Volume 11, Issue 6, June – 2026 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1781

Evolution of Volumetric Uncertainty: Understanding P10–P90 Gap Reduction Across the Reservoir Lifecycle

Chinweike Okeke O.[1]; Robert Nkpado[2]

[1]Reservoir Engineer First Exploration and Petroleum Development Company Lagos, Nigeria
[2]Project Engineer Strides Energy & Maritime Ltd Port Harcourt, Rivers State, Nigeria

Publication Date: 2026/07/17

Abstract: Accurate estimation of hydrocarbon volumes is fundamental to field development planning, reserves booking, investment decisions, and corporate valuation. At every stage of reservoir maturation, subsurface uncertainty influences estimate of Original Oil in Place (OOIP), Gas Initially in Place (GIIP), and recoverable reserves. Probabilistic volumetric distributions, particularly P10, P50, and P90 estimates, commonly represent this uncertainty. A key indicator of uncertainty reduction throughout the reservoir lifecycle is the narrowing of the gap between P10 and P90 volumetric estimates. During exploration, this gap may exceed several hundred per cent due to limited geological and petrophysical information. As appraisal, development, and production data become available, uncertainty progressively decreases, and volumetric outcomes converge. This paper argues that the P10–P90 spread is a practical measure of reservoir uncertainty and that it should narrow as field knowledge increases. It examines how uncertainty evolves from exploration through mature production, identifies the principal drivers of reduction, quantifies expected changes in spread, and presents a case study illustrating the evolution of uncertainty within a typical clastic oil reservoir. The paper further proposes a framework for tracking uncertainty maturity, using the P10–P90 ratio as a reservoir management metric.

Keywords: *Volumetric Uncertainty, P10, P50, P90, Reserves Estimation, Reservoir Lifecycle, Uncertainty Quantification, Monte Carlo Simulation, Reservoir Characterisation.*

How to Cite: Chinweike Okeke O.; Robert Nkpado (2026) Evolution of Volumetric Uncertainty: Understanding P10–P90 Gap Reduction Across the Reservoir Lifecycle. *International Journal of Innovative Science and Research Technology,* 11(6), 3595-3599. https://doi.org/10.38124/ijisrt/26jun1781

I. INTRODUCTION

Subsurface decision-making is inherently uncertain. Reservoir engineers and geoscientists routinely make predictions based on incomplete information regarding:

- Reservoir extent
- Net-to-gross distribution
- Porosity
- Hydrocarbon saturation
- Fluid contacts
- Recovery factor

These uncertainties directly impact volumetric calculations and economic evaluations.

Industry practice commonly expresses uncertainty using probabilistic estimates:

Table 1 Probabilistic Estimates

Probability	Interpretation
P90	Conservative estimate (90% chance actual volume exceeds value)
P50	Best estimate (median case)
P10	Optimistic estimate (10% chance actual volume exceeds value)

The spread between P10 and P90 provides a quantitative measure of reservoir uncertainty and shows how far estimates remain from convergence.

A large P10–P90 gap indicates poor subsurface understanding, while a narrow gap suggests greater confidence in volumetric estimates and closer convergence.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1781

➢ *The Primary Objective of this Paper is to Understand:*

- Why does the P10–P90 gap exist?
- How does it evolve throughout field maturation?
- Which uncertainties are reduced at each lifecycle stage?
- What are the expected ranges of uncertainty reduction?
- What are the practical implications for reserves and development planning?
- How it evolves throughout field maturation.
- Which uncertainties are reduced at each lifecycle stage?
- Expected ranges of uncertainty reduction.
- Practical implications for reserves and development planning.

II. FUNDAMENTALS OF VOLUMETRIC UNCERTAINTY

Hydrocarbon volumes are commonly estimated using:

➢ *Oil in Place*

$$OOIP = \frac{7758Ah\phi\,(1 - S_w)}{B_o}$$

Where:

- A Area
- h Net Pay
- φ Porosity
- Sw Water Saturation
- Bo Formation Volume Factor

With each parameter possessing a level of uncertainty.

Consequently, volumetric estimates become probabilistic rather than deterministic.

➢ *Using Monte Carlo Simulation:*

$$OOIP = f(A, h, \phi, S_w, B_o)$$

Thousands of realisations generate a cumulative probability distribution.

From this distribution P90, P50 and P10 are extracted.

The difference: $Gap = P10 - P90$ or normalised uncertainty: $\frac{P10}{P90}$ becomes an effective measure of volumetric confidence.

III. RESERVOIR LIFECYCLE AND INFORMATION GROWTH

Reservoir understanding evolves through several stages. The reservoir lifecycle is a progressive journey from exploration to abandonment, during which subsurface knowledge increases and uncertainty decreases. Information growth is the process by which data, interpretations, and reservoir understanding evolve through successive phases of field development. This concept is fundamental to reservoir management because investment decisions, reserves estimation, production forecasting, and field development planning all depend on the quantity and quality of available information.

