Subsurface Reclamation for an ICP Oil Shale Project

Colorado School of Mines

Colorado Energy Research Institute

31st Oil Shale Symposium

October 17-19, 2011

Erik Hansen[1], Michael Day[2], John Hardaway[3], and Gregory Monson[4]

1 – Shell International Exploration & Production, Inc.; 2 – Norwest Corp.; 3 – Independent Consultant; 4 - Shell Exploration & Production Co.

DEFINITIONS AND CAUTIONARY NOTE

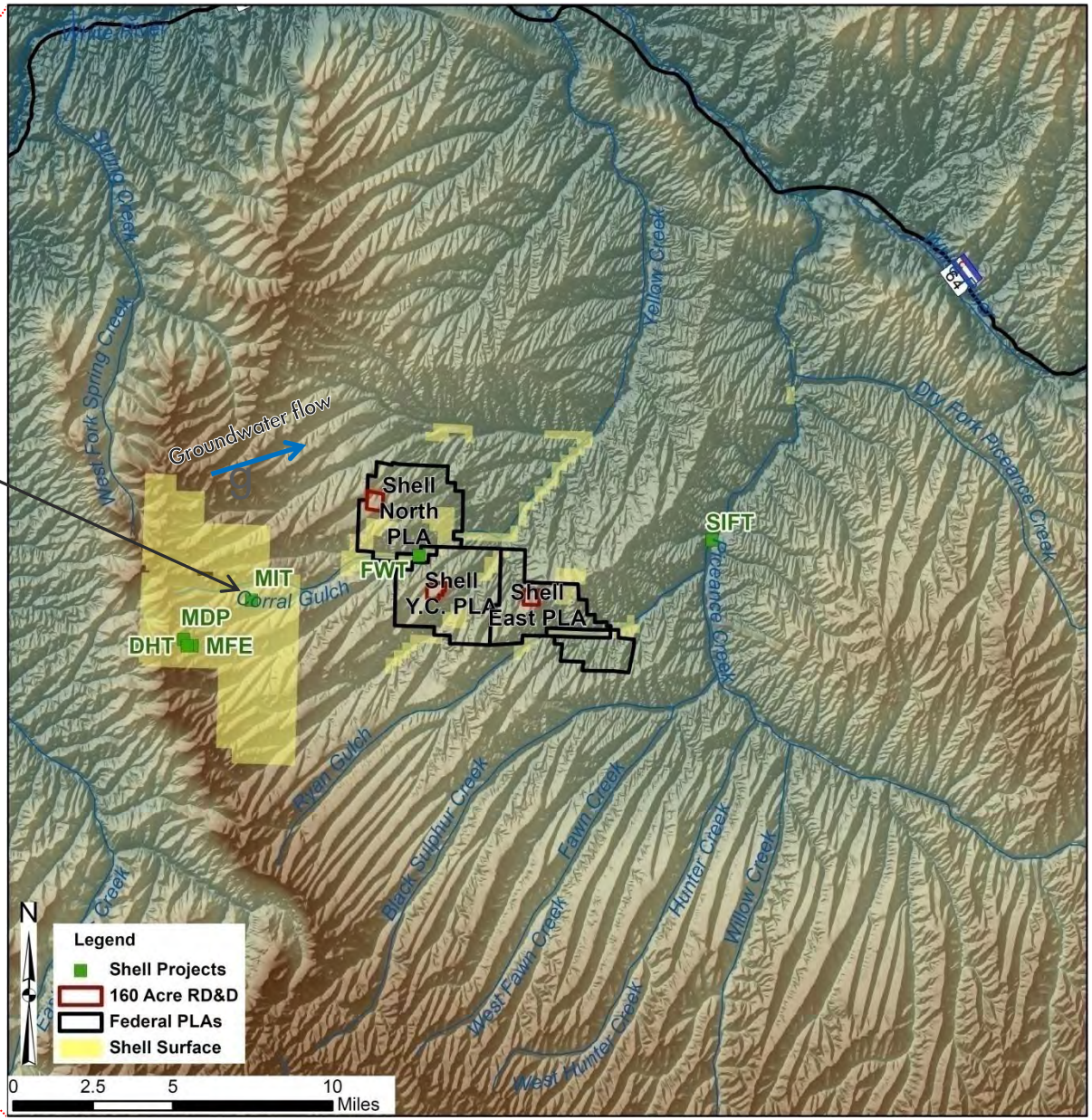
- The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this presentation "Shell", "Shell group" and "Royal Dutch Shell" are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. ''Subsidiaries'', "Shell subsidiaries" and "Shell companies" as used in this presentation refer to companies in which Royal Dutch Shell either directly or indirectly has control, by having either a majority of the voting rights or the right to exercise a controlling influence. The companies in which Shell has significant influence but not control are referred to as "associated companies" or "associates" and companies in which Shell has joint control are referred to as "jointly controlled entities". In this presentation, associates and jointly controlled entities are also referred to as "equity-accounted investments". The term "Shell interest" is used for convenience to indicate the direct and/or indirect (for example, through our 24% shareholding in Woodside Petroleum Ltd.) ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.
- This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''intend'', ''may'', ''plan'', ''objectives'', ''outlook'', ''probably'', ''project'', ''will'', ''seek'', ''target'', ''risks'', ''goals'', ''should'' and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including potential litigation and regulatory measures as a result of climate changes; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional factors that may affect future results are contained in Royal Dutch Shell's 20-F for the year ended 31 December, 2010 (available at www.shell.com/investor and www.sec.gov). These factors also should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation, 18 October 2011. Neither Royal Dutch Shell nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation. There can be no assurance that dividend payments will match or exceed those set out in this presentation in the future, or that they will be made at all.
- We use certain terms in this presentation, such as discovery potential, that the United States Securities and Exchange Commission (SEC) guidelines strictly prohibit us from including in filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain these forms from the SEC by calling 1-800-SEC-0330.

