Drillstring Magnetic Interference

ISCWSA MWD Error Model Terms

Harry Wilson

ISCWSA 38, New Orleans, 3 October 2013

MWD Magnetic Azimuth

- Dominant error sources:
  - Uncertainty associated with nominal declination angle
  - Z axis disturbance field from magnetised BHA components
- Both quantified in the MWD (basic) error model

ISCWSA MWD Error Model

ISCWSA MWD, Rev. 2 (Standard) Details

Term	Value (1 sig...	D...	I...	A...	Description	Depth weighting function	Inclination weighting function	Azimuth weighting function	Prop. Meth...	Correcti...
ABX	0.004 m/s²	1	1	1	x-accelerometer bias	0	- cosI*sina/Gt	[tanq*(cosI*sinAm*sina - cosAm*cosa) + cotI*cosa]/Gt	Systematic	Standard
ABY	0.004 m/s²	1	1	1	y-accelerometer bias	0	- cosI*cosa/Gt	[tanq*(cosI*sinAm*cosa + cosAm*sina) - cotI*sina]/Gt	Systematic	Standard
ABZ	0.004 m/s²	1	1	1	z-accelerometer bias	0	- sinI/Gt	tanq*sinI*sinAm/Gt	Systematic	Standard
AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm	Systematic	Standard
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180	Systematic	Standard
ASX	0.0005 fract	1	1	1	x-accelerometer scale factor	0	sinI*cosI*sin2a	- [tanq*sinI*(cosI*sinAm*sina - cosAm*cosa) + cosI*cosa]*sina	Systematic	Standard
ASY	0.0005 fract	1	1	1	y-accelerometer scale factor	0	sinI*cosI*cos2a	- [tanq*sinI*(cosI*sinAm*cosa + cosAm*sina) - cosI*sina]*cosa	Systematic	Standard
ASZ	0.0005 fract	1	1	1	z-accelerometer scale factor	0	- sinI*cosI	tanq*sinI*cosI*sinAm	Systematic	Standard
AZ	0.36 °	1	1	1	Magnetic declination uncertainty	0	0	p/180	Global	Standard
DBH	5000 deg-nT	1	1	1	Magnetic declination uncertainty	0	0	p/180/(B*cosq)	Global	Standard
DREF	0.35 m	1	1	1	Depth reference, random	1	0	0	Random	Standard
DSF	0.00056 fract	1	1	1	Depth scale factor, systematic	D	0	0	Systematic	Standard
DST	2.5e-007 1/m	1	1	1	Depth stretch/temperature, global	D*V	0	0	Global	Standard
MBX	70 nT	1	1	1	x-magnetometer bias	0	0	(cosAm*cosa - cosI*sinAm*sina)/(B*cosq)	Systematic	Standard
MBY	70 nT	1	1	1	y-magnetometer bias	0	0	- (cosAm*sina + cosI*sinAm*cosa)/(B*cosq)	Systematic	Standard
MBZ	70 nT	1	1	1	z-magnetometer bias	0	0	- sinI*sinAm/(B*cosq)	Systematic	Standard
MSX	0.0016 fract	1	1	1	x-magnetometer scale factor	0	0	(cosI*cosAm*sina - tanq*sinI*sina + sinAm*cosa)*(cosAm*cosa - ...	Systematic	Standard
MSY	0.0016 fract	1	1	1	y-magnetometer scale factor	0	0	(- cosI*cosAm*cosa + tanq*sinI*cosa + sinAm*sina)*(cosAm*sin...	Systematic	Standard
MSZ	0.0016 fract	1	1	1	z-magnetometer scale factor	0	0	- sinI*sinAm*(sinI*cosAm + tanq*cosI)	Systematic	Standard
MXY...	0.06 °	1	1	1	xy tool misalignment, systematic	0	p/180*[1 + FIw*(sinI - 1)]	0	Systematic	Standard
MXY...	0.06 °	1	1	1	xy tool misalignment, systematic	0	0	- p/180*[1 + FIw*(sinI - 1)]/sinI	Systematic	Standard
MXY...	0.06 °	1	1	1	xy tool misalignment, systematic	0	p/180*FIw*|cosI|*cosAt	- p/180*FIw*|cosI|*sinAt/sinI	Systematic	Standard
MXY...	0.06 °	1	1	1	xy tool misalignment, systematic	0	p/180*FIw*|cosI|*sinAt	p/180*FIw*|cosI|*cosAt/sinI	Systematic	Standard
SAG	0.2 °	1	1	1	BHA sag	0	p/180*sinI	0	Systematic	Standard

Axial Drillstring Interference

- Cause
- Effect

Axial Drillstring Interference

- Induced magnetisation
  - Not included in the ISCWSA model
- Remnant/Permanent magnetisation
  - Included in ISCWSA model

ISCWSA Error Terms

1 sigma

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

- Why SinISinA?
- Why AMIF?

