OPUS by NOV

Applying BAT/BEP to optimise production & reduce environmental impact

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7th of November 2023

NOV Completion & Production Solutions

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OPUS by NOV

What is BAT/BEP?

BAT – Best Available Techniques

- *The latest stage of development (state-of-the art) processes, facilities or methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste.*

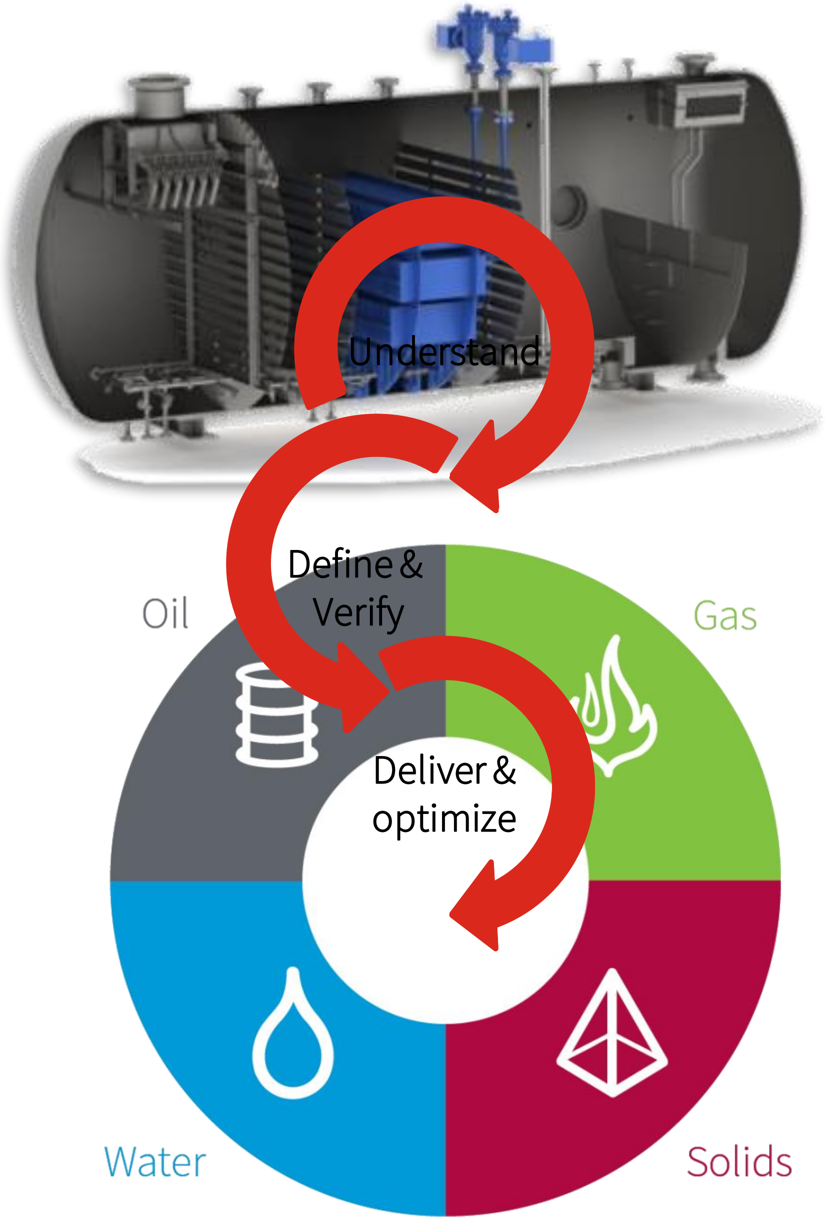
BEP – Best Environmental Practice

- *The application of the most appropriate combination of environmental control measures and strategies.*

Ref: OSPAR Convention

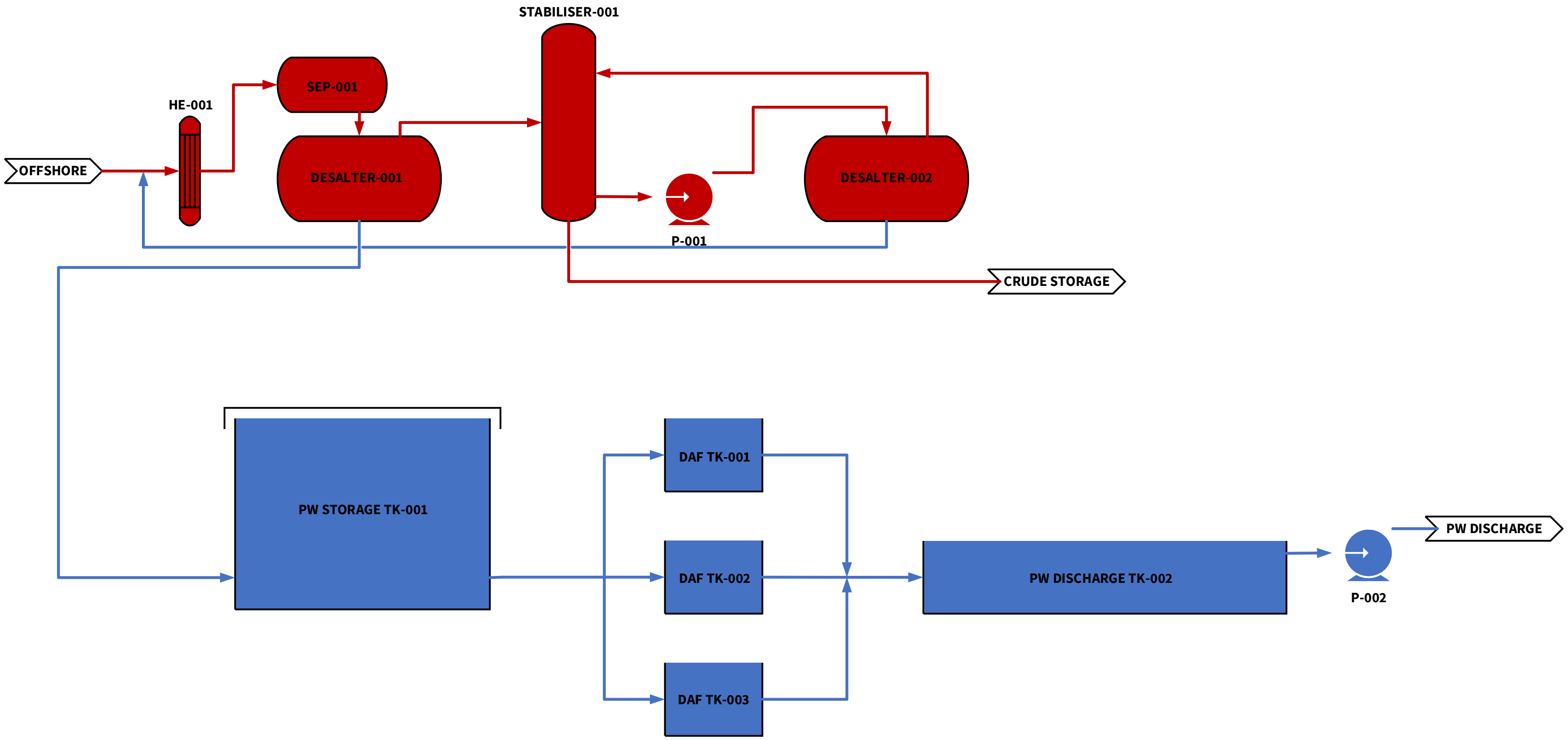
The *OPUS by NOV* BAT/BEP Approach

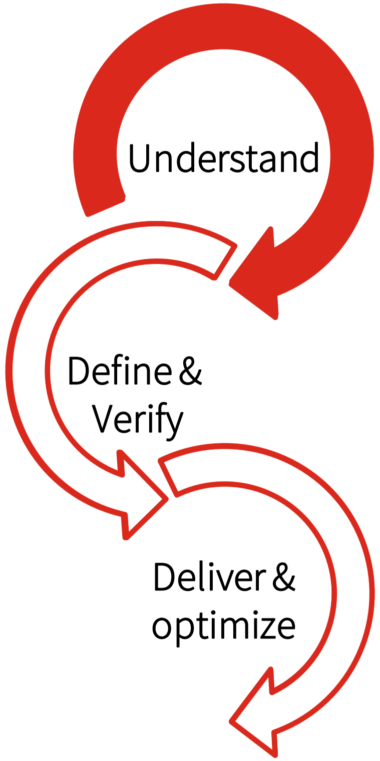
- *Apply multi-disciplined expertise to troubleshoot challenges or weaknesses in process systems and identify opportunities for performance optimization*



