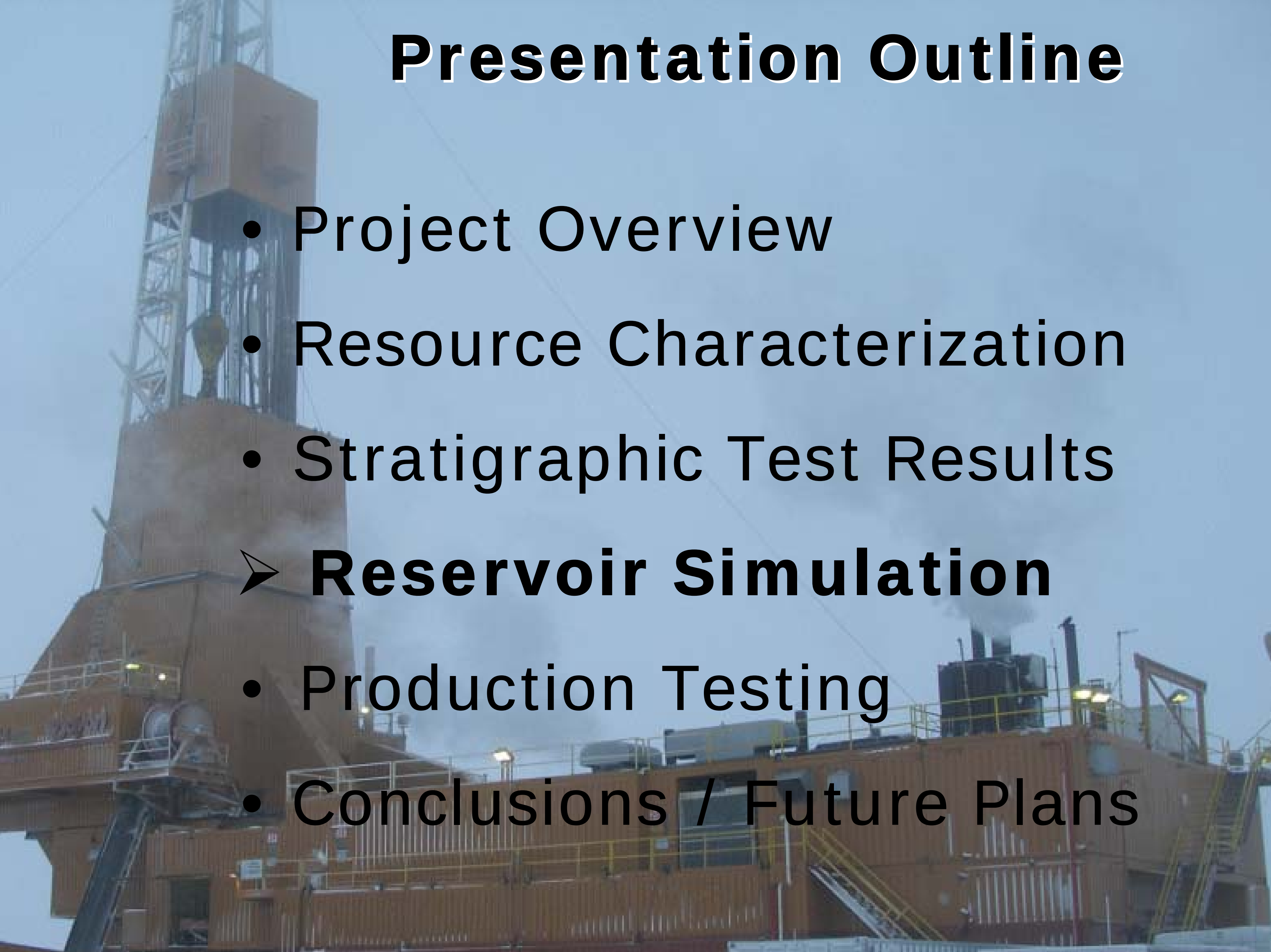
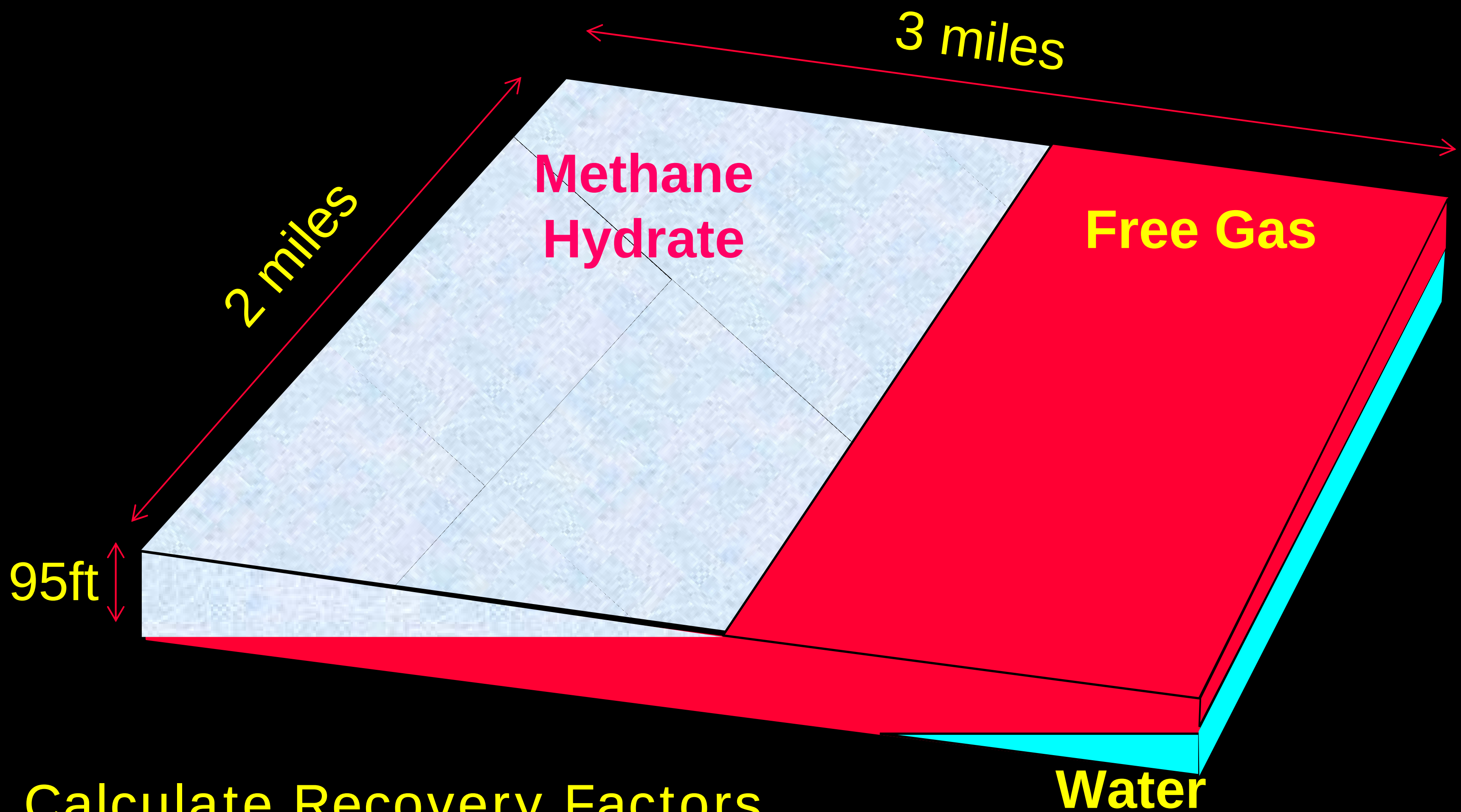


# Presentation Outline

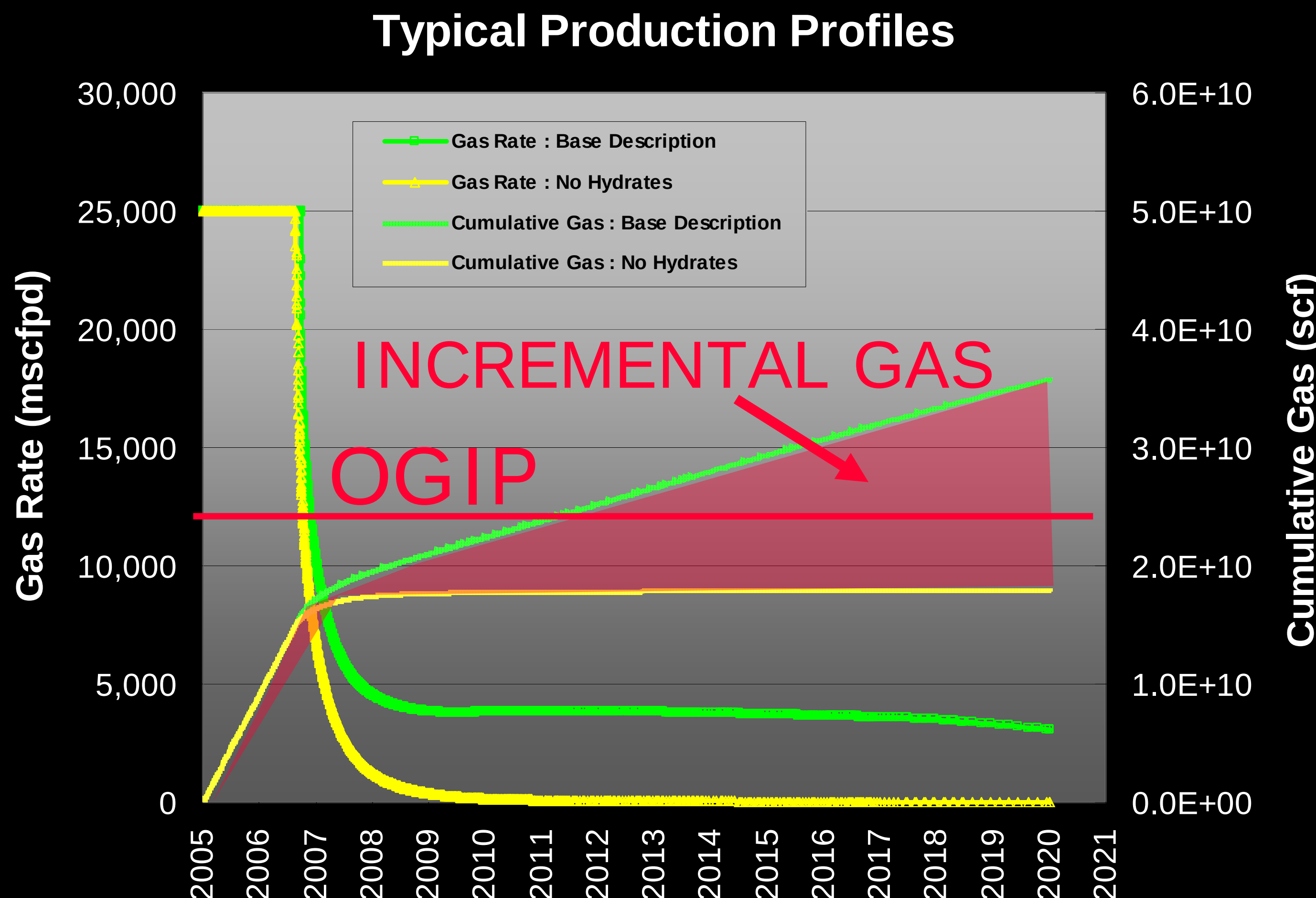
- Project Overview
- Resource Characterization
- Stratigraphic Test Results
- ➢ **Reservoir Simulation**
- Production Testing
- Conclusions / Future Plans

# Schematic Reservoir Model Development Scenario Options



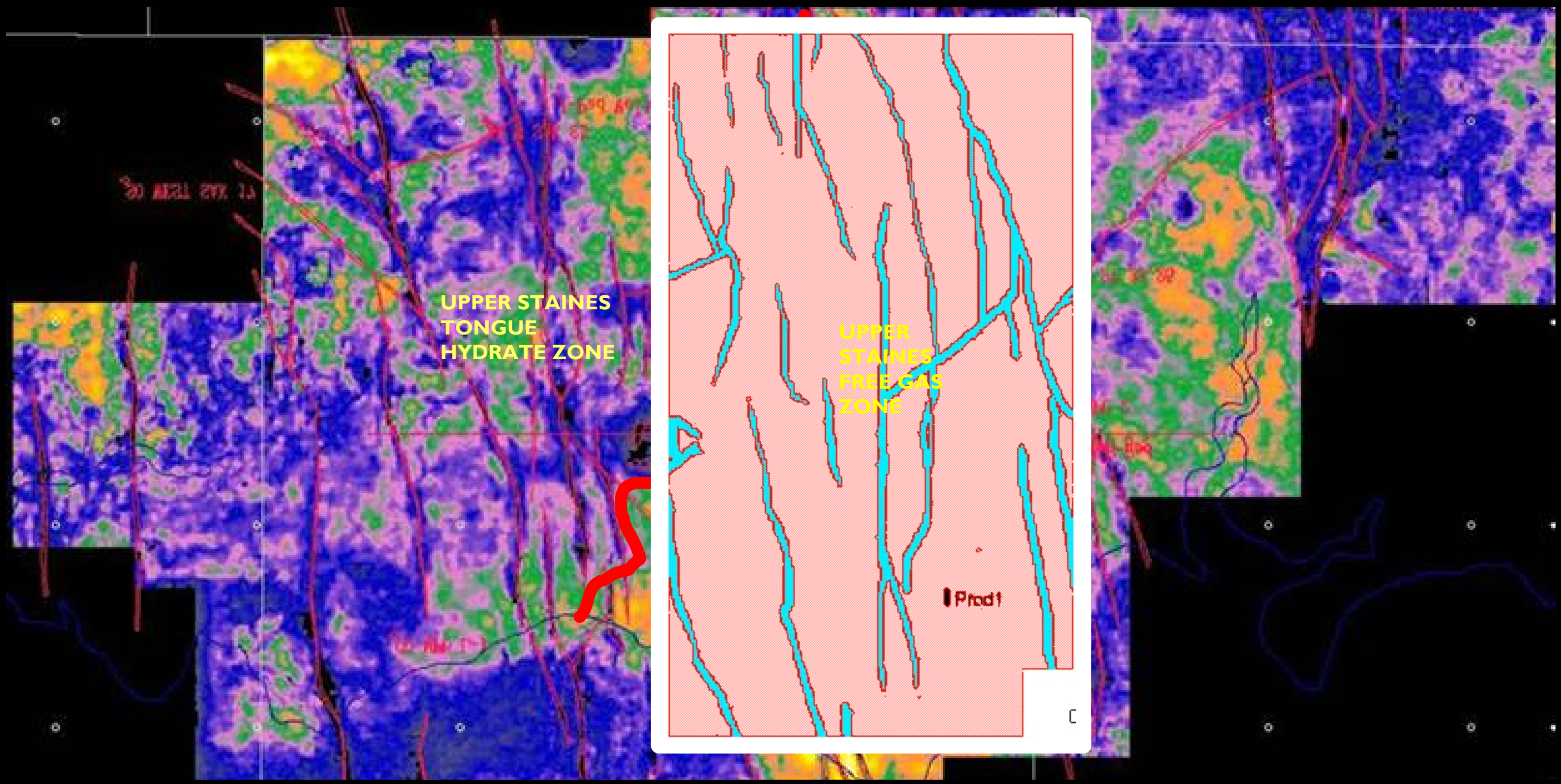

- Calculate Recovery Factors
- Evaluate/Contrast Single/Multiple Methods

# Simple Model: Depressurization Under Hydrate

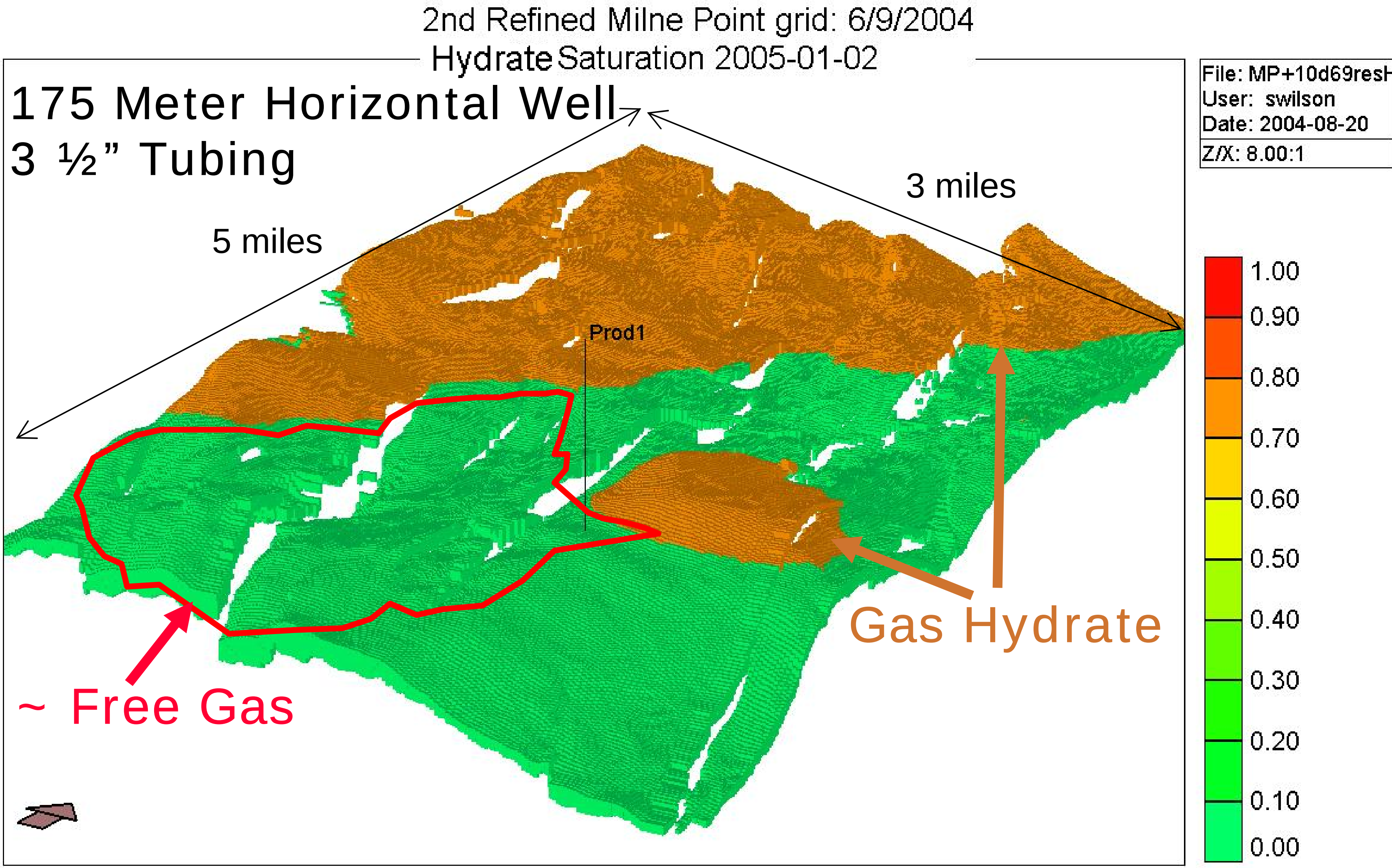



- Significant Production Increase (~2X) due to Free Gas Dissociation from Gas Hydrate
- Significant Uncertainties Remain

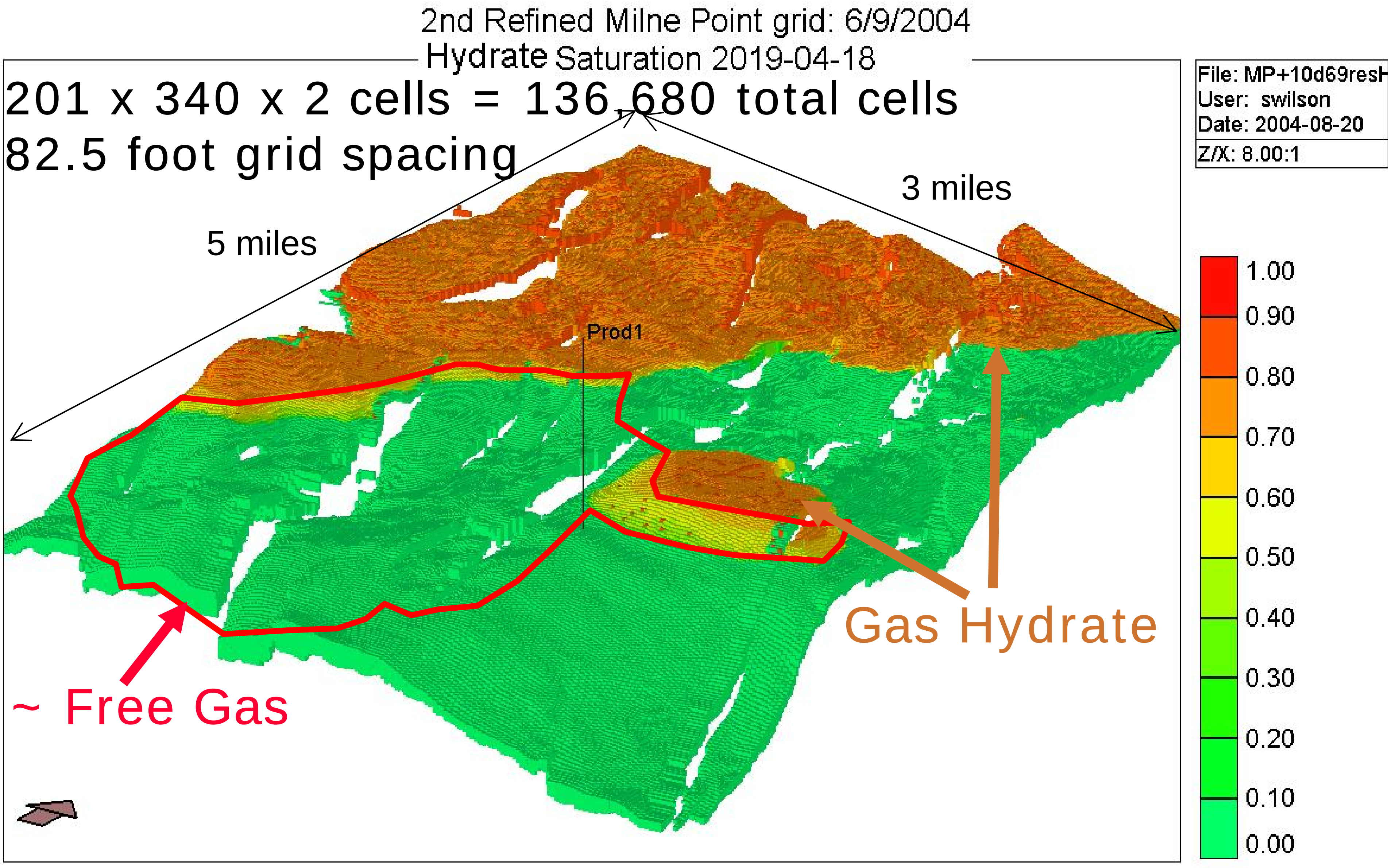
# Geologic Description → Simulation Model

