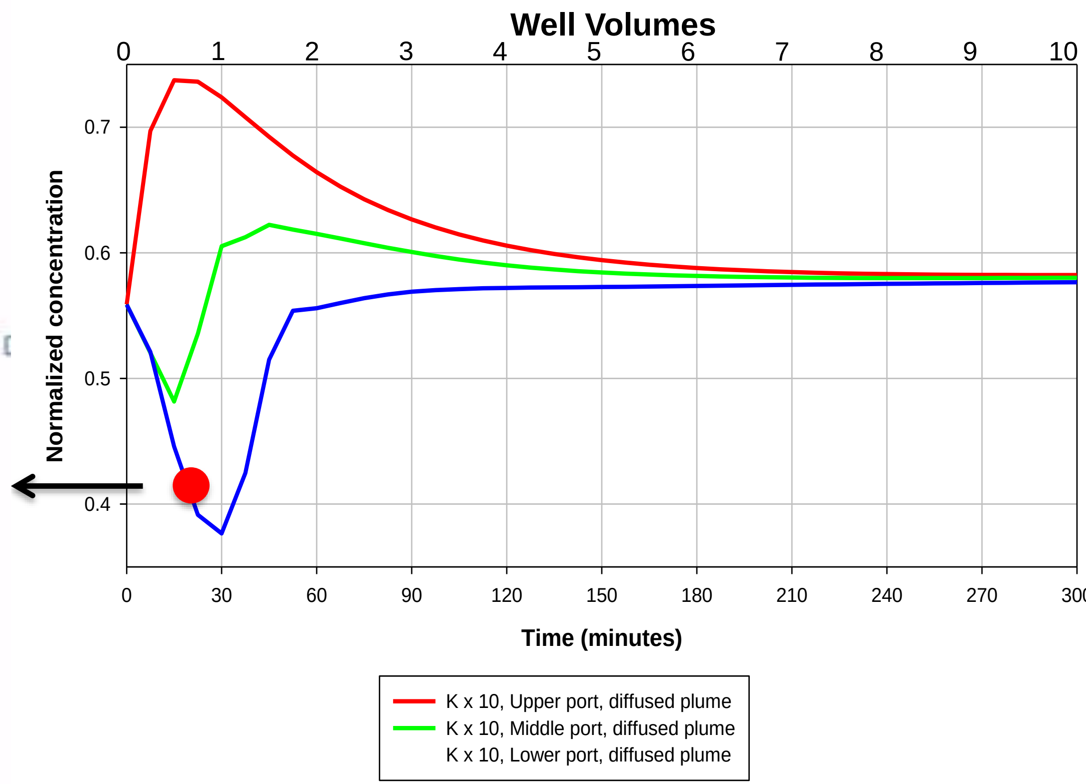
- Pumping rate
- Well diameter
- Well screen length

- @ 250ml/min in a 3m/10ft well….
  - 1WV in 50mm/2” takes ~23 minutes
  - 1WV in 100mm/4” well takes ~ 94 minutes

Modelled well flow



Pump near/far from contaminant inflow?



Britt, Sanford L., James Martin-Hayden, Mitchell A. Plummer, 2015, SERDP Project ER-1704 Final Report, An Assessment of Aquifer/Well Flow Dynamics: Identification of Parameters Key to Passive Sampling and Application of Downhole Sensor Technologies, 76p.

1 meter long, 10cm screen

250ml/minute pump rate

K= $1x10^{-2}$ cm/sec in contaminated zone, $1x10^{-3}$ in remaining aquifer

Pump located 10cm from bottom position

Field Confirmation….

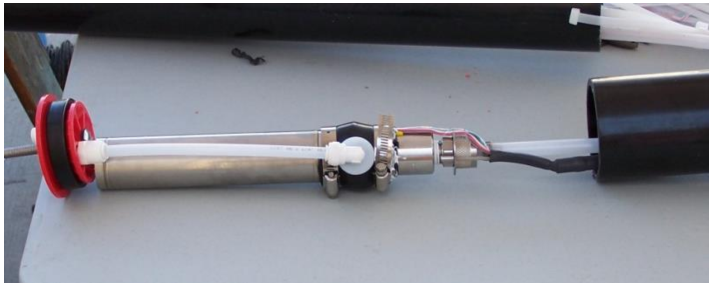
Stratification testing at ***existing*** wells

- 8 wells
- 2 to 4 depths
- prep for "purge curve" testing

Three ***new wells*** built to accommodate equipment

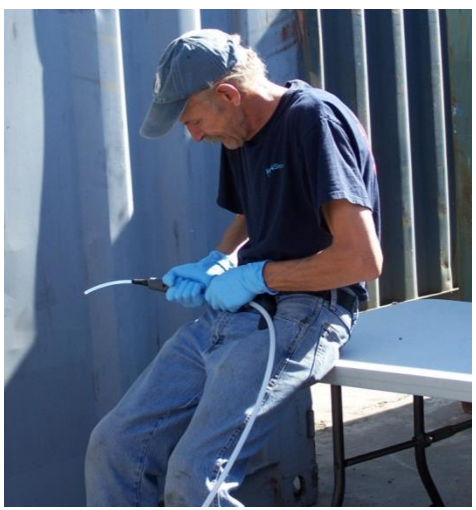
SERDP
DOD • EPA • DOE

Purge Test Set-Up



- Pump
- Sensors-level, Conductivity, pH, ORP, Chloride
- Snap Samplers— over/under…before/after

Low Rate purge—multiple VOC samples collected along "purge curve"



