TOP ANALYSIS

Thermal Oil Production Analysis

SPEE Intro – September 20th, 2016

Agenda

- Introduction to TOP Analysis
  - Top Analysis Software
  - Top Regulatory Software

- Initiatives in oil sands
  - Saskatchewan Developments
    - Previously depleted resource
  - Start up techniques
  - Co-injection
    - Gas
    - Solvent
  - Infill Wells

What is TOP Analysis

TOP Analysis offers multi discipline software solutions designed to expedite the evaluation of thermal developments in Alberta and Saskatchewan. The combination of the TOP Analysis and TOP Regulatory software allows any organization to maintain thermal surveillance with reduced resources.

TOP Analysis Software

- Administered linked wells to pairs, pairs/infill wells to pads and pads to projects
- Volumetric data, well design and operational information such as pressures and temperatures
- Regulatory applications automatically linked to objects within the company tree

TOP Regulatory Software

- A searchable application database updated daily
- Applications available for immediate download
- All AB application and category types, **including all SK Thermal applications**

Saskatchewan Thermal

Target formations – Mannville group

– Colony, Cummings, Lloyd, McLaren, Sparky, Rex, GP, Waseca

Smaller prolific channels

– 3000 – 10000 bbl/d (most recent designs < 6000 bbl/d)

– 10-15 year resource base

Economic advantages

– Low capital requirement due facility simplicity (No water recycle, River source typical)

– Favorable/certain regulatory structure (Short application turnaround)

– Low OPEX (little to no diluent, Low SOR, reduced emissions implications)

Undisturbed favorable thermal resource limited

– Significant Husky and CNRL land holdings

– Existing projects already have extremely small resource base

– Husky has started its first SAGD project (Edam West) in previous depletion

Saskatchewan Thermal History

Location	Owner	Applicant	Project	Type	Target Formation	Online	Shut in
12-50-27-W3	Husky	Husky	Aberfeldy	Fireflood	Sparky	1969	1982
23-46-18-W3	Serafina Energy	Texas Gulf	Meota	CSS/Steam flood	Lloydminster	1974	1986
20-49-26-W3	Husky	Husky	Aberfeldy	Steam flood	Sparky	1981	1988
1-50-24-W3	Husky	Husky	Pikes Peak	CSS/Steam flood/SAGD	Waseca	1981	N/A
14-48-23-W3	Husky	Husky	Golden Lake	Fireflood	Waseca	1982	1986
10-52-23-W3	Husky	Mobil	Celtic	CSS/Steam flood	Sparky/GP	1984	1989
23-52-25-W3	CNRL	Spectre Resources	Tangleflags	Steam flood/SAGD	Lloydminster	1988	N/A
22-35-26-W3	Baytex	Nexen	Plover Lake	Steam flood/CSS	Bakken	1991	2004
10-52-23-W3	Caltex	Mobil	Cactus Lake	CSS/Steam flood/SAGD	McLaren	1992	2000
30-52-23-W3	Husky	Husky	Bolney	CSS/SAGD	Colony	1995	N/A
10-52-23-W3	Husky	Mobil	Celtic	SAGD/Steam flood	Sparky/GP	1996	N/A
11-40-26-W3	CNRL	CS Resources	Senlac	Steam flood/SAGD	Cummings	1996	N/A
36-32-24-W3	Baytex	Stampeder	Kerrobert	CSS/SAGD	Waseca	1998	N/A
25-46-24-W3	Baytex	Baytex	Soda Lake	Vapex	Cummings	2001	1995
22-35-26-W3	Baytex	Nexen	Plover Lake	Vapex	Bakken	2001	2005
12-49-24-W3	Husky	Husky	PikesPeak South (Lashburn)	SAGD	Waseca	2004	N/A
5-56-27-W3	BlackPearl	Pearl	Onion Lake CSS Pilot	CSS	Cummings	2008	2009
04-48-21-W3	Husky	Husky	Rush Lake Pilot	SAGD	Sparky	2011	N/A
14-33-24-W3	QUATTRO	Petrobank	Kerrobert THAI	THAI	Waseca	2011	N/A
27-53-24-W3	Husky	Husky	Paradise Hill	SAGD	Colony	2012	N/A
15-51-24-W3	Husky	Husky	Sandall	SAGD	Colony	2013	N/A
5-56-27-W3	BlackPearl	Pearl	Onion Lake Pilot	SAGD/Steam flood	Cummings	2014	N/A
22-35-26-W3	Northern Blizzard	Northern Blizzard	Plover Lake	SAGD	McLaren	2014	N/A
5-56-27-W3	BlackPearl	Pearl	Onion Lake	Steam flood	Cummings	2015	N/A
04-48-21-W3	Husky	Husky	Rush Lake	SAGD	Sparky	2015	N/A
11-48-19-W3	Serafina Energy	Broadview Energy	Edam	SAGD	Lloydminster	2016	N/A
8-48-19-W3	Husky	Husky	Edam East	SAGD	Sparky/Rex	2016	N/A
19-48-20-W3	Husky	Husky	Edam West	SAGD	Sparky/GP	2016	N/A
1-48-19-W3	Husky	Husky	Vawn	SAGD	Sparky/Rex	2016	N/A