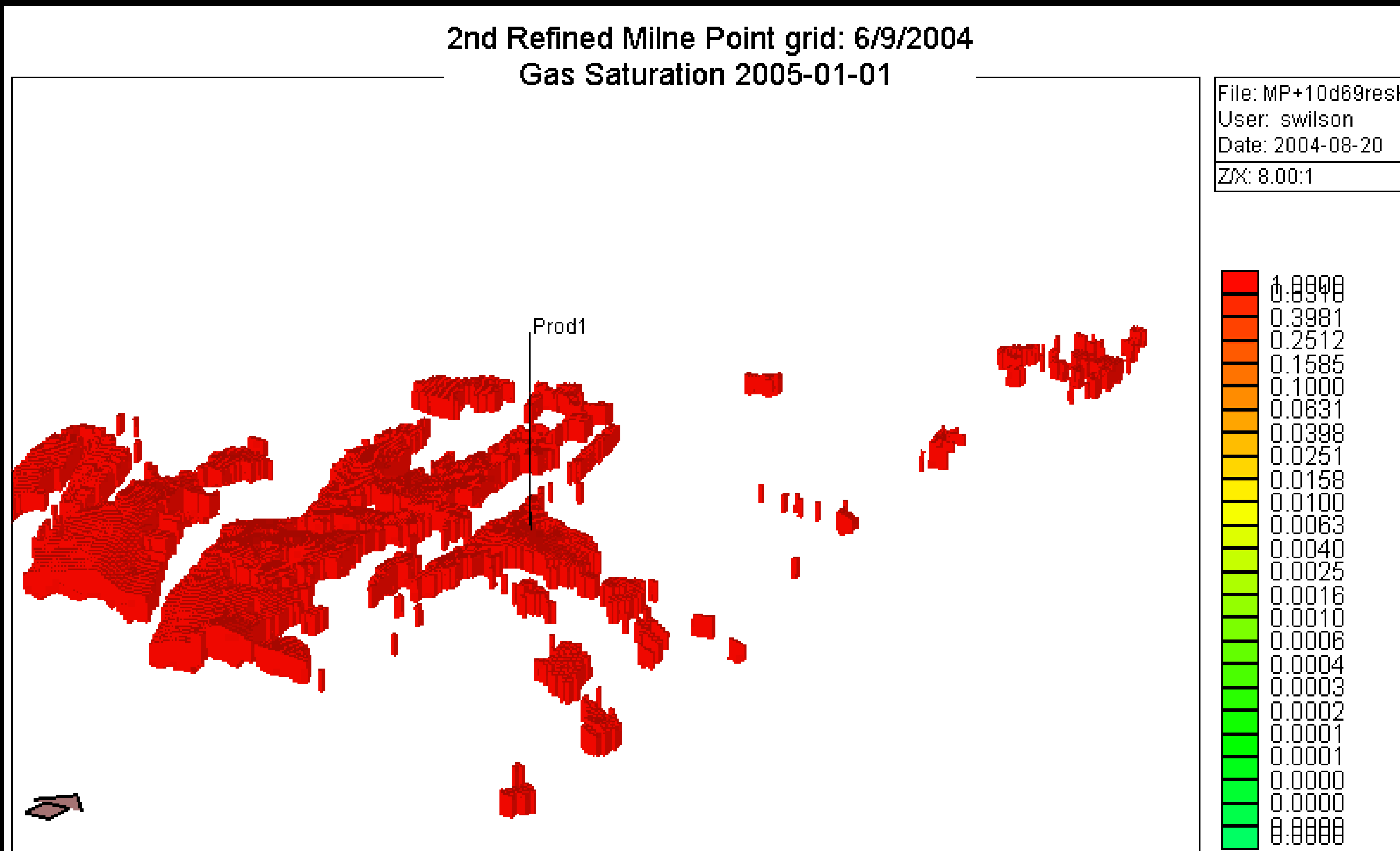


# CMG STARS Reservoir Model Results
# Gas Production & Gas Hydrate Dissociation



# CMG STARS Reservoir Model Results
# Gas Hydrate Dissociation after 15 years

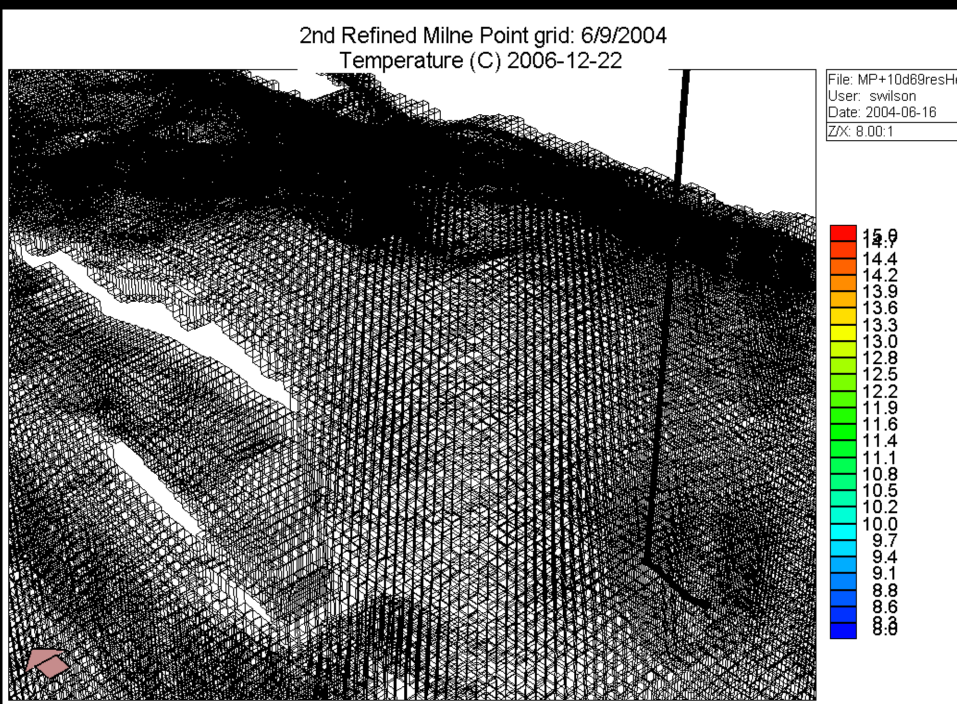


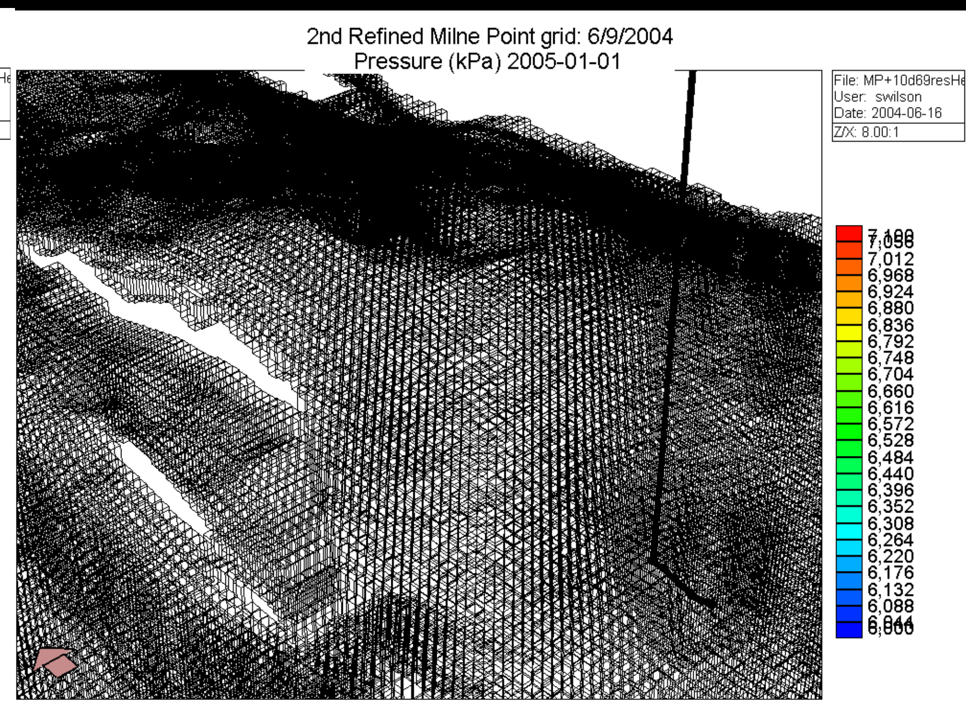

2nd Refined Milne Point grid: 6/9/2004
Gas Saturation 2005-01-01
File: MP+10d69resH
User: swilson
Date: 2004-08-20
Z/X: 8.00:1
Prod1
1.0000
0.3981
0.2512
0.1585
0.1000
0.0631
0.0398
0.0251
0.0158
0.0100
0.0063
0.0040
0.0025
0.0016
0.0010
0.0006
0.0004
0.0003
0.0002
0.0001
0.0001
0.0000
0.0000

# Moving front hydrate dissociation

Reactions at the hydrate/gas interface cause local cooling.

High net pressure is left behind the reaction front

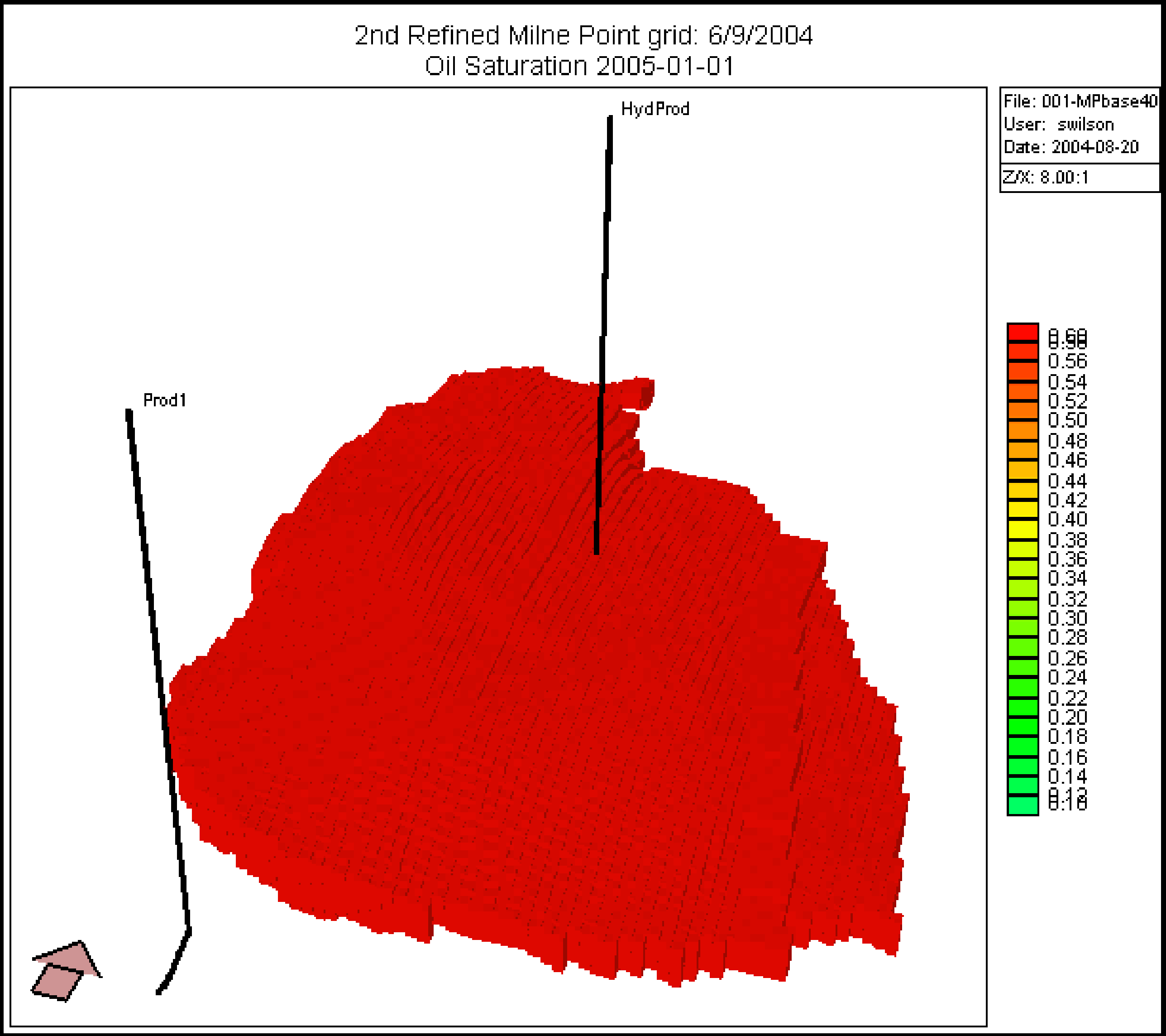


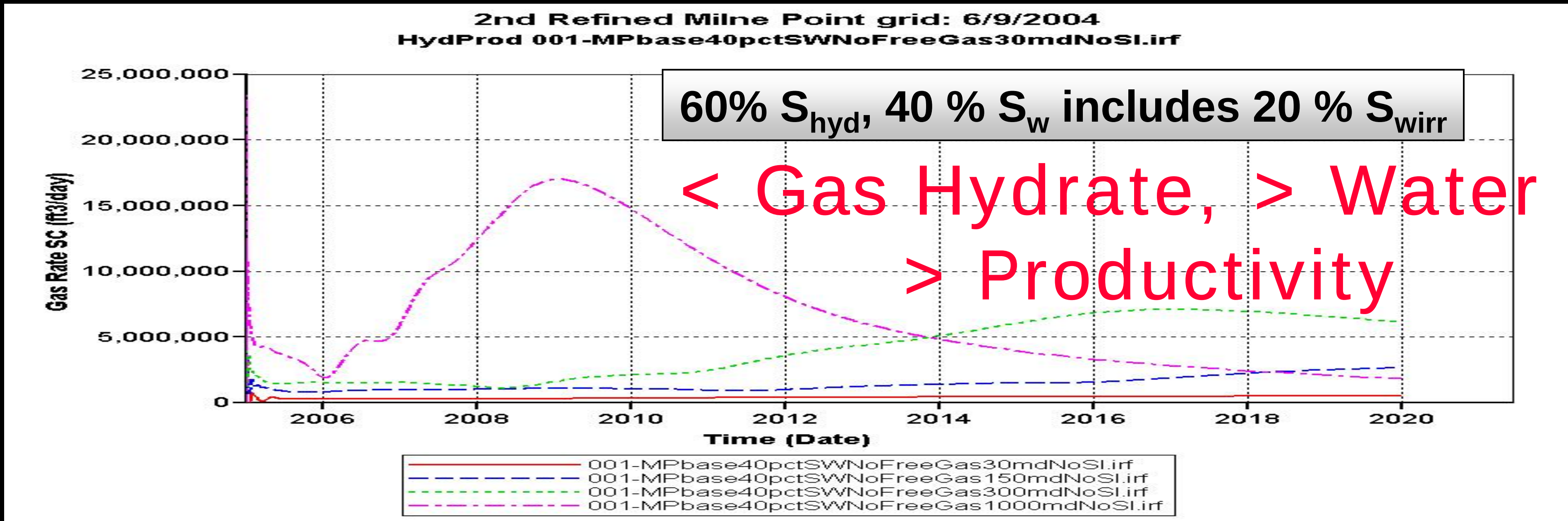
# Intra-Hydrate Production Scenarios

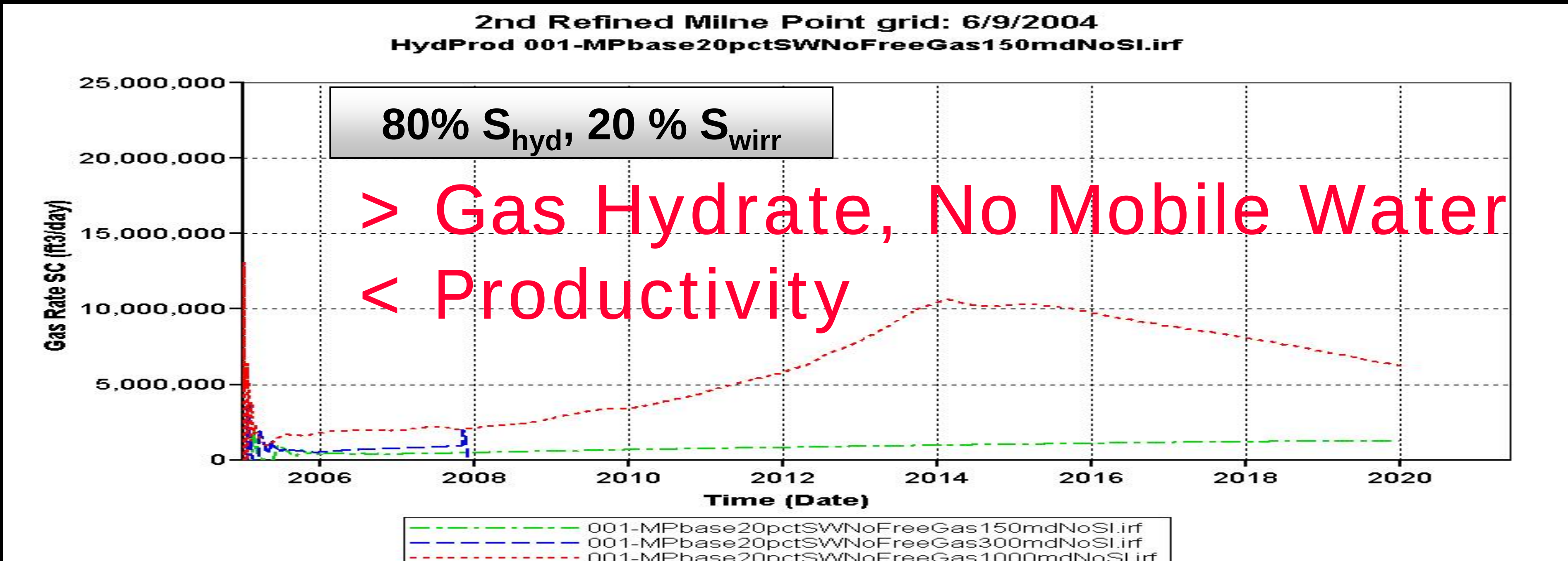
## Well Placement: In Hydrate zone where initial $S_w$ greater than or equal to irreducible $S_w$

