OMAE2008-57046 – Actual VIV Fatigue Response of Full Scale Drilling Risers: With and Without Suppression Devices

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Outline

- Background
- Key conclusions
- Observed VIV in-field
- Instrumentation
- VIV Software Calibration
- Key findings and software limitations
  - VIV occurrence in the field
  - Suppression devices
  - Higher harmonics
  - Time sharing
- Conclusions and recommendations

VIV Monitoring: Background and Objectives

- **Motivation**
  - Equipment damage
  - Excessive waiting on weather
  - Observed BOP stack VIV
  - Low confidence in conservative design tools
  - Limited performance data on off-the-shelf VIV suppression devices (fairings/fins)

What is *actually* happening to our risers?

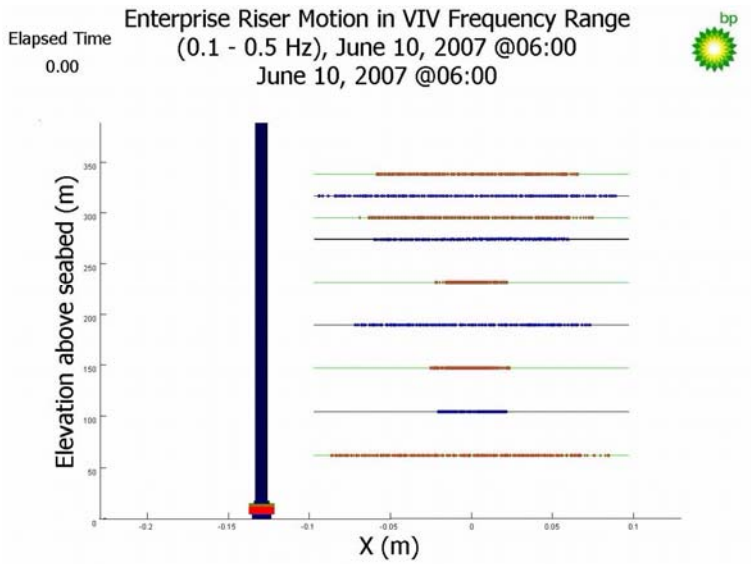
- **Approach**
  - GoM drilling riser VIV monitoring program kicked off
    - Drilling risers with and without suppression devices

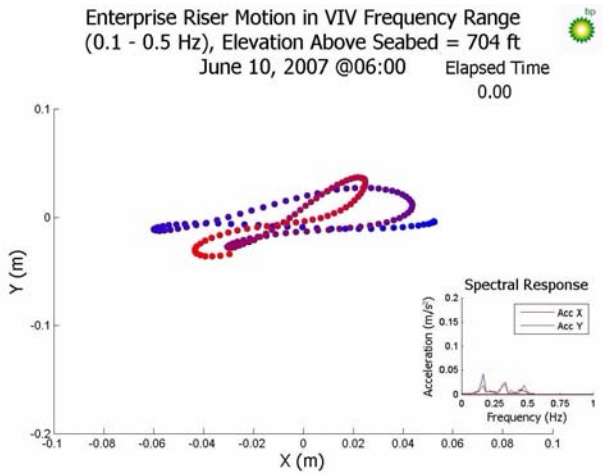
- **Objectives of Monitoring Campaign**
  - Ensure safe operations and feed back important information to wells teams
  - Calibrate design tool (SHEAR7) with field measurements
  - Identify and understand sources of discrepancies
  - Assess suppression performance via ad-hoc field trials

Key Conclusions

- VIV **DOES** occur in the field
- Measured damage is generally **less than predicted** – Risers are being operated safely
- VIV fatigue analysis tool SHEAR7 can be/is being calibrated using field data, however, only in an average sense
  - Large scatter in predictions requires use of a large FoS
- Complex fundamental physical phenomena have been observed that are not included in analysis models
- Revised VIV prediction tools/approaches are required to account for the physics involved as well as to reduce scatter
- Based on limited data, suppression devices that BP has employed appear to perform well
- Sufficient uncertainty in riser VIV response is identified to warrant continued monitoring

VIV Does Occur: Riser and BOP Stack Response





Gulf of Mexico BP Riser Monitoring

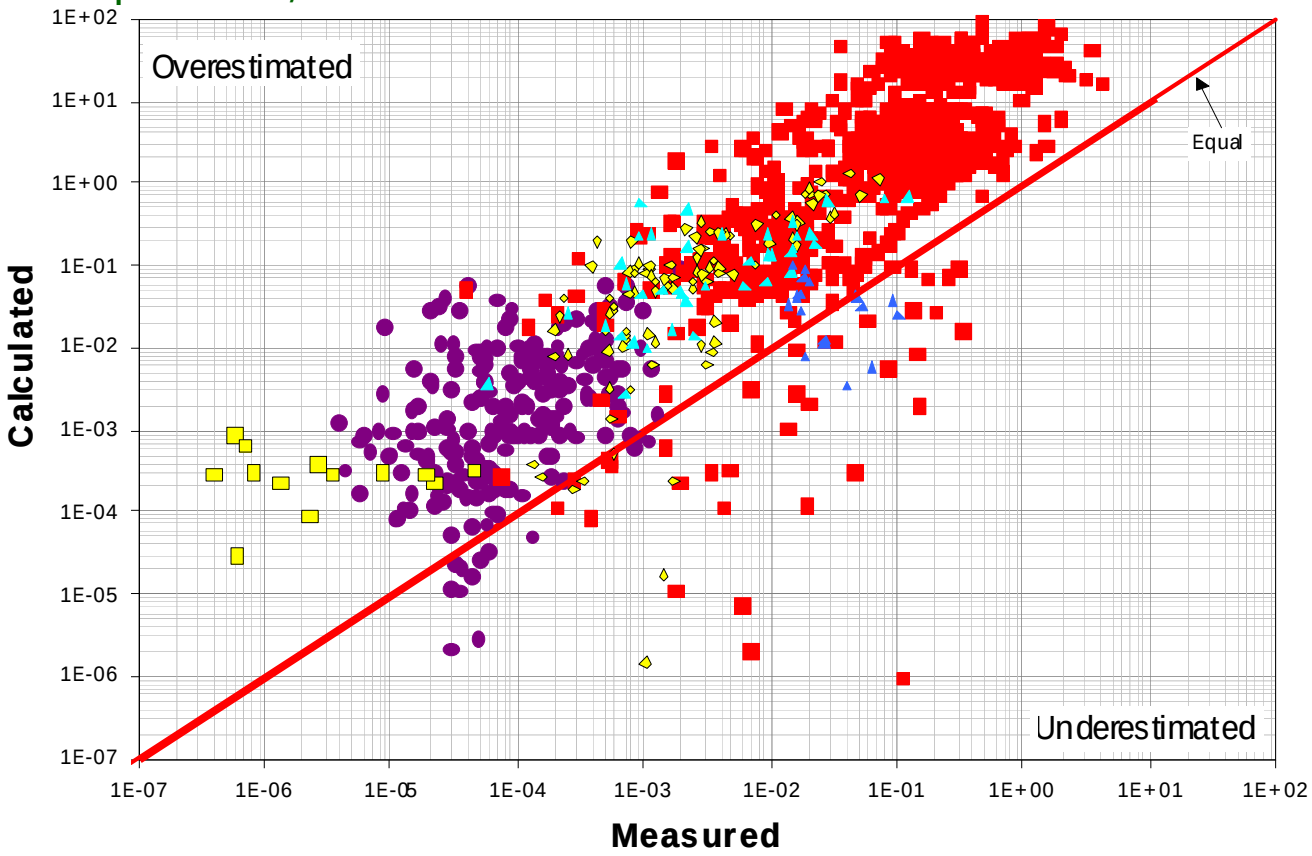
- 7 Drilling Risers
  - 4,100 – 6,800 ft WD
  - 10 – 20 accelerometers each
- Instrumentation – Accelerometers / Angular Rate Sensors

INTEGRI pod-M™

Analysis Tools Overpredict VIV Damage of Connected, Unsuppressed Drilling Risers

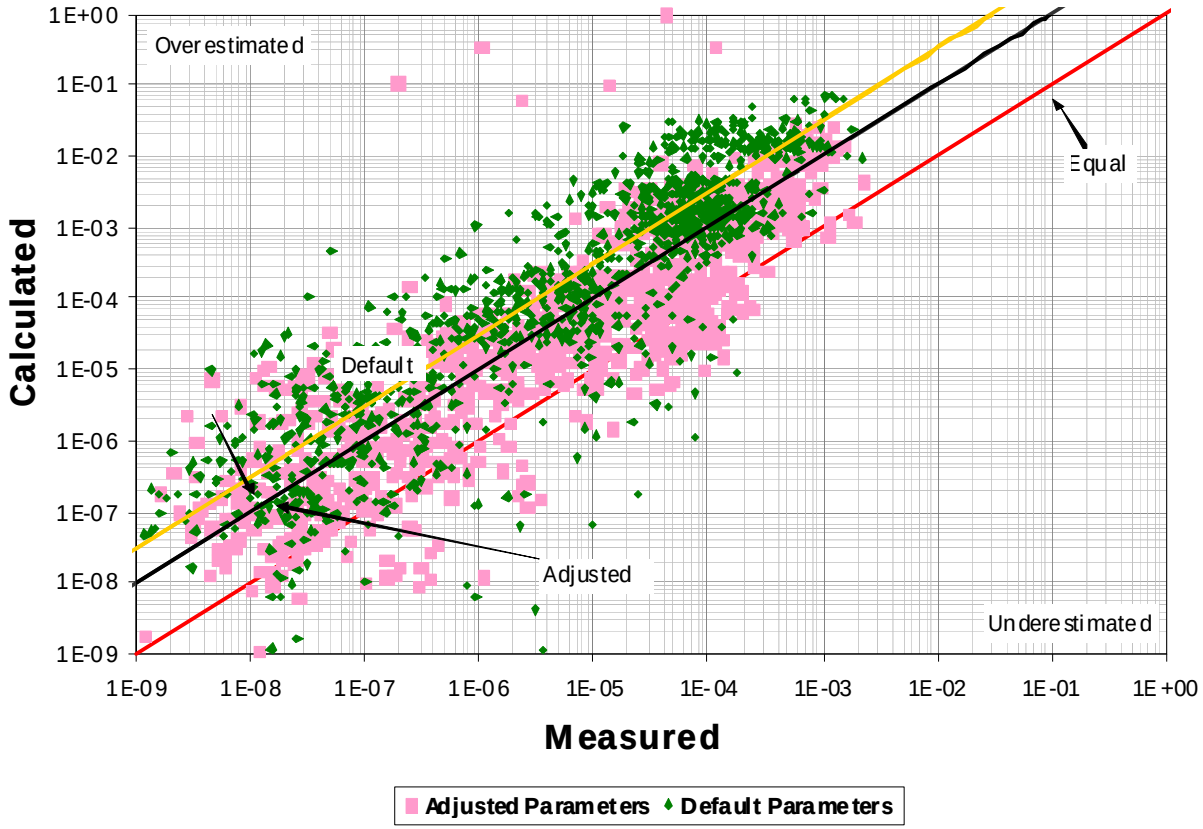
Typical design parameters – AVERAGE factor of 30 overprediction

