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Risk Analysis Application to the Petroleum Field Development , A Southern Iraqi Oil Field - case study.

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Abstract.

The development process of oil and gas fields is one of the most important technical and engineering challenges facing the oil companies operating in all areas of the oil sector during the production life of these fields, because of the variables and complexities associated with the development embodied in the analysis process of decision-making rational choices in the development stage of producing oil fields.

In this research approved the application of risk analysis as a decision-making in the implementation of the development project of the oilfield under study, which is located in southern Iraq, as well as determine the effect of inaccuracy of some variables in this analysis, which was quantified in two parts, the first of which was related to risk analysis in the event of current situation of the field in terms of productivity, while the second one related to the proposed development method, where it underwent the cases mentioned in this part of the risk analysis, except in cases where production runs up to the water cut in producing wells up to 80% were excluded from the analysis.

Results of this analysis for both parts were compared with the amount of accumulated production that were calculated previously for the same cases mentioned in previously Part II, which provided under the developmental study of the mentioned field in 2007 for one of the produced formation in the primary reservoir of the field. The comparison results reflect the importance and eligibility implications of the used tools as promising and supported in their decision-making in right way of engineering studies submitted for the development of oil fields.

As well as the results indicate the importance of adopting risk analysis is a good guide to evaluate the methodology and scalability performance of oil fields and the completion of operations associated with them.

تطبيق تحليل الخطورة في تطوير الحقول النفطية دراسة حالة حقل نفطي عراقي في جنوب العراق.

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الخلاصة.

تعتبر عملية تطوير الحقول النفطية والغازية واحدة من أهم التحديات الفنية والهندسية التي تواجه الشركات النفطية العاملة في القطاع النفطي وفي كافة المجالات وخلال العمر الإنتاجي لهذه الحقول بسب المتغيرات والتعقيدات المرتبطة بالعملية التطويرية والتي تتضمنها عملية تحليل واتخاذ القرارات المتعقلة في مرحلة التطوير للحقول النفطية المنتجة.

في هذا البحث أعتمد تطبيق تحليل الخطورة كوسيلة اتخاذ القرار في تنفيذ مشروع تطويري للحقل النفطي قيد الدراسة والذي يقع في جنوب العراق وكذلك تحديد تأثير عدم الدقة لبعض المتغيرات في هذا التحليل كميا والتي كانت على جزئين ، الأول منها كان متعلق بتحليل الخطورة في حالة اعتماد الوضع الحالي للحقل من حيث الطبيعة الإنتاجية والثاني يتعلق بالأسلوب المقترح للتطوير حيث خضعت الحالات المذكورة في هذا الجزء الى تحليل الخطورة بأستثناء الحالات التي يمتد فيها الإنتاج إلى أن يصل القاطع المائي في الآبار المنتجة الى حد ٨٠% حيث أستبعدت من التحليل.

نتائج هذا التحليل لكلا الجزئين تم مقارنتها مع كمية الأنتاج المتراكم والمحسوب سابقا ولنفس الحالات المذكورة في الجزء الثاني والتي قدمت سابقا بموجب دراسة تطويرية للحقل المذكور أعلاه عام ٢٠٠٧ ولأحدى الطبقات المنتجة في المكمن الرئيسي له. عكست نتائج المقارنة أحقية وأهمية المدلولات المستخدمة كأدوات واعدة ومعتمدة في أتخاذ القرار الهندسي الصائب في الدراسات المقدمة من أجل تطوير الحقول النفطية.

كذلك النتائج المستخلصة من الدراسة بينت أهمية أعتماد خاصية تحليل الخطورة تعتبر كدليل جيد لتثمين منهجية وأمكانية التطوير الأدائية للحقول النفطية وأنجاز العمليات المرتبطة بها.

Nomenclature:-

F.D.F. = Frequency Distribution Function
x= variable in the sample
f(x) = probability function within normal distribution
$\sigma =$ *Mean value*
$\mu =$ *Standard deviation*

1. Introduction

Reservoir development studies requires evaluations of many possible combinations of decision variables, such as the reservoir properties, well locations and production scheduling parameters,……..etc, to obtain the best economical strategies depending on development planes that were dealing with all parameters which are related to the whole production system.
A typical reservoir development involves many variables that affect the operational schedule involved in its management. These variables are usually used as input to a reservoir simulator that generates a forecast of the production profile. Development studies are coming through the production life of the fields depending on it's situation and field management decision tools.

The field life cycle consists of the following stages [1] , exploration, appraisal, development, production, and abandonment. The appraisal phase is strongly related to uncertainties, high investment and field development decisions. There are three main types of decisions involved in this phase:-

- Abandonment of the discovered field (low profit, low stock tank oil originally in place (STOIP), high oil viscosity, etc.).
- Continuation of the appraisal phase (risk mitigation).
- Development of the field.