Contaminant Chemistry

Sample ID	29-SS-L1	29-SS-U1	MW29-1	MW29-2	MW29-3	MW29-4
Sample Date			9/1/2009	9/1/2009	9/1/2009	9/1/2009
Laboratory Job Number			53966	53966	53966	53966
time			1112	1136	1200	1224
minutes elapsed	0	0	6	30	54	78
volume pumped	0	0	0.5	2.7	4.9	7.0
Acetone	18.4	19.3	10	10	10	10
Benzene	19.2	16.5	11.3	6.64	5.09	5.66
sec-Butylbenzene	1.18	0.78	0.5	0.5	0.5	0.5
Chlorobenzene	18.4	14.2	8.75	6.02	5.49	6.69
Chloroethane	39.2	32.8	24.1	14.2	11.9	10.3
1,2-Dichlorobenzene	0.5	1.38	0.5	0.5	0.5	0.5
1,1-Dichloroethane	6,000	4,000	3,920	2,710	2,490	2,590
1,2-Dichloroethane (EDC)	45	39.2	24.5	16.7	14.2	15.6
1,1-Dichloroethene	234	201	162	117	85.8	89.3
cis-1,2-Dichloroethene	111	98.5	85.3	58.5	44.8	45.9
trans-1,2-Dichloroethene	0.91	0.96	0.5	0.5	0.5	0.5
Ethylbenzene	5.98	4.8	1.63	1.02	0.68	0.75
Isopropylbenzene	0.84	0.6	0.5	0.5	0.5	0.5
p-Isopropyltoluene	0.5	0.5	0.5	0.5	0.5	0.5
4-Methyl-2-pentanone (MIBK)	63.4	31.5	12.8	3.12J	2.5	3.02
n-Propylbenzene	0.5	0.5	0.5	0.5	0.5	0.5
Tetrachloroethene	10.2	7.51	4.21	3.45	2.98	3.39
Toluene (Methyl benzene)	5.87	6.35	3.15	2.15	1.62	1.67
Trichloroethene	6.57	5.39	3.54	2.43	2.01	2.38
1,2,4-Trimethylbenzene	14.9	11.2	2.54	1.27	1.06	1.19
1,3,5-Trimethylbenzene	2.76	2.08	0.67	0.5	0.5	0.5
Vinyl chloride (Chloroethene)	332	297	228	170	118	117
o-Xylene	2.01	1.86	0.79	0.5	0.5	0.5
m,p-Xylenes	7.9	6.27	2.04	1.24	1	1
Diisopropyl ether (DIPE)	0.5	0.5	0.5	0.7	0.66	0.5
1,4-Dioxane	35,500	30,100	40,300	27,200	27,400	26,600

"Purge curve" samples collected from *pump discharge*

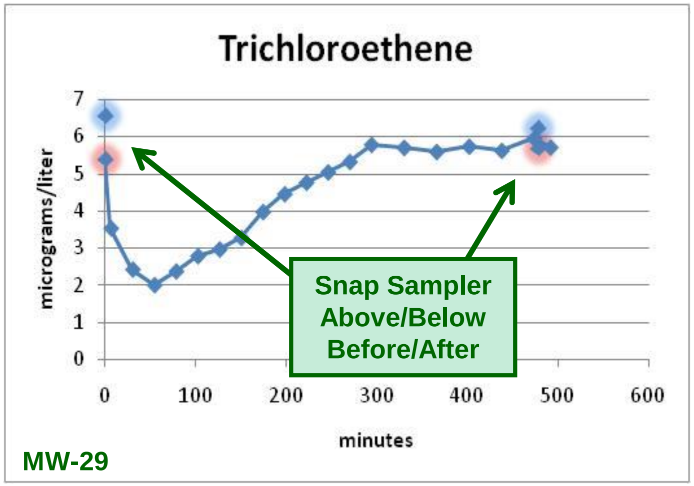
***In situ* Snap Samples collected**

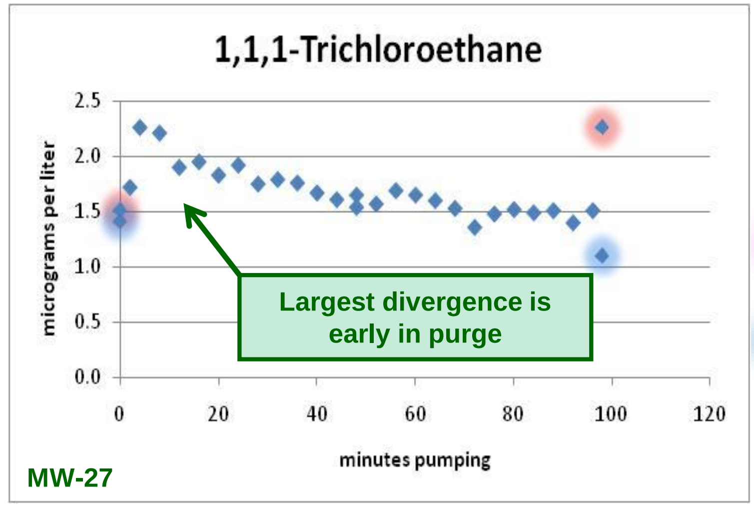
Above/below pump

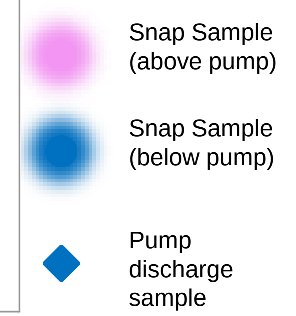
Before/after pumping

Purge "curve" test results

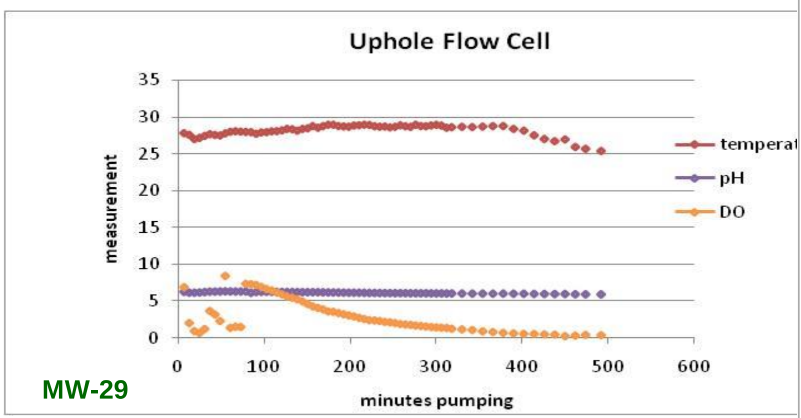
Contaminant Chemistry Curves over Five Well Volumes