Saskatchewan Regulatory

Download Application Files

Available Date	Description	Submitted Date	Size	
	MRO 399-14/Approval letter.pdf		(Archived)	
	MRO 399-14/MRO 399-14 Application.pdf		(Archived)	
	MRO 399-14/MRO 399-14 Approval.pdf		(Archived)	
	MRO 399-14/Well Applications(1).pdf		(Archived)	
	MRO 399-14/Well Applications(2).pdf		(Archived)	

Husky – **Edam West** (4K bbl/d)
Application Size ~ 11 MB
Application Length ~ 28 Pages
Supplemental Information Requests
-1 round < 10 Questions
Approval Time ~ 4 Months

Application submission to first steam
~ 16 Months*

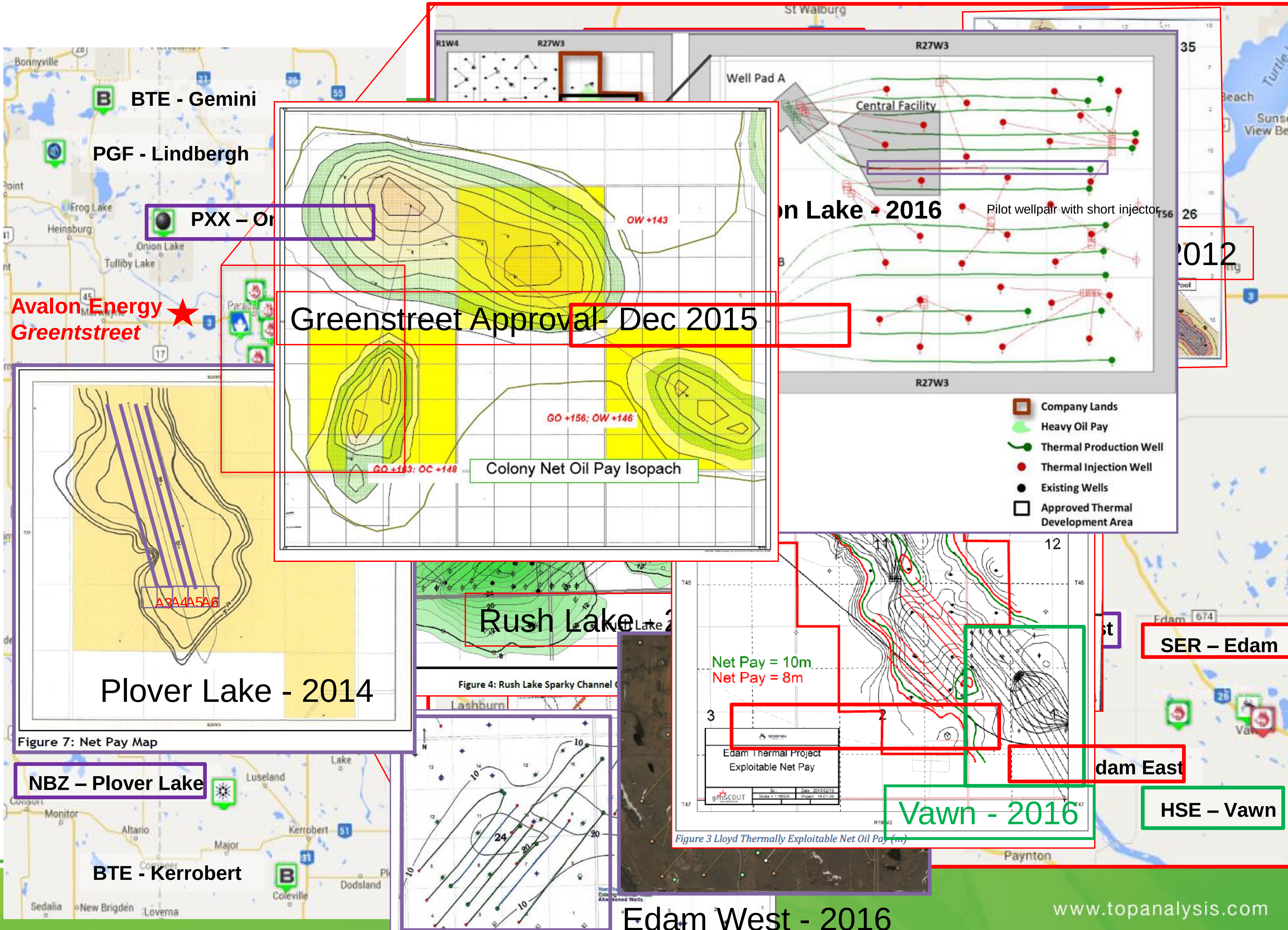
Download Application Files

Available Date	Description	Submitted Date	Size	
	1685028/12172-514_Hangingstone_Project_-_SIR_R1_Responses_		(Archived)	
	1685028/AOSC.....pdf		(Archived)	
	1685028/AOSC.pdf		(Archived)	
	1685028/AOSC_Hangingstone_Project_-_SIR_Round_2_Responses		(Archived)	
	1685028/AOSC_to_AOC_Name_Change_Notice_(2).pdf		(Archived)	
	1685028/Cover_Letter_for_SIR_-_ERCB_Application_1685028.pdf		(Archived)	
	1685028/Cover_Letter_for_SIR_2_-_ERCB_Application_No._16850		(Archived)	
	1685028/Cross_sections.pdf		(Archived)	
	1685028/ERCB_Withdrawal_letter_AOSC_Hangingstone.pdf		(Archived)	
	1685028/Hangingstone_Consultation_Summary_for_ERCB_Final_2		(Archived)	
	1685028/Hangingstone_Coverletter_Update.pdf		(Archived)	
	1685028/Hangingstone_Project_Application_.pdf		(Archived)	
	1685028/MOP_and_M_MCM_Sands.pdf		(Archived)	
	1685028/Objection_27680.pdf		(Archived)	
	[illegible]		(Archived)	
	[illegible]		(Archived)	
	1685028/Supplemental_Information_Request_-_ERCB_Application		(Archived)	
	[illegible]		(Archived)	

Athabasca Hangingstone (12K bbl/d)
Application Size ~ 93 MB
Application Length ~ 476 Pages
Supplemental Information Requests
-2 rounds > 100 Questions
Approval Time ~ 19 Months

Application submission to first steam
~ 48 Months

*Based on PXX/Onion Lake
*Husky/Paradise Hill ~ 12 Months


BTE - Gemini
PGF - Lindbergh
PXX – Or
Avalon Energy
Greentstreet
Greenstreet Approval- Dec 2015
Colony Net Oil Pay Isopach
OW +143
GO +156; OW +146
GO +163; OC +148
Well Pad A
Central Facility
R27W3