A petroleum field development requires large investments and any improvement
in the process can represent significant additional profit. However, in the 80's,
a usual production forecast based on deterministic reservoir simulation model.
In this way, production forecast had a deterministic approach, where most of them were optimistic. Thus, economical viability of oil and gas project was guaranteed by high prices practiced in the market. Therefore, decision analysis applied to the development phase of petroleum fields must take into account the risk associated to the several type of uncertainties.

Since few decades ago, probabilistic approach become one of the production forecasting methods besides the deterministic approach, which is based on numeric flow simulation of several models representing uncertainties of a petroleum reservoir and allows the evaluation of the uncertainty performance, like cumulative productions and oil rates, in any simulated time.
Most of the literatures [8 – 13] agree that the exploration and production of the hydrocarbon is highly risk venture. For more details of risk and risk analysis principals and ideology can be summarized below.

2. Risk and Risk Analysis.

Simply [2] risk is defined as possibility of loss, while analysis can be defined as an examination of complex, therefore, used jointly the word refer to "examination of complex possibility of loss".Those terms involved average complex, quite possibility loss of time, effort and investment.

The types of development risks that have to be considered in the decision making process are related to opportunity loss, un commercial development and suboptimal development.
Basically, development risk is function of geological, economical and technological uncertainties, as in Fig. (1). However, the quantification of the risk is not only affected by such uncertainties but also by the production strategy model and the management decision process. Especially for complex reservoirs, a precise risk assessment requires a level of detail in the reservoir production prediction that is only obtained by numerical simulation.

During the exploration stage, volumes in place and recovery factors are sufficient in the risk analysis. However, the field development stage, it is also necessary a detailed information about the speed of recovery, the necessary investments, number of wells, water and gas production, operational costs… etc. In some cases, these parameters may be not necessary but in many other cases, an incorrect development model can yield significant suboptimal development.
Some of the recent methodologies based on the numerical flow simulation have several possible reservoir scenarios were implemented which combining the uncertain attributes. The probability of each final model is equivalent to the product of the conditional probability of its attributes?.

But for the accurate and comprehensive definition [4], risk is related to the project risk management, where project risk is an uncertain event or condition that, when it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality (i.e., where the project time objective is to deliver in accordance with the agreed-upon schedule; where the project cost objective is to deliver within the agreed-upon cost; etc.). A risk may have one or more causes and one or more impacts if it occurs.
Most of the engineering projects are highly degree of economical evaluation related before executions, then when studding the project risk and risk analysis evaluation, one can access management of project risk according to the process concerning with estimation.

2.1 Project risk Management

Project risk management [4] includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project; most of these processes are updated throughout the project.
The objectives of Project Risk Management are to increase the probability and impact of positive events, and decrease the probability and impact of events adverse to the project. Figure (2) provides an overview of the Project Risk Management processes. The project risk management processes include the following [4]:

- Risk Management Planning – deciding how to approach, plan, and execute the risk management activities for a project.

- Risk Identification – determining which risks might affect the project and documenting their characteristics.

- Qualitative Risk Analysis – prioritizing risks for subsequent further analysis or action by assessing and combining their probability of occurrence and impact.

- Quantitative Risk Analysis – numerically analyzing the effect on overall project objectives of identified risks.

- Risk Response Planning – developing options and actions to enhance Opportunities, and to reduce threats to project objectives.

- Risk Monitoring and Control – tracking identified risks, monitoring residual risks, identifying new risks, executing risk response plans, and evaluating their effectiveness throughout the project life cycle.

These processes interact with each other and with the processes in the other knowledge areas as well. Each process can involve effort from one or more persons or groups of persons based on the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete elements with well-defined interfaces, in practice they may overlap and interact in ways not detailed here.
Now, in order to present, how to access the risk and risk analysis, one can perform a property valuation should attempt to recognize and account for the risk, there are several methods of analyzing risk and applying adjustment, the process has steps which can be generalized [5] as following:-

1. Define the risk.
2. Determine if the risk is measurable.
3. Define a range of values for the risk.
4. Select a risk evaluation method(s).
5. Apply risk adjustments to the evaluation.

3. Uncertainty

Decisions of field development and reservoir management are always related to risks involved because of the uncertainties are present in the reservoir studies and management process. The process is even more critical because most of the investments are made during the stage when the uncertainties are greater, even for a mature field, uncertainties are still present but the decisions are not very critical.
There are many uncertainties that can influence the success of an exploration and production project. The most common uncertainties occur in the geological model are volume in place, continuity, faults …etc. The recovery factor is a function of the reservoir properties and production strategy and the economic model is principally composed of prices. There are also other uncertainties such as technological, operational and political but they often have a secondary role.
Methodologies to measure the impact of uncertainties are frequently not well defined because the impact of these uncertainties varies with time and the amount of information available.
Most of studies about risk measurement are related to exploration phase where the uncertainties due to reservoir performance prediction have small impact and where probabilistic treatment combined with Monte Carlo techniques may be sufficient to reach the required precision. Nevertheless, the importance of considering uncertainties in the decision making process is unquestionable.
Recently, it is becoming more common the necessity of better accuracy in the process. Better accuracy is possible due to advances in the hardware and software and geological modeling. The use of reservoir simulation in the process is also increasing because it increases the reliability, improves the quality of the results and provides the output of other important variables such as water and gas production, pressure, detailed production strategy…., etc.

