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Techno-Economic Screening of Surfactant Flooding under Retention Uncertainty

High-temperature, high-salinity carbonates — a brownfield capital-allocation screen.

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01

The decision this screen serves

Incremental recovery from a mature high-temperature, high-salinity carbonate competes for capital against every other project in the portfolio.

Post-waterflood oil in a mature carbonate is a capital-allocation question

Reservoir temperature above 75–80 °C and formation brine above 80,000 ppm of total dissolved solids narrow the formulation window. What is then decided is whether the barrels left behind repay the chemical and facilities spend required to move them.

SECTOR OIL IN PLACE

15.0 MMstb

Original oil in place (OOIP) for a four-pattern five-spot module

RESIDUAL AFTER WATERFLOOD

0.350

Fraction of pore volume; initial oil saturation 0.700

FORMATION SALINITY

> 80,000 ppm TDS

With reservoir temperature above 75–80 °C

CHEMICAL SPEND COMMITTED

119.0 MMUSD

Fixed by the slug design, independent of what the flood recovers

- The chemical bill is set by slug design and injected volume, not by the oil produced. It is committed before the response is known.
- A screen is only useful if it ends where a portfolio ranks: net present value, internal rate of return and unit technical cost.
- It has to run from one laboratory quantity a core program can actually move.

Manuscript p.1, p.7 and p.8 Table 2 · chemical spend from p.10 Table 4A

SCOPE

The screen ranks candidates; it does not forecast field performance

Stated once. Everything after this slide is a screening output from a deterministic, pre-tax model in constant 2026 USD on a flat price deck.

What the screen delivers	What the model does not carry
Ranking of candidates on net present value and unit cost	Any forecast of field performance
Pilot screening against a measured retention value	Royalties, taxes, fiscal terms and financing
Breakeven retention, Brent price and sweep efficiency	Probabilistic outputs — no P10, P50 or P90
Point estimates in constant 2026 USD, flat price deck	A production decline or price escalation profile
Sector volumetrics anchored to published carbonate data	Sector area, thickness, permeability, well count

Manuscript p.7 (economic frame) and p.17 (limitations)

02

Retention as the bridge variable

Dynamic retention is measured on the same core that qualifies the formulation, and it is the laboratory quantity the economics respond to most strongly.

CALIBRATION

Retention is the laboratory quantity that carries the economics

Dynamic retention Γ integrates adsorption, precipitation, phase trapping and inaccessible-pore loss, and it is obtained from coreflood material balance. Phase behaviour and interfacial tension qualify a formulation; neither ties to chemical spend.

$$RF_{lab}(\Gamma) = 108 \times \exp(-1.23\,\Gamma)$$

Γ = dynamic surfactant retention (mg/g-rock) · RF_{lab} = laboratory tertiary recovery, in % S_{orw} — the oil left by waterflooding