- 40 % init $S_w$

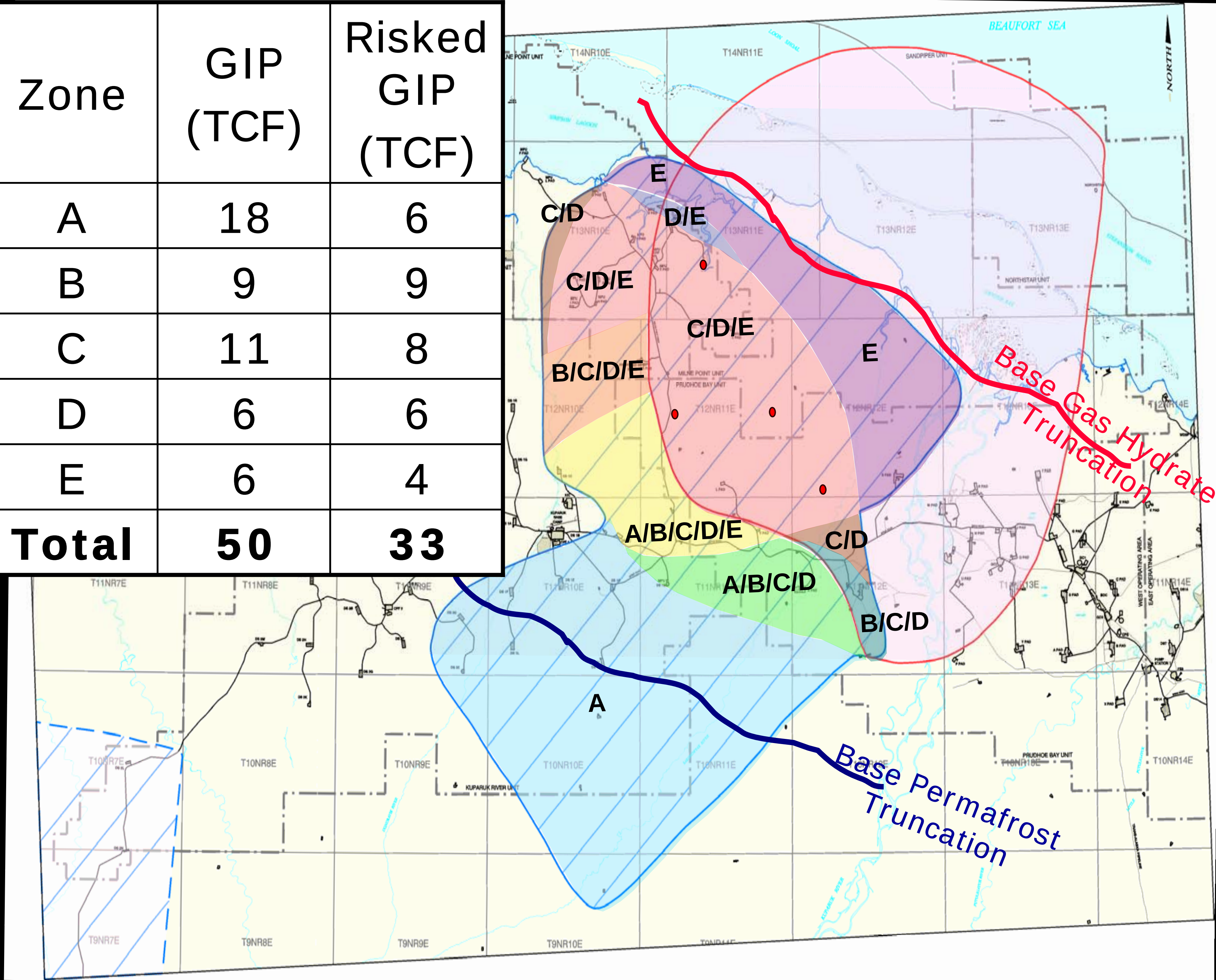


# Intra-Hydrate Production Scenarios

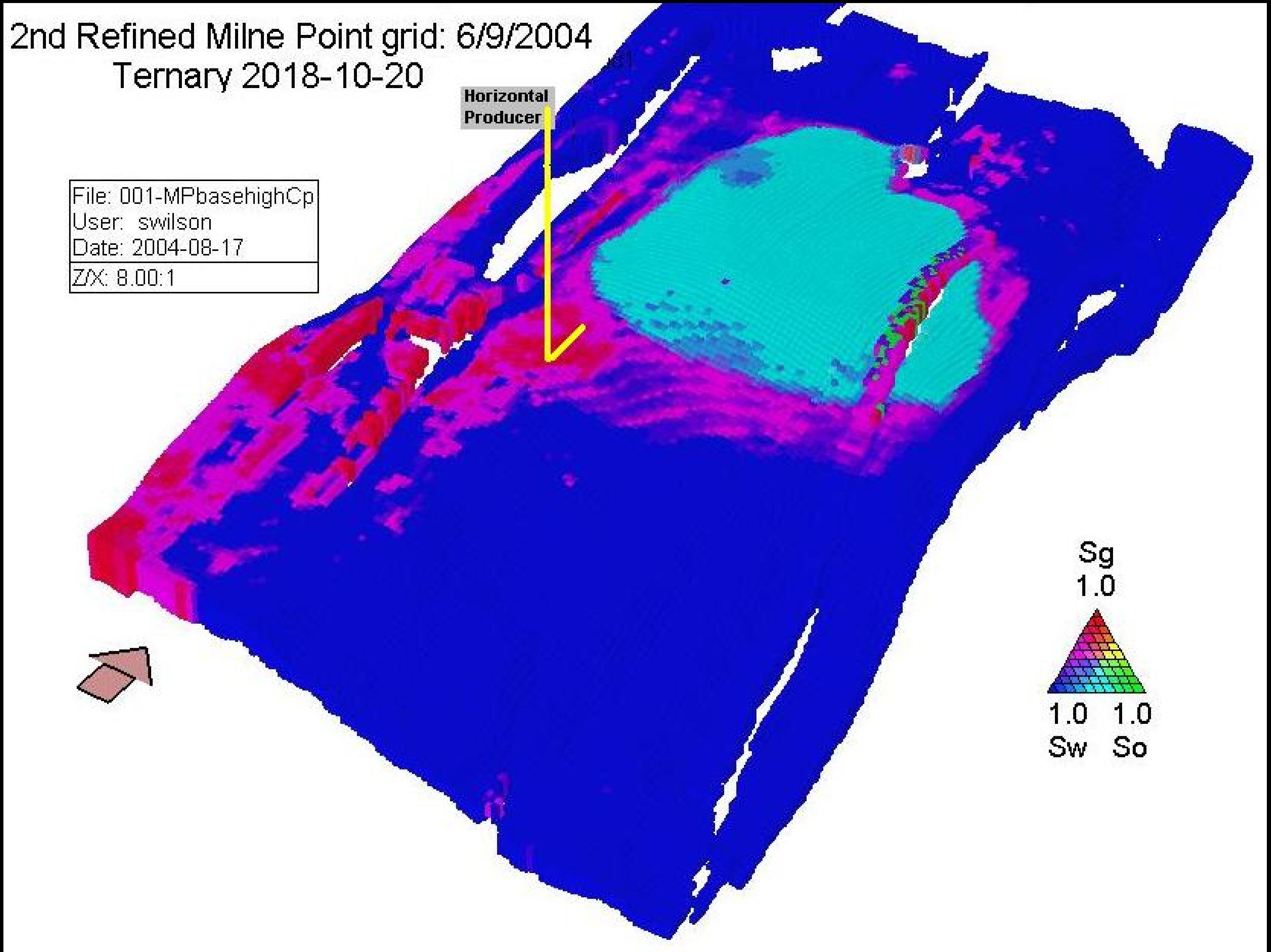


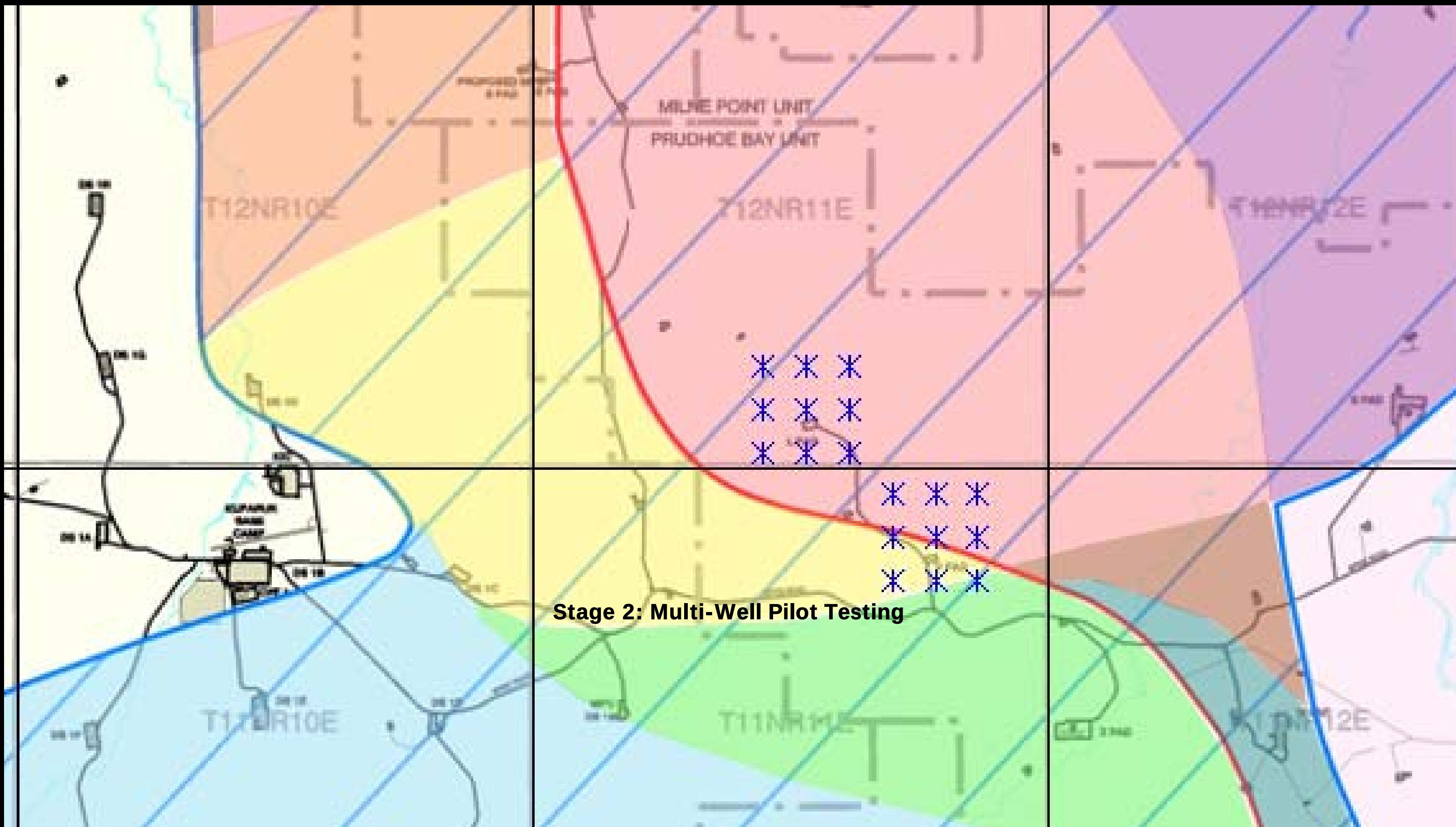
| Zone | GIP (TCF) | Risked GIP (TCF) |
|---|---|---|
| A | 18 | 6 |
| B | 9 | 9 |
| C | 11 | 8 |
| D | 6 | 6 |
| E | 6 | 4 |
| **Total** | **50** | **33** |



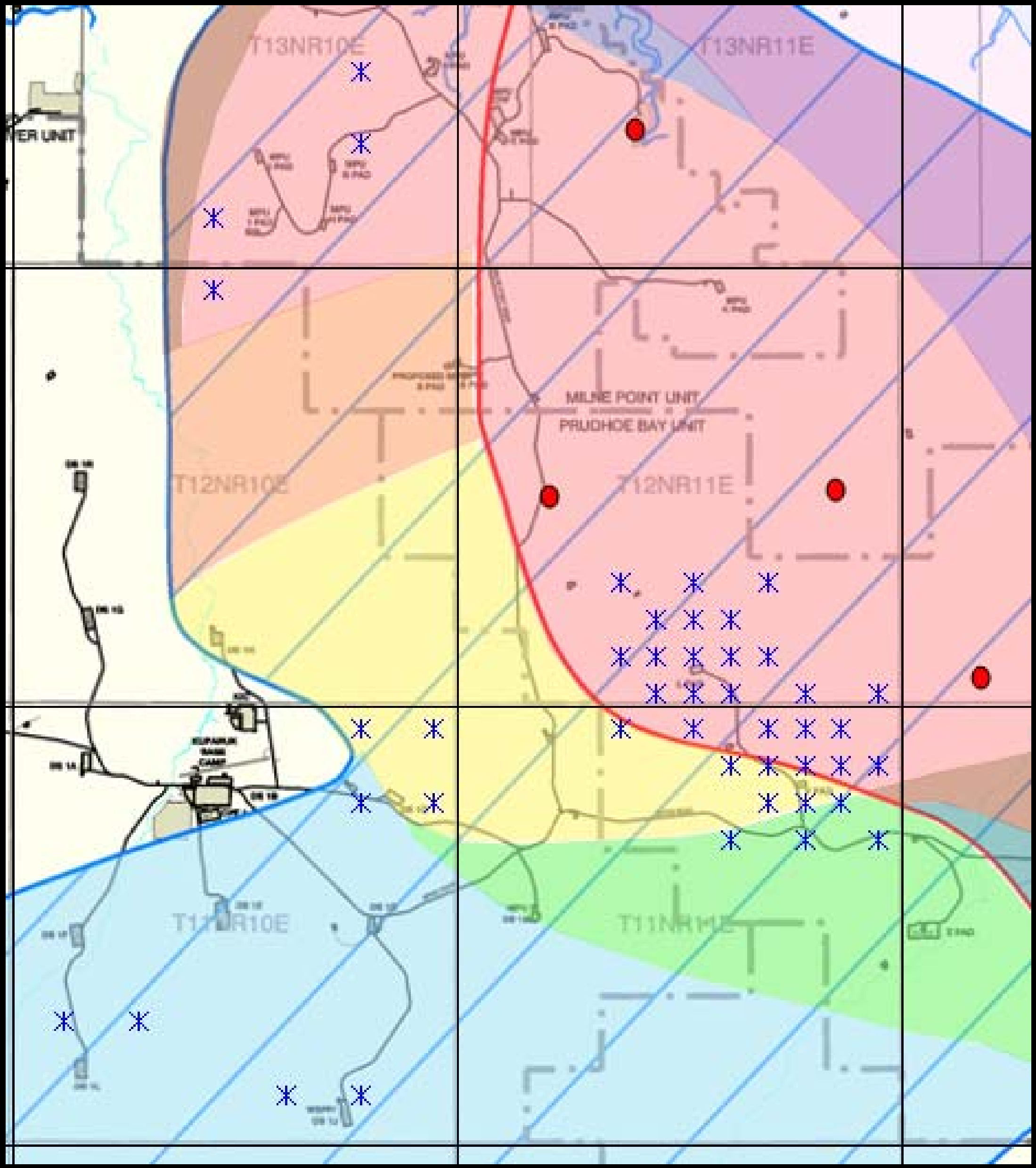
# Stage 1: Single Well Pilot Testing



# Stage 2: Multi-well testing/calibration

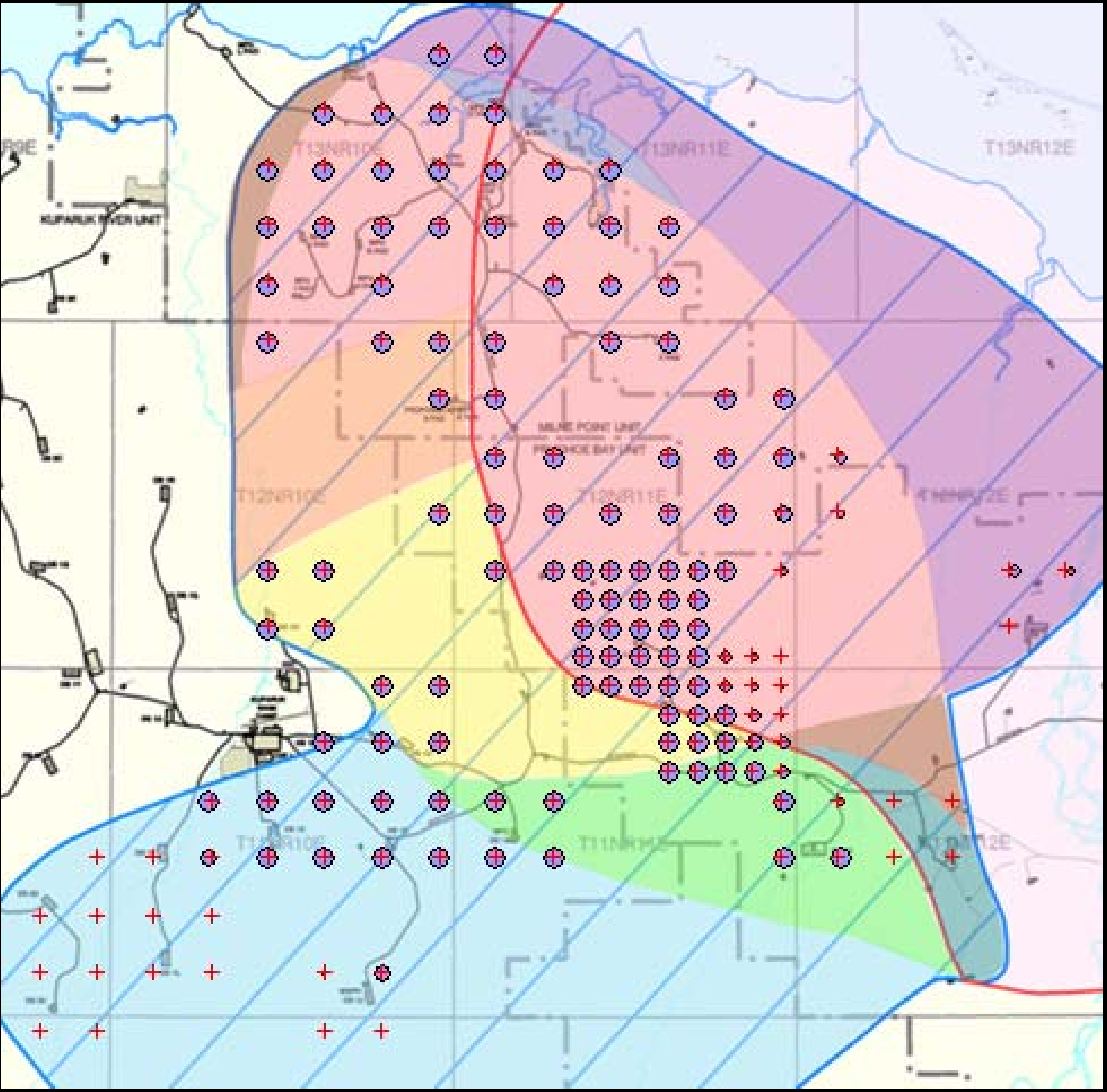


# Stage 3: Limited Initial Development



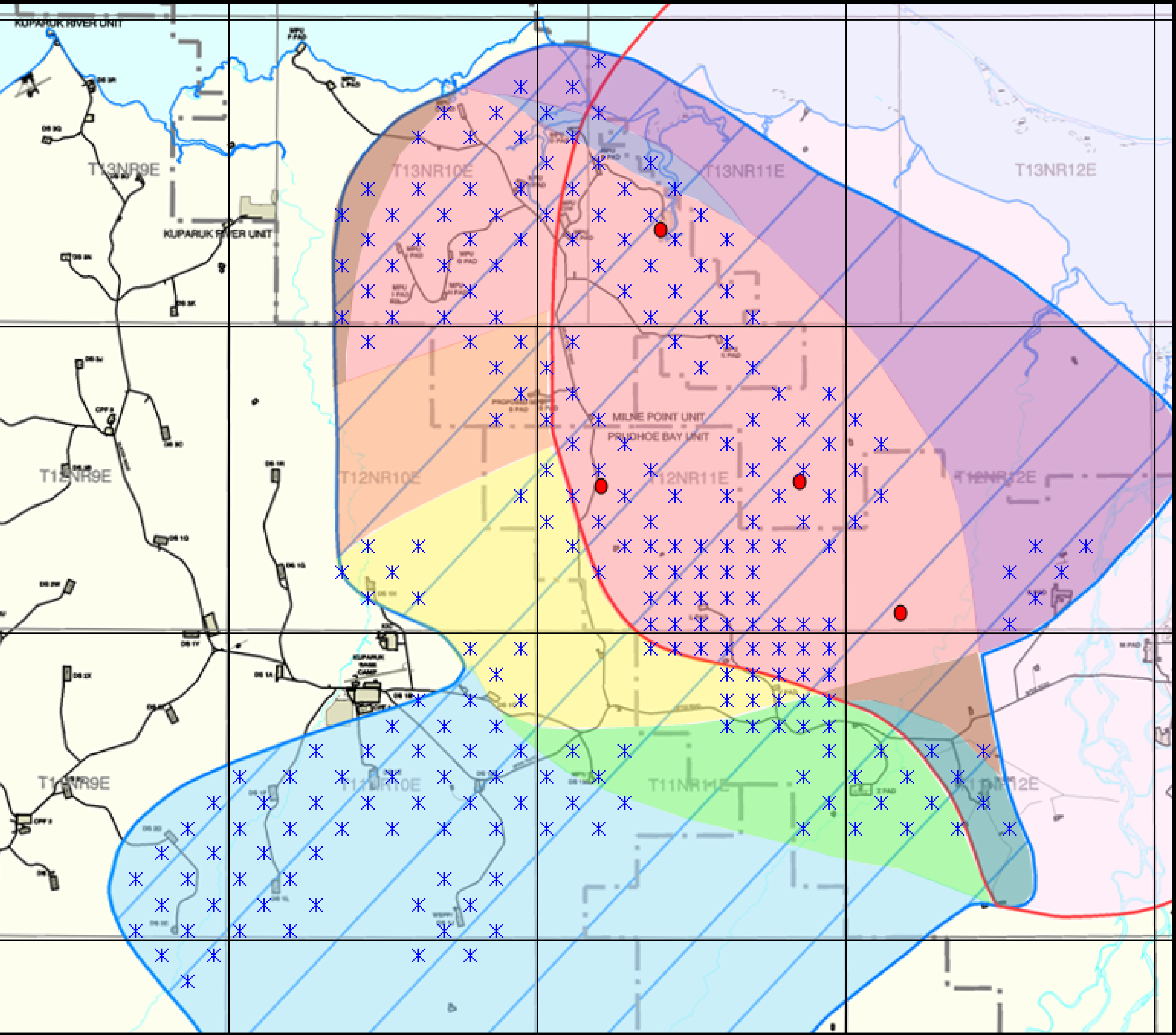

Similar in scope to WSak 1E/1J pilot in KRU viscous oil

# Stage 4: Full-field development

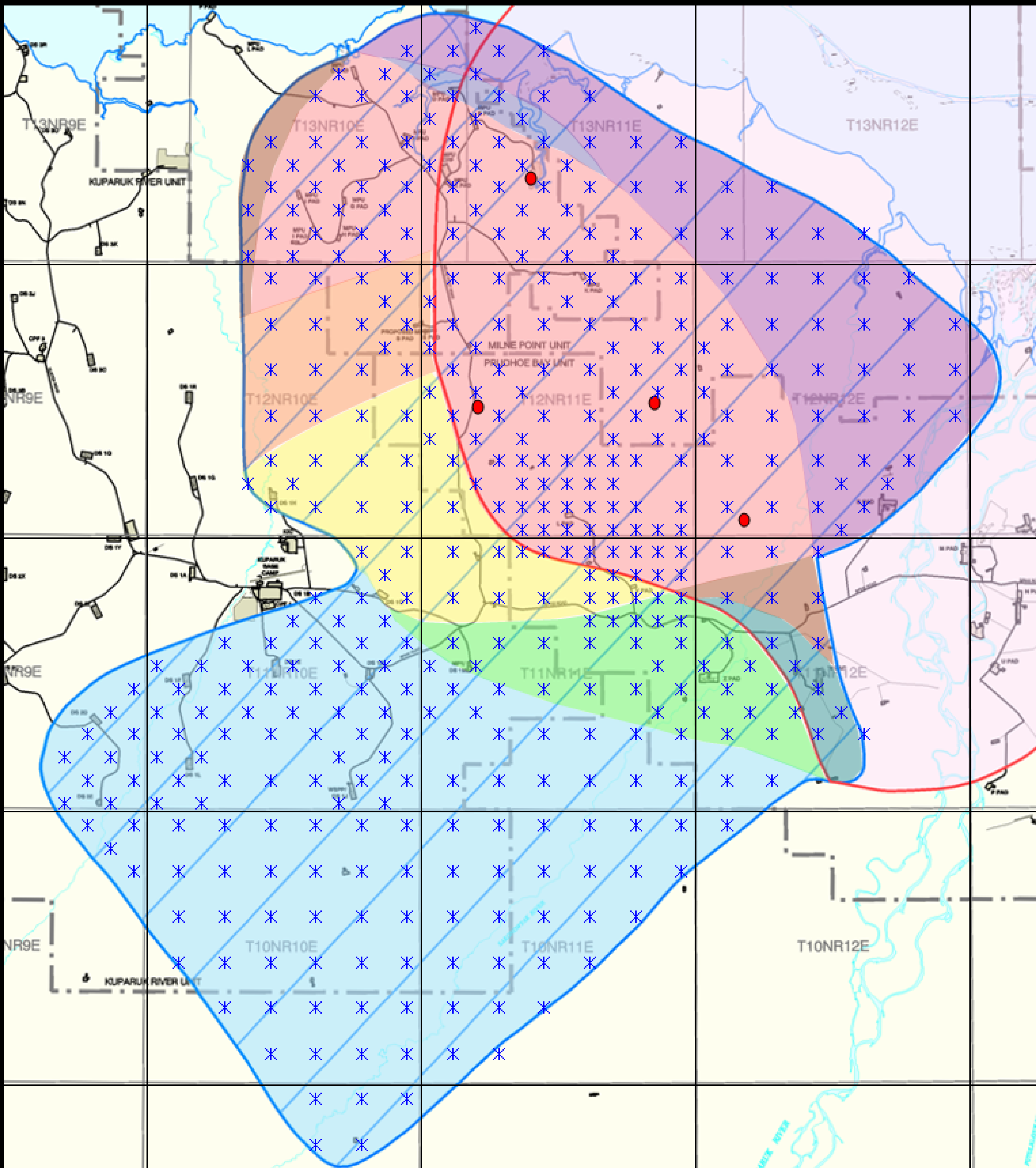



Filters applied to reduce wellcount to ~148 at 640 Acre Spacing in C & D sands > 0’ thickness

