

Iron Sulphide Scale Management in High H₂S and CO₂ Carbonate Reservoirs

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Sulphide and Carbonate Scale Prediction Workflow in Gas/Condensate Wells

Combine PVT and scale prediction modelling for accurate scaling profiles.

Like carbonate scales, the precipitation of sulphides depends on water pH and it is influenced by the in-situ three phase partitioning of H₂S and CO₂. This creates an additional level of complexity to the prediction of these scales (FeS, CaCO₃ and FeCO₃) which is often not addressed correctly.

In this project, we have developed a workflow (Figure 1) for the accurate prediction of in-situ sulphide and carbonate scales for gas/condensate wells in the Khuff reservoir in Saudi Arabia. The new approach integrates the use of Pressure, Volume, Temperature (PVT) modelling with scale prediction modelling.

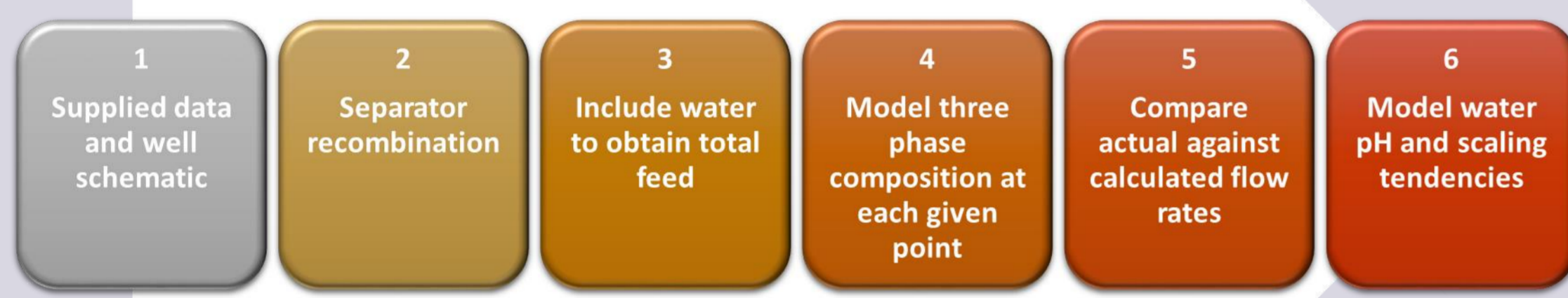


Figure 1 Workflow for combined carbonate and sulphide scale prediction in gas/condensate wells.

Modelling 3 Phase H₂S and CO₂ Partitioning

How 3 phase H₂S and CO₂ concentrations change in a gas/condensate well and their impact on pH.

Unlike other inorganic scales, sulphides and carbonates are pH dependent and they are influenced by the 3 phase CO₂/H₂S equilibrium.

Using a PVT model and mass balance equations we calculate the specific in-situ three phase concentration of H₂S and CO₂ at several points in the well, from the reservoir to the first stage of separation (Figure 2).

