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ON THE VALUE OF INFORMATION

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1. ABSTRACT

Often it has to be decided if additional information should be collected or if further studies are necessary before a new field development or an incremental development project can be initiated. Ideally, additional information should be gathered only as long as it contributes to improving the total project net present value and reduces the company's investment risk.

However, it is usually very difficult to attach an economic value to a specific data gathering activity. Lohrenz [1] presented a method for evaluating the value of information. This approach has been utilized in connection with decision making on: 1) a long term test of a vertical well in a small North Sea oil field, 2) a North Sea polymer pilot project, 3) extended production testing of a horizontal well in a reservoir with a thin oil rim. The method, its application and results for the three cases are described in this paper. Advantages and disadvantages of the method are also discussed.

2. INTRODUCTION

Very often it has to be decided if additional information should be gathered before an investment decision is taken.

In general, the value of gathering additional information depends on:

References and illustrations at end of paper

- degree of uncertainty
- representativeness of the additional information
- decision flexibility

Obviously, if there is a high degree of confidence attached to the present characterization of a reservoir, there is no reason to spend more money on data gathering activities, before a decision is taken. However, in the North Sea area the typical situation is that decisions are based on very limited and uncertain knowledge about the reservoirs.

The impact of reservoir description through the issue of representativeness is very important. When something (a pilot, a horizontal well, ...,) is to be tried out in the field, it is important that not the best and not the worst geological conditions available (but the most representative) be selected for the first trial if a field-wide application is envisioned at a later stage.

If decisions about platform concepts, number of wells, processing capacities etc. have already been made, the value of additional information might be very limited, specially if contracts on platforms and topsides have already been signed.

The additional information gathering process could consist of for example long-term testing of one or more wells, enhanced recovery pilot projects, drilling and testing of a horizontal well, etc. Ideally, such additional information should be gathered as long as it contributes to improving the total project net present value and reduces the investment risk.

However, it is usually very difficult to attach an economic value to a specific data gathering activity. Lohrenz [1] recently presented a method for evaluating the value of information. This method is illustrated below in connection with considerations about long-term test of a well, a polymer project, and testing of a horizontal well. The method and its application in the three cases are described and advantages and disadvantages of the method are discussed.

3. DESCRIPTION OF THE METHOD

The method is described in detail by Lohrenz [1]:

" The decision tree in Fig. 1 puts the decision to gather information pertinent to a subsequent decision into a rational framework. Information can be purchased (or gathered at cost) that, when known, can be characterized as good or bad news. Good news is synonymous with a more favourable view of doing what is proposed; bad news with a less favourable view. Any information, however, whether good or bad news, may turn out to be wrong or unrepresentative. The decision three defines the requisite frequencies and expected value outcomes used in Equation (1) to define C_{max}, the maximum amount that the information might be worth:

$$C_{max} = f_G\,[f_{GR}E_{GR} + (1-f_{GR})\,E_{GW}] + (1-f_G)\,[f_{BR}E_{BR} + (1-f_{BR})\,E_{BW}] - E_O \quad .... (1)$$

It would be reasonable to spend up to C_{max} for information, but no more; if C_{max} were negative, the information considered would have no positive value."

In other words, the value of information is calculated as the probability weighted outcome if the information is gathered, minus the outcome if the information is not gathered. Typically, the outcomes of the alternative events are expressed in terms of net present values.

As the method is described here, the maximum allowable cost of gathering information is a result of the calculation, and therefore this cost is not included in the estimated outcomes: E_{GR}, E_{GW}, E_{BR}, E_{BW} (Fig. 1). However, in certain cases the data gathering activity will be an integrated part of the succeeding activities, and therefore it can be difficult to define the cost of the data gathering activity. This can, for example, be the case in connection with long-term testing of a well, which will be part of a further development. In such cases, the data gathering activity can be included in the estimated outcomes, and the activity should then be initiated, if C_{max} is greater than 0.

One of the difficulties in applying the method is, how to establish probabilities of the alternative events. The following examples from the North Sea area illustrate how this difficulty can be solved.