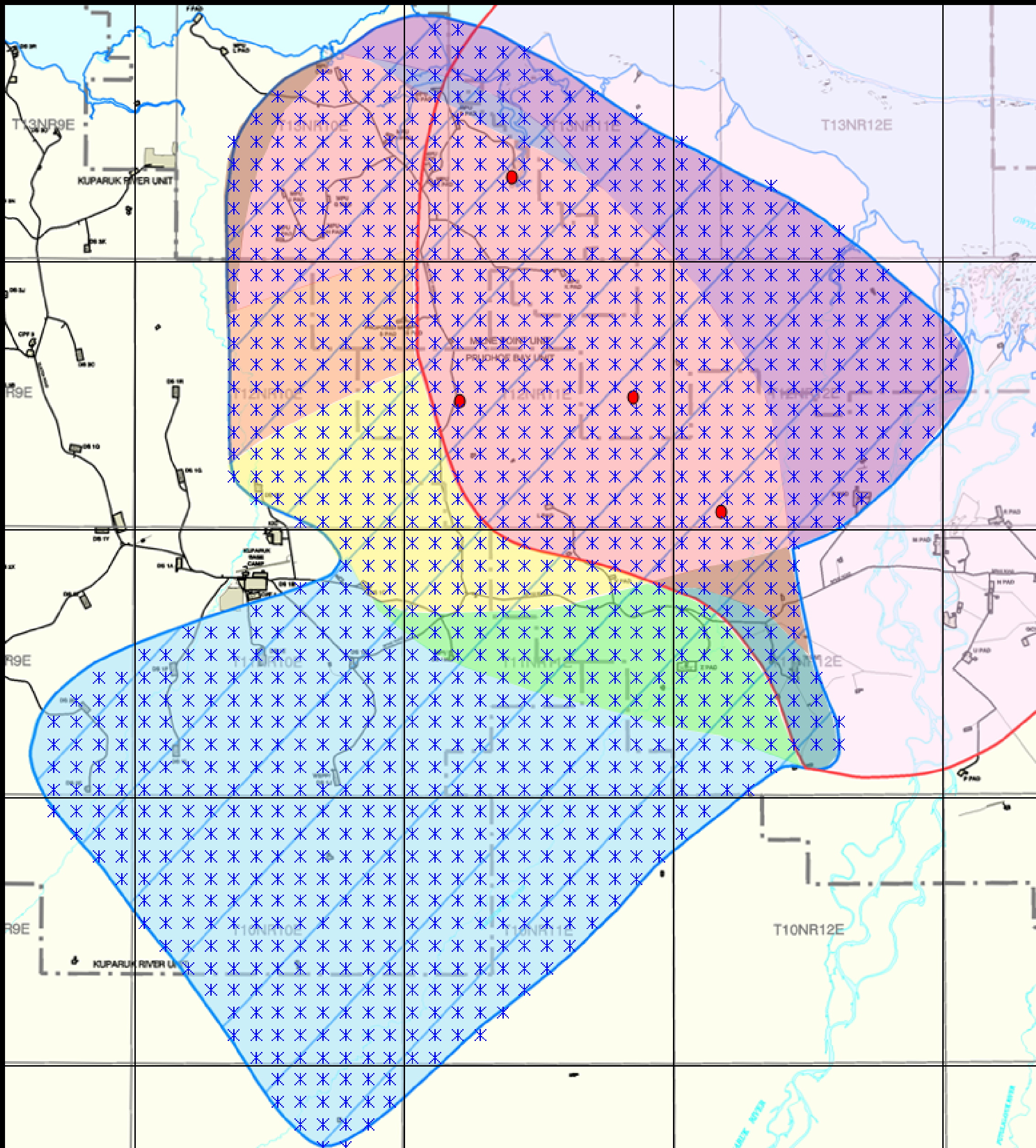
# Stage 5: Resource Harvesting



# Stage 6: Manage/Expand Resource

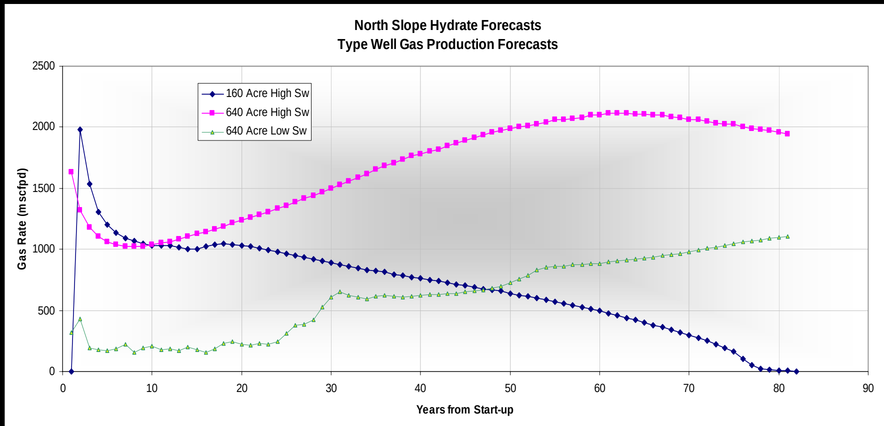


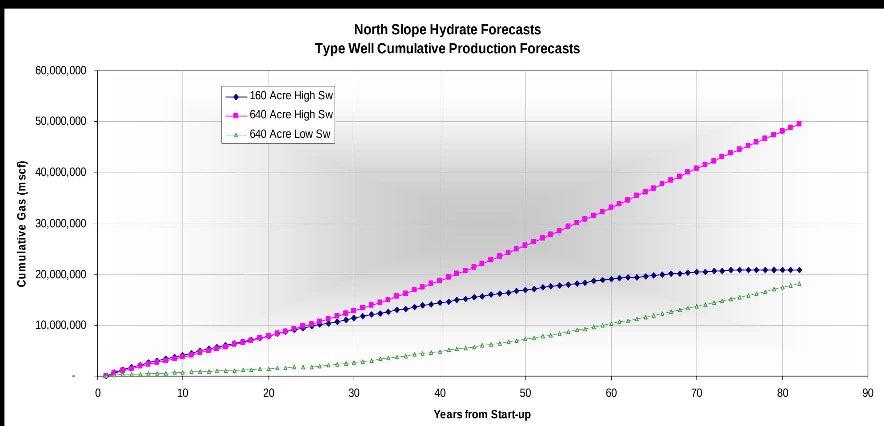
# Stage 7: New Technology/Infilling

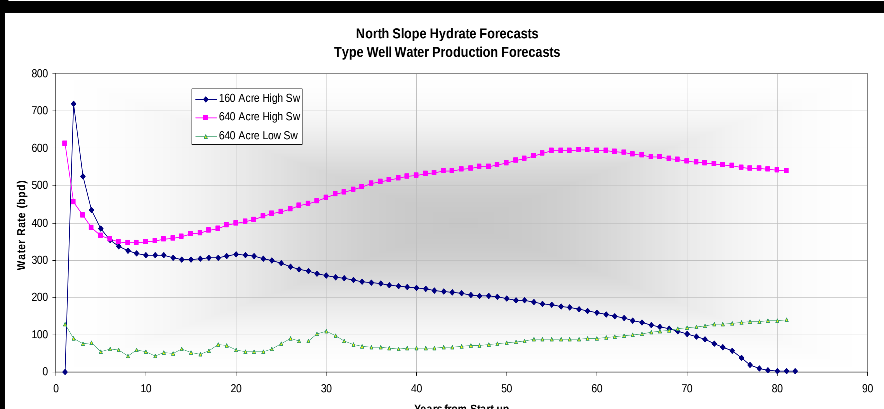


# Type Wells

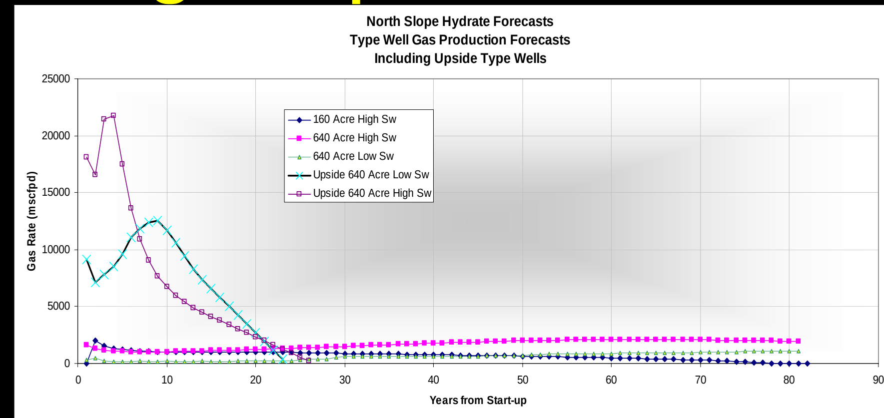
## Reference Case

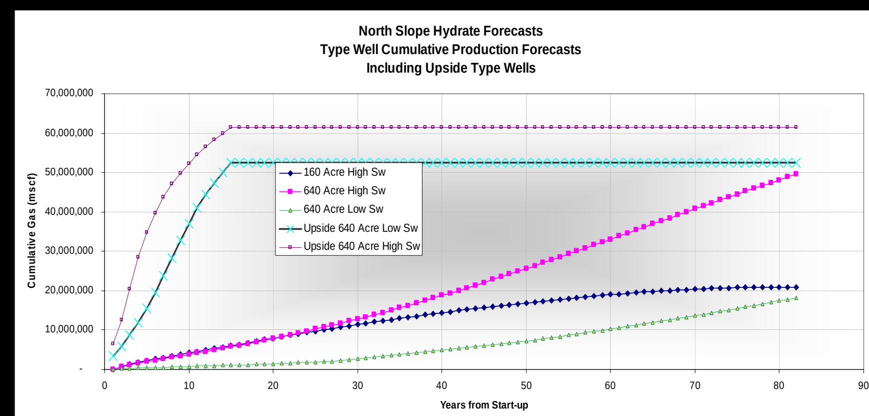


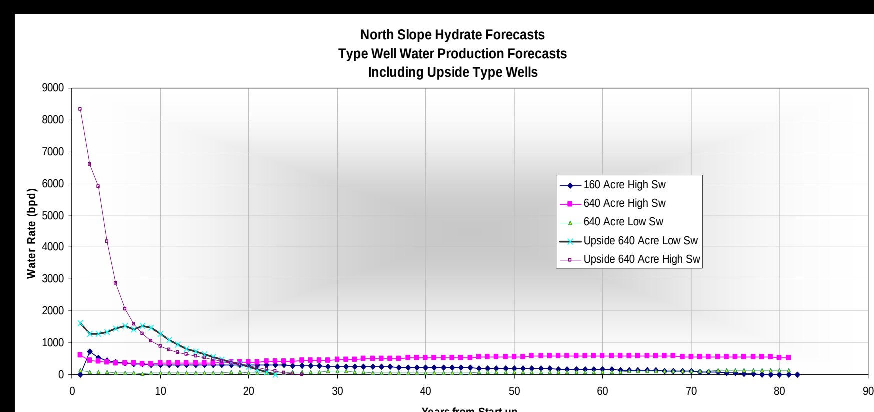



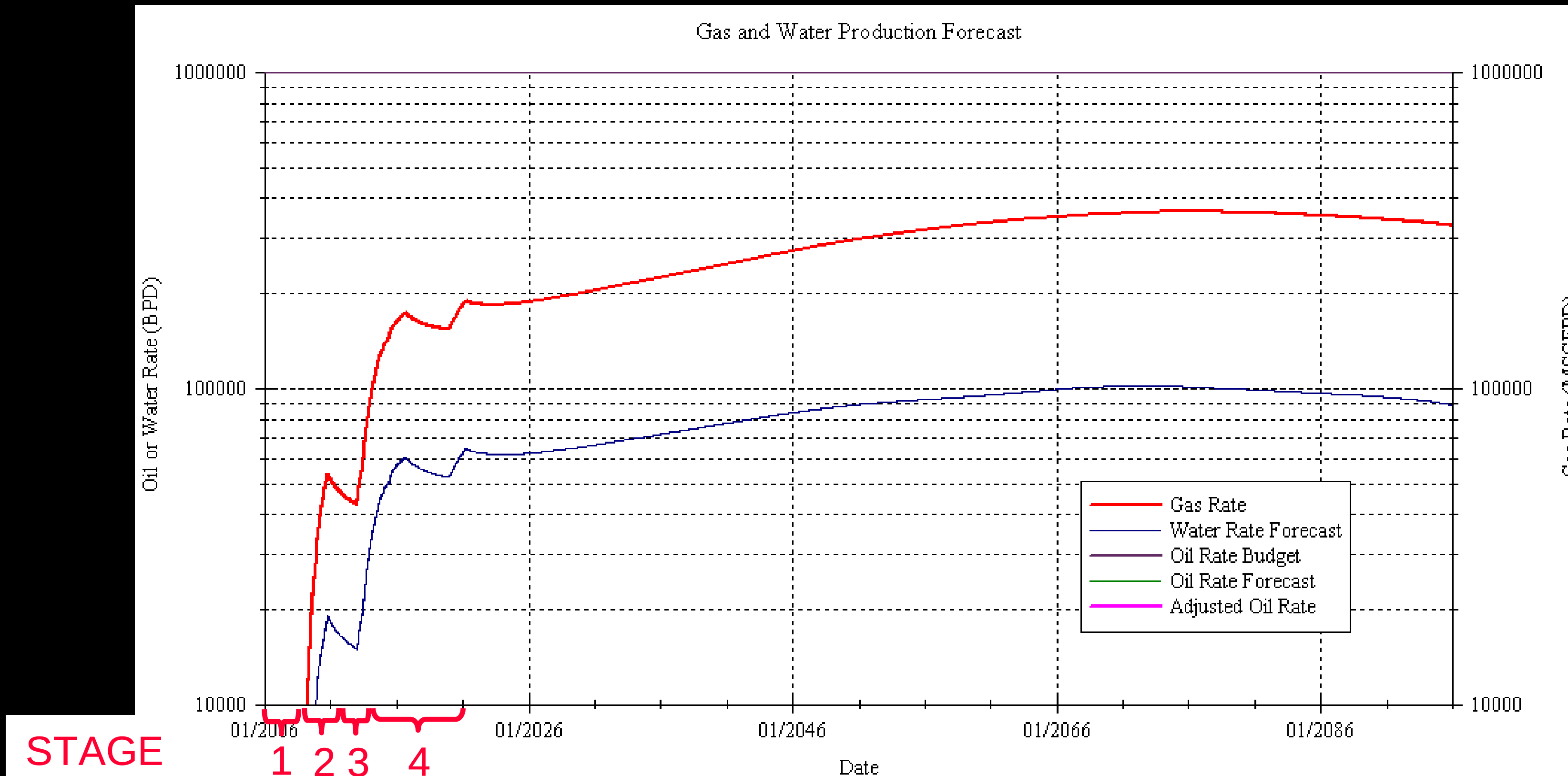

## High Upside Case

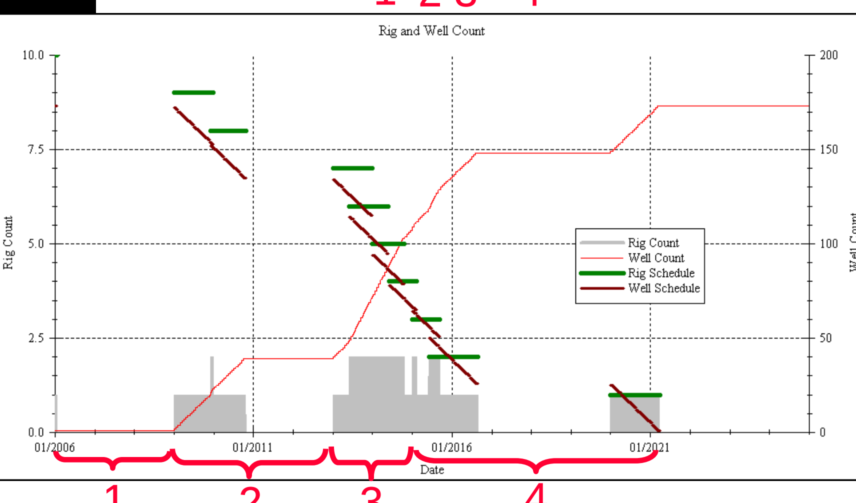


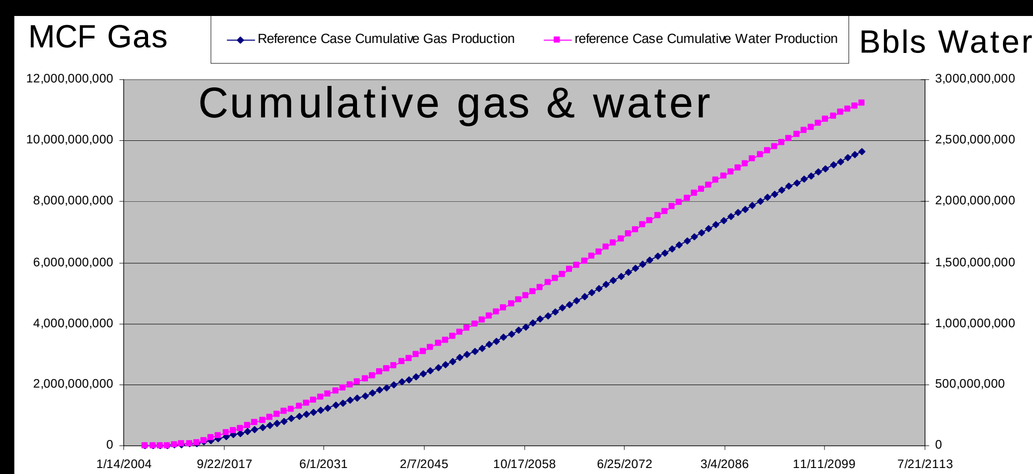



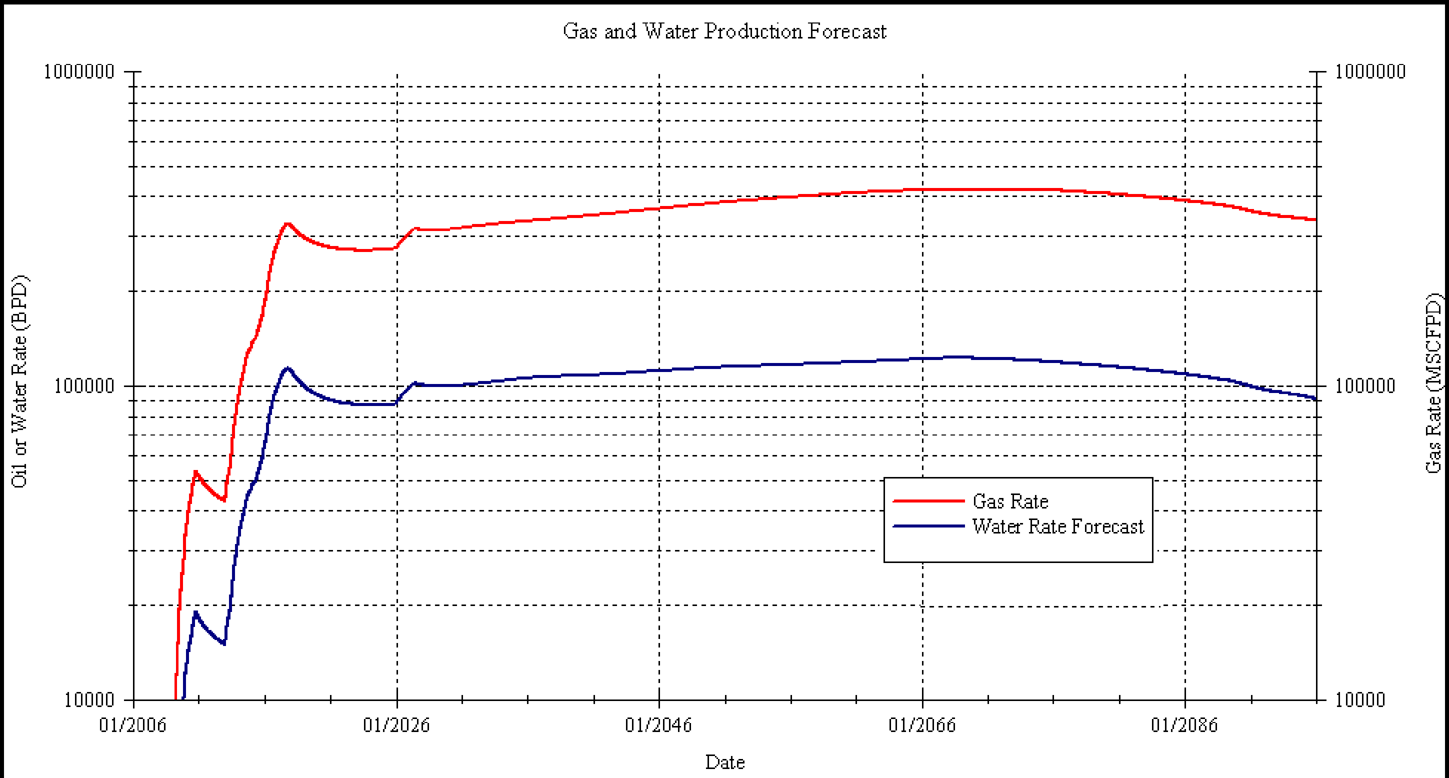
# Reference Case



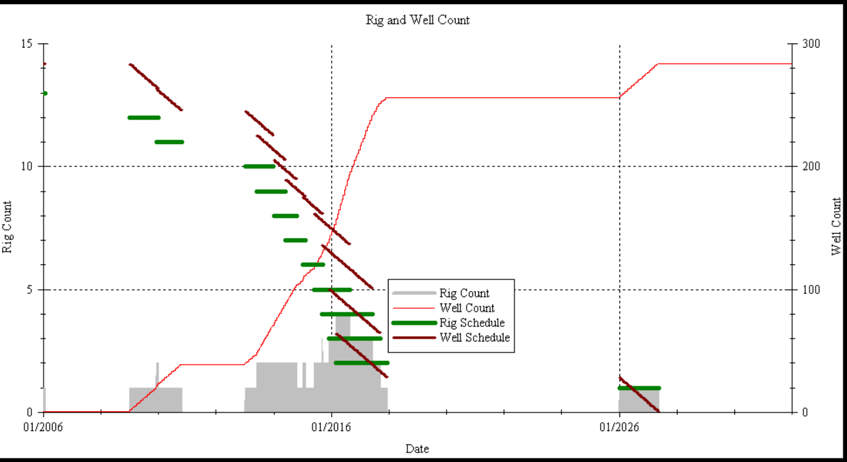



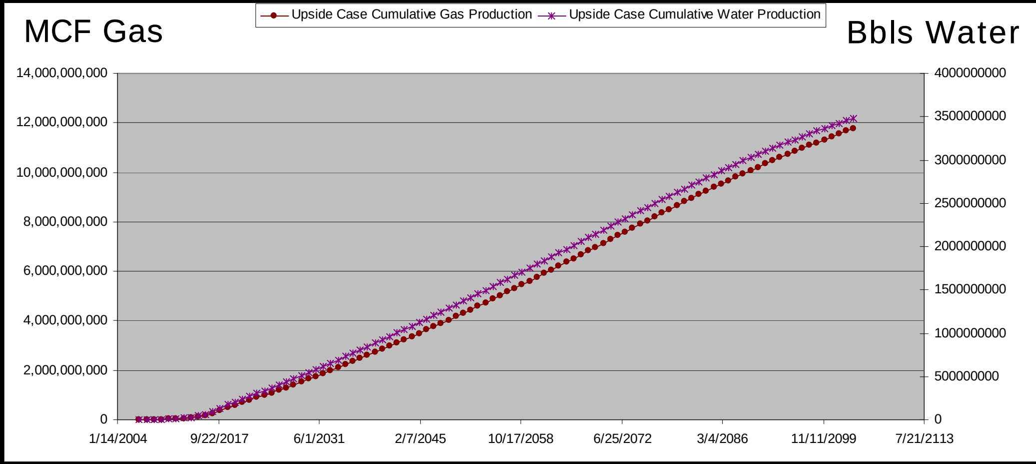
# Upside Case



Gas and Water Production Forecast
1000000
100000
10000
Oil or Water Rate (BPD)
Gas Rate (MSCFPD)
01/2006
01/2026
01/2046
01/2066
01/2086
Date
Gas Rate
Water Rate Forecast

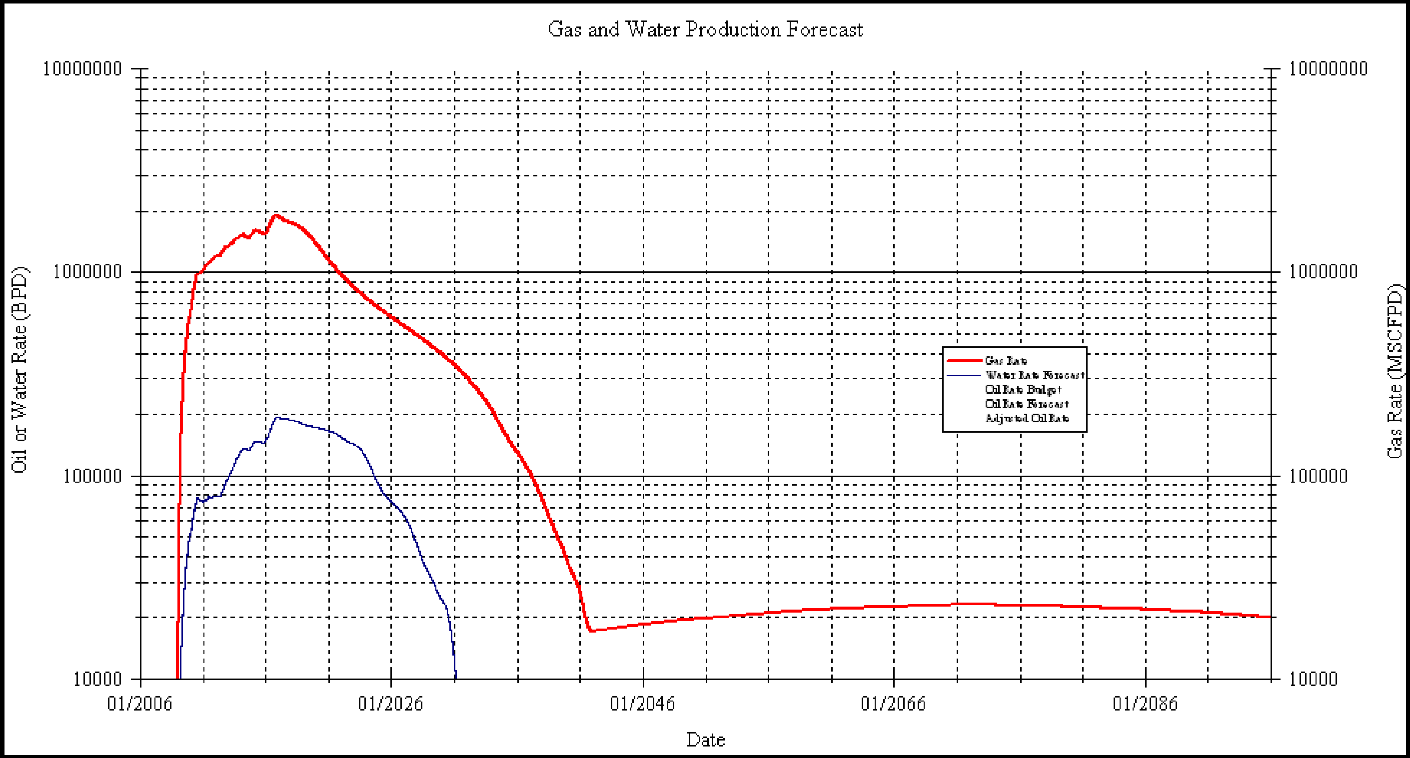



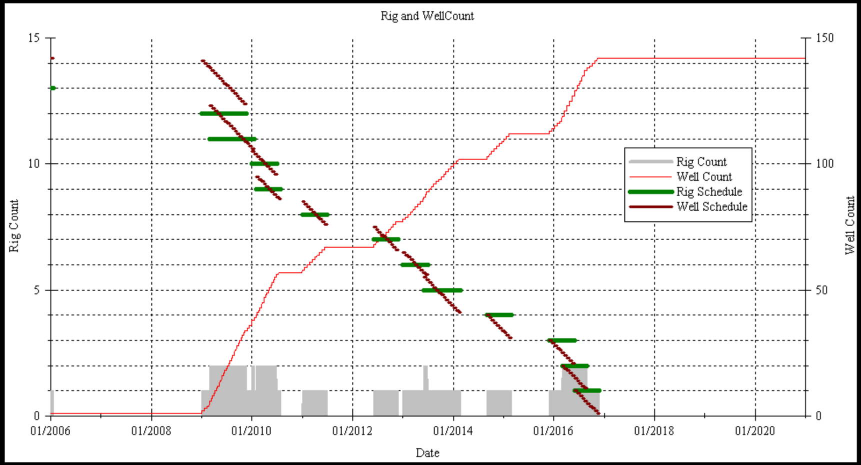
Rig and Well Count
15
10
5
0
300
200
100
0
Rig Count
Well Count
01/2006
01/2016
01/2026
Date
Rig Count
Well Count
Rig Schedule
Well Schedule

