The Decline in World Oil Reserves Predicted by the Parabolic Projection of Future Production and Discoveries

John H. Walsh

Energy Advisor

Abstract

The expected changes in world reserves of conventional oil were interpreted in terms of the standard convention defining resources and reserves. According to this convention, oil is produced exclusively from reserves which in turn are replenished only by discoveries. The change in reserves over one year is thus the sum of discoveries less the production for that year. The total discoveries were taken as the sum from two different sources: those arising from the normal exploration process and those that contribute to the Reserves Addition specified in the *Year 2000 Assessment* of the U.S. Geological Survey. These two quantities may change over time in opposite directions and it is this attribute that distinguishes this paper from previous studies.

The production projection taken from the previous underlying paper was based upon the Mean Value published in the Year 2000 Assessment of the U.S. Geological Survey. This paper also follows the earlier one in interpreting the Reserves Addition in two different ways that represent opposite boundary conditions. In Case 1, the Reserves Addition was only assumed active after the peak in production has passed and in Case 2, it was assumed to contribute to output through the whole production cycle. The actual situation is likely to lie between these two extremes. The changes in reserves were calculated year-by-year to 2050 for each case starting from values published in the literature for the end of 1999.

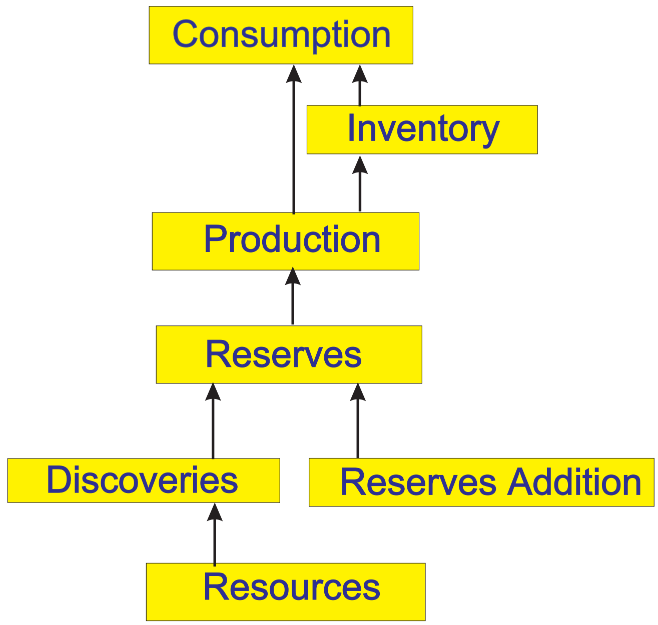
Despite this major difference in the two underlying assumptions, the predicted fall in reserves over time was found to be virtually the same in both cases. Moreover, the peak in the rate of discovery per year was found to occur after the peak in production had passed although the Reserves-to-Production Ratio fell faster in Case 2. The major conclusion of this paper is that the reported published reserves should decline only slowly in the next decade. Changes in published reserves are thus not a good predictor of when the peak in world conventional production of oil may be expected. Nevertheless, considerations of self-consistency of the data require this reported value to start falling soon.

Introduction

In a previous paper,[1] a parabolic technique was applied to the resource data published in the *Year 2000 Assessment of World Oil Resources* by the U.S. Geological Survey[2] to project future conventional oil production over time. In this paper, the Mean Value of this Assessment was used to compute the track of conventional world oil reserves for two different options for dealing with future discoveries. The end of 1999 value for world reserves was taken from the *BP Statistical Review of World Energy.*[3] This quantity is based upon the yearly assessment prepared by *The Oil and Gas Journal*[4] (a U.S. publication) but with natural gas liquids (NGLs) added to the total as is the practice in the *BP Review.*

The relationship between resources and reserves is illustrated in Figure 1. According to the Standard Convention, consumption is supplied either directly from current production or indirectly via reduction of inventories; production is derived only from the working of reserves; and reserves are considered the portion of the resource base already discovered. Reserves may be thought of as sufficiently 'proven' to serve as direct collateral in financial transactions. There is, however, considerable controversy concerning the accuracy of published values for world oil reserves. Some authorities[5] consider those published in *The Oil and Gas Journal* to be overstated for a number of political and commercial reasons. For reasons of this nature, the value of the change

Figure 1
The Standard Convention for Resources and Reserves Nomenclature



in reserves from year to year may be known with more certainty that the absolute value. The methodology devised for this paper allows for this possibility in interpreting the results.