SCREENED COREFLOODS

12

One surfactant family throughout, 78–100 °C, 40,000 ppm TDS and above

CALIBRATED RANGE

0.083 – 0.33 mg/g-rock

Outside this window the relation is not applied

COEFFICIENT OF DETERMINATION

0.90

R^2 across the twelve screened floods

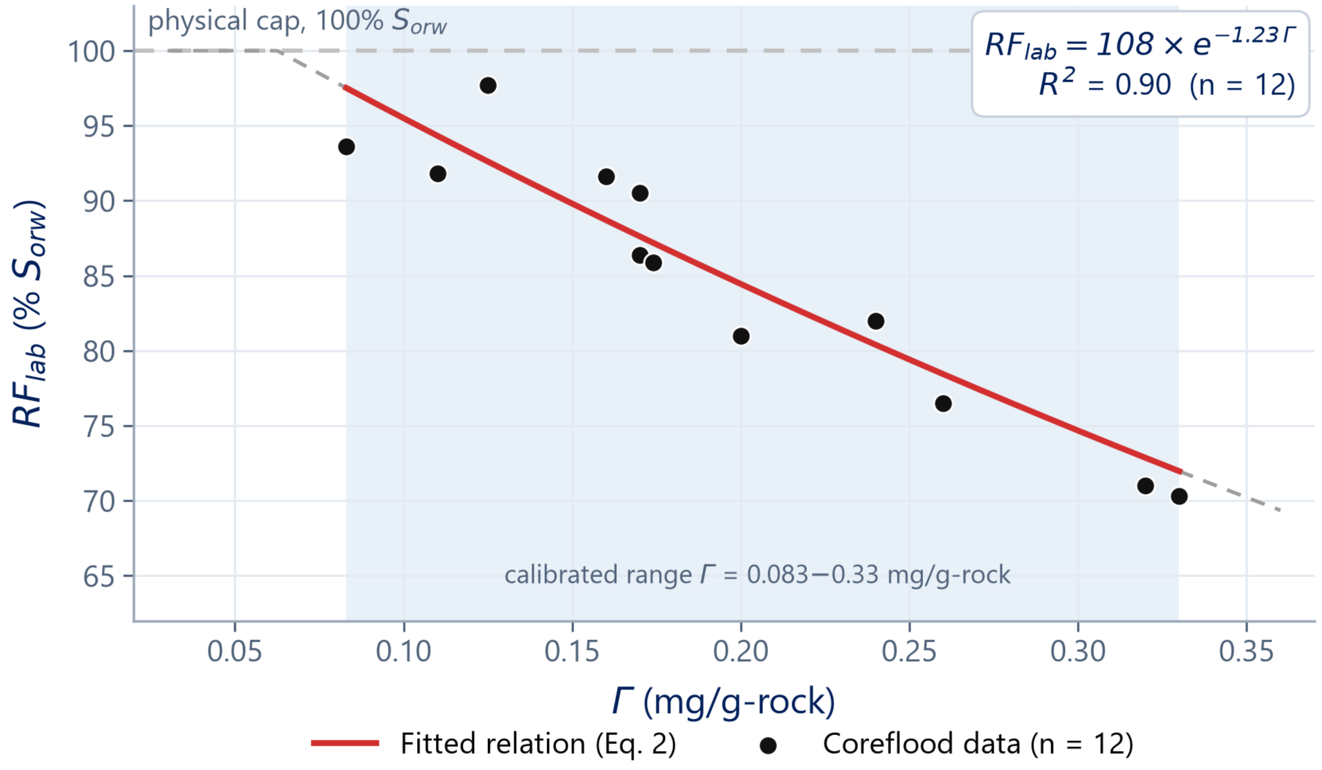
ROOT-MEAN-SQUARE ERROR

3.0 points

On RF_{lab}, in % S_{orw}, across the calibrated window

Manuscript p.4–p.6, Eq. (2) and Table 1 · workbook Retention-Recovery (F2), rows 5–16

Laboratory recovery falls as retention rises across the screened set



Black circles are the twelve screened corefloods. The red curve is RF_{lab} = 108 × exp(−1.23 Γ), R^2 = 0.90, valid over the shaded window Γ = 0.083–0.33 mg/g-rock. Grey segments outside the window are context only and are capped at the 100 % S_{orw} physical limit.

WHAT IT SHOWS

RF_{lab} falls from 97.5 to 72 % S_{orw} as retention rises across the calibrated range.

- Twelve corefloods, one surfactant family, 78–100 °C and 40,000 ppm TDS or above.
- Applied only inside Γ = 0.083–0.33 mg/g-rock. The relation is not extrapolated.
- The benchmark is a screened subset of optimized systems, so the economics sit at an upper bound.
- Field cases from Kuwait, the UAE and Oman constrain operability. None of them calibrates this relation.

Regional field cases bound operability; none of them calibrates the relation

Reported outcomes from carbonate chemical floods at 78–100 °C and 180,000–235,000 ppm TDS. They test whether the screening assumptions are operationally reachable. They do not fit any coefficient used here.

Case	Reported outcome	Use here
Kuwait, SAMA alkali–surfactant–polymer pilot	Oil-cut uplift near 12 percentage points, sustained six months	Operability
Kuwait, single-well chemical tracer test	Post-flood S_{orw} near 0.04	Operability
UAE offshore, one-spot surfactant–polymer	Post-flood residual oil near 4 per cent	Operability
Oman, Upper Shuaiba	Recovery fell beyond about 150,000 ppm TDS	Operability
Self-check of the framework against SAMA	Composite sweep–saturation term near 0.20 returns recovery of order 20 % OOIP	Order-of-magnitude check

Manuscript p.6 and p.16 · contextual cases only; they do not enter the calibration

03

The screen, end to end

From a retention measurement on a core plug to net present value, internal rate of return and unit technical cost for a four-pattern sector.

From a coreflood measurement to a capital metric

Laboratory recovery is scaled by volumetric sweep and the residual-oil ratio, carried through sector volumetrics into a five-year cash flow, and closed on net present value at 10 per cent (NPV_{10}), internal rate of return (IRR) and unit technical cost (UTC).

$$RF_{field} = RF_{lab} \times E_v \times (S_{orw} / S_{oi})$$

RF_{field} = screening recovery, in % OOIP · E_v = volumetric sweep efficiency, 0.550 · S_{orw}/S_{oi} = 0.350/0.700 = 0.500

1

Measure retention

Dynamic retention from coreflood material balance on the qualified formulation.

