Reservoir technical limits: Creating a system for continuous recovery improvement in mature fields

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Reservoir technical limits

• Philosophy, process and toolkit developed in BP
• Used ~400 times in >200 oil and gas fields
• Has added new opportunities for reserves growth even in very mature fields


Outline

• The problem: why is *rtl* needed?
• Key elements of the *rtl* process
• How *rtl* can help in mature fields
The problem

- Resource progression is not a conveyor belt
- Needs work!
  - Identify and describe opportunities
  - Prioritize and select
  - Define, approve, execute and deliver
- Opportunities can be missed, or can get stuck
- rtl helps to identify a rich set of opportunities, and describe them in a way that facilitates further progression
Why opportunities can get stuck

• Technology challenges
• Commercial challenges
• “Softer” issues
  – Decision making: If presented with different amounts, types and styles of information about opportunities in the portfolio, decision-makers find them difficult to evaluate, compare and prioritize
  – Communication and engagement: Opportunities are difficult to identify and progress when requiring insight and coordinated activity between multiple parts of an organization (e.g. Asset, Technology, Drilling, Projects)
  – Misalignment: Motivational biases, conscious or unconscious, lead to opportunities being suppressed by individuals or parts of an organization that would feel challenged (e.g. need to do more work) or conflicted (e.g. spend more and cut costs), despite there being an advantage to the wider company
How the \textit{rtl} approach can help

- \textit{rtl} is designed to overcome the sticking points by systematically identifying opportunities, and describing them transparently and consistently:
  - Opportunities easy to compare: better splitting, lumping and prioritization
  - Internal stakeholders part of the process and feel co-ownership of new opportunities
  - External stakeholders presented with easily understood data and logic
  - Distinguishes new opportunities from “base” activities
  - Activities linked to benefit (e.g. increase in ultimate recovery) so that additional work can be properly evaluated and resourced
Efficiency Factor Framework: Oil

- Recovery factor represented as function of 4 Efficiency factors:

  - **Pore-scale displacement efficiency**
    \[ Ep = 1 - \frac{S_o}{S_o i} \]

  - **Drainage efficiency**
    \[ Ed = \frac{\text{connected volume}}{\text{total volume}} \]

  - **Sweep efficiency**
    \[ Es = \frac{\text{swept volume}}{\text{total connected volume}} \]

  - **Cut-off efficiency**
    \[ Ec = \frac{\text{production volume produced before cut-off}}{\text{ideal producible volume}} \]
Efficiency Factor Framework: Gas

- Again there are 4 Efficiency factors:

  - **Pressure depletion efficiency**
    
    \[ Ep = 1 - \frac{P_a}{P_i} \]
    
    Adjusted for gas compressibility and aquifer influx volume \( V \).

  - **Drainage efficiency**
    
    \[ Ed = \frac{\text{connected volume}}{\text{total volume}} \]
    
    Sealing fault

  - **Secondary pay efficiency**
    
    \[ Es = 1 - \left( \frac{\text{secondary pay volume}}{\text{total connected volume}} \right) \]
    
    Sealing fault

  - **Cut-off efficiency**
    
    \[ Ec = \frac{\text{production volume produced before cut-off}}{\text{ideal producible volume}} \]
    
    Not produced
**rtl structure**

### Plan rtl workshop
- Define entity to be reviewed
- List current opportunities
- Estimate Base EFs
- Identify analogues
- Opportunity pre-screen
- Select review team
- Schedule review

### Perform rtl workshop
- Introduce entity & team
- Review Base EFs
- For each EF, identify improvement opportunities
- Describe and classify opportunities
- Internal QC: reconcile RF derived from EFs and volumes
- External QC: reconcile RF with analogues
- Generate summary report in consistent format

### Follow up
- Preliminary opportunity ranking
- Define technology requirements
- Enter opportunities in corporate database
- Ranked corporate opportunities
- Technical studies of best opportunities

EF = efficiency factor
rtl Workshop

• Create time and space for asset team to consider life-of-field opportunities to maximize recovery
• Supported by external experts & facilitator
• Identify opportunities in an innovative but structured setting
• Supporting toolkit
  – Pre-screening
  – Framework to help generate ideas in logical focused manner
  – Quality control of new ideas
  – Record opportunity set in consistent format
  – Create asset team ownership of opportunity set
Step 1: Characterise the Base

- Estimate efficiency factors using knowledge of reservoir and built-in guide ranges and analogue data

<table>
<thead>
<tr>
<th>Field</th>
<th>Efficiency Factor</th>
<th>Pore Scale Displacement</th>
<th>Drainage</th>
<th>Sweep</th>
<th>Cut-offs</th>
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RF = 30.4%
Step 1: Characterize the Base