The results of the discovery process are treated in a specific way in the text that follows. The conventional oil discovered during a given year is taken as the change in reserves between the last day of two successive years plus the production during the intervening period. This relationship may be represented mathematically by the following equation:

$$d_2 = (R_2 - R_1) + p$$

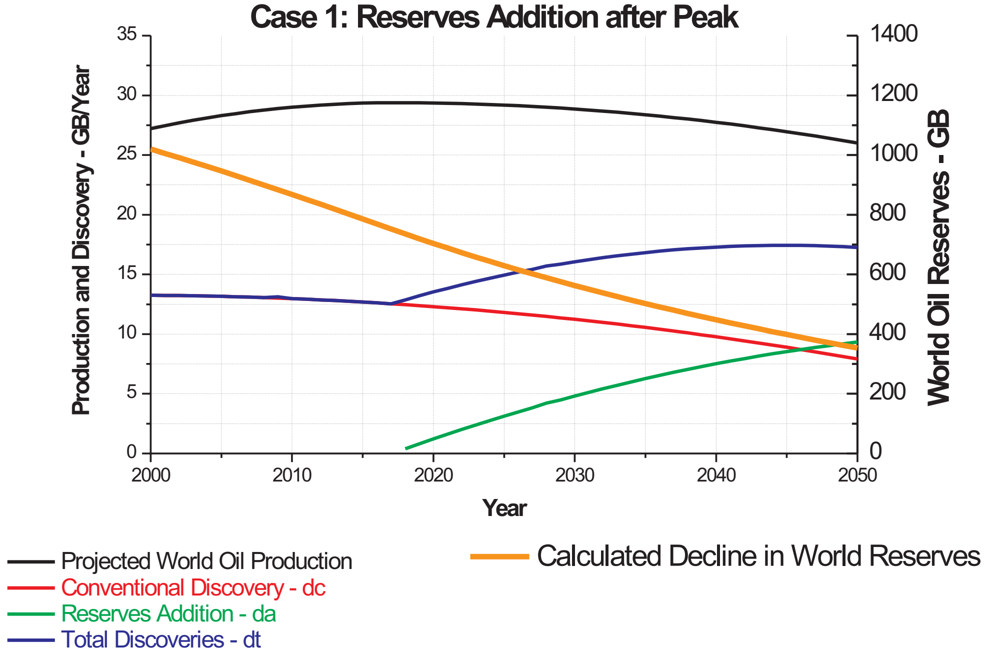
where d_2 represents the discoveries during the year 2, R_2 the reserves at the end of the Year 2, R_1 the reserves at the end of the previous year and p is the production during the year.

In the convention adopted here, upper case letters such as R (for reserves) represent absolute quantities and lower case letters such as p (for production) represent output for one year.

This narrow definition is essentially a bookkeeping convention in that it counts only quantities and does not distinguish differences in importance among the various discoveries during the year. Discoveries that are more-or-less expected within the normal range of success ratios have fewer implications for the future as opposed to the unexpected finds that lead to important upwards adjustments to resource assessments over the following years such as when a prolific new producing province is found. The frequency of the latter class of discoveries may, however, be expected to diminish with time as oil exploration becomes more mature around the world.

