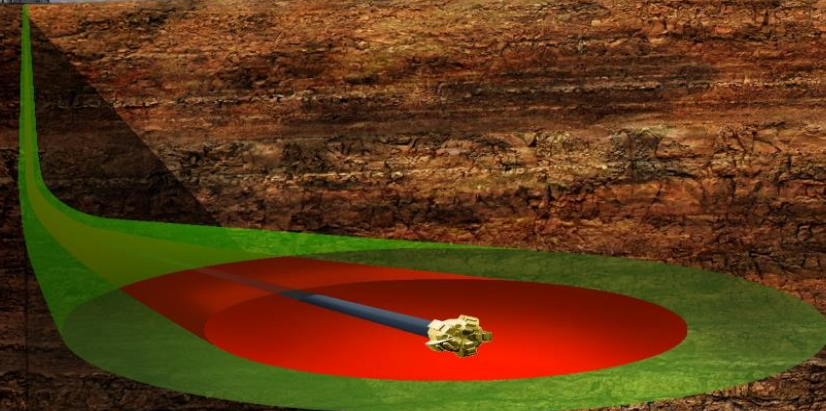


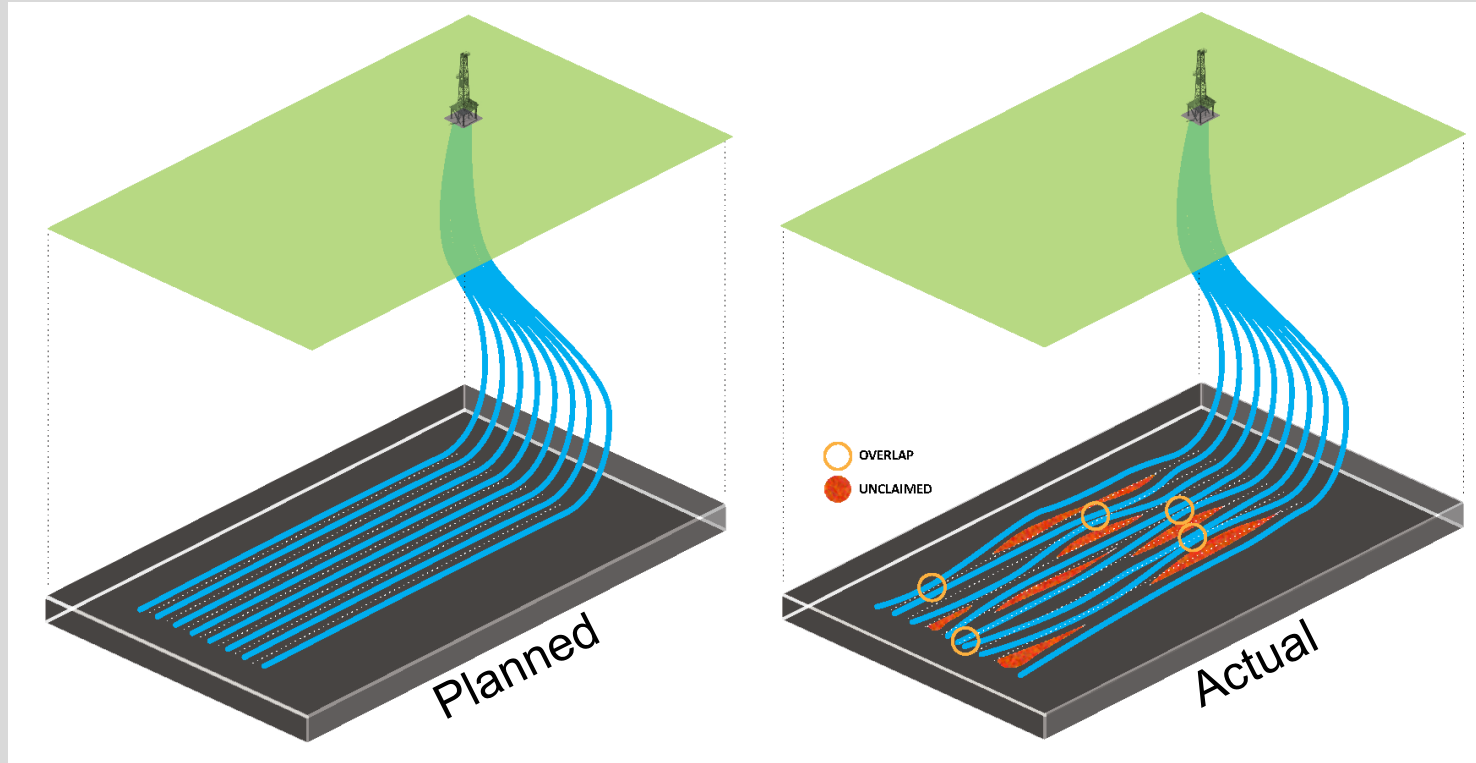
Estimating the Economic Impact of Wellbore Positioning Errors on Reservoir Recovery



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Shawn DeVerse (Surcon)
Lisa Grant (Noble Energy)
02/04/2016

Wellbores may not be where we think they are

Numerous error sources in MWD measurements cause significant uncertainty in the wellbore position.