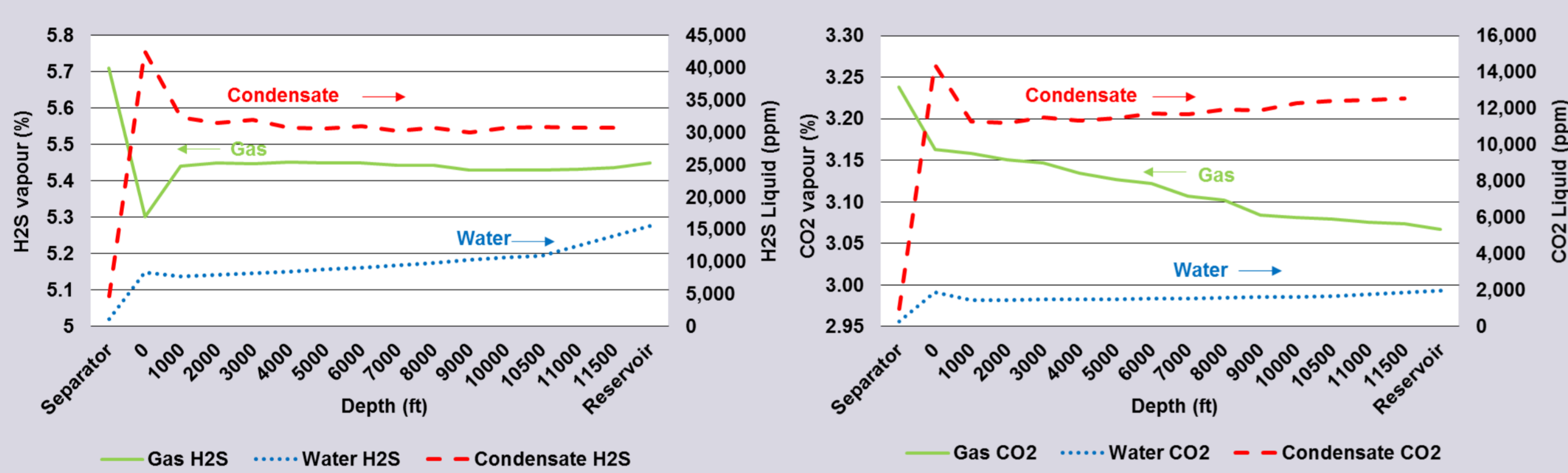


Figure 2 H₂S and CO₂ three phase partitioning from reservoir to separator for Well A.

In the reservoir, we include the calculated dissolved sulphide and carbonate species concentrations in the formation water composition and equilibrate it with the carbonate rock.

In the wellbore, we assume that only condensed water is produced and we use the calculated in-situ water H₂S and CO₂ concentrations to determine the pH trend (Figure 3).