on Lake - 2016
Pilot wellpair with short injector
Company Lands
Heavy Oil Pay
Thermal Production Well
Thermal Injection Well
Existing Wells
Approved Thermal Development Area
2012
Plover Lake - 2014
A3A4A5A6
Figure 7: Net Pay Map
NBZ – Plover Lake
Rush Lake - 2
Figure 4: Rush Lake Sparky Channel
Net Pay = 10m
Net Pay = 8m
Edam Thermal Project
Exploitable Net Pay
Figure 3 Lloyd Thermally Exploitable Net Oil Pay (m)
Vawn - 2016
SER – Edam
dam East
HSE – Vawn
BTE - Kerrobert
Edam West - 2016

Post CHOPS potential

Drilling through depletion

- Plan for and manage lost circulation
- Potential variation from planned drilling strategy

Operational challenges

- Bottom water influence more difficult to manage
- Accumulated solution gas could hinder heat transfer (not always bad)
- Conformance impacts
  - Robust downhole completion (ICD’s, rod pumps, high temp ESP’s)
- Operational upsets can result in significant reservoir changes
- Horizontal primary producers increase the potential issues encountered

Benefits

- Potential for larger resource base (vs undeveloped assets)
- Low initial reservoir viscosity
- Shorter start up
- Primary support (thermal and primary drainage)
- Existing infrastructure

Initiatives in Oil Sands

- Co-Injection (~100+ Regulatory Applications)
  - Natural Gas, Solvent, Surfactant

- Infill Wells (~60+ Regulatory Applications)

- Start Up Strategies (~45+ Regulatory Applications)
  - Solvent Soak, Dilation, Solvent Circulation, Electric Heat

- Inflow/Outflow control devices (Applications not always submitted)
  - Longer wells, reduced oil/water contact offset, chamber conformance

- Manipulating Reservoir Characteristics (~5+ Regulatory Applications)
  - Gas cap creation, lean zone dewatering, bottom water de-pressurization

Challenges

The largest challenge facing operators is the uncertainty of the performance of these different initiatives as development moves toward less desirable or unpredictable resource.

- Start Up Strategies
  - Each well needs to be evaluated for the likelihood of **failure** with a given strategy based on both drilling and reservoir characteristics.