Includes data from earlier monitoring campaigns WoS, Brazil, North Sea (OMAE Paper 2005)



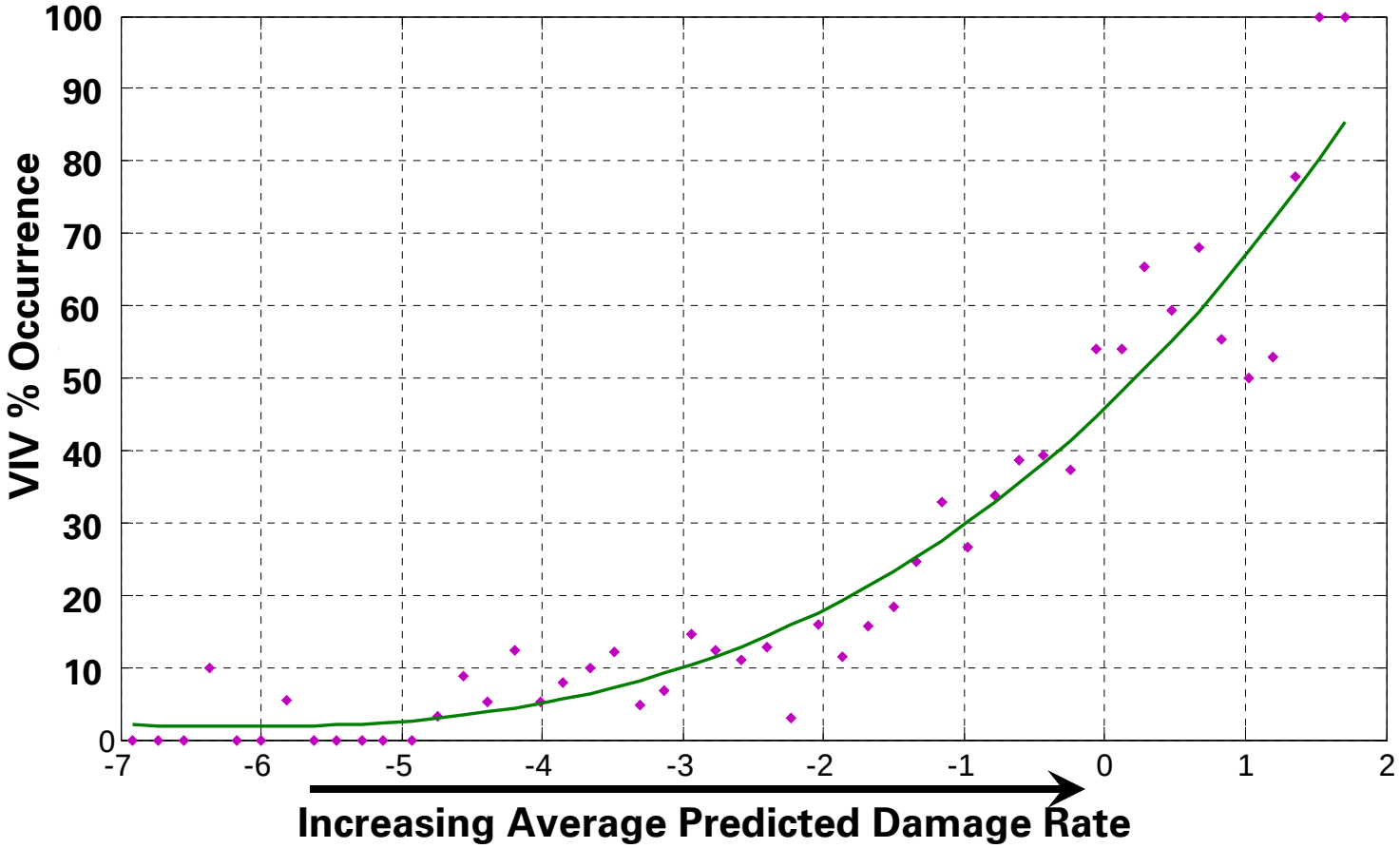
Adjust Input Parameters to Reduce Conservatism

- Overprediction reduced from factor of 30 to 10
- Difficult to reduce further because of scatter



Another Layer of Conservatism: VIV Does Not Occur as Often as Predicted

- Higher VIV occurrence in the field is observed for higher fatigue damage estimates
- Analysis tools almost ALWAYS predict VIV



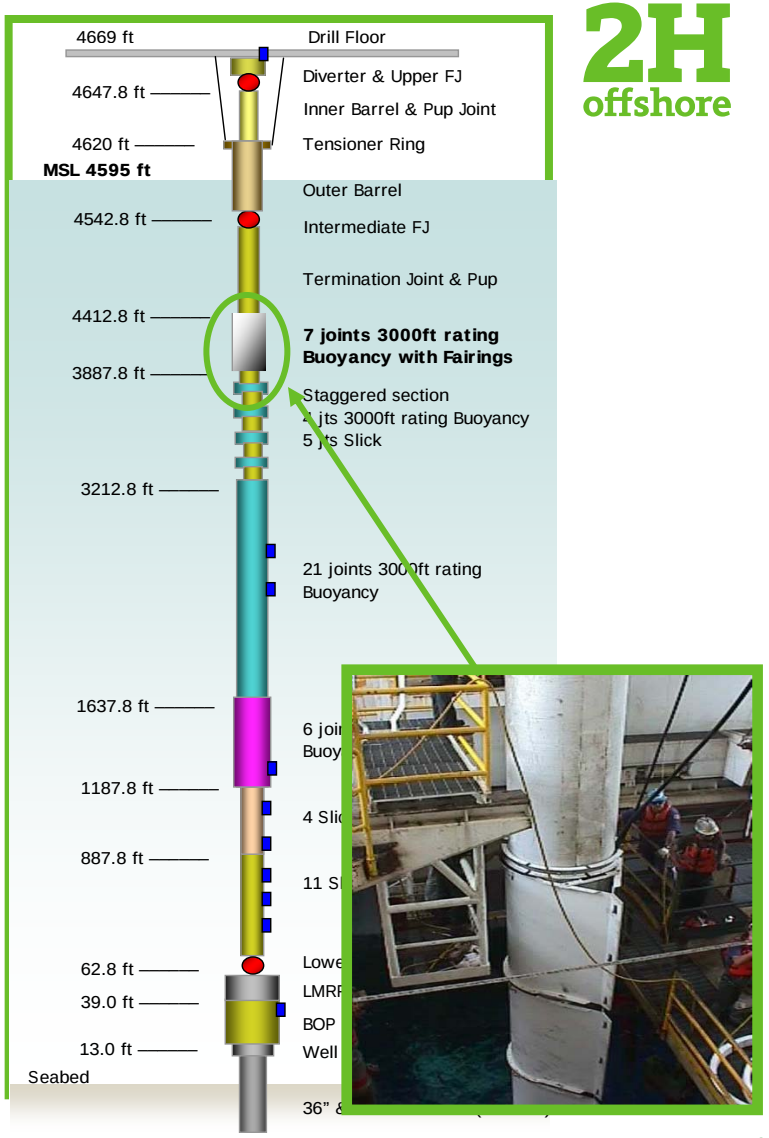
Suppression Performance: *Full-wrap* fairings

Fairings Data:

- 7 buoyant joints (525’) equipped with fairings
- Shell Global Solutions, Inc. (SGSI) - full wrap design
- Chord/Diameter (C/D) Ratio: 1.5
- Length: 6 ft

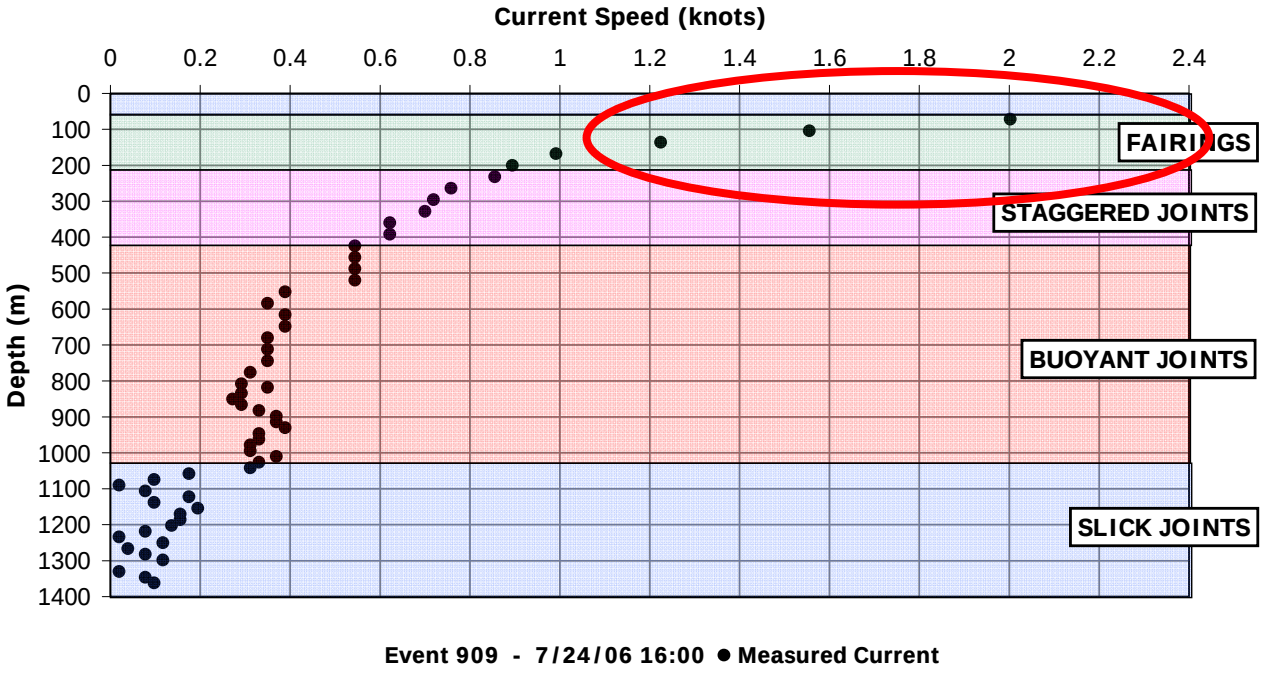
Monitoring Data:

- 9 months of monitoring
- 1.6% VIV occurrence
- Max current below 0.5 knots except for period of 21st July to 27th July 07 when a max current speed of 2.1 knots observed



Riser DOES NOT vibrate in one instance of high current in faired zone

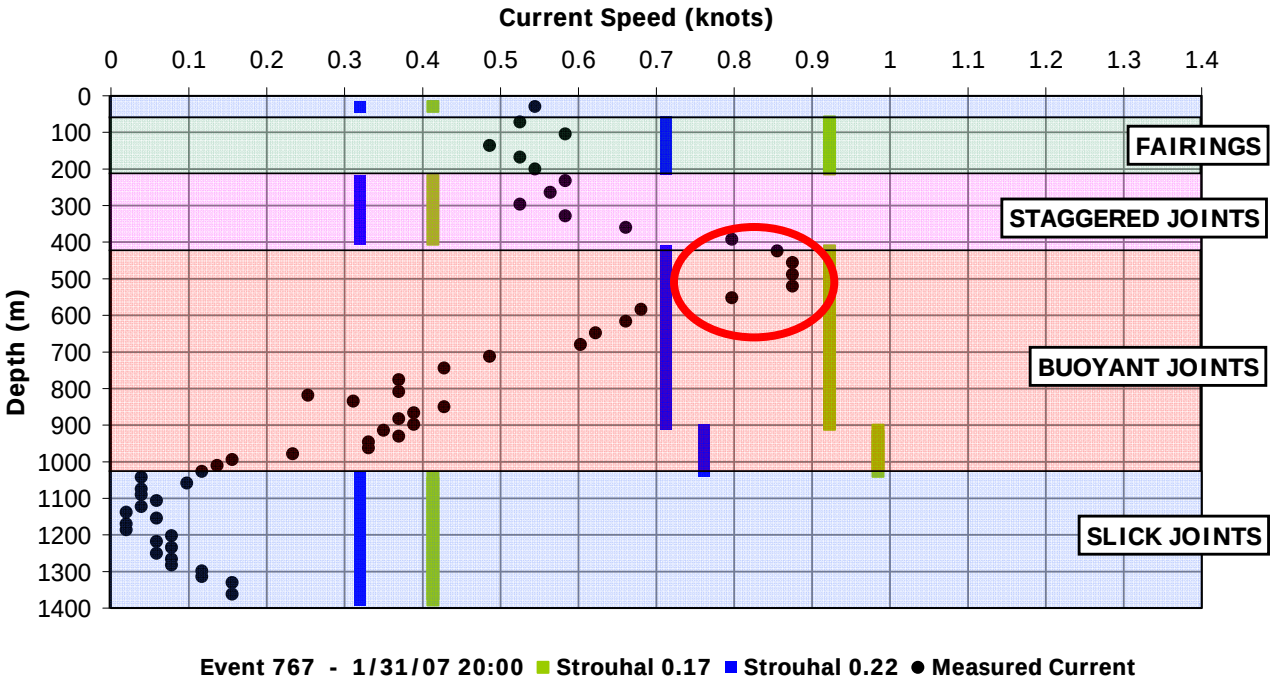
Full-wrap Fairing Performance



- From 21st July to 27th July 07 max current speed of 2.1 knots observed
- VIV did not occur with highly sheared 2 knot current loading on the fairings

Riser DOES vibrate when moderate currents are below faired region

Full-wrap Fairing Performance

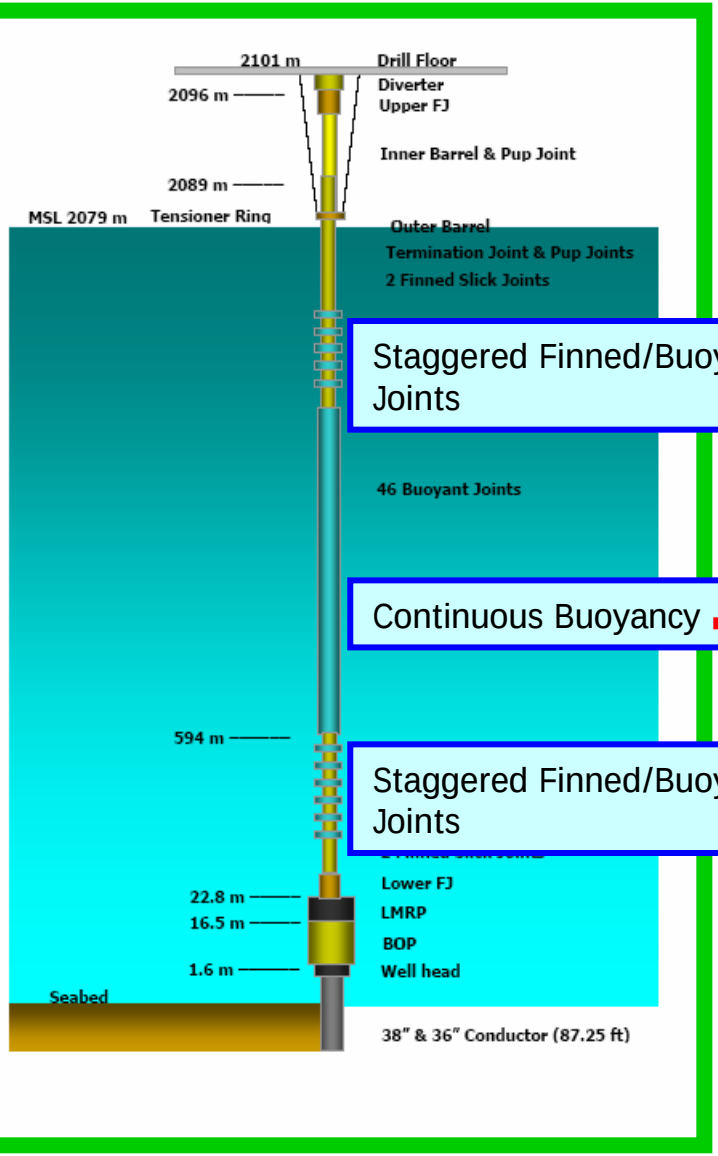


- 4 days of measured currents with ~0.8 knot mid-depth current
- VIV events identified during this period
- Buoyant joint VIV excitation: Mode = 2-3, Frequency = 0.0475 – 0.0627 Hz

Assessment - Fairings

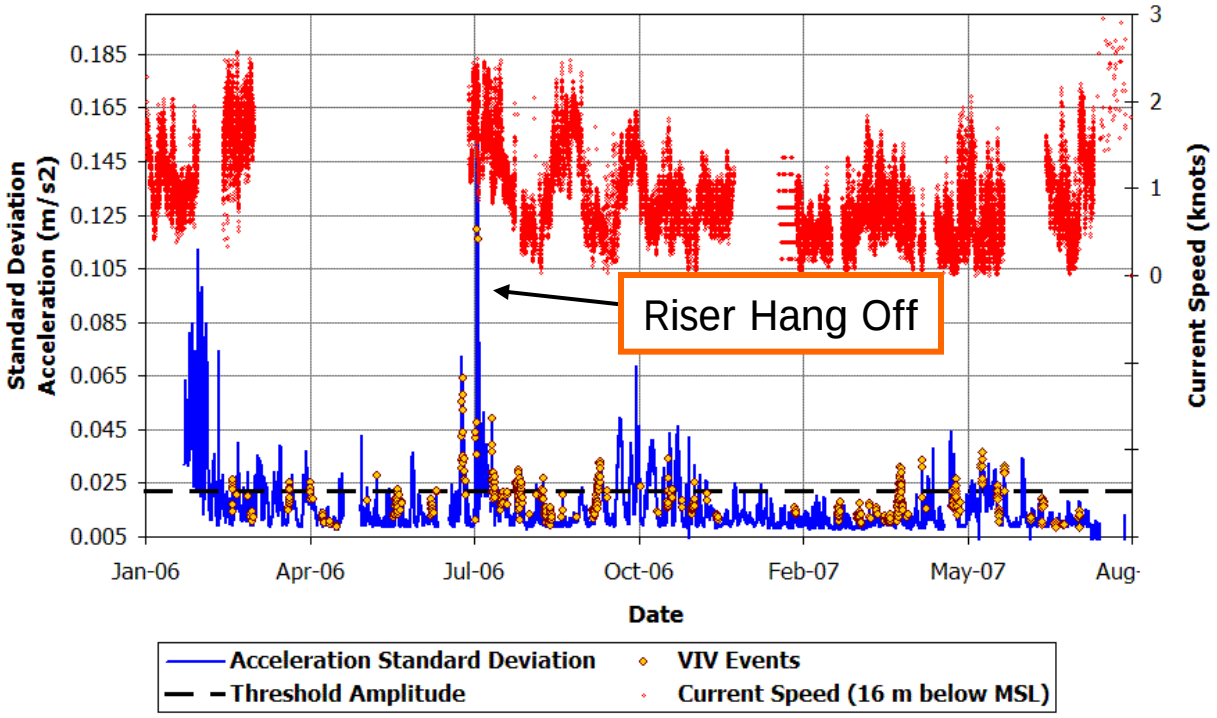
- Field measurements indicate that fairings suppress VIV
- The measured response of the risers with fairings showed no unstable behavior
- Operational personnel confirmed that the fairings improved operability
- Data are VERY limited and more are needed to confirm the effectiveness of fairings