Contents

- Introduction
- Overview of Shell's Mahogany Isolation Test (MIT) project
  - In Situ Conversion Process (ICP) / Freeze wall overview
  - Project main phases
- Baseline groundwater quality
- ICP-generated or increased residuals
- Active reclamation of groundwater
- Monitoring ICP residuals transport and attenuation

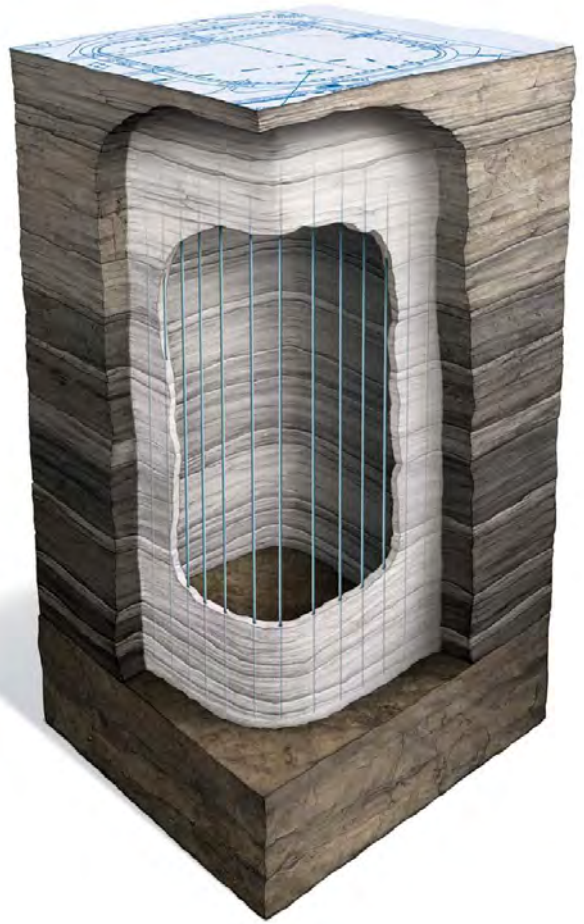
MIT Location

- On Shell fee property
  - NW Piceance Basin
- Groundwater gradient to the East-Northeast



The Objectives for the MIT

- Demonstrate frozen barrier technology (i.e., Freeze Wall) by using a life cycle approach
  - Create barrier (Freeze Wall)
  - Empty water inside/test Freeze Wall
  - Use in-situ heating to pyrolyze oil shale and produce hydrocarbons
  - Extract the hydrocarbons
  - Reclaim the project



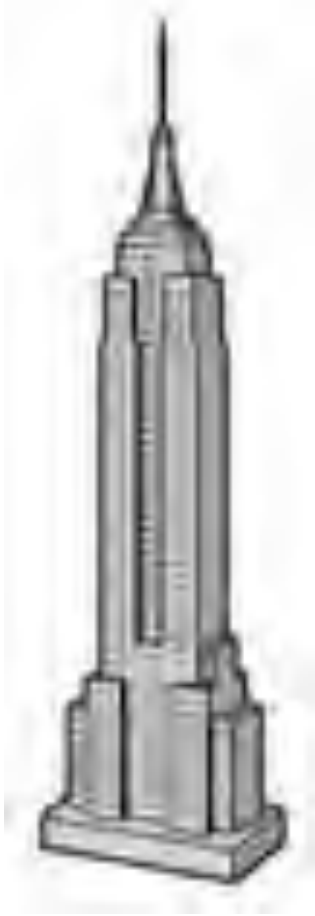
MIT Main Phases Timeline and Facts

Timeline

- Feb 2002 – Drilling begins
- Sep 2002 – Freezing begins
- May 2003 – Freeze wall formed/tested
- Jun 2003 – Heating begins – pyrolysis & production
- Nov 2003 – Heating ends, active reclamation begins (steam flushing)
- Feb 2004 – Steam flushing ends, water extraction/treatment/injection begins
- Aug 2004 – Active reclamation ends
- Oct 2004 – Permission to melt
- To Date – Monitoring attenuation of ICP residuals

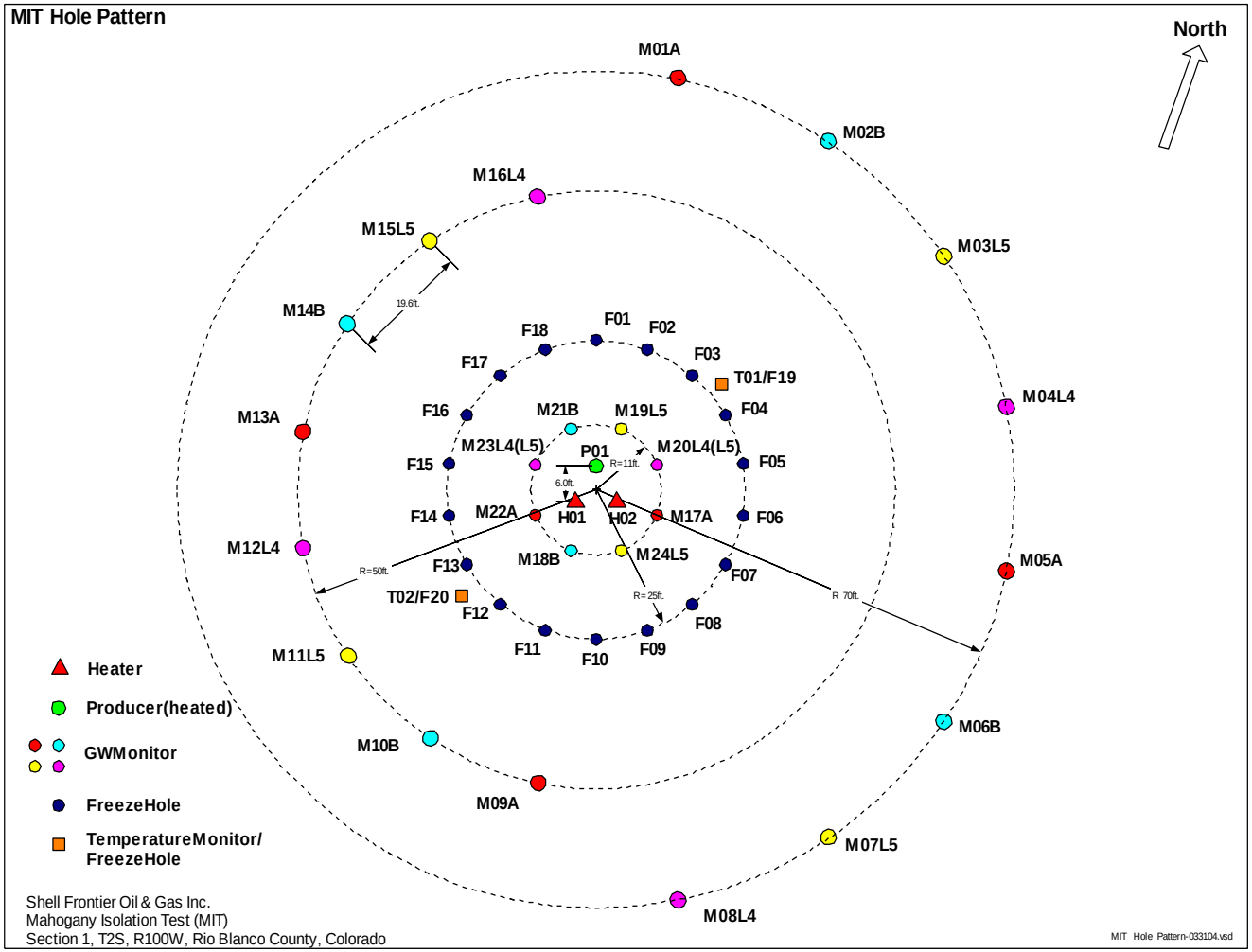
Facts

- Container Dimensions
  - 50 ft diameter
  - 1450 ft deep
    - Empire State Building (1454 ft)
- Volumes
  - Enclosing 712 thousand cubic ft of rock
  - Estimated18.5 thousand gallons of water

