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PRIMROSE, WOLF LAKE, AND BURNT LAKE ANNUAL DIRECTIVE 054 PERFORMANCE PRESENTATION PACKAGE

February 5, 2020

Directive 54: Performance Presentations, Auditing, and Surveillance of In Situ Oil Sands Schemes

- February 5, 2020
  - 3.1.1 Subsurface Issues Related to Resource Evaluation and Recovery
  - 3.1.2 Surface Operations, Compliance, and Issues Not Related to Resource Evaluation and Recovery

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SUBSURFACE ISSUES RELATED TO RESOURCE EVALUATION AND RECOVERY

February 5, 2020

PREMIUM VALUE. DEFINED GROWTH. INDEPENDENT.

Outline – Subsurface Issues Related to Resource Evaluation and Recovery

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Primrose, Wolf Lake, and Burnt Lake Directive 54 Presentation – Acronyms

AER	Alberta Energy Regulator
Avg.	average
bbls	barrels, petroleum, (42 U.S. gallons)
BHA	bottom hole assembly
Bit	bitumen
bitwt	bitumen weight
CD	cyclic drive
CDOR	calendar day oil rate
CDSR	calendar day steam rate
cP	centipoise
CSOR	cumulative steam to oil ratio
CSS	cyclic steam stimulation
Cumm	cumulative
dev	deviated
DFIT	diagnostic fracture injection testing
DI	depletion index
dP	pressure differential
DTS	distributed temperature sensing
e3m3	thousand cubic metres
EO	enforcement order
ESP	electric submersible pump(s)
ESRD	Environment and Sustainable Resource Development
FTS	flow to surface
FUP	follow up process
GPS	global positioning system
HP	horse power
HZ	horizontal
IHS	Inclined heterolithic stratification
InSAR	interferometric synthetic aperture radar
KB	Kelly Bushing
kg/m	kilograms per metre
kPA	kiloPascal
kPa/d	kiloPascal per day
LGR	Lower Grand Rapids
LIDAR	laser imaging, detection and ranging
LPCSS	low pressure cyclic steam stimulation
m	metre
m^3	cubic metres
m^3 /d	cubic metres per day
m^3 /well	cubic metre per well
Max.	maximum
MCMR	McMurray

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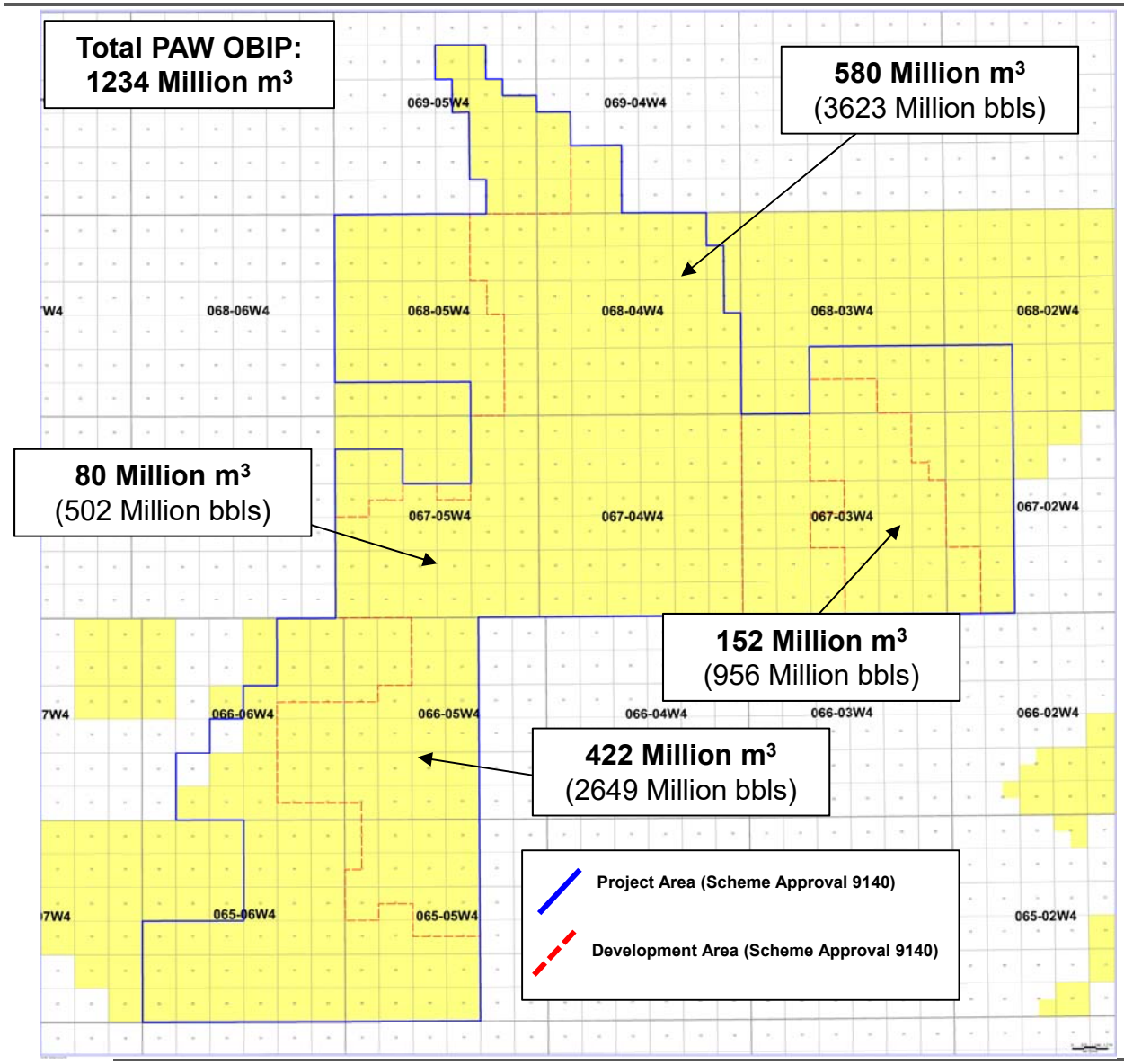
Primrose, Wolf Lake, and Burnt Lake Directive 54 Presentation – Acronyms *(cont'd)*

mD	milli-Darcy
mm	millimetre
MMbbl	million barrels
MPa	Mega Pascal
mTVD	metres true vertical depth
MWSDD	mixed-well steam drive drainage
OBIP	original bitumen in place
Obs	observation
ohm·m	ohm·metre
PAW	Primrose and Wolf Lake
PCP	progressive cavity pump
PRE	Primrose East
PRE A1	Primrose East Area 1
PRE A2	Primrose East Area 2
PRS	Primrose South
PRN	Primrose North
PV	pore volume
PVS	pore volume steam
RF	recovery factor
RTK	real-time kinematic
SAGD	steam assisted gravity drainage
SF	steamflood
SL	slotted liner
So	oil saturation
SOR	steam oil ratio
SPM	strokes per minute
SAR	synthetic aperture radar
Strat	stratigraphic
tbg.	tubing
TD	total depth
TVD	true vertical depth
VAF	volume above fill-up
WDI	water depletion index
WHT	wellhead temperature
WWS	wire-wrapped screen
YE	year end

Primrose and Wolf Lake OBIP within Scheme Approval 9140 Development Area



OBIP numbers include:

- **McMurray**
- **Clearwater**
- **Grand Rapids**

Pay criteria for each area and formation shown in subsequent slides

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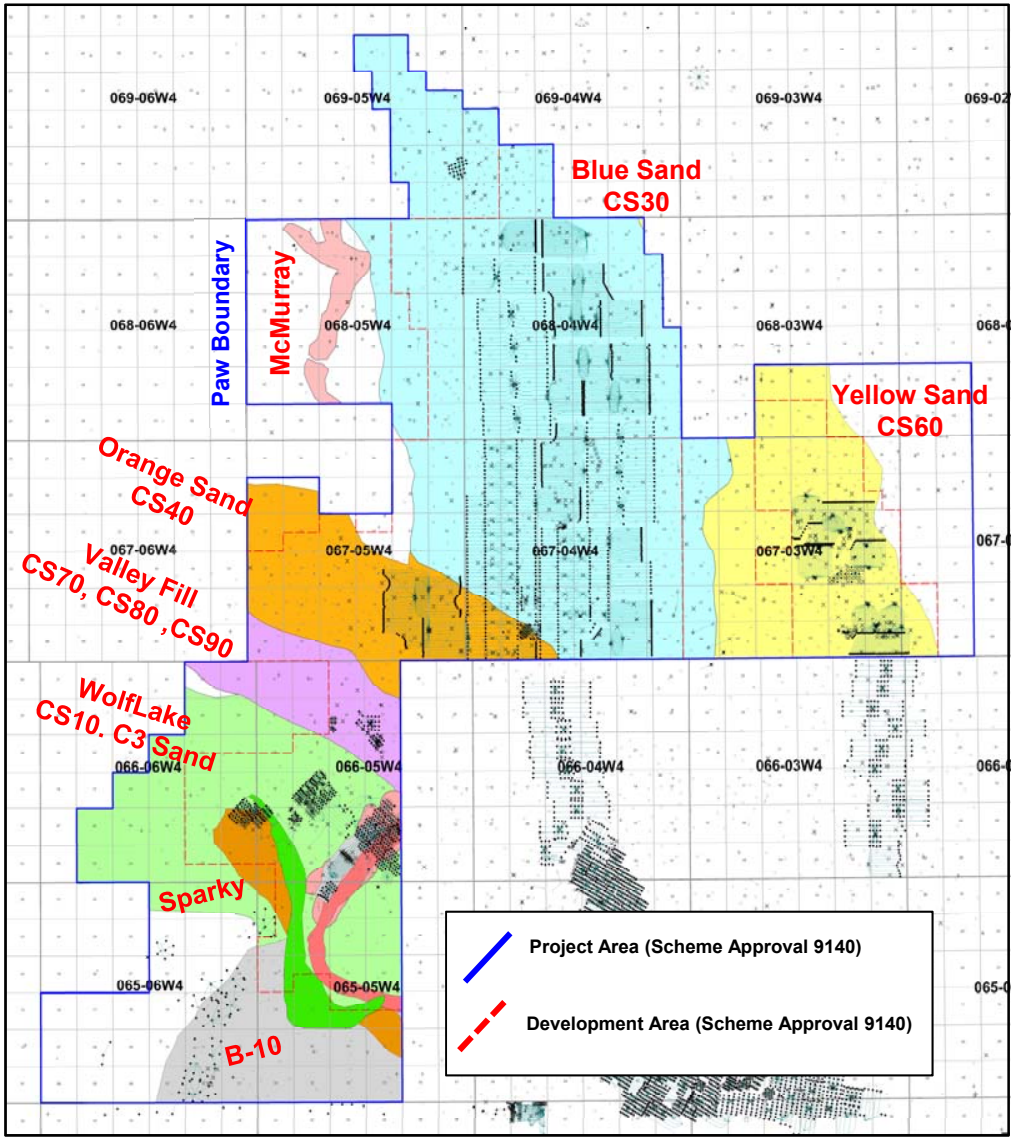
Primrose and Wolf Lake Index Map



Development History for PAW

Orange/Blue Sand (Primrose South and North)
1981-1983 (Dome): Moore Pilot Vertical Well CSS
1992 (Amoco): CDD Pilot Phase 5 Horizontal Well Steam Drive
1993-1999 (Amoco): Phase 1-20 Horizontal Well CSS
1996 (Amoco): Phase 2-3 MWSDD Steam Drive Drainage Pilot
1998 (Amoco): BD-18 SAGD Pilot
2000 (CNRL): Phase 21 Horizontal Well CSS
2003-2004: Phase 29-31 Horizontal Well CSS
2004-2006: Phase 51-55 Horizontal Well CSS
2003: Phase 14 Surfactant in Steam CSS
2003: Phase A1-A2 Cyclic Gas
2004: Phase A1 Cyclic Rich Gas
2005: Phase B2 Solvent in Steam CSS
2005-2007: Phase 27, 17 in-fill, 28 Horizontal CSS
2006: Phase BD-18 VAPEX
2008-2009: Phase 58, 59, 62, 63, 66, 67 Horizontal Well CSS
2010-2011: Phase 22-24 Horizontal Well CSS
2011-2012: Phase 25-26 Horizontal Well CSS
2011-2013: Phase 60,61,64,65,68 Horizontal Well CSS
2013: Phase 40-43 Horizontal Well CSS
2014: Phase 40-43 Horizontal Well CSS
2018-2019: Phase 72A-72B Horizontal Well CSS

Yellow Sand (Primrose East)
1986-1988 (Suncor): Phase 14A-14B Slant Pads
1996 (Suncor): Burnt Lake Pilot SAGD
2007-2008 (CNRL): Phase 74, 75, 77, 78 Horizontal Well CSS
2011-2012: Phase 90-95 Horizontal Well CSS

Valley Fill (Wolf Lake)
1988 (BP): Z8 Vertical Well CSS
1989 (Amoco): HWP1 SAGD Pilot
2005 (CNRL): Z13 Vertical Well CSS

C3 Sand (Wolf Lake)
1966 (BP): Phase A Vertical Well Pilot
1978-1988 (BP): Marguerite Lake Pilot
1980-1985 (BP): Wolf Lake 1 West Vertical Well CSS
1980-1985 (BP): Wolf Lake 1 East Vertical Well CSS
1987-1988 (BP): Wolf Lake 2 Vertical Well CSS
1994 (Amoco): Wolf Lake 1 East Horizontal MWSDD
1996 (Amoco): Wolf Lake 1 West Horizontal MWSDD
1999-2000 (CNRL): Phase E2 and N Horizontal CSS

B10 Sand (Wolf Lake)
1989 (BP): E14 Vertical Well CSS Pilot
1997 (Amoco): D2 Pair 1 SAGD
2000 (CNRL): D2 Pair 2-6 SAGD
2000-2001: SD9 SAGD
2001: S1A SAGD
2004: S1A SAGD re-drill
2010: S1B SAGD
2017: S1A SAGD re-drill

McMurray Sand (Wolf Lake)
2010 (CNRL): MC1 SAGD

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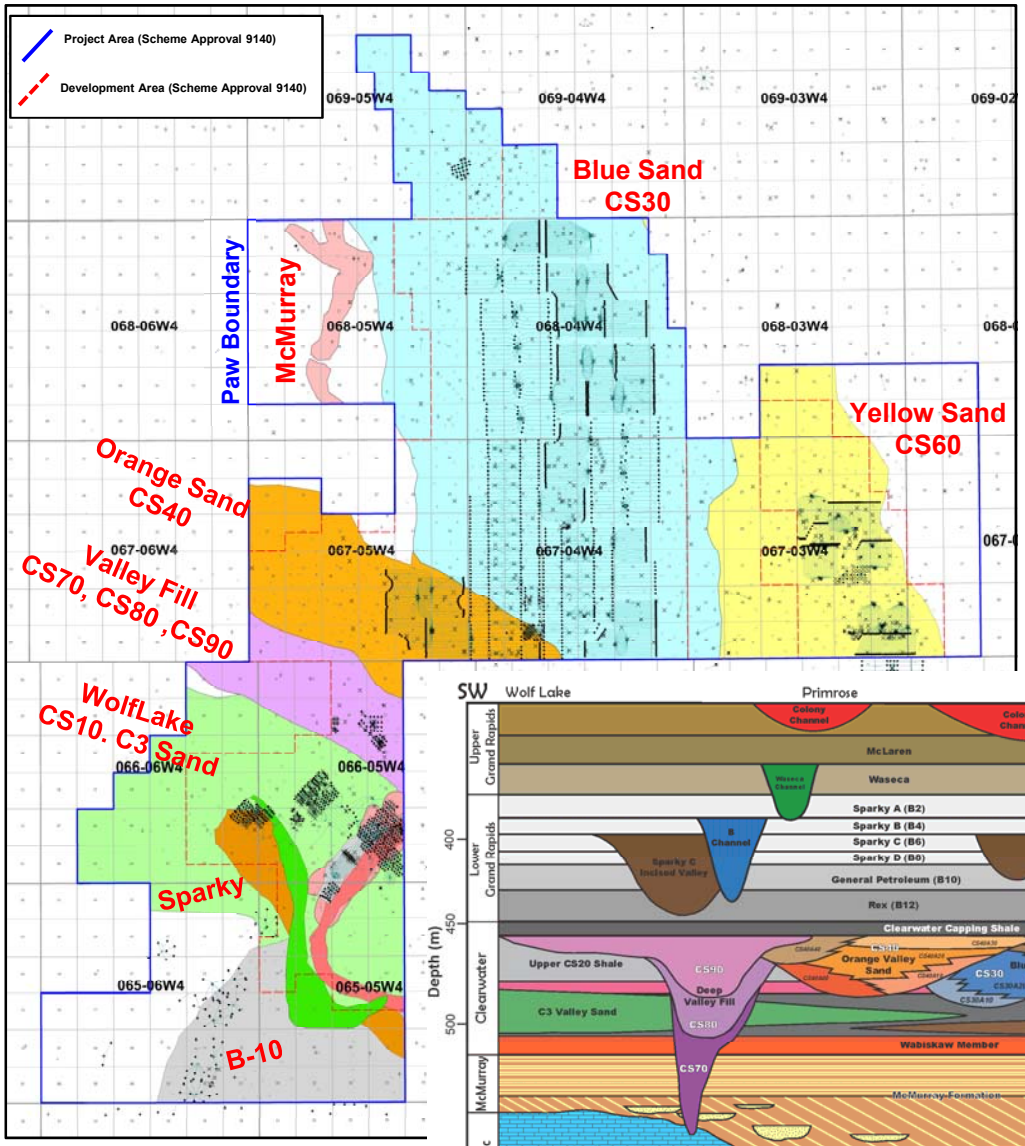
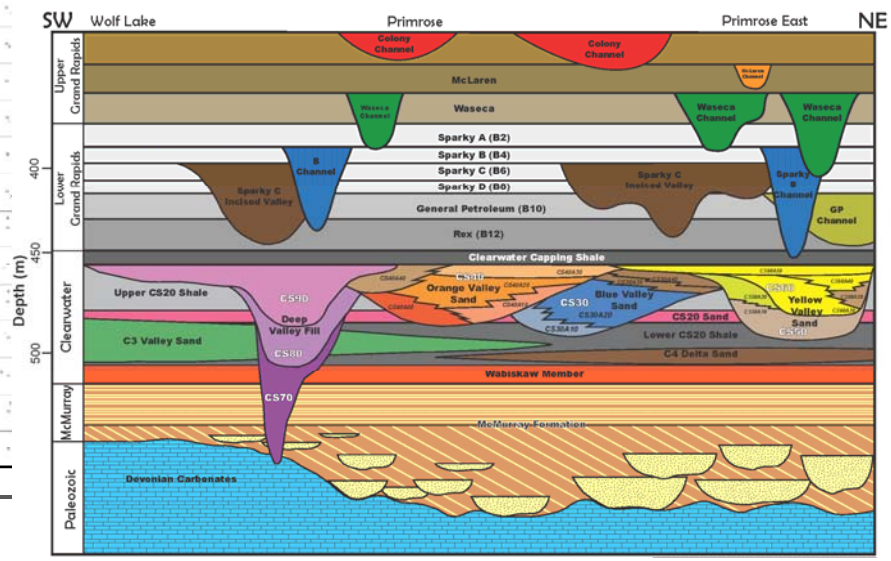
Regional Stratigraphy





McMurray: Estuarine to shoreface deposits

Clearwater: Compound incised valley system

Estuarine deposits vary from valley to valley

Valley specific reservoir facies assemblages

Grand Rapids: Shoreline deposits cut by channels

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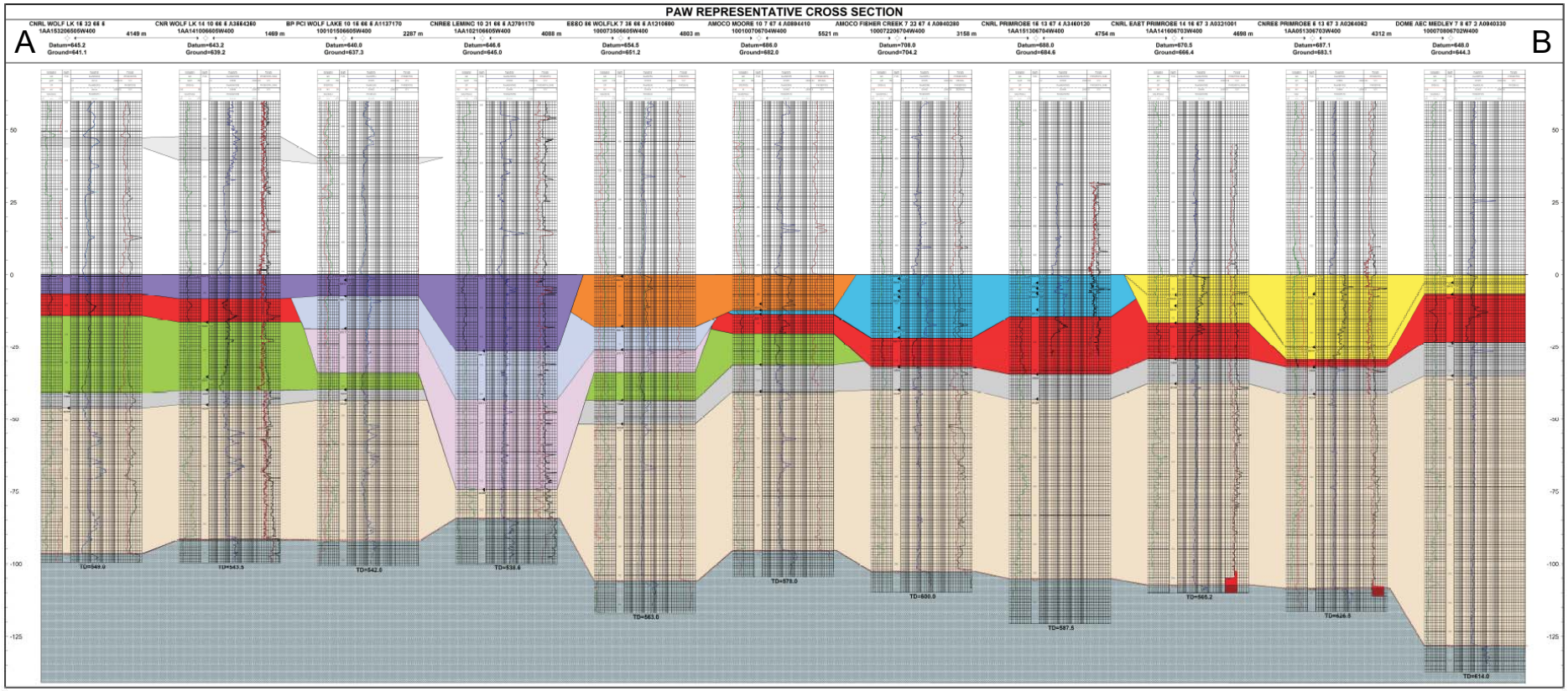
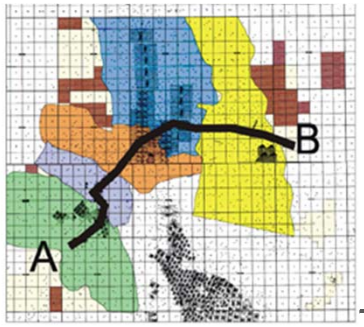
Representative Stratigraphic Cross Section





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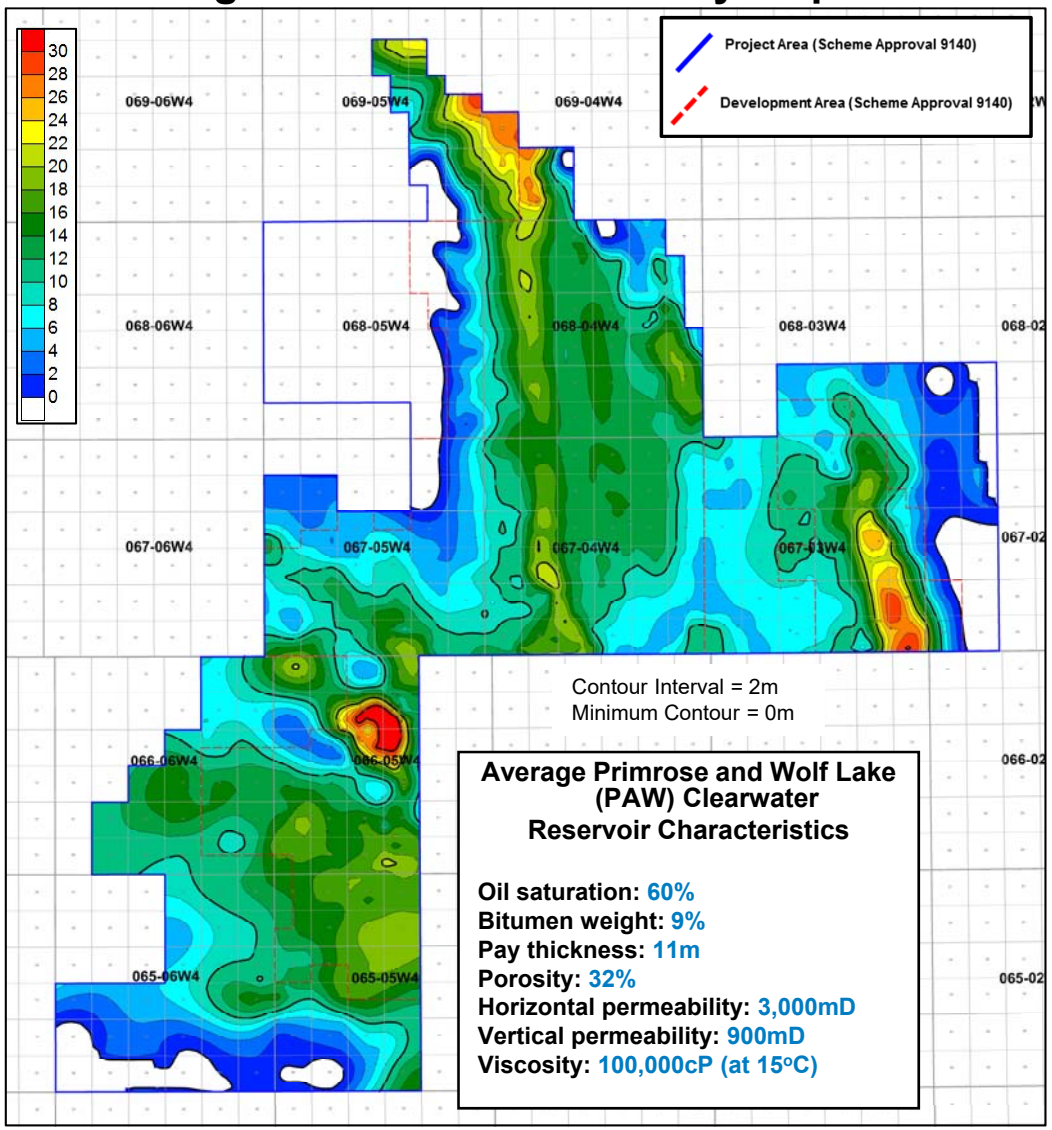
Clearwater Net Pay Isopach

Regional Clearwater Net Pay Isopach



Average Primrose and Wolf Lake (PAW) Clearwater Reservoir Characteristics

Oil saturation: 60%
Bitumen weight: 9%
Pay thickness: 11m
Porosity: 32%
Horizontal permeability: 3,000mD
Vertical permeability: 900mD
Viscosity: 100,000cP (at 15°C)

Primrose:

- Blue Valley
  - bitumen weight (bitwt) >6%, (FAA has no Berthierine and <10% mud)
- Orange Valley
  - bitwt >6%, (O30 <10% mud)
- Yellow Valley
  - bitwt >6%, (FA3 <10% mud, vertically continuous)

Wolf Lake:

- C3 sand
  - bitwt >6%,
- Valley Fill:
  - bitwt >6%

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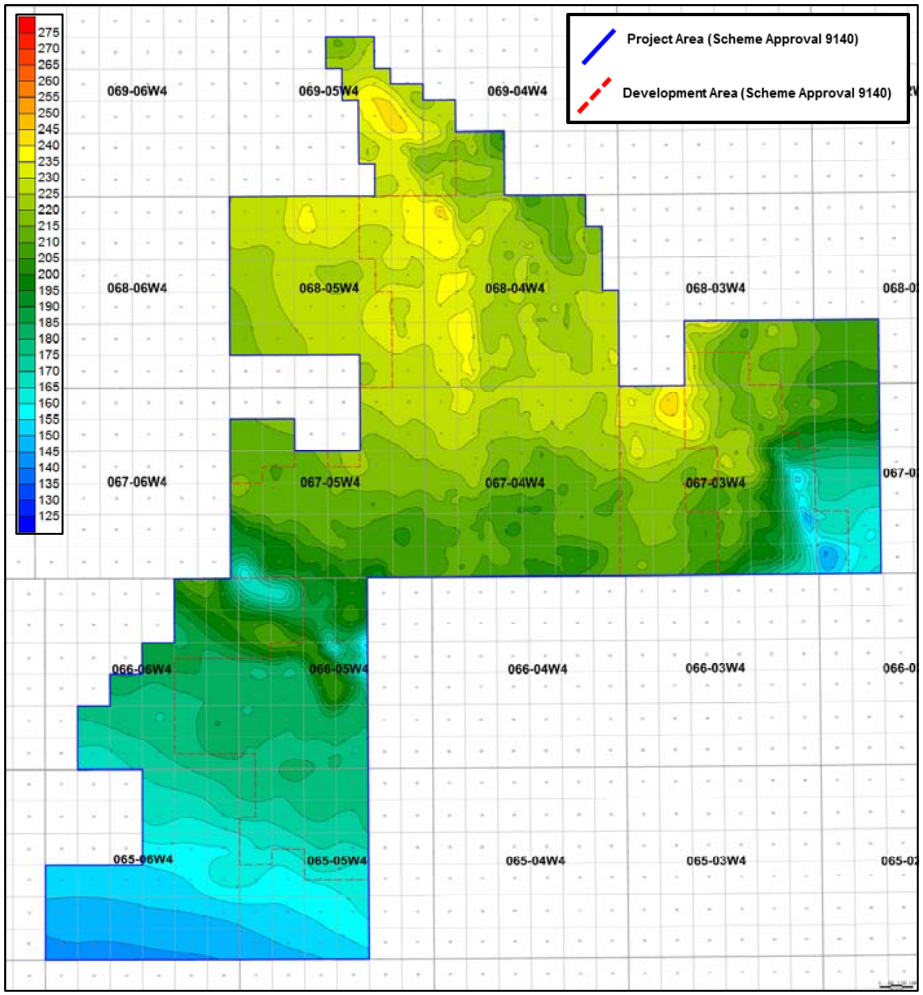
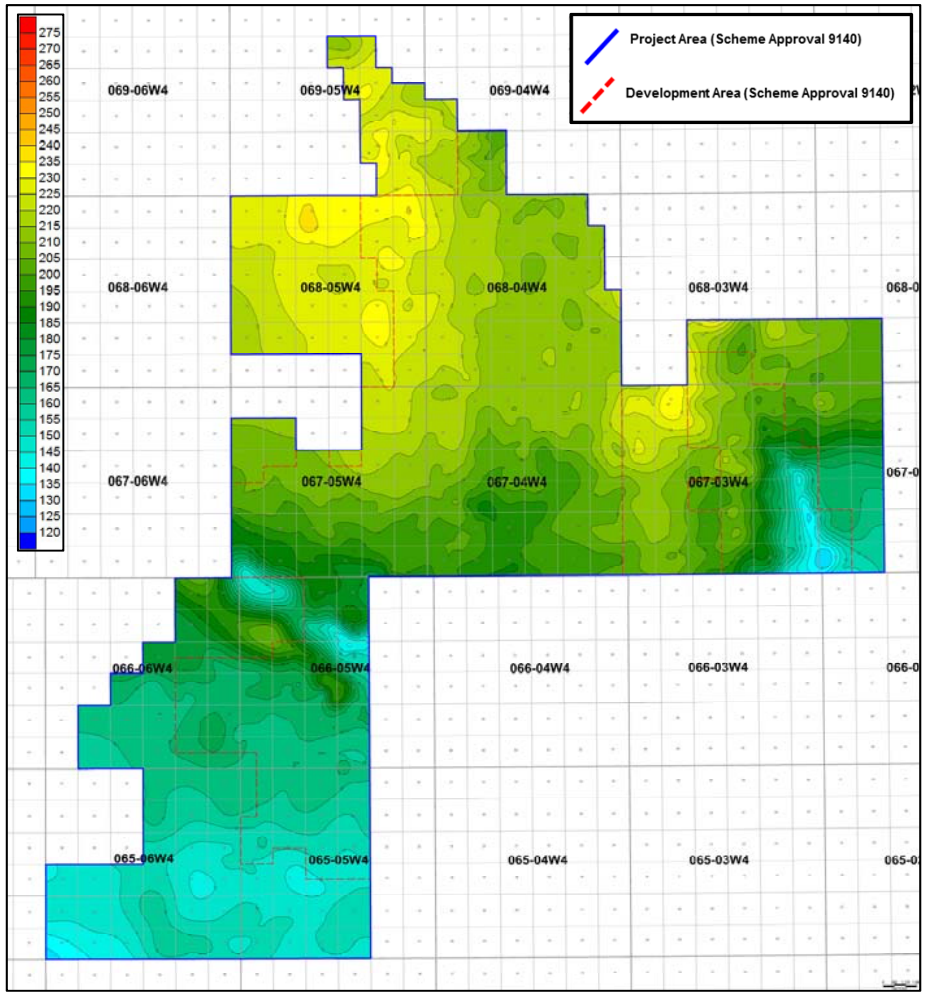
Clearwater Formation Structure