Impact of Wellbore Placement Errors

Positional uncertainty has a cost:

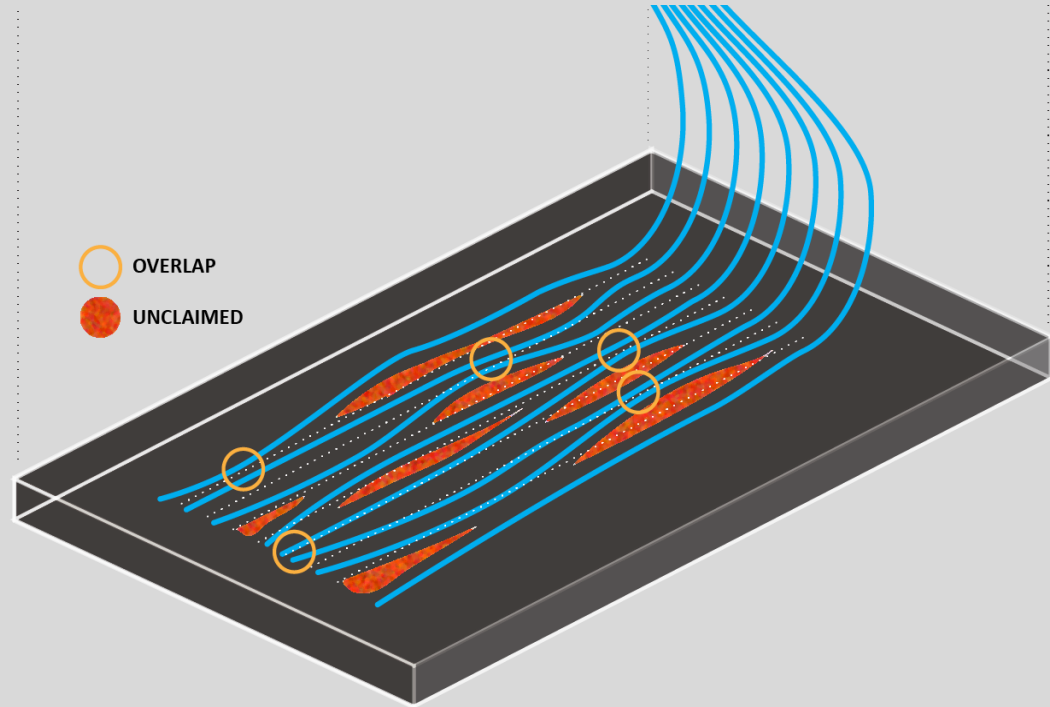
Risk-1: Wellbore collisions

Risk-2: Reduced oil recovery

Risk-3: Infracrossing of lease lines

Risk-4: Poor geological models

We have developed an open web-based simulator to quantify the economic impact of Risks 1 to 3.



Online Oil Recovery Simulator

Simulation Parameters

Number Of Wells:

Landing Point Uncertainty:
 FOOT

Survey Interval:

Tool Code(s):

Azimuth:

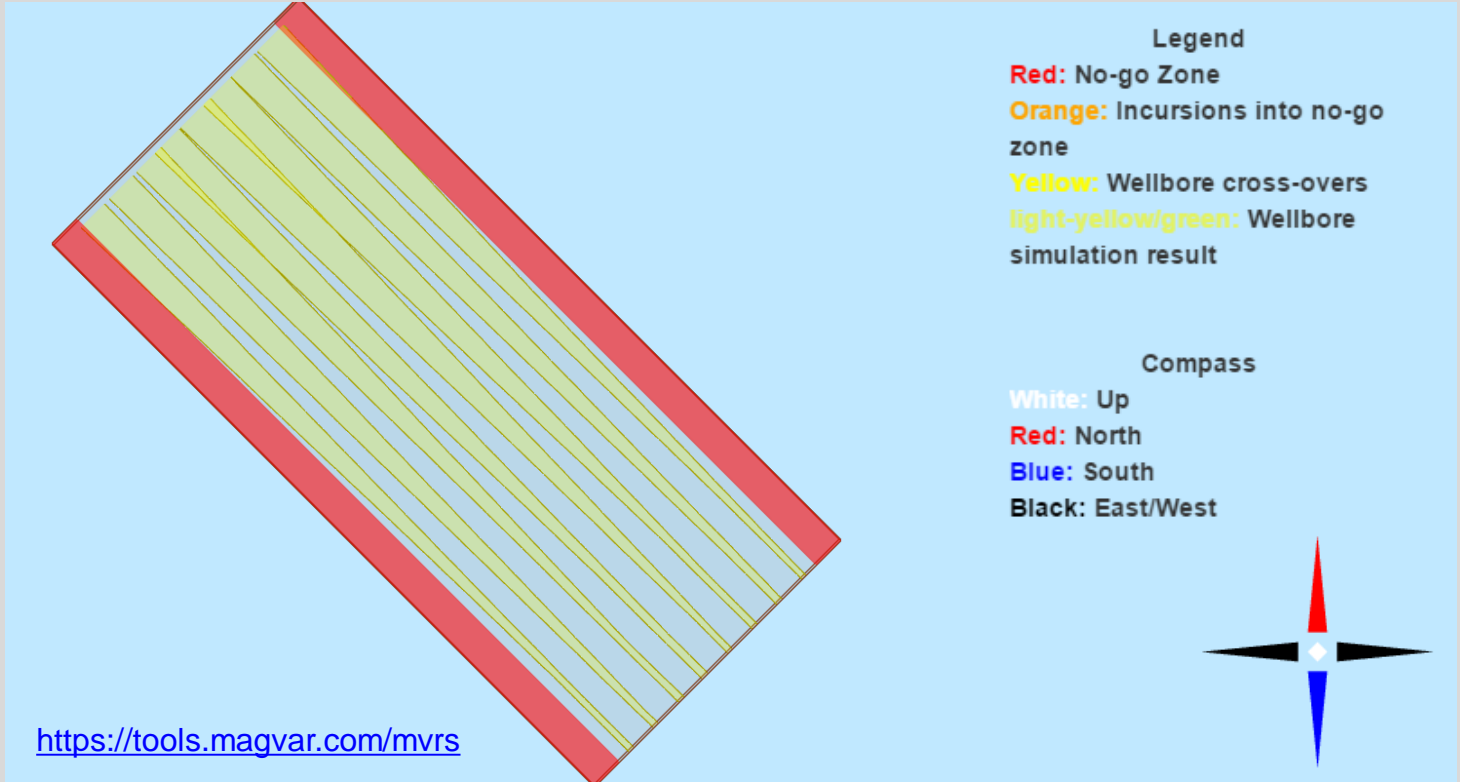
Slab Width:

No-Go Zone Width:

Slab Length:

Slab Thickness:

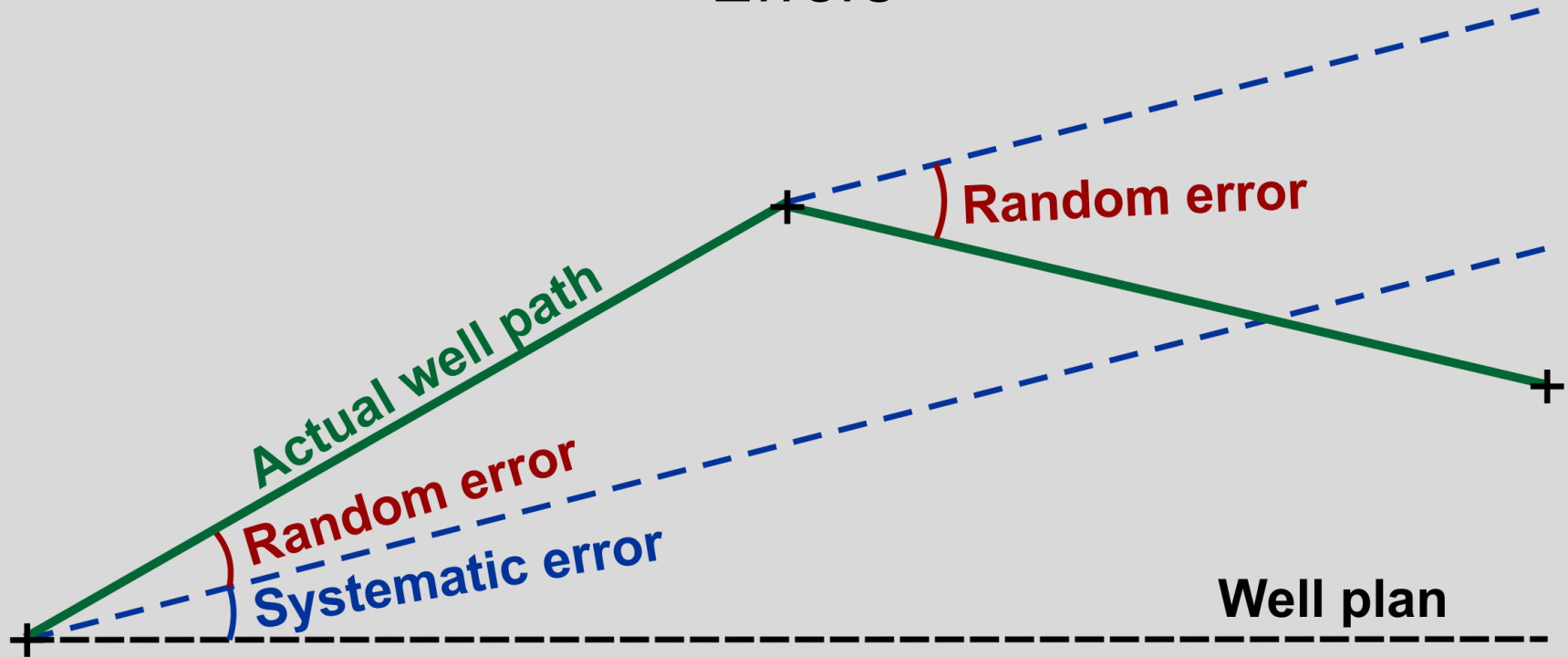
Oil Density:
 Units: vol %



Outline of Talk

1. Synthesis of wellbores with systematic and random errors
2. Underlying error models
3. Assumptions on the oil recovery envelope
4. Simulation results

Well Path Simulation of Systematic and Random Errors



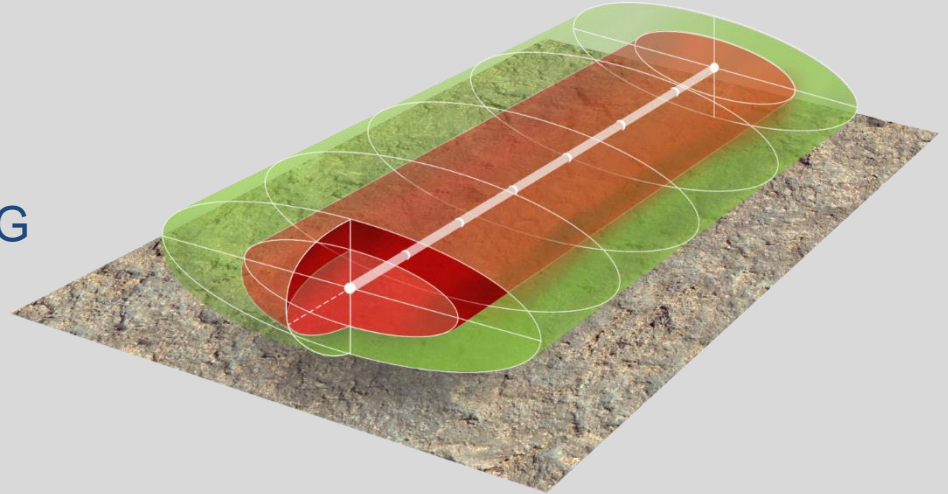
MWD Survey Error

The ISCWSA error model provides a method to compute systematic and random survey errors