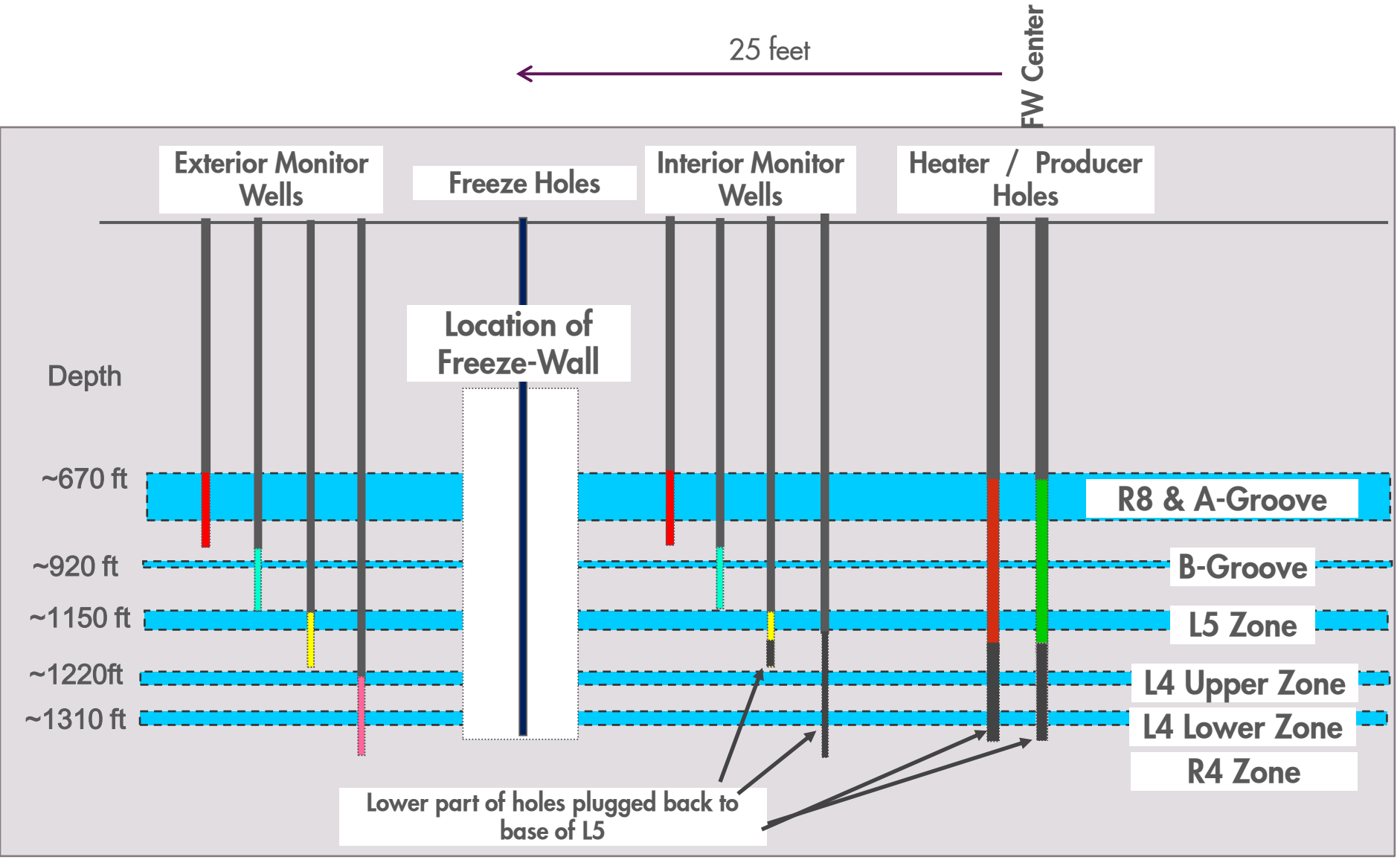


MIT Well Layout – Plan View

- Freeze barrier
- Heaters/Producer
- Monitors
  - Each zone
  - Level, temperature, sample
  - Gradient to east-northeast
  - Monitor all directions to be sure

