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Key Concerns on Petroleum Proved Reserves Evaluation in Different Development Stage for International Cooperated Assets under SEC Rules

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Abstract. The petroleum proved reserves estimation of companies listed in American stock market must follow the SEC rules. However, there are no specified guidelines on the reserves evaluation besides the issued general regulations. This paper presents the procedures and key concerns for sub-classification of proved reserves in different development stages which are summarized from many practical cases. The important concerns include the well test data, initial well productivity, recoverable volumes assessment, five-year development workload and investment, reservoir connectivity, evaluation unit classification, historical performance identification, infill wells recognition, operating cost split, abandonment cost, etc. This study can provide a meaningful reference for SEC reserves evaluation and assets transaction in petroleum industry.

1. Introduction

U.S. Securities and Exchange Commission (SEC) issued their reporting rules on petroleum industry in 1978. And they updated their regulations in 2009 which was executed in 2010 due to the development of technology [1]. Probable and possible reserves could be reported optionally. Large petroleum companies just prefer booking proved reserves. The petroleum companies listed in American stock market must follow the rules. However, there are no specified guidelines on the reserve's evaluation. And many large companies such as Shell, BP encountered inquiries from SEC staff [2] on their reporting reserves. Reserves of some inquired assets had to be revised due to unreasonable evaluation considerations. This could influence the stock impression and stock value of the inquired petroleum company. Therefore, SEC reserves evaluation is an important work in company's internal management.

SEC rules define the reserves consistent with the popular petroleum resources management system (PRMS) issued in 2007[3,4]. But SEC reserves are stricter on parameters estimation comparing with PRMS. The best evaluation results are the technically recoverable volumes of one evaluation unit should be positively revised with the further development. The comparison on proved reserves between SEC and PRMS is shown in table 1.



Table 1. Summary Comparison Table on Proved Reserves between SEC and PRMS

Item	SEC	PRMS
OWC or OGC Justification	The lower fluid contact defined by certainty technology	Pressure data with high quality define the fluid contact which meets 90% probability
Fault	If the fault displacement is greater than pay thickness, no reserves are defined. Otherwise, possible reserves are justified.	If the fault displacement is greater than pay thickness, possible reserves are defined. Otherwise, probable and possible reserves are justified based on the geological certainty.
PUD Offsets	Direct offsets for PUD locations. Fewer offsets if geologic or engineering or plan uncertainty exists. Existing, approved, or technically justified development spacing area is used to assign acreage of each offset.	No specified definition. Actually ultimately recoverable volumes are no less than the predicted volumes with 90% probability and high evidences.
Analogy Reservoir	Specified definition on the analogy reservoir consistent with PMRS	Specified definition and listed the analogy parameters
Certainty Technology	Specified definition. Addressed the technology conducted repeatedly and successfully.	No definition on this term.
Five-year rule for proved undeveloped reserves (PUD)	PUD more than five years could not be reported unless certain circumstances	Addressing reasonable development framework and five-year timetable.
Economically	Internal rate of return is greater than zero	Internal rate of return limit could be defined by various purposes
Prices	First-day of 12-month historically unweight average price, or contractual prices	Prices could be defined by evaluator due to various purposes
Costs	Forecasted based on cost data as of date without inflation.	Forecasted with inflation

2. Evaluation Procedure of SEC Proved Reserves

Reserves analysis covers all the data occurring in asset's operation, including technical data (geological, geophysical, production data, FDP, well test data, well spacing, PVT, etc.), financial data (operating cost, investment), contract (assets contract with host country, gas sales agreement), five-year development plan, surface facility and market constraints, etc[4]. This work needs an integrated group to complete. The first step is preparing the basic analysis data package. and the technical group estimate the technical recoverable volumes with the production profiles by year or month level through volumetric or performance dynamic analysis method. Economic group build the fiscally economic model based on the negotiated contract of internationally cooperated assets. And the entitlement/gross reserves and discounted present value will be obtained after inputting the production profile and economic parameters by running the economic model. The entitlement recognition depends on the type of petroleum contracts and detail fiscal terms [5-12]. The entitlement reserves or discounted present value will be reported in the disclosed annually report and used for impairment test. The whole procedures are summarized in figure 1.