Challenge

Reduce the environmental impact of a mature onshore oil processing terminal





The Operators Pain Points

Collaborative discussions developed an understanding of the underlying issues

- Outdated Process Design
- Modern Emission Targets
- Antiquated Process Equipment
- Limited Timeline
- CAPEX / OPEX Concerns

Defining the Approach

Identifying ways to overcome the underlying issues, defined the projects phases

Design	• Basis of Design
Emissions	• Fluids Characterisation (FC) & Environmental Impact Assessment (EIA)
Equipment	• Overall Assessment of Technology Options
Timeline	• Phased Upgrade Approach
Economics	• Cost Benefit Analysis (CBA)

Overlapping Project Phases

Key stages of each phase kicked off simultaneously to share the outcomes

Basis of Design

- Process Cases
- Production Data
- Literature Review
- Process Review

FC& EIA

- Fluids Characterisation
- RBA –Whole Effluent Assessment (WEA) & Dream Modelling

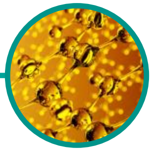
Technology Options

- Pre-Screening
- Concept Design
- Costing Estimation

Understanding the Regulations

Defined as BAT-AELs, with an emphasis on operating a BAT-designed plant to comply

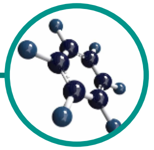
Best Available Techniques-Annual Emission Limits

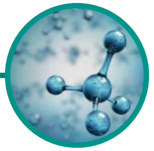

- Hydrocarbon Oil Index (HOI)


- Total Suspended Solids (TSS)


- Heavy Metals (Cadmium, Nickel, Lead & Mercury)

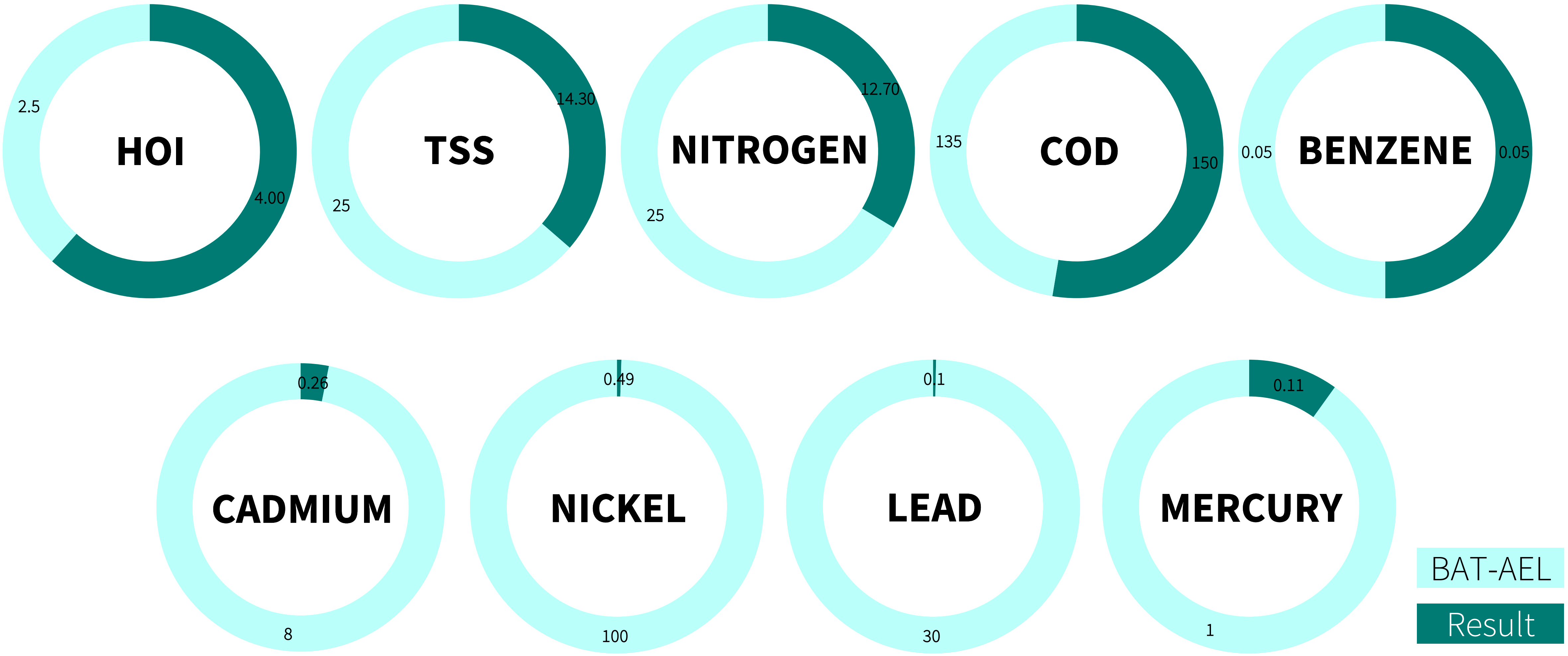

- Chemical Oxygen Demand (COD)