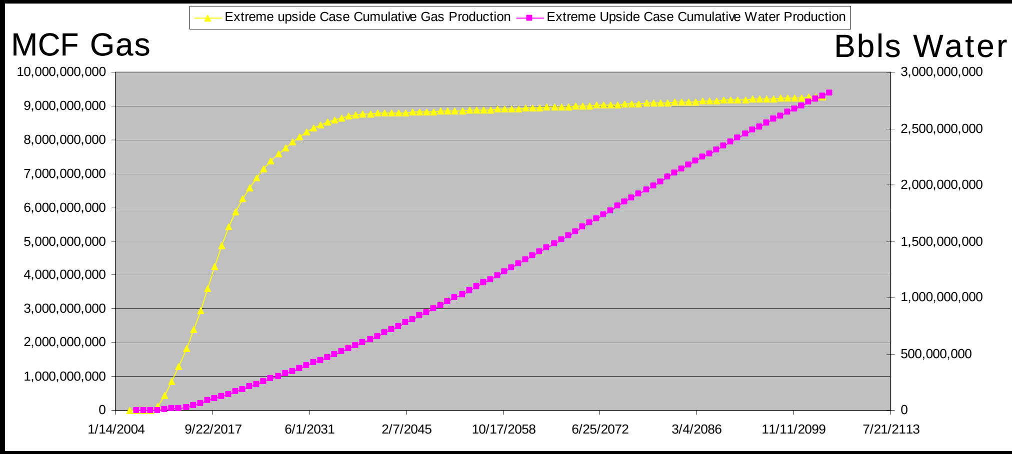



MCF Gas
Bbls Water
Upside Case Cumulative Gas Production
Upside Case Cumulative Water Production
14,000,000,000
12,000,000,000
10,000,000,000
8,000,000,000
6,000,000,000
4,000,000,000
2,000,000,000
0
4000000000
3500000000
3000000000
2500000000
2000000000
1500000000
1000000000
500000000
0
1/14/2004
9/22/2017
6/1/2031
2/7/2045
10/17/2058
6/25/2072
3/4/2086
11/11/2099
7/21/2113

# Extreme Upside Case



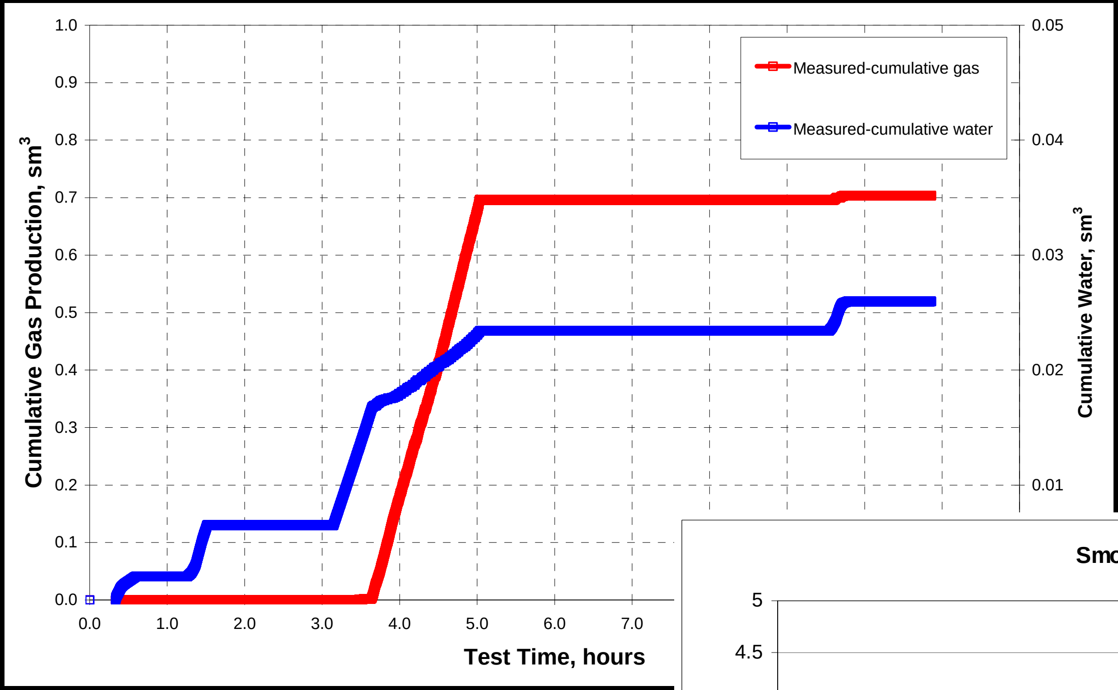



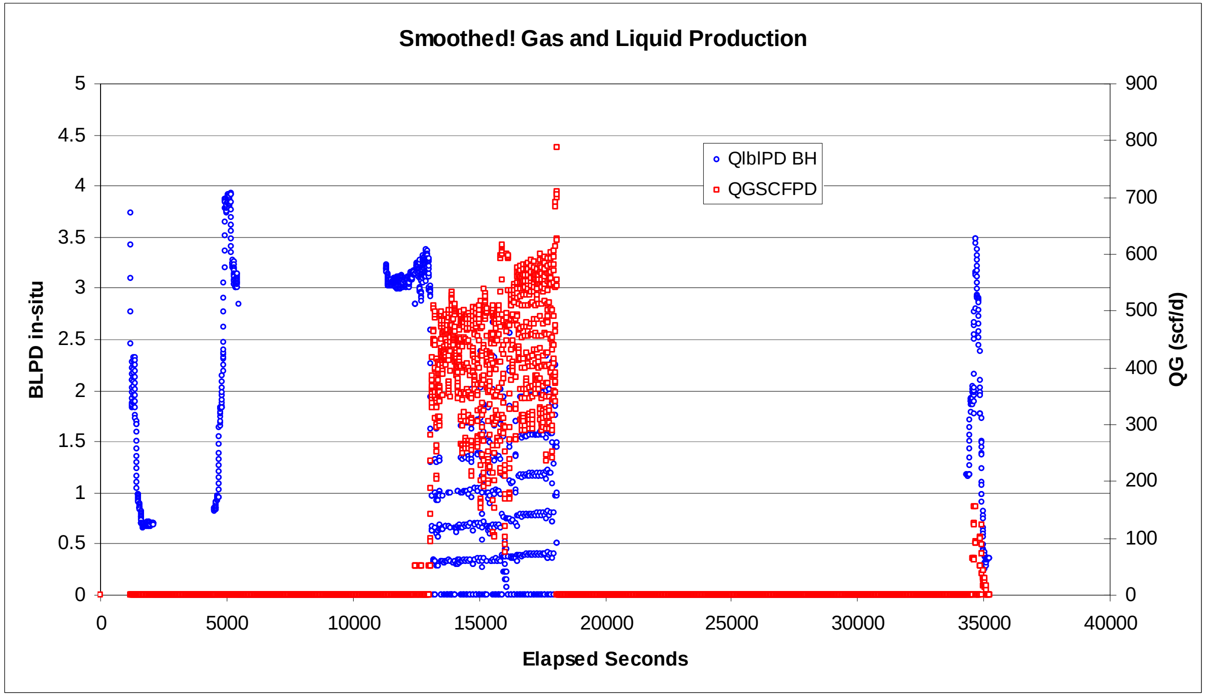



# Mount Elbert MDT
# Key Results

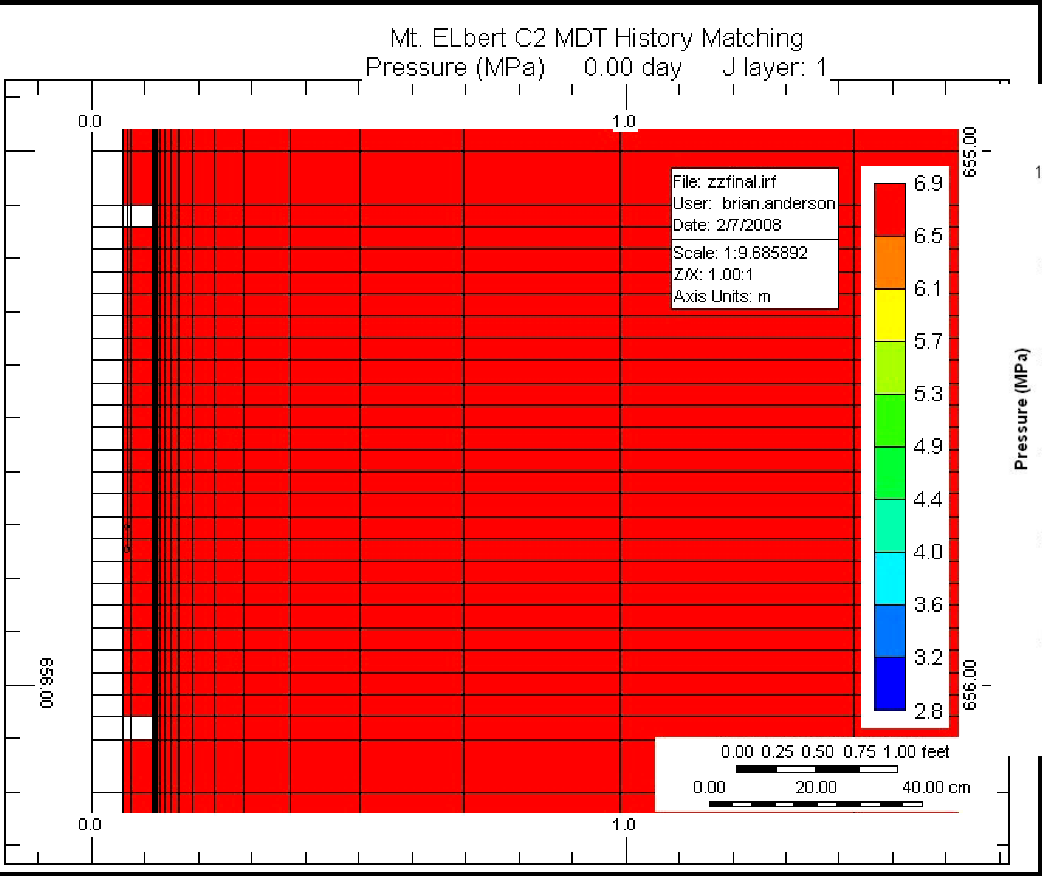
- Confirmation of gas release via depressurization
- Clear indication that depressurization alone may not be sufficient in select (T) settings
- Confirmation of mobile water phase
  - Sgh = 65%; 25% = Swirr
  - Sgh = 75%; 10% = Swirr
- Determination of intrinsic K
  - 0.12 – 0.17 mD
- Reformation kinetics may be important
- Detailed reservoir heterogeneity may control productivity

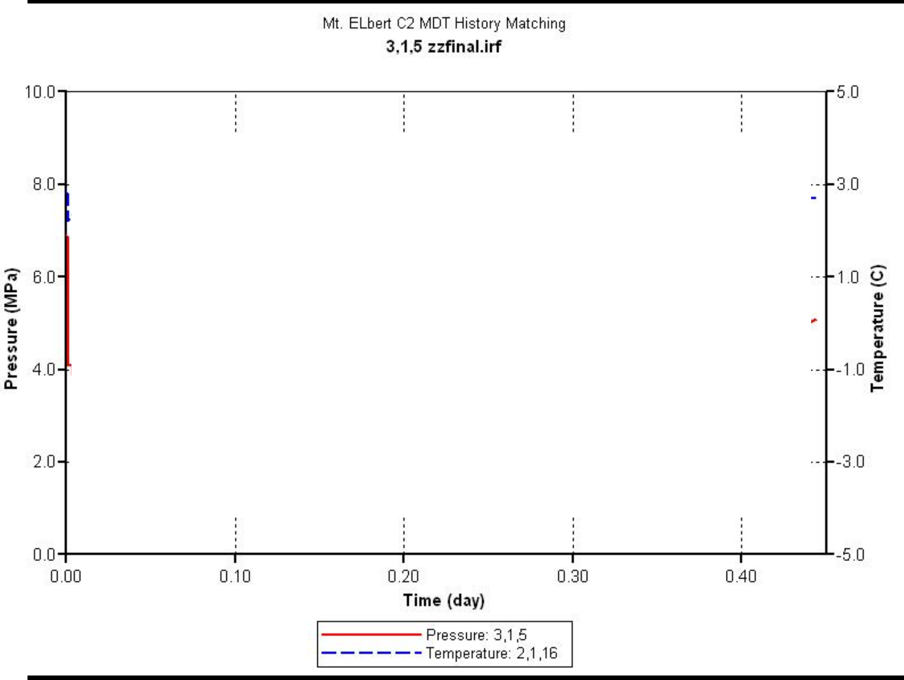
# Fluids Produced

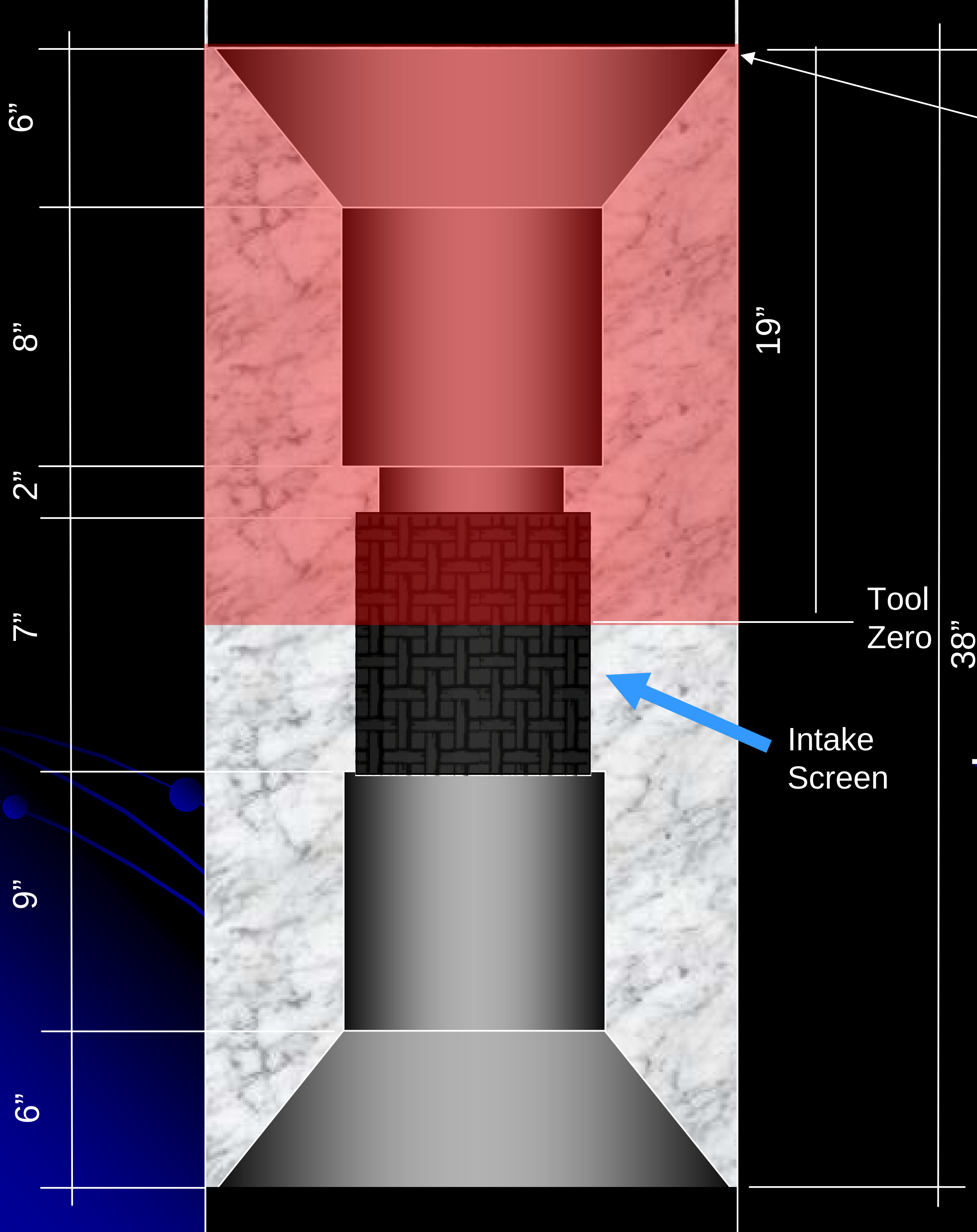


# MDT Testing
# Pulse pressures through the system : measure responses



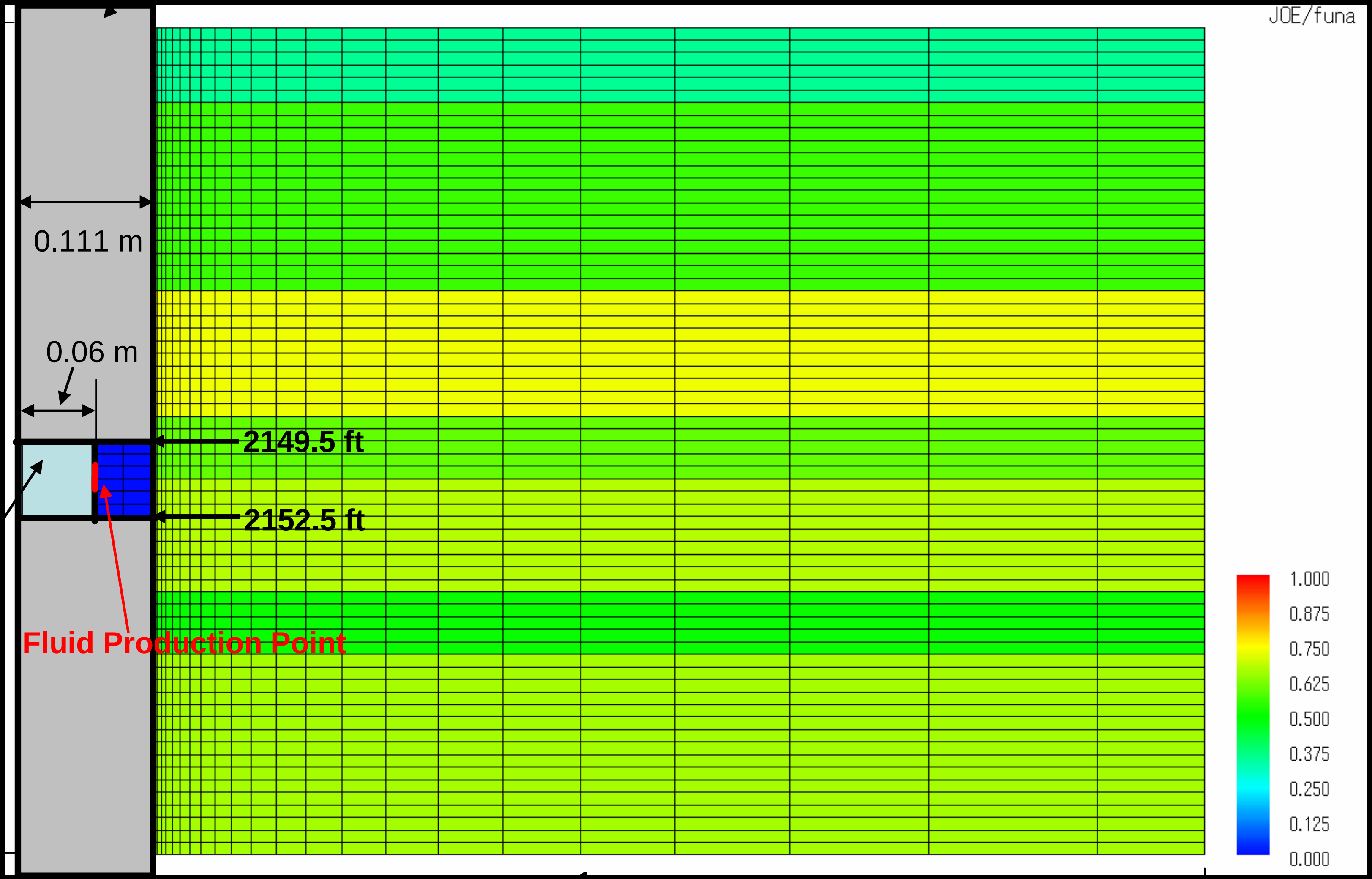





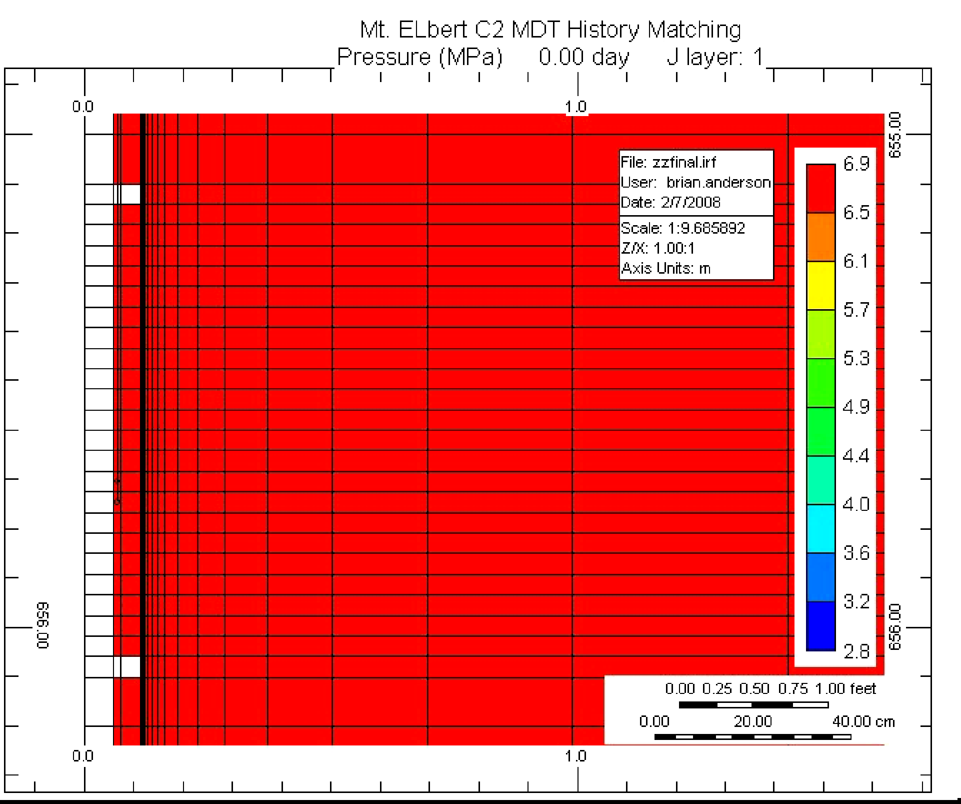

How much gas is 1.0 cf downhole?