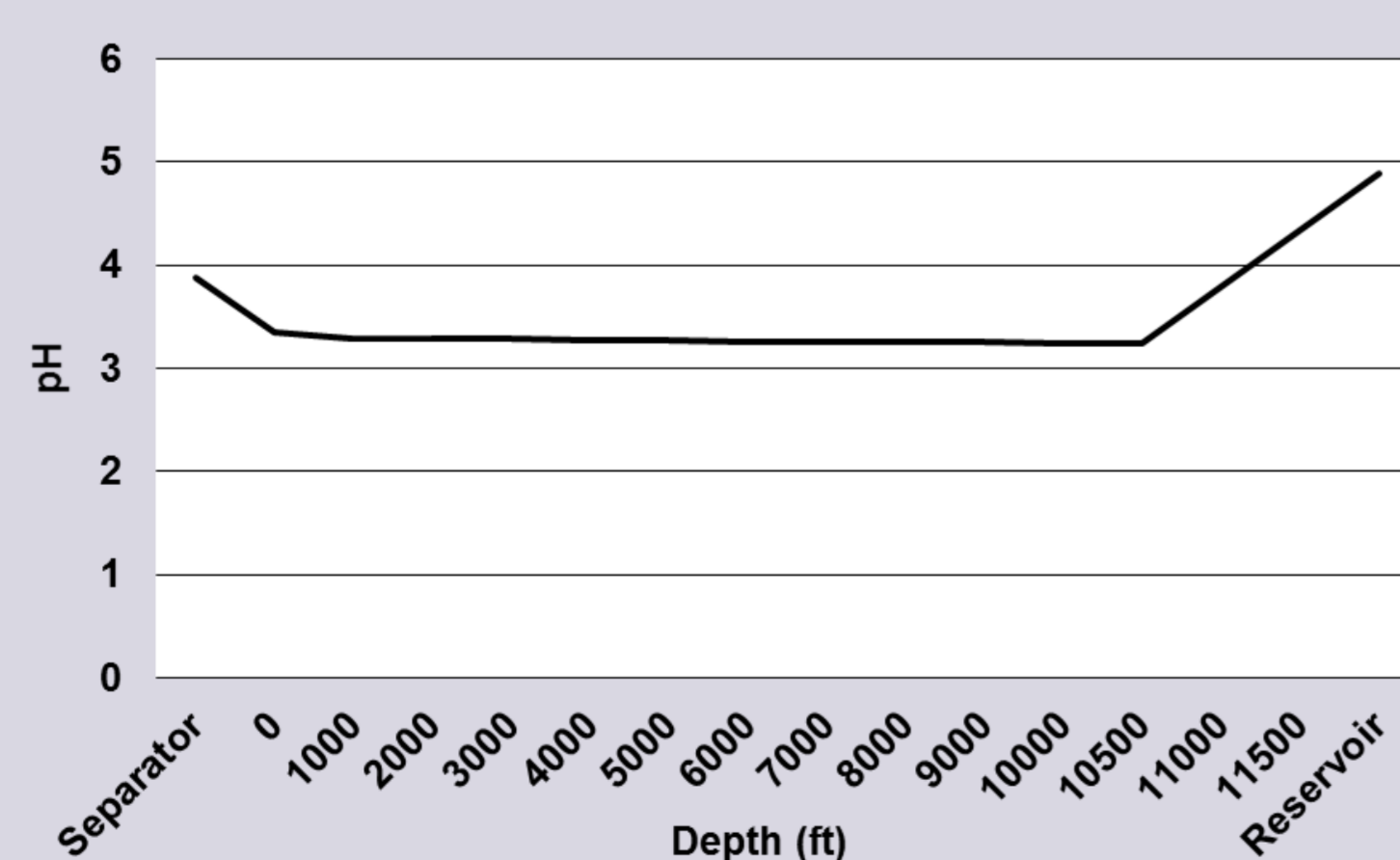


Figure 3 pH from reservoir to separator for Well A.

The significant pH drop from reservoir (pH ~ 4.8) to the wellbore (pH ~ 3.3) is caused by the fact that in the production tubing there is no carbonate formation to buffer the water pH (SR CaCO₃ = 1). Therefore, the carbonate pH is considerably lowered by the CO₂.

Along the wellbore, the pH remains almost constant up to the separator where the significant pressure drop releases a large amount of CO₂ to the gas phase thus increasing water pH.

Dissolved Iron in Carbonate Reservoirs

Is iron coming from formation fluids or corrosion?

To establish if Fe²⁺ can be present in soluble form at reservoir conditions, we calculate the reservoir equilibrium pH (with SR CaCO₃ = 1) using in-situ H₂S and CO₂ concentrations and then add Fe²⁺ to the water composition until FeS precipitates.

The maximum dissolved iron concentration represents the highest concentration of iron (Fe²⁺) stable in water before scale precipitation occurs. At reservoir conditions (H₂S = 2-6% And CO₂ = 2-4%) dissolved iron is not predicted to be very stable (Figure 4). That is, in the reservoir only very low levels of free Fe²⁺ can occur at high H₂S levels.

