PROJECT EXECUTION
TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance

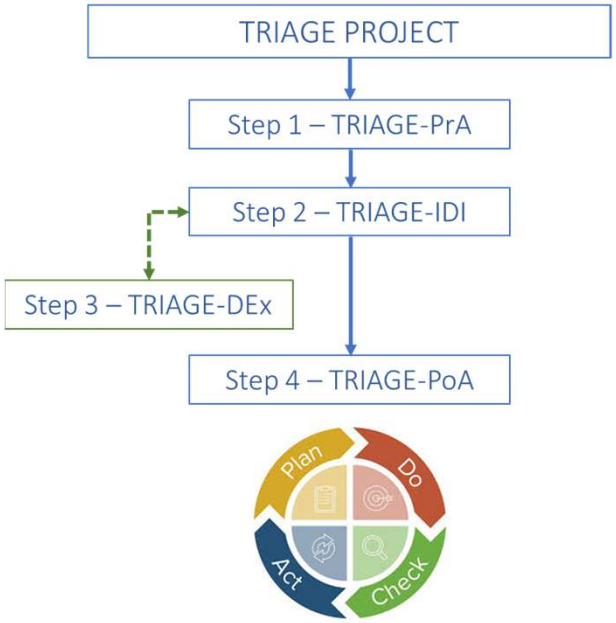
Internal Corrosion

		Increasing Likelihood of Pipeline Leak				
SEGMENT COUNT		1	2	3	4	5
Consequence Business Loss ($)	5	685	502	278	159	223
	4	216	212	244	167	135
	3	449	341	308	206	141
	2	632	551	605	394	247
	1	197	131	95	74	34
SUM		2179	1737	1530	1000	780
PERCENT OF TOTAL		30%	24%	21%	14%	11%

SEGMENT COUNT	
SUM	PERCENT
1847	21%
974	11%
1445	17%
2429	28%
531	6%

Corporte Summary		
SEGMENT COUNT		RISK CLASS
2336	32%	SERIOUS
2761	38%	MODERATE
2129	29%	LOW
7226	**100%**	**TOTAL**

Pin-Pointing the most Probable Locations for Corrosion Damage & Mitigation Guidance to Prevent Growth