4. EXAMPLES OF APPLICATION

4.1 Long-term Test

It is not known whether there will be aquifer support in the candidate structure. If there is no aquifer support, development of the structure is considered marginal. Therefore *it is relevant to consider long-term testing of a sub-sea completed well. If the long-term test shows no aquifer support, the test well will be produced as long as possible in order to minimize the economic loss. If the long-term test proves aquifer support, two additional wells will be drilled, and a high and low production case have been evaluated. Fig. 2 shows the decision tree for this particular case.*

Calculations have been performed using net present values from the economic evaluation of the example structure:

E_o = *NPV if field is abandoned*
E_{ah} = *NPV for high case with aquifer support*
E_{al} = *NPV for low case with aquifer support*
E_{na} = *NPV if no aquifer support*
f_a = *Probability of aquifer support*
f_{ah} = *Probability of high case with aquifer support*

The probability of aquifer support is not known, while there is considered to be equal probability of the high and low case with aquifer support (f_{ah} = 50%). Under these assumptions C_{max} versus f_a can be established as shown on Fig. 3.

The test will be an integrated part of the succeeding development, so the outcomes E_{ah}, E_{al} and E_{na} include the cost and income of the long-term testing.

Hence, the criteria for initiating the long term test will be points where $C_{max} > 0$. From Fig. 3 it can be seen that the long-term test should be initiated if the probability of aquifer support is greater than 13%.

In other words, even a relatively small probability of aquifer support can justify initiation of a long-term test. Case histories for comparable reservoirs might help in quantifying the probability of aquifer support. Also, geological expectations of aquifer size and permeability must be considered in this context.

In this way the decision problem has been simplified to a problem of determining the probability of aquifer support.

4.2 Polymer Pilot Project

A pilot polymer project has been proposed in order to investigate possible benefits from a large scale polymer project. It has to be considered if the pilot project can be economically justified. The critical factors are:

- *What are the chances of technical success of the pilot project?*

- *Will results from the proposed pilot project be representative for a large-scale project?*

Fig. 4 shows the decision tree for this situation. An example calculation has been performed using the following assumptions for a large-scale polymer project:

- *6 injection wells*
- *1020 ton polymer per well*
- *1700 ton biocide per well*
- *Additional investment = 60 mill. NOK (injection wells would be drilled in any case)*
- *Polymer cost incl. transp. = 50/100 NOK/kg*
- *Biocide cost incl. transp. = 12/24 NOK/kg*
- *Additional production = 5% of base case production from the relevant area.*

The net present values of the alternative events were estimated as:

E_o = NPV for base case, i.e. waterflood without polymer

E_{GR} = NPV assuming technical success of pilot and that results are representative (+5% production)

E_{GW} = NPV assuming technical success of pilot, but results are not representative (no additional production)

$E_{BR} = E_{BW}$ = NPV assuming technical failure of pilot, and no large-scale polymer project implemented

f_G = Probability of technical success of the pilot project

f_{GR}/f_{BR} = Probability of results from pilot project being representative.

From a survey of EOR projects [2] the probability of technical success of a polymer pilot project can be estimated to be approximately 84%. However, the statistics cover only onshore projects. As such a project has not yet been initiated offshore where well-spacing generally is much greater, it seems reasonable to apply a lower probability, say 50%.

From these estimates C_{max} versus f_{GR} can be established as shown on Fig. 5.

The cost of the polymer project is estimated to 90 mill. NOK. Hence, it can be seen from Fig. 5 that a very high probability of "results being representative" is required, if a pilot project should be initiated.

Also, it can be seen from the figure that a doubling of polymer/biocide prices means that under no circumstances should the pilot project be initiated. Similar sensitivity analyses can be made for the amount of additional production from a polymer project, or for alternative oil prices.

This analysis neither confirms nor rejects the question about initiation of a pilot polymer project, but it emphasizes the importance of "representativeness of the pilot" and of the polymer price (and additional production). Hence, a decision about the pilot project should not be taken before these factors have been studied in great detail.

4.3 Testing of a Horizontal Well

Fig. 6 defines a simplified decision tree for long-term testing of a horizontal well. The objective is to investigate the possible benefits of developing a thin oil zone under a large gas cap. The oil zone consists of two separate provinces, the main oil province and the secondary oil province.

If it is decided not to perform the test, there will be no basis for developing the oil province, and the net present value of this event will be zero (E_o=0).

If the test is initiated, two possibilities are considered. If the horizontal well is drilled and completed successfully, and test results are encouraging (technical success), a staged development will follow. Initially, the main oil province will be developed with a floating production platform and 4 horizon-

tal wells (including the test well). If production is as expected, i.e. if the test well is representative for the main oil province, the secondary oil province will be developed by 2 horizontal wells. If the test well is also representative for the secondary oil province, production will be as expected, and net present value is estimated to E_1 for the total development of the oil province.