Reservoir Top Structure



Reservoir Base Structure



- Clearwater reservoir base is the start of continuous deposits with bitwt >6% and <10% mud beds
- Clearwater reservoir top is the termination of continuous deposits with bitwt >6% and <10% mud beds

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Blue Sand (Primrose South and North)

Reservoir Characteristics

- Reservoir: FAB & FAA
- Avg. oil saturation: 62%
- Avg. bitumen weight: 9.3%
- Max. net pay thickness: 23 m
- Avg. porosity: 32%
- Avg. horizontal permeability: 3,000 mD
- Avg. vertical permeability: 900 mD
- Avg. viscosity: 100,000 cP (at 15°C)

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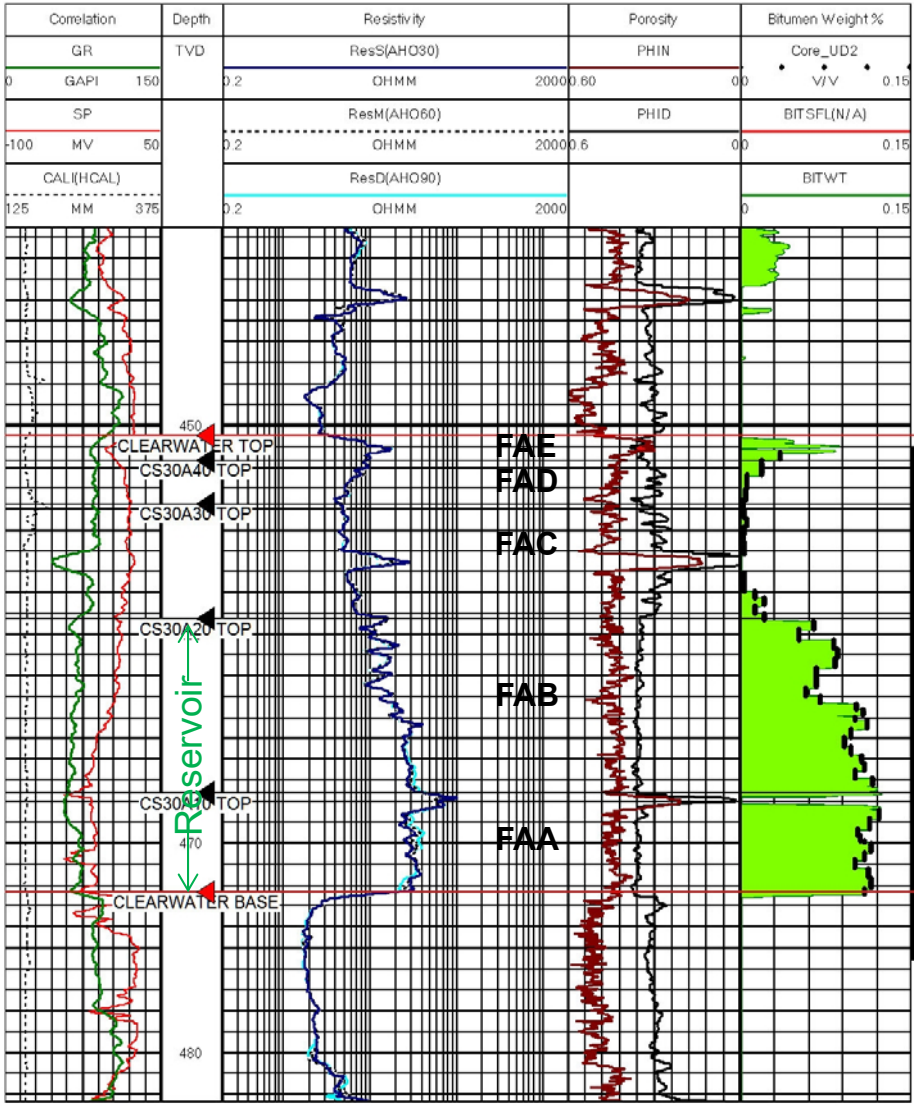

Orange Sand (Primrose South)

Reservoir Characteristics

- Reservoir: O10
- Avg. oil saturation: 65%
- Avg. bitumen weight: 9.8%
- Max. net pay thickness: 20 m
- Avg. porosity: 32%
- Avg. horizontal permeability: 3,000 mD
- Avg. vertical permeability: 900 mD
- Avg. viscosity: 100,000 cP (at 15°C)

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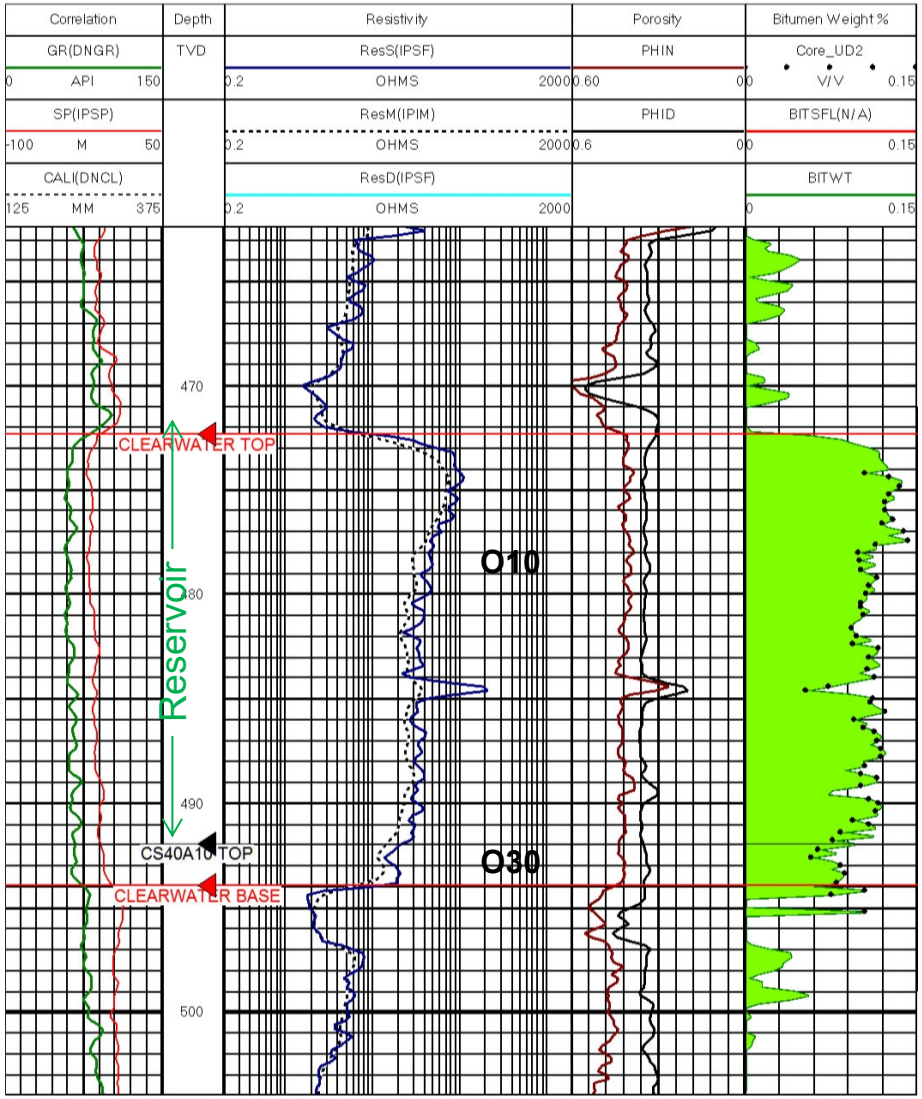

Yellow Sand (Primrose East)

Reservoir Characteristics

- Reservoir: FA7, FA8 & FA9
- Avg. oil saturation: 63%
- Avg. bitumen weight: 9.5%
- Max. net pay thickness: 29 m
- Avg. porosity: 32%
- Avg. horizontal permeability: 3,000 mD
- Avg. vertical permeability: 900 mD
- Avg. viscosity: 70,000 cP (at 15°C)

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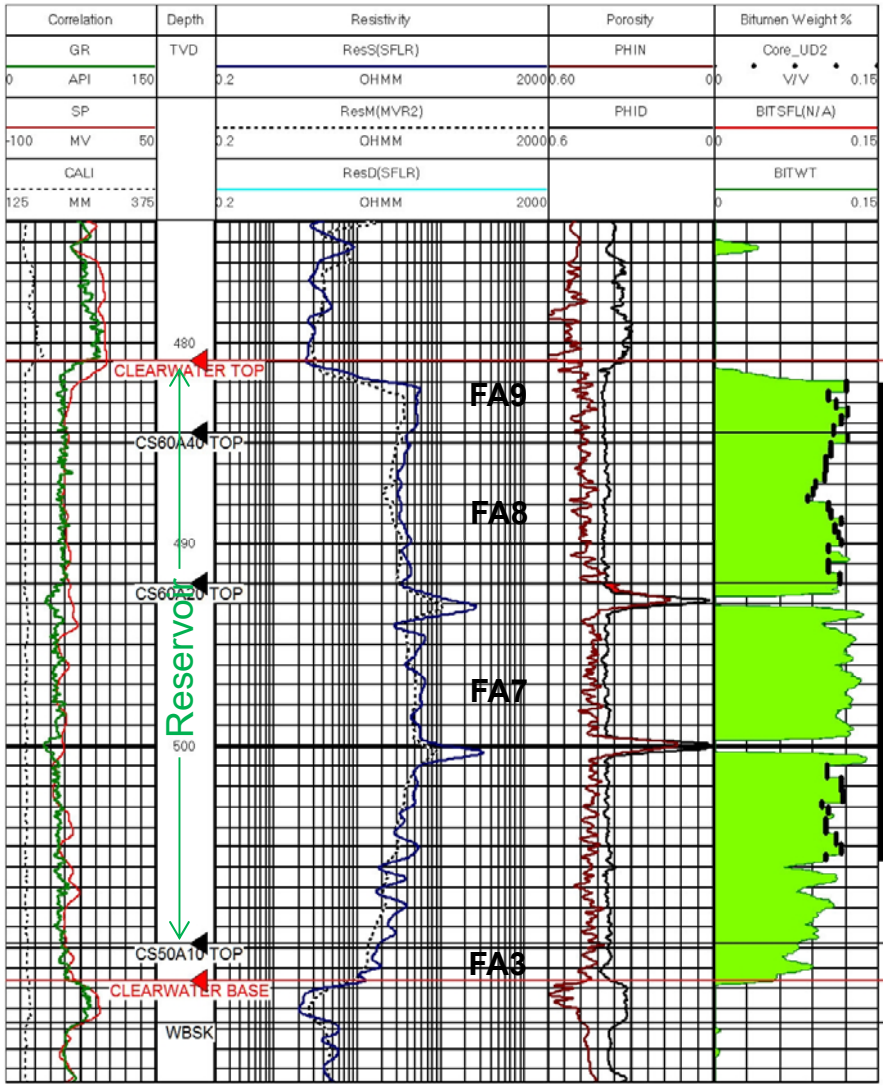

Valley Fill (Wolf Lake)

Reservoir Characteristics

- Reservoir: CS80
- Avg. oil saturation: 57%
- Avg. bitumen weight: 8.9%
- Max. net pay thickness: 42 m
- Avg. porosity: 32%
- Avg. horizontal permeability: 3,000 mD
- Avg. vertical permeability: 2,000 mD
- Avg. viscosity: 100,000 cP (at 15°C)

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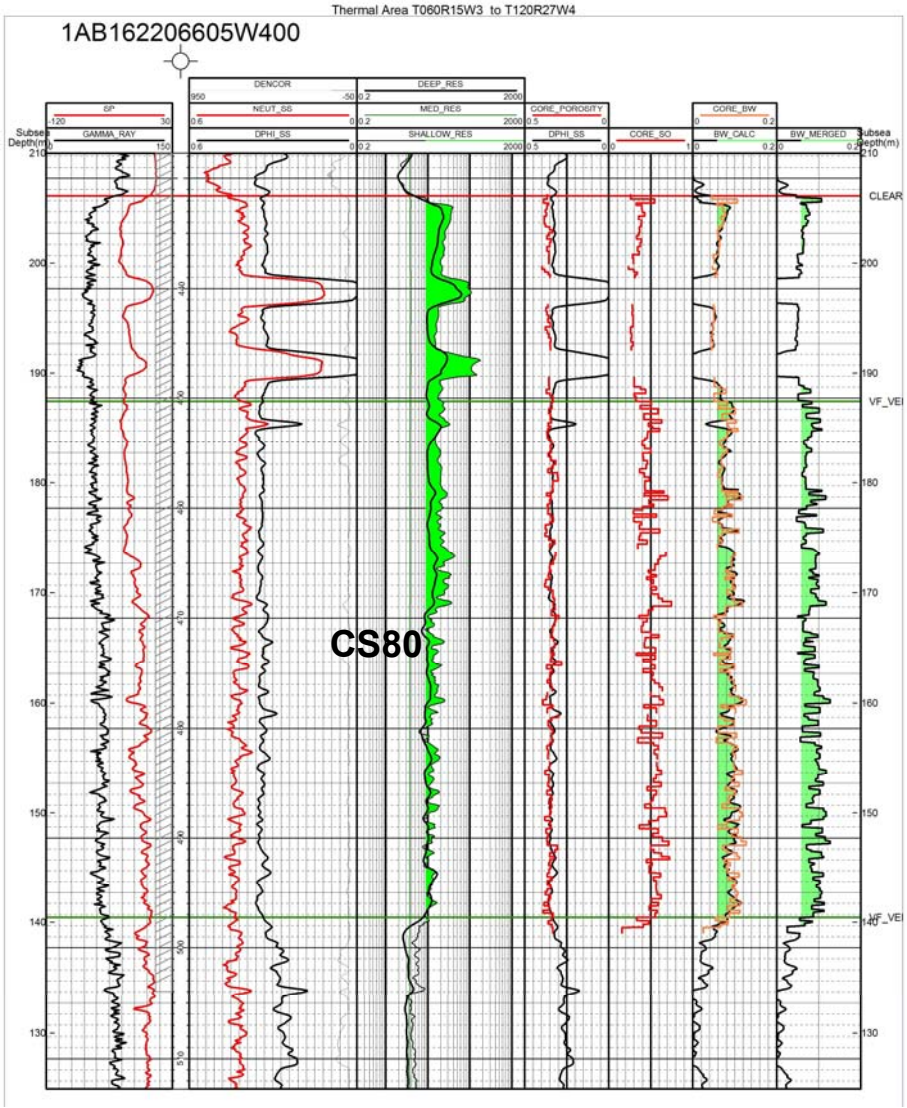

C3 Sand (Wolf Lake)

Reservoir Characteristics

- Reservoir: C3-20 & C3-30
- Avg. oil saturation: 50%
- Avg. bitumen weight: 7.8%
- Max. net pay thickness: 17 m
- Avg. porosity: 33%
- Avg. horizontal permeability: 2,000 mD
- Avg. vertical permeability: 200 mD
- Avg. viscosity: 100,000 cP (at 15°C)

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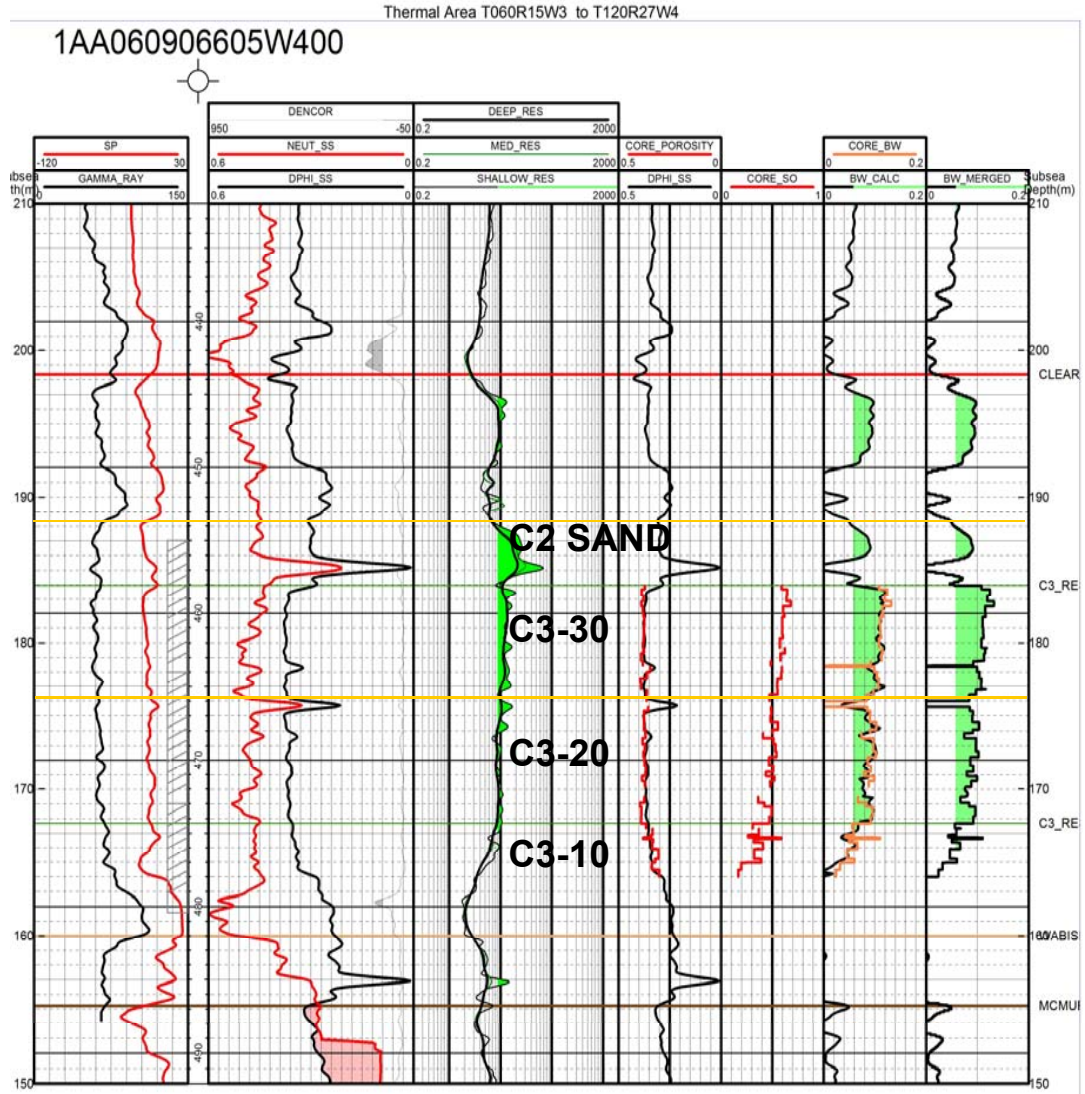

Wolf Lake SAGD B10 Sand Reservoir Characteristics

Reservoir Characteristics

- Reservoir: FA5 & FA4
- Average oil saturation: 75%
- Average bitumen weight: 11.5%
- Maximum net pay thickness: 16 m
- Average porosity: 33%
- Average HZ permeability: 3,200 mD
- Average Vertical Permeability: 2,500 mD
- Average Viscosity: 450,000 cP (at 20°C)
- No connected bottom water

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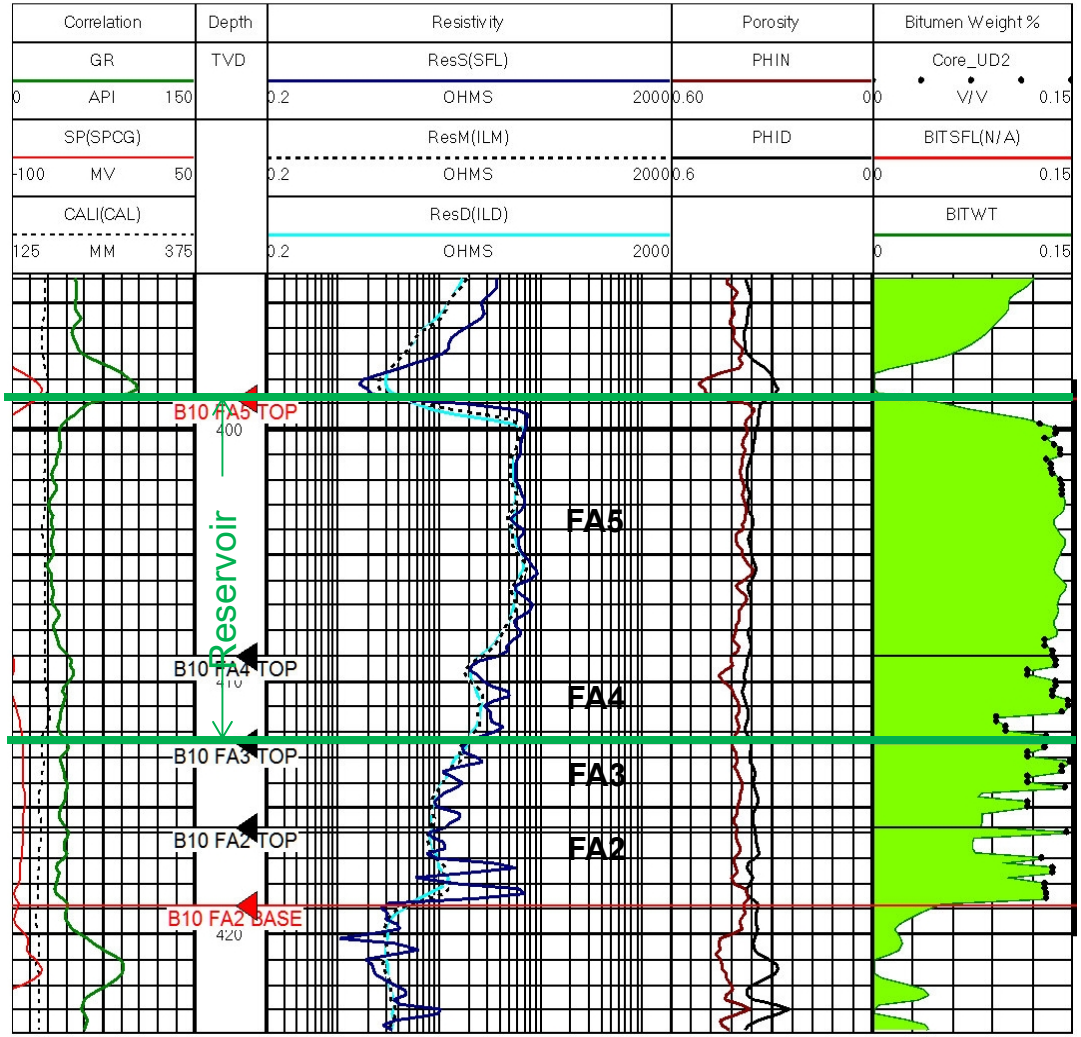
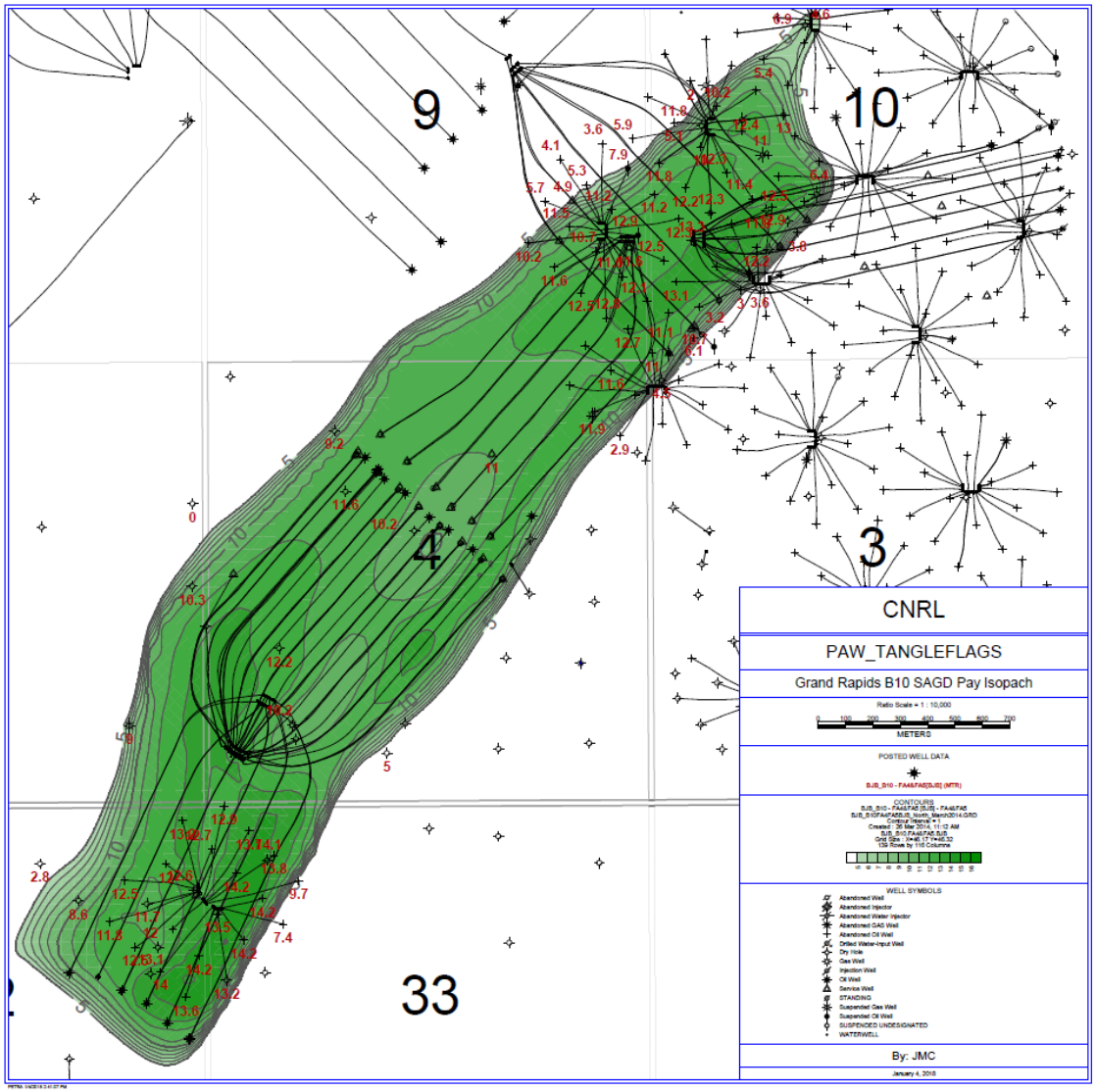


Grand Rapids B10 Pay Isopach

Grand Rapids B10

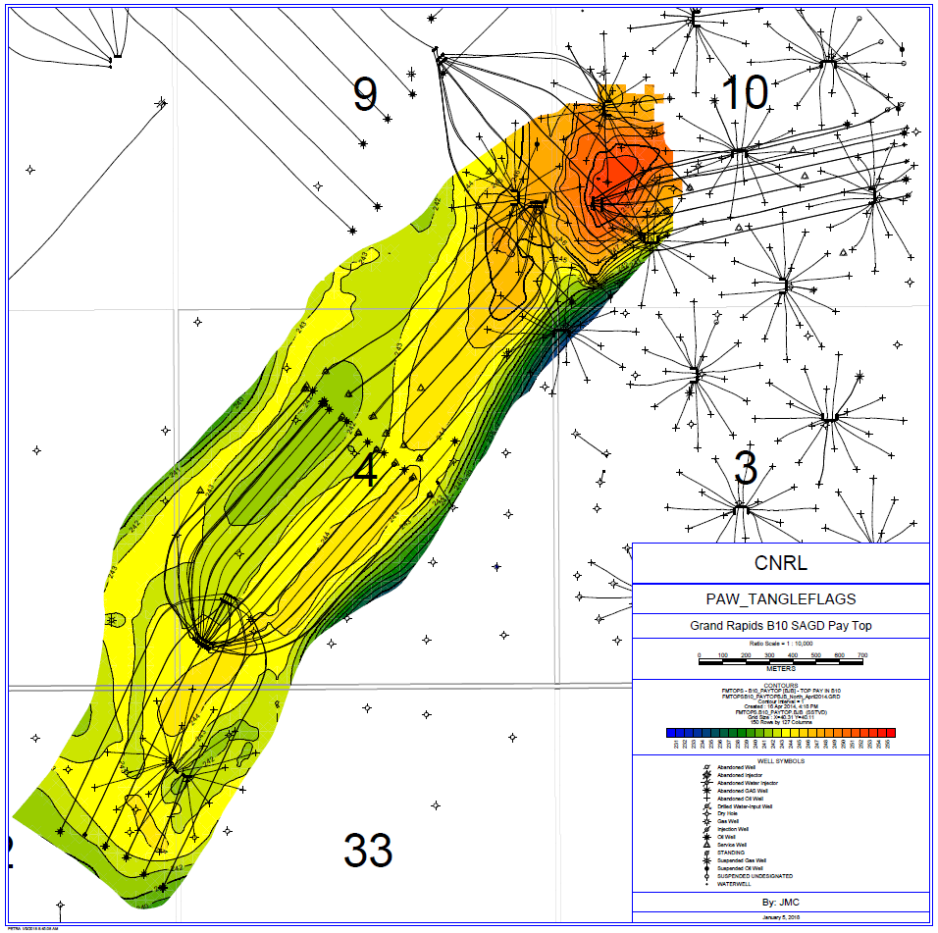
- Shoreface deposits in FA4 & FA5, (Net pay >10m for development)
- 1 post-steam cored well drilled in 2018