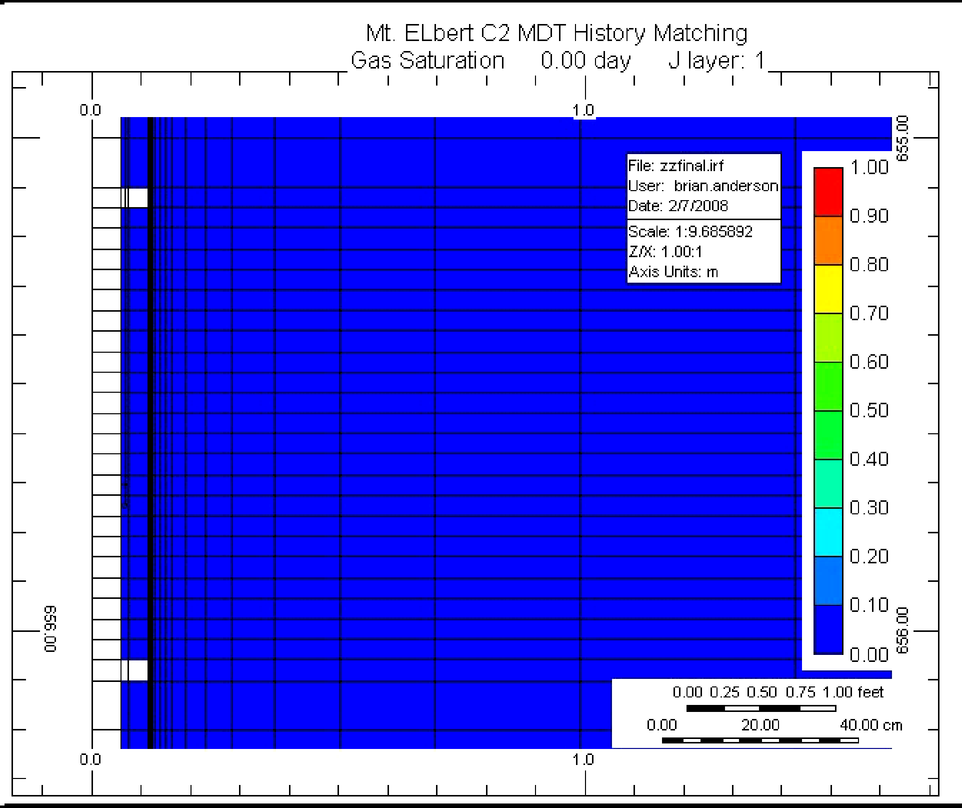
The red annular area to the left is 1.5 cf

# Gridding that recognizes the wellbore annulus



# MDT Testing
# Annular Space is critical in this low rate case



# MDT Results Reservoir Modeling International Code Comparison Group

A: Stomp-HYD (M. White – PNNL)

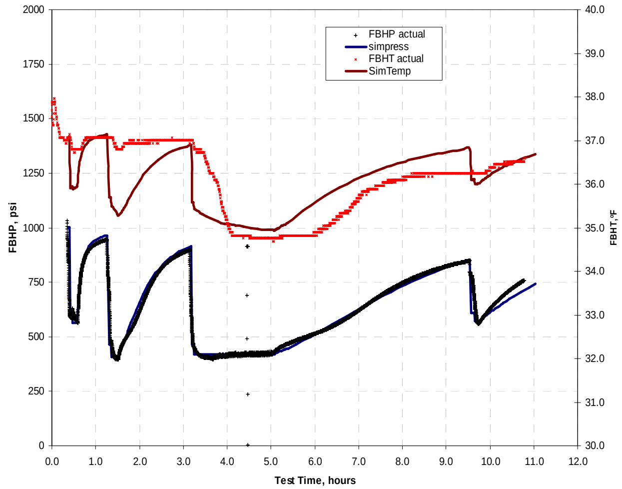
B: STARS (S. Wilson – RyderScott)

C: MH-21 (M. Kurihara – JOE)

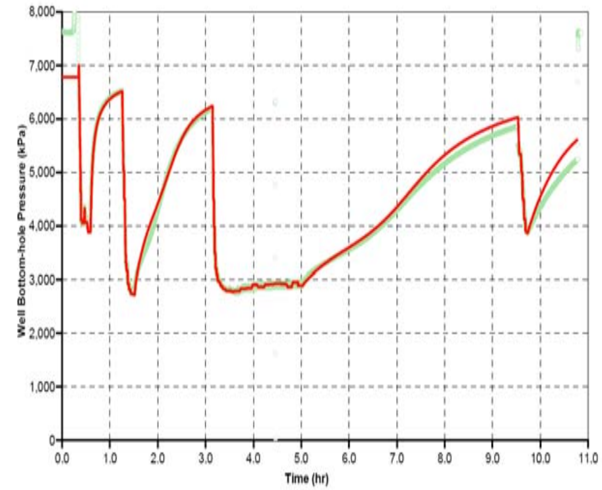
D: STARS (M. Pooladi-Darvish – Fekete)

E: Tough+/HYDRATE (G. Moridis – LBNL)

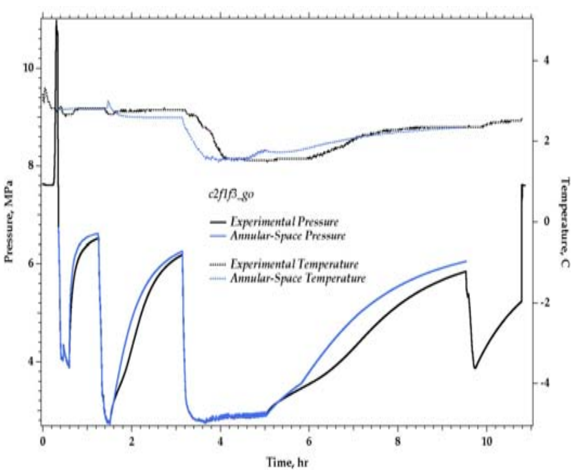
B



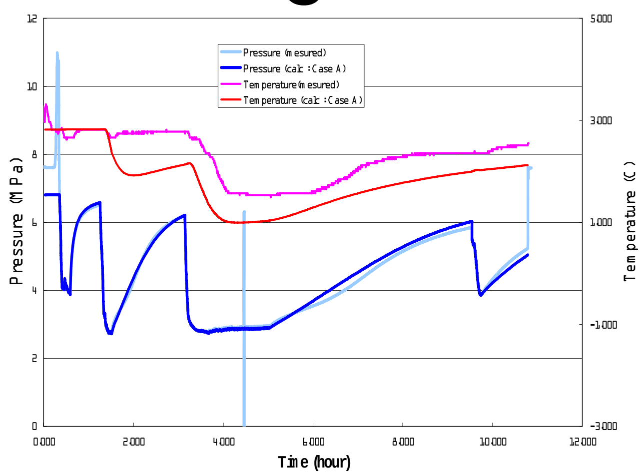

D



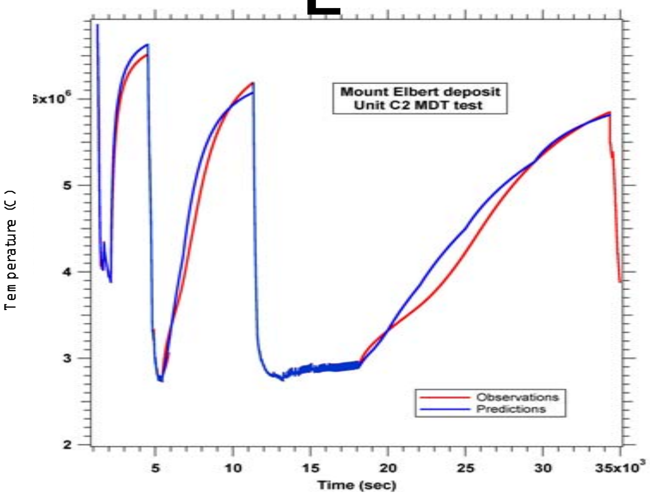

A




C




E



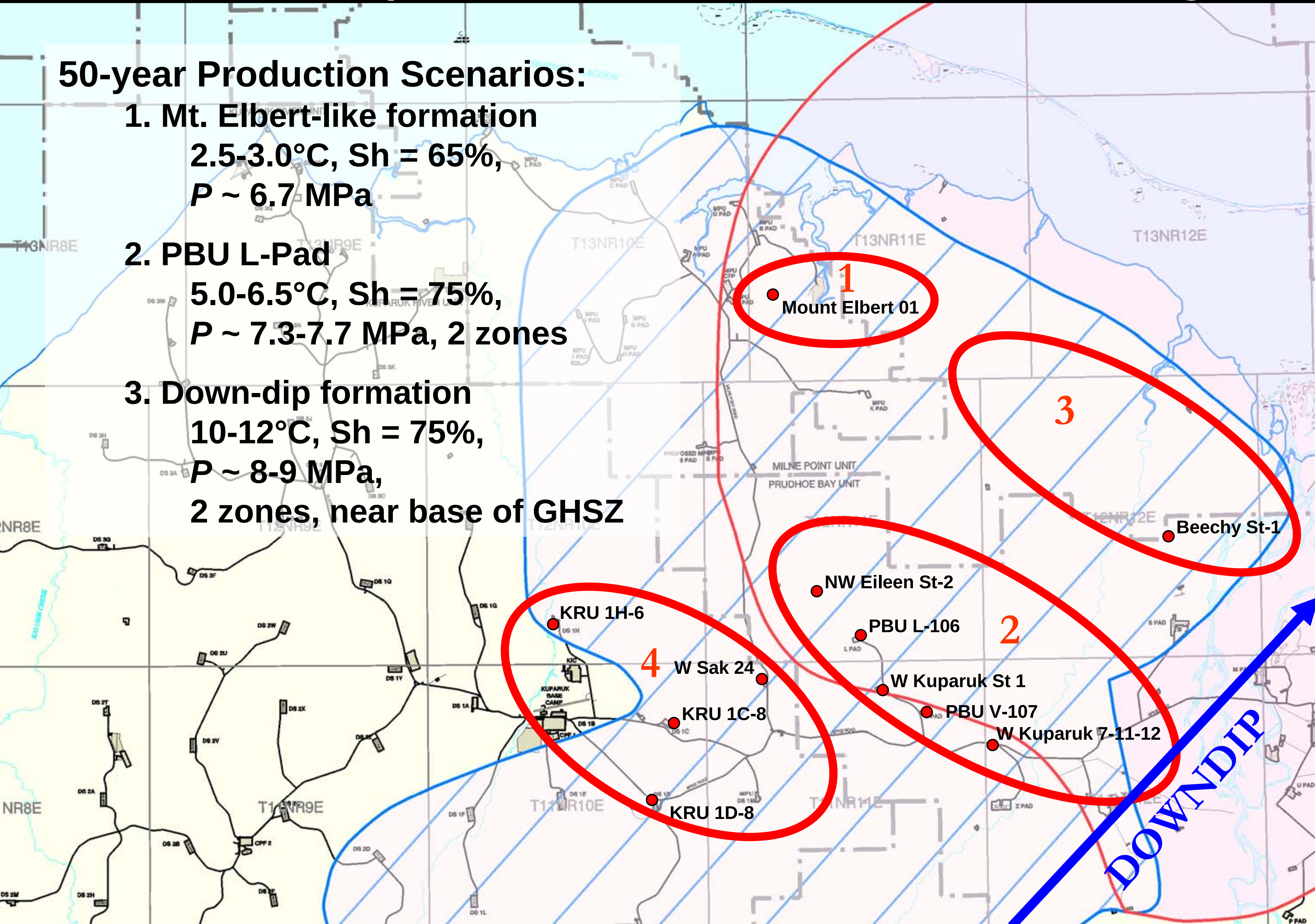
# Site Comparisons Reservoir Modeling

**50-year Production Scenarios:**

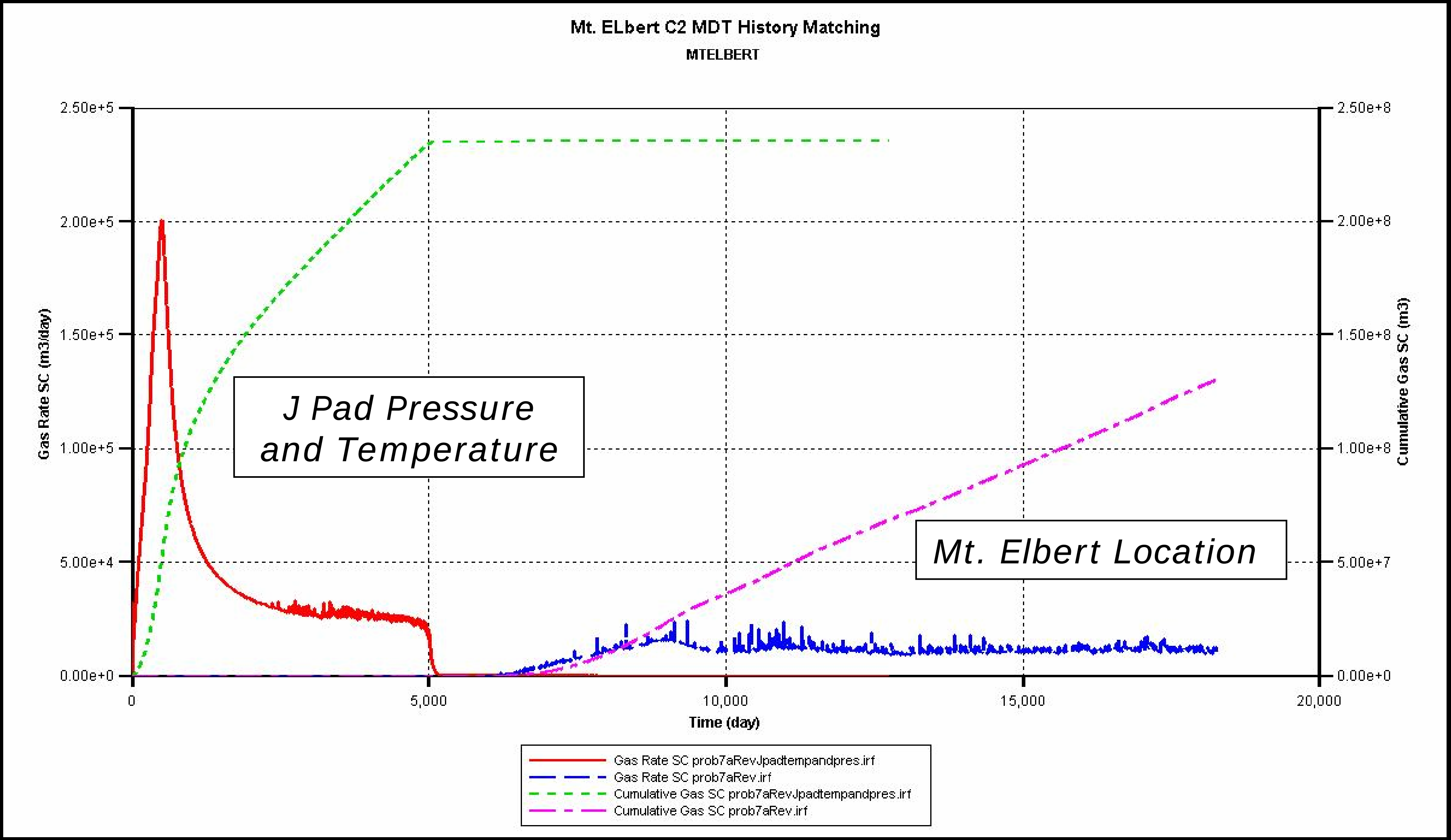
1. Mt. Elbert-like formation
   2.5-3.0°C, Sh = 65%,
   *P* ~ 6.7 MPa

2. PBU L-Pad
   5.0-6.5°C, Sh = 75%,
   *P* ~ 7.3-7.7 MPa, 2 zones

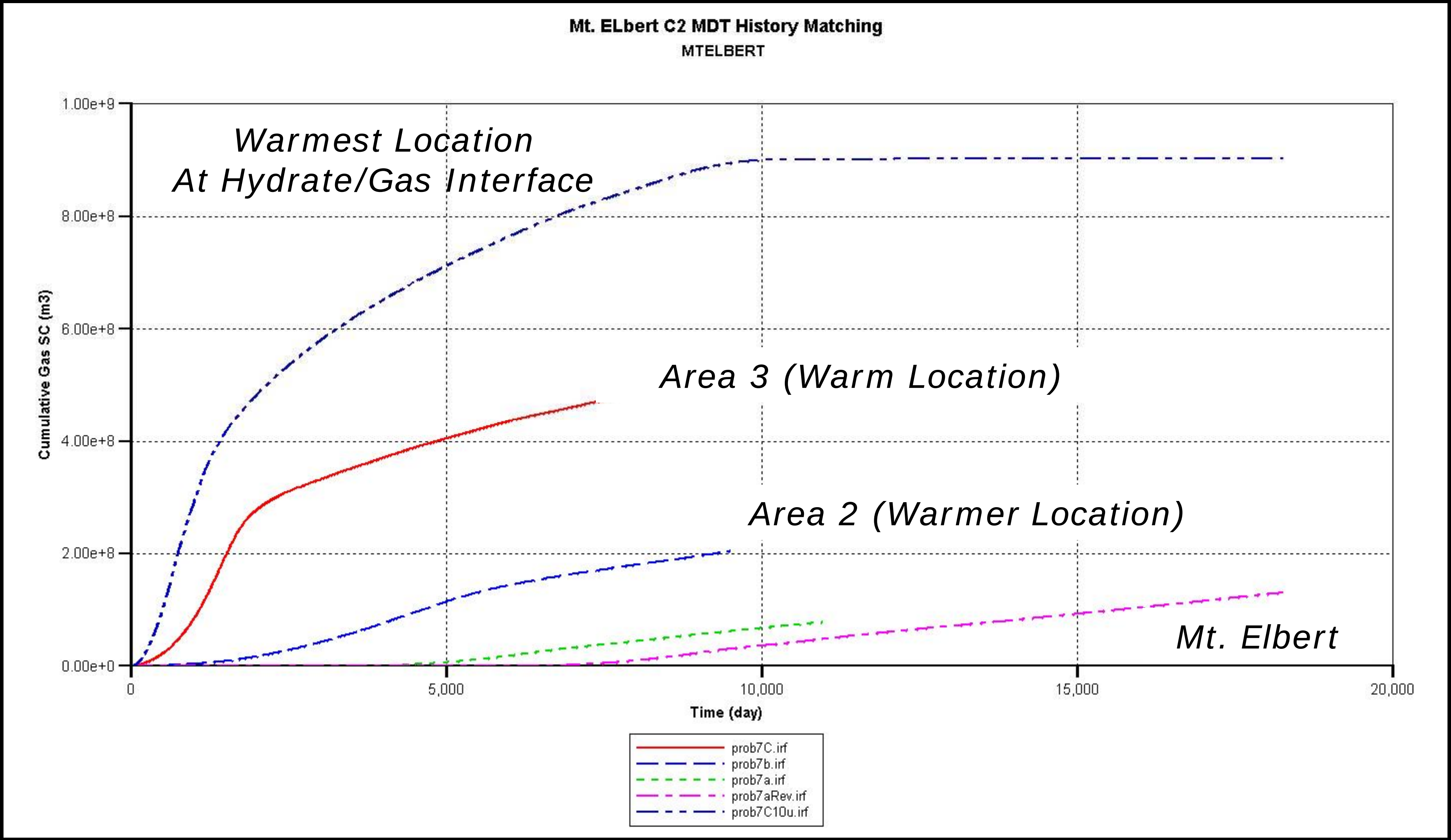
3. Down-dip formation
   10-12°C, Sh = 75%,
   *P* ~ 8-9 MPa,
   2 zones, near base of GHSZ