The quantity known as the Reserves Addition in the geological assessments presents a major difficulty. This significant quantity of oil arises from increased recovery either from known reservoirs or from extensions to known reservoirs over time made possible by advanced drilling practices and improved geological information and its interpretation. As some experts have noted,[6] some of the difficulty arises from the restrictions imposed by financial regulators and institutions such as stock markets regarding reporting `forward-looking' statements. For these legal reasons, only the oil that

Figure 2
Case 1: Reserves Addition after Peak



is sure is reported without reference to probable and possible additions.

In the earlier production paper,[1] this quantity was treated in two different ways. In Case 1, the Reserves Addition was assumed to become available only after the peak has passed on the grounds that prices would be sufficiently higher by that time to justify generally more expensive recovery practices. In contrast in Case 2, this quantity was assumed available at all times during the production period. These may be considered opposite or extreme cases with the actual result likely to lie in between the two procedures. This same distinction between the two cases is kept in this paper.

As a consequence, reserves can be increased from two quite different categories of discovery process: first, from the normal exploration and drilling process and, second, from the widespread adoption of practices that lead to the Reserves Addition.

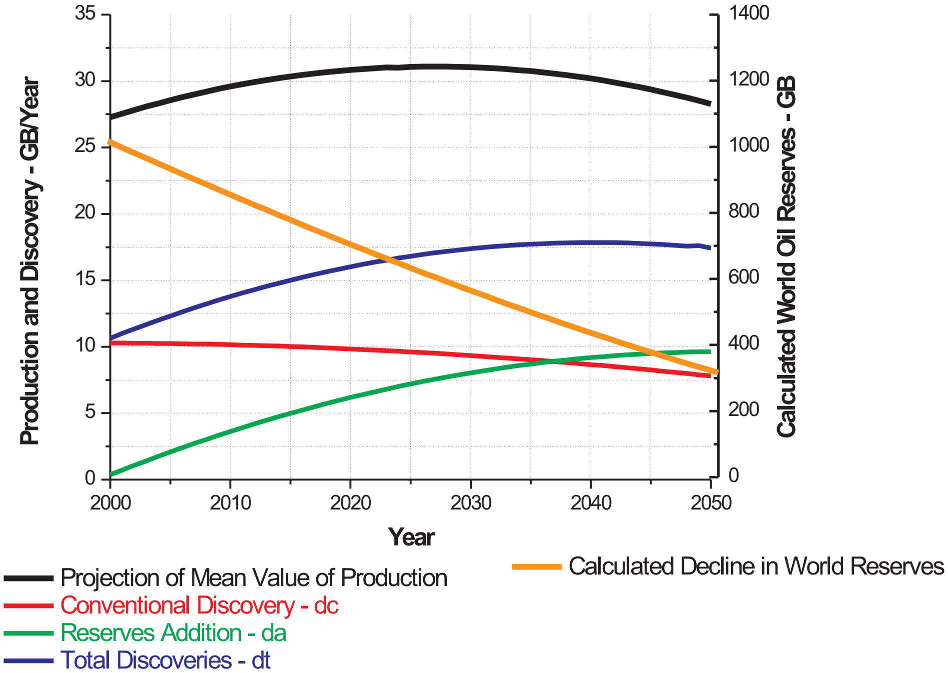
Methodology

Conventional discoveries in a given year are termed *dc* while contributions from the Reserves Addition are designated *da*. The total discoveries in a given year, *dt*, are thus the sum of *dc* + *da*. With this approach, it is quite possible to have the yearly contributions from *dc* and *da* moving in opposite directions over considerable periods of time. It is this aspect that distinguishes this study from previous ones in this field.

In Case 1, the conventional discoveries each year, *dc*, are assumed to fall parabolically from 1999, the base starting date of this study, to the end of the time period for the underlying production parabola from Reference 1 when it is assumed all the oil is discovered. To do this, the parabola is defined such that its area over time encompasses the quantity of oil predicted to be discovered in the Mean Case of the U.S. Geological Survey Assessment. These assumptions allow the computation of a curve that declines only slowly at first but falls more rapidly with time. This constantly decreasing quantity, *dc*, is calculated for each year to 2050.