`Γ = 0.20 mg/g-rock`

2

Translate recovery

Fitted relation returns RF_{lab}; E_v and the saturation ratio carry it to the field.

RF_{field} = 23.2 % OOIP

3

Apply volumetrics

Field recovery on 15.0 MMstb of oil in place gives incremental oil and gross revenue.

`3.48 MMstb · 209.0 MMUSD`

4

Build the cash flow

Fixed chemical spend, injection and production cost, and a Year-0 facilities charge.

`8.48 MMUSD/yr`

5

Return the metrics

Discounting over five operating years closes the screen on three capital measures.

NPV_{10} · IRR · UTC

INPUTS

Every input the base case carries

Deterministic and pre-tax, constant 2026 USD, flat price deck. No royalties, taxes, fiscal terms or financing are modelled. Sector area, thickness, permeability and well count are not stated by the sources and are not assumed here.

Reservoir and volumetrics	Value
Original oil in place	15.0 MMstb
Sector pore volume	26.79 MMbbl
Porosity φ / oil saturation S_{oi}	0.200 / 0.700
Post-waterflood residual, S_{orw}	0.350
Volumetric sweep efficiency, E_v	0.550

Cost and financial frame	Value
Facilities capital, Year 0	25.0 MMUSD
Chemical spend, fixed by slug design	119.0 MMUSD
Injection cost	0.94 USD/bbl injected
Production cost	5.00 USD/bbl of oil
Brent, flat / real discount rate	60.0 USD/bbl / 10.0 %

Manuscript p.7–p.9 and p.8 Table 2 · injection cost is 0.87 plus a 0.07 brownfield chemical-handling adder

Year-0 facilities charge plus five operating years · 1.2 pore volumes injected · staged slug, polymer drive one, polymer drive two

The base case returns 7.2 MMUSD of NPV_{10} at a 60 USD/bbl deck

Γ = 0.20 mg/g-rock, Brent 60 USD/bbl, E_v = 0.550, facilities capital 25.0 MMUSD, discounted at 10 per cent.

FIELD SCREENING RECOVERY

23.2 % OOIP

From RF_{lab} = 84.4 % S_{orw} at the base retention

INCREMENTAL OIL

3.48 MMstb

Against 15.0 MMstb of original oil in place

GROSS REVENUE

209.0 MMUSD

Flat 60 USD/bbl deck, no escalation

CHEMICAL COST PER BARREL

34.15 USD/bbl

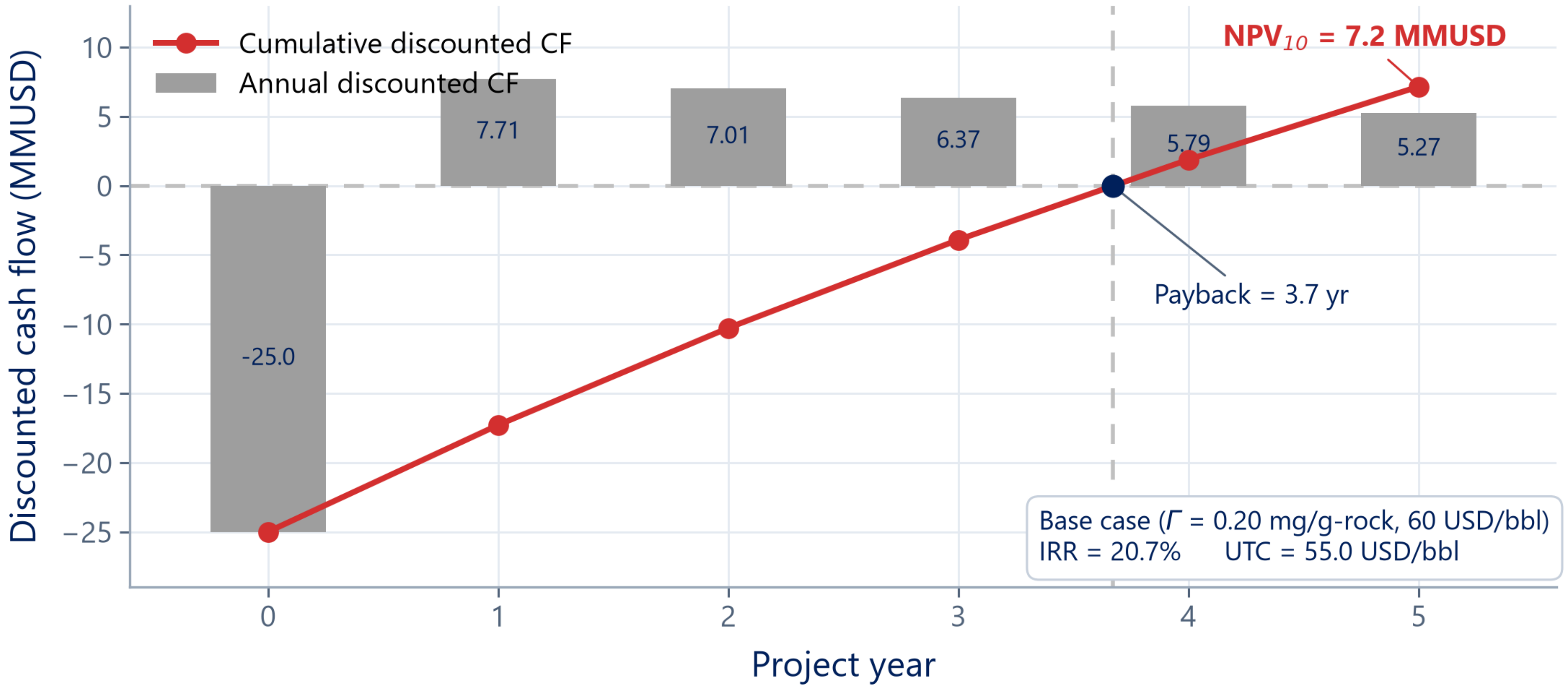
Of incremental oil; total chemical spend does not move with retention