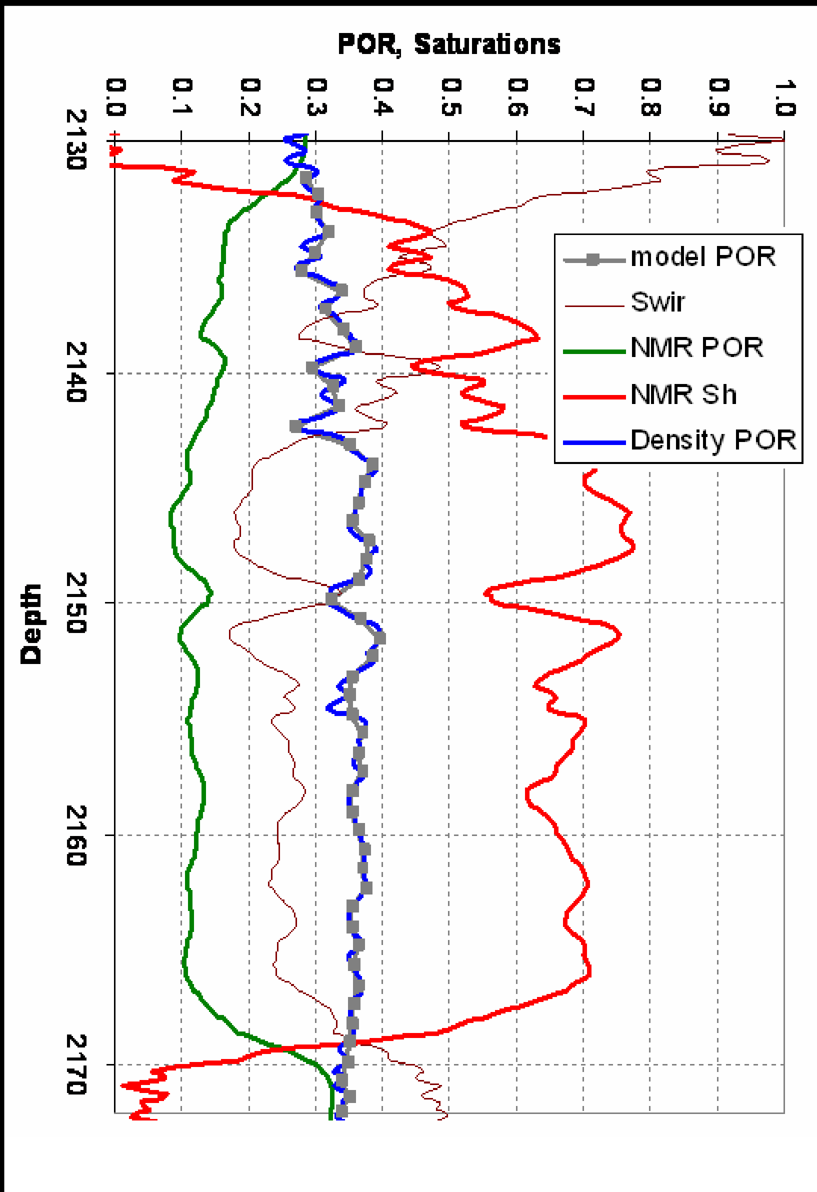
# Simulation of Alternative Locations

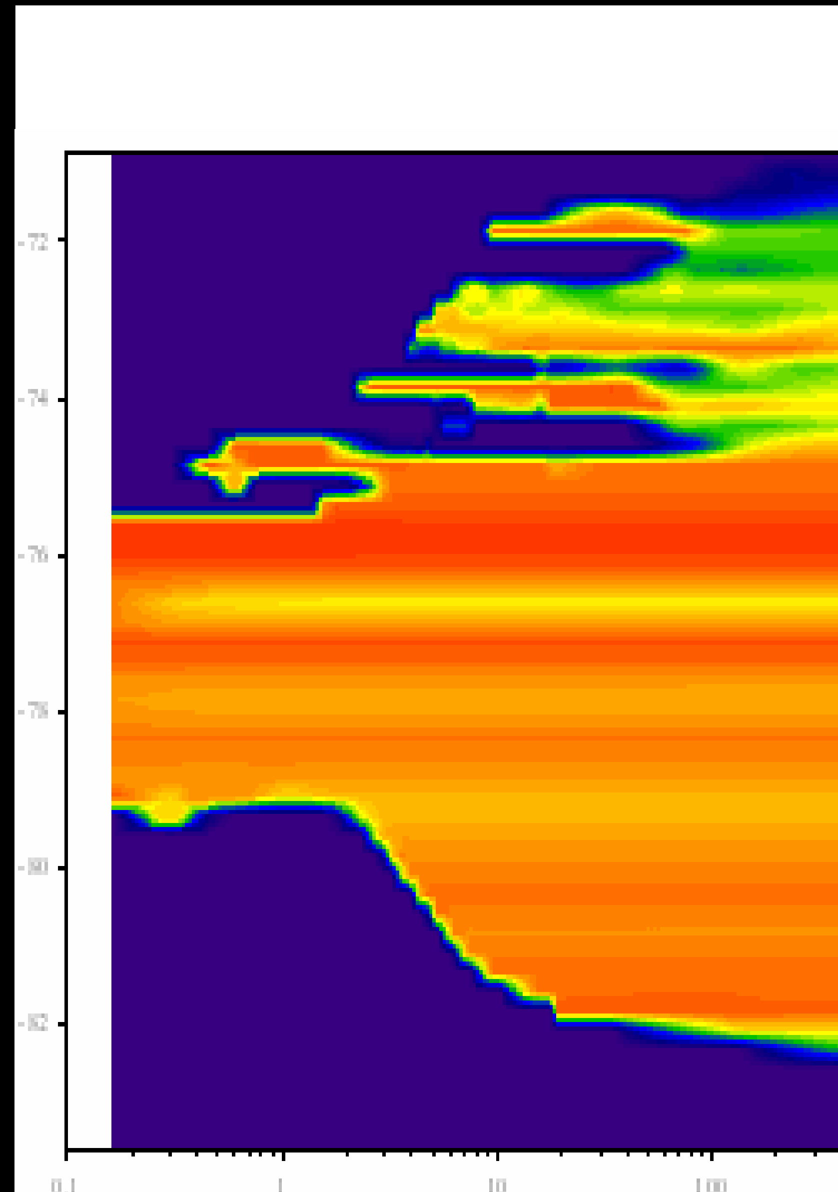


# Simulation of Alternative Locations

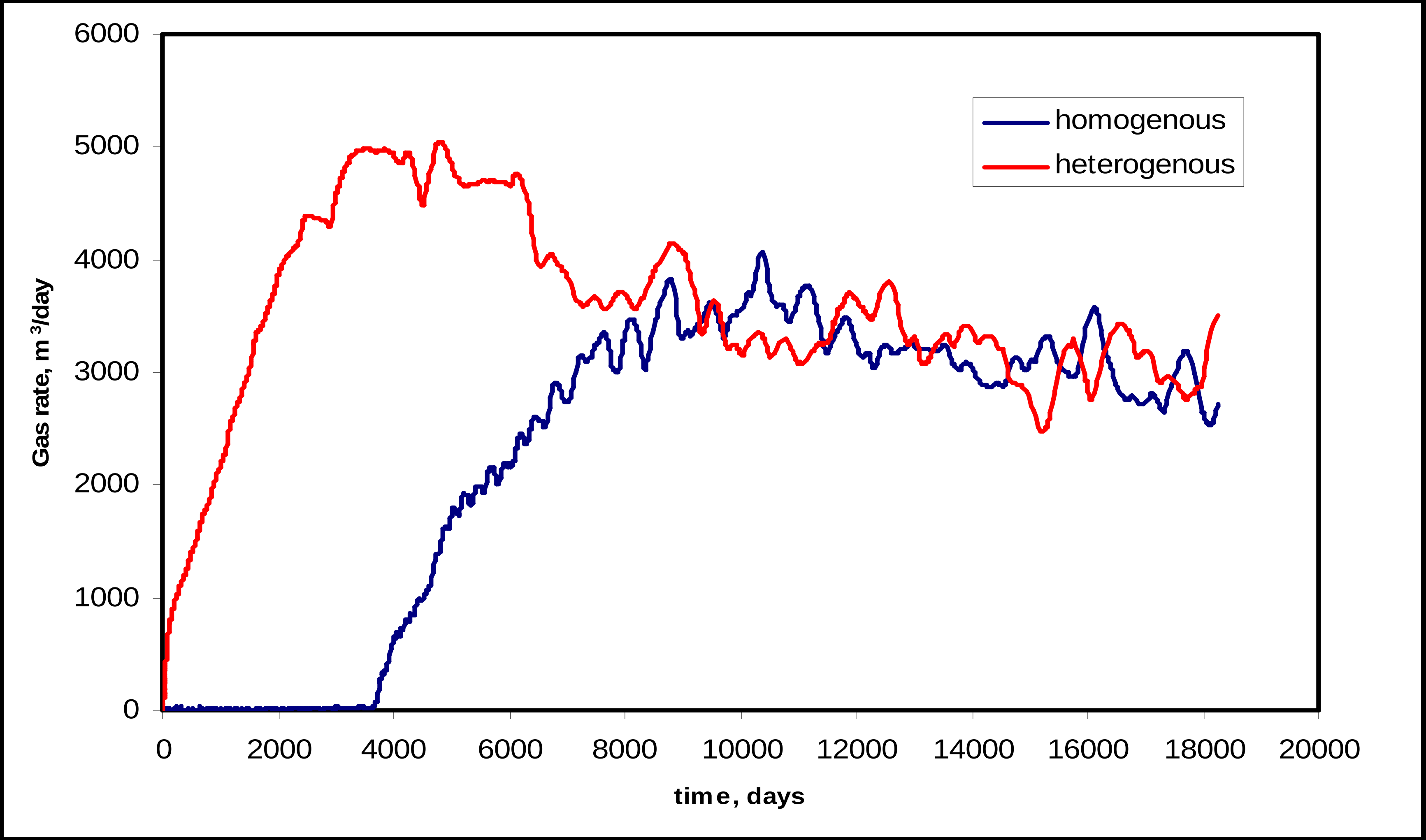


# C-Unit Heterogeneity Affects Simulation Saturation Profiles

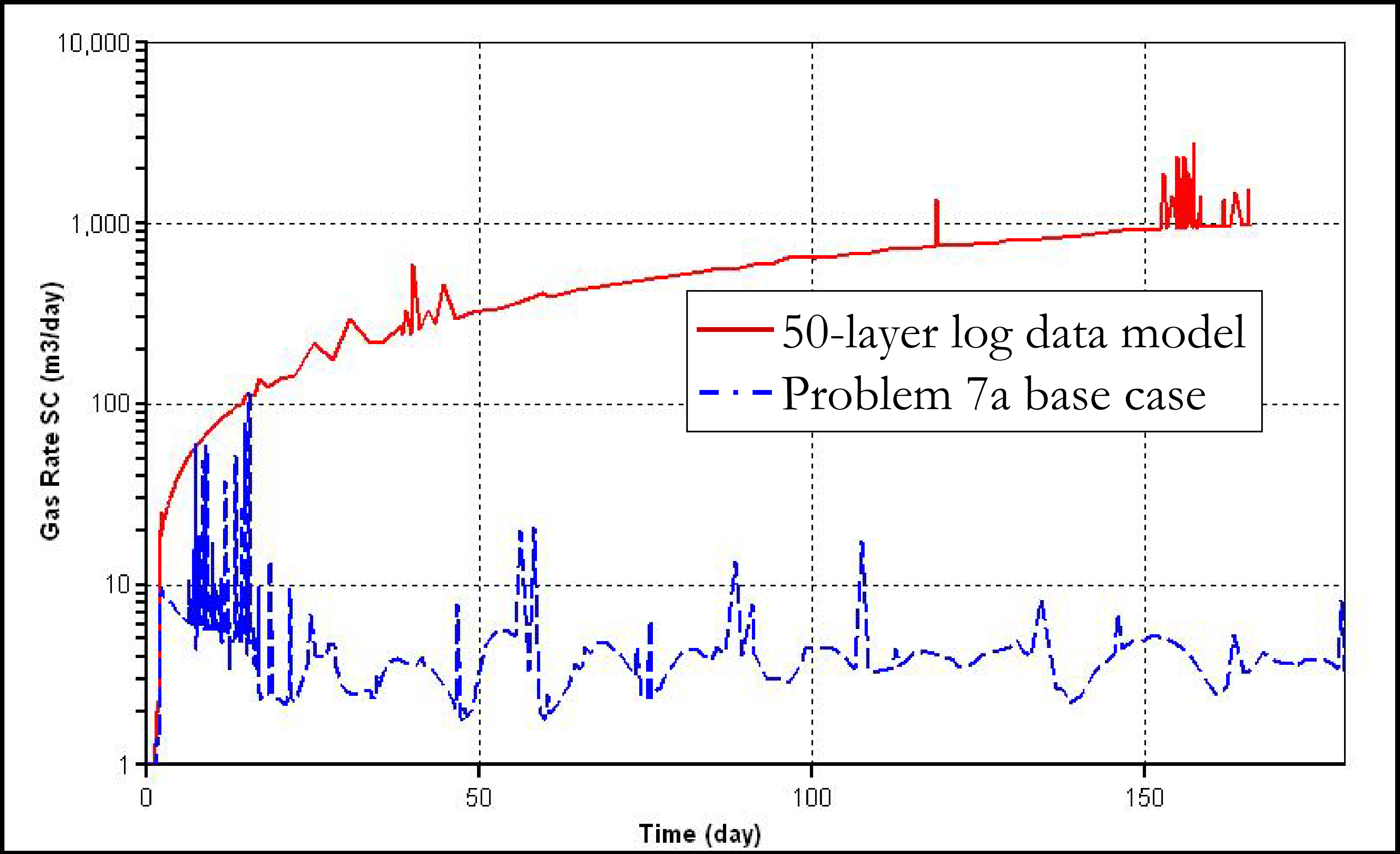


# Effect of permeability & porosity heterogeneity on predicted production rates

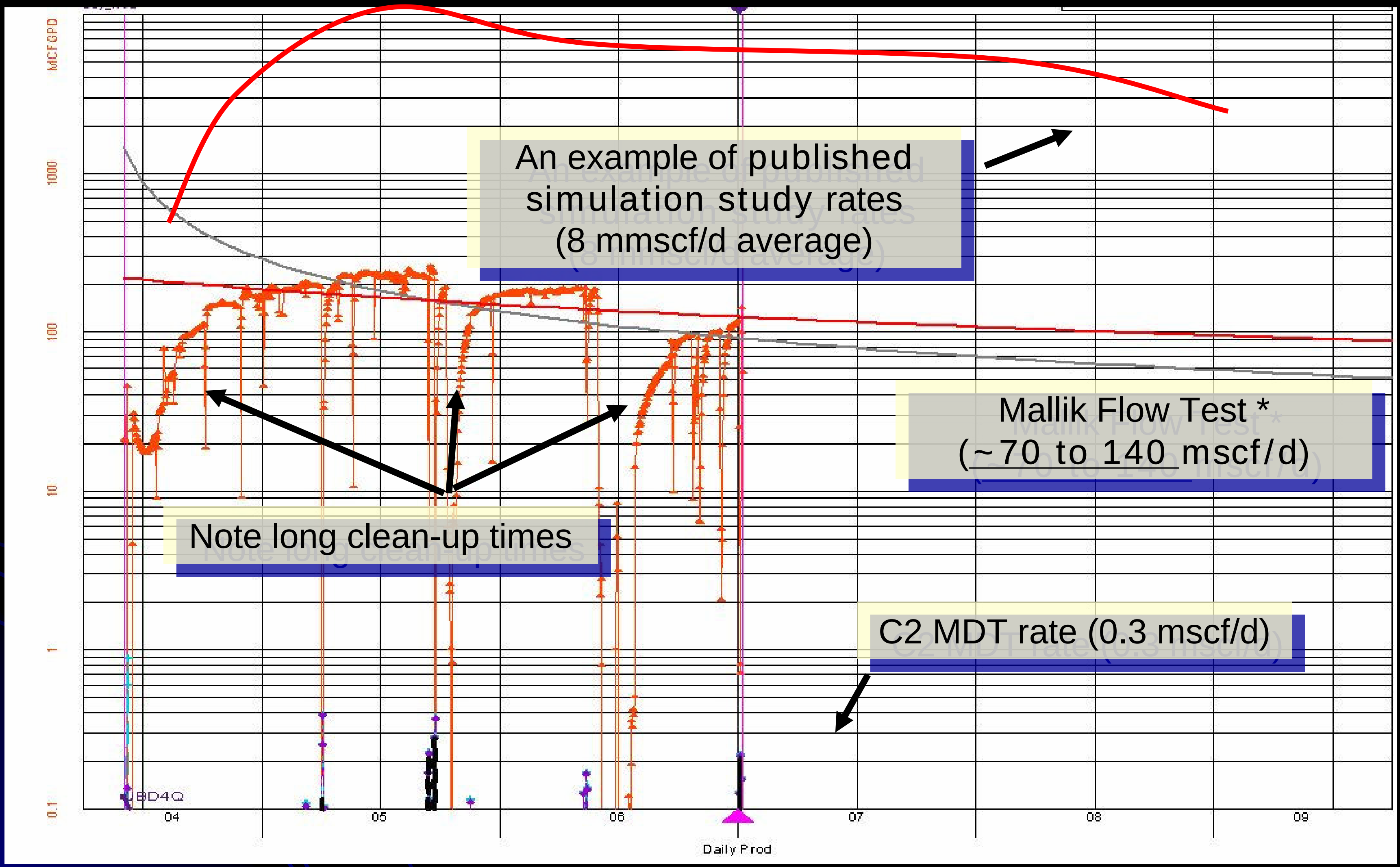


# Affects of Reservoir Heterogeneity Detail time Scale



# Typical Flow Rates in Commercial wells

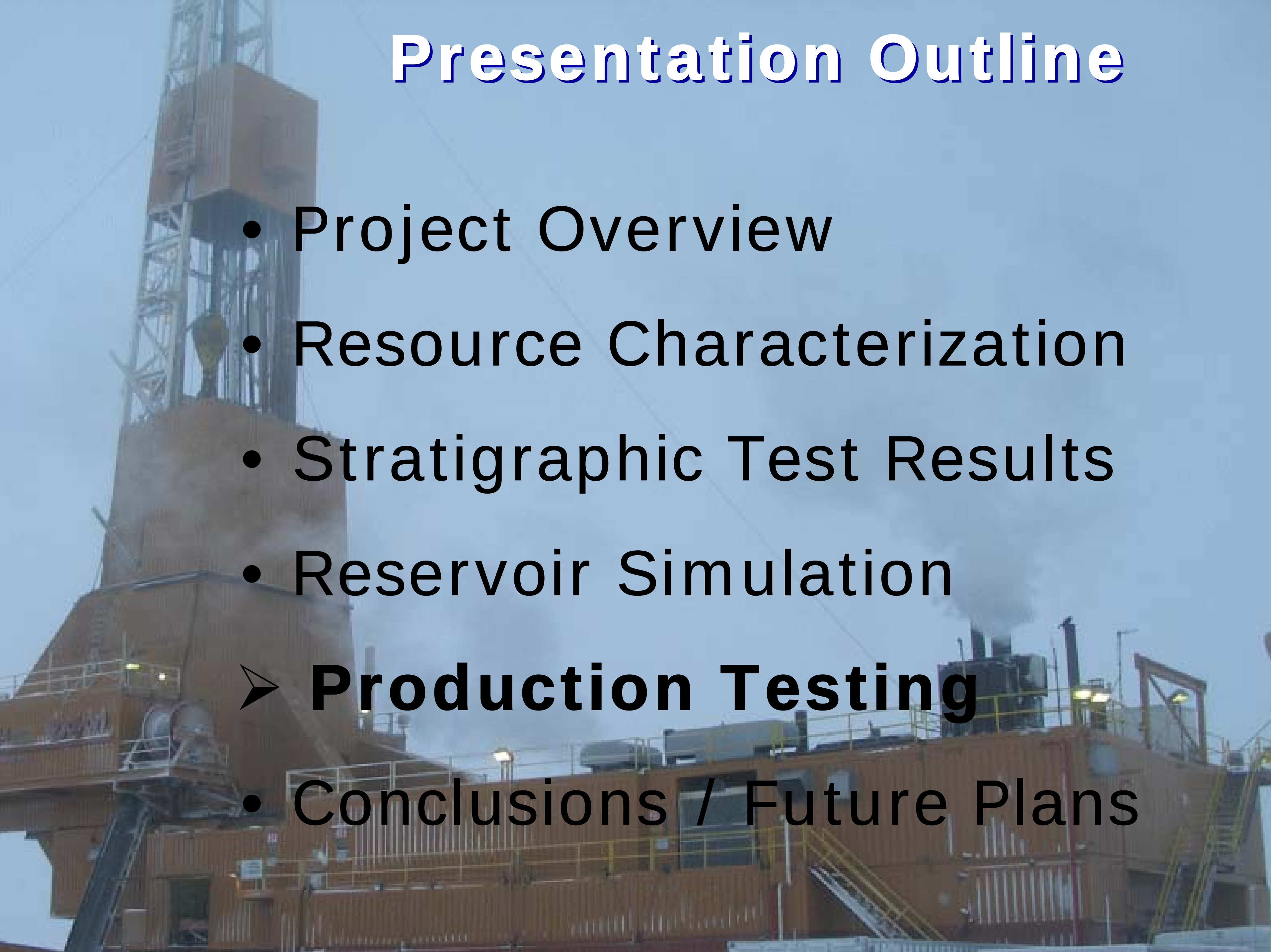
## this well also takes a long time to show its full potential



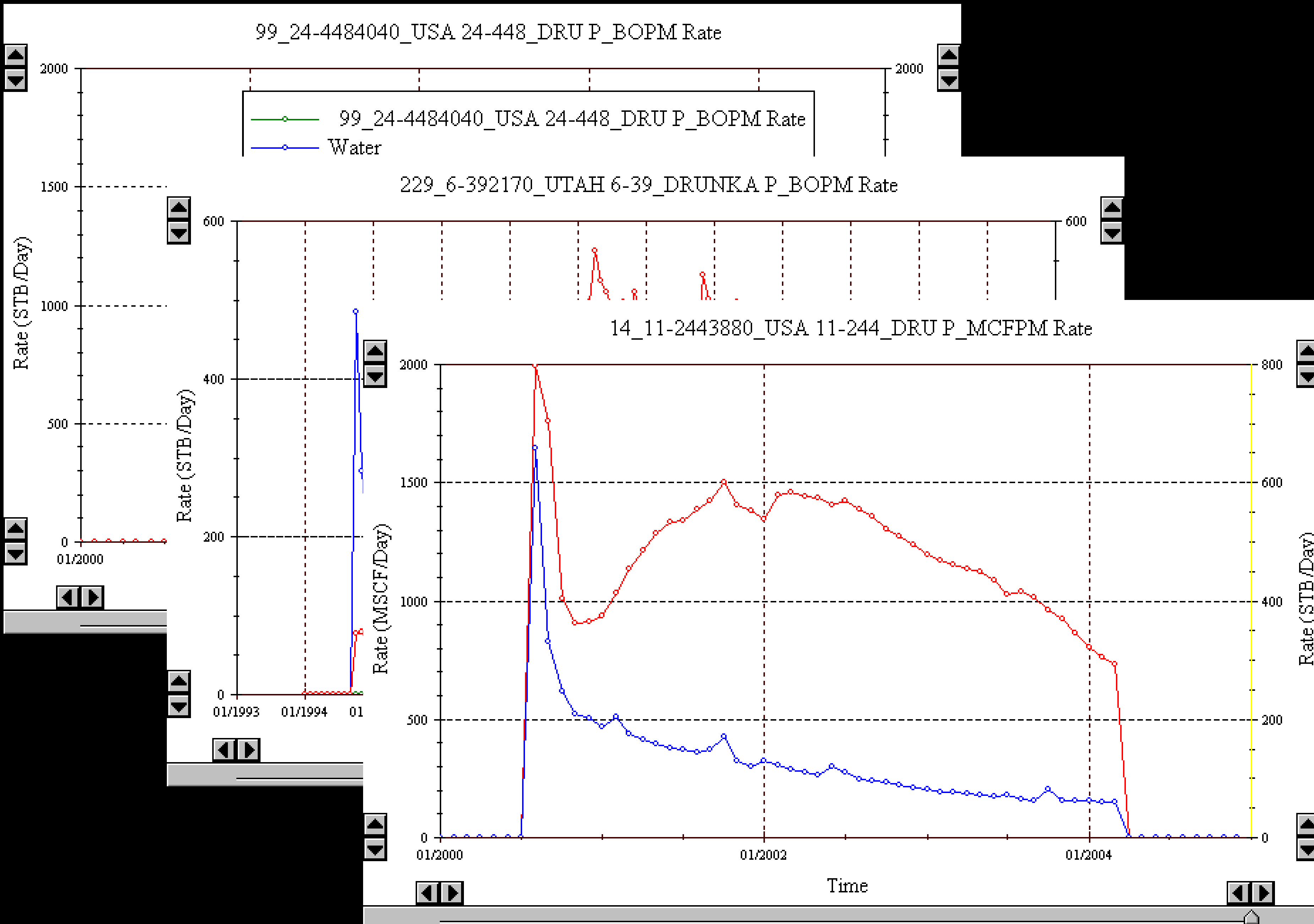

*** Yamamoto and Dallimore (2008)**
**Dallimore et al. (2008)**

# Presentation Outline

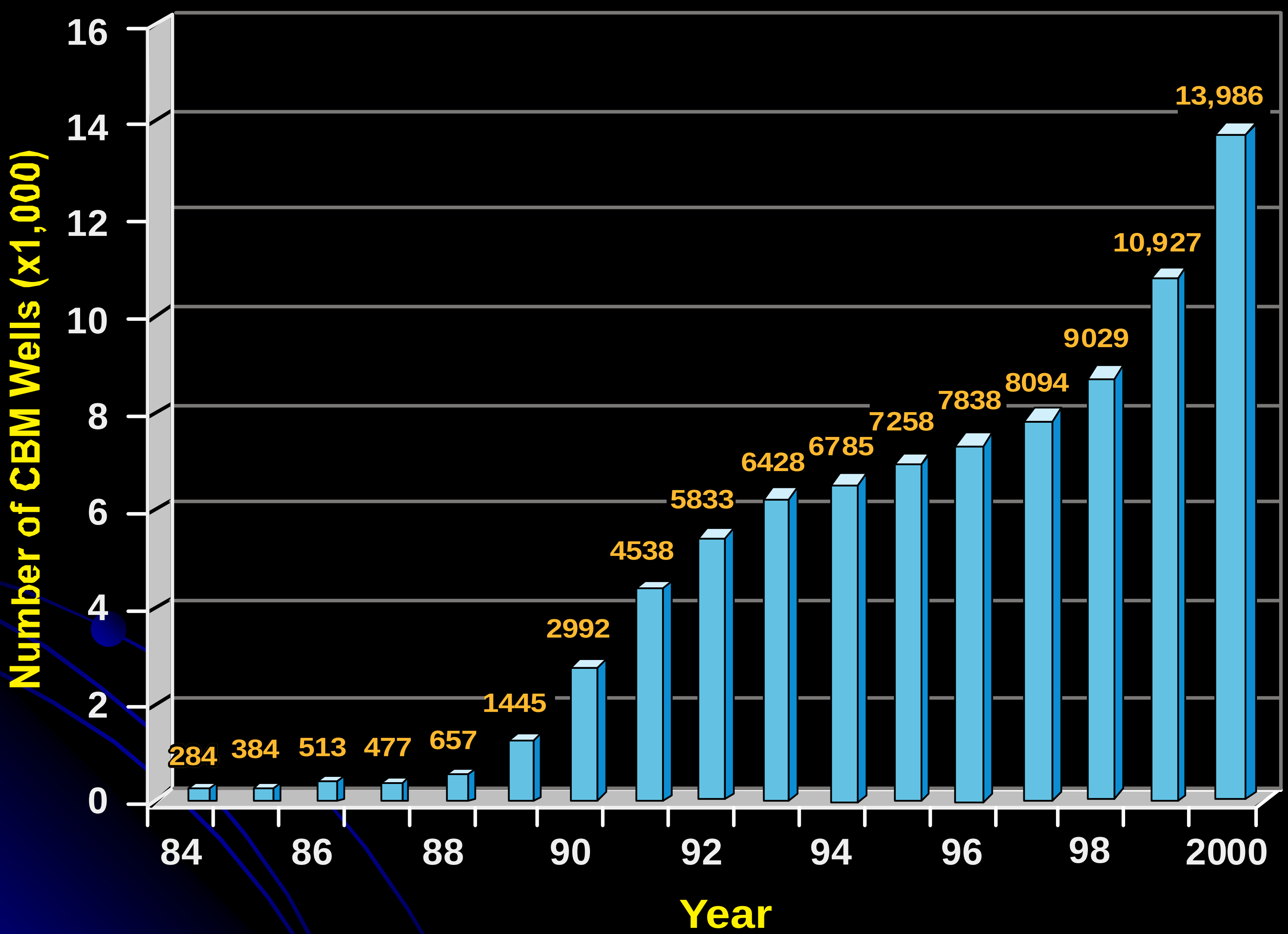
- Project Overview
- Resource Characterization
- Stratigraphic Test Results
- Reservoir Simulation
- ➤ **Production Testing**
- Conclusions / Future Plans