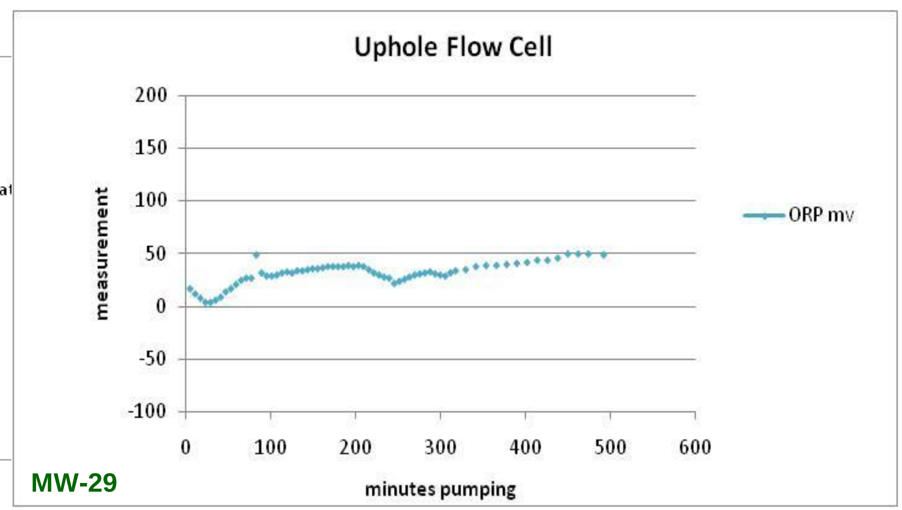






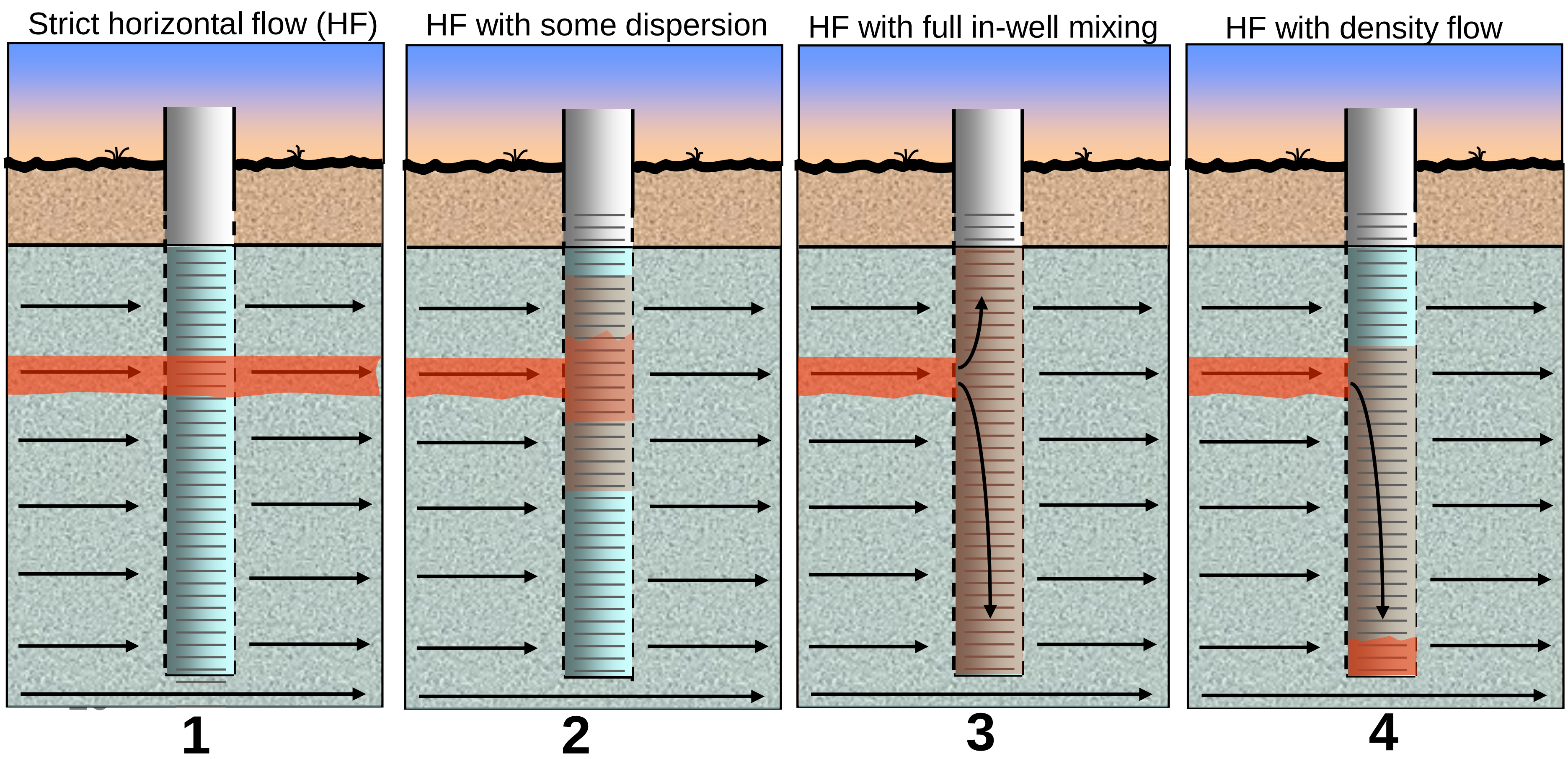
Indicator Parameters?





Passive flow-through concepts

Some conditions tested by Britt, 2005
density contrast, mild heterogeneity



Britt, S.L., 2005, Testing the In-Well Horizontal Laminar Flow Assumption with a Sand-Tank Well Model, GWMR, v.23, no. 3, p. 73-81.

Modeled in-well behavior

What resides in the well between sampling events?