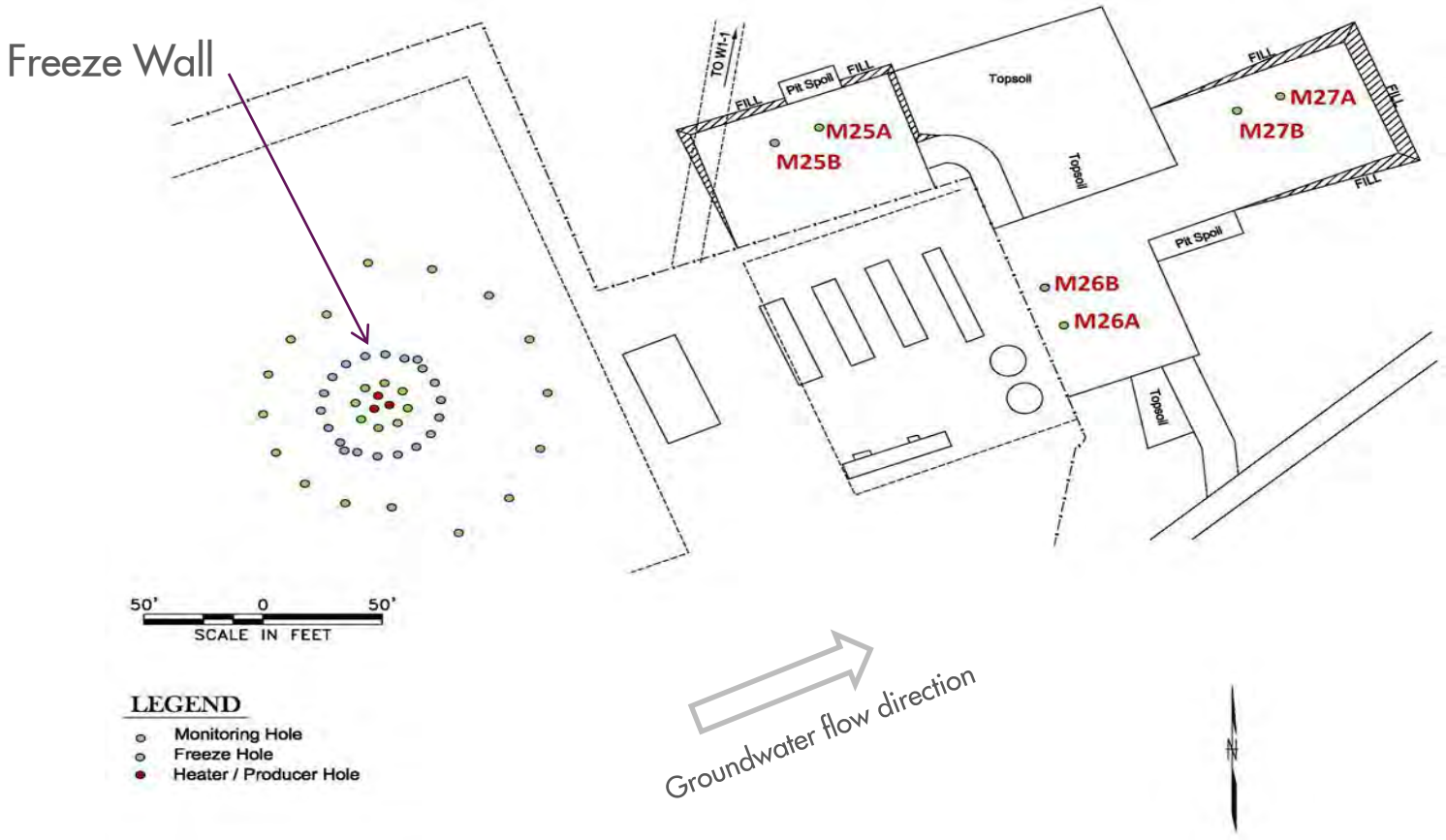


MIT Well Layout - Cross Section

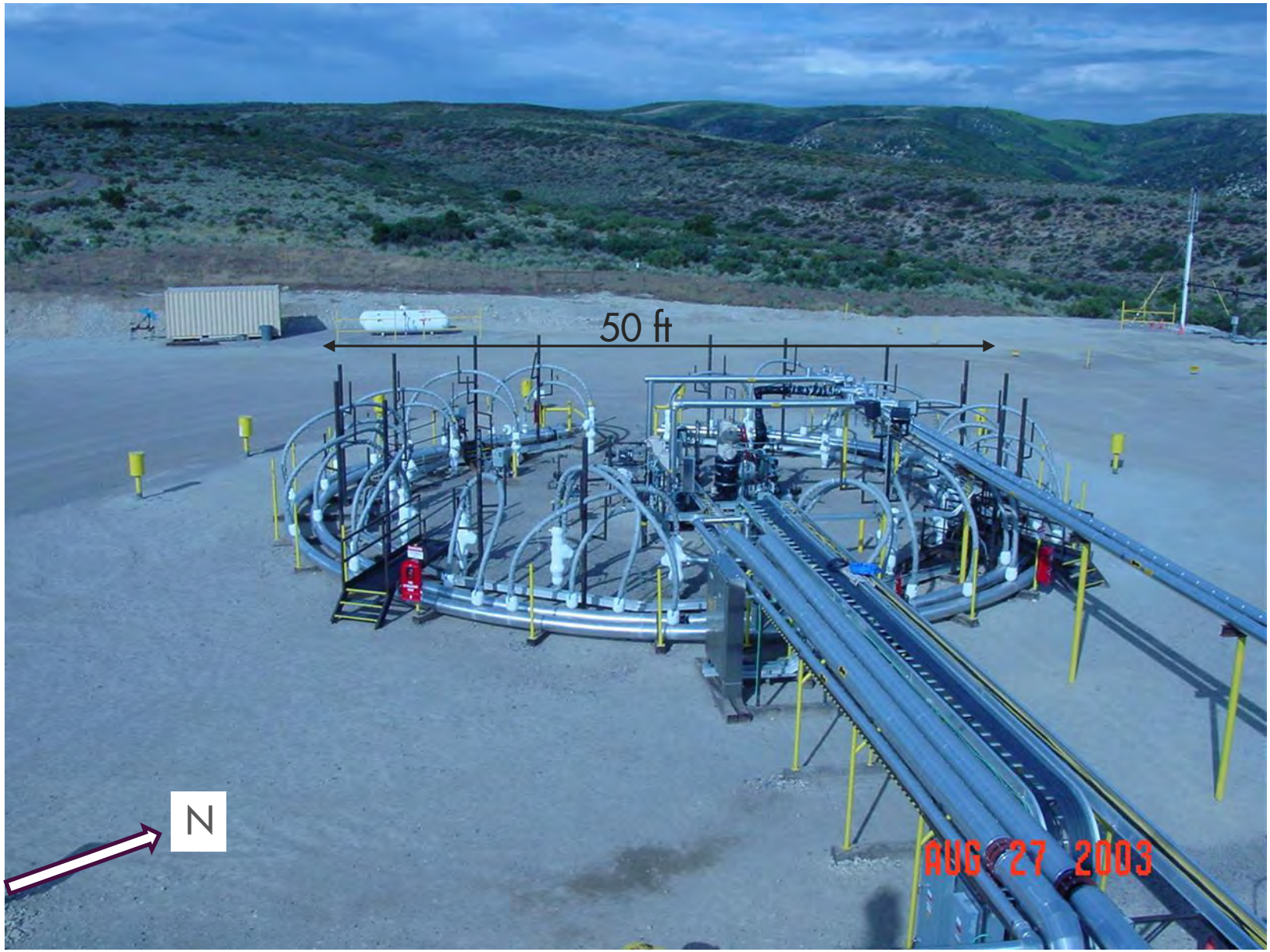


MIT Plot Plan

- Figure shows near-in hole pattern on left and support facilities to right of pattern.
- The six down gradient monitoring wells are spaced from 250 to 400 feet ENE of Test



MIT Site Photo



MIT Baseline Groundwater Quality (2002-3)

- Pre-heating measurements of ambient water quality in the four major hydrostratigraphic intervals provided baseline groundwater quality
- Existing background quality-85th percentiles. **Bold**=background exceeds table value standard.