4. Risk Analysis: field appraisal and development

Schoizer [6] presented a brief and simple vie point of risk analysis for the production during appraisal and development stage of production field life, it is clear that during the exploration phase, major uncertainties are related to volumes in place and economics.
As the level of information * increases, these uncertainties are mitigated and consequently the importance of the uncertainties related to the recovery factor increases, the situation is more critical in offshore fields and for heavy-oil reservoirs. In the preparation of development plans, field management decisions are complex issues because of:-

- Number and type of decisions.
- Great effort required to predict production with the necessary accuracy
- Dependency of the production strategy definition with the several types of uncertainty with significant impact on risk quantification.

The integration of risk analysis with production strategy definition is one of the most time consuming tasks because several alternatives are possible and restrictions have to be considered. Alternatives may vary significantly according to the possible scenarios.
Schiozer et al. (6) proposed an approach to integrate geological and economic uncertainties with production strategy using geologic representative models to avoid large computational effort. The integration is necessary in order to:-

(1) Quantify the impact of decisions on the risk of the projects.
(2) Calculate the value of information.
(3) Quantify the value of flexibility.

The understanding of these concepts is important to correctly investigate the best way to perform risk mitigation and to add value to E&P projects.
Therefore, risk analysis applied to the appraisal and development phase is a complex issue and it is no longer sufficient to quantify risk. Techniques today
are pointing to:-

(1) Quantification of value of information and flexibility.
(2) Optimization of production under uncertainty.
(3) Mitigation of risk.
(4) Treatment of risk as opportunity.

* Quality and availability of information
All these issues are becoming possible due to hardware and software
advances, allowing an increasing number of simulation runs of reservoir models with higher complexity.

5. Field Case Study – Southern Iraqi Oil Field.

Iraq is one of the most important oil and gas producer in the middle east region as well as it occupies a key position in the sequence of the OPEC organization, Also it is classified as third reserve of petroleum country in the world [7] .
Iraq had explored oil and gas on his lands since 1927, and from that time up to the present time it has good accumulation reservoir management knowledge and techniques. Therefore the directorate of the reservoir management and the field development in the south oil company (SOC) decide to develop one of it's main oil field in Basra Governorate. The development include the

implementation of the a new network of the horizontal wells in the production layer in the main reservoir of the concerned oil field [12] because of the vast advancement of the edge water front toward the productive oil wells due to the production from the main reservoir, while the another production layers within the same reservoir are flooded by rising of water and covering most of the productive perforated sections.

5.1 Objective of the study.

The objective of this study is to perform the risk analysis within the profitability index and study the uncertainty impact of the main variable factors related to the index relation ship formula, secondly the selling prices of the oil barrels in the world suffering from the down fall prices due to the world economic crisis that is blow violently the markets, banks, companies,……etc, therefore a decision was taken to re-evaluate the development study (re-entry horizontal wells network) of the southern Iraqi oil that was submitted in 2007 by implementation risk analysis application to the main reservoir of the concerning field beside the cumulative oil production results criteria obtained before.

6. Results and discussion

Four our purpose, risk analysis is defined as the process of:-

1. Obtaining the conventional profitability index analysis.
2. Defining the uncertainty in the factors by F.D.F.
3. Using the F.D.F to obtain probability function of the profitability index and to obtain sensitivity of the profitability index on each other.

- Sensitivity analysis: - is the process of determent how is the profitability index sensitive to change in one factor of the index relation ship formula while the others are holding constant.

Now, to perform the present work calculations, suppose that an opportunity to sell crude oil at 33$/bblo and we can get Q bbl/d of crude oil for a cost of C, then the conventional profitability analysis is:-

1. Define the index of profitability as net income before tax ………. P.
2. The factors of the problem are Q, C and the selling oil price.

Estimation of these factors for the base case are (Q = 0.45 MMbbls/D; C = 1.2375 MM$; CP = 33$/bblo).

3. The relation ship is

$$P = 33\,Q - C$$
$$= 33\ \$/\text{bbl}\ (0.45\ \text{MMbbls/D}) - 1.2375\ \text{MM}\ \$ = 13.6125\ \text{MM}\ \$$$

6.1 Risk Analysis Assessment.

In order to complete the calculation procedure, an additional input are needing, like the frequency distribution function for Q, C and sell prices respectively, then an estimation method can be used when the most likely value, the minimum and the maximum values are available. With these three values of the factors, one can do an approximation to the actual frequency distribution function and being easy to describe and use. Therefore the frequency distribution function is picking off from the values of Q, C and cell prices that are used for our sensitivity analysis. These values are *

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*The three values of each factor is taken from SOC at the present time (Feb.2009)

Field Production Rate Q (bblo/d).