- Co-Injection
  - Natural gas timing is crucial depending on its intent
  - Solvent success will vary significantly across each development area

- Infill Wells
  - Infill well timing, capital constraints, energy markets, and resource quality all play an important roll in how an infill well is deemed successful or not

Start Up Strategies

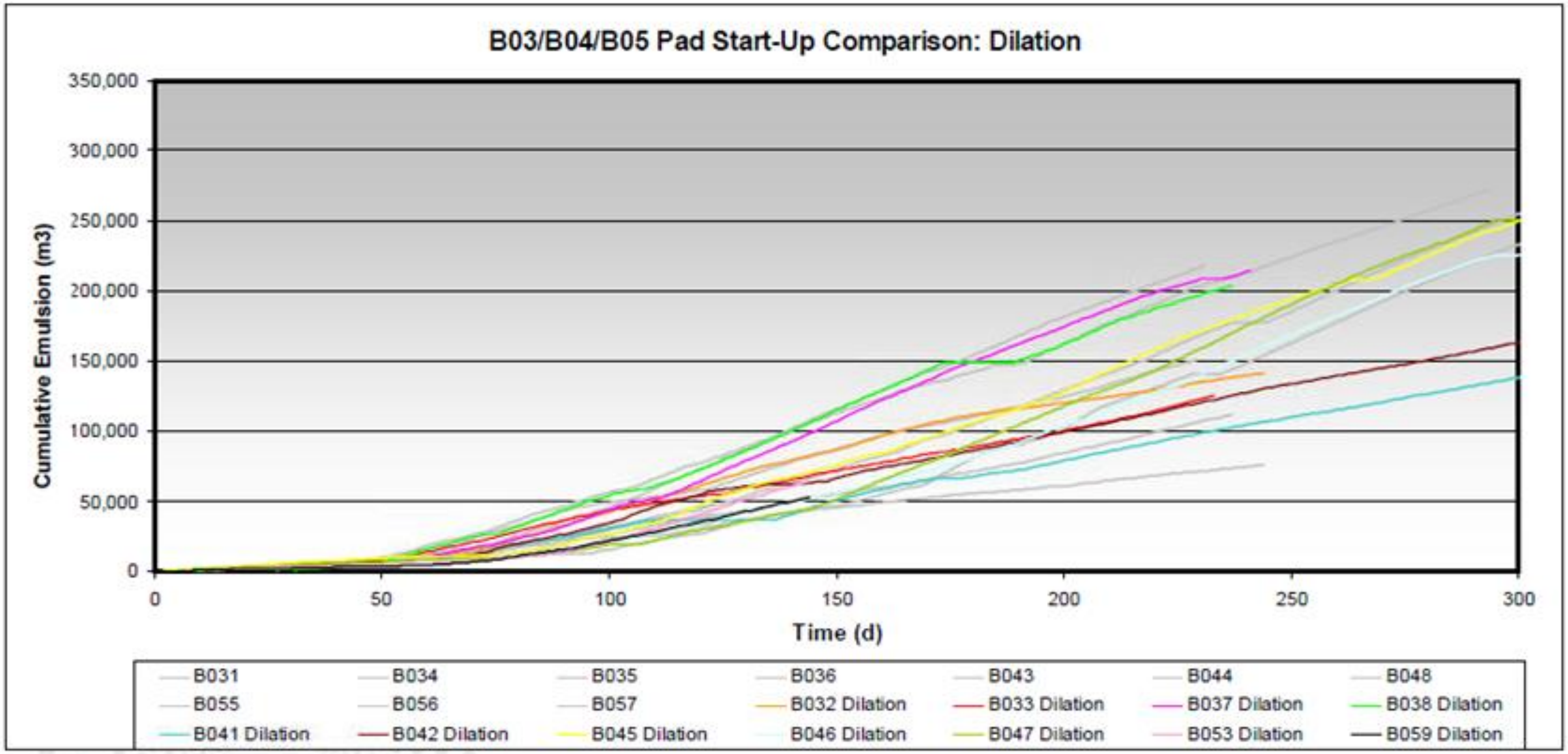
Circulation (Often combined with a bullhead phase)

Bullhead (Steam, Water, Solvent or any combination)

Solvent Soak (Diluent landed in producer/injector prior to start up)

Dilation (Steam, Water, Solvent or any combination)