If the test well is not representative for the secondary oil province a low case is considered, and the net present value in this case is estimated to E_2.

Similarly, if the test well is not representative of the main oil province, a low case is considered. In this scenario the secondary oil province will not be developed and the net present value is estimated to E_3.

Finally, if the test well is not drilled and completed successfully, and/or the test results are disappointing (technical failure), no further development will be initiated. The net present value in this case (E_4) will be negative, corresponding to the cost of the well.

As drilling and completion of horizontal wells are a relatively new technology, there is no statistical basis for estimating the probabilities required for this analysis. Therefore, sensitivity to the various probabilities is shown on Fig. 7.

The sensitivity of net present value to P_{E1} (probability of the test well being representative for the main oil province) is shown for two values of P_{E2} (probability of the test well being representative for the secondary oil province), and for two values of P_T (probability of technical success).

Fig. 7 illustrates clearly, that development of the secondary oil province has a limited impact on the total economic results (only small differences between P_{E2}=0.75 and P_{E2}=0.50). Hence, the test well should primarily be planned to be representative for the main oil province.

Also, it is seen from both figures that a lower probability of technical success (P_T=0.50 as compared to P_T=0.75) implies a requirement of higher probability of the test well being representative (the straight lines move to the left), before the long-term test should be initiated.

Finally, it can be concluded that the probability weighted net present value will almost inevitably be positive. For example, if P_T=P_{E1}=P_{E2}=50%, the net present value will be 120 mill. NOK.

5. DISCUSSION OF THE METHOD

Reservoir related decisions will always depend on estimates which are based on very limited and uncertain information. Therefore, often it has to be decided if gathering of further information (at a certain cost) can be justified by later improvement of the project.

The estimates on which a decision has be to taken will almost always be biased. As pointed out by Castle [3], Campbell [4], and Brush et al [5], it seems that people in the oil industry most often overestimate project performance, which results in many economically disappointing projects. The method illustrated above requires that the "estima-

tor" quantifies the probability of alternative events. Probably this will not remove bias in the estimates, but it will be more obvious for everybody involved in the project whether the expectations are optimistic or pessimistic.

It can be argued that the decision trees presented here are oversimplifications of the real world. Certainly, in reality a large variety of outcomes of the alternative events are possible, and if all possible outcomes should be considered, the decision tree would be extremely complicated and calculation of all relevant net present values would be almost impossible. However, no matter how the big decisions about field development are taken, some kind of simplification must be made. One of the biggest advantages connected to the method illustrated above, is the fact that management can see clearly how and where the simplifying assumptions have been made.

It will often be a problem to define probabilities of the alternative events. However, detailed studies of government reports, case histories, etc. will in many cases give a basis for "order of magnitude" probabilities. Also, a systematic application of the method would result in a statistical data base which could help in future analyses.

As shown in the polymer pilot example, the method can be used to illustrate which factors are critical for a project. even if it is not possible to quantify all probabilities. Hence, analyses of a project using this method can help in defining objectives for further studies.

Application of the method is limited to cases where the outcome of alternative events can be quantified as a net present value (or a similar economic measure). However, in connection with a long-term test the amount of flared hydrocarbons could be a critical factor. In such cases the method could be used to compare the amount of flared hydrocarbons to the expected additional recovery of hydrocarbons (the outcome of alternative events should then be expressed as amounts of produced hydrocarbons instead of net present values).

6. CONCLUSIONS

In conclusion, it is felt that the method described by Lohrenz [1] is a simple tool which in a very concentrated form can illustrate complex decision problems and emphasize the effect of critical factors.

Although the method in most cases implies a high degree of simplification, such simplications have to be made anyway, before complex decision problems can be solved. By using this method, it will be obvious for anybody involved, how and where the simplifying assumptions have been made.

NOMENCLATURE

Description of the method:

C_{max} = maximum value cost that could be incurred for information without expected value loss.

E_o = expected value of a project a prioi information under consideration.

E_{BR} = expected value of project when information is bad news that turns out to be correct.

E_{BW} = expected value of project when information is bad news, but turns out to be wrong.

E_{GR} = expected value of project when information is good news that turns out to be correct.