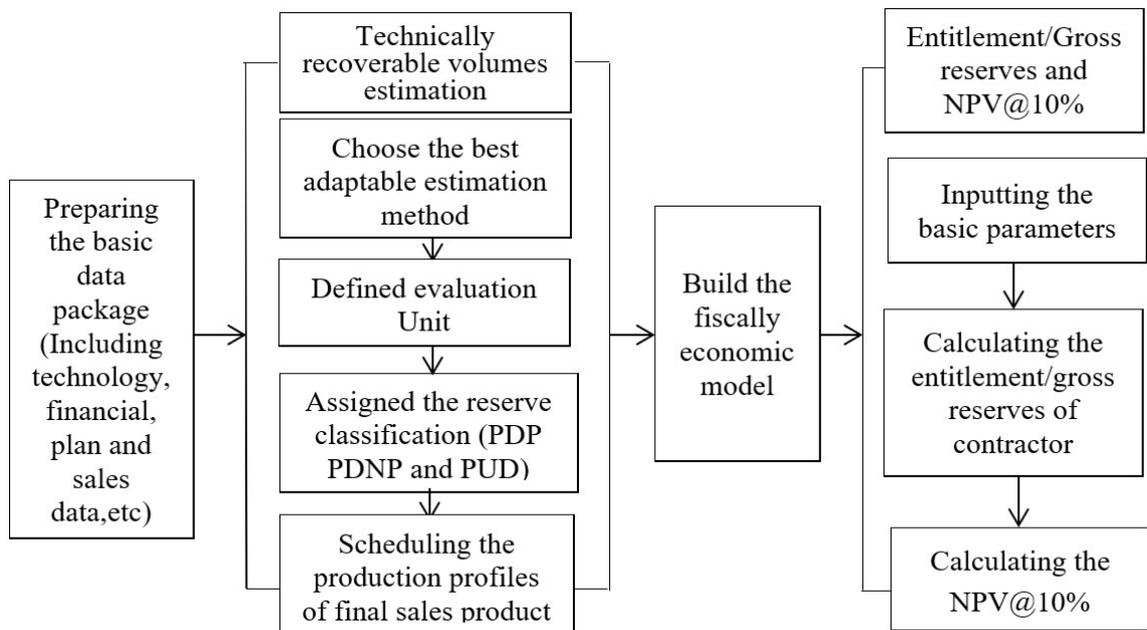


Figure 1. SEC Proved Reserves Estimation Procedures

3. Analysis on Proved Reserves Evaluation in Early Development Stage

The field in early development stage booking SEC proved reserves has 4 features which fit the requirements. a. The historical data is less than 1 year and has no obviously declining trend. b. The field has official development plan. c. The field has been discovered and with good field test results which meets the commerciality requirement. d. The field will be developed within 5-year. The following cases could not book SEC proved reserves. a. The official development plan is not available. b. The field is undiscovered. c. The well test shows uneconomic productivity. d. The field will be developed beyond 5-year due to limitation of facility, environment, strategy, market etc.

The volumetric and analogy estimation methods are usually used to complete the technical analysis due to shortage of production data. The key concerns on the estimation are following.

3.1. Important factors on calculation technically proved recoverable volumes

The workflow of the estimation is summarized in figure 2. The mainly key factors required to be noticed or deeply studied during the estimation including the following 6 points. a. Offset PUD wells could not be booked adjacent to the locations with lower productivity due to the uncertainty, while this existing well can be classified as PDP or PDNP as well. b. The recovery factor of technically proved recoverable volumes is usually defined as the primary recovery factor since the improved recovery measurement could not be conducted in this period. c. The production profiles are tentatively scheduled based on the original petroleum in-place multiplying recovery factor. In this stage, the well productivity should be defined based on the well test and available production data. d. The profiles should consider the facility and market constraints. e. The offset PUD locations must be completed within five-year. If not, only geological PUDs are defined even if the reservoir connectivity is quite better. f. Well spacing could be defined by well pressure test and well interference. The estimated volumes will meet 90% certainty once the above factors considered.