Electric preheat

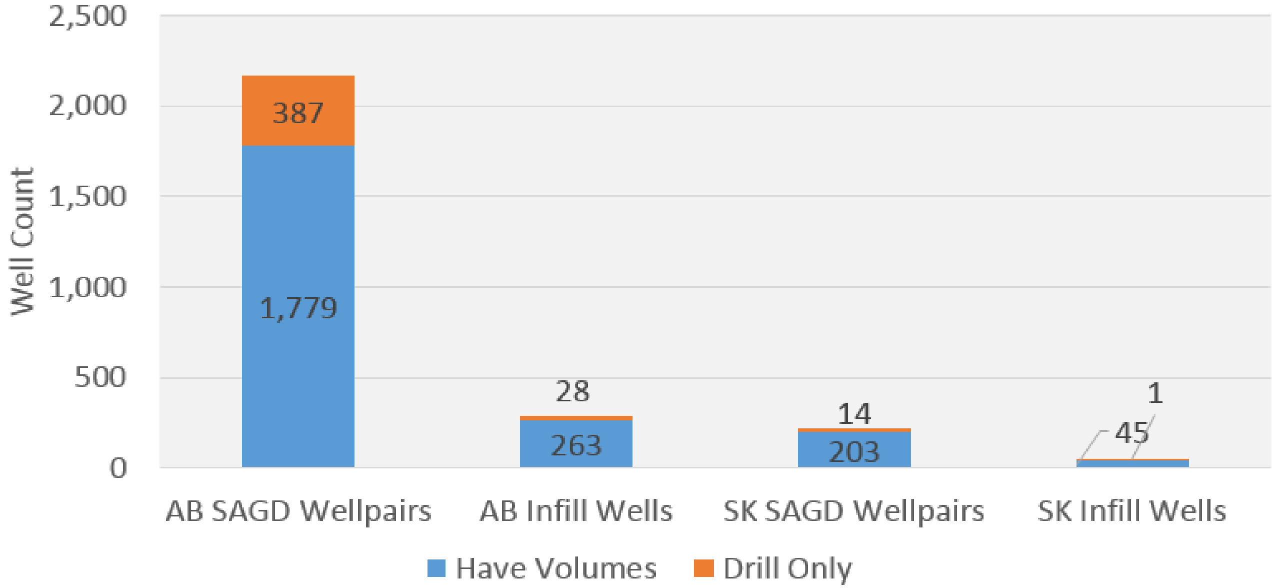


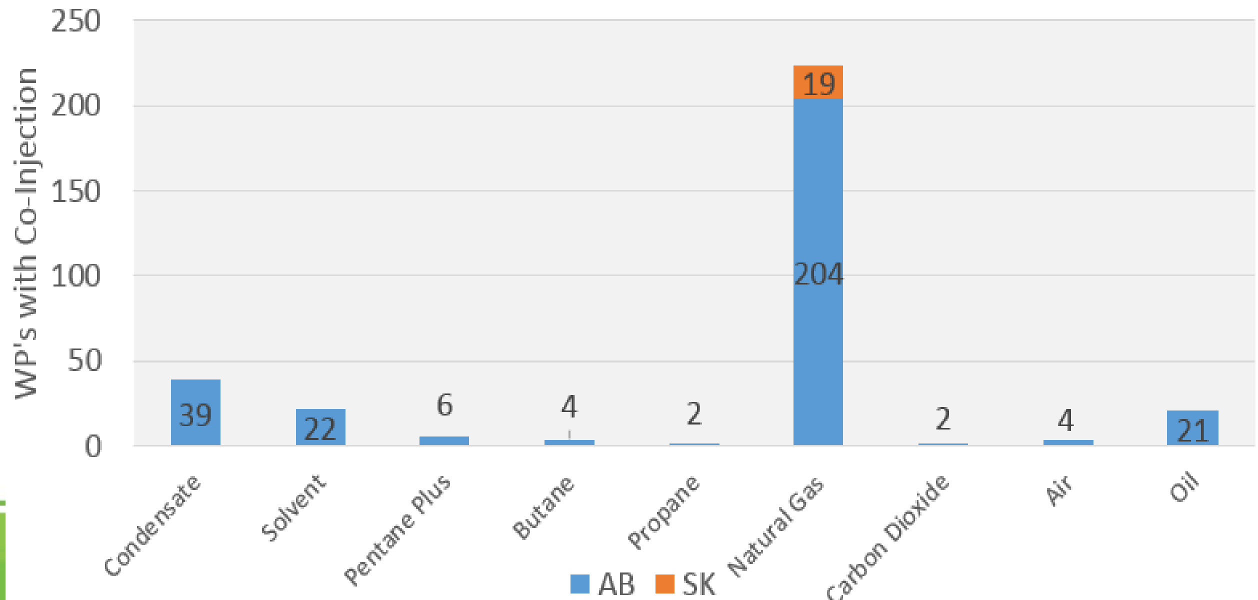
Co-injection

- Natural Gas
  - The majority of gas injected is immediately produced
  - Gas production a result of steam sweep, drag and dissolution
  - Partial pressure effect causes cooling and a slowdown of chamber growth
  - The reduction in steam quickly results in a reduction in oil production equivalent to the pre co-injection SOR, with only a short benefit **on that wellpair**

- Solvent
  - Multiple trials with vaporizing and condensing mixtures (Hexane dominated)
  - The solvent will increase incremental oil rate, but success is ultimately a function of reservoir retention (and surface solvent recovery)
  - Major obstacles are measurement uncertainty, reservoir retention (through losses and pore space retention) and lack of recovery equipment
    - Burning the solvent in boilers configured for natural gas has resulted in significant boiler outage and associated well downtime (from solvent trials)