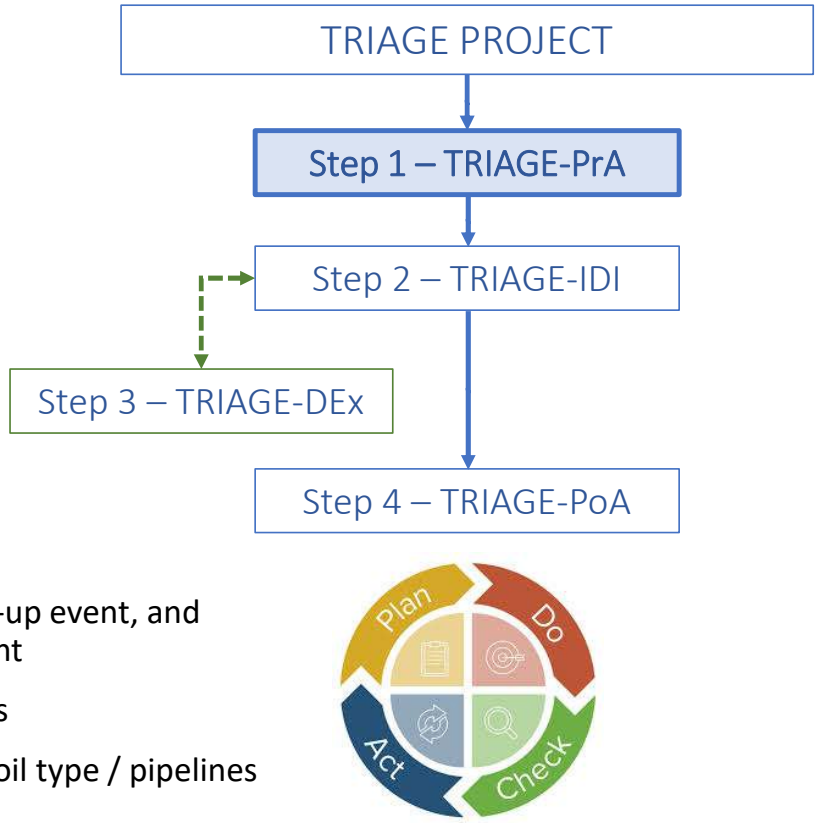


TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance

Step 1 – Preassessment – PrA

- AER Public Data Sources
  - Well - License Data / Well – Monthly Production Data (1978 – 2020)
    - hours / oil / gas / water
  - PL-100 Pipeline License Data
- Data Conditioning & Analysis
  - Apply Well-Pipeline-Facility Network Connectivity Algorithm
  - Apply Network (O/G/W) Production Allocation Algorithm
  - Apply Well Production Data Queries and Scoring Algorithm
    - Score A - Well Severity Score
      - Profile over-life hydraulic behaviour and consider likelihood well behavior will contribute to pipeline corrosion
      - Likelihood of biomass sludge incubation at time of drilling
    - Score B – Well – Pipeline Severity Score
      - Consideration of well dynamics, fugitive fluid up-lift at well start-up event, and spatial and sibling association with historical pipeline failure event
- Digital Elevation Data (DEM) / Create Elevation Profiles / Inclination Angle Profiles
- Spatial Data Interaction Queries (not mandatory) – water features / roadways / soil type / pipelines
- Client Data – TRIAGE Data Validation Form (not mandatory)

Pin-Pointing the most Probable Locations for Corrosion Damage & Mitigation Guidance to Prevent Growth

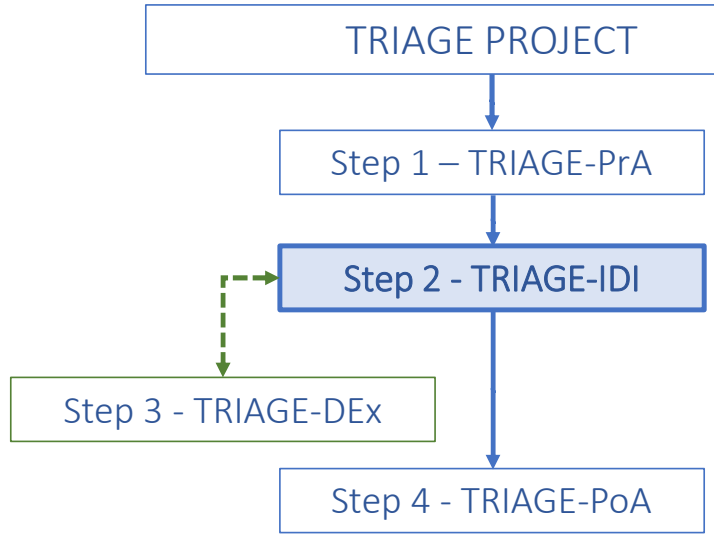


TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance

Step 2 – Indirect Inspection – IDI / Internal Corrosion

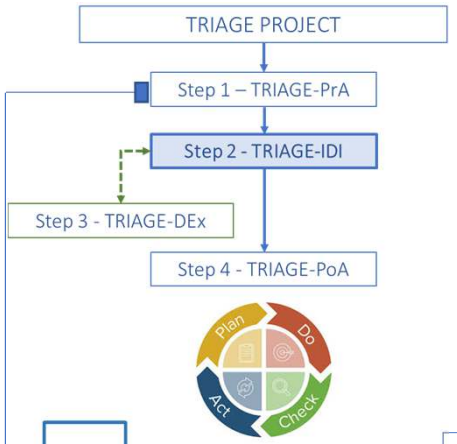
- TRIAGE Hazard Classification - Likelihood Scoring Algorithm
  - Calculate maximum expected corrosion rate by application of NACE – deWaard & Milliams corrosion rate model
    - Consider factors contributing to acceleration of corrosion rate
      - Environmental factors – bacteria / H2S / oxygen ingress
      - Fugitive fluid ingress – upstream facility upsets / biomass sludge ingress attributed to upstream well hydraulics
  - Calculation of water-film transport severity using NACE – ICDA critical inclination angle models as a determination of potential isolated pitting corrosion damage
  - Establish expected over-life unmitigated cumulative metal wall loss
- TRIAGE Consequence Algorithm
  - Consideration of business losses associated with a failure event; loss of asset / replacement cost / environmental impact and remediation cost
- TRIAGE Mitigation Guidance
  - Publish a hierarchy of prioritized mitigation options (versus singular directives) for consideration by field, operation / chemical teams