ISCWSA Error Terms

1 sigma

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

- Total DSI = sqrt($AMID^2$ + $AMIF^2$)
  - 0.25° at vertical or north/south
    - But zero positional effect at vertical
  - 0.65° at horizontal, east/west
- Need for fixed term may be questioned
- Values are arbitrary

ISCWSA Model Bias Option

1 sigma

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

- AMID
  - Treated as biased error displacing mean towards equator by 0.33˚
  - Uncertainty reduced to 0.5˚
- Now not recommended by ISCWSA

BHA Conformance with Model's Assumption

- Pre-job
  - Test BHA spacing for compliance with model's assumption
- While drilling
  - Dip and Bt QC tests include DSI uncertainty per error model

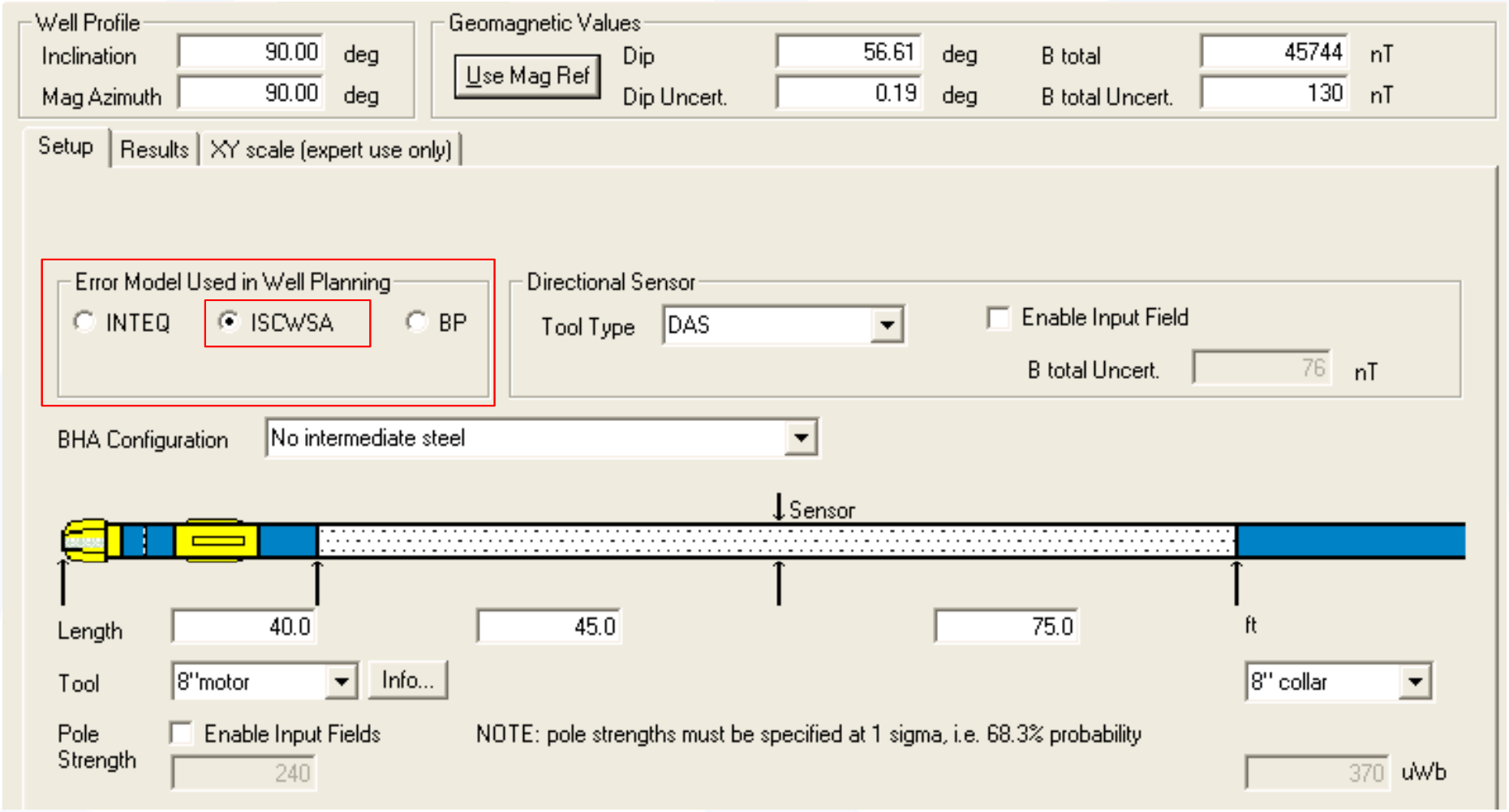
Pre-Job QC of BHA - Example

- Geomag location matters
  - Azimuth “signal” is B_H
  - BHA Interference-Field$_H$ is a competing signal
  - Resultant azimuth signal is the vector sum of the two