- Benzene


- Total Nitrogen

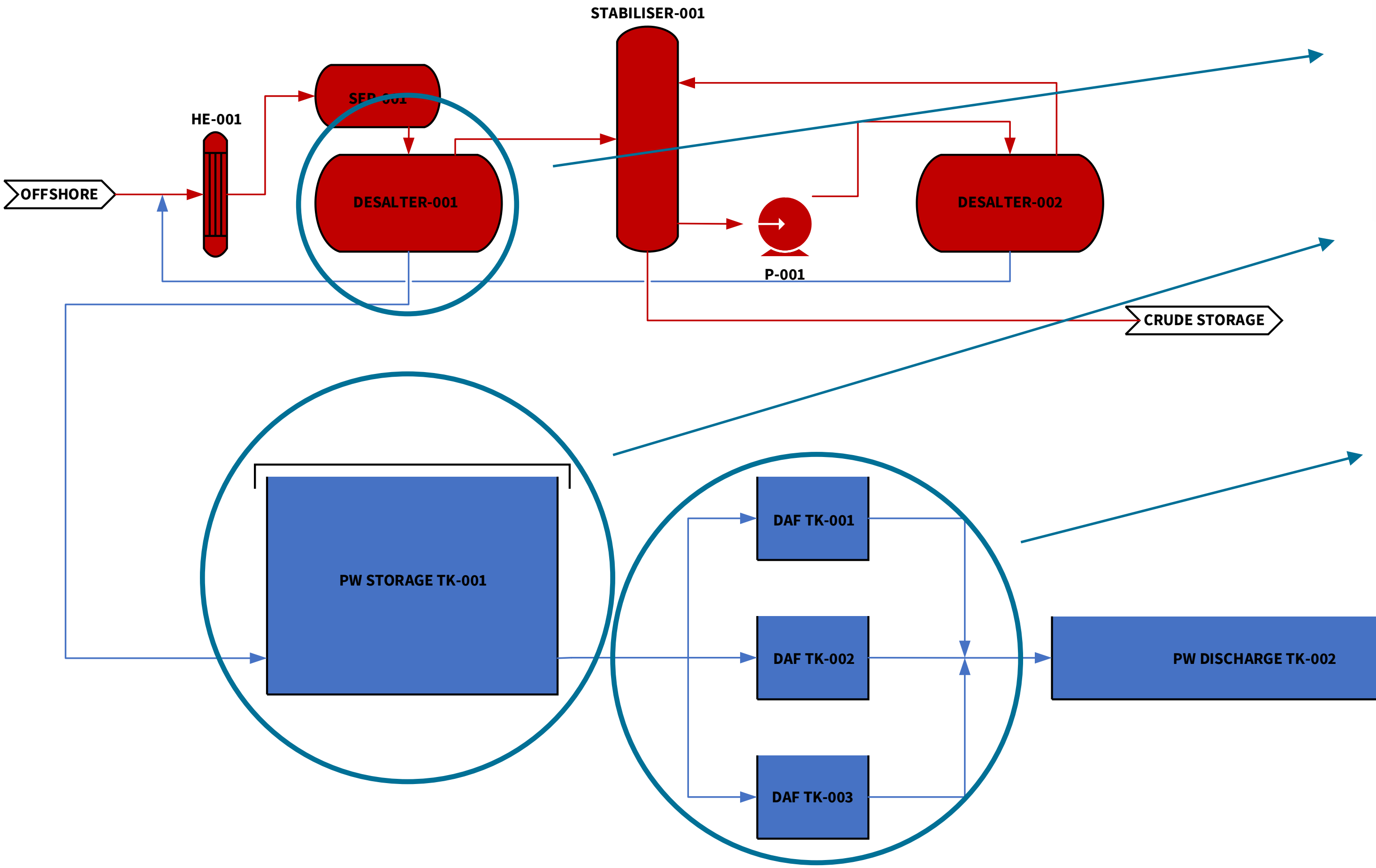
Assessing the current PW Discharge

Annual results revealed that only HOI, COD and Benzene were above limits

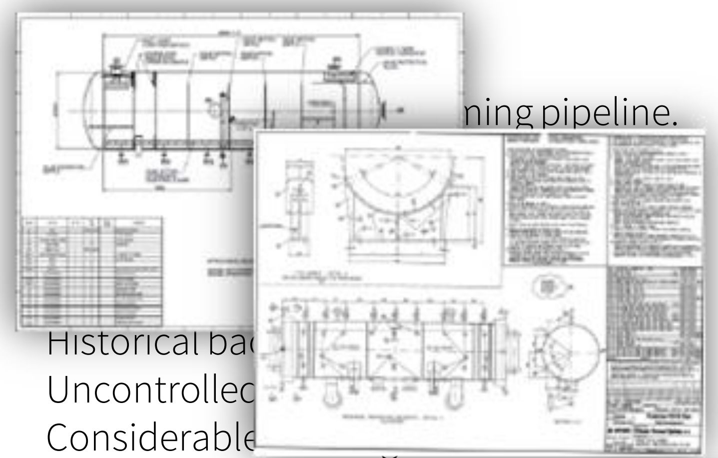


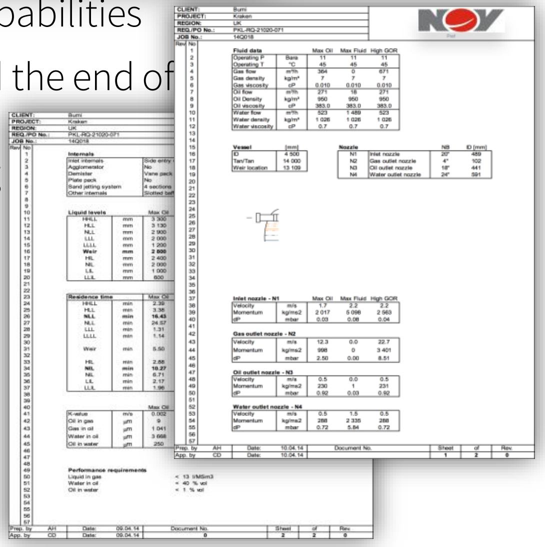
Process Engineering Review

Investigating the operating conditions revealed that the process required improvement



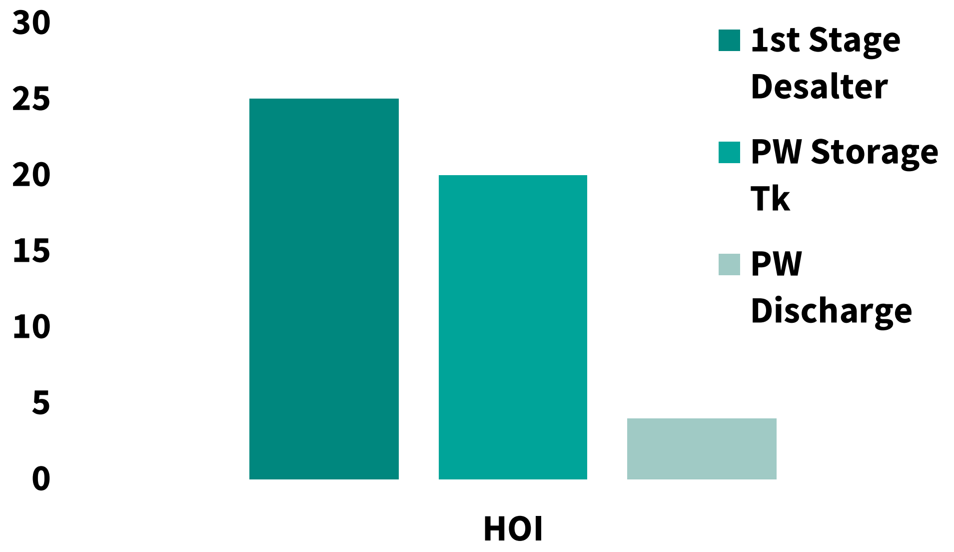
- ning pipeline.
-
-
-
- Historical bac
- Uncontrolled
- Considerable
- Ineffective skimming capabilities
- Integrity issues, reached the end of
- Oversized for service
- Uncontrolled degassing