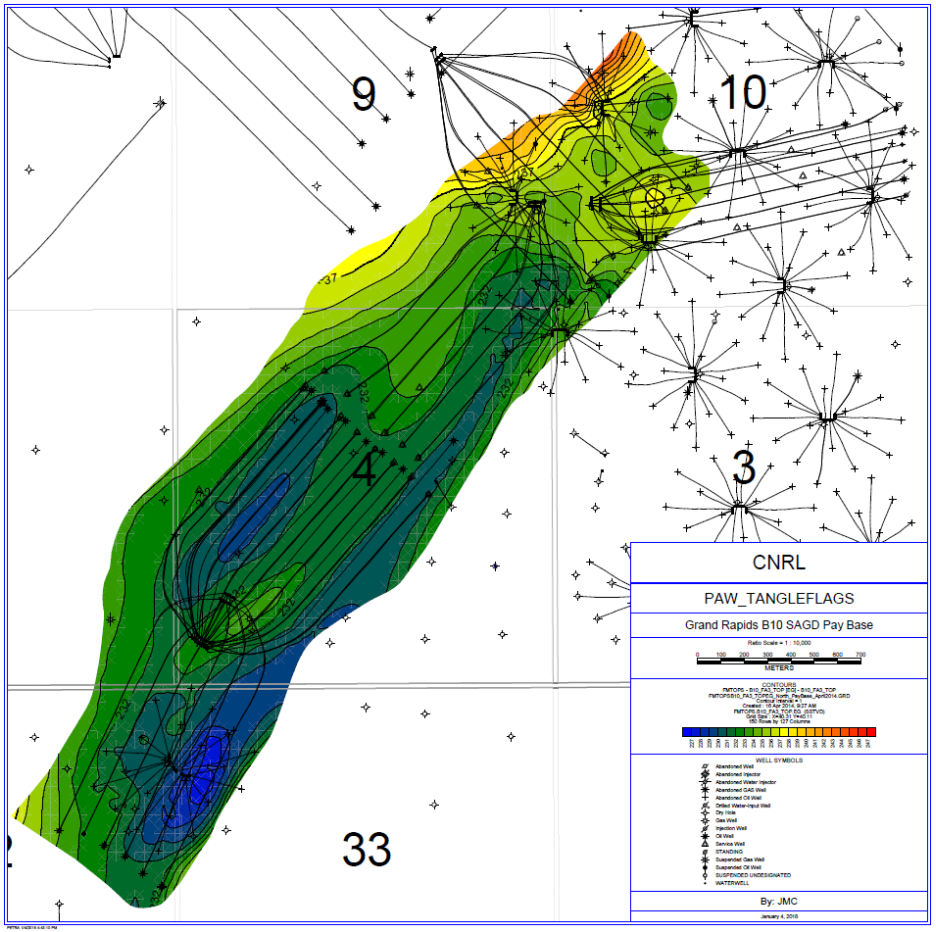
Contour Interval = 1m, Minimum 5m shown

Grand Rapids B10 Structure

Reservoir Top Structure



Reservoir Base Structure



SAGD pay defined as clean sand in FA4 and FA5

- Average bitumen weight 11.5%

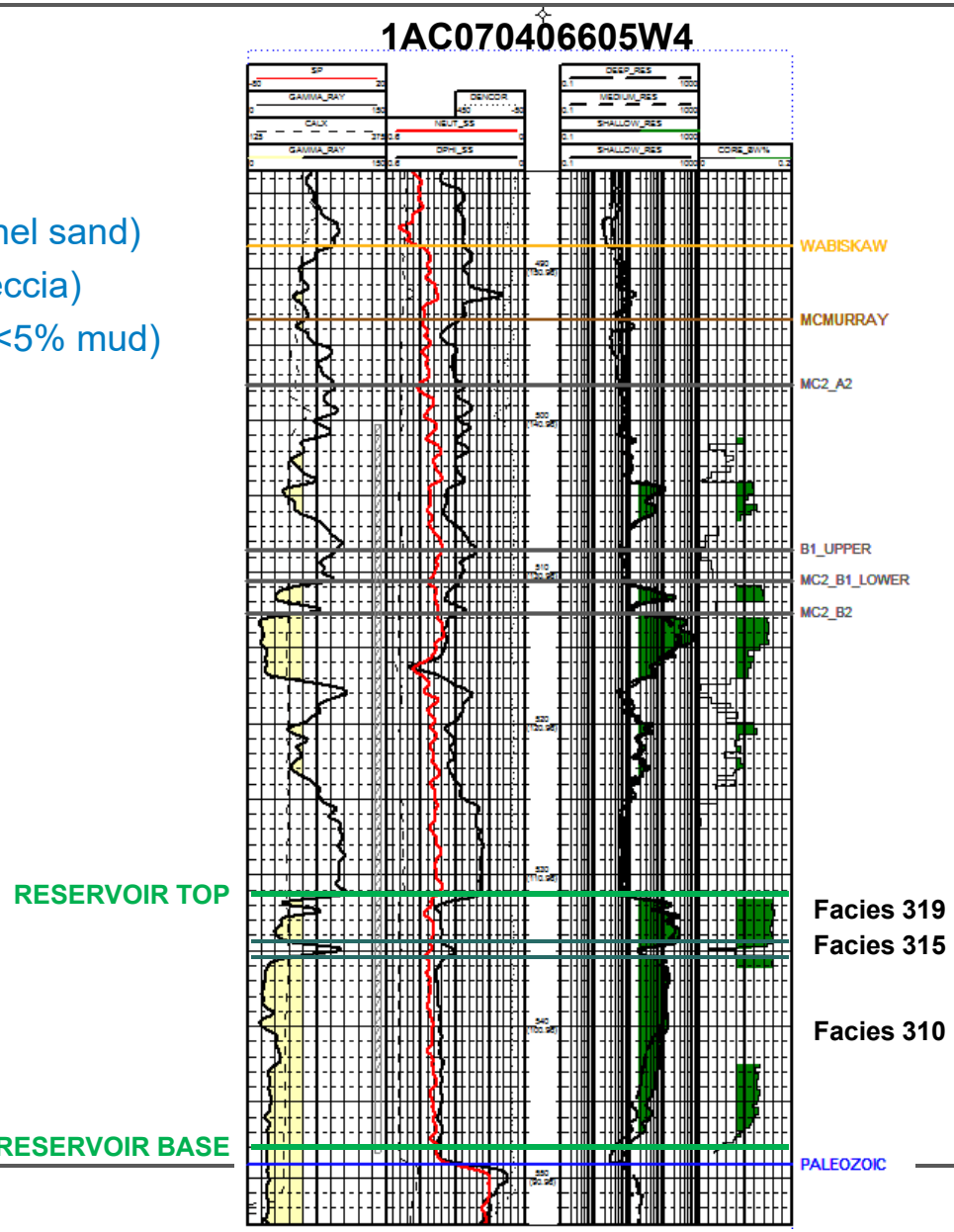
Contour Interval = 1m

Contour Interval = 1m

Reservoir Characteristics – Wolf Lake McMurray

Reservoir Characteristics

- Reservoir: Facies 310 (clean channel sand)
  Facies 315 (channel breccia)
  Facies 319 (sandy IHS <5% mud)
- Average oil saturation: 73%
- Average bitumen weight: 11.9%
- Maximum net pay thickness: 19 m
- Average porosity: 34%
- Average HZ permeability: 6,000 mD
- Average Vertical Permeability: 5,000 mD
- Average Viscosity: 600,000 cP (at 20°C)



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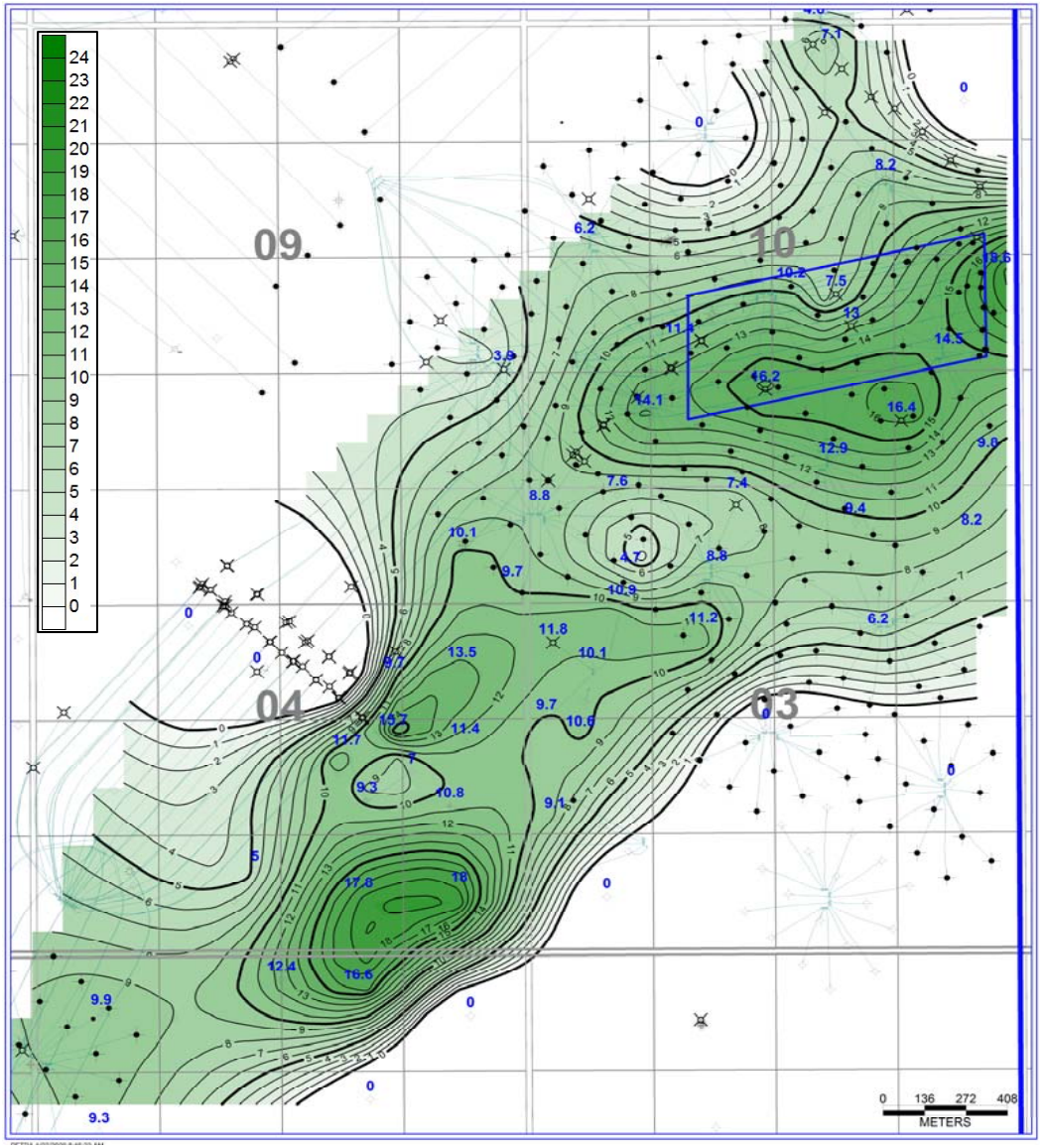
Wolf Lake McMurray SAGD Pay Isopach

McMurray Sand

- Channel deposits with btwt >8%
- Net pay >10m for development
- MC1 McMurray SAGD pad highlighted as blue polygon

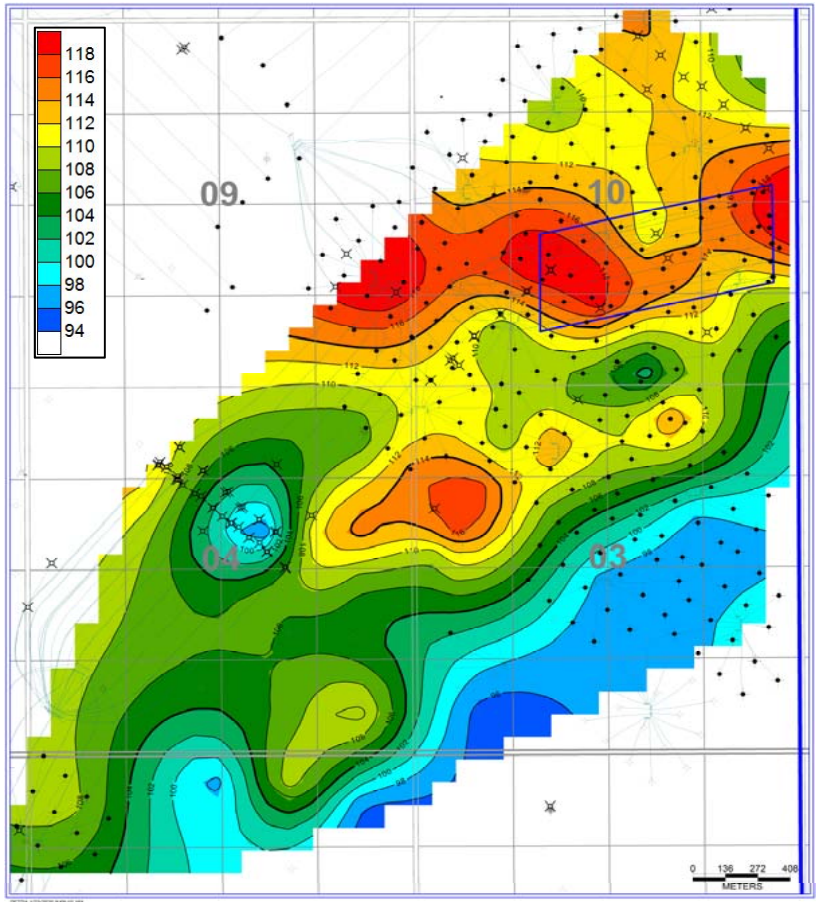
No 2019 McMurray Strat Wells

Contour Interval = 1 m



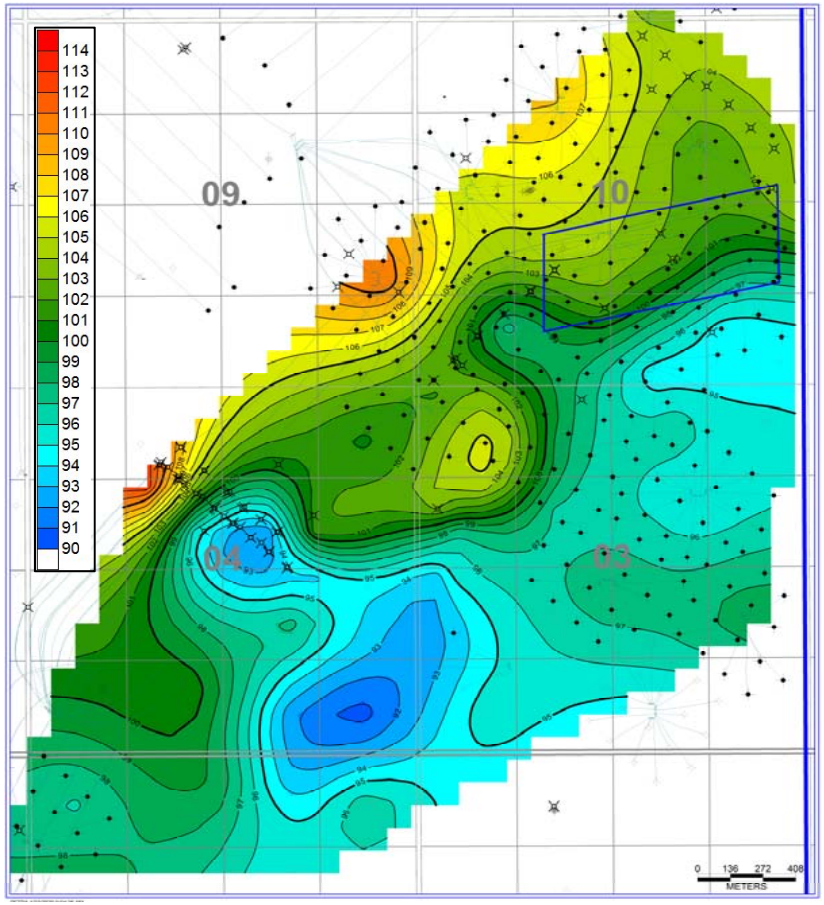
Wolf Lake McMurray SAGD Pay Structure

Reservoir Top Structure



Contour Interval = 2 m

Reservoir Base Structure



No 2019 McMurray Strat Wells

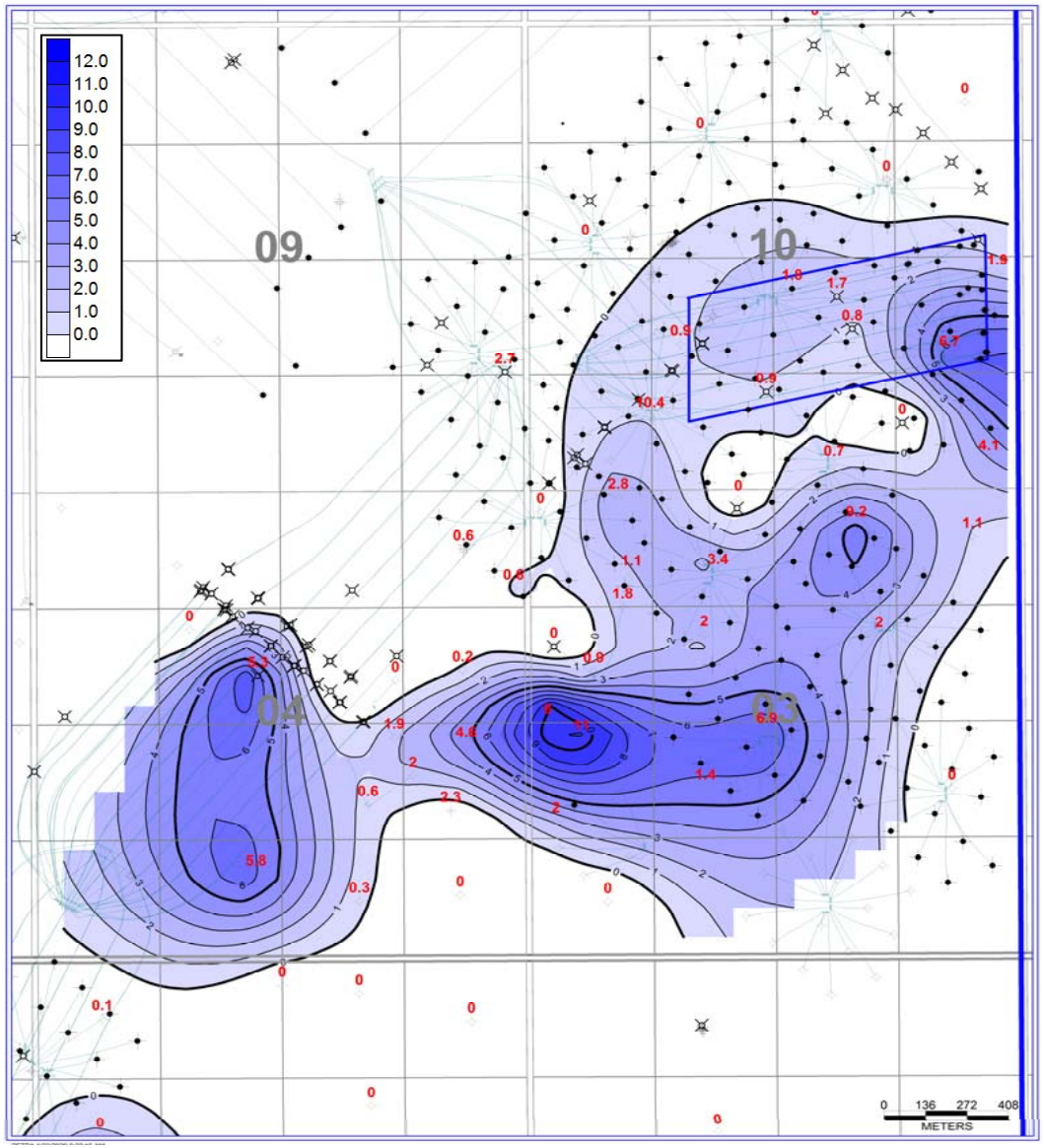
- SAGD Pay defined by continuous clean sand and breccia. IHS is not included.
- Base of reservoir, above bottom water, corresponds to bitumen weight 10% (~6 ohm·m).

Wolf Lake McMurray Bottom Water Isopach

- McMurray Bottom Water Isopach
- Cut-off is <6 ohm·m
- Isopach represents a gross water interval

No 2019 McMurray Strat Wells

Contour Interval = 1m



Reservoir Characteristics – Sparky "C"

Reservoir Characteristics

- Reservoir: Facies 1 clean sand
- Average oil saturation: 75%
- Average bitumen weight: 12.9%
- Maximum net pay thickness: 16.2 m
- Average porosity: 35%
- Average HZ permeability: 5,300 mD
- Average Vertical Permeability: 4,200 mD
- Average Viscosity: 180,000 cP (at 20°C)
- Average Bottom Water: 0.5m

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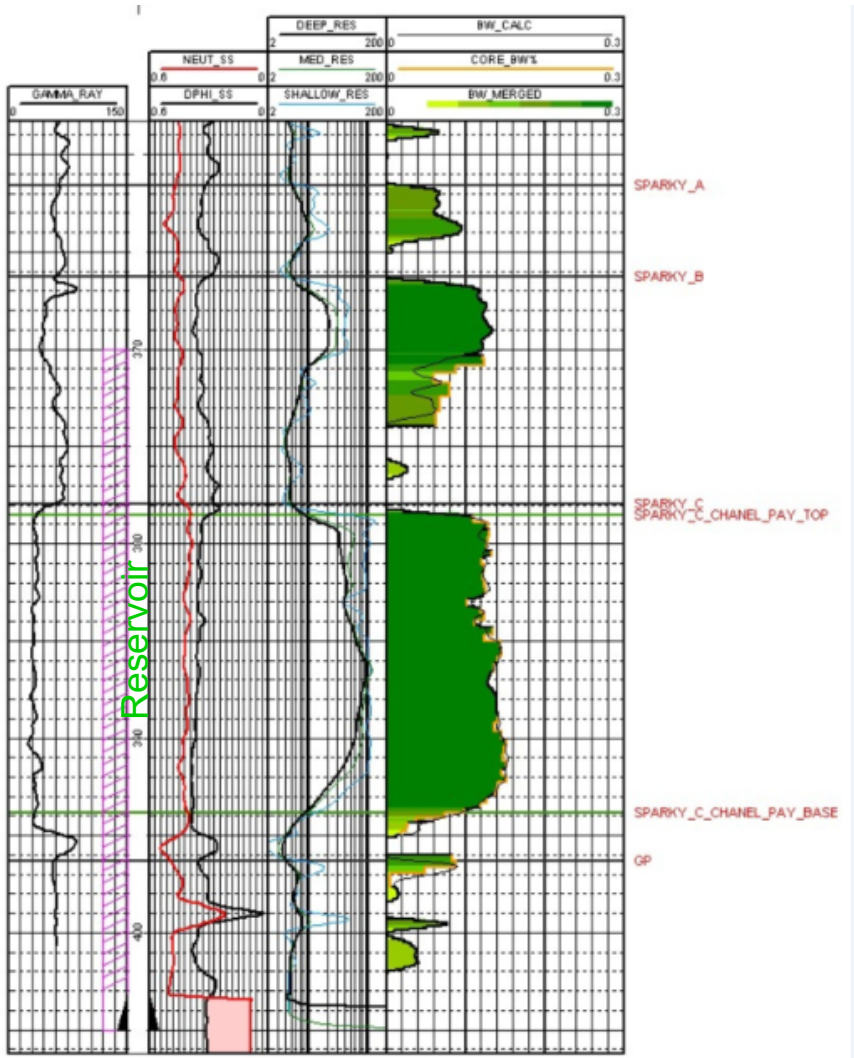
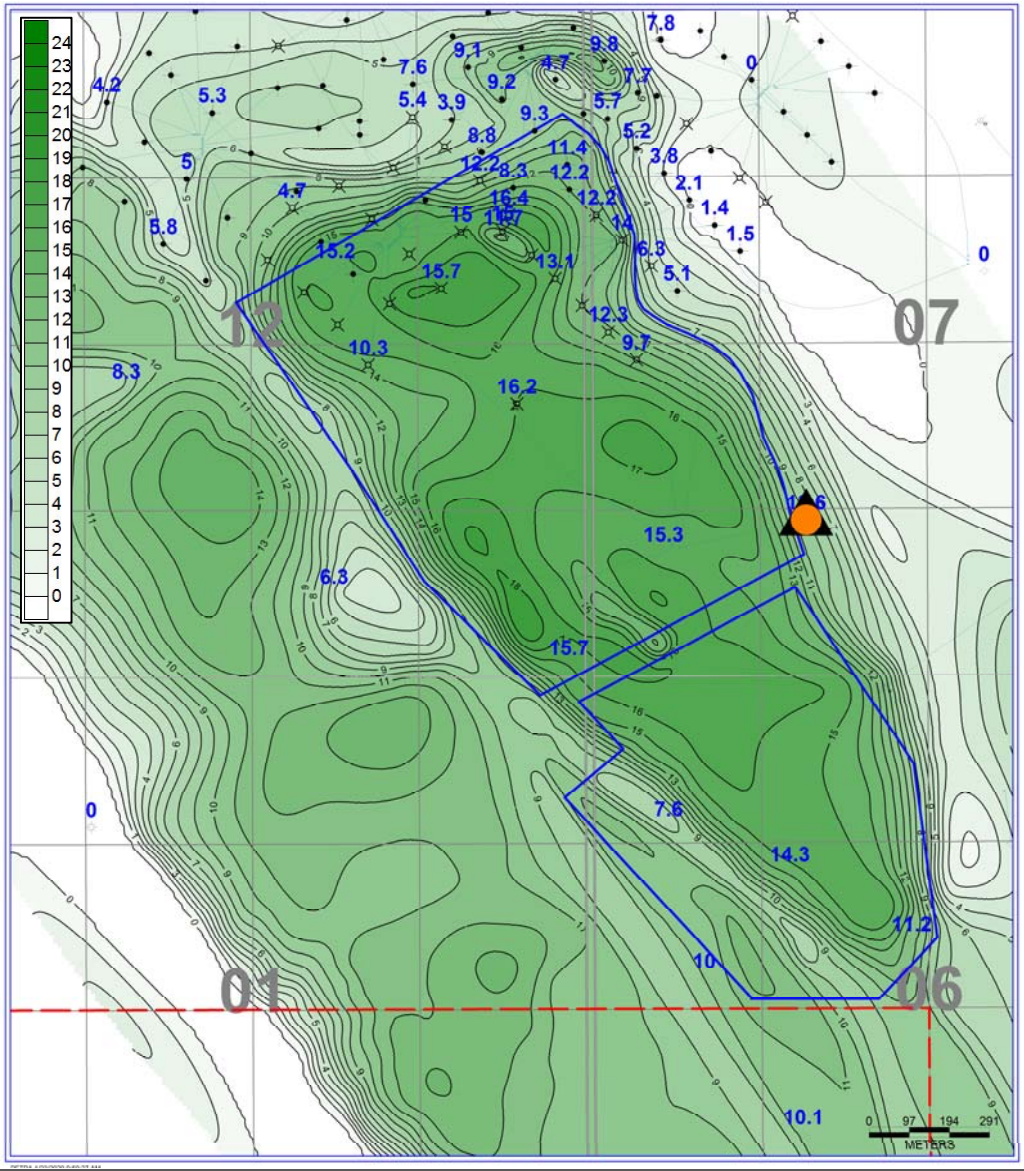


Wolf Lake Sparky “C” SAGD Pay Isopach

Sparky “C” Sand

- Channel deposits with bitwt >10%.
- Net pay >10 m for development



2019 Strats Drilled

Cored wells

Contour Interval = 1 m

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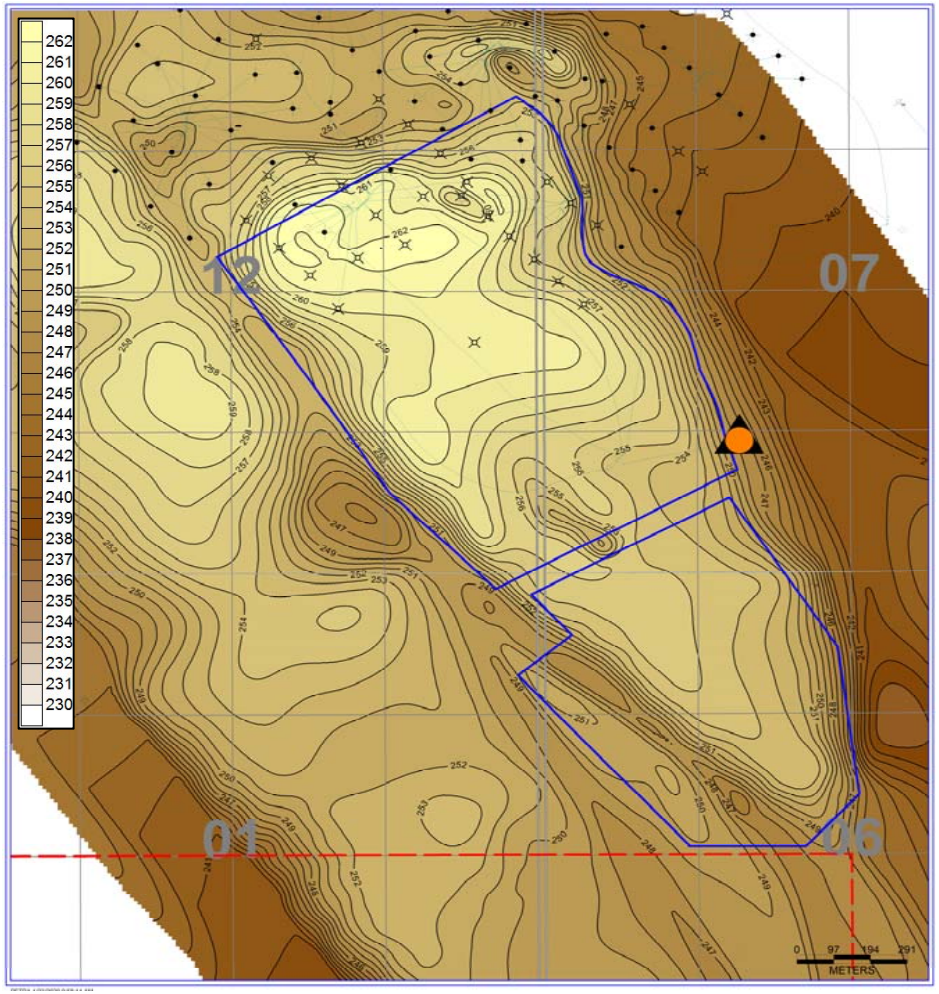
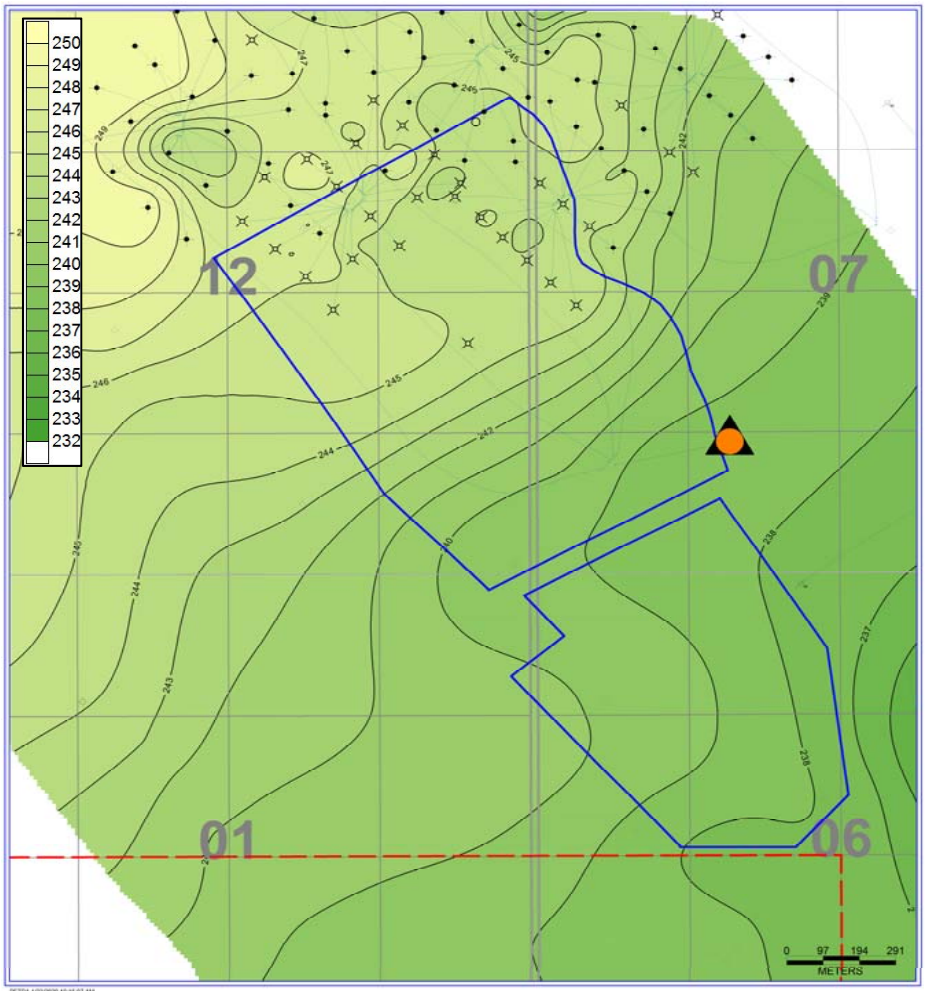
Sparky "C" SAGD Pay Structure

Reservoir Top Structure



Reservoir Base Structure



Contour interval = 1m 2019 Strats Drilled Cored wells Cored wells 2019 Strats Drilled Contour interval = 1m

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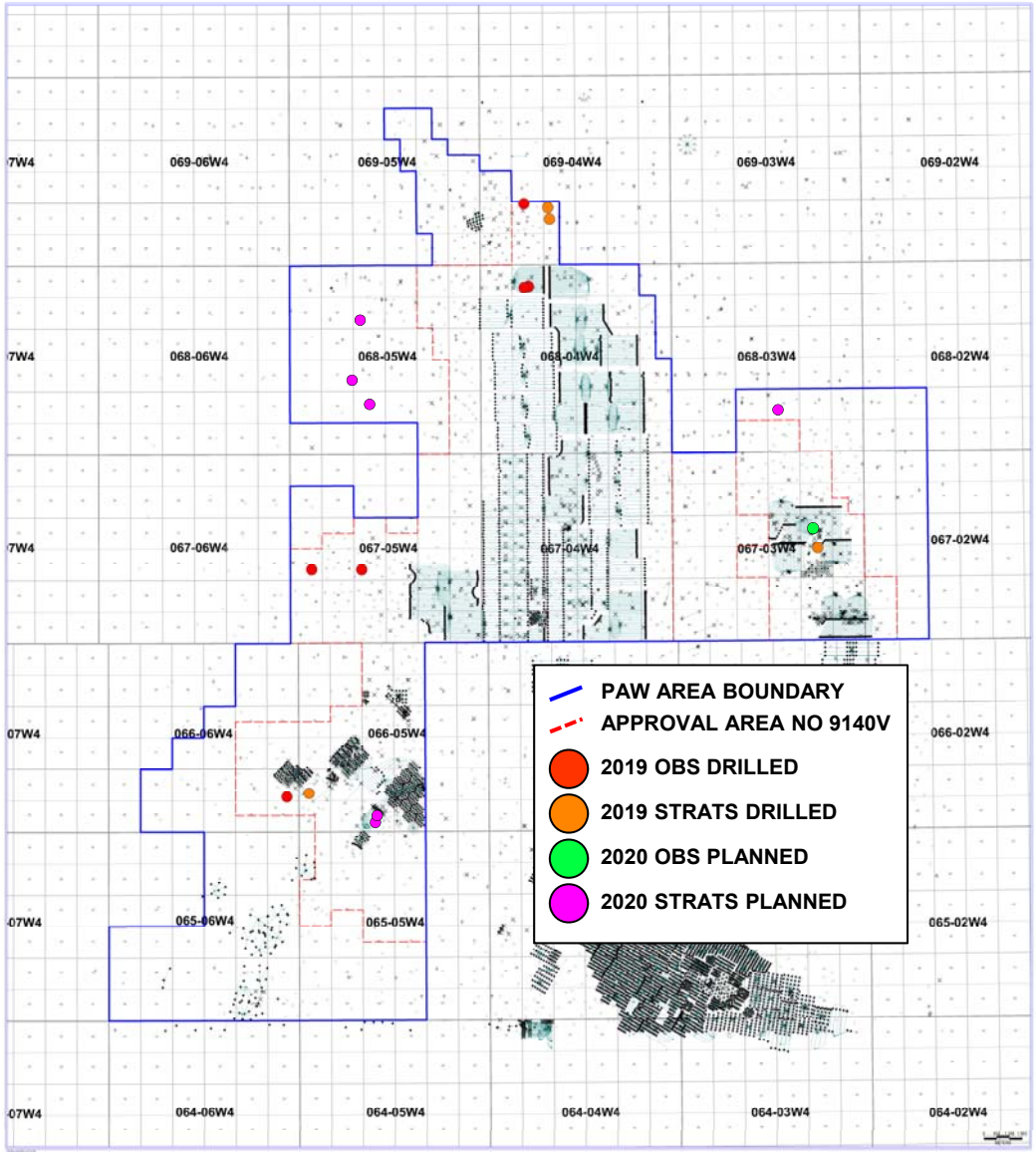
Progress in 2019 → Plans for 2020