In Case 1, the Reserves Addition, assumed to become effective after the predicted peak in world oil

Figure 3
Case 2: Reserves Addition Concurrent with Production

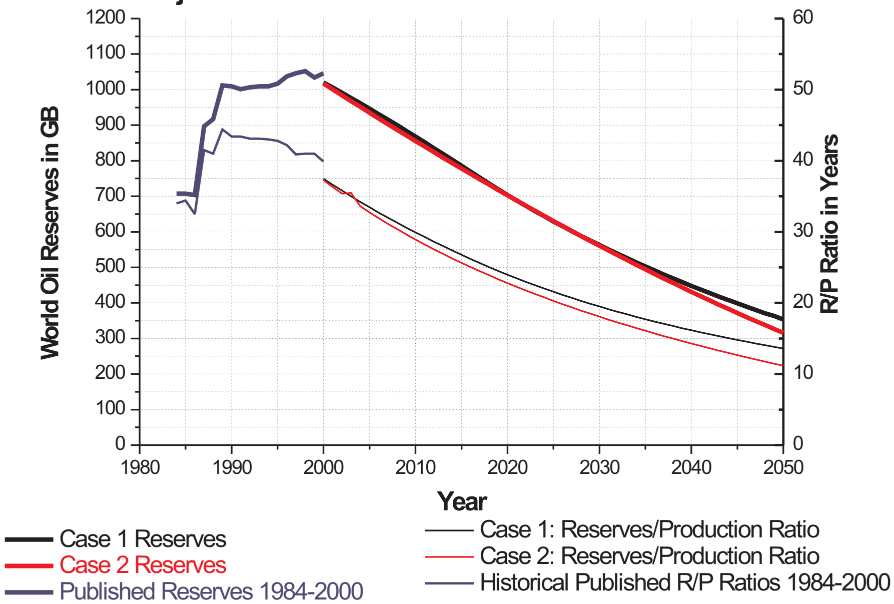


production has passed, is distributed parabolically such that the curve rises from zero in the peak production year and returns to zero to coincide with the completion of the Extended Parabola derived in the earlier paper. The value of *da*, which increases to a maximum and then decreases, is calculated for each year to 2050 in the same way as *dc*. The total discoveries in any one year, *dt*, is calculated from the sum of *dc* and *da.* The predicted production for a given year from Reference 1 is then deducted from the calculated total discoveries for that year. This value, normally negative, is deducted from the running total of the reserves starting with the published value at the end of 1999. The tracks of *dc, da, dt,* the production *p,* and the resulting fall in reserves are plotted in Figure 2 for the world over time.

Case 2 represents the other extreme in that the Reserves Addition contributes to total discoveries over the whole production period, not just past the peak. The conventional discoveries, *dc*, are derived year-by-year from a parabola whose area defines the quantity of oil specified by the U.S. Geological Survey Mean Case and whose time base extends through the whole production period defined in the underlying paper.[1] The Reserves Addition, *da*, is calculated from a parabola starting at zero in the base year (1999) and ending when the production time period also reaches zero. These quantities are plotted in Figure 3.

The year-by-year calculations were conducted in both cases until 2050. Given that the parabolic method assumes an absolute cut-off in oil production at a definite date rather than the slow tail-like decline expected in practice, the error introduced by this assumption is likely to become more significant passed this date.

Figure 4
Projection of Reserves and R/P Ratio for Cases 1 and 2



Case 1: Reserves Addition after the Peak in Production has Passed

In the early years, the rate of decline in conventional discoveries, *dc*, is small as would be expected for a parabolic curve and this decline is off-set after the peak in production is passed when contributions begin from the Reserves Addition *da*. Total yearly discoveries thus fall slowly until peak production has passed and then increase steadily under the influence of the Reserve Addition to a maximum when 17.34 GB is discovered in 2045. The predicted peak in world conventional oil production in the underlying paper is 29.38 GB/year in 2017.