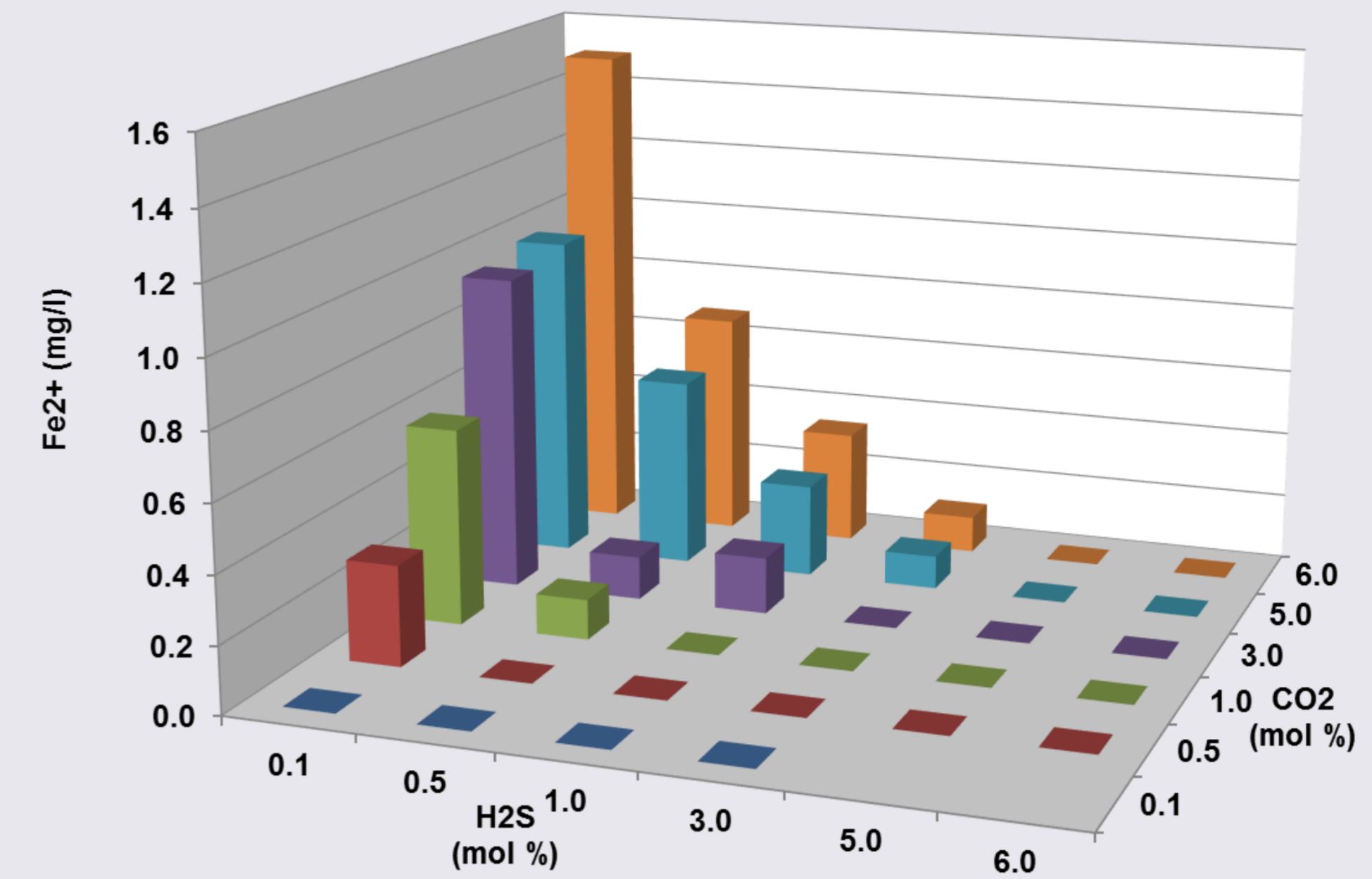


Figure 4 Maximum dissolved iron concentration for a defined gas/condensate well (fixed T and p) at variable H₂S and CO₂ concentrations.

It is likely that the drop in pH in the wellbore causes corrosion of the carbon steel tubulars in the wells investigated and that this is the most probable source of iron which may subsequently form FeS in the production tubing.

At the low pH levels in the wellbore (pH ~ 3.2 – 3.8) and at the lower up hole temperatures, high levels of dissolved iron (>100ppm) in the aqueous phase are possible at close to wellhead/surface conditions (Figure 5).