Suppression Performance: Riser Fins



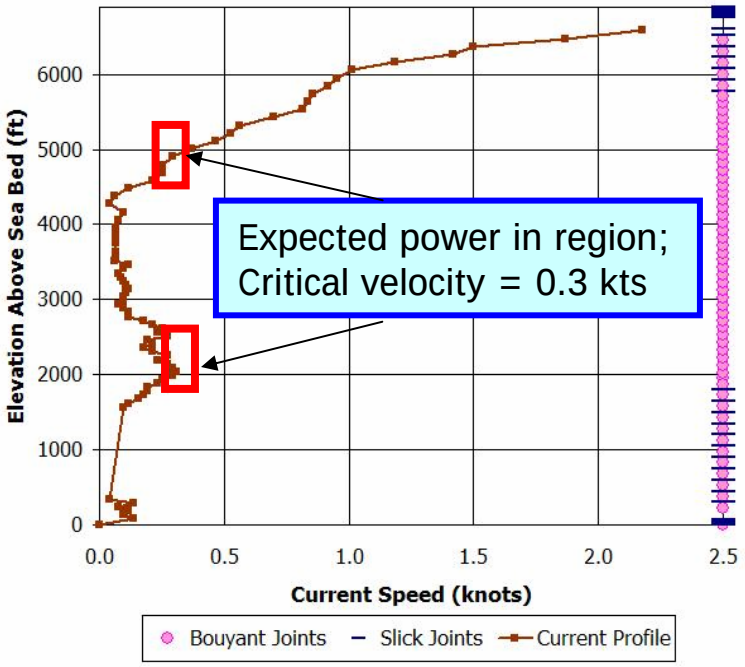
Percentage Occurrence of VIV: Riser with Fins

- VIV (above threshold) occurred only 2.02% of the time in 17 months
- For a similar period, VIV occurred 13.8% on a drilling riser w/o suppression
- 31.3% of finned riser VIV occurred when riser disconnected (fins retrieved)



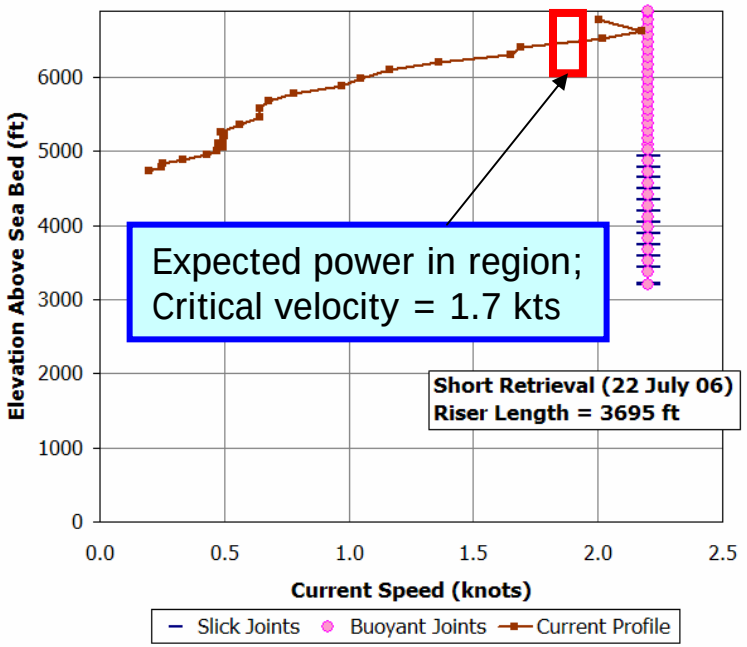
Example: Fins Reduce Damage

Finned Riser Response: Connected



Damage Rate = 2.2E-6 /yr

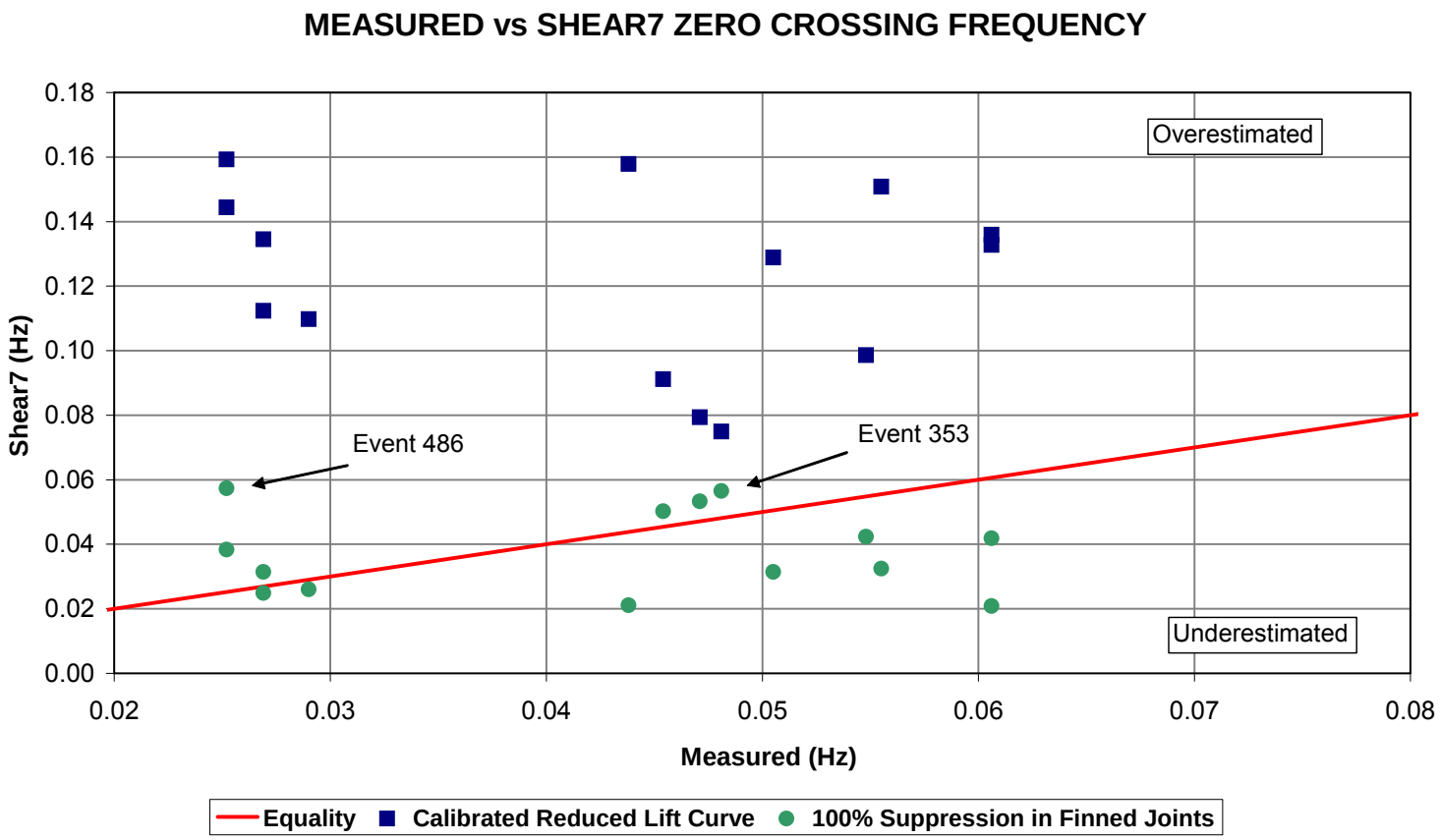
Finned Riser Response: Hung Off



Damage Rate = 0.2 /yr

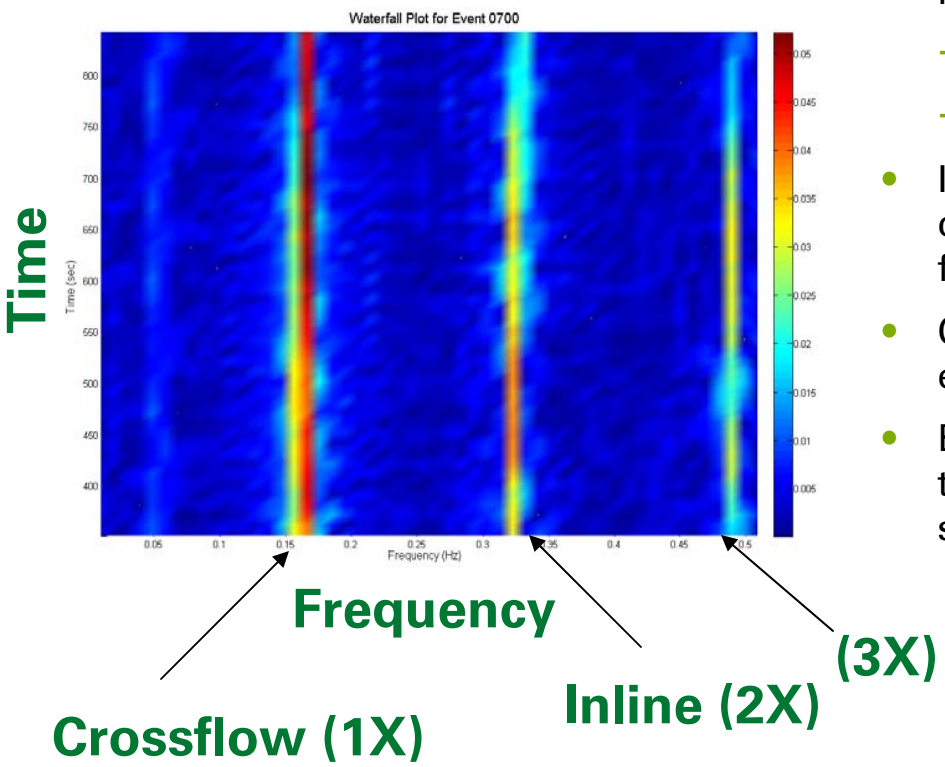
VIV response frequency comparison on *finned riser* data