Dye source with gravity feed to injection port

Upgradient/ influent reservoir

Effluent reservoir

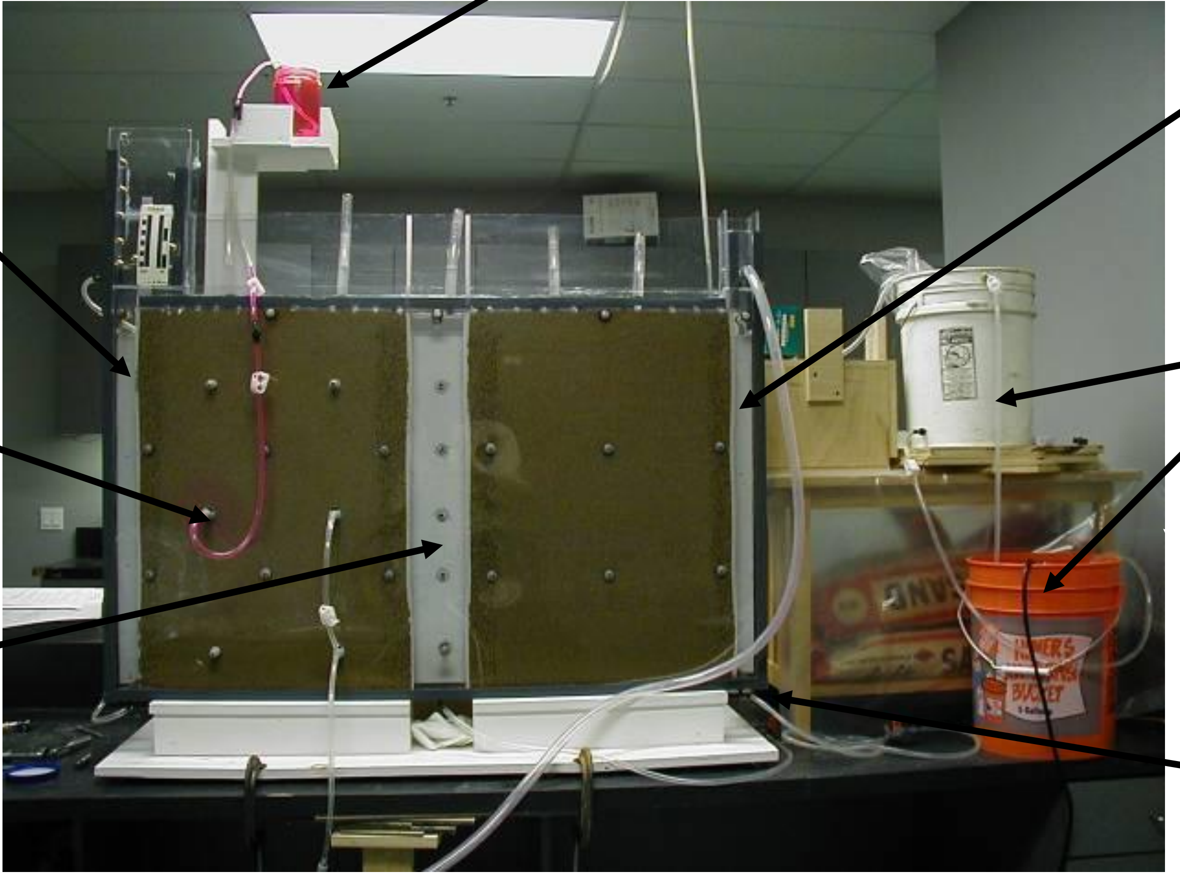
Constant head reservoir system

Dye port

Well

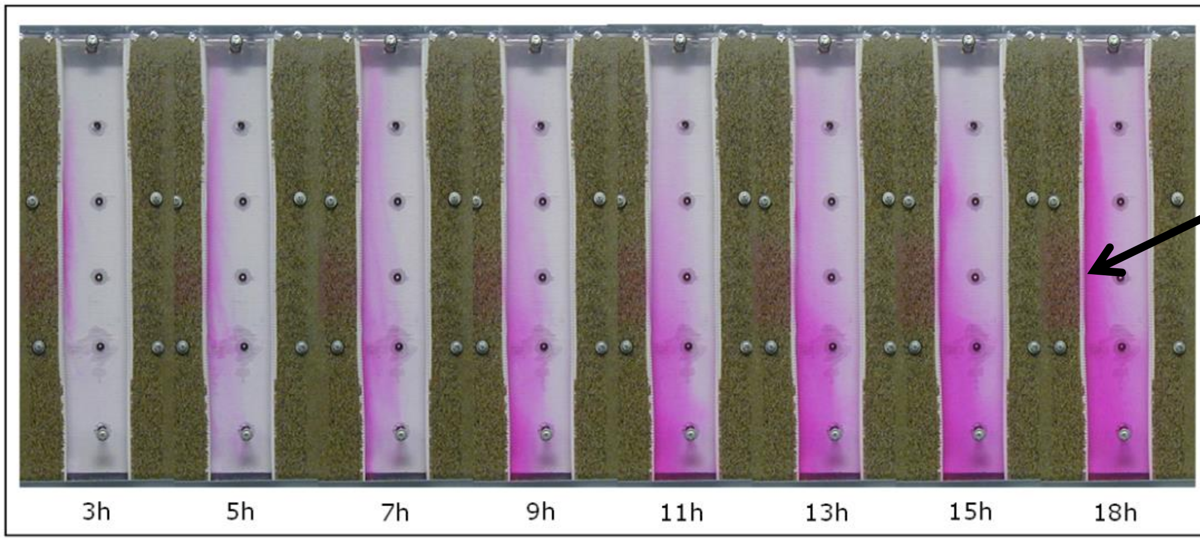
x-Section

Effluent drain



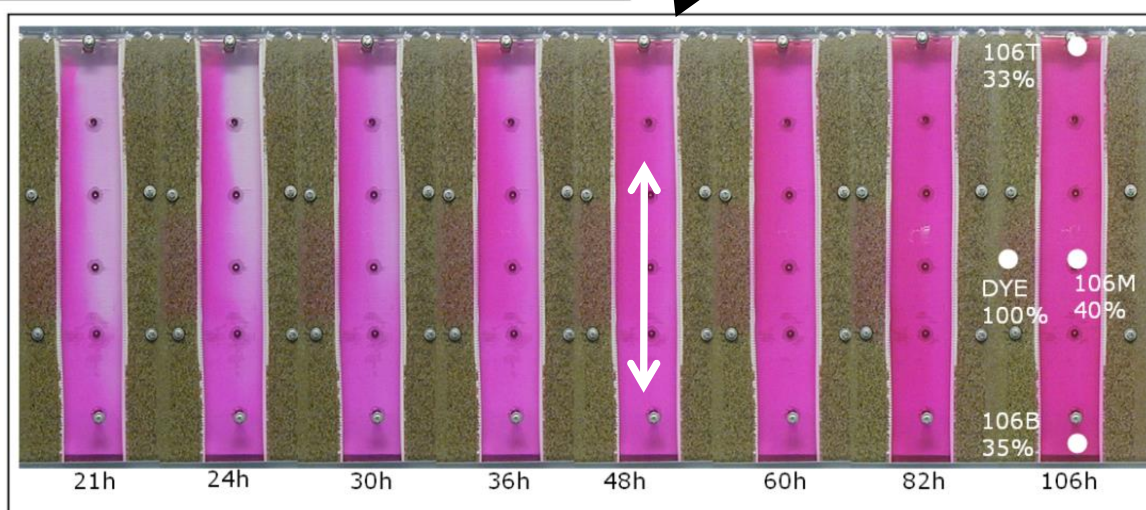
Britt, S.L., 2005, Testing the In-Well Horizontal Laminar Flow Assumption with a Sand-Tank Well Model, GWMR, v.23, no. 3, p. 73-81.