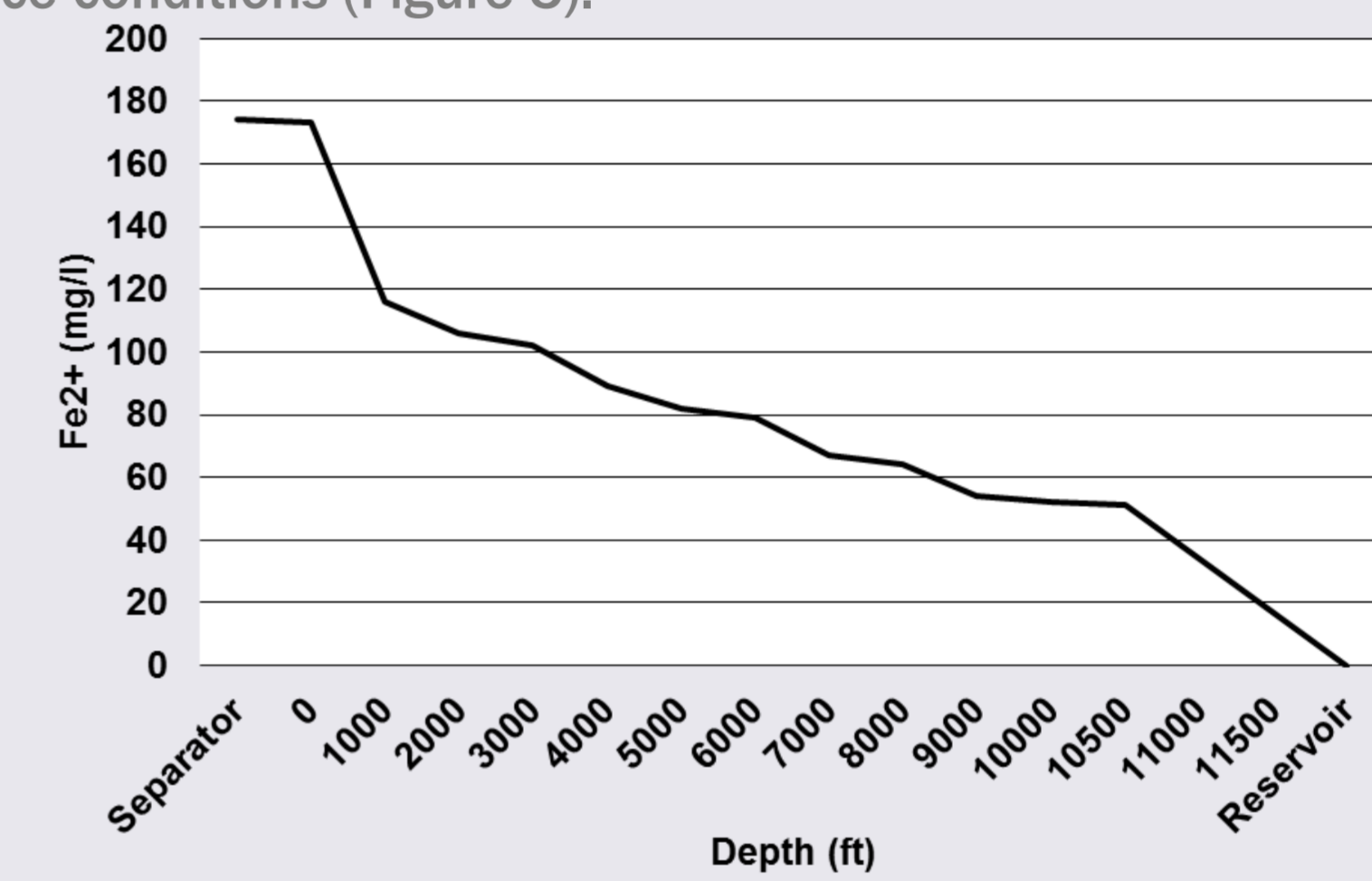


Figure 5 Maximum dissolved iron from reservoir to separator for Well A.

FeS Scale Prediction Trend

Applying the calculated in-situ H₂S and CO₂ concentrations and pH to obtain a scale prediction trend.

Since the true in-situ total iron concentration is unknown, scale predictions were run for three different scenarios, 10, 50 and 100 mg/l total iron. Due to the low pH, FeS does not form in the 10 and 50 mg/l scenario. FeS is more likely to form downhole rather than further up the well (Figure 6) because its formation is favored at higher temperatures.

