Are there opportunities for Upstream Sector in Peru? A comprehensive study of Peruvian Peak Oil Production with Hubbert Model

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ABSTRACT

Oil and gas industry in Peru has a long history with more than 100 years oil production with almost all coming from Talara and Marañón Basins. Peruvian oil production has decreased significantly up to **41 MBOPD in recent years**[1], with a cumulative oil production exceeding ***1.6 and 1.1 billion barrels in Talara and Marañón fields***[2] respectively. Despite, primary recovery factors ***represent just 9% and 20% respectively***. which may be an indicator of proved hydrocarbon potential that can be recovered with new development strategies and better technology.

This study explores the opportunities to increase the oil supply for the Upstream Sector in Peru by using the Hubbert Model to determine the peak oil and maturity degree of each production region, and for the whole country; a sound estimation of hydrocarbon potential would be crucial to trade off the negative impact in Peru's balance of payments and exchanges due to decreasing oil production and increasing oil imports.

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A multicycle Hubbert approach was used to model production history, determine the peak oil and maturity degree, and forecast oil supply for each production region in Peru. Based on analysis of production trends, reserves and contingent resources can be identified in each area, as well as the more suitable technologies and development plans can be proposed.

Typically, primary recovery factors for main fields in Peru are in between **5 to 50% with 14% average.** The multicycle Hubbert approach indicates that heavy oil recovery ***can be increased by at least 20% in Marañón Basin***, with new technology (horizontal drilling with autonomous inflow control devices and/or selective completion and/or chemical EOR).

On the other hand, mature Talara fields have shown in recent years low decline rates which also indicates that additional development plans, with more suitable technologies for tight reservoirs, along with new waterflooding or gas flooding projects may also ***raise recovery factors up to 15%.***

Keywords—Hubbert Model, Peak Oil, Recovery Factor, Heavy Oil, Tight Reservoirs, Talara Basin, Marañón Basin.

I. INTRODUCTION

Peruvian oilfields have been operated for more than 100 years with ***a cumulative production around 2.7 billion barrels,*** and ***14% average primary recovery factor***. During production history, a ***peak oil production around 205 MBOPD***[2] was arrived in October 1982, and since then, oil rate has significantly ***declined to 41 MBPD*** by December 2022; besides there is a production of ***natural gas liquids surpassing 77 MBPD***. In contrast, ***total hydrocarbons demand has considerably increased around 225 MBPD***[3] which points out a balance of payments highly depended to crude oil and fuel imports. **Figure 1** shows historical oil production in Peru.

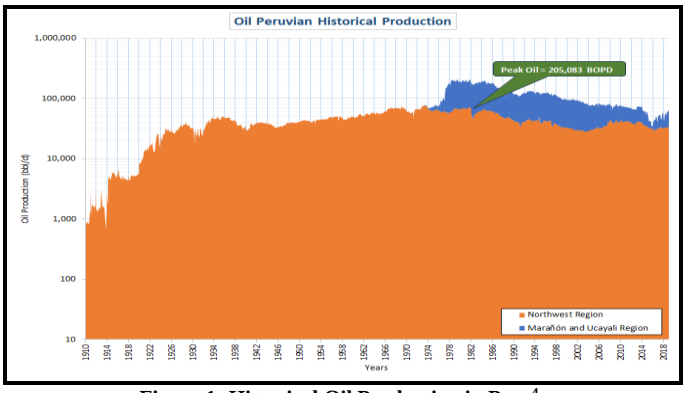

Figure 1: Historical Oil Production in Peru[4]

The relevance of the Northern Peruvian Jungle, and Norwest oilfields as strategic regions for the recovery of the upstream industry in Peru is considerable, due to the number of fields and oil resources (**see figure 2**). Even though, there is a constant decline of medium and light oil production in most of the fields in recent years (**see figures 3 & 4**), all efforts

[1] *Ministry of Energy and Mines, Directorate General of Hydrocarbons (DGH), 2022 Annual Report of Statistics of Peru.*
[2] *Ministry of Energy and Mines, Directorate General of Hydrocarbons (DGH), Historical Production from Annual Reports of Reserves of Peru.*
[3] *Ministry of Energy and Mines, Directorate General of Hydrocarbons (DGH), 2022 Annual Report of Statistics of Peru.*
[4] DGH-MINEM / PERUPETRO (2022). *Historical Production from Annual Reports of Reserves of Peru.*

should be put into the most innovative re-development strategies for the recent large heavy oil discoveries in the Marañón Basin. ***Peak oil production in Marañón basin*** was achieved by the end of seventies around ***140 MBOPD***.