Inflow and residence time yields flow-weighted mixing—



Central entry zone

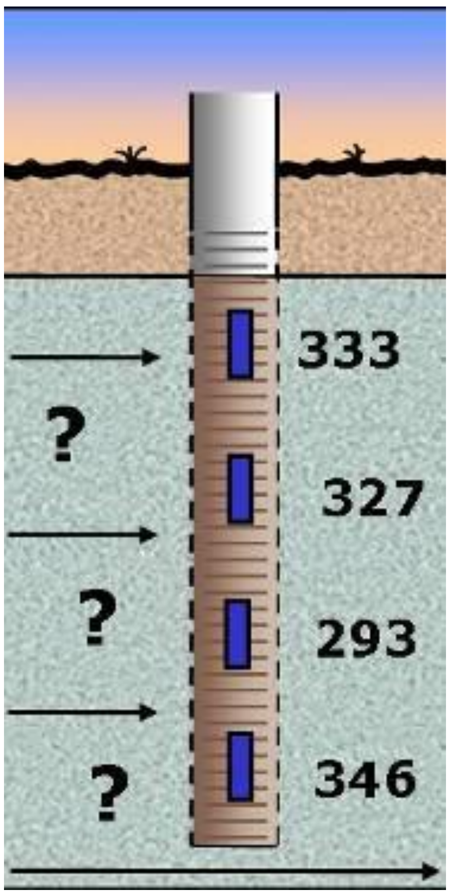
Vertical redistribution

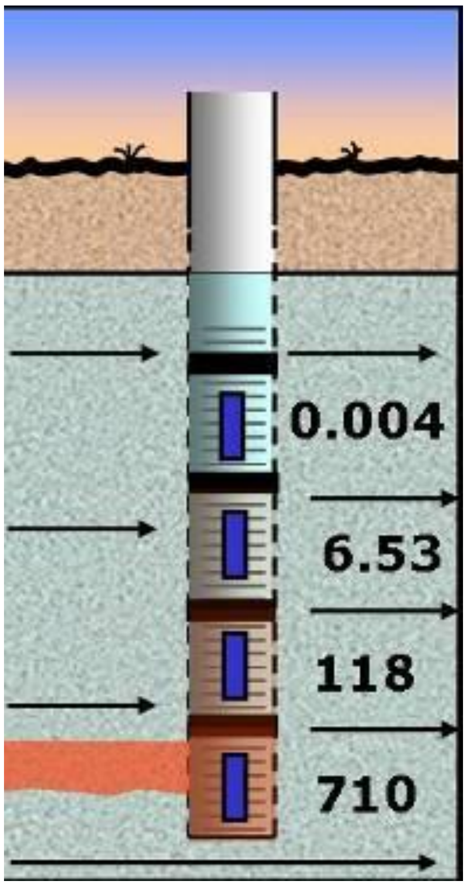


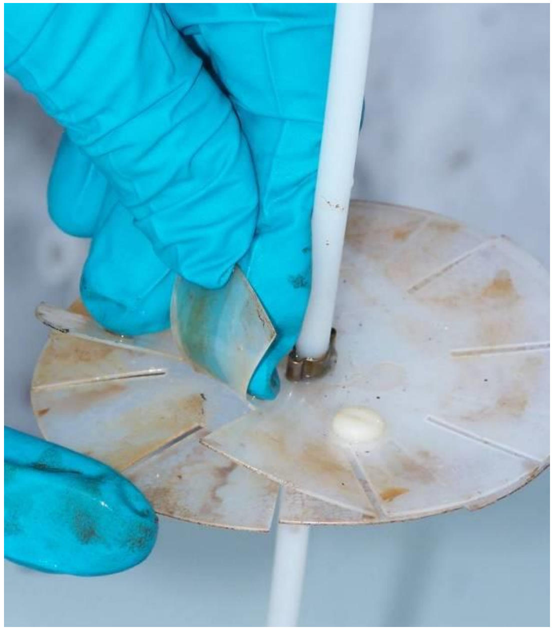
Britt, S.L., 2005, Testing the In-Well Horizontal Laminar Flow Assumption with a Sand-Tank Well Model, GWMR, v.23, no. 3, p. 73-81.

Field verification of concepts

Field example illustrates the flow-weighted mixing concept



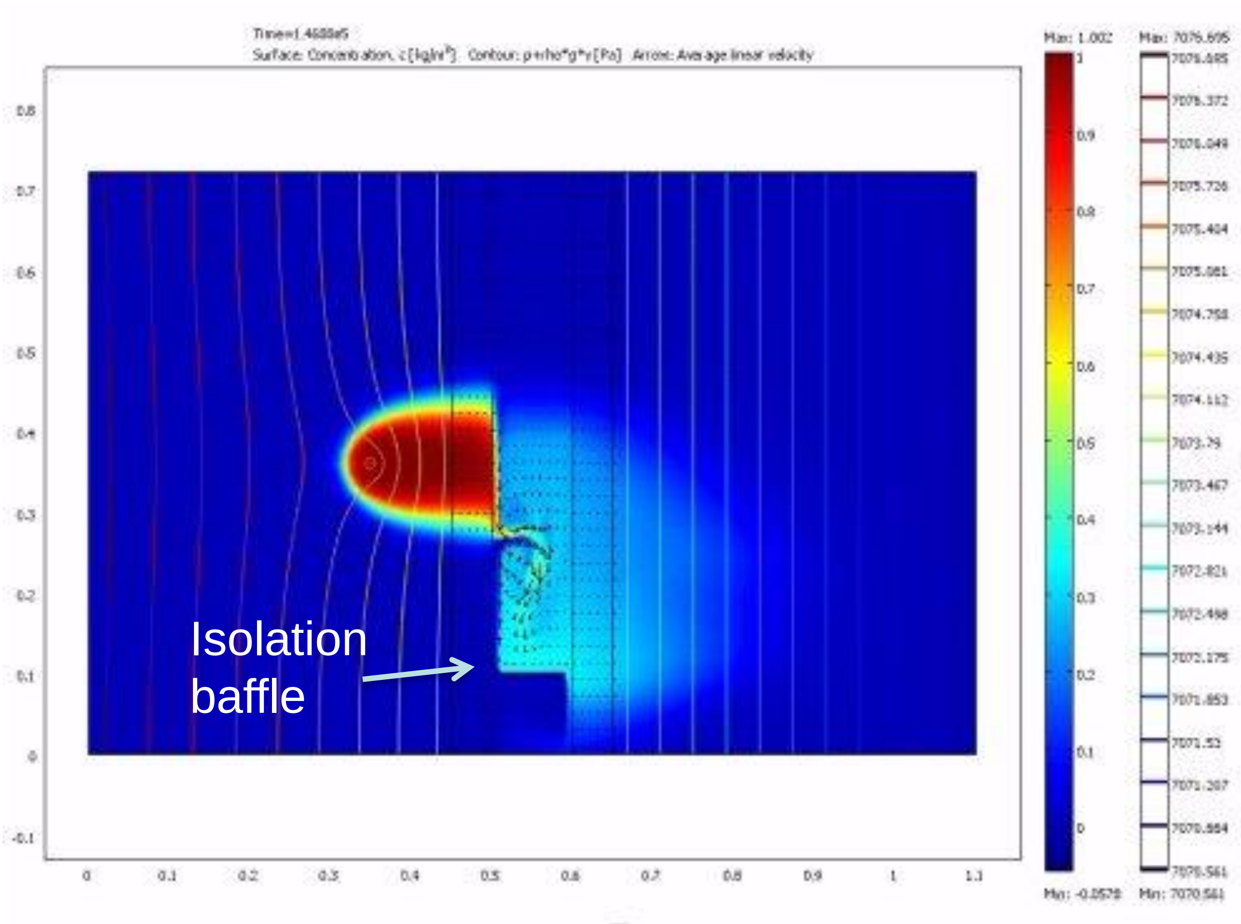




In-well baffle device/ Mixing inhibitor

Britt, SL and Calabria M, 2008, Baffles may allow effecting multilevel monitoring in traditional monitoring wells, Battelle Chlorcon Conference, Monterey California, May 2008