- Q min = 0.4 MM bblo/d
- Q max = 0.48 MM bblo/d
- Q most likely = 0.45 MM bblo/d

Field Production cost for each oil barrel C ($/bblo).

- C min = 2.5 $/bblo
- C max = 3 $/ bblo
- C most likely = 2.75 $ $/bblo

Field Production cell prices for each oil barrel CP ($/bblo).

- CP min. = 30 $/bblo
- CP max. = 133 $/bblo
- CP most likely = 35 $/bblo

For the arrangement and classification of the obtained results and prevention any overlapping for the reader continually, the results are classify into two parts, the first one for the base scenario case and the second for the future prediction of the oil field production.

6.1.1- PART I – (Base Case Scenario).

The present case of the oil field production, which has oil well production, water well injection as well as the natural water drive. The range of P for each factor can be summarizing in the table (1).
Thus we see that P is more sensitive to the uncertainty in Q and CP than to the uncertainty in the C. The next step is the great deal for more information about P than simple statement of (P = 13.612 MM$). The risk curve for the profitability index - (P) as shown in figure (3) depending on the probability approach, which is calculated by the probability function for the normal distribution as bellow (14):

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} Exp\left[\frac{-1}{2\left[(x-\mu)/\sigma\right]}^{2}\right]$$

The figure (3) is called risk curve for the profitability index – P of our concern oil field case study with the present daily production.
Having obtained the risk curve, one can reach to the clear decision according to that curve. The probability results from figure (3) are presented in table (5).

6.1.2 - *PART II: - The future prediction cases scenarios (Development scenario).*

This part dealing with the future prediction cases scenarios of oil field production for the re-entry horizontal well network within the first production layer of the main reservoir of the concerning southern Iraqi oil field.

The calculations of the suggested daily production from the same oil field but with the implementation of the new re-entry horizontal wells network within the first production layer as shown in the figure (4).
Table (2) explaining the suggested development strategy for the concerning production layer of the same oil field, while table (3) presents the cumulative oil production and average daily oil production for the period expanding from 2009 to 2020 for the predicted cases.

! As shown from the table (3) that we excluded the scenario cases of the future production when permitting the oil well produce with WC limit exceeded to 80%, because the oil barrel production cost is calculated according the WC limiting with 40%, as well as the facilities and the field water treatment units in the field design and working on the that WC limit up to 40% at the present time.
Table (4) shows the new profitability calculation results according to the scenario cases mentioned in the table (2).
The calculation results appeared in the table (4) depending on the following assumptions for the cases of the future profitability index prediction of the new re-entry horizontal wells network, these are:-

Field Production Rate Q (bblo/d).

- Q min = 50% of the daily production rate in table (3)
- Q max = daily production rate in table (3)
- Q most likely = Qmin + Q max.

Field production cost for each oil barrel C ($/bblo).

All the produce oil barrel cost is multiply by (3) - according to the rule of thumb form the literatures dealing with the horizontal well technology.

Field production cell prices for each oil barrel CP ($/bblo).

- CP min. = 30 $/bblo
- CP max. = 133 $/bblo
- CP most likely = 35 $/bblo

It is clear from the obtained results in this part of calculations which are shown in table (4) that the profitability index – P is also sensitive to the both Q and CP rather than the factor C – production oil barrel cost.
The probabilistic approach is also applied in this part of the results, figure (5) is the probability of profitability index for the scenario case I.1 which is called risk analysis curve, other cases have the same trend but with different values. Table (5) summarize the final probability results from the risk curves prepared for the concerning cases of the adopted case study.

6.2 Results Comparison.

For the validation and importance of the risk analysis within the field development planes according to the right and suitable decisions, one can do the comparison for many choices and dependent calculation criteria's. Cumulative oil production for the future prediction scenarios from the refer.(12) that were mentioned before tell us that the suggested development plane is encourage and can be apply with more confidence. Also the results of the risk analysis assessment for the present research work reach to the same goal and decision even that the economical crisis causes the oil prices in the world markets are down fall from 133$/bblo to the present prices nearly (33 – 35) $/bblo

7. Conclusions

1. The Development of oil fields in all extent can be considered as the application of the principles engineering strategy point of view, study taking into consideration all the aspects and possibilities in order to achieve the desired objective. Namely increasing the extraction of oil and gas with the best way of engineering coherent and logical in accordance with the standards and considerations of the reservoir requirements.
2. Risk analysis is one of the important tools in the evaluation of the best field development planes, especially when concerning all the factors that may affect the sharing constructed different models for the study.

3. It is clear from the literature, applications and adoption solutions for the field development planes that the probabilistic approach becomes an important for the decision making besides the deterministic approach. The results of the present work reflect this fact clearly and specially when using the out coming results from both of them.
4. The results of the studied cases in the present work for the future production of the Iraqi oil field give a wide range of the flexibility for the execution management that have an attributes with out pessimistic side down to 30$/bblo in selling prices.