SHEAR7 frequencies match measured VIV frequencies assuming finned joints have 100% suppression



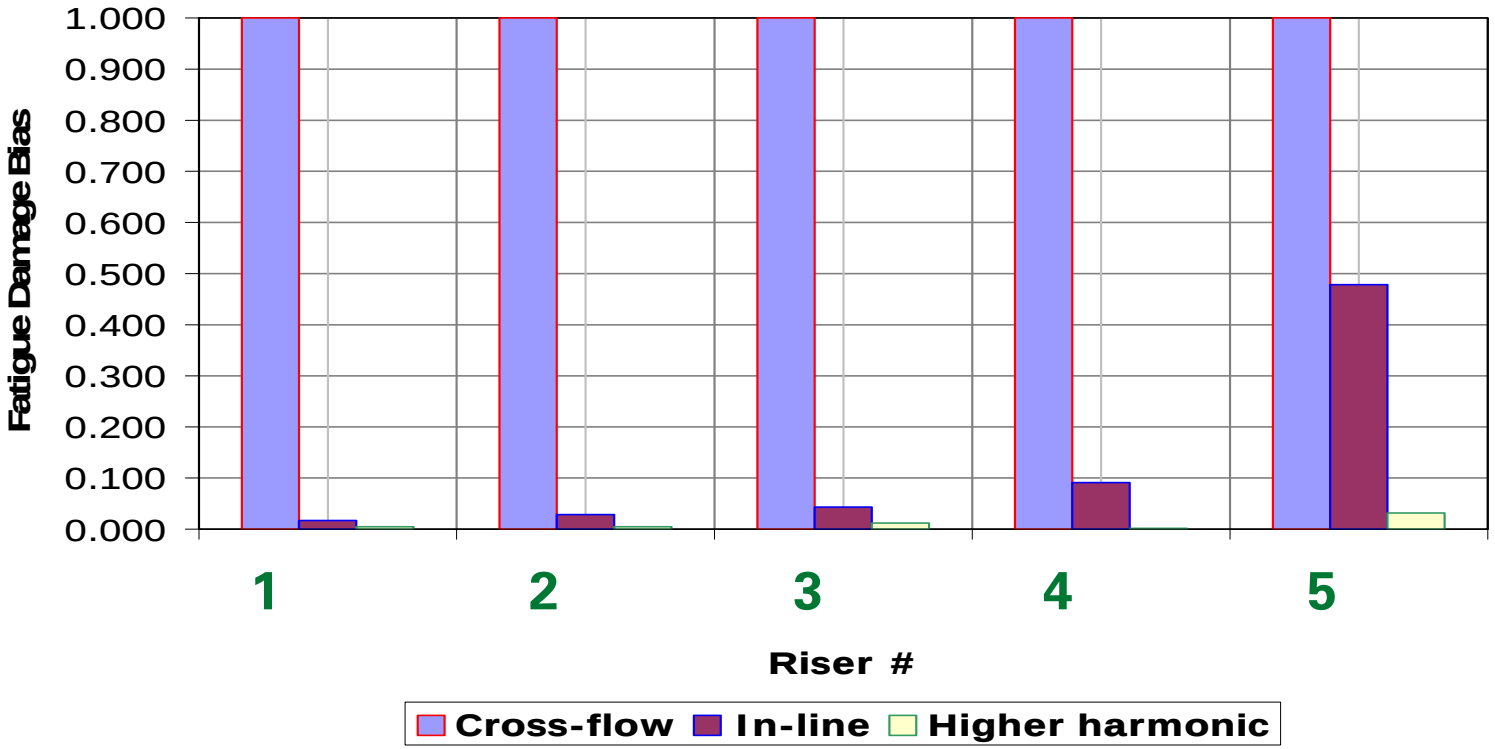
Higher Harmonics Prolific in Model Tests

Example higher harmonic response



- Higher harmonics observed in recent model tests
  - NDP high mode
  - Deepstar Miami - Gulf Stream
- In the tests higher harmonic fatigue damage can exceed cross flow VIV by > factor of 10
- Currently not considered by any of the existing industry VIV tools
- BP field measurements used to confirm the risk of higher harmonic VIV in full scale risers

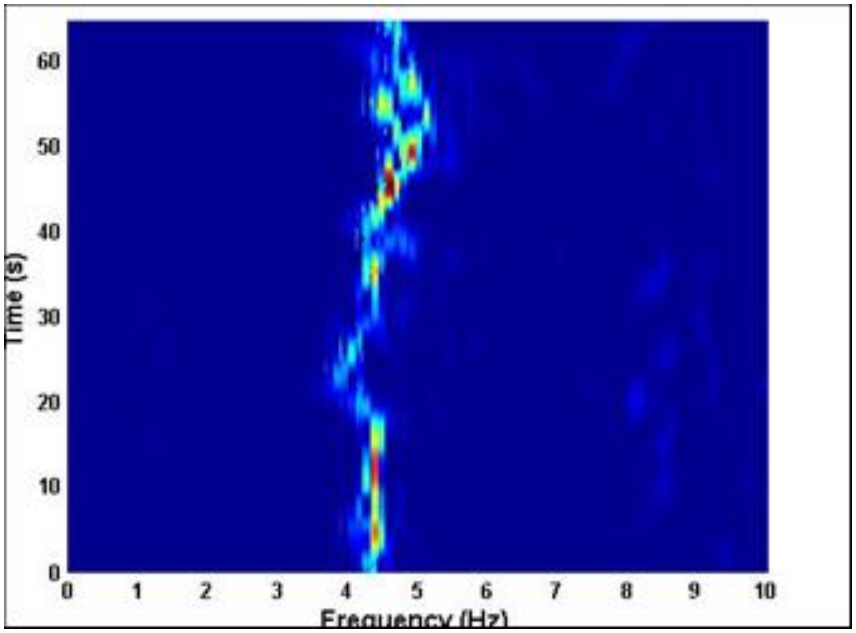
Higher Harmonics Contribute Little in the Field



- Higher harmonic fatigue does occur in full-scale drilling risers
- Resulting fatigue damage is minimal compared to cross flow VIV with exception of one occurrence during rig move
- Differences between tests and full scale are not yet fully understood
- Additional data would assist in understanding when higher harmonics are a risk

Time Sharing of Modes Prolific in Model Tests

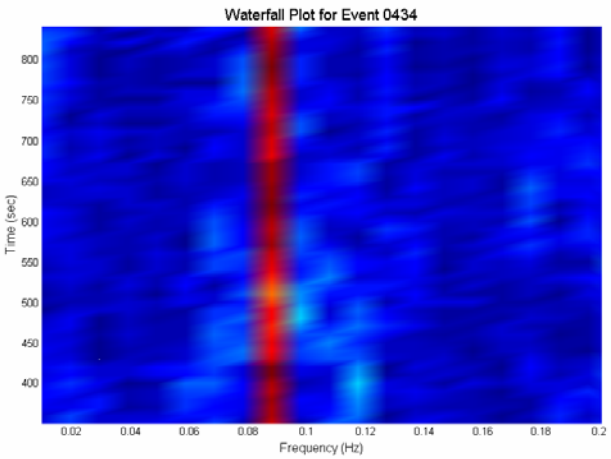
Time sharing example from Deepstar Gulf Stream test



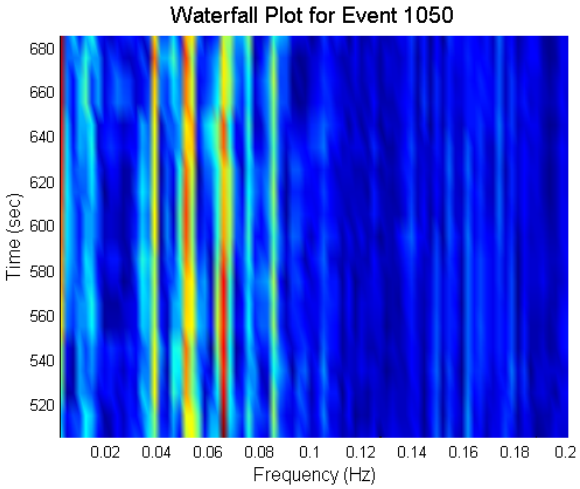
- Definition: Multiple VIV frequencies occurring non-concurrently under the same flow conditions
- SHEAR7 Version 4.5 has been developed based on the principle of time sharing
- Full scale drilling riser measurements used to confirm, or otherwise

Time Sharing of Modes is Rare in Field Observations

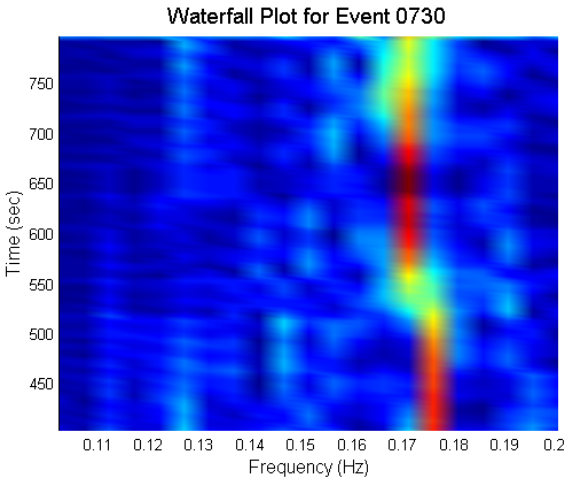
Single mode VIV



Multi mode VIV



Time sharing



- Single mode, multi mode and time sharing VIV observed
- Single mode VIV occurs majority of time
- **Occurrence of time sharing is low**
- Time sharing typically observed during rig moves – varying effective current speed