Coefficient values are provided by OWSG consolidated tool codes

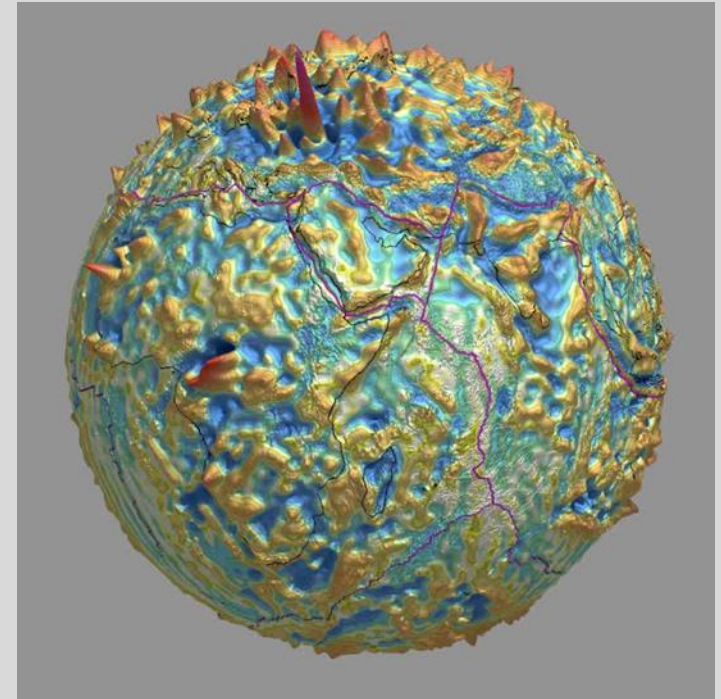
Error model coefficients differ by:

1. Magnetic reference model
2. Survey corrections



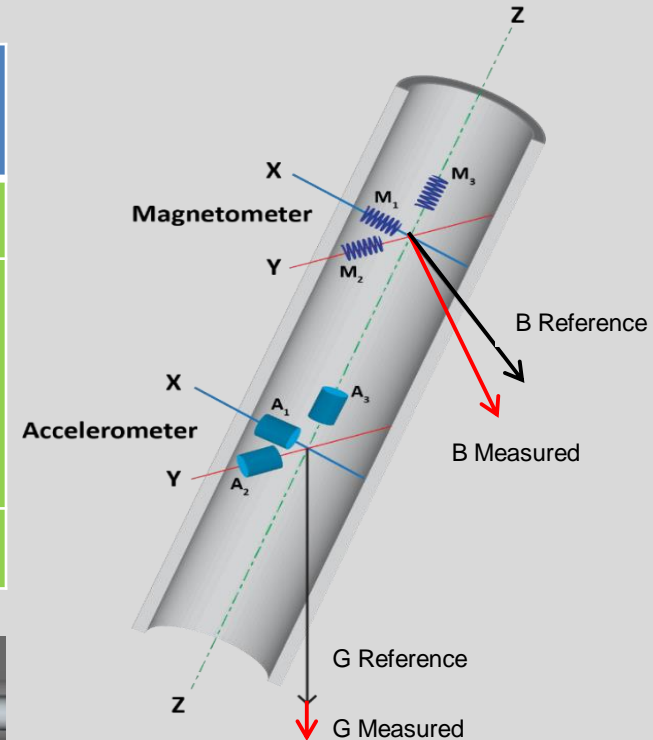
Magnetic Reference Error

	IGRF/ WMM	Std MWD	HRGM	IFR1	IFR2
Main Field	✓	✓	✓	✓	✓
Annual update		✓	✓	✓	✓
Global crustal field			✓	✓	✓
Local crustal				✓	✓
Disturbance field					✓