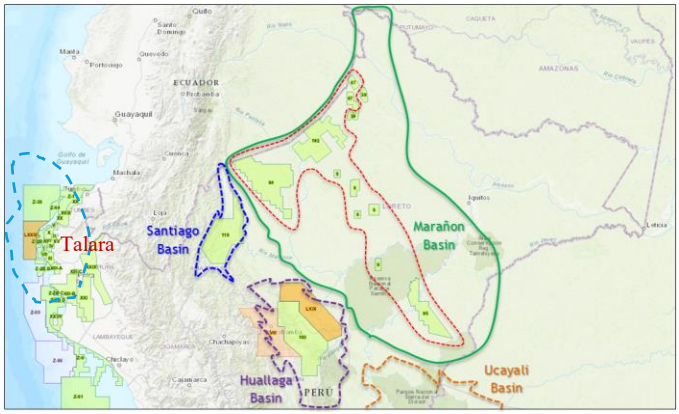

Figure 2: Central Marañón Basin Blocks 192, 64, 39, 67, 129, 123, 8 and 95 [5] have almost 1 billion barrels of oil resources.

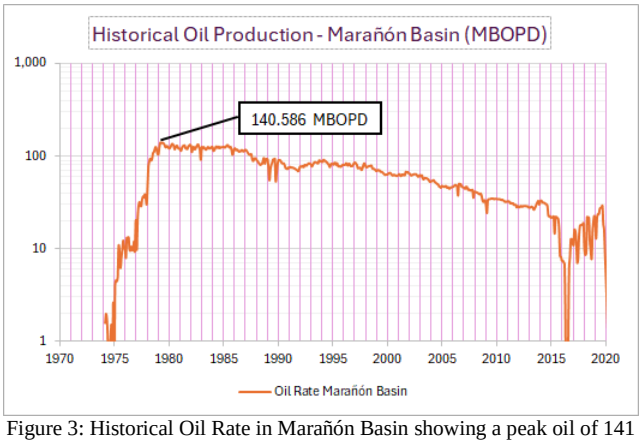

Figure 3: Historical Oil Rate in Marañón Basin showing a peak oil of 141 MBOPD.

According to an update of the *2022 Annual Book of Reserves and Contingent Resources of Peru* [6], more than 70% of the 3P+2C volumes are attributed to potential recoverable resources of heavy oil in the Northern Peruvian Jungle (see **table 1**). and this ratio keeps growing year after year since light oil production declines fast in the region; in particular, heavy oil blocks 67 & 39 accounts for more than ***400 MMSTB of resources*** that cannot be produced and transported efficiently and cost-effective through North Peruvian Pipeline without a diluent source or an insitu upgrading process.

LOTE	Reservas Probadas (P1) MMSTB	Reservas Probables (P2) MMSTB	Reservas Posibles (P3) MMSTB	Recursos Contingentes (2C) MMSTB	Producción Acumulada a Dic 2023 MMSTB
8	32.3	3.8	0.0	0.0	333.1
39	21.0	60.9	41.6	52.2	0.0
64	27.5	15.5	46.7	43.8	0.0
67	26.3	48.7	137.7	15.7	4.4
95	48.0	52.2	99.4	0.0	16.7
192	126.3	0.0	0.0	82.2	737.5
TOTAL	**281.4**	**181.1**	**325.4**	**193.9**	**1091.7**

Table 1: Update of the oil reserves and resources as of 31/12/2022 Report, Loreto Region, Marañón Basin

Several countries have tested new development and operational strategies as well as new technologies to increase oil recovery in a more cost-effective manner. An increase in the recovery factor in heavy oilfields of north Peruvian jungle is strongly dependent on proper completion technology, well placement and trajectories, availability of heavy oil diluent, economic feasibility of oil transportation, and effective reservoir management strategies[7]; many of these factors are strongly influenced by a sustainable management of field operations.