5. Sensitive analysis for the profitability index – P shows that the daily field oil production (Q) and the selling price (CP) have a significant effect on that index in comparison with the producing cost of the oil barrel (C) for the concerning oil field in our case study.

6. Both of the cumulative oil production and the index of the profitability evaluated by the frequent distribution function give an encourage results with the incorporation of the data range used to develop the first production layer in the main reservoir by adoption of the re-entry horizontal well network to increase the production from the concerning oil field.

8. References

1. E.L. Ligero and D.J. Schiozer. "Risk analysis applied to petroleum field development – automated method and parallel computing to speedup the process".

2. W.R.Sharp and R.D.Kidd, "Application of risk analysis to screen exploration and development prospects", SPE 3158, 1970.

3. E.L. Ligero, D.J. Schiozer and J.A.M.Santos, "Risk assessment for reservoir development under uncertainty", J.of the brazelian society of mechanic science and engineering. April – June 2004, vol.xxvI No.2, pp (213 – 217).
4. Jacqulin Jeynes. "A Guide to the Project Management Body of Knowledge" Third Edition, 238 @2004 Project Management Institute, Four Campus Boulevard, Newtown Square, PA 19073-3299 USA.

5. William C. Lyons. " Hand book of the petroleum and natural gas engineering ‹" Vol.2 – Gulf Professional Publishing. Chapter 7, pp (1027 – 1030).

6. Suslick, S.B. and D.J. Schiozer., " Risk analysis applied to petroleum exploration and production: an over view ", journal of petroleum science and engineering 44(2004), pp (1-9).

7. Energy information administration - Iraq full back ground information article. http://www.eia.doe.gov/emeu/cabs/Iraq/Background.html

8. Cuha, J.C. Demirdal B., Gui, P. "Quantitative risk analysis for uncertaintity quantification on drilling operations – review and lesson learned‹" oil and gas business, 2005

9. Dean Rietz, "Reserves asset management‹" Journal of petroleum technology, December 2007, pp (56 – 67).

10. Goodknight, R.C. and Thackuk, A.R., "Risk analysis – An aid in evaluation reservoir development" , SPE 3829, 1972

11. A.P.A, Coasta and D.J. Schiozer. "Decision and simplification criteria in the risk analysis to the development of petroleum field".

12. Jreou, G.N. "A study for increasing productivity from AB formation unit in southern oil field by designing a horizontal wells network", Ph.D dissertation, Baghdad university, October 2007.

13. Jordanove. J, Darachieve.I, Belogushev.V. " Oil and gas resource assessment methodologies: Implementation in national balance estimation and companies exploration policy " , Annual of the university of mining and geology – St.Ivan Rilski, Vol. 49, Part I, Geology and Geophysics, 2006

14. الأحصاء العملي لمهندسي النفط ، تاليف ال. تي . ستانلي – ترجمة الدكتور أبراهيم يوسف والدكتور حازم حسن العطار – جامعة بغداد / كلية الهندسة / قسم هندسة النفط والمناجم / ١٩٨٦.

Table (1) - Explaining the values of profitability index – P with the range of the depending factors.

Factor	Profit ability Index – P
Base Case	13.612 MM$
Production Rate Q (bblo/d).	2.64 MM$
Cost for each oil barrel C ($/bblo).	0.225 MM$
Sell prices for each oil barrel CP ($/bblo).	46.35 MM$

Table (2) – The outline of the prediction cases of the present study after ref. (12)

Prediction State	With Injection	Without Injection	Injection Rate (290546) bblw/D	Injection Rate (7500000) bblw/D	Injection Rate (7750000) bblw/D	Water Cut Limit = 40%	Water Cut Limit = 80%
Base Scenario	*		*			*	
Case I.1		*				*	
Case I.2		*					*
Case II.1	*		*			*	
Case II.2	*			*		*	
Case II.3	*				*	*	
Case III.1	*		*				*
Case III.2	*			*			*
Case III.3	*				*		*

Table (3) – The cumulative oil production and average oil production for the suggested scenarios after ref. (12).

Prediction State	Cumulative oil Production (MM STBO)	Average oil Production (STBO/D)
Base Case	1971	450000
Case I.1	184.9563	42227.465
Case I.2[!]	-	-
Case II.1	177.5668	40540.358
Case II.2	175.0899	39975
Case II.3	172.9369	39483.325
Case III.1[!]	-	-
Case III.2[!]	-	-
Case III.3[!]	-	-

Table (4) – The Profitability index for the prediction scenario cases.

Prediction State	Sensitive analysis of P index (MM$)		
	Daily Prod. Rate - Q	Oil Barrel Production Cost - C	Selling Price for each oil Barrel- CP
Base Case	2.64	- 0.225	46.35
Case I.1	0.69685	- 0.675	2.89962
Case I.2	-	-	-
Case II.1	0.6689	-0.6751	6.2635
Case II.2	0.6596	- 0.675	6.17613
Case II.3	0.651475	- 0.675	6.10015
Case III.1	-	-	-
Case III.2	-	-	-
Case III.3	-	-	-

Table (5) – The probability results from the risk curves of the different study cases.