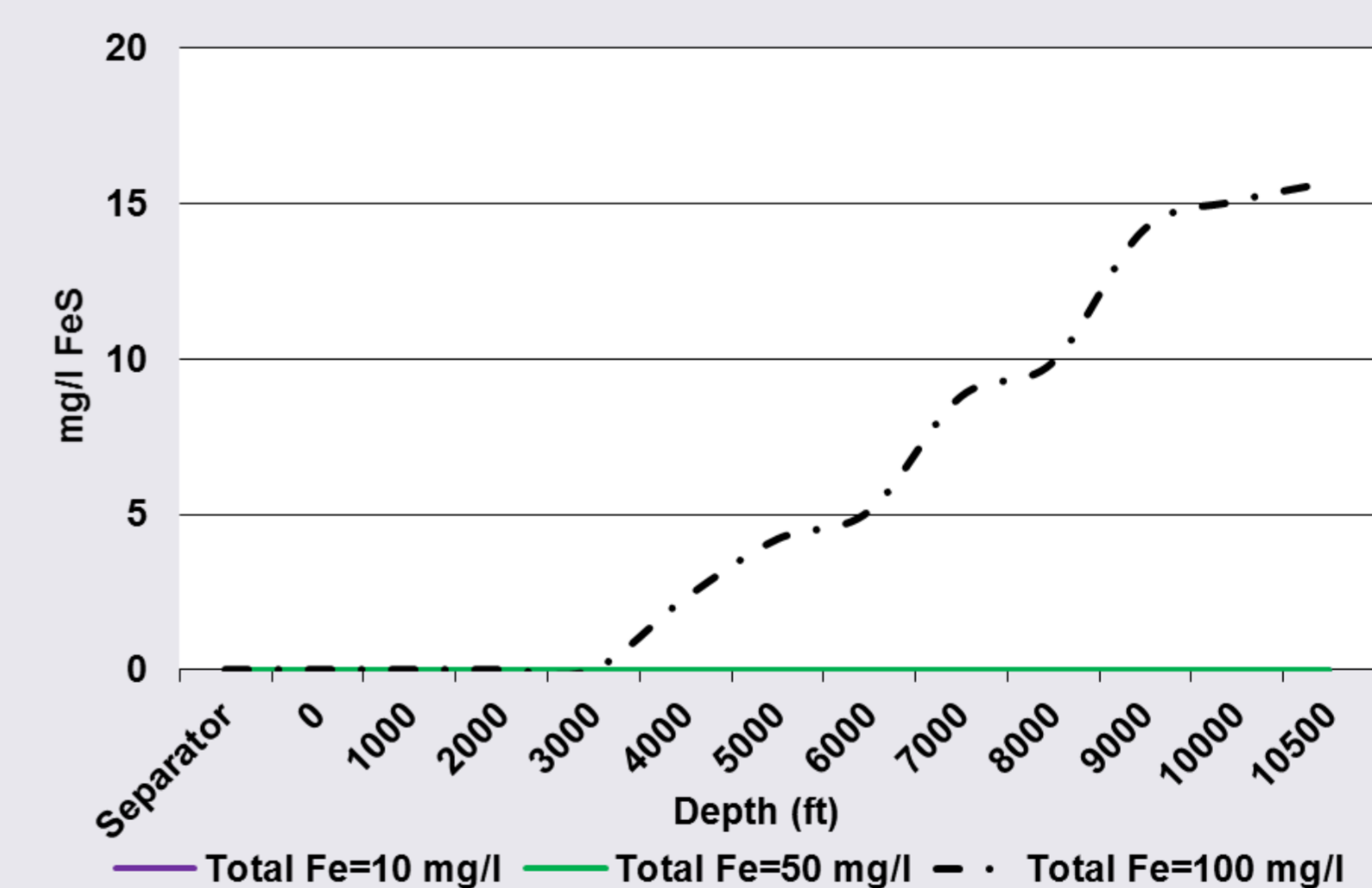


Figure 6 Iron sulphide scale prediction trend from reservoir to separator for Well A at variable total iron concentrations.

Sulphide scales are pH dependent and difficult to predict in producing wells.

We have developed and applied a new Workflow for accurate iron sulphide scale prediction from reservoir to separator.

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