In addition, as it is observed in **figure 2**, mature oilfields in Talara basin arrived at a ***peak oil by mid-seventies around 78 MBOPD,*** and since then, production declined in a slowly rate due to an aggressive and successful continuous campaign of downsizing spacing by infill drilling.

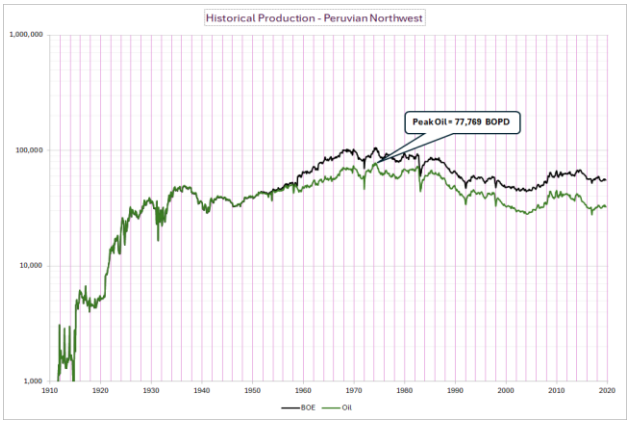

Figure 4: Historical Oil Rate in Peruvian Northwest showing a peak oil of 78 MBOPD.

Hence, to promote increasing oil productivity and rates of tight reservoirs in Northwest region, the application of new technologies for well trajectory, completion, and stimulation techniques, as well as successful pilot secondary recovery projects would be recommended to ***eventually increase primary recovery factor up to 15%***[8].

[5] *Perupetro website: www.perupetro.com.pe, North Peruvian Blocks Map.*
[6] *Ministry of Energy and Mines, Directorate General of Hydrocarbons (DGH), 2022 Annual Book of Reserves and Contingent Resources of Peru*

[7] *Babadagli, T. (2005). Mature Field Development – A Review. SPE 93884.*
[8] *Huerta, V. Palacios, N., Cervantes, R. (2015). Key Parameters to Revitalize Mature Oil and Gas Fields. SPE 177240.*

II. HUBBERT MODEL IN OIL AND GAS RESERVOIRS

The Hubbert model is a mathematical model that predicts the level of oil production over time[9][10]. According to his theory, the extraction of a well, or several wells from a reservoir, follows a curve with a maximum, peak of production, in its center. At that point each barrel of oil becomes progressively more expensive to extract until production stops being profitable as it is necessary to spend more crude oil than what is obtained from extracting it, that is, when it is necessary to consume the equivalent of a barrel of oil, or more to obtain that same barrel of crude oil from the reservoir.

Likewise, Hubbert also observed that, if the production curve of a well or a reservoir followed a simple Gaussian function, the production curve of entire countries and, by extension, the world would follow similar patterns (Hubbert curve). In the article "Worldwide Petroleum-Liquid Supply and Demand" a Gaussian distribution is shown characterizing the production of the USA and Canada, reaching "peak oil" in the mid-1980s[11]; This basically adjusts the first stage of development of the conventional resources of both countries; Subsequently, as has been noted in both countries, "unconventional" resources have been intensively developed since 2008, oil and gas in shales and tight reservoirs in the USA, as well as heavy and extra-heavy crude oil resources in Canada.

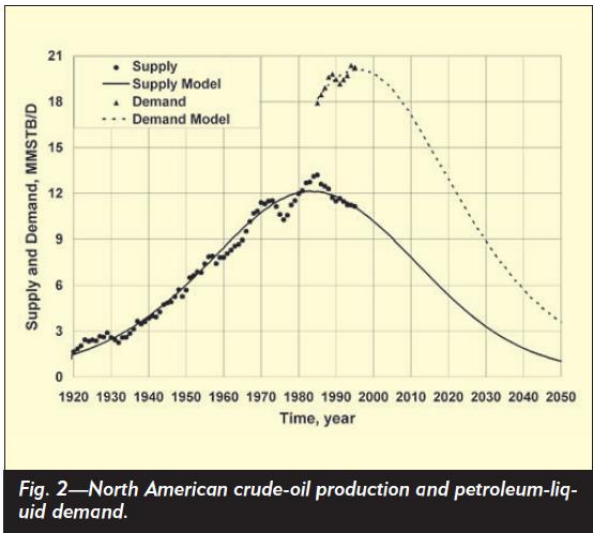

Figure 5: Hubbert Model for the Historical Oil Production in North America showing a peak oil around 12 MMBOPD.