E_{GW} = expected value of project when information is good news, but turns out to be wrong.

f_{BR} = frequency that information, given that it is bad news, turns out to be correct.

f_G = frequency that information is good news; $(1-f_G)$ is the frequency that information is bad news.

f_{GR} = frequency that information, given that it is good news, turns out to be correct.

Long-term Test Example:

E_o = NPV if field is abandoned.

E_{ah} = NPV for high case with aquifer support

E_{al} = NPV for low case with aquifer support

E_{na} = NPV if no aquifer support

f_a = Probability of aquifer support

f_{ah} = Probability of high case with aquifer support

Polymer Pilot Example:

E_o = NPV for base case, i.e. waterflood without polymer.

E_{GR} = NPV assuming technical success of pilot and that results are representative (+5% production).

E_{GW} = NPV assuming technical success of pilot, but results are not representative (no additional production).

$E_{BR} = E_{BW}$ = NPV assuming technical failure of pilot, and no large-scale polymer project implemented.

f_G = probability of technical success of the pilot project.

f_{GR}/f_{BR} = probability of results from pilot project being representative.

Horizontal Well Example:

E_0 = NPV if no test is performed (=0).

E_1 = NPV if test results are representative for the main <u>and</u> secondary oil provinces.

E_2 = NPV if test results are representative for the main oil province, but not for the secondary oil province.

E_3 = NPV if test results are not representative for the main oil province.

E_4 = NPV if test is a technical failure.

P_{E1} = probability of the test well being representative for the main oil province.

P_{E2} = probability of the test well being representative for the secondary oil province.

P_T = probability of technical failure.

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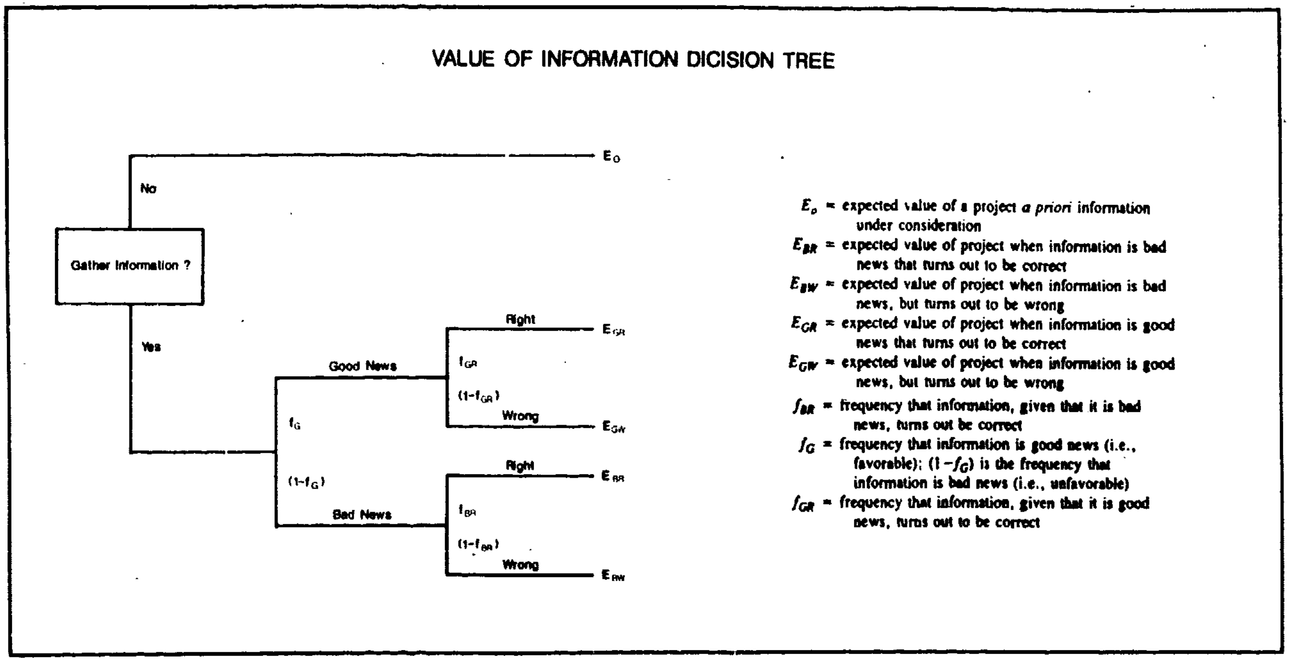