Cash stack, undiscounted	MMUSD
Gross revenue at 60 USD/bbl	209.0
Chemical spend	119.0
Injection operating cost	30.2
Production operating cost	17.4
Facilities capital, Year 0	25.0

Manuscript p.10 Tables 4A and 4B, p.11 · workbook Model Summary rows 10–17

Undiscounted profit 17.4 MMUSD over five operating years · uniform annual net cash flow 8.48 MMUSD

Discounted payback falls at 3.7 years and NPV_{10} reaches 7.2 MMUSD by year five



Grey bars are annual discounted cash flow by project year; the red line is cumulative discounted cash flow. Silver dashed lines mark the zero-cumulative threshold and the 3.7-year discounted payback. Base case: Γ = 0.20 mg/g-rock, Brent 60 USD/bbl, discount rate 10 %, IRR = 20.7 %, UTC = 55.0 USD/bbl.

SCREENING OUTPUT

At Γ = 0.20 mg/g-rock and a 60 USD/bbl deck the sector clears its hurdle by 7.2 MMUSD.

UTC is 55.0 USD/bbl against a 60 USD/bbl price. The operating margin is 5.0 USD/bbl of incremental oil on 3.48 MMstb, before any fiscal term.

NET PRESENT VALUE AT 10 %	INTERNAL RATE OF RETURN	UNIT TECHNICAL COST	DISCOUNTED PAYBACK
7.2 MMUSD	**20.7** %	**55.0** USD/bbl	**3.7** years

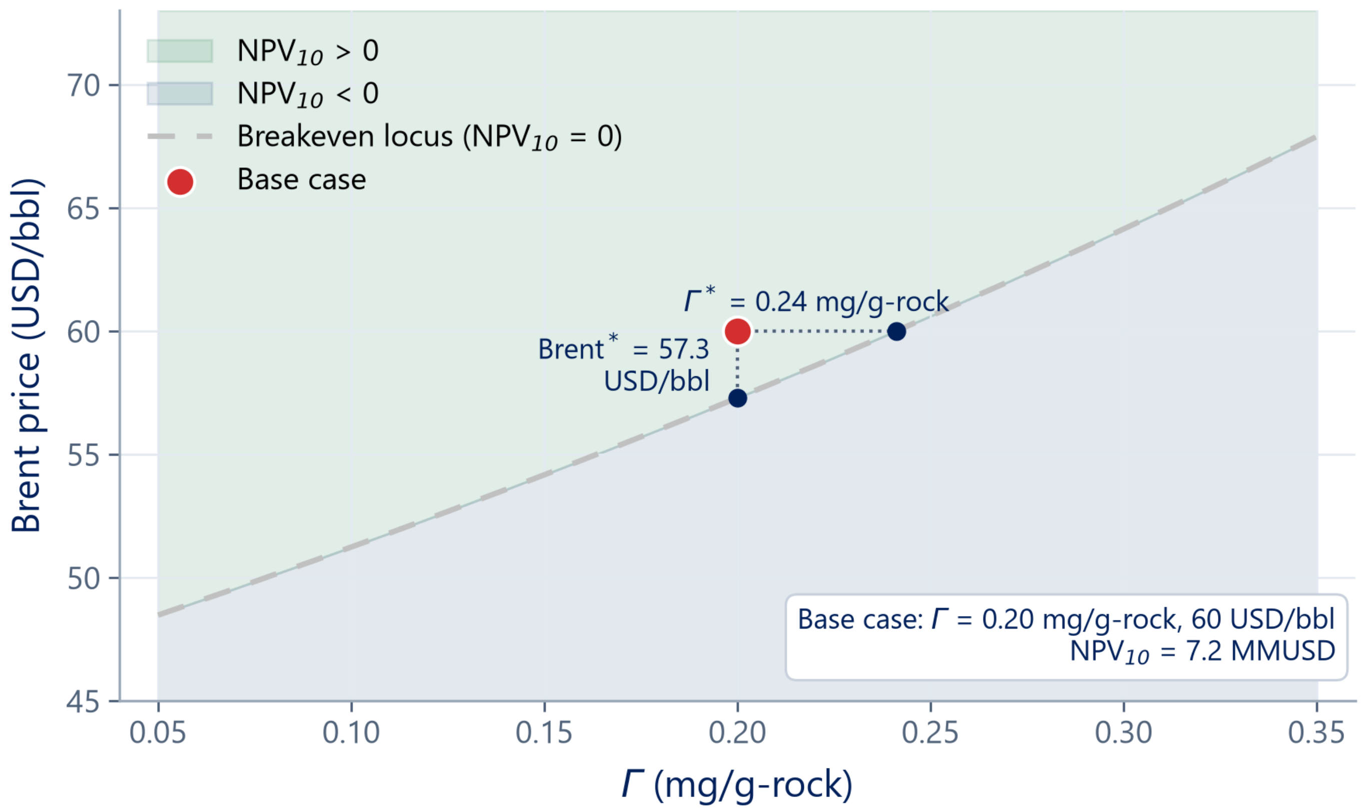
Manuscript p.11 and p.17 · workbook Model Summary rows 19–22