Injected Fluid Well Counts





Infill Well Performance

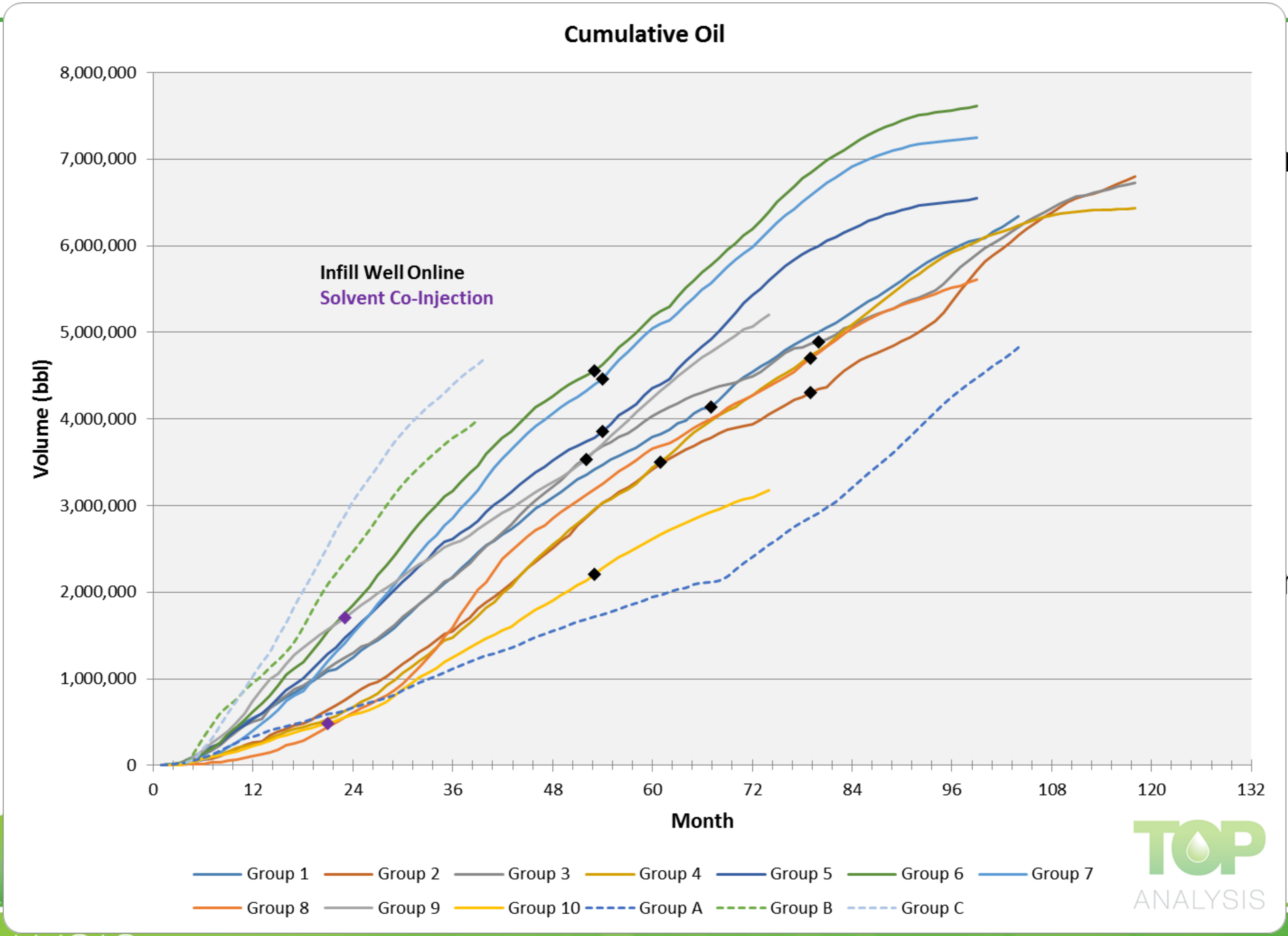
- Analysis is often difficult as no reservoir or even wellpad has consistent well performance which ultimately drives infill well success

- Recovery of offsetting wellpairs (timing of infill well)
- Resource quality and unique characteristics (ex. Varying viscosity gradient)
- Parent wellpairs steam chamber shape
  - Lower conformance is often a driver of success of an infill well as it helps with initial communication
- Wellpair separation and reservoir thickness
- Presence of bottom water and associated landing depth
- Start up strategy and completion