Pin-Pointing the most Probable Locations for Corrosion Damage & Mitigation Guidance to Prevent Growth



TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance / Internal Corrosion

Project Implementation - Step 2 – Indirect Inspection



TRIAGE Step 2 – IDI Project Execution

TRIAGE – Enhancements to Standard Methods:

- Score A – Data pattern analytics to evaluate severity of upstream well hydraulics to potential pipeline corrosion
- Score B – Consideration of biomass incubation at drilling and sibling association with historical pipeline failure events

Common to Industry & TRIAGE Methods:
NACE – CO2 Corrosion Rate / deWaard & Milliams
Critical Inclination Angle to Create Water Traps
Considers Corrosion by Production Fluids Only

AER WellCard All-Alberta

AER Production All-Alberta 1978 - Present

SCORE A CALCULATION PROCESS Data Queries / Well Severity Calculation

CALCULATION PROCESS O / G / W Allocation to Wells

SCORE B CALCULATION PROCESS Spatial Data Queries Incubation Biomass Sludge Sibling Association with Historical Failures

AER PipeCard All-Alberta

AER Facility Data All-Alberta

DEM Elevation Profiles

CALCULATION PROCESS O / G / W Network Connectivity & Production Allocation Algorithms

SCORE C CALCULATION PROCESS NACE Corrosion Rate & Stagnant Water Trap Severity Score