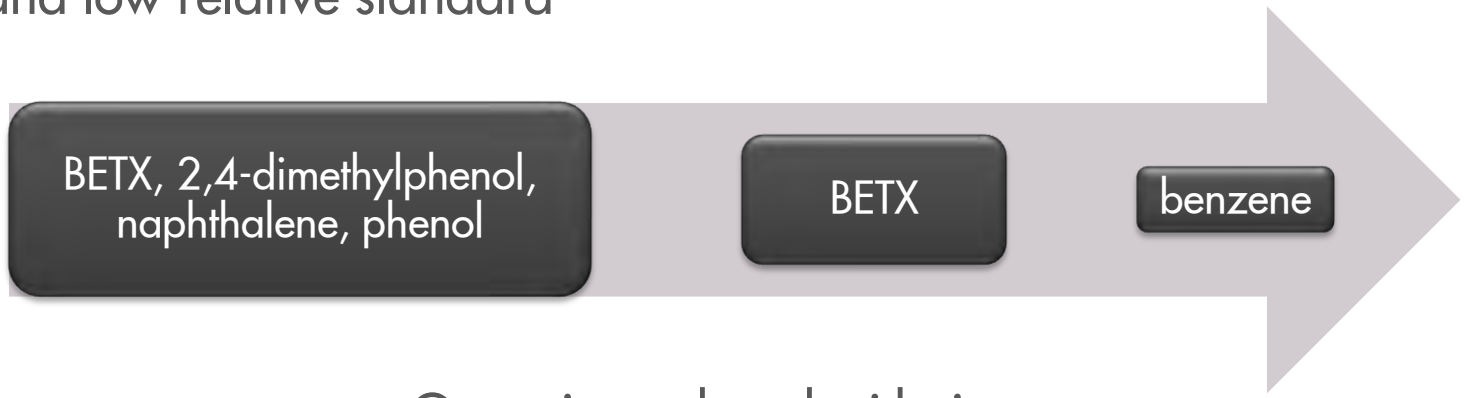
Units: mg/L	TDS	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Carbonate	Chloride	Sulfate	Fluoride	Nitrite + Nitrate	Ammonia
Standards								*250*	*250*	*2 & 4*	*10 & 100*	
A-Groove	988	102.59	53.32	187.45	1.60	445	0	15	**350**	1.08	0	0.87
B-Groove	707	21.75	17.98	181.95	1.88	346	10	7	160	1.80	0	1.28
L5	1005	39.12	41.91	240.50	2.96	435	24	13	290	1.28	0	1.14
L4	3601	45.00	29.52	1255.40	3.28	2146	512	**330**	220	**68.95**	0	4.13

Units: mg/L	Phosphorous	Arsenic	Beryllium	Boron	Cadmium	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Zinc
Standards		0.01 to 0.1	0.004 to 0.1	*5*	0.005 to 0.01	0.3 to 5	0.05 & 0.1	0.05 & 0.2	0.002 & 0.01	0.035	0.1 & 0.2	0.02 & 0.05	2 & 5
A-Groove	0	**0.028**	0	0.31	0	**4.89**	0	**0.091**	0	**0.579**	0	0	0.31
B-Groove	0	0.004	0	0.27	0	**4.14**	0	**0.055**	0	**0.089**	0	0	0.54
L5	0	**0.071**	0	0.23	0	**3.62**	0	**0.065**	0	**0.517**	0	0	1.01
L4	0.14	0.009	0	**10.95**	0	**2.50**	0	0.042	0	**0.119**	0	0	1.42

BTEX Units: µg/L	Benzene	Ethylbenzene	Toluene	Xylenes, Total		pH 85th percentile	pH 15th percentile
Standards	*5*	*700*	*1,000*	*1,400*		*6.5 - 8.5*	*6.5 - 8.5*
A-Groove	0	0	0.59	0		7.89	7.24
B-Groove	0	0	0	0		8.23	7.68
L5	0	0	0	0		8.48	7.89
L4	2.28	0	6.99	0		8.42	8.16

Organic analytes Detected During / Shortly After Active Reclamation

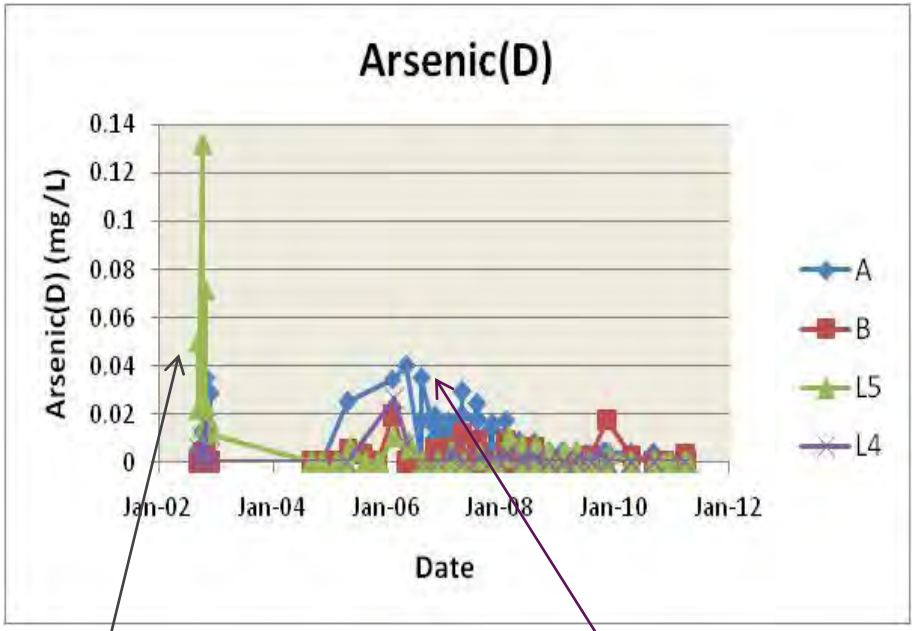
- 94 organic analytes measured (EPA GC/MS methods 8260 /8270)
- 7 regulated organic analytes reliably detected (not a lab/sampling contaminant or false positive prior to active reclamation):
  - 2,4-dimethylphenol, benzene, ethylbenzene, naphthalene, phenol, toluene, and xylenes
- Today, after further natural attenuation/decay, only 4 detected:
  - benzene, ethylbenzene, toluene, and xylenes (BETX)
- Benzene is the indicator analyte (surrogate) due to mobility/solubility and low relative standard