- Example Location: Offshore, Louisiana

Pre-Job QC of BHA - Example

- Location: Offshore, Louisiana



Pre-Job QC of BHA - Example

- Result (90Inc/90Az)

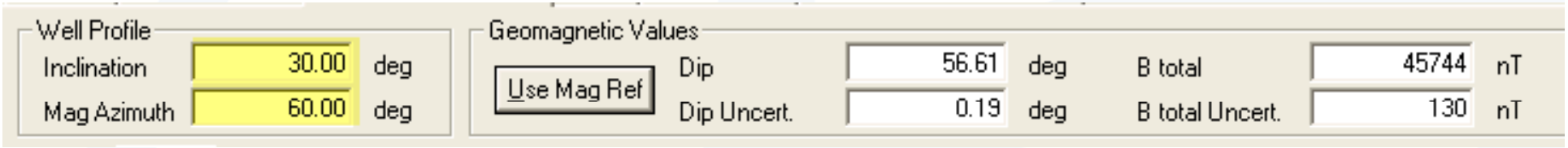
Uncorrected Option

	This BHA	Max Allowed		
Azimuth Uncert.	0.88	1.95	deg	PASS
Bz Uncert.	388	857	nT	

  - "Max Allowed" is error model assumption scaled to 3 sigma
  - "This BHA" also scaled to 3 sigma

