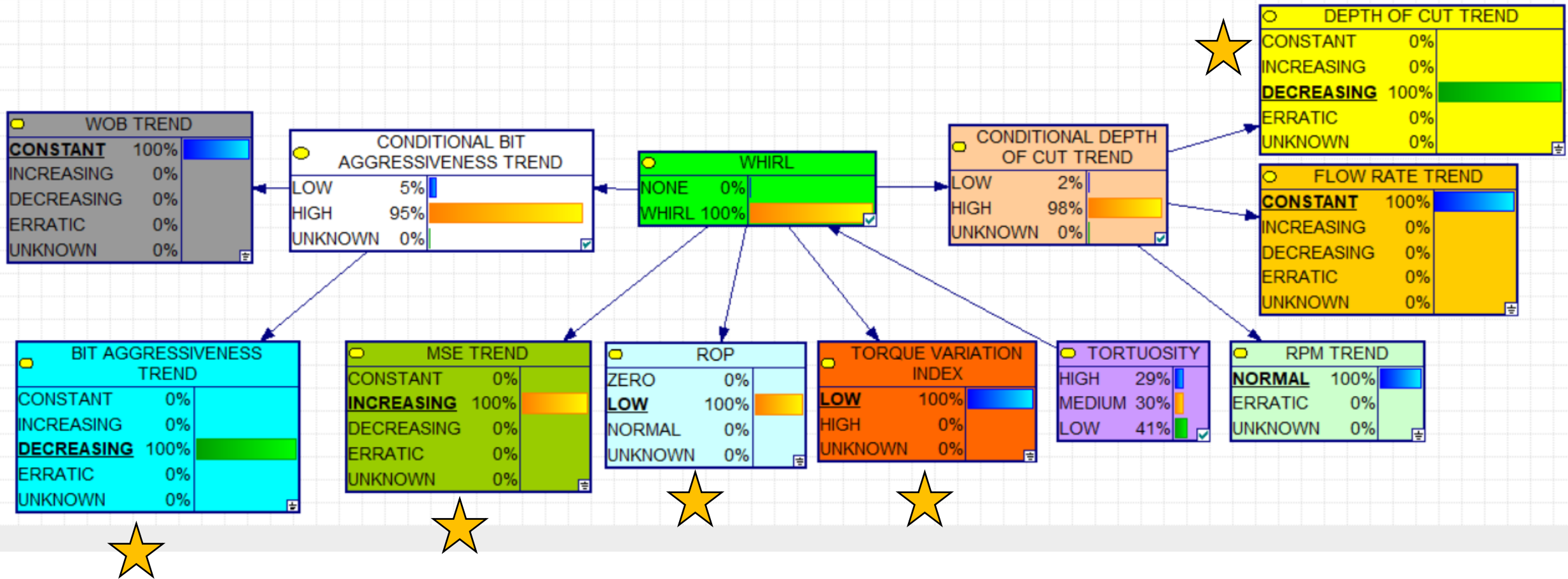


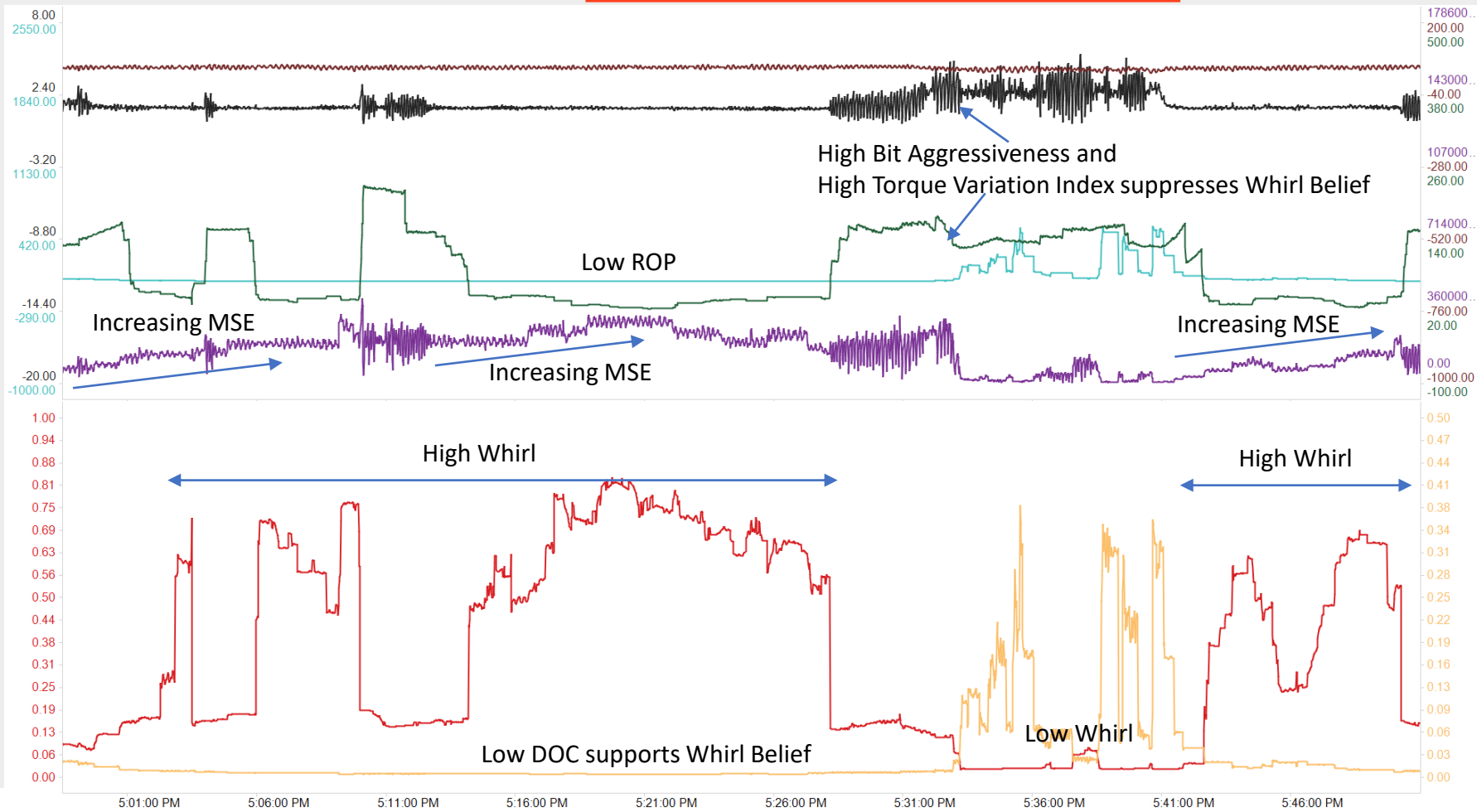
Whirl – Bayesian Network Model



Influential Features

Node	Feature Description	Node State Breakdown	State Conducive to Belief
Conditional Bit Aggressiveness Trend	Surface bit aggressiveness decreasing given constant WOB, where: $\text{Surface Bit Aggressiveness} = \frac{12 * T}{WOB * d}$	LOW: Bit aggressiveness not decreasing given constant WOB HIGH: Bit aggressiveness decreasing given constant WOB	High
Conditional Depth of Cut Trend	Depth of cut decreasing given constant flowrate and non-erratic RPM, where: $\text{Depth of Cut} = \frac{12 * ROP}{60 * (RPM + Q_{in} * RPG)}$	LOW: DOC not decreasing given constant flowrate and non-erratic RPM HIGH: DOC decreasing given constant flowrate and non-erratic RPM	High
ROP	Real-time .5ft cut foot ROP with respect to configurable expected ROP values	ZERO: Zero ROP LOW: ROP low compared to expected value NORMAL: ROP meets or exceeds expected value	Low
MSE Trend	Surface MSE trend over short time window where: $MSE_{surface} = \frac{4 * WOB}{\pi * (d)^2} + \frac{480 * RPM * T}{(d)^2 * ROP}$	CONSTANT: Constant MSE INCREASING: Increasing MSE DECREASING: Decreasing MSE ERRATIC: Erratic MSE	Increasing
Torque Variation Index	Erraticity of torque: $\text{Torque Variation Index} = \frac{\text{Torque}_{max} - \text{Torque}_{min}}{\text{Torque}_{avg}} \times 100$	LOW: Non-erratic torque HIGH: Erratic torque	Low

Illustration of Whirl Model in Action



- WOB
- Bit Aggressiveness
- Torque Variation Ind.
- ROP
- Surface MSE
- Depth of Cut
- Whirl Belief