2019

- 4 Strat wells Drilled
- 6 Observation wells Drilled

2020

- 6 Strat wells Planned
- 1 Observation well Planned



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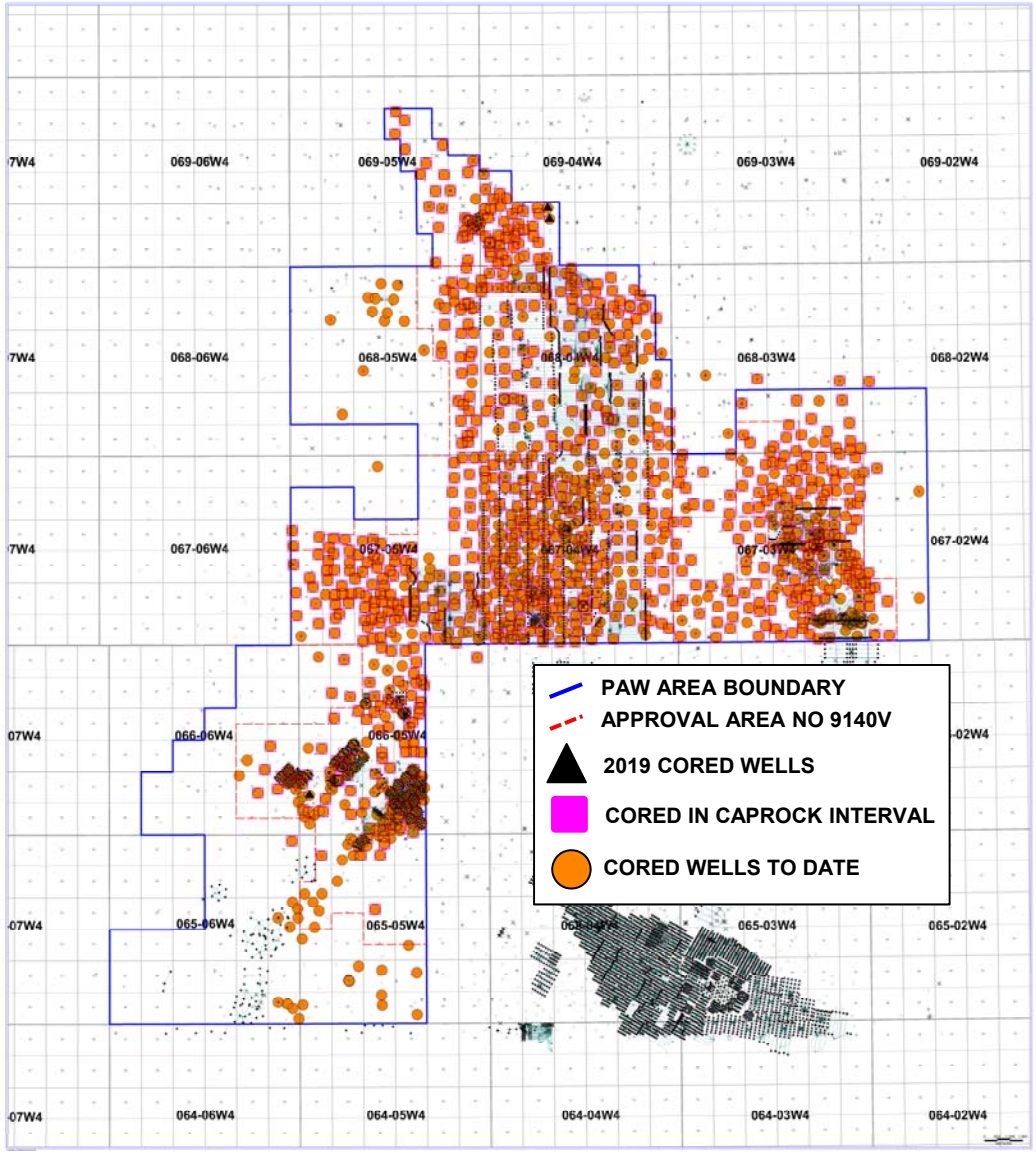
Cored Wells Within PAW

- Total wells cored: 1,200
- 2019 wells cored: 4
- Wells with Clearwater Capping Shale recovered in core interval: 865



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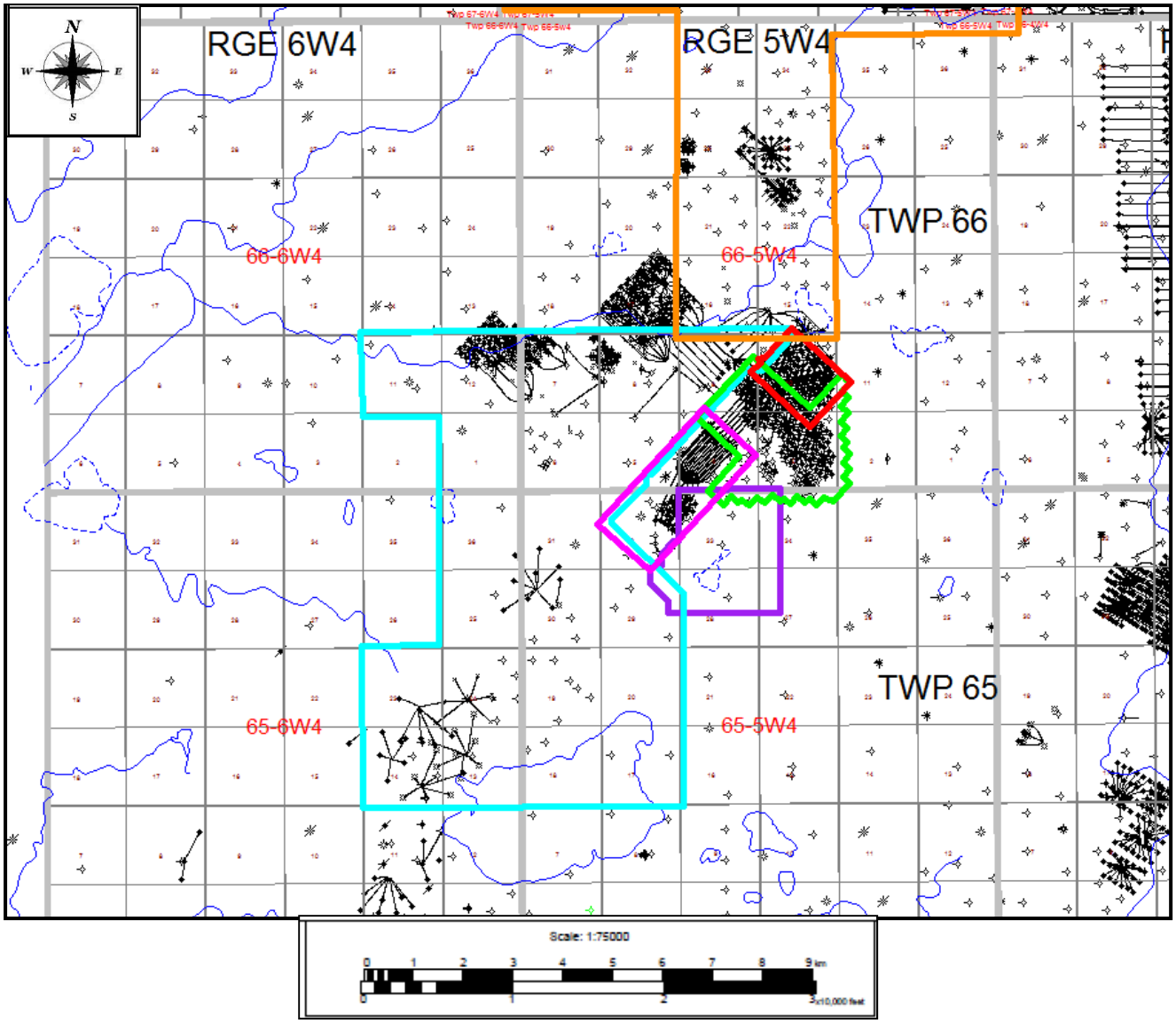
3D Seismic: Wolf Lake



	2014 3D
	2012 3D
	2011 3D
	2010 3D
	2009 3D
	2009 3D

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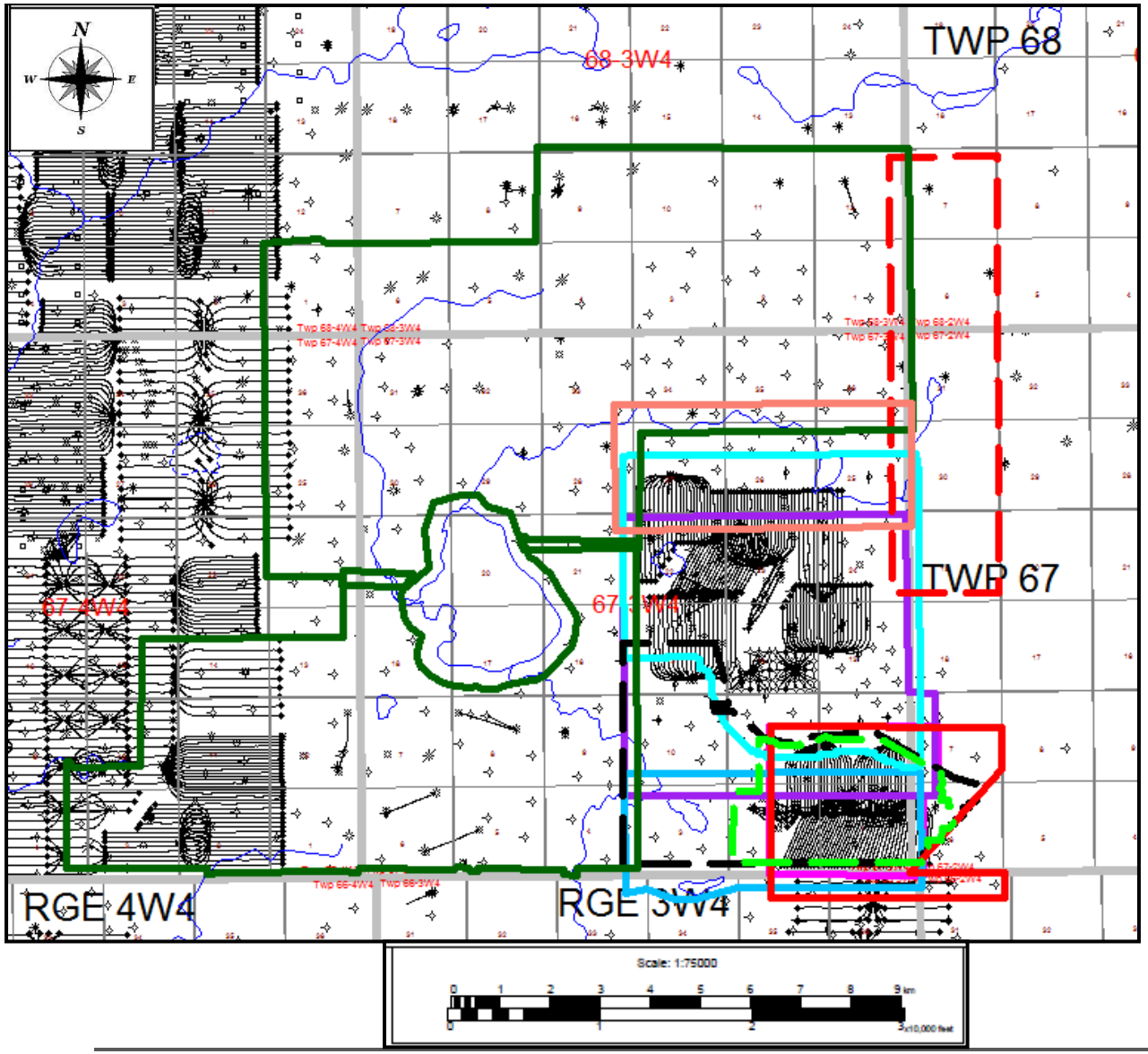
3D Seismic: Primrose East Seismic



	2018 4D
	2015 4D
	2013 4D
	2012 3D
	2011 3D
	2010 4D
	2010 3D
	2009 4D
	2008 3D
	2006 3D

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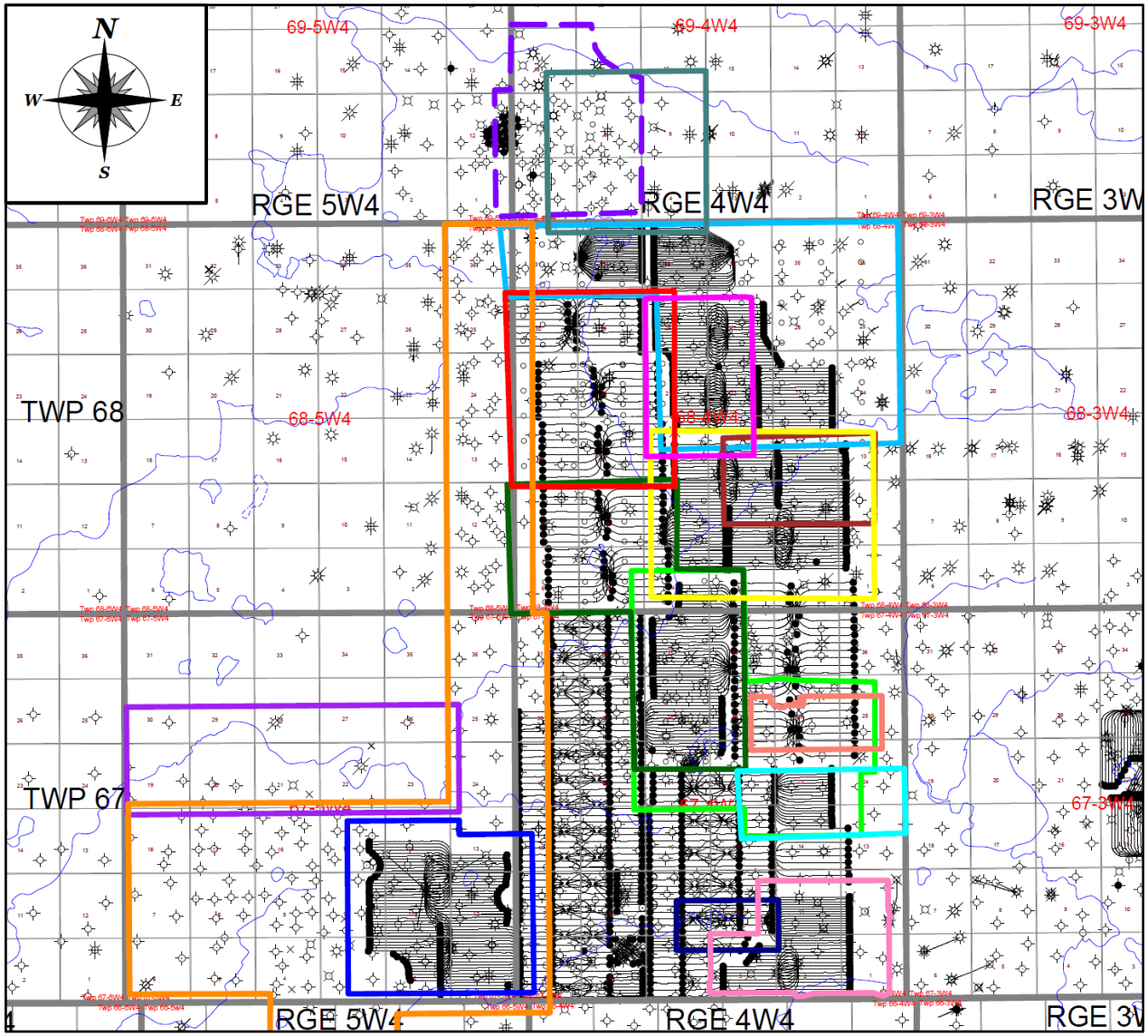
3D Seismic: Primrose North and South Seismic



- 2019 4D
- 2019 3D
- 2018 4D
- 2015 4D
- 2014 3D
- 2014 4D
- 2013 4D
- 2012 3D
- 2012 4D
- 2010 3D
- 2010 3D
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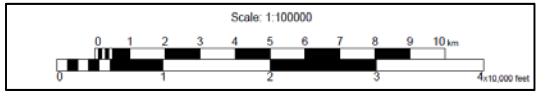
- 2009 3D
- 2009 4D
- 2007 3D
- 2006 3D



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Reservoir Performance

- Artificial Lift Summary
- Thermal Pad / Well Design
- Steam Quality
- SAGD Recovery Process Basics
- SAGD Typical Well Schematics
- Wolf Lake SAGD
- Burnt Lake SAGD Pilot
- CSS/SF Recovery Process Basics
- CSS/SF Typical Well Schematics
- Formation Integrity and Geomechanics Monitoring
- Wolf Lake CSS and Steamflood
- Primrose CSS and Steamflood
- Primrose and Wolf Lake Development

Artificial Lift Summary

Rod Pump Lift Capacity Range

Pump Size	Pump Jack	Stroke Length	SPM	Rate (m^3/d)
2.5"	456	120"	9	100
	456	144"	9	120
	1280	240"	9	200
3.25"	160	74"	9	105
	456	120"	9	170
	456	144"	9	200
	1280	240"	9	340
3.75"	VSH2	150"	7	220
	Rotoflex	288"	5	300
	1280	240"	9	450
	1824	240"	9	450
4.25"	1280	240"	9	580
	1824	240"	9	580
	SSI	288"	7	540
4.75"	Rotoflex	288"	5	480
	1280	240"	9	620
	1824	240"	9	720
5.5"	Rotoflex	288"	5	650
	1824	240"	9	970

- Operating temperature range: 50ºC to 330ºC
- Pump intake pressure: <500 kPa to 6,500 kPa
- 3.25” and 3.75” insert rod pumps are the most commonly used pump in CSS operations
- 4.25” insert pumps and 4.75” tubing pumps are used frequently in steamfloods
- ESP’s used for water source wells

ESP Capacity Range

Pump Stage Count	Recommended Pump Operating Range @ 60Hz (m^3/day)	Motor Type HP
40	205 - 800	168
44	380 - 740	86

Primrose CSS / Steamflood Pad Design

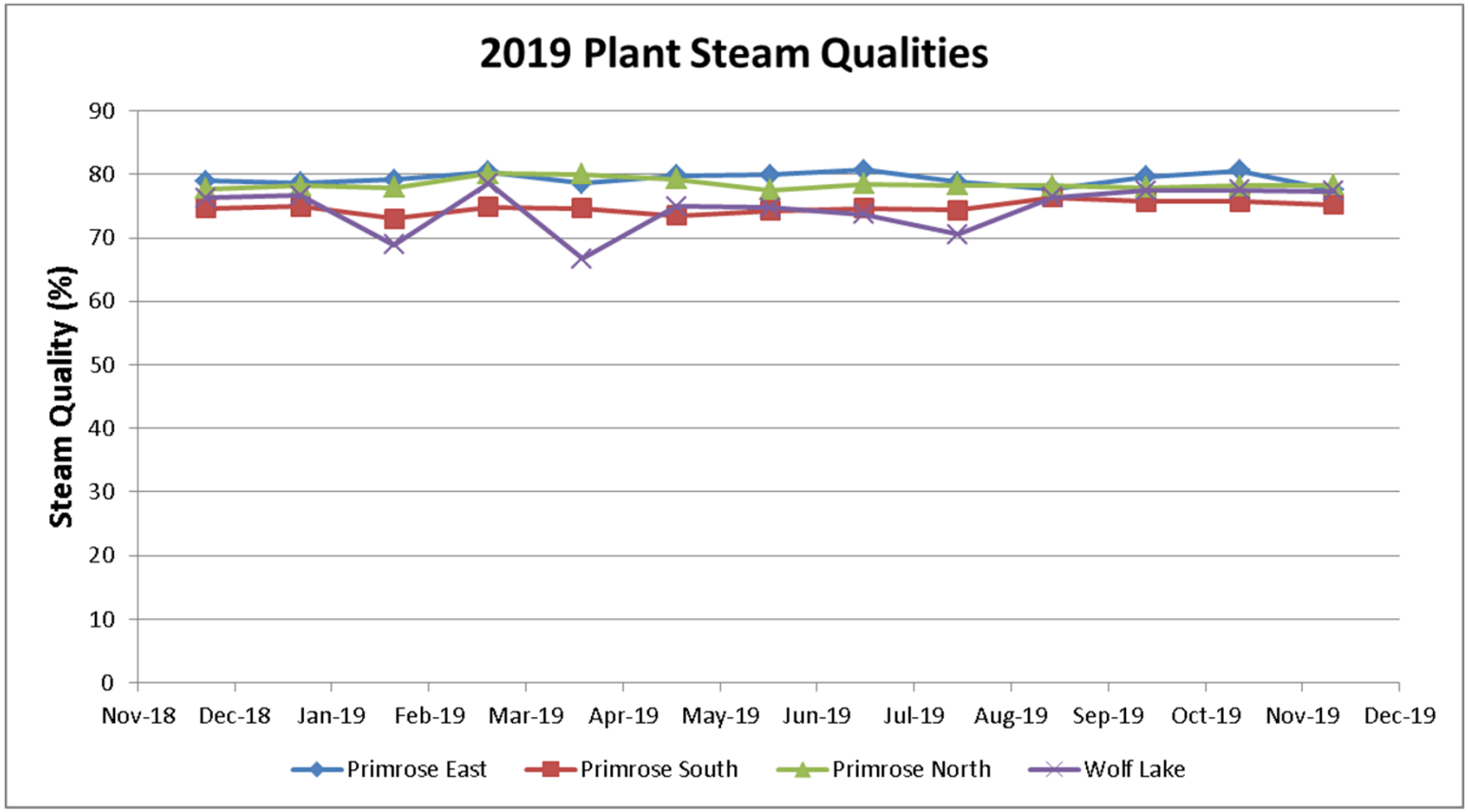
Phase	Wells per Pad	Design Spacing (m)	Well Length (m)	Development Date
1-21	8-12	160	600	1993-2000
29-31	20 hz 4 dev	188	1.200	2003-2004
51-54	16 hz 8 dev	188	1,200	2004-2006
55	20 hz 10 dev	160	1,200-1,400	2004-2006
27	9	160	1,400	2005-2006
28	10	75	1,000	2006-2007
74, 75, 77, 78	20	60	900	2007-2008
58, 59, 62, 63, 66, 67	20	80	1,000-1,700	2008-2009
22-24	18	80	1,200-1,700	2010-2011
90-95	10-25	60 - 80	800-1,600	2011-2012
25A/B, 26	15-20	60 & 80	600-1,700	2011-2012
60, 61, 64, 65, 68	20	80	1,000-1,800	2011-2013
40-43	24	74	800-1,700	2013-2014
72A, 72B	30-33	50 - 60	1,100 – 1,800	2018-2019

- Design evolution over life of project with goal of optimization of resource recovery
  - Reduction in pad capital per well
  - Increase areal recovery
  - Configuration integrates future follow up processes

Wolf Lake SAGD Pad Design

Phase	Wells Pairs	Design Spacing (m)	Well Length (m)	Development Date	Formation
D2	6	140	650	1997-2000	Grand Rapids
SD9	6	90	950	2001	Grand Rapids
S1A	8	100	950	2004	Grand Rapids
S1B	6	100	900	2010	Grand Rapids
MC1	6	70	900	2010	McMurray

Steam Quality – 2019



- The steam quality at most pads is between 0.5 and 1.0 percent lower than the quality at the plant (the furthest pads may be up to 4 percent lower)
- Quality change varies depending on the operating pressure, operating flow rates, line size and distance between the plant and the pad

SAGD Basics – Well Warm Up

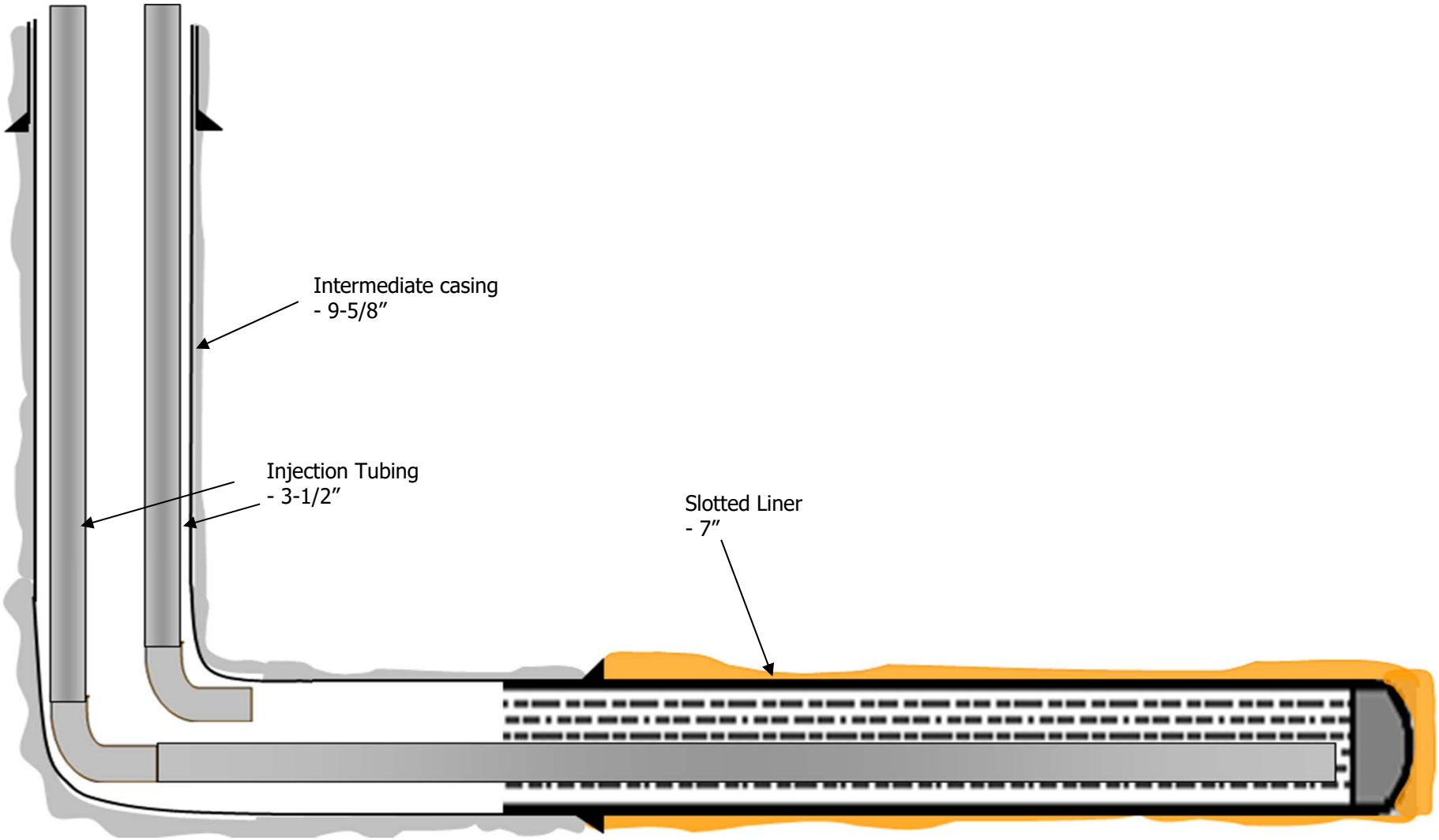
- For both wells of SAGD pair
  - Inject steam down tbg. string to toe
  - Produce water and steam via 2nd tbg. string from heel
- Continue steam circulation for 2 to 4 months
  - Duration determined by temperature and performance observations
- Measure and monitor injection and returned volumes, pressures and temperature

SAGD Basics – Injection / Production

- Inject steam into upper well
  - Balance between toe and heel
  - Control based on reservoir response and temperature observations in producer

- Pump fluid from lower well with artificial lift
  - Monitor bottomhole pressure data for both injection and production wells
  - Bottomhole temperature observations influence how wells are operated
  - Typical fluid production rates vary from 150 m^3/d to 600 m^3/d