Fig. 1 - Description of the Method

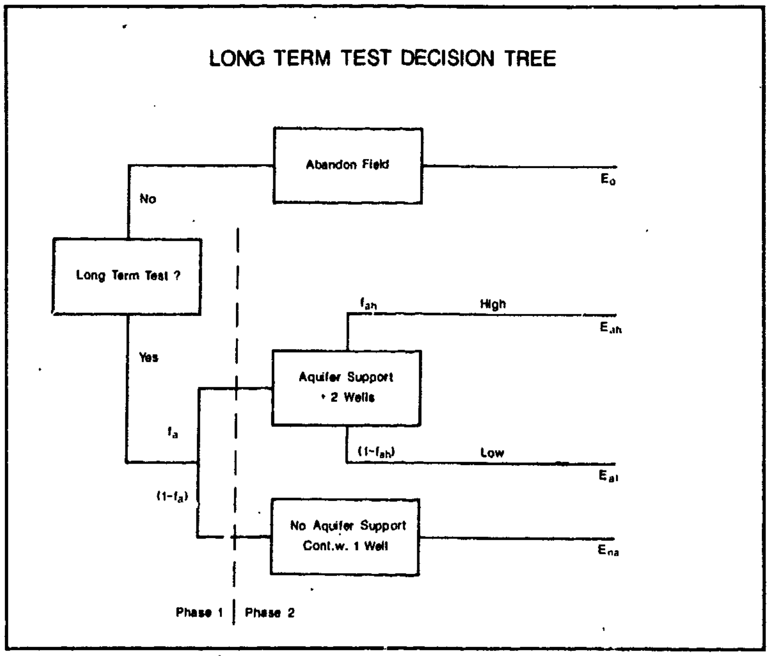


Fig. 2 - Long-term Testing of a Small Structure with unknown Aquifer

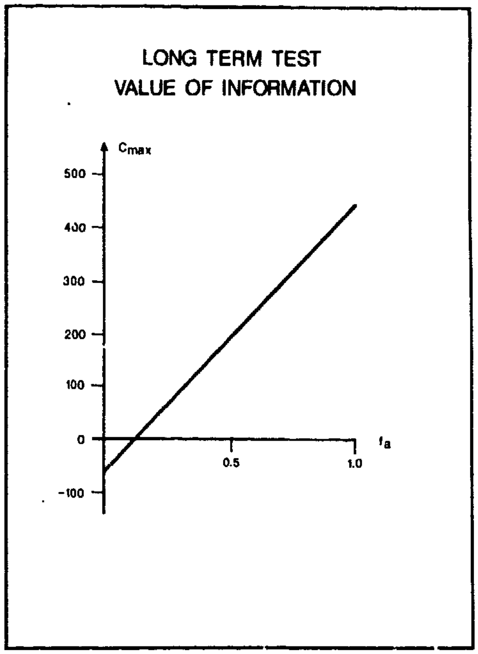


Fig. 3 - Maximum Cost of Test vs. Probability of Active Aquifer

