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REGULATORY ASPECTS OF GEOLOGICAL MODELLING

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ABSTRACT

Oil and gas companies around the world are facing a more common requirement to include geological models in the submission for regulatory approval of exploration and development proposals. This paper discusses the value of geological modelling for this purpose and highlights some of the potential problems associated with the evaluation of geological models.

The most important issue is to develop a consensus on what is meant by 'a good model' and whether a single model of the reservoir is sufficient for regulatory authorities to approve a plan. The second issue concerns the concept of certification; who is qualified to construct a model? Who is qualified to examine or audit a model? Without clear answers to these questions, it is difficult for the industry to provide the information that these authorities require. Moreover without precise definitions of the requirements of the authorities it is easy for industry to waste precious resources producing models that have no numerical validity or predictive capability.

This paper seeks to open discussion on these issues and to suggest areas where consensus needs to be established for the benefit of the government and the industry. Uncertainty in structural interpretation and uncertainty in deposition have significant impact on good reservoir management for individual companies and wise management of national resources. Specific areas of concern are; volumetric calculations, risk analysis and the problems associated with the development of geological models in areas where data is sparse. This paper will discuss alternative modelling strategies in these areas and recommend appropriate workflows.

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INTRODUCTION

The aim of geological modelling in the petroleum industry is, of course, to create geological models of oil and gas reservoirs. A good geomodeller is expected to construct good geological models. Auditing of geological models is much more advanced in those industries where the failure of a geological model is likely to have a danger to life, an exposure to litigation or a quantifiable cost. None of these appear to have been applied in the petroleum industry, but advances have been made in groundwater modelling, civil engineering and mining. As governments move towards requiring geological models for exploration and development approval, the spectre of litigation is likely to appear and the government may also begin to consider the ability to quantify cost.

The concept of the cost associated with an inaccurate model has not yet been explored with any vigour in the petroleum industry. Cruz (2000) and Deutsch (2002) have discussed the concept of loss function within the constraints of decision making in an uncertain environment, and other authors have used the loss function concept within the narrower confines of reducing errors in upscaling and of course, in the development of kriging algorithms (Matheron, 1963).

Loss functions in process engineering are largely associated with the work of Taguchi (1987), who disagreed with the existing experimental design procedures, based on Fischer (1926), because there was a need in industry to design to a tolerance and not simply to improve yield. In this case there is a penalty for over-estimation and under-estimation. The same is true for oil reservoirs where there is a significant financial penalty for under-estimating or over-estimating the size of the reservoir.

Any sensible governmental approach to the analysis and auditing of reservoir models would consider the impact to the country's resources and the revenue that may be lost by inaccurate or inappropriate modelling.

What is a good model?

In trying to define a good model it may be helpful to theorise about the existence of a perfect model. This, after all, is what we would like to create if we were unconstrained by time and money. So, a perfect geological model of the reservoir would contain perfect information on the geology of the reservoir.

What can be predicted from this perfect geological model of the reservoir? We would know the locations of all the shale barriers, the location of all the sand bodies and the locations and orientations of all the fractures. We could compute the connectivity of the reservoir and the pore volume. But, does this help us to understand the dynamic behaviour of the reservoir and the response of the reservoir fluids to changes in pressure?

To understand reservoir behaviour we need to think about numerical simulation of flow. In the late 1980s there was a big distinction between reservoir characterisation, or the understanding of reservoir behaviour, and the, more narrative, reservoir description. This distinction has been blurred significantly and the quest for increasing detail in reservoir description is now believed to be the pathway to improvements in the understanding of the reservoir's behaviour.

A good model of a reservoir has one simple quality: It should provide good predictions of the behaviour of the reservoir in response to certain conditions.

Let us consider the concept of a shared-earth model. In a shared earth model all the data from all the disciplines are combined in a 3D model of the reservoir. The advantage of this technique is that discrepancies between data from different sources can easily be identified. However, there is a tendency to assume that this model is correct and that its predictive capability is valid for all interrogations.

I do not believe that there is a positive correlation between increasing detail and increasing predictive capability of a geological model. This paper will show that better understanding of the reservoir, and therefore, better understanding of the opportunities and pitfalls of the management of a reservoir, would be better served by the construction of larger numbers of simpler models.

What can be expected of a model

In engineering a model would be expected to perform to its design specifications i.e. its response to different conditions. A perfect model would return the same response to interrogation as the real reservoir. For a reservoir with limited information it is clearly impossible to construct a model that fulfils this condition. But, it is possible to build models that are designed with different specifications. So we can build models which would respond the same as the real reservoir for a very narrow subset of possible interrogations.

For the purposes of regulation we would expect a model to respond in the same way as the real reservoir within the model's design specifications which must be defined, attached to the audit history of the model or reported in some other explicit way.

Prerequisites for good modelling

In their report to the New Zealand Department of the Environment; "Groundwater Modelling for the Environment", Pattle Delamore Partners Ltd (2002) made the following observation; "The most important first step in a modelling project is to define the modelling problem for which the modeller must find solutions ."

Defining the problem is central to the design of a successful modelling project or experiment. These design specifications set the limits on model performance. They will define predictions which can be made with confidence from the model. They should also clearly state those questions which may not be corrected answered by interrogation. An example might be that the model is unsuitable for upscaling because the choice of resolution for the grid does not support upscaling to the simulation scale.

The design stage is a useful place to ask the simple and important questions about the uncertainties in the reservoir. Is the problem stratigraphic or structural? What should be modelled explicitly and what has to be modelled implicitly? How many alternative geological concepts are valid for this reservoir and which of these should I model?