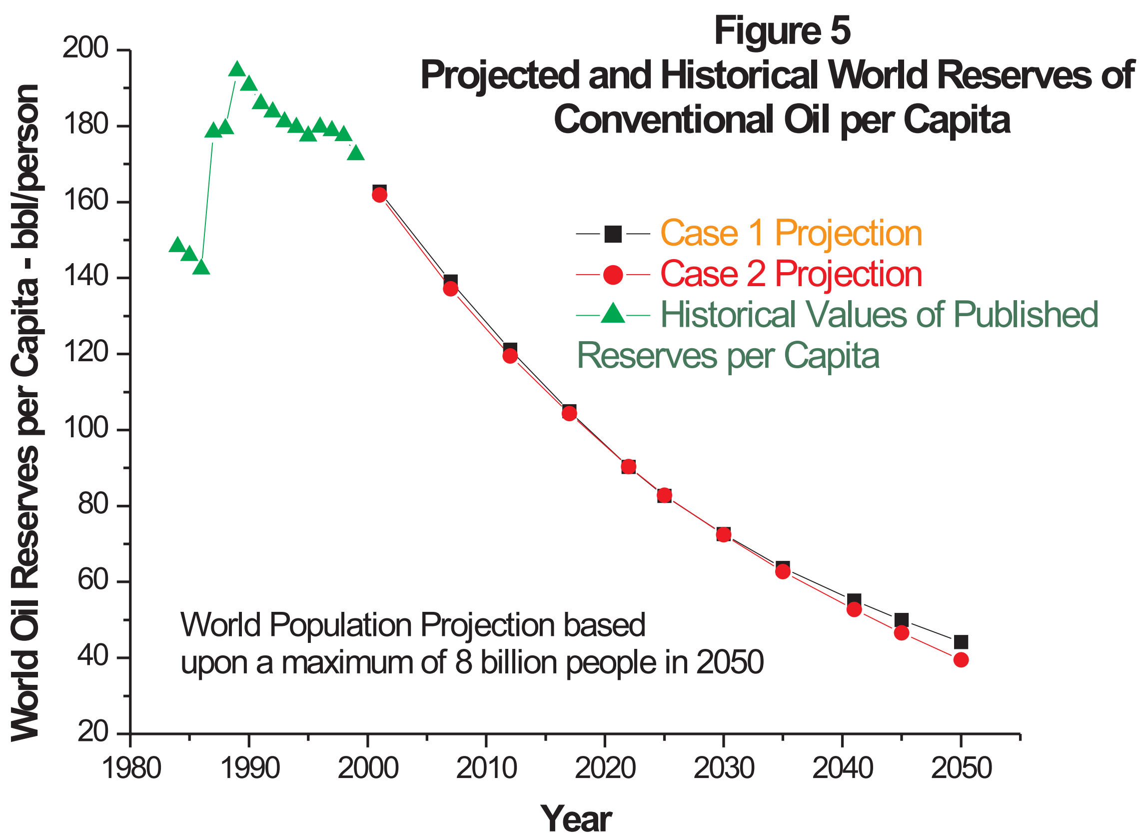
Somewhat counterintuitively, the rate of yearly discoveries continues to increase for 28 years after the peak in production has passed. The results plotted in Figure 2 predict a continuous decline in world conventional oil reserves that slows somewhat after 2030.

Case 2: Reserves Addition Throughout the Production Period

In Case 2, the total discoveries follow a different trend as illustrated in Figure 3 though world oil reserves also fall continuously as in Case 1. The total yearly discoveries *dt* increase steadily to reach a high of 17.85 GB/year in 2040 before beginning a very slow decline. The peak in world conventional oil production was predicted to be 31.10 GB/year in 2027 in Reference 1. As before, discoveries continue to increase after the peak in production has passed but for only 13 years in this case. Though the highest discovery rate is essentially the same as in Case 1, it occurs some five years earlier.