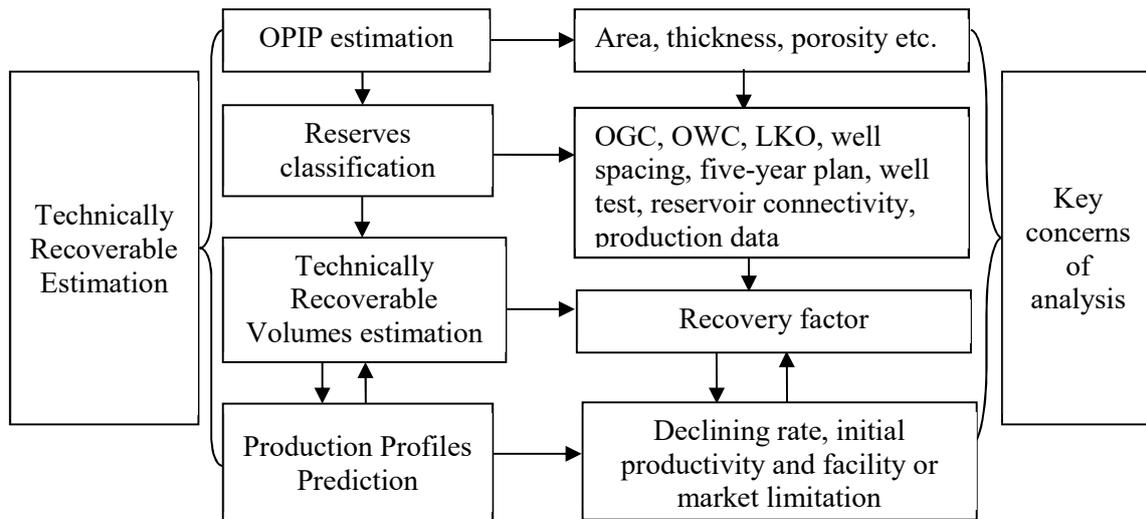


Figure 2. Workflow of technically proved recoverable volumes estimation in early stage

3.2. Important factors on calculation proved entitlement/gross reserves

Regarding the internationally cooperated assets, gross reserves mean the cumulative sales volumes from a given date to the economic limit when the cash flow is negative within the contract expiry date. And the entitlement reserves are recognized according to the specified fiscal agreement types by economic interest method. No matter which agreement, the entitlement/gross reserves have the common influencing key factors. a. The investment should not include the cost of improving recovery measurement. And the investment should match the predicted technically recoverable volumes. b. The residual asset value should match the evaluation scope. c. The operating cost should be split into variable and fixed costs. The fixed costs accounts for more percentage in this duration. The estimation procedures are shown in figure 3.

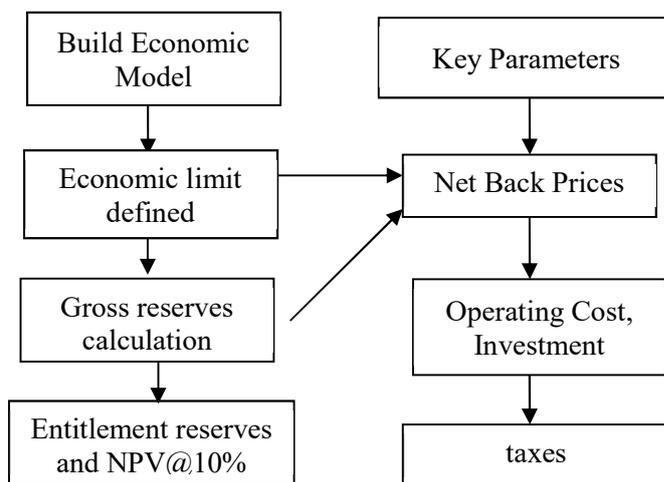


Figure 3. Workflow of entitlement/gross reserves and NPV estimation in early stage