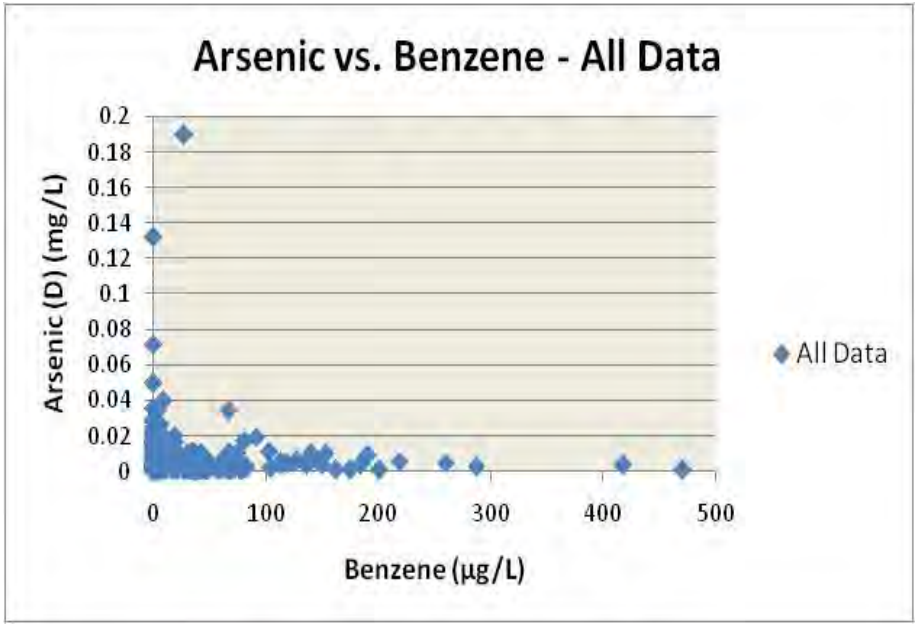


Organics reduced with time

Inorganics

- Pyrolysis did not increase the concentrations of the regulated inorganic analytes above background
  - May be due to project small scale and resulting mixing within freeze wall cylinder
- As an example, neither temporal plots for arsenic and boron nor bivariate plots of benzene/arsenic and benzene/boron show indications of a pyrolysis-related increase in the heated interval



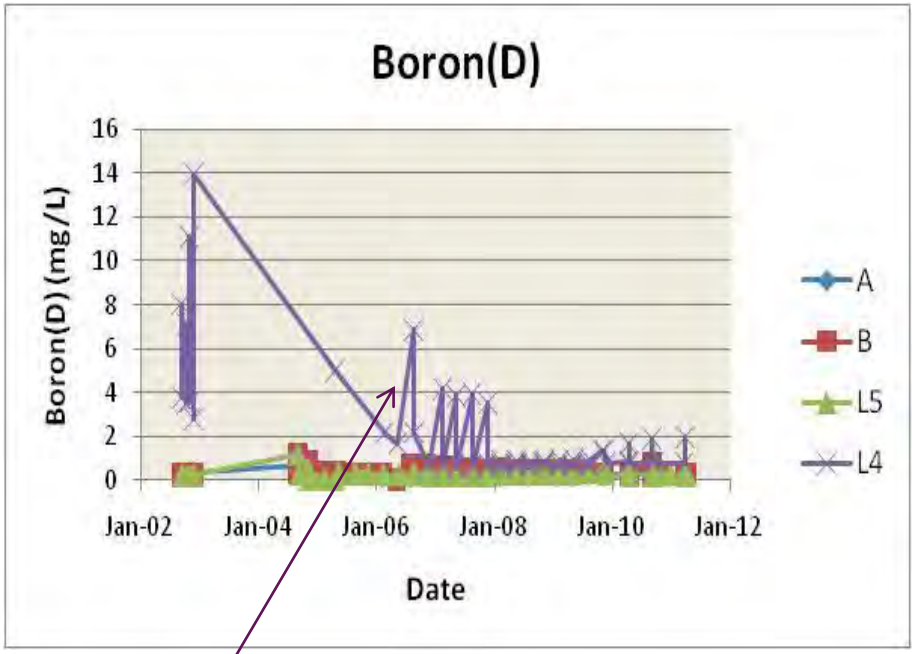


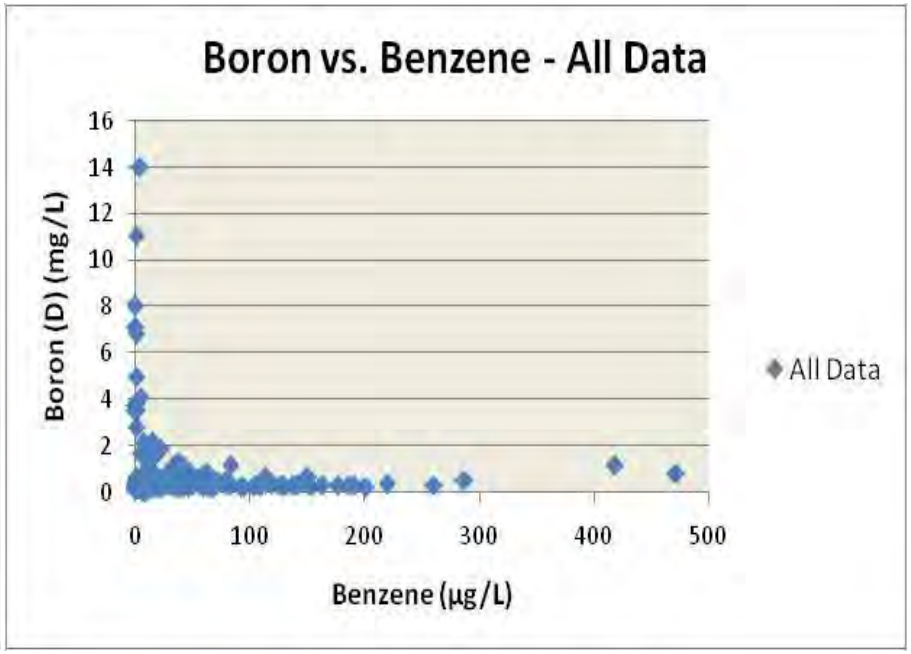
2002 "spikes" during background sampling prior to heating