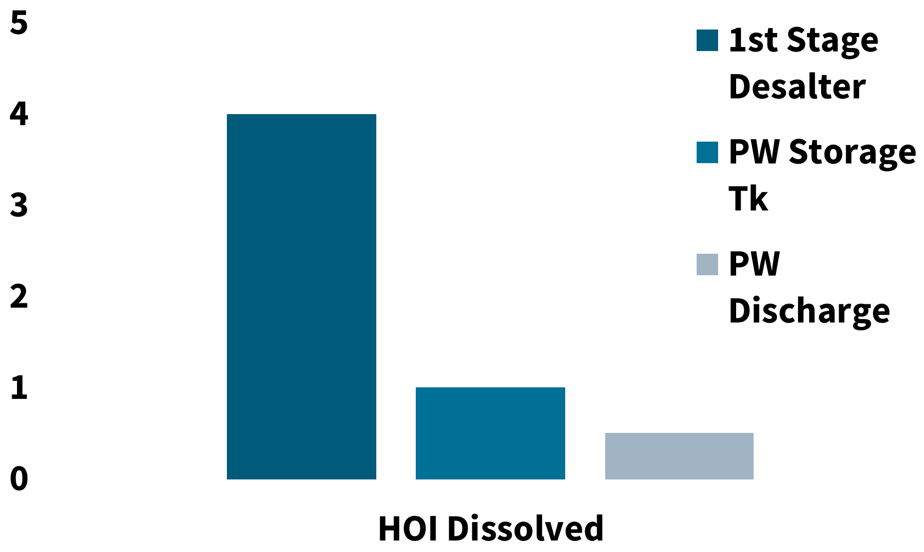




FC – Baseline Operating Conditions

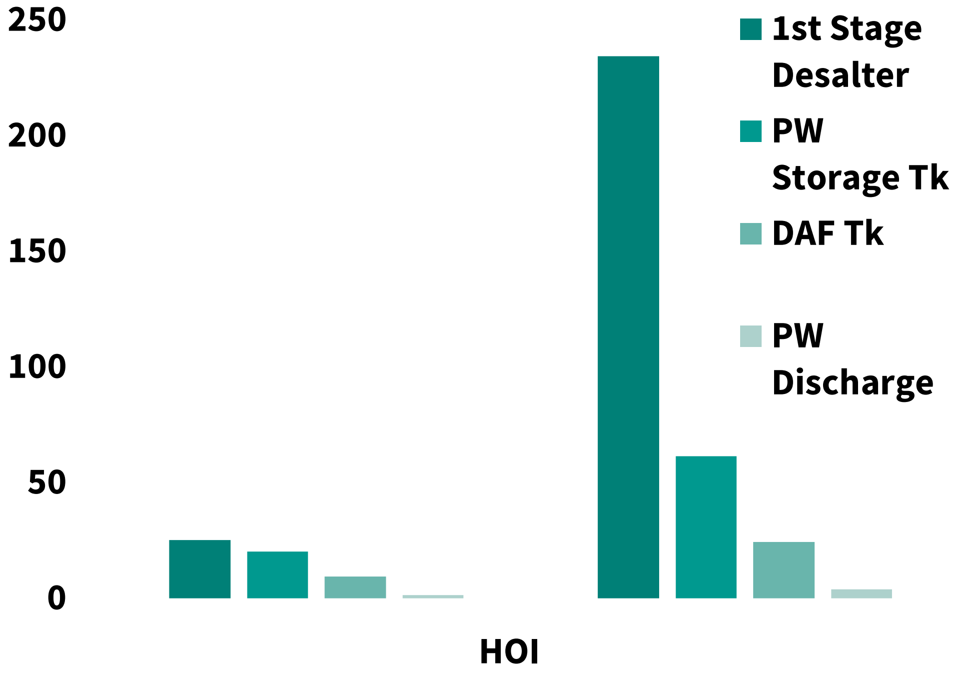
As the DAF Tanks had to be removed from service, the complete process was mapped

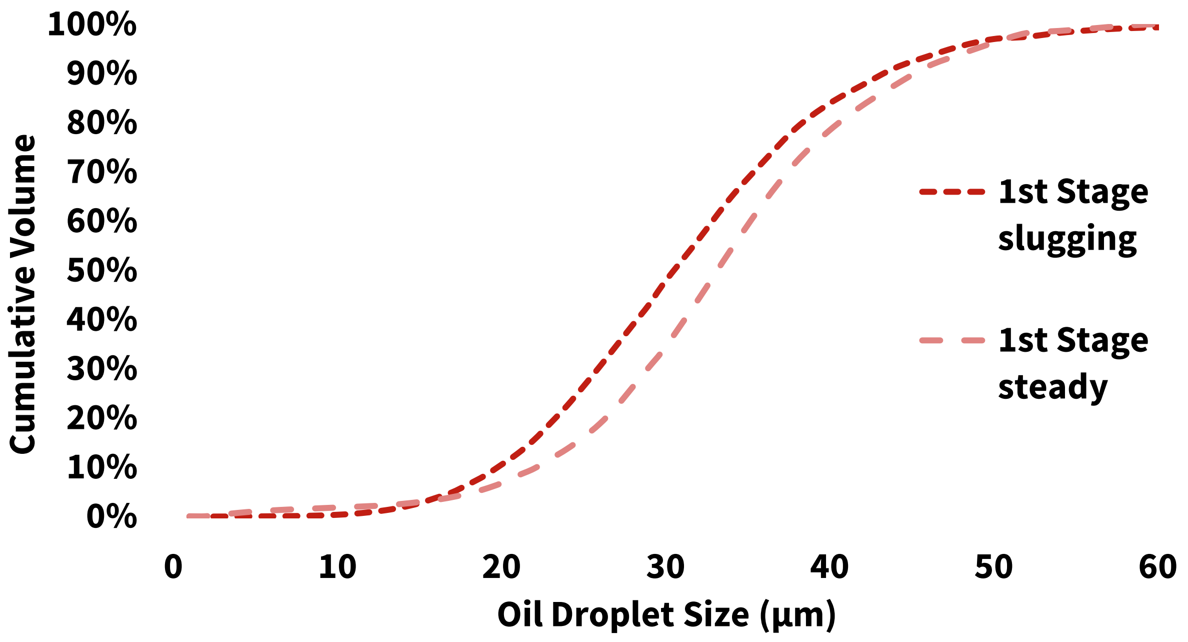




FC – Complex Operating Conditions

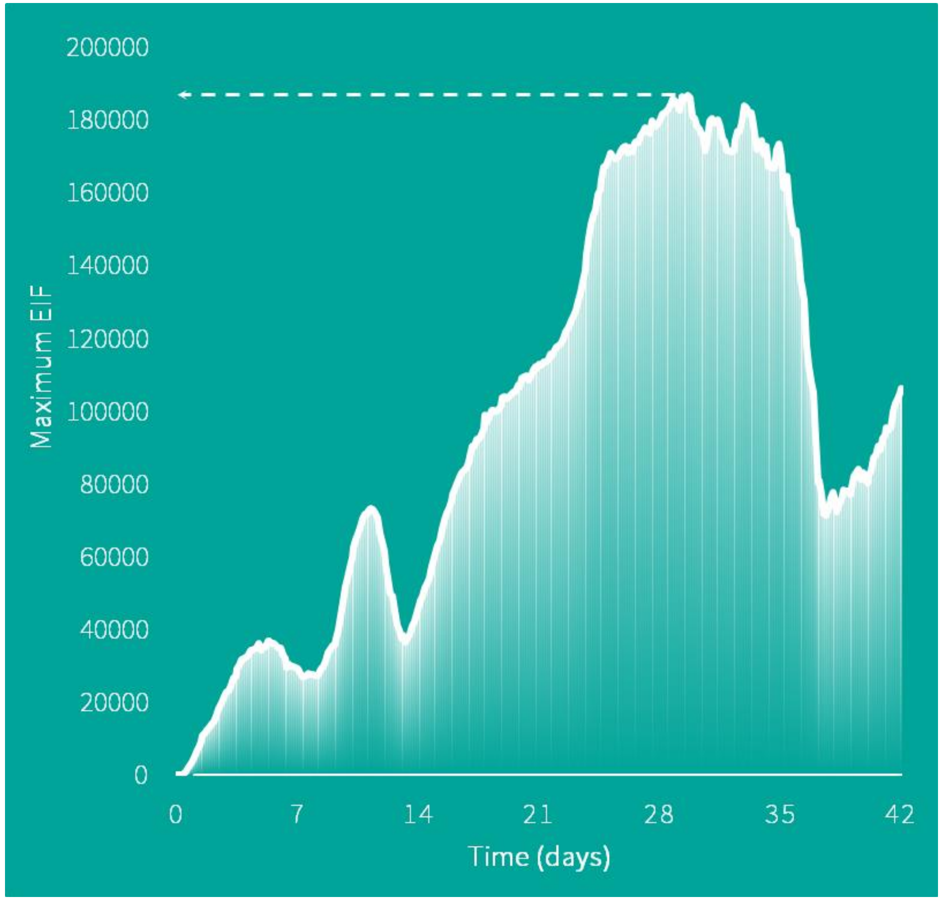
Capturing data during water slugs, provided an understanding of the impact