Sample Parallel String Injector Completion



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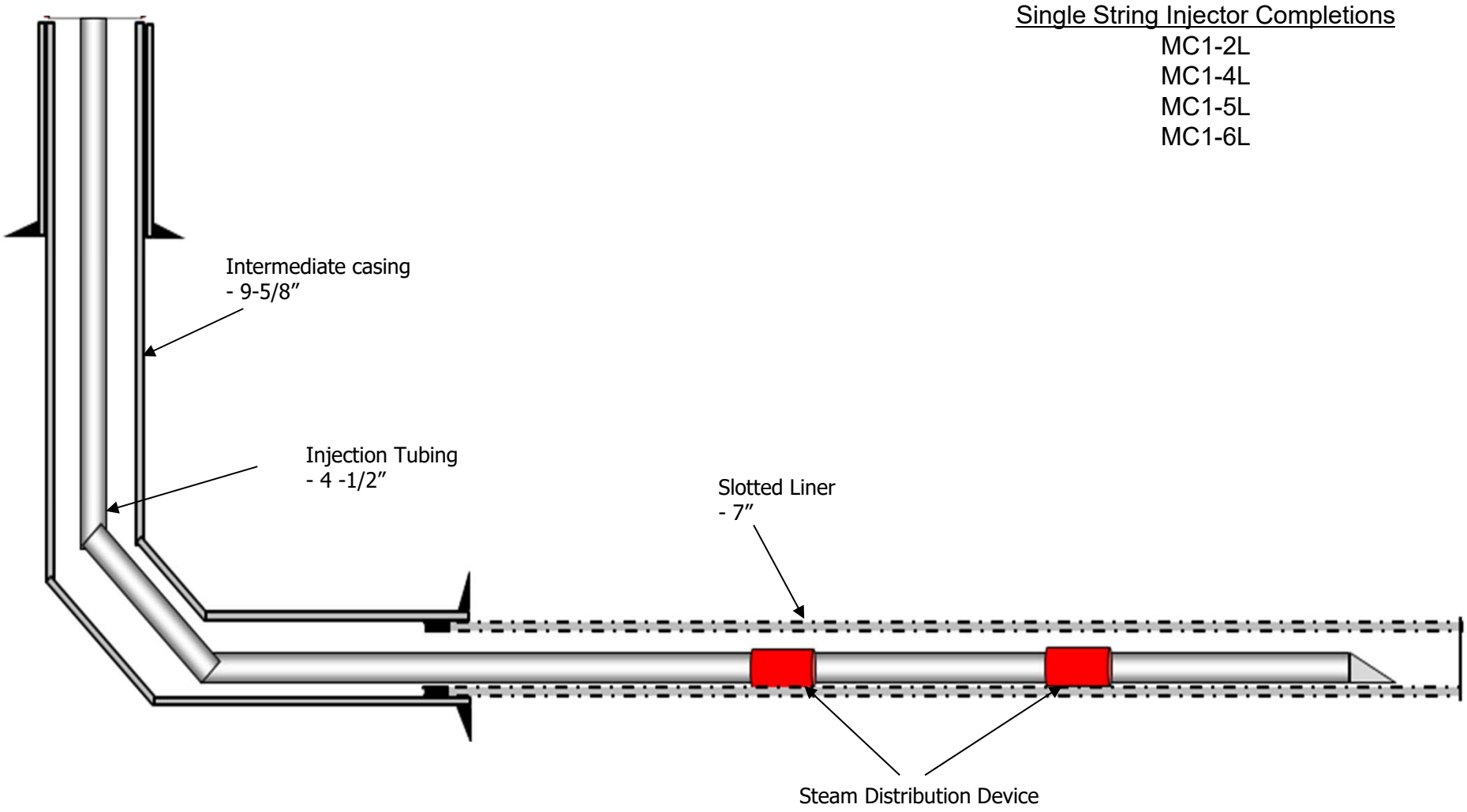
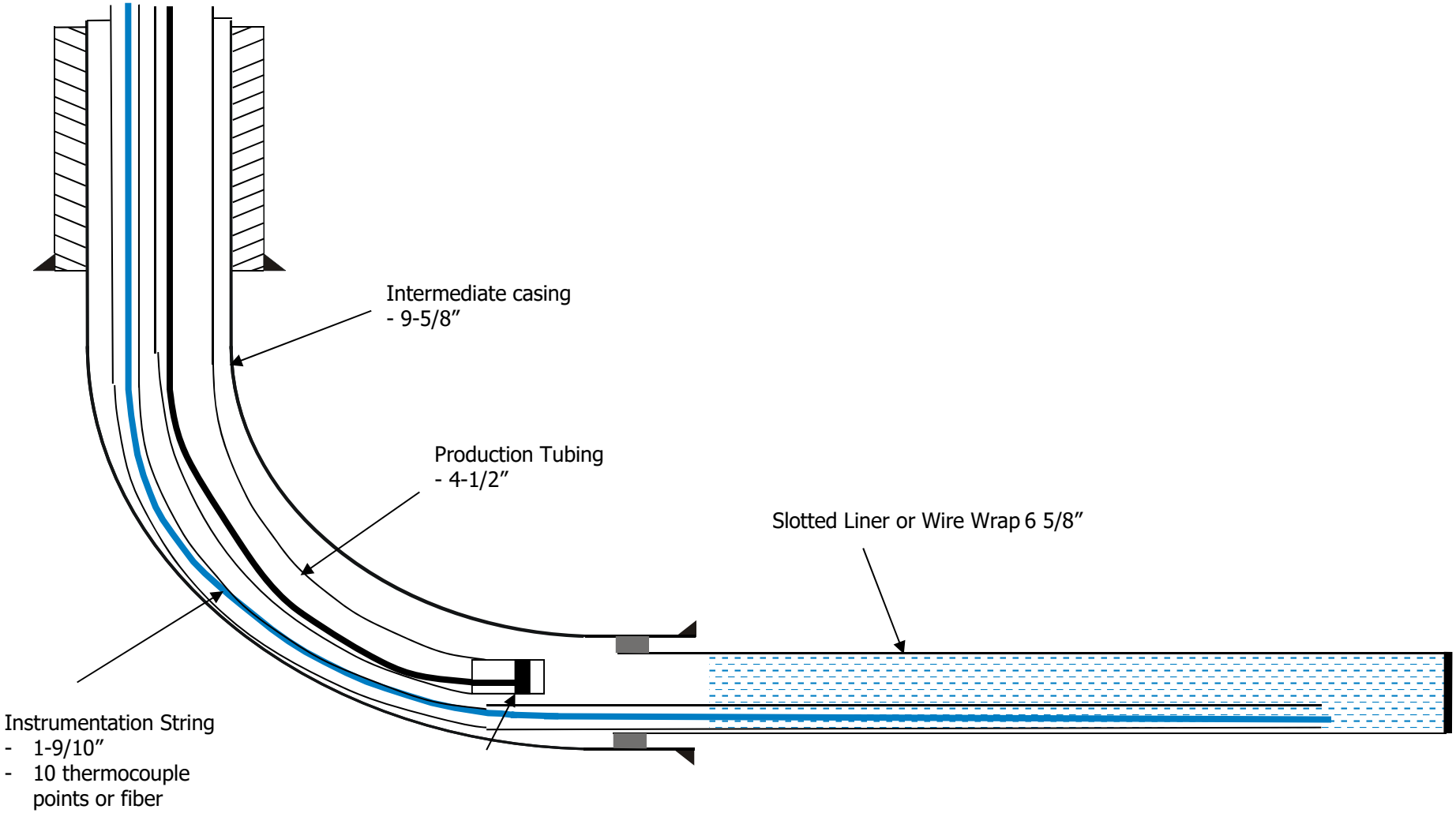
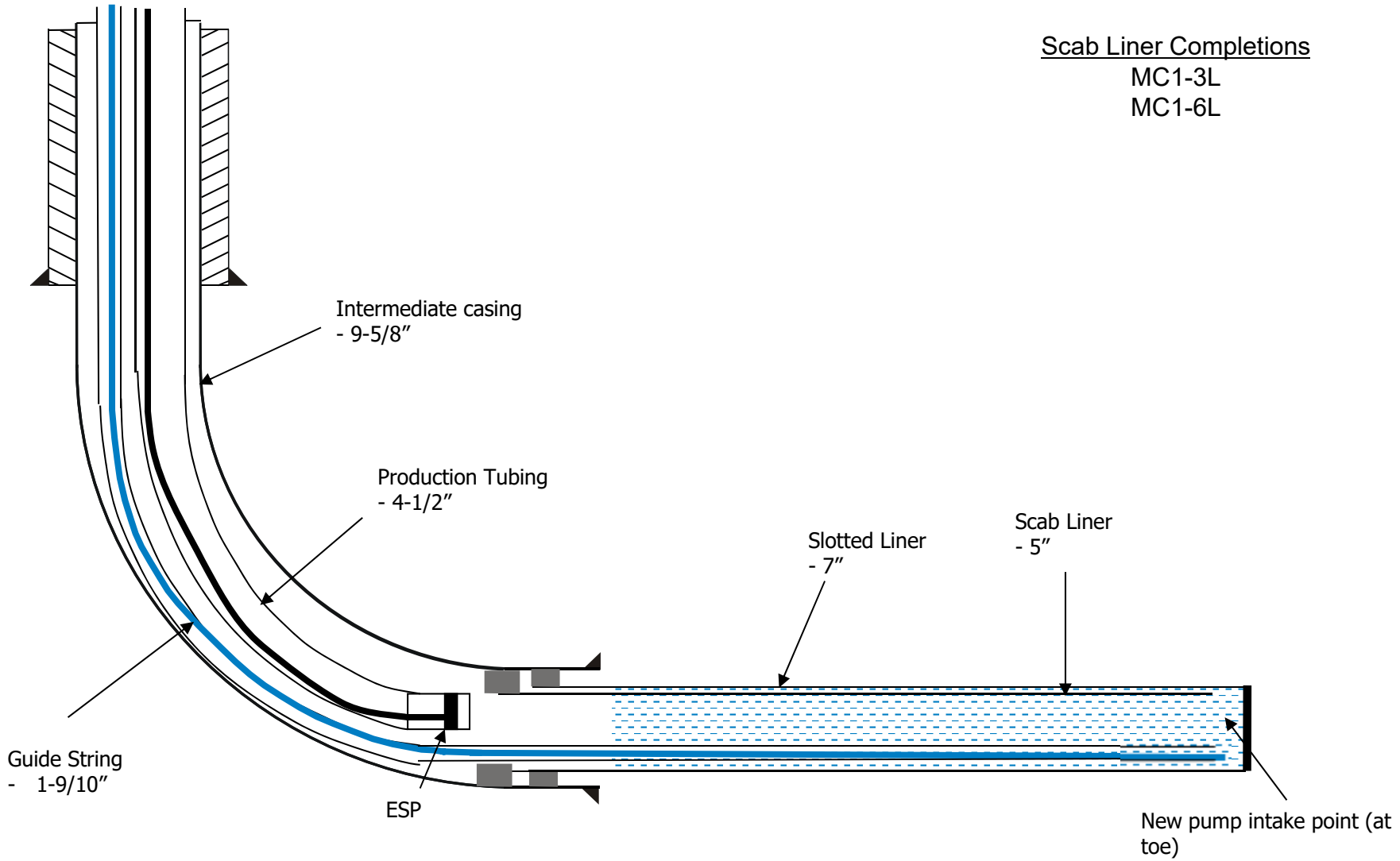
Sample Single String Injector Completion



Sample Producer with Rod Pump Completion

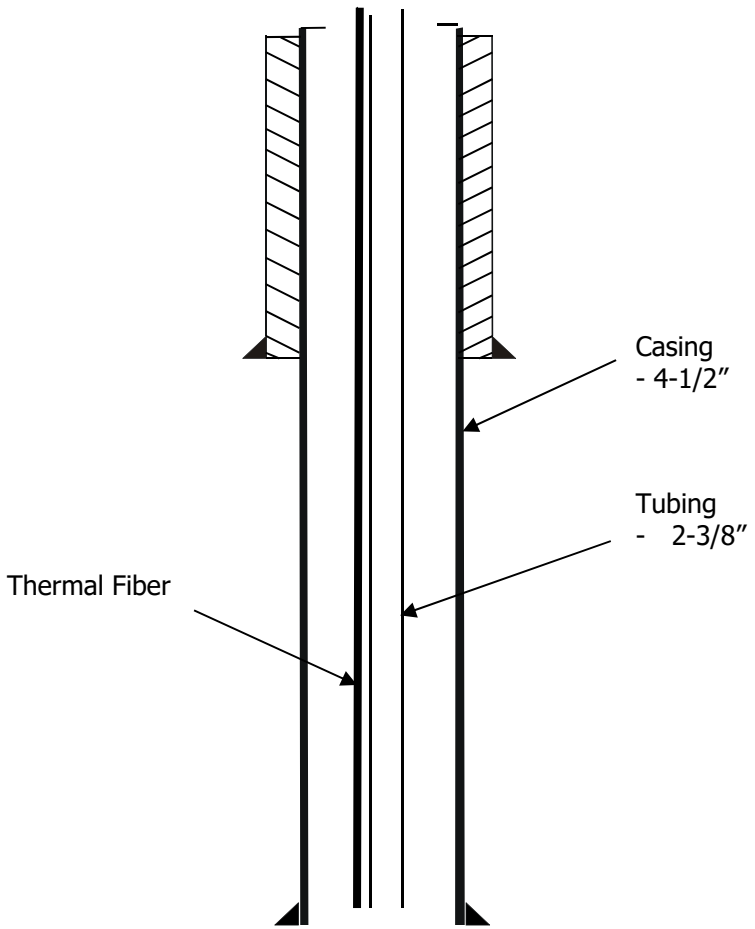


Sample Producer with Scab Liner Completion

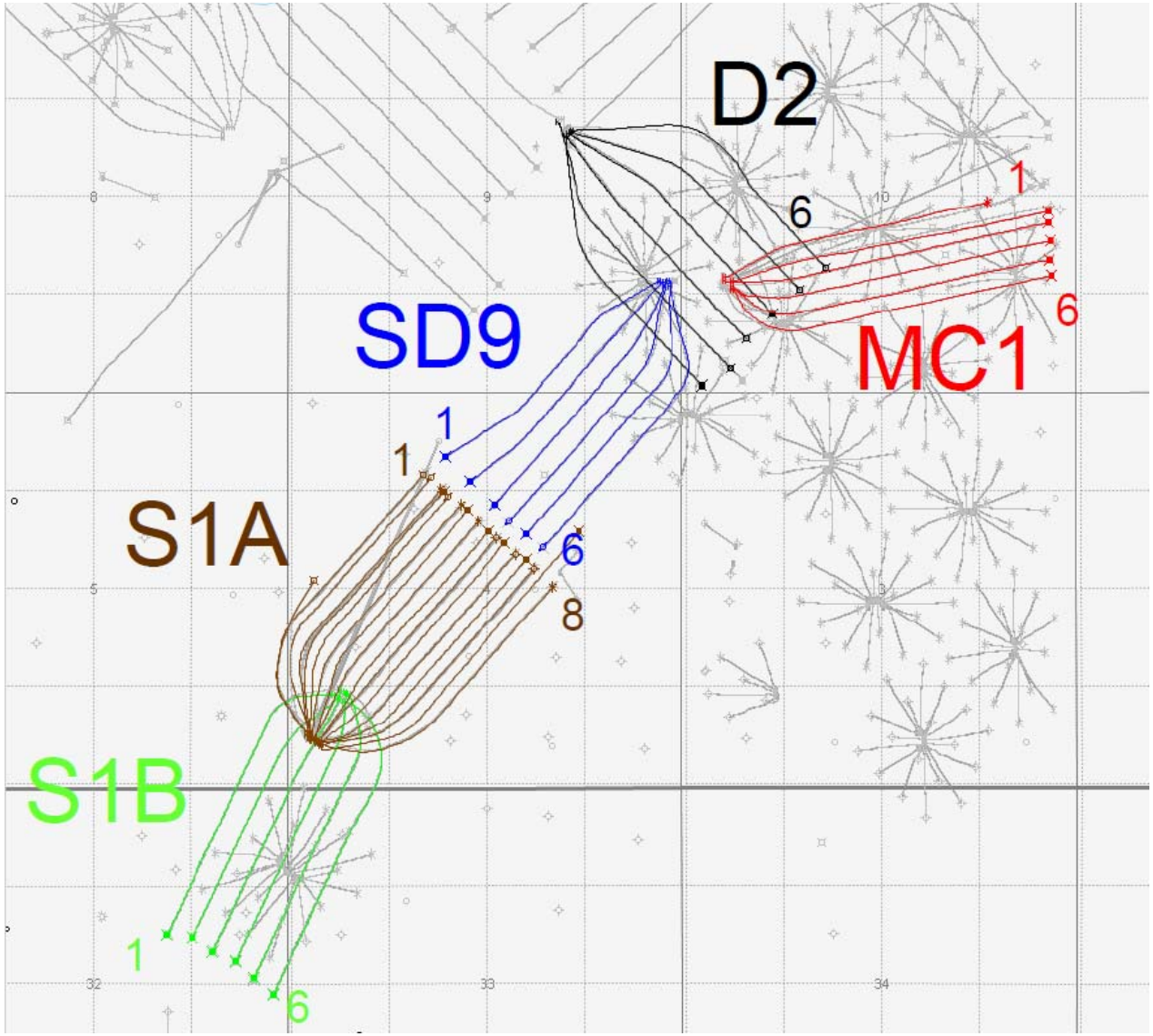


Sample Observation Well Completion

Temperature Only



Wolf Lake SAGD Location Map



Wolf Lake SAGD

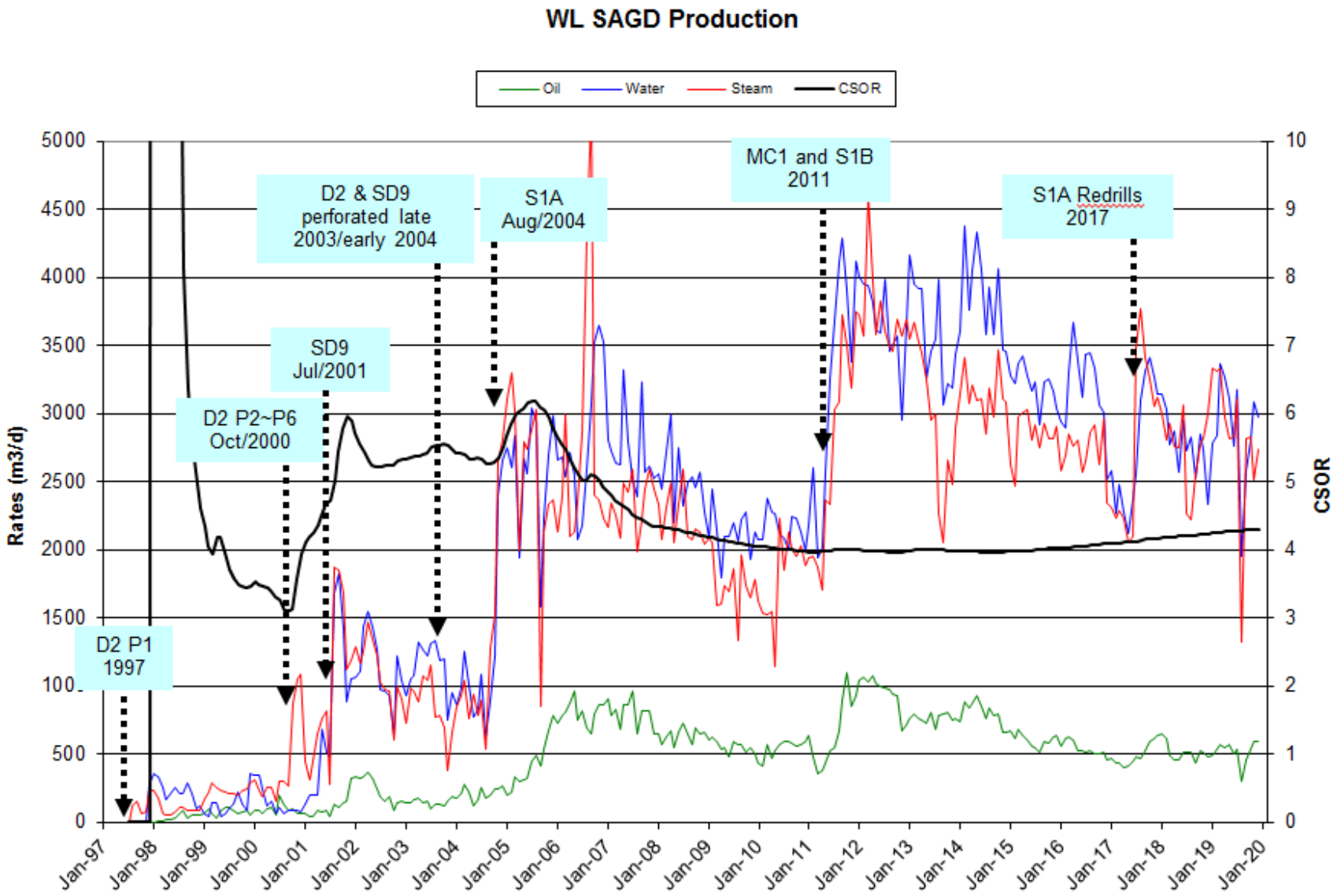
	D2 (B10)	SD9 (B10)	S1A (B10)	S1B (B10)	B10 Total	MC1 (MCMR)
Active Wellpairs	0	6	8	6	20	6
2019 Bit Prod, e3m^3	0	27	89	35	151	38
2019 Avg. SOR (*dry steam)	0	9.1	4.1	5.4	5.3	6.0
Cumm Bit, e3m^3	313	1,045	1,173	557	3,088	726
Cumm SOR (*dry steam)	4.9	4.4	4.5	3.9	4.4	4.0
OBIP, e3m^3	1,358	1,819	2,682	1,972	8,349	1,446
2019 YE RF, %	23	57	44	28	37	50
Estimated Ultimate RF, %	50	55-60	50	50	50	50

- Current production is from B10 Grand Rapids & MCMR
- SD9 recovery is over 50%, considering options for blowdown
- Estimated ultimate recovery of OBIP is expected to be > 50% in SAGD operations

Wolf Lake SAGD
Operational Strategy

- Operate wells based on a target steam chamber pressure, target sub-cool, and gross analog rates
- Steam chamber pressure is measured by annulus gas pressure in the injector and is controlled by the steam injection rate.
  - Current target pressure for SD9 is 2,850 kPa
  - Current target pressure for S1A is 2,850 kPa
  - Current target pressure for S1B is 2,700 kPa
  - Current target pressure for MC1 is 3,300 kPa
- Wolf Lake SAGD operational pads inject dry steam
- Sub-cool is determined based on the difference between the saturated temperature of the steam chamber pressure and the highest temperature along the producer lateral
  - Target to maintain a minimum 0-30 °C sub-cool

Wolf Lake SAGD Performance



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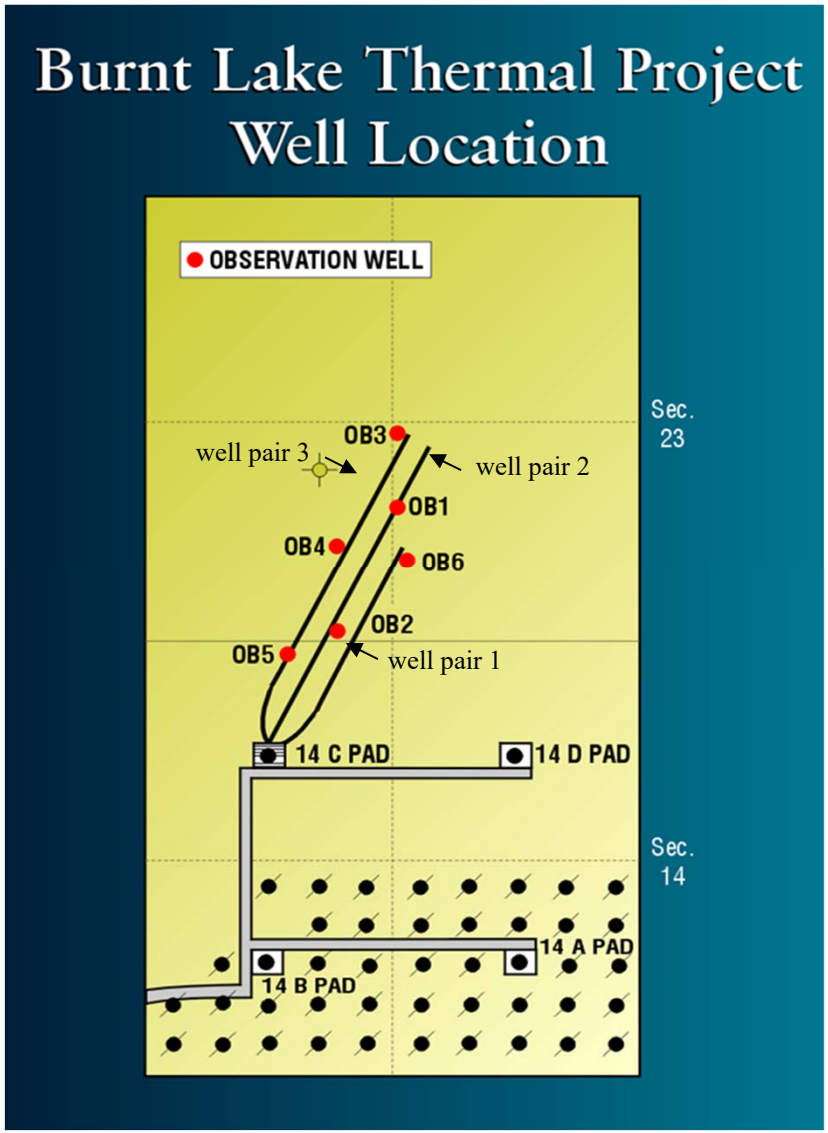
Wolf Lake SAGD – 2020 Plan

- Investigate blowdown strategies
- Investigate stimulation candidates
- Investigate infill and redrill possibilities from existing pad locations
- Continue to monitor performance and optimize redrills on S1A

Burnt Lake SAGD 2019 Performance Summary



Burnt Lake SAGD Pilot Production	
Well Pairs	3
2019 Bitumen Production (e3m^3)	27.7
2019 Average SOR	0
Cumulative Bitumen Production (e3m^3)	1,012
Cumulative SOR	3.9
OBIP (e3m^3)	1,493
Recovery Factor (%)	68

- Hz injector length: CP1: 940m, CP2,CP3: 1,200m
- Inter-well-pair spacing: 85m
- Avg. net pay: 22m
- Avg. So: 75%
- Avg. porosity: 33%
- Estimated Ultimate Recovery : 70%
- 80% quality steam
    - Wet steam results in downgrade to SOR vs dry steam

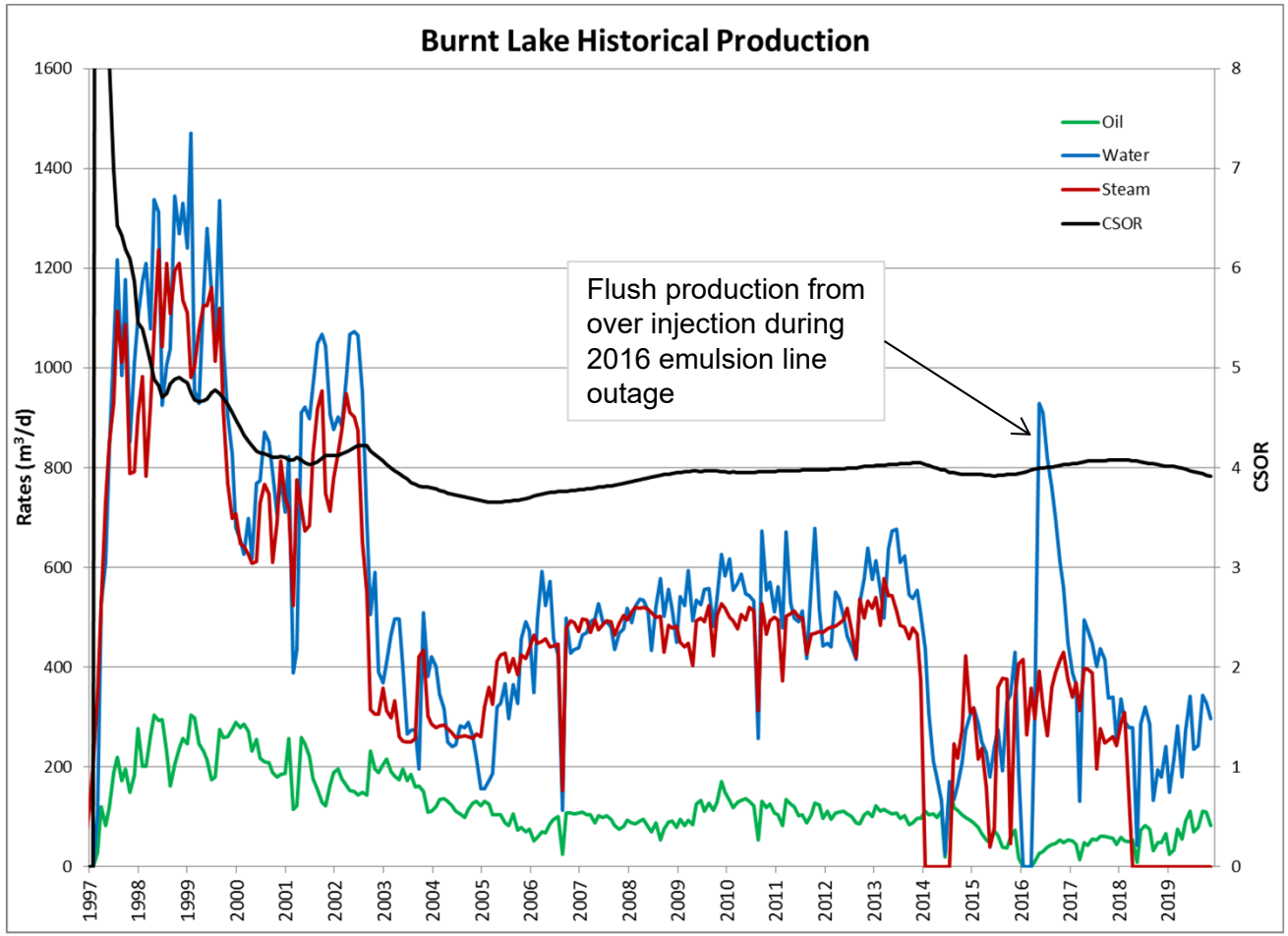
Burnt Lake SAGD Production Summary

2019 Highlights

- Repaired CP1, back on production as of August 2019
- Continued operation with no steam support

2020 Operational Plan

- Evaluate options for restoring BFW availability to restart steaming



PAW CSS and SF Depletion Overview

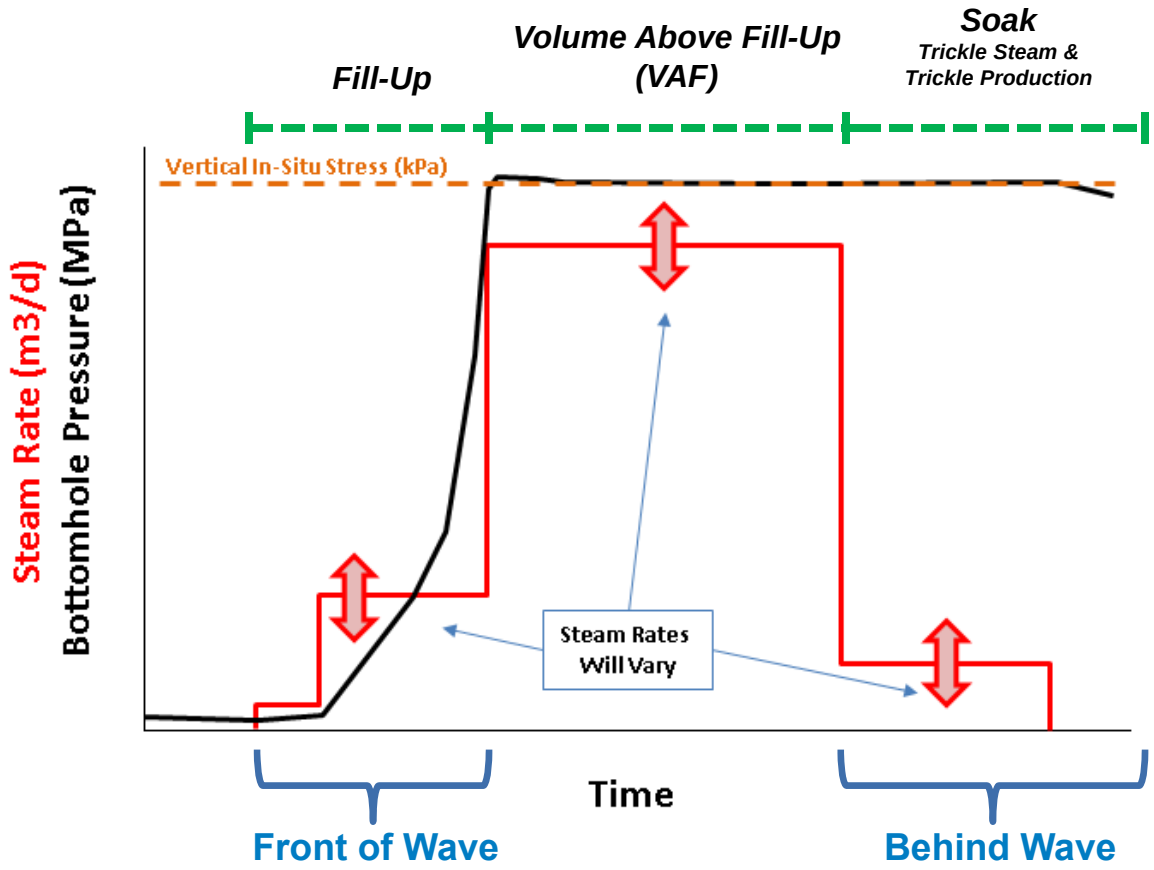
- Basics
  - CSS / SF
    - Steaming
    - Reservoir Pressure Management
    - Depletion
  - Well Design
  - Observation Wells/Monitoring
  - Geomechanics and Formation Integrity Monitoring
  - OBIP
  - Recovery
- Wolf Lake Update
  - Valley Fill
  - C3 Sands
- Oil, Water, Steam
- Primrose Update
  - Current and Potential Recoveries
  - Performance
  - 2020 Steam Schedule
  - Future Development

Basics – CSS and SF Steaming

- Steam Generation: quality of ~75%, ~15 MPa
- CSS (all wells cycle from steam injection to production)
  - Inject steam to dilate reservoir
    - Dilate reservoir with steam injection at the vertical in-situ stress (gradient is ~21 kPa/m at 500 m TVD, at ~10.5 MPa)
  - Wave steam strategy through majority of wells
    - Alternate steam strategies implemented where interwell communication & Clearwater dilation profile require
  - Rate and volumes are dependent on well geometry and cycle number
    - Steam strategy includes small volume commissioning cycles
    - Steam volumes selected to limit overburden uplift
    - Early cycles have limited steam volume growth
  - Reservoir pressure management
    - Fill up in front of wave to increase reservoir pressure ahead of post fill-up wells
    - Soak wells 3+ rows behind steam injection to reduce leak off on post fill-up wells
- Steamflood (alternating injector and producer configuration)
  - Inject steam to maintain target bottom hole reservoir pressure
    - Pressure varies depending on inter-well communication and steamflood phase
  - Support production at adjacent producers

CSS Basics – Steaming
Reservoir Pressure Management

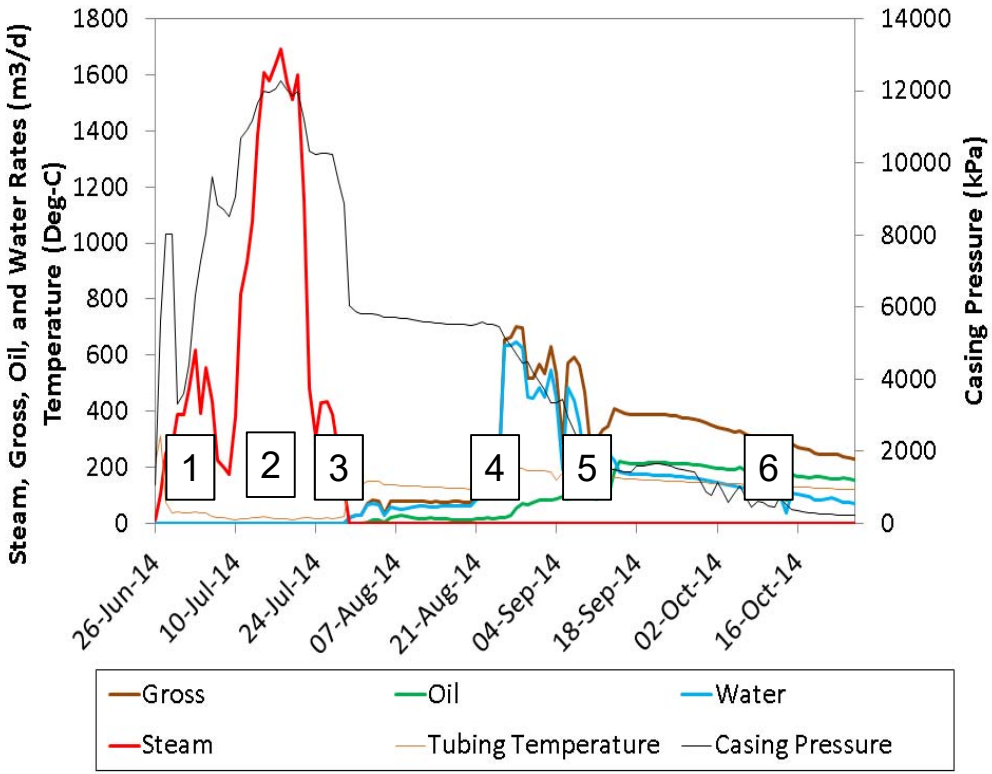
- Inter-well communication has been shown to reduce thermal efficiency. Risk managed by controlling pressure gradients around steam wave