Infill Timing – Cum Recovery Impact

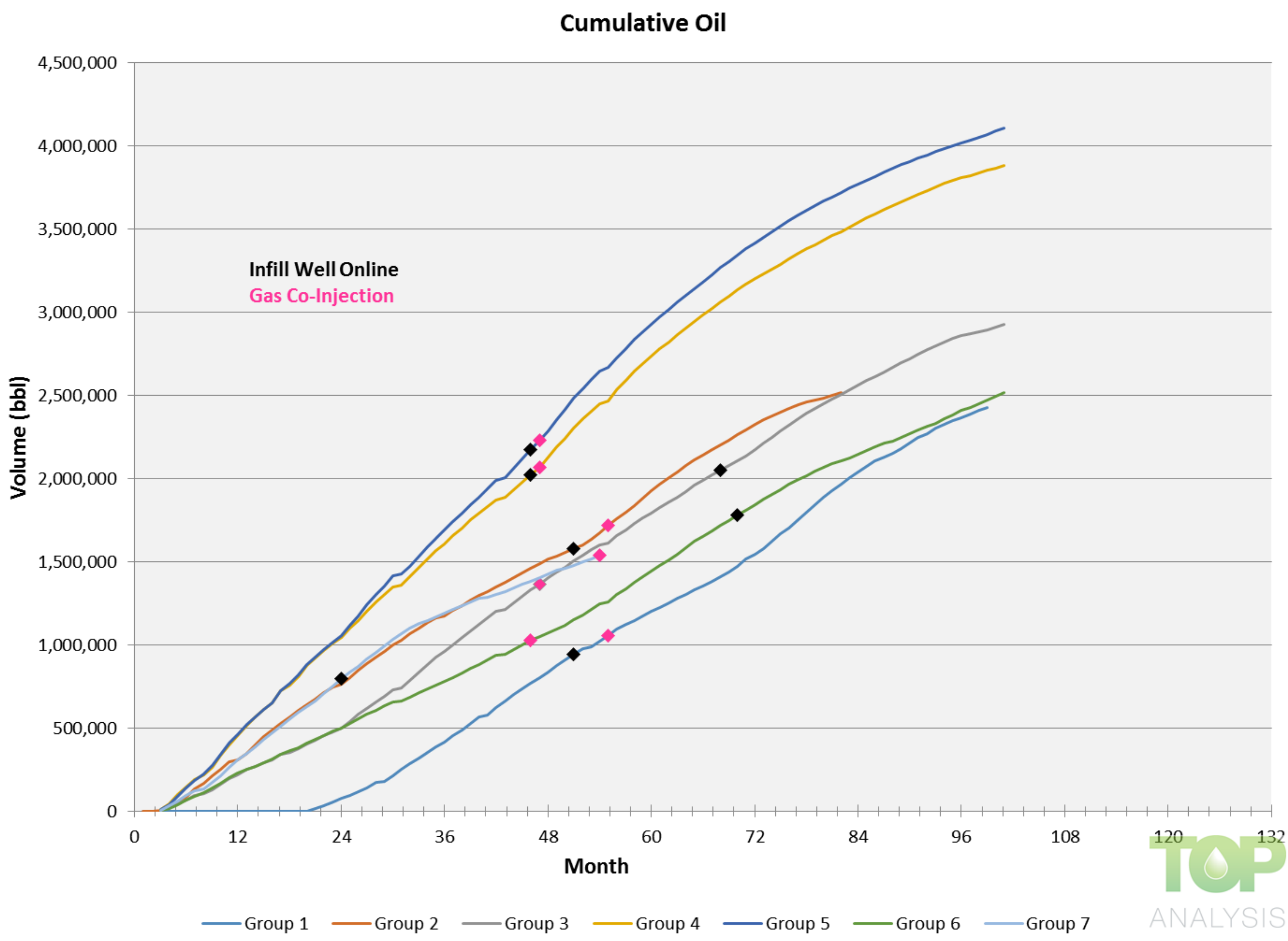
n WP

m WP

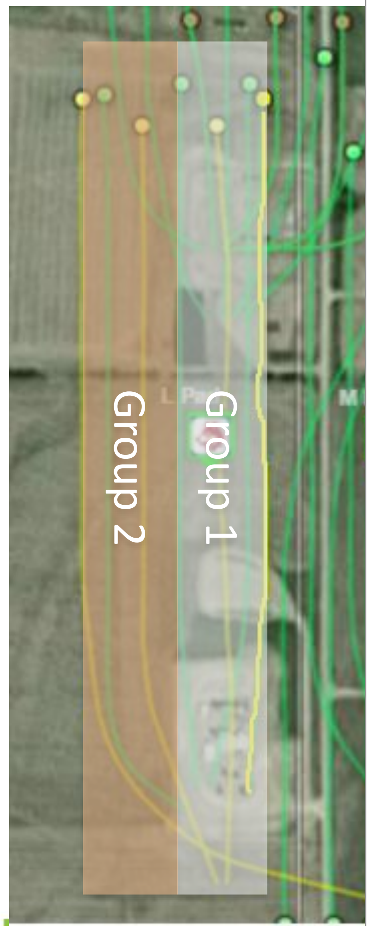


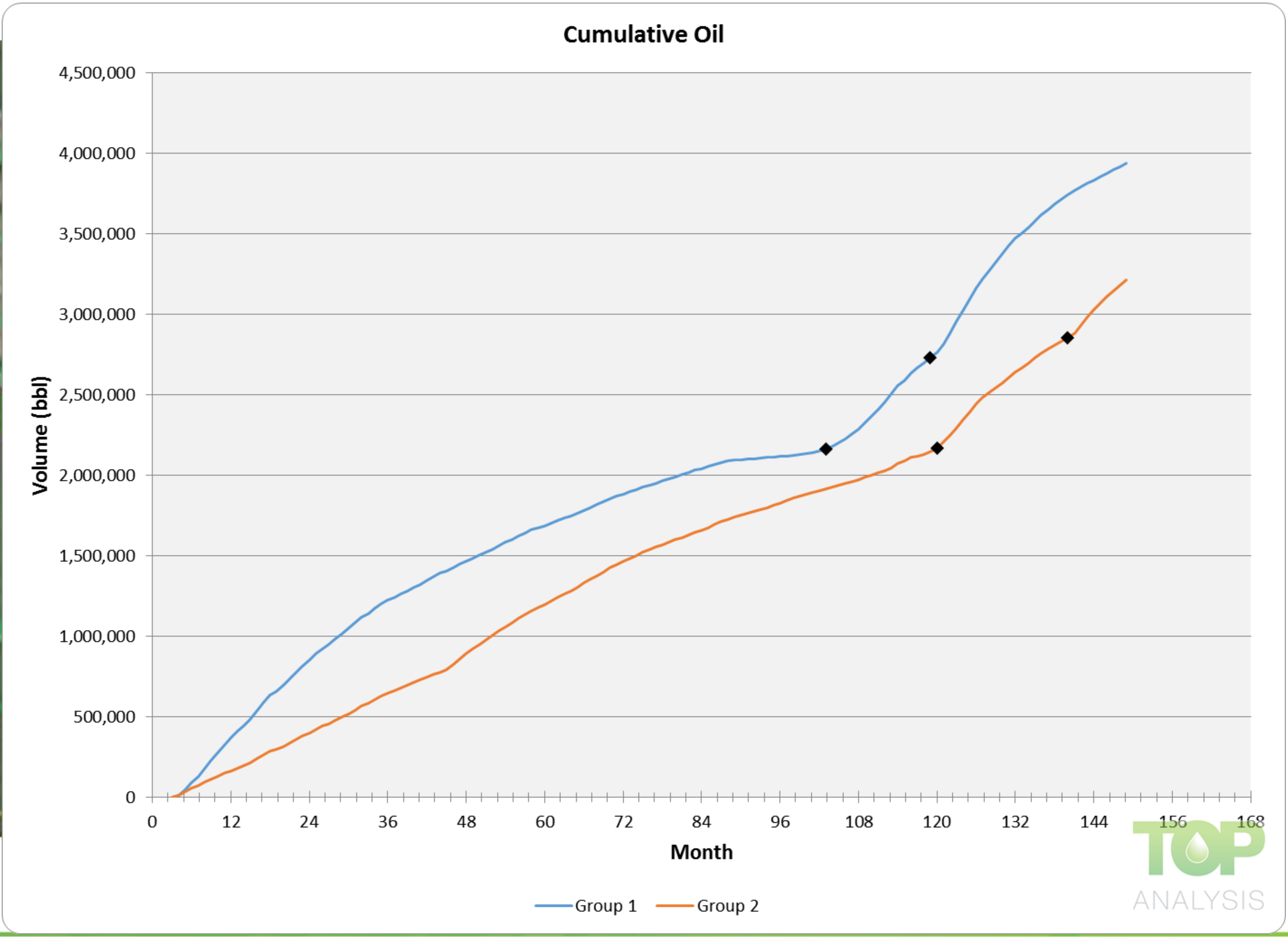
CVE/CL Pad B01/B02

Infill Timing – Cum Recovery Impact



Infill Timing – Cum Recovery Impact





Thermal development forecast

- Lower tier asset development
  - Previously exploited resource thermal developments (SK)
  - Subsurface patterns with thinner pay, more bottom water, presence of lean zones and general lower quality resource
  - **Longer circulation periods,** reduction in peak rates, an increase in SOR and ultimately an increase in downhole equipment and capital

- Longer wells, often at the sacrifice of recovery factor
  - ICD and completion optimization will help reduce RF impact

- Reduction new pad development cost through turnkey offerings
  - Corporate structure and philosophies will have to change

Questions/Comments?

TOP ANALYSIS

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