Conclusions and Recommendations

Conclusions

- Drilling riser monitoring has confirmed safe operations
- VIV design tools are conservative, on average
  - Lot of scatter >> high factor of safety
- Phenomena identified that are not currently considered in VIV design
  - Similarities and differences from model-scale
  - Suppression devices
- At this time uncertainties (and limited data to resolve them) justify continued monitoring

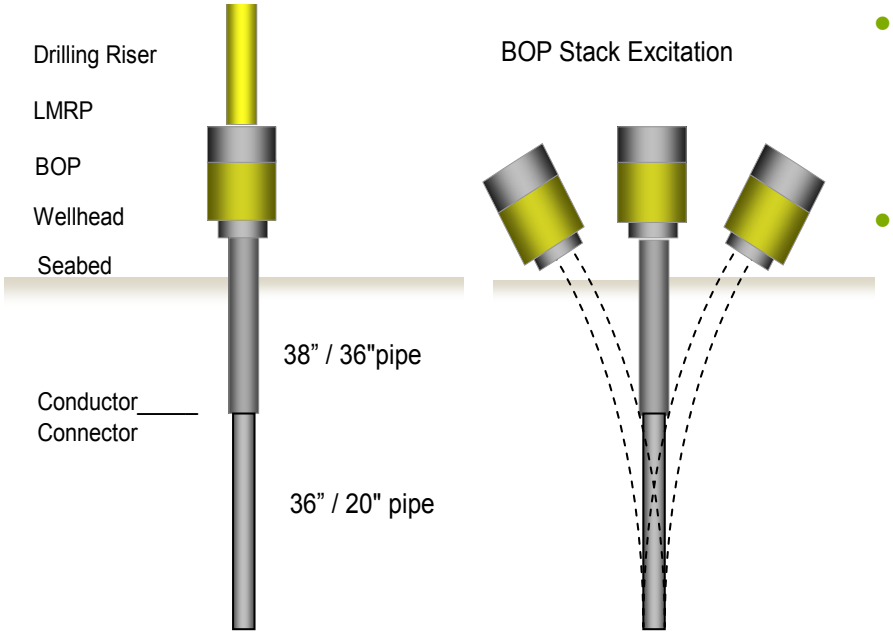
Recommendations

- Continue monitoring as the most reliable means of assessing VIV fatigue and extracting fundamental physics at full scale
- Pursue smarter monitoring that provides operational assistance
  - 1 rig day saved >> annual cost of instrumentation
- Champion development of improved software tools that reflect observed physics
  - DATASETS AVAILABLE ON BENCHMARKING WEBSITE
  - INITIATIVES IN DEEPSTAR AND RPSEA JIPs

Back up slides

BOP stack VIV

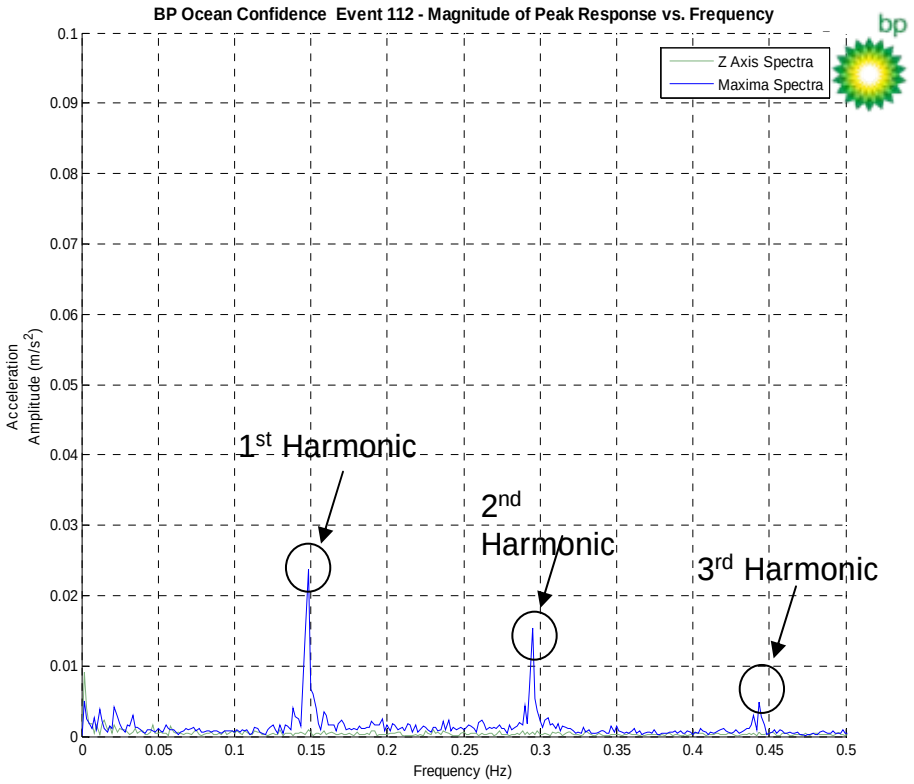
BOP stack excitation

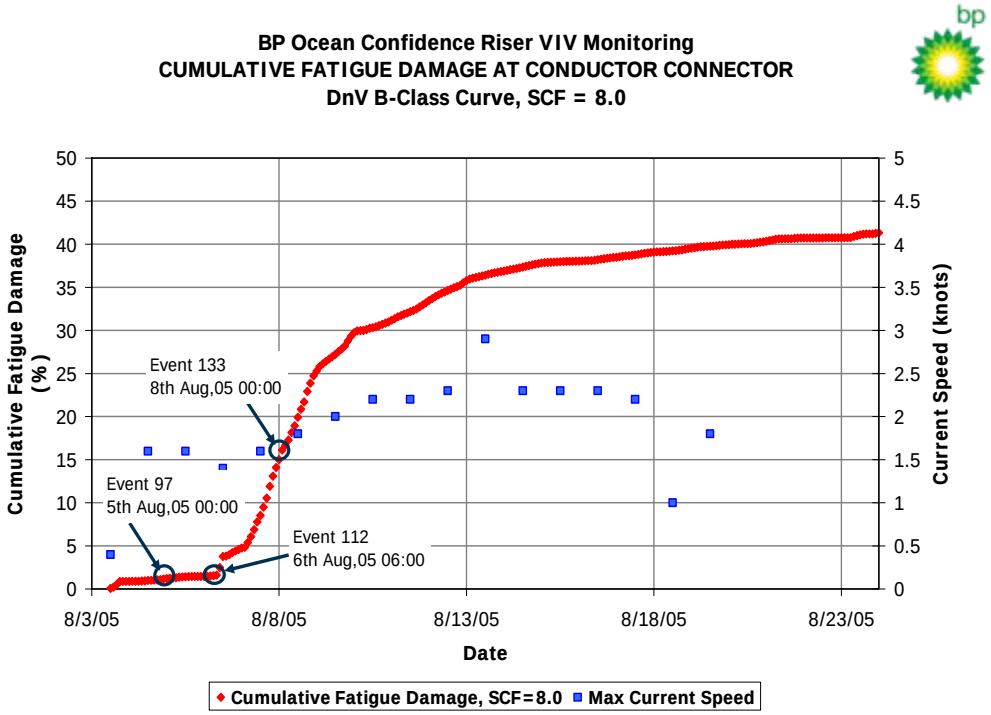


- BOP stack natural frequency excitation has been observed during relatively high-speed loop currents
- This can result in high accumulated fatigue damage at the fatigue critical conductor connector below the mudline
- Motion data collected from an accelerometer placed on the LMRP of the *Ocean Confidence* drilling riser is presented here

Just how bad is it?

- BOP stack vibration at 0.16Hz (6.25 sec stack natural period), and 2nd and 3rd harmonic
- Total fatigue consumption at the first connector is 40% in 12 days





Conclusions

- Loop currents can cause BOP stack excitation which poses serious threat to conductor integrity
- Resulting fatigue damage consumption can be high (40% in 12 days in the example here)
- This may result in insufficient fatigue margins for future well intervention or work-over activities
- Conditions that lead to large BOP motions are poorly understood
- Many unknown factors about what's going on below mudline (soil properties, quality of cement job)
- It is recommended that:
  - contributing factors to BOP VIV receive further study
  - fatigue critical connectors be placed well below the mudline to improve fatigue capacity

Gulf of Mexico BP riser monitoring

Field/MODU	Water depth	Monitoring system	Period of monitoring
1	6000 ft	13 INTEGRIpod-SM data loggers	May 04 – Present
2	6800 ft	1 INTEGRIpod-SM data logger	Nov 04 – Apr 05
3	6800 ft	20 INTEGRIpod-SM data loggers	Nov 05 – Present
4	4100 ft	10 INTEGRIpod-SM data loggers	Apr 06 – Present
5	4600 ft	10 INTEGRIpod-SM data loggers	May 06 – Feb 07
6	6000 ft	14 INTEGRIpod-SM data loggers 3 real-time strain sensors	Jan 07 – Present
7	4500 ft	12 INTEGRIpod-SM data loggers	Jan 07 – Present