The surprising result of this paper is the very minor difference predicted in the decline of world oil reserves for these two quite different boundary cases. In Figure 4, the track in the fall in world reserves is effectively the same for the two cases though the year-by-year value of the Reserves-to-Production Ratio (R/P) is always lower in Case 2

In Figure 5, the results are plotted in per capita terms using a relatively slow-growth world population scenario which peaks at eight billion in 2050. The projected results are essentially identical. The historical points show clearly the large change that resulted when the OPEC and some other nations re-



vised their published values of their reserves sharply upwards in the late 1980s. Per capita published reserves have generally fallen since then.

Given that the population of the world is projected to increase through the period to 2050 even in the slow-growth scenario employed here, the monitoring of world oil reserves on a per capita basis may make underlying trends more evident than other parameters.

Summary and Conclusions

Data for the discovery of oil is defined in this paper as the sum of two processes – first from conventional exploration and drilling activities and second from the extensions to reservoirs that result in the Reserves Addition reported by the U.S. Geological Survey. These two values may be opposite in sign. In Reference 1, a parabolic projection of future world oil production was based upon the Mean Case of the Year 2000 Resource Assessment of the U.S. Geological Survey. The Reserves Addition was interpreted for two opposite boundary conditions at each side of the range expected in the earlier paper and this procedure was continued here. In Case 1, the Reserves Addition was assumed only operative after the predicted peak in production was passed and in Case 2, it was assumed to contribute throughout the whole production cycle. In this paper, the published value for the world's reserves of conventional oil at the end of 1999 was extended year-by-year to 2050 for each of the two boundary cases by adding the expected net discoveries from the two discovery mechanisms and subtracting the production predicted in a given year.

The world reserves were found to decrease regularly to 2050 as would be expected with the results virtually the same in both cases. The total discovery rate, however, still increases for 28 years in Case 1 and 13 years in Case 2 after the peak in production had passed. This was an unexpected result. The Reserve-to-Production Ratio was found to fall somewhat faster in Case 2 than in Case 1. The per capita value of the reserves over time were found to be effectively the same in both cases based upon a slow-growth population scenario. It may be concluded that a high rate of reported discoveries does not necessarily mean that the peak in production of conventional oil in the world is not imminent.

Self-consistency considerations in this approach to the reserves problem do, however, require the published values for the world reserves to fall beginning within a decade. If they do not, the published value for world reserves is either wrong or there is more conventional oil to be discovered than the U.S. Geological Survey has estimated. Per capita values of the world reserves may be a sensitive indicator parameter since world population is predicted to continue increasing until at least 2050.

References

1. J.H. Walsh, *Parabolic Projection of World Conventional Oil Production Based on Year 2000 Resource Assessment of the U.S. Geological Survey*, Proceedings of the Canadian Association for the Club of Rome, Series **2**, Number 3, Spring/Summer 2001. (Web: pages.ca.inter.net/~jhwalsh/wusgs. html)

2. *U.S. Geological Survey World Petroleum Assessment 2000*, Four CD-ROM Set, DDS-60. (Web: www.usgs.gov/energy)

3. *BP Statistical Review of World Energy*, Published each June and available from BP Distribution Services, PO Box 934, Bournemouth, Dorset, BH8 8YY,UK. (Web: www.bp.com/worldenergy)

4. *The Oil and Gas Journal*, U.S. petroleum journal published weekly.

5. Colin J. Campbell, *The Imminent Peak of World Oil Production*, Presentation to a House of Commons All-Party Committee (U.K.), July 7, 1999. (Web: www.oil-crisis.com/campbell/commons.html)

6. Jean Laherrère, *Estimates of Oil Reserves,* Presented at the International Energy Workshop organized by the International Institute for Applied Systems Analysis, Laxonberg, Austria, June 19, 2001. (Web: www.iiasa.ac.at)

Revised July 2001

19 Lambton Avenue, Ottawa, Ontario K1M 0Z6
Tel: (613) 745-6279
E-Mail: jhwalsh@ca.inter.net
Web Site: http://pages.ca.inter.net/~jhwalsh/index.html