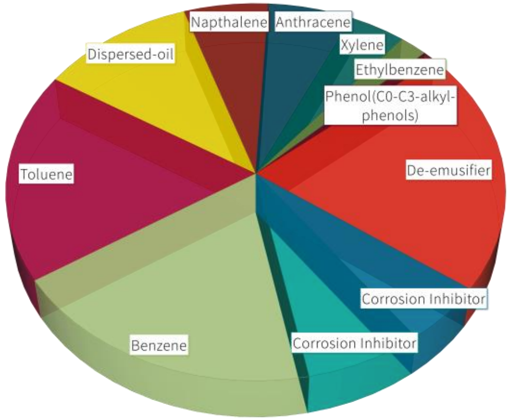




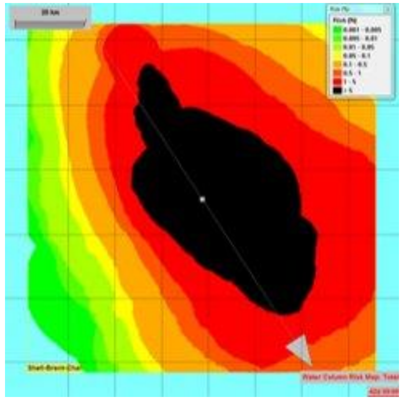
EIA – RBA WEA & DREAM Modelling

Evaluating the discharge at the component level

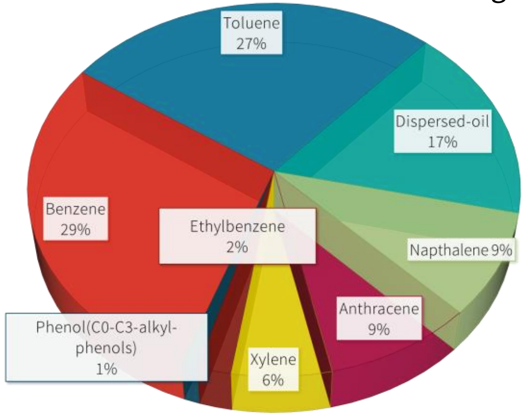




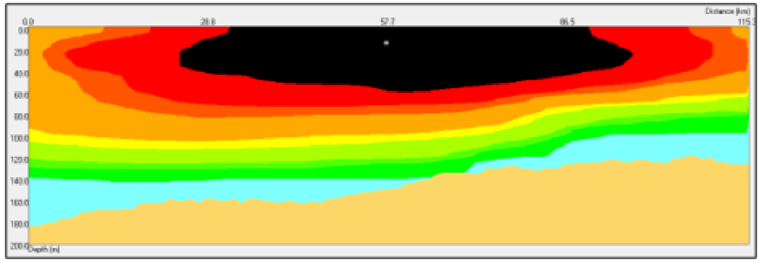
Produced water substances contributing to overall risk



Maximum risk of whole effluent



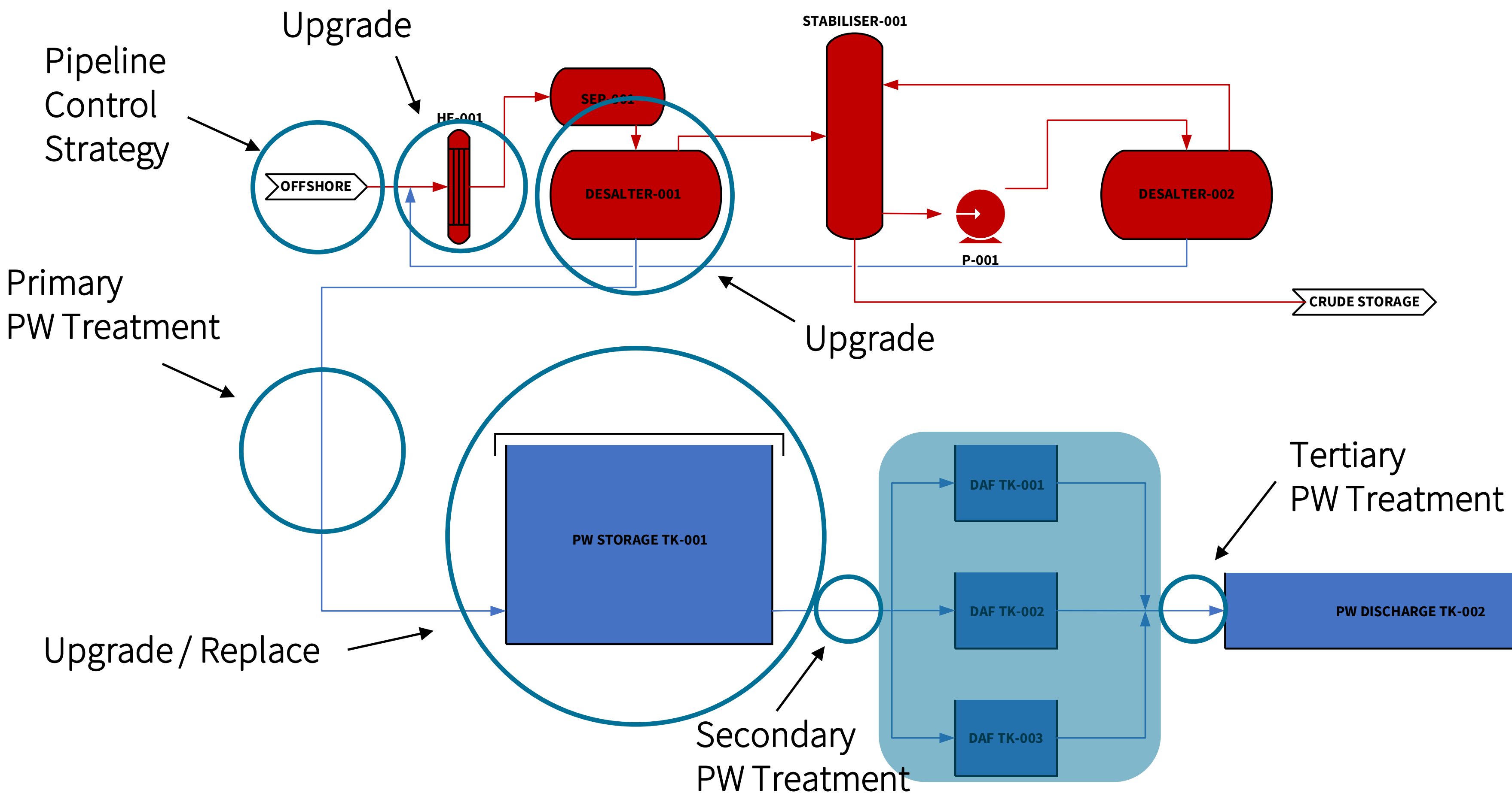
Naturally occurring chemicals only

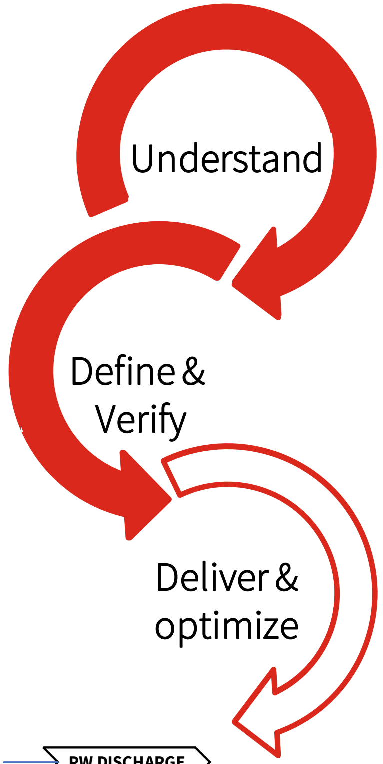


Transect through maximum risk of whole effluent

Proposed Locations for Optimisation

The combined findings determined the locations for optimisation





Basis Of Design

The locations selected were specific to the issues identified during the data collection

