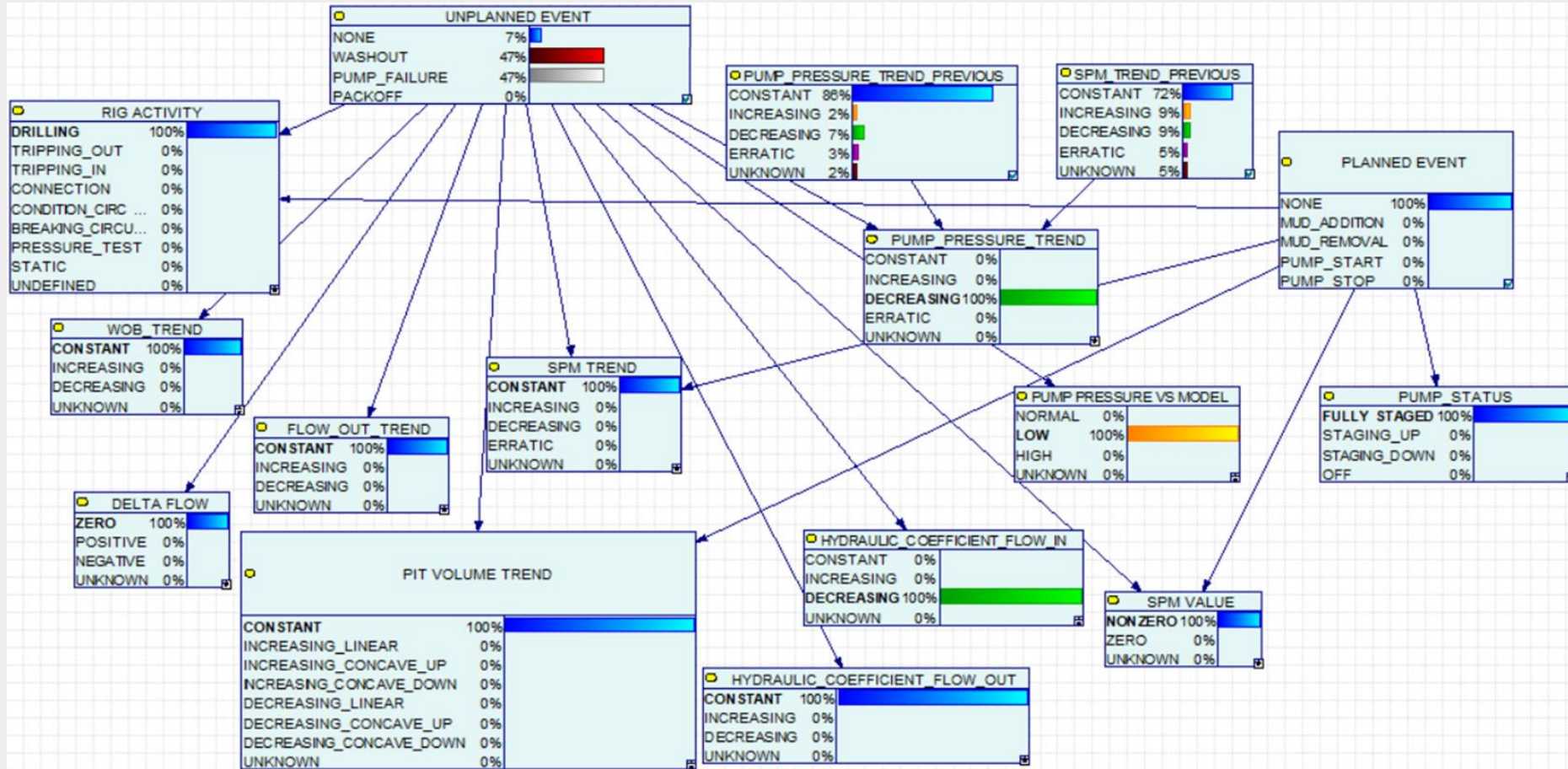
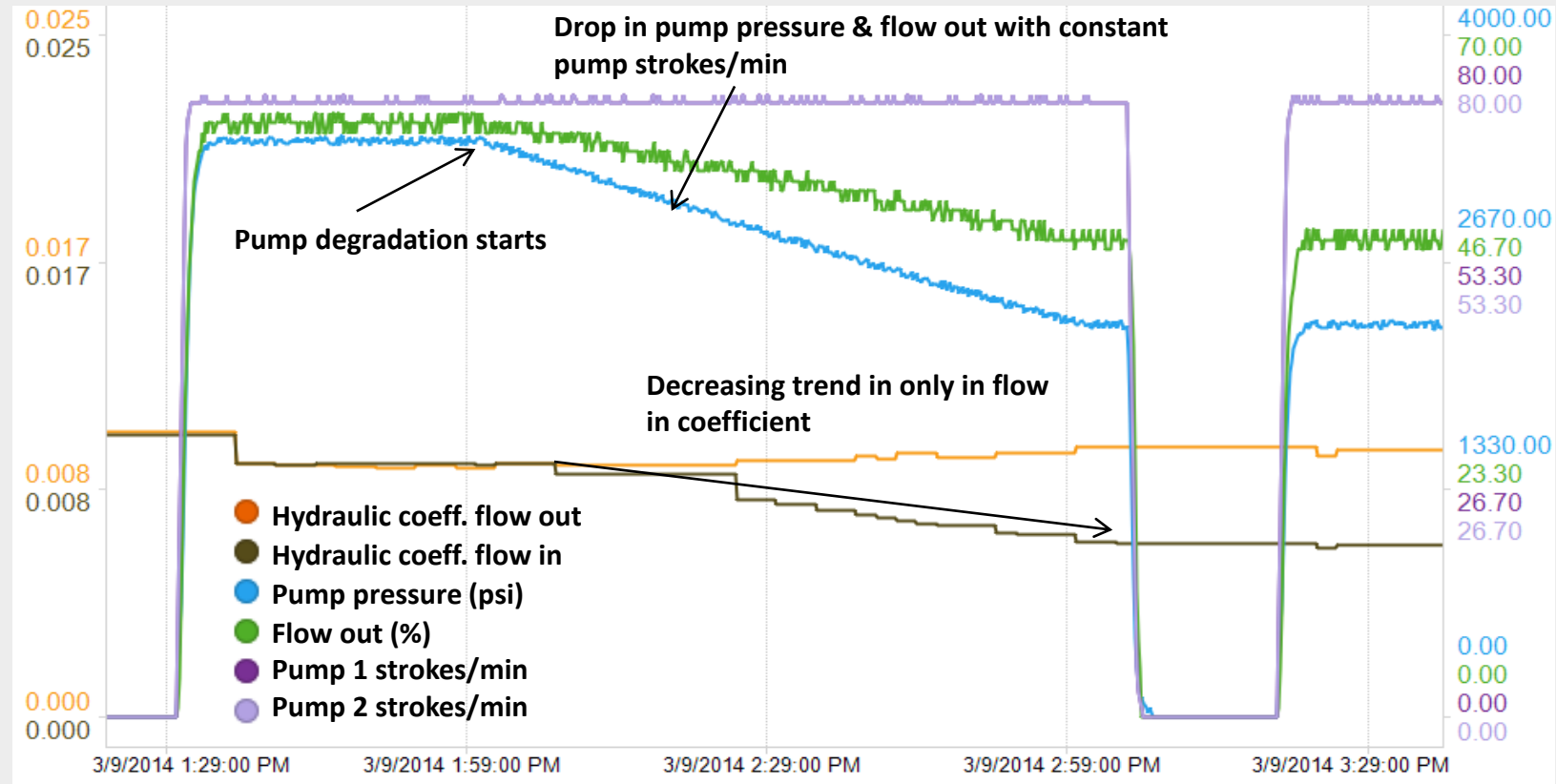