[9] Hubbert, M.K. 1956. Nuclear Energy and the Fossil Fuels. Presented at the Spring Meeting of the Southern District Division o Production, American Petroleum Institute, San Antonio, Texas, USA, 7–9 March.

[10] *https://es.wikipedia.org/wiki/Teor%C3%ADa_del_pico_de_Hubbert*

[11] Hubbert, M.K. 1982. *Techniques of Prediction as Applied to the Production of Oil and Gas*, No. 631. Washington, DC: NBS Special Publication, US Department of Commerce.

III. APPLICATION OF HUBBERT MODEL IN PERUVIAN OILFIELDS

A multicycle Hubbert approach was used to model production history, determine the peak oil and maturity degree, and forecast oil supply for each production region in Peru. As a first part of the study, the model was applied to historical total production of the country, validating ***the peak oil production around 200 MBOPD***, with a ***97% accuracy*** (see **figure 6**).

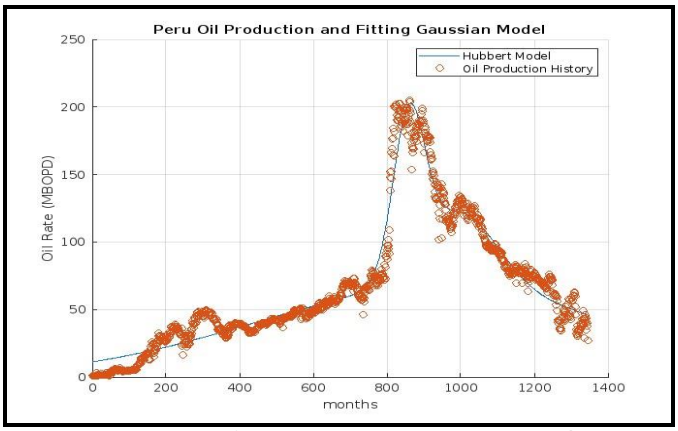

Figure 6: Hubbert Model for the Historical Oil Production in Perú showing a peak oil around 200 MBOPD.

Based on analysis of production trends (specially un recent years), it seems that Peruvian oilfields have arrived at a mature stage, and therefore, there is no hydrocarbon potential for next years. However, it is better to analyze production performance by region (Northwest and Marañón Basin) to discretize mature from green fields, and to be more accurate in identifying the right production trends.

The analysis of production history of Marañón basin confirmed the ***peak oil around 140 MBOPD***, followed by a decline trend; however, the Hubbert model shows a starting point of production increase in the recent years, due to the contribution of green heavy oil fields (see **figure 7**) in early development.

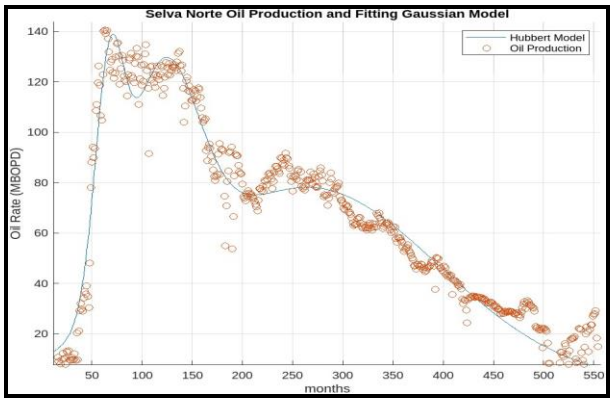

Figure 7: Hubbert Model for the Historical Oil Production in Marañón Basin showing a peak oil around 140 MBOPD.

Thereby, it was prepared a Hubbert model for only the historical heavy oil production in Marañón Basin (see **figures 8 and 9**); the analysis confirmed a cumulative heavy oil production of 442 MMSTB, a ***peak heavy oil around 55 MBOPD***, followed by a decline trend, and a starting point of production increase in the recent years, due to the contribution of Block 95 (see **figure 10**) in early development phase.