Single upgradient point; equal to background

Inorganics - continued

- Boron example



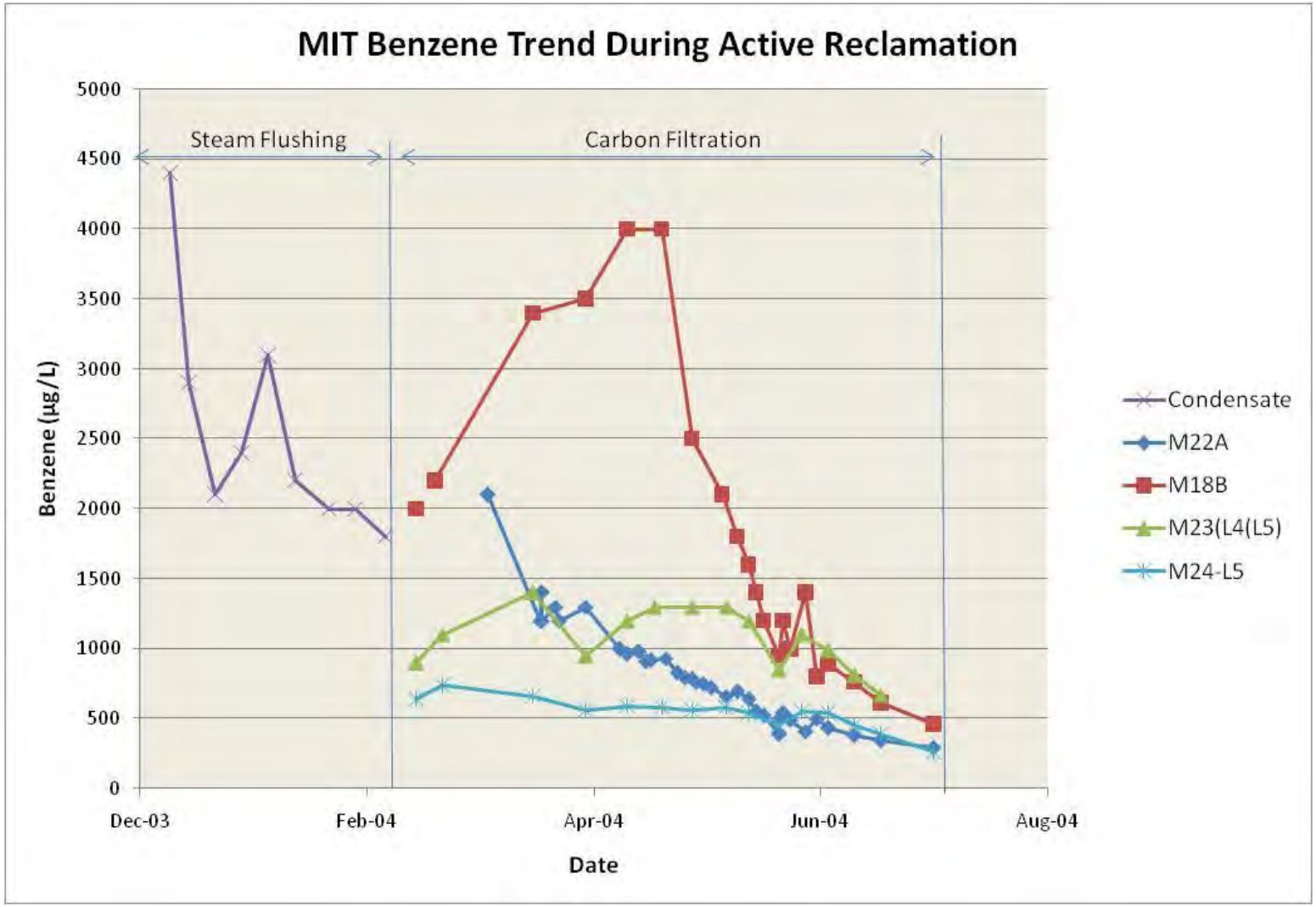


Single L4 point;
not heated.