Bayesian Network Model for Pump Failure Detection



Real-Time Data Trends During Pump Failure



Pump Failure: Influential Features I

Node	Feature Description	Node State Breakdown	State Conducive to Belief
Delta Flow	Flow Out-Flow In	ZERO: Close to zero delta flow POSITIVE: Positive delta flow NEGATIVE: Negative delta flow	Zero
Flow Out Trend	Flow out trend over short time window	CONSTANT: Constant flow out INCREASING: Increasing flow out DECREASING: Decreasing flow out	Constant
Hydraulic Coefficient Flow In	Flow in hydraulic coefficient trend over a long time window where: $h_{flow-in} = \frac{P}{Q_{in}^2}$	CONSTANT: Constant flow in hydraulic coefficient INCREASING: Increasing flow in hydraulic coefficient DECREASING: Decreasing flow in hydraulic coefficient	Decreasing
Hydraulic Coefficient Flow Out	Flow out hydraulic coefficient trend over a long time window where: $h_{flow-out} = \frac{P}{Q_{out}^2}$	CONSTANT: Constant flow out hydraulic coefficient INCREASING: Increasing flow out hydraulic coefficient DECREASING: Decreasing flow out hydraulic coefficient	Constant
Pit Volume Trend	Behavior of the pit volume curve over a short time window	CONSTANT: Constant pit volume INCREASING LINEAR: Pit volume increasing linearly INCREASING CONCAVE UP: Pit volume increasing concave up INCREASING CONCAVE DOWN: Pit volume increasing concave down DECREASING LINEAR: Pit volume decreasing linearly DECREASING CONCAVE UP: Pit volume decreasing concave up DECREASING CONCAVE DOWN: Pit volume decreasing concave down	Constant