Prediction Scenario Case	Probability of Risk	Probability of gain	Probability of gain at least	Probability of loss	Probability of gain ate max. limit
Base Case	0.22	0.78	0.32		
Case I.1	0.26	0.74	0.7	0.76	0.52
Case II.1, 2, 3	0.28	0.72	0.74	0.76	0.06

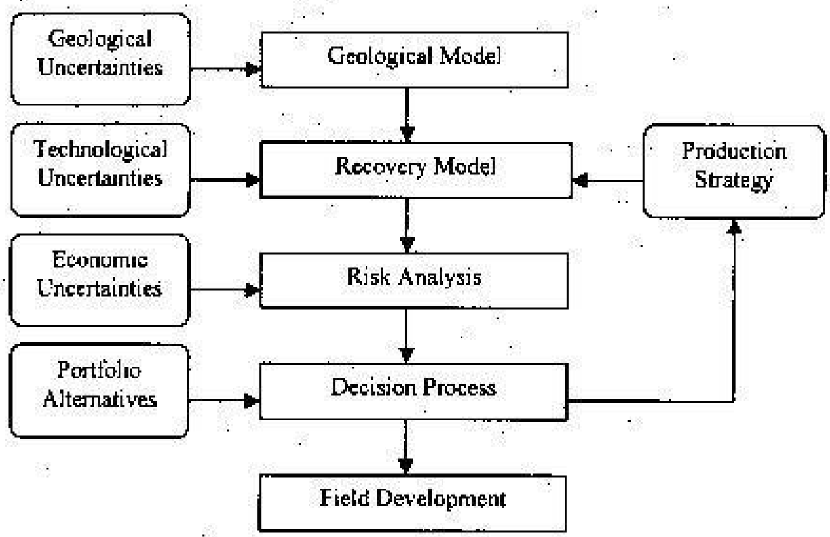

Figure (1) Reservoir management decision process under uncertainty after reference (3).