Pre-Job QC of BHA - Example

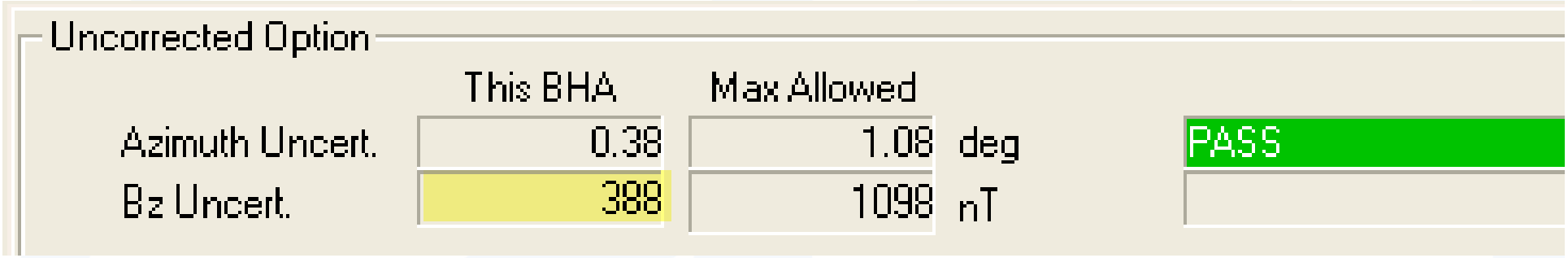
Location: Offshore, Louisiana



Pre-Job QC of BHA - Example

Location: Offshore, Louisiana

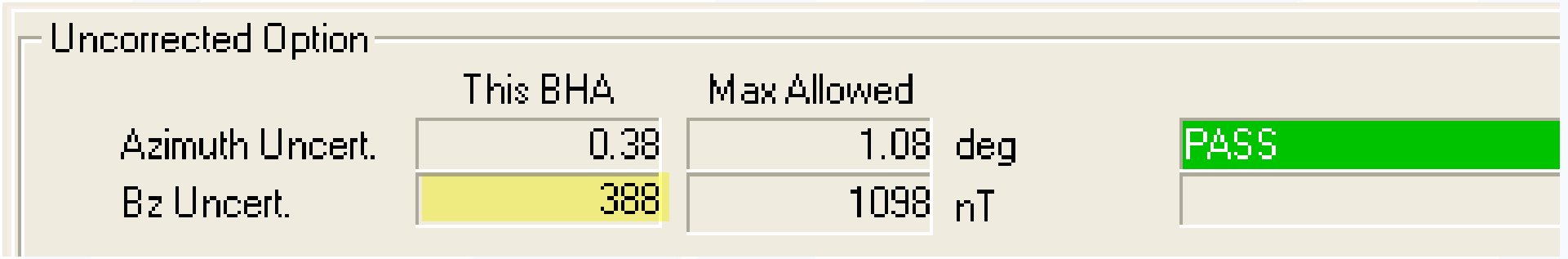
- 30Inc/60Az



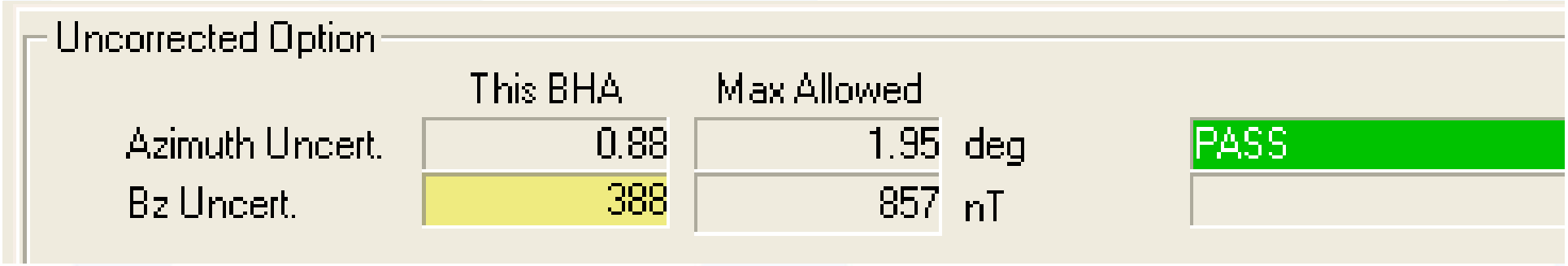
Pre-Job QC of BHA - Example

Location: Offshore, Louisiana

- 30Inc/60Az



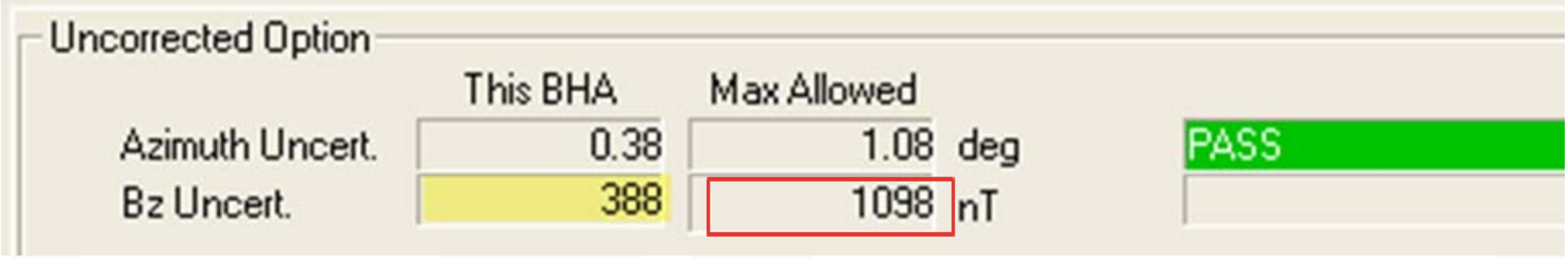
- 90Inc/90Az



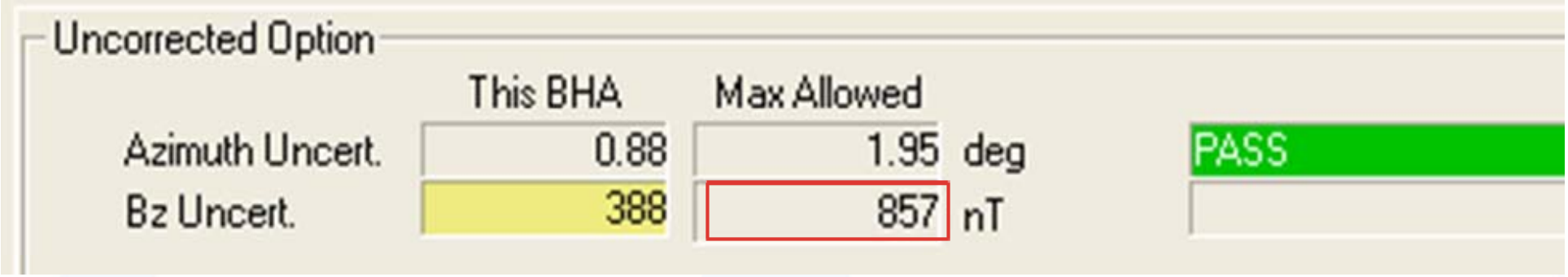
Pre-Job QC of BHA - Example

Max Allowed Bz Uncert feeds into QC test limit values

- 30/60

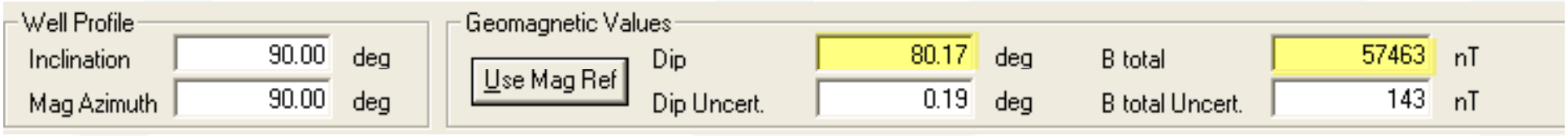


- 90/90



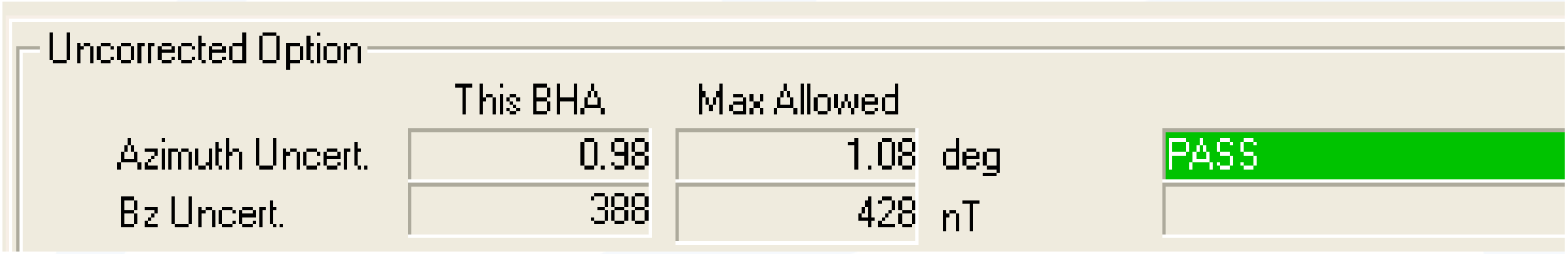
Pre-Job QC of BHA - Example

Location: North Slope, Alaska