- Reveal headroom for increasing each efficiency factor

![Graph showing base and remaining for each efficiency factor](chart.png)
## Typical efficiency-improving activities for oil

<table>
<thead>
<tr>
<th>Category</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Porescale</strong></td>
<td>Waterflooding, enhanced waterflooding, immiscible gas injection, miscible gas injection, blowdown, MEOR, wettability modifiers, viscosity modifiers etc</td>
</tr>
<tr>
<td><strong>Displacement</strong></td>
<td>Infill wells, recompletions, sidetracks, extended-reach etc</td>
</tr>
<tr>
<td><strong>Drainage</strong></td>
<td>Offtake management; infill wells, sidetracks, fracs; water/gas shut off, Bright Water, wellwork, intelligent completions etc</td>
</tr>
<tr>
<td><strong>Sweep</strong></td>
<td>Artificial lift, facilities upgrades, renegotiate commercial framework, ILX etc</td>
</tr>
<tr>
<td><strong>Cut-offs</strong></td>
<td>Extend field life</td>
</tr>
</tbody>
</table>
Step 2: Identify Opportunities

- Coarse pre-screening identifies **existing** technologies with the greatest potential to increase recovery
- Structured creative thinking exercises identify possible **new approaches** to increasing efficiency factors
Step 3: Opportunities typed based on Doability

- **Options**
  - Doable now (or almost)

- **Possibilities**
  - Potentially economic
  - May require incremental technology development

- **Barriered opportunities**
  - Technical or commercial barrier
  - Not currently doable or uneconomic
  - Requires step change
Step 3: Opportunities typed based on Doability

Eps
Ed
Es
Ec
RF

- Base
- Options
- Possibilities
- Bariered
- Remaining
Step 4: Opportunity Description

• Opportunities described in consistent manner:
  – Name
  – Activity involved
  – Which efficiency factor is being modified
  – Gross oil volume likely to be added
  – Estimates of cost, probability of success and key risks
  – Actions needed to begin opportunity progression
  – Timescale
  – Technology involved (if known)
  – Technology challenges; description of barriers
  – Current status
Step 5: Reality Check - Internal Consistency

- Efficiency factors estimated for Options, Possibilities & Barrireded
- Bottom-up (adding up opportunities) and top-down (product of efficiency factors) RFs compared
- Discrepancies discussed & corrected
Step 5: Reality Check - Analogue Comparison

- Recovery factors for Options, Possibilities & Barried compared with analogue data
- Discrepancies discussed & corrected

Trend lines based on analogue field data
Step 6: Review Opportunity Set & Plan Actions

- Agree on action plans and technology requirements needed to begin opportunity progression.
Example of an *rtl* Opportunity Set

Data from a mature onshore oil field

![Graph showing opportunity set with various options and recovery factors.](image)

- **Base Options**
  - MI in isolated segment
  - Bright Water
  - Increase water handling
  - EOR: CO2 injection
  - Gas Sales
  - Expanded LoSal™
  - Additional MI source
  - MI sweep optimization
  - Gas Cap water injection
  - LoSal™
  - Base

*Data from a mature onshore oil field.*
Progress through repeated *rtl* reviews

Data from a mature North Sea oil field

![Diagram showing recovery (%) for 2002 and 2005. The diagram is divided into sections representing different categories: Bariered, Possibilities, Options, Base, and Produced.]

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Wouldn’t it be nice….

…if we could know….

• For each field, the technologies required to optimize recovery
• The most important global technical barriers to resource progression, to help focus R&D
• The best fields to implement a particular technology
• Where to look for quick production
• Which reservoirs/fields/basins/countries have the greatest remaining short/medium/long-term recovery potential
• Which opportunities in the portfolio have the lowest $/bbl cost
• Etc.
With *rtl* outputs in a database, you can!

- **Geographical analysis**
  - e.g. best areas to deploy a particular technology

- **Relative comparisons**
  - e.g. what technologies offer most in a particular field or region

- **Absolute volumes**
  - e.g. best opportunities to add production for a given $/bbl or in a given time frame
Summary

- The *rtl* approach takes....
  - the people who know the field best
  - technology experts with broad global experience
  - and gives them a stimulating creative framework
  - to generate new ideas for increasing recovery
- Results in a rich, well-defined QC’d opportunity set, even in mature fields
- Identifies the key technical and commercial barriers and links these to the size of the potential recovery prize
- Helps progress stuck opportunities by:
  - Giving clear and consistent information to decision makers
  - Involving key stakeholders to generate shared ownership
  - Links activity to volumes, to ensure work to add volumes is properly resourced