04

Where it breaks

Three breakevens sit close to the base case, and the ranking of what moves them sets where measurement effort should go.

The base case sits 0.04 mg/g-rock from its own breakeven retention



The silver dashed line is the breakeven Brent price at each Γ, where NPV_{10} = 0; green shading is NPV_{10} > 0 and blue is NPV_{10} < 0. The red point is the base case, Γ = 0.20 mg/g-rock at 60 USD/bbl, NPV_{10} = 7.2 MMUSD.

WHAT IT SHOWS

Base-case Γ sits 0.04 mg/g-rock below the Γ* = 0.24 mg/g-rock breakeven at 60 USD/bbl.

- Breakeven Brent at Γ = 0.20 mg/g-rock is 57.3 USD/bbl, 2.7 USD/bbl under the deck.
- The price required climbs about 0.65 USD/bbl for every 0.01 mg/g-rock of Γ.
- Above Γ = 0.25 mg/g-rock, NPV_{10} turns negative at 60 USD/bbl.
- Two of the twelve benchmark corefloods measured Γ below 0.125 mg/g-rock.

Five cases run on the same model, not five forecasts

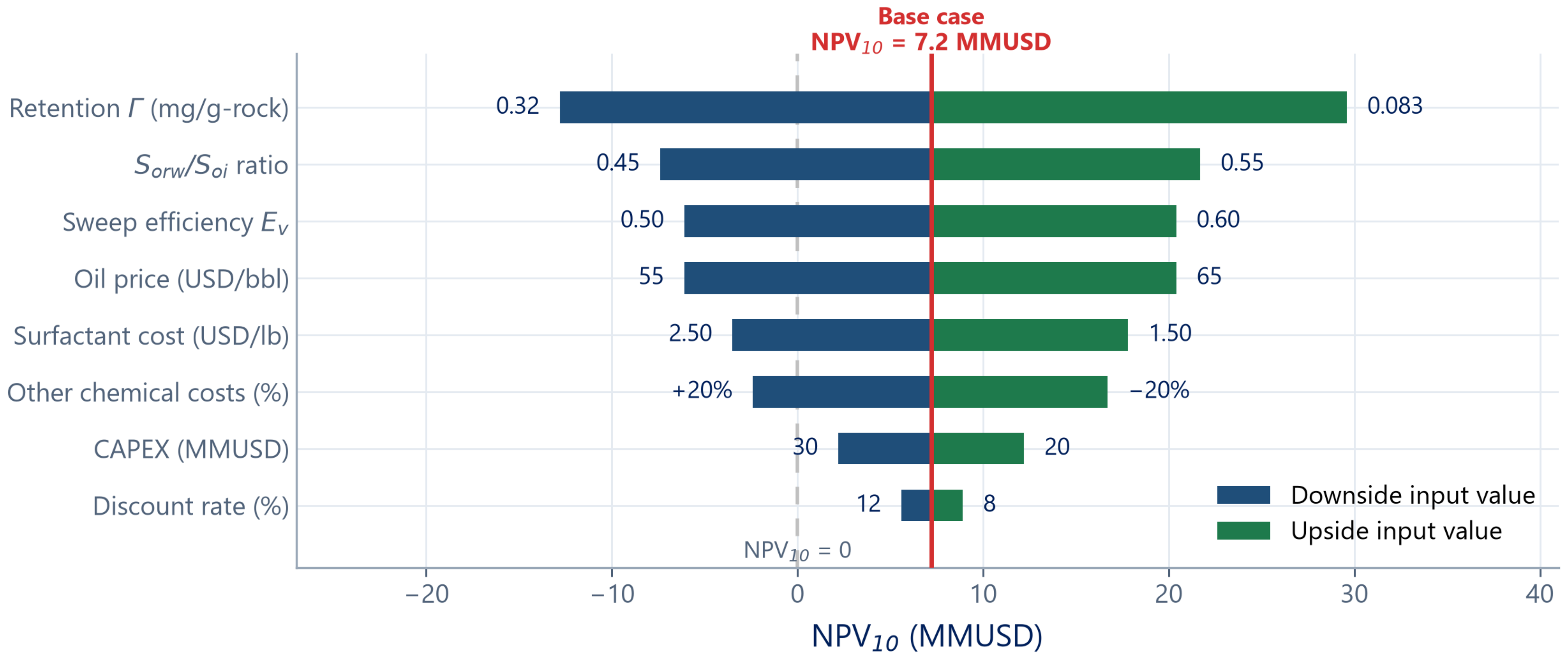
Each row is an evaluation of the screening model at the inputs shown. None is a prediction of what a flood would deliver.

Scenario	Γ (mg/g-rock)	Brent (USD/bbl)	NPV_{10} (MMUSD)	IRR (%)	UTC (USD/bbl)
Base case	0.20	60	+7.2	20.7	55.00
Retention breakeven	0.241	60	0.0	10.0	57.59
Brent downside	0.20	50	−19.3	negative	55.00
Sweep downside at 0.50	0.20	60	−6.1	0.0	60.00
Low-retention case	0.10	60	+26.2	45.8	49.22

Computed from the study's own screening model at the inputs shown; not forecasts · manuscript Tables 5–6, p.11 and p.15

Brent 50 returns a negative rate of return under the manuscript's convention · the breakeven case returns the discount rate by construction

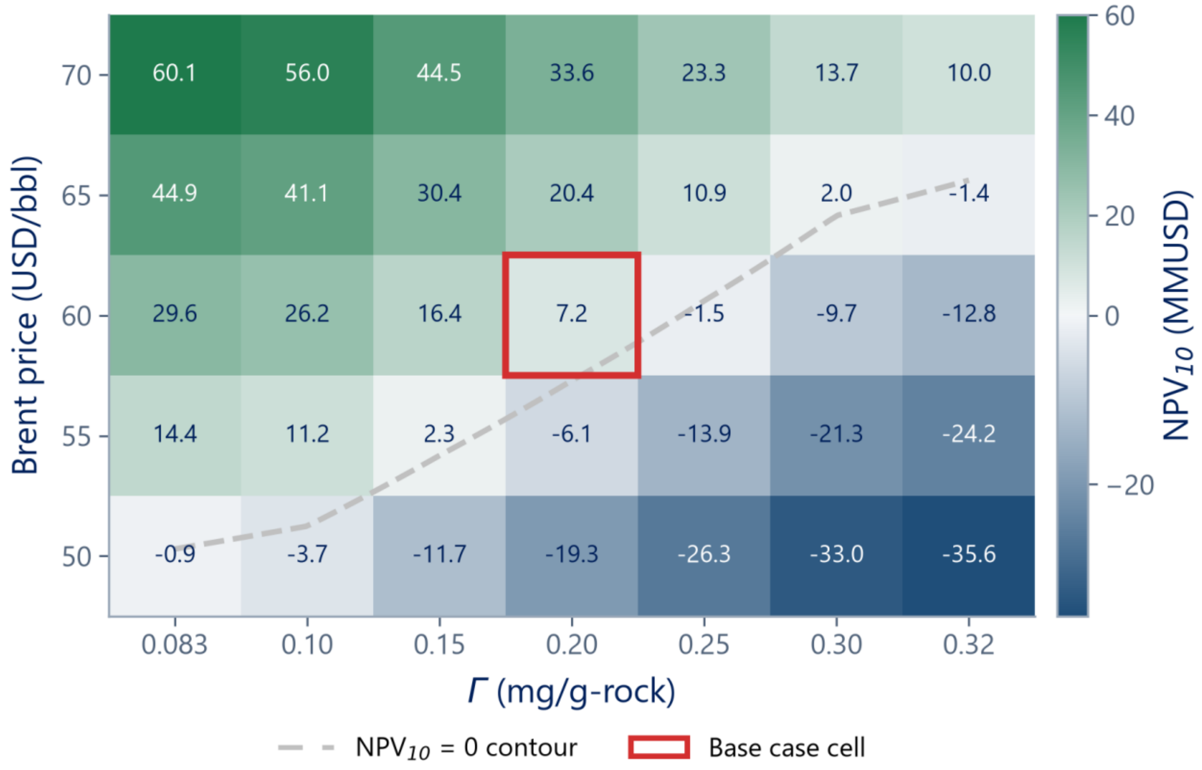
Retention Γ swings NPV_{10} by 42.4 MMUSD, about 1.5 times the next variable