Whilst designing the model and planning the experiments, it is important to remember that the less data you have, the more specific your models should be, and the more models you should construct.

Confidence, prediction and preparation

In many cases it becomes clear that the ability to predict anything with confidence about a reservoir that only has a few wells is essentially impossible. Consider Corbett and Jensen (1992) which studied the number of samples needed to derive the mean of a distribution with confidence. The mean is a single value representing location. To understand the distribution you would really need some measure of dispersion and ideally some visual representation of the distribution. This would lead us to believe that we should construct multiple models even if we just want to get the mean behaviour of the system.

What can be done in those cases where there simply isn't enough information to predict this behaviour within the confidence limits that Corbett and Jensen refer to? Well, rather than admit defeat, the investigation of multiple possible ideas, models, and scenarios will allow us to perform a very important function of management planning; preparation. In situations where prediction is impossible, preparation is vital. Preparation allows us to be ready to take advantage of unexpectedly good situations and gives us the ability to make the best decisions in unexpectedly bad situations. Quite bluntly, reliance on a single model to define a management strategy is naïve most of the time and foolish when prediction or forecasting is difficult.

Volumetrics

One of the most common reasons for constructing geological models is "to get more accurate volumetrics" and practitioners use the emphasis on "accuracy" to construct very detailed models, with grid cells that are as small as their computers can manage.

There is a big difference between accuracy and precision. Increasing the resolution of the geological model with millions and millions of smaller and smaller cells will only improve the precision, not the accuracy. The best way to improve the accuracy of the predicted volumes is again by constructing multiple lower resolution models with different ideas of the possible configurations of faults and horizons and fluid contacts. See Corbett and Jensen (1992). The resulting distribution of volumes provides a statistically valid basis for inference and prediction. Regulators usually are, and certainly should be, aware of this distinction and modellers too should familiarise themselves with these concepts.

Workflows

It is interesting that in recent years geological modelling software encourages modellers to follow predefined workflows. There is a benefit to the software companies in doing this because the number of possible options and therefore the number of errors that need to be fixed is significantly reduced. Users like this approach because it is easy. Actually you don't need to think too hard when using workflows, and that is the problem.

Let us compare another strategy for using programs. Most video games are designed so that you have to complete all the tasks at a given level to move to the next level. Would this be a more suitable paradigm to use for software that could have a significant cost liability? You can only build a geological model of a reservoir with faults if you have already built successful models of field without faults and understand the limitations of fault modelling. And then you can go to the next level.

For most cases there is only one high level workflow.

1. Define the problem, or suggest a hypothesis
2. Design the experiments
3. Run the experiments multiple times
4. Collate the results

This is the same workflow that has served the advancement of science over the last 500 years or so. Hypothesis, prediction, and experimental verification has proven itself to be a robust workflow for investigating the unknown (Popper, 1959). A reservoir is no different from the body of scientific knowledge and a smart way to proceed would be to suggest a hypothesis such as; "This reservoir contains at least 1 million barrels of recoverable oil", "The B sand has a connectivity of 80% in this region" or "Fractures may cause permeability anisotropy in the C reservoir". Each of these hypotheses can be tested with a set of experiments. Popperian falsification is then useful from an economic standpoint if the hypothesis is correctly phrased.

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Certification

There are strong arguments for and against certification of professionals. On one hand it allows the public to be more confident in their ability. On the other hand it often creates unreasonable barriers to entry, closed-shops, monopolies, and other restrictive practices that most economies would prefer not to encourage.

Most professionals recognise qualifications from independent institutions and understand the value of experience. A combination of well-trained and experienced geomodellers operating within clear modelling guidelines from the authorities would be sufficient to ensure a significant improvement in the quality of reservoir models.

Recommendations for auditors

The following questions represent a good starting point for the analysis of the suitability of a geological model;

1. Has the client provided clear design specifications for the model including limitations on the model's validity?

2. Has the client provided a single model? If so is there sufficient data to justify the use of a single model?

3. Does the set of models or single model fit the geological data and respect the geological concept or concepts that may be present in the reservoir?

4. Does the set of models or single model fit the dynamic data and the flow behavioural concept or concepts that may be present in the reservoir?

5. Is the response of the model or set of models suitable for predicting the response of the reservoir within the limits of the scope of the project?

6. Is a comprehensive audit trail available so that the auditors can evaluate the applicability of model design decisions?

7. If multiple models have been constructed, are they representative? For example, is a model described as a P90 model when it is really just an optimistic model?

8. If the primary reservoir uncertainty is structural has the client provided multiple structural models?

CONCLUSIONS

The requirement to create geological models of some fields appears to have some merit for the communication of development plans. Quantitative analysis of these models is a much difficult process for many fields, simply because the data are usually not sufficient to support the inferences that are being made. But, the true confidence in any quantitative analysis of a reservoir model is important for a regulator

Single models of all but the most mature reservoirs should be treated with extreme caution.

The technique of constructing a 'base-case model' and then making an 'optimistic' model and 'pessimistic' is an interesting concept which becomes dangerous if the base case, the optimistic case, and the pessimistic case are assumed to be the P50, P10 and P90 cases. This will never be true and yet it is a very common mistake.

In general the construction of a set of models which test the response of the reservoir to variations in input must be recommended as the most robust modelling strategy. This technique is valid regardless the quantity or quality of available reservoir information.

Hypothesis testing is a robust strategy for the analysis of uncertainty. It facilitates rapid construction of multiple experimental models with simple results that are readily incorporated into decision making and economic evaluation. Their perceived weakness is that they don't require detailed geological modelling. This should be seen as the strength.

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