Pre-Job QC of BHA – Example - Alaska

30/60



90/90

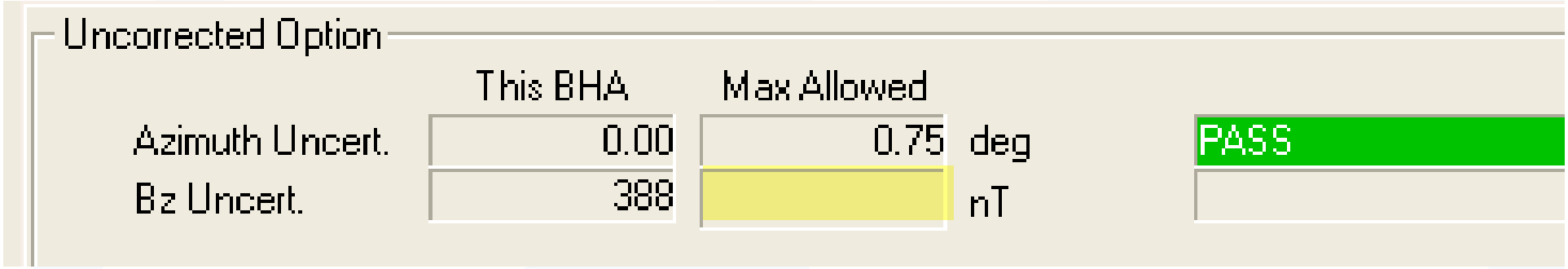
Must increase non-mag spacing

Why did it fail?

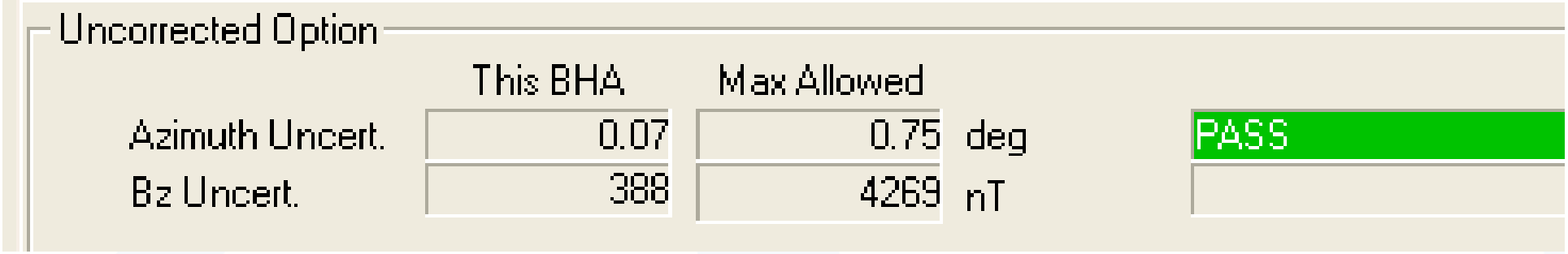
- Geomag location matters
  - Azimuth “signal” is B_H
    - Dip sensitive
  - BHA Interference-Field$_H$
    - Inc/Az sensitive

QC at Low Inclination or N/S

- 0/0, 90/0, 90/180



- 10/10



Summary

- Values are arbitrary
  - Therefore BHA must conform
- Weighting function models attitude sensitivity
- Biased option not recommended
- Uncertainty is not location dependent
  - Therefore spacing requirement *is* location dependent
- QC tests insensitive at low Inc and N/S