- Pipeline Control Strategy
  - Reduce the water content of Offshore Crude Export.
  - New pigging strategy, more frequent pigging.
- Upgrade Incoming Heat Exchanger
  - Waste heat recovery options.
  - New Heat exchanger U/S of 1st Stage Desalter.
- Upgrade 1st Stage Desalter
  - New Electrostatic grids, to prevent routine shorting.
  - New internals to enhance separation.
  - New internals for solids removal.
- Primary PW Separation Technologies
  - To reduce the dispersed oil content of water in PW Storage Tank.
  - To Degass the PW, reducing emissions to air.
  - To remove solids from PW stream, reducing bacterial impact.
- PW Storage Tank Upgrade / Replace
  - New oil skimming design.
  - Replace with alternative or new tank, of a more suitable size.
  - Remove open drainage system tie-in
- Secondary PW Separation Technologies
  - To reduce the dispersed oil content and TSS of water to polishing technology requirements.
- Tertiary PW Separation Technologies
  - To reduce the dispersed oil content and TSS of water to discharge requirements.
  - To reduce the dissolved components of the water to discharge requirements.

Pre-Screening

<table>
<tr><th>SURGE MANAGEMENT</th><th colspan="2">HEATING OF FLUIDS</th></tr>
<tr><td>• Improvements to offshore processes
• Pigging strategy review
• New Pig Launchers
• New pressure vessel D/S pig receiver (Slugcatcher)
• New pressure vessel D/S 1st Stage Desalter (Slugcatcher)
• New tank D/S 1st Stage Desalter (Atmospheric Tank)</td><td colspan="2">• Feed Pre-heater – Current Heat Exchanger new controls
• Any waste heat recovery option
• New Heat exchanger</td></tr>
<tr><th colspan="3">1st Stage Desalter Upgrade</th></tr>
<tr><td colspan="3">• New electrostatic grids
• New Internals Design
• New LCV type/locations</td></tr>
<tr><th>OPTIONS FOR REPURPOSING OF VESSELS FOR STORAGE / SURGE MANAGEMENT</th><th colspan="2">PW STORAGE TANK</th></tr>
<tr><td>• Mothballed Side draw accumulator vessel
• Fresh water tank 1 of 2</td><td colspan="2">• New skimming devices
• New outlet pipework design</td></tr>
<tr><th>PRIMARY (PWT) SEPARATION VESSELS/EQUIPMENT</th><th colspan="2">SECONDARY PWT SEPARATION VESSELS/EQUIPMENT</th></tr>
<tr><td>• API Separator
• Plate Pack Separator
• Deoiling Hydrocyclone
• Deoiling centrifuge
• ADEG Degasser
• HIGF
• CFU</td><td colspan="2">• CFU
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<tr><th>TERTIARY PW TREATMENT/POLISHING</th><th colspan="2">TERTIARY PW DISSOLVED HYDROCARBON & HEAVY METALS TREATMENT</th></tr>
<tr><td>• Media Filtration – Nutshell filtration
• Ceramic filtration
• Coalescing separator</td><td>• Activated carbon
• Osorb
• MPPE
• Biofilter package
• Reed bed</td><td>• Fixed Bed Biological System
• Suspended Bed Biological System
• Organoclay (PS85)
• Heavy Metals - Chemical Precipitation</td></tr>
<tr><th>SOLIDS MANAGEMENT</th><th colspan="2">CHEMICAL INJECTION</th></tr>
<tr><td>• Vessel Integrated Solids Removal Technology
• Solids cyclones
• Disk-stacked Centrifuge</td><td colspan="2">• Biocide review of operation philosophy
• Chemical injection options (Demulsifies, Deoilers, scavengers etc)</td></tr>
</table>

Pre-Screening

NAME: DEOILING HYDROCYCLONE	TYPE: PRIMARY PWT EQUIPMENT	ID: 1

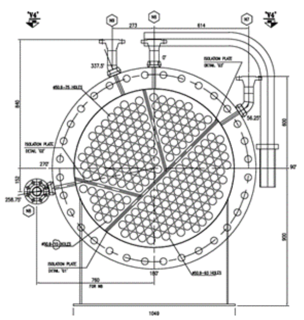
Description:

Deoiling Hydrocyclones operate under the principle of centrifugal separation and consist of multiple liquid/liquid hydrocyclone liners as shown below. The requisite number of hydrocyclone liners to attain the required throughput capacity is housed within a pressure vessel. The number of vessels provided will be in accordance with throughput, flexibility, sparing and maintenance requirements.

The produced water enters the liners tangentially; which due to the internal geometry of the liner, creates a spin. The concentric reducing section accelerates the fluid to high velocities, inducing separation forces several thousand times greater than gravity. As the oil-contaminated water spins down the cyclone, the denser phase is forced towards the wall under centrifugal forces whilst the lighter (oily phase) is drawn to the core by centripetal force. The denser phase or oil-free produced water continues down the tapered section of the liner and exits at the far end of the cyclone, whilst the lighter fraction consisting of the less dense, oily, phase exists via the overflow at the top of the cyclone.

Deoiling of produced water with hydrocyclones is OSPAR 'Best Available Technology'. However, for the application to be BAT, stable flow and pressure are required to be maintained. This can be achieved via:

- Multiple parallel units (different sizes) with active and blank liners – this may require frequent changeout.
- Multi-compartment (auto-isolated) design sized to handle full flow range
- Collection vessel upstream of hydrocyclones to manage surge – pre-separation required in a vessel to make this worth it as process pressure is used and pumps required
- Recycle loop to maintain flow during turndown - uses a pump to recirculate flow continuously – energy is wasted



Advantages:

- Uses system pressure to drive the process
- Robust with no moving parts
- Hydrocyclones can efficiently remove oil droplets down to 10-20 microns, sometimes lower.
- Treat up to 2000mg/l OIW at inlet down to around 50mg/l
- Small footprint and lightweight construction

Disadvantages:

- Reject flow needs to be stable and consistent
- Automatic PDR control system required – regular checks on dP/flow and PDR behaviour
- Limited turndown capability – requires careful design, min flow/recycle, partitioning and/or liner blanking
- Susceptible to fouling – solids filter upstream and regular backwashing required
- Performance heavily dependent on droplet size

SEMI-QUANTITATIVE PRE-SCREENING

Criteria	+/-Score	Criteria	+/-Score
H&S		Ecological	
Technical Risk		Maintenance	
Capex		Waste	
Operational Risk		Public Relations	

-5	-4	-3	-2	-1	0	1	2	3	4	5
Extreme negative	Major negative	Moderate negative	Minor negative	Negligible negative	Neutral	Negligible positive	Minor positive	Moderate positive	Major positive	Extreme positive

Screening Comments:

- Capital cost is £ high-level cost for 2 x 36" (turndown and flow variability is a big concern here)
- Low OPEX
- Low HSE – low exposure to volatile hydrocarbons

LOCATION:	D/S DESALTER	COST:	£	OPEX:	£	BENEFIT / PERFORMANCE:	%	Conclusion:	DO / ~~DO NOT~~ take forward

Pre-Screening

SURGE MANAGEMENT

- ~~Improvements to offshore processes~~
- ~~Pigging strategy review~~
- ~~New Pig Launchers~~
- ~~New pressure vessel D/S pig receiver (Slugcatcher)~~
- ~~New pressure vessel D/S 1st Stage Desalter (Slugcatcher)~~
- ~~New tank D/S 1st Stage Desalter (Atmospheric Tank)~~