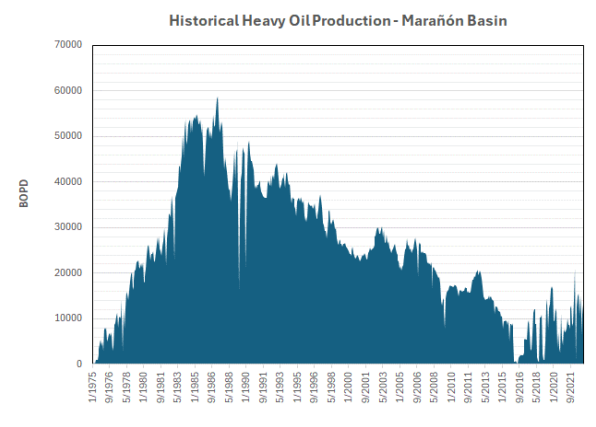

Figure 8: Historical Heavy Oil Rate in Marañón Basin showing a peak oil of 55 MBOPD.

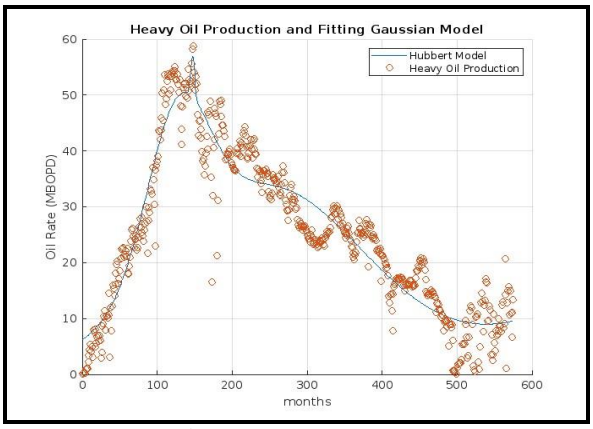

Figure 9: Hubbert Model for the Historical Heavy Oil Production in Marañón Basin showing a peak oil around 55 MBOPD.

In addition, an estimation **of 364 MMSTB of 2P** heavy oil reserves was done for Marañón Basin. As it is observed in **figure 9**, a new peak oil around **64 MBOPD** would be targeted if new investments and development plans were deployed in both green heavy oilfields, and mature fields.

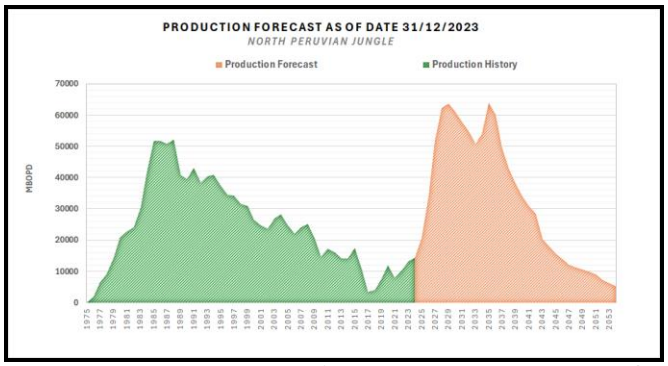

Figure 10: Oil Production Forecast for 2P Heavy Oil Reserves in Marañón Basin showing a new peak oil around 64 MBOPD.

The multicycle Hubbert model verified with a **94% degree** of accuracy that the scenario of heavy oil resources development in Peru with two peak oil production is feasible (**see figure 11**). This scenario would strongly depend on incorporating new technologies to increase the recovery factor of mature heavy oil fields ***from 20 to 25%*** **(see figure 12)** such as horizontal wells with selective completion and/or autonomous inflow control devices (AICDs)[12], as well as enhanced oil recovery applications[13] (polymer injection, cyclic steam stimulation, SAGD among others).