Alternative Quantification

- ISCWSA Standard

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

Alternative Quantification

- ISCWSA Standard

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

- Alternative to AMID

AMIBZ	150 nT	1	1	1	Axial magnetic interference, Bz bias	0	0	- sinI*sinAm/(B*cosq)

  - Bz bias effect, not azimuth
  - Value still arbitrary
  - Geomag location dependent via B*CosDip weighting
  - AMIF (AZ) optional

Alternative Quantification

- ISCWSA Standard

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

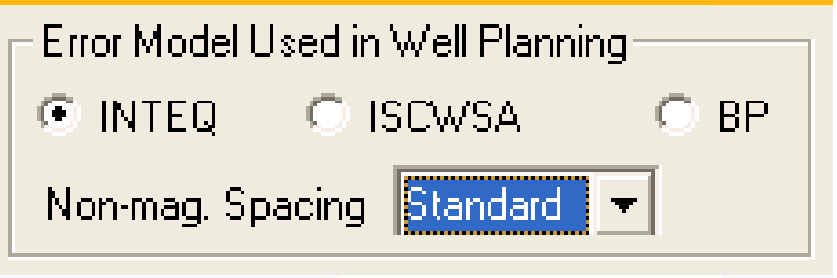
- Alternative to AMID

AMIBZ	150 nT	1	1	1	Axial magnetic interference, Bz bias	0	0	- sinI*sinAm/(B*cosq)

Adopted by ISCWSA Operator Wellbore Survey Group (AMIL)

