WATER FLOOD EXCELLENCE

Make Every Drop Of Water Count!

11 NOVEMBER 2018
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INTRODUCTION

❖ Majority of current oil production is supported by waterflood. Waterflood management is critical to future oil production & ultimate recovery.

❖ Current water injection is 4300 MBWPD & water production is 600 MBWPD. Produced water is expected to increase at the rate of 50-100 MBWPD per year.

❖ As illustrated below, water flooding requires a multi-disciplinary team effort to get it right.
## WATER INJECTION & PRODUCTION FORECAST

<table>
<thead>
<tr>
<th></th>
<th>TODAY (MBWPD)</th>
<th>2030 (MBWPD)</th>
<th>Fold Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADNOC ONSHORE INJECTION</td>
<td>2500</td>
<td>4700</td>
<td>X 2</td>
</tr>
<tr>
<td>ADNOC ONSHORE PRODUCTION</td>
<td>350</td>
<td>1450</td>
<td>X 4</td>
</tr>
<tr>
<td>ADNOC OFFSHORE INJECTION</td>
<td>1800</td>
<td>4000</td>
<td>X 2</td>
</tr>
<tr>
<td>ADNOC OFFSHORE PRODUCTION</td>
<td>260</td>
<td>1100</td>
<td>X 4</td>
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### ADNOC Onshore Water Injection (Annual Average Figures)

- Water Injection/Production (MMBPD)
- Year: 2018 to 2030

### ADNOC Offshore Water Injection (Annual Average Figures)

- Water Injection/Production (MMBPD)
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The focus areas demonstrate the activities for water flood excellence, including effective water management & handling throughout the cycle, i.e.

- Maintain reservoir model prediction to account for errors or changes & perhaps modify flooding
- Manage placement of water downhole to maximize efficiency of flood
- Monitor flooding to validate outflow & model, to then make possible changes
- Alter outflow of injector or water cut in producer by remediation
- Improve asset utilization & measurement of water flooding effectiveness
Water Flood Excellence – Multi-Disciplinary Project

Context:
- Vast majority of current production is supported by water flooding. Management of water both in the reservoir & on the surface is critical to future oil production & ultimate recovery.

Strategy:
- “Make every drop of water count”, by implementing effective water flooding versus just injection to improve reservoir sweep, production, recovery & water management.

Focus Areas:
1. Predict - review accuracy of reservoir models & benchmark recovery factor performance
2. Manage - implement ERD & MRC well technology to improve production, reservoir recovery & value.
4. Remediate – create toolbox of technologies for diagnostics & profile modification or shut-off solutions to address anomalies.
5. Optimize – review surface & sub-surface performance to improve system capability.

Value:
- Improved unit development cost
- Improved well productivity & injectivity
- Improved sweep efficiency
- Improved well management

1. Benchmarking our reservoirs against world’s best in class analogues to assess performance of reservoirs
2. Well optimized design with ICD liner giving >10% cumulative oil & 24% less water versus open hole
3. Developing World Class intervention capability to match ERD / MRC to monitor & treat wells
4. Long horizontal wells more challenging to remediate, requiring specialist treatments to prevent slumping & ensure isolation
5. Offshore platform with multi-phase pump to address high sea-line pressure
Water Flood Excellence – Multi-Disciplinary Project

Additional Focus Areas Undertakings:

A. Optimize quantity of injection wells with MLTBS technology to reduce cost & drilling complexity

Studied for synergy of reservoirs, potential cost saving of at least $10MM, reduction in slots plus avoiding potential collision issue & complexity of drilled wells

B. Optimize well direction with respect to SHmax to reduce risk of early water break-through

Water moves preferentially along fractures in direction of SHmax
(Ref.: SPE 101425, ADCO, 2006)

C. Optimize flood pattern from early field development to future field development to maximize field recovery

Pattern change over time in brownfield development to optimal line drive
(Ref.: SPE 181598, ADMA, 2016)
Water Flood Excellence – Multi-Disciplinary Project

Additional Focus Areas Undertakings:

D. Optimize liquid production with onset of increasing water cut by implementation of artificial lift plus segmenting wells to manage reservoir section

E. Optimize material selection & use for changing conditions away from dry oil & increasing water cut

- Inorganic Chemically Bonded Phosphate Ceramic (CBPC) coating for application to surface & downhole equipment – product test being pursued

- GRE lined tubing: higher initial CAPEX vs carbon steel or carbon steel + corrosion inhibitor, but surpassed after year 3-6 plus fewer workovers – ADNOC Onshore tested in disposal well
ESP WELL PERFORMANCE MONITORING & OPTIMIZATION

A SOLUTION TO EMPOWER OPERATORS IN MAXIMIZING VALUE FROM DATA

Project Vision
Application of data analytics and machine learning to predict ESP failure and suggest corrective actions to prolong ESP run life and optimize overall well performance.