# Coal Bed Methane Analog?

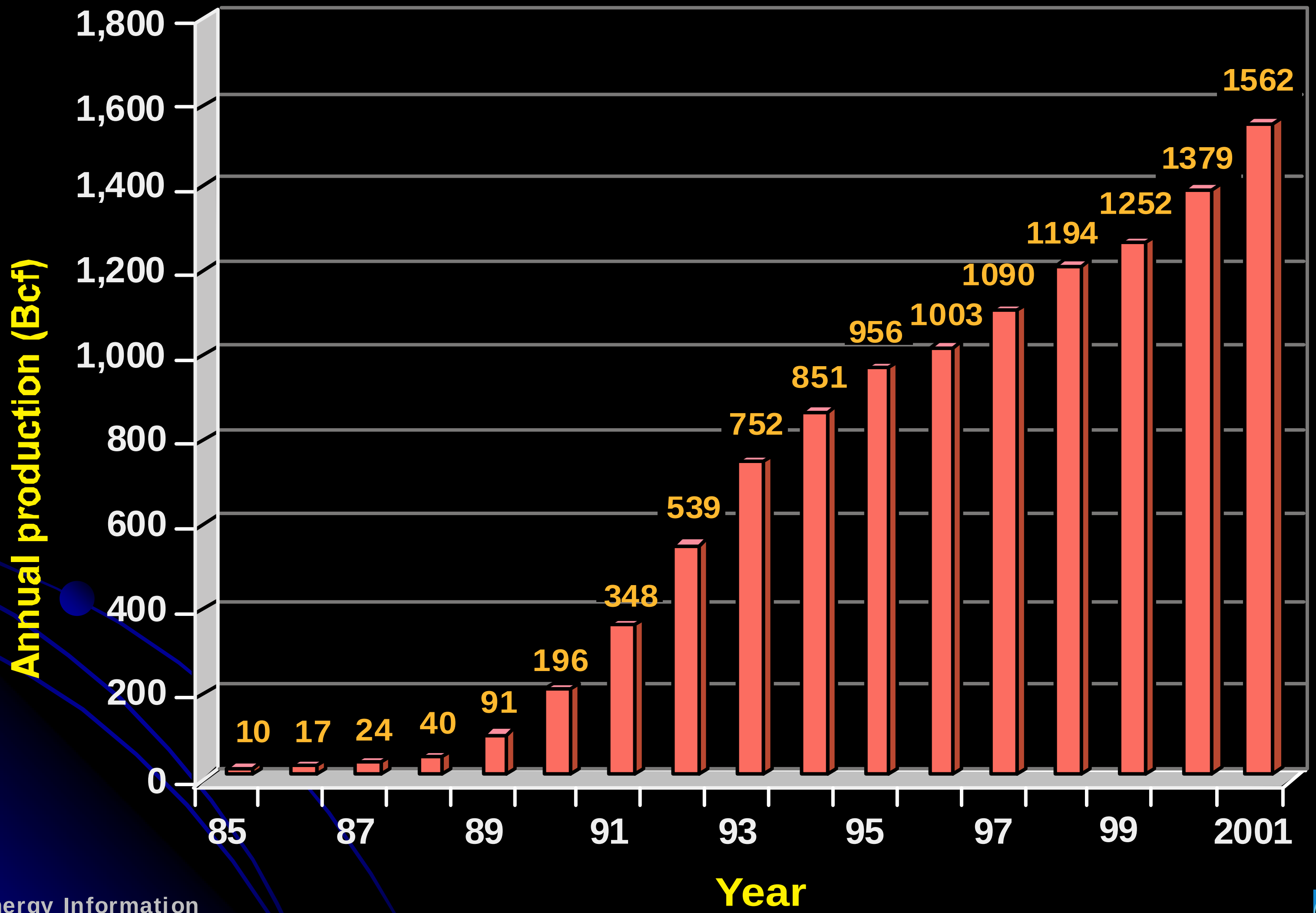


# COALBED METHANE WELLS IN U.S.




ALTUDA

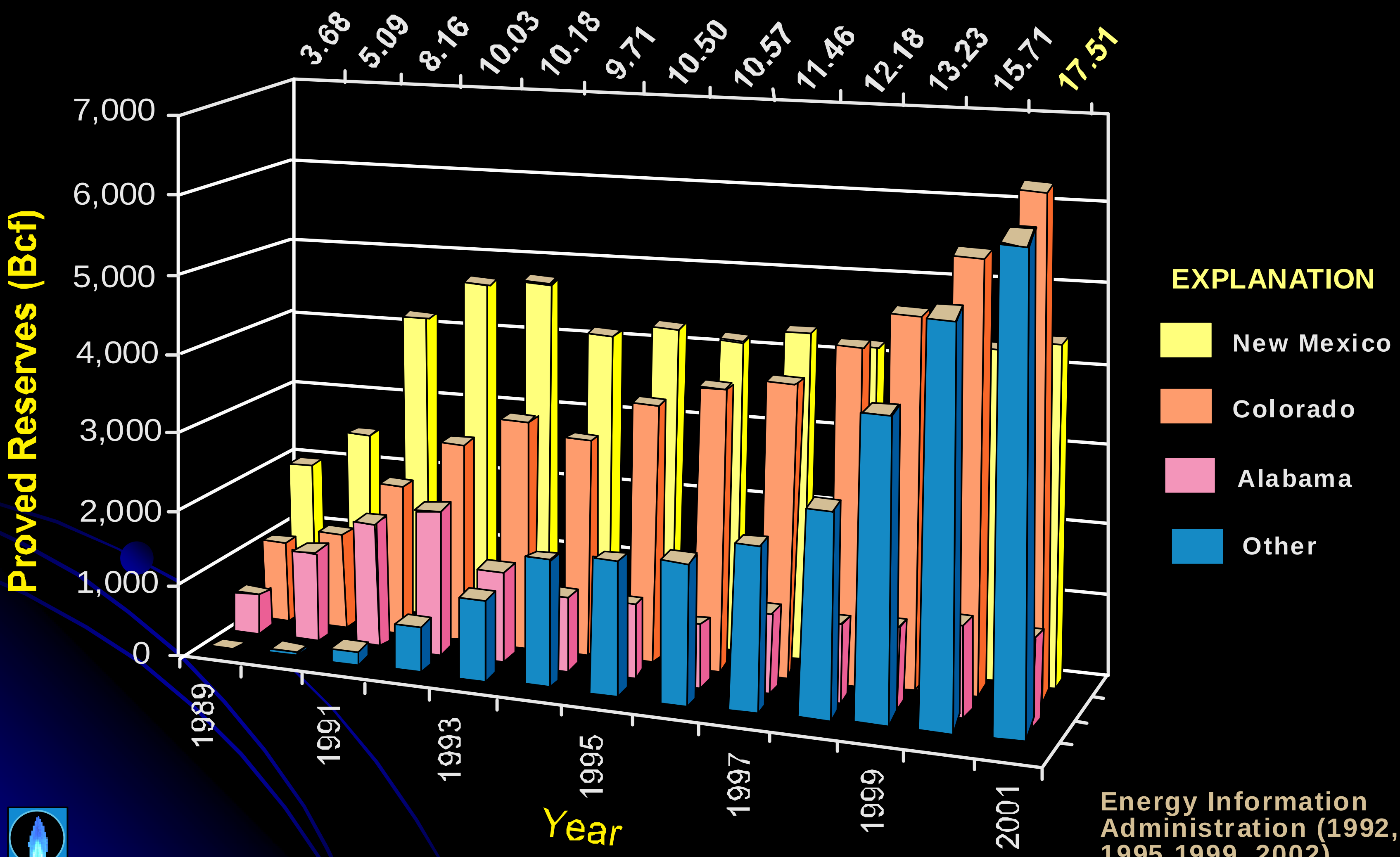
# COALBED METHANE PRODUCTION IN U.S.




Energy Information Administration (1992, 1995,1999, 2002)

ALTUDA

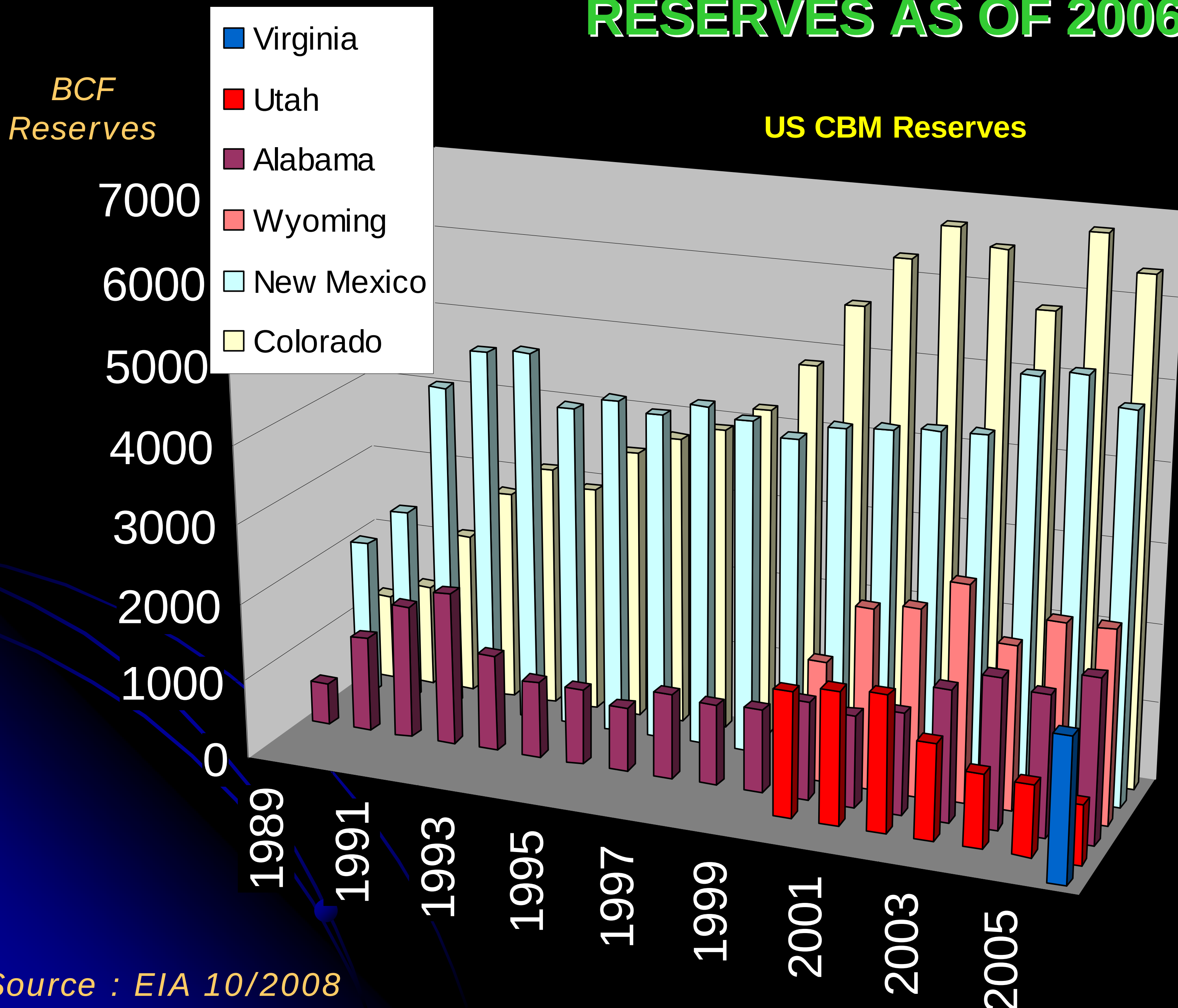
# PROVED COALBED METHANE RESERVES AS OF 2001




Energy Information Administration (1992, 1995,1999, 2002)

ALTUDA

# PROVED COALBED METHANE RESERVES AS OF 2006




*Source : EIA 10/2008*

# Coalbed-Methane Pilots: Timing, Design, and Analysis

Four distinct, sequential phases form a recommended process for coalbed-methane (CBM) -prospect assessment: initial screening, reconnaissance, pilot testing, and final appraisal. A stepwise approach through these phases provides a program of progressively ramping work and cost, while creating a series of discrete decision points at which analysis of results and risks can be assessed. The focus here is on the third phase, pilot testing, which normally takes place after reconnaissance and before final appraisal.

## Introduction

CBM gas accounts for 9% of US domestic natural-gas production. Its importance to the energy industry has grown dramatically in the past 20 years. CBM production is expected to continue to grow significantly over the next decade, both in the US and internationally.

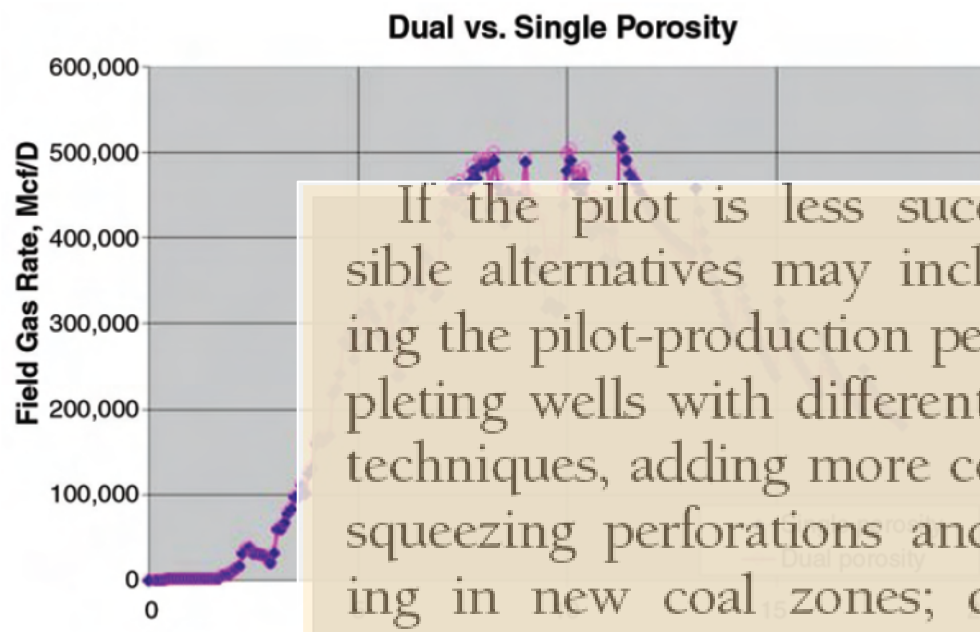



*Fig. 1—Comparison o*

A stepwise phased

If the pilot is less successful, possible alternatives may include extending the pilot-production period; recompleting wells with different stimulation techniques, adding more coal zones, or squeezing perforations and recompleting in new coal zones; drilling infill wells or adding wells to expand the pilot; shutting down the existing pilot and beginning reconnaissance or an alternative pilot test in another portion of the project; or abandoning the pilot, prospect, and, perhaps, the play through farm out or relinquishment. JPT

# THE FIRST SUCCESSFUL SHALE GAS PLAY

TECHNOLOGY FOCUS

## Unconventional Recovery

*Stephen Norris, SPE, is a Senior Staff Reservoir Engineer for J-W Operating Company and is responsible for all reservoir-engineering activities for*

Have you heard the story about the "17-year overnight sensation" (Durham 2005)? (If you work in northern Texas or are involved in unconventional resources, then your answer probably is yes, and if so, please bear with me—it is a great story and worthy of being repeated.)

In the early 1980s, in a county on the outskirts of Fort Worth, Texas, there was

The first well, the C.W. Slay No. 1, was an economic failure, as were the next 40 wells (Bowker 2003). It took 17 years for the company to develop an economic technique that worked. How many companies that you know have that kind of patience? In 1999, very few people had heard of the Barnett shale, but by 2001, it was well on the way to becoming the largest gas field in Texas.

I think that stories like this make unconventional recovery a very exciting arena in which to work. The resource is there, the demand is definitely there, and it is up to engineers, geologists, and enlightened managers to make it happen.

In this issue, we look at three great examples of applying new technology and know-how in the areas of coalbed methane, tight-gas-field deliquification, and gas hydrates. Is there another 17-year overnight sensation here? You be the judge. JPT

References

Bowker, K.A. 2003. Recent Developments of the Barnett Shale Play, Fort Worth Basin. *West Texas Geological Society Bulletin* **42** (6): 4–11.

Durham, L.S. 2005. The 17-Year Overnight Sensation. Explorer 2005 (May). www.aapg.org/explorer/2005/05may/barnett_shale.cfm. Accessed 5 June 2008.

# Gas Hydrate Flow Test Decision Scenario & Contingency Planning

**Technical Resource**

***MDT***

Predicted short depressurization test volumes are measurable

+

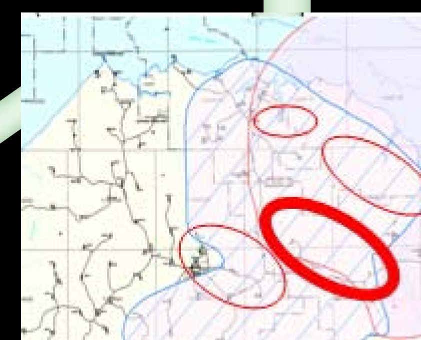
Design and run short term test with Rig

Rig off / design medium term test

+

Implement medium term test

-



-

Evaluate Stimulation Options
- Salt Water flush
- Matrix Acid job
- Cavitation
- Frac
- Propped Frac

-

Shut-down

+

Short term test promising stimulation options

-

+

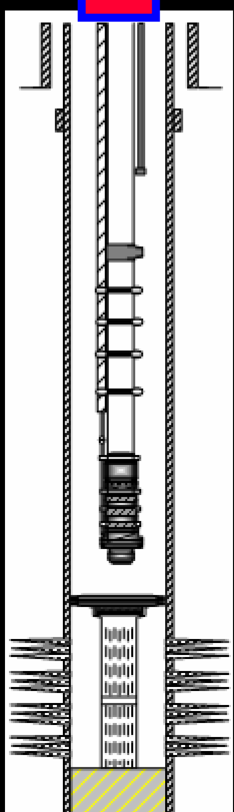
**Quantify Resource**

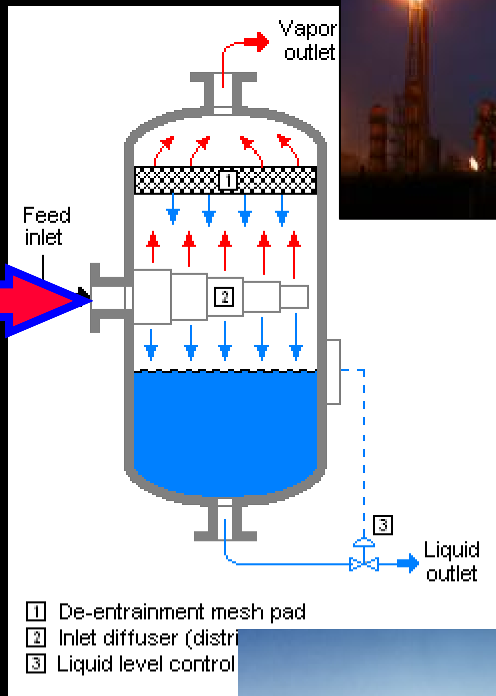
**Long-term tests**

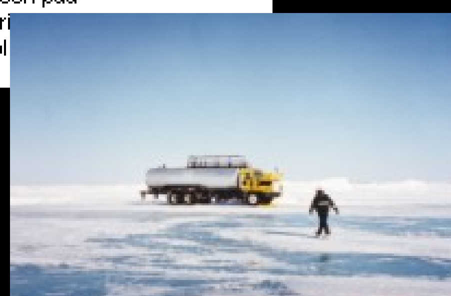
**Proved Reserves**

| Time Scale |
| --- |
| Short |
| Medium |
| Long |

# Drill and Test Vertical Well



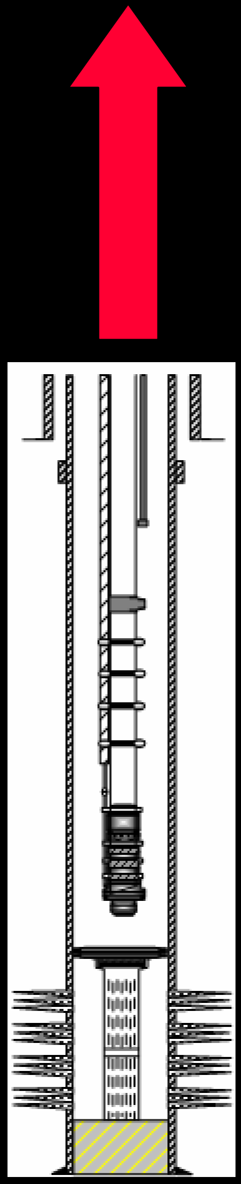


Potential issues

1. Solids create production problems:
   1. Install Gravel pack
   2. Produce sand
   3. (Pump) Frac sand back into fm
   4. Cavitation (CBM Model)
   5. Resin coat
   6. Some combination of the above
   7. Other
2. Wellbore freezes off:
   1. Inject methanol down capillary
   2. Circulate hot gas
   3. Add electrical well heating: Radiant or Induction
   4. Add downhole combustion
3. Production volumes very small but increasing slowly:
   1. Evaluate stimulation options
   2. Soak with destabilizing agents
   3. Hydraulic Fracture with conventional or unconventional fluids
   4. Evaluate sidetrack option

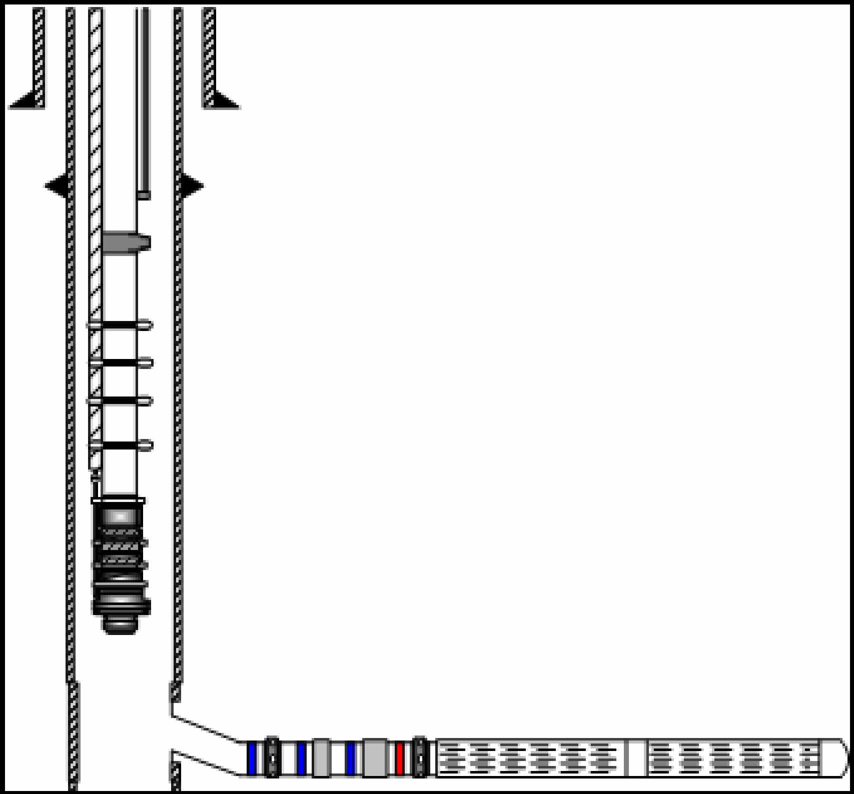
# Failure path 1: Evaluate Stimulation Options in Vertical Well



1. Evaluate secondary methods as a huff-n-puff (inject-soak-produce) to measure stimulation/extraction benefits

    1. Hot and cold, liquid and gas, slow and fast, matrix and fracture pressure
        1. Water/Steam
        2. Methane
        3. $CO_2$
        4. PBU gas = 12% $CO_2$
        5. Inhibitors, solvents, biological
    2. Continue until not successful

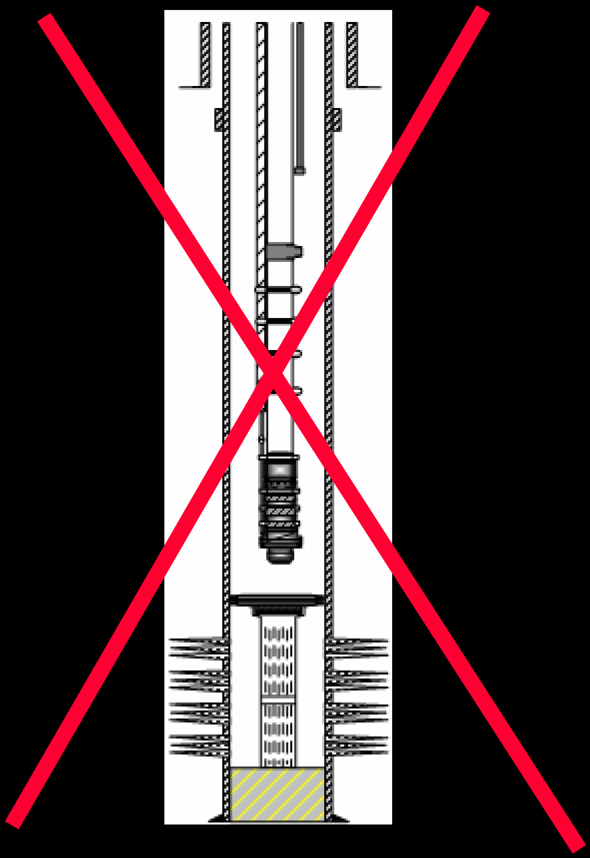
# Failure Path 2: Sidetrack Existing Well Drill Horizontal Section

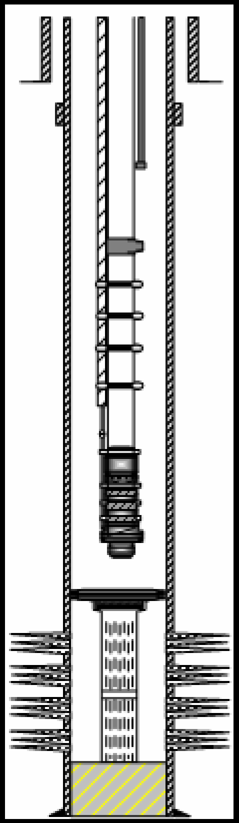


Design with expectation of severe sand production including dedicated circulation strings, sand capable pumps from toe and heel. Take advantage of significant experience in both West Sak and Steam Assisted Gravity Drainage (SAGD) operations.

1. Progress through prior technology sequence using the horizontal well.

# Failure path 3: Drill Second Vertical Pilot Location





- Drill second pilot location and attempt to confirm or overcome negative results
- Follow pilot study procedures proven successful in CBM, tight gas and Shale gas