- Front of Wave
  - Design for a fill-up steam bank ahead of wave which establishes a controllable pressure gradient ahead of the wave
- Behind Wave
  - Soaking wells
    - Use stress to confine steam injection
    - Number of rows increased with degree of inter-well communication
  - Flow back wells
    - Design a flow back rate that balances production while keeping reasonable pressure differentials (dPs) between wells

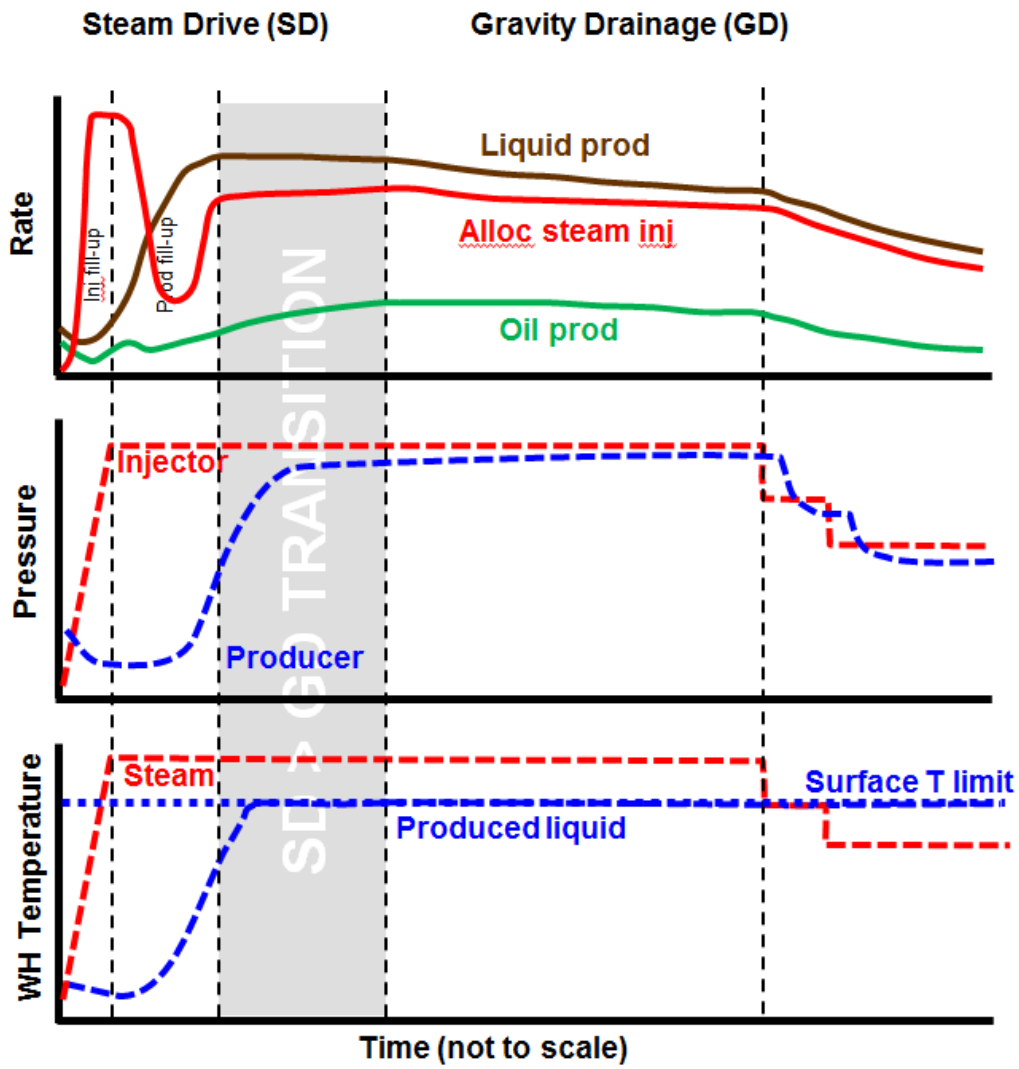
CSS Basics – Depletion
Fluid Recovery Basics

- Gross fluid profiles are analyzed as a function of Depletion Index, DI
  - DI is the ratio of total fluid produced to total steam injected
- Large variance in production rate throughout CSS cycle
- 5 components to the gross fluid vs. DI profile. Component expectation varies by cycle, reservoir and steam strategy.
  1. **Fill-up:** Sub-dilation volumes required to fill-up increase as depletion increases
  2. **Volume Above Fill-up:** Commercial cycle design limits overburden uplift
  3. **Soak / Pressure Management:**
     A) Trickle Steam
     B) Trickle Production
     Design influenced by interwell communication / reservoir pressure management strategy
  4. **Flowback:** Targeted rates designed to control pressure differentials between drainage boxes
  5. **Pump-limited Pumping:** Artificial lift capacity constrained
  6. **Declining Production:** Gas break out from solution, vapour recovery required

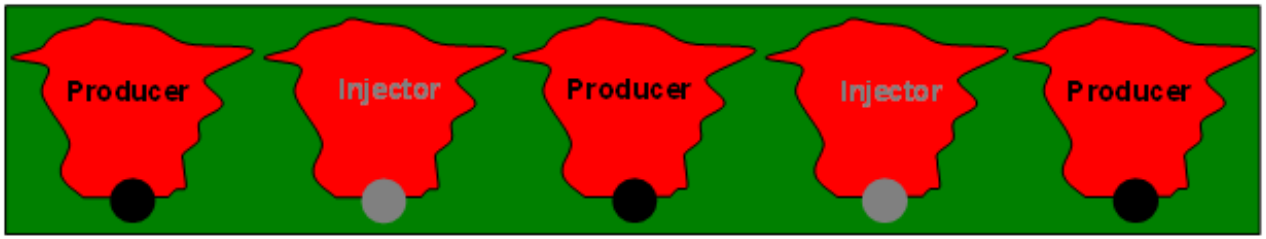


Steamflood Basics – Recovery Phases

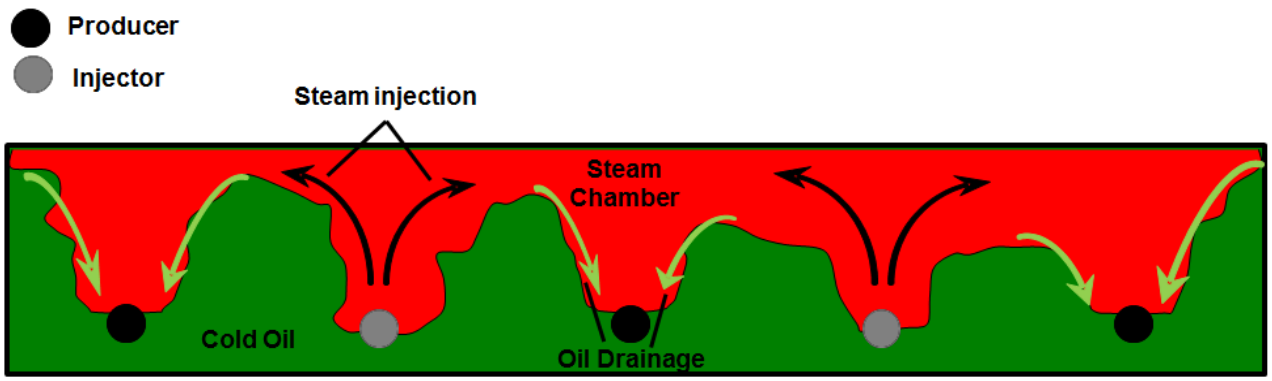
- Injector fill-up
  - High steam rate constrained by maximum injection pressure target
- Producer fill-up
  - Steam rate decreases as reservoir pressure increases
  - Producer liquid rate rises to max artificial lift capacity
  - Production temperature, pressure and oil rate increase
- SD > GD transition
  - Steam rate rises to maintain constant injection pressure
  - Liquid rate stays at ALC limit
  - Wellhead temperature reaches max dictated by surface group line pressure
  - Oil rate continues increasing
- Gravity drainage
  - Starts when approaching a liner zero subcool
  - Period of stable/declining CDSR, gross and oil



Steamflood Basics – Depletion



Remnants of interwell communication from last HPCSS cycle

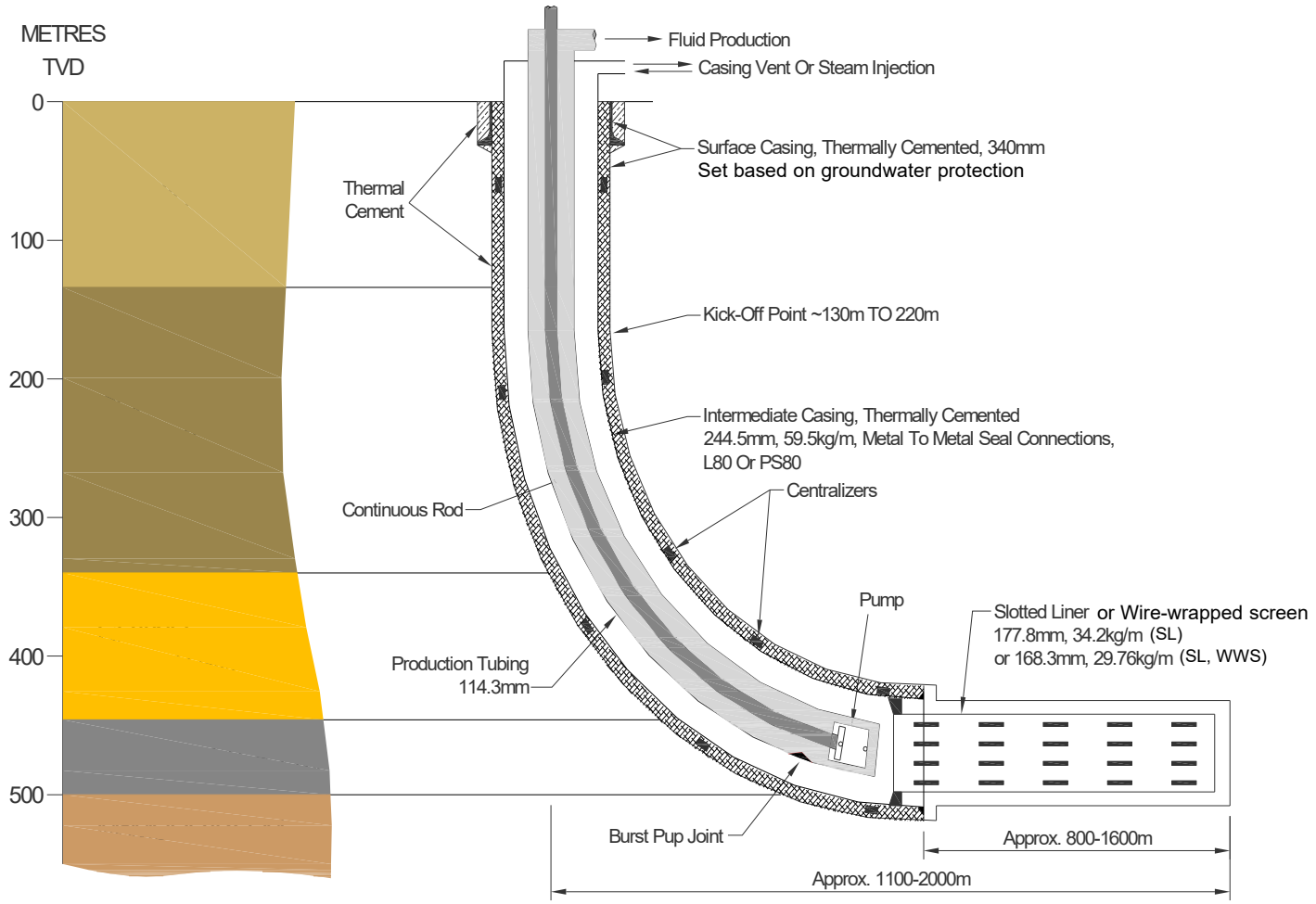


Interwell communication during gravity drainage dominated stage of SF

- SF initiated after previous CSS cycles have adequately depleted reservoir
  - Goal of SF is to transition to a gravity drainage recovery process
- Bottom Hole Injection Pressures: typically ~2-5 MPa
  - Flexibility to inject at ranges higher than the typical range (up to 9 MPa BHP) to promote interwell communication and steam chamber development
- Target Injection Rates: typically ~200-800 m^3/d CWE
  - Balance steam injection and produced water withdrawal to maintain reservoir pressure

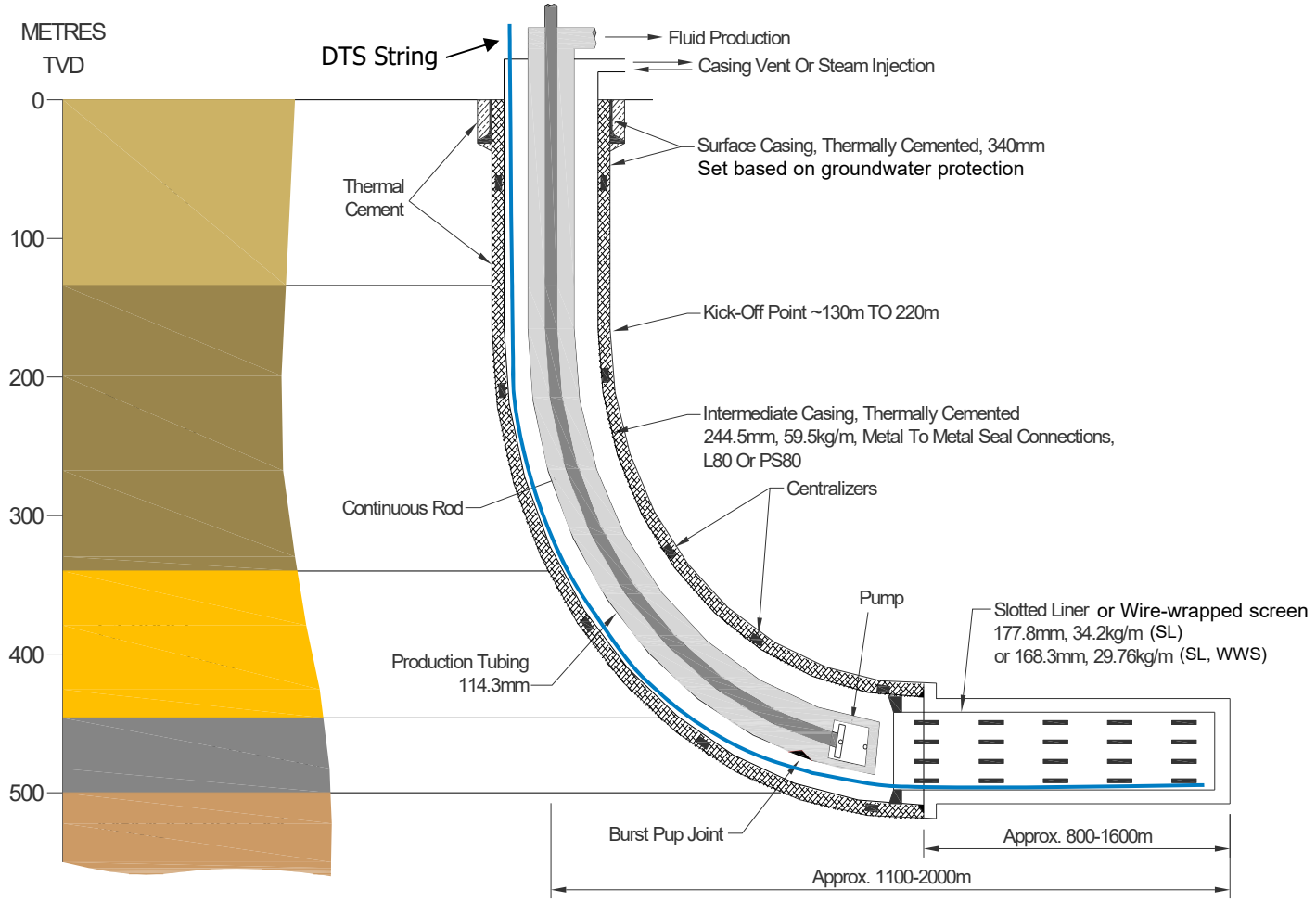
CSS/SF Basics – Standard Well Design

Typical Horizontal Well



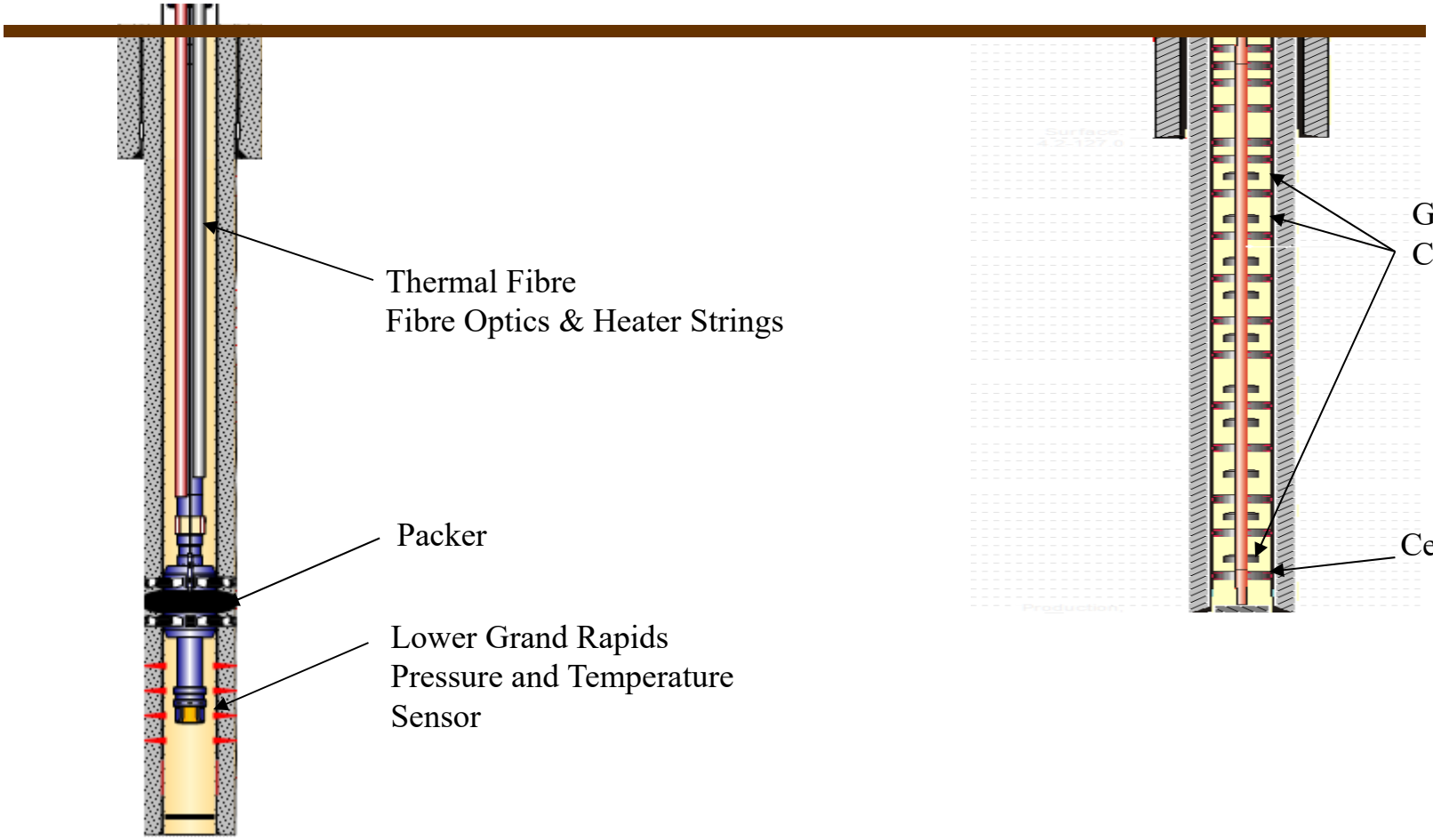
CSS/SF Basics – Well Design with DTS Installation

Typical Horizontal Well (Producer) Outfitted with DTS String



CSS/SF Basics – Observation Wells

Grand Rapids Monitoring **Ground Level** Passive Seismic Monitoring

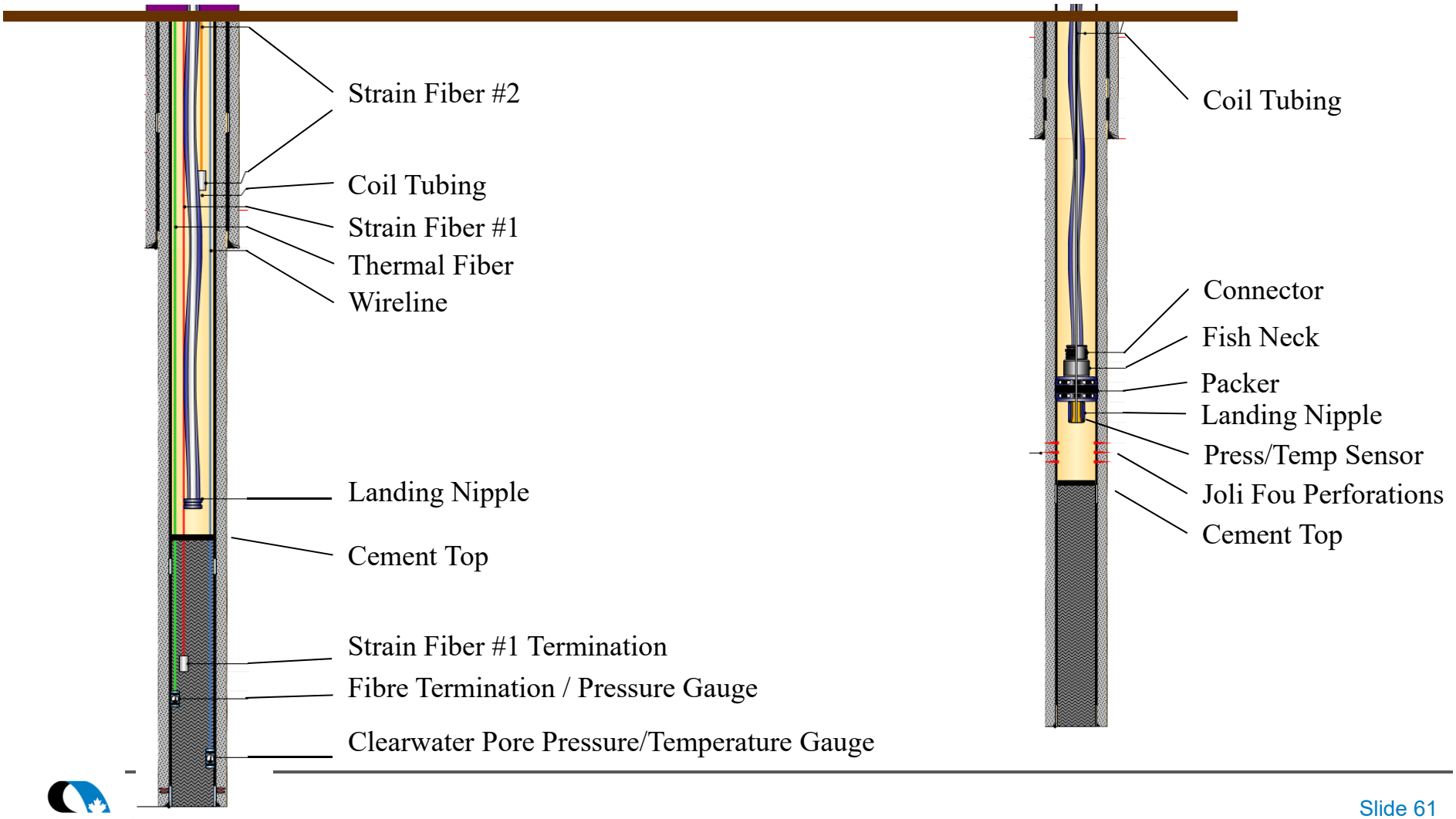


CSS Basics – Geomechanics Wells

Vertical Strain / CLWR Pore Pressure

Ground Level

Diagnostic Fracture Injection Testing



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Formation Integrity Monitoring, Passive Seismic and Geomechanics

- Passive seismic monitoring has been used since 2000 and is an effective tool for detecting out of zone casing failures

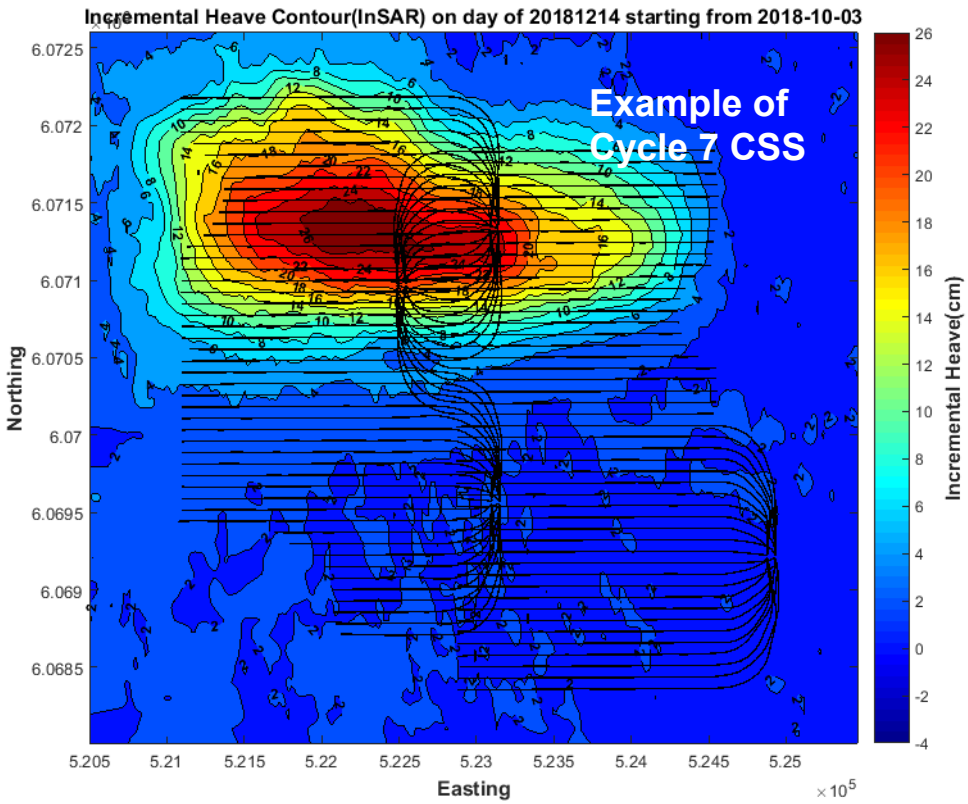
- Geomechanics Observation Wells on Pad 43
  - Improve understanding between steam injection volumes and uplift induced stress changes
  - Integration and evaluation of acquired data is ongoing
    - Surface heave
    - Vertical strain
    - Repeated DFIT within the Joli Fou Formation (since CSS Cycle #1)
    - Repeated DFIT within the Westgate Formation (since CSS Cycle #6)
    - Pore pressure measurement in the B12 and Quaternary
    - Steam injection volumes and pressures

- Geomechanics Observation Well (6-32) on Phase 72A
  - Pressure monitoring at bitumen fracturing obs well (6-32) for vertical stress change in WSGT formation during steaming
  - Optical fiber strain monitoring for vertical strain in the overburden during CSS

Surface Heave Measurement – Phases 40-43

- Continuing acquisition of InSAR over Primrose South Phases 40-43
- Ongoing image processing using InSAR
- Sample map of vertical deformation from InSAR showing cycle 7 heave
- Data processed in 2019

Incremental Heave
(Oct 2018 to End of Dec 15 2018)



Formation Integrity Monitoring
Lower Grand Rapids Pressure

- Lower Grand Rapids (LGR) pressure monitoring has proven to be an effective observation system regarding formation integrity surveillance during CSS
  - All CSS steaming pads are equipped with LGR pressure monitoring
  - The AER will be notified if a LGR pressure increase is greater than the approved threshold
  - Integration of independent data sources
    - LGR Monitoring, passive seismic, injectivity plots, production data

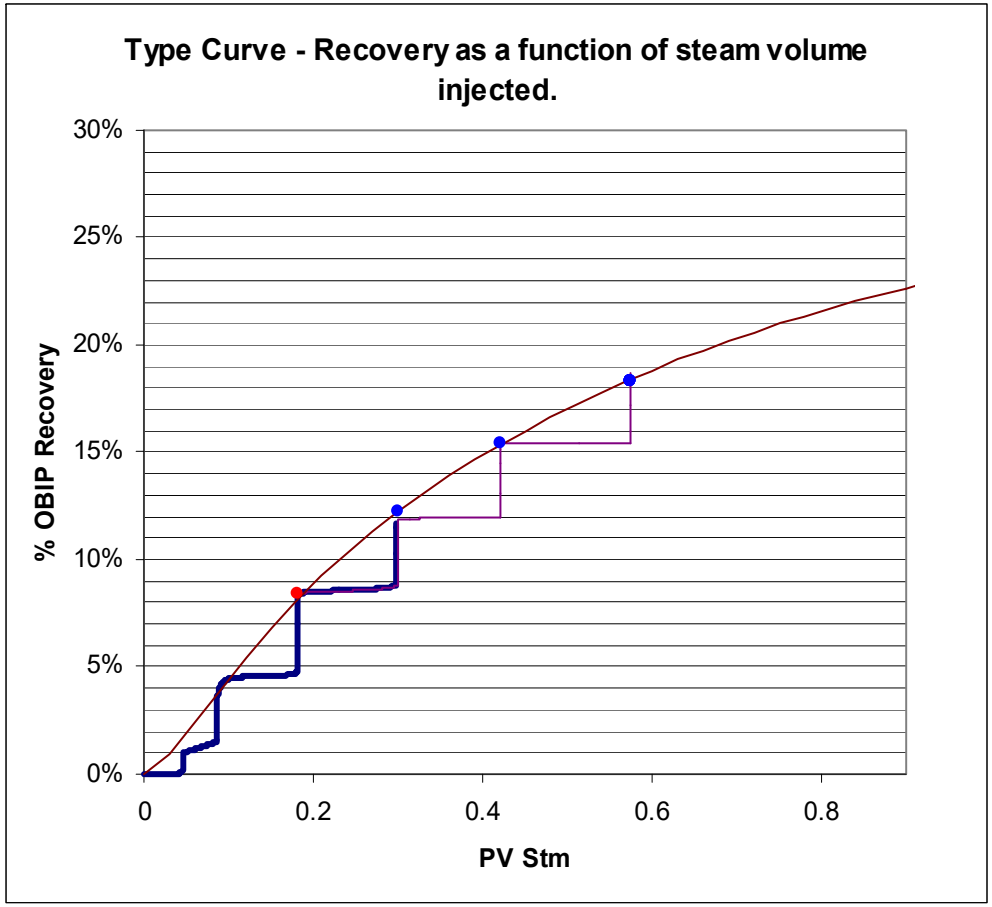
CSS / SF Basics – OBIP Assumptions

$$\text{OBIP} = \text{Area} \times \text{Net Pay} \times \text{Porosity} \times \text{Oil Saturation}$$