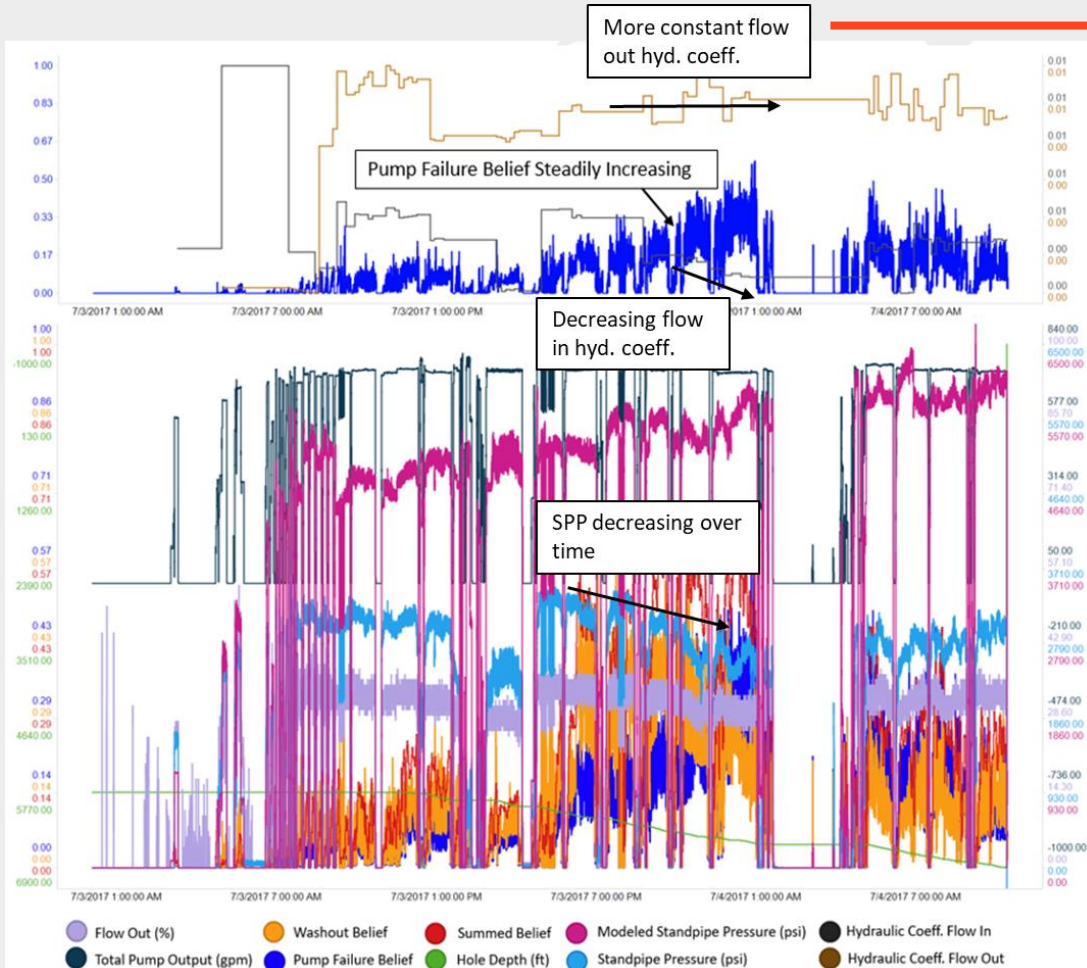
Pump Failure: Influential Features II

Node	Feature Description	Node State Breakdown	State Conducive to Belief
Rig Activity	Current rig state	DRILLING: Rig state drilling rotary or drilling slide TRIPPING OUT: Rig state tripping out TRIPPING IN: Rig state tripping in CONNECTION: Rig state connection drilling, connection trip in, or connection trip out CONDITION CIRC MUD: Rig state condition circulate mud BREAKING CIRC: Rig state breaking circulation PRESSURE TEST: Rig state pressure test STATIC: Rig state static	Drilling, condition circ mud
Pump Pressure Trend	Pump pressure trend over a short time window	CONSTANT: Constant pump pressure INCREASING: Increasing pump pressure DECREASING: Decreasing pump pressure ERRATIC: Erratic pump pressure	Decreasing
Pump Pressure vs Model	Raw pump pressure with respect to modeled pump pressure $P - P_{\text{model}}$	NORMAL: Pump pressure close to modeled pump pressure LOW: Pump pressure much lower than modeled pump pressure HIGH: Pump pressure much higher than modeled pump pressure	Low
SPM Trend	SPM trend over short time window	CONSTANT: Constant SPM INCREASING: Increasing SPM DECREASING: Decreasing SPM ERRATIC: Erratic SPM	Constant
SPM Value	Raw SPM	NONZERO: Nonzero SPM ZERO: Zero SPM	Nonzero
WOB Trend	WOB trend over short time window	CONSTANT: Constant WOB INCREASING: Increasing WOB DECREASING: Decreasing WOB ERRATIC: Erratic WOB	Constant

Washout and Pump Failure Beliefs – Use during Operations

- Washout and pump failure signatures are the same except for flow out hydraulic coefficient
 - Washout: decreasing flow out hyd. coefficient
 - Pump failure: constant flow out hyd. coefficient
- If flow out is unavailable or not calibrated properly, distinguishing between the two dysfunctions is even more impractical
- For this reason, the **sum of washout and pump failure beliefs are monitored** instead of each one individually
- If the sum of these beliefs reaches the event threshold, a washout/pump failure event is established
- From that point, the operator can verify which of the two dysfunctions is truly occurring

Pump Failure: Example



Check out paper SPE-189700-MS for more information

You can also email info@intellicess.com for a copy of the paper