4. Analysis on Proved Reserves Evaluation in Plateau Development Stage

The field in plateau development stage booking SEC proved reserves has two features which fit the requirements. a. The historical data are more than 1 year and have no obviously declining trend by field level due to continuously massive new wells tied-in. b. The field has official development plan.

The volumetric, dynamic and analogy estimation methods are usually used to complete the technical analysis. The key concerns on the estimation are following.

4.1. Important factors on calculation technically proved recoverable volumes

The workflow of the estimation is summarized in figure 4. The mainly key factors required to be noticed or deeply studied for estimation including the following 10 points. a. The volumetric method is optional in this period. And the 6 key concerns of the estimation in early stage are suitable for this period. b. Many dynamic performance trend methodologies will be conducted such as average well performance trend and typical well performance trend extrapolation in order to work out the reasonable result. c. The estimation unit assignment is important and should consider the reservoir type, developed period, production mode, etc. The result is more conservative while the estimation unit is by lower level such as by well or interval completion level. A comparative result table of one practical case is shown in table 2 by different evaluation unit. d. The infill wells sometimes should not be booked as PUD since these wells actually could not increase the technically recoverable. Evaluators should study the historical performance of existing infill wells and make their decision. e. The abnormal historical production point due to non-reservoir elements should be excluded for extrapolation. The estimated volumes will meet 90% certainty after the verification of results obtained from different ways.

4.2. Important factors on calculation proved entitlement/gross reserves

The recognition of entitlement/gross reserves is the same with section 3.2. The main points need to be concerned are summarized into 3 factors. a. The investment of improving recovery project cost needs to be justified whether to be considered in the economic analysis. If this measurement had been piloted and has positive response and the corresponding increasing volumes are booked as proved developed (PD) or proved undeveloped (PUD) reserves, these investments should be included. b. If there is any punishment in the contract due to the contractual production rate, it should not be considered in the SEC economic analysis. c. The variable operating cost usually account for more percentage in this period. The estimation procedures are shown in figure 4.