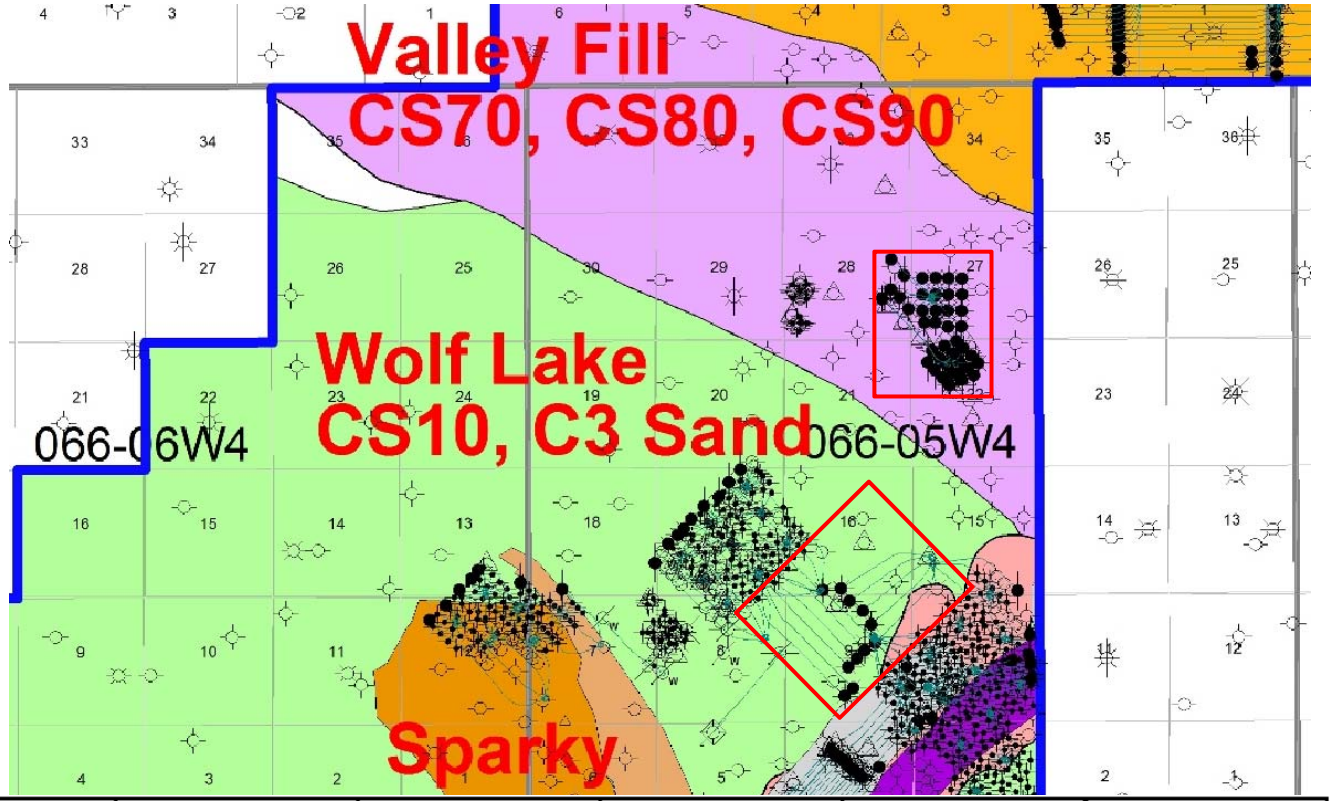
- Area is 1 well spacing wide by length of well plus ½ spacing on each end
- Net pay is as previously defined in the Geology section
- Oil saturation is determined from Bitumen Weight percentage assuming a sand/shale density of 2,650 kg/m^3, water/oil density of 1,000 kg/m^3, and 32% porosity

CSS Basics – Recovery

- CSS life is dictated by the economic limits (SOR)
- Typical economic SOR limit 10+
  - Oil/Gas price ratio dependent
- Forecasting is based on a type curve
- Recovery is a function of amount of steam injected
- Goal of steam scheduling is to maximize rates and recovery



Wolf Lake CSS/Steamflood 2019 Recoveries



	E2 & D2D (C3)	N (C3)	C3 Total	Z8 & HWP1 (VF)	Z13 (VF)	VF Total
Well Count	6	5	11	20	21	41
2019 Bit Prod, e3m3	16	14	30	34	2	36
2019 Steam Inj e3m3	103	112	215	275	0	275
Cumm Bit, e3m3	586	435	1,022	792	450	1,242
Cumm SOR	5.8	7.4	6.5	5.0	4.3	4.8
OBIP, e3m3	2,509	2,381	4,890	2,996	3,948	6,944
2019 YE RF, %	23%	18%	21%	26%	11%	18%

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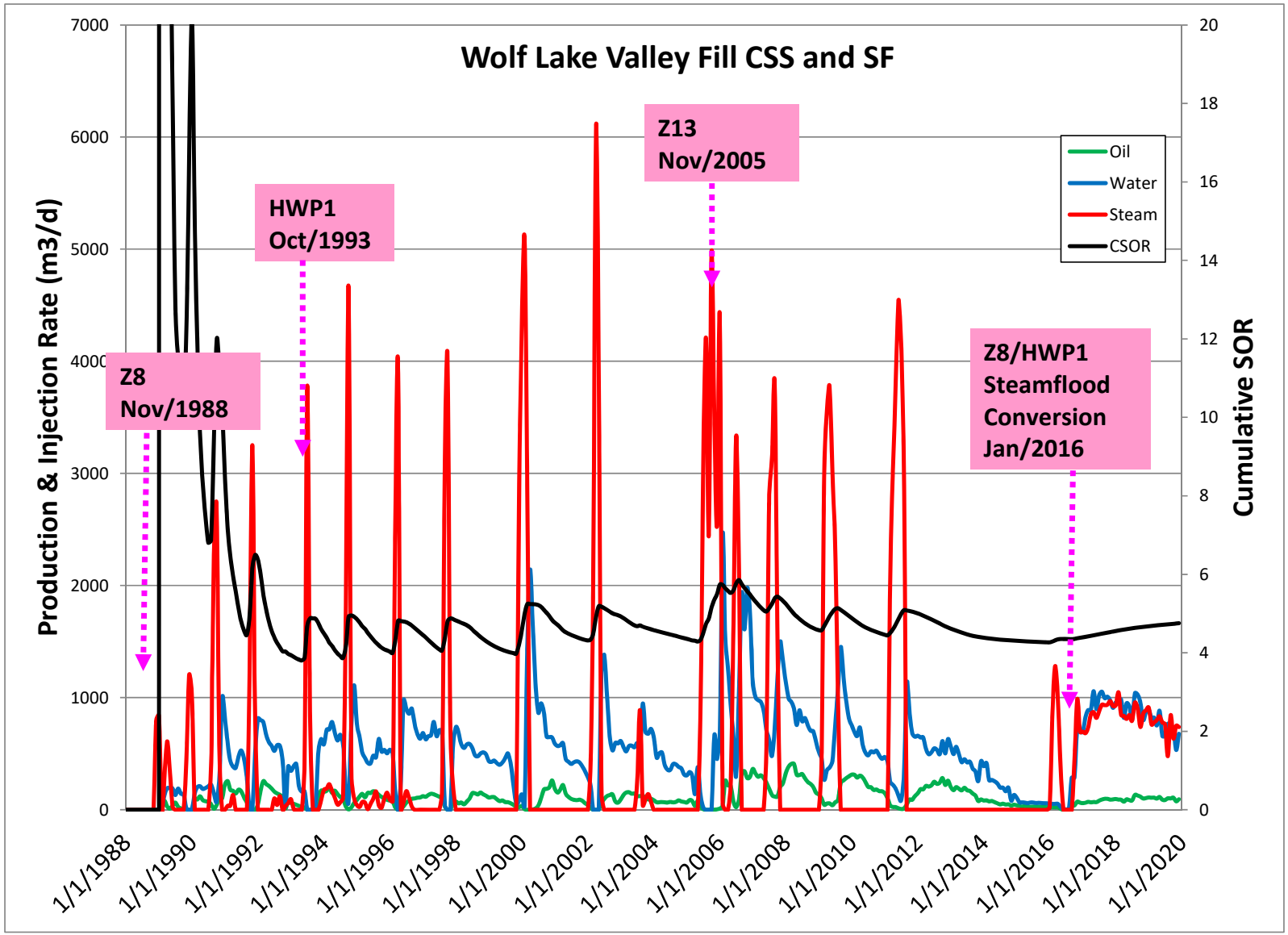
Wolf Lake Valley Fill, All Pads



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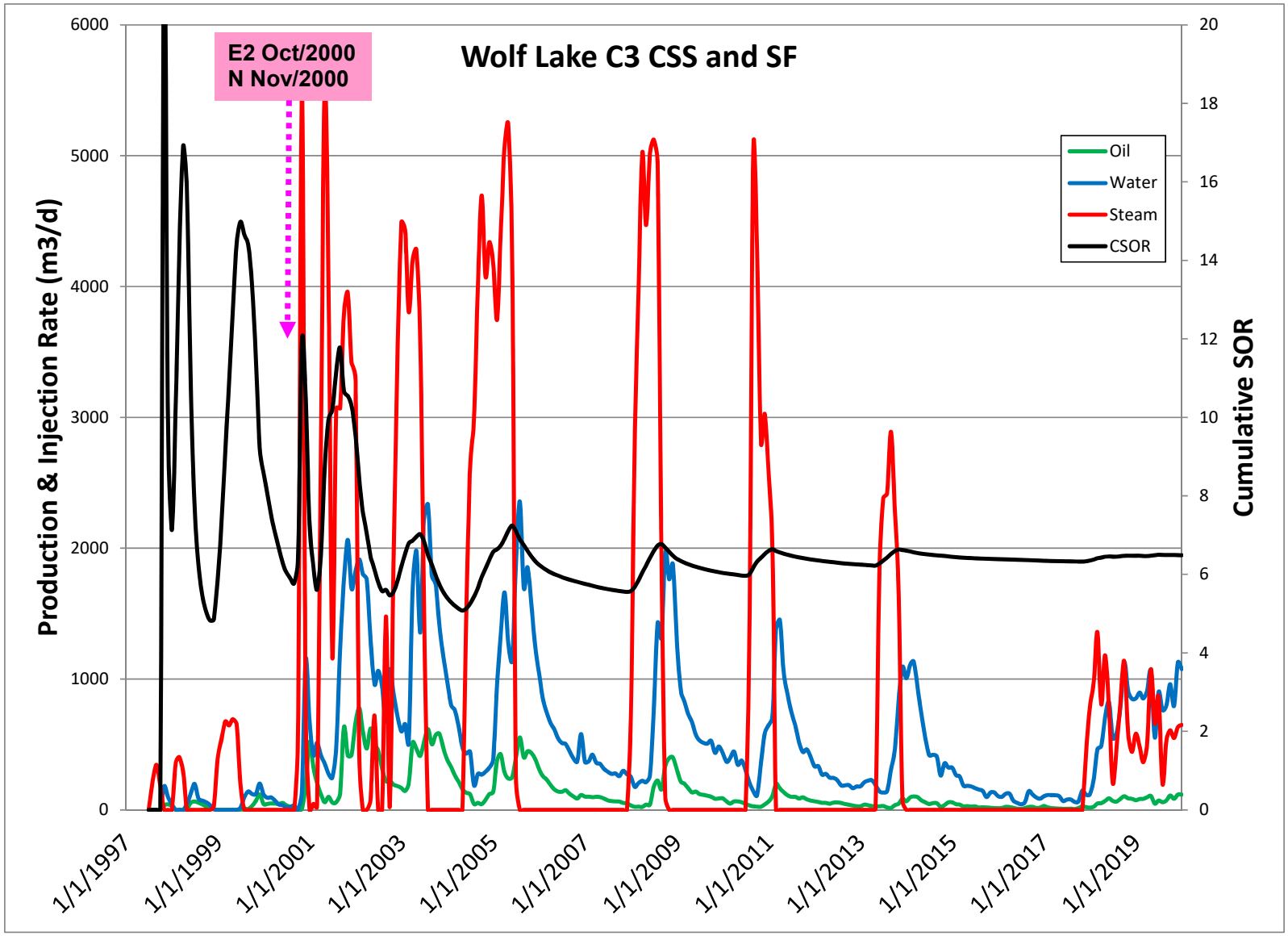
Wolf Lake C3 Sand – Phases E2, D2D & N



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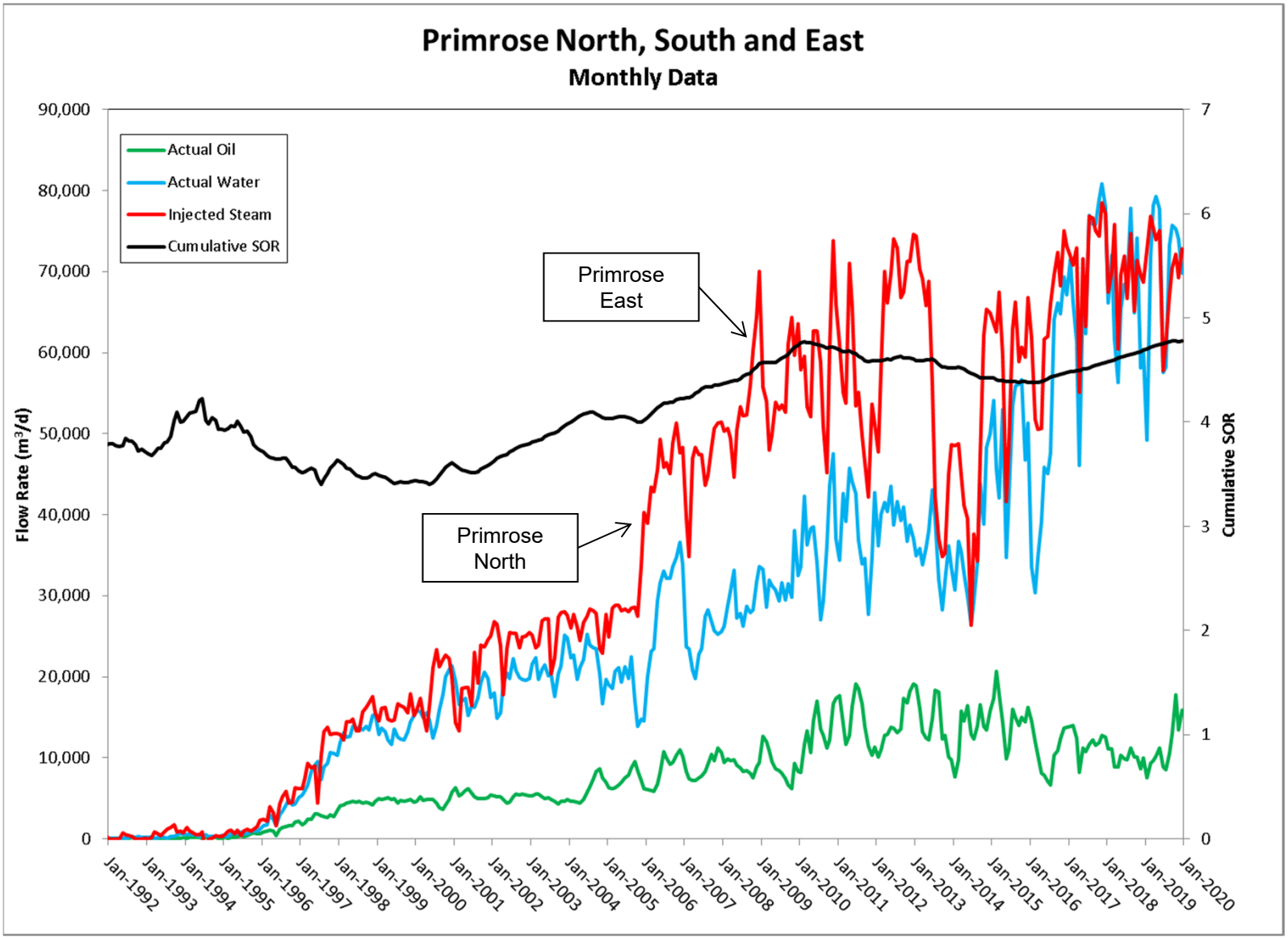
Wolf Lake Valley Fill and C3 – 2020 Plan

- Continue to optimize the valley fill and C3 steamflood trials
- Investigate redrills
- Investigate stimulation candidates

Primrose Oil, Water, Steam and SOR



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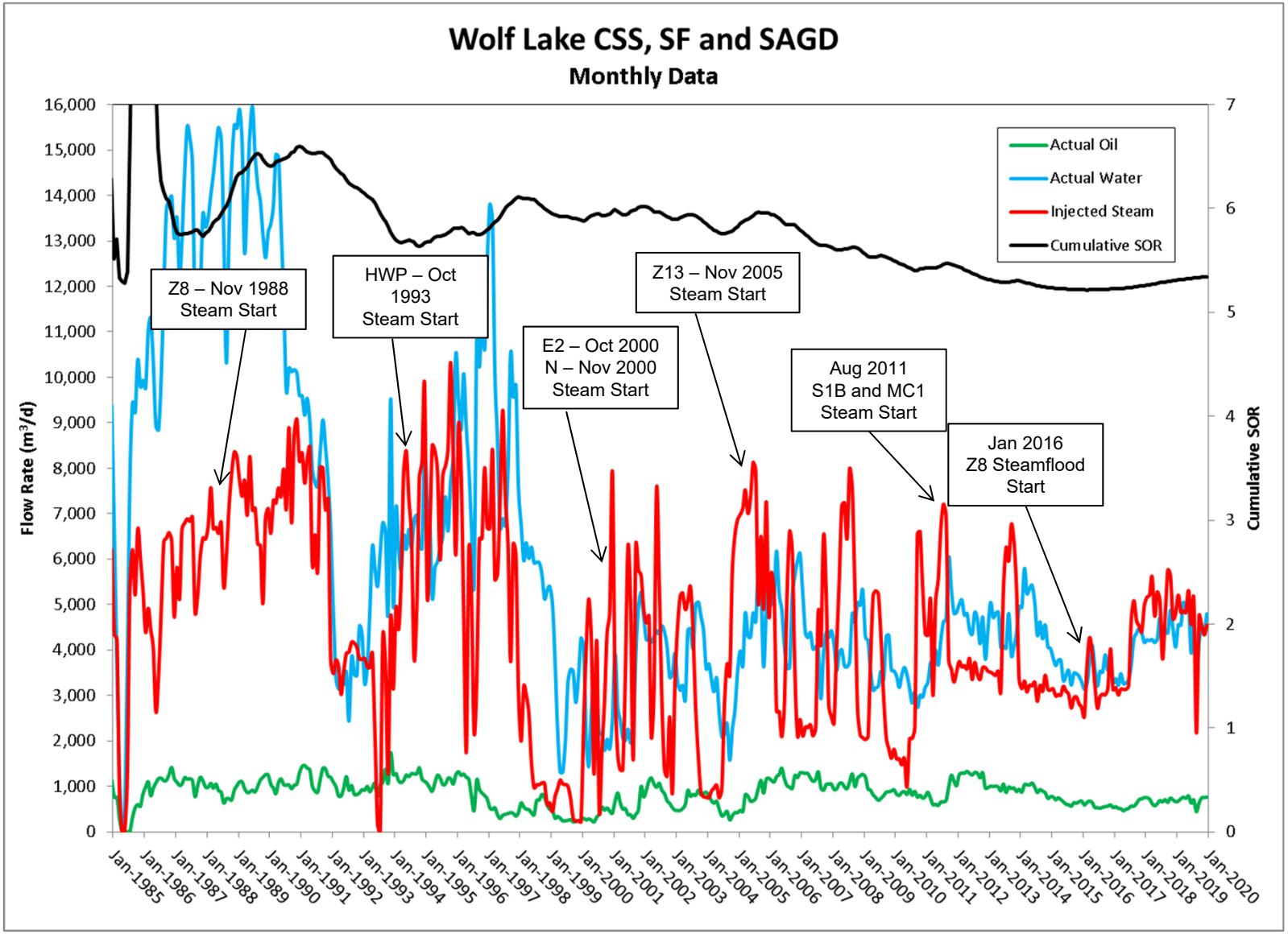
Wolf Lake Oil, Water, Steam and SOR



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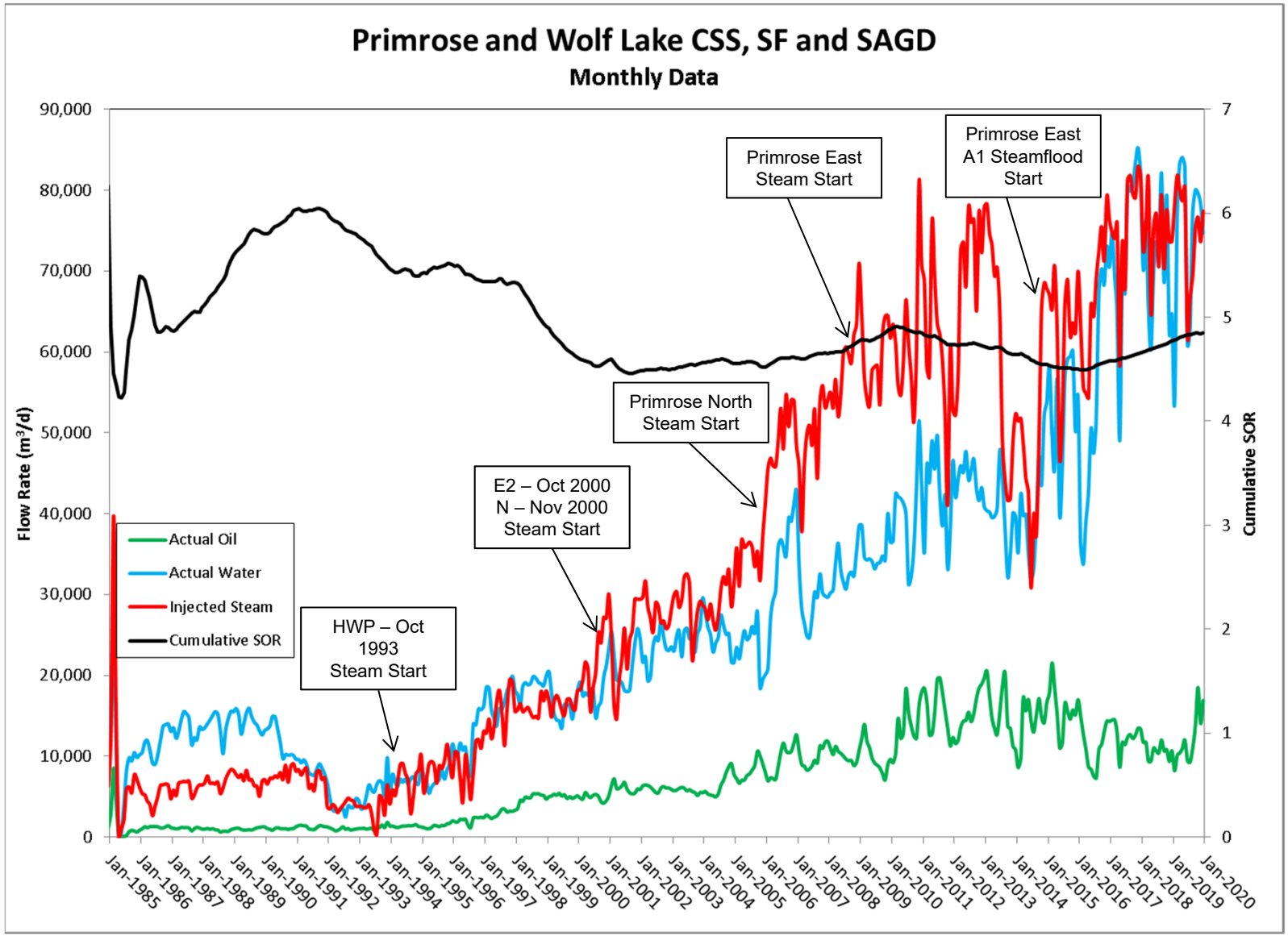
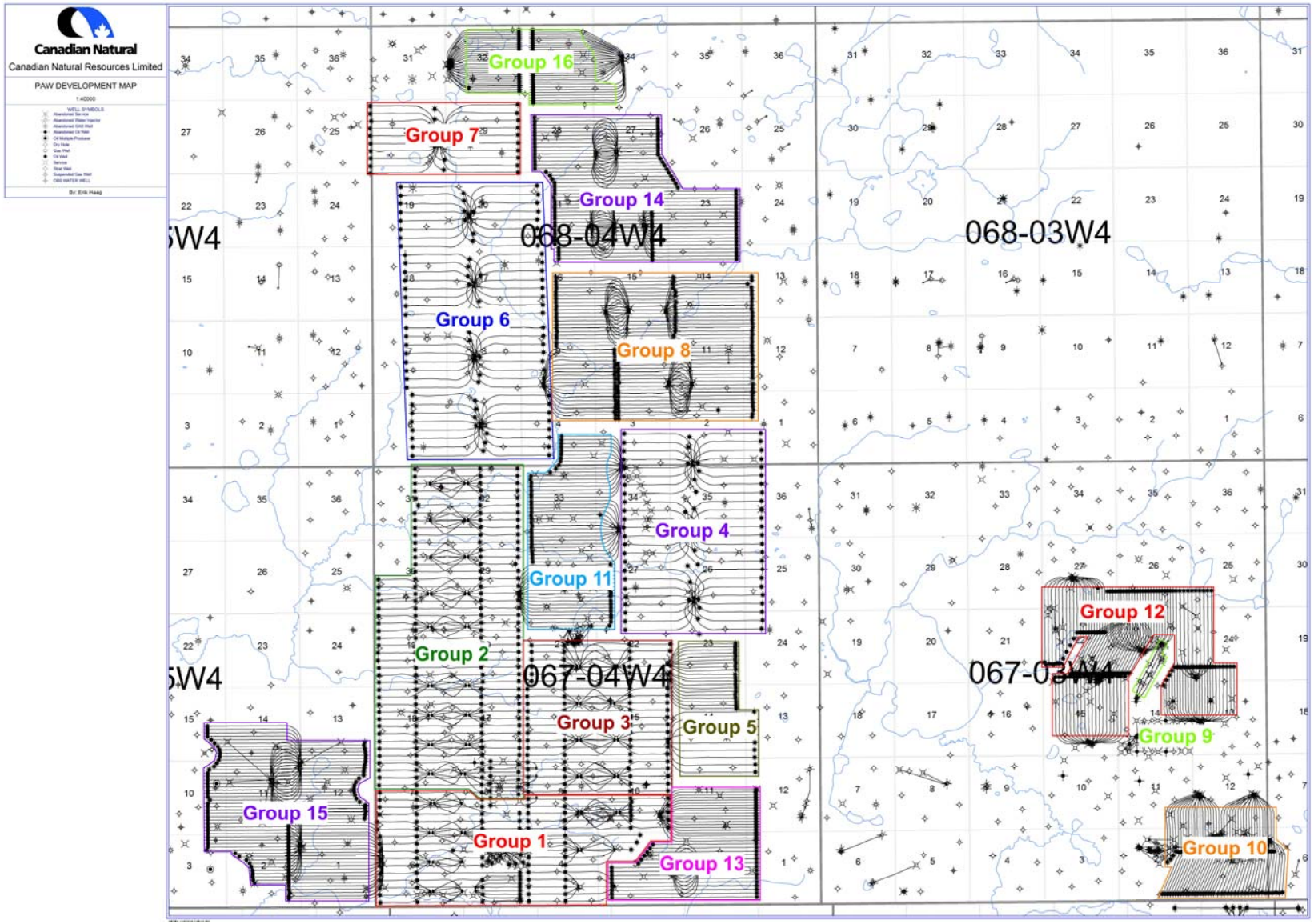
Primrose and Wolf Lake
Oil, Water, Steam and SOR



Primrose Current Recoveries – 2019



Primrose Current / Potential Recoveries

	OBIP (e3m3)	Area (m2)	Pay Thickness (m)	Porosity (dec)	Cum Oil (e3m3)	Current Recovery	Potential Recovery Range
Group 1:							
1	5,780	2,048,000	14.1	0.32	1,403	24%	35-40%
2	3,934	1,536,000	12.6	0.32	649	17%	24-30%
3	3,901	1,792,000	10.5	0.32	763	20%	26-32%
P-M WSDD	2,495	768,000	17.5	0.32	574	23%	26-32%
4	3,533	1,664,000	10.1	0.32	572	16%	20-26%
15	4,139	1,280,000	15.4	0.32	521	13%	26-32%
16	3,377	1,280,000	13.1	0.32	426	13%	22-28%
16C	766	444,347	8.7	0.32	67	9%	15-21%
17	5,259	2,560,000	10.3	0.32	995	19%	30-35%
Subtotal	**33,185**				**5,970**	**18%**	
Group 2:							
5	3,221	1,536,000	9.9	0.32	600	19%	21-27%
CDD	998	896,000	6.0	0.32	185	19%	20-22%
D5	1,231	668,077	9.5	0.32	70	6%	16-22%
6	5,625	2,048,000	13.6	0.32	772	14%	20-26%
7	5,679	2,048,000	13.9	0.32	951	17%	23-29%
8	5,691	2,048,000	14.0	0.32	897	16%	21-27%
9	5,229	2,048,000	12.9	0.32	896	17%	23-29%
10	5,616	2,048,000	13.9	0.32	956	17%	28-34%
11	6,735	2,560,000	13.5	0.32	1,018	15%	26-32%
12	5,058	1,920,000	13.5	0.32	729	14%	22-28%
13	5,270	1,920,000	14.0	0.32	752	14%	20-26%
14	5,112	1,920,000	13.6	0.32	755	15%	21-27%
Subtotal	**55,465**				**8,580**	**15%**	
Group 3:							
18	5,772	2,560,000	11.2	0.32	1,127	20%	24-30%
19	5,592	2,560,000	10.9	0.32	1,236	22%	29-35%
20	5,723	2,560,000	11.1	0.32	1,137	20%	23-29%
21	7,055	3,072,000	11.2	0.32	1,145	16%	21-27%
Subtotal	**24,142**				**4,645**	**19%**	
Group 4:							
29	10,394	4,175,104	10.4	0.32	1,891	18%	20-26%
30	10,380	4,175,104	10.4	0.32	2,093	20%	21-27%
31	11,334	4,175,104	11.3	0.32	2,226	20%	21-27%
Subtotal	**32,108**				**6,210**	**19%**	
Group 5:							
27	4,628	2,726,635	8.3	0.32	942	20%	20-26%
28	2,028	900,000	11.0	0.32	816	40%	60%+
28B	2,083	900,000	11.3	0.32	622	30%	60%+
Subtotal	**8,738**				**2,380**	**27%**	
Group 6:							
51	14,533	4,817,342	15.1	0.32	1,648	11%	13-19%
52	14,247	4,817,342	14.6	0.32	1,468	10%	13-19%
53	14,800	4,817,342	15.8	0.32	1,355	9%	13-19%
54	15,585	4,817,342	15.7	0.32	1,920	12%	13-19%
Subtotal	**59,165**				**6,391**	**11%**	
Group 7:							
55	16,927	5,537,441	15.9	0.32	1,921	11%	13-19%
Subtotal	**16,927**				**1,921**	**11%**	

	OBIP (e3m3)	Area (m2)	Pay Thickness (m)	Porosity (dec)	Cum Oil (e3m3)	Current Recovery	Potential Recovery Range
Group 8:							
58	5,441	2,064,800	14.0	0.32	1,529	28%	60%+
59	6,959	2,208,000	14.2	0.32	1,824	26%	60%+
62	6,342	2,230,006	13.2	0.32	1,457	23%	60%+
63	5,555	2,114,640	12.5	0.32	1,603	29%	60%+
66	6,708	2,582,960	12.0	0.32	1,584	24%	60%+
67	7,180	2,643,200	13.3	0.32	1,604	22%	60%+
Subtotal	**38,185**				**9,601**	**25%**	
Group 9:							
Burnt Lake	1,516	279,234	24.3	0.32	1,011	67%	60%+
Subtotal	**1,516**				**1,011**	**67%**	
Group 10:							
74	6,119	1,077,633	24.7	0.32	1,647	27%	60%+
75	7,168	1,234,303	25.2	0.32	2,497	35%	60%+
77	6,742	1,195,133	25.6	0.32	2,373	35%	60%+
78	6,881	1,200,000	25.9	0.32	1,737	25%	60%+
Subtotal	**26,910**				**8,254**	**31%**	
Group 11:							
22	6,736	2,531,371	13.2	0.32	1,195	18%	60%+
23	6,009	2,288,372	13.3	0.32	1,460	24%	60%+
24	5,204	1,926,224	13.4	0.32	1,191	23%	60%+
Subtotal	**17,949**				**3,846**	**21%**	
Group 12:							
90	5,478	1,542,997	19.5	0.32	1,540	28%	60%+
91	2,572	1,234,816	9.9	0.32	515	20%	60%+
92	5,849	1,485,956	18.1	0.32	1,041	18%	60%+
93	4,770	1,770,368	12.9	0.32	862	18%	60%+
94	4,166	1,200,403	16.1	0.32	328	8%	15-20%
95	4,554	1,969,724	11.4	0.32	921	20%	60%+
Subtotal	**27,389**				**5,207**	**19%**	
Group 13:							
25A	2,718	1,727,106	7.0	0.32	500	18%	60%+
25B	2,565	2,034,990	5.5	0.32	583	23%	60%+
26	3,077	2,083,550	7.0	0.32	801	26%	60%+
Subtotal	**8,360**				**1,884**	**23%**	
Group 14:							
60	5,052	1,720,000	14.2	0.32	1,285	25%	60%+
61	6,923	2,362,000	13.7	0.32	1,559	23%	60%+
64	5,262	1,856,000	12.9	0.32	1,440	27%	60%+
65	5,055	2,107,081	11.3	0.32	1,310	26%	60%+
68	7,220	2,894,006	10.5	0.32	1,864	26%	60%+
Subtotal	**29,512**				**7,458**	**25%**	
Group 15:							
40	4,106	3,008,352	6.8	0.32	878	21%	60%+
41	5,272	3,014,070	8.1	0.32	1,147	22%	60%+
42	6,761	3,130,144	10.2	0.32	1,095	16%	60%+
43	5,423	2,492,978	11.0	0.32	1,109	20%	60%+
Subtotal	**21,561**				**4,229**	**20%**	
Group 16:							
72A	5,329	1,649,715	17.4	0.32	189	4%	60%+
72B	6,594	2,456,054	12.2	0.32	352	5%	60%+
Subtotal	**11,923**				**541**	**5%**	
PR Total	**413,036**				**78,128**	**19%**	