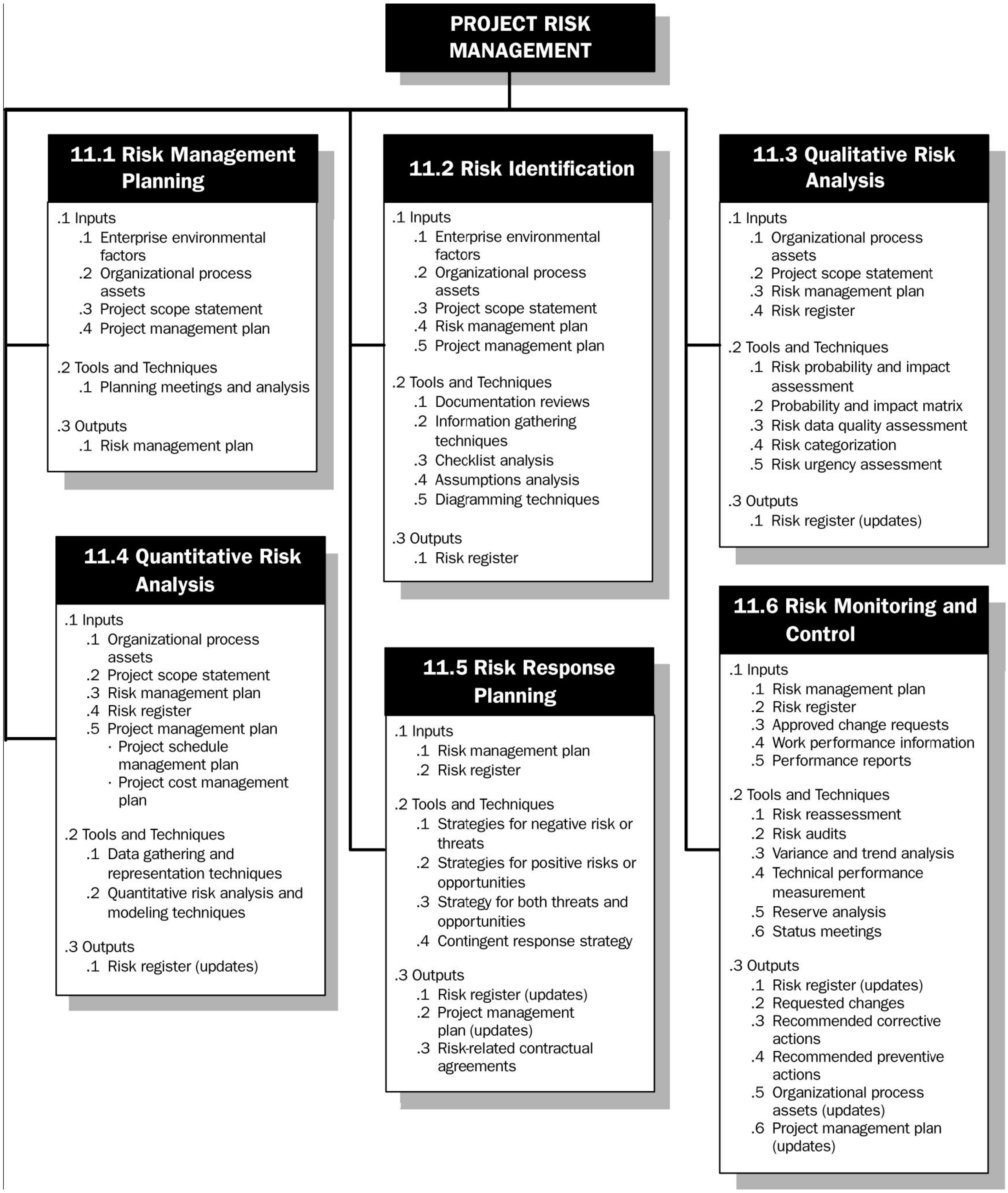

Figure (2) Project Risk Management Overview after reference (4).

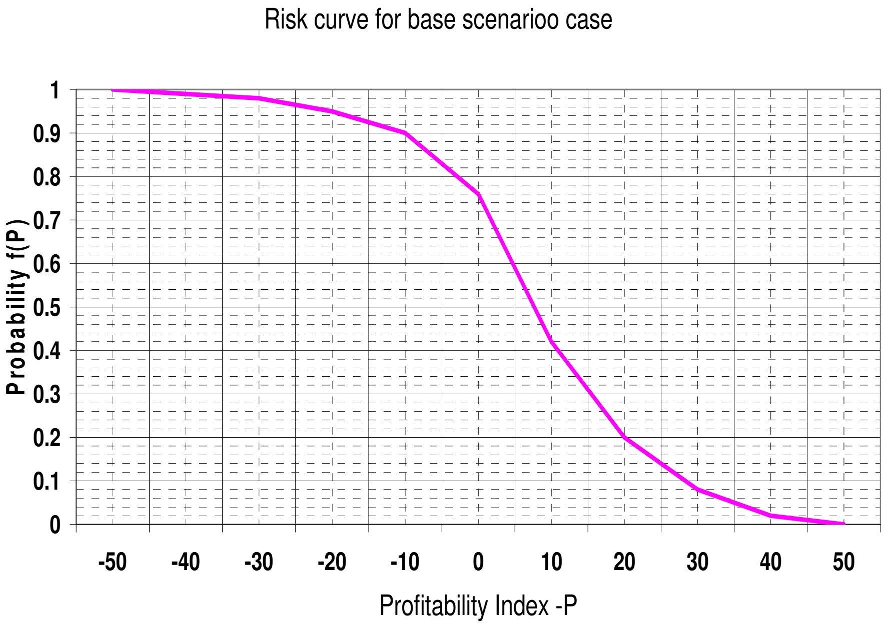

Figure (3) - Risk curve for the profitability index within base case scenario.

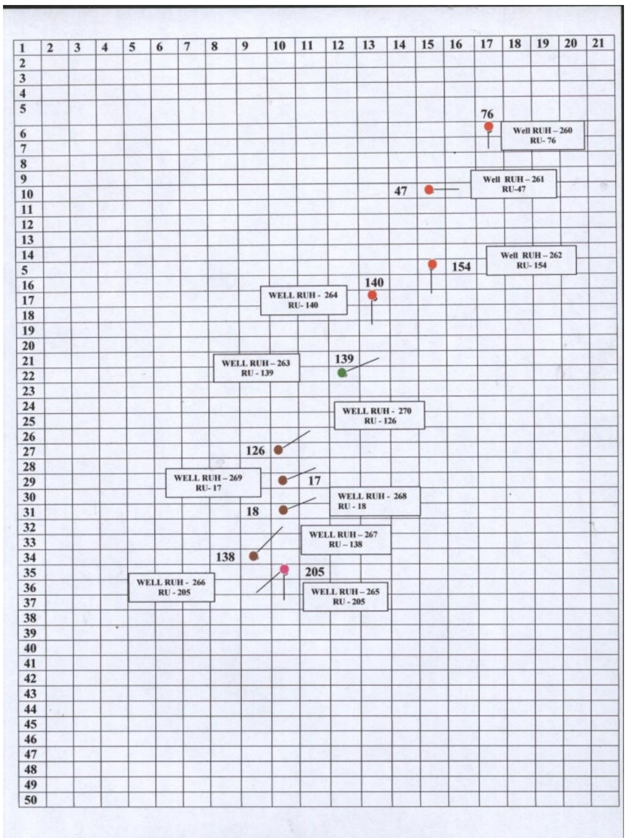

Figure (4) - Horizontal Re- Entry Wells Location on Griddling Map of the southern oil field in case study.