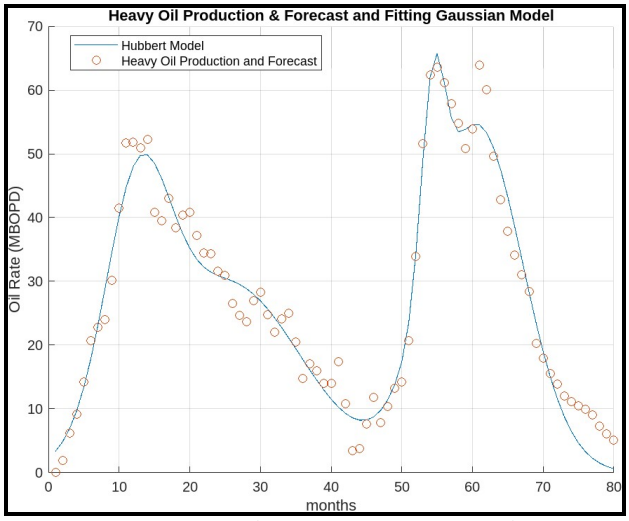

Figure 11: Hubbert Model for the History and Forecast of Heavy Oil Production in Marañón Basin showing an initial peak oil around 55 MBOPD a new peak oil around 62 MBOPD.

[12] *Huerta, V. Palacios, N., Cervantes, R. (2016). Assessment of Cold Production Strategies to Revitalize Mature Heavy Oilfields in the Peruvian Jungle. SPE 181150.*

[13] *Palacios, N. (2014). Assessment of Thermal Recovery: Steam Assisted Gravity Drainage (SAGD) to Improve Recovery Efficiency in the Heavy-Oilfields of the Peruvian Jungle. SPE 171108*

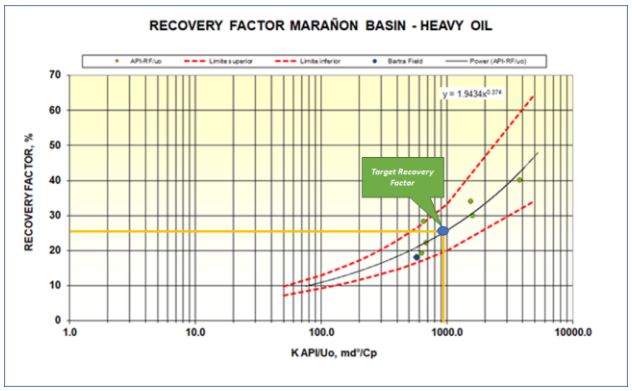

Figure 12: Expected Recovery Factor in Marañón Basin Heavy Oilfields vs. Mobility Index showing the target RF.

Moreover, this scenario also places on the development of "green" heavy oilfields (Blocks 95, 67 and 39), from which less than 5 % of 2P reserves has been produced, and ***15% recovery factor is expected*** (around ***250 MMSTB of heavy oil resources)***, with new development plans and improved oil recovery (IOR) technologies, as long as there were sufficient diluent source or in-situ upgrading plant, as well as enough infrastructure to transport crude oil to Talara Refinery in the Peruvian coast.

Hence, in order to promote these new studies and the application of new subsurface and surface technologies for mature and green heavy oilfields, the Peruvian Government should play an active role to incorporate some changes to the hydrocarbon regulations, including fiscal incentives and modifications in contractual agreements (royalty release policies) [14] for heavy oil; so that operators may increase investments in exploration and production, apply new technologies and deploy field optimization with cutting-edge reservoir management strategies.

IV. EXPECTED RESULTS AND CONCLUSIONS

a. The application of the multicycle Hubbert approach to the total oil production in Peru validated ***the peak oil production around 200 MBOPD***, with a ***97% accuracy.***

b. This comprehensive study proposes the multicycle Hubbert approach to analyse production performance by region (Northwest and Marañón Basin) to discretise mature from green fields, and to be more accurate in identifying the right production trends.

c. Multicycle Hubber model shows that heavy oil production in Marañón basin may arrive to a second peak oil around ***60 MBOPD***, if significant heavy oil resources might be developed with IOR technology and new reservoir management strategies.

d. Preliminary estimations indicates that the combined effect of selective completion with AICDs/AICVs may rise primary recovery factor in mature heavy oilfields from 20% to 25%.

e. Results would be useful for National Agency of Hydrocarbons to focus forthcoming bidding processes and establish competitive terms of reference to negotiate existing and future license contracts; thus, contributing with increasing oil production and reducing negative impact in balance of payments.

[14] *Voskanian, M. (2009). Incentives to Revitalize Mature Fields in an Environmentally Safe Manner. SPE 121819.*

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