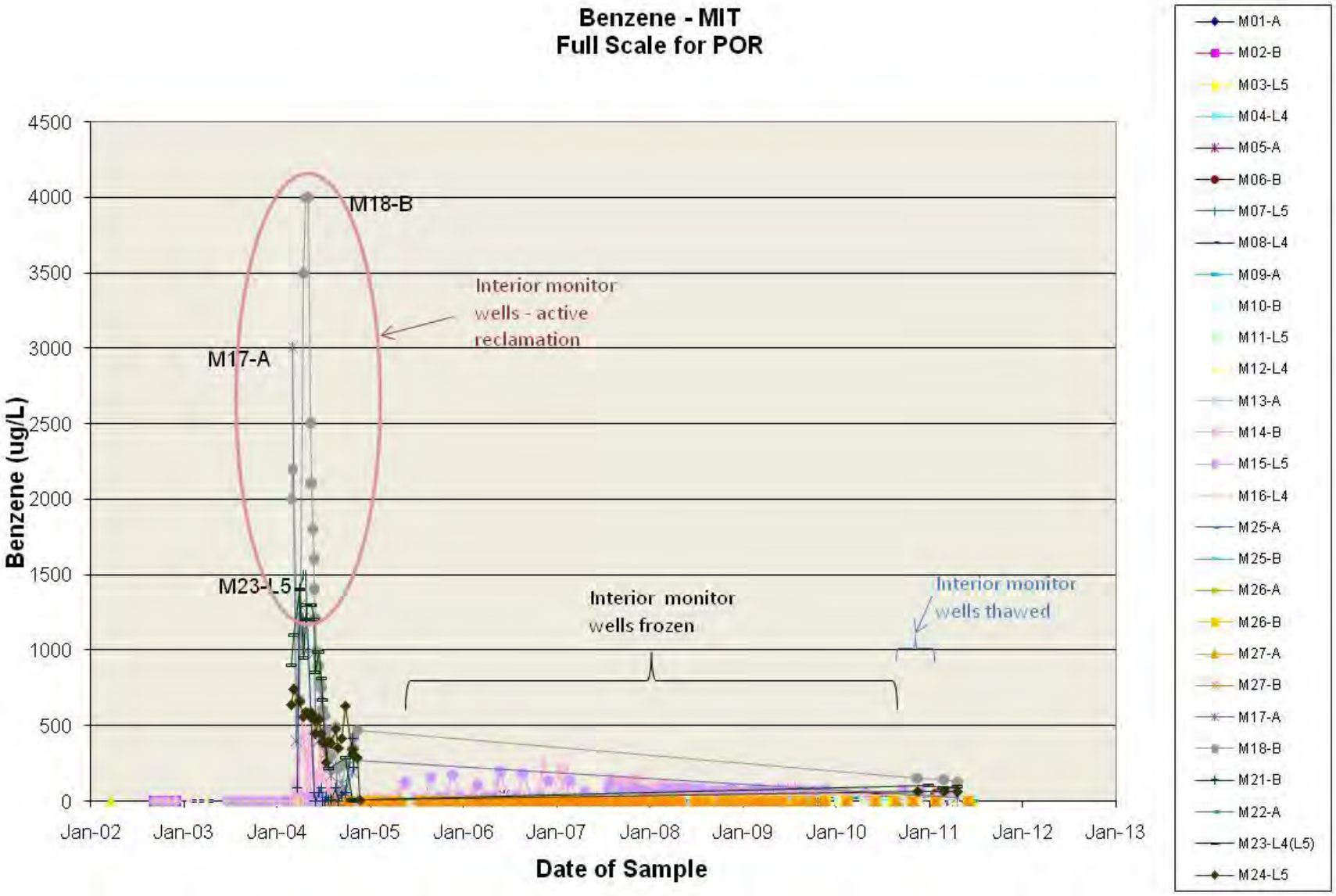
MIT Groundwater Reclamation

- Objectives
  - Pyrolysis sufficient for credible reclamation demonstration
  - Evaluate subsurface impacts
  - Reclaim to meet regulations
- Steam flushing phase:
  - Inject water
  - Hot rocks turns water to steam
  - Steam and BTEX recovered
- Water recirculation phase
  - Extract, treat, reinject
  - Reduced ICP residuals to a level that allowed the freeze wall to be melted
- Continue groundwater monitoring for the attenuation of residuals
- Groundwater transport model projections.

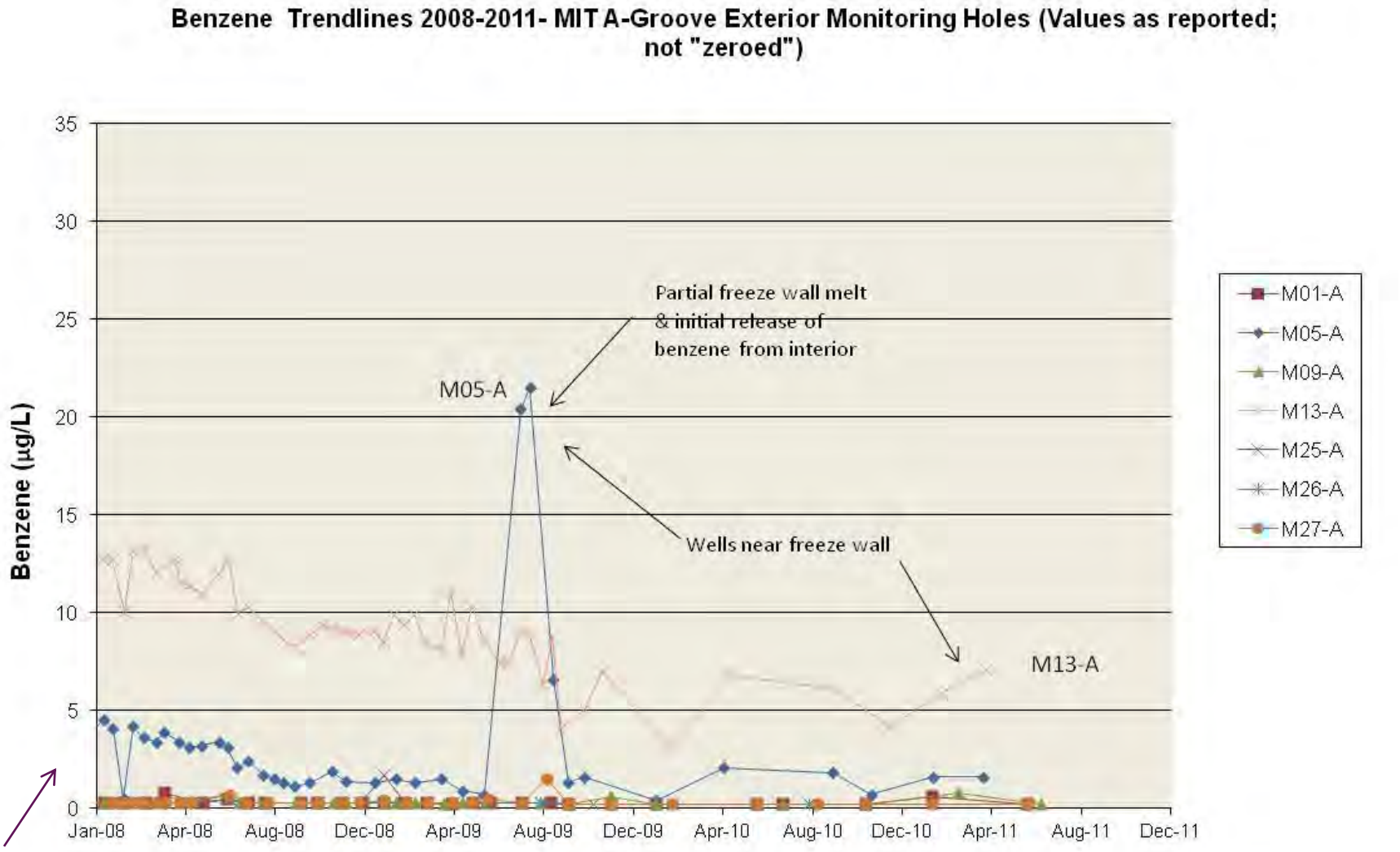
MIT Active Reclamation – Benzene Removal



Benzene in MIT Monitoring Holes



Benzene in A-Groove (most permeable) 2008-present



Note 100-fold increase in benzene scale compared to previous slide.

ICP Residuals Requiring Continuing Reclamation – 2011

- In 2011, the only pyrolysis generated hydrocarbons detected in groundwater are the BETX compounds
  - Only benzene above regulatory standard
  - The benzene migration and attenuation is being monitored and evaluated with a numerical fate and transport model:
    - Tracer test conducted in 2004 to refine solute transport parameters
    - Early (2004) models suggested interior source benzene concentration of 500 µg/L would result in acceptable plume migration length and subsequent attenuation
    - Current 2011 data, post freeze wall thaw, show source concentrations lower at about100 µg/L and plume attenuation distances less than 250 ft to concentrations less than 5 µg/L
    - Attenuation parameters including bio decay rate currently being further refined

MIT Subsurface Reclamation Conclusions

- Hydrocarbons generated; non-hydrocarbons not increased
- Hydrocarbons reduced to desired pre-freeze wall thaw level by active reclamation
- Benzene only hydrocarbon residual left above standards today
- Monitoring confirms migration /attenuation of benzene to below 5 µg/L standard in less than 250 feet in both AG and BG down gradient water bearing zones as of 2011 (heating occurred in late 2003)