HEATING OF FLUIDS

- Feed Pre-heater – Current Heat Exchanger new controls ✓
- ~~Any waste heat recovery option~~
- ~~New Heat exchanger~~

1st Stage Desalter Upgrade

- ~~New electrostatic grids~~
- New Internals Design ✓
- ~~New LCV type/location~~

OPTIONS FOR REPURPOSING OF VESSELS FOR STORAGE / SURGE MANAGEMENT

- ~~Mothballed Side draw accumulator vessel~~
- ~~Fresh water tank 1 of 2~~

PW STORAGE TANK

- New skimming devices ✓
- New outlet pipework design ✓

PRIMARY (PWT) SEPARATION VESSELS/EQUIPMENT

- ~~API Separator~~
- ~~Plate Pack Separator~~
- Deoiling Hydrocyclone ✓
- ~~Deoiling centrifuge~~
- ADEG Degasser ✓
- HIGF ✓
- ~~CFU~~

SECONDARY PWT SEPARATION VESSELS/EQUIPMENT

- ~~CFU~~
- ~~ADEG Degasser~~
- HIGF ✓
- Deoiling Hydrocyclone ✓

TERTIARY PW TREATMENT/POLISHING

- Media Filtration – Nutshell filtration ✓
- ~~Ceramic filtration~~
- Coalescing separator ✓

TERTIARY PW DISSOLVED HYDROCARBON & HEAVY METALS TREATMENT

- ~~Activated carbon~~
- ~~Osorb~~
- ~~MPPE~~
- ~~Biofilter package~~
- ~~Reed bed~~
- ~~Fixed Bed Biological System~~
- ~~Suspended Bed Biological System~~
- ~~Organoclay (PS85)~~
- ~~Heavy Metals - Chemical Precipitation~~

SOLIDS MANAGEMENT

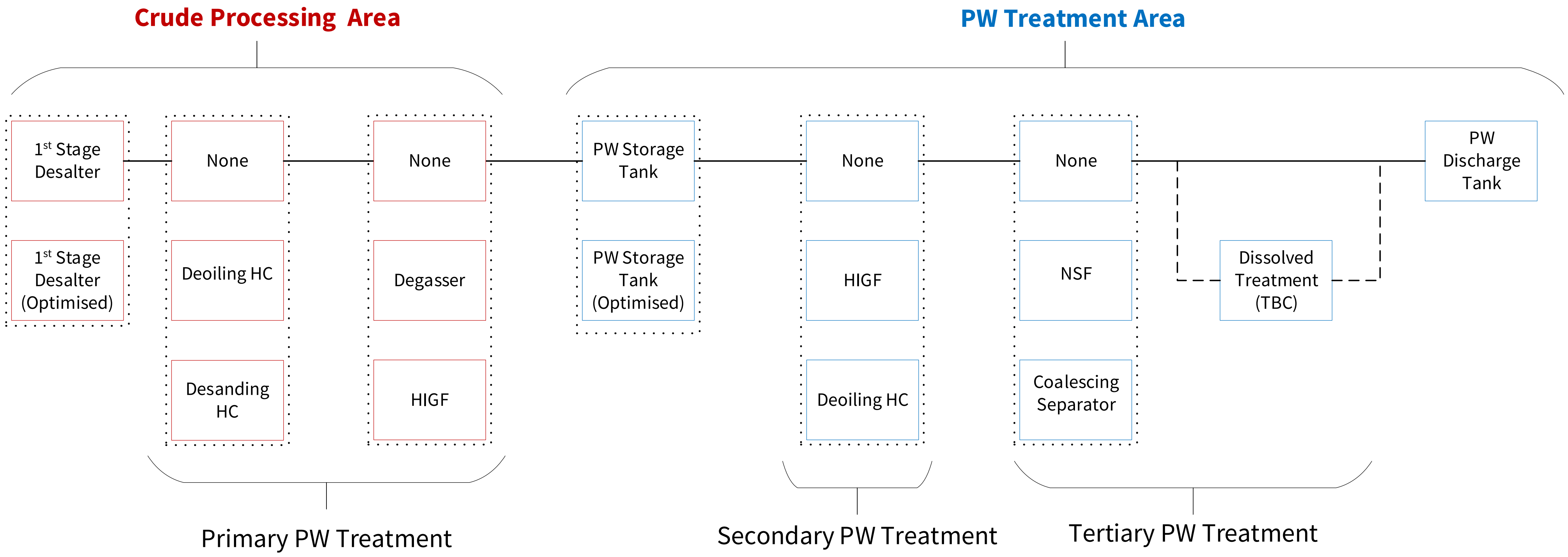
- Vessel Integrated Solids Removal Technology ✓
- Solids cyclones ✓
- ~~Disk-stacked Centrifuge~~

CHEMICAL INJECTION

- Biocide review of operation philosophy ✓
- ~~Chemical injection options (Demulsifies, Deoilers, scavengers etc)~~

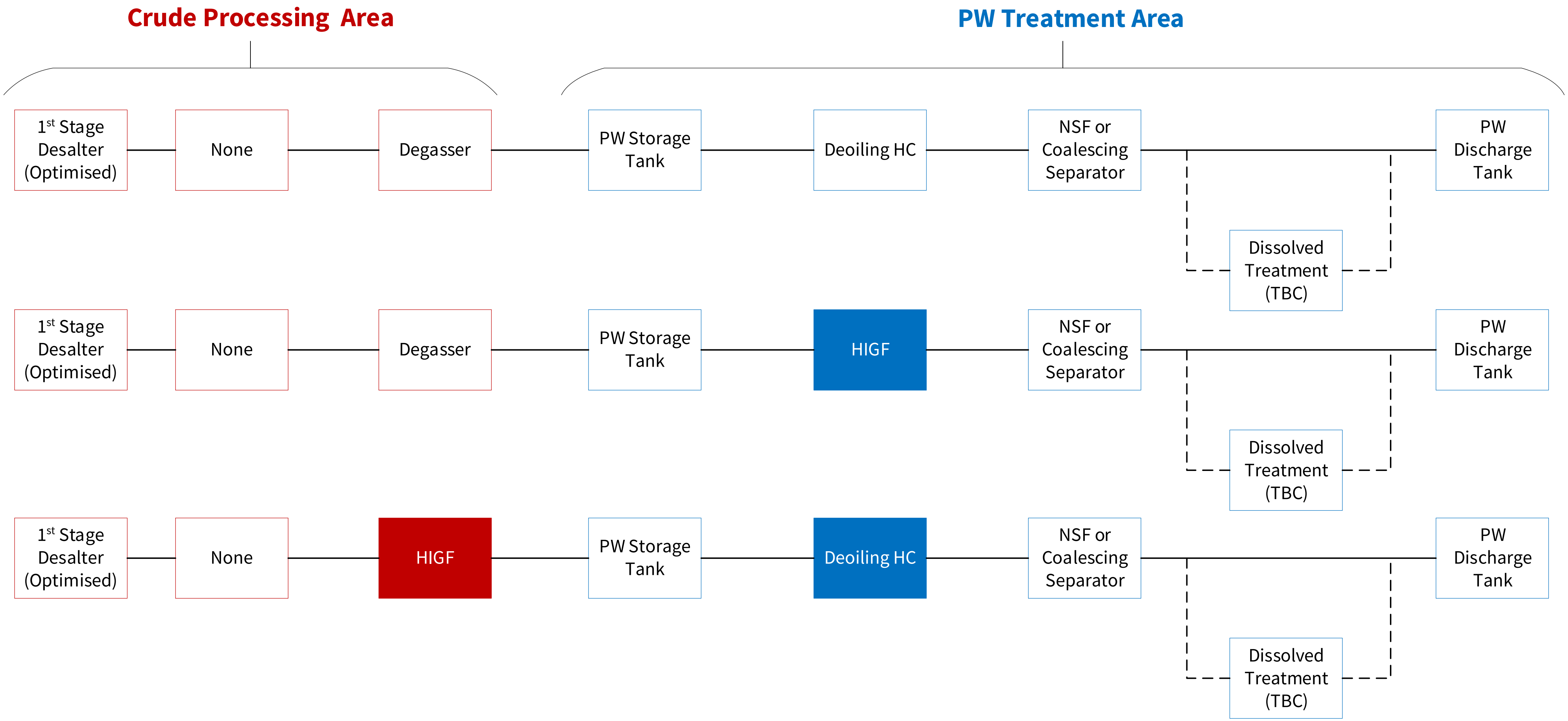
Designing Process Flow Diagrams

Once pre-screened, the preferred technologies were incorporated into PFDs to rank as concepts