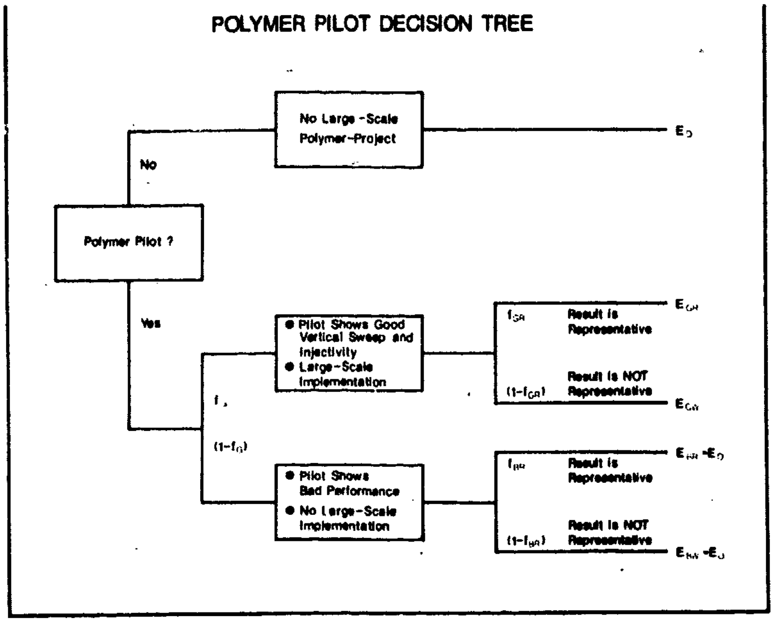


Fig. 4 - Pilot Project for Investigation of Large-scale Polymer Project

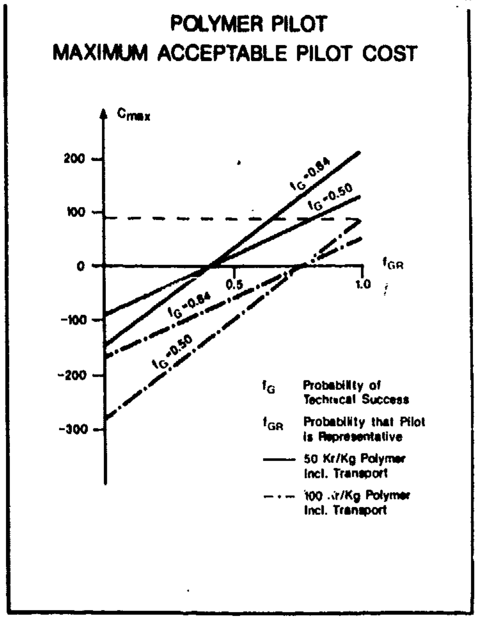
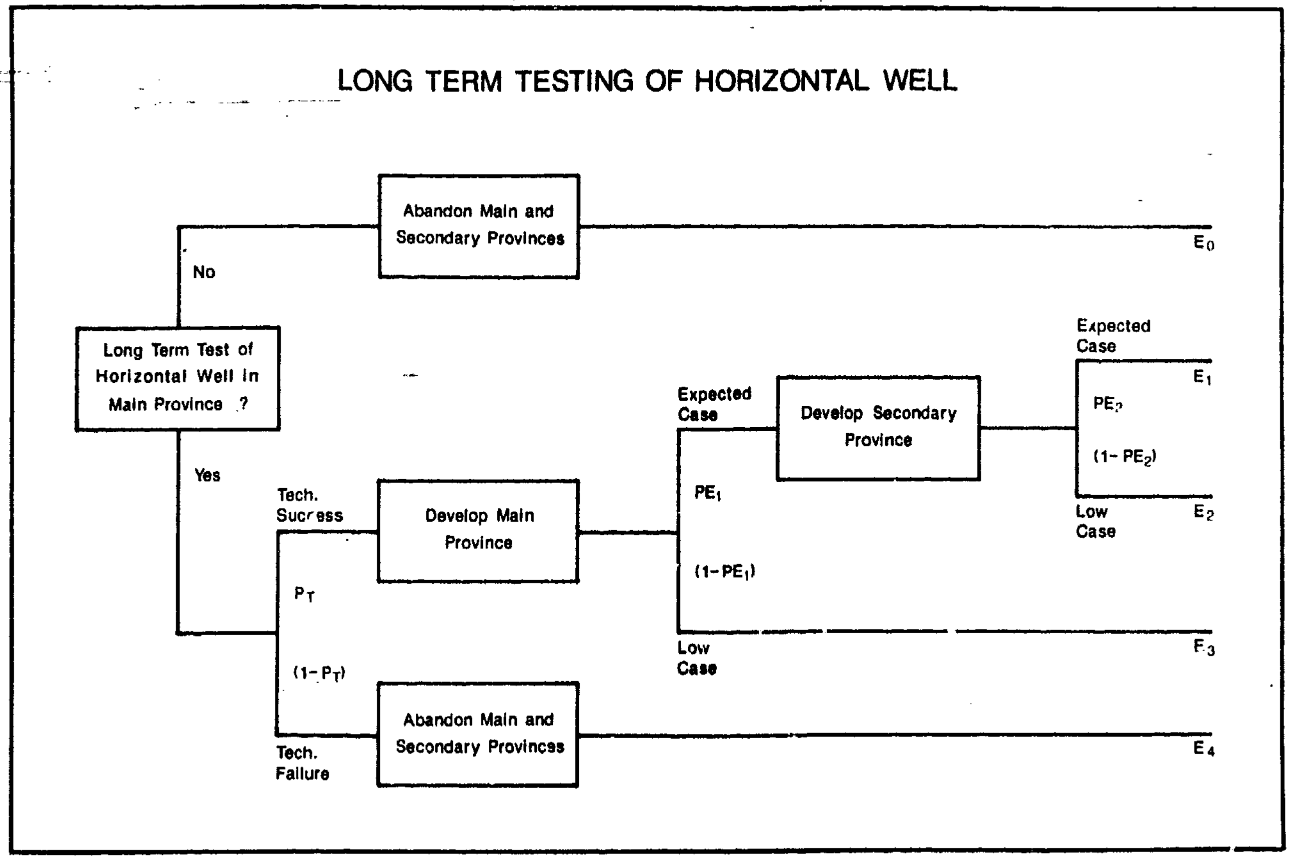