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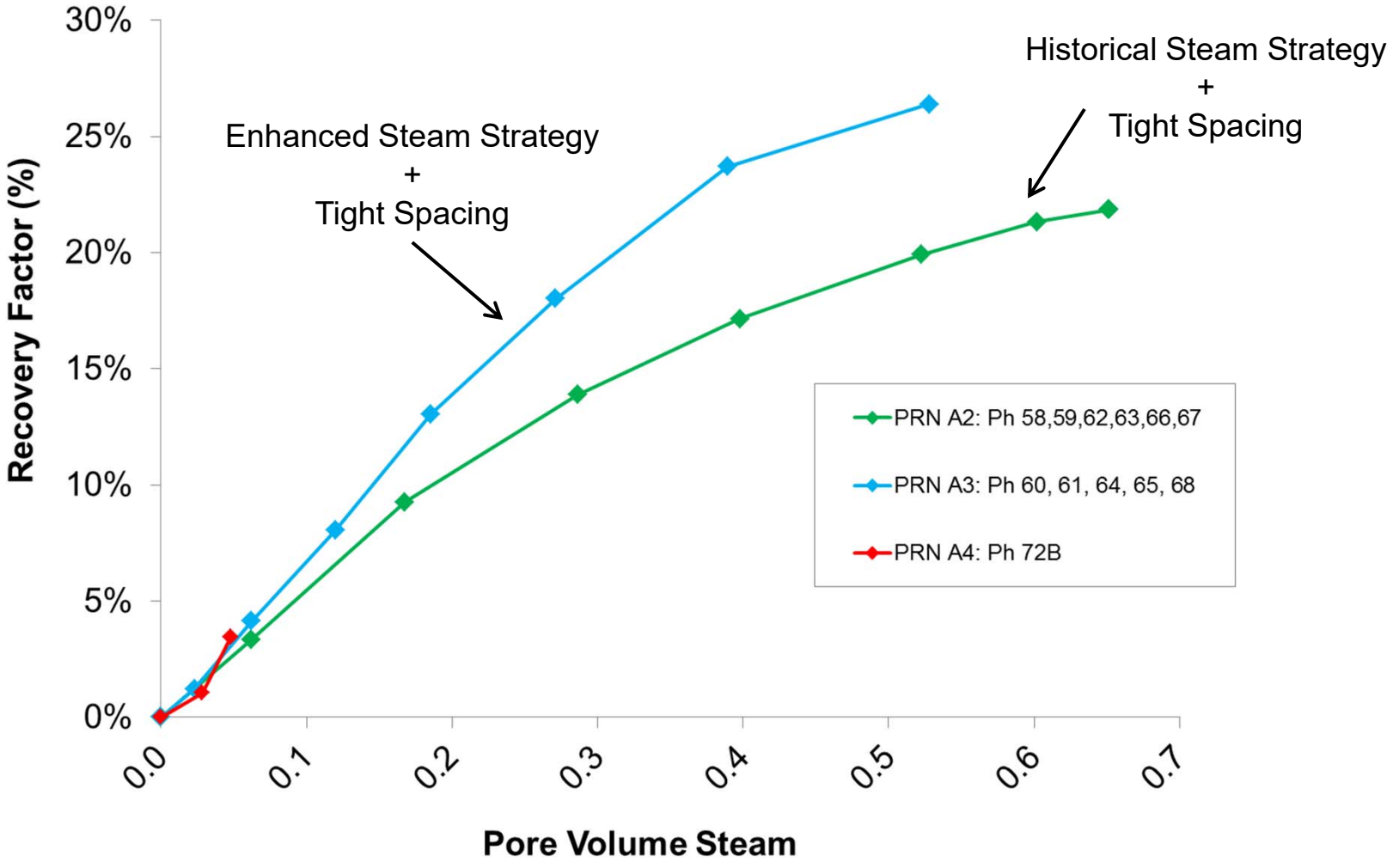
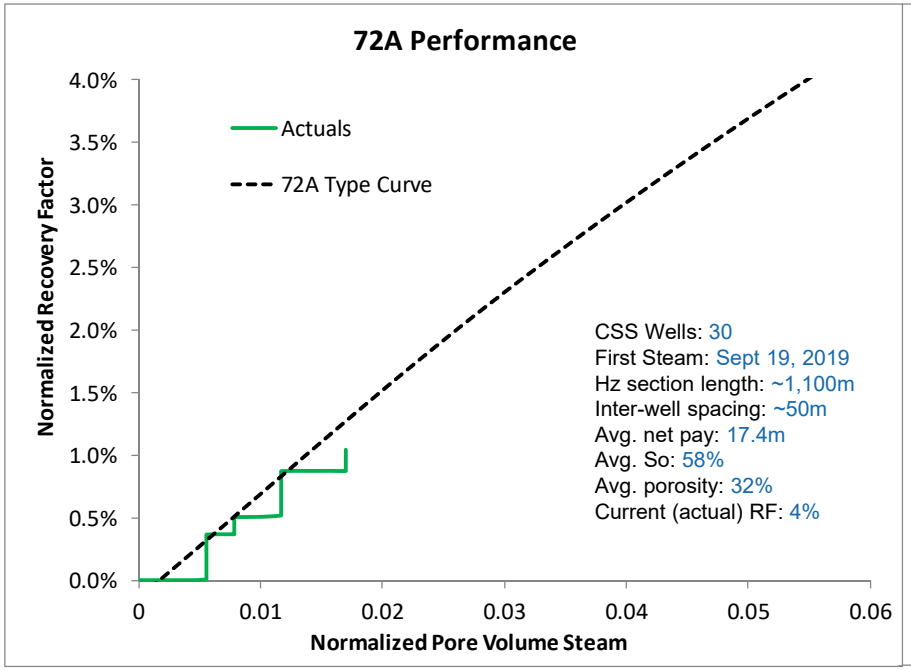
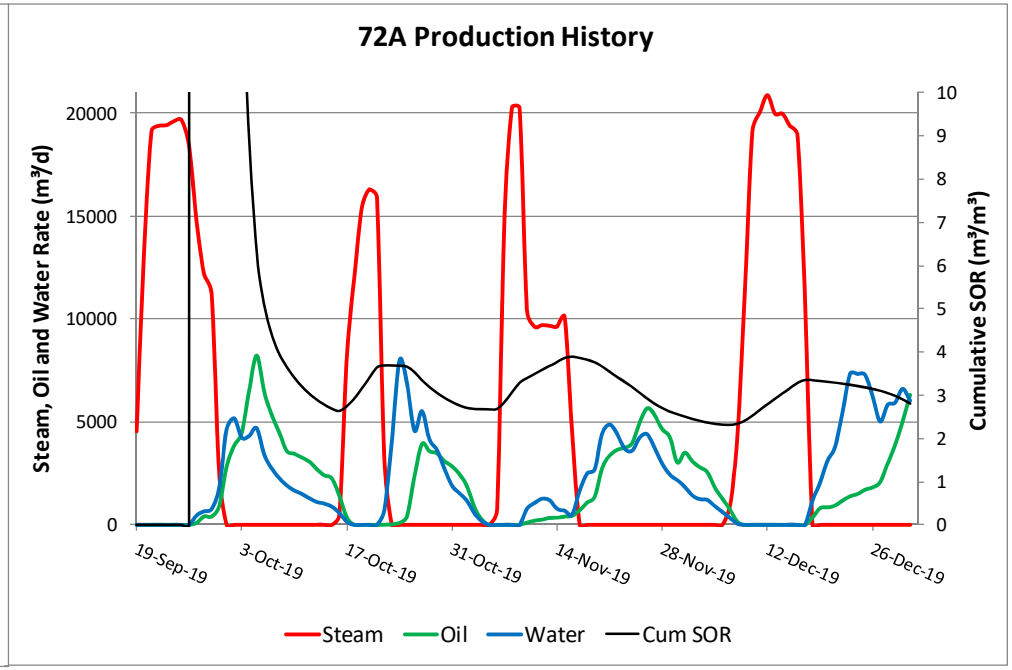
CSS Performance
Enhanced Steam Strategy Optimization

- Improved thermal efficiency with enhanced steam strategy



Early Recovery – Phase 72A
Type Curve & Production History

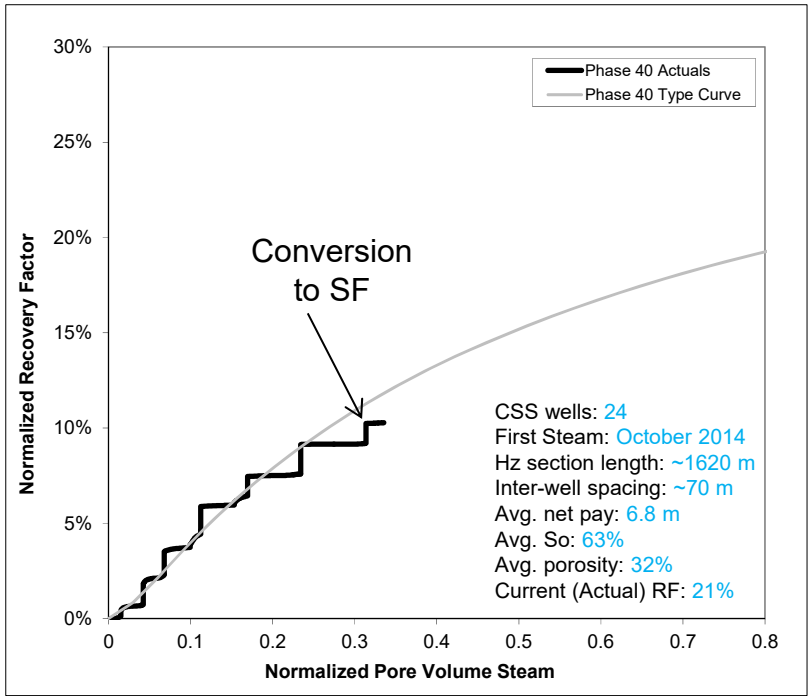


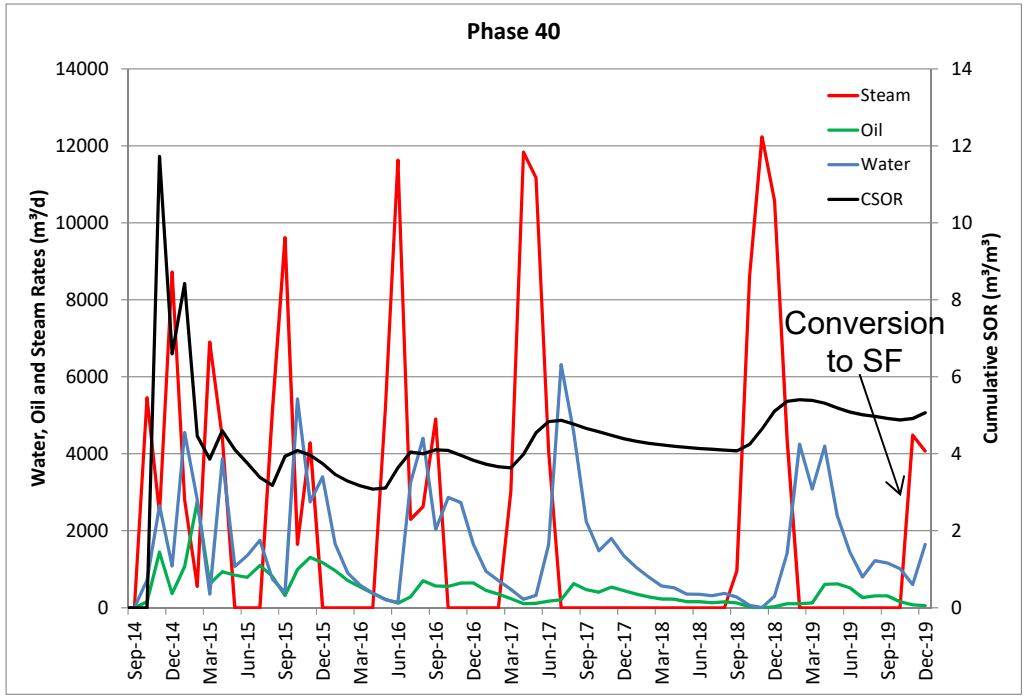


Normalized values calculated by using recoveries from actual well spacing and adjusting the drainage area to 160 m spacing
Actual Recovery Factor (%) = 160 m / [Well Spacing] m x [Normalized Recovery Factor (%)]

- 2019 Activity
  - Pad and facilities completion
  - Executed 3 commissioning cycles
  - Steamed commercial cycle 1 and began production
- 2020 Plan
  - Continue to steam using the Enhanced Steam Strategy

Mid Recovery – Phase 40
Type Curve & Production History



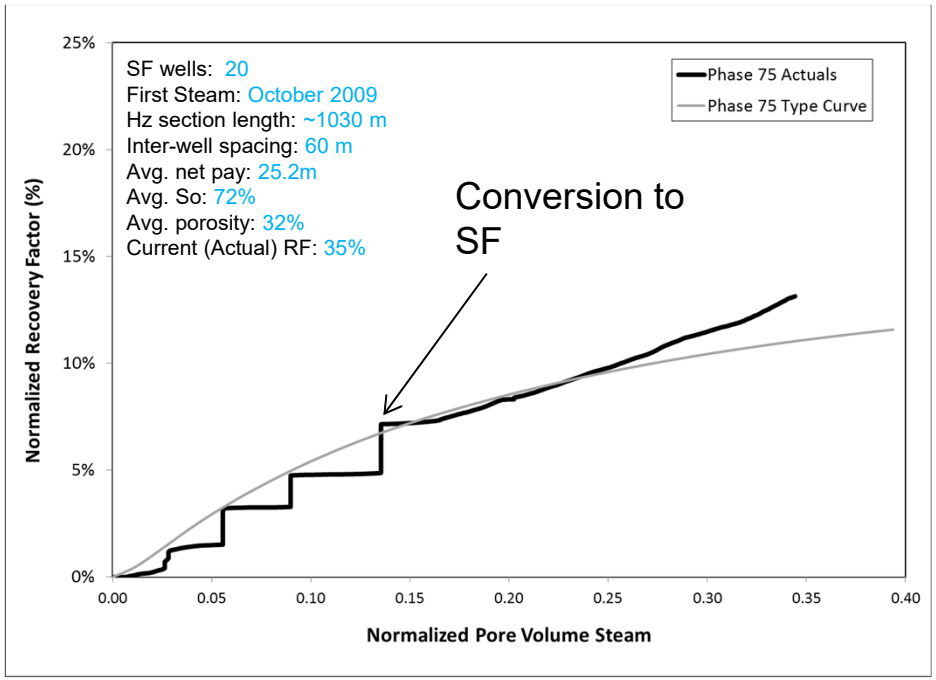


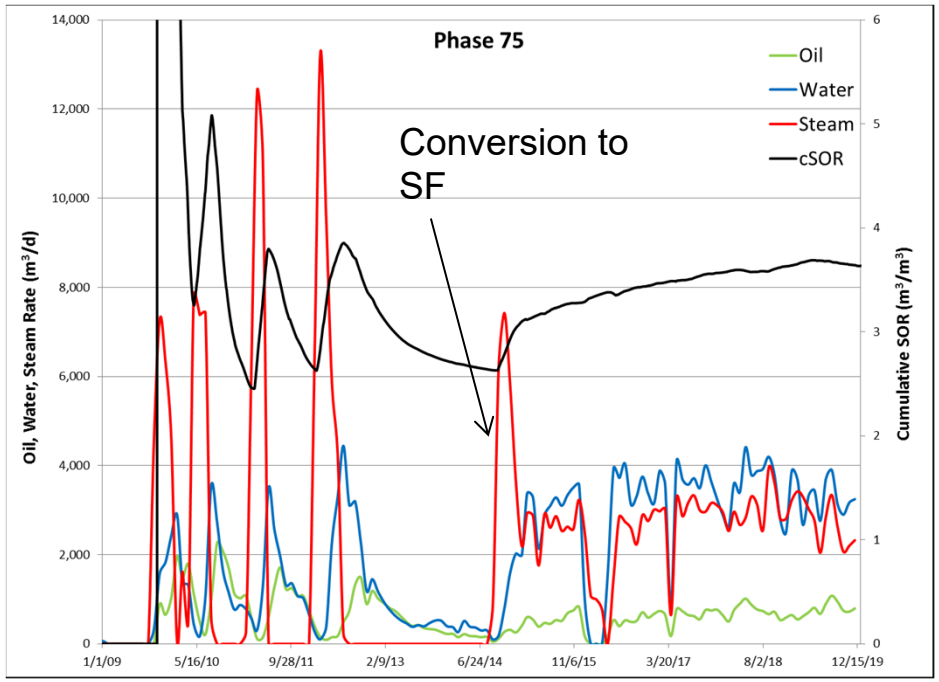
Normalized values calculated by using recoveries from actual well spacing and adjusting the drainage area to 160 m spacing
Actual Recovery Factor (%) = 160 m / [Well Spacing] m x [Normalized Recovery Factor (%)]

- 2019 Activity
  - Completed CSS Commercial Cycle 5 steaming and production
  - Converted Phase 40 to steamflood process

- 2020 Plan
  - Continue steamflood operation
  - Potential perforation program to remove scale and increase recovery rates

High Recovery – Phase 75
Type Curve & Production History





Normalized values calculated by using recoveries from actual well spacing and adjusting the drainage area to 160 m spacing
Actual Recovery Factor (%) = 160 m / [Well Spacing] m x [Normalized Recovery Factor (%)]

- 2019 Activity
  - Continued steamflood operation since conversion in September 2014
  - 3:1 producer-to-injector trial initiated
- 2020 Plan
  - Continued steamflood operation
  - Potential re-perforation of top producers due to continued scaling
  - Expansion of 3:1 producer-to-injector trial

2019 Primrose CSS Learnings

- CSS continues to be the best primary and initial recovery method in the Clearwater reservoir
  - Enhances vertical permeability of Clearwater reservoir
  - Conditions reservoir for follow-up recovery processes like steamflood

- PAW enhanced steaming strategy
  - Thermal efficiency continues to exceed historical performance in blue sands and orange sands
  - Continued improvement of total fluid recovery
  - Newest development (72A and 72B) is matching expectations

- Skin damage
  - Continued evidence of skin damage throughout PAW
    - Planning to avoid injecting high pH water into Clearwater
  - Well stimulation program optimization to maximize recovery: acid and perforations
    - Optimizing acid blends and deployment to reduce plant upsets and improve effectiveness
    - Monitoring results of zinc cased perforation charges

2019 Primrose Steamflood Learnings

- Steamflood performance primarily driven by conformance, net pay, and well placement
- Curtailing production leads to recovery process inefficiencies
  - Over-injection can lead to extended periods of increased water cuts
  - Managing water inventories is an important aspect of steamflood optimization
- Skin effects also impact steamflood operations
  - Skin restricts both gross production and steam rates
- Continuing to understand and improve longitudinal interwell conformance remains a primary objective for 2020
  - DTS implementation led to enhanced understanding of conformance, further guiding well servicing interventions
- Steam oil ratio optimization underway through:
  - Mitigation of adverse conformance impacts through steam management
  - Injector and producer swaps
  - Ongoing producer/injector diagnostics and associated interventions
- Unable to convert early life CSS to SF due to resource recovery challenges (Pad 94)

2020 PAW Steam Schedules

Primrose South

Month	Steam Start Date	Steam Volume/Well (m^3)
Jan-20	Phase D1	200 CDSR
Feb-20	Phase C17	200 CDSR
Mar-20	Phase 22-24	400 CDSR
Apr-20	Phase 40-43	325 CDSR
May-20	Phase 25A/B,26	200 CDSR
Jun-20	Phase 28	300 CDSR
Jul-20		
Aug-20		
Sep-20		
Oct-20		
Nov-20		
Dec-20		

Primrose North

Month	Steam Start Date	Steam Volume/Well (m^3)
Jan-20	Phase 58,59,62,63,66,67	450 CDSR
Feb-20	Phase 72A	12,000
Mar-20	Phase 72B	16,000
Apr-20	Phase 58,59,62,63,66,67	450 CDSR
May-20	Phase 72A,72B	22,000; 24,000
Jun-20		
Jul-20		
Aug-20	Phase 58,59,62,63,66,67	450 CDSR
Sep-20	Phase 58,59,62,63,66,67	450 CDSR
Oct-20	Phase 58,59,62,63,66,67	450 CDSR
Nov-20	Phase 72A,72B	32,000; 36,000
Dec-20		

Primrose East

Month	Steam Start Date	Steam Volume/Well (m^3)
Jan-20	Phase 74, 75, 77, 78	300 CDSR
	Phase 90, 91, 92, 93, 95	245-435 CDSR
	Phase 94 LPCSS	1,000-18,000
Feb-20		
Mar-20		
Apr-20		
May-20		
Jun-20		
Jul-20		
Aug-20		
Sep-20		
Oct-20		
Nov-20		
Dec-20		

Wolf Lake CSS

Month	Steam Start Date	Steam Volume/Well (m3)
Jan-20	Z8	75-425 CDSR
	E2/N/D2D	100-425 CDSR
Feb-20		
Mar-20		
Apr-20		
May-20		
Jun-20		
Jul-20		
Aug-20		
Sep-20		
Oct-20		
Nov-20		
Dec-20		

Wolf Lake SAGD

Month	Steam Start Date	Steam Volume/Well (m3)
Jan-20	SD9	35-200 CDSR
	S1A	40-250 CDSR
	S1B	40-140 CDSR
	MC1	75-210 CDSR
Feb-20		
Mar-20		
Apr-20		
May-20		
Jun-20		
Jul-20		
Aug-20		
Sep-20		
Oct-20		
Nov-20		
Dec-20		

Primrose North Development

Development Area (Primrose North)

-Phases 160-161

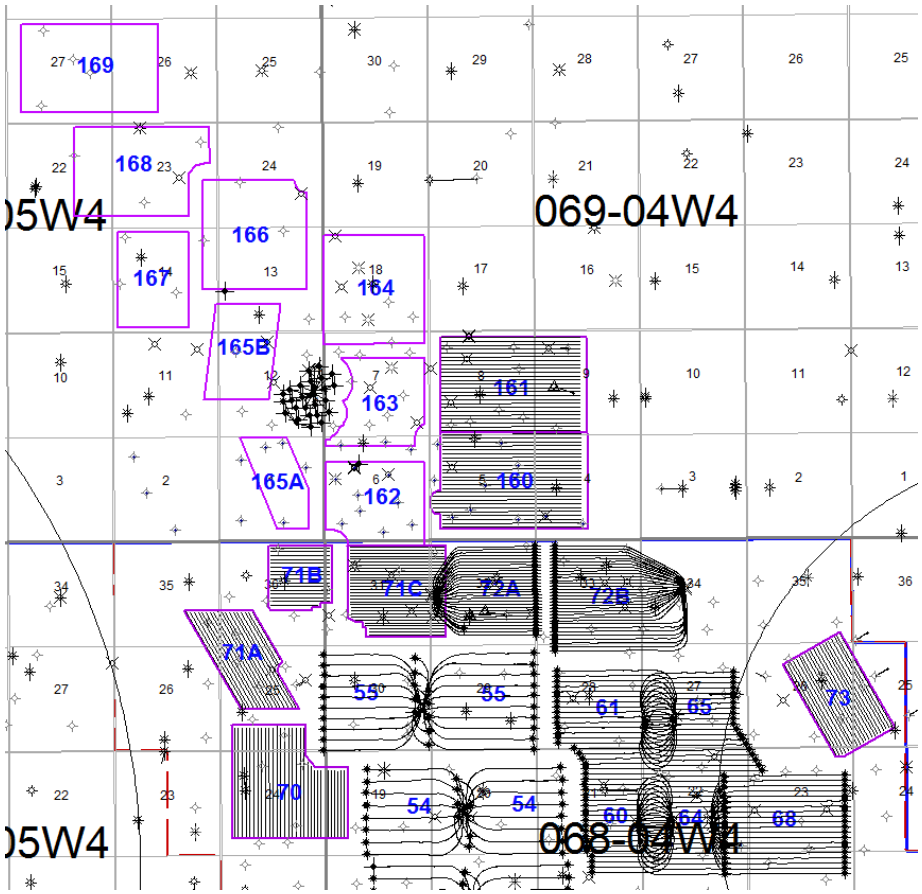
- 2 CSS Phases on 2 pads with 25 wells/pad
  - ~60 m well spacing
  - ~2,000 m laterals
- AER Approval received Nov 2019

-Phases 70, 71A/B/C & 73

- 5 CSS Phases on 4 pads with 20-32 wells/pad
  - ~50-60m well spacing
  - 600-1,700m laterals
- AER Approval received Oct 2017

-Project Area

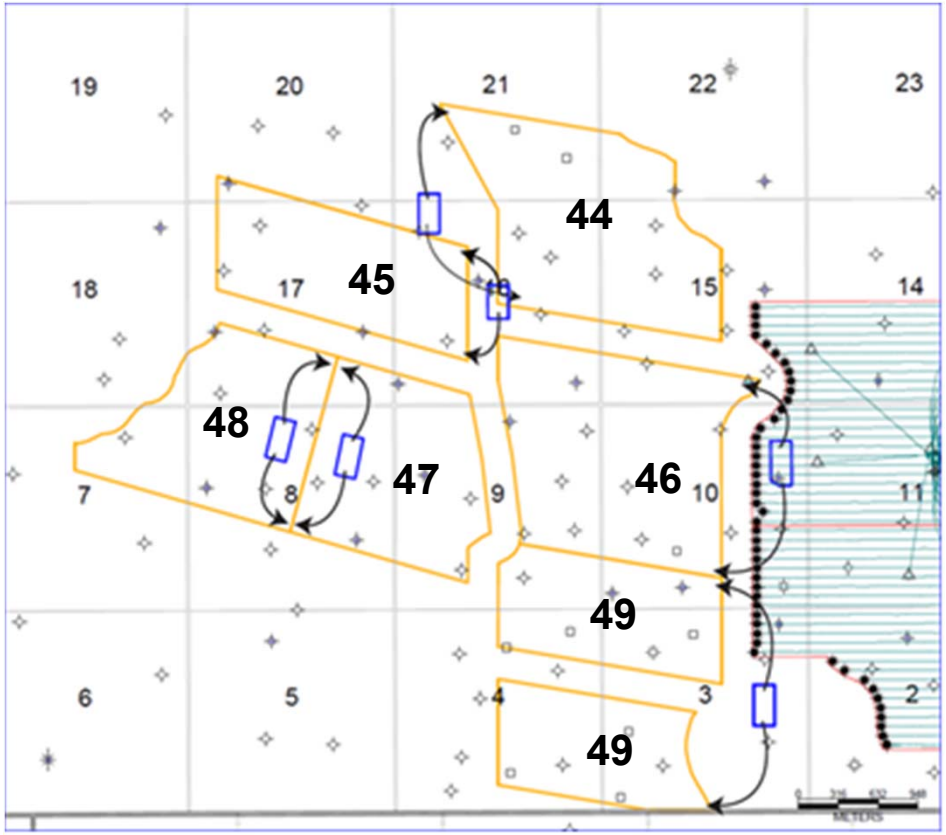
- Primrose North Phase 162-169
- 9 CSS Phases on 8 surface pads
  - ~200 wells



Primrose South Development

Primrose South Phases 44-49

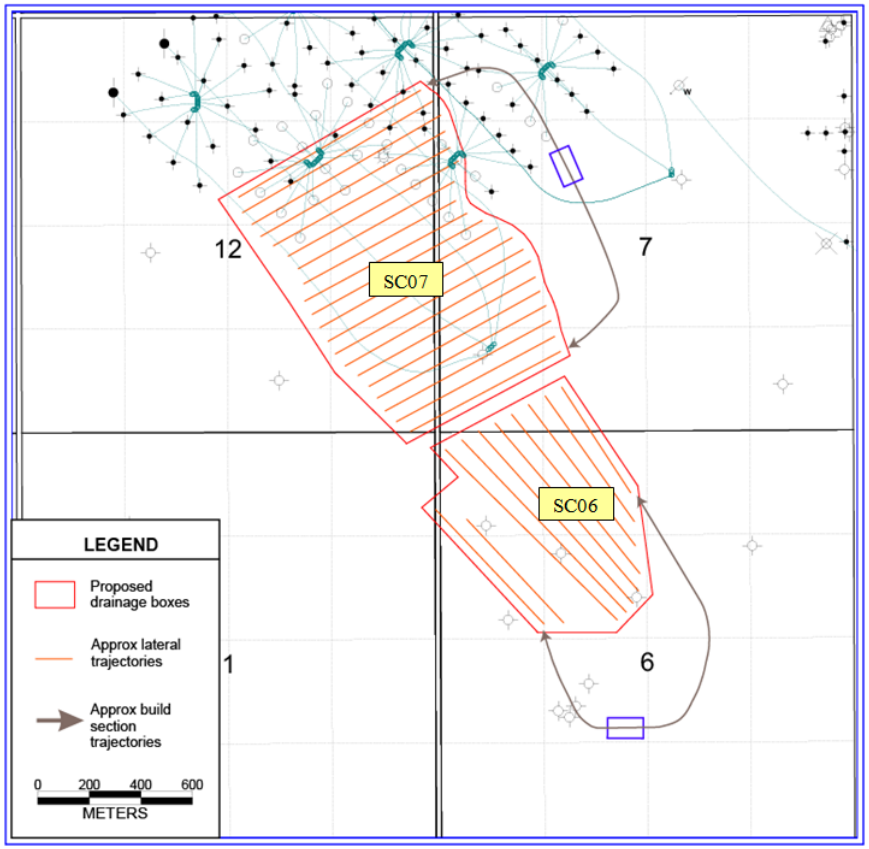
- 6 CSS Phases with 15-28 wells/pad
  - 149 wells total
  - ~50-60 m well spacing
- 800 – 2,000 m laterals
- Steam wave injection volumes
  - 3 small volume commissioning cycles to start
  - Commercial cycles limited by overburden uplift
- AER Approval received April 2017



Wolf Lake Grand Rapids Development

Wolf Lake Sparky C (Pads SC06-07)

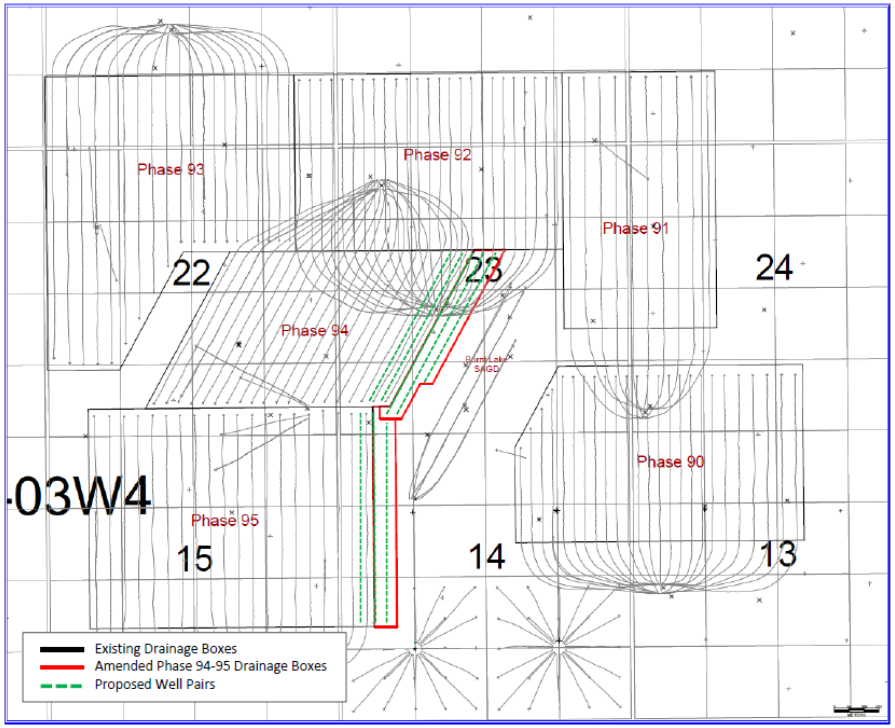
- 2 SAGD Phases
  - 30 well pairs total
  - 60 m well spacing
- 700m laterals (average)
- AER Approval received April 2016

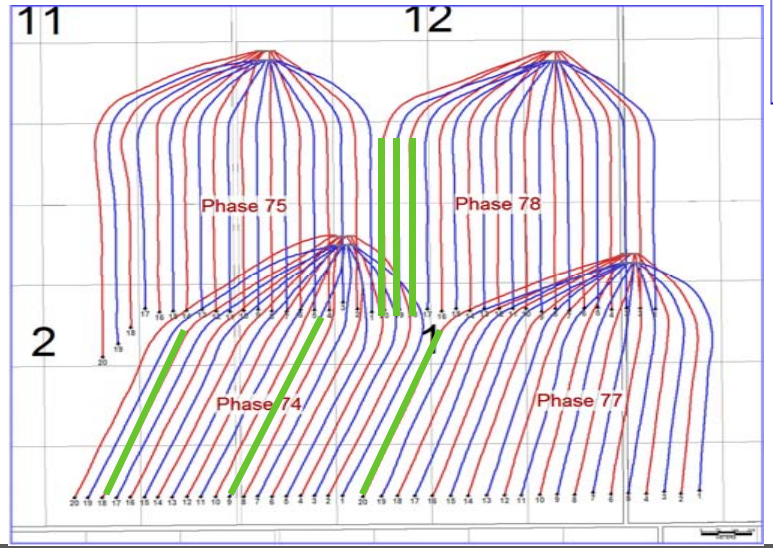


Primrose East Development

- Phases 94-95 proposed SAGD Step-outs
  - 8 SAGD well pairs to be drilled from existing Pads
    - 60-80m spacing
  - 900 – 1,200 m laterals
  - AER Application submitted Nov 2019

- Area 1 Proposed Redrills
  - Redrills of 5 to 6 impaired wells in Aug 2020





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