A key characteristic of reservoir lifecycle management is that uncertainty is highest during exploration and gradually reduces as more geological, geophysical, petrophysical, dynamic, and production data become available. This reduction is reflected in the narrowing of ranges between probabilistic estimates, such as P10, P50, and P90 reserves and production forecasts.

➢ *Exploration Stage*

The main objective of this stage is to identify hydrocarbon accumulations and estimate potential resources. Available Data ranges from regional geology, 2D/3D seismic, analogue fields, basin modelling, and geochemical studies.

- *Key Uncertainties:*

✓ Structural: Closure size, fault interpretation, spill-point definition.
✓ Stratigraphic: Reservoir presence, net-to-gross distribution, facies continuity.
✓ Petrophysical: Porosity, permeability, water saturation.
✓ Fluid: Hydrocarbon type, fluid contacts, gas composition, oil quality.
✓ Information Maturity: Very low; reservoir understanding remains largely conceptual.

- *Typical Confidence Level:*

✓ Chance of geological success: 10–40%
✓ Resource estimates characterised by wide STOIIP/GIIP ranges
✓ Large P10–P90 uncertainty gap, reflecting limited subsurface knowledge.

➢ *Appraisal Stage*

The appraisal stage is the phase between discovery and full-field development, during which additional data are acquired to reduce subsurface uncertainties and improve confidence in reserves, production forecasts, and development concepts.

- *Objectives of the Appraisal Stage*

The primary goals are to:

✓ Delineate the areal and vertical extent of the reservoir.
✓ Confirm hydrocarbon volumes and reserve estimates.
✓ Define fluid contacts (OWC, GOC, GWC).
✓ Assess reservoir continuity and compartmentalisation.
✓ Improve understanding of reservoir quality and heterogeneity.
✓ Characterise fluid properties and drive mechanisms.
✓ Reduce uncertainty sufficiently to support a Final Investment Decision (FID).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1781

- *Key Activities During Appraisal*
  Additional wells are drilled to:

- ✓ Test reservoir extension away from the discovery well.
- ✓ Confirm hydrocarbon contacts.
- ✓ Evaluate reservoir continuity.
- ✓ Obtain core, log, pressure, and fluid samples.

➢ *Development Planning Stage*

The Development Planning Phase is the stage in the reservoir lifecycle during which the discovered hydrocarbon accumulation is evaluated and developed into a technically and economically viable project. It bridges appraisal and field development execution.

- *Objectives*

- ✓ Maximize hydrocarbon recovery and project value.
- ✓ Select the optimal field development concept.
- ✓ Reduce remaining subsurface and commercial uncertainties.
- ✓ Prepare the basis for Final Investment Decision (FID).

- *Key Activities*

✓ *Integrated Reservoir Characterization*

- ▪ Update geological and reservoir models using appraisal data.
- ▪ Refine estimates of:

- Stock Tank Oil Initially In Place (STOIIP)
- Gas Initially In Place (GIIP)
- Recoverable reserves

- ▪ Assess reservoir heterogeneity and connectivity.

✓ *Dynamic Reservoir Studies*

- ▪ History matching (if production data exist).
- ▪ Reservoir simulation and forecasting.
- ▪ Recovery mechanism evaluation.
- ▪ Assessment of enhanced recovery opportunities.

➢ *Development Concept Selection*

Multiple development options are screened and compared:

Table 2 Concept Selection

Option	Description
Vertical Wells	Conventional development
Horizontal Wells	Increased reservoir contact
Multilateral Wells	Improved drainage efficiency
Water Injection	Pressure maintenance
Gas Injection	Improved recovery
Subsea Development	Offshore tie-back solutions
Fixed Platform/FPSO	Standalone offshore facilities

- *Main Deliverables*

- ✓ Field Development Plan (FDP)
- ✓ Reservoir Management Plan
- ✓ Reserves Certification
- ✓ Production Forecasts
- ✓ Development Well Schedule
- ✓ Surface Facilities Design Basis
- ✓ Economic Evaluation Report
- ✓ Risk Register
- ✓ Final Investment Decision (FID) Package

IV. DRIVERS OF P10–P90 GAP REDUCTION

➢ *Reservoir Area Definition*

Early uncertainty often stems from structural mapping.

- *Improvements Include:*

- ✓ Higher-quality seismic
- ✓ Depth conversion
- ✓ Fault interpretation

Area uncertainty frequently reduces by 60 – 80% through appraisal.

- *Net Pay Characterization*
  Appraisal drilling constraints:

- ✓ Gross thickness
- ✓ Net-to-gross
- ✓ Facies distribution

Net pay uncertainty typically decreases by 50 – 70%.

- *Petrophysical Uncertainty*
  Core calibration reduces uncertainty in:

- ✓ Porosity
- ✓ Saturation
- ✓ Cutoffs

Typical reduction: 20 – 40%.

- *Fluid Property Uncertainty*
  PVT analysis constraints:

- ✓ Bo
- ✓ Rs
- ✓ Fluid density

These uncertainties generally become negligible after appraisal.