Physical and Numerical Model results



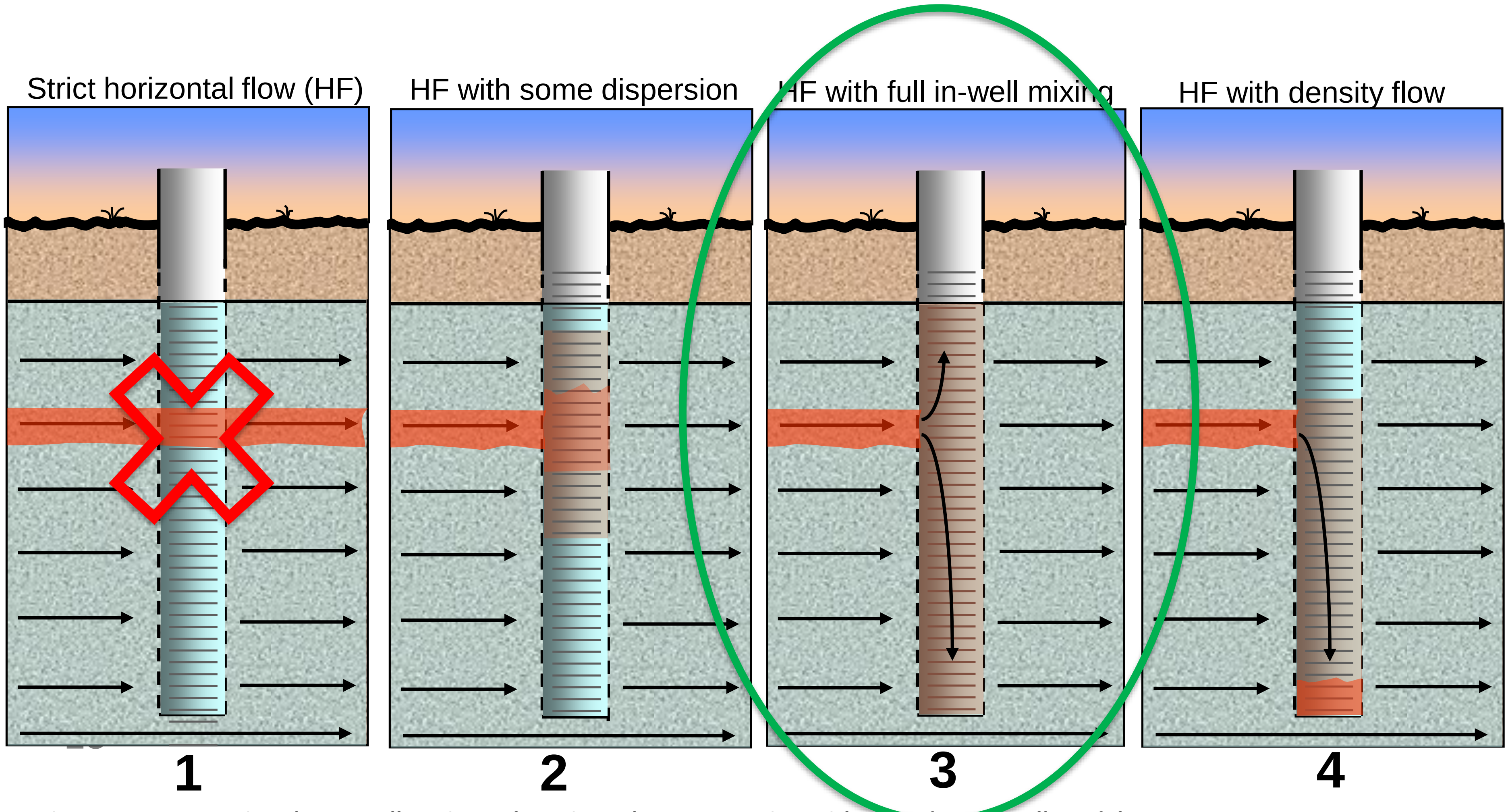
- **Physical Model**
- **Density nearly neutral**

- **Numerical Model**
- **Match is pretty good**
- **Density +3 x 10^{-7} greater than neutral**

Britt, S.L., 2005, Testing the In-Well Horizontal Laminar Flow Assumption with a Sand-Tank Well Model, GWMR, v.23, no. 3, p. 73-81.

Britt, Sanford L., James Martin-Hayden, Mitchell A. Plummer, 2015, SERDP Project ER-1704 Final Report, An Assessment of Aquifer/Well Flow Dynamics: Identification of Parameters Key to Passive Sampling and Application of Downhole Sensor Technologies, 76p.