PFD Cost Benefit Analysis Rankings

The concepts were ranked on performance vs costs and 3 were selected for Pre-FEED evaluation

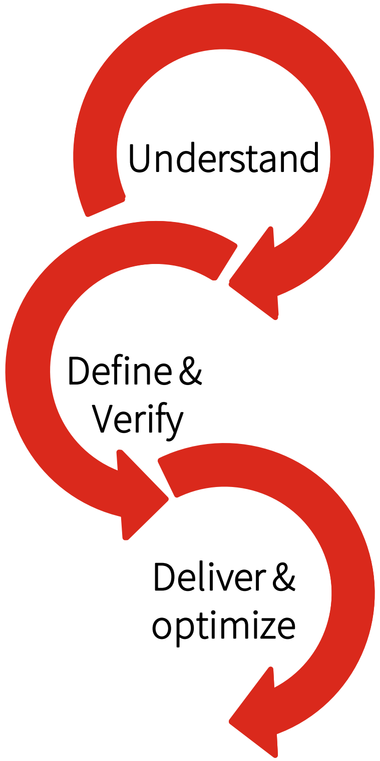


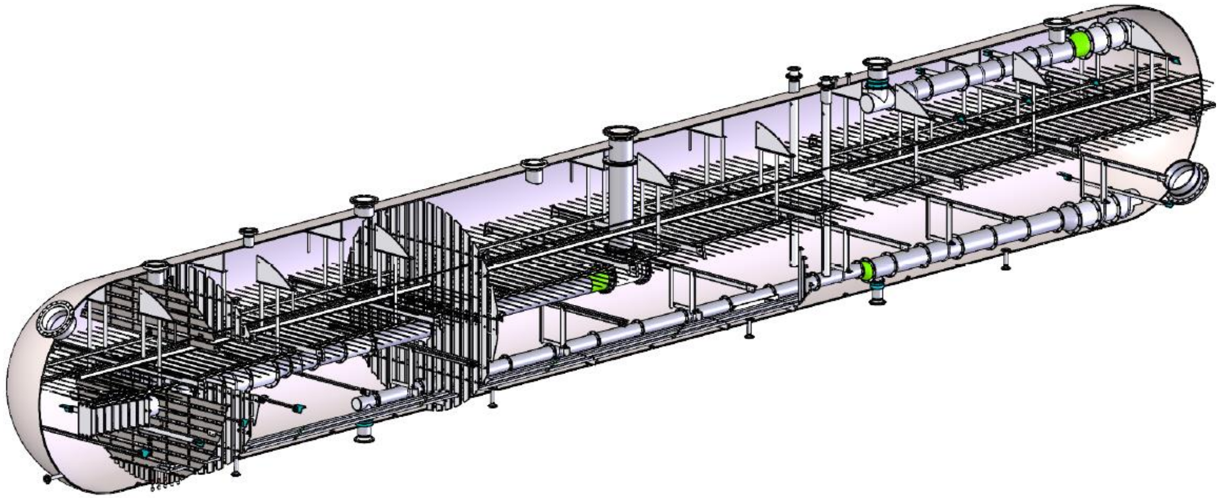
The next steps

One key upgrade is complete ✓ Technology trials will confirm the final design

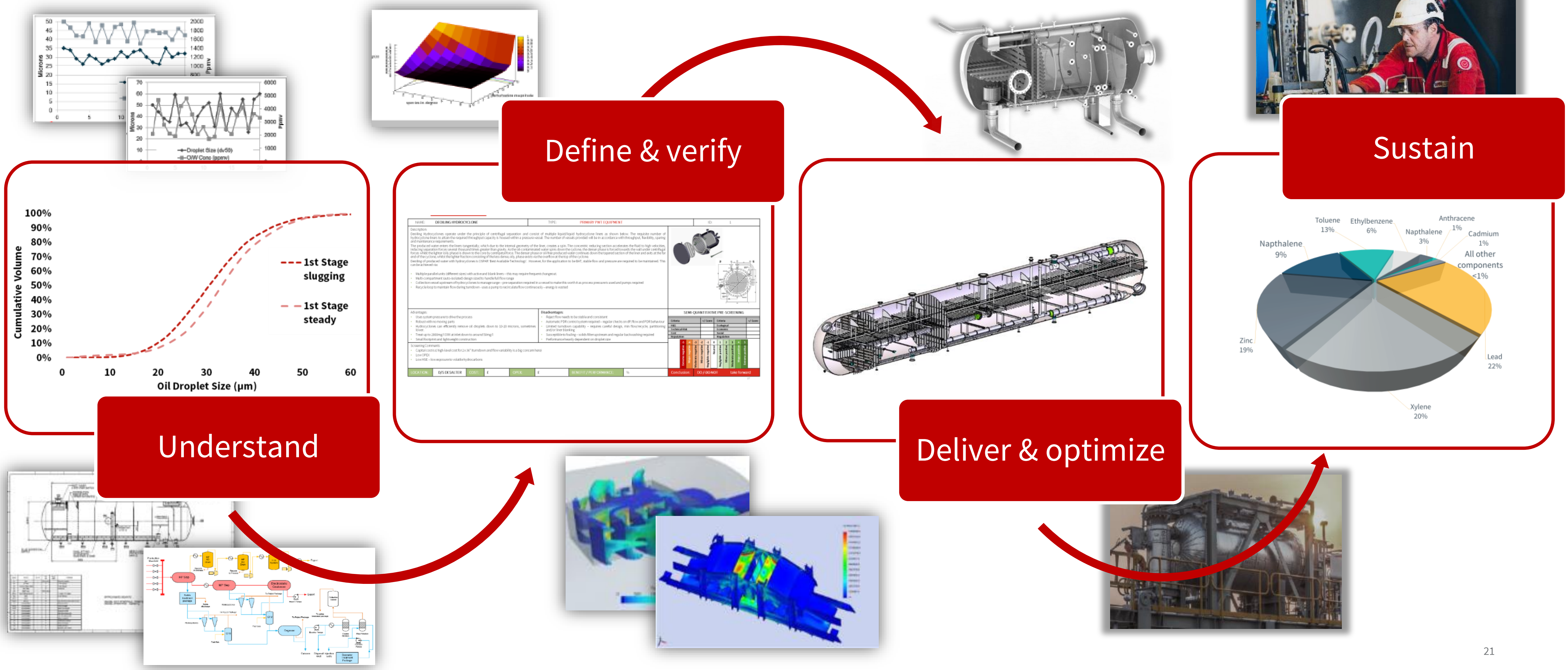
Optimised 1st Stage Desalter:

- Changed from vertical to horizontal flow arrangement.
- Inlet distribution header to distribute fluids across the length and width of the vessel.
- Oil outlet manifold and water manifolds located across the full length of the vessel at the top and bottom, respectively.
- Water outlet nozzles re-routed to minimise outlet velocity and associated impact on volume utilisation during water slugs.
- Integrated solids removal technology to be installed next shutdown.





The *OPUS by NOV* Approach



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