TRIAGE RISK CALCULATOR & MITIGATION GUIDANCE

DATA VALIDATION FORM From Client

AbaData 2.0

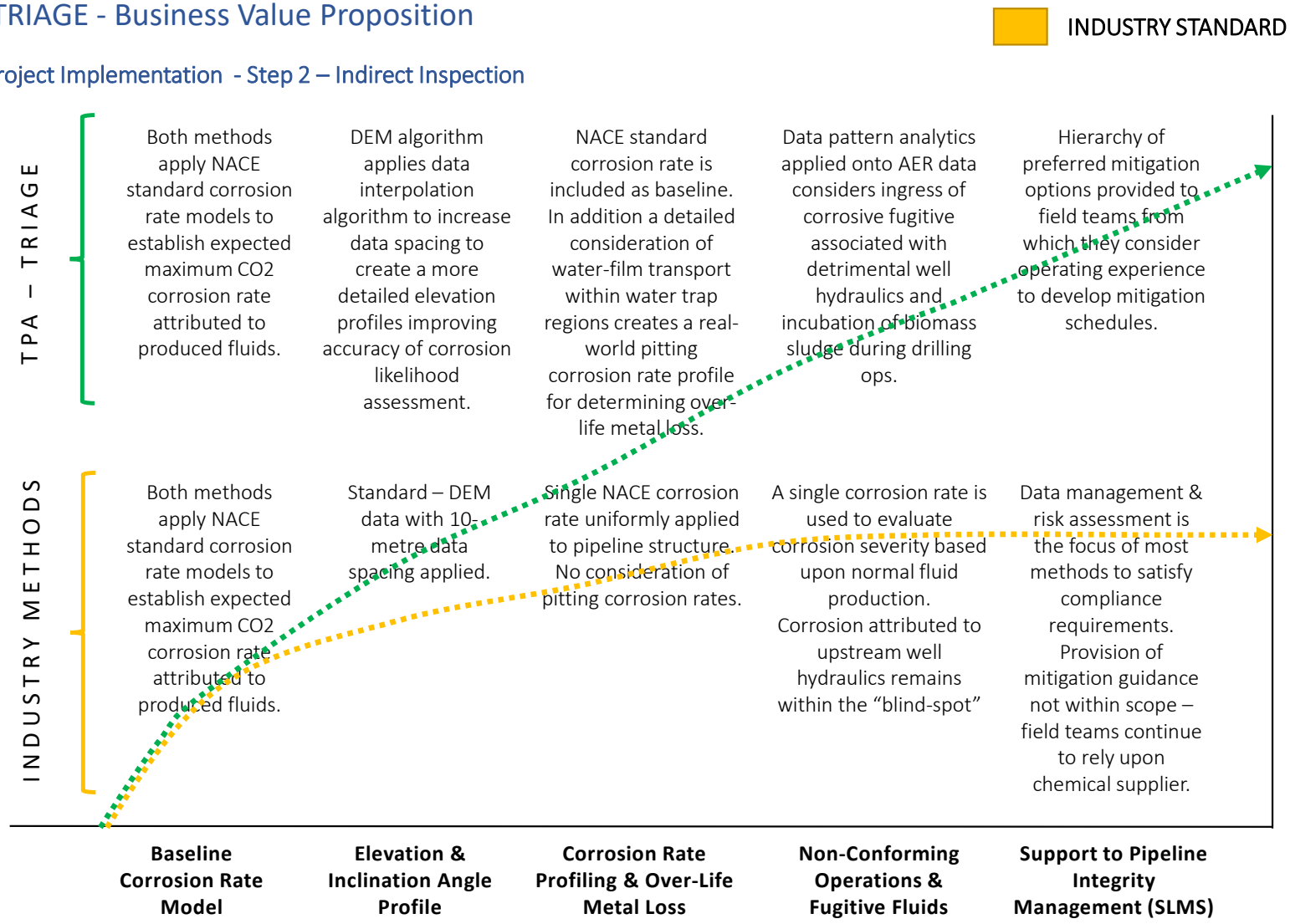
TRIAGE Fully Integrated Data Visualization & Reporting

Web Reports

- Pipeline & Operating Data;
- Corrosion Likelihood Score;
  - Produced fluids
  - Fugitive fluids
- Business Loss Consequence;
- 5x5 Risk Matrix Summary;
- Mitigation Guidance.

TRIAGE - Business Value Proposition

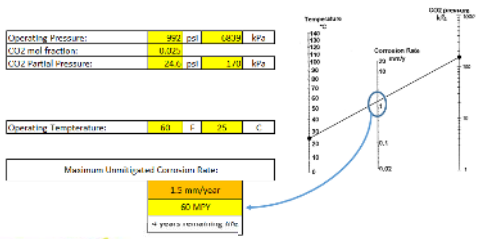
Project Implementation - Step 2 – Indirect Inspection



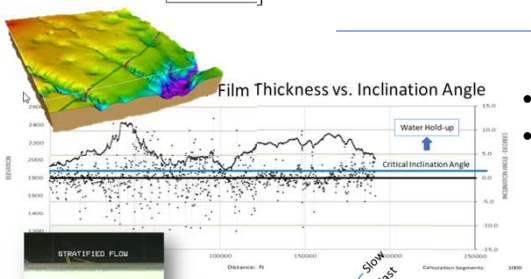
TRIAGE – Summary of Benefits

- TRIAGE considers former blind-spot integrity hazards associated with detrimental well hydraulics during start-up events
- TRIAGE provides a hierarchy of applicable mitigation options for consumption by field, operations teams from which they apply their knowledge to create the best mitigation strategy
- Field, operations are positioned to modify mitigation as changes to the hazard profile occur over time.