Fig. 5 - Maximum Cost of Pilot Project vs. Probabilities



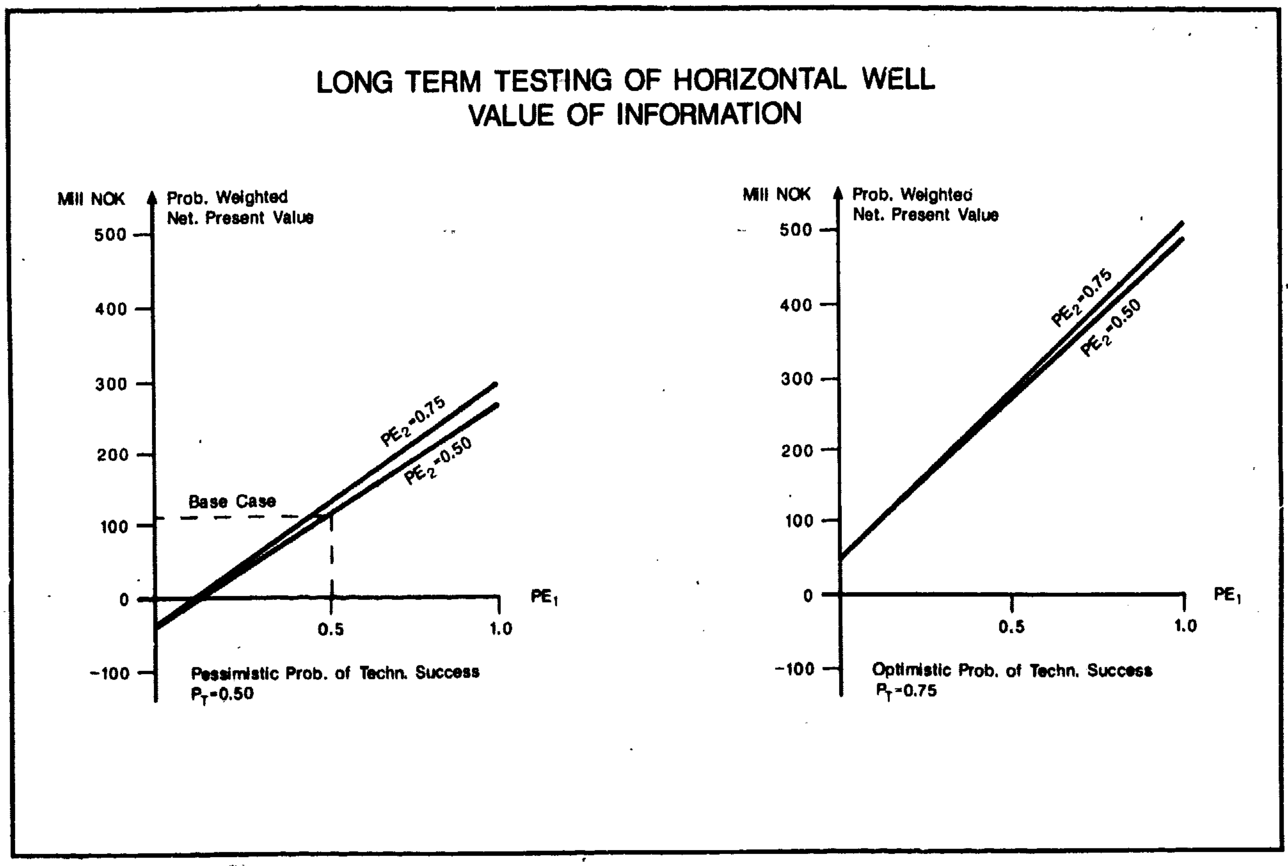


Fig. 7 - Sensitivity to Various Probabilities on Weighted Net Present Value