Passive flow-through expectation…



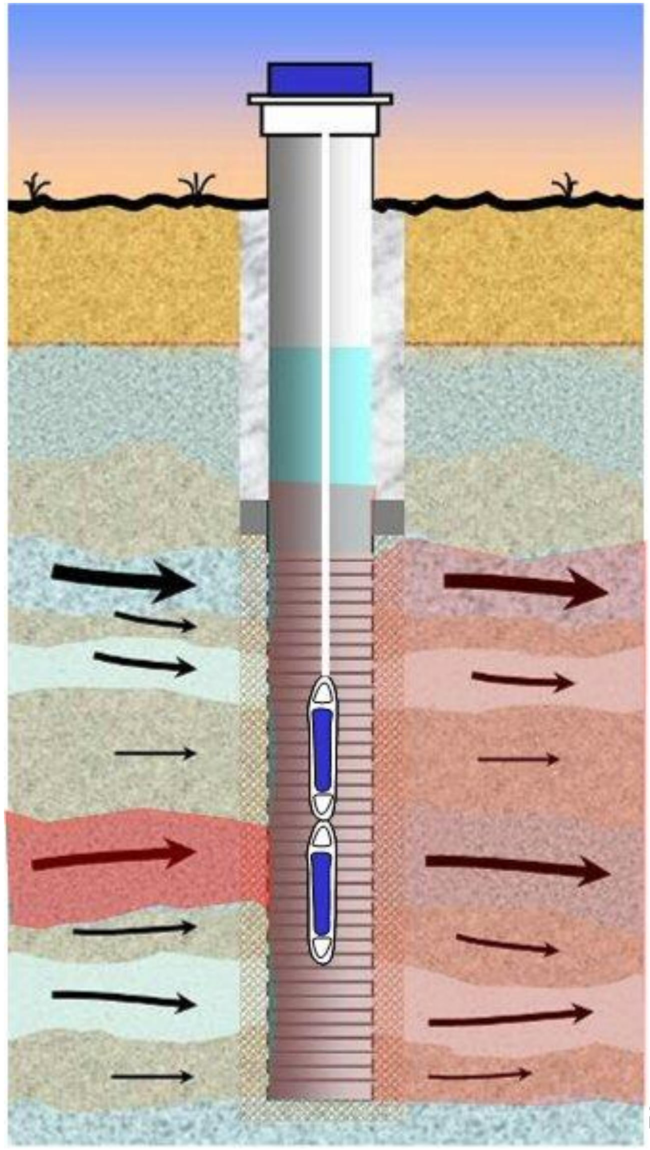
Britt, S.L., 2005, Testing the In-Well Horizontal Laminar Flow Assumption with a Sand Tank Well Model, GWMR, v.23, no. 3, p. 73-81.

The Take Away?

Passive equilibration is often <u>very similar</u> to end-stage purge-to-stability sampling

- **<u>Natural flow</u> delivered to well**
- **Ambient / <u>passive mixing</u> according to native flow dynamics**
- **<u>Flow-weighted averaging</u> effect**

Passive Sampling normally yields a Flow Weighted Average too



Less Work

…without this truck…

…and with almost none of this equipment

Safety **and** **efficiency** **is improved**

- No drums
- No generator
- No compressed gas
- No fuel
- Shorter time at the well

ESTCP

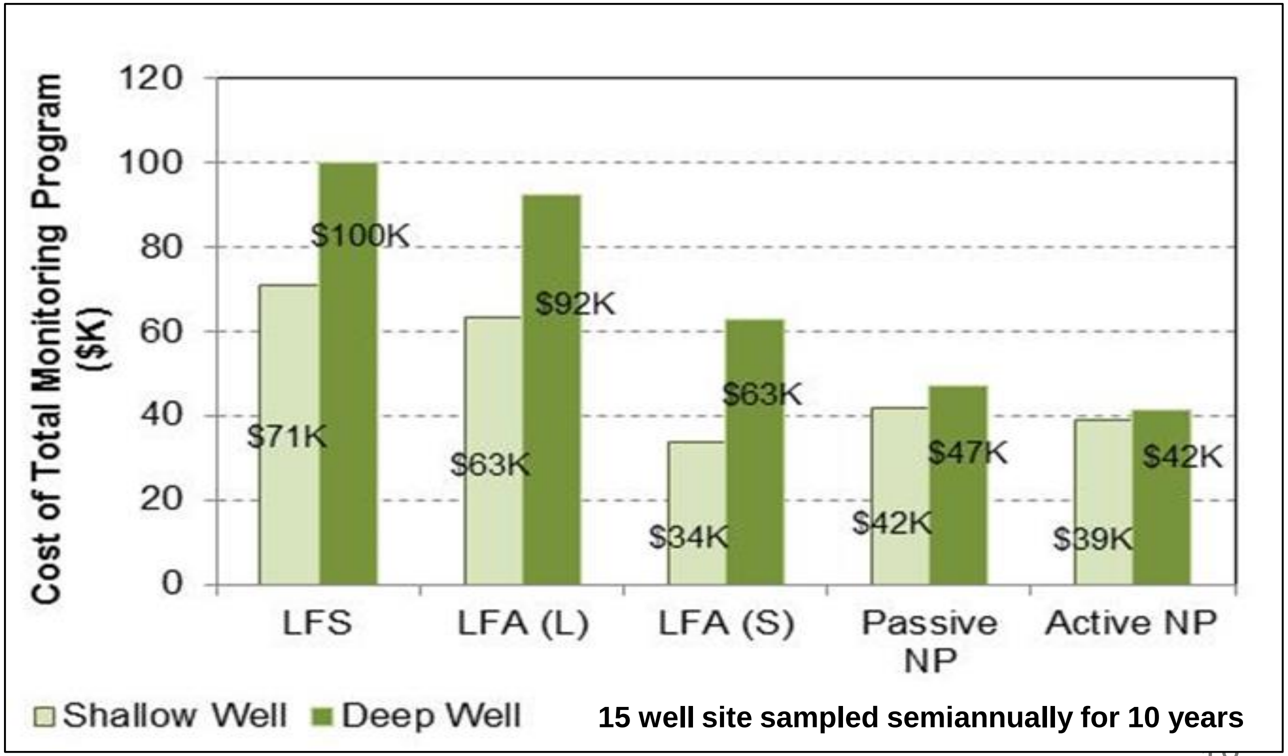
Lower Cost

Purging requires <u>time</u> in the field, <u>equipment</u>, and <u>waste</u>

Passive sampling allows you to <u>sample right away</u>

NO More:
- Equipment rentals
- Pumping
- Troubleshooting meters
- Measuring parameters
- Waste handling

ALWAYS:
- Sample right away
- Sample faster
- Know your sample
- Improve Data Quality



GSI Environmental, 2015, ESTCP ER-201209 Draft Final Report

Passive prove-out assessments

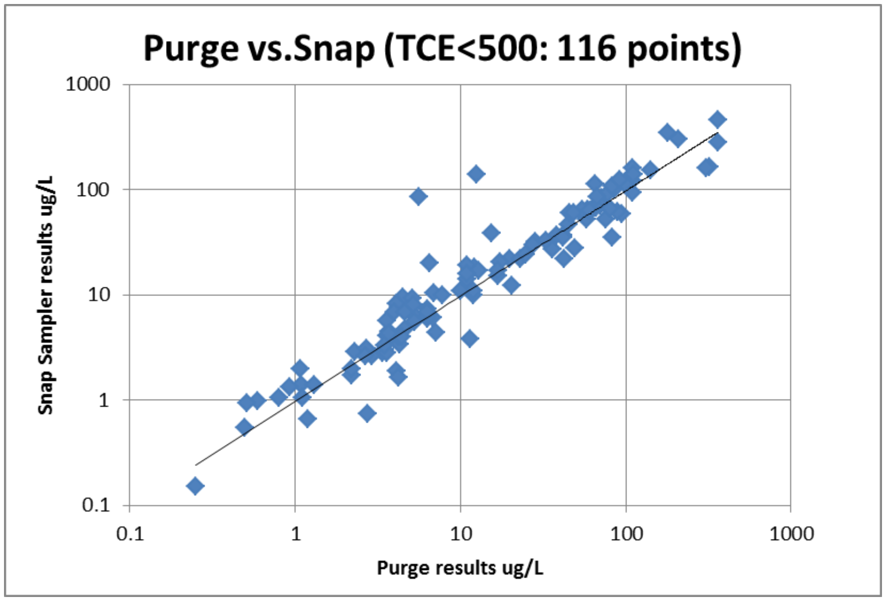
- *<u>Polyethylene Diffusion Sampler</u>*
  - *USGS Reports*
  - *US Air Force Reports*
  - *Peer-reviewed lit.*