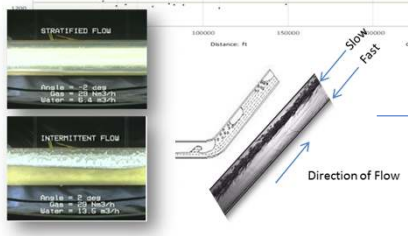
TRIAGE – Corrosion Assessment



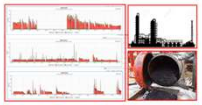
- NACE – CO2 corrosion rate
- Environmental factors causing an increase in corrosion

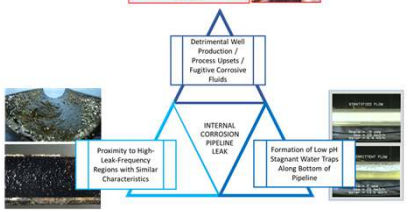


- Water-film transport
- Water-oil slippage & critical inclination angle to cause low pH water traps



- Factors that can cause increased corrosion within detrimental water traps





- Data pattern analytics to consider implication of upstream well behaviour
- Fugitive fluid ingress

Corrosion by Normal Produced Fluids

STEP 1 -- FLUID COMPOSITION FACTORS:

fc1(corrosion rate / NACE deWaard / age / remaining life)

ef1(corrosion scale by-product consideration of CO2 / H2S)

ef2(oxygen ingress ./ consideration of upstream facility)

"SUB-SCORE A" = Likelihood Score: Fluid Composition Aggressiveness

STEP 2 -- FLUID FLOW FACTORS:

Apply one of the Following:

apply: ff1(Gas Flow Severity: consideration of critical inclination angle exceedance)

or: ff2(Oil Flow Severity: water & oil phase slippage)

Sub-total – Fluid Flow Factors

environmental multiplier

apply greater of: ef3a (bacteria counts)

or: ef3b (suspended solids)

"SUB-SCORE B" = Likelihood Score: Fluid Flow Aggressiveness

STEP 3 -- SUB-TOTAL LIKELIHOOD SCORE "A" + "B"

Upstream Well Dynamics

STEP 4 -- CONSIDERATION OF TRIAGE / DATA ANALYTICS

TRIAGE Score A: UWI Severity Score (consider on-off-on cycles / production spikes / days-to-commission)

TRIAGE Score B: Spatial Score (consideration of historical failure data / sibling association)

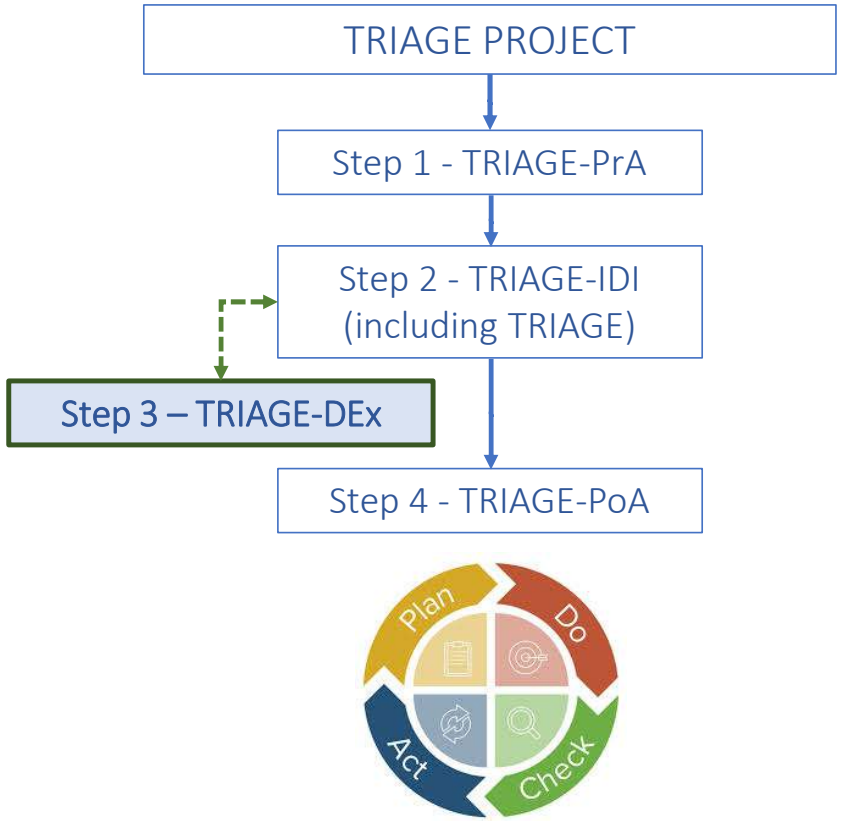
STEP 5 -- TRIAGE SCORE C: Final IC Severity Score (considers TRIAGE A & B + Step 3)

TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance

Step 3 – Direct Examination - DEx

- Execute Integrity Validation Plan
  - Pipeline excavations at most probable locations (MPL's)
    - Apply non-destructive (NDE) techniques to measure pipeline wall thickness
  - Perform in-line inspection of pipeline with coverage of MPL's

Pin-Pointing the most Probable Locations for Corrosion Damage & Mitigation Guidance to Prevent Growth



TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance

Step 4 – Post Assessment - PoA

- TRIAGE Project Report
  - Effectiveness of TRIAGE

TRIAGE IMPLEMENTATION OF INTEGRITY PLANS

- Implementation of Mitigation Guidance (from TRIAGE Step 2 – IDI)
  - Application of Mitigation Guidance published from IDI - Step 2
    - Workshops with field, operations teams
    - Consideration of system knowledge and operating experience to create final mitigation schedules
  - Ongoing support to implementation of performance-based (SLMS) pipeline integrity management process
    - Pipeline operating manuals
    - Activity tracking vs schedule
    - Compliance and tracking & KPI reporting
- Implementation of Corrosion Monitoring Plan
  - Project management & field implementation
    - Liaise with client – engineering & field, operations teams

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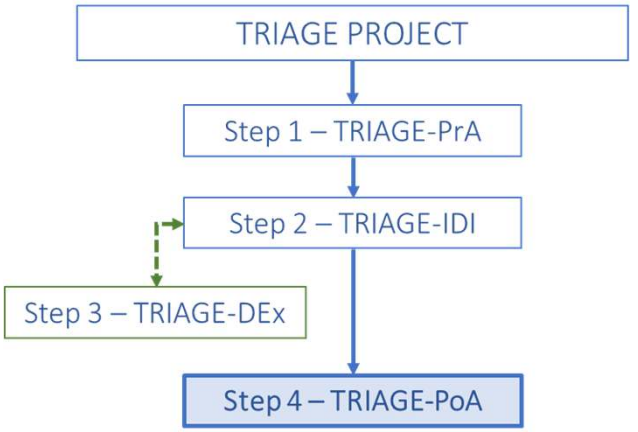