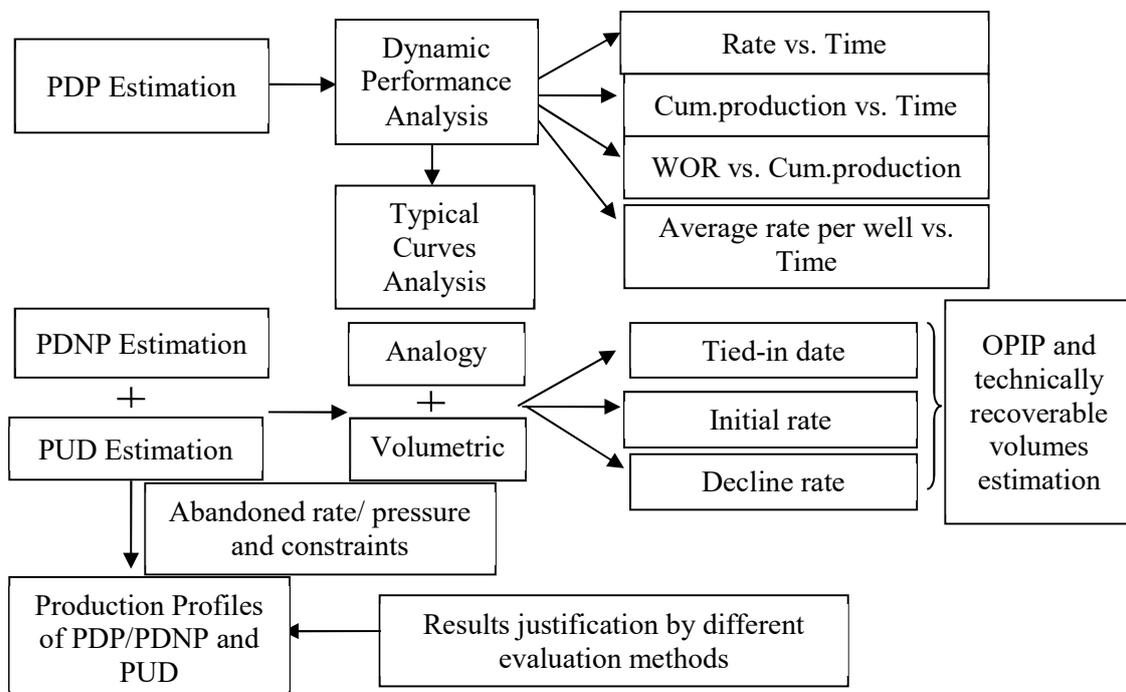


Figure 4. Workflow of technically proved recoverable volumes estimation in plateau stage

Table 2. Comparison table on technically PD results by different estimation unit of one case

Estimation unit Year	PD, Yearly oil Production, Mbbl		
	By fault/reservoir level	By reservoir	Total Field
1	922.1	960.5	969.0
2	681.5	729.0	771.0
3	508.6	557.1	615.4
4	381.2	427.2	491.2
5	287.7	329.5	393.0
6	215.1	253.5	312.7
7	157.2	192.5	249.6
Total	3153.3	3449.3	3801.8
Yearly decline rate	26.45%	24.86%	20.20%

5. Analysis on Proved Reserves Evaluation in Late Development Stage

The field in late development stage booking SEC proved reserves has 1 feature which fit the requirements. The field will be economically developed till abandoned.

The dynamic and analogy estimation methods are usually used to complete the technical analysis. The key concerns on conducting the estimation are following.

5.1. Important factors on calculation technically proved recoverable volumes

The workflow of the estimation is similar with section 4.1 except the volumetric method. The mainly key factors required to be noticed or deeply studied for the estimation including the following 2 points.

- The results from different dynamic performance curves usually have no big differences. Evaluators could decrease the number of estimation unit to save effort.
- Effective workover such as new production mode in future should be booked as PDNP or PUD reserves if there is work plan.

5.2. Important factors on calculation proved entitlement/gross reserves

The recognition of entitlement/gross reserves is the same with section 3.2. The main points need to be concerned are summarized into 2 factors.

- The fixed operating cost usually account for more percentage in this period. The occasionally maintenance costs should be excluded when predicting the costs.
- The abandonment costs in host country could not be considered in defining the economic limit.

The estimation procedures are shown in figure 4.

6. Conclusion

The main concerns on petroleum proved reserves estimation for field in different development stage are distinctive. Evaluators should seize the key points according to the position of the studied objects. The aim is the results conform to the SEC rules and the reported volumes are not fluctuated greatly with further development. Otherwise, the unreasonable booked information will be inquired and influence the stock market impression of the related company.

- In the early development stage, the primary recovery factor, facility or market constraints, reservoir connectivity, five-year plan, investments matching the evaluation scope, PUD locations defined by existing wells and plan are all required to be concerned. The evaluation results will be positive once the evaluator misses any one of them.

- In the plateau development stage, the results should be verified through different assessment methodologies such as volumetric, dynamic performance analysis and analogy. The evaluation units are suggested to be refined which usually keep the results positive revision. The infill wells whether increasing the technically recoverable volumes are required to be justified.

- In the late development stage, the estimation unit could be chosen by high level such as field or reservoir in some degree.

d. Operating cost split and abandonment costs need to be noted in each stage which directly influence the gross/entitlement reserves and discounted present value.

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