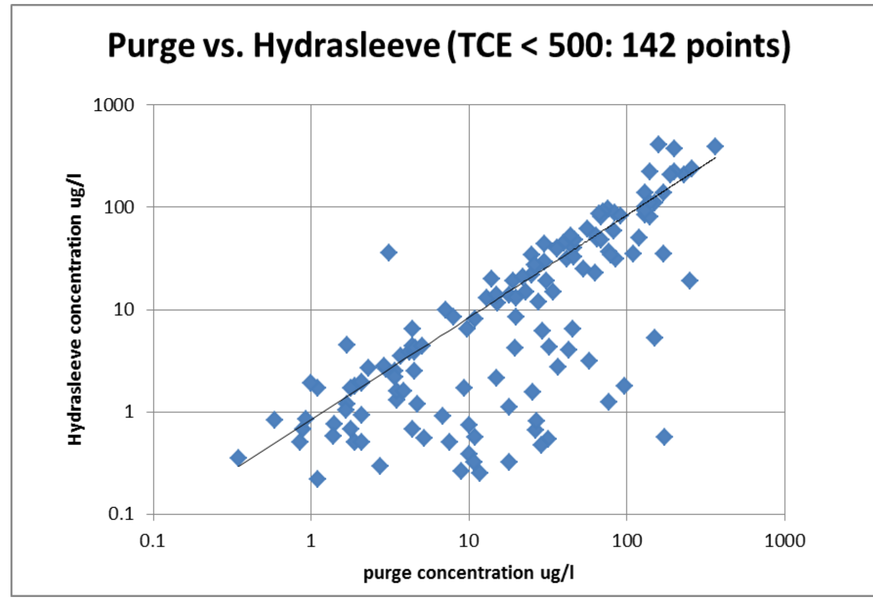
- *<u>Regenerated Cellulose Diffusion Sampler</u>*
  - ER-200313
  - 4 Reports by NAVFAC
  - *Peer-reviewed lit.*

- *<u>Snap Sampler</u>*
  - ER-200603
  - 5 Reports by Army Corps ERDC/CRREL
  - *Peer-reviewed lit.*

- *<u>Gore Module (AGI Sampler)</u>*
  - ER-200921
  - 2010 ESTCP Start

Snap Sampler Data Comparison





Snap Sampler 2x higher: 6 (5%)

Purge sample 2x higher: 5 (4%)

Snap Sampler 10x higher: 2 (2%)

Purge sample 10x higher: 0 (0%)

HydraSleeve 2x higher: 3 (2%)

Purge sample 2x higher: 53 (37%)

HS 10x higher: 1 (<1%)

Purge 10x higher: 22 (15%)

Zumbro, M., 2014, Performance Comparison of No-Purge Samplers for Long-Term Monitoring of a Chlorinated Solvent Plume, Battelle Recalcitrant Compounds Conference, Monterey California, May 2014, Abstract E-062

Regulatory guides ….

Designation: D7929 – 14

INTERNATIONAL

Standard Guide for Selection of Passive Techniques for Sampling Groundwater Monitoring Wells[1]

This standard is issued under the fixed designation D7929; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard provides guidance and information on passive sampling techniques for collecting groundwater from monitoring wells. Passive groundwater samplers are able to

oping groundwater monitoring wells in granular aquifers, and D6452 provides a standard guide for purging methods used in groundwater quality investigations. Consult ASTM Standard D6724 for a guide on the installation of direct-push ground-

Recent guide, 2014, applies to "passive" methods only

Snap Sampler, Diffusion, Sorptive

http://www.astm.org/Standards/D7929.htm

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

Technical and Regulatory Guidance

Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater

Early guide from 2007

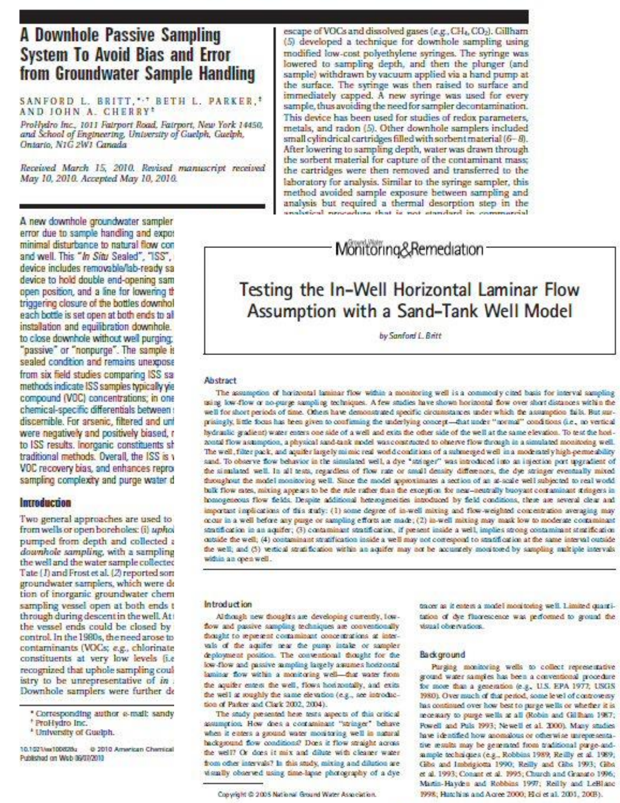
Snap Sampler, Diffusion, Sorptive, Sleeve

http://www.itrcweb.org/Guidance Documents/DSP-5.pdf

Wrap Up

- ***Wells normally flow through***
- ***Passive sampling takes advantage of well flow dynamics***
- ***Results are normally very similar to low flow purging***
- ***Several methods and approaches***
  - ***diffusion, grab, sorption***
- ***Cost savings is substantial, waste reduced, sustainability improved***
- ***Regulatory understanding and acceptance is growing***

Reports and Papers are Available….



https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Monitoring/ER-200630/ER-200630/(language)/eng-US