- *Dynamic Data Integration*
  Production data provides the greatest uncertainty reduction because it constrains:

- ✓ Connected pore volume
- ✓ Reservoir communication

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1781

✓ Sweep efficiency

Dynamic information often contributes more to uncertainty reduction than static data.

V. QUANTIFYING UNCERTAINTY MATURITY

A useful metric is the Uncertainty Ratio (UR):

$$UR = \frac{P10}{P90}$$

Table 3 UR Classification and Uncertainty Level:

UR	Uncertainty Level
>5	Very High
3–5	High
2–3	Moderate
1.5–2	Low
<1.5	Mature

This metric enables objective comparison across assets.

VI. CASE STUDY

➢ *Reservoir Description*

A deltaic sandstone reservoir M-F20 was discovered offshore West Africa, at 9,125 ft, gross thickness of 213 ft, with initial one well M-F20_3L and 14 development wells earlier planned.

- *During the Exploration Phase*

Monte Carlo Results:

Estimate	MMSTB
P90	95
P50	260
P10	700

UR: 7.37

- *Appraisal Phase*

After Three Appraisal Wells:

Estimate	MMSTB
P90	160
P50	280
P10	480

UR: 3.0

Reduction: 59%

- *Development Stage*

Integrated geomodel:

Estimate	MMSTB
P90	210
P50	290
P10	390

UR: 1.86

- *After Five Years Production*

History matching completed.

Estimate	MMSTB
P90	245
P50	285
P10	335

UR: 1.37

Total reduction from discovery: 81%

VII. ECONOMIC IMPLICATIONS

Reducing volumetric uncertainty provides substantial value through:

➢ *Improved Capital Allocation*

Smaller uncertainty bands reduce investment risk.

➢ *Better Well Placement*

Improved reservoir understanding increases drilling success.

➢ *Enhanced Reserves Confidence*

SEC and SPE reserves classifications benefit from reduced uncertainty.

➢ *Portfolio Optimization*

Companies can compare opportunities based on risk-adjusted metrics.

➢ *Emerging Technologies Accelerating Uncertainty Reduction*

Recent technologies are shortening the uncertainty reduction cycle.

- *Machine Learning*

Applications include:

✓ Facies prediction
✓ Property estimation
✓ Seismic inversion

- *Digital Rock Analysis*

Improves saturation and permeability estimates.

- *Time-Lapse Seismic (4D)*

Tracks fluid movement and sweep.

- *Closed-Loop Reservoir Management*

Continuously updates uncertainty using real-time production data.

These technologies accelerate convergence of P10, P50, and P90 estimates.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1781

VIII. DISCUSSION

Although uncertainty generally decreases with reservoir maturity, it does not always decline monotonically.

➢ *Examples Include:*

- Discovery of reservoir compartmentalisation.
- Identification of unexpected aquifer behaviour.
- Recognition of fault sealing.
- Revised fluid contacts.

In such cases, uncertainty may temporarily increase before additional data restores confidence. Therefore, uncertainty management should be viewed as an iterative process rather than a one-way reduction exercise.

IX. CONCLUSIONS

➢ The P10–P90 gap is a practical measure of volumetric uncertainty throughout the reservoir lifecycle.
➢ Exploration-stage reservoirs commonly exhibit P10/P90 ratios between 5 and 10.
➢ Appraisal drilling typically reduces uncertainty by 40–60%.
➢ Development data further narrows uncertainty to P10/P90 ratios below 2.
➢ Production history provides the strongest constraint on connected hydrocarbon volume.
➢ Mature reservoirs frequently achieve P10/P90 ratios below 1.5.
➢ A case study demonstrated an 81% reduction in uncertainty from discovery to mature production.
➢ Monitoring uncertainty maturity using the P10/P90 ratio provides a simple, effective framework for reservoir management and investment decision-making.

- *Nomenclature*

✓ *Symbol* *Description*

- A Reservoir Area
- h Net Pay Thickness
- φ Porosity
- Sw Water Saturation
- Bo Oil Formation Volume Factor
- OOIP Original Oil in Place
- GIIP Gas Initially in Place
- UR Uncertainty Ratio
- P10 Optimistic Estimate
- P50 Median Estimate
- P90 Conservative Estimate

REFERENCES

[1]. Society of Petroleum Engineers (SPE), *Petroleum Resources Management System (PRMS)*, latest edition.
[2]. Dake, L.P., *Fundamentals of Reservoir Engineering*, Elsevier.
[3]. Rose, P.R., *Risk Analysis and Management of Petroleum Exploration Ventures*.
[4]. McCain, W.D., *Reservoir Fluid Property Correlations*.
[5]. Ahmed, T., *Reservoir Engineering Handbook*, 5th Edition.
[6]. Haldorsen, H.H., and Damsleth, E., “Challenges in Reservoir Characterisation,” SPE Journal.
[7]. Cosentino, L., *Integrated Reservoir Studies*.
[8]. Deutsch, C.V., *Geostatistical Reservoir Modelling.*
[9]. Caers, J., Modelling *Uncertainty in the Earth Sciences*.
[10]. SPEE Monograph Series on Reserves and Resources Estimation.