Final Report of the Sub-Committee for Growth-to-Known Reserves of the Committee on Resource Evaluation (CORE) of the American Association of Petroleum Geologists

Introduction

This final sub-committee report is a culmination of the work of the AAPG CORE and its sub-committee on Growth-to-Known Reserves (GTK) in response to a 2006 request from the USGS Energy Resources Team. In that request, the USGS asked the CORE peer review and comment about the methods used to develop the Growth-to-Known (GTK) prediction factors for future resource assessments.

Members of the CORE initially met and reviewed the analysis with the Team in 2006/early 2007. During the course of the review, sub-committee recommendations about how this work and analysis might be performed were conveyed verbally to Survey personnel. At the 2007 Long Beach meeting, a summary report was compiled and reviewed by a quorum of the committee. Some members of the sub-committee met again with the Team on March 11-12, 2008. This meeting was in conjunction with the biennial Fourth Workshop on Reserve Growth conducted by the Team, led by Tim Klett. A draft report was submitted to the CORE at the 2008 San Antonio meeting. A second draft report was circulated prior to the 3-31-09 teleconference of CORE. Comments were received and a discussion of the draft was held.

These previous CORE and Team meetings identified that the key steps in the process of determining the GTK multiplication factors are:

1. Data source: North American data is the most lengthy and complete data set to develop and test predictive methodologies. The sources of these data are IHS, NRG Associates, and the EIA OGIFF.
2. The evaluation process should be clearly described.
3. Test the forecast accuracy and identify the forecast drivers.
4. Use abandoned fields as a benchmark.
5. Study a significant number of fields with all methods.
6. The use of stationary time series where the future = the past.
7. Perform hind casting against the results of well characterized field studies.

Status of USGS Energy Team GTK 2009

Early in 2009, Tim Klett advised that the USGS GTK Assessment Project was proceeding as planned. In 2008, the Team published Chapter I of USGS Bull. 2172. The title of the report is Geologic Controls on the Growth of Petroleum Reserves by Fishman, Turner, Peterson, Dyman, and Cook. No other reports on Reserve Growth were published by the team this past year. Tim Klett also advised that several of his team members will be presenting their GTK work at the June, 2009 Denver AAPG convention.

The Team will be using the NRG Associates 2008 Significant Oil and Gas Fields of the U.S. From this data base the Team will combine some NRG fields to "whole fields" where there exist boundary issues that create more than one data set for a named field. They will construct the reserve growth functions using the Lp-Norm Criterion (the renamed Monotone Least-Squares Method) and the Modified Arrington Methods. As reported in the summary of Chapter I, to add

more precision to these statistical methods, the USGS Team investigated some of the geologic factors that affect oil field reserve growth. In this study they identified 10 U.S. formations that possess gross geologic differences as determined by environments of deposition. Further they defined various categories of reservoirs within these formations on other basis such as: porosity and permeability; source rocks; traps and seals; structural evolution; and postdepositional history. They concluded that "(oil) fields with low production variability have the potential for more predictable growth than fields with high production variability". They attribute this conclusion to reservoir heterogeneity.

Additionally, they will use Individual Field Analysis Method (based on several field studies in the San Joaquin Valley, California) on significant "outliers" (big fields). This method involves determining probabilistic estimates of in-place hydrocarbons combined with probabilistic estimates of recovery factor. From this estimate of ultimate recovery, they will subtract cumulative production. The remaining reserve estimate can be used to determine future reserve growth. New reserve growth functions will be developed by the above methods, tested, and if satisfactory, applied to the "outliers" of U.S. reservoirs in future assessments.

Also, the USGS Team plans to apply the above statistical and field analysis approach for future world assessments using the IHS International data base.

Discussion and Recommendations

Key Steps 1 and 2; Data Source and Description of Methods; The sub-committee endorses the Team's use of NRG and IHS field data as the most complete available for historical growth. We think these data sets, in particular NRG in the U.S., will allow the development of the most detailed historical field growth functions by year and total field life to date. These are the data that most of the industry uses to study the growth of field reserves. With the NRG U.S. growth factors as a guide, the Team's will use the IHS international reserve data, which grows more complete each year, for World Assessments.

The recent (2008) publication of Chapter I, USGS Bulletin 2172, together with the presentations to be given at this year's convention, and at planned biennial Workshops show that the process of developing reserve growth functions are constantly being refined. The methods are clearly described by the Team in these public presentations.

Key Steps 2, 4, and 6; Evaluation, Forecast, and Time Series; The sub-committee endorses the use of both the Lp Norm (ex-Monotone) and Modified Arrington Methods for the statistical development of the field growth functions for future assessments. These methods are based on construction of a discovery table by either discovery year or year since first production, and using the data bases to identify the field reserve increases through time. Both methods use this table to calculate an annual growth factor and a cumulative growth factor. The Modified Arrington method was used to develop functions in past U.S. and World assessments.

Additionally, the Team continues to refine the results of the forecast methodology by evaluating the geologic factors affecting reserve growth. In Bulletin 2172-I, they selected 10 U.S. formations to investigate the variation of reserve growth function in siliciclastic and carbonate reservoirs. The functions for these gross categories also were studied by introducing depositional setting, source rock, and post-depositional alteration. Further studies of this nature can only help bring more geologic insight to what has been mainly a statistical prediction.

The development of the growth functions should continue to use of the most recent NRG data in the U.S. Some of the abandoned fields' growth functions while active are being used as

calibration of the predictions. The Team will remove "continuous plays" in analyzing the growth of field reserves. These continuous accumulations will be treated separately. It is worth noting that the USGS has requested the CORE to review separately their continuous assessment methodology. That work is just commencing

Key Step 3, Drivers; The sub-committee recommends the studies continue to identify the important drivers of growth. These drivers may be geologic, technologic, economic, or sociopolitical. Once the drivers have been identified, we suggested that the Team look at utilizing graphic presentation "tornado charts" to analyze the drivers and show their relative importance.

Key Step 5 Multiple Methods; The subcommittee endorses the use of statistical and field study methods on the big oil field "outliers". The analysis is based on studies of the large mature oil fields in the San Joaquin Basin. The method consists of an extensive field study that treats large fields as an assessment unit. In most mature petroleum provinces, the large or giant fields have the most volumetrically significant reserve growth. The reserve growth of several large fields will dominate the growth potential for the area or province. The field analysis involves acquiring the geologic characteristics of the field, information on the total resource in-place (OOIP), estimating how much of the oil will be recovered by all means, and comparing to known recoverable oil. The goal is to predict a range of increases in reserves based on the geology and future development technology. The production history plots are an excellent graphic to demonstrate field growth and relate cumulative production to OOIP. The cumulative plots could be extended for a forecast period by plotting the estimated growth calculated by the various methods. Like the estimates of OOIP, it would be a simple matter to place future time events on the graphic that might influence the shape of the extended creaming curve.

Summary

The sub-committee endorses the Energy Resources Team use of the statistical methods of the Lp Norm and Modified Arrington to develop field growth functions based on NRG Associates field data in future National and World Resource Assessments. Further, we endorse the continued refinement of the methods by the ongoing investigation of the effects of formation, reservoir type, and other factors at the reservoir level. Also, we support the use of field studies of the "big oil fields" to develop growth functions based on estimates of OOIP.

The members of the sub-committee wish to thank the Team for their co-operation during this review.

I wish to thank the members of the sub-committee for their comments on this report.

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