Bars show NPV_{10} (MMUSD) at the low-bound and high-bound test value of each parameter, swung one at a time from the 7.2 MMUSD base case (red line). Blue is the downside input value, green the upside; the grey dashed line marks NPV_{10} = 0. Numbers at bar ends are tested input values, not NPV_{10}. Manuscript Fig. 6, p.13.

Span, MMUSD: retention 42.4 · saturation ratio 29.0 · sweep 26.4 · oil price 26.4 · surfactant 21.3 · other chemicals 19.0 · capital 10.0 · discount rate 3.3

Viability is a joint condition on retention and price, not on either alone



Cells show NPV_{10} (MMUSD) at each combination of Γ (x-axis, mg/g-rock) and Brent price (y-axis, USD/bbl); blue is negative, green positive. The silver dashed contour is the interpolated NPV_{10} = 0 boundary and the red outline marks the base-case cell.

WHAT IT SHOWS

At Γ = 0.32 mg/g-rock, NPV_{10} stays negative even at 70 USD/bbl Brent.

- At 50 USD/bbl no tested Γ clears, from 0.083 through 0.32 mg/g-rock.
- Cutting facilities capital from 25 to 20 MMUSD does not restore a positive result at 50 USD/bbl.
- Γ = 0.10 mg/g-rock turns positive between 50 and 55 USD/bbl; Γ = 0.30 mg/g-rock only between 60 and 65 USD/bbl.

POSITION

The base case is 0.04 mg/g-rock of retention and 2.7 USD/bbl of Brent away from returning nothing.

Γ^* = 0.24 mg/g-rock at 60 USD/bbl. Breakeven Brent is 57.3 USD/bbl at Γ = 0.20. E_v^* = 0.523 against a base of 0.550, and E_v = 0.50 moves NPV_{10} to −6.1 MMUSD.

BREAKEVEN RETENTION

0.24 mg/g-rock

BREAKEVEN BRENT

57.3 USD/bbl

BREAKEVEN SWEEP

0.523 fraction

05

What follows for an asset team

Where the next measurement goes, and what the screen says about ranking this method against the alternatives at a low price deck.

PRIORITY

A coreflood retention measurement buys down more value at risk than a cost estimate

Ranked by the swing each input produces around the 7.2 MMUSD base case.

DYNAMIC RETENTION	FACILITIES CAPITAL	DISCOUNT RATE
42.4 MMUSD	**10.0** MMUSD	**3.3** MMUSD
Span of Γ across 0.083–0.32 mg/g-rock — the widest of any input; the swing is asymmetric	Span across 20–30 MMUSD, a quarter of the retention band	Span across 8–12 per cent, the narrowest input tested

- Retention Γ, the S_{orw}/S_{oi} ratio and sweep efficiency E_v are the three widest inputs. All three are subsurface, and all three can be measured before a pilot is sanctioned.
- Conformance and chemistry are claims on the same margin: E_v from 0.550 to 0.600 adds 13.2 MMUSD, then Γ from 0.20 to 0.10 mg/g-rock adds a further 20.7 MMUSD.
- Together they reach NPV_{10} = 41.1 MMUSD, with Γ supplying 61 per cent of the 33.9 MMUSD gain. Procurement and front-end cost work move the answer less than either.

Manuscript p.13 and p.15–p.16 · workbook Tornado Analysis (F6) and NPV Waterfall (F10)

One-at-a-time sensitivity, all other inputs held at the base case

WHAT THIS SUPPORTS

Measure retention before ranking the method

- Acquire dynamic retention on reservoir core from the candidate formulation before any pilot commitment. It is the input with the widest effect on the answer.
- Advance conformance work and surfactant development together: sweep alone reaches 20.4 MMUSD, retention alone 26.2 MMUSD, the pair 41.1 MMUSD.
- At a 50 USD/bbl deck, rank surfactant flooding against alternative recovery methods rather than defaulting to it. No tested retention case clears at that price.
- Above 110 °C there is no published retention data for this formulation class. A pilot in that window would be extrapolating the relation, not applying it.