Instrumentation for VIV

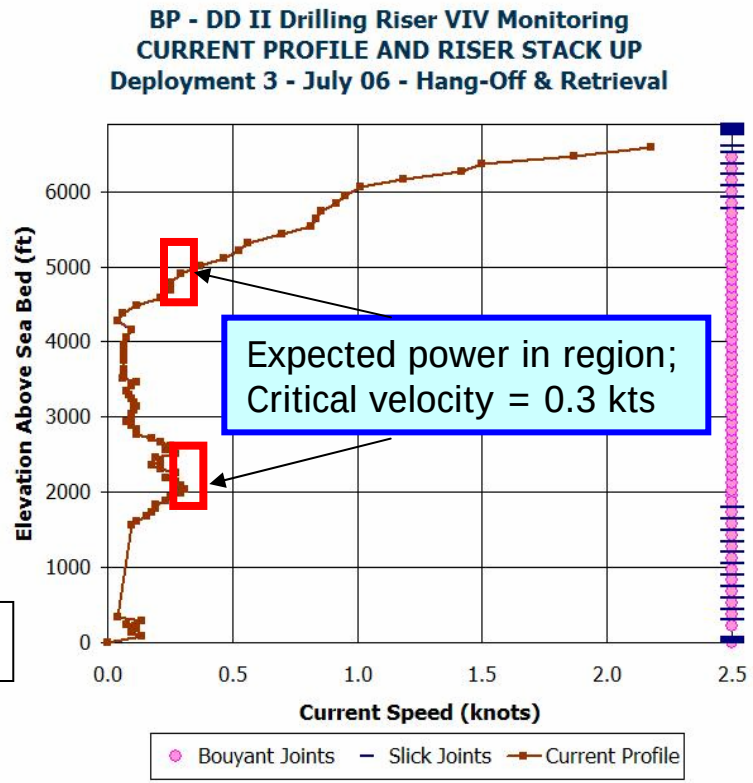
- Motion **INTEGRI pod-M™**

- Strain **INTEGRI stick™**

VIV software calibration

DD2 riser response whilst connected

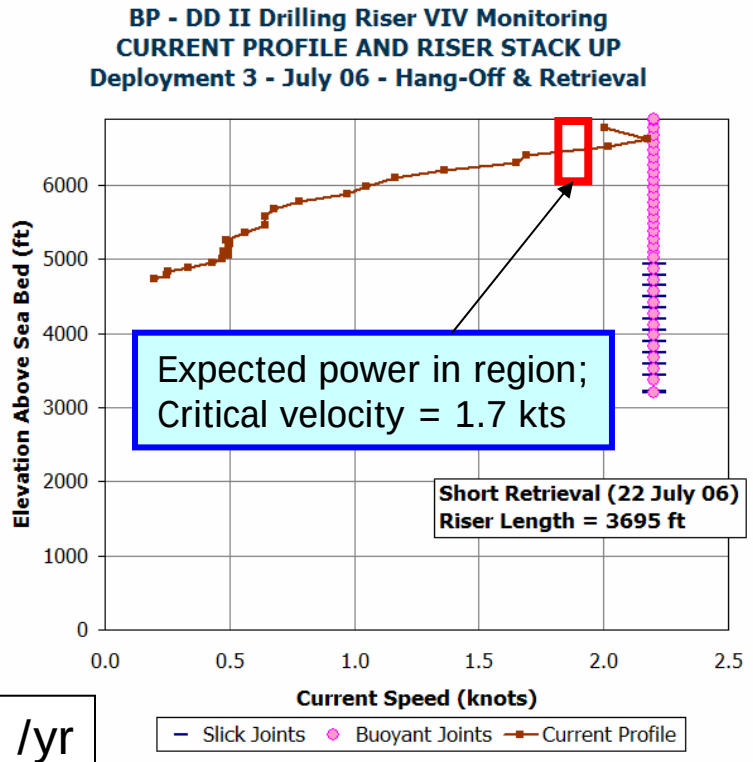
- Measured frequency = 0.025 Hz
- This indicates likely excitation in continuous buoyancy section
- Staggered finned and buoyant arrangement are not powered-in in spite of being subjected to high currents



Damage Rate = 2.2E-6 /yr

Hang Off Riser VIV

- Measured frequency = 0.13 Hz; Excitation in continuous buoyancy
- High currents in continuous buoyancy yields orders of magnitude higher fatigue damage than high currents in staggered buoyant and finned joints

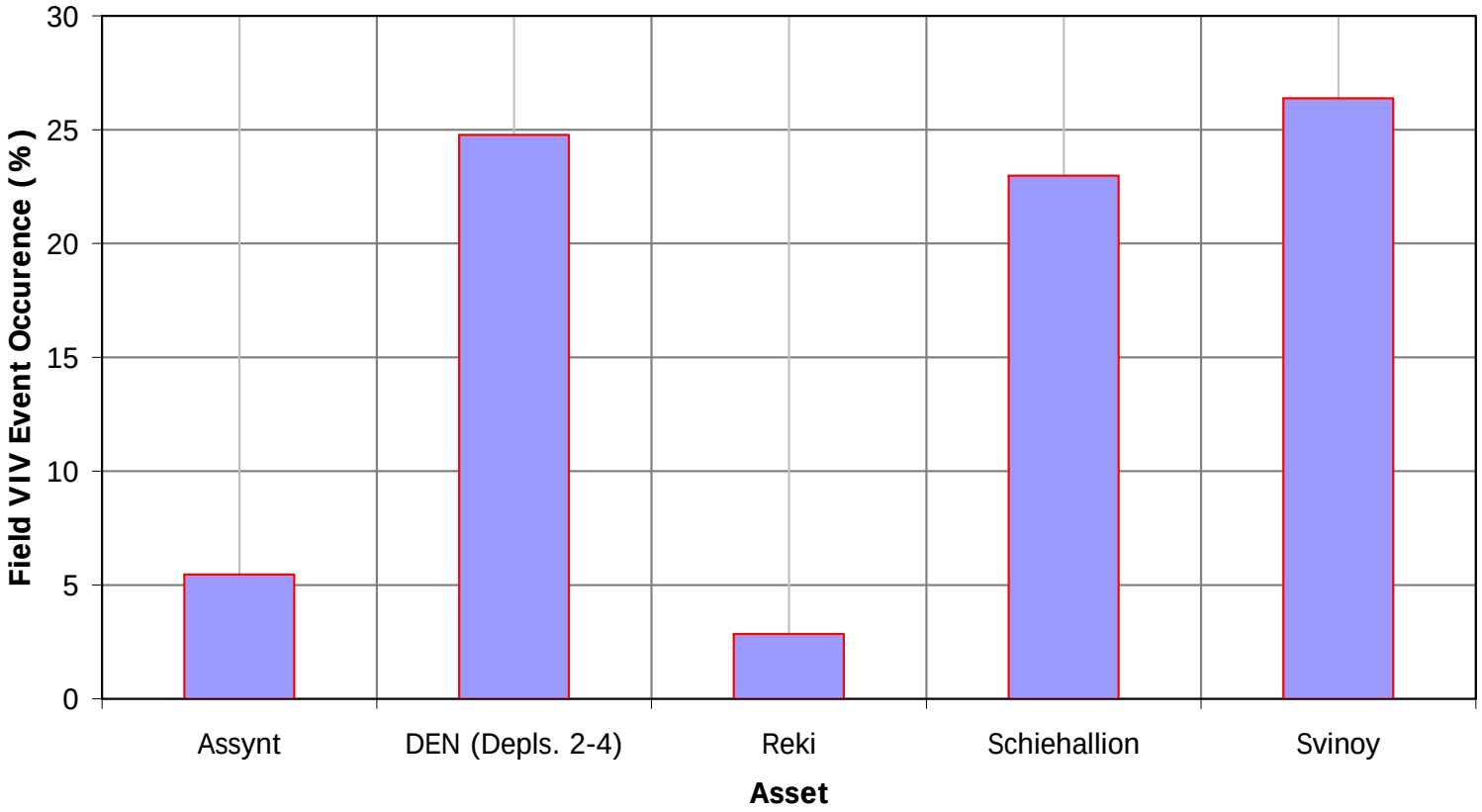


Damage Rate = 0.2 /yr

Key findings and software limitations

VIV occurrence in the field

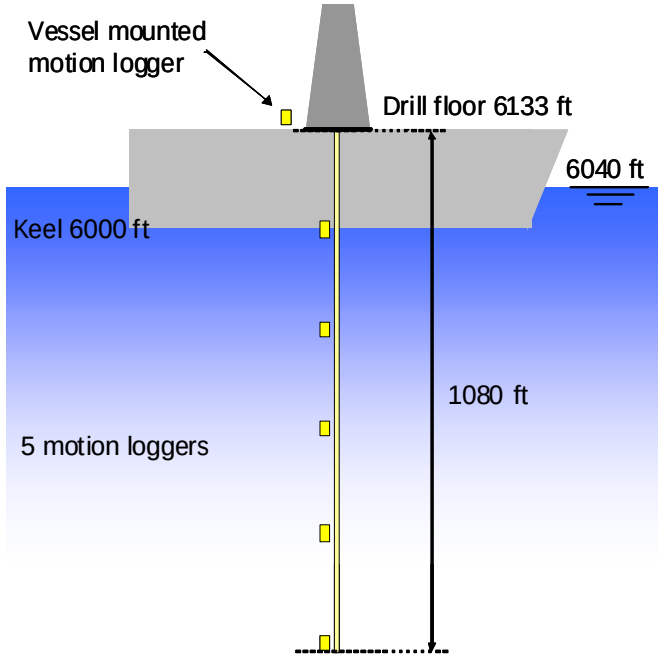
- VIV occurs 17% of the time for our monitored drilling risers
- VIV design tool identifies VIV majority of the time



Field data for determining higher harmonics

Field	Location	Rig	Water Depth (ft)
Schiehallion	West Of Shetland	Paul B. Lloyd	1,181
Svinoy	Faroes	West Navion	3,510
Assynt	Faroes	West Navion	3,166
Reki	Amazon Basin	C.R. Luigs	3,172
Thunder Horse	Gulf of Mexico	DEN	6,200

Drill pipe test



Conclusions

- *DD2* riser typically demonstrates mild VIV response compared to *Enterprise* which is in a similar water depth and current conditions and does not have any suppression.
- The difference between *DD2* and *Enterprise* is the presence of finned slick joints and staggered finned and buoyant joints
- Maximum VIV damage on *DD2* is accumulated when it is partially deployed and the continuous buoyancy section is exposed to high surface currents.