Pre-Job QC of BHA – Alternative Error Term

- Location: Offshore, Louisiana



- 30/60

Uncorrected Option

	This BHA	Max Allowed		
Azimuth Uncert.	0.38	0.44	deg	
Bz Uncert.	388	450	nT	PASS

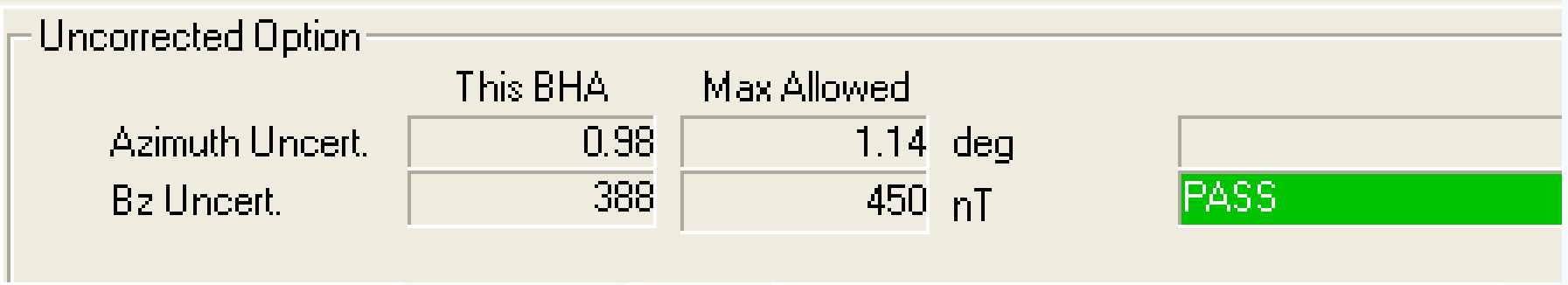
- 90/90

Uncorrected Option

	This BHA	Max Allowed		
Azimuth Uncert.	0.88	1.02	deg	
Bz Uncert.	388	450	nT	PASS

Pre-Job QC of BHA – Alternative Error Term

- Location: North Slope, Alaska
- 30/60

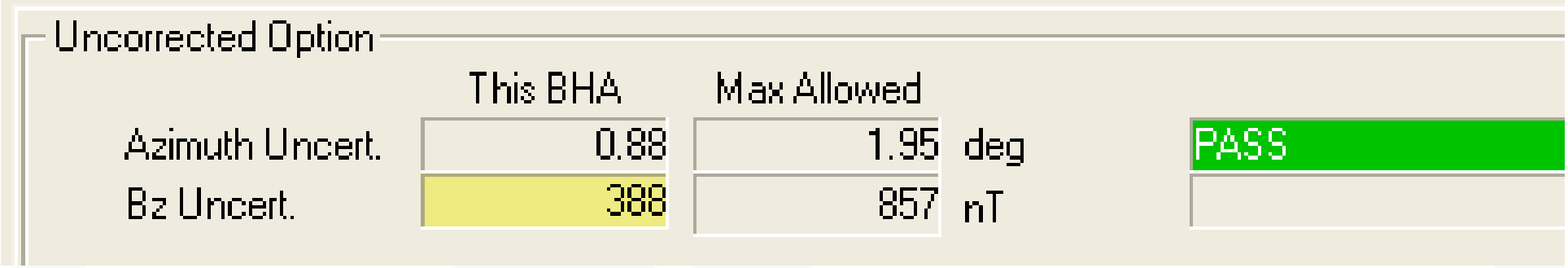


- 90/90

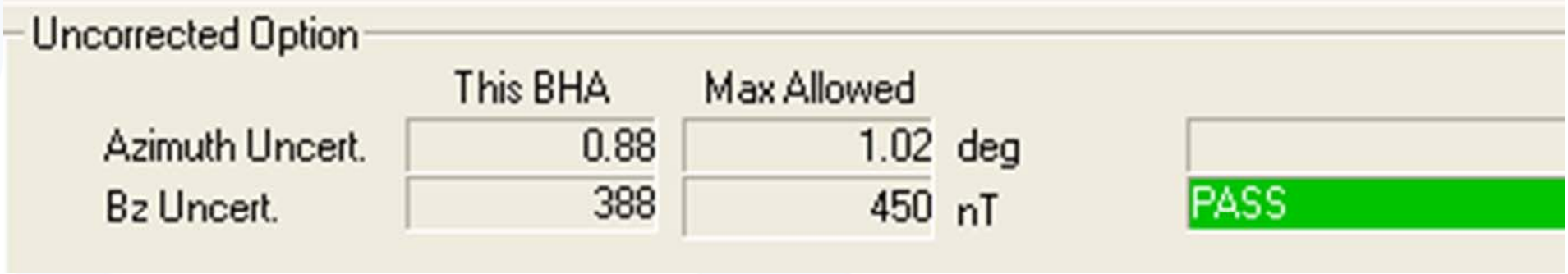
Pre-Job QC of BHA - Comparison

Location: Offshore, Louisiana, 90/90

- Standard



- Alternative



Pre-Job QC of BHA - Comparison

Location: North Slope, Alaska, 90/90

- Standard

Uncorrected Option

	This BHA	Max Allowed		
Azimuth Uncert.	2.27	1.95	deg	FAIL
Bz Uncert.	388	334	nT	

- Alternative

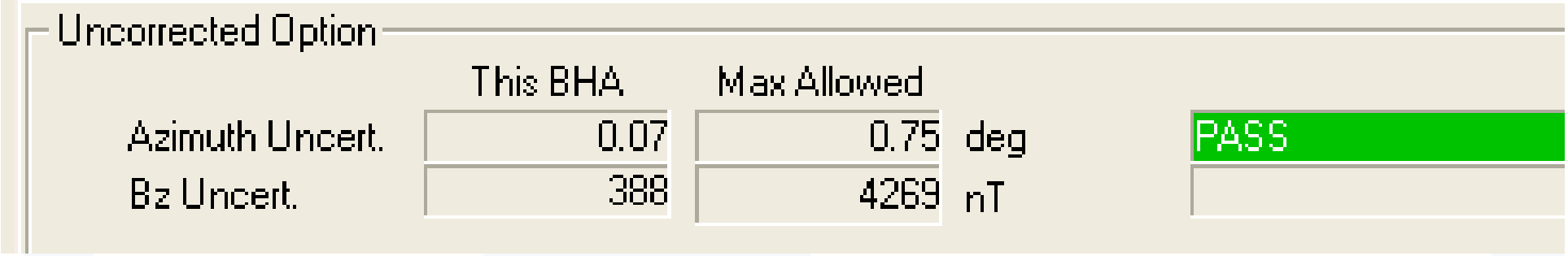
Uncorrected Option

	This BHA	Max Allowed		
Azimuth Uncert.	2.27	2.63	deg	
Bz Uncert.	388	450	nT	PASS

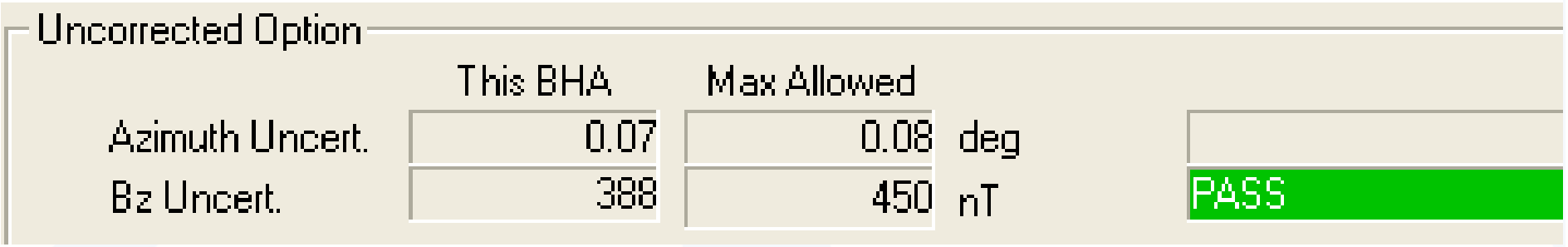
QC at Low Inclination or N/S

10/10

- Standard