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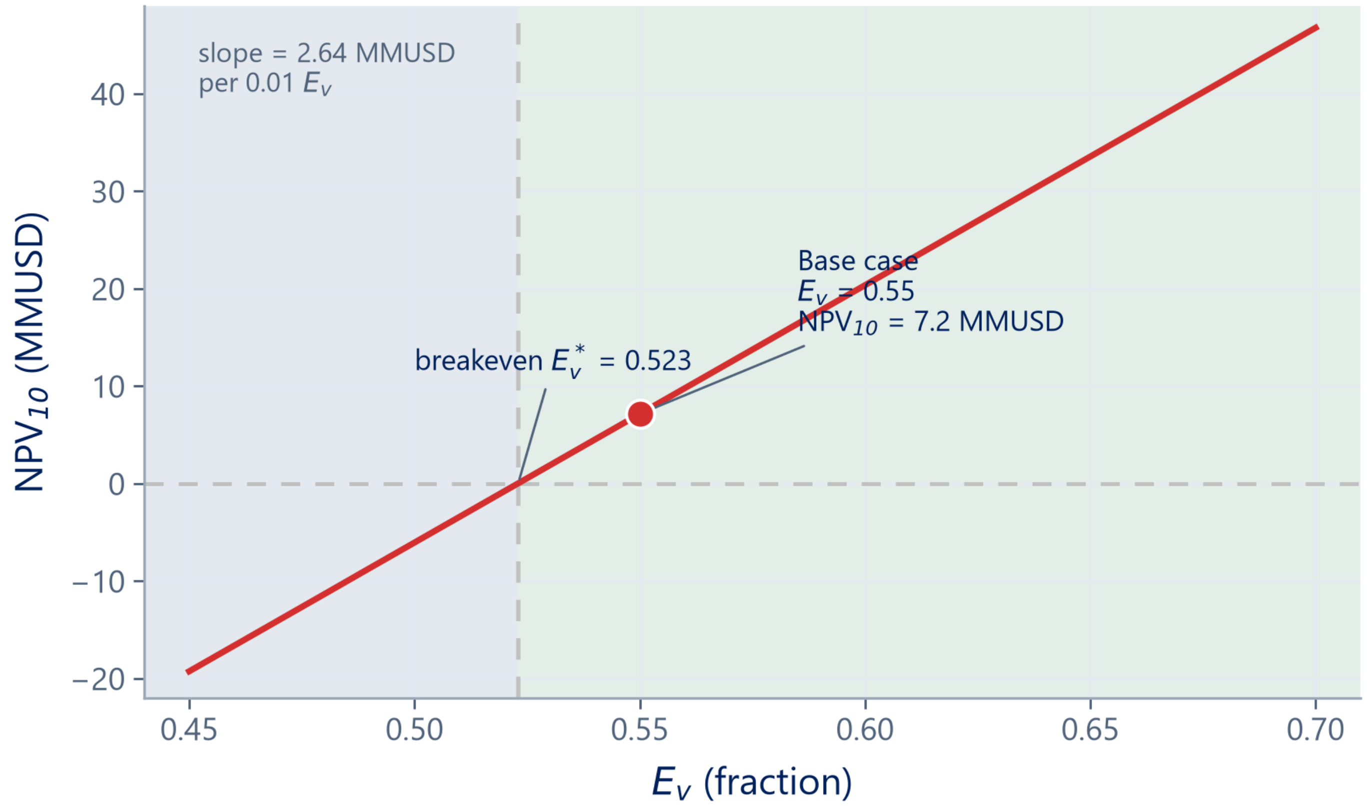
NPV_{10} responds linearly to volumetric sweep efficiency E_v



The red line is NPV_{10} (MMUSD) against E_v (fraction); green shading is NPV_{10} > 0 and blue is NPV_{10} < 0. The silver dashed line marks the breakeven E_v = 0.523 and the red point is the base case at E_v = 0.550.*

WHAT IT SHOWS

Breakeven sweep E_v* = 0.523 sits 0.027 below the base case E_v = 0.550.

- Slope is 2.64 MMUSD for every 0.01 of E_v, constant over E_v = 0.45–0.70.
- E_v = 0.50 instead of 0.550 moves NPV_{10} from +7.2 to −6.1 MMUSD.
- E_v is exogenous here. No mobility ratio, polymer rheology or conformance model sits behind it.

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Thank you

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