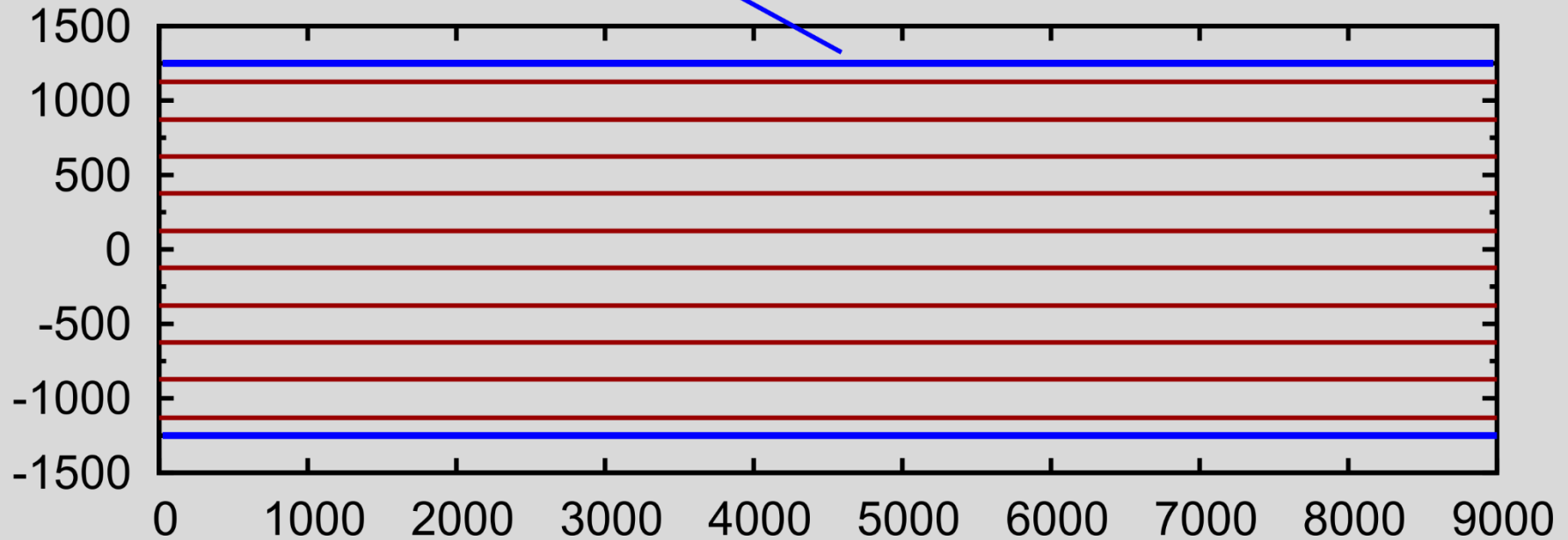
MWD Survey Corrections

Some example tool codes	MWD +IFR1+AX	MWD +IFR1+MS	MWD +IFR2+SAG+MS
Axial interference	✓	✓	✓
Cross-axial interference, instrument biases and scale factors		✓	✓
BHA Sag			✓