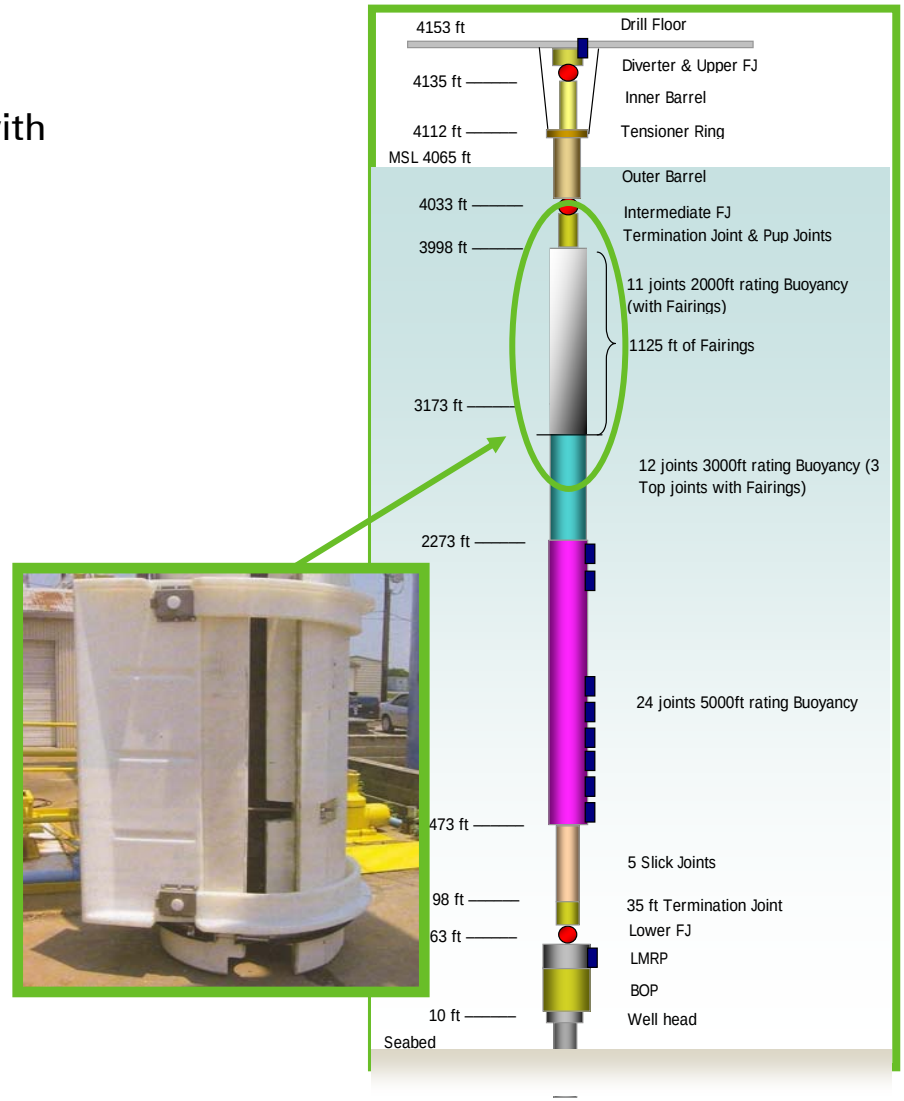
Tail-fin drilling riser fairings

Fairings Data:

- 14 buoyant joints (1050′) equipped with fairings
- SGSI - two strap **“Tailfin”** fairings
- Chord/Diameter (C/D) Ratio: 1.45
- Length: 6 ft

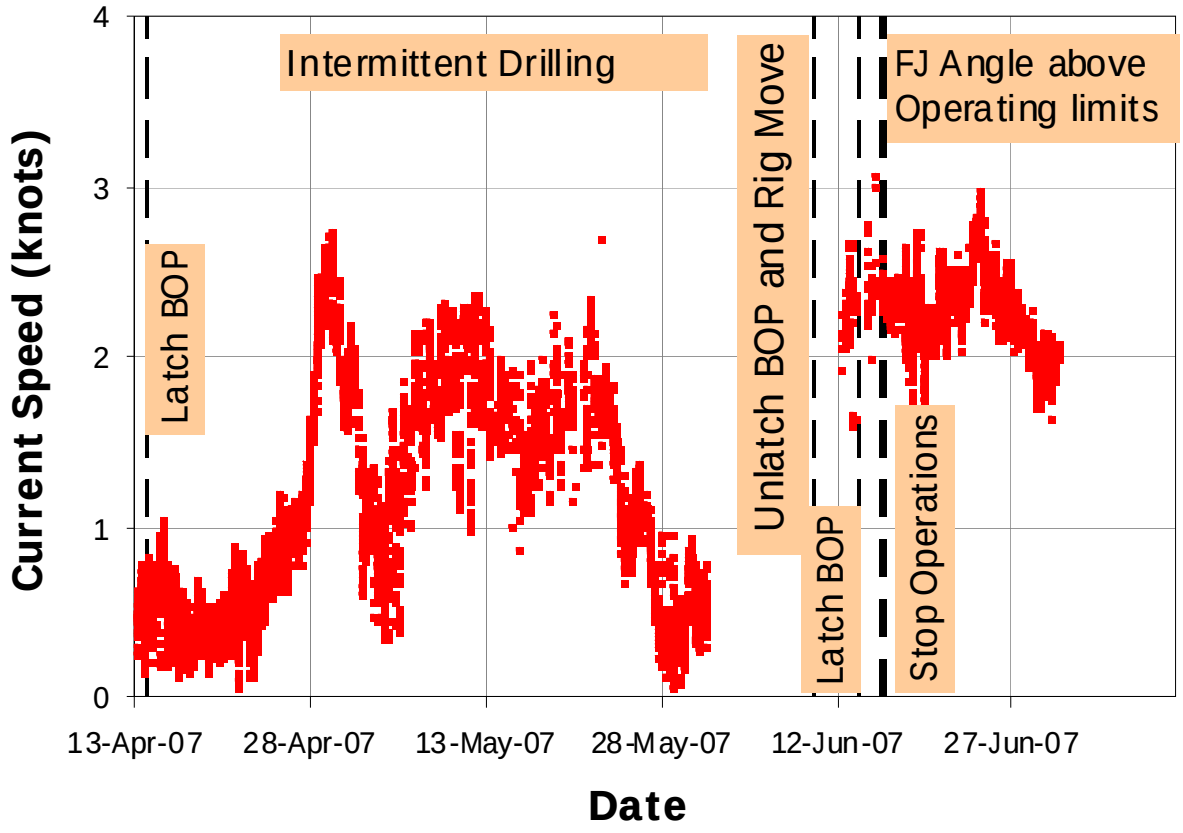
Monitoring Data:

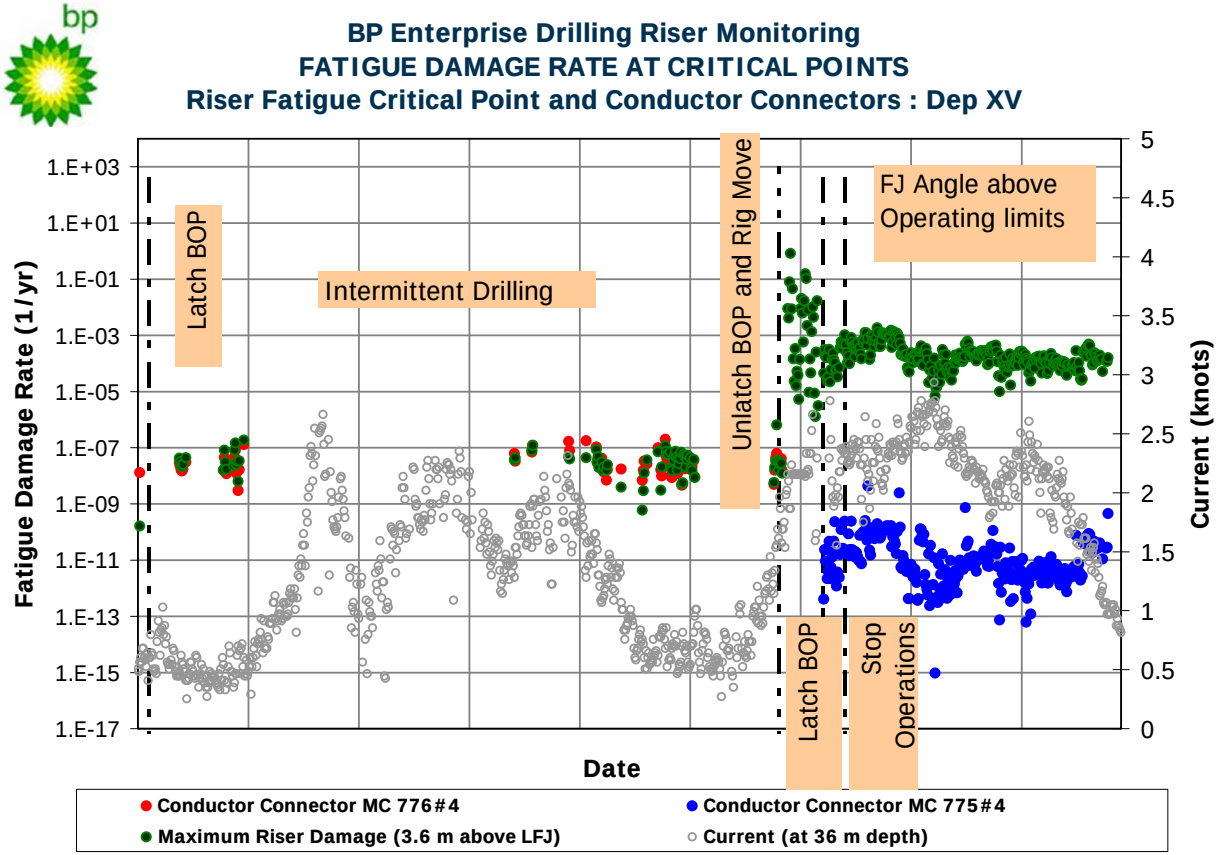
- 2 months of monitoring
- 4.1% VIV occurrence
- Max current speed: 0.95 knots



Case study – Does time sharing occur for a riser undergoing VIV?

Sustained currents > 2 knots and VIV observed 42% of time



Case study – Does time sharing occur?

Fatigue damage rates are 10 to 100 times higher during hang-off