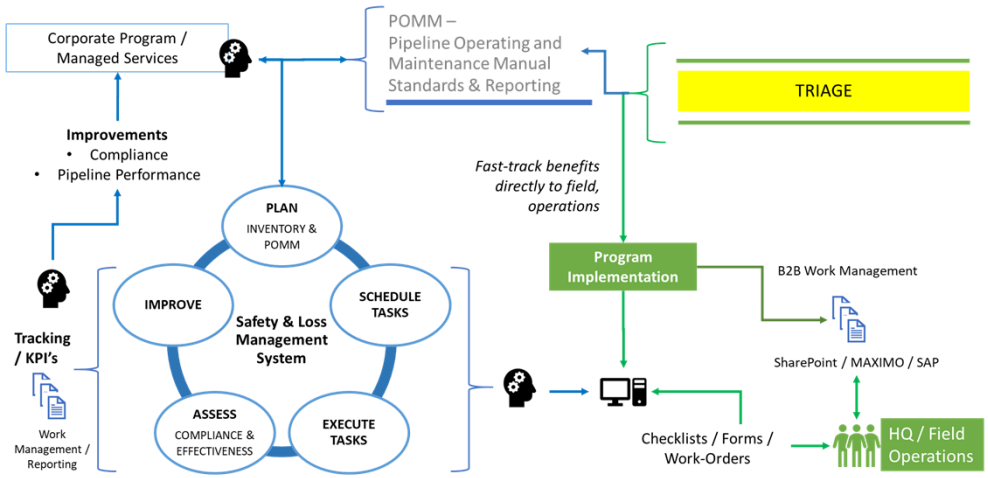

TRIAGE – Pipeline Integrity Hazard Classification & Mitigation Guidance

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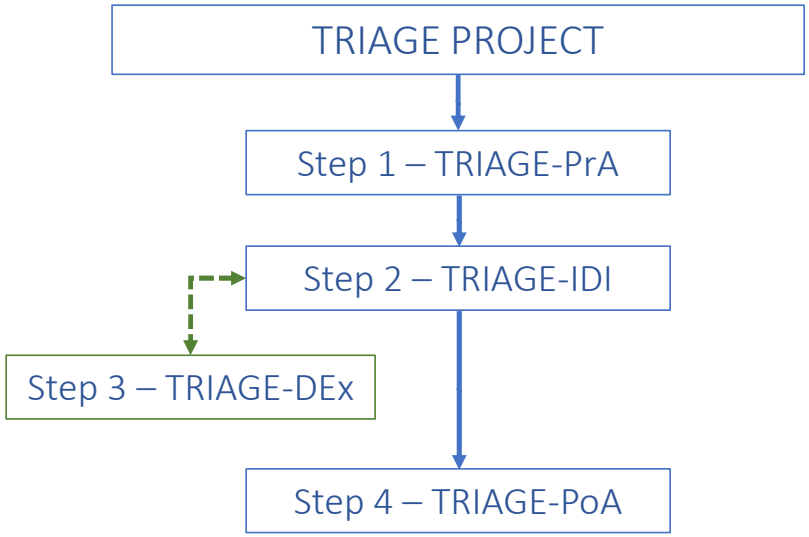

TRIAGE –
Corrosion Likelihood Scoring
Internal Corrosion

Technical Reference

Likelihood – Internal Corrosion

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Data Conditioning – Physical & Operating Data

Likelihood – Internal Corrosion

1. Data conditioning - license data –
   - construction date / diameter / length / material / status / internal protection / operating temperature / operating pressure / CO2 / H2S / chlorides / facility code - start / field separation
2. Data conditioning - year of construction / calculate age
3. Data conditioning - network connectivity algorithm – wells, pipelines, facilities
4. Data conditioning - oil / water / gas production flow apportionment algorithm
5. Data conditioning - establish operating temperature vs time profile
   - consider water allocation vs regional geothermal gradient to establish operating temperature
   - tally years vs temperature severity exposure classification (<25C / 25C – 35C / >35C)
6. Data conditioning - tally count on-off-on (hot-cold-hot) production / thermal cycles
7. Data conditioning - ratio non-operating days vs total operating life
8. Data conditioning - tally days between end-drilling and first-production
9. Data conditioning - incremental production at start-up events vs production at associated shut-in
10. Data conditioning - identification of production decline discontinuities versus natural decline
11. Data conditioning - identification of increased water-cut post start-up versus associated shut-in
12. Data conditioning - exposure to deviated well sources / fractured versus non-fractured well completions

Likelihood – Internal Corrosion

GIS Spatial Data Queries

1. Data query - count of historical IC failures events in proximity with shared sibling association
2. Data query - digital elevation mapping - elevation profile
3. Data query - digital elevation mapping - inclination angle profile – tally length by severity groups
    - <2 degrees / 2 – 5 degrees / 5 – 10 degrees / 10 – 15 degrees / 15 – 20 degrees / >20 degrees

Calculations

1. Calculation - calculate number of operating years beyond expected failure date
    - Consider sibling association with historical failure events
2. Calculation - operating parameters
    - pCO2 / pH2S / ratio pCO2:pH2S / gas velocity (superficial) / NACE – ICDA critical inclination angle to accumulate thick-water film / water-film velocity (actual) / oil-film velocity (actual) / oil-water slippage / residence time of water within stagnant water accumulation
3. Calculation - suspended solids loading / iron sulphide corrosion scale
4. Calculation - NACE-CO2 corrosion rate (NACE – deWaard & Milliams)
5. Calculation - pipeline remaining life (based upon NACE – CO2)