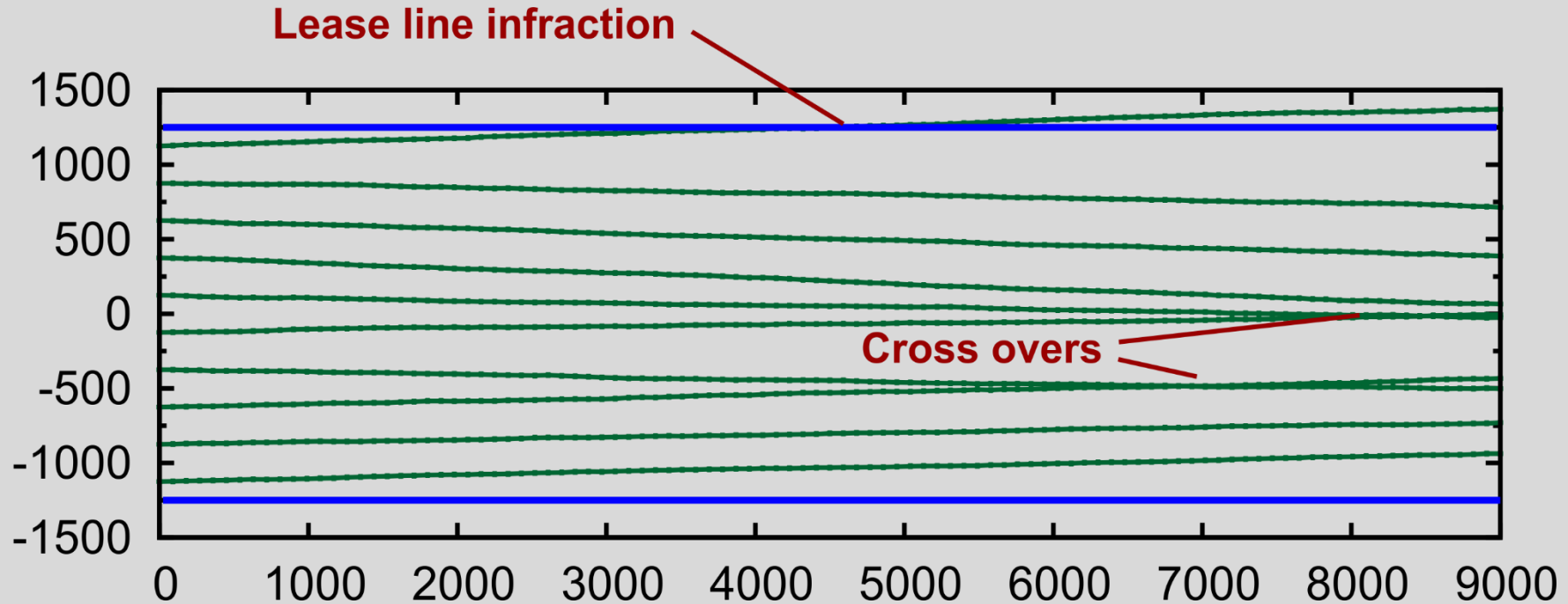


Planned Well Paths of a 10 Well Section

Lease line



Simulated Well Paths of a 10 Well Section



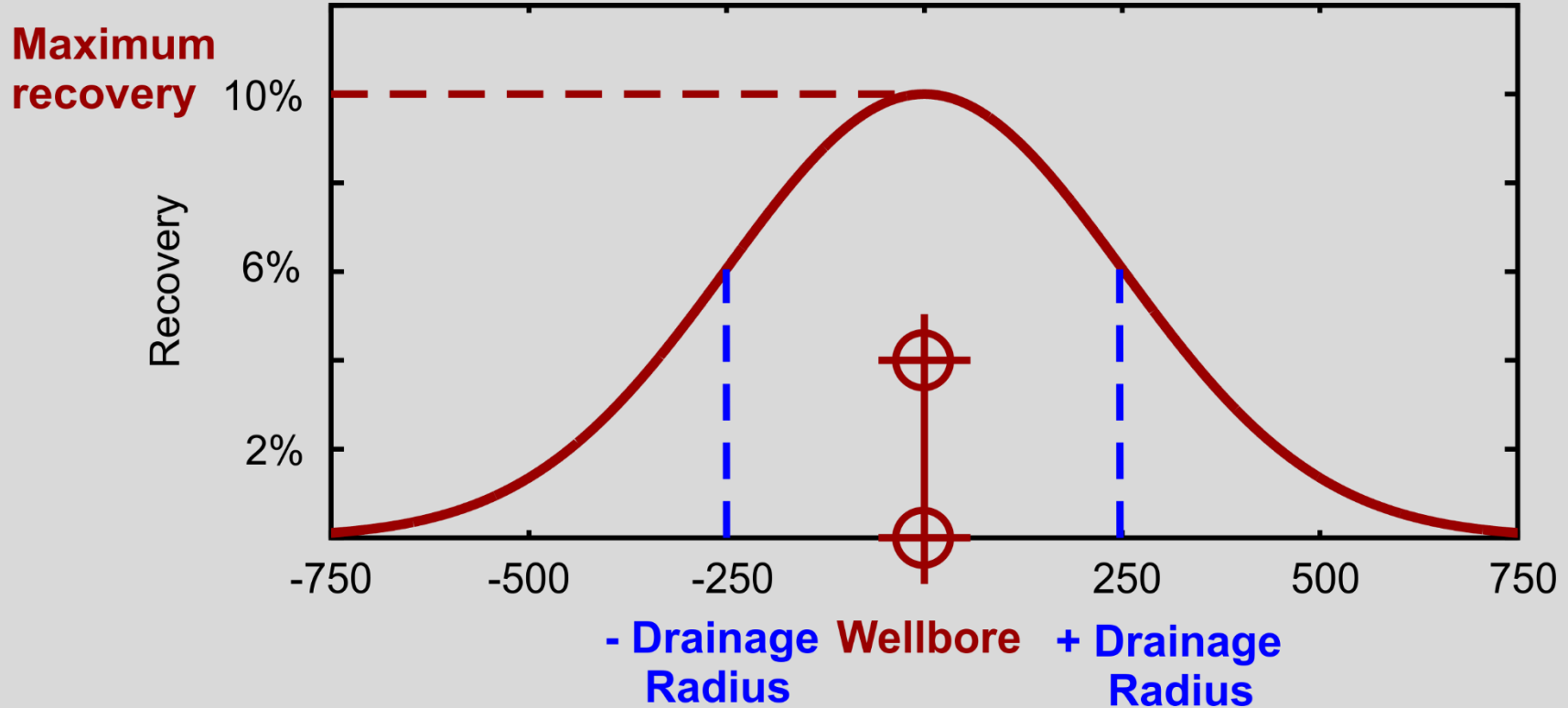