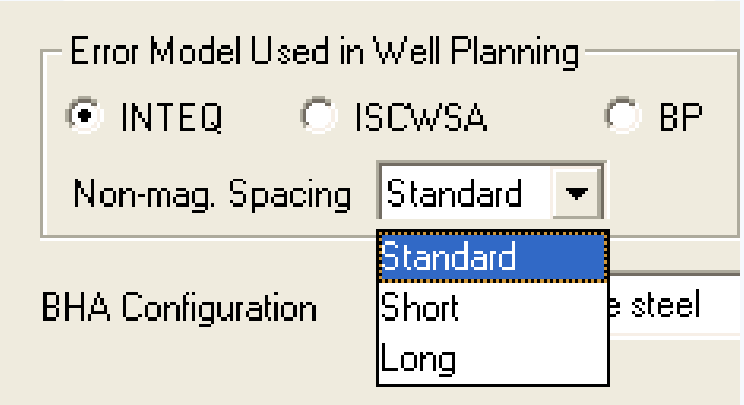


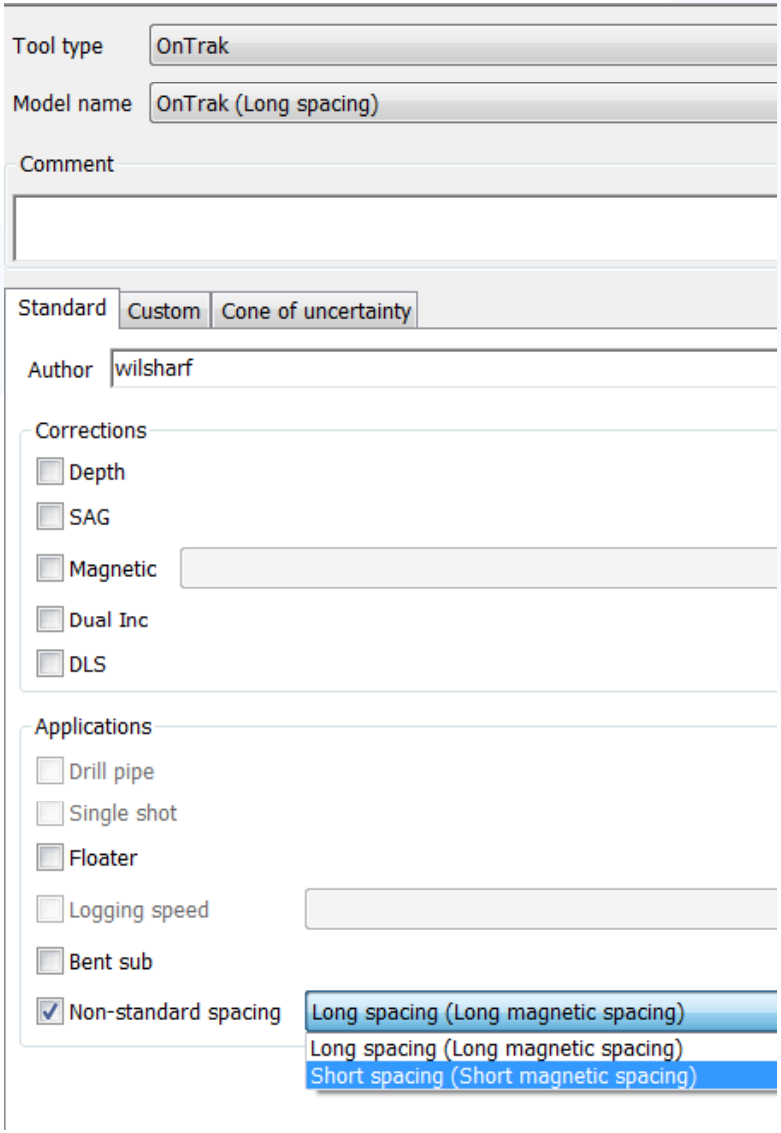
- Alternative



Error Model Variants - Spacing Options

- Single non-mag spacing option may be too restrictive





Summary 1

- Error terms model permanent magnetisation
- Fixed value term contributes uncertainty even at north/south
- Arbitrary term values
  - Therefore BHA must be evaluated for compliance with model
- Weighting function models attitude sensitivity

Summary 2

- ISCWSA terms
  - Uncertainty is not location dependent
  - Therefore spacing requirement is location dependent
- Alternative term
  - Uncertainty is location dependent
  - Therefore spacing requirement is not location dependent
  - Compliance more likely?
- Single spacing option is restrictive

Summary 3

- Survey QC tests should include model's DSI contribution
- ISCWSA terms result in QC tests that catch out-of-spec Az, but not out-of-spec condition
- ISCWSA terms reduce QC sensitivity at low inc and N/S
- QC tests derived from alternative term catch out-of-spec condition, but can trip with insignificant Az error