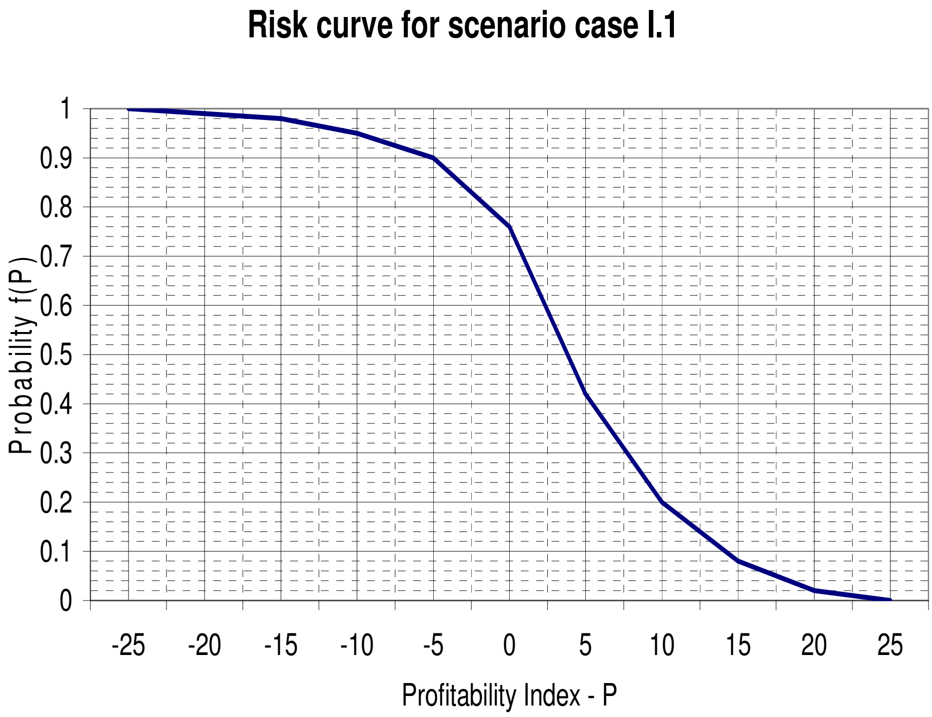

Figure (5) - Risk curve for the profitability index within scenario case I.1.

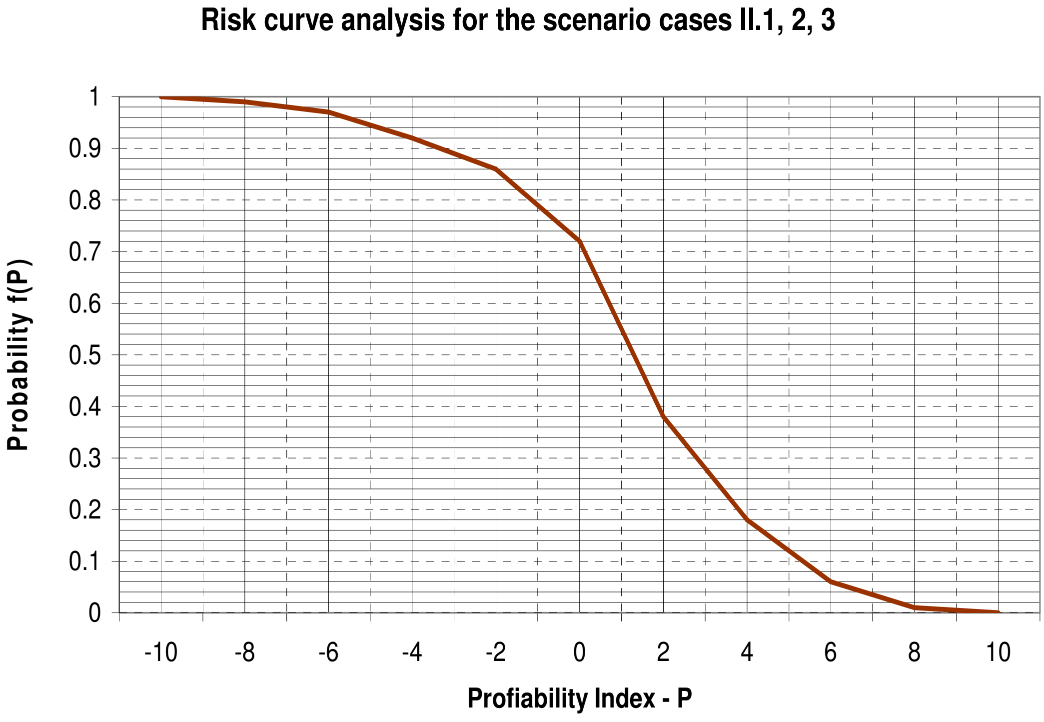

Figure (6) - Risk curve for the profitability index within scenario cases II.1, 2, 3.