Cross-overs and Lease Line Infringements

Based on 1000 simulations for a 5 well pad

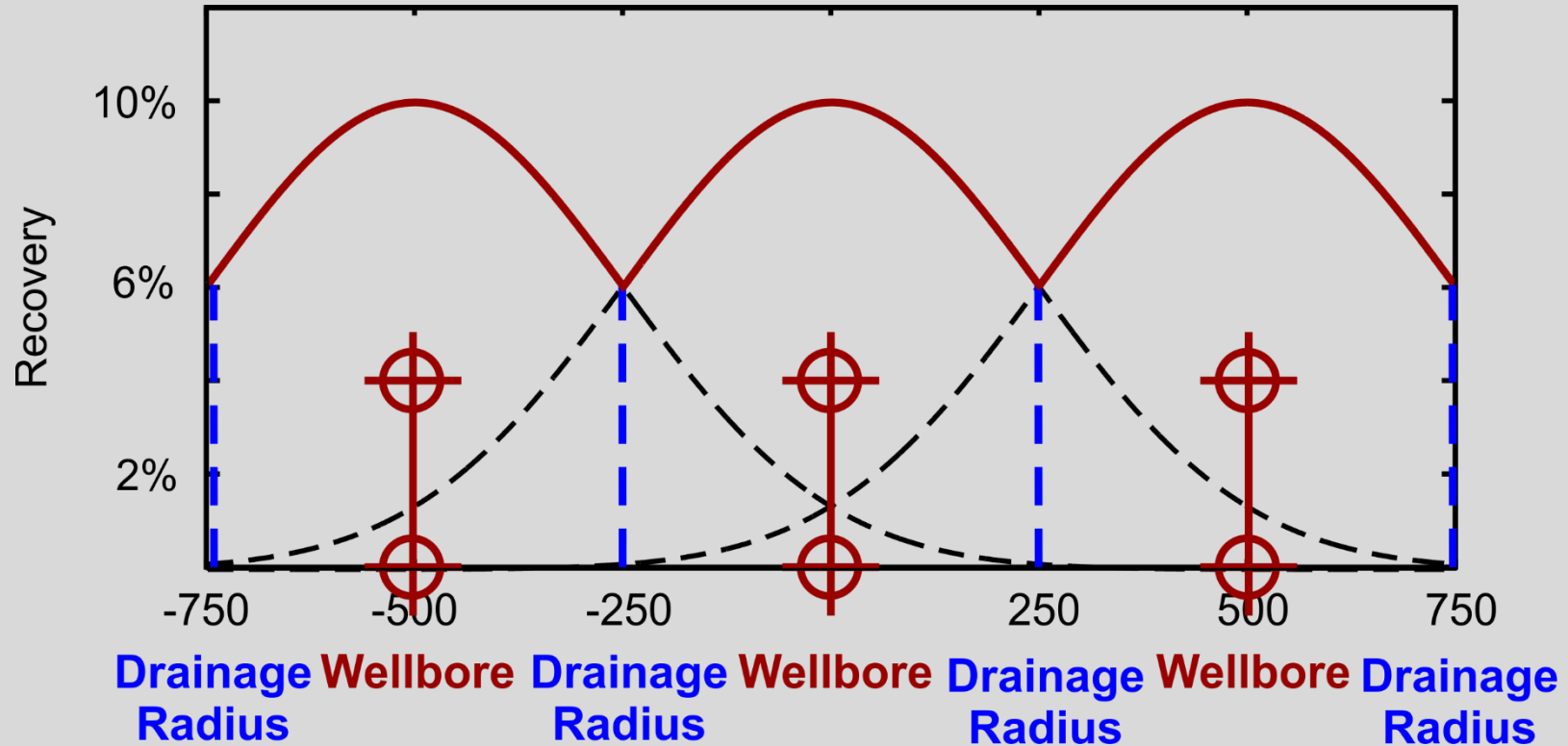
Lease line assumed to run parallel at half the spacing from the outer wellbores