Expected Benefits
1. Early ESP failure prediction.
2. Reducing production loss by ~30%.
3. Extending Mean Time to Failure by ~40%.
4. Increase people’s productivity and performance by ~50%.

Data Input
- SHs & Vendor Guidelines
- Downhole, Surface & Test Data
- Well Configuration

Analytics
AI Modeling

Well Optimizer Tool
- Optimize Well Performance
- Predict Failures
- Diagnose Conditions
- Pump Sizing

Optimum Operation Settings
- OPEX
- CAPEX

Satisfaction

Run Life
Production

Well Level Dashboard (Well XX-YY)

Well Level Dashboard
Optimum Operation Settings
Optimize Well Performance
Predict Failures
Diagnose Conditions
Pump Sizing

Run Level Dashboard
OPEX
CAPEX
Satisfaction

Home Dashboard

Well Level Dashboard (Well XX-YY)
Water Flood Excellence – Multi-Disciplinary Project

Additional Focus Areas Undertakings:

F. Monitor flood front over time with 4D seismic

Water saturation over time monitored by 4D seismic to compare against reservoir – ADNOC Offshore example of comparison of reservoir model to seismic

G. Optimise well placement by identifying flooded or non-flooded layers during well construction to then avoid or target layer then install suitable completion

Deep directional resistivity (DDR) drilling tool to give far reaching awareness of water location by 100’-200’ vs 6’

DDR drilling tool identify flooded & non-flooded layers - being reviewed by ADNOC On & Offshore
IMPLEMENTATION OF SEA WATER INJECTION FOR ONSHORE FIELDS

Motivation

- Represents a sustainable source for meeting future water injection demand
- It will help mitigate pressure decline observed in some of the regional aquifers
- It would minimize the flow to clean to desert (HSE) and significantly reduce the stimulation of the injectors damaged by the suspended solids in the aquifer water
- It would have a positive impact on future CAPEX & OPEX by reducing the number of water injection clusters, ESP’s, pulling hoist, manpower, power consumption, etc.
- It would make the co-development of gas cap and oil rim more economically attractive
- Centralization of water treatment facilities and chemicals will improve operational efficiency, system reliability and unit operating cost.
- Seawater injection would be particularly attractive as most of ADNOC Onshore assets are moving towards pad based drilling.
- Seawater, due to its lower salinity than aquifer water, is better suited for IOR/EOR projects. Moreover, it can be modified to low salinity water if required.
“MAKE EVERY DROP OF WATER COUNT” -
Effectively manage water as a necessary resource vs a commodity by implementing effective water flooding vs injection to improve reservoir sweep, production, recovery & water management that will deliver greatest value & performance excellence.

**Focus on injecting water for both pressure support & sweep**
- Review LTDPs to assess the timing & the pace of water flood expansion from peripheral to pattern floods
- Continue OPCO reviews to *optimize well direction in relation to SHmax* to reduce the risk of water short circuiting to production wells

**Focus on lower completion to manage water outflow & inflow & not solely upper completion**
- Progress strategy to run *segmented liner* as opposed to open hole to effectively manage & reduce water volumes to *delay the artificial lift requirements*.
- Progress strategy to justify downhole completion based on value as opposed to cost

**Improve efficiency & production related to water production management**
- Collaborate with OPCOs to *create an ADNOC Group MSA* for water flood *remediation solutions*
- Identify gaps in *new technologies* to be pursued under ADNOC Group R&D framework

**Achieve top quartile performance in water flooding**
- Develop & implement *diagnostic plots* for measuring water flood performance through ARPR & SPR
- Set KPI’s for water injection & water flood management through IRM
- Conduct *baseline assessment* for 82 reservoirs under water flood to identify & address gaps
- Initiate an *AI project* to demonstrate the value of data driven reservoir modeling for production/injection optimization
THANK YOU

Make Every Drop Of Water Count!