	Lateral length	Az	Spacing	MWD		MWD+IFR+MS	
				Lease crossings	Wellbore crossovers	Lease crossings	Wellbore crossovers
Alberta West	2500 m	315°	120 m	14.5%	7.1%	0.1%	0.0%
Bakken E/W	9600 ft	90°	500 ft	9.2%	3.6%	0.0%	0.0%
Permian	9200 ft	165°	330 ft	4.8%	0.8%	0.0%	0.0%
Eagle Ford	8000 ft	145°	400 ft	0.8%	0.2%	0.0%	0.0%

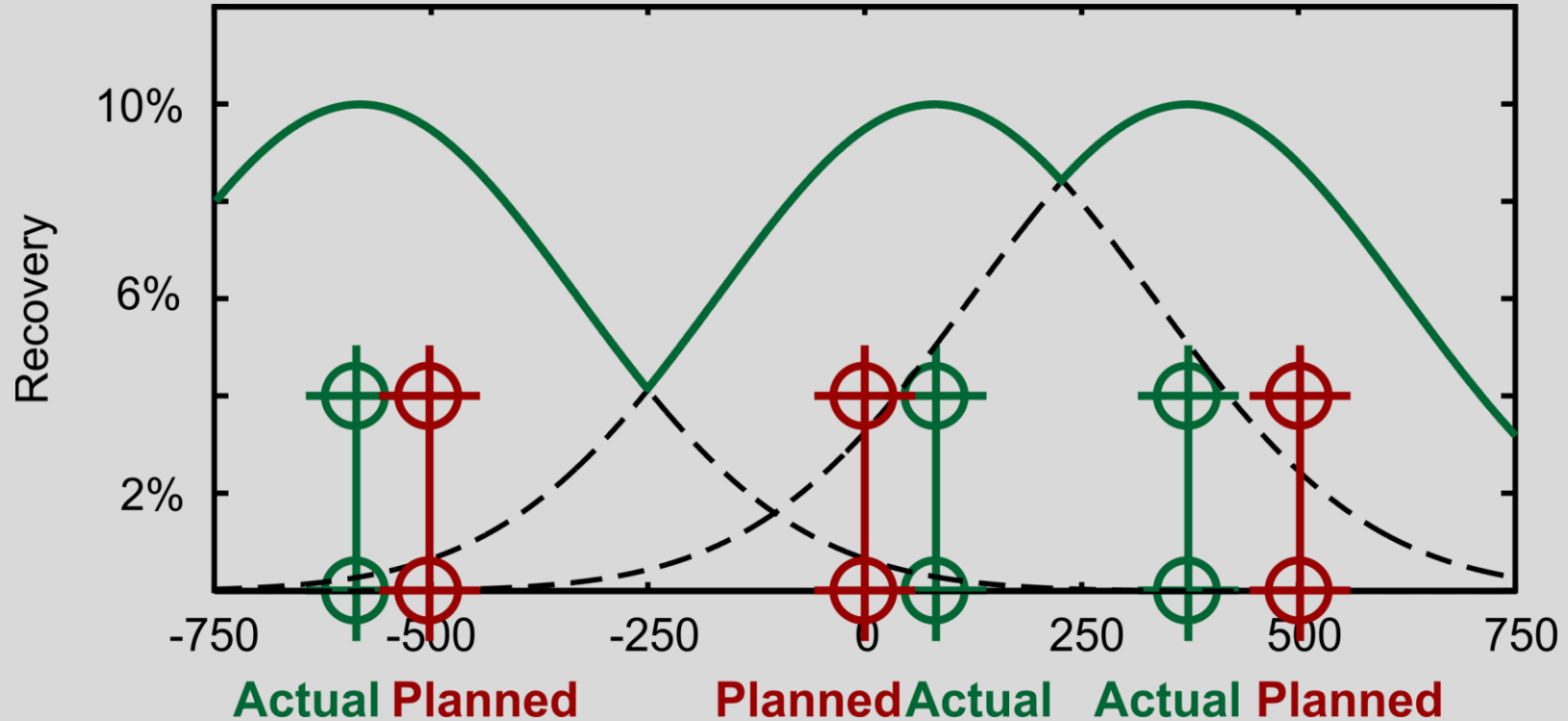
Drainage Envelope



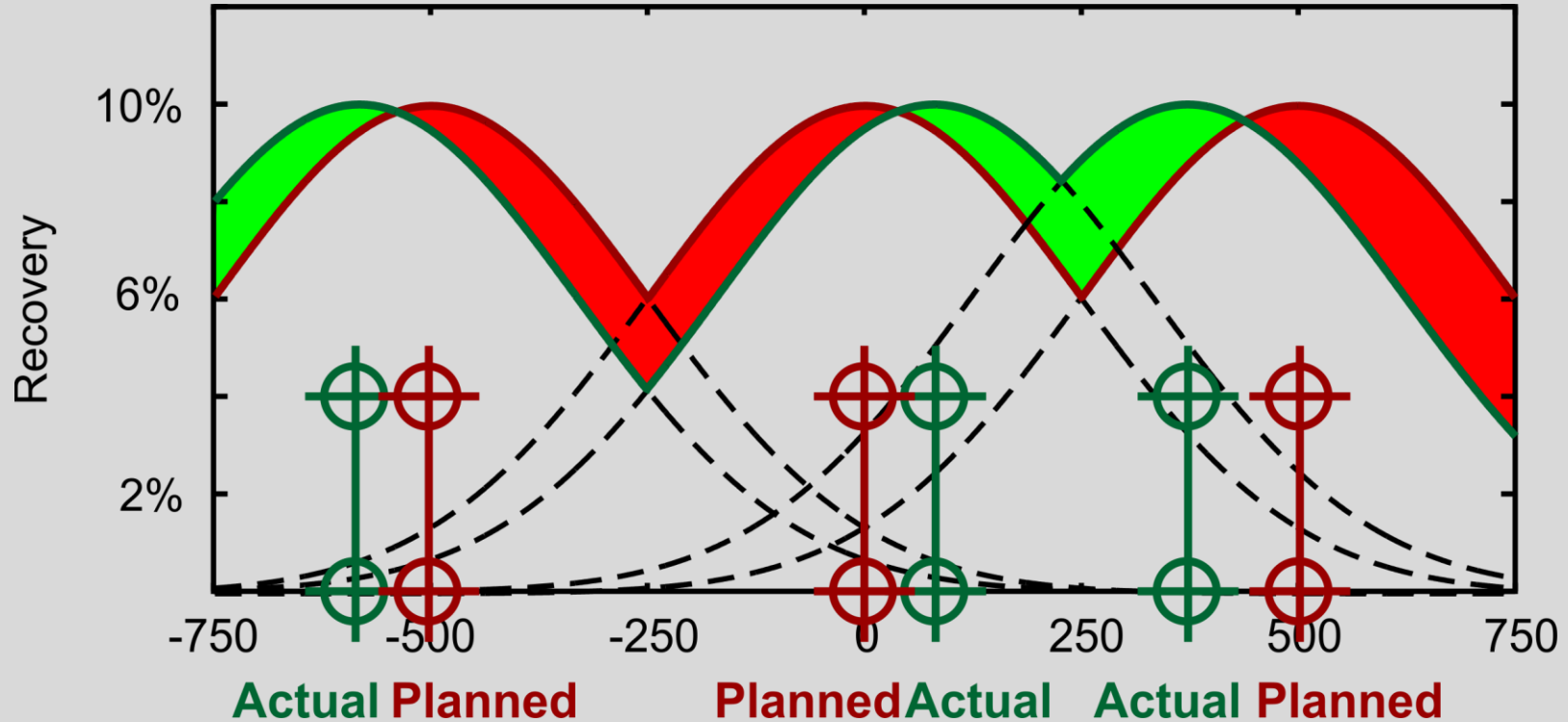
Ideal Recovery From Multiple Wells



Actual Recovery From Multiple Wells



Difference Actual vs Planned Recovery



Some Typical Recovery Simulation Results

Assumptions

Drainage radius: 250 ft

Daily production: 1500 bbl per well

	Lateral length	Az	Spacing	Recovery increase	Prod/day	bbl/year	@\$35/bbl
Alberta West	2500 m	315°	120 m	+ 1.8%	+27 bbl	+ 9855 bbl	+ \$345,000
Bakken E/W	9600 ft	90°	500 ft	+ 1.9%	+28 bbl	+ 10,400 bbl	+ \$364,000
Permian	9200 ft	165°	330 ft	+ 0.8%	+12 bbl	+ 4380 bbl	+ \$153,000
Eagle Ford	8000 ft	145°	400 ft	+ 0.7%	+10.5 bbl	+ 3833 bbl	+ \$136,000

Effect of Wellbore Lateral Length

Crossings

				MWD		MWD+IFR+MS	
	Lateral length	Az	Spacing	Lease crossings	Wellbore crossovers	Lease crossings	Wellbore crossovers
Eagle Ford	8000 ft	145°	400 ft	0.8%	0.2%	0.0%	0.0%
Eagle Ford	11,000 ft	145°	400 ft	6.7%	1.8%	0.0%	0.0%

Production

	Lateral	Daily prod	Recovery	Prod/day	bbbl/year	@\$35/bbl
Eagle Ford	8000 ft	1500 bbl/well	+ 0.7%	+10.5 bbl	+ 3833 bbl	+ \$136,000
Eagle Ford	11,000 ft	2062 bbl/well	+ 1.1%	+22.7 bbl	+ 8285 bbl	+ \$290,000

Effect of Wellbore Azimuth: E/W vs N/S

Crossings

	Lateral length	Az	Spacing	MWD		MWD+IFR+MS	
				Lease crossings	Wellbore crossovers	Lease crossings	Wellbore crossovers
Bakken E/W	9600 ft	90°	500 ft	9.2%	3.6%	0.0%	0.0%
Bakken N/S	9600 ft	180°	500 ft	0.9%	1.0%	0.0%	0.0%

Production

	Lateral length	Az	Spacing	Recovery increase	Prod/day	bbl/year	@\$35/bbl
Bakken E/W	9600 ft	90°	500 ft	+ 1.9%	+28 bbl	+ 10,400 bbl	+ \$364,000
Bakken N/S	9600 ft	180°	500 ft	+ 0.8%	+12 bbl	+ 4380 bbl	+ \$153,000

Some limitations

Actual recovery losses may be larger than simulated:

- Assumes that survey requirements are followed
 - Surveys are QC'ed and meet tool code specifications
 - Requirements for survey spacing are met
 - No gross errors
- Assumes survey errors are Gaussian, while actual errors are known to have heavy tailed distributions
 - In reality, large wellbore position errors more likely